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**Converse Consultants**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# INTERIM

# GEOTECHNICAL REPORT

## METRO RAIL PROJECT

## DESIGN UNIT A250

BY

CONVERSE CONSULTANTS, INC.
EARTH SCIENCES ASSOCIATES
GEO/RESOURCE CONSULTANTS

MAY 1984

Funding for this Project is provided by grants to the Southern California Rapid Transit District from the United States Department of Transportation, the State of California and the Los Angeles County Transportation Commission.

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May 25, 1984

Metro Rail Transit Consultants
548 South Spring Street
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83-1140-36

Attention: Mr. B.I. Maduke, Senior Geotechnical Engineer

Gentlemen:

This letter transmits our Interim Geotechnical Report for Design Unit A250 prepared in accordance with our Contract No. 503 agreement dated September 30, 1983 between Converse Consultants, Inc. and Metro Rail Transit Consultants (MRTC). This interim report provides geotechnical information and recommendations to be used by design firms in preparing designs for Design Unit A250.

In accordance with your letter of May 7, 1984, this is an interim report because the findings and conclusions may be revised as a result of:

(a) Bechtel's instrumented prototype test pit in the area of the Wilshire/Fairfax Station,

(b) ongoing construction at the southwest corner of Wilshire and Fairfax Avenue,

(c) readings from slope indicators installed by CCI.

Tunnel and station construction in "tar sands" will be a first in the USA.

Our study team appreciate the assistance provided by the MRTC staff, especially Mr. B.I. Maduke Special appreciation is extended to Bruce Smith of Thurber Consultants, Ltd. for his keen insight into a unique project. We also want to acknowledge the efforts of each member of the Converse team, in particular James A. Doolittle, Dr. Leonard T. Evans, Jr., and Howard A. Spellman, Jr.

Respectfully submitted,

Robert M. Pride, Senior Vice President
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This report has been prepared by CCI/ESA/GRC under the professional supervision of the principal soils engineer and engineering geologist whose seals and signatures appear hereon.

The findings, recommendations, specifications or professional opinions are presented, within the limits prescribed by the client, after being prepared in accordance with generally accepted professional engineering and geologic principles and practice. There is no other warranty, either express or implied.

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# Section 1.0

# Executive Summary

## 1.0 EXECUTIVE SUMMARY

This report presents the results of our geotechnical investigations and engineering analyses for the A250 Design Unit of the Southern California Rapid Transit District's Metro Rail Project in Los Angeles. The A250 Design Unit consists of the Wilshire/Fairfax Station and about 1.5 miles of tunnel line connecting the Wilshire/Fairfax Station to the Wilshire/LaBrea Station and the Beverly/Fairfax Station. The station will be constructed by cut-and-cover methods and extend in depth up to 95 feet below the existing ground surface. The lines extending from the ends of the station will be constructed by tunnelling methods and will have a variable depth of cover above the crowns of stacked and non-stacked tunnels. Construction will occur in mixed soil and rock conditions with high groundwater. For about one mile of the line the tunnel (and station) will encounter tar impregnated soils and rock in the vicinity of the LaBrea tar pits.

The planned construction includes tunnelling and an open excavation far deeper into the tar impregnated soils than ever attempted in Los Angeles. The behavioral characteristics of the tar impregnated soils at such depths and possible construction problems are unknown at this time. An instrumented, prototype test pit has been planned in the immediate vicinity of the Wilshire/-Fairfax Station. In addition, a nearby construction project extending about 70 feet below grade, which will bottom in tar sands, is currently being observed. Based on the results of observations of these two projects, this report is subject to modification regarding construction methods.

### 1.1 STATION

The subsurface conditions at the station consist of 20 to 45 feet of alluvium, primarily of silts, clays, clayey sands and silty sands. Underlying the alluvium the explorations encountered the San Pedro Sand formation varying generally in thickness from 55 to 65 feet; however, near the southeast end of the station the thickness of the formation increases to 115 feet. The San Pedro Sand formation is in turn underlain by interbedded siltstone and claystone of the Fernando formation; groundwater was estimated to be within about 10 feet of the ground surface at the station and the piezometric water head at the southeast end of the station was measured at about the present ground surface.

Station construction will consist of an excavation approximately 950 feet long, 40 to 115 feet wide and up to 95 feet deep. The excavation will extend through the alluvium, some of which is impregnated with tar, and will extend to near the bottom or slightly below the tar impregnated San Pedro Sand formation, except possibly at the southeast end of the station.

Temporary support of the station excavation will be either a soldier pile and wood lagging or slurry wall system with internal bracing or external tieback systems. Successful installation of solider piles, tieback anchors or slurry wall panels will require precautions to maintain the stability of the excavations within the tar impregnated soils. Lateral pressures and other guidelines for design of temporary support systems are provided in the report.

Dewatering of the non-tar bearing alluvium overlying the site will be generally unnecessary as these soils are relatively impervious. Dewatering of the tar bearing soils is not considered practical; however, depressurization of these soils will result in a significant improvement of the behavioral characteristics.

The undisturbed fine grained tar silts and the Fernando formation will adequately support the deep portion of the permanent station structure. Piles are recommended for the shallow mezzanine wings. Design lateral pressures for the permanent structure are outlined in the text of the report.

## 1.2 TUNNELS AND CROSSPASSAGES

Tunnelling media for the 1.5 mile bore consists of tar bearing San Pedro sands, non-tar bearing alluvial soils and interbedded siltstone, claystone and sandstone bedrock of the Fernando formation.

The entire length of the tunnel occurs below the groundwater level. Water levels, in large part, are near the ground surface.

The entire tunnel line is judged to be gassy, requiring an above normal ventilation system and emergency backup system.

For about one mile the primary tunneling media will be tar bearing sand which we believe will be viscous in an unconfined state. Mixed face conditions will occur periodically, such as old alluvium above and San Pedro sand below, as well as San Pedro Sand above and Fernando formation below. In our opinion, construction methods for driving the tunnel in this media should be with a fully shielded tunneling machine such as an earth pressure balanced shield or bentonite slurry shield. Advance freezing or depressurizing the tar sands would improve behavior of the tar sands, but we believe these methods would be impractical.

Cross passages between tunnels at Stations 549+45 and 556+62 will encounter saturated interlayered horizons of cohesive and cohesionless-like soils. The cross passages should be excavated by hand and/or mechanical excavation equipment, anticipating full face and crown support.

## 1.3 UNDERPINNING

Guidelines for assessing the need for underpinning of buildings adjacent to the Station construction are discussed in the report. Detailed analyses to identify and recommend which buildings and/or facilities shall be underpinned will be carried out by the section designer for this Design Unit.

## 1.4 SEISMIC CONSIDERATIONS

Analysis of the gradational characteristics and in-situ relative density of the granular soils indicate that liquefaction of such soils during a maximum design earthquake has a low probability.

Design procedures and criteria for underground structures under earthquake loading conditions are defined in the SCRTD report entitled "Guidelines for

Seismic Design of Underground Structures" dated March 1984. Seismological conditions which may impact the project and the operating and maximum design earthquakes which may be anticipated in the Los Angeles area are discussed in the "Seismological Investigation and Design Criteria" report dated May, 1983 prepared by Converse, et al for SCRTD. The 1984 report complements and supplements the 1983 report. Site specific static and dynamic properties for materials in design unit A250 are given in the report.

# Section 2.0

# Introduction

## 2.0 INTRODUCTION

This report presents the results of a geotechnical investigation for Design Unit A250. The unit consists of Wilshire/Fairfax Station, and about 1.5 miles of subsurface track line proceeding from the west end of the Wilshire/LaBrea Station to the south end of the Beverly/Fairfax crossover structure. The work performed for this report includes borings, laboratory tests, engineering analysis, and the development of recommendations and specifications for design and construction of the included station and tunnel. This Design Unit is a part of the 18.6-mile long Metro Rail Project (see Drawing 1, Vicinity Map).

Additional geotechnical information on the Metro Rail Project is included in the following reports, some of which may pertain to Design Unit A250.

- "Geotechnical Investigation Report, Metro Rail Project", Volume I - Report, and Volume II - Appendices, prepared by Converse Ward Davis Dixon, Earth Sciences Associates and Geo/Resource Consultants, submitted to RTD in November 1981. This report presents general geologic and geotechnical data for the entire project. The report also comments on tunneling and shoring experience and practices in the Los Angeles area.

- "Seismological Investigation & Design Criteria Metro Rail Project", prepared by Converse Consultants, Lindvall Richter & Associates, Earth Sciences Associates and Geo/Resource Consultants, submitted to RTD in May 1983. This report presents the results of a seismological investigation.

- "Geologic Aspects of Tunneling in the Los Angeles Area" (USGS Map No. MF866, 1977), prepared by the U.S. Geological Survey in cooperation with the U.S. Department of Transportation. This publication includes a compilation of geotechnical data in the general vicinity of the proposed Metro Rail Project and this Design Unit.

- "Rapid Transit System Backbone Route", Volume IV, Book 1, 2 and 3, prepared by Kaiser Engineers, June, 1962 for the Los Angeles Metropolitan Transit Authority. This report presents the results of a Test Boring Program for the Wilshire Corridor and logs of borings.

The design concepts discussed in this report are based on CBD to North Hollywood Line Plans, Drawings AP-16AAA-C-142 to AP-16AAA-C-150, dated July 1983; Preliminary Site Plans, Plans and Sections for the Wilshire/Fairfax Station, Drawings A-42, A-43, A-44, A-45A and A-45B dated November 1983; and CBD to North Hollywood Line Profile, Drawings SK-250-1A and SK-250-2A dated November 1983.

# Section 3.0

# Site and Project Description

## 3.0 SITE AND PROJECT DESCRIPTION

### 3.1 GENERAL

The existing ground surface Elevations along the alignment vary between approximately 197 feet on the east end and to about 165 feet at the Wilshire/Fairfax Station rising again to about Elevation 182 at the Beverly/ Fairfax crossover structure. The variation in elevation along the alignment resulted from the general south-southwest gradient of the site area combined with the direction change of the aligment at Wilshire/Fairfax Station.

All thoroughfares are paved and underlain by a variety of sensitive utilities and drainage facilities. Development along the A250 alignment includes high-rise structures, multi-family residential structures and single-family residential areas.

The construction features about 1.5 miles of twin bore tunnels, beyond the Station location, having an outside diameter of approximately 19 feet. The minimum depth of cover is approximately 30 feet, and the maximum depth of cover approaches 70 feet. The Station structure is located near the Wilshire Boulevard and Fairfax Avenue intersection. The depth to Station structure invert is approximately 95 feet.

There is no vent structure within A250; however, there will be cross passages located at Stations 549+45 and 556+52.

### 3.2 WILSHIRE/FAIRFAX STATION

The Wilshire/Fairfax station will be located beneath the existing May Company Budget Store and parking facilities (both a parking structure and surface parking) as shown on Drawing 4. Demolition of the Budget Store and a major portion of the existing parking structure will be required for construction. Other structures in the site area include the May Company department store to the southwest and the Los Angeles County Museum to the east. Development to the north and northwest of the site is residential. Existing ground surface elevations at the site range from about Elevation 165 feet at the southeast end to about Elevation 169 feet at the northwest end.

The Wilshire/Fairfax Station will be a reinforced concrete structure about 950 feet long and about 40 to 115 feet in width (outside wall dimension). The station is planned to be about 95 feet deep with two (upper and lower) platforms to accommodate the "stacked" rails planned at this location. The lower rail will be at about Elevation 78 feet and the upper rail at about Elevation 108 feet. In addition, a mezzanine level is planned above the platforms at about Elevation 128 feet. The width of the mezzanine level (90± feet) will be greater than that of the platform areas below (60 feet) and will "overhang" the platforms on the west side of the structure. The top of the station will range from about 20 to 25 feet below the ground surface. After the station is completed, fill will be placed above the structure to the ground surface. Two entrances are planned from the ground surface to the mezzanine level. One entrance will be located at the southeast end of the station near the intersection of Wilshire and Ogden, the other entrance will be at the northern end of the platform area near Fairfax Avenue. Ancilliary areas are planned at both the southeast and northwest ends of the station. Design loads for this station structure were not available at the time of this report.

## 3.3 TUNNEL ALIGNMENT

As shown on Drawings 2 and 3 the tunnel line in Design Unit A250 is about 1.5 miles long (excluding the station structure). The tunnel line consists of twin adjacent tunnels extending west from the west end of the Wilshire/LaBrea Station to approximately station 482+00. At this point the southern tunnel begins a grade and alignment change which is completed at about station 496+00 placing it below the other tunnel in a "stacked" configuration. The tunnels enter and exit the Wilshire/Fairfax station in the "stacked" configuration. North of the station the lower tunnel grade rises to reach the grade of the upper tunnel at about station 549+00. From that point the twin tunnels continue along the same gradient northward to the the southern end of the Fairfax/Beverly crossover structure.

# Section 4.0

# Field Exploration and Laboratory Testing

## 4.0 FIELD EXPLORATION AND LABORATORY TESTING

### 4.1 GENERAL

The information presented in this report is based primarily on the field and laboratory investigations performed in 1981, 1983 and 1984. This information was derived from field reconnaissance, borings, geologic reports and maps, ground water measurements, field gas measurements, field geophysical surveys, ground water quality tests, and laboratory tests on soil and rock samples. Geotechnical report references listed in Appendix H were utilized to complement and supplement the more recent information. Technical considerations presented in Appendix F include discussions on shoring practices in the Los Angeles area, seismicially induced earth pressures, liquefaction evaluation methods and previous tunnelling experience. Guidelines for earthwork are discussed in Appendix G.

### 4.2 BORINGS

For the A250 investigation, 24 borings were drilled along the alignment and at the station site. Fifteen rotary wash borings and two mansize auger borings were drilled along the alignment; seven rotary wash borings were drilled at the station site. The station was moved and deepened about 30 feet during the early part of the drilling program, and several holes had already been drilled to shallower depths. Subsurface data from two rotary wash borings from the Wilshire/La Brea Station (Design Unit A245) and three borings from the Beverly/Fairfax Station (Design Unit A275) are also included in this report. The location of the borings are shown on Drawings 2, 3 and 4 and the logs of the borings are provided in Appendix A. Also included in Appendix A are two borings previously drilled by Woodward Clyde Associates along the alignment.

Ground water levels were recorded in the 22 borings listed in Table 5-6. In addition pneumatic piezometeric transducers were installed in Borings 19-2, 19-3 and 20-1. Section 5.5 presents a summary of ground water and piezometric levels measured at these locations.

In 1962, Kaiser Engineers drilled 9 borings within the Design Unit A250 tunnel alignment section: Borings 34 to 42, inclusive. These borings were spaced about 500 feet apart and ranged from 50 to 80 feet deep at the locations shown on Drawings 2 and 3. The 9 Kaiser borings were used to interpret the depth of soil overlying the bedrock, but they were not used to evaluate ground water conditions. The Kaiser Boring Logs can be examined at the Southern California Rapid Transit District office in Vol. 4, Books 2 and 3, entitled "Test Boring Program" prepared for the Los Angeles Metropolitan Transit Authority, June 1962.

Another source of boring information is the U.S. Geological Survey paper, "Geologic Aspects of Tunneling in the Los Angeles Area" (USGS Map No. MF-866, 1977). The foundation investigation borings included in the USGS report are not shown on our drawings and were not used because, in large part, they were too shallow for proper interpretation of subsurface conditions along the proposed grade of the Metro Rail tunnel.

## 4.3 GEOPHYSICAL MEASUREMENTS

Downhole and crosshole compression and shear wave velocity surveys were performed in Borings CEG-18 and CEG-20 which were drilled during the initial 1981 investigation (see Drawings 2 and 3 for locations). In addition seven seismic refraction lines were recorded in the vicinity of Hancock Park located just east of the Wilshire/Fairfax station. Appendix B summarizes the field survey procedures as well as the results of the velocity measurements.

## 4.4 GEOTECHNICAL LABORATORY TESTING

The laboratory program developed to test representative soil and rock samples consisted of classification tests, bitumen content tests, consolidation tests, triaxial compression tests, dynamic triaxial tests, resonant column tests, unconfined compression tests, direct shear tests, and permeability tests.

Appendix C summarizes the testing procedures and presents detailed results of the 1983 program and summarizes the results of the 1981 laboratory program.

## 4.5 WATER QUALITY ANALYSES

Chemical analyses were performed and selected parameters were evaluated for water samples obtained in Borings CEG 19, 21, and 22. The chemical analyses and results of these tests are presented in Appendix D.

## 4.6 GAS ANALYSES

Sulphur and petroleum odors were noted at various depths in nearly all of the borings drilled in Design Unit A250. In the vicinity of the Wilshire/Fairfax station thick deposits of tar impregnated soils were encountered at depths as shallow as 12 feet. During the 1981 investigation gas chromatography analyses were performed in Borings CEG-19, CEG-21, and CEG-22. The results of the 1981 tests are presented in Appendix E.

# Section 5.0

# Subsurface Conditions

## 5.0 SUBSURFACE CONDITIONS

### 5.1 GENERAL

During the field programs conducted for this and the 1981 investigations, the contact between the Old and Young Alluvium was difficult to identify since the soils in these two deposits can be very similar. While the Young and Old Alluvium may be geologically different, our interpretation of the field and laboratory test data suggests that they do not differ significantly from an engineering standpoint. For the purposes of this report, Young and Old Alluvium have not been differentiated and are simply referred to as Alluvium.

Generalized geologic sections showing the major units encountered in the A250 Design Unit section are shown on Drawings 2 and 3. The following major soil and rock units have been identified.

- Alluvium
- San Pedro Sand
- Fernando Bedrock

A more complete description of these materials is given in the following sections.

### 5.2 ALLUVIUM

Alluvial soils were encountered from the surface to depths of up to 80 feet along this section of the proposed line. The Alluvium consists predominantly of interbedded silty clays, sandy clays and clayey sands and silts. Discontinuous lenses and seams of clean sands and silty sands (often water-bearing) are also present at intermediate depths within the Alluvium. It should be noted that, where the Alluvium is underlain by tar bearing San Pedro Sands, the lower 5 to 15 feet of the Alluvium is often impregnated with tar.

Standard Penetration Test (SPT) results and laboratory test results indicate that the Alluvium is generally stiff to very stiff, and granular layers are dense to very dense. Since these soils are generally silty and clayey in nature, both drained (effective) and undrained (total) strength parameters have been developed from results of direct shear and triaxial compression tests. The recommended strength parameters for this soil unit were selected based primarily on the results of tests performed on samples within this design unit, although strength test results obtained from other nearby design units were also considered for the non tar bearing Alluvium. The strength parameters adopted are given in Table 5-1.

TABLE 5-1
STRENGTH PARAMETERS FOR ALLUVIUM

| Type | c' (psf) | ø' (degrees) | $c_u$ (psf) | $ø_u$ (degrees) |
|---|---|---|---|---|
| Non tar bearing | 0 | 35 | 1000 | 17 |
| Tar bearing | 0 | 35 | 2000 | 20 |

Permeability tests performed on samples of non tar impregnated Alluvium obtained from other design units indicate that these soils can have a permeability ranging from about $10^{-5}$ to $10^{-8}$ cm/sec. However, since the soils were found to be interbedded and lenticular, slightly higher permeabilities are recommended for design. The presence of tar in the fine-grained Alluvium has only a minor effect on its effective strength and deformation properties. However, it does result in a reduction in the apparent permeability of the material (as defined in conventional civil engineering practice) because of the bitumen content.

## 5.3 SAN PEDRO SANDS

### 5.3.1 General

The Alluvium is underlain by the San Pedro Sands which are of Lower Pleistocene Age, and which are believed to have originated as a beach deposit. The surface of the San Pedro Sands was subjected to erosion when the overlying alluvial material was deposited, and hence the contact between the two soil units is highly variable. In this design section, the top of the San Pedro Sands was found to range from 15 to 65 feet below present grade. The San Pedro Sands consist predominantly of a clean, poorly graded fine sand. Petrographic analysis on a limited number of samples indicates the sands are composed of over 95% quartz. Lenses or layers of silty sands, silt and occasionally silty clay are present within the sands. Gravel seams are common, and boulders were encountered at some locations. In particular, a relatively large zone of gravel and boulders was located at the southeast end of the Wilshire/Fairfax Station, immediately above the bedrock, in what appears to be an old erosion channel. Concretions, consisting of hard cemented gravel or sands, have also been encountered within this soil unit.

The San Pedro Sands in the vicinity of the La Brea tar pits were found to contain a significant amount of bitumen, between approximately station 488+00 to station 545+00. Within the tar bearing sands, occasional isolated concretions consisting of solidified, hard bitumen have been observed. Occasional pockets of free bitumen, several feet in thickness (areal extent unknown), have also been reported. Occasional seams which contain free gas (as opposed to solution gas within the bitumen) were observed in several boreholes. Tar bearing sand is defined as a sand with the pore fluid containing 25% or more bitumen.

The non tar bearing (water bearing) San Pedro Sands at tunnel grade are between about stations 480+00 to 488+00 and again, between about stations 545+00 to 566+00.

Standard penetration tests carried out within the San Pedro Sands within this design unit indicate that the sand in its in-situ state is very dense. No significant difference in penetration resistance was found between the tar bearing and water bearing sands. Standard penetration resistance was found to range from 75 to 150 blows per foot, with an average resistance on the order of 100 blows per foot. It has been concluded that the in-situ penetration resistance is not affected significantly by the presence of the bitumen in the sands.

Within the station area, the lower few feet of the San Pedro Sand formation consisted of stiff silts and clays which were impregnated with tar. These soils appear to be quite similar to the underlying bedrock.

### 5.3.2 Strength Parameters

The strength parameters for both tar bearing and water bearing San Pedro Sands were determined. In the case of the tar sands, the strength parameters were determined on samples taken from the vicinity of the Wilshire/Fairfax Station. The peak, effective strength parameters were determined in triaxial tests, in direct shear tests and from insitu pressuremeter tests. The results are presented in Table 5-2.

The strength parameters of the water bearing San Pedro Sands were determined on samples taken from the vicinity of the Wilshire/LaBrea, the Wilshire/Western and the Wilshire/Normandie Stations. The strength parameters of these samples were measured in triaxial tests and in direct shear tests. These test results are presented in Table 5-3.

It is of interest to compare the results obtained from the tar bearing and water bearing San Pedro Sands as shown in Table 5-4:

TABLE 5-4

| TEST | AVERAGE EFFECTIVE ANGLE OF INTERNAL FRICTION* (degrees) Tar Bearing | Water Bearing | NUMBER OF TESTS |
|---|---|---|---|
| Direct Shear | 39.9 | 32.9 | 7 |
| Triaxial | 36.9 | 38.6 | 2 |
| Pressuremeter | 42.4 | - | 7 |

*Does not include tar bearing silts.

Based on the results obtained in the direct shear tests, the measured angle of friction is seen to be significantly lower in the water bearing San Pedro Sands as compared to the tar sands. This apparent difference could be because the direct shear tests in tar sand were run too quickly and either the tar sand did not drain (and hence generated negative pore pressures) or the high viscosity of the bitumen contributed to the strength during the relatively fast rates of testing. The results from the triaxial tests compare very favorably. In general, strength data as measured in triaxial tests are more reliable than data obtained from direct shear tests, since the samples are less disturbed and the triaxial results will not be as sensitive to the rate of testing because the triaxial tests are undrained with pore pressure measurement. The pressuremeter tests gave the highest angle of friction for the tar sands. This could be because the pressuremeter test involves the least amount of sample disturbance, or because the rate of strain in the pressuremeter is relatively fast, resulting in the generation of negative pore pressures and an apparent higher strength.

## TABLE 5-2
## STRENGTH PARAMETERS
## TAR BEARING SAN PEDRO SANDS
## WILSHIRE/FAIRFAX STATION

### MULTI-STAGE TRIAXIAL TESTS

| TEST HOLE | DEPTH (ft) | STRENGTH** PARAMETERS c' (psf) | φ' (degrees) | STRAINS AT $(\sigma_1-\sigma_3)_{max}$ (%) | STRAINS AT† $(\sigma_1/\sigma_3)_{max}$ (%) | | | WATER CONTENT (%) | BITUMEN CONTENT (%) | BULK DENSITY (pcf) |
|---|---|---|---|---|---|---|---|---|---|---|
| 19-4 | 86.3* | 0 | 39.0 | 21.6 | 2.4 | 5.6 | 8.2 | 8.8 | 17.5 | 123.4 |
| 19-5 | 61.0 | 0 | 37.2 | 17.6 | 4.9 | 6.0 | 7.0 | 5.6 | 18.7 | 125.9 |
| 19-5 | 62.0 | 0 | 36.6 | 14.2 | 1.8 | 7.6 | 8.8 | 7.7 | 18.7 | 123.0 |

*Tar bearing silt in San Pedro Sand Formation.

**Strengths are for $(\sigma_1-\sigma_3)_{max}$ and are lower than for $(\sigma_1/\sigma_3)_{max}$ failure criteria.

†Strain values for all three stages.

### DIRECT SHEAR TESTS

| TEST HOLE | DEPTH (ft) | c' (psf) | φ' (degrees) | SAMPLE TEMPERATURE (°F) |
|---|---|---|---|---|
| 19-4 | 28 | 0 | 37 | 72 |
| 19-5 | 38* | 0 | 37 | 72 |
| 19-5 | 53 | 0 | 38 | 72 |
| 19-5 | 95* | 0 | 41 | 72 |
| 19-7 | 43 | 0 | 37 | 72 |
| 20-1 | 53 | 0 | 43 | 72 |
| 20-1 | 73 | 0 | 30 | 72 |
| 20-1 | 103* | 0 | 49 | 72 |
| 20-1 | 43 | 0 | 46.7 | 120 |
| 20-1 | 43 | 0 | 47.4 | 72 |

*Tar bearing silt in San Pedro Sand Formation.

### PRESSUREMETER TESTS

| TEST HOLE | DEPTH (ft) | c' (psf) | φ' (degrees) |
|---|---|---|---|
| 19-8P | 39.5 | 0 | 28 |
| 19-8P | 48.0 | 0 | 63 |
| 19-8P | 50.5 | 0 | 46 |
| 19-8P | 63.5 | 0 | 52 |
| 19-9P | 18.0 | 0 | 46 |
| 19-9P | 25.0 | 0 | 36 |
| 19-9P | 60.0 | 0 | 26 |

## TABLE 5-3
## STRENGTH PARAMETERS
## WATER BEARING SAN PEDRO SANDS

### MULTI-STAGE TRIAXIAL TESTS

| TEST HOLE | DEPTH (ft) | c' (psf) | ø' (degrees) | STRAIN† (%) | | |
|---|---|---|---|---|---|---|
| 14-2 | 79.5 | 0 | 35.8 | 1.5 | 4.0 | 6.8 |
| 15-3 | 76.5 | 0 | 41.2 | 2.4 | 3.4 | 4.8 |
| 8-2 | 68.5 | 0 | 38.7 | | | |

†Strain at maximum ($\sigma_1/\sigma_3$) for three stages.

### DIRECT SHEAR TESTS

| TEST HOLE | DEPTH (ft) | c' (psf) | ø' (degrees) |
|---|---|---|---|
| 14-2 | 74.0 | 0 | 35.0 |
| 14-3 | 58.0 | 0 | 30.2 |
| 14-3 | 62.0 | 0 | 30.2 |
| 15-1 | 66.5 | 0 | 35.0 |
| 15-4 | 79.4 | 0 | 40.9 |
| 15-5 | 71.3 | 0 | 31.7 |
| 18-1 | 72.0 | 0 | 31.0 |
| 18-3 | 63.0 | 0 | 29.5 |

The conclusion drawn from the foregoing test results is that, from a practical point of view, there is no significant difference between the strength parameters of the tar bearing and water bearing San Pedro Sands when in a confined state.

### 5.3.3 Effect of Temperature on Strength

The effect which temperature has on the peak angle of internal friction of the tar sands was assessed by undertaking drained direct shear tests on six samples taken from the same core. These results are included on Table 5-2. An average peak effective angle of friction of 46.7° was measured on the samples tested at about 120°F, while the average of the samples tested at about 72°F was found to be 47.4°. The relatively minor difference in the values most likely reflects a difference in texture between the samples tested rather than a change in strength as a result of temperature.

### 5.3.4 Creep Behavior

In Table 5-4 the average effective stress angles of internal friction (ø) are listed for various testing procedures. It was noted that ø decreased for the tar bearing sands as a function of the testing rate. In order to investigate this phenomenon, a number of constant load direct shear (creep) tests were carried out on tar bearing San Pedro Sands to assess whether the samples would creep under long-time loads. The tests were run at a room temperature of about 72°. In the context of this report, creep is defined as a reduction in the effective strength parameters of the material. Loads were applied in increments and held constant after each increment until the failure load was reached.

Typical test results in the form of time versus deformation plots are given in Appendix C.

Based on the results in Table 5-4, the angle of internal friction of the tar sands is in excess of 36°. On this basis and assuming no effective cohesion, the available shearing resistance should be at least 72% of the effective normal stress. In all of the creep tests performed, at shearing loads of 70% to 75% of the normal stress, the measurable deformation of the samples was small or negligible. For one test, a shear load equal to the normal load held with no strain for at least 16 hours and then failed abruptly. See Appendix C.

On the basis of these test results, it has been concluded that the tar sands do not exhibit creep behavior in a confined state at shear loads of about 70% or less of the normal load, or an effective peak strength angle of internal friction of 35° (in a confined state).

### 5.3.5 Angle of Friction on Steel

Direct shear tests were undertaken to determine the angle of friction between a smooth mild steel plate and the San Pedro Sands. The following results were obtained:

|  | ANGLE OF FRICTION ON MILD-STEEL (degrees) |
|---|---|
| Water bearing sand | 24.5 |
| Tar bearing sand | 22.5 |

These results are typical for the angle of friction between mild steel and quartz sands. The difference between the results obtained with the tar bearing and water bearing sands is, most likely, caused by differences in texture between the samples tested.

### 5.3.6 Deformation Parameters

The maximum Shear Modulus for the sands were calculated from the shear wave velocity. The following values were obtained:

| TEST HOLE | SOIL DESCRIPTION | SHEAR WAVE VELOCITY (fps) CROSSHOLE | DOWNHOLE | AVERAGE | CALCULATED $G_{max}$ (psi) |
|---|---|---|---|---|---|
| 18 | Water Bearing San Pedro Sands | 966 | 1326 | 1146 | 35,400 |
| 20 | Tar Bearing San Pedro Sands | 1225 | 1021 | 1123 | 34,000 |

The calculated values for the maximum Shear Modulus of the water and tar bearing sands are in close agreement. The values are also in close agreement with values measured by others on conventional, dense, water bearing sands. A value of 35,000 psi has been recommended for design in both tar bearing and water bearing San Pedro Sands when functioning in a confined state.

Variation in Shear Modulus (G) with strain for the tar bearing San Pedro Sands was also investigated. Shear Modulus was calculated at various strains from the triaxial and pressuremeter data. The results have been plotted on Figure 5-1. The continuous curve shown on Figure 5-1 for saturated granular soils was obtained from published test data. It is clear that the variation in shear modulus for the tar bearing San Pedro Sands is in close agreement with the data for conventional sands.

Hysteretic damping of the tar bearing sand could not be established as we have no experimental data. It can be expected that the damping characteristics of the tar sand will be the same or greater than water bearing sand. For most conventional dynamic analyses, it will be conservative (safe) to use the same damping curve for the tar sand as has been recommended for the water bearing sand as shown on Figure 5-2.

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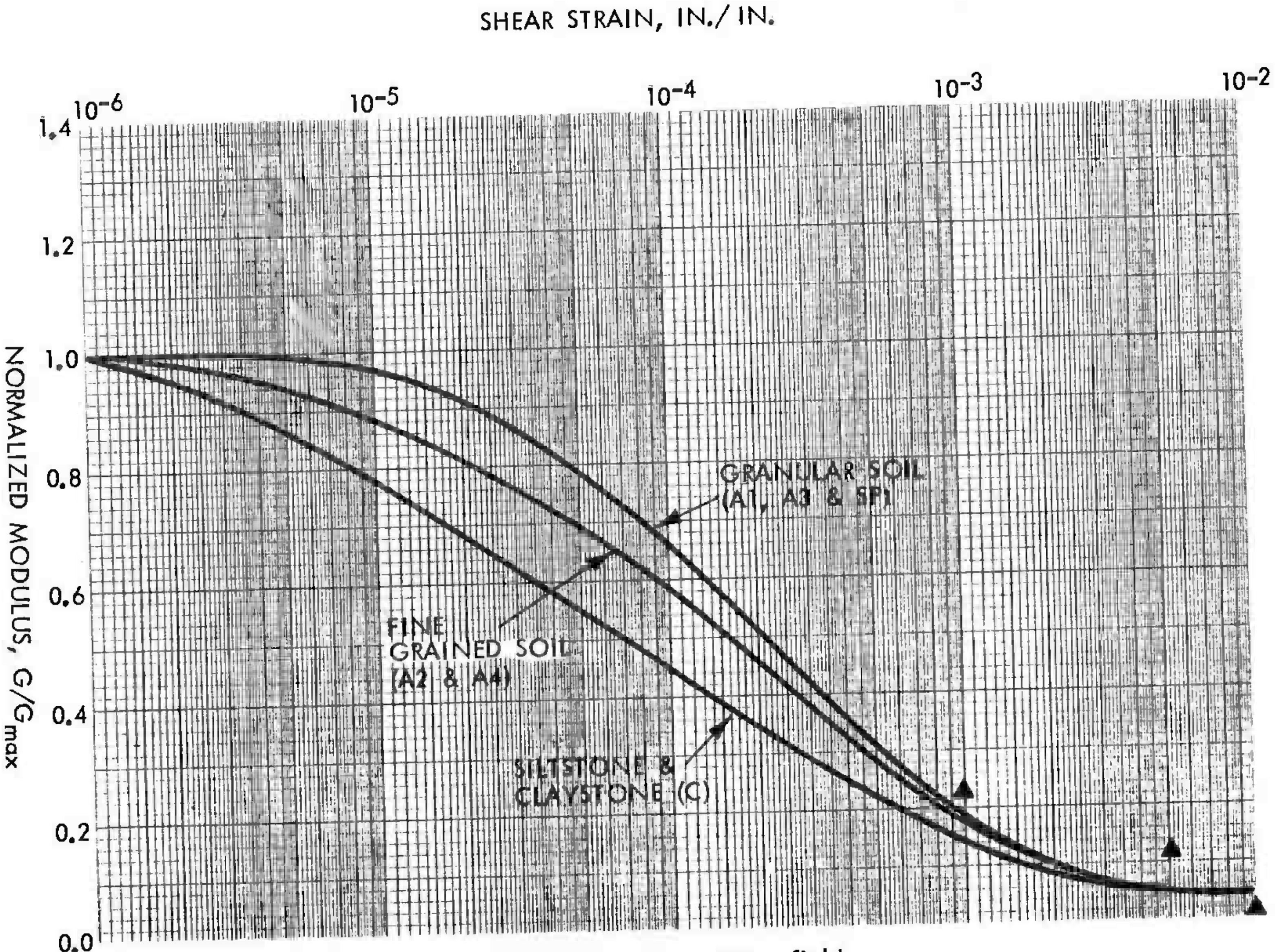

▲ Values calculated for Tar sand from field and laboratory test data

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## RECOMMENDED DYNAMIC SHEAR MODULUS RELATIONSHIPS

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Figure No.
5-1

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# RECOMMENDED DYNAMIC DAMPING RELATIONSHIPS

DESIGN UNIT A250
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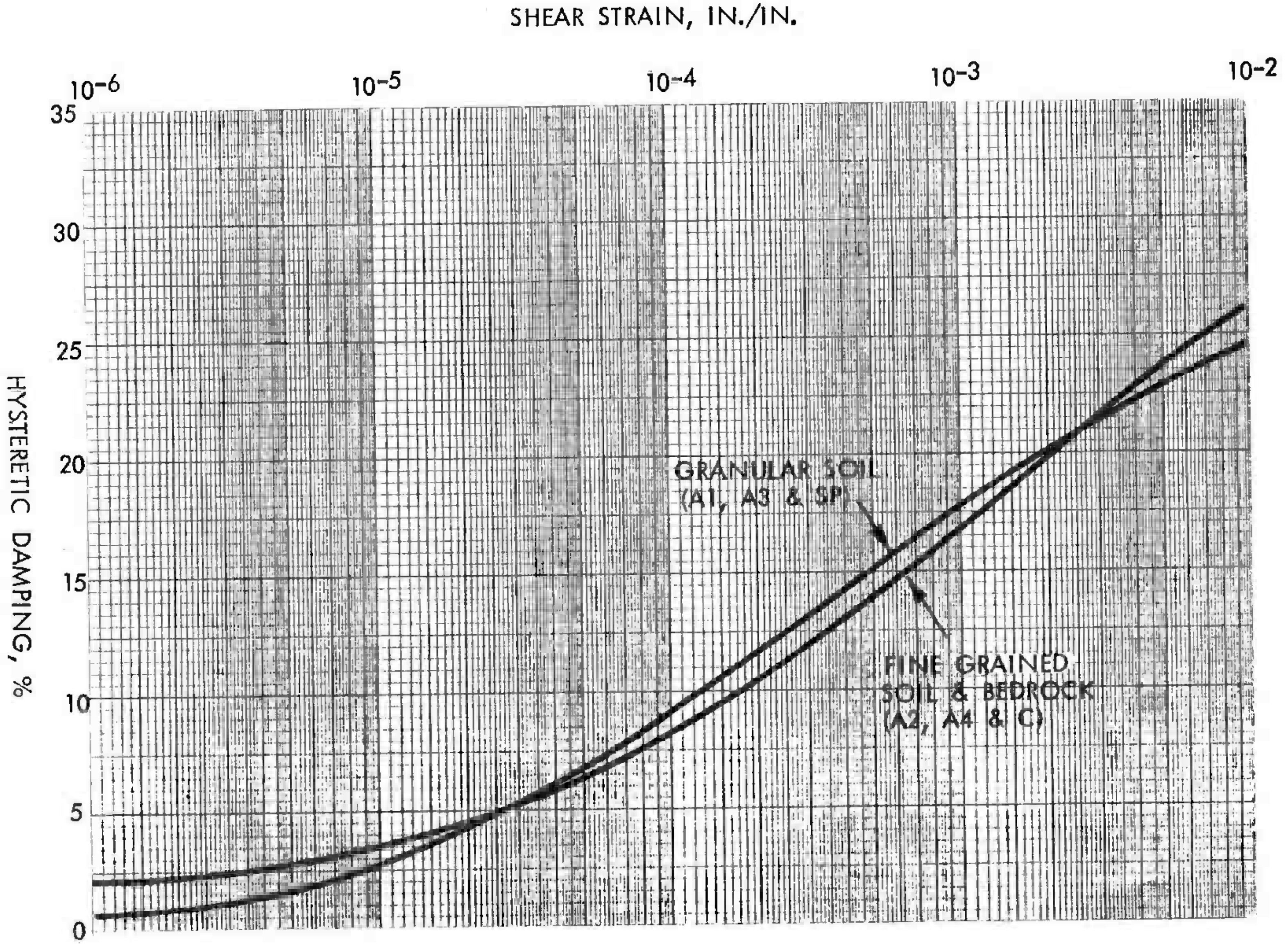
Project No.
83-1140

Figure No.
5-2



### 5.3.7 Permeability

Permeability (as defined in conventional civil engineering practice) of the tar bearing San Pedro Sands was calculated from test data obtained in a conventional consolidation test. The permeability was found to range from $1x10^{-8}$ to $1x10^{-9}$ cm/sec. This permeability is significantly lower than the measured permeability of water bearing San Pedro Sands, as measured at other locations, which were found to range from $1x10^{-2}$ to $1x10^{-3}$ cm/sec. It can be demonstrated that the apparent difference in permeability is due entirely to the presence of the bitumen. Bitumen viscosity of the tar in the sand sample was found to be about $1x10^{6}$ centipoise at room temperature a million times higher than the viscosity of water. Since permeability is inversely proportional to viscosity, it is not surprising that the calculated permeability of the tar sands was about one-millionth of the permeability of the water bearing San Pedro Sands. Thus, the true permeability of the tar sands (which depends only on porosity) is the same for both the tar bearing and water bearing sands.

### 5.3.8 Effect of Bitumen on Behavior of the Tar Sands

The available data indicate that the soil skeleton of the tar bearing San Pedro Sands does not differ significantly from the soil skeleton of the water bearing sands. Differences in behavior of the two materials can be traced almost entirely to the properties of the bitumen contained in the tar bearing deposits. It may be useful to explain the effect of the bitumen on the behavior of the tar sand.

As total load is removed from conventional materials which have a low permeability, the pressure in the water becomes negative, the intergranular stress remains constant and the sample exhibits an apparent unconfined strength (cohesion).

When the total load is removed from tar sands, a complex series of events takes place as gas comes out of solution from the bitumen and water as a result of the drop in confining pressure. As a result, the intergranular stresses in the tar sand drop to very low values and the unconfined (but impervious) sand exhibits a very low strength. The result of the presence of the gas in the bitumen is that in an undisturbed, confined state, the bearing capacity of the tar sands will be essentially the same as conventional water bearing sands. However, if an open excavation is made into the tar sands, the material will tend to flow into the excavation, not because it is loose or has a low strength in its original in-situ stress state, but because it has a high initial in situ fluid pressure. If the fluid pressure were reduced prior to excavation, the tar sands would remain as stable as a water bearing sand deposit which has been properly dewatered.

## 5.4 FERNANDO BEDROCK

The bedrock which underlies this design unit is of Upper Miocene age. The surface of the bedrock is an erosional unconformity, therefore, its elevation is highly variable. In our opinion, based on the geologic history, the upper 5 to 10 feet of the bedrock is weathered and may contain filled vertical fractures, although this has not been confirmed.

The bedrock consists primarily of well stratified, locally folded, weak interbedded claystone, siltstone and sandstone. Local hard cemented sandstone layers, ranging from less than 1 inch to more than 3 feet in thickness, may be encountered. It is estimated that these hard zones comprise considerably less than 1% of the formation in Design Unit A250.

The undrained shear strength of the bedrock was found to range from 2000 to 3200 psf, with an average value of 2500 psf. The strength of the rock can be expected to increase with depth and, therefore, a modest undrained friction angle of 20° is recommended.

Bedrock elastic properties were selected based on consideration of field performance data, laboratory test data and published information combined with engineering judgement.

## 5.5 GROUND WATER

The minimum depth to ground water below the ground surface is 8 feet near Station 566+00 at the south end of the Beverly/Fairfax Station. The maximum depth to ground water is reported to be 25 feet at several locations along the tunnel line.

Pneumatic piezometers were installed in Borings 19-2, 19-3 and 20-1 to provide data on the piezometric surface (pressure head). Pressure transducer readings were supplemented by rising water observed at a boring that bottomed in the San Pedro Sands drilled at the California Federal Savings and Loan building and was dry when drilled in 1959 then subsequently filled to a few feet above the surrounding ground surface (personal communication, L.T. Evans, Jr., 1984). Such may have been the case had Boring 18A been left open. Based on the above information, the piezometric surface is believed to be at or above the ground surface from about Station 497+00 to 520+50 (see Table 5-5 and Drawings 2 and 3).

TABLE 5-5
PIEZOMETRIC SURFACE
(Pressure Surface)

| BORING No. | ELEVATION (ft) | REMARKS |
|---|---|---|
| CAL FED | unknown | 2 feet above ground surface - estimated |
| 18A | 195 | 2 feet above ground surface - estimated |
| 19 | 190 | 3 feet above ground surface - estimated |
| 19-2 | 177 | 3 feet above ground surface - pneumatic piezometer |
| 19-3 | 163 | 3 feet below ground surface - pneumatic piezometer |
| 20-1 | 157 | 12 feet below ground surface - pneumatic piezometer |

Table 5-6 presents ground water levels and fluctuations measured in piezometers and man-sized borings within the limits of A250.

## TABLE 5-6
## GROUND WATER OBSERVATION WELL DATA

| | GROUND WATER ELEVATION[a] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1982 | 1983 | | | | 1984 |
| BORING | 1977 | 1981 | APRIL | FEB. | OCT. | NOV. | DEC. | MARCH |
| 18 | | 179[b] | | | | | | |
| 18-1 | | | | | | 181 | 177 | 181 |
| WC-6 | 181 | | | | | | | |
| 18A | | | | | 150? | | | |
| 19 | | 173 | 190 | | | | | |
| 19-2 | | | | | | | | 177[c] |
| 19A | | | | seep | | | | |
| 20A | | | | | dry | | | |
| 19-3 | | | | | | | | 163[c] |
| 20 | | 146[b] | | | | | | |
| 20-1 | | | | | | | | 157[c] |
| WC-7 | 136 | | 141 | | | | | |
| 20-4 | | | | | | | | 155 |
| 21 | | 145[d] | | | | | | |
| 22 | | 144 | 146 | | | | | |
| 20-10 | | | | | | | | 167 |
| 23-4 | | | | | | 175[b] | | |
| 23-3 | | | | | | 177[b] | | |
| 23-2 | | | | | | 179[b] | | |
| 23B | | | | 181[b] | | | | |
| 23 | | 179 | 178[d] | | | | | |
| 23-1 | | | | | | 180[b] | | |

[a] Rounded to the nearest foot.

[b] No piezometer installed; water level measured during drilling.

[c] Piezometric surface from pressure transducer readings.

[d] Destroyed.

The ground water observations indicate that the near surface alluvium and the underlying bedrock are relatively impervious aquicludes. The San Pedro Sands are an aquifer which is sandwiched between these two formations. Artesian pressures occur in the San Pedro Sands in the vicinity of the Wilshire/Fairfax Station because of a general rise in topography to the north of this site.

We believe that water seepage into the tunnel excavation from fresh, unfaulted, slightly fractured, fine-grained bedrock of the Fernando Formation will likely by of small amounts; i.e., dripping conditions.

Ground water inflows from saturated, non-tar bearing, alluvial and San Pedro Sand materials in the entire segment of this tunnel are likely to be significant with attendant caving problems. For instance, flowing ground was observed in the San Pedro Sand at depths of 43 to 50 feet (bottom of hole) in man-sized auger Boring 18A, accompanied by ground water inflow.

Mineral analyses of the alluvial ground water from Borings 21, 22 and 23 (Drawing 3) indicate the total dissolved solids (TDS) are less than 1000 parts per million (ppm). This is considered good quality water compared to mineral analyses of ground water originating from bedrock. For example, ground water originating from the bedrock in Boring 19, is a sodium chloride-type water containing a TDS of 15,425 ppm (probably Connate water from the Salt Lake Oil Field). For details on corrosion, refer to the "Corrosion Control Final Report" dated June 30, 1983 for SCRTD by Professional Services Group, Inc.), Waters Consultants Division. The mineral analyses for ground water from Borings 19, 21, 22 and 23 are in Appendix C.

## 5.5 OIL, GAS AND FAULTS

Oil (tar) was encountered in all test holes drilled into the San Pedro Sands, between approximately Stations 488+00 and 547+00. A major portion of the tunnels and the entire Wilshire/Fairfax Station will be located in this zone.

The oil is contained primarily within the San Pedro Sands; however, the lower 5 to 10 feet of the overlying Alluvium were often found to contain significant quantities of hydrocarbons in the pore fluids. In addition, the underlying bedrock also contains bitumen, within fractures as well as being uniformly distributed within the pore spaces of the intact rock. The depth of bitumen saturation within the bedrock is not known. However, information from deep borings made for this study at other locations along the alignment suggests the rock in this area contains oil to depths of over 200 feet. Oil wells that produced, or are still producing, in the underlying Salt Lake Oil Field confirm this.

Bitumen was extracted from samples of the tar sand and the following properties were measured:

| TEMPERATURE °C | DYNAMIC VISCOSITY (centipoise)<br>Samples From Tar Sand | <br>Samples From Tar Silt |
|---|---|---|
| 30 | 950,000 | 360,000 |
| 36 | 86,000 | 35,000 |
| 45 | 10,000 | 5,000 |

For comparison, the dynamic viscosity of pure water at 22°C would be about 1 centipoise. It is of interest to note that the less viscous bitumen was extracted from the silt sample, which has a lower permeability than the sand.

The bitumen and water contents of the sand and silt samples were calculated and the following results were obtained:

| | SAMPLE FROM TAR SAND | SAMPLE FROM TAR SILT |
|---|---|---|
| BITUMEN CONTENT (% by weight dry soil) | 18.7 | 17.5 |
| WATER CONTENT (% by weight dry soil) | 3.4 | 8.7 |
| TOTAL FLUID CONTENT (% by weight dry soil) | 22.1 | 26.2 |

Based on the measured total fluid content and the bulk densities of the in situ soil, we conclude that, in general, there is no free gas within the tar sand at the in situ fluid pressures. Gas would, of course, be expected to be in solution and come out of solution if the fluid pressures were lowered.

Pockets which contain significant quantities of free gas have been encountered in some test holes. This gas will be under pressure and can be released if encountered in excavations for either the station or the tunnels. The quantities of gas which may be encountered in such zones is difficult to predict; however, it is expected that the gas would be limited in quantity and should drain from the formation after several hours or days. Contingency plans, such as providing equipment to flare the gas, should be developed for dealing with gas from such zones.

Gas solubility tests and gas composition analyses were not carried out, as it is understood that such work is being carried out by others.

The tunnel alignment for Design Unit A250 will cross the projected traces of the 6th Street and 3rd Street faults (Drawings 2 and 3). Both faults are judged to be inactive. The inactive rating is based on the absence of these faults on published fault maps such as:

- Fault Rupture Study Areas, Active and Potentially Active Faults, Plate 1, Los Angeles City's (March 1975) Seismic Safety Plan
- Hollywood Quadrangle, Special Studies Zone Map, California Division of Mines and Geology (1976)
- Geologic Map of California, Los Angeles Sheet, California Division of Mines and Geology (1969)
- Fault Map of California, California Division of Mines and Geology (1975)

The near-surface locations of these fault zones are not well defined. The implications on tunnel construction are described in Section 7.7.

## 5.7 IN-SITU STRESS MEASUREMENTS

In-situ stresses were measured in the vicinity of the Wilshire/Fairfax Station using a self boring pressuremeter. The results were quite variable and inconclusive. In our judgement, an insufficient quantity of tests were performed to develop reliable in-situ horizontal stress values. The high values obtained are not consistent with the known geologic history, nor are they consistent with foundation engineering experience in the Los Angeles area.

## 5.8 RECOMMENDED ENGINEERING PARAMETERS

For purposes of our engineering evaluations, we have grouped the subsurface materials encountered within this project into three general subsurface units. These subsurface units are Alluvium, San Pedro Sand and Fernando Bedrock. The soil units have been further subdivided into tar bearing and non tar bearing soils. Table 5-7 presents static engineering parameters used in our analyses.

Dynamic soil parameters required for input into the various types of analyses recommended in the seismic design criteria report are presented in Table 5-8. These include values of dynamic Young's modulus, dynamic constrained modulus, and dynamic shear modulus at low strain levels.

## TABLE 5-7

## MATERIAL PARAMETERS SELECTED FOR STATIC DESIGN

| MATERIAL PROPERTY | ALLUVIUM | | SAN FERNANDO SAND | | | FERNANDO BEDROCK |
|---|---|---|---|---|---|---|
| | Non Tar Bearing | Tar Bearing | Non Tar Bearing | Tar Sand | Tar Silt | |
| Bulk Density (pcf) | 130 | 130 | 130 | 130 | 120 | 120 |
| Effective Stress Strength<br>ø' (degrees)<br>c' (psf) | <br>35<br>0 | <br>35<br>0 | <br>35<br>0 | <br>35<br>0 | <br>35<br>0 | <br>35<br>0 |
| Total Stress Strength<br>ø (degrees)<br>c (psf) | <br>17<br>1000 | <br>20<br>2000 | <br>-<br>- | <br>-<br>- | <br>20<br>2000 | <br>20<br>2000 |
| Unconfined Compressive Strength (psf) | 2000 | - | - | - | | 5000 |
| Permeability (cm/sec) | $10^{-3}$ to $10^{-6}$ | $10^{-6}$ to $10^{-7}$ | $10^{-2}$ to $10^{-3}$ | $10^{-8}$ to $10^{-9}$ | $10^{-6}$ to $10^{-7}$ | $10^{-6}$ to $10^{-7}$ |
| Secant Modulus (psf) | $200\sigma_{v'}$* | - | - | $480\sigma_{v'}$* | $175\sigma_{v'}$* | $3x10^5+40\sigma_{v'}$* |
| Poisson's Ratio | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |

* $\sigma_{v'}$ is the effective overburden pressure (psf) equal to effective density times overburden depth. Moist density should be used to determine $\sigma_{v'}$ above the water table and submerged density (saturated density minus water density) used for the effective density of soils below the water table.

TABLE 5-8

RECOMMENDED DYNAMIC MATERIAL PARAMETERS FOR USE IN DESIGN

| | ALLUVIUM | | SAN PEDRO SANDS | | | FERNANDO BEDROCK |
|---|---|---|---|---|---|---|
| | Non Tar Bearing | Tar Bearing | Non Tar Bearing | Tar Sand | Tar Silt | |
| Average Compression Wave Velocity, $V_c$ (ft/sec) | 4000 | 4000 | 5500 | 4500 | 5000 | 5000 |
| Average Shear Wave Velocity, Vs (ft/sec) | 1100 | 1100 | 1150 | 1100 | 1200 | 1200 |
| Poisson's Ratio | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| Young's Modulus, E, (psi) | 85000 | 85000 | 100000 | 100000 | 100000 | 100000 |
| Constrained Modulus, $E_c$, (psi) | 400000 | 400000 | 800000 | 500000 | 650000 | 650000 |
| Shear Modulus, $G_{max}$, (psi) | 30000 | 30000 | 35000 | 35000 | 35000 | 35000 |

# Section 6.0

# Geotechnical Evaluation - Wilshire/Fairfax Station

## 6.0 GEOTECHNICAL EVALUATION - WILSHIRE/FAIRFAX STATION

### 6.1 GENERAL

The planned construction of the Wilshire/Fairfax Station will include an excavation far deeper into the tar sands than attempted previously. The behavioral characteristics of the tar sands and possible construction problems are currently being observed at a nearby construction site at Wilshire Boulevard and Fairfax Avenue. In addition, it is planned to observe the construction at a proposed instrumented test pit in the immediate vicinity of the proposed station. Thus, the observations regarding behavior and construction problems noted in this report are subject to modification based on the experience gained from observation of the above projects.

A plan and profile of the Wilshire/Fairfax Station are presented in Drawings 4 and 5, respectively. These drawings show the proposed layout for the station and the stratigraphy at the site.

The station will be roughly 950 feet long, 40 to 65 feet wide and will extend to a depth of about 95 feet below existing grade.

The mezzanine level at each end of the station will be wider than the lower portions of the station. The floor slab for the wider portions of the mezzanine level will be placed about 40 feet below existing grade, or 15 to 20 feet below the top of tar bearing material.

The tunnels will enter and exit the station, one above the other, as indicated on Drawing 5.

Excavation for the station will be carried through roughly 20 to 30 feet of non-tar bearing alluvium. The alluvium consists predominantly of a stiff silty clay which is relatively impervious. Occasional silt and sand layers will be encountered within the alluvium, the latter of which may contain free water. The water table in the alluvium was estimated to vary from 5 to 10 feet below existing grade, and may be higher following prolonged periods of rainfall.

Non-tar bearing alluvium is underlain by 0 to 20 feet of tar bearing alluvium which in turn is underlain by 55 to 60 feet of tar bearing sands of the San Pedro Formation. The tar bearing San Pedro Sands are dense in-situ to very dense. Occasional lenses or layers of silt or silty clay are present within the sands. Pore fluid within the tar sand consists of water, gas and bitumen. While occasional pockets of free gas may be present within the tar sand, it is believed that at the in-situ fluid pressure, most of the gas is present as solution gas within the bitumen and water. Fluid pressure within the tar sand at the station location was found to be equivalent to a water pressure head located at a depth of 2 to 10 feet below existing grade. Since this pressure is slightly higher than the measured water table in the overlying alluvium, it is apparent that the overlying fine-grained alluvium is acting as an aquiclude and, as a result, there is a slight artesian pressure in the tar sands.

Tar sands are generally underlain at a depth of 75 to 95 feet by stiff tar silts and clays or by the Fernando formation bedrock. The surface of the bedrock is seen to vary moderately over the majority of the station site. At the southeast end of the station, the bedrock surface dips down to a depth of about 135 feet below grade as shown on Drawing 5. This dip in the bedrock surface is believed to be an old erosion channel. It should be noted that the erosion channel has been infilled with relatively coarse gravel and occasional boulders which are tar bearing. Should the deep erosion channel extend to within the areas of the station, serious problems may be expected in construction of any shoring system. Prior to construction, the depth to rock should be determined at the southeast end of the station. If the surface of rock is found to be significantly deeper than in the remainder of the station, it may be advisable to re-site the station slightly to the northwest along the alignment.

The bedrock consists of very stiff siltstone and claystone. Bitumen is present within the pores of the bedrock. The upper 5 to 10 feet of the bedrock is weathered and is expected to contain relatively tight fractures. The bedrock is relatively water-tight; however, some minor seepage of water or bitumen can be expected from fractures, which will tend to open up once the overlying materials have been excavated.

## 6.2 EXCAVATION FLUID DEPRESSURIZATION

The act of depressurization, as defined in this report, is to reduce the pore pressure at any given point within a soil mass so that the pressure head at that point is equal to or less than the unit weight of water times the distance between the ground surface and that point.

Dewatering of the non-tar bearing alluvium overlying the site is generally unnecessary since these soils are relatively impervious. It can be expected that water-bearing seams of silt or sand will be encountered within the alluvium. These lenses or seams are expected to be of limited extent and can be drained into sumps within the base of the excavation. Care will be required during excavation to prevent the loss of ground from these water-bearing seams.

As mentioned earlier, the fluid pressures within the tar sand are slightly artesian. If these fluid pressures could be reduced prior to excavation, the stability of the tar sand would be greatly increased.

It is not known if it is practical to depressurize the tar sand using conventional techniques such as pumping from wells. While it is possible to install well casing into the tar sand and bail the tar and water which collects in the well, the radius of drawdown around the well is expected to be only a few feet. This is because of the low permeability of the tar sand combined with the presence of gas in solution which will come out of solution within the bitumen and water. As the fluid pressure is reduced in the formation, the solution gas comes out of solution and tends to maintain the original in-situ fluid pressure. Another concern with respect to depressurization is whether the wells can be installed such that the formation sand will not flow into the well. These sands will not only plug off the wells, so they cannot be bailed, but will also result in loss of ground around the well. While gravel packing can be used around the outside of the well casing to overcome this problem, the installation cost of a large number of such wells may be very large.

The concerns with regard to depressurization are such that they can only be resolved by installing a test well and undertaking a depressurization test in the tar sand. Since depressurization will result in a very significant improvement in the behavior of the tar sand adjacent to the excavation, particularly in the case of a soldier pile shoring system, it is recommended that such testing be given further consideration.

## 6.3 UNDERPINNING

### 6.3.1 General

The need to underpin and the appropriate type of underpinning for specific buildings located adjacent to the proposed excavation depends on many factors related to both engineering and economics and cannot be generalized. Thus each structure needs to be evaluated separately. To aid the designers in evaluating underpinning requirements, this Section presents general geotechnical underpinning guidelines.

Figure 6-1 presents guidelines for assessing when underpinning needs to be considered in the area of the station excavation. Economic and other considerations beyond the scope of this investigation should be considered in any final decisions regarding underpinning.

A more conservatively designed shoring wall could be constructed which may sufficiently reduce ground movements and eliminate the need to underpin.

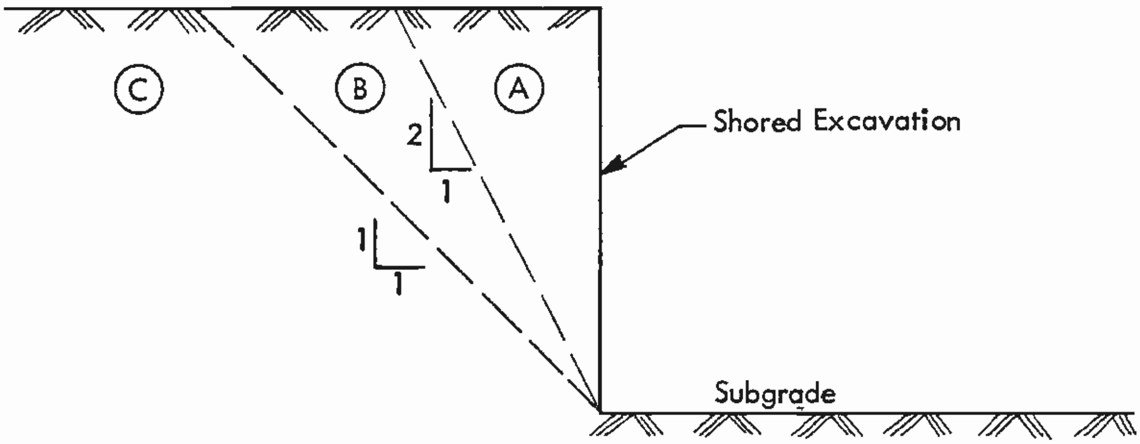
Several of the commonly used methods for underpinning, including conventional jacked piles and hand-dug pits or piers, are not considered feasible at this station due to the presence of the tar sands. Underpinning methods which are considered as practical are discussed in 6.3.2.

### 6.3.2 Underpinning/Support Methods

Several underpinning/support methods are considered feasible including:

- Slant Drilled Piles: This method consists of placing a steel pile in a shaft (generally 12- to 24-inch diameter) drilled from the side of the foundation. The shaft is drilled at a small angle or slant under the foundation and then back-reamed to provide a vertical slot below the foundation. A steel pile is placed under the foundation, and the shaft is filled with concrete. The actual connection to the footing can be made by shimming or "drypack" concrete. Pre-loading could be accomplished using jacks and shims similar to jacked piles. In weak soils or in ground subject to sloughing, this method can result in settlement if there is loss of ground into the drilled hole.

  Piles Bottoming in Tar Sands: This method consists of drilling a pile excavation into the tar sands. Drilling mud will be required. The shaft is drilled at a small angle or slant under the foundation and then is back-reamed to provide a vertical slot below the foundation. If a friction pile is desired, a steel cage or H section is placed and the pile excavation filled with tremie concrete. For an end bearing pile, a



NOTES: 1. Subject to modification as indicated in Section 6.1

2. For structure foundations bearing in zones A, B, or C, the following guidelines are presented:

Ⓐ Underpinning (designed to support lateral loads from building foundations with acceptably small ground movements) must be considered. Area "A" represents No Support Zone for slurry wall construction. See Figure 6-2.

Ⓑ Properly designed and constructed slurry wall shoring system generally adequate without underpinning unless adjacent to especially sensitive structures. Underpinning must be considered for soldier pile and wood lagging support system. Area "A" and "B" represents No Support Zone for soldier pile and wood lagging construction. See Figure 6-2.

Ⓒ No Special Provisions

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## UNDERPINNING GUIDELINES

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Figure No.
6-1

closed end steel pipe is placed in the excavation and filled with concrete. For either type of pile, it will be necessary to seat the pile by jacking the pile.

Piles Bottoming in Fernando Formation: This method is somewhat similar to that given above except the piles penetrate into the underlying rock and higher capacities can be obtained. Essentially, a pile excavation is drilled to the top of the rock formation using drilling mud, an open-end steel pipe is inserted in the hole, and the drilling is continued to the required depth. The drilling mud should not be bailed out as this would create a large imbalance in the fluid pressure in the top of the rock formation, resulting in tar seeping from the rock. Concrete is then tremied into the excavation.

° Column Pick-Up: This technique provides a method of releveling specific structural elements without underpinning in the event that excessive settlements occur. A structural break is made between the column (or wall) and its foundation. Special connections are made to transmit loads around the structural break and jacking, or other means, is used to relevel the column or wall. After completion of the excavation, a permanent connection between the building and foundation is re-established. Since this method does not transfer foundation loads to a lower stratum, both shoring and permanent walls must be designed for surcharge loads imposed by the existing structure.

### 6.3.3 Design Criteria

Figure 6-2 illustrates the procedures for determining the geometry of the support zones and the total capacity of the underpinning pile. No support should be allowed within the "no support" zone shown on Figure 6-2. Two types of underpinning piles have been considered:

1. poured-in-place concrete friction piles
2. concrete-filled steel pipe end bearing piles.

For either type, it will be necessary to jack the pile to develop the desired capacity.

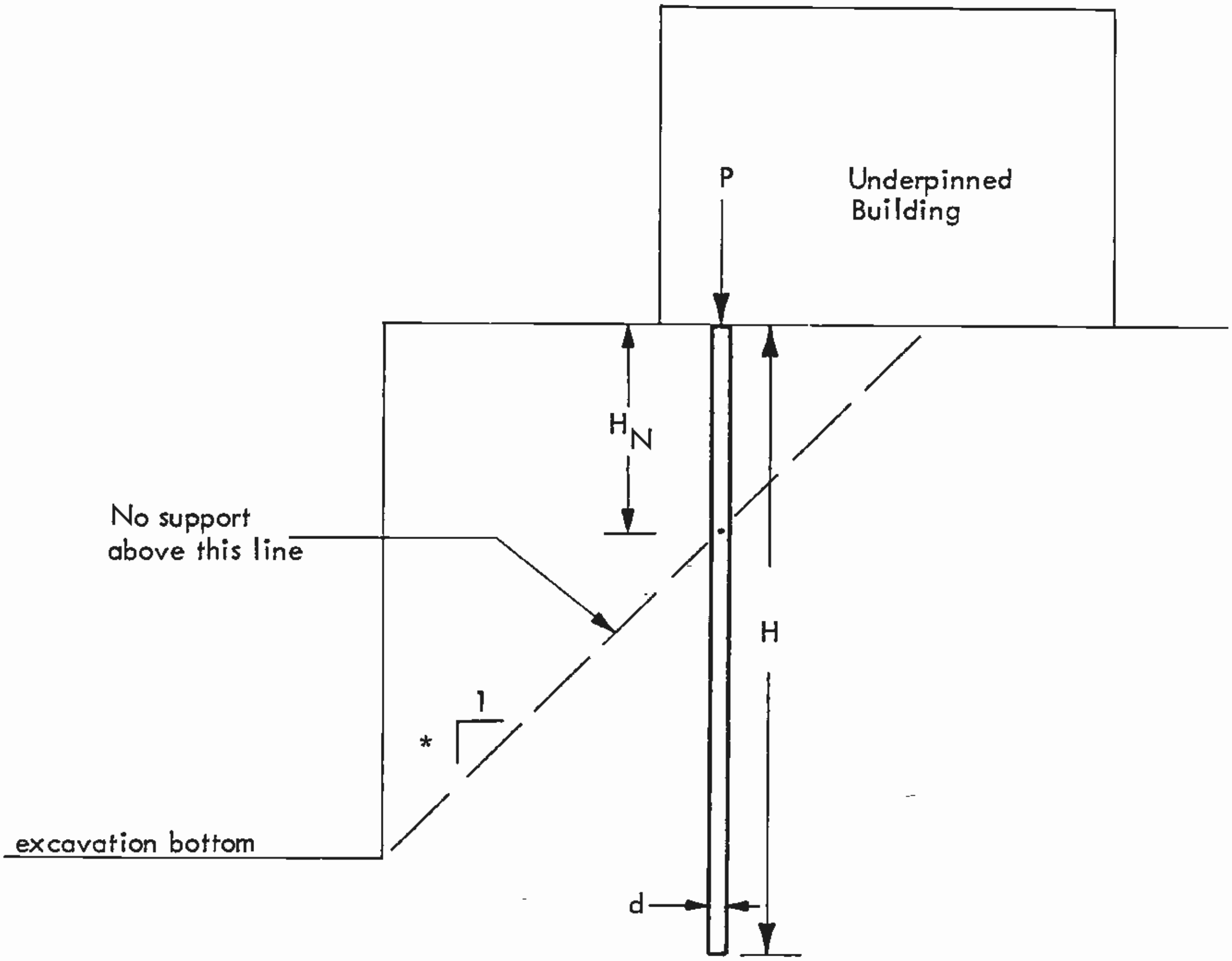
For underpinning friction piles bottoming in the tar sand formation, where the frictional resistance occurs from soil on concrete contact, the allowable pile capacity is given by the following relationship:

$$P = 10d\ (H^2 - H_N{}^2) \qquad (6.1)$$

Where:

$P$ = axial load in pounds
$d$ = pile diameter in feet
$H$ = depth from ground surface to pile tip in feet
$H_N$ = depth to bottom of no support zone in feet.

Where a steel pipe is inserted in the pile excavation and filled with concrete, the softening of the sidewall and lack of contact between the steel



* See Figure 6-1 for limits of No Support Zone

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# UNDERPINNING - DESIGN GEOMETRY

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Figure No.
6-2

pipe and surrounding soil will severely limit the side friction. End bearing in the tar sand will develop as the pile is loaded and the soils below the pile tip reconsolidate. The end bearing capacity is given by the following relationship:

$$P = 700 \cdot d^2 \cdot H \qquad (6.2)$$

Where:

P = axial load in pounds
d = pile diameter in feet
H = depth from ground surface to pile tip in feet.

For pipe piles extending to rock and drilled out in the rock, an allowable end bearing pressure of 16 ksf may be used provided the pile bottoms at least 5 pile diameters into the rock. In addition, a frictional resistance of 1.5 ksf may be assumed for the portion of the pile embedded in rock. No frictional resistance is assumed between the steel pipe and the tar sands.

### 6.3.4 Underpinning Performance

Underpinning is not a guarantee that the structure will be totally free from either settlement or lateral movement. Some settlement may occur during the underpinning process. Additional vertical and/or lateral movement may occur during the construction of the main excavation, depending on the performance of both the shoring and underpinning elements.

### 6.3.5 Underpinning Instrumentation

Elevation reference points should be established on each foundation element to be underpinned. The points should be monitored on a regular basis consistent with the construction progress (readings may be required daily). Maximum allowable movements should be established for each element by the design engineer prior to underpinning. If it appears that these limits may be exceeded, immediate measures should be taken such as restressing underpinning elements, adding more supports or changing installation procedures.

Where a group of three or more piles is used to underpin a foundation element, load relaxation of previously installed piles can occur. Methods should be implemented to evaluate this problem and re-load piles if necessary.

## 6.4 TEMPORARY EXCAVATIONS

### 6.4.1 General

We understand that the excavation system for the Wilshire/Fairfax Station will be chosen and designed by the contractor in accordance with specified criteria and subject to the review and acceptance by the Metro Rail Construction Manager.

In our opinion, the contractor may propose either a soldier pile wall or a slurry wall to support the sides of the excavation. In either case, the wall could be supported either by tiebacks or with internal bracing.

The discussion and design criteria presented in this section pertain to these shoring methods. Other shoring support systems may also be appropriate and may be considered by the contractor.

### 6.4.2 Soldier Pile and Lagging Support Systems

6.4.2.1 Construction Aspects: A soldier pile and lagging shoring system consisting of soldier piles installed in predrilled holes is a common method of shoring deep excavations in the Los Angeles area. However, soldier pile walls have been used in only a few instances to support excavations in the tar sands; and, in these cases, the depth of excavation into the tar sands was limited to roughly 15 feet or less.

A number of construction difficulties can be anticipated with the use of soldier pile walls in tar sand, particularly considering the depth of the proposed excavation.

It is conventional practice in the Los Angeles area to install soldier piles in predrilled holes and backfill the holes with concrete. At this site, the soldier piles will have to be placed to a depth of over 100 feet, through 50 to 80 feet of tar sand. It is expected that the walls of the holes will close in and/or slough during excavation and after completion of the boring, particularly in the highly tar impregnated horizons. Hence, placement of concrete by tremie methods may not produce a satisfactory pile installation capable of supporting the theoretical loads given in Figure 6-4. It may be necessary to install temporary casing in the holes in order to ensure the concrete can be placed at the base of the piles. Alternatively, a slurry could be used in the pile holes to reduce sloughing. Theoretically, a heavy oil field type slurry may limit the closing of the holes, but the efficiency of such a procedure has not been verified in practice in tar sand type materials under discussion here.

Trafficability for construction equipment on the tar sand is expected to be a problem. While the tar sand in its in-situ, confined state is dense and has a relatively high angle of friction, it also has a high in-situ fluid pressure. As the tar sand is unloaded by excavation, the confining stresses are reduced; however, the fluid pressure is maintained at a relatively high value as a result of gas coming out of solution from the bitumen. As a result, the tar sand swells and becomes loose and has a lower strength in the upper 2 to 5 feet below the base of excavation. The thickness of the loose zone is expected to become greater as the depth of excavation increases.

Based on past observations of other projects bottoming in tar sands, it is anticipated that wheeled vehicles will not be able to operate on the surface of the tar sand. If it is necessary to operate wheeled vehicles inside the excavation, it will be necessary to place 2 to 3 feet of gravel over the tar sand. Light tracked vehicles should be able to operate on the surface of the tar sand. However, it is anticipated that as the depth of excavation increases, tracked vehicles will also have difficulty. Depending on circumstances of the work, it would be preferable to use draglines or a clam shell to excavate the tar sands from outside the excavation.

Another concern with respect to the use of soldier pile walls in the tar sand is loss of ground. As the depth of excavation increases, the tar sand will tend to flow out from between the soldier piles before the lagging can be placed. The amount of ground lost from behind the wall will depend on the depth of tar sand exposed, the distance between the soldier piles, and the speed with which the lagging is placed. To limit or prevent such behavior, the lagging should be installed immediately to the excavated level.

We anticipate that ventilation of the excavation will be a major requirement for safe conduct of the work. The excavation will be deep and relatively narrow, and heavier gases may accumulate at the base of the excavation.

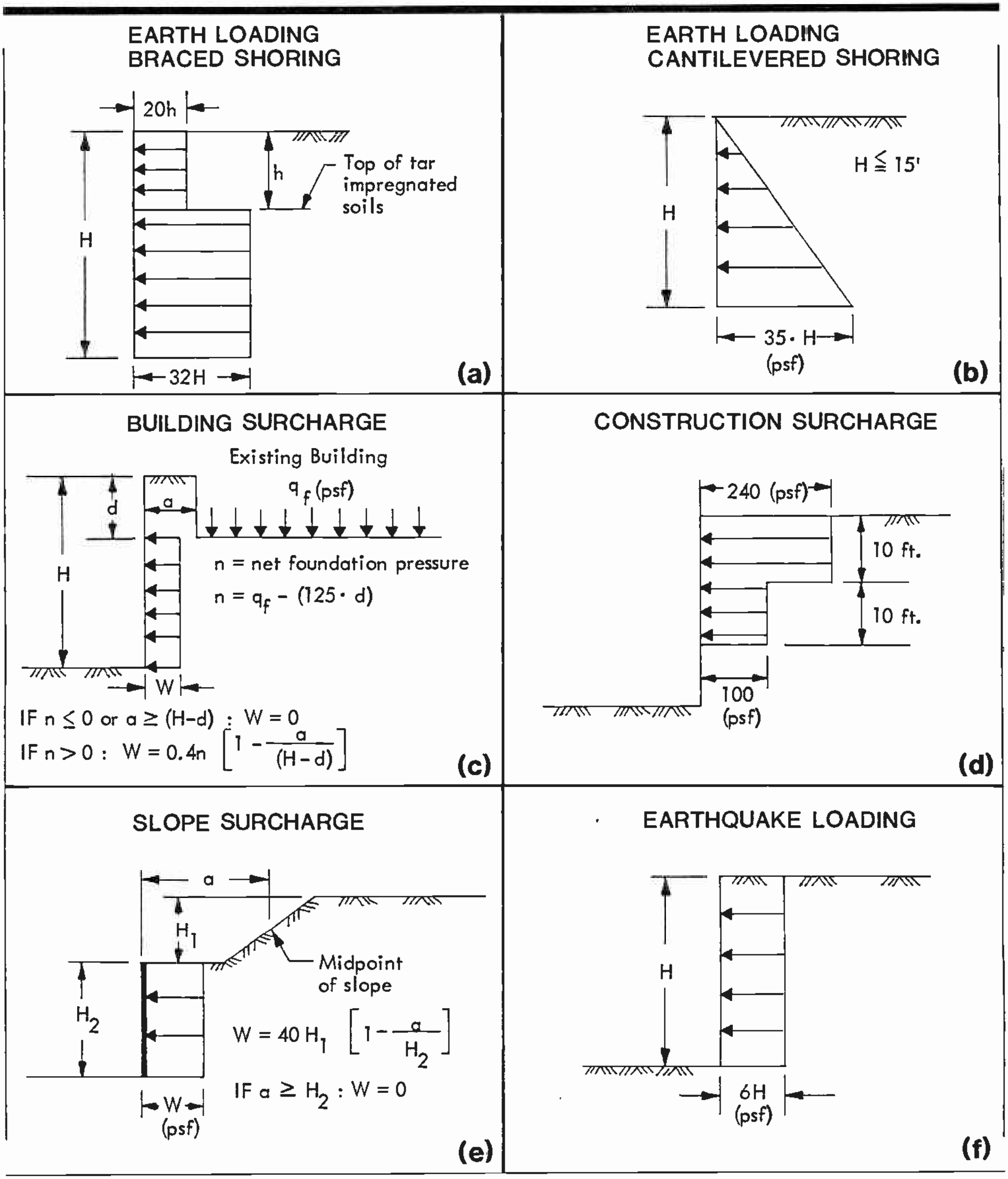
6.4.2.2 Shoring Design Criteria: This section provides design criteria for a soldier pile and wood lagging shoring system. The soldier piles are assumed to consist of steel WF or H sections installed in predrilled circular holes. It is assumed that the drilled shaft will be filled with concrete in such a manner as to provide the end and shaft areas assumed in the design calculations.

The design criteria presented in this section are based on experience with soldier pile walls in the Los Angeles area as well as in other areas of the United States, modified to reflect the unique properties of the tar sands. It should be recognized, however, that the use of soldier pile walls to depths of 100 feet in the tar sands is unprecedented, and the behavioral characteristics of the tar sands at such depths are unknown.

- Design Wall Pressures: The recommended lateral earth pressure diagrams for the design of soldier pile walls are presented in Figure 6-3. Appendix D.2 provides technical support for the recommended seismic pressures of Figure 6-3f.

  The full loading diagram above the bottom of excavation should be used to determine the design loads on tieback anchors and the required depth of embedment of the soldier piles.

- Construction Surcharge: Since construction equipment will be operating near the edge of the excavation, the loads imposed by the equipment must be considered in the design of the wall. A pressure distribution due to construction equipment for conventional equipment is presented in Figure 6-3(d). If the excavation is to be carried out by a dragline or clamshell, the


EARTH LOADING BRACED SHORING (a)

EARTH LOADING CANTILEVERED SHORING (b)

BUILDING SURCHARGE (c)

CONSTRUCTION SURCHARGE (d)

SLOPE SURCHARGE (e)

EARTHQUAKE LOADING (f)

## LATERAL LOADS ON SOLDIER PILE SHORING

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Figure No.
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loads imposed by this equipment should be evaluated and, if necessary, the construction surcharge given in Figure 6-3(d) should be increased.

- Depth of Pile Embedment: The embedment depth of the soldier pile below the lowest anticipated excavation depth must be sufficient to satisfy both the lateral and vertical loads under static and dynamic loading conditions.

  The required depth of embedment to satisfy vertical loading should be computed based on the allowable vertical capacities shown on Figure 6-4.

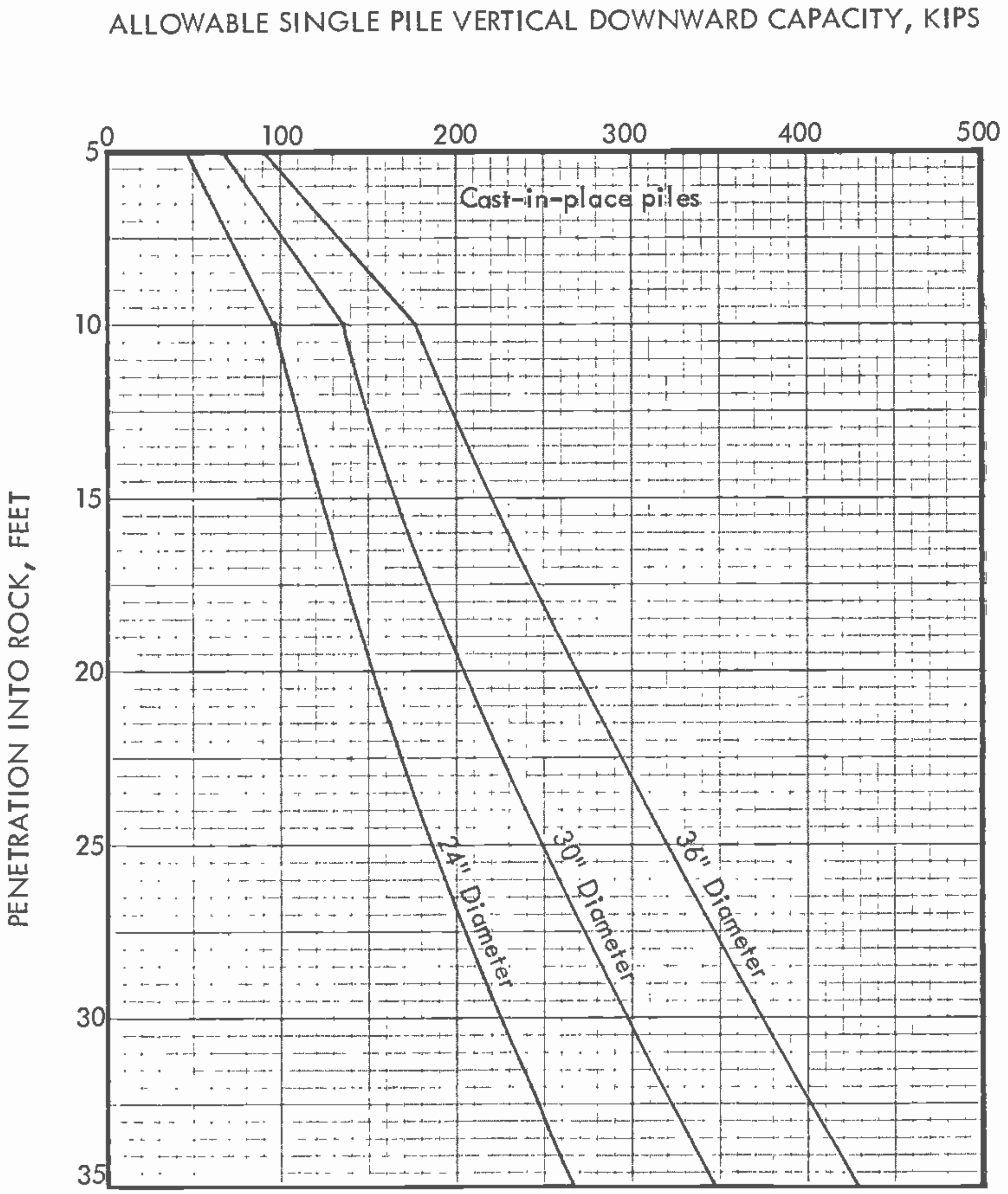
  The required depth of embedment to satisfy lateral loads should be computed based on the net allowable passive resistance (total passive resistance of the soldier pile minus the active earth pressure below the excavation). Due to arching effects, it is recommended that the effective pile diameter be assumed equal to 1.5 pile diameters or half of the pile spacing, whichever is less. Figure 6-5 indicates the recommended method to compute net passive resistance.

- Pile Spacing and Lagging: The optimum pile spacing depends on many factors including soil type, soil loads, member sizes and costs. Based on present knowledge, we believe the pile spacing should be limited to about 8 feet and that continuous lagging be placed to prevent loss of ground between soldier piles. Continuous lagging may not be necessary in the upper fine-grained soils. The contractor should limit the temporary exposed soil height to less than 2 feet to control loss of ground, particularly in the tar sand. The exposed height may have to be reduced to less than this at greater depths within the tar sand.

- Intermediate Stages of Construction: The designer of the shoring system must check the stability of the soldier pile wall at intermediate stages of construction. The intermediate states of construction may be critical, since the passive resistance of the tar sand below the intermediate base of the excavation will be significantly lower than the passive resistance which can be achieved in the bedrock.

6.4.2.3 Tiebacks: The soldier pile wall may be supported by tiebacks. Tiebacks have an advantage over internal bracing in that their use produces an open excavation which can significantly simplify the excavation procedure and construction of the permanent structure.

There are numerous types of tieback anchors available including large diameter straight shaft friction anchors, belled anchors, high pressure grouted anchors, high pressure regroutable anchors, and others. Generally, in the Los Angeles area, high capacity straight shaft or belled anchors have been used in soils which are stable and dewatered. It is doubtful if belled anchors will remain stable in



NOTE:

1) For seismic design, capacities may be increased 33%.
2) Assumes pile penetration starts in rock.
3) Assumes frictional and end bearing resistance in rock.

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# VERTICAL CAPACITY OF CONCRETE PILES FOR SHORING AND DECKING

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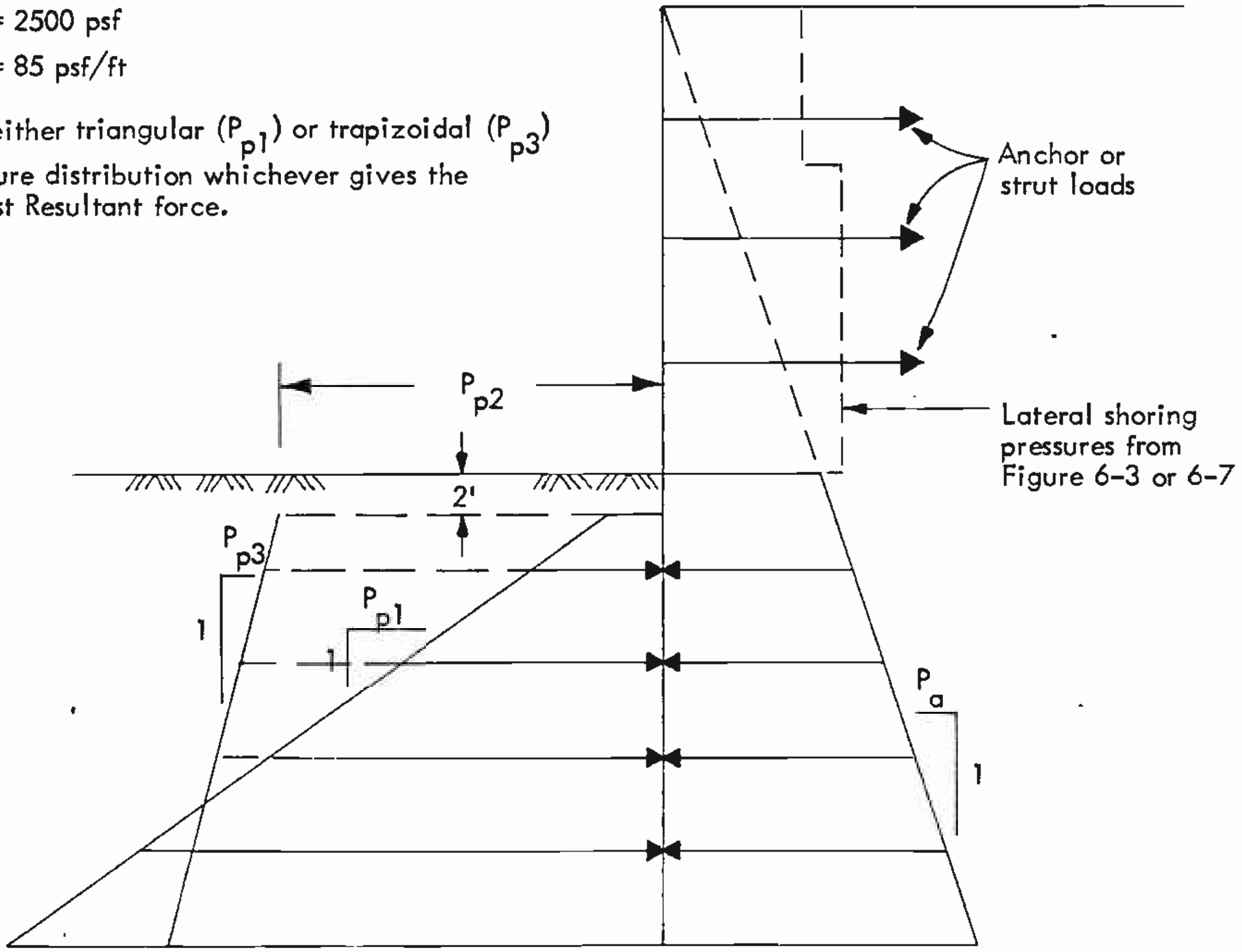
Figure No.
6-4

## *Recommended Unit Pressures*

$P_a$ = 35 psf/ft
$P_{p1}$ = 300 psf/ft
$P_{p2}$ = 2500 psf
$P_{p3}$ = 85 psf/ft

Use either triangular ($P_{p1}$) or trapizoidal ($P_{p3}$) pressure distribution whichever gives the lowest Resultant force.



Where: $P_p$ = Total allowable unit passive pressure in stiff tar silts immediately above the rock and in the rock
$P_a$ = Unit active pressure in same materials as $P_p$

NOTE:
1) Available passive pressure = Total passive - Active
2) Available passive pressure can be assumed to act on 1.5 pile diameters or ½ the pile spacing whichever is less.
3) Active pressure shown is for evaluation of available passive pressure.

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## SHORING PASSIVE RESISTANCE (IN BEDROCK)

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Figure No.
6-5

the tar sands, and difficulties are also expected in the tar sands with straight shafted holes, particularly at greater depths. There is no experience record to date with the installation of tieback anchors in tar sands below a depth of about 50 feet below the ground surface. If straight shafted anchors are used, it is expected that they will have to be installed in slurry filled holes or through large diameter hollow stem augers.

As noted earlier, trafficability on the tar sands is expected to be poor, and it will be necessary to place 2 or 3 feet of gravel over the tar sand to permit the drill rig to install the anchors at each level.

The anchor capacity which can be achieved in the tar sand is uncertain, since it will depend on the method of drilling the hole and the behavior of the walls of the hole and the installion of the anchors. In view of the large number of tieback anchors which will be used at this station, it is recommended that a variety of tieback anchors be installed and tested well in advance of construction. Such tests may be carried out in vertical holes at the existing ground surface. For these tests, the anchors should be placed within the tar sand at depths of between 60 to 90 feet below the surface.

For preliminary design purposes, the capacity of drilled straight shaft friction anchors can be calculated from the following equation:

$$P = \pi DLq \tag{6.3}$$

Where:

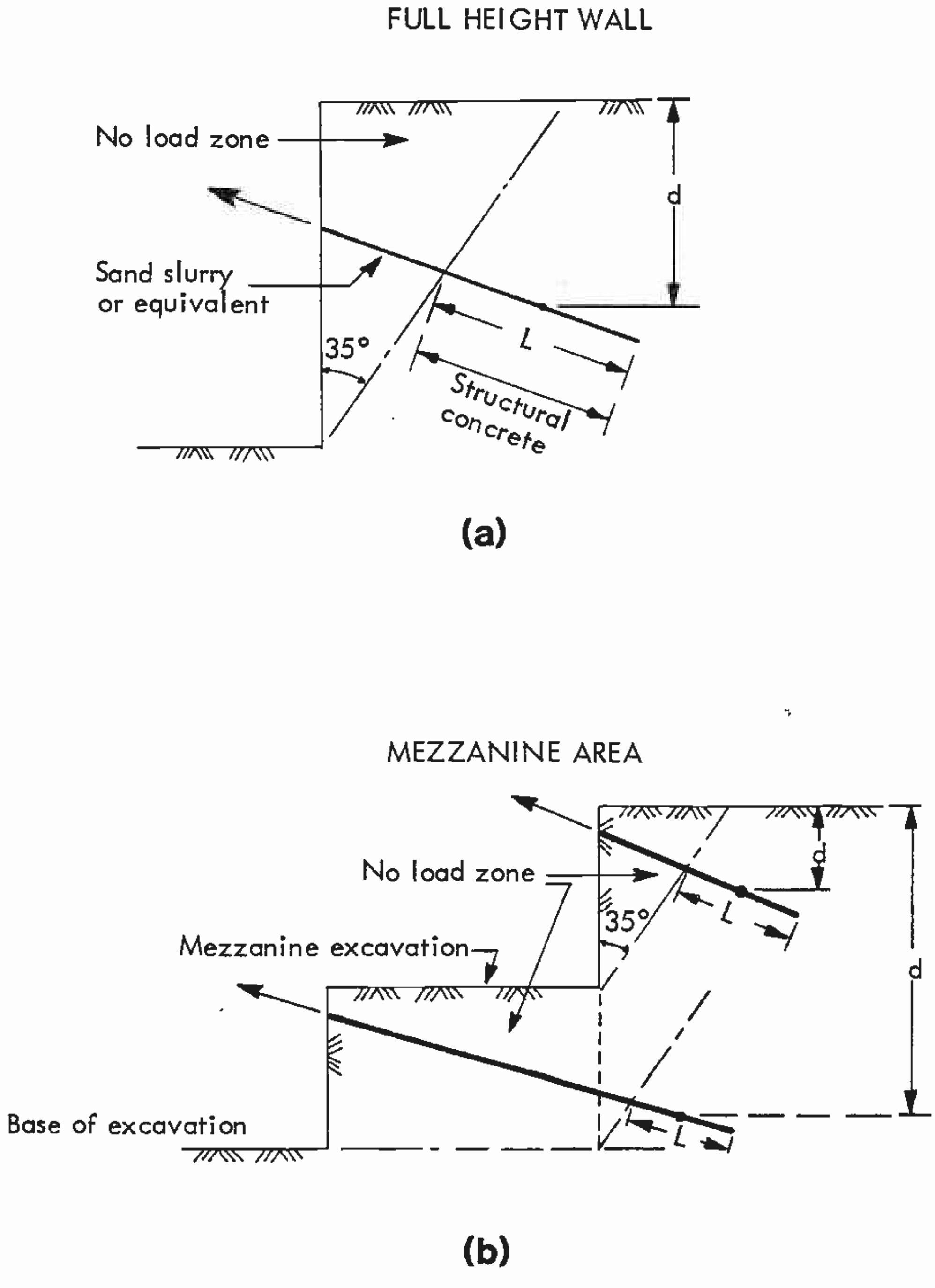
$P$ denotes the allowable anchor design load in pounds,
$D$ denotes the anchor diameter in feet,
$L$ denotes the anchor length beyond no load zone in feet, and
$q$ denotes the soil adhesion in psf.

The following values for design adhesion are recommended for preliminary design.

| MATERIAL | DESIGN ADHESION $q$ (psf) |
|---|---|
| Bedrock | 750 |
| Tar Sand | $10d \leq 600$ |
| Alluvium (no tar) | $15d + 330 \leq 600$ |

Where:

$d$ = the average depth of the anchor in feet beyond the no-load zone; measured vertically from the ground surface. See Figure 6-6.



(a)

(b)

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# FRICTION ANCHOR CRITERIA

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Figure No.
6-6

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Figure 6-6 gives criteria for determination of required anchor lengths. At each end of the station, the excavation for the widened mezzanine level will result in very low overburden stresses for anchors installed below mezzanine level. As a result, the anchor capacity for anchors installed below the mezzanine level will be less than predicted using the design values recommended above. One method of mitigating such effects is shown in Figure 6-6(b).

The anchors may be installed at a suitable angle below the horizontal. Structural concrete should be placed in the lower portion of the anchor up to the limit of the no-load zone. Placement of the anchor grout should be done by pumping the concrete through a tremie pipe extending to the bottom of the shaft. The anchor shaft between the no-load zone and the face of the shoring must be backfilled with a sand slurry or equivalent, after concrete placement. Alternatively, special bond breakers can be applied to the strands or bars in the no-load zone and the entire shaft filled with concrete. After placement of the structural concrete immediate filling of the remainder of the hole should reduce the possibility of the tar sand squeezing inward and displacing the structural concrete.

It is expected that the holes drilled for the tieback anchors will slough in the tar sand. The contractor should be required to use a drilling method which minimizes sloughing and caving of the holes. Uncontrolled caving not only causes installation problems but could result in surface subsidence and settlement of overlying buildings due to loss of ground. To minimize caving, casing could be installed as the hole is advanced but must be pulled as the concrete is poured. Alternatively, the hole could be filled with slurry or a large diameter hollow stem auger could be used.

It is recommended that each tieback anchor be test loaded to 150% of the design load and then locked off at the design load. At 150% of the design load, the anchor deflection should not exceed 0.1 inches over a 15-minute period. In addition, 5% to 10% of the anchors should be loaded tested to 200% of the design load and then locked off at the design load. At 200% of design load the anchor deflections should not exceed 0.15 inches over a 15-minute period. The rate of deflection should consistently decrease during the test period. If the rate of deflection does not decrease the test should not be considered satisfactory.

In the Los Angeles area, it is generally a requirement that the load on tiebacks be released once the permanent wall struts have been placed. For walls which are poured directly against the soldier pile walls, a window needs to be left in the concrete to permit access to the tieback bolts so that the load can be released. The windows are then filled with concrete. The foregoing procedure is not recommended for the Wilshire/Fairfax Station as it is not believed practical to seal the windows effectively to prevent tar or gas from seeping through the concrete openings.

6.4.2.4 Internal Bracing: The soldier pile wall could be supported with internal bracing rather than with tiebacks. The use of internal bracing has a number of disadvantages compared to tiebacks, in that it is more difficult to carry out the excavation and form the walls of the station with the bracing inside the excavation. On the other hand, the use of internal bracing eliminates many of the difficulties associated with the installation of tieback anchors in the tar sand.

The contractor should not be allowed to extend the excavation an excessive distance below the lowest strut level prior to installing the next strut level. The maximum vertical distance depends on several specific details such as the design of the wall and the allowable ground movement. These details cannot be generalized. However, as a guideline, the vertical distance between struts should not exceed 8 to 12 feet in the tar sand materials.

In addition, the contractor should not be allowed to extend the excavation more than 3 feet below the designated support level before placing the next level of struts.

To remove slack and limit ground movement, the struts should be preloaded. A preload equal to 50% of the design load is normally desirable. The shoring design, preload procedures, and monitoring/ maintenance procedures must provide for the effects of temperature changes to maintain the shoring support.

6.4.2.5 Ground Movements: The ground movements associated with an excavation supported by a soldier pile wall depend on many factors including the sequence of excavation, vertical distance between supports, support system loads, distance between soldier piles, and the height of soil left exposed prior to placing the lagging.

The distribution and magnitude of ground movements are, therefore, difficult to predict. Based on shoring performance data for excavations in the Los Angeles area combined with an assessment of the probable behavior of the tar sands, we estimate that the ground movements associated with properly designed and carefully constructed soldier pile shoring systems will be as follows:

- For a soldier pile wall with tieback anchors, the maximum horizontal wall deflection will equal about 0.1% to 0.2% of the excavation depth. The maximum horizontal movement should occur near the top of the wall and decrease with depth. The maximum vertical movement behind the wall should be equal to about 50% to 100% of the maximum horizontal movement and will probably occur at a distance behind the wall equal to about 25% to 50% of the excavation depth.
- For a soldier pile wall with internal bracing, the maximum horizontal movement will be similar to that anticipated with tiebacks. However, the maximum horizontal movement will probably occur near the bottom of the excavation decreasing to about 25% of the maximum at the surface.

The above listed ground movements are based on experience in non tar bearing soils. There is no experience record on excavations of the depth planned for this project in tar bearing sands.

### 6.4.3 Slurry Trench Wall Support Systems

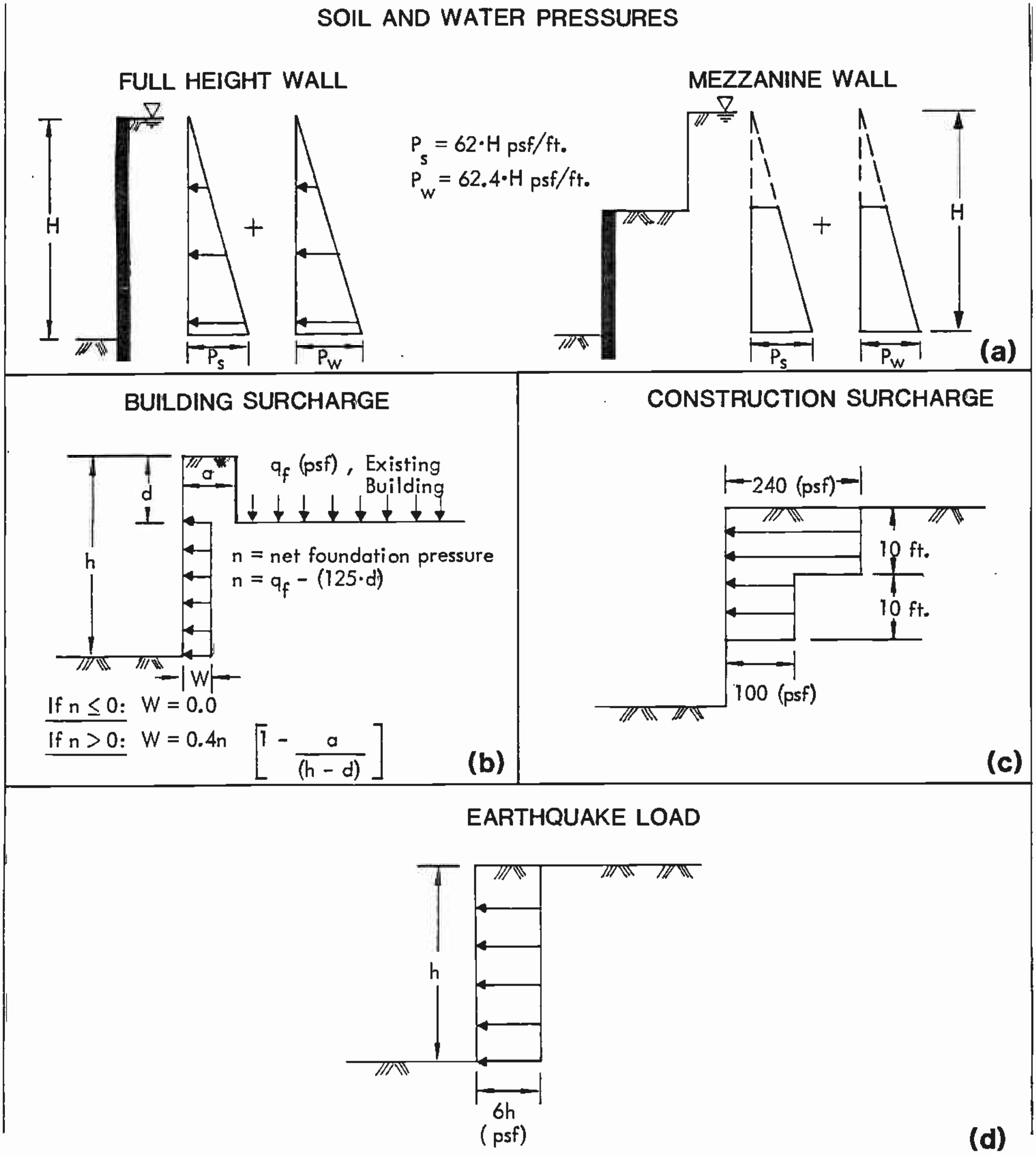
6.4.3.1 General: A slurry wall installation would normally involve the excavation of a narrow trench or slot to full depth along the wall line in short panels typically 10 to 20 feet long. The excavating is carried out in the wet using special excavating tools with trench support being provided by a fluid pressure of a specifically designed bentonite slurry. Trench stability is normally evaluated based on experience and test sections. Once a trench is excavated, the usual practice is to lower a reinforcing cage and place tremie concrete which displaces the slurry mixture. Alternately, precast panels can be placed. With precast panels, special additives are mixed with the slurry to produce a stiff clay material between the precast panel and the native ground. The slurry wall technique produces a relatively stiff and reasonably water-tight, continuous wall which can provide the temporary excavation support and may become a part of the permanent wall. As with soldier pile walls, internal bracing or tiebacks may be used to support such walls during construction period.

A properly designed and constructed wall will generally result in less ground movement as compared to a conventional soldier pile shoring system. This will be particularly true for the proposed excavation in tar sand where loss of ground due to the tar sand flowing below the lagging of a soldier pile wall is expected to be significantly greater than that which occurs in conventional soils. Use of slurry walls does not, however, eliminate potential problems associated with ground movements. Poor construction procedures particularly associated with poor slurry control and wide wall sections can result in excessive ground movement during construction of the panels. Since the use of a slurry trench wall in the tar sands is unprecedented, the mud density required to ensure the stability of the walls of the trench will have to be established by trial and adjustment.

The slurry trench wall offers an advantage in that it can probably accommodate a wider range of unforeseen problems such as the presence of gas-bearing zones, boulders and other obstructions which can present serious problems to the use of conventional soldier pile shoring.

The slurry trench wall generally requires a greater working area for construction. Areas must be provided for mixing and storing the mud.

6.4.3.2 Slurry Wall Design Criteria: The earth pressures developed on a slurry wall system will be larger than those for a soldier pile and lagging wall due to the greater rigidity of the slurry wall system. The design earth pressures given in Figure 6-7 may be used for the design of the slurry walls. As indicated on Figure 6-7, since the slurry wall will be essentially water-tight, the wall must be



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## LATERAL LOADS ON THE TEMPORARY SLURRY WALL (NO DEWATERING)

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Figure No.
6-7

designed to resist the in-situ fluid pressure as well as the effective soil pressure. The stability of the wall must also be checked at various stages, since critical design loadings may occur during construction.

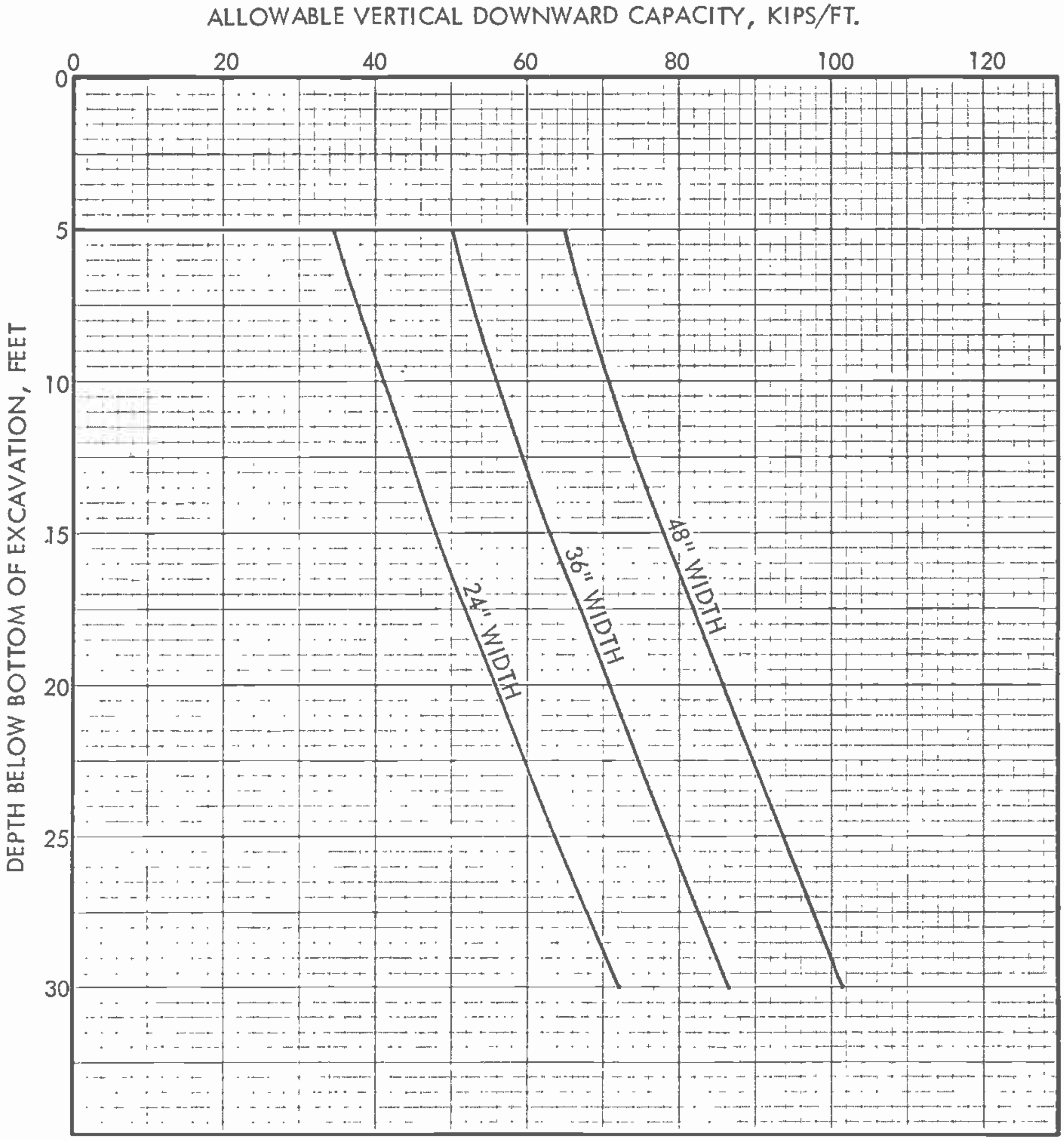
- <u>Depth of Embedment</u>: The slurry wall must be embedded sufficiently below the maximum depth of the excavation to support applied vertical loads (dead loads, deck loads, and tieback vertical loads) as well as to develop sufficient passive resistance. Figure 6-5 illustrates the recommended method of calculating passive resistance. The total passive pressure should be based on consideration of both the triangular and trapezoidal pressure distributions, and the lower resultant force should be used. Net passive pressure should be determined as the difference between the total passive pressure and the sum of the active and hydrostatic pressure. Figure 6-8 indicates the allowable vertical loads on slurry walls for different embedment depths. The recommended vertical capacities include both end bearing and side friction (below the level of the maximum excavation depth).

- <u>Slurry Composition</u>: An unsuitable bentonite slurry may lead to excessive viscosity for pumping, or flocculation and attendant loss of fluid resulting in instability of the excavated face. Some factors which affect the slurry are pH; contamination by salt, iron, calcium or organics. In particular, there is concern as to the effect which the presence of hydrocarbons from the tar sand will have on the properties and behavior of a slurry. The liquid hydrocarbons may be miscible with the slurry. If not, they should be skimmed from the settling tanks and disposed. It can be expected that gas will be liberated from the slurry as it is pumped to the surface and confining pressures are reduced. In addition to possibly being explosive and/or toxic to workmen, the gas may collect in the pumps causing them to cavitate. If a slurry wall is to be used, the foregoing concerns must be investigated in further detail.

- <u>Panel Length</u>: In areas immediately adjacent to existing footings, a panel section should not be adjacent to more than half the length of the footing. The intent is to ensure that major isolated exterior footings straddle the wall panels. This would minimize potential movements during the installation phase of the wall.

- <u>Existing Basement Voids</u>: Voids from old basements could be encountered which could lead to loss of mud. In these areas, the voids would have to be filled, the section sealed off, or the top of the slurry section lowered below the void.

6.4.3.3 Tiebacks: The comments and recommendations given for tiebacks for soldier pile walls also apply to the slurry trench wall.



Bottom of excavation assumed to be in bedrock.

NOTE: 1) For seismic design, capacities may be increased 33%.

# VERTICAL SUPPORT CAPACITY OF SLURRY WALL

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Figure No.
6-8

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6.4.3.4 Internal Bracing: The comments and recommendations given earlier for internal bracing for soldier pile walls also apply to the slurry trench wall.

6.4.3.5 Ground Movement: The ground movements which will occur using a slurry trench wall will depend on a number of factors including the loads applied to temporary tiebacks or bracing and the sequence of construction. In general, the ground movements associated with a properly designed and constructed slurry trench wall can be expected to be less than those which occur with the soldier pile wall.

## 6.5 SUPPORT OF TEMPORARY DECKING

Temporary street decking may require center support piles. These piles would have to extend below the maximum proposed excavation level for support. At these depths, the piles would be founded within the Fernando Formation. These materials are suitable for supporting pile loads.

Concrete piles drilled into rock (using drilling mud) and filled with tremie concrete or conventional driven piles may be considered. For the concrete piles, it would be advisable to set a steel casing to the top of rock to reduce the possibility of hole squeezing. Driven piles will require predrilling to rock in order to insert the pile section.

Vertical capacities for drilled concrete piles are given in Figure 6-4. For steel piles predrilled through the tar sands and then driven in the rock, cleaned out and filled with concrete, an end bearing capacity of 18 ksf may be used provided the pile penetrates at least 10 feet into rock. Adhesion between the steel pile and rock may be assumed as:

$$f = 680 + 18''Z \text{ psf} \qquad (6.4)$$

Where:

$f$ = shearing resistance between rock and pile, psf

$Z$ = depth of penetration into rock below the bottom of excavation, feet.

## 6.6 CONSTRUCTION OBSERVATION

In our opinion the proposed Wilshire/Fairfax Station excavation should be instrumented to reduce liability by documenting its performance, to confirm design assumptions, to identify problems before they become critical, and to obtain data valuable for future designs.

We recommend the following program of observations:

- <u>Preconstruction Survey</u>: A qualified civil engineer should complete a visual inspection and comprehensive photographic record of all streets and structures adjacent to the site prior to construction. This will provide data to minimize the risks associated with claims against the owner/contractor. If substantial cracks are noted in the existing structures, they should be measured and periodically remeasured during construction.

- Surface Survey Control: It is recommended that several locations around the excavation and on any nearby structures be surveyed prior to any construction activity and then periodically resurveyed to monitor potential vertical and horizontal movement to the nearest 0.01 feet. In addition, survey markers should be established at the top of the shoring at intervals of not more than 25 feet.

- Tiltmeters: Tiltmeters are used to monitor the verticality of buildings adjacent to the excavation and can provide a forewarning of distress. Normally ceramic plates are glued to the building walls and read using a portable tiltmeter containing the same type of tilt sensor used in inclinometers. It is recommended that a few tiltmeters be placed on the exterior walls of buildings which are located within the underpinning zone defined on Figure 6-1. Baseline readings should be made prior to all construction activity, and subsequent readings should be made at intervals through to the end of construction.

- Inclinometers: It is recommended that several inclinometers be installed and monitored around the station excavation. Inclinometers should be located on each side of the excavation. The casing could be installed within the soldier pile holes or in separate holes immediately adjacent to the shoring wall; however, the bottom of the inclinometer casings must extend at least 30 feet below the base of excavation. Baseline readings of the inclinometers should be made shortly after installation. Subsequent readings should be made at selected intervals throughout construction.

- Heave Monitoring: The magnitude of the total ground heave should be measured. This information will be valuable in determining the ground response to load change and as an indirect check on the magnitude of the predicted settlement of the station structure.

  We recommend that heave gages be installed in the bedrock along the longitudinal centerline of the excavation on about 200 foot centers. The devices could consist of conical steel points installed in boreholes. The top of the points should be at least 1 foot below the bottom of the final excavation to protect them from damage during excavation.

  The points should be installed and surveyed prior to starting excavation. Once the excavation reaches bedrock, readings should be taken at about two-week intervals until all heave has stopped.

- Convergence Measurements: We recommend the use of tape extensometers to measure the convergence between points at opposite faces of the excavation during various stages of excavation. These measurements provide inexpensive data to supplement the inclinometer and survey information.

- Strut Loads: If internal bracing is used, we recommend that the loads on at least four struts at each support level be monitored during construction through the use of load cells or strain gauges. These measurements provide data on support loads and a forewarning of unexpected load increases.

- Tieback Loads: If tiebacks are used to support the shoring, it is recommended that load cells be installed on selected tiebacks so that loads on these tiebacks can be readily monitored on a routine basis throughout construction. These data are required to confirm the behavior of the tar sand during construction.

- Lagging Inspection: It is recommended that the behavior of the lagging within the tar sand be visually inspected during construction in order to provide a qualitative indication of the pressure acting against the lagging. These inspections should include penetration resistance tests behind the lagging at selected locations to establish the zone of disturbance of the tar sand behind the wall.

- Piezometers: It is recommended that a number of pneumatic piezometers be installed at selected locations around the excavation. The data from the piezometers provide valuable information regarding the fluid pressures in the tar sand and are essential to confirm design assumptions, particularly during the early stages of construction.

- Thermister Strings: Increases in ground temperature may cause increases in the fluid pressure within the tar sand, with a corresponding reduction in the strength of the material. It is recommended that thermister strings be installed with the pneumatic piezometers so that the relationship between ground temperatures and fluid pressures can be monitored during construction.

- Frequency of Readings: An appropriate frequency of instrumentation readings depends on many factors including the construction progress, the results of the instrumentation readings (i.e., if any unusual readings are obtained), costs, and other factors which cannot be generalized. The devices should be installed and initial readings should be taken as early as possible. Readings should then be taken as frequently as necessary to determine the behavior being monitored. For ground movements this should be no greater than one to two-week intervals during the major excavation phases of the work. Strut load measurements should be more frequent, possibly even daily, when significant construction activity is occurring near the strut (such as excavation, placement of another level of struts, etc.).

  The frequency of the readings should be increased if unusual behavior is observed.

In our opinion, it is important that the installation and measurement of the instrumentation devices be under the direction and control of the Engineer. Experience has shown when the instrumentation program has been included in the bid package as a furnish and install item, the quality of the work has often been inadequate such that the data are questionable. By defining Support Work

(Contractor) and Specialist Work (Engineer) in the bid documents, RTD could allow the contractor to provide support to the Engineer for installing the instrumentation.

## 6.7 EXCAVATION HEAVE AND SETTLEMENT OF THE STATION STRUCTURE

The proposed station excavation will substantially change the ground stresses below and adjacent to the excavation. The proposed 95 to 100 foot deep excavation will decrease the total vertical ground stresses by about 12,000 psf. Stress reduction caused by the excavation will result in rebound or heave of the bedrock below the excavation. The station structure and subsequent backfilling will reload the bedrock. We estimate that the net station loads will be about 6000 psf. Thus, even though the weight of the excavated soil exceeds the weight of the final structure, the structure will experience some ground settlement due to elastic recompression.

The test boring information indicates that the base of the station will bottom either in the stiff tar silts or in bedrock, except possibly at the southeast end of the station. In a few locations, it may be necessary to subexcavate tar sand which is present in dips in the bedrock or stiff tar silt surface and backfill with compacted gravel. It is estimated that, provided all tar sand is removed down to bedrock or the stiff tar silt, the maximum heave at the center of the excavation will be in the order of 2 inches. Due to the dense and hard consistency of the underlying material, the majority of the deformation will be elastic rebound. Therefore, most of the heave will occur as the excavation is carried out.

It is expected that the imposed loads from the structure and backfill will induce settlements on the order of 1 to 1 1/2 inches. Again, these settlements are expected to be the result of elastic recompression of the bedrock and, therefore, are expected to occur during construction. Due to the long, narrow shape of the imposed load, the theoretical differential settlement is relatively small, on the order of 0.5 inches over the width of the structure. This correlates to an angular rotation of about 1:700.

The preceding elastic movements are based on a uniform foundation bearing pressure which could result only from a uniformly loaded and perfectly flexible structure. In reality, the station structure will be quite stiff. Thus, the actual differential settlement will be less than that assumed for an assumed flexible foundation. The anticipated heave and structural differential settlements could be estimated more accurately through the use of a finite element deformation analysis which would more correctly model soil-structure interaction. Such an analysis is beyond the scope of the present study but should be considered once the design of the station has proceeded to a more advanced stage.

It is understood that the mezzanine level at each end of the station will be widened such that approximately 45 to 55 feet of tar sand will remain below the widened portion of the mezzanine floor slab. The tar sand below both these areas is competent in its confined state, and if these portions of the station were structurally separated from the balance of the station, it would be possible to place these portions on a mat foundation bearing on the tar sand. However, it is anticipated that the tar sand will heave significantly more than the bedrock on excavation, and may settle significantly more on reloading. Hence, significant differential movements will occur if these wider portions of the mezzanine are founded on the tar sands. The differential settlements may result in vertical cracking and loss of water, gas and oil tightness of the proposed structure.

## 6.8 FOUNDATION SYSTEMS

### 6.8.1 Main Station

The main station will consist of two parts:

a. A 40-foot wide section extending about 90 to 95 feet below grade bearing on either the tar silts or rock.

b. Side wings varying in width up to about 75 feet which bottom at the mezzanine level about 40 feet below grade bearing on a thick horizon of tar impregnated soils.

It is understood that the deep portion of the proposed A250 Station will be supported on thick base slabs which will function as massive mat foundations. We estimate that the net mat foundation bearing pressures will be about 1000 to 2000 psf. In our opinion, this portion of the station can be adequately supported on a mat foundations bearing on tar silts or rock.

From a construction standpoint, any tar-impregnated sands left in place below the bottom of the mat excavation may be incompetent to support foundations. Based on Section A-A', Drawing 5, it appears that the stiff tar silts and clays will be encountered at the final base of the excavation except possibly near the two ends of the station. In order to provide a suitable working surface for personnel and equipment, at least 2 feet of the tar-soaked soils should be removed and replaced with a compacted fill of clean granular soils. For improved settlement characteristics, all of the tar sands should be removed down to the Fernando Formation or stiff tar silts and clays.

If the mezzanine wings were supported on mat foundations, the expected differential settlement between the mats supported on tar sands and the mat for the deep portion of the station would not be compatible. Further, the lateral surcharge on the adjacent deep station exterior wall caused by the vertical load of the mezzanine plus backfill would be large. Accordingly, piles are recommended for the support of the mezzanine wings.

The vertical pile capacities given in Figure 6-4 for drilled concrete piles may be used for design of piling for the mezzanine wings. As an alternate, steel piles predrilled to rock and then driven may be designed for an end bearing of 18 ksf and the following frictional resistance:

$$f = 1700 + 18 \cdot Z \text{ psf} \qquad (6.5)$$

Where:

f = shearing resistance between rock and pile, psf

Z = depth of penetration into rock below the bottom of excavation, feet.

### 6.8.2 Support of Surface Structures

Surface structures can be generally supported on conventional spread footings founded on undisturbed stiff natural soils. If suitable natural soils do not exist at the surface structure site, footings may be founded on a zone of properly compacted structural fill (see Appendix E). Allowable bearing pressures and estimated total settlements of spread footings bearing on the natural alluvium or compacted structural fill can be determined based on Figures 6-9 and 6-10. These figures are based on analytical procedures and experience in the Los Angeles area but are generally conservative due to lack of detailed information on structural loadings and site conditions at the surface structure location. Detailed site specific studies should be performed to provide final design recommendations for specific structures.

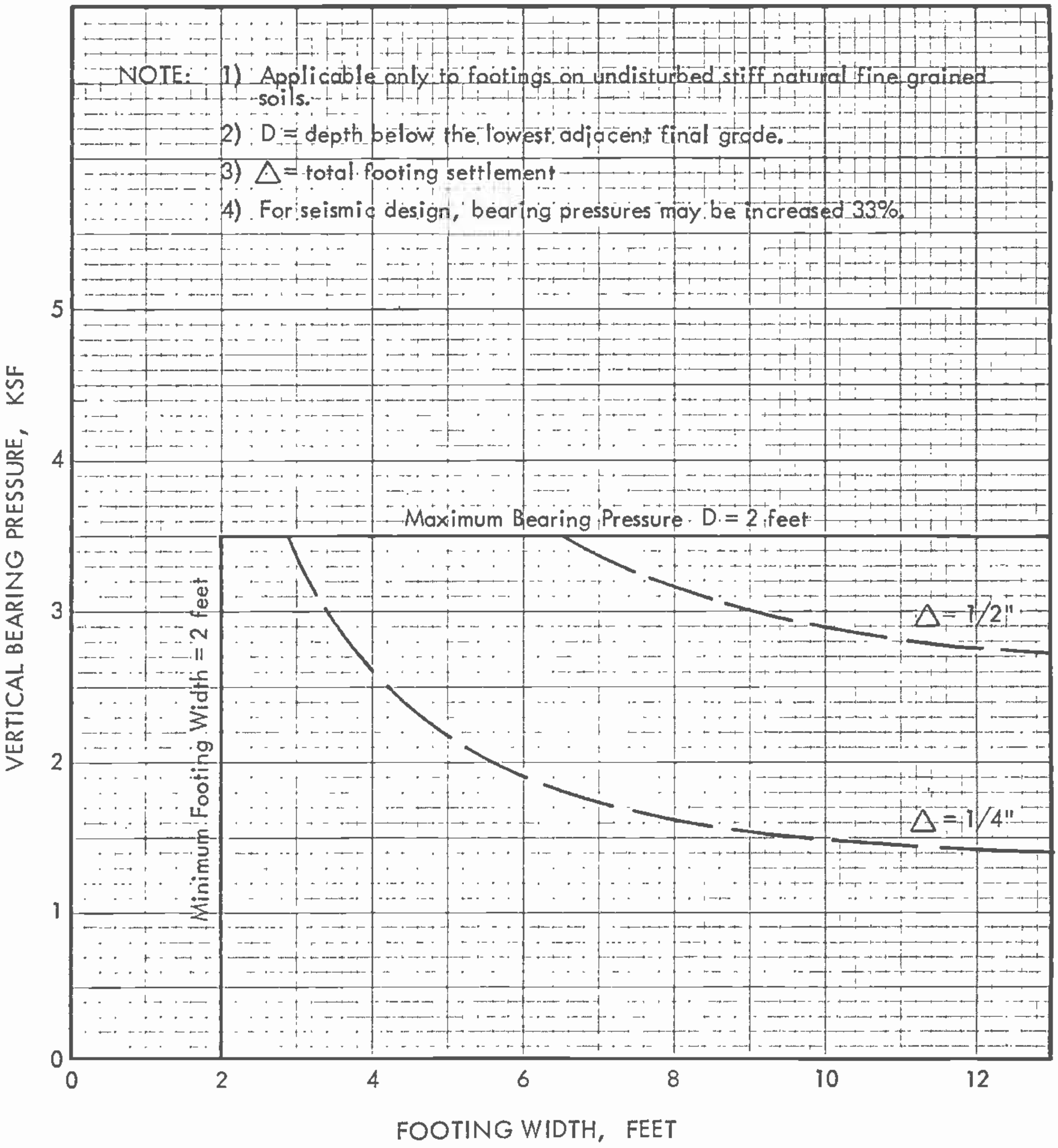
All spread footing foundations should be founded at least 2 feet below the lowest adjacent final grade and should be at least 2 feet wide. The bearing values shown on Figures 6-9 and 6-10 are for full dead load and frequently applied live load. For transient loads, including seismic and wind loads, the bearing values can be increased by 33%. Differential settlements between adjacent footings should be estimated as 1/2 of the average total settlements or the difference in the estimated total settlements shown on Figures 6-9 and 6-10, whichever is larger.

For design, resistance to lateral loads on surface structures can be assumed to be provided by passive earth pressure and friction acting on the foundations. An allowable passive pressure of 300 psf/ft may be used for the sides of footings poured neat against dense or stiff alluvium or properly compacted fill. The maximum passive pressure should not exceed 3000 psf. Frictional resistance at the base of foundations should be determined using a frictional coefficient of 0.35 with dead load forces.

## 6.9 STATIC LOADS ON STATION STRUCTURE

### 6.9.1 GENERAL

The design criteria for earth and fluid loads on the completed structure are shown schematically on Figure 6-11.



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**ALLOWABLE BEARING & SETTLEMENT FOR SPREAD FOOTING ON FINE-GRAINED SOILS**

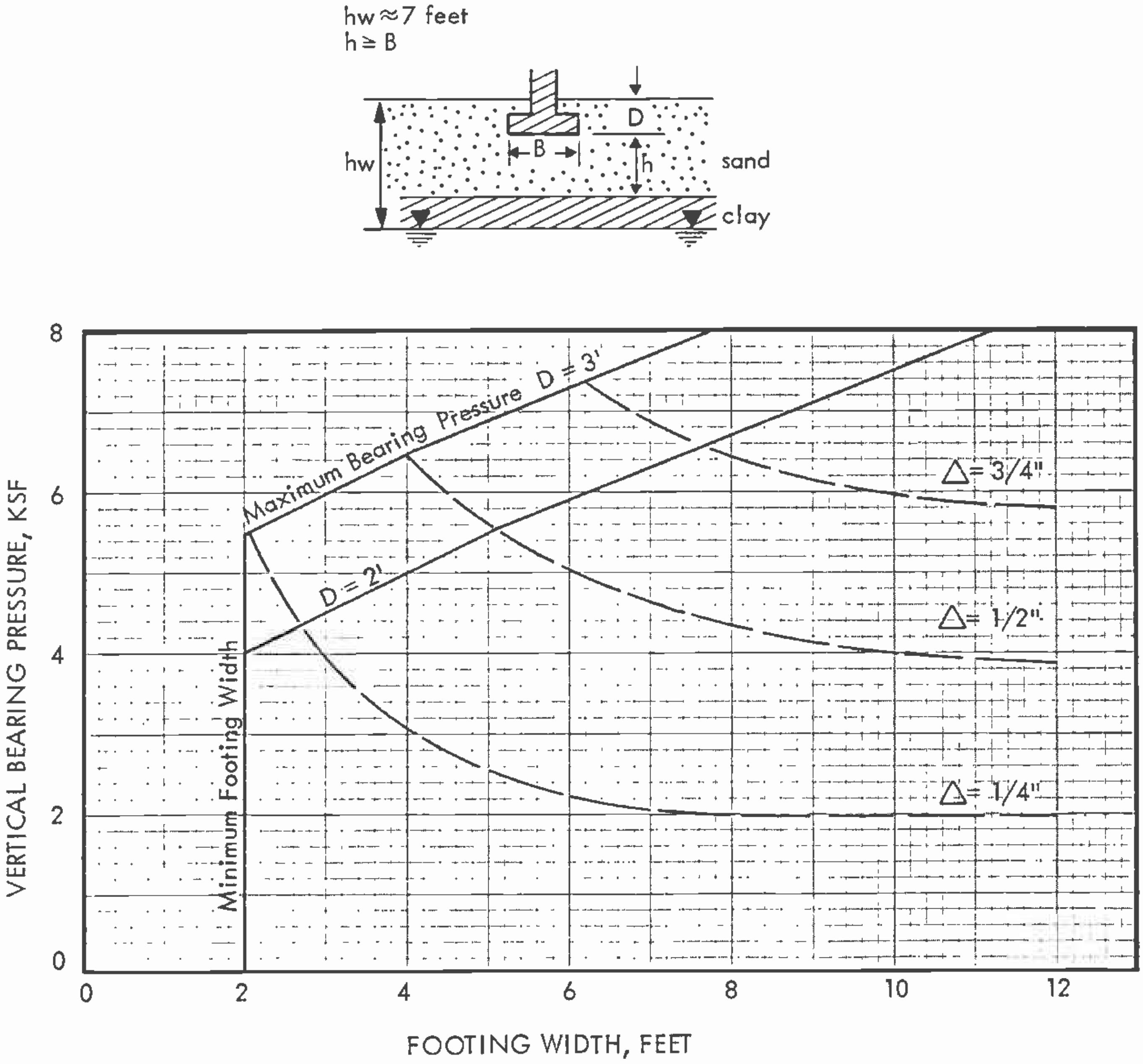
DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Project No.
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Figure No.
6-9

NOTE:
1) Applicable only to footings on a layer of properly compacted granular fill at least one footing width thick.
2) D = depth below the lowest adjacent final grade.
3) △ = total footing settlement
4) For seismic design, bearing pressures may be increases 33%.



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# SPREAD FOOTING BEARING/SETTLEMENT ON GRANULAR SOILS

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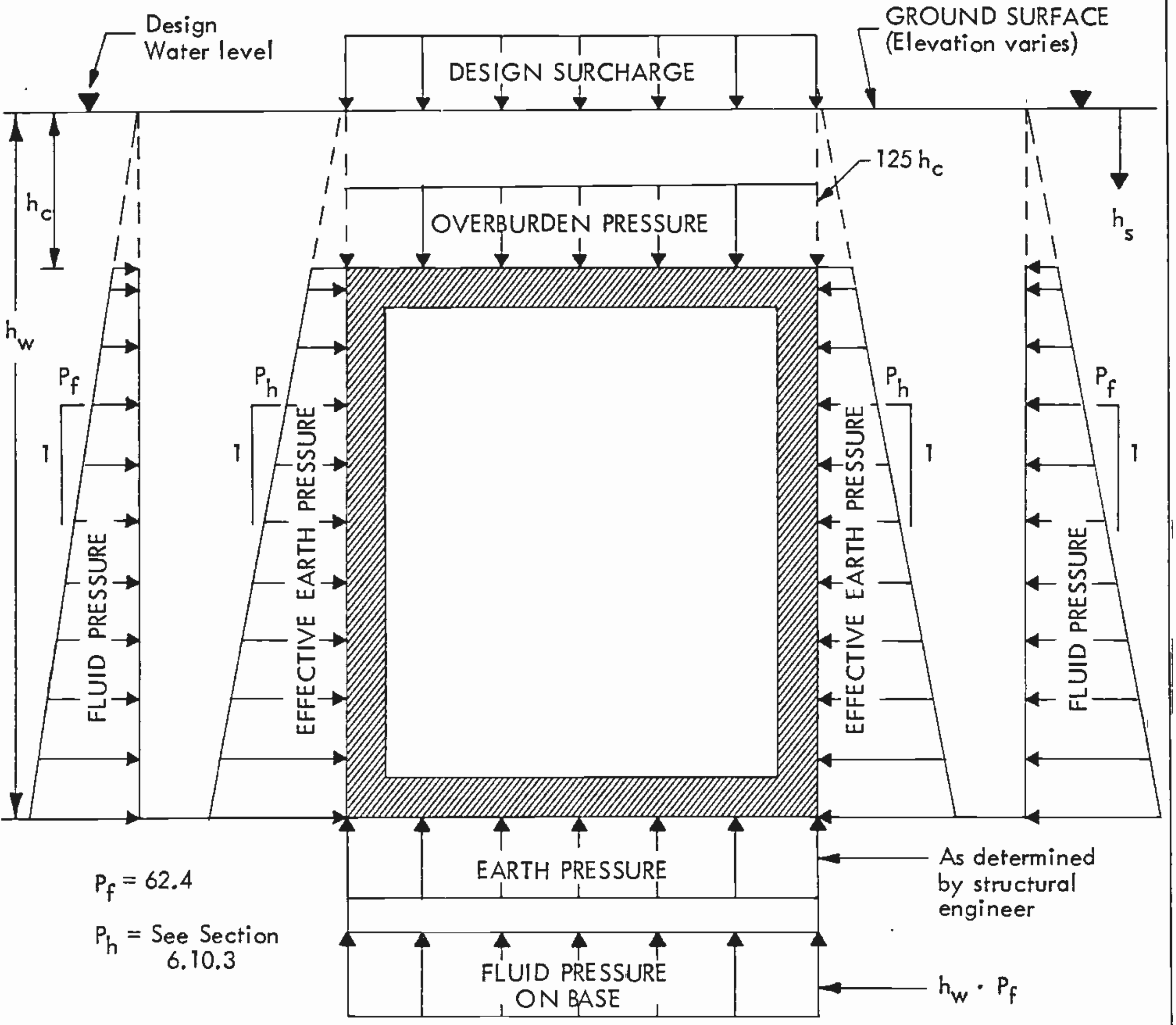
Figure No.
6-10



## LOADS ON PERMANENT WALLS

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83-1140

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Figure No.
6-11

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The loads which must be considered in design include the fluid pressures and effective horizontal earth pressures, which act on the walls; the overburden pressure acting on the roof of the structure; and the net bearing pressure and fluid pressure which act on the base of the structure. Loads imposed at the ground surface must also be considered. In addition, the uplift of the structure due to buoyancy should also be checked.

The foregoing loads are discussed in more detail in the following sections and design values have been provided, where appropriate.

### 6.9.2 FLUID PRESSURES

As mentioned earlier, the fluid pressure measured in the tar sand is equivalent to a head of water which, at the station location, is near the existing ground surface.

It is recommended a design ground water level elevation equal to the existing ground surface be used for hydrostatic design features of the completed station. Permanent dewatering of the station area is not recommended because the water and bitumen which would accumulate in the drainage system would give off gases which are possibly hazardous. In addition, the bitumen would have to be disposed of in a special manner. The fluid pressure can be calculated from the formula:

$$P_f = 62.4\ h_w \tag{6.6}$$

Where

$P_f$ denotes the pressure (psf) at depth $h_w$, and

$h_w$ denotes the depth (feet) below ground surface.

### 6.9.3 EFFECTIVE HORIZONTAL EARTH PRESSURE

The effective horizontal earth pressure acting on the walls of the structure, which should be added to the fluid pressure, can be calculated from the following formula:

$$P_h = k\gamma'\ h_s \tag{6.7}$$

Where

$P_h$ denotes the effective horizontal earth pressure (psf) at depth $h_s$,

$h_s$ denotes the depth (feet) below finished ground surface,

$\gamma'$ denotes the buoyant unit weight (62 pcf) of the soil, and

k denotes the ratio of the horizontal to vertical effective soil stresses.

The value for k is affected by many factors including the method and sequence of construction, the rigidity of the finished structure, and the long-term behavior of the soil.

If the station is constructed using a soldier pile wall and lagging support system and the permanent concrete walls are cast against the soldier pile wall, then the effective horizontal earth pressure acting after construction will be approximately equal to the earth pressure acting against the soldier pile wall, provided the tiebacks are released after the permanent horizontal bracing has been placed. In this case, the value for k can be expected to range from 0.3 in the short term to 0.5 in the long term. The horizontal stresses tend to increase over the long term due to the effects of vibration, earthquakes and other phenomena.

Where a soldier pile and lagging support system penetrates through the tar sand, there is, in theory at least, no reason to believe that the value for k will increase in the long term to a value greater than about 0.5. However, there are few documented case histories of permanent structures in tar sand formations and, therefore, there remains a possibility that k may approach the in-situ value which existed in the formation prior to construction ($k_o$). It is our opinion that the value of k will probably not exceed 0.5 and is very unlikely to exceed 1.0 over the life of this structure.

If the station walls are constructed using the slurry trench method, then the value for k at the end of construction could range from a minimum of 0.5 to a probable maximum of 1.0. The value for k will be very dependent in this case on the method used to support the station walls, as excavation proceeds inside the station. If rigid internal bracing is used and the bracing is jacked into place, then the earth pressure acting on the walls will be high. If a more flexible bracing system is used, or if the vertical distance between horizontal struts is increased (resulting in a less rigid overall structure), then wall pressures will be reduced. The increase in k which will occur over the life of the structure if slurry wall construction is used is also difficult to predict; however, it is considered unlikely that the value will exceed 1.5.

It is recommended that the final design wall pressures for this station be established in discussions between the structural designer and the geotechnical consultants in order to ensure that the final design is not overly conservative. For example, at this time, it would appear that a reasonable approach would be to design the structure with a relatively high structural factor of safety for the lower bound values of the horizontal effective earth pressure, and to use a relatively low factor of safety for the upper bound estimate of the long term horizontal effective earth pressure.

For purposes of preliminary design, a value of k=1 is recommended.

### 6.9.4 OVERBURDEN PRESSURE

For design purposes, the pressure acting on the roof of the structure should be calculated from the following formula:

$$P_r = 125\ h_c \tag{6.8}$$

Where

$P_r$ denotes the pressure (psf) acting on the roof of the structure, and

$h_c$ denotes the distance (feet) from ground surface to the roof of the structure.

It should be noted that there is no need to add fluid pressure acting on the roof of the structures if equation 6.8 is used.

### 6.9.5 SURCHARGE LOADS

Surcharge loads from existing buildings, which are adjacent to the station and not underpinned, must be added to the horizontal design earth pressure loads. The horizontal surcharge loads can be calculated using the method recommended earlier for temporary walls.

Vertical surcharge loads due to surface traffic, etc. should also be included in roof design. In addition, consideration should be given to loads imposed by earthmoving equipment during backfill operations.

### 6.9.6 PRESSURES ON BASE OF STRUCTURE

The total pressure acting on the base slab will be equal to the total weight of the structure (including live and dead loads), plus the weight of the overburden pressure acting on the roof of the structure, plus design surcharge loads, minus the fluid pressure acting on the base. The maximum fluid pressure acting on the base of the structure can be calculated from equation 6.6, once the elevation of the base slab has been established.

In practice, the total pressure calculated in this way will be greater than the actual pressure which acts on the base of the station, because of skin friction acting on the walls of the station. However, for design purposes, it is recommended that skin friction on the walls be neglected.

### 6.9.7 BUOYANCY

Uplift of the structure due to buoyancy should be checked. Due to the depth of the station and the high phreatic surface, it may be necessary to provide means to mitigate a possible buoyance problem.

## 6.10 LIQUEFACTION POTENTIAL

The generalized subsurface cross section has been described in Section 5.0 and is shown in Drawing 5.

As the sands at this station are impregnated with tar and are relatively dense, the natural soils encountered would not be subject to significant liquefaction during the operating design earthquake. This conclusion is based on the effect of the bitumen on the permeability and viscosity of the pore fluid.

## 6.11 EARTHWORK CRITERIA

Site development is expected to consist primarily of excavation for the subterranean structure but will also include general site preparation, foundation preparation for near surface structures, slab subgrade preparation, and backfill for subterranean walls and footings and utility trenches. Recommendations for major temporary excavations are presented in Section 6.4. Suggested guidelines for site preparation, minor construction excavations, structural fill, foundation preparation, subgrade preparation, site drainage, and utility trench backfill are presented in Appendix G. Recommended specifications for compaction of fill are also presented in Appendix G. Construction specifications should clearly establish the responsibilities of the contractor for construction safety in accordance with CALOSHA requirements.

It will be desirable at the Wilshire/Fairfax Station to provide a relatively impervious fill zone of fine-grained soils at least 10 feet thick above the buried structure. Such a barrier will aid in preventing future tar seeps penetrating to the ground surface because of the artesian pressure in the San Pedro Sands.

Excavated fine-grained alluvium free of tar may be re-used as compacted fill barrier, provided it is moisture-conditioned to near the optimum moisture content and is then compacted to the required density. At present, much of the upper alluvium is nearly saturated and may require drying.

## 6.12 PAVEMENT SECTION

Minimum flexible pavement sections for assumed Traffic Index (TI) values of 5.0, 7.0 and 9.0, and a subgrade R-value of 40 were developed using CALTRANS design method. Pavement sections provided below include the recommended thickness of compacted subgrade, base course and asphaltic concrete for the three Traffic Index values.

| ASSUMED TRAFFIC INDEX (TI) | THICKNESS (in inches) | | | |
|---|---|---|---|---|
| | A.C. with Base Course | | Full Depth Asphaltic Concrete | Compacted Subgrade (R ≥40) |
| | A.C. | Base Course | | |
| 5.0 | 2.0 | 6.5 | 4.5 | 24.0 |
| 7.0 | 3.0 | 8.5 | 7.0 | 36.0 |
| 9.0 | 4.0 | 11.0 | 9.5 | 36.0 |

We understand that the City of Los Angeles requires a minimum pavement section along major streets (such as Wilshire Boulevard) consisting of 8 inches of asphaltic concrete over 12 inches of base course. Therefore, the City of Los Angeles should be consulted regarding final selection of the replacement pavement sections.

Subgrade soil preparation should include processing of any disturbed subgrade areas, and excavation and replacement as required to provide a properly compacted subgrade of select granular material ("R" Value ≥40) to the depths indicated above. Subgrade fill compaction should be performed in accordance with recommended specifications presented in Appendix G.

Base course material should be Type II aggregate base conforming with Section 26-1.023 of CALTRANS' Standard Specifications (1978).

## 6.13 SUPPLEMENTARY INVESTIGATIONS

Based on the available data and the current design concepts, the following supplementary geotechnical investigations are recommended;

- Current Construction: A high rise building is currently being constructed at Wilshire Boulevard and Fairfax Avenue. This structure will require an excavation to a total depth of 60 feet, with the base of excavation varying from 20 to 30 feet below the top of the tar sand. It is recommended that a program of observations be undertaken during excavation in order to provide data which can be used to confirm the predicted behavior of the tar sand as well as to provide a better indication of construction difficulties.

- Test Shaft: It is understood that a test shaft at the proposed site is planned in order to provide data which can be used for design and to predict the behavior of the tar sand during construction of the station. The test shaft should be fully instrumented and monitored.

- Test Borings: Consideration should be given to drilling additional borings at the sites of any proposed at-grade ancillary structures near the station. At least one additional test boring should be drilled at the southeast end of the station, after the existing structure has been demolished, in order to establish the depth to bedrock at that location.

- Borehole Convergence Test: It is recommended that a borehole convergence test be conducted to assess the rate and magnitude of borehole convergence which can occur in a slurry filled hole in the tar sand. The data are required in order to assess the stability of holes for tieback anchors, as well as to provide a better indication of convergence and loss of ground associated with the construction of slurry trench walls in the tar sand.

- Depressurization Test: It is recommended that a depressurization test be undertaken to determine whether or not it is practical to stabilize the tar sands by reducing the in-situ fluid pressure by bailing from wells prior to excavation. The data from such a test would provide an indication as to whether or not depressurization to any significant distance from an open excavation is possible. The test would involve the drilling and installation of a well and bailing out any fluid which collects inside. Pneumatic piezometers should be installed at distances of about 5, 10 and 15 feet from the well so that the radius of fluid pressure drawdown can be measured with time.

- Tieback Load Tests: If tiebacks are to be used to support the excavation shoring, it is recommended that load tests be carried out in vertical holes from the existing ground surface, in order to establish design loads for tiebacks in tar sand at depth. These tests should be completed well in advance of construction.

- Slurry Investigation: If a slurry wall is used for the construction of the station, a detailed investigation should be undertaken to establish a suitable type of slurry for use in the tar sand. The investigation should be aimed at resolving the potential difficulties described earlier in this report.

- Deformation Analysis: Once the design of the structure has proceeded to a more advanced stage and the construction procedure has been definitely established, it may be worthwhile to carry out a more comprehensive deformation analysis of the excavation and station structure in order to optimize the design and provide a more precise means of assessing observed construction behavior. The analysis could be undertaken using recently developed finite element computer program which incorporates the unique properties of the tar sand into the solution.

- Observation Well Monitoring: The ground water observation wells and pneumatic piezometers should be read several times a year until project construction and more frequently during construction, if possible. These data will aid in confirming the recommended maximum design fluid pressures. They will also provide valuable data to the contractor in determining his construction schedule and procedures.

- Review Final Design Plans and Specifications: A qualified geotechnical engineer should be consulted during the development of the final design concepts and should complete a detailed review of the geotechnical aspects of the plans and specifications.

- Shoring Design Review: Assuming that the shoring system is designed by the contractor, a qualified geotechnical engineer should review the proposed system in detail, including a review of engineering computations. This review would not be a certification of the contractor's plan but rather an independent review made to ensure the owner's interests are met.

- Construction Observations: A qualified geotechnical engineer should be on site full time during installation of the shoring system, preparation of foundation bearing surfaces, and placement of structural backfills. The geotechnical engineer should also be available for consultation to review the shoring monitoring data and respond to any specific geotechnical problems that occur.

# Section 7.0

# Geotechnical Evaluation - Tunnels

# 7.0 GEOTECHNICAL EVALUATION - TUNNELS

## 7.1 GENERAL

The major soil and rock units which will be encountered along the proposed tunnel alignment are shown on Drawings 2 and 3, and described in Sections 5.2, 5.3 and 5.4. These major units are:

- Alluvium ($A_3/A_4$): consisting primarily of fine-grained, stiff silt and silty clays. Occasional water bearing silt and sand seams are present in this soil unit.

- San Pedro Sands (SP): consisting predominately of a sand filled with bitumen ("tar sand") and a clean, fine sand not filled with tar. Several silt and silty clay layers are present in this unit. Gravel and cobbles were occasionally encountered in some locations.

- Fernando Bedrock (C): consisting predominately of siltstone and claystone. The unweathered bedrock is fractured and fissured and has an unconfined compressive strength ranging from 28 to 44 psi. Occasional thin layers of very hard sandstone, on the order of 5,000 to 15,000 psi in unconfined compressive strength may also be present within the bedrock.

The fluid pressures (piezometric pressures) as measured along the tunnel alignment are shown on Drawing 2 and 3 and range from 3 feet above ground surface at Boring 19-2 to 12 feet below the present ground surface at Boring 20-1. It should be noted that, in the area east of the Wilshire/Fairfax Station, the fluid pressures as measured in the San Pedro Sands were found to be slightly artesian; i.e. the fluid pressure rises about 3 feet above the surrounding ground surface.

The approximate limits of the area where the San Pedro Sands are believed to be tar bearing, rather than water bearing, at tunnel grade, are between Station 488+00 and 545+00 (Drawings 2 and 3). It will be noted that most of the tunnelling to be undertaken in this design section is located within this zone. Within this zone, most of the bedrock (within the depth of exploration) and the lower portions of the alluvium were also found to contain tar.

Very hard cemented layers and/or nodules of unknown dimensions were occasionally encountered in the San Pedro Sand at tunnel grade as in Borings 18-1, 20-7 and 20-8. A very hard, vitreous, brittle nodule of tar, about 5 feet in diameter, was encountered in the San Pedro tar sands during pile driving for the Cal Fed building (Drawing 2) in 1960 (personal communication, L.T. Evans, Jr., 1984).

Occasional pockets and/or lenses of very sticky, viscous tar accompanied by 100% Lower Explosive Limit (LEL) gas should be anticipated; for example, as in Boring 19-3. Gasses coming out of solution caused soil to expand, and extruded from the sampling tube as in Boring 19-2 at 55 feet, Boring 20-1 at 36 feet, and 20-10 at 83 feet. Locally, gas encountered during drilling created a froth in the drill fluid, such as the noxious sulfurous gas in

Borings 19-4 and 20-10. At Boring 18A (Station 498+40), 100% LEL gas readings were detected from the explosimeter.

Concrete tiebacks were encountered in Boring 20A (Station 523+00) at a depth of 30 feet below the ground surface. The boring is located 150 feet south of the tunnel centerline (Drawing 3). Construction records should be kept for all operations along the tunnel line and Wilshire/Fairfax Station.

Between approximately Station 545+00 and the Fairfax/Beverly Station, both tunnels will be excavated in alternating layers of cohesive and cohesionless-like alluvial soils.

## 7.2 STRATIGRAPHIC, GROUND WATER AND TUNNELLING CONDITIONS

The following describes the varying stratigraphic horizons, tar, gas, ground water and tunnelling conditions encountered in borings between cut-and-cover stations. The ground water level is consistently above the crown of the tunnels the entire length.

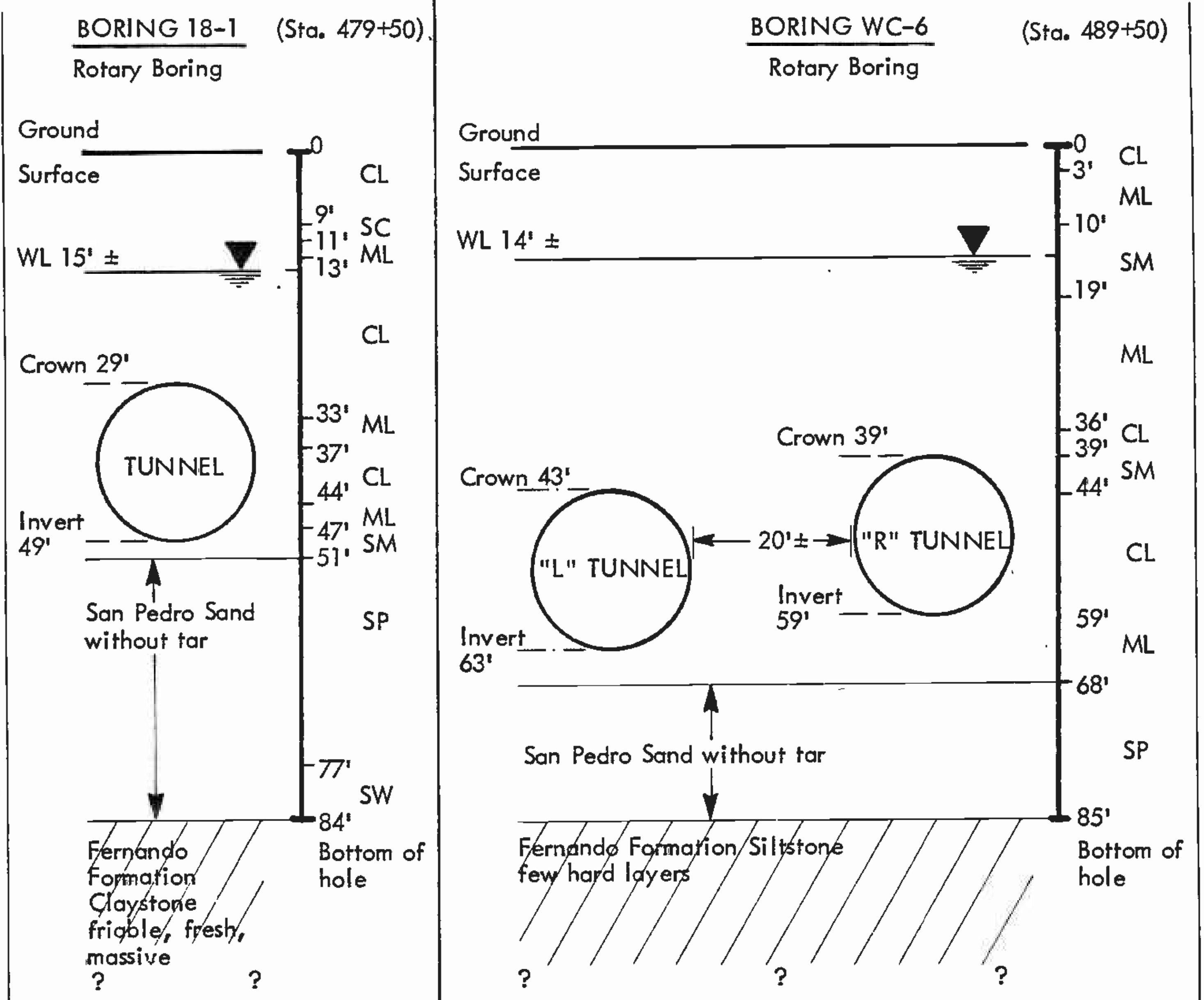
### 7.2.1 Station 480+00 and Station 490+00 (1,000 feet, Drawing 2)

The tunnels between the LaBrea Station and Station 490+00 will encounter saturated, non-tar bearing alluvium, consisting of cohesive and cohesionless-like soils (Drawing 2). Ground water levels range from 12 feet above the tunnel crown at Boring 18-1 to 24 feet at Boring WC-6. Stiff alluvial silts and clays should be encountered at tunnel grade (Figure 7-1). However, the tunnel invert may only be 5 feet above the San Pedro Sand. The San Pedro Sand may be under significant hydrostatic pressure, and a blow-out at the tunnel invert should not be overlooked.

### 7.2.2 Station 490+00 and Station 524+00 (3,400 feet, Drawings 2 and 3)

At Station 490+00, the tunnels begin to diverge vertically, the "L" track dropping below the "R" track. The primary tunnelling media will be San Pedro sands and Fernando bedrock materials; the former of which is judged to be viscous in an unconfined state while both are judged to be gassy. The ground water level is approximately at ground surface throughout this length of alignment.

Between Stations 495+50 and 524+00, the "L" track tunnel will encounter mixed face conditions, pass entirely into the Fernando formation and emerge out of the Fernando into the San Pedro tar sands in a mixed face condition before terminating entirely in tar sands at the east end of the station. Variations in the bedrock surface may result in mixed face conditions in the area of the crown between Stations 501+00 and 518+00. The "L" track emerges out of the Fernando formation at approximately Station 518+00 passing through a mixed face condition entirely into San Pedro tar sands before terminating at the east end of the Wilshire/Fairfax Station directly below the "R" track tunnel. The "L" track tunnel passes over a buried channel (the longitudinal limits of



# EXAMPLES OF STRATIGRAPHIC VARIATIONS

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Project No.
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Figure No.
7-1

Approved for publication 3/28/84 by

which are not completely defined at this time) at approximately Station 523+00, containing some 50 feet of tar bearing sands and gravels. The tunnel invert on each side of the channel may be supported on rock, and some differential settlement may result in this length of the line.

Between Stations 495+50 and 524+00, the "R" track tunnel will pass through tar impregnated San Pedro sands in its entirety except that the invert may pass in and out of Fernando bedrock materials between Stations 505+00 and 513+00.

Figures 7-2, 7-3 and 7-4 are transverse sections showing the relationship between the variable soil stratigraphy and vertical tunnel alignment.

### 7.2.3 Station 534+00 and Station 566+00 (3,200 feet, Drawing 3)

The stacked tunnels emerge from the north end of the station in tar impregnated sands. Within approximately 500 feet, both tunnels pass out of tar impregnated soils. The "R" track tunnel passes into tar free old alluvium within a distance of approximately 200 feet encountering mixed face conditions throughout this length. The "L" track tunnel passes into tar free San Pedro sands within a distance of approximately 500 feet rising through the San Pedro sands to parallel the "R" track tunnel at approximately Station 550+00. Both tunnels continue northward through old alluvial soils terminating at the south end of the Fairfax/Beverly Station. Mixed face conditions of old alluvium above and San Pedro sand below are anticipated between Stations 545+00 and 552+00. The entire length of the tunnels in this segment occurs below the ground water level, the potential hydrostatic head at the crown varying between 60 feet at Station 534+00 and 15 feet at Station 562+00.

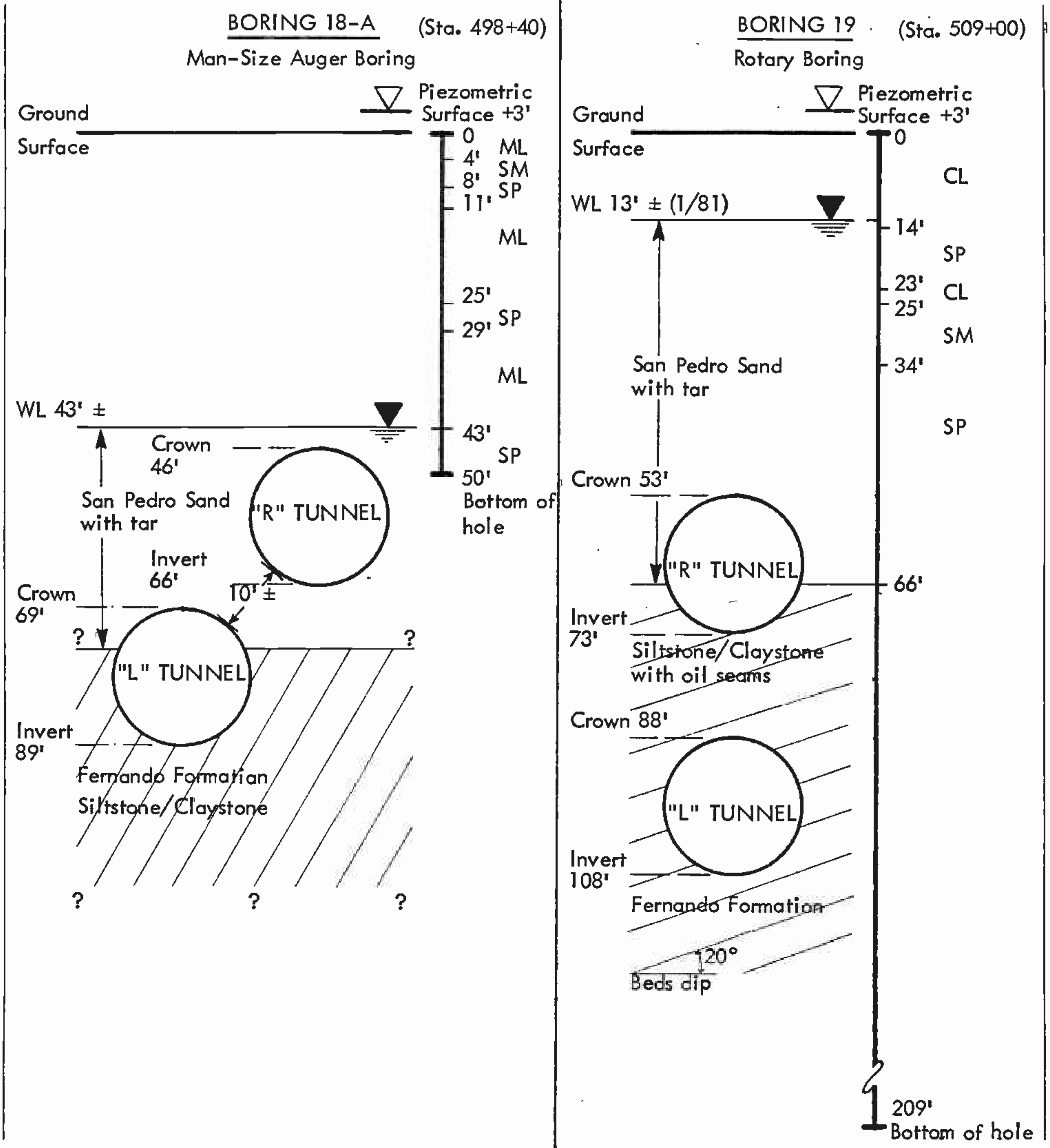
Figures 7-5, 7-6 and 7-7 show transverse sections relating the variable soil stratigraphy with the vertical tunnel alignment.

## 7.3 METHODS OF CONSTRUCTION

It is understood that the contractor will be responsible for selecting the method of tunnel construction, which is tailored to meet the design and scheduling criteria established by RTD. However, a few general comments with regard to the method of construction using a fully shielded tunnelling machine may be useful.

The following general methods of driving the proposed tunnels with a fully shielded tunnelling machine in Design Unit A250 have been examined because of the anticipated viscous behavior of tar sand materials in an unconfined state. The behavior of the tar sands will be better understood after Bechtel's prototype test pit is completed at the Wilshire/Fairfax station. Perhaps when all the results are in, the old fashioned hand method may be the best in certain materials. The tunneling methods considered are:

- ° Earth Pressure Balanced Shield
- ° Bentonite Slurry Shield.



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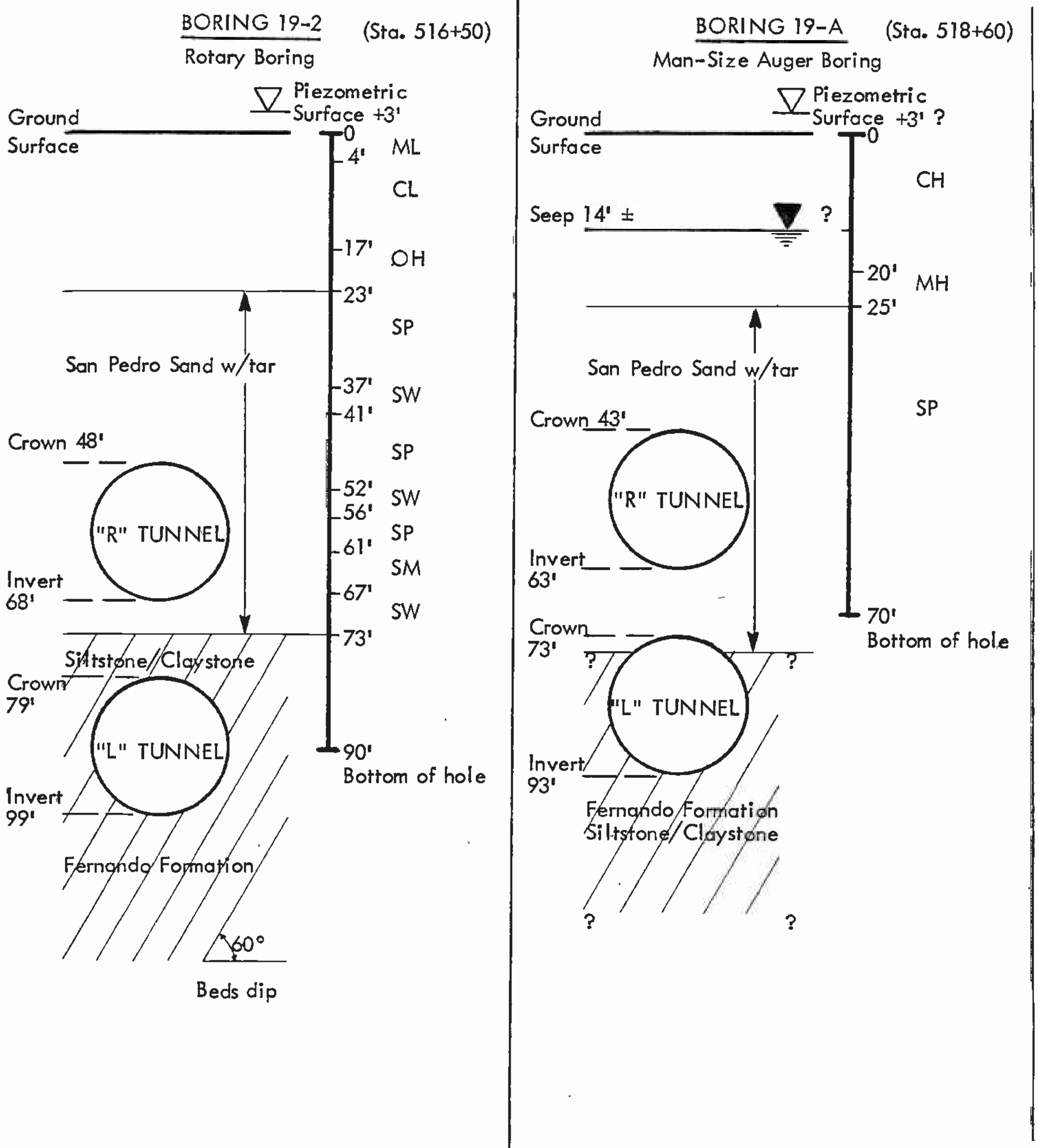
**EXAMPLES OF STRATIGRAPHIC VARIATIONS**

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Project No.
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Figure No.
7-2



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# EXAMPLES OF STRATIGRAPHIC VARIATIONS

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Project No.
83-1140

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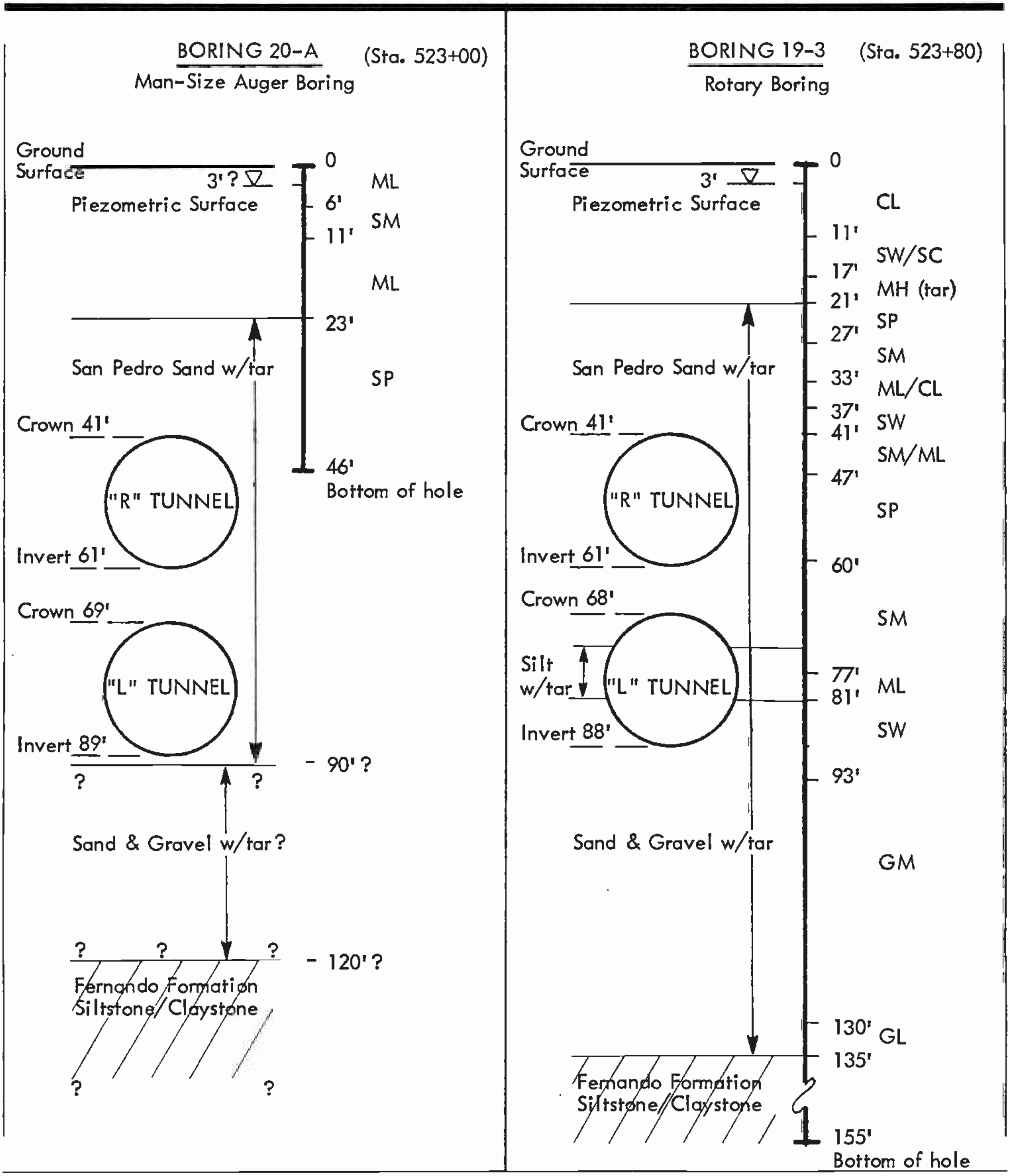
Figure No.
7-3



# EXAMPLES OF STRATIGRAPHIC VARIATIONS

DESIGN UNIT A250
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Figure No.
7-4

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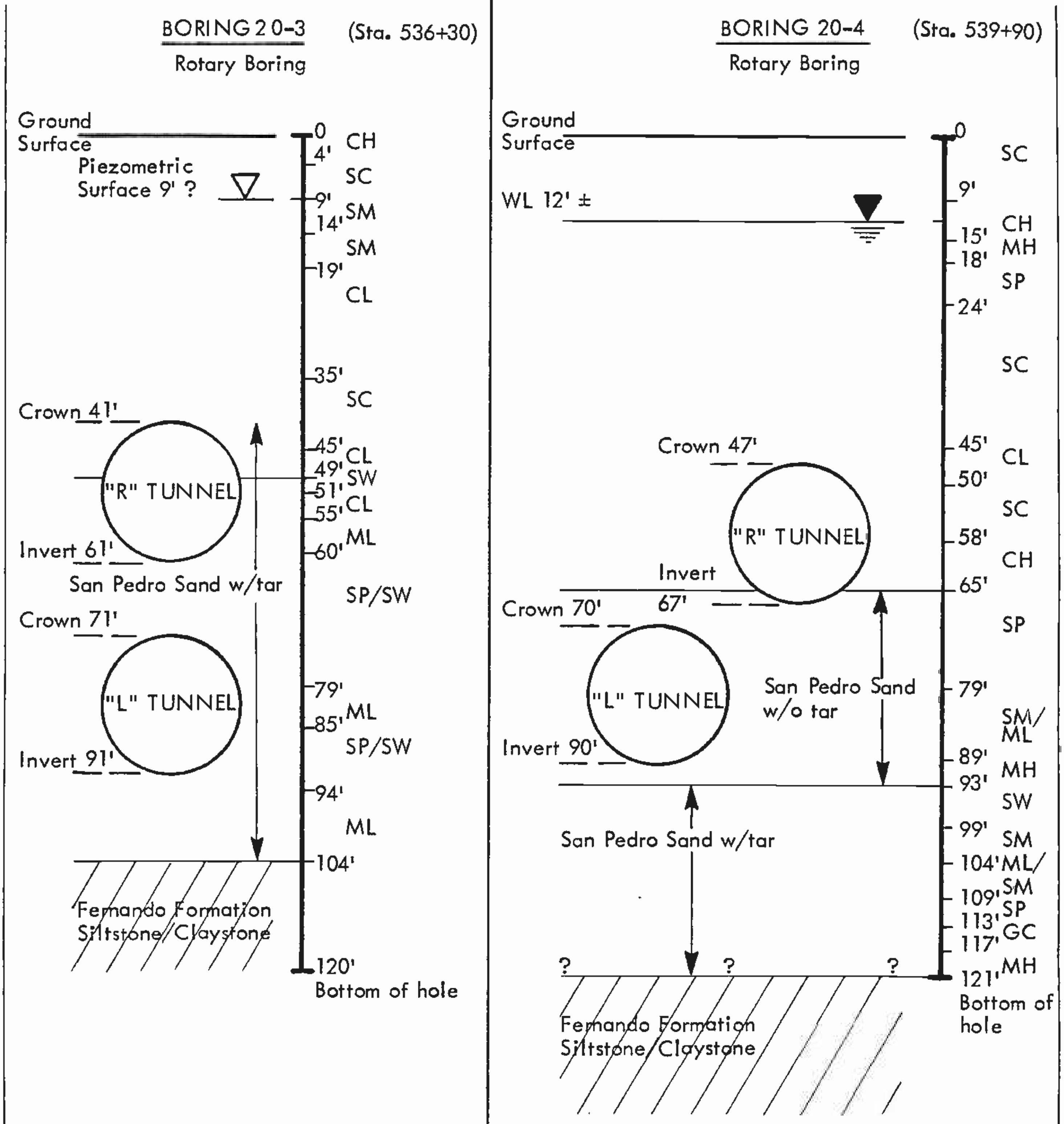

## EXAMPLES OF STRATIGRAPHIC VARIATIONS

DESIGN UNIT A250
Southern California Rapid Transit District
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Project No.
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Figure No.
7-5

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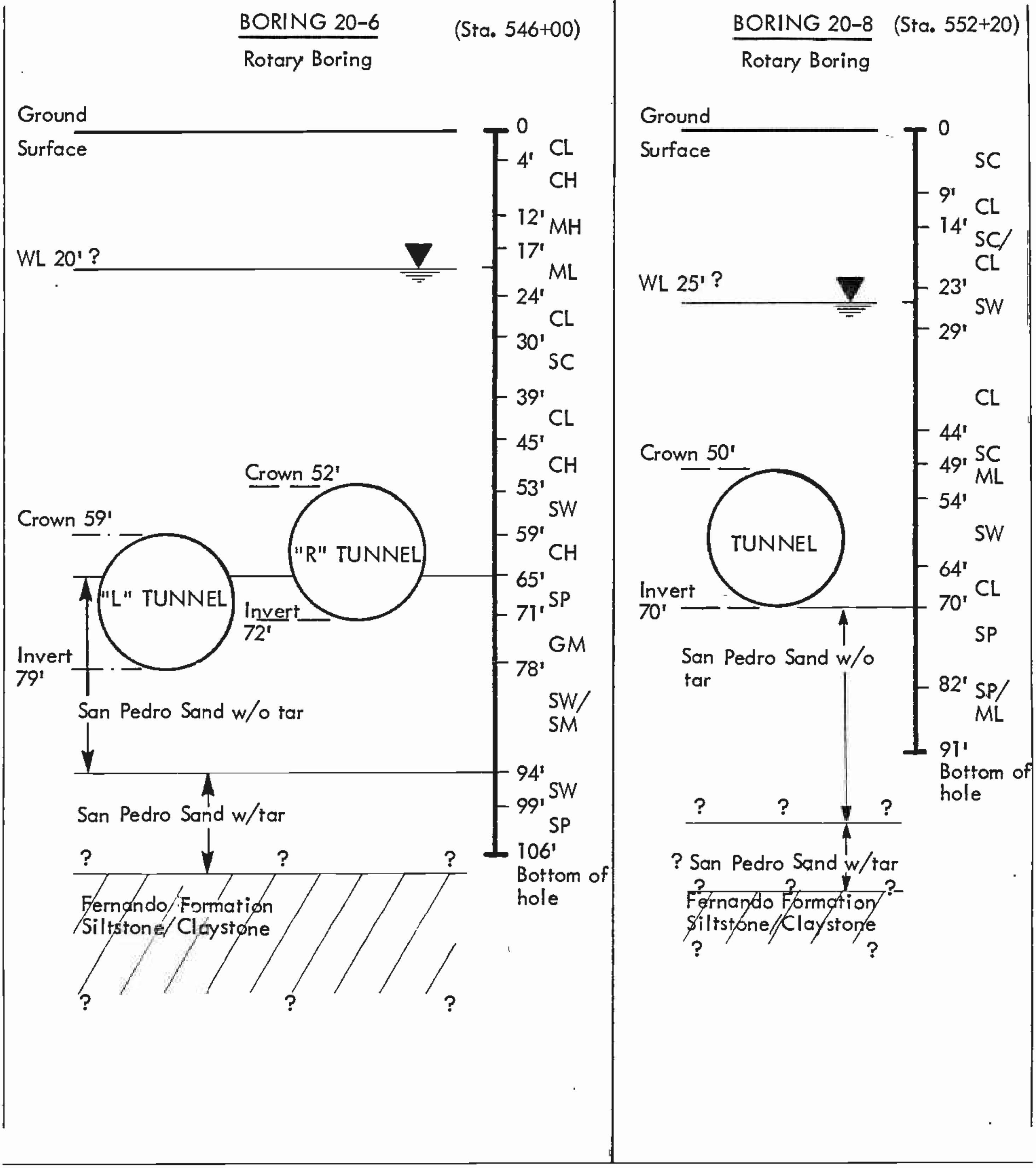

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EXAMPLES OF STRATIGRAPHIC VARIATIONS

DESIGN UNIT A250
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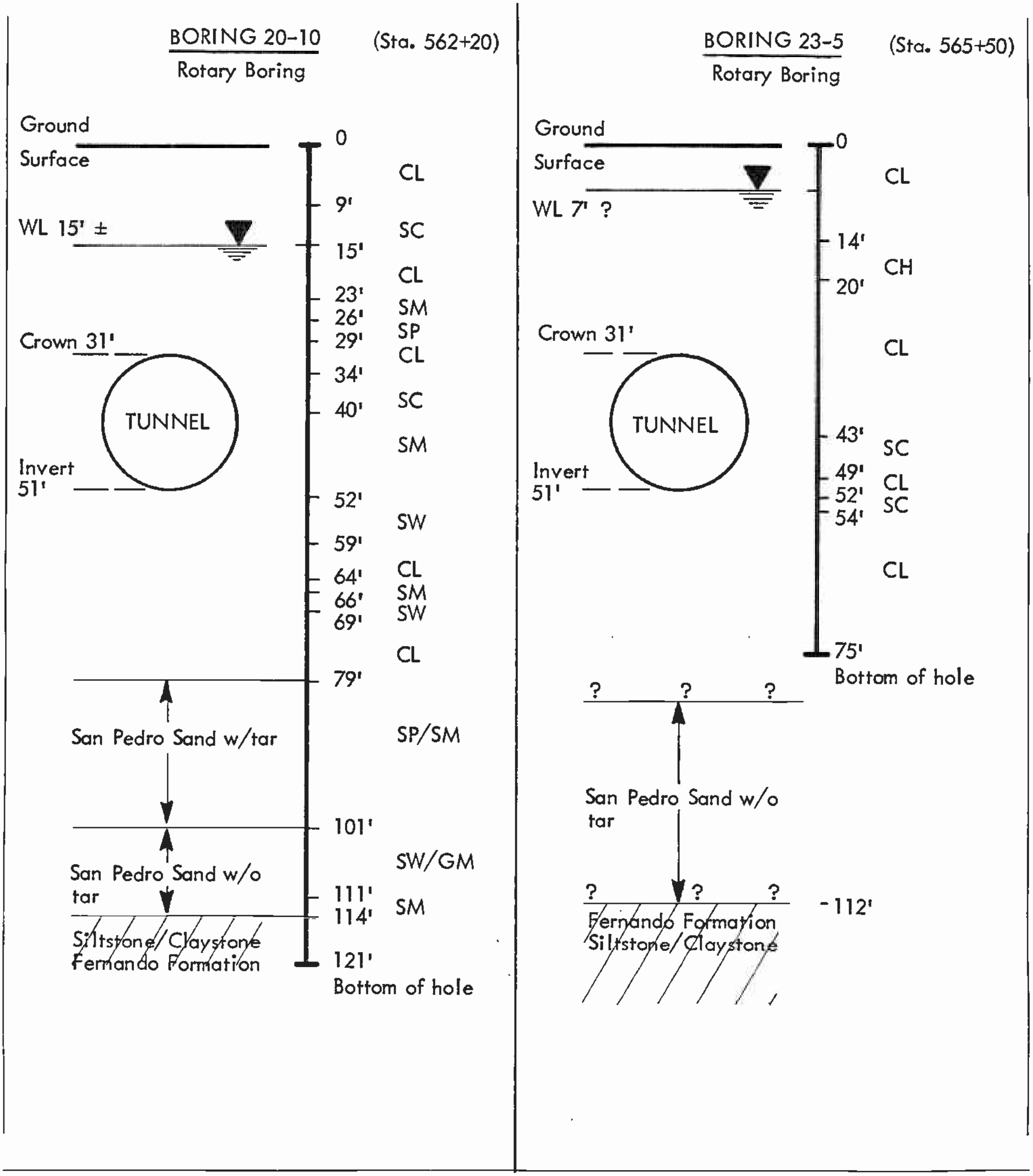
Figure No.
7-6



## EXAMPLES OF STRATIGRAPHIC VARIATIONS

DESIGN UNIT A250
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METRO RAIL PROJECT

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83-1140

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Figure No.
7-7

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Both these methods should minimize ground instability and reduce the need for:

- ° freezing
- ° depressurizing.

Advance freezing of the tar sands will not result in a significant improvement in the strength and stability of these materials unless the ground temperatures can be reduced below roughly -50°C. At this temperature, tunnelling is not considered practical because workability and excavatability of materials is very difficult, and miners may not be able to tolerate these temperatures.

The behavior of the tar sands could be improved if the fluid pressures can be reduced. At this time, however, it is not known whether or not it is practical to depressurize the tar sands because advance depressurization would require bailing bitumen from numerous closely spaced depressurization wells. If spacing on a 10-foot grid along the line is required, depressurization wells would be prohibitive.

Several types of fully shielded tunnel machines are available. Since it is essential to minimize surface settlements due to loss of ground, it would be desirable to use either an earth pressure balanced type of machine or a bentonite slurry faced machine. Such equipment has been developed in both Germany and Japan and has been used on several projects to date, including a constructed section of the San Francisco Sewer Project in 1979.

The Japanese earth pressure balance machine is essentially a closed face wheel cutting machine which fully supports the working face and is ideally suited for soft silty clays and clays which are relatively impervious and exhibit some cohesion. The excavated material extrudes through a slotted head and into an auger chamber. The earth pressure at the face is kept at near the in-situ stress state by jacking the assembly against the face to the required pressure. Loss of ground due to inflow of material at the working face can, therefore, be controlled. Cuttings are normally fed to a conveyor belt system behind the working face and moved to the surface. The temporary or permanent tunnel lining is assembled inside the tail of the machine. In most applications, the lining consists of segmented precast concrete or steel liner plate. Once the machine advances beyond each lining section, the space between the outside of the lining and the ground is filled with grout.

The Japanese designed slurry faced tunnel machine is similar in operation to the earth pressure balanced type described above except that a slurry chamber is placed behind the wheel cutting machine. This machine is more suitable to tunnelling in silts or sands which are relatively pervious. Cuttings are mixed with the slurry and are then pumped to the surface. With this machine, the effective earth pressure is balanced by the horizontal pressure on the cutter and the formation fluid pressures are balanced by the pressure in the slurry. The machine offers control over both soil and fluid pressure and hence can minimize loss of ground.

The German bentonite slurry shield machine is similar to the Japanese machine in that a separate chamber at the face, containing bentonite slurry, supports not only the face but also the walls. However, the German machine cuts the soil using a moveable boom and cutter head which operates inside the slurry chamber. The pressure in the slurry chamber is maintained at a value which counter balances both the soil and formation fluid pressures. An advantage of the German machine over the Japanese machine is that the German machine can more readily deal with obstacles such as cobbles or boulders which may be encountered within the formation.

In our opinion, either the Japanese or German slurry faced tunnel machines offer the best method of driving the tunnels within the water and tar bearing formations within this design section. The German type machine may have the edge because of the moveable boom. The use of the Japanese earth pressure balanced machine may result in loss of ground due to inflow of soil from the water bearing sands. In addition, if the Japanese machine was used in the tar sands, both solution gas and free gas from gas bearing seams would likely flow into the work area, and, because of the high fluid pressures within the tar sand, some sand may run into the tunnel at the working face, resulting in loss of ground.

## 7.4 CONSTRUCTION ASPECTS

The following concerns related to the construction of the tunnels are based on the assumption that the tunnels will be driven using either a Japanese or German slurry faced tunnel machine.

At this time, it is not known where the access shaft for the tunnels will be established; however, it is assumed it will be located at one or all of the stations. If the tunnel portals are established at the Wilshire/LaBrea Station, the water bearing sands at the portal can be dewatered so that the machine can be launched. If the tunnel portals are established at the Wilshire/Fairfax Station, some difficulties will be encountered in launching the machine unless the tar sands at the portal can be stabilized by depressurization or other means. If the machine is to be launched from the Wilshire/Fairfax Station, it is recommended that depressurization tests be undertaken in the tar sands to assess the feasibility of stabilizing the tar sand at the portal by this method.

Handling of the tar sands is generally a difficult task; however, with the slurry faced tunneling methods, most of these difficulties are avoided since the tar sand will simply be pumped to the surface as a slurry. There is some concern, however as to whether or not a suitable slurry can be developed in the tar sands. An unsuitable slurry may lead to excessive viscosity for pumping, or flocculation and attendant loss of fluid, resulting in instability of the working face and loss of ground. The liquid hydrocarbons may be miscible with the slurry or they may have to be skimmed from the settling tanks and disposed of. It can be expected that gas will be liberated from the slurry as it is pumped to the surface and its pressure is reduced. In addition to being highly explosive and toxic to workmen, this gas may collect in the slurry pumps, causing them to cavitate.

Gas zones are not expected to be a major difficulty if the slurry faced tunnelling method is used, because the formation pressure will be maintained at the working face so the gas should not flow unimpeded into the tunnel. Some gas will accumulate into the tunnel, however, and ventilation within the tunnel will be essential during construction in order to provide complete removal of any gasses. The ventilation capacity required will probably be greatly in excess of normal tunnelling operations, and requirements for standy equipment should be very stringent.

The sands which collect in the settling tanks will have to be disposed of in a landfill that is appropriate to accept these materials. The sands from water bearing formations will be contaminated with drilling mud and will most likely be unsuitable as fill. The sands from the tar sands will be contaminated with both drilling mud and bitumen.

Cobbles, boulders and other obstacles will occasionally be encountered during tunnelling within the San Pedro Sands. These obstructions can cause difficulties within the slurry faced tunnel machine, and particularly with the full faced Japanese machine. Contingency plans should be developed in the event such obstructions are encountered.

Skin friction will act on the outside of the shell of the tunnel boring machine. The skin friction will be roughly the same in both the water and tar bearing formations. Preliminary tests indicate an angle of friction between the San Pedro Sands and smooth, mild steel is about 22° to 25°. The total friction forces on the skin of the machine can be calculated based on the effective soil pressure at the centerline of the tunnel. Friction forces between the alluvial soils and bedrock should be determined by testing.

The San Pedro Sands in their in-situ state are dense to very dense sands and consist dominantly of quartz minerals. It can be expected that cutterwear in both the water and tar bearing formations will be high. This aspect should be investigated in further detail.

A 1 or 2 inch clearance is left between the ground and the outside of the tunnel lining, once the tail of the machine has passed beyond the lining. Once the tail advances, the lining rests on the tunnel invert, so that a 2 to 4 inch clearance is left between the lining and the ground at the crown of the tunnel. This space must be filled with grout in order to minimize surface settlements.

In the water bearing sands, the sand is expected to flow into this space almost immediately after the tail advances. It will be necessary to provide a waterproof seal between the tail and the outside of the tunnel liner to prevent water and sand from flowing into the tunnel at this point. Loss of ground can be reduced by grouting around the tunnel lining shortly after the machine has advanced. The grout should penetrate into the loosened zone of sand around the lining.

In tar bearing sands, the sand is also expected to flow into the space left around the outside of the upper half of the lining. The tar sands are expected to flow or collapse into this space within 5 to 10 minutes after the tail of the machine has advanced. Even if the tar sand remained stable and did not flow into this space (which is unlikely), bitumen would flow into the space which would make grouting very difficult. In view of this situation, it is felt that the space between the liner and the ground should be filled with cement grout as soon as possible after the tail of the machine has advanced beyond each lining segment. As in the case of the water bearing sands, a seal should be placed between the tail of the machine and the liner to prevent the flow of gas or bitumen into the tunnel.

The maximum grouting pressure must be carefully controlled, particularly where the depth of cover between the ground surface is low, or in areas where the tunnel runs close to other underground structures or utility lines. In general, the grouting pressure should never exceed the total overburden pressure between the tunnel crown and the ground surface.

As mentioned earlier, the Fernando Bedrock contains occasional hard cemented lenses and layers which may cause difficulties for tunnelling machines.

## 7.5 CONSTRUCTION INSTRUMENTATION

It is considered essential that the behavior of the tunnels be instrumented and monitored, particularly along the first section constructed, in order to confirm the predicted behavior and, in particular, to ensure loss of ground is controlled and surface settlements remain within tolerable limits.

- Preconstruction Survey: A visual and photographic log of all buildings located over the centerline of the tunnels should be undertaken by a qualified civil engineer. If substantial cracks are noted in existing structures, they should be measured and periodically remeasured during and after the tunnel face has passed the area. The data obtained from this work is used to minimize the risks associated with claims against the owner and contractor.

- Surface Settlement Hubs: It is recommended that surface hubs be established at strategic locations over the centerlines of the tunnels in order to monitor surface settlements resulting from tunnel construction. Lines of the surface hubs should also be laid out perpendicular to the tunnel centerline at strategic locations. A large number of such hubs should be established in the first section of tunnelling. The number of hubs can be decreased, as appropriate, based on the observations and experience in the first section of the tunnelling.

- Piezometers: It is recommended that a number of standpipe and pneumatic piezometers be installed at selected locations along the tunnel alignment in order to monitor any changes in ground water or fluid pressures which develop as a result of construction.

- Inclinometers: It is recommended that several inclinometers be installed from ground surface and passing adjacent to the springline to monitor horizontal ground movements in the vicinity of the springline of the tunnel. Inclinometers should also be placed on centerline so that horizontal ground movements can be measured as the tunnel face approaches the inclinometer.

- Borehole Extensometers: It is recommended that borehole extensometers be installed at selected locations so that vertical ground movements in the vicinity of the tunnel can be measured.

- Liner Loads: Consideration should be given to installing strain gauges or load cells in selected liner segments, in order to establish actual liner loads, as well as to monitor changes in liner loads with time. This data would be of interest particularly in the tar sand.

## 7.6 GAS, OIL AND FAULTS

The entire tunnel line segment in Design Unit A250 should be classified gassy. This classification is from the California Administrative Code, Title 8, page 684.18. Appropriate tunnelling equipment should conform with CALOSHA requirements and California Tunnel Safety Orders. For details on gas, refer to studies performed for SCRTD by Engineering Science, Arcadia, California.

The majority of the tunnel line contains bitumen (tar, oil, etc.). Engineering parameters and behavior are discussed in Sections 5.3 and 5.6.

The projected trace of the 6th Street and 3rd Street faults cross the tunnel line (Drawings 2 and 3). The 3rd Street fault is believed to be below track grade. Somewhere in the vicinity of Station 509+00, the 6th Street fault should be encountered at tunnel grade. The 6th Street fault may have influenced the physical properties of the rock as well as acting as a barrier and/or vent for oil and gas at tunnel grade. The two faults are described below:

- 6th Street Fault: This fault is believed near-vertical with north side up relative to the south side. The fault is judged not to penetrate the San Pedro Sand or Alluvium overlying the Fernando Formation. The location of the fault is based on the projection of some Salt Lake Oil Field data to the surface of the bedrock(Crowder, 1961). Hence, its location may vary from that shown. It is not known to be active or potentially active, but it is probably a barrier for gas and oil migration. The fault trace probably crosses the alignment twice, but only once at track grade. The fault trace crosses the alignment at a low angle, and may follow the tunnel excavation for some distance. The physical properties in and adjoining the fault are not known.

- 3rd Street Fault: Displacement on this fault is north side up relative to the south side and is in the Fernando Formation. This fault location is also based on the projection of some Salt Lake Oil Field data to the surface of the bedrock (Crowder, 1961). Hence, its location may vary from that shown. It is not known to be active or potentially active. Neither the physical condition nor the width of the fault is known, but the fault is likely a barrier for gas and oil.

## 7.7 SUPPLEMENTARY INVESTIGATIONS

The following supplementary investigations should be considered during future design phases of the tunnel.

- Additional Test Holes: We recommend drilling at least 8 borings to a depth of 2 tunnel diameters below the proposed invert elevation to obtain samples for laboratory tests and evaluation of tunneling conditions due to the lack of groundwater, tar sand and bedrock data near tunnel grade. The location, depth and purpose are listed below:

| Tunnel Station | Depth (ft.) | Purpose |
|---|---|---|
| 484+00 | 100 | Depth to groundwater, San Pedro Sand, tar sand and bedrock |
| 491+00 | 110 | As above |
| 498+00 | 120 | As above |
| 508+50 | 140 | As above, plus 6th Street fault condition |
| 521+00 | 120 | Better definition of longitudinal limits of buried channel |
| 524+50 | 140 | As above |
| 549+45 | 120 | Crosspassage; mixed face and groundwater condition; bedrock depth |
| 556+52 | 100 | Crosspassage; groundwater, San Pedro Sand, tar sand horizons |

- Direct Shear Tests: Direct shear tests should be undertaken to determine the angle of friction between mild steel and the Bedrock and Alluvium soil units.

- Slurry Investigation: An investigation should be undertaken to establish a suitable type of slurry to be used with a slurry faced tunnel boring machine in the tar sand. The investigation should be aimed at resolving the potential difficulties described earlier in this report.

- Depressurization Test: It is recommended that a depressurization test be undertaken to determine whether or not it is practical to stabilize the tar sands by bailing from wells prior to excavating the tunnel portal at the Wilshire/Fairfax Station. The tar sand must be stabilized at the portal in order to launch the tunnel boring machine.

- Cutterwear: It is recommended that further investigation be undertaken in order to establish the probable rate of cutterwear in the water and tar bearing San Pedro Sands. The rate of cutterwear will have a significant impact on the rate of tunnelling and costs.

- Observation Well Monitoring: The existing ground water observation wells and piezometers should be read several times a year until project construction, and more frequently during construction. These data will confirm current design parameters and will provide valuable information to the tunnelling contractor.

- Buoyant Forces: Uplift of the tunnels as a result of buoyant forces should also be considered in design. Tunnel uplift is not expected to be a significant problem, except in cases where the depth between the tunnel crown and the ground surface is minimal. The buoyancy of the tunnel should also be studied in more detail in those locations where one tunnel is located below the other tunnel.

- Lining Seals: If segmented tunnel lining is used in the tar sands, the type of rubber or neoprene seals used between the lining segments should be investigated further. Certain rubber compounds deteriorate rapidly in the presence of hydrocarbons, which would result in leakage of bitumen and gas into the tunnel.

- Concrete: Concrete is a pervious material, and it is common in many tunnels for water to seep through the concrete. In most cases, the water evaporates at the surface of the concrete faster than the rate at which it seeps through and, therefore, the concrete surface remains dry. In the case of the tar sands, the lighter hydrocarbons may seep through the concrete over the years. The possible effects of the hydrocarbons on the strength of the concrete and on its appearance should be investigated further.

- Review Final Design Plans and Specifications: A qualified geotechnical engineer should be consulted during final design and should undertake a detailed review of the geotechnical aspects of the plans and specifications.

- Construction Observations: A qualified geotechnical engineer should be onsite full time during tunnelling to monitor and interpret instrumentation and to resolve or report any unforeseen geotechnical problems which develop.

## 7.8 ENGINEERING PARAMETERS OF TUNNELLING MATERIALS

The geotechnical engineering parameters for alluvium, San Pedro Sand and Fernando bedrock Formation, as applied to tunnelling, are similar to those described in Sections 5.2, 5.3 and 5.4.

Squeezing of tar bearing alluvial and San Pedro Sand units will be a construction problem, as described in Sections 7.3 and 7.4.

## 7.9 CROSS PASSAGES

Southern California Rapid Transit District Drawing CSK-10 (Sheet 4 of 7) dated January 12, 1984, indicates cross passages are planned at Stations 549+45 and 556+52 only. Based on SCRTD tunnel standard Drawings SD-053 and SD-054, the cross passage dimensions are about 20 feet long, 10 feet wide, and 12 feet high. The plans also indicate the finished opening will be supported by a 2-foot thick concrete liner. The cross passages should encounter similar stratigraphic, ground water and tunnelling conditions described in Section 7.2.3. Of particular importance will be full face and crown support during mining between the twin-bores. Flowing ground from sandy horizons noted in Borings 20-6 and 20-8 (Figure 7-6) and Borings 20-7 and 20-9 should be anticipated. It should be noted that at Station 549+45 there exists a potential for mixed face excavation conditions, coupled with a high hydrostatic head.

## 7.10 SHAFTS

Shaft and/or vent structures are not shown on the SCRTD plans for Design Unit A250. However, Criteria and guidelines for the design and construction of shafts are provided in Section 7.11.1 should they be needed.

### 7.10.1 Guidelines for Circular Shafts

The radial effective pressure on shafts, developed by Terzaghi (1943) and Szechy (1970) were used herein for the design of shafts in soft-ground geologic units. Another more recent approach for design of shafts is the method suggested by Prater (1977).

The radial pressure on shafts in soft-ground units will depend on, but is not necessarily limited to, the type of unit, geometry of shaft and method of construction. For current design purposes, the radial pressures acting on vertical shafts, and shafts inclined at less than 10° from the vertical, can be estimated as follows:

- Fine-Grained Alluvium and San Pedro Sand (SP)

  Radial pressures can be assumed equal to the at-rest pressure based on effective stress plus the hydrostatic pressure. Thus,

$$\sigma_r = K_0 \sigma_s' + \mu$$

where

$\sigma_r$ = total radial pressure (psf)

$K_o$ = at-rest lateral earth pressure coefficient

- Alluvium and San Pedro Sand . . . $K_o = 0.5$

$\sigma_s'$ = effective vertical earth pressure at designated location (psf)

$\mu$ = anticipated ground water pressure at designated location (psf)

- Granular Alluvium and San Pedro Sand (SP)

  Theoretical analyses based on methods developed by Terzaghi (1943) and Szechy (1970) indicate the radial effective pressure on shafts in granular soils is nearly equal to the active pressure at shallow depths but approaches a constant pressure at great depths. Radial pressure on shafts can be estimated as:

$$\sigma_r = RK_a \sigma_s' + \mu$$

where:

$\sigma_r$ = estimated radial pressure

$K_a$ = active lateral earth pressure coefficient

- Alluvium and San Pedro Sand . . . $K_a = 0.3$

$\sigma_s'$ = effective vertical earth pressure at designated location (psf)

$\mu$ = anticipated ground water pressure at designated location (psf)

R = reduction factor based on ratio of depth (z) to shaft diameter (D) where (after Mueser, and others, 1967):

| z/D | 0 | 1 | 2 | 4 | 6 | 10 |
|---|---|---|---|---|---|---|
| R | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |

Shafts, other than circular shafts, may also be utilized for vent structures. Design of non-circular structures may be based on normal earth pressure values such as recommended for the station structures.

## 7.11 SEISMIC CONSIDERATIONS

### 7.11.1 SEISMIC DESIGN

Design procedures and criteria for underground structures under earthquake loading conditions are defined in the Southern California Rapid Transit District (SCRTD) report entitled "Guidelines for Design of Underground Structures", dated March, 1984. Evaluations of the seismologic conditions which may impact the project and the probable and maximum credible earthquakes, which may be anticipated in the Los Angeles area, are described in Converse's report to SCRTD entitled "Seismological Investigation & Design Criteria", dated May, 1983. The 1984 report complements and supplements the 1983 report.

### 7.11.2 LIQUEFACTION POTENTIAL

The generalized subsurface cross section has been described in Section 5.0 and is shown in Drawings 2 and 3. The ground water level along the tunnel alignment is shallow as described in Section 7.2. The soils which are saturated and, therefore, must be evaluated for liquefaction potential include the pockets of granular soils within the matrix of clay soils above the San Pedro Sands and the San Pedro Sands as well.

Our liquefaction evaluation was based on procedures and correlations published by Seed et al (1983) which utilized index soil properties and performance data for soils during previous earthquakes. Field Standard Penetration Tests (SPT) were used in our evaluation of liquefaction potential.

Index property tests (Atterberg Limits, moisture content, and grain size distribution) of the clayey alluvium which predominates compared with index properties of clayey soils vulnerable to liquefaction confirmed the onsite clayey soils to be non-liquefiable.

The referenced procedure include correlations of SPT data and liquefaction potential for granular soils. Considering the high SPT values in the San Pedro Sands and the tar content in these materials, the possibility of liquefaction of the San Pedro Sands is judged to be remote. Corrected "N" values (normalized to 2 ksf overburden pressure) for twenty SPT values in saturated granular alluvium zones ranged from 18 to 57 with an average of about 34. This represents data from the tunnel line between the Wilshire/Fairfax Station and the Beverly/Fairfax Station. Similar data are not available for the tunnel line between the Wilshire/La Brea Station and the Wilshire/Fairfax Station. Determination of dynamic strength was based on an M6.0 event for the operating design earthquake (ODE) and an M7.0 event for the maximum design earthquake (MDE). The results of the SPT analyses indicated a low potential for liquefaction of the granular lenses during the ODE and a possible moderate to high potential for liquefaction of the granular lenses during the MDE event.

Based on the above, we expect that liquefaction of localized granular soil zones in the non tar bearing alluvium may occur during the MDE event. However, in our opinion, liquefaction of the granular layers within the clayey soil matrix will not result in catastrophic changes in the overall dynamic soil loads on the tunnel because the clayey soils are expected to maintain their integrity.

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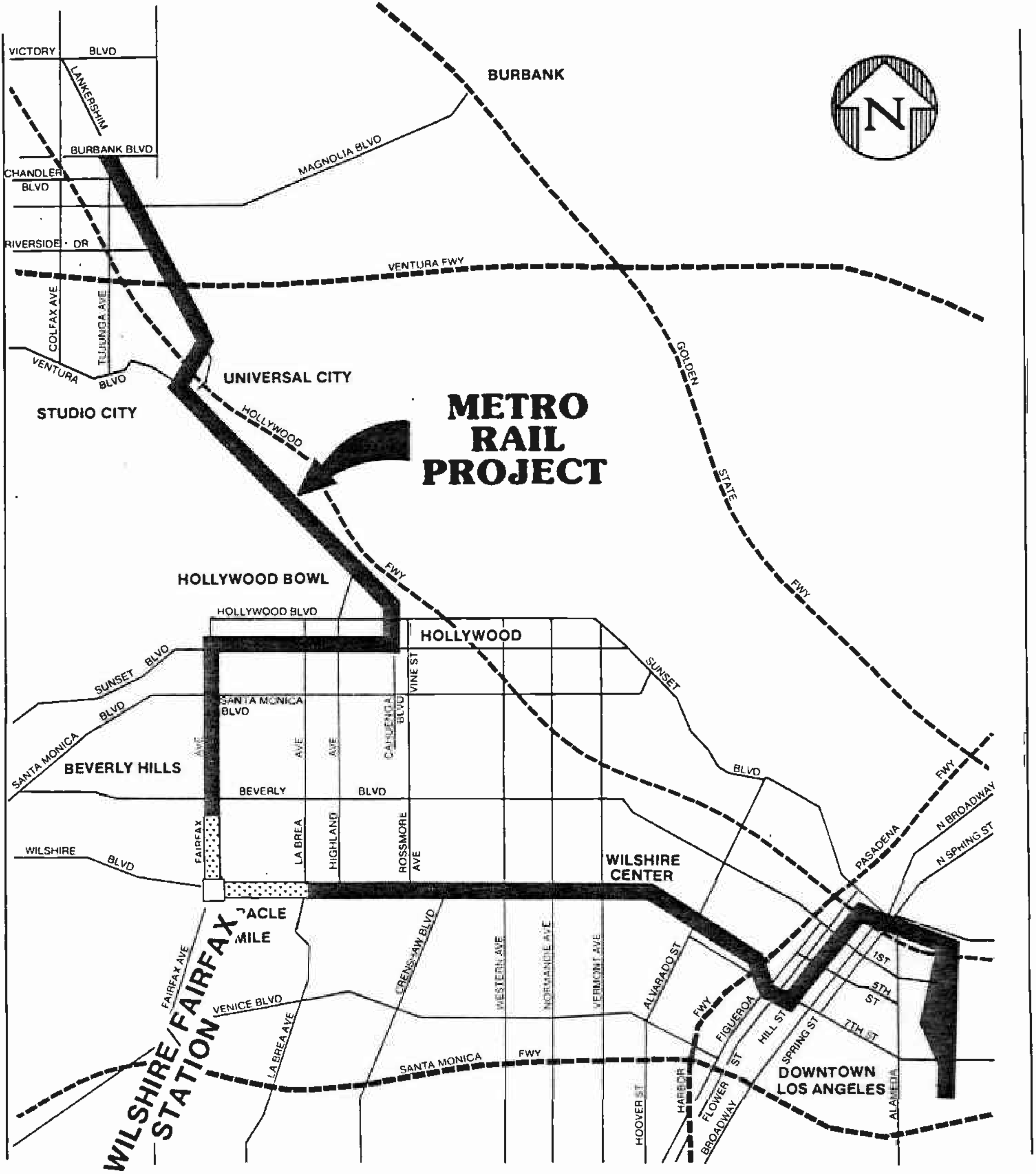
# Drawings



# VICINITY MAP

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

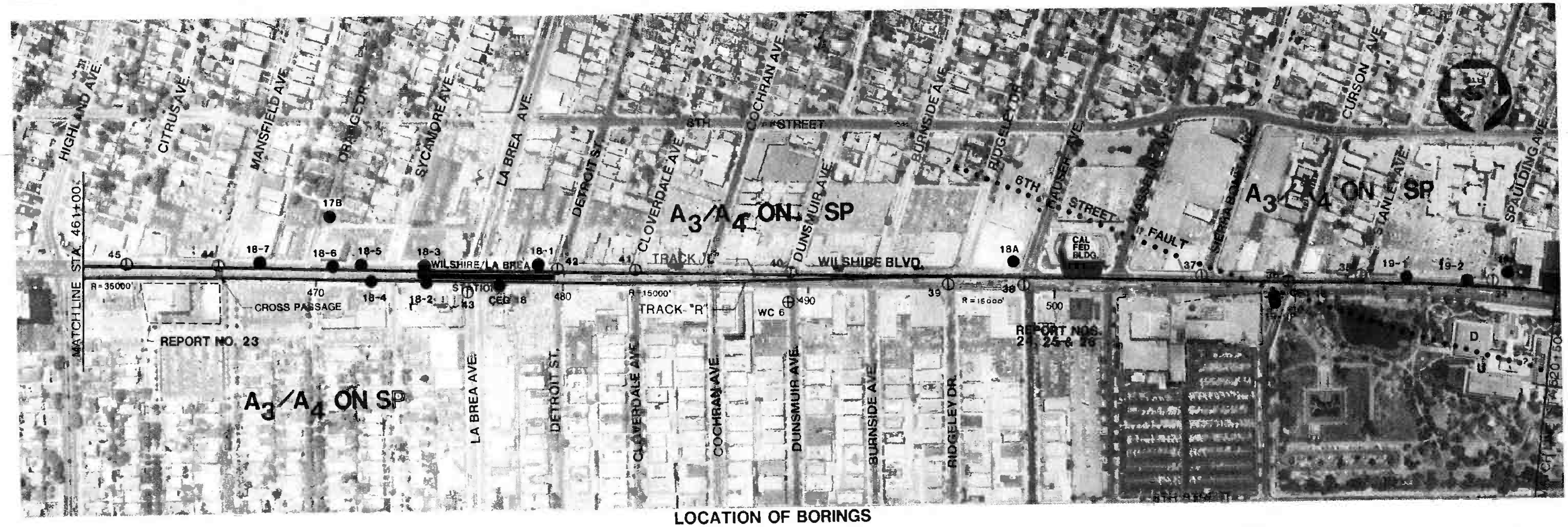
Project No
83-1140

Drawing No
1

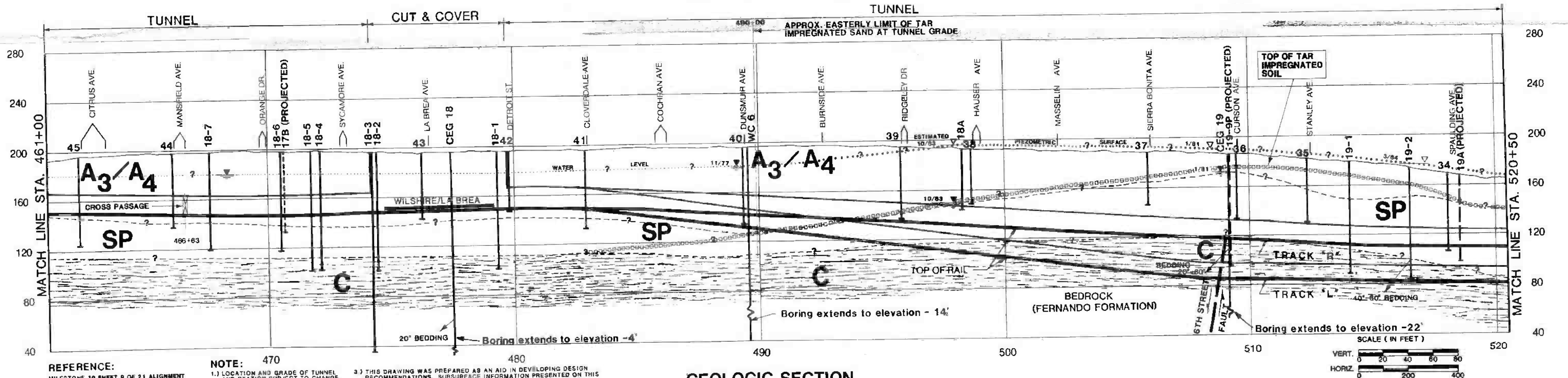
**Converse Consultants** Geotechnical Engineering and Applied Sciences

Approved for publication ________ by ________

0/81



## LOCATION OF BORINGS



## GEOLOGIC SECTION

**REFERENCE:**
MILESTONE 10 SHEET 9 OF 21 ALIGNMENT PLAN & PROFILE STATION 461+00 TO STATION 520+50 DATED NOV. 1983

**NOTE:**
1.) LOCATION AND GRADE OF TUNNEL AND STATION SUBJECT TO CHANGE
2.) FOR EXPLANATION OF GEOLOGIC SYMBOLS SEE DRAWING NO. 6.
3.) THIS DRAWING WAS PREPARED AS AN AID IN DEVELOPING DESIGN RECOMMENDATIONS. SUBSURFACE INFORMATION PRESENTED ON THIS DRAWING IS BASED ON INTERPOLATION AND EXTRAPOLATION OF SUBSURFACE DATA BETWEEN AND BEYOND BORING LOCATIONS. ACTUAL CONDITIONS ENCOUNTERED DURING CONSTRUCTION MAY BE DIFFERENT.

| REV. | DATE | BY | SUB. | APP. | DESCRIPTION |
|---|---|---|---|---|---|

THE PREPARATION OF THIS DRAWING HAS BEEN FINANCED IN PART THROUGH A GRANT FROM THE U. S. DEPARTMENT OF TRANSPORTATION, URBAN MASS TRANSPORTATION ADMINISTRATION, UNDER THE URBAN MASS TRANSPORTATION ACT OF 1964, AS AMENDED, AND IN PART BY THE TAXES OF THE CITIZENS OF LOS ANGELES COUNTY AND OF THE STATE OF CALIFORNIA

| REV. | DATE | BY | SUB. | APP. | DESCRIPTION |
|---|---|---|---|---|---|

DESIGNED BY
DRAWN BY
CHECKED BY
IN CHARGE
DATE

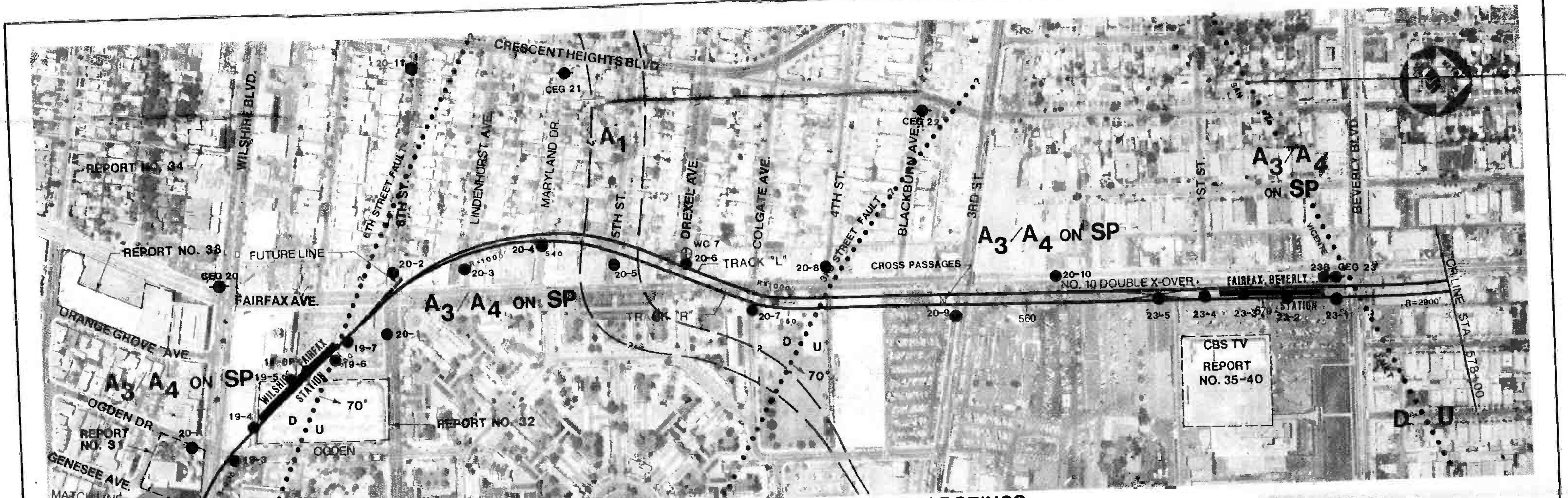
SOUTHERN CALIFORNIA RAPID TRANSIT DISTRICT
METRO RAIL PROJECT
RTD

CCI/ESA/GRC
General Geotechnical Consultants
Submitted
Date May, 1984

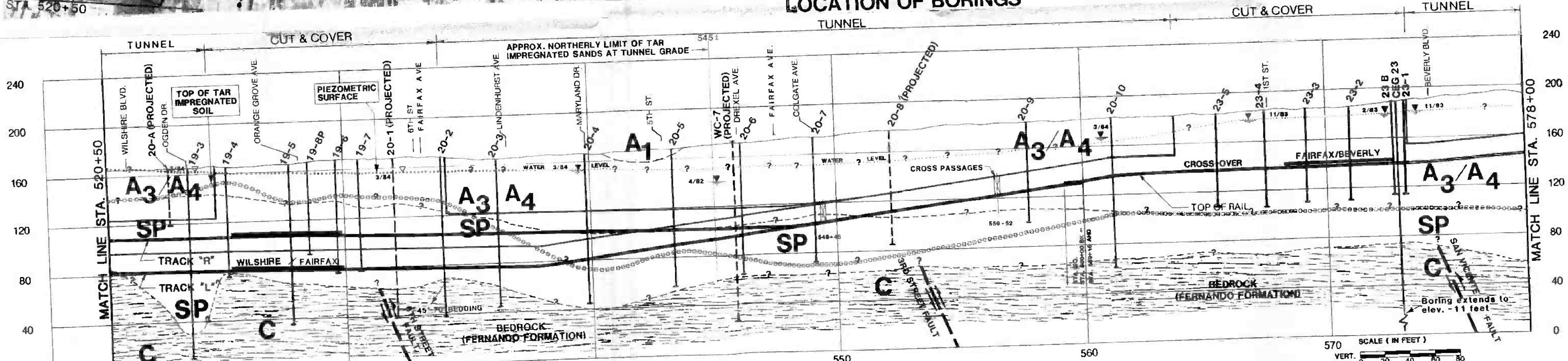
DMJM/PBQD/KE/HWA
A JOINT VENTURE
GENERAL CONSULTANTS
APPROVED

# DESIGN UNIT A250
# LOCATION OF BORINGS
# AND GEOLOGIC SECTION

PROJECT NO. 83-1140
DRAWING NO. 2
REV.
SCALE AS SHOWN



## LOCATION OF BORINGS



## GEOLOGIC SECTION

**REFERENCE:**
MILESTONE 10 SHEET 10 OF 21 ALIGNMENT PLAN AND PROFILE STATION 520+50 TO STATION 578+00 DATED MARCH 1983

**NOTES:**
1.) LOCATION AND GRADE OF TUNNEL AND STATION SUBJECT TO CHANGE
2.) FOR EXPLANATION OF GEOLOGIC SYMBOLS SEE DRAWING NO. 4.
3.) THIS DRAWING WAS PREPARED AS AN AID IN DEVELOPING DESIGN RECOMMENDATIONS. SUBSURFACE INFORMATION PRESENTED ON DRAWING IS BASED ON INTERPOLATION AND EXTRAPOLATION OF SUBSURFACE DATA BETWEEN AND BEYOND BORING LOCATIONS. ACTUAL CONDITIONS ENCOUNTERED DURING CONSTRUCTION MAY BE DIFFERENT.

| REV. | DATE | BY | SUB. | APP. | DESCRIPTION |
|---|---|---|---|---|---|

THE PREPARATION OF THIS DRAWING HAS BEEN FINANCED IN PART THROUGH A GRANT FROM THE U. S. DEPARTMENT OF TRANSPORTATION, URBAN MASS TRANSPORTATION ADMINISTRATION, UNDER THE URBAN MASS TRANSPORTATION ACT OF 1964, AS AMENDED, AND IN PART BY THE TAXES OF THE CITIZENS OF LOS ANGELES COUNTY AND OF THE STATE OF CALIFORNIA

| REV. | DATE | BY | SUB. | APP. | DESCRIPTION |
|---|---|---|---|---|---|

DESIGNED BY
DRAWN BY
CHECKED BY
IN CHARGE
DATE

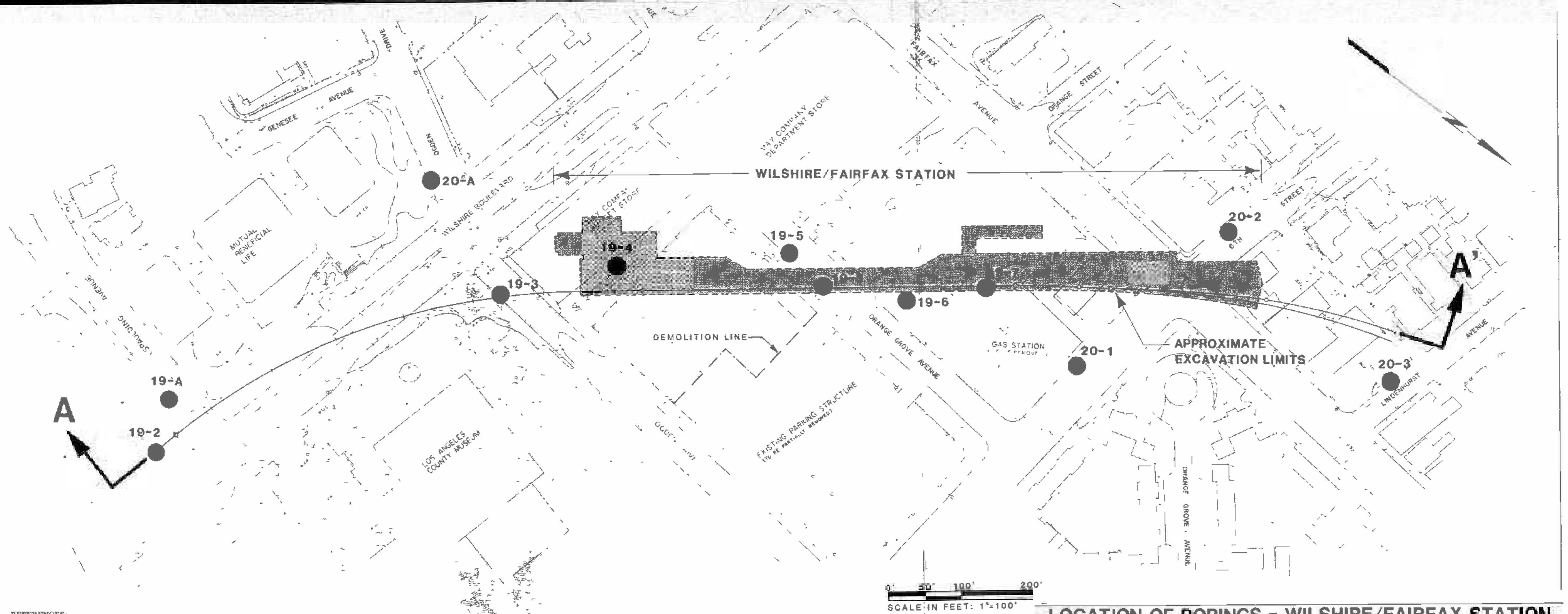
SOUTHERN CALIFORNIA RAPID TRANSIT DISTRICT
METRO RAIL PROJECT
RTD

CCI/ESA/GRC
General Geotechnical Consultants
Submitted R.M. Pride Date May, 1984

DMJM/PBQD/KE/HWA
A JOINT VENTURE
GENERAL CONSULTANTS
APPROVED

# DESIGN UNIT A250
# LOCATION OF BORINGS AND GEOLOGIC SECTION

PROJECT NO. 83-1140
DRAWING NO. 3
REV.
SCALE AS SHOWN
SHEET NO.



REFERENCES:

"CBD TO NORTH HOLLYWOOD LINE PLAN" WILSHIRE/FAIRFAX STATION, DRAWING NOS. APS. AP-16AAA-C-146, AP-16AAA-C-147, A-42, SHEET NOS. 14, 16 & 27 OF 34, PREPARED BY A JOINT VENTURE OF DMJM/PBQD. SCALED 1"=40' REDUCED TO 1"=100', DATED JULY 1983.

NOTES:

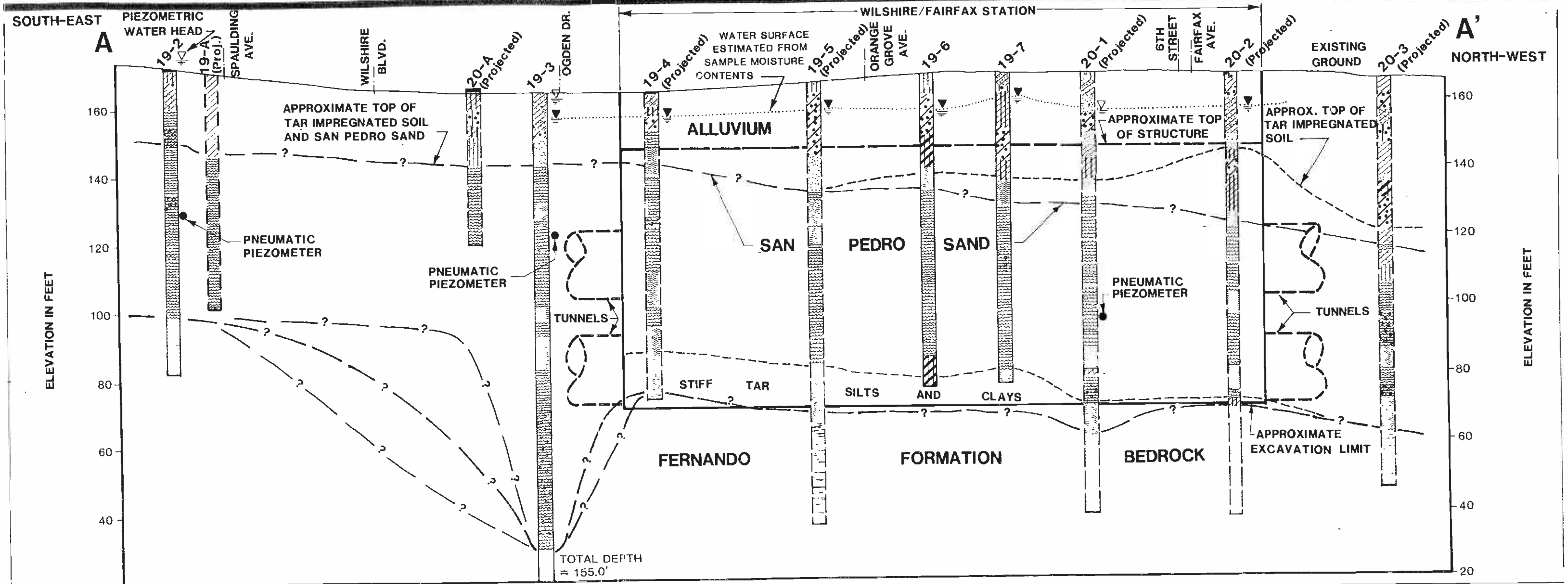
1) FOR SUBSURFACE SECTION A-A' SEE DRAWING NO. 5
2) FOR EXPLANATION OF SYMBOLS SEE DRAWING NO. 6
3) SUBSURFACE SECTION A-A' LINE ALONG ℄ OF AR/AL TRACKS.

# LOCATION OF BORINGS - WILSHIRE/FAIRFAX STATION

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Converse Consultants
Geotechnical Engineering
and Applied Sciences

Scale As Shown
Prepared by MF
Checked by RG
Approved by LTE
Project No 83-1140
Date MAY, 1984
Drawing No 4



NOTES:

1) FOR LOCATION OF SUBSURFACE SECTION A-A' SEE DRAWING NO. 4

2) FOR EXPLANATION OF SYMBOLS SEE DRAWING NO. 6

SCALE:

HOR. 100' 0' 100' 200'

VER. 20' 0' 20' 40'

## SUBSURFACE SECTION A-A' WILSHIRE/FAIRFAX STATION

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Converse Consultants
Geotechnical Engineering and Applied Sciences

| | |
|---|---|
| Scale As Shown | Project No 83-1140 |
| Prepared by MF | Date MAY, 1984 |
| Checked by RG | Drawing No 5 |
| Approved by LTE | |

# GEOLOGIC UNITS

**SOFT GROUND TUNNELLING**

| | | | |
|---|---|---|---|
| QUATERNARY | HOLOCENE | A1 | YOUNG ALLUVIUM (Granular). Includes clean sands. silty sands, gravelly sands. sandy gravels, and locally contains cobbles and boulders Primarily dense, but ranges from loose to very dense. |
| | | A2 | YOUNG ALLUVIUM (Fine-grained)· Includes clays. clayey silts, sandy silts, sandy clays, clayey sands. Primarily stiff, but ranges from firm to hard. |
| | PLEISTOCENE | A3 | OLD ALLUVIUM (Granular). Includes clean sands. silty sands, gravelly sands, and sandy gravels. Primarily dense. but ranges from medium dense to very dense. |
| | | A4 | OLD ALLUVIUM (Fine-grained) Includes clays. clayey silts. sandy silts, sandy clays, and clayey sands Primarily stiff. but ranges from firm to hard. |
| | | SP | SAN PEDRO FORMATION: Predominantly clean, cohesionless, fine to medium-grained sands, but includes layers of silts. silty sands and fine gravels Primarily dense. but ranges from medium dense to very dense Locally impregnated with oil or tar. |
| TERTIARY | PLIOCENE | C | FERNANDO AND PUENTE FORMATIONS· Claystone. siltstone. and sandstone; thinly to thickly bedded Primarily low hardness. weak to moderately strong Locally contains very hard. thin cemented beds and cemented nodules |

**ROCK TUNNELLING**
(Terzaghi Rock Condition Numbers apply)*

| | | | |
|---|---|---|---|
| TERTIARY | MIOCENE | 3 | ←Terzaghi Rock Condition Number<br>←Approximate boundary between Terzaghi numbers |
| | | 2-5 | TOPANGA FORMATION Conglomerate. sandstone. and siltstone: thickly bedded, primarily hard and strong (Geologic symbol Tt) |
| | | 1-5 | TOPANGA FORMATION Basalt. intrusive. primarily hard and strong (Geologic symbol Tb). |

**TERZAGHI ROCK CONDITION NUMBERS:***

1 Hard and intact

2 Hard and stratified or schistose

3 Massive. moderately jointed

4 Moderately blocky and seamy

5 Very blocky and seamy (closely jointed)

6 Crushed but chemically intact rock or unconsolidated sand, may be running or flowing ground

7 Squeezing rock, moderate depth

8 Squeezing rock, great depth

9 Swelling rock

*In practice, there are not sharp boundaries between these categories, and a range of several Terzaghi Numbers may best describe some rock

# SYMBOLS

| | |
|---|---|
| - - - - - -? | Geologic contact: approximately located; queried where inferred |
| U<br>●●●●●?<br>D | Fault (view in plan). dotted where concealed, queried where inferred; (U) upthrown side, (D) downthrown side |
| ⇌? | Fault (view in geologic section). approximately located. queried where inferred. arrows indicate probable movement; attitude in profile is an apparent dip and is not corrected for scale distortion |
| ↙40 | Dip of bedding from unoriented core samples. bedding attitudes may not be correctly oriented to the plane of the profile. but represent dips to illustrate regional geologic trends; number gives true dip in degrees. as encountered in boring |
| ......▼......? | Ground water level. approximately located. queried where inferred |
| -●- | Boring – CEG (1981) |
| ● | Boring — CCI/ESA/GRC (1983) |
| ○ | Boring - Nuclear Regulatory Commission (1980) |
| ⊕ | Boring — Woodward-Clyde (1977) |
| ⦶ | Boring — Kaiser Engineers (1962) |
| ⊖ | Boring — Other (USGS 1977 and various foundation studies) |

NOTES 1) The geologic sections are based on interpolation between borings and were prepared as an aid in developing design recommendations. Actual conditions encountered during construction may be different.

2) Borings projected more than 100' to the profile line were considered in some of the interpretation of subsurface conditions However. final interpretation is based on numerous factors and may not reflect the boring logs as presented in Appendix A.

3) Displacements shown along faults are graphic representations. Actual vertical offsets are unknown.

| | |
|---|---|
| ▥ | SILT |
| ▨ | CLAY |
| ▥ | SANDY SILT |
| ▨ | SANDY CLAY |
| ▥ | CLAYEY SILT |
| ▨ | SILTY CLAY |
| ▦ | SILTY SAND |
| ▨ | CLAYEY SAND |
| ▒ | SAND |
| ▒ | GRAVELLY SAND |
| ▒ | SANDY GRAVEL |
| ▒ | GRAVEL |
| ▨ | GRAVELLY CLAY |
| ▤ | TAR SILT & CLAY |
| ▤ | TAR SAND |
| ▩ | FILL |
| ▤ | SILTSTONE |
| ▤ | CLAYSTONE |
| ▤ | INTERBEDDED SANDSTONE WITH SILTSTONE OR CLAYSTONE |
| ▒ | SANDSTONE |
| ▒ | SANDSTONE. CONGLOMERATE |
| ▢ | CEMENTED ZONE |
| ▩ | META—SANDSTONE |
| ▢ | BASALT |
| ▢ | BRECCIA |
| ▢ | SHEAR ZONE |

## GEOLOGIC EXPLANATION

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Scale N/A
Date MAY, 1984
Prepared by RG
Checked by JAD
Approved By HAS
Project No 83-1140
Drawing No 6

# Appendix A

# Field Exploration

# APPENDIX A FIELD EXPLORATION

## A.1 GENERAL

Field exploration data presented in this report for Design Unit A250 includes logs of borings drilled for the 1981 Geotechnical Investigation Report, and the 1983 and 1984 borings drilled for this A250 investigation. The specific boring logs included are summarized below:

- <u>1981</u>

  18, 19, 21, 22

- <u>1983</u>

  18-A, 18-1, 19-A, 20-A 23-3 through 23-5

- <u>1984</u>

  19-1 through 19-7, 20-1 through 20-11

Locations of the borings are shown on Drawings 2, 3 and 4. Ground water observation wells (piezometers) were installed in the borings listed in Section 5.5 (Table 5.6). Geophysical downhole surveys were made for the 1981 investigation at Boring CEG-18 and 20 within the A250 investigation site.

The borings were drilled to depths generally ranging from 25 to 209 feet, and penetrated through the alluvium and tar soils and some penetrated into the underlying bedrock of the Fernanto Formation. All borings were sampled at regular intervals using the Converse ring sampler, pitcher barrel sampler and the standard split spoon sampler. Sample recovery was generally good.

The following subsections describe the field exploration procedures and provide explanations of symbols and notation used in preparing the field boring logs. Copies of the field boring logs are presented following the text of this appendix.

## A.2 FIELD STAFF AND EQUIPMENT

### A.2.1 <u>Technical Staff</u>

Members of the three firms (CCI/ESA/GRC) participated in the drilling exploration program. The field geologist continuously supervised each boring during the drilling and sampling operation. The geologist was also responsible for preparing detailed lithologic logs and for sample/core identification, labeling and storage of all samples, and installation of piezometer pipe, gravel pack and bentonite seals.

### A.2.2 Drilling Contractor and Equipment

Most of the drilling was performed by Pitcher Drilling Company of East Palo Alto, California, with Failing 750 and 1500 rotary wash rigs, each operated by a two-man crew. A&W Drilling Company of Brea, California, provided the man-sized bucket auger rig.

## A.3 SAMPLING AND LOGGING PROCEDURES

Logging and sampling were performed in the field by the project geologists. The following describes sampling equipment and procedures and notations used on the lithologic logs to indicate drilling and sampling modes.

### A.3.1 Sampling

In the overburden at about 10-foot intervals, the Converse ring sampler was driven using a down-hole 320-pound to 340-pound slip-jar hammer with an 18-inch drop. The Converse sampler was followed with a standard split spoon sample (SPT) driven with a 140-pound hammer with a 30-inch stroke. Where the alluvium and Fernando Formation were encountered, the borings were generally continuously sampled using a Pitcher Barrel sampler and Converse ring sampler.

The most common cause for loss of samples or altering the sample interval was when gravel was encountered at the desired sampling depth. Standard penetration blow count information can often be misleading in this type of formation, and it is difficult to recover an undisturbed sample. Therefore, at some locations, borings were advanced until drill response and cutting suggested a change in formation.

The following symbols were used on the logs to indicate the type of sample and the drilling mode:

| Log Symbol | Sample Type | Type of Sampler |
|---|---|---|
| B | Bag | - |
| J | Jar | Split Spoon |
| C | Can | Converse Ring |
| S | Shelby Tube | Pitcher Barrel |
| Box | Box | Pitcher Barrel, Core Barrel |

| Log Symbol | Drilling Mode |
|---|---|
| AD | Auger Drill |
| RD | Rotary Drill |
| PB | Pitcher Barrel Sampling |
| SS | Split Spoon |
| DR | Converse Drive Sample |
| C | Coring |

### A.3.2 Field Classification of Soils

All soil types were classified in the field by the field geologist using the "Unified Soil Classification System". Based on the characteristics of the soil, this system indicates the behavior of the soil as an engineering construction material. (For a more complete discussion of the Unified Soil Classification System, refer to Corps of Engineers, Technical Memorandum No. 3-357, March 1953, or Department of the Interior, Bureau of Reclamation, Earth Manual, 1963.) Although particle size distribution estimates were based on volume rather than weight, the field estimates should fall within an acceptable range of accuracy. A description of the Unified Soil Classification Symbols used on the borings logs is presented in Table A-1 below.

TABLE A-1
UNIFIED SOIL CLASSIFICATION SYMBOLS

GRANULAR SOILS

| SYMBOL | DESCRIPTION |
|---|---|
| GW | Well-graded gravels, gravel-sand mixtures, little or no fines |
| GP | Poorly graded gravels, gravel-sand mixtures, little or no fines |
| GM | Silty gravels, gravel-sand-silt mixtures |
| GC | Clayey gravels, gravel-sand-clay mixtures |
| SW | Well-graded sands, gravelly sands, little or no fines |
| SP | Poorly graded sands, gravelly sands, little or no fines |
| SM | Silty sands, sand-silt mixtures |
| SC | Clayey sands, sand-clay mixtures |

FINE-GRAINED SOILS

| SYMBOL | DESCRIPTION |
|---|---|
| ML | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity |
| 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 |
| MH | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts |
| CH | Inorganic clays of high plasticity, fat clays |
| OH | Organic clays or medium to high plasticity, organic silts |
| Pt | Peat and other highly organic soils |

Table A-2 shows the correlation of standard penetration information and the physical description of the consistency of clays (hand-specimen) and the compactness of sands used by the field geologists for describing the materials encountered.

TABLE A-2 Correlation of N-Values and Consistency/Compactness of Soil Obtained in the Field

| N-Values (blows/foot) | Hand-Specimen (clay only) | Consistency (clay or silt) | Compactness (sand only) | N-Values (blows/foot) |
|---|---|---|---|---|
| 0 - 2 | Will squeeze between fingers when hand is closed | Very soft | Very loose | 0 - 4 |
| 2 - 4 | Easily molded by fingers | Soft | Loose | 4 - 10 |
| 4 - 8 | Molded by strong pressure of fingers | Firm | --- | --- |
| 8 - 16 | Dented by strong pressure of fingers | Stiff | Medium dense | 10 -.30 |
| 16 - 32 | Dented only slightly by finger pressure | Very stiff | Dense | 30 - 50 |
| 32+ | Dented only slightly by pencil point | Hard | Very dense | 50+ |

### A.3.3 Field Description of the Formations

The description of the formations is subdivided in two parts: lithology and physical condition. The lithologic description consists of:

- rock name;
- color of wet core (from GSA rock color chart);
- mineralogy, textural and structural features; and
- any other distinctive features which aid in correlating or interpreting the geology.

The physical condition describes the physical characteristics of the rock believed important for engineering design consideration. The form for the description is as follows:

Physical condition: ____________ fractured, minimum ________, maximum ________, mostly ____________; ____________ hardness; ________ strength; ________ weathered.

Bedrock description terms used on the boring logs are given on Table A-3. In addition, the rock quality designation (RQD) based on core recovery is shown on the boring logs in the "Remarks" column. The RQD percentage represents the approximate percentage of intact pieces of core that are more than 10 cm (4 inches) long from a particular core run.

## A.4 PIEZOMETER INSTALLATION

Standpipe piezometers were installed in borings 18-1, 18-A, 19, 20-4, 21 and 22. Procedures for piezometer installation were as follows:

A 2-inch diameter plastic ABS pipe was installed in the boring. At least the lower 20 feet of the ABS pipe was perforated, and the annulus of the boring around the perforated portion of the pipe was backfilled with a coarse sand/pea gravel aggregate. Concrete/bentonite slurry was used to backfill around the non-perforated portion of the pipe to prevent surface water from artificially recharging the gravel-packed hole or contaminating local ground water. After the piezometer was installed, the boring was flushed using air lift provided by a trailer-mounted air compressor. The piezometer was covered with a standard 7-inch diameter steel water meter cap held at surface grade by a grouted in-place 3- to 4-foot long, 5-inch diameter plastic sleeve. Ground water data obtained from the standpipe piezometers are presented in Section 5.5 of the text.

Pneumatic piezometric tranducers were installed in borings 19-2, 19-3 and 20-1. The borings were flushed to clear the drilling fluid and the lower portions below the tranducer depth were grouted with a concrete/bentonite slurry. About 2 feet of clean sand was tremied in above the slurry. The tranducer, placed in a sand-filled cloth bag was lowered to rest on the sand and an additional 2 to 3 feet of clean sand was tremied into the hole. Concrete/bentonite slurry was used to backfill the remainder of the hole, sealing around the pneumatic tubing leads. Piezometric levels indicated by the tranducers are presented in Section 5.5 of the text.

TABLE **A-3** Bedrock Description Terms

| PHYSICAL CONDITION* | SIZE RANGE | REMARKS |
|---|---|---|
| Crushed | -5 microns to 0.1 ft | Contains clay |
| Intensely Fractured | 0.05 ft to 0.1 ft | Contains no clay |
| Closely Fractured | 0.1 ft to 0.5 ft | |
| Moderately Fractured | 0.5 ft to 1.0 ft | |
| Little Fractured | 1.0 ft to 3.0 ft | |
| Massive | 4.0 ft and larger | |

| HARDNESS** | |
|---|---|
| Soft | - Reserved for plastic material |
| Friable | - Easily crumbled or reduced to powder by fingers |
| Low Hardness | - Can be gouged deeply or carved with pocket knife |
| Moderately Hard | - Can be readily scratched by a knife blade; scratch leaves heavy trace of dust |
| Hard | - Can be scratched with difficulty; scratch produces little powder & is often faintly visible |
| Very Hard | - Cannot be scratched with knife blade |

| STRENGTH | |
|---|---|
| Plastic | - Easily deformed by finger pressure |
| Friable | - Crumbles when rubbed with fingers |
| Weak | - Unfractured outcrop would crumble under light hammer blows |
| Moderately Strong | - Outcrop would withstand a few firm hammer blows before breaking |
| Strong | - Outcrop would withstand a few heavy ringing hammer blows but would yield, with difficulty, only dust & small fragments |
| Very Strong | - Outcrops would resist heavy ringing hammer blows & will yield with difficulty, only dust & small fragments |

| WEATHERING | DECOMPOSITION | DISCOLORATION | FRACTURE CONDITION |
|---|---|---|---|
| Deep | - Moderate to complete alteration of minerals, feldspars altered to clay, etc. | Deep & thorough | All fractures extensively coated with oxides, carbonates, or clay |
| Moderate | - Slight alteration of minerals, cleavage surfaces lusterless & stained | Moderate or localized & intense | Thin coatings or stains |
| Little | - No megascopic alteration in minerals | Slight & intermittent & localized | Few stains on fracture surfaces |
| Fresh | - Unaltered, cleavage surface glistening | None | |

*Joints and fractures are considered the same for physical description, and both are referred to as "fractures"; however, mechanical breaks caused by drilling operation were not included.

**Scale for rock hardness differs from scale for soil hardness.

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 18

**Proj:** DESIGN UNIT A245
**Date Drilled** 1-19-27-81
**Ground Elev.** 194'
**Drill Rig** Failing 1500
**Logged By** L. Schoeberlein
**Total Depth** 200.6'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 140 lb 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | CONC | 3" CONCRETE FILL | | | AD | Auger to 3', set casing to 4', 1' stick-up |
| | CL | 0.2-4.5 SILTY CLAY: olive black; mostly fines, trace of sand; firm; moist | | | | |
| 2 | | | | | | |
| | | | | | RD | |
| 4 | | | | | | |
| | CL | ALLUVIUM<br>4.5-11.0 SANDY CLAY: Moderate yellowish brown to pale yellowish brown; mostly clays and fine sand; very stiff; moist | J-1 | 5<br>6<br>9 | SS | 1.3/1.5 recovery |
| 6 | | | | | | |
| | | | | | RD | |
| 8 | | | | | | |
| | | grading coarser with depth | | | | |
| 10 | | | J-2 | 5<br>10<br>12 | SS | 1.2/1.5 recovery |
| | SC | 11.0-15.0 CLAYEY SAND: pale yellowish brown; mostly fine to medium angular sand with occasional gravel and little fines; medium dense; moist | | | RD | |
| 12 | | | | | | |
| 14 | | | | | | |
| | | gravelly lens | | | | |
| | CL | 15.0-37.5 SANDY CLAY: pale yellowish green mottled with light greenish grey, mostly clay and fine to medium sand; stiff; moist | | | | |
| 16 | | | J-3 | 4<br>6<br>8 | SS | 1.5/1.5 recovery |
| | | | | | RD | |
| 18 | | | | | | |
| | | | C-1 | 8<br>11 | DR | |
| 20 | | | | | | |

Sheet 1 of 9

Project DESIGN UNIT A-245 Date Drilled 1-19-27-81 Hole No. 18

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CL | 15.0-37.5 SANDY CLAY: continued | J-4 | 9<br>12<br>15 | SS | 1.5/1.5 recovery |
| 22 | | | | | RD | |
| | | color change to dusky yellow mottled with pale greenish yellow | | | | |
| 24 | | | | | | |
| | | | J-5 | 5<br>10<br>17 | SS | 1.5/1.5 recovery |
| 26 | | | | | RD | |
| 28 | | | | | | |
| 30 | | sandy clay lens; medium bluish grey | J-6 | 10<br>17<br>17 | SS | 1.5/1.5 recovery |
| | | | | | RD | |
| 32 | | | | | | |
| | | medium sand lens | | | | |
| 34 | | grading sandier with depth | | | | |
| | | | J-7 | 11<br>11<br>16 | SS | 1.5/1.5 recovery |
| 36 | | | | | RD | |
| 38 | SC | 37.5-44.0 CLAYEY SAND: dusky yellow; mostly fine to medium subangular sand and clay, interbedded with sandy clay; dense to very dense; moist | | | | |
| | | | C-2 | 16<br>18 | DR | 1.0/1.0 recovery |
| 40 | | | J-8 | 17<br>24<br>30 | SS | 1.5/1.5 recovery |
| | | | | | RD | |
| 42 | | | | | | |
| | | becoming more clayey | | | | |
| 44 | | | | | | |

Sheet 2 of 9

**Project** DESIGN UNIT A-245 **Date Drilled** 1-19-27-81 **Hole No.** 18

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | CL | 44.0-48.5 SILTY CLAY: dark greenish-grey; mostly fines, trace of sand; occasional concretions; very stiff to hard; moist | | | RD | |
| | | | J-9 | 8<br>18<br>20 | SS | 1.5/1.5 recovery |
| 46 | | | | | | 1/19/81 |
| | | | | | RD | 1/20/81<br>water at 15' in am |
| | | grading coarer | | | | |
| 48 | | | | | | |
| | ML | 48.5-55.4 CLAYEY SILT: dark greenish grey; very stiff to hard; moist | | | | |
| 50 | | | J-10 | 18<br>20<br>20 | SS | 1.5/1.5 recovery |
| | | | | | RD | |
| 52 | | | | | | |
| 54 | | | | | | |
| | | | Box 1 | | PB | begin continuous pitcher samples<br>2.2/2.5 recovery |
| | SP | 55.4-84.8 SAND: greyish green; mostly fines; granular to subangular sand, trace silt; moist to wet; dense; sulfur odor; occasional gravel | | | | |
| 56 | | | | | | |
| 58 | | | | | | 2.0/2.5 recovery |
| | | | | | | pocket penetrometer 0.5 tsf 2/9/81 |
| 60 | | | | | RD | |
| 62 | | | | | | |
| 64 | | | C-3 | 32<br>44 | DR | 1.0/1.0 recovery |
| | | | J-11 | 12<br>50 | SS | 15/.5, 50/.4 |
| 66 | | very dense | | | RD | |
| 68 | | | | | | |

Sheet 3 of 9

**Project** DESIGN UNIT A-245 **Date Drilled** 1-19-27-81 **Hole No.** 18

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SP | 55.4-84.8 SAND: continued | | | RD | |
| | | gravel and coarse sand lens | | | | |
| 70 | | | J-12 | 28<br>33<br>45 | SS | 1.3/1.5 recovery |
| | | | | | RD | |
| 72 | | little subrounded medium gravel | | | | |
| 74 | | | | | | checked gas: 21% $O_2$<br>0% combustibles |
| | | | S-1 | | PB | 1.5/2.4 recovery |
| 76 | | silty claystone | | | | |
| | | | | | | chatter |
| | | | Box 1 (cont.) | | | |
| 78 | | | | | | 1.7/2.6 recovery |
| 80 | | coarse sand lens | | | | |
| | | | | | | 1.4/2.5 recovery |
| 82 | | shells and angular to round sand and gravel | | | | intense rig chatter |
| 84 | | | | | | 0/2.5 recovery |
| | | FERNANDO FORMATION<br>84.8-200.6 SILTY CLAYSTONE: olive grey; moist; interbedded zones of banded colors, little compositional change, dips 10-30°<br>Physical Condition: moderately fractured to massive; friable to weak strength; little weathered | | | | pocket penetrometer 1.0 tsf (broke apart) 2/9/81 |
| 86 | | | | | | 0.3/2.5 recovery |
| 88 | | | | | | 0/2.5 recovery |
| 90 | | | | | RD | added polydrill |
| | | | Box 1 (cont.) | | PB | |
| 92 | | | | | | |

**Sheet** 4 **of** 9

**Project** DESIGN UNIT A-245 **Date Drilled** 1-19-27-81 **Hole No.** 18

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | | 84.0-200.6 SILTY CLAYSTONE: | Box 1 (cont.) | | PB | 1.8/2.5 recovery<br>samples disturbed |
| 94 | | | | | | 1.5/2.5 recovery |
| 96 | | | | | RD | sample disturbed<br>drilled out to try to recover rock |
| 98 | | | Box 2 | | PB | |
| 100 | | | | | | 2.5/2.5 recovery<br>pocket penetrometer<br>3.0 2/9/81<br>picked up rock in tube |
| | | | S-2 | | | |
| 102 | | silt lens, dry | | | | 2.1/2.5 recovery |
| | | interbedded lenses of silty claystone and clayey siltstone | Box 2 (cont) | | | |
| 104 | | | | | | 1.8/2.5 recovery |
| 106 | | | | | | chatter |
| | | thin cemented lens | | | | 1.3/2.8 recovery |
| 108 | | | | | | |
| 110 | | | | | | 1.5/2.8 recovery |
| 112 | | | | | | 1.2/2.8 recovery |
| 114 | | | | | | pocket penetrometer<br>>4.5 tsf 2/9/81 |
| | | | S-3 | | | |
| 116 | | | | | | |

**Project** DESIGN UNIT A-245 **Date Drilled** 1-19-27-81 **Hole No.** 18

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 116 | | 84.8-200.6 SILTY CLAYSTONE: cont.<br>Physical Condition: moderately fractured to massive; friable to low hardness; friable to weak strength; little weathered | | | PB | 1.8/2.8 recovery |
| 118 | | | Box 2 (cont) | | | chatter<br>2.4/2.8 recovery |
| 120 | | | Box 3 | | | |
| | | | | | | 1.9/2.8 recovery |
| 122 | | | | | | |
| 124 | | | | | | 1.5/2.8 recovery |
| 126 | | | | | | 1.4/2.8 recovery |
| 128 | | | | | | |
| 130 | | | S-4 | | | 2.8/2.8 recovery<br>pocket penetrometer<br>>4.5 tsf 2/9/81 |
| | | | Box 3 (cont) | | | |
| 132 | | | | | | 2.3/2.3 recovery |
| 134 | | | | | | 1.2/2.8 recovery |
| 136 | | | | | | |
| | | | | | | 1/20/81<br>1/21/81 water at 15' in am |
| 138 | | bedding dips 20° from horizontal | | | | 2.8/2.8 recovery |
| 140 | | | | | | |

**Sheet** 6 **of** 9

Project DESIGN UNIT A-245 Date Drilled 1-19-27-81 Hole No. 18

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 140 | | 84.8-200.6 SILTY CLAYSTONE: continued Physical Condition: moderately fractured to massive; friable to low hardness; friable to weak strength; little weathered | Box 3 (cont) | | PB | 1.5/2.8 recovery |
| 142 | | 142.0-150.0 interbedded silty claystone with siltstone and fine sandstone; 30° dip of bedding; very thinly bedded; olive grey w/ dusky yellow green interbeds; 144.0', very thin layer of white ash with 10° dip | Box 4 | | | |
| 144 | | | | | | 2.8/2.8 recovery<br>pocket penetrometer >4.5 tsf 2/9/81 |
| 146 | | | S-5 | | | 2.1/2.8 recovery |
| 148 | | | Box 4 (cont) | | | |
| 150 | | | | | | 2.8/2.8 recovery |
| 152 | | | | | | 2.3/2.8 recovery |
| 154 | | minor cross bedding present | | | | 1.7/2.8 recovery |
| 156 | | | | | | |
| 158 | | | | | | |
| 160 | | 160', light bluish grey, thin, fine sandstone lens | Box 5 | | | pocket penetrometer >4.5 2/9/81<br>1.5/2.8 recovery |
| 162 | | | S-6 | | | 2.0/2.8 recovery |
| 164 | | | | | | |

Sheet 7 of 9

**Project** DESIGN UNIT A-245 **Date Drilled** 1-19-27-81 **Hole No.** 18

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 164 | | 84.8-200.6 <u>SILTY CLAYSTONE</u>: continued<br><u>Physical Condition</u>: moderately fractured to massive; friable to low hardness; friable to weak strength; little weathered | S-6<br>Box 5 | | PB | 2.2/2.8 recovery |
| 166 | | 166.0 thin silty fine sandstone lens, light bluish grey | | | | gas: 0% combustibles<br>21% $O_2$ |
| 168 | | | | | | pocket penetrometer<br>>4.5 tsf<br>1.4/2.8 recovery |
| 170 | | 170.8 very thin silty fine sandstone lens<br>171.2 very thin silty fine sandstone | | | | 1.3/2.8 recovery |
| 172 | | | | | | |
| 174 | | 174.4 very thin fine sandstone lens bedding dip change to 10°, most fractures along sandstone and siltstone. | | | | pocket penetrometer<br>>4.5 tsf 2/9/81<br>2.4/2.8 recovery |
| 176 | | 177.5 thin claystone lens, soft | | | | 1.7/2.2 recovery |
| 178 | | 178.0-179.2 well cemented siltstone lens, closely fractured | | | | intense chatter<br>0.2/2.8 recovery<br>drilling smoothed out |
| 180 | | | | | | |
| 182 | | | S-7 | | | 2.3/2.8 recovery |
| 184 | | | Box 6 | | | 2.2/2.8 recovery |
| 186 | | 187.0 very thin fine sandstone lens | | | | 1.9/2.8 recovery |
| 188 | | | | | | |

Project DESIGN UNIT A-245 Date Drilled 1-19-27-81 Hole No. 18

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 188 | | 84.8-200.6 SILTY CLAYSTONE: continued<br>Physical Condition: moderately fractured to massive; friable to low hardness; friable to weak strength; little weathered | Box 6 (cont) | | PB | 1.1/2.8 recovery<br>pocket penetrometer >4.5 tsf |
| 190 | | 190.0 very thin sandstone lens | | | | |
| 192 | | | | | | 1.6/2.8 recovery |
| 194 | | | | | | |
| 196 | | | | | | 1.0/2.8 recovery |
| 198 | | | | | | disturbed sample<br>0/2.8 recovery |
| 200 | | | | | | |
| | | B.H. 200.6 - Terminated hole at 2:30 1/21/81, E-logged 1/21/81, down hole geophysics 1/21/81, water level noted on Sheet 1 following stabilization for 4 days prior to pressure test. Water pressure test attemped 1/26/81 problems with minor pack leakage and problems seating lower packer. Water loss was probably in fractured cemented zone at 178'. Hole reamed 1/27/81 to 6", 4" casing installed to 100'. | | | | |
| 202 | | | | | | |
| 204 | | | | | | |
| 206 | | | | | | |
| 208 | | | | | | |
| 210 | | | | | | |
| 212 | | | | | | |

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**Geo/Resource Consultants**

# BORING LOG 18-A

**Proj:** DESIGN UNIT A250
**Date Drilled** 10-25-83
**Ground Elev.** 193'
**Drill Rig** Bucket Auger
**Logged By** J. Stellar
**Total Depth** 50'
**Hole Diameter** 33"
**Hammer Weight & Fall**

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | ML | FILL<br>0.0-4.0 SILT: dark grey to black moist; firm; with clay | | | | |
| 2 | | | | | | |
| 4 | SM | ALLUVIUM<br>4.0-8.0 SILTY SAND: light brown, moist, medium dense | | | | |
| 6 | | | | | | |
| 8 | SP | 8.0-11.0 SAND: light green; moist; medium dense | | | | |
| 10 | | | | | | |
| | ML | 11.0-25.0 SILT: dark greenish blue; moist; stiff; numerous calcareous streaks with thin layers of clayey silt | | | | |
| 12 | | | | | | |
| 14 | | | | | | |
| 16 | | becoming more clayey and firm | | | | |
| 18 | | | | | | |
| 20 | | | | | | |

Sheet 1 of 3

**Project** DESIGN UNIT 250 **Date Drilled** 10-25-83 **Hole No.** 18A

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | ML | 11.0-25.0 SILT: (continued) | | | | |
| 22 | | | | | | |
| 24 | | | | | | |
| 26 | SP | 25.0-29.0 SAND: dark brown; wet; medium dense; streaks and layers of silty sand | | | | strong $SO_2$ odor perched water at 25' (±2 gpm enbry ).±2' of belling @ 25' N.E. side of hole - minor oil seeps |
| 28 | | | | | | |
| 30 | ML | 29.0-37.0 SILT: dark greenish grey, very moist; numerous calcareous streaks; with layers of clayey silt | | | | |
| 32 | | | | | | |
| 34 | | | | | | |
| 36 | | | | | | |
| 38 | ML | 37.0-43.0 SILT: dark brown; moist; hard; with streaks of tar sand | | | | very slow; hard drilling @ 37'; petroleum odor @ 37' |
| 40 | | increase in tar sand layers | | | | |
| 42 | | | | | | |
| 44 | SP | 43.0-50.0 TAR SAND: black; loose | | | | |

**Project** DESIGN UNIT A 250 **Date Drilled** 10-25-83 **Hole No.** 18A

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SP | 43.0-50.0 <u>TAR SAND</u>: (continued)<br>loose | | | | |
| 46 | | | | | | hole caved back to 44.5'-running ground |
| 48 | | | | | | |
| 50 | BH | 50.0 Terminated Hole<br>100% lower explosive limit gas reading; | | | | after 2 hrs water level is @ 43'- no downhole inspection due to very high gas reading |
| 52 | | | | | | |
| 54 | | | | | | |
| 56 | | | | | | |
| 58 | | | | | | |
| 60 | | | | | | |
| 62 | | | | | | |
| 64 | | | | | | |
| 66 | | | | | | |
| 68 | | | | | | |

**Sheet** 3 **of** 3

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

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# BORING LOG 18-1

**Proj:** DESIGN UNIT A-245 **Date Drilled** 10-8-9-83 **Ground Elev.** 192.5'
**Drill Rig** Failing 1500 **Logged By** L. Schoeberlein **Total Depth** 94.7'
**Hole Diameter** 4 7/8" **Hammer Weight & Fall** 140 lb @ 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | CONC | 0.0-0.7 CONCRETE | | | GB | start drilling 10:00 |
| | GP | 0.7-2.2 Base Rock - sandy gravel | | | AD | water immediately below concrete |
| 2 | | | | | | |
| | CL | FILL<br>2.2-8.8 SANDY CLAY: brownish black; mostly fines with trace of fine sand; very stiff; moist to wet; petroleum odor | | 7 | DR | 0.9/1.0 |
| | | | C-1 | 10 | | |
| 4 | | | | | RD | set tub and cased to 4.5' |
| | | | J-1 | 6 | SS | 1.3/1.5 |
| | | little sand | | 8 | | |
| 6 | | | | 11 | | |
| | | | | | RD | |
| 8 | | increase to some sand; becoming stiff | | 4 | DR | 1.0/1.0 |
| | CH | | C-2 | 7 | | |
| | SC | 8.8-11.0 CLAYEY SAND: greenish black; mostly fine sand, with some fines; medium dense; wet; strong petroleum odor | | | RD | |
| 10 | | | | 5 | SS | 1.3/1.5 |
| | | | J-2 | 5 | | |
| | | | | 6 | | |
| | ML | 11.0-12.5 SANDY SILT: greenish black; mostly fines and fine sand; stiff wet; strong petroleum odor | | | RD | |
| 12 | | | | | | |
| | CL | OLD ALLUVIUM<br>12.5-17.0 SANDY CLAY: greyish green; mostly fines, with little sand; stiff; wet; weak petroleum odor; contains cemented nodules | | 3 | DR | pocket pen 1.5 tsf<br>1.0/1.0 |
| | | | C-3 | 4 | | |
| 14 | | | | | RD | add casing to 13.5'<br>losing circulation |
| | | | | 3 | SS | no recovery |
| | | | | 5 | | |
| 16 | | | | 7 | | |
| | | | | | RD | |
| | CL<br>SC | 17.0-28.2 SANDY CLAY: yellowish olive grey; mostly fines with little fine to medium sand; very stiff; moist; contains cemented nodules; ferrous staining; & clayey sand | | 5 | DR | 1.0/1.0 |
| 18 | | | C-4 | 15 | | pocket pen 2.75 tsf |
| | | | | | RD | |
| | | | J-3 | 6 | SS | 1.3/1.5 |
| 20 | | | | 9 | | |

**Sheet** 1 **of** 5

Project DESIGN UNIT A-245 Date Drilled 10-8-9-83 Hole No. 18-1

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CL | 17.0-28.2 SANDY CLAY/CLAYEY SAND: cont. | | 11 | SS | |
| | | | | | RD | |
| 22 | | some sand with some clayey sand lenses, ferrous staining, decrease in cemented nodules | | 14 | DR | 0.9/1.0 recovery |
| | SC/CL | | C-5 | 24 | | |
| | | | | | RD | |
| 24 | | | J-4 | 5 | SS | 1.4/1.5 |
| | | | | 8 | | |
| | | | | 9 | | |
| 26 | | | | | RD | |
| | | | | 36 | DR | 1.0/1.0 |
| | | heavily ferrous stained thin gravel lens | C-6 | 48 | | |
| 28 | | | | | RD | |
| | CL | 28.2-32.8 SILTY CLAY: dark greenish grey; hard; moist; contains cemented nodules | J-5 | 7 | SS | 1.5/1.5 |
| 30 | | | | 19 | | |
| | | | | 20 | | |
| | | | | | RD | |
| 32 | | silt becoming clayey | | 33 | DR | 1.0/1.0 |
| | | | C-7 | 46 | | |
| | ML | 32.8-38.0 SANDY SILT: dark greenish grey; mostly fines with some fine sand; hard; moist; contains few cemented nodules; strong sulfur odor | | | RD | |
| 34 | | | J-6 | 6 | SS | 1.0/1.5 |
| | | | | 19 | | |
| | | | | 30 | | |
| 36 | | | | | RD | |
| | | thin silty sand lens | | 27 | DR | 1.0/1.0 |
| | | | C-8 | 41 | | |
| 38 | SM | 38.0-42.0 SILTY SAND: dark greenish grey; moist; weakly cemented; dense; strong sulfur odor | | | RD | |
| | | | J-7 | 6 | SS | 1.5/1.5 |
| 40 | | | | 18 | | |
| | | | | 25 | | |
| | | sand content decreases | | | RD | |
| 42 | CL | 42.0-44.0 SILTY CLAY: moist; stiff | | 12 | DR | 1.0/1.0 |
| | | | C-9 | 24 | | |
| | | | | | RD | |
| 44 | | | | | | |

Sheet 2 of 5

**Project** DESIGN UNIT A-245 **Date Drilled** 10-8-9-83 **Hole No.** 18-1

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | ML | 44.0-47.0 CLAYEY SILT: dark greenish grey; very stiff; moist | J-8 | 7<br>13<br>18 | SS | 1.1/1.5 |
| 46 | | | | | RD | |
| | SM | 47.0-51.0 SILTY SAND: dark greenish grey; mostly fine sand, with little fines; very dense; moist; contains silt lenses | C-10 | 17<br>50-5" | DR | 0.9/0.9 |
| 48 | | | | | RD | |
| 50 | | | J-9 | 5<br>35<br>50-4.5" | SS | 1.4/1.4 |
| | SP | SAN PEDRO FORMATION<br>51.0-77.0 SAND: dark greenish grey; mostly fine sand, trace of silt; very dense; wet | | | RD | |
| 52 | | | C-11 | 45<br>50-3 | DR<br>" | 0.6/0.7 |
| | | | | | RD | |
| 54 | | | J-10 | 32<br>50-5 | SS<br>" | 0.7/0.9 |
| 56 | | | | | RD | |
| | | | | 53<br>50-3 | DR<br>" | no recovery |
| 58 | | | | | RD | |
| | | | J-11 | 26<br>52 | SS | 0.7/1.0 |
| 60 | | | | | RD | |
| 62 | | | C-12 | 37<br>50-4.5" | DR | 0.7/0.9 |
| | | – and silty sand | | | RD | |
| 64 | | | J-12 | 31<br>39<br>46 | SS | 1.2/1.5 |
| 66 | | | | | RD | |
| 68 | | | C-13 | 35<br>50-4.5" | DR | 0.7/0.9 |

Project DESIGN UNIT A-245 Date Drilled 10-8-9-83 Hole No. 18-1

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SP | 51.0-77.0 SAND: continued | | | RD | |
| | | | J-13 | 23<br>50- | SS<br>5.5" | 0.6/1.0 |
| 70 | | | | | RD | |
| 72 | | occastional gravelly lenses | C-14 | 68<br>50-3 | DR<br>" | 0.7/0.7 |
| | | | | | RD | |
| 74 | | | J-14 | 36<br>50 | SS | 0.7/1.0 |
| | | | | | RD | |
| 76 | | | | | | |
| | SM | 77.0-84.0 GRAVELLY/SILTY SAND: grey and dark greenish grey; interbedded; very dense; wet; strong sulfur odor; increased gravel | C-15 | 86<br>50-2 | DR<br>" | 0.6/0.9<br>6:00 10/8/83<br>7:00 am |
| 78 | | | | | RD | |
| | | | J-15 | 53 | SS | 0.4/0.5 |
| | | | | | RD | |
| 80 | | numerous shells | | | | rig chatter |
| 82 | | | C-16 | 54<br>60-3.5" | DR | 0.8/0.8 |
| | | | | | RD | |
| 84 | | FERNANDO FORMATION<br>84.0-94.7 CLAYSTONE: olive grey and dark greenish grey; irregular color variations; not bedded; sulfur odor; no cementation | C-17 | 25<br>50-5 | DR<br>" | 0.8/0.9 |
| | | | | | RD | |
| 86 | | | | | | |
| 88 | | | | | | |
| | | Physical Condition: little fractured to massive; friable hardness and strength; little weathered to fresh | C-18 | 48<br>50-4 | DR<br>" | 0.8/0.8 |
| 90 | | | | | RD | |
| 92 | | | | | | |

Sheet 4 of 5

**Project** DESIGN UNIT A-245 **Date Drilled** 10-8-9-83 **Hole No.** 18-1

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | | 84.0-94.7 CLAYSTONE: continued | | | RD | |
| 94 | | | C-19 | 47<br>50-3" | DR | 0.7/0.7 |
| | | B.H. 94.7 Terminated hole, installed piezometer to bottom, 75'-95' slotted, pea gravel backfill to surface | | | | complete drilling and flusing 9:15 am |
| 96 | | | | | | |
| 98 | | | | | | |
| 100 | | | | | | |
| 102 | | | | | | |
| 104 | | | | | | |
| 106 | | | | | | |
| 108 | | | | | | |
| 110 | | | | | | |
| 112 | | | | | | |
| 114 | | | | | | |
| 116 | | | | | | |

Sheet 5 of 5

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

**Converse Consultants, Inc.**
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## BORING LOG 19

**Proj:** DESIGN UNIT A 250 **Date Drilled** 1/12-15/81 **Ground Elev.** 186'

**Drill Rig** Failing **Logged By** Gallinatti **Total Depth** 209.0'

**Hole Diameter** 4 7/8" **Hammer Weight & Fall** 140lbs., 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.5 CEMENT | | | AD | |
| | CL | ALLUVIUM<br>0.5-9.0 SANDY CLAY: greenish black; soft; moist | | | | |
| 2 | | | | | | |
| 4 | | | | | | |
| | | 5.0-8.0 charcoal wood fragments | | | RD | |
| 6 | | | | | | |
| 8 | | | | | | |
| | CL | 9.0-14.0 OIL CLAY: greenish black; petroleum throughout material; oily smell; moist, stiff to very stiff | | | | |
| 10 | | | J-1 | 4<br>6<br>12 | SS | recovery 1.5/1.5<br>pocket pene. 1.5 tsf<br>2-9-81 |
| | | | | | RD | |
| 12 | | | | | | |
| 14 | SP | 14.0-23.0 TAR SAND: black with occasional fines; saturated with oil; medium dense | | | | |
| 16 | | | | | | |
| 18 | | | | | | |
| 20 | | | | | | |

Sheet 1 of 9

**Project** DESIGN UNIT A 250 **Date Drilled** 1/12/81 **Hole No.** 19

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | SP | 14.0-23.0 TAR SAND: (continued) | C-1 | | DR | recovery 0.8/1.0 |
| | | | J-2 | 15<br>26<br>37 | SS | petroleum sample 20-22' |
| 22 | | | | | | |
| | CL | 23.0-24.5 CLAY: dark greenish grey; firm to stiff | | | RD | recovery 1.5/1.5<br>22.5' gas test:<br>$O_2$ - 16%<br>combustibles: off the scale (reads over 100%) |
| 24 | | | | | | |
| | SM | 24.5-34.0 SILTY TAR SAND: greenish black; saturated with petroleum; medium dense to dense | | | | |
| 26 | | | | | | |
| 28 | | | | | | |
| 30 | | | J-3 | 7<br>13<br>23 | SS | recovery 1.5/1.5, pocket pene: 2.5 tsf<br>2-9-81 |
| 32 | | | | | RD | |
| 34 | SP | 34.0-66.0 GASEOUS TAR SAND: black; saturated with petroleum; loose to medium dense; material is very porous; | | | | |
| 36 | | | | | | |
| 38 | | | | | | |
| 40 | | | C-2 | | DR | recovery 0.8/1.0 |
| | | | J-4 | 7<br>5 | SS | recovery 1.0/1.0<br>1-12-81 |
| 42 | | | | | RD | petroleum sample 40'-42'<br>1-13-81 |
| 44 | | | | | | |

Sheet 2 of 9

Project DESIGN UNIT A 250 Date Drilled 1-13-81 Hole No. 19

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SP | 34.0-66.0 TAR SAND: (continued) | | | RD | 42' gas test: combustibles - off the scale (over 100%) |
| 46 | | | | | | |
| 48 | | | | | | |
| 50 | | becoming very dense | J-5 | 18<br>50 | SS | recovery 0.5/0.9 |
| | | | | | RD | refusal at 11" |
| 52 | | | | | | |
| 54 | | | | | | |
| 56 | | | | | | |
| 58 | | | | | | gas bubbling out of hole |
| 60 | | | C-3 | | DR | |
| | | | J-6 | 10<br>39<br>50 | SS | recovery 0.7/0.9<br>petroleum sample 60'-62' |
| 62 | | | | | RD | recovery 1.4/1.4 |
| 64 | | | | | | |
| 66 | | BEDROCK<br>66.0-69.0 CLAYSTONE: greyish olive; very well cemented; hard; thin laminations; physical conditions unknown | | | | (no samples of claystone) |
| 68 | | | | | | |

Sheet 3 of 9

**Project** DESIGN UNIT A 250 **Date Drilled** 1-13-81 **Hole No.** 19

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | | 66.0-69.0 CLAYSTONE: (continued) | | | RD | |
| | | 69.0-78.0 OIL CLAYSTONE: moderate brown; oil smell with a few visible oil seams; very stiff to hard; moist.<br>Physical Condition: little fractured to massive; low to friable hardness fresh | | | | |
| 70 | | | J-7 | 10<br>25<br>36 | SS | recovery 1.0/1.5<br>pocket pene: > 4.5 tsf, 2-9-81 |
| 72 | | | | | RD | |
| 74 | | becoming siltier with depth | | | | |
| 76 | | | | | | |
| 78 | | 78.0-108.00 OILY SILTY SANDSTONE: moderate brown; oil smell; very dense; moist<br>Physical Condition: little fractured to massive; low to friable hardness; fresh | | | | |
| 80 | | | | | DR | no recovery:(sample fell out) |
| | | | J-8 | 15<br>15<br>45 | SS | pocket pene: > 4.5tsf<br>recovery 1.0/1.5 |
| 82 | | | | | RD | |
| 84 | | | | | | |
| 86 | | | | | | |
| 88 | | | | | | |
| 90 | | | | | PB | 90' abundant gas bubblin |
| 92 | | | S-1 | | | |

Project DESIGN UNIT A250 Date Drilled 1-13-81 Hole No. 19

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | | 78.0-108.0 <u>OILY SILTY SANDSTONE</u>: (continued) | S-1 | | PB | recovery 1.7/2.5 |
| | | 93.0 Oily sandy siltstone<br>Physical Condition: little to moderately fractured, low hardness; friable; fresh | | | | |
| 94 | | | | | | recovery 0.4/1.0<br>hole caving<br>recovery 0.4/1.5 |
| 96 | | | | | | |
| | | | | | | recovery 0.5/2.5 |
| 98 | | | | | | |
| | | | | | | recovery 0.6/2.5 |
| 100 | | | | | | pocket pene: 4.5 tsf<br>2-9-81 |
| 102 | | | | | | recovery 0.0/2.5 |
| 104 | | | | | | 104' stop drilling |
| | | | | | | resume drilling 1-14-81<br>tube on run 8 is bent<br>with 3" cobble in tube |
| 106 | | | | | | |
| | 20 | | | | | |
| 108 | | 108.0-145.0 <u>OILY SILTSTONE:</u> dark moderate brown; oily; moist<br>Physical Condition: little fractured to massive; low hardness; friable; fresh | | | | |
| 110 | | | S-2 | | | |
| 112 | | | Box 1 Cont. | | | recovery 0.9/215 |
| | | | | | | recovery 1.9/2.5<br>pocket pene: > 4.5tsf<br>2-9-81 |
| 114 | | | | | | |
| 116 | | | | | | |

**Project** DESIGN UNIT A250 **Date Drilled** 1-15-81 **Hole No.** 19

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 116 | | 108.0-145.0 OILY SILTSTONE: (continued) | Box 1 | | PB | |
| | | | | | | recovery 2.3/2.5 |
| 118 | | 118.0-126.0 scattered fine sand | | | | |
| | | | | | | recovery 2.1/2.5<br>pocket pene: > 4.5 tsf<br>2-9-81 |
| | | no apparent bedding | | | | |
| 120 | | | Box 2 | | | |
| 122 | | Physical Condition: little fractured; low hardness; friable; fresh | S-3 | | | recovery 1.8/2.5 |
| 124 | | | Box 2 Cont. | | | recovery 2.4/2.5 |
| 126 | | 127.5-132.0 becoming clayey | | | | recovery 2.3/2.5 |
| 128 | | | | | | |
| | | gas in formation | | | | recovery 2.3/2.5 |
| 130 | | | | | | |
| 132 | | 132.0-137.0 becoming sandy with occasional thin sand lenses | | | | recovery 1.5/2.5<br>pocket pene: > 4.5tsf<br>2-9-81 |
| 134 | | | | | | recovery 1.9/2.5 |
| | 40 | | | | | |
| 136 | | | Box 3 | | | |
| | | | | | | recovery 1.9/2.5 |
| 138 | | | | | | |
| 140 | | | | | | |

Sheet 6 of 9

**Project** DESIGN UNIT A250 **Date Drilled** 1-15-81 **Hole No.** 19

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 140 | | 108.0-145.0 OILY SILTSTONE: (continued)<br>140.0-145.0 occasional thin sand lenses | Box 1 | | PB | recovery 2.3/2.5 |
| 142 | 35 | | | | | |
| 143 | | | | | | recovery 2.5/2.5<br>pocket pene: > 4.5 tsf<br>2/9/81 |
| 144 | 40 | | Box 1 | | | recovery 2.4/2.5 |
| 145 | | 145.0-209.0 OILY CLAYEY SILTSTONE: dark moderate brown; moist to dry | | | | |
| 146 | | Physical Condition: little fractured to massive; low hardness; friable, fresh | | | | recovery 2.5/2.5 |
| 148 | | | | | | |
| 150 | | | | | | recovery 2.2/2.5 |
| 151 | | | Box 4 | | | recovery 2.5/2.5 |
| 152 | | | | | | |
| 154 | | | | | | recovery 2.3/2.5 |
| 155 | 30 | 155.2 thin sand lens dipping at 30° | | | | |
| 156 | | | | | | |
| 157 | | | | | | recovery 2.5/2.5<br>pocket pene: > 4.5 tsf<br>2/9/81 |
| 158 | | | | | | recovery 2.5/2.5 |
| 160 | | | S-5 | | | |
| 161 | | | | | | recovery 2.4/2.5 |
| 162 | | 162.2 thin sand lens | | | | |
| 163 | | 163.5 thin sand lens dipping at 50° | | | | |
| 164 | | | | | | |

Sheet 7 of 9

Project DESIGN UNIT A250 Date Drilled 1-15-81 Hole No. 19

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 164 | | 145.0-209.0 OILY CLAYEY SILTSTONE: (continued) | Box 4 | | PB | recovery 2.5/2.5 |
| | 40 | | | | | |
| 166 | | | Box 5 | | | recovery 2.4/2.5 |
| | | Physical Condition: little fractured to massive, low hardnessl friable, fresh | | | | pocket pene: >4.5tsf<br>2-9-81 |
| 168 | | | | | | recovery 2.3/2.5 |
| 170 | | | | | | |
| 172 | | 172.5- - thin sand lens dipping @ 40° | | | | recovery 2.3/2.5 |
| 174 | | | | | | recovery 2.4/2.5 |
| 176 | | | | | | |
| | | | | | | recovery 2.5/2.5 |
| 178 | | 177.5-179.0 sandy silt layer | Box 6 | | | 1-15-81 |
| | | | | | | 1-16-81<br>pocket pene: >4.5tsf<br>2-9-81 |
| | | | S-6 | | | |
| 180 | | | | | | recovery 2.5/2.5 |
| | | | Box 6 Cont. | | | |
| 182 | | | | | | recovery 2.2/2.5 |
| 184 | | 184.9 - thin sand lens | | | | recovery 2.5/2.5 |
| | 60 | | | | | recovery 2.3/2.5 |
| 186 | | | | | | |
| 188 | | 189.3' sand lens | | | | |

Project DESIGN UNIT A250 Date Drilled 1-16-81 Hole No. 19

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 188 | ML | 145.0-209.0 OILY CLAYEY SILTSTONE: (Cont.) | Box 6 | | PB | recovery 2.4/2.5 |
| 190 | | Physical Condition: little fractured to massive; low hardness; friable; fresh | | | | |
| 192 | | | Box 7 | | | recovery 2.4/2.5<br>pocket pene: >4.5tsf<br>2-9-81 |
| 194 | | | | | | recovery 2.4/2.5 |
| 196 | | becoming more clayey with depth | | | | recovery 2.5/2.5 |
| 198 | | | | | | |
| 200 | | | S-7 | | | recovery 2.5/2.5 |
| 202 | | | Box 7 Cont. | | | recovery 2.5/2.5 |
| 204 | | | | | | recovery 2.4/2.5<br>pocket Pene: >4.5tsf<br>2-9-81 |
| 206 | | | Box 8 Cont. | | | 2.5/2.5 |
| 208 | 50 | | | | | |
| 210 | BH | 209.0' Terminate Hole<br>Piezometer installed to 210'; with cloth covered performation 40' to 80' and 170' to 200', (40 to 50' was unclothed). Gravel pack to 42'. ~5' Bentonite plug 37' to 42' and grout from 37' up to surface | | | | run e-logs; install piezometer; reinstate ground, surface |
| 212 | | | | | | |

Sheet 9 of 9

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 19-A

**Proj:** DESIGN UNIT A 250 **Date Drilled** 2-7-83 **Ground Elev.** 170.5'
**Drill Rig** B. Auger **Logged By** D. Gillette **Total Depth** 70.0'
**Hole Diameter** 36" **Hammer Weight & Fall**

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | AF | 0.0-0.8 ASPHALT<br>0.8-1.2 BASE MATERIAL | | | | |
| | | ALLUVIUM | | | | 1.2-35.0 hole stands well |
| | CL | 1.2-13.0 CLAY: greenish grey with dark yellowish orange streaks | | | | |
| 2 | | | | | | |
| 4 | | | | | | |
| 6 | | | | | | |
| 8 | | 8.0-10.0 very dusky red | | | | |
| 10 | | 10.0-10.5 siltstone; greyish green | | | | 10.0-10.5 very hard drilling |
| 12 | | | | | | |
| | CL/OL | 13.0-20.0 CLAY: blackish red; very moist; soft; with peat | | | | 14' groundwater entry from all sides of hole (± ½gpm) |
| 14 | | | | | | |
| 16 | | | | | | |
| 18 | | 18.0-18.5 3/4" oil seams | | | | petroleum odor |

Sheet 1 of 4

**Project** DESIGN UNIT A 250 **Date Drilled** 2-7-83 **Hole No.** 19A

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CL | 20.0-25.0 SILTY CLAY: greyish green; and very dusky red; moist; firm to soft | | | | |
| 22 | | | | | | |
| 24 | | | | | | |
| 26 | SP | 25.0-36.0 TAR SAND: black and light grey moist; medium dense | | | | |
| 28 | | | | | | |
| 30 | | | | | | |
| 32 | | | | | | |
| 34 | | | | | | 35.0-55.0 hole stands well |
| 36 | SM | 36.0-55.0 SILTY TAR SAND AND GRAVEL: greyish green and black;fine to coarse gravel with clean lenses of sand | | | | |
| 38 | | | | | | |
| 40 | | | | | | |
| 42 | | | | | | |
| 44 | | | | | | |

**Sheet** 2 **of** 4

**Project** DESIGN UNIT A 250 **Date Drilled** 2-7-83 **Hole No.** 19A

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SM | 36.0-55.0 SILTY TAR SAND AND GRAVEL: (cont) | | | | |
| | | 42.0-50.0 streaks of pure tar | | | | |
| 46 | | | | | | |
| 48 | | | | | | |
| 50 | | | | | | |
| 52 | | | | | | |
| 54 | | | | | | 55.0-70.0 hole shows slight belling (1" on 2 sides) |
| | SP | 55.0-66.5 TAR SAND: black and light grey with gravel and trace silt; moist; medium dense | | | | |
| 56 | | | | | | |
| 58 | | | | | | |
| 60 | | | | | | |
| | | 62.0-64.0 streaks of tar | | | | |
| 62 | | | | | | |
| 64 | | | | | | |
| 66 | | | | | | |
| | | 66.5-70.0 TAR SAND AND BOULDERS: black and light grey; medium dense | | | | |
| 68 | | | | | | |

**Sheet** 3 **of** 4

Project DESIGN UNIT A 250 Date Drilled 2-7-83 Hole No. 19-A

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SP | 66.5-70.0 TAR SAND AND BOULDERS: (continued)<br>boulders to 18" | | | | drilling stopped due to nested boulders |
| 70 | BH | 70.0 Terminated Hole | | | | No water; slight seep @ 14'; slight belling 55'-70'<br>Hole backfilled with slurry to base of concrete. |
| 72 | | | | | | |
| 74 | | | | | | |
| 76 | | | | | | |
| 78 | | | | | | |
| 80 | | | | | | |
| 82 | | | | | | |
| 84 | | | | | | |
| 86 | | | | | | |
| 88 | | | | | | |
| 90 | | | | | | |
| 92 | | | | | | |

Sheet 4 of 4

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 19-1

**Proj:** DESIGN UNIT A250
**Date Drilled** 1-15-16-94
**Ground Elev.** 180.0'
**Drill Rig** Failing 1500
**Logged By** M. Schluter
**Total Depth** 90.0'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 140 lbs. @30"/325 lbs. @18"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.7 CONCRETE<br>0.7-1.0 BASE GRAVEL | | | C | started drilling 1-15-84 |
| | SC | ALLUVIUM<br>1.0-4.0 CLAYEY SAND: grayish olive brown, loose to medium dense, slightly moist | C-1 | 6<br>10 | DR | |
| 2 | | | | | | |
| | | | | | A | |
| 4 | SC | 4.0-12.0 CLAYEY SAND: mottled grayish green and light olive brown, medium dense, moist, with gravel, petroliferous | | | RD | rotary wash |
| | | | J-1 | 6<br>9<br>11 | SS | 1.5/1.5 recovery |
| 6 | | | | | RD | |
| | | | C-2 | 6<br>9 | DR | |
| 8 | | | | | RD | |
| 10 | | | PB 1 | | PB | 2.0/2.5 recovery |
| 12 | SM/SC | 12.0-15.0 SILTY TAR SAND/CLAYEY TAR SAND: greenish black and brownish black, moist, trace gravel, med. dense ,with petroleum | C-3 | 9<br>12 | DR | |
| 14 | | | | | | |
| | CH/CL | 15.0-24.0 SILTY TAR CLAY: greenish black to grayish black, moist, with sand, very stiff to hard | J-2 | 8<br>12<br>14 | SS | petroleum odor<br>1.5/1.5 recovery |
| 16 | | | | | | |
| | | | | | RD | |
| 18 | | small pockets of tar, highly petroliferous | PB 2 | | PB | 1.5/2.5 recovery<br>disturbed sample |
| 20 | | | | | | |

**Sheet** 1 **of** 4

Project DESIGN UNIT A 250 Date Drilled 1-15-84 Hole No. 19-1

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CH<br>CL | 15.0-24.0 SILTY TAR CLAY: continued | | | PB | |
| | | | J-3 | 15<br>23<br>32 | SS | 1.5/1.5 recovery |
| 22 | | | | | RD | |
| | | | PB 3 | | PB | |
| 24 | CL | 24.0-31.0 SILTY TAR CLAY: mottled grayish green and grayish black, very stiff, moist, scattered black tar inclusions, highly petroliferous | | | | 2.0/2.5 recovery |
| 26 | | | C-4 | 17<br>35 | DR | petroleum odor |
| | | | | | RD | |
| 28 | | | PB 4 | | PB | |
| 30 | | | J-4 | 12<br>23<br>29 | SS | |
| | SM<br>SP | 31.0-48.0 SILTY TAR SAND/TAR SAND: black, dense to very dense, with petroleum | | | | |
| 32 | | | | | RD | petroleum odor |
| | | | PB 5 | | PB | 2.1/2.5 recovery |
| 34 | | | | | | |
| 36 | | | C-5 | 41<br>50 | DR | refusal at 10" |
| | | | | | | |
| 38 | | with gravel | PB 6 | | PB | |
| 40 | | | | | | sample expanding out end of pitcher barrel. |
| | | | J-5 | 20<br>50 | SS | refusal at 11" |
| 42 | | | | | RD | |
| | | | PB 7 | | PB | |
| 44 | | | | | | |

Sheet 2 of 4

**Project** DESIGN UNIT A250 **Date Drilled** 1-15-16-84 **Hole No.** 19-1

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SM<br>SP | 31.0-48.0 SILTY TAR SAND/TAR SAND: cont. | PB 7 | | PB | 2.2/2.5 recovery |
| | | gravel lenses | | | | |
| 46 | | | C-6 | 49<br>65 | DR | refusal at 10.5" |
| | | | | | RD | |
| 48 | SM | 48.0-54.0 SILTY TAR SAND: black, contains gravel, dense to very dense, highly petroliferous, gravel layer 1-1.5' thick | PB 8 | | PB | 2.5/2.5 recovery |
| 50 | | | J-6 | 44<br>50 | SS | petroleum odor<br>0.9/0.9 recovery<br>refusal at 11" |
| 52 | | | | | RD | |
| | | | PB 9 | | PB | 1.7/2.5 recovery |
| 54 | SP<br>SM | 54.0-56.0 TAR SAND/SILTY TAR SAND: black, contains gravel, dense to very dense, with petroleum | | | | |
| | | | C-7 | 75<br>75 | DR | refusal at 8"<br>petroleum odor |
| 56 | SW | 56.0-64.0 GRAVELLY TAR SAND: black, contains fines, very dense, occasional gravel lenses, highly petroliferous | | | RD | |
| 58 | | | PB 10 | | PB | 1.7/2.5 recovery |
| 60 | | | J-7 | 43<br>50 | SS | 0.9/0.9 recovery<br>refusal at 11"<br>coarse gravel in sampler<br>1-15-84 |
| 62 | | | | | RD | |
| | | | PB 11 | | PB | 1-16-84<br>0-5% reading on explosimeter<br>1.9/2.5 recovery |
| 64 | SM | 64.0-71.0 SILTY TAR SAND: black, contains gravel, very dense, with petroleum, scattered tar inclusions | | | | |
| | | | | 58<br>61 | DR | sample not recovered<br>petroleum odor<br>rig chatter |
| 66 | | | | | | |
| | | gravel lenses | | | | |
| 68 | | | | | | |

**Sheet** 3 **of** 4

**Project** DESIGN UNIT A250 **Date Drilled** 1-16-84 **Hole No.** 19-1

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SM | 64.0-71.0 <u>SILTY TAR SAND</u>: continued | PB<br>12 | | PB | |
| 70 | | | | | | rig chatter |
| | | | J-8 | 26<br>54 | SS | 1.0/1.0 recovery<br>refusal at 12" |
| 72 | | BEDROCK<br>71.0-90.0 <u>SILTSTONE/CLAYSTONE</u>: olive black, with fines, very stiff to hard, moist, trace of gravel, massive, petroliferous | | | RD | petroleum odor |
| 74 | | | PB<br>13 | | PB | gas bubbling at ends of barrel<br>1.9/2.5 recovery |
| 76 | | gravel lenses | C-8 | 22<br>78 | DR | |
| 78 | | fracture angles 45-70° | PB<br>14 | | PB | 1.8/2.5 recovery |
| 80 | | | J-9 | 13<br>43<br>38 | SS | |
| 82 | | | | | | |
| 84 | | | PB<br>15 | | PB | 1.4/2.5 recovery |
| 86 | | gravel lenses, color change to dark greenish gray | C-7 | 22<br>48 | DR<br>RD | |
| 88 | | | PB<br>16 | | PB | finished drilling<br>1-16-84 |
| 90 | | END OF BORING 90.0'<br>4 sac slurry backfill | | | | 0-5% explosimeter reading |
| 92 | | | | | | |

Sheet 4 of 4

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 19-2

**Proj:** DEISGN UNIT A250
**Date Drilled** 1-17-84
**Ground Elev.** 174.0'
**Drill Rig** Failing 1500
**Logged By** M. Schluter
**Total Depth** 90.0'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 140# @30"/325# @ 18"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.7 CONCRETE | | | C | 1-17-84 started drilling |
| | ML<br>MH | ALLUVIUM<br>0.7-4.0 CLAYEY SILT: dusky yellowish brown with sand, soft to firm, moist, rootlets | C-1 | 3<br>8 | DR | disturbed |
| 2 | | | | | | |
| 4 | SC | 4.0-6.0 CLAYEY SAND: grayish olive green, moist, loose to medium dense | J-1 | 4<br>7<br>11 | SS | 1.5/1.5 recovery |
| | | | | | RD | |
| 6 | CL<br>SC | 6.0-12.0 SANDY CLAY/CLAYEY SAND: light olive gray, firm loose, slightly petroliferous, moist, | C-2 | 4<br>6 | DR | 1-17-84<br>1-18-84 |
| 8 | | | | | RD | |
| 10 | | | PB 1 | | PB | 2.2/2.5 recovery |
| | | tar content increasing with depth | | | | |
| 12 | SC | 12.0-17.0 CLAYEY TAR SAND: greenish black to grayish black, moist, dense to very dense, contains petroleum | J-2 | 18<br>32<br>33 | SS | 1.5/1.5 recovery<br>petroleum odor |
| 14 | | | | | | |
| 16 | | | PB 2 | | PB | 0.9/2.5 recovery |
| | CL<br>CH | 17.0-23.0 TAR CLAY: brownish black, stiff, moist, contains petroleum | | 8<br>13 | DR | |
| 18 | | | | | | |
| 20 | | | | | | |

Sheet 1 of 4

**Project** DESIGN UNIT A250 **Date Drilled** 1-18-84 **Hole No.** 19-2

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CL<br>CH | 17.0-23.0 TAR CLAY: continued | PB 2 | | PB | |
| 22 | | | | | RD | |
| | SP<br>SM | 23.0-32.0 TAR SAND/SILTY TAR SAND: black, dense to very dense, highly petroliferous | PB 3 | | PB | 2.4/2.5 recovery |
| 24 | | | | | | |
| 26 | | | J-3 | 12<br>32<br>44 | SS | petroleum odor<br>1.5/1.5 recovery |
| | (SC) | olive black clayey sand inclusions | | | RD | |
| 28 | | | C-3 | 22<br>49 | DR | |
| | | | | | RD | |
| 30 | | | PB 5 | | PB | |
| 32 | | | J-4 | 31<br>50 | SS | 0.8/0.9 recovery<br>refusal at 10" |
| 34 | | | | | RD | |
| 36 | | | PB 6 | | PB | |
| | SW | 37.0-41.0 GRAVELLY TAR SAND: black, dense to very dense, with petroleum | C-4 | 49<br>60 | | 2.2/2.5 recovery<br>refusal at 10" |
| 38 | | | | | RD | petroleum odor |
| 40 | | | PB 7 | | PB | |
| | SP<br>SM | 41.0-46.0 TAR SAND/SILTY TAR SAND: black, dense to very dense, gravel lenses, higly petroliferous | | | | |
| 42 | | | J-5 | 22<br>37<br>51 | SS | 2.5/2.5 recovery |
| 44 | | | | | | |

**Sheet** 2 **of** 4

**Project** DESIGN UNIT A250 **Date Drilled** 1-18-84 **Hole No.** 19-2

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SP<br>SM | 41.0-46.0 TAR SAND/SILTY TAR SAND: cont. | | | RD | |
| | | | PB 8 | | PB | 2.4/2.5 recovery |
| 46 | SM | 46.0-52.0 SILTY TAR SAND: black, trace gravel, dense to very dense, with petroleum | | | | |
| | | | C-5 | 52<br>75 | DR | 0.8/0.9 recovery<br>refusal at 10" |
| 48 | | | | | RD | petroleum odor |
| 50 | | | PB 9 | | PB | 2.1/2.5 recovery |
| 52 | SW<br>SM | 52.0-56.0 TAR SAND/SILTY TAR SAND: black, dense to very dense, trace gravel, highly petroliferous | J-6 | 56 | SS | 0.5/0.5 recovery<br>refusal at 6" |
| | | | | | RD | |
| 54 | | | | | | |
| 56 | SP<br>SM | 56.0-61.0 TAR SAND/SILTY TAR SAND: black, dense to very dense, trace gravel, highly petroliferous | PB 10 | | PB | |
| | | | C-6 | 85<br>65 | DR | refusal at 8" |
| 58 | | | | | RD | petroleum odor |
| 60 | | | PB 11 | | PB | 1.5/2.5 recovery |
| | SM<br>ML | 61.0-67.0 SILTY TAR SAND/SANDY TAR SILT: black, hard / very dense, trace gravel, highly petroliferous | | | | |
| 62 | | | J-7 | 31<br>35<br>43 | SS | 1.5/1.5 recovery |
| 64 | | | | | | |
| | | | PB 12 | | PB | petroleum odor |
| 66 | | | | | | |
| | SW<br>SM | 67.0-73.0 TAR SAND/SILTY TAR SAND: | | | | |
| 68 | | | | 49 | DR | |

Sheet 3 of 4

**Project** DESIGN UNIT A250 **Date Drilled** 1-18-84 **Hole No.** 19-2

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SW<br>SM | 67.0-73.0 TAR SAND/SILTY TAR SAND: cont. dense to very dense, trace gravel, with petroleum | C-7 | 75 | | refusal at 9" |
| | | | | | RD | petroleum odor |
| 70 | | | | | | |
| 72 | | | PB 13 | | PB | |
| | | BEDROCK<br>73.0-90.0 SILTSTONE/CLAYSTONE: olive black, with sand, very stiff to hard, fractures with tar infilling, petroliferous, massive (siltstone) | | | | 2.1/2.5 recovery |
| 74 | | | J-8 | 17<br>30<br>46 | SS | 1.5/1.5 recovery |
| 76 | | | | | RD | petroleum odor |
| 78 | | 78.0 tar oozing from fractures, minor gas bubbles | C-8 | 34<br>96 | DR | |
| 80 | | | | | RD | |
| 82 | | | PB 14 | | PB | 2.5/2.5 recovery |
| 84 | | | C-9 | 39<br>75 | DR | 0.8/0.8 recovery<br>refusal at 10" |
| | | | J-9 | 19<br>54 | SS | |
| 86 | | | | | RD | |
| 88 | | | PB 15 | | PB | 1.7/2.5 recovery<br>gas bubbling in sampler<br>finished drilling |
| 90 | | END OF BORING 90.0'<br>1-18-84 added 3 sac/42 gallon backfill slurry<br>1-19-84 pnuemantic transducer installation | | | | 1-18-84<br>10% reading on explosi<br>meter |
| 92 | | | | | | |

**Sheet** 4 **of** 4

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 19-3

**Proj:** DESIGN UNIT A250 **Date Drilled** 1/13-14/84 **Ground Elev.** 165'
**Drill Rig** FAILING **Logged By** M. Schluter **Total Depth** 155'
**Hole Diameter** 4 7/8" **Hammer Weight & Fall** 140 lbs. @ 30", 325 lbs. @ 18"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.6 CONCRETE | | | C | started drilling 1-13 |
| | CL | 0.6-11.0 SANDY CLAY: moderate brown; stiff to very stiff; contains gravel and rootlets; moist | | | | |
| 2 | | | | | DR<br>325 | sample not recovered |
| | | | | 7 | DR<br>325 | 1-13-84 |
| | | | C-1 | 7 | | |
| | | | | | | 1-14-84 |
| 4 | | | | | | |
| 6 | | | | | | |
| | | | | 10<br>10 | SS<br>140 | |
| 8 | | | J-1 | 7 | | |
| | | | | | RD | |
| 10 | | | PB1 | | PB1 | |
| | SC | 11.0-13.0 CLAYEY SAND:greyish green; medium dense with gravel | | | | |
| 12 | | | | | | 2.5/2.5 recovery |
| | | | | 7 | DR<br>325 | |
| | | | C-7 | 15 | | |
| | SP<br>SC | 13.0-17.0 SAND/CLAYEY SAND:greyish green dense to very dense; with gravel | | | | |
| 14 | | | | | RD | |
| | | | | 19<br>39 | SS<br>140 | 0.3/1.5 recovery<br>rock in sampler |
| 16 | | | J-2 | 39 | | |
| | | | | | RD | |
| | CL/<br>ML | 17.0-21.0 SILTY TAR CLAY/CLAYEY TAR SILT greyish olive green and olive black; containing sand; stiff; moist with petroleum | | | | |
| 18 | | | | 8 | DR<br>325 | sulfurous and petroleum<br>odor |
| | | | C-3 | 35 | | |
| 20 | | | | | | |

Sheet 1 of 7

**Project** DESIGN UNIT A250 **Date Drilled** 1/13-14/84 **Hole No.** 19-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CL/<br>ML | 17.0-21.0 SILTY TAR CLAY/CLAYEY TAR SILT: (continued) | PB2 |  | PB | 2.5/2.5 recovery<br>petroleum odor |
|  | SP/<br>SM | 21.0-27.0 TAR SAND/SILTY TAR SAND: mottled black and greyish olive green; contains gravel; dense to very dense; petroliferous |  |  |  |  |
| 22 |  |  |  |  |  |  |
|  |  |  |  | 28 | SS<br>140 | 1.0/1.0 recovery |
|  |  |  | J-3 | 53 |  | refusal @ 12" |
| 24 |  |  |  |  | RD |  |
| 26 |  |  | PB3 |  | PB |  |
|  | SM | 27.0-33.0 SILTY TAR SAND: greyish black; dense to very dense; trace gravel; highly petroliferous | C-4 | 103 | DR<br>325 | 2.5/2.5 recovery<br>refusal @ 6" |
| 28 |  |  |  |  | RD |  |
|  |  |  |  |  |  | petroleum odor |
| 30 |  |  | PB4 |  | PB | 2.5/2.5 recovery |
| 32 |  | with black gravel lenses |  | 39 | SS<br>140 | refusal at 9" |
|  |  |  | J-4 | 50 |  | 0.8/0.8 recovery |
|  | ML/<br>SC | 33.0-37.0 CLAYEY TAR SILT/CLAYEY TAR SAND: greyish black to black; very dense/hard with gravel and petroleum; stratified |  |  | RD |  |
| 34 |  |  |  |  |  |  |
|  |  |  | PB5 |  | PB |  |
| 36 |  |  |  |  |  |  |
|  | SP/<br>SM | 37.0-41.0 TAR SAND/SILTY TAR SAND: black; very dense; contains gravel and petroleum |  | 123 | DR<br>325 | 2.1/2.5 recovery<br>refusal at 6" |
| 38 |  |  |  |  | RD |  |
| 40 |  |  | PB6 |  | PB | petroleum odor |
|  | SM | 41.0-47.0 SILTY TAR SAND :black; trace of gravel; very dense; contains petroleum |  | 40 | SS<br>140 | 2.5/2.5 recovery |
| 42 |  |  | J-4 | 50 |  | 0.9/0.9 recovery<br>refusal at 11" |
| 44 |  |  |  |  |  |  |

**Project** DESIGN UNIT A250 **Date Drilled** 1-14-84 **Hole No.** 19-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SM | 41.0-47.0 SILTY TAR SAND: (continued) | | | RD | |
| | | | PB7 | | PB | |
| 46 | | | | | | 1.8/2.5 recovery<br>refusal at 6" |
| | SP/<br>SM | 47.0-60.0 TAR SAND/SILTY TAR SAND: Very dense; with gravel; highly petroliferous | C-6 | 97 | DR<br>325 | |
| 48 | | | | | RD | petroleum odor |
| 50 | | | PB8 | | PB | 2.5/2.5 recovery<br>0.5/0.5 recovery<br>refusal at 6" |
| 52 | | | J-6 | 72 | SS<br>140 | |
| 54 | | thin gravel lenses | -- | | RD | |
| | | | PB9 | | PB | |
| 56 | | | | | | 2.4/2.5 recovery |
| | | | C-7 | 150 | DR<br>325 | refusal at 5: |
| 58 | | | | | RD | |
| 60 | SM | 60.0-63.0 SILTY TAR SAND: black; trace gravel; very dense with petroleum | PB10 | | PB | petroleum odor |
| 62 | | | | | | 2.4/2.5 recovery |
| | | | J-7 | 52 | SS<br>140 | refusal at 6" |
| | ML/<br>MH | 63.0-67.0 CLAYEY TAR SILT/SANDY TAR SILT: black; contains petroleum and gravel | | | | |
| 64 | | | | | | |
| | | | PB11 | | PB | |
| 66 | | | | | | |
| 68 | SM | 67.0-72.0 SILTY TAR SAND: | C-8 | 75<br>50 | DR<br>325 | |

**Sheet** 3 **of** 7

Project DESIGN UNIT A250 Date Drilled 1-14-84 Hole No. 19-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SM | 67.0-72.0 SILTY TAR SAND: (continued) black with petroleum | | | RD | refusal at 9"<br>petroleum odor |
| 70 | | | PB12 | | PB | |
| 72 | | | | | | 2.0/2.5 recovery |
| | OH/ SM | 72.0-77.0 ORGANIC CLAYEY TAR SILT/SILTY TAR SAND: interbedded; olive black and black; hard/very dense; moist with roots; peat and petroleum | J-8 | 32<br>52 | SS<br>140 | refusal at 12"<br>1.0/1.0 recovery |
| 74 | | | | | RD | |
| 76 | | | PB13 | | PB | 2.3/2.5 recovery |
| | ML | 77.0/81.0 CLAYEY TAR SILT: black; with fine sand; contains petroleum; very stiff to hard | C-9 | 133 | DR<br>325 | refusal at 6" |
| 78 | | | | | RD | petroleum odor |
| 80 | | | PB14 | | PB | |
| | SW/ SM | 81.0-93.0 TAR SAND/SILTY TAR SAND: black highly petroliferous | | | | 2.5/2.5 recovery |
| 82 | | | J-9 | 62 | SS<br>140 | refusal at 6" |
| 84 | | | | | | petroleum odor |
| | | | PB15 | | PB | |
| 86 | | thin gravel lenses | | | | 2.4/2.5 recovery |
| | | | C-10 | 108 | DR<br>325 | refusal at 6" |
| 88 | | | | | | |
| 90 | | | PB16 | | PB | 2.5/2.5 recovery |
| 92 | | | | | RD | |

Sheet 4 of 7

**Project** DESIGN UNIT A250 **Date Drilled** 1-14-84 **Hole No.** 19-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | SM | 81.0-93.0 TAR SAND/SILTY TAR SAND: (cont.) | | | RD | |
| | SW | | | | | |
| | GW<br>GM | 93.0-130.0 SANDY TAR GRAVEL: black; trace fines; dense to very dense with petroleum; occasional tar pockets | | | | |
| 94 | | | | | | petroleum odor |
| | | | C-11 | 115 | DR<br>325 | refusal @ 4", disturbed sample |
| 96 | | | | | | |
| | | | | | | rig chatter |
| 98 | | | | | | 2.2/2.2 recovery<br>barrel damaged |
| | | color change to dark grey | PB17 | | PB | |
| 100 | | | C-12 | 150 | DR<br>325 | refusal at 5"<br>sampler tip damaged<br>damaged sample |
| 102 | | | | | | heavy rig chatter |
| 104 | | | | | | |
| | | | C-13 | 150 | DR<br>325 | refusal at 6"<br>disturbed sample |
| 106 | | | | | | rig chatter |
| 108 | | | PB18 | | PB | |
| | | | | | | 1.8/1.8 recovery |
| | | | C-14 | 143 | DR<br>325 | refusal @ 6"<br>distrubed sample |
| 110 | | | | | | |
| 112 | | | | | | rig chatter |
| 114 | | | | | | refusal at 6" |
| | | | C-15 | 112 | DR<br>325 | |
| 116 | | | | | | |

**Sheet** 5 **of** 7

**Project** DESIGN UNIT A250 **Date Drilled** 1-14-84 **Hole No.** 19-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 116 | GM<br>GW | 93.0-130.0 SANDY TAR GRAVEL: (continued) | | | | |
| 118 | | | | | | rig chatter |
| | | | PB19 | | PB | |
| 120 | | | | | | 2.5/2.5 recovery |
| | | | | 56 | DR | refusal @ 8" |
| 122 | | | | 50 | 325 | sample not recovered |
| 124 | | | | | | |
| | | gas foam frothing out of casing; 80-100% reading on explosimeter | C-16 | 59 | DR | |
| | | | | 100 | 325 | refusal at 9"<br>1-14-84 |
| 126 | | | | | RD | 1-15-84 |
| 128 | | 127.8-129.0 heavy rig chatter; possible cobble | | | | |
| | | | PB20 | | PB | |
| 130 | GC | 130.0-135.0 CLAYEY TAR GRAVEL: brownish black with sand; moist; dense to very dense; contains petroleum | | | | 2.0/2.5 recovery |
| 132 | | | | 23 | DR | refusal @ 9" |
| | | | C-17 | 70 | 325 | |
| | | | | | RD | petroleum odor |
| 134 | | | | | | |
| | | 135.0-155.0 BEDROCK | C-18 | 82 | DR | refusal at 9" |
| 136 | | SILTSTONE/CLAY STONE: dusky yellowish brown; trace gravel; moist; very stiff to hard; massive; friable | | 50 | 325<br>RD | |
| | | | | | | petroleum odor |
| 138 | | | PB21 | | PB | 2.5/2.5 recovery |
| | | gaseous; with petroleum | | | | |
| 140 | | | | | | |

**Sheet** 6 **of** 7

**Project** DESIGN UNIT A250 **Date Drilled** 1-14-84 **Hole No.** 19-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 140 | | 135.0-155.0 SILTSTONE/CLAYSTONE: (continued) | | | PB | |
| | | | | 27 | DR | refusal @ 11" |
| | | | C-19 | 100 | 325 | |
| 142 | | | | | RD | |
| | | | | | | occasional rig chatter |
| 144 | | gravel lenses | | | | |
| | | | C-20 | 81 | DR | refusal at 9" |
| 146 | | | | 50 | 325 | |
| 148 | | | PB22 | | PB | |
| 150 | | | | | | 2.5/2.5 recovery |
| | | | | 45 | DR<br>325 | refusal at 10" |
| | | | | 55 | | |
| 152 | | | | | RD | |
| 154 | | | PB23 | | PB | 2.5/2.5 recovery |
| | B.H. | 155.0' Terminated Hole | | | | Completed drilling 1-15-84 |
| 156 | | | | | | |
| 158 | | | | | | |
| 160 | | | | | | |
| 162 | | | | | | |
| 164 | | | | | | |

Sheet 7 of 7

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 19-4

**Proj:** DESIGN UNIT A250
**Date Drilled** 1-16-17-84
**Ground Elev.** 165.0'
**Drill Rig** Failing 1500
**Logged By** M. Schluter
**Total Depth** 90.0'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 325# @ 18"/140# @ 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.2 A.C. PAVEMENT | | | C | started drilling<br>1-16-84 |
| | SW | ALLUVIUM<br>0.2-1.0 SAND: moderate brown, moist, loose | | | | |
| | CL | 1.0-4.0 SILTY CLAY: mottled dusky green and grayish black, with sand, moist, with rootlets, soft | C-1 | 3<br>3 | DR | |
| 2 | | | | | A | |
| 4 | SM<br>SC | 4.0-7.0 SILTY SAND/CLAYEY SAND: black, loose, with organic inclusions, slightly moist, peaty, slightly petroliferous | J-1 | 2<br>2<br>2 | SS | 1.4/1.5 recovery |
| | | | | | RD | |
| 6 | | | | | | |
| | CL | 7.0-11.0 SANDY CLAY: dusky green, with gravel, moist, soft to firm | C-2 | 4<br>4 | DR | |
| 8 | | | | | RD | |
| 10 | | gravel lens | PB 1 | | PB | |
| | SC | 11.0-16.0 CLAYEY TAR SAND: dusky green to black, with gravel, dense, with petroleum | | | | 2.5/2.5 recovery<br>petroleum odor |
| 12 | | | J-2 | 12<br>22<br>25 | SS | 1.0/1.5 recovery |
| 14 | | | | | RD | |
| | | | PB 2 | | PB | |
| 16 | MH | 16.0-24.0 CLAYEY TAR SILT: contains sand, stiff, with gravel and petroleum | | | | |
| | | | C-3 | 12<br>41 | DR | |
| 18 | | 18.0-18.4 gravel layer | | | | |
| 20 | | | | | | |

Sheet 1 of 4

**Project** DESIGN UNIT A250 **Date Drilled** 1-16-84 **Hole No.** 19-4

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | MH | 16.0-24.0 CLAYEY TAR SILT: continued | PB 3 | | PB | 2.4/2.5 recovery |
| 22 | | | | | | |
| | | | J-3 | 27<br>41<br>49 | SS | 1.5/1.5 recovery |
| 24 | SM | 24.0-37.0 SILTY TAR SAND: black, dense to very dense, trace gravel, highly petroliferous | | | RD | 1-16-84<br>1-17-84<br>0-5% reading explosimeter @ top fluid filled boring |
| | | | PB 4 | | PB | |
| 26 | | | | | | |
| 28 | | | C-4 | 41<br>50 | DR | 2.4/2.5 recovery<br>refusal at 10" |
| | | | | | RD | |
| 30 | | gravel lenses | PB 5 | | PB | 2.5/2.5 recovery |
| 32 | | | | | | |
| | | | J-4 | 43<br>50 | SS | refusal at 10"<br>0.8/0.9 recovery |
| 34 | | | | | RD<br>RD | |
| 36 | | | PB 6 | | PB | 2.3/2.5 recovery |
| | SP | 37.0-39.0 GRAVELLY TAR SAND: black, trace fines, very dense, contains petroleum | | | | |
| 38 | | | C-5 | 97<br>50 | DR | refusal at 9"<br>petroleum odor |
| | | | | | RD | |
| | SM | 39.0-48.0 SILTY TAR SAND: black, very dense, with gravel, highly petroliferous, thin gravel lenses | | | | |
| 40 | | | PB 7 | | PB | 1.6/2.5 recovery |
| 42 | | | | | | |
| | | | J-5 | 50 | SS | refusal at 4"<br>0.3/0.5 recovery |
| 44 | | | | | | |

Project DESIGN UNIT A250 Date Drilled 1-17-84 Hole No. 19-4

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SM | 39.0-48.0 SILTY TAR SAND: continued | | | RD | |
| | | gravel lenses | PB 8 | | PB | 2.4/2.5 recovery |
| 46 | | | | | | |
| 48 | | | C-6 | 136 | DR | refusal at 6" |
| | SM | 48.0-53.0 SILTY TAR SAND: black, with gravel, very dense, highly petroliferous | | | RD | petroleum odor |
| 50 | | | PB 9 | | PB | |
| | | | | | | 2.5/2.5 recovery |
| 52 | | | | | | |
| | | | J-6 | 30<br>50 | SS | 0.9/0.9 recovery<br>refusal at 11" |
| | MH<br>CL | 53.0-59.0 CLAYEY TAR SILT/SANDY TAR CLAY dark greenish gray to moderate brown, moist, stiff to very stiff, wood/reed grass fragments, petroliferous | | | | |
| 54 | | | | | | |
| | | | PB 10 | | PB | 2.5/2.5 recovery |
| 56 | | | | | | |
| | | | C-7 | 12<br>30 | DR | |
| 58 | | | | | | |
| | ML<br>SM | 59.0-63.0 CLAYEY TAR SILT/SILTY TAR SAND: black, trace gravel, very stiff/ very dense, highly petroliferous | | | | petroleum odor |
| 60 | | | PB 11 | | PB | 2.5/2.5 recovery |
| 62 | | | | | | |
| | | | J-7 | 50 | SS | refusal at 5"<br>0.4/0.4 recovery |
| | SM | 63.0-69.0 SILTY TAR SAND: black, trace gravel, highly petroliferous, thin gravel lenses | | | RD | |
| 64 | | | | | | |
| | | | PB 12 | | PB | |
| 66 | | | | | | |
| | | | | | | 2.1/2.5 recovery |
| 68 | | | | 72 | DR | |

Sheet 3 of 4

Project DESIGN UNIT A250 Date Drilled 1-17-84 Hole No. 19-4

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SM | 63.0-69.0 SILTY TAR SAND: continued | C-8 | 64 | DR | refusal at 11" |
|  |  |  |  |  | RD | strong sulfurous odor |
|  | ML | 69.0-76.0 CLAYEY TAR SILT/SANDY TAR SILT: black, very stiff to hard, trace gravel, highly petroliferous |  |  |  |  |
| 70 |  |  | PB 13 |  | PB | 2.5/2.5 recovery |
| 72 |  |  | J-8 | 57 | SS | 0.5/0.5 recovery<br>petroleum odor |
|  |  |  |  |  | RD |  |
| 74 |  |  |  | - - | - - |  |
|  |  |  |  |  | RD |  |
|  |  |  | PB 14 |  | PB |  |
| 76 | MH | 76.0-88.0 CLAYEY TAR SILT: brownish black to grayish black, very stiff, with petroleum |  |  |  |  |
|  |  |  | C-9 | 33 | DR | 1.3/2.5 recovery |
| 78 |  |  |  | 86 |  |  |
|  |  |  |  |  | RD |  |
| 80 |  |  | PB 15 |  | PB | 1.7/2.5 recovery |
| 82 |  |  | J-9 | 17 | SS | refusal at 12" |
|  |  |  |  | 53 |  | 0.9/1.0 recovery |
| 84 |  |  |  |  | RD |  |
|  |  |  | PB 16 |  | PB | 1.2/2.5 recovery<br>petroleum odor |
| 86 |  |  |  |  |  |  |
| 88 |  | BEDROCK<br>88.0-90.0 SILTSTONE: very stiff to hard, dark greenish gray, tar infilling in fractures, petroliferous | PB 17 |  | PB | 2.5/2.5 recovery |
| 90 |  | END OF BORING 90.0'<br>4 sac/ 75 gallon backfill |  |  |  | finished drilling<br>1-17-84 |
| 92 |  |  |  |  |  |  |

Sheet 4 of 4

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 19-5

**Proj:** DESIGN UNIT A250 **Date Drilled** 1-9-84 **Ground Elev.** 167.0'

**Drill Rig** Failing 1500 **Logged By** M. Schluter **Total Depth** 130.0'

**Hole Diameter** 4 7/8" **Hammer Weight & Fall** 324# @ 18"/ 140# @ 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.3 A.C. PAVEMENT | | | C | started drilling 1-9-84 |
| | ML | ALLUVIUM<br>0.3-2.5 SANDY SILT: brownish black, stiff moist | | | | |
| 2 | (SM) | becoming silty sand | C-1 | 4<br>4 | DR | |
| | SC<br>CL | 2.5-13.0 CLAYEY SAND/SANDY CLAY: grayish olive black, interbedded, medium dense to dense; stiff to very stiff, moist | | | C | |
| 4 | | | J-1 | 7<br>16<br>19 | SS | 1.4/1.5 recovery |
| | | | | | RD | |
| 6 | | | | | | 6.5' rig chatter |
| | | coarse gravel lenses | C-2 | 6<br>11 | DR | |
| 8 | | | | | RD | |
| 10 | | | PB 1 | | PB | 2.7/2.8 recovery |
| 12 | | | | | RD | |
| | CL | 13.0-15.0 SANDY CLAY: light olive gray | C-3 | 4<br>11 | DR | sulfurous odor |
| 14 | | | | | RD | |
| | SC | 15.0-22.0 CLAYEY SAND: grayish green, medium dense to dense | J-2 | 7<br>8<br>12 | SS | 1.3/1.5 recovery |
| 16 | | | | | | |
| | | | | | RD | |
| 18 | | | | 4 | DR | |
| | (SP) | decreasing fines | C-4 | 5 | | |
| 20 | | | | | | |

Sheet 1 of 6

**Project** DESIGN UNIT A250 **Date Drilled** 1-9-84 **Hole No.** 19-5

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | SC | 15.0-22.0 CLAYEY SAND: continued | PB 2 | | PB | 2.5/2.5 recovery |
| 22 | SP | 22.0-32.0 SAND: grayish green, with gravel, medium dense | | | RD | |
| | (SC) | becoming clayey | C-5 | 17<br>25 | DR | |
| 24 | | | | | RD | |
| | | | J-3 | 4<br>6<br>11 | SS | 0.3/1.5 recovery |
| 26 | | | | | RD | |
| 28 | (SM) | scattered dark brown to black silty, with peat | C-6 | 8<br>16 | DR | |
| | | | | | RD | |
| 30 | | | PB 3 | | PB | 2.5/2.5 recovery |
| 32 | ML | 32.0-35.0 SANDY TAR SILT: brownish black, with petroleum, stiff to very stiff | | | RD | |
| | | | C-7 | 27<br>43 | | petroleum odor |
| 34 | | | | | RD | |
| | ML | 35.0-42.0 TAR SILT/CLAYEY TAR SILT: grayish black, very stiff to hard, occasional gravel, petroliferous | J-4 | 10<br>26<br>48 | SS | 1.5/1.5 recovery |
| 36 | | | | | RD | |
| 38 | | | C-8 | 21<br>47 | DR | |
| | | | | | RD | |
| 40 | | | PB 4 | | PB | gas explosimeter 0% reading<br>1.6/2.5 recovery |
| 42 | SP<br>SM | 42.0-43.0 TAR SAND/SILTY TAR SAND | | | RD | |
| | SP<br>SM | 43.0-48.0 TAR SAND/SILTY TAR SAND | C-9 | 25<br>46 | | |
| 44 | | | | | | |

**Project** DESIGN UNIT A250 **Date Drilled** 1-9-84 **Hole No.** 19-5

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SP<br>SM | 43.0-48.0 TAR SAND/SILTY TAR SAND: cont. stratified gray black, occasional gravel, with petroleum, dense to very dense | | | RD | |
| | | | J-5 | 17<br>37<br>38 | SS | 1.0/1.5 recovery |
| 46 | | | | | RD | |
| 48 | SP | 48.0-52.0 TAR SAND : gray black, occasional gravel, dense | C-10 | 33<br>64 | DR | |
| | | | | | RD | |
| 50 | | | PB 5 | | PB | 2.5/2.5 recovery |
| | | increasing saturation with tar | | | | |
| 52 | SP<br>SM | 52.0-70.0 TAR SAND/SILTY TAR SAND: with gravel, black, dense to very dense, saturated with petroleum | | | RD | |
| | | | C-11 | 85<br>65 | DR | refusal at 10" |
| 54 | | | | | RD | |
| | | | J-6 | 26<br>50 | SS | 0.9/1.0 recovery<br>refusal at 10" |
| 56 | | | | | RD | |
| 58 | | | C-12 | 70<br>50 | DR | refusal at 7"<br>disturbed sample |
| | | | | | RD | |
| 60 | | strong petroleum odor | PB 6 | | PB | 2.4/2.5 recovery |
| 62 | | | | | | 1-9-84 |
| | | | | | RD | 1-10-84 |
| | | | C-13 | 93<br>50 | DR | refusal at 7" |
| 64 | | | | | RD | |
| | | very dense | J-7 | 71 | SS | 0.5/0.6 recovery |
| 66 | | | | | | Refusal at 6" |
| 68 | | | | | | |

Sheet 3 of 6

**Project** DESIGN UNIT A250 **Date Drilled** 1-10-84 **Hole No.** 19-5

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SP<br>SM | 52.0-70.0 TAR SAND/SILTY TAR SAND: cont. | C-14 | 137 | DR | refusal at 6" |
| 70 | SM<br>ML | 70.0-78.0 SILTY TAR SAND/CLAYEY TAR SILT: black, dense to very dense /very stiff to hard, with gravel, saturated with tar/petrolem | PB 7 | | PB | 2.2/2.5 recovery<br>petroleum odor |
| 72 | | | | | RD | |
| | | | C-15 | 126 | DR | |
| 74 | | | | | RD | |
| | | | J-8 | 100 | SS | 0.5/0.5 recovery<br>refusal at 5" |
| 76 | | | | | RD | |
| 78 | SP<br>SM | 78.0-83.0 TAR SAND/SILTY TAR SAND: black, saturated with tar/petroleum | C-16 | 148 | DR | refusal at 6" |
| | | | | | RD | |
| 80 | | | PB 8 | | PB | 2.3/2.5 recovery |
| 82 | | | | | RD | |
| | ML | 83.0-97.0 CLAYEY TAR SILT: brownish black and grayish olive green, contains sand, very stiff to hard, trace gravel, with petroleum, moist | C-17 | 21<br>61 | DR | petroleum odor |
| 84 | | | | | RD | |
| | | | J-9 | 13<br>27<br>55 | SS | 1.5/1.5 recovery |
| 86 | | | | | | |
| 88 | | | PB 9 | | PB | 2.0/2.5 recovery |
| 90 | | | | | | |
| 92 | | | | | | |

Sheet 4 of 6

Project DESIGN UNIT A250 Date Drilled 1-10-84 Hole No. 19-5

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | ML | 83.0-97.0 CLAYEY TAR SILT: continued decreasing petroleum | | | RD | |
| 94 | | | | | | |
| | | | C-18 | 40<br>72 | DR | refusal at 11" |
| 96 | | | | | RD | |
| | | BEDROCK<br>97.0-130.0 SILTSTONE: olive gray, with sand, very stiff to hard, with petroleum, massive, moist | | | | |
| 98 | | | | | | |
| 100 | | | C-19 | 28<br>52 | DR | moderate petroleum odor |
| 102 | | | | | | |
| | | | | | RD | |
| 104 | | | | | | |
| 106 | | | | | | |
| 108 | | | | | | |
| 110 | | fractures 45°-65°, gaseous | C-20 | 30<br>72 | DR | |
| | | | | | RD | |
| 112 | | | | | | |
| 114 | | | | | | |
| 116 | | | | | | |

Sheet 5 of 6

**Project** DESIGN UNIT A250 **Date Drilled** 1-10-84 **Hole No.** 19-5

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 116 | | 97.0-130.0 SILTSTONE: continued | | | RD | |
| 118 | | | | | | |
| 120 | | olive black, with petroleum, gaseous, hard | C-21 | 40<br>63 | DR | |
| | | | | | RD | |
| 122 | | | | | | |
| 124 | | | | | | |
| 126 | | | | | | |
| 128 | | | C-22 | 30<br>69 | DR | |
| 130 | | END OF BORING 130.0'<br>5 sac/120 gallon backfill | | | | finished drilling<br>1-10-84 |
| 132 | | | | | | |
| 134 | | | | | | |
| 136 | | | | | | |
| 138 | | | | | | |
| 140 | | | | | | |

**Sheet** 6 **of** 6

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 19-6

**Proj:** DESIGN UNIT A250
**Date Drilled** 1-12-13-84
**Ground Elev.** 168.0'
**Drill Rig** Failing 1500
**Logged By** M. Schluter
**Total Depth** 92.0'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 140# @ 185/325# @ 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.3 A.C. PAVEMENT | | | C | started drilling 1-12-84 |
| | | ALLUVIUM | | | | |
| | SM | 0.3-4.0 SILTY SAND: grayish brown, with gravel, medium dense, moist | | | | |
| 2 | | | | 6<br>7 | DR | sample not recovered |
| | | | | | C | |
| 4 | ML<br>SC | 4.0-6.0 CLAYEY SILT/CLAYEY SAND: dark yellowish brown, medium dense stiff, moist, with rootlets | J-1 | 6<br>14<br>29 | SS | 1.5/1.5 recovery |
| 6 | SW | 6.0-8.0 GRAVELLY SAND: dark yellowish brown, contains fines, medium dense, moist | | | RD | |
| | | | C-1 | 11<br>13 | DR | |
| 8 | SC | 8.0-18.0 CLAYEY SAND: grayish olive brown, medium dense, little gravel | | | RD | |
| 10 | | | PB 1 | | PB | 2.5/2.5 recovery |
| 12 | | | | | RD | |
| | | | C-2 | 6<br>9 | DR | |
| 14 | | thin gravel lenses | | | RD | |
| | | | J-2 | 6<br>9<br>13 | SS | 1.5/1.5 recovery |
| 16 | | | | | RD | |
| 18 | CL | 18.0-24.0 SILTY CLAY: grayish brown, with sand, moist, stiff | C-3 | 10<br>15 | DR | |
| | | | | | RD | |

Sheet 1 of 4

**Project** DESIGN UNIT A250 **Date Drilled** 1-12-13-84 **Hole No.** 19-6

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CL | 18.0-24.0 SILTY CLAY: continued | PB<br>2 | | PB | 2.5/2.5 recovery |
| 22 | | | | | | 1-12-84<br>1-13-84 |
| | | | | | RD | |
| | (ML) | sandy silt | C-4 | 15<br>34 | DR | |
| 24 | CL | 24.0-28.0 SILTY CLAY: greenish gray, contains sand, moist, very stiff to hard | | | RD | |
| | | | J-3 | 9<br>15<br>25 | SS | 1.5/1.5 recovery |
| 26 | | | | | RD | |
| 28 | ML | 28.0-34.0 CLAYEY TAR SILT: olive black, with sand, stiff to very stiff, trace gravel, petroliferous | C-5 | 73<br>66 | DR | gravel lens at contact |
| | | | | | RD | petroleum odor |
| 30 | | | PB 3 | | PB | 2.4/2.5 recovery |
| 32 | | | | | RD | |
| | | becoming hard | J-4 | 17<br>32<br>49 | SS | |
| 34 | SM | 34.0-56.0 SILTY TAR SAND: grayish black, dense to very dense, with gravel, highly petroliferous | | | RD | petroleum odor |
| | | | PB<br>4 | | PB | |
| 36 | | | | | | |
| | | | C-6 | 63<br>70 | DR | 1.9/2.5 recovery<br>refusal at 10" |
| 38 | | | | | RD | |
| 40 | | | PB<br>5 | | PB | 2.5/2.5 recovery |
| 42 | | | J-5 | 31<br>52 | SS | refusal at 12"<br>1.0/1.0 recovery |
| | | | | | RD | |
| 44 | | | | | | |

Sheet 2 of 4

**Project** DESIGN UNIT A250 **Date Drilled** 1-13-84 **Hole No.** 19-6

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SM | 34.0-56.0 SILTY TAR SAND: continued | | | RD | samples dilating at end of pitcher barre |
| | | | PB 6 | | PB | |
| 46 | | | | | | |
| | | with fine gravel | | | | 2.0/2.5 recovery |
| | | | C-7 | 95 | DR | refusal @ 7" |
| 48 | | | | 50 | | |
| | | | | | RD | |
| 50 | | | PB 7 | | PB | |
| 52 | | | | | | 1.8/2.5 recovery |
| | | | J-6 | 40 | SS | 0.8/0.8 recovery |
| | | | | 50 | | |
| 54 | | | | | RD | |
| | | | PB 8 | | PB | |
| 56 | SM<br>ML | 56.0-61.0 SILTY TAR SAND/CLAYEY TAR SILT: black, very dense to hard, contains gravel and petroleum | | | | 1.8/2.5 recovery |
| | | | C-8 | 47 | DR | petroleum odor |
| 58 | | | | 67 | | |
| 60 | | | PB 9 | | PB | 1.9/2.5 recovery |
| 62 | | | J-7 | 50 | SS | refusal at 4" |
| | SP<br>SM | 61.0-68.0 TAR SAND/SILTY TAR SAND: black, with gravel, very dense, highly petroliferous | | | RD | petroleum odor |
| 64 | | | PB 10 | | PB | rig chatter |
| 66 | | | | | | |
| | | | | | | 2.5/2.5 recovery |
| 68 | | | C-9 | 142 | DR | |

**Sheet** 3 **of** 4

**Project** DESIGN UNIT A250 **Date Drilled** 1-13-84 **Hole No.** 19-6

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SW<br>SM | 68.0-73.0 TAR SAND/SILTY TAR SAND: black, very dense, with gravel and petroleum | | - - | RD | refusal at 6" |
| | | | | | | petroleum odor |
| 70 | | | PB 11 | | PB | |
| 72 | | | J-8 | 73 | SS | 0.5/0.5 recovery<br>refusal at 6" |
| | SM<br>ML | 73.0-83.0 SILTY TAR SAND/CLAYEY TAR SILT: black, with gravel, very dense, hard highly petroliferous | | | | |
| 74 | | | | | | |
| | | | PB 12 | | PB | |
| 76 | | | | | | 2.4/2.5 recovery |
| | | | C-10 | 123 | DR | refusal at 6" |
| 78 | | | | | RD | |
| 80 | | | PB 13 | | PB | 2.5/2.5 recovery<br>petroleum odor |
| 82 | | | J-9 | 20<br>30<br>51 | SS | 1.5/1.5 recovery |
| | CL | 83.0-92.0 SILTY CLAY: grayish olive green to olive gray, contains sand, very stiff to hard, moist, slightly petroliferous | | | | |
| 84 | | | | | | gradational contact |
| | | | PB 14 | | PB | |
| 86 | | | | | | 2.5/2.5 recovery |
| | | | | 25 | DR | |
| 88 | | | C-11 | 66 | | |
| | | | | | RD | |
| 90 | | | PB<br>15 | | PB | 2.5/2.5 recovery<br>finished drilling 1-13 |
| 92 | | END OF BORING 92.0', 4 sac/75 gallon backfill | | | | |

**Sheet** 4 **of** 4

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

## BORING LOG 19-7

**Proj:** DESIGN UNIT A250
**Date Drilled** 1-11-12-84
**Ground Elev.** 168.0'
**Drill Rig** Failing 1500
**Logged By** M. Schluter
**Total Depth** 91.0'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 140# @ 18"/325# @30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0.-0.2 A.C. PAVEMENT | | | C | started drilling 1-11-84 |
| | CL | ALLUVIUM<br>0.2-3.0 SANDY CLAY: olive black, stiff, moist | | | | |
| | | | C-1 | 5<br>10 | DR | |
| 2 | | | | | | |
| | | | | | A | |
| | SM | 3.0-4.5 SILTY SAND: brownish black, medium dense, moist | J-1 | 7<br>12<br>16 | SS | 1.5/1.5 recovery |
| 4 | | | | | | |
| | ML/CL | 4.5-15.0 CLAYEY SILT/SANDY CLAY: dark greenish gray, trace gravel, stiff moist | | | RD | |
| 6 | | | | | | |
| | | | C-2 | 7<br>11 | DR | |
| 8 | | | | | RD | |
| | | thin gravel lenses | | | | |
| 10 | | | PB 1 | | PB | 2.2/2.5 recovery |
| 12 | | | | | | |
| | | | | | RD | |
| | | | C-3 | 9<br>11 | DR | sample disturbed |
| 14 | | | | | RD | |
| | | petroliferous, occasional gray black sand lenses | | | | |
| | SC/CL | 15.0-21.0 CLAYEY SAND/SANDY CLAY: dark green gray, moist, dense, very stiff to hard | J-2 | 9<br>16<br>27 | SS | 1.4/1.5 recovery |
| 16 | | | | | | |
| | | | | | RD | |
| 18 | | | | | | |
| | | | C-4 | 13<br>20 | DR | |
| | (SM) | becoming silty | | | | |
| 20 | | | | | | |

**Project** DESIGN UNIT A250 **Date Drilled** 1-11-84 **Hole No.** 19-7

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | SC<br>CL | 15.0-21.0 CLAYEY SAND/SANDY CLAY: cont. | PB 2 |  | PB | 2.3/2.4 recovery |
|  | SC | 21.0-25.0 CLAYEY SAND: dusky green, with gravel, moist, medium dense to dense |  |  |  |  |
| 22 |  |  |  |  |  |  |
|  |  |  |  |  | RD |  |
|  |  |  |  | 10 | DR |  |
|  | (CL) | becoming sandy clay | C-5 | 41 |  |  |
| 24 |  |  |  |  | RD |  |
|  | CL | 25.0-31.0 SANDY CLAY: dark greenish gray, very stiff to hard, moist | J-3 | 7<br>15<br>21 | SS | 1.5/1.5 recovery |
| 26 |  |  |  |  | RD |  |
| 28 |  |  | C-6 | 9<br>21 | DR |  |
|  |  |  |  |  | RD |  |
| 30 |  |  | PB 3 |  | PB | 2.5/2.5 recovery |
|  | ML | 31.0-38.0 CLAYEY TAR SILT: brownish black, with sand, very stiff to hard, petroliferous |  |  |  |  |
| 32 |  |  |  |  |  | petroleum odor |
|  |  |  |  |  | RD |  |
|  |  |  | C-7 | 23<br>70 | DR |  |
| 34 |  |  |  |  | RD |  |
|  |  |  | J-4 | 18<br>34<br>50 | SS | refusal at 17"<br>1.5/1.5 recovery |
| 36 |  |  |  |  |  | samples dilate at ends of pitcher barrel |
|  |  |  |  |  | RD |  |
| 38 | SP<br>SM | 38.0-52.0 TAR SAND/SILTY TAR SAND: grayish black, dense to very dense, trace gravel, stratified petroliferous | C-8 | 58<br>60 | DR | refusal at 10"<br>petroleum odor |
|  |  |  |  |  | RD |  |
| 40 |  |  |  |  |  |  |
|  |  |  | PB 4 |  | PB | 2.3/2.5 recovery |
| 42 |  |  |  |  |  |  |
|  |  |  |  |  | RD |  |
|  |  |  | C-9 | 51<br>75 | DR |  |
| 44 |  |  |  |  |  |  |

**Sheet** 2 **of** 4

Project DESIGN UNIT A250 Date Drilled 1-11-12-84 Hole No. 19-7

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SP<br>SM | 38.0-52.0 TAR SAND/SILTY TAR SAND: cont. brownish black, dense to very dense, gravel lens | | | RD | |
| | | | J-5 | 25<br>50 | SS | 1.0/1.0 recovery<br>refusal at 11" |
| 46 | | | | | RD | |
| 48 | | | | 120 | DR | sample not recovered<br>refusal at 6" |
| 50 | | | PB 6 | | PB | 2.5/2.5 recovery |
| 52 | SM<br>GM | 52.0-58.0 SILTY TAR SAND/SANDY TAR GRAVEL: black to dark greenish gray, dense to very dense, highly petroliferous | | | RD | |
| | | | C-10 | 120 | DR | refusal at 6" |
| | | | | | RD | petroleum odor |
| 54 | | | | | | |
| | | | J-6 | 38<br>50 | SS | 0.8/0.8 recovery<br>refusal at 9" |
| 56 | | | | | RD | |
| 58 | SM | 58.0-76.0 SILTY TAR SAND: black, dense to very dense, trace gravel, highly petroliferous | C-11 | 113 | DR | refusal at 6"<br>1-11-84 |
| | | | | | RD | 1-12-84<br>petroleum odor |
| 60 | | | PB 6 | | PB | 2.5/2.5 recovery |
| 62 | | | | | | |
| | | | | | RD | |
| | | gravel lenses | J-7 | 25<br>50 | SS | refusal at 11" |
| 64 | | | | | RD | |
| | | | PB 7 | | PB | 2.4/2.5 recovery |
| 66 | | | | | | |
| 68 | | | | | RD | |

Sheet 3 of 4

**Project** DESIGN UNIT A250 **Date Drilled** 1-12-84 **Hole No.** 19-7

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SM | 58.0-76.0 SILTY TAR SAND: continued | | 108 | DR | refusal at 6" |
| | | | | | RD | |
| 70 | | | PB 8 | | PB | 2.5/2.5 recovery |
| 72 | | thin gravel lenses | J-8 | 50 | SS | refusal at 4.5"<br>4.5/4.5 recovery |
| 74 | | | | | RD | |
| | | | PB 9 | | PB | 1.9/2.5 recovery |
| 76 | SP<br>SM | 76.0-78.0 TAR SAND/SILTY TAR SAND: black, with gravel, very dense | | | | |
| | | | C-13 | 121 | DR | petroleum odor<br>refusal at 6" |
| 78 | ML | 78.0-87.0 CLAYEY TAR SILT: black, very stiff to hard, trace gravel, highly petroliferous | | | RD | 0.5/0.5 recovery |
| 80 | | | PB 10 | | PB | 2.5/2.5 recovery |
| 82 | | | | | | |
| | | | J-9 | 44<br>50 | SS | 0.8/0.8 recovery<br>refusal at 9" |
| 84 | | | | | RD | |
| 86 | | | PB 11 | | PB | 2.5/2.5 recovery |
| | ML<br>CL | 87.0-91.0 CLAYEY TAR SILT/SILTY TAR CLAY: brownish black, containing sand, moist, petroliferous | C-14 | 31<br>85 | DR | petroleum odor |
| 88 | | | PB 12 | | PB | 2.5/2.5 recovery |
| 90 | | | | | | finished drilling 1-12- |
| 92 | | END OF BORING 91.0' 4 sac/70 gallon backfill | | | | **Sheet** 4 **of** 4 |

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# BORING LOG 20-A

**Proj:** DESIGN UNIT A 250
**Date Drilled** 10-24-83
**Ground Elev.** ±165'
**Drill Rig** BUCKET AUGER
**Logged By** J. Stellar
**Total Depth** 46'
**Hole Diameter** 32"
**Hammer Weight & Fall**

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.5 ASPHALT<br>FILL<br>0.5-1.5 BASE MATERIAL: sand and gravel | | | | hole stood well from 0' to 46'-no caving |
| 2 | ML | ALLUVIUM<br>1.5-6.0 CLAYEY SILT: dark grey brown and orange brown; moist; stiff; with laminations of clayey sand | | | | |
| 4 | | | | | | |
| 6 | SM | 6.0-11.0 SILTY SAND: medium brown; medium dense; very moist; with gravel | | | | |
| 8 | | | | | | |
| 10 | | | | | | |
| | ML | 11.0-14.0 CLAYEY SILT: blue grey, stiff; moist | | | | |
| 12 | | | | | | |
| 14 | ML | 14.0-19.0 SANDY SILT: dark grey; firm to stiff; moist; very slight tar content | | | | petroleum odor at 14' |
| 16 | | | | | | |
| 18 | | | | | | |
| | ML | 19.0-23.0 SILT: blue grey; stiff; moist | | | | |
| 20 | | | | | | |

Sheet 1 of 3

**Project** DESIGN UNIT A-250 **Date Drilled** 10-24-83 **Hole No.** 20A

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | ML | 19.0-23.0 SILT: (continued) | | | | |
| 22 | | | | | | |
| | SP | 23.0-46.0 TAR SAND: black; loose | | | | |
| 24 | | | | | | |
| | | 25.0-28.0 very dense tar layer | | | | hard, slow drilling @ 25' |
| 26 | | | | | | |
| 28 | | | | | | |
| 30 | | 30.0-32.0 concrete tieback | | | | very hard, slow drilling |
| | | | | | | ½% LEL reading |
| 32 | | | | | | |
| 34 | | becomes very loose | | | | |
| 36 | | | | | | |
| 38 | | | | | | |
| 40 | | | | | | |
| 42 | | | | | | |
| 44 | | | | | | |

**Sheet** 2 **of** 3

Project DESIGN UNIT A 250 Date Drilled 10-24-83 Hole No. 20A

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SP | 23.0-46.0 TAR SAND: (continued) | | | | |
| 46 | BH | 46.0' Terminated Hole | | | | End of bearing at 45' due to inability to case below 30' ½% LEL gas reading<br>no downhole inspection |
| 48 | | | | | | |
| 50 | | | | | | |
| 52 | | | | | | |
| 54 | | | | | | |
| 56 | | | | | | |
| 58 | | | | | | |
| 60 | | | | | | |
| 62 | | | | | | |
| 64 | | | | | | |
| 66 | | | | | | |
| 68 | | | | | | |

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

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**Geo/Resource Consultants**

# BORING LOG 20-1

**Proj:** DESIGN UNIT A250
**Date Drilled** 1-24-84
**Ground Elev.** 168.0'
**Drill Rig** Failing 1500
**Logged By** M. Schluter
**Total Depth** 129.5'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 140 lbs. @ 30"; 320 lbs. @ 18"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.2 A.C. PAVEMENT | | | C | started drilling @ 0730 |
| | SW<br>SM | ALLUVIUM<br>0.2-2.0 SAND/SILTY SAND: grayish black, with gravel, moist, medium dense | C-1 | 10<br>11 | DR | |
| 2 | SC<br>CL. | 2.0-7.0 SANDY CLAY/CLAYEY SAND: moderate brown, medium dense to dense/hard; moist, trace gravel | | | A | |
| 4 | | | J-1 | 10<br>18<br>20 | SS | 1.5/1.5 recovery |
| 6 | | | | | RD | |
| 8 | SW<br>SM | 7.0-12.0 SAND/SILTY SAND: dark yellowish brown, moist, medium dense, contains gravel | C-2 | 10<br>17 | DR | |
| 10 | | | PB 1 | | PB | 2.5/2.5 recovery |
| 12 | SC | 12.0-17.0 CLAYEY SAND: mottled dark yellowish green, moist, medium dense, petroliferous inclusions, trace gravel | C-3 | 6<br>6 | DR | |
| 14 | | | | | RD | |
| | | | J-2 | 6<br>6<br>10 | SS | 0.3/1.5 recovery |
| 16 | | | | | RD | |
| 18 | SW<br>SM | 17.0-21.0 SAND/SILTY SAND: light olive gray, moist, medium dense, trace gravel, black petroliferous inclusions | C-4 | 7<br>14 | DR | |
| 20 | | | | | | |

Sheet 1 of 6

**Project** DESIGN UNIT A250 **Date Drilled** 1-24-84 **Hole No.** 20-1

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | SW<br>SM | 17.0-21.0 SAND/SILTY SAND: continued | PB 2 |  | PB |  |
|  | CH | 21.0-25.0 SILTY CLAY: mottled dusky green and moderate olive brown, with sand, firm, moist |  |  |  |  |
| 22 |  |  |  |  |  |  |
|  |  |  | C-5 | 17 | DR | 2.2/2.5 recovery |
|  |  |  |  | 26 |  |  |
| 24 |  |  |  |  | RD |  |
|  | ML<br>CL | 25.0-31.0 CLAYEY SILT/SILTY CLAY: grayish olive green, with sand, moist, very stiff | J-3 | 4 | SS | 0.8/1.5 recovery |
|  |  |  |  | 8 |  |  |
| 26 |  |  |  | 11 |  |  |
| 28 |  |  | C-6 | 24 | DR |  |
|  |  |  |  | 30 |  |  |
|  |  |  |  |  | RD |  |
| 30 |  |  | PB 3 |  | PB |  |
|  | ML | 31.0-36.0 SANDY TAR SILT: brownish black, stiff, moist, highly petroliferous |  |  |  | 2.2/2.5 recovery<br>petroleum odor |
| 32 |  |  |  |  |  |  |
|  |  |  | C-7 | 39 | DR | refusal at 11" |
|  |  |  |  | 62 |  |  |
| 34 |  |  |  |  | RD |  |
|  |  |  | PB 4 |  | PB |  |
| 36 | SP<br>SM | 36.0-56.0 TAR SAND/SILTY TAR SAND: black, very dense, highly petroliferous |  |  |  | 1.6/2.5 recovery |
|  |  |  | J-4 | 23 | SS | refusal at 17" |
| 38 |  |  |  | 38 |  |  |
|  |  |  |  | 50 |  |  |
|  |  |  |  |  | RD | petroleum odor |
| 40 |  |  | PB 5 |  | PB |  |
| 42 |  |  |  |  |  | 2.5/2.5 recovery |
|  |  |  | C-8 | 60 | DR | refusal at 10" |
|  |  |  |  | 76 |  |  |
| 44 |  |  |  |  | RD |  |

Sheet 2 of 6

**Project** DESIGN UNIT A250 **Date Drilled** 1-24-84 **Hole No.** 20-1

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SP<br>SM | 36.0-56.0 TAR SAND/SILTY TAR SAND: cont. | | | RD | |
| | | | PB 6 | | PB | 2.5/2.5 recovery |
| 46 | | | | | | |
| | | 47.0-54.0 thin gravel lenses | | | | |
| 48 | | | J-5 | 26<br>53 | SS | 0.9/1.0 recovery<br>refusal at 12" |
| | | | | | RD | |
| 50 | | | | | | |
| | | | PB 7 | | PB | |
| 52 | | | | | | |
| | | | C-9 | 75<br>70 | DR | 2.4/2.5 recovery<br>refusal at 9" |
| | | | | | RD | |
| 54 | | | | | | |
| | | | PB 8 | | PB | petroleum odor<br>1.8/2.5 recovery |
| 56 | SM | 56.0-62.5 SILTY TAR SAND: black, dense to very dense, occasional thin gravel lenses, highly petroliferous | | | | |
| 58 | | | J-6 | 25<br>53 | SS | 0.9/1.0 recovery<br>refusal at 12" |
| | | | | | RD | |
| 60 | | | | | | |
| | | | PB 9 | | PB | |
| 62 | | | | | | |
| | Pt | 62.5-63.0 PEATY DEPOSIT: reed grass, decomposed, portions recognizable | J-7 | 55 | DR | 2.3/2.5 recovery |
| | SP<br>SM | 63.0-72.0 TAR SAND/SILTY TAR SAND: black, dense to very dense, contains gravel, highly petroliferous | C-10 | 75 | | refusal at 11" |
| 64 | | | | | RD | |
| | | | PB 10 | | PB | petroleum odor |
| 66 | | | | | | 2.5/2.5 recovery<br>refusal at 6" |
| | | | J-8 | 61 | SS | 0.4/0.5 recovery |
| 68 | | | | | | |

Project DESIGN UNIT A250 Date Drilled 1-24-25-84 Hole No. 20-1

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SP<br>SM | 63.0-72.0 TAR SAND/SILTY TAR SAND: cont. | | | | |
| 70 | | | PB 11 | | PB | |
| 72 | SW<br>SM | 72.0-81.0 TAR SAND/SILTY TAR SAND: black, very dense, with gravel, highly petroliferous | C-11 | 150 | DR | 2.2/2.5 recovery<br>refusal at 5" |
| | | | | | RD | 1-24-84<br>1-25-84<br>petroleum odor |
| 74 | | | | | | |
| 76 | | | PB 12 | | PB | |
| | Pt | 77.3-77.6 PEATY DEPOSIT: decaying organic material, dusky yellowish brown | J-9 | 73 | SS | 2.2/2.5 recovery<br>refusal at 6"<br>0.5/0.5 recovery |
| 78 | SW<br>SM | | | | | |
| 80 | | | PB 13 | | PB | |
| | ML | 81.0-87.0 SANDY TAR SILT: black, very stiff to hard , trace gravel, highly petroliferous | | | | petroleum odor<br>2.5/2.5 recovery |
| 82 | | | C-12 | 99<br>50 | DR | refusal at 7"<br>0.5/0.6 recovery |
| 84 | | | | | | |
| 86 | | | PB 14 | | PB | |
| | ML<br>MH | 87.0-88.5 CLAYEY SILT: greenish black, contains sand, hard, petroleum saturation, with peaty deposits | J-10 | 21<br>36<br>50 | SS | 2.5/2.5 recovery<br>slight petroleum odor<br>refusal at 17"<br>1.3/1.4 recovery |
| 88 | SM | 88.5-92.0 SILTY TAR SAND: brownish black, dense to very dense, trace gravel, petroliferous | | | RD | |
| 90 | | | PB 15 | | PB | 2.5/2.5 recovery |
| 92 | | | | | | |

Sheet 4 of 6

**Project** DESIGN UNIT A250 **Date Drilled** 1-25-84 **Hole No.** 20-1

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | GW<br>GM | 92.0-97.0 SANDY TAR GRAVEL: black to brownish black, dense, highly petroliferous, with tar pockets | PB |  | PB | disturbed sample |
|  |  |  | C-13 | 142 | DR | refusal at 6"<br>petroleum odor |
|  |  |  |  |  | RD |  |
| 94 |  |  |  |  |  | heavy rig chatter |
|  |  |  | PB<br>16 |  | PB | 2.5/2.5 recovery |
| 96 |  |  |  |  |  |  |
| 98 | ML<br>MH | 97.0-106.0 CLAYEY TAR SILT/CLAYEY SILT: mottled dark greenish gray and black, contains sand, very stiff to hard, petroliferous | J-11 | 36<br>54 | SS | 0.9/1.0 recovery<br>refusal at 12"<br>petroleum odor |
|  |  |  |  |  | RD |  |
| 100 |  |  | PB<br>17 |  | PB |  |
| 102 |  | decreasing petroleum content with depth | C-14 | 37<br>54 | DR | 2.2/2.5 recovery |
| 104 |  | gradational contact |  |  |  |  |
|  |  |  | PB<br>18 |  | PB | 2.5/2.5 recovery<br>moderate petroleum odor |
| 106 |  | BEDROCK<br>106.0-129.5 SILTSTONE/CLAYSTONE: olive gray, with sand, very stiff to hard, massive, moist, gaseous, petroliferous, with tar filled fractures |  |  |  |  |
| 108 |  |  | J-12 | 21<br>54 | SS | 0.9/1.0 recovery<br>refusal at 12" |
|  |  |  |  |  | RD |  |
| 110 |  |  | PB<br>19 |  | PB |  |
| 112 |  |  |  |  |  | 2.4/2.5 recovery |
|  |  |  | C-15 | 45<br>70 | DR | refusal at 10" |
| 114 |  |  |  |  | RD |  |
| 116 |  |  | PB<br>20 |  | PB |  |

Sheet 5 of 6

Project DESIGN UNIT A250 Date Drilled 1-25-84 Hole No. 20-1

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 116 | | 106.0-129.5 SILTSTONE/CLAYSTONE: continued siltstone cobble, hard, olive gray, fresh | PB 20 | | PB | 2.3/2.5 recovery |
| 118 | | | | 150 | DR | refusal at 5" sample not recovered |
| | | | | | RD | |
| 120 | | | PB 21 | | PB | 2.0/2.0 recovery |
| 122 | | occasional siltstone cobbles, hard, fresh | | 48 | DR | |
| | | | C-16 | 65 | | |
| 124 | | | | | RD | |
| 126 | | | PB 22 | | PB | 2.0/2.5 recovery<br>rig chatter |
| 128 | | gravel/cobble lenses, hard, high degree of petroleum saturation within lenses | PB 23 | | PB | rig chatter<br>1.9/2.0 recovery |
| 130 | | END OF BORING 129.5' | | | | 1-25-84<br>1600 hrs 20% explosimeter reading @ top of fluid filled hole. |
| 132 | | | | | | |
| 134 | | | | | | |
| 136 | | | | | | |
| 138 | | | | | | |
| 140 | | | | | | |

Sheet 6 of 6

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

## BORING LOG 20-2

**Proj:** DESIGN UNIT A250
**Date Drilled** 1/26-27/84
**Ground Elev.** 166'
**Drill Rig** FAILING 1500
**Logged By** M. Schluter
**Total Depth** 130.0'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 325# @ 18"/140# @ 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.4 A. C. PAVING | | | C | started drilling @11:3 |
| | SM | 0.4-1.5 ALLUVIUM<br>SILTY SAND: moderate brown; moist loose | | | | |
| | | | | 4 | DR | |
| 2 | CL | 1.5-4.0 SILTY CLAY: dark grey; with sand; moist; firm | C-1 | 6 | 325 | |
| | | | | | A | |
| 4 | SC | 4.0-7.0 CLAYEY SAND: greyish green; medium dense to dense; moist | | 11 | SS | Hydrogen sulfide odor |
| | | | | 16 | 140 | 1.5/1.5 recovery |
| 6 | | | J-1 | 18 | | |
| | | | | | RD | |
| | CL | 7.0-18.0 SANDY CLAY: dark greenish grey; firm to stiff; moist | | | | |
| 8 | | | | 14 | DR | |
| | (SC) | becoming clayey sand | C-2 | 10 | 325 | |
| | | | | | RD | |
| 10 | | | PB 1 | | PB | |
| | | | | | | 2.5/2.5 recovery |
| 12 | | | | | | |
| | (CH) | | C-3 | 8 | DR | |
| | | | | 12 | 325 | |
| 14 | | | | | RD | |
| | | | | 7 | SS | |
| 16 | | | J-2 | 14 | 140 | |
| | | becoming hard | | 22 | RD | 1.5/1.5 recovery |
| 18 | | | | 11 | DR | |
| | SW/SM | 18.0-22.0 SAND/SILTY SAND: dark greenish grey; medium dense; moist; sulfurous odor | C-4 | 30 | 325 | |
| | | | | | RD | |

**Sheet** 1 **of** 6

**Project** DESIGN UNIT A250 **Date Drilled** 1/26-27/84 **Hole No.** 20-2

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | SW/<br>SM | 18.0-22.0 SAND/SILTY SAND: (cont.) | PB 2 | | PB | 2.5/2.5 recovery |
| 22 | ML/<br>CL | 22.0-25.0 CLAYEY SILT/SILTY CLAY: greenish black; with sand; firm ; moist | C-5 | 19<br>32 | DR<br>325 | slight petroleum odor |
| 24 | | | | | RD | |
| | SC | 25.0-30.0 CLAYEY SAND: greenish black; dense to very dense; moist; trace gravel | | 16<br>32 | SS<br>140 | |
| 26 | | | J-3 | 50 | | 1.5/1.5 recovery<br>petroleum odor |
| | | | | | RD | |
| 28 | | | C-6 | 32<br>61 | DR<br>325 | |
| | (CL) | increasing clay | | | | |
| | | | | | RD | |
| 30 | ML/<br>CL | 30.0-40.0 CLAYEY SILT/SILTY CLAY: greenish black; with sand; stiff; sulfurous odor; moist | PB 3 | | PB | 2.5/2.5 recovery |
| 32 | | tar - small infillings | C-7 | 39<br>72 | DR<br>325 | petroleum odor |
| 34 | | very stiff to hard<br>slight petroleum mottling | | | | |
| 36 | | | J-4 | 16<br>29<br>40 | SS<br>140 | 1.5/1.5 recovery |
| | | | | | RD | |
| 38 | | increasing petroleum content | C-8 | 37<br>62 | DR<br>325 | |
| 40 | ML | 40.0-44.0 CLAYEY TAR SILT: olive black; very stiff to hard; petroliferous | PB 4 | | PB | petroleum odor<br>2.5/2.5 recovery<br>0.4/1.4 recovery |
| 42 | | | | 16<br>30 | SS<br>140 | |
| 44 | | | J-5 | 50 | | |

**Sheet** 2 **of** 6

**Project** DESIGN UNIT A250 **Date Drilled** 1/26-27/84 **Hole No.** 20-2

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SP/<br>SM | 44.0-50.0 TAR SAND/SILTY TAR SAND: brownish black; dense; petroliferous | | | RD | petroleum odor |
| | | | PB 5 | | PB | |
| 46 | | | | | | 2.5/2.5 recovery |
| 48 | | | | 50 | DR | |
| | | | C-9 | 59 | | refusal @ 10" |
| 50 | SM | 50.0-64.0 SILTY TAR SAND: brownish black to black; with gravel; dense to very dense; thin gravel lenses | PB 6 | | PB | 2.0/2.5 recovery<br>petroleum odor |
| 52 | | | | 31 | SS | refusal @ 11" |
| | | | J-6 | 51 | 140 | 0.9/0.9 recovery |
| 54 | | | | | RD | |
| 56 | | | PB-7 | | PB | 1.7/2.5 recovery |
| 58 | | | | 57 | DR | refusal at 11" |
| | | | C-10 | 75 | 325 | |
| | | | | | RD | |
| 60 | | gravel and gravel lenses | PB 8 | | PB | |
| 62 | | | | | | 2.4/2.5 recovery |
| | | | | 27 | SS | |
| | | | J-7 | 40 | 140 | 1-26-84 |
| 64 | | | | 50 | | |
| | ML | 64.0-70.0 SANDY TAR SILT: brownish black; very stiff to hard; trace gravel highly petroliferous | | | RD | 1-27-84<br>petroleum odor |
| 66 | | | PB 9 | | PB | 2.0/2.5 recovery |
| 68 | | | | 55 | DR<br>325 | |

Sheet 3 of 6

**Project** DESIGN UNIT A250 **Date Drilled** 1-27-84 **Hole No.** 20-2

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | ML | 64.0-70.0 SANDY TAR SILT: (cont) | C-11 | 70 | DR | |
| | | | | | RD | |
| 70 | SP/SM | 70.0-82.0 TAR SAND/SILTY TAR SAND: black; dense to very dense; highly petroliferous | PB10 | | PB | 2.5/2.5 recovery |
| 72 | | | | | | petroleum odor |
| | | | | 45 | SS | refusal @ 10" |
| | | | J-8 | 50 | 140 | |
| 74 | | | | | RD | 0.9/0.9 recovery |
| 76 | | | PB 11 | | PB | 2.5/2.5 recovery |
| 78 | | | C-12 | 122 | DR | refusal at 6" |
| 80 | | | PB 12 | | PB | |
| | | | | | | 2.5/2.5 recovery |
| 82 | | | | | | refusal at 4.5" |
| | SW/SM | 82.0-86.0 TAR SAND/SILTY TAR SAND: black; dense to very dense; trace gravel; highly petroliferous | J-9 | 50 | SS | 0.4/0.4 recovery |
| | | | | | 140 | petroleum odor |
| 84 | | | | | | |
| | | | PB 13 | | PB | |
| 86 | ML | 86.0-92.5 SANDY TAR SILT/CLAYEY TAR SILT: black; very stiff to hard; trace gravel; highly petroliferous | | | | 2.2/2.5 recovery |
| | | | | | | refusal at 8" |
| | | | C-13 | 75 | DR | |
| 88 | | | | 75 | 325 | petroleum odor |
| 90 | | | PB 14 | | PB | 2.5/2.5 recovery |
| 92 | | | | | | |

Sheet 4 of 6

**Project** DESIGN UNIT A250 **Date Drilled** 1-27-84 **Hole No.** 20-2

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | ML | 86.0-96.5 SANDY TAR SILT/CLAYEY TAR SILT: (cont.) | | | PB | |
| | | | J-10 | 50 | SS | refusal at 3" |
| | GW/ GM | 92.5-95.5 SANDY TAR GRAVEL: black; dense to very dense; highly petroliferous | | | 140 | 0.25/0.25 recovery |
| 94 | | | | | RD | petroleum odor |
| | CL | 95.5-98.0 SILTY CLAY: dark greenish grey; with sand; very stiff;moist | | | | |
| 96 | | | PB15 | | PB | |
| | | | | | | 2.2/2.5 recovery |
| 98 | | 98.0-130.0 BEDROCK SILTSTONE/CLAYSTONE:dark greenish grey; contains sand; very stiff to hard; massive | | 20 | DR | |
| | | | C-14 | 39 | 325 | |
| | | | | | RD | |
| 100 | | | PB16 | | PB | |
| 102 | | fractures 45°-70° | | | | 1.5/2.5 recovery |
| | | shell and shell fragments | | 20 | DR | |
| | | | C-15 | 40 | 325 | |
| 104 | | | | | RD | |
| | | | PB 17 | | PB | |
| 106 | | | | | | |
| | | | | | | 1.5/2.5 recovery |
| | | | | 24 | DR | |
| 108 | | color change to olive black | | | | slight petroleum odor |
| | | | C-16 | 63 | 325 | |
| 110 | | | PB 18 | | PB | |
| 112 | | | | | | 1.5/2.5 recovery |
| | | | | 26 | DR | |
| | | occasional tar and petroleum inclusions | C-17 | 55 | 325 | |
| 114 | | | | | | |
| 116 | | | PB 19 | | PB | |

Project DESIGN UNIT A250 Date Drilled 1-27-84 Hole No. 20-2

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 116 | 98 | 0-130.0 SILTSTONE/CLAYSTONE: (cont.) | PB19 |  | PB | 2.5/2.5 recovery |
| 118 |  |  |  | 22 | DR |  |
|  |  |  | C-18 | 43 | 325 |  |
|  |  |  |  |  | RD |  |
| 120 |  | Tar/Petroleum inclusions |  |  |  |  |
|  |  |  | PB20 |  | PB | 1.5/2.5 recovery |
| 122 |  |  |  |  |  |  |
|  |  |  |  | 36 | DR |  |
|  |  |  | C-19 | 49 | 325 |  |
| 124 |  |  |  |  | RD |  |
| 126 |  |  | PB21 |  | PB | 2.0/2.5 recovery |
| 128 |  |  | PB22 |  | PB | 1.6/2.5 recovery |
| 130 | BH | 130.0' Terminated Hole |  |  |  | 1-27-84<br>Hole produced near/surface hydrogen sulfide odors after slurry placement |
| 132 |  |  |  |  |  |  |
| 134 |  |  |  |  |  |  |
| 136 |  |  |  |  |  |  |
| 138 |  |  |  |  |  |  |
| 140 |  |  |  |  |  |  |

Sheet 6 of 6

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 20-3

**Proj:** DESIGN UNIT A250 **Date Drilled** 2/8-9/84 **Ground Elev.** 20-3

**Drill Rig** ~~FAILING 1500~~ **Logged By** M. Schluter **Total Depth** 120.0'

**Hole Diameter** 4 7/8" **Hammer Weight & Fall** 325# @ 18"/140# @30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.3 A. C. PAVEMENT | | | C | started Drilling 0730 |
| | CL | 0.3-4.0 ALLUVIUM<br>SANDY CLAY: brownish black; soft to firm; moist | | | | |
| 2 | | | | | A | |
| 4 | SC | 4.0-9.0 CLAYEY SAND: dark yellowish brown; medium dense; moist | | | | |
| | | | | 5 | DR | |
| 6 | | | C-1 | 11 | 325 | |
| 8 | | | | | RD | |
| | CL | 9.0-14.0 SANDY CLAY: light olive grey; firm to stiff; moist | | | | |
| 10 | | | | 5 | SS | 1.0/1.5 recovery |
| | | | | 6 | 140 | |
| | | | J-1 | 9 | | |
| 12 | | | | | | |
| 14 | SM | 14.0-19.0 SILTY SAND: light olive grey; medium dense; slightly moist to moist | | | | |
| | | | | 11 | DR | |
| | | | C-2 | 14 | 325 | |
| 16 | | | | | RD | |
| 18 | | | | | | |
| | CL | 19.0-29.0 SANDY CLAY: | | | | |

Sheet 1 of 6

**Project** DESIGN UNIT A250 **Date Drilled** 2-8-84 **Hole No.** 20-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CL | 19.0-29.0 SANDY CLAY: mottled dark greenish grey and medium bluish grey; moist stiff to very stiff | | 6 | SS | 1.5/1.5 recovery |
| | | | | 9 | | |
| | | | J-2 | 14 | | |
| 22 | | | | | RD | |
| 24 | | | | | | |
| | | | | 21 | DR | |
| 26 | | | C-3 | 25 | 325 | |
| | | | | | RD | |
| 28 | | | | | | |
| | SP/ SM | 29.0-30.5 SAND/SILTY SAND: dark greenish grey; medium dense | | | | |
| 30 | | | | 9 | SS | |
| | CL | 30.5/35.0 SILTY CLAY: dark greenish grey; with sand; moist; very stiff to hard | J-3 | 15 | 140 | 1.3/1.5 recovery |
| | | | | 20 | | |
| 32 | | | | | RD | |
| 34 | | | | | | |
| | SC | 35.0-45.0 CLAYEY SAND: dark greenish grey; little gravel; cemented inclusions; medium dense to dense; moist; pettroleum inclusions | | 28 | DR | |
| | | | C-4 | 41 | 325 | |
| 36 | | | | | RD | hydrogen sulfide odor |
| 38 | | | | | | |
| 40 | | | | 7 | SS | |
| | | becoming very dense | J-4 | 19 | 140 | 1.5/1.5 recovery |
| | | | | 36 | | |
| 42 | | | | | RD | |

**Project** DESIGN UNIT A250 **Date Drilled** 2-8-84 **Hole No.** 20-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SC | 35.0-45.0 CLAYEY SAND: (continued) | | | RD | |
| | CL | 45.0-49.0 SANDY CLAY: greenish black; stiff; moist; sulfur odor | C-5 | 28<br>48 | DR<br>325 | |
| 46 | | | | | RD | |
| 48 | | | | | | |
| | SW/SM | 49.0-51.0 TAR SAND/SILTY TAR SAND: brownish black; dense to very dense; trace gravel; petroliferous | | | | |
| 50 | | | | 33<br>32 | SS<br>140 | petroleum odor<br>1.4/1.5 recovery |
| | CL | 51.0-55.0 SANDY CLAY: dark greenish grey; stiff; moist; petroleum inclusions | J-5 | 46 | | |
| 52 | | | | | RD | |
| 54 | | | | | | |
| | ML | 55.0-60.0 SANDY SILT: dark greenish grey; moist; stiff | C-6 | 20<br>32 | DR<br>325 | |
| 56 | | | | | | |
| | | | | | RD | |
| 58 | | | | | | |
| 60 | SP/SM | 60.0-69.0 TAR SAND/SILTY TAR SAND: dark greenish grey and brownish black; dense to very dense; petroliferous | J-6 | 31<br>50 | SS<br>140 | refusal @ 10" |
| | | | | | RD | 0.7/0.9 recovery<br>petroleum odor |
| 62 | | | | | | |
| 64 | | color change to black; trace gravel highly petroliferous | | | | |
| | | | C-7 | 76<br>75 | DR<br>325 | refusal @ 9" |
| 66 | | | | | RD | |
| 68 | | | | | | |

**Project** DESIGN UNIT A 250 **Date Drilled** 2/8-9/84 **Hole No.** 20-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SP/ SM | 60.0-69.0 TAR SAND/SILTY TAR SAND: (cont) | | | RD | rig chatter |
| | SW/ SM | 69.0-79.0 GRAVELLY TAR SAND/SILTY TAR SAND: brownish black; dense to very dense; petroliferous | | | | |
| 70 | | | J-7 | 52 | SS<br>140 | refusal at 6"<br>0.4/0.5 recovery<br>petroleum odor |
| | | | | | RD | |
| 72 | | | | | | |
| 74 | | | | | | |
| | | highly petroliferous | | 66 | DR | |
| | | | C-8 | 60 | 325 | refusal at 9" |
| 76 | | | | | RD | |
| 78 | | | | | | minor rig chatter |
| | | | | | | petroleum odor |
| | ML | 79.0-85.0 SANDY TAR SILT: black; very stiff to hard; trace gravel; highly petroliferous | | | | |
| 80 | | | | 41 | SS | refusal @ 9" |
| | | | J-8 | 50 | 140 | 0.6/0.9 recovery |
| 82 | | | | | RD | |
| 84 | | | | | | |
| | SP/ SM | 85.0-90.0 TAR SAND/SILTY TAR SAND: black; dense to very dense; highly petroliferous | C-9 | 150 | DR<br>325 | refusal at 6" |
| 86 | | | | | RD | petroleum odor |
| 88 | | | | | | |
| 90 | SW | 90.0-94.0 GRAVELLY TAR SAND: black; dense to very dense | J-9 | 62 | SS<br>140 | refusal at 6"<br>0.2/0.5 recovery |
| 92 | | | | | | |

**Project** DESIGN UNIT A250 **Date Drilled** 2-9-84 **Hole No.** 20-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | SW | 90.0-94.0 GRAVELLY TAR SAND: (cont.) highly petroliferous | | | RD | started drilling 2-9-84 |
| | | | | | | petroleum odor |
| 94 | ML | 94.00-104.0 SANDY TAR SILT: black; very stiff to hard; with gravel; highly petroliferous | | 70 | DR | refusal @ 8" |
| | | | C-10 | 70 | 325 | |
| 96 | | | | | RD | |
| 98 | | | | | | |
| 100 | | | | 33 | SS | refusal @ 8" |
| | | | J-10 | 50 | 140 | 0.5/0.6 recovery |
| 102 | | | | | | |
| | | gravel and gravel lenses | | | RD | |
| | | | | | | rig chatter |
| 104 | | 104.0-120.0 BEDROCK SILTSTONE/CLAYSTONE: dark greenish grey; with sand; moist; very stiff to hard; massive;shell fragments; petroliferous | | 33 | DR | slight petroleum odor |
| | | | C-11 | 73 | 325 | |
| 106 | | | | | RD | |
| 108 | | | | | | |
| 110 | | | | 27 | SS | |
| | | fractures 40°-65° | | 42 | 140 | refusal @ 16"<br>1.4/1.5 recovery |
| | | | J-11 | 50 | | |
| 112 | | gaseous | | | RD | |
| 114 | | | | | | |
| | | | | 27 | DR | refusal @ 10" |
| 116 | | | C-12 | 60 | 325 | |

**Sheet** 5 **of** 6

**Project** DESIGN UNIT A250 **Date Drilled** 2-9-84 **Hole No.** 20-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 116 | | 104.0-120.0 SILTSTONE/CLAYSTONE: (continued) | | | RD | |
| 118 | | | | | | |
| | | | | 37 | DR | |
| | | | C-13 | 71 | | 2-9-84 |
| 120 | B.H | 120.0' Terminated Hole | | | | Tremied4 sac/95 gal. slurry mix into hole |
| 122 | | | | | | |
| 124 | | | | | | |
| 126 | | | | | | |
| 128 | | | | | | |
| 130 | | | | | | |
| 132 | | | | | | |
| 134 | | | | | | |
| 136 | | | | | | |
| 138 | | | | | | |
| 140 | | | | | | |

**Sheet** 6 **of** 6

**Converse Consultants, Inc.**
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# BORING LOG 20-4

**Proj:** DESIGN UNIT A250 **Date Drilled** 2-1-84 **Ground Elev.** 20-4

**Drill Rig** FAILING 1500 **Logged By** M. Schluter **Total Depth** 121.0'

**Hole Diameter** 4 7/8" **Hammer Weight & Fall** 325 lbs. @ 18", 140 lbs. @ 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.6 CONCRETE CURBING | | | C | started drilling @ 0715 |
| | SC | 0.6-9.0 ALLUVIUM<br>CLAYEY SAND: dusky yellow; moist; loose to medium dense; trace gravel | | | A | |
| 2 | | | | | | |
| 4 | | | | | | |
| | | | | 20 | DR | |
| | | | C-1 | 42 | 325 | |
| 6 | | | | | RD | |
| 8 | | | | | | |
| | CL | 9.0-15.0 CLAY/SANDY CLAY: yellowish grey; moist; firm to stiff; occasional petroliferous inclusions | | | | |
| 10 | | | | 4 | SS | |
| | | | | 6 | 140 | |
| | | | J-1 | 9 | | |
| 12 | | | | | RD | 1.5/1.5 recovery |
| 14 | | | | | | |
| | | | | 6 | DR | |
| | CL | 15.0-18.0 SILTY CLAY: greyish green; contains sand; moist; firm to stiff; rootlets | | | 325 | |
| 16 | | | C-2 | 10 | | |
| | | | | | RD | |
| | | | | | | minor rig chatter |
| 18 | | | | | | |
| | SP/SM | 18.0-24.0 SAND/SILTY SAND: | | | | |

**Project** DESIGN UNIT A250 **Date Drilled** 2-1-84 **Hole No.** 20-4

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | SP/ SM | 18.0-24.0 SAND/SILTY SAND: dusky green; very dense; moist | | 8 | SS | |
| | | | | 24 | 140 | 1.5/1.5 recovery |
| | | | J-2 | 33 | | |
| 22 | | | | | RD | |
| 24 | SC | 24.0-45.0 CLAYEY SAND: dusky green; medium dense; trace gravel; sulfurous odor; trace rootlets | | | | |
| | | | | 26 | DR | |
| 26 | | | C-3 | 42 | 325 | |
| | | | | | RD | |
| 28 | | | | | | |
| 30 | | | | 4 | SS | |
| | | | | 9 | 140 | |
| | | | J-3 | 14 | | |
| 32 | | | | | RD | 1.4/1.5 recovery |
| 34 | | coarse gravel | | | | |
| | | | | 20 | DR | |
| 36 | | | C-4 | 26 | 325 | |
| | | | | | RD | |
| 38 | | | | | | |
| 40 | | becoming very dense | | 10 | SS | 1.5/1.5 recovery |
| | | | | 21 | 140 | |
| | | | J-4 | 36 | | |
| 42 | | | | | RD | |
| 44 | | | | | | |

**Sheet** 2 **of** 6

**Project** DESIGN UNIT A250 **Date Drilled** 2-1-84 **Hole No.** 20-4

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SC | 24.0-45.0 CLAYEY SAND: (continued) | | | RD | |
| | CL | 45.0-50.0 SANDY CLAY: dusky green; stiff to very stiff; trace gravel; sulfurous odor; organic inclusions | C-5 | 23<br>28 | DR<br>325 | |
| 46 | | | | | RD | |
| 48 | | | | | | |
| 50 | SC | 50.0-58.0 CLAYEY SAND: dusky green; dense to very dense; trace gravel; sulfurous odor | J-5 | 8<br>22<br>29 | SS<br>140 | 1.4/1.5 recovery |
| 52 | | | | | RD | |
| 54 | | | | | | |
| | | | C-6 | 11<br>39 | DR<br>325 | |
| 56 | | | | | RD | |
| 58 | CL | 58.0-65.0 CLAY/SANDY CLAY: dusky green; very stiff to hard; moist; trace petroleum inclusions | | | | |
| 60 | | | J-6 | 9<br>19<br>31 | SS<br>140 | 1.5/1.5 recovery |
| 62 | | | | | RD | |
| | | | | | | minor rig chatter refusal @ 8" |
| 64 | SP/<br>SM | 65.0-79.0 SAND/SILTY SAND: medium grey to medium dark grey; dense to very dense | C-7 | 75<br>50 | DR<br>325 | |
| 66 | | | | | | |
| 68 | | | | | | |

Project DESIGN UNIT A250 Date Drilled 2-1-84 Hole No. 20-4

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SP/<br>SM | 65.0-69.0 SAND/SILTY SAND: (cont.) | | | RD | |
| 70 | | | J-7 | 61 | SS<br>140 | refusal @ 6" |
| 72 | | gravel | | | RD | |
| 74 | | | | | | |
| | | | C-8 | 135 | DR<br>325 | refusal @ 6" |
| 76 | | | | | RD | |
| 78 | | | | | | |
| | SM | 79.0-89.0 SILTY SAND: medium dark grey; dense to very dense; with gravel | | | | |
| 80 | | | J-8 | 65 | SS<br>140 | refusal @ 6" |
| 82 | | sulfurous odor; trace petroleum | | | | |
| 84 | | | | | | |
| | | | C-9 | 118 | DR<br>325 | refusal @ 6" |
| 86 | | | | | | |
| 88 | | | | | | |
| | ML | 89.0-93.0 CLAYEY SILT: dark greenish grey; contains sand; very stiff to hard; moist | | | | |
| 90 | | | | 13<br>16 | SS<br>325 | |
| | | | J-9 | 17 | | |
| 92 | | | | | | |

Sheet 4 of 6

**Project** DESIGN UNIT A250 **Date Drilled** 2-1-84 **Hole No.** 20-4

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | ML | 89.0-93.0 CLAYEY SILT: (continued) | | | RD | |
| | SW/SM | 93.0-99.0 TAR SAND/SILTY TAR SAND:black; dense to very dense; contains gravel; highly petroliferous | | | | |
| 94 | | | | | | |
| | | | C-10 | 125 | DR<br>325 | petroleum odor<br>refusal @ 6" |
| 96 | | | | | | |
| | | | | | RD | |
| 98 | | | | | | |
| | SM | 99.0-104.00 SILTY TAR SAND:black; dense to very dense; trace gravel; highly petroliferous | | | | |
| 100 | | | J-10 | 60 | SS<br>140 | refusal @ 6"<br>petroleum odor |
| 102 | | | | | | |
| 104 | ML | 104.0-109.0 SANDY TAR SILT: brownish black; dense to very dense; with gravel; petroliferous | | | | |
| | | | C-11 | 128 | DR<br>325 | refusal @ 6" |
| 106 | | | | | RD | |
| 108 | | | | | | |
| | SP/SM | 109.0-113.0 TAR SAND/SILTY TAR SAND: black dense to very dense; trace gravel; highly petroliferous | | | | |
| 110 | | | J-11 | 80 | SS<br>140 | refusal @ 5"<br>petroleum odor |
| 112 | | | | | RD | occasional rig chatter |
| | GC | 113.0-117.0 CLAYEY GRAVEL: greyish olive green; dense to very dense | | | | |
| 114 | | | C-12 | 150 | DR<br>325 | refusal @ 4.5"<br>slight petroleum odor |
| 116 | | | | | | |

**Project** DESIGN UNIT A250 **Date Drilled** 2-1-84 **Hole No.** 20-4

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 116 | GC | 113.0-117.0 CLAYEY GRAVEL:(Cont.) | | | RD | |
| | CL | 117.0-121.0 SILTY CLAY: olive grey; with sand; very stiff to hard; moist | | | | |
| 118 | | | | | | |
| | | | | 13 | SS | |
| 120 | | | J-12 | 21 | | |
| | | | | 27 | | |
| | B.H. | 121.0' Terminated Hole | | | | 2-1-84, 5 sac/90 gal. slurry backfill, 30' piezometer well (10 foot perforated section) casing with steel cap |
| 122 | | | | | | |
| 124 | | | | | | |
| 126 | | | | | | |
| 128 | | | | | | |
| 130 | | | | | | |
| 132 | | | | | | |
| 134 | | | | | | |
| 136 | | | | | | |
| 138 | | | | | | |
| 140 | | | | | | |

**Sheet** 6 **of** 6

**Converse Consultants, Inc.**
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# BORING LOG 20-5

**Proj:** DESIGN UNIT A250
**Date Drilled** 1-30-84
**Ground Elev.** 168.0'
**Drill Rig** Failing 1500
**Logged By** M. Schluter
**Total Depth** 111.0'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** SS: 140 lbs @ 30"; DR 325 lbs @ 18

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.2 A.C. PAVEMENT | | | C | started drilling at 1435 |
| | CL | ALLUVIUM<br>0.2-3.0 SANDY CLAY: olive black, soft, moist, contains gravel | | | | |
| 2 | | | | | A | |
| | CL | 3.0-8.0 SANDY CLAY: greenish black, firm to stiff, moist, slightly petroliferous with gravel | | | | petroleum odor |
| 4 | | | | | | |
| | | | C-1 | 5<br>18 | DR | |
| 6 | | | | | RD | |
| 8 | CL | 8.0-21.0 CLAY/SANDY CLAY: grayish green, firm to stiff, petroleum/tar inclusions | | | | |
| 10 | | | J-1 | 3<br>4<br>7 | SS | 1.5/1.5 recovery |
| 12 | | | | | | |
| 14 | | | | | | |
| | | with gravel | C-2 | 13<br>14 | DR | |
| 16 | | | | | | |
| 18 | | | | | | |

Sheet 1 of 5

**Project** DESIGN UNIT A250 **Date Drilled** 1-30/31-84 **Hole No.** 20-5

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CL | 8.0-21.0 CLAY/SANDY CLAY: contined | J-2 | 8<br>14<br>18 | SS | 1.5/1.5 recovery<br>1-30-84<br>1-31-84 |
|  | SM | 21.0-24.0 SILTY SAND: grayish green, medium dense, moist |  |  |  |  |
| 22 |  |  |  |  | RD |  |
| 24 | SC | 24.0-34.0 CLAYEY SAND: grayish green, medium dense to dense, moist, slight sulfurous odor, trace gravel |  |  |  |  |
|  |  |  | C-3 | 16<br>33 | DR |  |
| 26 |  |  |  |  |  |  |
|  |  |  |  |  | RD |  |
| 28 |  |  |  |  |  |  |
| 30 |  |  | J-3 | 9<br>17<br>18 | SS | 1.5/1.5 recovery |
| 32 |  |  |  |  | RD |  |
| 34 | CL | 34.0-45.0 SANDY CLAY: dusky green, stiff to very stiff, moist, sulfurous odor |  |  |  |  |
|  |  |  | C-4 | 11<br>26 | DR |  |
| 36 |  |  |  |  | RD |  |
| 38 |  |  |  |  |  |  |
| 40 |  | becoming hard | J-4 | 10<br>13<br>24 | SS | 1.5/1.5 recovery |
| 42 |  |  |  |  | RD |  |
| 44 |  |  |  |  |  |  |

**Sheet** 2 **of** 5

**Project** DESIGN UNIT A250 **Date Drilled** 1-31-84 **Hole No.** 20-5

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | CL | 34.0-45.0 SANDY CLAY: continued | | | RD | |
| | SC | 45.0-50.0 CLAYEY SAND: grayish green, medium dense, with gravel, moist; occasional small rootlets, trace tar inclusions | C-5 | 16<br>31 | DR | |
| 46 | | | | | RD | sulfurous odor |
| 48 | | | | | | |
| 50 | SW<br>SC | 50.0-54.0 SAND/CLAYEY SAND: dusky green, dense to very dense, little gravel | J-5 | 15<br>38<br>50 | SS | refusal at 17"<br>1.5/1.5 recovery<br>slight sulfurous odor |
| 52 | | | | | RD | |
| 54 | CL | 54.0-64.0 CLAY/SANDY CLAY: dusky green, moist, very stiff to hard | | | | |
| | | | C-6 | 21<br>31 | DR | |
| 56 | | | | | RD | |
| 58 | | | | | | |
| 60 | | | | 12<br>22<br>36 | SS | sample not recovered |
| 62 | | | | | RD | |
| 64 | SP | 64.0-70.0 SAND: grayish green, dense to very dense | | | | |
| | | | C-7 | 134 | DR | refusal at 6" |
| 66 | | | | | RD | |
| 68 | | | | | | |

**Sheet** 3 **of** 5

**Project** DESIGN UNIT A250 **Date Drilled** 1-31-84 **Hole No.** 20-5

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SP | 64.0-70.0 SAND: continued | | | RD | |
| 70 | SW<br>GW | 70.0-76.0 GRAVELLY SAND/SANDY GRAVEL: medium gray, moderately well cemented, very dense, alternating layers of variable hardness | | 65 | SS | refusal at 6"<br>sample not recovered<br>70.5 - rig chatter |
| | | | | | RD | |
| 72 | | | | | | |
| 74 | | | | | | |
| | | | C-8 | 105 | DR | refusal at 1.5" |
| 76 | SM | 76.0-84.0 SILTY SAND: medium dark gray to dark gray, very dense | | | RD | |
| 78 | | | | | | |
| 80 | | | J-6 | 41<br>50 | SS | refusal at 9" |
| | | | | | RD | |
| 82 | | | | | | |
| 84 | SM<br>SP | 84.0-99.0 SILTY TAR SAND/TAR SAND: mottled dark gray and black, dense to very dense, with gravel, petroliferous | | | | |
| | | | C-9 | 130 | DR | refusal at 6"<br>distrubed sample<br>petroleum odor |
| 86 | | | | | | |
| | | | | | RD | |
| 88 | | | | | | |
| | | gravel lenses | | | | rig chatter |
| 90 | | | | 83 | SS | refusal at 6"<br>sample not recovered |
| 92 | | | | | | |

**Sheet** 4 **of** 5

**Project** DESIGN UNIT A250 **Date Drilled** 1-31-84 **Hole No.** 20-5

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | SM<br>SP | 84.0-99.0 SILTY TAR SAND/TAR SAND: cont. | | | RD | |
| 94 | | | | | | |
| | | increasing petroleum content | C-10 | 137 | DR | refusal at 6"<br>disturbed sample |
| 96 | | | | | | |
| | | | | | RD | |
| 98 | | | | | | |
| | SW<br>SM | 99.0-104.0 TAR SAND/SILTY TAR SAND: black, very dense, with gravel, highly petroliferous | | | | |
| 100 | | | J-7 | 59 | SS | refusal at 6"<br>petroleum odor |
| 102 | | | | | | |
| 104 | SM | 104.0-110.0 SILTY TAR SAND: dark gray, dense to very dense, contains gravel, petroliferous<br>107.5-108.5 gravel layer | | | RD | |
| | | | C-11 | 73<br>50 | DR | petroleum odor<br>refusal at 9" |
| 106 | | | | | RD | |
| 108 | | | | | | |
| | | | J-8 | 17<br>27<br>39 | SS | petroleum odor<br>1-31-84 |
| 110 | CL | 110.0-111.0 SILTY CLAY: olive gray, with sand, very stiff to hard, slightly petroliferous, moist | | | | |
| | | END OF BORING 111.0'<br>4 sac/90 gallon backfill | | | | |
| 112 | | | | | | |
| 114 | | | | | | |
| 116 | | | | | | |

**Sheet** 5 **of** 5

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 20-6

**Proj:** DESIGN UNIT A250 **Date Drilled** 2-7-84 **Ground Elev.** 177.0'

**Drill Rig** Failing 1500 **Logged By** M. Schluter **Total Depth** 106.0'

**Hole Diameter** 4 7/8" **Hammer Weight & Fall** SS: 140 lbs @ 30"; DR: 325 lbs @ 18

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.2 A.C. PAVEMENT | | | C | started drilling at 0730 |
| | SC | ALLUVIUM<br>0.2-2.0 CLAYEY SAND: brownish black, loose, moist | | | A | |
| 2 | SC | 2.0-4.0 CLAYEY SAND: grayish olive green, loose, moist | | | | |
| 4 | CL<br>CH | 4.0-12.0 SANDY CLAY: grayish olive green, stiff, moist | | | | |
| | | | C-1 | 12<br>23 | DR | rotary wash |
| 6 | | | | | | |
| 8 | | with gravel | | | RD | |
| | | becoming very stiff | | | | |
| 10 | | | J-1 | 4<br>10<br>11 | SS | 1.5/1.5 recovery |
| 12 | CL | 12.0-17.0 SILTY CLAY: light olive gray, with sand, moist, firm to stiff, | | | RD | |
| 14 | | | | | | |
| | | | C-2 | 12<br>11 | DR | |
| 16 | | | | | | |
| | ML | 17.0-24.0 CLAYEY SILT: dark greenish gray, with fine sand, moist, stiff to very stiff, slight sulfurous odor | | | RD | |
| 18 | | | | | | |

Sheet 1 of 5

**Project** DESIGN UNIT A250 **Date Drilled** 2-7-84 **Hole No.** 20-6

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | ML | 17.0-24.0 CLAYEY SILT: continued | J-2 | 4<br>11<br>21 | SS | 1.5/1.5 recovery |
| 22 | | | | | RD | |
| 24 | CL | 24.0-30.0 SANDY CLAY: dark greenish gray. moist, firm to stiff, with gravel | C-3 | 12<br>22 | DR | |
| 26 | | | | | RD | |
| 28 | | | | | | |
| 30 | SC | 30.0-39.0 CLAYEY SAND: dark greenish gray, moist, dense, contains gravel, sulfurous odor, occasional clean sand lenses | J-3 | 7<br>15<br>21 | SS | 1.4/1.5 recovery |
| 32 | | | | | RD | |
| 34 | | | C-4 | 17<br>24 | DR | |
| 36 | | | | | RD | |
| 38 | | | | | | |
| | SC | 39.0-45.0 CLAYEY SAND: dark greenish gray, moist, dense, with gravel, slight sulfur odor | | | | |
| 40 | | | J-4 | 8<br>16<br>25 | SS | 1.5/1.5 recovery |
| 42 | | | | | RD | |
| 44 | | | | | | |

**Sheet** 2 **of** 5

**Project** DESIGN UNIT A250 **Date Drilled** 2-7-84 **Hole No.** 20-6

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SC | 39.0-45.0 CLAYEY SAND: continued | | | RD | |
| | CL | 45.0-53.0 SANDY CLAY: mottled dark greenish gray and greenish gray, moist, stiff to very stiff, sulfurous odor | C-5 | 18<br>24 | DR | |
| 46 | | | | | | |
| | | | | | RD | |
| 48 | | | | | | |
| 50 | | with gravel, becoming hard | J-5 | 12<br>17<br>27 | SS | 1.5/1.5 recovery |
| 52 | | | | | RD | |
| | SW<br>SM | 53.0-59.0 SAND/SILTY SAND: dark greenish gray, with gravel, dense to very dense | | | | |
| 54 | | | | | | |
| | | | C-6 | 107<br>40 | DR | refusal at 8" |
| 56 | | | | | RD | variable rig chatter |
| 58 | | | | | | |
| | CL | 59.0-65.0 CLAY: dark greenish gray, with sand, moist, very stiff to hard, trace gravel | | | | |
| 60 | | | J-6 | 21<br>22<br>28 | SS | 1.1/1.5 recovery |
| 62 | | | | | RD | |
| 64 | | | | | | |
| | SP<br>SM | 65.0-71.0 SAND/SILTY SAND: dark greenish gray, dense to very dense | C-7 | 63<br>60 | DR | refusal at 9" |
| 66 | | | | | RD | |
| 68 | | | | | | |

Sheet 3 of 5

**Project** DESIGN UNIT A250 **Date Drilled** 2-7-84 **Hole No.** 20-6

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SP<br>SM | 65.0-71.0 SAND/SILTY SAND: continued | | | RD | |
| 70 | | | J-7 | 46<br>50 | SS | refusal at 9" |
| | GM | 71.0-80.0 SANDY GRAVEL: medium gray, dense to very dense; with fines | | | RD | rig chatter |
| 72 | | | | | | |
| | | with moderately cemented layers | | | | heavy rig chaater |
| 74 | | | | | | |
| | | | | 110 | DR | refusal at 2"<br>sample not recovered |
| 76 | | | | | | |
| 78 | SW<br>SM | 78.0-94.0 SAND/SILTY SAND: medium dark gray, dense to very dense, with gravel, slight sulfur odor | | | RD | |
| 80 | | | | | | |
| | | | | 75 | SS | 0.0/0.5 recovery<br>refusal at 5" |
| | | | C-8 | 90<br>60 | DR | refusal at 9" |
| 82 | | | | | | |
| | | | | | RD | |
| 84 | | | | | | |
| | | | C-9 | 75<br>75 | DR | refusal at 9" |
| 86 | | | | | | |
| | | | | | RD | |
| 88 | | | | | | |
| 90 | | thin gravel lenses | J-8 | 71 | SS | refusal at 6"<br>0.4/0.5 recovery |
| 92 | | | | | | |

**Sheet** 4 **of** 5

**Project** DESIGN UNIT A250 **Date Drilled** 2-7-84 **Hole No.** 20-6

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | SW<br>SM | 78.0-94.0 SAND/SILTY SAND: continued | | | RD | |
| 94 | SW<br>(SM) | 94.0-99.0 TAR SAND: grayish black, with fines, dense to very dense, with gravel, petroleum odor | | 145 | DR | refusal at 6"<br>sample not recovered<br>variable rig chatter |
| 96 | | | | | RD | |
| 98 | | | | | | |
| | SP<br>SM | 99.0-104.0 SAND/SILTY SAND: medium dark gray, very dense with gravel | | | | |
| 100 | | | J-9 | 54 | SS | 0.4/0.5 recovery<br>refusal at 6" |
| 102 | | | | | RD | |
| 104 | SM | 104.0-106.0 SILTY SAND: medium dark gray, moist, very dense | | | | |
| | | | C-10 | 85<br>75 | DR | refusal at 10" |
| 106 | | END OF BORING 106.0'<br>Tremied 4 sac/90 gallon slurry into hole | | | | completed drilling 1500 |
| 108 | | | | | | |
| 110 | | | | | | |
| 112 | | | | | | |
| 114 | | | | | | |
| 116 | | | | | | |

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

## BORING LOG 20-7

**Proj:** DESIGN UNIT A250
**Date Drilled** 2-9-84
**Ground Elev.**
**Drill Rig** Failing 1500
**Logged By** M. Schluter
**Total Depth** 101.0'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 325# @ 18"/140# @ 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.4 A.C. PAVEMENT | | | C | started drilling at 1230 |
| | SM | FILL<br>0.4-4.0 SILTY SAND: moderate brown, loose to medium dense, moist, with gravel | | | A | |
| 2 | | | | | | |
| 4 | SM | 4.0-8.5 SILTY SAND: grayish brown, with gravel, medium dense, moist | C-1 | 17<br>29 | DR | |
| 6 | | | | | RD | rotary wash |
| 8 | CL | ALLUVIUM<br>8.5-14.0 SANDY CLAY: mottled yellowish gray and light olive gray, moist, firm to stiff | | | | |
| 10 | | | J-1 | 3<br>6<br>7 | SS | 1.5/1.5 recovery |
| 12 | | | | | RD | |
| 14 | ML | 14.0-19.0 SANDY SILT: light olive gray, moist, firm | C-2 | 9<br>18 | DR | |
| 16 | | | | | RD | |
| 18 | | | | | | |
| | SC | 19.0-24.0 CLAYEY SAND | | | | |

Sheet 1 of 5

**Project** DESIGN UNIT A250 **Date Drilled** 2-9-84 **Hole No.** 20-7

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | SC | 19.0-24.0 CLAYEY SAND: continued drak greenish gray, moist, dense, contains gravel | J-2 | 11<br>20<br>28 | SS | 1.5/1.5 recovery |
| 22 | | | | | RD | |
| 24 | SW/SM | 24.0-37.0 SAND/SILTY SAND: dark greenish gray, medium dense to dense, with gravel | | | | |
| | | | C-3 | 8<br>23 | DR | |
| 26 | | | | | | |
| | | | | | RD | |
| 28 | | | | | | |
| 30 | | | J-3 | 8<br>16<br>23 | SS | 1.4/1.5 recovery |
| 32 | | | | | RD | |
| 34 | | increasing gravel content; with gravel lenses | | | | minor rig chatter |
| | | | C-4 | 49<br>43 | DR | |
| 36 | | | | | | |
| | CL | 37.0-49.0 SANDY CLAY: mottled dark greenish gray, moist, sulfurous odor; very stiff | | | RD | |
| 38 | | | | | | |
| 40 | | | J-4 | 4<br>11<br>13 | SS | 1.5/1.5 recovery |
| 42 | | | | | RD | |
| 44 | | | | | | |

Sheet 2 of 5

**Project** DESIGN UNIT A250 **Date Drilled** 2-9-84 **Hole No.** 20-7

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | CL | 37.0-49.0 SANDY CLAY: continued | | | RD | |
| | | cemented nodules | C-5 | 15<br>41 | DR | |
| 46 | | | | | | |
| | | | | | RD | |
| 48 | | | | | | |
| | SP<br>SM | 49.0-54.0 SAND/SILTY SAND: dark greenish gray, very dense | | | | |
| 50 | | | J-5 | 19<br>27<br>41 | SS | 1.2/1.5 recovery |
| 52 | | | | | RD | |
| 54 | CL | 54.0-62.0 SANDY CLAY: dark greenish gray, moist, very stiff, sulfurous odor | | | | |
| | | | C-6 | 34<br>59 | DR | |
| 56 | | | | | | |
| | | | | | RD | |
| 58 | | | | | | |
| 60 | | hard | J-6 | 16<br>26<br>33 | SS | 1.4/1.5 recovery |
| 62 | SP | 62.0-73.5 SAND: dark greenish gray, trace fines, dense to very dense, sulfurous odor, with cemented layers | | | RD | |
| 64 | | | | | | |
| | | | C-7 | 69<br>75 | DR | refusal at 10" |
| 66 | | | | | RD | |
| 68 | | | | | | |

Sheet 3 of 5

**Project** DESIGN UNIT A250 **Date Drilled** 2-9-10-84 **Hole No.** 20-7

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SP | 62.0-73.5 SAND: continued | | | RD | |
| 70 | | | | 50 | SS | refusal at 1.5"<br>sample not recovered<br>2-9-84 |
| | | | | | | 2-10-84<br>rig chatter |
| 72 | | cemented layer or nodules, with gravel | | | RD | |
| 74 | SP<br>SM | 73.5-89.0 SAND/SILTY SAND: medium dark gray, dense to very dense, sulfurous odor | | | | |
| | | | C-8 | 97<br>75 | DR | refusal at 9" |
| 76 | | | | | | |
| 78 | | | | | RD | |
| 80 | | thin gravel lenses | J-7 | 57 | SS | 0.1/0.5 recovery<br>refusal at 6" |
| 82 | | | | | | |
| | | | | | RD | |
| 84 | | | | | | |
| | | | C-9 | 67<br>90 | DR | |
| 86 | | | | | RD | |
| 88 | | | | | | |
| | SW<br>SM | 89.0-99.0 SAND/SILTY SAND: medium dark gray, dense to very dense, slight sulfurous odor, with gravel | | | | |
| 90 | | | J-8 | 76 | SS | 0.2/0.5 recovery<br>refusal at 6" |
| 92 | | | | | RD | |

**Sheet** 4 **of** 5

**Project** DESIGN UNIT A250 **Date Drilled** 2-10-84 **Hole No.** 20-7

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | SW<br>SM | 89.0-99.0 <u>SAND/SILTY SAND</u>: continued | | | RD | |
| 94 | | thin gravel lenses | | | | |
| | | | C-10 | 127 | DR | refusal at 6" |
| 96 | | | | | | |
| 98 | | | | | | |
| | SP<br>SM | 99.0-101.0 <u>SAND/SILTY SAND</u>: medium dark gray, very dense, with gravel | | | | |
| 100 | | | J-9 | 76 | SS | 0.1/0.5 recovery<br>refusal at 5" |
| | | END OF BORING 101.0'<br>tremied a 4 sac/90 gallon slurry backfill | | | | finished drilling at 0930 |
| 102 | | | | | | |
| 104 | | | | | | |
| 106 | | | | | | |
| 108 | | | | | | |
| 110 | | | | | | |
| 112 | | | | | | |
| 114 | | | | | | |
| 116 | | | | | | |

**Sheet** 5 **of** 5

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

**Converse Consultants, Inc.**
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# BORING LOG 20-8

**Proj:** DESIGN UNIT A250

**Date Drilled** 2-10-84

**Ground Elev.** 178.0'

**Drill Rig** Failing 1500

**Logged By** M. Schluter

**Total Depth** 91.0'

**Hole Diameter** 4 7/8"

**Hammer Weight & Fall** 325# @ 18"/140# @ 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.3 A.C. PAVEMENT | | | C | started drilling at 1200 |
| | SC | ALLUVIUM<br>0.3-9.0 CLAYEY SAND: moderate brown, moist, loose to medium dense | | | A | |
| 2 | | | | | | |
| 4 | | with gravel | | | | |
| | | | C-1 | 8 | DR | |
| 6 | | | | 12 | | rotary wash |
| | | | | | RD | |
| 8 | | | | | | |
| | CL | 9.0-14.0 SANDY CLAY: mottled light olive gray and yellowish gray, moist, soft | | | | |
| 10 | | | J-1 | 1<br>2<br>2 | SS | 1.5/1.5 recovery |
| 12 | | | | | RD | |
| 14 | SC<br>CL | 14.0-23.0 CLAYEY SAND/SANDY CLAY: yellowish gray, dense / very stiff, contains cemented nodules | | | | |
| | | | C-2 | 8<br>21 | DR | |
| 16 | | | | | | |
| | | | | | RD | |
| 18 | | | | | | |
| 20 | | | | | | |

Sheet 1 of 4

**Project** DESIGN UNIT A250 **Date Drilled** 2-10-84 **Hole No.** 20-8

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | SC<br>CL | 14.0-23.0 CLAYEY SAND/SANDY CLAY: cont. | J-2 | 12<br>14<br>18 | SS | 1.5/1.5 recovery |
| | | with gravel, mottled | | | | |
| 22 | | | | | RD | |
| | SM<br>SW | 23.0-29.0 SILTY SAND/GRAVELLY SAND: moderate brown, medium dense, moist | | | | rig chatter |
| 24 | | | | | | |
| | | | C-3 | 13<br>42 | DR | |
| 26 | | | | | | |
| | | | | | RD | |
| 28 | | | | | | |
| | CL | 29.0-44.0 SANDY CLAY: dark yellowish brown, moist, stiff to very stiff | | | | |
| 30 | | | J-3 | 4<br>7<br>12 | SS | 1.2/1.5 recovery |
| 32 | | | | | RD | |
| 34 | | | | | | |
| | | with gravel | C-4 | 7<br>12 | DR | |
| 36 | | | | | | |
| | | | | | RD | |
| 38 | | | | | | |
| 40 | | | | 5<br>8<br>15 | SS | 0.0/1.5 recovery |
| 42 | | | | | RD | |
| 44 | | | | | | |

**Sheet** 2 **of** 4

**Project** DESIGN UNIT A250 **Date Drilled** 2-10-84 **Hole No.** 20-8

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SC | 44.0-49.0 CLAYEY SAND: continued greenish black, moist, medium dense to dense, with gravel | | | RD | |
| | | | C-5 | 20<br>35 | DR | |
| 46 | | | | | RD | |
| 48 | | | | | | |
| | ML | 49.0-54.0 CLAYEY SILT: dark greenish gray, with sand, moist, very stiff to hard | | | | |
| 50 | | | J-4 | 13<br>29<br>40 | SS | 1.4/1.5 recovery |
| 52 | | | | | RD | |
| 54 | SW<br>SM | 54.0-64.0 SAND/SILTY SAND: dark greenish gray, well graded, dense to very dense, with gravel, slight sulfurous odor | | | | |
| | | | C-6 | 41<br>93 | DR | rig chatter |
| 56 | | | | | RD | |
| 58 | | | | | | |
| 60 | | | | 16<br>23<br>25 | SS | 0.0/1.5 recovery |
| 62 | | | | | RD | |
| | | cemented layer and/or nodules | | | | rig chatter |
| 64 | CL | 64.0-70.0 SANDY CLAY: greenish black, moist,very stiff | | | | |
| | | | C-7 | 18<br>34 | DR | |
| 66 | | | | | RD | |
| 68 | | | | | | |

Sheet 3 of 4

**Project** DESIGN UNIT A250 **Date Drilled** 2-10-84 **Hole No.** 20-8

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | CL | 64.0-70.0 SANDY CLAY: continued | | | RD | |
| 70 | SP<br>SM | 70.0-82.0 SAND/SILTY SAND: dark greenish gray, dense to very dense | J-5 | 21<br>61 | SS | 0.7/1.0 recovery<br>refusal at 12" |
| 72 | | | | | RD | |
| 74 | | | | | | |
| | | with gravel | C-8 | 81<br>64 | DR | refusal at 9" |
| 76 | | | | | RD | |
| 78 | | | | | | |
| 80 | | | J-6 | 34<br>50 | SS | 0.7/0.9 recovery<br>refusal at 10" |
| 82 | SM | 82.0-91.0 SILTY SAND: dark, greenish gray, dense to very dense | | | RD | |
| 84 | | | | | | |
| | | | C-9 | 160<br>50 | DR | refusal at 7.5" |
| 86 | | | | | RD | |
| 88 | | | | | | |
| 90 | | | J-7 | 48<br>50 | SS | 0.5/0.7 recovery<br>refusal at 9" |
| 92 | | END OF BORING 91.0' tremied 2 sac/60 gal. slurry | | | | **Sheet** 4 **of** 4 |

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 20-9

**Proj:** DESIGN UNIT A250 **Date Drilled** 2-11-84 **Ground Elev.** ______

**Drill Rig** Failing 1500 **Logged By** M. Schluter **Total Depth** 81.0

**Hole Diameter** 4 7/8" **Hammer Weight & Fall** 325# @ 18"/SPT 140# 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.7 A.C. PAVEMENT | | | C | started drilling @ 0700 |
| | SM | ALLUVIUM<br>0.7-6.0 SILTY SAND: moderate brown, medium dense, moist, with gravel and clay | | | A | |
| 2 | | | | | | |
| 4 | | | C-1 | 8<br>12 | DR | |
| 6 | SC | 6.0-9.0 CLAYEY SAND: light olive gray, moist, medium dense, with gravel | | | RD | Rotary Wash |
| 8 | | | | | | |
| | SC | 9.0-14.0 CLAYEY SAND: dark greenish gray, moist, medium dense; slight petroleum odor and trace petroleum inclusions | | | | |
| 10 | | | J-1 | 4<br>11<br>14 | SS | 1.5/1.5 recovery |
| 12 | | | | | RD | |
| 14 | CL | 14.0-20.0 SANDY CLAY: mottled medium bluish gray and dark greenish gray, moist, firm, petroleum inclusions slight petroleum odor | | | | |
| | | | C-2 | 8<br>8 | DR | |
| 16 | | | | | RD | |
| 18 | | | | | | |

Sheet 1 of 4

**Project** DESIGN UNIT A250 **Date Drilled** 2-11-81 **Hole No.** 20-9

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | SC | 20.0-23.0 CLAYEY SAND: moderate yellowish brown, moist, medium dense, with gravel | J-2 | 6<br>9<br>14 | SS | 1.4/1.5 recovery |
| | | | | | RD | |
| 22 | | | | | | |
| | GC<br>SW | 23.0-33.0 SANDY GRAVEL/GRAVELLY SAND: moderate brownwith fines, dense to very dense; moist | | | | rig chatter |
| 24 | | | | | | |
| | | | C-3 | 15<br>13 | DR | |
| 26 | | | | | RD | |
| 28 | | | | | | slight rig chatter |
| 30 | | | J-3 | 28<br>59 | SS | 0.2/1.0 recovery<br>refusal at 12"<br>variable rig chatter |
| | | gravel lenses | | | | |
| 32 | | | | | | |
| | SM | 33.0-39.0 SILTY SAND: moderate brown with gravel, dense, moist | | | | |
| 34 | | | | | | |
| | | | C-4 | 43<br>76 | DR | |
| 36 | | | | | RD | |
| 38 | | | | | | |
| | SM<br>SW | 39.0-43.0 SILTY SAND/GRAVELLY SAND: greenish black with fines, very dense | | | | |
| 40 | | | J-4 | 19<br>35<br>43 | SS | 1.0/1.5 recovery |
| | | | | | RD | |
| 42 | | | | | | |
| | SM | 43.0-49.0 SILTY SAND: | | | | |
| 44 | | | | | | |

Project DESIGN UNIT A250 Date Drilled 2-11-84 Hole No. 20-9

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SM | 43.0-49.0 SILTY SAND: continued greenish black with gravel, dense | | | RD | |
| | | | | 51 | DR | |
| | | | C-5 | 72 | | |
| 46 | | | | | RD | |
| 48 | | | | | | |
| | SM | 49.0-54.0 SILTY SAND: dark greenish gray with gravel, dense | | | | |
| 50 | | | J-5 | 27 | SS | 1.0/1.0 recovery |
| | | | | 29 | | |
| | | | | | RD | |
| 52 | | | | | | |
| 54 | SC | 54.0-60.0 CLAYEY SAND: dark greenish gray, dense, moist, slight sulfurous odor | | | | |
| | | | | 29 | DR | |
| | | | C-6 | 35 | | |
| 56 | | | | | RD | |
| 58 | | | | | | |
| 60 | CL | 60.0-69.0 SILTY CLAY: dark greenish gray, moist, hard | J-6 | 11 | SS | 1.5/1.5 recovery |
| | | | | 17 | | |
| | | | | 20 | | |
| 62 | | | | | RD | |
| 64 | | mottled with medium bluish gray | | | | |
| | | | | 15 | DR | |
| | | | C-7 | 27 | | |
| 66 | | | | | RD | |
| 68 | | | | | | |

Sheet 3 of 4

**Project** DESIGN UNIT A250 **Date Drilled** 2-11-84 **Hole No.** 20-9

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | CL | 60.0-69.0 <u>SILTY CLAY</u>: continued | | | RD | |
| | SC | 69.0-71.5 <u>CLAYEY SAND</u>: dark greenish gray, very dense, moist, sulfurous odor, cemented layer or nodules @ 71.0'-71.5' | | | | |
| 70 | | | J-7 | 24<br>36<br>50 | SS | 1.3/1.4 recovery<br>refusal @ 17" |
| 72 | SP<br>SM | 71.5-81.0 <u>SAND/SILTY SAND</u>: medium dark gray, trace fines, very dense, sulfurous odor | | | RD | |
| 74 | | | | | | |
| | | | C-8 | 78<br>60 | DR | refusal @ 10" |
| 76 | | | | | RD | |
| 78 | | | | | | |
| 80 | | | J-8 | 56 | SS | 0.2/0.5 recovery<br>refusal at 6" |
| 82 | | END OF BORING 81.0'<br>Tre a 3 sac/60 gallon slurry into hole | | | | |
| 84 | | | | | | |
| 86 | | | | | | |
| 88 | | | | | | |
| 90 | | | | | | |
| 92 | | | | | | |

Sheet 4 of 4

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 20-10

**Proj:** DESIGN UNIT A250
**Date Drilled** 2/11-12/84
**Ground Elev.** 182'
**Drill Rig** Failing 1500
**Logged By** M. Schluter
**Total Depth** 121.0'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 325 lb @ 18", 140 lb @ 18"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.7 CONCRETE GUTTER | | | AD | started drilling @ 1300 |
| | | 0.7-1.2 GRAVEL BASE | | | | |
| 2 | CL | ALLUVIUM<br>1.2-9.0 SANDY CLAY: moderate brown; moist; soft | | | | |
| 4 | | | | | | |
| | | | C-1 | 8<br>25 | DR | |
| 6 | | | | | RD | rotary wash |
| 8 | | | | | | |
| 10 | SC | 9.0-15.0 CLAYEY SAND: dark yellowish brown; medium dense; moist, trace gravel | | 3 | SS | |
| | | | J-1 | 5<br>7 | | |
| 12 | | | | | RD | |
| 14 | | | | | | |
| | CL | 15.0-23.5 SANDY CLAY: dark yellowish brown; stiff; moist; petroliferous inclusions | C-2 | 3<br>5 | DR | |
| 16 | | | | | RD | |
| 18 | | | | | | |

Sheet 1 of 6

**Project** DESIGN UNIT A250 **Date Drilled** 2-11/12-84 **Hole No.** 20-10

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CL | 15.0-23.5 SANDY CLAY: continued | | 5 | SS | 1.5/1.5 recovery |
| | | | | 10 | | |
| | | | J-2 | 5 | | |
| 22 | | | | | RD | |
| | | increasing sand content | | | | |
| 24 | SM | 23.5-26.0 SILTY SAND: dark greenish gray; medium dense; moist; trace micaceous; $CaCO_3$ infilling | | | | |
| | | | | 15 | DR | |
| | | | C-3 | 41 | | |
| 26 | SP | 26.0-29.0 SAND: dark greenish gray; poorly graded; medium dense; moist; subangular gravel | | | RD | |
| 28 | | | | | | |
| | CL | 29.0-34.0 SILTY CLAY: greenish black; moist; hard; trace micaceous | | | | |
| 30 | | | | 9 | SS | 1.5/1.5 recovery |
| | | | | 17 | | |
| | | | J-3 | 23 | | 2-11-84 |
| 32 | | | | | RD | 2-12-84 |
| 34 | SC | 34.0-40.0 CLAYEY SAND: dark greenish gray; moist; medium dense; well graded; $CaCO_3$ infilling; trace gravel | | | | |
| | | | | 14 | DR | |
| 36 | | | C-4 | 32 | | |
| | | | | | RD | |
| 38 | | | | | | |
| 40 | SM | 40.0-52.0 SILTY SAND: dark greenish gray; well graded; moist; very dense subangular sand grains; trace gravel; trace micaceous | | 11 | SS | 1.4/1.5 recovery |
| | | | J-4 | 26 | | |
| | | | | 34 | | |
| 42 | | | | | RD | |

**Project** DESIGN UNIT A250 **Date Drilled** 2-12-84 **Hole No.** 20-10

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SM | 40.0-52.0 SILTY SAND: continued | | | RD | |
| | | | | 22 | DR | |
| | | | C-5 | 37 | | |
| 46 | | | | | RD | |
| 48 | | | | | | |
| 50 | | slight sulfurous odor | | 7 | SS | 1.5/1.5 recovery |
| | | | J-5 | 23 | | |
| | | | | 31 | | |
| 52 | SW | 52.0-59.0 SAND: greenish black; well graded, medium dense to dense; subangular grains; trace gravel; slightly micaceous | | | RD | |
| 54 | | | | | | |
| | | | C-6 | 41 | DR | |
| | | | | 63 | | |
| 56 | | | | | RD | |
| 58 | | | | | | |
| | CL | 59.0-64.0 SANDY CLAY: dark greenish gray; moist; hard; micaceous | | | | |
| 60 | | | | 26 | SS | 1.5/1.5 recovery |
| | | | | 38 | | |
| | | | J-6 | 41 | | |
| 62 | | | | | RD | |
| 64 | SM | 64.0-66.0 SILTY SAND: dark greenish gray; moist; dense; micaceous | | | | |
| | | | C-7 | 112 | DR | refusal @ 7" |
| | | | | 50- | 1 | |
| 66 | SW | 66.0-69.0 SAND: dark greenish gray; well graded; dense; trace gravel | | | RD | |
| 68 | | | | | | |

**Sheet** 3 **of** 6

Project DESIGN UNIT A250 Date Drilled 2-12-84 Hole No. 20-10

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SW | 66.0-69.0 SAND: continued | | | RD | |
| | CL | 69.0-73.5 SILTY CLAY: greenish black; moist; very stiff to hard; trace micaceous light brown gray - mottling | | | | |
| 70 | | | J-7 | 11<br>21<br>22 | SS | 1.5/1.5 recovery |
| | | | | | RD | |
| 72 | | | | | | |
| 74 | CL | 73.5-79.0 SANDY TAR CLAY: greenish black, brownish black; stiff to very stiff; moist; petroleum odor; slightly sticky | | | | |
| | | | C-8 | 51<br>70- | DR<br>5" | refusal @ 11" |
| 76 | | | | | RD | |
| 78 | | | | | | |
| | SP<br>SC | 79.0-83.0 TAR SAND/CLAYEY TAR SAND: brownish black; poorly graded; dense to very dense; petroleum odor; sticky | | | | |
| 80 | | | J-8 | 41<br>50- | SS<br>3" | 0.1/0.1 recovery<br>refusal @ 8" |
| | | | | | RD | |
| 82 | | | | | | |
| | SP | 83.0-87.0 TAR SAND: black; poorly graded; dense to very dense; petroleum odor; sticky | | | | |
| 84 | | | C-9 | 106<br>50- | DR<br>1" | refusal @ 7"<br>5.5/5.5 ring recovered |
| | | | | | RD | |
| 86 | | | | | | |
| | SP<br>SM | 87.0-94.0 TAR SAND/SILTY TAR SAND: black; poorly graded; dense to very dense; petroleum odor; sticky | C-10 | 83<br>70- | DR<br>2" | refusal @ 8" |
| 88 | | | | | RD | |
| | | micaceous; trace gravel 5-30mm | | | | |
| 90 | | | C-11 | 90<br>60 | DR | refusal @ 9" |
| | | gravels - cemented zone? | | | RD | |
| 92 | | | | | | |

Sheet 4 of 6

Project DESIGN UNIT A250 Date Drilled 2-12-84 Hole No. 20-10

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | SM | 87.0-94.0 TAR SAND/SILTY TAR SAND: (cont.) | | | RD | |
| 94 | SM<br>ML | 94.0-101.0 SILTY TAR SANDS: black; poorly graded; dense to very dense; petroleum odor; sticky | C-12 | 105<br>50- | DR<br>1 | refusal @ 7" |
| | | | | | RD | |
| 96 | | becoming more silty | | | | |
| | | | C-13 | 106<br>50- | DR<br>1 | refusal @ 7" |
| 98 | ML | | | | RD | |
| | | micaceous; trace gravel 5-25 mm | | | | |
| 100 | | | C-14 | 138 | DR | refusal @ 6" bag<br>4.9/4.9 rings recovered |
| | SW<br>GM | 101.0-111.0 GRAVELLY SAND/SANDY GRAVEL: black; well graded; dense to very dense; gravels: subangular to subrounded; 5-25 mm; clean; petroleum odor; sticky | | | RD | |
| 102 | | | | | | |
| 104 | | | C-15 | 145 | DR | refusal @ 6" bag<br>4.8/4.8 rings recovered |
| | | | | | RD | Drill rig chatter |
| 106 | | | | | | |
| | | | C-16 | 142 | DR | refusal @ 6"<br>3.5/3.5 rings recovered |
| 108 | | | | | RD | |
| 110 | | | | | | |
| | SM | 111.0-114.4 GRAVELLY SILTY SAND: black; 5-25 mm; subrounded; dense to very dense; trace to little gravel; petroleum odor; sticky | C-17 | 131 | DR | refusal @ 6" bag<br>3.5/3.5 rings recovered |
| 112 | | | | | RD | |
| 114 | | | C-18 | 76<br>75- | DR<br>5 | refusal @ 11" |
| | | FERNANDO FORMATION<br>114.4-121.0 SILTSTONE/CLAYSTONE: | | | RD | |
| 116 | | | | | | |

Project DESIGN UNIT A250 **Date Drilled** 2-12-84 **Hole No.** 20-10

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 116 | | 114.4-121.0 <u>SILTSTONE/CLAYSTONE</u>: cont. dark greenish gray; very stiff to hard; micaceous; shells & shell fragments; massive; moist; slight petroleum odor; gaseous | | | RD | 116.5 - drill rig chatter; cemented layer;<br>117.0 - Gas Pocket foamed drilling fluid; 80-100% explosive reading on foam; 0% at hole; rapid gas release;<br>118.0 - rig quieted down |
| 118 | | | | | | |
| 120 | | | C-19 | 40<br>96 | DR | |
| | | End of Boring 121.0'<br>tremmied a 4 sac/90 gallon slurry mix into hole | | | | Finished drilling @ 1530 |
| 122 | | | | | | |
| 124 | | | | | | |
| 126 | | | | | | |
| 128 | | | | | | |
| 130 | | | | | | |
| 132 | | | | | | |
| 134 | | | | | | |
| 136 | | | | | | |
| 138 | | | | | | |
| 140 | | | | | | |

Sheet 6 of 6

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 20-11

**Proj:** DESIGN UNIT A250
**Date Drilled** 2-13-84
**Ground Elev.** ______
**Drill Rig** Failing 1500
**Logged By** M. Schluter
**Total Depth** 81.0'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 325# @ 18"/SPT 140# @ 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.4 A.C. PAVEMENT | | | C | started drilling @0950 |
| | SC | ALLUVIUM<br>0.4-4.0 CLAYEY SAND: moderate brown, moist loose to medium dense | | | A | |
| 2 | | | | | | |
| 4 | ML/SM | 4.0-9.0 SANDY SILT/SILTY SAND: dark yellowish brown, firm/loose; moist | C-1 | 8<br>19 | DR | |
| 6 | | | | | RD | rotary wash |
| 8 | | | | | | |
| | SC | 9.0-14.0 CLAYEY SAND: dark yellowish brown, moist, dense to very dense, with gravel | | | | |
| 10 | | | J-1 | 16<br>25<br>37 | SS | 1.5/1.5 recovery |
| 12 | | | | | RD | |
| 14 | SM | 14.0-23.0 SILTY SAND: dark greenish gray, moist, medium dense | | | | |
| | | | C-2 | 8<br>10 | DR | |
| 16 | | | | | RD | |
| 18 | | | | | | |

**Project** DESIGN UNIT A250 **Date Drilled** 2-13-84 **Hole No.** 20-11

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | SM | 14.0-23.5 SILTY SAND: continued becoming very dense | J-2 | 21<br>28<br>36 | SS | 1.4/1.5 recovery |
| 22 | | decreasing fines | | | RD | |
| | CL | 23.0-26.0 SANDY CLAY: light olive gray; moist; stiff | | | | |
| 24 | | | | | | |
| | | | C-3 | 10<br>23 | DR | |
| 26 | SM<br>SW | 26.0-28.0 SAND/GRAVELLY SAND: moderate brown, dense, moist | | | RD | slight rig chaater |
| 28 | SM | 28.0-34.0 SILTY SAND: light olive gray, very dense, moist | | | | |
| 30 | | | J-3 | 9<br>22<br>42 | SS | 1.4/1.5 recovery |
| | | | | | RD | |
| 32 | | | | | | |
| 34 | SW | 34.0-39.0 GRAVELLY SAND: dark greenish gray, trace fines, medium dense to dense | | | | |
| | | | C-4 | 130 | DR | refusal @ 6"<br>disturbed sample |
| 36 | | | | | RD | |
| 38 | | | | | | |
| | SC | 39.0-45.0 CLAYEY SAND: greenish black, moist, dense to very dense, with gravel | | | | |
| 40 | | | J-4 | 15<br>37<br>49 | SS | 1.5/1.5 recovery |
| | | | | | RD | |
| 42 | | | | | | |
| 44 | | | | | | |

**Sheet** 2 **of** 4

**Project** DESIGN UNIT A250 **Date Drilled** 2-13-84 **Hole No.** 20-11

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SC | 39.0-45.0 CLAYEY SAND: continued | | | RD | |
| | ML | 45.0-49.0 SANDY SILT: greenish black, very stiff, moist, with gravel | C-5 | 36<br>65 | DR | |
| 46 | | | | | RD | |
| 48 | | | | | | |
| | SP/SM | 49.0-55.0 SAND/SILTY SAND: dark greenish gray, moist, very dense, with gravel | | | | |
| 50 | | | J-5 | 30<br>50 | SS | 0.5/0.5 recovery<br>refusal at 11" |
| 52 | | | | | | |
| 54 | | | | | | |
| | SM | 55.0-60.0 SILTY SAND: dark greenish gray, moist, dense, with cemented nodules | C-6 | 36<br>58 | DR | |
| 56 | | | | | RD | |
| 58 | | | | | | |
| 60 | | | J-6 | 56 | SS | refusal at 6" |
| | SP/SM | 60.0-81.0 SAND/SILTY SAND: dark greenish gray, very dense, moist; slight sulfurous odor | | | RD | |
| 62 | | | | | | |
| 64 | | | | | | |
| | | | C-7 | 115 | DR | refusal at 6" |
| 66 | | | | | RD | |

Sheet 3 of 4

**Project** DESIGN UNIT A250 **Date Drilled** 2-13-84 **Hole No.** 20-11

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SP<br>SM | 60.0-81.0 SAND/SILTY SAND: continued | | | RD | |
| 70 | | medium dark gray; sulfurous odor | J-7 | 40<br>50 | SS | 0.5/0.8 recovery<br>refusal at 9" |
| | | | | | RD | |
| 72 | | | | | | |
| 74 | | | | | | |
| | | | C-8 | 97<br>60 | DR | refusal at 7" |
| 76 | | | | | RD | |
| 78 | | | | | | |
| 80 | | | J-8 | 65 | SS | refusal at 6" |
| | | END OF BORING 81.0'<br>Tremied 3 sac/75 gallon cement slurry into hole | | | | finished drilling @ 1350 |
| 82 | | | | | | |
| 84 | | | | | | |
| 86 | | | | | | |
| 88 | | | | | | |
| 90 | | | | | | |
| 92 | | | | | | |

**Sheet** 4 **of** 4

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

**BORING LOG** 21

**Proj:** DESIGN UNIT A250
**Date Drilled** 1-16-22-80
**Ground Elev.** 159.0'
**Drill Rig** Failing 1500
**Logged By** L. Schoeberlein
**Total Depth** 200.0'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 140 lb 30"

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | AC | 0.0-0.3 ASPHALT<br>0.3-0.5 BASE ROCK | | | AD | |
| | CL | ALLUVIUM<br>0.5-4.5 SANDY CLAY: dark yellowish brown; dry to moist | | | | |
| 2 | | | | | | |
| 4 | | | | | | |
| | SP | 4.5-6.0 SAND: greyish green; trace fines; dry | | | | |
| 6 | CL | 6.0-8.5 SANDY CLAY: greyish green color grading to light olive grey | | | | |
| 8 | | | | | | |
| | SC | 8.5-14.0 CLAYEY SAND: light olive grey, dense; dry to moist; interbedded with sandy clay | | | | 12-18-80 |
| 10 | | | J-1 | 12<br>19<br>28 | SS | 12-19-80<br>1.5/1.5 recovery |
| 12 | | | | | RD | |
| 14 | CL | 14.0-17.0 SILTY CLAY: pale yellowish brown; soft to firm | | | | |
| 16 | | | | | | |
| | CL | 17.0-18.8 SILTY CLAY: greyish blue green | | | | |
| 18 | | | S-1 | | PB | 1.6/2.0 recovery |
| | (ML) | 19.0 fine sandy silt<br>18.8-27.5 SAND: greyish blue green, trace fines | | | | |

**Project** DESIGN UNIT A250 **Date Drilled** 12-18-22-80 **Hole No.** 21

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | SP | 18.8-27.5 SAND: continued<br>dense; moist | J-2 | 13<br>15<br>25 | SS | 1.5/1.5 recovery |
| 22 | | | | | RD | |
| 24 | | | | | | |
| 26 | | | | | | |
| 28 | CL | 27.5-37.5 SILTY CLAY: medium bluish gray;<br>very stiff to hard; moist | | | | |
| 30 | | | J-3 | 8<br>14<br>20 | SS | 1.5/1.5 recovery |
| 32 | | | | | RD | |
| 34 | | | | | | |
| 36 | | becoming sandy | | | | |
| 38 | SC | 37.5-55.0 CLAYEY SAND: medium bluish grey;<br>dense; moist; interbedded with<br>sandy clay; with gravel | | | | |
| | | | C-1 | | DR | 1.0/1.0 recovery |
| 40 | (SM<br>ML) | becoming silty | J-4 | 16<br>18<br>25 | SS | 1.5/1.5 recovery |
| 42 | | becoming more clayey | | | RD | |
| 44 | | | | | | |

**Sheet** 2 **of** 9

**Project** DESIGN UNIT A250 **Date Drilled** 12-18-22-80 **Hole No.** 21

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SC | 37.5-55.0 CLAYEY SAND: continued | | | RD | |
| 46 | | | | | | |
| 48 | | | | | | |
| 50 | | | J-5 | 10<br>16<br>21 | SS | 1.5/1.5 recovery |
| 52 | | | | | RD | |
| 54 | | becoming sandier | | | | |
| | SP | 55.0-64.0 SAND: medium bluish grey; very dense; moist | | | | |
| 56 | | | | | | |
| 58 | | oil odor | | | | |
| | | wet sample | C-2 | | DR | 0.8/1.0 recovery |
| 60 | | | J-6 | 23<br>32<br>36 | SS | 1.1/1.5 recovery |
| | | clayey sand lens | | | | |
| 62 | | | | | RD | |
| 64 | CL | 64.0-69.4 SILTY CLAY: medium bluish grey; stiff | | | | |
| 66 | | | | | | |
| | | soft | | | | |
| 68 | | | | | | |

**Project** DESIGN UNIT A250 **Date Drilled** 12-18-22-80 **Hole No.** 21

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | | 64.0-69.4 SILTY CLAY: continued | | | RD | |
| | | becoming stiff | | | | |
| | SC | 69.4-74.4 CLAYEY SAND: greenish grey; very dense; moist | | | | |
| 70 | | | J-7 | 16 | SS | 1.5/1.5 recovery |
| | | | | 25 | | |
| | | | | 34 | | |
| 72 | | | | | RD | |
| 74 | | | | | | |
| | SP | 74.4-83.0 SAND: greenish grey; very dense | | | | minor chatter |
| 76 | | | | | | |
| | | slight gravel | | | | minor chatter |
| 78 | | | | | | |
| | (SM) | becoming silty | C-3 | | DR | 0.8/1.0 recovery |
| 80 | | | J-8 | 44 | SS | 0.75/0.75 recovery<br>refusal at 9" |
| | | | | 50 | | |
| | | | | | RD | |
| 82 | | | | | | |
| | SW | 83.0-85.5 GRAVELLY SAND: olive black | | | | rig chatter |
| 84 | | | | | | |
| 86 | SP | 85.5-98.3 SAND: olive black with fines; very dense; moist | | | | |
| | | 86.5 gravelly lens | | | | |
| 88 | | | | | | |
| 90 | | sulfur odor, wet | J-9 | 40 | SS | 1.2/1.5 recovery |
| | | | | 36 | | |
| | | | | 44 | | |
| 92 | | | | | RD | |

**Project** DESIGN UNIT A250 **Date Drilled** 12-18-22-80 **Hole No.** 21

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | SP | 85.5-98.3 SAND: continued | | | RD | |
| 94 | | | | | | |
| 96 | | | | | | |
| 98 | SM | 98.3-109.0 SILTY SAND: mottled greenish grey and dark greenish grey; dense; moist | | | | |
| | | | C-4 | | DR | 0.9/1.0 recovery |
| 100 | | | J-10 | 8<br>14<br>20 | SS | 1.4/1.5 recovery |
| 102 | | | | | RD | |
| 104 | | | | | | |
| 106 | | | | | | |
| 108 | | | | | | |
| | SW | 109.0-116.0 TAR SAND: olive black with petroleum binder; very dense; intermittant gravel or silt lens | | | | |
| 110 | | | J-11 | 52<br>58 | SS | 1.0/1.0 recovery<br>refusal at 12" |
| | | | | | RD | 12/19/80<br>12/20/80<br>$H_2O$ at 13' |
| 112 | | grading coarser | | | | |
| 114 | | | | | | |
| 116 | | | | | | |

Sheet 5 of 9

**Project** DESIGN UNIT A250 **Date Drilled** 12-18-22-80 **Hole No.** 21

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 116 | SM | 116.0-125.0 SILTY SAND: greenish grey mottled with dark greenish grey; very dense; moist; contains petroleum inclusions | | | RD | |
| 118 | | | | | | |
| 120 | | | S-2 | | PB | 1.2/1.2 recovery |
| | | | Box 1 | | | 1.2/1.2 recovery<br>pocket penetrometer 3.75 tsf (broke apart)<br>1.2/1.2 recovery<br>1.2/2.5 recovery |
| 122 | | | | | | |
| 124 | | grading coarser gravelly lens | | | | |
| | ML/SM | 125.0-131.0 SANDY SILT/SILTY SAND: medium grey, dry to moist; very stiff, dense | | | | |
| 126 | | | S-3 | | RD<br>PB | 1.4/2.4 recovery |
| 128 | | thin gravel lens | | | | |
| | | | Box 1 (cont) | | PB | 1.2/1.2 recovery |
| 130 | | | | | | petroleum sample<br>1.3/1.3 recovery<br>pocket penetrometer 1.5 tsf 2/9/81 |
| | SP/SW | 131.0-136.0 TAR SAND: olive black; oil rich; with gravel; | | | | |
| 132 | | | | | RD | |
| | | 132.6 increased gravel content | | | | rig chatter |
| 134 | | | | | | |
| 136 | SP | 136.0-147.5 SAND: greenish grey; dense; moist; with gravel | | | | |
| 138 | | | Box 1 (cont) | | PB | 1.0/1.0 recovery<br>pocket penetrometer 0.5 tsf 2/9/81 |
| | | 138.7 gravel lens | | | | |
| 140 | (SM) | becoming silty | S-4 | | | 1.0/1.0 recovery |

**Project** DESIGN UNIT A250 **Date Drilled** 12-18-22-80 **Hole No.** 21

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 140 | SP | 136.0-147.5 SAND: continued | | | RD | |
| 142 | | 142.7-143.0 gravel lens | | | | |
| 144 | | | | | | |
| 146 | | 146.0-147.5 gravel lens | | | | |
| 148 | | BEDROCK<br>147.5-200.0 SILTSTONE: medium bluish grey; dry to moist; occasional cemented siltstone lenses<br>Physical Condition: massive; friable hardness and strength; little weathered to fresh | S-5 | | PB | 2.4/3.0 recovery |
| 150 | | | | | | |
| | | 151.0 silty claystone | | | | |
| 152 | | 151.8-152.0 cemented lens | Box 1 (cont) | | | rig chatter<br>1.6/2.0 recovery<br>pocket penetrometer >4.5 tsf 2/9/81<br>rig chatter entire run |
| | 45 | 153.5 cemented | | | | |
| 154 | | 154.3 cemented | Box 2 | | RD | 1.5/1.7 recovery |
| | | 155.5 cemented | | | | |
| 156 | | | | | | |
| 158 | | | | | | |
| 160 | | | S-6 | | PB | 1.7/2.5 recovery |
| 162 | | | | | | pocket penetrometer >4.5 tsf 2/9/81 |
| | | | Box 2 (cont) | | | 2.3/2.5 recovery |
| 164 | | | | | | |

**Sheet** 7 **of** 9

Project DESIGN UNIT A250 Date Drilled 12-18-22-80 Hole No. 21

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 164 | | 147.5-200.0 SILTSTONE: continued. physical condition as previously described | Box 2 (cont) | | PB<br>RD | 12-20-80<br>12-21-80 |
| 166 | | | | | PB | gas detector indicated 19% $O_2$ and < 0% combustibles, water at 15' in am.<br>1.7/2.5 recovery |
| 168 | | | | | | 2.1/2.5 recovery |
| 170 | | | | | | 2.5/2.5 recovery |
| | | | S-7 | | | |
| 172 | | 172.0 silty claystone | | | | |
| | | | Box 2 (cont) | | | 2.5/2.5 recovery |
| 174 | | | | | | pocket penetrometer >4.5 ksf 2/9/81 |
| 176 | | | | | | 2.5/2.5 recovery |
| 178 | | | Box 3 | | | 1.9/2.5 recovery |
| | | 179.0-179.5 contains shell fragments | | | | |
| 180 | | | S-8 | | | 2.2/2.7 recovery |
| 182 | | | | | | |
| | | 183.3 thin clay lens | Box 3 (cont) | | | 2.5/2.8 recovery |
| 184 | | | | | | pocket penetrometer >4.5 tsf 2/9/81 |
| 186 | | contains shells, minor slickensides | | | | 2.6/2.7 recovery |
| 188 | | | | | | |

Sheet 8 of 9

Project DESIGN UNIT A250 Date Drilled 12-18-22-80 Hole No. 21

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 188 | | 147.5-200.0 SILTSTONE: continued physical condition as previous described | Box 3 (cont) | | | 1.8/2.8 recovery |
| 190 | | | S-9 | | | |
| 192 | | | Box 3 (cont) | | | 2.8/2.8 recovery |
| | | 6" zone of shells | | | | |
| 194 | | | | | | 2.5/2.8 recovery |
| 196 | | concretion | | | | |
| | | concretion | | | | |
| | | | | | | 2.8/2.8 recovery |
| 198 | | | | | | |
| | | | S-10 | | | |
| 200 | | End of Boring 200.0' Set 2" ABS to 200' with slots at 120'-150' and 180'-195', gravel pack to 120'. Bentonite seal at 110'-120', 3/4" PVC to 0 to 110' with slots at 15'-40' and 105'-70', gravel pack 110' to 8'. Bentonite seal 8' to surface. E-logged hole 12/22/80 prior to piezometer installation. | | | | hole bailed to 25', water at 19'after 10 min., hole caving during bailing operations<br>water sampled 1/7/81 |
| 202 | | | | | | |
| 204 | | | | | | |
| 206 | | | | | | |
| 208 | | | | | | |
| 210 | | | | | | |
| 212 | | | | | | |

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## BORING LOG 22

**Proj:** DESIGN UNIT A 250
**Date Drilled** 12-19-80
**Ground Elev.** 162'
**Drill Rig** Failing
**Logged By** Gallinatti
**Total Depth** 200.3
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 140lbs, 30 inches

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-1.0 ASPHALT | | | AD | |
| | ML | ALLUVIUM<br>1.0/7.5 CLAYEY SILT: olive grey; soft; dry to moist | | | | |
| 2 | | | | | | |
| 4 | | | | | RD | |
| 6 | | | | | | |
| 8 | SW | 7.5-12.0 GRAVELLY SAND: pale yellowish brown; dense | | | | |
| 10 | | | J-1 | 15<br>16<br>17 | SS | recovery 1.0/1.5 |
| 12 | ML | 12.0-15.0 SANDY SILT: moderate yellowish brown; soft | | | RD | |
| 14 | | | | | | |
| | CL | 15.0-45.0 SANDY CLAY: medium dark grey; stiff to very stiff; dry to moist | | | | |
| 16 | | | | | | |
| 18 | | | | | | |
| 20 | | 20.0 becoming silty | | | | |

Sheet 1 of 9

**Project** DESIGN UNIT A250 **Date Drilled** 12-19-80 **Hole No.** 22

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CL | 15.0-45.0 <u>SANDY CLAY</u>: (Continued) | C-1 | | DR | recovery 1.0/1.0 |
| | | | J-2 | 6<br>7<br>8 | SS | |
| 22 | | | | | RD | recovery 1.5/1.5 |
| 24 | | | | | | |
| 26 | | thin gravelly lenses at 26' and 28' | | | | |
| 28 | | | | | | |
| 30 | | becoming hard | J-3 | 11<br>15<br>37 | SS | recovery 1.5/1.5 |
| 32 | | | | | RD | |
| 34 | | | | | | |
| 36 | | | | | | |
| 38 | | | | | | |
| 40 | (SC) | becoming very sandy | C-2 | | DR | recovery 0.8/1.0 |
| | | | J-4 | 7<br>11<br>21 | SS | recovery 1.5/1.5 |
| 42 | | | | | RD | |
| 44 | | | | | | |

**Sheet** 2 **of** 9

**Project** DESIGN UNIT A250 **Date Drilled** 12-19-80 **Hole No.** 22

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | CL | 15.0-45.0 SANDY CLAY: (continued) | | | RD | |
| | SC | 45.0-70.5 CLAYEY SAND: dark medium grey; medium dense to dense; moist | | | | |
| 46 | | | | | | |
| 48 | | | | | | |
| 50 | | | J-5 | 7<br>12<br>17 | SS | recovery 1.5/1.5 |
| 52 | | | | | RD | |
| 54 | | | | | | |
| 56 | | | | | | |
| 58 | | | | | | |
| 60 | (ML) | 60.0 clayey silt | C-3 | | DR | recovery 1.0/1.0 |
| | | | J-6 | 11<br>17<br>29 | SS | recovery 0.8/1.5 |
| 62 | | | | | RD | |
| 64 | | | | | | |
| 66 | | | | | | |
| 68 | | | | | | |

**Sheet** 3 **of** 9

**Project** DESIGN UNIT A250 **Date Drilled** 12-19-80 **Hole No.** 22

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | SC | 45.0-70.5 CLAYEY SAND: (continued) | | | RD | |
| 70 | SC | 70.5-77.0 CLAYEY SAND: brownish black; petroleum throughout sand; very dense | J-7 | 17<br>29<br>55 | SS | recovery 0.8/1.5 |
| 72 | | | | | RD | |
| 74 | | | | | | |
| 76 | | | | | | |
| | CL | 77.0-88.5 GRAVELLY CLAY: mottled dark yellowish brown and medium grey; petroleum throughout material; coarse gravel; hard | | | | |
| 78 | | | | | | |
| 80 | | becoming silty | C-4 | | DR | recovery 0.8/0.8 |
| | | | J-8 | 20<br>29<br>55 | SS | recovery 1.0/1.5 |
| 82 | | | | | RD | |
| 84 | | | | | | |
| 86 | | | | | | |
| 88 | | | | | | 90' explosivemeter doesn't register |
| | SP | 88.5-139.0 TAR SAND: black; fine to medium sand; saturated with oil; very dense | | | | |
| 90 | | | J-9 | 29<br>50 | SS | recovery 1.0/1.0<br>refusal at 12" |
| | | | | | RD | |
| 92 | | | | | | |

**Sheet** 4 **of** 9

**Project** DESIGN UNIT A250 **Date Drilled** 12-19-80 **Hole No.** 22

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 92 | | 88.5-139.0 TAR SAND: | | | RD | |
| 94 | | | | | | |
| 96 | | | | | | |
| 98 | | | | | | |
| 100 | | 99.5-100.0 CEMENTED SAND: medium grey; hard cemented sandstone layer | S-1 | | PB | recovery 1.5/2.5 |
| 102 | | | | | | |
| | | | J-10 | 25<br>50 | SS | |
| 104 | | | | | RD | recovery 0.9/0.9 refusal at 11" |
| 106 | | | | | | |
| 108 | | | | | | |
| 110 | | | J-11 | 21<br>60 | SS | |
| 112 | | | | | RD | recovery 1.0/1.0 refusal at 12" |
| 114 | | occasional cemented sand layers ~0.5' thick | | | | |
| 116 | | | | | | |

**Project** DESIGN UNIT A250 **Date Drilled** 1-19-80 **Hole No.** 22

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 116 | SP | 88.5-139.0 TAR SAND: continued | | | RD | |
| 118 | | scattered fine to coarse gravel | | | | |
| 120 | | | S-2 | | PB | 1.8/2.5 recovery |
| 122 | | | J-12 | 11<br>50 | SS | 0.4/0.8 recovery<br>refusal at 10" |
| 124 | | | | | RD | |
| 126 | | | | | | |
| 128 | | | | | | |
| 130 | | | J-13 | 21<br>50 | SS | 1.0/1.0 recovery<br>refusal at 12" |
| | | | | | RD | 12-18-80<br>12-19-80 |
| 132 | | | | | | |
| 134 | | | | | | |
| 136 | | | | | | |
| 138 | | BEDROCK<br>139.0-200.3 SILTSTONE: grayish green, moist | | | | |
| 140 | | | | | | |

**Sheet** 6 **of** 9

Project DESIGN UNIT A250 Date Drilled 12-20-80 Hole No. 22

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 140 | | 139.0-200.3 SILTSTONE: continued<br>Physical Condition: massive; friable strength and hardness; little weathered to fresh | S-3 | | PB | 2.0/2.5 recovery |
| 142 | | | | | | |
| | | | J-14 | 19<br>50 | SS | 1.0/1.0 recovery<br>refusal at 12" |
| 144 | | | | | RD | |
| 146 | | | | | | |
| 148 | | | | | | |
| 150 | | | Box 1 | | PB | pocket penetrometer >4.5 2/9/81<br>1.4/2.5 recovery |
| 152 | | | | | | |
| | | | | | | 2.4/2.5 recovery |
| 154 | | | | | | |
| 156 | | | S-4 | | | 2.0/2.5 recovery |
| 158 | | | Box 1 (cont) | | | 1.4/2.5 recovery |
| 160 | | | | | | 2.1/2.5 recovery |
| 162 | | | | | | |
| | | | S-5 | | | 2.0/2.5 recovery |
| 164 | | | | | | |

Sheet 7 of 9

**Project** DESIGN UNIT A250 **Date Drilled** 12-20-80 **Hole No.** 22

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 164 | | 139.0-200.3 <u>SILTSTONE</u>: continued physical condition as previously described | S-5 | | PB | pocket penetrometer >4.5 tsf 2/9/81<br>1.9/2.5 recovery |
| 166 | | | Box 1 (cont) | | | 1.7/2.5 recovery |
| 168 | | | | | | |
| 170 | | | | | | 1.7/2.5 recovery |
| 172 | | | S-6 | | | |
| | | | Box 2 | | | 1.9/2.5 recovery |
| 174 | | | | | | 2.0/2.5 recovery |
| 176 | | | | | | |
| 178 | | occasional thin clayey layers | | | | 2.8/2.8 recovery |
| 180 | | | | | | 1.6/2.5 recovery<br>pocket penetrometer >4.5 tsf 2/9/81 |
| | | 180.4 organic inclusions | | | | |
| | | 181.0-181.2 layer of shell fragments | | | | |
| 182 | | | | | | 1.7/2.5 recovery |
| | | 183.8 shell fragments | | | | |
| 184 | | | | | | |
| | | | | | | 1.6/2.5 recovery |
| 186 | | | S-7 | | | |
| 188 | | | | | | |

**Sheet** 8 **of** 9

**Project** DESIGN UNIT A250 **Date Drilled** 12-20-80 **Hole No.** 22

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 188 | | 139.0-200.3 SILTSTONE: continued physical condition as previously described | Box 2 (cont) | | PB | 2.0/2.5 recovery |
| | | 188.8 wood fragments | Box 3 | | | |
| 190 | | | | | | 1.7/2.5 recovery |
| 192 | | 192.0 trace fossils | | | | |
| | | 193.4 wood fragments | | | | 1.7/2.5 recovery |
| 194 | | | | | | |
| | | 194.5 trace fossils | | | | pocket penetrometer >4.5 tsf 2/9/81<br>1.9/2.5 recovery |
| 196 | | | | | | |
| 198 | | | S-8 | | | 2.1/2.5 recovery |
| | | 199.0 shell fragments | | | | |
| 200 | | | | | | |
| | | END OF BORING 200.3'<br>12-21-80 - Bailed hole to 50'. Hole quickly recharged to 30'. Bailed to 50' again. Surface packing installed and gas samples taken in upper 50'. No. 1 (2") PVC piezometer installed from 185' to surface with perforations at 165' to 180' and 125' to 145'. Hole bridged at 135' before gravel could be installed. Bentonite plug from 135' to 125'. No. 2 (3/4") PVC piezometer installed from 130' to surface. Perforations from 20' to 125' and from 30' to 50'. | | | | 12/20/80<br>ESA ran e-logs, 12/20/8<br>Gas analysis and installed perforated piezometers 12/21/80.<br>Water sampled 2/16/81 |
| 202 | | | | | | |
| 204 | | | | | | |
| 206 | | | | | | |
| 208 | | | | | | |
| 210 | | | | | | |
| 212 | | | | | | |

Sheet 9 of 9

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

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# BORING LOG 23-3

**Proj:** DESIGN UNIT A-275 **Date Drilled** 11/4/83 **Ground Elev.** 184.5'

**Drill Rig** Failing 750 **Logged By** S. Slaff **Total Depth** 75.8'

**Hole Diameter** 4 7/8" **Hammer Weight & Fall** SS: 140 lbs @ 30", DR: 320 lbs @ 18

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.4 ASPHALT | | | GB | Drilled 0.0-0.7' with 7" garbage barrel. |
| | | FILL | | | | |
| | | ALLUVIUM | | | AD | Drilled 0.7-6.5' with 6" flight auger. |
| 2 | CH | 0.6-2.6 SILTY CLAY: dusky yellowish brown trace of sand; stiff; petroleum odor; moist | | | | |
| | CL | 2.6-4.8 SANDY CLAY: dark yellowish brown; very stiff; petroleum odor | | 8 | DR | 1.0/1.0 recovery |
| | | | C-1 | 15 | | |
| 4 | | 3.5' color change to pale yellowish brown | | | AD | |
| 6 | SC | 4.8-8.8 CLAYEY SAND: moderate yellowish brown; trace of gravel; medium dense; moist | J-1 | 4<br>5<br>6 | SS | 1.5/1.5 recovery<br>set 5" steel surface casing from 0.0-6.2', drilling on with 4 7/8" drag bit |
| | | | | | RD | |
| 8 | | | | 3 | DR | 1.0/1.0 recovery |
| | | | C-2 | 5 | | |
| | CL/SC | 8.8-9.8 SANDY CLAY/CLAYEY SAND: light olive gray; trace of gravel; firm; wet | | | RD | |
| 10 | CL/SC | 9.8-12.6 SANDY CLAY/CLAYEY SAND: dark greenish gray; stiff; medium dense; wet | J-2 | 4<br>4<br>2 | SS | 1.3/1.5 recovery<br>rig chatter |
| 12 | | 11.0-12.2 gravel lens | | | RD | |
| | SM | 12.6-29.2 SILTY SAND: dark greenish gray; medium dense; faint petroleum odor; occasional gravel; wet | | 9 | DR | 1.0/1.0 recovery |
| | | | C-3 | 18 | | |
| 14 | | | | | RD | |
| | | | J-3 | 9<br>14<br>14 | SS | 1.0/1.5 recovery |
| 16 | | 16.6' thin gravel lens | | | RD | rig chatter |
| 18 | | | | 12 | DR | 1.0/1.0 recovery |
| | | | C-4 | 15 | | |
| | | | | | RD | |

**Sheet** 1 **of** 4

**Project** DESIGN UNIT A-275 **Date Drilled** 11/4/83 **Hole No.** 23-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | SM | 12.6-29.2 SILTY SAND: (continued) | J-4 | 10<br>12<br>16 | SS | 0.9/1.5 recovery |
| 22 | | | | | RD | |
| 24 | | | S-1 | | PB | 1.9/2.5 recovery lost bottom 0.6' due to zone of softer material |
| 26 | | | J-5 | 19<br>18<br>11 | SS | 1.3/1.5 recovery |
| | | 27.2' small gravel lens | | | RD | rig chatter |
| 28 | | | C-5 | 7<br>28 | DR | 1.0/1.0 recovery |
| | | | | | RD | 29.5' drilling harder |
| 30 | ML<br>SM | 29.2-46.0 SANDY SILT/SILTY SAND: grayish green; hard/dense; faint sulfurous odor; wet | J-6 | 7<br>14<br>19 | SS | 1.5/1.5 recovery |
| 32 | | | | | RD | |
| 34 | (GM)<br>(SM) | 33.3-34.4' sand & gravel lens | C-6 | 22<br>32 | DR | 1.0/1.0 recovery |
| | | | | | RD | |
| 36 | | | J-7 | 8<br>16<br>22 | SS | 1.5/1.5 recovery |
| | | | | | RD | |
| 38 | | | C-7 | 17<br>27 | DR | 1.0/1.0 recovery |
| | | | | | RD | |
| 40 | | | J-8 | 9<br>22<br>30 | SS | 1.5/1.5 recovery |
| 42 | | | | | RD | |
| 44 | | | PB-2 | | PB | |

**Sheet** 2 **of** 4

**Project** DESIGN UNIT A-275 **Date Drilled** 11/4/83 **Hole No.** 23-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | ML<br>SM | 29.2-46.0 SANDY SILT /SILTY SAND: (continued) | S-2 | | PB | 2.0/2.5 recovery |
| 46 | SM | 46.0-49.6 SILTY SAND: grayish green; dense; occasional fine to coarse gravel; wet | J-9 | 9<br>13<br>25 | SS | 0.9/1.5 recovery |
| | | | | | RD | |
| 48 | | | C-8 | 16<br>19 | DR | 0.9/1.0 recovery |
| | | | | | RD | |
| 50 | SM | 49.6-52.0 SILTY SAND: dusky green; petroleum streaks; very dense; wet | J-10 | 12<br>24<br>28 | SS | 0.8/1.5 recovery |
| 52 | CL | 52.0-75.8 SILTY CLAY: mottled- olive black, light olive gray, and pale green; some sand; low petroleum content; hard; wet | | | RD | |
| | | | C-9 | 22<br>38 | DR | 1.0/1.0 recovery |
| 54 | | | | | RD | |
| 56 | | | J-11 | 11<br>19<br>18 | SS | 0.2/1.5 recovery |
| | | color change to dusky brown | | | RD | |
| 58 | (ML) | becoming more sandy and silty | C-10 | 37<br>50 | DR | 0.8/1.0 recovery |
| | | | | | RD | |
| 60 | | | J-12 | 16<br>36<br>47 | SS | 1.0/1.5 recovery |
| 62 | | | | | RD | |
| 64 | | | S-3 | | PB | 2.5/2.5 recovery |
| 66 | | | J-13 | 37<br>50 | SS | 0.9/0.9 recovery<br>refusal at 11" |
| | | | | | RD | petroleum froth floating on mud tub |
| 68 | | | | | | |

Sheet 3 of 4

**Project** DESIGN UNIT A-275 **Date Drilled** 11/4/83 **Hole No.** 23-3

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | CL | 52.0-75.8 SILTY CLAY: (continued)<br>occasional fine gravel | C-11 | 55<br>50 | DR | 0.75/0.75 recovery |
| | | | | | RD | |
| 70 | | | J-14 | 66 | SS | 0.5/0.5 recovery |
| | | | | | RD | |
| 72 | | color also mottled with grayish green | | | | |
| | | | C-12 | 100 | DR | 0.5/0.5 recovery |
| 74 | | | | | RD | |
| | | | J-15 | 36<br>50 | SS | 0.8/0.8 recovery |
| 76 | | B.H. 75.8' Terminated hole | | | | |
| | | | | | | Tremmied 4 sack cement grout into hole. Covered hole with steel cover.<br>11/8/83 removed steel cover, capped hole with concrete. |
| 78 | | | | | | |
| 80 | | | | | | |
| 82 | | | | | | |
| 84 | | | | | | |
| 86 | | | | | | |
| 88 | | | | | | |
| 90 | | | | | | |
| 92 | | | | | | |

**Sheet** 4 **of** 4

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 23-4

**Proj:** DESIGN UNIT A275
**Date Drilled** 11/3/83
**Ground Elev.** 183.2
**Drill Rig** Failing 750
**Logged By** S. Slaff
**Total Depth** 76.3'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 320 lbs, 18" DR, 140 lbs, 30" SS

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 |  | 0.0-0.25 ASPHALT |  |  | GB | Drilled 0.0-0.5 with 7" garbage barrel. |
|  | SC | FILL |  |  | AD | Drilled 0.5-3.0 with 6" auger. |
|  | OH | ALLUVIUM<br>0.8-1.8 SILTY CLAY: grayish black; trace of sand; stiff; strong petroluem odor |  |  |  |  |
| 2 | ML | 1.8-3.8 SANDY SILT: mottled - grayish brown, dusky brown, grayish olive green; very stiff; occasional fine gravel; moist; strong petroleum odor |  | 14 | DR | 1.0/1.0 recovery |
|  |  |  | C-1 | 16 |  |  |
| 4 | CL | 3.8-6.6 SANDY CLAY: dusky yellowish brown; stiff; moist | J-1 | 3<br>6<br>6 | SS | 1.0/1.5 recovery |
|  |  |  |  |  | AD | set 5" steel surface casing from 0.0-6.2'. Drilling on with 4 7/8" drag bit. |
| 6 |  |  |  |  |  |  |
|  | CL | 6.6-11.0 SANDY CLAY: light olive gray; stiff; moist |  | 4 | DR | 1.0/1.0 recovery |
| 8 |  |  | C-2 | 8 |  |  |
|  |  |  |  |  | RD |  |
|  |  |  | J-2 | 2<br>3<br>3 | SS | 1.4/1.5 recovery |
| 10 |  |  |  |  | RD |  |
|  | GC |  |  |  |  |  |
|  | CL/SC | 11.0-34.0 SANDY CLAY/CLAYEY SAND: grayish green; medium dense to dense/stiff to hard; occasional fine to coarse gravel; wet |  |  |  |  |
| 12 |  |  | S-1 |  | PB | 2.5/2.5 recovery |
| 14 | SC |  |  |  |  |  |
|  | CL/SC |  | J-3 | 5<br>6<br>9 | SS | 0.6/1.5 recovery |
| 16 |  |  |  |  | RD |  |
| 18 |  |  | lost | 12<br>23 | DR | 0.0/1.0 recovery<br>lost sample, rig chatte |
|  | GC | 19.2-20.0 gravel lens |  |  | RD |  |

**Sheet** 1 **of** 4

Project DESIGN UNIT A275 Date Drilled 11/3/83 Hole No. 23-4

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CL/SC<br>SP | 11.0-34.0 SANDY CLAY/CLAYEY SAND: cont.<br>20.2-22.0 silty sand lens | J-4 | 6<br>18<br>15 | SS | 0.5/1.0 recovery |
| 21 | | | | | RD | |
| 22 | CL/<br>SC | | | | | |
| 23 | | | | 4 | DR | 0.0/1.0 recovery |
| | | | lost | 15 | | |
| 24 | | | | | RD | |
| 25 | | | J-5 | 7<br>13<br>18 | SS | 1.5/1.5 recovery |
| 26 | | color change to dusky green | | | RD | |
| 28 | | | | 17 | DR | 1.0/1.0 recovery |
| | | becoming silty | C-3 | 28 | | |
| 29 | | | | | RD | |
| 30 | | | J-6 | 5<br>7<br>12 | SS | 1.5/1.5 recovery |
| 32 | | | | | | |
| 33 | | | S-2 | | PB | 2.5/2.5 recovery<br>tube damaged by grave |
| 34 | SP | 34.0-38.2 CLAYEY SAND: dusky green; very dense; wet | | | | |
| 36 | | 36.0- weak sulfurous odor | J-7 | 12<br>24<br>33 | SS | 1.5/1.5 recovery |
| 37 | | | | | RD | rig chatter |
| 38 | ML<br>SM | 38.2-49.2 SANDY SILT/SILTY SAND: mottled-dusky green; hard; dense; wet | C-4 | 20<br>38 | DR | 1.0/1.0 recovery |
| 39 | | | | | RD | |
| 40 | | | J-8 | 11<br>20<br>22 | SS | 1.3/1.5 recovery |
| 42 | | | | | RD | |
| 44 | | | | 15 | DR | |

Sheet 2 of 4

**Project** DESIGN UNIT A275 **Date Drilled** 11-3-83 **Hole No.** 23-4

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | ML<br>SM | 38.2-49.2 SANDY SILT/SILTY SAND: cont. | C-5 | 30 | DR | 1.0/1.0 recovery |
| | | | | | RD | |
| 46 | | | J-9 | 7<br>15<br>19 | SS | 1.5/1.5 recovery |
| | | | | | RD | |
| 48 | | becoming sandy | C-6 | 43<br>50 | DR | 0.9/0.9 recovery |
| | SP | 49.2-50.0 TAR SAND: very dusky red; some fines; low petroleum content; dense; moist | | | RD | |
| 50 | CL | 50.0-54.0 SANDY CLAY: mottled - grayish green with blackish red, very dusky red; grayish brown and dusky brown; hard; with petroleum; moist | J-10 | 10<br>16<br>22 | SS | 1.5/1.5 recovery |
| 52 | | | | | RD | |
| 54 | CL | 54.0-63.8 SILTY CLAY: dark greenish gray; trace of fine sand and gravel; low petroleum content; hard; moist | S-3 | | PB | 1.9/2.5 recovery |
| 56 | | | J-11 | 11<br>23<br>30 | SS | 1.5/1.5 recovery |
| 58 | | | | | RD | slow drilling zone 57.0-59.0 |
| | | | C-7 | 21<br>43 | DR | 1.0/1.0 recovery |
| 60 | | | | | RD | |
| | | | J-12 | 8<br>20<br>30 | SS | 1.5/1.5 recovery petroleum froth forming on top of mud tub |
| 62 | | | | | RD | |
| 64 | CL | 63.8-76.3 SILTY CLAY: light olive gray; trace of sand and petroleum; trace of gravel; hard; moist | C-8 | 55<br>50 | DR | 0.8/0.8 recovery refusal at 10" |
| | | | | | RD | |
| 66 | | 66.0- olive black | J-13 | 23<br>50 | SS | 1.0/1.0 recovery refusal at 11-1/2" |
| | | | | | RD | |
| 68 | | | | | | |

**Project** DESIGN UNIT A275 **Date Drilled** 11-3-83 **Hole No.** 23-4

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | CL | 63.8-76.3 SILTY CLAY: continued | | | RD | |
| | | | C-9 | 65 | DR | 0.5/0.5 recovery |
| 70 | | | | | RD | |
| | | | | | PB | 2.5/2.5 recovery |
| 72 | | strong petroleum odor | PB-4 | | | tube damaged by gravel |
| 74 | | | | | RD | |
| | | | | 20 | SS | 1.3/1.3 recovery |
| | | | J-14 | 35 | | refusal at 16" |
| 76 | | | | 50 | | 11/3/83 |
| | | B.O.H. 76.3' Terminated hole. | | | | 11/4/83 circulated and conditioned hole. Tremmied grout through drill pipe. Used 5 sacks cement. Covered hole with steel street cover.<br>11/9/83 removed steel hole cover. Capped with concrete. |
| 78 | | | | | | |
| 80 | | | | | | |
| 82 | | | | | | |
| 84 | | | | | | |
| 86 | | | | | | |
| 88 | | | | | | |
| 90 | | | | | | |
| 92 | | | | | | |

**Sheet** 4 **of** 4

THIS BORING LOG IS BASED ON FIELD CLASSIFICATION AND VISUAL SOIL DESCRIPTION, BUT IS MODIFIED TO INCLUDE RESULTS OF LABORATORY CLASSIFICATION TESTS WHERE AVAILABLE. THIS LOG IS APPLICABLE ONLY AT THIS LOCATION AND TIME. CONDITIONS MAY DIFFER AT OTHER LOCATIONS OR TIME.

**Converse Consultants, Inc.**
**Earth Sciences Associates**
**Geo/Resource Consultants**

# BORING LOG 23-5

**Proj:** DESIGN UNIT A275
**Date Drilled** 11/2/83
**Ground Elev.** 184'
**Drill Rig** Failing 750
**Logged By** S. Slaff
**Total Depth** 74.9'
**Hole Diameter** 4 7/8"
**Hammer Weight & Fall** 320 lbs, 18" DR, 140 lbs, 30" SS

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 0 | | 0.0-0.2 ASPHALT | | | GB | Drilled 0.0-0.4' with 7" garbage barrel. |
| | GM | FILL: dark yellowish brown; sandy gravel, some fines; med. dense, dry to moist | | | AD | Drilled 0.4-3.0 with 6" auger. |
| 2 | CL | ALLUVIUM<br>1.4-13.6 SANDY CLAY: dark yellowish brown; hard; moist | | | | |
| | | | | 13 | DR | 1.0/1.0 recovery |
| 4 | | | C-1 | 25 | | |
| | | | | | AD | |
| | | 4.5-5.4 increasing sand content<br>4.5 moderate yellowish brown | J-1 | 10 | SS | 1.5/1.5 recovery |
| | | | | 17 | | |
| 6 | | | | 26 | | set 5" steel surface casing from 0.0-6.3'. Drilling on with 4 7/8" drag bit. |
| | | | | | AD | |
| 8 | | | | 16 | DR | 1.0/1.0 recovery |
| | | becoming very sandy and very stiff | C-2 | 28 | | |
| | | | | | RD | |
| 10 | | | J-2 | 7 | SS | 1.5/1.5 recovery |
| | | 10.8-12.0 sandy zone | | 11 | | |
| | | | | 13 | | |
| 12 | | 12.0-12.5 gravelly zone; moderate yellowish brown to grayish orange | | | RD | rig chatter |
| | | | | 4 | DR | 1.0/1.0 recovery |
| 14 | SC | 13.6-15.2 CLAYEY SAND: moderate yellowish brown; medium dense; moist | C-3 | 9 | | |
| | | | | | RD | |
| | | | J-3 | 3 | SS | 1.5/1.5 recovery |
| 16 | CL | 15.2-19.4 SILTY CLAY: mottled - moderate yellowish brown to very pale orange; trace of sand; stiff; moist | | 5 | | |
| | | | | 8 | | |
| | | | | | RD | rig chatter |
| 18 | | mottled with light brown; becoming hard; becoming sandier | | 18 | DR | 1.0/1.0 recovery |
| | | | C-4 | 32 | | |
| | | | | | RD | |
| | CL | 19.4-42.6 SANDY CLAY: greenish black | | | | |

**Sheet** 1 **of** 4

**Project** DESIGN UNIT A275 **Date Drilled** 11/2/83 **Hole No.** 23-5

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 20 | CL | 19.4-42.6 SANDY CLAY: continued<br>hard; occasional fine gravel;<br>moist | J-4 | 7<br>18<br>21 | SS | 1.5/1.5 recovery |
| 22 | | | | | RD | |
| | | dark greenish gray; becoming less sandy | C-5 | 21<br>36 | DR | 1.0/1.0 recovery |
| 24 | | | | | RD | |
| | (SP) | 25.5-26.4 silty sand lens | J-5 | 11<br>19<br>25 | SS | 1.2/1.5 recovery |
| 26 | CL | | | | RD | |
| 28 | | | C-6 | 28<br>42 | DR | 1.0/1.0 recovery |
| | (SP) | 28.9-29.5 silty sand lens | | | RD | |
| 30 | CL | becoming very stiff | J-6 | 8<br>15<br>14 | SS | 1.5/1.5 recovery |
| 32 | | | | | RD | |
| | | | C-7 | 26<br>40 | DR | 1.0/1.0 recovery |
| 34 | | | | | RD | |
| | | weak sulfurous odor | J-7 | 11<br>13<br>16 | SS | 1.5/1.5 recovery |
| 36 | | | | | RD | |
| 38 | | | S-1 | | PB | 2.5/2.5 recovery |
| 40 | | | J-8 | 7<br>9<br>13 | SS | 1.5/1.5 recovery |
| 42 | | | | | RD | |
| | SM | 42.6-49.0 SILTY SAND: dark greenish gray; | | | | |
| 44 | | | | | | |

**Sheet** 2 **of** 4

**Project** DESIGN UNIT A275 **Date Drilled** 11/2/83 **Hole No.** 23-5

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 44 | SM | 42.6-49.0 SILTY SAND: (continued) medium dense; wet | C-8 | 26<br>48 | DR | 1.0/1.0 recovery |
| 46 | | | | | RD | |
| 48 | | | lost | 9<br>14<br>16 | SS | 0.0/1.5 recovery lost sample probably since check ball did not seat. |
| | CL | 49.0-51.4 SANDY CLAY: dark greenish gray; hard; wet | | | RD | |
| 50 | | | C-9 | 21<br>35 | DR | 1.0/1.0 recovery |
| | | | | | RD | |
| 52 | SC | 51.4-54.0 CLAYEY SAND: dark greenish gray; very dense; wet | lost | 12<br>22<br>28 | SS | 0.0/1.5 recovery |
| 54 | CL | 54.0-66.3 SANDY CLAY: dark greenish gray; hard; interbedded thin clayey sand lenses; wet | | | RD | |
| 56 | | | PB-2 | | PB | 2.5/2.5 recovery |
| 58 | (SP) | 58.1-58.9 silty sand lens | J-9 | 16<br>43<br>46 | SS | 1.5/1.5 recovery |
| | | | | | RD | |
| 60 | | | C-10 | 33<br>60 | DR | 1.0/1.0 recovery |
| 62 | | | | | RD | |
| | | mild sulfurous odor | J-10 | 12<br>20<br>24 | SS | 1.5/1.5 recovery |
| 64 | | | | | RD | |
| 66 | | | C-11 | 22<br>50 | DR | 0.9/0.9 recovery refusal at 11" |
| | CH | 66.3-74.9 SILTY CLAY: dark greenish gray; trace of sand, gravel and petroleum; hard; moist; | | | RD | |
| 68 | | | | | | |

Sheet 3 of 4

**Project** DESIGN UNIT A275 **Date Drilled** 11/2/83 **Hole No.** 23-5

| DEPTH | USCS | MATERIAL CLASSIFICATION | SAMPLE | BLOWS (6") | DRILL MODE | REMARKS |
|---|---|---|---|---|---|---|
| 68 | CH | 66.3-74.9 SILTY CLAY: continued<br>strong petroleum odor | J-11 | 22<br>37<br>50 | SS | 1.4/1.4 recovery |
| 70 | | | | | RD | |
| 72 | | | S-3 | | PB | 2.5/2.5 recovery |
| 74 | | | J-12 | 31<br>47<br>50 | SS | 1.4/1.4 recovery<br>refusal at 17"<br>11/2/83 |
| 76<br>78<br>80<br>82<br>84<br>86<br>88<br>90<br>92 | | B.O.H. 74.9' Terminated hole. | | | | Circulated fluid to condition hole. Tremmied in 2 sack cement grout through drill pipe 1' off bottom of hole. Cleaned site, covered hole with steel cover<br>11/5/83<br>Removed steel hole cover. Capped hole with concrete. |

Sheet 4 of 4

# Appendix B

# Geophysical Exploration

## APPENDIX B GEOPHYSICAL EXPLORATION

### B.1 DOWNHOLE SURVEY

### B.1.1 Summary

Downhole shear wave velocity surveys were performed in Borings CEG-18 and 20 for Design Unit A250. Measurements were made at 5-foot intervals from the ground surface to depths of 100 feet. A description of the technique and a summary of the results are attached.

### B.1.2 Field Procedure

Shearing energy was generated by using a sledge hammer source on the ends of a 4-by-6-inch timber positioned under the tires of a station wagon, tangential to the borehole. A 12-channel signal enhancement seismograph (Geometrics Model ES1210) allowed the summing of several blows in one direction when necessary to increase the signal-to-noise ratio. Shear waves were identified by recording wave arrivals with opposite first motions on adjacent channels of the seismograph.

### B.1.3 Data Analysis

For the purpose of illustration, typical wave arrival records from a downhole geophysical survey are reproduced in Figure B-1. The timing line shows a 20 millisecond (MS) break at the end of the record, indicating that each vertical line is 10 MS. The time of the first arrivals of compressional shear energy is indicated by P and S, respectively. Wave arrival records similar to Figure B-1 were analyzed to estimate wave travel times and velocities for Borings CEG-18 and 20.

### B.1.4 Discussion of Results

Estimated velocity structures are summarized in Table B-1. Velocity estimates are based on selection of linear portions of the downhole arrival time curves (see Figures B-2 and B-3).

The error analysis performed for these surveys involved a least squares fit of these data by estimating the mean of the slope ($\bar{V}$) in Table B-1 and the standard deviation of this estimate of the slope. This estimate of the standard deviation was combined with an estimate of the overall accuracy to produce the best estimated velocity (V*). Vp* are the values to be used for studies of the response of these sites. N is the number of data points used for the straight line fit for each velocity estimate.

## B.2 CROSSHOLE SURVEY

### B.2.1 Summary

Crosshole measurements for the determination of seismic wave velocities were performed in Borings CEG-18 and 20. The crosshole technique for determining shear wave velocities of in-situ materials was utilized in a three-borehole array. The array consisted of boring CEG-18 and 20 and two additional holes drilled approximately 15 feet away from each boring. All boreholes were drilled to a depth of 100 feet. Compressional wave and shear wave velocities are presented in Table B-2.

### B.2.2 Field Procedure

The shear wave hammer is placed in an end hole of the array, and vertical geophones are placed in the remaining two boreholes. The shear wave generating hammer and the two geophones are lowered to the same depth in all boreholes. The hammer is coupled to the wall of the hole by means of hydraulic jacks, and the geophones are coupled by means of expanding heavy rubber balloons which protrude from one side of the geophone housings. The hammer is then used to create vertically polarized shear waves with either an up or down first motion. A 12-channel signal enhancement seismograph with oscilloscope and electrostatic paper camera is used as a signal storage device. Seismic wave velocity determinations were made at 5-foot intervals from 10 feet below ground surface to a depth of 100 feet (see Figures B-4 through B-7).

### B.2.3 Data Analysis

For the data analysis actual crosshole distances were determined to within ±0.01 feet. These distances were computed between each of the three boreholes at the elevations of shear measurements. From the crosshole records (seismograms), the travel times for both compressional and shear wave arrivals at each borehole and at each depth were measured. Shear wave arrivals were identified by the reversed first motion on the seismograms. Compression and shear wave estimates were based on the wave arrival records.

### B.2.4 Discussion of Results

The shear wave velocity ($V_s$) is equal to the difference in travel path distance from the shear source to each geophone divided by the difference in shear wave arrival times. The results of the compressional and shear wave velocity analyses are shown in Table B-2. It should be noted that compression wave velocities below the ground water table may be masked by the compression wave response of the water ($V_c$ = 5000 fps) particularly in highly porous materials.

## B.3 SEISMIC REFRACTION SURVEY

### B.3.1 Summary

Seven seismic refraction lines were recorded in the vicinity of Hancock Park (Lines S-37 through S-43) at the locations shown on Figure B-8. The purpose of these lines was to evaluate the alluvium/bedrock interface in this area and check for evidence of faulting. Interpreted results indicate that alluvial deposits range in thickness form 60 to 100 feet across the area surveyed.

Two anomalies of a type commonly associated with faulting were observed in the area underlying Lines S-38 and S-39.

### B.3.2 Detailed Description

Seismic refraction Lines S-37 through S-40 were recorded end to end from the northwest corner towards the southeast corner of Hancock Park. Lines S-41 through S-43 were recorded at approximate right angles to Lines S-37 through S-40 across the park.

As shown on the cross sections of Figures B-9 through B-12, the area is underlain by low compression wave velocity material (900 to 1,070 ft/sec) to depths of 2 to 9 feet beneath the ground surface. This low velocity zone is underlain by low to medium velocity material (2,260 to 3,000 ft/sec) to depths of 60 to 100 feet where medium to high velocity material (5,540 to 9,900 ft/sec) is encountered. The medium to high velocity zone extends to at least the maximum depth explored (approximately 100 feet).

The low velocity zone is interpreted to represent less consolidated alluvial deposits and fill. The low to medium velocity zone represents more consolidated alluvial deposits, and the medium to high velocity zone is interpreted to represent sedimentary bedrock. High velocity near-surface anomalies were noted beneath both ends of Line S-41 and appear to be the results of alluvium/bedrock interface beneath Lines S-38 and S-39 may be associated with faulting.

# Table B-1

# DOWN HOLE VELOCITIES

| Boring No. | Depth (ft) | COMPRESSIONAL WAVE | | | | | SHEAR WAVE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\overline{V}p$ | σp | Ep | Np | Vp* | $\overline{V}s$ | σs | Es | Ns | Vs* |
| 18 | 10-80 | 6038 | 209 | 302 | 13 | 6040±510 | 1234 | 28 | 62 | 15 | 1230±90 |
| | 80-150 | 5176 | 307 | 259 | 16 | 5180±570 | 1326 | 32 | 66 | 15 | 1330±100 |
| | 150-192 | 6373 | 477 | 319 | 8 | 6370±800 | 1168 | 465 | 58 | 9 | 1170±520 |

| Boring No. | Depth (ft) | COMPRESSIONAL WAVE | | | | | SHEAR WAVE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\overline{V}p$ | σp | Ep | Np | Vp* | $\overline{V}s$ | σs | Es | Ns | Vs* |
| 20 | 20-50 | 3515 | 284 | 176 | 6 | 3520±460 | 1021 | 209 | 51 | 11 | 1020±260 |
| | 50-75 | 4849 | 555 | 242 | 26 | 4849±800 | 1021 | 209 | 51 | 11 | 1020±260 |
| | 75-190 | 4849 | 555 | 242 | 26 | 4849±800 | 1176 | 48 | 59 | 23 | 1180±110 |

$\overline{V}p$ = mean estimate of compressional wave velocity

$\overline{V}s$ = mean estimate of shear wave velocity

σp = standard deviation of estimated compressional wave velocity

σs = standard deviation of estimated shear wave velocity

Ep = estimated accuracy of compressional survey

Es = estimated accuracy of shear survey

Np = number of points used for straight line fit of compressional wave

Vp* = overall accuracy of compressional wave velocity estimate

Vs* = overall accuracy of shear wave velocity estimate

Ns = number of points used for straight line fit of shear wave velocity data

# Table B-2

## CROSS HOLE VELOCITIES

| Boring No. | Depth (ft) | COMPRESSIONAL WAVE |  |  |  |  | SHEAR WAVE |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | $\vec{V}$p | σp | Ep | Np | Vp* | $\vec{V}$s | σs | Es | Ns | Vs* |
| 18 | 10 |  |  |  |  |  | 687 | 14 | 34 | 14 | 690±50 |
|  | 15 |  |  |  |  |  | 881 | 12 | 44 | 13 | 880±60 |
|  | 20 | 6030 | ---- | 600 | 1 | 6030±600 | 1070 | 53 | 53 | 11 | 1070±110 |
|  | 25 | 8351 | 1030 | 418 | 5 | 8350±1450 | 1107 | 24 | 55 | 11 | 1110±80 |
|  | 30 | 7263 | 587 | 363 | 6 | 7260±950 | 1290 | 40 | 65 | 7 | 1290±100 |
|  | 35 | 5423 | 1328 | 271 | 5 | 5420±1600 | 1246 | 103 | 62 | 5 | 1250±170 |
|  | 40 | 6393 | 613 | 320 | 7 | 6390±930 | 1140 | 27 | 57 | 8 | 1140±80 |
|  | 45 | 6957 | 187 | 298 | 6 | 6960±490 | 1190 | 33 | 60 | 8 | 1190±90 |
|  | 50 | 6207 | 1083 | 310 | 4 | 6210±1390 | 1121 | 37 | 56 | 6 | 1120±90 |
|  | 55 | 5768 | 670 | 288 | 6 | 5770±960 | 1045 | 34 | 52 | 8 | 1050±90 |
|  | 60 | 5338 | 458 | 267 | 10 | 5340±460 | 958 | 33 | 48 | 12 | 960±80 |
|  | 65 | 5549 | 490 | 277 | 8 | 5550±770 | 959 | 9 | 48 | 12 | 960±60 |
|  | 70 | 5390 | 880 | 270 | 10 | 5390±1150 | 928 | 12 | 46 | 12 | 930±60 |
|  | 75 | 6096 | 641 | 305 | 7 | 6100±950 | 908 | 6 | 45 | 8 | 910±50 |
|  | 80 | 6390 | 1155 | 315 | 5 | 6310±1470 | 999 | 31 | 50 | 10 | 1000±80 |
|  | 85 | 5403 | ---- | 540 | 1 | 5400±540 | 937 | 29 | 47 | 6 | 940±80 |
|  | 90 | 4591 | ---- | 460 | 1 | 4590±460 | 1093 | 10 | 55 | 7 | 1090±70 |
|  | 95 | 4970 | ---- | 500 | 1 | 4970±500 | 1212 | 48 | 61 | 8 | 1210±110 |
|  | 97 | 4660 | ---- | 470 | 1 | 4660±470 | 1124 | 34 | 56 | 8 | 1120±90 |
| 20 | 10 | 2065 | 11 | 103 | 6 | 270±120 | 829 | 5 | 41 | 10 | 830±50 |
|  | 15 | 4482 | 107 | 224 | 9 | 4480±330 | 792 | 1 | 40 | 9 | 790±40 |
|  | 20 | 4969 | 557 | 248 | 10 | 4970±810 | 779 | 11 | 39 | 12 | 780±50 |
|  | 25 | 4324 | 280 | 216 | 10 | 4320±500 | 915 | 11 | 46 | 10 | 920±60 |
|  | 30 | 4573 | 37 | 460 | 3 | 4570±460 | 1101 | 19 | 53 | 4 | 1100±70 |
|  | 35 | 4140 | 1249 | 207 | 4 | 4140±1460 | 1309 | 22 | 65 | 11 | 1310±90 |
|  | 40 | 4354 | 77 | 218 | 2 | 4350±300 | 1324 | 68 | 66 | 16 | 1320±130 |

$\vec{V}$p = mean estimate of compressional wave velocity

$\vec{V}$s = mean estimate of shear wave velocity

σp = standard deviation of estimated compressional wave velocity

σs = standard deviation of estimated shear wave velocity

Ep = estimated accuracy of compressional survey

Es = estimated accuracy of shear survey

Np = number of points used for straight line fit of compressional wave

Vp* = overall accuracy of compressional wave velocity estimate

Vs* = overall accuracy of shear wave velocity estimate

Ns = number of points used for straight line fit of shear wave velocity data

a - constrained to

b = plus or minus 10%

# Table B-2 (Continued)

## CROSS HOLE VELOCITIES

| Boring No. | Depth (ft) | COMPRESSIONAL WAVE | | | | | SHEAR WAVE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\overline{V}p$ | σp | Ep | Np | Vp* | $\overline{V}s$ | σs | Es | Ns | Vs* |
| 20 | 45 | 4540 | | 450 | 1 | 4540±450 | 1502 | 11 | 75 | 10 | 1500±90 |
| | 50 | 4297 | 0 | 215 | 6 | 4300±215 | 1300 | 39 | 65 | 8 | 1300±100 |
| | 55 | 3533 | 167 | 177 | 6 | 3530±340 | 1266 | 15 | 63 | 11 | 1270±80 |
| | 60 | 3720 | 256 | 186 | 5 | 3720±442 | 1178 | 16 | 59 | 6 | 1180±80 |
| | 65 | 4404 | | 440 | 2 | 4400±440 | 1087 | 13 | 54 | 6 | 1090±70 |
| | 70 | 4495 | 391 | 225 | 4 | 4500±620 | 1211 | 25 | 61 | 11 | 1210±90 |
| | 75 | 4209 | 0 | 210 | 4 | 4210±210 | 1160 | 11 | 58 | 7 | 1160±70 |
| | 80 | 4465 | 169 | 223 | 10 | 4470±390 | 1059 | 32 | 53 | 9 | 1060±90 |
| | 85 | 4805 | 169 | 240 | 7 | 4810±410 | 1177 | 11 | 59 | 9 | 1180±70 |
| | 90 | 4833 | 294 | 242 | 9 | 4830±540 | 1289 | 53 | 64 | 10 | 1290±120 |
| | 95 | 4877 | 0 | 244 | 2 | 4880±240 | 1239 | 31 | 62 | 8 | 1240±90 |
| | 97 | 4725 | | 470 | 1 | 4730±470 | 1236 | 37 | 62 | 7 | 1240±100 |

$\overline{V}p$ = mean estimate of compressional wave velocity

$\overline{V}s$ = mean estimate of shear wave velocity

σp = standard deviation of estimated compressional wave velocity

σs = standard deviation of estimated shear wave velocity

Ep = estimated accuracy of compressional survey

Es = estimated accuracy of shear survey

Np = number of points used for straight line fit of compressional wave

Vp* = overall accuracy of compressional wave velocity estimate

Vs* = overall accuracy of shear wave velocity estimate

Ns = number of points used for straight line fit of shear wave velocity data

Approved for publication 5/84 by JAD

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# DOWNHOLE SAMPLE RECORD

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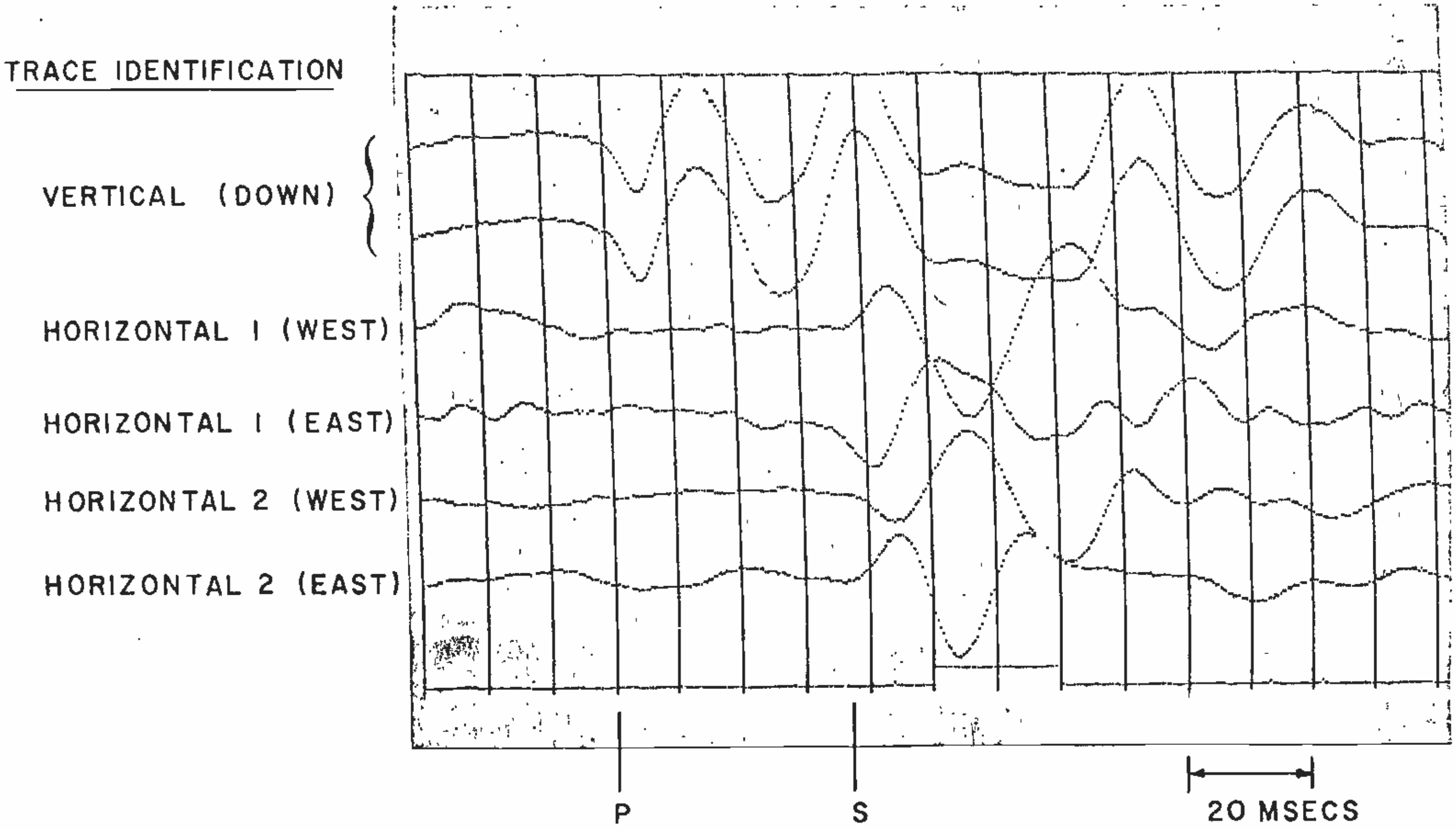
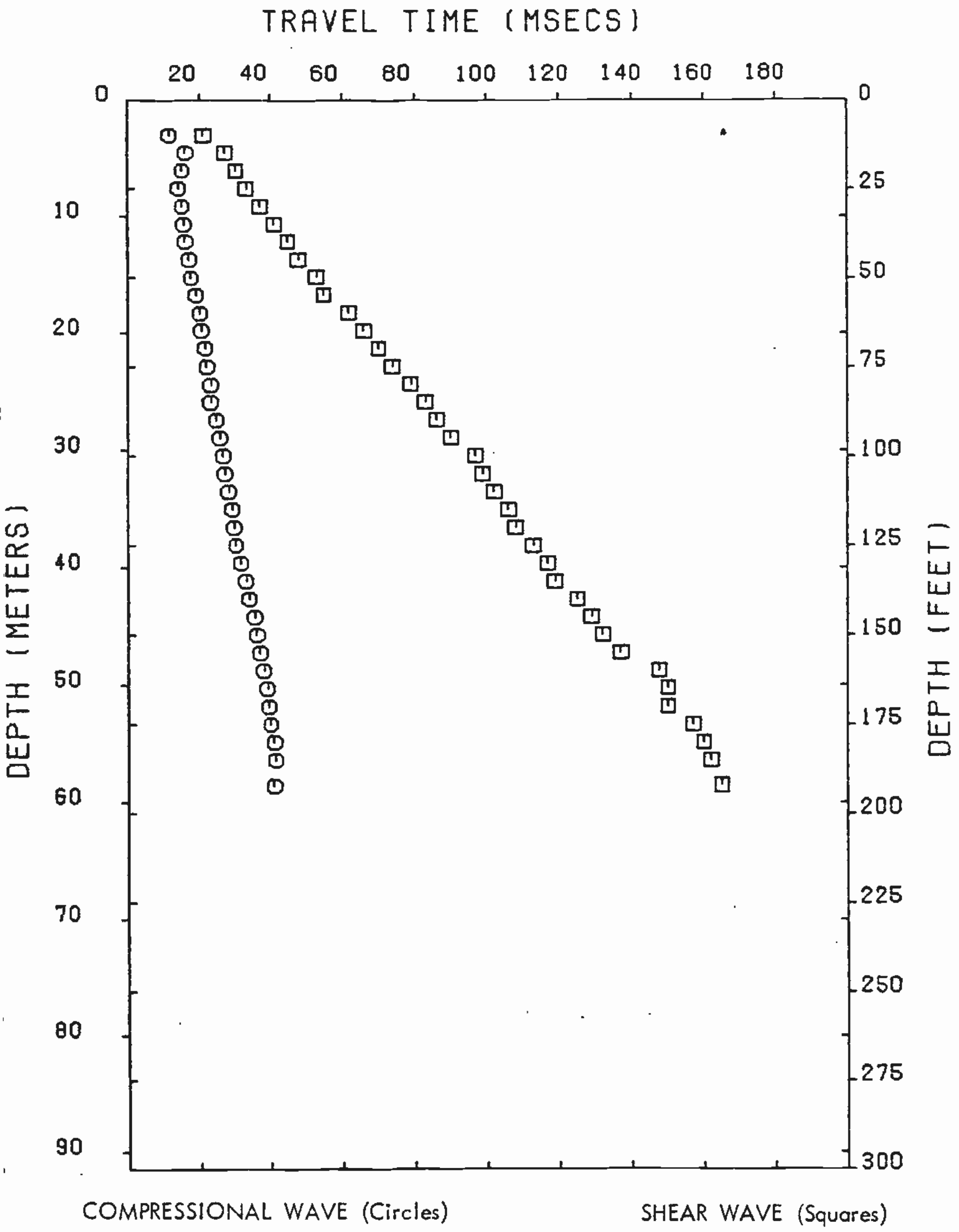
Project No.
83-1140

Figure No.
B-1



BOREHOLE: 13

DEPTH: 70 FT



DOWNHOLE TRAVEL TIME PROFILE - BORING 18

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METRO RAIL PROJECT

Project No.
83-1140

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Figure No.
B-2

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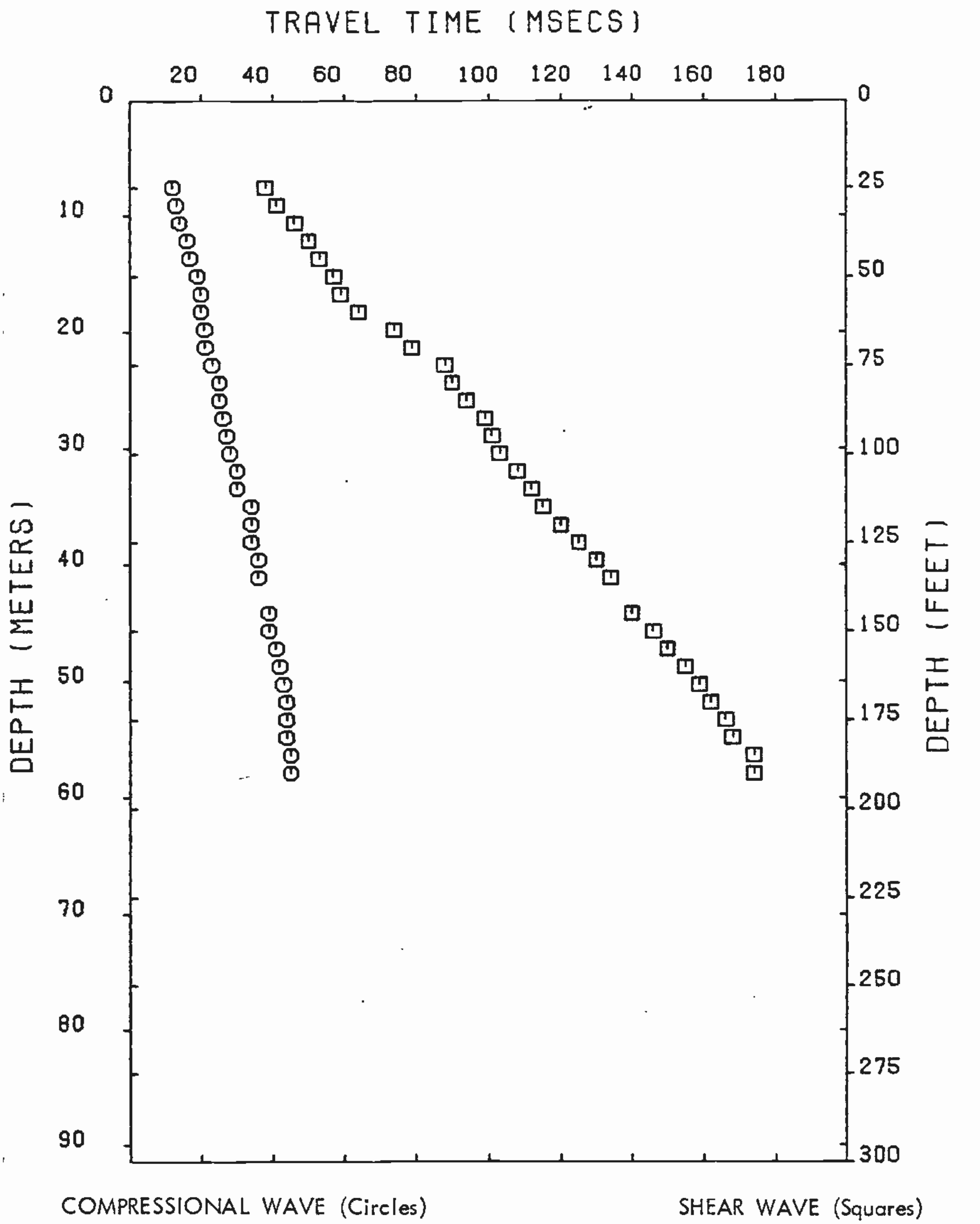

DOWNHOLE TRAVEL TIME PROFILE - BORING 20

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METRO RAIL PROJECT

Project No.
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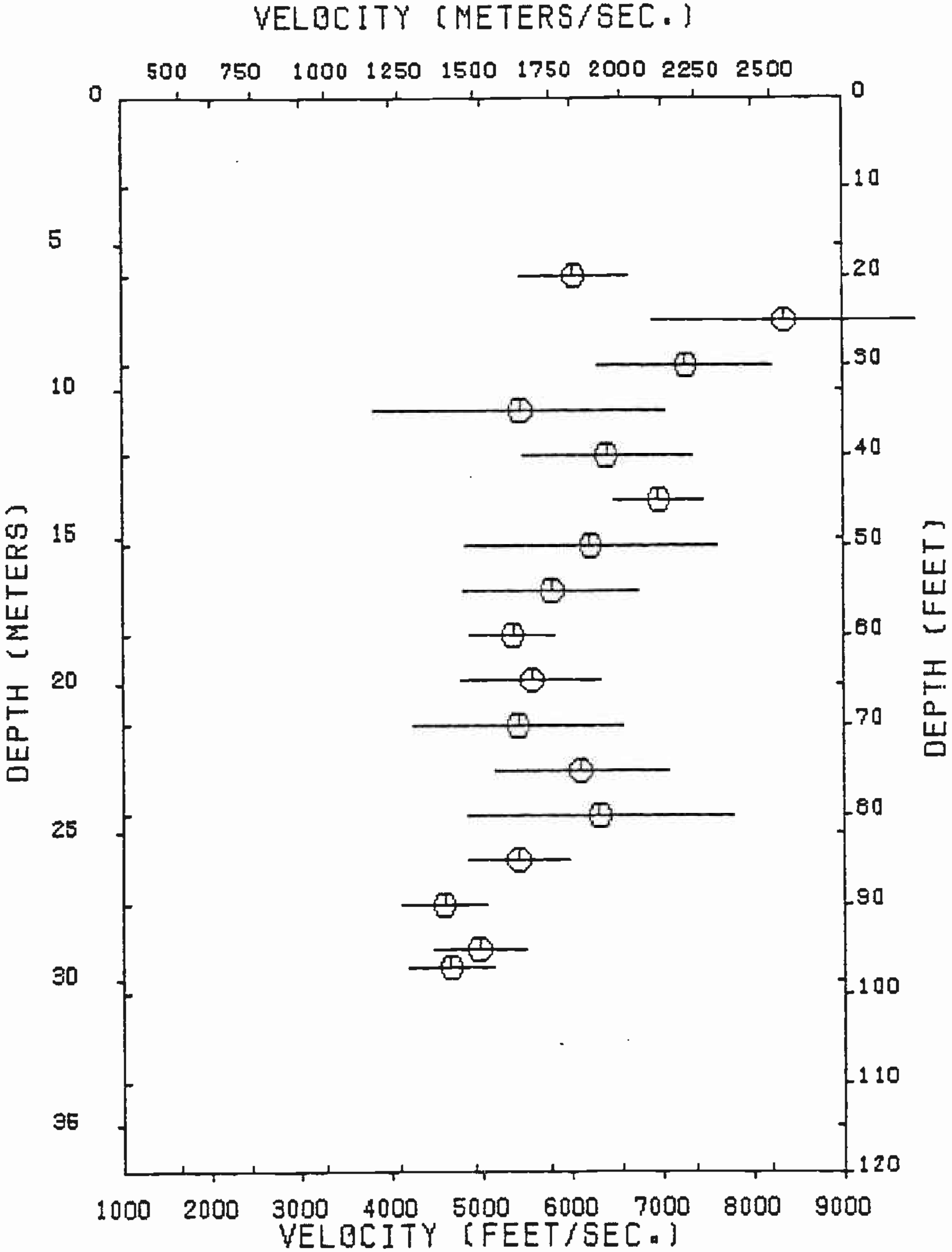
Figure No.
B-3

Approved for publication 5/5/4 by TAD



COMPRESSIONAL WAVE VELOCITY/DEPTH PROFILE - BORING SITE 18

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METRO RAIL PROJECT

Project No.
83-1140

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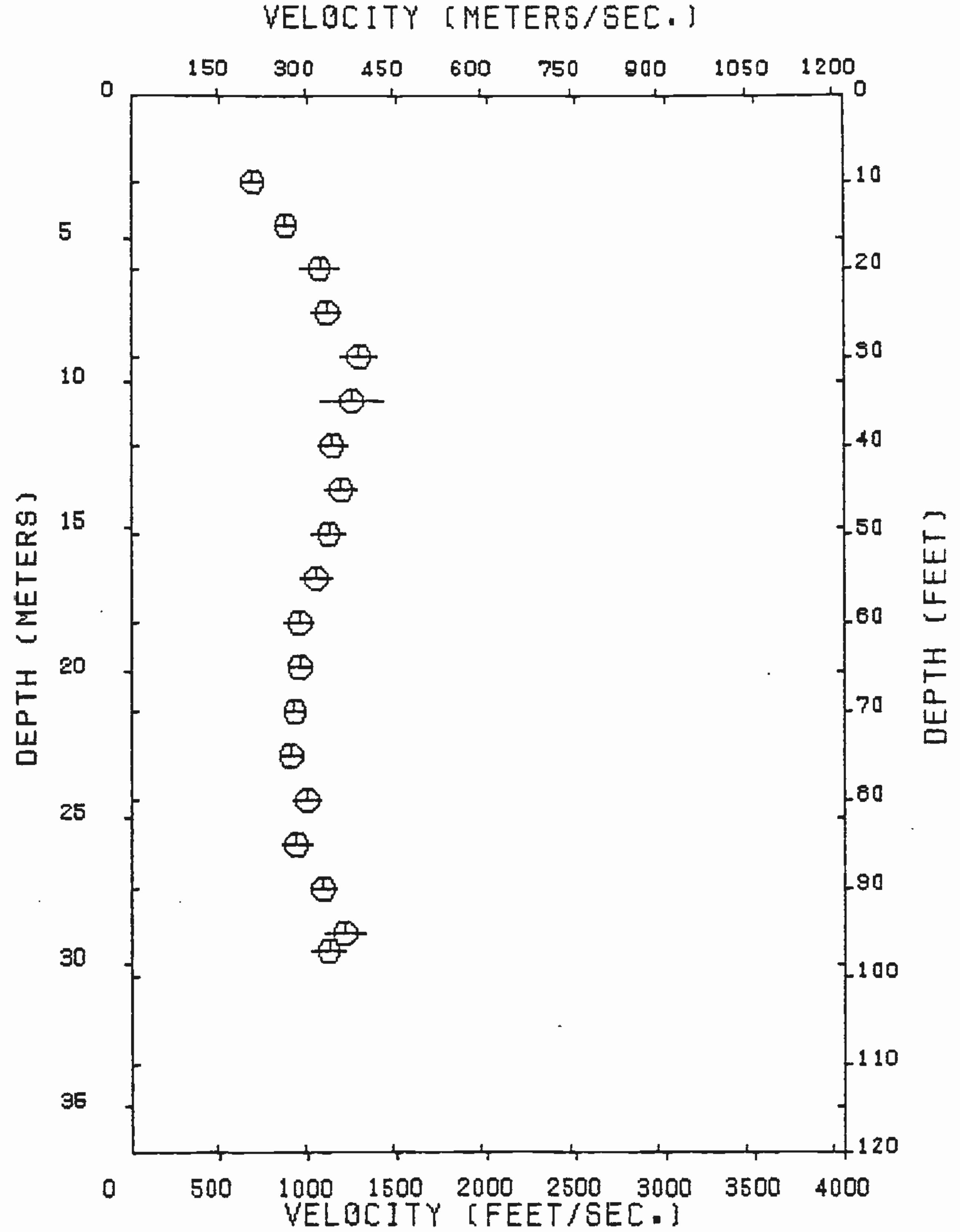
Figure No.
B-4

Approved for publication 5/84 by



SHEAR WAVE VELOCITY/DEPTH PROFILE - BORING SITE 18

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Southern California Rapid Transit District
METRO RAIL PROJECT

Project No.
83-1140

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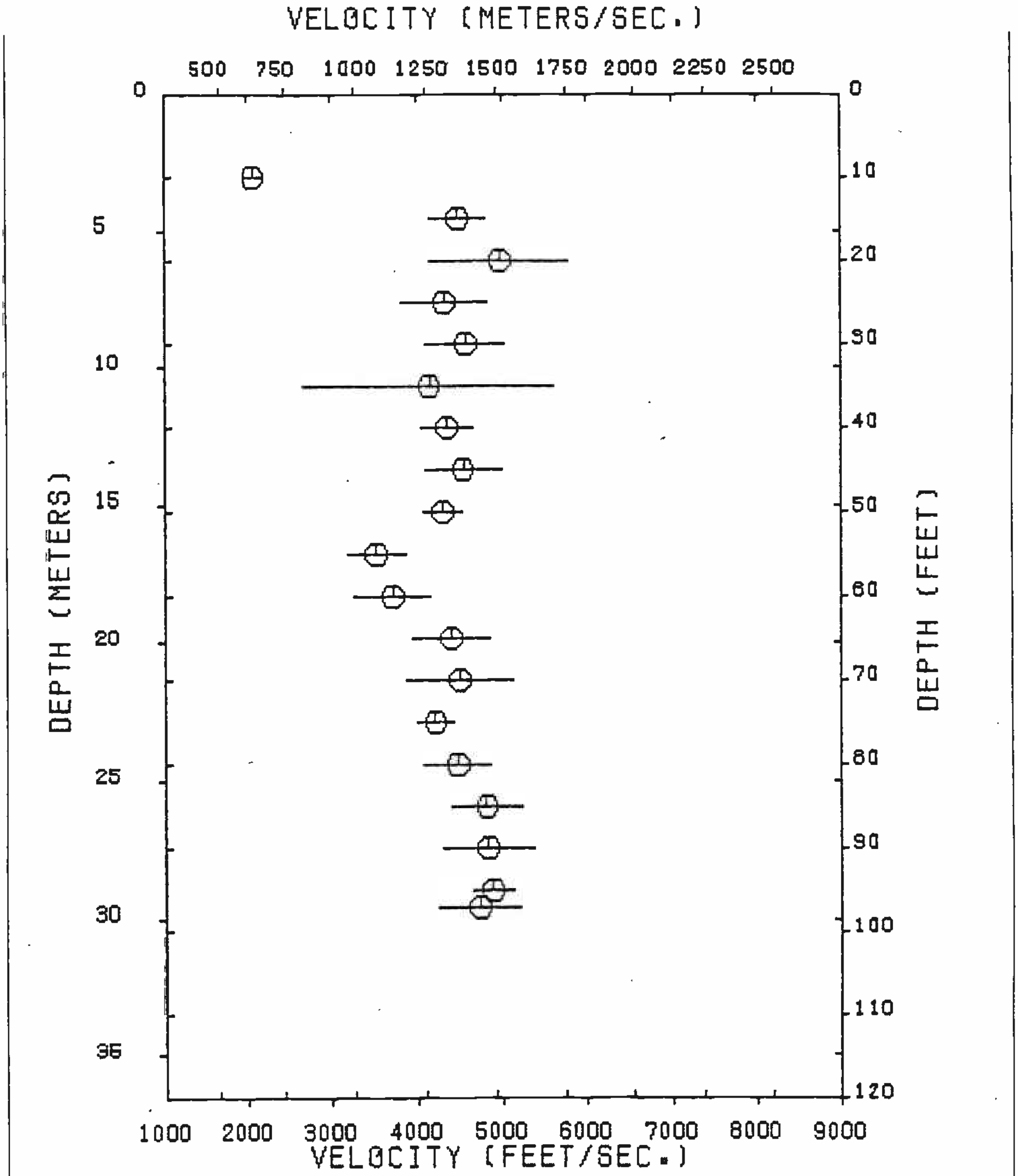
Figure No.
B-5

Approved for publication 5/84 by

Approved for publication 5/84 by FAD



COMPRESIONAL WAVE VELOCITY/DEPTH PROFILE - BORING SITE 20

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83-1140

Figure No.
B-6

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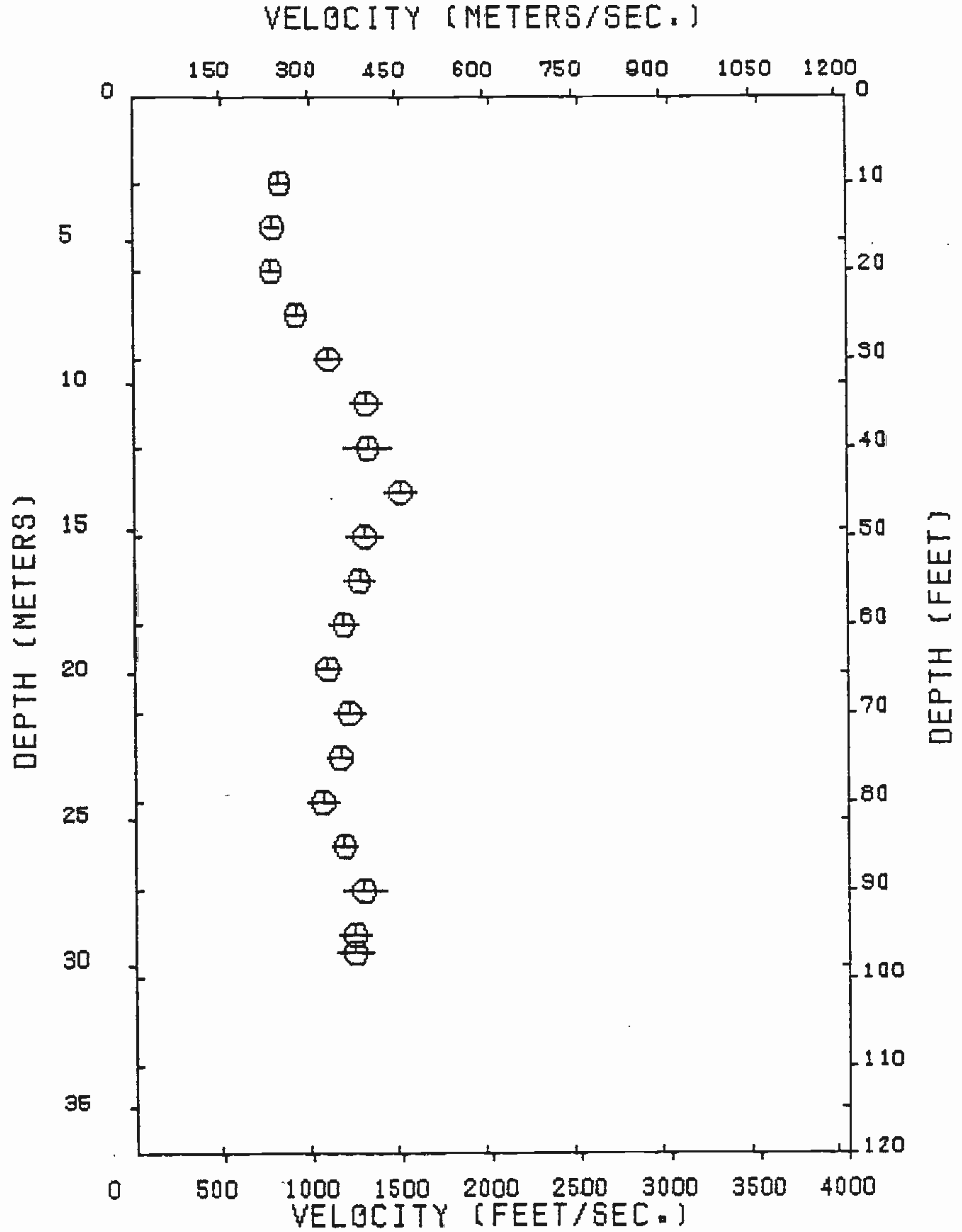

SHEAR WAVE VELOCITY/DEPTH PROFILE - BORING SITE 20

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Figure No.
B-7

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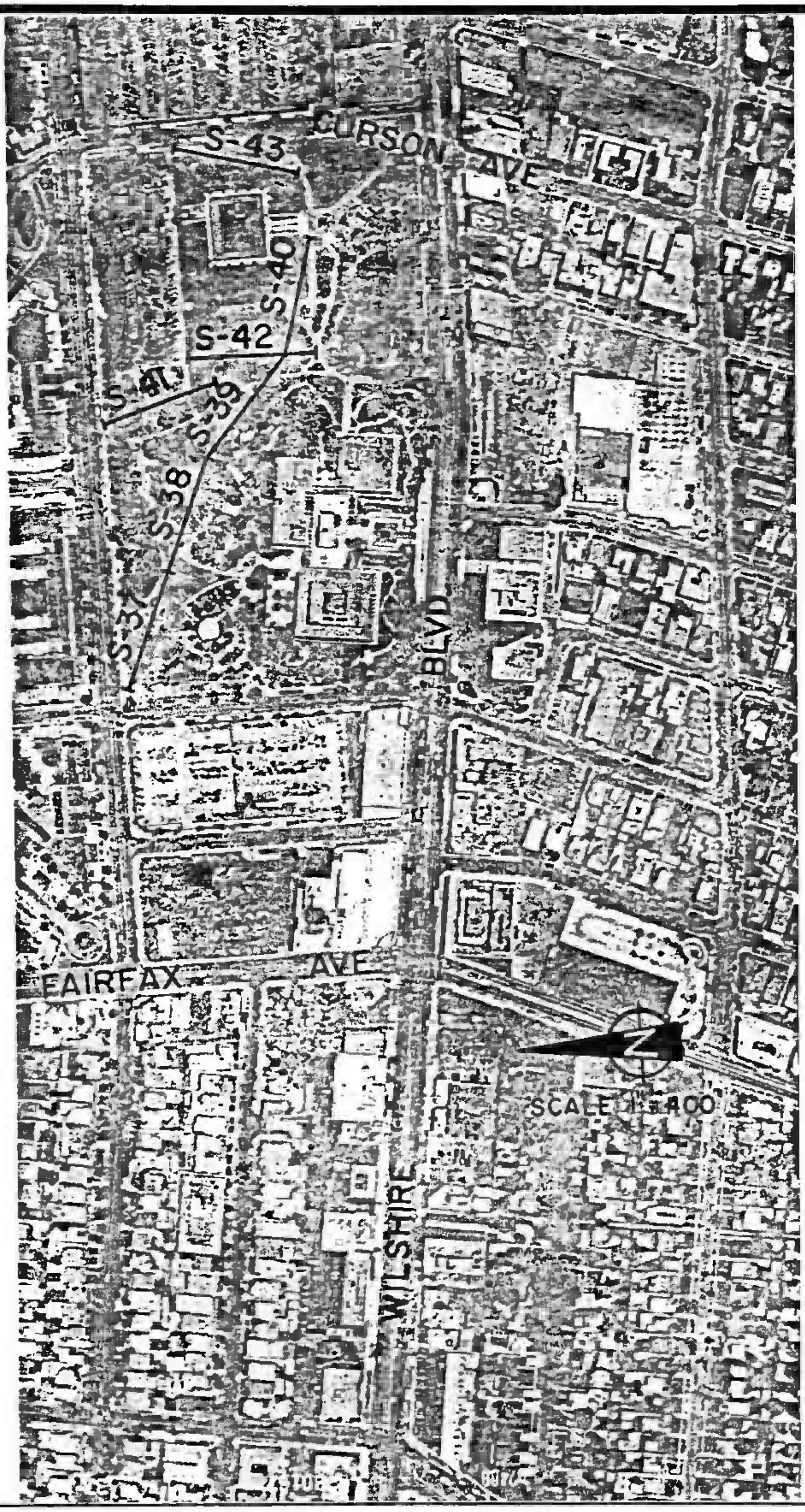

## SEISMIC REFRACTION SURVEY - AREA 2

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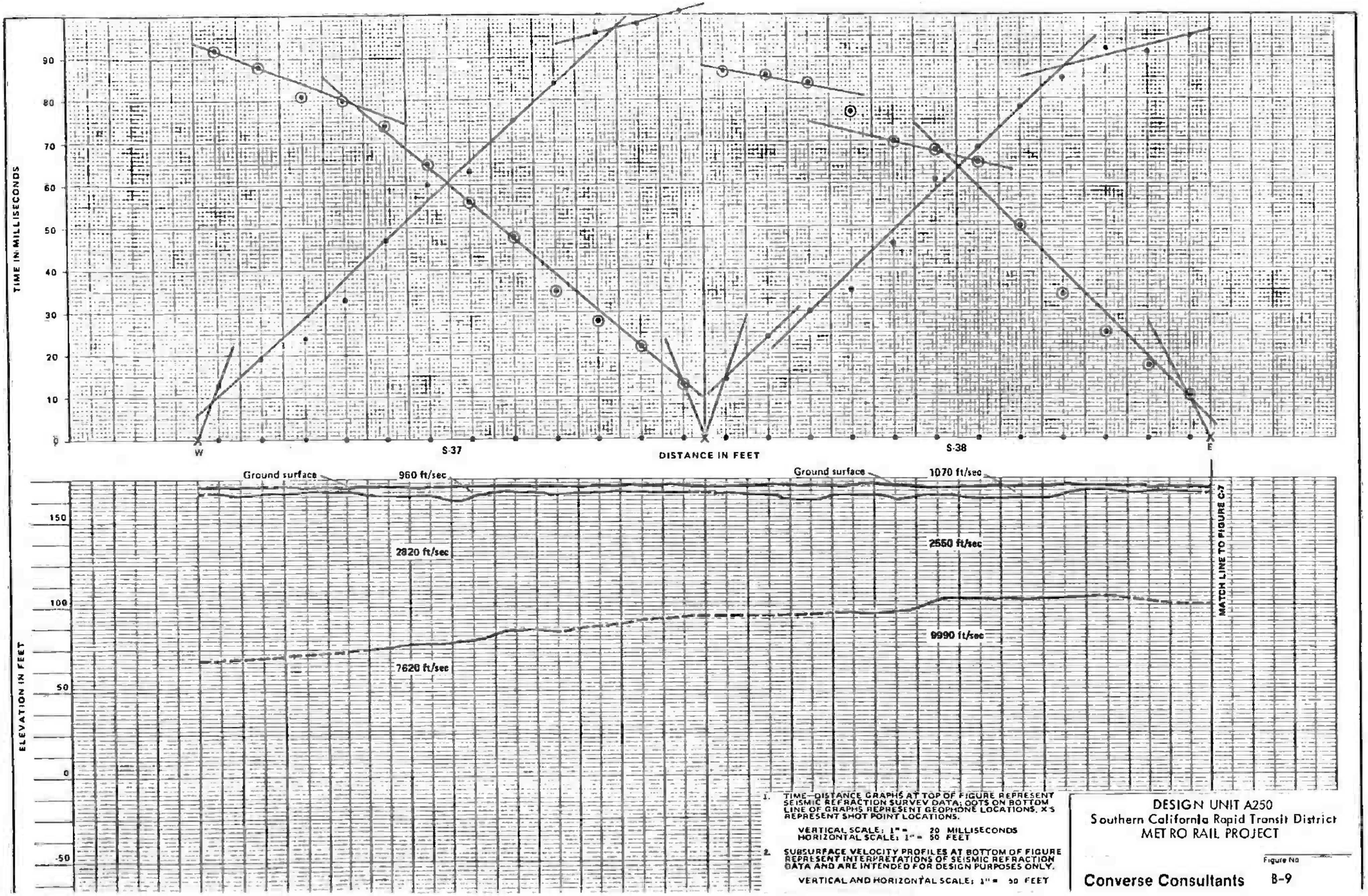
Figure No.
B-8



1. TIME—DISTANCE GRAPHS AT TOP OF FIGURE REPRESENT SEISMIC REFRACTION SURVEV DATA; DOTS ON BOTTOM LINE OF GRAPHS REPRESENT GEOPHONE LOCATIONS. X'S REPRESENT SHOT POINT LOCATIONS.

   VERTICAL SCALE: 1" = 20 MILLISECONDS
   HORIZONTAL SCALE: 1" = 50 FEET

2. SUBSURFACE VELOCITY PROFILES AT BOTTOM OF FIGURE REPRESENT INTERPRETATIONS OF SEISMIC REFRACTION DATA AND ARE INTENDED FOR DESIGN PURPOSES ONLY.

   VERTICAL AND HORIZONTAL SCALE: 1" = 50 FEET

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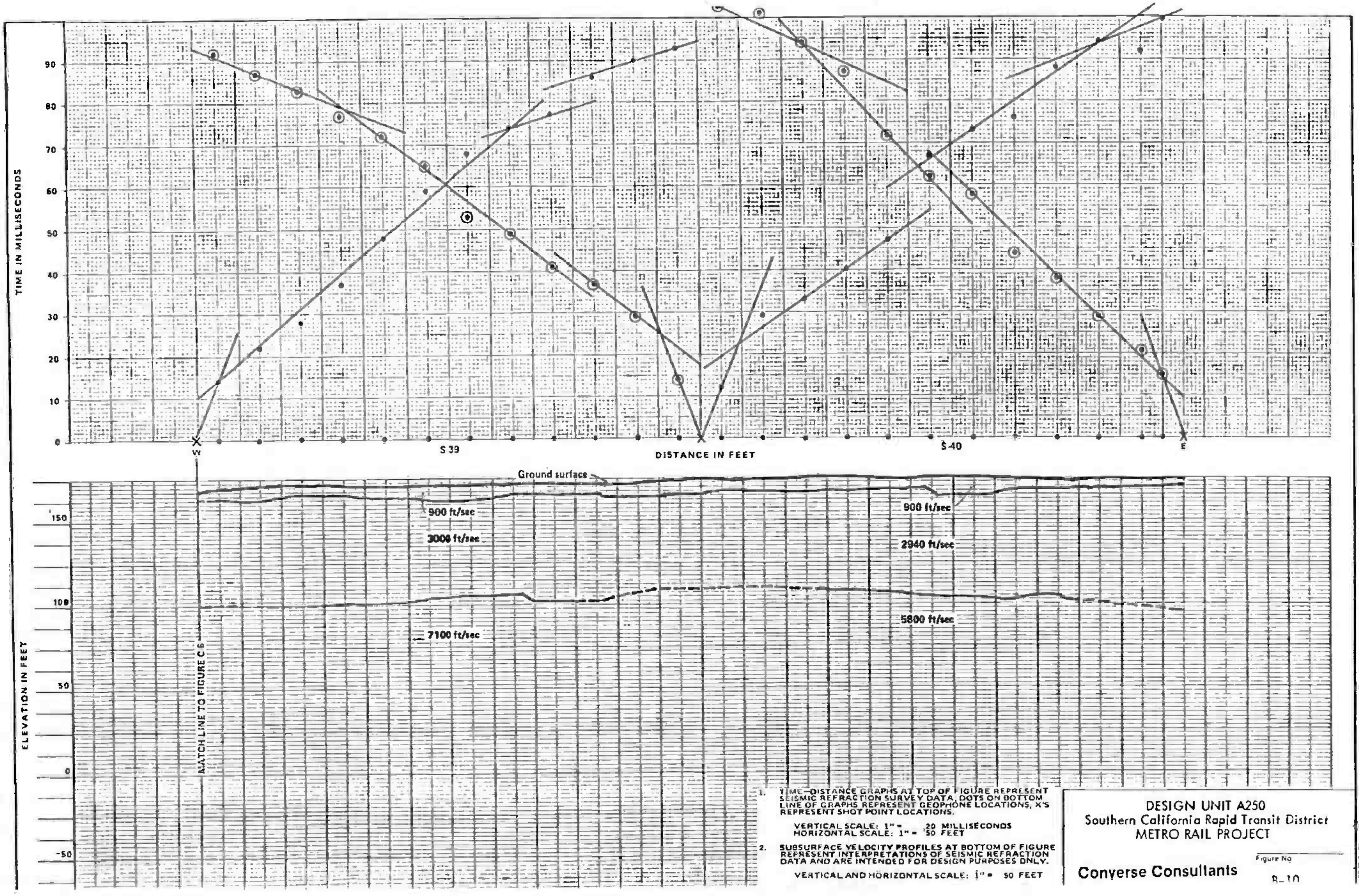
Figure No
**Converse Consultants** B-9



1. TIME–DISTANCE GRAPHS AT TOP OF FIGURE REPRESENT SEISMIC REFRACTION SURVEY DATA, DOTS ON BOTTOM LINE OF GRAPHS REPRESENT GEOPHONE LOCATIONS, X'S REPRESENT SHOT POINT LOCATIONS.

   VERTICAL SCALE: 1" = 20 MILLISECONDS
   HORIZONTAL SCALE: 1" = 50 FEET

2. SUBSURFACE VELOCITY PROFILES AT BOTTOM OF FIGURE REPRESENT INTERPRETATIONS OF SEISMIC REFRACTION DATA AND ARE INTENDED FOR DESIGN PURPOSES ONLY.

   VERTICAL AND HORIZONTAL SCALE: 1" = 50 FEET

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METRO RAIL PROJECT

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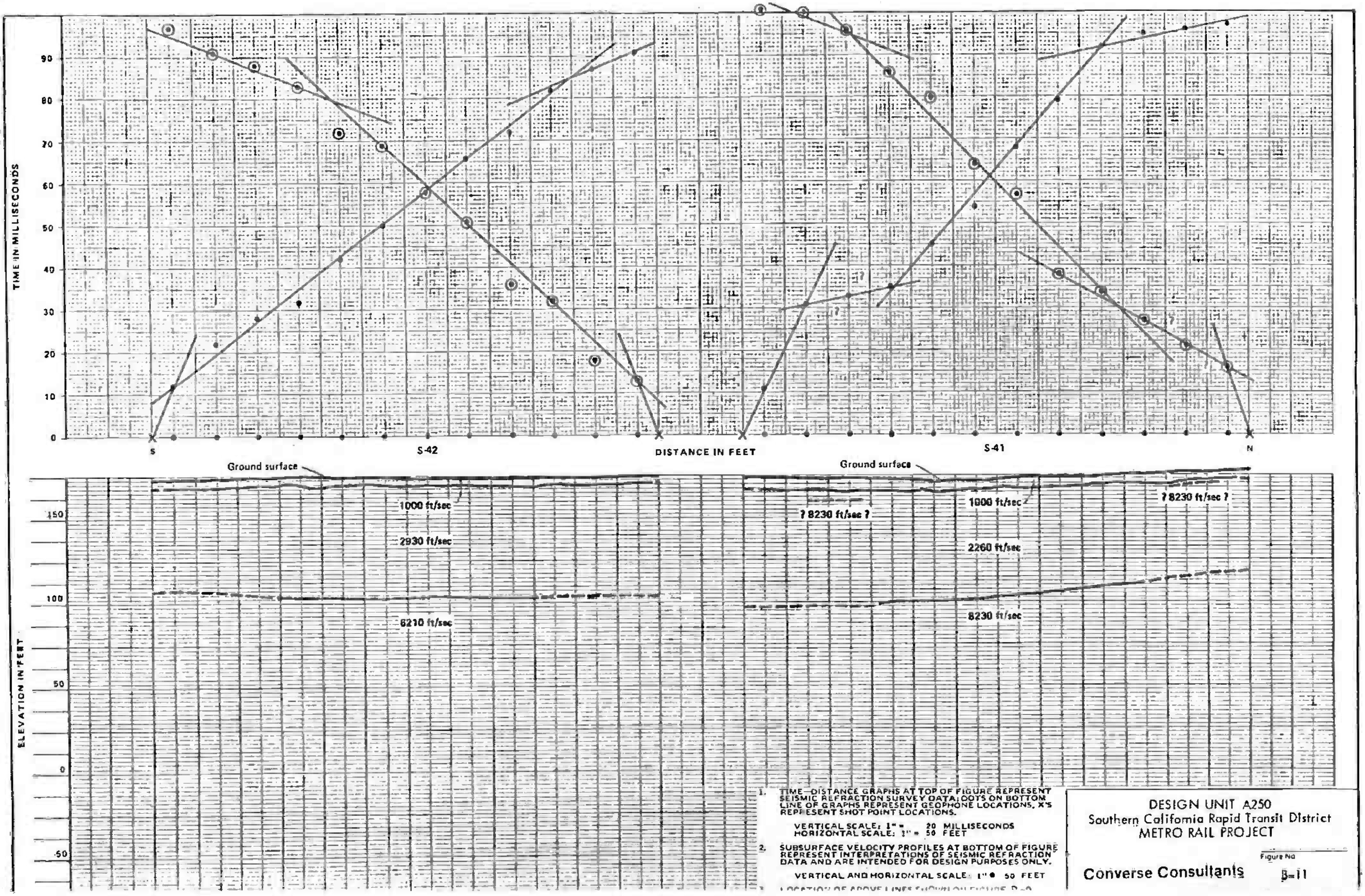
Figure No
B-10



1. TIME—DISTANCE GRAPHS AT TOP OF FIGURE REPRESENT SEISMIC REFRACTION SURVEY DATA; DOTS ON BOTTOM LINE OF GRAPHS REPRESENT GEOPHONE LOCATIONS, X'S REPRESENT SHOT POINT LOCATIONS.

   VERTICAL SCALE: 1" = 20 MILLISECONDS
   HORIZONTAL SCALE: 1" = 50 FEET

2. SUBSURFACE VELOCITY PROFILES AT BOTTOM OF FIGURE REPRESENT INTERPRETATIONS OF SEISMIC REFRACTION DATA AND ARE INTENDED FOR DESIGN PURPOSES ONLY.

   VERTICAL AND HORIZONTAL SCALE: 1" = 50 FEET

3. LOCATION OF ABOVE LINES SHOWN ON FIGURE B-9

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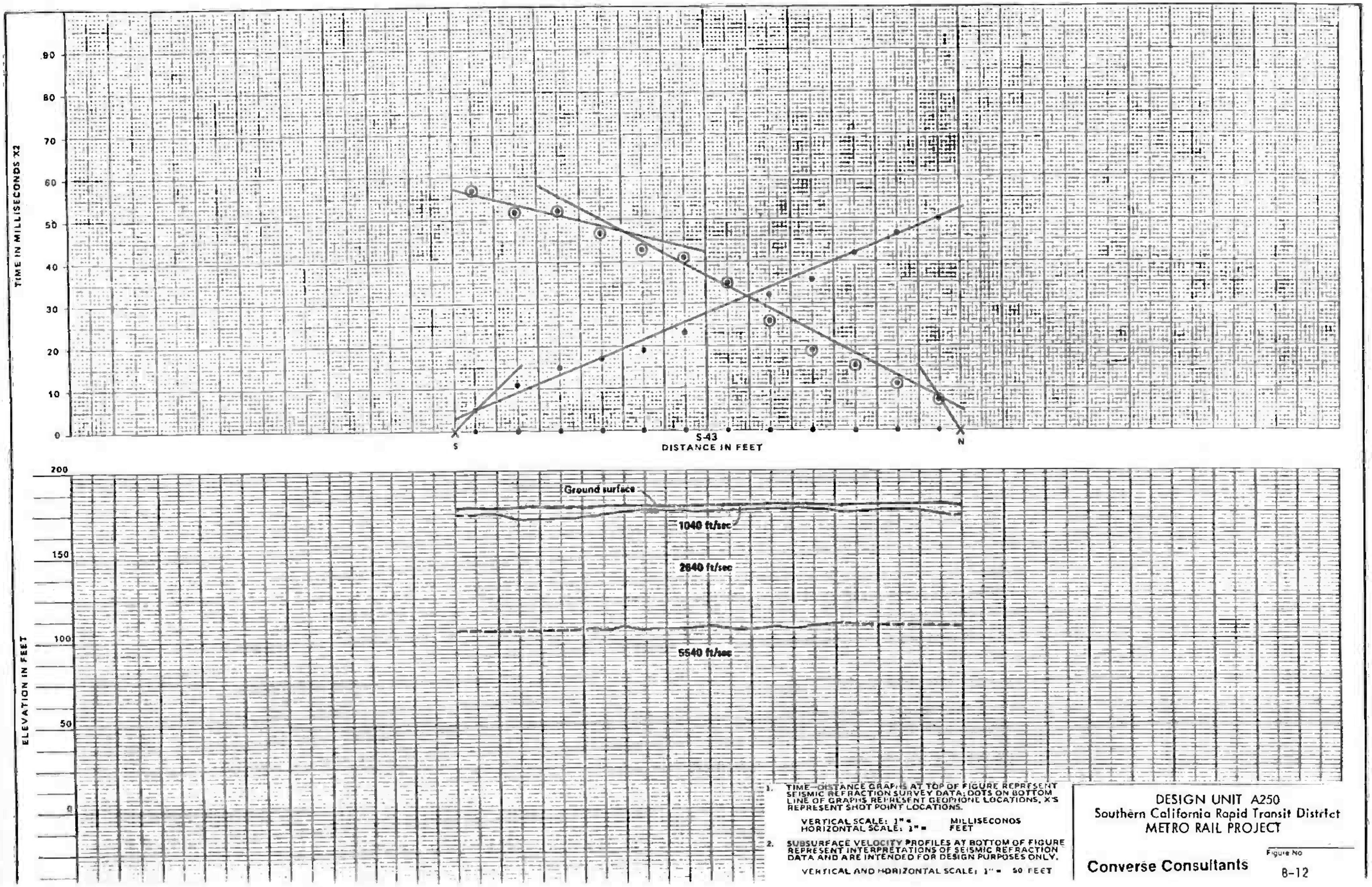
METRO RAIL PROJECT

Converse Consultants

Figure No
B-11



1. TIME–DISTANCE GRAPHS AT TOP OF FIGURE REPRESENT SEISMIC REFRACTION SURVEY DATA; DOTS ON BOTTOM LINE OF GRAPHS REPRESENT GEOPHONE LOCATIONS, X'S REPRESENT SHOT POINT LOCATIONS.

   VERTICAL SCALE: 1" = MILLISECONDS
   HORIZONTAL SCALE: 1" = FEET

2. SUBSURFACE VELOCITY PROFILES AT BOTTOM OF FIGURE REPRESENT INTERPRETATIONS OF SEISMIC REFRACTION DATA AND ARE INTENDED FOR DESIGN PURPOSES ONLY.

   VERTICAL AND HORIZONTAL SCALE: 1" = 50 FEET

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Figure No
B-12

# Appendix C

# Geotechnical Laboratory Testing

# APPENDIX C GEOTECHNICAL LABORATORY TESTING

## C.1 INTRODUCTION

This appendix presents laboratory geotechnical tests performed by Converse Consultants and Thurber Consultants of Edmonton, Alberta, on selected soil and bedrock samples obtained from the borings drilled within Design Unit A250.

The soil tests performed may be classified into two broad categories:

- Index or identification tests which included visual classification, grain-size distribution, Atterberg Limits, moisture content, bitumen content and unit weight testing;
- Engineering properties testing which included unconfined compression, triaxial compression, direct shear, consolidation, permeability, and dynamic triaxial tests.

The laboratory test data from the present investigation are presented in Table C-1, while data from the 1981 geotechnical investigation are presented in Table C-2. Table C-3 summarizes representative bitumen contents performed in both the 1981 and 1983 investigation. Figures C-1 through C-16 summarize strength and modulus data for alluvium, tar bearing alluvium, tar bearing sands, and bedrock at this site.

## C.2 INDEX AND IDENTIFICATION

### C.2.1 Visual Classification

Field classification was verified in the laboratory by visual examination in accordance with the unified Soil Classification System and ASTM D-2488-69 test method. When necessary to substantiate visual classifications, tests were conducted in accordance with the ASTM D-2478-69 test method.

### C.2.2 Grain-Size Distribution

Grain-size distribution tests were performed on representative samples of the geologic units to assist in the soils classification and to correlate test data between various samples. Sieve analyses were performed on that portion of the sample retained on the No. 200 sieve in accordance with ASTM D-422-63 test method. Combined sieve and hydrometer analyses were performed on selected samples which had a significant percentage of soil particles passing the No. 200 sieve. Results of these analyses are presented in the form of grain-size distribution or gradation curves on Figures C-17 through C-23.

It should be noted that the grain-size distribution tests were performed on samples secured with 2.42- and 2.87-inch ID samplers. Thus, material larger than those dimensions may be present in the natural deposits although not indicated on the gradation curves.

### C.2.3 Atterberg Limits

Atterberg Limit Tests were performed on selected soil samples to evaluate their plasticity and to aid in their classification. The testing procedure was in accordance with ASTM D-423-66 and D-424-59 test methods. Test results are presented on Figures C-24 and C-25, and Tables C-1 and C-2.

### C.2.4 Moisture Content

Moisture content determinations were performed on selected soil samples to assist in their classification and to evaluate ground water location. The testing procedure was the ASTM D-2261 test method. Test results are presented on Tables C-1 and C-2.

### C.2.5 Unit Weight

Unit weight determinations were performed on selected undisturbed soil samples to assist in their classification and in the selection of samples for engineering properties testing. Samples were generally the same as those selected for moisture content determinations.

The test procedure entailed measuring specimen dimensions with a precision ruler or micrometer. Weights of the sample were than determined at natural moisture content. Total unit weight was computed directly from data obtained from the two previous steps. Dry density was calculated from the moisture content found in Section C.2.4 and the total unit weight. Results of the unit weight tests are presented as dry densities on Tables C-1 and C-2.

### C.2.6 Bitumen Content

Bitumen contents were determined on selected samples of the tar bearing silts and sands to separate natural bitumen content from moisture content, and correlate test data between various samples. Generally, bitumen contents were performed on samples utlized in engineering properties tests usch as direct shear and triaxial compression.

Test procedures entailed weighing a 25 to 50 gram sample and drying at low temperatures (approximately 40°C) to deterimine mositure content. The dry sample was then soaked in carbon disulfide to liberate the bitumen into solution. The solution was then filtered, dryed and reweighed to deterimine bitumen content as a percentage of sample dry weight.

This test procedure follows ASTM Designation D-4. Results of bitumen contents are presented in Table C-1 and C-3.

## C.3 ENGINEERING PROPERTIES: STATIC

### C.3.1 Unconfined Compression

Unconfined compression tests were performed on selected samples of alluvium tar silts and tar sands from the test borings for the purpose of evaluating the undrained, unconfined shear strength of the various geologic units. The tests were performed in accordance with the ASTM D-2166 test method. Results of the unconfined compression tests are presented on Tables C-1 and C-2.

### C.3.2 Triaxial Compression

Consolidated undrained and unconsolidated undrained (quick) triaxial compression tests were performed on selected undisturbed soil samples. The tests were conducted in the following manner:

### C.3.2.1 Consolidated Undrained (CU) Tests

- The undisturbed test specimen was trimmed to a length to diameter ratio of approximately 2.0.
- The specimen was then covered with a rubber membrane and placed in the triaxial cell.
- The triaxial cell was filled with water and pressurized, and the specimen was saturated using back-pressure.
- When saturation was complete, the specimen was consolidated at the desired effective confining pressure.
- After consolidation, an axial load was applied at a controlled rate of strain. In the case of the undrained test, flow of water from the specimen was not permitted, and the resulting pore water pressure change was measured.
- The specimen was then sheared to failure or until a maximum strain of 15% to 20% was reached.

Some of the tests were performed as progressive tests. The procedure was the same as above except that, when the soil specimen approached but did not reach failure (usually to peak effective stress ratio), the axial load was removed and the specimen was consolidated at a higher confining pressure. The axial load was again applied at a constant rate of strain, and the load was removed before the specimen failed.

Results of the triaxial compression tests are presented on Figures C-26 through C-32.

### C.3.3 Direct Shear

Direct shear tests were performed on selected undisturbed soil samples using a constant strain rate direct shear machine.

Each test specimen was trimmed, soaked and placed in the shear machine, a specified normal load was applied, and the specimen was sheared until a maximum shear strength was developed. Fine-grained samples were allowed to consolidate prior to shearing. The maximum developed shear strengths are summarized on Tables C-1 and C-2.

Progressive direct shear tests were performed on selected undisturbed samples of coarse-grained material. After the soil specimen had developed maximum shear resistance under the first normal load, the normal load was removed and the specimen was pushed back to its original undeformed configuration. A new normal load was then applied, and the specimen was sheared a second time. This process was repeated for several different normal loads. Results of the progressive direct shear tests are summarized on Tables C-1 and C-2.

### C.3.4 Consolidation

Consolidation tests were performed on selected undisturbed soil samples placed in 1 inch high by 2.42-inch diameter brass rings, or 3-inch diameter Shelby tubes trimmed to a 2.42-inch diameter.

Apparatus used for the consolidation test is designed to receive the 1 inch high brass rings directly. Porous stones were placed in contact with both sides of the specimens to permit ready addition or release of water. Loads were applied to the test specimens in several increments, and the resulting settlements recorded.

Results of consolidation tests on the undisturbed samples are presented on Figures C-33 through C-42.

### C.3.5 Permeability

Permeability tests were performed on undisturbed specimens selected for testing, or in conjunction with the static triaxial tests, using the same selected undisturbed samples of soil. Permeability was measured during back-pressure saturation by applying a differential pressure to the ends of the sample and measuring the resulting flow. Results of the tests are tabulated on Tables C-1 and C-2.

### C.3.6 Constant Stress "Creep Tests"

Constant stress or "creep" type tests were performed on undisturbed samples of tar bearing silts and sands to determine deformation versus time characteristics of the viscous tar bearing materials under a prolonged constant shear load condition.

Samples were trimmed and placed in a confining box which restricted movement to a horizontal plane through the approximate center of the sample. A normal load was then applied and the sample allowed to consolidate. A constant shear load was appled along the shear plane of the sample via a dead load system. Generally, shear loads were initiated at approximately 50% of the normal load and increased by increments of 10% of normal load. Horizontal deformation and time readings were taken for each load increment until horizontal movement had stopped. The next load increment was then applied and subsequent readings taken. This procedure was continued until sample failure occurred. The procedures for this tests were devised by Converse Consultants and all equipment was manufactured in house.

Results of constant stress "creep test" are presented in Table C-1 and Figures C-43 through C-45.

### C.3.7 Metal Friction Shear Test

Shear tests were performed on both tar bearing sand and non-tar sand placed in contact with a stationary smooth metal surface in order to determine the frictional effects of the viscous tar materials on steel surfaces. Procedures used to determine metal friction are similar to those described in Section C.3.3 except a metal disk was substituted for the lower half of the test specimen prior to shearing, thus producing a soil to metal shear plane. Test results are presented in Section 5.3.5 of the text.

### C.3.8 Heat Effects of Shear Strength

It is estimated that the exposed tar bearing material in a cut and cover excavation could reach temperatures in excess of 120°F during periods of extended warm weather. In order to determine the effects of temperature increase on shear strength, field conditions were simulated by heating shear specimens to 120°F prior to shearing. Test results of heat controlled shear testing are presented in Table C-1.

## C.4 ENGINEERING PROPERTIES: DYNAMIC

### C.4.1 Resonant Column

The resonant column test provides data by which the shear modulus and damping of soil specimens can be determined for shear strains of approximately $10^{-6}$ to $10^{-4}$ inches per inch. A solid cylindrical soil specimen is encased in a thin membrane, placed in a pressure cell and subjected to the desired ambient stress conditions. The specimen is caused to vibrate at resonance in torsion by fixing one end and applying sinusoidally varying torque to the free end. The response of the soil specimen is measured using an accelerometer coupled to the free end. Shear modulus and damping values are calculated from the response data.

#### C.4.1.1 Sample Preparation and Handling

The test apparatus used for this procedure accepts a 1.4-inch diameter by approximately 3.5-inch length specimen. Undisturbed samples were prepared by trimming the 1.4-inch diameter samples from the larger Shelby, Pitcher or Converse ring samples.

#### C.4.1.2 Test Conditions and Parameters

The resonant column test is considered non-destructive because the shear strain amplitudes are relatively small. Therefore, a single specimen may be used for several tests. For this test program, several of the specimens were tested at confining pressures, ($\sigma$3c), varying from 15 to 50 psi. Although the apparatus is capable of applying anisotropic consolidation stresses, specimens for this program were consolidated isotropically. The specimens were tested beginning at the lower confining pressures and progressing to the higher confining pressures. At each confining pressure, shear modulus and damping data were obtained at several different values of shear strain within the limiting range of the test apparatus. Damping data were obtained for steady state vibration conditions. A summary of pertinent resonant column test data is presented on Figures C-46 through C-49.

### C.4.1.3 Apparatus

The device used in this test program was designed and built by Soil Dynamics Instruments, Inc., of Lexington, Kentucky, and is sometimes referred to as a Hardin Oscillator, after Dr. B.O. Hardin, the designer. Essentially, it consists of the main component groups listed below.

- Pressure Cell and Frame: The unit is aluminum with a transparent plexiglass cylinder designed for maximum operating pressures of approximately 150 psi. The bottom specimen end cap is brass and affixed to the base of the unit.

  Pressure lines and fittings are provided to pressurize the cell and for back pressure or sample drainage, if desired. A pneumatic device is also provided to support the weight of the excitation device during specimen setup.

- Excitation Device: This mechanism consists of a torque-producing apparatus mounted on the underside of a hollow stainless steel cylinder. Its mass is very large in comparison to the test specimen. The driving torque is produced by a system of electromagnetic coils attached to the cylinder and permanent magnets coupled to the top specimen load cap through a system of restoring springs. The device is driven by an audiooscillator having a frequency range of approximately 20 Hz to 40 kHz. Because the device is designed to have a large mass in comparison to the specimen, a lever and weight system supports the weight of the device during the test. A strain gauge load cell is built into the excitation device to monitor the axial load applied to the specimen. In operation, the device applies a sinusoidal torque to the specimen. The driving torque is determined by measuring the voltage drop across a precision resistor in series with the electromagnetic coils.

- Accelerometer and Charge Amplifier: A Columbia Research Labs accelerometer is attached to the excitation device. The accelerometer output is amplified by a charge amplifier, and the system is calibrated to produce output voltage in proportion to the amplitude of angular displacement of the excitation device, and thus of the specimen. Shear strains are calculated from the amplitude of angular displacement.

- Readout Devices: Output voltages produced by the accelerometer, load cell-bridge system, and driving torque are read by a digital multimeter. Resonance of the specimen is determined using a cathode ray oscilloscope connected to display the Lissajous pattern.

### C.4.1.4 Data Reduction

Data obtained from the resonant column tests were reduced in accordance with the ASTM "suggested Methods of Test for Shear Modulus and Damping of Soils by the Resonant Column" using a proprietary computer program developed by Converse Consultants.

### C.4.2 Cyclic Triaxial Compression

Evolved from the static triaxial procedure, this test evaluates soil shear strength, liquefaction, and deformation characteristics under cyclic loading conditions. A cylindrical specimen of soil is encased in a thin rubber membrane, subjected to a confining pressure in a closed cell, brought to the desired equilibrium stress and saturation conditions, and cyclically loaded in the axial direction.

### C.4.2.1 Sample Preparation and Handling

These tests were performed on undisturbed cylindrical samples obtained from rotary borings using a sampler lined with either brass rings or Shelby tubes. Samples from the brass rings were 2.42 inches in diameter by 5 inches in length; those from the Shelby tubes were 2.87 inches in diameter by 6 inches in length. The samples were extruded, weighed and placed in the test cell.

### C.4.2.2 Test Conditions and Parameters

Test conditions and parameters may vary in the cyclic triaxial test. The procedures followed for this project were:

- Stress controlled: Cyclic axial loads of relatively constant magnitude and loading frequency were applied, and the resulting axial strains and specimen pore pressures were measured.

- Saturation: The specimens were artificially saturated using flushing and back pressure techniques. Typical back pressures of 60 to 100 psi were required to saturate the specimens. The degree of saturation was measured using Skempton's B parameter, $\Delta u/\Delta\sigma_{3c}$. The saturation level criterion for this project was a minimum B value of 0.95, except for a few tests which reached a minimum of 0.94.

- Consolidation: Specimens were allowed to consolidate under the specified static ambient stress levels. Consolidation was monitored either by measuring specimen volume changes or by closing the drainage lines and verifying that buildup of pore pressures did not occur. A consolidation ratio ($K_c = \sigma_{1c}/\sigma_{3c}$) of 1.0 was used for this program.

### C.4.2.3 Apparatus

The pneumatic loading system used for these tests was custom-designed and built for Converse Consultants. The device consists of the four main component groups described below.

- Triaxial Chambers and Cyclic Loading Device: The triaxial chambers are comprised of stainless steel and aluminum cells designed for operating pressures up to 400 psi. (Pressures of up to 160 psi were used for this project.) A pneumatic, double-acting piston, capable of applying both static and cyclic loads, is mounted above the triaxial chamber and connected to the specimen load cap by a low-inertia stainless steel rod. The rod passes through the top of the chamber and is held in place by low friction bushings and pressure seals.

- Control Console: This unit contains the various pressure regulators and reservoir systems for controlling cell pressure, back pressures, and sample saturation and drainage. The controls on the console regulate the wave form, frequency, and magnitude of the static and cyclic axial loads.

- Transducer System and Signal Conditioners: The electronic transducers produce electrical voltages in proportion to the key parameters being measured during the test. Parameters monitored and transducer type employed for this program are:

| PARAMETER MONITORED | TRANSDUCER TYPE |
|---|---|
| Axial displacement | Linear variable differential transformers (LVDT's) mounted internally to the specimen load caps |
| Soil pore water pressure | Unbonded wire resistance strain-gauge-type transducers mounted external to the chamber on sample drainage lines |
| Axial load | Bonded resistance strain-gauge-type load cell mounted between double-acting piston and rod connected to specimen load cap |

  Signal conditioners such as power supplies and variable gain amplifiers are used to excite the transducers and amplify the signals to recordable levels.

- Recording Devices: These include (a) a 4-channel continuous strip chart recorder, thermal pens and heat-sensitive paper, frequency response adequate for frequencies normally employed in cyclic triaxial testing, and (b) a cathode ray oscilloscope.

### C.4.2.4 Data Reduction

The following methods and definitions were used in the reduction of test data from the continuous strip chart recording:

- Axial stress: Given in terms of axial load and the unconsolidated specimen cross section area.
- The cyclic testing apparatus is designed to maintain relatively constant axial loads, and no correction is made for changing cross sectional areas of the sample during the test. This is common practice for this type of test.
- Axial strain: Given in terms of the consolidated specimen length. No correction is made for changing specimen length during the test.
- Cyclic axial strain: The larger of the zero-to-peak axial strain or the double amplitude, peak-to-peak, strain for the given cycle of loading.
- Pore pressure ratio: Ratio of the maximum net pore pressure change recorded during the cycle, divided by the net confining pressure, $\sigma_{3c}$.
- Failure criteria: A 10% double amplitude axial strain in the cyclic triaxial tests was selected for plotting.

Graphs of the test results appear in Figure C-50.

### C.4.3 Dynamic Triaxial Compression

This test evolved from the static triaxial procedure and is designed to evaluate the stress-strain properties of the soils under dynamic loading conditions. This test differs from the cyclic triaxial test in that it is designed to obtain dynamic stress-strain data at various strain levels, while the cyclic test measures deformation and liquefaction susceptibility at a given level of cyclic stress. Shear strain data is obtained generally in the range of $10^{-4}$ to $10^{-2}$ inch/inch.

### C.4.3.1 Sample Preparation and Handling

These tests were performed on undisturbed cylindrical samples obtained from rotary borings using a sampler lined with either brass rings or Shelby tubes. Samples from the brass rings were 2.42 inches in diameter by 5 inches in length; those from the Shelby tubes were 2.87 inches in diameter by 6 inches in length. The samples were extruded, weighed and placed in the test cell.

### C.4.3.2 Test Conditions and Parameters

Test conditions and parameters may vary in the dynamic triaxial test. The procedures followed for this project were:

- Stress controlled: After specimen preparation, the specimens were loaded cyclically at several levels of cyclic stress. Generally, one or two cycles of a relatively low stress were applied, the specimen was reconsolidated and loaded again for one or two additional cycles at a slightly higher stress level. This procedure was repeated until the resulting strain levels became large enough to cause significant permanent strain, precluding further satisfactory data (strain of about $10^{-2}$ inch/inch or until the maximum cycle stress level possible with the procedure was reached, corresponding to $\sigma_{cyclic}/2\sigma_{3c} = 0.5$.

- Saturation: The specimens were artificially saturated using flushing and back pressure techniques. Typical back pressures of 60 to 100 psi were required to saturate the specimens. The degree of saturation was measured using Skempton's B parameter, $\Delta u/\Delta\sigma_{3c}$. A minimum value of B = 0.95 was obtained for all test specimens which were saturated.

- A few of the test specimens were tested in their in situ moisture condition, without artificial saturation, in order to evaluate the stress-strain properties of unsaturated samples. The tests which were not saturated are identified on the figures.

- Consolidation: Specimens were allowed to consolidate under the specified static ambient stress levels. Consolidation was monitored either by measuring specimen volume changes or by closing the drainage lines and verifying that buildup of pore pressures did not occur. A consolidation ratio ($K_c = \sigma_{1c}/\sigma_{3c}$) of 1.0 was used for this program.

- Waveform and Frequency: A sinusoidal waveform at a frequency of 0.5Hz was used for this test program.

### C.4.3.3 Apparatus

The apparatus described in Section F.4.2.3 was used for this test. In addition, for the dynamic triaxial tests, an x-y flatbed recorder was utilized to record the hysteretic stress stain curve for each load cycle.

### C.4.3.4 Data Reduction

The following methods and definitions were employed in the reduction of test data from the dynamic triaxial tests.

- Axial stress: Given in terms of axial load and the unconsolidated specimen crosssectional area.

- Axial strain: Given in terms of the consolidated specimen length.

- Dynamic axial strain: The peak-to-peak axial strain for any given loading cycle.

- Shear modulus and shear strain conversion: Axial stress, axial strain and Young's modulus, E, were converted to equivalent shear stress, shear strain and shear modulus, G, using a Poisson's ratio of 0.5 (undrained, zero volume change condition) for tests on saturated samples, and an assumed Poisson's ratio of 0.40 for tests on saturated specimens tested at their in situ moisture contents. Shear strain values are the strains on a plane located at 45° to the principal stress plane, which has been shown to be the plane of maximum shear strain during triaxial loading.

- Modulus: Shear modulus values are defined as the equivalent linear modulus corresponding to the straight line connecting the end points of the hysteresis loop of each loading cycle.

- Shear strain: Shear strain values given are the maximum shear strains between the end points of the hysteresis loop for a given cycle. The maximum shear strain is calculated according to the equations of solid body mechanics as 1.5 x the maximum axial strain.

Results of the dynamic triaxial tests are presented in Figures C-51 and C-52.

TABLE C-1 LABORATORY TEST DATA

| BORING No. | SAMPLE No. | DEPTH (ft) | VISUAL CLASSIFICATION | BITUMEN CONTENT | DRY DENSITY (pcf) | MOISTURE CONTENT (%) | ATTERBERG LIMITS | | Kv, COEFFICIENT OF PERMEABILITY (cm/sec) (Confining Pressure, psi) | UNCONFINED COMPRESSIVE STRENGTH (ksf)* | DIRECT SHEAR STRENGTH ENVELOPE | | ONE-DIMENSIONAL SWELL (%) (Normal Load, ksf) | SWELL PRESSURE (ksf) | SIEVE ANALYSIS | HYDROMETER ANALYSIS | OEDOMETER | TRIAXIAL COMPRESSION (Stages) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | LL | PI | | | ϕ, deg | c, ksf | | | | | | |
| 19-3 | 1 | 2 | Sandy Clay | | 111 | 14 | 45 | 27 | | | 27.0 | 1.00 | | | | | X | |
| | 2 | 13 | Sand | | 110 | 20 | | | | | | | | | | | | |
| 19-4 | 1 | 2 | Silty Clay | | 90 | 29 | | | | 3.42 | | | | | | | | |
| | 2 | 8 | Sandy Clay | | 99 | 25 | 50 | 32 | | | | | | | | | X | |
| | 4 | 28 | Tar Sand | 17.7 | - | 5.3 | | | | | 28.0 | 0.70 | | | | | | |
| | 4 | 28 | Tar Sand | 17.7 | - | 5.3 | | | | | 37.0* | 0* | | | | | | |
| | PB-16 | 85 | Tar Silt | 17.5 | 123 | 8.8 | | | | | | | | | X | X | | X(3) |
| 19-5 | 1 | 2 | Silty Sand | | 114 | 13 | | | | | | | | | | | | |
| | 2 | 8 | Clayey Sand | | 114 | 17 | | | | | | | | | | | | |
| | 3 | 13 | Sandy Clay | | 116 | 15 | 28 | 11 | | | | | | | X | X | | X(2) |
| | 4 | 19 | Sand | | 114 | 18 | | | | | | | | | | | | |
| | 5 | 23 | Clayey Sand | | 110 | 19 | | | | | 36.0 | 0.37 | | | | | | |
| | 6 | 29 | Silty Sand | | 100 | 27 | | | | | | | | | | | | |
| | 8 | 38 | Tar Silt | 15.3 | - | 16.8 | | | | | 22.0 | 1.10 | | | | | | |
| | 8 | 38 | Tar Silt | 15.3 | - | 16.8 | | | | | 37.0* | 0* | | | | | | |
| | 11 | 53 | Tar Sand | | - | - | | | | | 32.2 | 0.10 | | | | | | |

*Constant Stress "Creep" Test.

TABLE C-1 LABORATORY TEST DATA

| BORING No. | SAMPLE No. | DEPTH (ft) | VISUAL CLASSIFICATION | BITUMEN CONTENT | DRY DENSITY (pcf) | MOISTURE CONTENT (%) | ATTERBERG LIMITS |  | Kv, COEFFICIENT OF PERMEABILITY (cm/sec) (Confining Pressure, psi) | UNCONFINED COMPRESSIVE STRENGTH (ksf)* | DIRECT SHEAR STRENGTH ENVELOPE |  | ONE-DIMENSIONAL SWELL (%) (Normal Load, ksf) | SWELL PRESSURE (ksf) | SIEVE ANALYSIS | HYDROMETER ANALYSIS | OEDOMETER | TRIAXIAL COMPRESSION (Stages) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  | LL | PI |  |  | ø, deg | c, ksf |  |  |  |  |  |  |
| 19-5 | PB-6 | 61 | Tar Sand | 18.7 | 126 | 5.6 |  |  |  |  |  |  |  |  | X | X |  | X(3) |
|  | PB-6 | 62 | Tar Sand | 18.7 | 123 | 7.7 |  |  |  |  |  |  |  |  | X | X | X | X(3) |
|  | 18 | 95 | Tar Silt |  |  |  |  |  |  |  | 34.4 | 0.50 |  |  |  |  |  |  |
|  | 18 | 95 | Tar Silt |  |  |  |  |  |  |  | 41.0* | 0* |  |  |  |  |  |  |
|  | 19 | 100 | Clayey Siltstone |  | 102 | 17 |  |  |  | 6.43 |  |  |  |  |  |  |  |  |
|  | 20 | 110 | Clayey Siltstone |  | 103 | 21 |  |  |  | 4.00 |  |  |  |  |  |  |  |  |
|  | 21 | 121 | Clayey Siltstone |  | 109 | 13 |  |  |  |  |  |  |  |  |  |  | X(2) |  |
|  | 22 | 130 | Clayey Siltstone |  | 103 | 16 |  |  |  | 4.79 |  |  |  |  |  |  |  |  |
| 19-6 | 1 | 8 | Gravelly Sand |  | 124 | 11 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2 | 14 | Clayey Sand |  | 110 | 21 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 3 | 19 | Silty Clay |  | 87 | 40 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 4 | 24 | Sandy Silt |  | 96 | 30 | 40 | 11 |  |  |  |  |  |  |  | X |  |  |
| 19-7 | 1 | 2 | Sandy Clay |  | 111 | 11 | 24 | 10 |  |  |  |  |  |  |  |  | X |  |
|  | 2 | 8 | Sandy Clay |  | 106 | 23 |  |  |  |  | 26.0 | 0.77 |  |  |  | X |  |  |
|  | 3 | 14 | Sandy Clay |  | 115 | 19 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 4 | 19 | Silty Sand |  | 111 | 22 |  |  |  |  | 16.0 | 1.80 |  |  | X |  |  |  |

*Constant Stress "Creep" Test.

TABLE C-1 LABORATORY TEST DATA

| BORING No. | SAMPLE No. | DEPTH (ft) | VISUAL CLASSIFICATION | BITUMEN CONTENT | DRY DENSITY (pcf) | MOISTURE CONTENT (%) | ATTERBERG LIMITS | | Kv, COEFFICIENT OF PERMEABILITY (cm/sec) (Confining Pressure, psi) | UNCONFINED COMPRESSIVE STRENGTH (ksf) | DIRECT SHEAR STRENGTH ENVELOPE | | ONE-DIMENSIONAL SWELL (%) (Normal Load, ksf) | SWELL PRESSURE (ksf) | SIEVE ANALYSIS | HYDROMETER ANALYSIS | OEDOMETER | TRIAXIAL COMPRESSION (Stages) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | LL | PI | | | ø, deg | c, ksf | | | | | | |
| 19-7 | 5 | 23 | Sandy Clay | | 103 | 25 | | | | | 41.6 | 0.28 | | | | | | |
| | 6 | 29 | Sandy Clay | | 111 | 22 | | | | | | | | | | | | |
| | 7 | 33 | Tar Silt | | 111 | 13 | | | | | 39.5 | 1.75 | | | | | | |
| | 9 | 44 | Tar Sand | | - | - | | | | | 36.0* | 0.0* | | | | | | |
| | 14 | 88 | Clayey Silt | | 102 | 18 | | | | 5.49 | | | | | | | | |
| 20-1 | 1 | 2 | Sand-Disturbed | | 122 | 5 | | | | | | | | | | | | |
| | 2 | 8 | Sand | | 115 | 12 | | | | | | | | | | | | |
| | 3 | 13 | Clayey Sand | | 111 | 22 | | | | | | | | | | | | |
| | 4 | 19 | Silty Sand | | 114 | 19 | | | | | 30.0 | 0.35 | | | X | | | |
| | 5 | 23 | Silty Clay | | 96 | 31 | 85 | 52 | | | | | | | | X | | |
| | 6 | 29 | Clayey Silt | | 107 | 23 | 43 | 24 | | | 20.0 | 1.12 | | | | | | |
| | 7 | 33 | Tar Silt | | 111 | 12 | | | | | 34.5 | 1.90 | | | | | | |
| | 8 | 43 | Tar Sand | | - | - | | | | | 42.0** | 0** | | | | | | |
| | 9 | 53 | Tar Sand | | - | - | | | | | 36.3 | 0.40 | | | | | | |
| | 9 | 53 | Tar Sand | | - | - | | | | | 43.0* | 0* | | | | | | |
| | 11 | 73 | Tar Sand | | - | - | | | | | 23.5 | 0.30 | | | | | | |

*Constant Stress "Creep" Test.

**Heat Controlled Shear Test.

TABLE C-1 LABORATORY TEST DATA

| BORING No. | SAMPLE No. | DEPTH (ft) | VISUAL CLASSIFICATION | BITUMEN CONTENT | DRY DENSITY (pcf) | MOISTURE CONTENT (%) | ATTERBERG LIMITS |  | Kv, COEFFICIENT OF PERMEABILITY (cm/sec) (Confining Pressure, psi) | UNCONFINED COMPRESSIVE STRENGTH (ksf) | DIRECT SHEAR STRENGTH ENVELOPE |  | ONE-DIMENSIONAL SWELL (%) (Normal Load, ksf) | SWELL PRESSURE (ksf) | SIEVE ANALYSIS | HYDROMETER ANALYSIS | OEDOMETER | TRIAXIAL COMPRESSION (Stages) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  | LL | PI |  |  | ϕ, deg | c, ksf |  |  |  |  |  |  |
| 20-1 | 12 | 83 | Tar Silt | 21.4 | - | 3.8 |  |  |  |  | 44.0 | 0 |  |  |  |  |  |  |
|  | 12 | 83 | Tar Silt | 21.4 | - | 3.8 |  |  |  |  | 48.0* | 0* |  |  |  |  |  |  |
|  | 14 | 103 | Tar Silt |  | - | - |  |  |  |  | 38.5 | 1.0 |  |  |  |  |  |  |
|  | 15 | 113 | Siltstone |  | 103 | 15 |  |  |  |  |  |  |  |  |  |  | X |  |
|  | 16 | 123 | Siltstone |  | 109 | 12 |  |  |  |  |  |  |  |  |  |  |  | Q |
| 20-2 | 1 | 2 | Silty Clay |  | 100 | 27 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 2 | 9 | Clayey Sand |  | 109 | 18 |  |  |  | 2.26 |  |  |  |  |  |  |  |  |
|  | 3 | 13 | Sandy Clay |  | 95 | 29 | 51 | 31 |  |  |  |  |  |  | X | X |  | X(2) |
|  | 4 | 19 | Sand |  | 121 | 10 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 5 | 23 | Silty Clay |  | 100 | 24 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 6 | 29 | Sandy Clay |  | 106 | 20 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 7 | 33 | Clayey Silt |  | 111 | 22 | 49 | 22 |  |  | 23.0 | 1.72 |  |  |  |  |  |  |
|  | 8 | 39 | Silty Clay |  | 118 | 19 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | 12 | 78 | Tar Sand |  | - | - |  |  |  |  | 39.2 | 0 |  |  |  |  |  |  |
|  | 12 | 78 | Tar Sand |  | - | - |  |  |  |  | 45.0* | 0* |  |  |  |  |  |  |
|  | 14 | 98 | Siltstone |  | 94 | 30 |  |  |  |  |  |  |  |  |  |  |  | X(2) |

*Constant Stress "Creep" Test.

TABLE C-1 LABORATORY TEST DATA

| BORING No. | SAMPLE No. | DEPTH (ft) | VISUAL CLASSIFICATION | BITUMEN CONTENT | DRY DENSITY (pcf) | MOISTURE CONTENT (%) | ATTERBERG LIMITS |  | Kv, COEFFICIENT OF PERMEABILITY (cm/sec) (Confining Pressure, psi) | UNCONFINED COMPRESSIVE STRENGTH (ksf) | DIRECT SHEAR STRENGTH ENVELOPE |  | ONE-DIMENSIONAL SWELL (%) (Normal Load, ksf) | SWELL PRESSURE (ksf) | SIEVE ANALYSIS | HYDROMETER ANALYSIS | OEDOMETER | TRIAXIAL COMPRESSION (Stages) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  | LL | PI |  |  | ø, deg | c, ksf |  |  |  |  |  |  |
| 20-2 | 15 | 103 | Siltstone |  | 90 | 31 |  |  |  |  |  |  |  |  |  |  | X |  |
|  | 17 | 113 | Siltstone |  | 92 | 29 |  |  |  |  |  |  |  |  |  |  |  | Q |
|  | 19 | 123 | Siltstone |  | 99 | 25 |  |  |  |  |  |  |  |  |  |  |  | Q |
| 20-3 | 12 | 116 | Siltstone |  | 105 | 19 |  |  |  |  |  |  |  |  |  |  |  | Q |

TABLE C-2 COMPREHENSIVE LIST OF SOILS ENGINEERING PROPERTIES FROM LABORATORY TESTS

| CEG BORING No. | SAMPLE No. | DEPTH (ft) | VISUAL CLASSIFICATION | GEOLOGIC UNIT | DRY DENSITY (pcf) | MOISTURE CONTENT (%) | ATTERBERG LIMITS | | PARTICLE SIZE CUMULATIVE % PASSING SIEVE No. | | | UNCONFINED COMPRESSION STRENGTH (psi) | $K_v$, COEFFICIENT OF PERMEABILITY (cm/sec) | COEFFICIENT OF CONSOLIDATION $C_c$ (in/in per Log Cycle) | SPECIFIC GRAVITY | POROSITY (n) | UNDRAINED QUICK DIRECT SHEAR | | ONE-DIMENSIONAL SWELL (%) (Normal Load, ksf) | CYCLIC TRIAXIAL (Liquefaction) | DYNAMIC TRIAXIAL (Stress/Strain) | RESONANT COLUMN | TRIAXIAL COMPRESSION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | LL | PI | 4 | 40 | 200 | | | | | | $\phi$, deg | c, ksf | | | | | |
| 19 | C1 | 20 | Tar sand | SP | 190 | 10 | | | | | | 8.1 | | | | | | | | | | | |
| | C3 | 61 | Tar sand | SP | | | | | | | | | | | | | | | | | | | Q |
| | S1 | 93 | Oily siltstone | C | 87 | 23 | | | | | | 25.9 | | | | | | | | | | | |
| | S2 | 110 | Oily siltstone, Occ. sand lenses | C | 87 | 24 | | | | | | 37.6 | | | | | | | | | | | |
| | S4 | 143 | Oily siltstone, folded | C | 92 | 21 | | | | | | 22.0 | | | | | | | | | | | |
| | S6 | 180 | Oily silstone, folded | C | 83 | 28 | | | | | | 36.1 | | | | | | | | | | | |
| | S7 | 200 | Oily siltstone, folded | C | 92 | 22 | | | | | | 3.5 | | | | | | | | | | | |
| 20 | C1 | 20 | Clayey, fine to medium sand | $A_4$ | 112 | 15 | | | | | | | | | | | | | | | | X | |
| | C1 | 21 | Sandy clay | $A_2$ | 110 | 18 | | | | | | | | | | | 21 | 1.05 | | | | | |
| | S1 | 119 | Oily, sandy siltstone | C | 99 | 20 | | | | | | 28.0 | | | | | | | | | | | |
| | S2 | 131 | Oily, sandy siltstone | C | 100 | 24 | | | | | | 53.9 | | | | | | | | | | | |
| | S3 | 146 | Oily, Sandy siltstone | C | 94 | 28 | | | | | | 69.6 | | | | | | | | | | | |
| | S4 | 176 | Siltstone | C | | | | | | | | | 3.1E-8 | | | | | | | | | | |
| | S6 | 191 | Silty claystone | C | 107 | 15 | | | | | | 95.6 | | | | | | | | X | | | |

TABLE C-2 COMPREHENSIVE LIST OF SOILS ENGINEERING PROPERTIES FROM LABORATORY TESTS

| CEG BORING No. | SAMPLE No. | DEPTH (ft) | VISUAL CLASSIFICATION | GEOLOGIC UNIT | DRY DENSITY (pcf) | MOISTURE CONTENT (%) | ATTERBERG LIMITS |  | PARTICLE SIZE CUMULATIVE % PASSING SIEVE No. |  |  | UNCONFINED COMPRESSION STRENGTH (psi) | $K_v$, COEFFICIENT OF PERMEABILITY (cm/sec) | COEFFICIENT OF CONSOLIDATION $C_c$ (in/in per Log Cycle) | SPECIFIC GRAVITY | POROSITY (n) | UNDRAINED QUICK DIRECT SHEAR |  | ONE-DIMENSIONAL SWELL (%) (Normal Load, ksf) | CYCLIC TRIAXIAL (Liquefaction) | DYNAMIC TRIAXIAL (Stress/Strain) | RESONANT COLUMN | TRIAXIAL COMPRESSION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  | LL | PI | 4 | 40 | 200 |  |  |  |  |  | ø, deg | c, ksf |  |  |  |  |  |
| 21 | S1 | 19 | Fine sandy silt | $A_4$ | 93 | 28 |  |  | 100 | 100 | 79 |  |  | .068 |  |  |  |  |  |  |  |  | Q |
|  | C1 | 40 | Silty fine to medium sand | $A_3$ | 103 | 22 |  |  |  |  |  |  | 5.3E-7 |  |  | 35.7 |  |  |  |  |  |  |  |
|  | C1 | 40 | Silty fine to medium sand | $A_3$ | 114 | 14 |  |  |  |  |  |  |  |  |  |  | 39.5 | 0.99 |  |  |  |  |  |
|  | C1 | 40 | Silty fine to medium sand | $A_3$ | 106 | 22 |  |  |  |  |  |  |  |  |  |  |  |  | 0.0 |  |  |  |  |
|  | J4 | 40 | Sandy silt | $A_4$ |  |  |  |  | 99 | 85 | 53 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | C2 | 60 | Sand, fine to medium | $A_3$ | 110 | 17 |  |  |  |  |  |  | 1.2E-6 |  | 2.86 | 38.3 | 32.0 | 0.38 |  |  |  |  |  |
|  | J8 | 80 | Silty fine sand | $A_3$ |  |  |  |  | 100 | 82 | 9 |  |  |  |  |  |  |  |  |  |  |  |  |
|  | C3 | 80 | Clean to silty fine sand | $A_3$ | 107 | 20 |  |  |  |  |  |  | 7.0E-4 |  | 2.66 | 38.2 |  |  |  |  |  |  |  |
|  | C3 | 80 | Clean to silty fine sand | $A_3$ | 103 | 21 |  |  | 100 | 92 | 10 |  |  |  |  |  |  |  |  |  |  |  | cup |
|  | C4 | 100 | Silty fine sand | SP | 108 | 19 |  |  |  |  |  |  |  |  |  |  | 29.5 | 0.34 |  |  |  |  |  |
|  | C4 | 100 | Silty fine sand | SP |  |  |  |  |  |  |  |  |  |  |  |  | 35.0 | 0.44 |  |  |  |  |  |
|  | S2 | 121 | Silty sand | SP | 107 | 20 |  |  |  |  |  |  | 8.8E-5 |  |  | 36.3 | 29.5 | 0.25 |  |  |  |  |  |
|  | S2 | 121 | Silty fine sand | SP | 97 | 23 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |  |
|  | S3 | 127 | Sandy silt | SP | 99 | 24 |  |  |  |  |  | 20.2 |  |  | 2.69 | 41.3 |  |  |  |  |  |  |  |
|  | S3 | 127 | Sandy silt | SP | 101 | 24 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |

TABLE C-2 COMPREHENSIVE LIST OF SOILS ENGINEERING PROPERTIES FROM LABORATORY TESTS

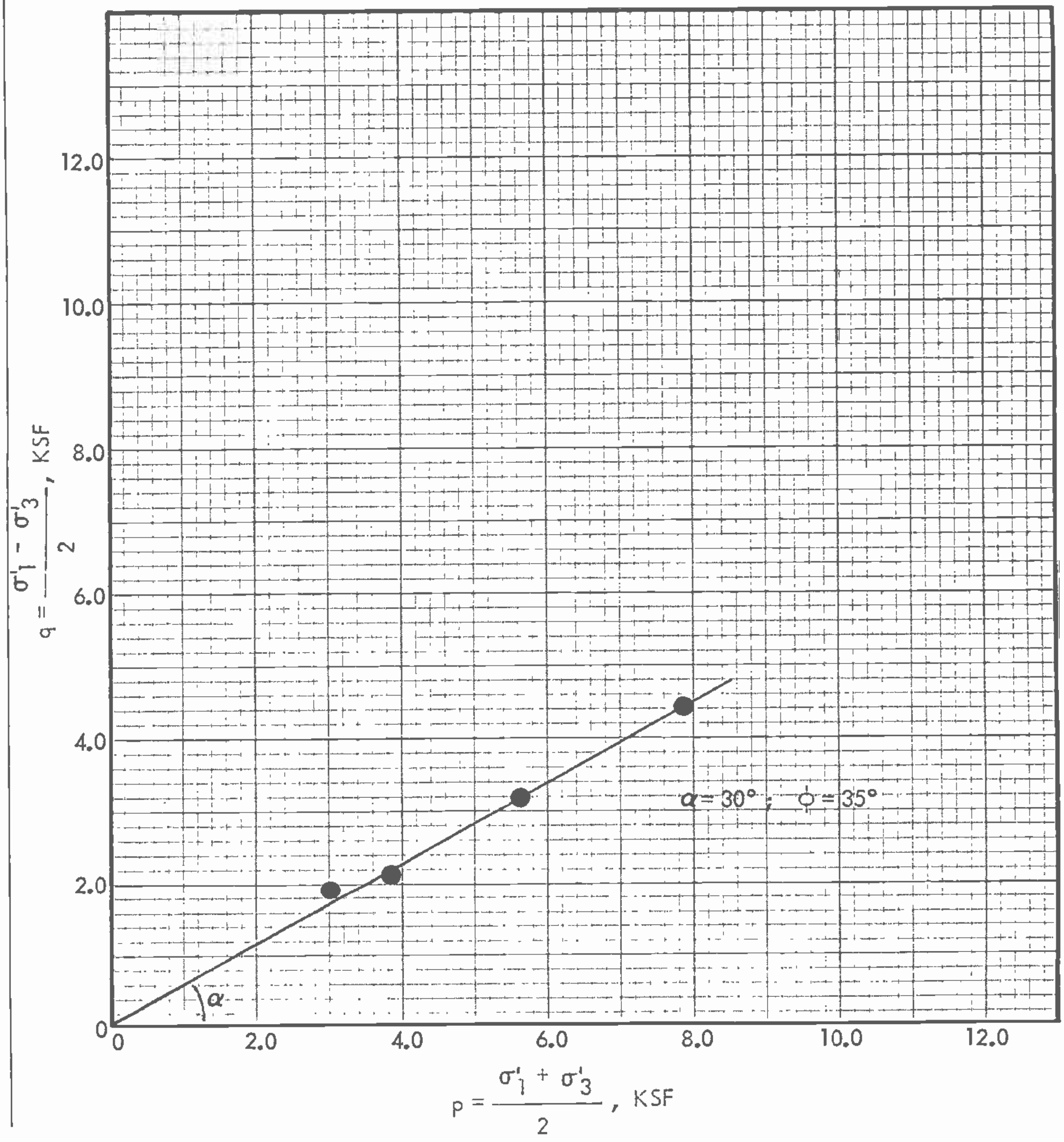
| CEG BORING No. | SAMPLE No. | DEPTH (ft) | VISUAL CLASSIFICATION | GEOLOGIC UNIT | DRY DENSITY (pcf) | MOISTURE CONTENT (%) | ATTERBERG LIMITS | | PARTICLE SIZE CUMULATIVE % PASSING SIEVE No. | | | UNCONFINED COMPRESSION STRENGTH (psi) | Kv, COEFFICIENT OF PERMEABILITY (cm/sec) | COEFFICIENT OF CONSOLIDATION $C_c$ (in/in per Log Cycle) | SPECIFIC GRAVITY | POROSITY (n) | UNDRAINED QUICK DIRECT SHEAR | | ONE-DIMENSIONAL SWELL (%) (Normal Load, ksf) | CYCLIC TRIAXIAL (Liquefaction) | DYNAMIC TRIAXIAL (Stress/Strain) | RESONANT COLUMN | TRIAXIAL COMPRESSION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | LL | PI | 4 | 40 | 200 | | | | | | ø, deg | c, ksf | | | | | |
| 21 | S4 | 140 | Fine to medium silty sand | SP | 109 | 16 | | | | | | | | | | | 34 | 0.31 | | | | | |
| | S5 | 151 | Silty claystone | C | 104 | 22 | | | | | | 57.6 | | | | | | | | | | | |
| | S6 | 161 | Siltstone | C | 102 | 23 | | | | | | 62.8 | | | | | | | | | | | |
| | S6 | 161 | Siltstone | C | 103 | 22 | | | | | | | | .020 | | | | | | | | | |
| | S6 | 161 | Siltstone | C | 105 | 20 | | | | | | | | | | | 35.5 | 0.88 | | | | | |
| | S7 | 172 | Silty claystone | C | 100 | 25 | | | | | | 98.9 | | | | | | | | | | | |
| | S9 | 190 | Siltstone | C | 106 | 21 | 31 | 7 | 100 | 100 | 94 | | | | | | | | | | | | Q |
| | S10 | 199 | Siltstone | C | 103 | 24 | 33 | 7 | 100 | 100 | 96 | | | | | | | | | | | | Q |
| | S3 | 31 | Silty clay | $A_4$ | | | 47 | 31 | | | | | | | | | | | | | | | |
| 22 | C1 | 20 | Silty clay | $A_4$ | 107 | 21 | | | | | | | | | | | | | 2.04 | | | | |
| | C1 | 20 | Silty clay | $A_4$ | 107 | 21 | | | | | | | | | | | 32.5 | 1.16 | | | | | |
| | C2 | 40 | Clayey fine to medium sand | $A_3$ | 110 | 19 | | | | | | | 3.2E-7 | | 2.63 | 33.9 | | | | | | | |
| | C2 | 40 | Clayey fine to medium sand | $A_3$ | 107 | 20 | | | | | | | | .042 | | | 35.0 | 0.69 | | | | | |
| | J4 | 42 | Fine sandy clay | $A_4$ | | | 80 | 51 | 99 | 96 | 60 | | | | | | | | | | | | |
| | C3 | 60 | Clayey silt | $A_4$ | 101 | 26 | | | | | | | | .064 | | | 36.5 | 0.80 | 4.14 | | | | |

## TABLE C-2 COMPREHENSIVE LIST OF SOILS ENGINEERING PROPERTIES FROM LABORATORY TESTS

| CEG BORING No. | SAMPLE No. | DEPTH (ft) | VISUAL CLASSIFICATION | GEOLOGIC UNIT | DRY DENSITY (pcf) | MOISTURE CONTENT (%) | ATTERBERG LIMITS | | PARTICLE SIZE CUMULATIVE % PASSING SIEVE No. | | | UNCONFINED COMPRESSION STRENGTH (psi) | Kv, COEFFICIENT OF PERMEABILITY (cm/sec) | COEFFICIENT OF CONSOLIDATION $C_c$ (in/in per Log Cycle) | SPECIFIC GRAVITY | POROSITY (n) | UNDRAINED QUICK DIRECT SHEAR | | ONE-DIMENSIONAL SWELL (%) (Normal Load, ksf) | CYCLIC TRIAXIAL (Liquefaction) | DYNAMIC TRIAXIAL (Stress/Strain) | RESONANT COLUMN | TRIAXIAL COMPRESSION |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | LL | PI | 4 | 40 | 200 | | | | | | $\phi$, deg | c, ksf | | | | | |
| 22 | C3 | 60 | Clayey silt | $A_4$ | 97 | 27 | | | | | | | | | | | | | | | | | |
| | J6 | 62 | Clayey sand | $A_3$ | | | 38 | 18 | 94 | 71 | 41 | | | | | | | | | | | | |
| | C4 | 80 | Silty clay | $A_4$ | 105 | 22 | | | | | | | | | | | | | | | | | |
| | S3 | 141 | Siltstone | C | 99 | 25 | | | | | | | | .029 | | | 41.0 | 0.62 | 1.49 | | | | |
| | S3 | 141 | Siltstone | C | 104 | 22 | | | | | | 64.8 | | | | | | | | | | | |
| | S4 | 156 | Siltstone | C | 100 | 25 | 35 | 5 | | | | | | | | | | | | | | | Q |
| | S4 | 156 | | C | 98 | 26 | | | | | | 67.9 | | | | | | | | | | | |
| | S5 | 164 | Siltstone, massive | C | 99 | 26 | | | | | | 56.4 | | | | | | | | | | | |
| | S6 | 171 | Siltstone, massive | C | 103 | 20 | | | | | | | | | | | | | | | | | Q |
| | S6 | 171 | Siltstone, massive | C | 96 | 28 | 36 | 8 | 100 | 100 | 99 | 61.6 | | | | | | | | | | | |
| | S7 | 186 | Siltstone, massive | C | 96 | 27 | | | | | | | 5.2E-8 | | | | 30.5 | 1.33 | | | | | |
| | S7 | 186 | Siltstone, massive | C | 94 | 28 | | | | | | 68.6 | | | | | | | | | | | |
| | S8 | 199 | Siltstone, massive | C | 97 | 27 | | | | | | | | | | | | | | | | | Q |
| | S8 | 199 | Siltstone, massive | C | 104 | 19 | 36 | 3 | 100 | 100 | 99 | 95.7 | | | | | | | | | | | |

TABLE C-3 PETROLEUM SAMPLES, BITUMEN AND WATER CONTENTS

| BORING No. | SAMPLE | DEPTH OF SAMPLE BELOW SURFACE (ft) | BITUMEN CONTENT (% of dry weight) | WATER CONTENT (% of dry weight) |
|---|---|---|---|---|
| 19 | C-1 | 20 - 22 | 14.5 | 8.1 |
| | C-2 | 40 - 42 | 11.8 | 8.0 |
| | C-3 | 60 - 62 | 15.4 | 8.6 |
| 19-4 | C-4 | 28 | 17.7 | 5.3 |
| | PB-16 | 85 - 87 | 17.5 | 9.0 |
| 19-5 | C-8 | 38 | 15.3 | 16.8 |
| | PB-6 | 61 | 18.7 | 6.0 |
| | PB-6 | 62 | 18.7 | 8.0 |
| 20 | PB-1 | 42 | 6.5 | 8.4 |
| | PB-4 | 80 | 20.3 | 3.7 |
| 20-1 | C-12 | 83 | 21.4 | 3.8 |
| 21 | PB-8 | 131 - 132 | 3.6 | 13.2 |



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# SUMMARY OF EFFECTIVE STRENGTH DATA – NON TAR BEARING ALLUVIUM

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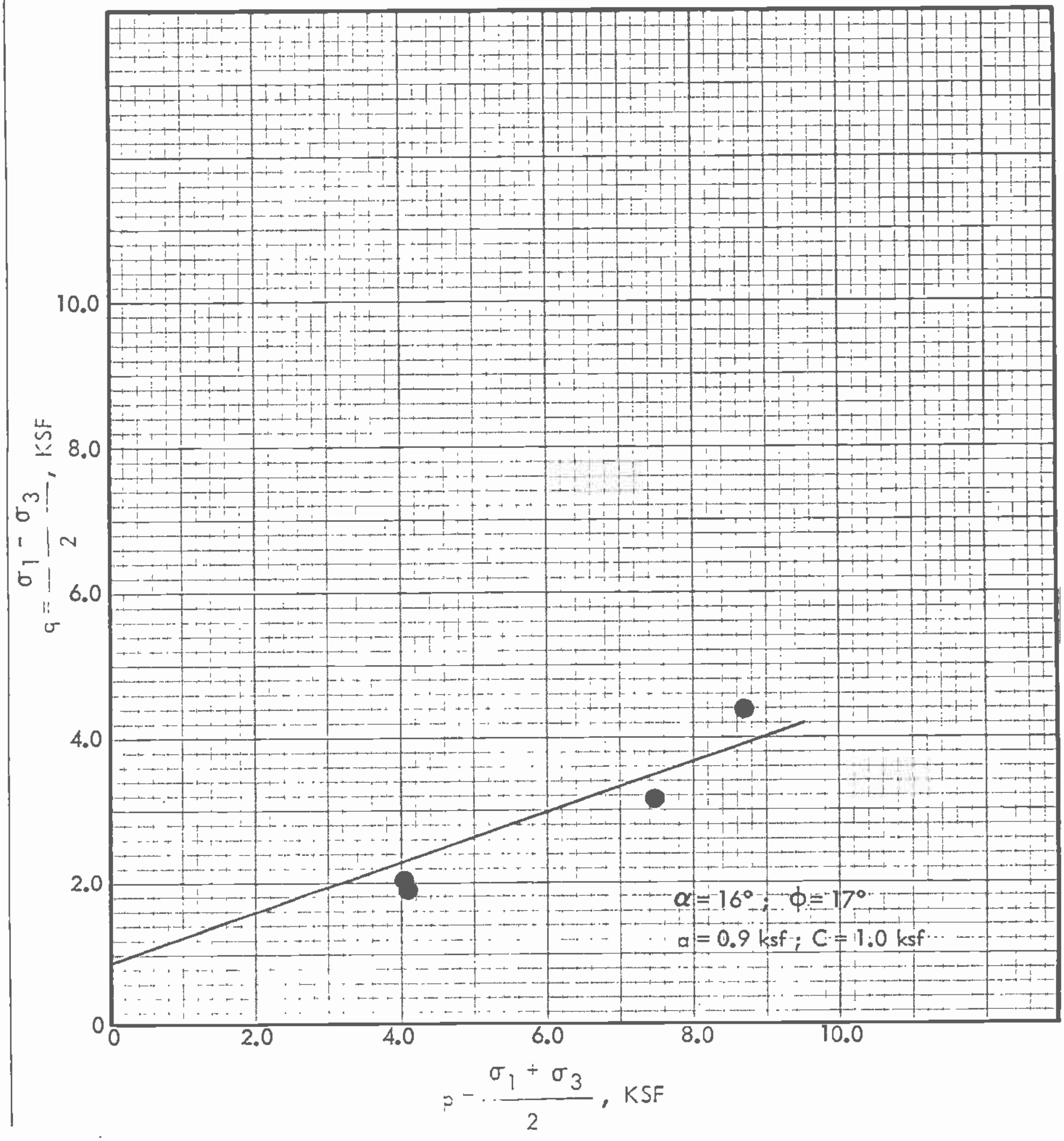
Figure No.
C-1



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# SUMMARY OF TOTAL STRENGTH DATA - NON TAR BEARING ALLUVIUM

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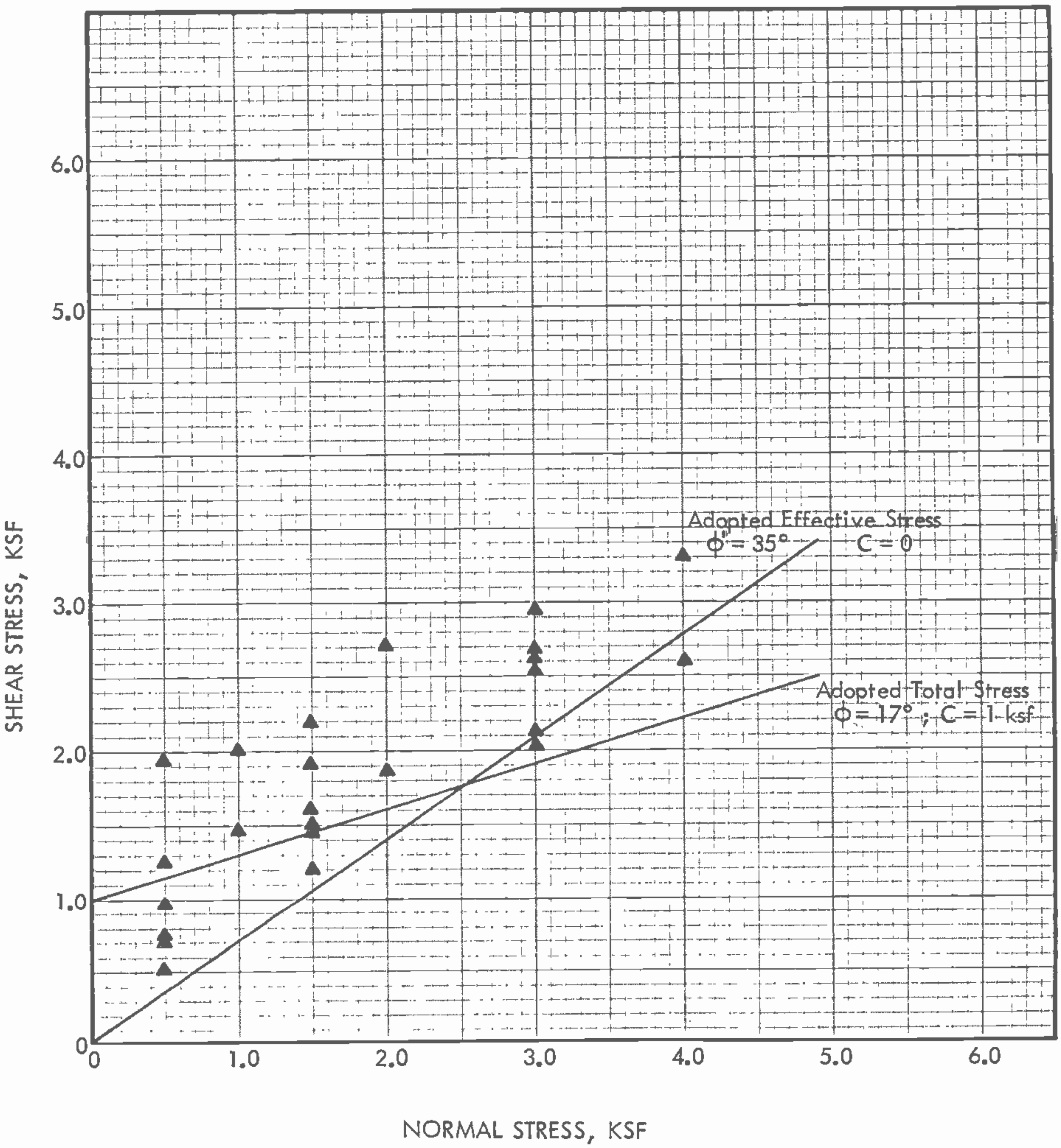
Figure No.
C-2



## SUMMARY OF DIRECT SHEAR DATA – ALLUVIUM

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Figure No.
C-3

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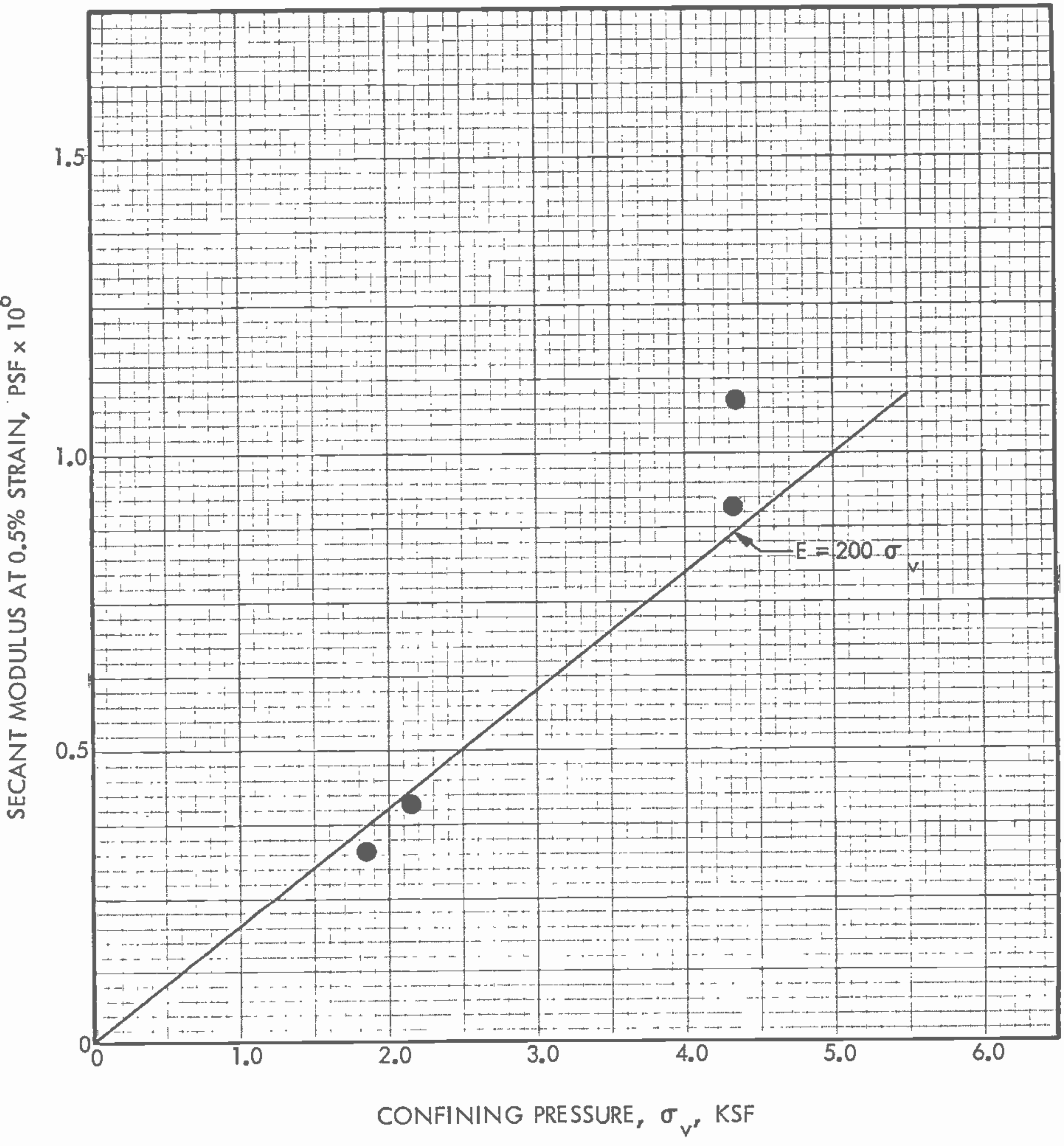

## SUMMARY OF MODULUS DATA - ALLUVIUM

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Figure No.
C-4

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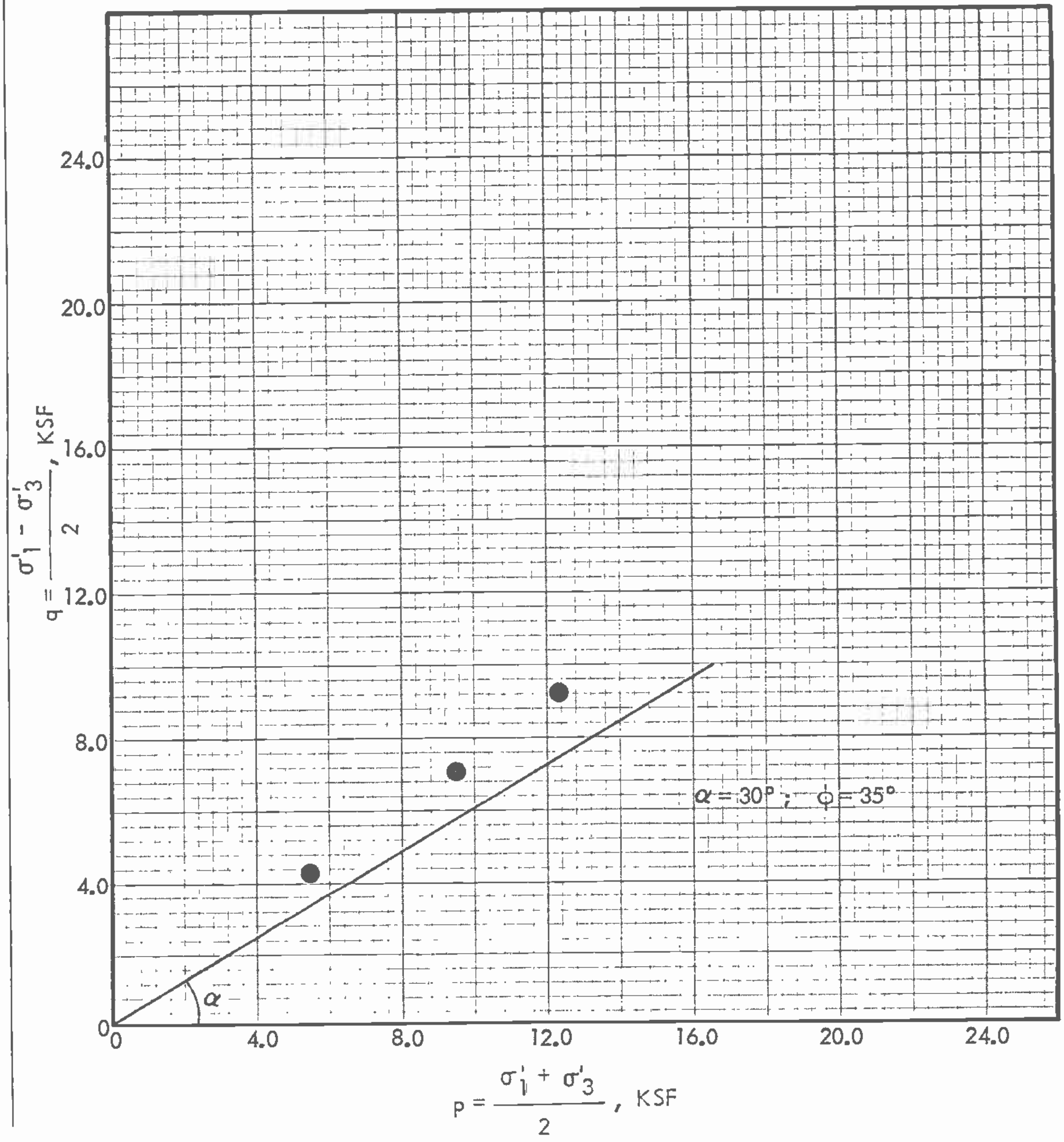

## SUMMARY OF EFFECTIVE STRENGTH DATA – TAR BEARING SILT FORMATIONS

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Figure No.
C-5

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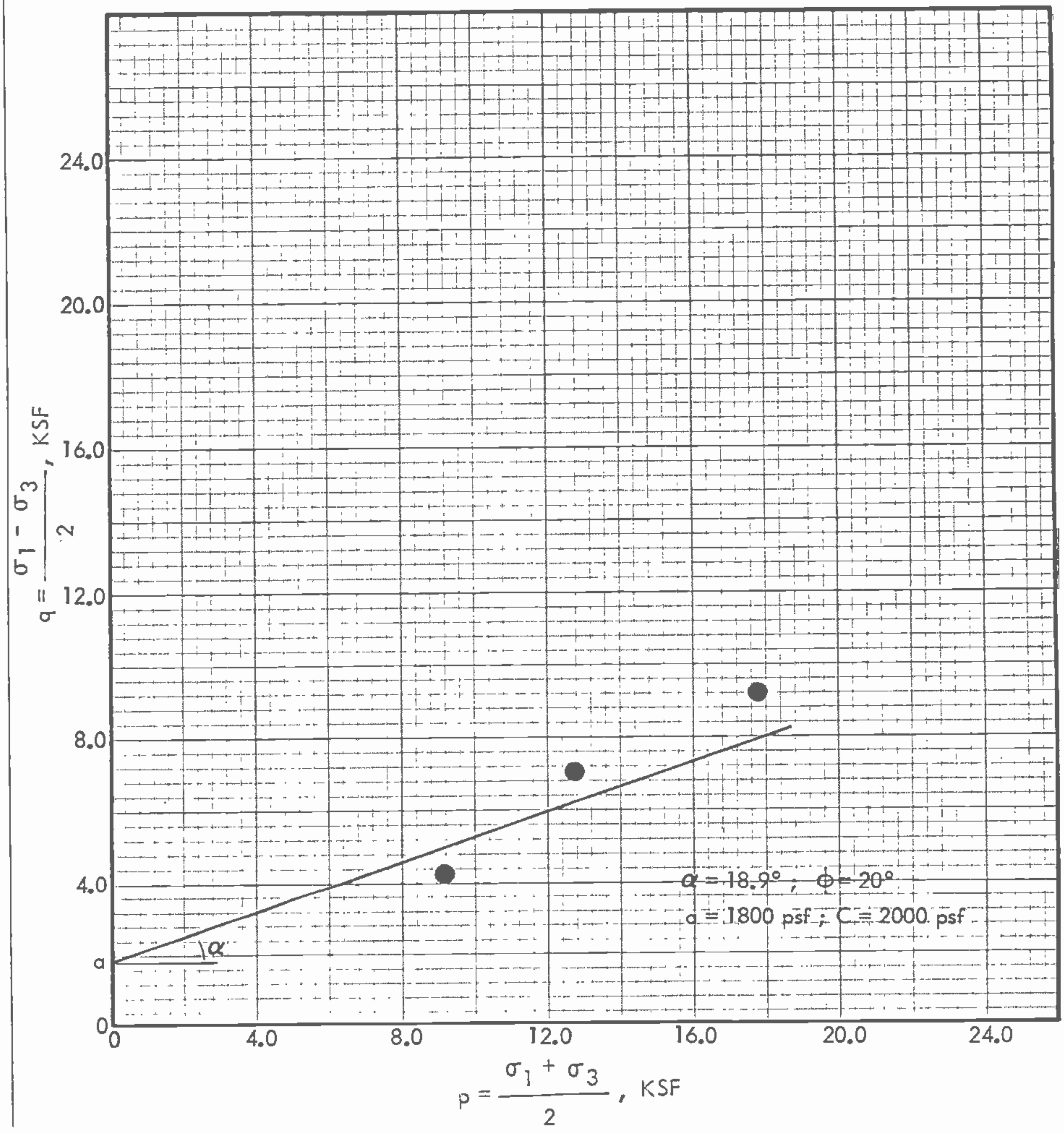

## SUMMARY OF TOTAL STRENGTH DATA - TAR BEARING SILT FORMATIONS

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Figure No.
C-6

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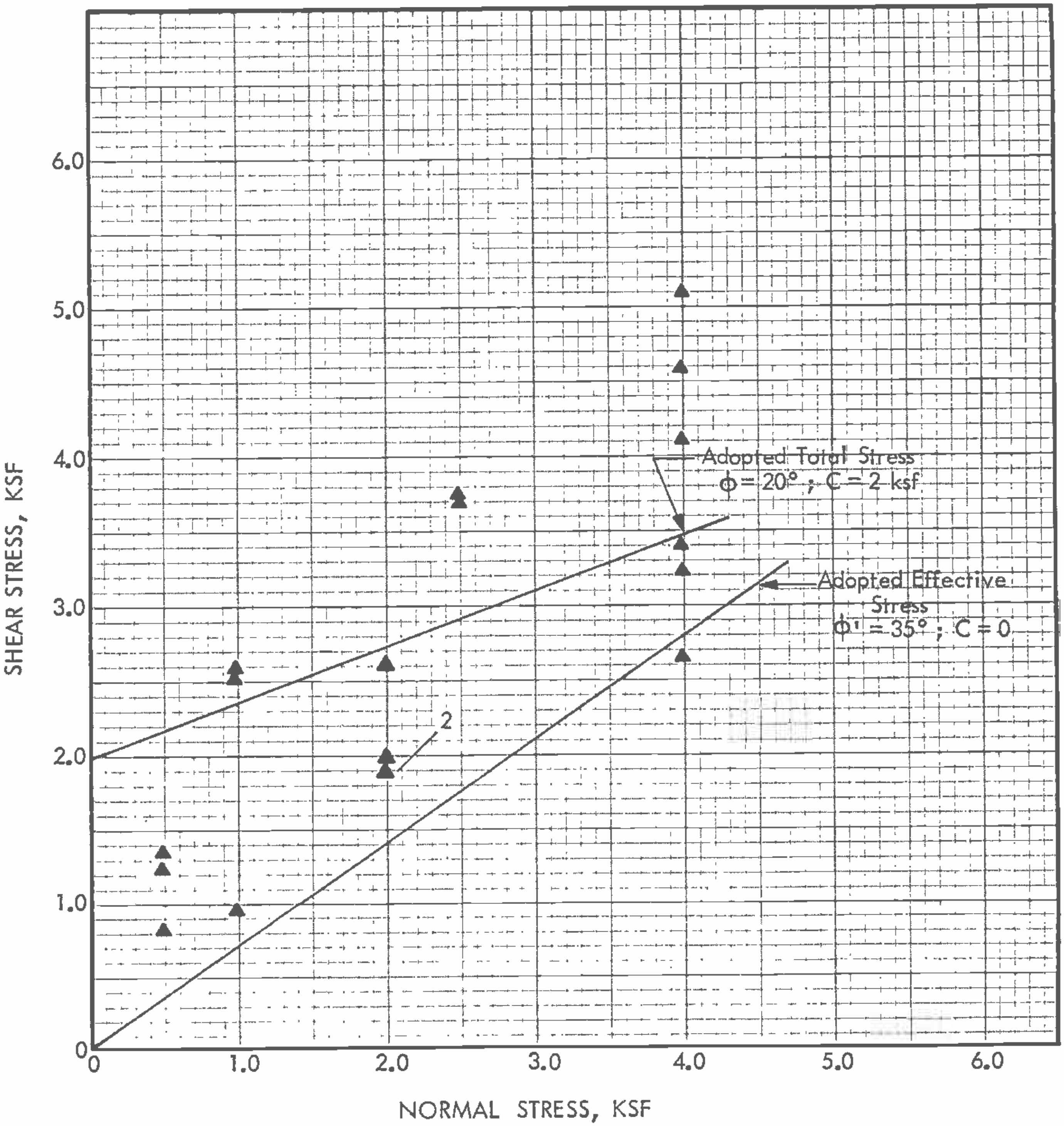

# SUMMARY OF DIRECT SHEAR DATA - TAR BEARING SILT FORMATIONS

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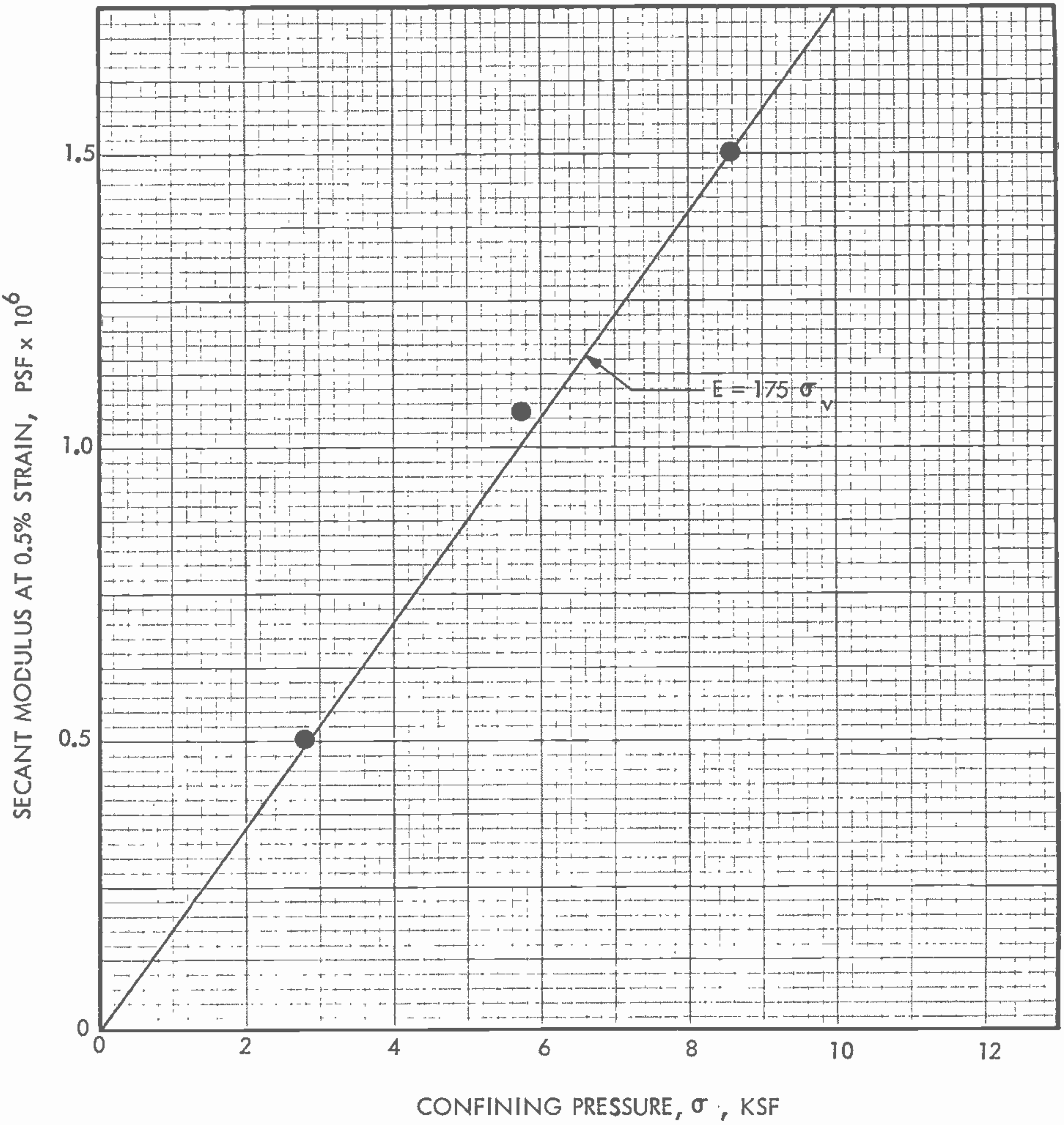
Figure No.
C-7



## SUMMARY OF MODULUS DATA – TAR BEARING SILT FORMATIONS

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Figure No.
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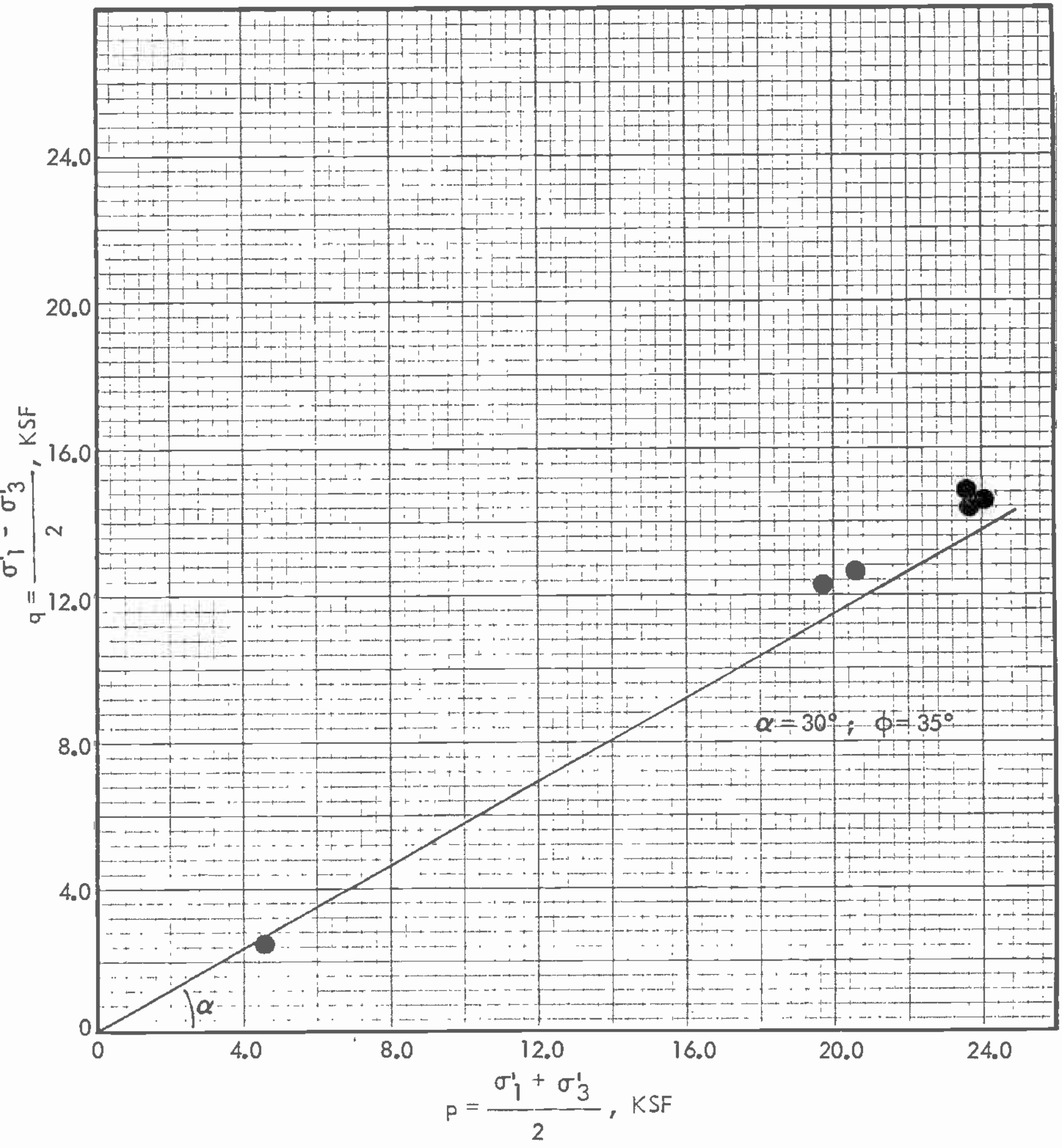

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## SUMMARY OF EFFECTIVE STRENGTH DATA - TAR BEARING SAN PEDRO SAND

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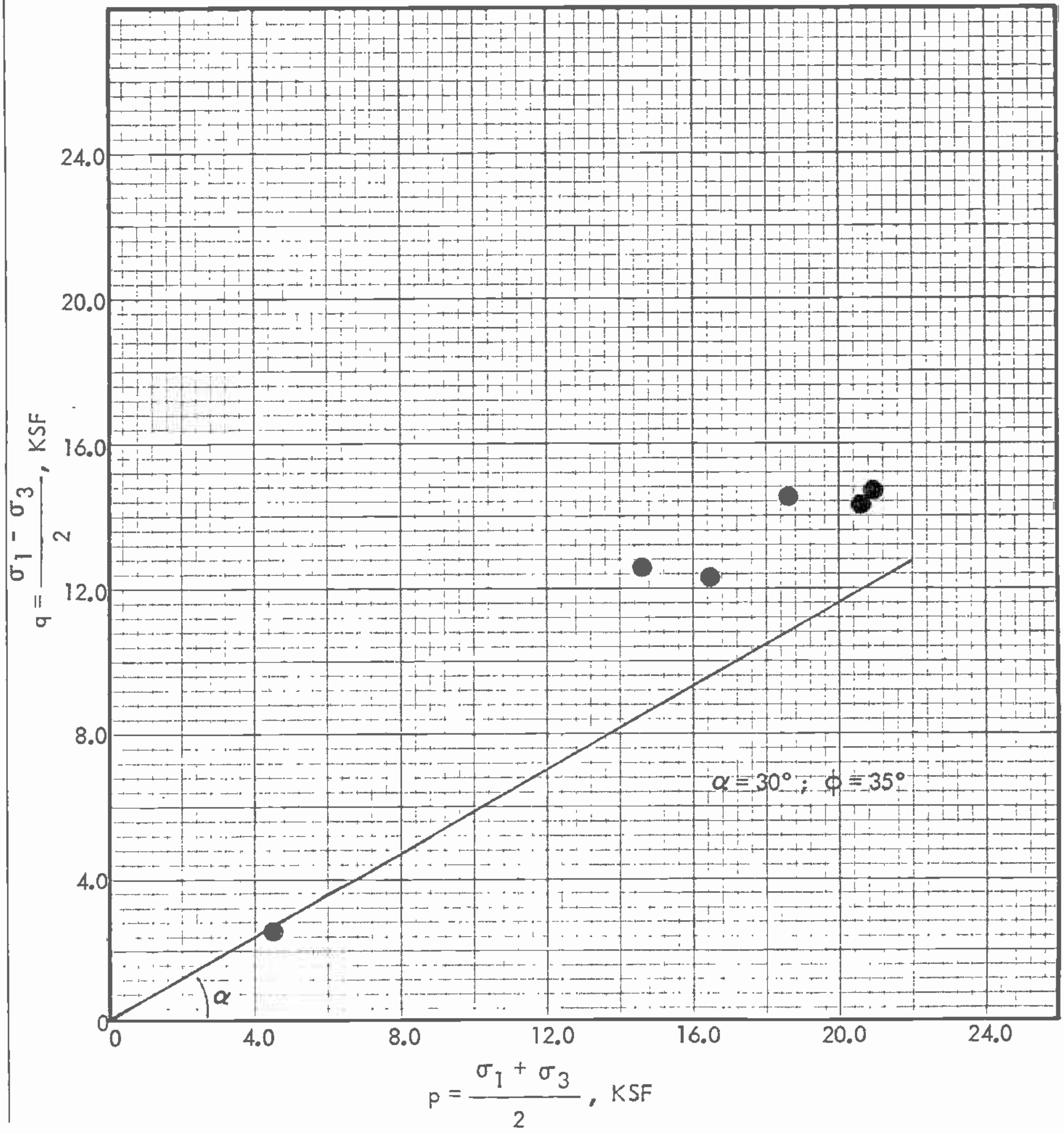
Figure No.
C-9



## SUMMARY OF TOTAL STRENGTH DATA - TAR BEARING SAN PEDRO SANDS

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Figure No.
C-10

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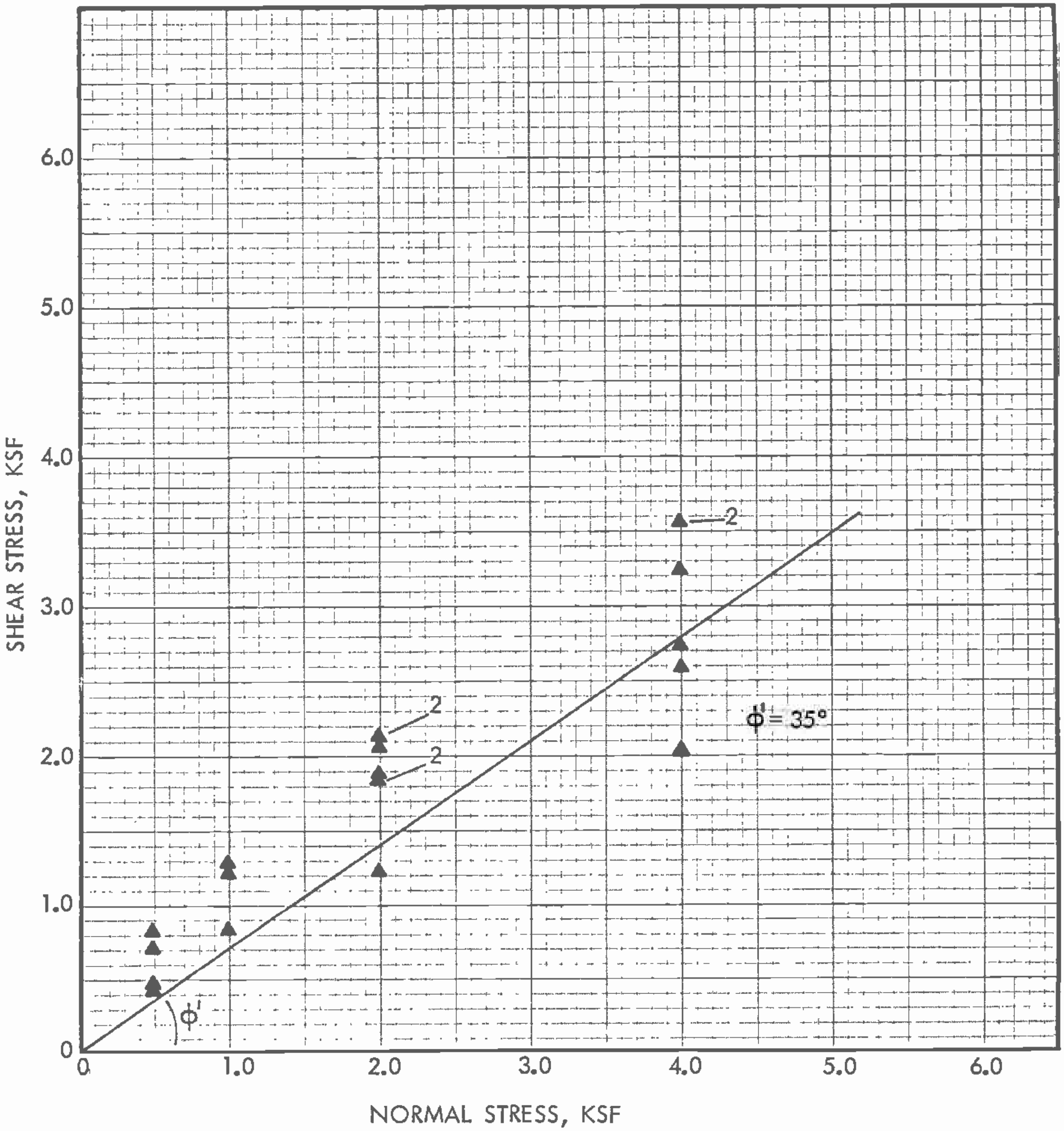

## SUMMARY OF DIRECT SHEAR DATA - TAR BEARING SAN PEDRO SAND

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Figure No.
C-11

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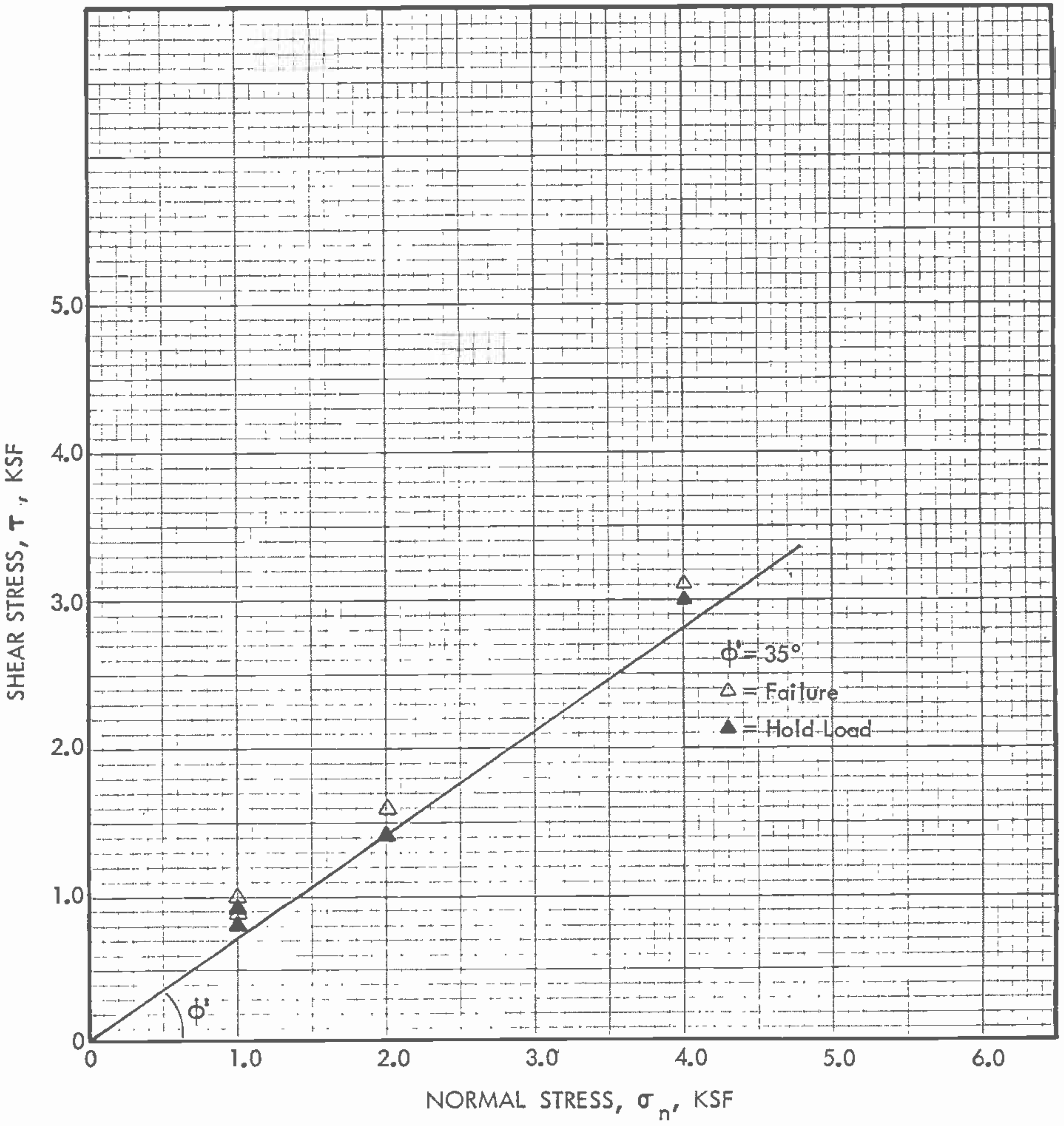

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## SUMMARY OF CONSTANT STRESS "CREEP TESTS" - TAR BEARING SAN PEDRO SAND

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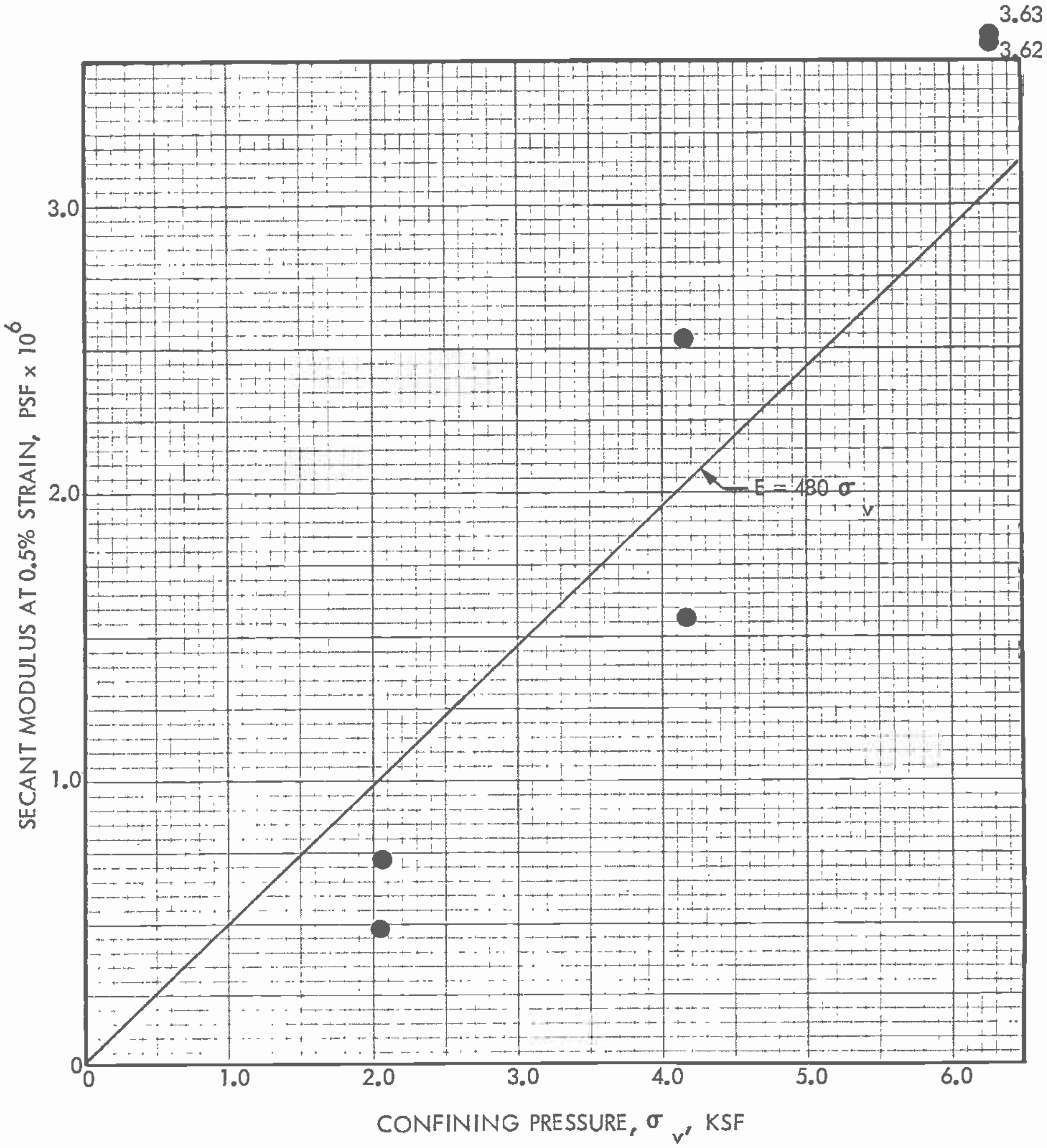
Figure No.
C-12



## SUMMARY OF MODULUS DATA – TAR BEARING SAN PEDRO SAND

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Figure No.
C-13

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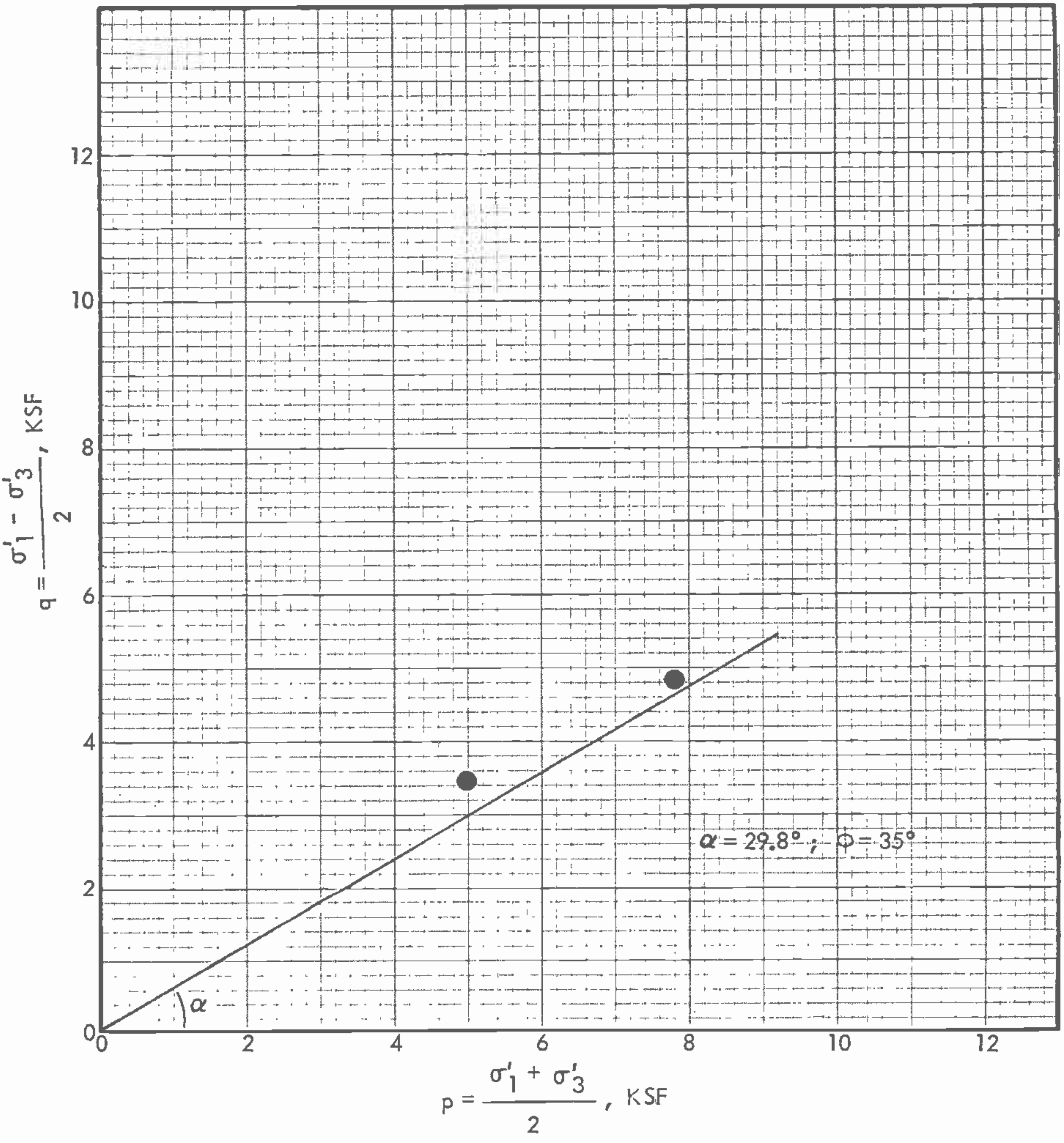

## SUMMARY OF EFFECTIVE STRENGTH DATA - BEDROCK

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Figure No.
C-14

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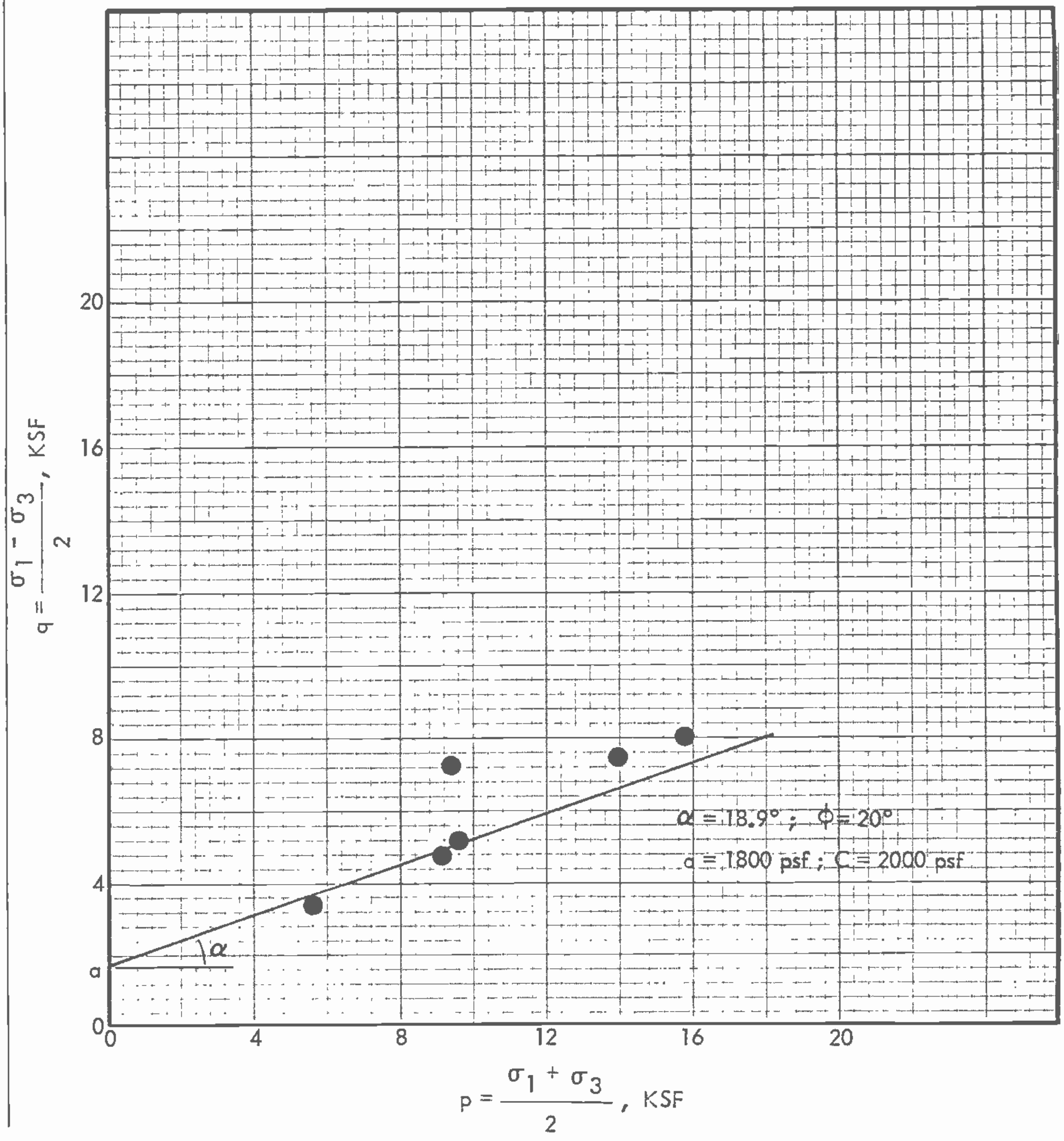

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## SUMMARY OF TOTAL STRENGTH DATA - BEDROCK

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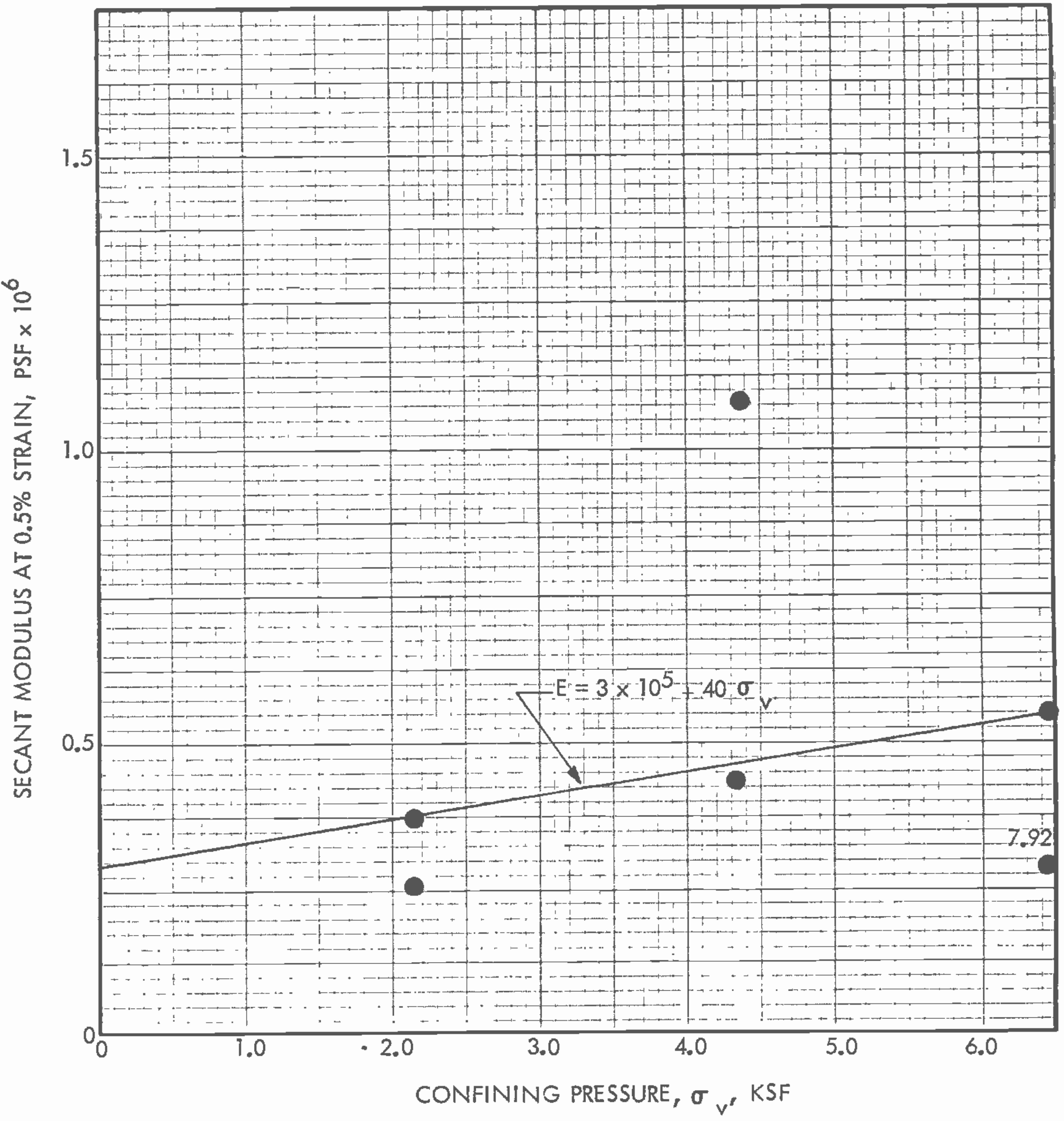
Figure No.
C-15



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## SUMMARY OF MODULUS DATA - BEDROCK

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Figure No.
C-16

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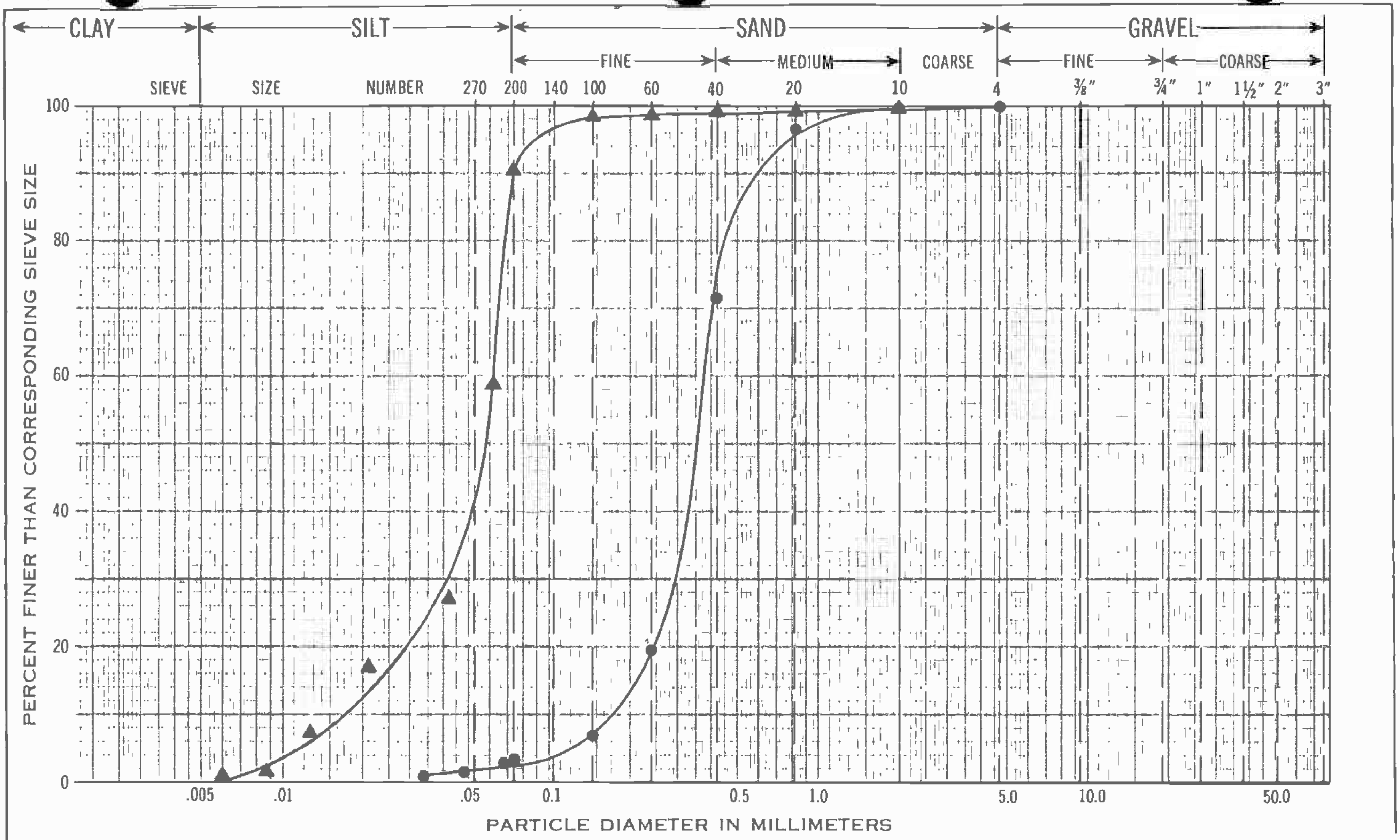

| SYMBOL | BORING | SAMPLE | DEPTH |
|---|---|---|---|
| ● | 19/5 | PB-6 | 60'-62.5' |
| ▲ | 19/4 | PB-16 | 85'-87.5' |

## GRAIN-SIZE DISTRIBUTION CHART

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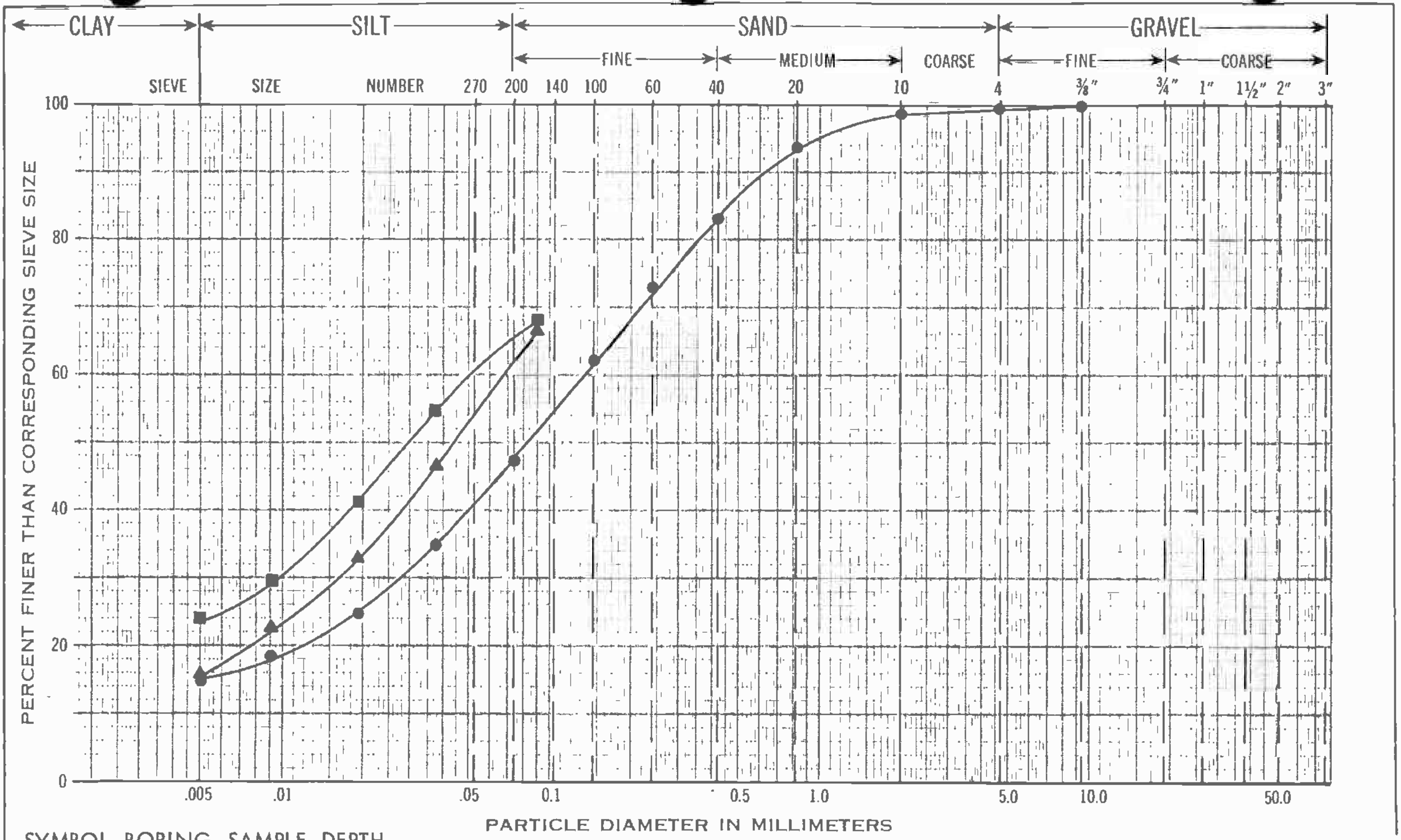
C-17

FORM NO. D-3-10/8 Approved for publication 5/84 by JAD



| SYMBOL | BORING | SAMPLE | DEPTH |
|---|---|---|---|
| ● | 19/5 | C-3 | 13.5' |
| ▲ | 19/6 | C-4 | 23.5' |
| ■ | 19/7 | C-2 | 7.5' |

## GRAIN-SIZE DISTRIBUTION CHART

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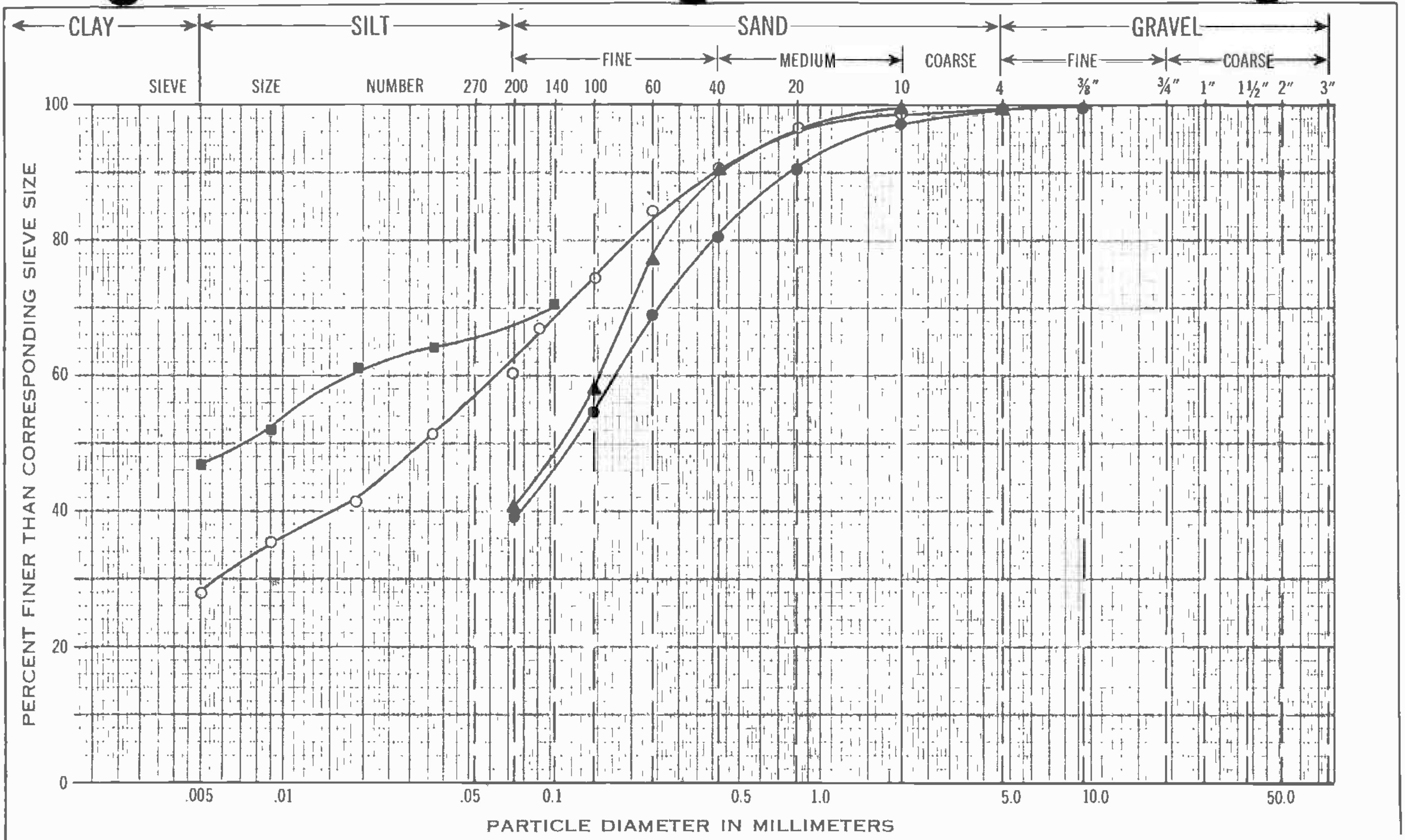
Drawing No.
C-18

FORM NO. D-3-19 Approved for publication 5/84 by



| SYMBOL | BORING | SAMPLE | DEPTH |
|---|---|---|---|
| ● | 19/7 | C-4 | 18.5' |
| ▲ | 20/1 | C-4 | 18.5' |
| ■ | 20/1 | C-5 | 23' |
| ○ | 20/2 | C-3 | 13.5' |

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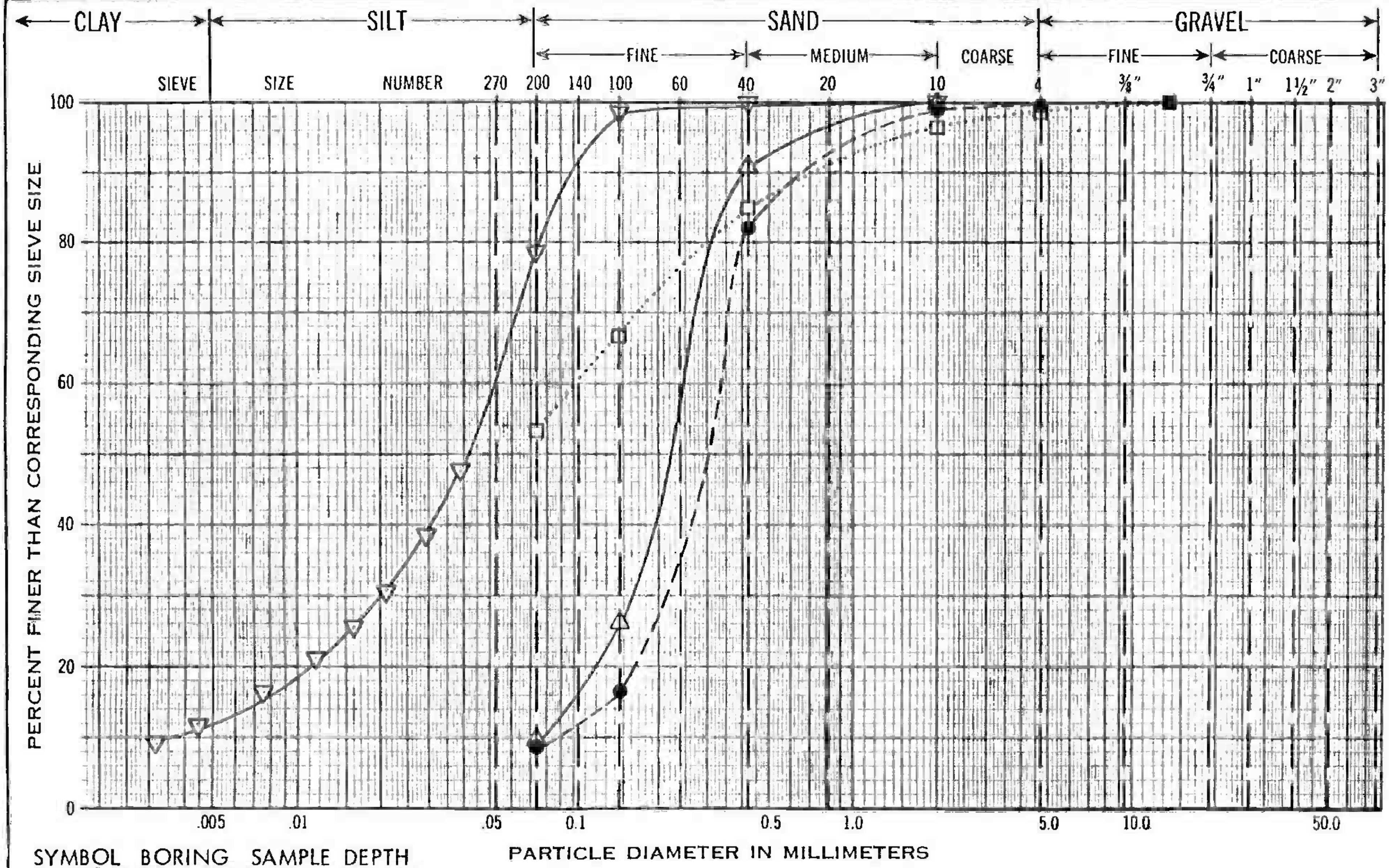
Drawing No.
C-19

FORM NO. D22 Approved for publication 5/84 by JAD

GRAIN-SIZE ANALYSIS OF SOILS AST GNATION: D422



| SYMBOL | BORING | SAMPLE | DEPTH |
|---|---|---|---|
| —▽— | 21 | S-1 | 18' |
| ·····□····· | 21 | J-4 | 40' |
| —△— | 21 | C-3 | 79' |
| - - ● - - | 21 | J-8 | 80' |

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Figure No.
C-20

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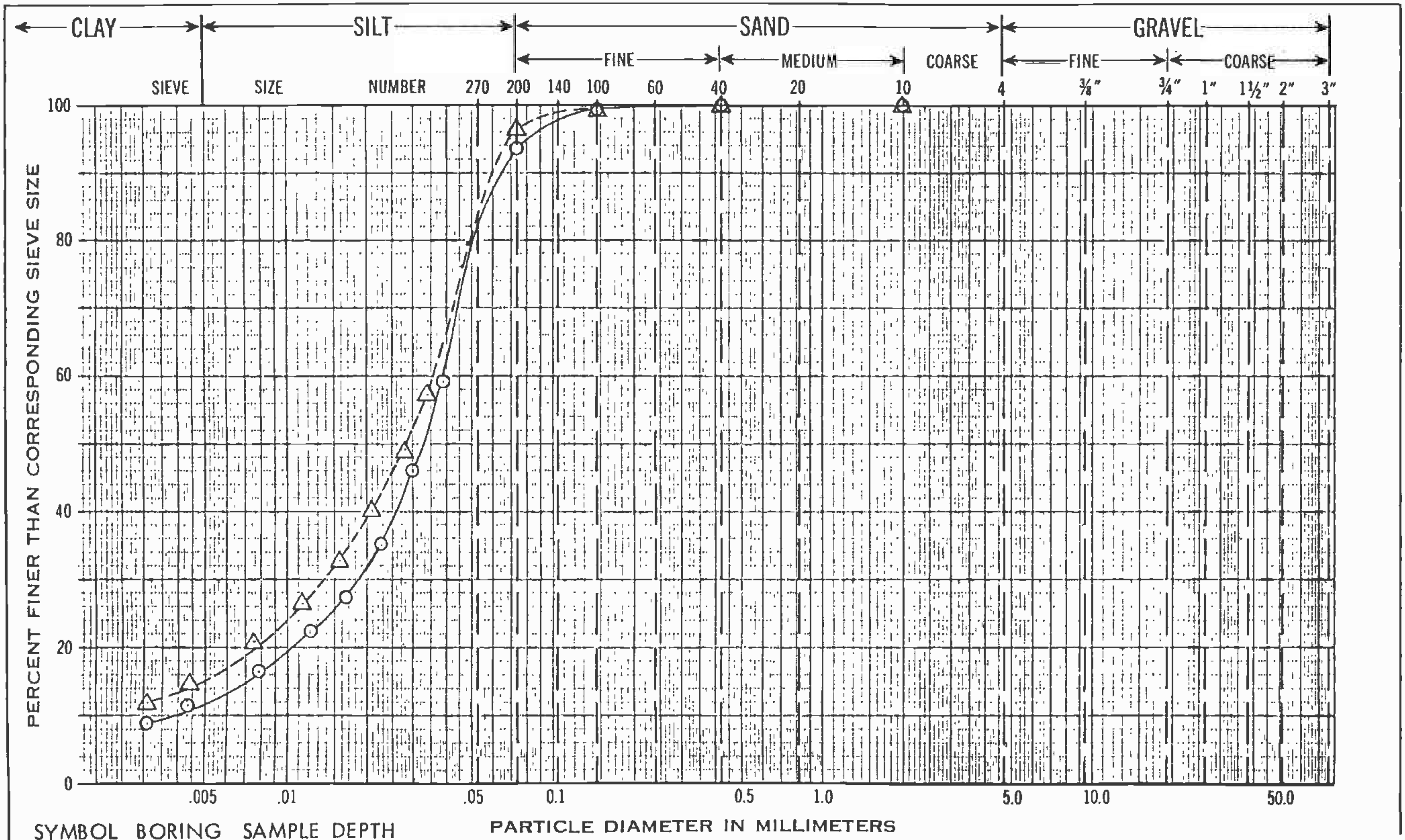
FORM NO. D22 Approved for publication 5/84 by JAD

GRAIN-SIZE ANALYSIS OF SOILS AST GNATION: D422



| SYMBOL | BORING | SAMPLE | DEPTH |
|---|---|---|---|
| —○— | 21 | S-9 | 190' |
| --△-- | 21 | S-10 | 200' |

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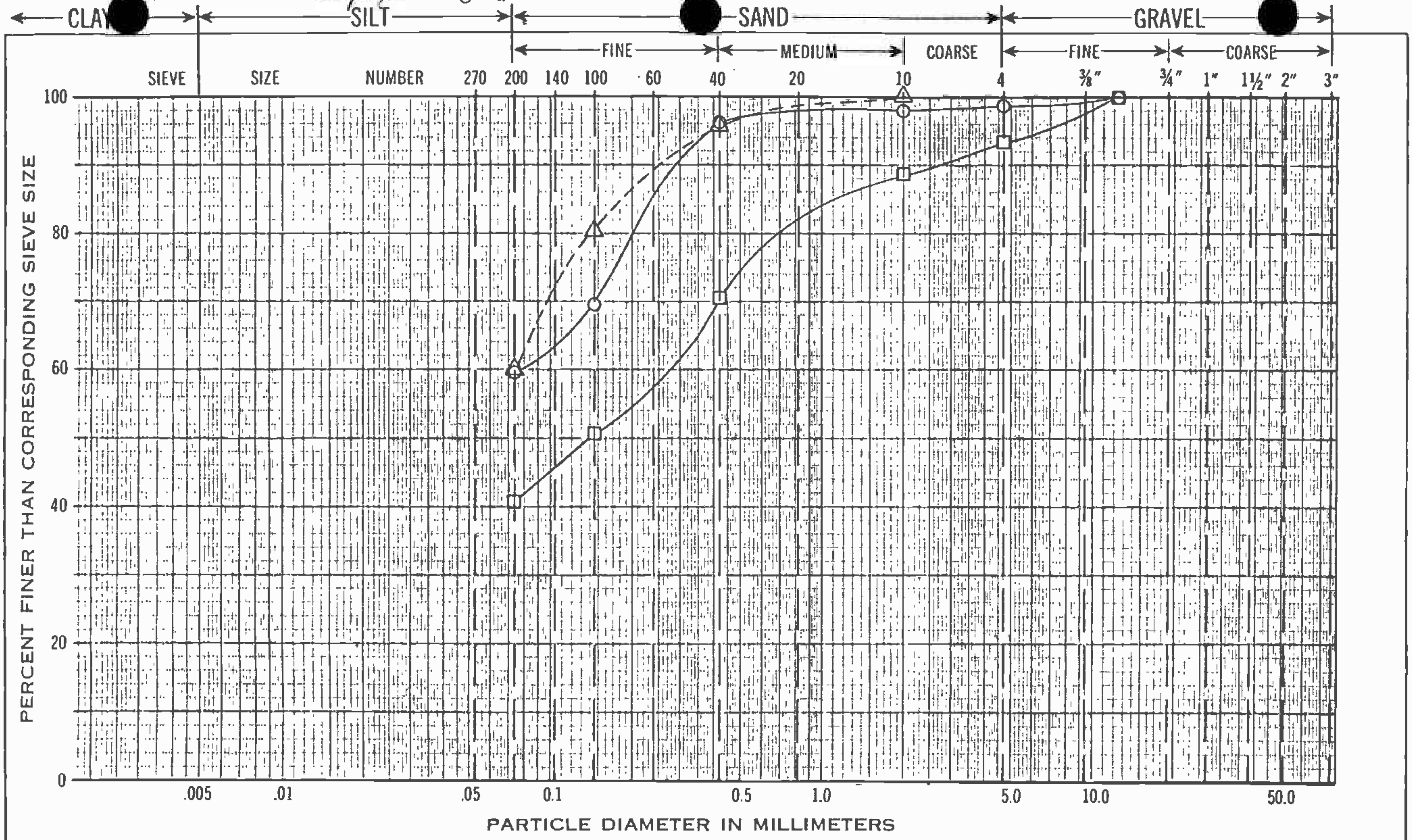
Project No.
83-1140

Figure No.
C-21

**Converse Consultants** Geotechnical Engineering and Applied Sciences

FORM NO. D22/ Approved for publication 5/84 by JAD

GRAIN-SIZE ANALYSIS OF SOILS ASTM DESIGNATION: D422



| SYMBOL | BORING | SAMPLE | DEPTH |
|---|---|---|---|
| —○— | 22 | J-4 | 42' |
| —□— | 22 | J-6 | 62' |
| ---△--- | 22 | S-4 | 156' |

## GRAIN-SIZE DISTRIBUTION CHART

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

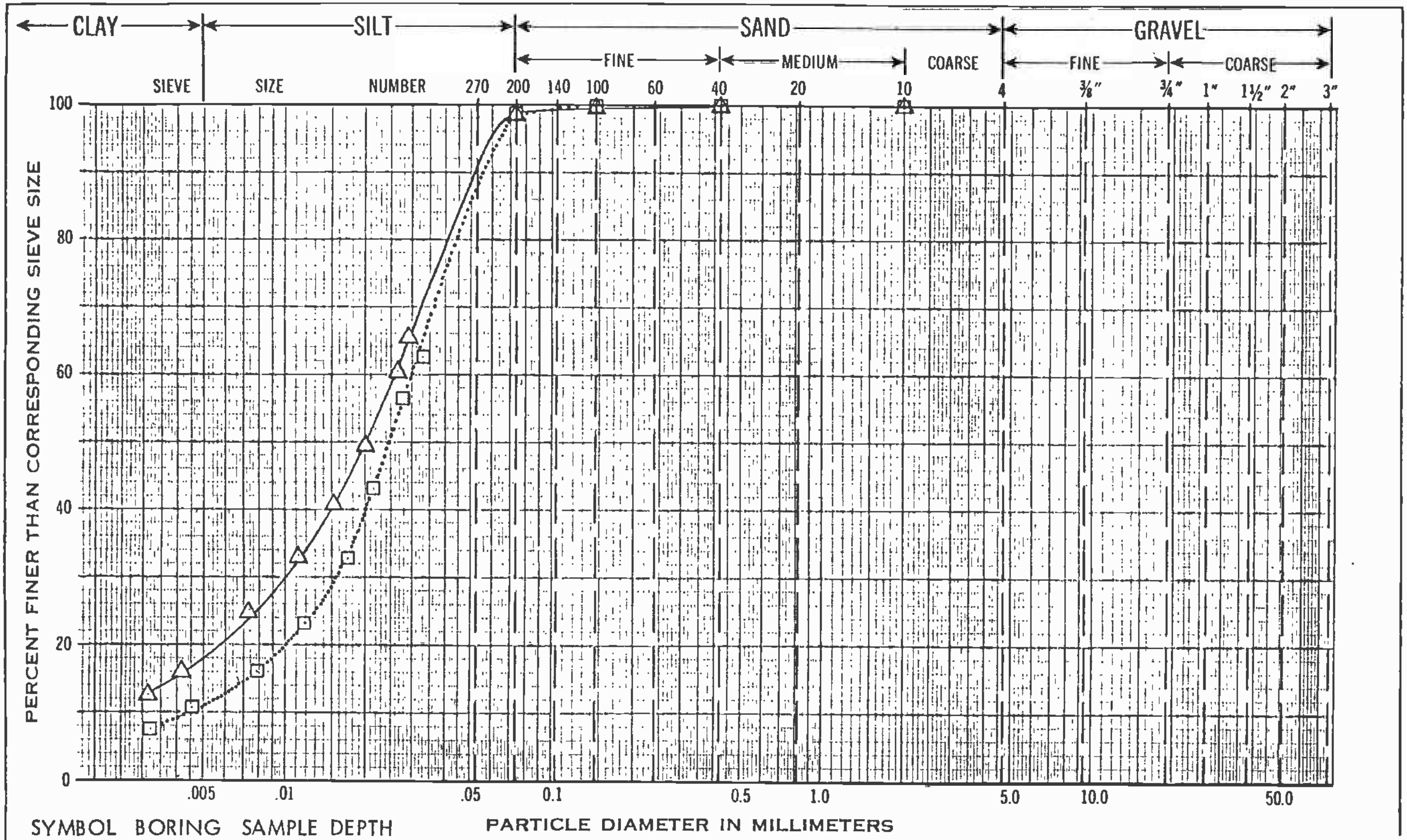
Project No.
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Figure No.
C-22

FORM NO. 02 Approved for publication 5/84 by

GRAIN-SIZE ANALYSIS OF SOILS AS IGNATION: D422



| SYMBOL | BORING | SAMPLE | DEPTH |
|---|---|---|---|
| ······□······ | 22 | S-6 | 171' |
| —△— | 22 | S-8 | 200' |

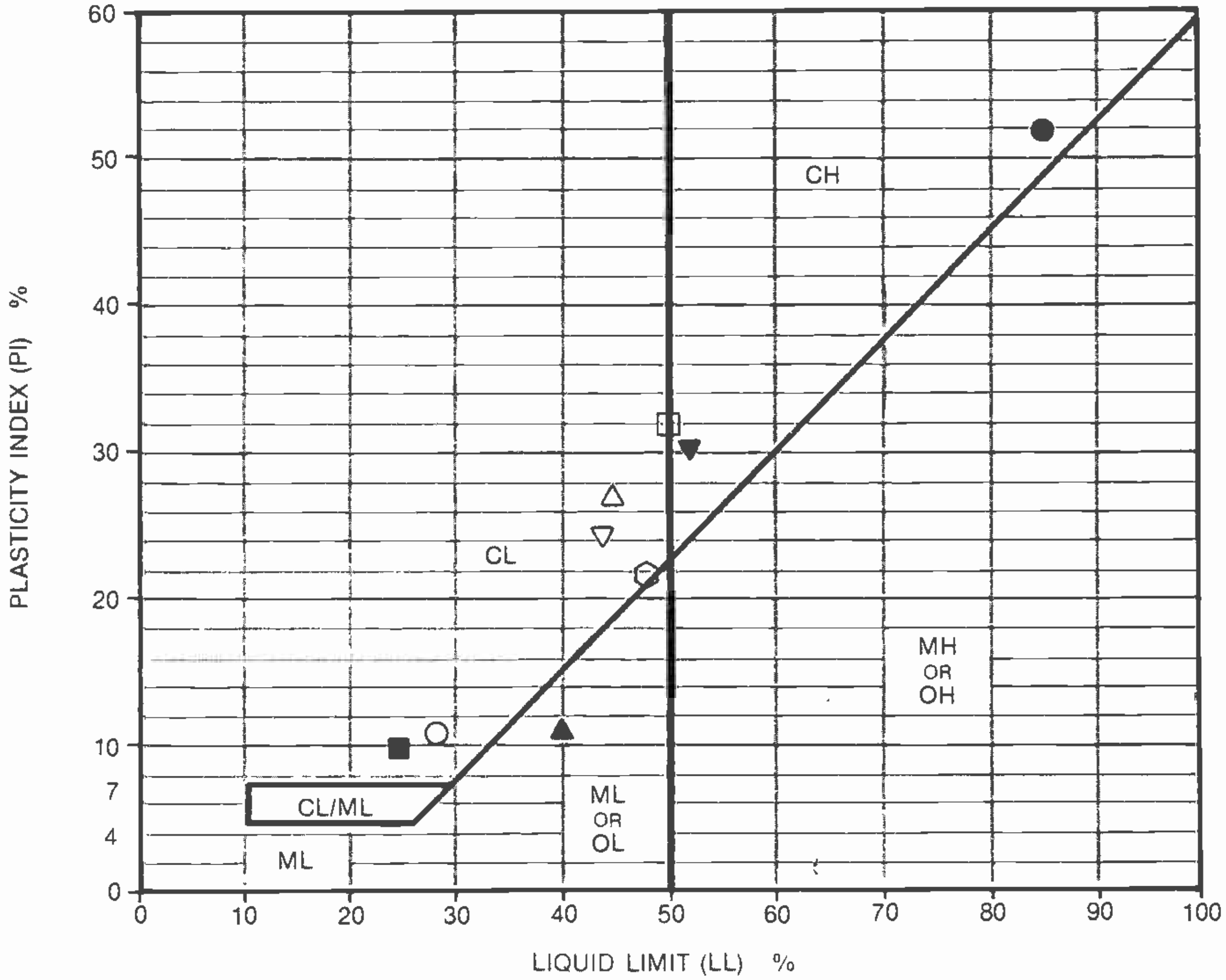
## GRAIN-SIZE DISTRIBUTION CHART

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Project No.
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Figure No.
C-23



| Symbol | Classification and Source | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) | % Passing 200 Seive |
|---|---|---|---|---|---|
| △ | BH 19/3, C-1 3' CL | 45 | 18 | 27 | - |
| □ | BH 19/4, C-2 7' CL/CH | 50 | 18 | 32 | - |
| ○ | BH 19/5, C-3 13.5' CL | 28 | 17 | 11 | 48 |
| ▲ | BH 19/6, C-4 24' ML | 40 | 29 | 11 | 62 |
| ■ | BH 19/7, C-1 2' CL | 24 | 14 | 10 | - |
| ● | BH 20/1, C-5 23' CH | 85 | 33 | 52 | 68 |
| ▽ | BH 20/1, C-6 28.5' CL | 43 | 19 | 24 | - |
| ▼ | BH 20/2, C-3 13.5' CH | 51 | 20 | 31 | 62 |
| ⬡ | BH 20/2, C-7 33' CL | 49 | 27 | 22 | - |

PLASTICITY CHART

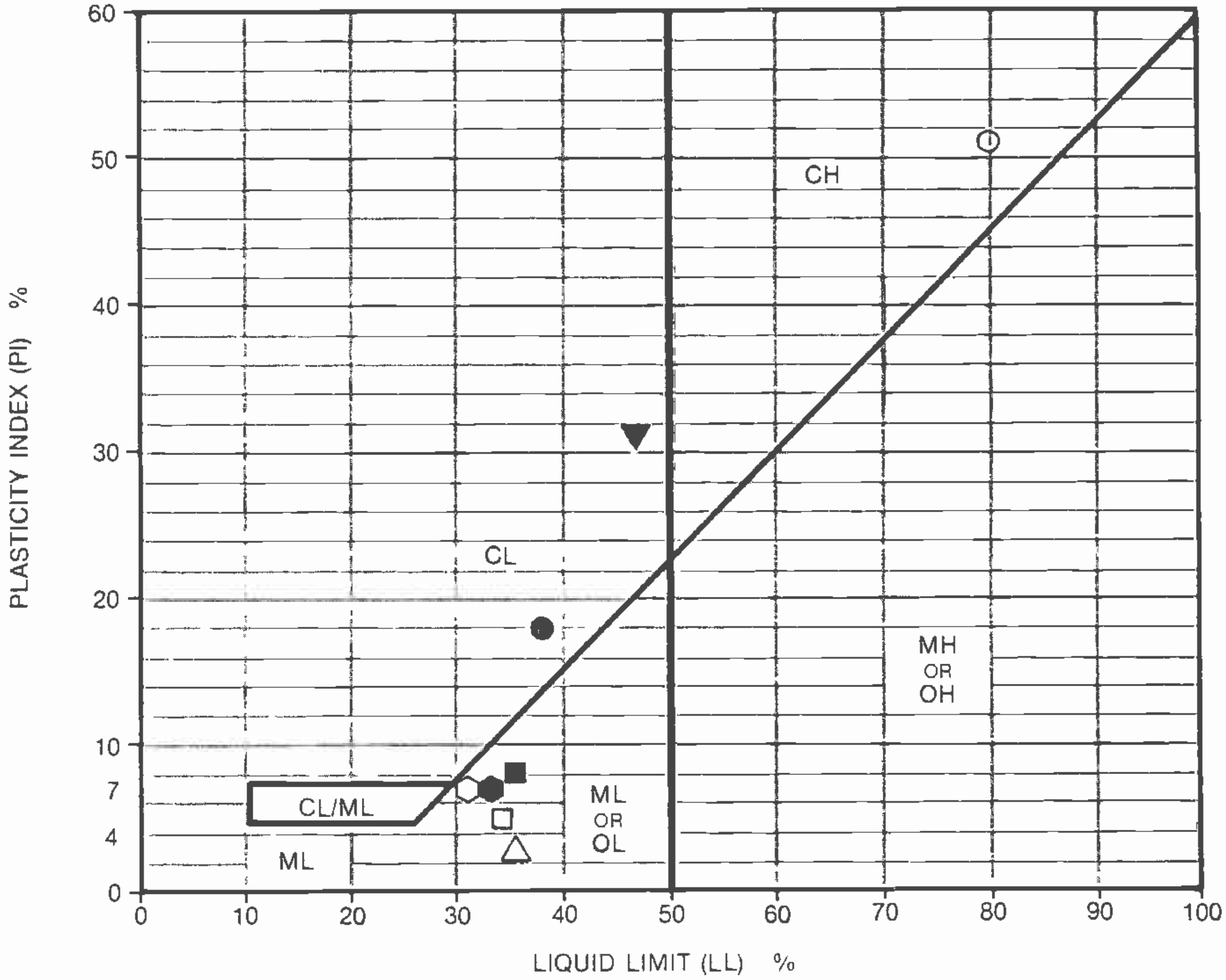
DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Project No
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Figure No
C-24

Approved for publication 5/84 by



| Symbol | Classification and Source | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) | % Passing 200 Seive |
|---|---|---|---|---|---|
| ▼ | BH 21, 31' (CL) | 47 | 16 | 31 | - |
| ⬡ | BH 21 191' (ML) | 31 | 24 | 7 | 94 |
| ⬢ | BH 21 199' (ML) | 33 | 26 | 7 | 96 |
| ○ | BH 22 42' (CH) | 80 | 29 | 51 | 60 |
| ● | BH 22 62' (CL) | 38 | 20 | 18 | 41 |
| □ | BH 22 155' (ML) | 35 | 30 | 5 | 60 |
| ■ | BH 22 170' (ML) | 36 | 29 | 8 | 99 |
| △ | BH 22 198' (ML) | 36 | 33 | 3 | 99 |

Approved for publication 5/84 by

## PLASTICITY CHART

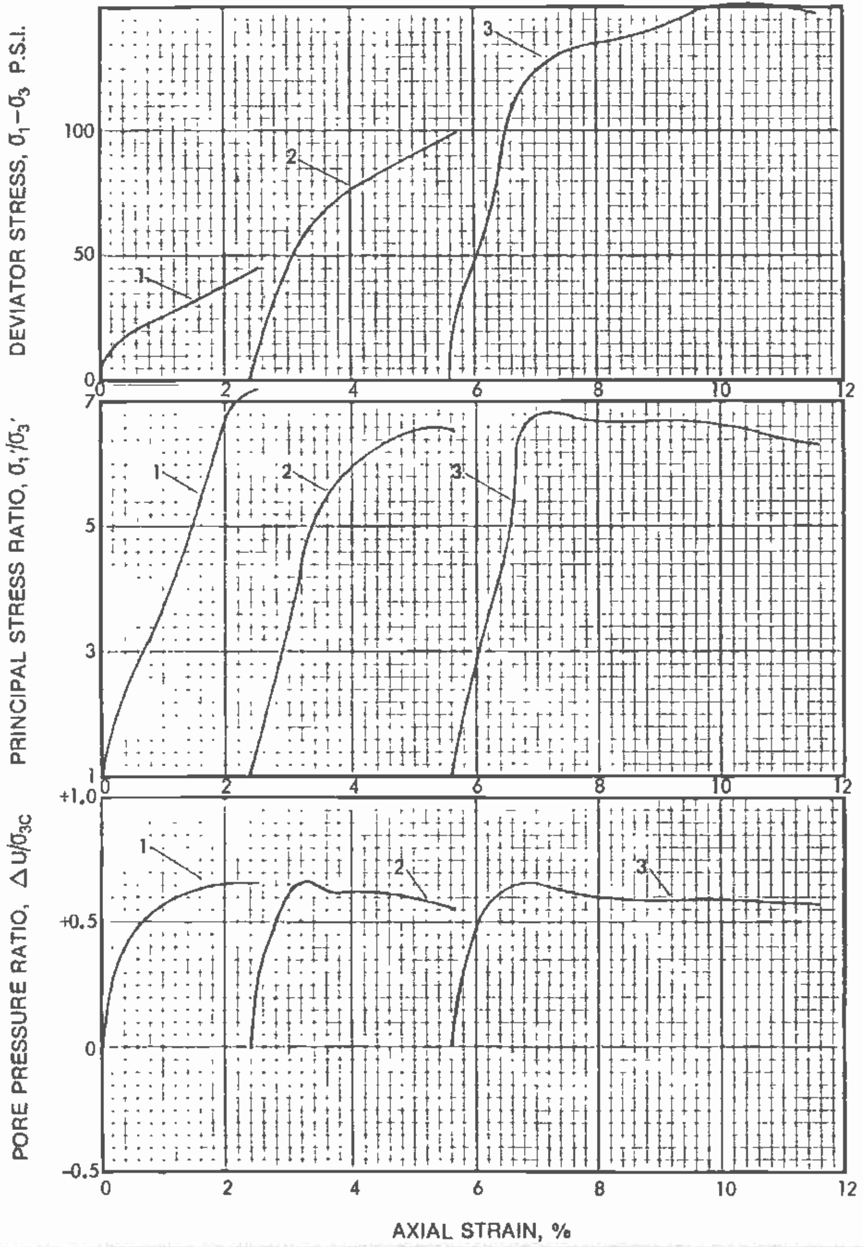
DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

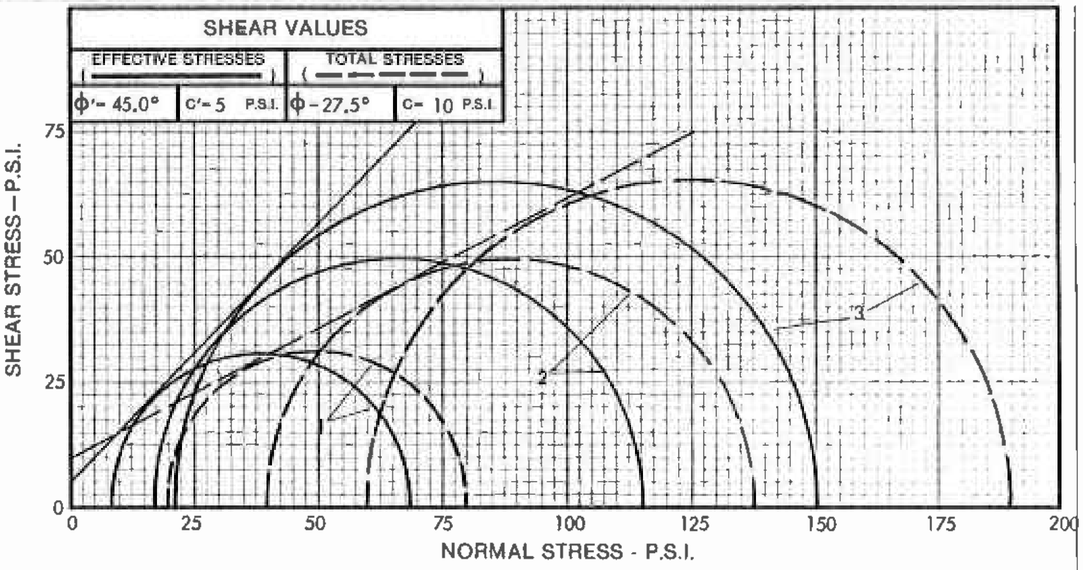
Project No
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Figure No
C-25

Approved for publication ____________by ____________





| SHEAR VALUES | | | |
|---|---|---|---|
| EFFECTIVE STRESSES ( —— ) | | TOTAL STRESSES ( — — — ) | |
| $\phi'$- 45.0° | c'= 5 P.S.I. | $\phi$ - 27.5° | c= 10 P.S.I. |

| SPECIMEN NUMBER | SPECIMEN LOCATION | | | INITIAL SPECIMEN DATA | | | | | | SAMPLE TYPE |
|---|---|---|---|---|---|---|---|---|---|---|
| | BORING NUMBER | SAMPLE NUMBER | DEPTH (FEET) | SOIL CLASSIFICATION | LENGTH (INCHES) | DIAMETER (INCHES) | DRY DENSITY (P.C.F.) | MOISTURE CONTENT (PERCENT) | BITUMEN CONTENT (PERCENT) | |
| | 19-4 | PB-16 | 85-87.5 | tar silt | 6.00 | 2.85 | 123 | 8.8 | 17.5 | P.B. |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

| SPECIMEN NUMBER | SYMBOL | EFFECTIVE CONSOL. PRESSURE $\sigma_{3C}$ (P.S.I.) | TEST VALUES AT FAILURE (MAXIMUM $\sigma_1'/\sigma_3'$) | | | | TEST TYPE |
|---|---|---|---|---|---|---|---|
| | | | TOTAL DEVIATOR STRESS $\sigma_1$-$\sigma_3$ (P.S.I.) | PORE PRESSURE CHANGE $\Delta U$ (P.S.I.) | MINOR EFFECTIVE STRESS $\sigma_3'$ (P.S.I.) | MAJOR EFFECTIVE STRESS $\sigma_1'$ (P.S.I.) | |
| | 1 | 20.3 | 60.5 | 12.1 | 8.2 | 68.7 | TX CUE PROGRESSIVE |
| | 2 | 40.6 | 98.4 | 23.1 | 17.5 | 115.9 | |
| | 3 | 60.9 | 127.9 | 38.9 | 22.0 | 149.9 | |
| | | | | | | | |

# TRIAXIAL COMPRESSION TESTS

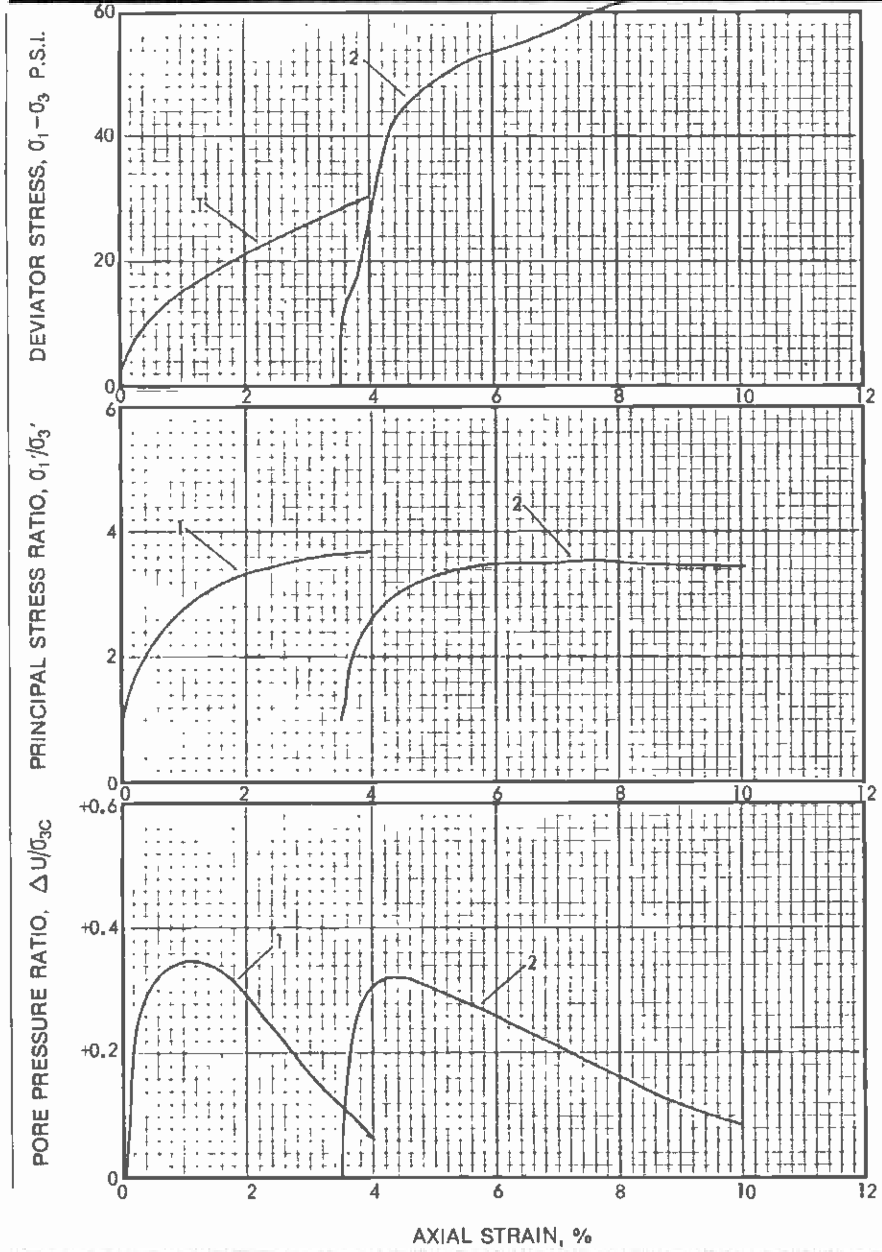
DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

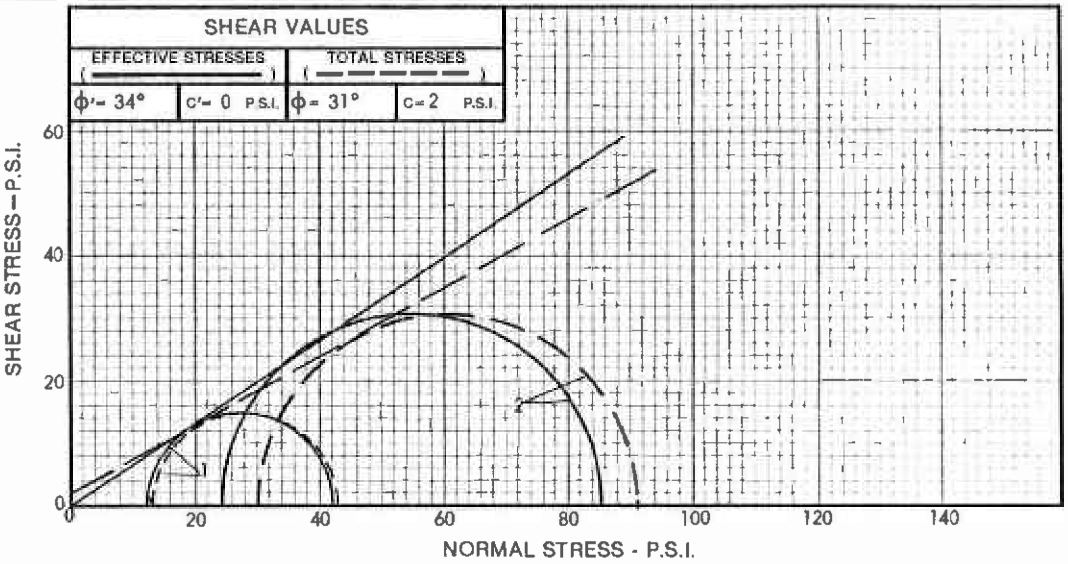
Project No
83-1140

**Converse Consultants**
Geotechnical Engineering
and Applied Sciences

Figure No
C-26

Approved for publication 5/84 by





| SHEAR VALUES | | | |
|---|---|---|---|
| EFFECTIVE STRESSES ( ——— ) | | TOTAL STRESSES ( — — — ) | |
| $\phi' = 34°$ | $c' = 0$ P.S.I. | $\phi = 31°$ | $c = 2$ P.S.I. |

| SPECIMEN NUMBER | SPECIMEN LOCATION | | | INITIAL SPECIMEN DATA | | | | | SAMPLE TYPE |
|---|---|---|---|---|---|---|---|---|---|
| | BORING NUMBER | SAMPLE NUMBER | DEPTH (FEET) | SOIL CLASSIFICATION | LENGTH (INCHES) | DIAMETER (INCHES) | DRY DENSITY (P.C.F.) | MOISTURE CONTENT (PERCENT) | |
| | 19-5 | C-3 | 13.5' | CL | 5.0 | 2.42 | 115.7 | 14.6 | 5 RING CONVERSE |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| SPECIMEN NUMBER | SYMBOL | EFFECTIVE CONSOL. PRESSURE $\sigma_{3C}$ (P.S.I.) | TEST VALUES AT FAILURE (MAXIMUM $\sigma_1'/\sigma_3'$) | | | | TEST TYPE |
|---|---|---|---|---|---|---|---|
| | | | TOTAL DEVIATOR STRESS $\sigma_1$-$\sigma_3$ (P.S.I.) | PORE PRESSURE CHANGE $\Delta U$ (P.S.I.) | MINOR EFFECTIVE STRESS $\sigma_3'$ (P.S.I.) | MAJOR EFFECTIVE STRESS $\sigma_1'$ (P.S.I.) | |
| | 1 | 13 | 31.6 | +0.8 | 12.2 | 42.0 | TX CUE PROGRESSIVE |
| | 2 | 30 | 61.3 | +5.6 | 24.4 | 85.6 | |
| | | | | | | | |
| | | | | | | | |

# TRIAXIAL COMPRESSION TESTS

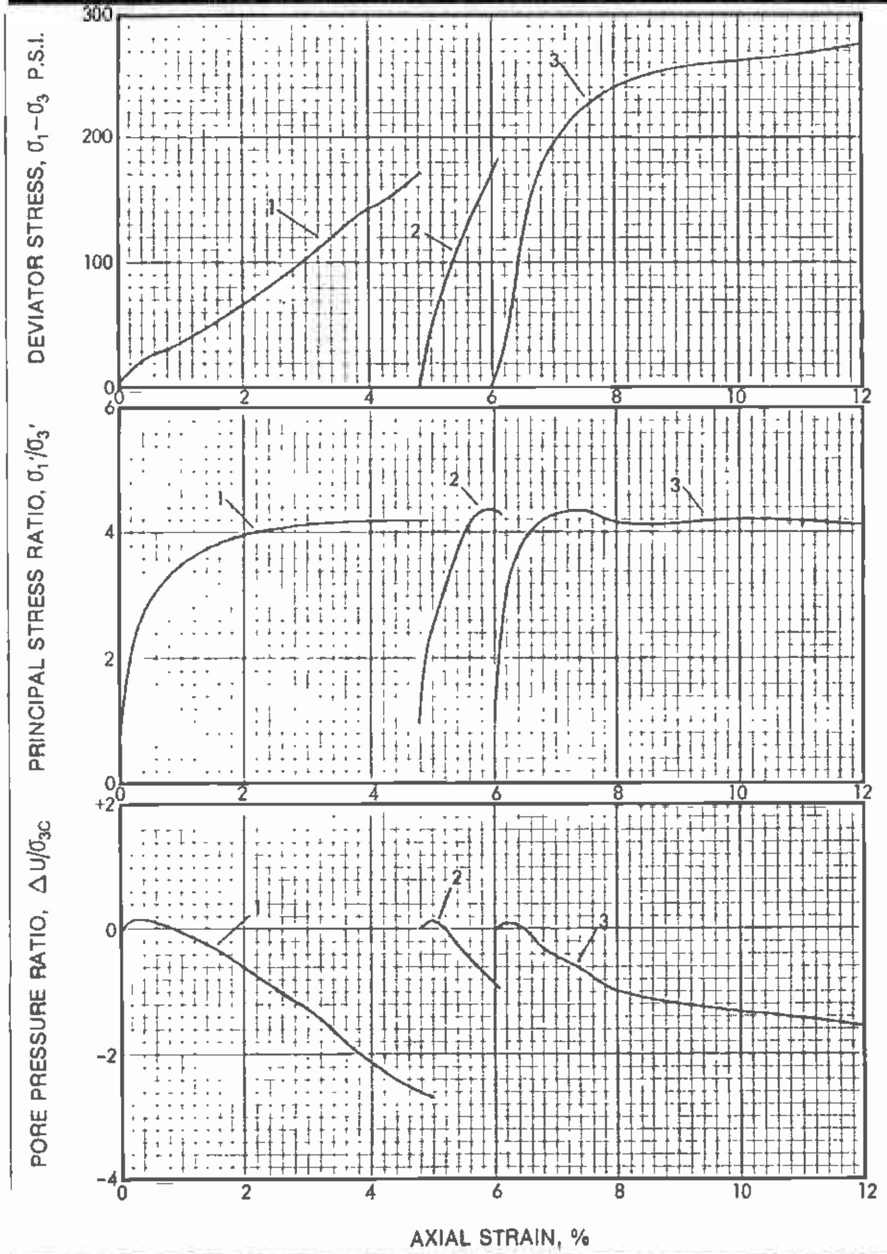
DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

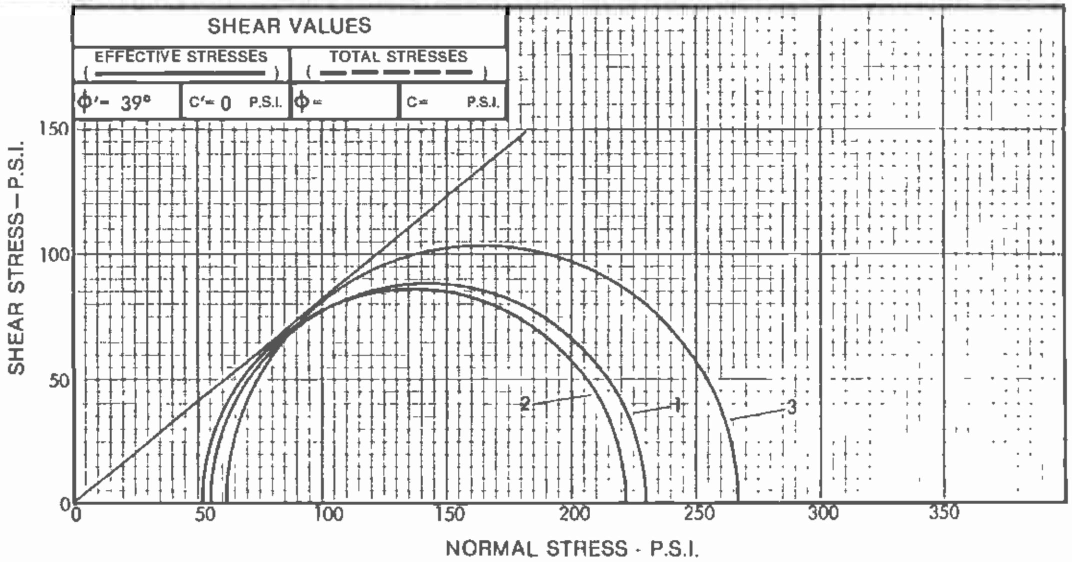
Project No
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Figure No
C-27

Approved for publication 5/11 by





| SHEAR VALUES | | | |
|---|---|---|---|
| EFFECTIVE STRESSES ( —— ) | | TOTAL STRESSES ( – – – ) | |
| $\phi'$ = 39° | C' = 0 P.S.I. | $\phi$ = | C = P.S.I. |

| SPECIMEN NUMBER | SPECIMEN LOCATION | | | INITIAL SPECIMEN DATA | | | | | | SAMPLE TYPE |
|---|---|---|---|---|---|---|---|---|---|---|
| | BORING NUMBER | SAMPLE NUMBER | DEPTH (FEET) | SOIL CLASSIFICATION | LENGTH (INCHES) | DIAMETER (INCHES) | DRY DENSITY (P.C.F.) | MOISTURE CONTENT (PERCENT) | BITUMEN CONTENT (PERCENT) | |
| | 19/5 | PB-6 | 60-62.5 | tar sand | 6.08 | 2.87 | 126 | 5.6 | 18.7 | P.B. |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

| SPECIMEN NUMBER | SYMBOL | EFFECTIVE CONSOL. PRESSURE $\sigma_{3C}$ (P.S.I.) | TEST VALUES AT FAILURE (MAXIMUM $\sigma_1'/\sigma_3'$) | | | | TEST TYPE |
|---|---|---|---|---|---|---|---|
| | | | TOTAL DEVIATOR STRESS $\sigma_1$-$\sigma_3$ (P.S.I.) | PORE PRESSURE CHANGE $\Delta$U (P.S.I.) | MINOR EFFECTIVE STRESS $\sigma_3'$ (P.S.I.) | MAJOR EFFECTIVE STRESS $\sigma_1'$ (P.S.I.) | |
| | 1 | 14.5 | 175.6 | -40.2 | 54.7 | 230.3 | TX CUE PROGRESSIVE |
| | 2 | 29.0 | 171.8 | -22.2 | 51.2 | 223.0 | |
| | 3 | 43.5 | 205.4 | -17.8 | 61.4 | 266.8 | |
| | | | | | | | |

# TRIAXIAL COMPRESSION TESTS

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Project No
83-1140

**Converse Consultants**
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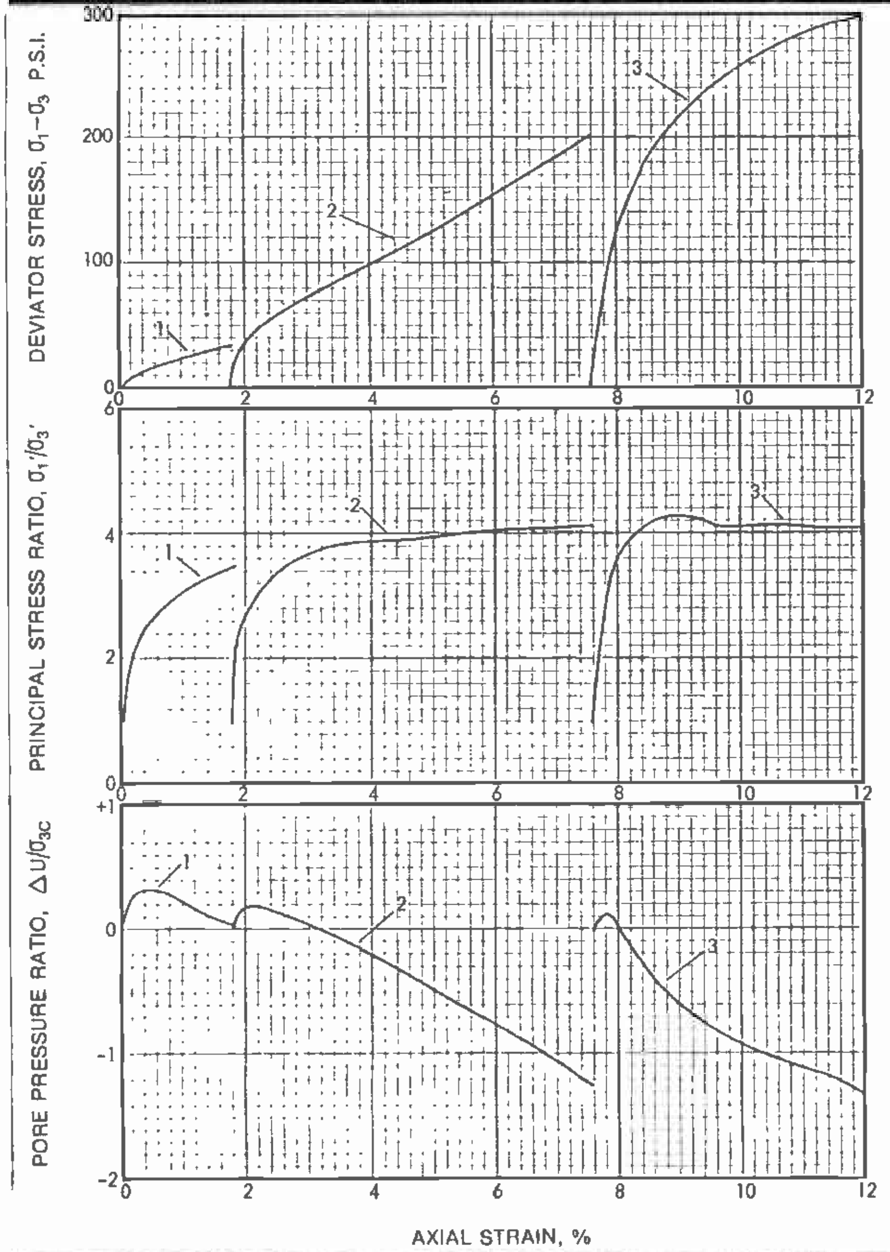
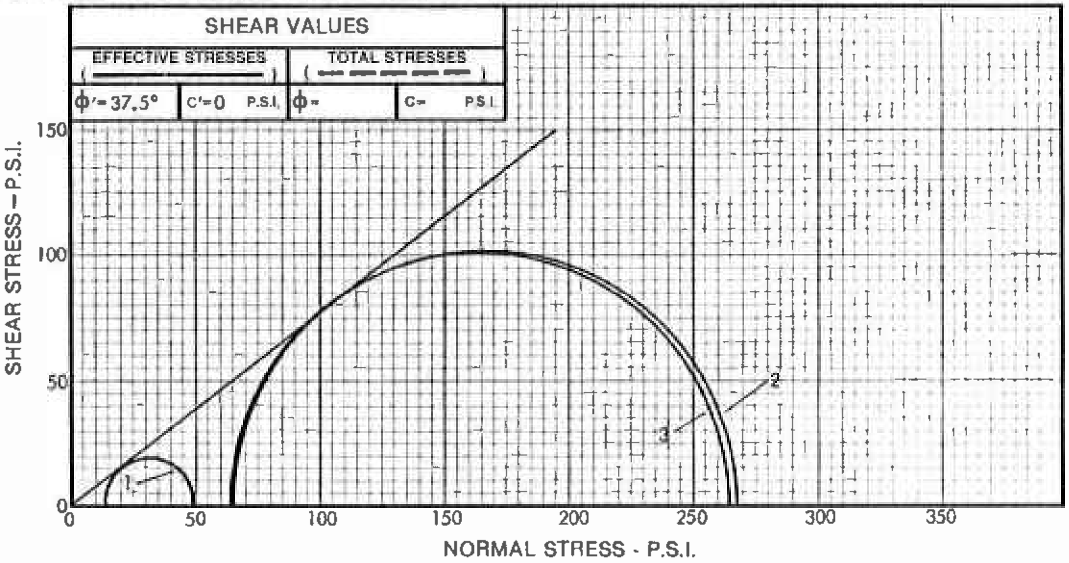
Figure No
C-28

Approved for publication 5/84 by TAD





| SHEAR VALUES | | | |
|---|---|---|---|
| EFFECTIVE STRESSES (———) | | TOTAL STRESSES (— — — —) | |
| $\phi' = 37.5°$ | C'=0 P.S.I. | $\phi$ = | C= P.S.I. |

| SPECIMEN NUMBER | SPECIMEN LOCATION | | | INITIAL SPECIMEN DATA | | | | | | SAMPLE TYPE |
|---|---|---|---|---|---|---|---|---|---|---|
| | BORING NUMBER | SAMPLE NUMBER | DEPTH (FEET) | SOIL CLASSIFICATION | LENGTH (INCHES) | DIAMETER (INCHES) | DRY DENSITY (P.C.F.) | MOISTURE CONTENT (PERCENT) | BITUMEN CONTENT (PERCENT) | |
| | 19/5 | PB-6 | 60-62.5 | tar sand | 6.01 | 2.80 | 123 | 7.7 | 18.7 | P.B. |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

| SPECIMEN NUMBER | SYMBOL | EFFECTIVE CONSOL. PRESSURE $\sigma_{3C}$ (P.S.I.) | TEST VALUES AT FAILURE (MAXIMUM $\sigma_1'/\sigma_3'$) | | | | TEST TYPE |
|---|---|---|---|---|---|---|---|
| | | | TOTAL DEVIATOR STRESS $\sigma_1$-$\sigma_3$ (P.S.I.) | PORE PRESSURE CHANGE $\Delta U$ (P.S.I.) | MINOR EFFECTIVE STRESS $\sigma_3'$ (P.S.I.) | MAJOR EFFECTIVE STRESS $\sigma_1'$ (P.S.I.) | |
| | 1 | 14.5 | 35.5 | 0.3 | 14.2 | 49.7 | TX CUE<br>PROGRESSIVE |
| | 2 | 29.0 | 202.8 | -36.6 | 65.6 | 268.4 | |
| | 3 | 43.5 | 201.0 | -20.7 | 64.2 | 265.2 | |
| | | | | | | | |

# TRIAXIAL COMPRESSION TESTS

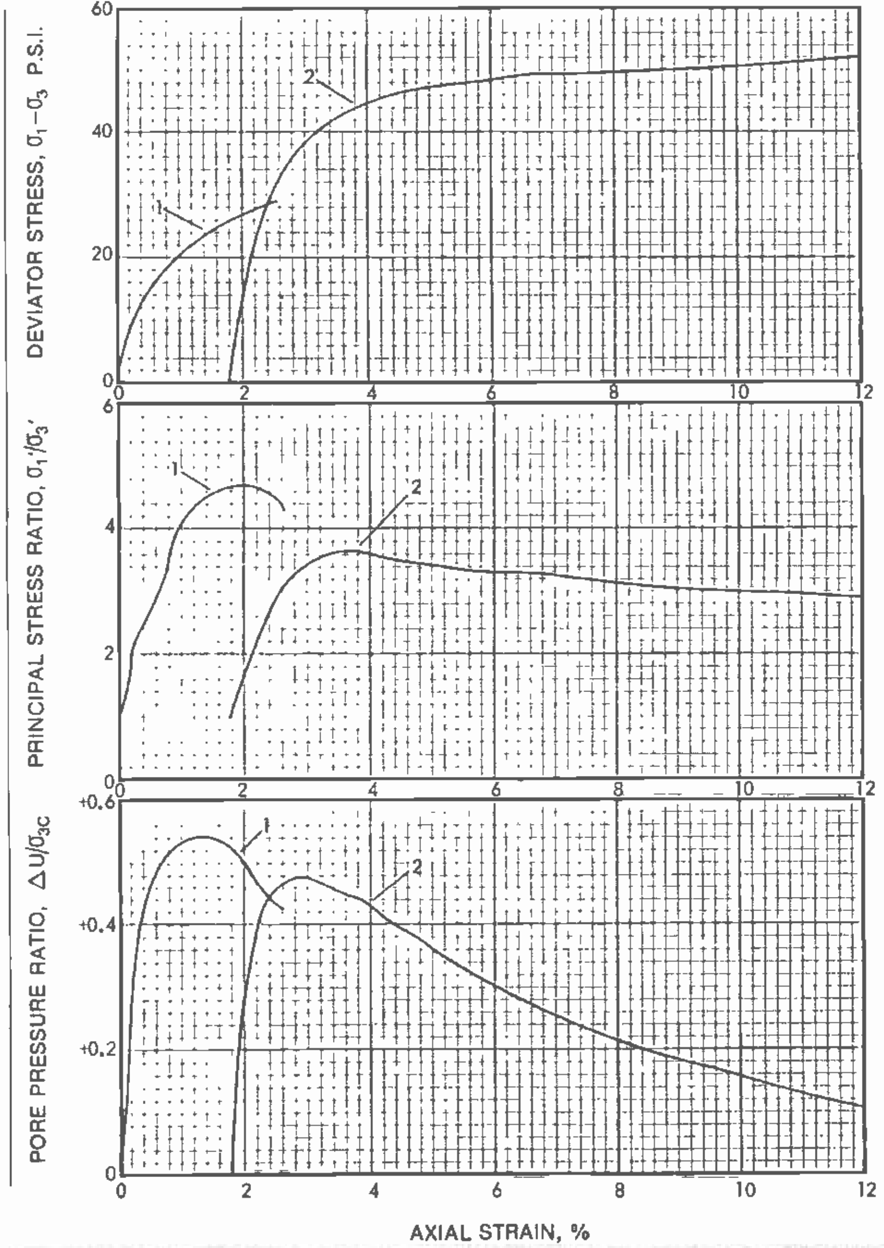
DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

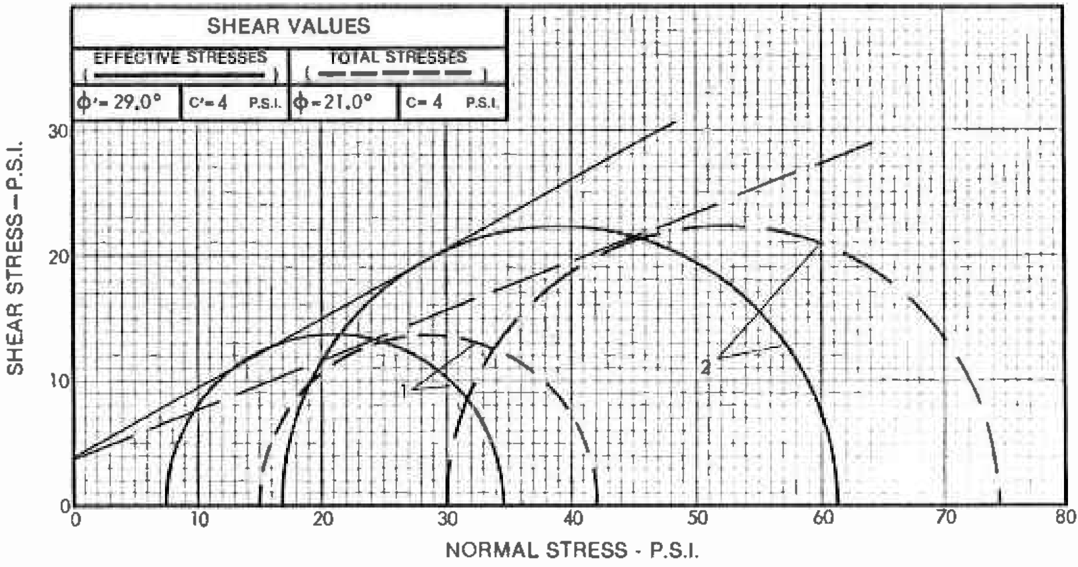
Project No
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Figure No
C-29

Approved for publication 5/14 by





| SHEAR VALUES | | | |
|---|---|---|---|
| EFFECTIVE STRESSES ( ——— ) | | TOTAL STRESSES ( — — — ) | |
| $\phi' = 29.0°$ | C' = 4 P.S.I. | $\phi = 21.0°$ | C = 4 P.S.I. |

| SPECIMEN NUMBER | SPECIMEN LOCATION | | | INITIAL SPECIMEN DATA | | | | | SAMPLE TYPE |
|---|---|---|---|---|---|---|---|---|---|
| | BORING NUMBER | SAMPLE NUMBER | DEPTH (FEET) | SOIL CLASSIFICATION | LENGTH (INCHES) | DIAMETER (INCHES) | DRY DENSITY (P.C.F.) | MOISTURE CONTENT (PERCENT) | |
| | 20/2 | C-3 | 13.5 | CL | 5.0 | 2.42 | 95.4 | 28.6 | 5 RING CONVERSE |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| SPECIMEN NUMBER | SYMBOL | EFFECTIVE CONSOL. PRESSURE $\sigma_{3C}$ (P.S.I.) | TEST VALUES AT FAILURE (MAXIMUM $\sigma_1'/\sigma_3'$) | | | | TEST TYPE |
|---|---|---|---|---|---|---|---|
| | | | TOTAL DEVIATOR STRESS $\sigma_1-\sigma_3$ (P.S.I.) | PORE PRESSURE CHANGE $\Delta U$ (P.S.I.) | MINOR EFFECTIVE STRESS $\sigma_3'$ (P.S.I.) | MAJOR EFFECTIVE STRESS $\sigma_1'$ (P.S.I.) | |
| | 1 | 15 | 27.3 | +7.5 | 7.5 | 34.8 | TX CUE PROGRESSIVE |
| | 2 | 30 | 44.4 | +13.1 | 16.9 | 61.3 | |
| | | | | | | | |
| | | | | | | | |

# TRIAXIAL COMPRESSION TESTS

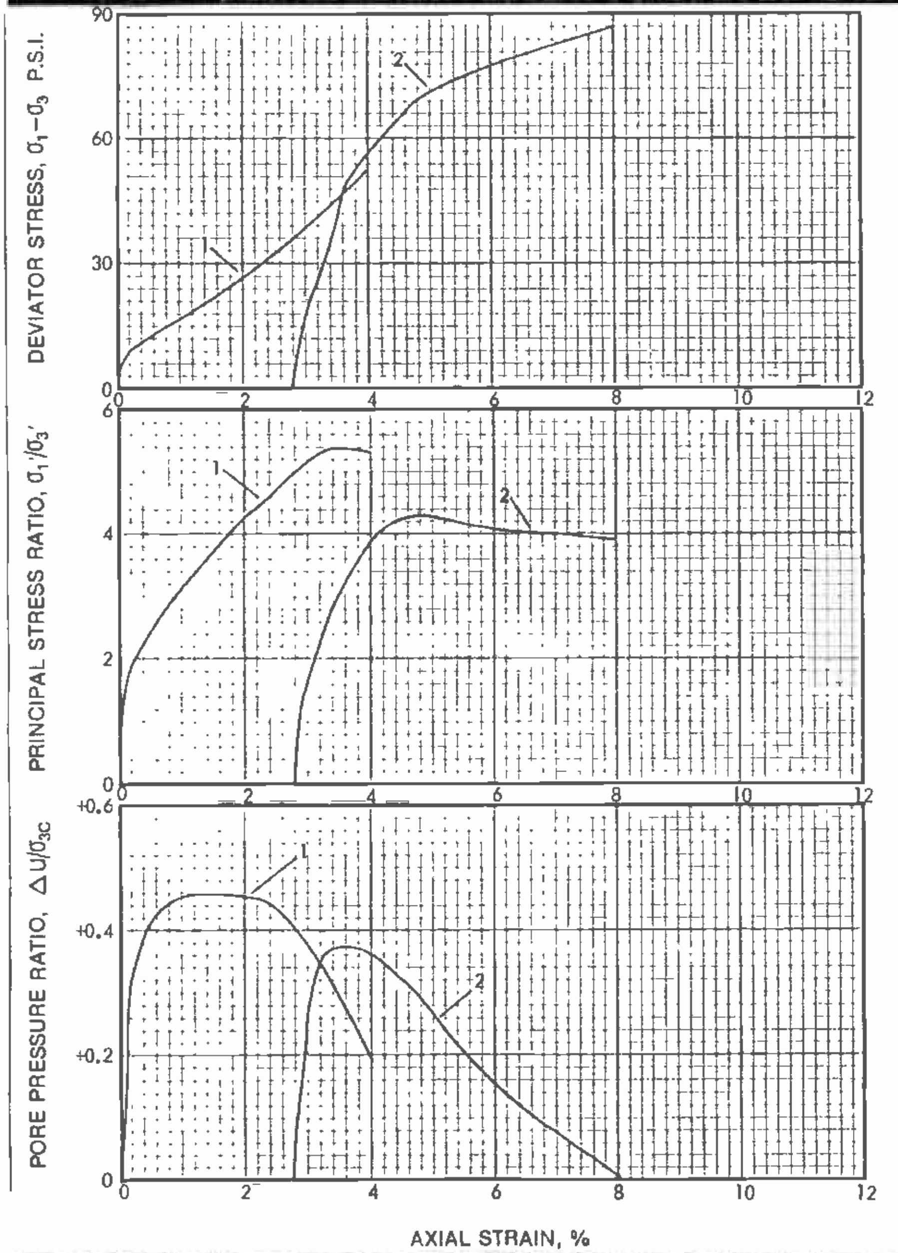
DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

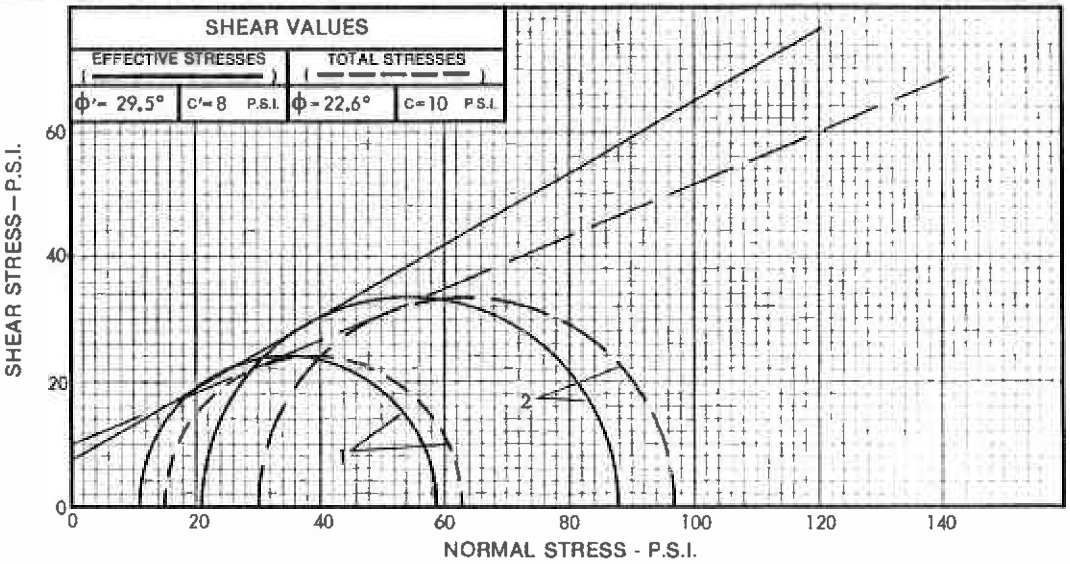
Project No
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Figure No
C-30

Approved for publication 5/5/41 by JAD





SHEAR VALUES

| EFFECTIVE STRESSES | | TOTAL STRESSES | |
|---|---|---|---|
| ━━━━━━━ | | — — — — — | |
| φ'= 29.5° | c'=8 P.S.I. | φ = 22.6° | c=10 P.S.I. |

| SPECIMEN NUMBER | SPECIMEN LOCATION | | | INITIAL SPECIMEN DATA | | | | | SAMPLE TYPE |
|---|---|---|---|---|---|---|---|---|---|
| | BORING NUMBER | SAMPLE NUMBER | DEPTH (FEET) | SOIL CLASSIFICATION | LENGTH (INCHES) | DIAMETER (INCHES) | DRY DENSITY (P.C.F.) | MOISTURE CONTENT (PERCENT) | |
| | 20/2 | C-14 | 98' | ML/CL | 5.0 | 2.42 | 94.4 | 28.9 | 5 RING CONVERSE |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| SPECIMEN NUMBER | SYMBOL | EFFECTIVE CONSOL PRESSURE $\sigma_{3C}$ (P.S.I.) | TEST VALUES AT FAILURE (MAXIMUM $\sigma_1'/\sigma_3'$) | | | | TEST TYPE |
|---|---|---|---|---|---|---|---|
| | | | TOTAL DEVIATOR STRESS $\sigma_1-\sigma_3$ (P.S.I.) | PORE PRESSURE CHANGE $\Delta U$ (P.S.I.) | MINOR EFFECTIVE STRESS $\sigma_3'$ (P.S.I.) | MAJOR EFFECTIVE STRESS $\sigma_1'$ (P.S.I.) | |
| | 1 | 15 | 47.7 | 4.1 | 10.9 | 58.6 | TX CUE PROGRESSIVE |
| | 2 | 30 | 67.3 | 9.5 | 20.5 | 87.8 | |
| | | | | | | | |
| | | | | | | | |

# TRIAXIAL COMPRESSION TESTS

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Project No
83-1140

**Converse Consultants**
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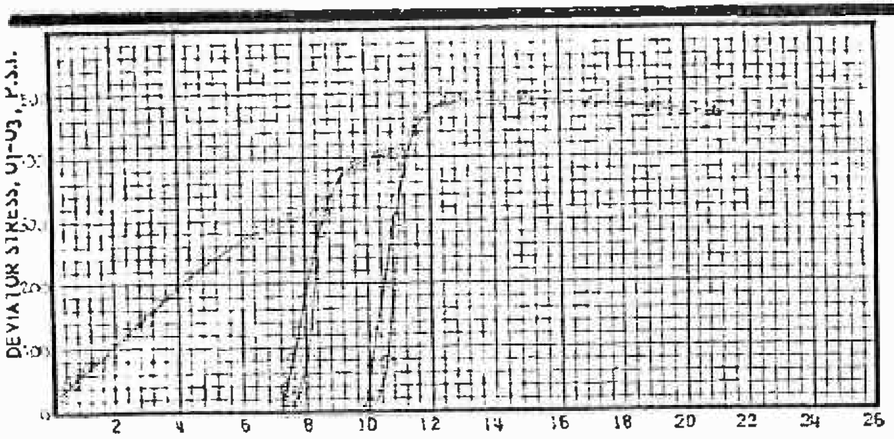
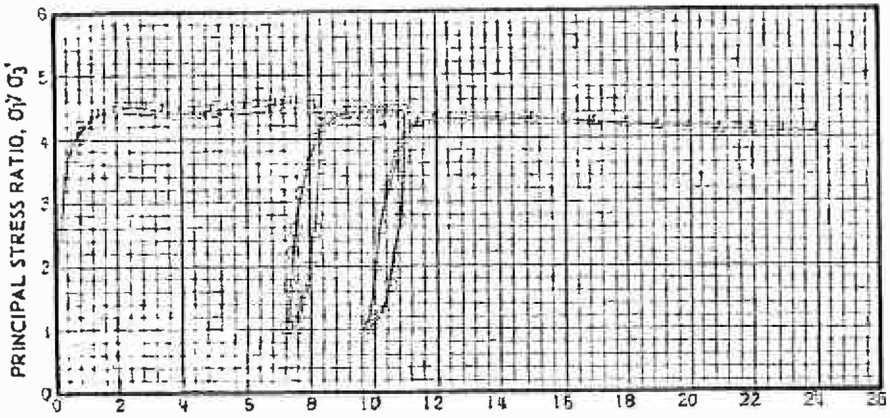
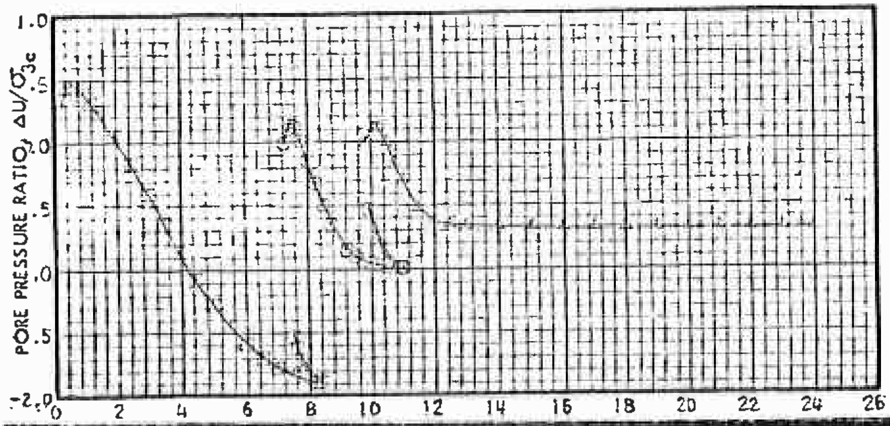
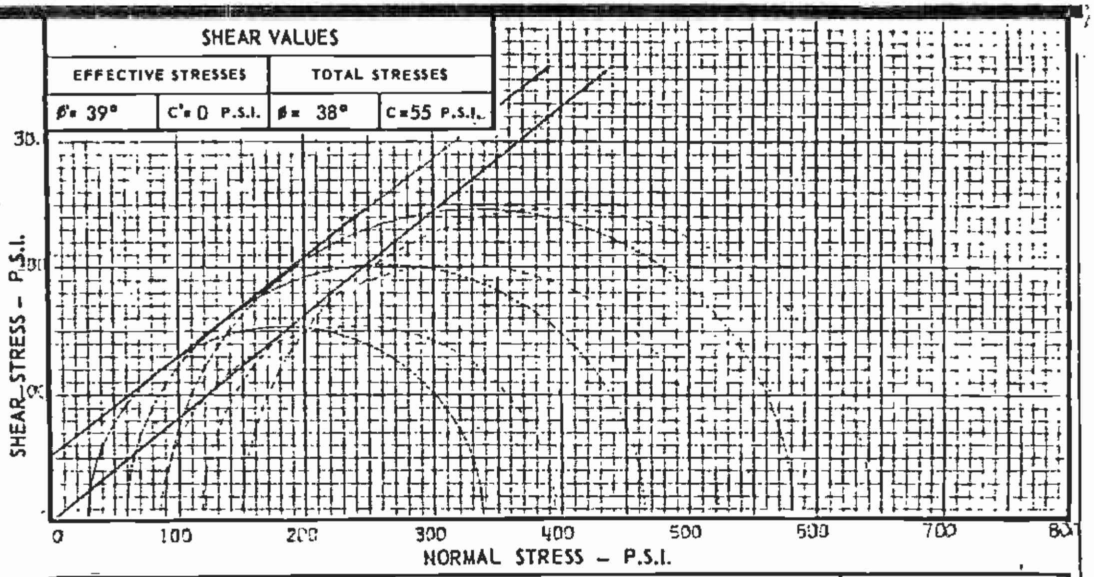
Figure No
C-31









| SHEAR VALUES | | | |
|---|---|---|---|
| EFFECTIVE STRESSES | | TOTAL STRESSES | |
| ø'= 39° | c'= 0 P.S.I. | ø= 38° | c=55 P.S.I. |

| SPECIMEN NUMBER | SPECIMEN LOCATION | | INITIAL SPECIMEN DATA | | | | | TYPE OF SAMPLE |
|---|---|---|---|---|---|---|---|---|
| | BORING NUMBER | DEPTH IN FEET | SOIL CLASSIFICATION | LENGTH IN INCHES | DIAMETER IN INCHES | DRY DENSITY (P.C.F.) | MOISTURE CONTENT IN PERCENT | |
| C3 | 21 | 80 | SP | 4.98 | 2.42 | 102.60 | 21.10 | UNDISTURBED |
| C3 | 21 | 80 | SP | 4.98 | 2.42 | 102.60 | 21.10 | UNDISTURBED |
| C3 | 21 | 80 | SP | 4.98 | 2.42 | 102.60 | 21.10 | UNDISTURBED |
| | | | | | | | | |

| SYMBOLS | SPECIMEN NUMBER | APPLIED LATERAL PRESSURE $\sigma_3$ (P.S.I.) | MAXIMUM DEVIATOR STRESS $\sigma_1 - \sigma_3$ (P.S.I.) | TEST VALUES AT FAILURE – MAXIMUM $\sigma_1'/\sigma_3'$ | | BACK PRESSURE (P.S.I.) | TYPE OF TEST |
|---|---|---|---|---|---|---|---|
| | | | | EFFECTIVE LATERAL PRESSURE $\sigma_3'$ (P.S.I.) | MAJOR EFFECTIVE STRESS $\sigma_1'$ (P.S.I.) | | |
| ⊓ | C3 | 30.0 | 309.8 | 86.6 | 398.4 | 50.0 | CU PROGRESSIVE |
| ⊤ | C3 | 60.0 | 406.1 | 118.8 | 524.2 | 50.0 | CU PROGRESSIVE |
| · | C3 | 90.0 | 493.0 | 150.3 | 943.3 | 50.0 | CU PROGRESSIVE |
| | | | | | | | |

# TRIAXIAL COMPRESSION TESTS

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Project No
83-1140

**Converse Consultants**
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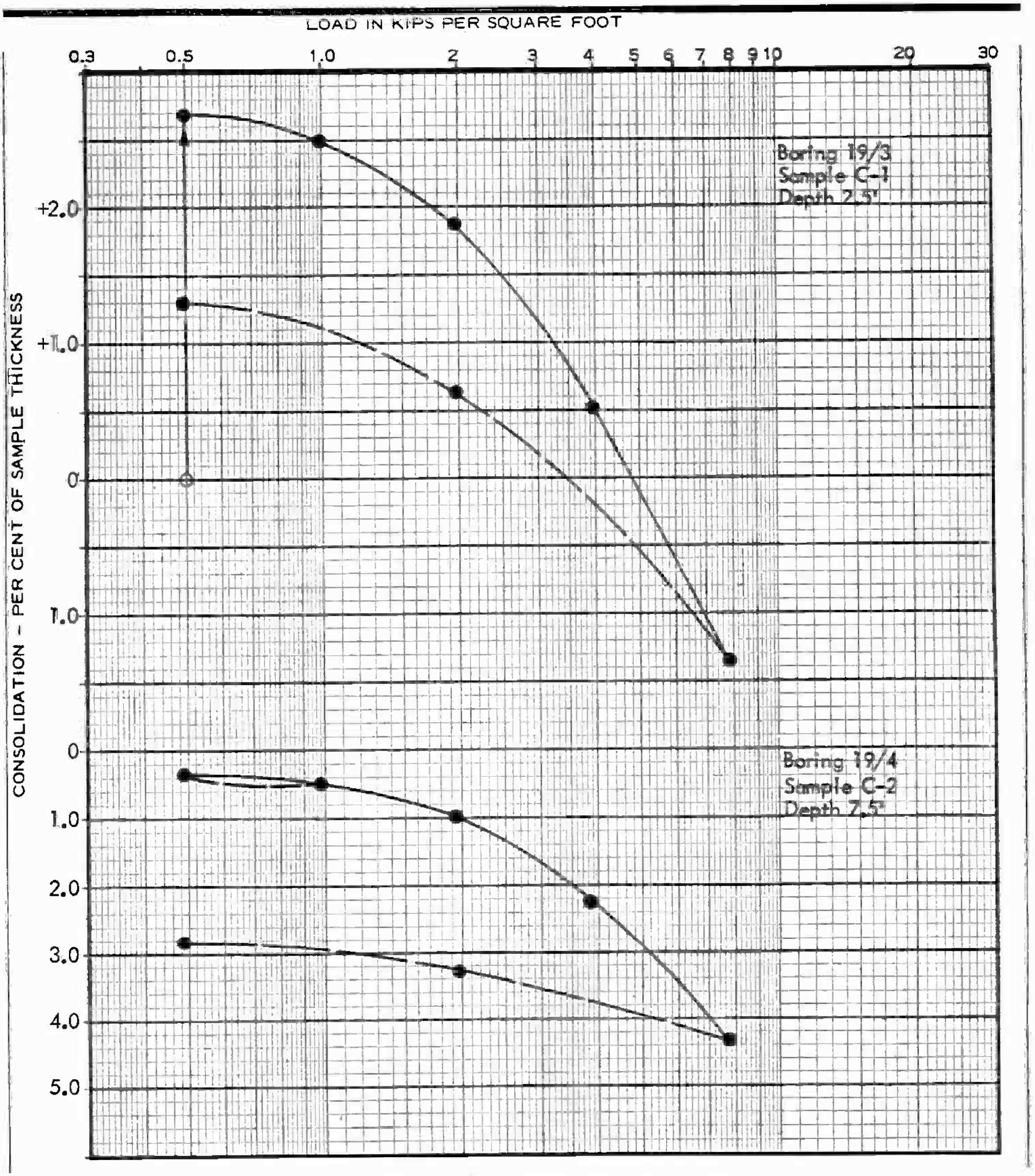
Figure No.
C-32

Approved for publication 5/84 by



● READINGS AFTER SATURATION WITH WATER

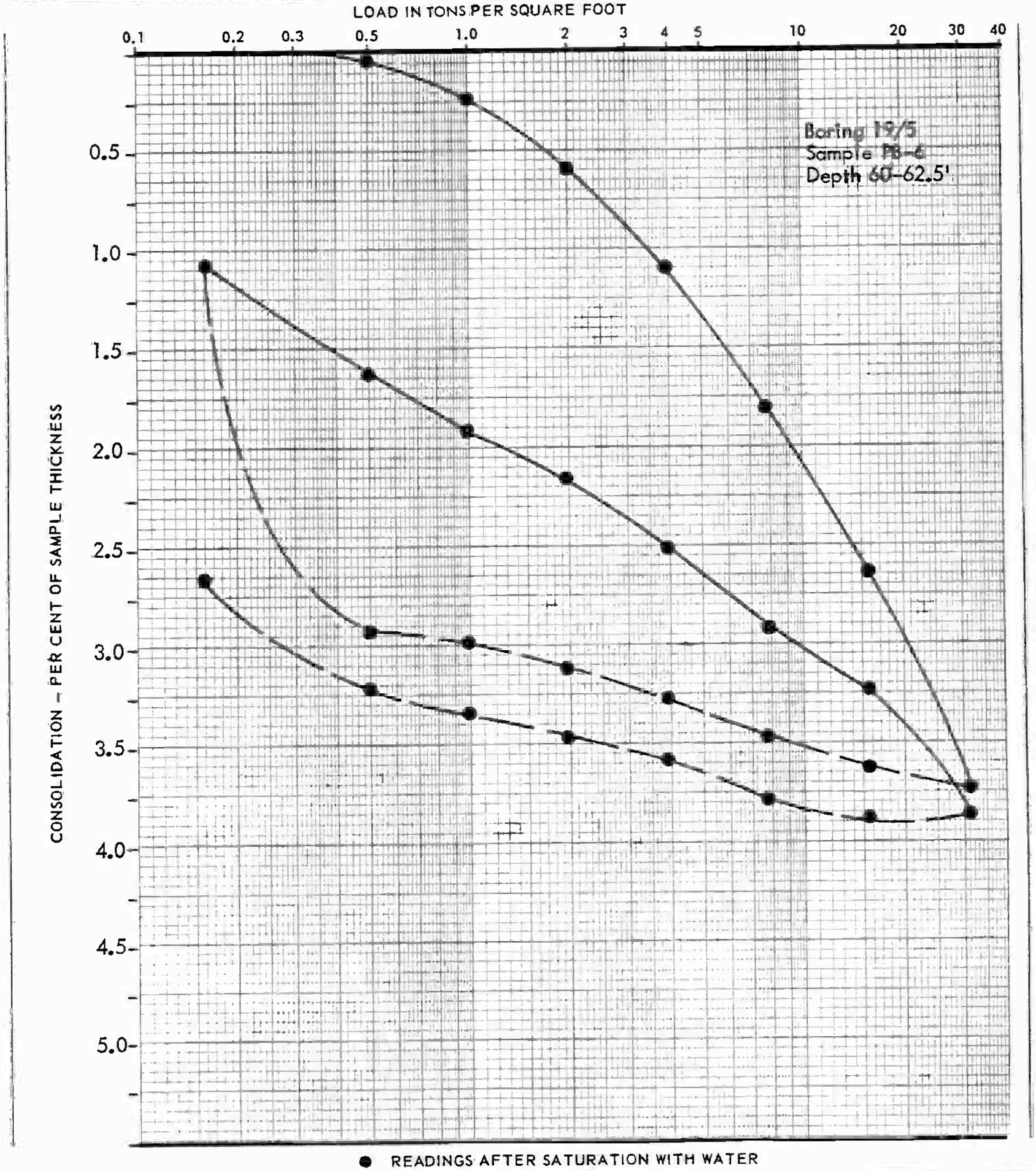
## CONSOLIDATION TESTS

DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Project No.
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Drawing No.
C-33



## CONSOLIDATION TESTS

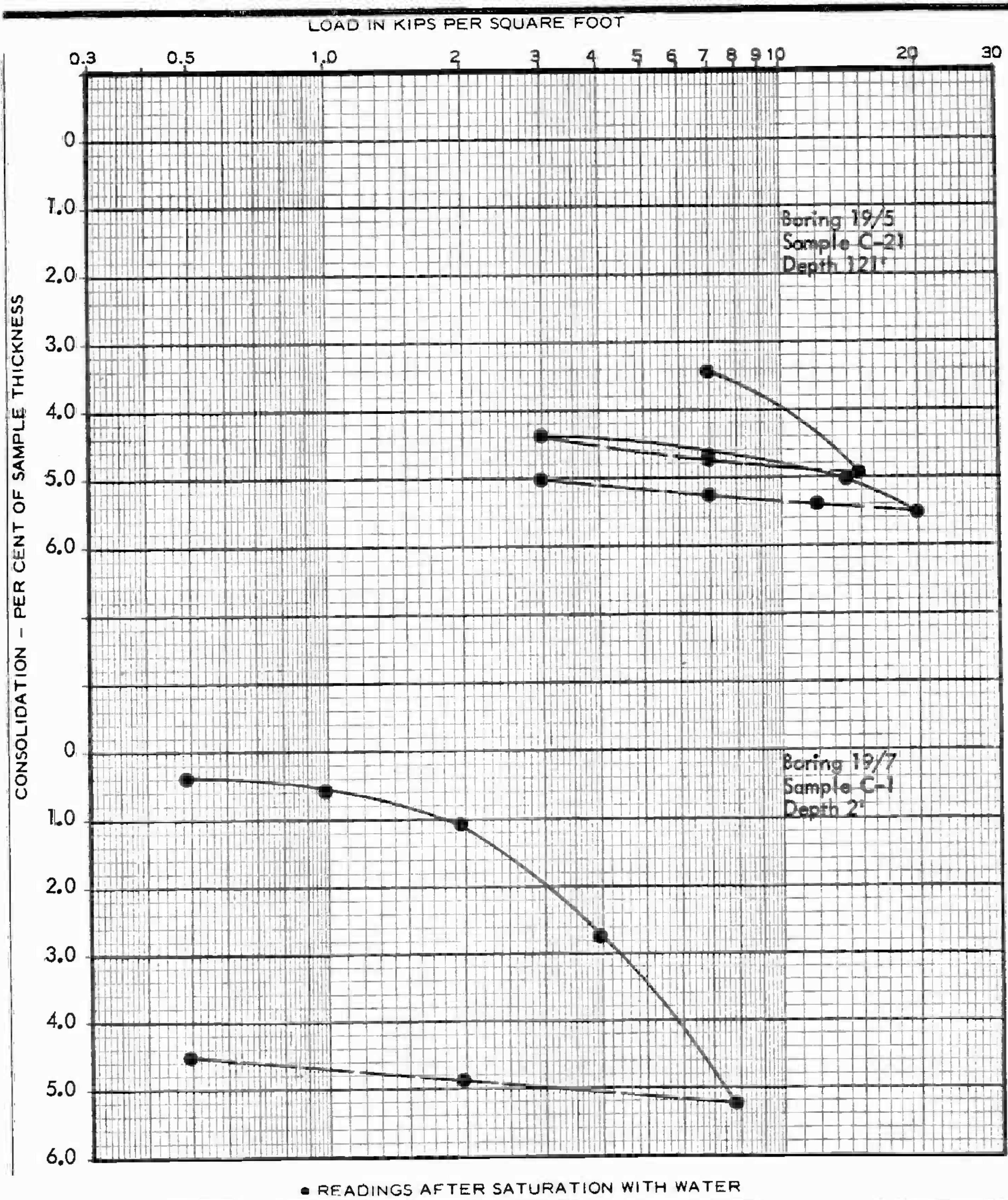
DESIGN UNIT A250
Southern California Rapid Transit District
METRO RAIL PROJECT

Project No.
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Drawing No.
C-34

Approved for publication 5/84 by



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## CONSOLIDATION TESTS

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83-1140

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Drawing No
C-35

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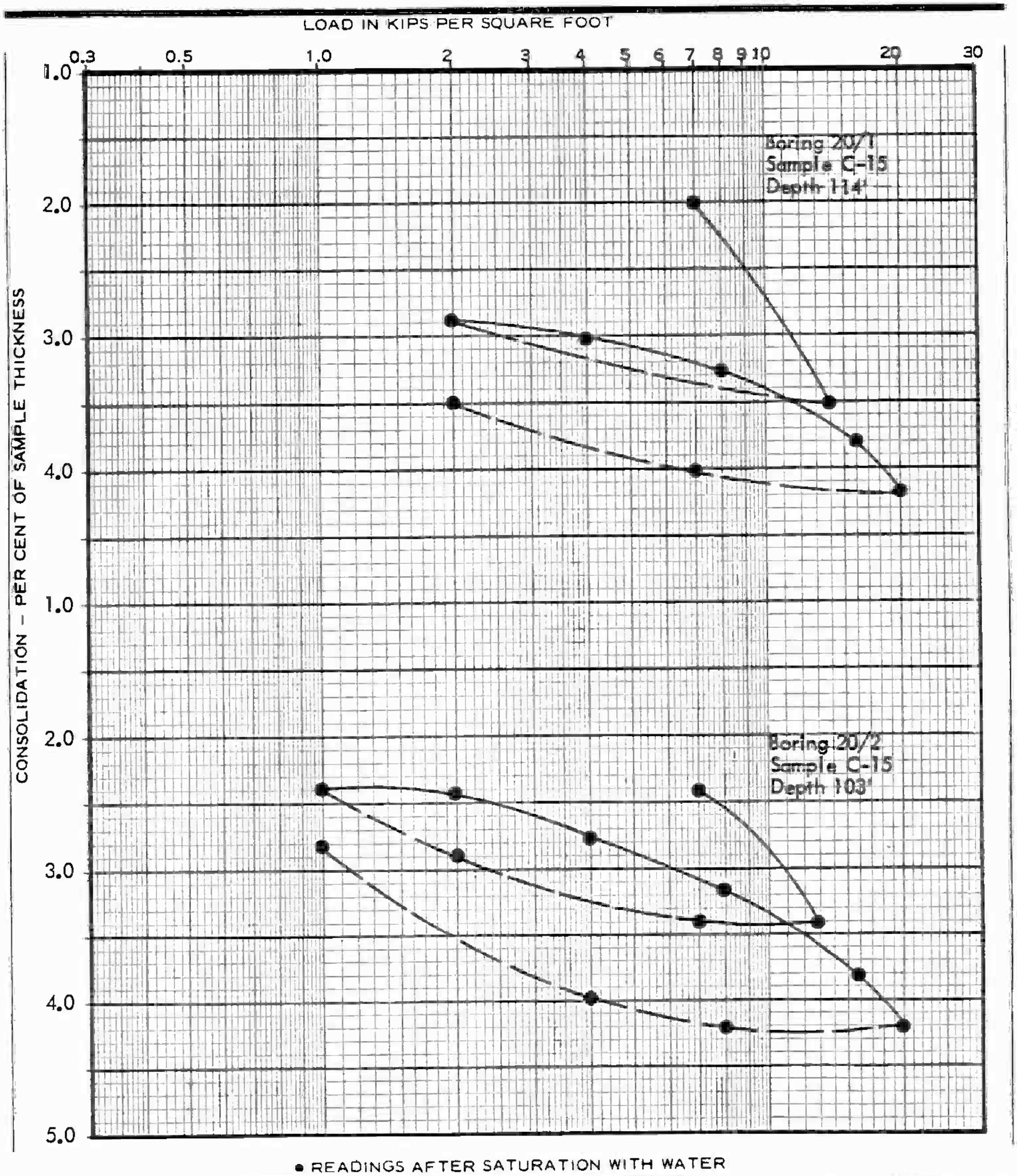

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Drawing No.
C-36

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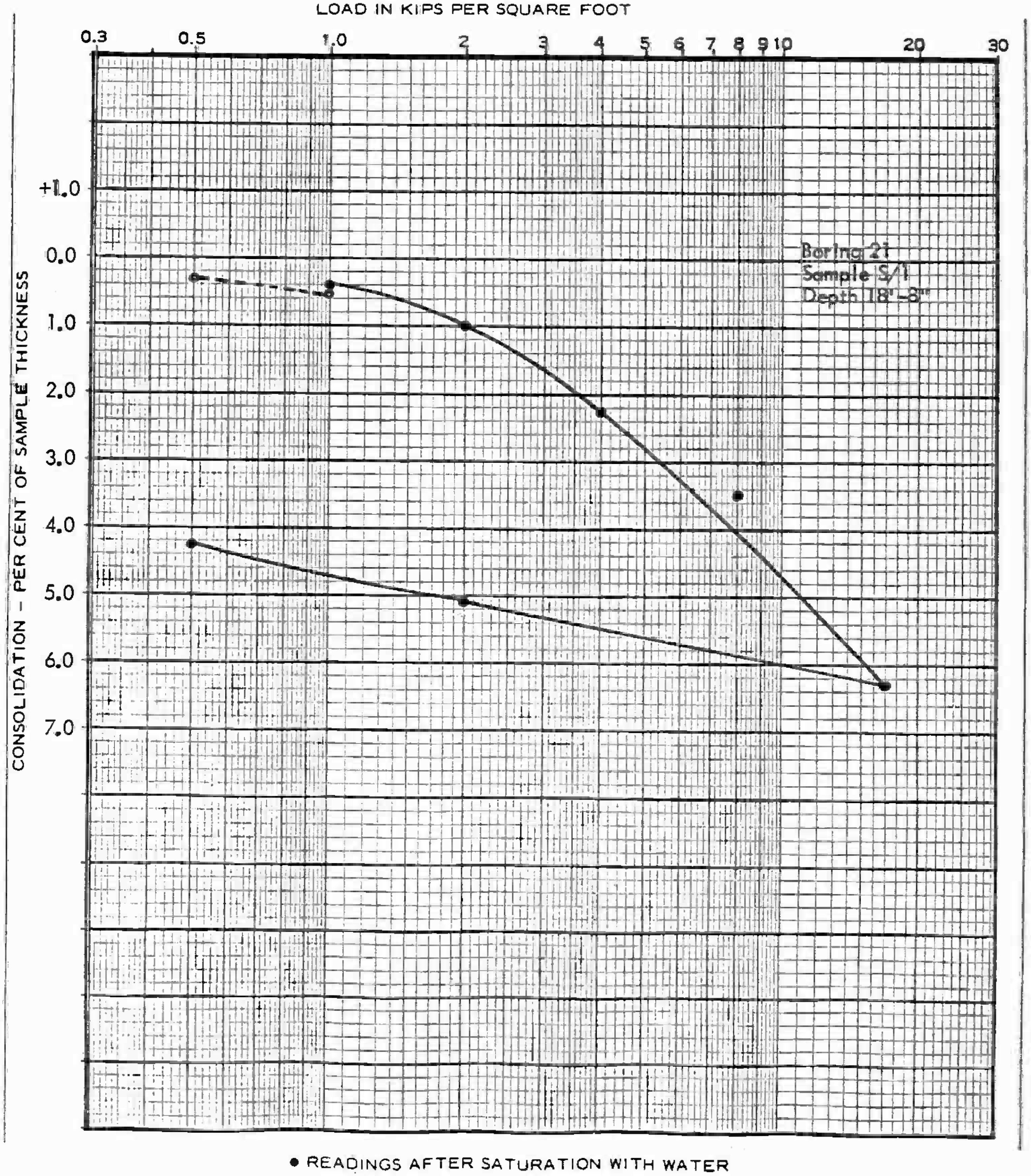

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Figure No.
C-37

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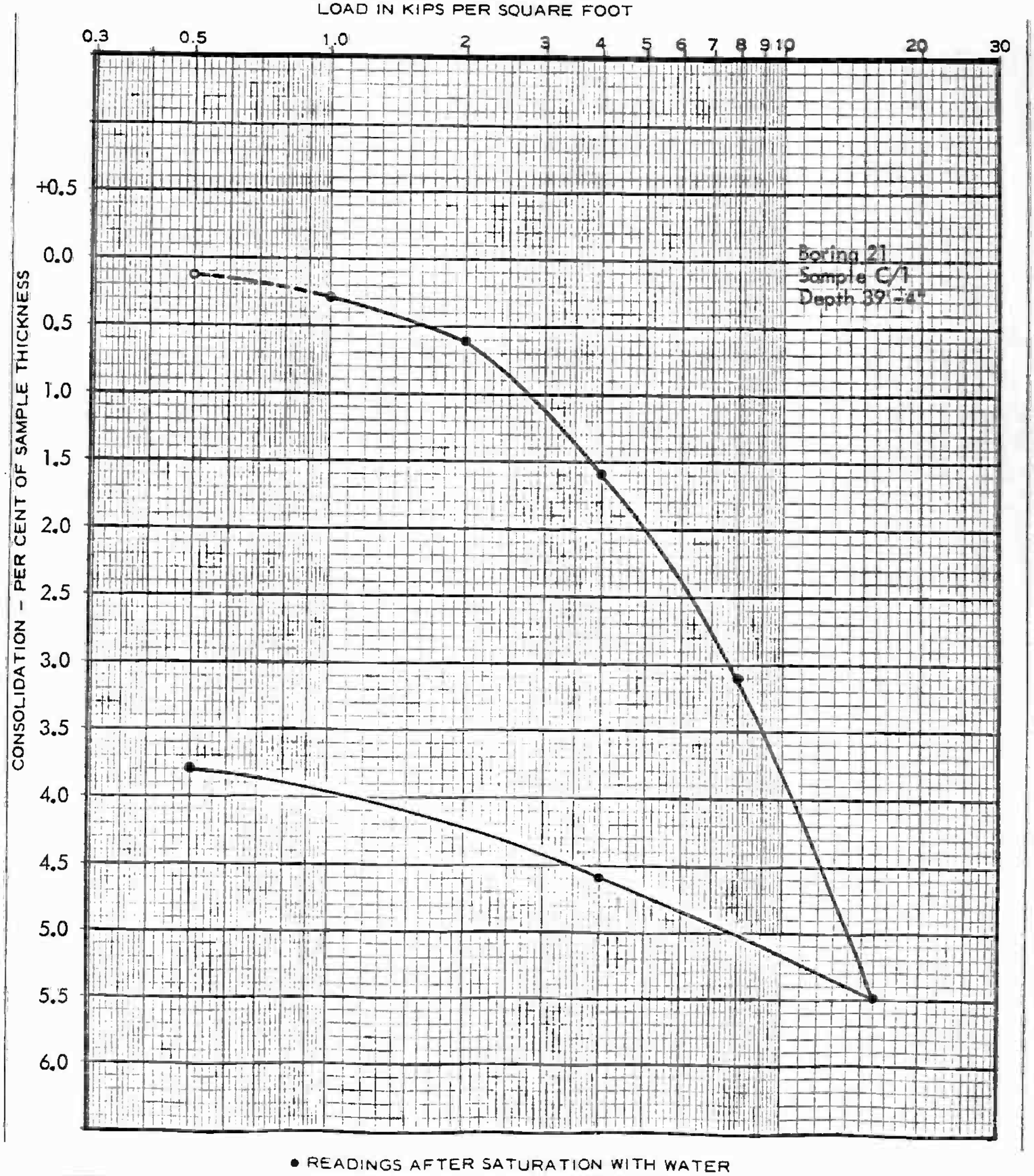

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Figure No.
C-38

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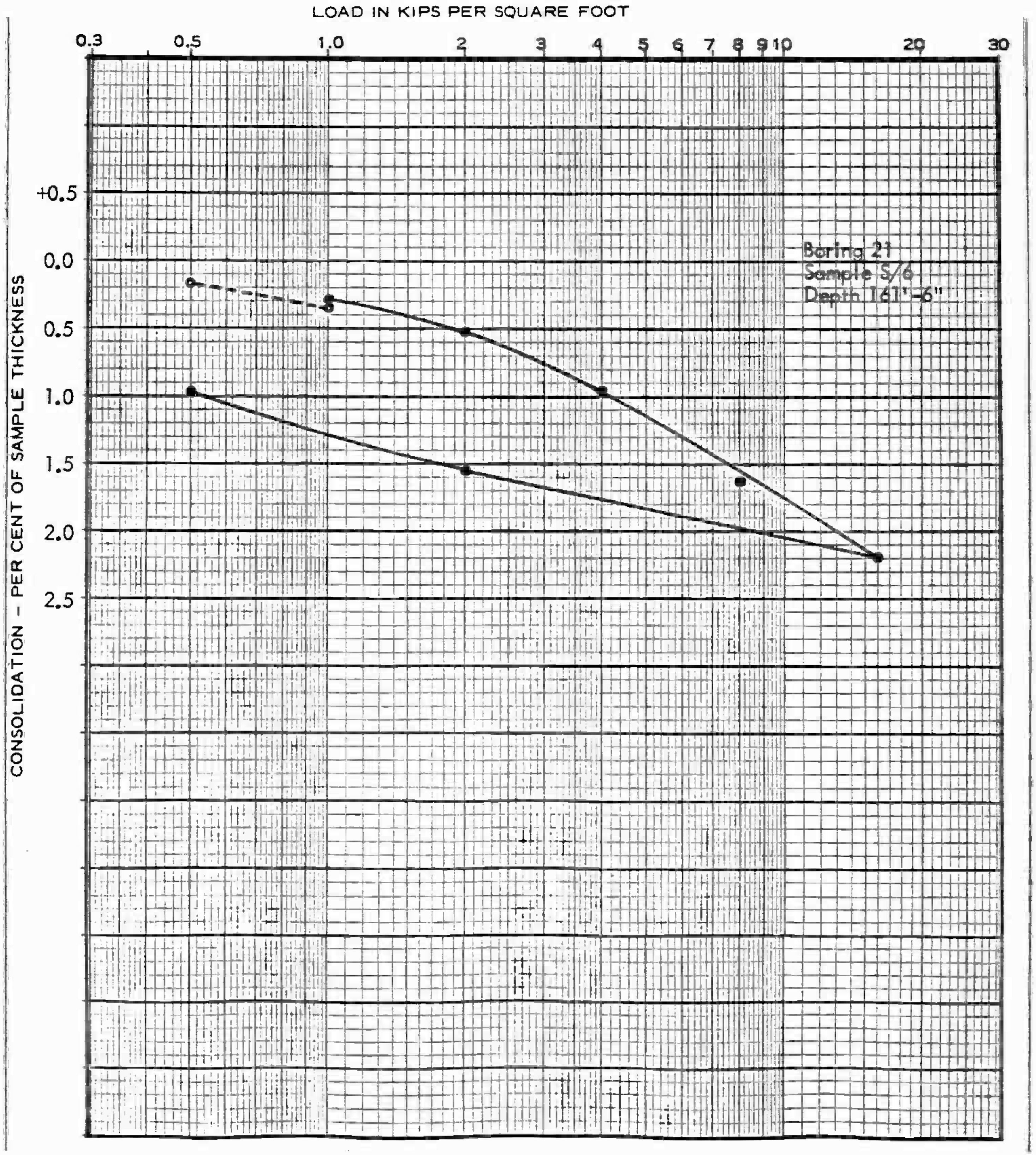

● READINGS AFTER SATURATION WITH WATER

# CONSOLIDATION TESTS

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83-1140

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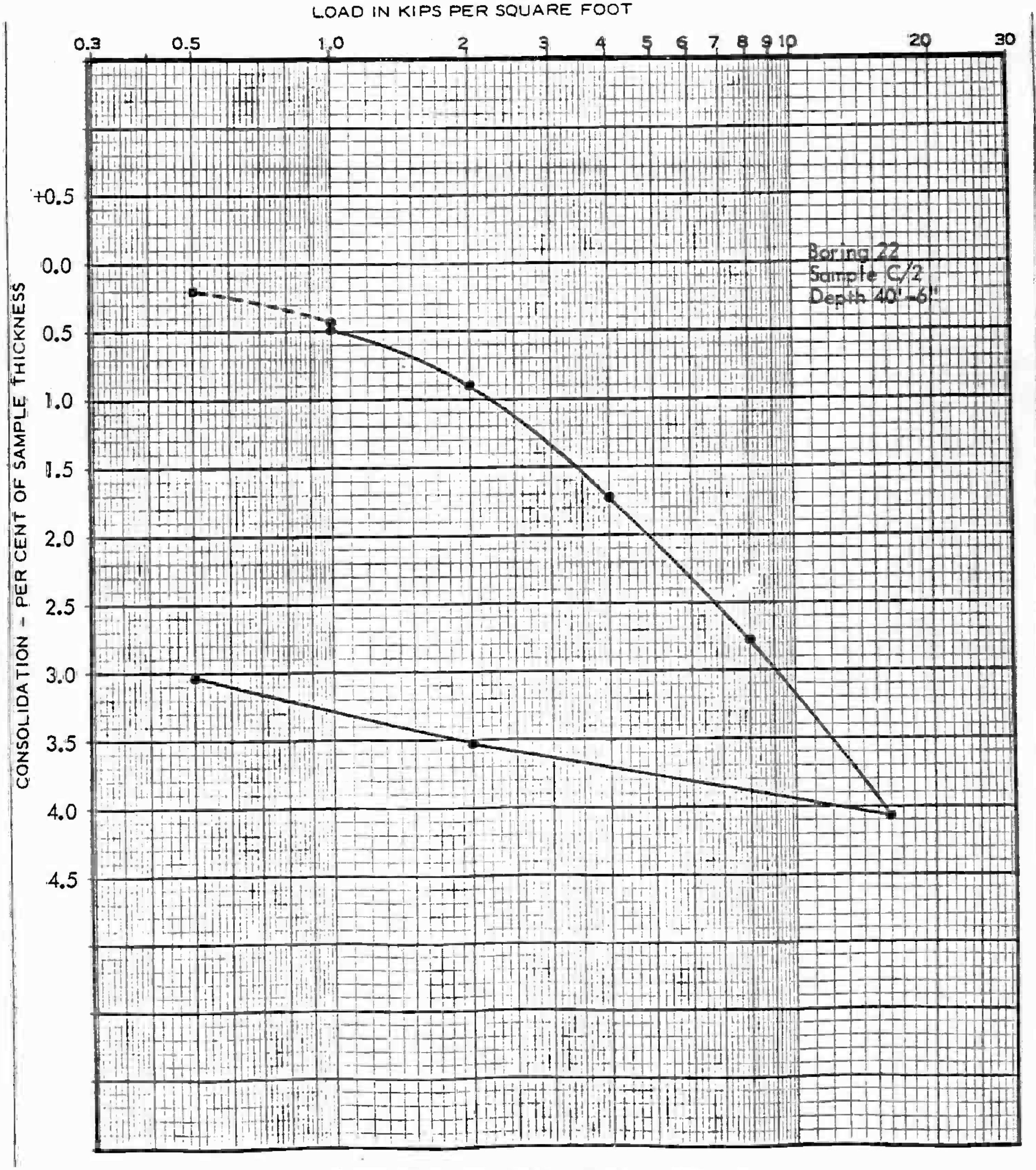
Figure No.
C-39

FORM NO. D

Approved for publication 5/84 by JAD



● READINGS AFTER SATURATION WITH WATER

# CONSOLIDATION TESTS

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Project No.
83-1140

Figure No.
C-40

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FORM NO. D1

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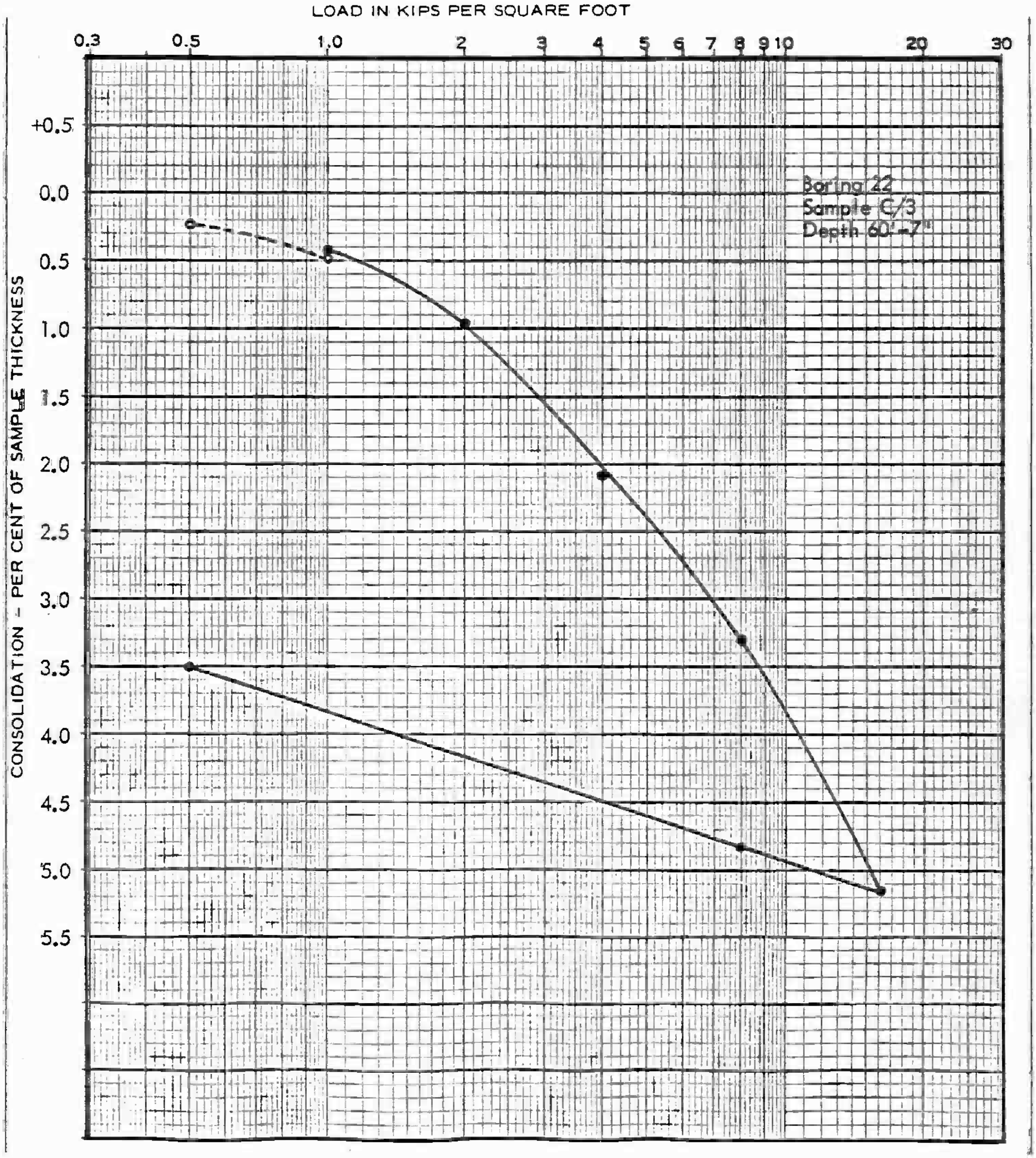

● READINGS AFTER SATURATION WITH WATER

## CONSOLIDATION TESTS

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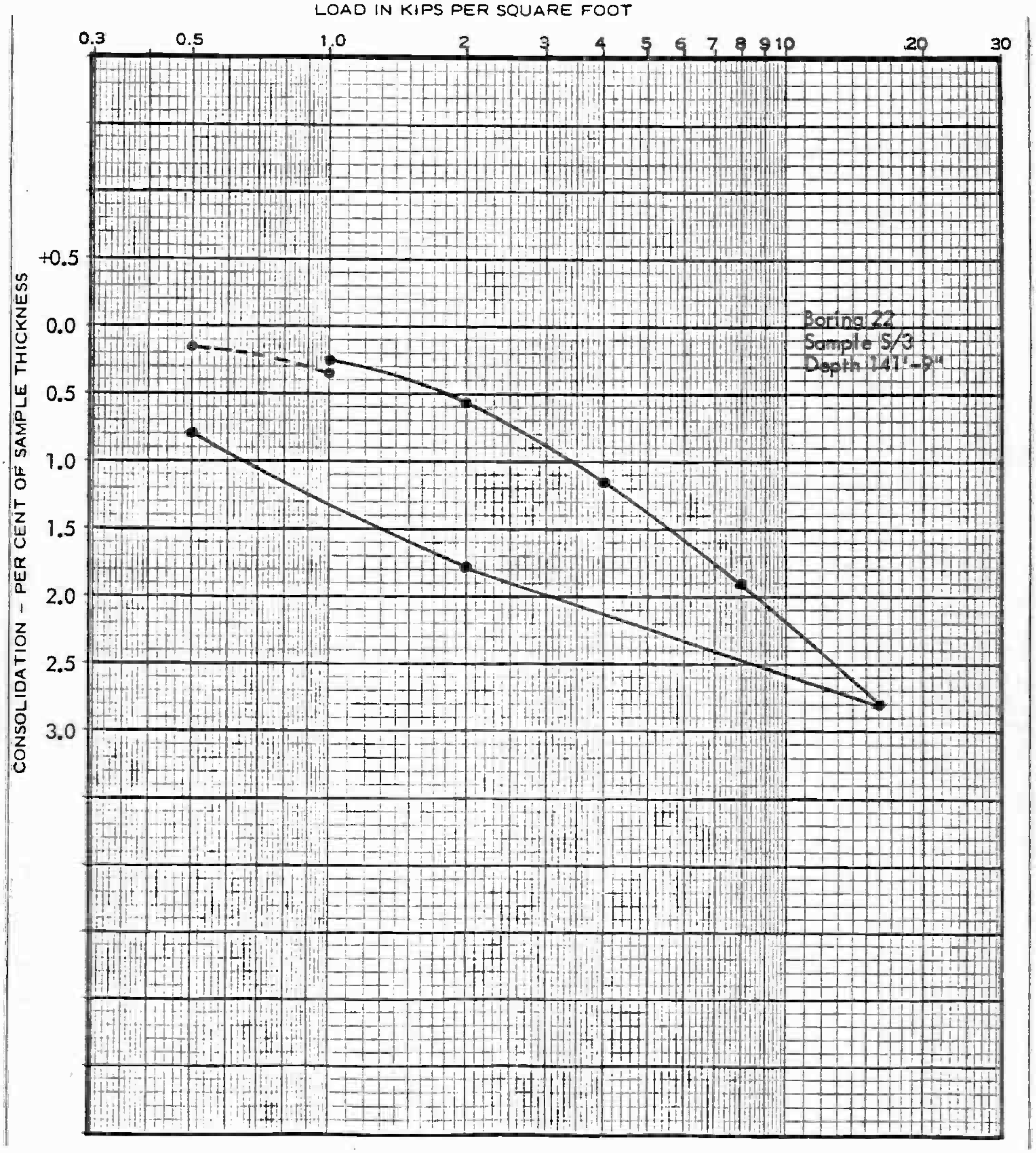
Project No.
83-1140

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Figure No.
C-41

FORM NO. DI Approved for publication 5/8/84 by



● READINGS AFTER SATURATION WITH WATER

# CONSOLIDATION TESTS

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Project No.
83-1140

Figure No.
C-42

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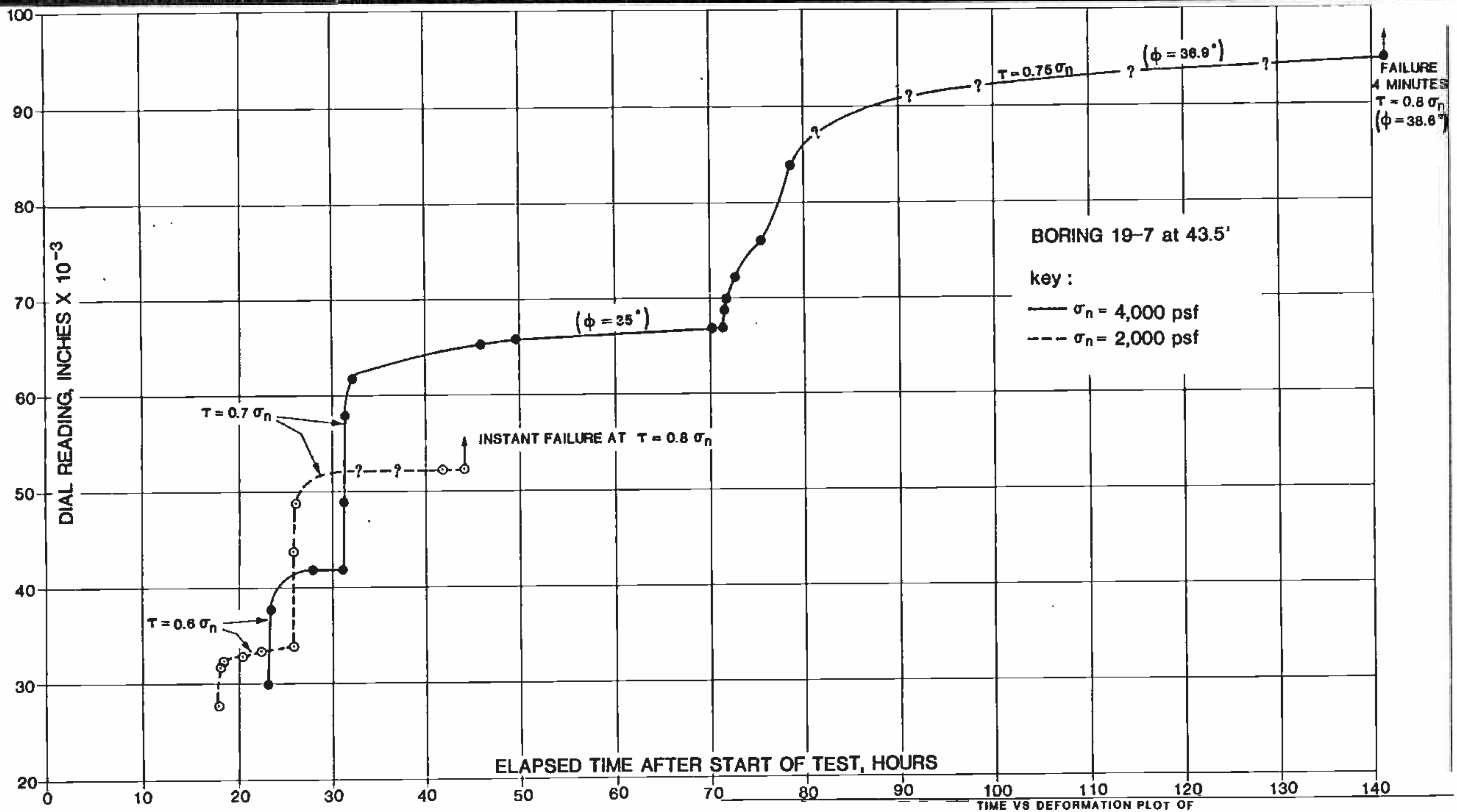
FORM NO. D



TIME VS DEFORMATION PLOT OF
CONSTANT STRESS "CREEP TEST" - TAR BEARING SAN PEDRO FORMATION

DESIGN UNIT A250
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METRO RAIL PROJECT

**Converse Consultants** Geotechnical Engineering and Applied Sciences

Scale As Shown
Date MAY, 1984
Prepared by RG
Checked by LTE
Approved By RMP
Project No 83-1140
Drawing No C-43

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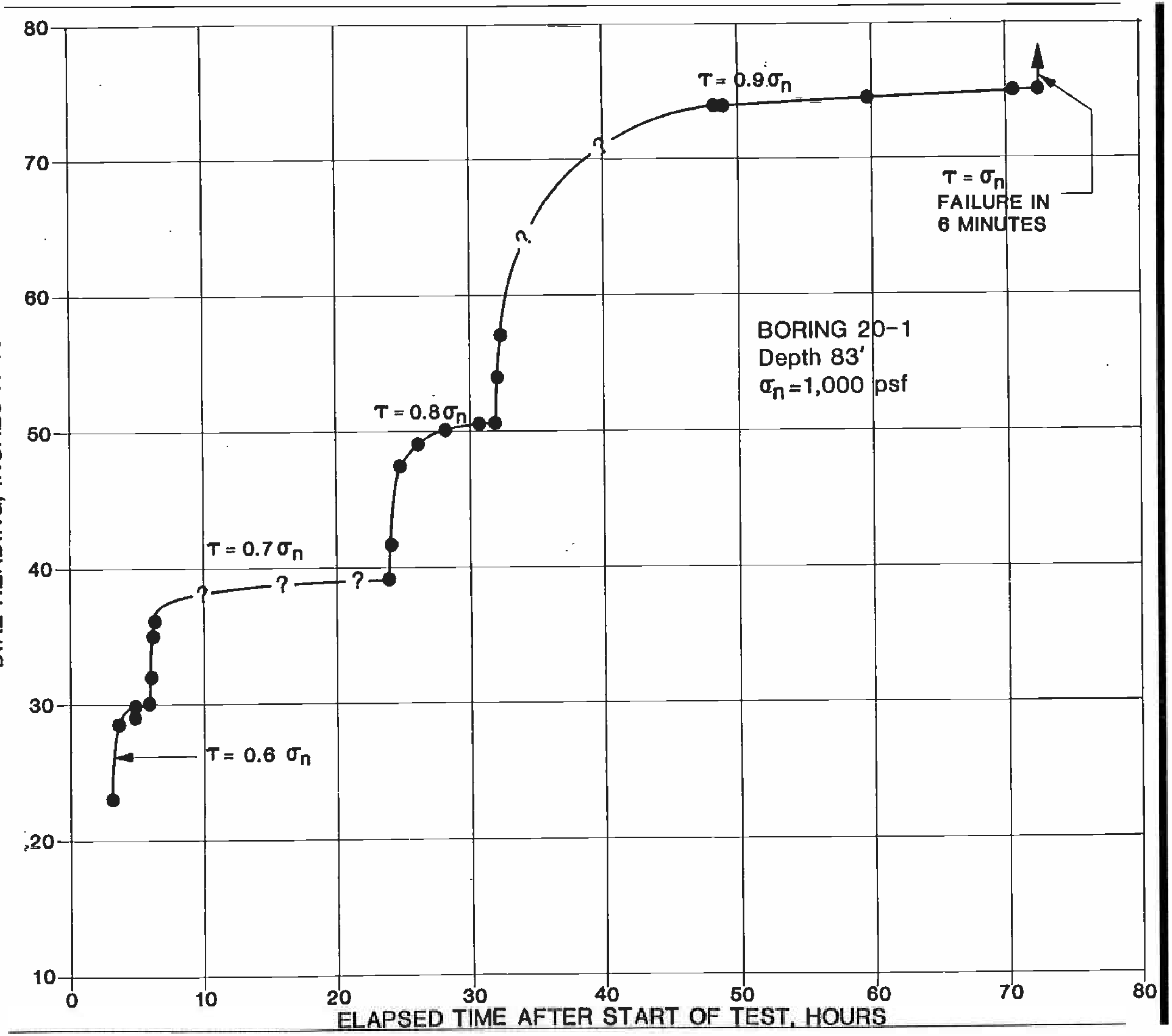
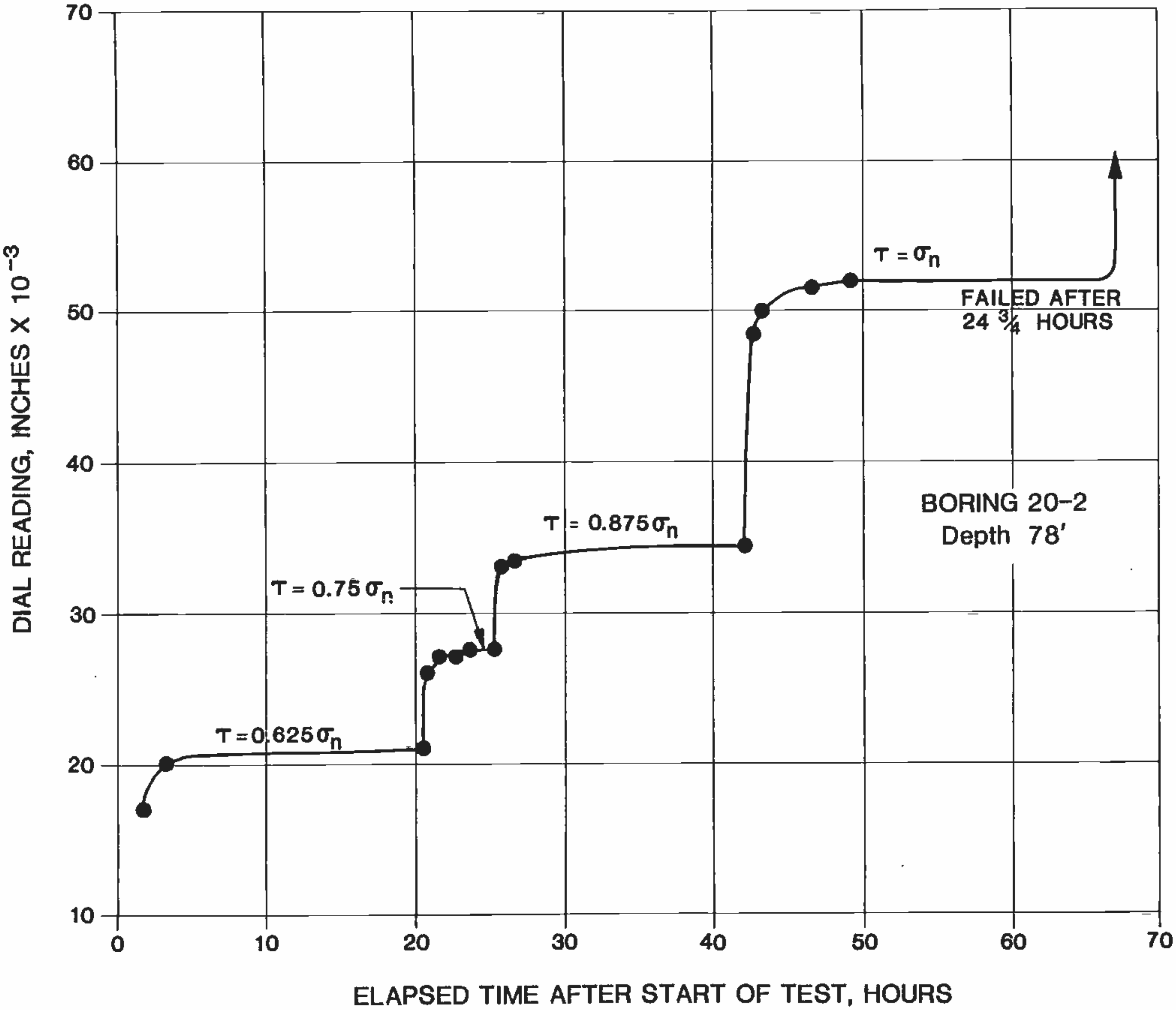
## TIME VS DEFORMATION PLOT OF CONSTANT STRESS "CREEP TEST" - TAR BEARING SAN PEDRO FORMATION



Project No.
83-1140

Figure No.
C-44

Approved for publication 5/8/11 by



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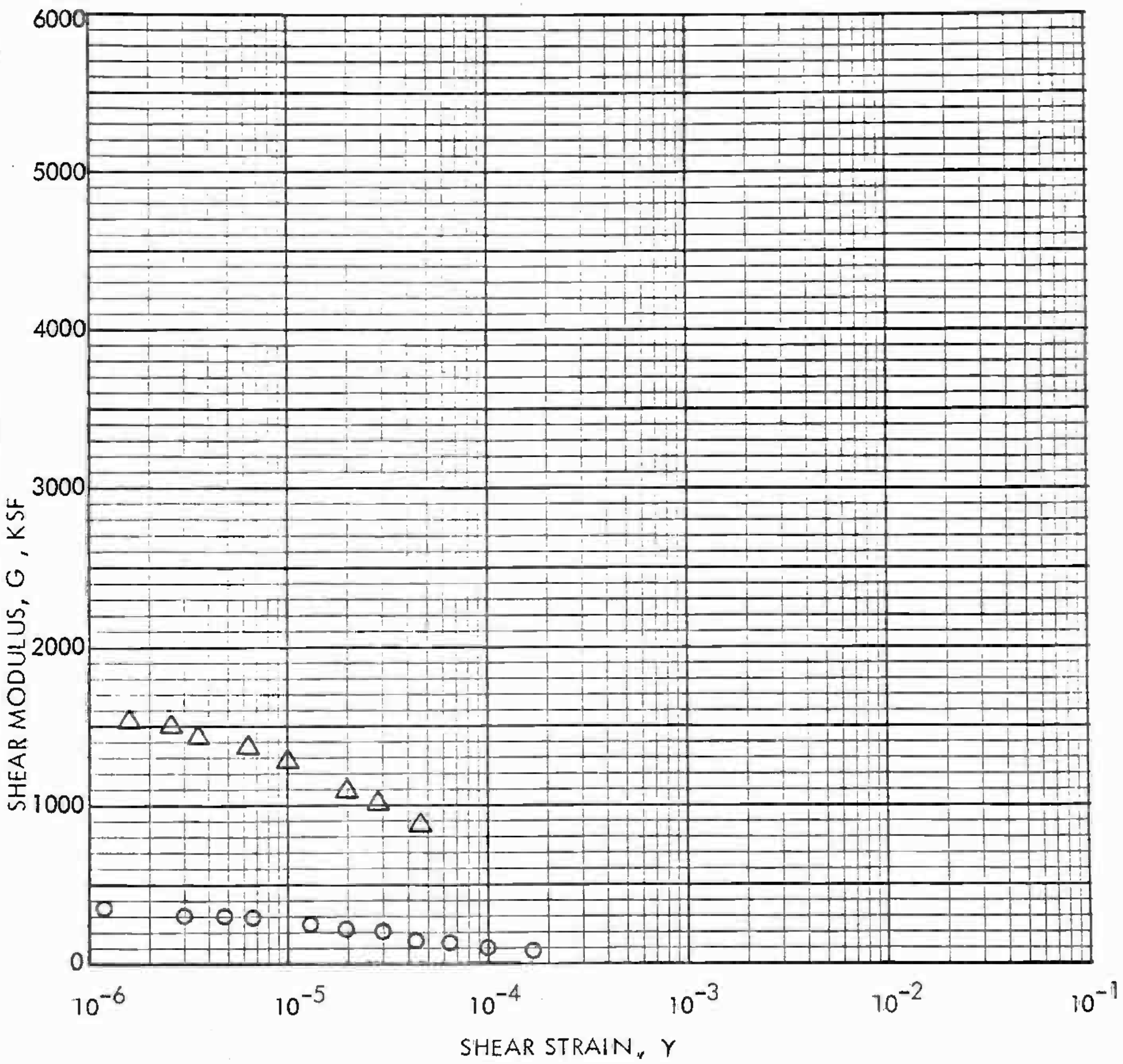
## TIME VS DEFORMATION PLOT OF CONSTANT STRESS "CREEP TEST" - TAR BEARING SAN PEDRO FORMATION

Project No.
83-1140

Figure No.
C-45

## STRAIN DEPENDENT DYNAMIC SHEAR MODULUS



| BORING | SAMPLE | DEPTH(FT) | $\gamma_d$(PCF) | $w_o$(%) | $\bar{\sigma}_c$(PSI) | SYMBOL |
|---|---|---|---|---|---|---|
| 20 | C-1 | 20 | 112 | 15 | 15 | ○ |
|  |  |  |  |  | 50 | △ |

Sample Description: Yellow-Brown Clayey Fine to Medium Sand, trace organics; moist, medium dense

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## RESONANT COLUMN TEST

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Project No.
83-1140

Figure No.
C-46

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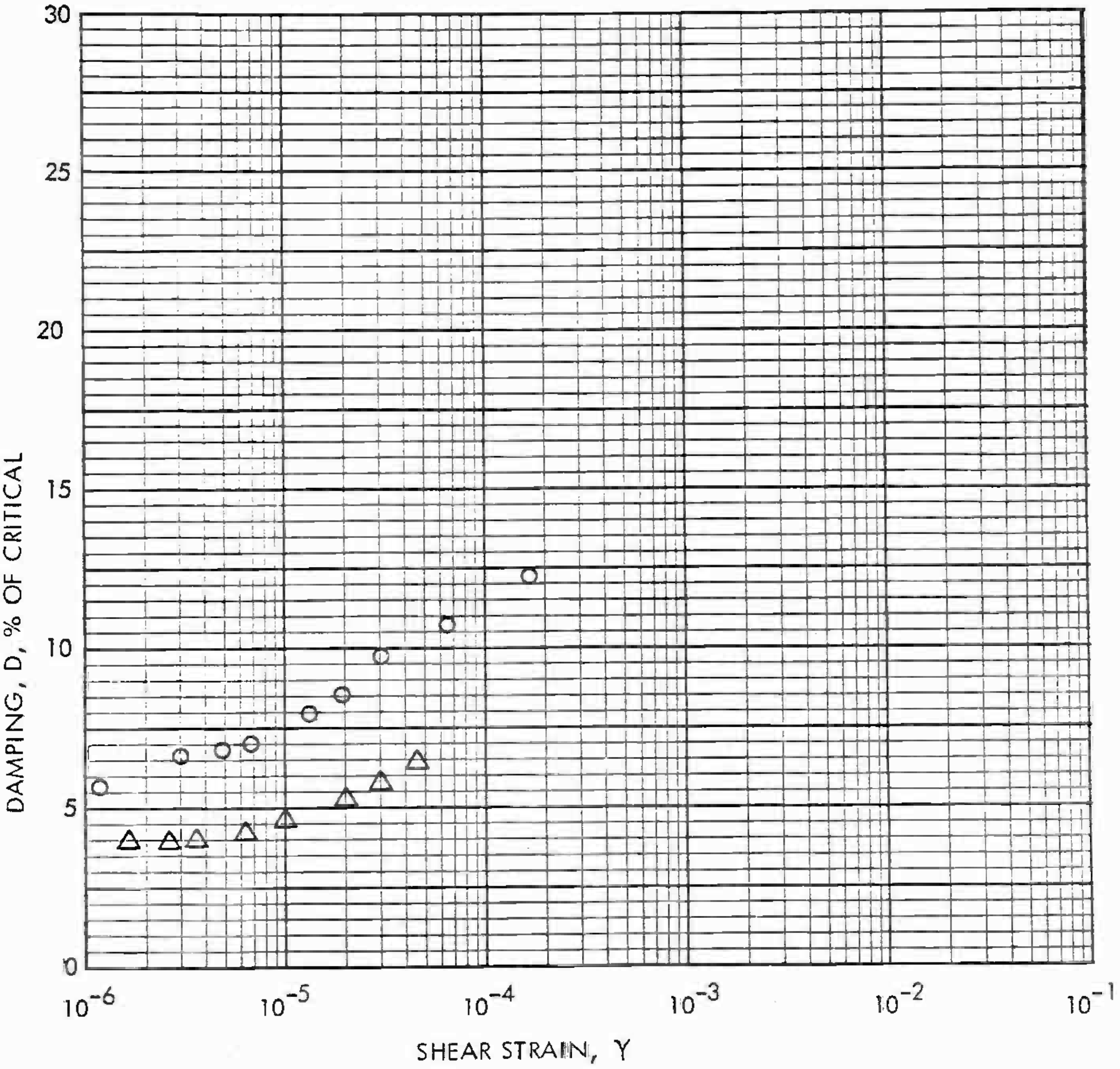
STRAIN DEPENDENT DAMPING



| BORING | SAMPLE | DEPTH(FT) | $\gamma_d$(PCF) | $w_o$(%) | $\bar{\sigma}_c$(PSI) | SYMBOL |
|---|---|---|---|---|---|---|
| 20 | C-1 | 20 | 112 | 15 | 15 | ○ |
| | | | | | 50 | △ |

Sample Description: Yellow-Brown Clayey Fine to Medium Sand, trace organics; moist, medium dense

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RESONANT COLUMN TEST

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METRO RAIL PROJECT

Project No.
83-1140

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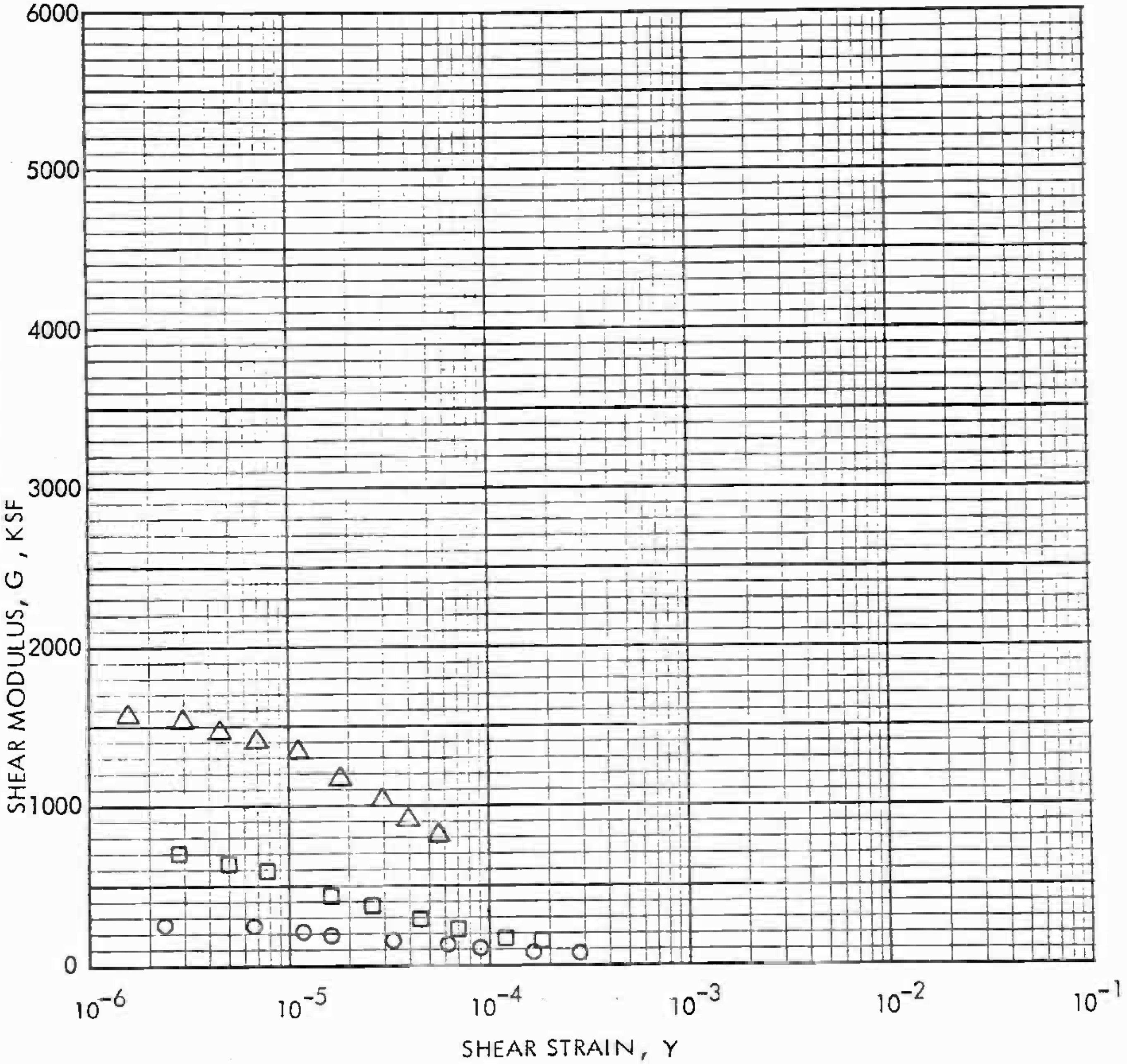
Figure No.
C-47

## STRAIN DEPENDENT DYNAMIC SHEAR MODULUS



| BORING | SAMPLE | DEPTH(FT) | $\gamma_d$(PCF) | $w_o$(%) | $\bar{\sigma}_c$(PSI) | SYMBOL |
|---|---|---|---|---|---|---|
| 21 | S-3 | 127 | 101 | 24 | 15 | ○ |
| | | | | | 30 | □ |
| | | | | | 50 | △ |

Sample Description: Gray Silty Fine Sand; moist, medium dense

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RESONANT COLUMN TEST

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Figure No.
C-48

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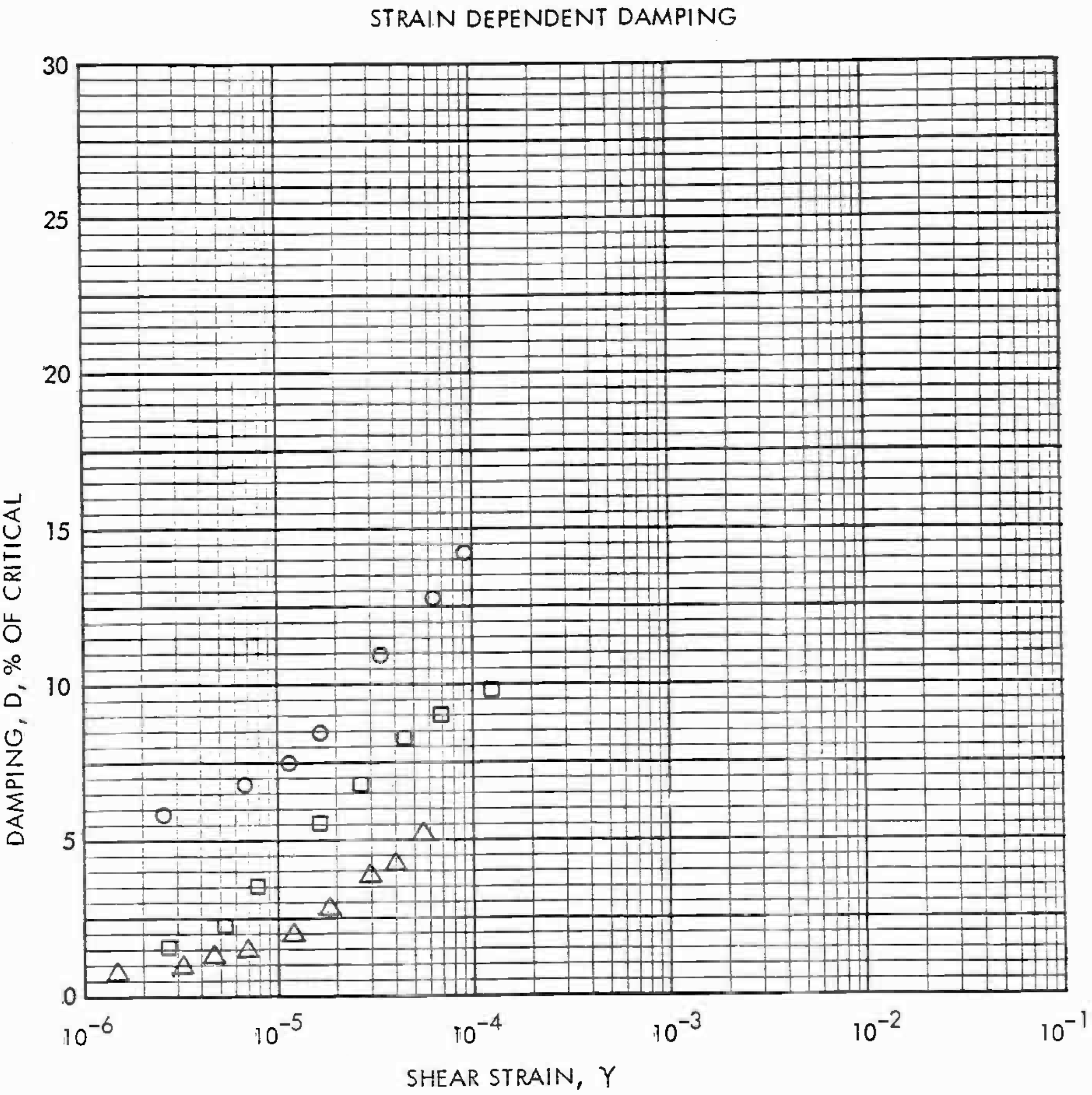

| BORING | SAMPLE | DEPTH(FT) | $\gamma_d$(PCF) | $w_o$(%) | $\bar{\sigma}_c$(PSI) | SYMBOL |
|---|---|---|---|---|---|---|
| 21 | S-3 | 127 | 101 | 24 | 15 | ○ |
| | | | | | 30 | □ |
| | | | | | 50 | △ |

Sample Description: Gray Silty Fine Sand; moist, medium dense

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RESONANT COLUMN TEST

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Southern California Rapid Transit District
METRO RAIL PROJECT

Project No.
83-1140

Figure No.
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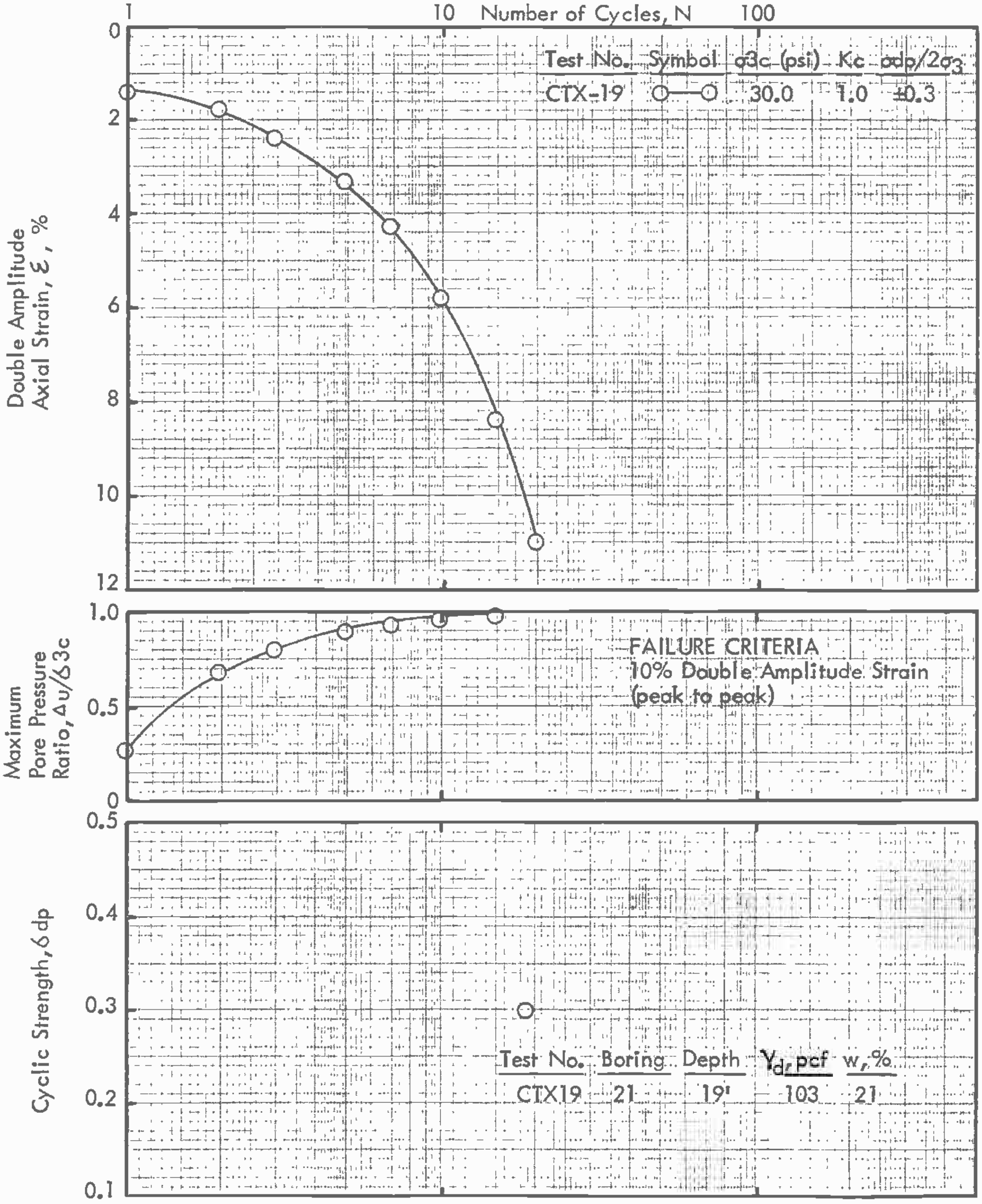

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# CYCLIC TRIAXIAL COMPRESSION TEST RESULTS

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METRO RAIL PROJECT

Project No.
83-1140

Figure No.
C-50

**Converse Consultants**
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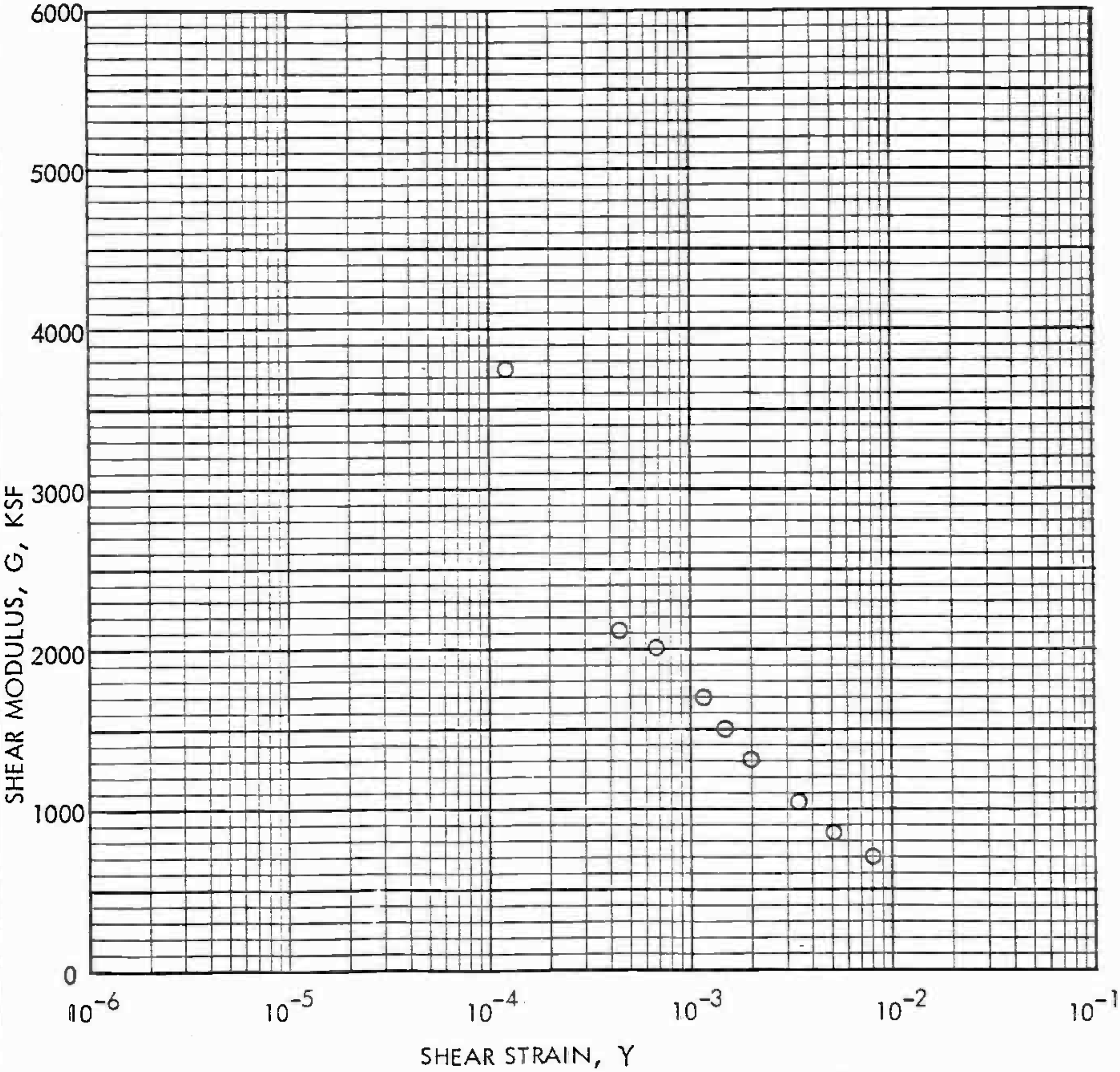
## STRAIN DEPENDENT DYNAMIC SHEAR MODULUS



| BORING | SAMPLE | DEPTH(FT) | $\gamma_d$(PCF) | $w_o$(%) | $\bar{\sigma}_c$(PSI) | SYMBOL |
|---|---|---|---|---|---|---|
| 21 | S-2 | 121 | 97 | 23 | 50 | ○ |

Sample Description: Gray-Brown Silty very fine Sand; dense

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## DYNAMIC TRIAXIAL TEST

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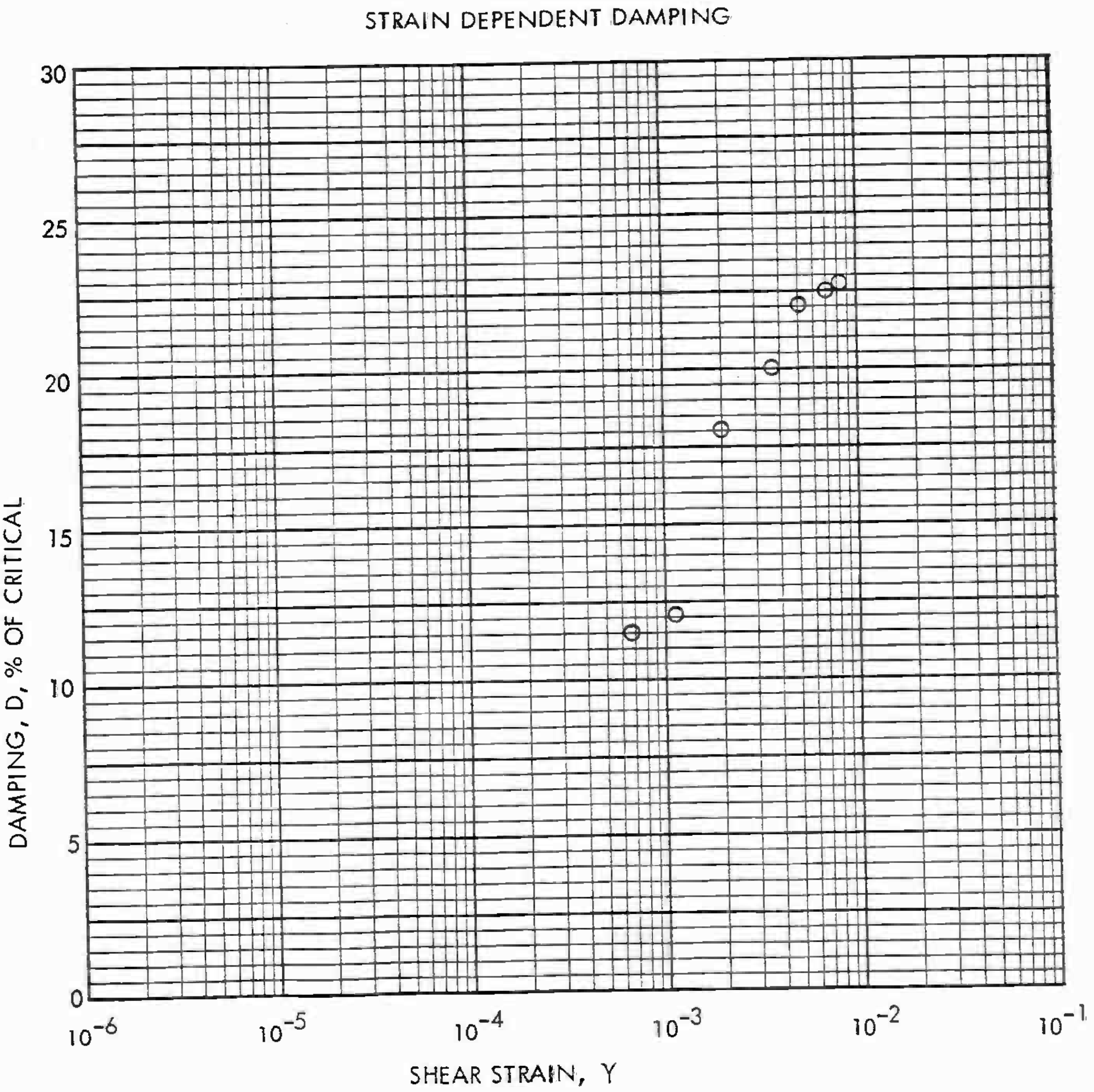
Figure No.
C-51



| BORING | SAMPLE | DEPTH(FT) | $\gamma_d$(PCF) | $w_o$(%) | $\bar{\sigma}_c$(PSI) | SYMBOL |
|---|---|---|---|---|---|---|
| 21 | S-2 | 121 | 97 | 23 | 50 | ○ |

Sample Description: Gray-Brown Silty very fine Sand; dense

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## DYNAMIC TRIAXIAL TEST

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Project No.
83-1140

Figure No.
C-52

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# Appendix D

# Water Quality Analysis

# APPENDIX D WATER QUALITY ANALYSIS

## D.1 RESULTS

Water samples were taken from Borings CEG-19, CEG-21 and CEG-22 during the 1981 investigation. The purpose was to evaluate water chemicals that could have significant influence on design requirements and to identify chemical constituents for compliance with EPA requirements for future tunneling activities. The chemical constituents tested are attached.

## D.2 FIELD PROGRAM

The boreholes were flushed and established as piezometers. At a later date (often several weeks) the established piezometer holes were again flushed and cleaned out. Upon achieving a clean hole, water samples were collected with an air-lifting procedure from various depths within the borehole. The water samples were collected in sterilized one-quart glass containers which were properly identified and marked in the field. The water samples were delivered to both Jacobs Laboratories and Brown and Caldwell Consulting Engineers for testing.

Converse Ward Davis Dixon

Lab No. P81-02-186-4

No. Samples : 7
Sampled By : Client
Brought By : Client
Date Received: 2-20-81

Sample labeled: HOLE 19-2"

Conductivity: 24,000 µ mhos/cm

Turbidity: NTU

pH 7.0 @ 25°C
pHs @ 60°F (15.6°C)
pHs @ 140°F (60°C)

|  | Milligrams per liter (ppm) | Milli-equivalents per liter |
|---|---|---|
| Cations determined: |  |  |
| Calcium, Ca | 51 | 2.54 |
| Magnesium, Mg | 410 | 33.73 |
| Sodium, Na | 5,000 | 217.50 |
| Potassium, K | 248 | 6.34 |
| Total |  | 260.11 |
| Anions determined: |  |  |
| Bicarbonate, as $HCO_3$ | 1,467 | 24.04 |
| Chloride, Cl | 8,680 | 244.86 |
| Sulfate, $SO_4$ | 240 | 5.00 |
| Fluoride, F | 0.2 | 0.01 |
| Nitrate, as N | 0.2 | 0.01 |
| Total |  | 273.92 |
| Carbon dioxide, $CO_2$, Calc. | 211 |  |
| Hardness, as $CaCO_3$ | 1,810 |  |
| Silica, $SiO_2$ | 52 |  |
| Iron, Fe | < 0.01 |  |
| Manganese, Mn | < 0.01 |  |
| Boron, B | 10.5 |  |
| Total Dissolved Minerals, (by addition: $HCO_3$ -> $CO_3$) | 15,425 |  |

Converse Ward Davis Dixon

Lab No. P81-02-123-3

No. Samples : 6
Sampled By : Client
Brought By : Client
Date Received: 2-12-81

Sample labeled: #21 3/4" PVC WS-1

Conductivity: 1,430 μ mhos/cm

Turbidity: NTU

pH 7.6 @ 25°C
pHs @ 60°F (15.6°C)
pHs @ 140°F (60°C)

| | Milligrams per liter (ppm) | Milli-equivalents per liter |
|---|---|---|
| Cations determined: | | |
| Calcium, Ca | 41 | 2.04 |
| Magnesium, Mg | 45 | 3.70 |
| Sodium, Na | 198 | 8.61 |
| Potassium, K | 5.5 | 0.14 |
| | Total | 14.49 |
| Anions determined: | | |
| Bicarbonate, as $HCO_3$ | 419 | 6.87 |
| Chloride, Cl | 78 | 2.21 |
| Sulfate, $SO_4$ | 263 | 5.48 |
| Fluoride, F | 0.6 | 0.03 |
| Nitrate, as N | 0.3 | 0.02 |
| | Total | 14.61 |
| Carbon dioxide, $CO_2$, Calc. | 15 | |
| Hardness, as $CaCO_3$ | 288 | |
| Silica, $SiO_2$ | 25 | |
| Iron, Fe | < 0.01 | |
| Manganese, Mn | < 0.01 | |
| Boron, B | 0.58 | |
| Total Dissolved Minerals, (by addition: $HCO_3$ -> $CO_3$) | 867 | |

Converse Ward Davis Dixon

Lab No. P81-02-123-6

No. Samples : 6
Sampled By : Client
Brought By : Client
Date Received: 2-12-81

Sample labeled: #21 2" PVC WS-#2

Conductivity: 2,500 µ mhos/cm

Turbidity: NTU

pH 7.4 @ 25°C
pHs @ 60°F (15.6°C)
pHs @ 140°F (60°C)

| | Milligrams per liter (ppm) | Milli-equivalents per liter |
|---|---|---|
| Cations determined: | | |
| Calcium, Ca | 60 | 2.99 |
| Magnesium, Mg | 42 | 3.45 |
| Sodium,Na | 430 | 18.71 |
| Potassium, K | 15 | 0.38 |
| | | Total 25.53 |
| Anions determined: | | |
| Bicarbonate, as $HCO_3$ | 446 | 7.30 |
| Chloride, Cl | 577 | 16.27 |
| Sulfate, $SO_4$ | 67 | 1.40 |
| Fluoride, F | 0.6 | 0.03 |
| Nitrate, as N | 1.1 | 0.08 |
| | | Total 25.08 |
| Carbon dioxide, $CO_2$, Calc. | 25 | |
| Hardness, as $CaCO_3$ | 323 | |
| Silica, $SiO_2$ | 31 | |
| Iron, Fe | 0.12 | |
| Manganese, Mn | 0.20 | |
| Boron, B | 1.74 | |
| Total Dissolved Minerals, (by addition: $HCO_3 \rightarrow CO_3$) | 1,448 | |

Converse Ward Davis Dixon

Lab No. P81-02-142-1

No. Samples : 7
Sampled By : Client
Brought By : Client
Date Received: 2-17-81

Sample labeled: HOLE 22-1",40'

Conductivity: 1,170 µ mhos/cm

Turbidity: NTU

pH 8.0 @ 25°C
pHs @ 60°F (15.6°C)
pHs @ 140°F (60°C)

| | Milligrams per liter (ppm) | Milli-equivalents per liter |
|---|---|---|
| **Cations determined:** | | |
| Calcium, Ca | 7.2 | 0.36 |
| Magnesium, Mg | 52 | 4.28 |
| Sodium, Na | 136 | 5.92 |
| Potassium, K | 2.0 | 0.05 |
| | | Total 10.61 |
| **Anions determined:** | | |
| Bicarbonate, as $HCO_3$ | 423 | 6.93 |
| Chloride, Cl | 122 | 3.44 |
| Sulfate, $SO_4$ | 149 | 3.10 |
| Fluoride, F | 0.4 | 0.02 |
| Nitrate, as N | 0.6 | 0.04 |
| | | Total 13.53 |
| Carbon dioxide, $CO_2$, Calc. | 6 | |
| Hardness, as $CaCO_3$ | 397 | |
| Silica, $SiO_2$ | 37 | |
| Iron, Fe | < 0.01 | |
| Manganese, Mn | < 0.01 | |
| Boron, B | 0.24 | |
| Total Dissolved Minerals, (by addition: $HCO_3$ -> $CO_3$) | 718 | |

Converse Ward Davis Dixon

Lab No. P81-02-142-2

No. Samples : 7
Sampled By : Client
Brought By : Client
Date Received: 2-17-81

Sample labeled: HOLE 22-2", 200'

Conductivity: 1,170 µ mhos/cm

Turbidity: NTU

pH 7.7 @ 25°C
pHs @ 60°F (15.6°C)
pHs @ 140°F (60°C)

| | Milligrams per liter (ppm) | Milli-equivalents per liter |
|---|---|---|
| **Cations determined:** | | |
| Calcium, Ca | 38 | 1.90 |
| Magnesium, Mg | 56 | 4.61 |
| Sodium, Na | 174 | 7.57 |
| Potassium, K | 6.1 | 0.16 |
| | | Total 14.24 |
| **Anions determined:** | | |
| Bicarbonate, as $HCO_3$ | 489 | 8.02 |
| Chloride, Cl | 107 | 3.01 |
| Sulfate, $SO_4$ | 124 | 2.58 |
| Fluoride, F | 0.5 | 0.03 |
| Nitrate, as N | 0.2 | 0.01 |
| | | Total 13.65 |
| Carbon dioxide, $CO_2$, Calc. | 14 | |
| Hardness, as $CaCO_3$ | 325 | |
| Silica, $SiO_2$ | 29 | |
| Iron, Fe | < 0.01 | |
| Manganese, Mn | < 0.01 | |
| Boron, B | 0.42 | |
| Total Dissolved Minerals, (by addition: $HCO_3$ -> $CO_3$) | 779 | |

# Appendix E

# Gas Chromatographic Analyses

# APPENDIX E GAS CHROMATOGRAPHIC ANALYSES

## E.1 INTRODUCTION

Gas Chromatographic analyses were performed at Borings CEG-19, 21 and 22. To provide a measure of the distribution and extent of the hazardous hydrocarbon and non-hydrocarbon gases, a program of in-situ quantitative analyses was conducted by Converse's special consultant, RYLAND-CUMMINGS, INC.

The hydrocarbon gases identified were: methane, ethane; n-butane; isobutane; n-pentane, isopentane; and $C_6$+, undifferentiated. The non-hydrocarbon gases identified were: nitrogen; oxygen; carbon monoxide; carbon dioxide; and hydrogen sulfide.

## E.2 FIELD PROGRAM FOR GAS CHROMATOGRAPHIC ANALYSIS

Specific hydrocarbon and non-hydrocarbon gases were collected during the 1981 investigation at shallow depths in Borings CEG-19, 21 and 22. Samples of air were analyzed to provide an ambient base. Approximately 10 ml of gas were analyzed for each sample. All samples were analyzed in the field using an analytical gas chromatograph.

### Gas Collection - Air Samples

Samples of air were collected, using a syringe specifically designed for gas chromatographic analysis. The air sample was injected into the gas chromatograph and analyzed in the field.

### Gas Collection - Borehole Samples

Most of the natural hydrocarbon gases are heavier than air and must be drawn to the surface to be sampled. One gas, methane, is lighter than air; and another gas, ethane, has approximately the same density as air.

The gas in the borehole was collected through a perforated tube that was inserted into the borehole, and the gas was drawn to the surface by a vacuum pump. The vacuum pump was operated by a portable 120-volt, 1500-watt generator; the generator also supplied power to the gas chromatograph and strip chart recorder. The borehole was temporarily sealed above the level of sampling. The seal prevented contamination of air or gases from the surface.

The hole was pumped for several minutes; the air and gases wasted before a representative sample was collected for analysis. The purpose for wasting these gases was to purge the borehole of any anomalous accumulations of gas or air due to the drilling operation. After this purge, a sample of gas was collected using the special syringe, and the gas was inserted into the gas chromatograph for analysis in the field.

## E.3 DESCRIPTION OF ANALYTICAL GAS CHROMATOGRAPH

The instrument used for quantitative analysis was a Carle thermal conductivity analytical gas chromatograph, Series-S, with a minimum detectability limit of $5 \times 10^{-10}$ g/ml of propane at 150°C. The unit uses a built-in valve programmer that automatically actuates the correct sequence of internal switching events that are required to perform the complete analysis. Because the instrument is fully automated, errors that might be introduced during the analysis by the operator are eliminated. The gases that were detected were recorded on a strip chart; the written record is called a chromatogram. Chromatograms of the samples and a legend are attached to Appendix E.

### Chromatographic System and Operation

A sample of gas is injected into the chromatograph. The injected sample is carried through the instrument by an inert gas (helium) at a constant temperature (70°C), at a constant pressure (60 psi), and at a constant flow rate (30 ml/min). The gas flows through a series of columns, or tubes, that are packed with materials that have specific adsorptive properties; these properties help to separate individual gases from the sample as it flows through the instrument. Each column is designed to separate and identify specific gases. A pressure regulator is used to assure uniform pressure to the column inlet, thereby resulting in a constant rate of flow throughout the analysis.

Depending on the complexity of the gas to be detected, the gas stream may be shunted through a series of valves that direct the gas sample into different columns containing the appropriate adsorptive materials for proper separation.

The column selectively retards the gas components according to their molecular weight and polar characteristics until the components form separate concentrations, or bands, in the carrier (helium) gas. These bands are recorded on a strip chart as a function of time.

### The Chromatograph; Methods of Interpretation

The record of the gases is printed on a strip chart; the abscissa is time, and the ordinate is millivolts. The chromatogram can be used immediately to qualitatively identify the gases in the sample. Quantitative analyses require additional steps and auxiliary operations. Several different methods can be used to quantify the data; each method has advantages and disadvantages, and not every method is applicable to a particular problem.

A series of gas standards that have different, known percents of the components are allowed to flow through the instrument; the components are recorded on a strip chart. The areas and heights of the peaks are calculated for each different component and for each percent; these data are used to draw a set of graphs of percent of gas vs. peak area or peak height. These graphs provide a basis for comparison to the unknown volumes of gas sampled in the field. The procedure would be as follows: the area corresponding to a gas depicted on the field chromatogram is measured (using, for example, a compensating polar planimeter); that area can be compared to the standard to determine the volume percent of gas in the unknown sample.

To determine weight percent, the data on the field chromatogram must be normalized with respect to the total area of all components. To convert the field data to weight percent, a correction factor corresponding to the gas must be used. The correction factor is necessary because the areas on the graph corresponding to each component are not directly proportional to the percent composition. This is so because different compounds have different responses to the detector depending on the molecular weight of the gas. To determine the correction factor, the relative thermal response per mole of the gas is divided into the molecular weight.

Both the volume method and weight method were used in our analyses of the data for this project. The results of one method provide a check of the other.

## E.4 RESULTS

The chromatogram for Borings CEG-19, 21 and 22 are attached. The results of the analyses, reported as parts per million, are given in Table E-1. The reason for selecting "parts per million" to report the results is because this measure provides the most direct conversion to percent by volume; percent by volume is the basis for classifying tunnels in terms of safety (California Administrative Code, Title 8, Article 8, Section 8422). Table E-1 also identifies (1) the lower limit of flammability, (2) tunnel classification at the 5 percent and 20 percent lower explosive limit (LEL), and (3) the threshold limit values of selected non-hydrocarbon gases. These columns, abstracted from the more complete Tables E-2 and E-3 are included in Table E-1 for convenience. Table E-2 indicates the limits of flammability for the gases. Table E-3 indicates the threshold limit value (TLV) of selected non-hydrocarbon gases.

### Samples Collected in Air

None of the gases detected reached a value that would be considered hazardous (Table E-1).

Hydrocarbon gases in air are not necessarily from natural sources, such as emanations from oil fields. Automobile exhaust is a major source. Exhaust from automobiles includes ethane, propane, isobutane, n-butane, isopentane, n-pentane, $C_6$+ (California Air Resources Board, Nov. 1980, Hydrocarbon profile of motor vehicle exhaust, 1980, Project HS-11-SHC, 4p). Hydrogen sulfide can come from either natural or industrial sources. There is no need for differentiating the sources for this project. However, they can be differentiated by studying the isotopic composition of the gases.

Methane is likely to have a natural source. Because the gas is lighter than air, it can work its way up through the rocks and soils, eventually reaching the surface. Some of the hydrogen sulfide undoubtedly has a natural source. The gas, could be smelled near some of the open boreholes and from the water pumped from the subsurface; the gas is highly soluble in water (Table E-4). During our testing, we noticed that the gas did not flow continuously out of the boreholes; rather, it came out in pulses. Detection of hydrogen sulfide by smell does not necessarily indicate a hazardous condition; the lower limit of detection can be less than 10 ppm (Table E-3), depending on the sensitivity of the individual.

## Samples Collected in Boreholes

Gas samples were collected in the boreholes from levels above the uppermost perched water table or within the saturated zone of the uppermost perched water table. Samples were collected in cased piezometers; perforations in the casing were within the saturated zone and the gas sampling point was above the line of the water in the cased piezometer. Field conditions did not allow for sampling of gas below the perched water table or at tunnel level or at the point of origin of the gas. Details of the sampling depth and the depth of the water at the time of sampling are given in Table E-1.

## Sources of Gas

Geologic exploration for natural gas fields clearly indicates that perched ground water acts to seal the gases below the water (Masters, 1979). The water inhibits the upward migration of the gases. In some field examples discussed in Masters (1979), the gases and water are in the same permeable sandstone, and no impermeable barrier or lithology exists between the water and the gases. Although small amounts of hydrocarbon gases can be absorbed in the water, the limit of saturation for these gases is extremely low, not exceeding 65 ppm (Table E-4). Among the non-hydrocarbon gases, only carbon dioxide and hydrogen sulfide are significantly soluble (1449 ppm and 3375 ppm, respectively; Table E-4). Because only small amounts of gas can be present in the water, only small amounts can come out of the water. Thus, only a very small amount of hydrocarbon gases detected in the boreholes came from within the water. The gases can enter the water and bubble up through it if the gases are subjected to a high differential pressure. Gases can also enter the water-saturated zone and bubble up through it if the source of the gases is within the saturated zone.

A review of the lithologic logs of the boreholes along the proposed alignment indicates geologic conditions analogous to those described in Masters (1979). Direct evidence of such conditions along the alignment comes from reports of the drilling operations. The gas "sniffers" detected gas concentrations during the drilling and after the holes had been capped temporarily. The lower level of detection of the "sniffers" was above the lowest limit of sensitivity of the gas chromatograph; the chromatograph recorded levels of gas concentrations lower than that which would trigger the "sniffers." Apparently, the "sniffers" detected the pulse of the gas that was trapped below the water table when the water table was pierced by the drilling. These geologic conditions have significance along the proposed alignment because the natural gases that formed at depth and related to the oil fields are likely to be trapped below the perched water tables. The gases that accumulate along the base of the perched water would likely migrate laterally. Because the gases can migrate laterally below the perched water table, the gases may be present outside the immediate vicinity of known oil fields. The concentrations of gas would depend on the permeability of the rock and soils as well as the concentration and production of gases at the source. Consequently, gases may also be present along the alignment in areas away from the known oil fields. The gases can accumulate in pockets or zones in the soils or bedrock against faults, or against other impermeable barriers such as igneous dikes. These accumulations can be miles away from known or suspected sources.

The lateral migration of gases from their source in one oil field can cause them to mix with other gases from another oil field. A gas sample from a borehole may not provide a characteristic signature of the gases produced by the nearby oil field due to contamination related to the lateral migration of these gases.

Surface and near-surface deposits of petroleum are extremely difficult to analyze because the normal hydrocarbon compounds have been appreciably altered by weathering, bacterial degradation, and contamination due to washing by water. These processes change the characteristics of the original oil. Weathering, water-washing, and/or immaturity are the most commonly accepted reasons for oils of low gravity. Bacterial degradation and/or immaturity commonly result in an absence of normal paraffins. Previous work done by oil companies on other near-surface deposits produced similar results.

No normal traces were found in the other samples, indicating that they contain immature hydrocarbon with many complex aromatic compounds and asphaltenes.

Nevertheless, we were able to group samples that were partially similar in composition (Table E-2). To determine samples that have similar compositional characteristics, the chromatograms were compared to each other and peaks were matched. Only certain peaks matched on some chromatograms; other chromatograms produced no matching peaks. The groupings do not necessarily indicate that samples in the same group came from the same oil field or that the samples in the same group have been subjected to the same developmental history.

Samples from Borings CEG-19, 22 and 22 indicate immature hydrocarbons containing no normal paraffin compounds. The immature hydrocarbons may be the result of either (1) the immaturity of the oil where the normal paraffins may not have developed, or (2) alteration of the oil that destroyed the normal paraffins.

The hydrocarbons that were tested are very low gravity and could be considered tar. The normal hydrocarbons have not developed because the oil is either immature or has been appreciably altered by (1) weathering, (2) bacterial (biochemical) degradation, and (3) contamination resulting from washing by water. Consequently, the chromatograms of the tested samples could not be matched to chromatographs of standards of normal hydrocarbons. The absence of normal hydrocarbon "signs posts" does not allow a rigorous description of the types or characteristics of deeper petroleum deposits.

Because the petroleum is crude oil, it could be the source of hazardous gases. Any deposit of crude oil must be considered as a potential hazard. Faults, fissures, and similar features exist along the proposed A250 alignment and may be considered as areas for accumulation of the more volatile components of the hydrocarbons.

TABLE E-1 Summary of Data from Gas Chromatograms

| GAS | Lower Limit of Flammability* (ppm) | TUNNEL CLASSIFICATION** | | BORING NUMBER | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | | 2 | | 10 | | 11 | | 19 | | 21 | | 22 | | 23 | | 23A | |
| | | GASSY 5% LEL (ppm) | EXTRA HAZARDOUS 20% LEL (ppm) | Air (ppm) | Cased Piezometer Sampled @ 10' Water Level @ 10' (ppm) | Air (ppm) | Cased Piezometer Sampled @ 10' Water Level @ 20' (ppm) | Air (ppm) | Cased Piezometer Sampled @ 15' Water Level @ 20' (ppm) | Air (ppm) | Cased Piezometer Sampled @ 40' Water Level @ 45' (ppm) | Air (ppm) | Cased Piezometer Sampled @ 9' Water Level @ 10' (ppm) | Air (ppm) | Refer to Notes a, b, c' (ppm) | Air (ppm) | Alluvium Open Hole Sampled @ 15' Water Level @ 20' (ppm) | Air (ppm) | Cased Piezometer Sampled @ 12' Water Level @ 13' (ppm) | Air (ppm) | Cased Piezometer Sampled @ 13' Water Level @ 15' (ppm) |
| Methane | 50,000 | 2,500 | 10,000 | - | 100 | - | 200 | - | - | | | - | trace | - | a trace<br>b -<br>c - | trace | trace | - | - | - | trace |
| Ethane | 30,000 | 1,500 | 6,000 | trace† | 300 | - | 300 | - | - | | | - | 2,000 | 100 | a trace<br>b trace<br>c trace | 100 | 1,800 | - | - | 150 | 350 |
| Propane | 21,250 | 1,063 | 4,240 | - | trace | - | trace | - | - | | | - | - | - | a trace<br>b -<br>c - | - | - | - | - | trace | - |
| n-Butane | 19,050 | 953 | 3,720 | - | trace | - | trace | - | - | | | - | trace | - | a trace<br>b -<br>c - | - | trace | - | trace | trace | - |
| Isobutane | 18,000 | 900 | 3,600 | - | trace | - | trace | - | - | | | - | 150 | - | a trace<br>b -<br>c - | - | trace | - | trace | trace | - |
| n-Pentane | 14,000 | 700 | 2,800 | - | trace | - | trace | - | - | | | - | trace | - | a trace<br>b -<br>c - | - | - | - | trace | trace | - |
| Isopentane | 13,200 | 660 | 2,640 | - | trace | - | trace | - | - | | | - | trace | - | a trace<br>b -<br>c - | - | - | - | trace | trace | - |
| $C_6$+ | ‡ | - | - | 800 | 1,000 | 1,600 | 1,500 | 400 | 1,200 | | | 1,100 | 4,500 | 500 | a 500<br>b 2,000<br>c trace | 100 | 1,300 | 1,500 | 3,500 | 2,500 | 2,500 |
| Nitrogen | - | - | - | 772,000 | 771,000 | 773,000 | 773,000 | 773,000 | 773,000 | | | 775,000 | [illegible] | 772,000 | a [illegible]<br>b 773,000<br>c 773,000 | 773,000 | 773,000 | 763,000 | [illegible] | 763,500 | [illegible] |
| Oxygen | - | - | - | 200,000 | 213,000 | 200,000 | 200,000 | 201,000 | 200,000 | | | 200,000 | [illegible] | 201,000 | a 201,000<br>b 200,000<br>c 201,000 | 201,000 | 200,000 | 200,000 | 201,000 | 203,000 | 200,000 |
| Carbon monoxide | 125,000 | 6,250 | 25,000 | - | trace | - | trace | - | - | | | trace | trace | trace | a trace<br>b -<br>c - | - | trace | - | trace | trace | trace |
| Carbon dioxide | - | - | - | 27,000 | 29,000 | 29,000 | 26,000 | 26,000 | 28,000 | | | 25,000 | 28,000 | 28,000 | a 28,[illegible]<br>b 27,000<br>c 25,000 | 28,000 | 27,000 | 27,000 | 27,000 | 29,000 | 27,000 |
| Hydrogen sulfide | 43,500 | 2,175 | 8,700 | trace | trace | - | trace | - | trace | | | trace | trace | trace | a trace<br>b trace<br>c 100 | trace | trace | trace | trace | trace | trace |

| GAS | THRESHOLD LIMIT VALUES OF SELECTED NONHYDROCARBON GASES | | BORING NUMBER | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | | 2 | | 10 | | 11 | | 19 | | 21 | | 22 | | 23 | | 23A | |
| | ppm § | ppm §§ | Air (ppm) | Cased Piezometer @ 10' (ppm) | Air (ppm) | Cased Piezometer @ 15' (ppm) | Air (ppm) | Cased Piezometer @ 15' Water Level @ 20' (ppm) | Air (ppm) | Hole (ppm) | Air (ppm) | Hole (ppm) | Air (ppm) | Hole (ppm) | Air (ppm) | Hole (ppm) | Air (ppm) | Hole (ppm) | Air (ppm) | Hole (ppm) |
| Carbon monoxide | 50 | 100, 200, 400, 1,200; 2,000 | - | trace | - | trace | - | - | | | trace | trace | trace | a trace<br>b -<br>c - | - | trace | - | trace | trace | trace |
| Carbon dioxide | 5,000 | 5,000, 50,000, 90,000 | 27,000 | 29,000 | 29,000 | 29,000 | 26,000 | 26,000 | | | 24,000 | 29,000 | 28,000 | a 25,000<br>b 27,000<br>c 28,000 | 28,000 | 27,000 | 27,000 | 27,000 | 29,000 | 27,000 |
| Hydrogen sulfide | 10 | 10; 100; 200 | trace | trace | - | trace | - | trace | | | trace | trace | trace | a trace<br>b trace<br>c 100 | trace | trace | trace | trace | trace | trace |
| Oxygen | # | - | 200,000 | 200,000 | 200,000 | 200,000 | 201,000 | 200,000 | | | 200,000 | 193,000 | 201,000 | a 201,000<br>b 201,000<br>c 201,000 | 201,000 | 200,000 | 200,000 | 200,000 | 200,000 | 200,000 |

* See Table F1-2 for levels of selected gases.

** Based on information in Table F1-2; see California Administrative Code, Title 8, Article 8, Appendix D, Part 3, section 7956a,b,c, 7955c, 7955d. Hole samples normalized to indicate ppm. Small errors result from rounding of values.

† Less than 100 ppm.

‡ Not differentiated.

§ Title 8, California Administrative Code, General Industry Safety Order. NOTE: Nitrogen dioxide not tested. TLV requirements not more than 5 ppm.

§§ See Table F1-1 for details of different levels.

\# Not less than 180,000 ppm.

Notes for Boring 21 Description
a = Alluvium Open Hole Sampled @ 15'
b = Cased 3/4" Piezometer Sampled @ 15'; water @ 16'
c = Cased 2" Piezometer Sampled @ 50'; water @ 55'

TABLE E-2 Limits of Flammability

| Gas | Formula | Limits of Flammability in Air | | | |
|---|---|---|---|---|---|
| | | Percent by Volume* | | Parts per Million | |
| | | Lower | Upper | Lower | Upper |
| Methane | $CH_1$ | 5.00 | 15.00 | 50,000 | 150,000 |
| Ethane | $C_2H_6$ | 3.00 | 12.50 | 30,000 | 125,000 |
| Propane | $C_3H_8$ | 2.12 | 9.35 | 21,200 | 93,500 |
| n-Butane | $C_4H_{10}$ | 1.86 | 8.41 | 18,600 | 84,100 |
| Isobutane | $C_4H_{10}$ | 1.80 | 8.44 | 18,000 | 84,400 |
| n-Pentane | $C_5H_{12}$ | 1.40 | 7.80 | 14,000 | 78,000 |
| Isopentane | $C_5H_{12}$ | 1.32 | - | 13,200 | - |
| Hexane** | $C_6H_{14}$ | 1.18 | 7.40 | 11,800 | 74,000 |
| Heptane ($C_7$) | - | 1.10 | 6.70 | 11,000 | 67,000 |
| Octane ($C_8$) | - | 0.95 | - | 9,500 | - |
| Nonane ($C_9$) | - | 0.83 | - | 8,300 | - |
| Decane ($C_{10}$) | - | 0.77 | 5.35 | 7,700 | 53,000 |
| Carbon monoxide | CO | 12.50 | 74.20 | 125,000 | 742,000 |
| Hydrogen sulfide | $H_2S$ | 4.30 | 28.50 | 43,000 | 285,000 |

*Handbook of Chemistry and Physics, 41st ed., p. 1927-1929.

**Instrument used in analyses combined all hydrocarbon gases, $C_6$ and greater, including those greater than $C_{10}$.

TABLE E-3 Threshold Limit Value of Selected Non-Hydrocarbon Gases

| Gas | Concentration by Volume in Air* Parts per Million | Comments* |
|---|---|---|
| Carbon monoxide | 100 | Threshold limit value (TLV);<br>no adverse effects. |
| | 200 | Headache after about 7 hours if resting;<br>about 2 hours of work. |
| | 400 | Headache and discomfort, possibility of collapse after 2 hours at rest or 45 minutes of exertion. |
| | 1,200 | Palpitation after 30 minutes rest or 10 minutes of exertion. |
| | 2,000 | Unconsciousness after 30 minutes rest or 10 minutes of exertion. |
| Carbon dioxide | 5,000 | TLV; lung ventilation slightly increased. |
| | 50,000 | Breathing is labored. |
| | 90,000 | Depression of breathing begins. |
| Hydrogen sulfide | 10 | TLV. |
| | 100 | Irritation to eyes and throat; headache. |
| | 200 | Maximum concentration tolerable for one hour. |
| | 1,000 | Immediate unconsciousness. |
| Sulfur dioxide (not tested) | 1 to 5 | Can be detected by taste at lower level, by smell at upper level. |
| | 5 | TLV; onset or irritation to nose and throat. |
| | 20 | Irritation to eyes. |
| | 400 | Immediately dangerous to life. |

*National Coal Board, 1978, Spoil Heaps and Lagoons, Technical Handbook, N.C.B., London.

TABLE E-41 Solubility of Gases in Water

| Gas | Solubility in Water Parts per Million |
|---|---|
| Hydrocarbon* | |
| Methane | 24.4 ± 1.0 |
| Ethane | 60.4 ± 1.3 |
| Propane | 6.24 ± 2.1 |
| n-Butane | 61.4 ± 2.6 |
| Isobutane | 48.9 ± 2.1 |
| n-Pentane | 38.5 ± 2.0 |
| Isopentane | 48.9 ± 1.6 |
| $(C_6)$ | 9.5 ± 1.3 |
| $(C_7)$ | 2.93 ± 0.20 |
| $(C_8)$ | 0.66 ± 0.06 |
| Non-Hydrocarbon** | |
| Nitrogen | 17.5 |
| Oxygen | 39.3 |
| Carbon monoxide | 26.0 |
| Carbon dioxide | 1,449 |
| Hydrogen sulfide | 3,375 |

*McAuliffe, C., 1963, Solubility in Water of $C_1$ - $C_9$ hydrocarbons: Nature, v. 200, no. 4911, p. 1092-1093.

**Handbook of Chemistry and Physics, 41st ed., p. 1706-1707.

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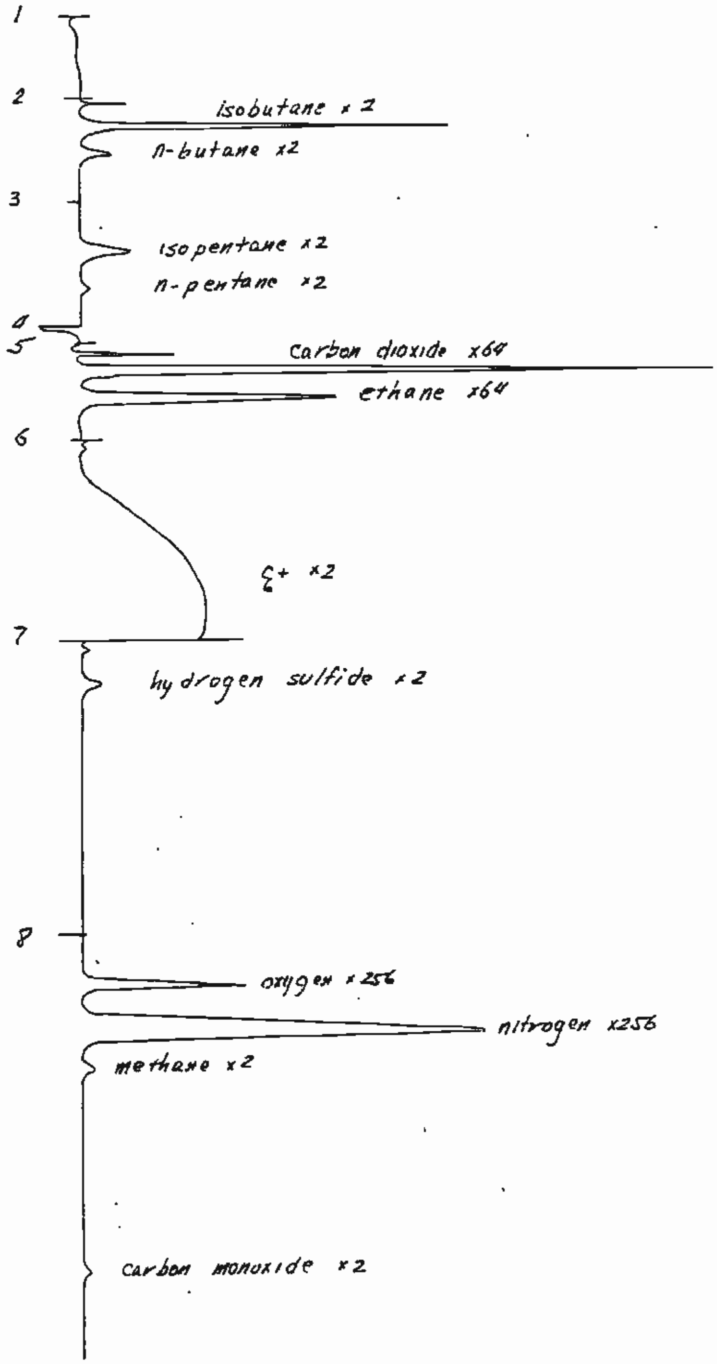
**Ryland-Cummings, Inc.**

# Gas Chromatography
## Boring No. 19

Date Sampled 1/22/81
Tested by DC
Depth of Sample 9ft water @ 10ft
Column Temp. 70°C
Chart Speed 0.5 in/min
Formation cased piezometer
Helium 30 ml/min flow rate @ 60 psig
Sample Size 10 ml
Attenuation Range as shown



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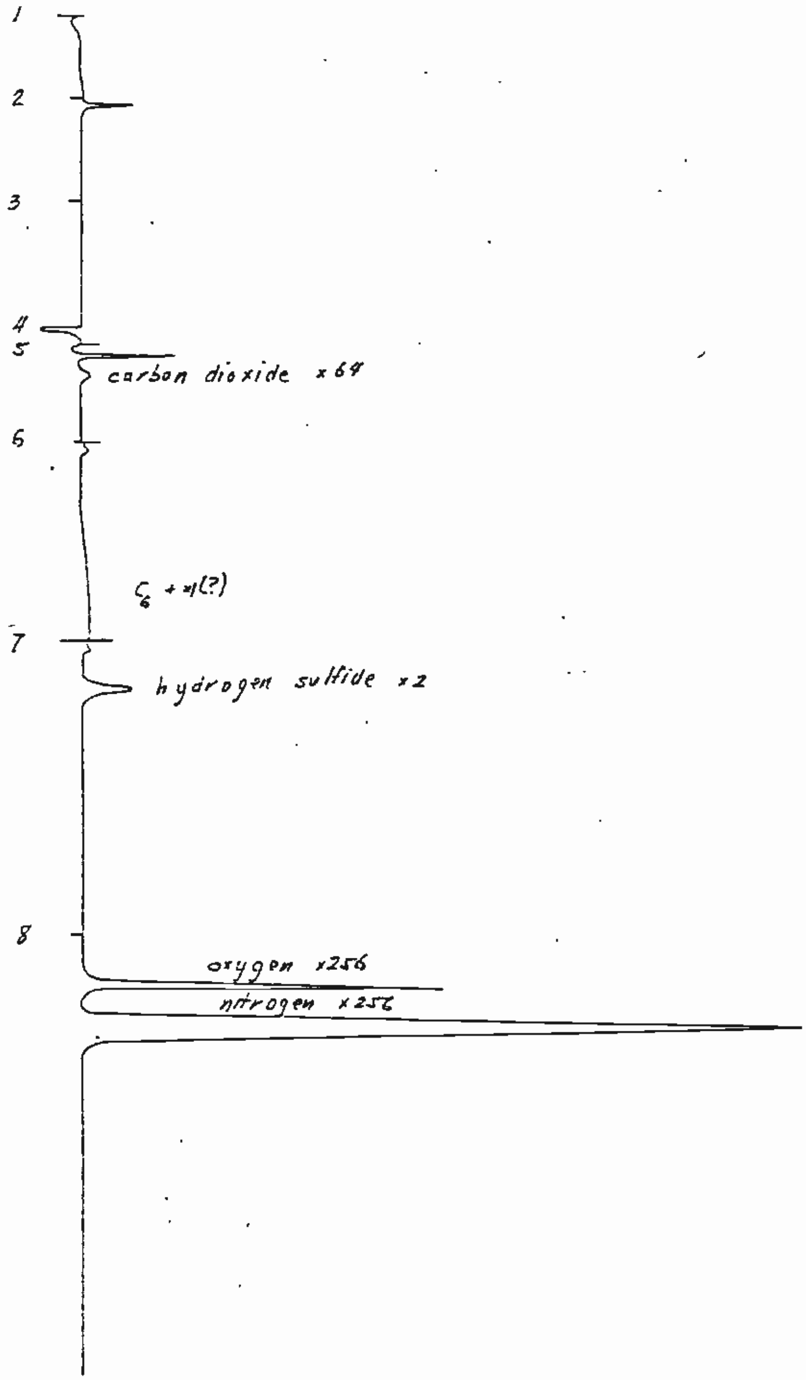
**Ryland-Cummings, Inc.**

## Gas Chromatography
## Boring No. 21

Date Sampled 1/7/81
Tested by DC SLR
Depth of Sample 50 ft water @ 55 ft
Column Temp. 70°C
Chart Speed 0.5 in/min
Formation 2" cased piezometer
Helium 30 ml/min flow rate @ 60 psig
Sample Size 10 ml
Attenuation Range as shown



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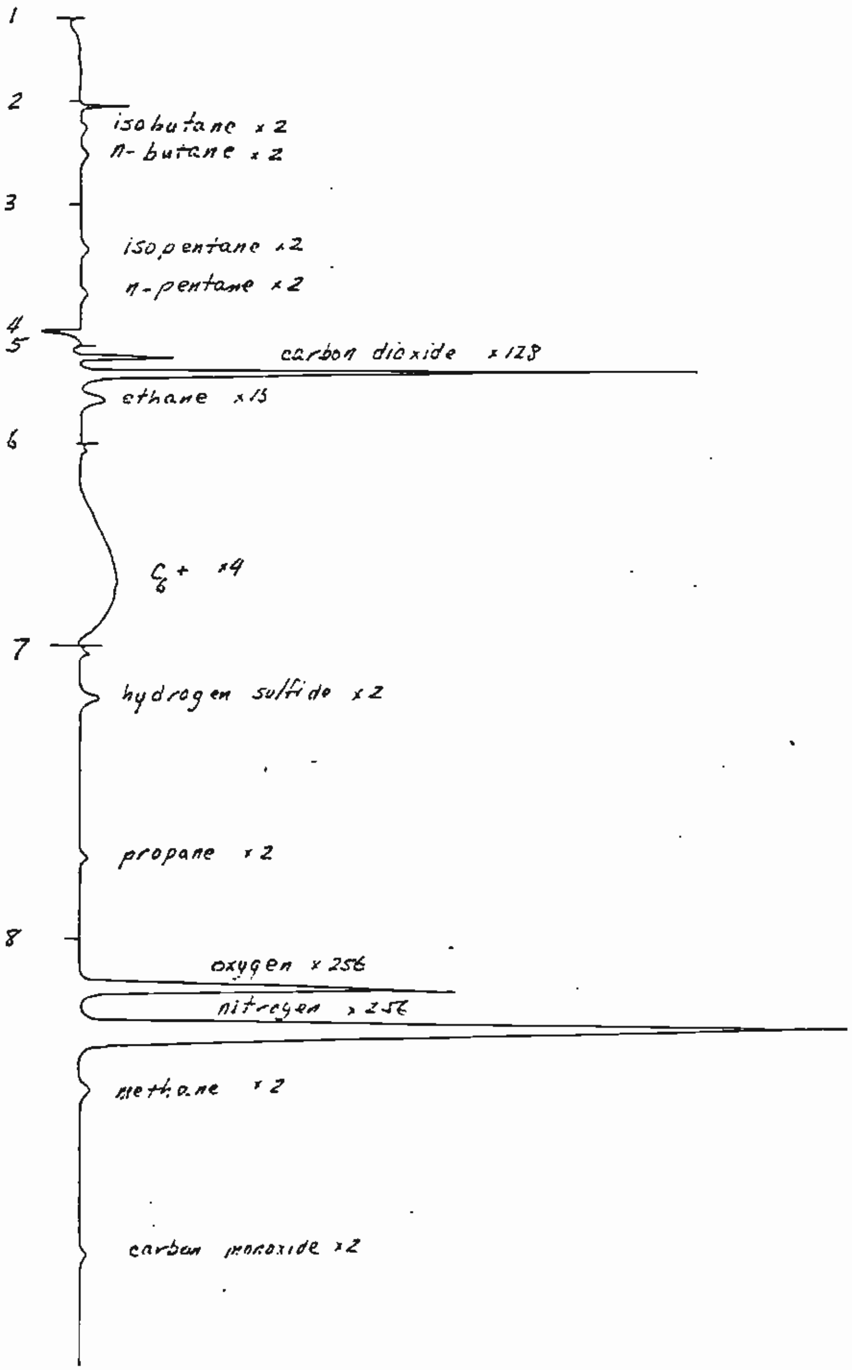
## Gas Chromatography
## Boring No. 21

Date Sampled 12/21/80
Tested by DC, SLR
Depth of Sample 13ft water @ 15ft
Column Temp. 70 °C
Chart Speed 0.5 in/min
Formation alluvium — open hole
Helium 30 ml/min flow rate @ 60 psig
Sample Size 10 ml
Attenuation Range as shown



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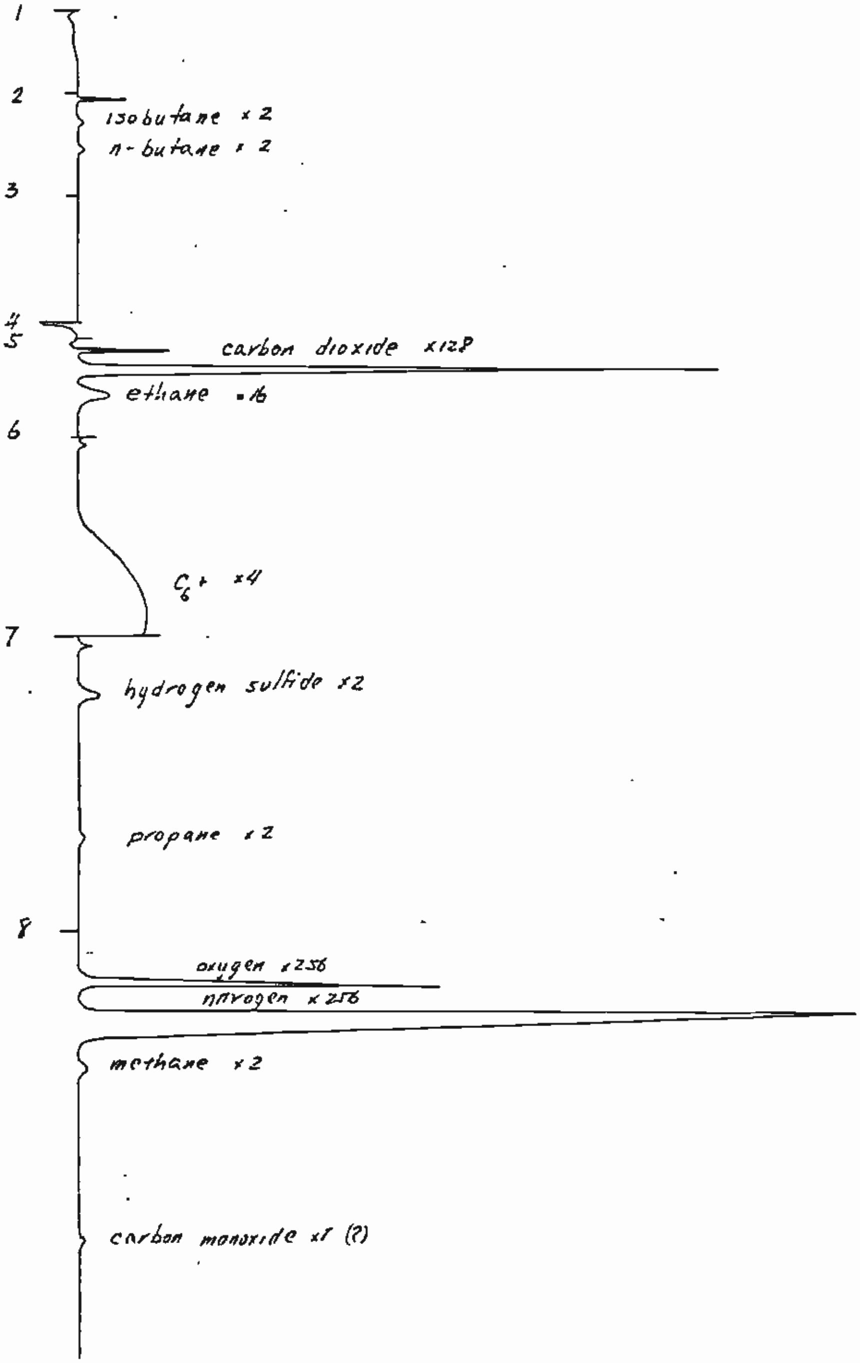
# Gas Chromatography
## Boring No. 22

Date Sampled 12/21/80
Tested by DC, SLR
Depth of Sample 15 feet water @ 15 ft
Column Temp. 70° C
Chart Speed 0.5 in/min
Formation alluvium – open hole
Helium 30 ml/min flow rate @ 60 psig
Sample Size 10 ml
Attenuation Range as shown



# Appendix F

# Technical Considerations

# APPENDIX F TECHNICAL CONSIDERATIONS

## F.1 SHORING PRACTICES IN THE LOS ANGELES AREA

### F.1.1 General

Deep excavations for building basements in the Los Angeles area are commonly supported with soldier piles with tieback anchors. Two case studies involving deep excavations into materials similar to those anticipated at the proposed site are presented below.

### F.1.2 Mutual Benefit Life (Converse, 1965)

This project involved a shored excavation to approximately 40 feet in depth in the alluvial deposits and tar impregnated San Pedro Sand formation. The project is located between Borings 19A and 20A, within 250 feet of the proposed location of the Wilshire/Fairfax Station. Key elements of the design and construction included:

- Basic subsurface materials were stiff, mainly cohesive soils to 22-30 feet in depth underlain by dense silty tar sands up to 50 feet in thickness. These were underlain by siltstone and claystone permeated with oil and tar, to depths in excess of 150 feet. Groundwater was observed, perched above the soil sand, reaching a level of about 14 feet.
- Shoring system consisted of steel, wide flange (WF) soldier piles set in pre-drilled holes, backfilled with structural concrete in the "toe" and a lean concrete mix above.
- Tieback anchors consisted of straight shaft anchors.
- Timber lagging was used between the soldier piles to support the exposed soils.
- Shoring design pressure averaged 11.7H through the upper clayey soils and 15.7H within the tar sands, where H was the total depth of the excavation.
- Shoring performance was less than desired as more than 4 inches of lateral deflection occurred at some locations on the Wilshire Boulevard side of the shoring system. This resulted in temporary closure of several lanes of traffic on Wilshire Boulevard. On the other sides of the shoring system large deflections were not observed.

### F.1.3 Proposed Office Building (LeRoy Crandall, 1984)

This project, under construction at the present time, involves a shored excavation to a depth of about 60 feet into tar impregnated sand deposits. The project is located at the junction of Wilshire Boulevard and Fairfax Avenue approximately 600 feet southwest of the proposed location of the Wilshire/Fairfax Station. Key elements of the design and construction include:

- Basic subsurface materials consists of firm to stiff silts and clays, and medium dense to dense deposits of sand and silty sand to depths varying from 35 to 50 feet. Below these deposits dense tar impregnated sands were encountered to depths of 98 to 112 feet below grade. The tar sands were underlain by siltstone and dense sandstone. Groundwater was encountered at and below a depth of 13 feet.

- Shoring system consists of steel, wide flange (WF) soldier piles set in pre-drilled holes, backfilled with structural concrete in the "toe" and a lean concrete mix above.

- Timber lagging is being used between the soldier piles to support the subsurface soils.

- Shoring design pressures average 17.1 $H_a$ in the non tar bearing cohesive soils and 29H in the tar sands. $H_a$ denotes the thickness of the cohesive soils and H is the total height of the shoring in feet.

- Lateral deflection of the shoring system is currently being monitored and no conclusions as to shoring performance can be made at this time.

## F.2 SEISMICALLY INDUCED EARTH PRESSURES

The increase in lateral earth pressure due to earthquake forces has usually been taken into consideration by using the Monobe-Okabe method which is based on a modification of Coulomb's limit equilibrium earth pressure theory. This simple pseudo-static method has been applied to the design of retaining structures both in the U.S. and in numerous other countries around the world, mainly because it is simple to use. However, just as the use of the pseudo-static method is not really appropriate for evaluating the seismic stability of earth dams, those same shortcomings are also applicable when using the method to evaluate dynamic lateral pressures.

During an earthquake the inertia forces are cyclic in nature and are constantly changing throughout its duration. It is unrealistic to replace these inertia forces by a single horizontal (and/or vertical) force acting only in one direction. In addition, the selection of an appropriate value of the horizontal seismic coefficient is completely arbitrary. Nevertheless, the pseudo-static method is still being used since it provides a simple means for assessing the additional hazard to stability imposed by earthquake loadings.

Monobe-Okabe originally developed an expression for evaluating the magnitude of the total (static plus dynamic) active earth pressure acting on a rigid retaining wall backfilled with a dry cohesionless soil. The method was developed for dry cohesionless materials and based on the assumptions that:

- The wall yields sufficiently to produce minimum active pressures.

- When the minimum active pressure is attained, a soil wedge behind the wall is at the point of incipient failure, and the maximum shear strength is mobilized along the potential sliding surface.

- The soil behind the wall behaves as a rigid body so that accelerations are uniform throughout the mass.

Monobe-Okabe's method gives only the total force acting on the wall. It does not give the pressure distribution nor its point of application. Their formula for the total active lateral force on the wall, $P_{AE}$, is as follows:

$$P_{AE} = 1/2\gamma\ H^2(1-k_v)K_{AE}$$

Where:

$$K_{AE} = \frac{COS^2\ (\phi-\theta-\beta)}{COS\ \theta\ COS^2\beta COS\ (\delta+\beta+\theta)\ \left(1+\sqrt{\frac{SIN\ (\phi+\delta)\ SIN\ (\phi-\theta-i)}{COS\ (\delta+\beta+\theta)\ COS\ (i-\beta)}}\right)^2}$$

$$\theta\ = \tan^{-1}\frac{K_h}{1-K_v}$$

$\gamma$ = unit weight of soil

$\phi$ = angle of internal friction of soil

i = angle of soil slope to horizontal

$\beta$ = angle of wall slope to vertical

$k_h$ = horizontal earthquake coefficient

$K_v$ = vertical earthquake coefficient

$\delta$ = angle of wall friction.

For a horizontal ground surface and a vertical wall,

$$i = \beta = 0$$

The expression for $K_{AE}$ then becomes,

$$KAE = \frac{COS^2(\phi-\theta-\beta)}{COS\ \theta\ COS\ (\delta+\theta)\ \left(1+\sqrt{\frac{SIN\ (\theta+\delta)\ SIN\ (\phi-\theta)}{COS\ (\theta+\delta)}}\right)^2}$$

The seismic component, $\Delta P_{AE}$, of the total lateral load $P_{AE}$ can be determined by the following equation:

$$\Delta P_{AE} = 1/2\ \gamma\ (total)\ H^2\ \Delta K_{AE}$$

Where:

$$\Delta K_{AE} = K_{AE}\ (static+seismic) - K_{AE}\ (static)$$

Inspection of actual acceleration time histories recorded during strong motion earthquakes indicates that the accelerations are quite variable both in amplitude and with time. For any given acceleration component the values fluctuate significantly during the entire duration of the record. Statistical analyses of the positive and negative peaks do indicate, however, that when one considers the entire record there are generally an equal number of positive and negative peaks of equal intensity. In the past it has been common practice to use the peak value of acceleration recorded during the earthquake as a value of engineering significance. However, this peak value might occur only once during the entire earthquake duration and is usually not representative of the average acceleration which might be established for the entire duration of shaking.

It has been common practice in the past to ignore the effects of the vertical acceleration and to set the value of the vertical earthquake coefficient, $k_v$, equal to zero when using Monobe-Okabe's equation. This appears reasonable in the "light" of the above discussion since the vertical acceleration will act in upward direction about as often as it will act in the downward direction. It has also been common practice to set the value of the horizontal seismic coefficient, $k_h$, equal to the peak ground acceleration.

This is extremely conservative since the peak acceleration acts only on the wall for an instant of time. In addition, for a deep excavation the soil mass behind the wall will not move as a rigid body and will have a seismic coefficient significantly less than the peak ground acceleration (analogous to a horizontal seismic coefficient acting on a failure surface for an earth dam).

For evaluating dynamic earth pressures for this study, we recommend that the value of the horizontal seismic coefficient be taken equal to 65% of the peak ground acceleration and that the vertical seismic coefficient, $k_v$, be set equal to zero.

In a saturated soil medium the change in water pressure during an earthquake has usually been established on the basis of the method of analysis originally developed by Westergaard (1933). His method of analysis was intended to apply to the hydrodynamic forces acting on the fact of a concrete dam during an earthquake. However, it was used by Matsuo and O'Hara (1960) to determine the dynamic water pressure (due to the pore fluid within the soil) acting on quay walls during earthquakes, and has been used by various other engineers for evaluating dynamic water pressures acting on retaining walls backfilled with saturated soil. Unless the soil is extremely porous, it is difficult to visualize that the pore water can actually move in and out quick enough for it to act independently of the surrounding soil media. For most natural soils, the soil and pore water would move together in phase during the duration of the earthquake such that the dynamic pressure on the wall would be due to the combined effect of the soil and water. Thus, the total weight of the saturated soil should be used in calculating dynamic earth pressure values.

The Allowable Building Code stress increases for seismic loading (33%) translates into an allowable uniform seismic earth pressure on the temporary shoring of about magnitude 6H. This earth pressure corresponds to a seismic coefficient ($K_h$) of about 0.15g and a peak ground acceleration of about 0.23g (using the recommended procedures). Data from Part I Seismological Investigation indicates the 0.23g peak acceleration to have a probability of exceedance less than 5% during an average two-year period (a reasonable construction period). The average recurrence of this ground motion level was indicated to be about 100 to 150 years. Based on consideration of the above, the 6H uniform seismic pressure was recommended for design of the temporary wall (see Figure 6-5).

# Appendix G

# Earthwork Recommendations

# APPENDIX G  EARTHWORK RECOMMENDATIONS

The following guidelines are recommended for earthwork associated with site development. Recommendations for de-pressurization and major temporary excavations are presented in the text sections 6.2 and 6.4, respectively.

- Site Preparation (surface structures): Existing vegetation, debris, and soft or loose soils should be stripped from the areas that are to be graded. Soils containing more than 1% by weight of organics may be re-used in planter areas, but should not be used for fill beneath building and paved areas. Organic debris, trash, and rubble should be removed from the site. Subsoil conditions on the site may vary from those encountered in the borings. Therefore, the soils engineer should observe the prepared graded area prior to the placement of fill.

- Minor Construction Excavations: Temporary dry excavations for foundations or utilities may be made vertically to depths up to 5 feet. For deeper dry excavations in existing fill or natural materials up to 15 feet, excavations should be sloped no steeper than 1:1 (horizontal to vertical). Recommendations for major shored excavations are presented in Section 6.4.

- Impervious Fill Blanket: In Section 6.12 it was suggested that consideration be given to the use of an impervious fill blanket over the top of the buried structure to reduce the possibility of future tar seeps. Such a fill, if used, should be composed of relatively fine grained soils and not granular soils as recommened elsewhere in this appendix for general backfill.

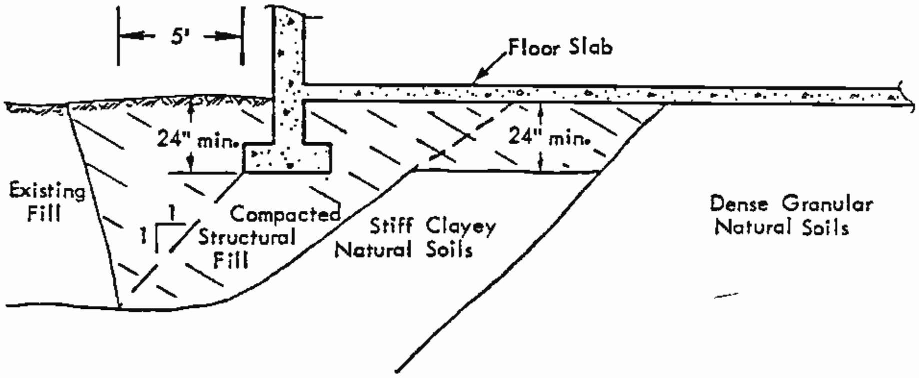
- Structural Fill and Backfill: Where required for support of near surface foundations or where subterranean walls and/or footings require backfilling, excavated onsite granular soils or imported granular soils are suitable for use as structural fill. Loose soil, formwork and debris should be removed prior to backfilling the walls. Onsite soils or imported granular soils should be placed and compacted in accordance with "Recommended Specifications for Fill Compaction". In deep fill areas or fill areas for support of settlement-sensitive structures, compaction requirements should be increased from the normal 90% to 95% or 100% of the maximum dry density to reduce fill settlement.

  Where space limitations do not allow for conventional backfill compaction operations, special backfill materials and procedures may be required. Sand-cement slurry, pea gravel or other selected backfill can be used in limited space areas. Sand-cement slurry should contain at least 1-1/2 sacks cement per cubic yard. Pea gravel should be placed in a moist condition or should be wetted at the time of placement. Densification should be accomplished by vibratory equipment; e.g., hand-operated mechanical compactor, backhoe mounted hydraulic compactor, or concrete vibrator. Lift thickness should be consistent with the type of compactor used. However, lifts should never exceed 5 feet. A soils engineer experienced in the placement of pea gravel should observe the placement and densification procedures to render an opinion as to the adequate densification of the pea gravel.

If granular backfill or pea gravel is placed in an area of surface drainage, the backfill should be capped with at least 18 inches of relatively impervious type soil; i.e., silt-clay soils.

- Foundation Preparation: Where foundations for near surface appurtenant structures are underlain by existing fill soils, the existing fill should be excavated and replaced with a zone of properly compacted structural fill. The zone of structural fill should extend to undisturbed dense or stiff natural soils. Horizontal limits of the structural fill zone should extend out from the footing edge a distance equal to 5 feet or 1/2 the depth of the zone beneath the footing (a 1:1 ratio), whichever is larger. The structural fill should be placed and compacted as recommended under "Structural Fill and Backfill".

FOUNDATION/SUBGRADE PREPARATION



- Subgrade Preparation: Concrete slabs-on-grade at the subterranean levels may be supported directly on undisturbed stable soils. Where the subgrade soils pump or become unstable under traffic, the subgrade should be overexcavated and replaced with a gravel or decomposed granite blanket of suitable thickness to support construction equipment. If existing fill soils are encountered in near surface subgrade areas, these materials should be excavated and replaced with properly compacted granular fill. Where clayey natural soils (near existing grade) are exposed in the subgrade, these soils should be excavated to a depth of 24 inches below the subgrade level and replaced with properly compacted granular fill. Where dense natural granular soils are exposed at slab subgrade, the slab may be supported directly on these soils. All structural fill for support of slabs or mats should be placed and compacted as recommended under "Structural Fill and Backfill".

- Site Drainage: Adequate positive drainage should be provided away from the surface structures to prevent water from ponding and to reduce percolation of water into the subsoils. A desirable slope for surface drainage is 2% in landscaped areas and 1% in paved areas. Planters and landscaped areas adjacent to the surface structures should be designed to minimize water infiltration into the subsoils.

- Utility Trenches: Buried utility conduits should be bedded and backfilled around the conduit in accordance with the project specifications. Where conduit underlies concrete slabs-on-grade and pavement, the remaining trench backfill above the pipe should be placed and compacted in accordance with "Structural Fill and Backfill".

- Recommended Specifications for Fill Compaction: The following specifications are recommended to provide a basis for quality control during the placement of compacted fill.

1. All areas that are to receive compacted fill shall be observed by the soils engineer prior to the placement of fill.

2. Soil surfaces that will receive compacted fill shall be scarified to a depth of at least 6inches. The scarified soil shall be moisture-conditioned to obtain soil moisture near optimum moisture content. The scarified soil shall be compacted to a minimum relative compaction of 90%. Relative compaction is defined as the ratio of the inplace soil density to the maximum dry density as determined by the ASTM D1557-70 compaction test method.

3. Fill shall be placed in controlled layers the thickness of which is compatible with the type of compaction equipment used. The thickness of the compacted fill layer shall not exceed the maximum allowable thickness of 8 inches. Each layer shall be compacted to a minimum relative compaction of 90%. The field density of the compacted soil shall be determined by the ASTM D1556-64 test method or equivalent.

4. Fill soils shall consist of excavated onsite soils essentially cleaned of organic and deleterious material or imported soils approved by the soils engineer. All imported soil shall be granular and non-expansive or of low expansion potential (plasticity index less than 15%). The soils engineer shall evaluate and/or test the import material for its conformance with the specifications prior to its delivery to the site. The contractor shall notify the soils engineer 72 hours prior to importing the fill to the site. Rocks larger than 6 inches in diameter shall not be used unless they are broken down.

5. The soils engineer shall observe the placement of compacted fill and conduct inplace field density tests on the compacted fill to check for adequate moisture content and the required relative compaction. Where less than 90% relative compaction is indicated, additional compactive effort shall be applied and the soil moisture-conditioned as necessary until 90% relative compaction is attained. The contractor shall provide level testing pads for the soils engineer to conduct the field density tests on.

# Appendix H

# Geotechnical Reports References

# APPENDIX H GEOTECHNICAL REPORTS REFERENCES

| REPORT No. | REPORT DATE | LOCATION | CONSULTANT |
|---|---|---|---|
| 23 | 04/14/47 | Block bounded by Wilshire, Mansfield, Carling and Citrus | L.T. Evans |
| 24 | 03/04/47 | Northeast corner Wilshire & Curson | L.T. Evans |
| 25 | 04/22/47 | Northeast corner Wilshire & Sierra Bonita | L.T. Evans |
| 26 | 10/27/69 | Block bounded by Wilshire, Masselin, Eighth and Curson | L.T. Evans |
| 31 | 09/30/65 | South of Wilshire, between Spaulding & Ogden | L.T. Evans |
| 32 | 02/23/53 | North of Wilshire between Ogden & Orange Grove | L.T. Evans |
| 33 | 04/30/68 | Southeast corner Wilshire/Fairfax | LeRoy Crandall |
| 34 | 04/16/68 | 6200 Wilshire | Nilcola |
| 35 | 01/02/51 | CBS - southeast corner Beverly & Fairfax | L.T. Evans |
| 36 | 04/24/51 | CBS - southeast corner Beverly & Fairfax | L.T. Evans |
| 37 | 12/04/56 | CBS - southeast corner Beverly & Fairfax | L.T. Evans |
| 38 | 08/28/68 | CBS - southeast corner Beverly & Fairfax | L.T. Evans |
| 39 | 04/15/75 | CBS - southeast corner Beverly & Fairfax | L.T. Evans |
| 40 | 10/22/76 | CBS - southeast corner Beverly & Genese | L.T. Evans |