# ENGINEERING GEOLOGY OF THE NORTHERN ESTANCIA VALLEY, NORTH-CENTRAL NEW MEXICO

By

Don Barrie

Submitted in partial fulfillment

of the Master of Science degree

in Geology

New Mexico Institute of Mining and Technology

Socorro, New Mexico

December, 1987

# ABSTRACT

The study area occupies approximately 655 $mi^2$ and is located in the northern part of the Estancia Valley. Rocks of Precambrian to Tertiary age are present. Late Cenozoic valley-fill material is up to 405 ft thick and consists of alluvial and lacustrine deposits. Historically, seismicity has been low; there are no known active faults present. Depth to ground water ranges from 30 to over 350 ft.

Clayey, lacustrine soil contains varying amounts of kaolinite, illite, smectite, and mixed-layer illite-smectites. The plasticity of lacustrine soil is probably more strongly affected by the amount of clay-size material present than by clay mineralogy.

The results of various soil index tests and field observations are used to assess five important engineering concerns:

(1) Conditions favorable for liquefaction are not present in the study area. Soils are not typically cohesionless, the water table is too deep, and predicted ground accelerations likely to be caused by earthquakes are too low.

(2) Generally, the shrink-swell potential of soil units is low, although expansive soils occur locally.

(3) Soils most likely to be collapsible include the granular varieties of older alluvium.

(4) Granular soils are fairly well suited as subgrade (natural substratum) for road construction purposes. Cohesive soils are less suitable, although typically high N-values indicate that they can probably furnish adequate support for most traffic loads.

(5) Generally, both granular and cohesive soils exhibit good bearing capacity for foundations due to cementation by secondary calcium carbonate. Consolidation of saturated, lacustrine soil is not a critical concern due to its low compressibility. Foundation settlement related to ground water withdrawl is not currently a concern.

Rock index test results and field observations are used to assess four additional engineering concerns:

(1) Most surface rock in the study area is not rippable, whereas lower-strength rocks occurring primarily in the shallow subsurface are rippable.

(2) The shrink-swell potential of rock units is minimal; however, weakly consolidated Dockum Group siltstone and mudstone are locally expansive.

(3) The overall resource potential for crushed rock aggregate, building stone, sand, gravel, and caliche, is high and should be adequate to support most future construction projects.

(4) For lower-strength rocks, allowable contact pressures imposed by large foundation loads may be limited by rock strength and rock quality. In contrast, contact pressures on higher-strength rocks are limited only by rock quality.

## CONTENTS

# LIST OF FIGURES

## LIST OF TABLES

# LIST OF APPENDICES

# INTRODUCTION AND BACKGROUND

## NMBMMR SSC Project

In December 1985 the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) produced a report on the Estancia Valley in north-central New Mexico (NMBMMR Staff, 1985). They concluded that the site appeared suitable for construction of the Superconducting Super Collider (SSC), an oval-shaped particle accelerator approximately 53 mi in circumference and 12 ft in diameter. A preliminary geotechnical characterization of the Estancia Valley site begun in June 1986 and completed in January 1987, encountered no "fatal flaws" that would preclude siting the SSC in the northern Estancia Valley (Johnpeer et al., 1987). A further study documenting ground subsidence potential, tunneling conditions, and water quality and availability was conducted between January and May 1987. The scope of work was interdisciplinary and included: aerial photograph interpretation, engineering geologic mapping, drilling, reviewing published seismicity data, ground motion monitoring, shallow trenching, downhole geophysical logging, surface geophysical surveys, aerial flyovers, and laboratory testing. The results of this effort were summarized in volume 3 of the eight-volume SSC proposal submitted to the U.S. Department of Energy (DOE) for review September, 1987. As a project research assistant, the writer was involved principally with the laboratory testing of soil and rock samples and also participated in sample collecting, engineering geologic mapping, logging of geotechnical boreholes and trenches, and aerial reconnaissance. The final SSC report (New Mexico SSC Proposal, 1987, v. 3) and accompanying laboratory data released a large amount of new information. However, due to time constraints and also to the objectives of the study, emphasis was placed primarily on identifying any geotechnical conditions that would adversely affect the Estancia Valley site as a possible location for the SSC.

### Purpose and Scope of Present Study

The main objective of this study is to investigate in detail some of the important engineering (geotechnical) properties of soil and rock units within the northern Estancia Valley. This objective was met by analyzing the abundant laboratory data that became available as a result of NMBMMR studies and by completing additional laboratory tests beyond the scope of the NMBMMR effort. This study assigns average engineering properties to soil and rock units present in the study area. Most importantly, this information was used to evaluate a number of important engineering concerns. It is hoped that this study will aid planners, contractors, and engineers in any future development of the northern Estancia Valley.

## LOCATION AND EXTENT

The study area is located in the northern part of the Estancia Valley in central New Mexico (Fig. 1). It occupies an area of approximately 655 mi$^2$ and is bounded on the north by 35°15' N latitude, on the south by 34°50' N latitude, on the east by 105°49' W longitude, and on the west by 106°15' W longitude. From north to south the study area is 26.5 miles long and from east to west it is 24.7 miles wide. Most of it lies within Santa Fe and Torrance Counties, although a small portion extends into Sandoval and Bernalillo Counties toward the west. The town of Moriarty, located in the south-central part of the study area, is approximately 35 miles east of Albuquerque.

## TOPOGRAPHY

The Estancia Valley is an elliptical, topographically closed basin of approximately 2,000 mi$^2$ located near the geographic center of New Mexico (Fig. 1). To the north the valley is bounded by a broad saddle at about 6,500 ft in elevation, which separates the Estancia Valley from the Galisteo Valley. To the west the valley is bordered by the Sandia and Manzano Mountains. South Mountain and San Pedro Mountain border the valley to the northwest. Chupadera Mesa borders the valley to the south; the Pedernal Hills and Rattlesnake Hill border it to the east.

The study area ranges in elevation from 8,748 ft at the top of South Mountain to about 6,128 ft along the southern boundary near McIntosh (Fig. 2). Except for local relief due to drainages and minor hills, the central part of the valley floor in

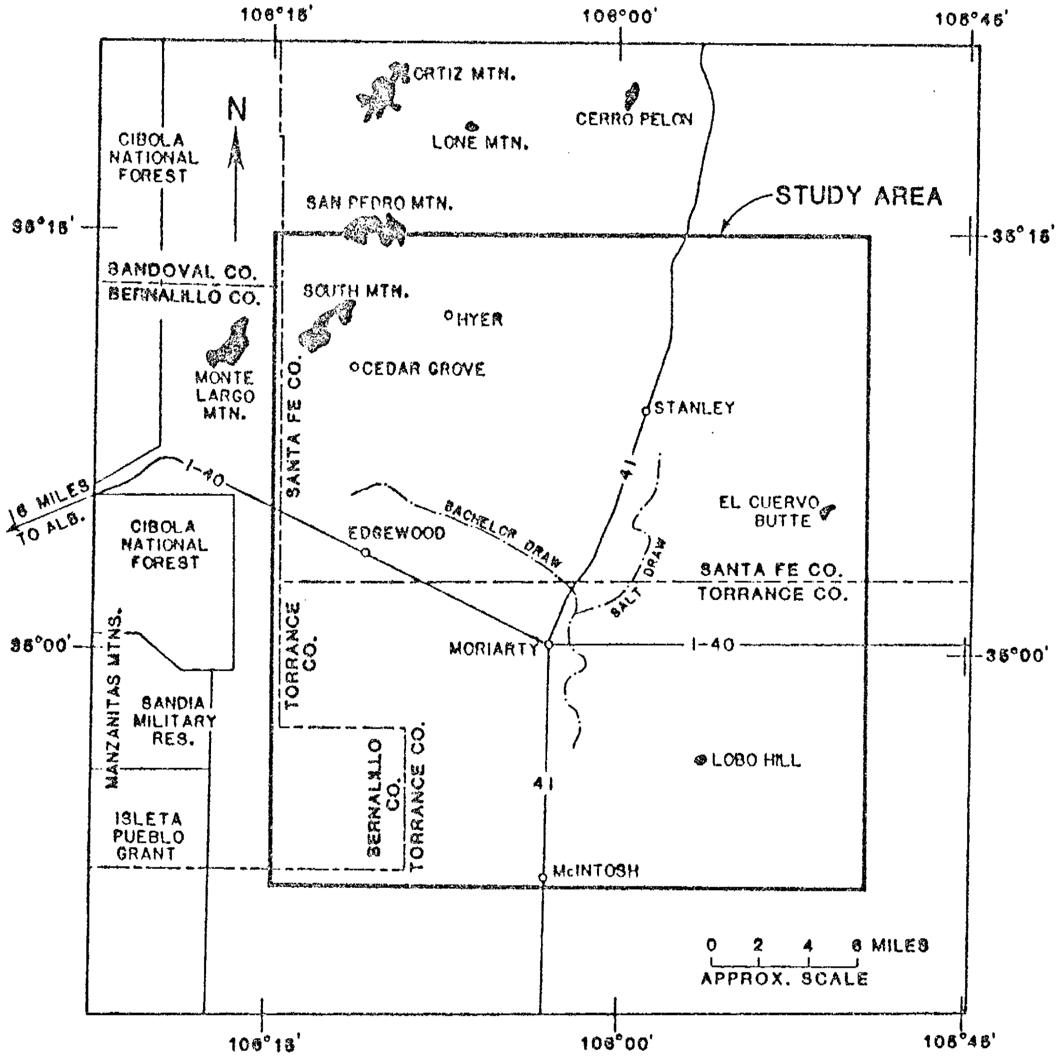


FIGURE 1--Location map (from Johnpeer et al., 1987).

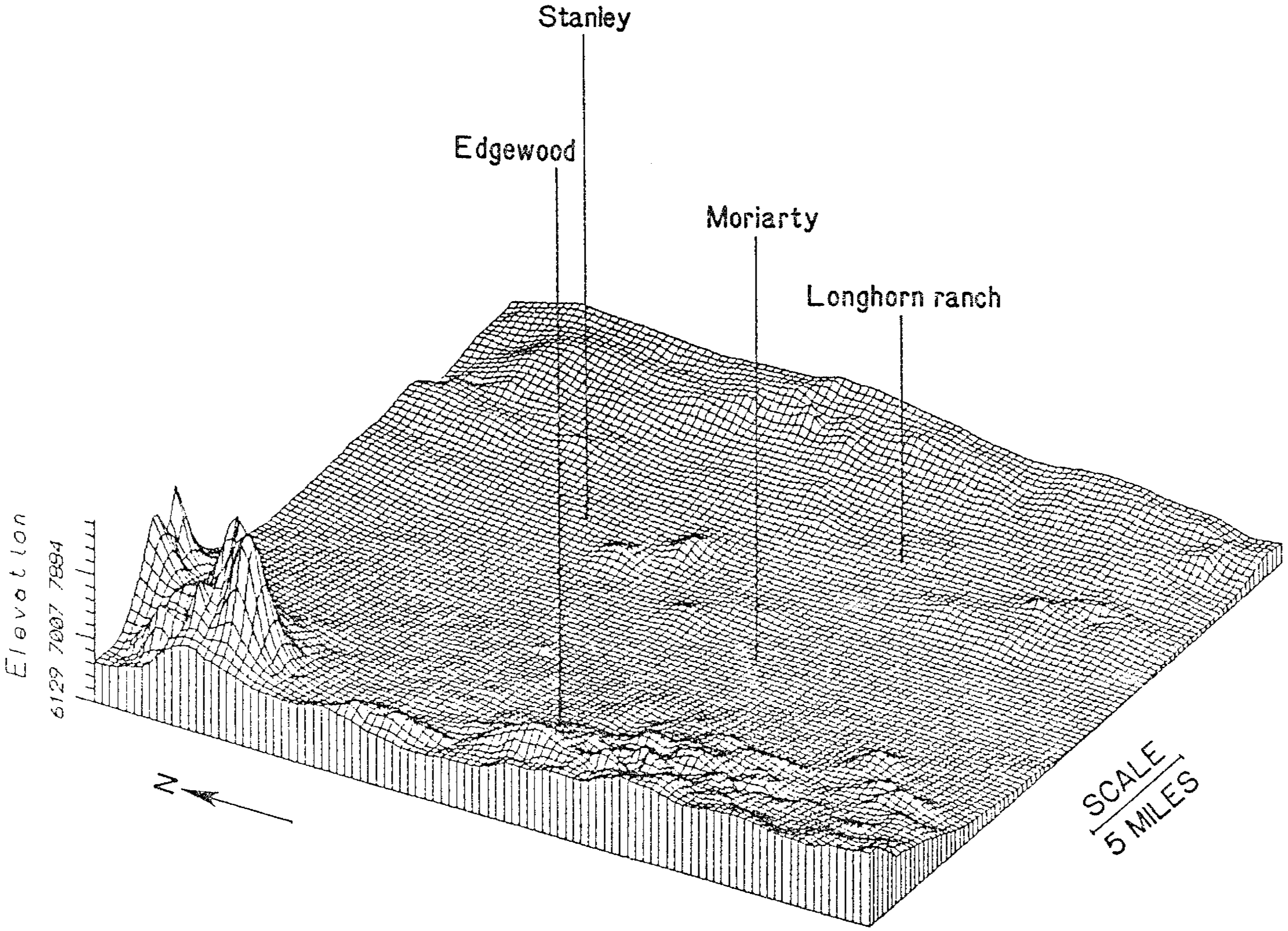


FIGURE 2--Three-dimensional topographic plot of the study area (vertically exaggerated).

the study area is relatively flat and slopes toward the south at approximately 15 ft per mile. Westward from the break in slope above the valley floor, slopes rise at about 40 to 50 ft per mile toward the base of the Manzano and Sandia Mountains. Eastward, slopes rise between about 40 and 100 ft per mile toward the Pedernal Hills.

# SETTING

## Climate

Rainfall data collected from various locations in the Estancia Valley display annual averages between 11.2 and 13.7 inches (Gabin and Lesperance, 1977). July and August are the wettest months, typically receiving between 2 to 3 inches each month. Most of this moisture falls during brief, heavy thundershowers. The amount of precipitation increases rapidly with elevation, rising to over 22 inches per year at higher mountain elevations such as at the summit of South Mountain (Soil Conservation Service, 1970).

Temperatures within the valley vary greatly both on a diurnal and an annual scale. The daily temperature range throughout the year is usually between 30° and 40° F, and the annual range is as much as 100° to 120° F (Soil Conservation Service, 1970). The monthly mean temperature during the winter months (December and January) is about 30° to 35°F. During the summer months (June, July, and August) it is about 65° to 70° F (New Mexico SSC Proposal, 1987, v. 3).

## Vegetation and Land Use

Native plants within the study area consist mainly of various grasses with some pinon and juniper (Soil Conservation Service, 1975). Grazeland predominates in the northern and eastern parts of the study area. Irrigated cropland predominates in the central part, where alfalfa, corn, potatoes, sugar beets, pinto beans, barley, wheat, and pumpkin are grown (Soil Conservation Service, 1970). Approximately 85% of the land in the study area is privately owned. State and federal land leases account for the remaining 15% (Fig. 3). Population centers are clustered in the central and western parts of the study area in McIntosh, Moriarty, Stanley, and Edgewood. Land uses adjacent to the study area include Cibola National Forest along the Sandia and Manzano Mountains, the Isleta Pueblo land grant to the southwest, and the Sandia Military Reservation to the west (Fig. 1).

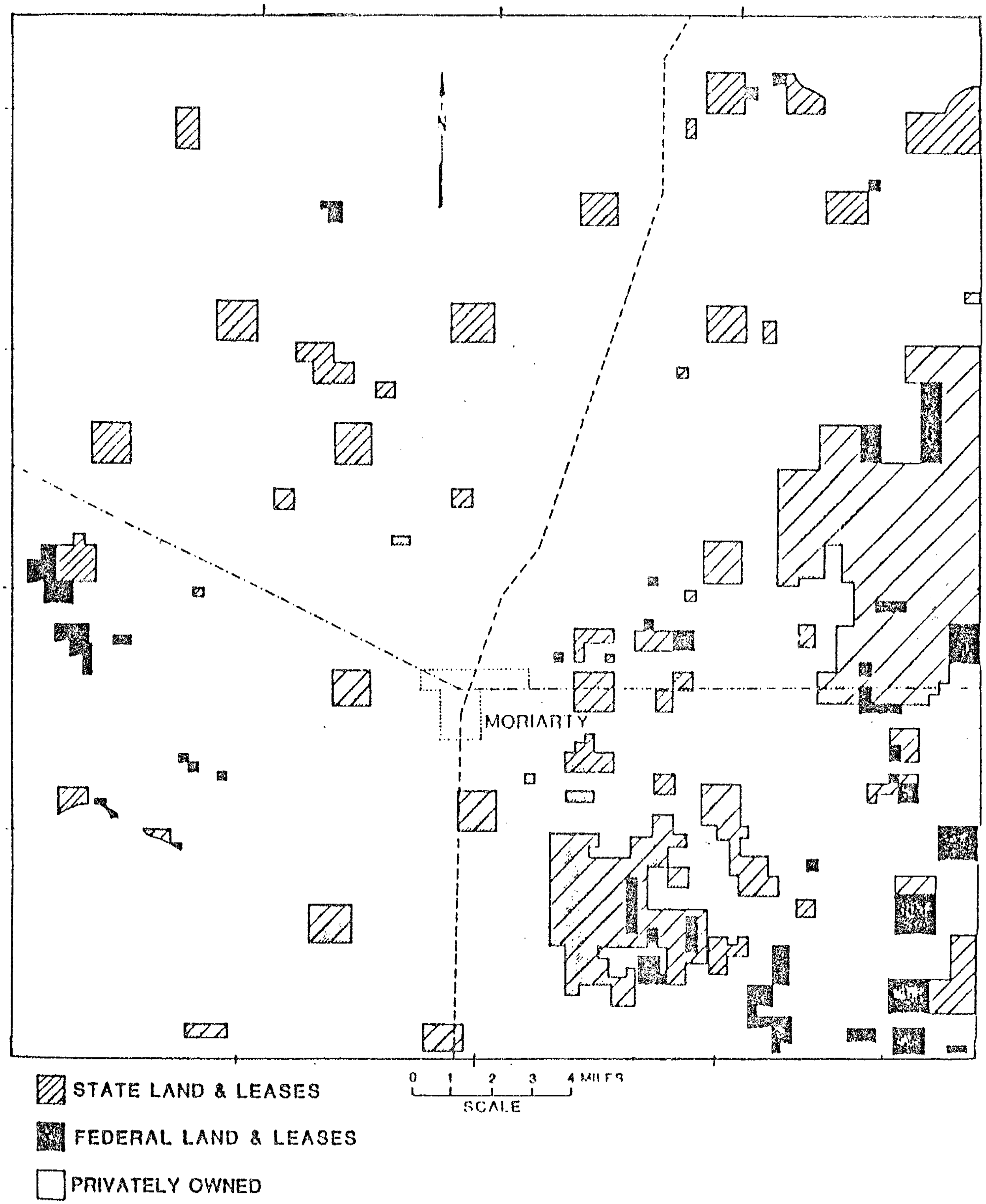


FIGURE 3--Land ownership (from Johnpeer et al., 1987).

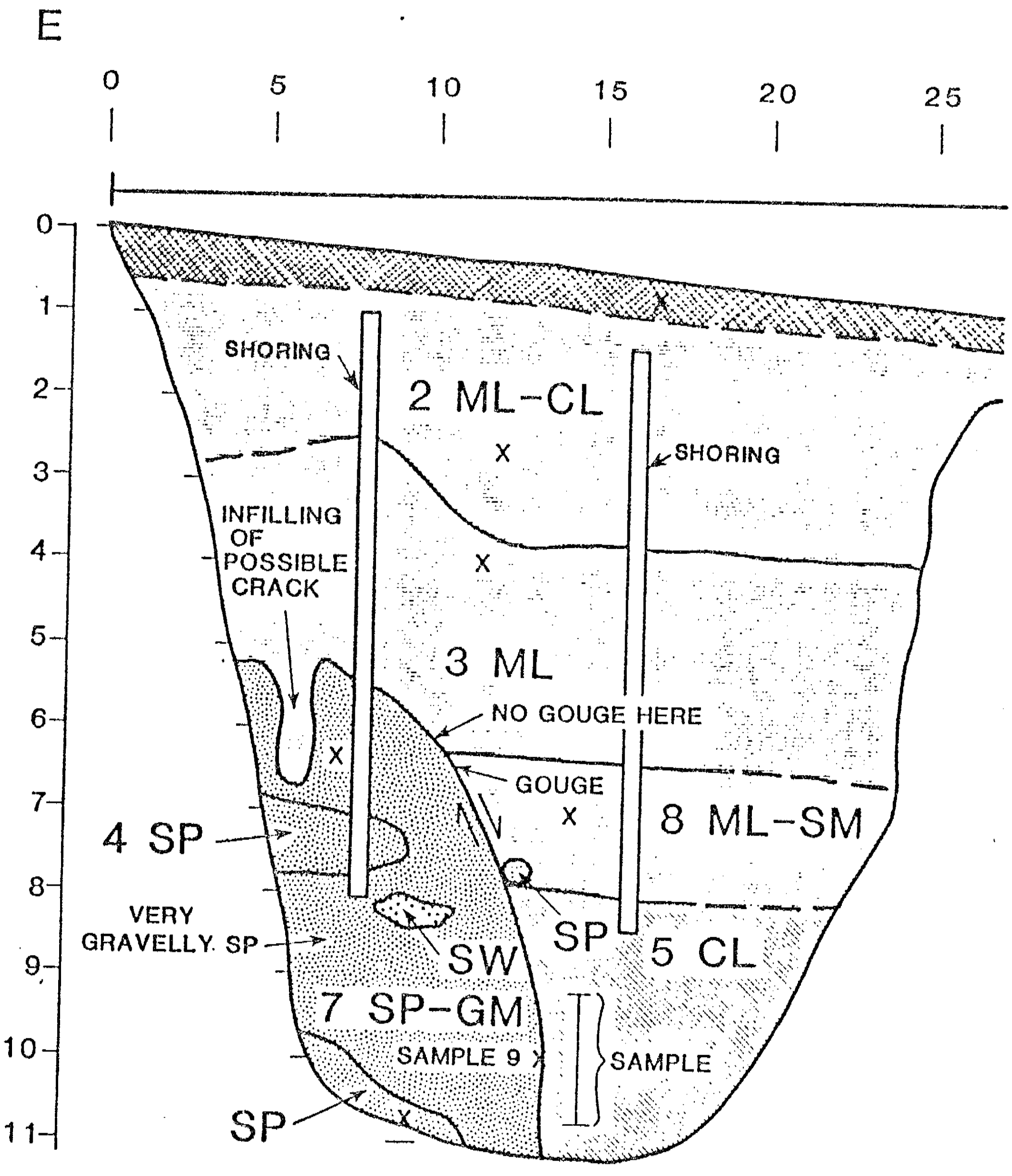


FIGURE 8--Partial log of backhoe trench 10 (BH-10, Appendix II) showing previously unmapped fault (USCS designations from ASTM D2487-85).

# HYDROLOGIC SETTING

Due to its topographic closure the Estancia Valley has no external drainage. Recharge by precipitation is the source of all ground water (Jenkins, 1982). Based on 14 well hydrographs (New Mexico SSC Proposal, 1987, v. 3) the average rate of decline of the water table has been approximately 1 ft per year (since 1955).

## Principal Aquifers

Valley fill is the principal aquifer in the main part of the Estancia Valley. As stated previously, the valley fill is at least 405 ft thick near Stanley and consists of four units: (1) Quaternary-Tertiary alluvium, (2) older (Quaternary) alluvium, (3) lacustrine deposits, and (4) younger (Holocene) alluvium. The lacustrine deposits generally confine ground water to the underlying alluvium (Jenkins, 1982), although the interbedded sands present in the lake deposits cause perched water locally. The quality of water in the valley fill varies with locality. West of NM-41, in Torrance County (Fig. 1), water from wells in the valley fill is satisfactory for domestic use. East of NM-41, water quality is poorer. Most of the water in this area is unsatisfactory for domestic use, and some of it is unsatisfactory for irrigation and undesirable for stock animals (Smith, 1957).

The arkosic limestone member of the Madera Formation is the principal aquifer in the western part of the study area. Much of the ground-water recharge for the study area occurs in the Madera Formation of the Manzano Mountains to the west (Jenkins, 1982). As an aquifer the Madera is less reliable for yield and permanence than the valley fill (Smith, 1957). The Madera is a heterogeneous, fractured-rock aquifer in which availability of ground water is site dependent. Permeability and porosity are secondary, controlled mainly by fractures, joints, and solution cavities. Well yields often vary greatly over short distances because saturated fractures are not evenly distributed throughout the rock (Jenkins, 1982). High-yield wells in the Madera, capable of producing over 1,000 gpm, occur locally. Dry wells occur also. Ground water is available in sufficient quantities for domestic use from most of the area underlain by the Madera Formation (Jenkins, 1982).

Sandstone of the Glorieta Formation is the principal aquifer in the central and east-central parts of the study area. Permeability of the Glorieta is generally low, although locally, well yields of more than 3,000 gpm have been reported (Smith, 1957). Water from the Glorieta is used for irrigation, stock and for domestic purposes.

The Yeso Formation is the main aquifer in the areas east of Moriarty and Lobo Hill (Fig. 1). Well yields from the Yeso in this area are typically about 15 gpm, although yields of over 3,000 gpm exist locally where the Yeso is fractured (Smith, 1957). Permeability and porosity in the Yeso are mostly in sandstone, although some water wells produce from cavities in limestone (Titus, 1969). Water quality from the Yeso varies from satisfactory to unsatisfactory for domestic use and irrigation. Generally, water from the Yeso is satisfactory for stock (Smith, 1957).

## Depth to Ground water

A generalized depth to ground water map, based on 68 well measurements, is shown for the central part of the study area in Figure 9. Water depths were taken from selected well logs on file at the office of the State Engineer (written comm., 1987), from data provided by Robert White of the USGS (written comm., 1987), and from geotechnical borehole logs (Appendix I).

Depth to ground water is dependent both upon the potentiometric surface and the surface topography. Generally, depth to ground water in the area shown in Figure 9 increases with elevation so that it is deeper in the northern part of this area than in the southern part. Ground-water depths are also greater along the margins this area than in the central part of the area. Depths to ground water range from about 30 ft east-southeast of Moriarty to more than 359 ft about 7.5 mi north-northwest of Edgewood.

Figure 10 is a contour map of the regional potentiometric surface for the same area shown in Figure 9. Figure 11 is a three-dimensional view of this potentiometric surface. These two figures show that the potentiometric surface is generally flat in the central part of the area shown and slopes gently toward the south and inward from the margins of the area. This is consistent with Smith's (1957) observation that water entering upland recharge areas flows toward lower discharge areas in the southern part of the Estancia Valley. The southwest part of

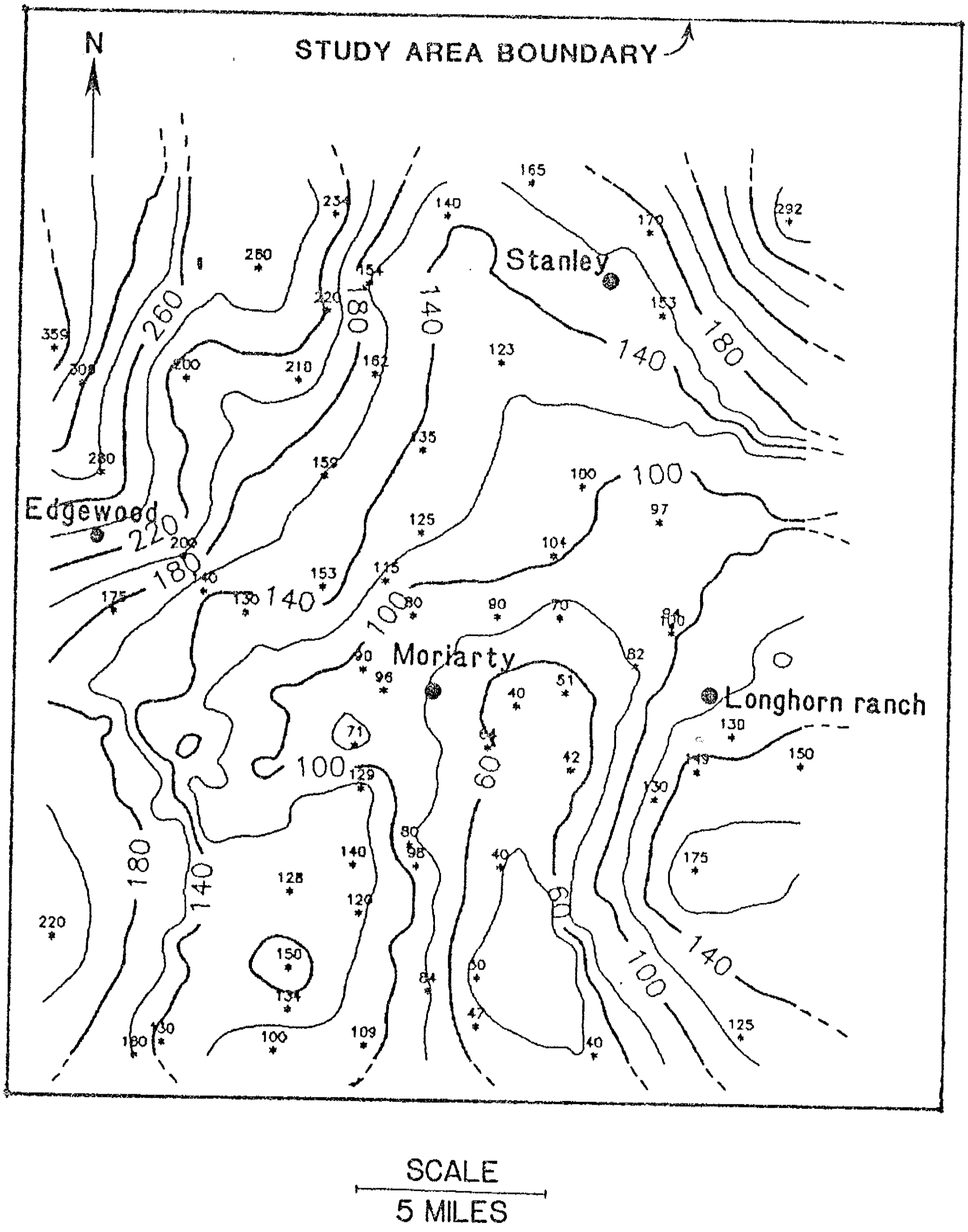
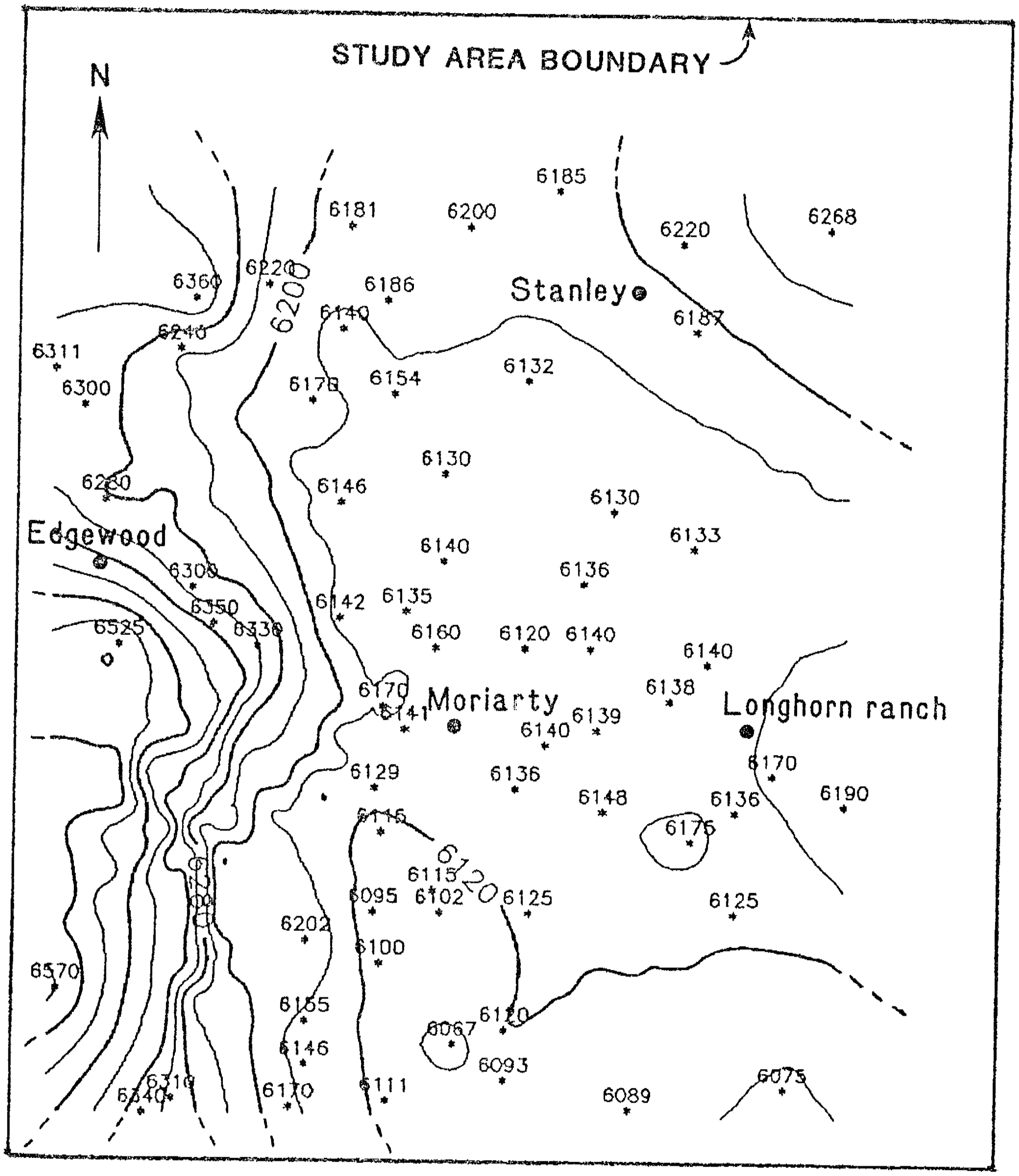


FIGURE 9--Contour map of depth to water.



SCALE
5 MILES

FIGURE 10--Contour map of elevation of the regional potentiometric surface.

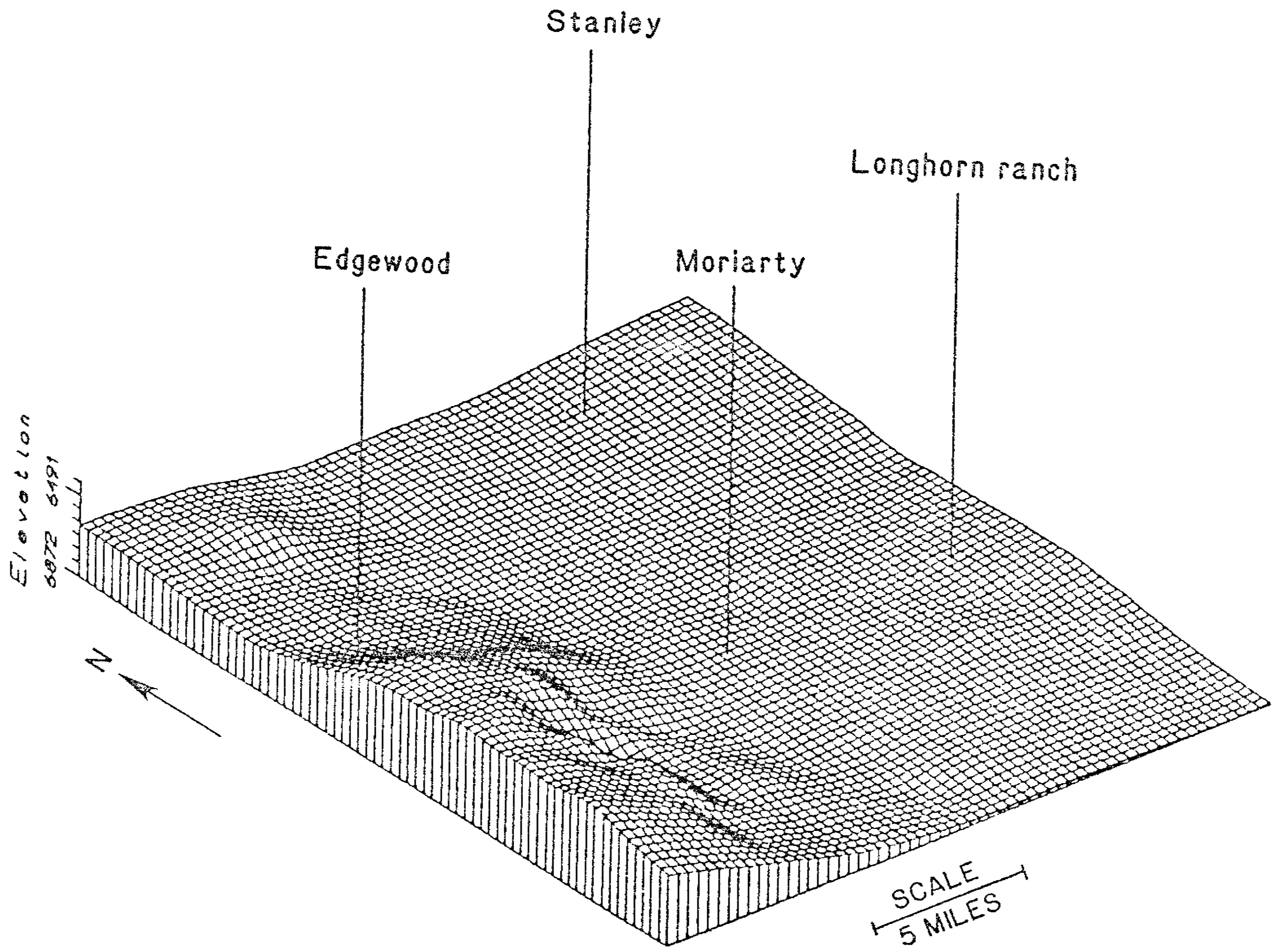


FIGURE 11--Three-dimensional view of the regional potentiometric surface shown in Figure 10 (vertically exaggerated).

the area shown in Figures 10 and 11 is probably elevated because this area is adjacent to the major recharge area of the Manzano Mountains to the west. It is noted that Figures 9, 10, and 11 are generalized and do not always accurately reflect local groundwater conditions. Nonetheless, these figures are useful because they indicate regional hydrologic trends.

# GEOTECHNICAL CHARACTERIZATION OF SOIL UNITS

## Introduction

In this section the engineering properties of soil units in the study area are considered. The construction and maintenance of engineered structures such as building foundations, tunnels, highways, and embankments depends primarily on the physical characteristics of underlying soil or rock units. As used in this study, *soil* is defined as a naturally occurring, unconsolidated superficial deposit overlying bedrock (International Conference of Building Officials, 1982) and includes material both above and below the root zone.

In this section soils are classified according to two systems specifically designed for engineering use. These include the Unified Soil Classification System (USCS) and the American Association for State Highway and Transportation Officials system (AASHTO). These systems are most commonly used in engineering practice because they provide a systematic method of categorizing soils according to their engineering behavior. Only a particle-size distribution (sieve analysis) and the Atterberg limits are necessary to completely classify a soil according to these systems. Knowing the USCS and/or AASHTO classification of a soil allows one to make initial estimates of its engineering properties.

Further geotechnical characterization of soil units in the study area involved additional testing. Moisture content determinations, calculation of liquidity indexes, and standard penetration tests were also done. Unconfined compressive strength and shear strength measurements were made in backhoe trenches with a pocket penetrometer and a Torvane shear device, respectively. X-ray diffraction (XRD) analyses were done on selected lacustrine clay (Qld) samples.

With the exception of XRD analyses, all of the above tests are easily and quickly done, and offer an efficient, economical means of obtaining important information regarding the engineering behavior of soils. These tests are known as index tests, and the test results are index parameters. These parameters are quite useful because they correlate with the engineering properties of soils. Both the engineering index parameters and the engineering properties of a soil (i.e., unconfined compressive strength, shear strength, relative density, compression index, etc.) are affected by the same things. These include: clay mineralogy, moisture content, secondary cement, particle size, and gradation. Index tests are more time- and cost-effective than more elaborate tests such as the triaxial shear and consolidation (oedometer) tests; therefore, more data can be obtained quicker and cheaper. The results, however, are only approximate and in most cases cannot serve as a substitute for more elaborate testing, although they can sometimes be used in preliminary design work. Index testing is therefore more appropriate for initial feasibility studies than for detailed, specific site investigations. Index-test results can help to outline critical engineering concerns. Because this study is meant to be a broad, reconnaissance-type investigation, index testing is relied upon heavily.

The objectives of this section are twofold: (1) to generally characterize soil units in the study area in terms of several important engineering properties, and (2) to utilize this information in assessing five basic engineering concerns. These concerns are: liquefaction potential, expanse potential, collapse potential, suitability of various soils for road construction, and certain foundation design considerations. Following a discussion of sampling methods and test procedures, the test results are presented. Finally and foremost, test results are used in evaluating the above five engineering concerns.

## Sampling Methods

Three types of soil samples were collected for this investigation: (1) geotechnical drill hole samples, (2) backhoe trench samples, and (3) samples obtained from hand-dug pits and man-made cuts. Forty-one samples collected from hand-dug pits were sampled at regular intervals along topographic survey lines (SL-1 to SL-3, Plate 1). Figure 12 shows the locations of sample collection sites. Both disturbed and undisturbed samples were collected from drill holes, although time constraints prevented extensive testing of undisturbed samples. Disturbed samples were obtained with a standard 18-inch split-spoon sampler, and undisturbed samples were obtained with standard 3-inch diameter galvanized, thin-walled Shelby tubes.

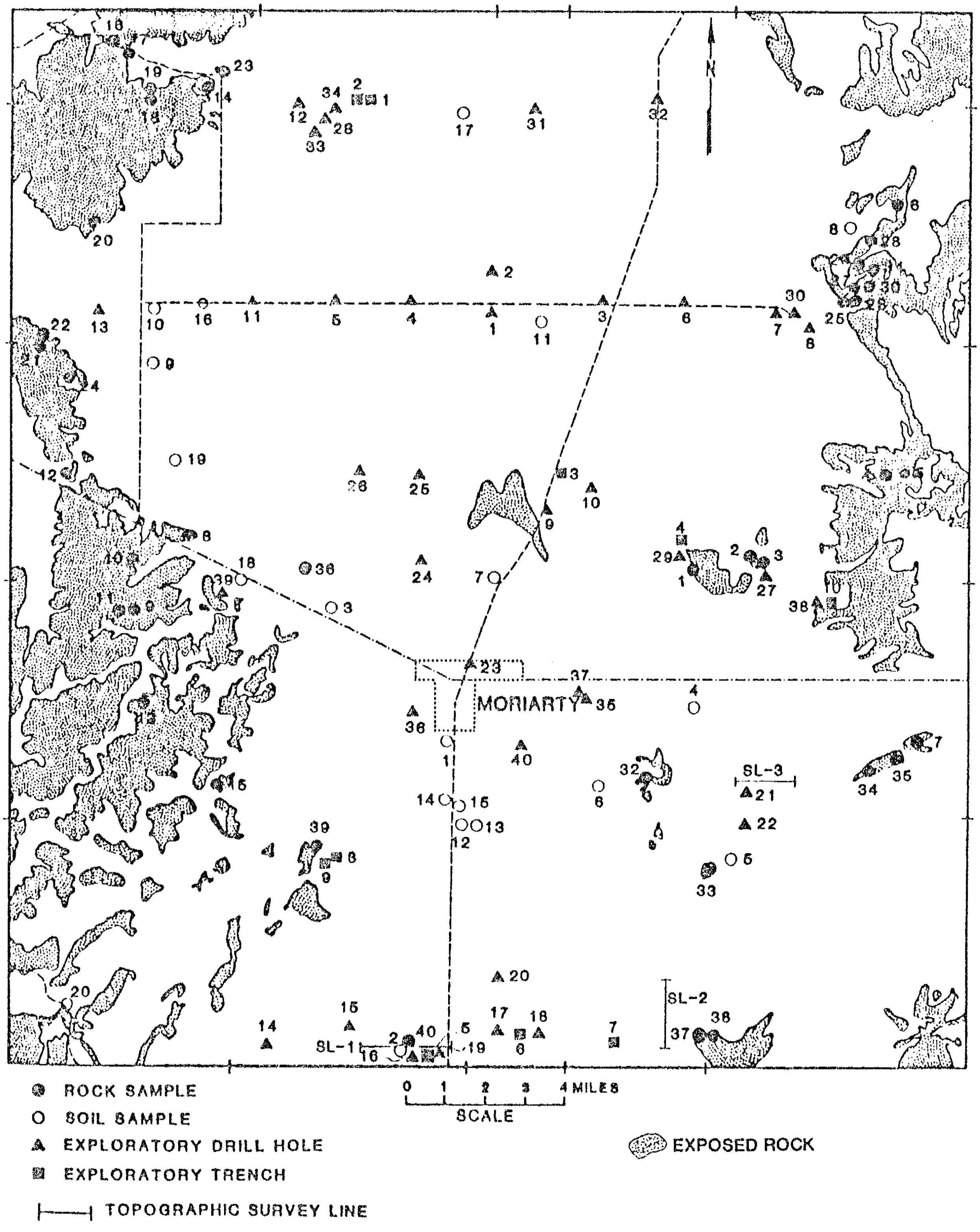


FIGURE 12--Activity location map (after New Mexico SSC Proposal, v. 3, 1987).

## Test Procedures

### Gradation (particle-size distribution)

Particle-size distribution and Atterberg limits are used for classification in the Unified and AASHTO systems. Two hundred forty-five of the 313 soil samples collected for this investigation were analyzed to determine their particle-size distributions. The procedure used generally conforms to ASTM designations D421-85, D422-72, and D1140-71 and consisted of passing a representative soil sample through a series of 8-inch diameter, standard sieves. Because of high percentages of fines (particles smaller than 0.075 mm) it was necessary in most cases to wash samples through sieves with distilled, deionized water. For the purpose of this investigation only the particle-size distribution of the gravel- and sand-size portion of soil samples (particles larger than 0.075 mm) was determined.

### Atterberg limits

The Atterberg limits of a soil correspond to moisture contents at certain critical stages of soil behavior. The liquid limit (LL) marks the boundary between plastic and liquid behavior, whereas the plastic limit (PL) denotes the boundary between semi-solid and plastic behavior. The shrinkage limit (SL) denotes the boundary between semi-solid and solid behavior and corresponds to the moisture content below which no further volume decrease occurs (Fig. 13). Mean shrinkage limit values were estimated using a procedure outlined by Holtz and

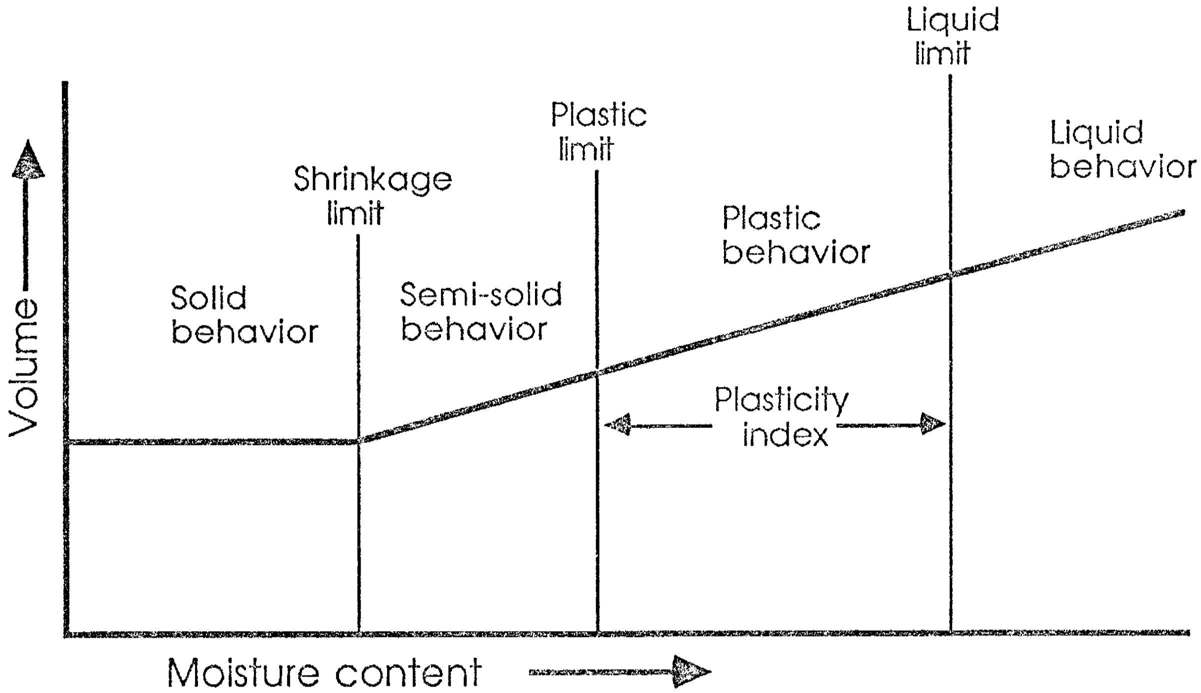


FIGURE 13--Graphical representation of Atterberg limits.

Kovacs (1981). The plasticity index (PI), equal to the liquid limit minus the plastic limit, specifies the range over which the soil behaves as a plastic. Highly plastic soils have high plasticity indexes. Liquid limits, plastic limits, and plasticity indexes of 228 soil samples were determined using procedures outlined by Lambe (1951) and by ASTM designation D4318-84.

The Atterberg limits are particularly useful index parameters which have been found to correlate with important engineering properties such as shrink-swell potential and compressibility.

### Moisture content

The moisture content of a soil specimen is defined as the percentage ratio of the weight of water in the specimen to the weight of the dry specimen. Moisture content determinations were made on 246 soil samples following a procedure outlined by ASTM designation D2216-80.

### Liquidity index

Although the natural moisture content of a soil is itself a useful index property, the relationship between soil moisture content and the Atterberg limits is of greater significance because it provides an estimate of how a soil is likely to behave when sheared. This relation is expressed by the liquidity index (LI), which is defined by the following formula given by Holtz and Kovacs (1981):

$$LI = (w_n - PL)/PI$$

where $w_n$ is the natural moisture content, PL is the plastic limit, and PI is the plasticity index of the sample. If the liquidity index (LI) of a soil is greater than zero, the soil is likely to behave as a liquid when sheared or disturbed. Similarly, LI values between zero and one, and less than zero indicate plastic and solid behavior, respectively. Liquidity indexes were calculated from moisture content and Atterberg limits data for 126 samples. The Liquidity indexes of nonplastic (PI=0) soils were not determined.

### Standard penetration tests (SPT)

One hundred eighty-seven standard penetration tests (ASTM D1586-84) were conducted. The test involved driving a standard split-spoon sampler a distance of 18 inches into the undisturbed soil at the bottom of a drill hole using a 140-lb hammer free-falling from a height of 30 inches. The number of hammer blows required to drive the sampler the final 12 inches is designated the N-value. Although many factors affect the reproducibility of the test (i.e., overburden pressure, variations in hammer free-fall distance, improper seating of sampler, etc.) the standard penetration test is currently the most popular and economical means to obtain subsurface information (Bowles, 1982). Empirical correlations between N-value and important strength properties make this test quite useful in engineering practice.

## X-ray diffraction (XRD)

Clay mineralogy can have significant effects on the physical properties of a soil, particularly if the soil is fine grained. In order to identify the relative abundance of important clay mineral groups present in the lacustrine unit (Qld) semiquantitative x-ray diffraction analyses were conducted on 16 disturbed soil samples collected from drill hole 20 (Plate 1), which penetrated the lacustrine unit. Oriented, sedimented slides were prepared and run on a Rigaku x-ray diffractometer following procedures developed by Austin (written comm., 1987). Semiquantitative analyses (accurate to 1 part in 10) based on x-ray diffractogram peak heights were done using the method described by Austin (written comm., 1987) to determine the relative abundance of kaolinite, illite, smectite, chlorite, and illite-smectite mixed-layer clay mineral groups present.

## Soil classification

Both the Unified and AASHTO systems were used in this study to classify soils. In the Unified Soil Classification System (ASTM D2487-85), soils are either coarse- or fine-grained. Coarse-grained soils are divisible into gravel and sand and further divisible into eight groups based on grading and Atterberg limits. Fine-grained soils include silts and clays and are divisible into six groups based on Atterberg limits. Two additional divisions are made for highly organic soils. Figure 14 shows the general criteria used for assigning USCS group names.

The AASHTO classification system (ASTM D3282-83), used for determining

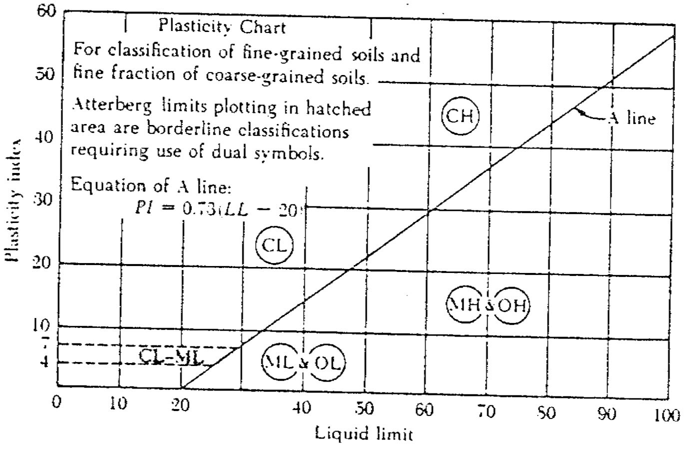
| Major divisions | | | Group symbols | Typical names | | Classification criteria | |
|---|---|---|---|---|---|---|---|
| Course-Grained Soils<br>More than 50% retained on No. 200 sieve† | Gravels<br>50% or more of coarse fraction retained on No. 4 sieve | Clean Gravels | GW | Well-graded gravels and gravel-sand mixtures, little or no fines | Classification on basis of percentage of fines<br>Less than 5% pass No. 200 sieve GW, GP, SW, SP<br>More than 12% pass No. 200 sieve GM, GC, SM, SC<br>5% to 12% pass No. 200 sieve Borderline classification requiring use of dual symbols | $C_u = D_{60}/D_{10}$ Greater than 4<br>$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 | |
| | | | GP | Poorly graded gravels and gravel-sand mixtures, little or no fines | | Not meeting both criteria for GW | |
| | | Gravels with Fines | GM | Silty gravels, gravel-sand-silt mixtures | | Atterberg limits plot below "A" line or plasticity index less than 4 | Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols |
| | | | GC | Clayey gravels, gravel-sand-clay mixtures | | Atterberg limits plot above "A" line and plasticity index greater than 7 | |
| | Sands<br>More than 50% of coarse fraction passes No. 4 sieve | Clean sands | SW | Well-graded sands and gravelly sands, little or no fines | | $C_u = D_{60}/D_{10}$ Greater than 6<br>$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 | |
| | | | SP | Poorly graded sands and gravelly sands, little or no fines | | Not meeting both criteria for SW | |
| | | Sands with Fines | SM | Silty sands, sand-silt mixtures | | Atterberg limits plot below "A" line or plasticity index less than 4 | Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols |
| | | | SC | Clayey sands, sand-clay mixtures | | Atterberg limits plot above "A" line and plasticity index greater than 7 | |
| Fine-Grained Soils<br>50% or more passes No. 200 sieve† | Silts and Clays<br>Liquid limit<br>50% or less | | ML | Inorganic silts, very fine sands, rock flour, silty or clayey fine sands | <br>Plasticity Chart<br>For classification of fine-grained soils and fine fraction of coarse-grained soils.<br>Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols.<br>Equation of A line:<br>$PI = 0.73(LL - 20)$<br> | | |
| | | | CL | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | | | |
| | | | OL | Organic silts and organic silty clays of low plasticity | | | |
| | Silts and Clays<br>Liquid limit<br>greater than 50% | | MH | Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts | | | |
| | | | CH | Inorganic clays of high plasticity, fat clays | | | |
| | | | OH | Organic clays of medium to high plasticity | | | |
| Highly Organic Soils | | | PT | Peat, muck, and other highly organic soils | Visual-manual identification. see ASTM Designation D2488. | | |

FIGURE 14--Unified Soil Classification System (USCS; from Das, 1985).

the relative quality of soils for use in road construction, is shown in Figure 15. Soils are divided into seven groups (A-1 to A-7) and several subgroups. Gravels and sands are classified as groups A-1 to A-3, whereas silts and clays fall into groups A-4 to A-7. Highly organic soils are placed in a separate group (A-8). To evaluate the relative quality of different soils within the same group, a number denoted as the group index (GI) is given in parentheses after the AASHTO group or subgroup designation. The group index is calculated from the following equation:

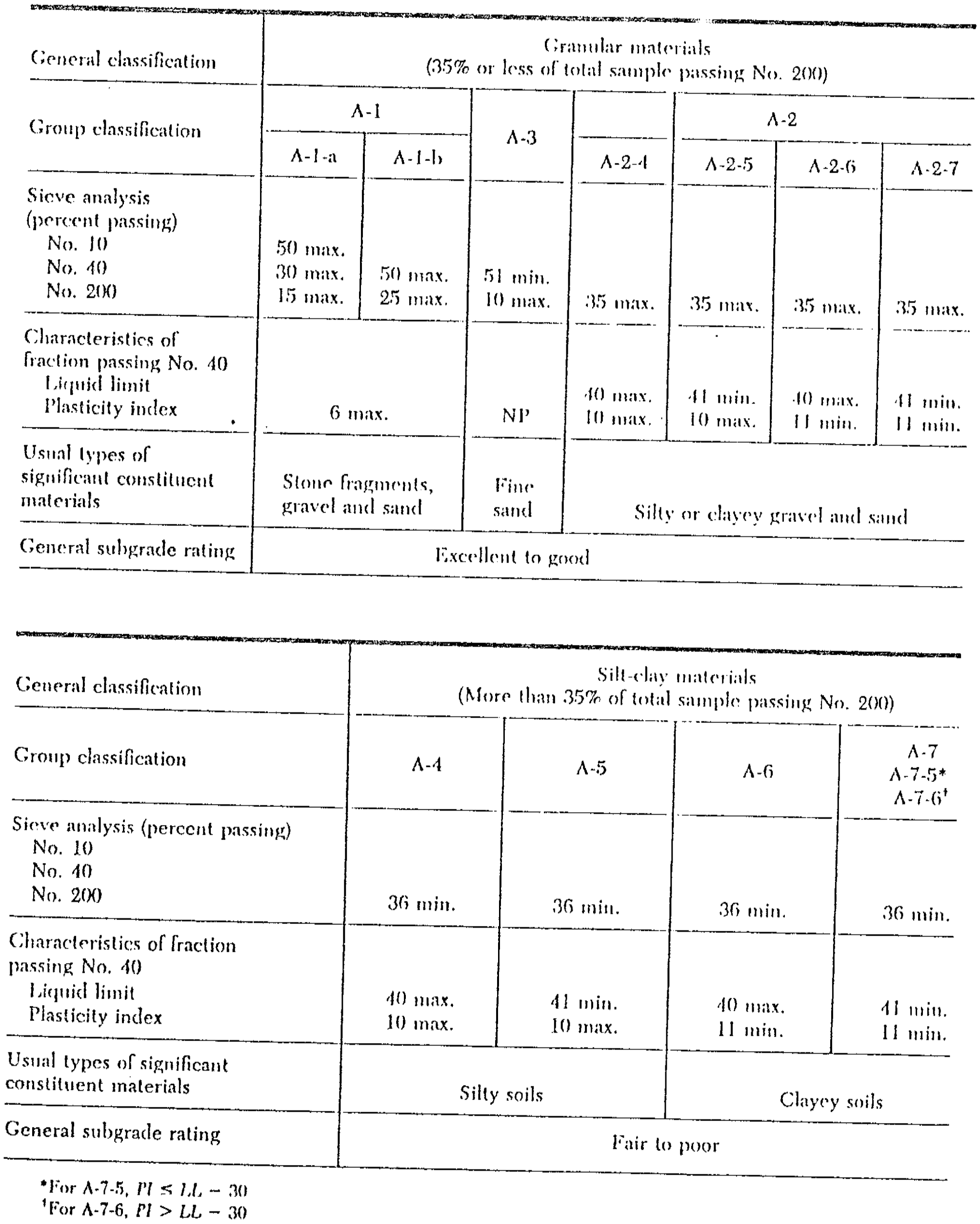
$$GI = (F - 35)[0.2 + 0.005(LL - 40)] + 0.01(F - 15)(PI - 10)$$

where GI is the group index, F is the weight percent passing the No. 200 sieve, LL is the liquid limit, and PI is the plasticity index. The group index (GI) is used in conjunction with other information (such as estimated traffic load) in the design of highway pavement thicknesses (Oglesby and Hicks, 1982).

## Test Results

### Engineering index parameters

Table 1 is a summary of the mean values and ranges of six important engineering index parameters for soil units in the study area. Common USCS and AASHTO designations are also given. Samples from each soil unit are divided into cohesive and granular varieties. Cohesive soils consist predominantly of low plasticity clays (CL) with varying amounts of sand and silty clays (CL-ML). Common granular soils include silty sands (SM) and clayey



| General classification | Granular materials (35% or less of total sample passing No. 200) | | | | | | |
|---|---|---|---|---|---|---|---|
| Group classification | A-1 | | A-3 | A-2 | | | |
| | A-1-a | A-1-b | | A-2-4 | A-2-5 | A-2-6 | A-2-7 |
| Sieve analysis (percent passing) | | | | | | | |
| No. 10 | 50 max. | | | | | | |
| No. 40 | 30 max. | 50 max. | 51 min. | | | | |
| No. 200 | 15 max. | 25 max. | 10 max. | 35 max. | 35 max. | 35 max. | 35 max. |
| Characteristics of fraction passing No. 40 | | | | | | | |
| Liquid limit | | | | 40 max. | 41 min. | 40 max. | 41 min. |
| Plasticity index | 6 max. | | NP | 10 max. | 10 max. | 11 min. | 11 min. |
| Usual types of significant constituent materials | Stone fragments, gravel and sand | | Fine sand | Silty or clayey gravel and sand | | | |
| General subgrade rating | Excellent to good | | | | | | |

| General classification | Silt-clay materials (More than 35% of total sample passing No. 200) | | | |
|---|---|---|---|---|
| Group classification | A-4 | A-5 | A-6 | A-7<br>A-7-5*<br>A-7-6† |
| Sieve analysis (percent passing) | | | | |
| No. 10 | | | | |
| No. 40 | | | | |
| No. 200 | 36 min. | 36 min. | 36 min. | 36 min. |
| Characteristics of fraction passing No. 40 | | | | |
| Liquid limit | 40 max. | 41 min. | 40 max. | 41 min. |
| Plasticity index | 10 max. | 10 max. | 11 min. | 11 min. |
| Usual types of significant constituent materials | Silty soils | | Clayey soils | |
| General subgrade rating | Fair to poor | | | |

*For A-7-5, $PI \leq LL - 30$
†For A-7-6, $PI > LL - 30$

FIGURE 15--AASHTO classification system (from Das, 1985).

TABLE 1--Summary of engineering index parameters for soils.

| | Qay | | Qld | | Qao | | QTa | |
|---|---|---|---|---|---|---|---|---|
| | cohesive* | granular# | cohesive* | granular# | cohesive* | granular# | cohesive* | granular# |
| mean liquid limit (LL) | 31 | 28 | 33 | 28 | 35 | 29 | 34 | 27 |
| range (min:max) | 24:43 | – | 20:79 | 19:42 | 24:60 | 19:39 | 23:53 | 19:36 |
| mean plasticity index (PI) | 11 | 4 | 15 | 7 | 16 | 8 | 14 | 7 |
| range (min:max) | 7:18 | – | 4:52 | 2:28 | 4:39 | 3:18 | 4:31 | 1:18 |
| estimated mean shrinkage limit (SL) | 18 | 23 | 15 | 19 | 16 | 19 | 17 | 19 |
| mean standard penetration (N) | 15 | 20 | 26 | 28 | 33 | 29 | 31 | 37 |
| range (min:max) | – | 14:34 | 5:56 | 7:56 | 7:>50 | 7:>50 | 11:59 | 6:>50 |
| mean moisture content (%) | 9 | 8 | 16 | 11 | 12 | 8 | 12 | 8 |
| range (min:max) | 6:12 | 3:12 | 4:40 | 3:21 | 7:22 | 2:20 | 4:21 | 2:19 |
| mean liquidity index (LI) | -1.2 | -3 | -0.4 | -2.5 | -0.8 | -2.1 | -1.1 | -2.5 |
| range (min:max) | -1.9:-0.05 | – | -2.7:0.71 | -5:-0.28 | -2.5:-0.59 | -6:-0.22 | -3.8:0.17 | -10:-0.2 |
| common USCS designations | CL<br>CL-ML | SM | CL<br>CL-ML | SM<br>ML | CL | SM<br>SC | CL-ML<br>CL | SM<br>SM-SC<br>SC |
| common AASHTO designations | A-4(2) | A-1-a(1)<br>A-4(0) | A-6(10)<br>A-4(2) | A-4(1)<br>A-2-4(0) | A-4(3)<br>A-6(9) | A-4(1)<br>A-2-4(0) | A-6(10)<br>A-4(1)<br>A-7-6(33) | A-4(1)<br>A-2-4(0) |

*i.e., clays.
#i.e., sands and silts.

sands (SC). Silts and sandy silts (ML) are less common and are grouped with granular soils. Clean sands and gravels (SP, SW, GP) occur locally in young alluvium (Qay) as stream channel deposits and as beach and bar deposits associated with lacustrine sediments (Titus, 1969). Common AASHTO soil designations include A-1-a (sandy and gravelly stream channel, beach, and bar deposits), A-2-4 and A-4 (silty, granular soils), and A-4 and A-6 (cohesive soils). A-4 soils are grouped under both cohesive and granular designations in Table 1, depending on whether their USCS equivalents are clays or silts and sands.

Mean liquid limit (LL) values for various soil units range from 27 to 35 and are based on soils exhibiting plasticity (i.e., PI ≥ 0). Cohesive soils within each unit exhibit liquid limits slightly higher than granular soils (Table 1). Liquid limits greater than 50 are uncommon, although they do occur locally in cohesive varieties of all units except young alluvium (Qay).

Mean plasticity index (PI) values range from 4 to 16 (Table 1). Cohesive soils exhibit higher mean PI values than granular soils. PI values greater than 30 are uncommon but occur locally in all cohesive soil units except young alluvium (Qay).

Mean shrinkage limit (SL) values range from 15 to 23 and are higher for granular soils than for cohesive soils (Table 1). In all cases, the estimated mean shrinkage limits are 1 to 3 percent below mean plastic limits (mean PL = mean LL minus mean PI).

Mean standard penetration test (N) values for lacustrine deposits (Qld), older alluvium (Qao), and Tertiary-Quaternary alluvium (QTa) range from 26 to 37 and are generally higher than N-values obtained in young alluvium (Qay; Table 1). This difference is attributable to accumulation of pedogenic calcium carbonate in older units. Actual mean N-values for these units are probably higher than indicated in Table 1 because standard penetration tests are terminated when N-value reaches 50 blows, and actual N-values obtained for all three of these units often are in excess of 50. No significant statistical difference in mean N-values exists for cohesive and granular soils within a given unit.

Mean moisture contents are typically between 8 and 16 percent for various soil units (Table 1). Cohesive soils exhibit slightly higher moisture content than granular soils. Except for several samples obtained from the lacustrine unit (Qld) all samples were collected from above the water table. Liquidity index (LI) values reflect this; they are almost exclusively negative for all soil units sampled, indicating that the natural moisture content of these soils are generally below their plastic limits. Therefore, soil units should fail by fracture if sheared or otherwise disturbed.

## Clay mineralogy

The engineering behavior of clayey soils is strongly influenced by clay mineralogy. Soil plasticity, in particular, is often dependent on the types of clay minerals present. Potentially problematic, highly plastic soils, for example, typically contain an abundance of montmorillonite. Kaolinitic soils, by contrast, typically exhibit lower plasticity (Holtz and Kovacs, 1981). In an attempt to determine if a relationship exists between clay mineralogy and the plasticity characteristics of clayey, lacustrine soils in the study area, semiquantitative x-ray diffraction (XRD) analyses and plasticity index (PI) determinations were made on 16 disturbed samples collected from the lacustrine unit (Qld). Samples were obtained from drill hole 20 (Plate 1), located approximately 6 mi south and 1 mi east of Moriarty, at sample intervals of 6 to 18 inches.

Table 2 compares the relative abundance of kaolinite, illite, smectite (Na and/or Ca montmorillonite), and illite-smectite mixed-layer clays determined from XRD analyses with plasticity index (PI) values. None of the samples tested contains measurable amounts of chlorite. Examination of Table 2 indicates no systematic relationship between clay mineralogy and plasticity index (PI). For example, the sample obtained from a depth interval of 18-19.5 ft exhibits a relatively high PI of 35 and contains only 2 parts in 10 smectite and 4 parts in 10 illite-smectite mixed-layer clays, both of which tend to exhibit higher plasticity than kaolinite and illite. Other samples containing up to 3 and 4 parts in 10 smectite and up to 4 parts in 10 illite-smectite mixed-layer clays exhibit much lower PI values. The sample obtained from a depth interval of 12-13 ft, for example, contains 4 parts in 10 smectite and 2 parts in 10 illite-smectite mixed-layer clays, and is nonplastic. Similarly, the sample obtained from a depth interval of 29-30.5 ft contains 4 parts in 10 smectite and 3 parts in 10 illite-smectite mixed-layer clays, and exhibits a PI of only 14.

TABLE 2--Comparison between clay mineralogy and plasticity index for selected samples obtained from drill hole 20 (DH-20).

| Drill Hole 20 Depth (ft.) | Clay mineral abundance (parts in ten) | | | | Plasticity Index (PI) |
|---|---|---|---|---|---|
| | Kaolinite | Illite | Smectite | Mixed layers | |
| 0-1.5 | 2 | 4 | 1 | 3 | 16 |
| 1.5-3 | 3 | 3 | 1 | 4 | 15 |
| 3-4.5 | 3 | 2 | 3 | 2 | 7 |
| 4.5-6 | 3 | 2 | 2 | 3 | 14 |
| 6-7.5 | 3 | 6 | 1 | 0 | 19 |
| 7.5-9 | 4 | 3 | 1 | 1 | 12 |
| 9-10.5 | 2 | 2 | 3 | 3 | 17 |
| 10.5-12 | 3 | 1 | 3 | 3 | 12 |
| 12-13* | 3 | 1 | 4 | 2 | NP |
| 13-13.5* | 4 | 3 | 1 | 2 | 17 |
| 13.5-15 | 2 | 3 | 1 | 4 | 26 |
| 15-16.5 | 2 | 3 | 2 | 3 | 30 |
| 18-19.5# | 2 | 2 | 2 | 4 | 35 |
| 19.5-21# | 2 | 1 | 3 | 4 | 27 |
| 21-22.5# | 2 | 2 | 3 | 4 | 21 |
| 29-30.5 | 2 | 1 | 4 | 3 | 14 |

*indicates 2 samples taken from same 18" interval.
#Data obtained from Karen Brown (written comm., 1987).

This lack of correlation between clay mineralogy and plasticity is probably due to other factors such as particle-size distribution that influence plasticity more strongly. The relative amount of clay-size material present in these lacustrine soils likely determines their plasticity characteristics rather than the clay mineralogy of these soils. Soils exhibiting higher PI values almost certainly contain a higher percentage of clay-size material than soils with lower PI values. Skempton (1953) found that the plasticity index (PI) of a soil linearly increases with the percent clay-size fraction (percent finer than 0.02 mm by weight) present in it. Hydrometer analyses were attempted in order to confirm this relationship for lacustrine soils. Unfortunately, even after samples were centrifuged and treated with dispersant, flocculation of clay-sized particles rendered hydrometer tests invalid. To summarize, the plasticity of lacustrine soils is probably more strongly affected by the amount of clay-size material present than by clay mineralogy.

## Engineering Applications

### Liquefaction potential

Ground motion during earthquakes may cause a loss of soil strength resulting from elevated pore pressures. This in turn can result in damage to engineered structures. The process leading to such a loss of strength is called soil liquefaction. Saturated granular soils without cohesive fines are most susceptible to liquefaction. The greater the content of clay and other fine particles contributing to plasticity, the less the susceptibility to sudden pore pressure build-up (National Academy of Sciences, 1985).

Liquefaction is not a major concern in the study area due to the lack of saturated, cohesionless soils and the low level of seismicity. Soils in the study area generally contain an abundance of fines (silt and clay), as indicated in **Table 1** and Appendix III. Clays (CL), silty clays (CL-ML), silty sands (SM), and clayey sands (SC) are quite common, whereas cohesionless sands and gravels (SP, SW, GP, GW) occur only locally and are only locally saturated. Only lacustrine soils (Qld) that occur below the 6,225 ft contour are saturated to near the ground surface and therefore offer any potential for liquefaction. These soils consist of interbedded sands (thin and cohesionless), plastic silts, silty clays, and clays up to approximately 100 ft thick. Saturated, cohesionless sands within this unit are typically only a few feet thick, however, and are not considered thick enough to be susceptible to liquefaction (New Mexico SSC Proposal, 1987, v. 3). Furthermore, soils most susceptible to liquefaction generally occur where ground water is 30 ft deep or less (National Academy of Sciences, 1985). Depth to water in the study area at its shallowest point is 30 ft and is typically 100 to 300 ft (Fig. 9).

Although liquefaction effects have occurred during earthquakes of Modified Mercalli intensity VI, liquefaction becomes common at intensity VII if susceptible deposits are present (National Academy of Sciences, 1985). The largest historic event in the region was an intensity VII event that occurred near Cerrillos, located about 35 miles north of the Moriarty, in 1918. This event caused shaking in

Moriarty of modified Mercalli intensities estimated to be only III-IV. No reports of liquefaction are associated with this event, and no evidence of liquefaction has been found in the study area (New Mexico SSC Proposal, 1987, v. 3).

Typical ground acceleration associated with earthquakes that have caused liquefaction has been estimated to be about 10 percent of gravity (National Academy of Sciences, 1985). According to Algermissen et al., (1982) the maximum probable horizontal ground acceleration likely to occur in the study area (in rock, with 90 percent probability of not being exceeded in 250 years) is about 6 percent of gravity. This suggests that earthquakes which could potentially cause liquefaction do not occur very frequently in the study area.

To summarize, conditions favorable for liquefaction are not present in the study area. Soils are generally not cohesionless, the water table is too deep, and predicted ground accelerations likely to be caused by earthquakes are too low.

### Expanse (shrink-swell) potential

Expansive soils are cohesive soils that shrink or swell excessively with changes in moisture content. Whether or not a soil is expansive depends upon several factors. Of greatest importance is the difference between the natural moisture content and the equilibrium moisture content that prevails both during and after construction of a structure. If the equilibrium moisture content during or after construction is substantially greater than the natural moisture content before construction, a potentially expansive soil may swell, causing damage to the overlying foundation. Similarly, if the equilibrium moisture content during or after construction is less than the natural moisture content before construction, shrinkage that can also cause foundation damage can result. Clay mineralogy strongly affects expanse potential. Soils containing an abundance of montmorillonite or illite-smectite mixed-layer clays high in smectite (i.e., some bentonites) tend to undergo greater volume changes than soils containing predominantly illite, kaolinite, or chlorite. Density, moisture, and soil structure also affect expanse potential. Soils of high density typically swell more than low-density soils; dry soils swell more than moist soils; and remolded soils swell more than undisturbed soils (Costa and Baker, 1981).

The identification of potentially expansive soils involves correlations between direct measurement of volume changes and various engineering index parameters. Peck et al. (1974) suggested that potentially expansive soils exhibit plasticity index (PI) values of 10 or more, whereas Costa and Baker (1981) stated that PI values greater than 15 usually indicate a swelling problem may exist. In a review of expansive soils, Snethen (1986) stated that liquid limits greater than 50 and PI values greater than 25 are reasonable lower limits for indicating potential problems. Gromko (1974) summarized various methods of predicting the degree of expansion from engineering parameters such as the shrinkage limit (SL), plasticity index (PI), and colloid content. Three of these systems are shown in Table 3. In general, three criteria are necessary for potentially damaging swelling to occur. These are (1) the presence of montmorillonite (smectite) in the soil; (2) a natural moisture content near the plastic limit (PL); and (3) an available source of

TABLE 3--Summary of engineering index systems used to estimate degree of expansion (after Gromko, 1974).

| Shrinkage limit (SL) (percent) | Degree of expansion |
|---|---|
| <10 | Critical |
| 10-12 | Marginal |
| >12 | Noncritical |

| Swell potential (S)* (percent) | Total expansion (1-psi load), air dry to saturated (percent) | Shrinkage index (=LL-SL) (percent) | Degree of expansion |
|---|---|---|---|
| 0-1.5 | 0-10 | 0-20 | Low |
| 1.5-5 | 10-20 | 20-30 | Medium |
| 5-25 | 20-35 | 30-60 | High |
| >25 | >35 | >60 | Very high |

| Colloid content (percent minus 0.01 mm)# | Plasticity index (PI)# | Shrinkage limit (SL)# | Degree of expansion |
|---|---|---|---|
| >28 | >35 | <11 | Very high |
| 20-31 | 25-41 | 7-12 | High |
| 13-23 | 15-28 | 10-16 | Medium |
| <15 | <18 | >15 | Low |

*Swell potential (S) = 60K(PI)exp(2.44); where K = 0.000036, and PI = plasticity index.

#Soil properties should not be used separately; all three must be considered to arrive at the estimated degree of expansion from air dry to saturated conditions.

water (Gromko, 1974).

Granular soils in the study area are generally not expansive, as indicated by mean PI values of less than 10 and estimated mean shrinkage limits in excess of 12 (Table 1). Estimates of the expanse potential for cohesive (clayey) soils in the study area range from low to medium, depending upon which engineering parameters are used to make the estimate. Cohesive soils in the study area typically exhibit PI values corresponding to the lower limit of those exhibited by expansive soils, as discussed above and in Table 3 (scheme 2). The mean natural moisture content of cohesive, lacustrine soils (Qld) is 16 percent, which is within 2 percent of their mean plastic limit (18), suggesting they might be expansive; however, the estimated mean shrinkage limit (SL) of cohesive lacustrine soils is 15 and their mean PI value is also 15, suggesting that these soils are not highly expansive according to schemes 1 and 3 in Table 3. Expansive soils typically exhibit shrinkage limits less than 10 (Table 3, scheme 1). Highly expansive clays, although uncommon, occur locally in lacustrine deposits (Qld), older alluvium (Qao), and Quaternary-Tertiary alluvium (QTa), as evidenced by liquid limits above 50 and PI values greater than 25 (Table 1; Appendix III). Table 3 (scheme 2) gives formulas whereby the swell potential (S) and the shrinkage index (SI) can be calculated from the PI. The mean swell potentials of lacustrine (Qld) and older alluvial (Qao) soils are equal to 1.6 and 1.9 percent, respectively, indicating that these soils exhibit a medium degree of expansion. Their mean shrinkage indexes, however, are equal to 18 and 19, respectively, indicating that these soil units exhibit a low degree of expansion.

The Soil Conservation Service (1970, 1975) has delineated two potentially expansive soil localities in the study area (Plate 1). One area occurs in the west-central part of the study area where clayey horizons exhibiting high plasticity have developed in residuum weathered from limestone bedrock of the Madera Formation. This soil is typically only about 3.5 feet thick, however, and therefore should not pose any significant threat to the stability of small structures such as single family houses, provided that the foundations of such structures are designed properly. Foundation footings should be seated below the depth to which highly expansive clays occur, and the floors of the overlying structures should be suspended above a crawl space. These clays are generally thin enough that this can probably be accomplished economically. As a precaution against potentially damaging soil heave, slab-type foundations that rest directly on the ground should possibly be avoided in this area, or, alternatively, specially designed to withstand soil heave. The economic feasibility of specially designed slab foundations will depend on the results of detailed, site-specific tests used to estimate the magnitude of swell (such as the oedometer test--ASTM D4546-85).

The other area of potentially expansive soil occurs in the northeast part of the study area (Plate 1) in association with floodplain deposits derived from sandstone, siltstone, and mudstone of the Dockum Group. The depth to bedrock underlying these deposits is typically greater than 5 ft. These deposits are of very limited aerial extent and can easily be avoided when selecting construction sites in the area. Overall, the natural expanse potential of soil units in the study area is considered to be low. With the exception of younger alluvium (Qay), soil units typically contain an abundance of secondary (pedogenic) calcium carbonate, which inhibits volume changes. In view of the typically low moisture content of soils, swelling (and subsequent shrinkage) can nonetheless occur where excess moisture is allowed to accumulate. This is particularly true in lowlying, lacustrine soils consisting of thick, clayey sequences. Leaky water lines and drains, sprinkler systems, and septic tanks associated with various structures can greatly increase soil moisture and could therefore lead to soil heave. Providing adequate surface drainage is the simplest method of controlling soil moisture. This can be achieved by grading the ground surface downward from the structure. Typically, a 1 to 3 percent slope provides proper drainage (Snethen, 1986). Other simple, preventive measures include subsurface drains, proper maintenance of water lines, special watering procedures for vegetation adjacent to structures, and locating septic tanks, vegetation, and sprinkler systems away from structures.

Compaction control is another method of controlling soil heave which could develop in association with construction on clayey, lacustrine soil. Expansive clays heave much less when compacted to low densities at high moisture contents. Gizienski and Lee (1965), for example, found that when a test soil was compacted to about 4.5 percent above optimum moisture content, its swell was negligible for any degree of compaction. Compaction at 3 percent below optimum, however, caused excessive swell even for low degrees of compaction. Compaction methods that induce kneeding (rather than static compaction methods) have also been found to reduce heave on wetting. This is due to the development of a more dispersed arrangement of soil particles (Gromko, 1974).

### Collapse potential

Collapsible, or hydrocompactive soils are those that exhibit a tendency to compact with the addition of water. Such soils occur throughout arid to semi-arid regions of the southwestern and central U.S. and in many places consist of silty and clayey sands (SM, SC) deposited by mud and debris flows on alluvial fans. They are typically Holocene (≤ 10,000 yrs) in age, exhibit low natural moisture contents, have low dry densities, and have never been wetted subsequent to deposition. When these soils are wetted they tend lose their dry strength and densify. Potential sources of wetting include disruption of natural runoff due to grading, roof runoff, leaky utility lines, and lawn watering (Johnpeer et al., 1987).

Correlations between soil collapsibility and various engineering parameters such as dry density, moisture content, Atterberg limits, and grain-size distribution have achieved limited success (Reimers, 1986). A modified form of the consolidation test has been used more successfully in predicting collapse potential (Jennings and Knight, 1975). In the test an undisturbed sample is placed in a consolidometer and incrementally loaded to its in-situ overburden stress. The sample is then flooded, and the amount of consolidation upon wetting is measured. The change in void ratio of the sample due to wetting gives a qualitative evaluation of collapse potential (Jennings and Knight, 1975).

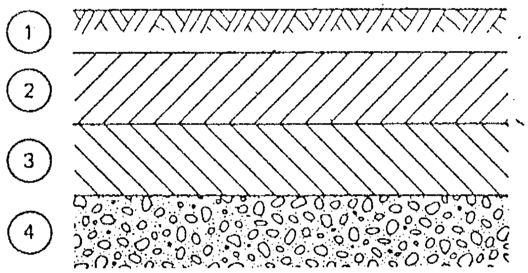
Due to the absence of available modified consolidation data for soil units in the study area, the susceptibility of soil units to collapse is difficult to estimate. Lacustrine soils (Qld) in the study area are probably not susceptible to collapse because they have been wetted many times subsequent to their deposition. Soils most likely to collapse include granular, uncemented older alluvium (Qao) and Tertiary-Quaternary alluvium (QTa). Granular soils within these units have low natural moisture content and consist of silty, clayey, and silty-clayey sands (SM, SC, SM-SC; Table 1). N-values within these soils average 29 (Qao) and 37 (QTa), respectively, suggesting that these units are relatively dense. This implies that collapsible soils within these units are not common, because collapsible soils typically exhibit low relative densities. An important factor regarding the collapsibility of cemented soils is the sensitivity to dissolution of their intergranular cement (Reginatto, 1971). The dissolution of calcium carbonate due to local use of groundwater (for irrigation, lawn watering, etc.) is not a concern. Research needs to be conducted to better understand the effects of increased water acidity on soil collapsibility.

### Suitability of various soils for road construction

The suitability of various soil units in the study area for road construction purposes is best assessed by considering their AASHTO designations. The

AASHTO soil classification system is designed specifically for this purpose. Figure 16 defines the terms relating to pavement systems used in this section. Table 1 indicates the general subgrade rating of the various AASHTO group or subgroup designations. Sandy and gravelly soils (groups A-1 to A-3) are considered excellent to good for use in subgrades (the native soil upon which the road is constructed) because they are less compressible than silty and clayey soils (groups A-4 to A-7) and can be compacted to higher densities, thereby giving them better bearing capacity. Soils falling into groups A-2-6, A-2-7, and A-4 to A-7 range in quality as subgrade from good to poor. Fair and poor subgrades typically require a layer of subbase material or an increased thickness of base coarse over that required for better subgrades in order to furnish adequate support. The mean group index (GI), shown in parentheses after the AASHTO group or subgroup designations for soil units in the study area (Table 1), is useful for approximate within-group evaluations. Under average conditions of good drainage and adequate compaction, the supporting ability (bearing capacity) of a subgrade varies as the inverse of its group index (GI); that is, a group index of zero indicates a relatively good subgrade material, whereas a group index of 20 or greater indicates a very poor subgrade (ASTM, 1987).

The granular varieties of soil units within the study area appear to be fairly well suited as subgrade. A-2-4 and A-4 soils are common; A-4 soils exhibit group index (GI) values of zero or one, indicating their overall suitability as subgrade (Table 1). Cohesive soils in the study area are less suitable as subgrade.



① Surface coarse: 20-25 cm Portland cement or 2-8 cm asphaltic concrete.

② Base coarse: 5-10 cm asphaltic concrete, 15-30 cm sand-gravel base, 20-30 cm soil-sement, or 15-20 cm asphalt stabilized sand.

③ Subbase (this layer may be omitted): 15-30 cm sand-gravel.

④ Subgrade: The natural soil at a site. The top 0.15-0.5 m is usually compacted prior to the placement of the other layers of the pavement.

FIGURE 16--Definitions of terms relating to pavement systems (after Holtz and Kovacs, 1981).

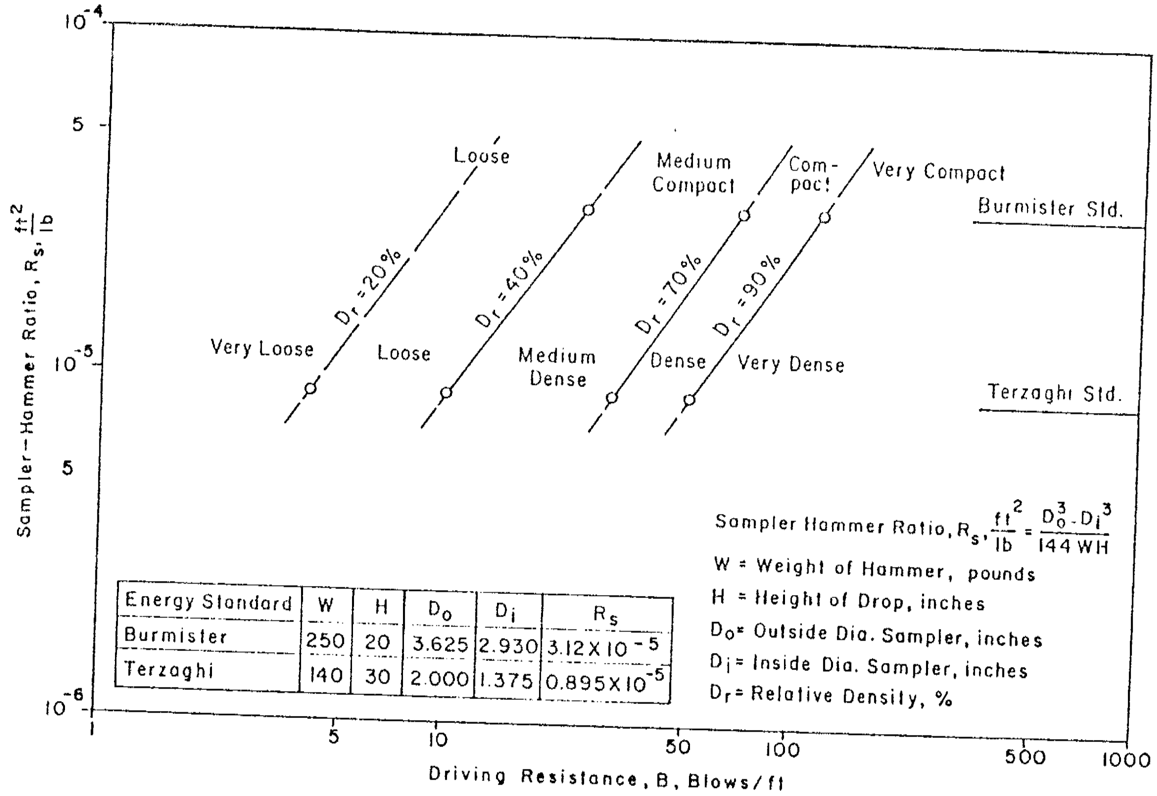
AASHTO designation A-6 is common, and the group index value of this designation is typically fairly high (9 or greater); however, A-4 designations exhibiting low group indexes are also common in the cohesive varieties of soil units (Table 1). Furthermore, the average N-value of cohesive soils within approximately 5 feet of the surface is 23, indicating that these soils can probably furnish adequate support for most traffic loads.

Suitable base coarse and subbase material can be obtained from rock and soil units exhibiting high-quality aggregate resource potential, as discussed in the aggregate resource potential section of this study and as shown in Table 11 (p.98 ). Crushed rock of excellent to good quality for base coarse and subbase can be obtained from the Madera and San Andres Formations, Tertiary monzonite, and Precambrian schist and quartzite. Good quality sand and gravel for base coarse and subbase can be obtained from beach and bar deposits associated with ancestral Lake Estancia. Lower quality sand and gravel generally requiring beneficiation is obtainable from young alluvium, older alluvium, and Quaternary-Tertiary alluvium.

### Foundation design considerations

The purpose of this section is to discuss briefly several geotechnical and geological concerns that directly affect the design of foundations on soils in the study area. Generally, the probable performance of a proposed foundation can be evaluated with respect to two types of unsatisfactory behavior: bearing capacity failure and excessive settlement (Peck et al., 1974). Bearing capacity failure results when the stress imparted to the underlying soil or rock by the foundation exceeds the inherent supporting ability of the soil or rock, and a local shear failure results. Alternatively, foundation settlement caused by consolidation of the underlying soil or rock due to the weight of the foundation and the overlying structure may be so great or uneven as to cause damage to the structure. Foundations are typically designed to minimize the potential for soil-bearing capacity failures and excessive settlements. Obviously, a proposed foundation design must take into account the engineering properties of the soil or rock beneath the foundation.

In general, both granular and cohesive soils in the study area exhibit good bearing capacity, as evidenced by typically high N-values for both granular and cohesive soils. Average N-values for various soil units range from 15 to 37, with N-values greater than 50 (refusal) common in all units except young alluvium (Table 1, Appendix IV). Figures 17 and 18 show correlations between N-value and relative density or shear strength, for granular and cohesive soils, respectively. Based on the N-value verses compactness relationship shown in Figure 17, granular soils in the study area range from medium dense to very dense (excluding young alluvium). Approximately half of these soils are dense to very dense (Appendix IV). As shown in Figure 17, the relative density of these soils typically exceeds 70 percent (based on typical N-values of 30 or greater); therefore, their bearing capacity is estimated to be high. It is emphasized,



Sampler Hammer Ratio, $R_s, \frac{ft^2}{lb} = \frac{D_o^3 - D_i^3}{144\,WH}$

W = Weight of Hammer, pounds

H = Height of Drop, inches

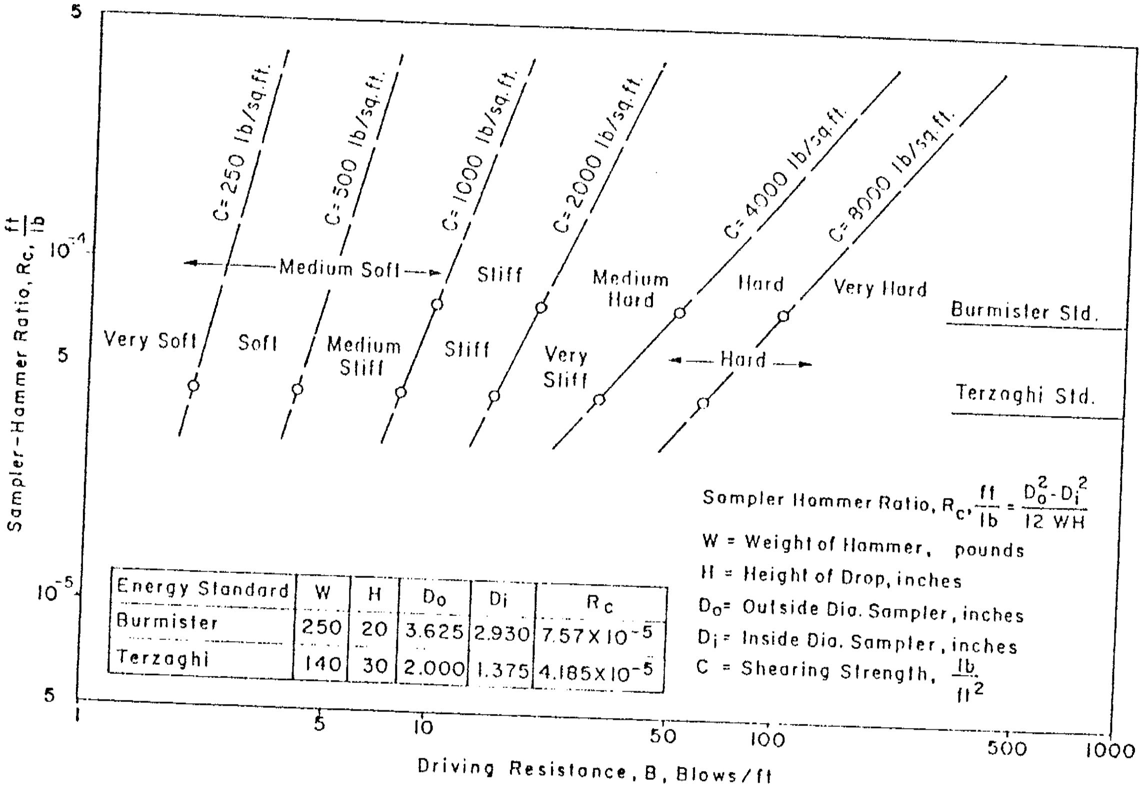
$D_o$ = Outside Dia. Sampler, inches

$D_i$ = Inside Dia. Sampler, inches

$D_r$ = Relative Density, %

| Energy Standard | W | H | $D_o$ | $D_i$ | $R_s$ |
|---|---|---|---|---|---|
| Burmister | 250 | 20 | 3.625 | 2.930 | $3.12 \times 10^{-5}$ |
| Terzaghi | 140 | 30 | 2.000 | 1.375 | $0.895 \times 10^{-5}$ |

FIGURE 17--Standard penetration (N) value vs. compactness--cohesionless soils (from Lowe and Zaccheo, 1975).



Sampler Hammer Ratio, $R_c, \frac{ft}{lb} = \frac{D_o^2 - D_i^2}{12\,WH}$

W = Weight of Hammer, pounds

H = Height of Drop, inches

$D_o$ = Outside Dia. Sampler, inches

$D_i$ = Inside Dia. Sampler, inches

C = Shearing Strength, $\frac{lb}{ft^2}$

| Energy Standard | W | H | $D_o$ | Di | Rc |
|---|---|---|---|---|---|
| Burmister | 250 | 20 | 3.625 | 2.930 | $7.57 \times 10^{-5}$ |
| Terzaghi | 140 | 30 | 2.000 | 1.375 | $4.185 \times 10^{-5}$ |

FIGURE 18--Standard penetration (N) value vs. consistency--cohesive soils (from Lowe and Zaccheo, 1975).

however, that estimates of relative density based on N-value are very approximate. The relationship between N-value and relative density strictly applies only to uncemented, cohesionless sands and silts.

The consistency of cohesive soils ranges from medium stiff to hard (Fig. 18). Medium stiff soils are exceedingly rare, whereas very stiff to hard soils are common (Appendix IV). Table 4 shows the mean undrained shear strengths of cohesive soils in the study area based on pocket penetrometer, Torvane, and N-value data. Although these various estimates of shear strength are only approximate, they agree with one another fairly well, indicating that cohesive soils in the study area generally possess high shear strength and good bearing capacity.

Time-dependent settlement (consolidation) of cohesive soils is generally of more concern than immediate settlement due to elastic deformation. This is because consolidation settlement can be several times greater than the immediate settlement (Das, 1985). The amount of consolidation settlement likely to occur in a clay layer of a given thickness and compressibility due to a specified, foundation-induced stress increase can be calculated from the results of a standard consolidation test (ASTM D2435-80). For general purposes, the compressibility of a saturated, cohesive soil can be estimated from the liquid limit (LL) by the following equation (Terzaghi and Peck, 1967):

$$C_C = 0.009(LL - 10)$$

where $C_C$ is the compression index and LL is the liquid limit. The larger the $C_C$,

TABLE 4--Shear strength estimates for cohesive soils based on pocket penetrometer, Torvane, and standard penetration test (SPT) data.

| Method used | Approximate mean undrained shear strength (tons/sq ft) | Number of tests done | Remarks |
|---|---|---|---|
| Pocket penetrometer | 1.9 | 11 | Measures unconfined compressive strength, q; undrained shear strength = q/2 (Holtz and Kovacs, 1981); q values shown on trench logs (appendix II). |
| Torvane | 2.3 | 4 | Torvane shear strength values shown on trench logs (appendix II). |
| Standard penetration (SPT) | 2 | 83 | Shear strength based on approximate correlation between N value and shear strength shown in figure 18. |

the more compressible the soil. The liquid limit of a saturated, cohesive soil sample from drill hole 35 (Plate 1) was determined to be 39, which gives a compression index ($C_c$) of 0.26 from the above equation. Comparison of this $C_c$ value with some typical $C_c$ values shown in Table 5 suggests that saturated, cohesive soils in the study area are not highly compressible. Foundation settlement caused by consolidation of saturated, lacustrine clays in the study area can therefore probably be controlled with standard foundation designs such as reinforced concrete slabs and spread footings. Furthermore, saturated, cohesive soils occur only in the lacustrine unit (Qld; Plate 1) below a depth of 30 ft. Consolidation settlement should therefore not be a concern for small to medium-size structures constructed on shallow, raft or footing foundations.

Finally, ground settlement due to drawdown of groundwater, although it may be a future concern, is not presently a problem. Hydrographs indicate that groundwater levels have been declining at a rate of about 1 ft per year since 1948 (New Mexico SSC Proposal, v. 3; 1987), although there are no reports of related subsidence. Throughout most of the study area, depth to the regional groundwater table is high, typically between 100 and 300 feet, and the well-cemented nature of most near-surface soils inhibits settlement due to groundwater withdrawl at depth. Only the central and south-central parts of the study area may possibly experience future settlement problems as ground water continues to decline. These are areas where cohesive, somewhat compressible lacustrine deposits are the thickest. Lacustrine soils might subside as much as a

TABLE 5--Typical values of the compression index $C_c$ (after Holtz and Kovacs, 1981).

| Soil | $C_c$ |
|---|---|
| Normally consolidated medium and sensitive clays | 0.2-0.5 |
| Chicago silty clay (CL) | 0.15-0.3 |
| Boston blue clay (CL) | 0.3-0.5 |
| Vicksburg buckshot clay (CH) | 0.5-0.6 |
| Swedish medium sensitive clays (CL-CH) | 1-3 |
| Canadian Leda clays (CL-CH) | 1-4 |
| Mexico City clay (MH) | 7-10 |
| Organic clays (OH) | 4 and up |
| Peats (Pt) | 10-15 |
| Organic silt and clayey silts (ML-MH) | 1.5-4.0 |
| San Francisco Bay Mud (CL) | 0.4-1.2 |
| San Francisco Old Bay clays (CH) | 0.7-0.9 |
| Bankok clay (CH) | 0.4 |

few inches in the next 50 years if water-level declines continue at their present rate (R. Raymond, written comm., 1987). Such declines are treatable using conventional foundation designs.

# GEOTECHNICAL CHARACTERIZATION OF ROCK UNITS

## Introduction

Characterization of rock for engineering purposes is necessary to obtain an estimate of how a given rock unit or rock mass will behave when used in construction. The properties of rock to be used for this purpose must be specified in terms that can be incorporated into foundation designs and construction techniques. To this end, many field and laboratory tests have been proposed, ranging from simple and inexpensive ones to more elaborate, costly ones requiring much time and effort.

For the purpose of this investigation, a number of field and laboratory tests were done on various rock units, including point load strength index (PLSI), strength anisotropy index (SAI), dry density, relative hardness, rock quality designation (RQD), percent recovery, and x-ray diffraction (XRD). Los Angeles wear values given by the New Mexico Highway Department (1975) and chemical analyses presented in the New Mexico SSC Proposal (1987, v. 3) were also utilized. The advantages of these tests are twofold: (1) they have been found to be quite useful in evaluating a variety of engineering concerns, and (2) they are, for the most part, easily and quickly done, which makes them both time- and cost-effective. Following an explanation of test procedures, test results are presented and discussed. Finally, the engineering applications section, which is of major importance to this thesis, is presented. In this section four important engineering concerns are evaluated for various rock units, including (1) basic foundation design considerations, (2) expanse (shrink-swell) potential, (3) rippability, and (4) aggregate resource potential.

## Test Procedures

### Point load strength index

The point load strength test is a relatively quick, simple, and inexpensive method of determining rock strength and classifying rocks for engineering purposes (Read et al., 1980). When first introduced, the point load strength test was used mainly to predict uniaxial compressive strength (UCS), which was formerly the established test for general-purpose rock strength classification. Point load strength now often replaces UCS in this role because when properly conducted it is as reliable as UCS and much quicker to measure (ISRM Commission on Testing Methods, 1985). It is an indirect tensile test; a concentrated vertical applied load creates a horizontal tensile stress and failure occurs by splitting along one or more planes parallel to the direction of load application (Boisen, 1977). Figure 19 shows the point load testing device used in this investigation.

Three types of point load strength tests were conducted: (1) diametral tests, (2) axial tests, and (3) block tests. Diametral tests were conducted parallel to the diameter of core segments in a direction parallel to bedding. Axial tests were conducted parallel to the central axis of core segments in a direction

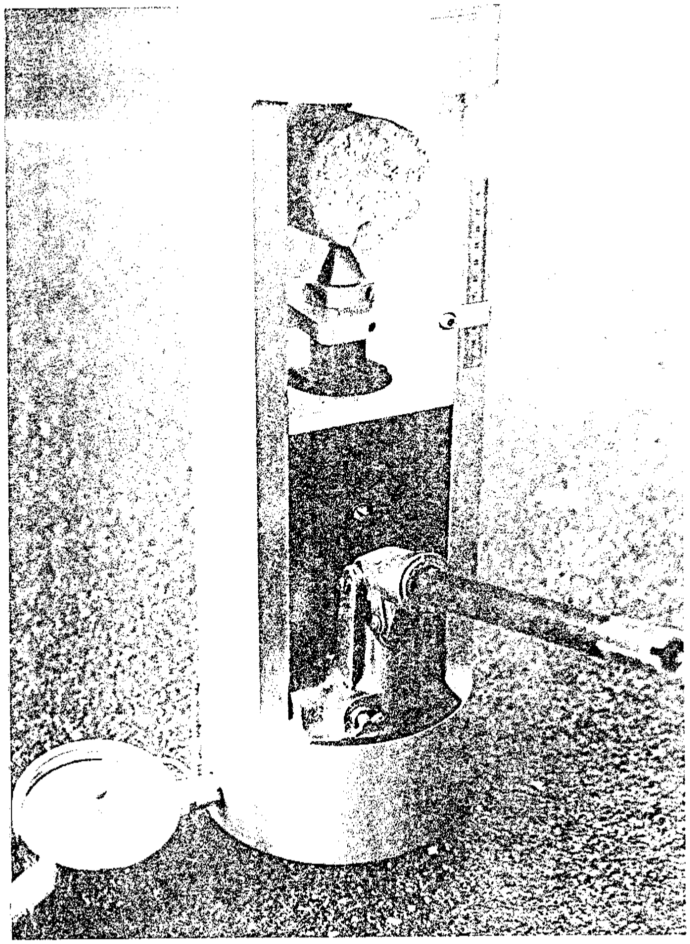


FIGURE 19--Point load strength testing device, model PIL-5.

perpendicular to bedding. Block tests were carried out on regular blocks cut from outcrop specimens perpendicular to bedding or foliation. A total of 312 point load strength index (PLSI) tests were done for this investigation.

Point load strength index (PLSI) values shown in Tables 6 and 7 are probably higher than the in-situ PLSI values of these rock units because core segments and outcrop samples were air-dried before testing, and point load strength index varies with moisture content. Oven-dried specimens, for example, are typically much stronger than moist ones (ISRM Commission on Testing Methods, 1985). In this study, testing of core segments at their natural moisture content could not be carried out because drilling fluids were used in obtaining the core. Outcrop samples were cut into blocks before testing with a water-lubricated saw. Therefore, specimens were thoroughly air-dried for a minimum of 1 week before testing so that moisture content would not vary greatly among samples.

Although intended as an index test for strength classification of rock material, the point load strength test has also been used to predict other strength parameters. Broch and Franklin (1972) and Franklin (1977), for example, have proposed that the unconfined compressive strength (UCS) of a rock material is equal to 24 times the size-corrected point load strength index (PLSI). The size-corrected point load strength index (PLSI) is defined as the point load strength that would have been measured by diametrally testing a standard-size core segment 50 mm in diameter (ISRM Commission on Testing Methods,1975). Pells (1975) and Read et al. (1980), however, have shown that the suggested conversion factor of 24 cannot be universally applied. In tests on many different rock types this conversion factor has been found to vary between 15 and 50 (ISRM Commission on Testing Methods, 1985). Therefore, correlations with UCS are only approximate.

### Strength anisotropy index

Certain rock types, particularly bedded sedimentary rocks and schistose metamorphic rocks, exhibit a higher point load strength index (PLSI) when tested perpendicular to the plane of greatest anisotropy (i.e., bedding and foliation) than when tested parallel to the plane of greatest anisotropy. Strength estimates of such rock types may therefore be misleading if rock specimens are tested in only one direction. In order to assess the likelihood of this condition for rock units in the study area, mean strength anisotropy index (SAI) values for various rock units were determined and are discussed in the results section. Strength Anisotropy Index (SAI) is defined as the ratio of point load strength index (PLSI) values measured perpendicular and parallel to bedding or foliation as determined from axial and diametral tests, respectively. A number of core samples that had previously been tested diametrally were also tested axially for the purpose of determining their SAI.

### Dry density and relative hardness

Dry densities were obtained by measuring the volume of an oven-dried specimen and then determining its weight. The relative hardness of a rock material is an estimate of how easily it can be scratched. Relative hardness designations range from very soft (can be scratched with a fingernail) to very hard (cannot be scratched with a knife).

Rock quality designation (RQD) and percent recovery

Both of these measurements provide estimates of in-situ rock quality. RQD is considered the better estimate and is defined as the percentage ratio of the total length of core segments at least 4 inches long to the total length of core barrel advance. Breaks obviously caused by drilling are ignored. Percent recovery is defined as the percentage ratio between the length of core recovered and the total length of core barrel advance, regardless of the number of fractures.

X-ray diffraction (XRD)

Semiquantitative x-ray diffraction analyses were conducted on samples of Dockum Group rocks in order to determine their clay mineralogy. Test procedures used are the same as those used for XRD analysis of lacustrine soil samples. An outline of these procedures is given in the test procedures section of the previous chapter (p.44).

## Test Results

Table 6 lists mean point load strength index (PLSI) values, strength anisotropy index (SAI) values, dry density measurements, and relative

TABLE 6--Summary of rock test data for subsurface (core) samples.

| Geologic Unit | Point Load Strength Index PLSI (MPa)* Mean#: Range# | PLSI Test Type** | Mean Strength Anisotropy Index SAI | Strength Designation## | Mean Dry Density (PCF) | URCS Density Designation### | Relative Hardness*** |
|---|---|---|---|---|---|---|---|
| ℙm | 4.8: 3.2-6.3 | D | 1.0 | very high | 168 | very dense | moderately hard-medium |
| Pg | 4.1: 2.6-6.0 | D | 1.1 | very high | 153 | dense | moderately hard-medium |
| Py | 1.4: 1.2-2.0 | D | 1.7 | high | 139 | light | medium-very soft |
| TRd | 0.9: 0.7-1.0 | D | 2.1 | medium | 149 | medium dense | soft-very soft |
| Km | 0.5: 0.4-0.5 | D | 2.4 | medium | 133 | light | very soft |

*1MPa = 10.44 ton/square ft.
#Extreme values deleted.
**D = Diametrical test.
##After Broch and Franklin (1972).
###After Williamson, 1984.
***Hardness ranges from very soft (can be scratched with fingernail) to moderately hard (can be scratched with knife).

hardnesses determined for various rock types from selected core segments. Mean PLSI strength designations and Unified Rock Classification System (URCS) density designations are after Broch and Franklin (1972) and Williamson (1984), respectively. Limestone of the Madera Formation (Pm) exhibits the highest mean PLSI of all rock units tested diametrally (parallel to bedding). PLSI values range from 3.2-6.3 MPa and average 4.8 MPa. A mean strength anisotropy index (SAI) of 1.0 indicates that Madera rocks exhibit similar PLSI values when tested both parallel and perpendicular to bedding. Therefore, engineering assessments that are based on the mean PLSI of this unit should not be influenced by directional considerations such as bedding attitude. For example, the rippability of the Madera, which can be estimated from its point load strength, is equally low for both flat-lying and steeply dipping rock masses. The same holds true for the Glorieta Sandstone, which also exhibits a high mean point load strength index (4.1 MPa) and a low mean strength anisotropy index (1.1; Table 6).

Table 6 indicates that dry density and relative hardness appear to correlate generally with point load strength index. The harder and more dense the rock, the higher its size-corrected point load strength index (PLSI). This suggests that dry density and relative hardness are also useful for estimating rock substance strength.

Rocks of the Yeso Formation (Py), the Dockum Group (Trd), and the Mancos Shale (Km) exhibit lower PLSI values and higher SAI values than rocks of the

Madera and Glorieta Formations. PLSI values for Yeso rocks range from 1.2-2.0 MPa, averaging 1.4 MPa. The low density of Yeso rocks (Table 6) may result from small, open cavities and unfilled fractures, as indicated by logs for drill holes 29 and 37 (Appendix I). Rocks of the Dockum Group (Trd) have a PLSI range between 0.7 and 1.0 MPa and an average PLSI of 0.9 MPa. Although Dockum Group rocks exhibit lower PLSI values and lower hardness designations than Yeso rocks, they are more dense (Table 6). This is an exception to the observation noted above that the more dense a rock, the higher its point load strength. The Mancos Shale (Km) exhibits the lowest mean PLSI value, the highest mean SAI value, the lowest dry density, and the lowest relative hardness of all rocks tested. Core segments are easily scratched with a fingernail and show a well-developed fissility parallel to bedding. For rock units tested both diametrally and axially, higher SAI values correspond to lower PLSI values; thus, weaker rocks are more anisotropic with regard to point load strength than stronger rocks, probably because they often break quite easily parallel to bedding. The in-situ substance strength of these units as measured by their PLSI will therefore be affected more strongly by bedding attitude in both subcrop and outcrop than will higher-strength units such as the Madera Formation and the Glorieta Sandstone.

Mean PLSI values for rocks of the Dockum Group (Trd), the Yeso Formation (Py), and the Abo Formation (Pa) are less representative than mean PLSI values determined for other rock types because these three units are highly variable with regard to lithology. Each unit contains relatively competent sandstones interbedded with less competent siltstones and mudstones. Generally, PLSI values for sandstones are higher than those for siltstones and mudstones. Dockum Group rocks clearly show this trend. Axial PLSI values determined on core segments consisting predominantly of siltstone and mudstone average 1.8 MPa, whereas axial PLSI values determined on Dockum Group outcrop specimens consisting primarily of sandstone average 4.4 MPa. In addition, mean PLSI values for the Abo and Yeso Formations (Tables 6 and 7) were determined only from specimens of sandstone and are probably higher than PLSI values for interbedded siltstones and mudstones, which were not tested.

Table 7 lists mean PLSI values, PLSI ranges, dry densities, and relative hardnesses of block specimens from outcrop. Precambrian quartzite (p€q) from Lobo Hill exhibits the highest mean axial PLSI value of all rock types tested (12.3 MPa), whereas rocks of the Dockum Group (Trd) exhibit the lowest PLSI value (4.4 MPa). Dry densities for Madera, Glorieta, and Dockum Group rocks shown in Table 7 generally agree with those values obtained in Table 6. PLSI values recorded in Table 7 are greater than those shown for the same rock units in Table 6. This is due in part to the testing method used. PLSI values in Table 7 were obtained by testing rock specimens perpendicular to bedding or foliation. PLSI values shown in Table 6, however, were obtained by diametrally testing core segments parallel to bedding. For Dockum Group rocks, PLSI values shown in

TABLE 7--Summary of rock test data for surface (outcrop) samples.

| Geologic Unit | Point Load Strength Index PLSI (MPa)* Mean#: Range# | PLSI Test Type** | Strength Designation## | Mean Dry Density (PCF) | URCS Density Designation### | Relative Hardness*** |
|---|---|---|---|---|---|---|
| p€q | 12.3: 10.6-13.4 | BP | extremely high | 165 | very dense | very hard |
| Pa | 10.7: 10.4-11.0 | BP | extremely high | 154 | dense | moderately hard |
| Pb/Psa | 9.8: 2.7-12.4 | BP | very high | 157 | dense | hard-soft |
| Tm | 8.4: 2.3-17.1 | BP | very high | 154 | dense | hard-soft |
| ℙm | 6.5: 4.6-8.9 | BP | very high | 168 | very dense | moderately hard |
| p€s | 6.0: 5.7-6.4 | BP | very high | 161 | very dense | hard |
| Pg | 5.8: 3.6-9.0 | BP | very high | 146 | medium dense | medium-hard |
| T̄Rd | 4.4: 2.7-7.5 | BP | very high | 148 | medium dense | moderately hard-medium |

*1MPa = 10.44 tons/sq ft.
#Extreme values deleted.
**BP = Block test; samples tested perpendicular to plane of greatest anisotropy (ie-bedding, foliation).
##After Broch and Franklin (1972); strength designations range from extremely low to extremely high.
###After Williamson (1984); density designations range from very light to very dense.
***Hardness ranges from very soft (can be scratched with fingernail) to very hard (cannot be scratched with knife).

Table 6 were obtained primarily from siltstone and mudstone, whereas PLSI values shown in Table 7 were obtained from more competent sandstone.

While point load strength index provides a means of estimating the substance strength of intact rock, rock quality designation (RQD) and percent recovery provide a better estimate of in-situ rock quality. Table 8 lists mean RQD values, mean percent recovery, and their ranges for eight holes drilled at various locations. Core of NX size was obtained from drill holes 27, 30, and 39. Core from other drill holes is of larger (3-inch) diameter, and RQD values could not be obtained (RQD only applies to core of NX size). Mean RQD values for drill holes 27, 30, and 39 indicate rock of fair to poor quality in these regions, according to the classification scheme shown in Table 9; however, information is too sparse to estimate the overall quality of rock units. Furthermore, as indicated by the wide ranges of percent recovery for various rock units, rock quality varies with location. RQD values for Glorieta rocks in the vicinity of drill hole 27 indicate rocks of fair-poor quality, although high recovery ratios of Glorieta rocks penetrated by drill hole 29 indicate excellent quality rocks in this area. Variable RQD values obtained in slightly fractured to very fractured limestone of the Madera Formation penetrated by drill hole 39 indicate good to very poor quality rock. Similarly, variable RQD values obtained for Glorieta Sandstone penetrated by drill hole 27 are also attributable to local fracturing of this unit. Recovery ratios for Dockum Group rocks (drill holes 30 and 34) vary from 50-100 percent, and recovery ratios for Yeso rocks (drill holes 29 and 37) vary from 27-93 percent,

TABLE 8--In-situ rock quality data for subsurface (core) samples.

| Drill Hole Number | Core Interval (ft)* | Geologic Unit | Mean RQD | RQD Range | Mean %Rec | %Rec Range | Description |
|---|---|---|---|---|---|---|---|
| DH-27 | 3-149 | Pg | 38% | 12-70% | 74% | 55-98% | gray to white quartz sandstone; vertical, iron-stained fractures; local copper staining; brecciated and highly weathered zones. |
| DH-29 | 20-230 | Pg | – | – | 96% | 90-100% | gray to white quartz sandstone with vertical, iron-stained fractures cemented by calcite. |
| DH-29 | 280-355 | Py | – | – | 37% | 27-48% | red sandstone, siltstone, and mudstone; local clay seams and quartz-filled fractures |
| DH-30 | 58-89 |  | 66% | 0-100% | 81% | 50-100% | red sandstone and mudstone with reduction spots and clay partings. |
| DH-32 | 140-155 | Km | – | – | 100% | 100% | black to gray, fissile, silty mudstone dipping 25°-42°; numerous calcite veins crosscutting and parallel to bedding; pyrite crystals. |
| DH-34 | 180-195 |  | – | – | 100% | 100% | red sandstone, siltstone, and fissile mudstone dipping at approx. 10-30°; mudstone contains expansive clays (sample barrel forced open upon recovery). |
| DH-37 | 120-135 | Py | – | – | 93% | 93% | red, vuggy sandstone, siltstone, and mudstone; calcite-filled cavities; calcite-filled and unfilled vertical and horizontal fractures. |
| DH-39 | 14.5-103 |  | 46% | 0-81% | 89% | 54-100% | slightly fractured to very fractured gray, fossiliferous limestone; minor shaley partings. |

*ft below surface.

TABLE 9--Relation between RQD and in-situ rock quality (from Peck et al., 1974).

| RQD (%) | Rock Quality |
|---|---|
| 90-100 | excellent |
| 75-90 | good |
| 50-75 | fair |
| 25-50 | poor |
| 0-25 | very poor |

indicating rock of variable quality.

## Engineering Applications

### Rippability

Read et al. (1980) proposed that point load strength index (PLSI) values can be used to estimate rock mass rippability. They noted that for particular tractor and ripper arrangements, and PLSI values up to 2.5 MPa, rock in the Melbourne, Australia, area broke readily regardless of the nature of rock mass defects. Above 2.5 MPa, however, rippability depended increasingly on the orientation, spacing, and interconnectedness of the defects. Table 10, based upon rippability designations suggested by Read et al. (1980), relates rippability and mean PLSI values for rock units within the study area. As indicated by Table 10, most surface rock in the study area exhibits PLSI values much higher than 2.5 MPa, and, in addition, it is not favorably jointed; therefore, it is not rippable in most cases. Sandstone of the Dockum Group (Trd) may be an exception, however. As shown in Figure 20, closely spaced, horizontal joints may render Dockum Group sandstone locally rippable. Subsurface samples of Mancos Shale (Km) and Dockum Group siltstone and mudstone (Trd) exhibit PLSI values below 2.5 MPa, and are therefore considered rippable. Subsurface samples of Yeso sandstone (Py) from drill holes 29 and 37 also exhibit low enough strength to be rippable; however, higher strength Yeso limestone exposed elsewhere (i.e., on El Cuervo Butte) indicates that the Yeso is not rippable everywhere.

TABLE 10--Relation between point load strength index (PLSI) and rippability (after Read et al., 1980).

| Rock Unit | Mean Point Load Strength Index PLSI (MPa)* | Lithology(s) | PLSI Test Type** | Occurrance of Samples Tested | Rippability Designation Usually Rippable by |
|---|---|---|---|---|---|
| Km | 0.5 | shale | D | subcrop | D7# |
| TRd | 0.9 | siltstone and mudstone | D | subcrop | D7# |
| Py | 1.4 | sandstone | D | subcrop | D7# |
| TRd | 4.4 | sandstone | B | outcrop | D9# with favorable defect pattern |
| Pg | 5.8/4.1 | sandstone | B/D | outcrop/subcrop | not rippable |
| p€s | 6.0 | schist | B | outcrop | not rippable |
| IPm | 6.5/4.8 | limestone | B/D | outcrop/subcrop | not ripable |
| Tm | 8.4 | monzonite | B | outcrop | not rippable |
| Pb/Psa | 9.8 | limestone and sandstone | B | outcrop | not rippable |
| Pa | 10.4 | sandstone | B | outcrop | not rippable |
| p€q | 12.3 | quartzite | B | outcrop | not rippable |

*1 MPa = 10.44 tons/sq ft.

**D = Diametral test; B = Block test.

#Caterpiller® tracter.

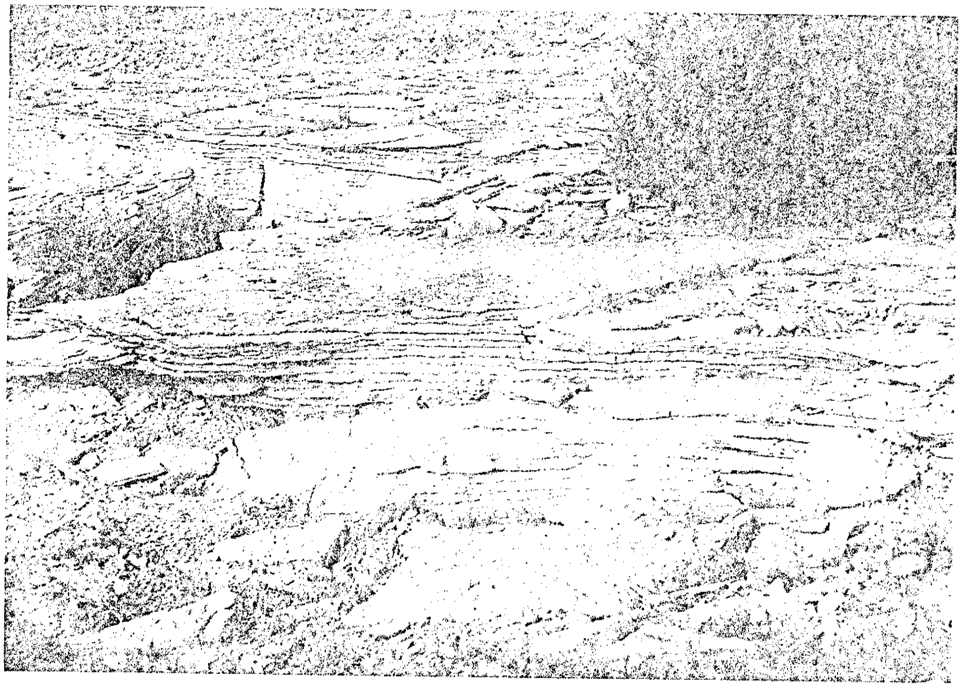


FIGURE 20--Closely spaced, horizontal joints in Dockum Group sandstone.

## Expanse (shrink-swell) potential

Generally, the swelling capacity of rock units in the study area is estimated to be minimal; however, both field and laboratory evidence indicate that siltstone and mudstone lithologies of the Dockum Group may be expansive locally. As noted in Table 8, core segments of Dockum Group rock obtained from drill hole 37 forced open the core barrel as the rock absorbed water used for drilling. Also, highly expansive clays derived from Dockum Group rocks have been identified in the northeast part of the study area by the Soil Conversation Service (1975). Semiquantitative x-ray diffraction (XRD) analysis of two Dockum Group samples from drill hole 37 indicates that potentially expandable mixed-layer illite-smectites represent a significant fraction (about 4 parts in 10) of the clay mineral portion of these rocks. Less competent lithologies within the Dockum Group may therefore swell if the equilibrium moisture content after construction is allowed to become higher than the natural moisture content of these rocks before and during construction.

## Aggregate Resource Potential

Aggregate resources are materials that can be used as riprap, ballast, subbase, fill, or as an additive to cement or asphalt. The American Society for Testing and Materials (ASTM, 1987) has established several important criteria by which the quality of aggregate can be assessed. The plasticity index (PI; ASTM

D4318-84), gives an indication of clay content and should be very low or equal to zero for high-quality aggregate. Materials with a high PI tend to absorb large amounts of water and undergo large volume changes, which inhibit aggregate performance.

Another common property used to assess aggregate quality is its resistance to abrasion as measured by the Los Angeles (LA) wear test (ASTM C131). In this test, a steel drum is loaded with about 5 kg of oven-dried aggregate of a specified grading and with a specified number of iron balls. The drum is rotated at 30-33 RPM for 500 revolutions. The wear caused by the tumbling and dropping of the aggregate and the balls in the drum is determined from the weight percentage of material which, after the test, will pass a No. 12 (0.066 in) sieve. General practice dictates that aggregate to be used in concrete should exhibit LA wear values less than about 40 to 50 percent. Los Angeles wear values for various aggregates have been found to correlate with their service behavior in concrete; i.e., low LA abrasion values indicate better performance. Such tests have also indicated that the lower the wear, the higher the flexural and compressive strength of the concrete (Troxell et al., 1968).

A third test used to assess aggregate quality is soundness loss (ASTM C88), which measures resistance to weathering. Samples are alternately saturated with sodium and magnesium sulphate and dried for a specified number of cycles. The amount of spalling or disintegration is a measure of the soundness. Weight loss is usually specified to be between 0 and 16 percent (Costa and Baker, 1981), although higher soundness loss values can occur. Other important procedures used to assess aggregate quality include classification of aggregate under the Unified and AASHTO systems (ASTM D2487-85 and D 3282-83), specific gravity and absorption (ASTM C127 and C 128), potential reactivity (ASTM C289), and petrographic examination.

The most common aggregate resources in the study area are limestone, quartzite, sand, gravel, and caliche. Rock resources will be discussed first, followed by a consideration of sand, gravel, and caliche resources.

### Rock

Limestone of the Madera Formation is the most important aggregate resource because of its high quality and availability. Typically low Los Angeles wear values of about 20-25, low soundness loss values, and low PI values indicate that limestone quarried from the Madera is well suited for aggregate and can be utilized for all road-building purposes, including base coarses and surface coarses. Shaly horizons within the Madera are rarely numerous or thick enough to adversely affect aggregate quality (New Mexico Highway Department, 1975). The lower gray limestone member of the Madera has been reported to be cherty, (Kottlowski, 1961) although it is not known whether chert accumulation is generally sufficient to adversely affect aggregate quality. A chemical analysis of the Madera Limestone indicates that it is low in silica, magnesium and iron oxide, and contains sufficient calcium to be usable in cement manfacture (New Mexico

SSC Proposal, v. 3; 1987). Other uses for the Madera include crushed stone for aggregate, road metal, ballast, stucco, soil conditioner, and dimension or building stone (McLemore, 1984).

Although of limited aerial extent within the study area, limestone of the San Andres Formation (Psa) also represents a high-quality aggregate resource. Los Angeles wear and soundness loss values for the San Andres Limestone are generally similiar to those of the Madera Limestone. According to the New Mexico Highway Department (1975), minor gypsum, sandstone, and siltstone interbeds can be avoided if loader operators exercise reasonable care. Thin limestone units within the Yeso Formation are unacceptable for most highway construction use because of low resistance to weathering (New Mexico Highway Department, 1975). These units may, however, offer some potential for local aggregate use in light-duty roads.

Limestones of the Madera and San Andres Formations are also well suited for use in bituminous mixtures such as asphalt. Due to electropositive surface charges, the best adhesion between bitumin and aggregate is obtained with strongly electropositive rock such as limestone (Orchard, 1976).

Tertiary monzonite (Tm) and Precambrian schist (p€s) are also generally good aggregate materials. When crushed to a specified size gradation, they are well suited for concrete mixes and road construction purposes.

Other rock types within the study area are generally unsuitable for aggregate. Sandstones of the Glorieta, Bernal, Yeso, and Abo Formations and the Dockum Group are unsuitable as aggregate material because they contain iron oxide and calcite cement which can cause staining and solution weathering (Costa and Baker, 1981). Finer-grained lithologies, including Dockum Group, Yeso, and Abo siltstones and mudstones, and the Mancos Shale, are unsuitable as aggregate material because they exhibit low strength and high plasticity indexes.

Dimension or building stone can be obtained from Precambrian quartzite and the Madera limestone. Precambrian quartzite suitable for dimension stone occurs on Lobo Hill (Fig. 1); however, production has been limited because of remoteness from potential markets (McLemore, 1984).

### Sand, gravel, and caliche

For aggregate resource purposes sand is usually defined as a granular material ranging in size from 2 mm to 0.075 mm. Gravel includes material coarser than 2 mm. Caliche is loosely defined as the "B" horizon of a soil profile enriched by the accumulation of secondary calcium carbonate (Lovelace, 1972). Sand, gravel, and caliche are low-value high-bulk commodities which must generally be mined close to construction sites. Cities, highways, and other areas of intense construction will therefore dictate the general location of excavations. Sand, gravel, and caliche are basic construction materials that are used primarily as aggregate for concrete, as permeable subgrades, in bituminous mixes, and for foundation support. Caliche is also used in cement manufacture, provided the magnesium oxide (MgO) content is less than 10 percent (Bateman, 1956).

Sand and gravel of fair to poor quality can be obtained from Quaternary-Tertiary alluvium (QTa), older alluvium (Qao), and younger alluvium (Qay). These units typically contain excessive amounts of silt, clay, and calcium carbonate ($CaCO_3$), and in most cases beneficiation will be required in order to remove deleterious materials and obtain gradation characteristics suitable for road construction, as specified by ASTM D448-86.

The lacustrine unit (Qld) is generally unsuitable as aggregate due to high amounts of fines and lack of abundant gravel; however, higher quality sand and gravel deposits related to late Pleistocene Lake Estancia are exploitable where they have accumulated in sufficient quantity as bars and spits. These deposits have been mapped by the Soil Conservation Service (1970) and are shown on Plate 1. Such deposits are potentially good sources of sand and gravel because in places they contain clean, well-graded to poorly-graded gravel and sand suitable for concrete as well as for road construction purposes. One such deposit which has been actively mined occurs approximately 2 miles south of Moriarty (Fig. 21). Soil samples S-12 and S-13 (Plate 1) were collected at this site. This deposit consists of clean, pebble-size gravel and interbedded poorly-graded sand.

Caliche deposits associated with Quaternary-Tertiary alluvium (QTa) occur locally in the north-central and east-central parts of the study area (Plate 1). These deposits have also been mapped by the Soil Conservation Service (1970;

FIGURE 21--A typical bar deposit mined for aggregate.

Plate 1) and are a potentially good source of poorly consolidated, nodular caliche that can be crushed and utilized for road construction. According to Gillette (1934) the best caliches for road construction are those that have low liquid limits and low plasticity indexes. Samples tested by the New Mexico Highway Department (1975) lack plasticity (PI = 0) and are therefore well-suited for road construction. To date, caliche has not been mined extensively in the study area; it is at present used for maintenance of pre-existing roads (New Mexico Highway Department, 1975). Additional laboratory testing and further exploration are necessary to better characterize the engineering properties and available reserves of caliche in the study area.

A special problem relating to aggregate utilization results from lack of water for washing gravel to be used as concrete aggregate (New Mexico Highway Department, 1975). Quantities of water required for washing gravel on large projects should be obtainable in most cases from wells.

Table 11 is a summary of available aggregate resources in the study area. Generally, the overall resource potential for crushed rock aggregate, dimension stone, sand, gravel, and caliche is high and should be adequate to supply most forseeable future construction needs.

### Foundation design considerations

Since most intact, unweathered rocks are much stronger than concrete, rock strength does not typically influence the design of foundations. Madera and

TABLE 11--Summary of aggregate resources.

Rock

| Unit | Lithology | Suitability as Aggregate | Uses/Notes |
|---|---|---|---|
| | limestone | excellent-good | cement, concrete, road construction, dimension stone |
| Psa | limestone | excellent-good | cement, concrete, road construction |
| pCq | quartzite | excellent-good | concrete, road construction, dimension stone |
| pCs | schist | good | concrete, road construction |
| Tm | monzonite | good | concrete, road construction |
| Pg | sandstone | unsuitable | low quality due to intergranular, calcite cement |
| Pb | sandstone, limestone | unsuitable | insufficient quantity to be exploitable |
| | sandstone, mudstone | unsuitable | plasticity of material is too high |
| Py | sandstone, siltstone, mudstone | unsuitable | unsuitable due to high plasticity and intergranular cement |
| Pa | sandstone siltstone, mudstone | unsuitable | unsuitable due to high plasticity and intergranular cement |
| Km | shale | unsuitable | plasticity of material is too high |

Nonrock

| Unit | Deposit Type | Suitability as Aggregate | Uses |
|---|---|---|---|
| Qay | alluvial | fair-poor | concrete, road construction (requires beneficiation) |
| Qld | bar and spit | good | concrete, road construction |
| Qld | lacustrine | unsuitable | plasticity of material is too high |
| Qao | alluvial | fair-poor | concrete, road construction (requires beneficiation) |
| QTa | alluvial | fair-poor | concrete, road construction (requires beneficiation) |
| QTa | caliche | good-fair | concrete, road construction |

Glorieta rocks, for example, generally exhibit very high point load strength indexes (PLSI), and the unconfined compressive strength (UCS) of these rock units as predicted by their point load strength greatly exceeds that of concrete, even by conservative estimates. The UCS of an intact core segment of Glorieta Sandstone from drill hole 27 (Plate 1) was measured at 92.5 MPa (966 tons/sq ft; New Mexico SSC Proposal, 1987, v. 3). In comparison, the unconfined compressive strength of concrete used for construction of most footings and piers ranges from 17.2 to 34.5 MPa (180-360 tons/sq ft; Peck et al., 1974). Allowable contact pressures beneath foundations will therefore be governed exclusively by settlement associated with rock defects rather than by rock strength. The same holds true for all other rock units generally exhibiting high PLSI values, including Precambrian rock (pCs and pCq), Tertiary monzonite (Tm), and rock of the Bernal and San Andres Formations (Pb/Psa).

Point load strength index (PLSI) values determined on core segments of shale, siltstone, mudstone, and sandstone from the Mancos Shale (Km), the Dockum Group (Trd), and the Yeso Formation (Py) are much lower than for other rock types. Pells (1975) found that for mudstones subjected to axial point load strength tests, the predicted unconfined compressive strength (UCS) of these rocks (based on a conversion factor of 24 proposed by Broch and Franklin, 1972) closely matched actual UCS values. Estimates of UCS values for shales, siltstones, and mudstones of the Mancos Shale (Km), and the Dockum Group (Trd), based on axial PLSI values and a more conservative conversion factor of

20, range from 22.8 to 35.2 MPa (238 to 367 tons/sq ft). In addition, the unconfined compressive strengths of two Yeso core segments tested were measured at 229 and 236 tons/sq ft (New Mexico SSC Proposal, v. 3; 1987). As stated above, the unconfined compressive strength (UCS) of concrete ranges from 17.2 to 34.5 MPa (180-360 tons/sq ft). UCS values of Mancos Shale, Dockum Group siltstone and mudstone, and Yeso sandstone thus may approximate that of concrete. Contact pressures imposed by large foundation loads could therefore be limited by rock strength as well as by rock defects, particularly if loads of high intensity are applied by a small number of piers or piles. Rocks of the Mancos Shale, Dockum Group, and Yeso Formation may therefore require more conservative foundation designs involving distribution of foundation loads among a greater number of piers or piles. Where rocks are unjointed and unfractured, anchoring foundations in more competent rock units may allow substantial increases in contact pressure. This is not applicable to fractured or jointed rocks, however, where contact pressure is limited by the compressibility of the rocks due to defects rather than to rock strength (Peck et al., 1974).

In summary, the predicted unconfined compressive strength of the Mancos Shale (Km), Dockum Group siltstones and mudstones (Trd), and Yeso sandstone (Py) may, by conservative estimates, be low enough that both rock strength and compressibility could limit allowable bearing pressures and thus affect the design of foundations on these units.

# CONCLUSIONS

Based upon field and laboratory test results, the following conclusions can be drawn from this investigation:

1) The engineering behavior of soils is improved by the presence of secondary (pedogenic) calcium carbonate. By acting as a natural soil cement, calcium carbonate increases soil bearing capacity, lowers soil expanse and soil liquefaction potential, and minimizes settlement due to ground-water withdrawl. The stability and economy of foundations constructed on soils is therefore improved. In addition, pedogenic calcium carbonate deposits can be mined locally as an aggregate resource for use in road construction.

2) Problem soils are uncommon. Expansive soils occur locally; however, they are generally thin. Where thicker, they are of such limited aerial extent that they can easily be avoided when selecting construction sites.

Soil and hydrologic conditions necessary for liquefaction are not present in the study area. Cohesionless sands and gravels occur only locally, the water table, in most places, is deep, and high earthquake-induced ground accelerations are unlikely.

Consolidation of saturated, lacustrine clay under foundation loads could possibly lead to settlement of structures in the south-central part of the study area; however, the compressibility of this clay is not exceedingly great. Therefore, structures can be designed to withstand such settlement.

3) Some rock types (the Mancos Shale and Dockum Group siltstones and mudstones) are rippable with a D7-type tractor-ripper arrangement regardless of joint spacing and orientation, due to their low strength. In contrast, the rippability of certain higher-strength rock types (Dockum Group sandstone) is determined only by joint spacing and orientation, not by rock strength. Dockum Group sandstone is locally rippable with a D9-type tractor-ripper arrangement.

4) Depending upon rock type, allowable contact pressures on rocks may be affected either solely by rock quality, or by both rock quality and rock strength. Most rock units exhibit predicted uniaxial compressive strength (UCS) values well in excess of concrete; therefore, only rock quality (and not rock strength) is a critical consideration in the design of foundations on most rock units. The Mancos Shale, Dockum Group siltstones and mudstones, and Yeso sandstone, however, exhibit predicted UCS values approximating that of concrete. For these units, both rock strength (because it is low) and rock quality may affect the design of foundations, particularly where very high foundation loads are involved.

5) Aggregate resources are adequate to supply most future construction needs. Lacustrine beach and bar deposits provide a good source of sand and gravel for concrete manufacture and for all road construction purposes. Lower quality sand and gravel generally requiring beneficiation can also be obtained from young alluvium, older alluvium, and Quaternary-Tertiary alluvium. Limestone from the Madera and San Andres Formations is of excellent to good quality and can also be used for concrete manufacture and for all road

construction purposes. Precambrian quartzite and schist from the Lobo Hill area and Tertiary monzonite from South Mountain are sources of building stone and crushed rock aggregate.

The northern Estancia Valley is geotechnically well suited to support future development and urbanization. Soil conditions are favorable and adequate aggregate resources exist. In addition, there is currently a wealth of geotechnical information available on the area in the form of geologic maps, soil surveys, water well logs, boring logs, trench logs, and laboratory test data for soil and rock units. Considerable savings in future foundation exploration programs can be realized f planners, contractors, and engineers review this information before more detailed, site-specific investigations are made. Information gathered from such sources, which include this investigation, can provide insight into the types of problems likely to be encountered during future construction projects.

# ACKNOWLEDGEMENTS

This project was completed with the help of several people. Special thanks are given to Danny Bobrow for critically editing earlier versions of this manuscript and for his many helpful suggestions regarding its improvement. Deb Shaw also deserves thanks for lending her editorial expertise. Becky Titus and Sylveen Robinson-Cook are acknowledged for their drafting work. Additional thanks are given to Danny Bobrow, Slyveen Robinson-Cook, and Joe Kelliher for assisting with laboratory work. I would also like to thank the New Mexico Bureau of Mines and Mineral Resources for providing me with a research assistantship. Finally and foremost, I am indebted to Gary Johnpeer, my technical advisor, for his constant encouragement and valuable advice regarding the content and improvement of this thesis.

# REFERENCES

Algermissen, S. T., Perkins, D. M., Thenhaus, P. C., Hanson, S. L., and Bender, B. L., 1982, Probabilistic estimates of maximum acceleration and velocity in rock in the contiguous United States: U. S. Geological Survey, Open-file Report 82-1033, 99 pp.

American Society for Testing and Materials, 1987, Annual book of ASTM standards; soil and rock; building stones; geotextiles: American Society for Testing and Materials, section 4, v. 04.08, 1189 pp.

Antevs, E., 1954, Climate of New Mexico during the last glacio-pluvial: Journal of Geology, v. 62, pp. 182-191.

Bachhuber, F. W., 1971, Paleoliminology of Lake Estancia and the Quaternary history of the Estancia Valley, central New Mexico: Unpublished Ph.D dissertation, University of New Mexico, 238 pp.

Bateman, A. M., 1956, Economic mineral deposits: John Wiley & Sons, Inc., New York, 916 pp.

Bates, R. L., Wilpot, R. H., MacAlpin, A. J., and Vorbe, G., 1947, Geology of the Gran Quivira quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 26, 57 pp.

Boisen, B. P., 1977, A hand portable point load tester for field measurements; in Proceedings of the 18th Symposium on Rock Mechanics, Keystone, Colorado, pp. 1-4.

Bowles, J. E., 1982, Foundation analysis and design, 3rd edition: McGraw-Hill, New York, 816 pp.

Broch, E., and Franklin, J. A., 1972, The point-load strength test: International Journal of Rock Mechanics and Mining Science, v. 9 pp. 669-697.

Costa, J. E., and Baker, V. R., 1981, Surficial geology; building with the earth: John Wiley & Sons, Inc., New York, 498 pp.

Das, B. M., 1985, Principles of geotechnical engineering: PWS Engineering, Boston, 571 pp.

Foster, R. W., 1970, Summary of the stratigraphy, structure, oil tests, and petroleum possibilities of Santa Fe County, New Mexico: Unpublished report on file at the New Mexico Bureau of Mines and Mineral Resources, 17 pp.

Franklin, J. A., 1977, Discussion of E. Hoek's paper "Rock mechanics laboratory testing in the context of a consulting engineering organization": International Journal of Rock Mechanics, Mining Science, and Geomechanics Abstracts, v. 17, pp. 297.

Gabin, V. L., and Lesperance, L. E., 1977, New Mexico climatological data; precipitation, temperature, evaporation, and wind; monthly and annual means 1850-1975: Wik, Summers, and Associates, Socorro, New Mexico, 436 pp.

Gillette, H. S., 1934, Soil tests useful in determining quality of caliche: Public Roads, v. 15, pp. 237-242.

Gizienski, S. F., and Lee, L. J., 1965, Comparison of laboratory swell tests to small scale field tests: in Engineering Effects of Moisture Changes in Soils; Concluding Proceedings, International Research and Engineering Conference on Expansive Clay Soils, Texas A & M Press, College Station, Texas, pp. 108-109.

Gonzalez, R., A., 1965, Petrography and structure of the Pedernal Hills, Torrance County, New Mexico: Unpublished M.S. thesis, University of New Mexico, 78 pp.

Goolsby, R. S., 1965, Geology of the Lamy-Canoncito area, Santa Fe County, New Mexico: Unpublished M.S. thesis, University of New Mexico, 68 pp.

Gromko, G. J., 1974, Review of expansive soils: Journal of the Geotechnical Engineering Division, American Society of Civil Engineers, v. 100, pp. 667-687.

Hawley, J. W., 1986, Physiograhic provinces; in Williams, J. L. (ed.), New Mexico in maps: University of New Mexico Press, Albuquerque, 409 pp.

Holtz, R. D., and Kovacs, W. D., 1981, An introduction to geotechnical engineering: Prentice-Hall, Inc., New Jersey, 733 pp.

International Conference of Building Officials, 1982, Uniform building code: International Conference of Building Officials, Washington DC, 780 pp.

International Society for Rock Mechanics Commission on Testing Methods, 1985, Suggested method for determining point load strength: International Journal of Rock Mechanics, Mining Science, and Geomechanics Abstracts, v. 22, pp. 51-60.

Jenkins, D. N., 1982, Geohydrology of the Madera Group, western Estancia Basin, New Mexico: New Mexico Geological Society, Guidebook to 33rd Field Conference, pp. 361-366.

Jennings, J. E., and Knight, K., 1975, A guide to construction on or with materials exhibiting additional settlement due to collapse of grain structure: Journal of Soil Mechanics and Foundation Engineering, 6th Regional Conference for Africa on Soil Mechanics and Foundation Engineering, Durban, South Africa, pp. 99-105.

Johnpeer, G. D., Bobrow, D. J., Robinson-Cook, S., and Barrie, D., 1987, Preliminary study for siting the Superconducting Super Collider in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 257, 65 pp.

Johnpeer, G. D., Love, D. W., Hawley, J. W., Bobrow, D. J., Hemingway, M., and Reimers, R. F., 1985, El Llano and vicinity geotechnical study--final report: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 226, 4 vols., 578 pp.

Johnpeer, G. D., Love, D. W., and Hemmingway, M., 1986, Assessment of earthquake hazads in New Mexico; in Proceedings of the Third U. S. National Conference on Earthquake Engineering, v. 1, pp. 233-244.

Keyes, C. R., 1903, Ephemeral lakes: American Journal of Science, v. 16, pp. 377-378.

Keyes, C. R., 1905, Structure of the basin ranges: Journal of Geology, v. 13, pp. 63-70.

Kelley, V. C., and Northrop, S. A., 1975, Geology of Sandia Mountains and vicinity, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 29, 136 pp.

Kottlowski, F. E., 1961, Pennsylvanian rocks in north-central New Mexico: New Mexico Geological Society, Guidebook to 12th Field Conference, pp. 197-203.

Lambe, W. T., 1951, Soil testing for engineers: John Wiley & Sons, Inc., New York, 165 pp.

Leopold, L. B., 1951, Pleistocene climate in New Mexico: American Journal of Science, v. 249, pp. 152-168.

Lovelace, A. D., 1972, Aggregate resources in central eastern New Mexico: New Mexico Geological Society, Guidebook to 23rd Field Conference, pp. 187-191.

Lowe, J., III, and Zaccheo, P. F., 1975, Subsurface explorations and sampling; in Winterkorn, H. F., and Fang, H. (eds.), Foundation engineering handbook: Van Nostrand Reinhold Company, New York, pp. 1-66.

Lyons, T. R., 1969, A study of the paleo-indian and desert culture complexes of the Estancia Valley area, New Mexico: Unpublished Ph.D. dissertation, University of New Mexico, 355 pp.

McLemore, V. T, 1984, Preliminary report on the geology and mineral-resource potential of Torrance County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 192, 211 pp.

Meinzer, O. E., 1911, Geology and water resources of Estancia Valley, New Mexico; with notes on ground-water conditions in adjacent parts of central New Mexico: U. S. Geological Survey, Water Supply Paper 275, 89 pp.

National Academy of Sciences, Committee on Earthquake Engineering, 1985, Liquefaction of soils during earthquakes: National Academy Press, Washington D.C., 240 pp.

Neef, G. H., 1950, Sedimentation of the Todilto Limestone in San Miguel County, New Mexico: Unpublished M.S. thesis, Texas Technological College, Lubbock, 21 pp.

New Mexico Bureau of Mines and Mineral Resources Staff, 1985, Proposed site for the Superconducting Super Collider (SSC) in central New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 234, 31 pp.

New Mexico Highway Department, 1975, Geology and aggregate resources, district V: New Mexico State Highway Department, 59 pp.

New Mexico SSC Proposal, 1987, Geology and tunneling: Unpublished report on file at the New Mexico Bureau of Mines and Mineral Resources, 8 vols., 44 pp.

Oglesby, C. H., and Hicks, G. R., 1982, Highway engineering: John Wiley & Sons, Inc., New York, 844 pp.

Olsen, C. E., 1979, Uranium hydrogeochemical and stream sediment pilot survey of Estancia Valley, Bernalillo, Santa Fe, San Miguel, and Torrance Counties, New Mexico: Los Alamos Scientific Laboratory, 32 pp.

Orchard, D. F., 1976, Concrete technology: John Wiley & Sons, Inc., New York, 281 pp.

Peck, R. B., Hanson, W. E., and Thornburn, T. H., 1974, Foundation engineering, 2nd edition: John Wiley & Sons, Inc., 514 pp.

Pells, P. J. N., 1975, The use of the point load test in predicting the compressive strength of rock materials: Australian Geomechanics Journal G5, pp. 54-56.

Read, J. R. L., Thornton, P. N., and Regan, W. M., 1980, A rational approach to the point load test; in Proceedings of the Third Australia, New Zealand Conference on Geomechanics, Wellington, New Zealand, v. 2, pp. 35-39.

Reginatto, A. R., 1971, Standard penetration tests in collapsible soils: Journal of Soil Mechanics and Foundation Engineering, Proceedings, 4th Pan-American Conference on Soil Mechanics and Foundation Engineering, pp. 77-84.

Reiche, P., 1949, Geology of the Manzanita and north Manzano Mountains, New Mexico: Geological Society of America Bulletin, v. 60, pp. 1183-1212.

Reimers, R. F., 1986, Geology and collapse mechanisms in El Llano, New Mexico: Unpublished M.S. thesis, New Mexico Institute of Mining and Technology, 166 pp.

Skempton, A. W., 1953, The colloidal activity of clays; in Proceedings of the International Conference on Soil Mechanics and Foundation Engineering, v. 1, pp. 57-61.

Smith, R. E., 1957, Geology and ground-water resources of Torrance County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Ground-Water Report 5, 186 pp.

Snethen, D. R., 1986, Expansive soils: Ground Failure, no. 3, pp. 12-16.

Soil Conservation Service, 1970, Soil survey of the Torrance area, New Mexico: U. S. Department of Agriculture, 120 pp.

Soil Conservation Service, 1975, Soil survey of the Santa Fe area, New Mexico; Sante Fe County and part of Rio Arriba County: U. S. Department of Agriculture, 114 pp.

Stover, C. W., Reagor, B. G., and Algermissen, S. T., 1983, Seismicity map of the state of New Mexico: U.S. Geological Survey, Miscellaneous Field Studies Map 1660, scale, 1:1,000,000.

Terzaghi, K., and Peck, R., 1967, Soil mechanics in engineering practice, 2nd edition: John Wiley & Sons, Inc., New York, 729 pp.

Thompson, T. B., 1963, The geology of the South Mountain area, Bernalillo, Sandoval, and Santa Fe Counties, New Mexico: Unpublished M.S. Thesis, University of New Mexico, 69 pp.

Titus, F. B., 1969, Late Tertiary and Quaternary hydrogeology of Estancia Basin, New Mexico: Unpublished Ph.D. dissertation, University of New Mexico, 179 pp.

Titus, F. B., 1973, Hydrogeologic evolution of Estancia Valley, a closed basin in central New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-file Report 69, 233 pp.

Troxell, G., Davis, H. E., and Kelly, J. W., 1968, Composition and properties of concrete, 2nd edition: McGraw-Hill, New York, 529 pp.

Williamson, D. A., 1984, Unified Rock Classification System: Bulletin of the Association of Engineering Geologists, v. XXI, pp. 345-354.

Woodward, L. A., 1982, Tectonic Framework of Albuquerque country: New Mexico Geological Society, Guidebook to 33rd Field Conference, pp. 141-145.

Woodward, L. A., Callender, J. F., and Zilinski, R. E., 1975, Tectonic map of the Rio Grande rift, New Mexico: Geological Society of America, Map and Chart Series MC-11, scale 1:500,000.

# APPENDIX I

## Geotechnical drill hole logs

BORING: SSC-DH-1
DATE DRILLED: 9/22/86
EQUIPMENT USED: SIMCO 2800 HS
LOCATION: NE¼,NE¼,Sec 36,T10N,R8E
ELEVATION: 6267
TOTAL DEPTH: 20 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA |  |  |  | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT |  |  |  |  |
| 6267 | 0-2 | 15 | 6 | NA | 26 | 19 | D | CL-ML | ▨ | Silty clay 0/46/54 |
| 6262 | 5-6½ | 8 | 6 | NA | 19 | 16 | D | ML | ▤ | Silt with sand 1/27/72 |
| 6259 | 8-8½ | 25 | 2 | NA | NP | NP | D | SW-SM | ░ | Well graded sand with silt 0/90/10 |
| 6253 | 14-15½ | 20 | 10 | NA. | 26 | 19 | D | CL-ML | ▨ | Silty clay 0/40/60 |

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NOTES:

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

BORING: SSC-DH-2
DATE DRILLED: 9/23/86
EQUIPMENT USED: SIMCO 2800 HS
LOCATION: NE¼ NE¼ SEC25 T11N R8E
ELEVATION: 6280
TOTAL DEPTH: 40.5 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA |  |  |  | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTICITY LIMIT |  |  |  |  |
| 6276 | 4-5½ | 6 | 7 | NA | 21 | NP | D | SM | ▩ | Silty sand 0/79/21 |
| 6271 | 9-10½ | 27 | 16 | NA | 53 | 22 | D | CH | ▧ | Clay 0/3/97 |
| 6261 | 19-20½ | 26 | 12 | NA | 25 | 19 | D | SM/SC | ▩ | Silty sand/clayey sand 0/64/36 |
| 6251 | 29-30½ | 27 | 9 | NA | 30 | 9 | D | SC | ▒ | Clayey sand 0/71/29 |
| 6241 | 39-40½ | 25 | 13 | NA | 28 | 16 | D | CL | ▨ | Clay 0/41/59 |

NOTES: Don King Ranch.
Heavy rains.

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NV=no value
NP=non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-3
**DATE DRILLED:** 9/24/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** SW¼, SE¼, Sec 28, T11N, R9E
**ELEVATION:** 6318
**TOTAL DEPTH:** 45.5 feet

|  |  |  | LABORATORY DATA |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
| 6309 | 9-10½ | 21 | 12 | NA | 38 | NP | D | SM | ▩ | Silty sand 0/67/33 |
| 6299 | 19-20½ | REF | 4 | NA | NP | NP | D | SP | ░ | Poorly-graded sand with gravel 24/76/0 |
| 6289 | 29-30½ | 30 | 9 | NA | 29 | 15 | D | CL | ▨ | Sandy lean clay 0/39/61 |
| 6273 | 45 | -- | 12 | NA | 32 | 17 | D | SC | ▒ | Clayey sand 0/66/34 |

NOTES: REF = refusal

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-4
**DATE DRILLED:** 9/25/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** SE¼ SE¼ SEC27 T11N R8E
**ELEVATION:** 6318
**TOTAL DEPTH:** 30 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA | | | | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTICITY LIMIT | | | | |
| 6314 | 4-5 | 14 | 10 | NA | 26 | 17 | D | SC | ░ | Clayey sand 1/69/30 |
| 6309 | 9-10 | 9 | 11 | NA | 23 | NP | D | SM | ▦ | Silty sand 0/72/28 |
| 6299 | 19-20 | 29 | 7 | NA | 25 | 21 | D | SM/SC | ▦ | Silty sand/clayey sand 0/69/31 |
| 6289 | 29-30 | 39 | 13 | NA | 32 | 17 | D | SC | ░ | Clayey sand 0/60/40 |

**NOTES:** On Highway 471, 2½ miles west of Don King Ranch.
Drilled by G.J.

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

BORING: SSC-DH-5
DATE DRILLED: 9/25/86
EQUIPMENT USED: SIMCO 2800 HS
LOCATION: SW¼, SW¼, Sec 28, T11N, R8E
ELEVATION: 6390
TOTAL DEPTH: 15 feet

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

| | | | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
| 6386 | 4-5 | 30 | 10 | NA | 27 | 16 | D | SC | ▨ | Clayey sand 0/77/23 |
| 6381 | 9-10 | 36 | 8 | NA | 36 | 18 | D | SC | ▨ | Clayey sand 0/60/40 |

NOTES:

NV=no value
NP=non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

BORING: SSC-DH-6
DATE DRILLED: 9/26/86
EQUIPMENT USED: SIMCO 2800 HS
LOCATION: SW¼, SE¼, Sec 26, T11N, R9E
ELEVATION: 6345
TOTAL DEPTH: 24 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA | | | | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | | | | |
| 6341 | 4-5 | 27 | 7 | NA | 27 | 20 | D | SM-SC | ▩ | Silty sand-clayey sand 3/67/30 |
| 6336 | 9-9½ | REF | 12 | NA | 42 | 23 | D | CL | ▨ | Lean clay with sand 0/20/80 |
| 6326 | 19-19½ | REF | 16 | NA | 51 | 22 | D | CH | ▧ | Fat clay 0/13/87 |

NOTES:

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-7
**DATE DRILLED:** 9/29/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** NW¼, NW¼, Sec 32, T11N, R10E
**ELEVATION:** 6400
**TOTAL DEPTH:** 30 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 6396 | 4-5 | 41 | 6 | NA | 23 | 19 | D | SM-SC | ▨ | Silty sand-clayey sand 0/57/43 |
| 6391 | 9-10 | 13 | 5 | NA | 22 | 21 | D | SM | | Silty sand 0/73/27 |
| 6381 | 19-20 | REF | 7 | NA | 29 | 23 | D | SM | | Silty sand 0/61/39 |
| 6371 | 29-30 | REF | 7 | NA | 28 | 26 | D | SM | | Silty sand 0/79/21 |

NOTES:

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-8
**DATE DRILLED:** 9/30/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** SE¼, NE¼, Sec 32, T11N, R10
**ELEVATION:** 6410
**TOTAL DEPTH:** 30 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA |  |  |  | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT |  |  |  |  |
| 6406 | 4-5½ | 25 | 5 | NA | 21 | 16 | D | SM-SC | ▩ | Silty sand-clayey sand 0/66/34 |
| 6401 | 9-10 | 23 | 7 | NA | 27 | 22 | D | CL | ▨ | Sandy lean clay 0/45/55 |
| 6391 | 19-20 | 28 | 5 | NA | 20 | 18 | D | SM | ▩ | Silty sand 0/54/46 |
| 6381 | 29-30 | 34 | 2 | NA | NP | NP | D | SP-SM | ░ | Poorly graded sand with silt and gravel 23/69/8 |

NOTES:

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-9
**DATE DRILLED:** 9/30/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** NE¼ NW¼ SEC29 T10N R9E
**ELEVATION:** 6229
**TOTAL DEPTH:** 30 feet

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

| | | | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTICITY LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
| 6225 | 4-5 | 12 | 13 | NA | 24 | 20 | D | CL/ML | ▨ | Silty clay 0/43/57 |
| 6220 | 9-10 | 15 | 10 | NA | 25 | 19 | D | SM/SC | ▩ | Silty sand/clayey sand 0/65/35 |
| 6210 | 19-20 | 25 | 19 | NA | 42 | 24 | D | SC | ▩ | Clayey sand 0/53/47 |
| 6200 | 29-30 | 45 | 14 | NA | 36 | 23 | D | CL | ▨ | Clay 0/25/75 |

**NOTES:** On Highway 41 right of way, near King Brothers Feed Lot.
Drilled by G.J.

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH 10
**DATE DRILLED:** 101 186
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** Central SEC21 T10N R9E
**ELEVATION:** 6220
**TOTAL DEPTH:** 30 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA | | | | | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTICITY LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | | | |
| 6216 | 4-5 | 21 | 13 | NA | 20 | NP | D | SM | ▩ | Silty sand 0/67/33 |
| 6211 | 9-10 | 36 | 6 | NA | NP | NP | D | SW/SM | ░ | Sand/silty sand 5/88/7 |
| 6201 | 19-20 | 12 | 15 | NA | 20 | 16 | D | CL/ML | ▨ | Silty clay 0/42/58 |
| 6191 | 29-30 | 32 | 13 | NA | 21 | 12 | D | CL | ▨ | Clay 0/37/63 |

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

**NOTES:** In potato field on King Brother's feed lot.
Drilled by S.R.C.

NV=no value
NP=non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

BORING: SSC-DH-11
DATE DRILLED: 10/20/86
EQUIPMENT USED: SIMCO 2800 HS
LOCATION: SE¼, SE¼, Sec 25, T11N, R7E
ELEVATION: 6500
TOTAL DEPTH: 25 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 6496 | 4-5½ | 22 | 7 | NA | 23 | NP | D | SM | ▨ | Silty sand 0/62/38 |
| 6491 | 9-9½ | REF | 7 | NA | 24 | 21 | D | ML | ▤ | Sandy silt 0/50/50 |
| 6481 | 19-20½ | 59 | 11 | NA | 26 | 22 | D | CL-ML | ▨ | Silty clay 0/17/83 |
| 6471 | 29-29½ | REF | 12 | NA | 35 | 23 | D | CL | ▨ | Sandy lean clay 0/30/70 |

NOTES: REF = refusal

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-13
**DATE DRILLED:** 10/21/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** Boundary of Sec 32 & 33, T11N,
**ELEVATION:** 6680
**TOTAL DEPTH:** 23 feet

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA | | | | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | | | | |
| 6676 | 4-5½ | 22 | 5 | NA | 23 | 19 | D | SM-SC | ▨ | Silty sand-clayey sand 0/70/30 |
| 6671 | 9-10½ | 22 | 11 | NA | 39 | 23 | D | CL | ▨ | Lean clay 0/4/96 |
| 6661 | 19-20½ | 17 | 7 | NA | 23 | 19 | D | CL-ML | ▨ | Sandy silty clay-sandy clayey silt 0/35/65 |

NOTES:

NV=no value
NP=non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

BORING: SSC-DH-14
DATE DRILLED: 10/22/86
EQUIPMENT USED: SIMCO 2800 HS
LOCATION: SW¼, SW¼, Sec 32, T8N, R8E
ELEVATION: 6327
TOTAL DEPTH: 29 feet

|  |  |  | LABORATORY DATA |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
| 6323 | 4-5½ | 23 | 11 | NA | 39 | 23 | D | CL | ▨ | Sandy lean clay 0/36/64 |
| 6318 | 9-10½ | 33 | 10 | NA | 39 | 19 | D | CL | ▨ | Lean clay 0/21/79 |
| 6308 | 19-19½ | REF | 9 | NA | 36 | 16 | D | CL | ▨ | Lean clay with sand 0/19/81 |

NOTES:

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

BORING: SSC-DH-15
DATE DRILLED: 10/22/86
EQUIPMENT USED: SIMCO 2800 HS
LOCATION: SW¼ NW¼, Sec 34, T8N, R8E
ELEVATION: 6260
TOTAL DEPTH: 29½ feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA | | | | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | | | | |
| 6256 | 4-5½ | 24 | 13 | NA | 51 | 26 | D | CH | ▨ | Sandy fat clay 0/40/60 |
| 6251 | 9-9½ | REF | 11 | NA | 57 | 26 | D | CH | ▨ | Fat clay 0/14/86 |
| 6241 | 19-20½ | REF | 13 | NA | 60 | 21 | D | CH | ▨ | Fat clay 0/11/89 |

NOTES: REF = refusal

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

BORING: SSC-DH-16
DATE DRILLED: 10/23/86
EQUIPMENT USED: SIMCO 2800 HS
LOCATION: NE¼, NE¼, Sec 2, T7N, R8E
ELEVATION: 6165
TOTAL DEPTH: 18 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA | | | | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | | | | |
| 6161 | 4-4½ | REF | 7 | NA | 28 | 19 | D | CL | ▨ | Lean clay 0/7/93 |
| 6156 | 9-10 | REF | 12 | NA | 42 | 20 | D | CL | ▨ | Lean clay 0/8/92 |

NOTES:

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

**BORING:** SSC-DH-17
**DATE DRILLED:** 10/24/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** NE¼, SE¼, Sec 31, T8N, R9E
**ELEVATION:** 6137
**TOTAL DEPTH:** 40 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA | | | | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | | | | |
| 6133 | 4-4½ | 56 | 15 | NA | NV | NV | D | CL-ML | | silty clay 0/1/99 0/1/99 |
| 6132½ | 4½-5½ | 56 | 6 | NA | 24 | 21 | D | ML | ▤ | Silt with sand 0/19/81 |
| 6128 | 9-10½ | 24 | 13 | NA | 38 | 20 | D | CL | ▨ | Lean clay 0/3/97 |
| 6113 | 19-19¼ | 22 | 13 | NA | NP | NP | D | GP | ⁘ | Gravel* |
| 6117 3/4 | 19¼-20½ | 22 | 40 | NA | 79 | 27 | D | CH | ▧ | Fat clay 0/9/91 |
| 6108 | 29-30½ | 26 | 14 | NA | 27 | 15 | D | CL | ▨ | Sandy lean clay 0/49/51 |

NOTES:
*Field description

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-18
**DATE DRILLED:** 10/24/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** NE¼, SE¼, Sec 32, T8N, R9E
**ELEVATION:** 6135
**TOTAL DEPTH:** 30 feet

| | | | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
| 6131 | 4-5½ | 29 | 7 | NA | 25 | 21 | D | SM-SC | ▩ | Silty sand-clayey sand 0/53/47 |
| 6122 | 9-9¾ | 21 | 11 | NA | 28 | 17 | D | CL | ▨ | Lean clay with sand 4/22/74 |
| 6121¼ | 9¾-10½ | 21 | 26 | NA | 30 | 16 | D | CL | ▨ | Lean clay 0/9/91 |
| 6112 | 19-20 | 39 | 4 | NA | NP | NP | D | SP-SM | ░ | Poorly graded sand with silt and gravel 21/70/9 |
| 6111 | 20-20½ | 39 | 10 | NA | 32 | 19 | D | CL | ▨ | Sandy lean clay 0/35/65 |
| 6102 | 29-30 | REF | 22 | NA | 63 | 23 | D | CH | ▧ | Fat clay 0/11/89 |

NOTES:

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-20
**DATE DRILLED:** 10/28/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** NW¼, NW¼, Sec 29, T8N, R9E
**ELEVATION:** 6146
**TOTAL DEPTH:** 30.5 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
| 6146 | 0-1½ | 9 | 16 | NA | 34 | 18 | D | CL | ▨ | Sandy lean clay 0/42/58 |
| 6144½ | 1½-3 | 14 | 8 | NA | 32 | 17 | D | CL | ▨ | Lean clay with sand 0/37/63 |
| 6143 | 3-4½ | 14 | 14 | NA | 32 | 25 | D | ML | ▤ | Silt 2/12/86 |
| 6141½ | 4½-6 | 17 | 15 | NA | 35 | 21 | D | CL | ▨ | Lean clay with sand 2/19/79 |
| 6140 | 6-7½ | 18 | 15 | NA | 34 | 15 | D | CL | ▨ | Lean clay with sand 2/23/75 |
| 6138½ | 7½-9 | 15 | 17 | NA | 29 | 17 | D | CL | ▨ | Lean clay with sand 0/20/80 |
| 6137 | 9-10½ | 18 | 18 | NA | 37 | 20 | D | CL | ▨ | Lean clay with sand 0/15/85 |
| 6135½ | 10½-12 | 15 | 16 | NA | 29 | 17 | D | CL | ▨ | Sandy lean clay 1/44/55 |
| 6134 | 12-13 | 13 | 11 | NA | 24 | NP | D | ML | ▤ | Silt 0/38/62 |
| 6133 | 13-13½ | -- | -- | NA | 32 | 15 | D | CL | ▨ | Lean clay with sand 0/19/81 |
| 6132½ | 13½-15 | 19 | 16 | NA | 41 | 15 | D | CL | ▨ | Lean clay with sand 0/15/85 |
| 6131 | 15-16½ | 21 | 26 | NA | 37 | 17 | D | CL | ▨ | Lean clay with sand 0/26/74 |
| 6129½ | 16-18 | 32 | 12 | NA | 31 | 14 | D | CL | ▨ | Lean clay with sand 3/18/79 |
| 6128 | 18-19½ | 14 | 30 | NA | 57 | 22 | D | CH | ▧ | Fat clay 1/11/88 |
| 6126½ | 19½-21 | 17 | 21 | NA | 43 | 16 | D | CL | ▨ | Lean clay 0/6/94 |
| 6125 | 21-22½ | 14 | 29 | NA | 40 | 19 | D | CL | ▨ | Lean clay 0/9/91 |
| 6117 | 29-30½ | 40 | 15 | NA | 34 | 20 | D | CL | ▨ | Lean clay 6/3/91 |

NOTES:

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NV = no value
NP = non-plastic

## BORING LOG

NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-21
**DATE DRILLED:** 10/29/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** NE¼, NW¼, Sec 31, T9N, R10E
**ELEVATION:** 6300
**TOTAL DEPTH:** 30 feet

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | LABORATORY DATA | | | | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | | | | |
| 6296 | 4-5½ | 18 | 5 | NA | 19 | 16 | D | SM | ▩ | Silty sand 0/69/31 |
| 6291 | 9-10½ | 25 | 7 | NA | 29 | 17 | D | SC | ▒ | Clayey sand 0/53/47 |
| 6281 | 19-20½ | 26 | 5 | NA | 22 | 14 | D | SM | ▩ | Silty sand 0/74/26 |
| 6276 | 24 | -- | 0.5 | NA | NP | NP | D | GP | ⁘ | Poorly-graded gravel |
| 6271 | 29-30½ | 33 | 9 | NA | 35 | 20 | D | CL | ▨ | Sandy lean clay 0/45/55 |

NOTES:

NV = no value
NP = non-plastic

## BORING LOG
## NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-22
**DATE DRILLED:** 10/29/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** SW¼, NE¼, Sec 6, T8N, R10E
**ELEVATION:** 6295
**TOTAL DEPTH:** 30.5 feet

| | | | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
| 6291 | 4-5½ | 14 | 11 | NA | 25 | 21 | D | CL-ML | ▨ | Silty clay 0/22/78 |
| 6286 | 9-10½ | 24 | 9 | NA | 24 | 17 | D | CL-ML | ▨ | Silty clay 0/32/68 |
| 6276 | 19-20½ | 31 | 5 | NA | 25 | 19 | D | SM-SC | ▩ | Silty sand-clayey sand 0/65/35 |
| 6266 | 29-30½ | 29 | 7 | NA | 22 | 19 | D | SM | ▩ | Silty sand 0/61/39 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NOTES:

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-23
**DATE DRILLED:** 10/30/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** NW¼, NE¼, Sec 13, T9N, R8E
**ELEVATION:** 6225
**TOTAL DEPTH:** 30.5 feet

|  |  |  | LABORATORY DATA |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
| 6221 | 5-5½ | 25 | 12 | NA | 44 | 20 | D | CL | ▨ | Lean clay with sand 0/23/77 |
| 6216 | 9-10½ | 23 | 7 | NA | 26 | 18 | D | CL | ▨ | Sandy lean clay 0/49/51 |
| 6206 | 19-20½ | 32 | 22 | NA | 47 | 23 | D | CL | ▨ | Lean clay 0/14/86 |
| 6196 | 29-30½ | 29 | 18 | NA | 38 | 19 | D | CL | ▨ | Lean clay with sand 0/15/85 |

NOTES:

*THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.*

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

BORING: SSC-DH-24
DATE DRILLED: 10/30/86
EQUIPMENT USED: SIMCO 2800 HS
LOCATION: SW¼, NW¼, Sec 35, T10N, R8E
ELEVATION: 6255
TOTAL DEPTH: 30.5 feet

|  |  |  |  | LABORATORY DATA |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
| 6251 | 4-5½ | 23 | 9 | NA | 32 | 20 | D | CL | ▨ | Lean clay 0/14/86 |
| 6246 | 9-10½ | 20 | 7 | NA | 29 | 19 | D | CL | ▨ | Lean clay 0/12/88 |
| 6236 | 19-20½ | 23 | 13 | NA | 24 | 21 | D | ML | ▤ | Silt with sand 7/21/72 |
| 6226 | 29-30½ | 7 | 22 | NA | 29 | 12 | D | CL | ▨ | Sandy lean clay 0/34/66 |

... BORING LOCATION AND AT THE DATE
... TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

NOTES:

NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE
NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

**BORING:** SSC-DH-25
**DATE DRILLED:** 10/31/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** NW¼, NW¼. Sec 23, T1ON, R8E
**ELEVATION:** 6275
**TOTAL DEPTH:** 30.5 feet

| | | | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
| 6271 | 4-5½ | 7 | 4 | NA | NP | NP | D | SP-SM | ░ | Poorly graded sand with silt and gravel 17/72/11 |
| 6266 | 9-9½ | 29 | 4 | NA | NP | NP | D | SP | ░ | Coarse sand * 18/47/35 |
| 6265½ | 9½-10½ | 29 | 9 | NA | 31 | 18 | D | CL | ▨ | Sandy lean clay 1/37/62 |
| 6256 | 19-19½ | REF | 8 | NA | 31 | 25 | D | CL | ▨ | Sandy lean clay 5/43/52 |
| 6255 | 20-20½ | REF | 8 | NA | 28 | 19 | D | CL | ▨ | Sandy lean clay 0/43/57 |
| 6246 | 29-30½ | 28 | 7 | NA | 28 | 16 | D | SC | ▓ | Clayey sand with gravel 49/20/31 |

NOTES: REF = refusal
*Field description

NV = no value
NP = non-plastic

## BORING LOG
## NEW MEXICO SSC PROPOSAL JULY 31, 1987

AT THE SPECIFIC BORING LOCATION AND AT THE DATE
INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

**BORING:** SSC-DH-26
**DATE DRILLED:** 10/31/86
**EQUIPMENT USED:** SIMCO 2800 HS
**LOCATION:** NW¼, NE¼, Sec 21, T10N, R8E
**ELEVATION:** 6305
**TOTAL DEPTH:** 30.5 feet

| | | | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE STD. PEN. TEST | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U=Undisturbed D=Disturbed | USCS SYMBOL | GEOLOGIC SYMBOL | SOIL DESCRIPTION Gravel/Sand/Fines (%) |
| 6301 | 4-5½ | 14 | 8 | NA | 30 | 19 | D | CL | ▨ | Sandy lean clay 0/38/62 |
| 6296 | 9-9½ | 20 | 4 | NA | 23 | 19 | D | CL-ML | ▨ | Lean clay-silt 4/46/50 |
| 6286 | 19-20½ | 39 | 16 | NA | 46 | 23 | D | CL | ▨ | Lean clay 0/12/88 |
| 6276 | 29-30½ | 19 | 21 | NA | 31 | 19 | D | CL | ▨ | Lean clay with sand 1/27/72 |

NOTES:

NV = no value
NP = non-plastic

## BORING LOG

NEW MEXICO SSC PROPOSAL JULY 31, 1987

IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

**BORING:** SSC-DH-27
**DATE DRILLED:** 4/20/87
**EQUIPMENT USED:** CME-55
**LOCATION:** NW¼, SE¼, Sec. 31, T10N, R10E
**ELEVATION:** 6380
**TOTAL DEPTH:** 149 feet

| | | | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U.D.C.P | USCS. AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
| 6380 | 0-3 | NA | NV | NV | NA | NA | NA | NA | NA | not sampled |
| 6377 | 3-9 | NA | NV | 150 | NA | NA | C | SS | Pg | clean quartz sandstone |
| 6371 | 9-19 | NA | NV | NV | NA | NA | C | SS | Pg | clean quartz sandstone with iron staining |
| 6361 | 19-29 | NA | NV | NV | NA | NA | C | SS | Pg | at 26 feet hit brecciated zone |
| 6351 | 29-39 | NA | NV | NV | NA | NA | C | SS | Pg | very fractured zone |
| 6341 | 39-49 | NA | NV | NV | NA | NA | C | SS | Pg | brecciated zone |
| 6331 | 49-59 | NA | NV | 150 | NA | NA | C | SS | Pg | minor limonitic seams |
| 6321 | 59-69 | NA | NV | NV | NA | NA | C | SS | Pg | limonitic partings |
| 6311 | 69-79 | NA | NV | NV | NA | NA | C | SS | Pg | very fractured |
| 6301 | 79-89 | NA | NV | NV | NA | NA | C | SS | Pg | very weathered, soft |
| 6291 | 89-99 | NA | NV | NV | NA | NA | C | SS | Pg | some minor heavy metals |
| 6281 | 99-109 | NA | NV | 162 | NA | NA | C | SS | Pg | clean quartz sandstone |
| 6271 | 109-119 | NA | NV | NV | NA | NA | C | SS | Pg | very fractured |
| 6261 | 119-129 | NA | NV | NV | NA | NA | C | SS | Pg | copper and manganese staining |
| 6251 | 129-139 | NA | NV | 156 | NA | NA | C | SS | Pg | cross-bedded sandstone |
| 6241 | 139-149 | NA | NV | 150 | NA | NA | C | SS | Pg | iron-stained sandstone |

**NOTES:** Located at Highway Department rock quarry approximately one and one-half mile southeast of Montoya Ranch.

NA = Not applicable
NV = no value
NP = non-plastic

**SAMPLE TYPES**

U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

BORING LOG

NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-28
**DATE DRILLED:** 4/20/87
**EQUIPMENT USED:** Failing 1500W
**LOCATION:** NW¼, NW¼, Sec. 4, T11N, R8E
**ELEVATION:** 6576
**TOTAL DEPTH:** 53 feet

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | LABORATORY DATA | | | | SAMPLE TYPE U.D.C.P. | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | | | | |
| 6576 | 0-5 | NA | NA | NV | NA | NA | P | ML-CL | ▤ | sandy silt-silty clay |
| 6571 | 5-10 | NA | NA | NV | NA | NA | P | ML | ▤ | Sandy silt |
| 6566 | 10-15 | NA | NA | NV | NA | NA | P | SM-ML | ▩ | Silty sand-sandy silt |
| 6561 | 15-20 | NA | NA | NV | NA | NA | P | SM-SP | ▩ | Silty sand-gravelly sand |
| 6556 | 20-25 | NA | NA | NV | NA | NA | P | SP | ░ | gravelly sand |
| 6551 | 25-30 | NA | NA | NV | NA | NA | P | SP | ░ | coarse sand |
| 6546 | 30-35 | NA | NA | NV | NA | NA | P | SP | ░ | medium sand |
| 6541 | 35-40 | NA | NA | NV | NA | NA | P | SP | ░ | gravelly sand |
| 6536 | 40-45 | NA | NA | NV | NA | NA | P | SP | ░ | gravelly sand |
| 6531 | 45-50 | NA | NA | NV | NA | NA | P | SP | ░ | medium sand with gravel |
| 6526 | 50-53 | NA | NA | NV | NA | NA | P | SP | ░ | medium sand with gravel |

**NOTES:** Drilling mud was used in hole after 20 feet. Drilled on King's land, 1 mile east of Hyer.

NA = Not applicable
NV = no value
NP = non-plastic

SAMPLE TYPES

U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

## BORING LOG

NEW MEXICO SSC PROPOSAL JULY 31, 1987

BORING: SSC-DH-29
DATE DRILLED: 4/21-22/87
EQUIPMENT USED: Failing 1500W
LOCATION: NW¼, NW¼, Sec. 36, T10N, R9E
ELEVATION: 6228
TOTAL DEPTH: 355 feet

ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE
INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | LABORATORY DATA | | | | SAMPLE TYPE U.D.C.P | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | | | | |
| 6228 | 0-5 | NA | NV | NA | NA | NA | P | SM | ▨ | silty sand, 70/25/5 |
| 6223 | 5-10 | NA | NV | NA | NA | NA | P | SM | ▨ | silty sand, 60/30/10 |
| 6218 | 10-15 | NA | NV | NA | NA | NA | P | ML-CL | ▤ | sandy silt-silty clay, 30/50/20 |
| 6213 | 15-20 | NA | NV | NA | NA | NA | P | SM-ML | ▨ | silty sand-sandy silt, 50/40/10 |
| 6208 | 20-35 | NA | NA | NA | NA | NA | C | SS | Pg | clean quartz sandstone |
| 6193 | 35-50 | NA | NA | 150 | NA | NA | C | SS | Pg | clean quartz sandstone |
| 6178 | 50-100 | NA | NA | NV | NA | NA | P | SS | Pg | clean quartz sandstone, water at 98 ft |
| 6128 | 100-120 | NA | NA | NV | NA | NA | P | SS | Pg | iron staining |
| 6108 | 120-135 | NA | NA | 150 | NA | NA | C | SS | Pg | well-cemented, some cross-bedding |
| 6093 | 135-160 | NA | NA | NV | NA | NA | P | SS | Pg | iron staining |
| 6068 | 160-175 | NA | NA | 156 | NA | NA | C | SS | Pg | some weathered zones |
| 6053 | 175-235 | NA | NA | NV | NA | NA | P | SS | Pg | color change to orange-red at 235 ft |
| 5993 | 235-280 | NA | NA | NV | NA | NA | P | SS | Py | orange and red fragments of siltstone and claystone |
| 5948 | 280-295 | NA | NA | 137 | NA | NA | C | SS | Py | silty sandstone, easily scratched, some weathered clay zones, abundant bioturbation |
| 5928 | 300-340 | NA | NA | NV | NA | NA | P | SS/Sh | Py | brick-red to gray sandstones and claystones |
| 5888 | 340-355 | NA | NA | 137 | NA | NA | C | Sh | Py | 4 feet of recovery, soft sandy claystone with drusy quartz growths |

NOTES: Permian Glorieta sandstone from 18 feet to 235 feet = 217 feet thick
Permian Yeso Formation from 235 feet

NA = Not applicable
NV = no value
NP = ~~non~~-plastic

SAMPLE TYPES
U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-30
**DATE DRILLED:** 4/21/87
**EQUIPMENT USED:** CME-55
**LOCATION:** NW¼, NE¼, Sec. 32, T11N, R10E
**ELEVATION:** 6400
**TOTAL DEPTH:** 89 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | LABORATORY DATA<br>MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U.D.C.P | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
|---|---|---|---|---|---|---|---|---|---|---|
| 6400 | 0-3 | NA | NA | NA | NA | NA | NA | NA | NA | not sampled |
| 6397 | 3-5 | NA | NV | NV | NV | NV | U | CL-ML | ▨ | silty clay |
| 6395 | 5-8 | 15 | 14 | NV | NV | NV | D | SC | ▒ | clayey sand |
| 6392 | 8-10 | NA | NV | NV | NV | NV | U | ML | ▤ | sandy silt |
| 6390 | 10-13 | 14 | 14 | NV | NV | NV | D | SM | ▩ | silty sand |
| 6387 | 13-15 | NA | NV | NV | NV | NV | U | SM | ▩ | silty sand |
| 6385 | 15-18 | 22 | 7 | NV | NV | NV | D | SM | ▩ | silty sand |
| 6382 | 18-20 | NV | NV | NV | NV | NV | U | SM | ▩ | silty sand |
| 6380 | 20-23 | 17 | 18 | NV | NV | NV | D | SM-SC | ▩ | silty sand-clayey sand |
| 6377 | 23-25 | NA | NV | NV | NV | NV | U | SM | ▩ | silty sand with gravel |
| 6375 | 25-28 | 34 | 8 | NV | NV | NV | D | SM | ▩ | silty sand |
| 6372 | 28-33 | >50 | 12 | NV | NV | NV | D | SS/Sh | Ʀd | dark red-top of Chinle |
| 6367 | 33-38 | >50 | 8 | NV | NA | NA | D | SS/Sh | Ʀd | maroon sandstone and claystone |
| 6362 | 38-43 | >50 | 7 | NV | NA | NA | D | SS/Sh | Ʀd | fissle sandstone and claystone |
| 6357 | 43-48 | >50 | 2 | NV | NA | NA | D | SS/Sh | Ʀd | green reduction spots |
| 6352 | 48-53.5 | >50 | 8 | NV | NA | NA | D | SS/Sh | Ʀd | red fissle sandstone |
| 6342 | 58-59 | NA | 8 | NV | NA | NA | C | SS/Sh | Ʀd | mottled green sandstone and claystone |
| 6341 | 59-69 | NA | 3 | 144 | NA | NA | C | SS/Sh | Ʀd | red sandstone and claystone |
| 6331 | 69-79 | NA | NV | NV | NA | NA | C | SS/Sh | Ʀd | red sandstone and claystone |
| 6321 | 79-89 | NA | NV | 147 | NA | NA | C | SS/Sh | Ʀd | red sandstone and claystone |

HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

**NOTES:** Located just northeast of Marshal Rowley Ranch
At 28 feet contact of Triassic Chinle Formation.
Rock from 33-61 feet very soft and weathered.

NA = Not applicable
NV = no value
NP = ~~non~~-plastic

SAMPLE TYPES
U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

THE DATE
CONDITIONS AT OTHER LOCATIONS AND TIMES.

**BORING:** SSC-DH-31
**DATE DRILLED:** 4/22/87
**EQUIPMENT USED:** CME-55
**LOCATION:** NE¼, NE¼, Sec. 6, T11N, R9E
**ELEVATION:** 6421
**TOTAL DEPTH:** 61½ feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U.D.C.P | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
| 6421 | 0-2 | >50 | NA | NA | NA | NA | NA | NA | NA | not sampled |
| 6419 | 2-7 | 33 | 7.47 | NV | NA | NA | D | SM | ▨ | silty sand with gravel |
| 6414 | 7-12 | >50 | 11.37 | NV | NA | NA | D | SM | ▨ | silty sand |
| 6409 | 12-17 | >50 | 10.27 | NV | NA | NA | D | SM-SC | ▨ | silty-clayey sand |
| 6404 | 17-22 | >50 | 1.86 | NV | NA | NA | D | SP | ░ | gravelly-fine sand |
| 6399 | 22-28 | >50 | 5.65 | NV | NA | NA | D | SM | ▨ | silty sand |
| 6393 | 28-34 | >50 | NV | NV | NA | NA | D | SM | ▨ | silty sand with caliche |
| 6387 | 34-40 | >50 | NV | NV | NA | NA | D | SM-ML | ▨ | silty sand-clayey silt |
| 6381 | 40-45 | >50 | NV | NV | NA | NA | D | SM | ▨ | silty sand |
| 6376 | 45-51 | >50 | NV | NV | NA | NA | D | SM | ▨ | silty sand |
| 6370 | 51-55 | >50 | NV | NV | NA | NA | D | SP | ░ | sand with gravel |
| 6366 | 55-61 | >50 | NV | NV | NA | NA | D | SM | ▨ | silty sand with gravel |

**NOTES:** On Hyer Road 3 miles west of NM-41.

NA = Not applicable
NV = no value
NP = non-plastic

SAMPLE TYPES
U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

**BORING:** SSC-DH-32
**DATE DRILLED:** 4/23/87
**EQUIPMENT USED:** Failing 1500W
**LOCATION:** SW¼, SW¼, Sec. 35, T12N, R9E
**ELEVATION:** 6540
**TOTAL DEPTH:** 155 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | LABORATORY DATA | | | | SAMPLE TYPE U,D,C,P | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | | | | |
| 6540 | 0-20 | NA | NA | NA | NA | NA | P | ML-CL | ▤ | sandy silt-silty clay |
| 6520 | 20-45 | NA | NA | NA | NA | NA | P | CL-ML | ▨ | silty clay-sandy silt (some caliche |
| | | | | | | | | | | zones) |
| 6495 | 45-55 | NA | NA | NA | NA | NA | P | SP-GP | ░ | coarse sand-fine gravel |
| 6485 | 55-75 | NA | NA | NA | NA | NA | P | SP-GP | ░ | coarse sand-fine gravel (minor clay |
| | | | | | | | | | | present) |
| 6465 | 75-95 | NA | NA | NA | NA | NA | P | ML-CL | ▤ | sandy silt-lean clay (minor gravel) |
| 6445 | 95-100 | NA | NA | NA | NA | NA | P | SP-GP | ░ | coarse sand-fine gravel |
| 6440 | 100-120 | NA | NA | NA | NA | NA | P | ML-CL | ▤ | sandy silt-lean clay (about 10% gravel) |
| 6420 | 120-140 | NA | NA | NV | NA | NA | P | Sh | Km | light-yellowish brown shale |
| 6400 | 140-155 | NA | NA | 134 | NA | NA | C | Sh | Km | blue-black sandy mudstone, breaks easily |
| | | | | | | | | | | along bedding planes, beds dipping at |
| | | | | | | | | | | 25-45° |

**NOTES:** Located at intersection of Hyer Road and Highway 41.
At 120 feet contact of Cretaceous Mancos Shale.

NA = Not applicable
NV = no value
NP = non-plastic

SAMPLE TYPES
U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-33
**DATE DRILLED:** 4/23-24/87
**EQUIPMENT USED:** CME-55
**LOCATION:** NW¼, NW¼, Sec. 4, T11N, R8E
**ELEVATION:** 6576
**TOTAL DEPTH:** 38.5 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | LABORATORY DATA<br>MOISTURE (% of dry wt.) | <br>DRY DENSITY (lbs./cu. ft.) | <br>LIQUID LIMIT | <br>PLASTIC LIMIT | SAMPLE TYPE U.D.C.P | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
|---|---|---|---|---|---|---|---|---|---|---|
| 6576 | 0-3 | NA | NA | NA | NA | NA | NA | NA | NA | not sampled |
| 6573 | 3-5 | NA | NV | NV | NV | NV | U | ML | ▤ | sandy silt |
| 6571 | 5-8 | 23 | 8.38 | NV | NV | NV | D | ML | ▤ | sandy silt with gravel |
| 6568 | 8-13 | 48 | 8.71 | NV | NV | NV | D | ML | ▤ | sandy silt with 0.5 inch carbonate |
| | | | | | | | | | | nodules |
| 6563 | 13-18 | 26 | 7.25 | NV | NV | NV | D | SM | ▩ | silty sand with interbedded sand |
| 6558 | 18-23 | >50 | 4.31 | NV | NV | NV | D | SM | ▩ | silty sand with gravel |
| 6553 | 23-28 | 32 | 6.16 | NV | NV | NV | D | SM-ML | ▩ | silty sand-sandy silt with carbonate |
| | | | | | | | | | | nodules |
| 6548 | 28-32 | >50 | NA | NA | NA | NA | NA | NA | NA | no sample recovered |
| 6544 | 32-37 | >50 | 9.36 | NV | NV | NV | D | SM-ML | ▩ | silty sand-sandy silt with gravel and |
| | | | | | | | | | | carbonate |
| 6539 | 37-38.5 | >50 | 6.82 | NV | NV | NV | D | ML | ▤ | sandy silt with gravel |

**NOTES:** Located on Hyer Road, same location as DH-28 and 34.
Hit hard caliche at approximately 10 feet.

**SAMPLE TYPES**
U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

NA = Not applicable
NV = no value
NP = non-plastic

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

BORING LOG

NEW MEXICO SSC PROPOSAL JULY 31, 1987

BORING: SSC-DH-34
DATE DRILLED: 4/24/87
EQUIPMENT USED: Failing 1500W
LOCATION: NW¼, NW¼, Sec. 4, T11N, R8E
ELEVATION: 6576
TOTAL DEPTH: 195 feet

... BORING LOCATION AND AT THE DATE
... IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

| | | | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U.D.C.P | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
| 6576 | 0-25 | NV | NA | NA | NA | NA | P | ML-CL | ▤ | Sandy silt-silty clay |
| 6551 | 25-65 | NV | NA | NA | NA | NA | P | SP-SM | ░ | Coarse sand with silt |
| 6541 | 65-105 | NV | NA | NA | NA | NA | P | SP | ░ | Coarse sand with fine gravel |
| 6471 | 105-135 | NV | NA | NA | NA | NA | P | SM-GM | ▩ | Medium sand-medium gravel with clay |
| 6441 | 135-160 | NV | NA | NA | NA | NA | P | SM-GM | ▩ | Medium sand-medium gravel with dark red clay |
| 6416 | 160-180 | NV | NA | NV | NA | NA | P | Sh | T̄R d | dark-red sandy claystone |
| 6496 | 180-195 | NV | NA | 156 | NA | NA | C | SS/Sh | T̄R d | dark-red sandy siltstone with claystone beds dip approximately 30°. Expansive claystone forced open sample barrel. |

**NOTES:** Located on Hyer Road, same location as DH-28 and 32.
At 160 feet, contact of Triassic Chinle claystone.
Some green claystone beds in Chinle.

NA = Not applicable
NV = no value
NP = non-plastic

SAMPLE TYPES
U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

BORING LOG

NEW MEXICO SSC PROPOSAL JULY 31, 1987

ION AND AT THE DATE
WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

**BORING:** SSC-DH-35
**DATE DRILLED:** 4/24/87
**EQUIPMENT USED:** CME-55
**LOCATION:** SE¼, SE¼, Sec. 17, T9N, R9E
**ELEVATION:** 6183
**TOTAL DEPTH:** 65 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | LABORATORY DATA | | | | SAMPLE TYPE U.D.C.P | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | | | | |
| 6183 | 0-3 | NA | NA | NA | NA | NA | NA | NA | NA | not sampled |
| 6180 | 3-4.75 | NA | NV | NV | NV | NV | U | CL | ▨ | green lean clay with gypsum |
| 6178 | 4.75-8 | 12 | 18 | NA | NV | NV | D | CL | ▨ | green clay with gypsum |
| 6175 | 8-9.75 | NA | 8 | NV | NV | NV | U | ML | ▤ | sandy silt |
| 6173 | 9.75-13 | 15 | 13 | NA | NV | NV | D | SM | ▩ | fine clean sand with some silts and clays |
| 6170 | 13-15 | NA | NV | NV | NV | NV | U | SM | ▩ | fine sand with mottled clay |
| 6168 | 15-18.5 | 7 | 18 | NA | NV | NV | D | ML-SP | ▤ | clayey silt with fine sand at top |
| 6164 | 18.5-20.25 | NA | NV | NV | NV | NV | U | CL-CH | ▨ | lean clay-plastic clay |
| 6163 | 20.25-23.25 | 5 | 32 | NA | NV | NV | D | CH | ▨ | plastic clay with carbon filaments |
| 6160 | 23.25-25 | NA | 16 | NV | NV | NV | U | SP | ░ | fine clean sand |
| 6158 | 25-28.25 | 30 | NV | NA | NV | NV | D | SP | ░ | fine clean sand-poorly graded sand |
| 6155 | 28.25-28.5 | NA | 14 | NV | NV | NV | U | SP | ░ | saturated gravelly sand |
| 6154 | 28.5-33 | NA | NA | NA | NA | NA | NA | NA | NA | no sample recovered |
| 6150 | 33-35 | NA | NV | NV | NV | NV | U | CL | ▨ | yellowish-red hard clay |
| 6148 | 35-38 | 15 | 30 | NA | NV | NV | D | CH | ▨ | very stiff clay with carbonate nodules |
| 6144 | 38.5 | NV | NA | NA | NA | NA | NA | NA | NA | no sample recovered, running sand, saturated |
| 6144 | 38.5-43.5 | NV | NA | NA | NA | NA | NA | NA | NA | no sample recovered, running sand, saturated |
| 6139 | 43.5 | NV | NA | NA | NA | NA | NA | NA | NA | no sample recovered, running sand, saturated |
| 6139 | 43.5-45 | 22 | 17 | NA | NV | NV | D | SM | ▩ | silty sand with clay at top |
| 6138 | 45-51 | 23 | 28 | NA | NV | NV | D | CL-SM | ▨ | stiff clay with silty sand at top |
| 6132 | 51-53 | NA | NA | NA | NA | NA | NA | NA | NA | no sample recovered |
| 6130 | 53-54.75 | NA | 25 | 104 | NV | NV | U | CH-SM | ▨ | yellow clay with running sand at top |
| 6128 | 54.75-58 | NA | NA | NA | NA | NA | NA | NA | NA | no sample recovered |
| 6125 | 58-59.25 | NA | NV | 103 | NV | NV | U | CL-ML | ▨ | silty clay with carbonate nodules |

**NOTES:** Located on Martinez Road just east of Salt Draw.
Water at 50.5 ft depth after 2 days.

**SAMPLE TYPES**
U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

NA = Not applicable
NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

(Cont.)

**BORING:** SSC-DH-35
**DATE DRILLED:** 4/24/87
**EQUIPMENT USED:** CME-55
**LOCATION:** SE¼, SE¼, Sec. 17, T9N, R9E
**ELEVATION:** 6183
**TOTAL DEPTH:** 65 feet

| | | | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U.D.C.P | USCS. AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
| 6124 | 59.25-63 | 30 | 22 | NA | NV | NV | D | CL | ▨ | sandy lean clay |
| 6120 | 63-65 | NA | NV | NV | NV | NV | U | NA | NA | no sample |

IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

**NOTES:** Located on Martinez Road just east of Salt Draw.
Water at 50.5 ft depth after 2 days.

NA = Not applicable
NV = no value
NP = non-plastic

**SAMPLE TYPES**

U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

BORING LOG

NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-36
**DATE DRILLED:** 4/24/87
**EQUIPMENT USED:** CME-55
**LOCATION:** NE¼, NE¼, Sec. 22, T9N, R8E
**ELEVATION:** 6235
**TOTAL DEPTH:** 54.5 feet

| | | | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U.D.C.P | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
| 6235 | 0-3 | NA | NA | NA | NA | NA | NA | NA | NA | not sampled |
| 6232 | 3-5 | NA | NV | NV | NV | NV | U | ML | ▤ | sandy silt |
| 6230 | 5-8 | 15 | NV | NA | NV | NV | D | SM/CL | ▩ | silty sand-lean clay, carbonate nodules |
| 6227 | 8-9.5 | 14 | NV | NA | NV | NV | D | SM | ▩ | silty sand, caliche |
| 6225 | 9.5-16 | NA | NA | NA | NA | NA | NA | NA | NA | no sample recovered |
| 6219 | 16-17.5 | NA | NV | NV | NV | NV | U | CL-ML | ▨ | lean clay-sandy silt, carbonate nodules |
| 6218 | 17.5-19 | 36 | 7 | NA | NV | NV | D | CL/ML | ▨ | lean clay-sandy silt, iron stained nodules |
| 6217 | 18-22.5 | >50 | 6 | NA | NV | NV | D | SM | ▩ | silty sand, much more carbonate |
| 6212 | 22.5-28 | 31 | 9 | NA | NV | NV | D | SM/ML | ▩ | lean clay-sandy silt, rip-ups of lake clay |
| 6207 | 28-33 | >50 | 11 | NA | NV | NV | D | CL/ML | ▨ | lean clay-sandy silt, gravel at top |
| 6202 | 33-38 | >50 | 11 | NA | NV | NV | D | SP-SM | ░ | poorly graded sand with silt |
| 6197 | 38-43 | >50 | 5 | NA | NV | NV | D | CL-ML | ▨ | red silty clay with organics |
| 6192 | 43-48 | 39 | 30 | NA | NV | NV | D | CL | ▨ | lean clay with carbon stringers |
| 6187 | 48-53 | NA | NA | NA | NA | NA | NA | NA | NA | no sample |
| 6182 | 53-55 | >50 | 15 | NA | NV | NV | D | D | ▨ | reddish-yellow clay, very hard |

**NOTES:** Located on Martinez Road West at George Stewart's place.

*THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.*

NA = Not applicable
NV = no value
NP = non-plastic

SAMPLE TYPES
U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

## BORING LOG

## NEW MEXICO SSC PROPOSAL JULY 31, 1987

THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

**BORING:** SSC-DH-37
**DATE DRILLED:** 4/25/87
**EQUIPMENT USED:** Failing 1500W
**LOCATION:** SE¼, SE¼, Sec. 17, T9N, R9E
**ELEVATION:** 6183
**TOTAL DEPTH:** 135 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | LABORATORY DATA |  |  |  | SAMPLE TYPE U.D.C.P | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT |  |  |  |  |
| 6113 | 70-75 | NA | NA | NA | NA | NA | P | SM | ▨ | silty sand with clay |
| 6108 | 75-80 | NA | NA | NA | NA | NA | P | ML-CL | ▤ | sandy silt-silty clay |
| 6103 | 80-85 | NA | NA | NA | NA | NA | P | -- |  | sample not described |
| 6098 | 85-90 | NA | NA | NA | NA | NA | P | SM | ▨ | silty sand with clay |
| 6093 | 90-95 | NA | NA | NA | NA | NA | P | SM | ▨ | silty sand with gravel |
| 6088 | 95-100 | NA | NA | NA | NA | NA | P | SM-CL | ▨ | silty sand-sandy clay |
| 6083 | 100-105 | NA | NA | NA | NA | NA | P | GC | ▨ | poorly graded gravel with chunk of red |
|  |  |  |  |  |  |  |  |  |  | clay |
| 6078 | 105-110 | NA | NA | NA | NA | NA | P | GC | ▨ | gravel with chunks red clay |
| 6073 | 110-115 | NA | NA | NA | NA | NA | P | GC | ▨ | gravel with shaley siltstone |
| 6068 | 115-120 | NA | NA | NA | NA | NA | P | SS | Py | shaley-fine sandstone |
| 6063 | 120-135 | NA | NA | NA | NA | NA | C | SS | Py | shaley-fine sandstone in places vuggy |

**NOTES:** Located on Louis O'Neill property 1 mile east of Salt Draw on Martinez Road East.
Depth to water 51 feet on 4/29/87
Description of cuttings starts at 70 feet - See DH-35 for description of soil from 0-65 feet.

NA = Not applicable
NV = no value
NP = non-plastic

SAMPLE TYPES
U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

BORING LOG

NEW MEXICO SSC PROPOSAL JULY 31, 1987

SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

**BORING:** SSC-DH-38
**DATE DRILLED:** 4/25/87
**EQUIPMENT USED:** CME-55
**LOCATION:** SE¼, NE¼, Sec. 4, T9N, R10E
**ELEVATION:** 6410
**TOTAL DEPTH:** 109.5 feet

| ELEVATION (ft.) | DEPTH (ft.) | N VALUE | LABORATORY DATA |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U,D,C,P | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
| 6410 | 0-3 | NA | NA | NA | NA | NA | NA | NA | NA | not sampled |
| 6407 | 3-8 | 9 | 12 | NA | NV | NV | D | SM | ▩ | silty sand with carbonate |
| 6402 | 8-13 | 38 | 4 | NA | NV | NV | D | ML | ▤ | sandy silt with gravel |
| 6397 | 13-18 | 46 | 6 | NA | NV | NV | D | SM | ▩ | silty sand |
| 6392 | 18-23 | >50 | 5 | NA | NV | NV | D | SP | ░ | very gravelly sand |
| 6387 | 23-28 | >50 | 7 | NA | NV | NV | D | SM | ▩ | very hard silty sand, stage II-III caliche |
| 6382 | 28-33 | >50 | 7 | NA | NV | NV | D | SM-SP | ▩ | silty sand-fine sand |
| 6377 | 33-38 | >50 | 9 | NA | NV | NV | D | ML/CL | ▤ | sandy silt-silty clay |
| 6372 | 38-43 | >50 | NA | NA | NA | NA | NA | NA | NA | nc recovery |
| 6367 | 43-73 | >50 | 9 | NA | NV | NV | D | SP | ░ | sand with carbonate |
| 6337 | 73-98 | >50 | 3 | NA | NV | NV | D | SP | ░ | coarse sand with gravel |
| 6312 | 98-108 | 44 | 6 | NA | NV | NV | D | SM | ▩ | clean silty sand |
| 6302 | 108-109.5 | >50 | 6 | NA | NV | NV | D | SM/SP | ▩ | silty sand to clean fine sand |

**NOTES:** Located at Valley of Estancia Ranchettes.

**SAMPLE TYPES**

U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

NA = Not applicable
NV = no value
NP = non-plastic

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

**BORING:** SSC-DH-39
**DATE DRILLED:** 4/26/87
**EQUIPMENT USED:** CME-55
**LOCATION:** NE¼, NE¼, Sec. 2, T9N, R7E
**ELEVATION:** 6560
**TOTAL DEPTH:** 103 feet

| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | LABORATORY DATA |  |  |  | SAMPLE TYPE U,D,C,P | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT |  |  |  |  |
| 6560 | 0-3 | NA | NA | NA | NA | NA | NA | NA | NA | not sampled |
| 6557 | 3-8 | 11 | 19 | NA | NV | NV | D | ML/CL | ▤ | sandy silt-silty clay with caliche |
| 6552 | 8-13 | >50 | 8 | NA | NV | NV | D | CL/ML | ▨ | silty clay, caliche coated ₽m boulder |
| 6547 | 13-14.5 | >50 | 2 | NA | NA | NA | D | LS | ₽m | ₽m fragments in this soil |
| 6545 | 14.5-37.5 | NA | NA | 168 | NA | NA | C | LS | ₽m | very fractured, highly fossiliferous |
| 6530 | 29.5-39.5 | NA | NA | NV | NA | NA | C | LS | ₽m | more competent, few fossils |
| 6520 | 39.5-49.5 | NA | NA | NV | NA | NA | C | LS | ₽m | micritic, few fossils, very coherent |
| 6510 | 49.5-69.5 | NA | NA | 175 | NA | NA | C | LS | ₽m | some shale partings |
| 6490 | 69.5-89.5 | NA | NA | 159 | NA | NA | C | LS | ₽m | fractured, very fossiliferous, minor shale |
| 6470 | 89.5-103 | NA | NA | 175 | NA | NA | C | LS | ₽m | very fractured and fossiliferous, shaley limestone |

**NOTES:** Located at Nanneman's.
At 14 feet contact of Pennsylvanian Madera Formation.

NA = Not applicable
NV = no value
NP = non-plastic

**SAMPLE TYPES**

U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

[illegible] BORING LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

BORING LOG

NEW MEXICO SSC PROPOSAL JULY 31, 1987

IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

**BORING:** SSC DH-40
**DATE DRILLED:** 4/27/87
**EQUIPMENT USED:** CME-55
**LOCATION:** SE¼, SE¼, Sec. 19, T9N, R9E
**ELEVATION:** 6198
**TOTAL DEPTH:** 69.5 feet

| | | | LABORATORY DATA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (ft.) | DEPTH (ft.) | "N" VALUE | MOISTURE (% of dry wt.) | DRY DENSITY (lbs./cu. ft.) | LIQUID LIMIT | PLASTIC LIMIT | SAMPLE TYPE U.D.C.P | USCS, AGI SYMBOL | GEOLOGIC SYMBOL OR FORMATION | DESCRIPTION OF ROCK AND SOIL |
| 6198 | 0-3 | NA | NA | NA | NA | NA | NA | NA | NA | not sampled |
| 6195 | 3.25-5 | NA | NV | NV | NV | NV | U | ML | ▤ | sandy silt |
| 6193 | 5-8 | 9 | 9 | NV | NV | NV | D | ML | ▤ | sandy silt with rock fragments |
| 6190 | 8-10 | NA | NV | NV | NV | NV | U | SM | ▦ | silty sand |
| 6188 | 10-13 | 28 | 11 | NV | NV | NV | D | ML/SM | ▤ | sandy silt-silty sand with caliche nodules |
| 6185 | 13-14.25 | NA | NV | NV | NV | NV | U | CL-ML | ▧ | sandy silty clay |
| 6184 | 14.25-18 | 18 | 16 | NV | NV | NV | D | CL-ML | ▧ | sandy, silty clay |
| 6180 | 18-18.5 | NA | NV | NV | NV | NV | U | SM | ▦ | silty sand with gravel |
| 6179 | 18.5-23 | 28 | 10 | NV | NV | NV | D | ML/CL | ▤ | sandy silt-silty clay, siltier at top |
| 6175 | 23-28 | 22 | 20 | NV | NV | NV | D | CL | ▧ | gravel at top, white lake clay bottom |
| 6170 | 28-33 | 41 | 14 | NV | NV | NV | D | SP-SM | ░ | poorly graded sand with silt |
| 6165 | 33-38 | 41 | 11 | NV | NV | NV | D | SP | ░ | fine sand, iron staining |
| 6160 | 38-43 | 29 | 21 | NV | NV | NV | D | CH | ▧ | clay with some gravelly sand stringers |
| 6155 | 43-48 | 23 | 19 | NV | NV | NV | D | CL-ML | ▧ | silty clay-clayey silt with carbonate stringers |
| 6150 | 48-53 | 22 | 21 | NV | NV | NV | D | SP-ML | ░ | fine sand-sandy silt |
| 6145 | 53-55 | NA | NV | NV | NV | NV | U | SC | ▦ | clayey sand |
| 6143 | 55-58 | 26 | 18 | NV | NV | NV | D | SM-SC | ▦ | silty, clayey sand with carbonate nodules |
| 6140 | 58-63 | 27 | 18 | NV | NV | NV | D | SM/ML | ▦ | silty sand-sandy silt with marl clasts |
| 6135 | 63-68 | 31 | 24 | NV | NV | NV | D | ML/CL | ▤ | sandy silt-stiff clay with gravel |
| 6130 | 68-69.5 | >50 | 8 | NV | NV | NV | D | GW | ░ | sandy gravel, mostly Pm clasts |

**NOTES:** Located on west end of airport.

NA = Not applicable
NV = no value
NP = non-plastic

SAMPLE TYPES
U = undisturbed soil
D = disturbed soil
C = rock core
P = plug (cuttings recovered)

BORING LOG
NEW MEXICO SSC PROPOSAL JULY 31, 1987

# APPENDIX II

## Backhoe trench logs

# APPENDIX III

## Laboratory test data for soil

| Sample No. | Depth of Sample (ft) | Eng. Geo. Unit | Moisture Content (%) | Atterberg Limits | | Sieve Analysis (% Passing) | | | | | | | | | | | USCS SOIL DESCRIPTION | | AASHTO SOIL DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LL | PI | 1/2" | 3/8" | 1/4" | No. 4 | No. 20 | No. 40 | No. 60 | No. 80 | No. 100 | No. 140 | No. 200 | GROUP SYMBOL | GROUP NAME | |
| S-1 | 2 | Qld | | NP | NP | 100 | 100 | 100 | 100 | 99 | 97 | 94 | 88 | 77 | 41 | 12 | SP | sand | A-2-4(0) |
| S-2 | 2 | Qld | | 24 | 5 | 100 | 100 | 100 | 100 | 95 | 92 | 87 | 83 | 73 | 65 | 50 | CL-ML | silty clay with sand | A-4(0) |
| S-3 | 2 | Qao | | 33 | 13 | 100 | 100 | 100 | 100 | 98 | 97 | 96 | 96 | 95 | 88 | 75 | CL | clay | A-6(8) |
| S-4 | 2 | Qao | | 21 | 4 | 89 | 83 | 80 | 77 | 69 | 63 | 48 | 42 | 39 | 34 | 26 | SM-SC | clayey sand with silt | A-2-4(0) |
| S-5 | 2 | Qao | | 29 | 8 | 100 | 100 | 100 | 81 | 65 | 64 | 63 | 62 | 58 | 52 | 44 | SM | silty sand with gravel | A-4(1) |
| S-6 | 2 | Qay | | NP | NP | 90 | 81 | 71 | 63 | 25 | 14 | 9 | 8 | 7 | 6 | 5 | SW | sand with gravel | A-1-a(0) |
| S-7 | 2 | Qld | | 27 | 10 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 95 | 88 | 68 | CL | clay with sand | A-4(4) |
| S-10 | 2 | Qay | | 29 | 10 | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 96 | 92 | 83 | 66 | CL | sandy clay | A-4(4) |
| S-11 | 2 | Qao | | 25 | 6 | 100 | 100 | 100 | 99 | 99 | 98 | 97 | 94 | 89 | 75 | 56 | CL-ML | silty clay | A-4(1) |
| S-12 | 2 | Qay | | NP | NP | 100 | 100 | 100 | 100 | 99 | 97 | 94 | 88 | 76 | 39 | 12 | SP-SM | sand with silt | A-2-4(0) |
| S-13 | 2 | Qay | | NP | NP | 96 | 91 | 77 | 60 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | SP | sand with gravel | A-1-a(0) |
| S-14 | 2 | Qld | | NP | NP | 87 | 85 | 82 | 78 | 27 | 13 | 7 | 6 | 5 | 4 | 3 | SW | sand with gravel | A-1-b(0) |
| S-15 | 2 | Qld | | 34 | 14 | 100 | 100 | 100 | 100 | 83 | 79 | 75 | 73 | 70 | 61 | 46 | SC | clayey sand | A-6(3) |
| S-16 | 2 | QTa | | 28 | 11 | 100 | 100 | 100 | 97 | 97 | 96 | 95 | 94 | 92 | 87 | 74 | CL | sandy clay | A-6(6) |
| S-17 | 2 | QTa | | NP | NP | 28 | 24 | 20 | 18 | 10 | 8 | 7 | 6 | 6 | 5 | 4 | GP | gravel | A-1-a(0) |
| S-18 | 2 | QTa | | 30 | 13 | 100 | 100 | 100 | 100 | 98 | 98 | 98 | 97 | 96 | 94 | 88 | CL | clay | A-6(10) |
| S-19A | 2 | Qay | | 25 | 6 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 96 | 92 | 78 | 53 | CL-ML | silty clay with sand | A-4(1) |
| S-19B | 2 | Qay | | NP | NP | 53 | 42 | 35 | 31 | 16 | 13 | 11 | 10 | 9 | 7 | 4 | GP | gravel with sand | A-1-a(0) |
| S-20 | 2 | Qay | | 43 | 18 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 97 | 96 | 87 | 59 | CL | sandy clay | A-7-6(9) |
| DH-1 | 2 | Qay | 6 | 26 | 7 | 100 | 100 | 100 | 100 | 96 | 88 | 79 | 75 | 71 | 63 | 54 | CL-ML | silty clay | A-4(1) |
| DH-1 | 5 | QTa | 6 | 19 | 3 | 100 | 100 | 100 | 99 | 97 | 93 | 88 | 85 | 82 | 76 | 72 | ML | silt with sand | A-4(0) |
| DH-1 | 8 | QTa | 2 | NP | NP | 100 | 100 | 100 | 100 | 58 | 36 | 24 | 20 | [illegible] | 13 | 10 | SW-SM | sand with silt | A-1-b(0) |
| DH-1 | 14 | QTa | 10 | 26 | 7 | 100 | 100 | 100 | 100 | 100 | 98 | 96 | 94 | 90 | 74 | 60 | CL-ML | silty clay | A-4(2) |
| DH-2 | 4-5.5 | QTa | 7 | 21 | NP | 100 | 100 | 100 | 100 | 100 | 95 | 82 | 71 | 63 | 40 | 21 | SM | silty sand | A-2-4(0) |
| DH-2 | 9-10.5 | QTa | 16 | 53 | 31 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 97 | CH | clay | A-7-6(34) |
| DH-2 | 19-20.5 | QTa | 12 | 25 | 6 | 100 | 100 | 100 | 100 | 96 | 83 | 74 | 68 | 63 | 50 | 36 | SM-SC | clayey sand with silt | A-4(0) |
| DH-2 | 29-30.5 | QTa | 9 | 30 | 11 | 100 | 100 | 100 | 100 | 98 | 90 | 83 | 77 | 72 | 52 | 29 | SC | clayey sand | A-2-6(0) |
| DH-2 | 39-40.5 | QTa | 13 | 28 | 12 | 100 | 100 | 100 | 100 | 97 | 95 | 91 | 88 | 83 | 74 | 59 | CL | clay | A-6(4) |

Laboratory Test Data for Soil Units. NP = nonplastic

| Sample No. | Depth of Sample (ft) | Eng. Geo. Unit | Moisture Content (%) | Atterberg Limits | | Sieve Analysis (% Passing) | | | | | | | | | | | USCS SOIL DESCRIPTION | | AASHTO SOIL DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LL | PI | 1/2" | 3/8" | 1/4" | No. 4 | No. 20 | No. 40 | No. 60 | No. 80 | No. 100 | No. 140 | No. 200 | GROUP SYMBOL | GROUP NAME | |
| DH-3 | 9-10.5 | Qao | 12 | 38 | NP | 100 | 100 | 100 | 100 | 91 | 75 | 63 | 56 | 52 | 43 | 33 | SM | silty sand | A-2-4(0) |
| DH-3 | 19 | Qao | 4 | NP | NP | 100 | 99 | 86 | 76 | 38 | 22 | 12 | 9 | 4 | 1 | 0 | SP | sand with gravel | A-1-b(0) |
| DH-3 | 30 | Qao | 9 | 29 | 14 | 100 | 100 | 100 | 100 | 89 | 87 | 84 | 83 | 80 | 73 | 61 | CL | sandy clay | A-6(6) |
| DH-3 | 45 | Qao | 12 | 32 | 15 | 100 | 100 | 100 | 100 | 78 | 67 | 60 | 55 | 52 | 44 | 34 | SC | clayey sand | A-2-6(1) |
| DH-4 | 4-5 | QTa | 10 | 26 | 9 | 100 | 100 | 99 | 99 | 95 | 83 | 72 | 66 | 60 | 46 | 30 | SC | clayey sand | A-2-4(0) |
| DH-4 | 9-10 | QTa | 11 | 23 | NP | 100 | 100 | 100 | 100 | 99 | 93 | 83 | 76 | 70 | 53 | 28 | SM | silty sand | A-2-4(0) |
| DH-4 | 19-20 | QTa | 7 | 25 | 4 | 100 | 100 | 100 | 100 | 97 | 90 | 83 | 77 | 72 | 55 | 31 | SM-SC | clayey sand with silt | A-2-4(0) |
| DH-4 | 29-30 | QTa | 13 | 32 | 15 | 100 | 100 | 100 | 100 | 97 | 88 | 78 | 72 | 67 | 56 | 40 | SC | clayey sand | A-6(2) |
| DH-5 | 4-5 | QTa | 10 | 27 | 11 | 100 | 100 | 100 | 100 | 95 | 84 | 75 | 68 | 60 | 40 | 23 | SC | clayey sand | A-3(0) |
| DH-5 | 9-10 | QTa | 8 | 36 | 18 | 100 | 100 | 100 | 100 | 97 | 89 | 81 | 76 | 72 | 59 | 40 | SC | clayey sand | A-6(3) |
| DH-6 | 4-5 | QTa | 7 | 27 | 7 | 100 | 100 | 98 | 97 | 90 | 83 | 76 | 70 | 64 | 47 | 30 | SM-SC | clayey sand with silt | A-2-4(0) |
| DH-6 | 9-9.5 | QTa | 12 | 42 | 19 | 100 | 100 | 100 | 100 | 98 | 96 | 94 | 92 | 90 | 86 | 80 | CL | clay with sand | A-7-6(15) |
| DH-6 | 19-19.5 | QTa | 16 | 51 | 29 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 97 | 96 | 93 | 87 | CH | clay | A-7-6(27) |
| DH-7 | 4-5 | QTa | 6 | 23 | 4 | 100 | 100 | 100 | 96 | 92 | 90 | 84 | 81 | 76 | 60 | 43 | SM-SC | clayey sand with silt | A-4(0) |
| DH-7 | 9-10 | QTa | 5 | 22 | 1 | 100 | 100 | 100 | 100 | 97 | 91 | 84 | 78 | 72 | 51 | 27 | SM | silty sand | A-2-4(0) |
| DH-7 | 19-20 | QTa | 7 | 29 | 6 | 100 | 100 | 100 | 100 | 98 | 91 | 77 | 69 | 63 | 53 | 39 | SM | silty sand | A-4(0) |
| DH-7 | 29-30 | QTa | 7 | 28 | 2 | 100 | 100 | 100 | 99 | 88 | 76 | 65 | 56 | 49 | 34 | 21 | SM | silty sand | A-2-4(0) |
| DH-8 | 4-5 | QTa | 5 | 21 | 5 | 100 | 100 | 100 | 100 | 99 | 92 | 82 | 76 | 71 | 55 | 34 | SM-SC | clayey sand with silt | A-2-4(0) |
| DH-8 | 9-10 | QTa | 7 | 27 | 9 | 100 | 100 | 100 | 100 | 100 | 96 | 90 | 86 | 83 | 75 | 55 | CL | sandy clay | A-4(2) |
| DH-8 | 19-20 | QTa | 5 | 20 | 2 | 100 | 100 | 100 | 100 | 100 | 98 | 91 | 84 | 78 | 65 | 46 | SM | silty sand | A-4(0) |
| DH-8 | 29-30 | QTa | 2 | NP | NP | 100 | 93 | 82 | 77 | 56 | 47 | 29 | 22 | 17 | 12 | 8 | SP-SM | sand with silt | A-1-b(0) |
| DH-9 | 4-5 | Qld | 13 | 24 | 4 | 100 | 100 | 100 | 100 | 100 | 99 | 96 | 94 | 91 | 78 | 57 | CL-ML | silty clay | A-4(0) |
| DH-9 | 9-10 | Qld | 10 | 25 | 6 | 100 | 100 | 100 | 100 | 99 | 93 | 87 | 82 | 77 | 59 | 35 | SM-SC | clayey sand with silt | A-2-4(0) |
| DH-9 | 19-20 | Qld | 19 | 42 | 18 | 100 | 100 | 100 | 100 | 99 | 92 | 83 | 76 | 72 | 62 | 47 | SC | clayey sand | A-7-6(5) |
| DH-9 | 29-30 | Qld | 14 | 36 | 13 | 100 | 100 | 100 | 100 | 100 | 99 | 95 | 90 | 86 | 83 | 75 | CL | clay | A-6(9) |

Laboratory Test Data for Soil Units. NP = nonplastic

| Sample No. | Depth of Sample (ft) | Eng. Geo. Unit | Moisture Content (%) | Atterberg Limits LL | Atterberg Limits PI | Sieve Analysis (% Passing) 1/2" | 3/8" | 1/4" | No. 4 | No. 20 | No. 40 | No. 60 | No. 80 | No. 100 | No. 140 | No. 200 | USCS SOIL DESCRIPTION GROUP SYMBOL | GROUP NAME | AASHTO SOIL DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DH-10 | 4-5 | Qld | 13 | 20 | NP | 100 | 100 | 100 | 100 | 99 | 95 | 88 | 81 | 75 | 57 | 33 | SM | silty sand | A-2-4(0) |
| DH-10 | 9-10 | Qld | 6 | NP | NP | 100 | 100 | 100 | 98 | 70 | 46 | 33 | 28 | 24 | 19 | 14 | SM | silty sand | A-1-b(0) |
| DH-10 | 19-20 | Qld | 15 | 20 | 4 | 100 | 100 | 100 | 100 | 99 | 99 | 92 | 83 | 78 | 71 | 58 | CL-ML | silty clay | A-4(0) |
| DH-10 | 29-30 | Qld | 13 | 21 | 9 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 97 | 95 | 83 | 63 | CL | clay | A-4(2) |
| DH-11 | 4.5-5 | QTa | 7 | 23 | NP | 100 | 100 | 100 | 100 | 100 | 99 | 95 | 89 | 74 | 52 | 38 | SM | silty sand | A-4(0) |
| DH-11 | 9-9.5 | QTa | 7 | 24 | 3 | 100 | 100 | 100 | 100 | 100 | 99 | 96 | 94 | 89 | 69 | 50 | ML | sandy silt | A-4(0) |
| DH-11 | 19-20.5 | QTa | 11 | 26 | 4 | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 98 | 97 | 94 | 83 | CL-ML | silty clay | A-4(2) |
| DH-11 | 29-29.5 | QTa | 12 | 35 | 12 | 100 | 100 | 100 | 100 | 100 | 99 | 96 | 93 | 90 | 81 | 70 | CL | sandy clay | A-6(7) |
| DH-12 | 4-5.5 | QTa | 7 | 25 | 5 | 100 | 100 | 100 | 100 | 98 | 88 | 78 | 72 | 68 | 54 | 36 | SM-SC | clayey sand with silt | A-4(0) |
| DH-12 | 9-10.5 | QTa | 6 | 24 | 6 | 100 | 100 | 100 | 100 | 99 | 92 | 81 | 73 | 68 | 55 | 40 | SM-SC | clayey sand with silt | A-4(0) |
| DH-12 | 19-20.5 | QTa | 8 | 29 | 10 | 100 | 100 | 100 | 100 | 99 | 91 | 82 | 75 | 70 | 57 | 40 | SC | clayey sand | A-4(1) |
| DH-13 | 4-5.5 | QTa | 5 | 23 | 4 | 100 | 100 | 100 | 100 | 94 | 89 | 78 | 68 | 49 | 40 | 30 | SM-SC | clayey sand with silt | A-2-4(0) |
| DH-13 | 9-10.5 | QTa | 11 | 39 | 16 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 99 | 98 | 96 | CL | clay | A-6(17) |
| DH-13 | 19-20.5 | QTa | 7 | 23 | 4 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 96 | 89 | 65 | CL-ML | silty clay with sand | A-4(0) |
| DH-14 | 4-5.5 | QTa | 11 | 39 | 16 | 100 | 100 | 100 | 100 | 97 | 94 | 91 | 88 | 85 | 76 | 64 | CL | sandy clay | A-6(9) |
| DH-14 | 9-10.5 | QTa | 10 | 39 | 20 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 97 | 96 | 89 | 79 | CL | clay | A-6(15) |
| DH-14 | 19-19.5 | QTa | 9 | 36 | 20 | 100 | 100 | 100 | 100 | 99 | 98 | 96 | 96 | 95 | 91 | 81 | CL | clay with sand | A-6(15) |
| DH-15 | 4-5.5 | Qao | 13 | 51 | 25 | 100 | 100 | 100 | 100 | 94 | 90 | 86 | 84 | 82 | 73 | 60 | CH | sandy clay | A-7-6(13) |
| DH-15 | 9-9.5 | Qao | 11 | 57 | 31 | 100 | 100 | 100 | 100 | 97 | 96 | 95 | 94 | 93 | 91 | 86 | CH | clay | A-7-6(29) |
| DH-15 | 19-20.25 | Qao | 13 | 60 | 39 | 100 | 100 | 100 | 100 | 98 | 97 | 96 | 96 | 95 | 94 | 89 | CH | clay | A-7-6(38) |
| DH-16 | 4-4.5 | Qld | 7 | 28 | 8 | 100 | 100 | 100 | 100 | 96 | 96 | 96 | 95 | 95 | 95 | 93 | CL | clay | A-4(7) |
| DH-16 | 9-9.83 | Qld | 12 | 42 | 22 | 100 | 100 | 100 | 100 | 96 | 96 | 96 | 95 | 95 | 95 | 92 | CL | clay | A-7-6(21) |

Laboratory Test Data for Soil Units. NP = nonplastic

| Sample No. | Depth of Sample (ft) | Eng. Geo. Unit | Moisture Content (%) | Atterberg Limits | | Sieve Analysis (% Passing) | | | | | | | | | | | USCS SOIL DESCRIPTION | | AASHTO SOIL DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LL | PI | 1/2" | 3/8" | 1/4" | No. 4 | No. 20 | No. 40 | No. 60 | No. 80 | No. 100 | No. 140 | No. 200 | GROUP SYMBOL | GROUP NAME | |
| DH-17 | 4-4.5 | Qld | 15 | | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | CL-ML | silty clay | |
| DH-17 | 4.5-5.5 | Qld | 6 | 24 | 3 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 97 | 94 | 81 | ML | silt with sand | A-4(1) |
| DH-17 | 9-10.5 | Qld | 13 | 38 | 18 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 99 | 97 | CL | clay | A-6(18) |
| DH-17 | 19.25-20.5 | Qld | 40 | 79 | 52 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 91 | CH | clay | A-7-6(54) |
| DH-17 | 29-30.5 | Qld | 14 | 27 | 12 | 100 | 100 | 100 | 100 | 99 | 94 | 89 | 85 | 82 | 70 | 51 | CL | sandy clay | A-6(3) |
| DH-17 | 40 | Qld | 17 | 36 | 18 | 100 | 100 | 100 | 93 | 88 | 87 | 87 | 86 | 86 | 84 | 80 | CL | clay | A-6(13) |
| DH-18 | 4-5.5 | Qld | 7 | 25 | 4 | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 96 | 92 | 71 | 47 | SM-SC | clayey sand with silt | A-4(0) |
| DH-18 | 9-9.75 | Qld | 11 | 28 | 11 | 100 | 100 | 100 | 96 | 91 | 89 | 88 | 88 | 88 | 87 | 74 | CL | clay with sand | A-6(6) |
| DH-18 | 9.75-10.5 | Qld | 26 | 30 | 14 | 100 | 100 | 100 | 100 | 99 | 99 | 99 | 98 | 98 | 94 | 91 | CL | clay | A-6(11) |
| DH-18 | 19-20 | Qld | 4 | NP | NP | 79 | 79 | 79 | 79 | 64 | 49 | 31 | 25 | 21 | 15 | 9 | SP-SM | sand with silt and gravel | A-1-b(0) |
| DH-18 | 20-20.5 | Qld | 10 | 32 | 13 | 100 | 100 | 100 | 100 | 98 | 97 | 96 | 94 | 92 | 81 | 65 | CL | sandy clay | A-6(6) |
| DH-18 | 29-30 | Qld | 22 | 63 | 40 | 100 | 100 | 100 | 100 | 96 | 95 | 94 | 93 | 93 | 91 | 89 | CH | clay | A-7-6(39) |
| DH-19 | 4-4.5 | Qld | 9 | 22 | 6 | 100 | 100 | 100 | 100 | 97 | 97 | 96 | 96 | 94 | 93 | 87 | CL-ML | silty clay | A-4(3) |
| DH-19 | 9-9.5 | Qld | 11 | 27 | 13 | 100 | 100 | 100 | 100 | 88 | 86 | 83 | 82 | 79 | 74 | 63 | CL | sandy clay | A-6(5) |
| DH-19 | 19.5 | Qld | 15 | 22 | 7 | 100 | 100 | 100 | 100 | 91 | 88 | 84 | 77 | 73 | 67 | 58 | CL-ML | silty clay | A-4(1) |

Laboratory Test Data for Soil Units. NP = nonplastic

| Sample No. | Depth of Sample (ft) | Eng. Geo. Unit | Moisture Content (%) | Atterberg Limits | | Sieve Analysis (% Passing) | | | | | | | | | | | USCS SOIL DESCRIPTION | | AASHTO SOIL DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LL | PI | 1/2" | 3/8" | 1/4" | No. 4 | No. 20 | No. 40 | No. 60 | No. 80 | No. 100 | No. 140 | No. 200 | GROUP SYMBOL | GROUP NAME | |
| DH-20 | 0-1.5 | Qld | 16 | 34 | 16 | 100 | 100 | 100 | 100 | 100 | 99 | 96 | 95 | 92 | 83 | 58 | CL | sandy clay | A-6(6) |
| DH-20 | 1.5-3 | Qld | 8 | 32 | 15 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 95 | 85 | CL | clay with sand | A-6(12) |
| DH-20 | 3-4.5 | Qld | 14 | 32 | 7 | 100 | 100 | 100 | 100 | 97 | 94 | 92 | 91 | 89 | 89 | 86 | ML | silt | A-4(6) |
| DH-20 | 4.5-6 | Qld | 15 | 35 | 14 | 100 | 100 | 100 | 98 | 96 | 95 | 94 | 93 | 92 | 86 | 79 | CL | clay with sand | A-6(10) |
| DH-20 | 6-7.5 | Qld | 15 | 34 | 19 | 100 | 100 | 100 | 98 | 97 | 96 | 95 | 94 | 93 | 87 | 75 | CL | clay with sand | A-6(12) |
| DH-20 | 7.5-9 | Qld | 17 | 29 | 12 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 97 | 96 | 90 | 80 | CL | clay with sand | A-6(8) |
| DH-20 | 9-10.5 | Qld | 18 | 37 | 17 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 97 | 96 | 92 | 85 | CL | clay with sand | A-6(14) |
| DH-20 | 10.5-12 | Qld | 16 | 29 | 12 | 100 | 100 | 100 | 99 | 94 | 89 | 86 | 84 | 82 | 75 | 55 | CL | sandy clay | A-6(4) |
| DH-20 | 12-13 | Qld | 11 | 24 | NP | 100 | 100 | 100 | 100 | 98 | 95 | 89 | 87 | 84 | 74 | 62 | ML | silt | A-4(0) |
| DH-20 | 13-13.5 | Qld | | 32 | 17 | 100 | 100 | 100 | 100 | 98 | 98 | 97 | 97 | 96 | 92 | 81 | CL | clay with sand | A-6(12) |
| DH-20 | 13.5-15 | Qld | 16 | 41 | 26 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 95 | 85 | CL | clay with sand | A-7-6(21) |
| DH-20 | 15-16.5 | Qld | 26 | 37 | 20 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 92 | 74 | CL | clay with sand | A-6(13) |
| DH-20 | 16.5-18 | Qld | 12 | 31 | 17 | 100 | 100 | 100 | 97 | 93 | 92 | 91 | 91 | 90 | 87 | 79 | CL | clay with sand | A-6(11) |
| DH-20 | 18-19.5 | Qld | 30 | 57 | 35 | 100 | 100 | 100 | 99 | 98 | 97 | 97 | 97 | 97 | 95 | 88 | CH | clay | A-7-6(33) |
| DH-20 | 19.5-21 | Qld | 21 | 43 | 27 | 100 | 100 | 100 | 100 | 99 | 99 | 99 | 99 | 98 | 98 | 94 | CL | clay | A-7-6(26) |
| DH-20 | 21-22.5 | Qld | 29 | 40 | 21 | 100 | 100 | 100 | 100 | 99 | 99 | 99 | 99 | 99 | 98 | 91 | CL | clay | A-6(20) |
| DH-20 | 29-30.5 | Qld | 15 | 34 | 14 | 100 | 100 | 100 | 94 | 93 | 93 | 93 | 93 | 93 | 93 | 91 | CL | clay | A-6(13) |
| DH-21 | 4-5.5 | Qao | 5 | 19 | 3 | 100 | 100 | 100 | 100 | 84 | 80 | 70 | 57 | 48 | 39 | 31 | SM | silty sand | A-2-4(0) |
| DH-21 | 9-10.5 | Qao | 7 | 29 | 12 | 100 | 100 | 100 | 100 | 91 | 88 | 81 | 78 | 75 | 57 | 47 | SC | clayey sand | A-6(2) |
| DH-21 | 19-20.5 | Qao | 5 | 22 | 8 | 100 | 100 | 100 | 100 | 83 | 78 | 67 | 61 | 54 | 40 | 26 | SC | clayey sand | A-2-4(0) |
| DH-21 | 29-30.5 | Qao | 9 | 35 | 15 | 100 | 100 | 100 | 100 | 97 | 95 | 87 | 81 | 77 | 70 | 55 | CL | sandy clay | A-6(6) |
| DH-22 | 4-5.5 | Qao | 11 | 25 | 4 | 100 | 100 | 100 | 100 | 99 | 99 | 97 | 94 | 92 | 86 | 78 | CL-ML | silty clay | A-4(2) |
| DH-22 | 9-10.5 | Qao | 9 | 24 | 7 | 100 | 100 | 100 | 100 | 100 | 100 | 97 | 92 | 87 | 79 | 68 | CL-ML | silty clay | A-4(2) |
| DH-22 | 19-20.5 | Qao | 5 | 25 | 6 | 100 | 100 | 100 | 100 | 98 | 97 | 86 | 73 | 65 | 50 | 35 | SM-SC | clayey sand with silt | A-4(0) |
| DH-22 | 29-30.5 | Qao | 7 | 22 | 3 | 100 | 100 | 100 | 100 | 97 | 95 | 88 | 83 | 77 | 65 | 39 | SM | silty sand | A-4(0) |

Laboratory Test Data for Soil Units. NP = nonplastic

| Sample No. | Depth of Sample (ft) | Eng. Geo. Unit | Moisture Content (%) | Atterberg Limits | | Sieve Analysis (% Passing) | | | | | | | | | | | USCS SOIL DESCRIPTION | | AASHTO SOIL DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LL | PI | 1/2" | 3/8" | 1/4" | No. 4 | No. 20 | No. 40 | No. 60 | No. 80 | No. 100 | No. 140 | No. 200 | GROUP SYMBOL | GROUP NAME | |
| DH-23 | 4-5.5 | Qao | 12 | 44 | 24 | 100 | 100 | 100 | 100 | 99 | 98 | 97 | 95 | 92 | 85 | 77 | CL | clay with sand | A-7-6(18) |
| DH-23 | 9-10.5 | Qao | 7 | 26 | 8 | 100 | 100 | 100 | 100 | 96 | 95 | 94 | 94 | 90 | 78 | 51 | CL | sandy clay | A-4(1) |
| DH-23 | 19-20.5 | Qao | 22 | 47 | 24 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 95 | 86 | CL | clay | A-7-6(22) |
| DH-23 | 29-30.5 | Qao | 18 | 38 | 19 | 100 | 100 | 100 | 100 | 99 | 99 | 99 | 98 | 97 | 94 | 85 | CL | clay with sand | A-6(16) |
| | | | | | | | | | | | | | | | | | | | |
| DH-24 | 4-5.5 | Qao | 9 | 32 | 12 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 96 | 86 | CL | clay | A-6(10) |
| DH-24 | 9-10.5 | Qao | 7 | 29 | 10 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 88 | CL | clay | A-4(8) |
| DH-24 | 19-20.5 | Qao | 13 | 24 | 3 | 100 | 100 | 100 | 93 | 92 | 92 | 91 | 89 | 87 | 82 | 72 | ML | silt with sand | A-4(0) |
| DH-24 | 29-30.5 | Qao | 22 | 29 | 17 | 100 | 100 | 100 | 100 | 99 | 98 | 96 | 95 | 92 | 83 | 66 | CL | sandy clay | A-6(8) |
| | | | | | | | | | | | | | | | | | | | |
| DH-25 | 4-5.5 | Qao | 4 | NP | NP | 96 | 94 | 89 | 83 | 65 | 52 | 37 | 29 | 24 | 17 | 11 | SP-SM | sand with silt and gravel | A-2-4(0) |
| DH-25 | 9-9.5 | Qao | 4 | | | 100 | 100 | 85 | 82 | 66 | 58 | 54 | 53 | 51 | 47 | 35 | SM-SC | clayey sand with silt | |
| DH-25 | 9.5-10.5 | Qao | 9 | 31 | 13 | 100 | 100 | 100 | 99 | 93 | 90 | 88 | 86 | 84 | 77 | 62 | CL | sandy clay | A-6(6) |
| DH-25 | 19-19.5 | Qao | 8 | 31 | 8 | 100 | 100 | 100 | 95 | 85 | 80 | 75 | 72 | 69 | 61 | 52 | CL | sandy clay | A-4(2) |
| DH-25 | 20-20.5 | Qao | 8 | 28 | 9 | 100 | 100 | 100 | 100 | 98 | 95 | 92 | 89 | 85 | 74 | 57 | CL | sandy clay | A-4(3) |
| DH-25 | 29-30.5 | Qao | 7 | 28 | 12 | 51 | 51 | 51 | 51 | 51 | 50 | 50 | 49 | 47 | 39 | 31 | SC | clayey sand with gravel | A-6(0) |
| | | | | | | | | | | | | | | | | | | | |
| DH-26 | 4-5.5 | QTa | 8 | 30 | 11 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 96 | 84 | 62 | CL | sandy clay | A-6(5) |
| DH-26 | 9-9.5 | QTa | 4 | 23 | 4 | 100 | 100 | 100 | 96 | 85 | 81 | 78 | 77 | 75 | 65 | 50 | CL-ML | silty clay with sand | A-4(0) |
| DH-26 | 9.5-10.5 | QTa | 10 | 41 | 23 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 92 | 80 | CL | clay with sand | A-7-6(18) |
| DH-26 | 19-20.5 | QTa | 16 | 46 | 23 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 96 | 88 | CL | clay | A-7-6(22) |
| DH-26 | 29-30.5 | QTa | 21 | 31 | 12 | 100 | 100 | 100 | 99 | 98 | 97 | 97 | 96 | 95 | 87 | 72 | CL | clay with sand | A-6(7) |
| | | | | | | | | | | | | | | | | | | | |
| DH-30 | 5-6.5 | Qay | 14 | | | | | | | | | | | | | | | | |
| DH-30 | 10-11.5 | Qay | 14 | | | | | | | | | | | | | | | | |
| DH-30 | 15-16.5 | Qay | 7 | | | 100 | 100 | 95 | 92 | 72 | 63 | 56 | 51 | 48 | 42 | 34 | SM* | silty sand | |
| DH-30 | 20-21.5 | Qay | 18 | | | | | | | | | | | | | | | | |
| DH-30 | 25-26.5 | Qay | 8 | | | 100 | 97 | 87 | 84 | 63 | 58 | 54 | 49 | 46 | 39 | 29 | SM* | silty sand | |
| DH-30 | 28-29.5 | Qay | 12 | | | | | | | | | | | | | | | | |

*USCS designation based on estimated plasticity.

Laboratory Test Data for Soil Units. NP = nonplastic

| Sample No. | Depth of Sample (ft) | Eng. Geo. Unit | Moisture Content (%) | Atterberg Limits | | Sieve Analysis (% Passing) | | | | | | | | | | | USCS SOIL DESCRIPTION | | AASHTO SOIL DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LL | PI | 1/2" | 3/8" | 1/4" | No. 4 | No. 20 | No. 40 | No. 60 | No. 80 | No. 100 | No. 140 | No. 200 | GROUP SYMBOL | GROUP NAME | |
| DH-31 | 2-3.5 | QTa | 7 | | | 95 | 88 | 72 | 64 | 43 | 37 | 33 | 30 | 28 | 25 | 20 | SM* | silty sand | |
| DH-31 | 7-8.5 | QTa | 11 | | | | | | | | | | | | | | | | |
| DH-31 | 12-13.5 | QTa | 10 | | | 100 | 100 | 100 | 99 | 95 | 90 | 76 | 69 | 63 | 45 | 34 | SM-SC* | clayey sand with silt | |
| DH-31 | 18-19 | QTa | 2 | | | | | | | | | | | | | | | | |
| DH-31 | 22.5-24 | QTa | 6 | | | 100 | 79 | 73 | 70 | 37 | 32 | 27 | 24 | 21 | 15 | 6 | SM* | silty sand | |
| DH-33 | 5-6.5 | QTa | 8 | | | 92 | 92 | 92 | 92 | 91 | 90 | 87 | 85 | 81 | 66 | 47 | SM* | silty sand | |
| DH-33 | 8-9.5 | QTa | 9 | | | | | | | | | | | | | | | | |
| DH-33 | 13-14.5 | QTa | 7 | | | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 96 | 91 | 71 | 46 | SM* | silty sand | |
| DH-33 | 18-18.5 | QTa | 4 | | | | | | | | | | | | | | | | |
| DH-33 | 23-24.5 | QTa | 6 | | | 100 | 100 | 98 | 97 | 94 | 85 | 69 | 61 | 55 | 49 | 40 | SM* | silty sand | |
| DH-33 | 32-33.5 | QTa | 9 | | | | | | | | | | | | | | | | |
| DH-33 | 37-38.5 | QTa | 7 | | | 100 | 100 | 100 | 99 | 93 | 86 | 75 | 67 | 63 | 55 | 43 | SM* | silty sand | |
| DH-35 | 4.5-6 | Qld | 25 | | | 100 | 100 | 100 | 100 | 98 | 97 | 95 | 94 | 93 | 91 | 86 | CL* | clay | |
| DH-35 | 5-6.5 | Qld | 10 | | | | | | | | | | | | | | | | |
| DH-35 | 8-9.5 | Qld | 8 | | | | | | | | | | | | | | | | |
| DH-35 | 9.5-11 | Qld | 13 | | | 100 | 97 | 97 | 96 | 95 | 95 | 94 | 94 | 91 | 79 | 57 | ML* | sandy silt | |
| DH-35 | 15-16.5 | Qld | 18 | | | | | | | | | | | | | | | | |
| DH-35 | 20-21.5 | Qld | 32 | | | | | | | | | | | | | | | | |
| DH-35 | 25-26.5 | Qld | 16 | | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 94 | 69 | 27 | SP* | sand | |
| DH-35 | 28-28.5 | Qld | 14 | | | | | | | | | | | | | | | | |
| DH-35 | 35-36.5 | Qld | 30 | | | 100 | 100 | 100 | 100 | 96 | 94 | 93 | 93 | 93 | 90 | 84 | CL* | clay with sand | |
| DH-35 | 43.5-45 | Qld | 17 | | | | | | | | | | | | | | | | |
| DH-35 | 48.5-50 | Qld | 28 | | | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 97 | 97 | 95 | 90 | CL* | clay | |
| DH-35 | 53 | Qld | 25 | | | | | | | | | | | | | | | | |
| DH-35 | 59.5-61 | Qld | 22 | | | 100 | 100 | 100 | 100 | 99 | 99 | 97 | 95 | 93 | 86 | 69 | CL* | sandy clay | |

*USCS designation based on estimated plasticity.

Laboratory Test Data for Soil Units. NP = nonplastic

| Sample No. | Depth of Sample (ft) | Eng. Geo. Unit | Moisture Content (%) | Atterberg Limits |  | Sieve Analysis (% Passing) |  |  |  |  |  |  |  |  |  |  | USCS SOIL DESCRIPTION |  | AASHTO SOIL DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | LL | PI | 1/2" | 3/8" | 1/4" | No. 4 | No. 20 | No. 40 | No. 60 | No. 80 | No. 100 | No. 140 | No. 200 | GROUP SYMBOL | GROUP NAME |  |
| DH-36 | 17.5-19 | Qao | 7 |  |  | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 97 | 92 | 76 | CL* | clay with sand |  |
| DH-36 | 20-21.5 | Qao | 6 |  |  | 100 | 100 | 100 | 99 | 92 | 86 | 79 | 76 | 71 | 64 | 48 | SM* | silty sand |  |
| DH-36 | 25.5-27 | Qao | 9 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| DH-36 | 30-31.5 | Qao | 11 |  |  | 89 | 83 | 83 | 83 | 83 | 83 | 82 | 81 | 81 | 75 | 62 | CL* | sandy clay |  |
| DH-36 | 33-34.5 | Qao | 11 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| DH-36 | 38-38.5 | Qao | 5 |  |  | 100 | 100 | 95 | 91 | 52 | 32 | 22 | 21 | 19 | 16 | 12 | SP-SM* | sand with silt |  |
| DH-36 | 43-44.5 | Qao | 30 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| DH-36 | 53-54.5 | Qao | 15 |  |  | 100 | 100 | 100 | 100 | 99 | 99 | 99 | 98 | 98 | 96 | 92 | CL* | clay |  |
| DH-38 | 3-4.5 | QTa | 12 |  |  | 100 | 100 | 92 | 90 | 82 | 77 | 64 | 54 | 49 | 43 | 35 | SM* | silty sand |  |
| DH-38 | 8-9.5 | QTa | 4 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| DH-38 | 13-14.5 | QTa | 6 |  |  | 100 | 100 | 100 | 96 | 95 | 94 | 82 | 69 | 62 | 53 | 39 | SM* | silty sand |  |
| DH-38 | 18-19.5 | QTa | 5 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| DH-38 | 23-24.5 | QTa | 7 |  |  | 100 | 98 | 88 | 82 | 64 | 59 | 50 | 43 | 39 | 34 | 26 | SM* | silty sand |  |
| DH-38 | 28-29.5 | QTa | 7 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| DH-38 | 33-34.5 | QTa | 9 |  |  | 100 | 98 | 92 | 89 | 83 | 81 | 70 | 57 | 49 | 38 | 24 | SM* | silty sand |  |
| DH-38 | 43-44.5 | QTa | 9 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| DH-38 | 73-74.5 | QTa | 3 |  |  | 100 | 87 | 81 | 78 | 66 | 64 | 47 | 35 | 30 | 23 | 18 | SC* | clayey sand |  |
| DH-38 | 98-99.5 | QTa | 6 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| DH-38 | 108-109.5 | QTa | 6 |  |  | 100 | 100 | 100 | 99 | 98 | 98 | 92 | 85 | 78 | 62 | 42 | SM* | silty sand |  |
| DH-39 | 3-4.5 | QTa | 19 |  |  | 100 | 100 | 100 | 98 | 97 | 97 | 96 | 96 | 96 | 93 | 82 | CL-ML* | silty clay |  |
| DH-39 | 8-8.5 | QTa | 8 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| DH-39 | 13-13.5 | QTa | 2 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

*USCS designation based on estimated plasticity.

Laboratory Test Data for Soil Units. NP = nonplastic

| Sample No. | Depth of Sample (ft) | Eng. Geo. Unit | Moisture Content (%) | Atterberg Limits | | Sieve Analysis (% Passing) | | | | | | | | | | | USCS SOIL DESCRIPTION | | AASHTO SOIL DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LL | PI | 1/2" | 3/8" | 1/4" | No. 4 | No. 20 | No. 40 | No. 60 | No. 80 | No. 100 | No. 140 | No. 200 | GROUP SYMBOL | GROUP NAME | |
| DH-40 | 5-6.5 | Qld | 9 | | | 100 | 100 | 100 | 100 | 99 | 99 | 97 | 96 | 94 | 87 | 70 | ML* | sandy silt | |
| DH-40 | 10-11.5 | Qld | 11 | | | | | | | | | | | | | | | | |
| DH-40 | 14.5-15.5 | Qld | 16 | | | 100 | 100 | 100 | 100 | 100 | 99 | 97 | 96 | 95 | 89 | 78 | CL-ML* | silty clay | |
| DH-40 | 18-18.5 | Qld | 13 | | | | | | | | | | | | | | | | |
| DH-40 | 18.5-20 | Qld | 10 | | | | | | | | | | | | | | | | |
| DH-40 | 23-24.5 | Qld | 20 | | | 94 | 89 | 80 | 79 | 75 | 74 | 74 | 74 | 74 | 74 | 72 | CL* | gravelly clay | |
| DH-40 | 28-29.5 | Qld | 14 | | | | | | | | | | | | | | | | |
| DH-40 | 33-34.5 | Qld | 11 | | | 100 | 100 | 100 | 100 | 98 | 93 | 87 | 83 | 79 | 70 | 52 | ML* | sandy silt | |
| DH-40 | 38.5 | Qld | 12 | | | | | | | | | | | | | | | | |
| DH-40 | 38-39.5 | Qld | 21 | | | | | | | | | | | | | | | | |
| DH-40 | 43-44.5 | Qld | 19 | | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 95 | CL-ML* | silty clay | |
| DH-40 | 48-49.5 | Qld | 21 | | | | | | | | | | | | | | | | |
| DH-40 | 55-56.5 | Qld | 18 | | | 100 | 100 | 100 | 97 | 69 | 66 | 61 | 57 | 53 | 40 | 24 | SC* | clayey sand | |
| DH-40 | 58-59.5 | Qld | 18 | | | | | | | | | | | | | | | | |
| DH-40 | 63-64.5 | Qld | 24 | | | 100 | 100 | 96 | 94 | 90 | 88 | 86 | 85 | 84 | 80 | 74 | CL* | clay with sand | |
| BH-1 | 4 | QTa | 9 | 35 | 10 | 100 | 100 | 100 | 100 | 99 | 97 | 95 | 93 | 91 | 86 | 73 | ML | silt with sand | A-4(7) |
| BH-1 | 6.6 | QTa | 6 | NP | NP | 100 | 94 | 91 | 89 | 77 | 74 | 72 | 71 | 68 | 58 | 48 | SM | silty sand | A-4(0) |
| BH-1 | 8.2 | QTa | 10 | 27 | 5 | 100 | 100 | 100 | 100 | 100 | 99 | 97 | 96 | 92 | 69 | 47 | SM | silty sand | A-4(0) |
| BH-1 | 9.4 | QTa | 9 | 26 | 4 | 100 | 100 | 100 | 100 | 99 | 98 | 97 | 96 | 91 | 75 | 53 | CL-ML | silty clay | A-4(0) |
| BH-2 | 1.2 | QTa | 19 | 26 | 6 | 100 | 100 | 100 | 100 | 99 | 96 | 92 | 84 | 74 | 62 | 43 | SM-SC | clayey sand with silt | A-4(0) |
| BH-2 | 3 | QTa | 11 | 37 | 13 | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 98 | 96 | 93 | 86 | CL | clay | A-6(12) |
| BH-2 | 5.5 | QTa | 7 | 36 | 9 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 96 | 92 | 87 | 80 | ML | silt with sand | A-4(7) |
| BH-2 | 6.9 | QTa | 10 | 30 | 8 | 100 | 100 | 100 | 100 | 100 | 100 | 89 | 79 | 70 | 53 | 28 | SC | clayey sand | A-4(0) |
| BH-2 | 7 | QTa | 10 | 26 | 6 | 100 | 100 | 100 | 100 | 99 | 98 | 96 | 94 | 91 | 85 | 70 | CL-ML | silty clay | A-4(2) |
| BH-2 | 11.5 | QTa | 7 | 21 | NP | 72 | 72 | 70 | 70 | 68 | 65 | 61 | 55 | 49 | 39 | 26 | SM | silty sand with gravel | A-6(0) |

*USCS designation based on estimated plasticity.

*Laboratory Test Data for Soil Units. NP = nonplastic*

| Sample No. | Depth of Sample (ft) | Eng. Geo. Unit | Moisture Content (%) | Atterberg Limits | | Sieve Analysis (% Passing) | | | | | | | | | | | USCS SOIL DESCRIPTION | | AASHTO SOIL DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LL | PI | 1/2" | 3/8" | 1/4" | No. 4 | No. 20 | No. 40 | No. 60 | No. 80 | No. 100 | No. 140 | No. 200 | GROUP SYMBOL | GROUP NAME | |
| BH-3 | 0.4 | Qld | 10 | 20 | NP | 100 | 100 | 100 | 100 | 98 | 88 | 73 | 62 | 52 | 34 | 19 | SM | silty sand | A-2-4(0) |
| BH-3 | 1 | Qld | 12 | 19 | NP | 100 | 100 | 100 | 100 | 99 | 96 | 85 | 78 | 70 | 55 | 37 | SM | silty sand | A-4(0) |
| BH-3 | 3 | Qld | 10 | 19 | NP | 100 | 100 | 100 | 100 | 92 | 83 | 71 | 58 | 41 | 32 | 23 | SM | silty sand | A-2-4(0) |
| BH-3 | 5 | Qld | 3 | NP | NP | 100 | 100 | 100 | 100 | 71 | 28 | 10 | 7 | 6 | 4 | 2 | SP | sand | A-1-b(0) |
| BH-3 | 7.8 | Qld | 13 | 34 | NP | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 98 | 97 | 91 | 81 | CL | clay with sand | A-6(1) |
| BH-4 | 1 | Qay | 12 | NP | NP | 100 | 100 | 100 | 100 | 97 | 94 | 84 | 78 | 71 | 59 | 44 | SM | silty sand | A-4(0) |
| BH-4 | 3 | Qay | 3 | NP | NP | 100 | 100 | 100 | 100 | 97 | 94 | 85 | 71 | 63 | 54 | 36 | SM | silty sand | A-4(0) |
| BH-4 | 4.4 | Qay | 5 | NP | NP | 61 | 60 | 49 | 42 | 24 | 19 | 14 | 13 | 11 | 9 | 8 | GW-GM | gravel with silt | A-1-a(0) |
| BH-4 | 4.6 | Qay | 6 | NP | NP | 100 | 100 | 100 | 100 | 100 | 100 | 96 | 86 | 77 | 53 | 18 | SM | silty sand | A-2-4(0) |
| BH-4 | 5 | Qay | 12 | 28 | 4 | 100 | 100 | 100 | 100 | 90 | 88 | 85 | 84 | 82 | 69 | 51 | ML | sandy silt | A-4(0) |
| BH-4 | 6.6 | Qay | 12 | 24 | 8 | 100 | 100 | 100 | 100 | 98 | 96 | 94 | 92 | 90 | 83 | 71 | CL | clay with sand | A-4(3) |
| BH-5 | 1 | Qld | 21 | 26 | 6 | 100 | 100 | 100 | 100 | 96 | 95 | 94 | 92 | 89 | 80 | 69 | CL-ML | silty clay with sand | A-4(2) |
| BH-5 | 4 | Qld | 11 | 21 | 4 | 100 | 100 | 100 | 100 | 98 | 98 | 95 | 94 | 93 | 89 | 75 | CL-ML | silty clay with sand | A-4(1) |
| BH-5 | 6.8 | Qld | 8 | 23 | 3 | 100 | 100 | 100 | 100 | 98 | 97 | 97 | 96 | 96 | 93 | 87 | ML | silt | A-4(1) |
| BH-6 | 0.2 | Qld | 12 | 27 | 8 | 100 | 100 | 100 | 100 | 99 | 92 | 84 | 81 | 79 | 75 | 65 | CL | sandy clay | A-4(3) |
| BH-6 | 1.8 | Qld | 21 | NP | NP | 100 | 100 | 100 | 100 | 99 | 98 | 96 | 94 | 87 | 43 | 19 | SM | silty sand | A-2-4(0) |
| BH-6 | 3.2 | Qld | 4 | 26 | 6 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 96 | 90 | 71 | CL-ML | silty clay with sand | A-4(2) |
| BH-6 | 4.6 | Qld | 5 | 24 | 0 | 100 | 100 | 100 | 100 | 95 | 90 | 87 | 84 | 82 | 74 | 48 | SM | silty sand | A-4(0) |
| BH-6 | 5.4 | Qld | 4 | 29 | 11 | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 98 | 93 | 59 | 28 | SC | clayey sand | A-2-6(0) |
| BH-6 | 6 | Qld | | | | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 98 | 88 | ML * | silt | |
| BH-6 | 6.5 | Qld | 10 | NP | NP | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 97 | 94 | 72 | 30 | SM | silty sand | A-2-4(0) |
| BH-6 | 7.3 | Qld | 8 | 24 | 6 | 100 | 100 | 100 | 100 | 100 | 99 | 98 | 97 | 95 | 90 | 57 | CL-ML | silty clay with sand | A-4(1) |
| BH-6 | 7.9 | Qld | 11 | NP | NP | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 96 | 75 | 32 | SM | silty sand | A-2-4(0) |
| BH-6 | 8.4 | Qld | 5 | 30 | 12 | 100 | 100 | 100 | 100 | 100 | 99 | 97 | 95 | 75 | 71 | 54 | CL | sandy clay | A-6(4) |
| BH-6 | 9 | Qld | 15 | 22 | NP | 100 | 100 | 100 | 100 | 100 | 98 | 95 | 89 | 76 | 48 | 32 | SM | silty sand | A-2-4(0) |

*USCS designation based on estimated plasticity.

Laboratory Test Data for Soil Units. NP = nonplastic

| Sample No. | Depth of Sample (ft) | Eng. Geo. Unit | Moisture Content (%) | Atterberg Limits | | Sieve Analysis (% Passing) | | | | | | | | | | | USCS SOIL DESCRIPTION | | AASHTO SOIL DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LL | PI | 1/2" | 3/8" | 1/4" | No. 4 | No. 20 | No. 40 | No. 60 | No. 80 | No. 100 | No. 140 | No. 200 | GROUP SYMBOL | GROUP NAME | |
| BH-7 | 0.4 | Qld | 12 | 25 | NP | 100 | 100 | 100 | 100 | 100 | 100 | 96 | 93 | 91 | 86 | 44 | SM | silty sand | A-4(0) |
| BH-7 | 2.9 | Qld | 14 | 24 | NP | 100 | 100 | 100 | 100 | 100 | 100 | 97 | 93 | 89 | 77 | 50 | ML | sandy silt | A-4(0) |
| BH-7 | 3.9 | Qld | 6 | 26 | NP | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 98 | 95 | 67 | 25 | SM | silty sand | A-2-4(0) |
| BH-7 | 5.2 | Qld | 21 | 21 | NP | 100 | 100 | 100 | 100 | 100 | 100 | 98 | 94 | 84 | 72 | 50 | ML | sandy silt | A-4(0) |
| BH-7 | 6.3 | Qld | 8 | 27 | NP | 100 | 100 | 100 | 100 | 100 | 100 | 98 | 95 | 92 | 86 | 85 | ML | silt with sand | A-4(0) |
| BH-7 | 6.7 | Qld | 17 | 39 | 16 | 100 | 100 | 100 | 100 | 99 | 98 | 97 | 96 | 96 | 96 | 93 | CL | clay | A-4(16) |
| BH-7 | 7.3 | Qld | 3 | 23 | NP | 100 | 100 | 100 | 100 | 100 | 100 | 98 | 94 | 80 | 62 | 45 | SM | silty sand | A-4(0) |
| BH-7 | 7.7 | Qld | 8 | 35 | 16 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 99 | 97 | 86 | CL | clay | A-6(13) |
| BH-7 | 8.1 | Qld | 8 | 22 | NP | 100 | 100 | 100 | 100 | 100 | 97 | 90 | 76 | 56 | 37 | 19 | SM | silty sand | A-3(0) |
| BH-8 | 1.2 | Qao | 20 | 27 | 5 | 100 | 100 | 100 | 100 | 100 | 100 | 97 | 91 | 85 | 66 | 65 | ML | sandy silt | A-4(2) |
| BH-8 | 4.6 | Qao | 16 | 38 | 18 | 100 | 100 | 100 | 100 | 100 | 100 | 89 | 78 | 68 | 48 | 33 | SC | clayey sand | A-2-6(1) |
| BH-8 | 6 | Qao | 16 | 33 | 8 | 100 | 100 | 100 | 100 | 100 | 100 | 91 | 82 | 74 | 55 | 54 | ML | sandy silt | A-4(2) |
| BH-8 | 8.6 | Qao | 12 | 31 | 8 | 100 | 100 | 100 | 100 | 100 | 100 | 90 | 80 | 72 | 56 | 51 | ML | sandy silt | A-4(2) |
| BH-9 | 0.6 | Qao | 60 | 29 | 9 | 67 | 67 | 67 | 67 | 51 | 49 | 48 | 47 | 45 | 41 | 34 | SC | clayey sand with gravel | A-2-4(0) |
| BH-9 | 2.4 | Qao | 6 | 33 | 4 | 74 | 72 | 66 | 62 | 39 | 35 | 32 | 30 | 28 | 26 | 22 | SM | silty sand with gravel | A-1-b(0) |
| BH-9 | 7.2 | Qao | 2 | NP | NP | 55 | 47 | 41 | 39 | 14 | 5 | 3 | 2 | 2 | 2 | 2 | GP | gravel with sand | A-1-a(0) |
| BH-9 | 9.2 | Qao | 9 | 30 | 4 | 100 | 98 | 96 | 95 | 87 | 73 | 60 | 53 | 49 | 46 | 39 | SM | silty sand | A-4(0) |

Laboratory Test Data for Soil Units. NP = nonplastic

| Sample No. | Depth of Sample (ft) | Eng. Geo. Unit | Moisture Content (%) | Atterberg Limits | | Sieve Analysis (% Passing) | | | | | | | | | | | USCS SOIL DESCRIPTION | | AASHTO SOIL DESCRIPTION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LL | PI | 1/2" | 3/8" | 1/4" | No. 4 | No. 20 | No. 40 | No. 60 | No. 80 | No. 100 | No. 140 | No. 200 | GROUP SYMBOL | GROUP NAME | |
| BH-10 | 0.5 | QTa | 12 | | | | | | | | | | | | | | SM** | silty sand | |
| BH-10 | 1.8 | QTa | 14 | | | | | | | | | | | | | | CL-ML** | silty clay | |
| BH-10 | 2.5 | QTa | 12 | | | | | | | | | | | | | | CL-ML** | silty clay | |
| BH-10 | 4a* | QTa | 17 | | | | | | | | | | | | | | ML** | silt | |
| BH-10 | 4b* | QTa | 13 | | | | | | | | | | | | | | ML** | silt | |
| BH-10 | 6.5 | QTa | 4 | | | | | | | | | | | | | | SP-SM** | silty sand | |
| BH-10 | 7 | QTa | 10 | | | | | | | | | | | | | | ML/SM** | silt/silty sand | |
| BH-10 | 7.25 | QTa | 4 | | | | | | | | | | | | | | SP** | sand | |
| BH-10 | 8.5 | QTa | 4 | | | | | | | | | | | | | | GP-GW** | gravel | |
| BH-10 | 9.5 | QTa | 7 | | | | | | | | | | | | | | CL** | clay | |
| BH-10 | 10 | QTa | 5 | | | | | | | | | | | | | | fault gouge | | |
| BH-10 | 9.25-10.75 | QTa | 15 | | | | | | | | | | | | | | CL** | clay | |
| BH-10 | 10.75 | QTa | 4 | | | | | | | | | | | | | | SP** | sand | |

*BH-10 4a located at station 12; BH-10 4b located at station 37.

**USCS designation assigned in the field.

# APPENDIX IV

## Standard penetration test (SPT) results

| Drill Hole Number | Depth of Sample (ft) | Eng. Geo. Unit | USCS GROUP SYMBOL | USCS GROUP NAME | N-Value (blows/ft) | Consistency (cohesive soils)*/ Compactness (cohesionless soils)* |
|---|---|---|---|---|---|---|
| DH-1 | 2 | Qay | CL-ML | silty clay | 15 | Stiff/Very Stiff |
| DH-1 | 5 | QTa | ML | silt with sand | 8 | Loose |
| DH-1 | 8 | QTa | SW-SM | sand with silt | 25 | Medium Dense |
| DH-1 | 14 | QTa | CL-ML | silty clay | 20 | Very Stiff |
| DH-2 | 4-5.5 | QTa | SM | silty sand | 6 | Loose |
| DH-2 | 9-10.5 | QTa | CH | clay | 27 | Very Stiff |
| DH-2 | 19-20.5 | QTa | SM-SC | clayey sand with silt | 26 | Medium Dense |
| DH-2 | 29-30.5 | QTa | SC | clayey sand | 27 | Medium Dense |
| DH-2 | 39-40.5 | QTa | CL | clay | 25 | Very Stiff |
| DH-3 | 9-10.5 | Qao | SM | silty sand | 21 | Medium Dense |
| DH-3 | 19-20.5 | Qao | SP | sand with gravel | >50 | Very Dense |
| DH-3 | 29-30.5 | Qao | CL | sandy clay | 30 | Very Stiff/Hard |
| DH-3 | 44-45.5 | Qao | SC | clayey sand | -- | -- |
| DH-4 | 4-5 | QTa | SC | clayey sand | 14 | Medium Dense |
| DH-4 | 9-10 | QTa | SM | silty sand | 9 | Loose |
| DH-4 | 19-20 | QTa | SM-SC | clayey sand with silt | 29 | Medium Dense |
| DH-4 | 29-30 | QTa | SC | clayey sand | 39 | Dense |
| DH-5 | 4-5 | QTa | SC | clayey sand | 30 | Medium Dense/Dense |
| DH-5 | 9-10 | QTa | SC | clayey sand | 36 | Dense |
| DH-6 | 4-5 | QTa | SM-SC | clayey sand with silt | 27 | Medium Dense |
| DH-6 | 9-9.5 | QTa | CL | clay with sand | >50 | Hard |
| DH-6 | 19-19.5 | QTa | CH | clay | >50 | Hard |

*After Low and Zaccheo, 1975.

Standard Penetration Data. TSF = tons/sq ft

| Drill Hole Number | Depth of Sample (ft) | Eng. Geo. Unit | USCS GROUP SYMBOL | USCS GROUP NAME | N-Value (blows/ft) | Consistency (cohesive soils)*/ Compactness (cohesionless soils)* |
|---|---|---|---|---|---|---|
| DH-7 | 4-5 | QTa | SM-SC | clayey sand with silt | 41 | Dense |
| DH-7 | 9-10 | QTa | SM | silty sand | 13 | Medium Dense |
| DH-7 | 19-20 | QTa | SM | silty sand | >50 | Very Dense |
| DH-7 | 29-30 | QTa | SM | silty sand | >50 | Very Dense |
| DH-8 | 4-5 | QTa | SM-SC | clayey sand with silt | 25 | Medium Dense |
| DH-8 | 9-10 | QTa | CL | sandy clay | 23 | Very Stiff |
| DH-8 | 19-20 | QTa | SM | silty sand | 28 | Medium Dense |
| DH-8 | 29-30 | QTa | SP-SM | sand with silt | 34 | Dense |
| DH-9 | 4-5 | Qld | CL-ML | silty clay | 12 | Stiff |
| DH-9 | 9-10 | Qld | SM-SC | clayey sand with silt | 15 | Medium Dense |
| DH-9 | 19-20 | Qld | SC | clayey sand | 25 | Medium Dense |
| DH-9 | 29-30 | Qld | CL | clay | 45 | Hard |
| DH-10 | 4-5 | Qld | SM | silty sand | 21 | Medium Dense |
| DH-10 | 9-10 | Qld | SM | silty sand | 36 | Dense |
| DH-10 | 19-20 | Qld | CL-ML | silty clay | 12 | Stiff |
| DH-10 | 29-30 | Qld | CL | clay | 32 | Hard |
| DH-11 | 4.5-5 | QTa | SM | silty sand | 22 | Medium Dense |
| DH-11 | 9-9.5 | QTa | ML | sandy silt | >50 | Very Dense |
| DH-11 | 19-20.5 | QTa | CL-ML | silty clay | 59 | Hard |
| DH-11 | 29-29.5 | QTa | CL | sandy clay | >50 | Hard |
| DH-12 | 4-5.5 | QTa | SM-SC | clayey sand with silt | 33 | Dense |
| DH-12 | 9-10.5 | QTa | SM-SC | clayey sand with silt | 19 | Medium Dense |
| DH-12 | 19-20.5 | QTa | SC | clayey sand | 20 | Medium Dense |

*After Low and Zaccheo, 1975.

Standard Penetration Data. TSF = tons/sq ft

| Drill Hole Number | Depth of Sample (ft) | Eng. Geo. Unit | USCS GROUP SYMBOL | USCS GROUP NAME | N-Value (blows/ft) | Consistency (cohesive soils)*/ Compactness (cohesionless soils)* |
|---|---|---|---|---|---|---|
| DH-13 | 4-5.5 | QTa | SM-SC | clayey sand with silt | 22 | Medium Dense |
| DH-13 | 9-10.5 | QTa | CL | clay | 22 | Very Stiff |
| DH-13 | 19-20.5 | QTa | CL-ML | silty clay | 17 | Very Stiff |
| DH-14 | 4-5.5 | QTa | CL | sandy clay | 23 | Very Stiff |
| DH-14 | 9-10.5 | QTa | CL | clay | 33 | Hard |
| DH-14 | 19-19.5 | QTa | CL | clay with sand | >50 | Hard |
| DH-15 | 4-5.5 | Qao | CH | sandy clay | 24 | Very Stiff |
| DH-15 | 9-9.5 | Qao | CH | clay | >50 | Hard |
| DH-15 | 19-20.25 | Qao | CH | clay | 48 | Hard |
| DH-15 | 29-29.5 |  | -- | -- | >50 | Hard |
| DH-16 | 4-4.5 | Qld | CL | clay | >50 | Hard |
| DH-16 | 9-9.83 | Qld | CL | clay | >50 | Hard |
| DH-17 | 4-4.5 | Qld | CL-ML | silty clay | 56 |  |
| DH-17 | 4.5-5.5 | Qld | ML | silt with sand | 56 | Very Dense |
| DH-17 | 9-10.5 | Qld | CL | clay | 24 | Very Stiff |
| DH-17 | 19-19.25 | Qld | -- | -- | 22 | -- |
| DH-17 | 19.25-20.5 | Qld | CH | clay | 22 | Very Stiff |
| DH-17 | 29-30.5 | Qld | CL | sandy clay | 26 | Very Stiff |
| DH-17 | 40 | Qld | CL | clay | -- | -- |

*After Low and Zaccheo, 1975.

Standard Penetration Data. TSF = tons/sq ft

| Drill Hole Number | Depth of Sample (ft) | Eng. Geo. Unit | USCS GROUP SYMBOL | USCS GROUP NAME | N-Value (blows/ft) | Consistency (cohesive soils)*/ Compactness (cohesionless soils)* |
|---|---|---|---|---|---|---|
| DH-18 | 4-5.5 | Qld | SM-SC | clayey sand with silt | 29 | Medium Dense |
| DH-18 | 9-9.75 | Qld | CL | clay with sand | 21 | Very Stiff |
| DH-18 | 9.75-10.5 | Qld | CL | clay | 21 | Very Stiff |
| DH-18 | 19-20 | Qld | SP-SM | sand with silt and gravel | 31 | Dense |
| DH-18 | 20-20.5 | Qld | CL | sandy clay | 31 | Hard |
| DH-18 | 29-30 | Qld | CH | clay | >50 | Hard |
| DH-19 | 4-4.5 | Qld | CL-ML | silty clay | >50 | Hard |
| DH-19 | 9-9.5 | Qld | CL | sandy clay | >50 | Hard |
| DH-19 | 19.0-19.5 | Qld | CL-ML | silty clay | >50 | Hard |
| DH-20 | 0-1.5 | Qld | CL | sandy clay | 9 | Stiff |
| DH-20 | 1.5-3 | Qld | CL | clay with sand | 14 | Stiff |
| DH-20 | 3-4.5 | Qld | ML | silt | 14 | Medium Dense |
| DH-20 | 4.5-6 | Qld | CL | clay with sand | 17 | Very Stiff |
| DH-20 | 6-7.5 | Qld | CL | clay with sand | 18 | Very Stiff |
| DH-20 | 7.5-9 | Qld | CL | clay with sand | 15 | Stiff/Very Stiff |
| DH-20 | 9-10.5 | Qld | CL | clay with sand | 18 | Very Stiff |
| DH-20 | 10.5-12 | Qld | CL | sandy clay | 15 | Stiff/Very Stiff |
| DH-20 | 12-13 | Qld | ML | silt | 13 | Medium Dense |
| DH-20 | 13-13.5 | Qld | CL | clay with sand | 13 | Stiff |
| DH-20 | 13.5-15 | Qld | CL | clay with sand | 19 | Very Stiff |
| DH-20 | 15-16.5 | Qld | CL | clay with sand | 21 | Very Stiff |
| DH-20 | 16.5-18 | Qld | CL | clay with sand | 32 | Hard |
| DH-20 | 18-19.5 | Qld | CH | clay | 14 | Stiff |
| DH-20 | 19.5-21 | Qld | CL | clay | 17 | Very Stiff |
| DH-20 | 21-22.5 | Qld | CL | clay | 14 | Stiff |
| DH-20 | 29-30.5 | Qld | CL | clay | 40 | Hard |

*After Low and Zaccheo, 1975.

Standard Penetration Data. TSF = tons/sq ft

| Drill Hole Number | Depth of Sample (ft) | Eng. Geo. Unit | USCS GROUP SYMBOL | USCS GROUP NAME | N-Value (blows/ft) | Consistency (cohesive soils)*/ Compactness (cohesionless soils)* |
|---|---|---|---|---|---|---|
| DH-21 | 4-5.5 | Qao | SM | silty sand | 18 | Medium Dense |
| DH-21 | 9-10.5 | Qao | SC | clayey sand | 25 | Medium Dense |
| DH-21 | 19-20.5 | Qao | SC | clayey sand | 26 | Medium Dense |
| DH-21 | 29-30.5 | Qao | CL | sandy clay | 33 | Hard |
| DH-22 | 4-5.5 | Qao | CL-ML | silty clay | 14 | Stiff |
| DH-22 | 9-10.5 | Qao | CL-ML | silty clay | 24 | Very Stiff |
| DH-22 | 19-20.5 | Qao | SM-SC | clayey sand with silt | 31 | Dense |
| DH-22 | 29-30.5 | Qao | SM | silty sand | 29 | Medium Dense |
| DH-23 | 4-5.5 | Qao | CL | clay with sand | 25 | Very Stiff |
| DH-23 | 9-10.5 | Qao | CL | sandy clay | 23 | Very Stiff |
| DH-23 | 19-20.5 | Qao | CL | clay | 32 | Hard |
| DH-23 | 29-30.5 | Qao | CL | clay with sand | 29 | Very Stiff |
| DH-24 | 4-5.5 | Qao | CL | clay | 23 | Very Stiff |
| DH-24 | 9-10.5 | Qao | CL | clay | 20 | Very Stiff |
| DH-24 | 19-20.5 | Qao | ML | silt with sand | 23 | Medium Dense |
| DH-24 | 29-30.5 | Qao | CL | sandy clay | 7 | Medium Stiff |
| DH-25 | 4-5.5 | Qao | SP-SM | sand with silt and gravel | 7 | Loose |
| DH-25 | 9-9.5 | Qao | SM-SC | clayey sand with silt | 29 | -- |
| DH-25 | 9.5-10.5 | Qao | CL | sandy clay | 29 | Very Stiff |
| DH-25 | 19-19.5 | Qao | CL | sandy clay | >50 | Hard |
| DH-25 | 20-20.5 | Qao | CL | sandy clay | >50 | Hard |
| DH-25 | 29-30.5 | Qao | SC | clayey sand with gravel | 28 | Medium Dense |

*After Low and Zaccheo, 1975.

Standard Penetration Data. TSF = tons/sq ft

| Drill Hole Number | Depth of Sample (ft) | Eng. Geo. Unit | USCS GROUP SYMBOL | USCS GROUP NAME | N-Value (blows/ft) | Consistency (cohesive soils)*/ Compactness (cohesionless soils)* |
|---|---|---|---|---|---|---|
| DH-26 | 4-5.5 | QTa | CL | sandy clay | 14 | Stiff |
| DH-26 | 9-9.5 | QTa | CL-ML | silty clay with sand | 20 | Very Stiff |
| DH-26 | 9.5-10.5 | QTa | CL | clay with sand | 20 | |
| DH-26 | 19-20.5 | QTa | CL | clay | 39 | Hard |
| DH-26 | 29-30.5 | QTa | CL | clay with sand | 19 | Very Stiff |
| DH-30 | 5-8 | Qay | SC | clayey sand | 15 | Medium Dense |
| DH-30 | 10-13 | Qay | SM | silty sand | 14 | Medium Dense |
| DH-30 | 15-18 | Qay | SM | silty sand | 22 | Medium Dense |
| DH-30 | 20-23 | Qay | SM-SC | clayey sand with silt | 17 | Medium Dense |
| DH-30 | 25-28 | Qay | SM | silty sand | 34 | Dense |
| DH-31 | 0-2 | QTa | | | >50 | |
| DH-31 | 2-7 | QTa | SM | silty sand with gravel | 33 | Very Dense |
| DH-31 | 7-12 | QTa | SM | silty sand | >50 | Very Dense |
| DH-31 | 12-17 | QTa | SM-SC | clayey sand with silt | >50 | Very Dense |
| DH-31 | 17-22 | QTa | SP | sand with gravel | >50 | Very Dense |
| DH-31 | 22-28 | QTa | SM | silty sand | >50 | Very Dense |
| DH-31 | 28-34 | QTa | SM | silty sand | >50 | Very Dense |
| DH-31 | 34-40 | QTa | SM/ML | silty sand/silt | >50 | Very Dense |
| DH-31 | 40-45 | QTa | SM | silty sand | >50 | Very Dense |
| DH-31 | 45-51 | QTa | SM | silty sand | >50 | Very Dense |
| DH-31 | 51-55 | QTa | SP | sand with gravel | >50 | Very Dense |
| DH-31 | 55-61 | QTa | SM | silty sand with gravel | >50 | Very Dense |

*After Low and Zaccheo, 1975.

Standard Penetration Data. TSF = tons/sq ft

| Drill Hole Number | Depth of Sample (ft) | Eng. Geo. Unit | USCS GROUP SYMBOL | USCS GROUP NAME | N-Value (blows/ft) | Consistency (cohesive soils)*/ Compactness (cohesionless soils)* |
|---|---|---|---|---|---|---|
| DH-33 | 5-8 | QTa | ML | sandy silt with gravel | 23 | Medium Dense |
| DH-33 | 8-13 | QTa | ML | sandy silt | 48 | Dense |
| DH-33 | 13-18 | QTa | SM | silty sand | 26 | Medium Dense |
| DH-33 | 18-23 | QTa | SM | silty sand with gravel | >50 | Very Dense |
| DH-33 | 23-28 | QTa | SM/ML | silty sand | 32 | Dense |
| DH-33 | 28-32 | QTa | | | >50 | |
| DH-33 | 32-37 | QTa | SM/ML | silty sand | >50 | Very Dense |
| DH-33 | 37-38.5 | QTa | ML | sandy silt with gravel | >50 | Very Dense |
| | | | | | | |
| DH-35 | 4.75-8 | Qld | CL | clay | 12 | stiff |
| DH-35 | 9.75-13 | Qld | SM | silty sand | 15 | Medium Dense |
| DH-35 | 15-18.5 | Qld | ML/SP | silt with sand at top | 7 | loose |
| DH-35 | 20.25-23.25 | Qld | CH | clay | 5 | Medium Stiff |
| DH-35 | 25-28.25 | Qld | SP | sand | 30 | Medium Dense/Dense |
| DH-35 | 35-38 | Qld | CH | clay | 15 | Stiff/Very Stiff |
| DH-35 | 43.5-45 | Qld | SM | silty sand | 22 | Medium Dense |
| DH-35 | 45-51 | Qld | CL/SM | clay | 23 | Very Stiff |
| DH-35 | 59.25-63 | Qld | CL | sandy clay | 30 | Very Stiff/Hard |
| | | | | | | |
| DH-36 | 5-8 | Qao | SM/CL | silty sand/lean clay | 15 | Stiff/Very Stiff |
| DH-36 | 8-9.5 | Qao | SM | silty sand | 14 | Medium Dense |
| DH-36 | 17.5-19 | Qao | CL/ML | lean clay/sandy silt | 36 | Hard |
| DH-36 | 18-22.5 | Qao | SM | silty sand | >50 | Hard |
| DH-36 | 22.5-28 | Qao | CL/ML | lean clay/sandy silt | 31 | Hard |
| DH-36 | 28-33 | Qao | CL/ML | lean clay/sandy silt | >50 | Hard |
| DH-36 | 33-38 | Qao | SP-SM | sand with silt | >50 | Very Dense |
| DH-36 | 38-43 | Qao | CL-ML | silty clay | >50 | Hard |
| DH-36 | 43-48 | Qao | CL | clay | 39 | Hard |
| DH-36 | 53-55 | Qao | CL | clay | >50 | Hard |
| | | Qao | | | | |

*After Low and Zaccheo, 1975.

Standard Penetration Data. TSF = tons/sq ft

| Drill Hole Number | Depth of Sample (ft) | Eng. Geo. Unit | USCS GROUP SYMBOL | USCS GROUP NAME | N-Value (blows/ft) | Consistency (cohesive soils)*/ Compactness (cohesionless soils)* |
|---|---|---|---|---|---|---|
| DH-38 | 3-8 | QTa | SM | silty sand | 9 | Loose |
| DH-38 | 8-13 | QTa | ML | sandy silt with gravel | 38 | Dense |
| DH-38 | 13-18 | QTa | SM | silty sand | 46 | Dense |
| DH-38 | 18-23 | QTa | SP | sand with gravel | >50 | Very Dense |
| DH-38 | 23-28 | QTa | SM | silty sand | >50 | Very Dense |
| DH-38 | 28-33 | QTa | SP-SM | sand with silt | >50 | Very Dense |
| DH-38 | 33-38 | QTa | ML/CL | sandy silt/silty clay | >50 | Hard |
| DH-38 | 38-43 | QTa | | | >50 | |
| DH-38 | 43-73 | QTa | SP | sand | >50 | Very Dense |
| DH-38 | 73-98 | QTa | SP | sand with gravel | >50 | Very Dense |
| DH-38 | 98-108 | QTa | SM | silty sand | 44 | Dense |
| DH-38 | 108-109.5 | QTa | SM/SP | silty sand to sand | >50 | Very Dense |
| DH-39 | 3-8 | QTa | ML/CL | sandy silt/silty clay | 11 | Stiff |
| DH-39 | 8-13 | QTa | CL-ML | silty clay | >50 | Hard |

*After Low and Zaccheo, 1975.

Standard Penetration Data. TSF = tons/sq ft

| Drill Hole Number | Depth of Sample (ft) | Eng. Geo. Unit | USCS GROUP SYMBOL | USCS GROUP NAME | N-Value (blows/ft) | Consistency (cohesive soils)*/ Compactness (cohesionless soils)* |
|---|---|---|---|---|---|---|
| DH-40 | 5-8 | Qld | ML | sandy silt | 9 | Loose |
| DH-40 | 10-13 | Qld | ML/SM | sandy silt/silty sand | 28 | Medium Dense |
| DH-40 | 14.25-18 | Qld | CL-ML | silty clay with sand | 18 | Very Stiff |
| DH-40 | 18.5-23 | Qld | ML/CL | sandy silt/silty clay | 28 | Medium Dense/Very Stiff |
| DH-40 | 23-28 | Qld | CL | clay | 22 | Very Stiff |
| DH-40 | 28-33 | Qld | SP-SM | sand with silt | 41 | Dense |
| DH-40 | 33-38 | Qld | SP | sand | 41 | Dense |
| DH-40 | 38-43 | Qld | CH | clay | 29 | Very Stiff |
| DH-40 | 43-48 | Qld | CL-ML | silty clay | 23 | Very Stiff |
| DH-40 | 48-53 | Qld | SP/ML | sand | 22 | Medium Dense |
| DH-40 | 55-58 | Qld | SM-SC | clayey sand with silt | 26 | Medium Dense |
| DH-40 | 58-63 | Qld | SM/ML | silty sand/sandy silt | 27 | Medium Dense |
| DH-40 | 63-68 | Qld | ML/CL | sandy silt/clay | 31 | Dense/Hard |
| DH-40 | 68-69.5 | Qld | GW | gravel with sand | >50 | Very Dense |

*After Low and Zaccheo, 1975.

# APPENDIX V

## Laboratory test data for rock

| Drill Hole Number | Depth of Sample (ft) | Geologic Unit | Lithology | Diametral PLSI (MPa)* |
|---|---|---|---|---|
| DH-27 | 6 | Pg | sandstone | 5.66 |
| DH-27 | 6 | Pg | sandstone | 5.95 |
| DH-27 | 6 | Pg | sandstone | 2.99 |
| DH-27 | 6 | Pg | sandstone | 4.74 |
| DH-27 | 6 | Pg | sandstone | 4.91 |
| DH-27 | 13.5 | Pg | sandstone | 4.08 |
| DH-27 | 13.5 | Pg | sandstone | 4.08 |
| DH-27 | 13.5 | Pg | sandstone | 3.58 |
| DH-27 | 19 | Pg | sandstone | 5.90 |
| DH-27 | 32 | Pg | sandstone | 2.69 |
| DH-27 | 32 | Pg | sandstone | 3.06 |
| DH-27 | 44 | Pg | sandstone | 4.42 |
| DH-27 | 47 | Pg | sandstone | 4.42 |
| DH-27 | 47 | Pg | sandstone | 5.02 |
| DH-27 | 47 | Pg | sandstone | 4.59 |
| DH-27 | 47 | Pg | sandstone | 4.25 |
| DH-27 | 55 | Pg | sandstone | 4.23 |
| DH-27 | 55 | Pg | sandstone | 3.05 |
| DH-27 | 55 | Pg | sandstone | 3.89 |
| DH-27 | 62 | Pg | sandstone | 3.74 |
| DH-27 | 62 | Pg | sandstone | 4.42 |
| DH-27 | 69 | Pg | sandstone | 5.66 |
| DH-27 | 79 | Pg | sandstone | 4.25 |
| DH-27 | 79 | Pg | sandstone | 3.59 |
| DH-27 | 79 | Pg | sandstone | 4.57 |
| DH-27 | 85 | Pg | sandstone | 6.29 |
| DH-27 | 85 | Pg | sandstone | 5.12 |
| DH-27 | 89 | Pg | sandstone | 7.28 |
| DH-27 | 92 | Pg | sandstone | 4.66 |
| DH-27 | 92 | Pg | sandstone | 3.50 |
| DH-27 | 92 | Pg | sandstone | 4.31 |
| DH-27 | 101 | Pg | sandstone | 4.13 |
| DH-27 | 101 | Pg | sandstone | 2.81 |
| DH-27 | 112 | Pg | sandstone | 4.25 |
| DH-27 | 112 | Pg | sandstone | 4.34 |
| DH-27 | 112 | Pg | sandstone | 4.51 |
| DH-27 | 116 | Pg | sandstone | 4.00 |
| DH-27 | 116 | Pg | sandstone | 3.33 |
| DH-27 | 124 | Pg | sandstone | 2.50 |
| DH-27 | 124 | Pg | sandstone | 4.58 |
| DH-27 | 124 | Pg | sandstone | 4.41 |
| DH-27 | 128 | Pg | sandstone | 3.71 |
| DH-27 | 128 | Pg | sandstone | 3.23 |
| DH-27 | 135 | Pg | sandstone | 3.51 |
| DH-27 | 145 | Pg | sandstone | 3.79 |
| DH-27 | 145 | Pg | sandstone | 4.05 |
| DH-27 | 145 | Pg | sandstone | 4.23 |
| DH-29 | 41.5 | Pg | sandstone | 2.31 |
| DH-29 | 45 | Pg | sandstone | 4.51 |
| DH-29 | 45 | Pg | sandstone | 3.07 |
| DH-29 | 121.5 | Pg | sandstone | 2.55 |
| DH-29 | 122 | Pg | sandstone | 2.63 |
| DH-29 | 133 | Pg | sandstone | 4.79 |
| DH-29 | 173 | Pg | sandstone | 5.42 |
| | | | | |
| DH-32 | 44.5 | Km | shale | 0.49 |
| DH-32 | 46.5 | Km | shale | 0.42 |
| DH-32 | 50.5 | Km | shale | 0.49 |

*1MPa = 10.44 tons/sq ft

| Number | Sample (ft) | Unit | Lithology | PLSI (MPa*) |
|---|---|---|---|---|
| DH-39 | 14.5 | Pm | limestone | 4.00 |
| DH-39 | 17 | Pm | limestone | 2.39 |
| DH-39 | 22.5 | Pm | limestone | 3.83 |
| DH-39 | 22.5 | Pm | limestone | 3.33 |
| DH-39 | 32.5 | Pm | limestone | 6.60 |
| DH-39 | 32.5 | Pm | limestone | 4.38 |
| DH-39 | 39.5 | Pm | limestone | 7.83 |
| DH-39 | 39.5 | Pm | limestone | 5.16 |
| DH-39 | 39.5 | Pm | limestone | 5.33 |
| DH-39 | 54 | Pm | limestone | 4.94 |
| DH-39 | 54 | Pm | limestone | 3.80 |
| DH-39 | 54 | Pm | limestone | 4.78 |
| DH-39 | 59 | Pm | limestone | 6.11 |
| DH-39 | 59 | Pm | limestone | 3.16 |
| DH-39 | 59.5 | Pm | limestone | 4.94 |
| DH-39 | 59.5 | Pm | limestone | 3.50 |
| DH-39 | 59.5 | Pm | limestone | 4.17 |
| DH-39 | 62 | Pm | limestone | 6.25 |
| DH-39 | 62 | Pm | limestone | 4.78 |
| DH-39 | 66 | Pm | limestone | 5.76 |
| DH-39 | 66 | Pm | limestone | 4.45 |
| DH-39 | 66 | Pm | limestone | 2.61 |
| DH-39 | 72.5 | Pm | limestone | 4.80 |
| DH-39 | 72.5 | Pm | limestone | 4.14 |
| DH-39 | 79.5 | Pm | limestone | 6.58 |
| DH-39 | 85.5 | Pm | limestone | 5.61 |
| DH-39 | 85.5 | Pm | limestone | 3.72 |
| DH-39 | 85.5 | Pm | limestone | 4.71 |

| Number | Depth of Sample (ft) | Geologic Unit | Lithology | Diametral PLSI (MPa*) |
|---|---|---|---|---|
| DH-39 | 89.5 | Pm | limestone | 6.33 |
| DH-39 | 90 | Pm | limestone | 5.93 |
| DH-39 | 90 | Pm | limestone | 3.79 |
| DH-39 | 126 | Pm | limestone | 5.76 |
| DH-39 | 126 | Pm | limestone | 5.10 |
| DH-39 | 126 | Pm | limestone | 5.12 |
| DH-39 | 147 | Pm | limestone | 5.54 |
| DH-39 | 147 | Pm | limestone | 4.84 |
| DH-39 | 147 | Pm | limestone | 4.50 |
| | | | | |
| DH-29 | 281.5 | Py | sandstone | 1.64 |
| DH-29 | 289 | Py | sandstone | 0.74 |
| DH-29 | 354 | Py | sandstone | 0.93 |
| DH-37 | 120 | Py | sandstone | 1.24 |
| DH-37 | 120 | Py | sandstone | 1.24 |
| DH-37 | 120 | Py | sandstone | 0.82 |
| DH-37 | 127.5 | Py | sandstone | 1.81 |
| DH-37 | 127.5 | Py | sandstone | 2.51 |
| DH-37 | 127.5 | Py | sandstone | 1.97 |
| | | | | |
| DH-30 | 59.5 | Trd | mudstone | 0.73 |
| DH-30 | 59.5 | Trd | mudstone | 0.72 |
| DH-30 | 66.5 | Trd | sandstone | 0.69 |
| DH-30 | 69 | Trd | mudstone | 0.98 |
| DH-30 | 69 | Trd | mudstone | 0.97 |
| DH-30 | 72 | Trd | mudstone | 1.08 |
| DH-30 | 72 | Trd | mudstone | 0.89 |
| DH-30 | 74 | Trd | mudstone | 0.92 |

*1MPa = 10.44 tons/sq ft

| Drill Hole Number | Depth of Sample (ft) | Geologic Unit | Lithology | Diametral PLSI (MPa)* |
|---|---|---|---|---|
| DH-30 | 74 | Trd | mudstone | 0.75 |
| DH-30 | 74.5 | Trd | mudstone | 0.71 |
| DH-30 | 78 | Trd | mudstone | 1.07 |
| DH-30 | 78 | Trd | mudstone | 0.71 |
| DH-30 | 86.5 | Trd | mudstone | 1.04 |
| DH-30 | 86.5 | Trd | mudstone | 1.03 |
| DH-30 | 88.7 | Trd | mudstone | 0.83 |
| DH-34 | 186 | Trd | sandstone | 0.52 |
| DH 34 | 186 | Trd | sandstone | 0.92 |
| DH 34 | 193.5 | Trd | sandstone | 0.99 |
| DH 34 | 193.5 | Trd | sandstone | 0.79 |
| DH-34 | 193.5 | Trd | sandstone | 0.48 |

*1 MPa = 10.44 tons/sq ft

| Drill Hole Number | Depth of Sample (ft) | Geologic Unit | Lithology | Axial PLSI (MPa*) |
|---|---|---|---|---|
| DH-27 | 13.5 | Pg | sandstone | 3.55 |
| DH-27 | 13.5 | Pg | sandstone | 4.51 |
| DH-27 | 13.5 | Pg | sandstone | 4.35 |
| DH-27 | 47 | Pg | sandstone | 4.15 |
| DH-27 | 47 | Pg | sandstone | 4.86 |
| DH-27 | 47 | Pg | sandstone | 4.24 |
| DH-27 | 79 | Pg | sandstone | 3.90 |
| DH-27 | 79 | Pg | sandstone | 4.70 |
| DH-27 | 79 | Pg | sandstone | 3.72 |
| DH-27 | 112 | Pg | sandstone | 4.02 |
| DH-27 | 112 | Pg | sandstone | 4.75 |
| DH-27 | 112 | Pg | sandstone | 4.88 |
| DH-27 | 124 | Pg | sandstone | 5.89 |
| DH-27 | 124 | Pg | sandstone | 5.38 |
| DH-27 | 124 | Pg | sandstone | 5.38 |
| DH-29 | 41.5 | Pg | sandstone | 2.92 |
| DH-29 | 41.5 | Pg | sandstone | 3.81 |
| DH-29 | 45 | Pg | sandstone | 2.88 |
| DH-29 | 45 | Pg | sandstone | 3.23 |
| DH-29 | 45 | Pg | sandstone | 2.97 |
| DH-29 | 133 | Pg | sandstone | 5.29 |
| DH-29 | 133 | Pg | sandstone | 4.62 |
| DH-29 | 173 | Pg | sandstone | 4.50 |
| DH-29 | 173 | Pg | sandstone | 5.71 |
| DH-30 | 59.5 | Trd | mudstone | 1.70 |
| DH-30 | 59.5 | Trd | mudstone | 2.23 |
| DH-30 | 66.5 | Trd | sandstone | 1.32 |
| DH-30 | 66.5 | Trd | sandstone | 1.36 |
| DH-30 | 69 | Trd | mudstone | 1.30 |
| DH-30 | 69 | Trd | mudstone | 2.19 |
| DH-30 | 74 | Trd | mudstone | 2.05 |
| DH-30 | 74 | Trd | mudstone | 1.61 |
| DH-30 | 74 | Trd | mudstone | 1.55 |
| DH-30 | 86.5 | Trd | mudstone | 2.87 |
| DH-30 | 86.5 | Trd | mudstone | 1.24 |
| DH-30 | 88.7 | Trd | mudstone | 1.55 |
| DH-30 | 88.7 | Trd | mudstone | 1.30 |
| DH-34 | 186 | Trd | sandstone | 3.60 |
| DH-34 | 186 | Trd | sandstone | 5.69 |
| DH-34 | 193.5 | Trd | mudstone | 1.14 |
| DH-34 | 193.5 | Trd | mudstone | 1.88 |
| DH-32 | 146.5 | Km | shale | 1.38 |
| DH-32 | 146.5 | Km | shale | 1.23 |
| DH-32 | 150.5 | Km | shale | 0.81 |
| DH-29 | 281.5 | Py | sandstone | 2.11 |
| DH-29 | 354 | Py | sandstone | 1.36 |
| DH-37 | 120 | Py | sandstone | 2.92 |
| DH-37 | 120 | Py | sandstone | 2.84 |
| DH-37 | 127.5 | Py | sandstone | 3.35 |
| DH-37 | 127.5 | Py | sandstone | 3.38 |

*MPa = 10.44 tons/sq ft.

| Drill Hole Number | Depth of Sample (ft) | Geologic Unit | Lithology | Axial PLSI (MPa*) |
|---|---|---|---|---|
| DH-39 | 32.5 | Pm | limestone | 3.49 |
| DH-39 | 39.5 | Pm | limestone | 4.60 |
| DH-39 | 39.5 | Pm | limestone | 4.43 |
| DH-39 | 39.5 | Pm | limestone | 5.22 |
| DH-39 | 54 | Pm | limestone | 5.60 |
| DH-39 | 62 | Pm | limestone | 5.06 |
| DH-39 | 62 | Pm | limestone | 4.91 |
| DH-39 | 85.5 | Pm | limestone | 6.59 |
| DH-39 | 85.5 | Pm | limestone | 8.52 |
| DH-39 | 85.5 | Pm | limestone | 7.22 |

*MPa = 10.44 tons/sq ft.

| Sample Number | Block Number | Geologic Unit | Lithology/Description | Block PLSI (MPa)* | PLSI Test Type** | Dry Density (PCF) |
|---|---|---|---|---|---|---|
| R-3 | 1 | Psa/Pg | tan sandstone, mod.-poorly indurated | 2.89 | BP | 142 |
| R-3 | 2 | Psa/Pg | tan sandstone, mod.-poorly indurated | 4.38 | BP | |
| R-3 | 3 | Psa/Pg | tan sandstone, mod.-poorly indurated | 4.42 | BP | |
| R-6 | 1 | Trd | tan sandstone, mod. indurated, hematite stains | 2.67 | BP | 132 |
| R-6 | 2 | Trd | tan sandstone, mod. indurated, hematite stains | 3.73 | BP | |
| R-6 | 3 | Trd | tan sandstone, mod. indurated, hematite stains | 4.27 | BP | |
| R-6 | 4 | Trd | tan sandstone, mod. indurated, hematite stains | 4.29 | BP | |
| R-6 | 5 | Trd | tan sandstone, mod. indurated, hematite stains | 2.42 | BP | |
| R-6 | 6 | Trd | tan sandstone, mod. indurated, hematite stains | 2.47 | BP | |
| R-7 | 1 | Pg | purpleish-grey sandstone, hematite stains | 9.76 | BP | 150 |
| R-7 | 2 | Pg | purpleish-grey sandstone, hematite stains | 9.24 | BP | |
| R-7 | 3 | Pg | purpleish-grey sandstone, hematite stains | 8.95 | BP | |
| R-7 | 4 | Pg | purpleish-grey sandstone, hematite stains | 8.96 | BP | |
| R-7 | 5 | Pg | purpleish-grey sandstone, hematite stains | 6.43 | BP | |
| R-7 | 6 | Pg | purpleish-grey sandstone, hematite stains | 6.97 | BP | |
| R-8 | 1 | Pm | greyish brown limestone., v. well indurated | 8.90 | BP | 168 |
| R-8 | 2 | Pm | greyish brown limestone., v. well indurated | 8.13 | BP | |
| R-8 | 3 | Pm | greyish brown limestone., v. well indurated | 6.75 | BP | |
| R-8 | 4 | Pm | greyish brown limestone., v. well indurated | 7.33 | BP | |
| R-8 | 5 | Pm | greyish brown limestone., v. well indurated | 6.42 | BP | |
| R-8 | 6 | Pm | greyish brown limestone., v. well indurated | 5.98 | BP | |

*1MPa = 10.44 tons/sq ft

**BP = Block test; samples tested perpendicular to plane of greatest anisotropy (i.e., bedding, foliation).

| Sample Number | Block Number | Geologic Unit | Lithology /Description | Block PLSI (MPa)* | PLSI Test Type** | Dry Density (PCF) |
|---|---|---|---|---|---|---|
| R-14 | 1 | Pg | sandstone, well indurated, hematitic | 5.75 | BP | NP |
| R-14 | 2 | Pg | sandstone, well indurated, hematitic | 4.89 | BP | |
| R-14 | 3 | Pg | sandstone, well indurated, hematitic | 5.38 | BP | |
| R-14 | 4 | Pg | sandstone, well indurated, hematitic | 6.67 | BP | |
| R-14 | 5 | Pg | sandstone, well indurated, hematitic | 5.40 | BP | |
| R-14 | 6 | Pg | sandstone, well indurated, hematitic | 7.85 | BP | |
| R-16 | 1 | Pm | gray limestone with iron oxide solution bands | 7.02 | BP | 167 |
| R-16 | 2 | Pm | gray limestone with iron oxide solution bands | 3.30 | BP | |
| R-16 | 3 | Pm | gray limestone with iron oxide solution bands | 9.38 | BP | |
| R-16 | 4 | Pm | gray limestone with iron oxide solution bands | 4.86 | BP | |
| R-17 | 1 | Tm | monzonite, very altered, hematite stains | 2.31 | BP | 149 |
| R-17 | 2 | Tm | monzonite, very altered, hematite stains | 6.05 | BP | |
| R-17 | 3 | Tm | monzonite, very altered, hematite stains | 7.71 | BP | |
| R-17 | 4 | Tm | monzonite, very altered, hematite stains | 7.56 | BP | |
| R-18 | 1 | Tm | monzonite, altered | 5.21 | BP | 164 |
| R-18 | 2 | Tm | monzonite, altered | 7.14 | BP | |
| R-19 | 1 | Pa | light brown sandstone, v. well indurated | 10.98 | BP | 154 |
| R-19 | 2 | Pa | light brown sandstone, v. well indurated | 11.40 | BP | |
| R-19 | 3 | Pa | light brown sandstone, v. well indurated | 10.64 | BP | |
| R-19 | 4 | Pa | light brown sandstone, v. well indurated | 9.59 | BP | |
| R-19 | 5 | Pa | light brown sandstone, v. well indurated | 10.42 | BP | |

*1MPa = 10.44 tons/sq ft

**BP = Block test; samples tested perpendicular to plane of greatest anisotropy (i.e., bedding, foliation).

| Sample Number | Block Number | Geologic Unit | Lithology/Description | Block PLSI (MPa)* | PLSI Test Type** | Dry Density (PCF) |
|---|---|---|---|---|---|---|
| R-20 | 1 | Tm | monzonite, fresh | 17.05 | BP | 153 |
| R-20 | 2 | Tm | monzonite, fresh | 11.53 | BP | |
| R-20 | 3 | Tm | monzonite, fresh | 17.89 | BP | |
| R-20 | 4 | Tm | monzonite, fresh | 17.08 | BP | |
| R-20 | 5 | Tm | monzonite, fresh | 18.25 | BP | |
| R-21 | 1 | Pm | brown limestone, highly fractured, v. well indurated | 6.38 | BP | 168 |
| R-21 | 2 | Pm | brown limestone, highly fractured, v. well indurated | 4.67 | BP | |
| R-21 | 3 | Pm | brown limestone, highly fractured, v. well indurated | 6.25 | BP | |
| R-21 | 4 | Pm | brown limestone, highly fractured, v. well indurated | 7.58 | BP | |
| R-21 | 5 | Pm | brown limestone, highly fractured, v. well indurated | 5.29 | BP | |
| R-22 | 1 | Pm | grayish-broun limestone | 4.89 | BP | NP |
| R-22 | 2 | Pm | grayish-broun limestone | 4.89 | BP | |
| R-22 | 3 | Pm | grayish-broun limestone | 4.00 | BP | |
| R-22 | 4 | Pm | grayish-broun limestone | 4.61 | BP | |
| R-22 | 5 | Pm | grayish-broun limestone | 6.74 | BP | |
| R-23 | 1 | Tm | monzonite, slightly altered, hematite stains | 7.73 | BP | 149 |
| R-23 | 2 | Tm | monzonite, slightly altered, hematite stains | 2.85 | BP | |
| R-23 | 3 | Tm | monzonite, slightly altered, hematite stains | 1.70 | BP | |
| R-23 | 4 | Tm | monzonite, slightly altered, hematite stains | 2.18 | BP | |
| R-24 | 1 | Pm | tan limestone, v. well indurated | 9.04 | BP | 164 |
| R-24 | 2 | Pm | tan limestone, v. well indurated | 6.34 | BP | |
| R-24 | 3 | Pm | tan limestone, v. well indurated | 7.03 | BP | |
| R-24 | 4 | Pm | tan limestone, v. well indurated | 7.45 | BP | |

*1MPa = 10.44 tons/sq ft

**BP = Block test; samples tested perpendicular to plane of greatest anisotropy (i.e., bedding, foliation).

| Sample Number | Block Number | Geologic Unit | Lithology /Description | Block PLSI (MPa)* | PLSI Test Type** | Dry Density (PCF) |
|---|---|---|---|---|---|---|
| R-26 | 1 | Pb | pinkish-grey quartz sandstone, fractured, v. well indurated | 5.85 | BP | 172 |
| R-26 | 2 | Pb | pinkish-grey quartz sandstone, fractured, v. well indurated | 10.99 | BP | |
| R-26 | 3 | Pb | pinkish-grey quartz sandstone, fractured, v. well indurated | 11.17 | BP | |
| R-26 | 4 | Pb | pinkish-grey quartz sandstone, fractured, v. well indurated | 12.14 | BP | |
| R-27 | 1 | Pg | pink sandsone, cracks parallel to bedding, well indurated | 4.28 | BP | NP |
| R-27 | 2 | Pg | pink sandsone, cracks parallel to bedding, well indurated | 6.44 | BP | |
| R-27 | 3 | Pg | pink sandsone, cracks parallel to bedding, well indurated | 7.38 | BP | |
| R-27 | 4 | Pg | pink sandsone, cracks parallel to bedding, well indurated | 4.84 | BP | |
| R-27 | 5 | Pg | pink sandsone, cracks parallel to bedding, well indurated | 3.07 | BP | |
| R-28 | 1 | Trd | sandstone, well indurated | 3.98 | BP | 156 |
| R-28 | 2 | Trd | sandstone, well indurated | 5.43 | BP | |
| R-28 | 3 | Trd | sandstone, well indurated | 5.52 | BP | |
| R-28 | 4 | Trd | sandstone, well indurated | 5.26 | BP | |
| R-29 | 1 | Pb-Psa | white sandstone, poorly indurated | 2.71 | BP | 135 |
| R-29 | 2 | Pb-Psa | white sandstone, poorly indurated | 1.15 | BP | |
| R-29 | 3 | Pb-Psa | white sandstone, poorly indurated | 1.98 | BP | |
| R-30 | 1 | Pb | gray limestone, well indurated | 12.22 | BP | 163 |
| R-30 | 2 | Pb | gray limestone, well indurated | 11.23 | BP | |
| R-30 | 3 | Pb | gray limestone, well indurated | 13.66 | BP | |
| R-30 | 4 | Pb | gray limestone, well indurated | 15.54 | BP | |
| R-30 | 5 | Pb | gray limestone, well indurated | 9.61 | BP | |
| R-30 | 6 | Pb | gray limestone, well indurated | 12.36 | BP | |
| R-32 | 1 | pCs | schist, well-developed foliation | 6.42 | BP | 161 |
| R-32 | 2 | pCs | schist, well-developed foliation | 5.67 | BP | |
| R-32 | 3 | pCs | schist, well-developed foliation | 5.82 | BP | |

*1MPa = 10.44 tons/sq ft

**BP = Block test; samples tested perpendicular to plane of greatest anisotropy (i.e., bedding, foliation).

| Sample Number | Block Number | Geologic Unit | Lithology/Description | Block PLSI (MPa)* | PLSI Test Type** | Dry Density (PCF) |
|---|---|---|---|---|---|---|
| R-33 | 1 | pCq | purpleish-gray metaquartzite, well indurated | 12.89 | BP | 165 |
| R-33 | 2 | pCq | purpleish-gray metaquartzite, well indurated | 13.40 | BP | |
| R-33 | 3 | pCq | purpleish-gray metaquartzite, well indurated | 10.01 | BP | |
| R-33 | 4 | pCq | purpleish-gray metaquartzite, well indurated | 10.61 | BP | |
| R-33 | 5 | pCq | purpleish-gray metaquartzite, well indurated | 13.43 | BP | |
| R-34 | 1 | Pg | tan sandstone, moderately indurated | 3.97 | BP | 140 |
| R-34 | 2 | Pg | tan sandstone, moderately indurated | 3.88 | BP | |
| R-34 | 3 | Pg | tan sandstone, moderately indurated | 3.55 | BP | |
| R-34 | 4 | Pg | tan sandstone, moderately indurated | 4.43 | BP | |
| R-34 | 5 | Pg | tan sandstone, moderately indurated | 3.94 | BP | |
| R-35 | 1 | Pg | purpleish-gray siltstone, v. well indurated | 7.20 | BP | 148 |
| R-35 | 2 | Pg | purpleish-gray siltstone, v. well indurated | 5.62 | BP | |
| R-35 | 3 | Pg | purpleish-gray siltstone, v. well indurated | 5.27 | BP | |
| R-35 | 4 | Pg | purpleish-gray siltstone, v. well indurated | 6.75 | BP | |
| R-35 | 5 | Pg | purpleish-gray siltstone, v. well indurated | 6.69 | BP | |
| R-36 | 1 | QTa | pebble conglomerate, poorly indurated | 1.24 | BP | NP |
| R-36 | 2 | QTa | pebble conglomerate, poorly indurated | 1.63 | BP | |
| R-36 | 3 | QTa | pebble conglomerate, poorly indurated | 2.85 | BP | |
| R-36 | 4 | QTa | pebble conglomerate, poorly indurated | 3.28 | BP | |
| R-37 | 1 | Trd | tan sandstone, moderately indurated, hematite stains | 2.75 | BP | 145 |
| R-37 | 2 | Trd | tan sandstone, moderately indurated, hematite stains | 3.31 | BP | |
| R-37 | 3 | Trd | tan sandstone, moderately indurated, hematite stains | 3.16 | BP | |
| R-37 | 4 | Trd | tan sandstone, moderately indurated, hematite stains | 3.94 | BP | |
| R-37 | 5 | Trd | tan sandstone, moderately indurated, hematite stains | 3.26 | BP | |

*1MPa = 10.44 tons/sq ft

**BP = Block test; samples tested perpendicular to plane of greatest anisotropy (i.e., bedding, foliation).

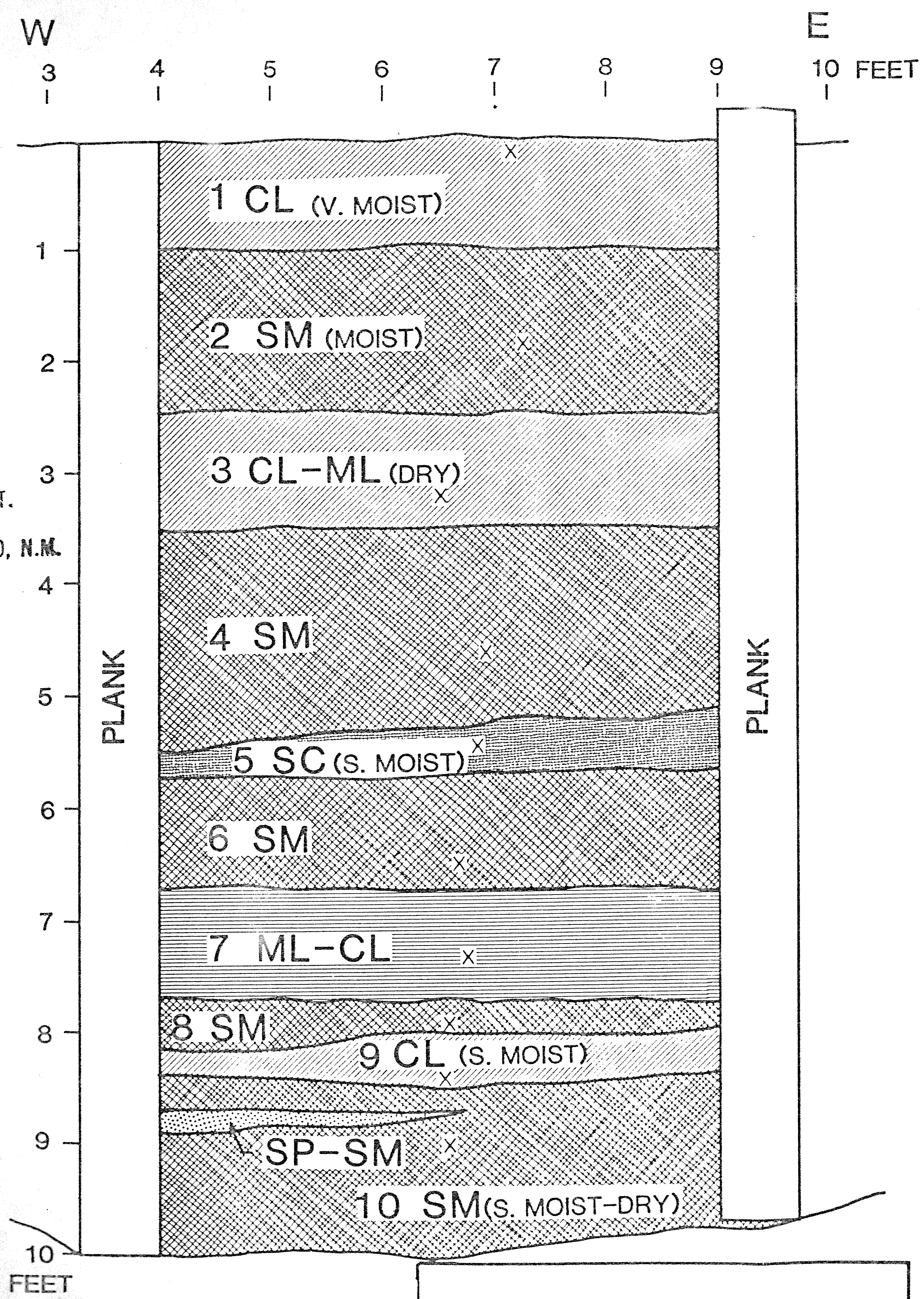
| Sample Number | Block Number | Geologic Unit | Lithology/Description | Block PLSI (MPa)* | PLSI Test Type** | Dry Density (PCF) |
|---|---|---|---|---|---|---|
| R-38 | 2 | Trd | grayish-brown sandstone, v. well indurated, iron oxide stains | 7.54 | BP | |
| R-38 | 3 | Trd | grayish-brown sandstone, v. well indurated, iron oxide stains | 5.50 | BP | |
| R-38 | 4 | Trd | grayish-brown sandstone, v. well indurated, iron oxide stains | 7.62 | BP | |
| R-38 | 5 | Trd | grayish-brown sandstone, v. well indurated, iron oxide stains | 8.72 | BP | |
| R-38 | 6 | Trd | grayish-brown sandstone, v. well indurated, iron oxide stains | 6.20 | BP | |
| R-39 | 1 | Pm | gray limestone, v. well indurated | 6.92 | BP | 171 |
| R-39 | 2 | Pm | gray limestone, v. well indurated | 7.01 | BP | |
| R-39 | 3 | Pm | gray limestone, v. well indurated | 7.35 | BP | |
| R-39 | 4 | Pm | gray limestone, v. well indurated | 6.33 | BP | |
| R-39 | 5 | Pm | gray limestone, v. well indurated | 7.01 | BP | |
| R-39 | 6 | Pm | gray limestone, v. well indurated | 7.09 | BP | |
| R-40 | 1 | QTa | pebble conglomerate, poorly sorted, poorly indurated | 0.90 | BP | NP |
| R-40 | 2 | QTa | pebble conglomerate, poorly sorted, poorly indurated | 1.25 | BP | |
| R-40 | 3 | QTa | pebble conglomerate, poorly sorted, poorly indurated | 1.90 | BP | |
| R-40 | 4 | QTa | pebble conglomerate, poorly sorted, poorly indurated | 0.77 | BP | |

*1MPa = 10.44 tons/sq ft

**BP = Block test; samples tested perpendicular to plane of greatest anisotropy (i.e., bedding, foliation).

Laboratory Test Data for Rock Units. PCF = pounds per cubic foot

| Drill Hole Number | Depth of Sample (ft) | Geologic Unit | Geologic Period | Lithology | Dry Density (PCF) |
|---|---|---|---|---|---|
| DH-27 | 6 | Pg | Permian | clean quartz sandstone | 148 |
| DH-27 | 55 | Pg | Permian | sandstone with minor limonitic seams | 149 |
| DH-27 | 101 | Pg | Permian | clean quartz sandstone | 160 |
| DH-27 | 133.5 | Pg | Permian | sandstone, crossbedded, very fractured | 157 |
| DH-27 | 142 | Pg | Permian | sandstone, iron stained, fractured | 151 |
| DH-29 | 45 | Pg | Permian | clean quartz sandstone, fractured | 153 |
| DH-29 | 120 | Pg | Permian | sandstone, iron stained | 151 |
| DH-29 | 169 | Pg | Permian | sandstone, weathered | 156 |
| DH-29 | 282 | Py | Permian | silty sandstone | 137 |
| DH-29 | 354 | Py | Permian | sandy mudstone | 140 |
| DH-30 | 62.3 | Trd | Triassic | sandstone + mudstone | 142 |
| DH-30 | 74.5 | Trd | Triassic | sandstone + mudstone | 146 |
| DH-30 | 88.5 | Trd | Triassic | sandstone + mudstone | 153 |
| DH-32 | 144 | Km | Cretaceous | sandy shale | 131 |
| DH-32 | 154 | Km | Cretaceous | sandy shale | 136 |
| DH-34 | 182 | Trd | Triassic | sandy siltstone | 154 |
| DH-37 | 124 | Py | Permian | shaly fine sandstone, vuggy | 135 |
| DH-37 | 127.5 | Py | Permian | shaly fine sandstone, vuggy | 144 |
| DH-39 | 25.5 | Pm | Pennsylvanian | limestone, very fractured | 167 |
| DH-39 | 54 | Pm | Pennsylvanian | limestone with shale partings | 173 |
| DH-39 | 78 | Pm | Pennsylvanian | limestone, fractured | 158 |
| DH-39 | 85.5 | Pm | Pennsylvanian | limestone, fractured | 165 |
| DH-39 | 90 | Pm | Pennsylvanian | shaly limestone, fractured | 176 |



X = SAMPLE LOCATION
PPV= POCKET PENETROMETER VALUE
TSS=TORVANE SHEAR STRENGTH
S= SLIGHTLY

LOG OF TRENCH SSC-BH-6

JULY 31, 1987

NEW MEXICO SSC PROPOSAL

1 CL, SANDY, LEAN CLAY, V. MOIST, SOFT, PPV = 1.5kg/cm$^2$, TSS = 1.75kg/cm$^2$, VERY ORGANIC, WORM CASTINGS, ABUNDANT ROOTS, FEW $CaCO_3$ NODULES (LAKE), DARK BROWN.

2 SM, SILTY SAND, MOIST, SOFT, PPV = 1.5kg/cm$^2$, TSS=2.5kg/cm$^2$, ABUNDANT BURROWS, GRUBS, SOFT $CaCO_3$ NODULES, PALE YELLOW.

3 CL-ML, SANDY SILTY CLAY, DRY, HARD, PPV > 4.5kg/cm$^2$, TSS=2kg/cm$^2$, UPPER CONTACT GRADATIONAL, ABUNDANT ROOTS, FEW CLAY-FILLED BURROWS, ABUNDANT $CaCO_3$ NODULES, PALE YELLOW.

4 SM, SILTY SAND, HARD, PPV > 4.5kg/cm$^2$, TSS= 1kg/cm$^2$, MOTTLED AND STREAKED WITH RED/YELLOW IRON STAINING, YELLOW.

5 SC, CLAYEY SAND, S. MOIST, HARD, PPV > 4.5kg/cm$^2$, TSS = 3kg/cm$^2$, LOW PLASTICITY CLAY INTERBEDDED WITH SAND, FEW ROOTS, UPPER CONTACT WAVEY, V. PALE BROWN.

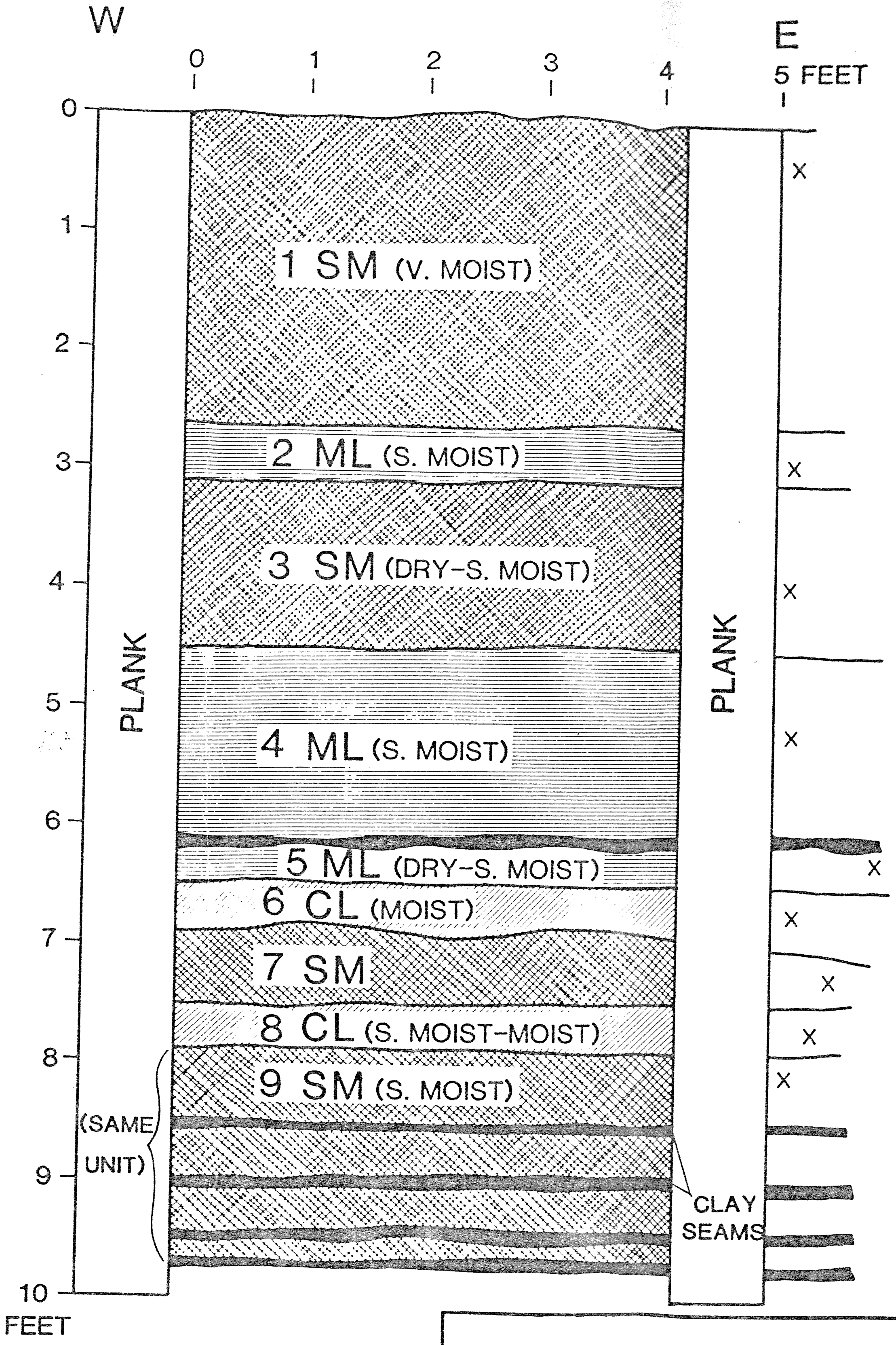
6 SM, SILTY FINE SAND, SMALL CLAYEY SILT NODULES THROUGHOUT, SCATTERED $CaCO_3$ NODULES, MOTTLED AND STREAKED WITH YELLOWISH RED IRON STREAKS, PALE BROWN.

7 ML-CL, INTERBEDDED SILTY CLAYS AND CROSSBEDDED FINE SAND, STIFF, PPV > 4.5kg/cm$^2$, TSS=2kg/cm$^2$, YELLOWISH BROWN.

8 SM, SILTY SAND, CROSSBEDDED, HARD, PPV > 4.5kg/cm$^2$, TSS = 1.0kg/cm$^2$, FEW ROOTS, UPPER MUCH MORE CLAYEY, UPPER CONTACT IS WAVY, LIGHT YELLOWISH BROWN.

9 CL, SANDY LEAN CLAY, S. MOIST, MASSIVE, STIFF, PPV > 4.5kg/cm$^2$, TSS=3kg/cm$^2$, YELLOWISH BROWN.

10 SM, SILTY SAND, CROSSBEDDED, S. MOIST-DRY, HARD, PPV > 4.5kg/cm$^2$, TSS = 1.5kg/cm$^2$, FEW ROOTS, DISCONTINUOUS LAYERS OF SP-SM, LIGHT YELLOWISH BROWN.



X= SAMPLE LOCATION
PPV=POCKET PENETROMETER VALUE
TSS=TORVANE SHEAR STRENGTH
S=SLIGHTLY

LOG OF TRENCH SSC-BH-7

JULY 31, 1987

NEW MEXICO SSC PROPOSAL

1 SM, SILTY SAND, V. MOIST, SOFT, PPV=0.5kg/cm$^2$, TSS=1.0kg/cm$^2$, ABUNDANT ROOTS, A FEW SOFT $CaCO_3$ NODULES BELOW 1.5 FEET, NO STRUCTURE, DARK YELLOWISH BROWN.

2 ML, SANDY SILT, S. MOIST, PPV=4.0kg/cm$^2$, TSS=2.5kg/cm$^2$, NEARLY PLUGGED WITH $CaCO_3$, NUMEROUS 0.5 INCH WORM BURROWS, GRADATIONAL CONTACT WITH UNIT 3 BELOW, WHITE.

3 SM, SILTY SAND, DRY TO SLIGHTLY MOIST, HARD, PPV=4.5kg/cm$^2$, TSS=3.0kg/cm$^2$, A FEW 0.5 INCH DIAMETER BURROWS, YELLOW MOTTLED WITH YELLOW IRON OXIDE STAINING.

4 ML, SANDY SILT, S. MOIST, HARD, PPV=4.5kg/cm$^2$, TSS=1.0kg/cm$^2$; POORLY CROSSBEDDED, SCATTERED $CaCO_3$ NODULES AND FEW ROOTS, UPPER CONTACT GRADATIONAL, V. PALE BROWN MOTTLED WITH ORANGE IRON OXIDE STAINING.

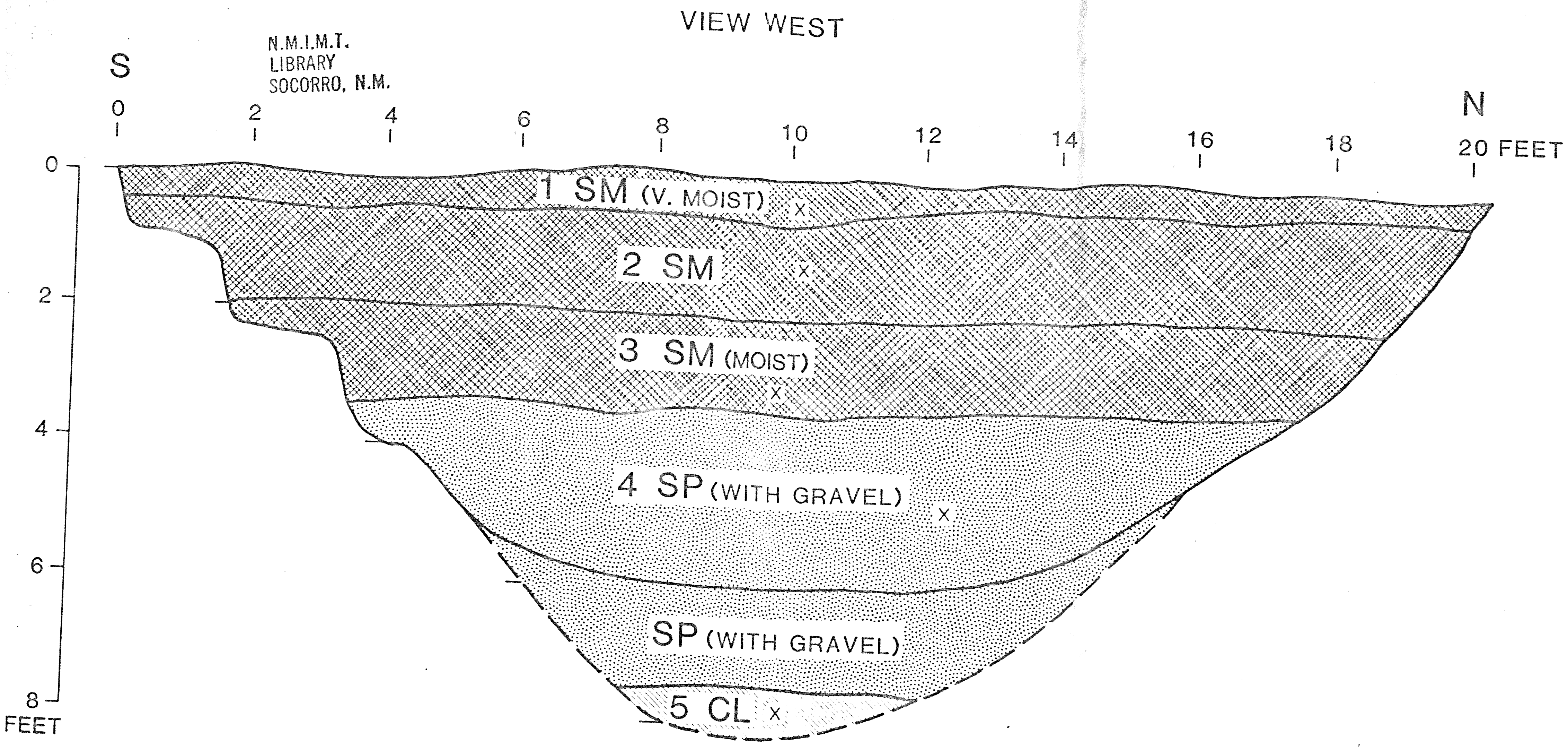
5 ML, SILT WITH SAND, DRY TO S. MOIST, FIRM, PPV=3.5kg/cm$^2$, TSS=1.0kg/cm$^2$, CROSSBEDDED, LIGHT BROWNISH GREY.

6 CL, LEAN CLAY, MOIST, HARD, PPV>5 4.5kg/cm$^2$, TSS=5.0kg/cm$^2$, SOME GYPSUM STRINGERS, ROOTS, V. PALE BROWN, IRON STAINED.

7 SM, SILTY SAND, SOFT, PPV=1.0kg/cm$^2$, TSS=1.0kg/cm$^2$, CROSSBEDDED, NUMEROUS CLAY CONCRETIONS UP TO .25 INCH DIAMETER, SHARP UPPER SURFACE, REWORKED $CaCO_3$ CONCRETIONS, YELLOW.

8 CL, LEAN CLAY, S. MOIST TO MOIST, STIFF, PPV=4.5kg/cm$^2$, TSS=5.5kg/cm$^2$, CONCRETIONS OF GYPSUM AT BASE, IRON OXIDE COLORATION ON PED SURFACES, UNIDENTIFIED RED ORGANIC FILAMENTS, LIGHT BROWNISH GREY.

9 SM, SILTY SAND, S. MOIST, HARD, PPV=4.5kg/cm$^2$, TSS=2kg/cm$^2$, STREAKED AND MOTTLED WITH ORANGE IRON OXIDE STAINING, FEW ROOTS, $CaCO_3$ LAMINAE AND CLAY SEAMS AT 9.0, 9.4, 8.5, AND 8.7 FEET, LIGHT BROWNISH GREY.



| UNIT | |
|---|---|
| 1 | SM, SILTY SAND, V. MOIST, LOOSE, CONTAINS ABUNDANT ROOTS AND ORGANIC MATTER. |
| 2 | SM, SILTY SAND, LOOSE, ABUNDANT ROOTS, FEW CaCO₃ NODULES. |
| 3 | SM, SILTY SAND, MOIST, LOOSE, ABUNDANT CaCO₃ NODULES, PEA-SIZED GRAVEL. |
| 4 | SP, POORLY GRADED SAND WITH GRA LENSES, RUNNING SAND, GRAVEL CLASTS UP TO 0.5 INCH, LITHOLOGIE IGNEOUS ROCKS, QUARTZ, FELDSPAR |
| 5 | CL, LEAN CLAY WITH SAND, S. MOIST STIFF, WHITE, BLOCKY TEXTURE (LA DEPOSIT). |

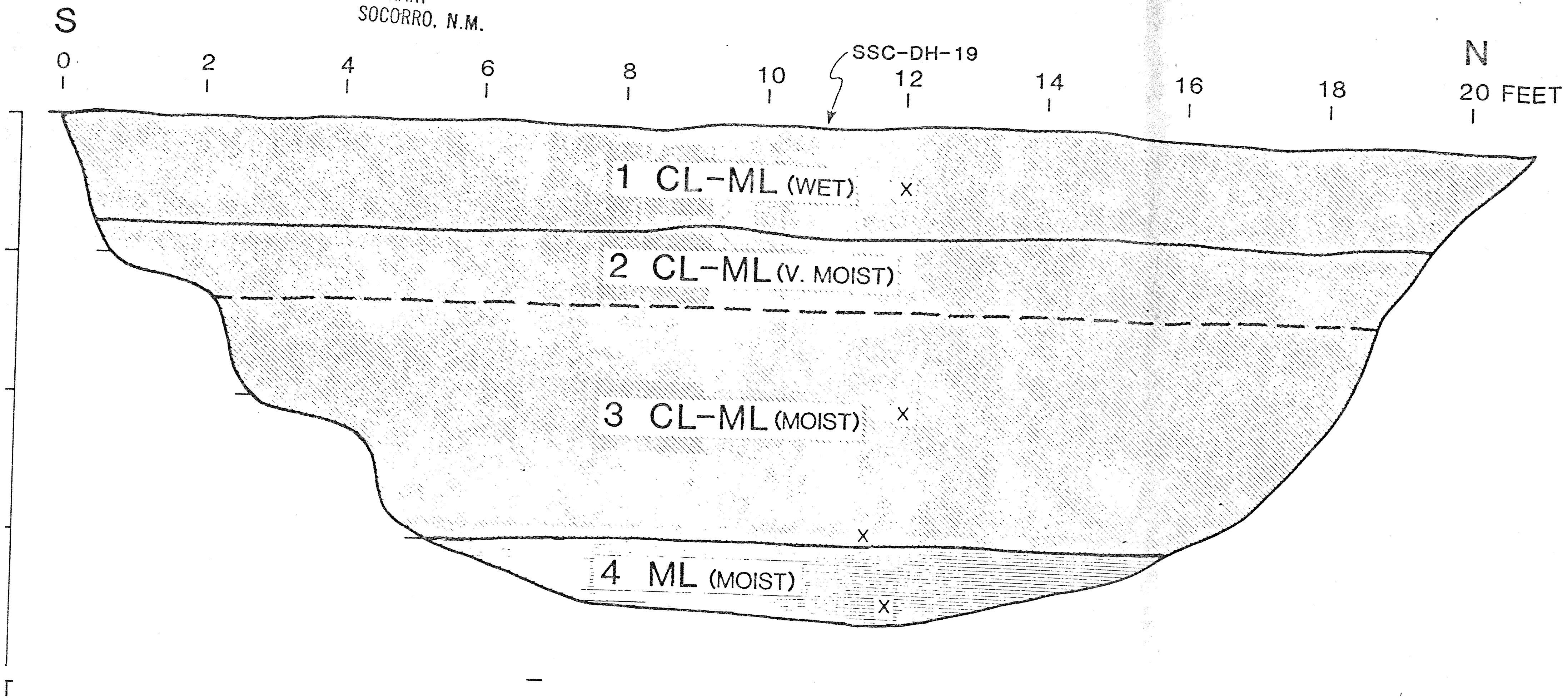
X = SAMPLE LOCATION
PPV = POCKET PENETROMETER VALUE
TSS = TORVANE SHEAR STRENGTH
S = SLIGHTLY

LOG OF TRENCH SSC-BH-3

JULY 31, 1987

NEW MEXICO SSC PROPOSAL

VIEW WEST



UNIT

1 CL-ML, SANDY-SILTY CLAY, WET, SOFT, PPV < 0.5kg/cm², GREEN/OLIVE (LAKE).

2 CL-ML, SANDY-SILTY CLAY, V. MOIST, SOFT-FIRM, PPV ≈ 2kg/cm², WHITE.

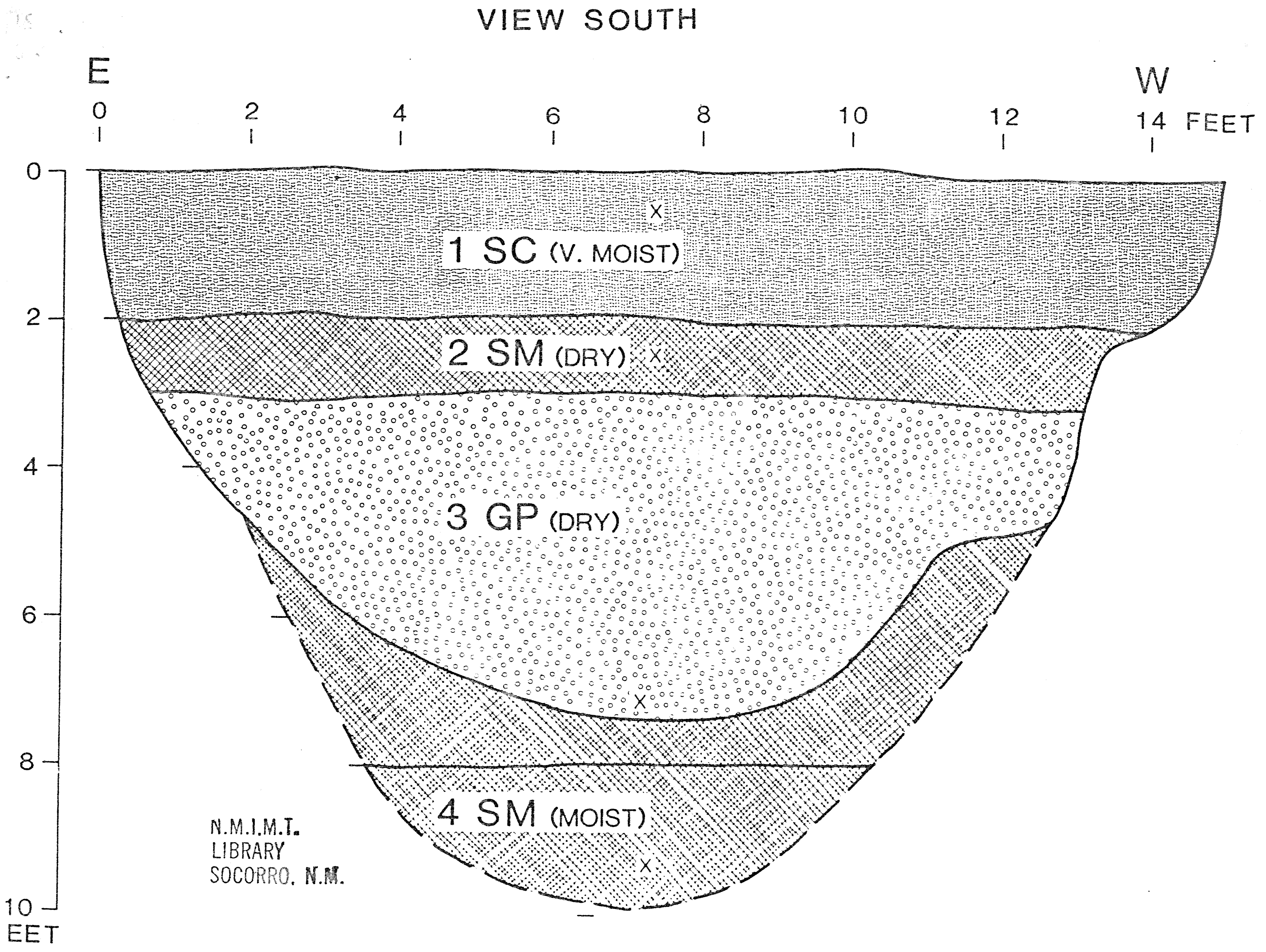
3 CL-ML, SILTY CLAY, WITH SAND, MOIST, STIFF-HARD, PPV > 4.5kg/cm², WHITE.

4 ML, SILT, S. MOIST, STIFF, PPV > 4.5kg/cn ROCK-LIKE IN CHARACTER, VUGGY, $CaCO_3$ CRYSTALS ON VUG SURFACES, WHITE (LAKE MARE).

X = SAMPLE LOCATION
PPV = POCKET PENETROMETER VALUE
TSS = TORVANE SHEAR STRENGTH
S = SLIGHTLY

LOG OF TRENCH SSC-BH-5

JULY 31, 1987



UNIT

1 SC, CLAYEY SAND WITH GRAVEL, V. MOIST, SOFT, VERY ORGANIC, ABUNDANT WORMS AND WORM BURROWS, SCATTERED GRAVEL (FINE TO MEDIUM).

2 SM, DRY, STAGE IV, $CaCO_3$.

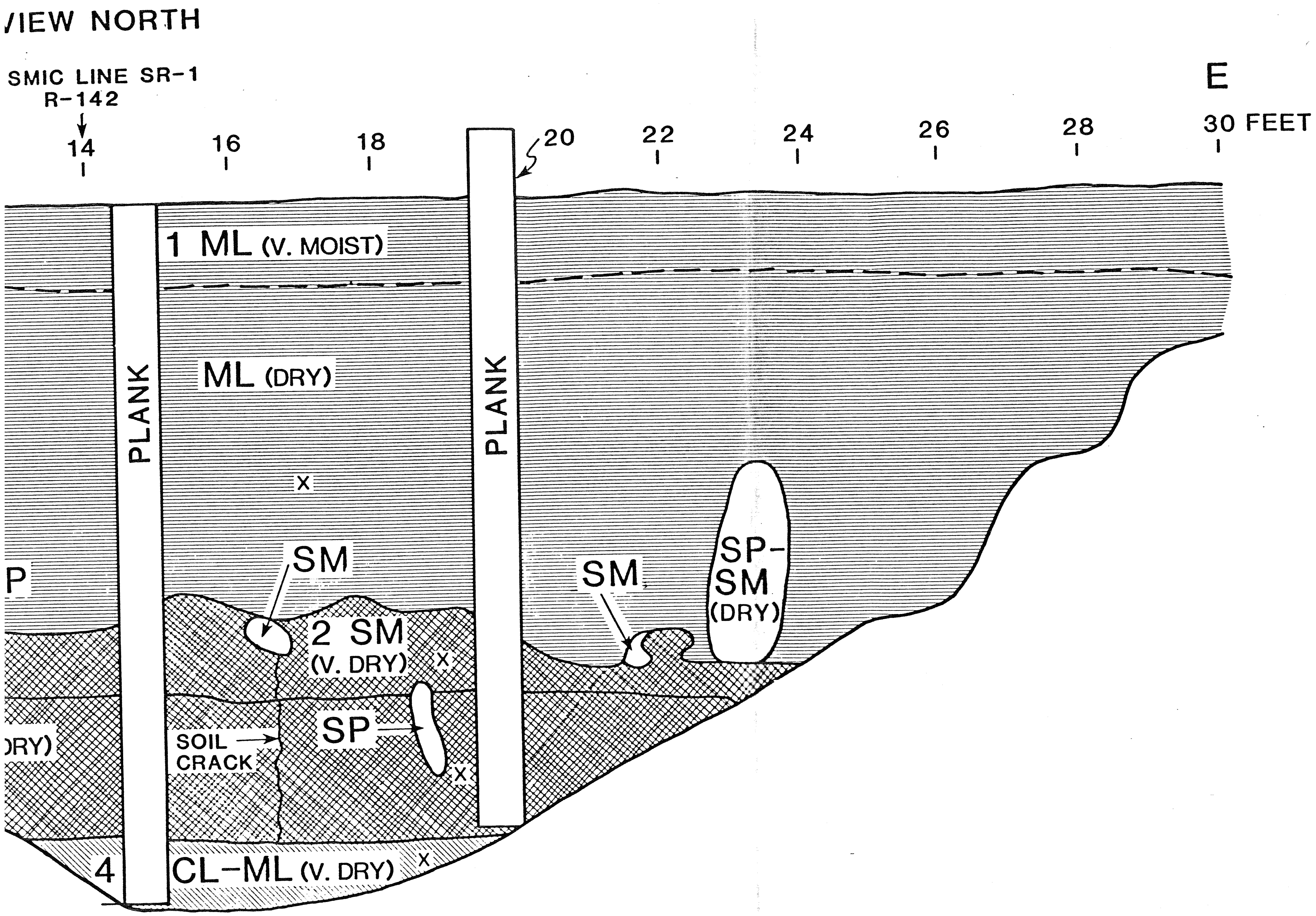
3 GP, POORLY-GRADED GRAVEL WITH SAND, AND SCATTERED BOULDERS AND COBBLES, DRY, CLASTS ARE MADERA LIMESTONE, SUBANGULAR TO SUBROUNDED, MOST ARE WELL COATED WITH $CaCO_3$.

4 SM, SILTY SAND , MOIST, DENSE, CLASTS TO 0.5 INCH, SUBROUNDED, ALL MADERA LIMESTONE, BROWN TO DARK BROWN.

X = SAMPLE LOCATION
PPV = POCKET PENETROMETER VALUE
TSS = TORVANE SHEAR STRENGTH

LOG OF TRENCH SSC-BH-9

JULY 31, 1987



UNIT

1 ML, SANDY SILT, V. MOIST AT SURFACE, DRY BELOW 1 FOOT, SOFT AT SURFACE, STIFF BELOW 1 FOOT, CONTAINS GRAVEL SIZE CLASTS OF IGNEOUS AND LIMESTONE ROCK (SUBANGULAR), $CaCO_3$ NODULES AND FILAMENTS.

2 SM, SILTY SAND, V. DRY, HARD, $CaCO_3$ LAMINAR-SUBLAMINAR STAGE IV IN PLACES, BROKEN INTO GRAVEL SIZE PIECES THROUGHOUT. EXTENSIVELY BURROWED. BURROWS FILLED WITH FINE DARK COLORED SP-SM (GRAVELLY SAND-SILTY SAND), DRY, SOFT.

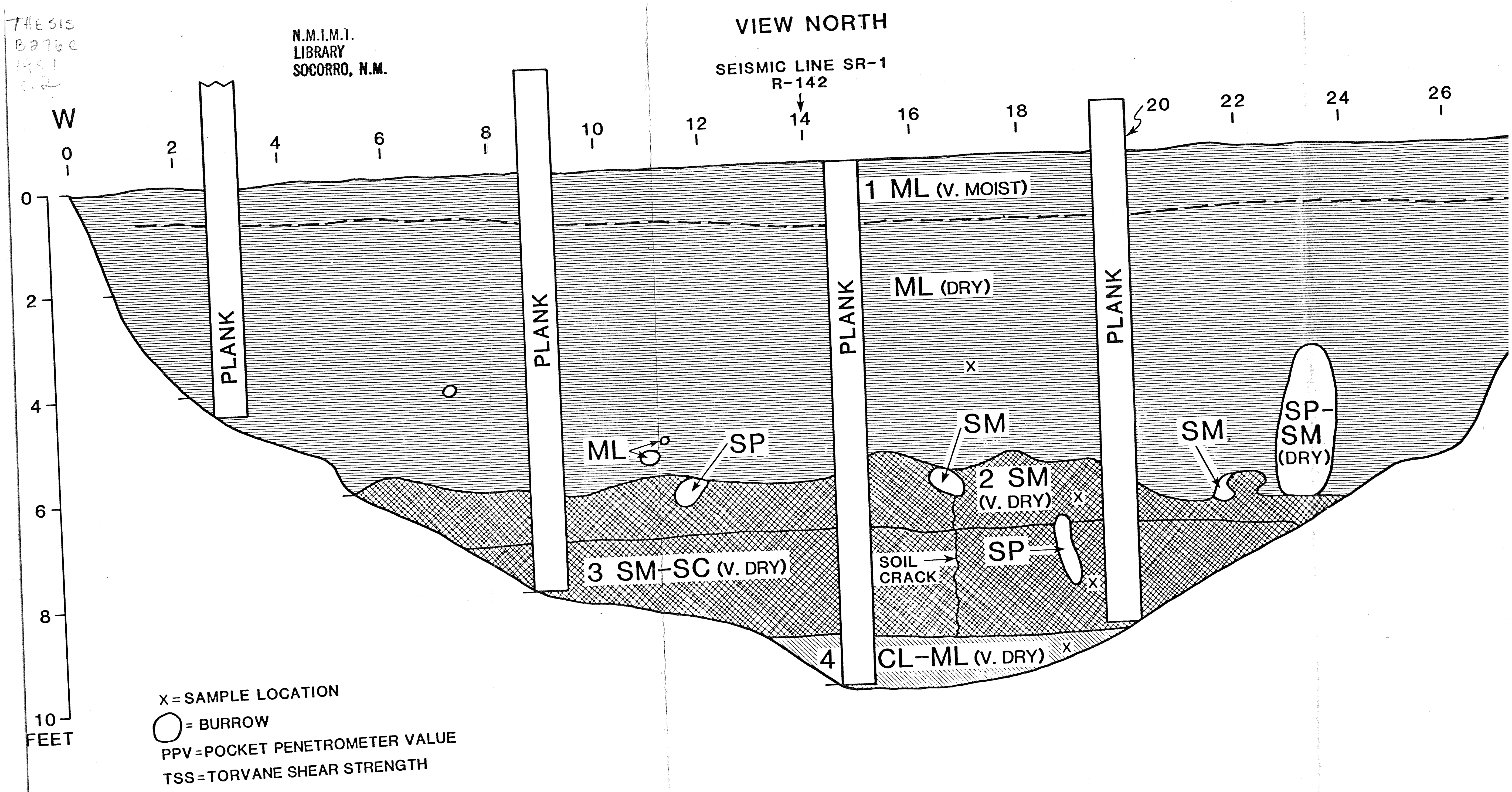
3 SM-SC, SILTY SAND-CLAYEY SAND, V. DRY, SOMEWHAT BURROWED.

4 CL-ML, SILTY CLAY, V. DRY, SCATTERED CARBON.

NOTES:
SOIL CRACK IS COATED WITH $CaCO_3$, NO OFFSET NOTED.

SMALL ROOTS TO 6 FEET.

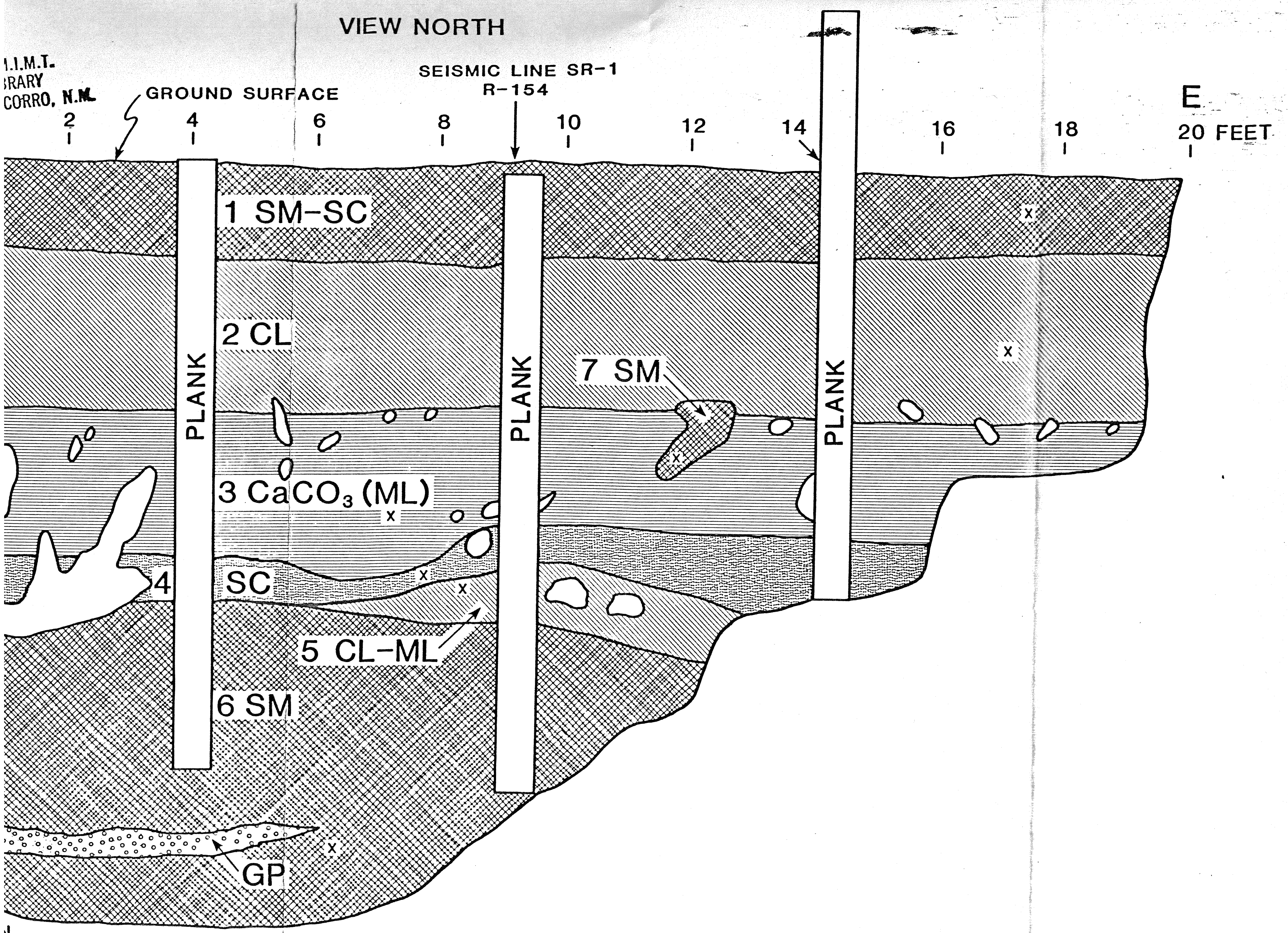
NO EVIDENCE FOR FAULTING IN TRENCH.



LOG OF TRENCH SSC-BH-1

JULY 31, 1987

NEW MEXICO SSC PROPOSAL



| UNIT | |
|---|---|
| 1 | SM-SC, SILTY SAND-CLAYEY SAND, MOIST, SOFT, PPV = 1.0 $kg/cm^2$, MANY ROOTS. |
| 2 | CL, LEAN CLAY, DRY, HARD, PPV > 4.5$kg/cm^2$, CONTAINS FILAMENTS AND NODULES, MANY ROOTS. |
| 3 | ML, $CaCO_3$, SILT WITH SAND, DRY, HARD-V. HARD, WHITE, STAGE III (NO LAMINAE), PPV > 4.5$kg/cm^2$. |
| 4 | SC, CLAYEY SAND, HARD, PPV > 4.5$kg/cm^2$. |
| 5 | CL-ML, SANDY SILTY CLAY, DRY, SOFT, FINELY LAMINATED FINE SAND, PPV < 0.5$kg/cm^2$, CONTAINS .25 INCH SIZE INTRACLASTS OF CLAY, RODENT BONES. |
| 6 | SM, SILTY SAND, DRY, MED. DENSE, PPV > 4.5$kg/cm^2$, DISCONTINUOUS GRAVEL LENSES. |
| 7 | SM, SILTY SAND, HARD-VERY HARD, FROM BURROW AT 5.5 FEET. |

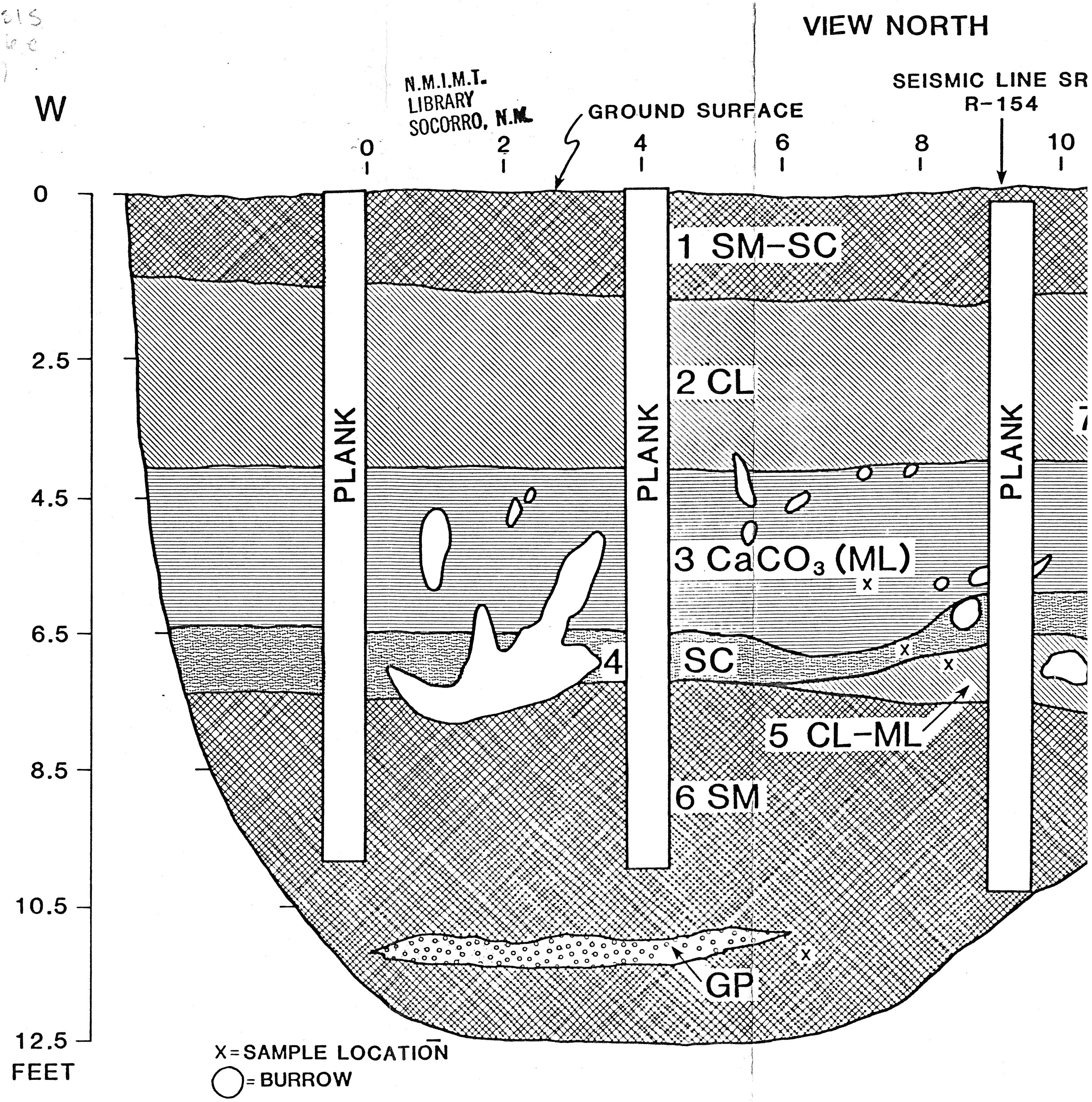
N

OMETER VALUE
STRENGTH

H SSC-BH-2

1987

C PROPOSAL

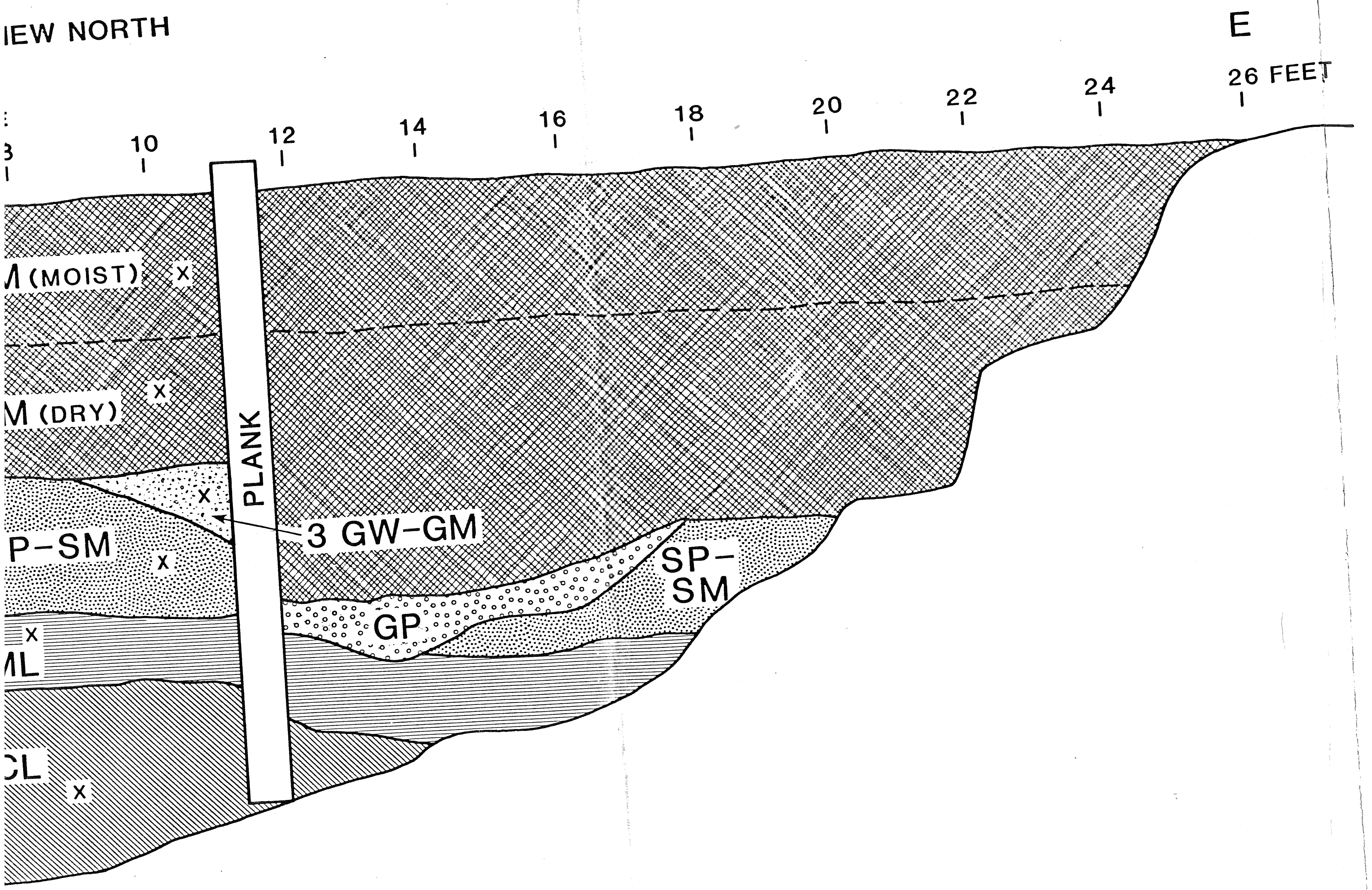


X=SAMPLE LOCATION
○= BURROW
PPV=POCKET PENETROMETER VALUE
TSS=TORVANE SHEAR STRENGTH

LOG OF TRENCH SSC-BH-2

JULY 31, 1987

NEW MEXICO SSC PROPOSAL



UNIT

1 SM, SILTY SAND, S. MOIST, LOOSE.

2 SM, SILTY SAND-GRAVELLY LENSES OF GM, (SILTY GRAVEL) AND SP, (CLEAN SAND). DRY, LOOSE, SNAIL SHELLS.

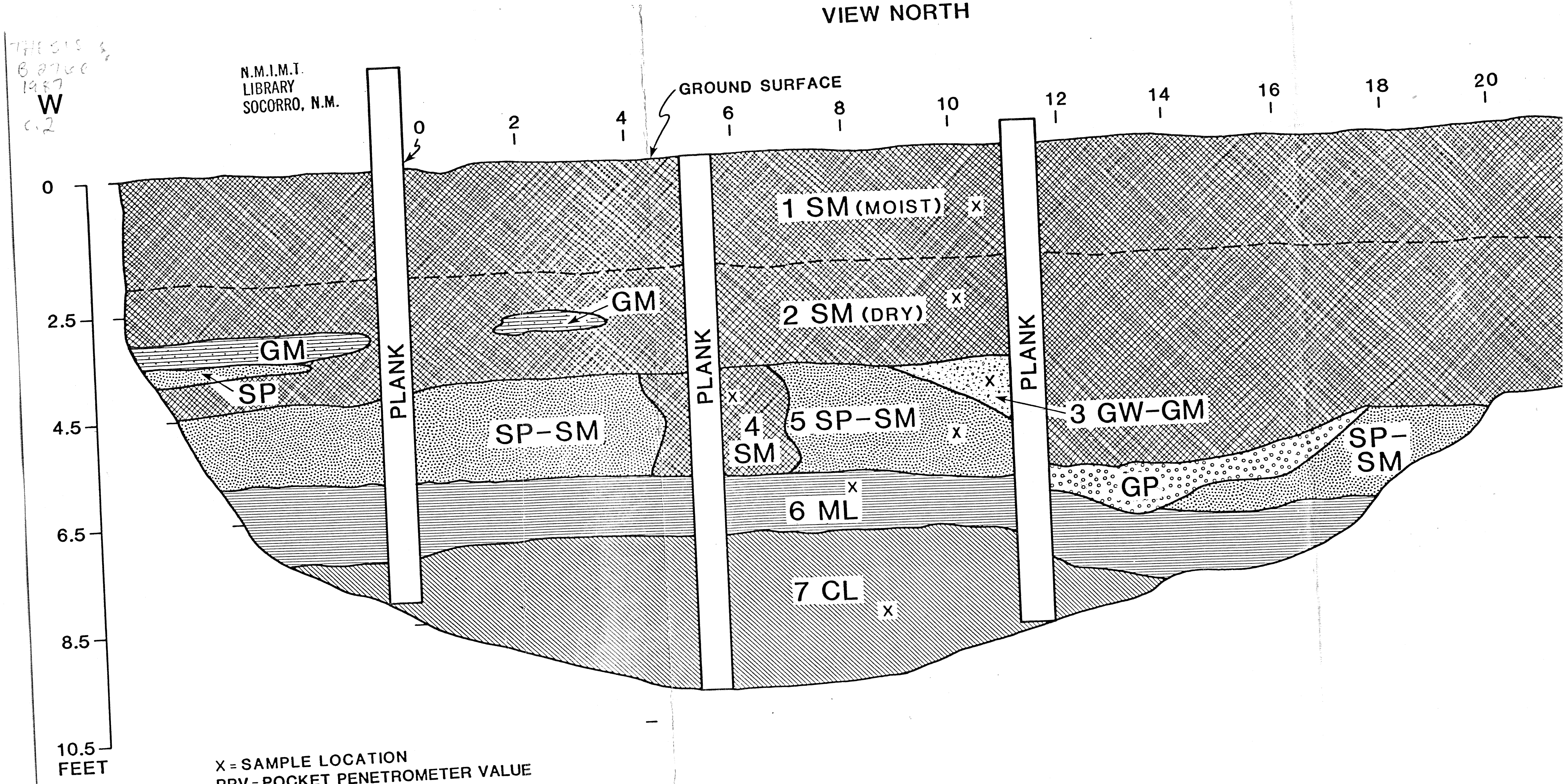
3 GW-GM, WELL GRADED GRAVEL WITH SILT.

4 SP, FINE SAND.

5 SP-SM, FINE SAND-SILTY SAND, DRY, MED. DENSE TO LOOSE, LAMINATED.

6 ML, SANDY SILT, DRY, STIFF, PPV > 4.5kg/cm² .

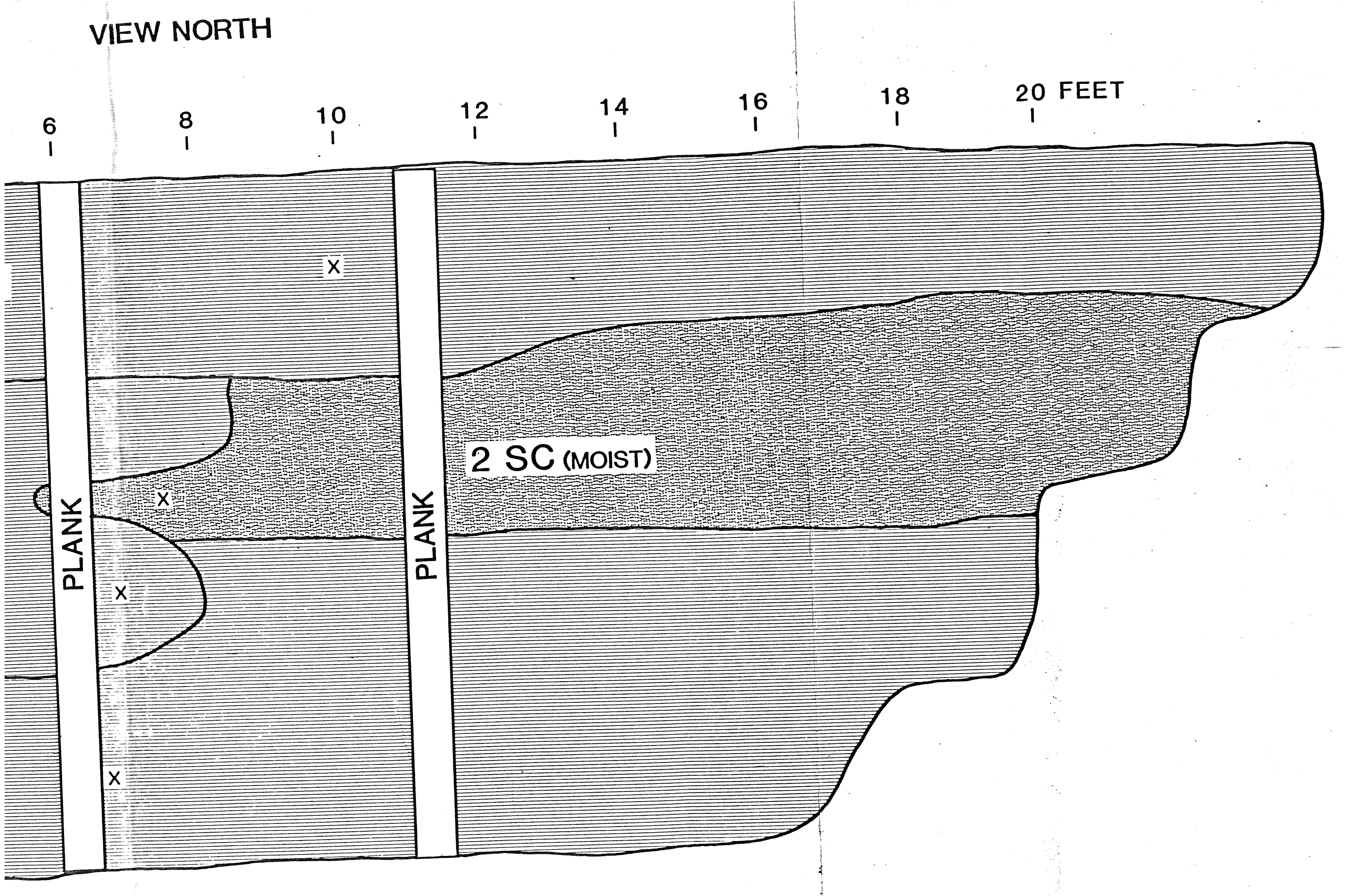
7 CL, LEAN CLAY WITH SAND, DRY-S. MOIST, STIFF-HARD, PPV > 4.5kg/cm² . WHITE.



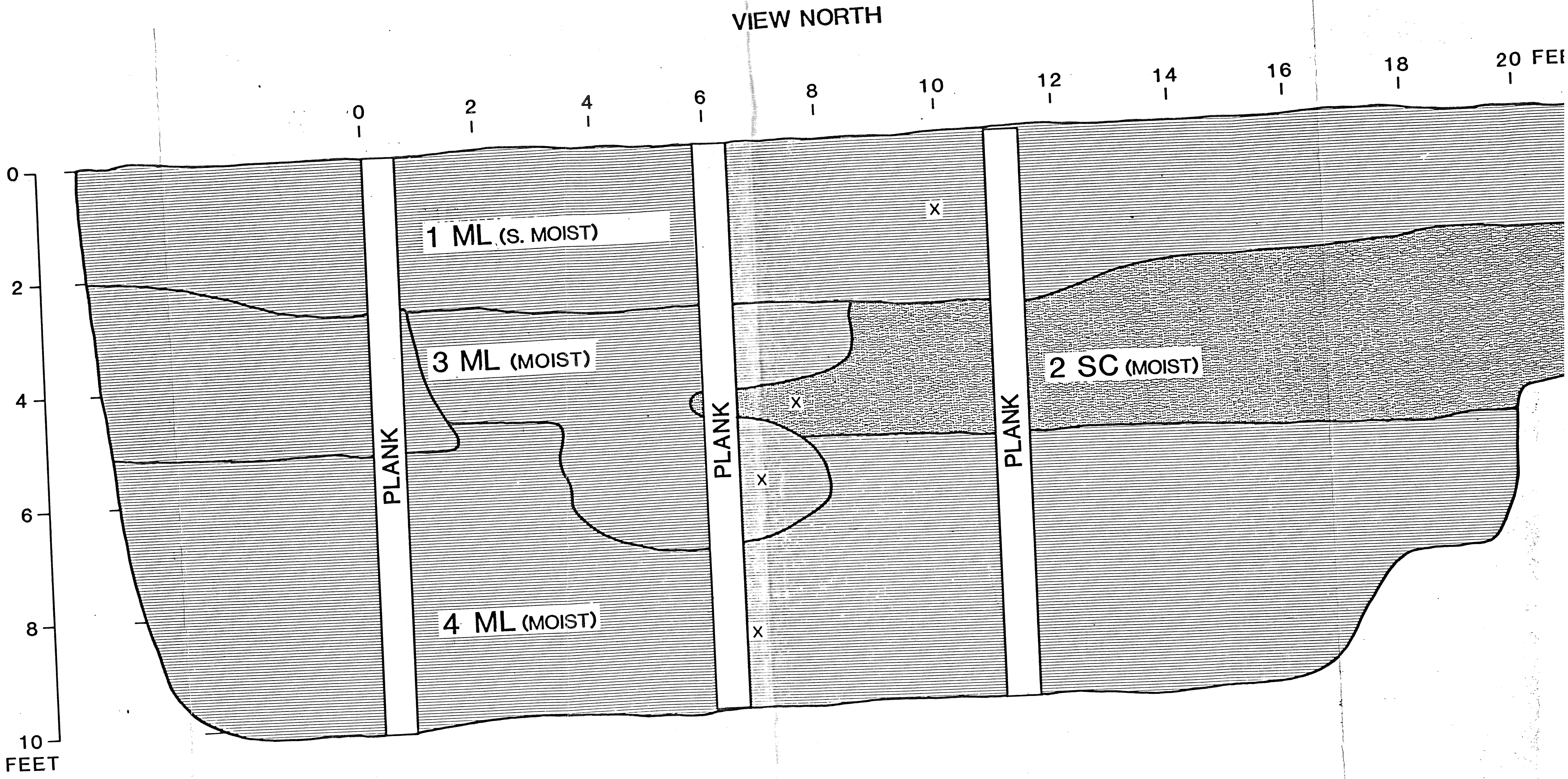
X = SAMPLE LOCATION
PPV = POCKET PENETROMETER VALUE
TSS = TORVANE SHEAR STRENGTH
S = SLIGHTLY

LOG OF TRENCH SSC-BH-4

JULY 31, 1987



| UNIT | |
|---|---|
| 1 | ML, SANDY SILT, MOIST, PPV = 2.0kv/$cm^2$, TSS = 1.5kg/$cm^2$, ORGANIC RICH, HEAVILY BURROWED, MANY $CaCO_3$ NODULES, SOME REWORKED CLASTS FROM UNIT 2 BELOW, DARK YELLOWISH BROWN (POSSIBLY ALLUVIUM). |
| 2 | SC, CLAYEY SAND, MOIST, HARD, PPV > 4.5kg/$cm^2$, TSS = 9.5kg/$cm^2$, FINE ROOTS, CONTACTS BETWEEN UNITS ABOVE AND BELOW ARE SHARP, V. PALE BROWN (LAKE). |
| 3 | ML, SILT TO SANDY SILT, MOIST, SOFT, PPV = 1.5kg/$cm^2$, TSS = 0.5kg/$cm^2$, MORE ORGANIC THAN OTHER UNITS, DISTINGUISHED FROM OTHER UNITS BY DARKER COLOR, STRONG REACTION TO HCl, FINE ROOTS, YELLOWISH BROWN. |
| 4 | ML, SANDY SILT, MOIST, HARD, PPV > 4.5kg/$cm^2$, TSS = 3.0kg/$cm^2$, FEW ROOTS, STRONG REACTION TO HCl, GRADATIONAL CONTACT TO UNIT 3 ABOVE, STRONG BROWN. |

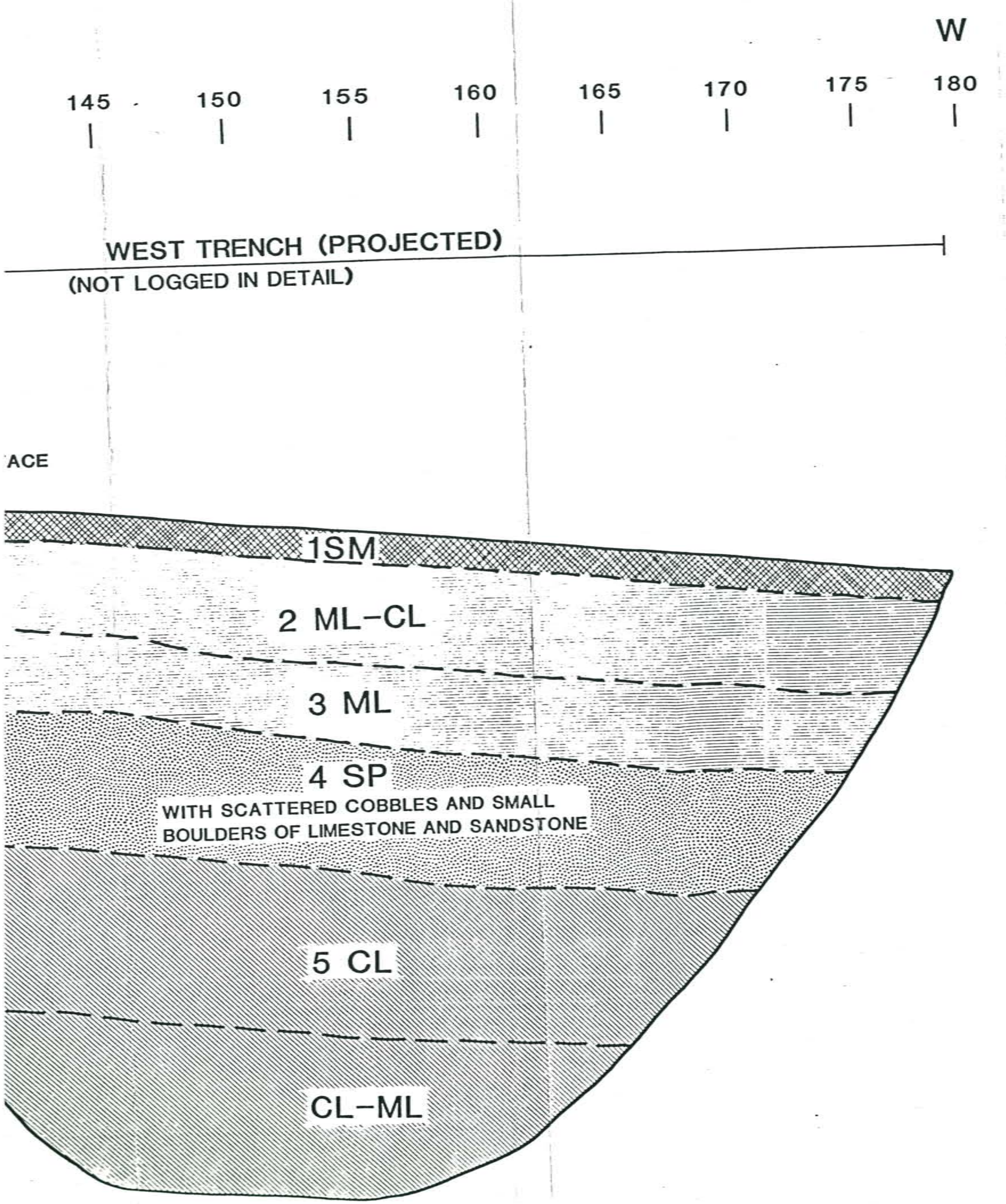


X=SAMPLE LOCATION
PPV=POCKET PENETROMETER VALUE
TSS=TORVANE SHEAR STRENGTH

LOG OF TRENCH SSC-BH-8

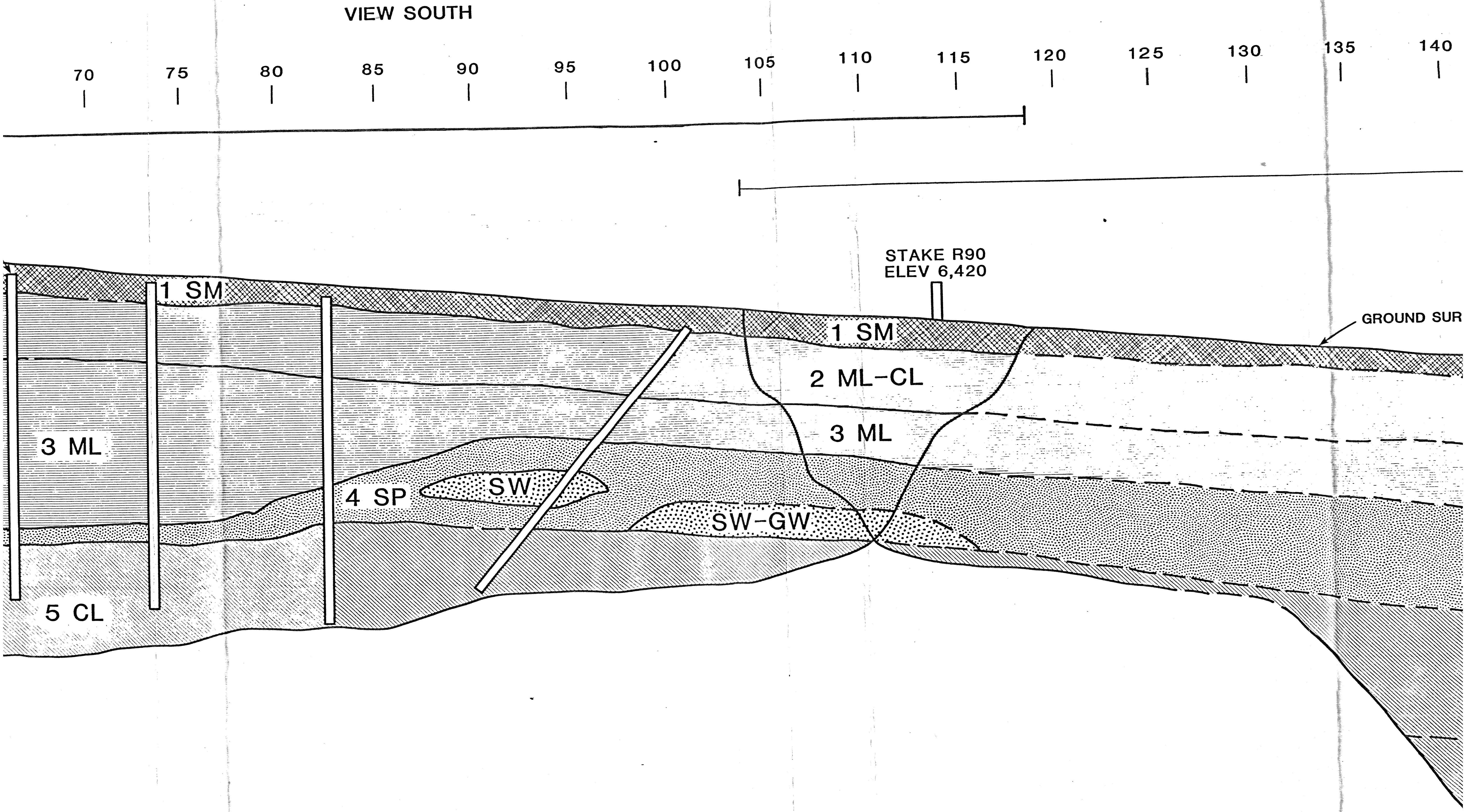
JULY 31,1987

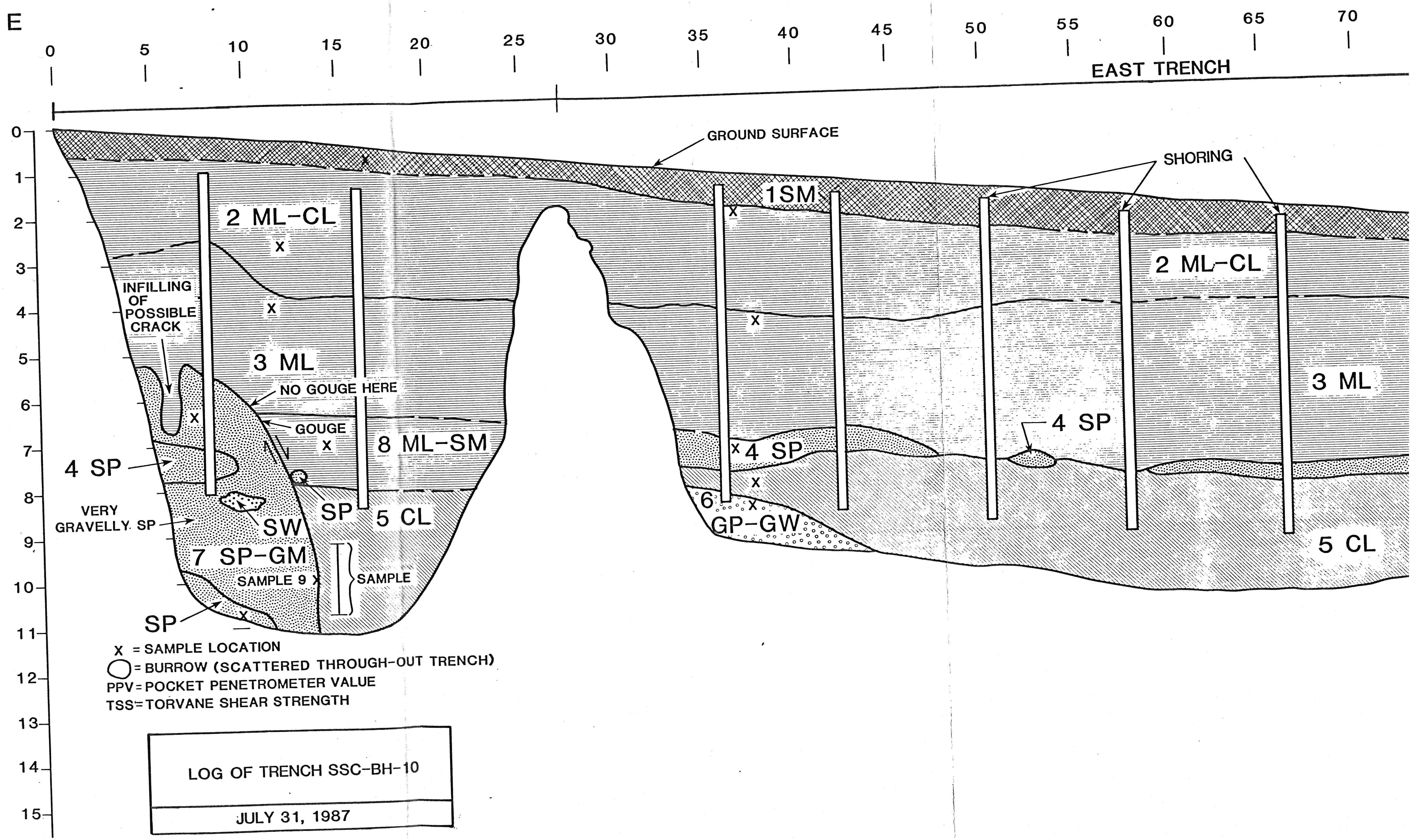
NEW MEXICO SSC PROPOSAL



| UNIT | |
|---|---|
| 1 | SM, FINE SAND, A HORIZON, MANY ROOTS, SCATTERED FINE GRAVEL, VERY MOIST-MOIST, 5YR 4/4 TO 4/6, REDDISH BROWN TO YELLOWISH RED. |
| 2 | ML-CL, SANDY SILT TO SILTY CLAY, PEDOGENIC ARGILLIC HORIZON, SOFT CARBONATE NODULES, SCATTERED FINE GRAVEL (SOME COARSE GRAVEL), SLIGHTLY MOIST-MOIST, MANY SMALL ROOTS, 5 YR 5/6 TO 5/8, YELLOWISH RED. |
| 3 | ML, SANDY SILT, PEDOGENIC CALCIC HORIZON IN UPPER PART, SCATTERED COARSE GRAVEL INCLUDING LIMESTONE AND VERY SOFT YELLOWISH SANDSTONE CLASTS, FEW ROOTS, 5YR 7/4 TO 6/6, PINK TO REDDISH YELLOW. |
| 4 | SP, COARSE GRAVELLY SAND, 35% GRAVEL, MANY GRAVELS HAVE THICK CALCIUM CARBONATE RINDS, CONTAINS LENSES OF CLEAN SAND (SW), UP TO 1 INCH CARBONATE NODULES, 5 YR 5/4 TO 6/6, REDDISH BROWN TO REDDISH YELLOW. |
| 5 | CL, SILTY CLAY WITH GRAVEL, BURIED STRONG PEDOGENIC CA HORIZON, VERY BLOCKY STRUCTURE; UP TO 2 INCH DIAMETER, HARD, WHITE, CARBONATE NODULES; BLACK STAINS ON PED SURFACES; CONTACTS WITH UNITS ABOVE AND BELOW ARE UNDULATORY; 7.5YR 8/2 TO 8/4 ; PINKISH WHITE TO PINK. |
| 6 | GP-GW, POORLY TO WELL-GRADED GRAVEL, VERY HARD SANDY GRAVEL. 0.25 TO 0.5 INCH CLASTS, BACKHOE COULD NOT PENETRATE THIS BED. |
| 7 | SP-GM, GRAVELLY SAND-SILTY GRAVEL, HARD, 7.5YR 7/6, REDDISH YELLOW. |
| 8 | ML-SM, SANDY SILT-FINE SAND, CONTAINS RIP UP CLASTS OF UNIT 6, DRY, SCATTERED FINE GRAVEL, A FEW FINE ROOTS, GRADATIONAL CONTACT WITH UNIT 3, 5YR 4/6, YELLOWISH RED. |

NOTE:
SAMPLE 9 - FROM FAULT GOUGE ZONE, LAMINATIONS IN GOUGE ARE PARALLEL TO FAULT PLANE.


VIEW SOUTH
70
75
80
85
90
95
100
105
110
115
120
125
130
135
140
STAKE R90
ELEV 6,420
GROUND SUR
1 SM
1 SM
2 ML-CL
3 ML
3 ML
4 SP
SW
SW-GW
5 CL



LOG OF TRENCH SSC-BH-10

JULY 31, 1987