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VADOSE ZONE MONITORING OBSERVATIONS AT THE TA-16 AREA P LANDFILL

by

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FYI

Any comments or suggestions?

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THIS PRELIMINARY REPORT IS SUBJECT TO FINAL REVIEW

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VADOSE ZONE MONITORING OBSERVATIONS AT THE TECHNICAL AREA 16 AREA P LANDFILL

by

Stephen G. McLin

ABSTRACT

A vadose monitoring system consisting of eight separate wells clustered together into four well nests was installed into and below the landfill at Technical Area 16 (TA-16) Area P during the fall of 1988. Each well nest consists of either a single or duel completion pressure-vacuum lysimeter borehole, and an adjacent neutron moisture access well. The four lysimeter boreholes contain a total of seven independent lysimeters located at varying depths in and below the landfill, while the neutron access wells penetrate into the underlying native Bandelier tuff down to a maximum depth of 30 feet.

Soil and tuff core samples collected during these installations indicate that barium in excess of 18,000 mg/l is present in the eastern half of the landfill, while the western portion has barium below detection limits. This barium occurs as barium oxide in white crystalline stringers of wastes located several feet below the surface. These wastes originated from barium nitrate contaminated sands associated with HE waste processing and disposal operations dating from the 1950s. At least some of this barium has been mobilized by infiltrating precipitation, and has penetrated to a depth of approximately 19 feet, or at least six feet below the landfill bottom. Four of the seven lysimeters have yielded small volumes of water at routine sampling intervals over a one year period; all of these lysimeters are adjacent to landfill materials. Barium concentrations in these water samples ranged from 1.1 to 37.8 mg/l, and averaged 9.23 mg/l. The three remaining lysimeters that did not yield water are all located below the landfill-tuff contact.

Monthly neutron moisture access well measurements from March to September 1989 have shown a consistently stable moisture distribution in four landfill access wells, and five perimeter access wells. The volumetric moisture contents over depth from individual landfill access wells is consistently higher than for the perimeter wells. Background volumetric moisture contents typically exceed 15% in the top one foot, but quickly drop below 5% at 4 feet, and remain relatively constant down to 170 feet. However the eastern landfill wells show moisture contents between 15 to 25% above the landfill-tuff contact, and between 15 to 20% in the tuff. Western landfill wells show similar moisture contents compared to those in the east, but higher moistures extend to greater depths. Western portions of the landfill have waste and fill deposits that are thicker than in the east, and contain more clayey materials.

I. INTRODUCTION

An industrial landfill, located in Technical Area 16 Area P (TA-16 Area P) at the Los Alamos National Laboratory (LANL), was actively used from the early 1950s until about 1985. At that time several landfill soil samples revealed the presence of barium in excess of Extraction Procedure (EP) toxicity limits defined in 40 CFR 261.24, and the landfill was subject to regulation under the Resource Conservation and Recovery Act (RCRA) of 1976, as amended. The vadose zone monitoring activities described herein were conducted in support of the main aquifer ground-water monitoring waiver demonstration (McLin and Purtymun, 1988) and the interim status closure and post-closure care plans (Delta H Engineering, 1985; HSE-8, 1988) that were submitted to the New Mexico Environmental Improvement Division (NMEID).

There is very little documentation of the types or quantities of wastes placed into the Area P landfill. The site was used in the early 1950s to dispose of burned equipment that had been contaminated with high explosives (HE), and building demolition rubble. The procedure for handling HE-contaminated equipment and wastes has been relatively constant over the years; the notable exception is that sand-covered burn pads have recently been replaced by fire-brick lined metal trays that are elevated above the ground surface. Initially any equipment or waste debris that is potentially HE-contaminated is partially disassembled and all surfaces are cleaned. Prior to 1987, this equipment ~~was~~ then taken to ~~one of three~~ sand-covered burn pad~~s~~ and flashed, along with other combustible material needed to support the fire. ~~Currently fire-brick lined metal trays are used for this flashing operation~~. After the thermal treatment, waste equipment and debris are inspected for any unburned HE residue. Before 1985 all flashed HE-free wastes, including the burn pad sands, were removed from the flash pads and placed in the landfill; since 1985 ~~these~~ ash wastes have be drummed after thermal treatment and transported to TA-54 for subsequent disposal. The source of elevated barium in the waste residue is barium nitrate that was used in the formulation of some HE materials. Barium concentrations in the sand wastes vary with barium nitrate concentrations in the HE, and with HE concentrations in the wastes. At elevated temperatures associated with the thermal treatment process, nitrates would be reduced to volatile oxides of nitrogen, and would tend to be absent in the ash.

The Area P landfill (Figs. 1 and 2) is located in a topographic saddle on a short, east-trending narrow mesa. This saddle is near the southern rim of Canon de Valle immediately north of the TA-16 thermal treatment pad number 387. The elliptically shaped landfill is about 170 wide in the north-south direction, and 400 feet long in the east-west direction; it contains an estimated 13,000 cubic yards of waste construction debris, crushed tuff and sandy clay fill material, and barium contaminated sands. Landfilling activities progressed from west to east. The western portion was closed by leveling and covering wastes with crushed tuff and sandy clay soils. These leveling operations resulted in some landfill debris

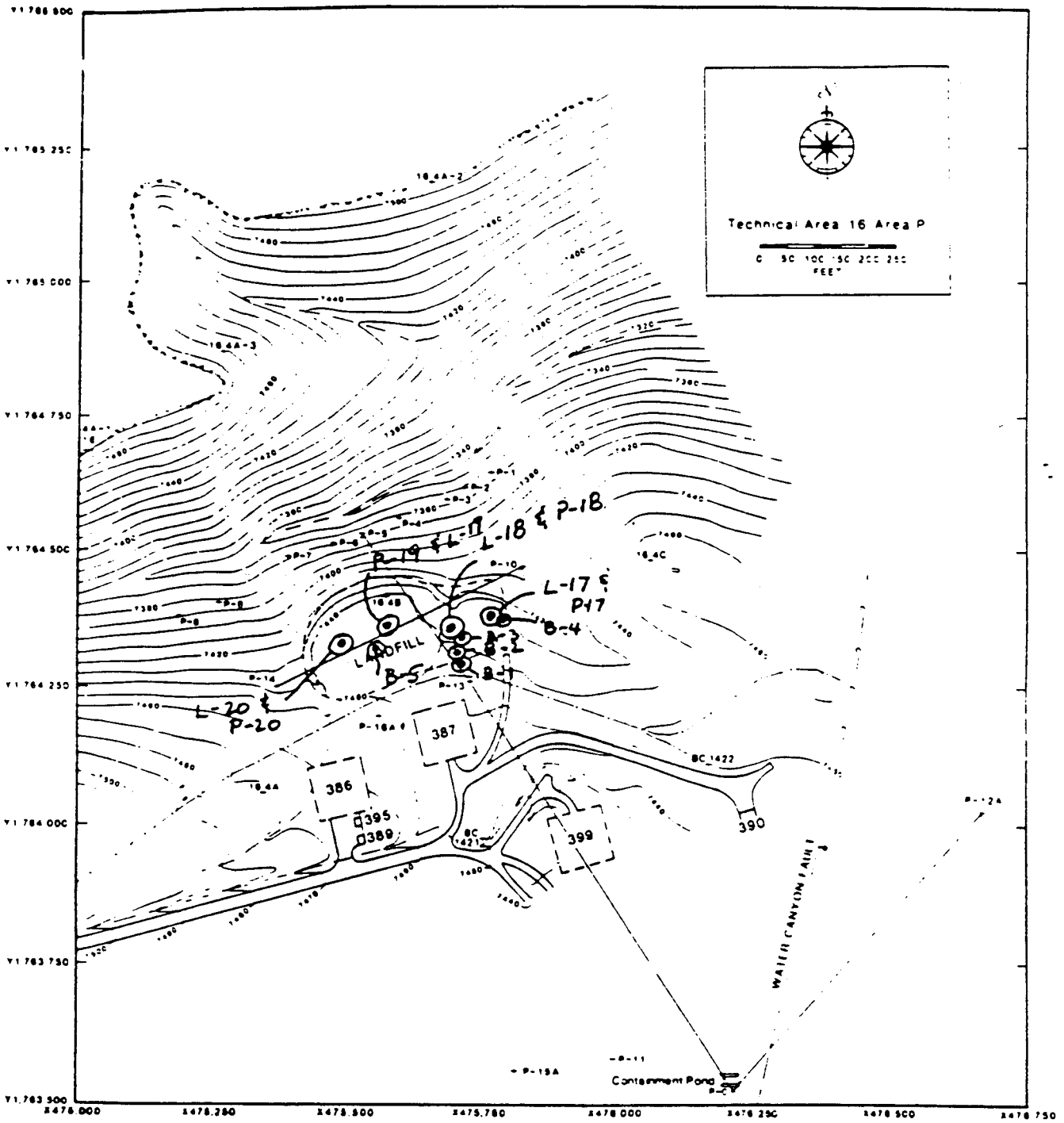


Figure 1. Site map of TA-16 Area P. Boreholes are marked with crosses, numbered P-0 through P-20, and L-17 through L-20. Additional crosses are survey marks (after Brown, et al., 1988).

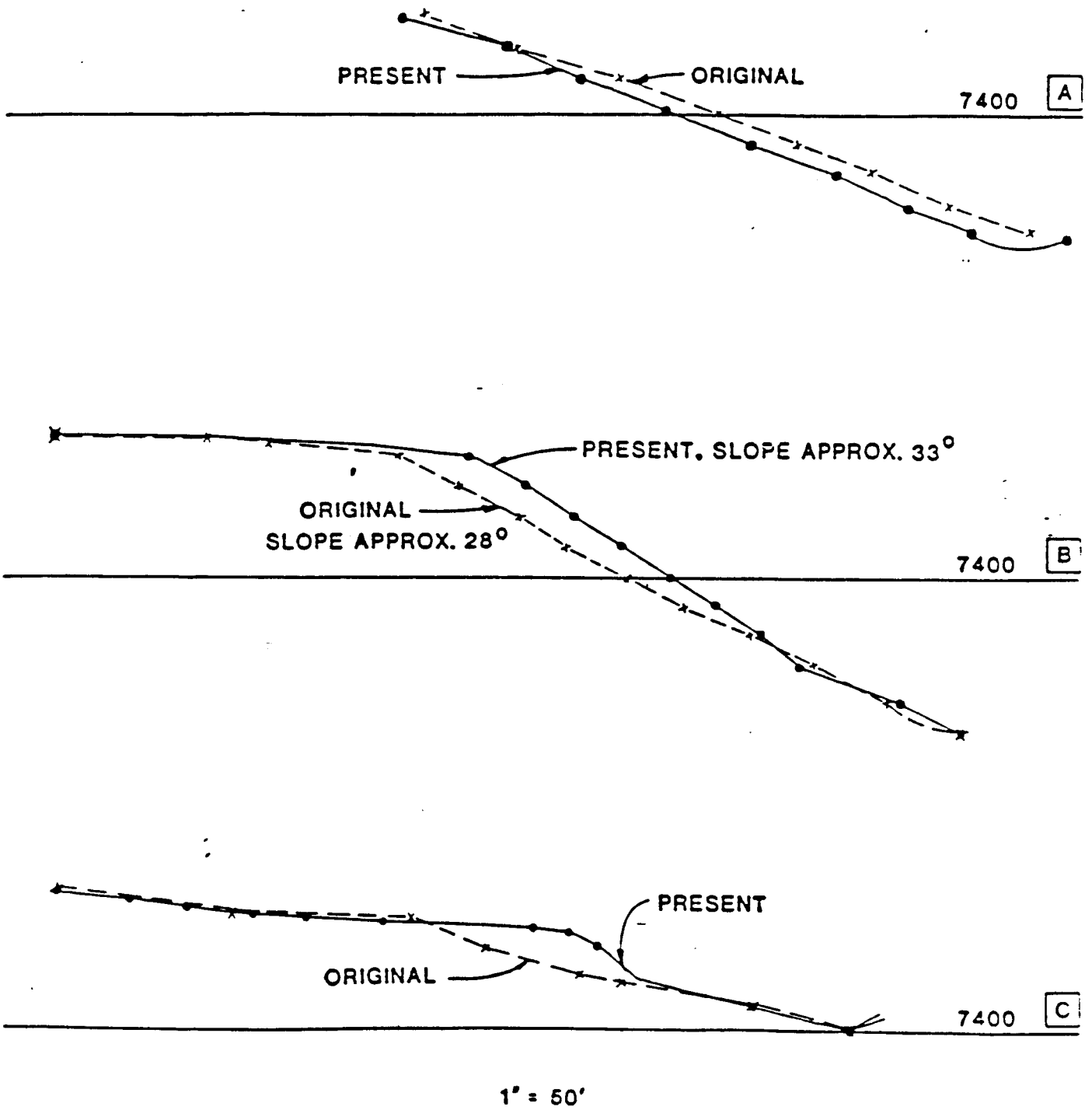


Figure 2. Map of three cross sections of waste disposal Area P showing locations of original and present land surfaces relative to elevation of 7400 feet. Cross sections A, B, and C are roughly north-south transects located immediately west of the landfill, through the middle of the landfill, and through the middle of the east portion of the landfill, respectively (after Nyhan, 1989).

overflowing the canyon rim along the northwest quadrant. Earlier investigations, including a site geological characterization (Brown, et al. 1988) and a water balance study (Nyhan, 1989), have reported that waste deposition reaches only 30 to 40 feet back from the canyon rim, and extends down the slope to the canyon floor. However, results from this study indicate that waste deposition extends at least 100 feet back from the existing canyon rim; furthermore, barium wastes may or may not be present in the entire landfill area. Elevations across the landfill vary from about 7,350 feet above mean sea level in the canyon bottom, to about 7,450 feet at the landfill top.

The western portion of the landfill has been naturally revegetated with grasses, wild rose, wormwood, oak brush, and juniper. There are occasional protrusions of concrete rubble, steel pipe, and metal that aids in binding the mass together. In the recently active eastern portion, fill has progressed from south to north with cover soil being added as the fill advanced. Wastes on the northern face of the landfill are exposed, and no appreciable natural revegetation has occurred in the eastern portion.

II. GEOLOGY AT AREA P

The regional and site geology of the Area P landfill has been previously reported in detail (Brown, et al., 1988). However a brief geological summary is presented here to assist the reader in understanding site drilling logs presented in this report.

There are about 1,230 feet of unsaturated Bandelier Tuff and Puye fanglomerates with interbedded volcanics underlying the mesa at TA-16 (Purtymun, 1984; Purtymun and Stoker, 1987; and McLin and Purtymun, 1988). The thickness of the tuff is at its maximum along the western edge of Pajarito Plateau, roughly delineated by New Mexico Highway 4 west of LANL and the TA-16 entrance gate. This tuff gradually thins to about 600 feet in thickness near the Rio Grande located approximately 10 miles to the east. The thickness of the unsaturated tuff and sediments below the TA-16 area is indicated below in Table 1.

The 950 feet of unsaturated tuff beneath the mesa at TA-16 consists of quartz and sanadine crystals and crystal fragments, and small rock fragments of latite, rhyolite, and pumice in a glassy gray ash matrix. The degree of welding in the tuff increases westward across the plateau toward the source area at Valles Caldera. This increase in welding reduces the porosity and capillary size of the pores. It is also likely that the hydraulic transmitting characteristics of the unsaturated tuff are also reduced with increased degrees of tuff welding (Abeele, 1984; and Stephens, 1988).

In order to establish the shallow subsurface geology at Area P, 17 boreholes (numbered P-0 through P-16) were drilled in the fall of 1987. In addition, 13 auxiliary boreholes were drilled in the fall

Table 1. Geologic Section at TA-16.

Geologic Section	Thickness (ft)	Depth (ft)
BANDELIER TUFF		
Tshierege Member		
Unit 3	190	190
Unit 2	150	340
Unit 1	360	700
Otowi Member	210	910
Guaje Member	40	950
PUYE CONGLOMERATE		
Fanglomerate with interbedded volcanics	500	1,450
TESUQUE FORMATION		
Siltstones and sandstones, occasional conglomerates interbedded with volcanics, earlier volcanics, and sediments	2,000	3,450
PRECAMBRIAN		
Basement rocks	unknown	+3,450

of 1988 (numbered P-17 through P-20, L-17 through L-20, and B-1 through B-5). All of these drill logs are contained in Appendix A of this report and in HSE-8 (1988); all borehole locations are shown in Fig. 1. A rotary drilling technique utilizing air and either 4 or 6 inch continuous flight auger were employed. Continuous drill cuttings were recovered with the 4-inch solid-stem auger, while the 6-inch hollow-stem auger allowed continuous core recovery when a split-spoon sampler was employed. Lithologic logging was done for each borehole; however, logs from continuously cored holes are more accurate. Each log description was based on the following characteristics: (1) color; (2) degree of welding; (3) shape and abundance of pumice lapilli; and (4) distribution of lithic fragments. Four distinct types of welding were recognized during drilling operations, and included:

1. Nonwelded: High porosity, low cohesion of glassy fragments, and crumbly texture. In core samples, this can be recognized by disaggregation and little or no flattening of pumice lapilli.

2. Moderately Welded: Less porosity, moderate cohesion, brittle texture, and slight deformation of glassy fragments. In core samples, this texture crumbles easily in the hand and contains some noticeably flattened pumice lapilli.

3. Welded: Low porosity, good cohesion, brittle texture, and noticeable deformation of glassy fragments. This texture

normally requires a hammer to break, and the majority of pumice fragments are noticeably flattened.

4. Densely Welded: Texture noticeably impedes or halts drilling, with little or no drill-bit penetration and poor core recovery.

Two major lithologic units of the Bandelier Tuff were identified at Area P during drilling operations (Fig. 3 and Table 1). The uppermost Unit 3 consists of four individual ash flows that appear to have cooled contemporaneously, forming a single compound unit. These ash flows were designated by Brown, et al. (1988) as Subunits 3a, 3b, 3c, and 3d (bottom to top). Unit 3 rests conformably above Unit 2, the lowermost unit encountered. In general, the Bandelier Tuff dips 2 to 5 degrees toward the east; however, at the landfill no dip was apparent and the units are essentially horizontal and of uniform thickness.

Subunit 3a consists of a welded dark yellowish brown tuff, with rare pumice lapilli that are slightly flattened. This subunit also contains abundant pebble-sized red porphyritic quartz latite and gray rhyolite lithic fragments. The ratio of quartz to rhyolite increases towards the base of the subunit. The contact between Subunit 3a and the underlying Unit 2 tends to be densely welded in the vicinity of the landfill, but is nonwelded farther east near P-12.

Subunit 3b consists of a welded pale yellowish brown tuff, with common gray and red pumice lapilli that are noticeably flattened. This subunit also contains rare pebble-sized rhyolite lithic fragments. This subunit weathers to a dark brown, and may also contain abundant clayey pumice lapilli.

Subunit 3c consists of a moderately welded brownish gray to yellowish brown tuff, with common gray pumice lapilli that are noticeably flattened, and rare pebble-sized rhyolite lithic fragments. Clay-filled vertical fractures are common throughout this subunit. The contact between 3c and 3d tends to be densely welded.

Subunit 3d outcrops along the higher rim of the topographic saddle at the landfill, and consists of a moderately welded yellowish brown tuff, with rare pebble-sized rhyolite lithic fragments ans common gray pumice lapilli. Subunit 3d is overlain by scattered deposits of El Cajete Pumice.

Locally, Unit 2 consists of a welded to densely welded tuff, light gray to pinkish gray in color, with common pumice lapilli and pebble-sized rhyolite fragments. Because of this dense welding, the drill bit was only able to penetrate the upper 5 to 10 feet of this unit.

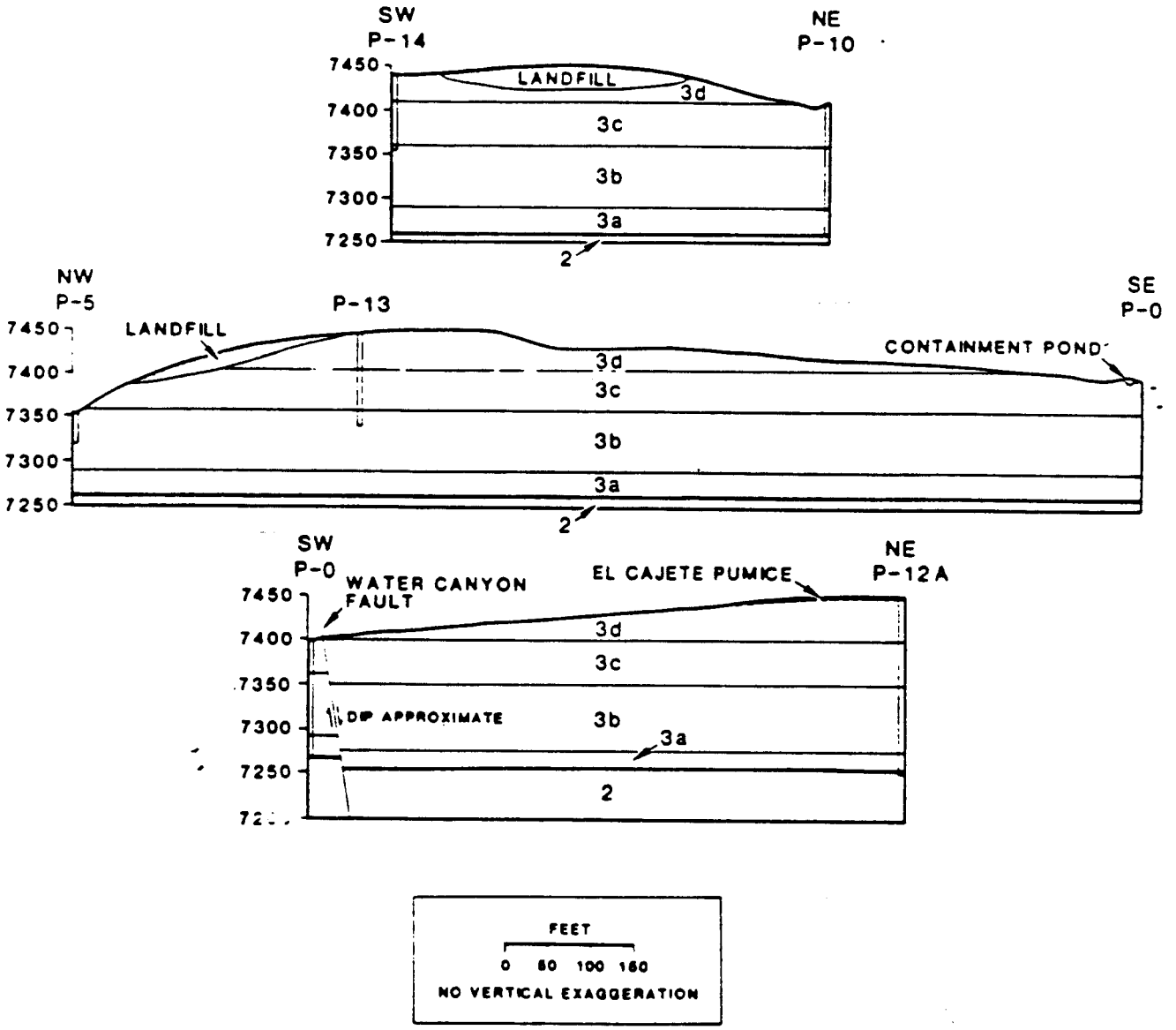


Figure 3. Geologic cross sections through Area P. Section lines are shown in Figure 1 (after Brown, et al., 1988).

Additional hydrogeological information from the Area P landfill is contained in the Delta H Engineering (1985) closure plan, the HSE-8 closure plan modifications (HSE-8, 1988), McLin and Purtymun (1988), and Stephens (1988).

III. SHALLOW VADOSE ZONE MONITORING SYSTEM

The geological profile extending from the ground surface downward to the upper surface of the principal water-bearing formation has been defined as the vadose zone (Everett, et al., 1984). These authors present an extensive discussion on field methods for monitoring pollution movement in the vadose zone at active or abandoned sites. According to this source, ceramic-type suction samplers are the best available technology for in-situ sampling of unsaturated media. In fact, it is not physically possible for saturated monitoring systems to extract water from the vadose zone because water held here is below atmospheric pressure. Hence a coupled network of pressure-vacuum lysimeters and neutron moisture access wells was installed at the Area P landfill to supplement the existing ground-water monitoring system and neutron moisture access wells. This vadose zone monitoring system is described below.

Of the 17 boreholes drilled in the fall of 1987 (HSE-8, 1988), eight were completed as saturated monitoring wells (i.e, boreholes P-1, and P-3 through P-9 in Appendix A), 5 were completed as neutron moisture access wells (i.e., boreholes P-0, P-12 through P-14, and P-16), and 4 were sealed closed (i.e., boreholes P-2, P-10, P-11, and P-15) after logging. In the fall of 1988, 13 additional boreholes were installed to complete a vadose monitoring system. Each of these boreholes penetrated through the landfill and into the underlying native Bandelier tuff. These boreholes were completed as a coupled network of seven pressure-vacuum lysimeters utilizing multiple completions in four boreholes (i.e., boreholes L-17 through L-20), four neutron moisture access wells (i.e., boreholes P-17 through P-20), and five exploration boreholes (i.e., B-1 through B-5) that were plugged and abandoned after logging. Completion summaries are provided for each of these in Appendix A.

The pressure-vacuum lysimeter and neutron moisture access boreholes were completed as two-well nests, with approximately six to eight feet of horizontal separation between nest boreholes to avoid interference effects. Hence lysimeter L-17 is within eight feet of neutron moisture access well P-17, and so on for the other three nests (i.e., numbered 18 to 20). The 4.0 inch diameter neutron moisture access boreholes were cased with 12 foot lengths of 2.50 inch O.D. seamless aluminum tubing having a 0.049 inch wall thickness. Two 12 foot sections of tubing were welded together into a single 24 foot section, and these 24 foot sections were joined together using a two-inch stainless steel coupling with internal neoprene liner; the bottom section of tubing contained an end-cap plug. The remaining 0.75 inch borehole annulus was filled with a fine to medium grained silica sand to provide uniform density and

compaction. A concrete surface seal and protective top-cap were installed to prevent any borehole infiltration.

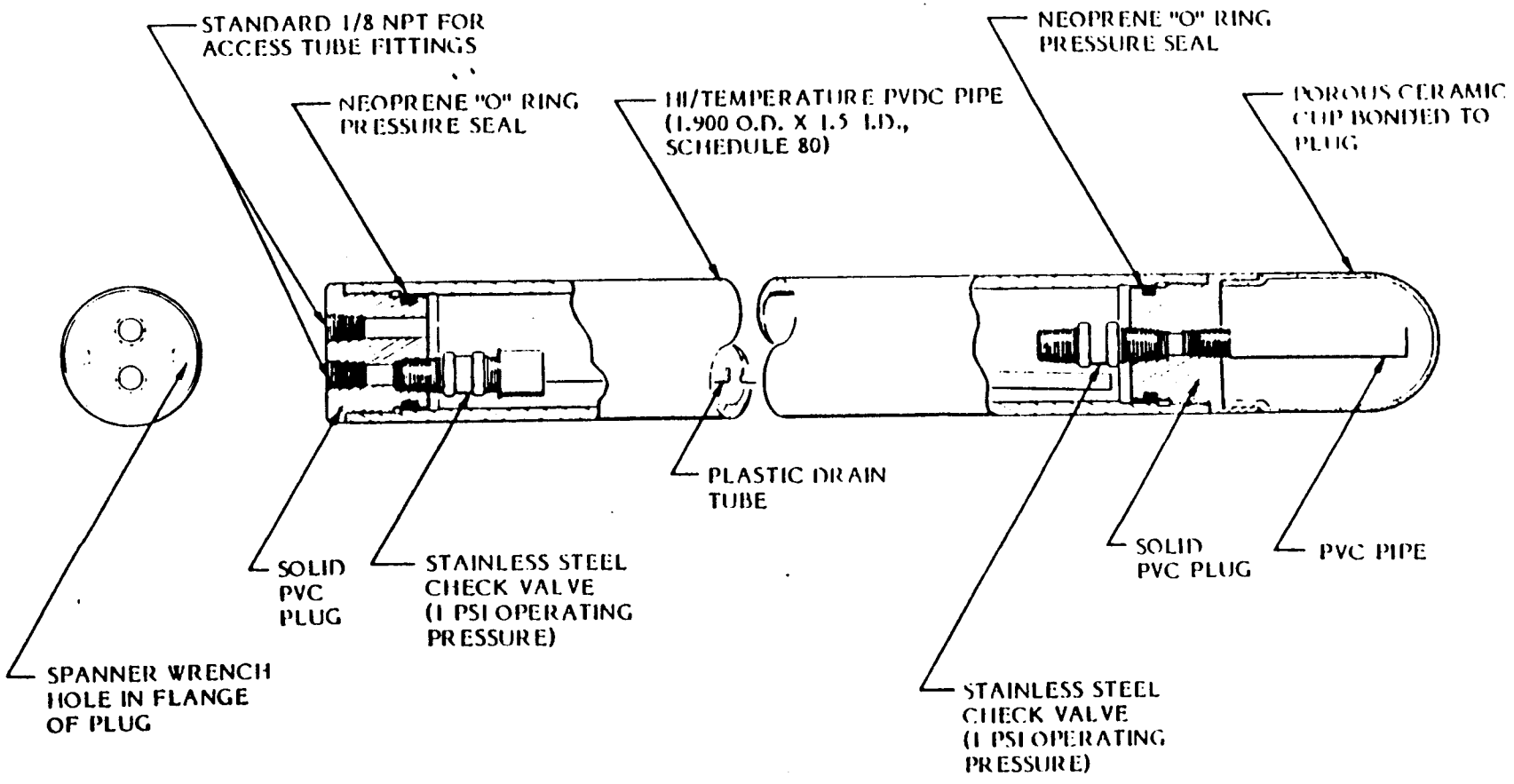
Each lysimeter borehole was cored with 6-inch hollow-stem auger and split-spoon sampler. Multiple pressure-vacuum lysimeter depth locations were identified from core samples in the field; individual completion details are listed with the drilling logs in Appendix A. All lysimeters were manufactured by Soilmoisture Equipment Corporation, model number 1940. A lysimeter schematic is shown in Fig. 4. For wells P-17, P-18, and P-20, one lysimeter was placed at a depth slightly above the landfill-tuff contact, and a deeper lysimeter was placed below this contact. For well P-19, only a single lysimeter was installed above the landfill-tuff contact. The borehole annulus surrounding each lysimeter was filled with a fine to medium pure silica sand. A one to two foot concrete seal was installed between each lysimeter to prevent borehole infiltration, and a concrete surface seal and locking steel cap was also installed.

During borehole coring and drilling operations, landfill soil and undisturbed tuff samples were collected for barium, nitrate, and residual explosives analyses. Barium was analyzed using the EP toxicity test procedure specified in 40 CFR 261 Appendix II, and represents barium solubility in a mixture agitated for 24 hours at 20 to 40 degrees Celsius. This mixture has a constant pH of 5.0, and consists of soil, deionized water, and 0.5 N acetic acid. Since precipitation in Los Alamos County typically has a pH of about 5.5 to 6.5, this procedure provides a crude indication of barium leaching potential in the landfill. All of these chemical data are summarized in Appendix B.

IV. MOISTURE AND WATER QUALITY DATA

At periodic intervals, each lysimeter was evacuated to approximately 50 centibars (cb) vacuum pressure (equivalent to 15 inches of mercury or 7.4 psig). This vacuum pressure was maintained for approximately one week before a water sample was collected. Four of the seven lysimeters have yielded water using this procedure, although at sporadic intervals coinciding with heavy precipitation or snow melt periods. All of the lysimeters located in the undisturbed tuff have consistently failed to yield any water, while the landfill lysimeters have yielded small volumes (i.e., less than 25 ml) on occasion. When sufficient water volumes could be collected, they were analyzed for barium and nitrate. Results of these chemical analyses are shown in Appendix C.

During the fall of 1988, a stream sampling survey was conducted along Canon de Valle upstream of Area P to New Mexico Highway 4. Stream water and sediment samples were collected at periodic distances for barium and nitrate analyses; results are summarized in Appendix D. These data suggest that the NPDES outfall at TA-16 Building 260 is a primary source of observed barium contamination in



MODEL 1940 HI/PRESSURE-VACUUM SOIL WATER SAMPLER

OVERALL DIMENSIONS: 1.9" OUTSIDE DIAMETER BY 24" LONG

SOILMOISTURE equipment corp

HI PRESSURE VACUUM SOIL WATER SAMPLER

SCHEMATIC

1940

Figure 4. Schmetic of pressure vacuum lysimeter.

both surface waters and sediments in Canon de Valle at the landfill boundary.

Since March 1988, all of the neutron moisture access wells were tested monthly for moisture contents using a model 503-DR hydroprobe manufactured by Campbell Pacific Nuclear Corporation. This moisture gauge contains a Cesium-137 and Americium-241 sealed high energy neutron source, and a slow thermal neutron detector. Its design is based on the principal that any hydrogen present in the vadose zone opposite the cased wellbore will attenuate the fast moving neutrons from the probe source and be detected. This probe is capable of producing raw data in the form of neutron counts, or a variety of calibrated moisture content readings corresponding to these counts. The probe was factory calibrated to pure silica sand at a density of 2.65 grams per cubic centimeter (gm/cc) over the moisture range from dry to fully saturated. It was also calibrated to crushed Bandelier tuff by HSE-8 personnel at a density of 1.45 gm/cc over the same moisture range following the procedure of Nyhan, et al. (1983). Neutron moisture data were recorded in neutron counts, and later converted to volumetric moisture contents for this report using the factory calibration curve. Since all of the calibration curves were nearly identical (see Appendix E), the factory curve was used for these data conversions. In addition, it should be noted that the landfill materials have a density midway between that for Bandelier tuff and silica sand.

Monthly volumetric moisture contents recorded in individual neutron moisture access wells did not vary significantly during the period from March to September 1989. The six month average volumetric moisture content versus depth for each well is shown in Figs. 5-13 in Appendix F; each figure also shows the maximum and minimum moisture values recorded at each depth over the six-month period. The tabulated volumetric moisture data is also shown in Appendix F for future reference.

For well P-12 in Fig. 13, one should interpret the maximum-minimum moistures as an approximate instrument error band, and not as actual moisture fluctuations. However, in the remaining wells shown in Figs. 5-12, temporal moisture fluctuation are apparent even though these have not been segregated from small instrument fluctuation. These observations suggest that the landfill-tuff contact is exposed to a small but dynamic system of moisture infiltration, and that the dynamic equilibrium between moisture contents, unsaturated hydraulic conductivities, and infiltration rates increases toward the surface and decreases with depth. This equilibrium is obviously controlled at the surface by evapotranspiration and precipitation. Still, individual moisture profiles depicted in Figs. 5-13 are approximately at steady state conditions, and transient moisture fluctuations at depth can not be adequately measured at the monthly time interval utilized here. Hence these observations also suggest that average moisture profiles for individual neutron wells have not significantly changed below about 5 to 10 feet (i.e., in the lower portions of the landfill and in the undisturbed tuff below the landfill) during the past six months at this site.

V. CONCLUSION AND RECOMMENDATIONS

After a detailed review of the information presented in the Appendices section of this report, the following conclusions have been reached.

1. Barium concentrations as high as 18,000 mg/l were detected in landfill core samples using the EP toxicity method. All of these elevated barium concentration levels were from samples collected in the eastern half of the landfill. Samples from the western portion of the landfill exhibited barium concentration levels below the detection limit at 5 mg/l. A clear delineation of barium concentration levels in the eastern and western portions of the landfill has not been made. These same core samples also indicate that nitrate concentrations in the landfill are at or below 2.6 mg/l.

2. There is evidence that at least some barium contamination has occurred below the landfill near boreholes B-4 and L-17. Elevated barium levels were recorded in core samples from the undisturbed tuff in these boreholes to a depth of 19 feet, and represent at least 6 feet of barium penetration into the tuff.

3. Barium concentration levels in sediment and water samples collected in Canon de Valle immediately upstream and downstream of the landfill indicate that extensive soil erosion from the landfill does not appear to be a significant problem. A stream sampling survey indicates that the majority of barium present in Canon de Valle has probably originated from the NPDES outfall at Building 260, located approximately 1,700 feet upstream of Area P. Data from this survey are summarized in Appendix D.

4. Four of seven pressure-vacuum lysimeters installed within and below the landfill have yielded at least some water. Three of these water yielding lysimeters are within the eastern portion of the landfill, and the forth is in the western portion. Recovered water volumes range from 1 to 25 milliliters (ml) after one week of 50 centibar (cb) vacuum pressure, indicating that at least some precipitation infiltration has penetrated into the landfill. Lysimeter locations that have yielded water correspond to volumetric moisture readings above 20%, while lysimeter locations not yielding water have volumetric moistures below 20%. Several imaginary horizontal planes throughout the landfill consistently have moisture contents above 20%, but do not have any lysimeters installed nearby. Barium concentrations in recovered lysimeter waters are generally less than about 3 mg/l, suggesting that extensive barium mobilization has not occurred. However, one of the first lysimeter water samples showed barium as high as 37.8 mg/l. This elevated barium level was probably created in response to lysimeter water additions during well completion; these municipal water supply additions are required for proper installation. All of the lysimeters that have yielded water

samples are located within the landfill, while those that have not yielded any water are completed into the underlying tuff.

5. All of the soil and core samples listed in Table B-1 (Appendix B) were field screened for residual explosives contamination. Twelve of these samples that showed a slightly positive indication were submitted to the M-1 Analytical Laboratory for detailed analyses using a high pressure liquid chromatography procedure (Baytos, 1989); results of these tests are summarized in Tables B-3 and B-4 (Appendix B). The residual explosives content from replicate samples for all cases was below the 1.68% level. These results suggest that landfill materials do not contain a dangerously high level of residual explosives contamination. However, landfill waste deposition activities were never fully documented. Hence there remains an unknown element of risk at this site with regard to landfill excavation.

6. Unsaturated core samples recovered from the shallow tuff immediately south of the landfill were tested for saturated and unsaturated hydraulic transmitting characteristics in 1987 (Stephens, 1987). These data indicate that the shallow tuff has a saturated hydraulic conductivity approaching that of the main aquifer located some 1,230 feet below ground surface. However, because this tuff is unsaturated, its relative (i.e., unsaturated) hydraulic conductivity is three to six orders of magnitude below its saturated value. Hence the downward movement of water in the vadose zone is greatly restricted. In addition, there are several densely welded tuff units at depths under the landfill that have lower unsaturated hydraulic conductivity versus moisture content relationships than these shallow cores. However, if this shallow tuff material ever becomes fully saturated, it will readily convey water vertically downward to deeper flow restricting units at a rapid rate. It should also be recognized that the Area P landfill has no engineered under-liner; however, a thin natural clay layer may be present immediately above the unsaturated tuff and below the landfill.

7. Neutron moisture access wells that penetrate the landfill (i.e., P-17 through P-20) consistently have shown a higher volumetric moisture inventory over depth than those neutron wells completed elsewhere. In addition, these landfill wells have consistently shown a higher moisture inventory in landfill materials than in the underlying native tuff. Well P-12, the background neutron moisture access well, has shown the lowest moisture inventory of all wells over its entire depth. Well P-0 is immediately south of the TA-16 surface impoundment, and its moisture inventory over depth may have been influenced by impoundment precipitation seepage because the hypolon liner and all wastes were removed in 1988. Wells P-13, P-14, and P-16 are located to the immediate south and west of the Area P landfill. These landfill perimeter wells have respective moisture inventories that are higher than at P-12, but are

consistently lower than landfill well moisture inventories. This observation tends to support the conclusion that landfill moisture inventories are the result of direct precipitation infiltration through the existing landfill cover, and that landfill infiltration rates are higher than those for surrounding undisturbed areas. Nyhan (1988), however, suspects that the unlined diversion ditch located south of the landfill is primarily responsible for the elevated moisture inventory in the landfill. His water balance study was conducted prior to the installation of wells P-17 through P-20, so he has not benefited from these recent data.

8. While no detailed evaluation of maximum landfill infiltration rates has been made, one can reasonably argue that they are probably on the order of 25 milliliters per week per square foot of surface area (i.e., equivalent to 0.0384 cm/sec). This upper limit infiltration rate estimate is equal to the maximum water volume that was ever collected from an individual landfill lysimeter. It is 243 times larger than the maximum saturated hydraulic conductivity value (Stephens, 1988, Table 4) measured in a Bandelier tuff core sample recovered in well P-16 at 7.5 feet below the surface (i.e. sample no. 7-8 in Stephens); furthermore, it is about 243,000 times larger than the unsaturated hydraulic conductivity of this same core sample when the moisture content is at 20% (Stephens, 1988, unnumbered figure entitled, "Relative Hydraulic Conductivity vs. Moisture Content, Sample No. 7-8"). One can also argue that landfill infiltration rates are considerably lower in the western portions of the landfill as compared to the eastern portions becasuse eastern landfill lysimeters have consistently yielded more water than western landfill lysimeters. Finally, one can conclude that infiltration rates vary throughout the year, and are probably highest during the spring snow-melt season.

9. A similar procedure to estimate infiltration rates in the underlying tuff can not be made because these lysimeters never yielded any water. However, if one uses the relative hydraulic conductivity vs. moisture content data of Stephens (1988), the neutron moisture data presented herein, and assumes a unit unsaturated hydraulic gradient for these tuff units, then an infiltration rate can be estimated. One concludes from this procedure that the tuff underlying the landfill is completely restricting all deep infiltration below the landfill.

The following recommendations are made with regard to the Area P landfill.

1. Additional lysimeters should only be installed after an adjacent neutron moisture access well has been completed and moisture readings have been recorded. Preliminary results in this study indicate that lysimeters can extract water from a target horizon only when the moisture content in an adjacent

neutron moisture access well exceeds about 20%. Hence neutron moisture access wells can be used as indicators to target optimal depth locations for subsequent lysimeter placement.

2. Unsaturated laboratory column leaching studies at infiltration rates typical of those in the landfill would be helpful in characterizing any future barium mobility from the landfill. This recommendation implies that an average infiltration rate into the landfill should be computed to support these soil column studies. These soil column leaching studies would support or refute the contention that no deep aquifer monitoring below the 1,230 foot interval is necessary. A sufficient volume of these waste barium sands is currently held in drum storage for off-site disposal, and could be used to perform such studies.

3. Two and three dimensional vadose zone flow modeling studies should be used as a supplement the above recommendations, and would assist in the evaluation of alternative landfill cover designs that might eventually proposed.

4. Additional vadose zone monitoring wells should be installed through the landfill and into the shallow tuff to supplement the existing monitoring network by giving more spatial coverage over the 1.5 acre site. During these drilling operations, additional soil samples should be collected so that the areal and vertical extent of barium contamination is completely defined. Furthermore, vadose zone monitoring wells should also be installed on the floor of Canon de Valle immediately north of the landfill. Locations should be similar to the saturated monitoring system that is presently in place, unless the vadose zone modeling efforts indicate more optimal locations are desirable.

VI. REFERENCES

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VII. APPENDICES

Appendix A. Borehole Logs from TA-16 Area P Landfill

See Figure 1 for borehole locations

DRILLING LOG

BOREHOLE	: B-1	**ELEVATION**	: Not Surveyed
GEOLOGIST	: Purtymun & McLin	**TOTAL DEPTH**	: 5 feet
DATE DRILLED	: August 26, 1988	**DIAMETER**	: 6.875 in
LOCATION	: Eastern Landfill	**CASING MATERIAL**	: Cuttings Fill

DEPTH	DESCRIPTION
0- 2	Dark brown clay soil, moist
2- 5	Dark brown sandy clay soil - looks like cover-fill material

WELL COMPLETION SUMMARY

Borehole B-1 was used as an exploration hole; it was then filled with bentonite and drill cuttings before being abandoned. No samples were collected.

DRILLING LOG

BOREHOLE	: B-2	**ELEVATION**	: Not Surveyed
GEOLOGIST	: Purtymun & McLin	**TOTAL DEPTH**	: 4 feet
DATE DRILLED	: August 26, 1988	**DIAMETER**	: 6.875 in
LOCATION	: Eastern Landfill	**CASING MATERIAL**	: Cuttings Fill

DEPTH	DESCRIPTION
0- 2	Dark brown clay soil, moist
2- 4	Dark brown sandy clay soil - looks like cover-fill material

WELL COMPLETION SUMMARY

Borehole B-2 was used as an exploration hole; it was then filled with bentonite and drill cuttings before being abandoned. No samples were collected.

DRILLING LOG

BOREHOLE	: B-3	**ELEVATION**	: Not Surveyed
GEOLOGIST	: Purtymun & McLin	**TOTAL DEPTH**	: 14 feet
DATE DRILLED	: August 26, 1988	**DIAMETER**	: 6.875 in
LOCATION	: Eastern Landfill	**CASING MATERIAL**	: Cuttings Fill

DEPTH	DESCRIPTION
0- 1	Dark brown sandy clay cover, moist
1- 4	Mixture of brown clay and sand waste - white BaO crystals 95% Core recovery; moderate moisture
4- 8	Dark brown sticky clay with some gray sand - waste material Fragments of tuff and charcoal throughout 80% Core recovery; moderate moisture
8-13	Dark brown to black sticky clay with tuff & BaO fragments 85% Core recovery; optimal moisture; solid tuff in bit
13-14	Tuff; Unit 3d; low moisture

WELL COMPLETION SUMMARY

Borehole B-3 was used as an exploration hole ; it was then filled with bentonite and drill cuttings before being abandoned. No samples were collected.

DRILLING LOG

BOREHOLE	: B-4	**ELEVATION**	: Not Surveyed
GEOLOGIST	: McLin & Purtymun	**TOTAL DEPTH**	: 19 feet
DATE DRILLED	: August 30, 1988	**DIAMETER**	: 6.875 in
LOCATION	: Eastern Landfill	**CASING MATERIAL**	: Cuttings Fill

DEPTH	DESCRIPTION
0- 3	Brown clay with black burn debris inclusions 50% Core recovery, little moisture Tests positive for explosive compounds using field test kit
4- 9	Brown clay and sand with black burn debris inclusions 10% Core recovery, very little moisture
9-14	Brown clay and sand mixture with burn debris inclusions 5% Core recovery, very dry
14-19	Tuff, Unit 3d, non-welded, very low moisture 85% Core recovery; coarse to medium grain size tuff

WX-12 field representative confirms presence of explosives and drilling operation terminated until M-1 Analytical Lab verified. On 9-1-88 M-1 Lab reported < 1% TNT, HMX, and RDX was present in sample.

WELL COMPLETION SUMMARY

Borehole B-4 was used as an exploration hole and for sample recovery; it was then filled with bentonite and drill cuttings before being abandoned.

DRILLING LOG

BOREHOLE	: B-5	**ELEVATION**	: Not Surveyed
GEOLOGIST	: Purtymun & McLin	**TOTAL DEPTH**	: 12 feet
DATE DRILLED	: September 15, 1988	**DIAMETER**	: 6.875 in
LOCATION	: Western Landfill	**CASING MATERIAL**	: Cuttings Fill

DEPTH	DESCRIPTION
0- 1	Topsoil of crushed tuff, sand, and clay mixture
1- 4	Brown crushed tuff cover-fill material 50% Core recovery; dry
4- 8	Brown crushed tuff cover-fill material; moderately dry 60% Core recovery; saturated clay lense 6-7 ft
8-12	Brown dense clay; moderately dry 90% Core recovery; waste not apparent

WELL COMPLETION SUMMARY

Borehole B-5 was used as an exploration hole and for sample recovery; it was then filled with bentonite and drill cuttings before being abandoned.

DRILLING LOG

BOREHOLE	: L-17	**ELEVATION**	: Not Surveyed
GEOLOGIST	: McLin & Purtymun	**TOTAL DEPTH**	: 19 feet
DATE DRILLED	: September 6, 1988	**DIAMETER**	: 6.875 in
LOCATION	: Eastern Landfill	**CASING MATERIAL**	: Lysimeters

DEPTH	DESCRIPTION
0- 1	Light brown sandy clay soil
1- 2	Dark brown clay with black sandy waste
2- 4	Black sandy waste with white BaO crystalline stringers 60% Core recovery 0-4 ft; all moderately dry
4-11	Light brown clayey sand; wood chips at 9 ft Less than 10% core recovery
11-19	Tuff; Unit 3d, non-welded, lt. brown color 50% recovery 9-14 ft; 100% recovery 14-19 ft.

LYSIMETER COMPLETION SUMMARY - DUEL COMPLETION

```
LOCKING STEEL CAP IN CEMENT ->KC| |<---- TOPSOIL COVER
                              C| |<---- TOP OF LANDFILL AT 1 FT
                              T| |
                              T| |
                              T| |
                              S| |
SHALLOW LYSIMETER AT 7 FT --->SL| |
ONE FT CEMENT SEAL 7-8 FT ---->C| |
                              T| |
                              T| |<----- BASE OF LANDFILL AT 11 FT
                              T| |<----- TUFF CONTACT AT 11 FT
                              T| |
                              S| |
                              S| |
                              S| |
                              S| |
DEEP LYSIMETER AT 17 FT ----->SL| |
                              S| |
                              T| |<----- TOTAL DEPTH AT 19 FT
```

DIAGRAM NOT TO SCALE

STEEL LOCKING CAP.....K
CEMENT SLURRY SEAL.....C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
PRESSURE-VACUUM LYSIMETER...L
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-17	**ELEVATION**	: Not Surveyed
GEOLOGIST	: McLin & Purtymun	**TOTAL DEPTH**	: 30 feet
DATE DRILLED	: September 21, 1988	**DIAMETER**	: 4.00 in
LOCATION	: Eastern Landfill	**CASING MATERIAL**	: Aluminum

DEPTH	**DESCRIPTION**
0-19	Off-set from L-17 6 ft; see drilling log for L-17 & B-4
19-30	Tuff; Unit 3d; low moisture; not cored Light brown tuff with rhyolite fragments Appears to be non-welded to moderately welded

NEUTRON ACCESS WELL COMPLETION SUMMARY

```
ONE FT CEMENT SEAL AND CAP -->CA| |<---- TOPSOIL COVER
ANNULUS FILLED WITH SAND ---->SA| |<---- TOP OF LANDFILL AT 1 FT
                              SA| |
                              SA| |
                              SA| |
                              SA| |<---- BASE OF LANDFILL AT 11 FT
                              SA| |<---- TUFF CONTACT AT 11 FT
                              SA| |
                              SA| |
                              SA| |
                              SA| |
                              SA| |
                              SA| |
                              SA| |
                              SA|P|<---- TOTAL DEPTH AT 30 FT
```

DIAGRAM NOT TO SCALE

```
-----------------------------
CEMENT SLURRY SEAL...........C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
ALUMINUM CASING, 2 in ID....A
END-CAP PLUG................P
CAVED IN....................X
-----------------------------
```

DRILLING LOG

BOREHOLE	: L-18	**ELEVATION**	: Not Surveyed
GEOLOGIST	: McLin & Purtymun	**TOTAL DEPTH**	: 19 feet
DATE DRILLED	: September 8, 1988	**DIAMETER**	: 6.875 in
LOCATION	: Eastern Landfill	**CASING MATERIAL**	: Lysimeters

DEPTH	**DESCRIPTION**
0- 1	Light brown sandy soil cover
1- 4	Light to bark brown clay with sand stringers; some moisture Some white BaO crystals; 95% Core recovery
4-13	Dark brown sticky black clay with some gray sand at 4 ft Fragments of charcoal and tuff 5-8 ft; BaO crystals 8-12 ft 80% Core recovery; optimal moisture; hard tuff in bit 13 ft
13-19	Tuff; Unit 3d; non-welded, low moisture Light grey to light brown color; 100% Core recovery

LYSIMETER COMPLETION SUMMARY - DUEL COMPLETION

```
LOCKING STEEL CAP IN CEMENT ->KC|  |<---- TOPSOIL COVER
                              C|  |<---- TOP OF LANDFILL AT 1 FT
                              T|  |
                              T|  |
                              T|  |
                              S|  |
SHALLOW LYSIMETER AT 7 FT --->SL|  |
                              T|  |
                              T|  |
                              T|  |
                              C|  |
THREE FT CEMENT SEAL 10-13 FT->C|  |<----- BASE OF LANDFILL AT 13 FT
                              T|  |<----- TUFF CONTACT AT 13 FT
                              T|  |
                              T|  |
                              S|  |
                              S|  |
DEEP LYSIMETER AT 18 FT ----->SL|  |
                              T|X|<----- TOTAL DEPTH AT 19 FT
```

DIAGRAM NOT TO SCALE

STEEL LOCKING CAP.....K
CEMENT SLURRY SEAL.....C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
PRESSURE-VACUUM LYSIMETER...L
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-18	**ELEVATION**	: Not Surveyed
GEOLOGIST	: McLin & Purtymun	**TOTAL DEPTH**	: 30 feet
DATE DRILLED	: September 21, 1988	**DIAMETER**	: 4.00 in
LOCATION	: Eastern Landfill	**CASING MATERIAL**	: Aluminum

DEPTH	**DESCRIPTION**
0-19	Off-set from L-18 6 ft; see drilling log for L-18 & B-3
19-30	Tuff; Unit 3d; low moisture; not cored Light brown tuff with rhyolite and sanadine fragments Appears to be non-welded to moderately welded

NEUTRON ACCESS WELL COMPLETION SUMMARY

```
ONE FT CEMENT SEAL AND CAP -->CA|  |<---- TOPSOIL COVER
ANNULUS FILLED WITH SAND ---->SA|  |<---- TOP OF LANDFILL AT 1 FT
                              SA|  |
                              SA|  |
                              SA|  |
                              SA|  |
                              SA|  |<----- BASE OF LANDFILL AT 13 FT
                              SA|  |<----- TUFF CONTACT AT 13 FT
                              SA|  |
                              SA|  |
                              SA|  |
                              SA|  |
                              SA|  |
                              SA|  |
                              SA|P |<----- TOTAL DEPTH AT 30 FT
```

DIAGRAM NOT TO SCALE

CEMENT SLURRY SEAL.....C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
ALUMINUM CASING, 2 in ID....A
END-CAP PLUG.....P
CAVED IN.....X

DRILLING LOG

BOREHOLE	: L-19	**ELEVATION**	: Not Surveyed
GEOLOGIST	: McLin & Purtymun	**TOTAL DEPTH**	: 14 feet
DATE DRILLED	: September 14, 1988	**DIAMETER**	: 6.875 in
LOCATION	: Western Landfill	**CASING MATERIAL**	: Lysimeters

DEPTH	DESCRIPTION
0- 1	Sandy soil cover; dry
1- 4	Crushed tuff fill 60% Core recovery; moderately dry
4- 9	Crushed tuff fill; no wastes apparent 70% Core recovery; moderately dry
9-14	Crushed tuff fill; no wastes apparent 75% Core recovery; moderately dry

LYSIMETER COMPLETION SUMMARY - SINGLE COMPLETION

```
LOCKING STEEL CAP IN CEMENT ->KC|  |<---- TOPSOIL COVER
                              C|  |<---- TOP OF LANDFILL WASTE
                              T|  |                NOT APPARENT
                              T|  |
                              T|  |
                              T|  |
                              T|  |
                              T|  |
                              T|  |
                              T|  |
                              S|  |
SINGLE LYSIMETER AT 12 FT --->SL|  |<----- BASE OF LANDFILL NOT
                              T|X|                     DETECTED
                              T|X|<----- TOTAL DEPTH AT 14 FT
```

DIAGRAM NOT TO SCALE

STEEL LOCKING CAP.....K
CEMENT SLURRY SEAL.....C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
PRESSURE-VACUUM LYSIMETER...L
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-19	**ELEVATION**	: Not Surveyed
GEOLOGIST	: McLin & Purtymun	**TOTAL DEPTH**	: 30 feet
DATE DRILLED	: September 20, 1988	**DIAMETER**	: 4.00 in
LOCATION	: Western Landfill	**CASING MATERIAL**	: Aluminum

DEPTH	DESCRIPTION
0-14	Off-set from L-19 6 ft; see drilling log for L-19
19-30	Tuff; Unit 3d; low moisture; not cored Light brown tuff with rhyolite and sanadine fragments Appears to be non-welded to moderately welded

NEUTRON ACCESS WELL COMPLETION SUMMARY

```
ONE FT CEMENT SEAL AND CAP -->CA| |<---- TOPSOIL COVER
ANNULUS FILLED WITH SAND ---->SA| |<---- TOP OF LANDFILL WASTES
                               SA| |                NOT APPARENT
                               SA| |
                               SA| |
                               SA| |
                               SA| |
                               SA| |<----- APPROXIMATE TUFF CONTACT
                               SA| |          AT 15 FT
                               SA| |
                               SA| |
                               SA| |
                               SA| |
                               SA| |
                               SA|P|<----- TOTAL DEPTH AT 30 FT
```

DIAGRAM NOT TO SCALE

CEMENT SLURRY SEAL.....C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
ALUMINUM CASING, 2 in ID....A
END-CAP PLUG.....P
CAVED IN.....X

DRILLING LOG

BOREHOLE	: L-20	**ELEVATION**	: Not Surveyed
GEOLOGIST	: McLin & Purtymun	**TOTAL DEPTH**	: 29 feet
DATE DRILLED	: September 15, 1988	**DIAMETER**	: 6.875 in
LOCATION	: Western Landfill	**CASING MATERIAL**	: Lysimeter

DEPTH	**DESCRIPTION**
0- 4	Sandy crushed tuff and soil mixture; concrete at 3 ft 50% Core Recovery; dry; does not look like waste sands
4-13	Sandy light brown crushed tuff and soil mixture 50% Core Recovery; dry
13-15	Dark brown sandy clay soil; wastes not apparent 50% Core Recovery; dry
15-21	Tuff fill and brown clay with charcoal fragments & waste 70% Core Recovery; some moisture
21-22	Brown native clay soil; moderately moist 75% Core Recovery
22-29	Tuff; Unit 3d; non-welded, low moisture 100% Core Recovery

LYSIMETER COMPLETION SUMMARY - DUEL COMPLETION

```
LOCKING STEEL CAP IN CEMENT ->KC| |<---- TOP SOIL COVER
                              T| |<---- TOP OF LANDFILL AT 1 FT
                              S| |
SHALLOW LYSIMETER AT 8 FT --->SL| |
                              S| |
                              T| |
                              T| |
                              T| |
                              T| |<----- LANDFILL BASE AT 21 FT
                              T| |<----- NATIVE 1 FT CLAY LAYER
                              T| |<----- TUFF CONTACT AT 22 FT
ONE FT CEMENT PLUG 22-23 FT -->C| |
                              T| |
                              S| |
DEEP LYSIMETER AT 29 FT ----->SL| |<----- TOTAL DEPTH AT 29 FT
```

DIAGRAM NOT TO SCALE

STEEL LOCKING CAP.....K
CEMENT SLURRY SEAL.....C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
PRESSURE-VACUUM LYSIMETER...L
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-20	**ELEVATION**	: Not Surveyed
GEOLOGIST	: McLin & Purtymun	**TOTAL DEPTH**	: 30 feet
DATE DRILLED	: September 20, 1988	**DIAMETER**	: 4.00 in
LOCATION	: Western Landfill	**CASING MATERIAL**	: Aluminum

DEPTH	DESCRIPTION
0-29	Off-set from L-20 6 ft; see drilling log for L-20 & B-5
29-30	Tuff; Unit 3d; low moisture; not cored Light brown tuff with rhyolite and sanadine fragments Appears to be non-welded to moderately welded

NEUTRON ACCESS WELL COMPLETION SUMMARY

```
ONE FT CEMENT SEAL AND CAP -->CA|  |<---- TOPSOIL COVER
ANNULUS FILLED WITH SAND ---->SA|  |<---- TOP OF LANDFILL AT 1 FT
                              SA|  |
                              SA|  |
                              SA|  |
                              SA|  |
                              SA|  |
                              SA|  |
                              SA|  |
                              SA|  |<----- BASE OF LANDFILL AT 21 FT
                              SA|  |<----- NATIVE 1 FT CLAY LAYER
                              SA|  |<----- TUFF CONTACT AT 22 FT
                              SA|  |
                              SA|  |
ALUMINUM CASING TO 26 FT ---->SA|P|
                               T|X|
                               T|X|
                               T|X|<----- TOTAL DEPTH AT 30 FT
```

DIAGRAM NOT TO SCALE

CEMENT SLURRY SEAL.....C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
ALUMINUM CASING, 2 in ID....A
END-CAP PLUG.....P
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-0	**ELEVATION**	: 7399
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 135 feet
DATE DRILLED	: July 21, 1987	**DIAMETER**	: 6.875 in
LOCATION	: S of TA-16 Pond	**CASING MATERIAL**	: Aluminum
COORDINATES	: X=476215, Y=1763523	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

NEUTRON ACCESS WELL COMPLETION SUMMARY

```
ONE FT CEMENT SEAL AND CAP -->CA| |<---- TOPSOIL COVER
ANNULUS FILLED WITH TUFF ---->TA| |<---- UNIT 3c CONTACT AT 3 FT
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |<---- UNIT 3b CONTACT AT 40 FT
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |<---- UNIT 3a CONTACT AT 110 FT
                              TA| |
CASING PLUG AT 120 FT ------->TA|P|
                               T|X|
                               T|X|
TOTAL DEPTH AT 135 FT -------> T|X|<---- UNIT 2 CONTACT AT 135 FT
```

DIAGRAM NOT TO SCALE

CEMENT SLURRY SEAL.....C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
ALUMINUM CASING, 2 in ID....A
WELDED END CAP PLUG.....P
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-1	**ELEVATION**	: 7344
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 35 feet
DATE DRILLED	: July 29, 1987	**DIAMETER**	: 6.875 in
LOCATION	: Canon de Valle	**CASING MATERIAL**	: 2 in PVC
COORDINATES	: X=475756, Y=1764645	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

GROUND-WATER MONITORING WELL COMPLETION SUMMARY

```
LOCKING STEEL CAP IN CEMENT->KCV| |<---- TOPSOIL COVER
                             CV| |<---- UNIT 3b CONTACT AT 4 FT
                             CV| |
                             CV| |
                             CV| |
                             CV| |
BOTTOM OF CEMENT AT 13 FT --->CV| |
                             BV| |
BOTTOM OF BENTONITE AT 15 FT->BV| |
                             SF|=|
                             SF|=|
                             SF|=|
                             SF|=|
20 FT FACTORY SLOTTED SCREEN->SF|=|
   0.010 in SLOTTED PVC      SF|=|
                             SF|=|
                             SF|=|
                             SF|=|
                             SF|=|
TOTAL DEPTH AT 35 FT -------->SF|P|
```

DIAGRAM NOT TO SCALE

STEEL LOCKING CAP.....K
CEMENT SLURRY SEAL.....C
BENTONITE PELLETS.....B
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
PVC CASING 2 in ID.....V
FACTORY SLOTTED 0.010 in....F
PVC END CAP.....P
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-2	**ELEVATION**	: 7341
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 10 feet
DATE DRILLED	: July 23, 1987	**DIAMETER**	: 6.875 in
LOCATION	: Canon de Valle	**CASING MATERIAL**	: Abandoned
COORDINATES	: X=475708, Y=1764617	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

EXPLORATION BOREHOLE LOG SUMMARY

```
                                  T|  |<---- SANDY LOAM TOP SOIL
                                  T|  |
                                  T|  |<---- UNIT 3b CONTACT AT 3 FT
                                  T|  |
                                  T|  |
                                  T|  |
                                  T|  |
                                  T|  |
                                  T|  |
TOTAL DEPTH AT 10 FT ---------->T|  |
```

DIAGRAM NOT TO SCALE

BENTONITE PELLET SEAL.....B
BACKFILLED TUFF CUTTINGS....T
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-3	**ELEVATION**	: 7342
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 9 feet
DATE DRILLED	: July 23, 1987	**DIAMETER**	: 6.875 in
LOCATION	: Canon de Valle	**CASING MATERIAL**	: 2 in Teflon
COORDINATES	: X=475676, Y=1764596	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

GROUND-WATER MONITORING WELL COMPLETION SUMMARY

```
LOCKING STEEL CAP IN CEMENT->KCE|  |<---- TOPSOIL COVER
CEMENT 0-1 & PELLETS 1-2 FT ->BE|  |
                              SF|  |<---- UNIT 3b CONTACT AT 3 FT
5 FT THREADED TEFLON SCREEN ->SF|  |
   0.01 in FACTORY SLOTTED    SF|  |
                              SF|  |
TEFLON END CAP AT 7 FT ------>SF|P|
                                |X|
TOTAL DEPTH AT 9 FT --------->  |X|
```

DIAGRAM NOT TO SCALE

STEEL LOCKING CAP.....	K
CEMENT SLURRY SEAL.....	C
BENTONITE PELLETS.....	B
BACKFILLED TUFF CUTTINGS....	T
MEDIUM GRAIN SILICA SAND....	S
THREADED TEFLON CASING.....	E
FACTORY SLOTTED 0.010 in....	F
TEFLON END CAP PLUG.....	P
CAVED IN.....	X

DRILLING LOG

BOREHOLE	: P-4	**ELEVATION**	: 7348
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 10 feet
DATE DRILLED	: July 28, 1987	**DIAMETER**	: 6.875 in
LOCATION	: Canon de Valle	**CASING MATERIAL**	: 2 in Teflon
COORDINATES	: X=475588, Y=1764562	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

GROUND-WATER MONITORING WELL COMPLETION SUMMARY

```
LOCKING STEEL CAP IN CEMENT->KCE| |<---- TOPSOIL COVER
CEMENT 0-1 & PELLETS 1-3 FT ->BE| |
                              BE| |
                              SF| |<---- UNIT 3b CONTACT AT 4 FT
5 FT THREADED TEFLON SCREEN ->SF| |
   0.01 in FACTORY SLOTTED    SF| |
                              SF| |
TEFLON END CAP AT 8 FT ------>SF|P|
                                |X|
TOTAL DEPTH AT 10 FT -------->  |X|
```

DIAGRAM NOT TO SCALE

STEEL LOCKING CAP.....K
CEMENT SLURRY SEAL.....C
BENTONITE PELLETS.....B
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
THREADED TEFLON CASING.....E
FACTORY SLOTTED 0.010 in....F
TEFLON END CAP PLUG.....P
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-5	**ELEVATION**	: 7353
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 35 feet
DATE DRILLED	: July 29, 1987	**DIAMETER**	: 6.875 in
LOCATION	: Canon de Valle	**CASING MATERIAL**	: 2 in PVC
COORDINATES	: X=475520, Y=1764532	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

GROUND-WATER MONITORING WELL COMPLETION SUMMARY

```
LOCKING STEEL CAP IN CEMENT->KCV| |<---- TOPSOIL COVER
                             CV| |<---- UNIT 3b CONTACT AT 3 FT
                             CV| |
                             CV| |
                             CV| |
                             CV| |
BOTTOM OF CEMENT AT 13 FT --->CV| |
                             BV| |
BOTTOM OF BENTONITE AT 15 FT->BV| |
                             SF|=|
                             SF|=|
                             SF|=|
                             SF|=|
20 FT FACTORY SLOTTED SCREEN->SF|=|
   0.010 in SLOTTED PVC      SF|=|
                             SF|=|
                             SF|=|
                             SF|=|
                             SF|=|
TOTAL DEPTH AT 35 FT -------->SF|P|
```

DIAGRAM NOT TO SCALE

STEEL LOCKING CAP.....K
CEMENT SLURRY SEAL.....C
BENTONITE PELLETS.....B
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
PVC CASING 2 in ID.....V
FACTORY SLOTTED 0.010 in....F
PVC END CAP.....P
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-6	**ELEVATION**	: 7352
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 10 feet
DATE DRILLED	: July 28, 1987	**DIAMETER**	: 6.875 in
LOCATION	: Canon de Valle	**CASING MATERIAL**	: 2 in Teflon
COORDINATES	: X=475467, Y=1764514	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

GROUND-WATER MONITORING WELL COMPLETION SUMMARY

```
LOCKING STEEL CAP IN CEMENT->KCE|  |<---- TOPSOIL COVER
CEMENT 0-1 & PELLETS 1-2 FT ->BE|  |
                              SF|  |
5 FT THREADED TEFLON SCREEN ->SF|  |<---- UNIT 3b CONTACT AT 4 FT
   0.01 in FACTORY SLOTTED    SF|  |
                              SF|  |
TEFLON END CAP AT 7 FT ------>SF|P|
                                |X|
                                |X|
TOTAL DEPTH AT 10 FT -------->  |X|
```

DIAGRAM NOT TO SCALE

STEEL LOCKING CAP	K
CEMENT SLURRY SEAL	C
BENTONITE PELLETS	B
BACKFILLED TUFF CUTTINGS	T
MEDIUM GRAIN SILICA SAND	S
THREADED TEFLON CASING	E
FACTORY SLOTTED 0.010 in	F
TEFLON END CAP PLUG	P
CAVED IN	X

DRILLING LOG

BOREHOLE	: P-7	**ELEVATION**	: 7356
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 35 feet
DATE DRILLED	: July 29, 1987	**DIAMETER**	: 6.875 in
LOCATION	: Canon de Valle	**CASING MATERIAL**	: 2 in PVC
COORDINATES	: X=475381, Y=1764491	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

GROUND-WATER MONITORING WELL COMPLETION SUMMARY

```
LOCKING STEEL CAP IN CEMENT->KCV|  |<---- TOPSOIL COVER
                              CV|  |<---- UNIT 3b CONTACT AT 2 FT
                              CV|  |
                              CV|  |
                              CV|  |
                              CV|  |
BOTTOM OF CEMENT AT 13 FT --->CV|  |
                              BV|  |
BOTTOM OF BENTONITE AT 15 FT->BV|  |
                              SF|=|
                              SF|=|
                              SF|=|
                              SF|=|
20 FT FACTORY SLOTTED SCREEN->SF|=|
   0.010 in SLOTTED PVC       SF|=|
                              SF|=|
                              SF|=|
                              SF|=|
                              SF|=|
TOTAL DEPTH AT 35 FT -------->SF|P|
```

DIAGRAM NOT TO SCALE

STEEL LOCKING CAP.....K
CEMENT SLURRY SEAL.....C
BENTONITE PELLETS.....B
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
PVC CASING 2 in ID.....V
FACTORY SLOTTED 0.010 in....F
PVC END CAP.....P
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-8	**ELEVATION**	: 7370'
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 10 feet
DATE DRILLED	: July 28, 1987	**DIAMETER**	: 6.875 in
LOCATION	: Canon de Valle	**CASING MATERIAL**	: 2 in Teflon
COORDINATES	: X=475257, Y=1764405	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

GROUND-WATER MONITORING WELL COMPLETION SUMMARY

```
LOCKING STEEL CAP IN CEMENT->KCE|  |<---- TOPSOIL COVER
CEMENT 0-1 & PELLETS 1-2 FT ->BE|  |
                              SF|  |<---- UNIT 3b CONTACT AT 3 FT
5 FT THREADED TEFLON SCREEN ->SF|  |
   0.01 in FACTORY SLOTTED    SF|  |
                              SF|  |
TEFLON END CAP AT 7 FT ------>SF|P|
                                |X|
                                |X|
TOTAL DEPTH AT 10 FT -------->  |X|
```

DIAGRAM NOT TO SCALE

STEEL LOCKING CAP.....K
CEMENT SLURRY SEAL.....C
BENTONITE PELLETS.....B
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
THREADED TEFLON CASING.....E
FACTORY SLOTTED 0.010 in....F
TEFLON END CAP PLUG.....P
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-9	**ELEVATION**	: 7376
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 35 feet
DATE DRILLED	: July 29, 1987	**DIAMETER**	: 6.875 in
LOCATION	: Canon de Valle	**CASING MATERIAL**	: 2 in PVC
COORDINATES	: X=475183, Y=1764381	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

GROUND-WATER MONITORING WELL COMPLETION SUMMARY

```
LOCKING STEEL CAP IN CEMENT->KCV| |<---- TOPSOIL COVER
                             CV| |<---- UNIT 3c CONTACT AT 3 FT
                             CV| |
                             CV| |
                             CV| |
                             CV| |
BOTTOM OF CEMENT AT 13 FT --->CV| |
                             BV| |
BOTTOM OF BENTONITE AT 15 FT->BV| |<---- UNIT 3b CONTACT AT 15 FT
                             SF|=|
                             SF|=|
                             SF|=|
                             SF|=|
20 FT FACTORY SLOTTED SCREEN->SF|=|
   0.010 in SLOTTED PVC      SF|=|
                             SF|=|
                             SF|=|
                             SF|=|
                             SF|=|
TOTAL DEPTH AT 35 FT -------->SF|P|
```

DIAGRAM NOT TO SCALE

STEEL LOCKING CAP.....	K
CEMENT SLURRY SEAL.....	C
BENTONITE PELLETS.....	B
BACKFILLED TUFF CUTTINGS....	T
MEDIUM GRAIN SILICA SAND....	S
PVC CASING 2 in ID.....	V
FACTORY SLOTTED 0.010 in....	F
PVC END CAP.....	P
CAVED IN.....	X

DRILLING LOG

BOREHOLE	: P-10	**ELEVATION**	: 7411
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 150 feet
DATE DRILLED	: July 30, 1987	**DIAMETER**	: 6.875 in
LOCATION	: E of Landfill	**CASING MATERIAL**	: Abandoned
COORDINATES	: X=475814, Y=1764473	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

EXPLORATION BOREHOLE LOG SUMMARY

```
                                T| |<---- SANDY LOAM TOP SOIL
                                T| |<---- UNIT 3c CONTACT AT 3 FT
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |<---- UNIT 3b CONTACT AT 50 FT
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |<---- UNIT 3a CONTACT AT 120 FT
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
TOTAL DEPTH AT 150 FT -------->T| |<---- UNIT 2 CONTACT AT 150 FT
```

DIAGRAM NOT TO SCALE

BENTONITE PELLET SEAL.....B
BACKFILLED TUFF CUTTINGS....T
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-11	**ELEVATION**	: 7409
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 70 feet
DATE DRILLED	: August 27, 1987	**DIAMETER**	: 6.875 in
LOCATION	: W of TA-16 Pond	**CASING MATERIAL**	: Abandoned
COORDINATES	: X=475991, Y=1763584	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

EXPLORATION BOREHOLE LOG SUMMARY

```
                                   T| |<---- SANDY LOAM TOP SOIL
                                   T| |<---- UNIT 3c CONTACT AT 2 FT
                                   T| |
                                   T| |
                                   T| |
                                   T| |
                                   T| |
                                   T| |
                                   T| |
                                   T| |<---- UNIT 3b CONTACT AT 50 FT
                                   T| |
                                   T| |
                                   T| |
TOTAL DEPTH AT 70 FT --------->T| |
```

DIAGRAM NOT TO SCALE

BENTONITE PELLET SEAL.....B
BACKFILLED TUFF CUTTINGS....T
CAVED IN.....X

VII. APPENDICES

Appendix B. Chemical Data from Soil Core Samples

TABLE B-1. EP Toxic Barium Concentrations in mg/l.

DEPTH (ft)	BOREHOLE NUMBER ===> B-4	B-5	L-17	L-18	L-19	L-20
1	686.5		2486.4	18114.4	< 5.0	
2		< 5.0	13206.9		< 5.0	< 5.0
3	4169.7			12.3		
4			16803.3	11.0		
5					< 5.0	
6		< 5.0		7.5		
7	11300.0					
8				< 5.0		< 5.0
9			3014.8	< 5.0		
10			2048.5		< 5.0	< 5.0
11	1839.5			< 5.0		
12		< 5.0	6.5			
13				< 5.0		< 5.0
14		< 5.0	17.8	< 5.0		
15			9.0			< 5.0
16	229.3		8.8	< 5.0		
17	23.4					
18	20.7			< 5.0		< 5.0
19	14.8					
20						< 5.0
21						
22						
23						< 5.0
24						
25						< 5.0
26						< 5.0
27						
28						< 5.0
29						< 5.0
30						

Appendix B. Chemical Data from Soil Core Samples

TABLE B-2. Nitrate Concentrations in mg/l.

DEPTH (ft)	BOREHOLE NUMBER ===> B-4	B-5	L-17	L-18	L-19	L-20
1	0.3		0.7	0.5	0.7	
2		< 0.2	6.0		< 0.3	< 0.2
3	0.5			0.3		
4			2.6	0.8		
5					< 0.2	
6		< 0.2		0.8		
7	1.2					
8				< 0.2		< 0.2
9			< 0.7	< 0.2		
10			2.2		< 0.3	< 0.2
11	2.6			< 0.2		
12		0.4	1.0			
13				< 0.2		< 0.2
14		0.4	0.4	< 0.2		
15			0.3			< 0.2
16	< 0.2		0.9	1.8		
17	< 0.2					
18	0.3			< 0.2		0.2
19	0.25					
20						< 0.2
21						
22						
23						< 0.2
24						
25						< 0.3
26						< 0.2
27						
28						< 0.2
29						< 0.2
30						

Appendix B. Chemical Data from Soil Core Samples

TABLE B-3. Average residual high explosives content, expressed as soluble acetonitrile (wt %).

DEPTH (ft)	BOREHOLE NUMBER ===> B-2	B-4	B-5	L-17	L-18	L-19	L-20
1				0.27			
2	0.12			0.98			
3		1.46			0.07		
4				0.78	0.06		
5							
6					0.09		0.12
7		0.20					
8							
9				0.77			
10				0.56			
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

Appendix B. Chemical Data from Soil Core Samples

TABLE B-4. Residual high explosives content.

BOREHOLE NUMBER	DEPTH (ft)	ACETONITRILE (soluble wt %)	HMX (ppm)	RDX (ppm)	TNT (ppm)	DNT (ppm)
B-2	2	0.11	0	0	0	0
B-2	2	0.12	0	0	0	0
B-4	3	1.68	730	343	7869	0
B-4	3	1.24	1010	292	7115	0
B-4	7	0.21	585	13	26	0
B-4	7	0.18	370	4	12	0
L-17	1	0.27	1201	32	0	0
L-17	1	0.27	1301	139	1	0
L-17	2	0.95	2551	2206	0	0
L-17	2	1.00	2582	2138	0	0
L-17	4	0.77	821	4133	594	0
L-17	4	0.78	1099	4132	557	0
L-17	9	0.70	164	1195	211	0
L-17	9	0.83	146	983	406	0
L-17	10	0.58	220	2639	1497	0
L-17	10	0.53	270	2655	1275	0
L-18	3	0.06	14	3	17	0
L-18	3	0.08	0	0	54	0
L-18	4	0.08	22	2	4	0
L-18	4	0.04	22	1	0	0
L-18	6	0.10	0	2	0	0
L-18	6	0.07	5	0	7	0
L-20	6	0.18	21	50	27	0
L-20	6	0.05	0	0	0	0

VII. APPENDICES

Appendix C. Pressure-Vacuum Lysimeter Water Samples[1]

Sample Number	Sample Date	Volume Recovered	Barium Concentration	Nitrate Concentration
L-18S	11-23-88	10 ml	37.8 mg/l	3.4 mg/l
L-18D[3]	11-23-88	< 1 ml	NA[2]	NA[2]
L-18S[3]	11-29-88	10 ml	18.5 mg/l	1.2 mg/l
L-17S	3-17-89	2 ml	1.1 mg/l	5.5 mg/l
L-18S	3-17-89	10 ml	1.1 mg/l	0.735 mg/l
L-19	3-17-89	25 ml	3.0 mg/l	0.44 mg/l
L-17S	3-28-89	< 1 ml	NA[2]	NA[2]
L-18S	3-28-89	2 ml	1.1 mg/l	2.37 mg/l
L-19	3-28-89	10 ml	2.0 mg/l	0.21 mg/l
L-17S	6-02-89	< 1 ml	NA[2]	NA[2]
L-18S	6-02-89	< 1 ml	NA[2]	NA[2]
L-19	6-02-89	< 1 ml	NA[2]	NA[2]
L-17S	8-11-89	trace	NA[2]	NA[2]
L-18S	8-11-89	< 1 ml	NA[2]	NA[2]
L-19	8-11-89	trace	NA[2]	NA[2]

[1] = All other lysimeters failed to yield water on the sample dates indicated above. Samples were collected after one week of 50 cb vacuum pressure was applied.

[2] = Not Analyzed; insufficient water volume

[3] = S represents the shallow lysimeter in a duel completion borehole, while D means the deep lysimeter in the same borehole.

VII. APPENDICES

Appendix D. Canon de Valle Stream Survey Samples

TABLE D-1. Barium and Nitrate Concentrations in Water Samples. See location map for station numbers.

STATION	STATION DESCRIPTION	BARIUM (mg/l)[1]	NITRATE (mg/l)[2]
1	Channel at Hiway-4.....	dry	dry
2	Channel below old pond...	35.8	< 0.2
3	Channel above Bldg-260...	9.9	0.8
4	Bldg-260 NPDES outfall...	4.4	0.8
5	Tributary above outfall..	dry	dry
6	Tributary below outfall..	6.4	7.7
7	Tributary below outfall..	38.1	< 0.2
8	Tributary below outfall..	39.9	2.5
9	Channel below outfall....	10.0	0.8
10	Channel below outfall....	12.4	0.7
11	Channel below outfall....	9.1	0.8
12	Channel below outfall....	8.7	0.6
13	Channel above landfill...	9.5	0.6
14	Channel below landfill...	9.5	NA[3]

TABLE D-2. Barium and Nitrate Concentrations in Sediment Samples. See location map for station numbers.

STATION	STATION DESCRIPTION	BARIUM (mg/l)[1]	NITRATE (mg/l)[2]
1	Channel at Hiway-4.....	< 5.0	< 0.2
2	Channel below old pond...	< 5.0	< 0.3
3	Channel above Bldg-260...	5.6	< 0.2
4	Bldg-260 NPDES outfall...	< 5.0	< 0.2
5	Tributary above outfall..	< 5.0	< 0.2
6	Tributary below outfall..	6.4	< 0.2
7	Tributary below outfall..	33.5	< 0.2
8	Tributary below outfall..	51.2	0.3
9	Channel below outfall....	< 5.0	< 0.2
10	Channel below outfall....	< 5.0	< 0.2
11	Channel below outfall....	< 5.0	< 0.2
12	Channel below outfall....	< 5.0	< 0.2
13	Channel above landfill...	< 5.0	0.4
14	Channel below landfill...	< 5.0	NA[3]

[1] = EP toxicity test procedure.

[2] = Total inorganic nitrates.

[3] = Not Analyzed.

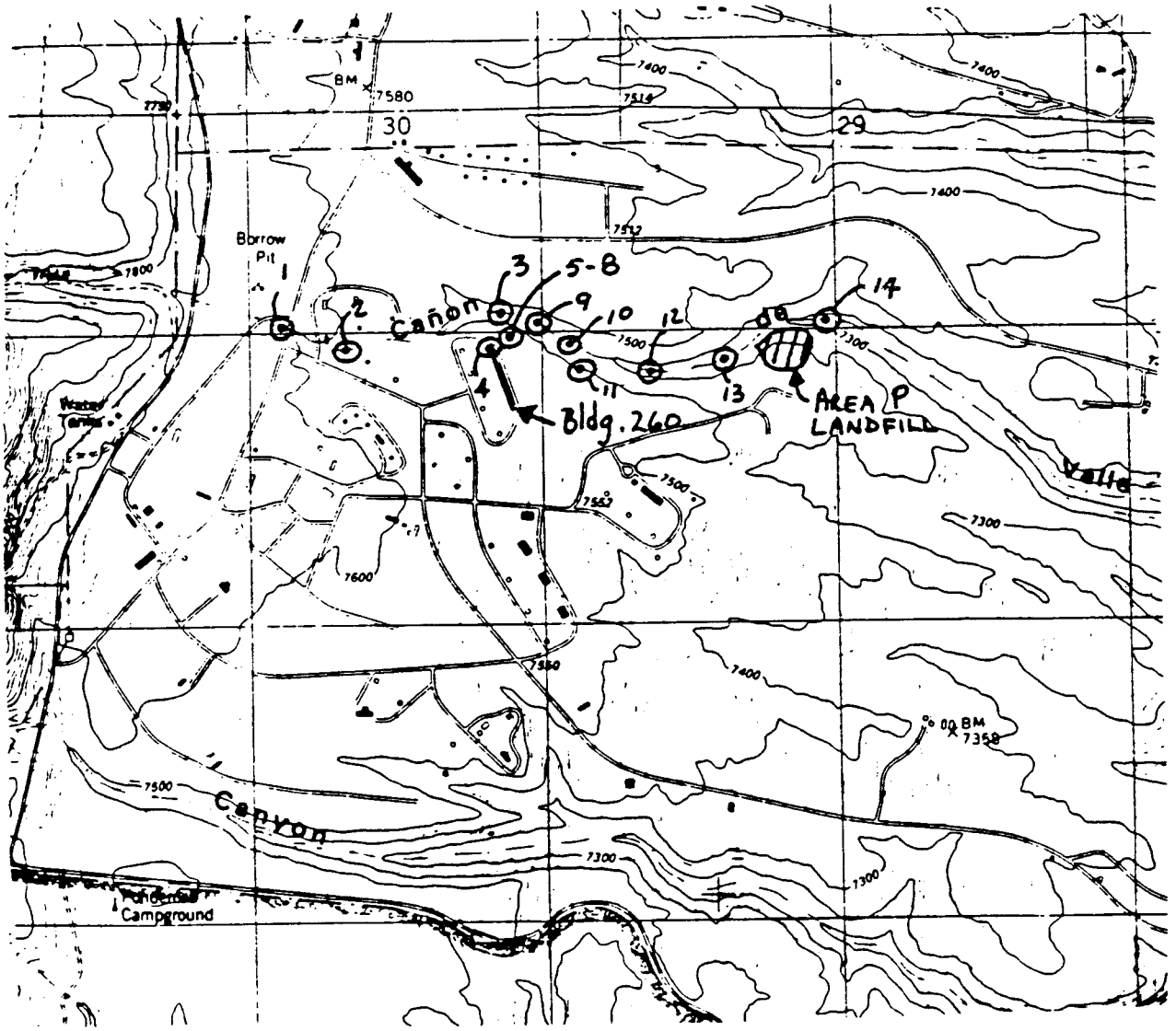


Figure D-1. Location map for Canon de Valle stream samples.

VII. APPENDICES

Appendix E. Calibration Curves for the Neutron Moisture Probe

Calibration curves for the CPN Model 503-DR Hydroprobe, serial number H36076933, are shown in the attached figure.

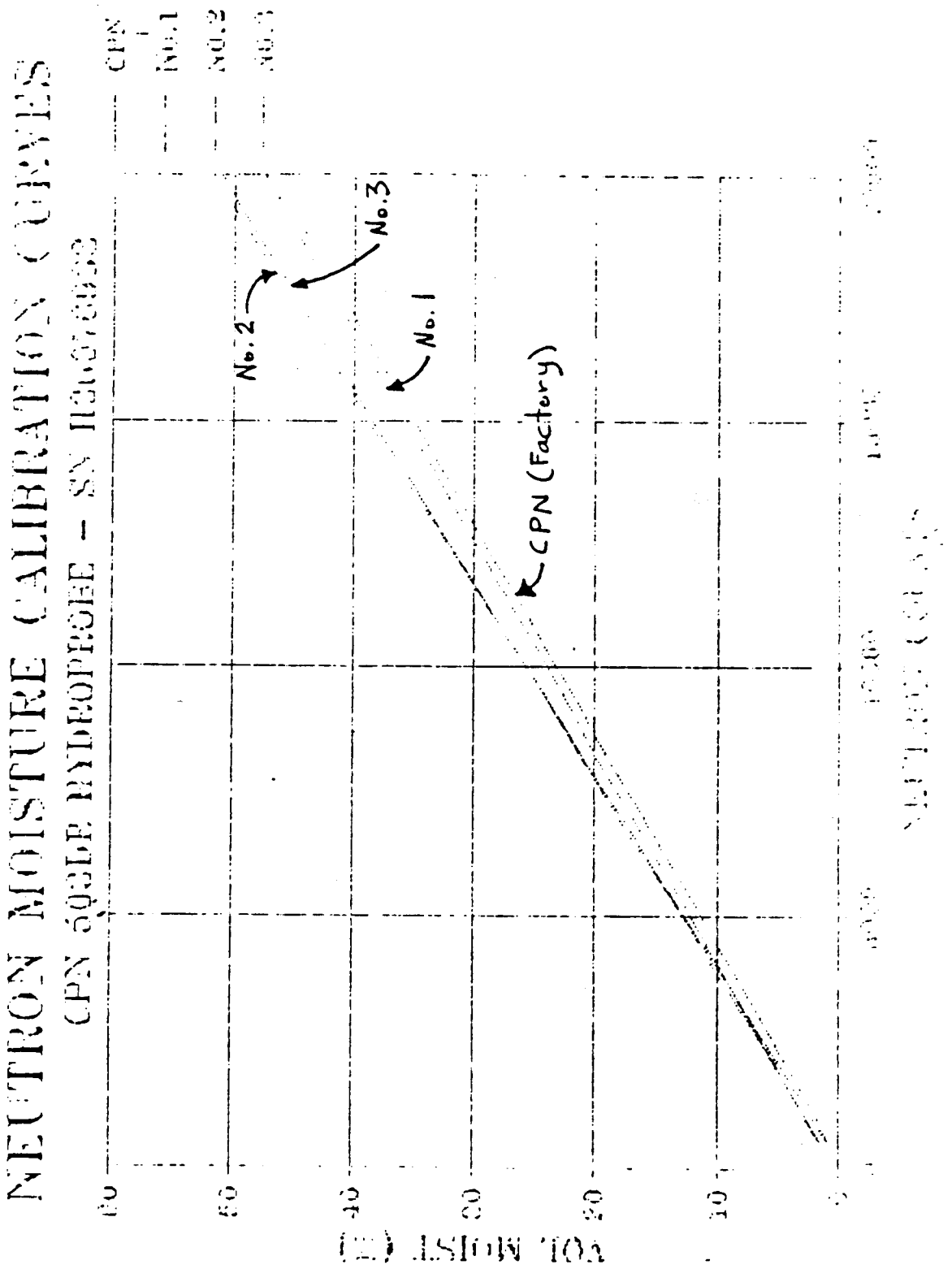
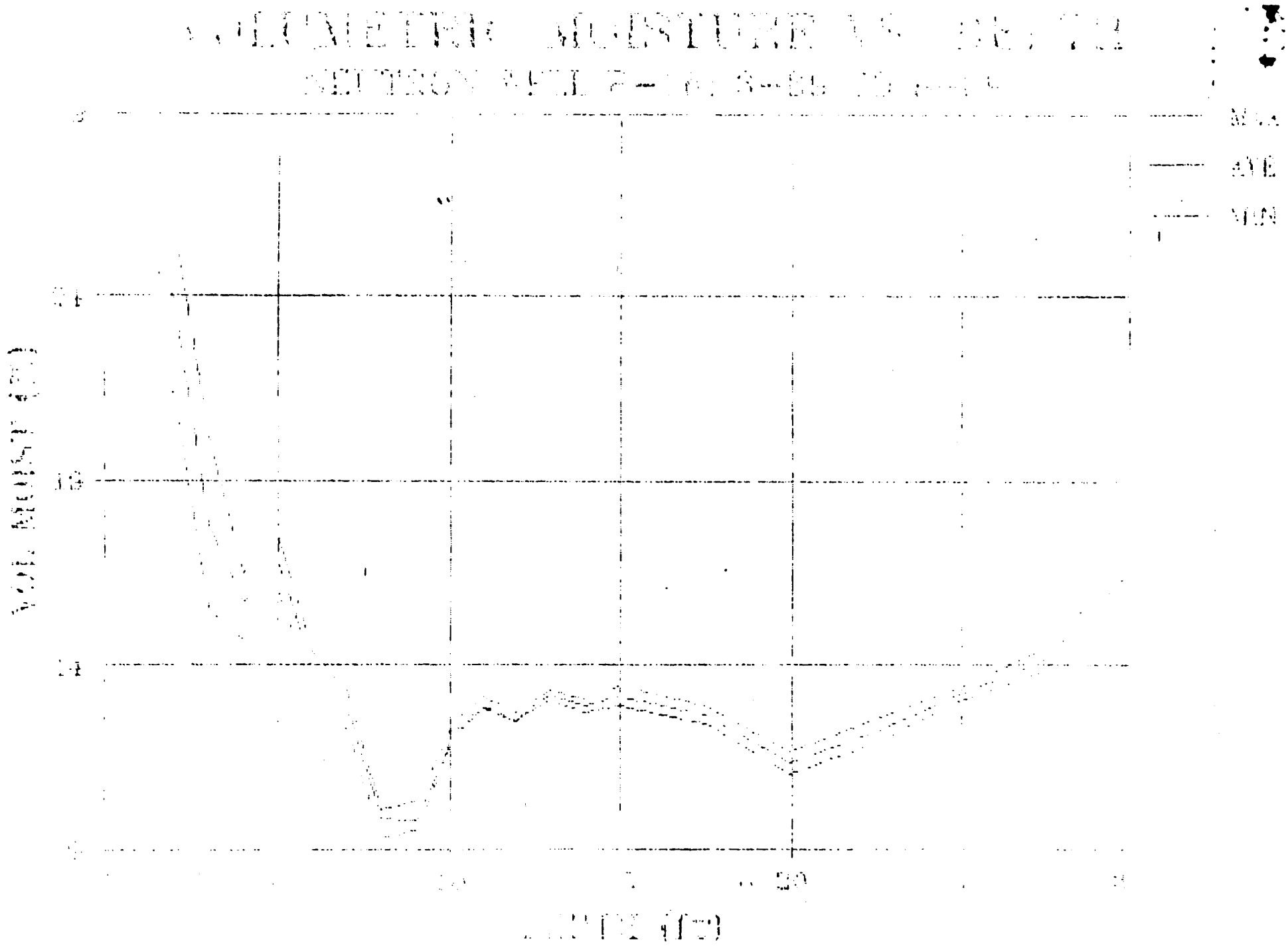


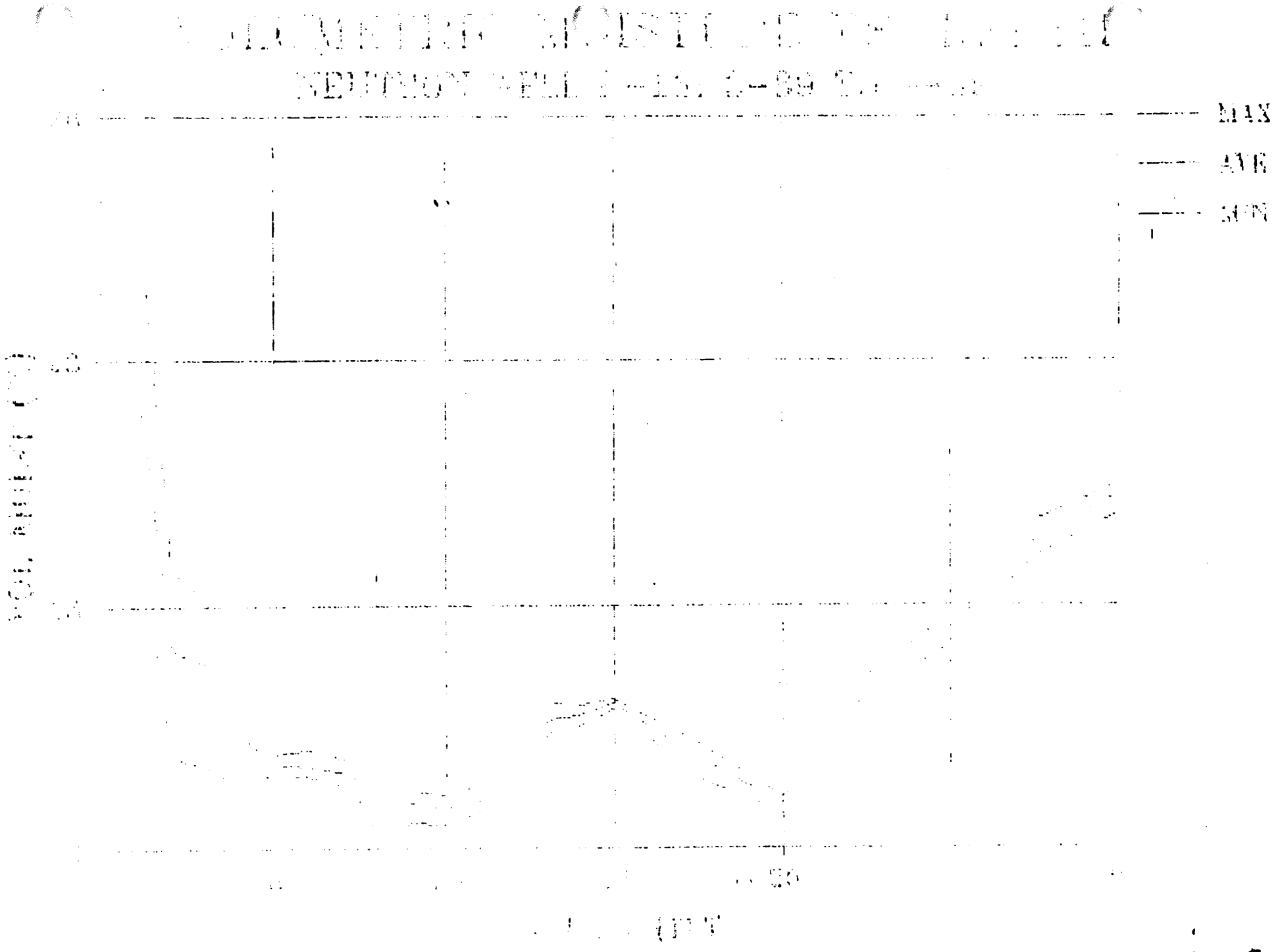
Figure E-1. Calibration curves for the neutron moisture probe.

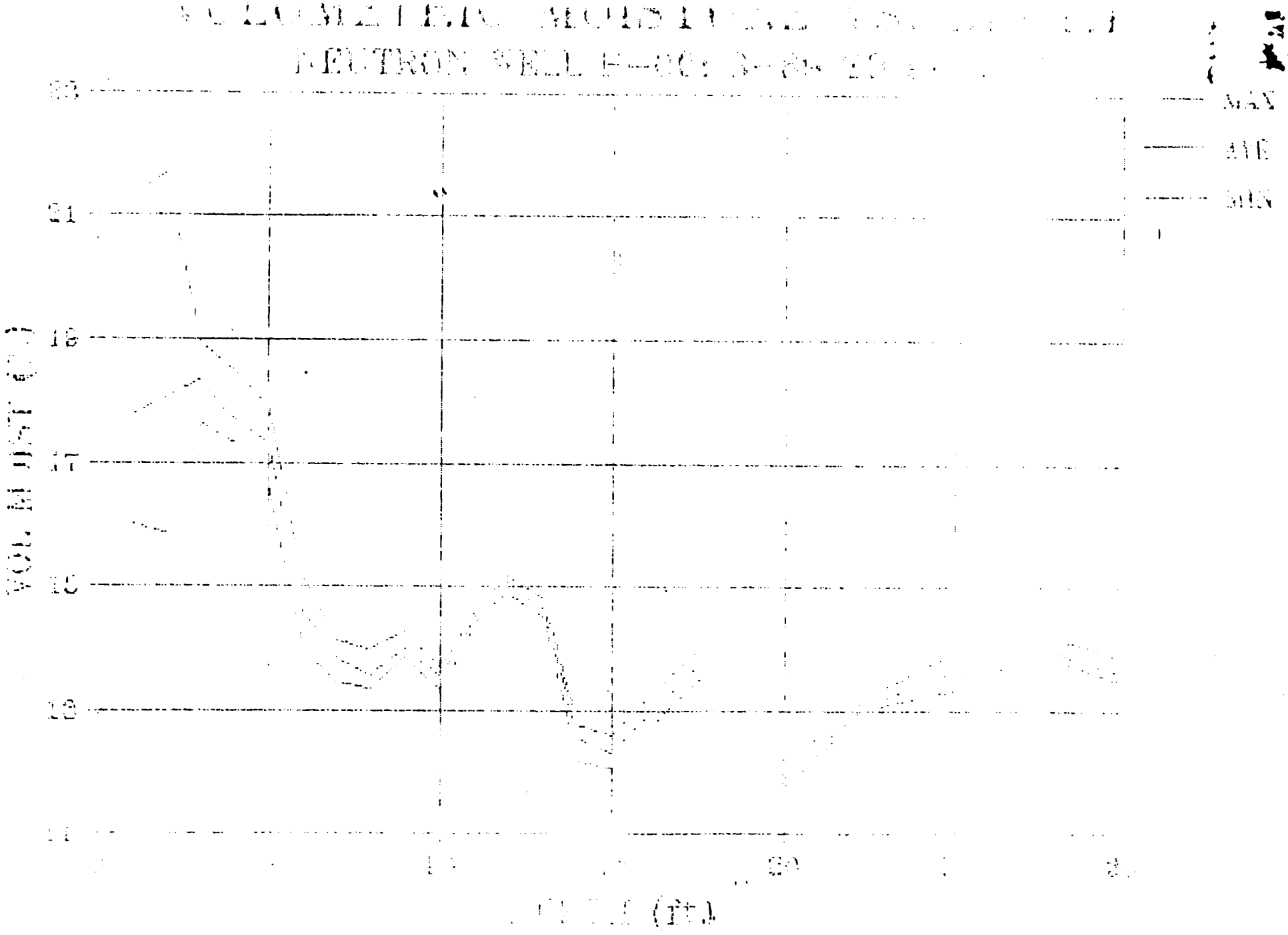
VII. APPENDICES

Appendix F. Neutron Moisture Readings

Plots of volumetric moisture content versus depth below ground surface are attached. These data are from neutron access wells numbered P-0, P-12, P-13, P-14, P-16, P-17, P-18, P-19 , and P-20. Tabulated data were recorded on a monthly basis from March through September 1989, and are also attached for reference purposes.

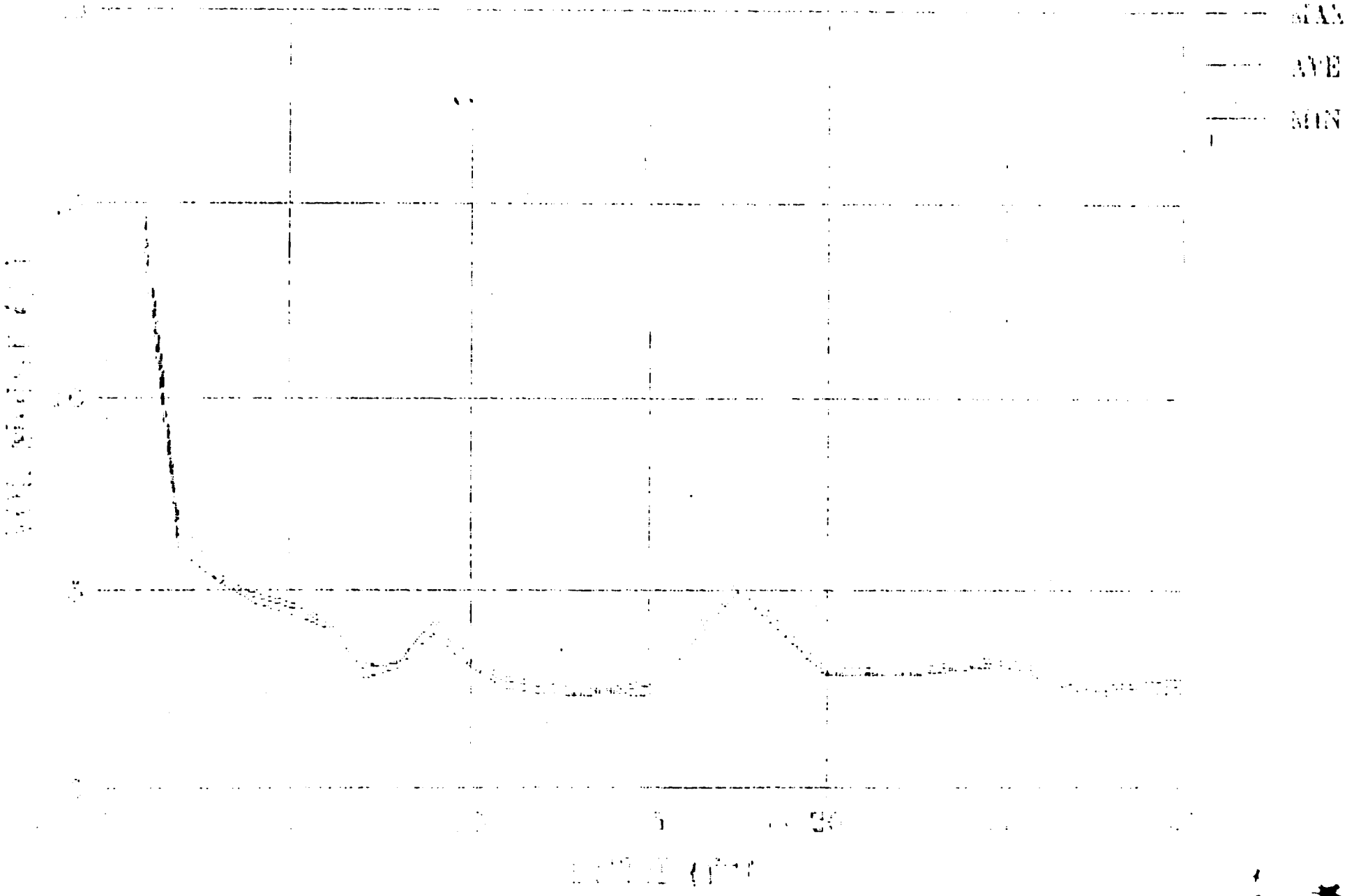

MAX
AVE
MIN


MAX
AVG
MIN


MAX
AVE
MIN
21
18
17
16
15
14
(ft)

VOLUMETRIC MOISTURE VS. DEPTH

NEUTRON WELL F-12: 3-09 TO 1-06



DRILLING LOG

BOREHOLE	: P-12	**ELEVATION**	: 7448
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 200 feet
DATE DRILLED	: August 21, 1987	**DIAMETER**	: 6.875 in
LOCATION	: NW of TA-16 Pond	**CASING MATERIAL**	: Aluminum
COORDINATES	: X=476664, Y=1764036	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

NEUTRON ACCESS WELL COMPLETION SUMMARY

```
ONE FT CEMENT SEAL AND CAP -->CA| |<---- TOPSOIL COVER
ANNULUS FILLED WITH TUFF ---->TA| |<---- UNIT 3d CONTACT AT 3 FT
                               TA| |
                               TA| |
                               TA| |
                               TA| |
                               TA| |<---- UNIT 3c CONTACT AT 50 FT
                               TA| |
                               TA| |
                               TA| |
                               TA| |
                               TA| |
                               TA| |
                               TA| |
                               TA| |
                               TA| |<---- UNIT 3b CONTACT AT 102 FT
                               TA| |
                               TA| |
                               TA| |
                               TA| |
                               TA| |
                               TA| |
                               TA| |
                               TA| |
                               TA| |
CASING PLUG AT 171 FT ------->TA|P|
                                T|X|<---- UNIT 3a CONTACT AT 173 FT
                                T|X|
                                T|X|
                                T|X|<---- UNIT 2 CONTACT AT 195 FT
TOTAL DEPTH AT 200 FT -------> T|X|
```

DIAGRAM NOT TO SCALE

CEMENT SLURRY SEAL.....C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
ALUMINUM CASING, 2 in ID....A
WELDED END CAP PLUG.....P
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-13	**ELEVATION**	: 7445
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 103 feet
DATE DRILLED	: October 3, 1987	**DIAMETER**	: 6.875 in
LOCATION	: S of Landfill	**CASING MATERIAL**	: Aluminum
COORDINATES	: X=475720, Y=1764264	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

NEUTRON ACCESS WELL COMPLETION SUMMARY

```
ONE FT CEMENT SEAL AND CAP -->CA| |<---- TOPSOIL COVER
ANNULUS FILLED WITH TUFF ---->TA| |<---- UNIT 3d CONTACT AT 0 FT
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |<---- UNIT 3c CONTACT AT 38 FT
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |<---- UNIT 3b CONTACT AT 84 FT
                              TA| |
CASING PLUG AT 92 FT -------->TA|P|
                               T|X|
                               T|X|
TOTAL DEPTH AT 103 FT -------> T|X|
```

DIAGRAM NOT TO SCALE

CEMENT SLURRY SEAL.....C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
ALUMINUM CASING, 2 in ID....A
WELDED END CAP PLUG.....P
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-14	**ELEVATION**	: 7437
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 85 feet
DATE DRILLED	: August 28, 1987	**DIAMETER**	: 6.875 in
LOCATION	: W of Landfill	**CASING MATERIAL**	: Aluminum
COORDINATES	: X=475365, Y=1764251	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

NEUTRON ACCESS WELL COMPLETION SUMMARY

```
ONE FT CEMENT SEAL AND CAP -->CA|  |<---- TOPSOIL COVER
ANNULUS FILLED WITH TUFF ---->TA|  |<---- UNIT 3d CONTACT AT 4 FT
                              TA|  |
                              TA|  |
                              TA|  |
                              TA|  |
                              TA|  |<---- UNIT 3c CONTACT AT 30 FT
                              TA|  |
                              TA|  |
                              TA|  |
                              TA|  |
                              TA|  |
                              TA|  |
                              TA|  |
                              TA|  |
                              TA|  |<---- UNIT 3b CONTACT AT 75 FT
CASING PLUG AT 79 FT -------->TA|P|
                               T|X|
TOTAL DEPTH AT 85 FT -------->  T|X|
```

DIAGRAM NOT TO SCALE

CEMENT SLURRY SEAL.....C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
ALUMINUM CASING, 2 in ID....A
WELDED END CAP PLUG.....P
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-15	**ELEVATION**	: 7413
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 70 feet
DATE DRILLED	: August 27, 1987	**DIAMETER**	: 6.875 in
LOCATION	: W of TA-16 Pond	**CASING MATERIAL**	: Abandoned
COORDINATES	: X=475803, Y=1763520	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

EXPLORATION BOREHOLE LOG SUMMARY

```
                                T| |<---- SANDY LOAM TOP SOIL
                                T| |<---- UNIT 3c CONTACT AT 4 FT
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |
                                T| |<---- UNIT 3b CONTACT AT 55 FT
                                T| |
                                T| |
TOTAL DEPTH AT 70 FT --------->T| |
```

DIAGRAM NOT TO SCALE

BENTONITE PELLET SEAL.....B
BACKFILLED TUFF CUTTINGS....T
CAVED IN.....X

DRILLING LOG

BOREHOLE	: P-16	**ELEVATION**	: 7452
GEOLOGIST	: Brown & Purtymun	**TOTAL DEPTH**	: 105 feet
DATE DRILLED	: September 4, 1987	**DIAMETER**	: 6.875 in
LOCATION	: S of Landfill	**CASING MATERIAL**	: Aluminum
COORDINATES	: X=475550, Y=1764200	**MAP SYSTEM**	: NM State

See Appendix D (in HSE-8, 1988) for detailed log.

NEUTRON ACCESS WELL COMPLETION SUMMARY

```
ONE FT CEMENT SEAL AND CAP -->CA| |<---- TOPSOIL COVER
ANNULUS FILLED WITH TUFF ---->TA| |
                              TA| |<---- UNIT 3d CONTACT AT 7 FT
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |<---- UNIT 3c CONTACT AT 42 FT
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |
                              TA| |<---- UNIT 3b CONTACT AT 87 FT
CASING PLUG AT 88 FT -------->TA|P|
                               T|X|
                               T|X|
TOTAL DEPTH AT 105 FT -------> T|X|
```

DIAGRAM NOT TO SCALE

CEMENT SLURRY SEAL.....C
BACKFILLED TUFF CUTTINGS....T
MEDIUM GRAIN SILICA SAND....S
ALUMINUM CASING, 2 in ID....A
WELDED END CAP PLUG.....P
CAVED IN.....X

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

memorandum

TO S. McLin, HSE-8, MS K490

DATE August 9, 1989

THRU E. D. Loughran

MAIL STOP/TELEPHONE C920/7-3094

FROM J. F. Baytos

SYMBOL M-1

SUBJECT EXPLOSIVE CONTENT OF CORE SOIL SAMPLES FROM TA-16-389 DUMP

The dozen core soil samples that you selected from the 50 samples you have screened by spot test analysis have been analyzed for residual explosives content by high-pressure liquid chromatography (HPLC). The results are given on the attached report sheets.

The explosive content in all cases was below the 1.5% level. This number is the upper limit for classification as an environmental sample for transportation outside explosive areas.

The samples were dried before analysis, and were broken up prior to Soxhlet extraction. No other treatment was given the samples. The inhomogeneous samples gave larger spreads, and in no case was the total explosive more than 1.5% (15000 ppm).

John F Baytos

John F. Baytos

JFB:egm

Attach: Lab Report #20567

Cy w/attach: T. E. Larson/L. E. Hatler
E. D. Loughran
J. F. Baytos
Lab File 20567
M-1 File

M-1, Explosives Technology
Revised: 8/31/84

GROUP M-1 ANALYTICAL LABORATORY REPORT

Requestor: S. McLin, HSE-8, K490, X51721 Lab. No.: 20567

Sample: 12 Core Soil Samples from TA-16-389 Area P.O. No.: W57R

Analysis Requested: High Explosives Content Date Rec'd.: 3/24/89

Operator: JFB/CAM/WFK Reported: 7/16/89

HSE-8 Sample #	* Acetonitrile Solubles (wt%)	** (ppm)	HPLC Method for Determining Explosives HMX	RDX	TNT	DNT	
89.01248-SGM	1.68		730	343	7869	0	
	1.24		1010	292	7115	0	
89.01249-SGM	0.58		220	2639	1497	0	
	0.53		270	2655	1275	0	
89.01250-SGM	0.08		22	2	4	0	
	0.04		22	1	0	0	
89.01251-SGM	0.06		14	3	17	0	
	0.08		0	0	54	0	
Control (3/4%)	0.87		2639	2605	2314	0	

Remarks: * The acetonitrile solubles come from the Soxhlet extraction on a dried sample. This filtrate includes explosives, decomposition products, plastics, oils, decaying flora and fauna, and other natural acetonitrile soluble materials.

** Ref: Bongiovanni, Podolak, Clark, & Scarborough; Am Ind Hyg Assoc J; (45), 4, 222-226, 1984

M-1, Explosives Technology
Revised: 8/31/84

GROUP M-1 ANALYTICAL LABORATORY REPORT

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Sample: 12 Core Soil Samples from TA-16-389 Area P.O. No.: W57R

Analysis Requested: High Explosives Content Date Rec'd.: 3/24/89

Operator: JFB/CAM/WFK Reported: 7/16/89

HSE-8 Sample #	* Acetonitrile Solubles (wt%)	** (ppm)	HPLC Method for Determining Explosives HMX	RDX	TNT	DNT	
89.01252-SGM	0.77		821	4133	594	0	
	0.78		1099	4132	557	0	
89.01253-SGM	0.70		164	1195	211	0	
	0.83		146	983	406	0	
89.01254-SGM	0.27		1201	32	0	0	
	0.27		1301	139	1	0	
89.01255-SGM	0.95		2551	2206	0	0	
	1.00		2582	2138	0	0	
Control (Blank soil)	0.14		0	0	0	0	

Remarks: * The acetonitrile solubles come from the Soxhlet extraction on a dried sample. This filtrate includes explosives, decomposition products, plastics, oils, decaying flora and fauna, and other natural acetonitrile soluble materials.

* Ref: Bongiovanni, Podolak, Clark, & Scarborough; Am Ind Hyg Assoc J; (45), 4, 222-226, 1984

M-1, Explosives Technology
Revised: 8/31/84

GROUP M-1 ANALYTICAL LABORATORY REPORT

Requestor: S. McLin, HSE-8, K490, X51721 Lab. No.: 20567

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Analysis Requested: High Explosives Content Date Rec'd.: 3/24/89

Operator: JFB/CAM/WFK Reported: 7/16/89

HSE-8 Sample #	* Acetonitrile Solubles (wt%)	** (ppm)	HPLC Method for Determining Explosives HMX	RDX	TNT	DNT	
89.01256-SGM	0.11		0	0	0	0	-
	0.12		0	0	0	0	
89.01257-SGM	0.18		21	50	27	0	
	0.05		0	0	0	0	
89.01258-SGM	0.10		0	2	0	0	
	0.07		5	0	7	0	
89.01259-SGM	0.21		585	13	26	0	
	0.18		370	4	12	0	
Control (3/4%)	***		2295	2782	2824	0	

Remarks: * The acetonitrile solubles come from the Soxhlet extraction on a dried sample. This filtrate includes explosives, decomposition products, plastics, oils, decaying flora and fauna, and other natural acetonitrile soluble materials.

** Ref:Bongiovanni,Podolak,Clark,& Scarborough; Am Ind Hyg Assoc J; (45),4, 222-226, 1984

*** This control sample was dissolved in acetonitrile and filtered.