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Environmental Characterization and Remediation Program
Environmental Stewardship Division
Los Alamos National Laboratory

Final—February 2006

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GEOTECHNICAL AND HYDRAULIC CHARACTERIZATION AT THE TECHNICAL AREA 61 BORROW AREA
Los Alamos, New Mexico

February 2006

Prepared for:

Los Alamos National Laboratory
Environmental Stewardship Division
Los Alamos, New Mexico 87545

Prepared by:

Shaw Environmental, Inc.
5301 Central Avenue, Suite 700
Albuquerque, New Mexico 87108-1513

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Acronyms and Abbreviations

2D	two-dimensional
amsl	above mean sea level
ASTM	American Society of Testing and Materials
bgs	below ground surface
cm	centimeter(s)
cy	cubic yard(s)
DBS&A	Daniel B. Stephens and Associates
ET	evapotranspiration
FADL	Field Activity Daily Log
fps	feet per second
GPS	Global Positioning System
Ksat	saturated hydraulic conductivity
LANL	Los Alamos National Laboratory
MDA	Material Disposal Area
NPDC	Nambé Pueblo Development Corporation
sec	second
SFSWMA	Santa Fe Solid Waste Management Agency
Shaw	Shaw Environmental, Inc.
SPT	Standard Penetration Tests
TA	Technical Area
USDA	U.S. Department of Agriculture

1.0 Introduction

Shaw Environmental, Inc. (Shaw) performed site characterization and analysis activities at the Los Alamos National Laboratory (LANL) Technical Area (TA) 61 Borrow Area. The work was performed in accordance with the statement of work entitled *TA-61 Borrow Pit Characterization*, dated April 18, 2005. The work was performed under LANL subcontract number G6615, Task Order 27, Mod 2. Shaw was provided with technical and geotechnical laboratory assistance on this project through a subcontract with Daniel B. Stephens and Associates, Inc. (DBS&A).

The purpose of this project was to evaluate the soil at the TA-61 Borrow Area and at Nambé Pueblo for possible use as protective covers on former Material Disposal Areas (MDAs) at LANL. Ten former MDAs are present at various locations around LANL, and it is estimated that 1.5 million cubic yards (cy) of soil will be needed to construct adequate covers (DBS&A, 2005). The borrow area is located in TA-61 along the south side of East Jemez Road (also known as the truck bypass) (Figure 1). The area is just east of the Royal Crest Mobile Home Park and is bounded on the north by East Jemez Road and by Sandia Canyon on the south (Figure 2). Soil has been previously removed from the site for clean fill and other construction activities at LANL; more recently, the site has been used as a staging area for clean soil removed from LANL construction sites and for storage of miscellaneous construction materials (Figures 3 through 6).

A modified scope of work was issued on September 21, 2005, to include collection of soil samples from Nambé Pueblo (Mod 3 to Task Order 27). The pueblo is approximately 20 miles from LANL and 10 near-surface (less than 3 feet below ground surface [bgs]) samples were collected for geotechnical evaluation. No drilling was performed and soil was excavated with a backhoe.

Technical tasks specified in both the original and modified scope of work include the following:

- Drill soil borings to various depths at the borrow area. Characterize the local geology and collect drill cutting samples for geotechnical analysis at DBS&A's laboratory
- Perform a seismic refraction survey to determine the "rippability," or ease of excavation, of subsurface soils
- Perform material volume calculations to estimate the quantity of rippable soil at the area
- Perform a cost estimate for excavation and transportation of soil from the borrow area to the MDAs

- Collect near-surface soil samples (no drilling) from Nambé Pueblo and perform geotechnical analyses
- Estimate the cost to transport soil from Nambé Pueblo to LANL

The remainder of this report details the activities conducted for each of these items. Field notes, borehole logs, and laboratory data pertaining to this project are provided in the appendices.

2.0 Field Investigation

This section summarizes the procedures used during geotechnical characterization and drilling activities at the TA-61 Borrow Area. The objectives of the work (as listed in the Drilling Plan [Shaw, 2005]) were to describe the borrow area geology, collect tuff samples for geotechnical laboratory testing, and to quantitatively and qualitatively evaluate material strength through standard drilling test methods. Figure 7 shows the site and location of four boreholes.

2.1 Borehole Installation

The borrow area lies geologically in the Pajarito Plateau on Quaternary age ash flow and ash fall tuff (Broxton and Vaniman, 2005). The geology at TA-61 consists primarily of Quaternary Bandelier Tuff Tshirege Member Unit 3 (Qbt3). Qbt3 is a prominent cliff-former in the upper unit, grading down section to a grayish-white, poorly to nonwelded tuff. Tshirege Member Unit 2 (Qbt2) underlies Qbt3 across the site. These were the two dominant lithologies encountered during drilling. Geotechnical samples were collected from each unit in each of the four boreholes completed during drilling characterization.

The site consists of approximately 40 acres, varying in terrain and vegetation cover. Except for the existing borrow area, the site is forested with ponderosa pine and scrub oak, piñon, and juniper. Borehole locations varied from flat surfaces in the borrow area at BH3 to the mesa top at BH1. BH2 was on a hillside located between a small drainage and Sandia Canyon. BH4 was located east of the borrow area in a more heavily forested area adjacent to a dirt access road.

Drilling took place from August 29 to September 1, 2005; Field Activity Daily Logs (FADLs) were completed at the end of each day. FADLs were the primary means of communication between the field crew, the Shaw project manager, and LANL personnel. Key information presented in the FADLs includes: 1) description of field activities, 2) records of safety meetings, 3) field crew members present on site, and 4) equipment used on site on each particular day. A field logbook was also used to record events by the Field Team Leader and document the presence of personnel on site. Project FADLS are presented in Appendix A. A copy of the field logbook is presented in Appendix B.

2.1.1 Borehole Locations

Boreholes were drilled to gain geotechnical knowledge about the area in and around the borrow area. Four boreholes were drilled across TA-61, spanning from the west end of the site to the east. Borehole locations were chosen to sample different depths and types of tuff across the site. Borehole BH1 is the westernmost borehole, drilled to 150 feet bgs. It is located near a residential mobile home park and is higher in elevation than the other three boreholes. The

dominant lithology in the borehole was observed to be Qbt3 and it advanced into the underlying Qbt2. The area surrounding BH1 contains thick vegetation, and overhead power lines are located nearby. A thin layer of mesa top soil/alluvium was observed in the core samples of this borehole.

Borehole BH2 was located to the east of BH1 but west of the active borrow area central to TA-61. This borehole was drilled to 52 feet bgs. BH2 was located in a relatively dense forest area upslope from an intermittent stream that bisected the mobile home park and the borrow area.

BH3 was located southeast of the current borrow area, essentially near the middle of the disturbed area. BH3 was drilled to a total depth of 102 feet bgs. Borehole BH4 was located at the eastern edge of TA-61 in dense vegetation adjacent to a dirt access road and drilled to a total depth of 52 feet bgs. The locations and depths of all four boreholes are shown in Figure 7.

2.1.2 Drilling Methods

Prior to drilling, each borehole was hand-augered to approximately 5 feet bgs, or to refusal, whichever occurred first. BH1 was hand-augered to 10 inches, BH2 to 18 inches, BH3 to 24 inches, and BH4 to 12 inches. The purpose of using the hand auger instead of immediately proceeding with drilling was a health and safety measure to ensure the drill rig was not aligned over utility lines or other subsurface structures.

Each borehole was completed using hollow-stem-auger drilling methods with continuous core sampling from a 2-foot by 2-inch-diameter, stainless steel, split-spoon core barrel. A Central Mine Equipment Model 85 drill rig was used for its accessibility to, and ease of drilling in, the soft volcanic tuff at the site. Core samples were to be collected at 5-foot intervals. Therefore, drilling commenced with Standard Penetration Tests (SPT) of 18 inches, followed by drilling through the remaining 3 feet to the beginning of the next 5-foot interval. Borehole logs are provided in Appendix C and show the progression of drilling and the continuous logging of material at the site.

All boreholes were drilled vertically and were plugged and abandoned immediately after total depth was reached. Geotechnical samples were collected by DBS&A in 5-gallon, plastic buckets from homogenized drill cuttings and core samples taken from each of the four boreholes. Six geotechnical samples were collected at BH1 at 5- and 10-foot intervals based on core and drill-cutting recovery. Two samples were collected at BH2, four samples at BH3, and two samples at BH4. Borehole abandonment was completed using a bentonite/grout mixture combined with water in a slurry method.

A summary of the samples collected, including boreholes, depths, locations, and sample identification numbers, is presented in Table 1.

2.1.3 Lithologic Logging

Borehole logs were generated during all drilling activities, and geologic cores were recovered at 5-foot intervals. Each core and the drill cuttings were logged for color, matrix of ash, presence of phenocrysts, presence and percent of pumice, degree of welding, and any other features unique to that particular unit.

SPT samples were collected in 18-inch runs throughout the drilling. The SPT values generally gauge the degree of welding in the native tuff and provide a good indication of stability of the material. SPT values are shown in the remarks section of the borehole logs (Appendix C).

2.1.4 Geology of TA-61

This section presents a general description of each unit encountered during drilling characterization activities (Broxton and Vaniman, 2005).

At TA-61, natural or undisturbed surface soil and volcanic ash flow tuff cover the landscape. Natural soils on the mesa surface tend to be relatively thin and poorly developed. The soil is more coarse and sandy near the surface while more clay-rich underneath. Soil profiles tend to have higher organic content near natural drainages.

Qbt3 is typically 60 to 70 feet thick and is a prominent cliff-forming caprock along the Pajarito Plateau. Fresh tuff surfaces are generally light gray with exposed surfaces weathered to light orange-tan in color. Qbt3 is a non- to partially-welded ash flow tuff, also known as ignimbrite, that provides a thick, consistent cover across most of the Pajarito Plateau. The matrix is white to light-gray in the nonwelded tuff, light-gray to pinkish-gray ignimbrite with phenocrysts measuring 1 to 3 millimeters comprising 5 percent of the matrix in the slightly to moderately welded tuff category.

Pumice fragments range from recrystallized gray and dark gray to altered, clay-like, white pumice measuring 1 to 4 centimeters (cm) comprising 3 to 5 percent of the matrix. Hornblende is the main composition of phenocrysts in pumice in this interval.

Often, a 16- to 33-foot zone of nonwelded fine ash flow tuff (ignimbrite) lies between Qbt2 and Qbt3. This zone is typically phenocryst-rich with a white to light-gray, ashy matrix and little to no pumice clasts. Phenocrysts are abundant in this zone due to the nonwelded, porous nature of the ash flow matrix. Fractures are also common in this nonwelded zone, ranging in size from 2 to 4 cm. This is a key zone in identifying the sometimes gradual contact between Qbt2 and Qbt3.

Qbt2 is an approximately 82- to 90-foot-thick vertical cliff-forming unit. The upper contact is defined by the appearance of relatively thin, unconsolidated, nonwelded tuff. The unit is a series

of volcanic ash fall and ash flow deposits and is a distinctive slope-forming unit. The degree of welding is greatest in this unit down section where it contains abundant phenocrysts, particularly sanidine, and pumice fragments.

Matrix color grades lighter to darker with degrees of welding, from light pinkish-tan in nonwelded tuff to light purplish-gray in more moderately welded tuff. Pumice varies from gray to grayish-brown in color and in the percentage of phenocrysts within the pumice clasts.

Geologic cross sections showing the units in the four boreholes completed across the TA-61 Borrow Area are presented in Figures 8 through 10.

2.2 Geotechnical Analysis

The purpose of hydraulic properties testing of tuff material from TA-61 is to establish the suitability of the material as the main constituent in evapotranspiration (ET) covers for LANL MDAs. Standard geotechnical and hydraulic properties testing were conducted to allow calculation of parameters used in performance modeling and design of ET landfill covers. Material characteristics are used to establish proper thickness and construction specifications for a cover that will meet infiltration reduction performance and longevity benchmarks established by regulatory agencies. The anticipated use of the tuff material tested is construction of the primary soil rooting medium and topsoil layers in the ET covers, to allow vegetation to be established after construction is complete. In addition, the tuff will be used for subgrade select fill to build up the existing grade to final slopes that provide drainage to meet established specifications.

During borehole installation at TA-61, tuff samples were collected for laboratory testing to establish a feasibility-level evaluation of the material's suitability for MDA final covers. The tuff material properties testing provides the parameters necessary to complete preliminary cover performance assessment modeling and parameters important for estimating material costs. This section describes the tuff sample collection, laboratory testing procedures, and results.

2.2.1 Tuff Sample Collection

In order to collect representative samples of crushed tuff, samples of auger cuttings were collected during borehole drilling. Auger cuttings were segregated into 5-foot intervals by the drill crew. As each 5-foot auger flight was advanced down the borehole, the cuttings were shoveled away from the borehole into a separate pile for each 5-foot interval. The cuttings piles were laid out in sequence so that varying compositional and textural variations could be related to depth. After each 5-foot interval was penetrated, advancement of the auger was halted while the auger continued turning to bring the cuttings to the surface until the cuttings for that interval were cleared from the borehole. For each sampled interval, two 5-gallon buckets were filled

with auger cuttings from the selected depth interval. A total of 14 tuff cuttings samples were collected from representative depth intervals in the four auger boreholes.

Using cuttings samples for laboratory testing provided a partially crushed and blended material, which is reasonably representative of crushed tuff from an excavation operation. The tuff units encountered during drilling are Qbt2 and Qbt3; the upper Qbt3 is less welded than the densely welded Qbt2. The relatively soft tuff was pulverized by the drilling process into sand- and silt-size particles, leaving a small percentage of gravel- and cobble-size material. When tested, the drill cuttings fit the U.S. Department of Agriculture (USDA) classification of sandy loam.

Samples of intact tuff rock fragments were also collected for measurement of *in situ* tuff density. These tuff samples were selected from gravel- to cobble-size material (generally 1 to 3 inches in diameter) mixed in with the cuttings. The rock fragments were collected from the same sampling intervals as the auger cuttings. This measurement provides a determination of the bulking factor between bank density and loose density. A total of eight intact tuff samples were collected at the same depth intervals where cuttings samples were collected in each boring. Intact tuff samples could not be obtained for six of the borehole cuttings samples because the borehole cuttings were completely pulverized.

Additionally, one tuff sample was collected from the exposed cliff on the north side of the existing borrow area. This sample, designated as the North Cliff sample, was collected by shoveling the tuff into two 5-gallon buckets. The tuff is nonwelded in this location, allowing manual collection of a tuff sample. The North Cliff material was similar in nature to the other samples when received at the laboratory; though it had not been pulverized by interaction with the auger, it was still composed of sand- and silt-sized particles with some gravel-size pieces present. The particle size distribution for the North Cliff sample produced a USDA classification of loamy sand, whereas all cutting samples were classified as sandy loam.

2.2.2 Laboratory Methodology

The tuff samples were submitted to DBS&A's Hydrologic Testing Laboratory in Albuquerque, New Mexico, to complete hydrologic and geotechnical testing. To provide a basis for performance-based design of ET covers, laboratory analyses of the following hydrologic properties were conducted:

- Standard Proctor compaction
- Saturated hydraulic conductivity
- Moisture retention characteristic curve
- Grain size distribution
- Porosity

- Bulk density
- Atterberg limits

A discussion of each test is presented in the following sections. All laboratory data are summarized in Appendix D; additional, detailed laboratory data are provided on a compact disc in Appendix G.

2.2.2.1 Density and Hydrologic Properties Testing

The hydraulic properties of soil are strongly influenced by the compaction density. Accordingly, standard Proctor compaction tests were run first, and then the samples were prepared at specified densities for subsequent hydrologic testing. One of the most comprehensive design guides for ET covers, issued by the Interstate Technology and Regulatory Council (ITRC, 2003), recommends a compaction range of 75 to 85 percent of maximum Proctor density. Higher compaction densities can sometimes be difficult to avoid during normal earthwork activities for placing and grading material. Thus, each sample was tested at a laboratory-prepared target density of 82.5 percent of maximum. Additionally, six representative samples were tested for hydrologic properties at three or four target densities of 75, 82.5, 90, and 95 percent of maximum. A total of 30 hydrologic testing suites were performed for saturated hydraulic conductivity (Ksat), moisture retention characteristics, porosity, and bulk density.

Gravel corrections were calculated to adjust measured parameters for the larger grain size material, as required by American Society of Testing and Materials (ASTM) methods. As with any gravel-corrected calculation, care must be taken to interpret the results based on the specific use of these hydrologic parameters and the anticipated use of the material tested in the final construction design.

2.2.2.2 Bulking Factor Density Testing

Additional tests were performed for parameters important to planning tuff excavation and hauling. Sample material was tested to estimate increases in volume of *in situ* material as it expands during excavation and crushing (if necessary) to the placement in trucks for transport to the location of final placement. These tests indicate the *in situ* (bank) density, tested by the clod density method, and the bulking factor during tuff excavation, tested by the unconsolidated haul density method, to estimate the material density in trucks during transportation. A total of nine intact tuff samples were tested by the clod-density method, and a total of five crushed tuff samples were tested for unconsolidated haul density, comparable to the density when loaded in haul trucks.

No standard ASTM method exists for an unconsolidated haul density test; therefore, this testing followed a procedure used by DBS&A previously. DBS&A devised a simple soil free-fall test to mimic conditions of dumping soil from the bucket of a front-end loader into the bin of a haul

truck. The soil was dumped from a 5-gallon bucket from a height of 5 feet onto a series of empty brass sample rings. The rings were then carefully extracted from the pile of soil and weighed, and the soil density was calculated.

The results of the unconsolidated haul density tests are shown in the summary table in Appendix D. A comparison of densities calculated using the unconsolidated haul density test with the *in situ* densities calculated using the clod density method indicates a 1 to 14 percent increase in volume between *in situ* tuff and crushed tuff being hauled. This same comparison could be done to compare the haul density to the in-place density of the final cover when specifications for final as-built density have been determined.

2.2.2.3 Sample Settlement

The tuff sampled at TA-61 that was reduced to sand- and silt-size particles exhibited interesting characteristics that are not found in typical soils. Particles that make up the crushed tuff matrix are angular in nature, as would be expected when pulverizing a glassy, tuff-type material. Because of this angular nature, the particles do not pack together in the same manner as typical soil of similar particle size distribution. When tuff material was saturated during the hydraulic conductivity testing, significant settlement occurred. The settlement was greater for lower initial compaction densities and less for higher initial compaction densities. Compaction densities are presented as a percentage of maximum dry bulk density and are calculated using the standard Proctor method. These data are tabulated in Appendix G. The samples compacted to 75 percent of standard Proctor settled significantly, in some cases greater than 20 percent. The fact that so much settlement occurred indicates that the soil is not stable at lower compaction and will settle significantly when moisture conditions are near saturation.

2.2.3 Laboratory Testing Results and Observations

Complete laboratory testing results of the TA-61 crushed tuff are provided on a compact disc in Appendix G. Summary tables of results are provided as well in Appendix D. The crushed tuff material has a sandy loam grain size distribution and hydrologic characteristics that are comparable to typical "soils" used in ET landfill covers.

The density, water-holding capacity, and hydraulic conductivity of the crushed tuff can be modified over a significant range by altering the degree of compaction. The Ksat values of samples compacted to 82.5 percent of maximum Proctor density were in the range of 8.2×10^{-4} to 2.9×10^{-2} cm/second (sec). Samples compacted to 95 percent of maximum Proctor density typically have Ksat values approximately one to two orders of magnitude lower, in the range of 1.2×10^{-5} to 2.5×10^{-4} cm/sec, corresponding to a lower porosity in the more highly compacted samples. These results are consistent with data reported in Rogers and Gallaher (1995) for Bandelier Tuff.

The results of the unconsolidated haul density tests indicate that densities lower than 90 percent of maximum Proctor density are unlikely to be achieved in the field during construction and may not be maintained over the long term. Unconsolidated haul density tests produced densities of approximately 90 to 97 percent of maximum Proctor density, simply by allowing a 5-foot free fall, with consolidation occurring under the material's own weight. Placing the material by dumping it from a haul truck and grading the material with heavy equipment would likely produce densities higher than 90 to 95 percent of maximum Proctor density. In addition, settlement, compaction, and moisture conditions of the material are issues that will need to be addressed during the design, performance modeling, and construction phases of a final cover project. Confirmatory hydrologic and geotechnical testing should be performed on the excavated and processed material at the time the material is to be used.

Laboratory testing did not address the suitability of the crushed tuff material to support vegetation as related to nutrient availability and the ability of roots to penetrate material at the densities tested. The crushed tuff will have a very low organic carbon and nutrient content. As described by DBS&A (2005), nutrient addition using compost or other fertilizer is likely to improve establishment of vegetation. The addition of organic matter will have minor effects on the hydrologic and geotechnical material properties.

2.3 Geophysical Analysis

This section discusses the results of a seismic refraction tomography survey performed at the site to assess the rippability of the underlying tuff by measuring the seismic velocities of the subsurface material. Published tables are available (Caterpillar, 1978) and furnish the rippability conditions for specific rocks and sediment according to their seismic (compressional wave) velocities. In short, the rippability table correlates seismic velocity with ease of the material to be removed by a Caterpillar Model D9 bulldozer with a ripper attached to the back. The tuff at the borrow area presents different degrees of welding and suggests an inherently slow seismic velocity.

Four seismic lines were deployed across the site and near the boreholes described in Section 2.1. The locations of seismic refraction lines 1000, 2000, 3000, and 4000 are shown in Figure 11. A description of each line is discussed in the following sections.

2.3.1 Seismic Line 1000

BH1 is the westernmost borehole and is located near the western end of Line 1000 (Figure 11). It is slightly higher in elevation than the other three boreholes. This location was the most difficult in terms of laying out the refraction survey line due to thick vegetation and the presence of overhead power lines nearby. In addition, it appears that a relatively thin layer of more

densely welded tuff overlies a less welded tuff in the vicinity. It is likely that elevations are higher at this location due to the resistance to weathering from the denser tuff.

Seismic data were obtained over a 480-foot geophone array that followed a two-track road on the east side of the line up to approximately Geophone 14. Between Geophones 15 and 24, the line passed through a few areas of heavy vegetation (mainly scrub oak and piñon). Geophones were spaced at 20-foot intervals. The seismic source for each shotpoint was the DigiPulse Acoustic Wave Generator.

2.3.2 Seismic Line 2000

BH2 lies downhill from BH1 and west of the road that leads to the main entry gate for the borrow area (Figure 11). Because ponderosa pine trees in the area surrounding BH2 are widely spaced, there was little difficulty deploying the seismic refraction line, which was approximately 40 feet south of the borehole. Therefore, BH2 is approximately 40 feet north of the midpoint between Geophones 10 and 11. Data were collected over a 240-foot line (10-foot geophone spacing) with Geophone 1 approximately 50 feet west of an arroyo that roughly parallels the entrance road. A 20-pound sledge hammer and an aluminum plate were used to generate seismic energy for each shotpoint.

2.3.3 Seismic Line 3000

BH3 is located on the eastern edge of the disturbed section of the borrow area; the area is completely open and devoid of vegetation due to soil removal activities (Figure 11). The refraction line was placed approximately 70 feet north of the borehole (to avoid the effects caused by some surface asphalt present). BH3 is located 70 feet south of the eastern end of Line 3000. Data were collected over a 480-foot geophone spread (20-foot geophone intervals). The seismic source for each shotpoint was the DigiPulse Acoustic Wave Generator.

2.3.4 Seismic Line 4000

BH4 is the easternmost borehole and lies at the end of the two-track road that extends westward from the borrow area (Figure 11). Because ponderosa pine trees in the area surrounding BH4 are widely spaced, there was little difficulty placing the seismic refraction line. Data were collected over a 240-foot line (10-foot geophone spacing) with the eastern end of Line 4000 very close to BH4. A 20-pound sledge hammer and an aluminum plate were used to generate seismic energy for each shotpoint.

2.3.5 Instrumentation

This section describes the instruments used during the seismic refraction survey. The following list includes the devices that were used to obtain data during the survey:

- A Seistronics RAS-24 Seismograph
- 8-Hertz geophones and seismic cables
- A laptop field computer to run RAS software and store the raw data
- A DigiPulse Acoustic Wave Generator
- A 20-pound sledge hammer and 2-inch aluminum plate
- Trimble Pathfinder Pro-XRS Global Positioning System (GPS) to map the locations of geophones and shot points on each line

The RAS-24 was used to obtain seismic refraction data at the TA-61 Borrow Area. The RAS-24 receives earth response data from the geophone arrays and passes the information along to a laptop field computer where the data are stored. The seismograph provides a location for various cable connections allowing the transmission of data from each geophone to the laptop computer and is powered by an external 12-volt battery source. Geophone arrays were broken into 2 lines of 12 geophones, with each line separately connected to the seismograph.

Geophones are geophysical devices that detect the earth's response to arriving energy. A geophone consists of a cylindrical coil of wire mounted inside a magnet, both of which are housed in a protective plastic case. As the geophone moves along with the earth, relative motion between the coil and the magnet are induced due to the inertia of the coil. This motion generates a voltage that is proportional to the amount of ground displacement. A long metal spike on the underside of each geophone is used to anchor it into the ground.

A durable laptop field computer was used to run RAS software and store raw data in the field. The laptop computer in the field is necessary to store the data generated, as the RAS-24 only receives and transmits data and has no inherent data storage capability.

Two different seismic sources were used. For the shorter 240-foot geophone spreads, a 20-pound sledge hammer and 2-inch aluminum plate were used. This is a proven method for shorter lines and has been used by geophysicists for years. For the longer lines (480 feet) which require more energy, a DigiPulse Acoustic Wave Generator was used. This device attaches to the rear of a pickup truck and uses hydraulics and a large elastic band to trigger a powerful hammer that hits an aluminum plate on the ground surface. In this case, a 100-pound cylinder was accelerated into the earth for the shotpoints.

Each shotpoint was stacked in the field. Shot stacking occurs when multiple hammer strikes are made at the same shot location. This accomplishes the following two goals:

- Increases the amount of signal along each seismic trace
- Decreases the amount of random noise in each trace

The software processes the shot stacking automatically when the appropriate settings are selected and sums each shot within the stack, which increases the signal-to-noise ratio within each record. The arrival times for each geophone in the array are the same on each shot; therefore, the amplitudes are increased on the final record due to the summation. Alternatively, if random noise is present in a specific trace on one shot and nonexistent on the other shots within a stack, the amplitude of the noise is reduced on the final seismic record because the noise is cancelled out when the summation occurs. Table 2 presents the stack count used for each seismic refraction line.

A GPS was used to map the locations of each shot and certain geophones throughout each line. Differential GPS technologies provide location data at approximately 1.5-foot, real-time accuracy. The Trimble Pro-XRS allows each mapped feature (i.e., shot location or geophone) to be accurately recorded in New Mexico State Plane coordinates (North American Datum 83, New Mexico Central, Feet).

2.3.6 Seismic Refraction Field Setup

The field procedures were similar at each borehole location. Each refraction line employed 24 geophones placed at 10- or 20-foot intervals (based on the required depth of penetration). Once the geophones were all in place and connected to the seismic cable, the shot process began when the system was powered on and the software initiated.

BH1 and BH3 were drilled deeper, thus a greater depth of penetration was required to gather the appropriate data. In order to achieve more depth of penetration, it is necessary to increase the overall length of the geophone array by extending the distance between each geophone in the array. Table 3 provides the geometry of each line of seismic refraction data.

Shots occurred at the same five positions along the geophone array for each line; however, the distance between the shots differed according to the geophone spacing. Shotpoints were located at the end of each line (5 and 10 feet in-line off the end), in the middle of each line (between Geophones 12 and 13), between Geophones 6 and 7, and between Geophones 18 and 19. By convention, the first shot in each line is labeled zero and named according to the line number. For example, the first shot in Line 1 is "Shot 1000," and the shot number counts upward from there. Shots were conducted from the east to the west ends of each geophone spread for each seismic line. The first shot point (e.g., Shot 1000) was conducted off the east. The second shot

point (e.g., Shot 1001) was conducted between Geophones 6 and 7. The third shot point (e.g., Shot 1002) was conducted between Geophones 12 and 13 (center). The fourth shot point (e.g., Shot 1003) was conducted between Geophones 18 and 19. The final shot point (e.g., Shot 1004) was conducted off the west end.

As mentioned, the distance between the shots varies according to the distance between the geophones. Table 4 provides the location of each shot in the four refraction lines.

The geophysical data were processed using the seismic tomography method. Conventional seismic refraction processing methods divide the subsurface into seismic velocity layers. Each of these layers has an average seismic velocity even though the seismic velocities may vary within the layer. The tomography method generates a contour map of seismic velocities that allows observation of the seismic velocities as they are distributed in the subsurface. GeoCT I refraction tomography software was used to process the data.

The GeoCT I software is designed to perform continuous two-dimensional (2D) seismic wavefront ray tracing, nonlinear seismic travel-time tomographic imaging, and full wavefield velocity modeling. The program uses first arrival refraction data and a finite-element refraction velocity inversion process to develop a 2D seismic section that represents subsurface structure based on vertical and horizontal P-wave velocity gradients.

2.3.7 Results

The results of the seismic refraction tomography survey are presented in Figures 12 through 15. Each of the figures represents a cross section of seismic velocity; the horizontal axis is distance along the ground surface. For the most part, each seismic profile was conducted on flat terrain. Therefore, the vertical axis represents depth in feet bgs. In general, the seismic velocities for the tuff at TA-61 are considered very slow, ranging from 1,100 to 3,500 feet per second (fps) and all material is considered rippable with a small bulldozer. The porous, dry, friable nature of the tuff accounts for the slow seismic velocity. Figure 16 is reproduced from the *Handbook of Ripping* (Caterpillar, 1978) and shows that the 3,500-fps maximum velocity recorded for this project easily falls into the rippable category.

Figure 12 represents the seismic velocity cross section for line 1000 (length 480 feet). Velocities range from 1,100 to 3,400 fps to the depth of 150 feet bgs. A localized, higher-velocity zone occurs at the 400-foot mark along the profile, suggesting the tuff is more densely welded in that area. All the material is considered rippable.

Figure 13 shows the velocity cross section for line 2000 (length 240 feet). Velocities range from 1,100 to 2,200 fps, to the depth of 70 feet bgs. An uplift in seismic velocity occurs at the 60-foot

mark along the profile. At that point, slightly higher velocities occur near the ground surface; however, all materials are still considered rippable.

Figure 14 presents the seismic velocity cross section for line 3000 (length 480 feet). Velocities range from 1,100 to 3,300 fps at a depth of 150 feet bgs. A localized, higher-velocity zone occurs at the 260-foot mark along the profile and the tuff is likely more densely welded in that area. The localized high-velocity zone has relatively lower velocities on both sides of it. However, these are still considered slow seismic velocities and all materials are rippable.

Figure 15 shows the seismic velocity cross section for line 4000 (length 240 feet). Velocities range from 1,100 to 2,300 fps, to a depth of 70 feet bgs. An uplift in seismic velocity occurs at the 80-foot mark along the profile. At that point, slightly higher velocities occur near the ground surface. However, these are all considered slow seismic velocities and all materials are rippable.

3.0 Material and Shipment Cost Estimates

This section summarizes calculations on the volume of material available at TA-61, as well as the cost to ship material from TA-61 to the MDA cover construction sites.

3.1 Volume of Material

To meet the task goal of locating approximately 1.5 million cy of local material that could be readily excavated, the geologic and geophysical data collected at the TA-61 Borrow Area were analyzed. Current aerial photography and a digital elevation model of the area of interest, roughly bounded by Sandia Canyon on the south, East Jemez Road on the north, and a pipeline on the west, were used to create a base map in GIS [Geographic Information System]. Topographic contours were redrawn to represent the current configuration of the borrow pit (Figure 17). As shown in Figures 3 through 6, a steep slope (angled approximately 50 degrees from the horizontal and 80 feet high) comprises most of the northern side of the borrow pit, and a relatively flat floor covers much of the rest of the area. Based on the boreholes and the geophysical study discussed in Section 2.3, the thickness of readily useable volcanic tuff in the vicinity of the borrow pit is approximately 130 feet below the current borrow area elevation. BH3 is at an elevation of approximately 7,120 feet above mean sea level (amsl) and was used as a datum for subsequent volume calculations. The approximate elevation of the base of a proposed maximum excavation, which corresponds roughly with the bottom of Sandia Canyon, is therefore 6,990 feet amsl.

A proposed excavation boundary was established as delineated in Figure 17. A safety bench of 20 feet was defined at the base of the current steep slope, and then the proposed boundary was extended to the east along the southern side of the ridge until it reached the 6,990-foot contour. Similarly, the proposed boundary was extended to the west within approximately 100 feet of the pipeline, and then south to the canyon, and east along the canyon floor until the 6,990-foot contour was intercepted.

An excavation within the proposed boundary from the current surface to the 6,990-foot level was modeled with AutoCAD's Land Development Desktop module; the result is presented in Figure 18. Another 20-foot safety bench was assumed after 80 feet of similar slope, and the final excavation floor is assumed to be flat and unforested (at least initially). A cross section of the area of interest that displays the current configuration and the proposed configuration after excavation is included as Figure 19. Additional conceptual views are presented in Figure 20 (current configuration) and Figure 21 (post-excavation configuration).

The total volume of tuff within the modeled excavation was calculated by Land Development Desktop as 3.1 million cy. This is approximately double the volume estimated by LANL

required for the MDAs. Note that the presence of the radioactive liquid waste pipeline just west of the immediate borrow area presented some logistical challenges. While the material west of the pipeline is rippable, to do so would either require relocating the pipeline or excavating on both sides of it. As neither option is practical, only material east of the pipeline was considered in the volume calculations. As it is, the geologic and seismic data indicate there is more than sufficient material in this area, and it is not necessary to consider the logistics of excavating material west of the pipeline.

3.2 Cost of Material

Using the material cost estimates from DBS&A (2005), an updated cost estimate was prepared specifically for the TA-61 tuff borrow source. The preliminary cost estimate for crushed tuff and basalt to be used in construction of the MDA final covers includes material costs for excavation, crushing, loading, and haul truck transportation to each of the MDAs where cover construction is planned. Cost information was obtained from earthwork contractors, trucking companies, and standard cost-estimating guides.

The costs provided are considered to be reasonable planning-level estimates, and a contingency percentage is added for financial planning. The cost estimate includes material acquisition only, as the crushed tuff represents the primary material being considered for final cover construction. Costs for additional materials required for cover construction are provided by DBS&A (2005). The preliminary cost estimate is not a complete project cost estimate that includes engineering design, construction, management, permitting, and all other associated costs. Costs for environmental studies that are associated with material acquisition may vary greatly, depending on whether a Finding of No Significant Impact, Environmental Assessment, or Environmental Impact Statement is needed.

Costs are reported in projected 2006 dollars, based on 2004 and 2005 cost data. The final cost for material acquisition will depend on the MDA cover construction schedule and actual competitive bid prices for excavation and hauling that are obtained at the time of construction. Because the timing of various cover construction projects has not yet been established, the cost information is presented on an average unit cost basis that can be applied to any of the MDA covers. In all likelihood, larger projects will have somewhat more favorable pricing than smaller projects, due to economies of scale and typical contractor bidding practices.

3.2.1 Cost-Estimate Approach

For the purpose of establishing reasonable material cost estimates, material cost information was obtained from numerous sources, including contacts made with local construction contractors, trucking companies, and material providers. These types of sources provide cost-estimating accuracy by reflecting local knowledge and pricing. A list of contacts providing cost-estimate

information is reported in Table 5. DBS&A used the price quotes to develop reasonable average prices that can be expected when future material excavation and hauling bids are solicited.

Cost information was also obtained from *Heavy Construction Cost Data* (RSMeans, 2004), the most commonly used standard guide for construction cost estimating. This cost guide was used to compare the general reasonableness of local pricing information for material acquisition and transportation. The RSMeans cost data were also used to estimate excavation and processing costs, where heavy construction equipment would be used for excavating, crushing, loading, and hauling.

3.2.2 Material Quantities

Material quantities required for construction of the site-wide MDA final covers were calculated by DBS&A (2005), based on a minimum cover thickness of 1 meter and a maximum cover thickness of 2.5 meters. These preliminary material quantity estimates provide a reasonable basis to estimate expected costs for crushed tuff acquisition.

The estimated material quantities are based on the in-place material quantities necessary for the covers, at the soil density specified when the project is designed. In order to account for the soil consolidation that will occur when the cover soil is placed, the quantity required for material delivered for cover construction was conservatively estimated as 20 percent higher than the in-place quantity. An additional 10-percent contingency was also applied to the calculation of delivered material.

3.2.3 Angular Basalt Sources and Quantities

DBS&A examined possible sources to obtain angular basalt for slope stabilization and retaining wall construction, if necessary for some MDA final covers. Potential basalt borrow sources within LANL were examined, and commercial sources were also considered. LANL owns the mineral rights within its property, so the basalt is potentially available for borrow source development (Louderbough, 2004). To move forward with the on-site borrow source at LANL, the primary issues for further consideration concerning land use within LANL TAs where basalt is present and National Environmental Policy Act compliance and costs for specific sites.

The estimated basalt quantities that may be required for the LANL MDA final covers are provided in Table 6. The delivered quantities for all MDAs are estimated to be in the range of a minimum of 14,000 cy to a maximum 38,000 cy, depending on cover thickness. For the possible alternative of using angular basalt boulders for reinforcement on steep slopes, the basalt volume was estimated based on the volumes estimated for the more detailed cover layouts completed for MDAs C and L (DBS&A, 2005). For these sites, the basalt quantity was estimated as 30 percent of a 2-foot layer of rock and soil on the side slope areas with slopes of 25 percent or greater. For the other MDAs, the basalt quantity was estimated as the ratio of basalt to the total material

quantity for MDAs C and L. Whether to use basalt armoring or buttress structures will need to be determined during cover design.

Figure 22 shows the locations of basalt outcrops within LANL. The basalt is located primarily in the southeastern portion of LANL, in TAs-33, -36, -70, and -71. The basalt outcrop areas are based on four U.S. Geological Survey geologic quadrangle maps (Dethier, 1997 and 2003; Goff et al., 2002; Koning, 2002). The complete geologic maps, including formation names and labels, are included in DBS&A (2005). These maps have been adapted by highlighting just the basalt outcrops and overlaying both the LANL TA boundaries and the locations of MDAs where covers are planned.

A potential new source of basalt is currently being developed by the Santa Fe Solid Waste Management Agency (SFSWMA). At the Santa Fe Caja del Rio Landfill, basalt will need to be excavated for the construction of new landfill cell liners. The SFSWMA is conducting a market survey to determine the commercial potential of the basalt that will need to be excavated. It is estimated that approximately 500,000 cy of basalt will need to be removed annually to keep pace with expansion needs. The SFSWMA is considering whether the basalt may provide a source of revenue or at least provide a cost reduction offset for removal of the rock.

LANL may have future opportunities to acquire basalt from the SFSWMA under relatively favorable terms. As the basalt excavation is necessary and the quantities available are large, prices may be fairly low, accounting for only a fraction of the actual basalt excavation expense. LANL's primary cost may be the transportation expense to haul basalt to the MDA cover construction projects. Contact information for the SFSWMA is provided in Table 5.

3.2.4 Material Costs

Details of the material cost estimate calculations are provided in Appendix E. On-site excavation and material processing costs were estimated using the RSMeans data (RSMeans, 2004). Excavating costs were calculated based on the use of a trackhoe excavator with a 1.5-cy bucket, loading into a portable, track-mounted rock crusher. A front-end loader is included in the cost estimate to assist in loading the crusher or to load haul trucks; alternatively, a conveyor could be used to load trucks. For tuff excavation, use of a trackhoe excavator is expected to be an effective approach for welded tuff materials.

Transportation costs are based on a fleet of semi-trailer trucks pulling standard 22-cy trailers, which effectively carry 18 cy per load. A map showing preliminary haul routes from TA-61 to the MDA cover construction sites is provided in Figure 23. These preliminary haul routes were selected to avoid travel through the center of LANL and downtown Los Alamos; the mileage for each haul route is provided in Table 7. The mileage from TA-61 to each MDA is between 10 and 13 miles, with the exception of the three MDAs at TA-49, where the haul distance is

19 miles. Haul cycle times were estimated to account for loading, transporting, dumping, and passing through security check points (Appendix E). Because hauling contractors base costs on hourly rates rather than mileage, the costs for hauling to each site are based on an estimated cycle time of 1.5 hours per load.

The resulting material cost for crushed tuff delivered to the MDA final cover construction sites is estimated to be $8.22 per cy. Table 7 provides the total material cost for minimum and maximum tuff quantities necessary for each MDA final cover. Depending on the cover thickness, the crushed tuff material costs range from $9.3 to $19.7 million. To be conservative in estimating costs, contingencies (20 percent) were added to both material quantities and costs. These costs can be used by LANL for overall cost planning for the site-wide ET cover effort.

The cost for basalt excavation for a potential new borrow pit within LANL was estimated using the RSMeans data (RSMeans, 2004). Excavating costs were calculated based on drilling and blasting the rock. Costs are included for a Caterpillar Model D9 bulldozer to remove overburden and a front-end loader to load haul trucks (typical equipment for operations in a relatively small basalt borrow area). Transportation costs for basalt are based on a fleet of five dump trucks carrying 12 cy per load. Based on the general area of basalt outcrops, the estimated average one-way haul distance from the basalt borrow pit to MDAs was assumed to be 12 miles, the same average distance as the tuff haul distance from TA-61. To account for loading, transporting, dumping, and passing through security check points, a haul cycle time of 1.5 hours per load was estimated.

4.0 Nambé Pueblo Soil Collection and Analysis

In response to inquiries by the Nambé Pueblo Development Corporation (NPDC), LANL requested an assessment of potential borrow soil at Nambé Pueblo. NPDC has soil borrow material available from ongoing earthwork projects, and removal of the soil may facilitate development plans being pursued by Nambé Pueblo. NPDC has identified a multi-acre area in the southwestern corner of the pueblo where borrow material could be obtained. The general area being considered as a potential borrow source covers more than 200 acres, an area large enough to provide all of the borrow material necessary for the MDA final covers.

4.1 Soil Sampling Methods

A field investigation was conducted at Nambé Pueblo to collect samples of alluvial soil for laboratory testing. Sampling locations were selected during a field visit to verify accessible locations with representative materials. Shaw and DBS&A collected samples on October 13, 2005, with excavation assistance from the NPDC, which provided a backhoe and operator to excavate soil from test pits (Figure 24). Each sample consisted of two 5-gallon buckets filled by shoveling soil excavated from the test pits.

The material at Nambé Pueblo is comprised of Santa Fe Formation alluvium that is highly variable in its grain size characteristics. Based on field observations, the formation consists of stratified alluvium that ranges from plastic clay to poorly graded sand. Ten samples were collected to provide reasonably representative characterization of the materials potentially available.

The sampling locations at Nambé Pueblo are shown on a 2005 aerial photograph in Figure 25. Seven of the samples represent alluvium from below the depth of topsoil development. Three of those samples were collected along road cuts (NPDC-04, -05, and -10), and four were collected in an area that had already been regraded for future development of housing areas (NPDC-06, -07, -08, and -09). These latter four samples represent material that has already been excavated and relocated on site, resulting in a certain amount of blending of the alluvial materials. The final three samples were collected from the upper natural soil horizon (NPDC-01, -02, and -03), although the soil development is relatively immature in this area of sparse vegetation, significant erosive features, and badlands development. These three soil samples were a blend of soil from test pits excavated to approximately 3 feet bgs (Figures 26 and 27).

4.2 Laboratory Methodology

The purpose of the soil laboratory testing was to establish the suitability of the alluvial sediments at Nambé Pueblo as the primary component for construction of ET covers throughout LANL.

The same standard geotechnical and hydraulic properties testing performed for the TA-61 crushed tuff samples were conducted for the Nambé Pueblo alluvium to determine the parameters used in performance modeling and design of ET landfill covers. The laboratory tests provide the soil characteristics used to establish proper thickness and construction specifications for a cover that will meet infiltration reduction performance and longevity benchmarks established by regulatory agencies.

The Nambé Pueblo alluvial soil samples were submitted to DBS&A's Hydrologic Testing Laboratory in Albuquerque, New Mexico, to complete hydrologic and geotechnical testing. The following hydrologic properties tests were conducted:

- Standard Proctor compaction
- Saturated hydraulic conductivity
- Moisture retention characteristic curve
- Grain size distribution
- Porosity
- Bulk density
- Atterberg limits

As described in Section 2.2.2 for hydrologic testing of the crushed tuff samples, the alluvial soil samples from Nambé Pueblo were first tested for standard Proctor compaction and then prepared at specified densities for subsequent hydrologic testing. Each sample was tested at a laboratory-prepared target density of 82.5 percent of maximum. Additionally, five representative samples were tested for hydrologic properties at three target densities of 75, 82.5, and 95 percent of maximum. A total of 20 hydrologic testing suites were performed for Ksat, moisture retention characteristics, porosity, and bulk density.

Gravel corrections were calculated to adjust measured parameters for the larger grain size material, as is required in the ASTM method. As with any gravel-corrected calculation, care must be taken to interpret the results based on the specific use of these hydrologic parameters and the anticipated use of the tested material in the final construction design.

Additional density tests were performed for parameters important to planning soil excavation and hauling. Sample material was tested to estimate increases in volume of *in situ* material as it expands during excavation and placement in trucks for transport to the location of final placement during cover construction. These tests indicate the *in situ* (bank) density, tested by the clod density method, and the bulking factor during tuff excavation, tested by the unconsolidated haul density method, to estimate the material density in trucks during transportation. The clod samples tested were gravel- to cobble-size pieces of weakly consolidated alluvium that remained intact following sample collection. Five intact samples were tested by the clod density method,

and five unconsolidated soil samples were tested for unconsolidated haul density, comparable to the density when loaded in haul trucks. The unconsolidated haul density tests were conducted in the same manner as those described in Section 2.2.2.2.

The results of the unconsolidated haul density tests are shown in the summary table in Appendix F. A comparison of densities calculated using the unconsolidated haul density test with the *in situ* densities calculated using the clod density method indicates a 4 to 33 percent increase in volume between the pre-excavation *in situ* alluvium and the excavated alluvium being hauled. This same comparison could be done to compare the haul density to the in-place density of the final cover when specifications for final as-built density have been determined. Sample NPDC-3 produced anomalous results, indicating a very low density. In this case, the "clod" may have contained a large portion of organic material, as this sample was collected from the native upper soil profile.

4.3 Laboratory Testing Results and Observations

Summary tables of the laboratory testing results are provided in Appendix F. Complete laboratory testing data for the Nambé Pueblo alluvial soil are provided on a compact disc in Appendix G. Grain size analysis of the Nambé Pueblo alluvium indicates particle size distributions corresponding to USDA classifications of loam, sandy loam, and loamy sand. The alluvium sampled varied from loose sand to what would be considered weakly lithified material. Minor zones of moderately lithified sandstone were observed in the field; however, such competent rock was avoided during sampling. Though there are significant differences in the relative competence of the sediments sampled, all should be able to be extracted using standard excavation equipment.

The density, water holding capacity, and Ksat of the alluvium can be modified over a significant range by altering the degree of compaction. The Ksat values of samples compacted to 82.5 percent of maximum Proctor density was in the range of 8.1×10^{-6} to 2.7×10^{-3} cm/sec. Samples compacted to 95 percent of maximum Proctor density typically have Ksat values approximately one order of magnitude lower than the corresponding 82.5 percent compaction sample, while the samples compacted to 75 percent of maximum Proctor density typically have Ksat values approximately one order of magnitude higher.

The results of the unconsolidated haul density tests indicate that densities lower than about 85 percent of maximum Proctor density may be difficult to achieve and maintain in the field. Unconsolidated haul density tests produced densities of approximately 75 to 85 percent of maximum Proctor density, simply by allowing a 5-foot free fall, with consolidation occurring under the material's own weight. Placing the material by dumping it from a haul truck and grading the material with heavy equipment would likely produce densities higher than 85 percent of maximum Proctor density. In addition, settlement, compaction, and moisture conditions of

the material are issues that will need to be addressed during the design, performance modeling, and construction phases of a final cover project. Because of the variability of alluvial materials at Nambé Pueblo, confirmatory hydrologic and geotechnical testing should be performed on the excavated and processed material at the time the material is to be used.

Laboratory testing did not address the suitability of the Nambé Pueblo alluvium to support vegetation as related to nutrient availability and the ability of roots to penetrate material at the densities tested. Depending on the borrow source areas selected, native topsoil with a higher organic content than deeper alluvium may be managed in a way that will control this select material for use as a topsoil layer in the MDA final covers. As described by DBS&A (2005), the addition of nutrients such as compost or other fertilizer is likely to improve establishment of vegetation on the final covers. The addition of organic matter will have minor effects on the hydrologic and geotechnical material properties.

4.4 Nambé Pueblo Material Costs

A preliminary cost estimate for acquisition of alluvial soil at Nambé Pueblo was prepared using a material cost-estimating approach similar to that described in Section 3.2 for TA-61 crushed tuff. The preliminary cost estimate includes excavation and transportation of Nambé Pueblo alluvial soil for construction of the MDA final covers. Costs are reported in projected 2006 dollars based on 2004 and 2005 cost data. The costs provided are considered to be reasonable planning-level estimates, and a contingency percentage is added for financial planning.

The cost estimate includes material acquisition only, as the alluvium represents the primary material being considered for final cover construction. Costs for additional materials needed for cover construction were provided by DBS&A (2005). The preliminary cost estimate is not a complete project cost estimate that includes engineering design, construction, management, permitting, environmental compliance, and all associated costs. Costs are for earthwork only and do not account for any additional requirements from Nambé Pueblo.

For the purpose of establishing reasonable material cost estimates, cost information was obtained from contacts made with local construction contractors, trucking companies, and material providers. Cost information was also obtained from *Heavy Construction Cost Data* (RSMeans, 2004). This cost guide was used to compare the general reasonableness of local pricing information for material acquisition and transportation.

Material quantities required for construction of the site-wide MDA final covers were calculated by DBS&A (2005). As discussed in Section 3.2.2, the material quantities for minimum and maximum cover thicknesses of 1 and 2.5 meters include a planning contingency for the quantity of material needed for delivery to the MDA cover construction sites.

Details of the material cost estimate calculations are provided in Appendix E. On-site excavation and loading costs were estimated using the RSMeans data (RSMeans, 2004). Excavating costs were calculated based on scrapers excavating the weakly consolidated alluvium and transporting the soil to a stockpile. From there, front-end loaders will load haul trucks for transportation to LANL.

Transportation costs are based on a fleet of semi-trailer trucks pulling standard 22-cy trailers, which effectively carry 18 cy per load. A map showing preliminary haul routes from TA-61 to the MDA cover construction sites is provided in Figure 28. The mileage for each haul route is provided in Table 8. The mileage from the Nambé Pueblo borrow area to each MDA is between 21 and 26 miles, with the exception of the three MDAs at TA-49, where the haul distance is 32 miles. Haul cycle times were estimated to account for loading, transporting, dumping, and passing through security check points (Appendix E). Because hauling contractors base costs on hourly rates rather than mileage, the costs for hauling to each site are based on an estimated cycle time of 2.5 hours per load.

The resulting material cost for Nambé Pueblo alluvium delivered to the MDA final cover construction sites is estimated to be $13.73 per cy. Table 8 provides the total material cost for minimum and maximum soil quantities necessary for each MDA final cover. Depending on the cover thickness, the alluvial soil material costs range from $14.0 to $29.9 million. To be conservative in estimating costs, contingencies (20 percent) were added to both material quantities and costs (e.g., these costs can be used by LANL for cost planning for the site-wide ET cover effort).

5.0 Conclusions and Recommendations

The purpose of this project was to evaluate the suitability of TA-61 crushed tuff and Nambé Pueblo alluvial soil for use as protective covers on MDAs at LANL. Geotechnical data were collected at both sites. Tuff samples were collected from the TA-61 Borrow Area and soil samples were collected at Nambé Pueblo.

At the TA-61 Borrow Area, where the geologic material is tuff, four boreholes were drilled across the site to varying depths. Samples were collected from the drill cuttings and analyzed at DBS&A's laboratory in Albuquerque, New Mexico, for various hydraulic and geotechnical properties. In addition, a seismic refraction study was performed to ascertain the rippability of the tuff and to quantify how easily it could be removed. Finally, using the geologic and seismic data, an analysis was performed to calculate the volume of available tuff and to estimate the cost to transport it to the various MDA sites.

The tuff at TA-61 is suitable for landfill covers. The material was classified as a sandy loam, indicating good moisture retention characteristics, capability for compaction, and hydraulic conductivity on the order of 10^{-3} to 10^{-4} cm/sec. The material could be made finer and compacted further through on-site processing; conversely, materials representing different degrees of welding could be blended. Alternatively, clay or bentonite from an off-site source could be blended with the processed tuff, though the local material is appropriate for landfill covers in its *in situ* form. Approximately 3 million cy of excavatable tuff is available at the site, which exceeds LANL's estimate of cover material required for the MDAs. A numerical model of landfill cover performance should be used to estimate cover functionality for any proposed design. The estimated cost to excavate, process, and haul enough material for a 1-meter-thick cover from TA-61 to all 12 MDAs is approximately $9 million. This cost does not include any intersection or traffic-related modifications that may need to be implemented on East Jemez Road to facilitate trucks entering and leaving the TA-61 Borrow Area.

No drilling or geophysics evaluation was performed at Nambé Pueblo. Instead, samples were collected from the upper 3 feet of soil (using a backhoe) from 10 locations distributed across 200 acres of pueblo lands. Three samples represent topsoil, while seven samples represent deeper soil horizons from previously excavated areas. The material is comprised of Santa Fe Formation alluvium that is highly variable in grain size distribution. Field observations indicate the soil types vary from plastic clay to poorly graded sand. While the Nambé samples certainly contain more clay (hydraulic conductivities as low as 10^{-6} cm/sec) and are not as uniform as the TA-61 samples, the soil is still quite suitable for use as landfill covers. The distributed uniformity could be corrected with a formal processing plant; it is also possible that the process of excavating, stockpiling, loading, unloading, and spreading of soil will provide sufficient

mixing. The soil volume at Nambé Pueblo is more than adequate to meet LANL's requirements. As at TA-61, a model of cover performance should be implemented and evaluated prior to choosing a final cap design. The estimated cost to excavate, process, and haul enough material for a 1-meter-thick cover from Nambé Pueblo to all MDAs is approximately $14 million.

Basalt is also being considered as a possible MDA cover material. Basalt could be extracted from a new borrow area where basalt outcrops at several locations around LANL. In addition, construction of new landfill cells near Santa Fe may result in a large quantity of basalt available for use. Because the material will be excavated as a routine part of landfill construction and expansion activities, LANL's primary cost may only be transportation. The estimated cost to haul enough material for a 1-meter-thick cover from a LANL borrow source to all MDAs is approximately $138,000. No hydraulic or geotechnical analyses were performed on basalt for this report.

In summary, several sources for MDA cover material are available for use by LANL. Both the tuff at TA-61 and the sandy-clay alluvium at Nambé Pueblo are suitable cover materials from a hydraulic and geotechnical standpoint. In addition, both sites can provide sufficient quantities to meet LANL's requirements. The cost to haul the material to the different MDAs varies based on distance, the degree of processing required, and transportation costs.

6.0 References

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Tables

Table 1
Summary of Geotechnical Samples Collected during TA-61 Drilling Characterization

Borehole Number	Depth Sampled (ft)	Number and Type of Samples Collected	Location ID Number	Sample ID Number
BH1	15–25	(2) 5-gallon buckets	61-25137	RE61-05-63393
BH1	40–50	(2) 5-gallon buckets	61-25137	RE61-05-63394
BH1	65–75	(2) 5-gallon buckets	61-25137	RE61-05-63395
BH1	90–95	(2) 5-gallon buckets	61-25137	RE61-05-63396
BH1	120–125	(2) 5-gallon buckets	61-25137	RE61-05-63397
BH1	145–150	(2) 5-gallon buckets	61-25137	RE61-05-63398
BH2	10–15	(2) 5-gallon buckets	61-25135	RE61-05-63391
BH2	25–30	(2) 5-gallon buckets	61-25135	RE61-05-63392
BH3	5–10	(2) 5-gallon buckets	61-25130	RE61-05-63386
BH3	20–25	(2) 5-gallon buckets	61-25130	RE61-05-63387
BH3	60–65	(2) 5-gallon buckets	61-25130	RE61-05-63388
BH3	90–95	(2) 5-gallon buckets	61-25130	RE61-05-63389
BH4	10–15	(2) 5-gallon buckets	61-25143	RE61-05-63399
BH4	30–40	(2) 5-gallon buckets	61-25143	RE61-05-63400

BH = *Borehole.*
ft = *Feet.*
ID = *Identification.*
TA = *Technical Area.*

Table 2
Stack Count Used for Each Seismic Refraction Line, TA-61 Borrow Area Characterization

Location	Stack Count
BH1	4
BH2	5
BH3	4
BH4	4

BH = *Borehole.*
TA = *Technical Area.*

Table 3
Geometry of Each Line of Seismic Refraction Data, TA-61 Borrow Area Characterization

Location	Depth of Borehole (ft bgs)	Geophones in Array	Distance Between Geophones (ft)	Total Spread Length (ft)
BH1	150	24	20	480
BH2	50	24	10	240
BH3	100	24	20	480
BH4	50	24	10	240

bgs = *Below ground surface.*
BH = *Borehole.*
ft = *Feet.*
TA = *Technical Area.*

Table 4
Shot Locations on Each Seismic Refraction Line, TA-61 Borrow Area Characterization

Location	Shot 0 (ft along line)	Shot 1 (ft along line)	Shot 2 (ft along line)	Shot 3 (ft along line)	Shot 4 (ft along line)
BH1	-10	110	230	350	480
BH2	-5	55	115	175	235
BH3	-10	110	230	350	480
BH4	-5	55	115	175	235

BH = *Borehole.*
ft = *Feet.*
TA = *Technical Area.*

Table 5
Contacts for Materials Acquisition Cost Estimate, TA-61 Borrow Area

Agency	Address
Commercial	
Pacheco Trucking	119 Alameda Rd. NE, Albuquerque, NM 87113
Española Transit Mix	P.O. Box 38, Española, NM 87532
Western Mobile, Inc. / LaFarge	P.O. Box 27328, Albuquerque, NM 87125-7328
SG Western Construction	P.O. Box 729, Los Alamos, NM 87544
Central Concrete Products, Inc.	3 Demas Rd., Santa Fe, NM 87505
KSL Services, Inc.	P.O. Box 80, Los Alamos, NM 87544
Paul Parker Construction	P.O. Box 549, Los Alamos, NM 87544
Ulibarri Landscaping Material, Inc.	Route 6 Box 5, Santa Fe, NM 87501
MRT, Inc.	7335 Second St., Albuquerque, NM
MCT Transportation, Inc.	7451 Pan American Freeway NE, Albuquerque, NM 87109
Pueblos	
Nambé Pueblo	Nambé Pueblo Development Corporation
Pojoaque Pueblo	Tribal Works Office
Santa Clara Pueblo	Governor's Office
Government	
Los Alamos County	Waste Water Treatment Plant Pavement and Roads Division
City of Española	Waste Water Treatment Plant
Bureau of Land Management	Taos Field Office, 2226 Cruz Alta Rd., Taos, NM 87571
New Mexico Department of Transportation	District 3 Engineer
Santa Fe Solid Waste Management Agency	149 Wildlife Way, Santa Fe, NM 87506 Phone 505 424-1850

Table 6
Cost Estimate for Basalt Boulders
MDA Final Covers

Site		Mileage to Site from Borrow Area (mi)	Cover Volumes (cy)		Delivered Volumes[a] (cy)		Drill/Blast/ Load/Haul 12 mi[b] ($/cy)	Material Costs[b] ($)	
TA	MDA		Minimum (1.0 m thick)	Maximum (2.5 m thick)	Minimum (1.0 m thick)	Maximum (2.5 m thick)		Total for Minimum	Total for Maximum
50	C	Variable	1,314	3,591	1,734	4,740	39.57	14,254	38,962
54	L	Variable	134	365	176	482	39.57	1,450	3,962
	G	Variable	7,236	19,779	9,552	26,108	39.57	78,520	214,622
	H	Variable	33	91	44	120	39.57	362	991
21	A	Variable	139	380	184	502	39.57	1,510	4,127
	T	Variable	245	669	323	884	39.57	2,658	7,264
	B	Variable	668	1,826	882	2,410	39.57	7,248	19,811
	U	Variable	22	61	29	80	39.57	242	660
	V	Variable	98	268	129	353	39.57	1,063	2,906
49	AB	Variable	156	426	206	562	39.57	1,691	4,623
	Area 6	Variable	557	1,521	735	2,008	39.57	6,040	16,509
	Bottle House	Variable	33	91	44	120	39.57	362	991
		Total Materials	10,635	29,069	14,038	38,371	Subtotal	115,401	315,429
							20% Contingency	23,080	63,086
							Total Costs	138,481	378,514

[a]*Delivered material quantities were calculated using the following assumptions:*

- *Delivered volumes are 20% greater than in-place compacted volumes.*
- *A 10% contingency factor is added to the delivered material quantities.*

[b]*Cost adjusted at 3% per year from 2004/2005 to 2006 dollars.*

cy = *Cubic yard(s).*
m = *Meter(s).*
MDA = *Material Disposal Area.*
mi = *Mile(s).*
TA = *Technical Area.*
$ = *Dollar(s).*

Table 7
Cost Estimate for Crushed Tuff for MDA Final Covers
TA-61 Borrow Area

Site		Mileage to Site from Borrow Area (mi)	Cover Volumes (cy)		Delivered Volumes[a] (cy)		Excavate/Load/ Haul 12 mi[b] ($/cy)	Material Costs[b] ($)	
TA	MDA		Minimum (1.0 m thick)	Maximum (2.5 m thick)	Minimum (1.0 m thick)	Maximum (2.5 m thick)		Total for Minimum	Total for Maximum
50	C	12.80	57,112	156,106	116,600	247,272	8.22	958,518	2,032,720
54	L	11.71	5,808	15,875	11,858	25,146	8.22	97,476	206,717
	G	12.15	314,600	859,907	642,287	1,362,092	8.22	5,279,974	11,197,186
	H	10.70	1,452	3,969	2,964	6,287	8.22	24,369	51,679
21	A	10.85	6,050	16,537	12,352	26,194	8.22	101,538	215,331
	T	10.72	10,648	29,105	21,739	46,102	8.22	178,707	378,982
	B	10.04	29,040	79,376	59,288	125,732	8.22	487,382	1,033,586
	U	10.98	968	2,646	1,976	4,191	8.22	16,246	34,453
	V	10.46	4,259	11,642	8,696	18,441	8.22	71,483	151,593
49	AB	19.29	6,776	18,521	13,834	29,337	8.22	113,723	241,170
	Area 6	19.29	24,200	66,147	49,407	104,776	8.22	406,152	861,322
	Bottle House	19.29	1,452	3,969	2,964	6,287	8.22	24,369	51,679
		Total Materials	462,365	1,263,798	943,965	2,001,856	Subtotal	7,759,937	16,456,419
							20% Contingency	1,551,987	3,291,284
							Total Costs	9,311,925	19,747,702

[a]*Delivered material quantities were calculated using the following assumptions:*

- *20% of the maximum cover volume is added for subgrade for both the minimum and maximum delivered volumes.*
- *Delivered volumes are 20% greater than in-place compacted volumes.*
- *A 10% contingency factor is added to the delivered material quantities.*

[b]*Cost adjusted at 3% per year from 2004/2005 to 2006 dollars.*

cy = *Cubic yard(s).*
m = *Meter(s).*
MDA = *Material Disposal Area.*
mi = *Mile(s).*
TA = *Technical Area.*
$ = *Dollar(s).*

Table 8
Cost Estimate for Soil for MDA Final Covers
Nambé Pueblo Borrow Area

Site		Mileage to Site from Borrow Area (mi)	Cover Volumes (cy)		Delivered Volumes[a] (cy)		Excavate/Load/ Haul 25 mi[b] ($/cy)	Material Costs[b] ($)	
TA	MDA		Minimum (1.0 m thick)	Maximum (2.5 m thick)	Minimum (1.0 m thick)	Maximum (2.5 m thick)		Total for Minimum	Total for Maximum
50	C	25.64	57,112	156,106	116,600	247,272	12.44	1,450,407	3,075,864
54	L	24.55	5,808	15,875	11,858	25,146	12.44	147,499	312,800
	G	24.99	314,600	859,907	642,287	1,362,092	12.44	7,989,532	16,943,318
	H	23.55	1,452	3,969	2,964	6,287	12.44	36,875	78,200
21	A	21.52	6,050	16,537	12,352	26,194	12.44	153,645	325,833
	T	21.39	10,648	29,105	21,739	46,102	12.44	270,415	573,466
	B	20.72	29,040	79,376	59,288	125,732	12.44	737,495	1,563,999
	U	21.66	968	2,646	1,976	4,191	12.44	24,583	52,133
	V	21.14	4,259	11,642	8,696	18,441	12.44	108,166	229,386
49	AB	32.14	6,776	18,521	13,834	29,337	12.44	172,082	364,933
	Area 6	32.14	24,200	66,147	49,407	104,776	12.44	614,579	1,303,332
	Bottle House	32.14	1,452	3,969	2,964	6,287	12.44	36,875	78,200
		Total Materials	462,365	1,263,798	943,965	2,001,856	Subtotal	11,742,154	24,901,464
							20% Contingency	2,348,431	4,980,293
							Total Costs	14,090,584	29,881,756

[a]Delivered material quantities were calculated using the following assumptions:

- *20% of the maximum cover volume is added for subgrade for both the minimum and maximum delivered volumes.*
- *Delivered volumes are 20% greater than in-place compacted volumes.*
- *A 10% contingency factor is added to the delivered material quantities.*

[b]Cost adjusted at 3% per year from 2004/2005 to 2006 dollars.

cy = Cubic yard(s).
m = Meter(s).
MDA = Material Disposal Area.
mi = Mile(s).
TA = Technical Area.
$ = Dollar(s).

Figures

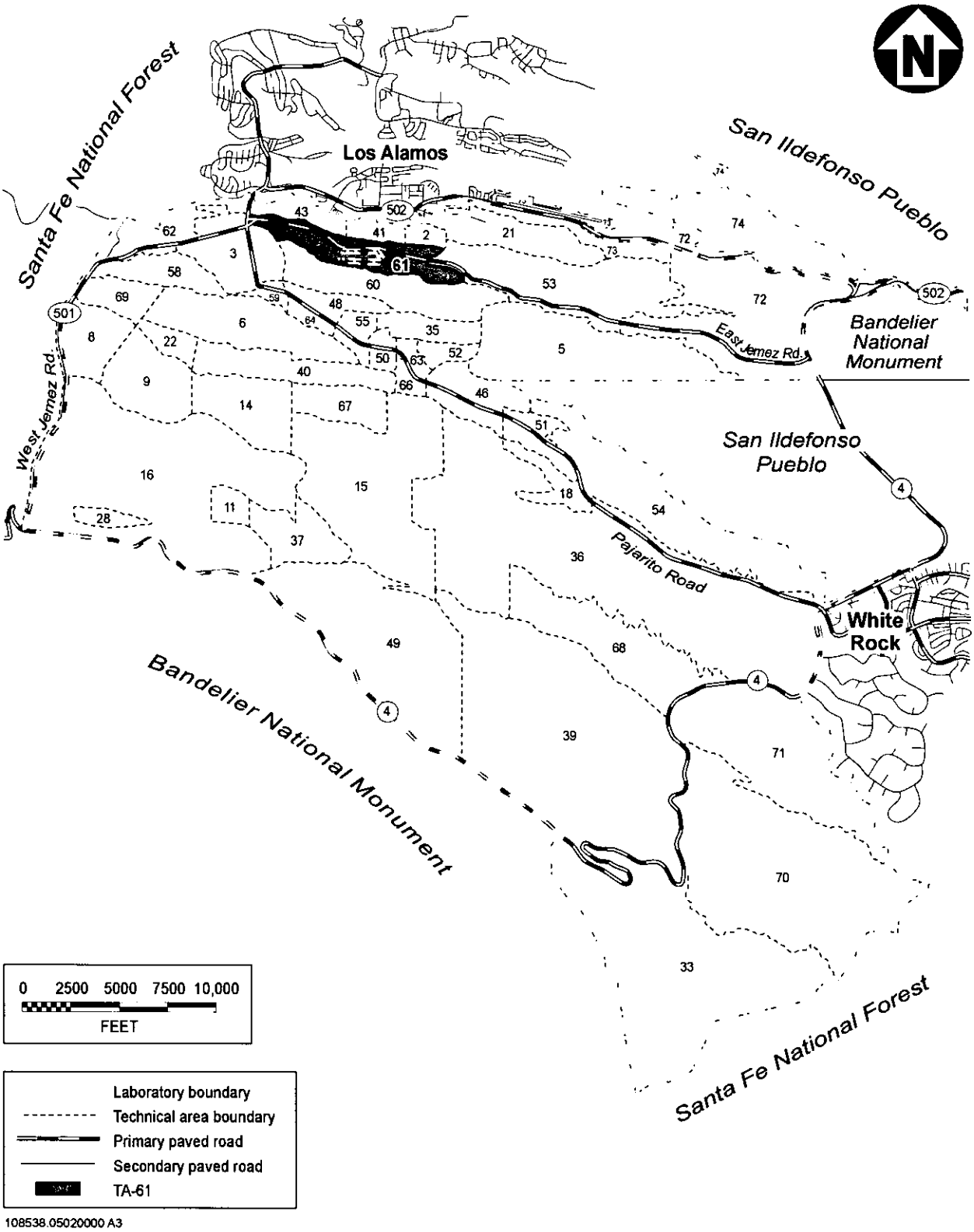

Figure 1. Location of TA-61 with Respect to Laboratory TAs and Surrounding Land Holdings

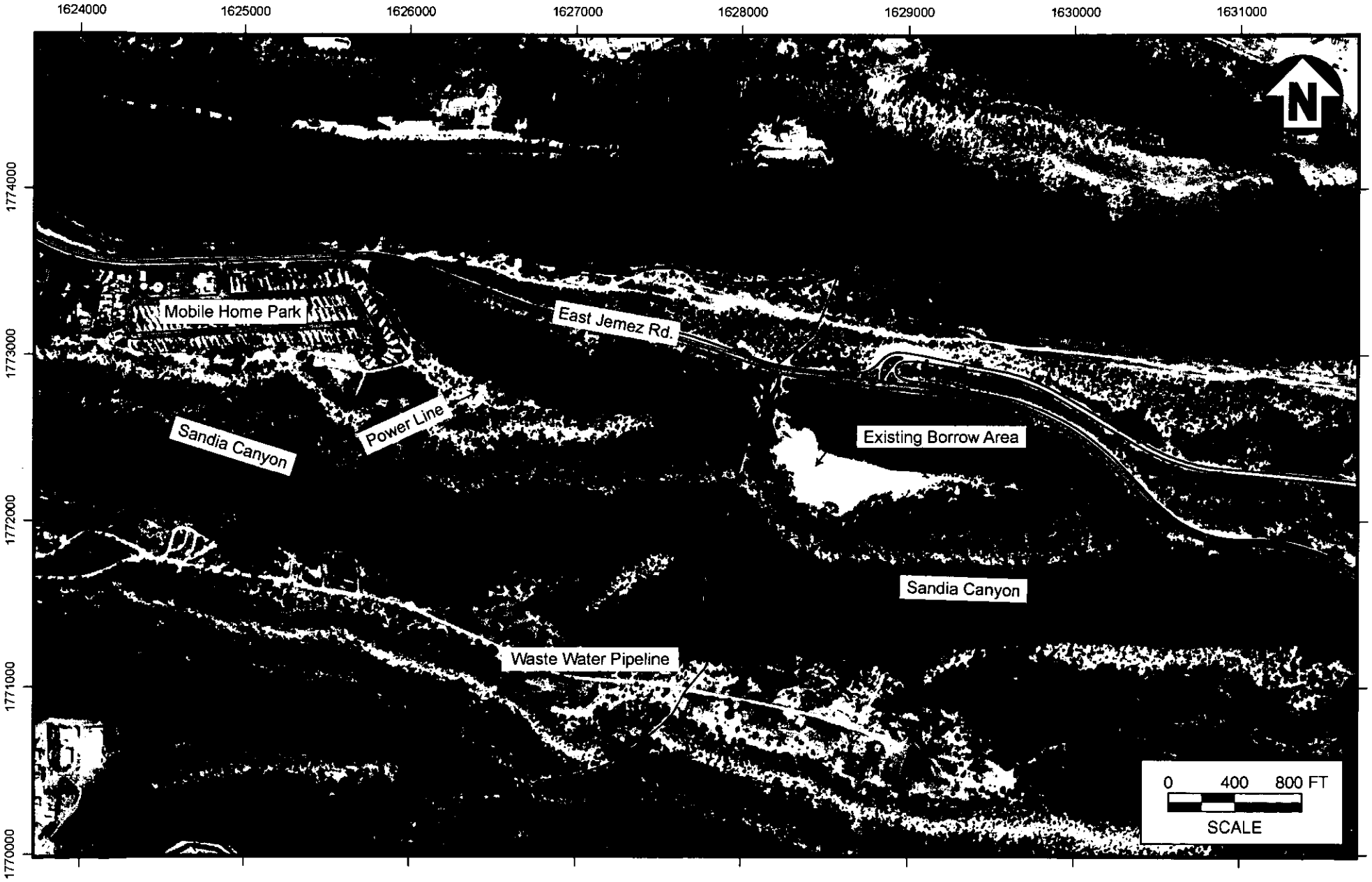

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Figure 2. **TA-61 Borrow Area**

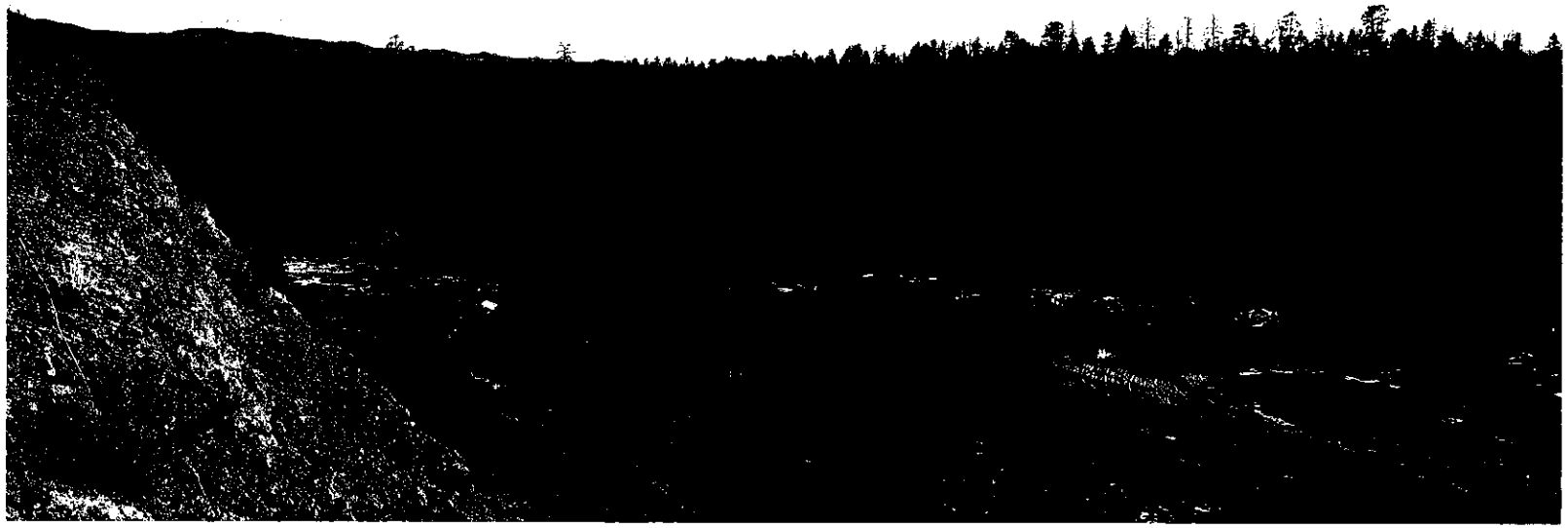

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Figure 3. **TA-61 Borrow Area, December 2005**
View to the Southeast

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Figure 4. East End of TA-61 Borrow Area, December 2005
View to the East

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Figure 5. **TA-61 Borrow Area, December 2005**
View to the East

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Figure 6. **West End of the TA-61 Borrow Area, December 2005**
View to the West

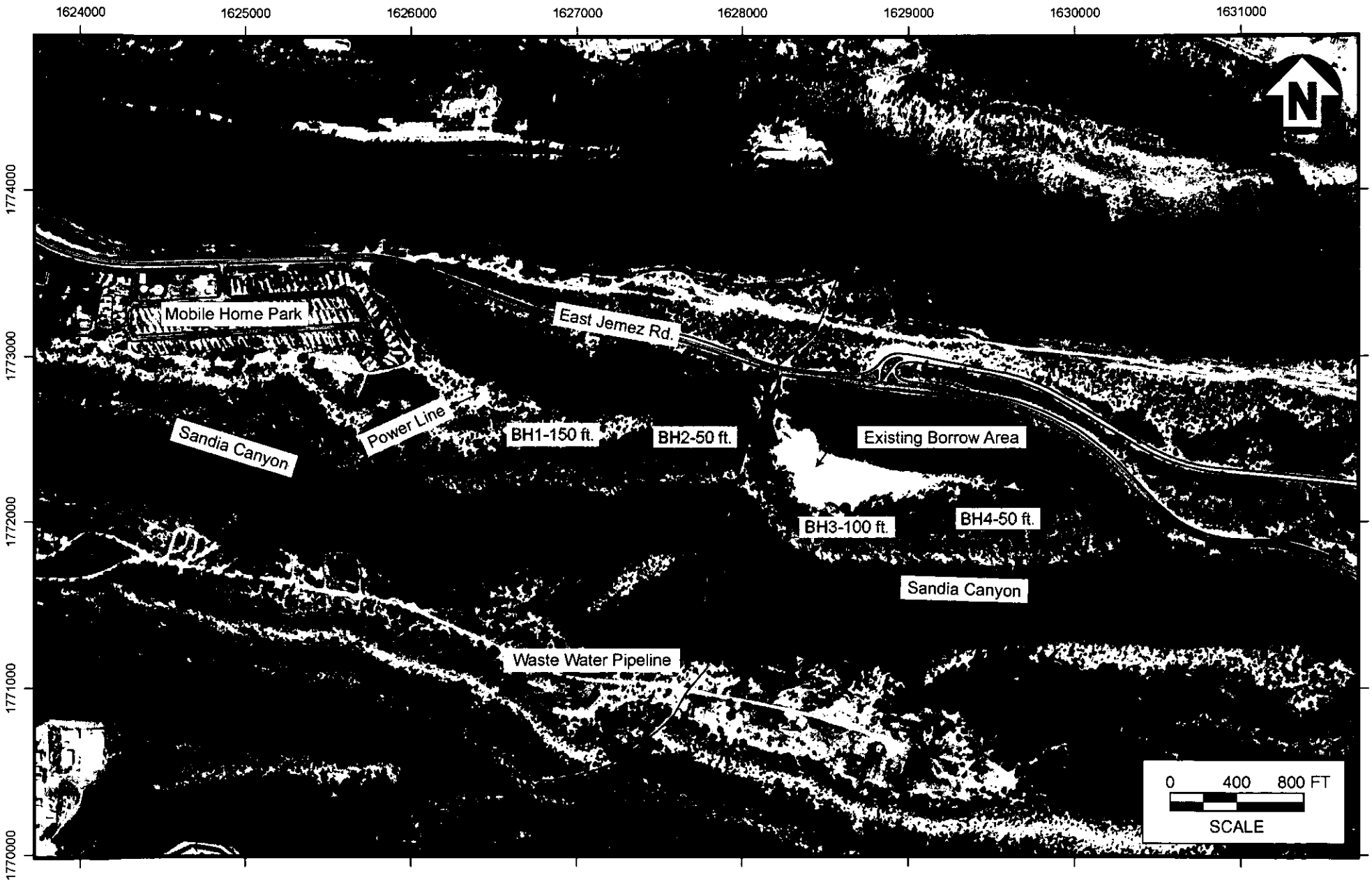

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Figure 7. **Borehole Locations and Depths, TA-61 Borrow Area**

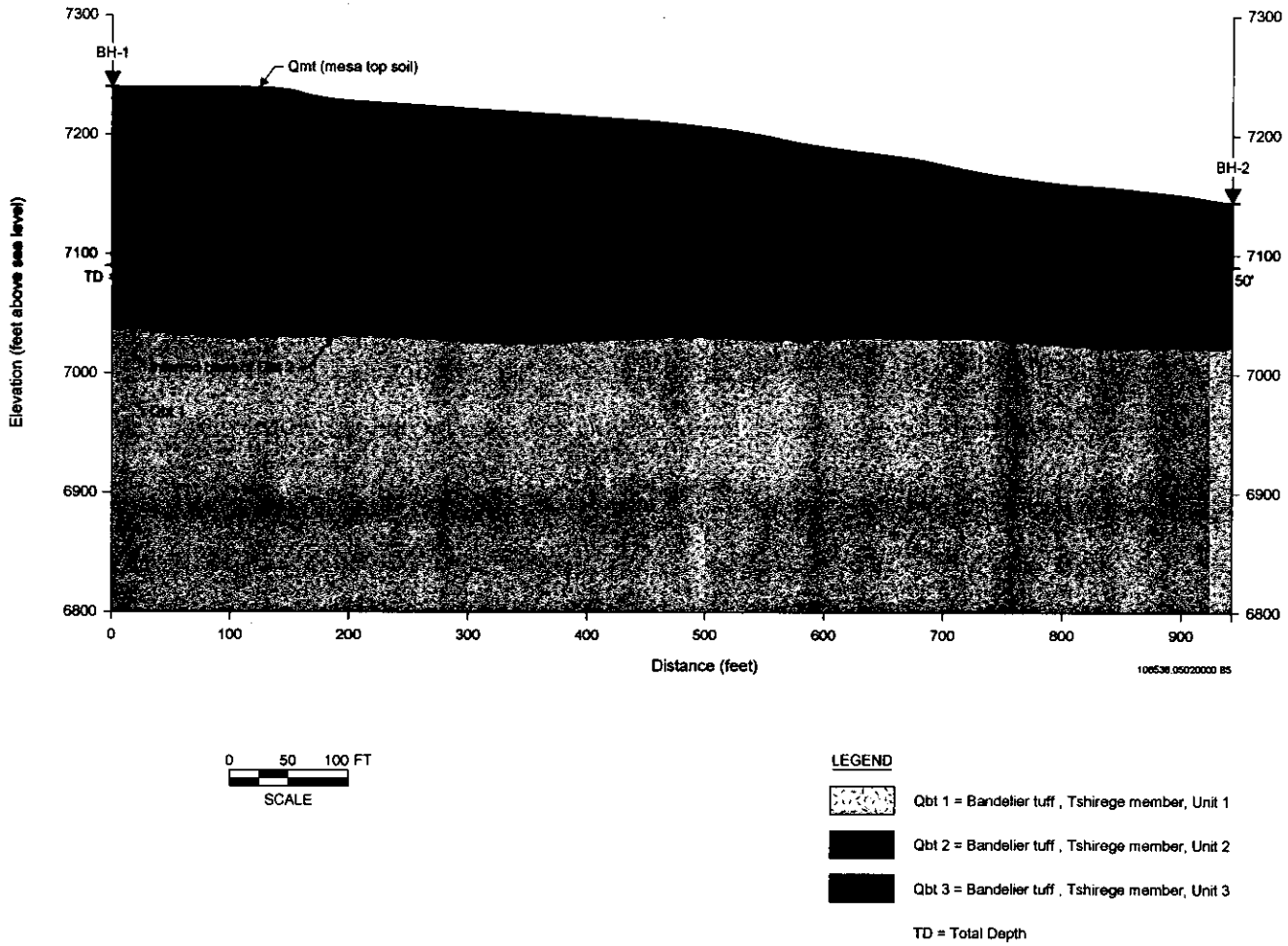

Figure 8. **BH-1 to BH-2 Cross Section, TA-61 Borrow Area Characterization**

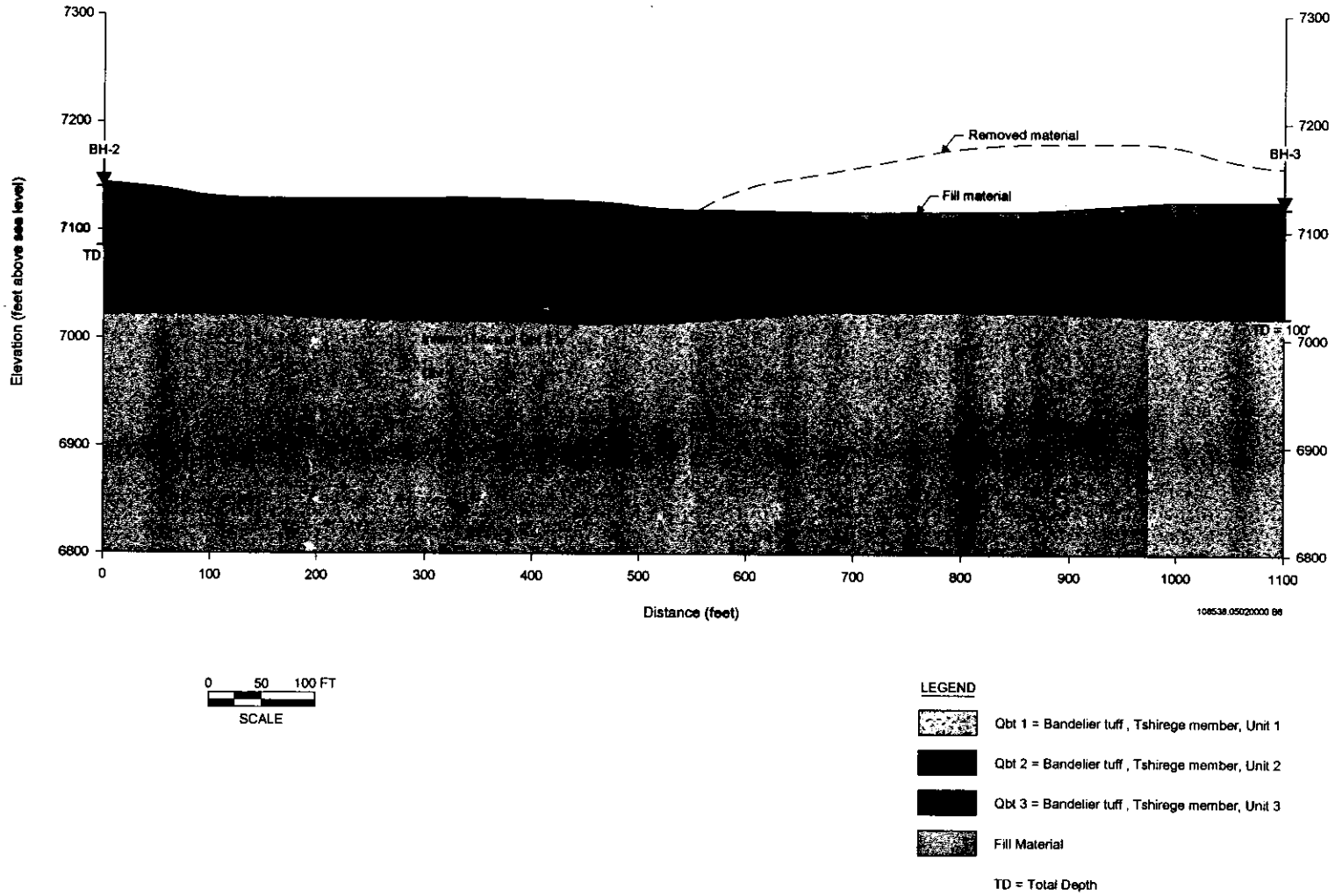

Figure 9. **BH-2 to BH-3 Cross Section, TA-61 Borrow Area Characterization**

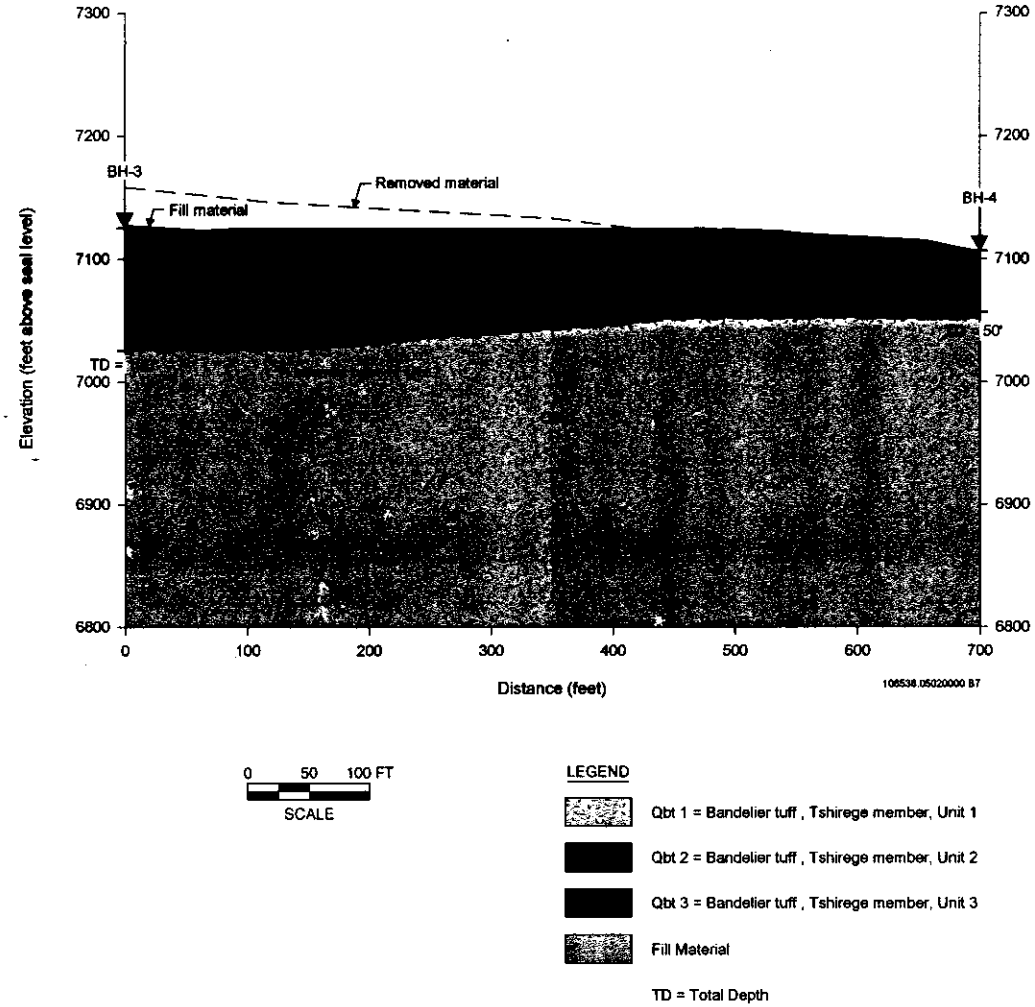

Figure 10. BH-3 to BH-4 Cross Section, TA-61 Borrow Area Characterization

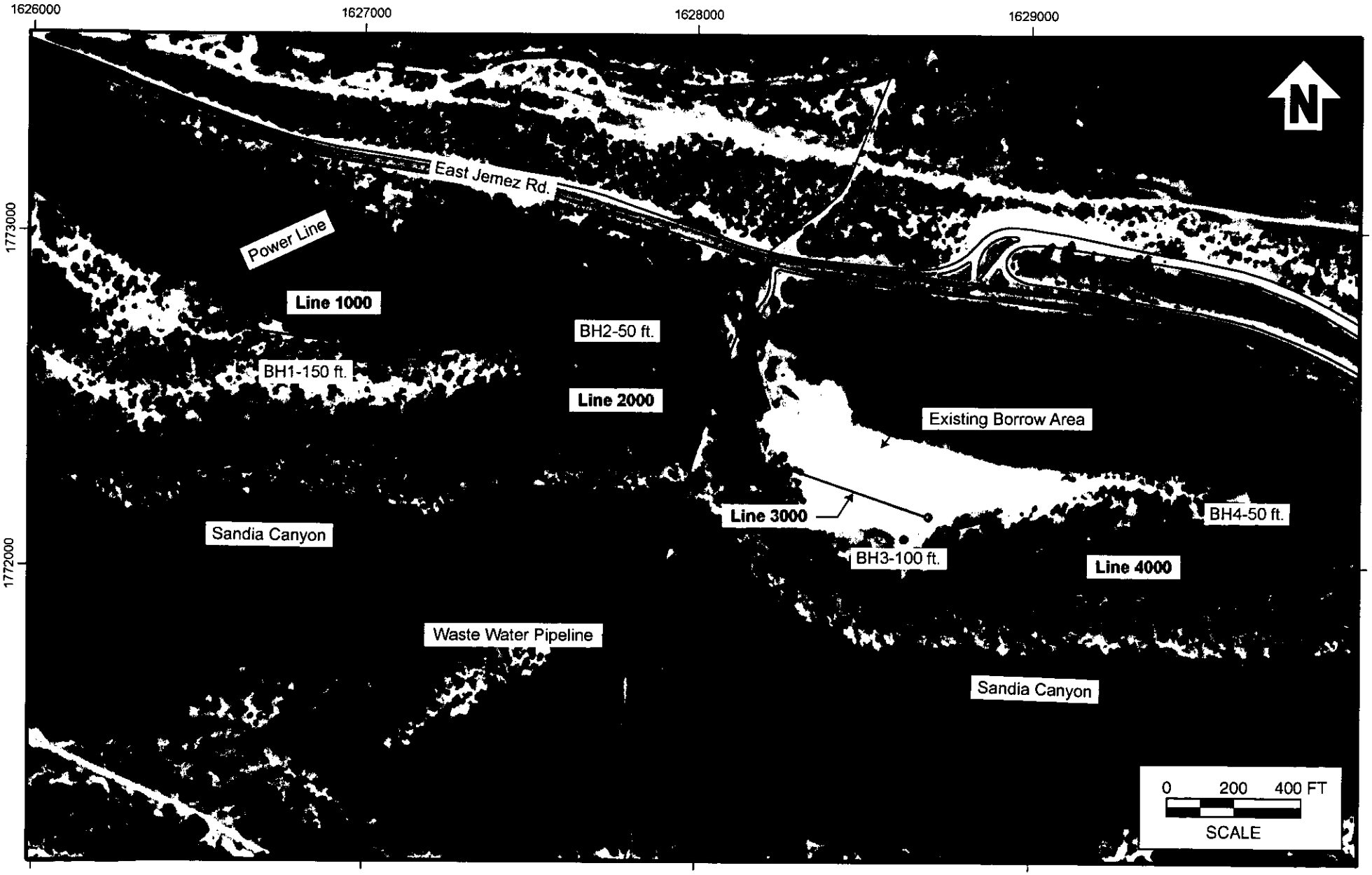

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Figure 11. Seismic Refraction Line Map, TA-61 Borrow Area

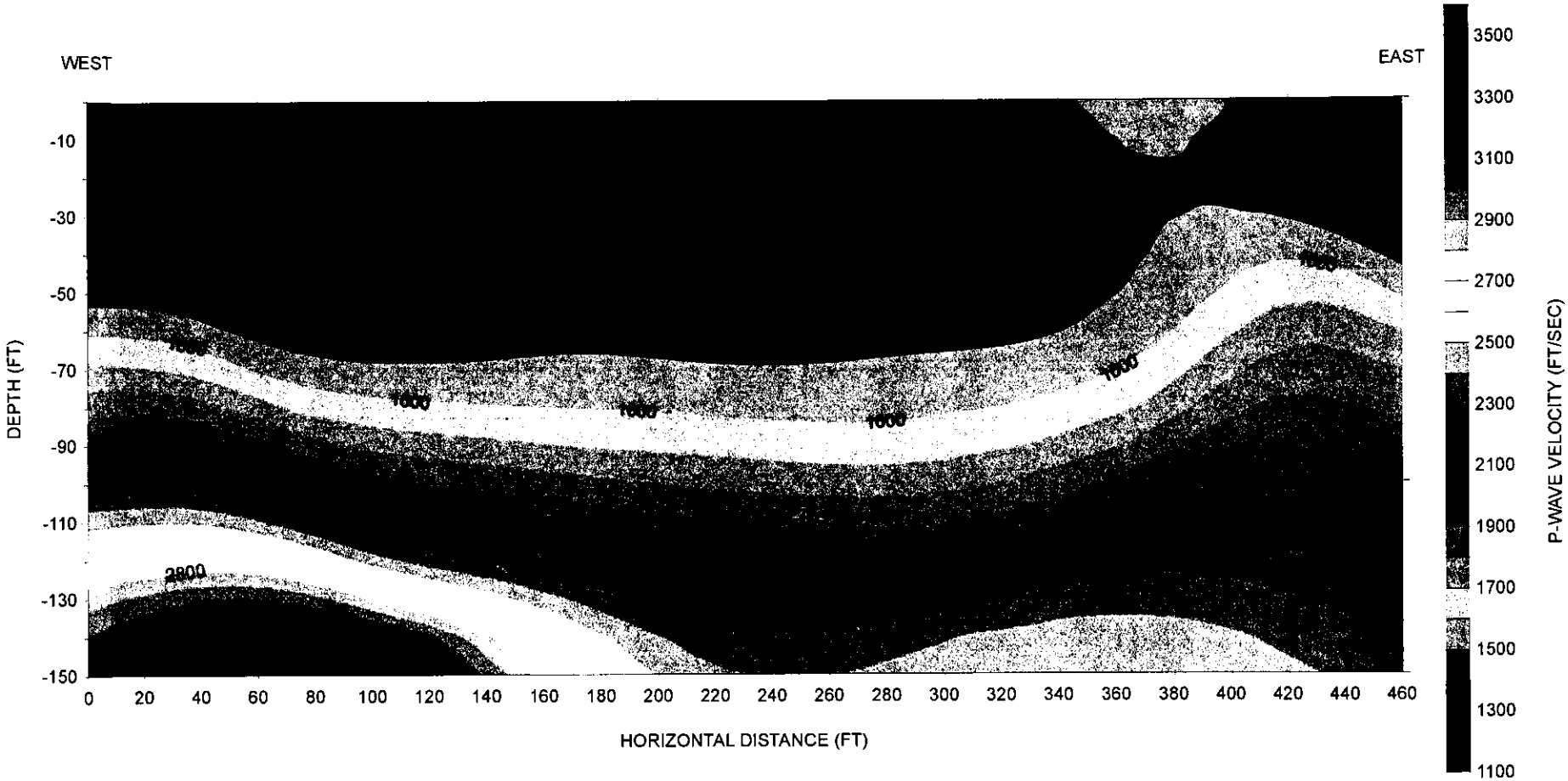

Figure 12. Seismic Velocity and Depth along Refraction Line 1000, TA-61 Borrow Area Characterization

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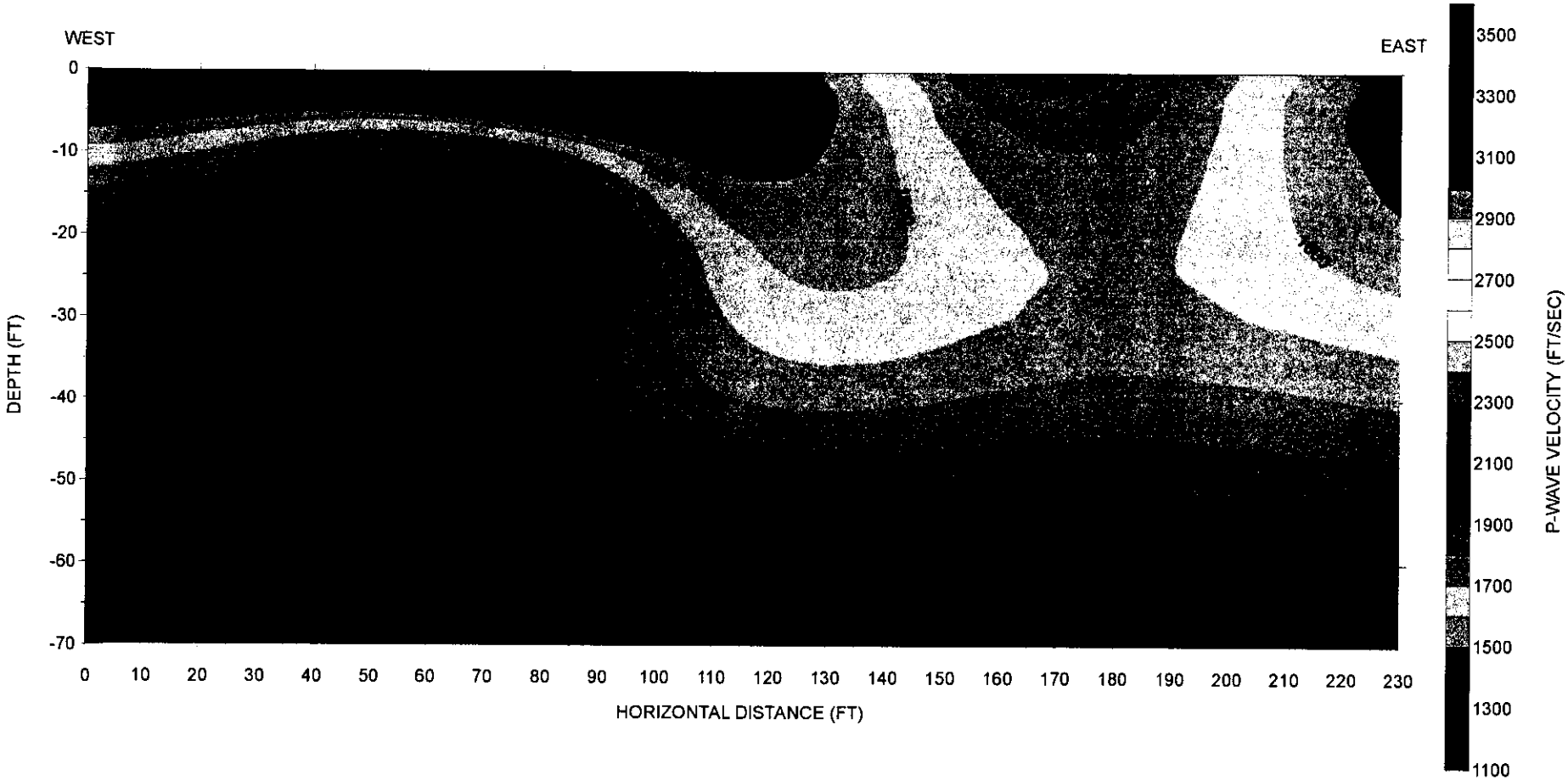

Figure 13. Seismic Velocity and Depth along Refraction Line 2000, TA-61 Borrow Area Characterization

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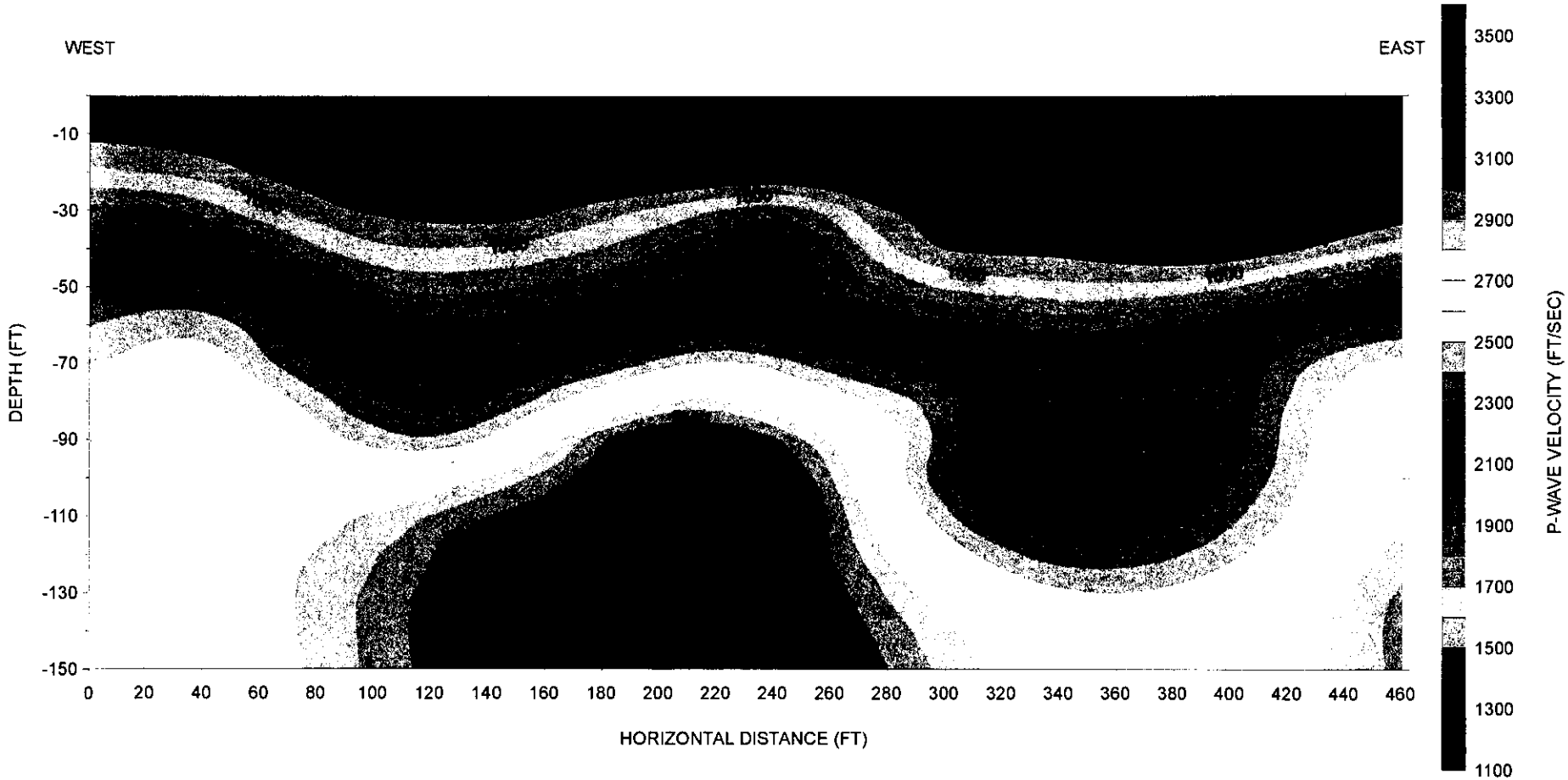

Figure 14. Seismic Velocity and Depth along Refraction Line 3000, TA-61 Borrow Area Characterization

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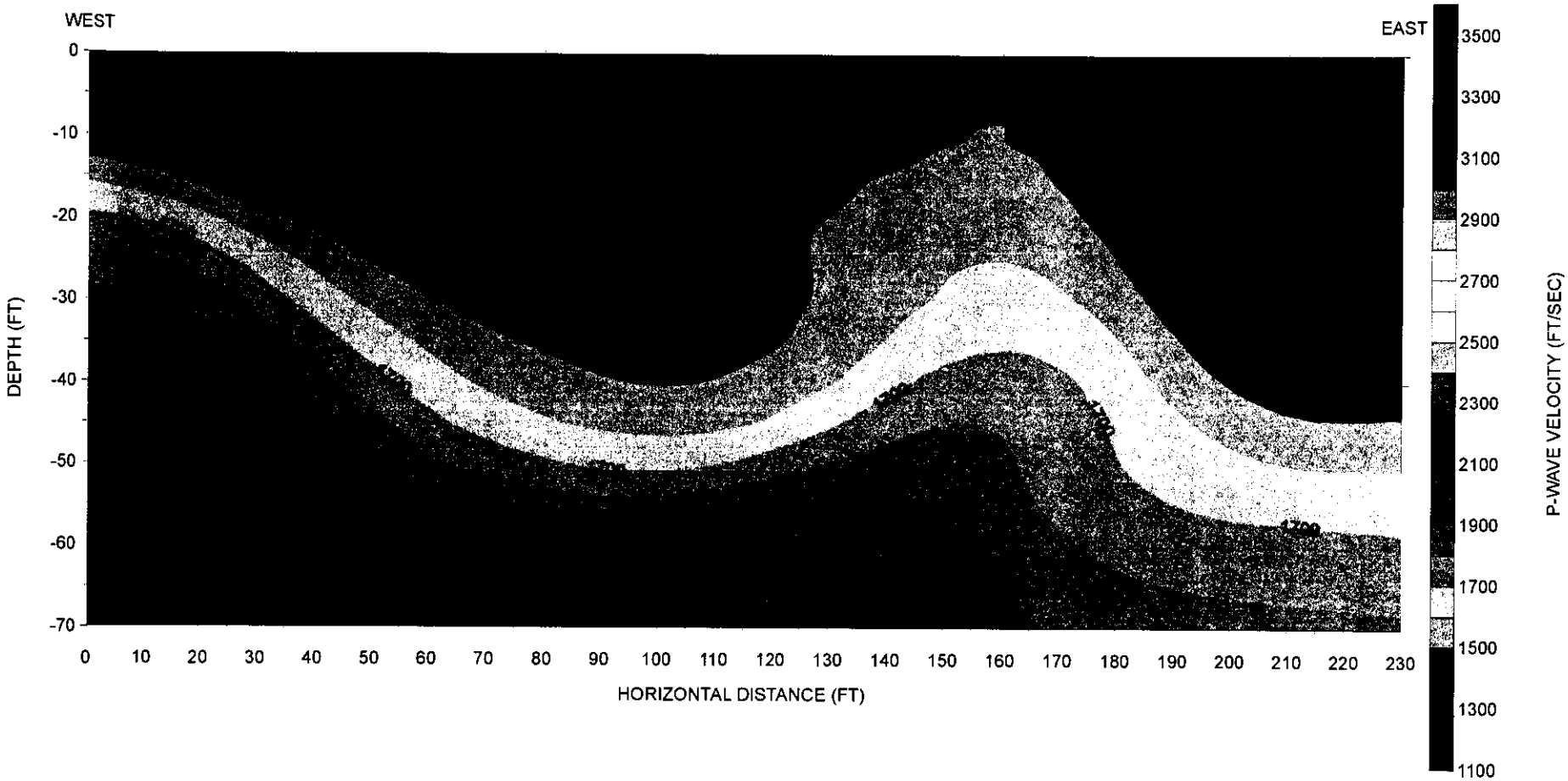

Figure 15. Seismic Velocity and Depth along Refraction Line 4000, TA-61 Borrow Area Characterization

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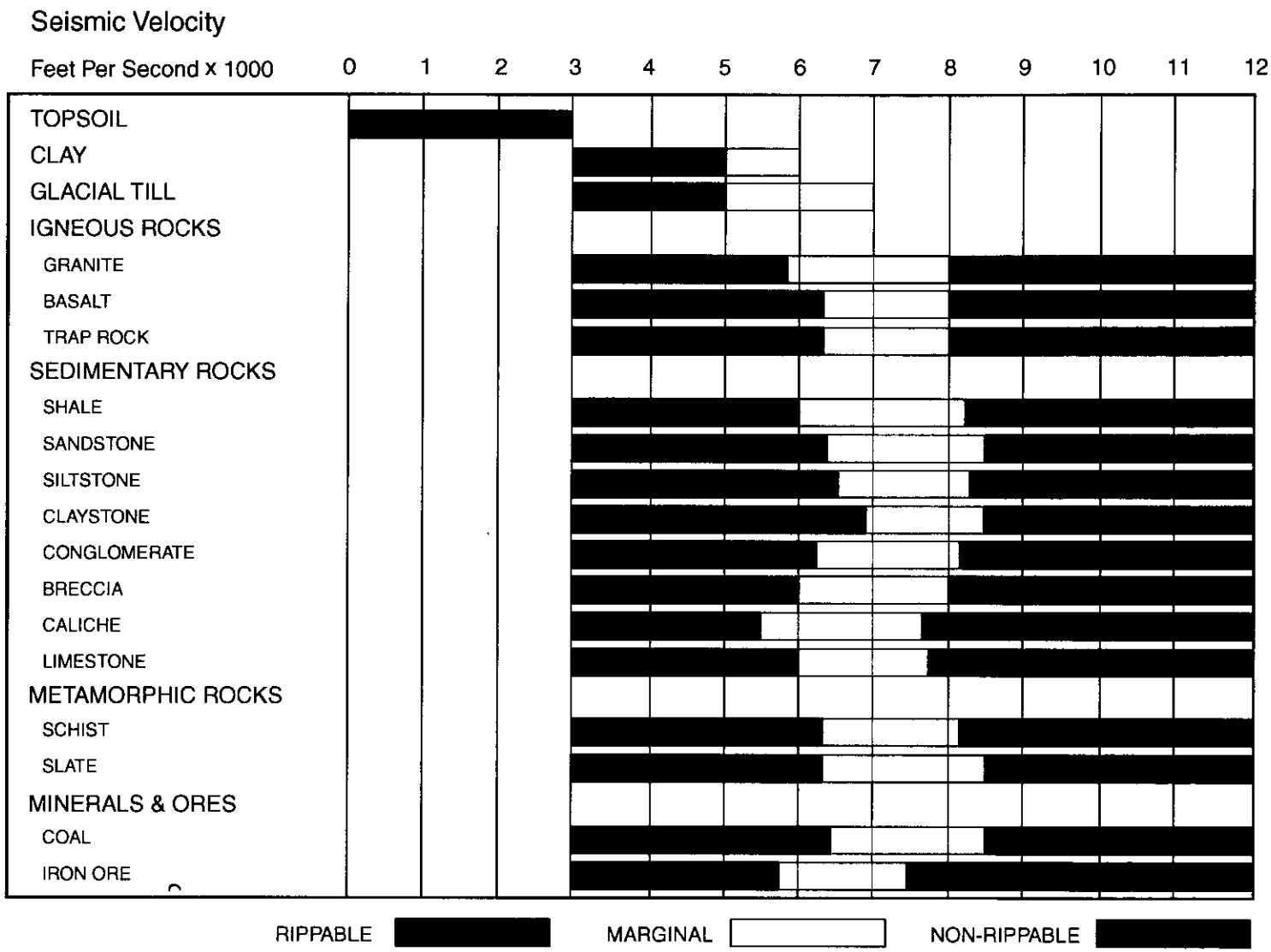

Figure 16. Rippability Chart (Catepillar, 1978) for TA-61 Borrow Area Characterization

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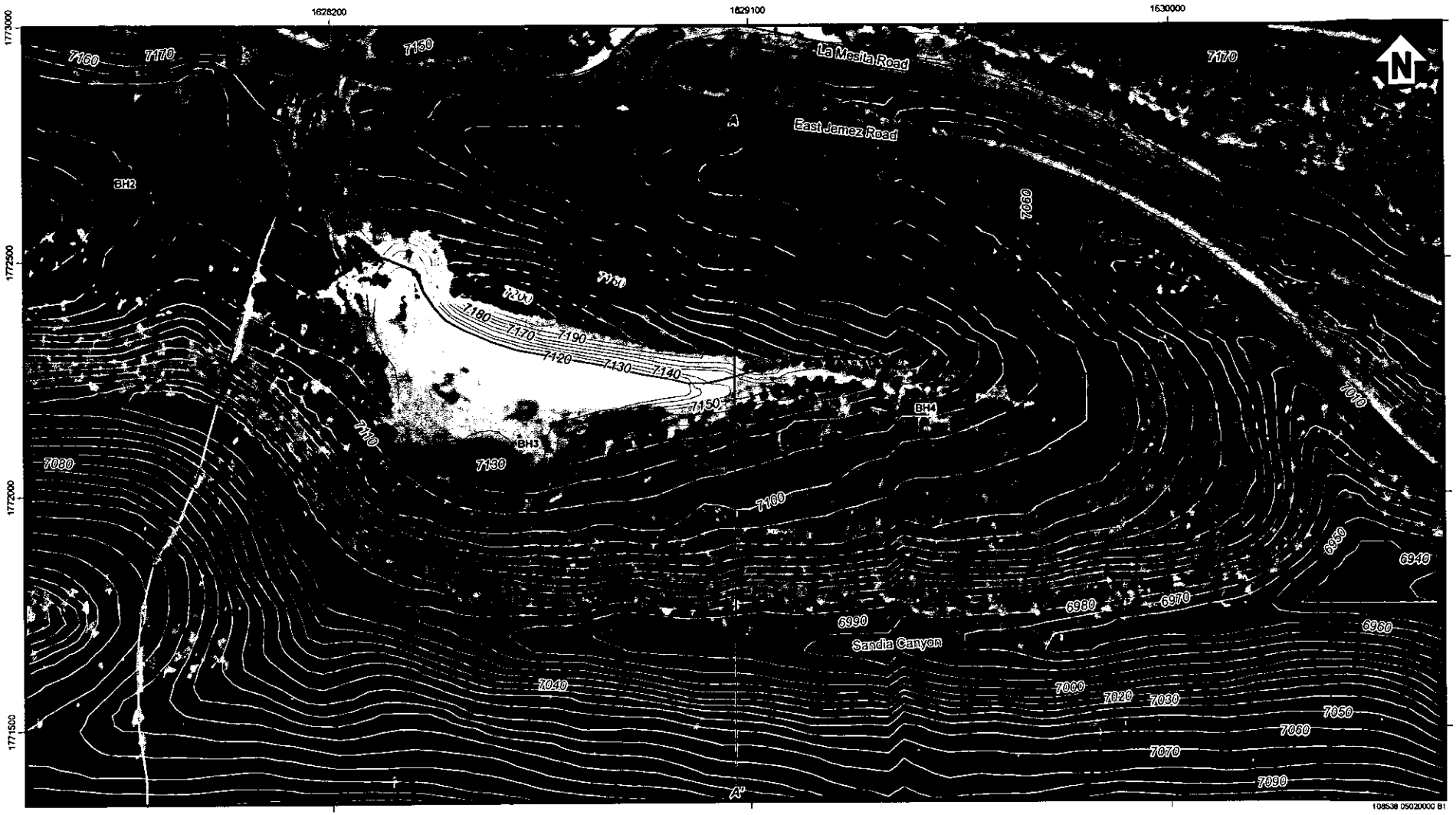

Figure 17. Site Map of TA-61 Borrow Area (aerial photo from October 1996)

Figure 18. **Map Showing Disturbed Area at TA-61 Following Proposed Excavation (aerial photo altered to simulate excavation)**

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Figure 19. **Cross Section, TA-61 Borrow Area (vertical factor = 2.5) (See Figure 17 for Cross Section Location.)**

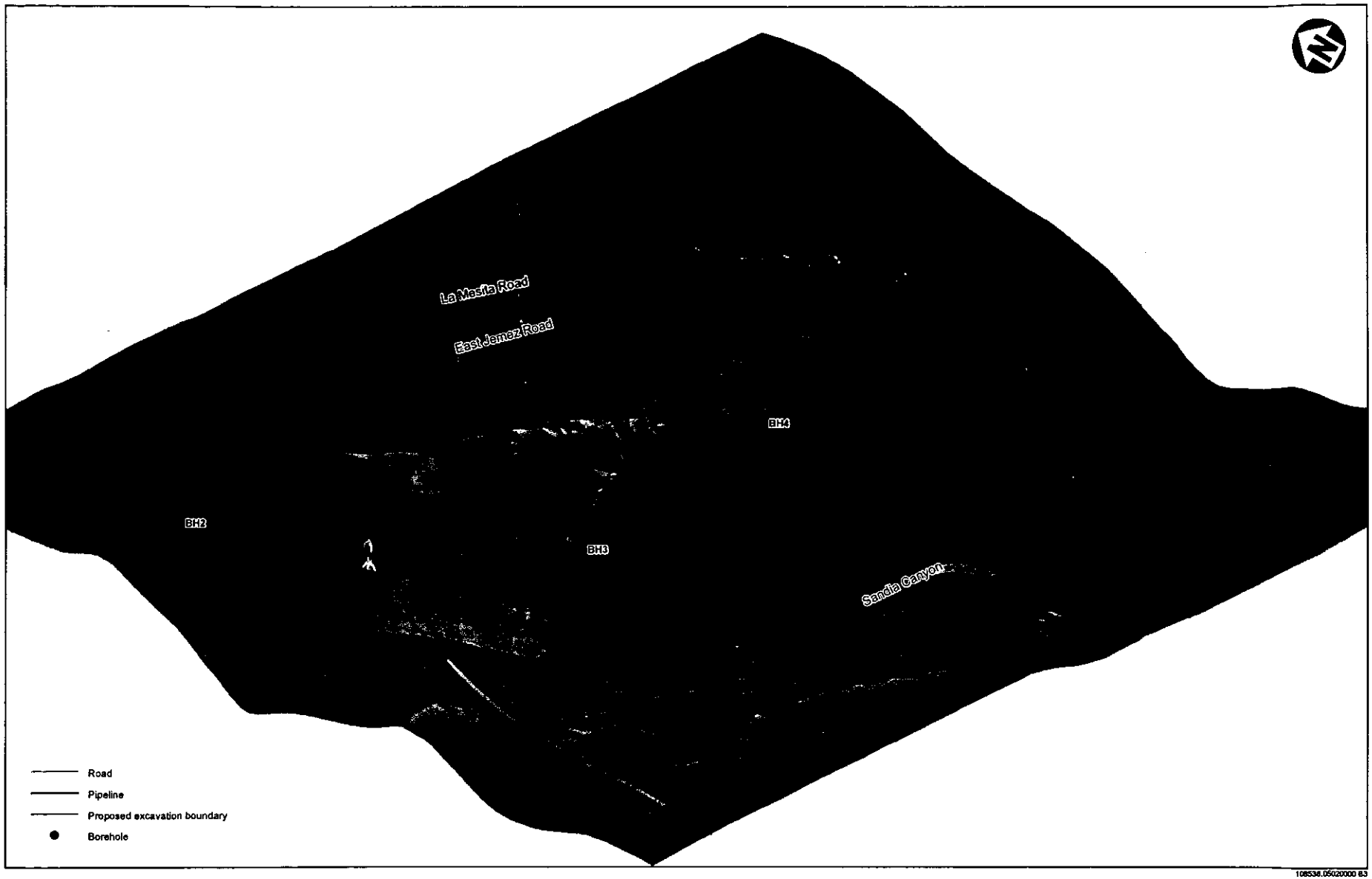

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Figure 20. **TA-61 Borrow Area Conceptual View Current Configuration**

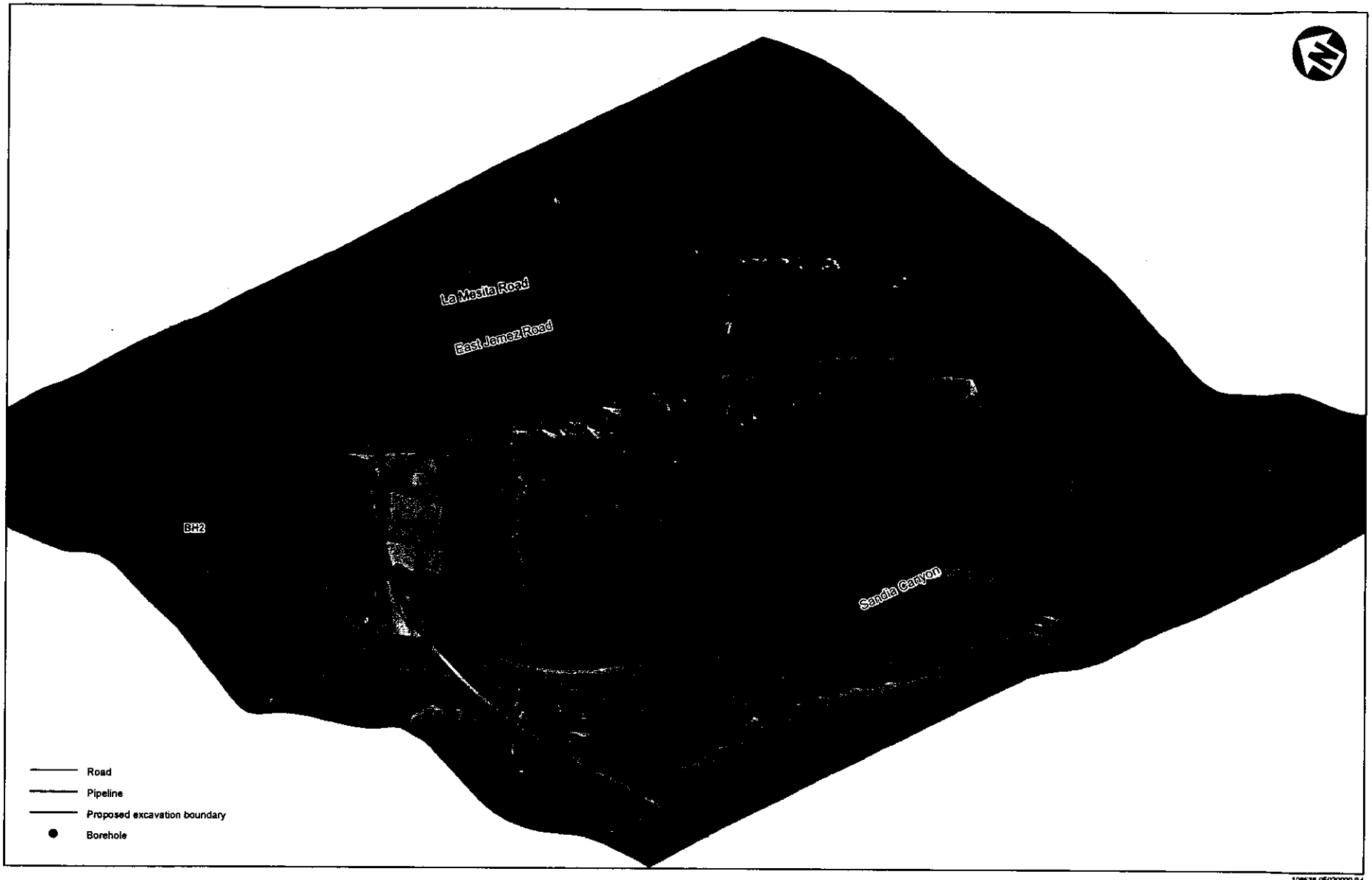


Figure 21. **TA-61 Borrow Area Conceptual View Post-Excavation Configuration**

108536.05020000 B4

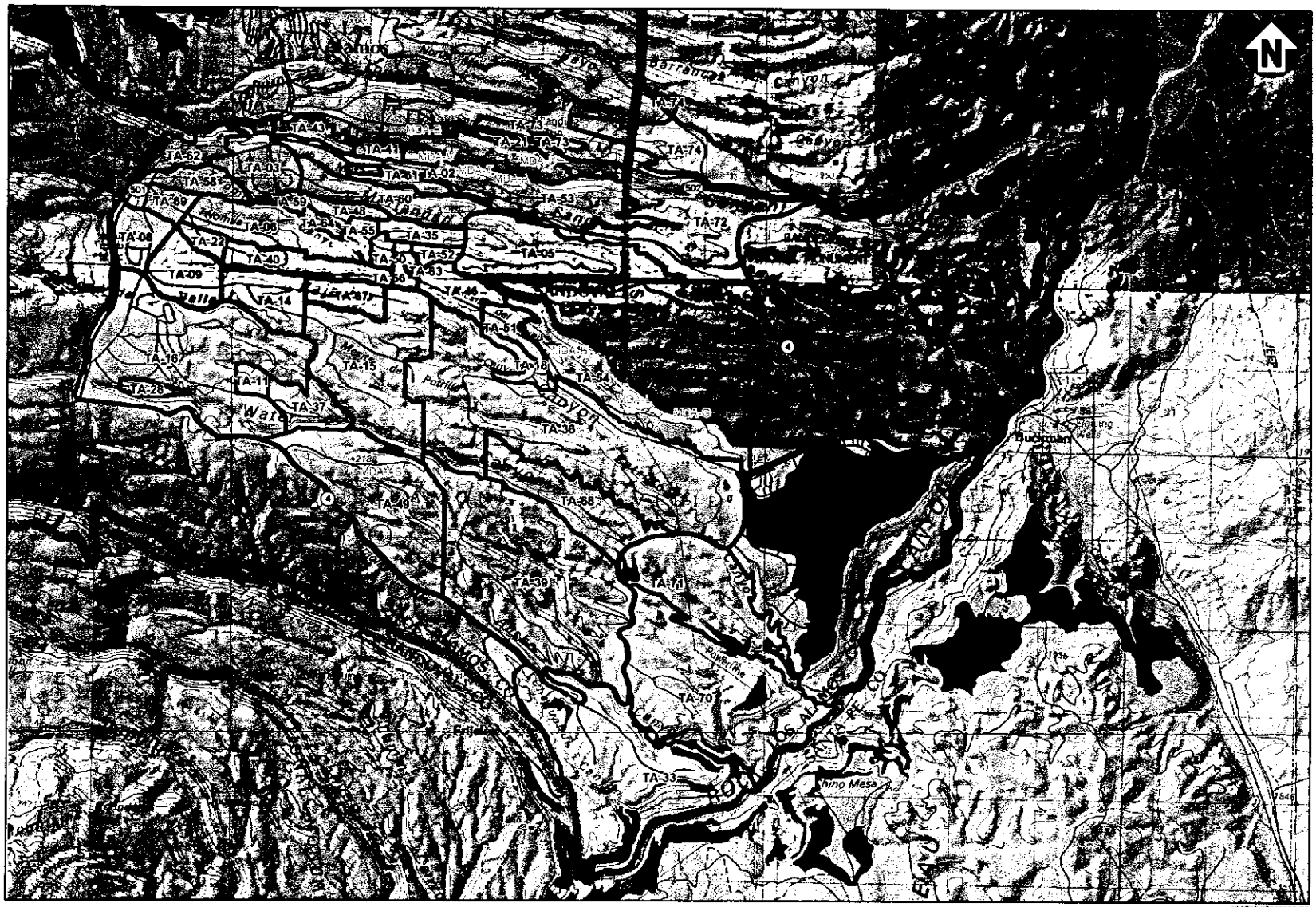


Figure 22. Basalt Outcrops at Los Alamos National Laboratory

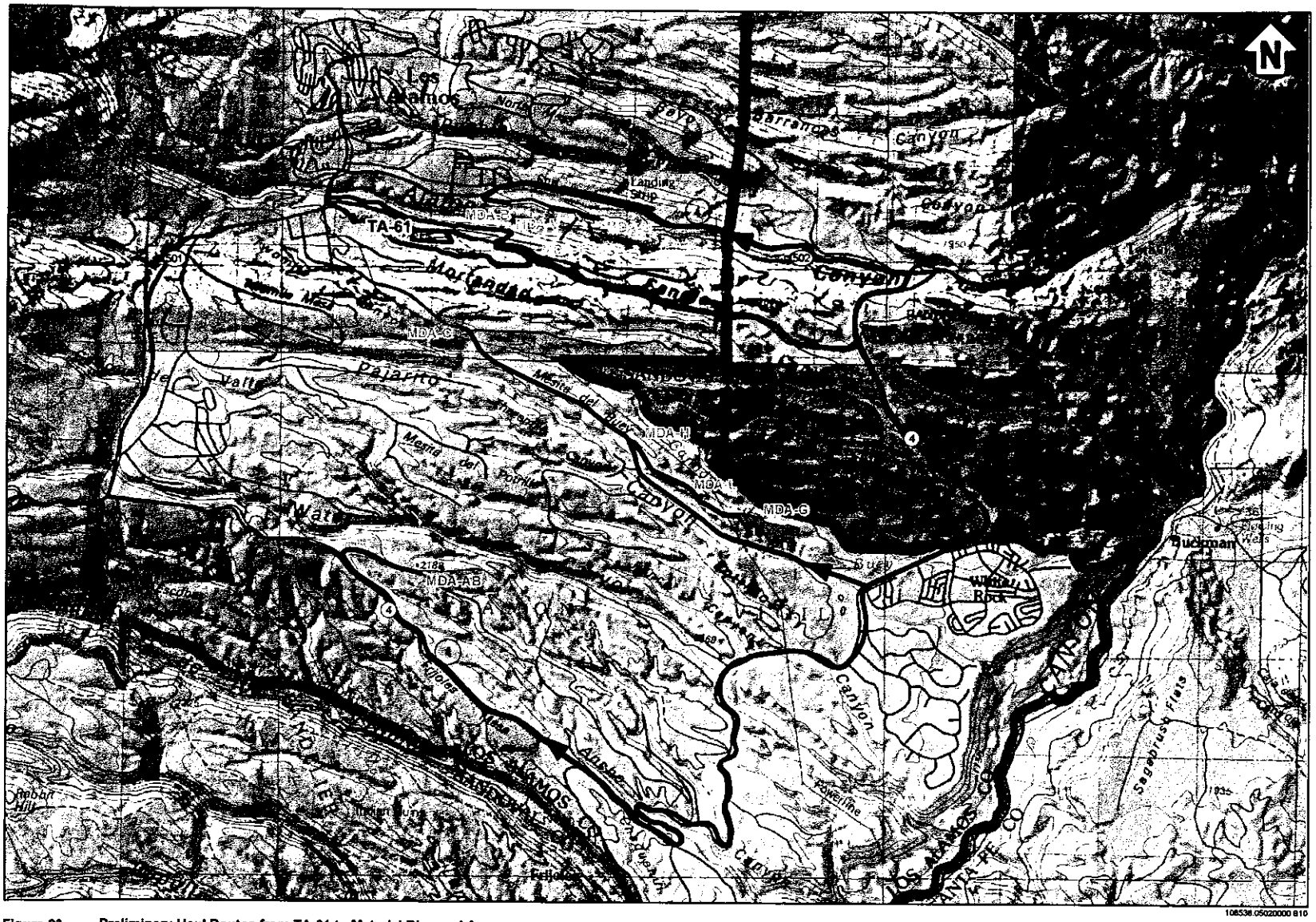
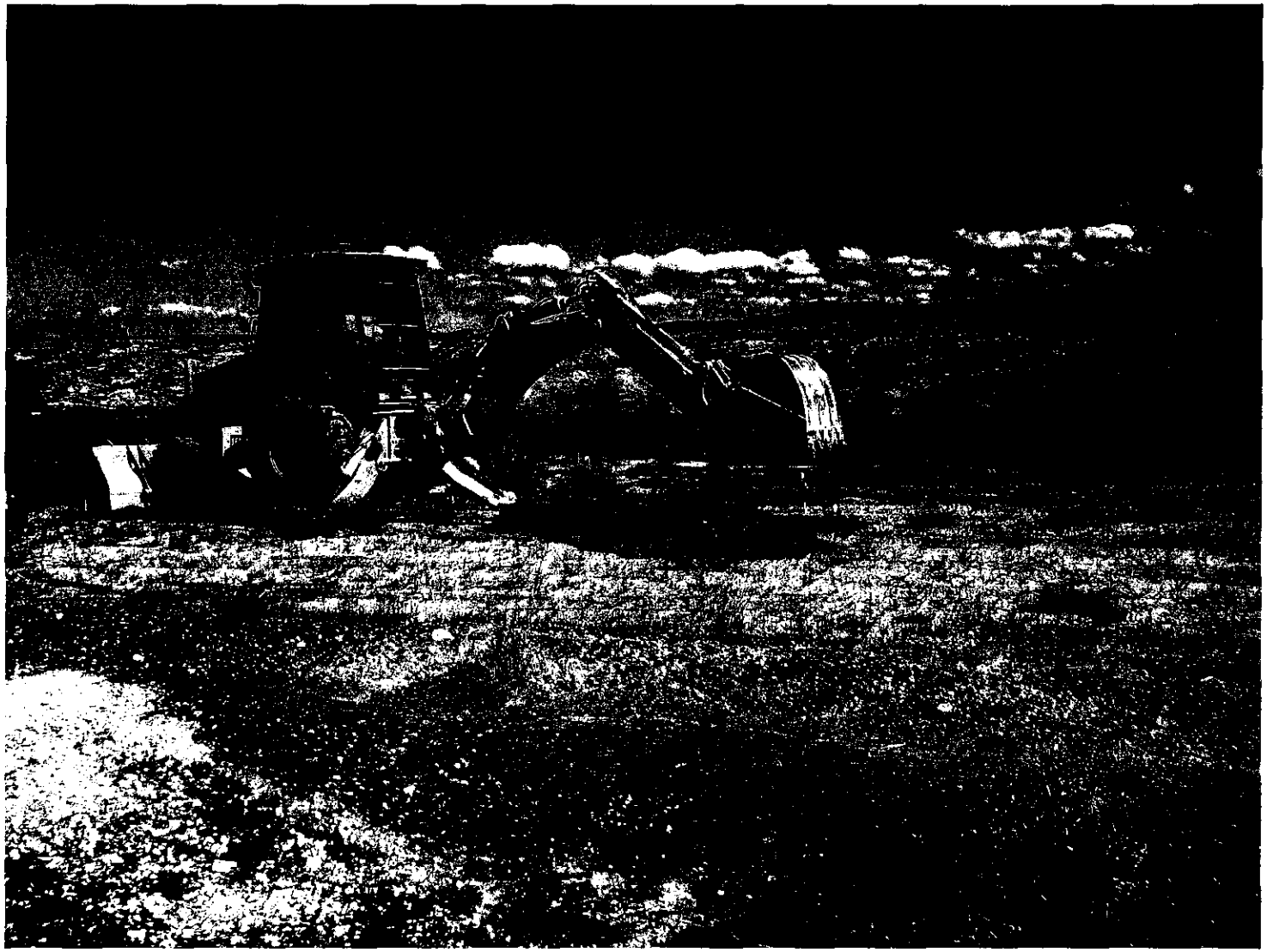


Figure 23. Preliminary Haul Routes from TA-61 to Material Disposal Areas



108538.05020000 A14

Figure 24. Backhoe Excavating Soil at Nambé Pueblo

Source: 2005 aerial photography from Santa Fe County GIS

108536 05020000 BB

● Soil sample location

▭ Nambé Pueblo boundary

0 300 600 FT

SCALE

Figure 26. Nambé Pueblo Soil Sampling Locations

108538.05020000 A13

Figure 26. Test Pit at Nambé Pueblo

Figure 27. Collecting Blended Soil in 5-Gallon Sample Container at Nambé Pueblo

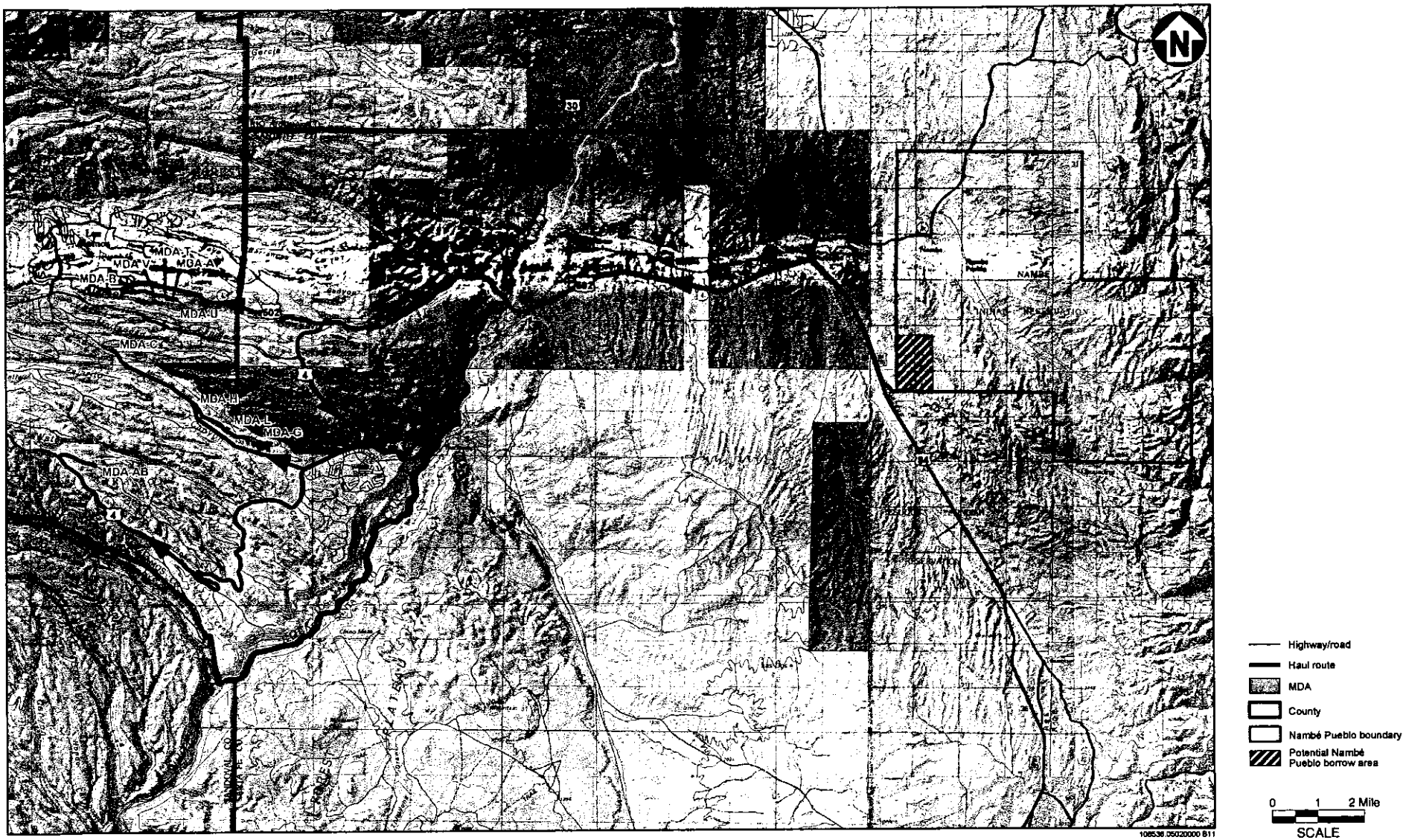


Figure 28. **Preliminary Haul Routes from Nambé Pueblo to Material Disposal Areas**

Appendix A
Field Activity Daily Logs from Borehole Drilling

PROJECT TITLE	LOCATION	REPORT DATE: 08/29/05
TA-61 Borrow Area Characterization	BH - 3	Start Time: 1300
		End Time: 1715

CONTRACTOR	CONTRACTOR'S REPRESENTATIVES
Shaw	Goodrich, Bowman, Martin

AM WEATHER	PM WEATHER	PRECIPITATION	MAX TEMP	MIN TEMP
NA	Hot, sunny	None	90°	75°

ON-SITE PERSONNEL AND TASKS PERFORMED/AREA OF RESPONSIBILITY

TRADE/TITLE	EMPLOYER	PERSONNEL	WORK DESCRIPTION	
FIELD TEAM LEADER	Shaw	A. Bowman (Angela)	Logbook, site control	
SITE SAFETY OFFICER	Shaw	P. Martin (Paul)	SSHASP/IWD Review	
GEOLOGIST	Shaw	A. Bowman	Log core	
WMC	N/A	N/A		
DRILLER	spectrum	D. Starnes (David)	Driller	
DRILLER ASSISTANT	spectrum	S. Henio (Shawn)	Driller Helper	
Geologist/Geotechnical Sampling	DBS+A	B. Gray (Bob)	Geotech. Sample	Collection
Project Manager	Shaw	M. Goodrich (Michael)	Site control, manage project.	

EQUIPMENT USED

DESCRIPTION	NO. OF UNITS	ARRIVAL DATE	LAST SAFETY CHECK	COMMENT
Drill Rig CME 85	1	8/29/05	8/29/05	OK

DESCRIPTION OF DAILY ACTIVITY

1. SSHASP Review and signature
2. IWD review and signature
3. Drilling 0–45' at BH-3. Collect geotechnical samples in 5-gall buckets (DBS+A). Geologic logs of core (Shaw Geologist), site photos.

4. Dustmeter # 3488 set up on drill rig.

Also, rig mobilized to site, rig inspection

SITE SAFETY	YES	NO
Was a safety meeting held today?	✓	
Any lost time accident occur?		✓
If yes, attach copy of completed report		
Any spills or hazardous waste released to the environment?		✓
If yes, attach copy of completed reports indicating response action and notification		
Any violations of job safety rules observed?		✓
If yes, attach copy of completed reports indicating response action		

Other Safety Comments

Dust meter battery died before end of day. Need to ensure battery won't die during full days onsite.

Date: 8/29/05

VISITOR LOG

NAME	Organization	Reason for being onsite	Time In	Time Out
Daniel Sandoval	LANL H+S	Safety Inspection	1330	1445
Medina Port-O'-Potty	Medina	Delivers Porta-John	1550	1600

TESTING AND QUALITY ACTIVITY PERFORMED

Geotechnical SPT Blow Counts collected every 5' run in two-foot core barrels (18-inches in a two foot core).

OFF-SITE SURVEILLANCE ACTIVITIES PERFORMED

NA

FIELD CHANGES

NA

SAMPLES COLLECTED

BH-3 5-10' (2) 5-gall. buckets 61-25130 Sample ID: RE61-05-63386

BH-3 20-25' (2) 5-gall. buckets 61-25130 Sample ID: RE61-05-63387

VIOLATIONS OBSERVED

None

NON-CONFORMANCE IDENTIFIED

None

OTHER COMMENTS

Drilling progressed from 0-45' @ BH-3. 2 geotechnical samples were collected in 2-5-gallon plastic buckets each. No intact core samples were collected, however, as the core was of too soft a material.

SPT blow-count samples were measured in two-foot cores at the beginning of each run. Each blow count was measured over 6-inches, three times in the 2-foot core. If the hammer took >50 counts to reach 6-inches, blow counts were suspended. Intervals from 15-40' all included blow counts >50/6 inches.

SIGNATURE OF SHAW FIELD TEAM LEADER	DATE
Angela L. Bowman Angela L. Bowman	08/29/05

Date: 8/29/05

PROJECT TITLE	LOCATION	REPORT DATE: 08/30/05
TA-61 Borrow Area Characterization	TA-61, Los Alamos BH-3	Start Time: 0630
		End Time: 1630

CONTRACTOR	CONTRACTOR'S REPRESENTATIVES
Shaw E+I	Bowman, Goodrich

AM WEATHER	PM WEATHER	PRECIPITATION	MAX TEMP	MIN TEMP
Cool, clear skies, sunny	Hot, partly cloudy	None	90°	56°

ON-SITE PERSONNEL AND TASKS PERFORMED/AREA OF RESPONSIBILITY

TRADE/TITLE	EMPLOYER	PERSONNEL	WORK DESCRIPTION	
FIELD TEAM LEADER	Shaw	Bowman/~~Goodrich~~ (AB) 8/30/05		
SITE SAFETY OFFICER	Shaw	Bowman		
GEOLOGIST	Shaw	Bowman		
WMC	—	—		
DRILLER	Spectrum	Starnes		
DRILLER ASSISTANT	Spectrum	Herio		
Geologist/Geotech Sampler	DBS+A	Gray		

EQUIPMENT USED

DESCRIPTION	NO. OF UNITS	ARRIVAL DATE	LAST SAFETY CHECK	COMMENT
CME 85	1	8/29/05	08/30/05	OK

DESCRIPTION OF DAILY ACTIVITY

1. Drilling at BH-3 from 45-100'. Completed at 1040. 4 geotechnical samples collected.
2. Trip out augers, bentonite grout BH-3.
3. Mob to BH-2 61-25135. Total depth of borehole anticipated 50'.
4. Complete drilling BH-2 to 50' bgs.
5. Trip out augers, bentonite grout BH-2.
6. Drill rig to stay @ BH-2 overnight. Will mob rig to BH-1 08/31/05 morning.

SITE SAFETY	YES	NO
Was a safety meeting held today?	✓	
Any lost time accident occur?		✓
If yes, attach copy of completed report		
Any spills or hazardous waste released to the environment?		✓
If yes, attach copy of completed reports indicating response action and notification		
Any violations of job safety rules observed?		✓
If yes, attach copy of completed reports indicating response action		

Other Safety Comments

Dust monitor set up at drill rig over BH-3.

Date: 08/30/05

VISITOR LOG				
NAME	Organization	Reason for being onsite	Time In	Time Out
MIKE GOODRICH	SHAW	PROJ. MGR.	0730	0930
Paul Martin	Shaw	safety	1000	1005
Sam Rogers	LANL	safety	1245	1300
Oliver Wilton	LANL	safety	1245	1300
Sam Rogers	LANL	safety	1320	1405
oliver wilton	LANL	safety	1320	1405
Scott den Baars	Shaw	Shaw Director	1425	1520
Roy McKinney	Shaw	Shaw V.P.	1425	1520

TESTING AND QUALITY ACTIVITY PERFORMED

NA

OFF-SITE SURVEILLANCE ACTIVITIES PERFORMED

NA

FIELD CHANGES

None

SAMPLES COLLECTED

1. BH-3 61-25130 (2) 5-gall. buckets 60-65' Sample ID: RE61-05-63388
2. BH-3 61-25130 (2) 5-gall buckets 90-95' Sample ID: RE61-05-63389
3. BH-2 61-~~25130~~ 25135 (2) 5-gall buckets 10-15' Sample ID: RE61-05-63391
4. BH-2 61-25135 (2) 5-gall. buckets 25-30' Sample ID: RE61-05-63392

VIOLATIONS OBSERVED

None

NON-CONFORMANCE IDENTIFIED

None

OTHER COMMENTS

Crew did not break for lunch. We worked straight through and ended work for day @ 1630

SIGNATURE OF SHAW FIELD TEAM LEADER	DATE
Angela Bowman Angela Bowman	08/30/05

Date: 08/30/05

PROJECT TITLE	LOCATION	REPORT DATE: 08/31/05
TA-61 Borrow Area Characterization	BH-1 TA-61	Start Time: 0700
		End Time: 1730

CONTRACTOR	CONTRACTOR'S REPRESENTATIVES
Shaw	Bowman, Howard

AM WEATHER	PM WEATHER	PRECIPITATION	MAX TEMP	MIN TEMP
Cool, Sunny	Hot, Sunny	None	90+	55°

ON-SITE PERSONNEL AND TASKS PERFORMED/AREA OF RESPONSIBILITY

TRADE/TITLE	EMPLOYER	PERSONNEL	WORK DESCRIPTION	
FIELD TEAM LEADER	Shaw	Bowman		
SITE SAFETY OFFICER	Shaw	Bowman		
GEOLOGIST	Shaw	Bowman		
WMC	—	—		
DRILLER	Spectrum	Starnes		
DRILLER ASSISTANT	Spectrum	Henio		
Training	Shaw	Howard (Amy)		
Geotechnical sampler	DBS+A	Bob Gray	onsite @ 1315	

EQUIPMENT USED

DESCRIPTION	NO. OF UNITS	ARRIVAL DATE	LAST SAFETY CHECK	COMMENT
CME 85	1	08/29/05	08/29/05	✓ OK

DESCRIPTION OF DAILY ACTIVITY

1. Mob drill rig to BH-1 from BH-2
2. Begin drilling 0900, BH-1 from 0. Refusal with hand auger @ 10".
3. Finish drilling @ 150' BH-1. Will finish last 20' 9/1/05 AM. Material became very hard @ 117'.

SITE SAFETY	YES	NO
Was a safety meeting held today?	✓	
Any lost time accident occur?		✓
If yes, attach copy of completed report		
Any spills or hazardous waste released to the environment?		✓
If yes, attach copy of completed reports indicating response action and notification		
Any violations of job safety rules observed?		✓
If yes, attach copy of completed reports indicating response action		

Other Safety Comments

Date: 08/31/05

VISITOR LOG				
NAME	Organization	Reason for being onsite	Time In	Time Out

TESTING AND QUALITY ACTIVITY PERFORMED

8/31/05 SPT blow counts conducted every 5 feet.
~~NA~~
(ab)

OFF-SITE SURVEILLANCE ACTIVITIES PERFORMED

NA

FIELD CHANGES

NA

SAMPLES COLLECTED

1) BH-1 61-25137 15-25' Sample ID: RE61-05-63393
2) BH-1 61-25137 40-50' Sample ID: RE61-05-63394
3) BH-1 61-25137 65-75' Sample ID: RE61-05-63395
4) BH-1 61-25137 90-95' Sample ID: RE61-05-63396
~~5) BH-1 61-25137 120-125' Sample ID: RE61-05-63397~~ (ab) 8/31/05
~~6) BH-1 61-25137 Sample ID:~~ (ab) 8/31/05

VIOLATIONS OBSERVED

NA

NON-CONFORMANCE IDENTIFIED

NA

OTHER COMMENTS

1. Fallen trees were cleared as of 1500 8/31/05. Drill rig will be moved to BH-4 ~~8/31/05~~ (ab) 09/01/05 morning after augers have been pulled and BH-1 has been grouted.
2. BH-1 contact Qbt 3/Qbt 2 gradational from 95'. Distinct hardness change at 117'; color change to pinkish gray from 95' but sanidine crystals present at 116'. Contact 117'.

SIGNATURE OF SHAW FIELD TEAM LEADER	DATE
Angela Bouman	08/31/05

Date: 08/31/05

PROJECT TITLE	LOCATION	REPORT DATE: 09/01/05
TA-61 Borrow Area Characterization	BH-1	Start Time: 0700
		End Time: 1630

CONTRACTOR	CONTRACTOR'S REPRESENTATIVES
Shaw	Bowman

AM WEATHER	PM WEATHER	PRECIPITATION	MAX TEMP	MIN TEMP
Cool, cloudy	storm clouds, rain	Afternoon Thundershowers	85°	50°

ON-SITE PERSONNEL AND TASKS PERFORMED/AREA OF RESPONSIBILITY

TRADE/TITLE	EMPLOYER	PERSONNEL	WORK DESCRIPTION	
FIELD TEAM LEADER 9/1/05	~~Bowman~~ Shaw	Bowman		
SITE SAFETY OFFICER	~~Bowman~~ ↓	↓		
GEOLOGIST				
WMC	—	—		
DRILLER	Spectrum	Starnes		
DRILLER ASSISTANT	Spectrum	Henio		
Geotechnical Sampler	DBS+A	Gray		

EQUIPMENT USED

DESCRIPTION	NO. OF UNITS	ARRIVAL DATE	LAST SAFETY CHECK	COMMENT
CME 85	1	08/29/05	09/01/05	OK ✓

DESCRIPTION OF DAILY ACTIVITY

1. Complete drilling and sampling from BH-1 130-150'. Complete @ 1000.
2. Trip augers, plug/abandon BH-1 with bentonite grout. Complete @ 1230.
3. Mob drill rig to BH-4. Set up @ BH-4 during rainstorm @ 1330.
4. Complete drilling at BH-4 from 0-50'. Complete @ 1530.
5. Complete trip out augers and grout/bentonite BH-4 @ 1630.

SITE SAFETY	YES	NO
Was a safety meeting held today?	✓	
Any lost time accident occur?		✓
If yes, attach copy of completed report		
Any spills or hazardous waste released to the environment?		✓
If yes, attach copy of completed reports indicating response action and notification		
Any violations of job safety rules observed?		✓
If yes, attach copy of completed reports indicating response action		

Other Safety Comments

None

Date: 09/01/05

VISITOR LOG				
NAME	Organization	Reason for being onsite	Time In	Time Out

TESTING AND QUALITY ACTIVITY PERFORMED

None

OFF-SITE SURVEILLANCE ACTIVITIES PERFORMED

None

FIELD CHANGES

None

SAMPLES COLLECTED

1. BH-1 61-25137 120-125' Sample ID: RE61-05-63397 (2) 5-gall. buckets
2. BH-1 61-25137 145-150' Sample ID: RE61-05-63398 (2) 5-gall. buckets
3. BH-4 61-25143 10-15' Sample ID: RE61-05-63399 (2) 5-gall. buckets
4. BH-4 61-25143 30-40' Sample ID: RE61-05-63400 (2) 5-gall. buckets

VIOLATIONS OBSERVED

None

NON-CONFORMANCE IDENTIFIED

None

OTHER COMMENTS

- Afternoon thunderstorms occurred onsite from 1230-1330 today. Crew set up drill rig and drilling commenced after worst of the rain had passed. The rain did not affect access to BH-4.
- Drill crew worked through lunch. Bowman, Gray took lunch (30 minutes).

SIGNATURE OF SHAW FIELD TEAM LEADER

DATE 09/01/05

Date: 09/01/05

Appendix B
Field Notes

TA-61 Borrow Area Characterization 08/29/05

1200 M. Goodrich (Shaw), D. Starnes, S. Henio (Spectrum) onsite.

1300 B. Gray (DBStephens), P. Martin, A. Bowman (Shaw) onsite.

1330 D. Sandoval (LANL Safety) onsite. Goodrich, Martin, Bowman setting up safety barrier.

1400 Tailgate safety meeting, SSHASP review and IWD review conducted by P. Martin (Shaw H+S). D. Sandoval present.

1500 Reviews complete. Sandoval offsite.

1510 Goodrich hand auger BH-3 to refusal at 24". Drilling to commence at BH-3. SPT (Standard blow-count Penetration Tests) will be conducted in 2-foot split spoon core barrels in three consecutive 6-inch measures. If blows are >50 counts in 6 inches or less, counting will be discontinued.

1715 Drilling complete for day at 40'. B. Gray from DBS+A offsite, samples containerized, labeled and kept under Gray's custody.

1730 Crew offsite. Will meet at 0700 Tuesday. Bowman to Shaw office to turn in Field Activity Daily Log.

Angela Bowman

08/29/05

[redacted]

TA-61 Borrow Area Characterization 08/30/05

0630 A. Bowman (Shaw FTL) onsite preparing for day's activities.

0700 S. Henio, D. Staines, B. Gray onsite. Daily Tailgate safety meeting conducted. Current weather cool, clear skies. High's expected in 80's today, little to no chance for thunderstorms. Fire danger low to moderate. Health + safety hazards include: slips/trips/falls, heavy lifting, rotating parts, overhead machinery.

0715 Commence drilling from 40 feet at BH-3.

0720 Hardness change (becoming slightly softer) noted at 48'. SPT blow counts continue to penetrate >50 counts for < 6 inches.

0750 M. Goodrich onsite. He signed Visitor Log as he is observing activity, but also signed Daily Tailgate Safety Form.

0830 Drill rig mast put down to repair center wench line.

0845 Mast put back up. Center wench line repaired. ~~Resume drilling.~~ 8/30/05

0850 Resume drilling. J. Hopkins call to check on progress.

0930 M. Goodrich offsite to Shaw office

1000 P. Martin onsite.

1005 Martin offsite.

1040 BH-3 complete to 102'. Crew taking break before proceeding with trippout augers and grout borehole.

1115 Crew tripping out augers and grout borehole. Crew will work through lunch since FTL Bowman must leave site at 4:00 pm today.

1230 Mob rig to BH-2, conduct site walk to ensure drill rig can make it to borehole. Driller confident rig can make it.

1245 Rogers, Wilton onsite

1300 Rogers, Wilton offsite, will return once we have rig mobed to site.

1315 Drill rig over BH-2.

1320 Crew setting up safety barrier. Rogers, Wilton return to site, drive up to BH-2.

1330 Conduct afternoon TGSM to reiterate dead/fallen trees, snakes, mice. Crew initial TGSM, Rogers, Wilton sign for first time.

1345 Begin drilling at BH-2. M. Goodrich hand auger to refusal at 18".

1405 Rogers, Wilton offsite.

1425 Scott den Baars, Roy McKinney onsite.

1530 Goodrich spoke to C. Trujillo to get fallen trees chopped for access to BH-4. Will hopefully be out tomorrow.

1535 Goodrich offsite.

08/30/05 (cont.) TA-61 Borrow Area Characterization

1600 Drillers complete pulling out augers and abandoning borehole with bentonite/grout mix.

1630 Crew finished cleaning up site and putting equipment away. Drillers will leave drill rig at BH-2 location for safety reasons and will mob rig to BH-1 8/31/05 morning.

1635 Crew offsite for day. Access gate closed and locked.

[signature]

8/30/05

TA-61 Borrow Area Characterization 08/31/05

0645 A. Bowman, A. Howard meet at Shaw office to get vehicle and mob to site.

0700 Bowman, Howard onsite at TA-61.

0715 Staines, Henio onsite to mob drill rig to BH-1.

0900 Drill rig at gate to get into BH-1. Drillers open gate by loosening hinge on gate and lifting. Gate remain open while drilling commencing.

Late Entry 0730 Bowman conducts tailgate safety meeting. Weather now cool, sunny, highs expected in 90's. BH-1 is on top of hill, exposed with little tree cover. Heat stress, sunburn and dehydration, as well as heavy lifting, overhead machinery, rotating parts. Today's activities include mob rig from BH-2 to BH-1, begin drilling at BH-1, collect geotechnical samples (DBS+A).

1130 Break for lunch

1215 Return from lunch, resume drilling.

1315 B. Gray (DBS+A) onsite.

1500 Bowman check on progress of tree clearing (Crew arrived at 1030 to begin clearing trees NOTE). Tree clearing complete; Bowman drove route with no trouble.

1715 Drillers reach 130'. Everyone in crew sunburned with no cover at this borehole location. Crew decides to end for day as drilling has also become much harder. Will continue from 130' at 0700 9/1/05.

1730 Crew offsite. Bowman to Shaw office to return truck and submit dailies.

[redacted]

TA-61 Borrow Area Characterization 09/01/05

0700 Bowman at Shaw office to pick up truck and supplies.

0730 Bowman, Starnes, Henio onsite. Bowman conduct TGSM. Hazards today include rain, wind, fallen and dead trees, heat stress, sunburn, overhead machinery, rotating parts, heavy lifting.

0745 Today's activities include: complete drilling to 150' at BH-1, trip out augers and plug/abandon BH-1 with bentonite grout, mob drill rig to BH-4, drill to 50' and collect geotech samples; trip augers and plug/abandon BH-4 with bentonite grout.

0800 check in with Shaw PM Mike Goodrich about status of BH-1.

1000 Complete drilling at BH-1. Refer to Field Activity Daily Logs for sample ID numbers. Drillers begin tripping out augers.

1100 Break for lunch. Gray offsite.

1130 Resume tripping out augers and abandoning hole with bentonite grout.

LATE ENTRY 0830 B. Gray onsite. Collect cuttings sample from 120-125'.

1230 Drillers finished with BH-1. Drill crew must refill water for abandoning BH-4. Bowman to Borrow Area to wait for crew ~~weather~~ 9/1/05 Storm clouds quickly approaching from the west. Strong chance of thundershowers this afternoon.

1235 Thundershowers begin, rain coming down steadily.

1315 Drillers and B. Gray onsite with equipment.

1325 Thundershowers pass through. Still very cloudy but will keep an eye on weather while we continue to BH-4.

1330 Mob rig to BH-4.

1500 Complete drilling to 50' bgs. Crew take break than begin plug and abandon of BH-4.

1600 Crew finished plug and abandon of BH-4, cleaning up site.

1630 Crew offsite. Bowman will clean truck, return site key, submit reports tomorrow morning.

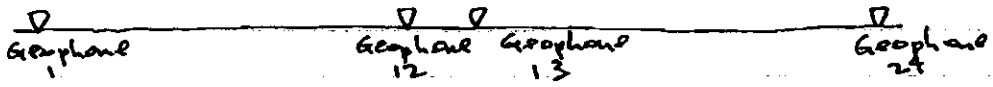
[signature] 9/1/05

TA-61 Seismic Refraction Survey 07.13.2005

07:15 Tailgate safety meeting with Mike Goodrich, Marty Miele, Amy Howard, Cory Gilbert (all Shaw Personnel)

0745 Site walk to all 4 boreholes

0800 Amy and Cory begin laying seismic equipment at borehole 4



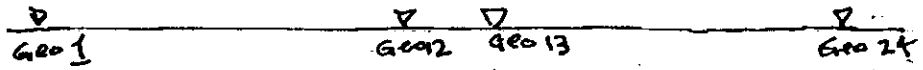
→ 10 foot spacing on geophones = 240 ft spread
→ shots five feet off each end, one in middle, and two at halfway points
shot total = 5

10:00 Begin data collection over borehole 4
Filename is 4000 - 4004 Shot stack = 4
Shots 4000 - 4004
Shots @ -5, 6 & 7 (Geos), 12 & 13 (Geos), 18 & 19 (Geos), +5

10:30 Done with borehole 4, pick up and collect GPS data
Filename is line 4000

11:30 LUNCH

12:15 Set-up seismic refraction survey for borehole 2



→ 10 foot spacing on geophones = 240 ft spread
→ shots five feet off each end, one in middle, and two halfway points = 5 total shots
NOTE: borehole is at ~10-11 (geophones) and ~30-40 ft north of seismic line

13:20 Begin data collection on borehole 2
Filename is 2000 - 2004 Shot stack = 5
Shots ~~2000~~ 4005 - 4009
Shots @ -5, 6 & 7 (Geos), 12 & 13 (Geos), 18 & 19 (Geos), +~~8~~ (UG) +5

13:40 Done with borehole 2, pick-up equipment

14:30 Collect GPS data over borehole 2
Filename is line 2000

14:50 Return to Shaw office

[redacted]

15:15 loading DigiPulse for work tomorrow
15:45 Return to hotel, download data

NOTES:

→ Both lines today had high frequency noise in the last four channels... not sure what is causing, but the data is good, and first picks will be pickable

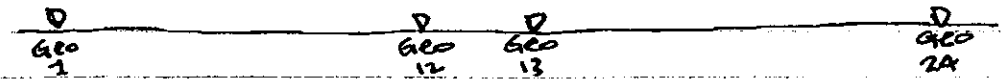
→ We forgot to change the shot numbers on the second line, so they are 4005 - 4009 instead of 2000 - 2004... filenames didn't changed... they are 2000 - 2004

TA-61 Seismic Refraction Survey 09.14.2005

0715 Tailgate safety meeting with Cory Gilbert, Marty Miele, and David Rust (all Shaw Personnel)

0725 Setting up digipulse source

0830 Laying out line for borehole 3



→ 20 foot spacing on geophones = 480 ft

→ shots at 10 ft off each end, one in middle, and two at halfway points

total shots = 5

0945 Begin data collection over borehole 3

Filename is 3000-3004

Shots 3000-3004

Shots -10, Geos 6 & 7, Geos 12 & 13, Geos 18 & 19, +10

1130 Finish data collection on borehole 3, pick-up

11:40 Collect GPS data over seismic line

Filename is line 3000

1210 Lunch

1245 Back to site, looking at area around borehole 1... we planned out the survey, but we don't have time to complete the survey by the end of the day

13:45 Back to area around borehole 3 to take apart the digipulse

1410 Putting extra equipment in the office storage unit

1430 At Shaw office getting some paperwork and arranging help for tomorrow

1450 Back to hotel to download data and finish paperwork

→ Shot stacks = 4

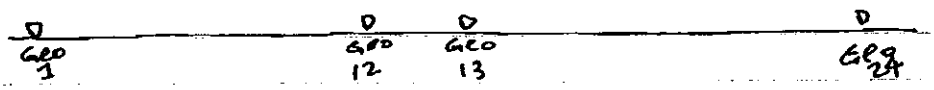
NOTES:

→ We noticed some problems (noise) with the first six channels after shot 3002... after changing the geophone cable, the problem was fixed and we re-shot 3001 & 3002

TA-61 Seismic Refraction Survey 07/15/2005

0730 Tailgate safety meeting with Cory Gilbert, Marty Miele, and Ross Lyon (all Shaw Personnel)

0745 Laying out seismic line over borehole 1



→ 20 ft spacing on geophones = 480 ft

→ shots at 10ft off each end, one in middle, and two at halfway points

total shots = 5

Begin data collection over borehole 1

→ Filename ~~x~~ 1000 - ~~1003~~ 1004

→ Shots are 1000 - ~~1003~~ 1004

→ Shots at -10, 6 Geos 7, 12 Geos 13, 18 Geos 19, 110

⇒ shot 1003 is approximately 5ft north of the line

Shot stacks = 4

1030 Finished with borehole 1, pick-up equipment

1040 GPS the line

Filename is line1000

1050 Leave for lunch

1130 Packing equipment at Shaw Office storage container

1210 At Shaw office packing equipment

1400 Back to hotel to download data and finishing packing

[redacted]

Nambe Pueblo Field Investigation 10/13/05
Documented by Amy Howard, Geologist
Activities / SOW: Provide professional oversight of DBS+A sampling efforts for characterization of materials potentially available to assist LANL with identification of cover borrow materials that will provide suitable performance for material disposal area (MDA) final covers and be cost effective.
A total of 10 samples will be collected by DBS+A to provide reasonably representation of the materials potentially available. Samples will be collected using a backhoe provided by the Nambe Pueblo Development Corporation (NPDC) earthwork contractor. Samples will be collected in 5-gallon buckets for transport to the LANL SMO.
The 10 sampling locations were pre-selected on October 6, 2005.
Weather: Cool, clear, high 40's. Scattered rain projected for mid afternoon.
Equipment: John Deere 310 SG Backhoe

Personnel: Amy Howard, Shaw Site Geologist
Bob Gray, DB+S Assoc., Senior Hydrogeologist
Herbert Yates, NPDC CEO
Will Vandergriff, NPDC Backhoe Operator from Colorado Springs

0740 I arrived on-site, introduced myself to Mr. Herbert Yates.
0750 Bob Gray with ~~&~~ DB+S Associates arrives on-site, we discuss scope of work w/ Herbert Yates
0830 Amy Howard conducted H&S Meeting. Herbert Yates Will Vandergriff, and Bob ~~Yates~~ Gray present.
0833 Will Vandergriff begins excavating first sample location identified as NPDC-10.
0837 Completed digging of 2 ft deep trench and collect soil sample ~~+~~ NPDC - 10.
Soil Description - Predominantly silt and fine grained

10/13/05 Nambe Pueblo Field Investigation
sand, very slight clay kaps w/ low plasticity at ~1.5 ft.
gray brown, moist, friable ~5% clay, 20% silt, 75% sand
Location ID: ~~to~~ 61-25281 Sample ID: RE~~to~~61-06-64284 AKH 10/13/05

0855 Bob Gray marks sample location using GPS to gain coordinates for mapping. Elevation: 6,278

0904 Will begins excavation soil sample location NPDC-3.

0910 Digging is completed at a depth of 3 ft-bgs.
Soil description: v.f.g sand and silt, poorly consolidated ~~to v.f.g sand~~ AKH 10/13/05 unconsolidated. Very slight clay content <1%, 25% silt, 75% sand, very moist upper 1 ft, mod. moist, loose, 1-3 ft.

0913 Bob obtains GPS reading: Elevation: 6,304 ft
Sample NPDC-3 was collected @ 0910. AKH 10/13/05
~~Location ID: to-61-25281 Sample ID: RE61-06~~
Location ID: 61-25282, Sample ID: RE61-06-64285

0920 Will V. began excavating soil at the base of a hill identified as sample location NPDC-4.

0935 Dug pit @ base of hill the material is uniform and is moderately consolidated to semi-consolidated v.f.g sand and silt, approx. <2% clay content. Gravel and cobbles are present on surface of hill but not in trenched test pit. Will V. will try to dig out an area approx. 15 ft above the ~~road~~ road to determine uniform soil characterization of this area.

0940 Bob marks sampling location w/ GPS unit.
Elevation = 6,153 ft.

0945 The upper test pit contains primarily the same material with some moderately friable siltstone. The backhoe could not quite reach hard gravely layer.

0945 NPDC-4, Location ID: 61-25283.
Sample ID: RE61-06-64286.

1000 Will V. begins excavating sample location NPDC-5
GPS elevation 6190 ft.

1009 Finish excavating sample location to approx. 1 ft-bgs

1012 Collected sample NPDC-5, Location ID: 61-25284
Sample ID: RE61-06-64287

10/13/05 Nambe Pueblo Field Investigation

Sample Description: v.f.g - f.g silty sand, consolidated ~~siltstone~~ sandstone AKH 10/13/05 no clay, moderately moist to slightly moist with depth, hard, moderately friable to friable.

1025 Backfilled NPDC-5 and NPDC-4 to surface grade

1045 Began excavating NPDC-2 to about 3ft-bgs. Soil in this area consists of unconsolidated to semi-consolidated silty sand, v.f.g - f.g silt and f-m.g sand. gravel is noted in upper 1-2" of soil, few cobbles are present on surface, few lenses of poorly consolidated friable sandstone, soil is moderately moist. Sand is quartz rich.

1050 GPS elevation: 6,234 ft

1052 Collected soil sample NPDC-2
Location ID: 61-25285, Sample ID: RE61-06-64288

1100 Will V. backfills NPDC-2 test pit to grade and compacts it.

1105 Began excavating soil sample location NPDC-21 test pit and completed the excavation to 3.5 ft-bgs.

1110 Completed excavation.
Sample description: Upper 1ft consists of topsoil composed of sand, silt and clay grading into a v.f.g. silty sandstone, poorly to semi-consolidated, very friable, slightly moist to dry.
GPS location: 6,264 ft elevation

1125 Collected soil sample NPDC-1
Location ID: 61-25286, Sample ID: RE61-06-64289

1140 Begin excavating NPDC-6 test pit. Excavated to approximately 3 ft-bgs.

1142 Completed excavation for NPDC-6
GPS location, elevation = 6.291 ft
Soil sample description: f.g sand and v.f.g silt, from 0-1.5ft-bgs, sand appears well-sorted and uniform, natural sedimentation stratification is observed. 1.5-3.0ft v.f.g. silty sandstone, poorly to moderately consolidated, very friable. thin ~~strati~~ beds of sand and silt apparent. AKH 10/13/05 (micaceous siltstone)

10/13/05 Nambe Pueblo Field Investigation
1150 Soil sample NPDC-6 collected.
Location ID: 61-25287, Sample ID: RE61-06-64290
1200 Begin excavating soil sample ~~location~~ test pit NPDC-7. GPS location: elevation = 6265 ft
1205 Completed excavating NPDC-7 test pit.
Soil Sample Description: Medium grained sand, well-sorted quartz sand, unconsolidated, lenses of micaceous siltstone @ approx. 1.0 ft-bgs v.f.g., hard to very hard, thin beds observed.
1210 Sample NPDC-7 collected.
Location ID: 61-25288, Sample ID: RE61-06-64291
1215 Backfilled NPDC-7 test pit to surface grade.
1220 Begin excavating NPDC-8 test pit, excavated to approximately 3.0 ft-bgs.
GPS location in elevation = 6264 ft
Sample Description: appears to consist of poorly graded, mixed (fill) material consisting of sand (f-mg), f.g. silt, small pebbles to gravel, and approx. 2-3% clay. covered with approximately 6" of topsoil and native vegetation.
1230 NPDC-8 collected. Location ID: 61-25289
Sample ID: RE61-06-64292. Backfilled NPDC-8 test pit to surface grade.
1238 Began excavating NPDC-9 test pit
1242 Completed excavating NPDC-9 test pit
GPS located elevation = 6208 ft
Sample Description: ~~6203 ft~~ AKH 10/13/05
Well-sorted f-m.g. sand few siltstone fragments, v.f.g., moderately to poorly consolidated, friable, moderately moist.
1245 Soil Sample collected @ test pit NPDC-9
Location ID: 61-25290, Sample ID: RE61-06-64293.
1250 Backfilled NPDC-9 test pit
1330 Met at NPDC office, departed site for lunch.
1430 Met w/ Bob Gray, made corrections to sample tracking paperwork.

10/13/05 Nimble Pueblo Field Investigation

1530 Departed NPDC project area..

1615 Met Bob Gray at the LANL Sample Management Office.

1645 Completed paperwork at SMO and drove to the LA Shaw Office.

Jimmy K. Howard 10/13/05

Appendix C
Geologic Logs from
Boreholes BH1, BH2, BH3, and BH4

BH-1

EXAMPLE

Location ID: 61-25137

Shaw
Shaw Environmental & Infrastructure, Inc.

VISUAL CLASSIFICATION OF ROCK LOG

PROJECT NUMBER: 108538
PROJECT NAME: TA-61 Borrow Area Characterization
APPROX. ELEV:
DRILLING METHOD: Hollow Stem Auger
COORDINATES:

FIELD GEOLOGIST: A. Bowman Shaw E+I
CORING/SAMPLING METHOD: 2.0' Split Spoon
CORE SIZE/DIA: 2.0"
DRILLER: D. Starnes Spectrum Exploration

PAGE: 1 OF: 5
BORING NO.: BH-1
DATE: 08/31/05
DATE STARTED: 08/31/05
DATE COMPLETED: 09/01/05

	RUN NUMBER	DEPTH ( )	RECOVERY ( )	% RECOVERY	% RQD	DESCRIPTION	JOINT SPACING MAXIMUM	JOINT SPACING MINIMUM	JOINT SPACING AVERAGE	REMARKS	
0	1		NA	NA		Hand auger refusal @ 10" Qal silty clay, dry, loose, to 1'				No SPT this run	0930
5	2		18/18/0	100		1-10' 5YR7/1 light gray tuff. Fine ash matrix, friable. Pumice fragments to 1cm, 3%. Phenocrysts, 1mm, <3%.				20/6 24/6 31/6	0940
10	3		18/18/0	100		Grade to 5YR 7/2 pinkish gray. Fine/medium ash, slightly welded. Phenocrysts 1-3 mm, 5%. Pumice fragments, 1 cm, 3%.				16/6 18/6 19/6	0950
15	4		18/18/0	100		Same				20/6 25/6 38/6	1020
20	5		18/18/0	100		Same with increasing pumice to 3 cm, altered gray.				17/6 30/6 33/6	1030
25	6		18/18/0	100		Same grading to fine ash matrix and 5YR 7/1 light gray tuff.				18/6 21/6 30/6	1040
30	7		18/18/0	100		5YR7/1 light gray tuff. Fine ash matrix. Pumice fragments 1cm, 5%. Phenocrysts 2mm, 5%, sanidine.				26/6 35/6 31/6	1050
35											

BH-1

EXAMPLE

Location ID: 61-25137

Shaw
Shaw Environmental & Infrastructure, Inc.

VISUAL CLASSIFICATION OF ROCK LOG

PROJECT NUMBER: 108538
PROJECT NAME: TA-61
APPROX. ELEV:
DRILLING METHOD: Hollow Stem Auger
COORDINATES:

FIELD GEOLOGIST: A. Bowman
CORING/SAMPLING METHOD: Split Spoon
CORE SIZE/DIA: 2"
DRILLER: D. Starnes

PAGE: 2 OF: 5
BORING NO.: BH-1
DATE: 8/31/05
DATE STARTED: 8/31/05
DATE COMPLETED: 9/1/05

	RUN NUMBER	DEPTH ( )	RECOVERY ( )	% RECOVERY	% RQD	DESCRIPTION	JOINT SPACING MAXIMUM	JOINT SPACING MINIMUM	JOINT SPACING AVERAGE	REMARKS	
35	8		18/18/0	100		Same				21/6 24/6 12/6	1100
40	9		18/18/0	100		Same				12/6 13/6 14/6	1235
45	10		18/18/0	100		Same grading to 5YR6/1 gray tuff. Pumice size increasing to 4cm, 5%.				11/6 19/6 18/6	1250
50	11		18/18/0	100		Same with light brown staining @ 51', 2 cm.				10/6 11/6 14/6	1300
55	12		18/18/0	100		Light brown staining @ 56.5 + 57' Same 5YR6/1 with altered, clay-like pumice to 3 cm, 5%.				10/6 13/6 15/6	1305
60	13		18/18/0	100		5YR 7/1 light gray tuff. Fine ash matrix. Gray pumice to 3 cm, 5%, altered clay-like. Phenocrysts 2cm, 3%. Welded nodules to 2cm, 3%.				7/6 8/6 7/6	1315
70	14		18/18/0	100		Same grading to 5YR 8/1 white tuff. Nonwelded, fine ash matrix.				11/6 10/6 12/6	1325

These standard policies and procedures are applicable to all members of The Shaw Environmental & Infrastructure, Inc., except where superseded or modified by the member Company.

BH-1

EXAMPLE

Location ID: 61-25137

Shaw Environmental & Infrastructure, Inc.

VISUAL CLASSIFICATION OF ROCK LOG

PROJECT NUMBER:
PROJECT NAME:
APPROX. ELEV:
DRILLING METHOD:
COORDINATES:

FIELD GEOLOGIST:
CORING/SAMPLING METHOD:
CORE SIZE/DIA:
DRILLER:

PAGE: 3 OF: 5
BORING NO.: BH-1
DATE: 8/31/05
DATE STARTED: 8/31/05
DATE COMPLETED: 9/1/05

	RUN NUMBER	DEPTH ( )	RECOVERY ( )	% RECOVERY	% RQD	DESCRIPTION	JOINT SPACING MAXIMUM	MINIMUM	AVERAGE	REMARKS	
70	15		18/18/0	100		5YR8/1 white tuff. Nonwelded. Very fine ash matrix. Large phenocrysts to 4mm, 5%. Minor lithics, 1cm, 3%.				7/6 10/6 11/6	1330
75	16		18/16/2	(ab) ~~100~~ 88		Same, however no lithics noted.				11/6 13/6 15/6	1355
80	17		18/18/0	100		Grading to 5YR7/1 light gray tuff. Nonwelded, very fine ash matrix. Large phenocrysts, 4mm, 5%. Large altered white pumice, 3cm, 3%.				13/6 16/6 18/6	1415
85	18		18/18/0	100		Same with pumice altered gray to dark gray, 3cm, 3%.				12/6 18/6 19/6	1425
90	19		18/18/0	100		Same with decreasing gray pumice, 1cm, <3%.				20/6 23/6 22/6	1435
95	20		18/18/0	100		5YR 6/2 pinkish gray tuff. Fine ash matrix, friable, nonwelded, phenocrysts 3mm, 3%. Pumice, gray, 1cm, 3%. Contact change @ 95'.				13/6 16/6 19/6	1445
100	21		NA	NA		Same				N/A No SPT recorded for this run.	1500
105											

BH-1

EXAMPLE

Location ID: 61-25137

Shaw Environmental & Infrastructure, Inc.

VISUAL CLASSIFICATION OF ROCK LOG

PROJECT NUMBER:
PROJECT NAME:
APPROX. ELEV:
DRILLING METHOD:
COORDINATES:

FIELD GEOLOGIST:
CORING/SAMPLING METHOD:
CORE SIZE/DIA:
DRILLER:

PAGE: 4 OF: 5
BORING NO.: BH-1
DATE: 8/31/05 - 9/1/05
DATE STARTED: 8/31/05
DATE COMPLETED: 9/1/05

	RUN NUMBER	DEPTH ( )	RECOVERY ( )	% RECOVERY	% RQD	DESCRIPTION	JOINT SPACING MAXIMUM	JOINT SPACING MINIMUM	JOINT SPACING AVERAGE	REMARKS	
105	22	110	18/18/0			5YR6/1 gray tuff. Moderately welded. Medium ash matrix. Phenocrysts 2mm, 3%. Lithics 1cm, <3%. Sanidine.				18/6 18/6 18/6	1515
	23	115	18/18/0			Same				10/6 10/6 10/6	1530
	24	120	18/10/8			Same increasing to welded tuff showing recrystallization. Hard@ 117!				37/6 50/4	1555
	25	125	18/4/14			5YR 6/1 gray tuff. Moderately welded. Phenocrysts 2mm, medium ash matrix. Recrystallized pumice to 1cm. Sanidine present.				50/4	1605
	26	130	18/3/15			Same.				50/4	1635
	27	135	18/3/15			Same with trace pumice only.				50/3	0815
	28	140	18/3/15			5YR 6/2 pinkish gray tuff. Moderately welded. Altered gray pumice, 3cm, 3%. Phenocrysts 2mm, 3%. Sanidine present.				50/3	0835

BH-1

EXAMPLE

Location ID: 61-25137

Shaw
Shaw Environmental & Infrastructure, Inc.

VISUAL CLASSIFICATION OF ROCK LOG

PROJECT NUMBER:
PROJECT NAME:
APPROX. ELEV:
DRILLING METHOD:
COORDINATES:

FIELD GEOLOGIST:
CORING/SAMPLING METHOD:
CORE SIZE/DIA:
DRILLER:

PAGE: 5 OF: 5
BORING NO.: BH-1
DATE: 9/1/05
DATE STARTED: 8/31/05
DATE COMPLETED: 9/1/05

	RUN NUMBER	DEPTH ( )	RECOVERY ( )	% RECOVERY	% RQD	DESCRIPTION	JOINT SPACING MAXIMUM	JOINT SPACING MINIMUM	JOINT SPACING AVERAGE	REMARKS	
140			18 / 3.5 / 14.5			Same				50/3.5	0900
145			18 / 3 / 15			5YR 6/2 pinkish gray tuff. slightly to moderately welded. Medium ash matrix. Phenocrysts 2 mm, 3%, sanidine. Gray pumice, 1 cm, <3%.				50/3	0925
150			18 / 3.5 / 14.5			Same				50/3.5	0955
152						T.D. 152' bgs					

BH-2

EXAMPLE

Location ID: 61-25135

Shaw
Shaw Environmental & Infrastructure, Inc.

VISUAL CLASSIFICATION OF ROCK LOG

PROJECT NUMBER: 108538
PROJECT NAME: TA-61
APPROX. ELEV:
DRILLING METHOD: Hollow Stem Auger
COORDINATES:

FIELD GEOLOGIST: A. Bowman
CORING/SAMPLING METHOD: Split Spoon
CORE SIZE/DIA: 2"
DRILLER: D. Staines

PAGE: 1 OF: 2
BORING NO.: BH-2
DATE: 8/30/05
DATE STARTED: 8/30/05
DATE COMPLETED: 8/30/05

	RUN NUMBER	DEPTH ( )	RECOVERY ( )	% RECOVERY	% RQD	DESCRIPTION	JOINT SPACING MAXIMUM	JOINT SPACING MINIMUM	JOINT SPACING AVERAGE	REMARKS	
0	1	5	NA			Hand auger refusal @ 18" Qal silty clay, loose, dry to 18"				NA	1345
10	2		18/18/0	100		5YR 7/1 light gray tuff. Fine ash matrix, friable, nonwelded. Phenocrysts 1mm, 3%. Pumice 1%, <1cm.				17/6 21/6 25/6	1350
15	3		18/18/0	100		Same				29/6 43/6 50/5.5	1400
20	4		18/10/8	55		Hard at 17'. 5YR 6/1 gray tuff. Fine ash matrix, moderately welded, Phenocrysts 2mm, 3%. trace altered pumice fragments.				37/6 50/4	1410
25	5		18/2.5/15.5	15		5YR 6/2 pinkish gray tuff. Fine ash matrix, moderately welded, Phenocrysts 2mm, 3%. Altered light gray pumice fragments (trace).				50/2.5	1420
30	6		18/1.5/16.5	10		Same				50/1.5	1430
35	7		18/3/15	15		Same with minor oxidation, <3%				50/3	1440

These standard policies and procedures are applicable to all members of The Shaw Environmental & Infrastructure, Inc., except where superseded or modified by the member Company.

BH-2

EXAMPLE

Location ID: 61-25135

Shaw
Shaw Environmental & Infrastructure, Inc.

VISUAL CLASSIFICATION OF ROCK LOG

PROJECT NUMBER:
PROJECT NAME:
APPROX. ELEV:
DRILLING METHOD:
COORDINATES:

FIELD GEOLOGIST:
CORING/SAMPLING METHOD:
CORE SIZE/DIA:
DRILLER:

PAGE: 2 OF: 2
BORING NO.: BH-2
DATE: 8/30/05
DATE STARTED: 8/30/05
DATE COMPLETED: 8/30/05

	RUN NUMBER	DEPTH ( )	RECOVERY ( )	% RECOVERY	% RQD	DESCRIPTION	JOINT SPACING MAXIMUM	JOINT SPACING MINIMUM	JOINT SPACING AVERAGE	REMARKS	
35	8		18 / 3 / 15	15		Same grading to 5YR6/2 to 6/1 tuff. Moderately welded, fine to medium ash matrix.				50/3	1445
45	9		18 / 3 / 15	15		5YR6/1 gray tuff. Fine to medium ash matrix, moderately welded, phenocrysts, 3mm, sanidine present. Altered white pumice. Nodules to 2cm.				50/3	1455
50	10		18 / 2.5 / 15.5	15		Same with increasing sanidine.				50/2.5	1510
						DTB 52'				50/1.5	1520

BH-3

EXAMPLE

Location ID: 61-25130

Shaw Environmental & Infrastructure, Inc.

VISUAL CLASSIFICATION OF ROCK LOG

PROJECT NUMBER: 108538
PROJECT NAME: TA-61 Borrow Area
APPROX. ELEV:
DRILLING METHOD: Hollow Stem Auger
COORDINATES:

FIELD GEOLOGIST: A. Bowman
CORING/SAMPLING METHOD: Split Spoon 2'
CORE SIZE/DIA: 2"
DRILLER: D. Staples
Spectrum Exploration

PAGE: 1 OF: 3
BORING NO: BH-3
DATE: 08/29/05
DATE STARTED: 08/29/05
DATE COMPLETED: 08/30/05

08/29/05

Depth	Run Number	Depth ( )	Recovery ( )	% Recovery	% RQD	Description	Joint Spacing Maximum	Joint Spacing Minimum	Joint Spacing Average	Remarks	
0–5	1		NA	NA	NA	Hand auger to 24" to refusal. Drill through to 5'. Asphalt compacted to 24".				No SPT completed for 0-5'.	1450
5–10	2			18 / 18 / 0		5YR6/1 gray tuff; altered; phenocrysts 1-3mm, 3% (quartz); minor pumice. Asphalt/FILL to 5.5'. Fine ash matrix. Geotechnical Cuttings Sample 5-10'				5-5.5' = 12/6 5.5-6' = 34/6 6-6.5' = 50/6	1505
10–15	3			18 / 18 / 0		Slough to ~~11~~ 10.5'. 10.5-12' same with 1-3mm phenocrysts, pumice fragments, light gray to 1cm. Fine ash matrix, sanidine <1mm. 13.5' hardness change to more welded material.				10-10.5' = 21/6 10.5-11' = 32/6 11-11.5' = 31/6	1520
15–20	4			18 / 5 / 13		Slough first 0.33' (asphalt). Same to 17', grading to 5/2 reddish gray tuff. Fine to medium ash matrix. Sanidine present, phenocrysts 1-3mm, 5%. Moderately welded nodules to 3cm,				15-15.5' = 50/5 15.5-16' = X 16-16.5' = X	1530
20–25	5			18 / 4 / 14		5YR 5/1 gray tuff, slightly welded. Large phenocrysts 2-4mm, 3%. Altered white/light gray pumice, medium ash matrix. Slough first 0.25'.				20-20.5 = 50/4 20.5-21 = X 21-21.5 = X	1550
25–30	6			50	0	Slough 0.5'. Cuttings 5YR6/1 gray tuff. Fine to medium ash matrix. Welded nodules, to 2cm. Phenocrysts 1-2 mm, 3%. Minor < 3% oxidation, sanidine present.				25-25.5' = 50/4.5 25.5-26' = X 26-26.5' = X	18/4.5/13.5 1610
30–35	7			50	0	Same 5YR 5/1 tuff, slightly welded. Medium ash matrix. Phenocrysts, sanidine, 1-2mm, 3%. Lithics present to 1cm, dacites, angular.				30-30.5 = 50/3 30.5-31 = X 31-31.5 = X	18/3/15 ab 8/29/05 ~~1630~~ 1620

NOTE: Time is when SPT Blow counts were taken.
SPT taken in 3 6-inch continuous runs in 2-foot core. First 6 inches of 2-foot core barrel considered slough.

BH-3

EXAMPLE

Location ID: 61-25130

Shaw Environmental & Infrastructure, Inc.

VISUAL CLASSIFICATION OF ROCK LOG

PROJECT NUMBER: 108538
PROJECT NAME: TA-61 Borrow Area
APPROX. ELEV:
DRILLING METHOD: Hollow Stem Auger
COORDINATES:

FIELD GEOLOGIST: A. Bowman Shaw E+I
CORING/SAMPLING METHOD: Split Spoon
CORE SIZE/DIA: 2.0"
DRILLER: D. Starnes Spectrum Exploration

PAGE: 2 OF: 3
BORING NO.: BH-3
DATE: 08/29-30/05
DATE STARTED: 08/29/05
DATE COMPLETED: 08/30/05

	RUN NUMBER	DEPTH ( )	RECOVERY ( )	% RECOVERY	% RQD	DESCRIPTION	JOINT SPACING MAXIMUM	JOINT SPACING MINIMUM	JOINT SPACING AVERAGE	REMARKS	
35	8		2/1/1	50		5YR 5/1 tuff, slightly welded. Medium ash matrix. Phenocrysts 1-2mm, sanidine present. Lithics to 1 cm, angular (dacites), 5%.				35-37' = 50/4	18/4/14 1630
40 45	9		2/1/1	50		5YR5/1 to 6/1 gray tuff. Fine ash matrix phenocrysts to 2mm, 3%. Altered white pumice, trace native (dacites).				40-42 = 50/4	18/4/14 1640
50	10		2/1/1	50		5YR5/1 gray tuff. Fine ash matrix to medium ash matrix. Phenocrysts 1-2 mm, 3%, sanidine present. Pumice fragments to 1 cm, gray to dark gray. friable. moist. Hardness change at 48"				45-47 = 50/4	18/4/14 0720
55	11		2/.75/1.25	40		same as above.				50-52 = 50/3.5	18/3.5/14.5 0735
60	12		2/.75/1.25	40		5YR 6/1 gray tuff. Fine to medium ash matrix. Trace phenocrysts; sanidine present; pumice fragments 1cm. friable. moist.				55-57 = 50/3	18/3/15 0750
65	13		2/.75/1.25	40		5YR 5/1 gray tuff. Medium ash matrix; phenocrysts 1-2mm, 3%, sanidine present. Pumice fragments to 1cm. friable, mod. welded nodules to 3 cm, moist				60-62 = 50/4	18/4/14 0805
70	14		2/0.5/1.5			5YR 5/1 to 4/1 dark gray tuff. Medium matrix, friable; welded nodules, stiff. Phenocrysts 1-2mm, 3%; lithics (dacites) to 1cm; pumice fragments, gray, < 1cm.				65-67 = 50/3.5	18/3.5/14.5 0825
						welded nodules to 3cm with large ~~nodules~~ phenocrysts 1-4mm, moist (DB) 8/30/05					

BH-3

EXAMPLE Location ID: 61-25130

Shaw
Shaw Environmental & Infrastructure, Inc.

VISUAL CLASSIFICATION OF ROCK LOG

PROJECT NUMBER: 108538
PROJECT NAME: TA-61 Borrow Area Characterization
APPROX. ELEV:
DRILLING METHOD: Hollow Stem Auger
COORDINATES:

FIELD GEOLOGIST: A. Bowman Shaw E & I
CORING/SAMPLING METHOD: Split Spoon
CORE SIZE/DIA: 2.0"
DRILLER: D. Staines Spectrum Exploration

PAGE: 3 OF: 3
BORING NO: BH-3
DATE: 08/30/05
DATE STARTED: 08/29/05
DATE COMPLETED: 08/30/05

	RUN NUMBER	DEPTH ( )	RECOVERY ( )	% RECOVERY	% RQD	DESCRIPTION	JOINT SPACING MAXIMUM	JOINT SPACING MINIMUM	JOINT SPACING AVERAGE	REMARKS	
70	15	75	2/2.8/1.2			5YR5/1 gray tuff. Fine to medium ash matrix, friable; welded nodules to 2cm; phenocrysts 1-3 mm, minor pumice fragments <1cm.				70-72' = 50/3.5	18/3.5/14.5 0900
80	16		2/0.5/1.5			5YR4/1 dark gray tuff. Fine ash matrix, ~~[illegible]~~ 2cm; phenocrysts 1-3mm, 3%, larger welded nodules 2-4 cm with large phenocrysts 2-4mm, sanidine present. moist.				75-77' = 50/4	18/4/14 0920
85	17		2/6.7/1.3			5YR 5/1 gray tuff. Medium ash matrix, friable. Trace phenocrysts to 1mm. Pumice fragments < 1 cm. Minor < 3% oxidation. Sanidine present.				80-82' = 50/4.5	18/4.5/13.5 0935
90	18		2/1/1	50		same as above with decreasing oxidation observed.				85-87' = 50/6	18/6/12 0950
95	19		2/2/0	100		5YR5/1 gray tuff. Fine to medium ash matrix, friable. Phenocrysts 1-3 mm, sanidine present. Minor lithics (native) <1cm; trace pumice fragments, altered white/lt. gray.				90-92' = 42/6 44/6 45/6	18/18/0 1005
100	20		2/1.7/3			same grading to 5YR 5/2 reddish gray tuff. Fine ash matrix, friable. Pumice altered light gray to 2 cm. Phenocrysts 1-3mm, 3%. Pumice 5%.				95-97' = 31/6 42/6 46/6	18/18/0 1020
102	21		2/2/1	100		5YR 5/2 reddish gray altered tuff with clay; altered pumice to 2 cm gray/lt. gray 5%; phenocrysts 1-3 mm, 5%. sanidine present. friable.				100-102' = 33/6 35/6 33/6	18/18/0 1040
						DTB 102'					

These standard policies and procedures are applicable to all members of The Shaw Environmental & Infrastructure, Inc., except where superseded or modified by the member Company.

BH-4

EXAMPLE

Location ID: 61-25143

Shaw Environmental & Infrastructure, Inc.

VISUAL CLASSIFICATION OF ROCK LOG

PROJECT NUMBER:
PROJECT NAME: TA-61 Borrow Area Characterization
APPROX. ELEV:
DRILLING METHOD:
COORDINATES:

FIELD GEOLOGIST: A. Bowman Shaw E+I
CORING/SAMPLING METHOD: 2.0' Split Spoon
CORE SIZE/DIA: 2.0"
DRILLER:

PAGE: 1 OF: 2
BORING NO.: BH-4
DATE: 09/01/05
DATE STARTED: 09/01/05
DATE COMPLETED:

	RUN NUMBER	DEPTH ( )	RECOVERY ( )	% RECOVERY	% RQD	DESCRIPTION	JOINT SPACING MAXIMUM	JOINT SPACING MINIMUM	JOINT SPACING AVERAGE	REMARKS	
0	1					Hand auger to refusal at 12". Light brown silty sand, moist (due to present rain) will drill to 5' to begin SPT.				NA STP	
5											1340
	2		18/18/0			5YR 5/2 reddish gray tuff. Nonwelded, friable, phenocrysts to 3mm, 5%. Large altered white pumice to 3 cm. Medium ash matrix.				4/6 6/6 9/6	
10											1350
	3		18/18/0			5YR 5/2 reddish gray tuff. pumice rich, altered white, clay-like pumice to 4 cm. Phenocrysts to 3mm, 5%. Medium ash matrix, friable.				7/6 9/6 12/6	
15											1400
	4		18/17.5/0.5			same as above becoming more welded. pumice rich matrix, pumice becoming more gray.				20/6 36/6 50/5.5	
20											1405
	5		18/11/7			5YR 5/2 moderately welded tuff. friable, fine to medium ash matrix. Phenocrysts to 4mm, 5%, Altered gray clay-like pumice to 3cm, 5%.				36/6 50/5	
25											1410
	6		18/12/6			5YR 5/1 gray moderately welded tuff. Medium to fine ash matrix, friable. Phenocrysts to 3mm, 5%. Decreasing altered gray pumice to 3%, 3cm. Hardness change 29'.				38/6 50/6	
30											1420
	7		18/4/14			5YR 6/1 gray welded tuff. fine hard ash matrix. Phenocrysts to 2mm, 3%, sanidine present. Minor pumice, 5mm, 3%.				50/4	
35											1430

These standard policies and procedures are applicable to all members of The Shaw Environmental & Infrastructure, Inc., except where superseded or modified by the member Company.

BH-4

EXAMPLE

Location ID: 61-25143

Shaw Environmental & Infrastructure, Inc.

VISUAL CLASSIFICATION OF ROCK LOG

PROJECT NUMBER:
PROJECT NAME:
APPROX. ELEV:
DRILLING METHOD:
COORDINATES:

FIELD GEOLOGIST:
CORING/SAMPLING METHOD:
CORE SIZE/DIA:
DRILLER:

PAGE: 2 OF: 2
BORING NO.: BH-4
DATE: 9/1/05
DATE STARTED: 9/1/05
DATE COMPLETED: 9/1/05

	RUN NUMBER	DEPTH ( )	RECOVERY ( )	% RECOVERY	% RQD	DESCRIPTION	JOINT SPACING MAXIMUM	MINIMUM	AVERAGE	REMARKS	
35	8		18/3/15			5YR 5/1 gray welded tuff, hard; fine to medium ash matrix. Phenocrysts 1-3mm 3%, sanidine present. Altered light gray pumice fragments 3%.				50/3	1440
40	9		18/3/15			same as above				50/3	1450
45	10		18/2/16			same				50/2	1500
50	11		18/3/15			5YR 5/1 gray welded tuff. Hard fine ash matrix. Phenocrysts 1-4mm, 5%, sanidine present. Minor altered gray pumice fragments <3%.				50/3	1510
52						T.D. 52' bgs					

Appendix D
Summary of TA-61 Borrow Area Hydraulic and Geotechnical Laboratory Data

Laboratory Report for

Los Alamos National Laboratory

Copy of Summary Sheets

Cover Borrow Source Survey-TA-61

(Req #: 3846S)

January 10, 2006

Daniel B. Stephens & Associates, Inc.

6020 Academy NE, Suite 100 • Albuquerque, New Mexico 87109

Daniel B. Stephens & Associates, Inc.

Summary of Tests Performed

Laboratory Sample Number	Initial Soil Properties[1] (θ, ρ_d, ϕ)	Saturated Hydraulic Conductivity[2]		Moisture Characteristics[3]					Unsaturated Hydraulic Conductivity	Particle Size[4]			Atterberg Limits	Particle Density	Clod Densities	Unconsolidated Haul Densities	Proctor Compaction
		CH	FH	HC	PP	TH	WP	RH		DS	WS	H					
BH-1 15'-25' (82.5%)	X	X		X	X		X	X	X		X	X	X				X
BH-1 40-50 (75%)	X	X		X	X		X	X	X		X	X	X				X
BH-1 40'-50' (82.5%)	X	X		X	X		X	X	X								
BH-1 40'-50' (90%)	X	X		X	X		X	X	X								
BH-1 40'-50' (95%)	X	X		X	X		X	X	X								
BH-1 65'-75' (82.5%)	X	X		X	X		X	X	X		X	X	X	X			X
BH-1 65'-75' (90%)	X	X		X	X		X	X	X								
BH-1 65'-75' (95%)	X	X		X	X		X	X	X								
BH-1 90'-95' (82.5%)	X	X		X	X		X	X	X		X	X	X				X
BH-1 120'-125' (82.5%)	X	X		X	X		X	X	X		X	X	X		X	X	X
BH-1 145'-150' (82.5%)	X	X		X	X		X	X	X		X	X	X		X	X	X
BH-2 10'-15' (82.5%)	X	X		X	X		X	X	X		X	X	X		X		X
BH-2 25'-30' (82.5%)	X	X		X	X		X	X	X		X	X	X		X	X	X
BH-2 25'-30' (90%)	X	X		X	X		X	X	X								
BH-2 25'-30' (95%)	X	X		X	X		X	X	X								

[1] θ = Initial moisture content, ρ_d = Dry bulk density, ϕ = Calculated porosity
[2] CH = Constant head, FH = falling head
[3] HC = Hanging column, PP = Pressure plate, TH = Thermocouple psychrometer, WP = Water activity meter, RH = Relative humidity box
[4] DS = Dry sieve, WS = Wet sieve, H = Hydrometer

Summary of Tests Performed (Continued)

Laboratory Sample Number	Initial Soil Properties[1] (θ, ρ_d, ϕ)	Saturated Hydraulic Conductivity[2]		Moisture Characteristics[3]					Unsaturated Hydraulic Conductivity	Particle Size[4]			Atterberg Limits	Particle Density	Clod Densities	Unconsolidated Haul Densities	Proctor Compaction
		CH	FH	HC	PP	TH	WP	RH		DS	WS	H					
BH-3 5'-10' (82.5%)	X	X		X	X		X	X	X		X	X	X		X		X
BH-3 20'-25' (82.5%)	X	X		X	X		X	X	X		X	X	X		X		X
BH-3 60'-65' (82.5%)	X	X		X	X		X	X	X		X	X	X		X		X
BH-3 60'-65' (90%)	X	X		X	X		X	X	X								
BH-3 60'-65' (95%)	X	X		X	X		X	X	X								
BH-3 90'-95' (75%)	X	X		X	X		X	X	X		X	X	X				X
BH-3 90'-95' (82.5%)	X	X		X	X		X	X	X								
BH-3 90'-95' (90%)	X	X		X	X		X	X	X								
BH-3 90'-95' (95%)	X	X		X	X		X	X	X								
BH-4 10'-15' (75%)	X	X		X	X		X	X	X		X	X	X	X			X
BH-4 10'-15' (82.5%)	X	X		X	X		X	X	X								
BH-4 10'-15' (90%)	X	X		X	X		X	X	X								
BH-4 10'-15' (95%)	X	X		X	X		X	X	X								
BH-4 30'-40' (82.5%)	X	X		X	X		X	X	X		X	X	X		X	X	X
North Cliff (82.5%)	X	X		X	X		X	X	X		X	X	X		X	X	X

[1] θ = Initial moisture content, ρ_d = Dry bulk density, ϕ = Calculated porosity
[2] CH = Constant head, FH = falling head
[3] HC = Hanging column, PP = Pressure plate, TH = Thermocouple psychrometer, WP = Water activity meter, RH = Relative humidity box
[4] DS = Dry sieve, WS = Wet sieve, H = Hydrometer

Summary of Sample Preparation

	As Received Data	Proctor Data		Target Remold Values*	Actual Remold Data			*Estimated Average* Measured Settled Densities**		
Sample Number	Moisture Content (% g/g)	Optimum Moisture Content (% g/g)	Maximum Dry Bulk Density (g/cm^3)	Target Remold Densities (g/cm^3)	Moisture Content (%, g/g)	Dry Bulk Density (g/cm^3)	% of Maximum Dry Bulk Density (%)	Average Settled Dry Bulk Density (g/cm^3)	Average % Settled After Remold (%)	% of Maximum Dry Bulk Density (%)
BH-1 15'-25' (82.5%)	0.9	15.1	1.69	1.39	8.8	1.38	81.7	1.69	18.4	100.2
BH-1 40'-50' (75%)	1.1	14.1	1.67	1.25	7.6	1.24	74.3	1.68	26.0	100.4
BH-1 40'-50' (82.5%)	1.1	14.1	1.67	1.38	8.2	1.37	82.0	1.71	19.7	102.6
BH-1 40'-50' (90%)	1.1	14.1	1.67	1.50	7.4	1.49	89.2	1.68	11.2	100.6
BH-1 40'-50' (95%)	1.1	14.1	1.67	1.58	7.7	1.56	93.4	1.69	7.4	100.9
BH-1 65'-75' (82.5%)	0.6	14.3	1.70	1.41	9.6	1.38	81.2	1.69	18.2	99.5
BH-1 65'-75' (90%)	0.6	14.3	1.70	1.53	7.8	1.41	82.9	1.77	20.2	104.1
BH-1 65'-75' (95%)	0.6	14.3	1.70	1.62	7.3	1.61	94.7	1.77	9.5	104.3
BH-1 90'-95' (82.5%)	0.8	12.1	1.79	1.48	7.5	1.47	82.1	1.71	14.3	95.6
BH-1 120'-125' (82.5%)	0.8	13.9	1.73	1.43	7.7	1.43	82.7	1.82	21.7	105.2

Summary of Sample Preparation

	As Received Data	Proctor Data		Target Remold Values*	Actual Remold Data			*Estimated Average* Measured Settled Densities**		
	Moisture Content	Optimum Moisture Content	Maximum Dry Bulk Density	Target Remold Densities	Moisture Content	Dry Bulk Density	% of Maximum Dry Bulk Density	Average Settled Dry Bulk Density	Average % Settled After Remold	% of Maximum Dry Bulk Density
Sample Number	(% g/g)	(% g/g)	(g/cm^3)	(g/cm^3)	(%, g/g)	(g/cm^3)	(%)	(g/cm^3)	(%)	(%)
BH-1 145'-150' (82.5%)	0.8	13.8	1.72	1.42	9.3	1.39	80.8	1.76	20.5	102.0
BH-2 10'-15' (82.5%)	1.8	14.6	1.69	1.39	8.9	1.38	81.7	1.57	12.0	92.9
BH-2 25'-30' (82.5%)	1.2	14.6	1.70	1.40	10.1	1.37	80.6	1.65	16.9	97.2
BH-2 25'-30' (90%)	1.2	14.6	1.70	1.53	8.4	1.52	89.4	1.77	13.7	103.9
BH-2 25'-30' (95%)	1.2	14.6	1.70	1.61	8.4	1.60	94.1	1.68	4.6	98.9
BH-3 5'-10' (82.5%)	2.5	12.1	1.71	1.41	8.5	1.40	81.9	1.78	21.3	103.8
BH-3 20'-25' (82.5%)	4.3	12.4	1.72	1.42	11.5	1.38	80.2	1.70	18.7	98.6
BH-3 60'-65' (82.5%)	7.2	12.5	1.76	1.45	11.9	1.42	80.7	1.63	12.5	92.5
BH-3 60'-65' (90%)	7.2	12.5	1.76	1.58	11.0	1.56	88.6	1.78	12.1	101.1
BH-3 60'-65' (95%)	7.2	12.5	1.76	1.67	10.4	1.66	94.3	1.75	5.2	99.6

Summary of Sample Preparation

	As Received Data	Proctor Data		Target Remold Values*	Actual Remold Data			*Estimated Average* Measured Settled Densities**		
Sample Number	Moisture Content (% g/g)	Optimum Moisture Content (% g/g)	Maximum Dry Bulk Density (g/cm^3)	Target Remold Densities (g/cm^3)	Moisture Content (%, g/g)	Dry Bulk Density (g/cm^3)	% of Maximum Dry Bulk Density (%)	Average Settled Dry Bulk Density (g/cm^3)	Average % Settled After Remold (%)	% of Maximum Dry Bulk Density (%)
BH-3 90'-95' (75%)	5.8	12.1	1.79	1.34	13.1	1.30	72.6	1.71	23.7	95.5
BH-3 90'-95' (82.5%)	5.8	12.1	1.79	1.47	12.0	1.43	79.9	1.75	18.1	97.5
BH-3 90'-95' (90%)	5.8	12.1	1.79	1.61	10.8	1.60	89.4	1.82	12.4	101.9
BH-3 90'-95' (95%)	5.8	12.1	1.79	1.70	10.7	1.69	94.4	1.74	2.9	97.2
BH-4 10'-15' (75%)	6.1	11.9	1.76	1.32	10.4	1.30	73.9	1.73	24.4	98.1
BH-4 10'-15' (82.5%)	6.1	11.9	1.76	1.45	10.2	1.44	81.8	1.75	18.1	99.4
BH-4 10'-15' (90%)	6.1	11.9	1.76	1.58	9.9	1.57	89.2	1.72	8.6	97.5
BH-4 10'-15' (95%)	6.1	11.9	1.76	1.67	9.2	1.67	94.9	1.74	4.0	98.7
BH-4 30'-40' (82.5%)	3.4	14.4	1.72	1.42	9.3	1.41	82.0	1.77	20.3	103.2
North Cliff (82.5%)	6.9	19.6	1.53	1.26	13.3	1.26	82.4	1.32	4.2	86.0

Summary of Sample Preparation

Notes:

*Target Remold Values: Target remold densities at 75%, 82.5%, 90%, and 95% of the respective proctor based maximum dry bulk density. Target percentages are noted in parentheses following the sample names. Target remold moisture content was between the as received moisture content and the proctor based optimum moisture content.

**Measure Settled Densities: Remolded samples settled significantly during saturated hydraulic conductivity testing, and continued settling throughout unsaturated hydraulic conductivity testing. Settled dimensions were estimated based on the average of the measurements obtained after saturated hydraulic conductivity testing and throughout unsaturated hydraulic conductivity testing. The test results provided are based on these averages of the estimated measured settled densities.

Summary of Initial Moisture Content, Dry Bulk Density Wet Bulk Density and Calculated Porosity

Sample Number	Moisture Content				Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
	As Received		Remolded				
	Gravimetric (%, g/g)	Volumetric (%, cm^3/cm^3)	Gravimetric (%, g/g)	Volumetric (%, cm^3/cm^3)			
BH-1 15'-25' (82.5%)	0.9	NA	8.8	12.2	1.38	1.50	47.8
BH-1 40-50 (75%)	1.1	NA	7.6	9.4	1.24	1.34	53.1
BH-1 40'-50' (82.5%)	1.1	NA	8.2	11.2	1.37	1.49	48.1
BH-1 40'-50' (90%)	1.1	NA	7.4	11.0	1.49	1.60	43.7
BH-1 40'-50' (95%)	1.1	NA	7.7	12.0	1.56	1.68	41.1
BH-1 65'-75' (82.5%)	0.6	NA	9.6	13.3	1.38	1.52	47.8
BH-1 65'-75' (90%)	0.6	NA	7.8	11.0	1.41	1.52	46.8
BH-1 65'-75' (95%)	0.6	NA	7.3	11.7	1.61	1.72	39.4
BH-1 90'-95' (82.5%)	0.8	NA	7.5	11.0	1.47	1.58	44.6
BH-1 120'-125' (82.5%)	0.8	NA	7.7	11.0	1.43	1.54	46.2
BH-1 145'-150' (82.5%)	0.8	NA	9.3	13.0	1.39	1.52	47.4
BH-2 10'-15' (82.5%)	1.8	NA	8.9	12.3	1.38	1.50	47.8

NA = Not analyzed

--- = This sample was not remolded

Summary of Initial Moisture Content, Dry Bulk Density Wet Bulk Density and Calculated Porosity (Continued)

Sample Number	Moisture Content: As Received, Gravimetric (%, g/g)	Moisture Content: As Received, Volumetric (%, cm^3/cm^3)	Moisture Content: Remolded, Gravimetric (%, g/g)	Moisture Content: Remolded, Volumetric (%, cm^3/cm^3)	Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
BH-2 25'-30' (82.5%)	1.2	NA	10.1	13.9	1.37	1.51	48.1
BH-2 25'-30' (90%)	1.2	NA	8.4	12.8	1.52	1.65	42.5
BH-2 25'-30' (95%)	1.2	NA	8.4	13.5	1.60	1.74	39.5
BH-3 5'-10' (82.5%)	2.5	NA	8.5	11.9	1.40	1.52	47.3
BH-3 20'-25' (82.5%)	4.3	NA	11.5	15.9	1.38	1.54	47.9
BH-3 60'-65' (82.5%)	7.2	NA	11.9	16.9	1.42	1.59	46.3
BH-3 60'-65' (90%)	7.2	NA	11.0	17.3	1.56	1.74	41.0
BH-3 60'-65' (95%)	7.2	NA	10.4	17.2	1.66	1.83	37.3
BH-3 90'-95' (75%)	5.8	NA	13.1	17.1	1.30	1.47	50.8
BH-3 90'-95' (82.5%)	5.8	NA	12.0	17.2	1.43	1.60	46.0
BH-3 90'-95' (90%)	5.8	NA	10.8	17.3	1.60	1.77	39.7
BH-3 90'-95' (95%)	5.8	NA	10.7	18.0	1.69	1.87	36.3

NA = Not analyzed

--- = This sample was not remolded

Summary of Initial Moisture Content, Dry Bulk Density Wet Bulk Density and Calculated Porosity (Continued)

Sample Number	Moisture Content				Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
	As Received		Remolded				
	Gravimetric (%, g/g)	Volumetric (%, cm^3/cm^3)	Gravimetric (%, g/g)	Volumetric (%, cm^3/cm^3)			
BH-4 10'-15' (75%)	6.1	NA	10.4	13.5	1.30	1.44	50.8
BH-4 10'-15' (82.5%)	6.1	NA	10.2	14.7	1.44	1.58	45.8
BH-4 10'-15' (90%)	6.1	NA	9.9	15.5	1.57	1.72	40.8
BH-4 10'-15' (95%)	6.1	NA	9.2	15.4	1.67	1.82	37.1
BH-4 30'-40' (82.5%)	3.4	NA	9.3	13.2	1.41	1.55	46.6
North Cliff (82.5%)	6.9	NA	13.3	16.7	1.26	1.43	52.5

NA = Not analyzed

--- = This sample was not remolded

Summary of Saturated Hydraulic Conductivity Tests

Sample Number	K_{sat} (cm/sec)	Method of Analysis	
		Constant Head	Falling Head
BH-1 15'-25' (82.5%)	4.9E-03	X	
BH-1 40-50 (75%)	1.1E-02	X	
BH-1 40'-50' (82.5%)	1.2E-02	X	
BH-1 40'-50' (90%)	2.9E-04	X	
BH-1 40'-50' (95%)	2.2E-04	X	
BH-1 65'-75' (82.5%)	1.3E-02	X	
BH-1 65'-75' (90%)	9.6E-03	X	
BH-1 65'-75' (95%)	2.2E-04	X	
BH-1 90'-95' (82.5%)	1.1E-02	X	
BH-1 120'-125' (82.5%)	1.4E-03	X	
BH-1 145'-150' (82.5%)	2.6E-03	X	
BH-2 10'-15' (82.5%)	9.4E-03	X	
BH-2 25'-30' (82.5%)	3.0E-03	X	
BH-2 25'-30' (90%)	1.1E-03	X	
BH-2 25'-30' (95%)	1.1E-04	X	
BH-3 5'-10' (82.5%)	1.3E-02	X	
BH-3 20'-25' (82.5%)	1.2E-02	X	
BH-3 60'-65' (82.5%)	9.5E-04	X	
BH-3 60'-65' (90%)	1.4E-04	X	
BH-3 60'-65' (95%)	1.2E-05	X	

Summary of Saturated Hydraulic Conductivity Tests (Continued)

Sample Number	K_{sat} (cm/sec)	Method of Analysis	
		Constant Head	Falling Head
BH-3 90'-95' (75%)	2.2E-02	X	
BH-3 90'-95' (82.5%)	2.2E-02	X	
BH-3 90'-95' (90%)	3.3E-04	X	
BH-3 90'-95' (95%)	9.4E-05	X	
BH-4 10'-15' (75%)	2.6E-03	X	
BH-4 10'-15' (82.5%)	8.2E-04	X	
BH-4 10'-15' (90%)	7.0E-04	X	
BH-4 10'-15' (95%)	2.5E-04	X	
BH-4 30'-40' (82.5%)	2.9E-02	X	
North Cliff (82.5%)	1.4E-02	X	

Summary of Moisture Characteristics of the Initial Drainage Curve

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
BH-1 15'-25' (82.5%)	0	27.0
	11	25.5
	42	24.9
	81	24.5
	510	17.9
	7750	3.8
	851293	0.4
BH-1 40-50 (75%)	0	27.2
	9	24.2
	39	23.3
	84	22.9
	510	15.8
	8668	2.5
	851293	0.2
BH-1 40'-50' (82.5%)	0	30.4
	11	27.1
	41	26.2
	79	25.6
	510	21.8
	8668	2.8
	851293	0.2
BH-1 40'-50' (90%)	0	37.1
	21	33.1
	48	31.3
	153	29.5
	510	17.2
	8668	3.1
	851293	0.3

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
BH-1 40'-50' (95%)	0	37.4
	21	32.7
	48	31.3
	153	29.6
	510	18.4
	8668	3.2
	851293	0.3
BH-1 65'-75' (82.5%)	0	37.8
	11	34.9
	42	33.9
	81	33.3
	510	24.1
	7954	2.7
	851293	0.2
BH-1 65'-75' (90%)	0	28.9
	10	26.6
	39	24.8
	84	24.2
	510	15.9
	7954	2.7
	851293	0.2
BH-1 65'-75' (95%)	0	37.3
	21	32.2
	48	30.6
	153	28.6
	510	16.6
	7954	3.1
	851293	0.2

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
BH-1 90'-95' (82.5%)	0	26.6
	11	23.8
	41	22.5
	79	22.0
	510	17.2
	9382	3.0
	851293	0.1
BH-1 120'-125' (82.5%)	0	26.1
	11	23.5
	41	22.5
	79	21.8
	510	17.7
	10912	1.9
	851293	0.1
BH-1 145'-150' (82.5%)	0	26.2
	8	24.8
	41	23.9
	87	23.0
	510	16.3
	14379	1.7
	851293	0.1
BH-2 10'-15' (82.5%)	0	31.1
	11	30.1
	41	28.4
	79	27.6
	510	17.4
	9586	2.2
	851293	0.3

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
BH-2 25'-30' (82.5%)	0	30.4
	11	28.0
	41	25.7
	79	24.7
	510	16.2
	8362	2.4
	851293	0.2
BH-2 25'-30' (90%)	0	30.2
	10	28.1
	39	26.8
	85	26.3
	510	18.7
	8362	2.6
	851293	0.3
BH-2 25'-30' (95%)	0	35.9
	10	34.5
	41	33.2
	80	32.0
	510	17.0
	8362	2.8
	851293	0.3
BH-3 5'-10' (82.5%)	0	26.6
	9	24.6
	41	23.4
	80	22.5
	510	13.4
	9382	2.0
	851293	0.1

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
BH-3 20'-25' (82.5%)	0	28.7
	9	26.4
	41	25.4
	80	24.5
	510	17.6
	9382	2.6
	851293	0.1
BH-3 60'-65' (82.5%)	0	30.0
	23	27.3
	50	26.0
	154	23.8
	510	19.3
	8158	2.9
	851293	0.1
BH-3 60'-65' (90%)	0	31.1
	8	28.6
	41	27.5
	81	26.4
	510	20.5
	8158	3.2
	851293	0.1
BH-3 60'-65' (95%)	0	33.8
	21	32.4
	51	31.8
	160	28.0
	510	20.1
	8158	3.4
	851293	0.1

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
BH-3 90'-95' (75%)	0	27.0
	10	24.8
	41	22.4
	79	20.7
	510	14.3
	9484	2.1
	851293	0.1
BH-3 90'-95' (82.5%)	0	28.0
	9	25.7
	41	24.4
	80	23.4
	510	14.7
	9484	2.3
	851293	0.1
BH-3 90'-95' (90%)	0	28.5
	20	26.6
	51	25.9
	159	24.4
	510	21.1
	9484	2.6
	851293	0.1
BH-3 90'-95' (95%)	0	33.5
	21	32.4
	48	31.5
	153	26.0
	510	18.4
	9484	2.7
	851293	0.1

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
BH-4 10'-15' (75%)	0	26.1
	10	24.4
	40	22.9
	81	21.5
	510	12.3
	7343	1.7
	851293	0.2
BH-4 10'-15' (82.5%)	0	28.4
	20	15.8
	52	14.5
	151	13.0
	510	7.2
	7343	1.9
	851293	0.2
BH-4 10'-15' (90%)	0	30.3
	20	28.6
	50	27.1
	147	25.1
	510	14.8
	7343	2.0
	851293	0.2
BH-4 10'-15' (95%)	0	36.2
	22	34.5
	50	33.5
	145	28.3
	510	13.7
	7343	2.2
	851293	0.2

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
BH-4 30'-40' (82.5%)	0	27.4
	9	25.8
	41	24.7
	80	24.0
	510	16.4
	8362	2.8
	851293	0.1
North Cliff (82.5%)	0	51.6
	11	48.1
	41	30.5
	79	24.9
	510	9.0
	7241	1.7
	851293	0.1

Summary of Calculated Unsaturated Hydraulic Properties

Sample Number	α (cm^{-1})	N (dimensionless)	θ_r	θ_s
BH-1 15'-25' (82.5%)	0.0027	1.6175	0.0000	0.2579
BH-1 40-50 (75%)	0.0035	1.6185	0.0000	0.2487
BH-1 40'-50' (82.5%)	0.0016	1.8406	0.0000	0.2745
BH-1 40'-50' (90%)	0.0051	1.6350	0.0000	0.3462
BH-1 40'-50' (95%)	0.0048	1.6105	0.0000	0.3452
BH-1 65'-75' (82.5%)	0.0023	1.8433	0.0000	0.3525
BH-1 65'-75' (90%)	0.0046	1.5707	0.0000	0.2688
BH-1 65'-75' (95%)	0.0057	1.6095	0.0000	0.3433
BH-1 90'-95' (82.5%)	0.0026	1.6213	0.0000	0.2403
BH-1 120'-125' (82.5%)	0.0020	1.7740	0.0000	0.2367
BH-1 145'-150' (82.5%)	0.0030	1.6553	0.0000	0.2485
BH-2 10'-15' (82.5%)	0.0040	1.6456	0.0000	0.2992
BH-2 25'-30' (82.5%)	0.0064	1.5061	0.0000	0.2841
BH-2 25'-30' (90%)	0.0028	1.7084	0.0000	0.2821
BH-2 25'-30' (95%)	0.0056	1.6327	0.0000	0.3500
BH-3 5'-10' (82.5%)	0.0058	1.5599	0.0000	0.2516
BH-3 20'-25' (82.5%)	0.0031	1.6447	0.0000	0.2665
BH-3 60'-65' (82.5%)	0.0029	1.6418	0.0000	0.2769
BH-3 60'-65' (90%)	0.0023	1.7127	0.0000	0.2869
BH-3 60'-65' (95%)	0.0037	1.6282	0.0000	0.3289

Summary of Sample Splits and Gravel Correction Calculations

Sample Number	Split Sieve	% Coarse Material* (%, g/g)	K_{sat} (cm/sec)	θ_i	θ_s	θ_r
BH-3 90'-95' (75%)	#4 (4.75 mm)	0.72	----	----	----	----
BH-3 90'-95' (82.5%)	#4 (4.75 mm)	0.72	----	----	----	----
BH-3 90'-95' (90%)	#4 (4.75 mm)	0.72	----	----	----	----
BH-3 90'-95' (95%)	#4 (4.75 mm)	0.72	----	----	----	----
BH-4 10'-15' (75%)	#4 (4.75 mm)	0.63	----	----	----	----
BH-4 10'-15' (82.5%)	#4 (4.75 mm)	0.63	----	----	----	----
BH-4 10'-15' (90%)	#4 (4.75 mm)	0.63	----	----	----	----
BH-4 10'-15' (95%)	#4 (4.75 mm)	0.63	----	----	----	----
BH-4 30'-40' (82.5%)	#4 (4.75 mm)	9.03	2.8E-02	0.1254	0.2463	0.0000
North Cliff (82.5%)	#4 (4.75 mm)	2.52	----	----	----	----

*Percentage of material retained on the sieve used to split the sample
* Based on particle size analysis
---- Calculations not necessary since coarse fraction < 5%

Summary of Sample Splits and Gravel Correction Calculations

Sample Number	Split Sieve	% Coarse Material* (%, g/g)	K_{sat} (cm/sec)	θ_i	θ_s	θ_r
BH-1 15'-25' (82.5%)	#4 (4.75 mm)	8.90	4.7E-03	0.1161	0.2454	0.0000
BH-1 40-50 (75%)	#4 (4.75 mm)	4.93	----	----	----	----
BH-1 40'-50' (82.5%)	#4 (4.75 mm)	4.93	----	----	----	----
BH-1 40'-50' (90%)	#4 (4.75 mm)	4.93	----	----	----	----
BH-1 40'-50' (95%)	#4 (4.75 mm)	4.93	----	----	----	----
BH-1 65'-75' (82.5%)	#4 (4.75 mm)	4.32	----	----	----	----
BH-1 65'-75' (90%)	#4 (4.75 mm)	4.32	----	----	----	----
BH-1 65'-75' (95%)	#4 (4.75 mm)	4.32	----	----	----	----
BH-1 90'-95' (82.5%)	#4 (4.75 mm)	2.04	----	----	----	----
BH-1 120'-125' (82.5%)	#4 (4.75 mm)	2.03	----	----	----	----
BH-1 145'-150' (82.5%)	#4 (4.75 mm)	4.30	----	----	----	----
BH-2 10'-15' (82.5%)	#4 (4.75 mm)	6.70	9.1E-03	0.1186	0.2884	0.0000
BH-2 25'-30' (82.5%)	#4 (4.75 mm)	16.92	2.7E-03	0.1258	0.2570	0.0000
BH-2 25'-30' (90%)	#4 (4.75 mm)	16.92	9.8E-04	0.1146	0.2526	0.0000
BH-2 25'-30' (95%)	#4 (4.75 mm)	16.92	9.8E-05	0.1202	0.3117	0.0000
BH-3 5'-10' (82.5%)	#4 (4.75 mm)	8.92	1.2E-02	0.1131	0.2392	0.0000
BH-3 20'-25' (82.5%)	#4 (4.75 mm)	13.11	1.1E-02	0.1474	0.2471	0.0000
BH-3 60'-65' (82.5%)	#4 (4.75 mm)	6.01	9.2E-04	0.1634	0.2677	0.0000
BH-3 60'-65' (90%)	#4 (4.75 mm)	6.01	1.3E-04	0.1667	0.2765	0.0000
BH-3 60'-65' (95%)	#4 (4.75 mm)	6.01	1.2E-05	0.1654	0.3162	0.0000

Summary of Calculated Unsaturated Hydraulic Properties (Continued)

Sample Number	α (cm^{-1})	N (dimensionless)	θ_r	θ_s
BH-3 90'-95' (75%)	0.0108	1.4092	0.0000	0.2551
BH-3 90'-95' (82.5%)	0.0058	1.5307	0.0000	0.2630
BH-3 90'-95' (90%)	0.0017	1.8006	0.0000	0.2673
BH-3 90'-95' (95%)	0.0055	1.5583	0.0000	0.3294
BH-4 10'-15' (75%)	0.0072	1.5582	0.0000	0.2486
BH-4 10'-15' (82.5%)	0.2799	1.2664	0.0000	0.2831
BH-4 10'-15' (90%)	0.0043	1.7389	0.0000	0.2908
BH-4 10'-15' (95%)	0.0057	1.8361	0.0034	0.3542
BH-4 30'-40' (82.5%)	0.0035	1.6232	0.0000	0.2593
North Cliff (82.5%)	0.0478	1.5601	0.0000	0.5230

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Summary of Particle Size Characteristics

Sample Number	d_{10} (mm)	d_{50} (mm)	d_{60} (mm)	C_u	C_c	Method	ASTM Classification	USDA Classification
BH-1 15'-25'	0.0081	0.32	0.68	84	0.42	WS/H	Silty sand	Sandy Loam †
BH-1 40'-50'	0.0071	0.31	0.64	90	0.39	WS/H	Silty sand	Sandy Loam †
BH-1 65'-75'	0.0083	0.48	0.82	99	0.40	WS/H	Silty sand	Sandy Loam
BH-1 90'-95'	0.0092	0.50	0.81	88	0.52	WS/H	Silty sand	Sandy Loam
BH-1 120'-125'	0.0083	0.30	0.55	66	0.50	WS/H	Silty sand	Sandy Loam
BH-1 145'-150'	0.0079	0.31	0.56	71	0.61	WS/H	Silty sand	Sandy Loam †
BH-2 10'-15'	0.0095	0.44	0.74	78	0.48	WS/H	Silty sand	Sandy Loam †
BH-2 25'-30'	0.0083	0.60	1.0	120	0.62	WS/H	Silty sand with gravel	Sandy Loam †
BH-3 5'-10'	0.0096	0.36	0.66	69	0.36	WS/H	Silty sand	Sandy Loam †
BH-3 20'-25'	0.0075	0.31	0.64	85	0.54	WS/H	Silty sand	Sandy Loam †
BH-3 60'-65'	0.011	0.16	0.38	35	0.24	WS/H	Silty sand	Sandy Loam †

d_{50} = Median particle diameter

Est = Reported values for d_{10}, C_u, C_c, and soil classification are estimates, since extrapolation was required to obtain the d_{10} diameter

$$C_u = \frac{d_{60}}{d_{10}}$$

$$C_c = \frac{(d_{30})^2}{(d_{10})(d_{60})}$$

DS = Dry sieve

H = Hydrometer

WS = Wet sieve

† Greater than 10% of sample is coarse material

Summary of Particle Size Characteristics (Continued)

Sample Number	d_{10} (mm)	d_{50} (mm)	d_{60} (mm)	C_u	C_c	Method	ASTM Classification	USDA Classification
BH-3 90'-95'	0.0063	0.11	0.26	41	0.63	WS/H	Silty sand	Sandy Loam
BH-4 10'-15'	0.013	0.37	0.63	48	0.44	WS/H	Silty sand	Sandy Loam
BH-4 30'-40'	0.0078	0.41	0.72	92	0.52	WS/H	Silty sand	Sandy Loam †
North Cliff	0.019	0.46	0.69	36	1.3	WS/H	Silty sand	Loamy Sand †

d_{50} = Median particle diameter

Est = Reported values for d_{10}, C_u, C_c, and soil classification are estimates, since extrapolation was required to obtain the d_{10} diameter

$$C_u = \frac{d_{60}}{d_{10}}$$

$$C_c = \frac{(d_{30})^2}{(d_{10})(d_{60})}$$

DS = Dry sieve

H = Hydrometer

WS = Wet sieve

† Greater than 10% of sample is coarse material

Summary of Atterberg Tests

Sample Number	Liquid Limit	Plastic Limit	Plasticity Index	Classification
BH-1 15'-25'	---	---	---	ML
BH-1 40'-50'	---	---	---	ML
BH-1 65'-75'	---	---	---	ML
BH-1 90'-95'	---	---	---	ML
BH-1 120'-125'	---	---	---	ML
BH-1 145'-150'	---	---	---	ML
BH-2 10'-15'	---	---	---	ML
BH-2 25'-30'	---	---	---	ML
BH-3 5'-10'	---	---	---	ML
BH-3 20'-25'	---	---	---	ML
BH-3 60'-65'	---	---	---	ML
BH-3 90'-95'	---	---	---	ML
BH-4 10'-15'	---	---	---	ML
BH-4 30'-40'	---	---	---	ML
North Cliff	---	---	---	ML

--- = Soil requires visual-manual classification due to non-plasticity

Summary of Particle Density Tests

Sample Number	Particle Density (g/cm^3)
BH-1 65'-75'	2.55
BH-4 10'-15'	2.56

Clod Density
Summary of Moisture Content, Dry Bulk Density Wet Bulk Density and Calculated Porosity

Sample Number	Initial Moisture Content Gravimetric (%, g/g)	Initial Moisture Content Volumetric (%, cm^3/cm^3)	Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
BH-1 120'-125'	0.0	0.0	1.70	1.70	36.0
BH-1 120'-125' (Dup)	0.0	0.0	2.18	2.18	17.8
BH-1 145'-150'	0.1	0.2	1.62	1.63	38.7
BH-1 145'-150' (Dup)	0.1	0.1	1.21	1.22	54.2
BH-2 10'-15'	0.1	0.1	1.25	1.25	52.7
BH-2 25'-30'	0.1	0.2	1.72	1.72	35.1
BH-2 25'-30' (Dup)	0.1	0.2	1.71	1.72	35.3
BH-3 5'-10'	0.1	0.1	1.60	1.60	39.7
BH-3 20'-25'	0.1	0.1	1.78	1.78	32.7
BH-3 20'-25' (Dup)	0.1	0.1	1.67	1.68	36.8
BH-3 60'-65'	0.0	0.1	1.65	1.65	37.8
BH-4 30'-40'	0.0	0.0	1.70	1.70	35.7
BH-4 30'-40' (Dup)	0.0	0.0	1.76	1.76	33.7
North Cliff	4.5	5.4	1.19	1.25	55.0
North Cliff (Dup)	4.6	6.3	1.39	1.45	47.5

NA = Not analyzed

Unconsolidated Haul Density*
Summary of Moisture Content, Dry Bulk Density
Wet Bulk Density and Calculated Porosity

Sample Number	Initial Moisture Content Gravimetric (%, g/g)	Initial Moisture Content Volumetric (%, cm^3/cm^3)	Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
BH-1 (120-125)	0.2	0.3	1.69	1.69	36.1
BH-1 (145-150)	0.1	0.2	1.65	1.65	37.7
BH-2 (25-30)	0.2	0.4	1.56	1.56	41.3
BH-3 (20-25)	0.2	0.3	1.53	1.53	42.3
BH-4 (30-40)	0.3	0.5	1.54	1.54	41.9
North Cliff	0.1	0.2	1.25	1.25	52.9

*Unconsolidated Haul Densities were estimated by droping unconsolidated sample material into a container of known volume from a height of approximately 5 feet.

Summary of Proctor Compaction Tests

Sample Number	Measured		Oversize Corrected	
	Optimum Moisture Content (% g/g)	Maximum Dry Bulk Density (g/cm^3)	Optimum Moisture Content (% g/g)	Maximum Dry Bulk Density (g/cm^3)
BH-1 15'-25'	15.1	1.69	13.8	1.74
BH-1 40'-50'	14.1	1.67	---	---
BH-1 65'-75'	14.3	1.70	---	---
BH-1 90'-95'	12.1	1.79	---	---
BH-1 120'-125'	13.9	1.73	---	---
BH-1 145'-150'	13.8	1.72	---	---
BH-2 10'-15'	14.6	1.69	13.7	1.73
BH-2 25'-30'	14.6	1.70	12.2	1.81
BH-3 5'-10'	12.1	1.71	11.0	1.77
BH-3 20'-25'	12.4	1.72	10.8	1.80
BH-3 60'-65'	12.5	1.76	11.8	1.80
BH-3 90'-95'	12.1	1.79	---	---
BH-4 10'-15'	11.9	1.76	---	---
BH-4 30'-40'	14.4	1.72	13.2	1.78
North Cliff	19.6	1.53	---	---

— = Oversize correction is unnecessary since coarse fraction < 5%

NA = Not analyzed

Appendix E
Detailed Cost Information for Excavation and Shipping of Various Soils

TA-61 (includes crusher)

Cycle

	Number of BCY per truck (12 CY dump truck)	Number of BCY per truck (22 CY semi dump truck)
R02315-400	1.5 cy/bucket	1.5 cy/bucket
p. 372	12 cy in 8 passes	22.5 cy in 15 passes
	with 18% swell factor yields	with 18% swell factor yields
	9.84 cy per load	18.45 cy per load

Truck Haul Cycle

Load	15 minutes	
Haul	12 miles	
Round Trip	24 miles	
RT	58 minutes	(Assumes 25 MPH average speed)
Security Check	5 minutes	
Dump	6 minutes	
Position	6 minutes	
	90 minutes per load	

Output

		Number	Hourly Output CY	Hr/day	Daily Output CY
02315 418 0250	Backhoe, hydraulic 1.5 CY	2	100.0	8.0	1600
02315 424 1250	Loader, 2.5 CY	2	95.0	8.0	1520
	Crusher Plant* (175 tons/hr)	1	227.5	8.0	1820
	Semi Truck (18 CY)	16	12.4	8.0	1581
				Daily Output =	**1520**

Cost

Source	Item	Number	Hr/day	Hourly Cost	Daily Cost	Subtotal
01590 200 0200	Excavator (includes operator)	2			$683.40	$1,366.80
	Crusher Plant	1			$1,500.00	$1,500.00
01590 200 4710	Loader (includes operator)	2			$295.60	$591.20
01590 200 5300	Dump Trucks (12 CY)	0			$476.60	$0.00
MRT Inc.	Semi Truck (18 CY)	16	8.0	$65.00	$8,320.00	$8,320.00
					Total per day =	$11,778.00
					Total per CY =	**$7.75**
					(Costs are in 2004 dollars)	

**Example of portable track mounted rock crusher plant:*
Eagle Crusher Company, EagleTraxx, track-mounted impactor plant.
The portable crusher is self-contained, but can work in tandem with other stationary or portable equipment.
It features a sculptured solid-steel, three-bar rotor, a 5/8-inch steel hopper, a remote operator's pendant, and optional hopper extensions or increased loading capacity and low travel height.
The plant, powered by a 280-horsepower diesel engine, can process 150 to 200 tons per hour.
http://www.aggman.com/articles/NewProds/may05sup.htm

Nambe (no crusher)

Cycle

Number of BCY per truck
(22 CY semi dump truck)
11 CY elevating scraper
22 cy in 2 passes
with 18% swell factor yields
18.04 cy per load

Truck Haul Cycle

Load	15 minutes	
Haul	25 miles	
Round Trip	50 miles	
RT	120 minutes	(Assumes 25 MPH average speed)
Security Check	5 minutes	
Dump	6 minutes	
Position	6 minutes	
	152 minutes per load	

Output

		Number	Hourly Output CY	Hr/day	Daily Output CY
02315 452 0300	Scraper 11 CY	2	75.0	8.0	1200
02315 424 1250	Loader, 2.5 CY	2	95.0	8.0	1520
	Semi Truck (18 CY)	21	7.1	8.0	1196
				Daily Output =	**1196**

Cost

Source	Item	Number	Hours/day	Hourly Cost	Daily Cost	Subtotal
01590 200 3550	Scraper, 11 CY, 4x4 self propelled	2			$1,468.00	$2,936.00
01590 200 4710	Loader (includes operator)	2			$295.60	$591.20
01590 200 5300	Dump Trucks (12 CY)	0			$476.60	$0.00
MRT Inc.	Semi Truck (18 CY)	21	8.0	$65.00	$500.00	$10,500.00
					Total per day =	$14,027.20
					Total per CY =	**$11.73**

(Costs are in 2004 dollars)

Basalt Boulders

Cycle

Number of BCY per truck
(12 CY dump truck)
2.5 cy/bucket
10 cy in 4 buckets
with no swell factor yields
8.2 cy per load

Truck Haul Cycle

Load	15 minutes	
Haul (1 way)	12 miles	
Round Trip	24 miles	
RT	58 minutes	(Assumes 25 MPH average speed)
Security Check	5 minutes	
Dump	5 minutes	
Position	5 minutes	
	88 minutes per load	

Output

		Number	Hourly Output CY	Hr/day	Daily Output CY
02315 416 0100	Drill/blast rock, open face, >1500CY	1	37.5	8.0	300
02315 424 1250	Loader, 2.5 CY	1	120	8.0	960
	Dump Trucks (12 CY)	5	8.2	8.0	328
02315 432 4400	Dozer, 200 HP (remove overburden)	2	33.75	8.0	540
				Daily Output =	**300**

Cost

Source	Item	Number	Hr/day	Hourly Cost	Daily Cost	Subtotal
02315 416 0100	Drill/Blast	1			$3,150.00	$3,150.00
02315 416 05020	Excavate and load boulders	1			$3,930.00	$3,930.00
01590 200 4260	Dozer, 200 HP	2			$863.40	$1,726.80
01590 200 5300	Dump Trucks (12 CY)	5			$476.60	$2,383.00
MRT Inc.	Semi Truck (18 CY)	0	8.0	$65.00	$0.00	$0.00

Total per day = $11,189.80
Total per CY = $ 37.30
(Costs are in 2004 dollars)

Find: Estimated volume of boulders needed for the covers.

Given: In-place volumes of materials for covers

Data Source: Borrow Source Survey for Evapotranspiration Covers at Los Alamos National Laboratories 4/12/2005, DBS&A

Method: Find the average percentage of total volume of Angular Boulders for MDAs C and L from the previous report. Apply this percentage to the estimated volumes for the additional MDAs for this study to estimate the boulder volumes needed.
Delivered Material Volumes* (Table 4. Borrow Material 4-05)

Assumptions: Removed overburden remains on site
Primarily open face rock
No permitting, access fees, access costs, site preparation, or surveying included
No property restoration is included

MDA C	MDA C (yd^3)		MDA L (yd^3)		
	1-meter cover	2.5-meter cover	1-meter cover	2.5-meter cover	
Soil rooting medium	49070	155522	6669	35892	
Top soil	10569	11685	1774	2557	
Select fill	68038	68592	3883	4961	
Gravel	1057	1168	177	256	
Cobbles	1057	1168	177	256	
Totals	129791	238135	12680	43922	
					Average
Angular boulders	1151	3604	657	711	Percentage
% of total volume	0.9%	1.5%	5.2%	1.6%	2.3%

*Delivered material quantities were calculated using the following assumptions:
Delivered volumes are 20% greater than in-place compacted volumes.
A 10% contingency factor is added to the delivered material quantities.

Laboratory Report for

Los Alamos National Laboratory

Copy of Summary Sheets

Cover Borrow Source Survey-Nambe

(Req #: 4066S)

January 17, 2006

Daniel B. Stephens & Associates, Inc.

6020 Academy NE, Suite 100 • Albuquerque, New Mexico 87109

Summary of Tests Performed

Laboratory Sample Number	Initial Soil Properties[1] (θ, ρ_d, ϕ)	Saturated Hydraulic Conductivity[2]		Moisture Characteristics[3]					Unsaturated Hydraulic Conductivity	Particle Size[4]			Atterberg Limits	Clod Density	Unconsolidated Haul Density	1/3, 15 Bar Points and Water Holding Capacity	Proctor Compaction
		CH	FH	HC	PP	TH	WP	RH		DS	WS	H					
NPDC-1 (75%)	X	X		X	X		X	X	X		X	X	X	X	X		X
NPDC-1 (82.5%)	X	X		X	X		X	X	X								
NPDC-1 (95%)	X	X		X	X		X	X	X								
NPDC-2 (75%)	X	X		X	X		X	X	X		X	X	X				X
NPDC-2 (82.5%)	X	X		X	X		X	X	X								
NPDC-2 (95%)	X	X		X	X		X	X	X								
NPDC-3 (75%)	X		X	X	X		X	X	X		X	X	X	X	X		X
NPDC-3 (82.5%)	X		X	X	X		X	X	X								
NPDC-3 (95%)	X		X	X	X		X	X	X								
NPDC-4 (82.5%)	X	X		X	X		X	X	X		X	X	X	X	X		X
NPDC-5 (82.5%)	X	X		X	X		X	X	X		X	X	X				X
NPDC-6 (82.5%)	X	X		X	X		X	X	X		X	X	X				X
NPDC-7 (75%)	X	X		X	X		X	X	X		X	X	X	X	X		X
NPDC-7 (82.5%)	X	X		X	X		X	X	X								
NPDC-7 (95%)	X	X		X	X		X	X	X								

[1] θ = Initial moisture content, ρ_d = Dry bulk density, ϕ = Calculated porosity
[2] CH = Constant head, FH = falling head
[3] HC = Hanging column, PP = Pressure plate, TH = Thermocouple psychrometer, WP = Water activity meter, RH = Relative humidity box
[4] DS = Dry sieve, WS = Wet sieve, H = Hydrometer

Summary of Tests Performed (Continued)

Laboratory Sample Number	Initial Soil Properties[1] (θ, ρ_d, ϕ)	Saturated Hydraulic Conductivity[2]		Moisture Characteristics[3]					Unsaturated Hydraulic Conductivity	Particle Size[4]			Atterberg Limits	Clod Density	Unconsolidated Haul Density	1/3, 15 Bar Points and Water Holding Capacity	Proctor Compaction
		CH	FH	HC	PP	TH	WP	RH		DS	WS	H					
NPDC-8 (75%)	X	X		X	X		X	X	X		X	X	X				X
NPDC-8 (82.5%)	X	X		X	X		X	X	X								
NPDC-8 (95%)	X		X	X	X		X	X	X								
NPDC-9 (82.5%)	X	X		X	X		X	X	X		X	X	X				X
NPDC-10 (82.5%)	X	X		X	X		X	X	X		X	X	X	X	X		X

[1] θ = Initial moisture content, ρ_d = Dry bulk density, ϕ = Calculated porosity
[2] CH = Constant head, FH = falling head
[3] HC = Hanging column, PP = Pressure plate, TH = Thermocouple psychrometer, WP = Water activity meter, RH = Relative humidity box
[4] DS = Dry sieve, WS = Wet sieve, H = Hydrometer

Summary of Sample Preparation

	As Received Data	Proctor Data		Target Remold Values*	Actual Remold Data			*Estimated Average* Measured Settled Densities**		
	Moisture Content	Optimum Moisture Content	Maximum Dry Bulk Density	Target Remold Densities	Moisture Content	Dry Bulk Density	% of Maximum Dry Bulk Density	Average Settled Dry Bulk Density	Average % Settled After Remold	% of Maximum Dry Bulk Density
Sample Number	(% g/g)	(% g/g)	(g/cm^3)	(g/cm^3)	(%, g/g)	(g/cm^3)	(%)	(g/cm^3)	(%)	(%)
NPDC-1 (75%)	12.7	16.5	1.76	1.32	15.2	1.32	75.0	----	0.0	----
NPDC-1 (82.5%)	12.7	16.5	1.76	1.45	13.2	1.47	83.7	----	0.0	----
NPDC-1 (95%)	12.7	16.5	1.76	1.67	14.5	1.68	95.2	----	0.0	----
NPDC-2 (75%)	11.0	14.1	1.76	1.32	12.9	1.32	75.2	1.49	11.0	84.5
NPDC-2 (82.5%)	11.0	14.1	1.76	1.45	13.0	1.45	82.2	----	0.0	----
NPDC-2 (95%)	11.0	14.1	1.76	1.67	12.9	1.67	95.0	----	0.0	----
NPDC-3 (75%)	9.1	15.4	1.82	1.36	13.2	1.37	75.3	1.46	6.0	80.2
NPDC-3 (82.5%)	9.1	15.4	1.82	1.50	13.4	1.51	82.9	----	0.0	----
NPDC-3 (95%)	9.1	15.4	1.82	1.73	13.3	1.73	95.1	----	0.0	----
NPDC-4 (82.5%)	16.7	17.2	1.74	1.44	11.2	1.50	86.0	----	0.0	----

Summary of Sample Preparation

	As Received Data	Proctor Data		Target Remold Values*	Actual Remold Data			*Estimated Average* Measured Settled Densities**		
	Moisture Content	Optimum Moisture Content	Maximum Dry Bulk Density	Target Remold Densities	Moisture Content	Dry Bulk Density	% of Maximum Dry Bulk Density	Average Settled Dry Bulk Density	Average % Settled After Remold	% of Maximum Dry Bulk Density
Sample Number	(% g/g)	(% g/g)	(g/cm^3)	(g/cm^3)	(%, g/g)	(g/cm^3)	(%)	(g/cm^3)	(%)	(%)
NPDC-5 (82.5%)	13.4	17.2	1.74	1.44	13.5	1.47	84.5	----	0.0	----
NPDC-6 (82.5%)	6.6	15.1	1.79	1.47	14.2	1.48	82.7	----	0.0	----
NPDC-7 (75%)	14.6	17.5	1.70	1.27	16.0	1.27	75.0	1.30	2.2	76.6
NPDC-7 (82.5%)	14.6	17.5	1.70	1.40	15.6	1.40	82.8	----	0.0	----
NPDC-7 (95%)	14.6	17.5	1.70	1.61	15.5	1.62	95.3	----	0.0	----
NPDC-8 (75%)	13.7	17.9	1.72	1.29	15.9	1.30	75.1	1.38	6.0	79.9
NPDC-8 (82.5%)	13.7	17.9	1.72	1.42	16.2	1.42	82.1	----	0.0	----
NPDC-8 (95%)	13.7	17.9	1.72	1.64	15.1	1.64	95.3	----	0.0	----
NPDC-9 (82.5%)	7.6	14.4	1.74	1.43	12.4	1.44	83.2	----	0.0	----
NPDC-10 (82.5%)	17.4	16.0	1.76	1.45	14.6	1.45	82.6	----	0.0	----

Summary of Sample Preparation

Notes:

*Target Remold Values: Target remold densities at 75%, 82.5%, 90%, and 95% of the respective proctor based maximum dry bulk density. Target percentages are noted in parentheses following the sample names. Target remold moisture content was between the as received moisture content and the proctor based optimum moisture content.

**Measure Settled Densities: Remolded samples settled significantly during saturated hydraulic conductivity testing, and continued settling throughout unsaturated hydraulic conductivity testing. Settled dimensions were estimated based on the average of the measurements obtained after saturated hydraulic conductivity testing and throughout unsaturated hydraulic conductivity testing. The test results provided are based on these averages of the estimated measured settled densities.

Summary of Initial Moisture Content, Dry Bulk Density Wet Bulk Density and Calculated Porosity

Sample Number	Moisture Content				Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
	As Received		Remolded				
	Gravimetric (%, g/g)	Volumetric (%, cm^3/cm^3)	Gravimetric (%, g/g)	Volumetric (%, cm^3/cm^3)			
NPDC-1 (75%)	12.7	NA	15.2	20.0	1.32	1.52	50.2
NPDC-1 (82.5%)	12.7	NA	13.2	19.4	1.47	1.67	44.5
NPDC-1 (95%)	12.7	NA	14.5	24.3	1.68	1.92	36.8
NPDC-2 (75%)	11.0	NA	12.9	17.1	1.32	1.49	50.1
NPDC-2 (82.5%)	11.0	NA	13.0	18.7	1.45	1.63	45.4
NPDC-2 (95%)	11.0	NA	12.9	21.5	1.67	1.89	36.9
NPDC-3 (75%)	9.1	NA	13.2	18.1	1.37	1.55	48.3
NPDC-3 (82.5%)	9.1	NA	13.4	20.2	1.51	1.71	43.1
NPDC-3 (95%)	9.1	NA	13.3	23.0	1.73	1.96	34.7
NPDC-4 (82.5%)	16.7	NA	11.2	16.8	1.50	1.67	43.4
NPDC-5 (82.5%)	13.4	NA	13.5	19.9	1.47	1.67	44.5
NPDC-6 (82.5%)	6.6	NA	14.2	21.1	1.48	1.69	44.2

Summary of Initial Moisture Content, Dry Bulk Density Wet Bulk Density and Calculated Porosity

Sample Number	Moisture Content				Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
	As Received		Remolded				
	Gravimetric (%, g/g)	Volumetric (%, cm^3/cm^3)	Gravimetric (%, g/g)	Volumetric (%, cm^3/cm^3)			
NPDC-7 (75%)	14.6	NA	16.0	20.3	1.27	1.47	52.0
NPDC-7 (82.5%)	14.6	NA	15.6	21.9	1.40	1.62	47.0
NPDC-7 (95%)	14.6	NA	15.5	25.0	1.62	1.87	39.0
NPDC-8 (75%)	13.7	NA	15.9	20.6	1.30	1.50	51.1
NPDC-8 (82.5%)	13.7	NA	16.2	22.9	1.42	1.65	46.6
NPDC-8 (95%)	13.7	NA	15.1	24.7	1.64	1.89	38.0
NPDC-9 (82.5%)	7.6	NA	12.4	17.9	1.44	1.62	45.5
NPDC-10 (82.5%)	17.4	NA	14.6	21.2	1.45	1.66	45.2

NA = Not analyzed

--- = This sample was not remolded

Summary of Saturated Hydraulic Conductivity Tests

Sample Number	K_{sat} (cm/sec)	Method of Analysis: Constant Head	Method of Analysis: Falling Head
NPDC-1 (75%)	4.3E-03	X	
NPDC-1 (82.5%)	8.2E-04	X	
NPDC-1 (95%)	5.6E-05	X	
NPDC-2 (75%)	8.7E-03	X	
NPDC-2 (82.5%)	2.7E-03	X	
NPDC-2 (95%)	2.1E-04	X	
NPDC-3 (75%)	1.3E-05		X
NPDC-3 (82.5%)	8.1E-06		X
NPDC-3 (95%)	1.2E-07		X
NPDC-4 (82.5%)	2.0E-04	X	
NPDC-5 (82.5%)	7.4E-04	X	
NPDC-6 (82.5%)	4.9E-03	X	
NPDC-7 (75%)	1.3E-03	X	
NPDC-7 (82.5%)	2.6E-04	X	
NPDC-7 (95%)	3.0E-05	X	
NPDC-8 (75%)	1.8E-03	X	
NPDC-8 (82.5%)	6.1E-04	X	
NPDC-8 (95%)	2.8E-06		X
NPDC-9 (82.5%)	1.6E-02	X	
NPDC-10 (82.5%)	7.1E-04	X	

Summary of Moisture Characteristics of the Initial Drainage Curve

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
NPDC-1 (75%)	0	51.1
	10	50.1
	39	44.7
	77	33.4
	510	21.7
	14889	11.2
	851293	3.3
NPDC-1 (82.5%)	0	43.1
	24	40.4
	51	39.0
	147	27.8
	510	21.3
	14889	12.5
	851293	3.7
NPDC-1 (95%)	0	39.8
	15	39.4
	51	39.3
	146	35.1
	510	26.3
	14889	14.3
	851293	4.2
NPDC-2 (75%)	0	46.6
	9	43.5
	40	41.8
	77	26.3
	510	14.1
	9586	8.3
	851293	2.0

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
NPDC-2 (82.5%)	0	45.6
	10	40.9
	41	40.1
	83	25.9
	510	16.7
	9586	9.0
	851293	2.2
NPDC-2 (95%)	0	37.5
	15	35.1
	51	34.9
	146	21.5
	510	17.6
	9586	10.4
	851293	2.6
NPDC-3 (75%)	0	41.6
	20	40.7
	52	40.0
	148	33.7
	510	28.3
	8362	15.4
	851293	3.9
NPDC-3 (82.5%)	0	42.0
	25	41.7
	98	39.0
	157	31.3
	510	28.5
	8362	16.9
	851293	4.3

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
NPDC-3 (95%)	0	33.4
	26	33.1
	101	32.6
	183	29.9
	510	26.8
	8362	19.4
	851293	5.0
NPDC-4 (82.5%)	0	39.6
	24	35.8
	51	34.9
	147	29.1
	510	23.4
	16113	15.5
	851293	5.7
NPDC-5 (82.5%)	0	42.2
	24	40.6
	51	39.3
	147	28.3
	510	21.4
	14175	12.3
	851293	4.1
NPDC-6 (82.5%)	0	43.9
	11	42.5
	38	34.1
	81	22.7
	510	17.3
	6119	8.2
	851293	2.0

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
NPDC-7 (75%)	0	52.0
	10	51.4
	40	46.2
	79	36.7
	510	23.2
	6629	14.2
	851293	3.4
NPDC-7 (82.5%)	0	46.5
	22	45.7
	50	44.7
	138	32.2
	510	24.9
	6629	15.7
	851293	3.7
NPDC-7 (95%)	0	41.5
	15	41.2
	51	41.2
	146	38.7
	510	28.4
	6629	18.1
	851293	4.3
NPDC-8 (75%)	0	45.7
	10	43.9
	38	42.1
	76	38.1
	510	27.3
	20396	15.4
	851293	5.0

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
NPDC-8 (82.5%)	0	47.9
	20	46.1
	49	40.4
	144	33.3
	510	29.4
	20396	16.8
	851293	5.5
NPDC-8 (95%)	0	38.3
	25	38.2
	99	35.9
	181	33.4
	510	30.7
	20396	19.5
	851293	6.4
NPDC-9 (82.5%)	0	45.4
	8	42.7
	40	40.4
	510	12.2
	10606	4.2
	21008	3.7
	851293	1.2
NPDC-10 (82.5%)	0	45.4
	21	45.3
	51	43.0
	136	31.9
	510	24.8
	7750	12.3
	851293	3.9

Summary of Calculated Unsaturated Hydraulic Properties

Sample Number	α (cm^{-1})	N (dimensionless)	θ_r	θ_s
NPDC-1 (75%)	0.0356	1.3246	0.0282	0.5203
NPDC-1 (82.5%)	0.0251	1.2882	0.0264	0.4384
NPDC-1 (95%)	0.0085	1.2348	0.0000	0.4038
NPDC-2 (75%)	0.0235	1.5996	0.0412	0.4633
NPDC-2 (82.5%)	0.0325	1.3856	0.0253	0.4503
NPDC-2 (95%)	0.0240	1.3273	0.0232	0.3782
NPDC-3 (75%)	0.0096	1.2385	0.0000	0.4177
NPDC-3 (82.5%)	0.0127	1.2162	0.0000	0.4264
NPDC-3 (95%)	0.0033	1.1986	0.0000	0.3321
NPDC-4 (82.5%)	0.0348	1.1678	0.0000	0.3956
NPDC-5 (82.5%)	0.0198	1.3202	0.0358	0.4314
NPDC-6 (82.5%)	0.0568	1.3396	0.0164	0.4504
NPDC-7 (75%)	0.0313	1.2936	0.0163	0.5297
NPDC-7 (82.5%)	0.0199	1.2733	0.0134	0.4793
NPDC-7 (95%)	0.0061	1.2486	0.0000	0.4212
NPDC-8 (75%)	0.0220	1.1974	0.0000	0.4553
NPDC-8 (82.5%)	0.0384	1.1776	0.0000	0.4844
NPDC-8 (95%)	0.0054	1.1738	0.0000	0.3816
NPDC-9 (82.5%)	0.0123	1.7589	0.0236	0.4436
NPDC-10 (82.5%)	0.0160	1.3261	0.0238	0.4665

Summary of Sample Splits and Gravel Correction Calculations

Sample Number	Split Sieve	% Coarse Material* (%, g/g)	K_{sat} (cm/sec)	θ_i	θ_s	θ_r
NPDC-1 (75%)	#4 (4.75 mm)	6.05	4.2E-03	0.1473	0.5041	0.0273
NPDC-1 (82.5%)	#4 (4.75 mm)	6.05	7.9E-04	0.1274	0.4233	0.0255
NPDC-1 (95%)	#4 (4.75 mm)	6.05	5.4E-05	0.2335	0.3880	0.0000
NPDC-2 (75%)	#4 (4.75 mm)	8.75	8.3E-03	0.1632	0.4422	0.0393
NPDC-2 (82.5%)	#4 (4.75 mm)	8.75	2.6E-03	0.1777	0.4279	0.0240
NPDC-2 (95%)	#4 (4.75 mm)	8.75	2.0E-04	0.2027	0.3566	0.0219
NPDC-3 (75%)	#4 (4.75 mm)	1.29	----	----	----	----
NPDC-3 (82.5%)	#4 (4.75 mm)	1.29	----	----	----	----
NPDC-3 (95%)	#4 (4.75 mm)	1.29	----	----	----	----
NPDC-4 (82.5%)	#4 (4.75 mm)	3.08	----	----	----	----
NPDC-5 (82.5%)	#4 (4.75 mm)	9.58	7.0E-04	0.1880	0.4075	0.0338
NPDC-6 (82.5%)	#4 (4.75 mm)	2.87	----	----	----	----
NPDC-7 (75%)	#4 (4.75 mm)	4.91	----	----	----	----
NPDC-7 (82.5%)	#4 (4.75 mm)	4.91	----	----	----	----
NPDC-7 (95%)	#4 (4.75 mm)	4.91	----	----	----	----
NPDC-8 (75%)	#4 (4.75 mm)	9.37	1.7E-03	0.1961	0.4333	0.0000
NPDC-8 (82.5%)	#4 (4.75 mm)	9.37	5.8E-04	0.2170	0.4590	0.0000
NPDC-8 (95%)	#4 (4.75 mm)	9.37	2.6E-06	0.2321	0.3587	0.0000
NPDC-9 (82.5%)	#4 (4.75 mm)	0.77	----	----	----	----
NPDC-10 (82.5%)	#4 (4.75 mm)	1.23	----	----	----	----

*Percentage of material retained on the sieve used to split the sample
* Based on particle size analysis
---- Calculations not necessary since coarse fraction < 5%

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Summary of Particle Size Characteristics

Sample Number	d_{10} (mm)	d_{50} (mm)	d_{60} (mm)	C_u	C_c	Method	ASTM Classification	USDA Classification	
NPDC-1	0.0014	0.059	0.080	57	6.5	WS/H	Sandy silt	Sandy Loam	
NPDC-2	0.025	0.15	0.18	7.2	2.0	WS/H	Silty sand	Loamy Sand	
NPDC-3	0.00021	0.041	0.055	262	8.0	WS/H	Lean clay with sand	Loam	(Est)
NPDC-4	0.00066	0.039	0.051	77	3.0	WS/H	Silt with sand	Loam	(Est)
NPDC-5	0.0018	0.068	0.092	51	8.3	WS/H	Sandy silt	Sandy Loam †	
NPDC-6	0.012	0.17	0.21	18	4.8	WS/H	Silty sand	Loamy Sand	
NPDC-7	0.0030	0.065	0.080	27	7.0	WS/H	Sandy silt	Sandy Loam	
NPDC-8	0.00047	0.055	0.087	185	3.5	WS/H	Sandy lean clay	Loam †	(Est)
NPDC-9	0.036	0.19	0.24	6.7	2.0	WS/H	Silty sand	Loamy Sand	
NPDC-10	0.0016	0.055	0.068	43	10	WS/H	Sandy silt	Sandy Loam	

d_{50} = Median particle diameter

Est = Reported values for d_{10}, C_u, C_c, and soil classification are estimates, since extrapolation was required to obtain the d_{10} diameter

$$C_u = \frac{d_{60}}{d_{10}}$$

$$C_c = \frac{(d_{30})^2}{(d_{10})(d_{60})}$$

DS = Dry sieve

H = Hydrometer

WS = Wet sieve

† Greater than 10% of sample is coarse material

Summary of Atterberg Tests

Sample Number	Liquid Limit	Plastic Limit	Plasticity Index	Classification
NPDC-1	---	---	---	ML
NPDC-2	---	---	---	ML
NPDC-3	30	22	8	CL
NPDC-4	32	25	7	ML
NPDC-5	---	---	---	ML
NPDC-6	---	---	---	ML
NPDC-7	---	---	---	ML
NPDC-8	32	22	10	CL
NPDC-9	---	---	---	ML
NPDC-10	---	---	---	ML

— = Soil requires visual-manual classification due to non-plasticity

Clod Density
Summary of Moisture Content, Dry Bulk Density
Wet Bulk Density and Calculated Porosity

Sample Number	Initial Moisture Content Gravimetric (%, g/g)	Initial Moisture Content Volumetric (%, cm^3/cm^3)	Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
NPDC-1	4.4	6.9	1.57	1.64	40.6
NPDC-3	2.7	2.7	1.01	1.04	61.7
NPDC-4	8.5	17.7	2.08	2.25	21.6
NPDC-7	3.3	5.5	1.66	1.71	37.4
NPDC-10	3.9	6.7	1.72	1.79	34.9

NA = Not analyzed

Unconsolidated Haul Density*
Summary of Moisture Content, Dry Bulk Density
Wet Bulk Density and Calculated Porosity

Sample Number	Initial Moisture Content		Dry Bulk Density	Wet Bulk Density	Calculated Porosity
	Gravimetric (%, g/g)	Volumetric (%, cm^3/cm^3)	(g/cm^3)	(g/cm^3)	(%)
NPDC-1	4.4	6.6	1.50	1.56	43.5
NPDC-3	2.3	3.0	1.32	1.35	50.0
NPDC-4	8.5	11.7	1.38	1.49	48.1
NPDC-7	4.2	5.9	1.38	1.44	48.0
NPDC-10	4.4	6.6	1.50	1.57	43.3

*Unconsolidated Haul Densities were estimated by droping unconsolidated sample material into a container of known volume from a height of approximately 5 feet.

NA = Not analyzed

Summary of Proctor Compaction Tests

Sample Number	Measured		Oversize Corrected	
	Optimum Moisture Content (% g/g)	Maximum Dry Bulk Density (g/cm^3)	Optimum Moisture Content (% g/g)	Maximum Dry Bulk Density (g/cm^3)
NPDC-1	16.5	1.76	15.5	1.80
NPDC-2	14.1	1.76	12.9	1.81
NPDC-3	15.4	1.82	---	---
NPDC-4	17.2	1.74	---	---
NPDC-5	17.2	1.74	15.5	1.80
NPDC-6	15.1	1.79	---	---
NPDC-7	17.5	1.70	---	---
NPDC-8	17.9	1.72	16.2	1.78
NPDC-9	14.4	1.74	---	---
NPDC-10	16.0	1.76	---	---

--- = Oversize correction is unnecessary since coarse fraction < 5%

NA = Not analyzed

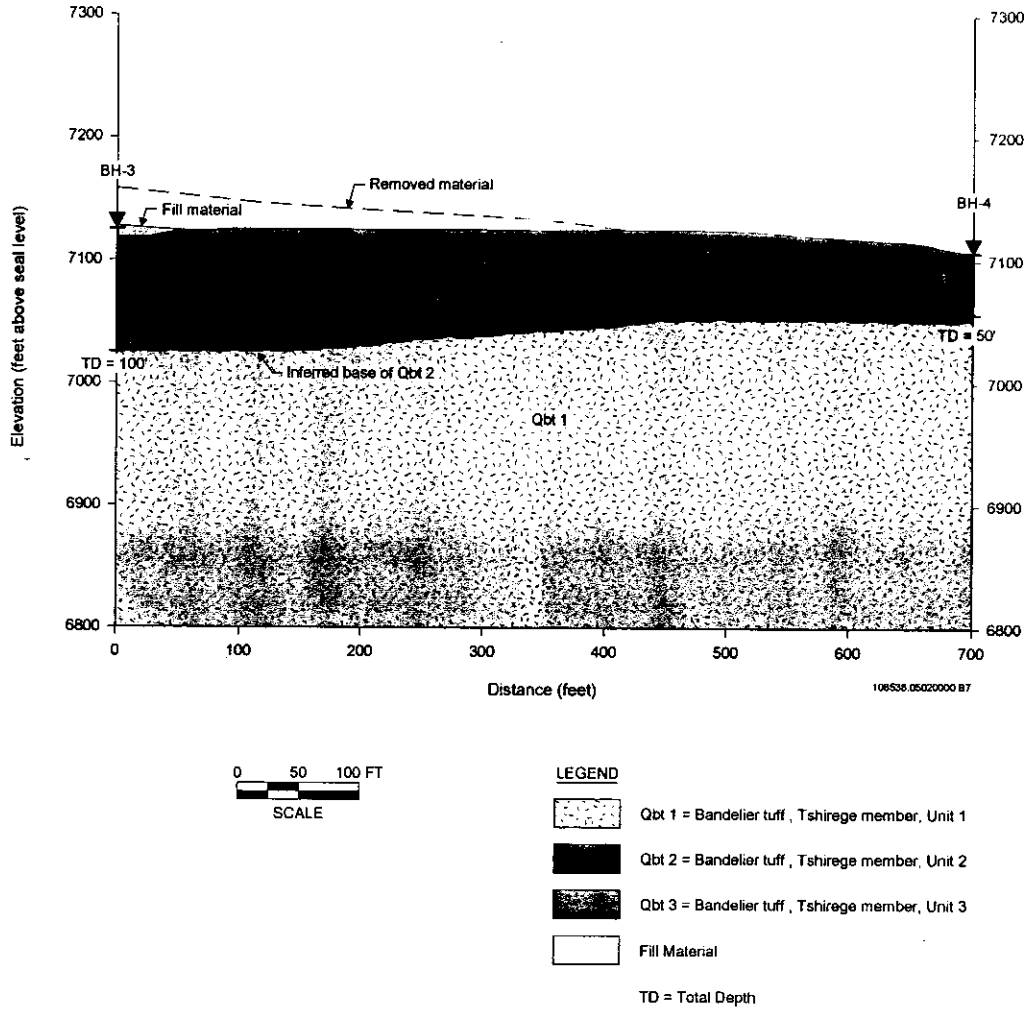

Figure 10. BH-3 to BH-4 Cross Section, TA-61 Borrow Area Characterization

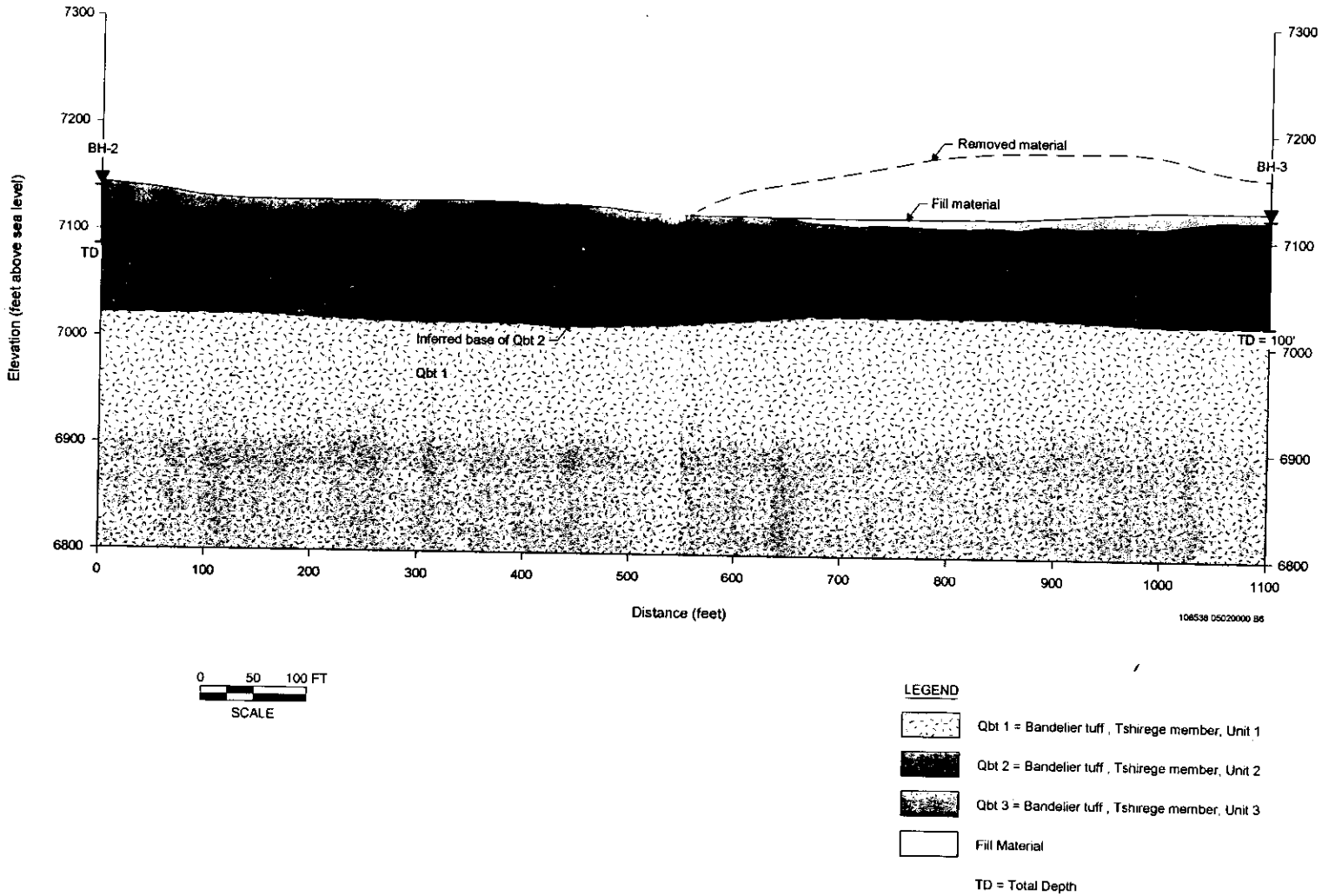

Figure 9. **BH-2 to BH-3 Cross Section, TA-61 Borrow Area Characterization**

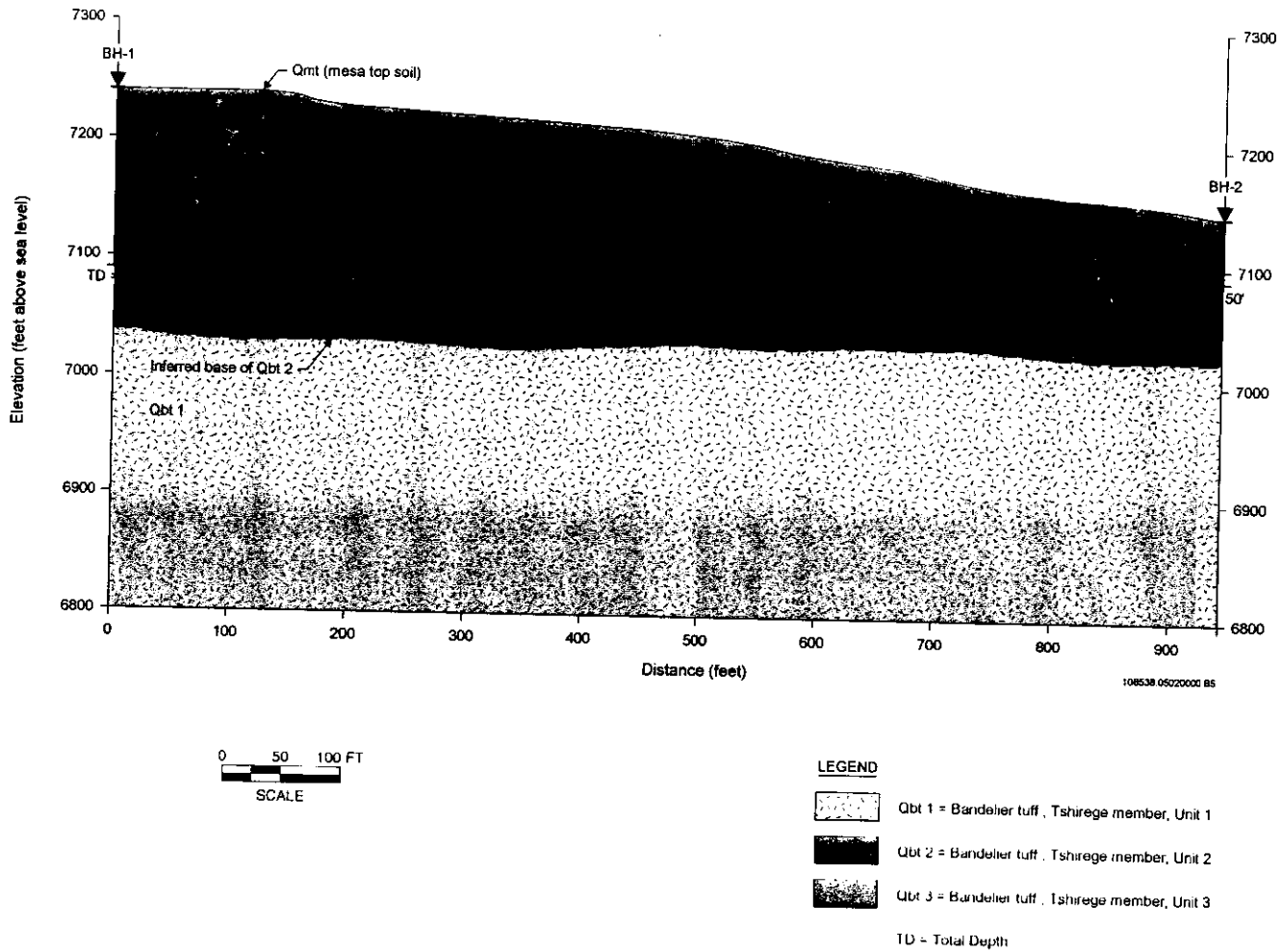

Figure 8. **BH-1 to BH-2 Cross Section, TA-61 Borrow Area Characterization**

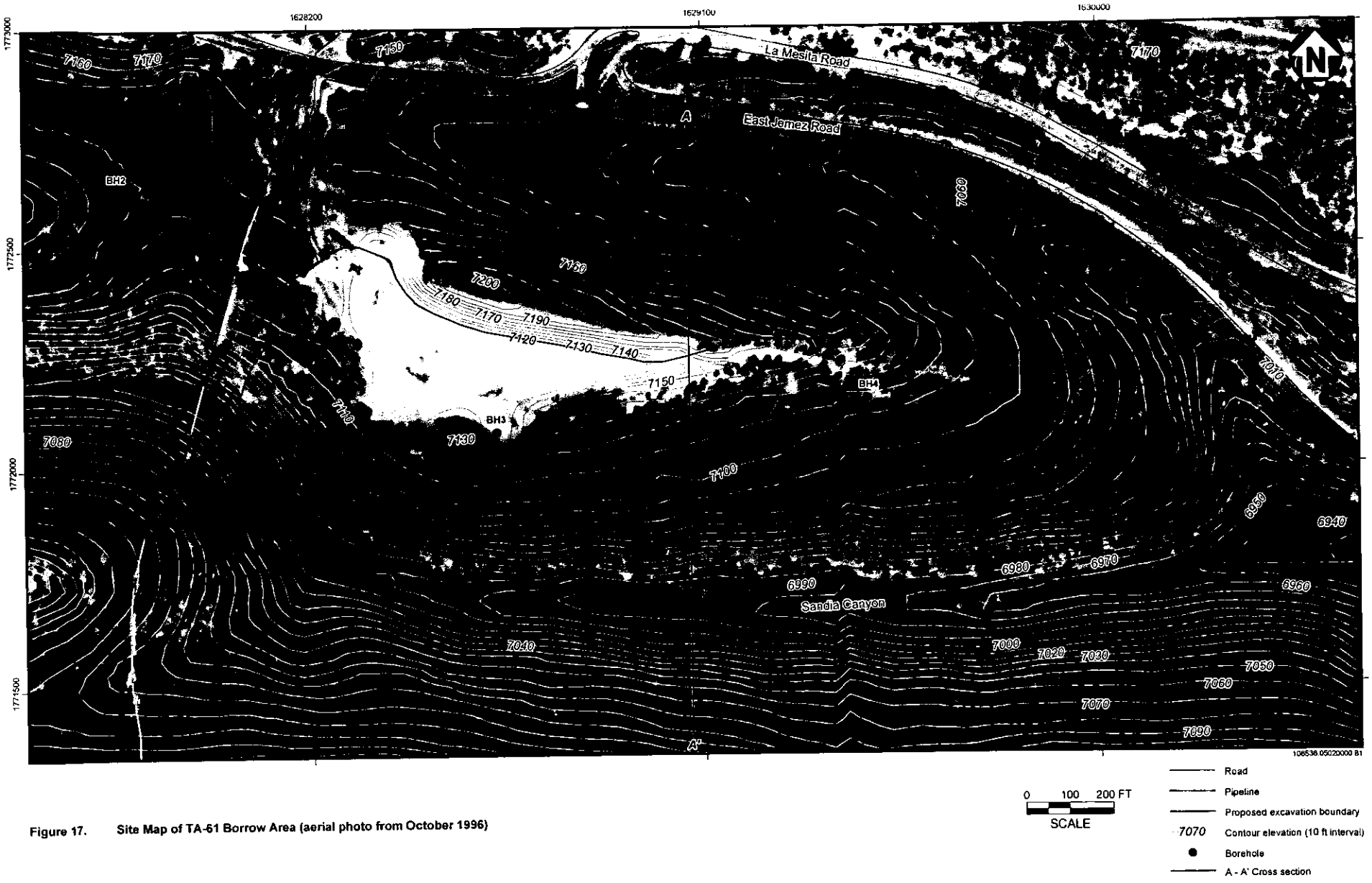

Figure 17. Site Map of TA-61 Borrow Area (aerial photo from October 1996)

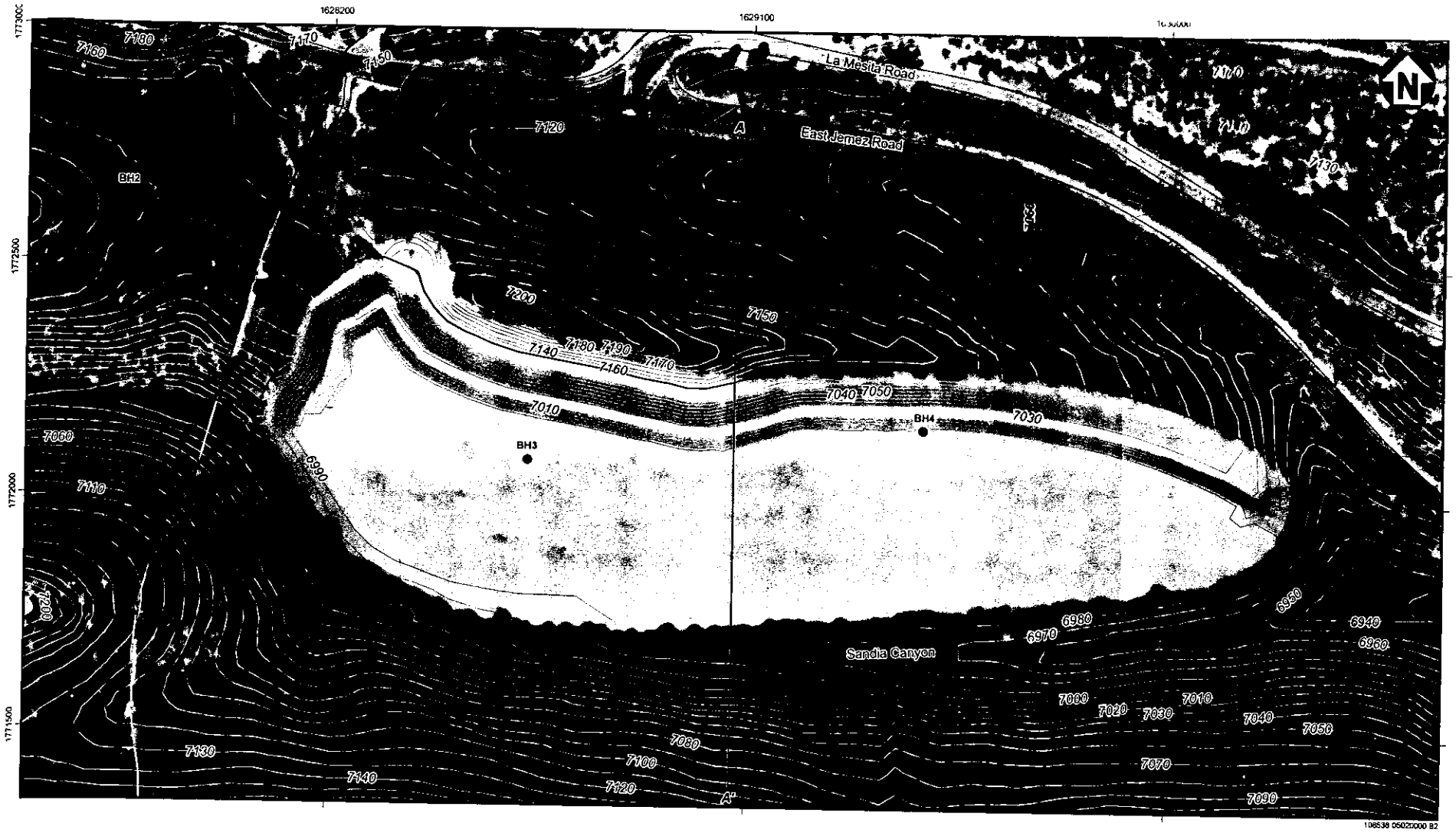

Figure 18. Map Showing Disturbed Area at TA-61 Following Proposed Excavation (aerial photo altered to simulate excavation)

0 100 200 FT
SCALE

Road
Pipeline
Proposed excavation boundary
7070 Contour elevation (10 ft interval)
Borehole
A - A' Cross section

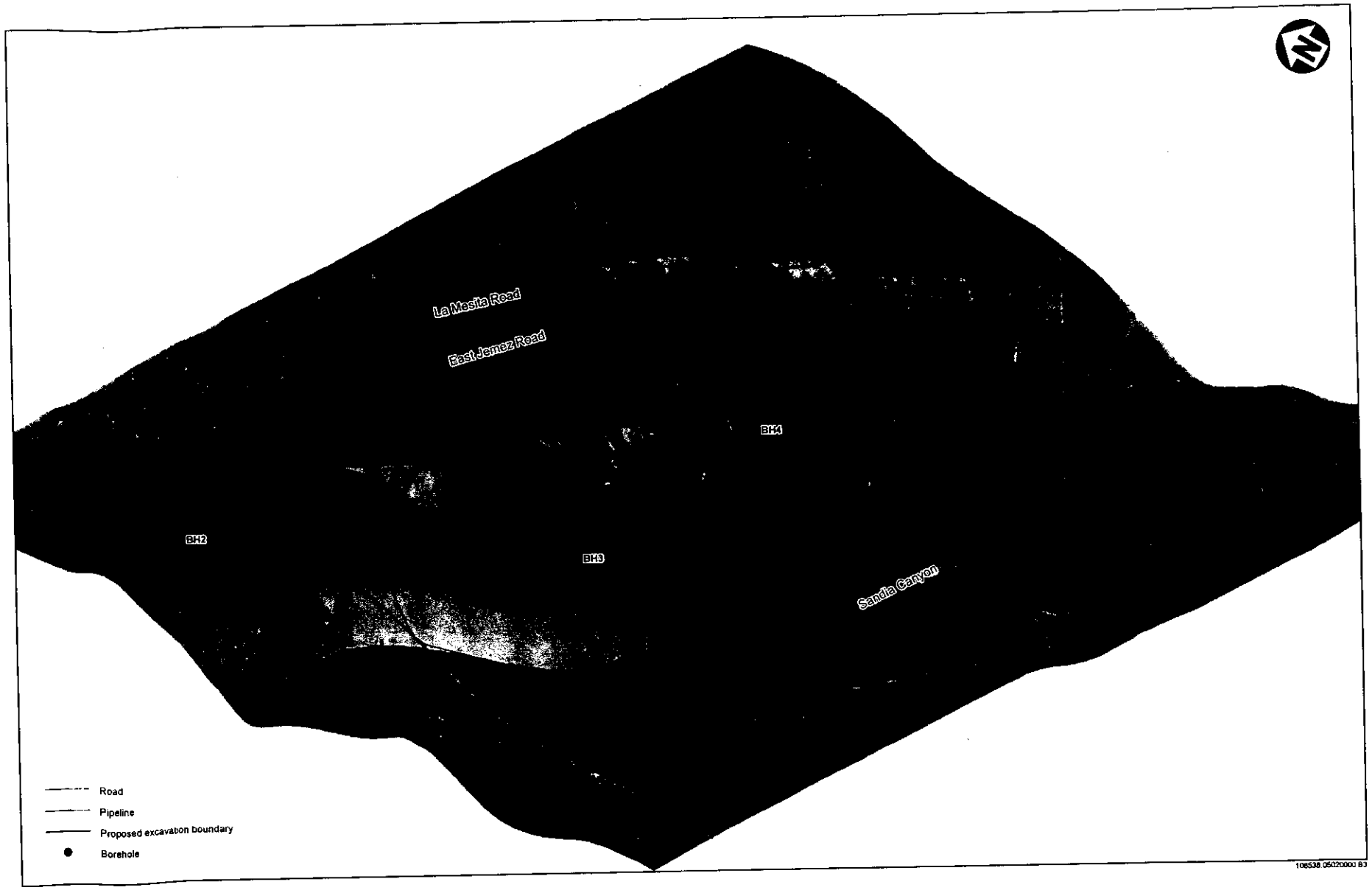

Figure 20. TA-61 Borrow Area Conceptual View Current Configuration

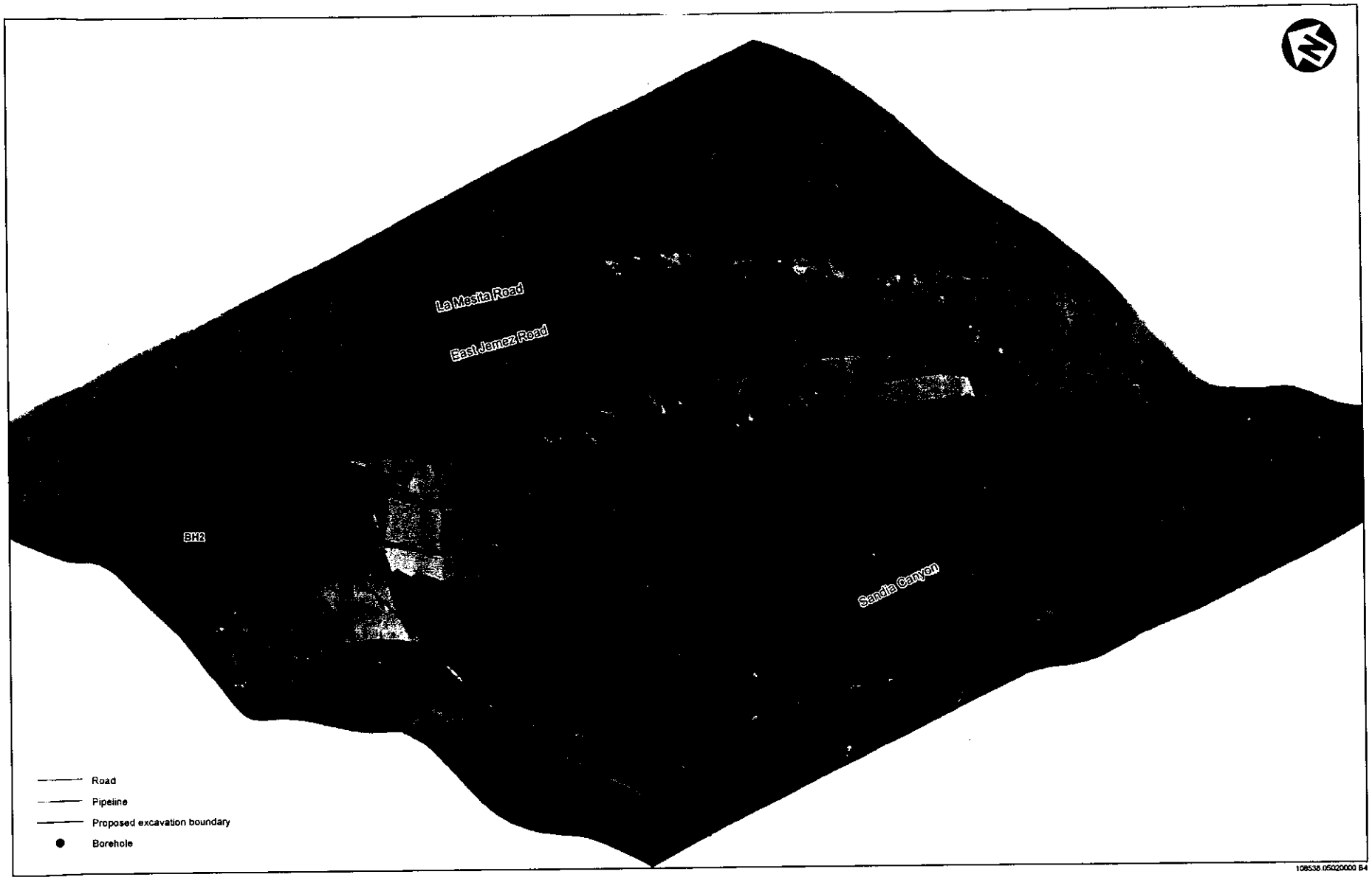

Figure 21. TA-61 Borrow Area Conceptual View Post-Excavation Configuration