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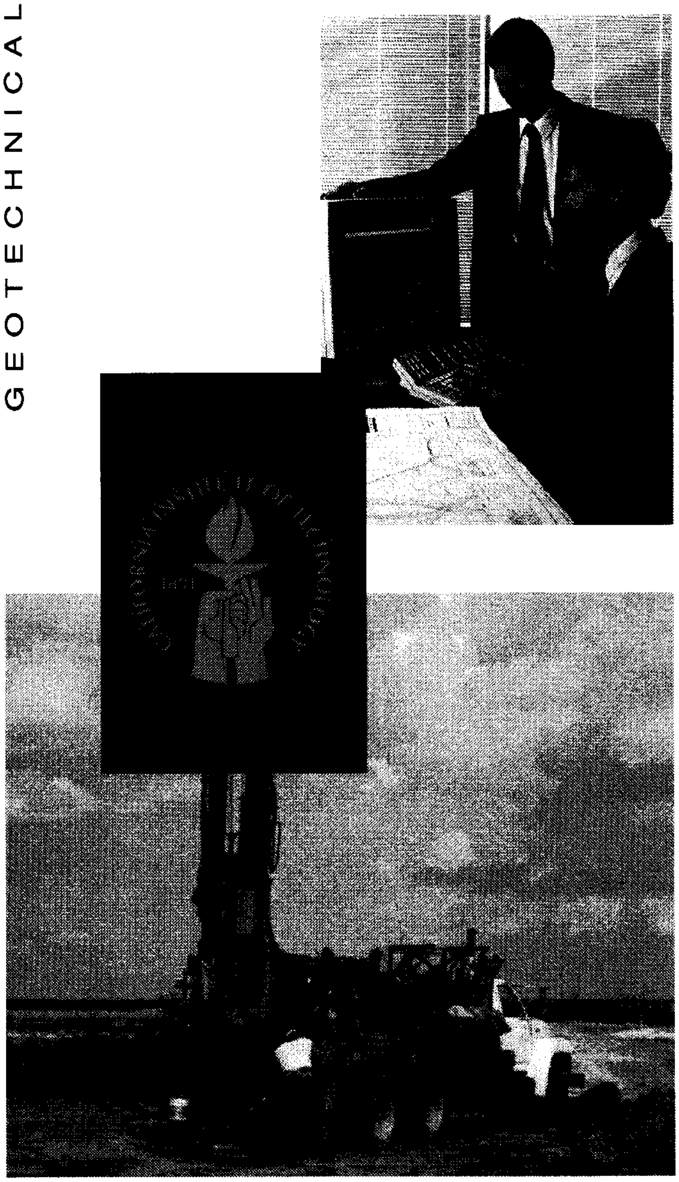
GEOTECHNICAL INVESTIGATION



Geotechnical Investigation of the LIGO Site

Prepared For:

CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

November 1994

WCC File 93B107C

Woodward-Clyde
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Engineering & science applied to the earth & its environment

November 28, 1994

Mr. Fred Asiri
LIGO Project
California Institute of Technology
102-33 Bridge Laboratory
Pasadena, California 91125

Re: LIGO Geotechnical Investigation
WCC No. 93B107C

Dear Mr. Asiri:

Please find attached a draft copy of the geotechnical report for the LIGO site at Livingstone, Louisiana for your review and comments. This draft copy does not contain a "Table of Contents". It will be provided when the report is finalized.

Sincerely,

Dennis E. Reece for

Robert SeGall, P.E.

Ara Arman, P.E.

AA:cew

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GEOTECHNICAL INVESTIGATION
LIVINGSTON, LA. LIGO SITE

We have completed the geologic and geotechnical investigation of the LIGO site located at Livingston, Louisiana. Please find below our findings and recommendations which are contained in the following sections. Detailed results of geotechnical tests performed are included as Appendix A. Appendix B contains the results of electronic Cone Penetrometer Tests (CPT), seismic piezocone tests (SCP) and crosshole seismic tests. Appendix C presents the results of seismicity research, and Appendix D contains idealized subgrade profile plots where both CPT and conventional geotechnical test results are summarized, and Appendix E includes the results of chemical and corrosion potential investigations.

SCOPE OF WORK:

This investigation was authorized by the California Institute of Technology on February 18, 1993 . The investigation was performed in general accordance with our proposal of January 8, 1993.

Field Investigation

The field geotechnical investigation included the drilling of twenty (20) conventional geotechnical borings, and performing forty nine (49) CPT soundings. The locations of borings and CPTs are shown in Figure A-1 of Appendix A. During the performance of borings the soil cores were visually classified and recorded on boring logs. Samples from these cores were, then, preserved and transported to the geotechnical laboratory for testing of selected samples to determine their engineering properties. Upon completion of the laboratory testing the logs of borings were revised to more accurately reflect the results of the laboratory tests. These are included in Appendix A. Borings were tremie-grouted full depth with bentonite mix upon completion in accordance with the drilling permit.

The attached boring logs indicate the types of soils and strata encountered. Relatively undisturbed 3-inch diameter tube samples were generally obtained in the cohesive, fine grained soils and disturbed 2-inch-diameter split-spoon samples were obtained in the coarse grained soils. Standard Penetration Tests (SPT) were performed on the split-spoon samples in boring B-1. This test consists of dropping a 140-pound hammer 30 inches and recording the number of blows required to drive the sampler. The number of blows on the final 12 inches is recorded on the boring log under the "SPT" column. The depths at which the driven and pushed split-spoon samples were obtained are indicated as cross-hatched square symbols and as a "V" symbol in the "Sample" column on the boring logs respectively. The depth between which the tube samples were obtained are shown as shaded symbols under the "Sample" column of the boring log.

Forty nine (49) CPTs were performed to further identify the in situ properties of these soils and to assess the variability or uniformity of engineering properties of various soil strata of the area investigated. The results of these soundings are shown in Appendix B. Also included in the same appendix are the results of three (3) Seismic Cone (piezocone) Penetrometer (SCP) tests and one crosshole seismic test performed to determine the dynamic properties of the subgrade.

WATER CONDITIONS

The ground water information was developed during the geotechnical sampling. In addition, temporary polyvinylchloride (PVC) pipes with screens and removable caps were installed in two (2) of the boreholes for overnight water observations. These are discussed later in this report. They were later removed and the holes were grouted.

LABORATORY TESTING

Selected samples obtained from the conventional geotechnical borings were tested in the geotechnical laboratory to assess the physical properties of the subsoil. Strength tests consisted of sixteen (16) unconfined compression tests, and fifteen (15) undrained triaxial compression tests. The results of these tests are shown on Appendix A. The compressibility of the soils were determined by performing twelve (12) consolidation tests. Detailed and summary results are shown in Appendix A. Appropriate columns of the boring logs also contain the results of laboratory tests. Eighty four (84) natural moisture content and thirty two (32) density tests were performed. In addition forty nine (49) Atterberg Limit determinations and twelve (12) percent finer than the No.200 sieve and two (2) grain size analyses were made.

Three composite samples representing the top strata from six to fifteen feet below the existing ground surface were prepared and submitted to other laboratories for testing. These samples were tested for corrosion potential, including pH, sulfates, sulfides, and chloride contents as well as resistivity. The summaries and copies of laboratory reports are included in Appendix E.

LIMITATIONS

Professional judgments and recommendations are presented in this report. They are based partly on evaluations of technical information gathered, partly on historical reports and partly on our general experience with subsurface conditions in the area. We do not guarantee the performance of the project in any respect other than that our engineering work and the judgment rendered meet the standards and care of our profession. If during construction soil conditions are encountered that vary from those discussed in this report or historical reports or if design loads and/or configurations change, Woodward-Clyde Consultants should be notified immediately in order that they may evaluate effects, if any, on foundation performance. It should be noted that the borings may not represent potentially unfavorable subsurface conditions between borings. If such conditions become evident, additional borings should be performed to characterize these conditions for design review. The recommendations presented in this report are applicable only to this specific site. This data should not be used for other purposes.

Included in Appendix A is a document entitled "Important Information About Your Geotechnical Engineering Report", which is published by ASFE, The Association of Engineering Firms Practicing In The Geosciences. This document should be considered as part of this report and should be furnished to all persons who receive part or all of the report.

ENGINEERING ANALYSIS

Prior to performing various engineering analysis the results of conventional geotechnical tests and the CPT results were compared and correlated. Where needed, additional geotechnical laboratory tests were performed to check earlier results.
Analyses were performed to determine stress distribution at various depths under the embankment. The results from the analyses were compared with unconfined compressive strength of soils at various elevations under the proposed embankment site. Results of Atterberg limits and natural moisture content tests for strata under the water table were used for preliminary determination of the compressibility of various soils. Consolidation test results, then were used to determine settlement properties of the subsoils. Settlement analyses were performed for worst case soil conditions for embankment and beam tube loads.

Pile capacity and bearing capacity analyses were also performed.

Pile capacities of subsoils at the apex were developed.

Drilled shaft capacities at the apex and at the tip of the southeast arm were computed. Slope stability analyses using Bishop method was performed for 10 ft. embankment height with the beam tube load imposed upon it. The subgrade was assumed to have a cohesion of 750 psf from the ground surface to a depth of 18ft. The adjacent borrow ditch was assumed to be 5ft deep. with embankment slopes of 1:2. Computations were also done using a 100 psf surcharge and an earthquake loading factor of 0.1, in both vertical and horizontal directions. The minimum cohesion of the embankment material was assumed to be 1000 psf. and the water table to be at the ground surface. The angle of internal friction for all soils were assumed to be 0 degrees.

In addition the Atterberg limits were used to determine the soil types, soil workability for embankment and other construction, and the suitability of soils for lime or portland cement stabilization.

SITE CONDITIONS AND GEOLOGY

The topography of the Livingston LIGO site, in general is featureless, and flat which results in parts of the site being poorly drained.

The site was originally used for tree farming with the majority of the remaining stands being composed of young Southern Pines with hardwood stands clustered in the lower and worse drained areas.

The site is located in the Coastal Plain Physiographic Province, which is an elevated sea bottom about two hundred miles wide following the shores of the Gulf of Mexico and extending North along the Atlantic coast to Cape Cod. In Louisiana the Coastal Plain is divided into a series of terraces which crudely follow the Gulf Of Mexico Shoreline. These terraces form low elevation "uplands" relative to the Mississippi River alluvial planes and coastal marshlands.

The alluvium at the Livingston site is estimated to be about 200 feet thick. The geologic conditions are sequential, and as seen from the geotechnical investigations show minor spatial variations.

The surface outcrops throughout the site are composed of; clays, silty clays, silts and sands. These deposits comprise the Prairie Terrace Formation of the Pleistocene Series which was deposited about 100,000 years ago. The beginning of the Pleistocene Series was approximately one million years ago. A thin veneer of Holocene Alluvial deposit (reworked Pleistocene) overlies the Prairie Terrace in the small creeks and branches. Due to the extensive timber logging operations in the area the top one to five feet of the Terrace Formation has been disturbed. Within the Prairie Terrace there are two prominent sand channel deposits. One is located at the apex of the LIGO and the other at the end of the southwest leg.

The remainder of the site consists primarily of clay and silty clay deposits interbedded with clayey silts and clayey sands with thin sand layers. Below the Prairie Terrace are deposits of the Intermediate and High Terrace Formations, forming the mid and basal

Pleistocene and upper Pliocene Series. Below these deposits is the upper Miocene which occurs at approximately 2100 to 2500 feet below the existing ground elevation.

SEISMICITY

GIVE UBC SITE FACTOR

The State of Louisiana is located in a Seismic Risk Zone 1 (Appendix C, Figure C-1) (Algermissen 1969), with ground accelerations of less than 0.1g. Recent seismic history of the state (Appendix C,Table C-1) shows that there have been minor tremors reported near Baton Rouge and Donaldsonville. The Baton Rouge events of 1905, 1957 and 1958 have been reported to have had Modified Mercalli (MM) intensities of V (Newman 1954).

The Donaldsonville event of 1930 was reported to have a MM intensity of VI. The hypocenter of this event is located about 50 miles from the LIGO site .

It has been predicted that a repeat of the New Madrid seismic event of 1811-1812 will affect the area at an MM intensity of V to VI.

FAULTS

There are no surface or near surface faults within the site that indicate topographic evidence of displacement (Appendix C,Figure C-2). The deep faults below the site are in the Tuscaloosa Trend Oil and Gas Production Zone and are approximately 15,000 to 20,000 feet deep. The faults shown on the map were transposed from the references cited in Appendix C, Table C-2, and their locations are approximate. The surface and near surface faults (Scotlandville-Denham Springs and the Baton Rouge Fault) were positioned based on observed structural damage or distress and prominent topographic escarpments , closely spaced contour lines, abrupt changes in direction of drainage features and geologic interpretation between known fault points. The closest of the surface faults to the site is the Scotlandville-Denham Springs Fault which is located about 5.5 to 8 miles south-southwest of the site. The two faults are part of the Tepetate-Baton Rouge Fault Zone which runs from Southwestern to Southeastern

Louisiana. The Bancroft Fault Zone, which is parallel to and north of the Tepetate-Baton Rouge Fault Zone is not known to extend as far as the LIGO site.

The surface and near surface faults have shown some movement in recent historical times. At the present time this movement has been attributed to ground water withdrawal rather than tectonic causes.

GEOTECHNICAL CONDITIONS

Soil Types:

A review of CPT and geotechnical boring and test results shows good agreement between two sets of data. Soil strata in general appears to show only gradual variations from one boring or CPT location to the other with some outcrops of sands/silts or clays showing between boreholes (Appendix D). CPT results indicate the presence of thin silt or sand layers in clays and clayey deposits. Some such thin layers could not be seen in conventionally obtained soil cores because of smearing of the surfaces inherent to shelby tube type sampling procedure.

The top two to five feet of the soils are primarily composed of silty clays and some sandy clays. The consistencies of the top strata vary from very stiff to very soft, depending on the soils relative elevation, drainage, and disturbance caused by timber harvesting operations. The surficial soils are underlain by medium to very stiff silty clays and clays interspersed with dense to very dense sand layers followed by medium to very stiff clays. The unified classification of the soils show the site deposits to be composed of CL-ML, CL and CH type soils. No discernible deposits of organic soils with the exception the thin veneer of top soil, were encountered at this site.

Soil Strength:

Unconfined compression and triaxial test results show the soil strengths ranging from 1,900 pounds per square foot (psf) to 5,500 psf with two slickensided or jointed specimen producing lows of 750 psf and 850 psf.

Consolidation:

Results of consolidation tests indicate soils at this site to be preconsolidated. The preconsolidation stresses vary from about 2 tsf to about 3 tsf.

The pleistocene clays of this area are generally slickensided and fissured due to desiccation during recent geologic times and due to deposition patterns. Some of the shallower pleistocene deposits are interlaced with thin (about 1/8-1/4 inch) lenses of silt, fine sand or ferrous oxide deposits. These lenses generally are not continuous and they do not contribute to the dissipation of excess hydrostatic pressures; thus, they do not significantly affect the consolidation process. However, they are responsible in developing fissures which may result in the exhibition of low strengths during some unconfined compressive strength tests.

Ground water, was encountered at varying depths at different locations; while , in general, the ground water was encountered at an average depth below the existing ground of about 8 feet at some locations the ground water was either not encountered or encountered at 13 ft. or 25 ft. below. Some of the shallow "ground waters" appear to be perched waters which is common to this area. These shallower "ground waters" appeared to be under slight artesian pressure which may be the result of the tilt of silty and sandy water bearing layers.

Ground Water:

It should be noted that the ground water elevations of the area is largely dependent on precipitation and will fluctuate with seasons. They should be verified prior to initating any construction operations, such as excavations, which it may affect.

DYNAMIC PROPERTIES

Three Seismic Cone Penetrometer (SCP) and one Crosshole test were performed to determine shear wave velocities of the natural deposits (Appendix 2). The Crosshole test was performed to provide local verification of the SCP data. Test results show good agreement. There appears to be relative uniformity in the dynamic properties of soils at three different locations tested. Data also show that the shear wave velocities of in-situ deposits are confined within a range of 550 fps to 850 fps (Plates 5, 6, and 7, Appendix B).

It should be noted that in the case where shallower layers have higher wave velocities than lower layers, seismic test results will not give reliable indication of the layering (See SCP test results B-SW-01-SC and B-SW-35-SC). Also in homogeneous layers the presence of the water table will reflect wave patterns falsely indicating them to be layered; however, these tests can accurately predict the depth of shallow water tables.

RESISTIVITY AND CHEMICAL ANALYSIS

The pH, resistivity and sulfate, sulfide and chloride contents of the soils were determined using three composite soil specimens representing typical soils of surface deposits from 6 feet to 20 feet below the ground elevation (Appendix E, Table E-1).

Soils having similar engineering properties were composited and submitted for testing to Soil Testing Engineers, Inc. and to Benchmark Laboratories both of Baton Rouge, Louisiana. Test results are included in Appendix E.

Resistivities of the soils at their natural moisture content indicate that they are "virtually non-aggressive" as far as their corrosion potential is concerned (Table E-2). A brief description of the resistivity test method used by the laboratory is also included in Appendix E. The pH tests of the composite specimens indicate the soil to be, practically, neutral.

STRESS-STRAIN PROPERTIES OF SOILS

Stress-strain moduli E_s, Poisson's Ratio μ, and moduli of subgrade reactions k_s, for various types of soils found at this site and the dynamic modulus G' are shown below. These values were obtained from a review of the stress-strain properties of the materials as exhibited in triaxial testing and by correlating the site soil characteristics with those shown in the literature and local experience. The Dynamic modulus G' was computed using a shear wave velocity of 700fps.

It should be noted that these elastic and dynamic properties are highly dependent on soil composition (i.e. ratio of silt to clay), density, moisture content at the time of testing, and stress-strain history of the deposits, testing methods. In other words, there are built-in uncertainties in these values.

The soils found in this area can be grouped into four categories;

Medium Clays	E_s=500-1, 000 ksf
Stiff Clays	E_s=1, 000-2000 ksf
Sandy/Silty Clays	E_s=500-3,000 ksf
Dense Sand	E_s=800-1, 500 ksf

Typical values for Poisson's Ratio μ are given below:

Saturated Clays	0.3-0.5
Clays above the Water Table	0.2-0.3
Sandy/Silty Clays	0.2-0.3

We recommend the use of a Poisson's Ratio of 0.4 for computations involving the in-situ soils at this site.

Typical Moduli of Subgrade reactions k_s for the existing deposits located 4 feet to 10 feet (assumes that 2 to 5 feet of loose surface materials are removed) below the existing ground elevation are shown below.

Clays and Silty/Sandy Clays	50-100 kcf
Silty Sands	100-225 kcf
Clayey Sands	175-350 kcf

Dynamic modulus, M', for the tested locations is 14 ksi.

EMBANKMENTS

Loads:

The beam tube for the LIGO facility and its associated equipment and the maintenance access road will be constructed over two connected embankments. At the time of the preparation of this report the final elevation of the crest of the embankment, loads to be imposed upon the embankment, the exact position of the loads vis-a-vis the embankment center line, or exact dimensions were not available. Thus this and following sections of the report are based on information which accompanied the California Institute of Technology contract for this work.

We have used values derived from the above source for our computations. Engineers performing the final design need to critically review these values and make proper compensations for changes in design parameters. Two embankment heights have been considered; 5 feet and 10 feet.

The beam tube which is shown to be 48 inches in diameter and manufactured of 1/8 inch thick stainless steel stock is assumed to have a weight of 67 pounds per linear feet. The stiffening rings and other peripheral equipment of the beam tube are assumed to weigh 30 pounds per linear feet. The concrete slab to support the beam tube is estimated to be 12 inches thick and 22 feet wide weighing 3,300 pounds per linear foot. The service road for the beam tube is assumed to be constructed with 6 inches thick mesh reinforced concrete at 1,500 pounds per linear feet. A unit dry weight of 120 pounds/cubic feet was used for the embankment materials.

Settlement:

Our analysis indicates that the foundation materials at this site are adequate to support the embankments and the loads as outlined above. It is expected that there will be 3/4 to 1 1/4 inches settlement due to the embankment loads. The majority of this settlement is expected to occur during the construction of the embankments.

Construction:

It is recommended that about 2 feet to 5 feet of the top loose and disturbed material be removed and replaced with compacted engineered fill material. The amount of material to be removed should be determined in the field after the site is graded and proof rolled to identify the location and the extent of soft and disturbed layers.

SIZE AND WT. OF PROOF ROLLER

The footprint of the LIGO embankment covers an area where a large number of trees were removed. Prior to the construction of the embankment the entire site should be inspected to assure that no stumps remain and should be proof rolled to identify unconsolidated stump holes.

THROUGH REMOVAL OF ORGANIC IN STUMP HOLES

Local borrow materials appear to be suitable for embankment construction. It should be noted, however, that fine sands and silts of this are generally composed of well rounded particles and, in their pure form (i.e.all fine sand or all silt), they present stability problems unless they are mixed with finer materials or stabilized with portland cement.

MISSING WORD

PI's 12-25 OK
>25 LIME, QUICK OR HYDRATED
<12 LIME, P.C. OR TYPE C FLYASH

Soils with plasticity indexes of 12 to 25 with liquid limit not exceeding 40% are suitable for the construction of these embankments. Soils with higher plasticities should be modified by mixing them with quick or hydrated lime. Soils with lower plasticities should be stabilized with either lime, portland cement, or a combination of Type C fly ash and lime. Modification of high plasticity soils should be performed to render them friable and workable. Stabilization is recommended for low plasticity soils to develop chemical cohesion and dimensional stability.

Embankment materials placed in the top 24 inches (with the exception of reinforced earth), stabilized or otherwise, should be compacted to obtain a minimum of 98% relative density as determined by the "Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort", ASTM D 698-91, soil materials placed

TOP 24" OF WHAT? FILL, EXIST. NATURAL SURFACE OR WHAT?

? D698

WHY NOT HIGHER STANDARD OF D1556 D1557?

below the top 24 inches should be compacted to a minimum relative density of 95% (ninety five percent) as determined by the above cited method.

As indicated by the soil profiles of the site, the type of natural materials vary spatially and vertically. When on site borrow materials are used for the construction of the embankment it will be necessary to develop a family of moisture/density curves for use by trained soil technicians to direct and monitor the compaction of embankment materials.

All embankment slopes should be blanketed with minimum of 8 inches of clayey soils compacted to 92% relative density (ASTM D 698-91), which in turn should be covered with 6 (six) inches of top soil suitable to develop a protective cover of vegetation.

The liquid limits of tested soils are, in general, less than 50 indicating that the swelling potential for their swelling potential is negligible.

All borrow materials should be tested at their source for characterization. Suitability of borrow materials for this embankment should be determined prior the approval of the borrow source.

Preliminary facility plans indicate that the load distribution across the embankment will not be uniform, thus non uniform subsidence of the embankment may be expected unless the crest of the embankment is reinforced to help distribute the loads more uniformly. This can be achieved by reinforcing the top 24 inches of the embankment with geosynthetics or by stabilizing the top 20 inches of the embankment materials with hydrated lime or portland cement, depending on the soil properties.

WHY NOT DESIGN FOR ΔS + LET ΔS OCCUR.

In general the foundation soils are suitable to carry the embankment loads without preloading or surcharging as discussed above. Soils in the vicinity of boring Nos. SW-21-GT and SW-25-GT produced lower strengths due to apparent slickensided and jointed structure of the deposits about 15 (fifteen) feet below the ground elevation, this isolated area may, depending on the final loading of the embankment at that site, need surcharging to avoid shear displacements. We recommend that surcharging of that area be considered pending the determination of final loads.

All computations and predictions presented here assume that buildings at the apex or at the tip of the embankments will be supported by foundations placed in or over the natural ground below the embankment. The founding of critical structures supported on piles or shafts over the fill is not recommended because of the probability of negative skin frictions affecting pile or shaft integrity. It is also assumed that the embankment will be allowed to settle and subside for a period of at least nine months prior to the construction of buildings or other facilities over it.

UNIT WEIGHTS

The average unit wet weight of all specimens is 124 pcf.with an average unit dry weight of 100 pcf . For computational purposes we recommend using 120 pcf.

BEARING CAPACITY

The shear strengths of soils tested are, in general, in excess of 1.2 tsf. For these soils the bearing capacity is determined to be 3,450 psf (with a safety factor of 2.5). The bearing capacity of weaker soils were computed to be 2,680 psf. We recommend that a bearing capacity of 2,700 psf be used for general design purposes. Soils at the apex of the facility yields a bearing capacity of 3,600 psf using a safety factor of 3.0.

STABILITY ANALYSIS

The Bishop's method for stability analysis using worst soil conditions, as discussed above, yielded safety factors of 2.3 for the condition of ground water at the ground elevation , and 2.0 for saturated, flooded condition .

DRILLED SHAFTS

Drilled shaft capacities have been computed for the soils at the apex and at the tip of the southeast arm. These capacities are listed in Tables 1 and 2 . as can be seen drilled shafts will provide high load capacities and they are recommended for use at this site. The shaft capacities as presented assume a cut-off of two feet below present grade. They will carry loads by both side friction and end bearing. We recombined that compression values be reduced by one half for shafts in tension. Reinforcing steel for shafts subject to uplift pressure should extend to within 6 inches of the bottom of the shaft.

Consideration should be given to the group effect of shafts installed in clusters of 4 or more. Shafts in clusters should be installed with a minimum center-to-center spacing of no less than 2 shaft diameters. Experience has shown that the group effect of large clusters of shafts is best accounted for in such materials through use of the "Perimeter Shear" formula. This formula assumes that the material enclosed within the shaft cluster tends to act as a large block and the forces resisting the movement of this block are compared with the total load on the block. If a safety factor of 2.5 or greater is obtained with this formula, no reduction in shaft capacity is necessary. Otherwise, the allowable foundation load is taken as 40 percent of the total supporting power of the block. The Perimeter Shear formula may be written as:

$$Q = P\left(\sum c_i\, L_i\right) + Aq$$

where:

- Q = Ultimate supporting capacity of the soil block (kips)
- P = Perimeter of shaft group (feet)
- c_i = Cohesion of soil layer (i)(kips/square feet)
- L_i = Length of shaft embedded in soil layer (i)(feet)
- A = Horizontal area of shaft (square feet)

For uplift loads the above equation should be used except that the second term (end bearing part) is not utilized.

The contractor installing shafts has to be made aware of the fact that the soil profile shows the presence of dense sand layers. Drilling of shafts through these layers may require the use of casing or bentonite slurry. We recommend that any casing used should penetrate at least one foot into the very stiff to hard layers to seal seepage and avoid sloughing of silts and sands. Concrete should be placed immediately after the excavation has been completed and inspected. In no event the excavation should remain open more than three hours. Should there be seepage in excess of one inch, the hole should be pumped dry and the concrete tremied in place properly. Casing should not be pulled above the concrete surface during the placement of concrete.

SYNTAX SHOULD POUR IMMEDIATELY

Shaft capacities for the tip of the southwest arm were not computed since the friction values for those soils are higher thus bearing capacities would be slightly higher than those for the southeast arm. We recommend the use of values computed for the southeast arm.

TABLE 1

STRAIGHT-SIDED SHAFT CAPACITIES AT TERMINAL ENDS OF THE ARMS

Depth of Tip Embedment (feet)*	Allowable Single Shaft Compressor Capacities (kips) Shaft Diameters (inches)				
	12	18	24	30	36
15	23	36	51	67	85
20	29	46	64	83	103
25	NR	58	79	102	126
30	NR	69	95	121	149
35	NR	71	110	141	172
40	NR	92	126	160	195
45	NR	104	181	179	218
50	NR	115	156	198	241

NOTES: Shafts are not recommended below 40 feet at the Southwest Terminal
* Feet below existing grade
NR Not Reocmmended

TABLE 2

STRAIGHT-SIDED SHAFT CAPACITIES AT APEX

Depth of Tip Embedment (feet)*	Allowable Single Shaft Compressor Capacities (kips) Shaft Diameters (inches)				
	12	18	24	30	36
15	8	12	17	23	29
20	15	23	33	44	56
25	NR	33	47	61	77
30	NR	45	63	81	101
35	NR	56	78	100	123
40	NR	67	92	118	145
45	NR	83	113	145	179
50	NR	97	132	169	207

NOTES:
* Feet below existing grade
NR Not Reocmmended

PILE CAPACITIES

Capacities of various size piles for the embankment apex area are shown in Table 3. The use of timber piles are not recommended at this site. Driving of timber piles to full depth to develop frictional resistance will most probably destroy the piles since they have to penetrate stiff to very stiff clays and dense sands.
We recommend the use of steel pipe or precast concrete piles. Considering the fact that the soil profile shows variations in type and properties we recommend that if a decision is made to use piles for foundation a test pile program be developed to determine field capacities.

TABLE 3

PILE CAPACITIES AT APEX

Depth of Tip Embedment (feet)	Allowable Single Pile Capacities (kips)						
	Square Precast Concrete (inches)			Steel Pipe Diameter (inches)			
	12	14	16	10	12	14	16
30	38	45	52	24	29	35	41
35	45	54	62	29	35	42	48
40	53	62	71	33	41	49	56
45	63	75	86	40	49	58	68
50	71	83	96	45	55	65	76

NOTES:

* Feet below existing grade

Pile Foundation Settlements:

Analysis of pile foundation settlement of proposed structures is dependent on the column loads as well as the size and configuration of the pile groups. Since specific configurations or criteria are not available at this stage a detailed settlement analysis is not performed. For pile driven in single rows widely spaced or used in small groups where the width of the pile cap is small relative to the pile length, the settlement of piles driven to 40 ft. to 45 ft. are estimated to be 1/4 in to 1/2 in. These movements are in addition of elastic shortening of piles, which depend on the type of the pile, actual applied load and the distribution of loads along the length of the pile.

Uplift

For piles subject to uplift forces, it is recommended that maximum tensile capacities not be greater than 30 percent of the maximum recommended single pile compression capacities.

Temporary Loads

The maximum recommended compression values may be increased by 30 percent for temporary wind loads.

Group Efficiency

No reductions from the single pile capacities appear necessary for the effects of group action in the case of clusters of piles driven to tip embedments in the very stiff to hard clays.

Driving to grade through the dense sands may be difficult. The hole should be no larger than 2 inches less than the outside diameter of the pile and no deeper than 5 feet less than the tip embedment. Care should be taken to avoid overwashing the holes. Piles may reach refusal in the very stiff to hard clays of the before reaching an embedment. Refusal driving resistances for steel and concrete piles may be estimated using the ENR formula. Higher blow counts may damage the piles. It is normally recommended that the maximum number of blows not exceed 100 and 75 blows per foot respectively for open-ended steel pipe and square precast concrete piles. However higher blow counts are sometimes allowed in order to get the piles to grade. This requires close inspection to reduce the chance of structurally damaging the piles.

Heave

When groups of piles are driven through stiff clays such as are found here, some of the previously driven piles can heave or be displaced due to driving later adjacent piles. The piles should be driven from the center outward. It is recommended that the butt elevations of each pile be determined immediately after it is driven and again when the group is completed. If any pile is noted to have heaved more than 1/4-inch, it should be redriven to at least its original final resistance.

Inspection

All pile driving operations should be inspected by a qualified geotechnical inspector and records of driving resistance versus depth, tip elevation, driving equipment, etc. should be permanently kept. The inspection services would determine when the desired embedments are attained and prevent overdriving ~~to~~ AND THUS avoid structural damage of the piles..

Spacing

It is recommended that the piles be driven on minimum center-to-center spacings of 3 pile diameters or 5 percent of pile length, whichever is greater.

Driving

It is recommended that the steel pipe piles, steel H-piles and prestressed concrete piles be driven with a hammer that develops a minimum manufacturer's rated energy of 19,500 foot-pounds per blow suspended from fixed leads.

SETTLEMENT

Settlement calculations made for the worst case scenarios show that at the apex the maximum expected primary consolidation near the center of the building site (1,000 ft.x 900 ft) for embankment and surcharge loads will be about 3 3/4 in. At other locations it will vary from 1 in. to 2 in.

Along the embankment settlements will vary from 1/2 in. to 2 in. depending on the height and soil types at the specific locations. It is expected that 90% of the primary consolidation will take place either during the construction or during the six months following the construction. Secondary settlement of these soils were found to be are negligible.

1. CAN WE SEE THE CALCS FOR THE 3 3/4 in "S"?
2. WHAT IS ΔS?
3. IF 9 MOS SURCHARGE IS USED & PILES THEN WHAT IS "S" SCENARIO?

No settlement or bearing capacity values for the embankment have been presented. They will depend on the properties of the compacted, or stabilized soils in the embankment.

The above is a summary of the geotechnical investigation authorized by the California Institute of Technology for the LIGO facility and it is prepared to satisfy the requirements of our contract with the Institute

APPENDIX A

GEOTECHNICAL LABORATORY TEST RESULTS

APPENDIX A
TABLE OF CONTENTS

IMPORTANT INFORMATION
ABOUT YOUR
GEOTECHNICAL ENGINEERING REPORT

More construction problems are caused by site subsurface conditions than any other factor. As troublesome as subsurface problems can be, their frequency and extent have been lessened considerably in recent years, due in large measure to programs and publications of ASFE/ The Association of Engineering Firms Practicing in the Geosciences.

The following suggestions and observations are offered to help you reduce the geotechnical-related delays, cost-overruns and other costly headaches that can occur during a construction project.

A GEOTECHNICAL ENGINEERING REPORT IS BASED ON A UNIQUE SET OF PROJECT-SPECIFIC FACTORS

A geotechnical engineering report is based on a subsurface exploration plan designed to incorporate a unique set of project-specific factors. These typically include: the general nature of the structure involved, its size and configuration; the location of the structure on the site and its orientation; physical concomitants such as access roads, parking lots, and underground utilities, and the level of additional risk which the client assumed by virtue of limitations imposed upon the exploratory program. To help avoid costly problems, consult the geotechnical engineer to determine how any factors which change subsequent to the date of the report may affect its recommendations.

Unless your consulting geotechnical engineer indicates otherwise, *your geotechnical engineering report should not be used*:

- When the nature of the proposed structure is changed, for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one;
- when the size or configuration of the proposed structure is altered;
- when the location or orientation of the proposed structure is modified;
- when there is a change of ownership, or
- for application to an adjacent site.

Geotechnical engineers cannot accept responsibility for problems which may develop if they are not consulted after factors considered in their report's development have changed.

MOST GEOTECHNICAL "FINDINGS" ARE PROFESSIONAL ESTIMATES

Site exploration identifies actual subsurface conditions only at those points where samples are taken, when they are taken. Data derived through sampling and subsequent laboratory testing are extrapolated by geotechnical engineers who then render an opinion about overall subsurface conditions, their likely reaction to proposed construction activity, and appropriate foundation design. Even under optimal circumstances actual conditions may differ from those inferred to exist, because no geotechnical engineer, no matter how qualified, and no subsurface exploration program, no matter how comprehensive, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than a report indicates. Actual conditions in areas not sampled may differ from predictions. *Nothing can be done to prevent the unanticipated, but steps can be taken to help minimize their impact.* For this reason, *most experienced owners retain their geotechnical consultants through the construction stage*, to identify variances, conduct additional tests which may be needed, and to recommend solutions to problems encountered on site.

SUBSURFACE CONDITIONS CAN CHANGE

Subsurface conditions may be modified by constantly-changing natural forces. Because a geotechnical engineering report is based on conditions which existed at the time of subsurface exploration, *construction decisions should not be based on a geotechnical engineering report whose adequacy may have been affected by time.* Speak with the geotechnical consultant to learn if additional tests are advisable before construction starts.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical report. The geotechnical engineer should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

GEOTECHNICAL SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND PERSONS

Geotechnical engineers' reports are prepared to meet the specific needs of specific individuals. A report prepared for a consulting civil engineer may not be adequate for a construction contractor, or even some other consulting civil engineer. Unless indicated otherwise, this report was prepared expressly for the client involved and expressly for purposes indicated by the client. Use by any other persons for any purpose, or by the client for a different purpose, may result in problems. *No individual other than the client should apply this report for its intended purpose without first conferring with the geotechnical engineer. No person should apply this report for any purpose other than that originally contemplated without first conferring with the geotechnical engineer.*

SUMMARY OF GEOTECHNICAL LABORATORY TEST RESULTS

LABORATORY DATA SUMMARY
LIGO 93B107C

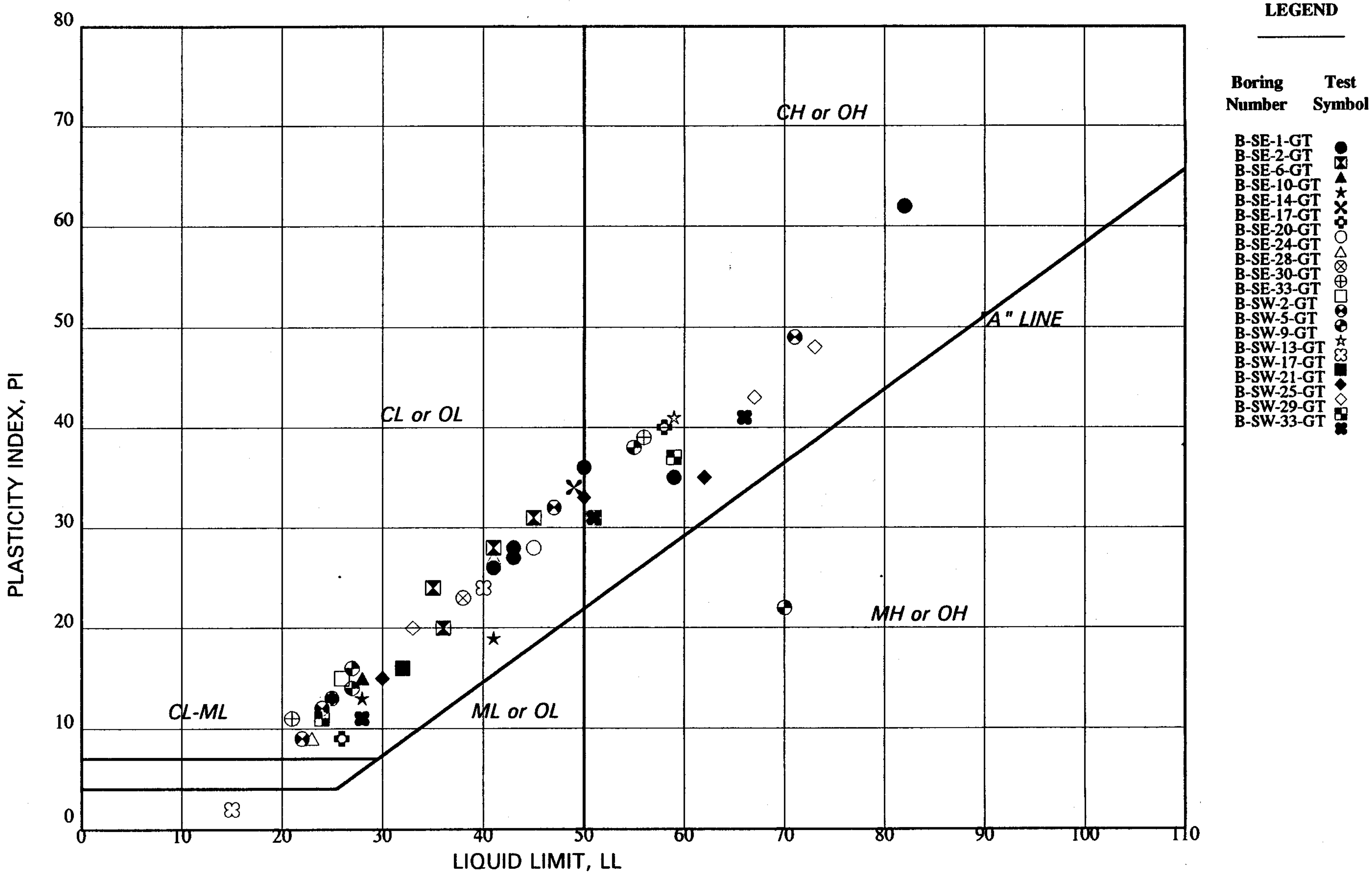
PT.ID	DEPTH	COMPRESS.	M%	WET DN	LL	PL	PI	SIEVE
B-SE-1-GT	0.5		16					70.9
B-SE-1-GT	2.0		19		43	15	28	
B-SE-1-GT	8.0	2.49*	24	125.3	43	16	27	
B-SE-1-GT	18.0		38					
B-SE-1-GT	28.0		25		41	15	26	
B-SE-1-GT	33.0	0.96	38	112.2	82	20	62	
B-SE-1-GT	38.0		24		50	14	36	
B-SE-1-GT	48.0		30		59	24	35	
B-SE-2-GT	4.0	1.53*	15	131.7	35	11	24	39.7
B-SE-2-GT	8.0		15		41	13	28	
B-SE-2-GT	14.5		21					9.2
B-SE-2-GT	28.0	1.95*	23	125.4	45	14	31	
B-SE-2-GT	38.0		31					
B-SE-2-GT	43.0	2.11	20	126.2	36	16	20	
B-SE-6-GT	4.0		17		28	13	15	
B-SE-6-GT	13.5		19					5.0
B-SE-6-GT	18.0		24					
B-SE-6-GT	22.5		29					
B-SE-10-GT	2.0		21					
B-SE-10-GT	8.0		21		28	15	13	
B-SE-10-GT	18.0	1.91*	23	123.0				
B-SE-10-GT	22.5	1.74						
B-SE-10-GT	23.0		31	122.6	41	22	19	
B-SE-14-GT	6.0		19					
B-SE-14-GT	13.0	2.23	23	124.6	49	15	34	
B-SE-14-GT	22.5		29					
B-SE-17-GT	4.0		14					
B-SE-17-GT	8.0		20		26	17	9	
B-SE-17-GT	18.0	2.32*	25	122.6	58	18	40	
B-SE-20-GT	2.0		21					
B-SE-20-GT	6.0		14					
B-SE-20-GT	8.0	1.30	16	129.2	45	17	28	
B-SE-20-GT	13.0		23					
B-SE-20-GT	18.0		23					
B-SE-24-GT	0.5		24					
B-SE-24-GT	2.0		22					
B-SE-24-GT	8.0		19		23	14	9	
B-SE-24-GT	18.0	1.85*	20	123.6	41	14	27	
B-SE-28-GT	0.5		22					
B-SE-28-GT	4.0		15					
B-SE-28-GT	8.0		23					
B-SE-28-GT	13.0	1.82	22	126.8	38	15	23	
B-SE-28-GT	22.5		25					

* denotes UU

LABORATORY DATA SUMMARY
LIGO 93B107C

B-SE-30-GT	4.0	1.06	14	134.9	21	10	11	
B-SE-30-GT	8.0		22					
B-SE-30-GT	13.0	2.36*	23	126.4	56	17	39	
B-SE-30-GT	22.5		37					
B-SE-33-GT	6.0	1.29	14	133.9	26	11	15	
B-SE-33-GT	18.0	0.97	30	119.4	51	20	31	
B-SW-2-GT	4.0		17		25	12	13	
B-SW-2-GT	6.0	1.77	19	123.5	47	15	32	
B-SW-2-GT	13.0	1.43*	15	130.4	22	13	9	
B-SW-2-GT	18.0		35		71	22	49	
B-SW-2-GT	28.0		27					
B-SW-2-GT	38.0	0.74*	16	126.4	24	12	12	
B-SW-5-GT	6.0		18		27	13	14	72.3
B-SW-5-GT	8.0	2.74	15	134.0	27	11	16	
B-SW-5-GT	13.0		29		70	48	22	98.7
B-SW-5-GT	18.0	1.90	24	124.1	55	17	38	
B-SW-9-GT	2.0		20					
B-SW-9-GT	8.0	1.81*	20	123.6				11.3
B-SW-9-GT	13.0		14					52.4
B-SW-9-GT	22.5	2.44	32	122.3	59	18	41	
B-SW-13-GT	8.0	1.89*	14	133.8				
B-SW-13-GT	13.0		13		15	13	2	
B-SW-13-GT	22.5		20		40	16	24	
B-SW-17-GT	8.0	2.24*	18	126.7	32	16	16	
B-SW-17-GT	22.5		37					98.2
B-SW-21-GT	4.0		17					
B-SW-21-GT	8.0	1.72*	15	131.8	25	12	13	
B-SW-21-GT	13.0		19		30	15	15	
B-SW-21-GT	18.0	0.72*	34	114.4	50	17	33	
B-SW-21-GT	22.5	0.81	43	115.4	62	27	35	
B-SW-25-GT	4.0		20		33	13	20	
B-SW-25-GT	10.5		19					8.9
B-SW-25-GT	13.0	0.37	56	100.9	73	25	48	
B-SW-25-GT	18.0	0.43	42	106.1	67	24	43	
B-SW-29-GT	4.0	1.06	19	127.0	24	13	11	
B-SW-29-GT	8.0		19					
B-SW-29-GT	15.5		20					8.8
B-SW-29-GT	22.5		34		59	22	37	
B-SW-33-GT	4.5		16					16.8
B-SW-33-GT	10.5		23					9.5
B-SW-33-GT	18.0	0.88*	51	104.9	66	25	41	
B-SW-33-GT	23.0		24		28	17	11	
B-SW-33-GT	33.0		28					
B-SW-33-GT	43.0		22		51	20	31	

* denotes UU

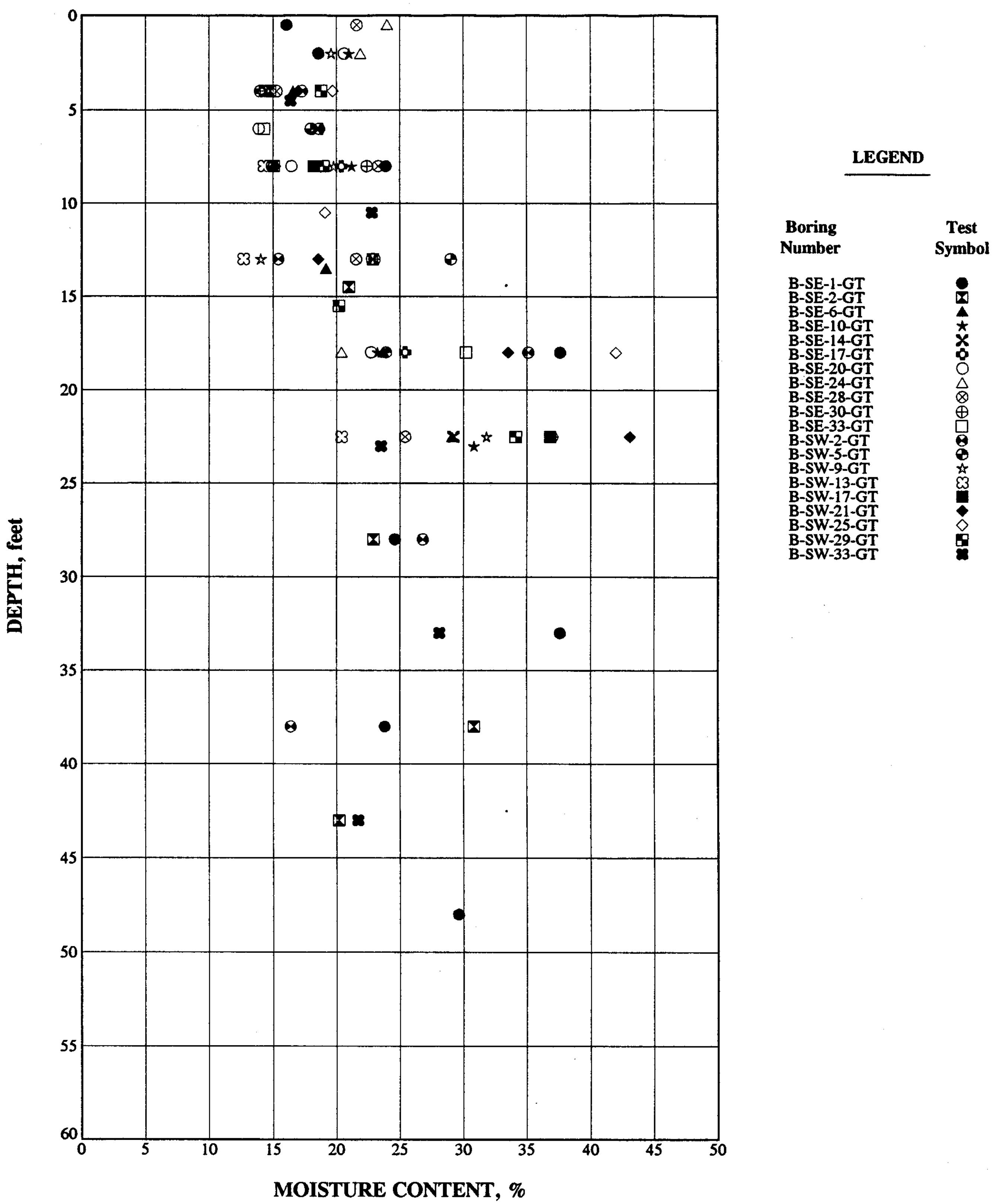


Project: *LIGO*
Project Number: *93B107C*

PLASTICITY CHART

11/21/94 sanaatt3 3B107

Woodward-Clyde Consultants



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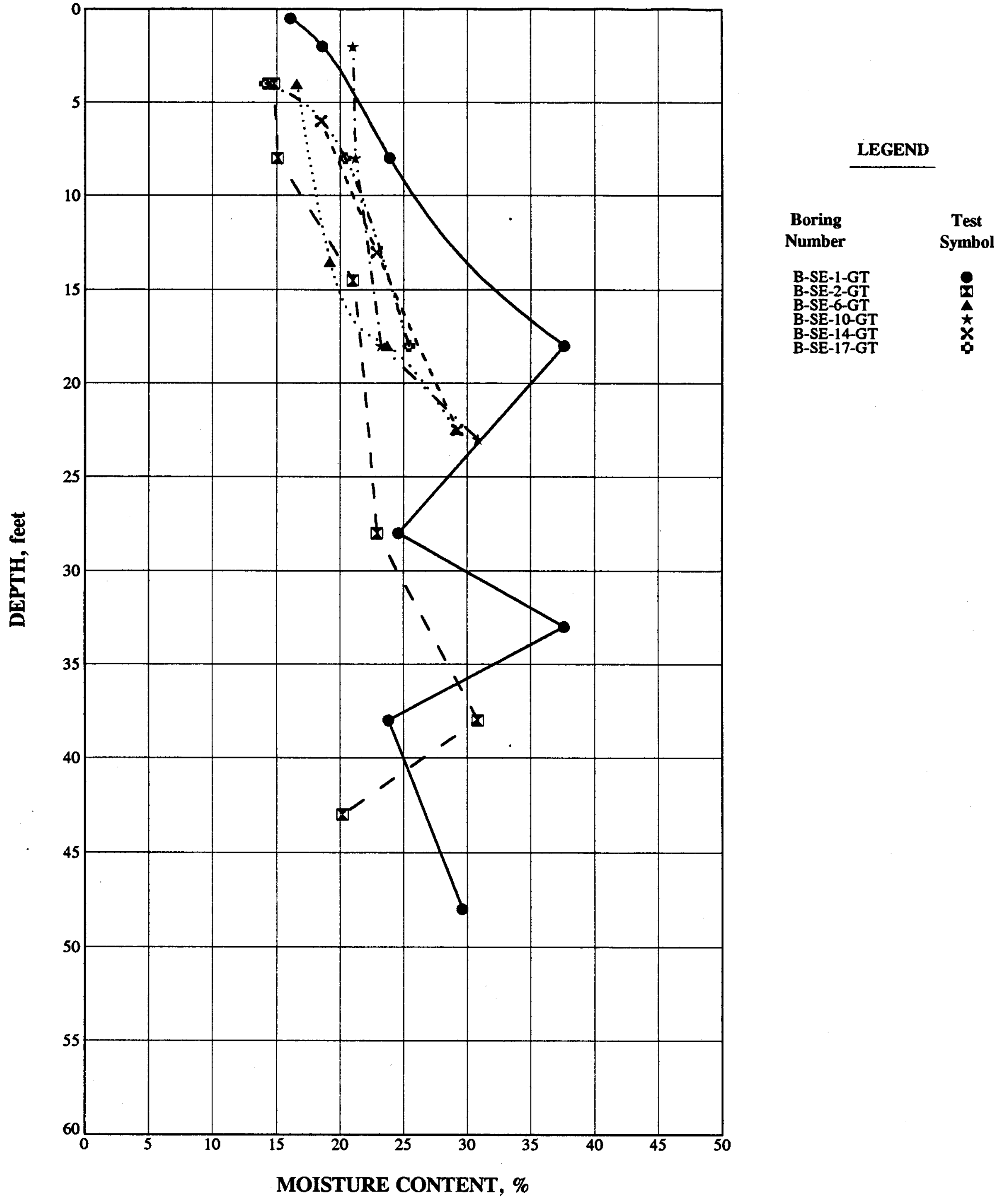
Project Number: **93B107C**

MOISTURE CONTENT vs DEPTH

Woodward-Clyde Consultants



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Project Number: 93B107C	

11/21/94 MCVSDPT 3B107

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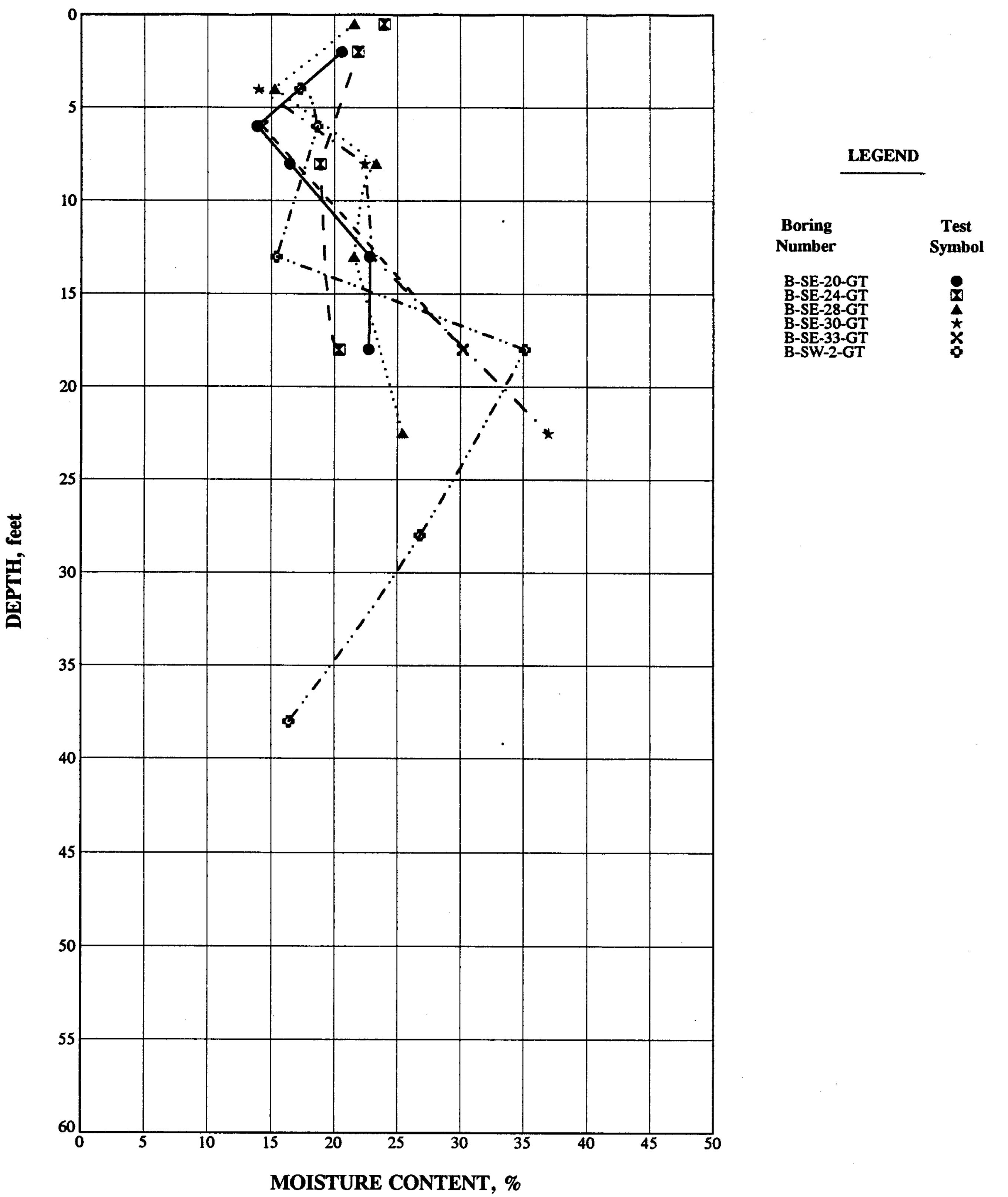

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MOISTURE CONTENT vs DEPTH

11/21/94 MCVSDPT 3B107

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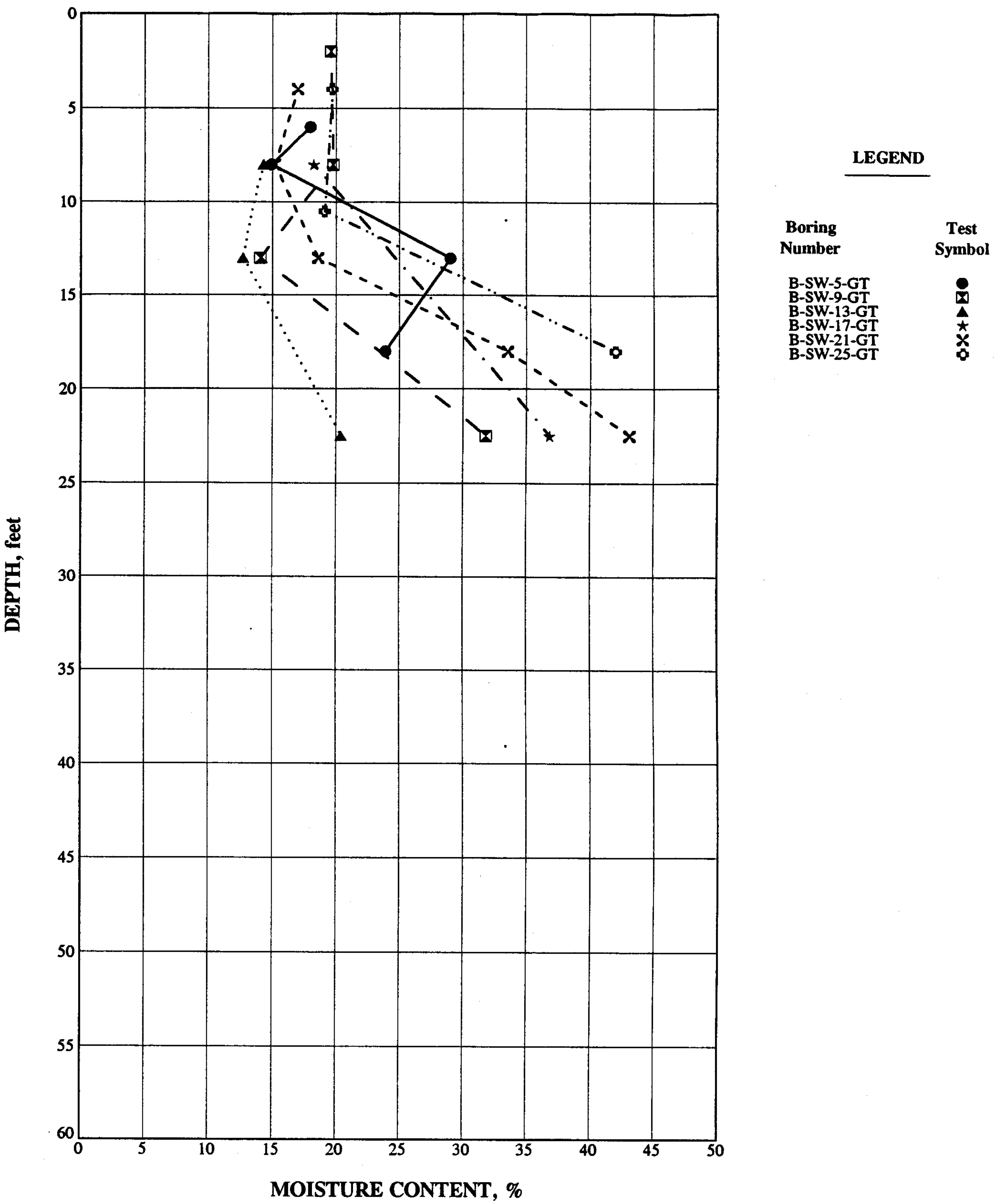

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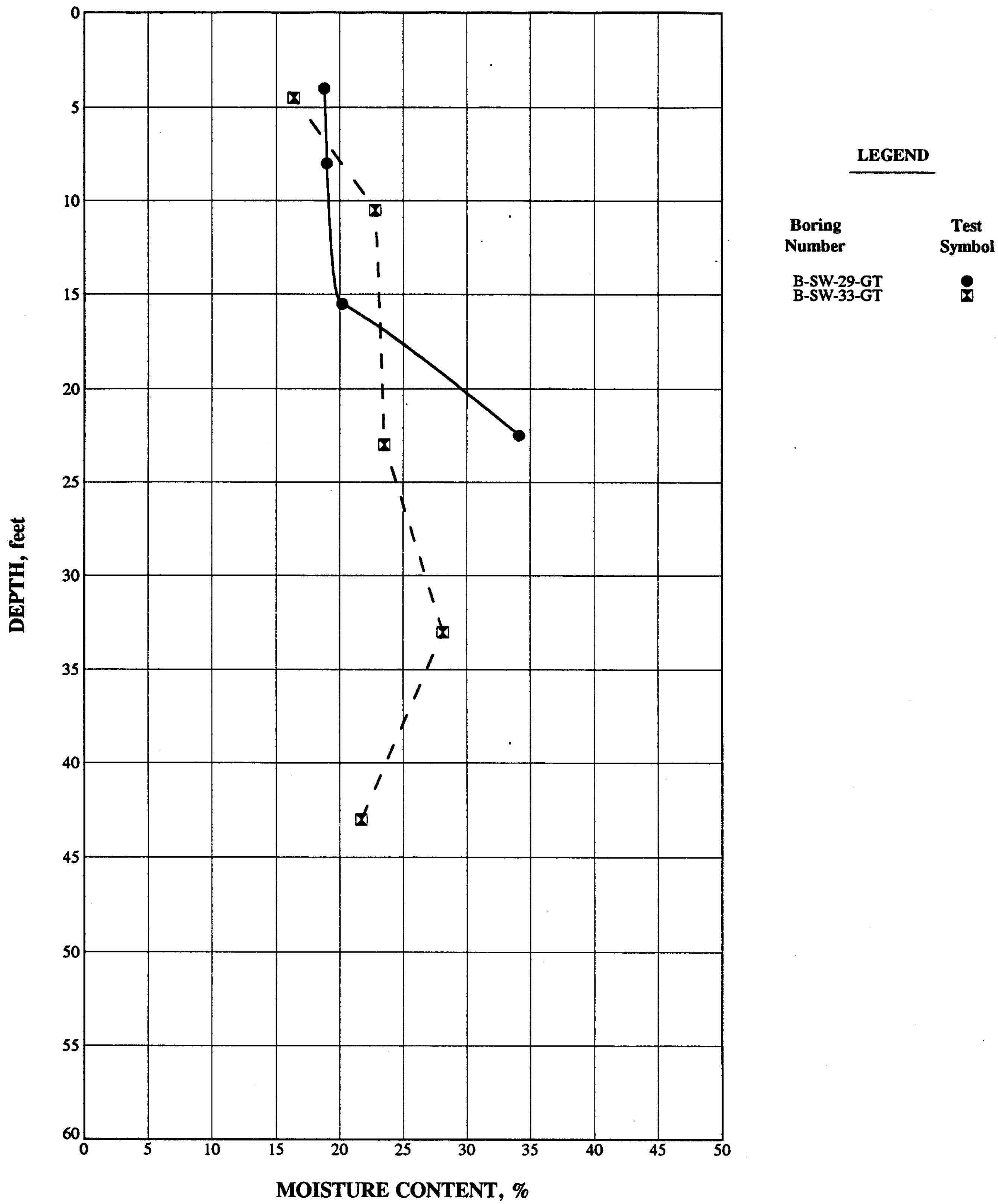

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Project Number: **93B107C**

MOISTURE CONTENT vs DEPTH

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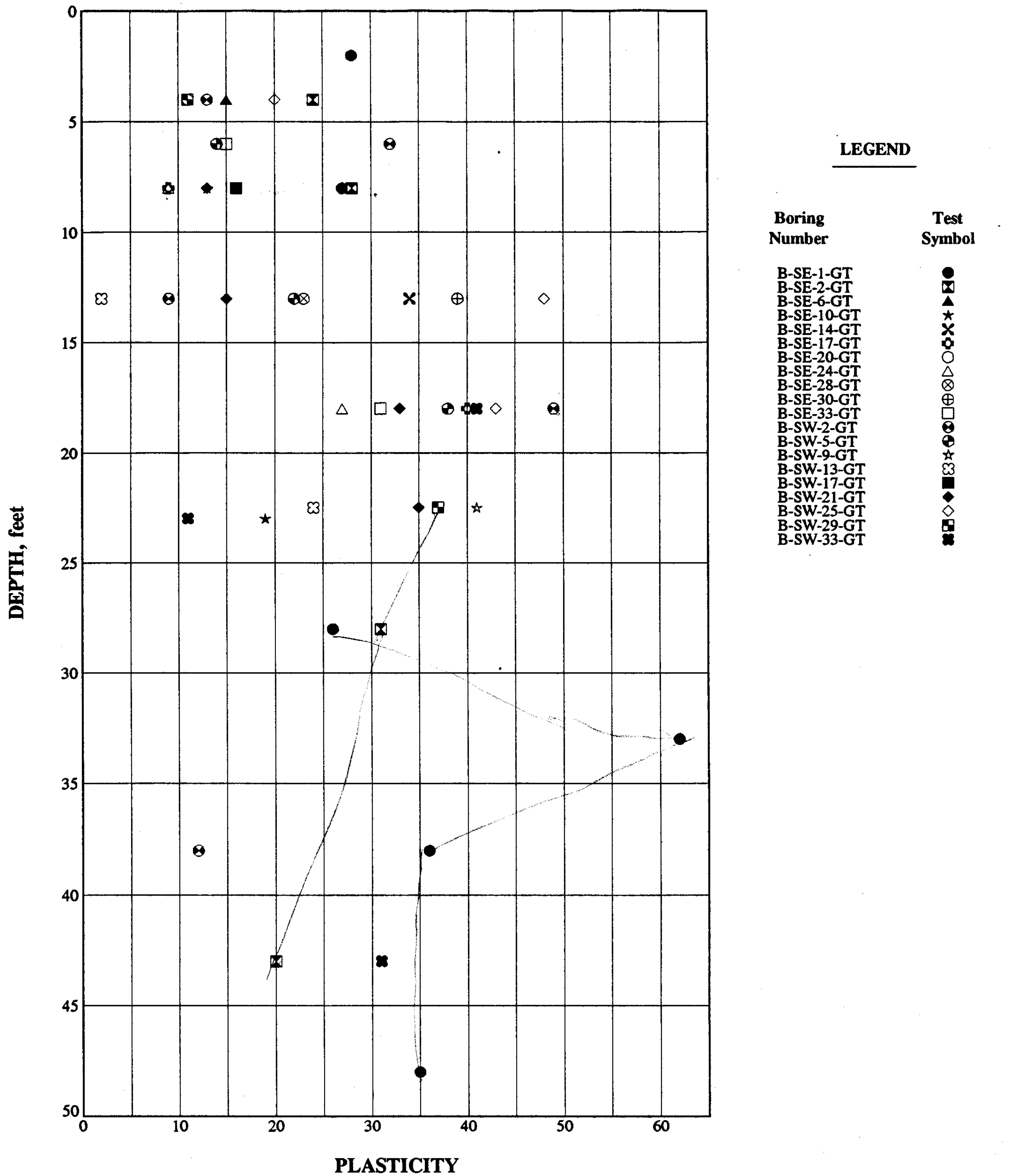

Project: **LIGO**
Project Number: **93B107C**

PLASTICITY INDEX vs DEPTH

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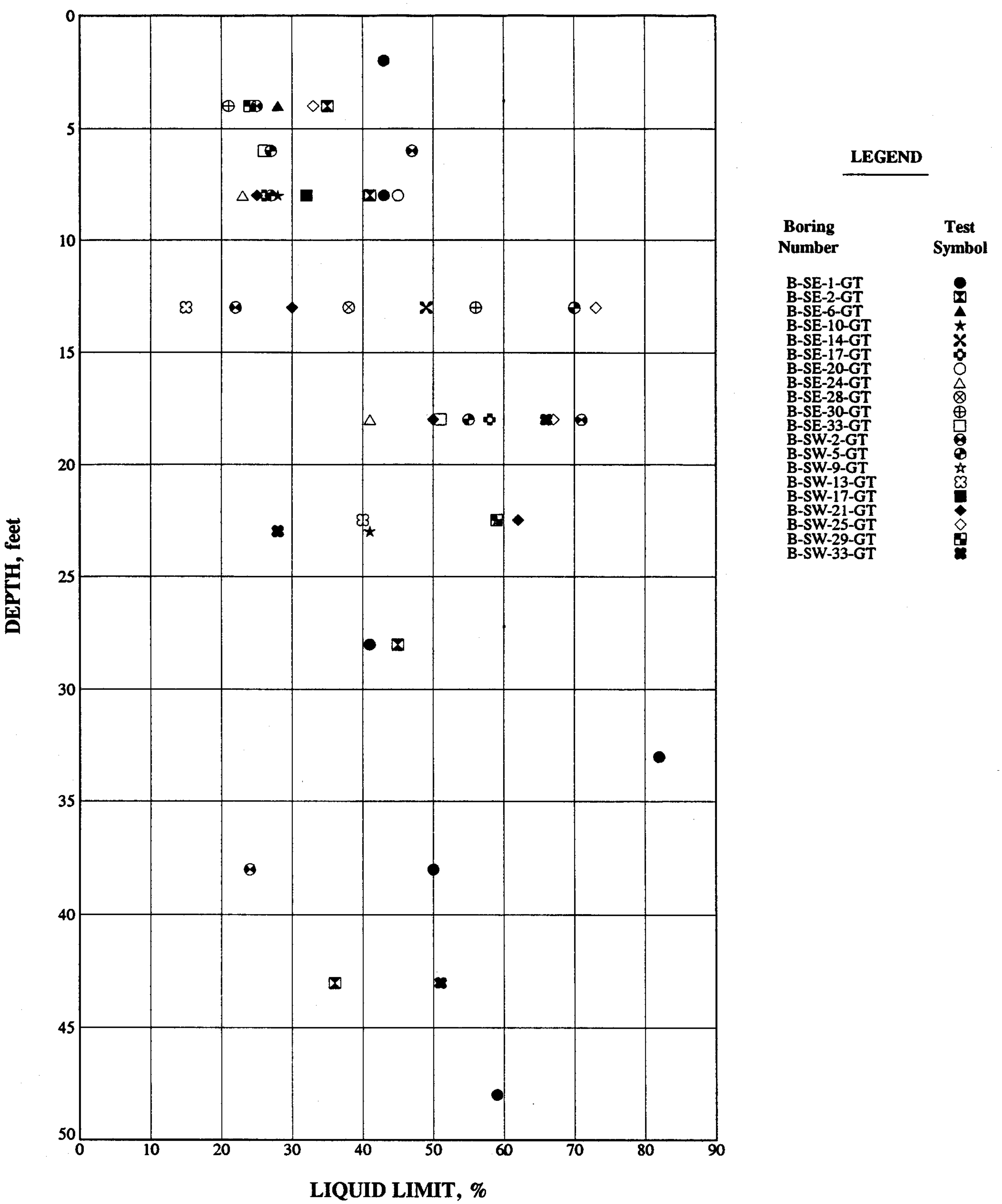

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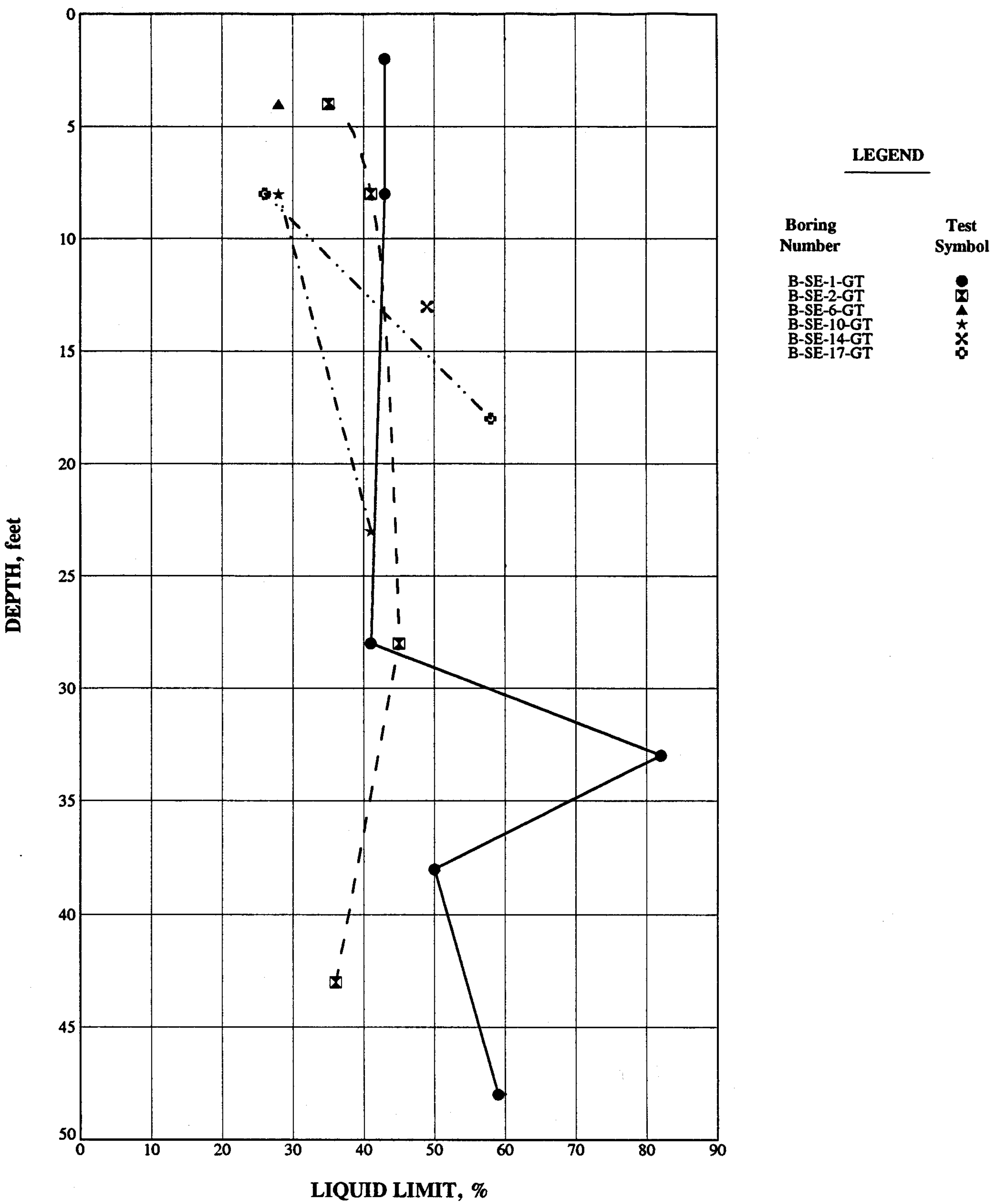
Project Number: **93B107C**

LIQUID LIMIT vs DEPTH

11/21/94 LLVSDPT 3B107

Woodward-Clyde Consultants



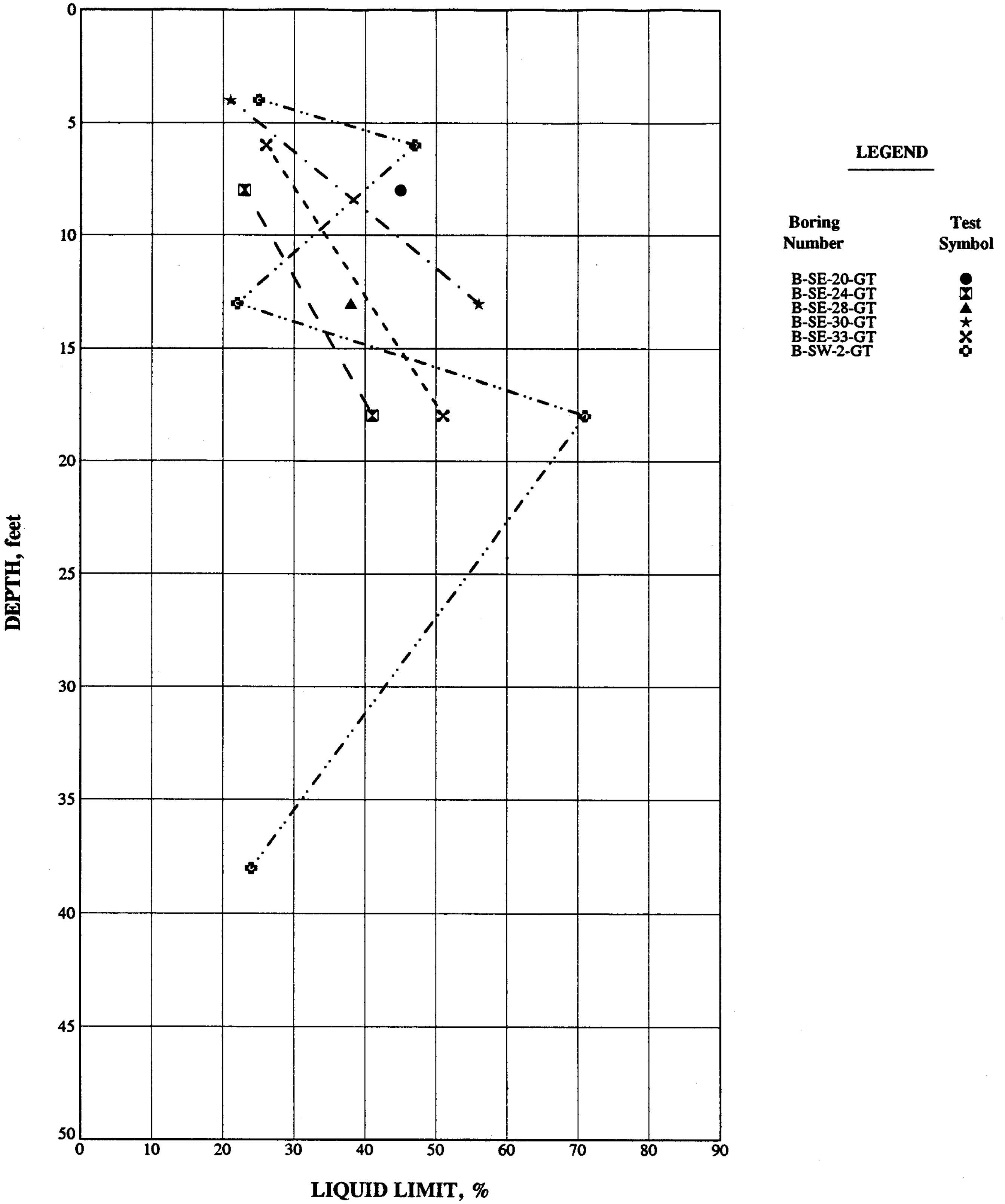
Project: **LIGO**

Project Number: **93B107C**

LIQUID LIMIT vs DEPTH

11/21/94 LLVSDPT 3B107

Woodward-Clyde Consultants



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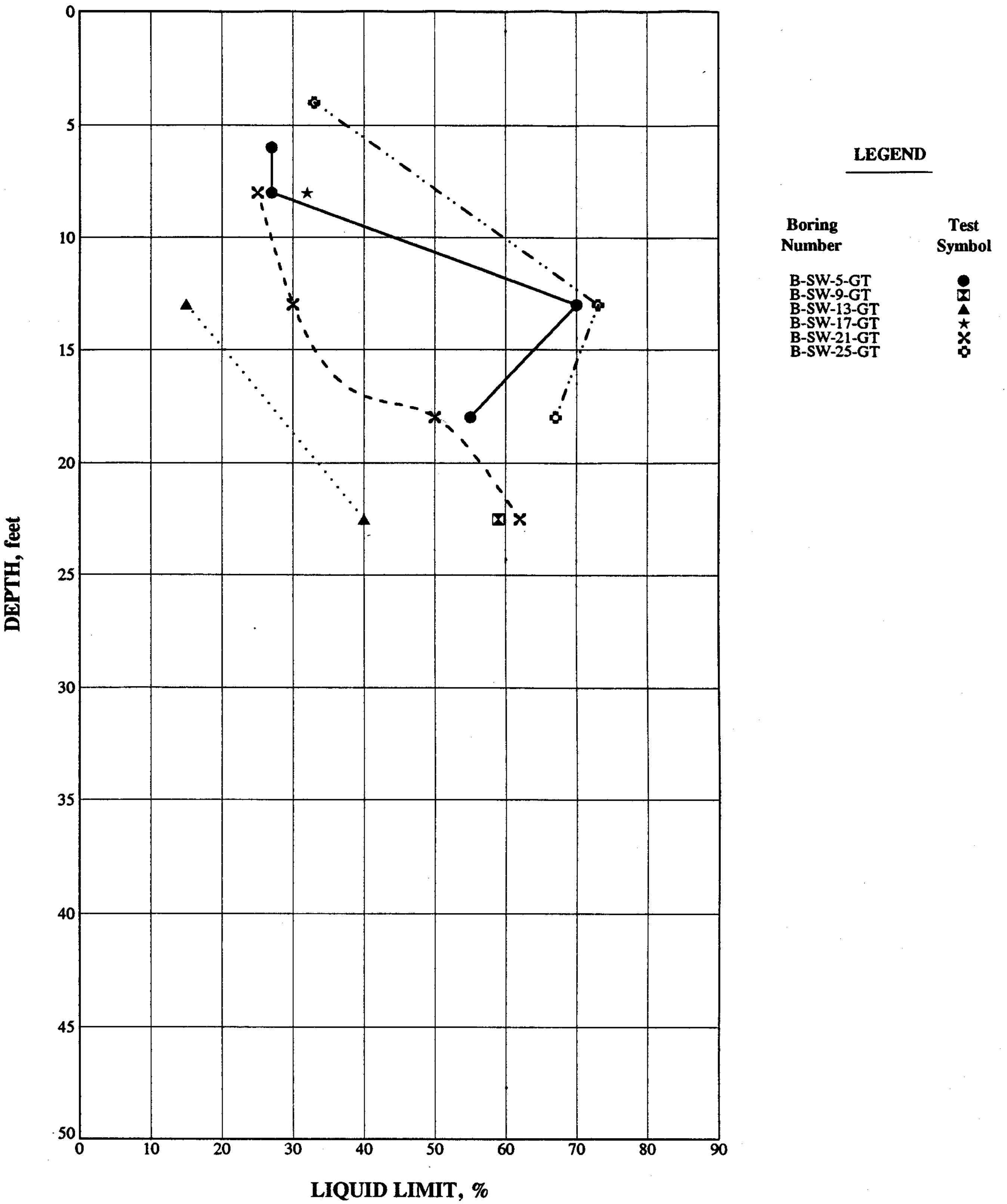

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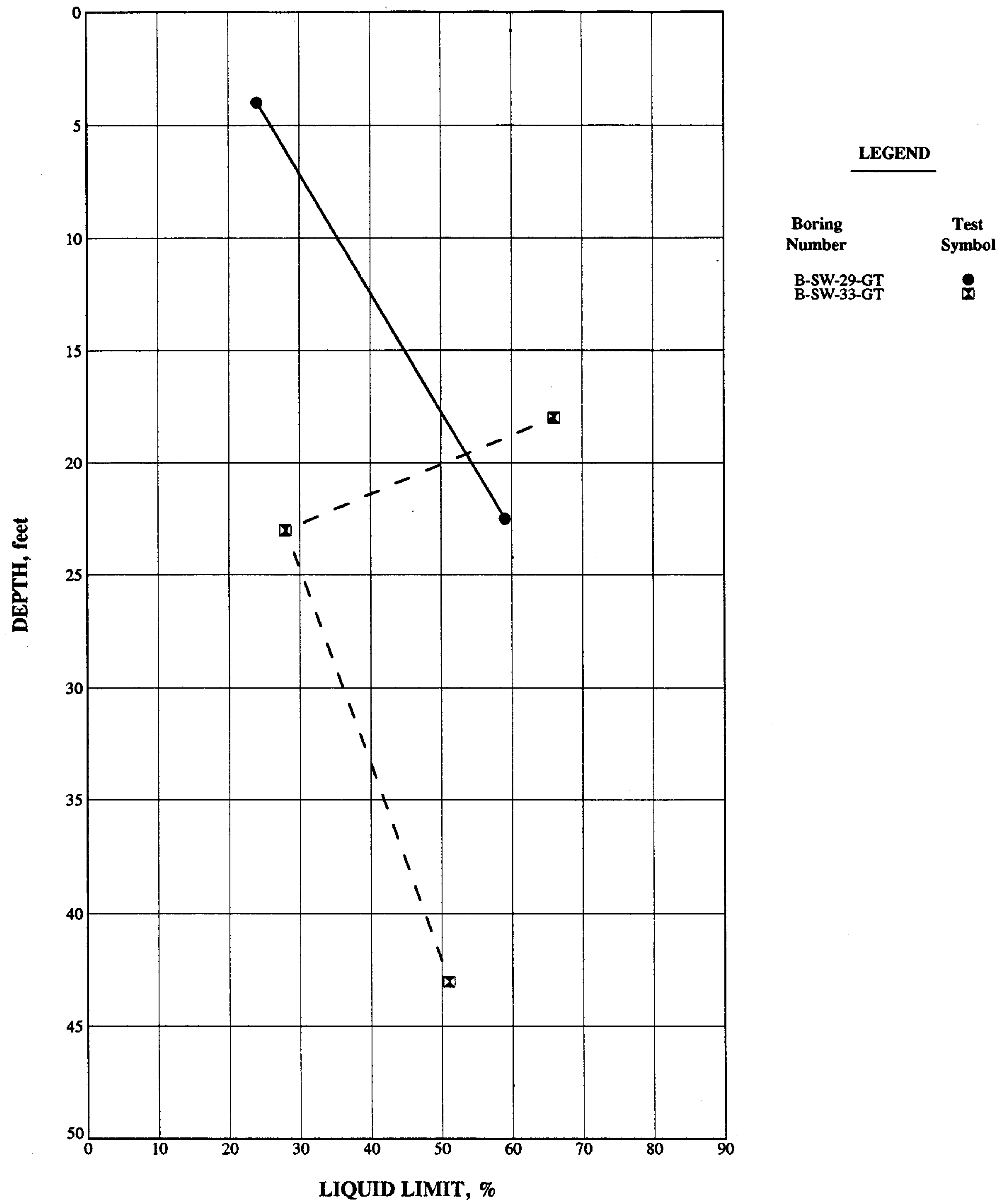


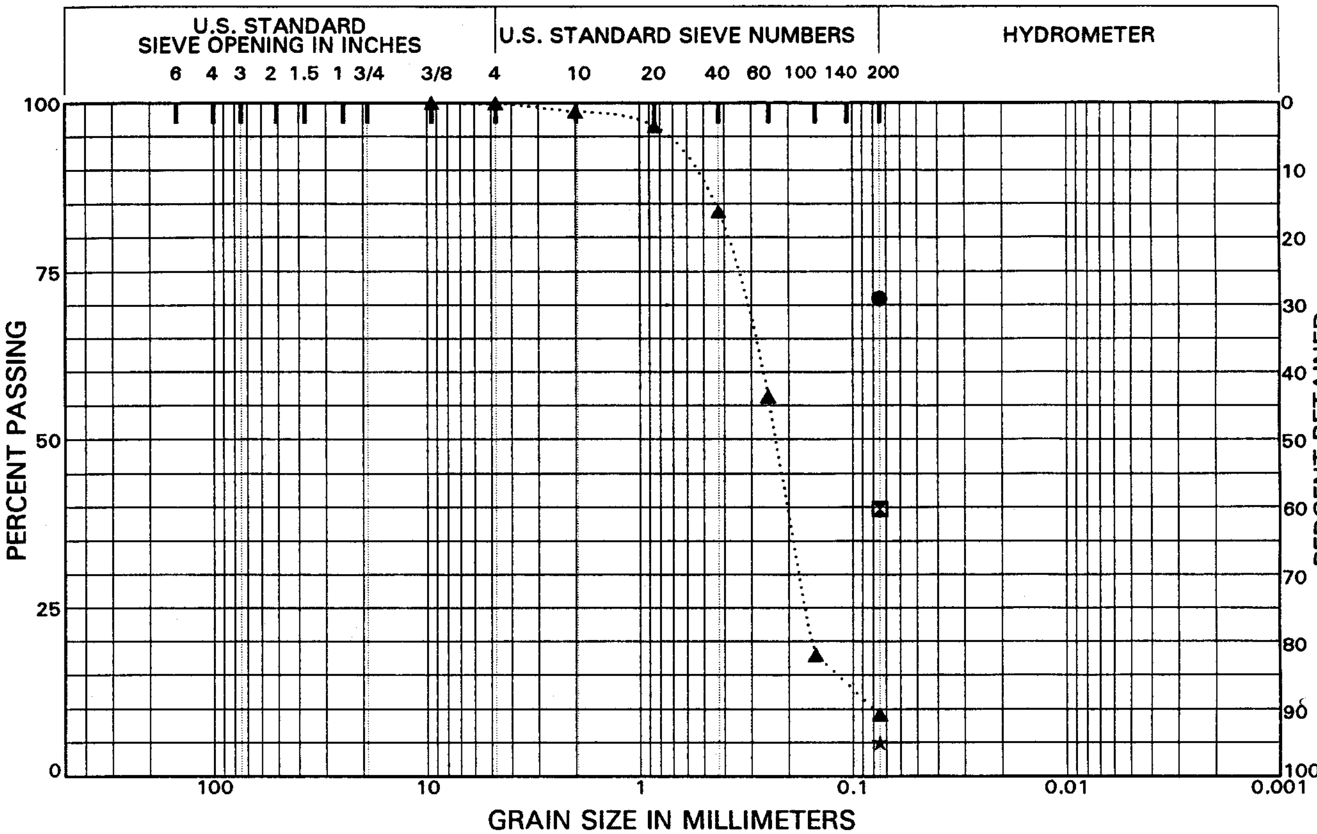
Project: LIGO
Project Number: 93B107C

LIQUID LIMIT vs DEPTH

11/21/94 LLVSDPT 3B107

Woodward-Clyde Consultants

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	



Boring Number	Depth (feet)	Symbol	Classification
B-SE-1-GT	0.5	●	(ML to CL)
B-SE-2-GT	4.0	⊠	(SC)
B-SE-2-GT	14.5	▲	(SP)
B-SE-6-GT	13.5	★	(SP)

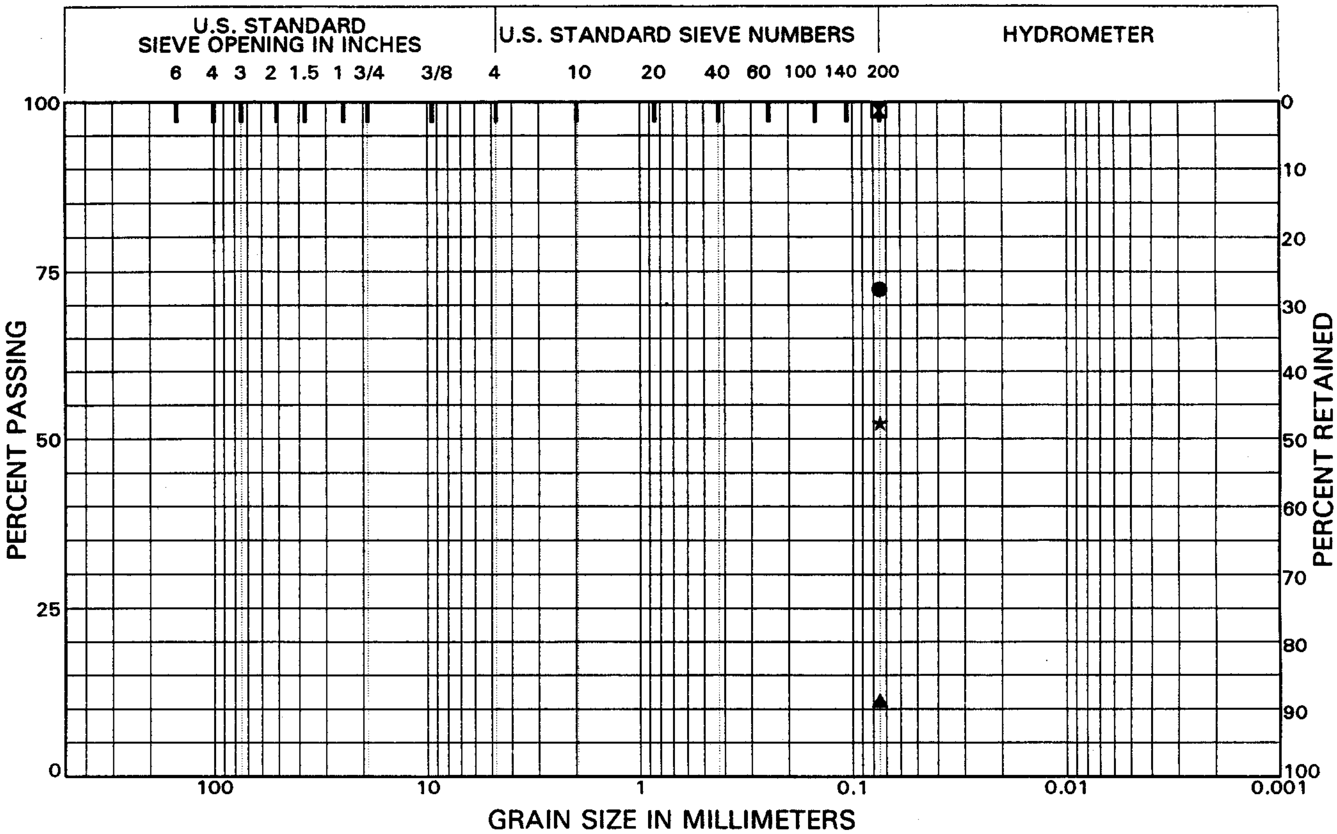
Project: LIGO
Project Number: 93B107C

GRAIN SIZE DISTRIBUTION CURVES

11/21/94 SVANLS7 38107

Woodward-Clyde Consultants

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	



Boring Number	Depth (feet)	Symbol	Classification
B-SW-5-GT	6.0	●	(CL)
B-SW-5-GT	13.0	⧗	(CH)
B-SW-9-GT	8.0	▲	(SP-SM)
B-SW-9-GT	13.0	★	(SM-ML)

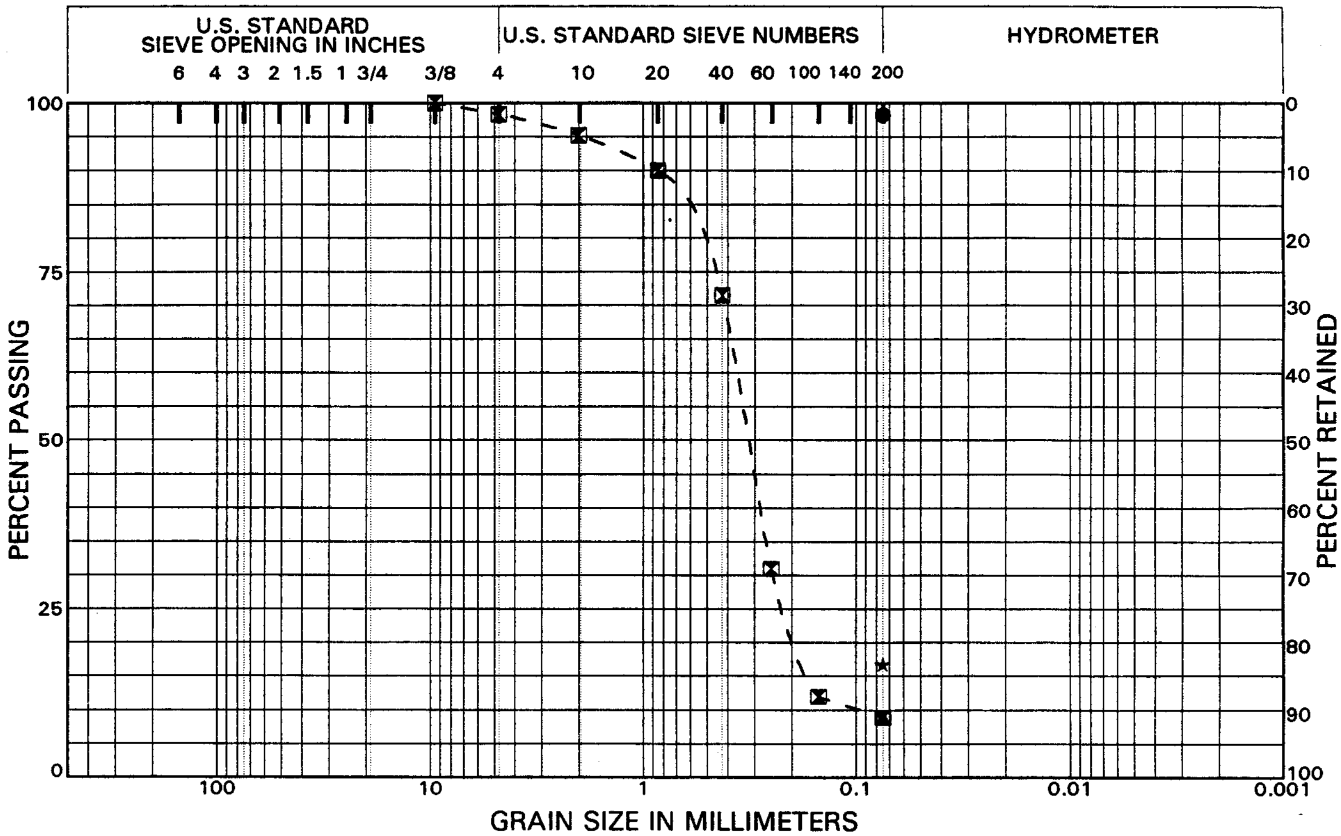
Project: LIGO
Project Number: 93B107C

GRAIN SIZE DISTRIBUTION CURVES

11/21/94 SVANLS7 3B107

Woodward-Clyde Consultants

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

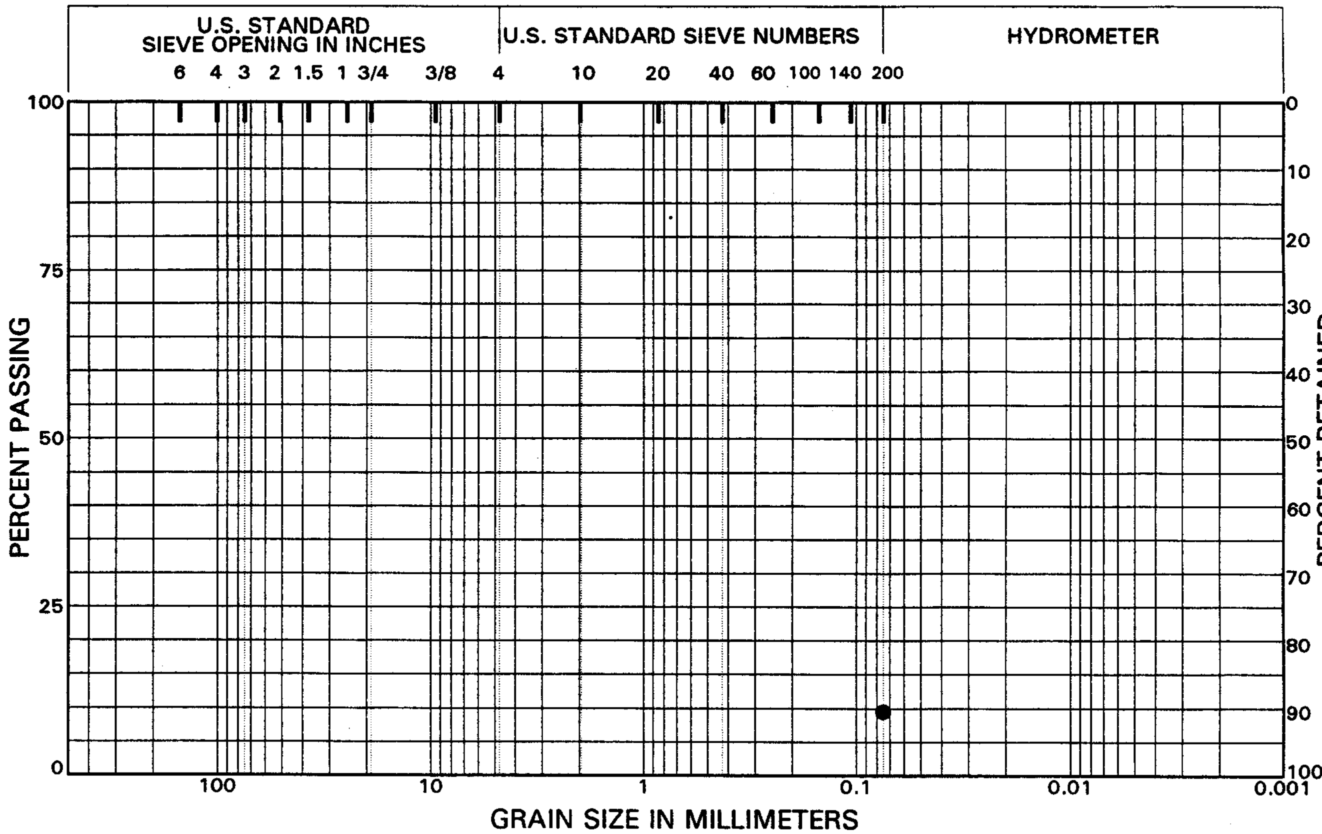


Boring Number	Depth (feet)	Symbol	Classification
B-SW-17-GT	22.5	●	(CL)
B-SW-25-GT	10.5	⊠	(SP)
B-SW-29-GT	15.5	▲	(SP-SM)
B-SW-33-GT	4.5	★	(SM)

Project: LIGO
Project Number: 93B107C

GRAIN SIZE DISTRIBUTION CURVES

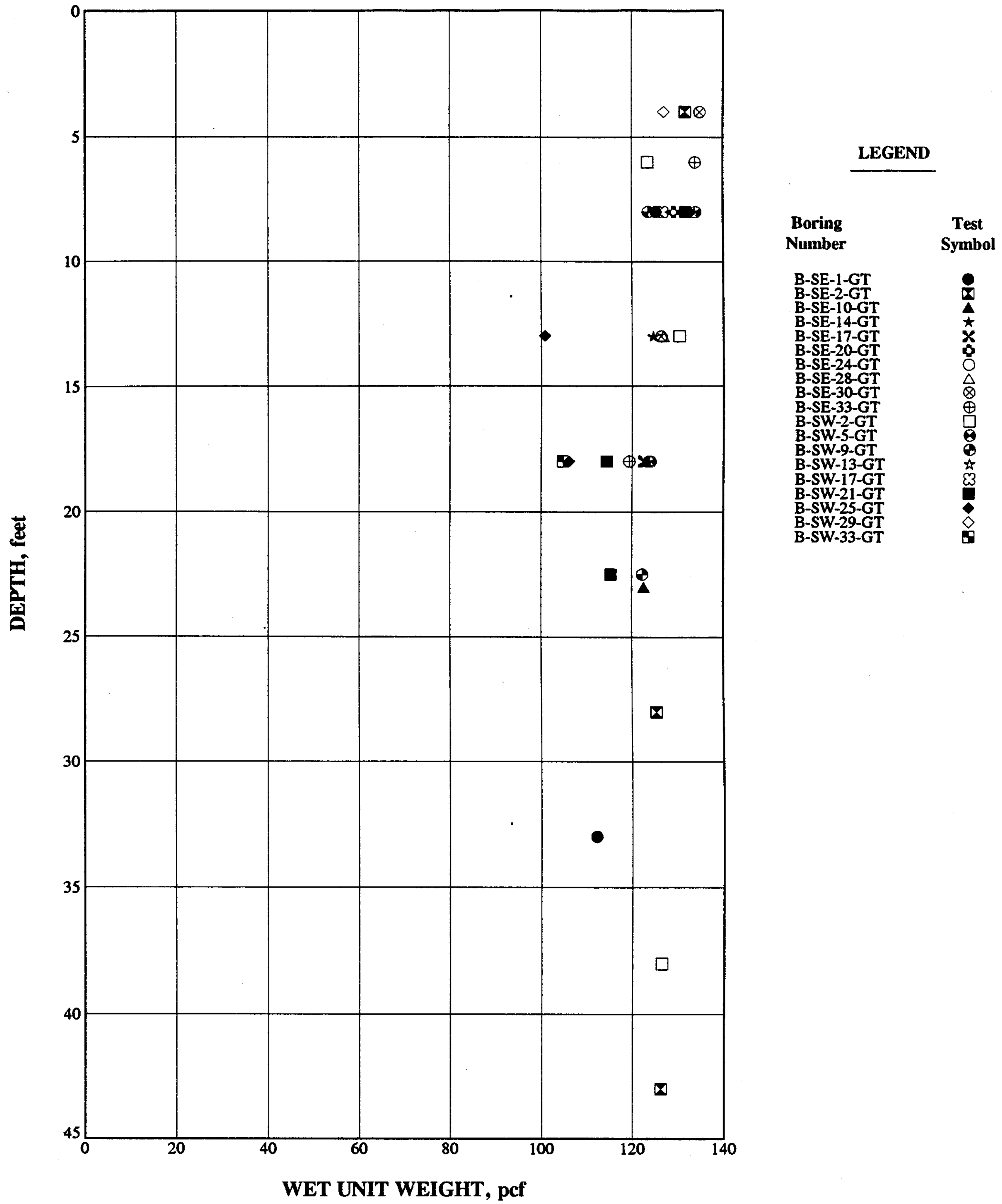
COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	



Boring Number	Depth (feet)	Symbol	Classification
B-SW-33-GT	10.5	●	(SP-SM)

Project: LIGO
Project Number: 93B107C

GRAIN SIZE DISTRIBUTION CURVES



Project: LIGO Project Number: 93B107C	**WET UNIT WEIGHT vs DEPTH**

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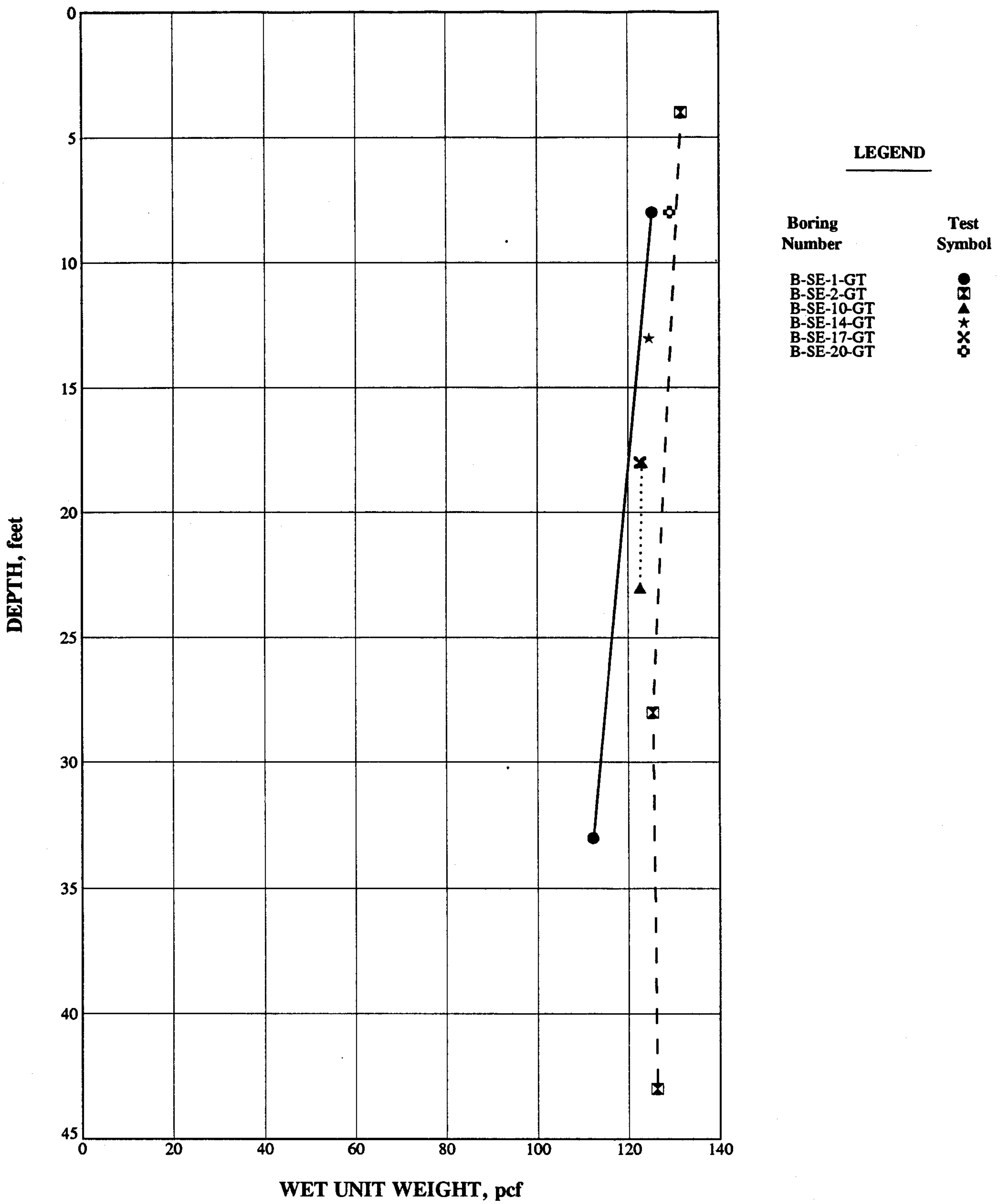
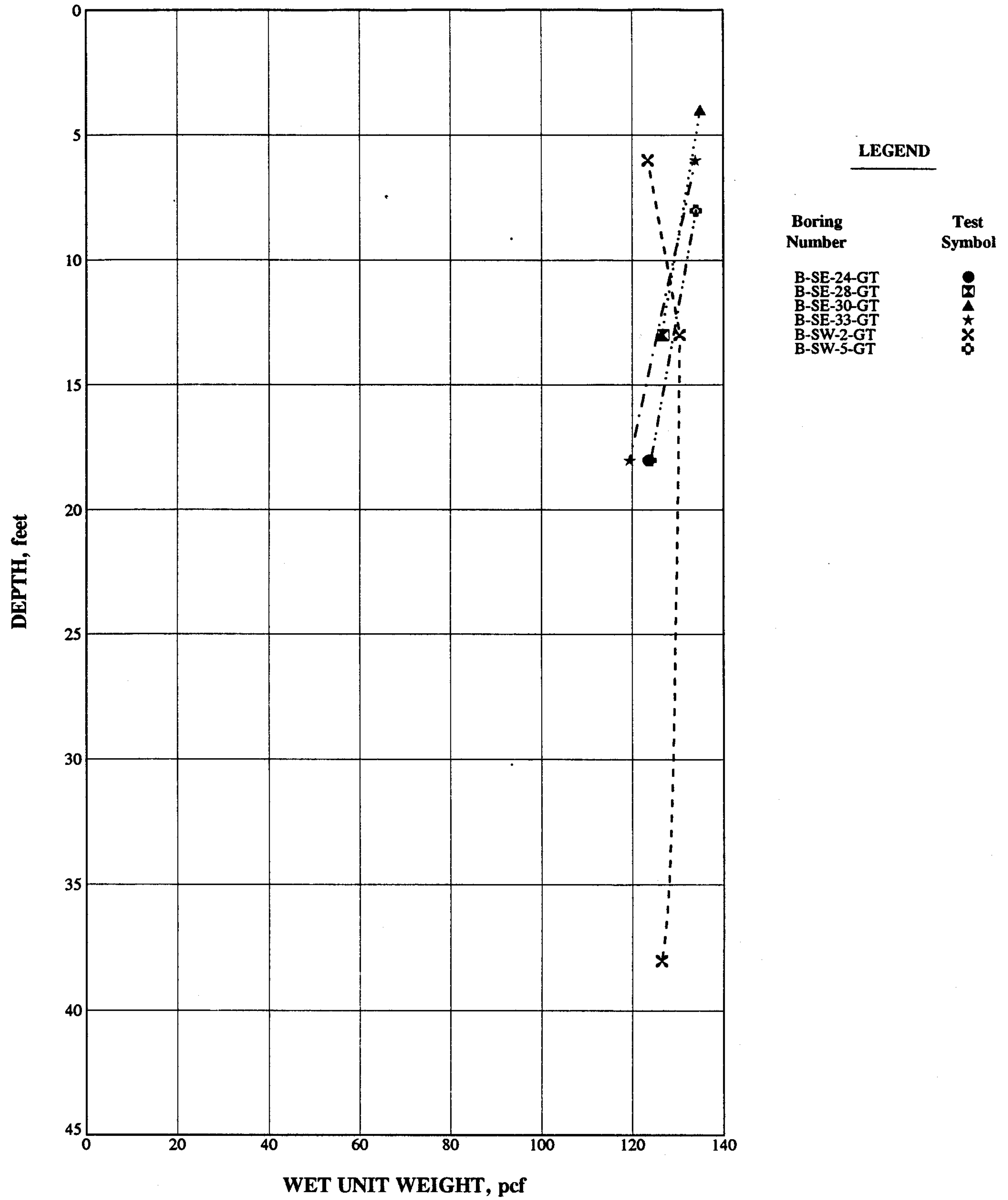


Project: LIGO
Project Number: 93B107C

WET UNIT WEIGHT vs DEPTH

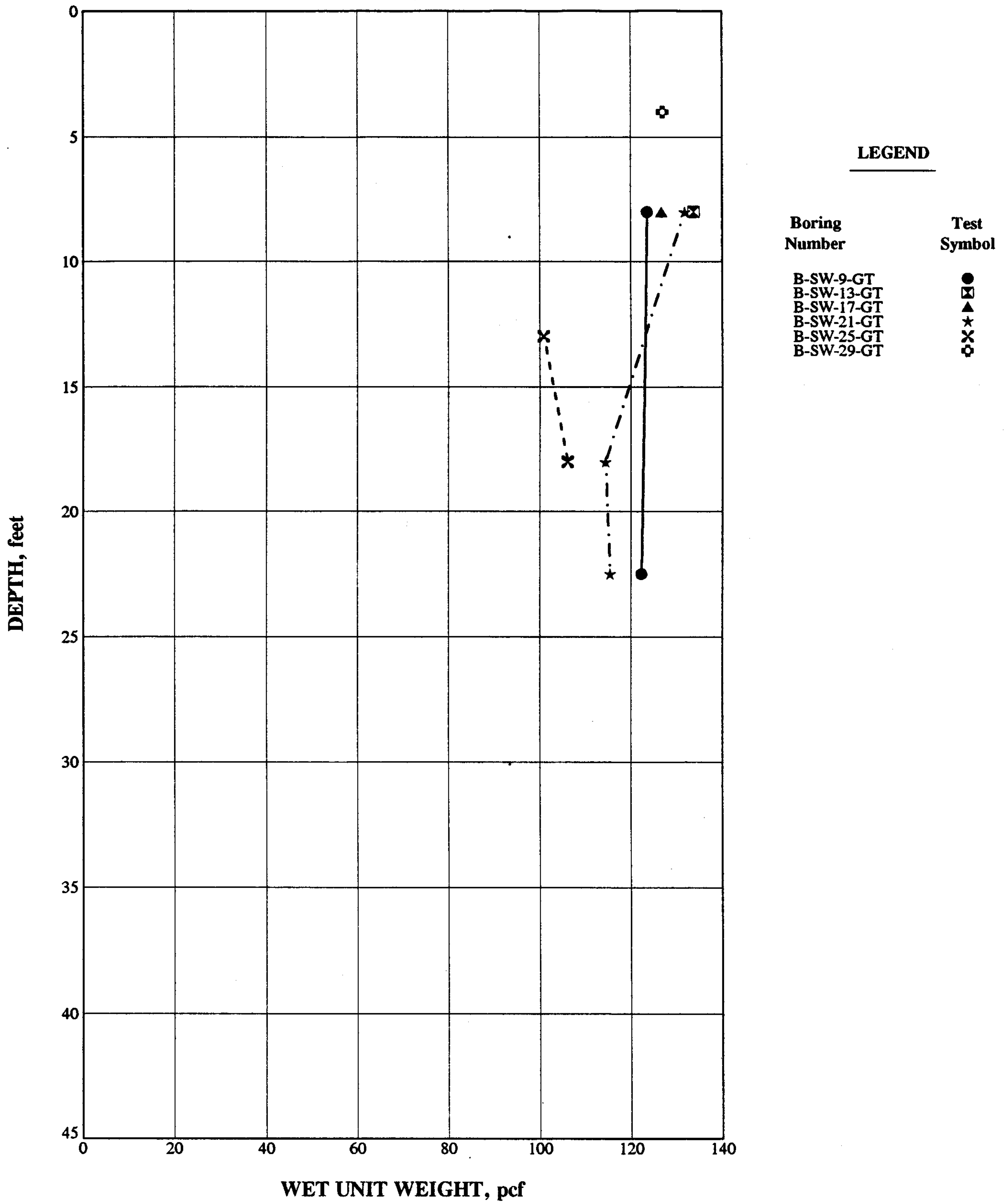
11/21/94 WTVDPT 3B107

Woodward-Clyde Consultants



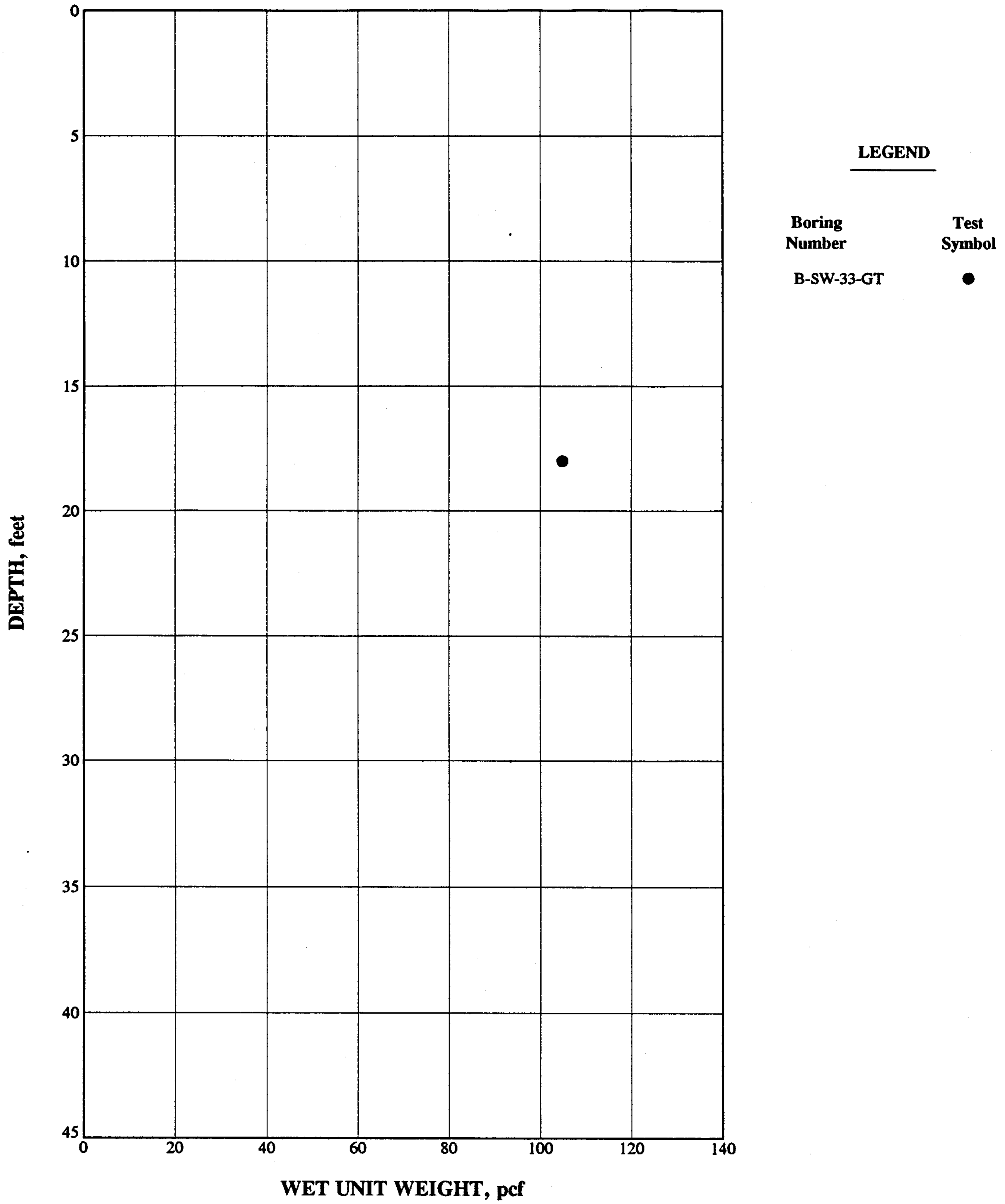
Project: LIGO
Project Number: 93B107C

WET UNIT WEIGHT vs DEPTH



Project: LIGO
Project Number: 93B107C

WET UNIT WEIGHT vs DEPTH

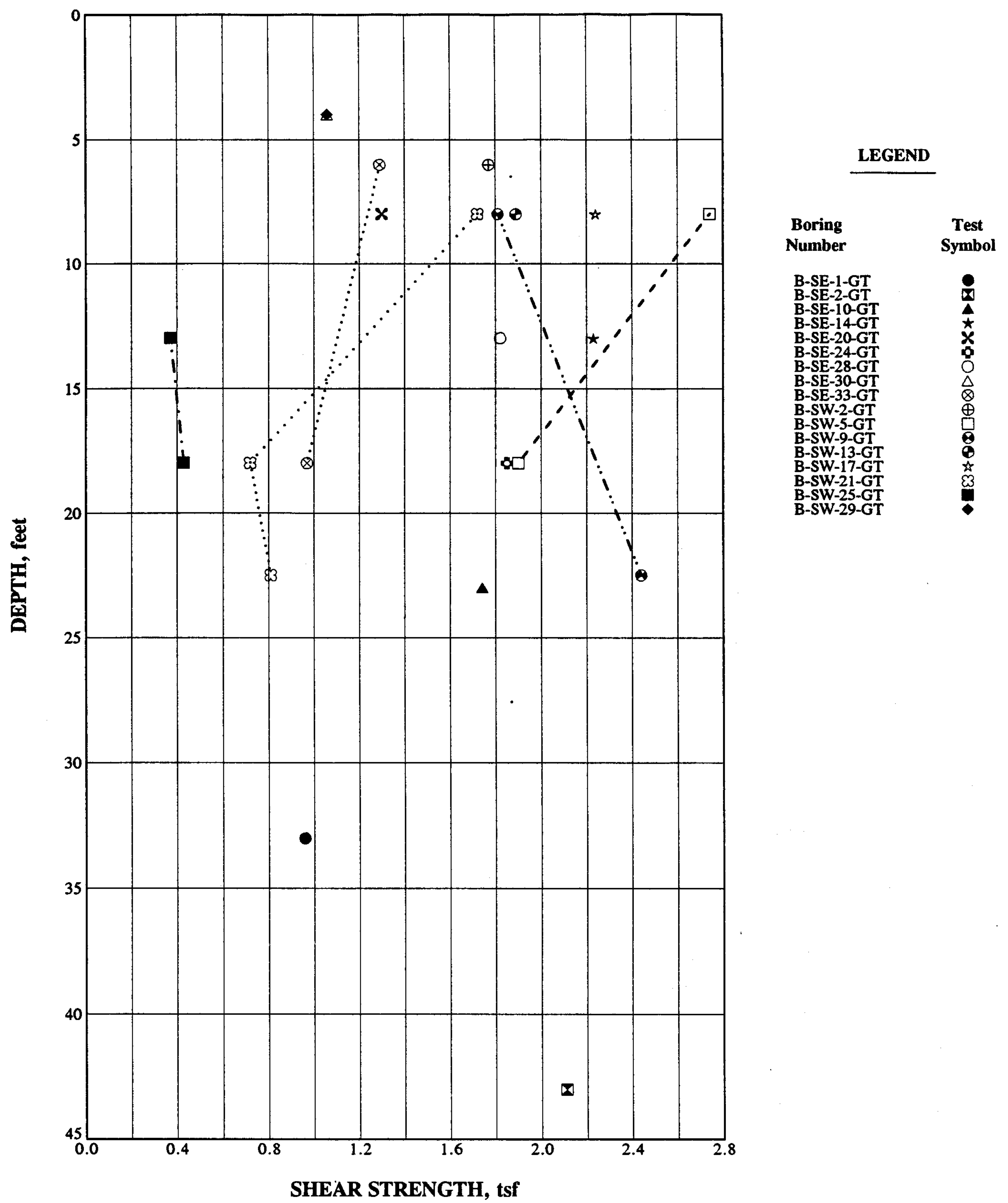


Project: LIGO
Project Number: 93B107C

WET UNIT WEIGHT vs DEPTH

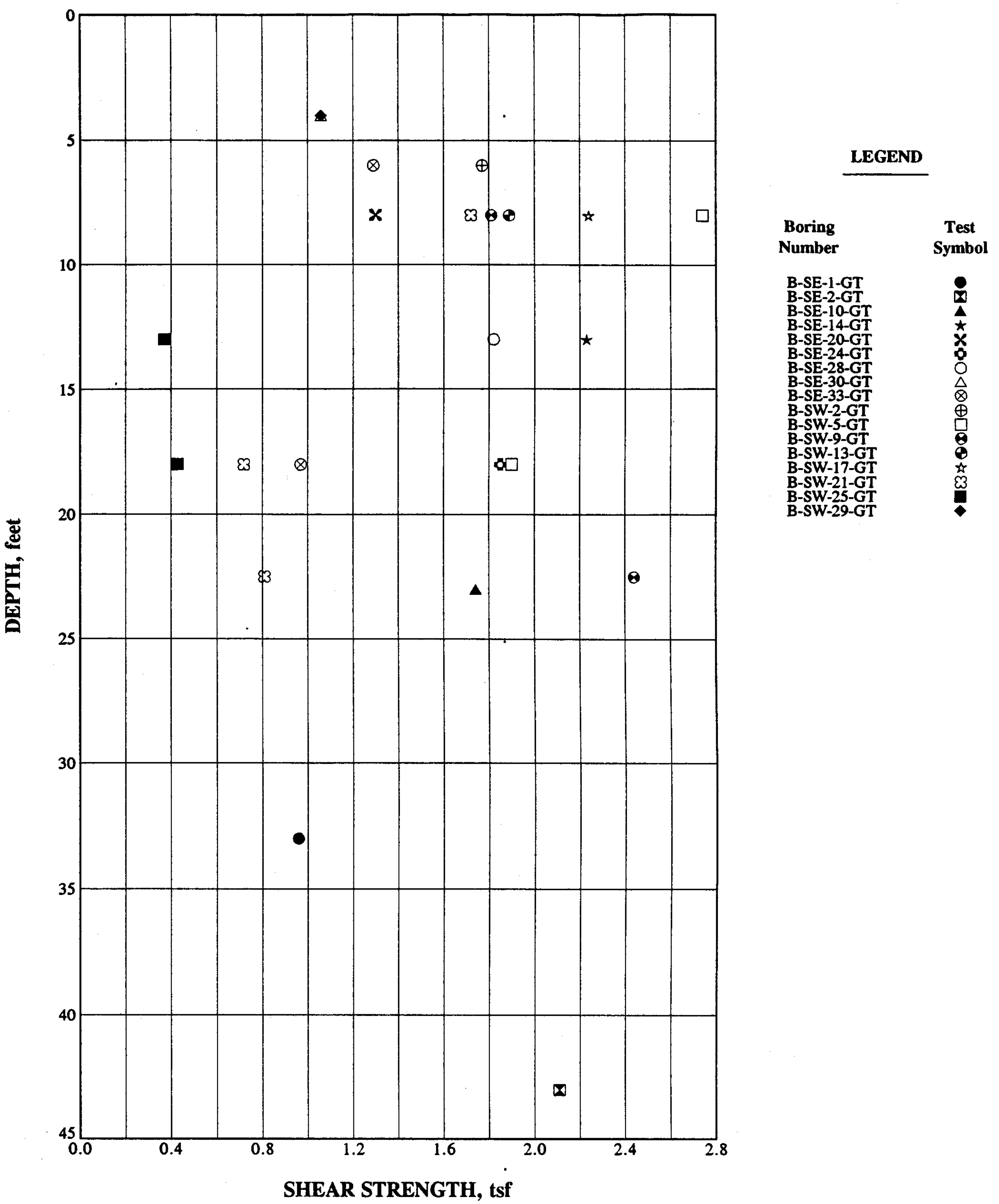
11/21/94 WTVDPT 3B107

Woodward-Clyde Consultants



Project: **LIGO**
Project Number: **93B107C**

SHEAR STRENGTH vs DEPTH



Project: **LIGO** Project Number: **93B107C**	**SHEAR STRENGTH vs DEPTH**

11/21/94 SHVDPT 3B107

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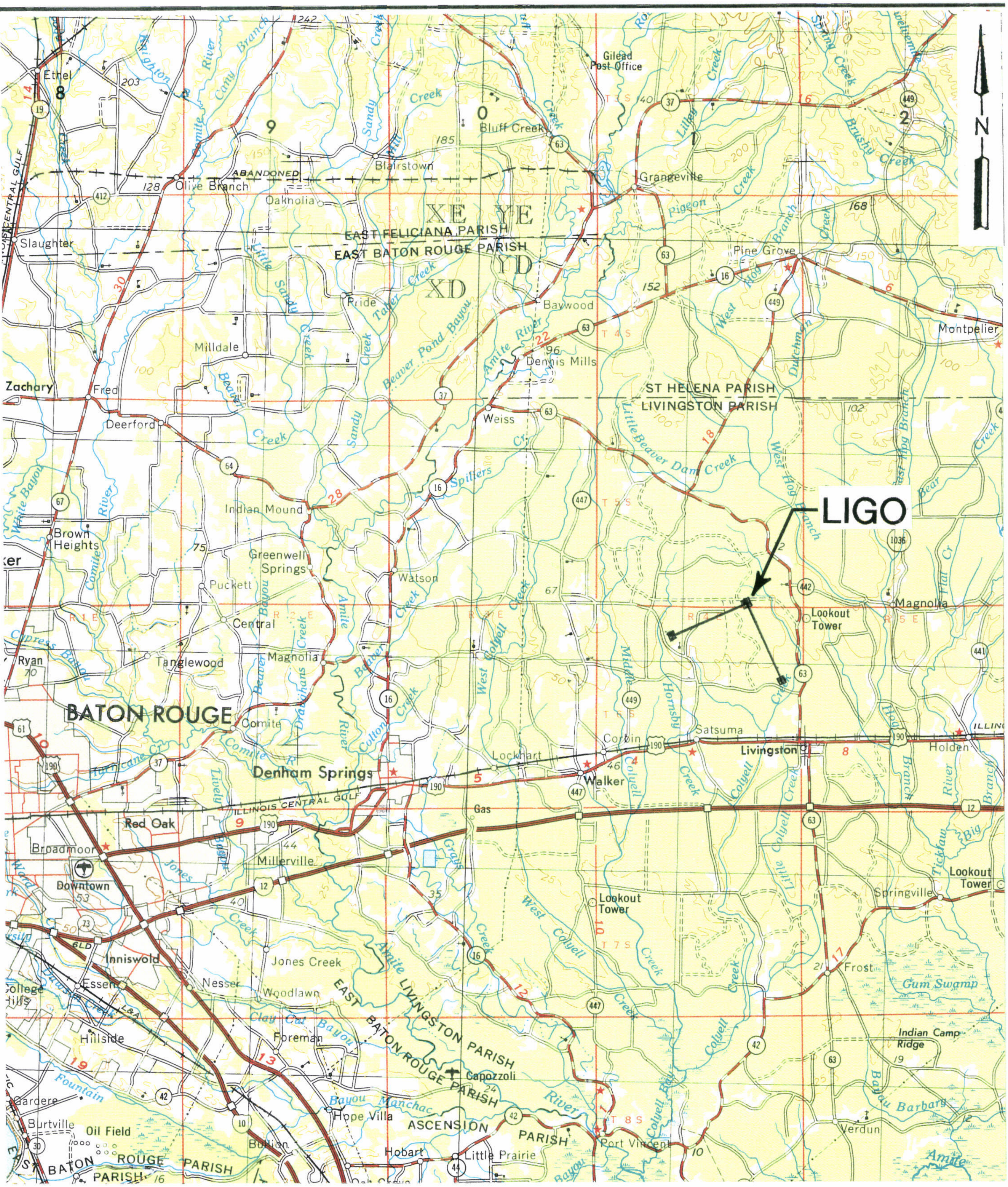
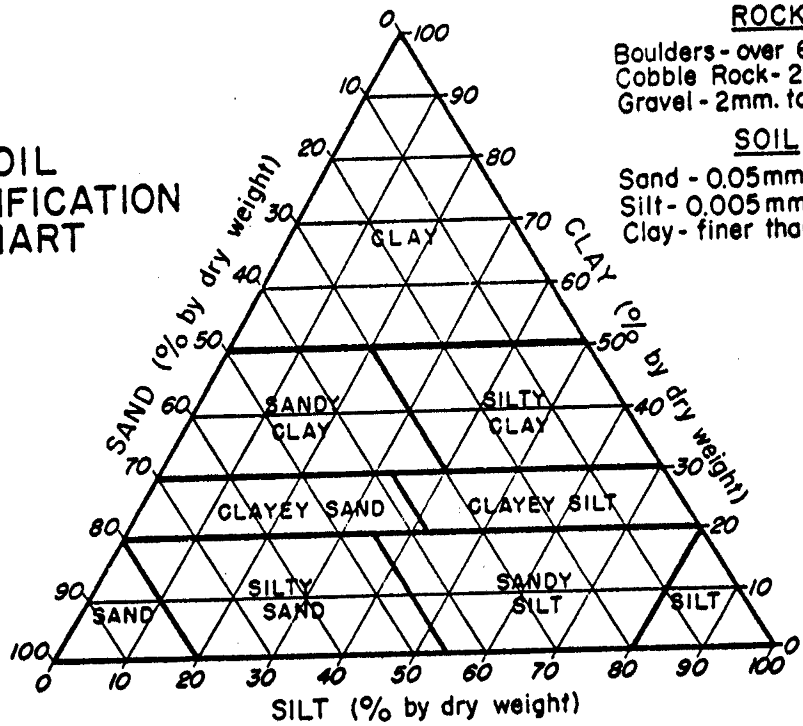
SITE LOCATION AND LOCATION OF BORINGS AND CPT TESTS



REFERENCE: U.S.G.S. NH 156 BATON ROUGE, LA. AND MISSISSIPPI PHOTOREVISED 1982.

LIGO CALIFORNIA INSTITUTE OF TECHNOLOGY PASADENA, CALIFORNIA	Woodward-Clyde Consultants Consulting Engineers, Geologists and Environmental Scientists Baton Rouge, Louisiana	SITE LOCATION MAP	FILE NO. 93B107C FIG. NO. A-1
	SCALE: 1:250,000 · DRAWN BY: PCG · DATE: 11/94 · CHKD. BY: Sanders · DATE: 16 Nov 94		

SOIL CLASSIFICATION CHART



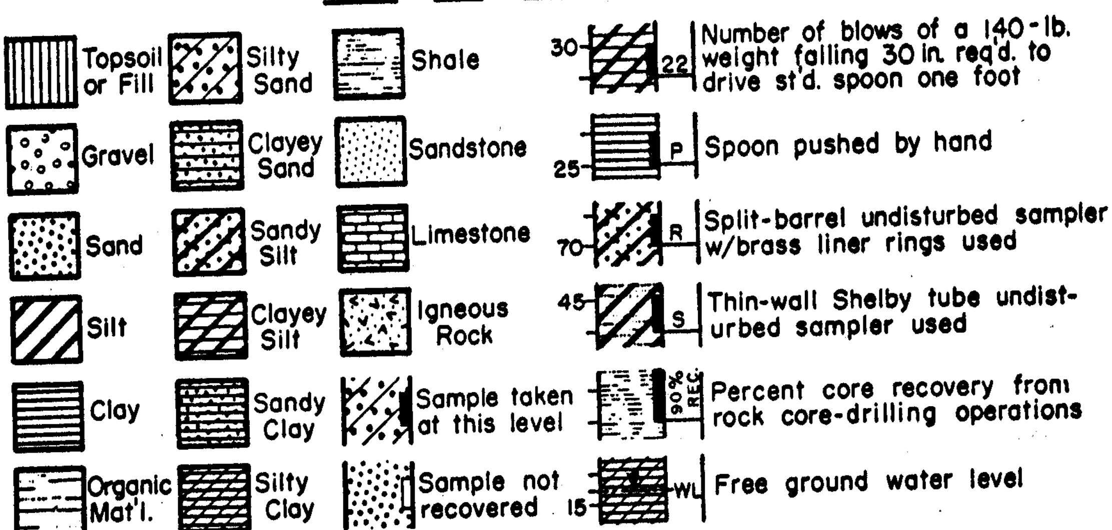
ROCK

Boulders - over 6 inches
Cobble Rock - 2 to 6 inches
Gravel - 2mm. to 2 inches

SOIL

Sand - 0.05mm. to 2mm.
Silt - 0.005mm. to 0.05mm.
Clay - finer than 0.005 mm.

KEY TO BORING LOGS



RELATIVE DENSITY (sand-silt)

Very Loose - Less than 4 blows per foot
Loose - 4 to 10 blows/ft.
Medium - 10 to 30 blows/ft.
Dense - 30 to 50 blows/ft.
Very Dense - More than 50 blows/ft.

CONSISTENCY (clay)

Very Soft - Less than 2 blows per foot
Soft - 2 to 4 blows/ft.
Medium - 4 to 8 blows/ft.
Stiff - 8 to 15 blows/ft.
Very Stiff - 15 to 30 blows/ft.
Hard - More than 30 blows/ft.

LOGS OF BORINGS AND CPTS

1. LEGEND FOR SYMBOLS
2. FUGRO BORINGS - OTHER THAN SYMBOLS & DESCRIPTION NOTES NOTHING IS QUANTIFIED (HERE)

(SHOWN LATER - BUT WHY NOT ON LOGS HERE?)

LOGS OF BORINGS AND CPTS

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SE-1-GT**
FILE: **93B107C**
DATE: **8/9/94**
TECHNICIAN: **M. Savoy**
APPROVED:

Dry Augered: 0' - 30' Wash Bored: 30' - 50'

Free water was encountered at a depth of 30' during dry augering. The water level rose to and remained at a depth of 27' after observation periods of 5 and 10 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0	(1)		16				Firm, light gray and reddish tan SILTS with some sand, a trace of clay and clay pockets to stiff, light gray and reddish tan Silty CLAYS (ML/CL)
			19		43	28	Very stiff, light gray and reddish tan Silty CLAYS with a trace of sand and ferrous nodules (CL)
		2.49 (2)	24	125	43	27	
10							Very stiff, light gray and tan CLAYS (CH)
			38				—light gray and gray, 18'- 20'
	(3)		25		41	26	Stiff, light gray and tan CLAYS with large silt pockets and streaks (CH/CL)
		0.96	38	112	82	62	Stiff, light gray and tannish gray CLAYS with silt pockets and streaks (CH)
			24		50	36	—very stiff, greenish gray, with silt pockets and calcareous nodules, 38'- 40'
40							

Continued Next Page

(1) 70.9% passing the #200 sieve.
(2) Unconsolidated, undrained triaxial compression test run at 7.5 psi confining pressure.
(3) Atterberg from more clayey portion.

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT:	LIGO	BORING:	B-SE-1-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/9/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	2 of 2

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
40									Very stiff, greenish gray CLAYS with silt pockets and calcareous nodules (CH)
45									
					30		59	35	—tan and light gray, jointed, with silt pockets below 48'
50									Bottom of boring at 50'. Borehole grouted full depth.

Unified Soil Classifications based on limited laboratory test data and visual observations.

NOV 21 94 WCSGBR8 3B107 BSE01GT

Woodward-Clyde Consultants

PROJECT:	LIGO	BORING:	B-SE-2-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/8/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 2

Dry Augered: 0' - 10' Wash Bored: 10' - 50'

Free water was encountered at a depth of 9' during dry augering. The water level rose to and remained at a depth of 2.5' after observation periods of 3 and 5 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Stiff, tan, reddish tan and light gray Silty CLAYS with fine sand and ferrous nodules (CL)
4–8	(1)	1.53 (2)	15	132	35	24	Firm, tan, reddish tan and light gray Clayey SANDS with a trace of fine gravel, clay streaks to more sandy (SC) —becoming firm sandy silt with clay, 6'- 8'
8–14.5			15		41	28	Very stiff, tan, red and light gray Silty CLAYS with some fine sand (CL)
10	31 b/ft						
14.5–22	65 b/8"	(3)	21				Very dense, tan and light gray fine SANDS with a trace of coarse and medium sand (SP)
18–20	50 b/8"						—very dense, white and tan, with silt and clay, 18'- 20'
22–40							Stiff, bluish gray CLAYS with light gray silt streaks and pockets (CH/CL)
28		1.95 (4)	23	125	45	31	—very stiff below 28' —bluish gray and tan, 28'- 38'
38			31				—tan, 38'- 42'
40							

Continued Next Page

(1) 39.7% passing the #200 sieve.

(2) Unconsolidated, undrained triaxial compression test run at 2.9 psi confining pressure.

(3) 9.2% passing the #200 sieve.

(4) Unconsolidated, undrained triaxial compression test run at 12.5 psi confining pressure.

Unified Soil Classifications based on limited laboratory test data and visual observations.

Woodward-Clyde Consultants

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SE-2-GT**
FILE: **93B107C**
DATE: **8/8/94**
TECHNICIAN: **M. Savoy**
APPROVED:
PAGE: **2 of 2**

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
40									Very stiff, tan CLAYS (CH)
				2.11	20	126	36	20	Very stiff, tan, light gray and greenish gray Silty CLAYS with fine sand (CL)
45									
									Very stiff, tan and light gray CLAYS (CH)
50									Bottom of boring at 50'. Borehole grouted full depth.

Unified Soil Classifications based on limited laboratory test data and visual observations.

Woodward-Clyde Consultants

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SE-3-CP**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									LAYERED CLAY, SILTY CLAY AND SANDY SILT
5									SILTY SAND
									CLAY
10									SAND
15									
20									
									SANDY SILT

PROJECT:	LIGO	BORING:	B-SE-4-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY WITH SILTY CLAY AND SANDY SILT LAYERS
5									
10									SAND AND SILTY SAND
15									ALTERNATING LAYERS OF SILTY CLAY, CLAY AND SANDY CLAY
20									

PROJECT:	LIGO	BORING:	B-SE-5-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									
2									SILTY CLAY WITH CLAY AND CLAYEY SILT LAYERS
5									
10									SAND
15									
18									SILTY SAND WITH SILTY CLAY LAYERS
20									
21									ALTERNATING LAYERS OF CLAY AND SILTY CLAY

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SE-6-GT**
FILE: **93B107C**
DATE: **8/10/94**
TECHNICIAN: **M. Savoy**
APPROVED:

Dry Augered: **0' - 8'** Wash Bored: **8' - 24.5'**

Free water was encountered at a depth of 8' during dry augering. The water level rose to and remained at a depth of 4.7' after observation periods of 5 and 10 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0 – 8			17		28	15	Very stiff, light gray, brown and tan Silty CLAYS with sand streaks and pockets (CL)
8 – 17	31 b/ft						Dense, light gray and tan SANDS (SP)
	54 b/10"	(1)	19				—very dense, white and tan below 13'
17 – 22			24				Very stiff, light gray, greenish gray and tan CLAYS with silt pockets and streaks (CH)
22 – 24.5			29				Firm, greenish gray and tan Clayey SILTS with clay pockets and a trace of fine sand (CL)
							Bottom of boring at 24.5'. Borehole grouted full depth.

(1) 5.0% passing the #200 sieve.

Unified Soil Classifications based on limited laboratory test data and visual observations.

Woodward-Clyde Consultants

PROJECT:	LIGO
LOCATION:	Livingston, Louisiana
CLIENT:	California Institute of Technology

BORING:	B-SE-7-CP
FILE:	93B107C
DATE:	Sept. 1994
DRILLER:	FUGRO
APPROVED:	
PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)*	L.L. (%)	P.I. (%)	Description of Stratum
0									SILTY CLAY WITH CLAY AND SILTY SAND LAYERS
5									
10									SILTY SAND WITH SAND AND SILTY CLAY LAYERS
15									
20									SILTY CLAY WITH SILTY SAND LAYERS

PROJECT:	LIGO	BORING:	B-SE-8-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY WITH SILTY CLAY LAYERS
5									
10									SILTY CLAY WITH CLAY AND SANDY SILT LAYERS
15									
20									

PROJECT:	LIGO	BORING:	B-SE-9-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY WITH SILTY CLAY LAYERS
5									
10									
									SILTY SAND
									SILTY CLAY
15									
									CLAY WITH SILTY CLAY LAYERS
20									

PROJECT:	LIGO	BORING:	B-SE-10-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/10/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

Dry Augered: 0' - 13' Wash Bored: 13' - 24.5'

Free water was encountered at a depth of 13' during dry augering.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Light gray, white and tan SILTS or Clayey SILTS with a trace of fine sand (ML-CL)
			21				Stiff, light gray and tan Silty CLAYS with clay pockets (CL)
5							Stiff, light gray and tan CLAYS (CH)
			21		28	13	Stiff, light gray and tan Silty CLAYS with large light gray sandy silt streaks and pockets (CL)
10							
15							Very stiff, tan and light gray CLAYS with silt pockets and streaks (CH/CL)
		1.91 (1)	23	123			—stiff below 18' —light gray, tan and white, with silty sand streaks and pockets, 18'-20'
20							
		1.74	31	123	41	19	—reddish brown, tan and light gray, with silt streaks and pockets, slickensides and silt lenses
							Bottom of boring at 24.5'. Borehole grouted full depth.

(1) Unconsolidated, undrained triaxial compression test run at 11.9 psi confining pressure.

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SE-11-CP**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:
PAGE: **1 of 1**

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
5									
10									SILTY SAND WITH SILTY CLAY AND SANDY SILT LAYERS
15									CLAY WITH SILTY CLAY LAYERS
20									

PROJECT: **LIGO**

LOCATION: **Livingston, Louisiana**

CLIENT: **California Institute of Technology**

BORING: **B-SE-12-CP**

FILE: **93B107C**

DATE: **Sept. 1994**

DRILLER: **FUGRO**

APPROVED:

PAGE: **1 of 1**

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
5									
10									
15									
20									

PROJECT:	LIGO	BORING:	B-SE-13-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
5									
10									
									SANDY SILT
15									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
20									

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SE-14-GT**
FILE: **93B107C**
DATE: **8/10/94**
TECHNICIAN: **M. Savoy**
APPROVED:
PAGE: **1 of 1**

Dry Augered: **Full Depth**
No free water was encountered during dry augering.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Tan and light gray Silty CLAYS (CL)
							Stiff, light gray and tan CLAYS with sand streaks, pockets and some silt (CH)
5			19				Stiff, light gray and tan Silty CLAYS with silt and sand streaks and pockets (CL)
10							Very stiff, tan and light gray Silty CLAYS (CL)
15		2.23	23	125	49	34	Very stiff, light gray, tan and greenish gray CLAYS with silt streaks and pockets (CH/CL)
20			29				—light gray and tan below 22.5'
							Bottom of boring at 24.5'. Borehole grouted full depth.

Unified Soil Classifications based on limited laboratory test data and visual observations.

Woodward-Clyde Consultants

PROJECT:	LIGO	BORING:	B-SE-15-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
5									
10									ALTERNATING LAYERS OF SILTY SAND, SANDY SILT AND SILTY CLAY
15									
									SILTY CLAY
20									

PROJECT:	LIGO	BORING:	B-SE-16-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									ALTERNATING LAYERS OF CLAY, SILTY CLAY AND SANDY CLAY
5									
									SAND AND CLAYEY SAND
10									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
15									
20									

Woodward-Clyde Consultants

PROJECT:	LIGO	BORING:	B-SE-17-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/11/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

Dry Augered: 0' - 13' Wash Bored: 13' - 24.5'

Free water was encountered at a depth of 13' during dry augering. The water level rose to depths of 13.2', 13.0' and 12.8' after observation periods of 5, 10 and 15 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Medium, light gray and tan Sandy CLAYS becoming very stiff, with some silt (CL)
5			14				Firm, light gray and tan Clayey SANDS with some silt and clay pockets (SC) —with fine gravel, 6'- 8'
10, 15			20		26	9	Firm, tan, light gray and brown SILTS with clay streaks, pockets and sand (ML/CL)
20		2.32 (1)	25	123	58	40	Very stiff, light gray, greenish gray and tan CLAYS with silty sand streaks and pockets (CH) —with silt streaks below 22.5'
							Bottom of boring at 24.5'. Borehole grouted full depth.

(1) Unconsolidated, undrained triaxial compression test run at 12.8 psi confining pressure.

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT: **LIGO**

LOCATION: **Livingston, Louisiana**

CLIENT: **California Institute of Technology**

BORING: **B-SE-18-CP**

FILE: **93B107C**

DATE: **Sept. 1994**

DRILLER: **FUGRO**

APPROVED:

PAGE: **1 of 1**

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY WITH SILTY CLAY LAYERS
5									ALTERNATING LAYERS OF SILTY SAND, SILT AND CLAYEY SAND
10									
15									CLAY WITH SILTY CLAY LAYERS
20									

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Woodward-Clyde Consultants

PROJECT:	LIGO	BORING:	B-SE-19-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
5									
									SILTY SAND
10									CLAY WITH SILTY CLAY LAYERS
15									
20									

PROJECT:	LIGO	BORING:	B-SE-20-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/11/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

Dry Augered: 0' - 10' Wash Bored: 10' - 24.5'

Free water was encountered at a depth of 10' during dry augering. The water level rose to depths of 9.5', 9.3' and 9.1' after observation periods of 5, 10 and 15 minutes, respectively.

DEPTH (FEET): 0, 5, 10, 15, 20 — SYMBOL — SAMPLE

S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
		21				Firm, tanish brown and light gray SILTS with clay pockets, a trace of sand and ferrous nodules (CL-ML)
		14				Firm, light gray and tan Sandy SILTS with clay pockets (SM)
	1.30	16	129	45	28	Stiff to very stiff, light gray and tan CLAYS with sand pockets and streaks to Sandy CLAYS (CH/CL)
		23				Stiff, light gray and greenish gray CLAYS with silt and sand streaks (CH)
		23				—very stiff, tan, light gray and greenish gray, with silt pockets, streaks and fine sand below 18'
						Bottom of boring at 24.5'. Borehole grouted full depth.

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT:	LIGO	BORING:	B-SE-21-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
5									
10									
15									
20									

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SE-22A-CP**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY
5									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
10									
									CLAY
15									
									SILTY CLAY WITH CLAY AND SILTY SAND LAYERS
20									

PROJECT: **LIGO**

LOCATION: **Livingston, Louisiana**

CLIENT: **California Institute of Technology**

BORING: **B-SE-23A-CP**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY
5									
10									
15									
20									SILTY SAND WITH SAND LAYERS

PROJECT:	LIGO	BORING:	B-SE-24-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/11/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

Dry Augered: 0' - 13' Wash Bored: 13' - 24.5'

Free water was encountered at a depth of 13' during dry augering. The water level rose to depths of 10.6', 10.4' and 9.9' after observation periods of 5, 10 and 15 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0			24 22				Soft to medium, light gray and tan Silty CLAYS, wet, with clay pockets, ferrous nodules becoming very soft to soft (CL) —medium, with sand, 2'- 4' —medium to stiff, 4'- 10' —with fine sand streaks and pockets, clay pockets and ferrous nodules, 4'- 6'
8			19		23	9	Medium to stiff, light gray and tan SILTS with silty sand streaks (ML/CL)
18	(1)	1.85	20	124	41	27	Stiff to very stiff, light gray and tan CLAYS with silty sand streaks and pockets to more sandy (CH/CL)
24.5							Bottom of boring at 24.5'. Borehole grouted full depth.

(1) Unconsolidated, undrained triaxial compression test run at 13.2 psi confining pressure.

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT:	LIGO		BORING:	B-SE-25-CP
LOCATION:	Livingston, Louisiana		FILE:	93B107C
			DATE:	Sept. 1994
			DRILLER:	FUGRO
CLIENT:	California Institute of Technology		APPROVED:	
			PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY WITH SILTY CLAY LAYERS
5									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
10									
15									CLAY
20									SILTY CLAY WITH CLAY LAYERS

PROJECT:	LIGO	BORING:	B-SE-26-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SILTY CLAY
									CLAY
5									
10									
									SILTY CLAY
15									CLAY
20									
									SILTY CLAY

PROJECT:	LIGO	BORING:	B-SE-27-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
CLIENT:	California Institute of Technology	DRILLER:	FUGRO
		APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SANDY SILT
									CLAY
5									
10									
15									LAYERED CLAY AND SILTY CLAY
20									

PROJECT:	LIGO	BORING:	B-SE-28-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/11/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

Dry Augered: 0' - 15' Wash Bored: 15' - 24.5'

Free water was encountered at a depth of 15' during dry augering. The water level rose to a depth of 13.3' after an observation period of 15 minutes.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0			22				Medium to stiff, light gray and tan Silty CLAYS with clay pockets, ferrous nodules and a trace of fine sand (CL)
5			15				Light gray, red and tan Clayey SANDS, Sandy CLAYS with a trace of medium sand (CL/SC)
			23				Very stiff, yellow, tan and light gray CLAYS with silt streaks, pockets and a trace of fine sand (CH)
10							
		1.82	22	127	38	23	
15							
							---gray and tan below 18'
20							
			25				---with silt and sand streaks and pockets, trace of roots and organics below 22.5'
							Bottom of boring at 24.5'. Borehole grouted full depth.

Unified Soil Classifications based on limited laboratory test data and visual observations.

Woodward-Clyde Consultants

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SE-29-CP**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:
PAGE: **1 of 1**

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SILTY CLAY WITH CLAY AND CLAYEY SAND LAYERS
5									
10									
15									
20									

PROJECT:	LIGO	BORING:	B-SE-30-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/12/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

Dry Augered: 0' - 10' Wash Bored: 10' - 24.5'

Free water was encountered at a depth of 10' during dry augering. The water level rose to depths of 9.5', 9.3' and 9.2' after observation periods of 5, 10 and 15 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Gray Silty CLAYS with roots, a trace of fine sand, organics, to light gray and brown with ferrous nodules and clay pockets (CL) —tan, 2'- 4'
5		1.06	14	135	21	11	Stiff, light gray, tan and yellow Sandy CLAYS with silty sand streaks (SC)
			22				Very stiff, brown, tan and light gray CLAYS with silt streaks and pockets (CH)
10							
		2.36 (1)	23	126	56	39	—light gray and tan, with silt streaks, pockets and a trace of fine sand, 13'- 15'
15							
							—with silt pockets below 18'
20							
			37				—stiff to very stiff, with sandy silt streaks, pockets and layers below 23'
							Bottom of boring at 24.5'. Borehole grouted full depth.

(1) Unconsolidated, undrained triaxial compression test run at 10.4 psi confining pressure.

Unified Soil Classifications based on limited laboratory test data and visual observations.

Woodward-Clyde Consultants

PROJECT:	LIGO	BORING:	B-SE-31-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SILTY SAND
5									CLAY WITH SILTY CLAY LAYERS
10									
15									SILTY CLAY
20									SILTY SAND

PROJECT:	LIGO	BORING:	B-SE-32-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 2

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									ALTERNATING LAYERS OF SILTY CLAY AND CLAY
9									SAND
11									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
23.5									SILTY CLAY
28									SILTY SAND
30.5									ALTERNATING LAYERS OF SILTY CLAY AND CLAY
40									

Continued Next Page

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SE-32-CP**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:
PAGE: **2 of 2**

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
40									
									SILTY CLAY
45									
50									

PROJECT:	LIGO		BORING:	B-SE-33-GT
LOCATION:	Livingston, Louisiana		FILE:	93B107C
			DATE:	8/12/94
			TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology		APPROVED:	
			PAGE:	1 of 2

Dry Augered: 0' - 10' Wash Bored: 10' - 50'

Free water was encountered at a depth of 10' during dry augering. The water level rose to depths of 10.3', 10.1' and 9.7' after observation periods of 5, 10 and 15 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Soft to medium, brown, light gray and tan Silty CLAYS with small roots, clay pockets and ferrous nodules (CL) ---with sand layer at 2'
5		1.29	14	134	26	15	Firm, tan and light gray Clayey SANDS with clay pockets and streaks becoming Sandy CLAYS (SC/CL)
10							
15		0.97	30	119	51	31	Very stiff, light gray and tan slickensided CLAYS with a trace of silt streaks and pockets (CH)
20							
25							Very stiff, light gray and tan Sandy CLAYS (CL)
30							Light gray and tan Silty CLAYS (CL)
35							
40							---gray and tan, 38'- 43'

Continued Next Page

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT:	LIGO	BORING:	B-SE-33-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/12/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	2 of 2

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
40									Hard, gray and tan Silty CLAYS (CL)
									—tan and light gray below 43'
45									
50									Bottom of boring at 50'. Borehole grouted full depth.

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT:	LIGO
LOCATION:	Livingston, Louisiana
CLIENT:	California Institute of Technology

BORING:	B-SE-34-SC
FILE:	93B107C
DATE:	Sept. 1994
DRILLER:	FUGRO
APPROVED:	
PAGE:	1 of 2

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY
5									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
10									
15									CLAY
20									ALTERNATING LAYERS OF CLAY AND SILTY CLAY
25									
30									SILTY SAND AND SANDY SILT
35									SILTY CLAY WITH CLAY LAYERS
40									

Continued Next Page

PROJECT:	LIGO	BORING:	B-SE-34-SC
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	2 of 2

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
40									
45									

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SW-01-SC**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SILTY CLAY
									CLAY
5									
									LAYERS OF SILTY CLAY AND CLAY
10									
									SAND
15									SILTY CLAY WITH CLAY AND SANDY SILT LAYERS
20									
25									
									SANDY SILT TO SILTY SAND
30									
35									
									SAND
40									

Continued Next Page

PROJECT:	LIGO	BORING:	B-SW-01-SC
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	2 of 2

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
40									
45									

PROJECT:	LIGO	BORING:	B-SW-2-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/14/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 2

Dry Augered: 0' - 6' Wash Bored: 6' - 50'

Free water was encountered at a depth of 6' during dry augering. Borehole caved in at 3', no water reading.

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									Firm, brown and light gray Clayey SILTS with clay streaks, pockets and small roots (CL-ML)
									Medium to stiff, light gray and tan Silty CLAYS with clay pockets, sand streaks and pockets and ferrous nodules (CL)
5					17		25	13	Medium, tannish brown and light gray Sandy CLAYS with sand pockets becoming white silty sand (CL/SM)
				1.77	19	123	47	32	Stiff, light gray, gray, brown and tan CLAYS with silt and sand streaks, pockets and ferrous nodules (CH/CL)
10									
15				1.43 (1)	15	130	22	9	Firm, white, gray, light gray and tan Clayey SANDS with clay pockets and sand (SC)
20					35		71	49	Very stiff, gray, tan and light gray CLAYS with silt lenses and streaks (CH)
25									Very stiff, light gray and tan Silty CLAYS (CL)
30					27				Stiff, gray CLAYS with sandy silt streaks and pockets (CH)
35									Medium, light gray Silty CLAYS with some fine sand and clayey sand layers (CL-SC)
40				0.74 (2)	16	126	24	12	

Continued Next Page

(1) Unconsolidated, undrained triaxial compression test run at 8.2 psi confining pressure.

(2) Unconsolidated, undrained triaxial compression test run at 18.2 psi confining pressure.

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SW-2-GT**
FILE: **93B107C**
DATE: **8/14/94**
TECHNICIAN: **M. Savoy**
APPROVED:

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
40									Medium, light gray Silty CLAYS with some fine sand and clayey sand layers (CL-SC)
			48 b/ft						Dense, tan SANDS (SP)
45									
			50 b/6"						—very dense, with a trace of gravel below 48'
50									Bottom of boring at 50'. Borehole grouted full depth.

Unified Soil Classifications based on limited laboratory test data and visual observations.

LOG OF CPT

PROJECT:	LIGO	BORING:	B-SW-3-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SANDY SILT WITH SILTY CLAY LAYERS
5									CLAY
10									SANDY SILT
									SAND
15									SANDY SILT
20 / 25									SILTY CLAY WITH SANDY SILT LAYERS
30									SANDY SILT WITH SAND LAYERS
35									SAND

LOG OF CPT

PROJECT:	LIGO	BORING:	B-SW-4-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SANDY SILT
									CLAY
5									SILTY CLAY
									CLAY
10									SAND WITH SANDY SILT LAYERS
15									
20									SILTY CLAY
									SILTY SAND

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SW-5-GT**
FILE: **93B107C**
DATE: **8/13/94**
TECHNICIAN: **M. Savoy**
APPROVED:
PAGE: **1 of 1**

Dry Augered: **0' - 13'** Wash Bored: **13' - 24.5'**

Free water was encountered at a depth of 13' during dry augering. The water level rose to depths of 5.8', 5.1' and 4.4' after observation periods of 5, 10 and 15 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Soft to medium, light gray and tan Silty CLAYS with clay pockets and silty sand pockets and streaks (CL)
							—medium, brown, light gray and tan, 2'- 4'
5							
	(1)		18		27	14	
		2.74	15	134	27	16	—very stiff, gray, light gray and tan, with some fine sand and ferrous nodules, 8'- 10'
10							
	(2)		29		70	22	Stiff to very stiff, tan and light gray CLAYS with silty sand streaks and pockets and a trace of ferrous nodules (CH)
15							
		1.90	24	124	55	38	
20							
							Bottom of boring at 24.5'. Borehole grouted full depth.

(1) 72.3% passing the #200 sieve.
(2) 98.7% passing the #200 sieve.

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT:	LIGO	BORING:	B-SW-6-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SILTY CLAY
									CLAY
5									
10									
									SAND AND SILTY SAND TO SANDY SILT
15									
									CLAY WITH SILTY CLAY LAYERS
20									

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SW-7-CP**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:
PAGE: **1 of 1**

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									
1 – 6.5									CLAY WITH SILTY CLAY LAYERS
6.5 – 20									SAND WITH SILTY SAND TO SANDY SILT LAYERS
20 – 22									SILTY CLAY
22 – 24.5									CLAY

NOV 22 94 WCSGBR8 3B107 BSW07CP

Woodward-Clyde Consultants

PROJECT:	LIGO	BORING:	B-SW-8-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY WITH SILTY CLAY LAYERS
10									SAND
									CLAY

PROJECT:	LIGO	BORING:	B-SW-9-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/13/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

Dry Augered: 0' - 8'   Wash Bored: 8' - 24.5'

Free water was encountered at a depth of 8' during dry augering. The water level rose to depths of 8.0', 7.0' and 6.1' after observation periods of 5, 10 and 15 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0 – 6			20				Soft, brown and tan Silty CLAYS with ferrous nodules (CL)
6 – 13	(1) (2)	1.81	20	124			Reddish brown and tan fine SANDS with some silt and a trace of clay (SP-SM)
13 – 18	(3)		14				Soft, light gray and tan Sandy SILTS or Silty SANDS with ferrous nodules and a trace of clay (SM-ML)
18 – 24.5		2.44	32	122	59	41	Very stiff, tan, light gray and bluish gray CLAYS with a trace of silt pockets (CH)
							Bottom of boring at 24.5'. Borehole grouted full depth.

(1) 11.3% passing the #200 sieve.

(2) Unconsolidated, undrained triaxial compression test run at 7.1 psi confining pressure.

(3) 52.4% passing the #200 sieve.

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT:	LIGO	BORING:	B-SW-10-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY WITH SILTY CLAY LAYERS
5									
10									SILTY SAND
15									CLAY WITH SILTY CLAY LAYERS
20									

PROJECT:	LIGO	BORING:	B-SW-11-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SILTY CLAY WITH CLAY LAYERS
5									
10									SANDY SILT
15									CLAY
									SILTY CLAY
20									
									SAND WITH SANDY SILT LAYERS

PROJECT:	LIGO	BORING:	B-SW-12-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY WITH SILTY CLAY LAYERS
5									SANDY SILT
									SILTY CLAY
10									SILTY SAND
									SILTY CLAY
15									CLAY
20									SILTY CLAY WITH SILTY SAND LAYERS

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SW-13-GT**
FILE: **93B107C**
DATE: **8/14/94**
TECHNICIAN: **M. Savoy**
APPROVED:
PAGE: **1 of 1**

Dry Augered: **0' - 10'** Wash Bored: **10' - 24.5'**

Free water was encountered at a depth of 10' during dry augering. The water level remained at a depth of 10' after observation periods of 5 and 10 minutes.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Very soft to soft, light gray, gray and tan Silty CLAYS with ferrous nodules, clay pockets and trace of fine sand (CL)
							Very stiff, tan and light gray CLAYS with silt pockets (CH)
5							
	(1)	1.89	14	134			Stiff, tan and light gray Sandy CLAYS with clay pockets (CL)
10							
			13		15	2	Firm, tan and light gray Sandy SILTS with a trace of clay (ML/SM)
15							
							Stiff to very stiff, tan, yellow, gray and light gray CLAYS with a trace of silt pockets and streaks (CH/CL)
20							
			20		40	24	—very stiff, gray and light gray, with silt and sandy silt pockets and streaks below 22.5'
							Bottom of boring at 24.5'. Borehole grouted full depth.

(1) Unconsolidated, undrained triaxial compression test run at 7.5 psi confining pressure.

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT: **LIGO**

LOCATION: **Livingston, Louisiana**

CLIENT: **California Institute of Technology**

BORING: **B-SW-14-CP**

FILE: **93B107C**

DATE: **Sept. 1994**

DRILLER: **FUGRO**

APPROVED:

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY
5									SILTY CLAY WITH SANDY SILT LAYERS
10									SILTY SAND WITH SANDY SILT AND SILTY CLAY LAYERS
15									SILTY CLAY WITH CLAY LAYERS
20									
									SILTY SAND

PROJECT:	LIGO	BORING:	B-SW-15-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SILTY CLAY
5									
10									SAND WITH SANDY SILT LAYERS
15									
20									SILTY CLAY

PROJECT:	LIGO	BORING:	B-SW-16-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SILTY CLAY WITH CLAY LAYERS
5									
10									SAND WITH SANDY SILT LAYERS
15									
20									CLAY

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SW-17-GT**
FILE: **93B107C**
DATE: **8/14/94**
TECHNICIAN: **M. Savoy**
APPROVED:

Dry Augered: **0' - 10'** Wash Bored: **10' - 24.5'**

Free water was encountered at a depth of 10' during dry augering. The water level rose to depths of 5.7', 5.5' and 5.1' after observation periods of 5, 10 and 15 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Very stiff, gray Silty CLAYS with ferrous nodules, small roots, becoming light gray and tan (CL) —with sand, 2'- 4'
5							Very stiff, tan and red Sandy CLAYS (CL)
10	(1)	2.24	18	127	32	16	Medium, tan and light gray Silty CLAYS with clay pockets and a trace of fine sand (CL)
							Very dense, tan Clayey SANDS (SC)
15	50 b/10"						Dense, tan SANDS with clay layers (SP)
20	19 b/ft						—with a trace of gravel, 18'- 20'
	(2)		37				Medium, gray CLAYS with a trace of wood and organics, some silt (CH)
							Bottom of boring at 24.5'. Borehole grouted full depth.

(1) Unconsolidated, undrained triaxial compression test run at 7.5 psi confining pressure.
(2) 98.2% passing the #200 sieve.

Unified Soil Classifications based on limited laboratory test data and visual observations.

Woodward-Clyde Consultants

PROJECT:	LIGO	BORING:	B-SW-18-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SANDY SILT
									CLAY
5									ALTERNATING LAYERS OF SAND, SILTY SAND AND SILTY CLAY
10									
									SAND WITH SANDY SILT LAYERS
15									
20									
									CLAY

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SW-19-CP**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:
PAGE: **1 of 1**

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY
5									SILTY CLAY
10									
15									SAND WITH SILTY SAND LAYERS
20									CLAY

PROJECT:	LIGO	BORING:	B-SW-20-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET) — 0, 5, 10, 15, 20

SYMBOL | SAMPLE

S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
						ALTERNATING LAYERS OF CLAY AND SILTY CLAY
						SAND WITH SILTY SAND LAYERS
						ALTERNATING LAYERS OF SILTY CLAY AND SAND
						SAND
						SILTY CLAY
						CLAY

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SW-21-GT**
FILE: **93B107C**
DATE:
TECHNICIAN: **M. Savoy**
APPROVED:

Dry Augered: **0' - 10'** Wash Bored: **10' - 24.5'**

Free water was encountered at a depth of 10' during dry augering. The water level rose to depths of 9.7', 8.9' and 8.7' after observation periods of 5, 10 and 15 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Soft to medium, tan, yellow and light gray Silty CLAYS with a trace of fine sand streaks and pockets and ferrous nodules (CL)
5			17				—stiff, 4'- 6'
							Stiff, light gray and tan Sandy CLAYS with some fine sand streaks and pockets (CL)
	(1)	1.72	15	132	25	13	—with clay pockets and silty sand pockets and streaks, 8'- 10'
10							
	(2)		19		30	15	Very stiff, light gray and tan Sandy SILTS with some clay pockets to yellow and tan jointed Silty CLAYS (SM/CL)
15							
	(3)	0.72	34	114	50	33	
20							Medium to stiff, gray CLAYS with silt pockets and streaks and a trace of organics (CL/CH)
		0.81	43	115	62	35	
							Bottom of boring at 24.5'. Borehole grouted full depth.

(1) Unconsolidated, undrained triaxial compression test run at 7.5 psi confining pressure.
(2) Atterberg limits performed on more clayey portion of sample.
(3) Unconsolidated, undrained triaxial compression test run at 12.1 psi confining pressure.

Unified Soil Classifications based on limited laboratory test data and visual observations.

Woodward-Clyde Consultants

LOG OF CPT

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SW-22-CP**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:
PAGE: **1 of 1**

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY
5									SILTY CLAY WITH CLAY AND CLAYEY SILT LAYERS
10									SAND
15									SANDY SILT
20									CLAY WITH SILTY CLAY LAYERS

PROJECT:	LIGO	BORING:	B-SW-23-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									SILTY CLAY
									CLAY
5									
									SILTY CLAY
10									CLAY
									SILTY CLAY WITH CLAY AND SANDY SILT LAYERS
15									
20									SANDY SILT
									SILTY CLAY

PROJECT:	LIGO	BORING:	B-SW-24-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY WITH SILTY CLAY LAYERS
5									
10									SANDY SILT
15									CLAY WITH SILTY CLAY LAYERS
20									

LOG OF BORING

PROJECT:	LIGO	BORING:	B-SW-25-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/15/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

Dry Augered: 0' - 8' Wash Bored: 8' - 24.5'

Free water was encountered at a depth of 8' during dry augering. The water level rose to depths of 3.6', 3.4' and 3.1' after observation periods of 5, 10 and 15 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Gray Silty CLAYS, wet, with roots, fine sand, trace of organics and ferrous nodules, becoming light gray and tan (CL)
5			20		33	20	—soft to medium, tan, light gray and greenish gray, with clay pockets, and silty sand streaks and pockets, 4'- 6'
	32 b/ft						Dense to very dense, tan fine SANDS with some silt and a trace of medium to coarse grained sand (SP)
10	50 b/10"	(1)	19				
		0.37	56	101	73	48	Medium, jointed gray and light gray slickensided CLAYS (CH)
15							
		0.43	42	106	67	43	
20							
							Stiff, greenish gray Silty CLAYS (CL)
							Bottom of boring at 24.5'. Borehole grouted full depth.

(1) 8.9% passing the #200 sieve.

Unified Soil Classifications based on limited laboratory test data and visual observations.

Woodward-Clyde Consultants

PROJECT:	LIGO	BORING:	B-SW-26-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY
5									SAND
10									
15									CLAY
20									

PROJECT:	LIGO	BORING:	B-SW-27-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY WITH SILTY CLAY LAYERS
5									
10									
15									
20									

LOG OF CPT

PROJECT:	LIGO	BORING:	B-SW-28-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY WITH SILTY CLAY AND SANDY SILT LAYERS
5									
10									SILTY SAND WITH THIN SILTY CLAY LAYERS
									SILTY CLAY
15									CLAY
20									
									SILTY SAND

PROJECT: LIGO
LOCATION: Livingston, Louisiana
CLIENT: California Institute of Technology

BORING: B-SW-29-GT
FILE: 93B107C
DATE: 8/15/94
TECHNICIAN: M. Savoy
APPROVED:
PAGE: 1 of 1

Dry Augered: 0' - 10' Wash Bored: 10' - 24.5'

Free water was encountered at a depth of 10' during dry augering. The water level rose to depths of 5.6', 5.4' and 5.4' after observation periods of 5, 10 and 15 minutes, respectively.

DEPTH (FEET)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Stiff, tan, gray and light gray Silty CLAYS with fine sand and small roots becoming Clayey SILTS (CL)
5		1.06	19	127	24	11	—stiff, with some fine sand and clay pockets, silty sand streaks and pockets, 4'- 6'
10			19				Stiff, tan and light gray Sandy CLAYS or Clayey SANDS becoming Silty SANDS (CL/SM)
	56 b/8"						Very dense, white and light gray fine SANDS with traces of silt, clay, coarse and medium grained sands and fine gravel (SP-SM)
15	52 b/8"	(1)	20				
	30 b/ft						—dense, 18'- 20'
20			34		59	37	Very stiff, tan and greenish gray CLAYS with a trace of silt and ferrous nodules (CH)
							Bottom of boring at 24.5'. Borehole grouted full depth.

(1) 8.8% passing the #200 sieve.

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT:	LIGO	BORING:	B-SW-30-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY
									SILTY SAND
5									CLAY WITH SILTY CLAY LAYERS
10									
15									
20									
									SILTY SAND
									CLAY

PROJECT:	LIGO	BORING:	B-SW-31-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAY WITH SILTY CLAY AND SANDY SILT LAYERS
5									
10									
15									
20									

PROJECT:	LIGO	BORING:	B-SW-32-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	1 of 1

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									LAYERED CLAY AND SILTY CLAY
5									
10									SAND WITH SILTY SAND LAYERS
15									
									CLAY
20									

LOG OF BORING

PROJECT: LIGO
LOCATION: Livingston, Louisiana
CLIENT: California Institute of Technology

BORING: B-SW-33-GT
FILE: 93B107C
DATE: 8/9/94
TECHNICIAN: M. Savoy
APPROVED:

Dry Augered: 0' - 4'   Wash Bored: 4' - 50'

Free water was encountered at a depth of 4' during dry augering. The water level rose to depths of 2.5', 1.8' and 1.5' after observation periods of 5, 10 and 15 minutes, respectively.

Depth (feet)	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0							Tan and light gray Silty CLAYS (CL)
							Tan and light gray Sandy SILTS (ML)
5	58 b/ft	(1)	16				Very dense, white and tan fine SANDS with trace of silt (SP-SM)
	50 b/8"						—with 4" clayey sand layer at 6'
	56 b/ft						—with a trace of gravel, 8'- 12'
10	34 b/ft	(2)	23				—dense at 10.5'
15	50 b/9"						—very dense at 14.5'
							Medium, gray and brown slickensided CLAYS with some organics (CH)
		0.88 (3)	51	105	66	41	
20							
			24		28	11	Firm, light gray and white Clayey SILTS with some fine sand and clay pockets (CL)
25							
							Very stiff, light gray, greenish gray, tan and yellow Silty CLAYS with sandy silt pockets and streaks (CL)
30							
	(4)		28				
35							
40							

Continued Next Page

(1) 17.8% passing the #200 sieve.
(2) 9.5% passing the #200 sieve.
(3) Unconsolidated, undrained triaxial compression test run at 8.4 psi confining pressure.
(4) Tests from clayey portion of sample.

Unified Soil Classifications based on limited laboratory test data and visual observations.

Woodward-Clyde Consultants

PROJECT:	LIGO	BORING:	B-SW-33-GT
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	8/9/94
		TECHNICIAN:	M. Savoy
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	2 of 2

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
40									Very stiff, light gray, greenish gray, tan and yellow Silty CLAYS with sandy silt pockets and streaks (CL)
45			(5)		22		51	31	Very stiff, light gray and greenish gray CLAYS with a trace of sand and silt becoming light gray Clayey SANDS (CH/CL)
50									Bottom of boring at 50'. Borehole grouted full depth.

(5) Tests from silty clay with sand portion of sample.

Unified Soil Classifications based on limited laboratory test data and visual observations.

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SW-34-CP**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
0									CLAYEY SILT
5									SILTY CLAY WITH SANDY SILT LAYERS
10									
15									SAND
20									
25									SILTY CLAY WITH SILTY SAND AND SANDY SILT LAYERS
30									
35									
40									ALTERNATING LAYERS OF SILTY CLAY AND CLAYEY SILT

Continued Next Page

PROJECT:	LIGO	BORING:	B-SW-34-CP
LOCATION:	Livingston, Louisiana	FILE:	93B107C
		DATE:	Sept. 1994
		DRILLER:	FUGRO
CLIENT:	California Institute of Technology	APPROVED:	
		PAGE:	2 of 2

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
40									
45									SILTY CLAY
50									

Woodward-Clyde Consultants

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SW-35-SC**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:
PAGE: **1 of 2**

DEPTH (FEET): 0, 5, 10, 15, 20, 25, 30, 35, 40

SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
								CLAY WITH SILTY CLAY AND CLAYEY SILT LAYERS
								SAND WITH SANDY SILT LAYERS
								SANDY SILT
								LAYERS OF SILTY SAND AND SANDY SILT
								SANDY SILT
								SANDY SILT, SILTY SAND AND SILTY CLAY

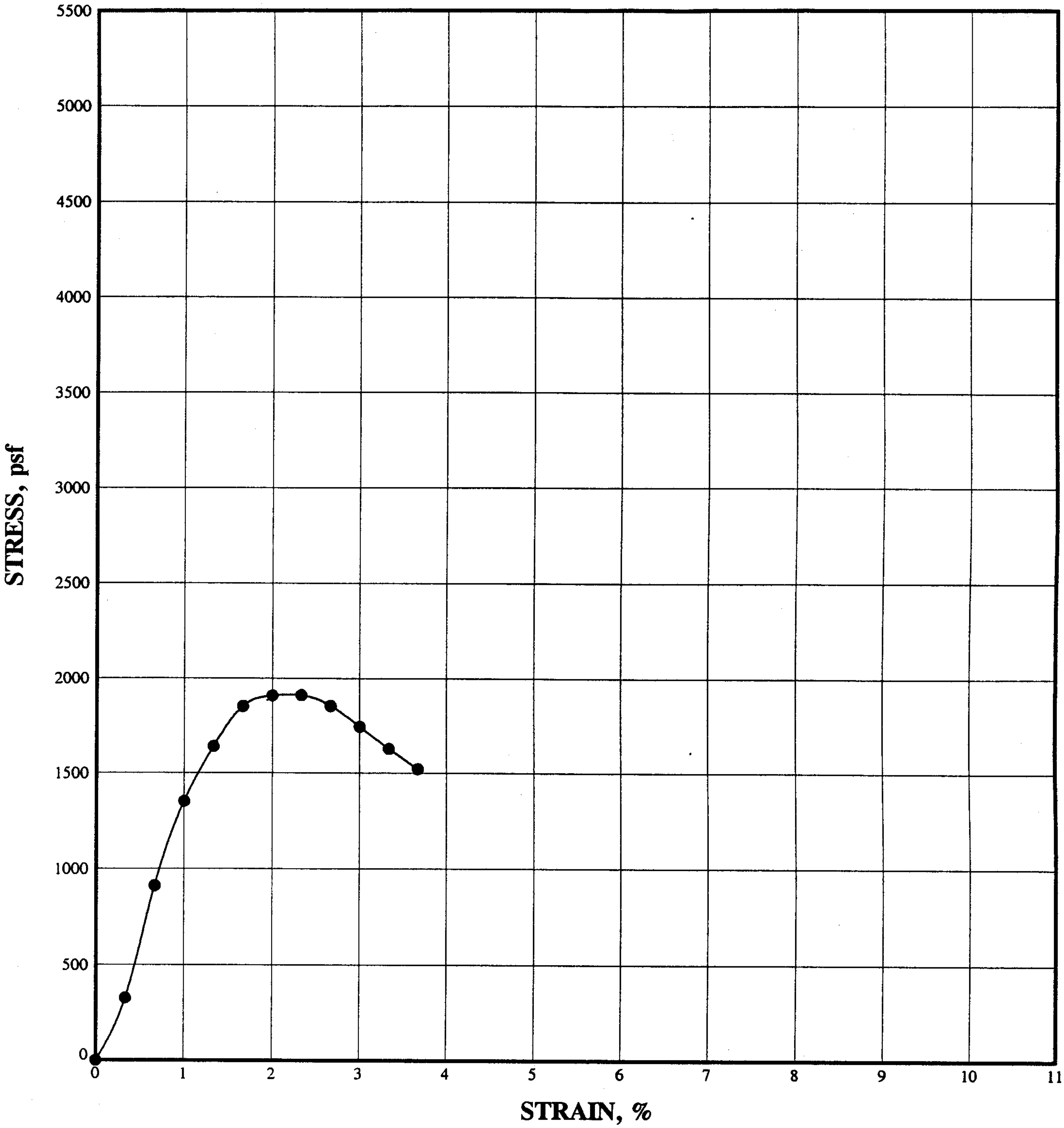
Continued Next Page

PROJECT: **LIGO**
LOCATION: **Livingston, Louisiana**
CLIENT: **California Institute of Technology**

BORING: **B-SW-35-SC**
FILE: **93B107C**
DATE: **Sept. 1994**
DRILLER: **FUGRO**
APPROVED:
PAGE: **2 of 2**

DEPTH (FEET)	SYMBOL	SAMPLE	S.P.T.	Compress. Stress (tsf)	Moist. Content (%)	Wet Unit Weight (pcf)	L.L. (%)	P.I. (%)	Description of Stratum
40									
45									

UNCONFINED COMPRESSION TEST



LEGEND:

Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
● B-SE-1-GT	33' - 35'	38	82.1	94	1910 psf	2.3 %	82	20	62

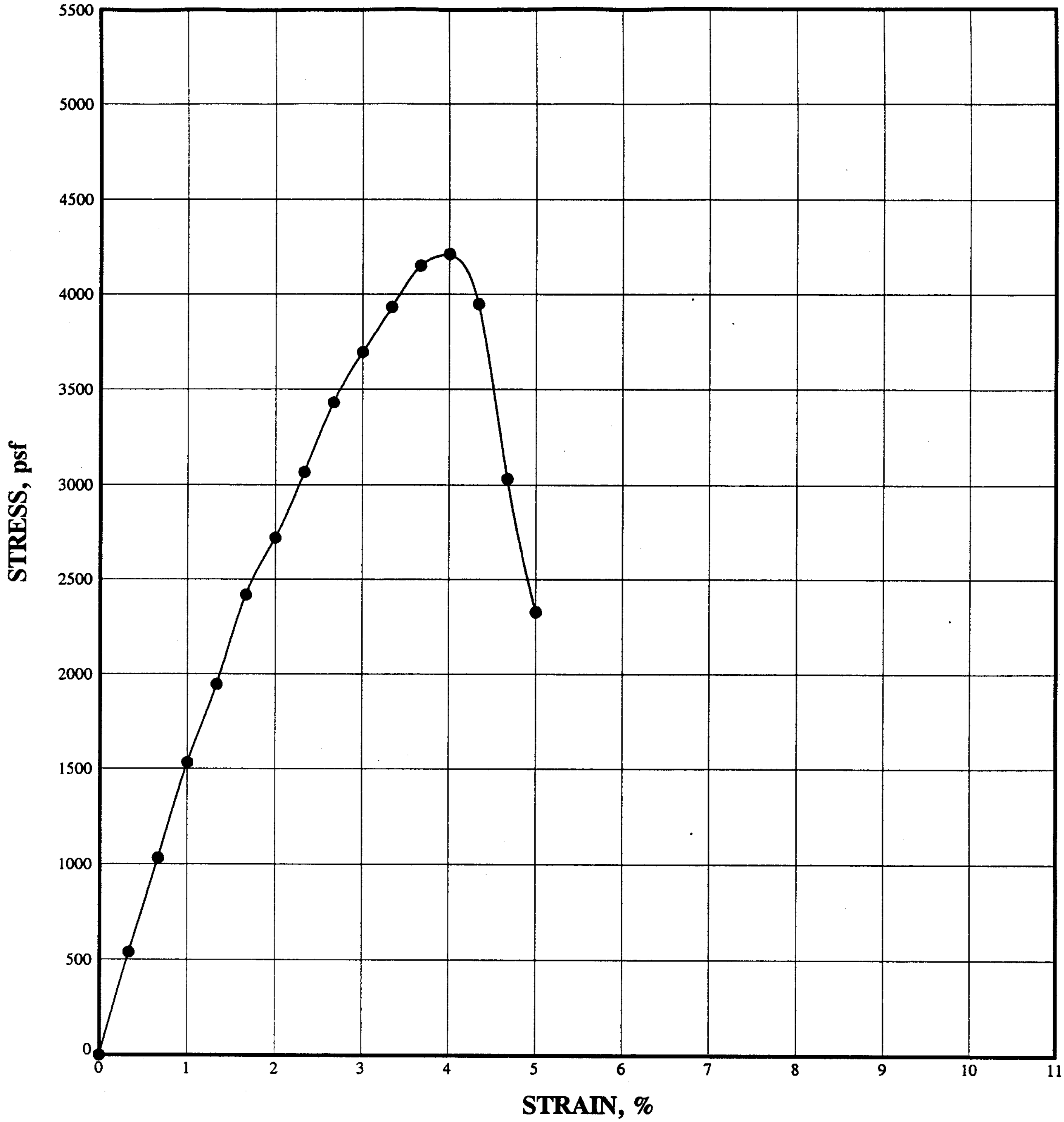
LIGO

UNCONFINED COMPRESSION TEST

ASTM D 2166-91

Woodward-Clyde Consultants

OCT 30 94 UNCONF3B 3B107



LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
●	B-SE-2-GT	43' - 45'	20	105.7	88	4211 psf	4.0 %	36	16	20

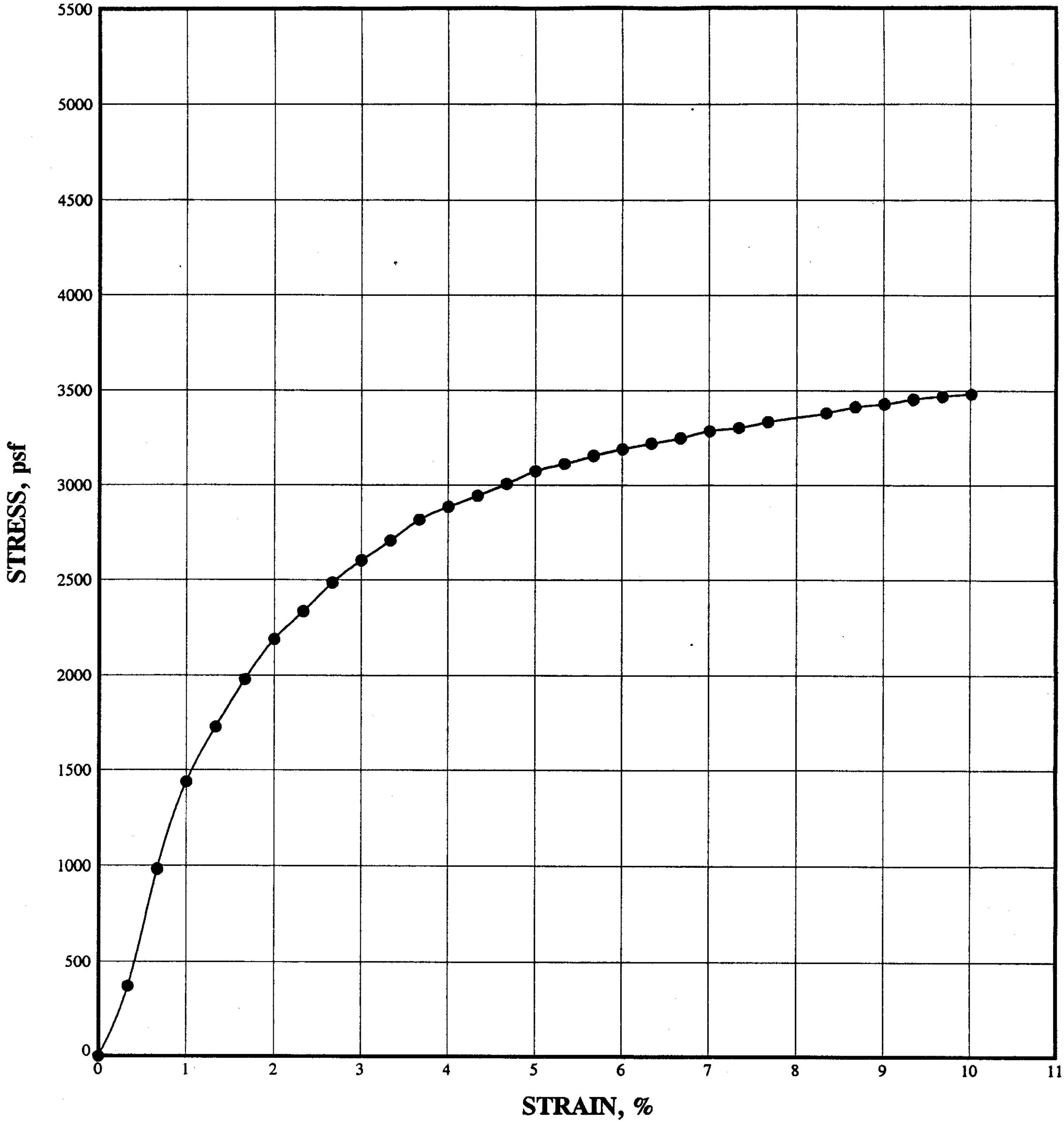
LIGO

UNCONFINED COMPRESSION TEST

ASTM D 2166-91

Woodward-Clyde Consultants

OCT 30 94 UNCONF3B 3B107



LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SE-10-GT	23' - 25'	31	94.3	103	3481 psf	10.0 %			

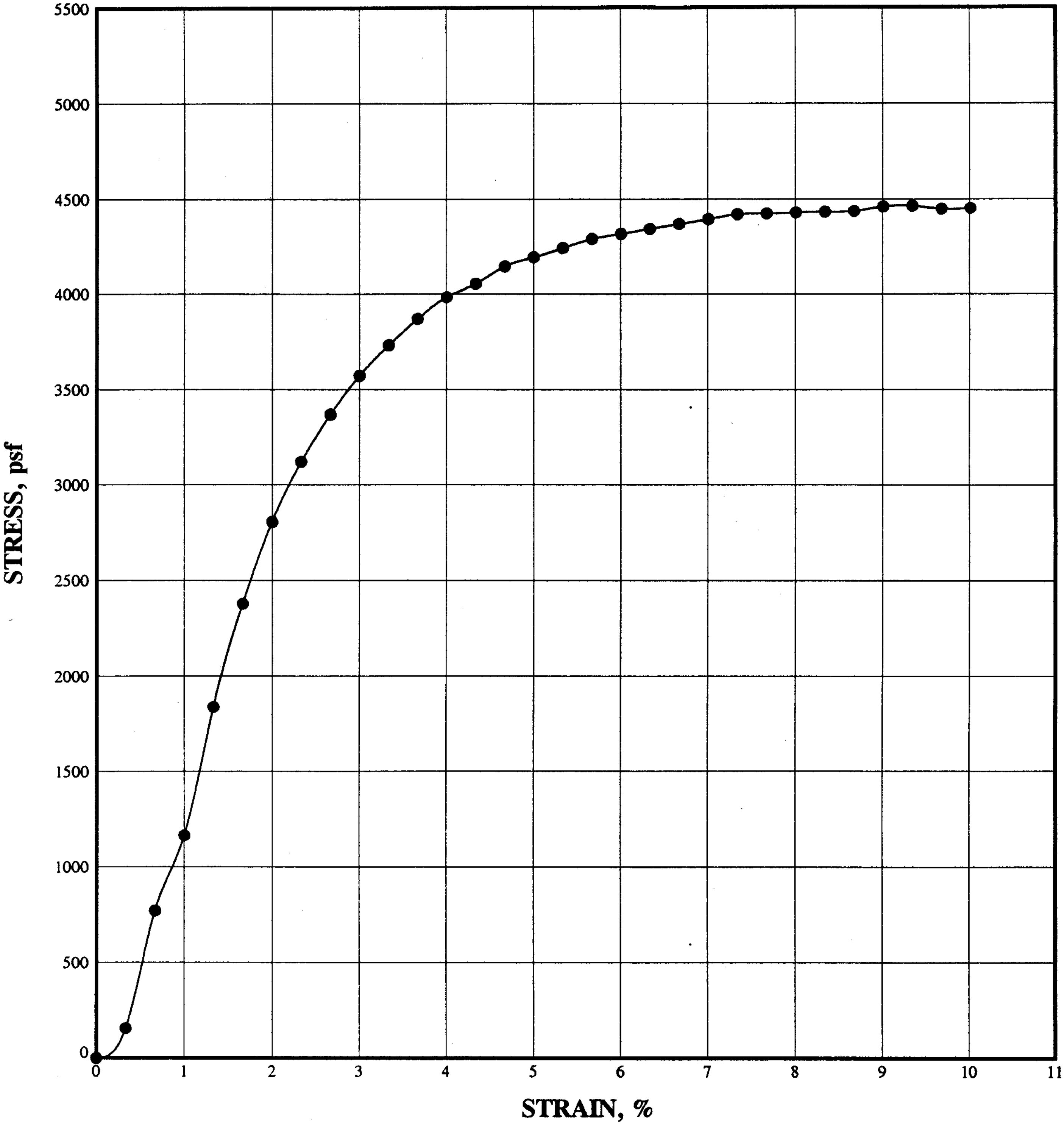
LIGO

UNCONFINED COMPRESSION TEST

ASTM D 2166-91

Woodward-Clyde Consultants

OCT 30 94 UNCONF3B 3B107



LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SE-14-GT	13' - 15'	23	102.1	92	4464 psf	9.3 %	49	15	34

LIGO

UNCONFINED COMPRESSION TEST

ASTM D 2166-91

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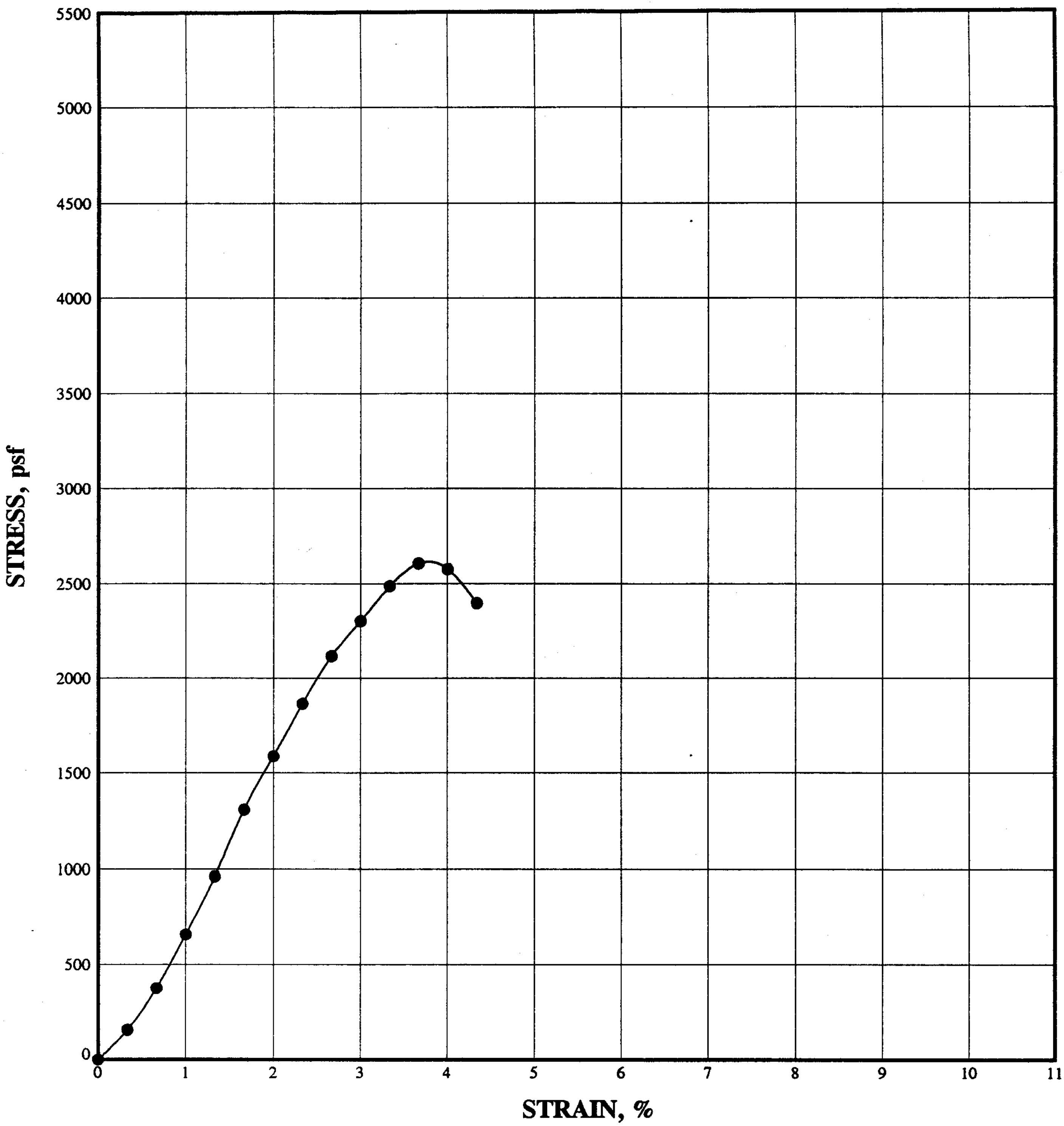

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SE-20-GT	8' - 10'	16	111.7	84	2607 psf	3.7 %	45	17	28

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UNCONFINED COMPRESSION TEST

ASTM D 2166-91

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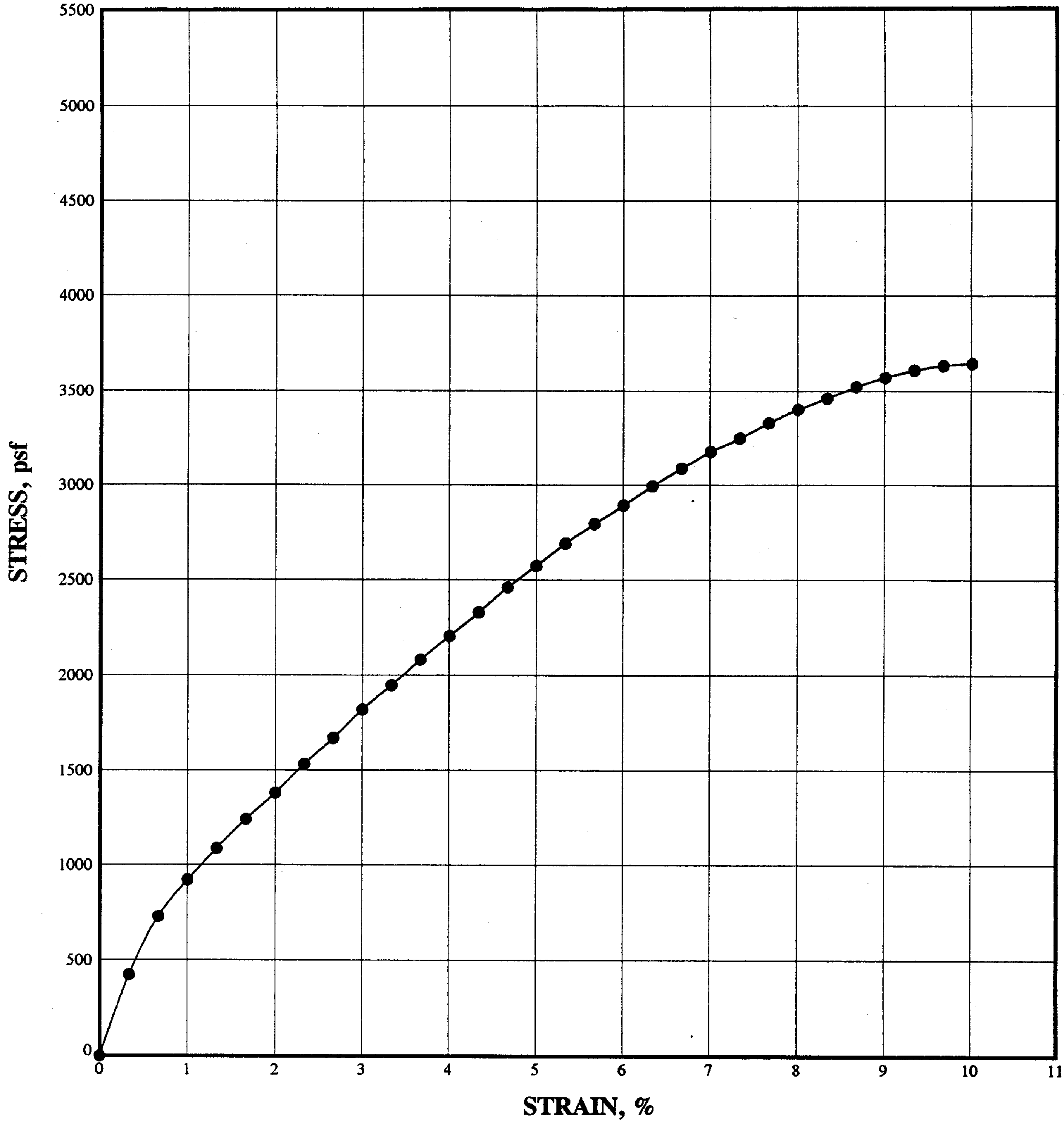

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
●	B-SE-28-GT	13' - 15'	22	105.1	93	3643 psf	10.0 %	38	15	23

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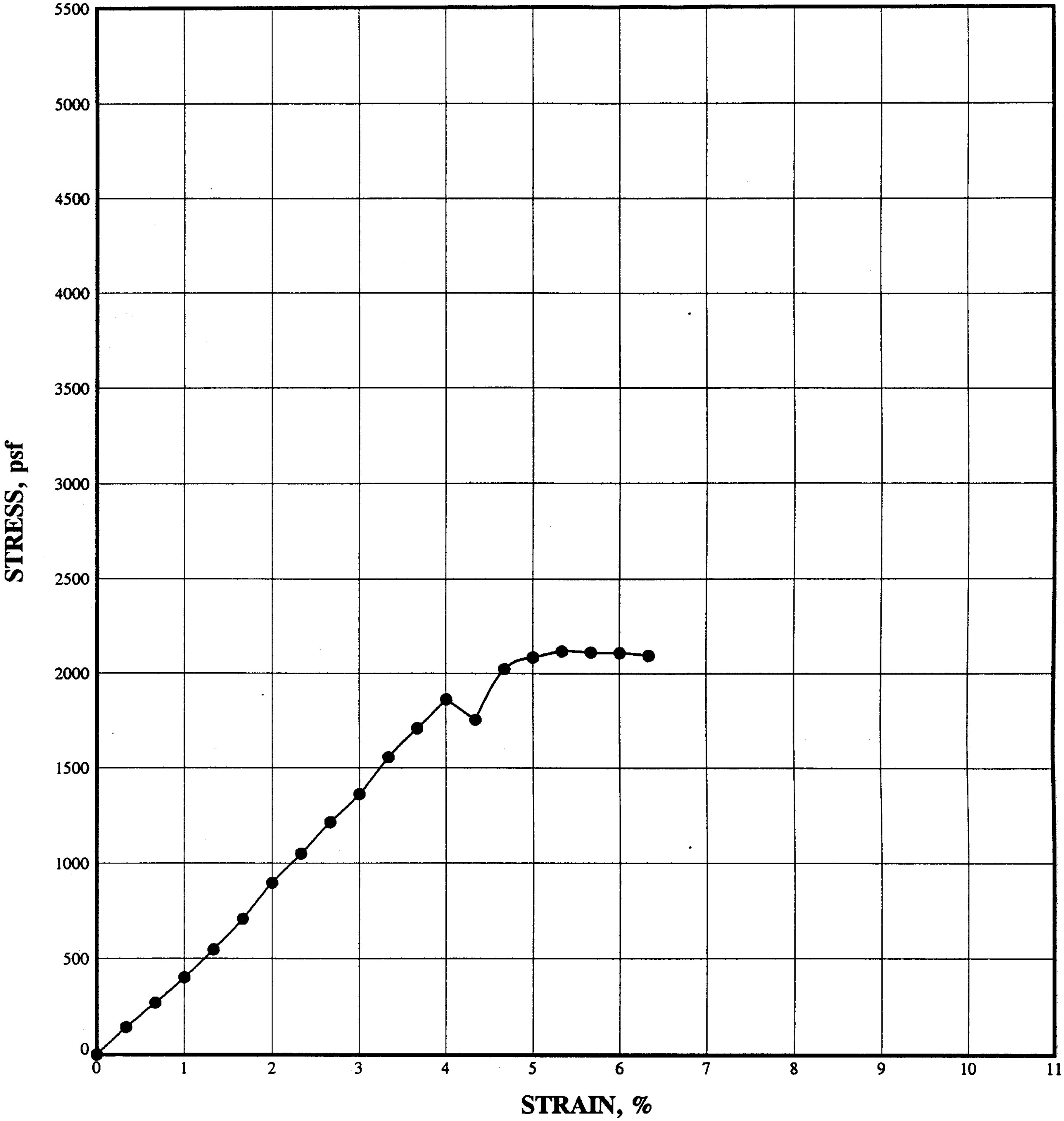

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
●	B-SE-30-GT	4' - 6'	14	119.2	87	2118 psf	5.3 %	21	10	11

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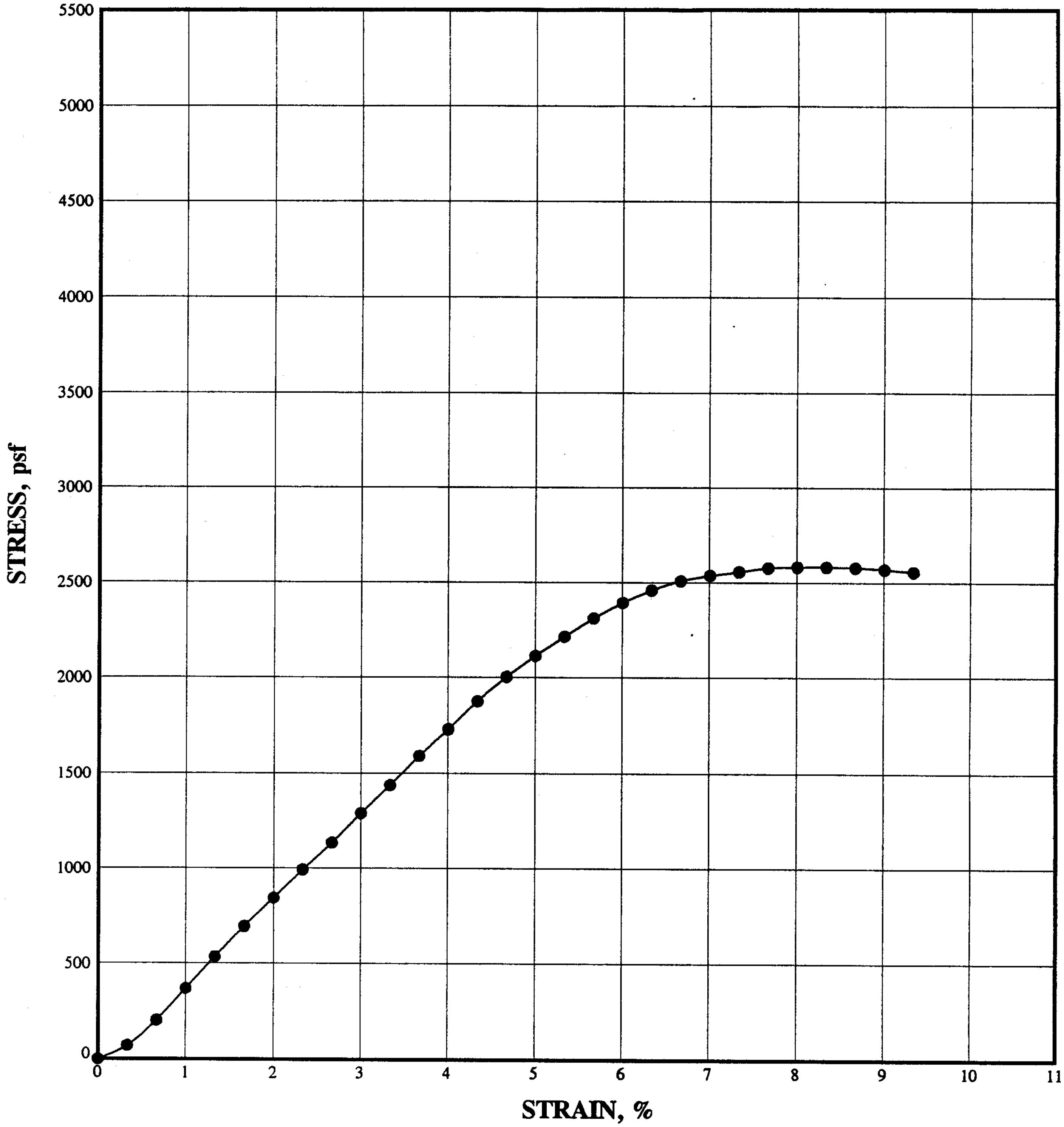

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
●	B-SE-33-GT	6' - 8'	14	118.0	86	2582 psf	8.3 %	26	11	15

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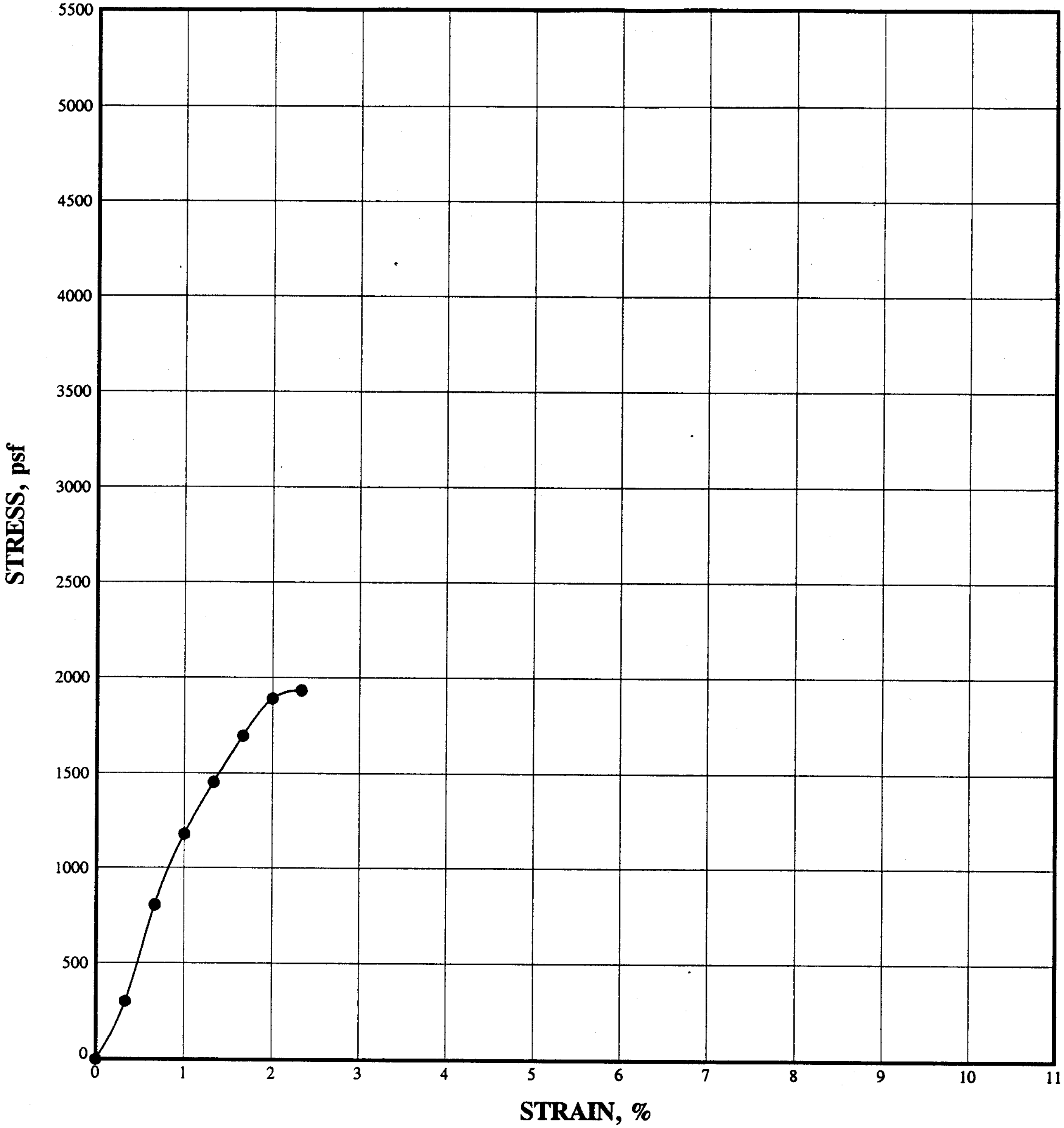

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
●	B-SE-33-GT	18' - 20'	30	92.3	96	1932 psf	2.3 %	51	20	31

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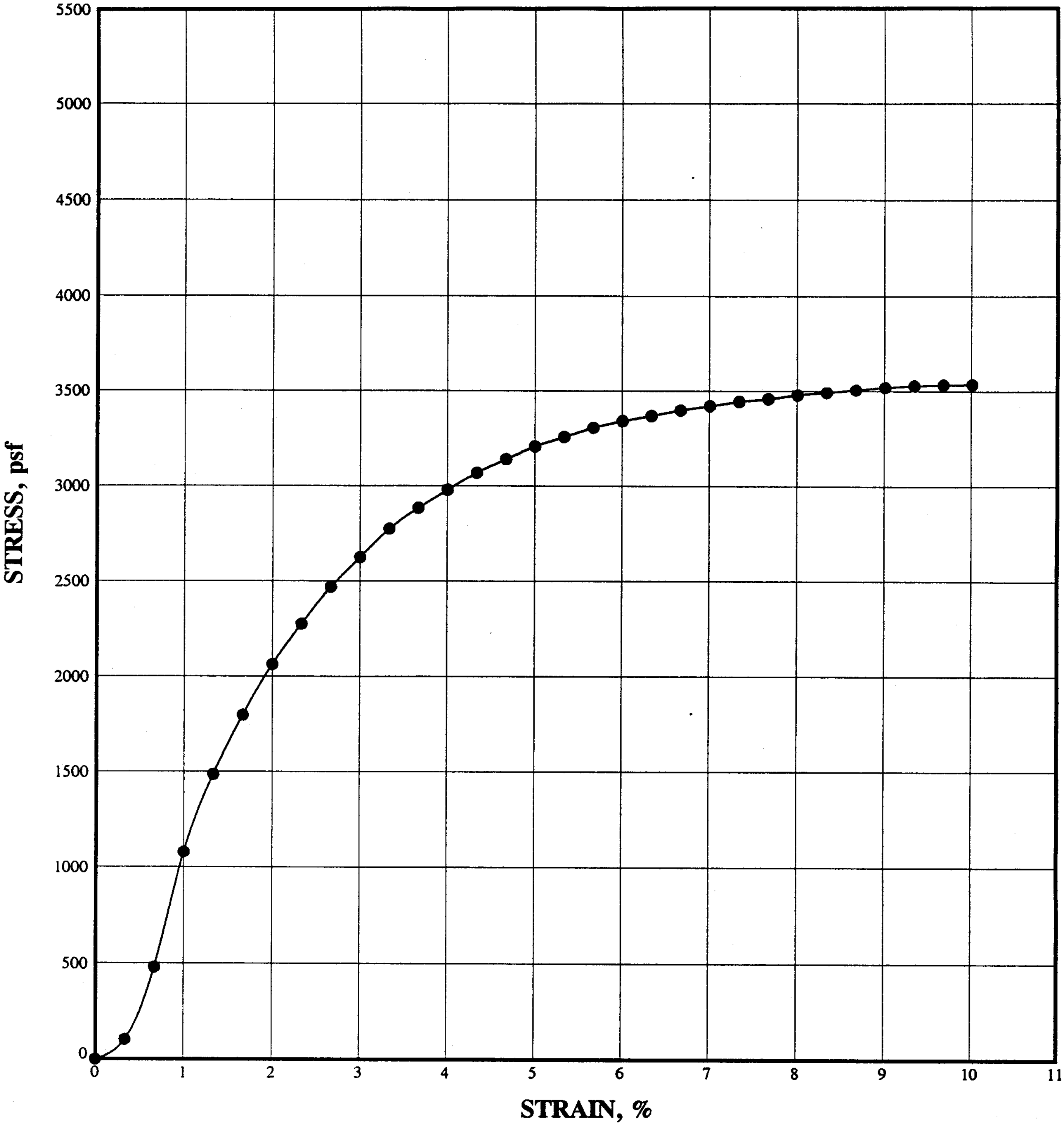

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SW-2-GT	6' - 8'	19	104.8	80	3537 psf	10.0 %	47	15	32

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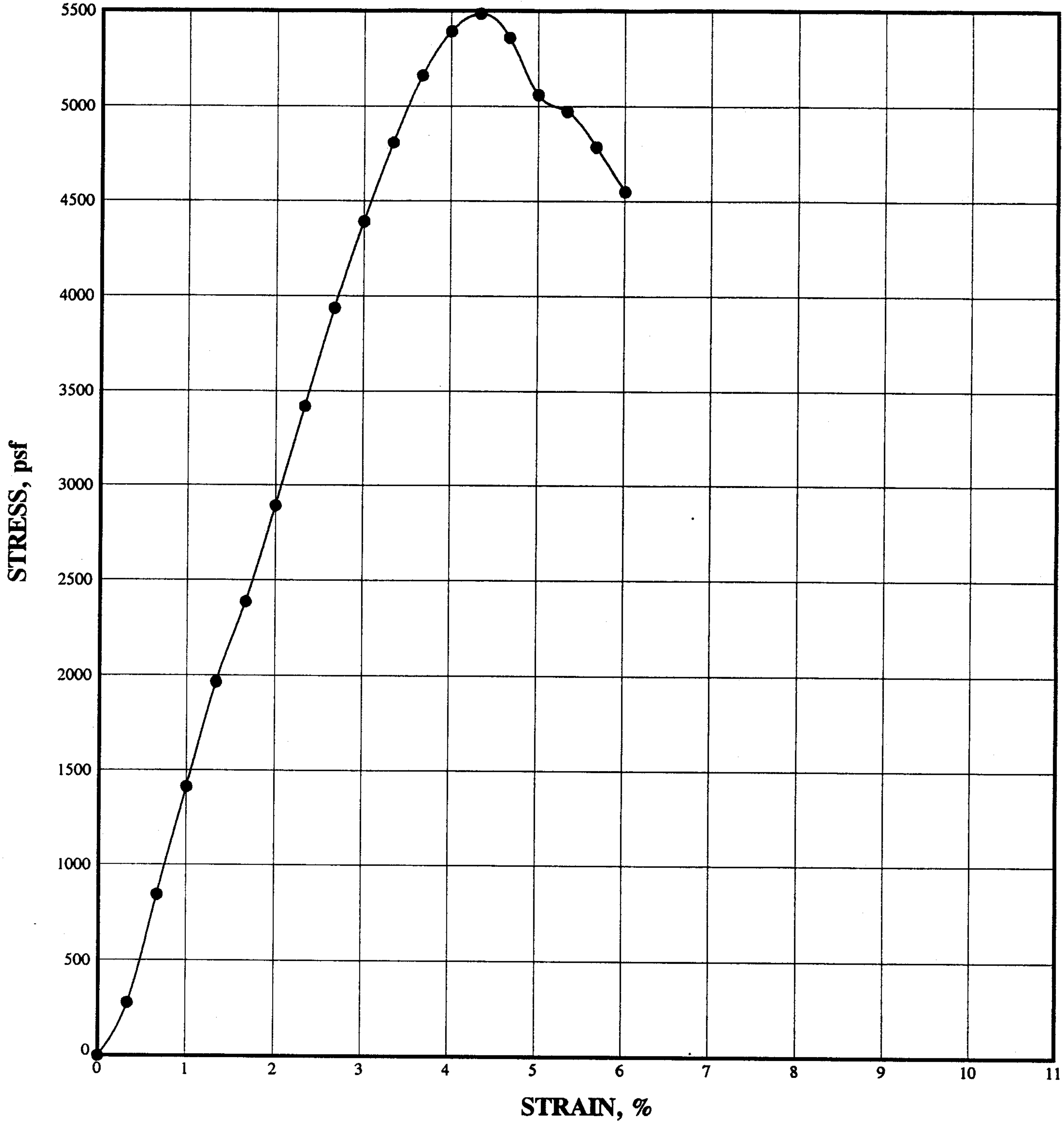

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SW-5-GT	8' - 10'	15	117.4	88	5482 psf	4.3 %	27	11	16

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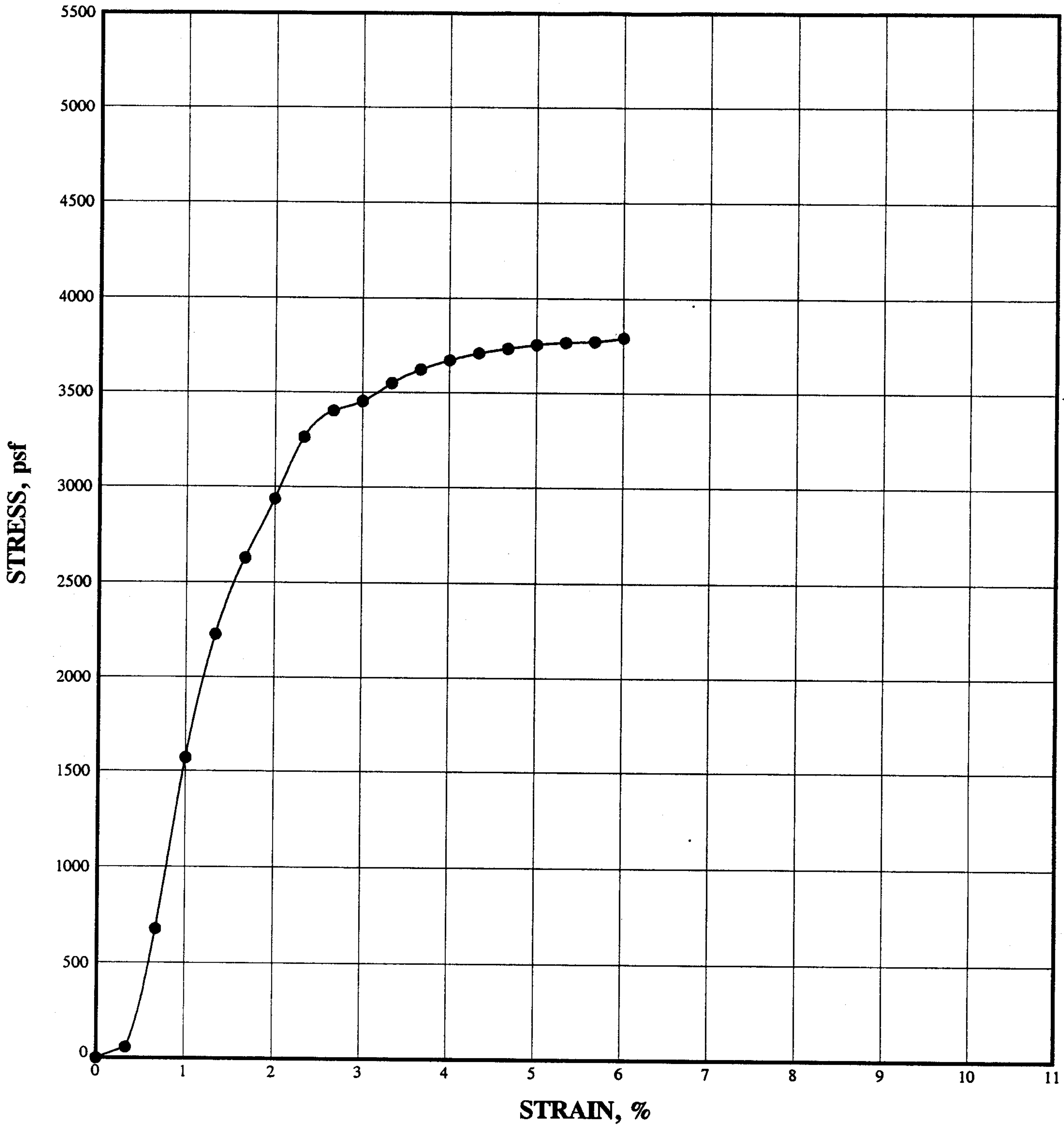

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
●	B-SW-5-GT	18' - 20'	24	100.9	93	3792 psf	6.0 %	55	17	38

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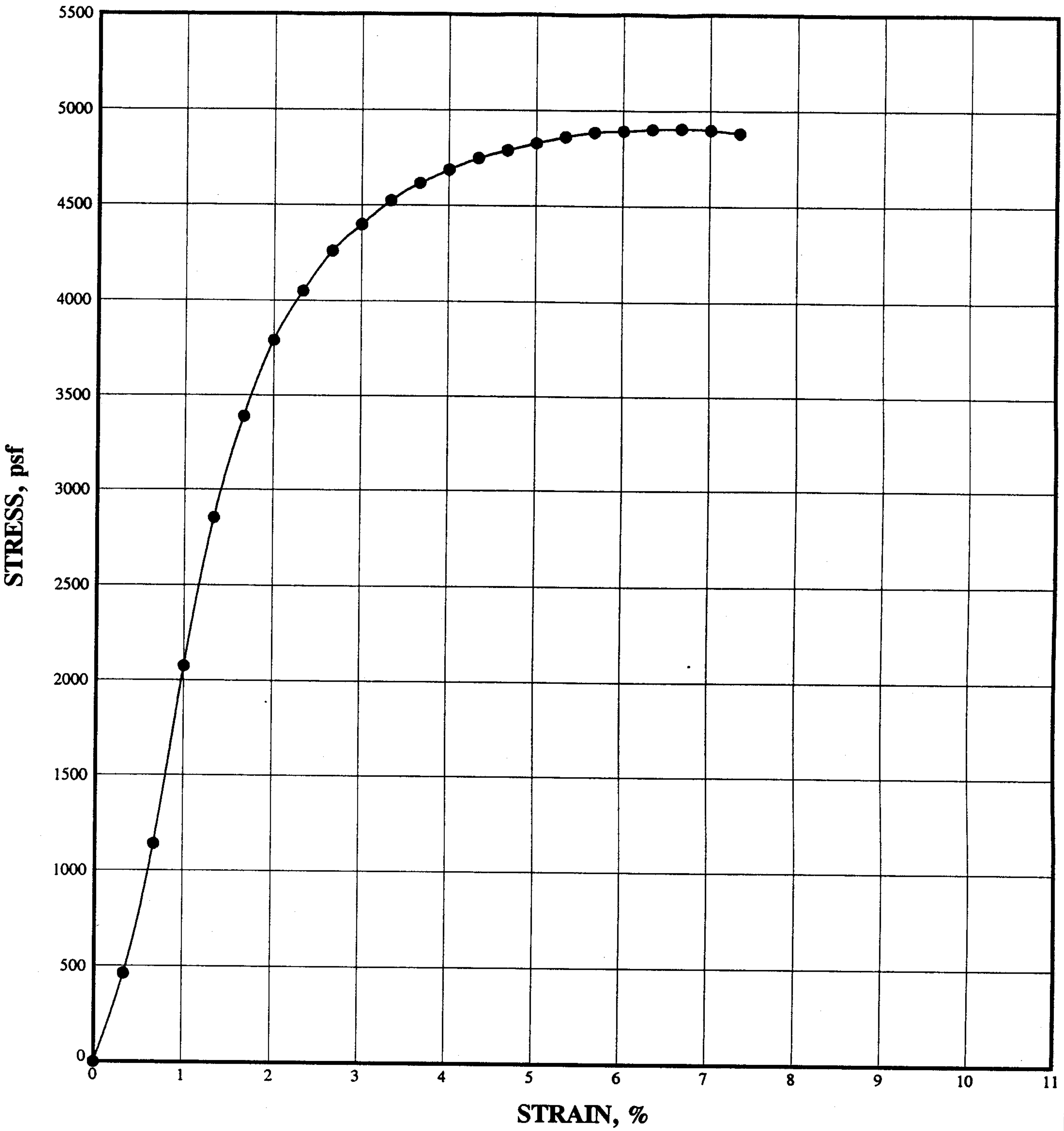

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
●	B-SW-9-GT	23' - 25'	32	93.4	104	4906 psf	6.7 %	59	18	41

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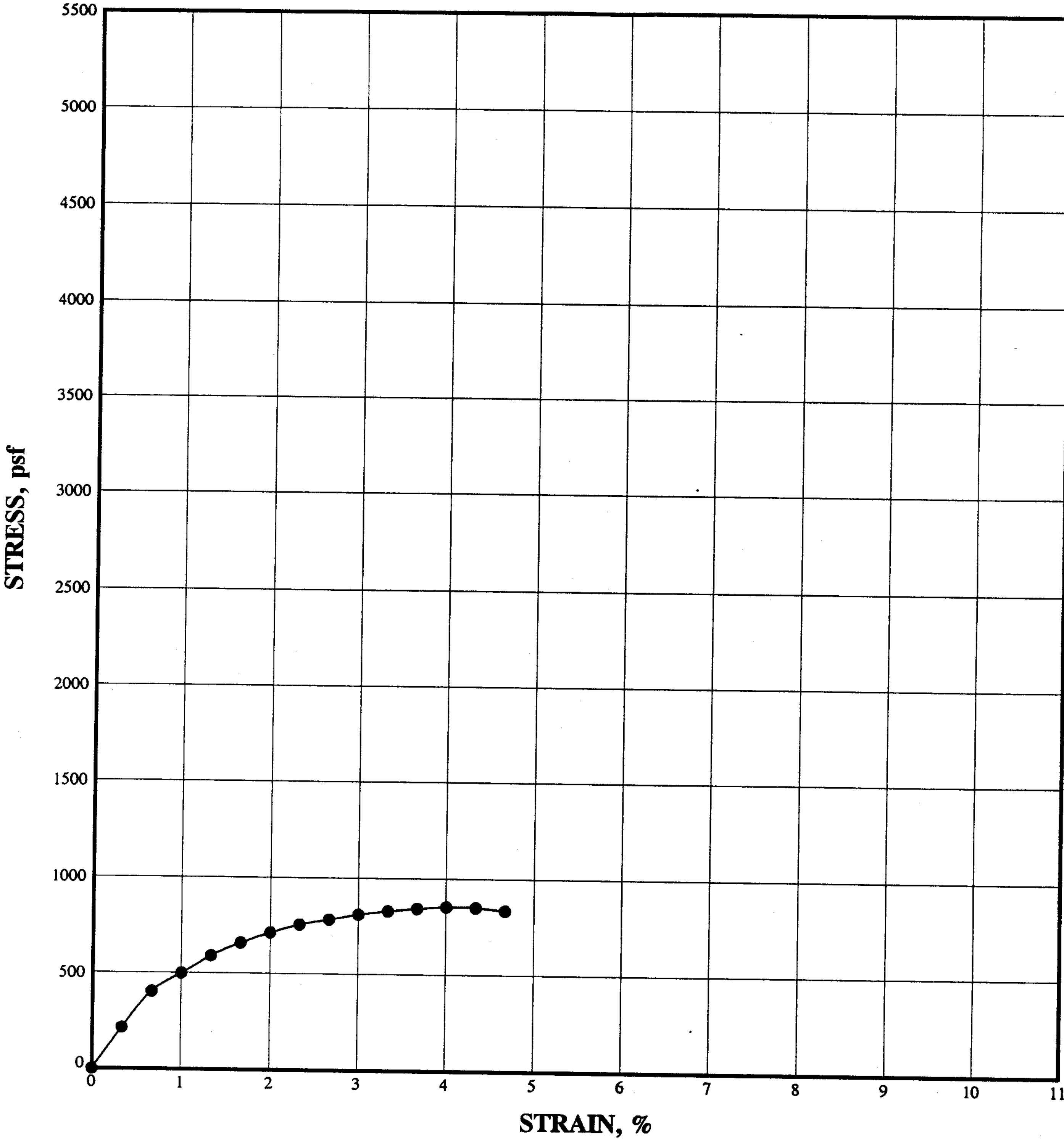

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
●	B-SW-25-GT	18' - 20'	42	75.3	90	854 psf	4.0 %	67	24	43

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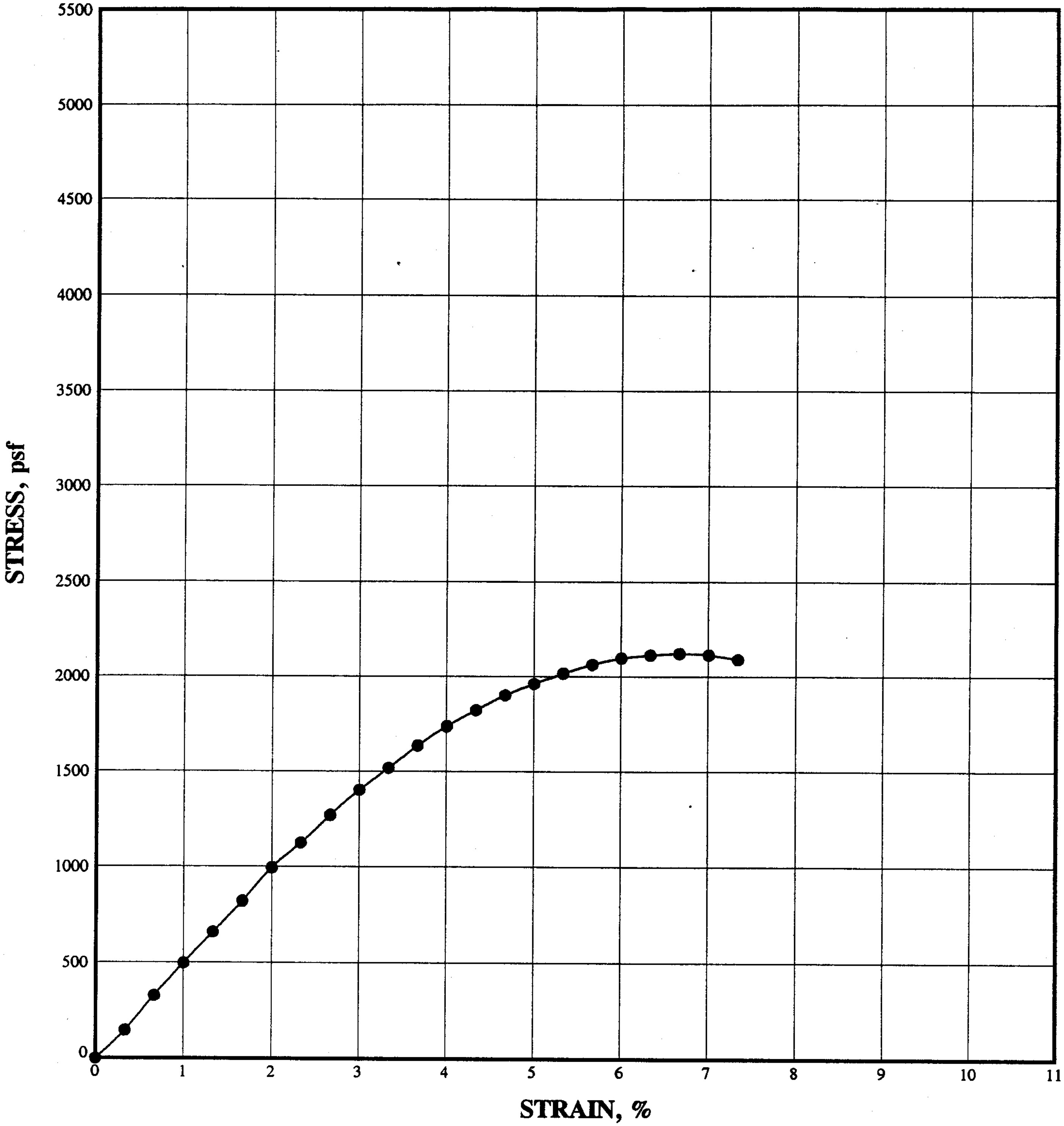

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
●	B-SW-29-GT	4' - 6'	19	107.7	86	2122 psf	6.7 %	24	13	11

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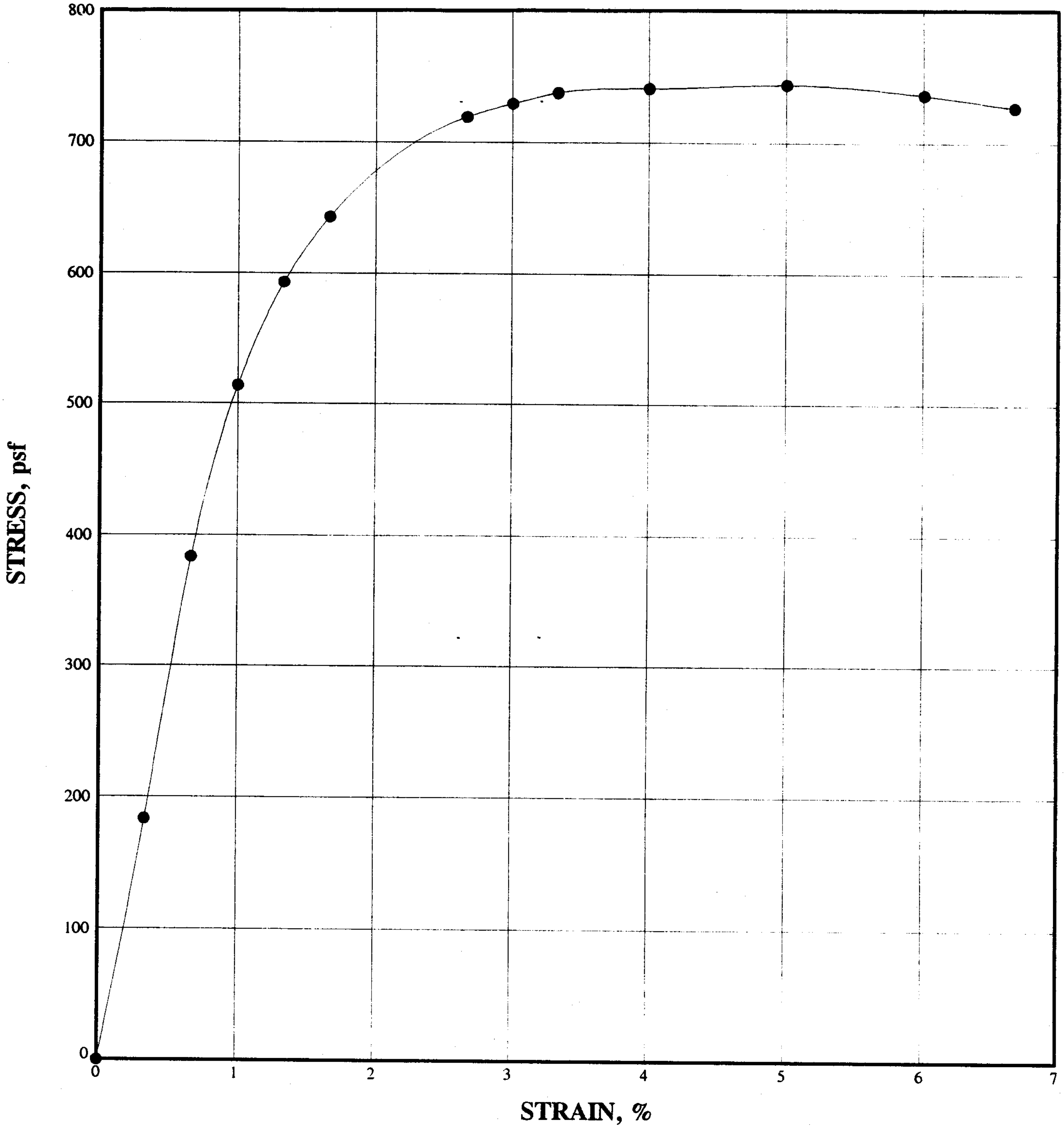

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
●	BSW25GT	13' - 15'	56	64.6	93	744 psf	5.0 %	73	25	48

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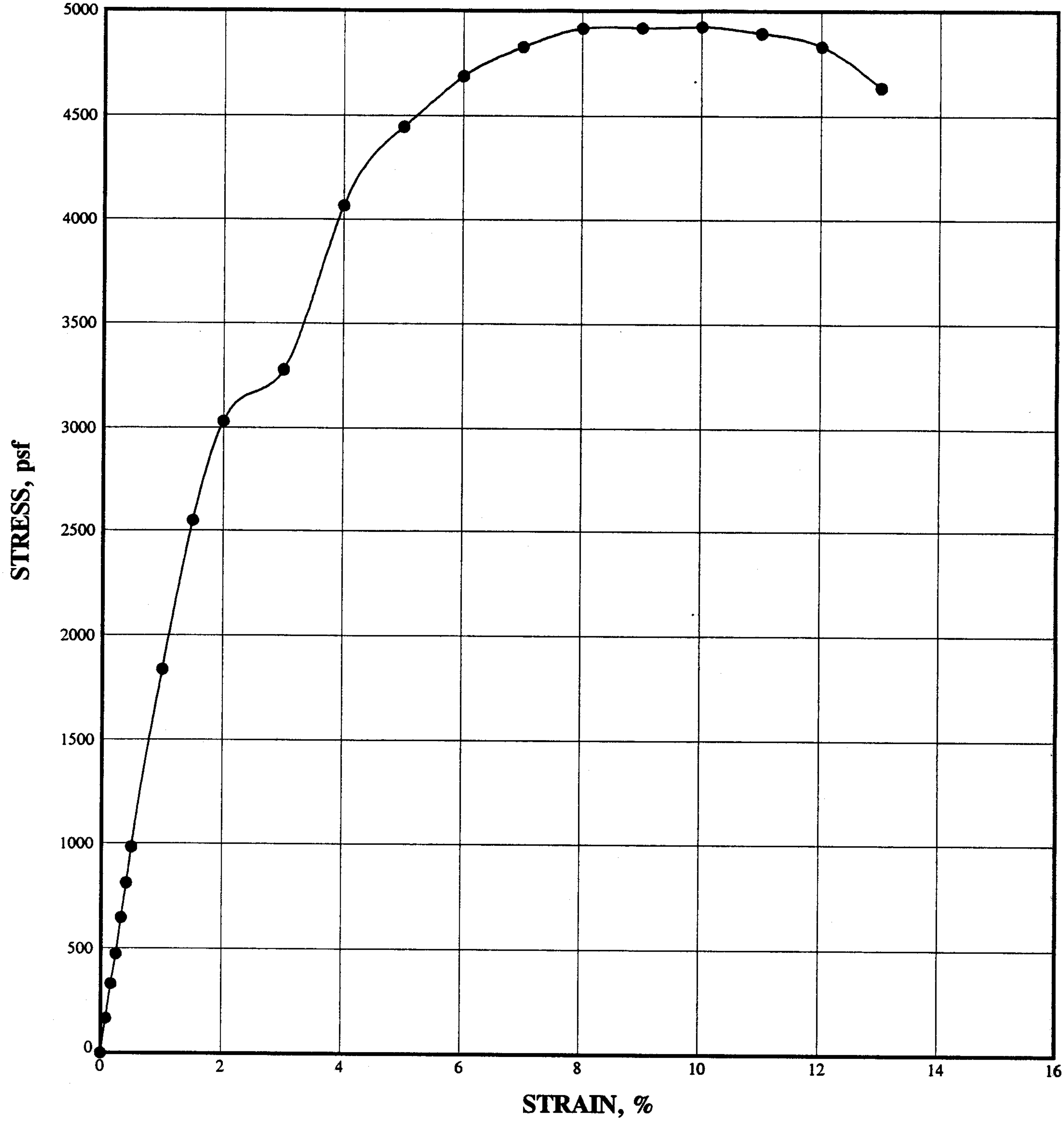
UNDRAINED TRIAXIAL TEST



LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
●	B-SE-1-GT	8' - 10'	24	102	95	4923 psf	10.0 %	43	16	27

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ASTM D 2850-87

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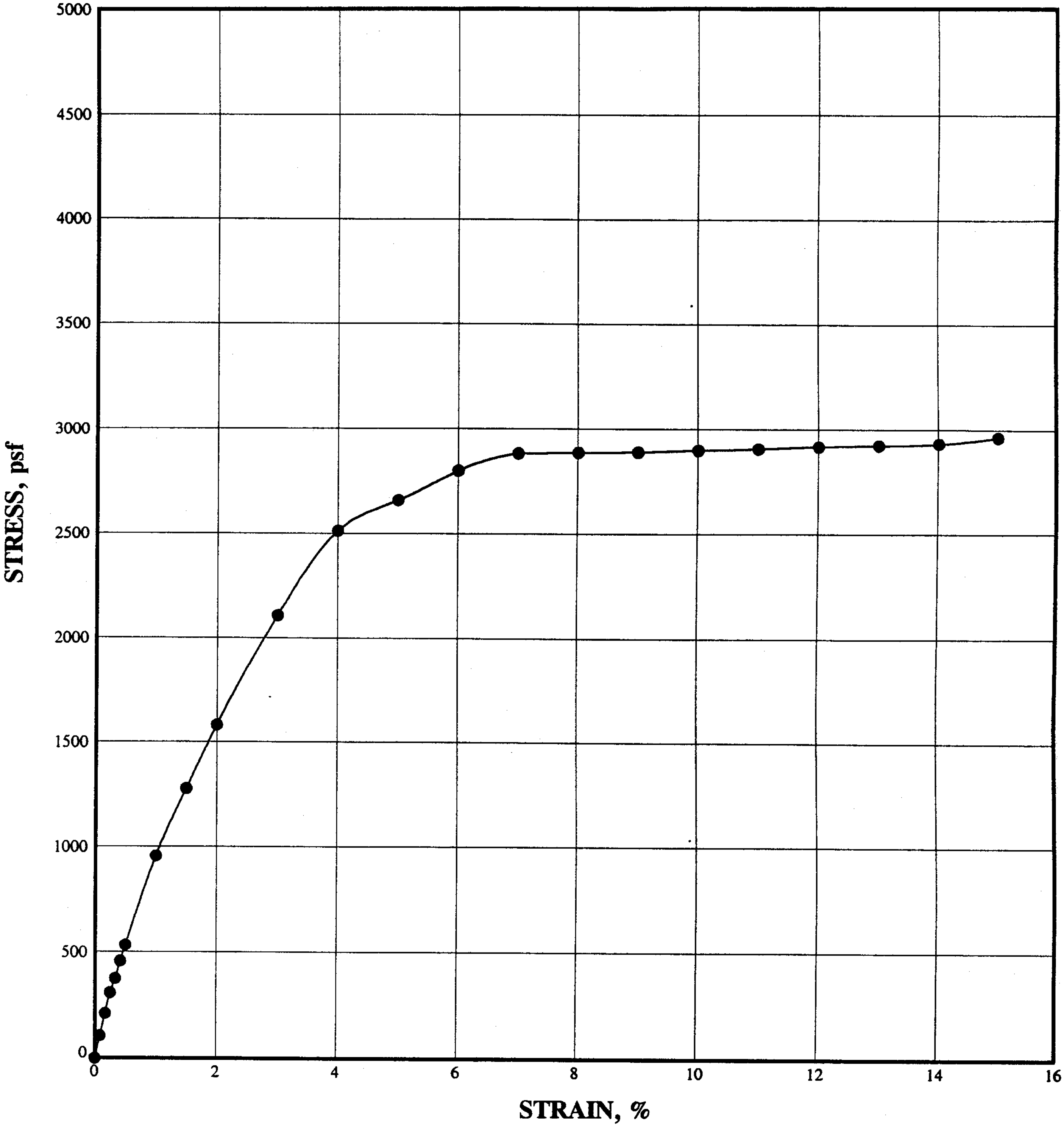

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SE-2-GT	4' - 6'	15	115	83	2963 psf	15.0 %	35	11	24

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ASTM D 2850-87

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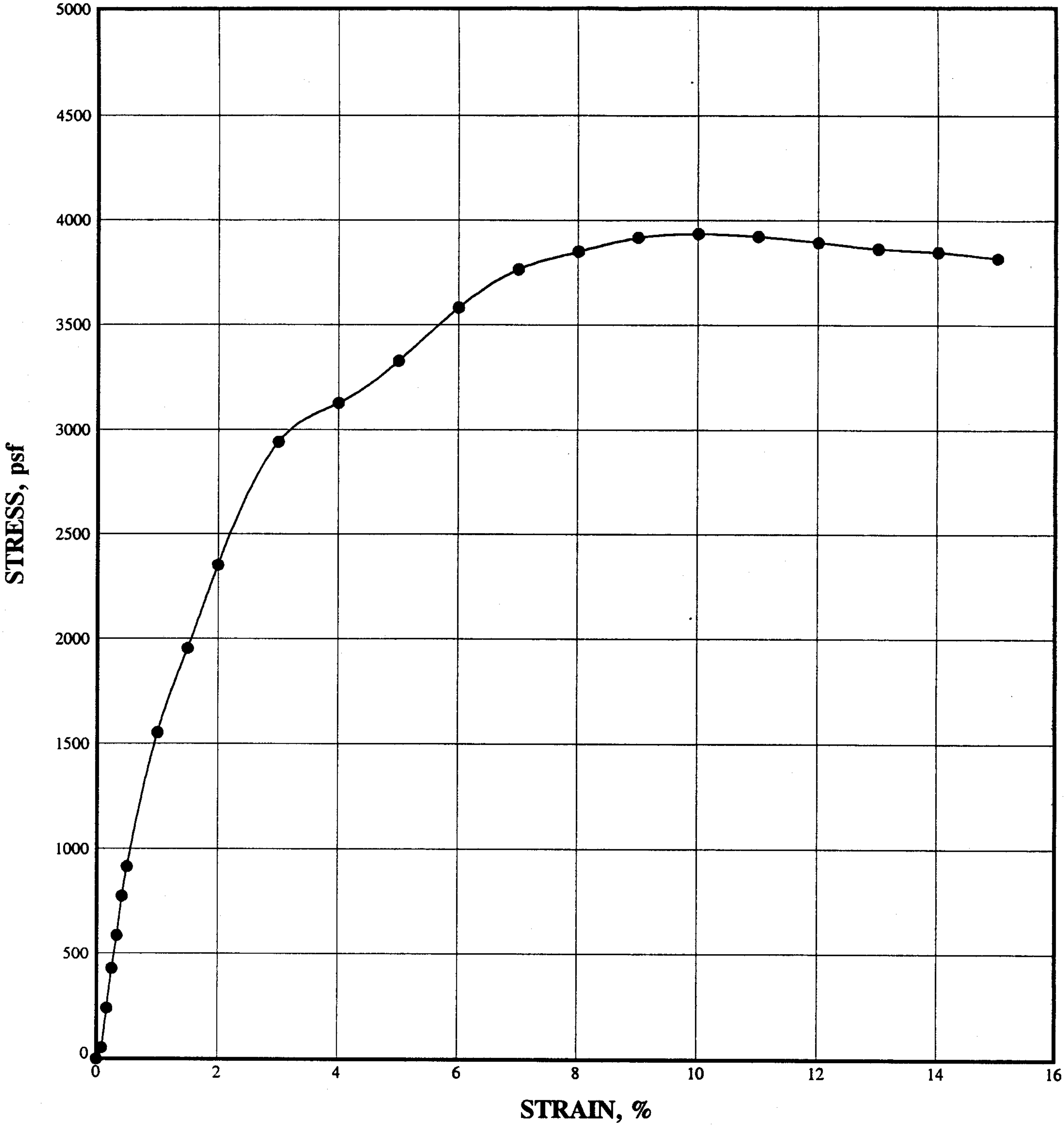

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SE-2-GT	28' - 30'	23	103	93	3934 psf	10.0 %	45	14	31

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ASTM D 2850-87

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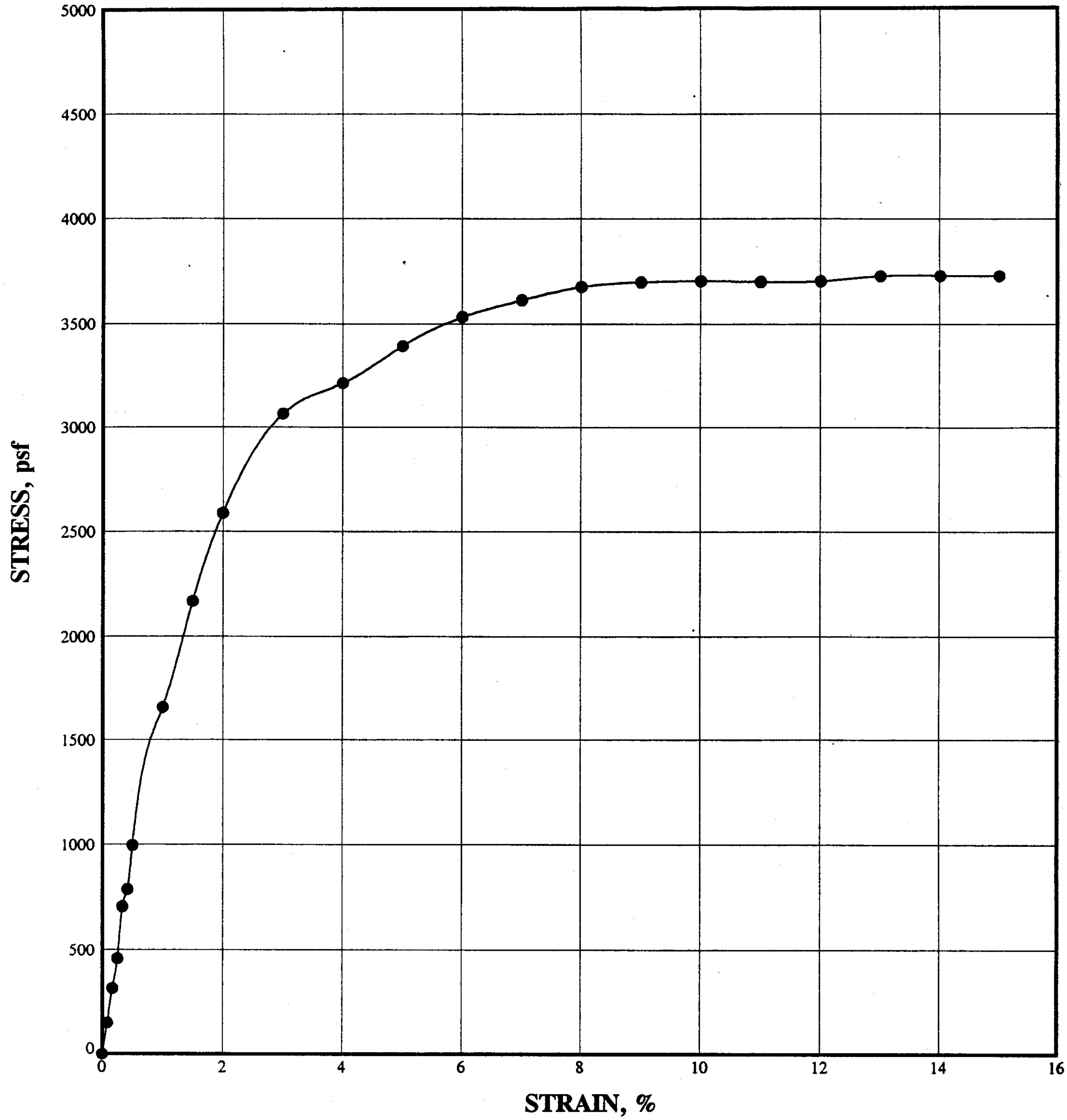

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
●	B-SE-10-GT	18' - 20'	23	100	90	3730 psf	15.0 %			

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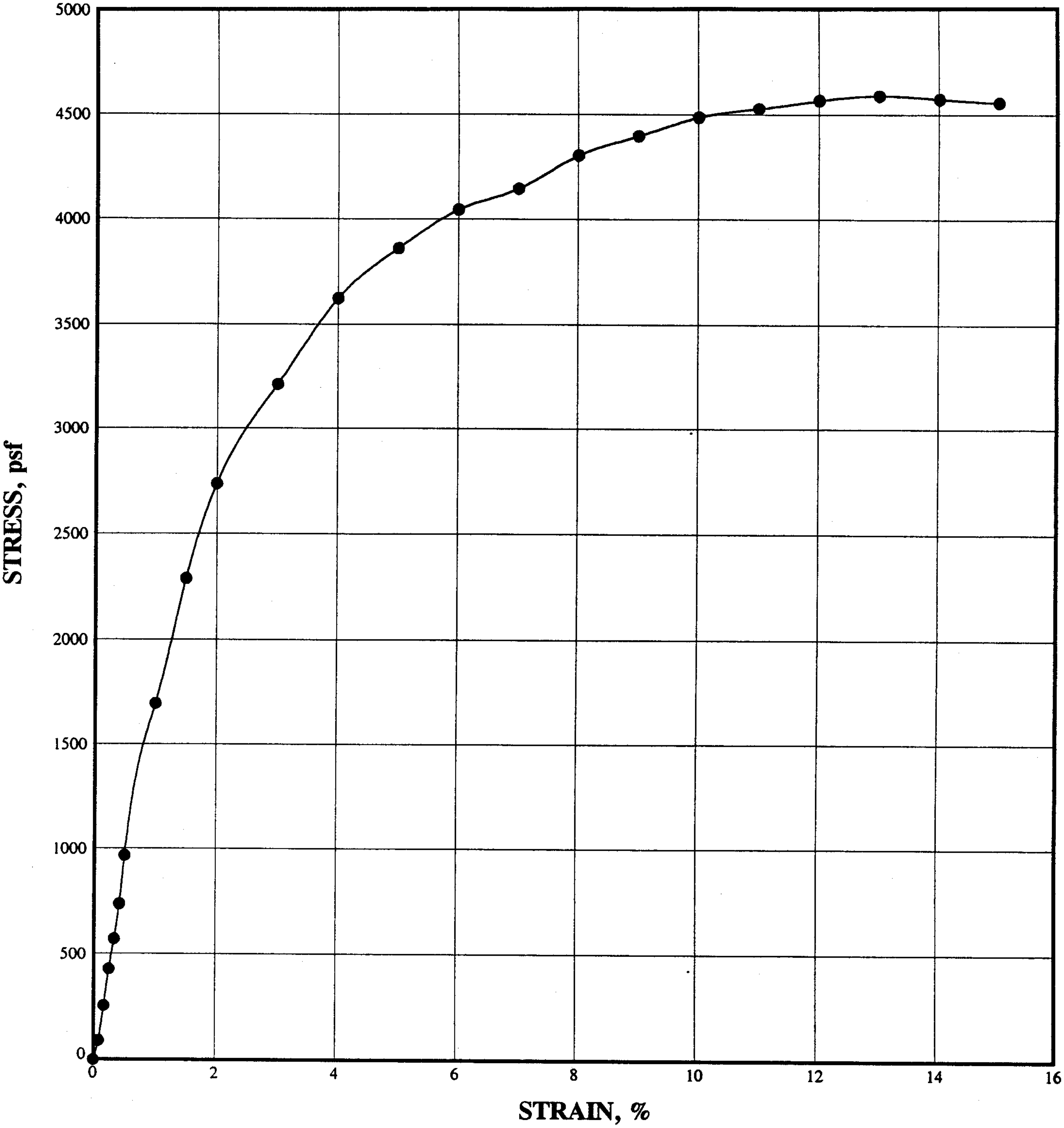

LEGEND:

Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
• B-SE-17-GT	18' - 20'	25	98	93	4588 psf	13.0 %	58	18	40

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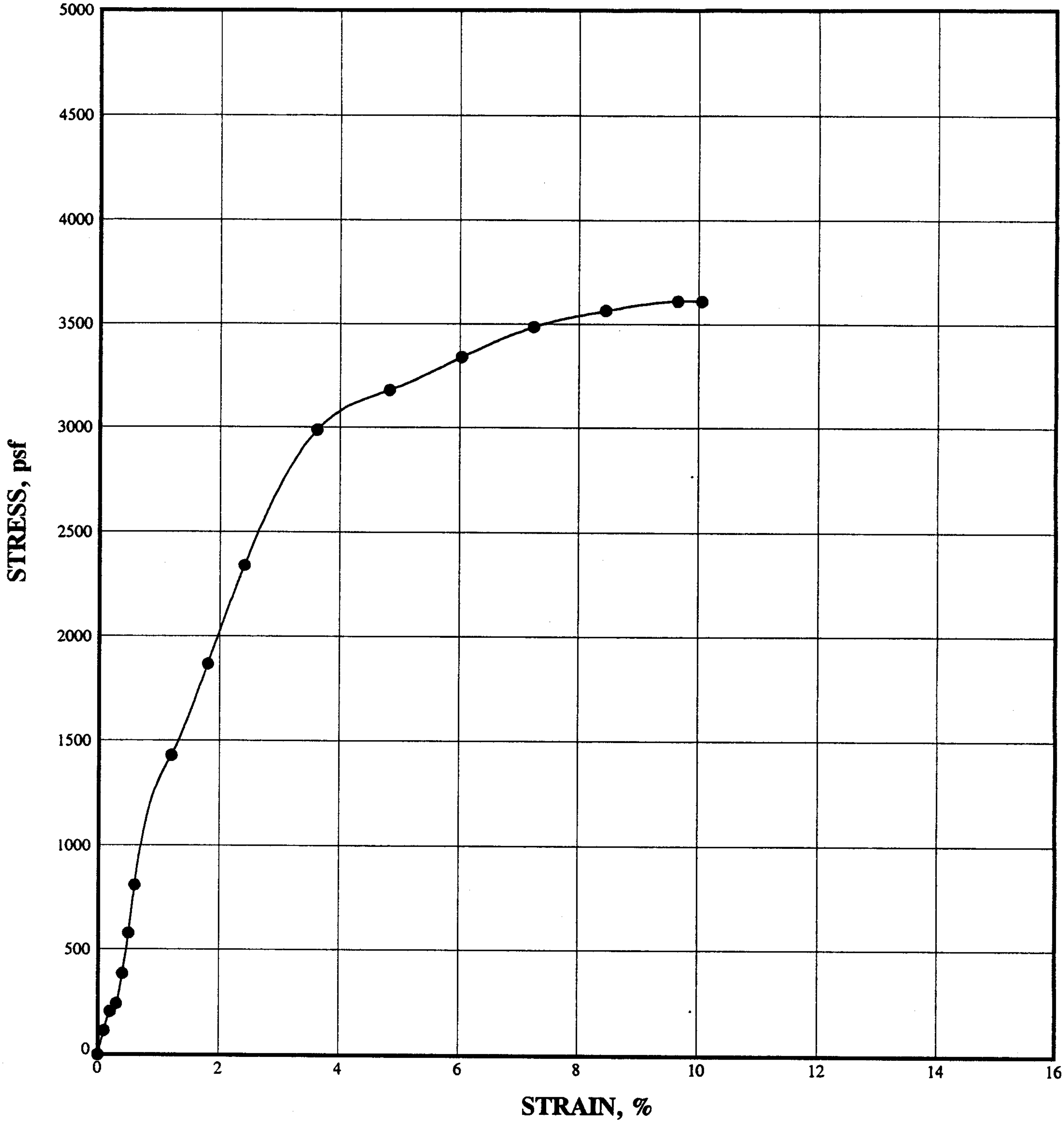

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SE-24-GT	18' - 20'	20	103	83	3611 psf	9.7 %	41	14	27

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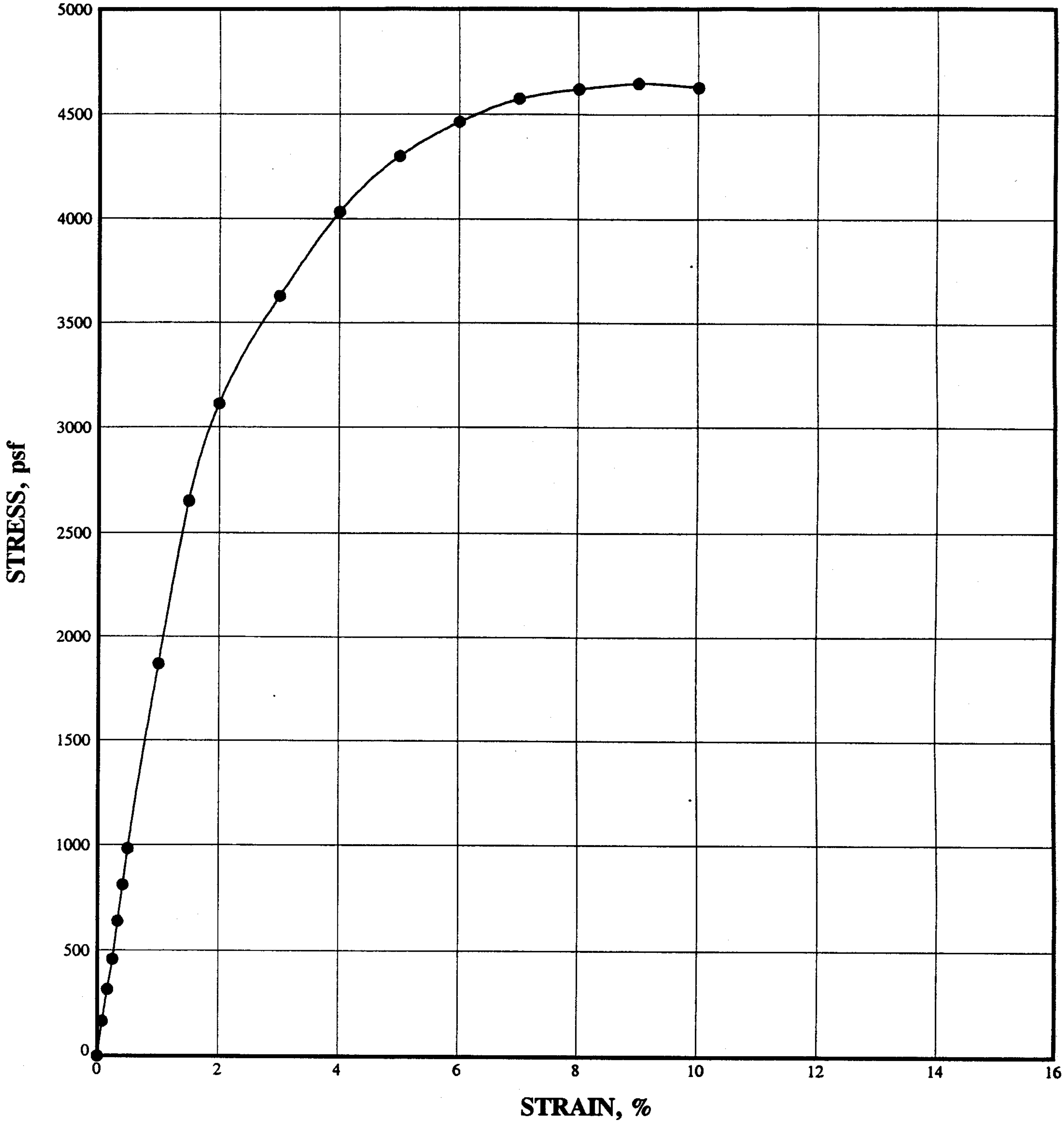

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SE-30-GT	13' - 15'	23	103	95	4644 psf	9.0 %	56	17	39

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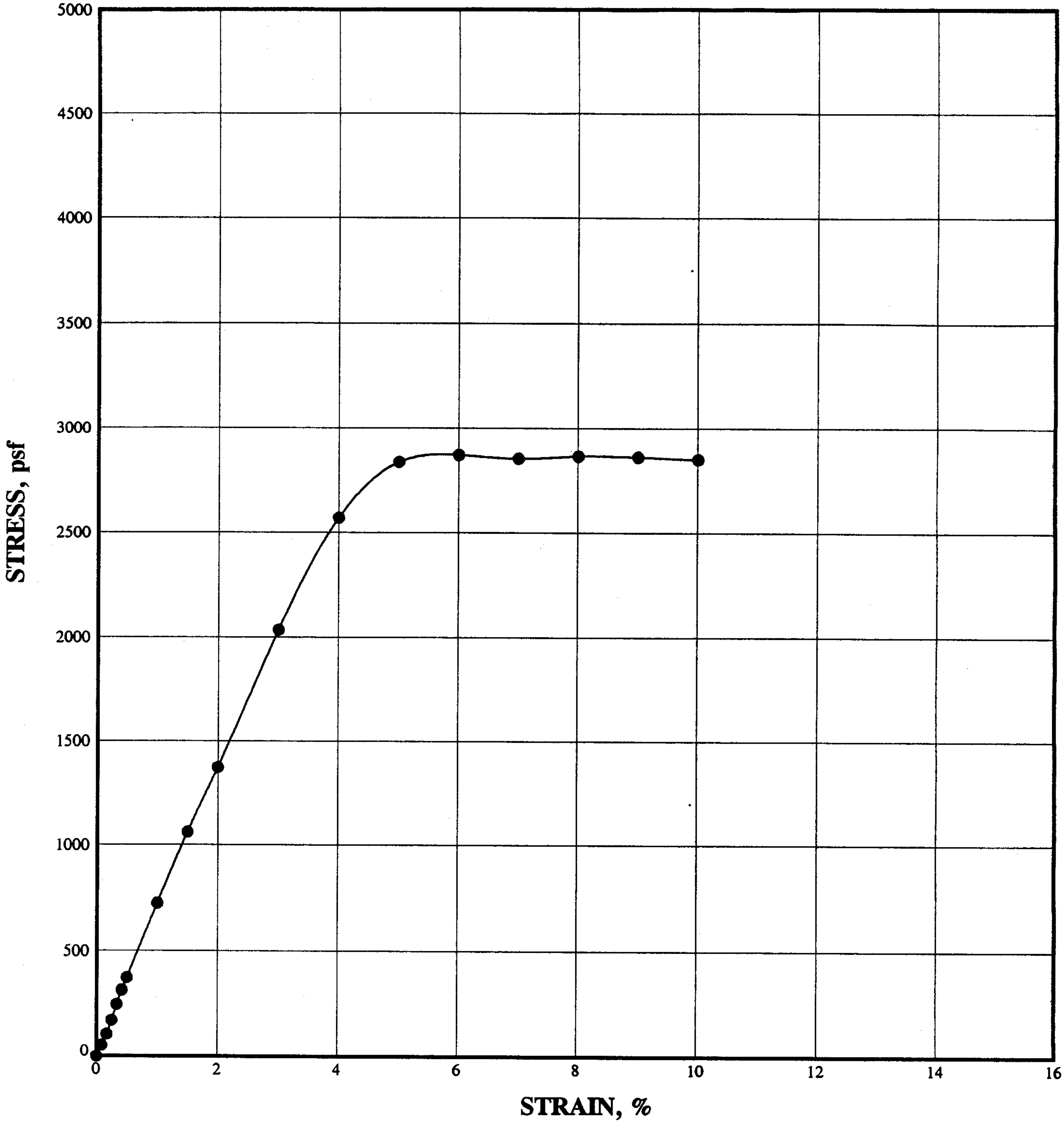

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SW-2-GT	13' - 15'	15	114	83	2871 psf	6.0 %	22	13	9

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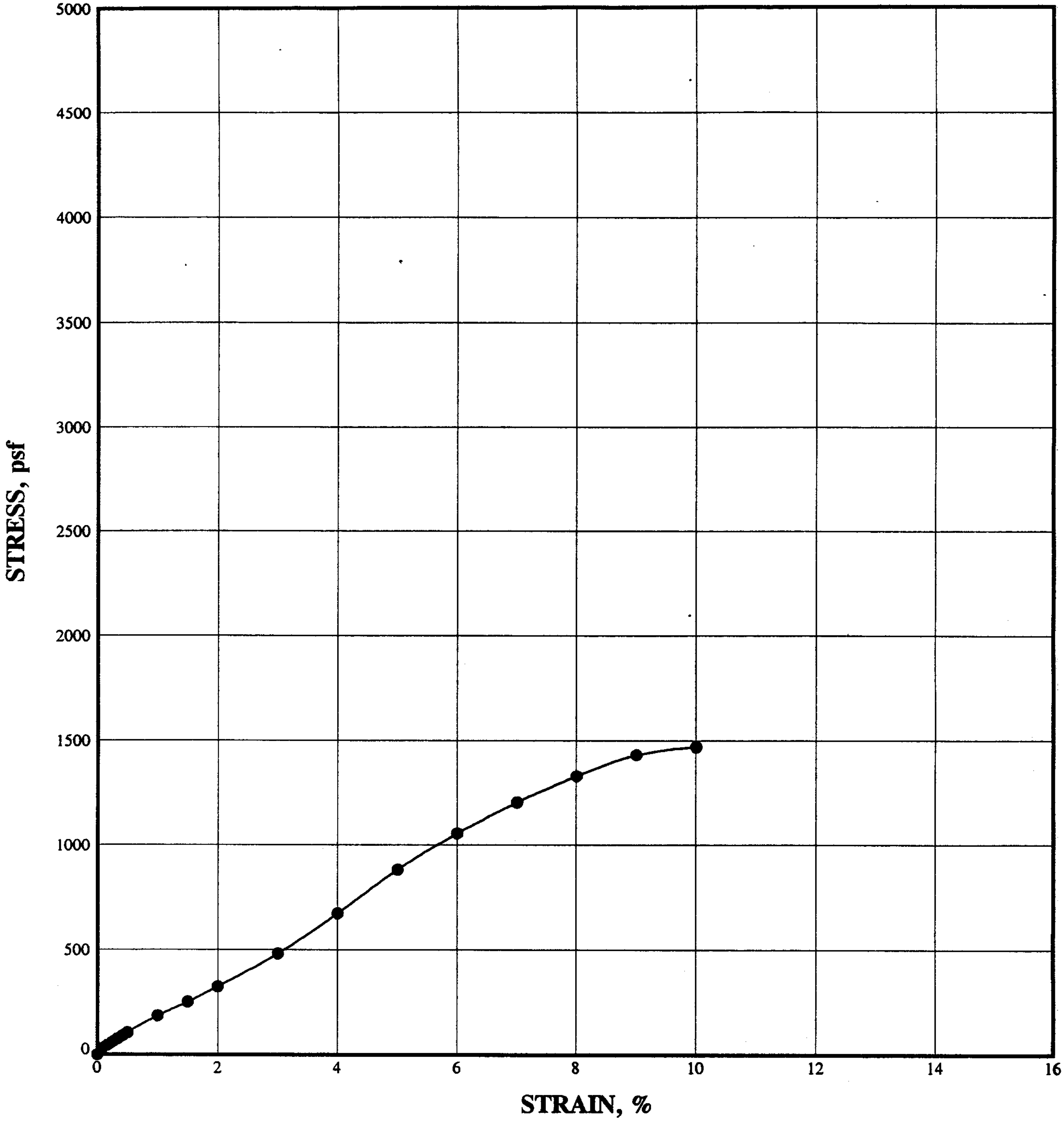

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SW-2-GT	38' - 40'	16	109	79	1473 psf	10.0 %	24	12	12

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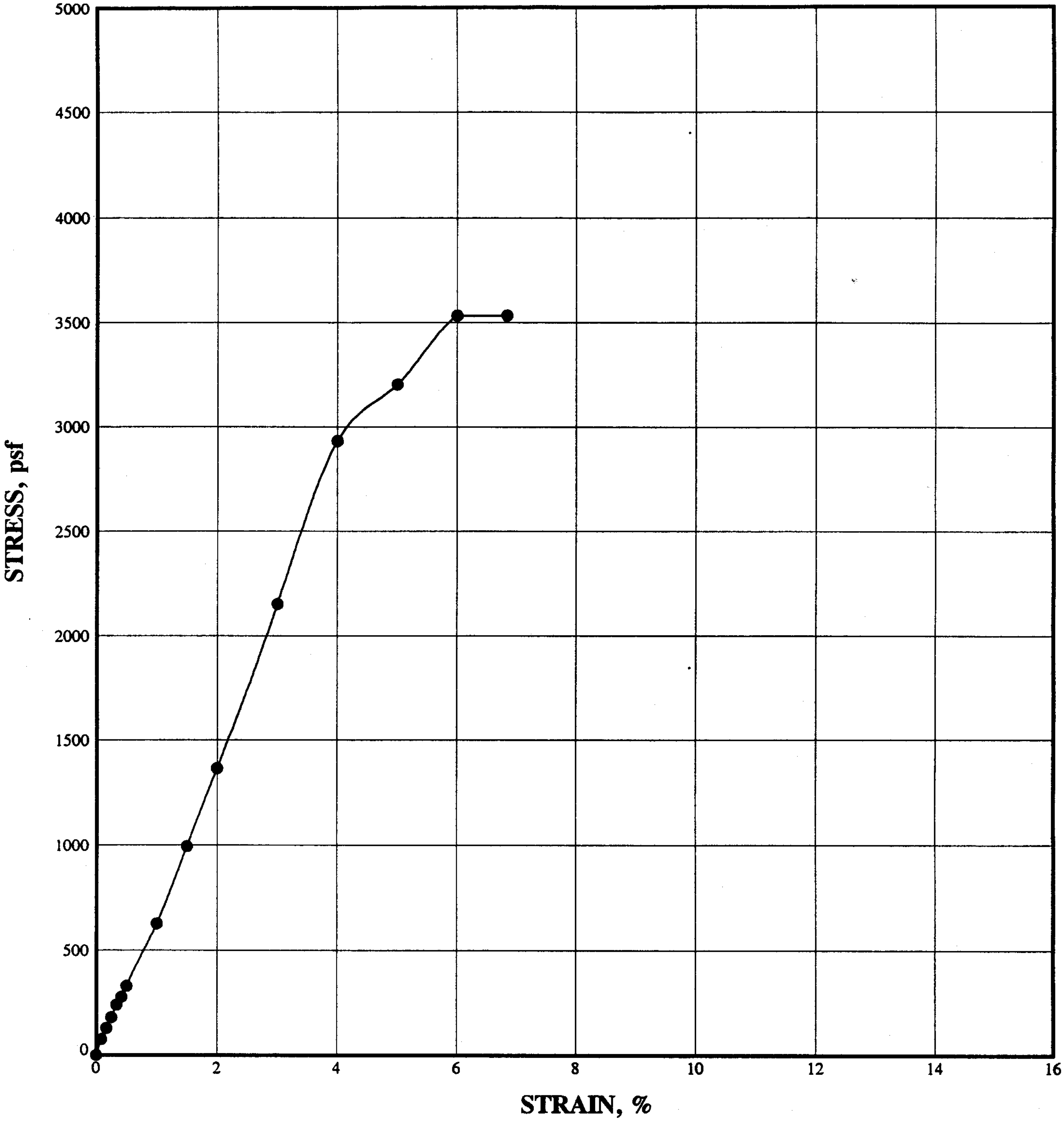

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SW-9-GT	8' - 10'	20	98	72	3533 psf	6.8 %			

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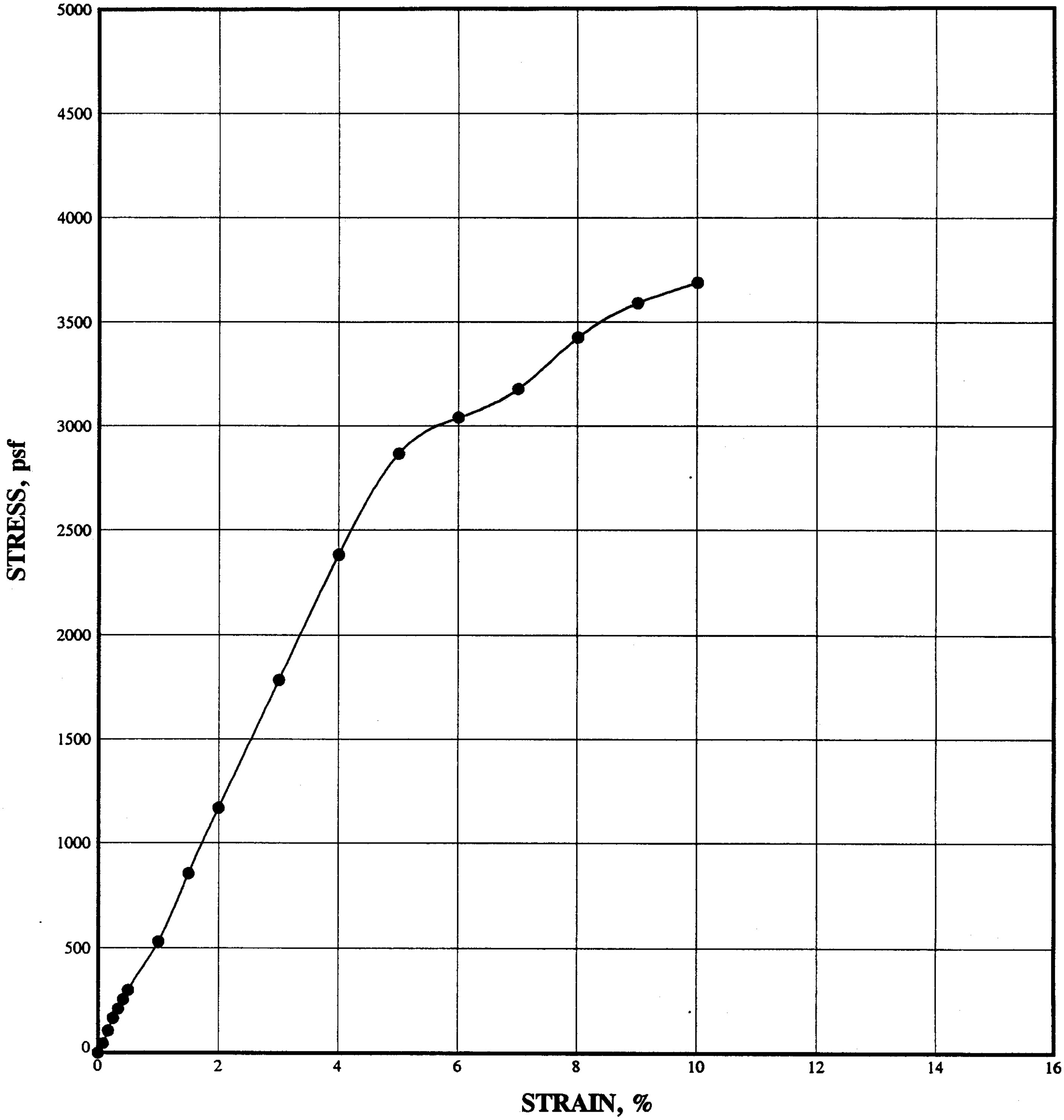

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SW-13-GT	8' - 10'	14	118	86	3689 psf	10.0 %			

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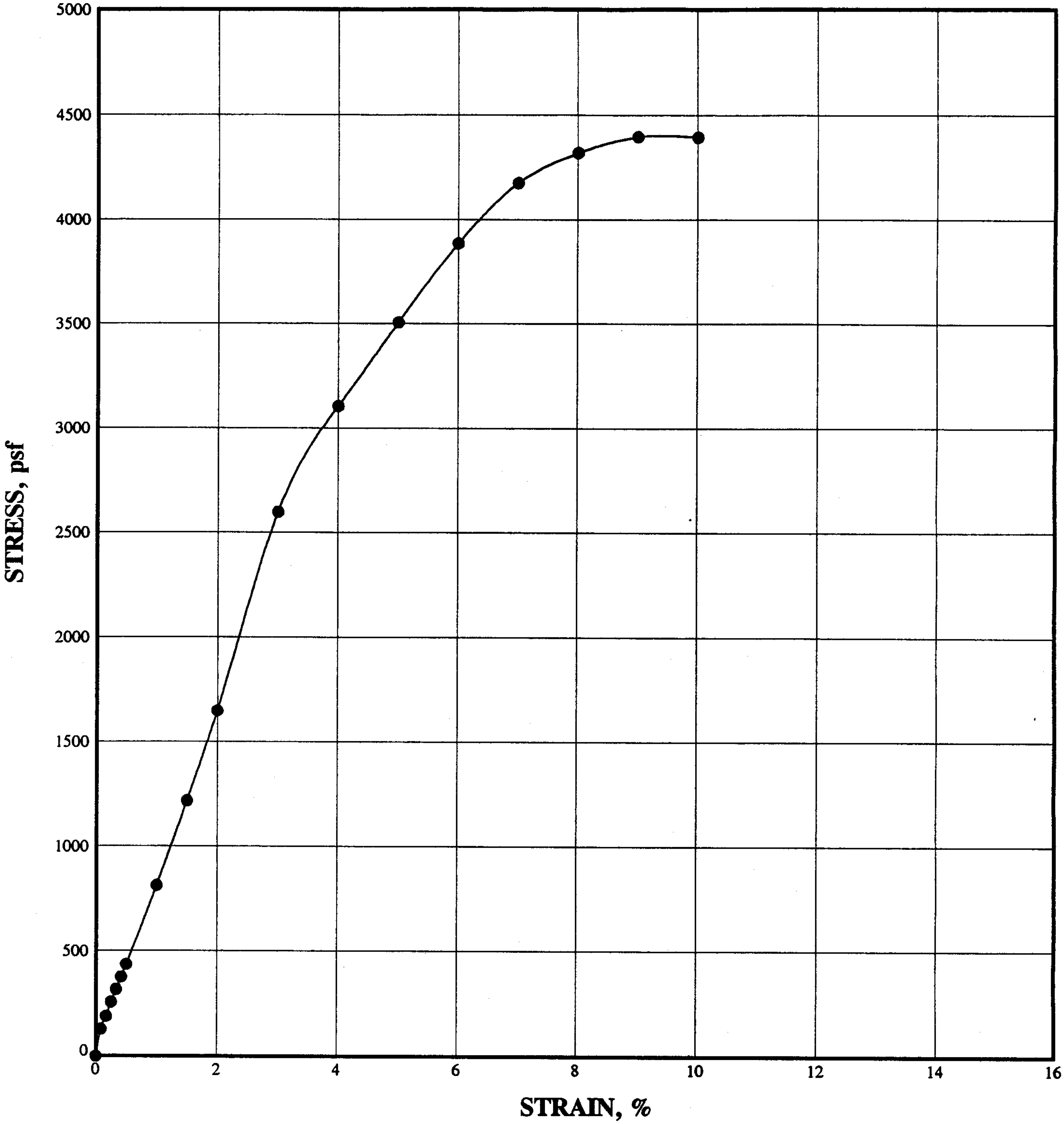

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SW-17-GT	8' - 10'	18	108	85	4396 psf	9.0 %	32	16	16

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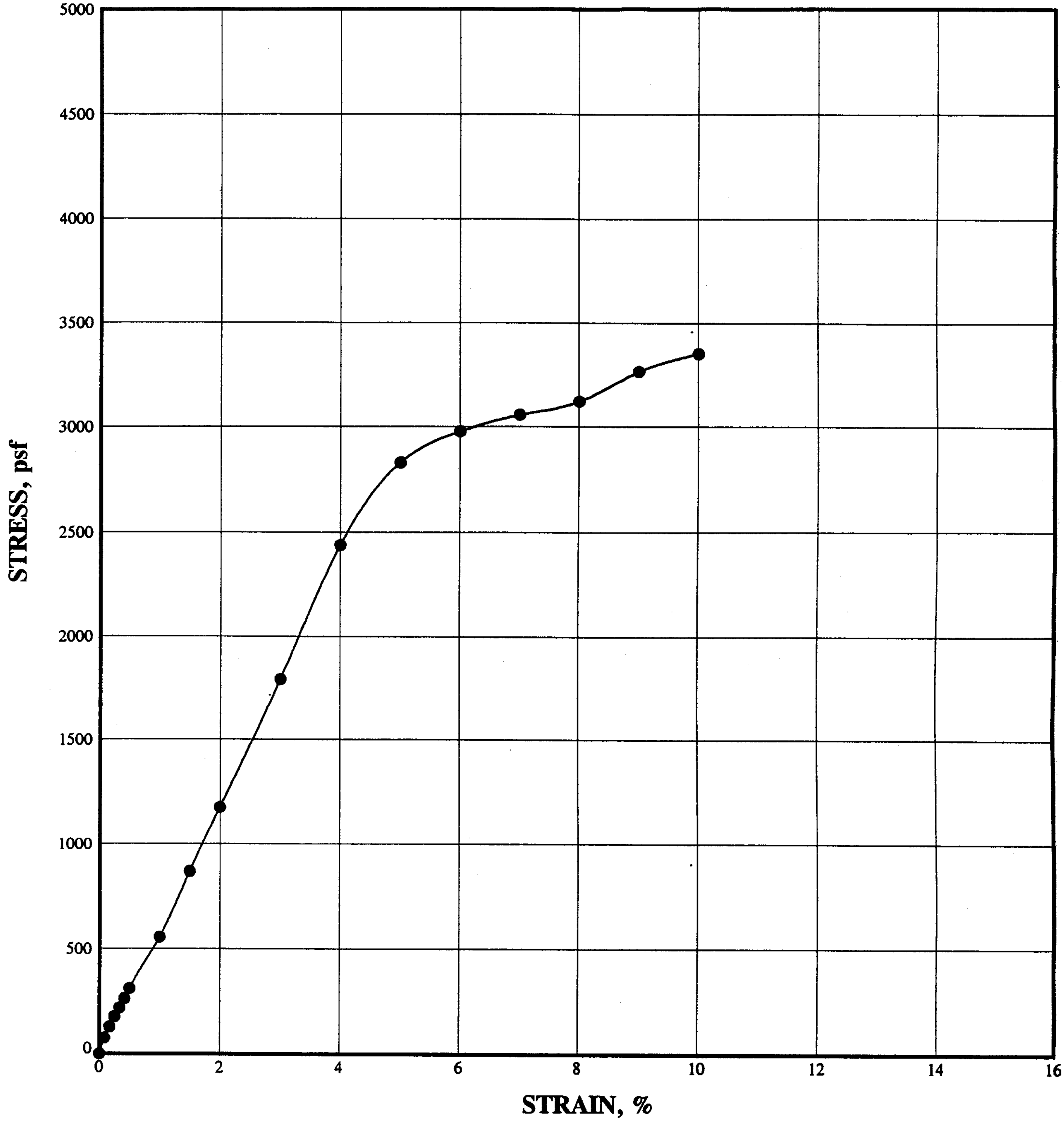

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SW-21-GT	8' - 10'	15	115	85	3352 psf	10.0 %	25	12	13

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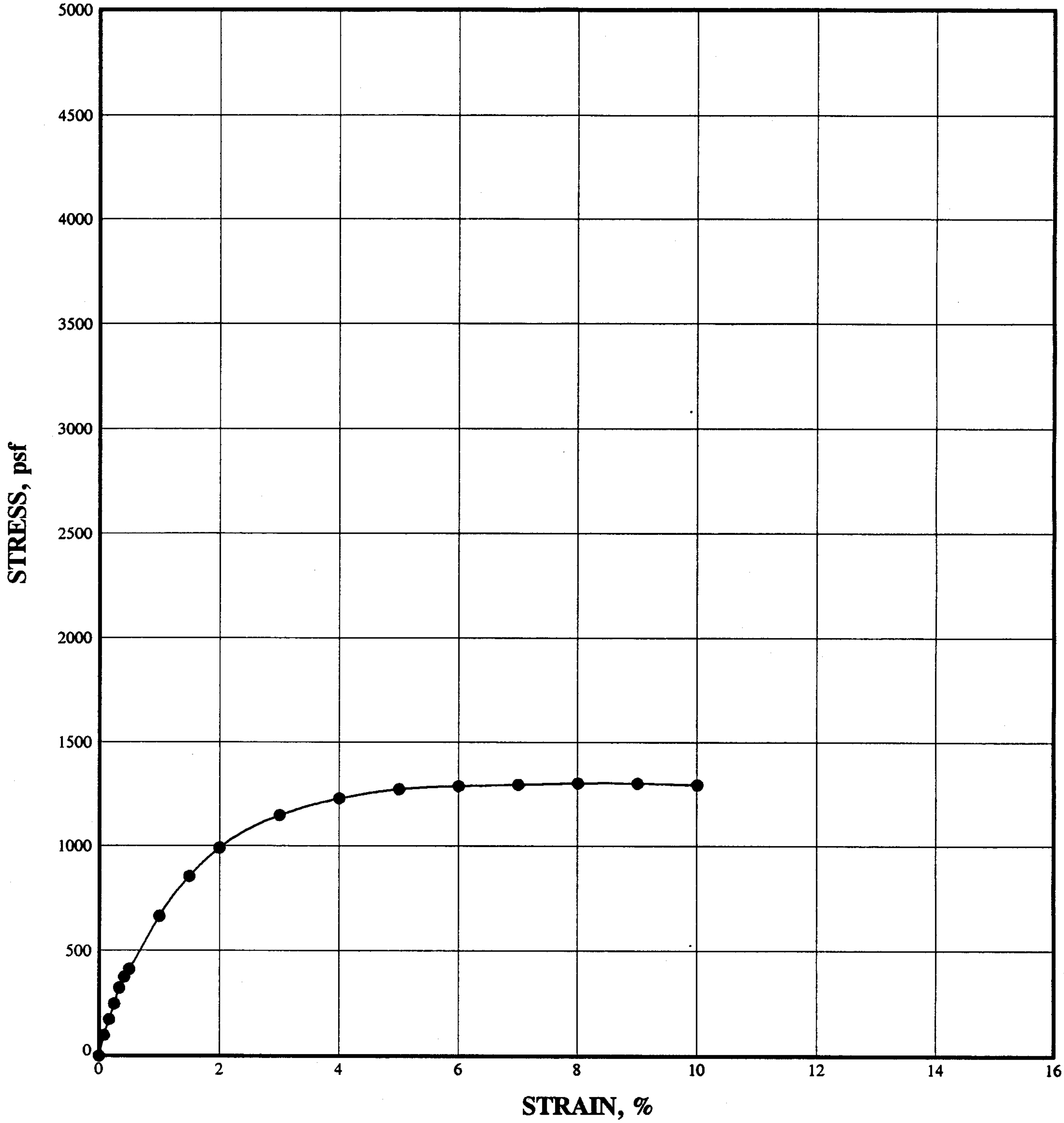

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SW-21-GT	19' - 19'	33	86	93	1304 psf	8.0 %	50	17	33

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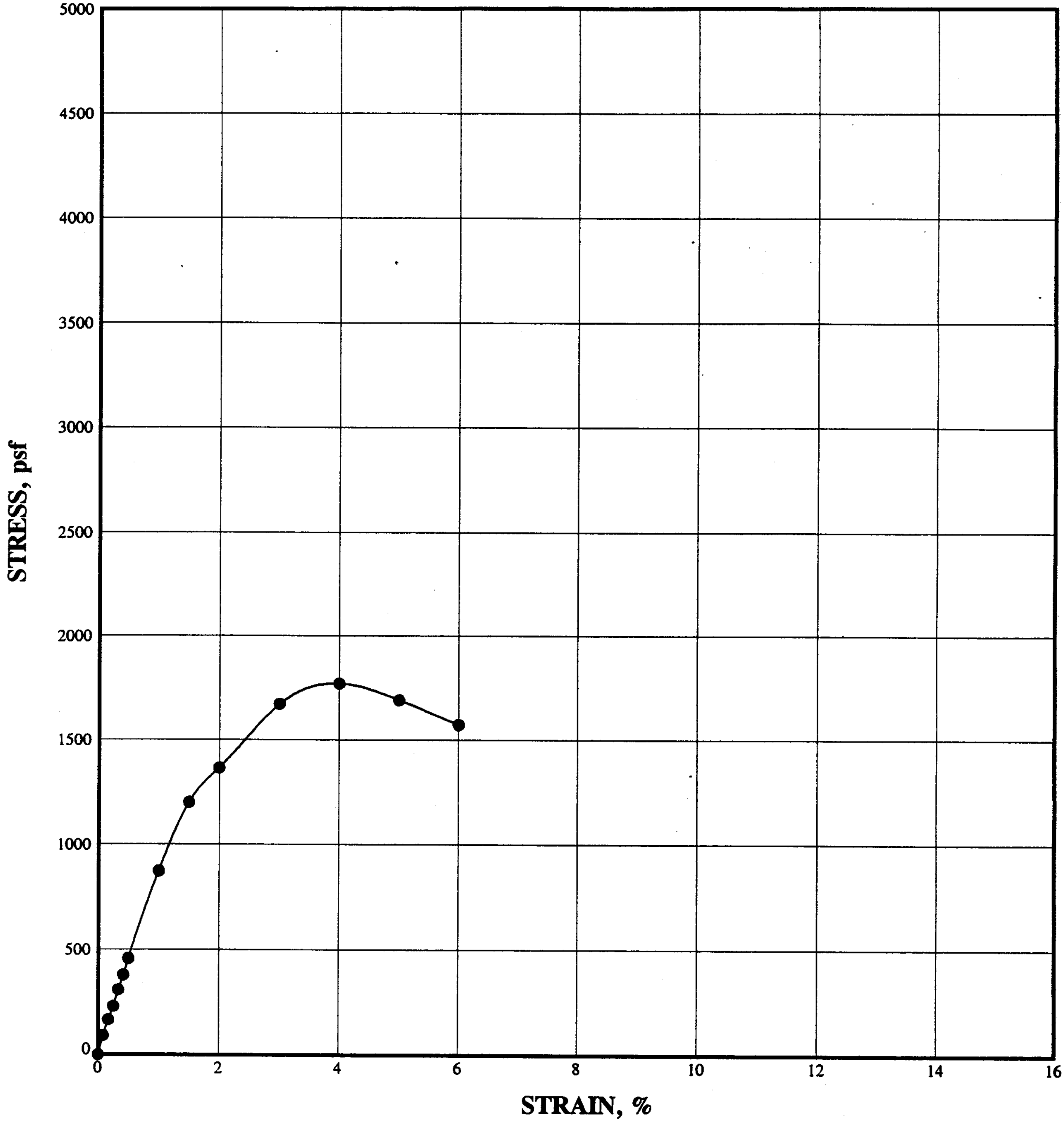

LEGEND:

	Point ID	Depth	Moisture Content %	Dry Density	Degree of Saturation	Peak Stress	Strain	LL	PL	PI
•	B-SW-33-GT	18' - 20'	51	70	96	1770 psf	4.0 %	66	25	41

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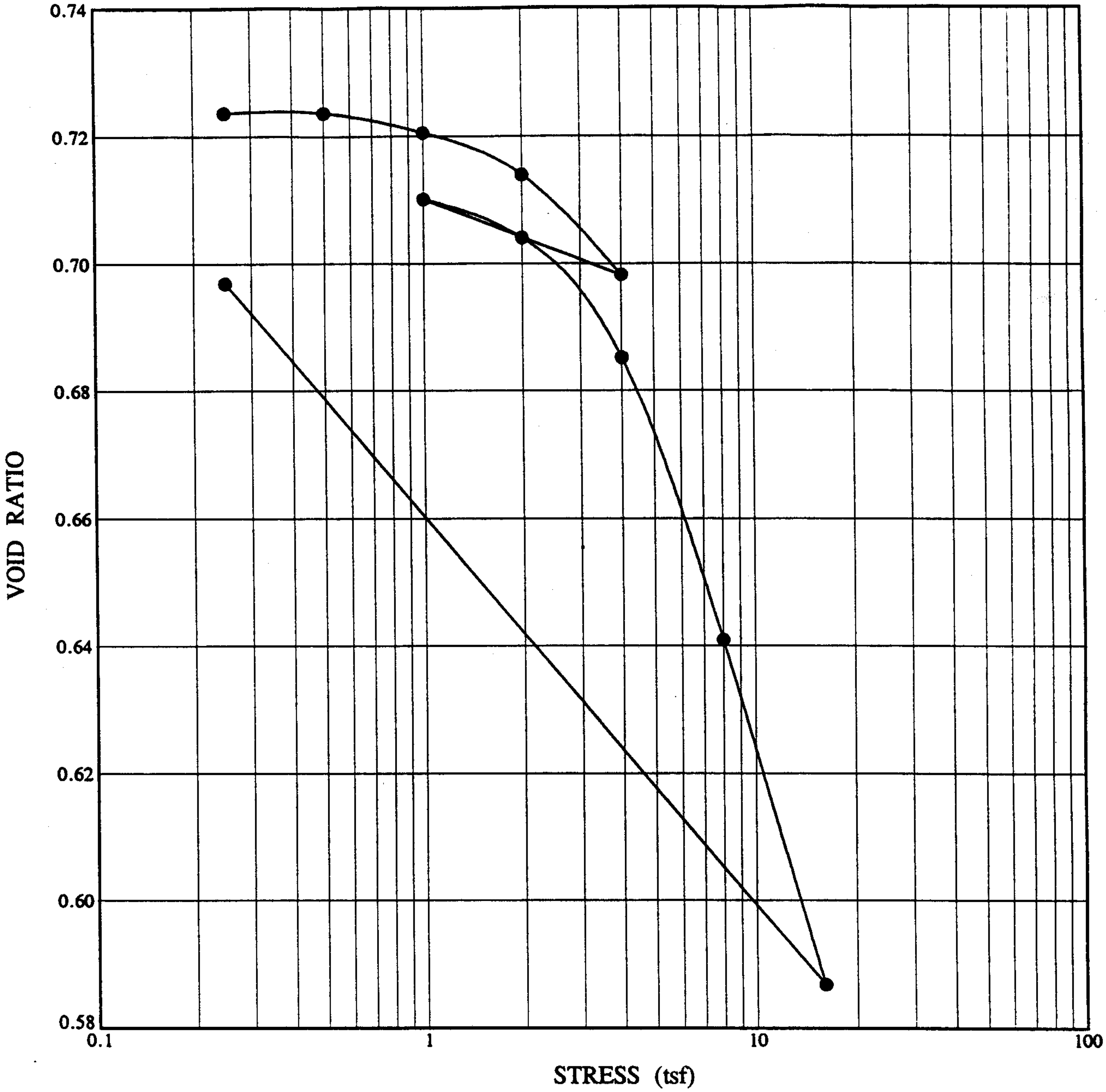
CONSOLIDATION TEST



● STRAIN READINGS

Sample Data:

FILE: 93B107C
BORING: B-SE-1-GT
DEPTH: 8' - 10'
DESCRIPTION: (CL)
SPECIFIC GRAVITY: 2.75
INITIAL MOISTURE CONTENT (%): 25
INITIAL DRY UNIT WEIGHT (pcf): 100
LL = 43 PL = 16 PI = 27
INUNDATION AT START

FINAL MOISTURE CONTENT (%): 27
FINAL DRY UNIT WEIGHT (pcf): 98

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CONSOLIDATION TEST
ASTM D 2435-80

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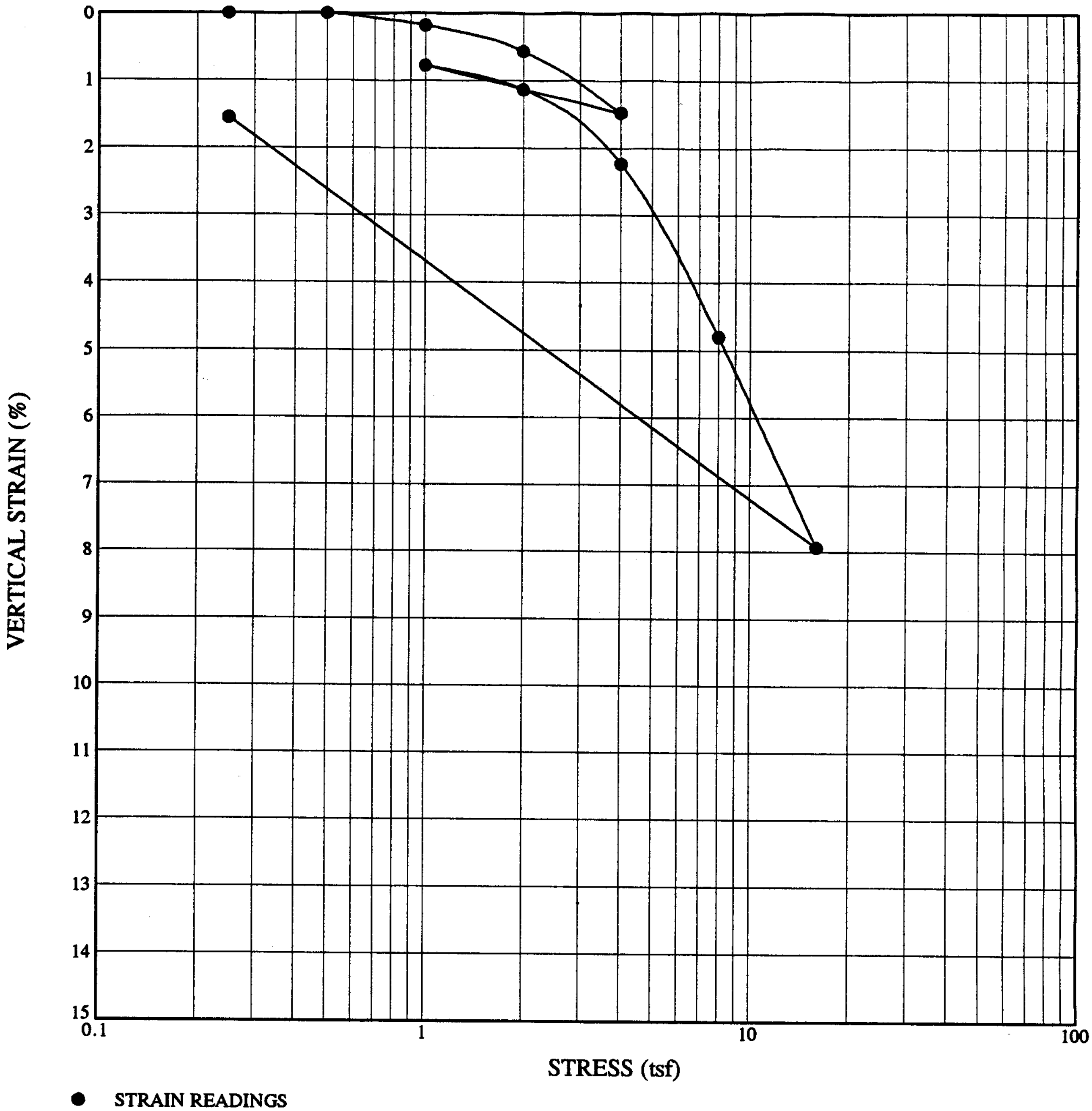

Sample Data:

FILE: 93B107C
BORING: B-SE-1-GT
DEPTH: 8' - 10'
DESCRIPTION: (CL)

SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL MOISTURE CONTENT (%): 25
INITIAL DRY UNIT WEIGHT (pcf): 100
LL = 43 PL = 16 PI = 27
INUNDATION AT START

FINAL MOISTURE CONTENT (%): 27
FINAL DRY UNIT WEIGHT (pcf): 98

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CONSOLIDATION TEST
ASTM D 2435-80

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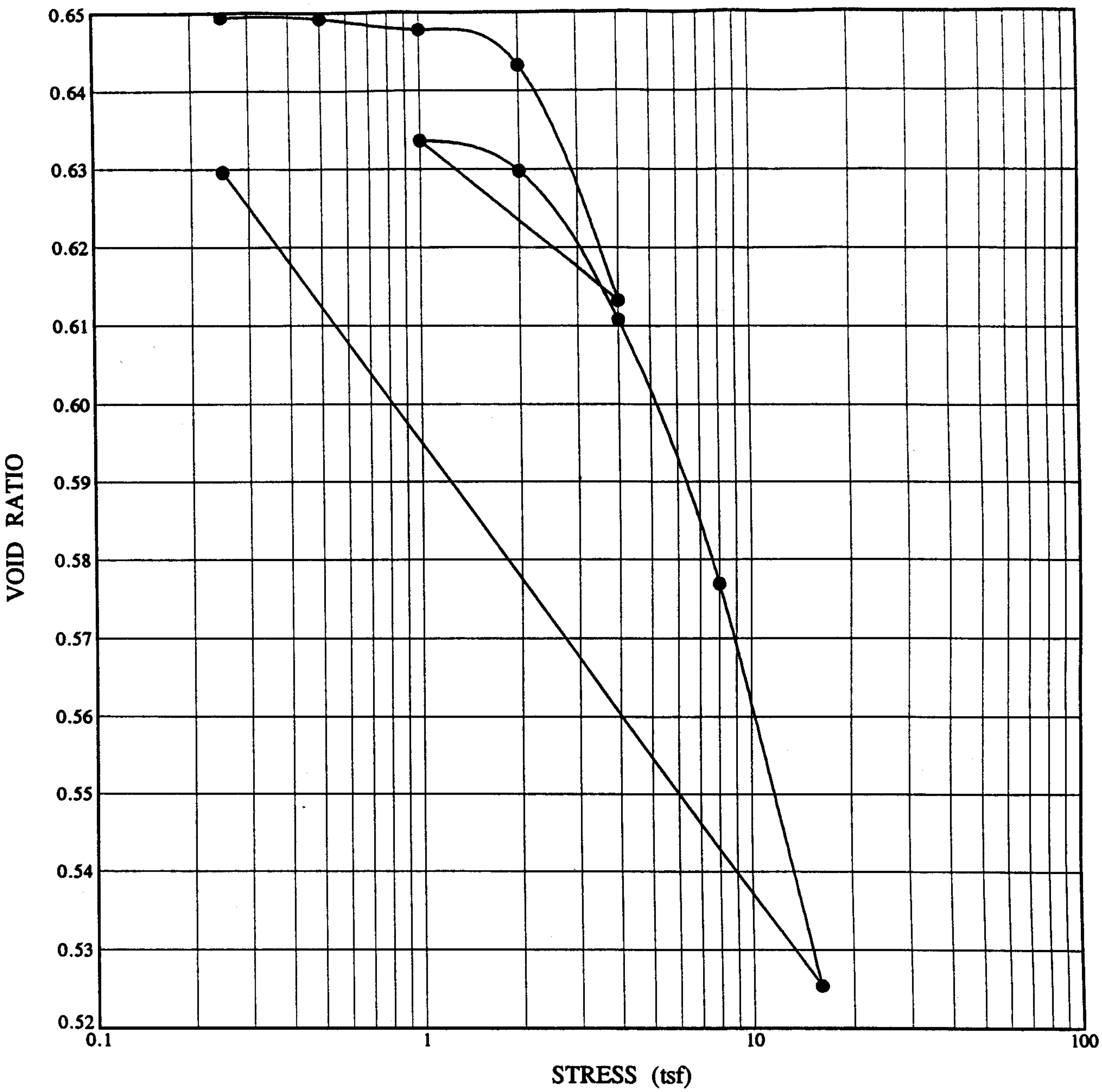

● STRAIN READINGS

Sample Data:

FILE: 93B107C
BORING: B-SE-1-GT
DEPTH: 38' - 40'
DESCRIPTION: (CL-CH)
SPECIFIC GRAVITY: 2.76
INITIAL MOISTURE CONTENT (%): 23
INITIAL DRY UNIT WEIGHT (pcf): 104
FINAL MOISTURE CONTENT (%): 24
FINAL DRY UNIT WEIGHT (pcf): 106
LL = 50 PL = 14 PI = 36
INUNDATION AT START

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

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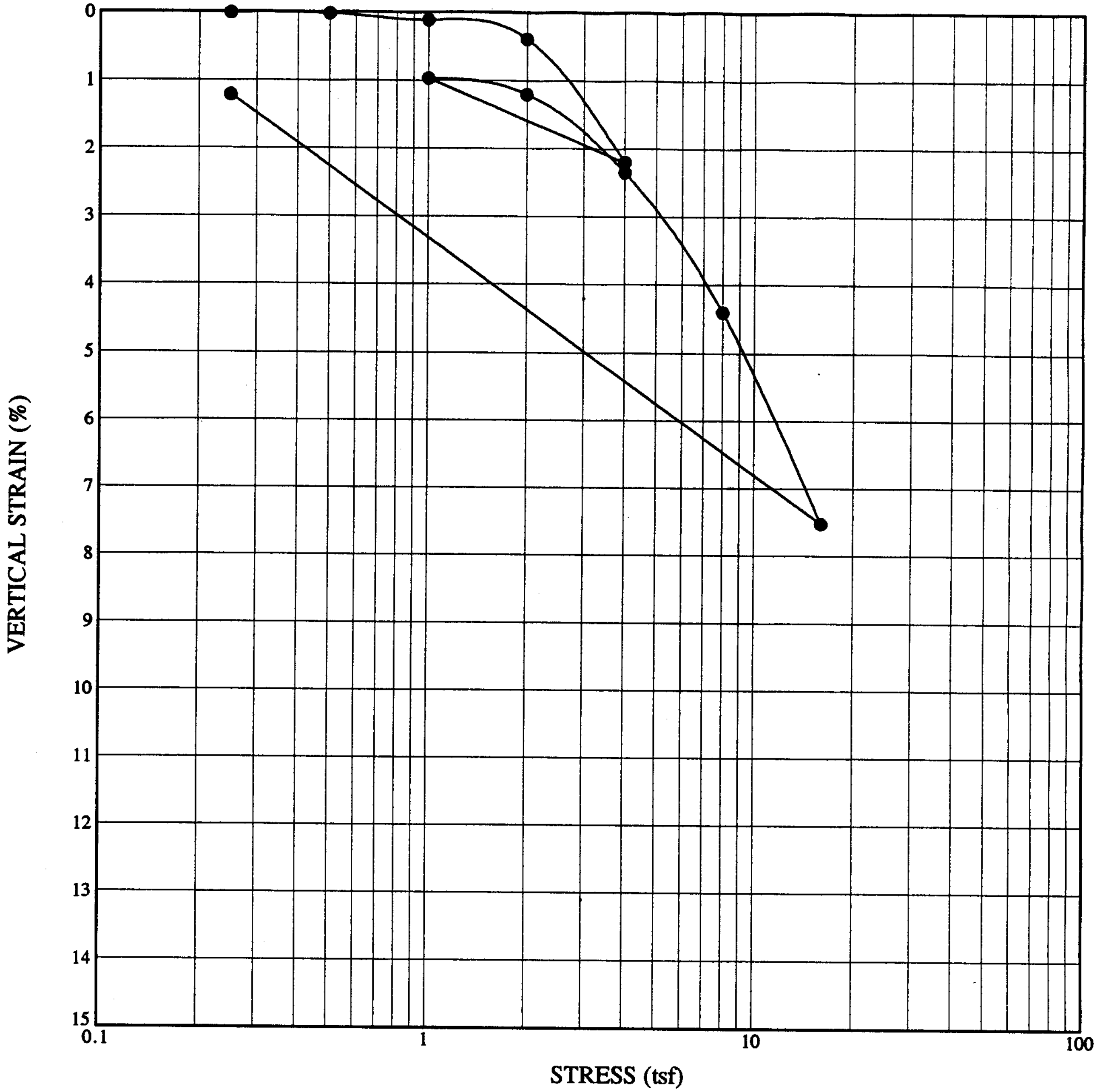
NOV 7 94 CONSLV1 3B107



● STRAIN READINGS

Sample Data:

FILE: 93B107C
BORING: B-SE-1-GT
DEPTH: 38' - 40'
DESCRIPTION: (CL-CH)

SPECIFIC GRAVITY: 2.76 (assumed)
INITIAL MOISTURE CONTENT (%): 23
INITIAL DRY UNIT WEIGHT (pcf): 104
LL = 50 PL = 14 PI = 36
INUNDATION AT START

FINAL MOISTURE CONTENT (%): 24
FINAL DRY UNIT WEIGHT (pcf): 106

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

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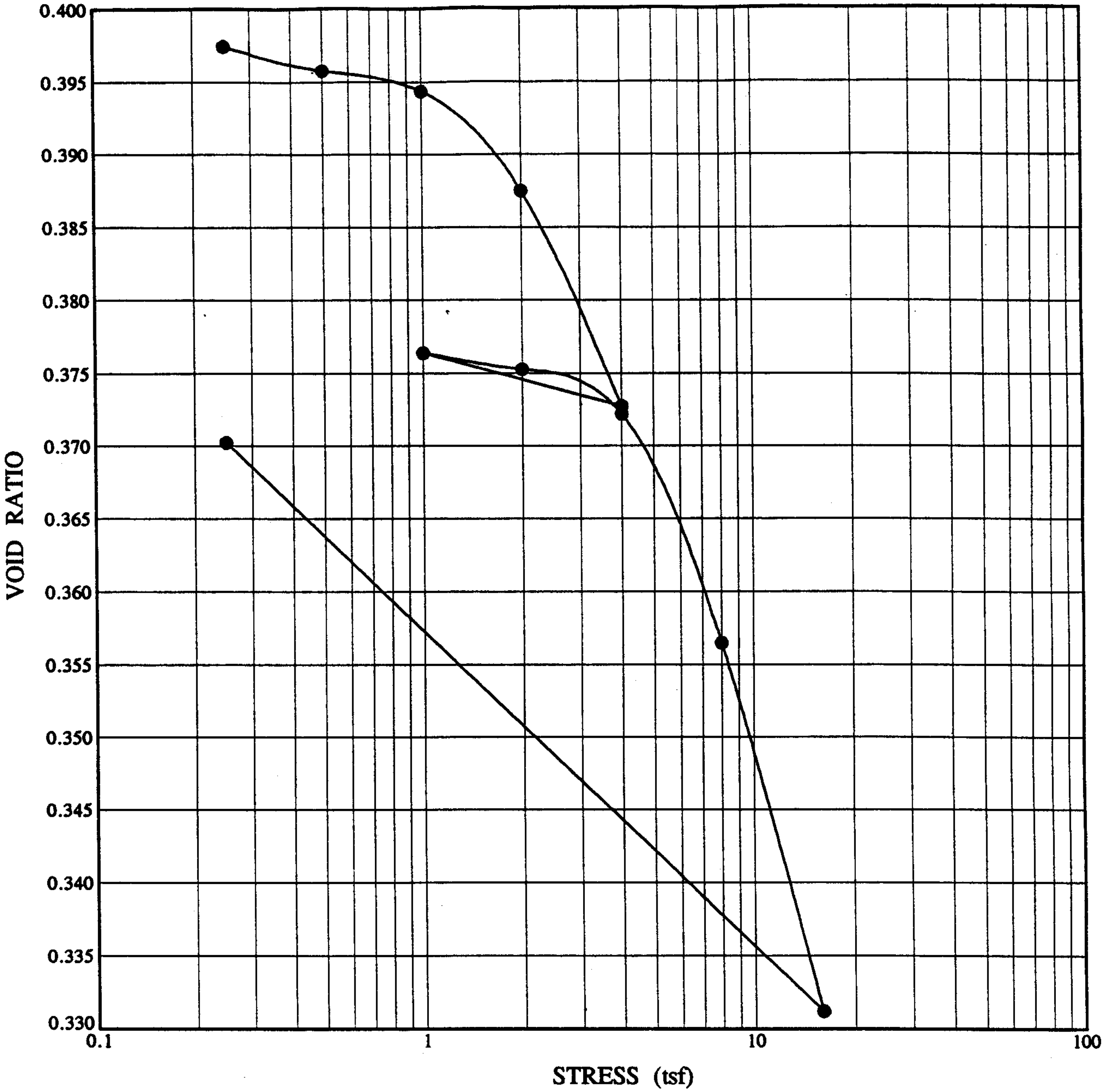

● STRAIN READINGS

Sample Data:

FILE: 93B107C
BORING: B-SE-2-GT
DEPTH: 8' - 10'
DESCRIPTION: (CL)
SPECIFIC GRAVITY: 2.68
INITIAL MOISTURE CONTENT (%): 14
INITIAL DRY UNIT WEIGHT (pcf): 120
LL = 41 PL = 13 PI = 28
INUNDATION AT START

FINAL MOISTURE CONTENT (%): 14
FINAL DRY UNIT WEIGHT (pcf): 121

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ASTM D 2435-80

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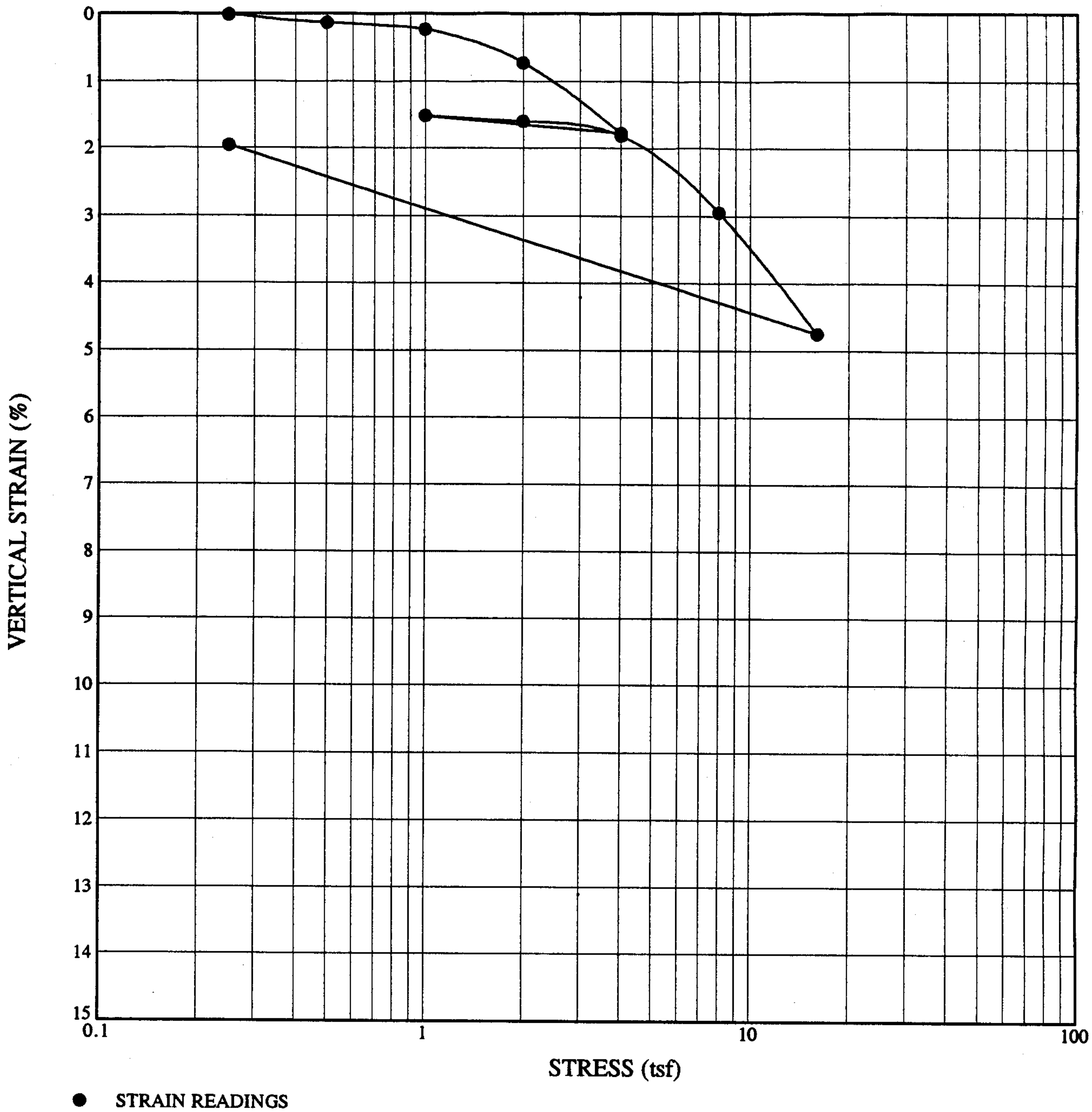


Sample Data:

FILE: **93B107C**
BORING: **B-SE-2-GT**
DEPTH: **8' - 10'**
DESCRIPTION: **(CL)**

SPECIFIC GRAVITY: **2.68 (assumed)**
INITIAL MOISTURE CONTENT (%): **14**
INITIAL DRY UNIT WEIGHT (pcf): **120**
LL = **41** PL = **13** PI = **28**
INUNDATION AT START

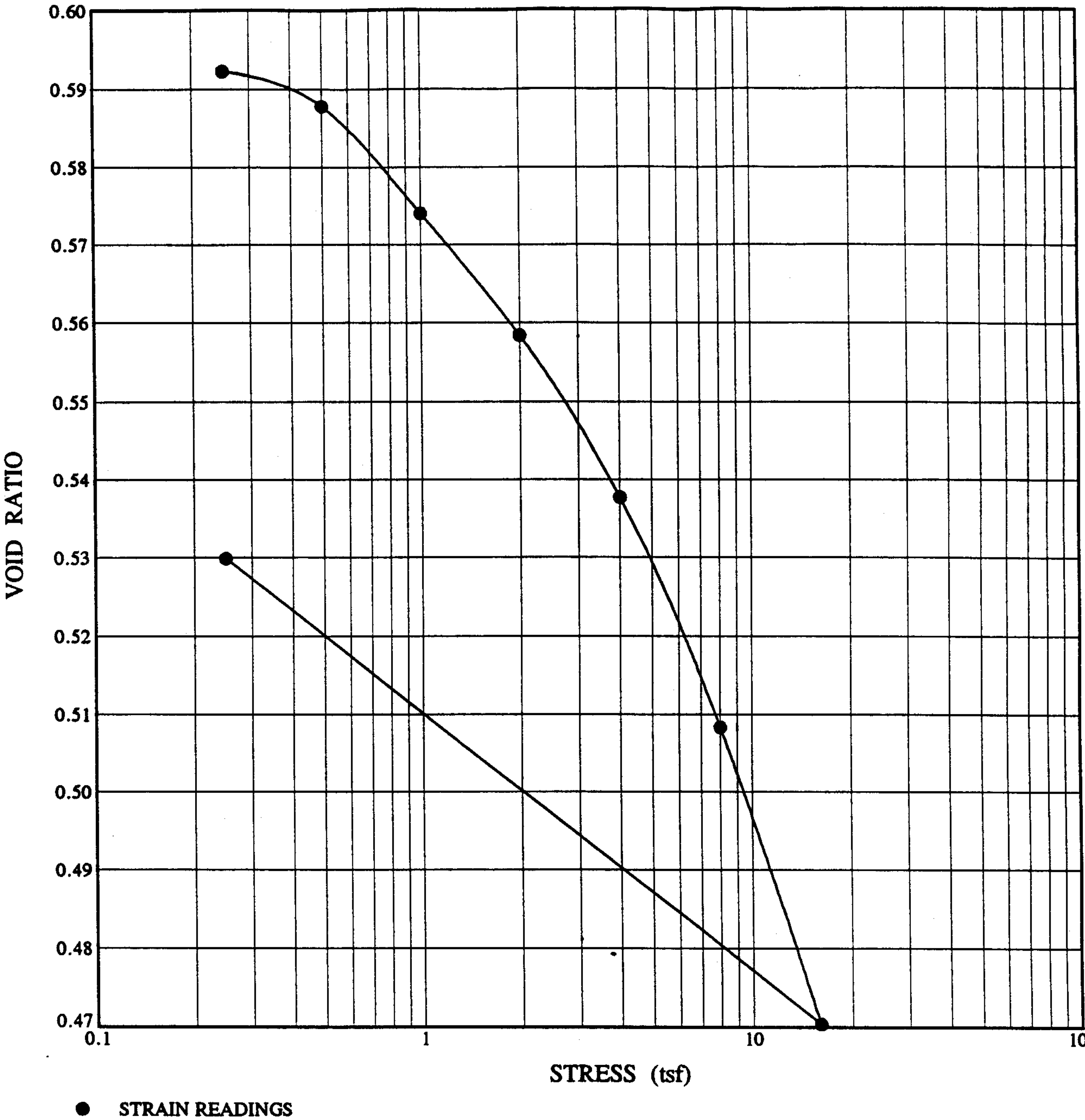
FINAL MOISTURE CONTENT (%): **14**
FINAL DRY UNIT WEIGHT (pcf): **121**

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants

NOV 21 94 CONSLD2 3B107



Sample Data:

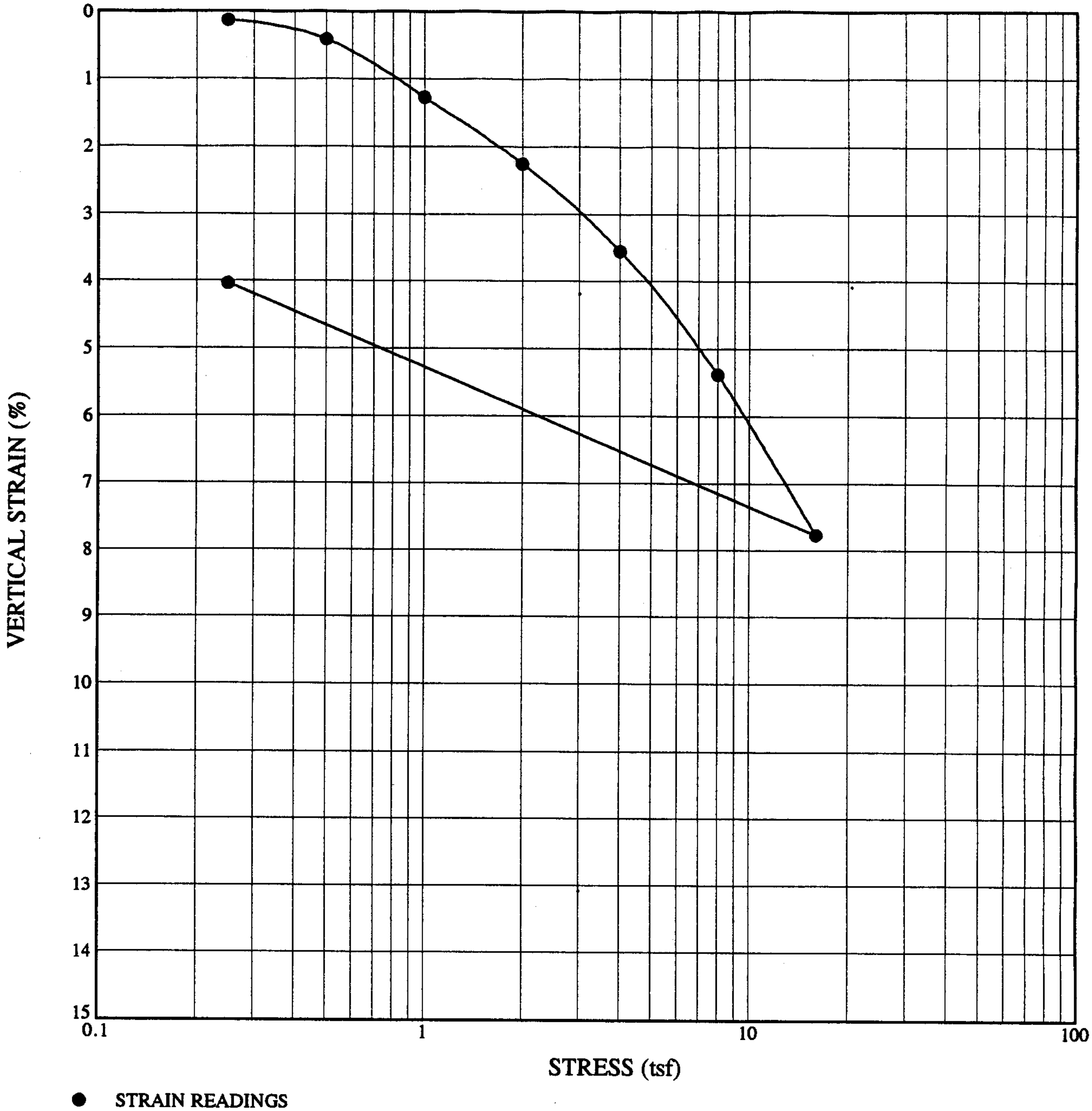
FILE: 93B107C
BORING: B-SE-28-GT
DEPTH: 13' - 15'
DESCRIPTION: (CL)
SPECIFIC GRAVITY: 2.70
INITIAL MOISTURE CONTENT (%): 21
INITIAL DRY UNIT WEIGHT (pcf): 106
FINAL MOISTURE CONTENT (%): 20
FINAL DRY UNIT WEIGHT (pcf): 110
LL = 38 PL = 15 PI = 23
INUNDATION AT START

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants

NOV 7 94 CONSLV1 3B107



Sample Data:

FILE: **93B107C**
BORING: **B-SE-28-GT**
DEPTH: **13' - 15'**
DESCRIPTION: **(CL)**

SPECIFIC GRAVITY: **2.70 (assumed)**
INITIAL MOISTURE CONTENT (%): **21**
INITIAL DRY UNIT WEIGHT (pcf): **106**
LL = **38** PL = **15** PI = **23**
INUNDATION AT START

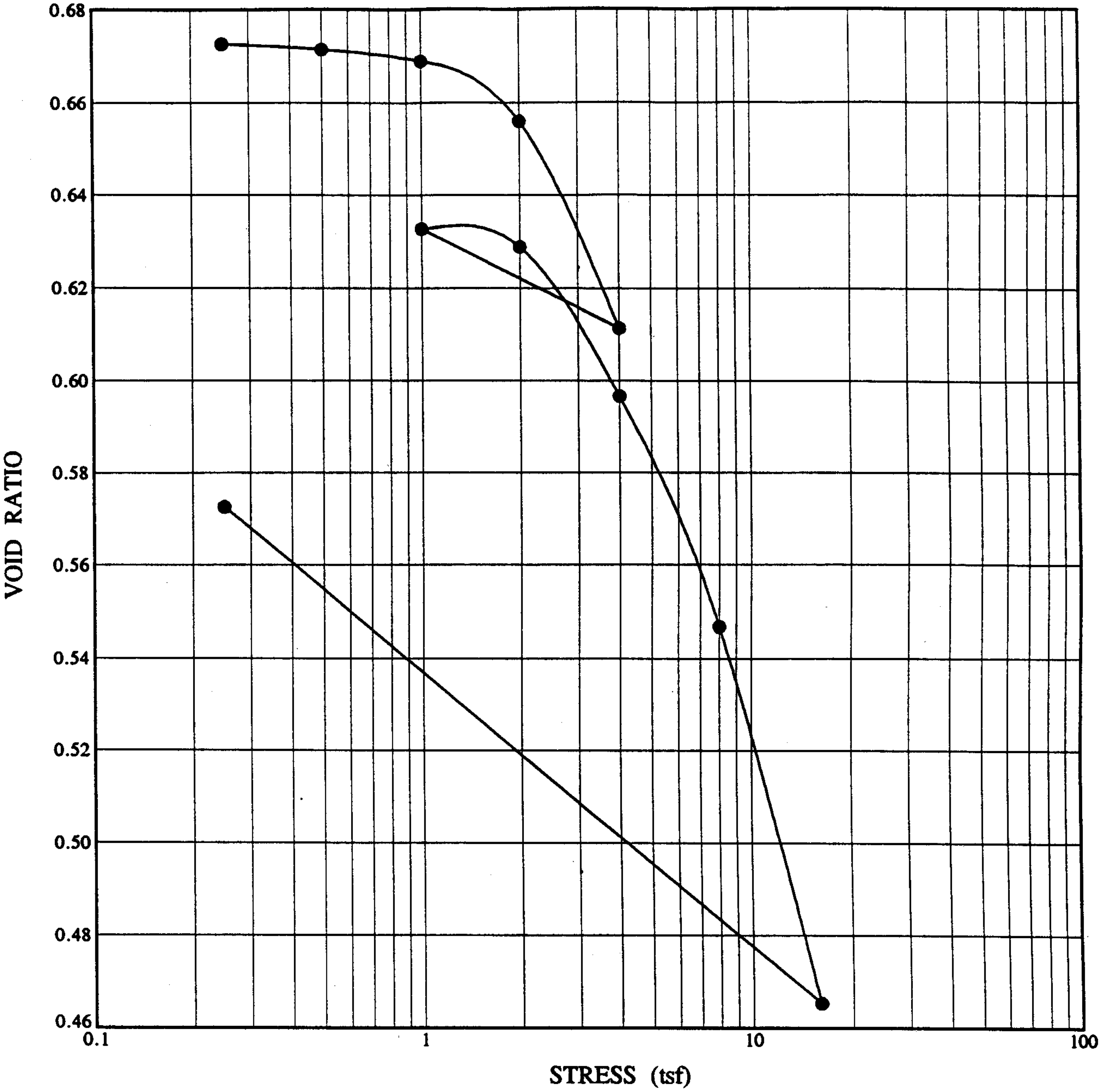
FINAL MOISTURE CONTENT (%): **20**
FINAL DRY UNIT WEIGHT (pcf): **110**

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants

NOV 21 94 CONSLD2 3B107



● STRAIN READINGS

Sample Data:

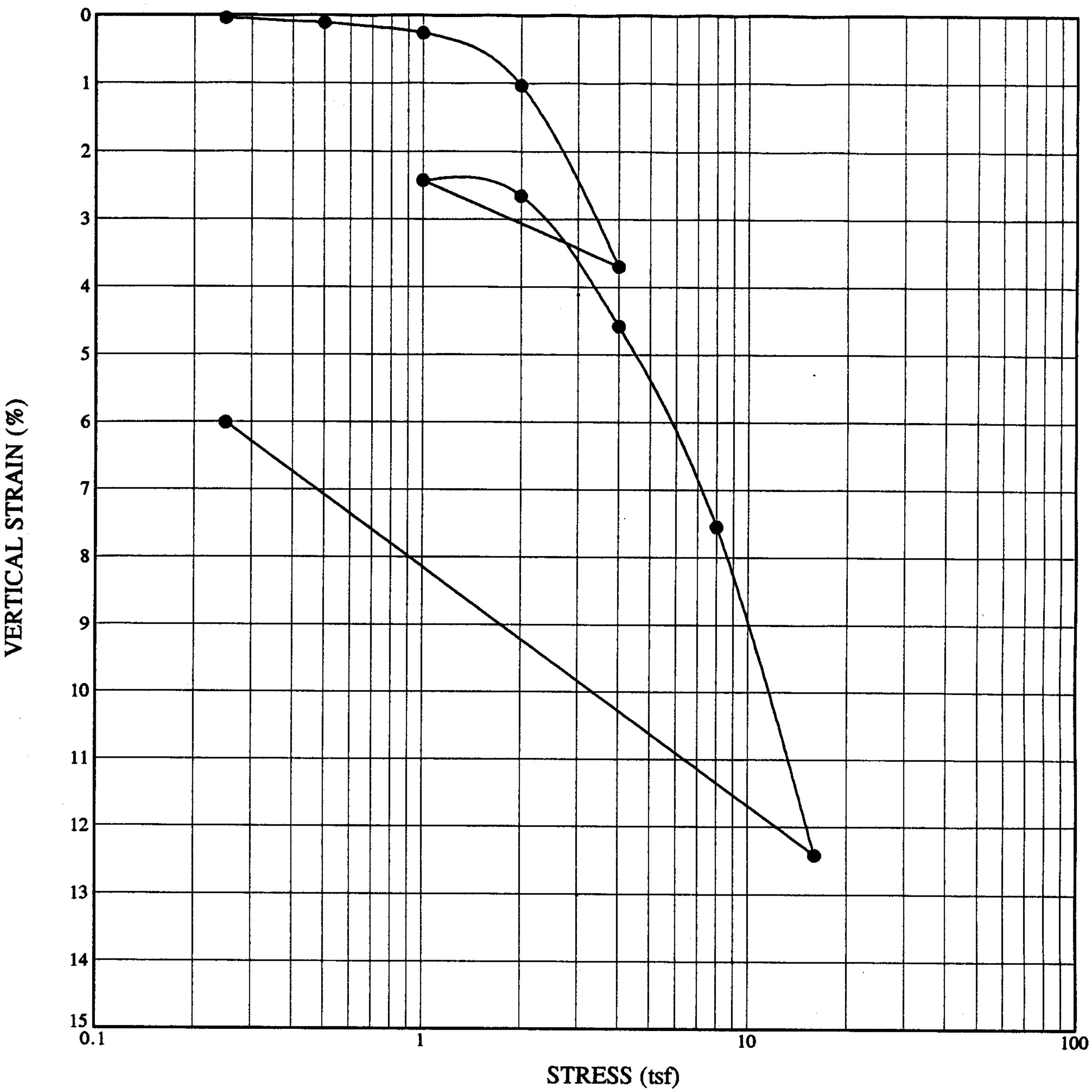
FILE: 93B107C
BORING: B-SE-30-GT
DEPTH: 13' - 15'
DESCRIPTION: (CH)
SPECIFIC GRAVITY: 2.75
INITIAL MOISTURE CONTENT (%): 24
INITIAL DRY UNIT WEIGHT (pcf): 103
LL = 56 PL = 17 PI = 39
INUNDATION AT START

FINAL MOISTURE CONTENT (%): 25
FINAL DRY UNIT WEIGHT (pcf): 106

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants



● STRAIN READINGS

Sample Data:

FILE: 93B107C
BORING: B-SE-30-GT
DEPTH: 13' - 15'
DESCRIPTION: (CH)

SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL MOISTURE CONTENT (%): 24
INITIAL DRY UNIT WEIGHT (pcf): 103
LL = 56 PL = 17 PI = 39
INUNDATION AT START

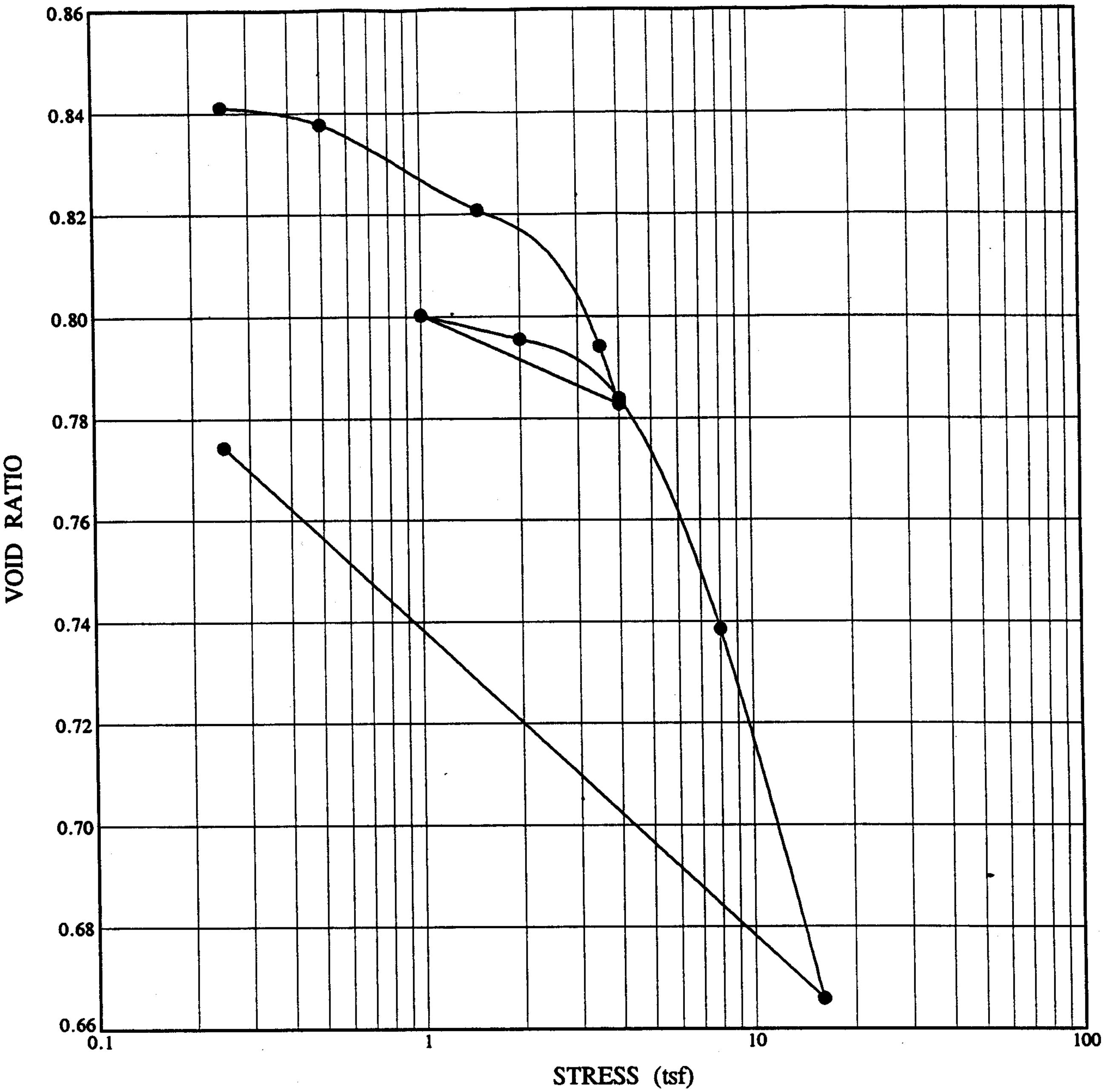
FINAL MOISTURE CONTENT (%): 25
FINAL DRY UNIT WEIGHT (pcf): 106

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants

NOV 21 94 CONSLD2 3B107



● STRAIN READINGS

Sample Data:

FILE: 93B107C
BORING: B-SE-33-GT
DEPTH: 18' - 20'
DESCRIPTION: (CH)
SPECIFIC GRAVITY: 2.72
INITIAL MOISTURE CONTENT (%): 28
INITIAL DRY UNIT WEIGHT (pcf): 92
LL = 51 PL = 20 PI = 31
INUNDATION AT START

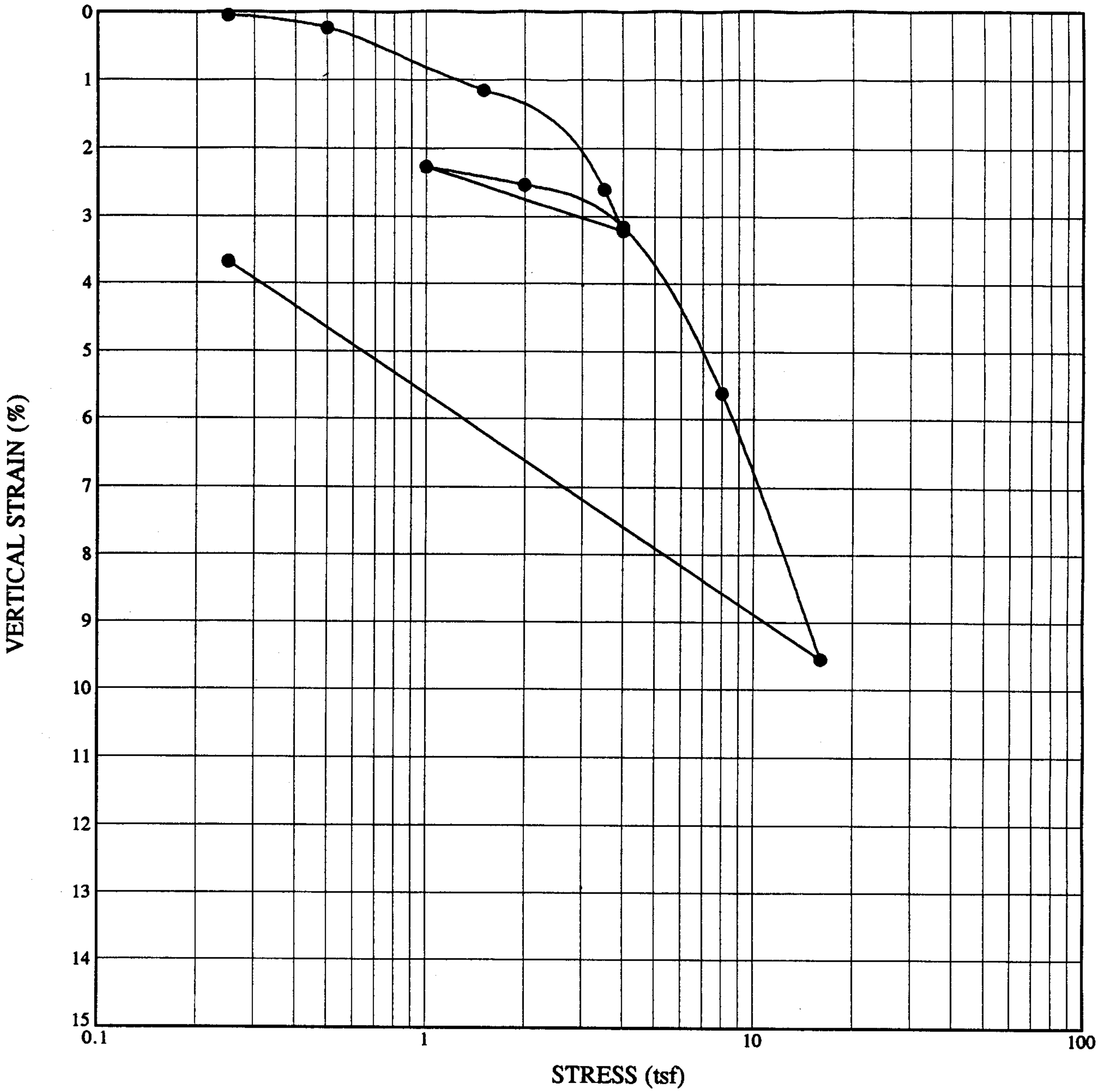
FINAL MOISTURE CONTENT (%): 29
FINAL DRY UNIT WEIGHT (pcf): 94

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants

NOV 7 94 CONSLV1 3B107



● STRAIN READINGS

Sample Data:

FILE: 93B107C
BORING: B-SE-33-GT
DEPTH: 18' - 20'
DESCRIPTION: (CH)

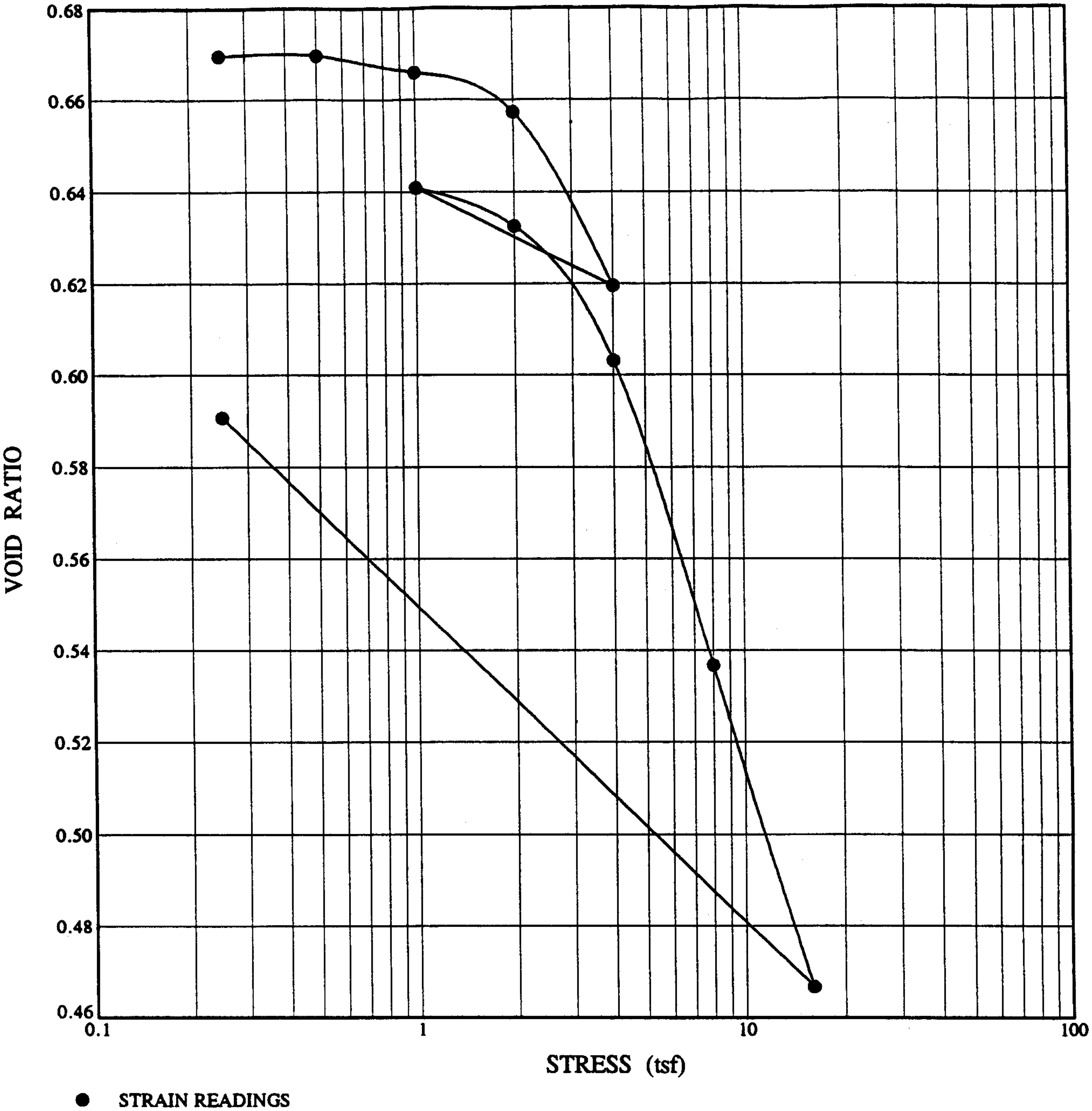
SPECIFIC GRAVITY: 2.72 (assumed)
INITIAL MOISTURE CONTENT (%): 28
INITIAL DRY UNIT WEIGHT (pcf): 92
LL = 51 PL = 20 PI = 31
INUNDATION AT START

FINAL MOISTURE CONTENT (%): 29
FINAL DRY UNIT WEIGHT (pcf): 94

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants



Sample Data:

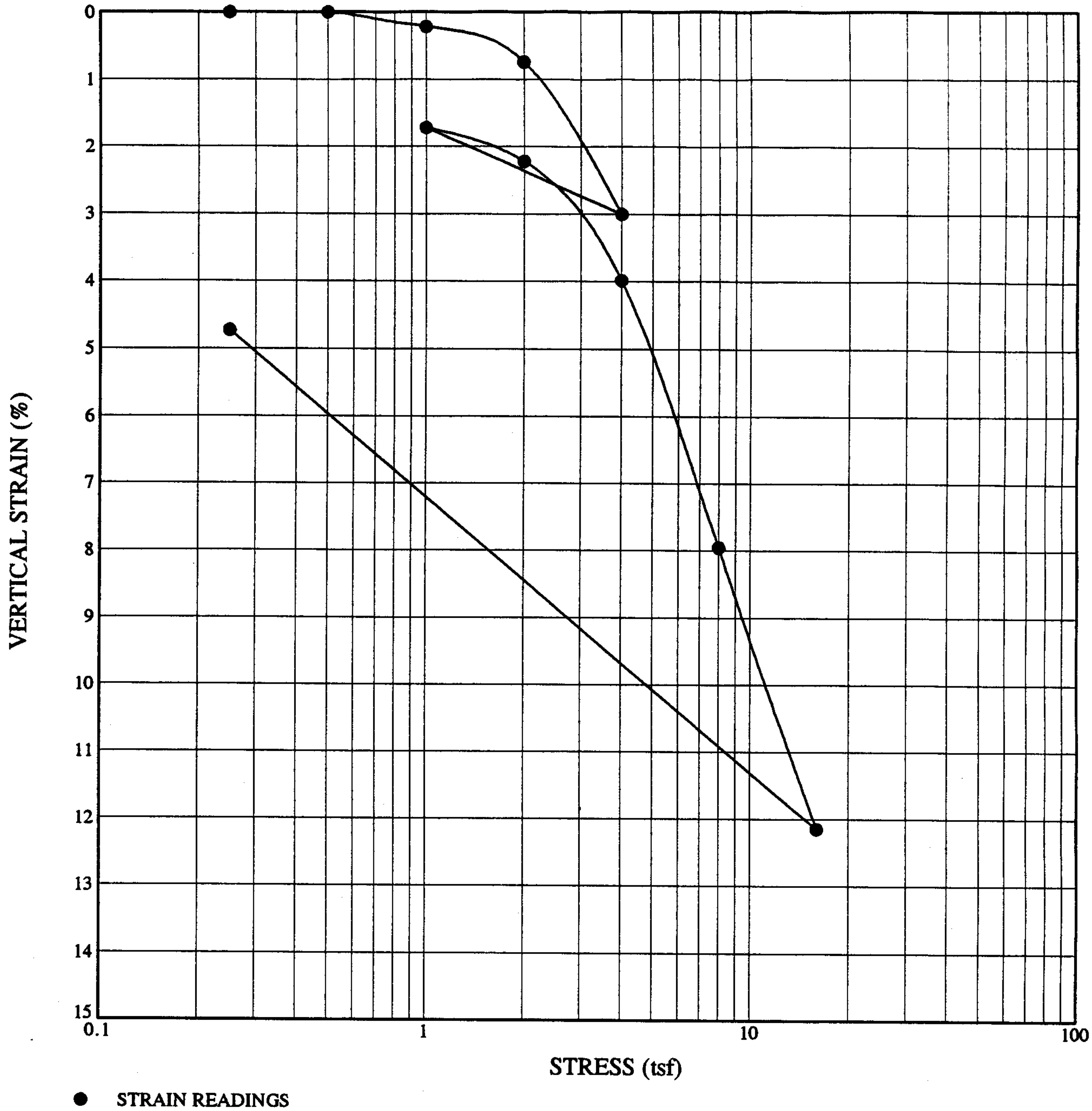
FILE: **93B107C**
BORING: **B-SW-2-GT**
DEPTH: **6' - 8'**
DESCRIPTION: **(CH)**
SPECIFIC GRAVITY: **2.75**
INITIAL MOISTURE CONTENT (%): **23**
INITIAL DRY UNIT WEIGHT (pcf): **103**
LL = 47 PL = 15 PI = 32
INUNDATION AT START

FINAL MOISTURE CONTENT (%): **26**
FINAL DRY UNIT WEIGHT (pcf): **103**

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants



Sample Data:

FILE: 93B107C
BORING: B-SW-2-GT
DEPTH: 6' - 8'
DESCRIPTION: (CH)

SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL MOISTURE CONTENT (%): 23
INITIAL DRY UNIT WEIGHT (pcf): 103
LL = 47 PL = 15 PI = 32
INUNDATION AT START

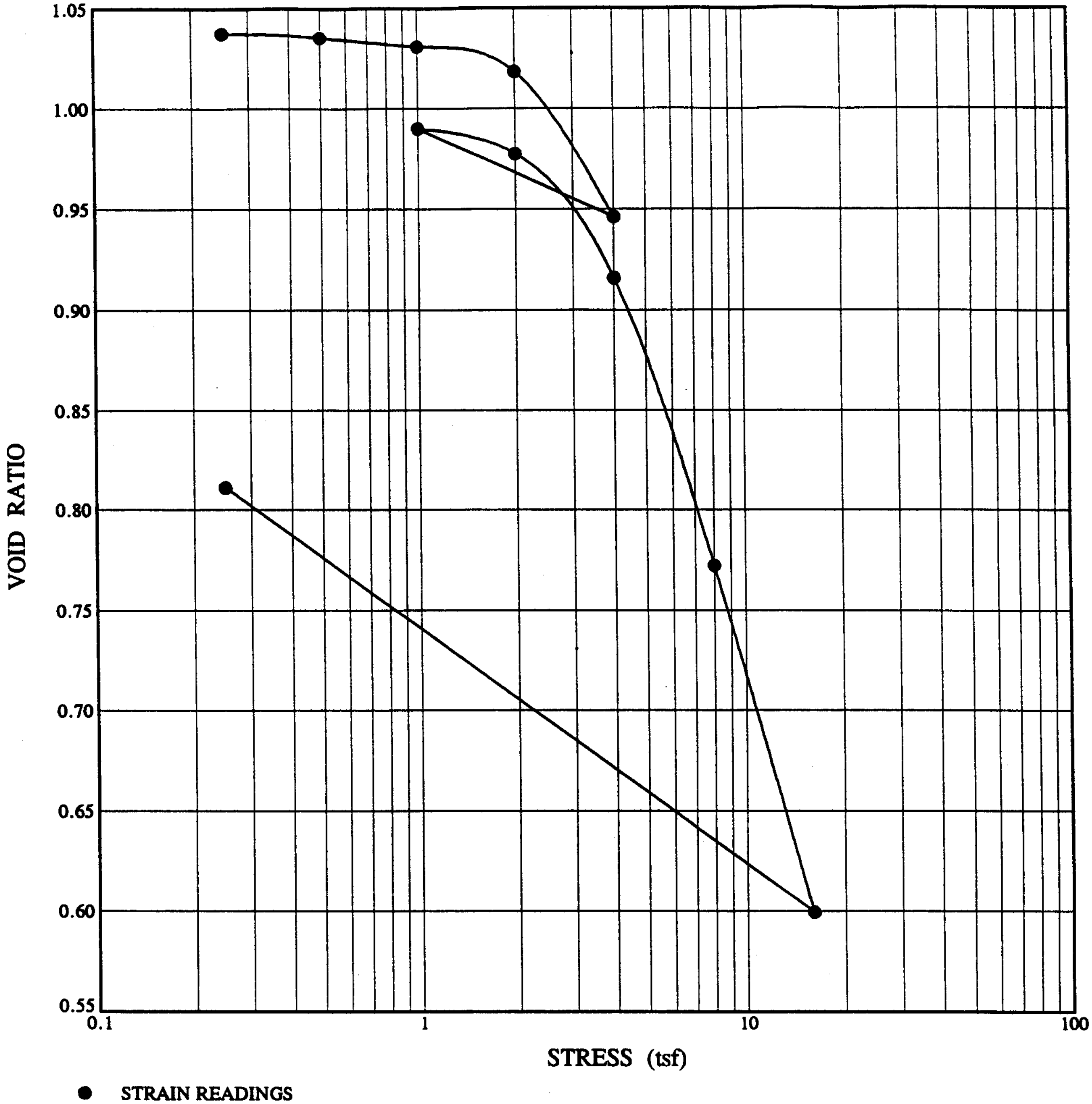
FINAL MOISTURE CONTENT (%): 26
FINAL DRY UNIT WEIGHT (pcf): 103

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants

NOV 21 94 CONSLD2 3B107



Sample Data:

FILE: 93B107C
BORING: B-SW-2-GT
DEPTH: 18' - 20'
DESCRIPTION: (CH)
SPECIFIC GRAVITY: 2.78
INITIAL MOISTURE CONTENT (%): 37
INITIAL DRY UNIT WEIGHT (pcf): 85
LL = 71 PL = 22 PI = 49
INUNDATION AT START

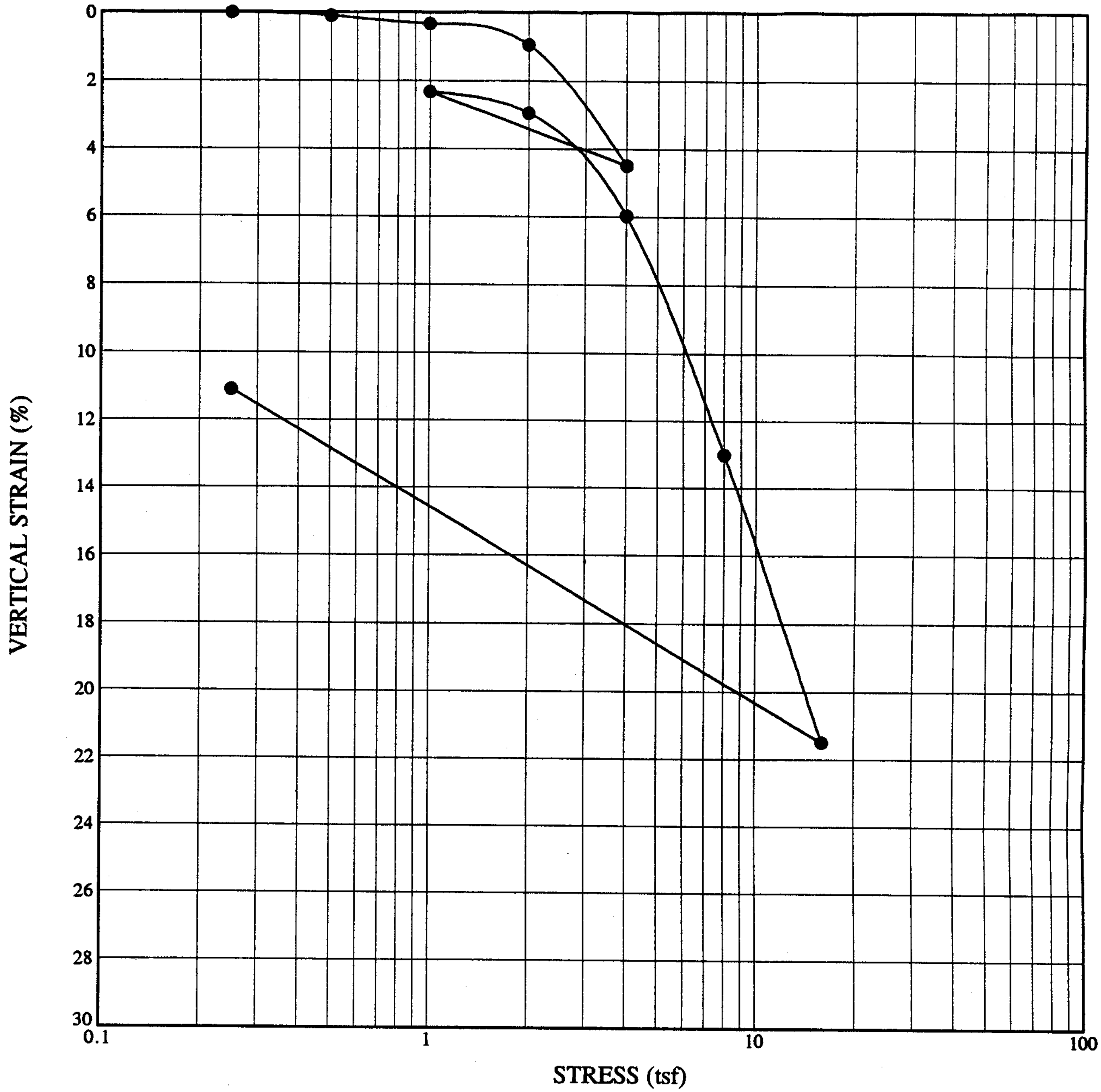
FINAL MOISTURE CONTENT (%): 38
FINAL DRY UNIT WEIGHT (pcf): 86

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants

NOV 7 94 CONSLV1 3B107



● STRAIN READINGS

Sample Data:

FILE: 93B107C
BORING: B-SW-2-GT
DEPTH: 18' - 20'
DESCRIPTION: (CH)

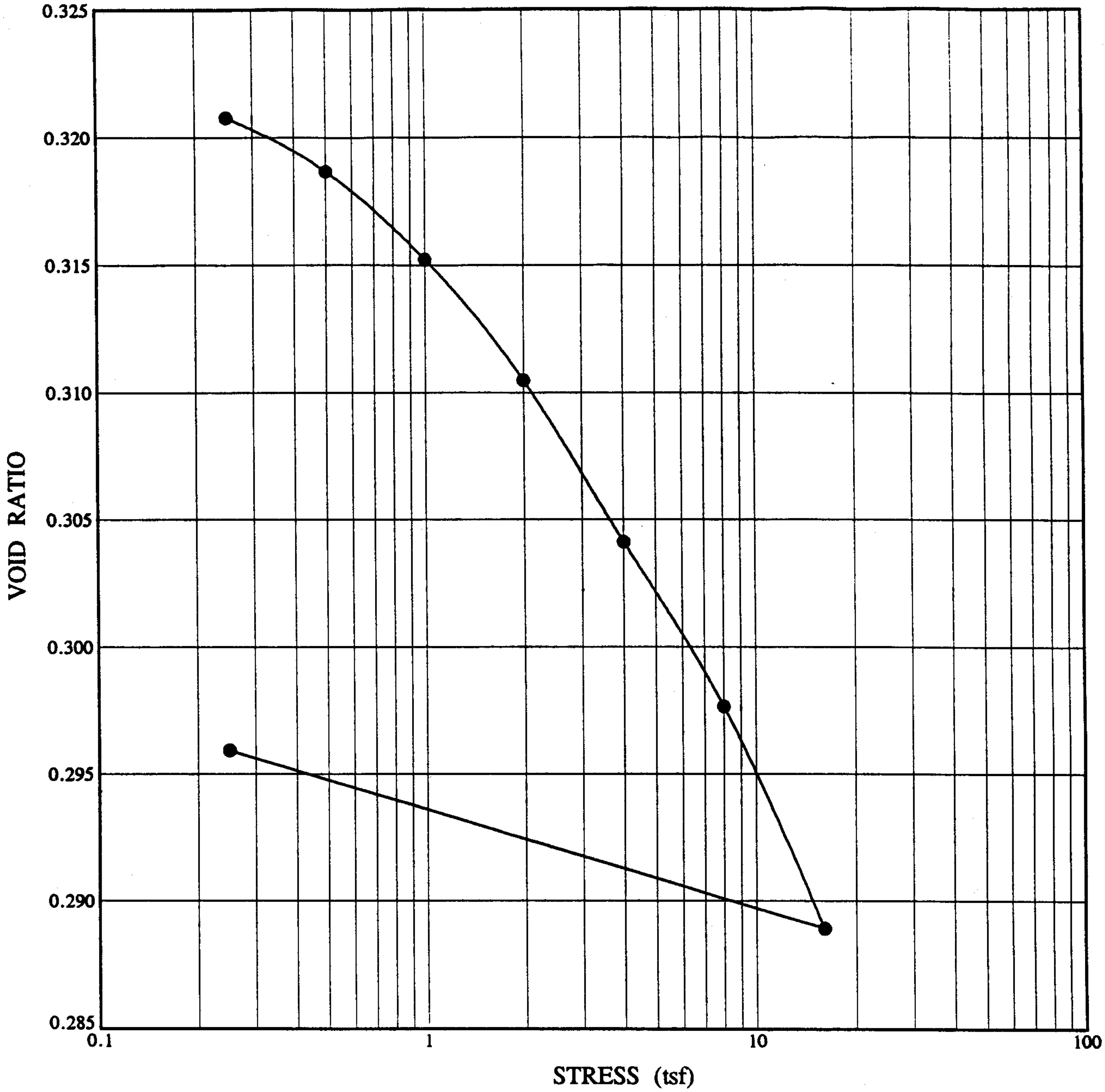
SPECIFIC GRAVITY: 2.78 (assumed)
INITIAL MOISTURE CONTENT (%): 37
INITIAL DRY UNIT WEIGHT (pcf): 85
LL = 71 PL = 22 PI = 49
INUNDATION AT START

FINAL MOISTURE CONTENT (%): 38
FINAL DRY UNIT WEIGHT (pcf): 86

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants



● STRAIN READINGS

Sample Data:

FILE: 93B107C
BORING: B-SW-13-GT
DEPTH: 13' - 15'
DESCRIPTION: (ML/SM)
SPECIFIC GRAVITY: 2.62
INITIAL MOISTURE CONTENT (%): 12
INITIAL DRY UNIT WEIGHT (pcf): 124
LL = 15 PL = 13 PI = 2
INUNDATION AT START

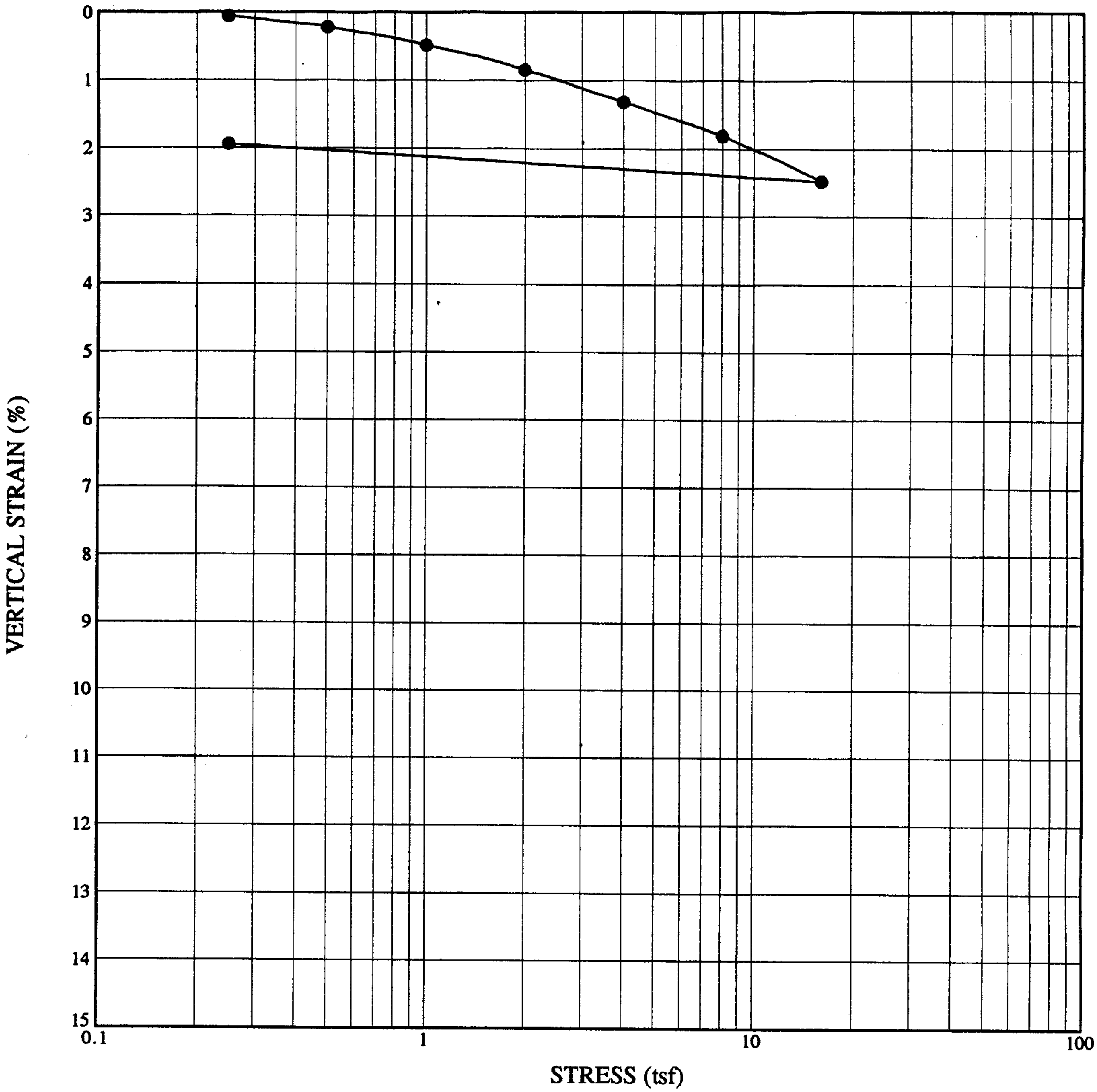
FINAL MOISTURE CONTENT (%): 13
FINAL DRY UNIT WEIGHT (pcf): 124

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants

NOV 7 94 CONSLV1 3B107



● STRAIN READINGS

Sample Data:

FILE: 93B107C
BORING: B-SW-13-GT
DEPTH: 13' - 15'
DESCRIPTION: (ML/SM)

SPECIFIC GRAVITY: 2.62 (assumed)
INITIAL MOISTURE CONTENT (%): 12
INITIAL DRY UNIT WEIGHT (pcf): 124
LL = 15 PL = 13 PI = 2
INUNDATION AT START

FINAL MOISTURE CONTENT (%): 13
FINAL DRY UNIT WEIGHT (pcf): 124

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

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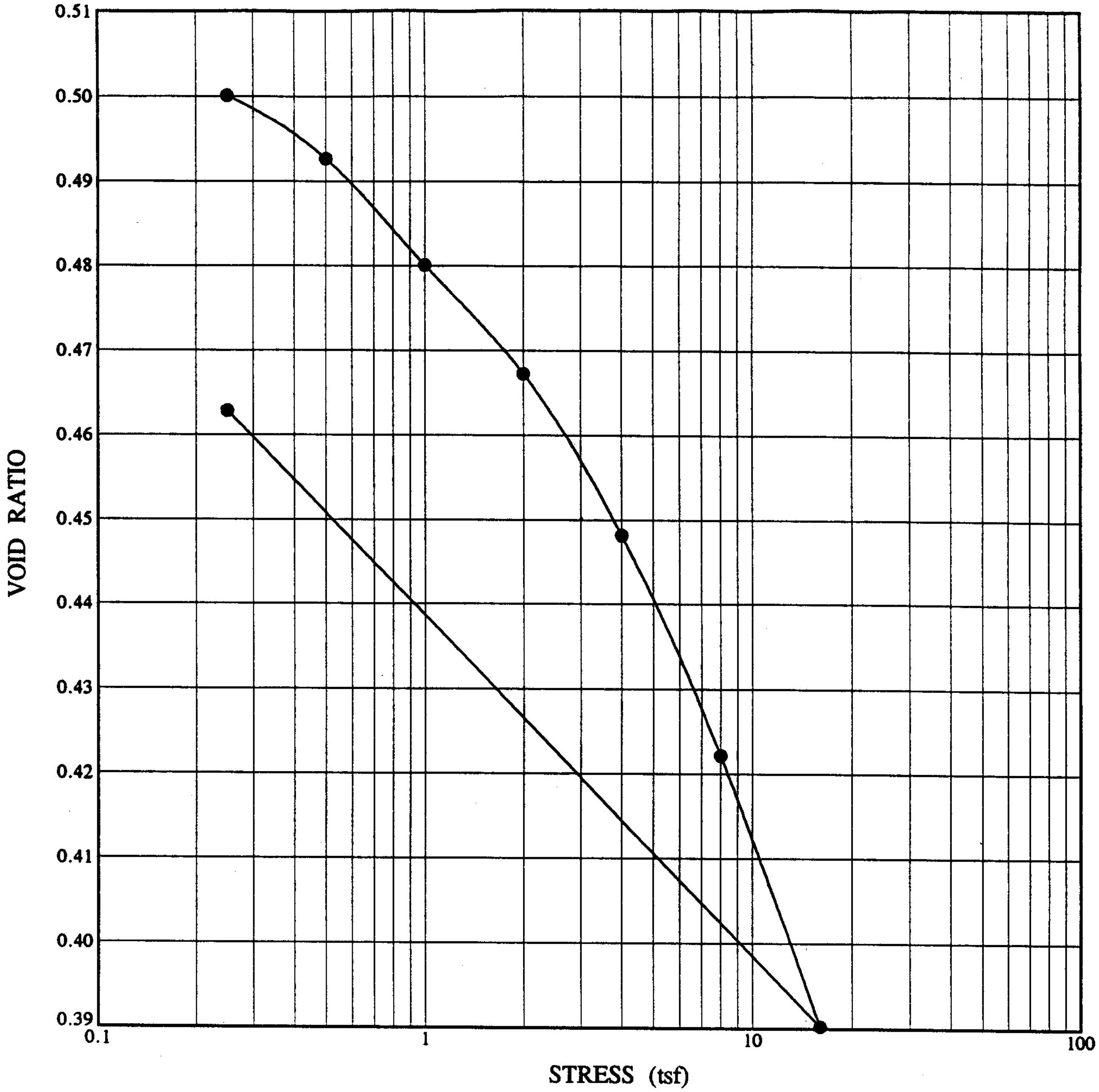
NOV 21 94 CONSLD2 3B107



● STRAIN READINGS

Sample Data:

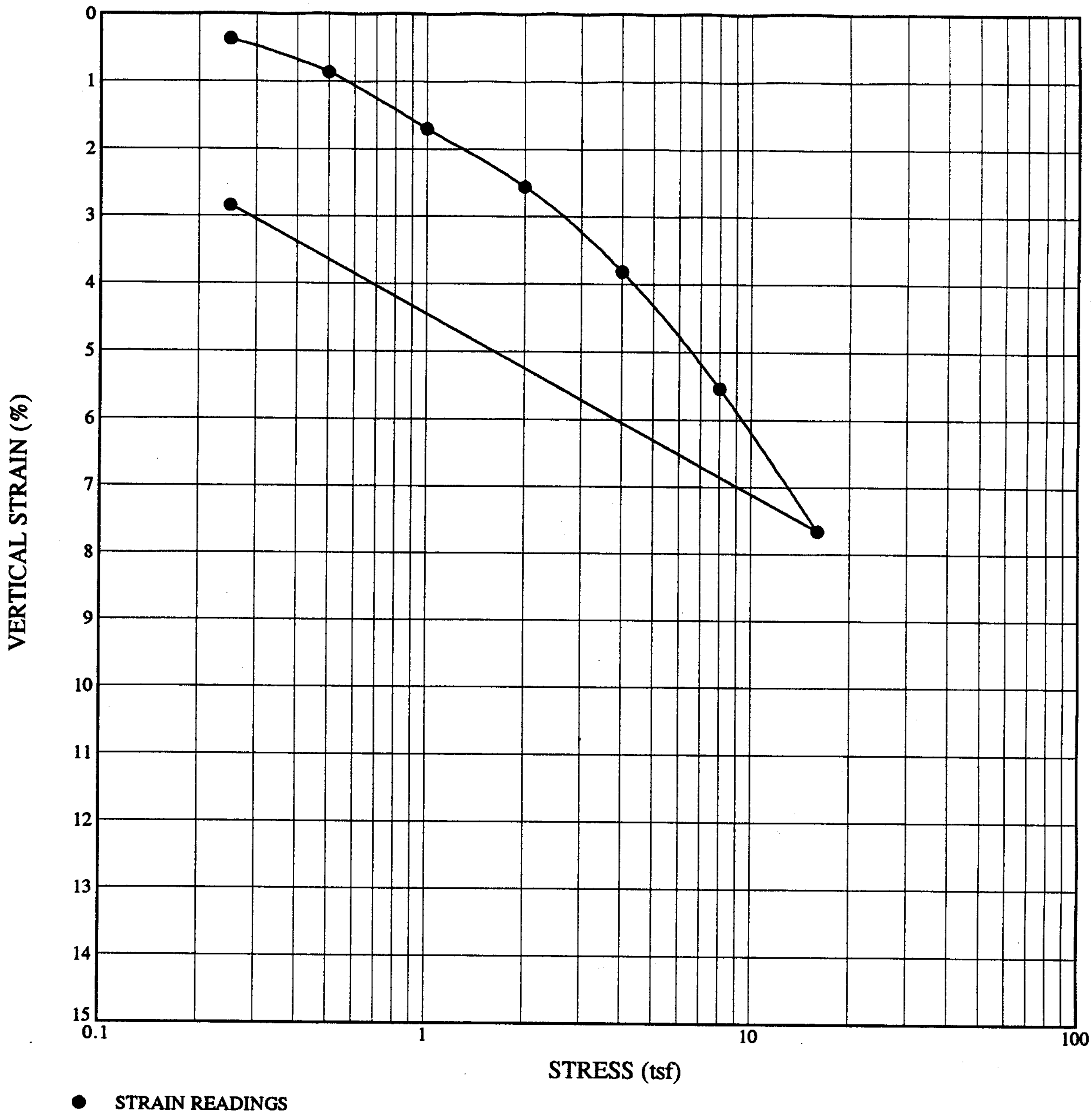
FILE: 93B107C
BORING: B-SW-21-GT
DEPTH: 8' - 10'
DESCRIPTION: (CL-SC)
SPECIFIC GRAVITY: 2.68
INITIAL MOISTURE CONTENT (%): 18
INITIAL DRY UNIT WEIGHT (pcf): 111
LL = 25 PL = 12 PI = 13
INUNDATION AT START

FINAL MOISTURE CONTENT (%): 17
FINAL DRY UNIT WEIGHT (pcf): 113

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants



Sample Data:

FILE: **93B107C**
BORING: **B-SW-21-GT**
DEPTH: **8' - 10'**
DESCRIPTION: **(CL-SC)**

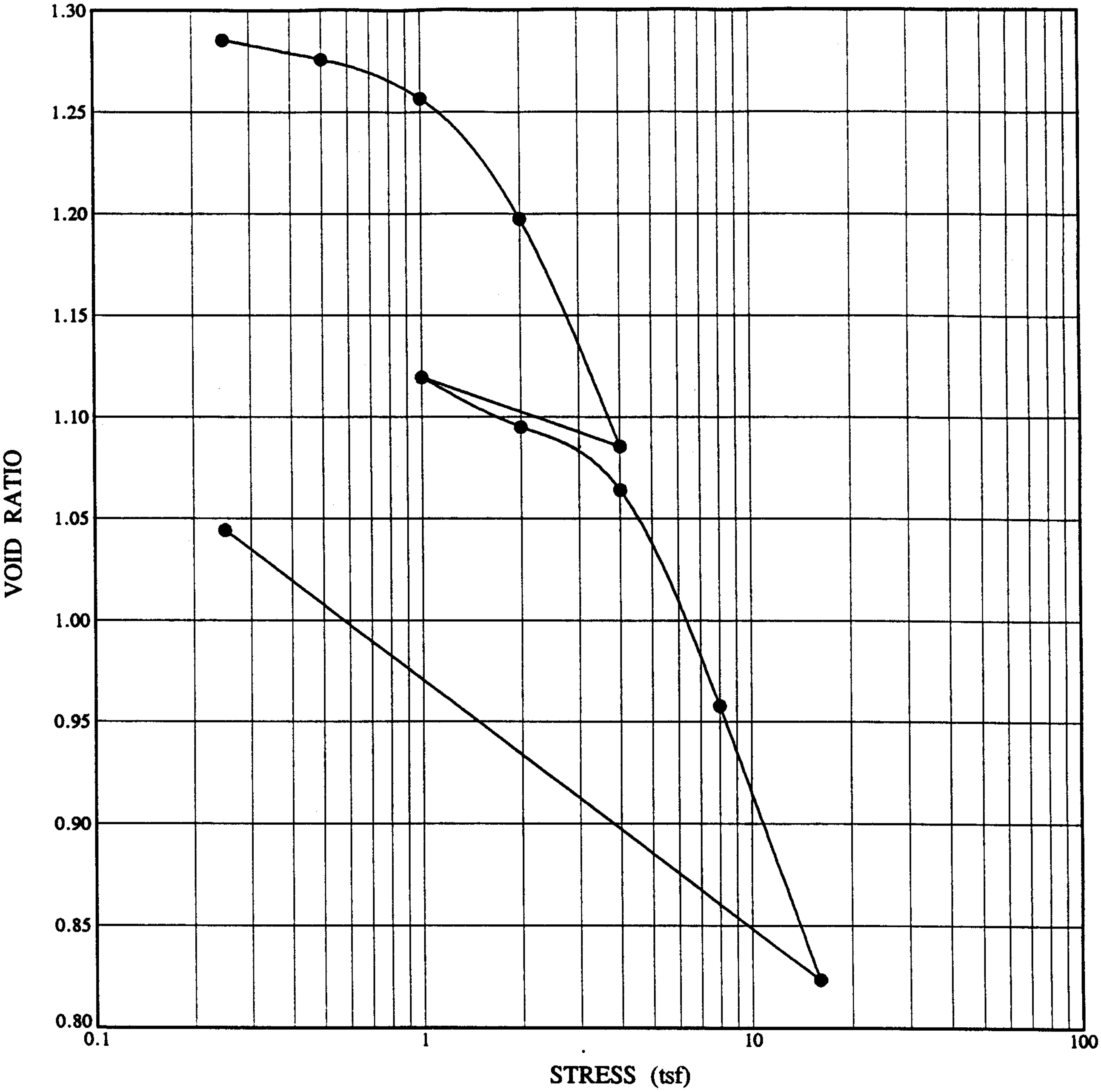
SPECIFIC GRAVITY: **2.68 (assumed)**
INITIAL MOISTURE CONTENT (%): **18**
INITIAL DRY UNIT WEIGHT (pcf): **111**
LL = **25** PL = **12** PI = **13**
INUNDATION AT START

FINAL MOISTURE CONTENT (%): **17**
FINAL DRY UNIT WEIGHT (pcf): **113**

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants



● STRAIN READINGS

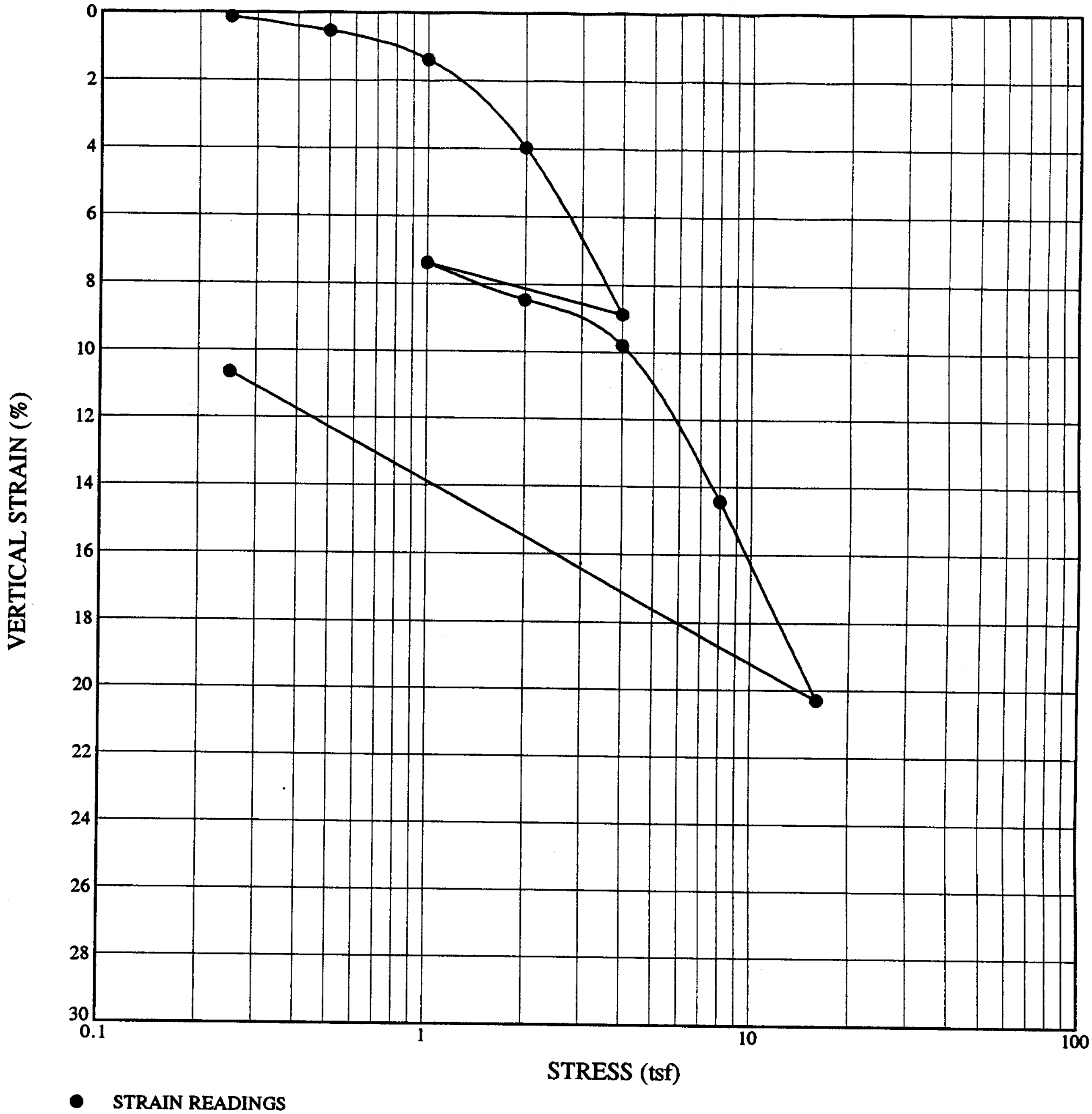
Sample Data:

FILE: 93B107C
BORING: B-SW-25-GT
DEPTH: 18' - 20'
DESCRIPTION: (CH)
SPECIFIC GRAVITY: 2.75
INITIAL MOISTURE CONTENT (%): 46
INITIAL DRY UNIT WEIGHT (pcf): 75
FINAL MOISTURE CONTENT (%): 38
FINAL DRY UNIT WEIGHT (pcf): 84
LL = 67 PL = 24 PI = 43
INUNDATION AT START

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants



Sample Data:

FILE: 93B107C
BORING: B-SW-25-GT
DEPTH: 18' - 20'
DESCRIPTION: (CH)

SPECIFIC GRAVITY: 2.75 (assumed)
INITIAL MOISTURE CONTENT (%): 46
INITIAL DRY UNIT WEIGHT (pcf): 75
LL = 67 PL = 24 PI = 43
INUNDATION AT START

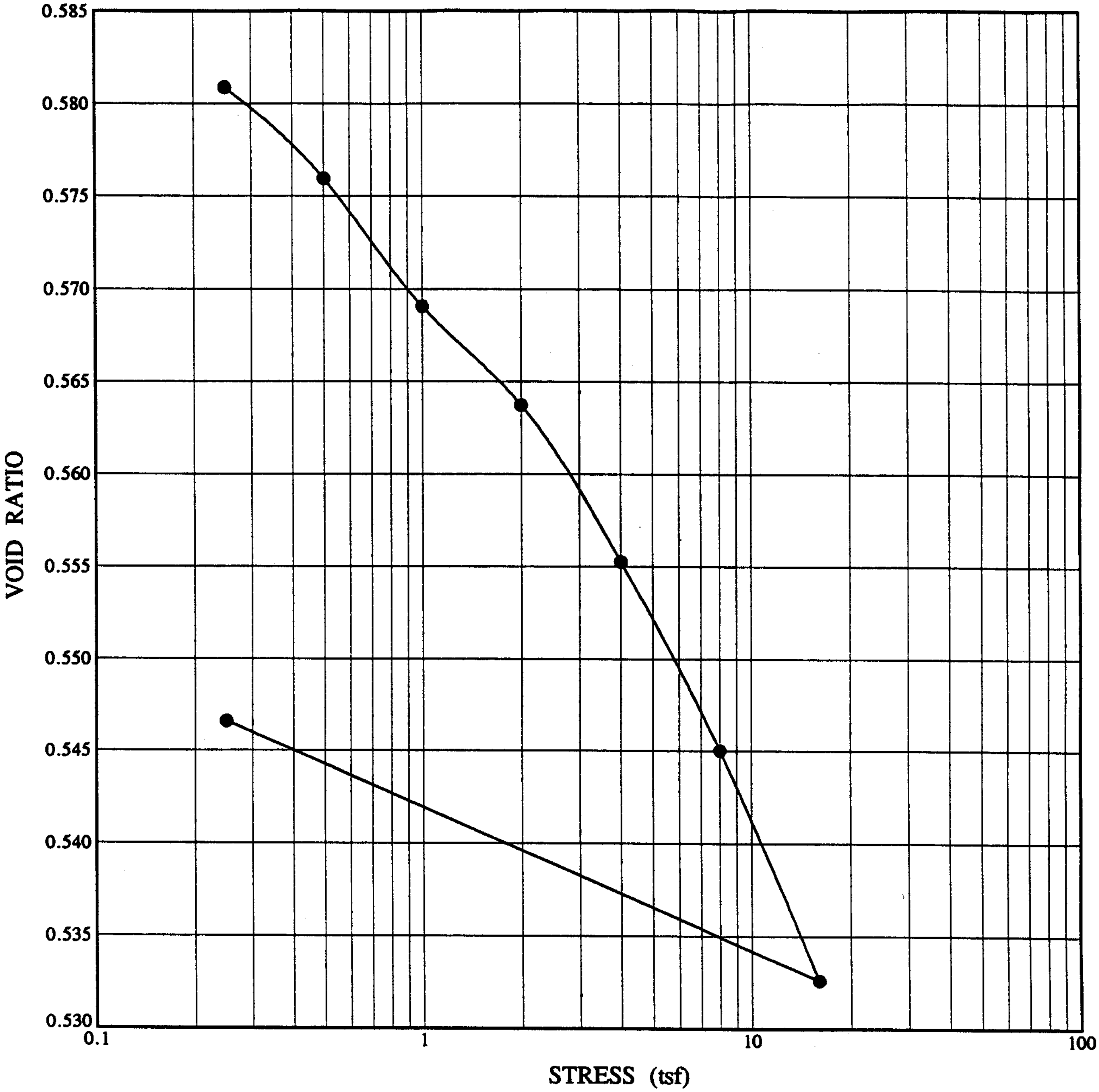
FINAL MOISTURE CONTENT (%): 38
FINAL DRY UNIT WEIGHT (pcf): 84

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants

NOV 21 94 CONSLD3 3B107



● STRAIN READINGS

Sample Data:

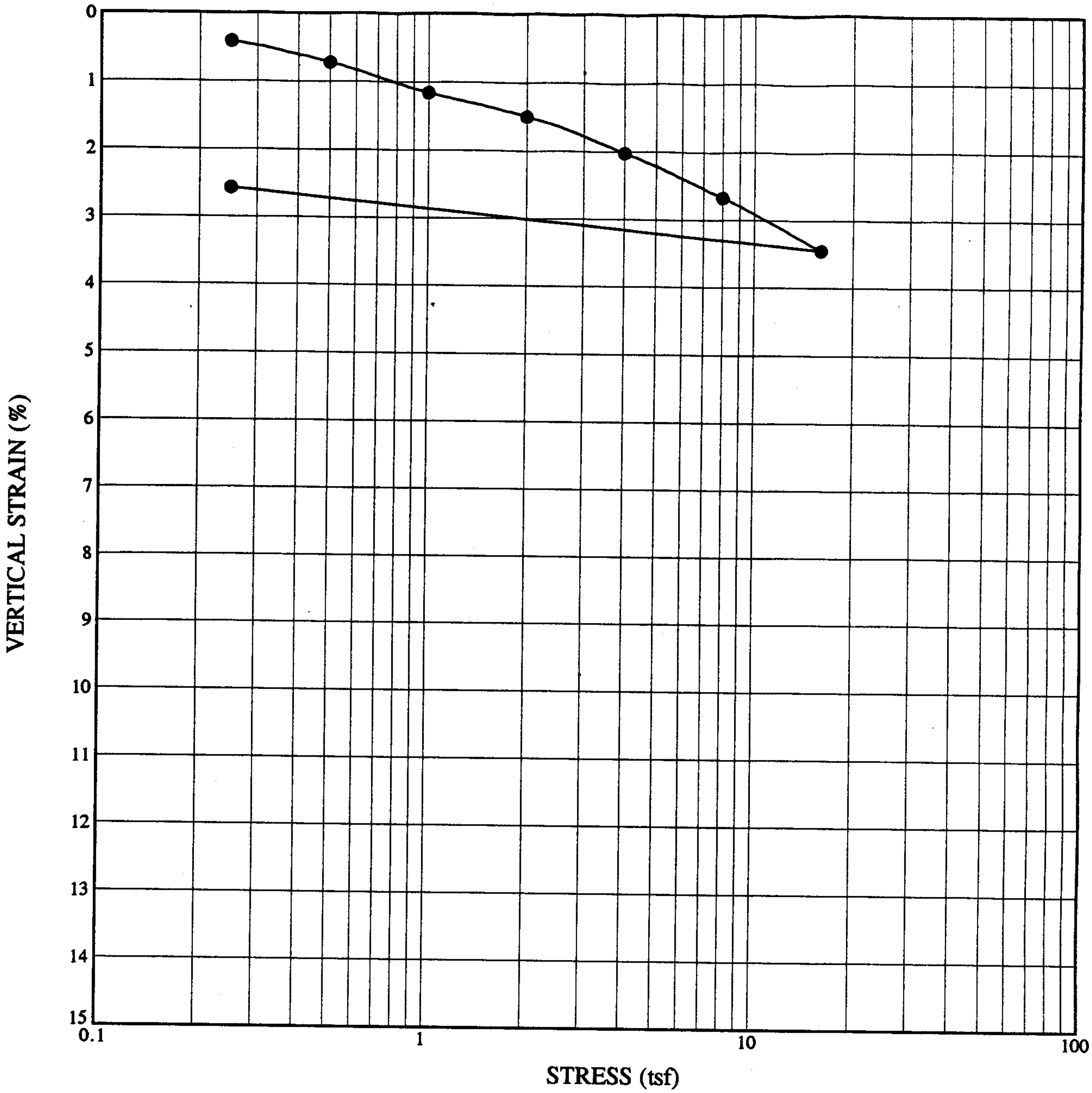
FILE: 93B107C
BORING: B-SW-33-GT
DEPTH: 23' - 25'
DESCRIPTION: (CL)
SPECIFIC GRAVITY: 2.68
INITIAL MOISTURE CONTENT (%): 22
INITIAL DRY UNIT WEIGHT (pcf): 105
FINAL MOISTURE CONTENT (%): 20
FINAL DRY UNIT WEIGHT (pcf): 109
LL = 28 PL = 17 PI = 11
INUNDATION AT START

LIGO

CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants

NOV 7 94 CONSLV1 3B107



● STRAIN READINGS

Sample Data:

FILE: 93B107C
BORING: B-SW-33-GT
DEPTH: 23' - 25'
DESCRIPTION: (CL)

SPECIFIC GRAVITY: 2.68 (assumed)
INITIAL MOISTURE CONTENT (%): 22
INITIAL DRY UNIT WEIGHT (pcf): 105
LL = 28 PL = 17 PI = 11
INUNDATION AT START

FINAL MOISTURE CONTENT (%): 20
FINAL DRY UNIT WEIGHT (pcf): 109

LIGO

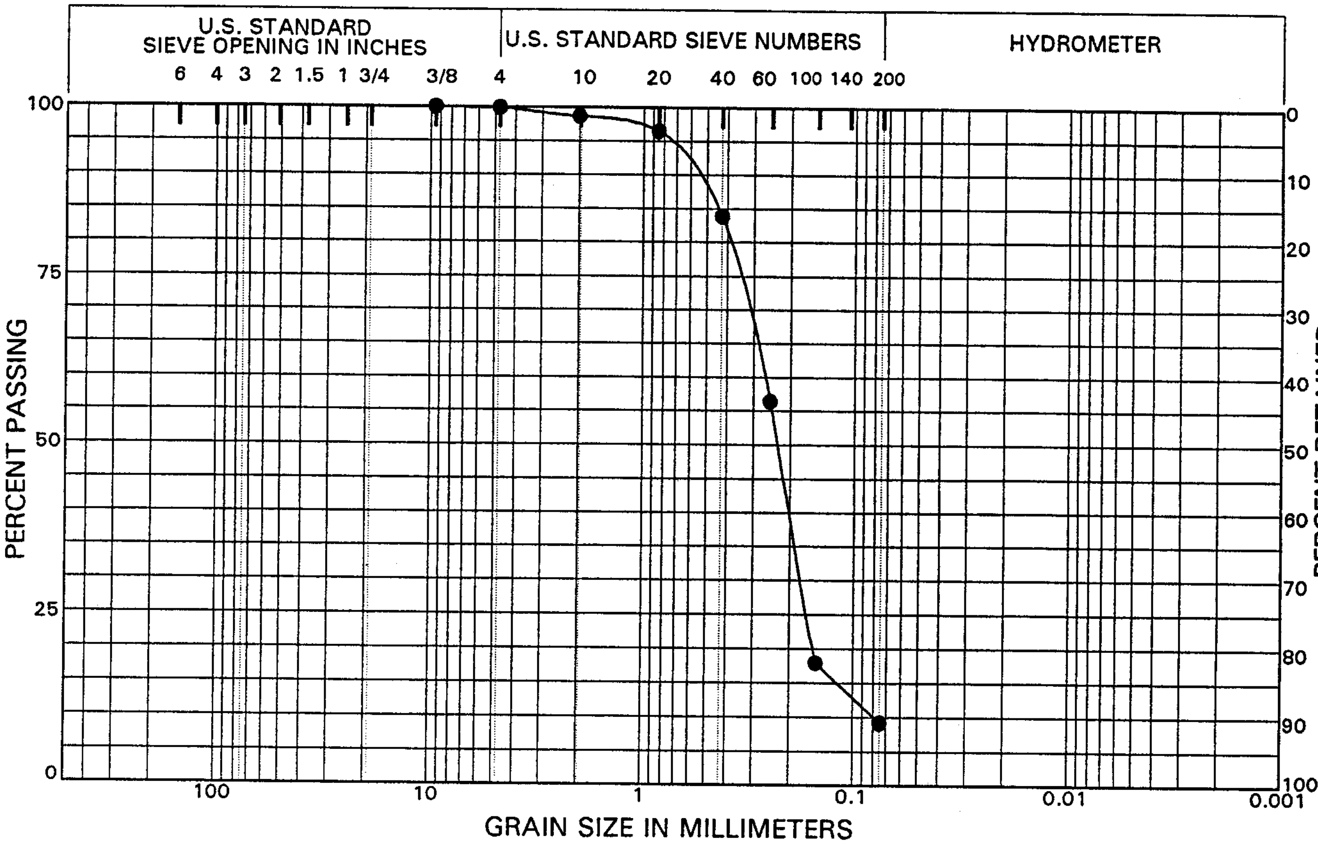
CONSOLIDATION TEST
ASTM D 2435-80

Woodward-Clyde Consultants

NOV 21 94 CONSLD2 3B107

SIEVE ANALYSIS

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	



Boring Number	Depth (feet)	Symbol	Classification
BSE2GT	14.5	●	(SP)

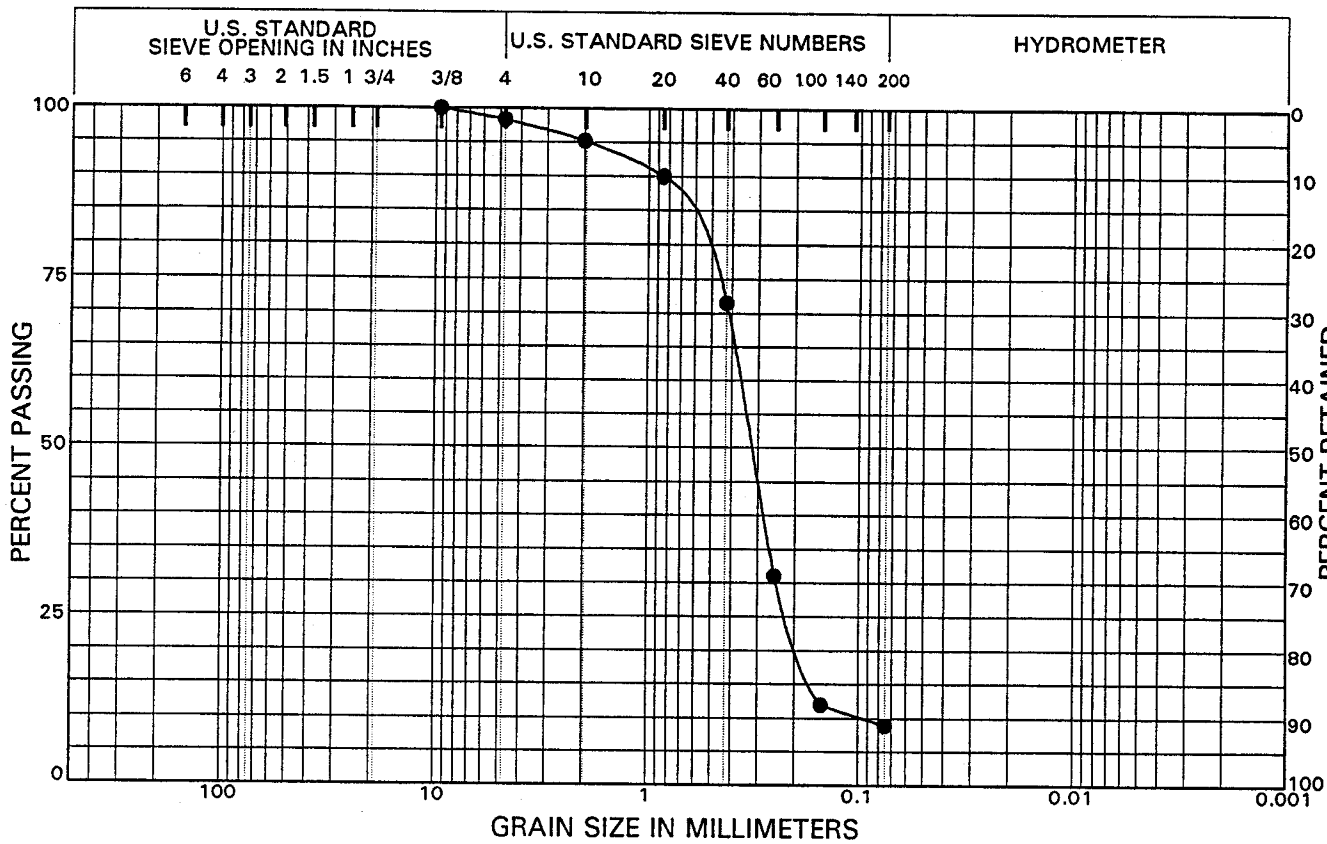
Project: LIGO
Project Number: 93B107C

GRAIN SIZE DISTRIBUTION CURVES

9/2/94 SVANLS6B 3B107

Woodward-Clyde Consultants

COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	



Boring Number	Depth (feet)	Symbol	Classification
BSW25GT	10.5	●	(SP)

Project: LIGO
Project Number: 93B107C

GRAIN SIZE DISTRIBUTION CURVES

9/2/94 SVANLS6B 3B107

Woodward-Clyde Consultants

APPENDIX B

CONE PENETROMETER, SEISMIC CONE AND CROSSHOLE TESTS

FUGRO GEOSCIENCES, INC.

6105 Rookin
Houston, Texas 77074
Tel: (713) 778-5580
Fax: (713) 778-5501

October 13, 1994
Report Number 0301-4108
Via Federal Express

Woodward-Clyde Consultants
2822 O'Neil Lane
Baton Rouge, LA 70816

Attention: Mr. Ara Arman
Mr. Bob Sanders

**CONE PENETROMETER TESTING
AND RELATED SERVICES
LIGO SITE
LIVINGSTON PARISH, LOUISIANA**

Dear Mssrs. Arman and Sanders:

Please find enclosed herewith the results of the cone penetrometer tests conducted at the above-referenced location. Also, results of the seismic cone penetrometer tests along with one (1) crosshole seismic test (B-W-35-SC) are included.

For your information, the soil stratigraphy was identified using Campanella and Robertson's Simplified Soil Behavior Chart. Please note that because of the empirical nature of the soil behavior chart, the soil identification should be verified locally.

Seismic Piezocone Test

At three (3) of the locations seismic piezocone tests were carried out. To design a foundation for dynamic loads, it is necessary to determine in-situ shear modules of the foundation soil. There are several methods to measure the shear modulus in-situ. One of the methods involves a penetrating cone in which geophones are incorporated to detect a shear wave which is generated at the surface. A shear wave is generated by means of a hammer blow against a wooden block. The shear wave travels to the piezocone in which three (3) seismometers are incorporated. A seismograph is triggered by the hammer blow and records the arrival of the shear waves. The results of the shear wave travel times versus depth are shown on Plates 1, 2, and 3. This can be repeated with both sides of the wooden beam to have polarized waves. After taking one set of measurements, the piezocone is pushed to the next depth, which is one-meter further. The difference in arrival time of the shear wave for the two penetrations is the travel time through the one-meter soil interval.

In this manner, a shear wave velocity profile can be given with one-meter intervals (Plate 5, 6, and 7).

Crosshole Testing

The crosshole seismic test was performed to measure in-situ shear wave velocities of the subsurface soils at the location of seismic cone penetrometer Sounding No. B-SW-35-SC. A schematic diagram of the crosshole test arrangement is shown on Plate 4. The crosshole method consists of generating shear waves in the soil surrounding a source borehole and measuring the arrival times of the shear waves at each of two receiver boreholes.

The shear waves are generated by striking the drill rod from the ground surface with a hammer. The bottom of the drill rod is in contact with the soil in the source borehole. Each impact of the hammer on the drill excites an accelerometer attached to the drill rod, which in turn triggers the recording equipment. The recording equipment consists of a recording digital oscilloscope. The shear waves travel through the soil, and their arrivals are monitored with vertically-oriented geophones, or receivers, positioned in the receiver boreholes (borings R-1 and R-2) at the same depth as the bottom of the drill rod. The geophones are firmly coupled to the receiver borehole using pneumatic packers. The shear wave arrivals at the geophones are recorded with the digital oscilloscope. The test is repeated at 5-foot intervals down to a 50-foot depth.

The recorded waveforms show travel times of the shear waves between the source and receiver boreholes. The shear wave velocities are calculated with the measured travel times and travel path distances. By calculating the shear wave velocity at each tested depth, we established a shear wave velocity versus depth profile, shown on Plate 6.

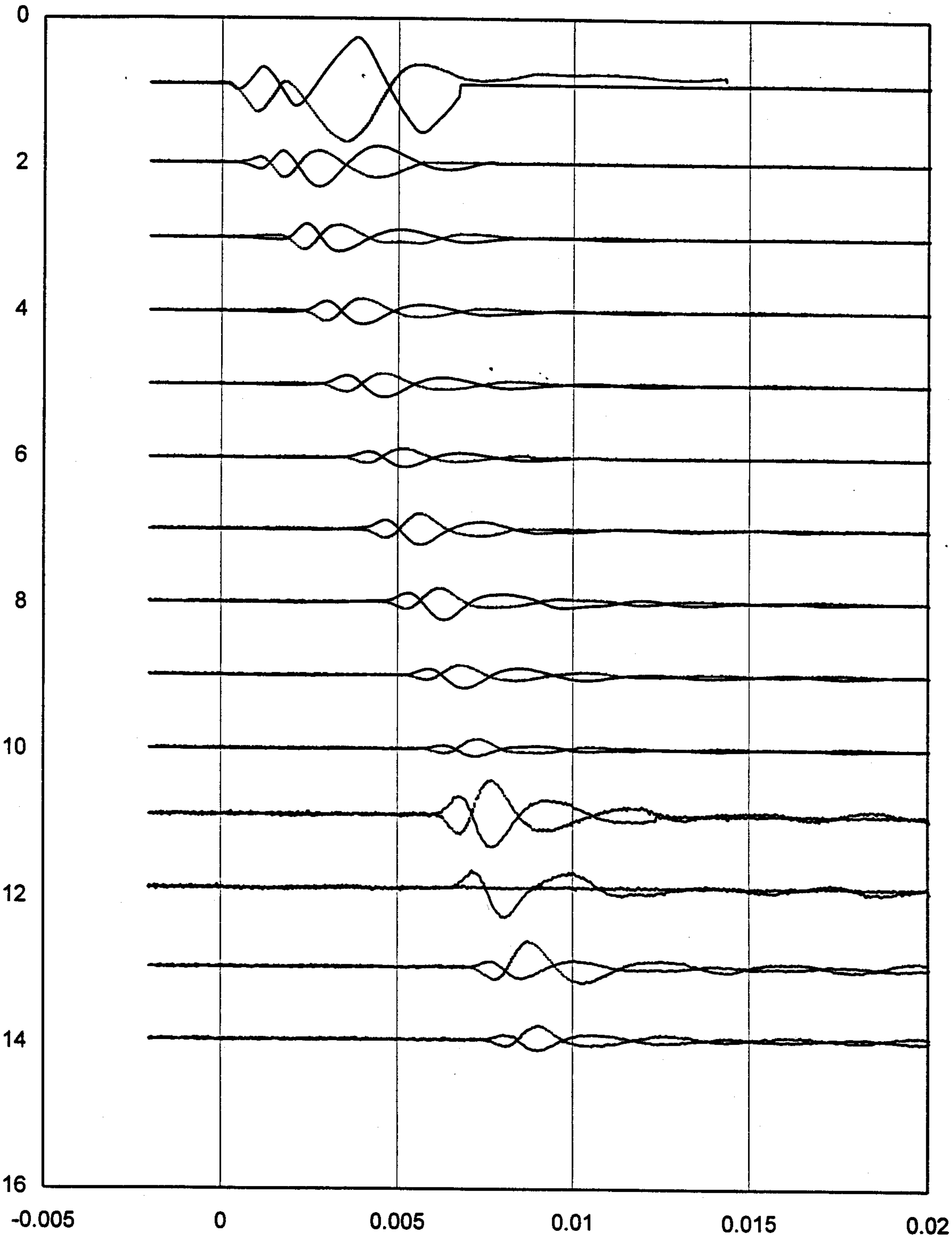
Fugro Geosciences appreciates the opportunity to be of service to your organization. If you should have any questions, or if we can be of further assistance, please do not hesitate to contact us. We look forward to working with you in the future.

Very truly yours,
FUGRO GEOSCIENCES, INC.

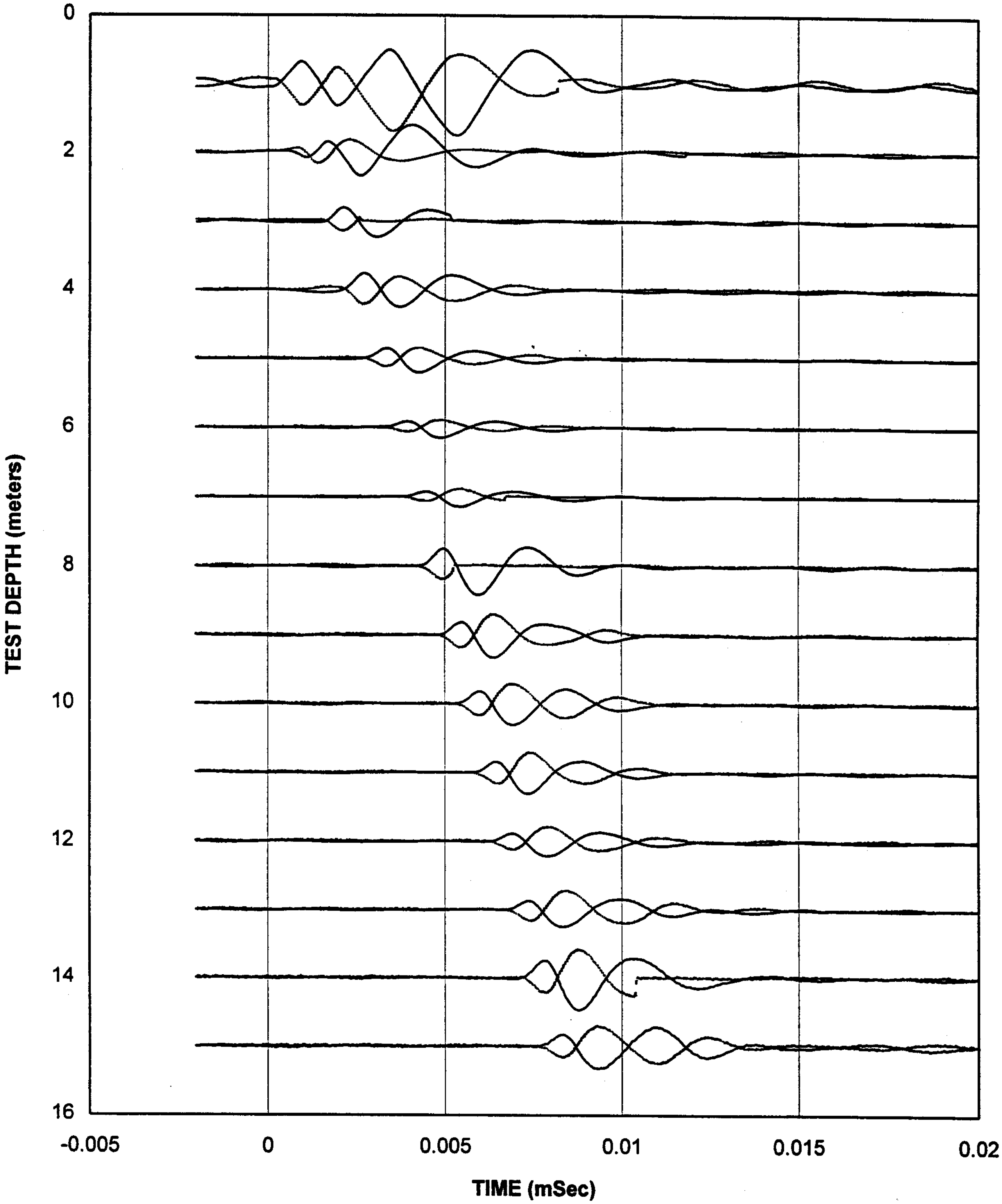
Recep Yilmaz
President

RY/cam

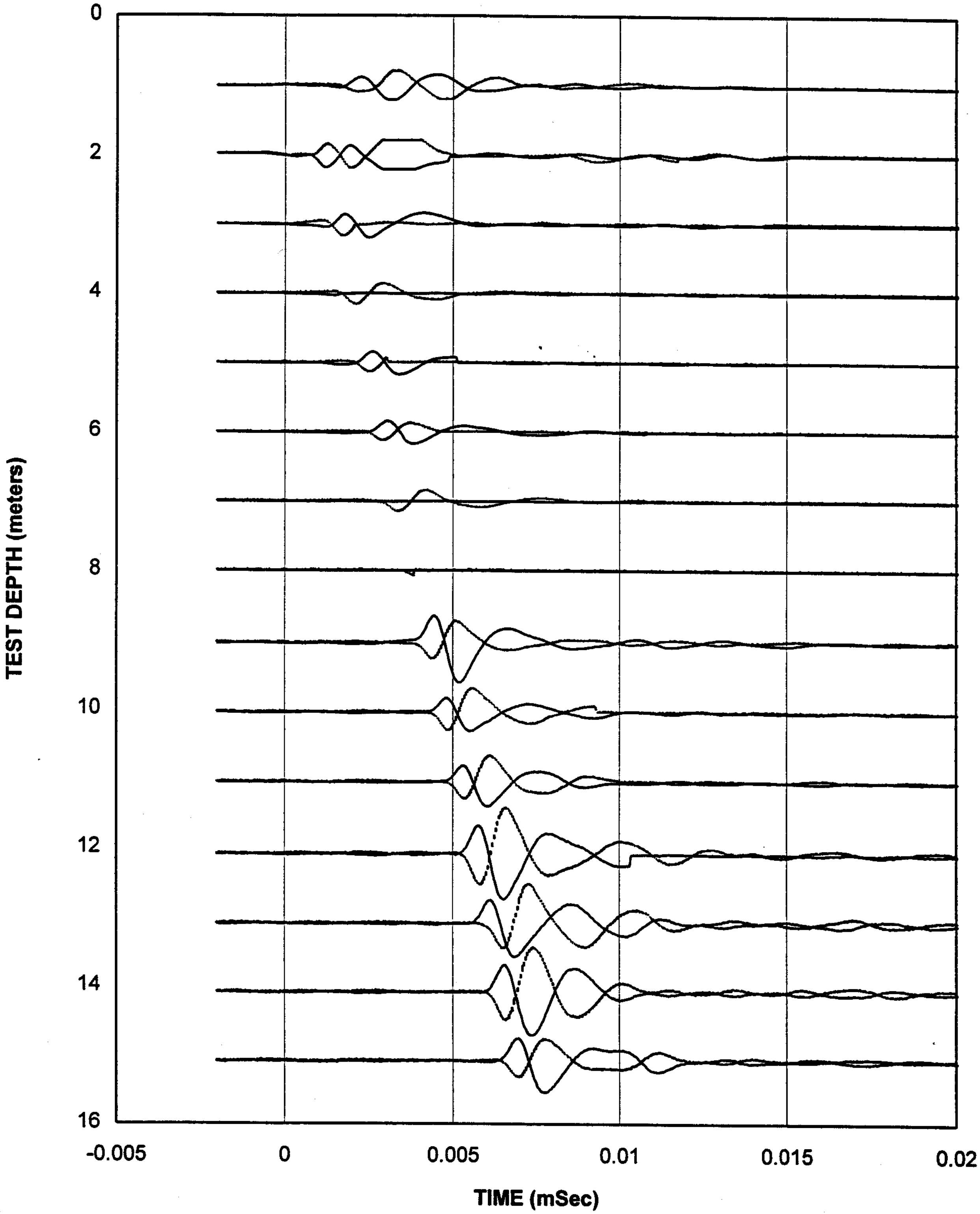
SOUNDING B-SW-1-SC

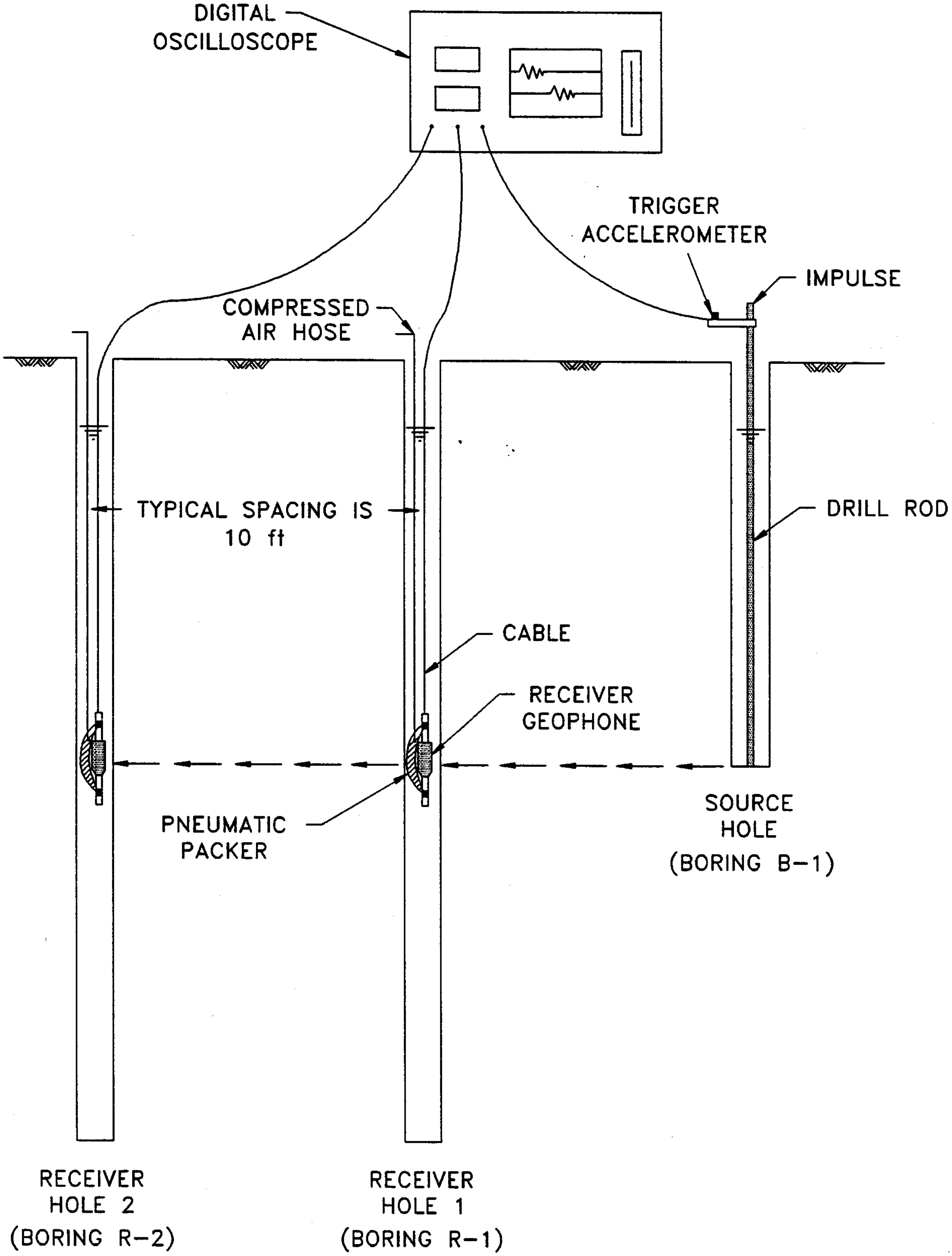


SOUNDING B-SE-34-SC

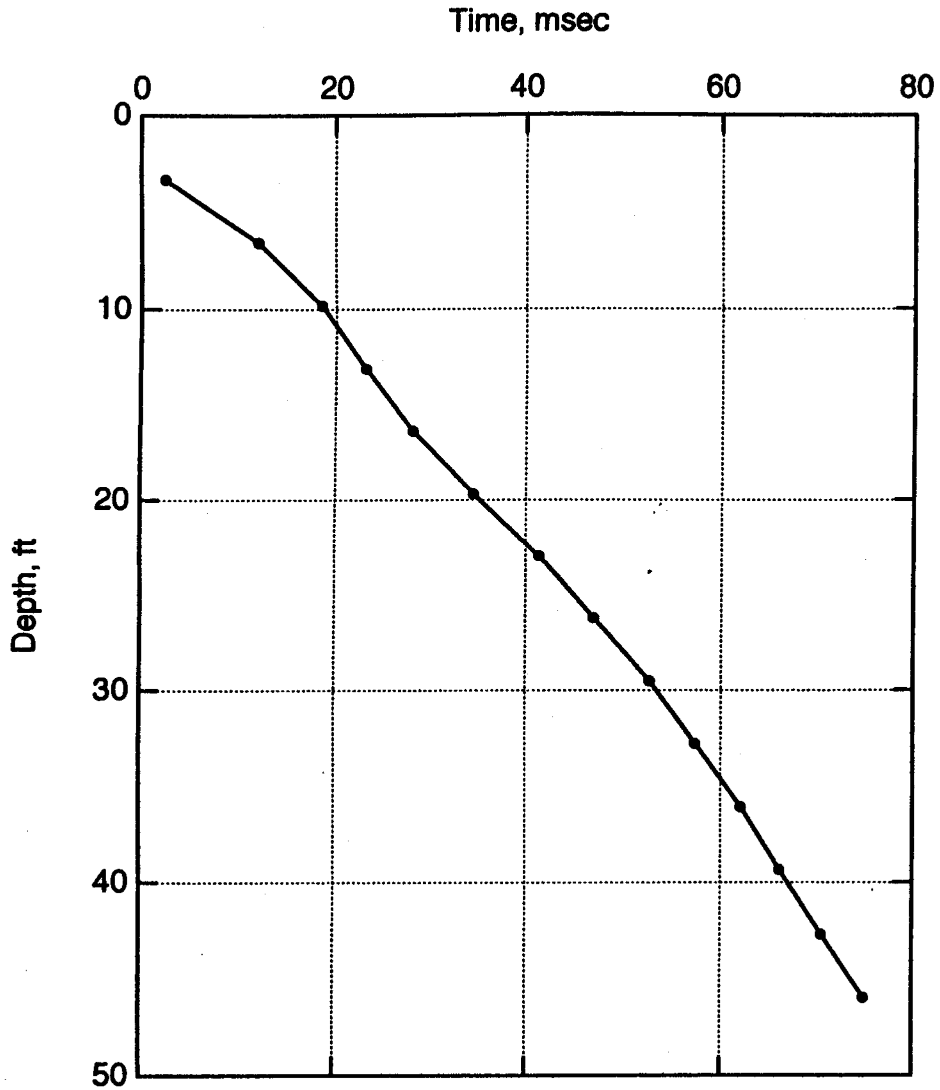


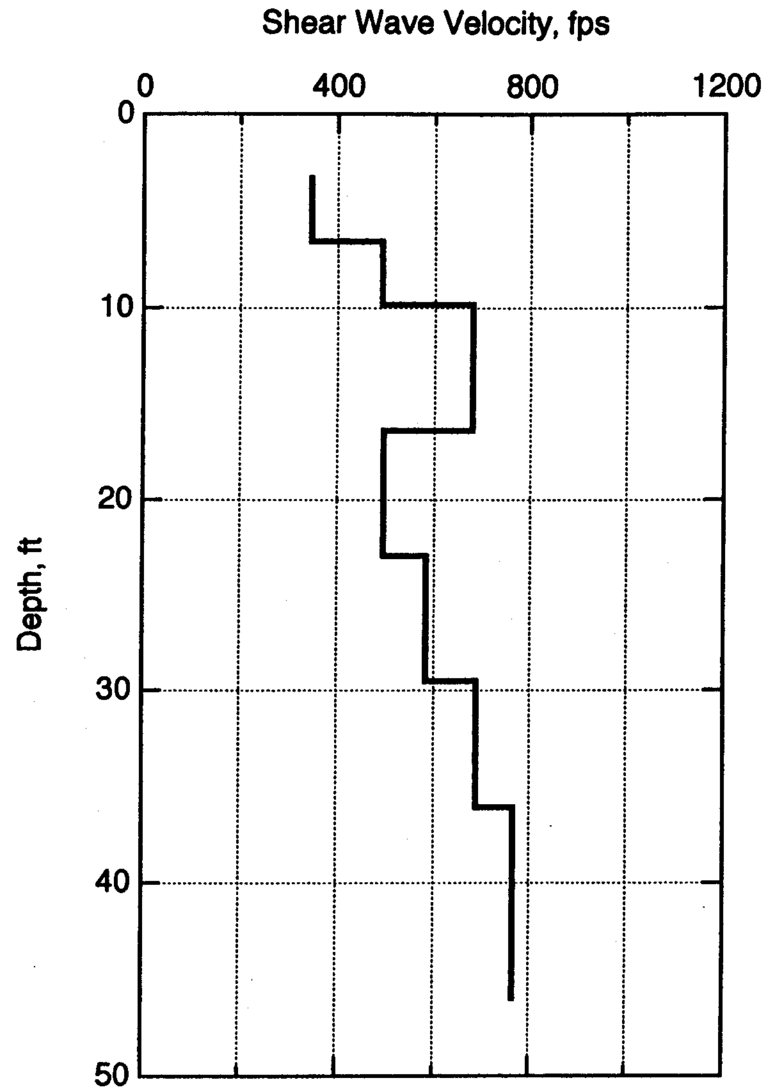
SOUNDING B-SW-35-SC





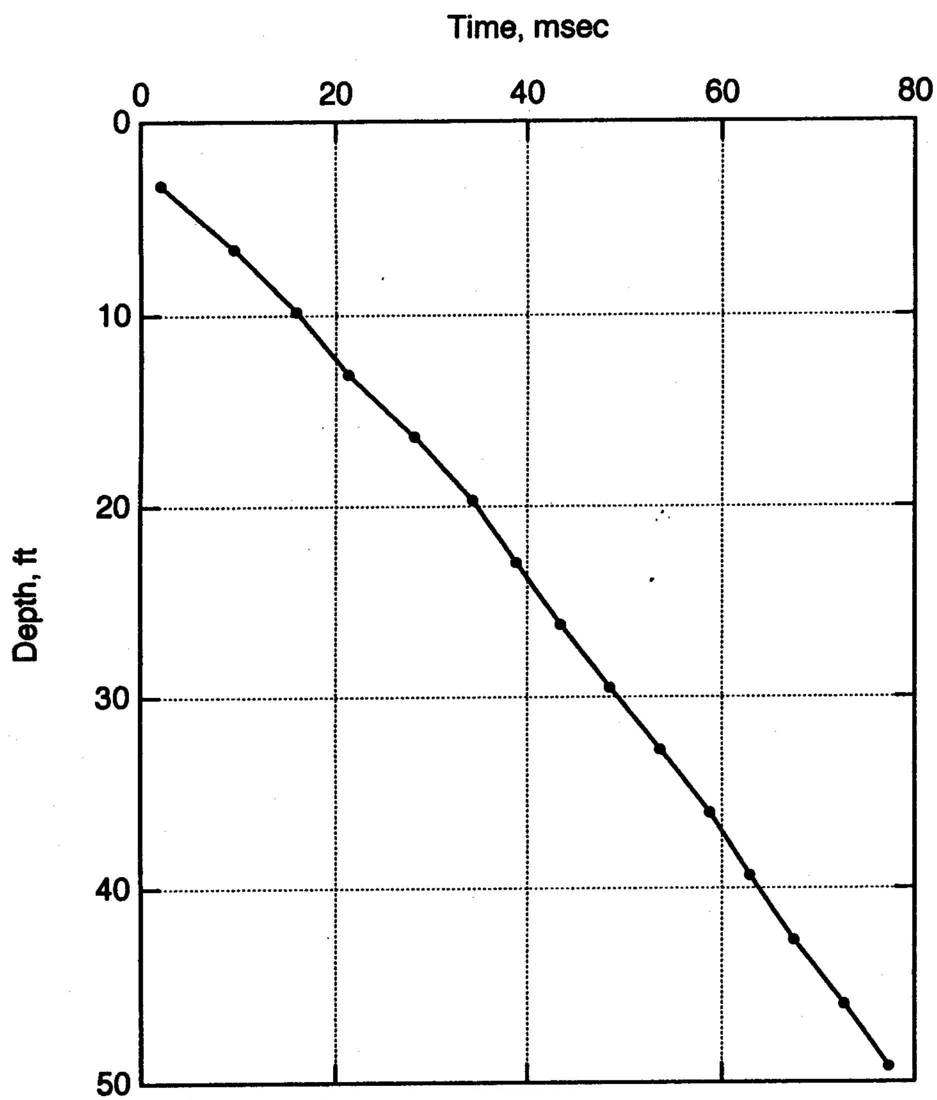
SCHEMATIC OF CROSSHOLE PROCEDURE
(Not to Scale)

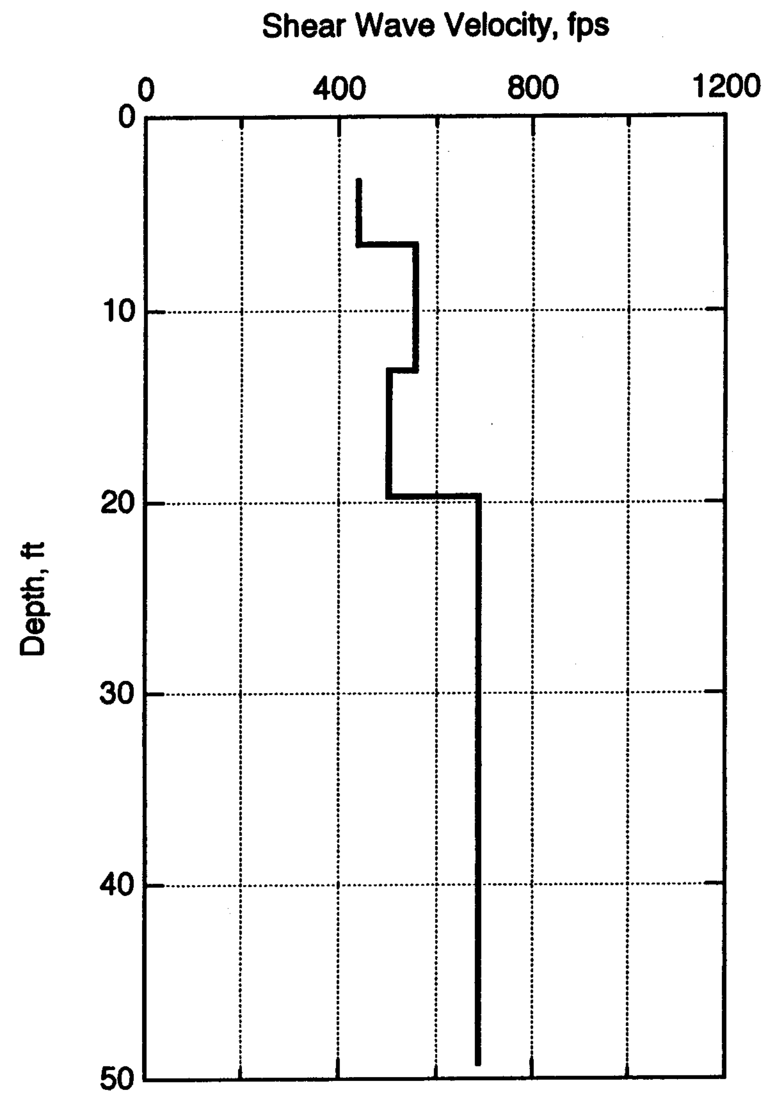




SEISMIC CONE PENETROMETER RESULTS
CPT SOUNDING B-SW-01-SC

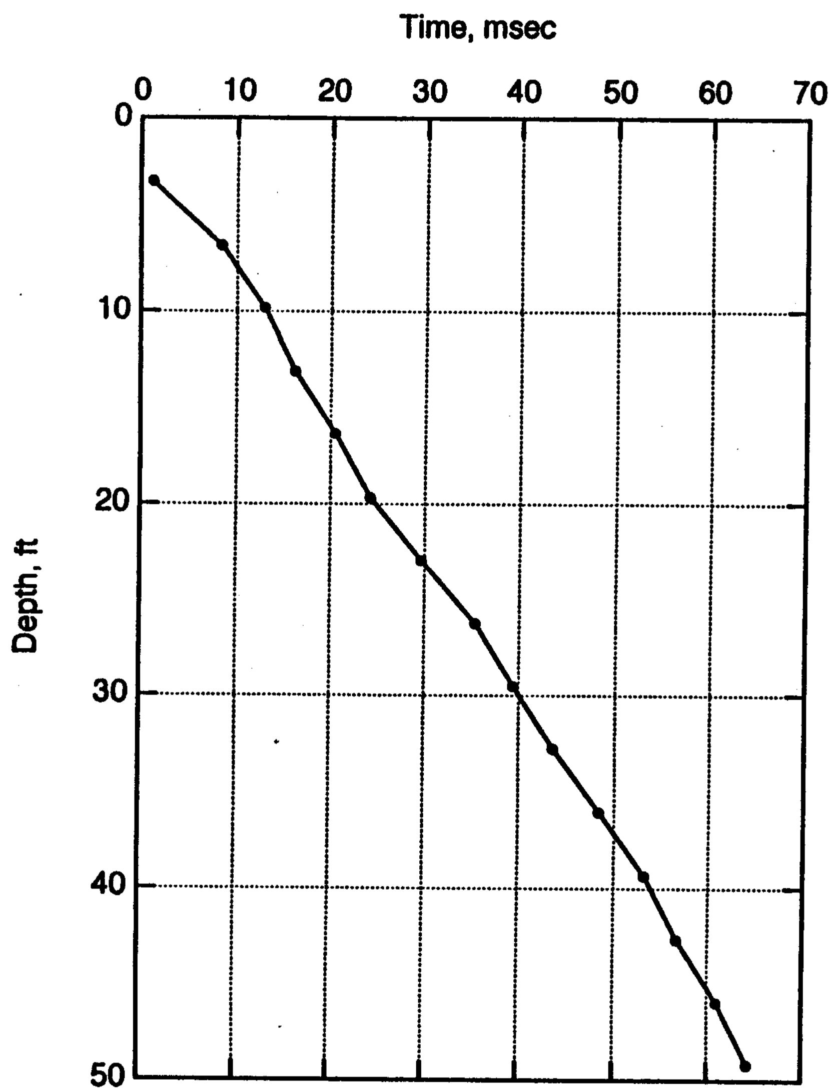
PLATE 5

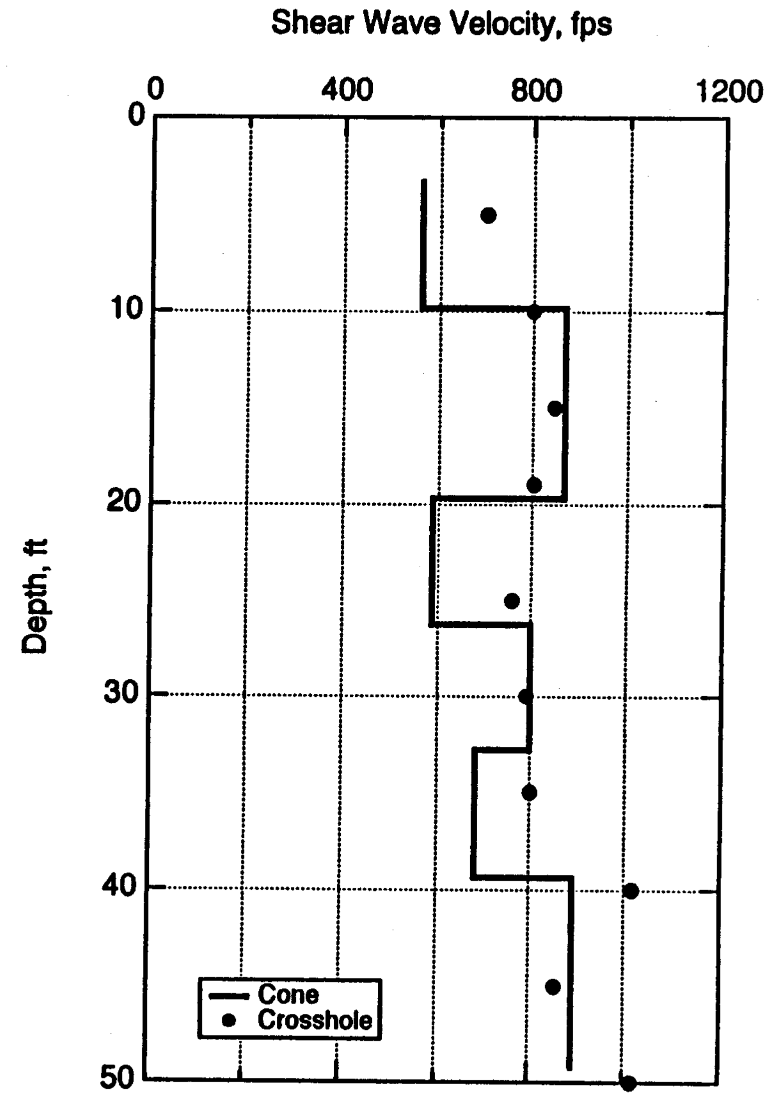




SEISMIC CONE PENETROMETER RESULTS
CPT SOUNDING B-SE-34-SC

PLATE 6





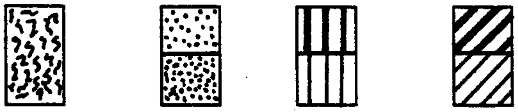
SEISMIC CONE PENETROMETER RESULTS
WITH CROSSHOLE TEST RESULTS
CPT SOUNDING B-SW-35-SC

PLATE 7

Key To Soil Classification and Symbols

SOIL TYPE
(Shown in Symbol Column)

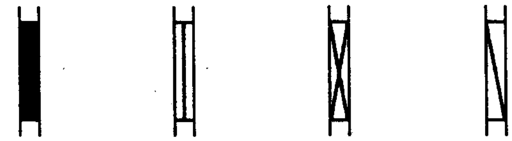
Sand Silt Clay



Fill Sandy Silty Clayey

Predominant Type Shown Heavy

SAMPLE TYPE
(Shown in Samples Column)



Undisturbed Rock Core Split Spoon No Recovery

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (Major portion Retained on No. 200 Sieve)
Includes (1) clean gravels and sand described as fine, medium or course, depending on distribution of grain sizes (2) silty or clayey gravels and sands and (3) fine grained low plasticity soils (PI < 10) such as sandy silts. Condition is rated according to relative density, as determined by lab tests or estimated from resistance to sampler penetration.

Descriptive Term	Penetration Resistance*	Relative Density
Loose	0 - 10	0 to 40%
Medium Dense	10 - 30	40 to 70%
Dense	30 - 50	70 to 90%
Very Dense	Over 50	90 to 100%

* Blows/Foot, 140# Hammer, 30" Drop

FINE GRAINED SOILS (Major Portion Passing No. 200 Sieve)
Includes (1) inorganic and organic silts and clays, (2) sandy, gravelly or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength, as indicated by penetrometer readings or by unconfined compression tests for soils with PI $\geq$ 10.

Descriptive Term	Cohesive Shear Strength Tons/Square Foot
Very Soft	Less Than 0.125
Soft	0.125 to 0.25
Firm	0.25 to 0.50
Stiff	0.50 to 1.00
Very Stiff	1.00 to 2.00
Hard	2.00 and Higher

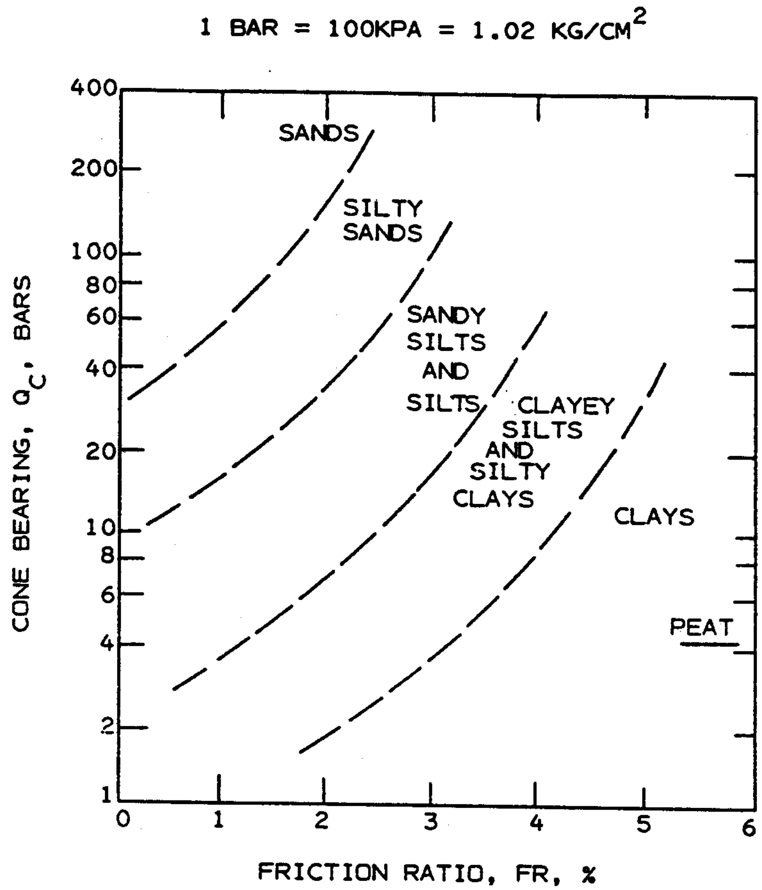
Note: Slickensided and fissured clay may have lower unconfined compressive strengths than shown above because of planes of weakness or shrinkage cracks; consistency ratings of such soils are based on hand penetrometer readings.

TERMS CHARACTERIZING SOIL STRUCTURE

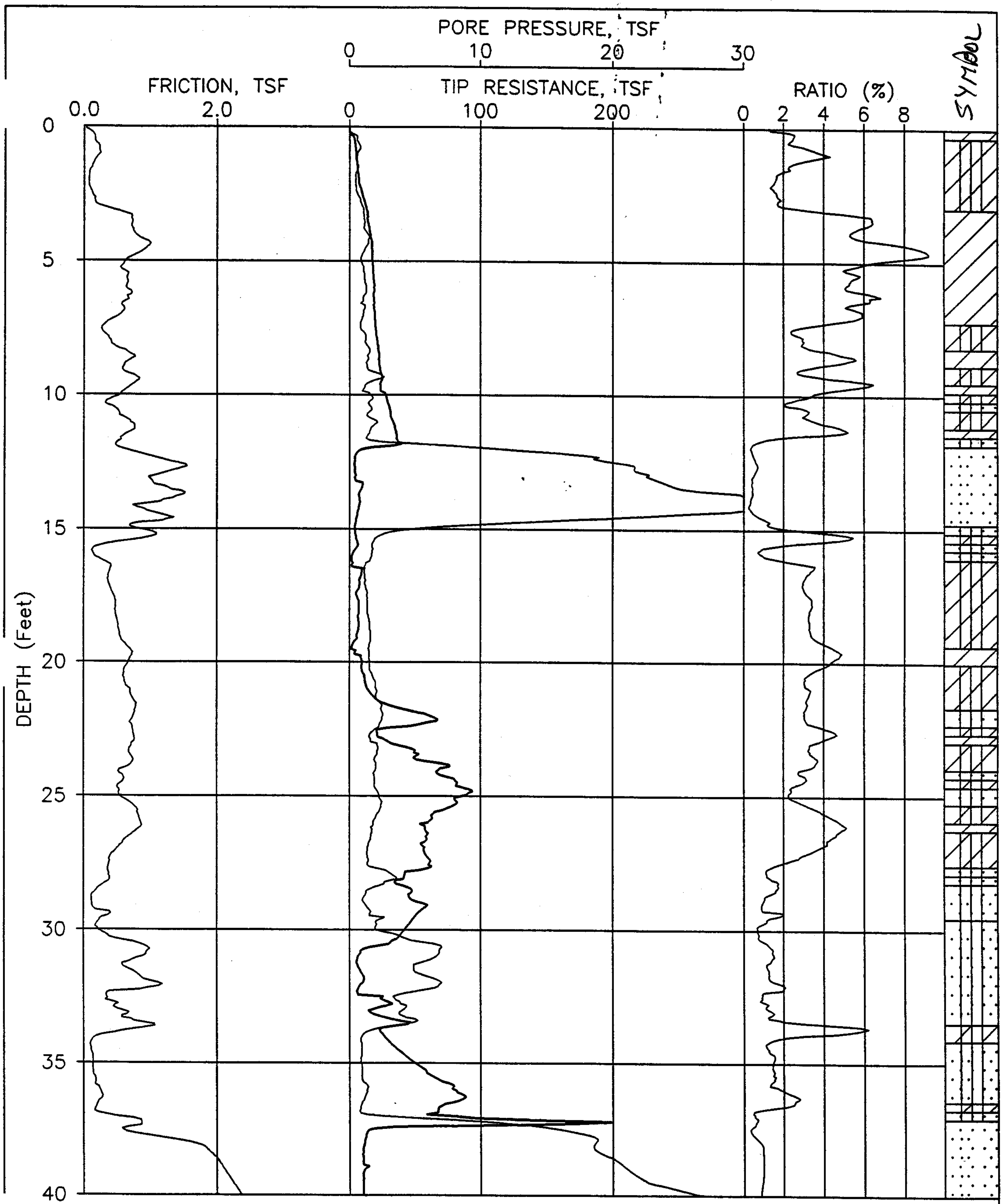
Parting: paper thin in size
Seam: 1/8" to 3" thick
Layer: greater than 3"
Fissured: containing shrinkage cracks, frequently filled with fine sand or silt, usually more or less vertical
Sensitive: pertaining to cohesive soils that are subject to appreciable loss of strength when remolded
Interbedded: composed of alternate layers of different soil types
Laminated: composed of thin layers of varying color and texture
Calcareous: containing appreciable quantities of calcium carbonate
Well Graded: having wide range in grain sizes and substantial amounts of all intermediate particle sizes
Poorly Graded: predominantly of one grain size, or having a range of sizes with some intermediate size missing
Flocculated: pertaining to cohesive soils that exhibit a loose knit or flakey structure
Slickensided: having inclined planes of weakness that are slick and glossy in appearance.

Degree of Slickensided Development

Slightly Slickensided: slickensides present at intervals of 1' to 2', soil does not easily break along these plates
Moderately Slickensided: slickensides spaced at intervals of 1' to 2', soil breaks easily along these planes
Extremely Slickensided: continuous and interconnected slickensides spaced at intervals of 4" to 12', soil breaks along the slickensides into pieces 3" to 6" in size
Intensely Slickensided: slickensides spaced at intervals of less than 4", continuous in all directions; soil breaks down along planes into nodules 1/4" to 2" in size.

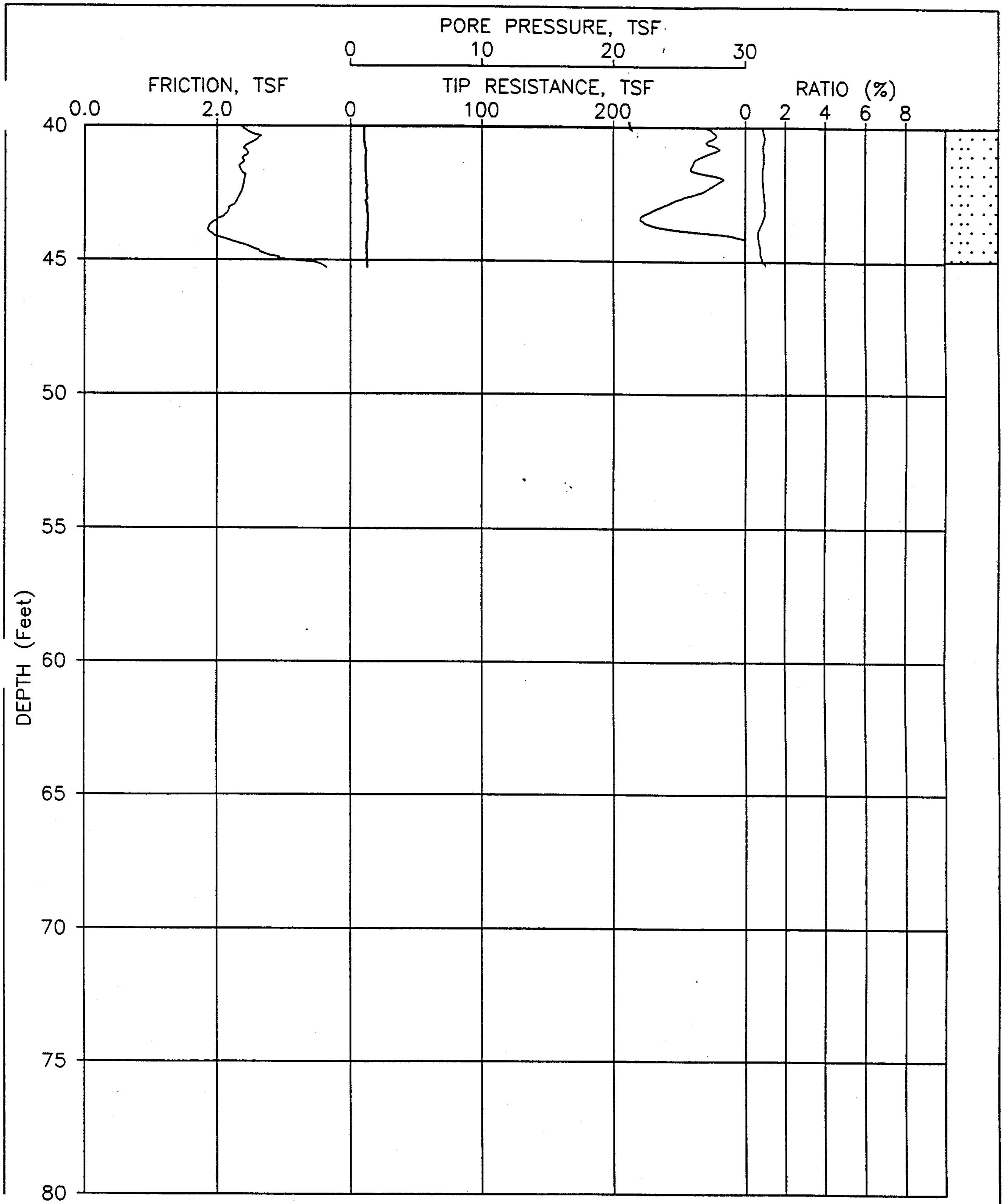


CAMPANELLA AND ROBERTSON CLASSIFICATION CHART



JOB NUMBER: 94-4108
ELEVATION: 0.00
CPT NUMBER: B-SW-01-SC
CONE NUMBER: F7.5CKE3SWV604
DATE: 09-14-1994
PLATE: 1 OF 2

FUGRO GEOSCIENCES,INC



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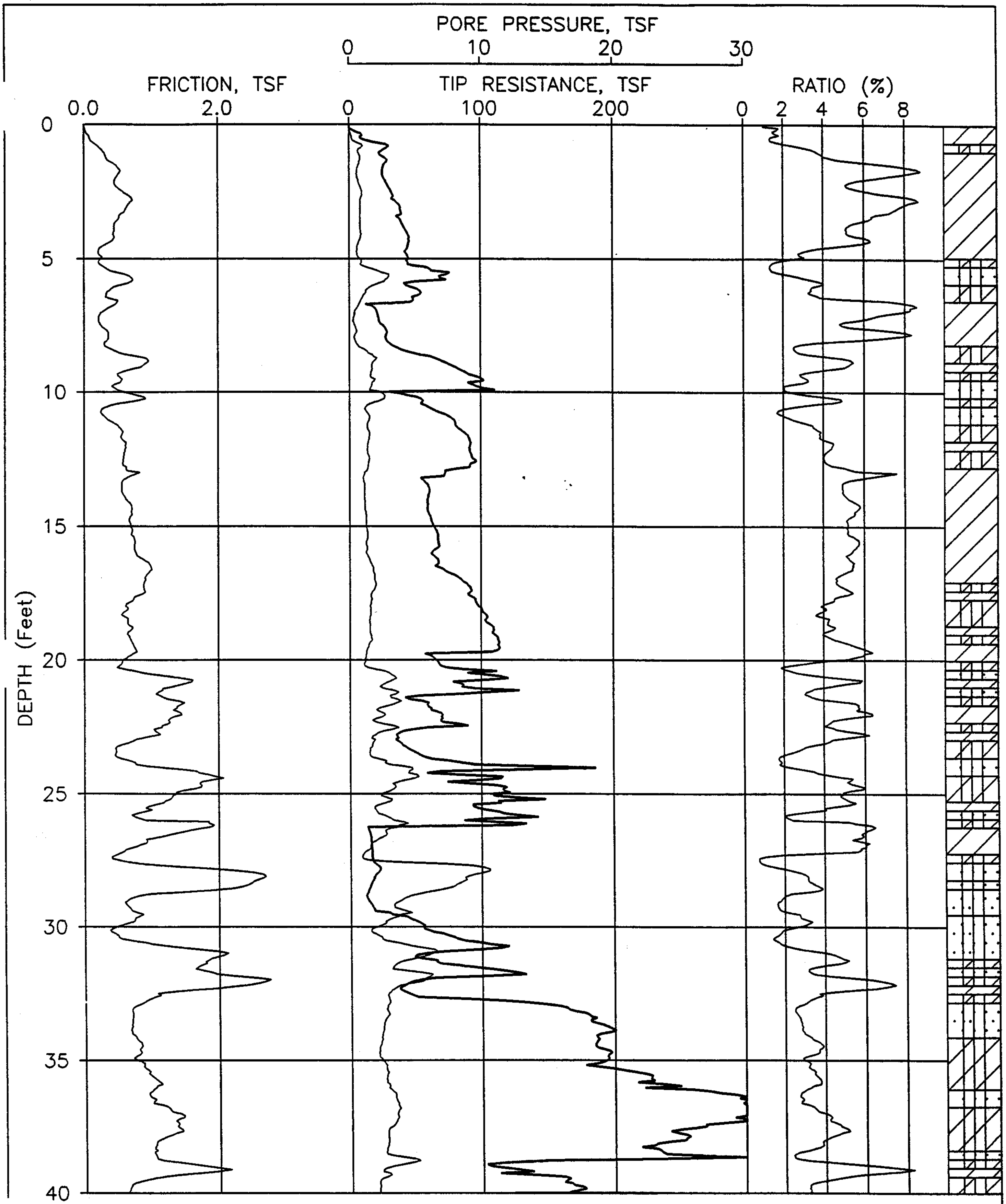
FUGRO GEOSCIENCES,INC



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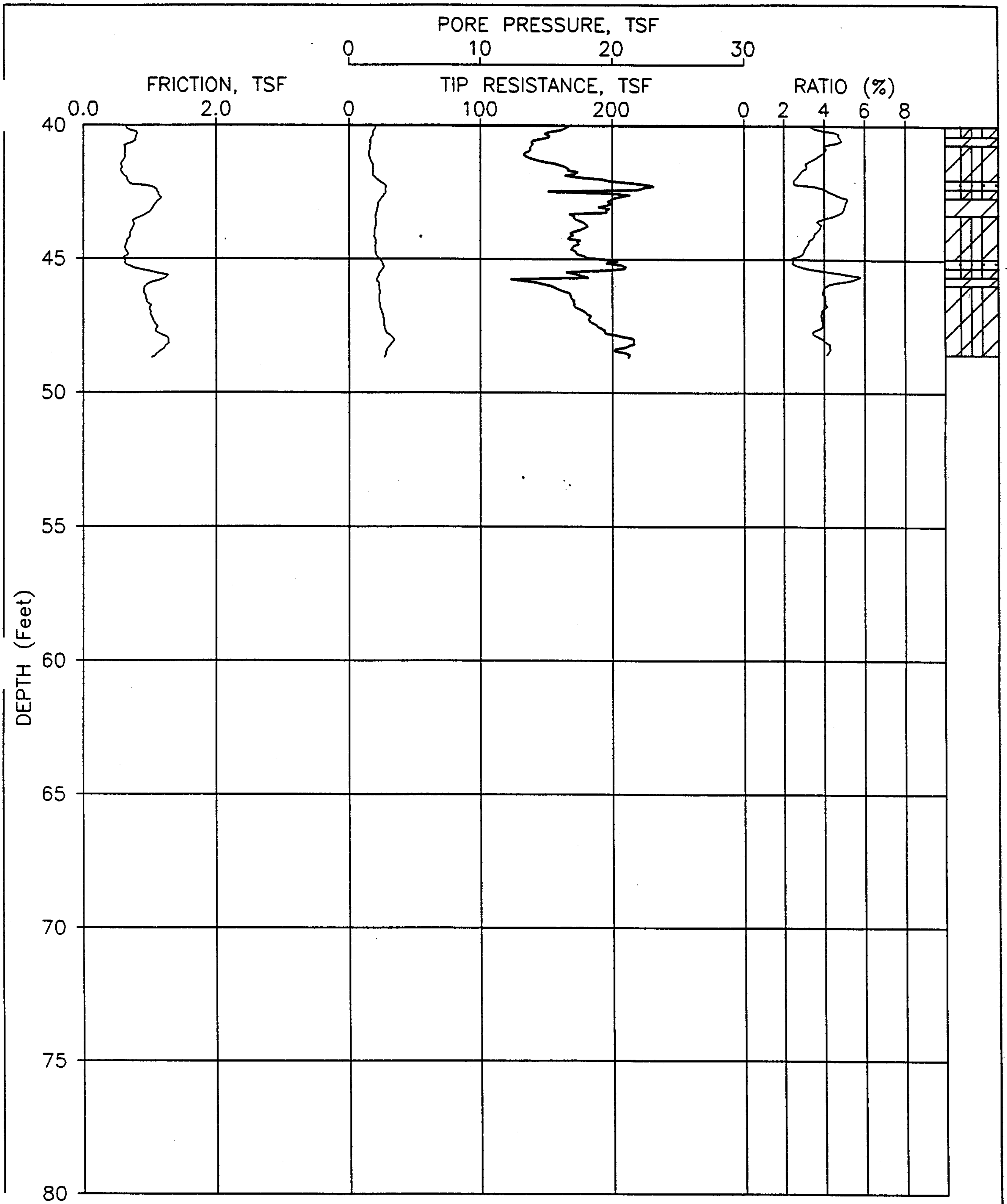

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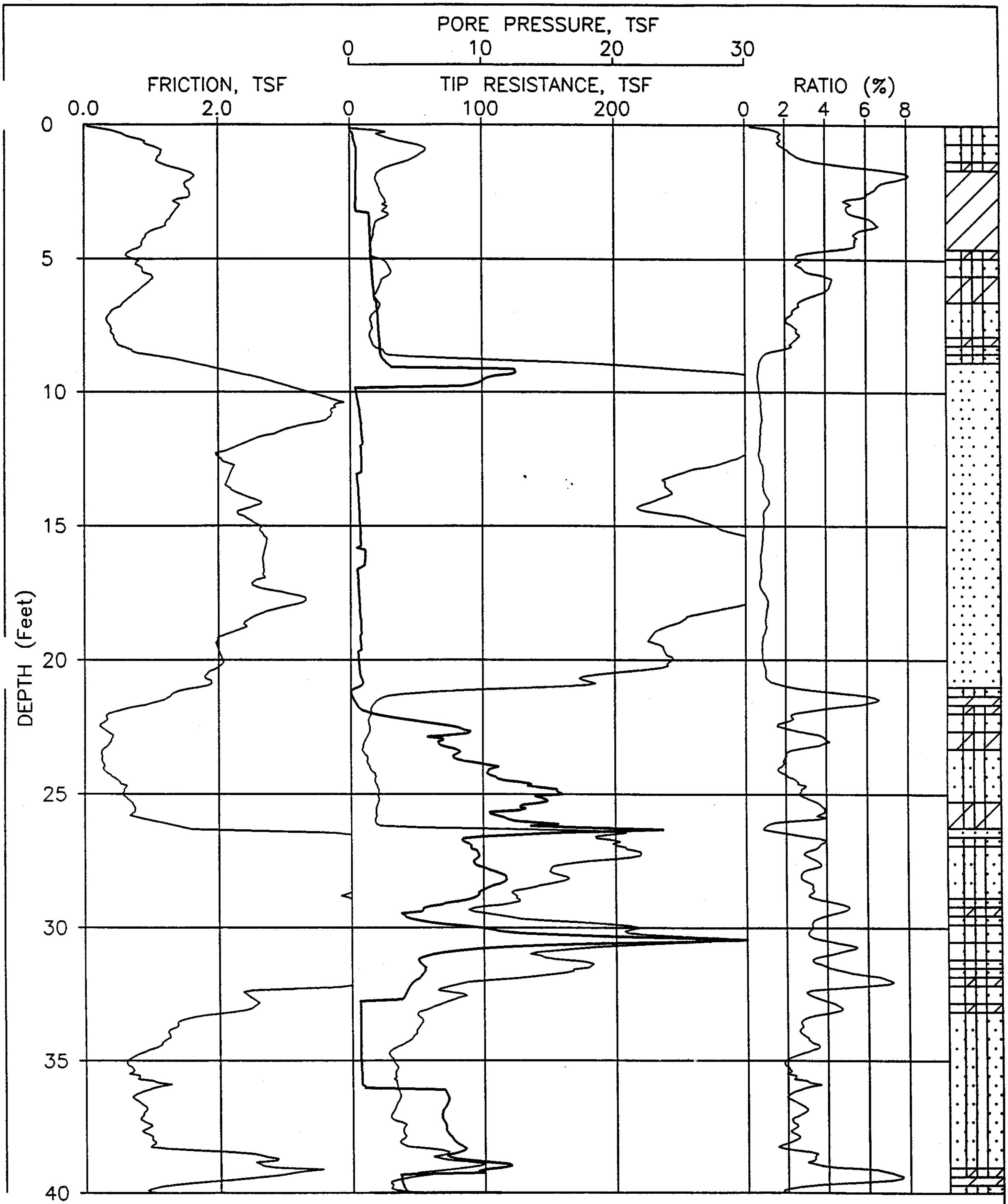

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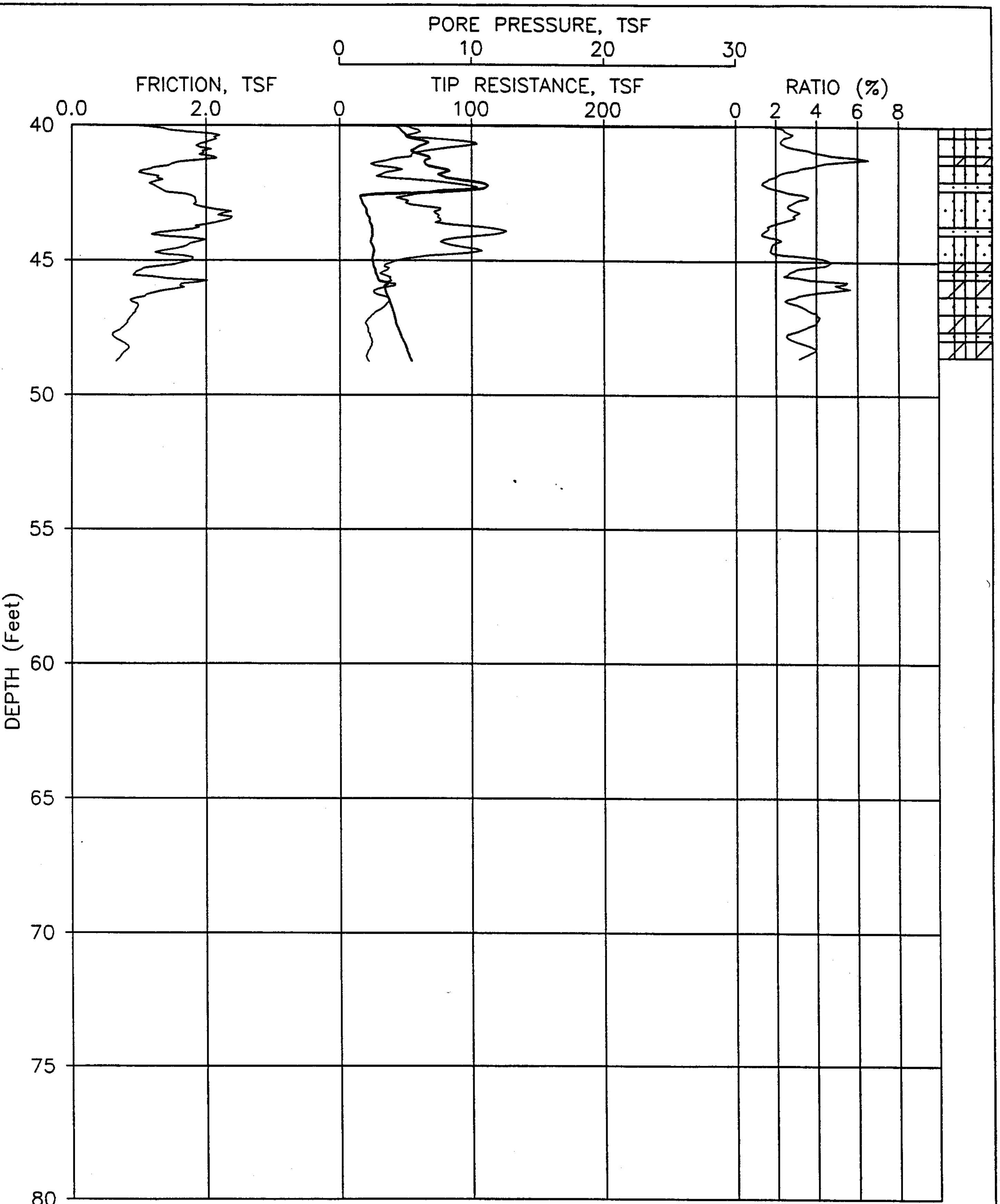

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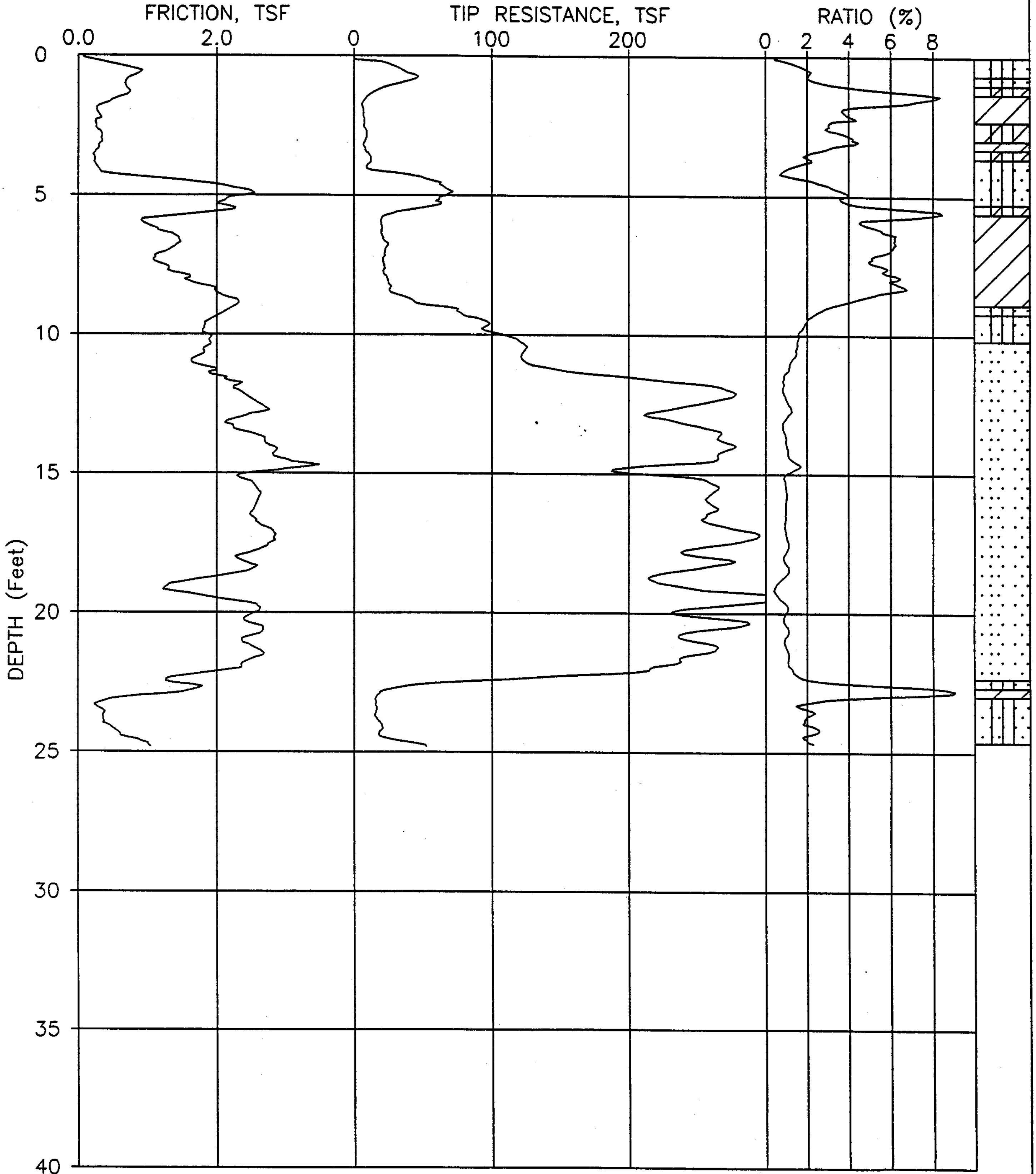

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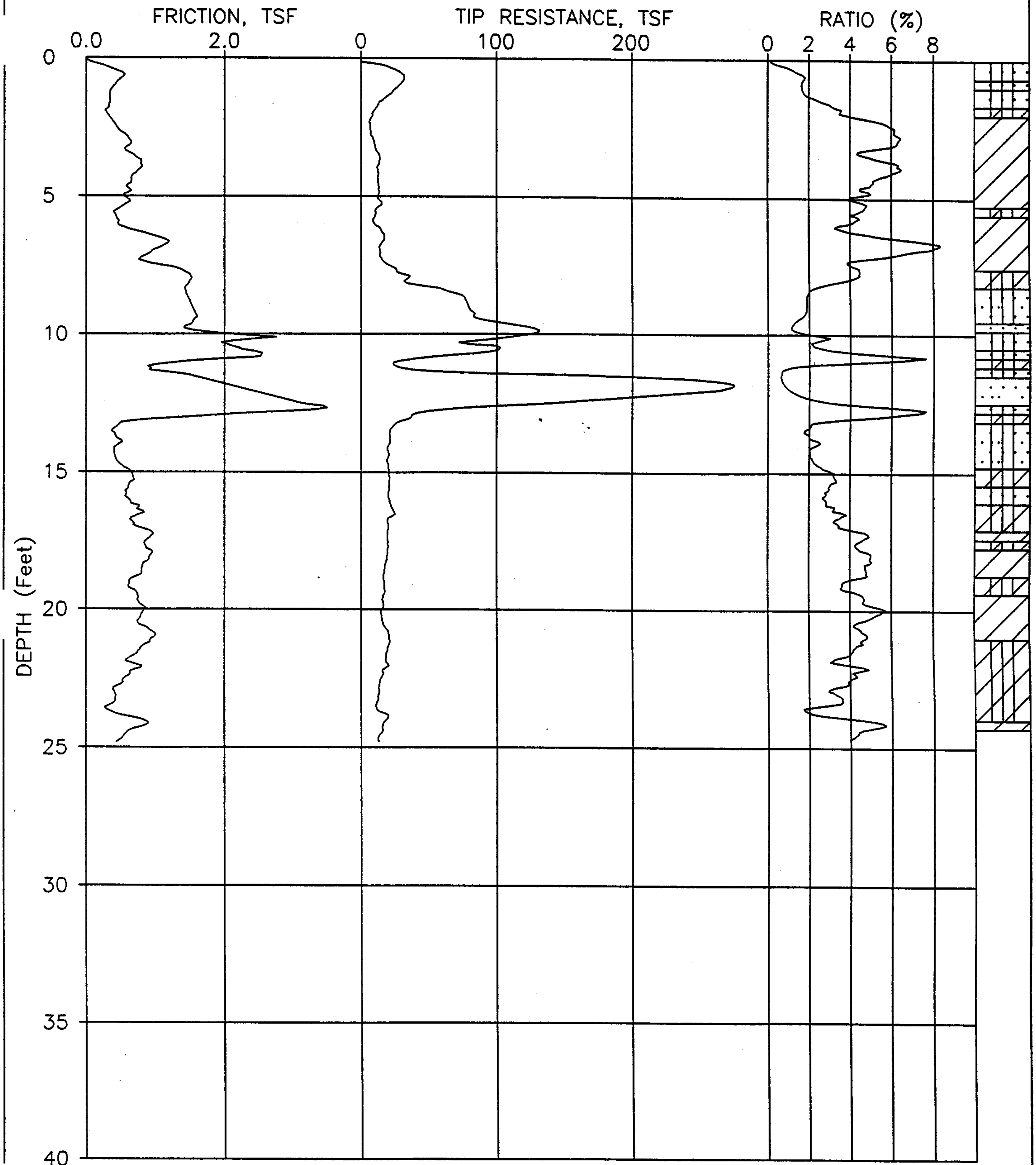

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DATE: 09-08-1994
PLATE: 1 OF 1

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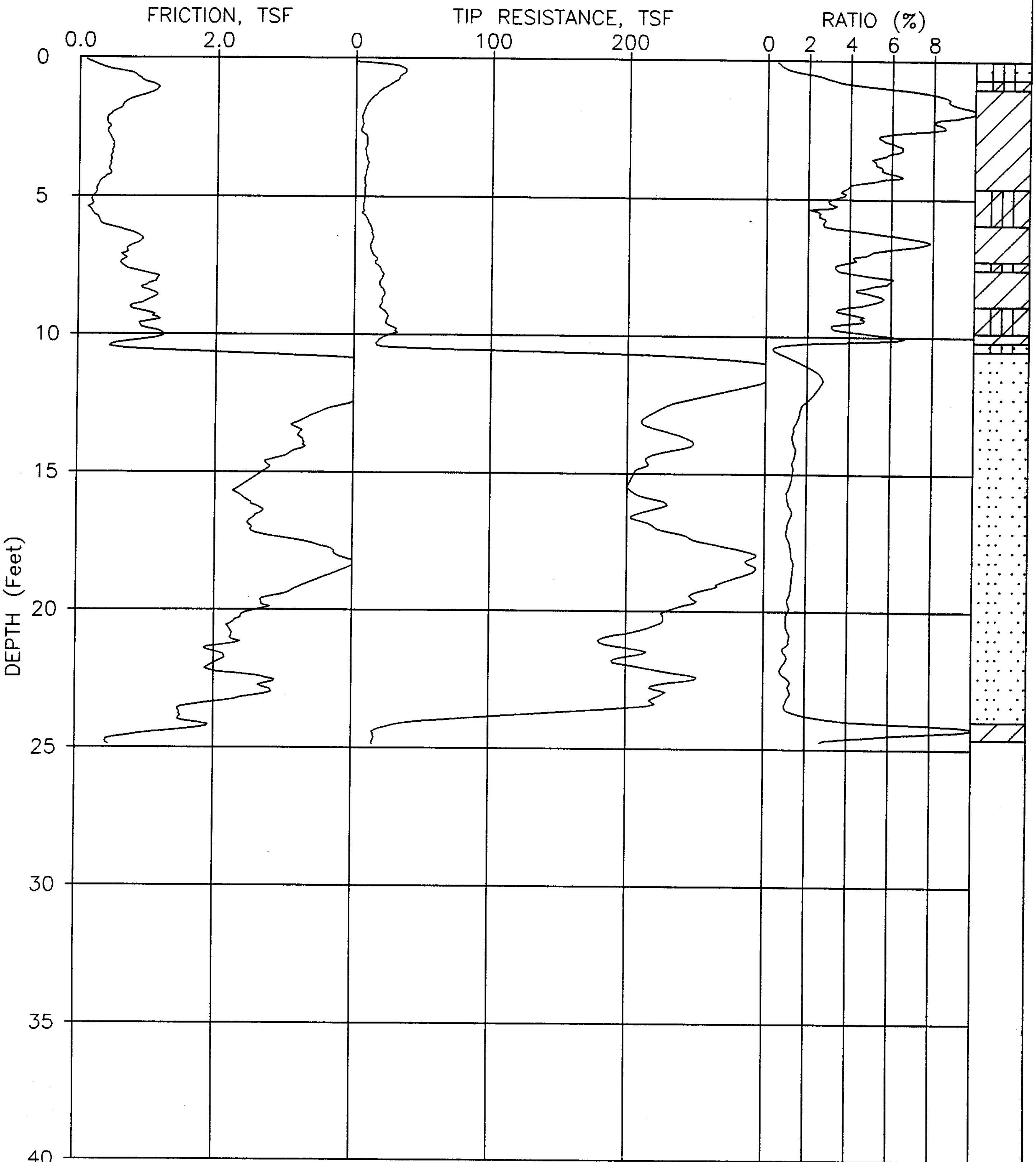

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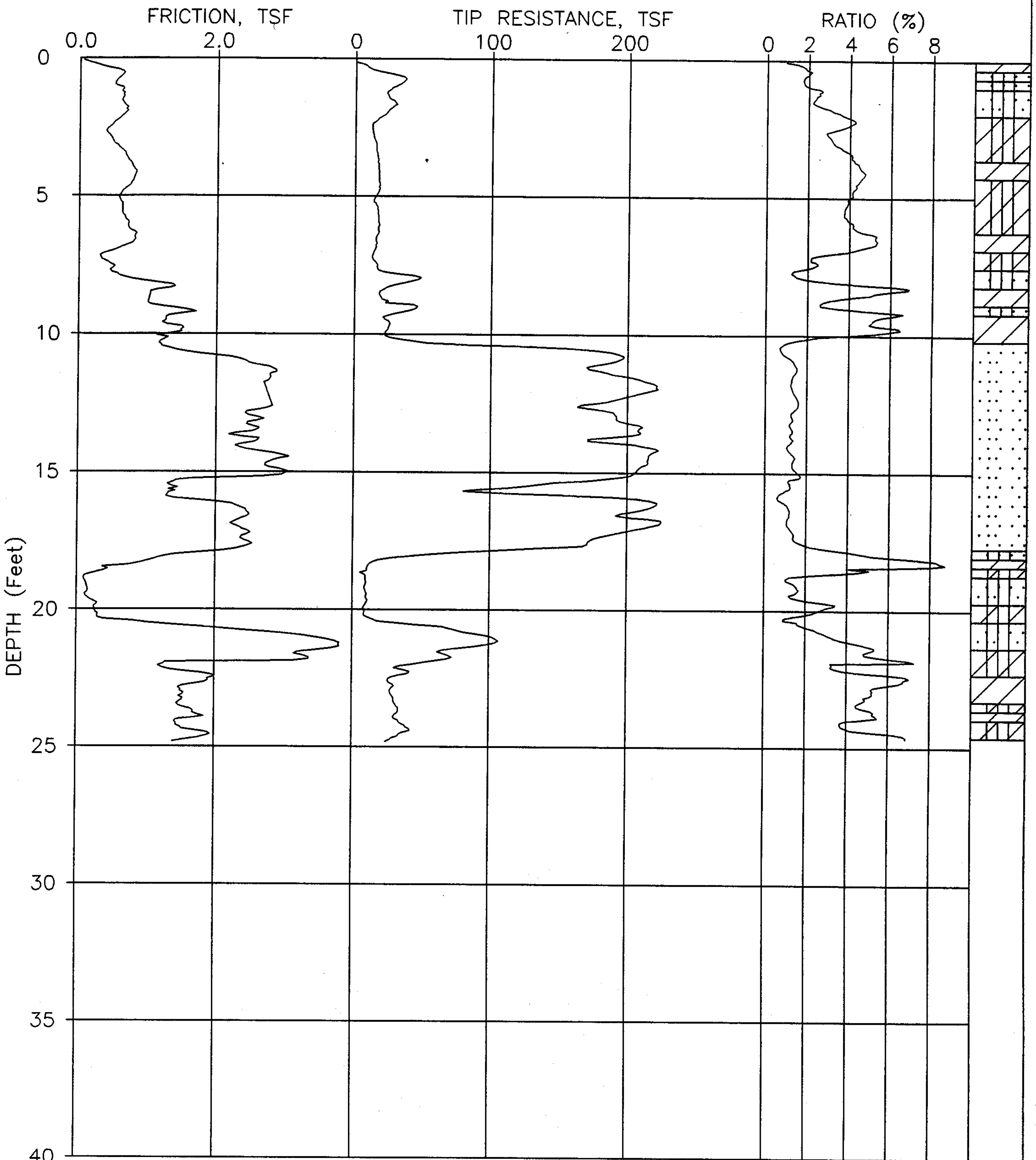

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PLATE: 1 OF 1

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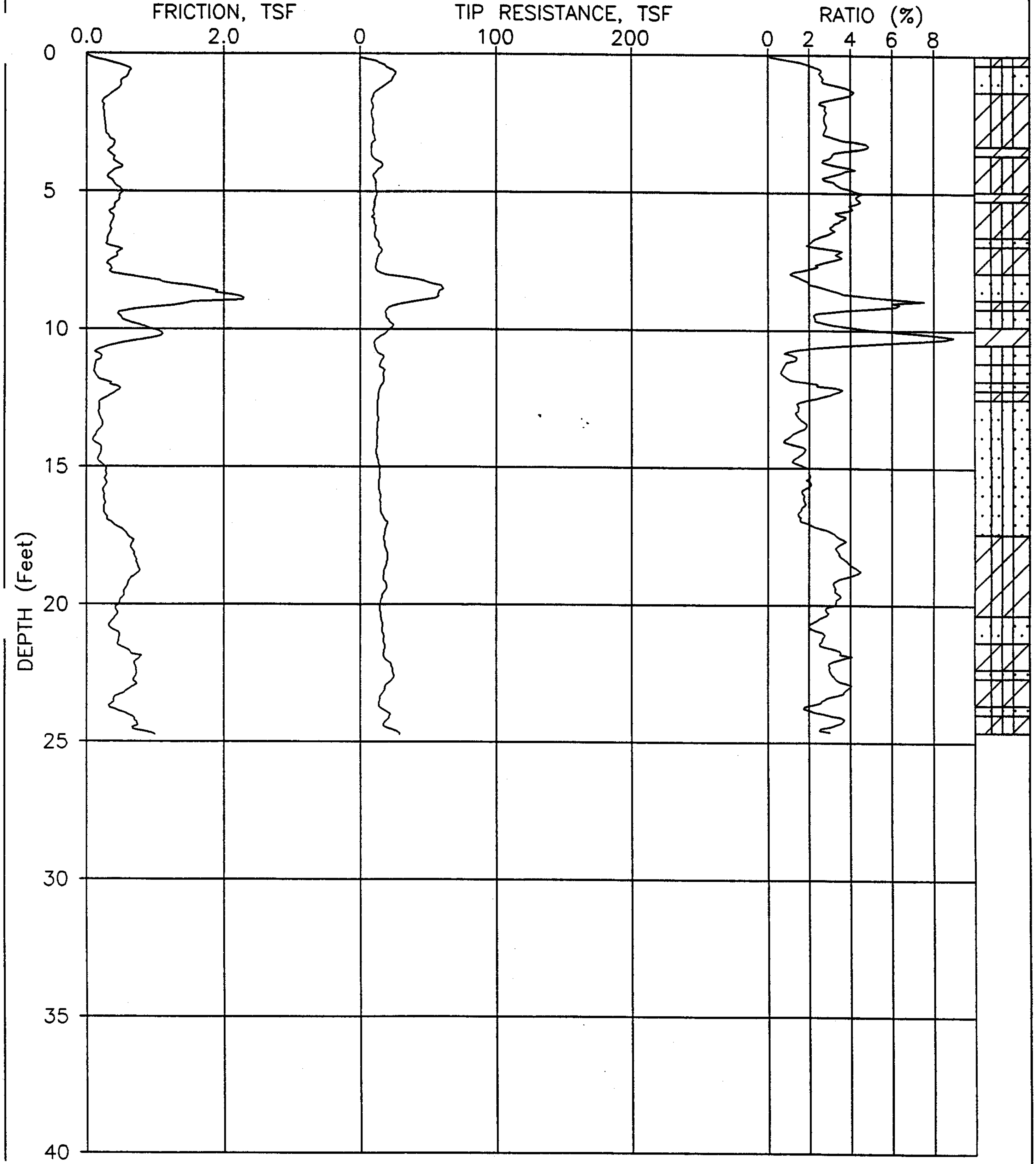

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DATE: 09-08-1994
PLATE: 1 OF 1

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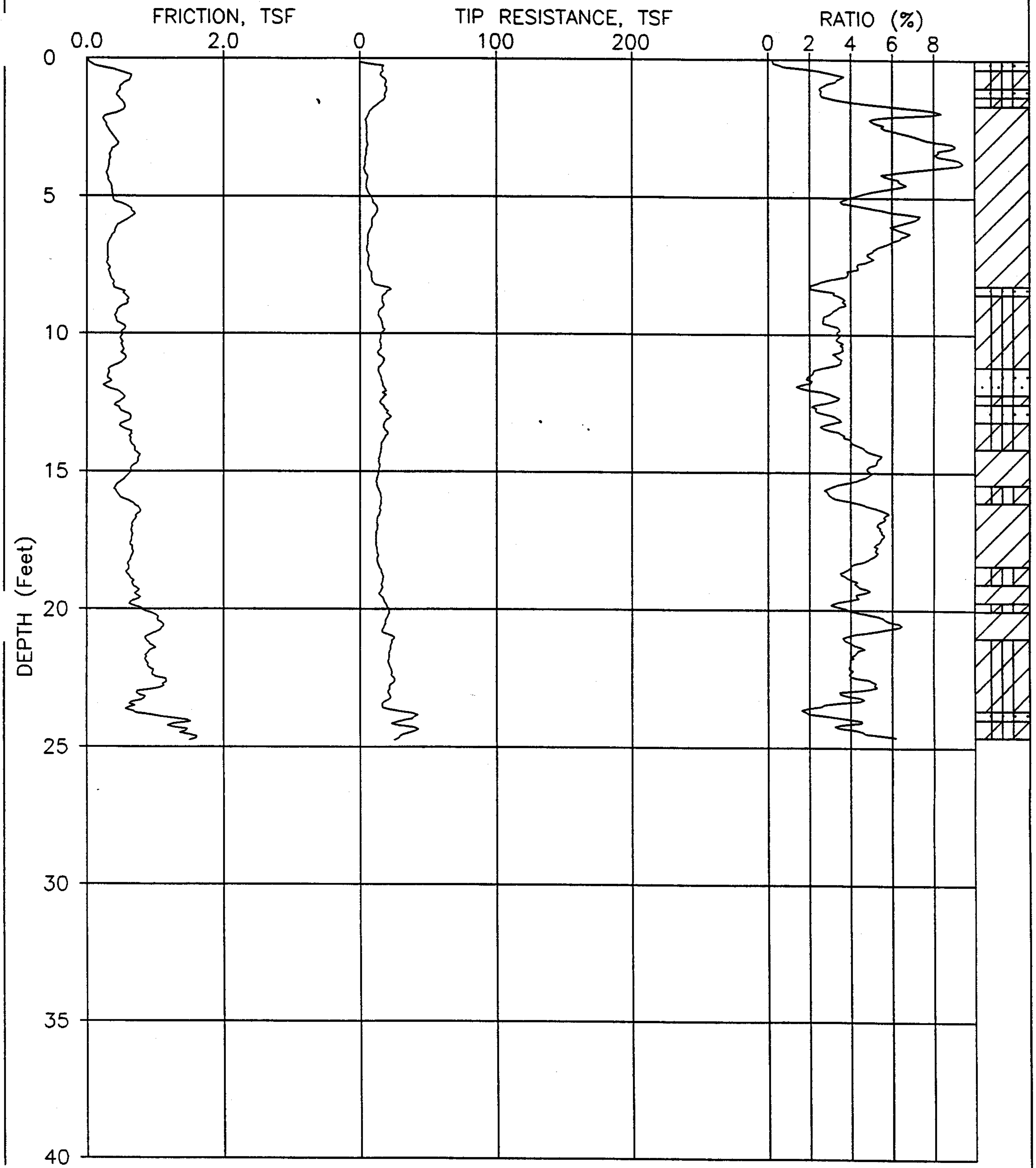

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DATE: 09-08-1994
PLATE: 1 OF 1

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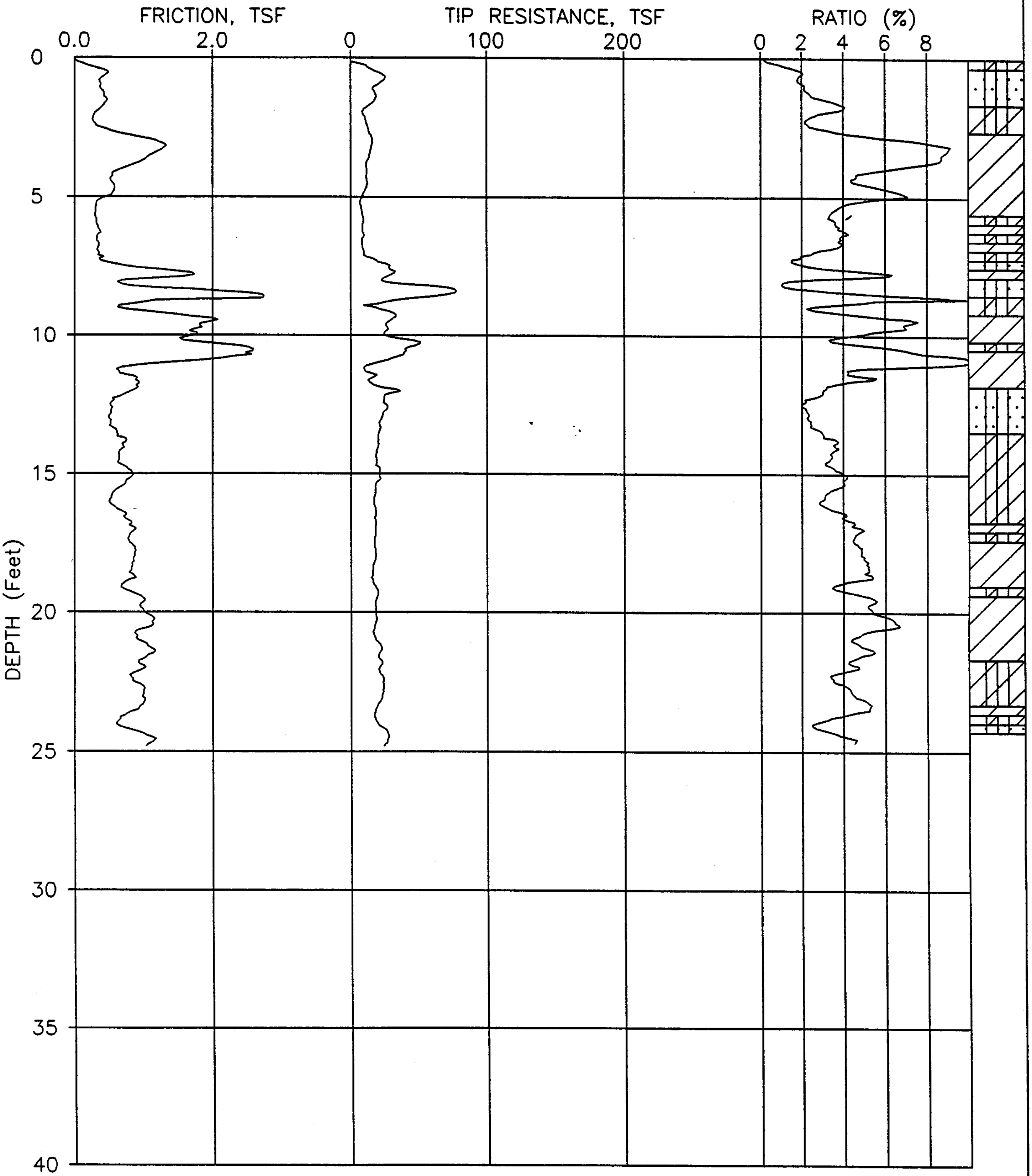

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PLATE: 1 OF 1

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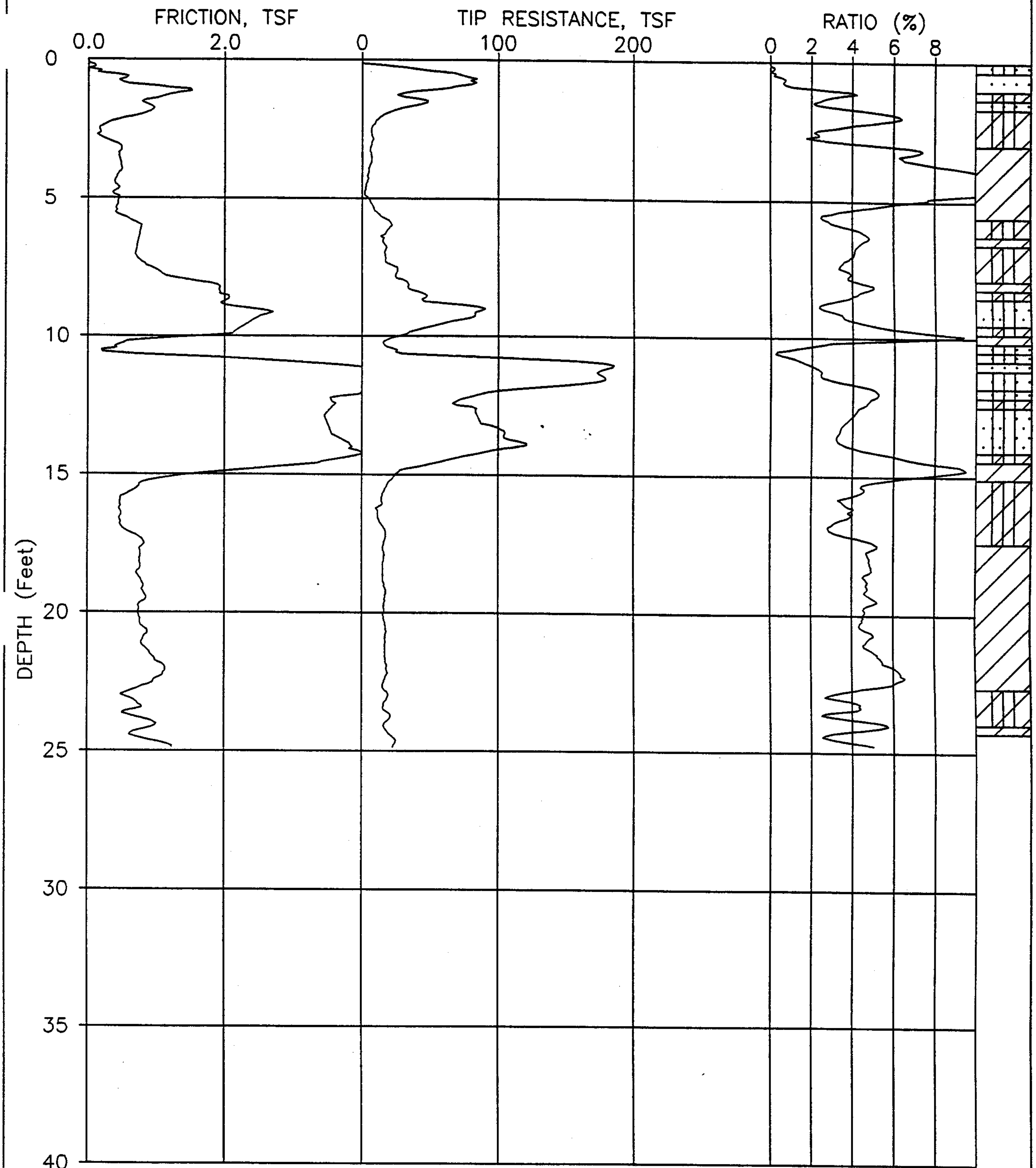

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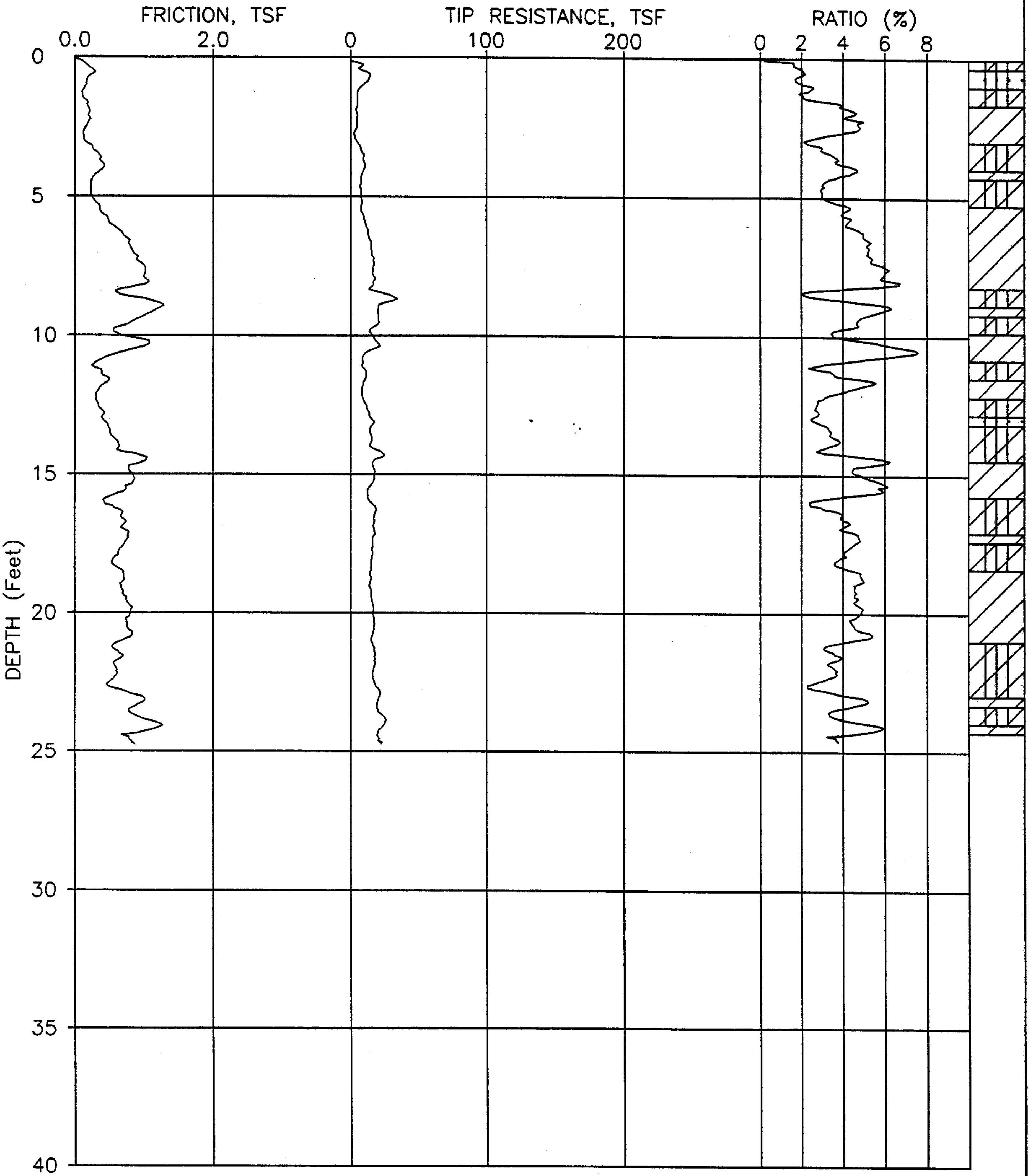

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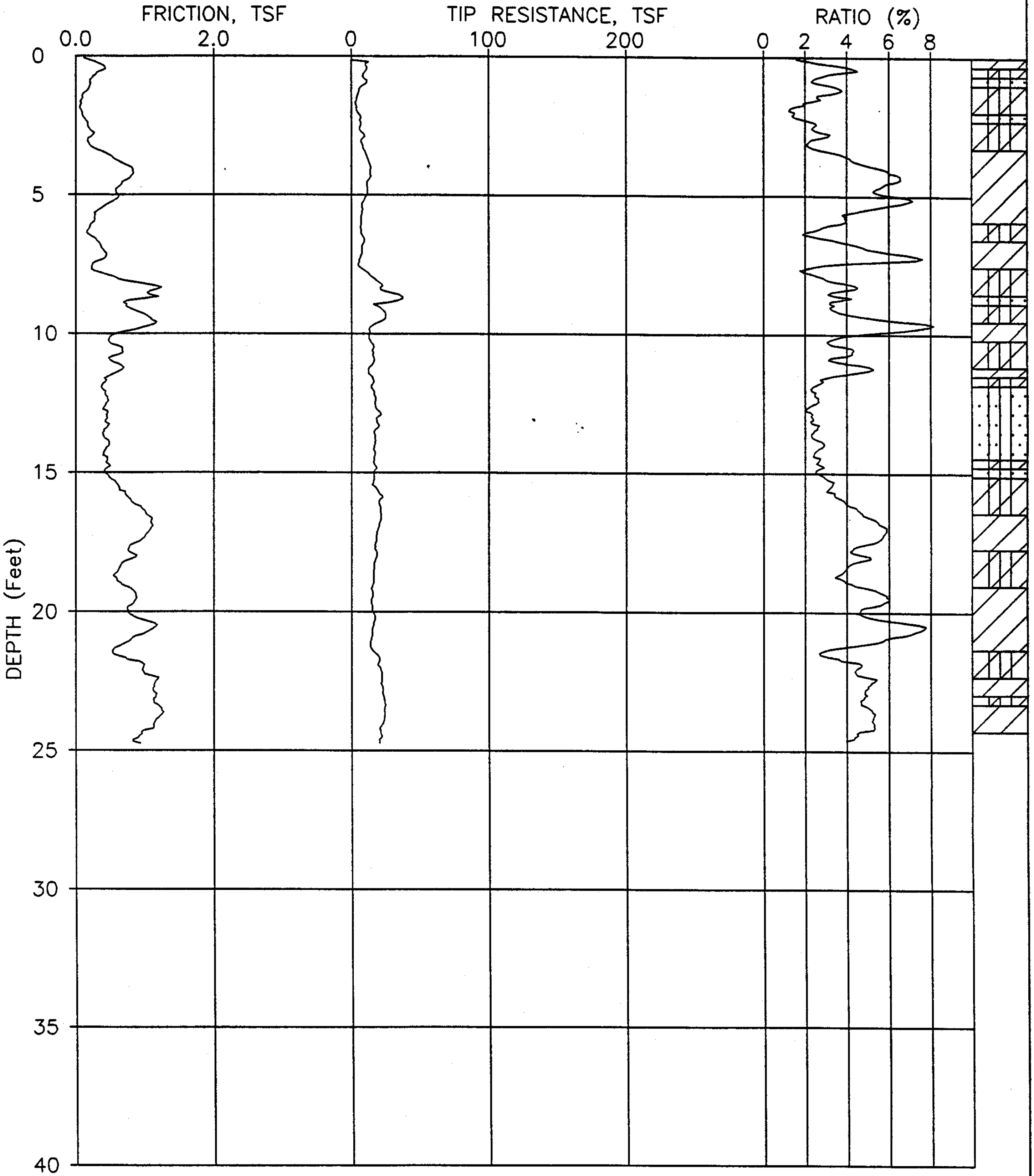

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PLATE: 1 OF 1

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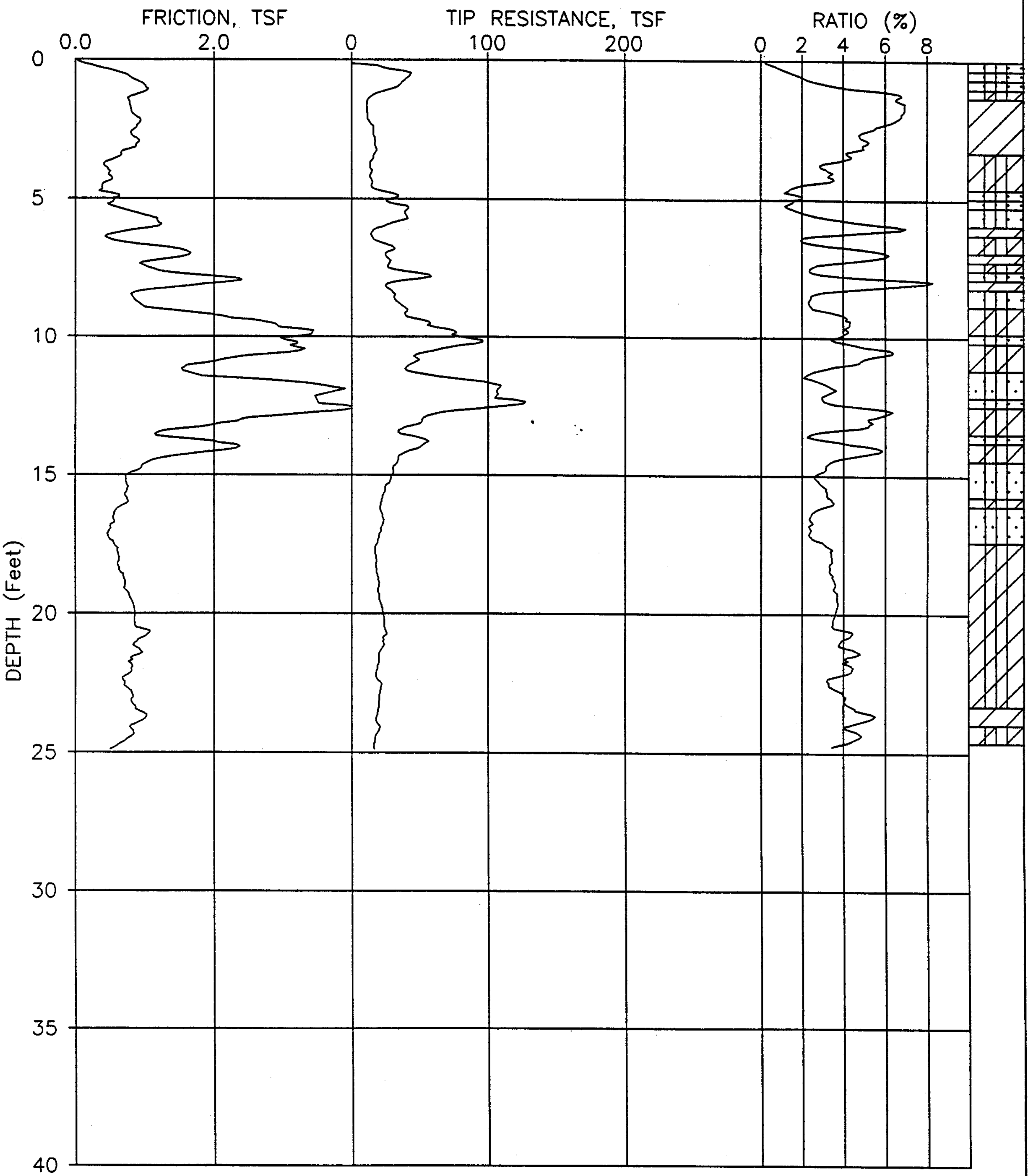

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PLATE: 1 OF 1

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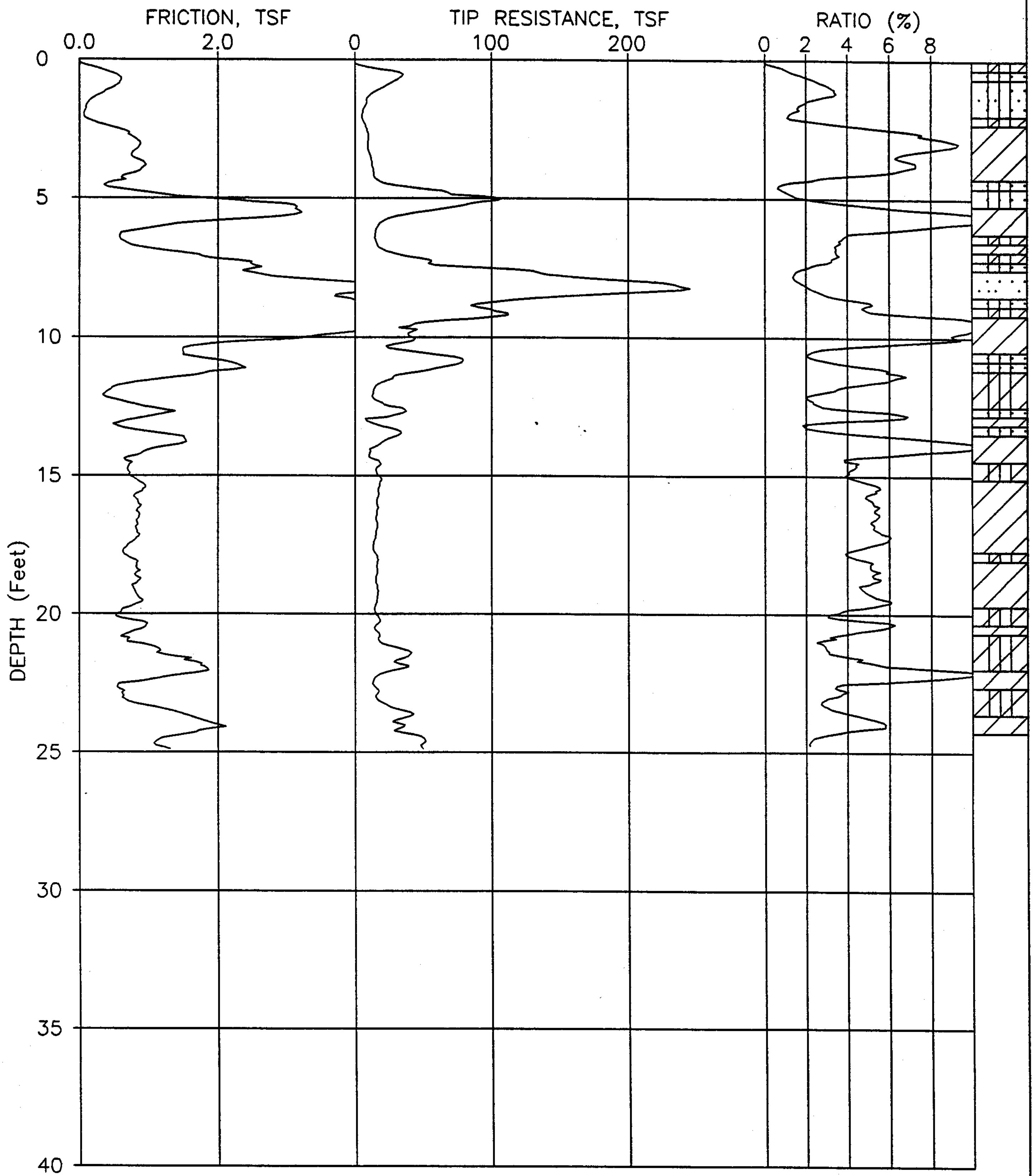

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PLATE: 1 OF 1

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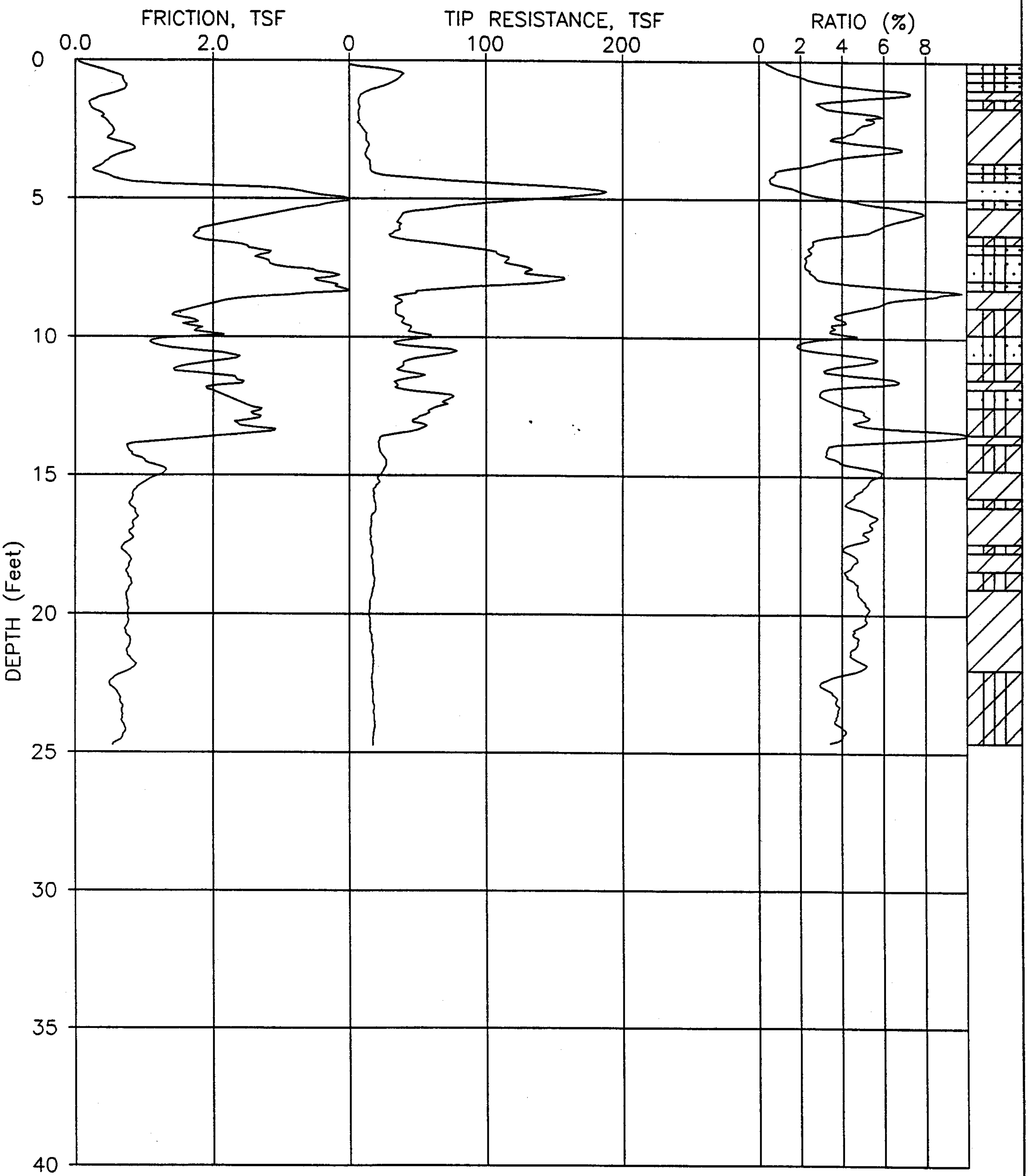

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PLATE: 1 OF 1

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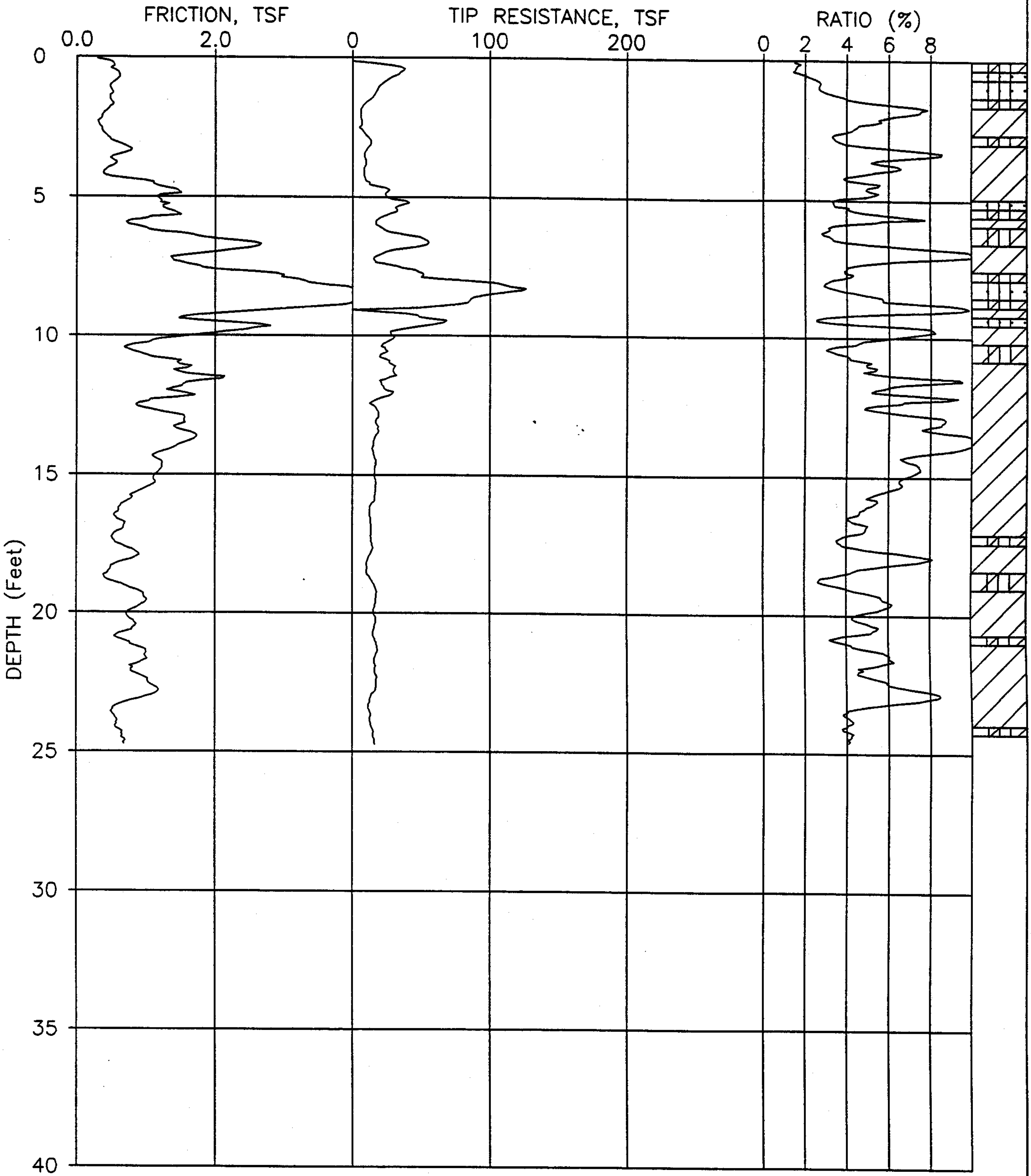

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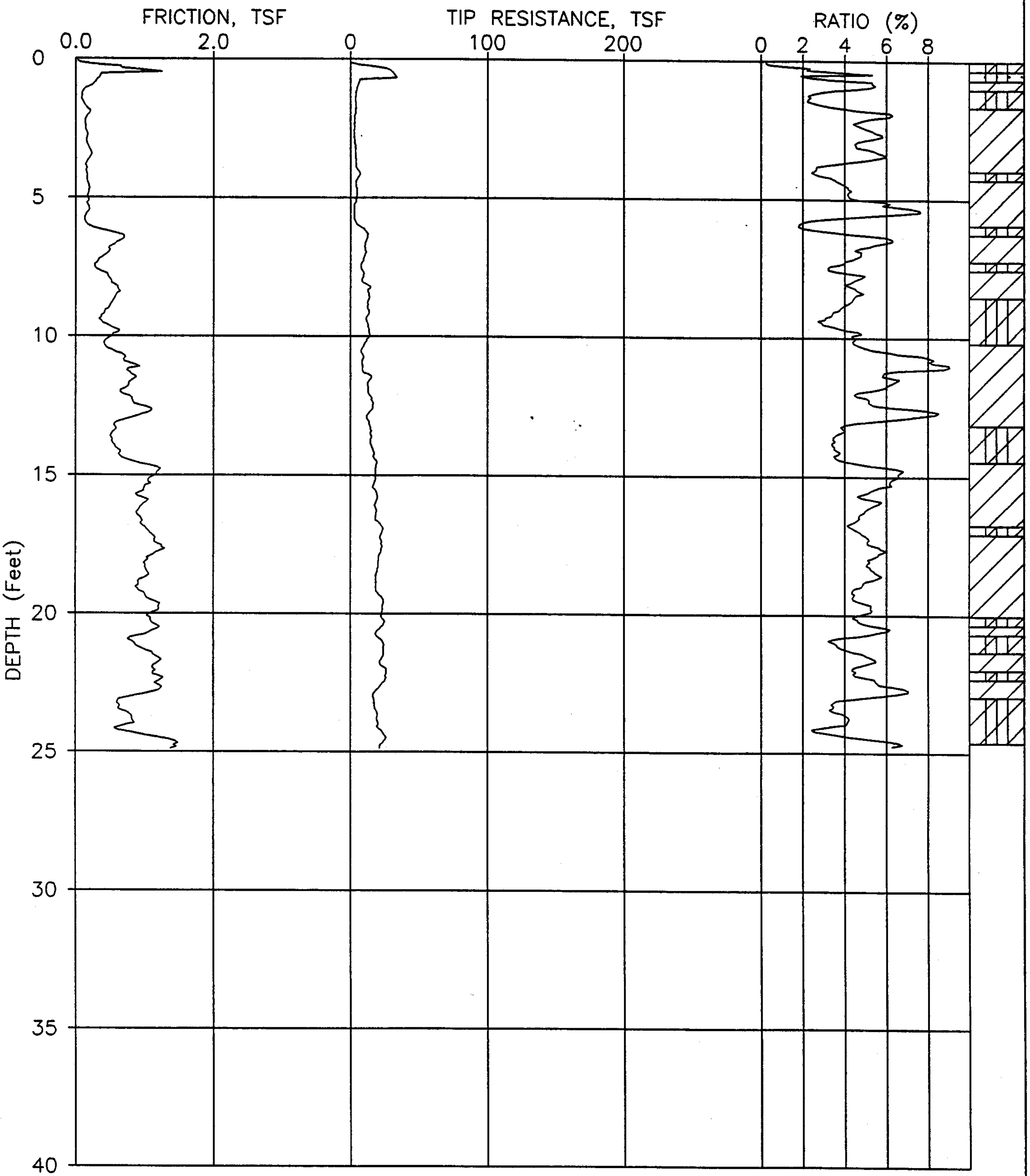

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DATE: 09-08-1994
PLATE: 1 OF 1

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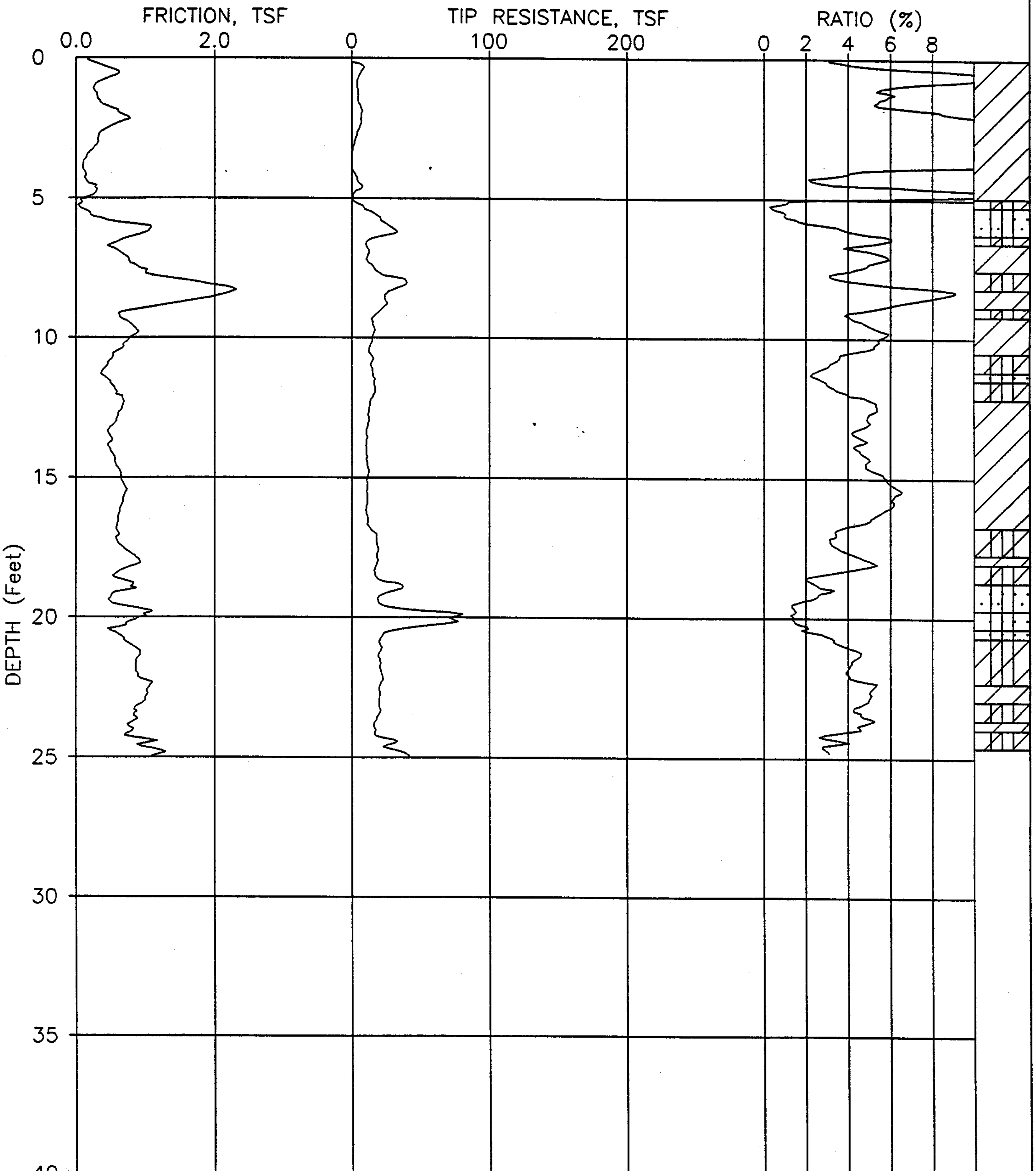

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DATE: 09-14-1994
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

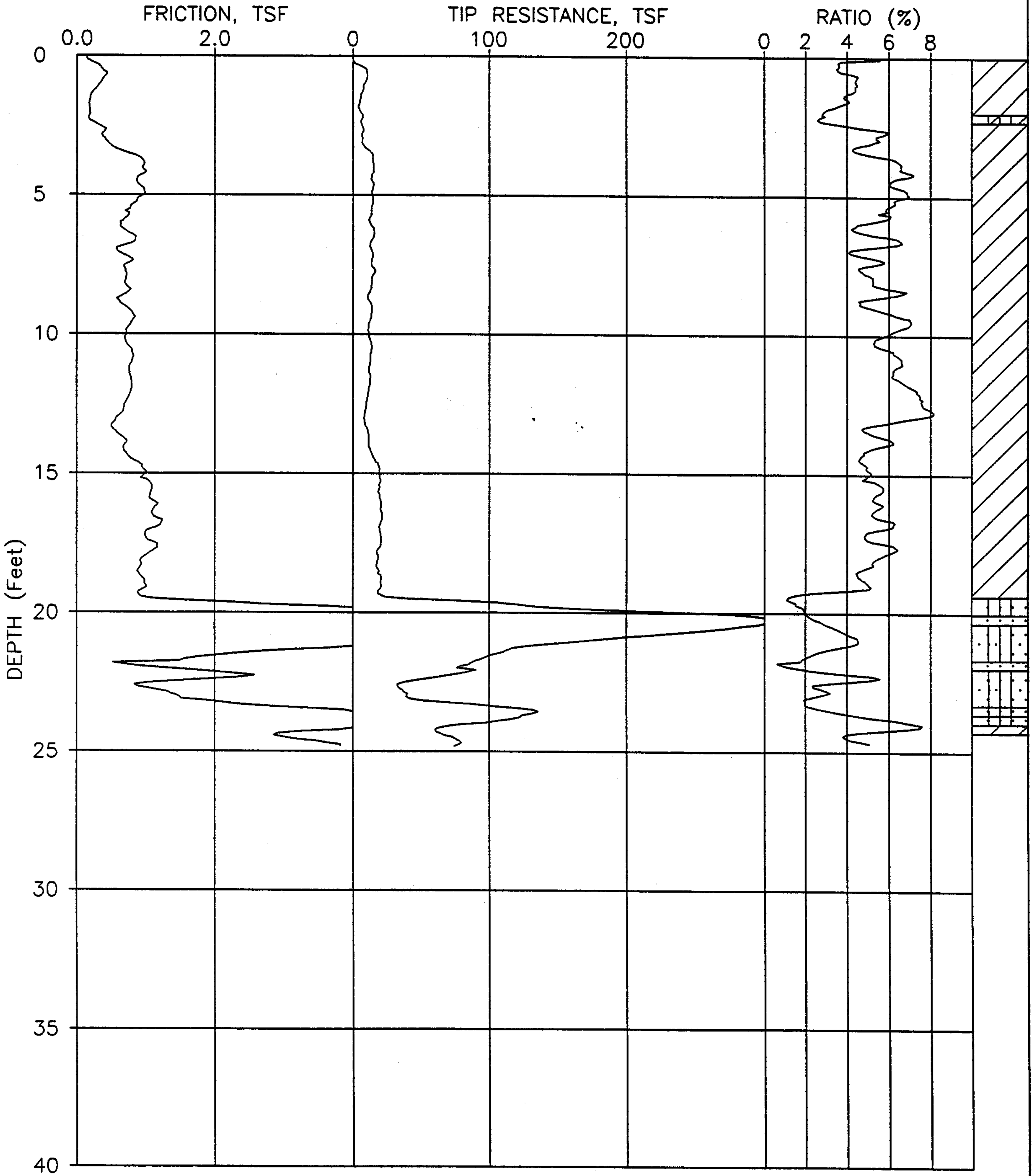

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PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

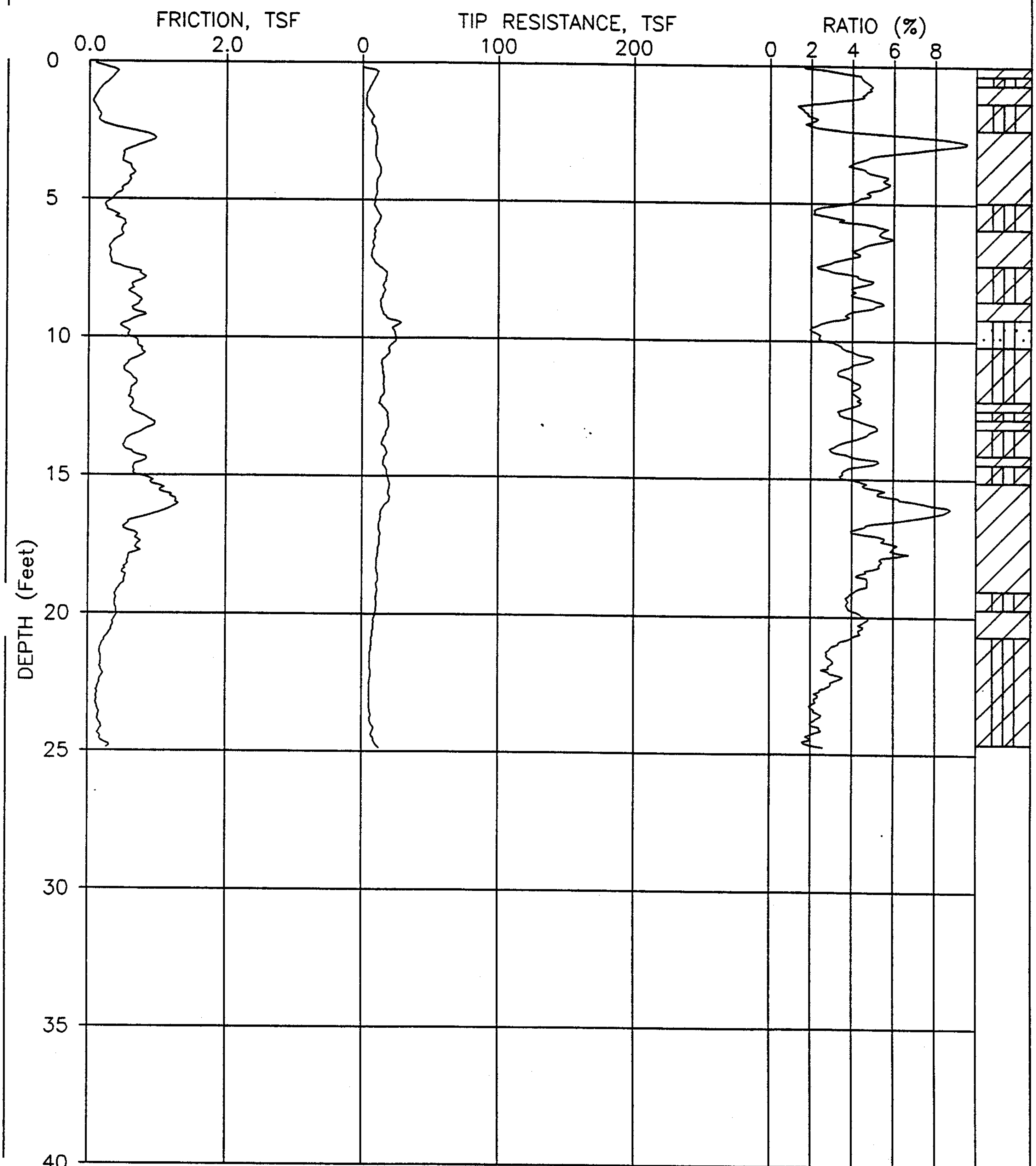

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PLATE: 1 OF 1

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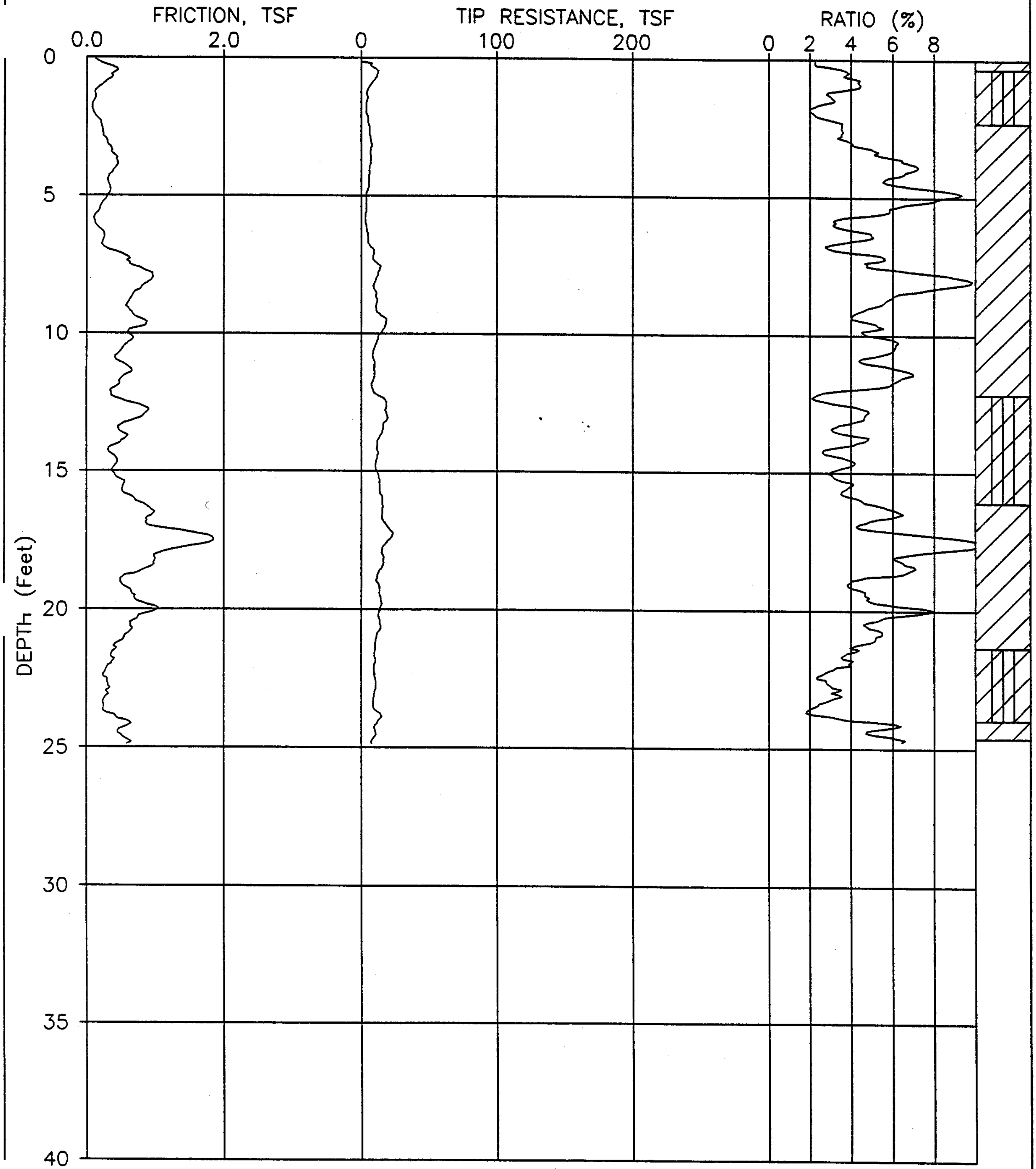

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PLATE: 1 OF 1

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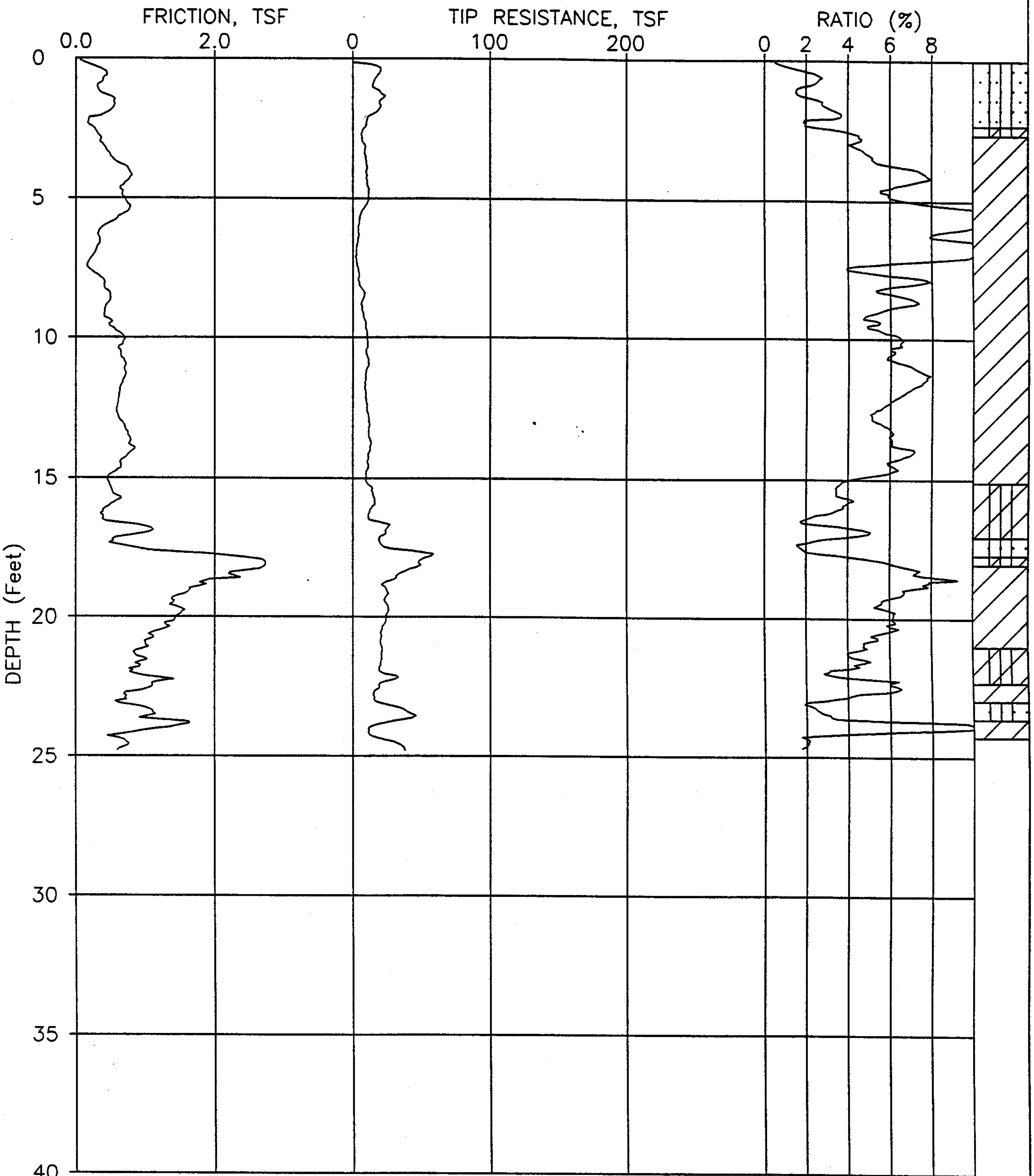

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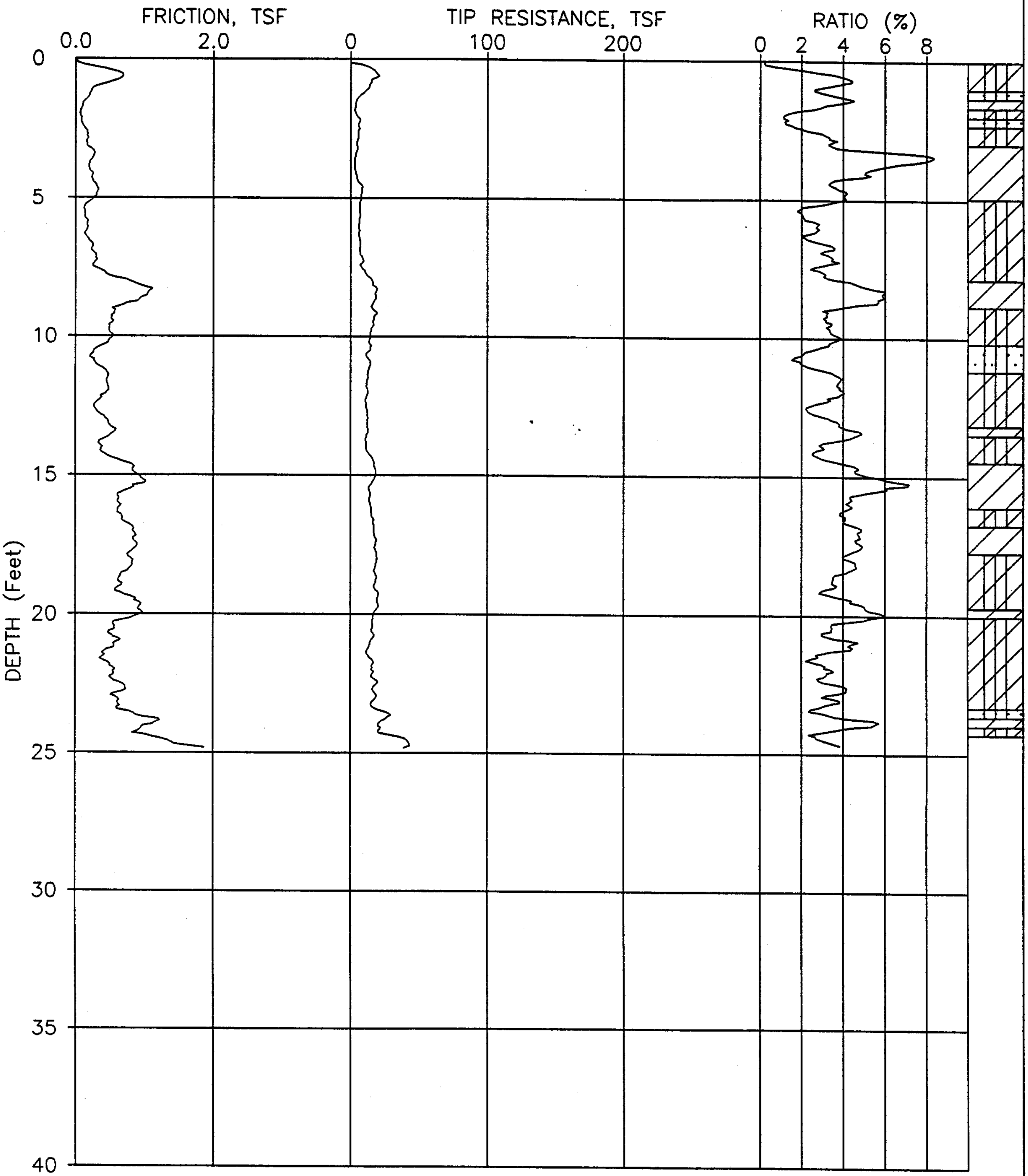

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DATE: 09–09–1994
PLATE: 1 OF 1

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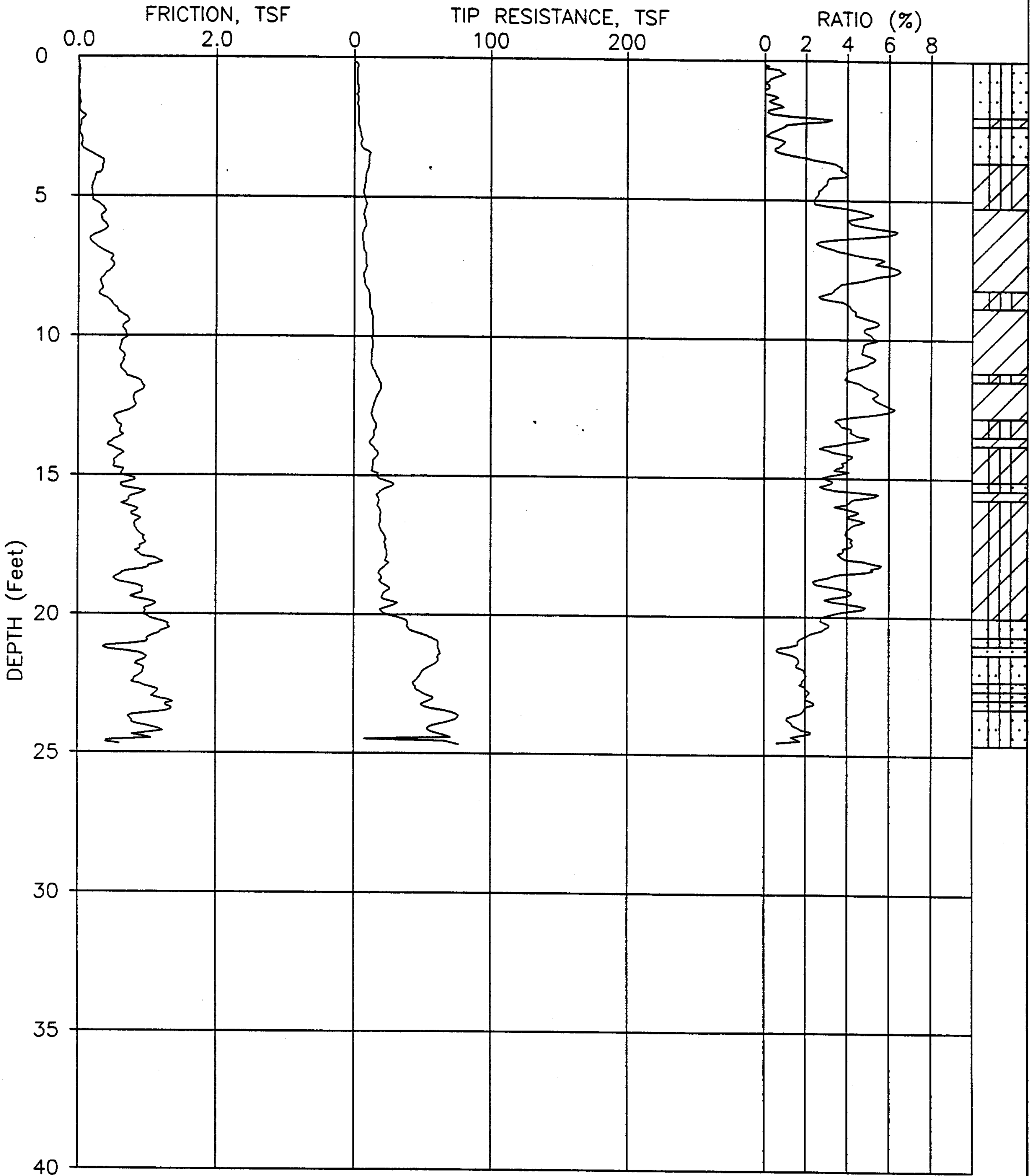

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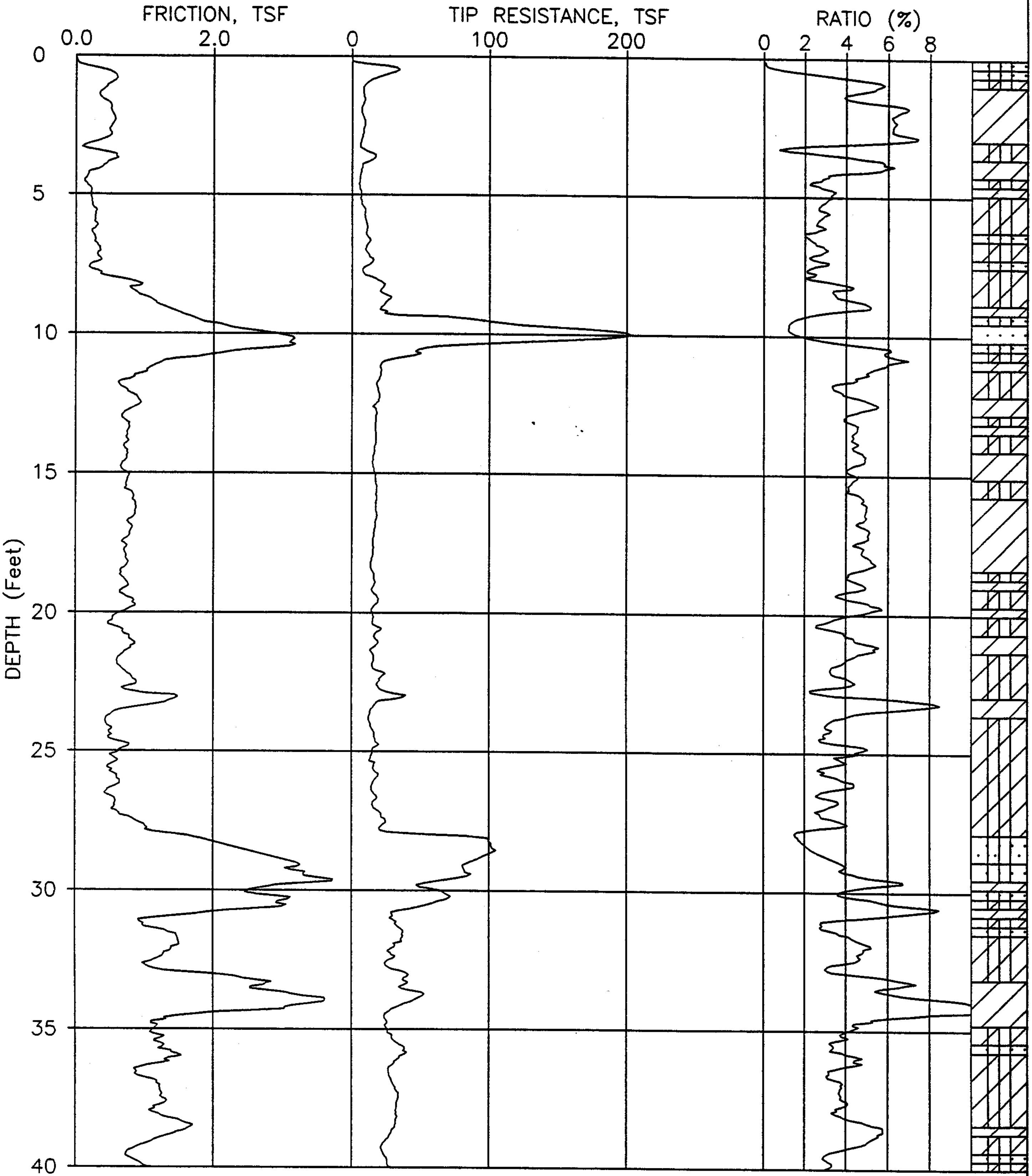

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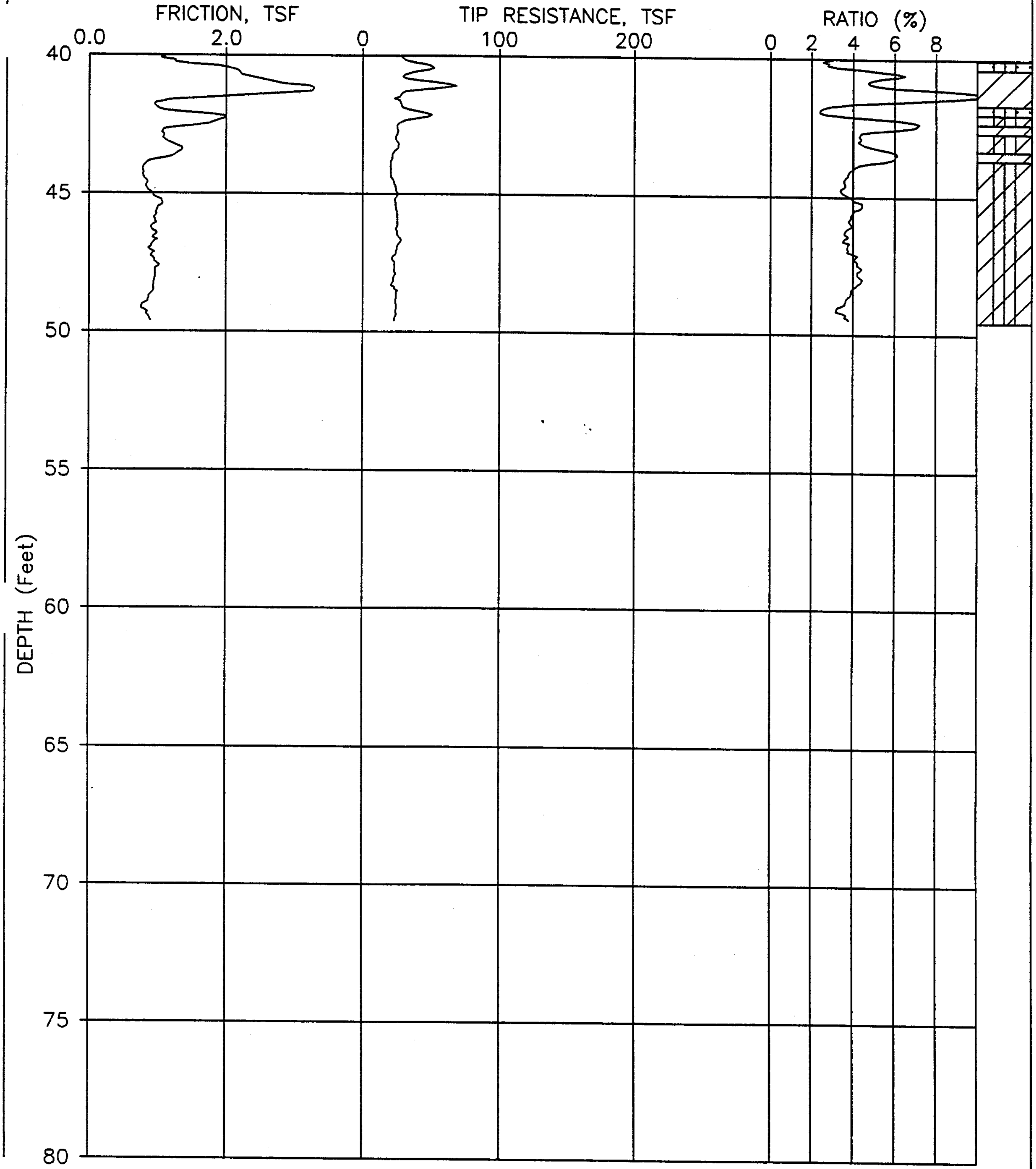

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PLATE: 2 OF 2

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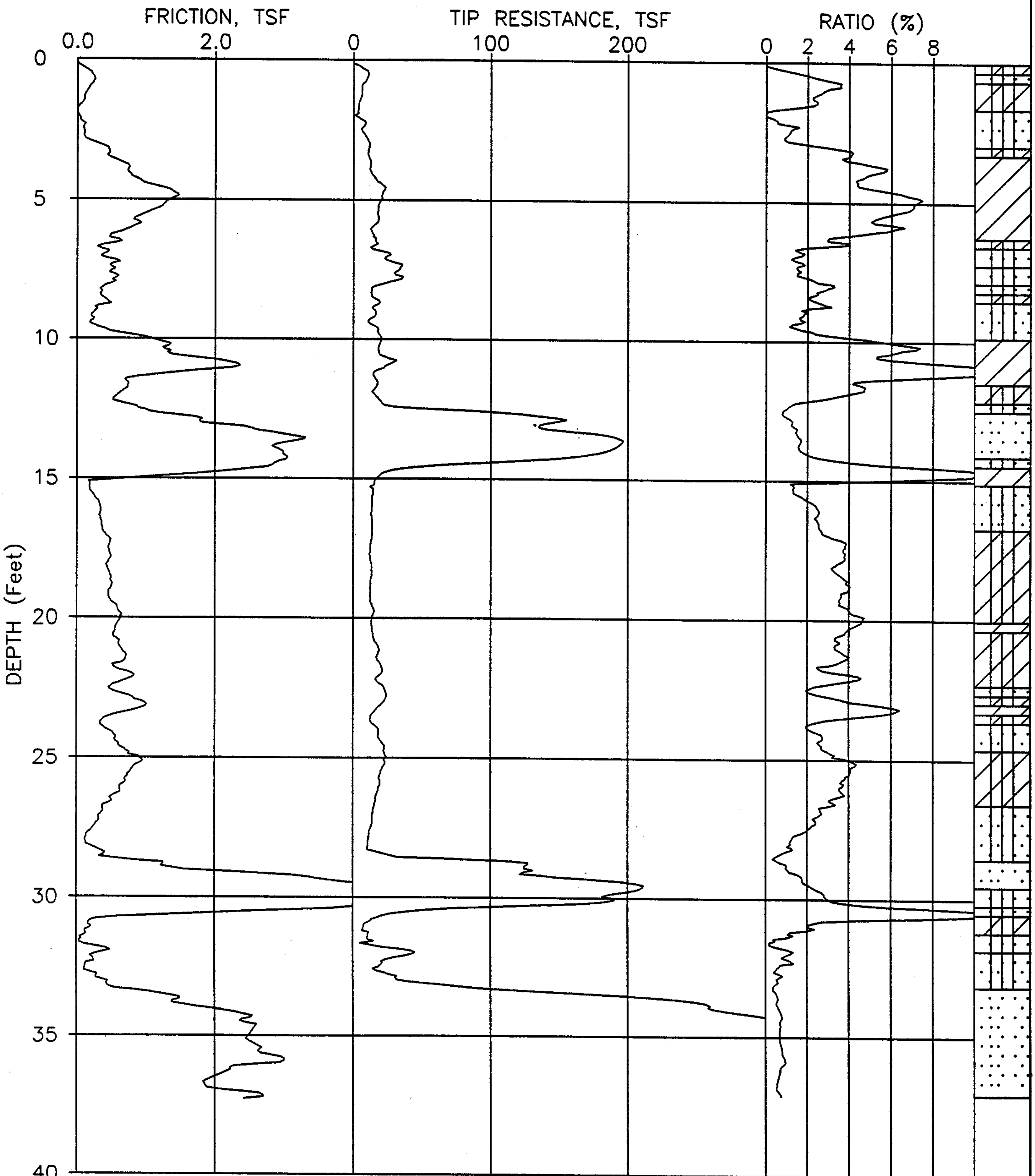

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PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

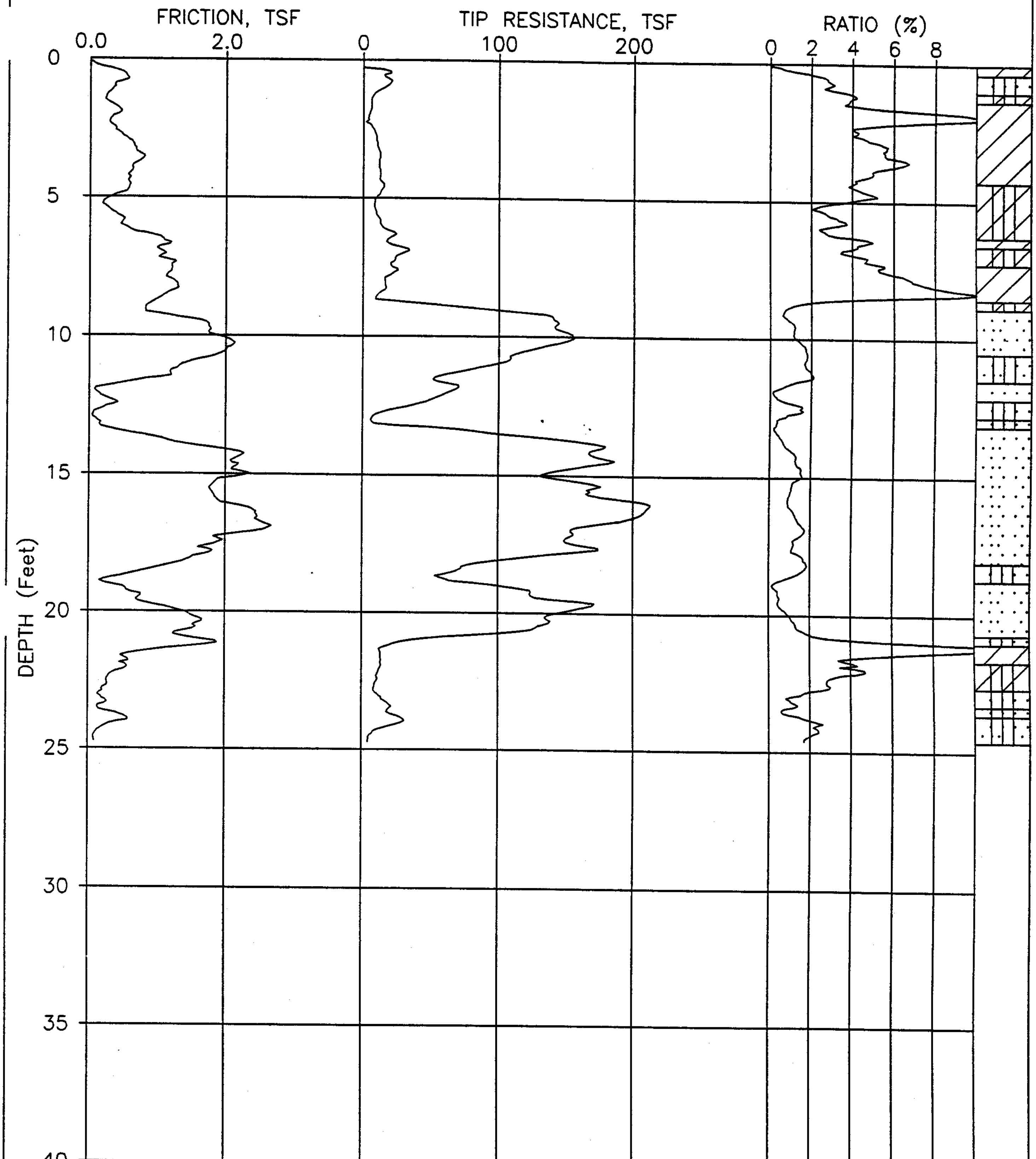

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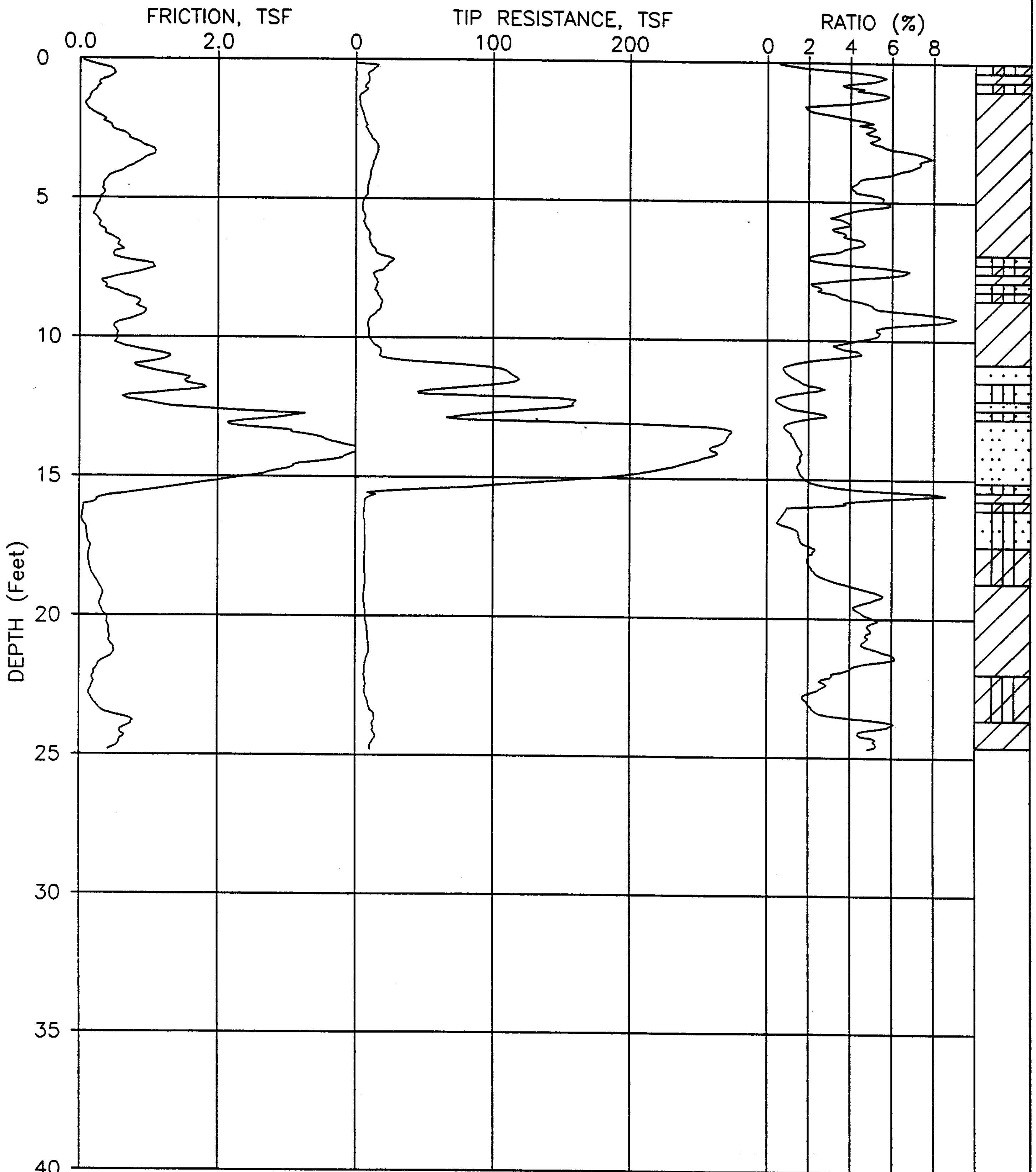
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



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FUGRO GEOSCIENCES,INC

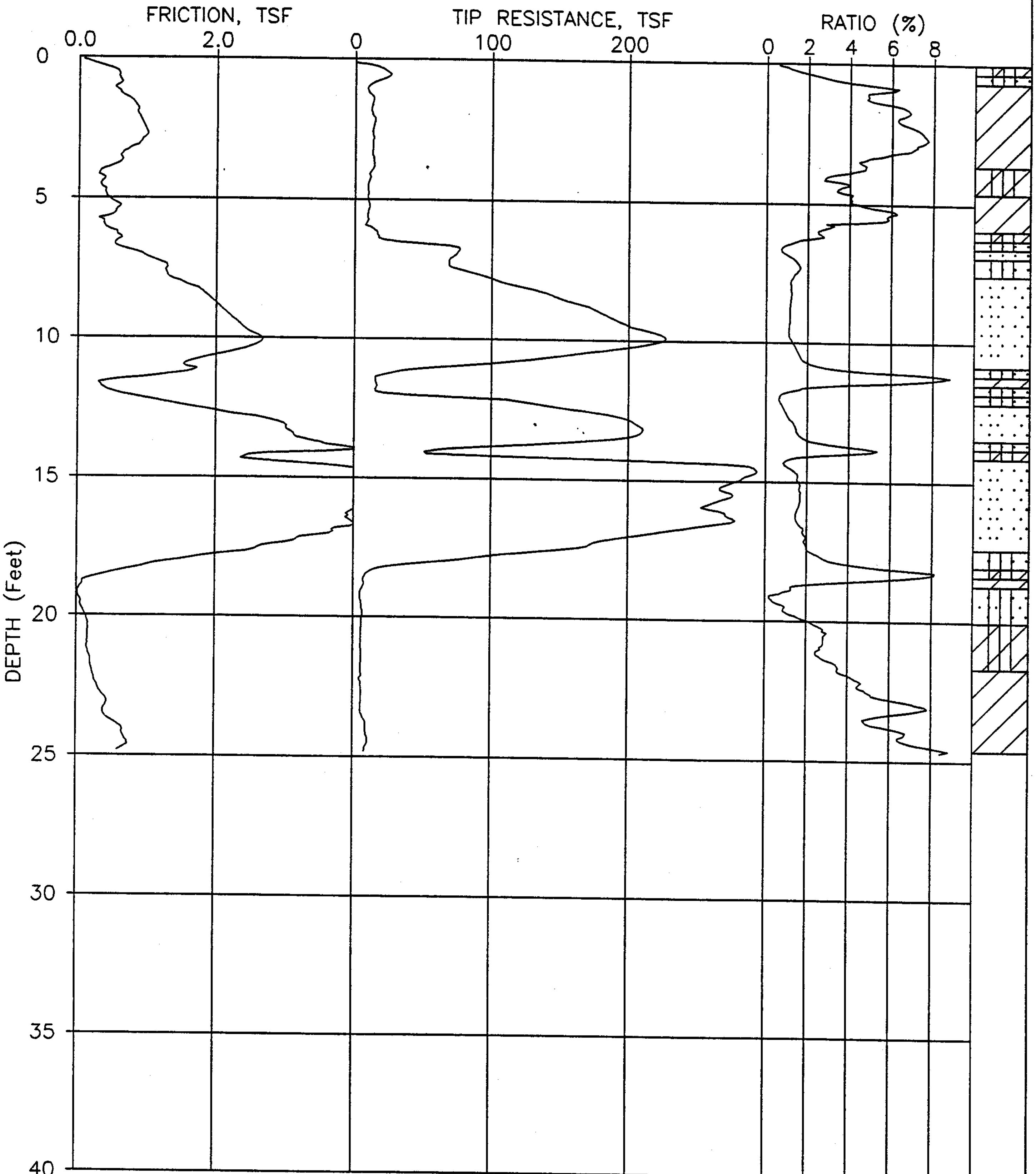

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PLATE: 1 OF 1

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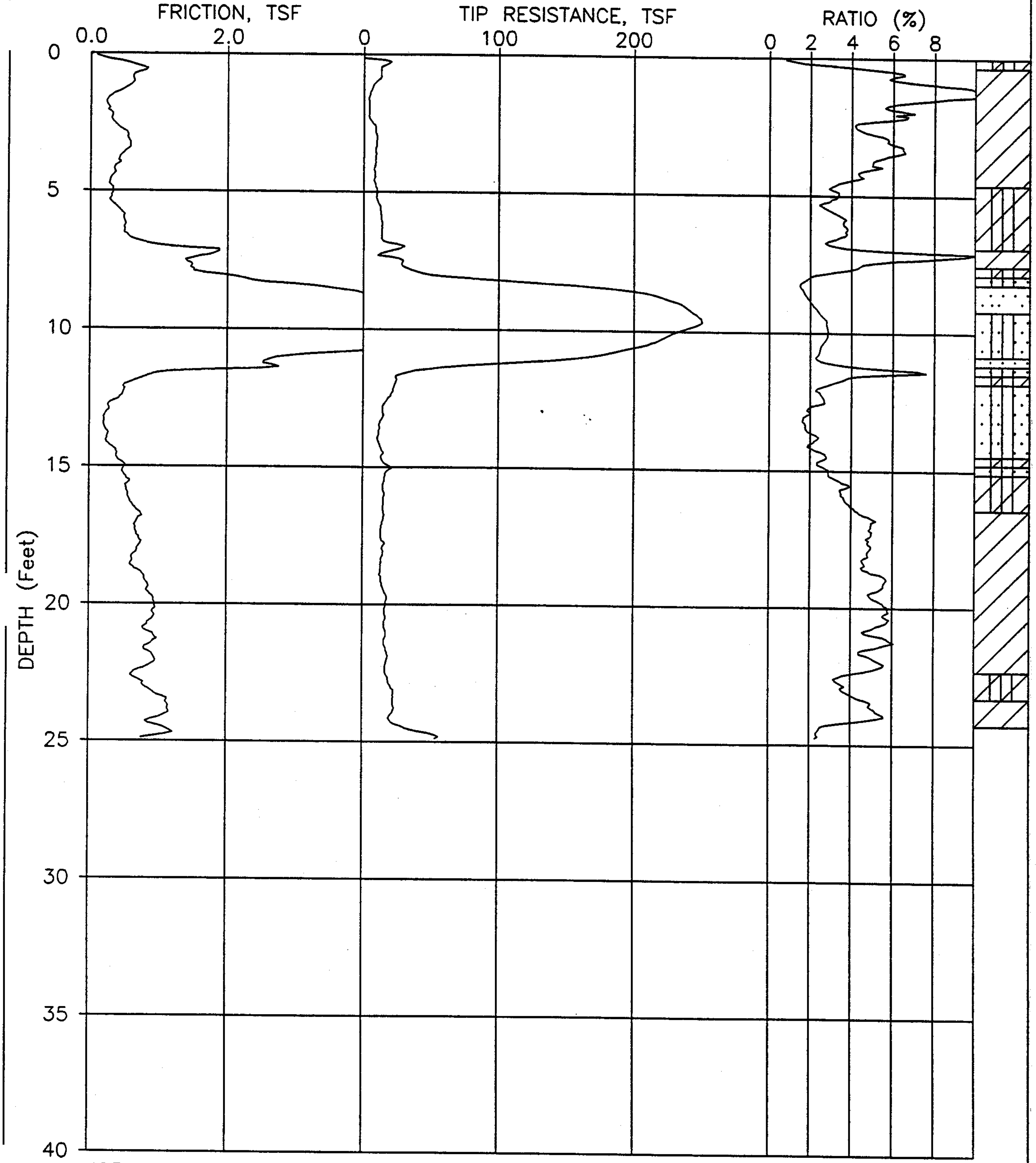

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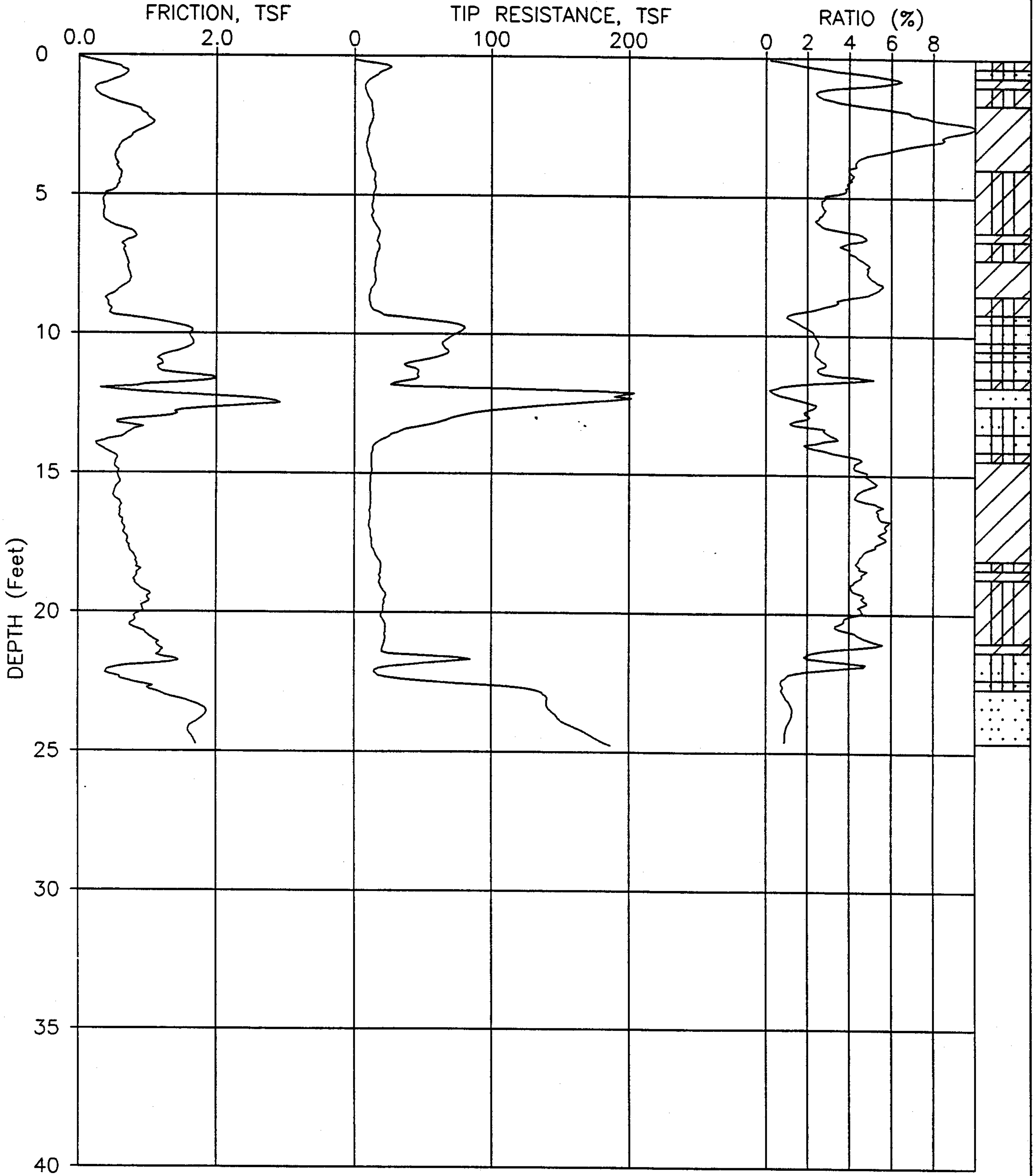
DATE: 09–09–1994
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



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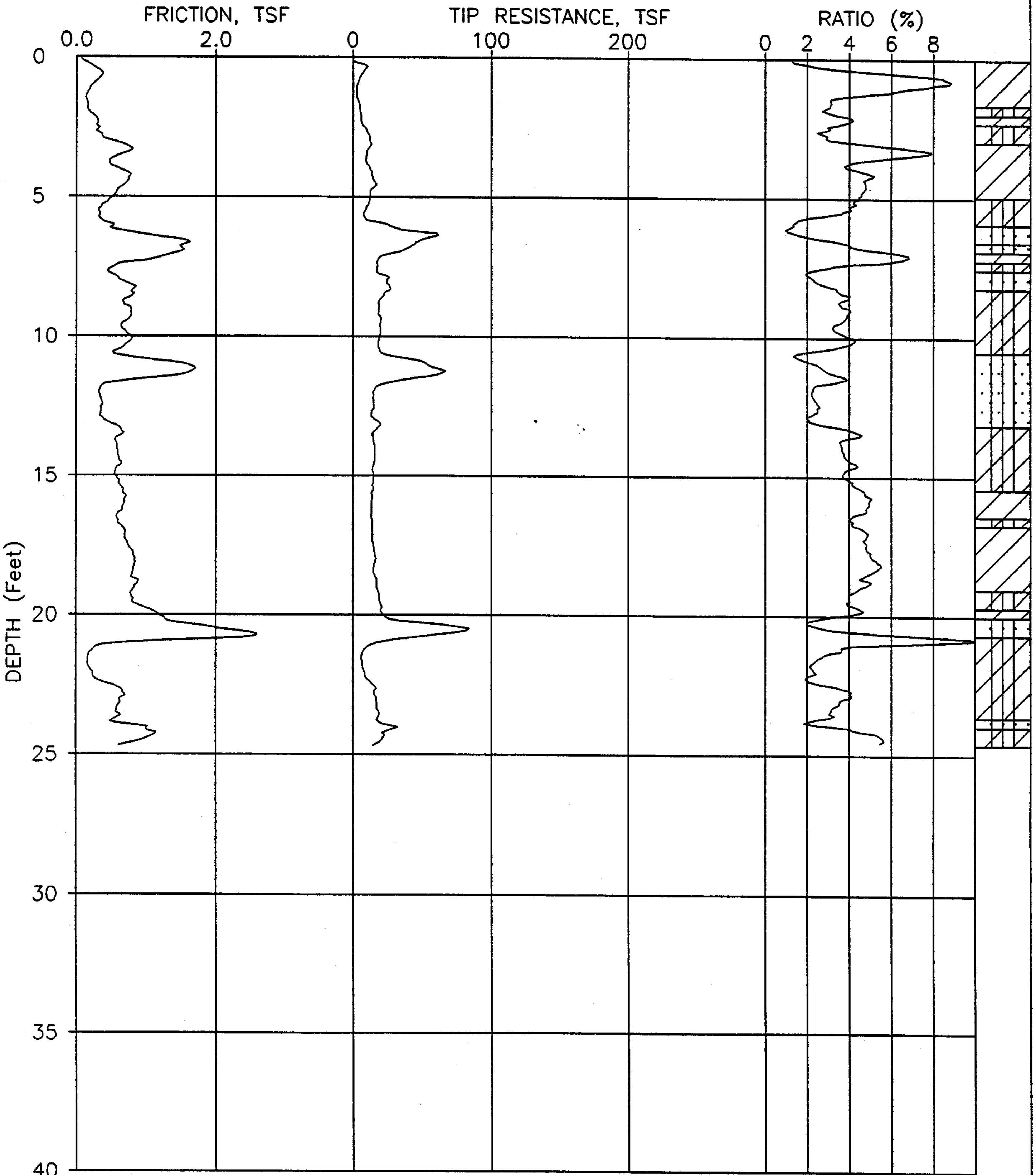

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PLATE: 1 OF 1

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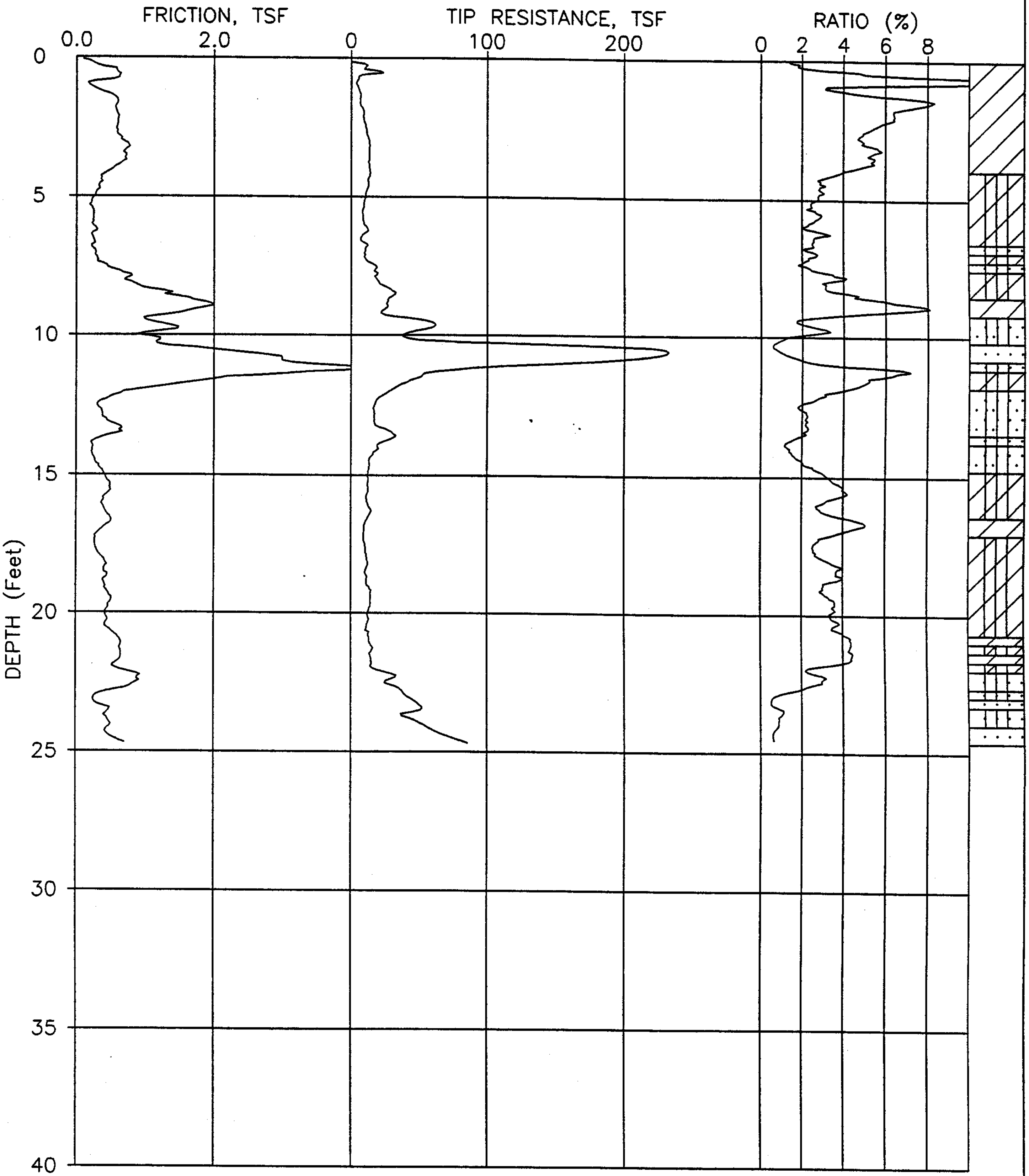

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PLATE: 1 OF 1

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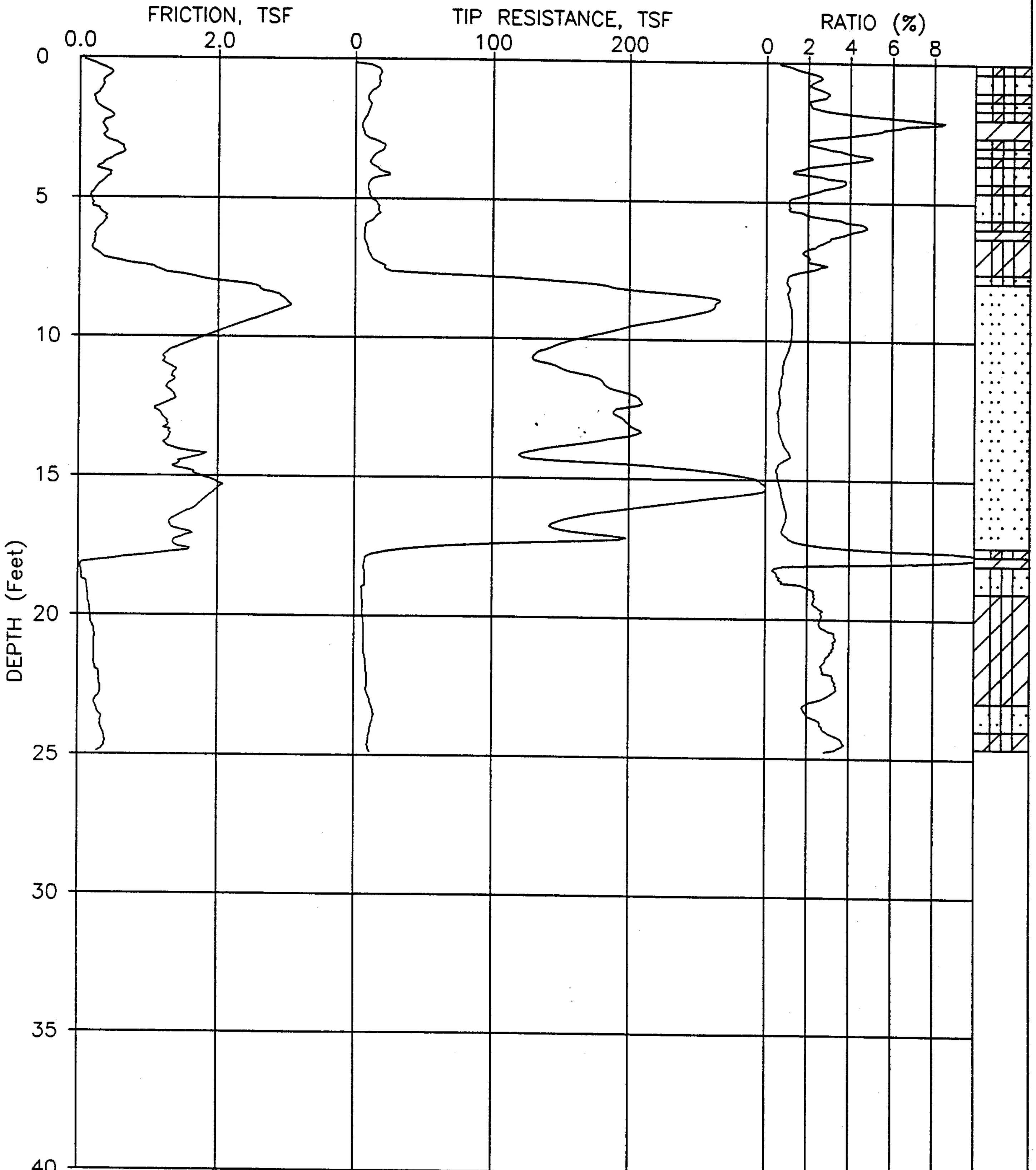

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PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC

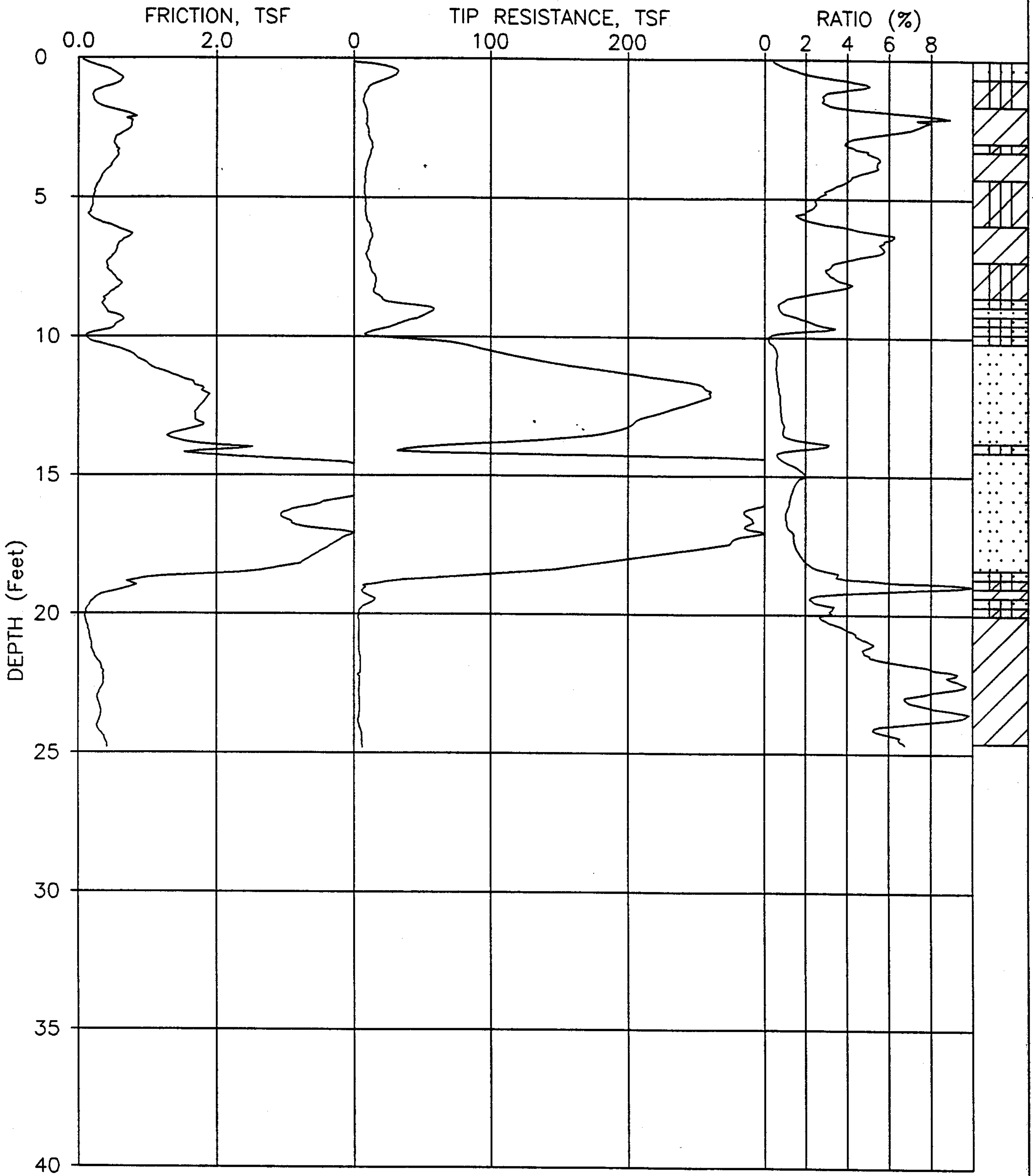

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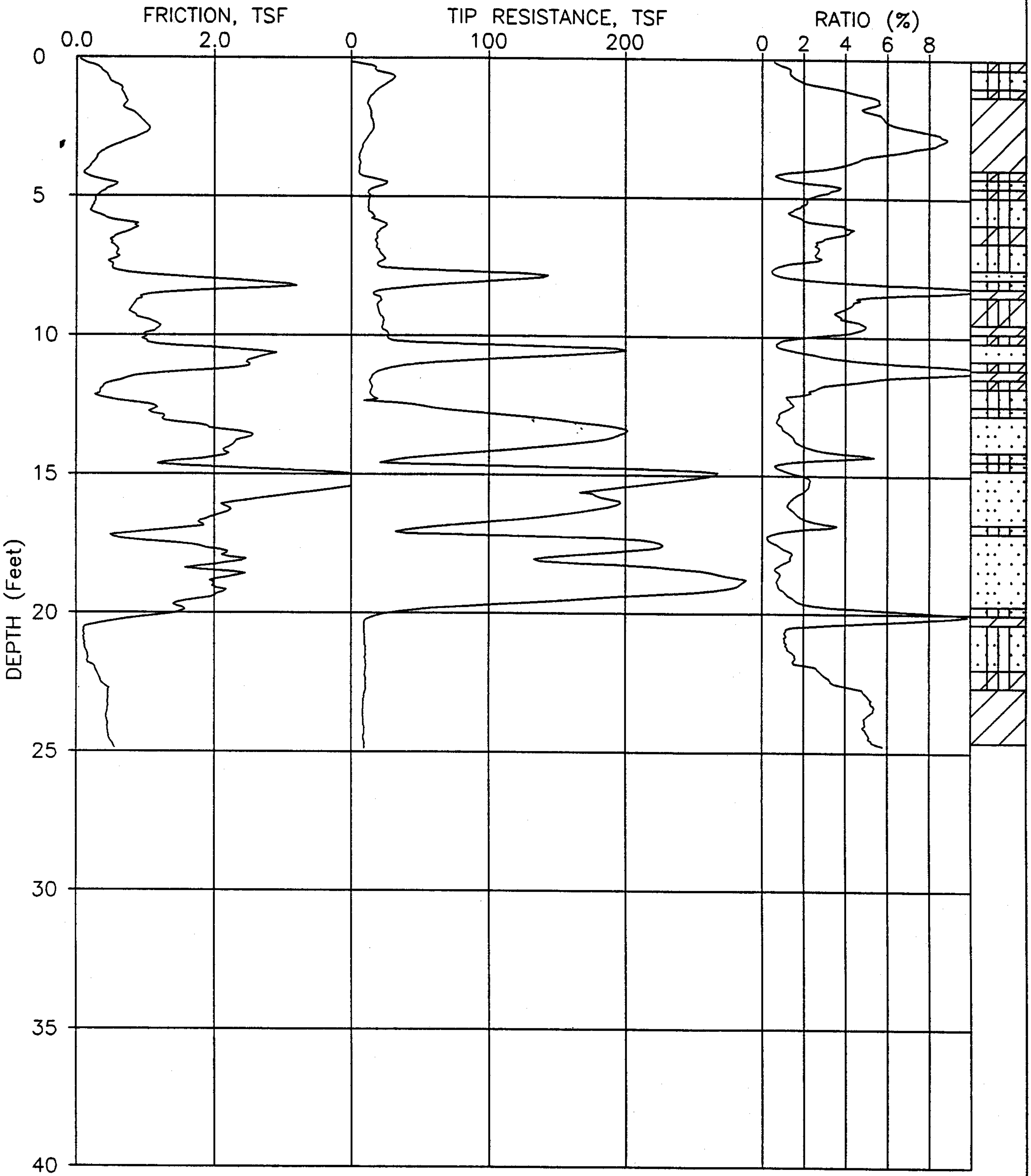
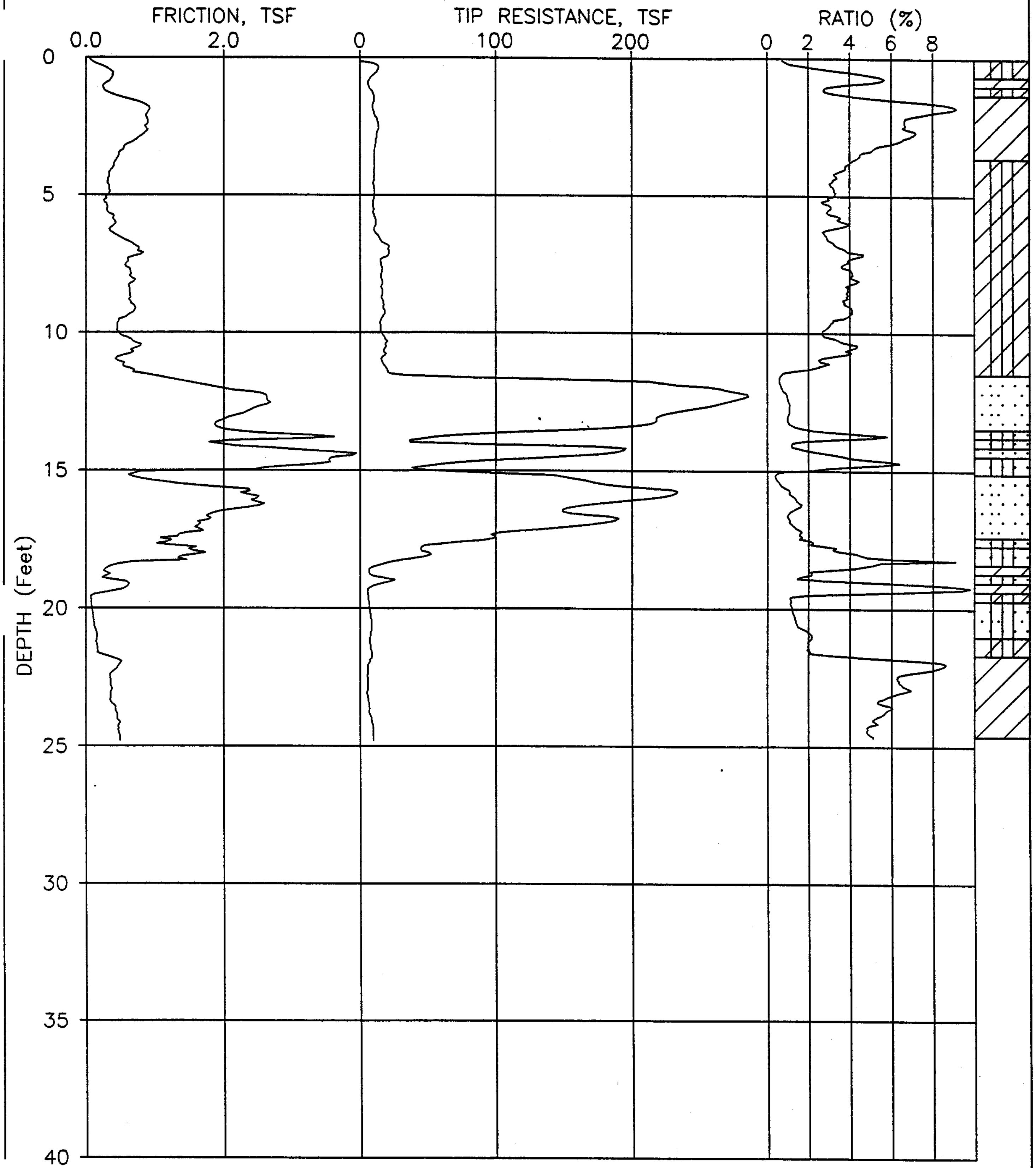
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



JOB NUMBER: 94-4108
ELEVATION: 0.00
CPT NUMBER: B-SW-18-CP
CONE NUMBER: F7.5CKEV080
DATE: 09-12-1994
PLATE: 1 OF 1

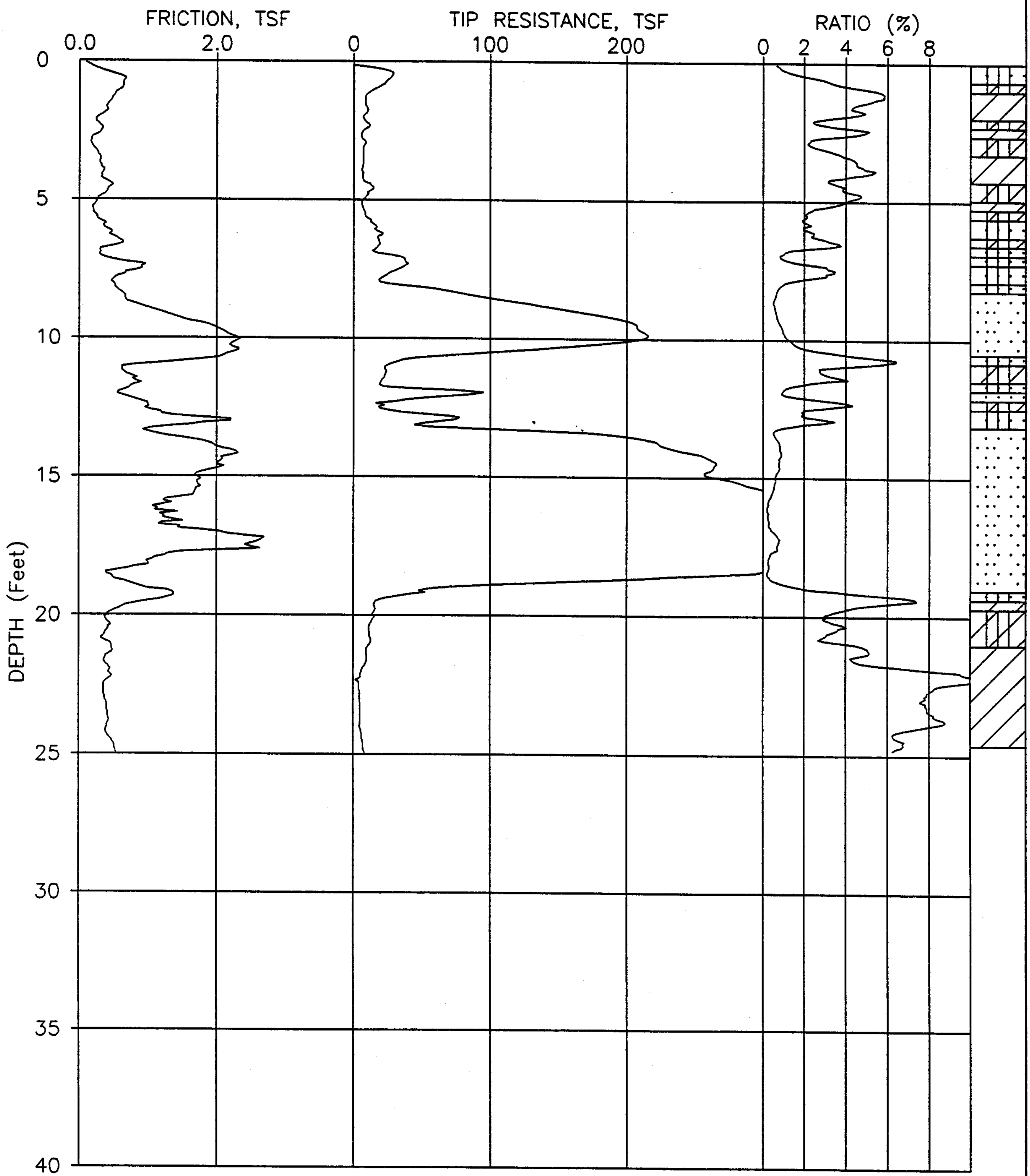
FUGRO GEOSCIENCES,INC



JOB NUMBER: 94-4108 CPT NUMBER: B-SW-19-CP DATE: 09-12-1994

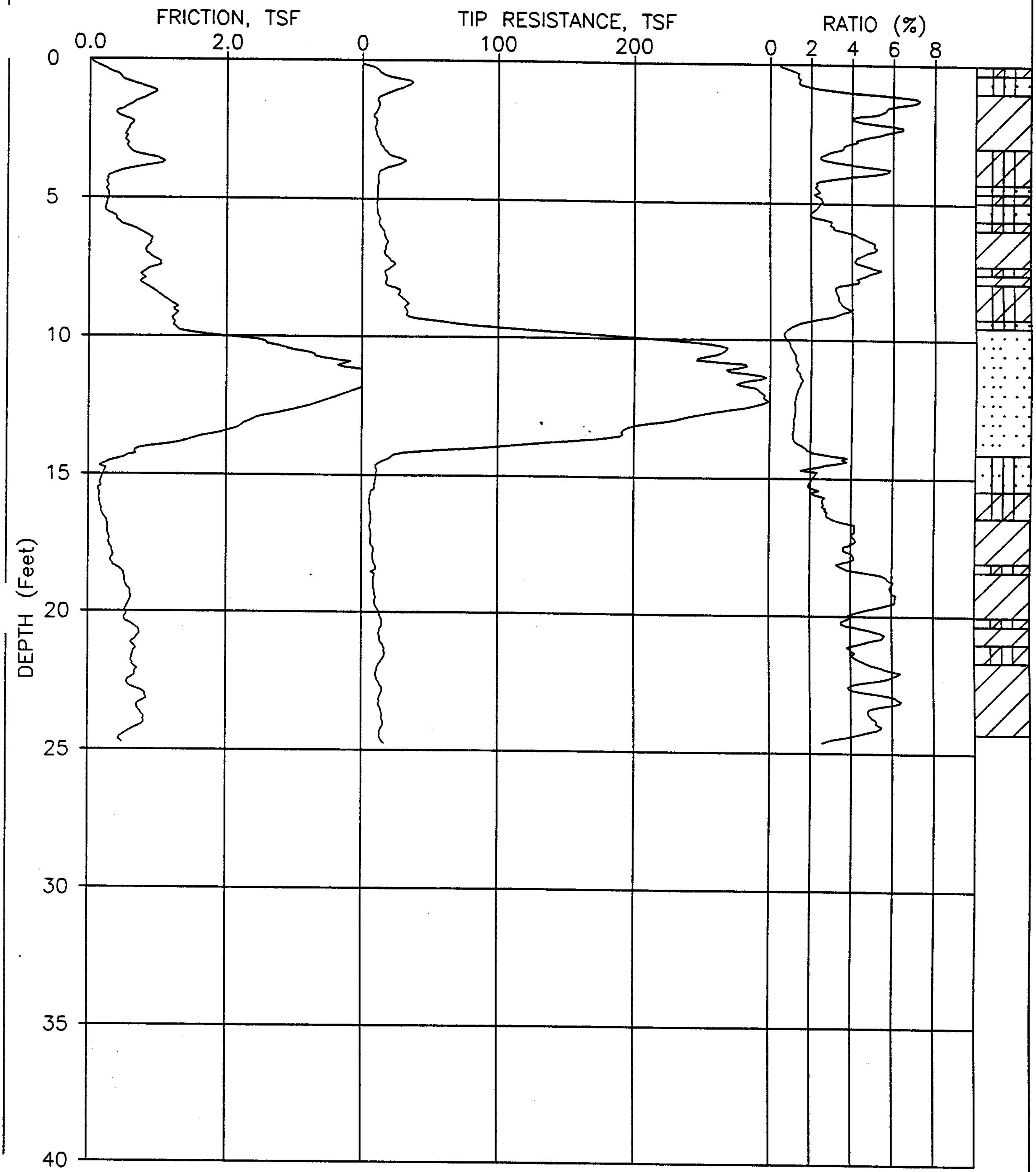
ELEVATION: 0.00 CONE NUMBER: F7.5CKEV080 PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



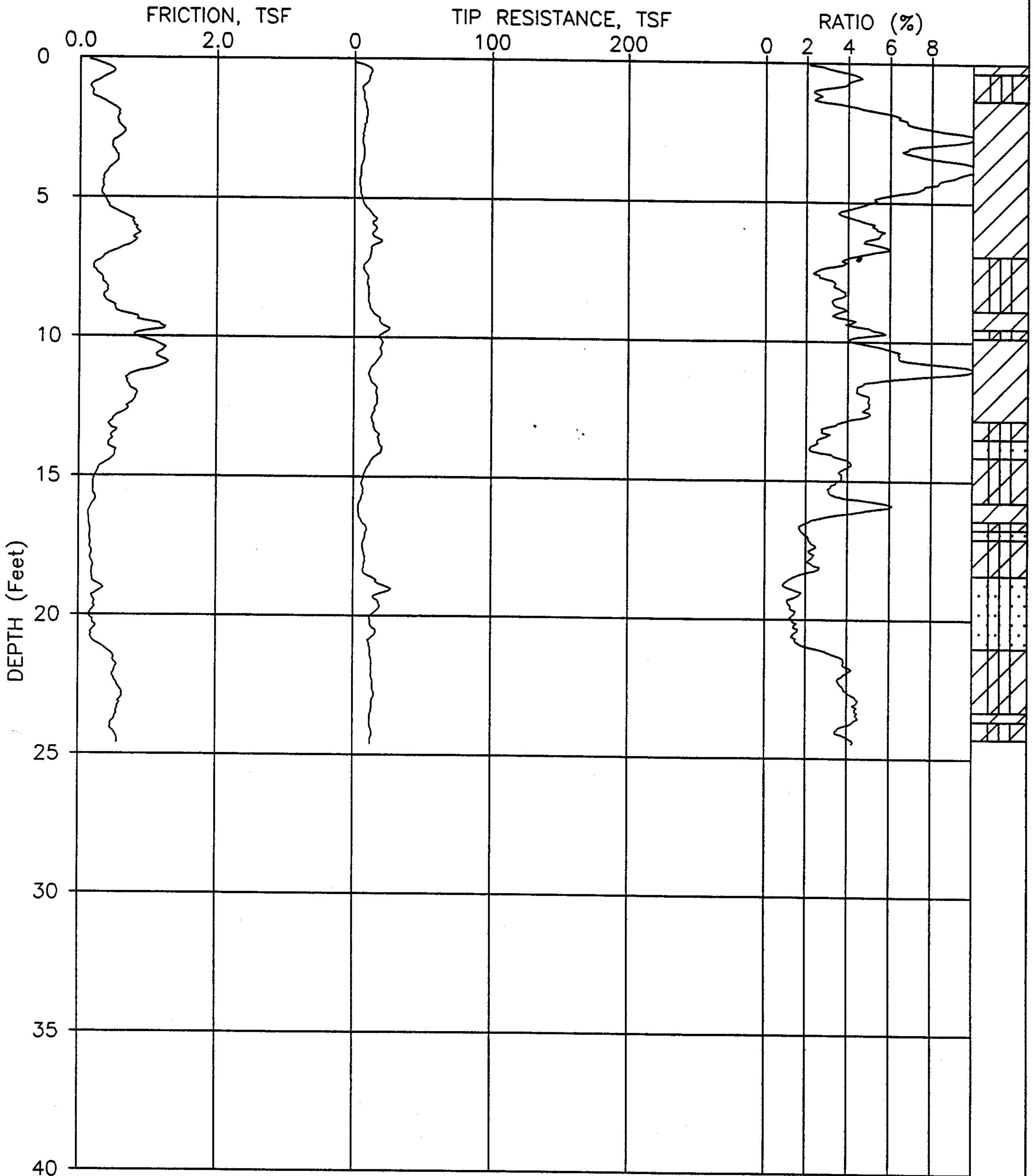
JOB NUMBER: 94-4108
ELEVATION: 0.00
CPT NUMBER: B-SW-20-CP
CONE NUMBER: F7.5CKEV080
DATE: 09-12-1994
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



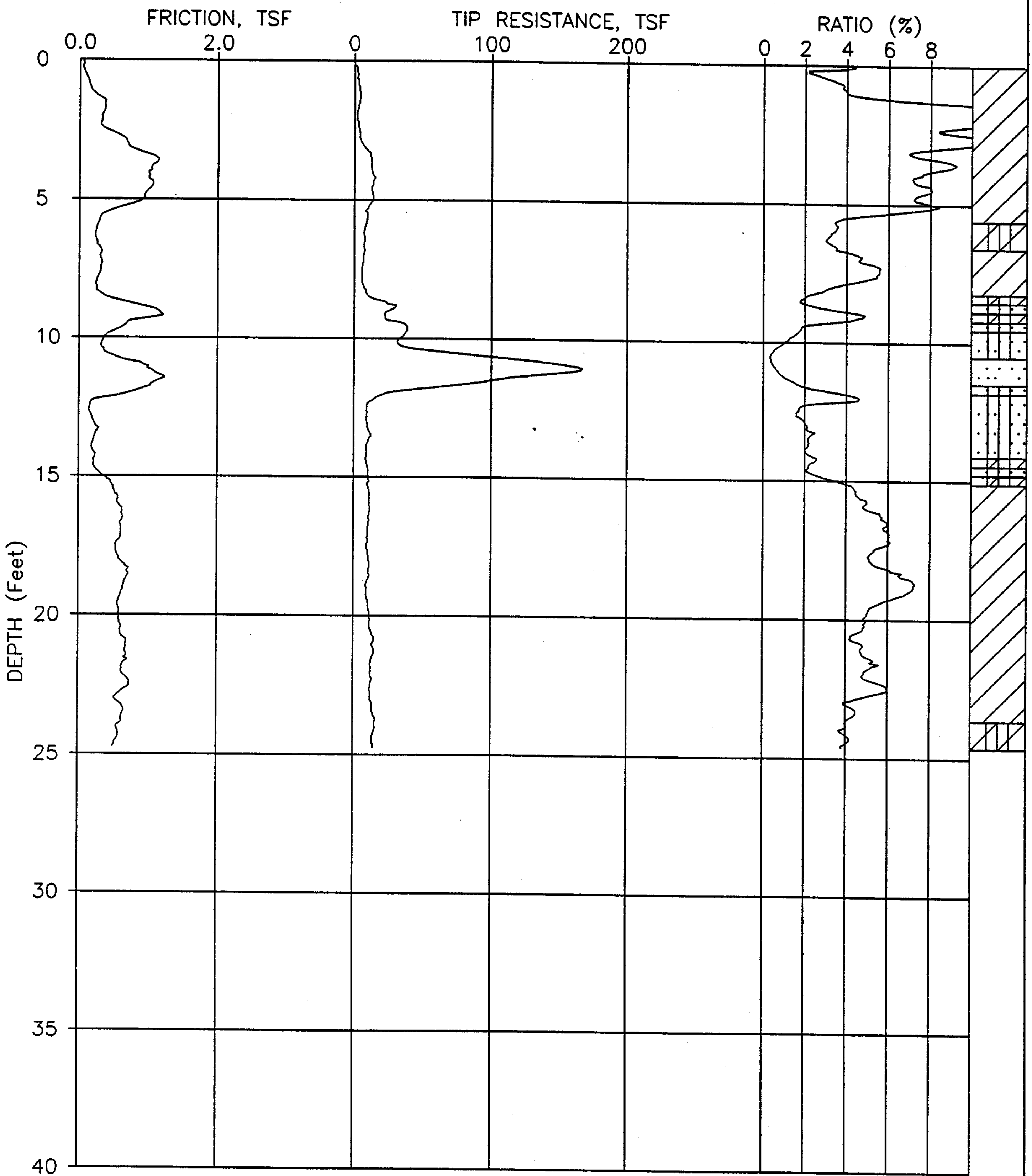
JOB NUMBER: 94-4108
ELEVATION: 0.00
CPT NUMBER: B-SW-22-CP
CONE NUMBER: F7.5CKEV080
DATE: 09-12-1994
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



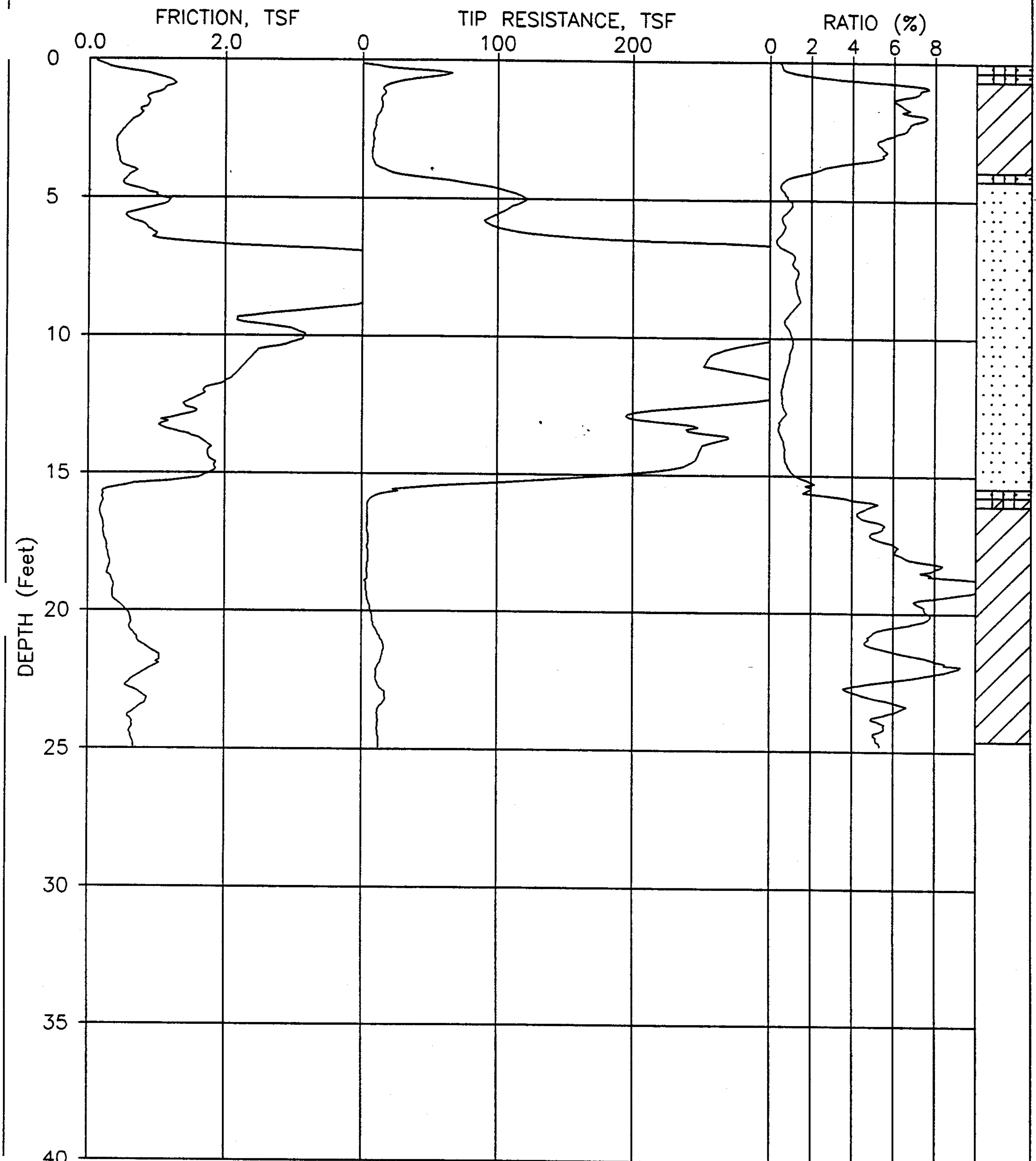
JOB NUMBER: 94-4108
ELEVATION: 0.00
CPT NUMBER: B-SW-23-CP
CONE NUMBER: F7.5CKEV080
DATE: 09-12-1994
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



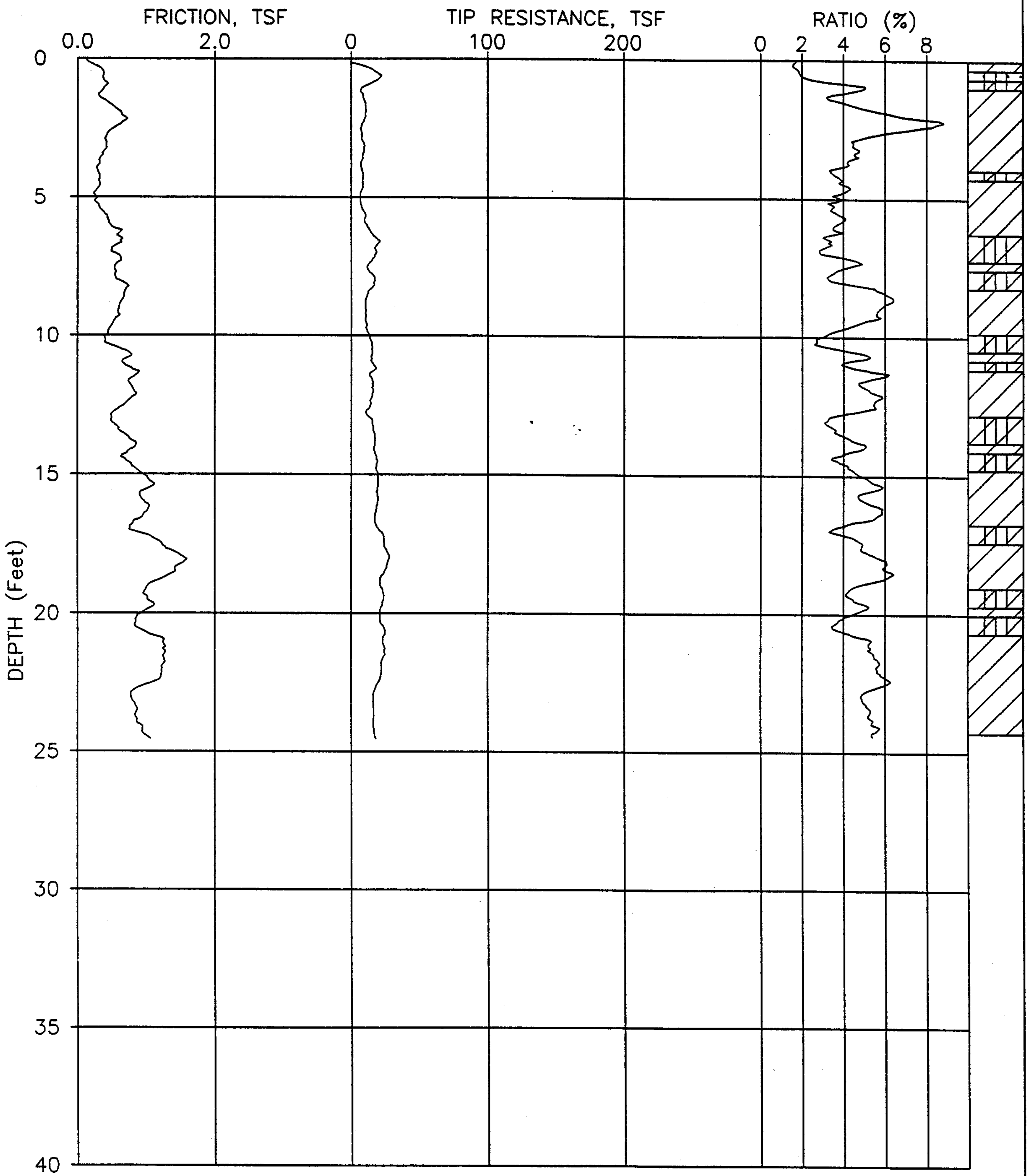
JOB NUMBER: 94-4108
ELEVATION: 0.00
CPT NUMBER: B-SW-24-CP
CONE NUMBER: F7.5CKEV080
DATE: 09-12-1994
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



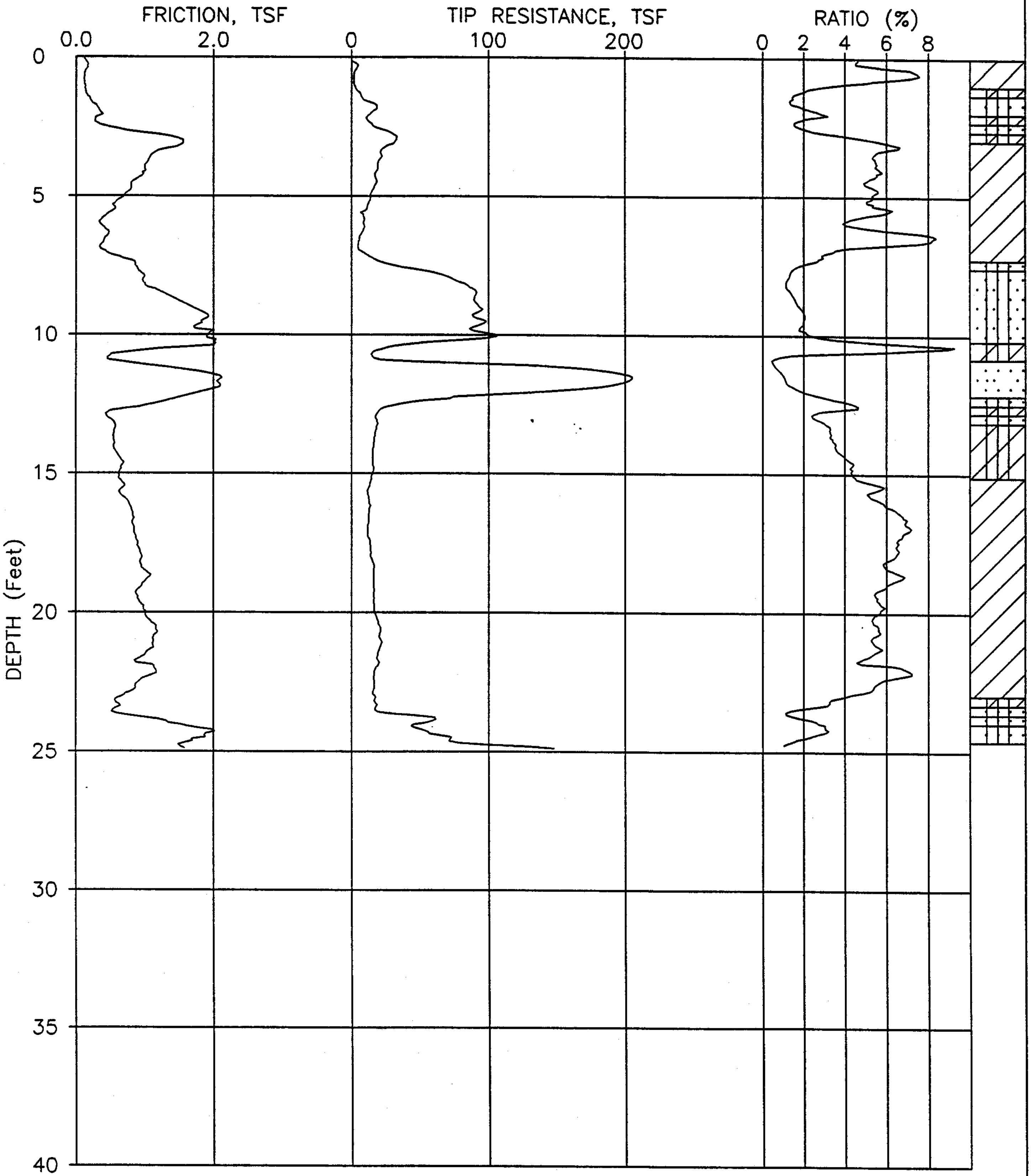
JOB NUMBER: 94-4108
ELEVATION: 0.00
CPT NUMBER: B-SW-26-CP
CONE NUMBER: F7.5CKEV080
DATE: 09-12-1994
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



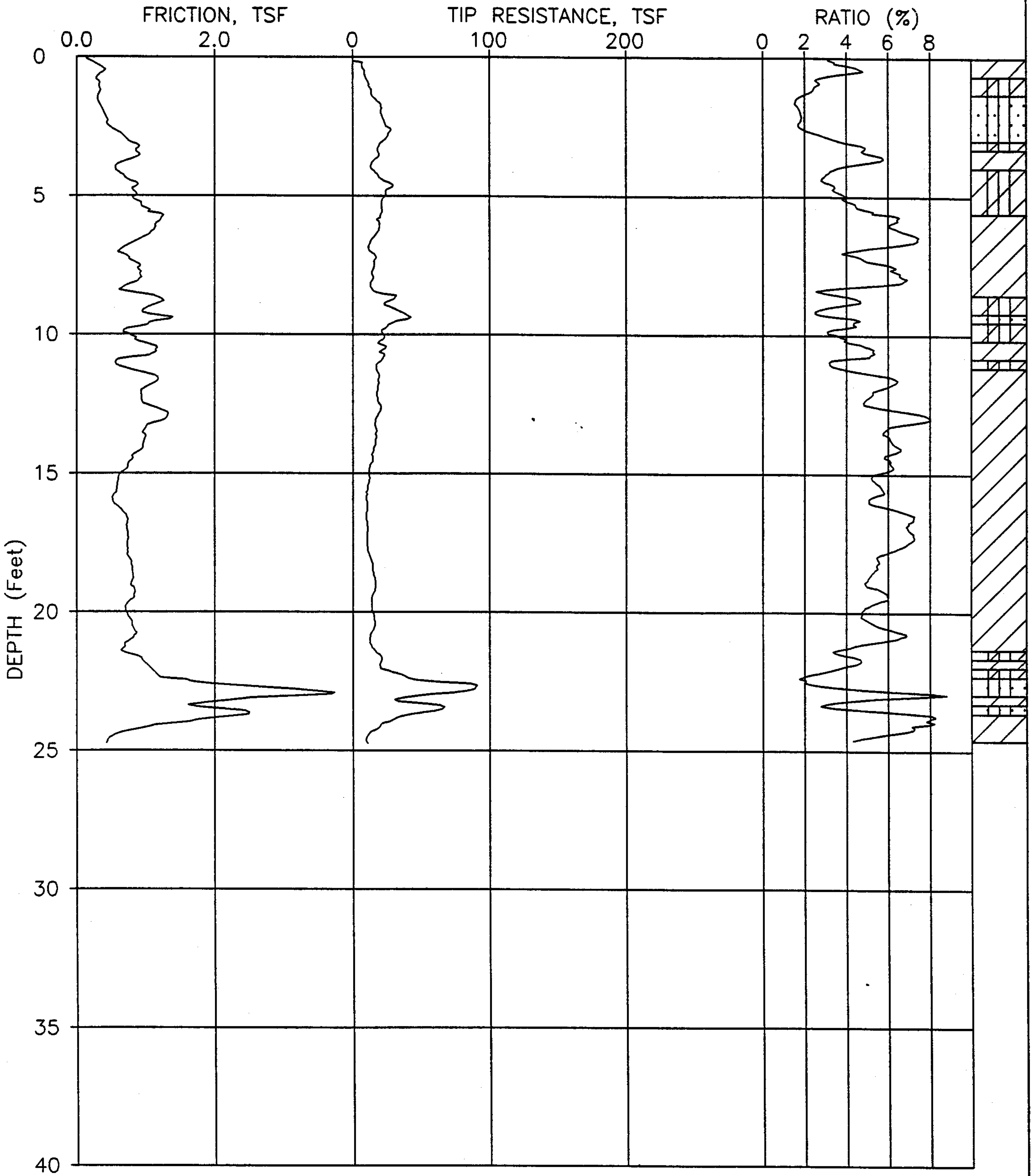
JOB NUMBER: 94-4108
ELEVATION: 0.00
CPT NUMBER: B-SW-27-CP
CONE NUMBER: F7.5CKEV080
DATE: 09-12-1994
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



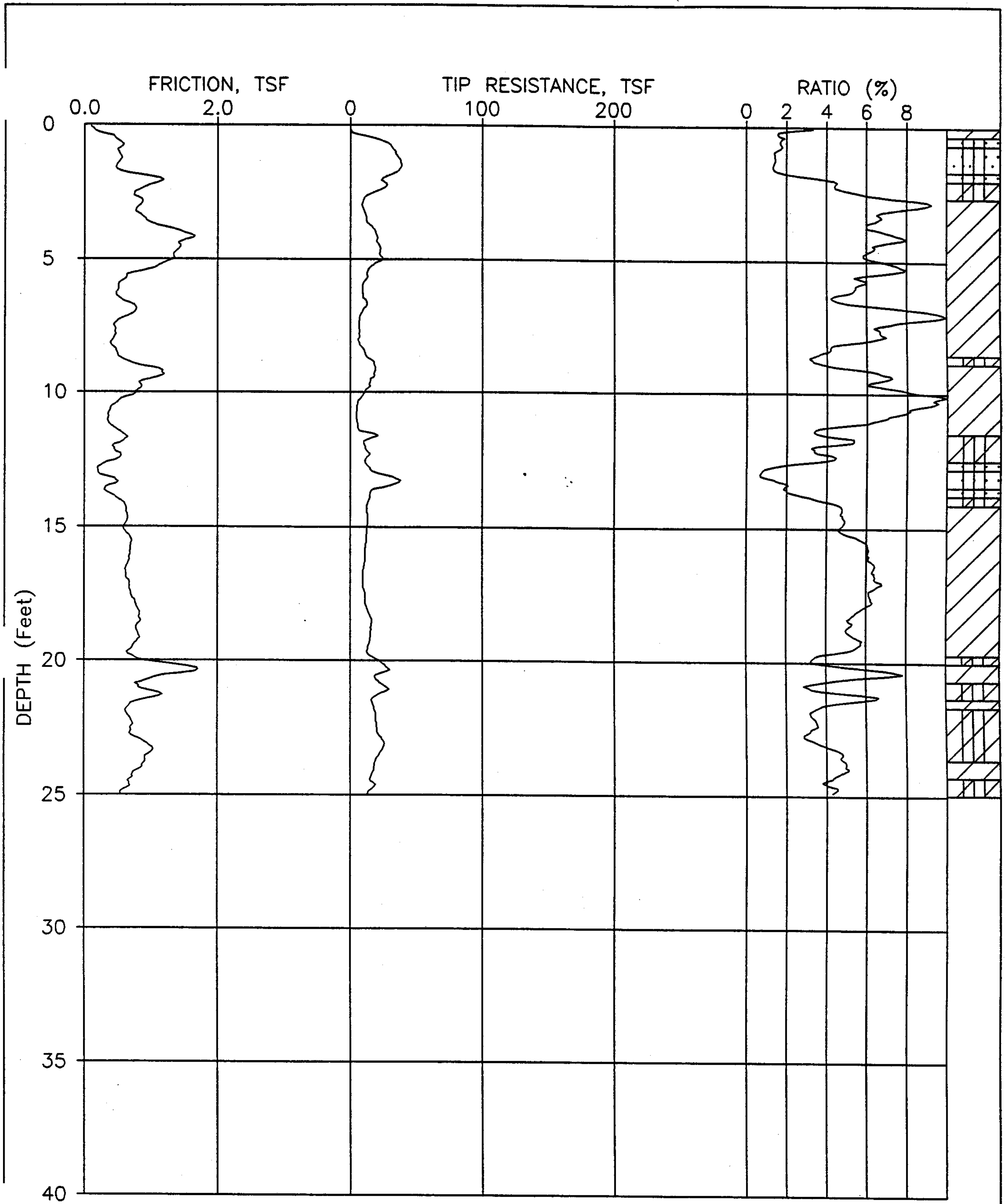
JOB NUMBER:	94-4108	CPT NUMBER:	B-SW-28-CP	DATE:	09-14-1994
ELEVATION:	0.00	CONE NUMBER:	F7.5CKEV080	PLATE:	1 OF 1

FUGRO GEOSCIENCES,INC



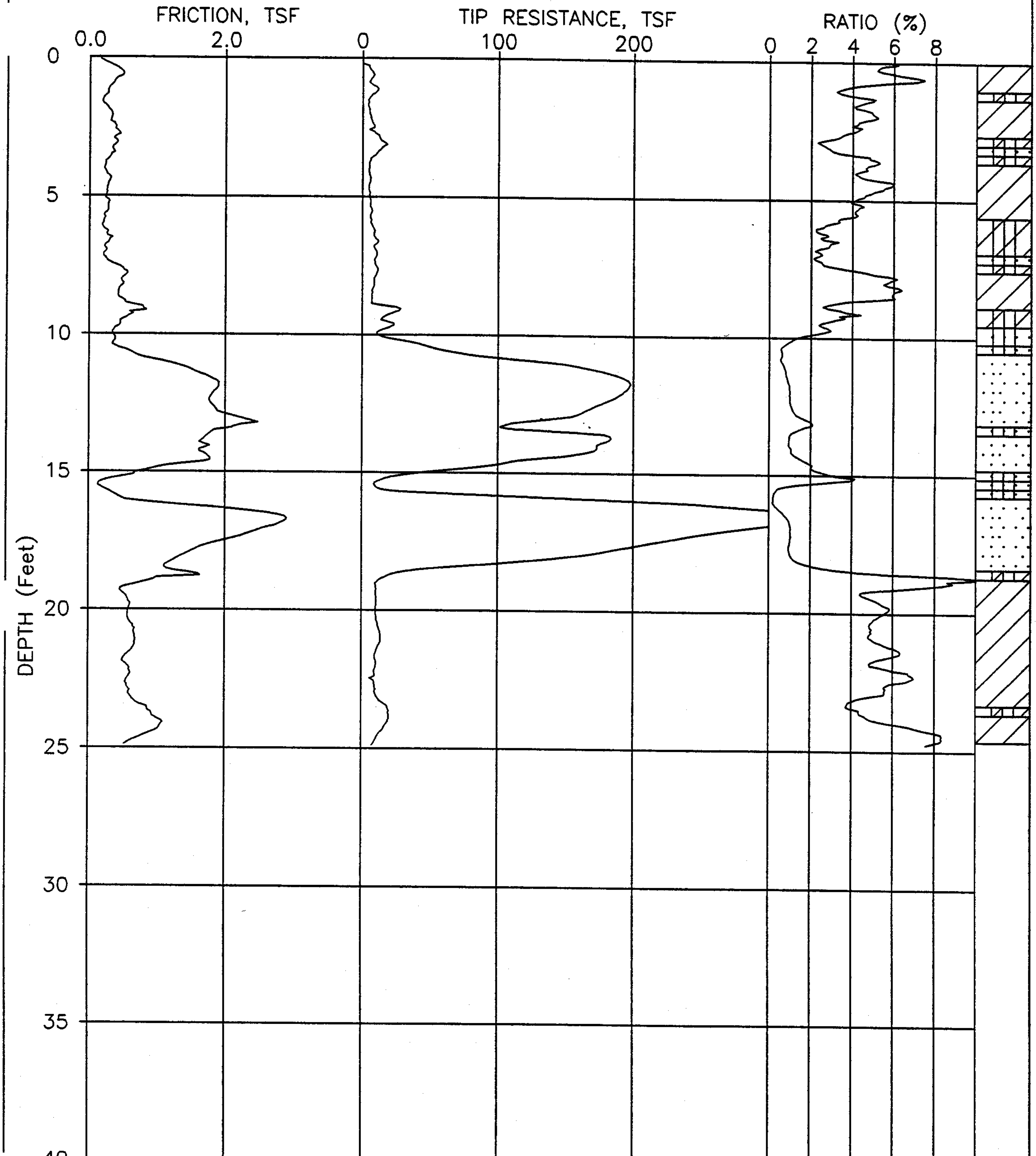
JOB NUMBER: 94-4108
ELEVATION: 0.00
CPT NUMBER: B-SW-30-CP
CONE NUMBER: F7.5CKEV080
DATE: 09-14-1994
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



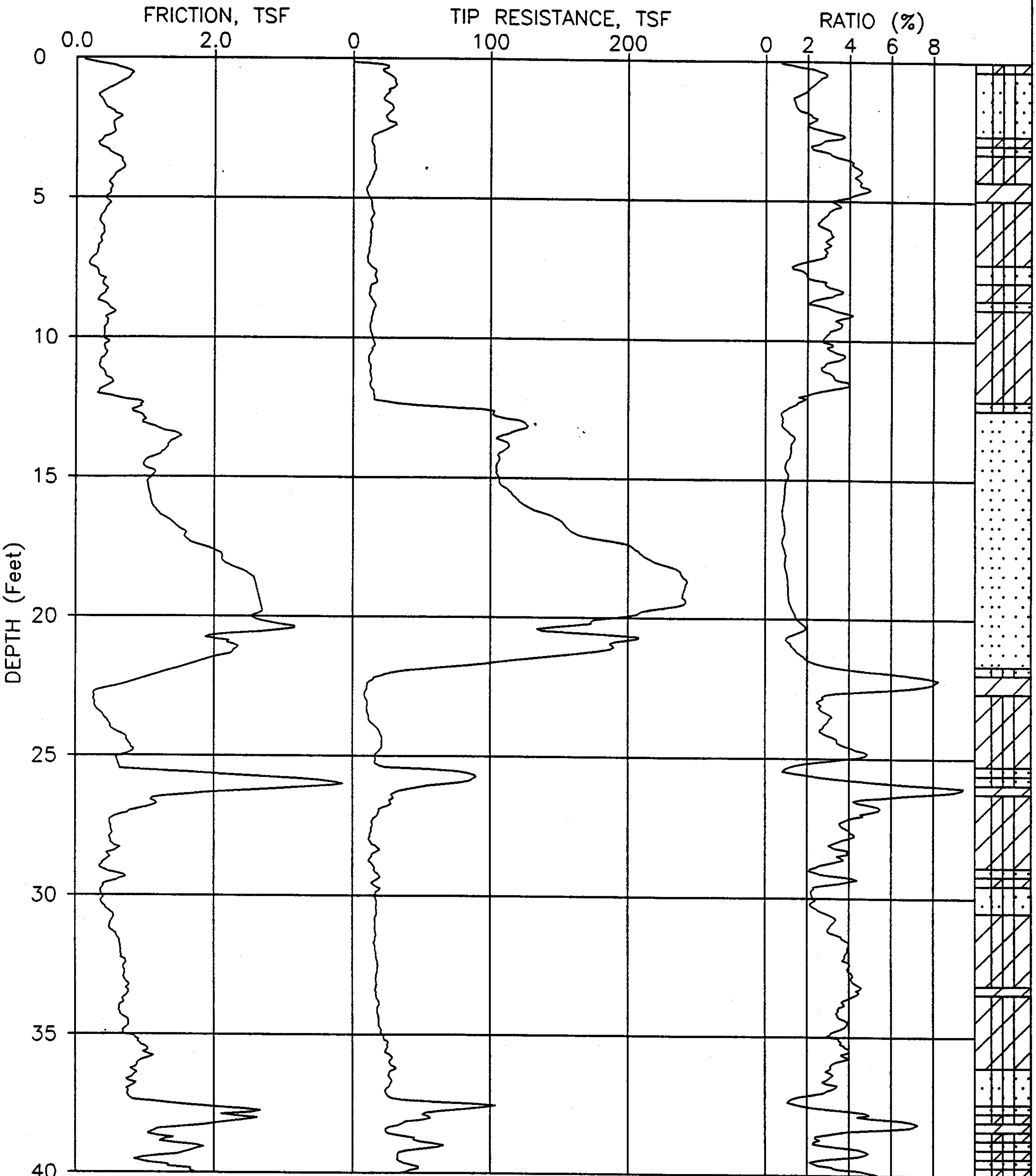
JOB NUMBER: 94-4108
ELEVATION: 0.00
CPT NUMBER: B-SW-31-CP
CONE NUMBER: F7.5CKEV080
DATE: 09-14-1994
PLATE: 1 OF 1

FUGRO GEOSCIENCES,INC



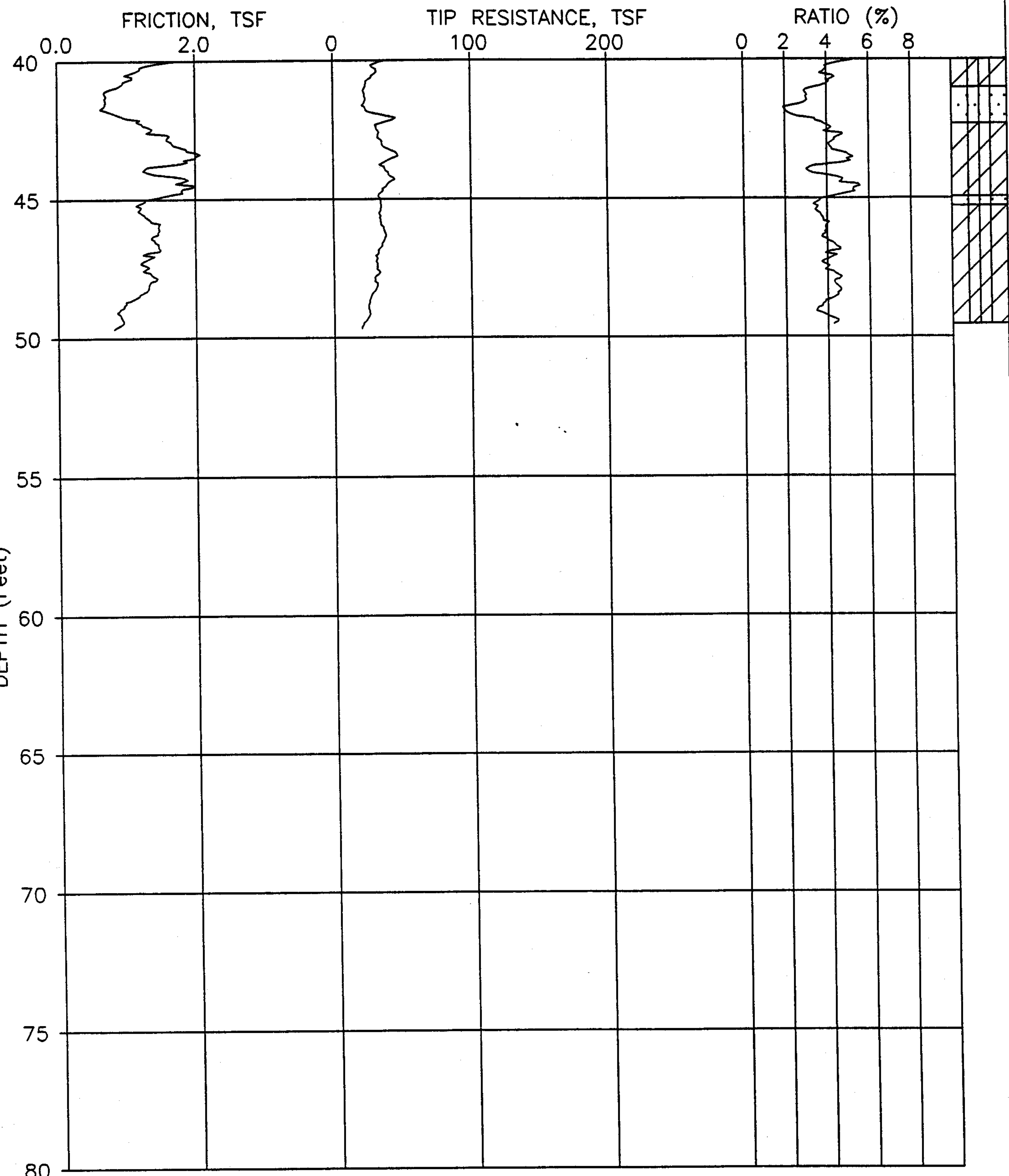
JOB NUMBER:	94-4108	CPT NUMBER:	B-SW-32-CP	DATE:	09-14-1994
ELEVATION:	0.00	CONE NUMBER:	F7.5CKEV080	PLATE:	1 OF 1

FUGRO GEOSCIENCES,INC



JOB NUMBER: 94-4108
ELEVATION: 0.00
CPT NUMBER: B-SW-34-CP
CONE NUMBER: F7.5CKEV091
DATE: 09-08-1994
PLATE: 1 OF 2

FUGRO GEOSCIENCES,INC



JOB NUMBER: 94-4108
ELEVATION: 0.00
CPT NUMBER: B-SW-34-CP
CONE NUMBER: F7.5CKEV091
DATE: 09-08-1994
PLATE: 2 OF 2

FUGRO GEOSCIENCES,INC

APPENDIX C
TABLE OF CONTENTS

STATE OF LOUISIANA SEISMIC RISK MAP FIGURE C-1

Copied From

SEISMICITY MAP OF THE STATE OF LOUISIANA

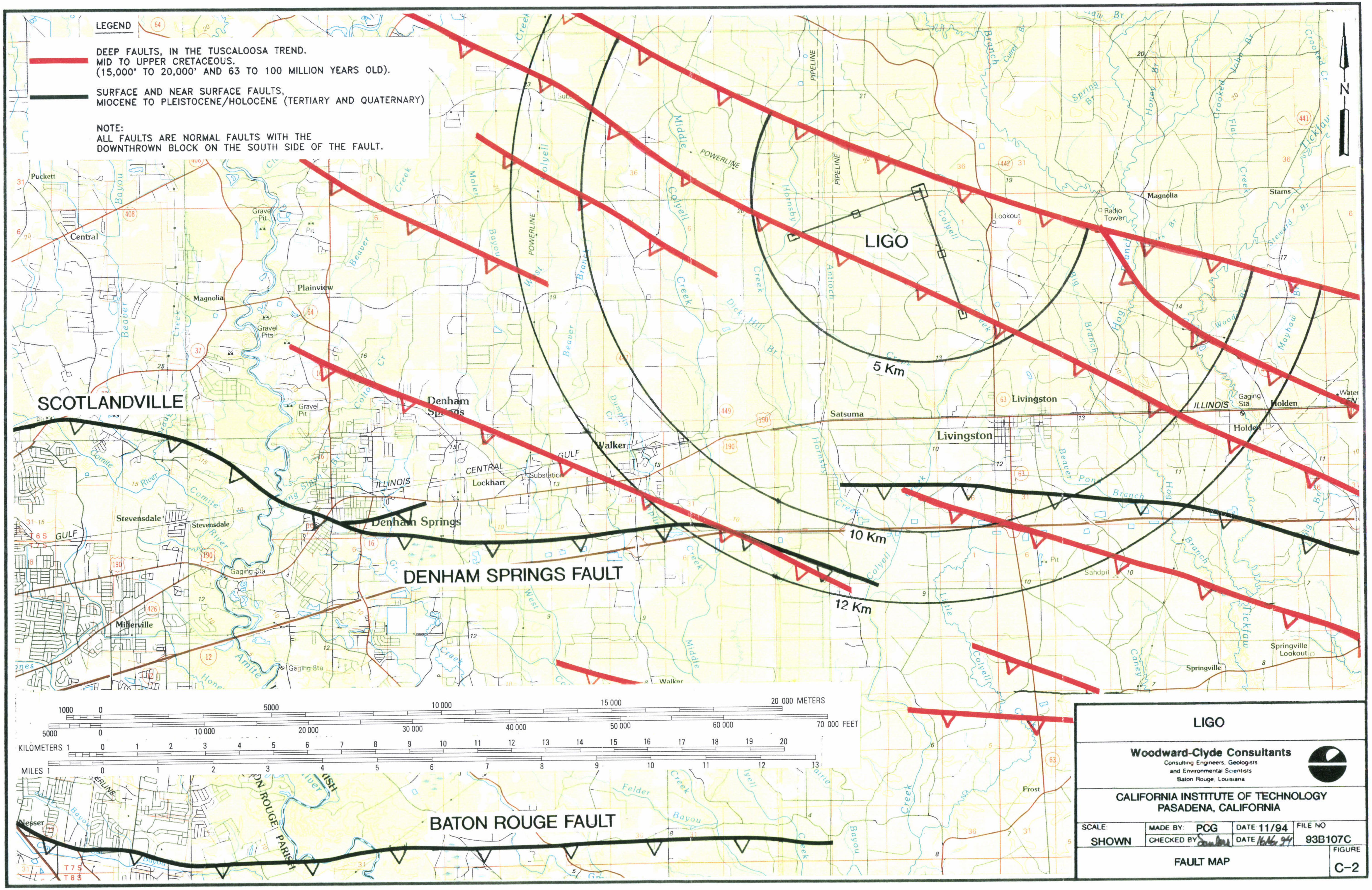
By

C.W. Stover, B. G. Reagor, and S. T. Algermissen

1979

CALIFORNIA INSTITUTE OF TECHNOLOGY PASADENA, CALIFORNIA	**Woodward-Clyde** Engineering & sciences applied to the earth & its environment Baton Rouge, Louisiana		SEISMICITY MAP OF THE STATE OF LOUISIANA	FILE NO. 93B107C-6
	SCALE: NTS	DRAWN BY: D.OLSON DATE: 11/01/94		FIG. NO.
		CHKD. BY: A.A. DATE: 11/01/94		C-1

STATE OF LOUISIANA FAULT MAP FIGURE C-2



LEGEND
DEEP FAULTS, IN THE TUSCALOOSA TREND.
MID TO UPPER CRETACEOUS.
(15,000' TO 20,000' AND 63 TO 100 MILLION YEARS OLD).
SURFACE AND NEAR SURFACE FAULTS,
MIOCENE TO PLEISTOCENE/HOLOCENE (TERTIARY AND QUATERNARY)
NOTE:
ALL FAULTS ARE NORMAL FAULTS WITH THE
DOWNTHROWN BLOCK ON THE SOUTH SIDE OF THE FAULT.
LIGO
5 Km
10 Km
12 Km
SCOTLANDVILLE
DENHAM SPRINGS FAULT
BATON ROUGE FAULT
Denham Springs
Livingston
Walker
Satsuma
Holden
Magnolia
Plainview
Central
Stevensdale
Millerville
Springville
KILOMETERS
MILES
METERS
FEET
LIGO
Woodward-Clyde Consultants
Consulting Engineers, Geologists
and Environmental Scientists
Baton Rouge, Louisiana
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA
SCALE: SHOWN
MADE BY: PCG
DATE 11/94
CHECKED BY
FILE NO 93B107C
FAULT MAP
FIGURE C-2

TABLE C-1

CHRONOLOGICAL LISTING OF EARTHQUAKES FOR THE STATE OF LOUISIANA

Date			Origin Time (UTC)			Lat.	Long.	Depth	Hypocenter		Magnitude		Intensity	
Year	Month	Day	H	M	S	(N)	(W)	(KM)	QUAL	REF	USGS	Other	MM	REF
1843	February	14	..	..	..	30.0	90.0	..	H	105	..	..	III*	105
1843	February	15	..	..	..	30.0	90.0	..	H	105	..	..	III*	105
1882	April	12	05	..	..	30.0	90.0	..	H	105	..	..	III	105
1886	January	22	16	38	..	30.4	92.0	..	G	105	..	..	II*	105
1905	February	03	..	..	..	30.5	91.1	..	G	106	..	..	V*	106
1927	December	15	04	30	..	29.0	89.4*	..	G	105	..	..	IV	105
1929	July	28	17	..	..	29.0	89.4	..	G	105	..	..	IV	105
1930	October	19	12	17	..	30.0	91.0	..	G	3	..	..	VI	38
1940	December	02	16	16	..	33.0	94.0*	..	G	105	..	..	IV	13
1947	September	20	21	30	..	31.9	92.7	..	G	105	..	..	V*	105
1958	November	06	23	08	..	30.0	90.0*	..	G	31	..	..	IV	31
1958	November	19	18	15	..	30.3	91.1	..	G	38	..	..	V	38
1959	October	15	15	45	..	29.6	93.1	..	H	105	..	..	IV	32
1959	October	15	..	..	..	29.6	93.1	..	H	105	..	..	III*	105
1964	April	24	07	33	53.0	31.6	93.8	..	B	37	3.7	..	V	37
1964	April	28	21	18	40.1	31.7	93.6	..	B	37	4.4	..	V	37

* Source U.S. Geological Survey

TABLE C-2

LIST OF LOUISIANA EARTHQUAKE DATA SOURCES

Neumann, F. and Bodle, R. R., 1932, United States Earthquakes 1930, U.S. Department of Commerce, Coast and Geodetic Survey, Serial No. 539, p. 1-25.

Neumann, F., 1942, United States Earthquakes 1940, U.S. Department of Commerce, Coast and Geodetic Survey, Serial No. 647, p. 1-74.

Brazee, R. J. and Cloud, W. K., 1960, United States Earthquakes 1958, U.S. Deaprtment of Commerce, Coast and Geodetic Survey, p. 1-76.

Eppley, R. A. and Cloud, W. K., 1961, United States Earthquakes 1959, U.S. Department of Commerce , Coast and Geodetic Survey, p. 1-115.

von Hake, C. A., and Cloud, W. K., 1966, United States Earthquakes 1964, U.S. Department of Commerce , Coast and Geodetic Survey, p. 1-91.

Coffman, J. L. and von Hake, C. A., 1973 Earthquake History of the United States, U.S. Department fo Commerce, National Oceanic and Atmospheric Administration, No. 41-1 (through 1970), p. 1-208.

Docekal, J., 1970, Earthquakes of the stable interior, with emphasis on the midcontinent, v. 2, A dissertation presented the faculty of the graduate college in the University of Nebraska in partial fulfillment of requirements for the degree of Doctor of Philosophy, p. 1-332.

Mississippi Power and Light Company, 1972, Preliminary Safety Analysis Report, Grand Gulf nuclear station, Units, 1 and 2, Nuclear Regulatory Commission, Publec Documents Room, Table C.3.2.

TABLE C-3

DATA SOURCES FOR SITE AND VICINITY FAULT MAP AND SEISMIC INFORMATION

- ECTO Engineers and Associates (Predecessor of Woodward-Clyde Consultants, Baton Rouge), A study of the Scotlandvile-Denham Springs Faults and their effect on school sites in East Baton Rouge Parish, 1971
- Louisiana Geological Survey, Geologic Map of Louisiana, 1984
- Louisiana Geological Survey, Regional Cross Sections, Louisiana Gulf Coast (Eastern Part) Folio Series No. 6, 1983
- McCulloh, R.P., Surface Faults in East Baton Rouge Parish, Louisiana Geological Survey, Open File Series No. 91-02, 1991
- Wallace, W.E., Fault and Salt Map of South Louisiana, 1982
- Nuclear Power Projects: GRAND GULF AND NEW ORLEANS (CHEF MENTEUR AREA), WCC Archives, title and date of report unknown
- Murray, G.E., Geology of the Atlantic and Gulf Coastal Provinces of North America, 1961
- Algermissen, S.T., 1969 Seismic rick studies in the United States: Fourth World Conference on Earthquake Engineering, Santiago, Chile, January 13-18, 1969 Proceedings, v. 1, p. 14-27
- Bath, Markus, 1966, Earthquake energy and magnitude, in v. 7 of Physics and chemistry of the Earth: Oxford and New York, Pergamon Press, p. 115-165
- Gutenberg, B. and Richter, C.F., 1956 Magnitude and energy of earthquakes: Annali di Geofisica, v. 9, no. 1, p. 1-15
- Nuttli, O.W., 1973, Seismic wave attenuation and magnitude relations for eastern North America: Journal of Geophysical Research, v. 78, n. 5, p. 876-885
- Richter, C.F., 1958, Elementary Seismology: San Francisco, California, W.H. Freeman and Co., Inc., p. 768
- Wood, H.O., and Neuman, F., 1931, Modified Mercalli Intensity Scale of 1931: Seismological Society of America Bulletin, v. 21, no. 4, p., 277-283

APPENDIX E
TABLE OF CONTENTS

TABLE E-1

LIGO
COMPOSITE SAMPLES FOR RESISTIVITY
AND CHEMICAL ANALYSIS

Composite Number	Boring Number	Depth (ft)	PI
1	BSE-2-GT	10-11	
	BSE-2-GT	18.5-20	
	BSE17-GT	6-8	
2	BSE-1-GT	14-16	
	BSE-24-GT	8-10	
	BSE-33-GT	13-5	
3	BSE-20-GT	6-8	
	BSE-6-GT	6-8	
	BSW-21-GT	8-10	
	BSW-21-GT	4-6	
	BSW-17-GT	6-8	
	BSE-1-GT	8-10	
	BSE-14-GT	8-10	

CHEMICAL ANALYSIS TEST RESULTS

STE
Soil Testing Engineers, Inc.
316 HIGHLANDIA DRIVE • P.O. BOX 83710 • BATON ROUGE, LOUISIANA 70884
TELEPHONE (504) 752-4790 • FAX (504) 752-4878

October 24, 1994

Mr. Ara Arman
Woodward-Clyde Consultants
P. O. Box 66317
Baton Rouge, Louisiana 70896

Re: LIGO Chemical Tests
STE File: 94-1666

Dear Mr. Arman:

Attached are the chemical test data performed for sulfates, sulfides and chlorides. The soil samples tested were the LIGO composite samples provided by Woodward-Clyde.

If there are any questions please call me.

Sincerely,

Charles S. Hedges, P.E.

CSH/slh

letter.002

94-1666

Benchmark Laboratories, Inc.

October 20, 1994

To: Soil Testing Engineers, Inc.
316 Highlandia Drive
Baton Rouge, LA 70810

The following analytical results have been obtained for the indicated sample which was submitted to this laboratory:

Sample I.D. AA27664 Location code: STE_BR
Location Description: Sample #1 (94-1666)
Sample collector: CLIENT
Lab submittal date: 10/10/94 Time: 11:45
Received by: JLS Validated by: CLB

Parameter: Sulfates(as SO4) (Turbidimetirc)
Method reference: EPA 375.4
Result: 434 mg/Kg MDL or sensitivity: 10
Date started: 10/18/94 Date finished: 10/18/94
Time started: 14:30 Analyst: LHD

Parameter: Sulfide
Method reference: SW-846/9030
Result: 118 mg/Kg MDL or sensitivity: 2.5
Date started: 10/14/94 Date finished: 10/14/94
Time started: 15:00 Analyst: LHD

Parameter: Chlorides (Specific Ion Probe)
Method reference: SM 4500 CL-D
Result: 241 mg/Kg MDL or sensitivity: 2.5
Date started: 10/18/94 Date finished: 10/18/94
Time started: 14:00 Analyst: LHD

If there are any questions regarding this data, please call.

Randal B. Myers

Randal B. Myers
Laboratory Manager

*11445 Rieger Road * Baton Rouge, LA 70809 * Phone (504) 752-4567 * Fax (504) 751-0781*

Benchmark
Laboratories, Inc.

October 20, 1994

To: Soil Testing Engineers, Inc.
316 Highlandia Drive
Baton Rouge, LA 70810

The following analytical results have been obtained for the indicated sample which was submitted to this laboratory:

Sample I.D. AA27665 Location code: STE_BR
Location Description: Sample #2 (94-1666)
Sample collector: CLIENT Sample collection date: 10/10/94
Lab submittal date: 10/10/94 Time: 11:45
Received by: JLS Validated by: CLB

Parameter: Sulfates(as SO4) (Turbidimetirc)
Method reference: EPA 375.4
Result: 1240 mg/Kg MDL or sensitivity: 10
Date started: 10/18/94 Date finished: 10/18/94
Time started: 14:30 Analyst: LHD

Parameter: Sulfide
Method reference: SW-846/9030
Result: 33.8 mg/Kg MDL or sensitivity: 2.5
Date started: 10/14/94 Date finished: 10/14/94
Time started: 15:00 Analyst: LHD

Parameter: Chlorides (Specific Ion Probe)
Method reference: SM 4500 CL-D
Result: 586 mg/Kg MDL or sensitivity: 2.5
Date started: 10/18/94 Date finished: 10/18/94
Time started: 14:00 Analyst: LHD

If there are any questions regarding this data, please call.

Randal B. Myers

Randal B. Myers
Laboratory Manager

11445 Rieger Road * Baton Rouge, LA 70809 * Phone (504) 752-4567 * Fax (504) 751-0781

Benchmark
Laboratories, Inc.

October 20, 1994

To: Soil Testing Engineers, Inc.
316 Highlandia Drive
Baton Rouge, LA 70810

The following analytical results have been obtained for the indicated sample which was submitted to this laboratory:

Sample I.D. AA27666 Location code: STE_BR
Location Description: Sample #3 (94-1666)
Sample collector: CLIENT Sample collection date: 10/10/94
Lab submittal date: 10/10/94 Time: 11:45
Received by: JLS Validated by: CLB

Parameter: Sulfates(as SO4) (Turbidimetirc)
Method reference: EPA 375.4
Result: 1240 mg/Kg MDL or sensitivity: 10
Date started: 10/18/94 Date finished: 10/18/94
Time started: 14:30 Analyst: LHD

Parameter: Sulfide
Method reference: SW-846/9030
Result: 192 mg/Kg MDL or sensitivity: 2.5
Date started: 10/14/94 Date finished: 10/14/94
Time started: 15:00 Analyst: LHD

Parameter: Chlorides (Specific Ion Probe)
Method reference: SM 4500 CL-D
Result: 214 mg/Kg MDL or sensitivity: 2.5
Date started: 10/18/94 Date finished: 10/18/94
Time started: 14:00 Analyst: LHD

If there are any questions regarding this data, please call.

Randal B. Myers
Randal B. Myers
Laboratory Manager

11445 Rieger Road * Baton Rouge, LA 70809 * Phone (504) 752-4567 * Fax (504) 751-0781

BENCHMARK LABORATORIES, INC.

QUALITY ASSURANCE/QUALITY CONTROL

BATCH SAMPLE

Client: STE-BR

DUPLICATES

TEST	DATE	UNITS	SAMPLE	DUPLICATE	% DIFF.*	QA/QC LIMITS LOW LEVEL**		QA/QC LIMITS HIGH LEVEL+
Cl	10/18/94	mg/Kg	4.27	4.31	<1	25%	(+/-)	10%
SO_4	10/18/94	mg/Kg	1240	1240	<1			

NO STANDARD ADDITIONS WERE MADE AND NO SPIKES WERE USED.

SPIKES

TEST	DATE	UNITS	SAMPLE RESULT	SPIKE AMOUNT	SPIKE RESULT	% RECOVERY	QA/QC LIMITS
Cl	10/18/94	mg/Kg	4.27	25.0	29.3	100	80 - 120%
SO_4	10/18/94	mg/Kg	25.4	5.00	29.5	82	

* Additions calculated as % of the known addition recovered, duplicates calculated as the difference as a percentage of the mean [100(x₁-x₂)x].

** Low-level refers to concentrations less than 20 times the MDL. High-level refers to concentrations greater than 20 times the MDL.

\+ Also acceptance limits for independent laboratory control standards and certification of operation competence.

Randal B. Myers

Randal B. Myers, Laboratory Manager

11445 Rieger Road, Baton Rouge, LA 70809, Phone (504) 752-4567, Fax (504) 751-0781

Benchmark Laboratories, Inc.

October 20, 1994

To: Soil Testing Engineers, Inc.
316 Highlandia Drive
Baton Rouge, LA 70810

The following analytical results have been obtained for the indicated sample which was submitted to this laboratory:

Sample I.D. AA27666
Location Description: Sample #3 (94-1666)
Sample collector: CLIENT
Lab submittal date: 10/10/94
Received by: JLS

Location code: STE_BR
Sample collection date: 10/10/94
Time: 11:45
Validated by: CLB

Parameter: Sulfates(as SO4) (Turbidimetirc)
Method reference: EPA 375.4
Result: 1240 mg/Kg
Date started: 10/18/94
Time started: 14:30
MDL or sensitivity: 10
Date finished: 10/18/94
Analyst: LHD

Parameter: Sulfide
Method reference: SW-846/9030
Result: 192 mg/Kg
Date started: 10/14/94
Time started: 15:00
MDL or sensitivity: 2.5
Date finished: 10/14/94
Analyst: LHD

Parameter: Chlorides (Specific Ion Probe)
Method reference: SM 4500 CL-D
Result: 214 mg/Kg
Date started: 10/18/94
Time started: 14:00
MDL or sensitivity: 2.5
Date finished: 10/18/94
Analyst: LHD

If there are any questions regarding this data, please call.

Randal B. Myers

Randal B. Myers
Laboratory Manager

11445 Rieger Road - Baton Rouge, LA 70809 * Phone (504) 752-4567 * Fax (504) 751-0781

Benchmark
Laboratories, Inc.

October 20, 1994

To: Soil Testing Engineers, Inc.
316 Highlandia Drive
Baton Rouge, LA 70810

The following analytical results have been obtained for the indicated sample which was submitted to this laboratory:

Sample I.D. AA27665
Location code: STE_BR
Location Description: Sample #2 (94-1666)
Sample collector: CLIENT
Sample collection date: 10/10/94
Lab submittal date: 10/10/94
Time: 11:45
Received by: JLS
Validated by: CLB

Parameter: Sulfates(as SO4) (Turbidimetirc)
Method reference: EPA 375.4
MDL or sensitivity: 10
Result: 1240 mg/Kg
Date finished: 10/18/94
Date started: 10/18/94
Analyst: LHD
Time started: 14:30

Parameter: Sulfide
Method reference: SW-846/9030
MDL or sensitivity: 2.5
Result: 33.8 mg/Kg
Date finished: 10/14/94
Date started: 10/14/94
Analyst: LHD
Time started: 15:00

Parameter: Chlorides (Specific Ion Probe)
Method reference: SM 4500 CL-D
MDL or sensitivity: 2.5
Result: 586 mg/Kg
Date finished: 10/18/94
Date started: 10/18/94
Analyst: LHD
Time started: 14:00

If there are any questions regarding this data, please call.

Randal B. Myers

Randal B. Myers
Laboratory Manager

11445 Rieger Road * Baton Rouge, LA 70809 * Phone (504) 752-4567 * Fax (504) 751-0781

Benchmark Laboratories, Inc.

October 20, 1994

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Time started: 14:30 Analyst: LHD

Parameter: Sulfide
Method reference: SW-846/9030
Result: 118 mg/Kg MDL or sensitivity: 2.5
Date started: 10/14/94 Date finished: 10/14/94
Time started: 15:00 Analyst: LHD

Parameter: Chlorides (Specific Ion Probe)
Method reference: SM 4500 CL-D
Result: 241 mg/Kg MDL or sensitivity: 2.5
Date started: 10/18/94 Date finished: 10/18/94
Time started: 14:00 Analyst: LHD

If there are any questions regarding this data, please call.

Randal B. Myers
Laboratory Manager

BENCHMARK LABORATORIES, INC.

QUALITY ASSURANCE/QUALITY CONTROL

BATCH SAMPLE

Client: STE-BR

DUPLICATES

TEST	DATE	UNITS	SAMPLE	DUPLICATE	% DIFF.*	QA/QC LIMITS LOW LEVEL**	QA/QC LIMITS HIGH LEVEL+
Cl	10/18/94	mg/Kg	4.27	4.31	<1	25% (+/-)	10%
SO_4	10/18/94	mg/Kg	1240	1240	<1		

NO STANDARD ADDITIONS WERE MADE AND NO SPIKES WERE USED.

SPIKES

TEST	DATE	UNITS	SAMPLE RESULT	SPIKE AMOUNT	SPIKE RESULT	% RECOVERY	QA/QC LIMITS
Cl	10/18/94	mg/Kg	4.27	25.0	29.3	100	80 - 120%
SO_4	10/18/94	mg/Kg	25.4	5.00	29.5	82	

* Additions calculated as % of the known addition recovered, duplicates calculated as the difference as a percentage of the mean [100(x₁-x₂)/x̄].
** Low-level refers to concentrations less than 20 times the MDL. High-level refers to concentrations greater than 20 times the MDL.
\+ Also acceptance limits for independent laboratory control standards and certification of operation competence.

Randal B. Myers

Randal B. Myers, Laboratory Manager

11445 Rieger Road, Baton Rouge, LA 70809, Phone (504) 753-4567, Fax (504) 751-0781

Benchmark Laboratories, Inc.

October 20, 1994

To: Soil Testing Engineers, Inc.
316 Highlandia Drive
Baton Rouge, LA 70810

The following analytical results have been obtained for the indicated sample which was submitted to this laboratory:

Sample I.D. AA27666
Location Description: Sample #3 (94-1666)
Sample collector: CLIENT
Lab submittal date: 10/10/94
Received by: JLS

Location code: STE_BR
Sample collection date: 10/10/94
Time: 11:45
Validated by: CLB

Parameter: Sulfates(as SO4) (Turbidimetirc)
Method reference: EPA 375.4
Result: 1240 mg/Kg
Date started: 10/18/94
Time started: 14:30
MDL or sensitivity: 10
Date finished: 10/18/94
Analyst: LHD

Parameter: Sulfide
Method reference: SW-846/9030
Result: 192 mg/Kg
Date started: 10/14/94
Time started: 15:00
MDL or sensitivity: 2.5
Date finished: 10/14/94
Analyst: LHD

Parameter: Chlorides (Specific Ion Probe)
Method reference: SM 4500 CL-D
Result: 214 mg/Kg
Date started: 10/18/94
Time started: 14:00
MDL or sensitivity: 2.5
Date finished: 10/18/94
Analyst: LHD

If there are any questions regarding this data, please call.

Randal B. Myers

Randal B. Myers
Laboratory Manager

11445 Rieger Road - Baton Rouge, LA 70809 • Phone (504) 752-4567 • Fax (504) 751-0781

Benchmark
Laboratories, Inc.

October 20, 1994

To: Soil Testing Engineers, Inc.
316 Highlandia Drive
Baton Rouge, LA 70810

The following analytical results have been obtained for the indicated sample which was submitted to this laboratory:

Sample I.D. AA27665
Location code: STE_BR
Location Description: Sample #2 (94-1666)
Sample collection date: 10/10/94
Sample collector: CLIENT
Time: 11:45
Lab submittal date: 10/10/94
Validated by: CLB
Received by: JLS

Parameter: Sulfates(as SO4) (Turbidimetirc)
Method reference: EPA 375.4
MDL or sensitivity: 10
Result: 1240 mg/Kg
Date finished: 10/18/94
Date started: 10/18/94
Analyst: LHD
Time started: 14:30

Parameter: Sulfide
Method reference: SW-846/9030
MDL or sensitivity: 2.5
Result: 33.8 mg/Kg
Date finished: 10/14/94
Date started: 10/14/94
Analyst: LHD
Time started: 15:00

Parameter: Chlorides (Specific Ion Probe)
Method reference: SM 4500 CL-D
MDL or sensitivity: 2.5
Result: 586 mg/Kg
Date finished: 10/18/94
Date started: 10/18/94
Analyst: LHD
Time started: 14:00

If there are any questions regarding this data, please call.

Randal B. Myers

Randal B. Myers
Laboratory Manager

11445 Rieger Road * Baton Rouge, LA 70809 * Phone (504) 752-4567 * Fax (504) 751-0781

Benchmark
Laboratories, Inc.

October 20, 1994

To: Soil Testing Engineers, Inc.
316 Highlandia Drive
Baton Rouge, LA 70810

The following analytical results have been obtained for the indicated sample which was submitted to this laboratory:

Sample I.D. AA27664 — Location code: STE_BR
Location Description: Sample #1 (94-1666)
Sample collector: CLIENT
Lab submittal date: 10/10/94 — Time: 11:45
Received by: JLS — Validated by: CLB

Parameter: Sulfates(as SO4) (Turbidimetirc)
Method reference: EPA 375.4
Result: 434 mg/Kg — MDL or sensitivity: 10
Date started: 10/18/94 — Date finished: 10/18/94
Time started: 14:30 — Analyst: LHD

Parameter: Sulfide
Method reference: SW-846/9030
Result: 118 mg/Kg — MDL or sensitivity: 2.5
Date started: 10/14/94 — Date finished: 10/14/94
Time started: 15:00 — Analyst: LHD

Parameter: Chlorides (Specific Ion Probe)
Method reference: SM 4500 CL-D
Result: 241 mg/Kg — MDL or sensitivity: 2.5
Date started: 10/18/94 — Date finished: 10/18/94
Time started: 14:00 — Analyst: LHD

If there are any questions regarding this data, please call.

Randal B. Myers

Randal B. Myers
Laboratory Manager

11445 Rieger Road * Baton Rouge, LA 70809 * Phone (504) 752-4567 * Fax (504) 751-0781

BENCHMARK LABORATORIES, INC.

QUALITY ASSURANCE/QUALITY CONTROL

BATCH SAMPLE

Client: STE-BR

DUPLICATES

						QA/QC LIMITS	
TEST	DATE	UNITS	SAMPLE	DUPLICATE	% DIFF.*	LOW LEVEL**	HIGH LEVEL+
Cl	10/18/94	mg/Kg	4.27	4.31	<1	25% (+/-)	10%
SO_4	10/18/94	mg/Kg	1240	1240	<1		

NO STANDARD ADDITIONS WERE MADE AND NO SPIKES WERE USED.

SPIKES

TEST	DATE	UNITS	SAMPLE RESULT	SPIKE AMOUNT	SPIKE RESULT	% RECOVERY	QA/QC LIMITS
Cl	10/18/94	mg/Kg	4.27	25.0	29.3	100	80 - 120%
SO_4	10/18/94	mg/Kg	25.4	5.00	29.5	82	

* Additions calculated as % of the known addition recovered, duplicates calculated as the difference as a percentage of the mean [100(x₁-x₂)/x].
** Low-level refers to concentrations less than 20 times the MDL. High-level refers to concentrations greater than 20 times the MDL.
\+ Also acceptance limits for independent laboratory control standards and certification of operation competence.

Randal B. Myers

Randal B. Myers, Laboratory Manager

11445 Bieger Road, Baton Rouge, LA 70809, Phone (504) 753-4567, Fax (504) 751-0701

LIGO/ Cal. Tech Project
Livingston Parish, Louisiana
for
Woodward-Clyde Consultants
Baton Rouge, Louisiana

Soil Sample Laboratory Resistivity and pH
Test Results

Composite Sample No.	Test No.	pH Content %	Moisture Content %	Test Reading ohms	Resistivity ohm-cm	Notes
1	Tan silty fine sand with small gravel					
	R_1	6.68	16.1 (N)	13,000	89,700	
	R_2		21.4	27,500	189,750	
	R_3		27.5	8000	55,200	
	R_4		33.1	3000	20,700	
	R_5		39.9	3000	20,700	
2	Light gray slightly silty clay					
	R_6	6.98	24.5 (N)	3500	24,150	
	R_7		35.7	15,000	103,500	
	R_8		44.5	20,000	138,000	
	R_9		56.9	4,000	27,600	
	R_{10}		76.2	13,000 5,000	89,700 34,500	(3)
3	Light gray and tan silty clay					
	R_{11}	6.52	15.8 (N)	3000	20,700	
	R_{12}		19.0	4000	27,600	
	R_{13}		22.9	4000	27,600	

NOTES:

1) N is natural moisture content of sample as received

2) Soil box factor (SBF) = 6.90 cm

3) First reading after 6 hour "cure." Second reading after 50 hour "cure." The high readings for R_7 and R_8, which had 6 hour cure, were apparently due to dielectric influence of the distilled water without of sufficient cure-time of allow "dissolution" and equillbrium of conductive clay minerals or chemical electrolyte salts.

LIGO/ Cal. Tech Project
Livingston Parish, Louisiana
for
Woodward-Clyde Consultants
Baton Rouge, Louisiana

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RESISTIVITY TEST RESULTS

STE

Soil Testing Engineers, Inc.

316 HIGHLANDIA DRIVE • P.O. BOX 83710 • BATON ROUGE, LOUISIANA 70884
TELEPHONE (504) 752-4790 • FAX (504) 752-4878

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VERNON C. ASHWORTH, MS
CERTIFIED PROFESSIONAL GEOLOGIST

KENNETH A. FLUKER, MSCE
DANIEL L. FRANKLIN, JR. MSCE

October 24, 1994

Mr. Ara Arman
Woodward-Clyde Consultants
P. O. Box 66317
Baton Rouge, Louisiana 70896

Re: LIGO Resistivity Tests
STE File: 94-1666

Dear Mr. Arman:

Attached is a data table of the resistivity soil test box determinations. The soil samples tested were the LIGO composite samples provided by Woodward-Clyde.

The tests were performed in accordance with the Texas DOT TEX-129-E (1986) and the LA DOTD TR 429-77 procedures.

The Sample 1 and Sample 2 test data shows a variation or "sharp" rise for the first tests (R_2, R_7, and R_8) after tested at initial/natural moisture content. I have reviewed the tests, the test method and resistivity technical literature. It appears that the resistivity rise is due, in part, to the dielectric effect of the distilled water used for the test.

The initial/natural moisture content (tests R_1, R_6, and R_{12}) are usable for in-situ conditions. The final tests values (tests R_5, R_{10}, and R_{13}) are applicable for flooded conditions.

The tests are applicable for natural effects but, probably not applicable for electrical, electromagnetic conditions, or static grounding conditions.

If there are any questions please call me.

Sincerely,

Charles S. Hedges, P.E.

ligo.let 94-1666

STE
Soil Testing Engineers, Inc.

LIGO/ Cal. Tech Project
Livingston Parish, Louisiana
for
Woodward-Clyde Consultants
Baton Rouge, Louisiana

Soil Sample Laboratory Resistivity and pH Test Results

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NOTES:

1) N is natural moisture content of sample as received

2) Soil box factor (SBF) = 6.90 cm

3) First reading after 6 hour "cure." Second reading after 50 hour "cure." The high readings for R_7 and R_8, which had 6 hour cure, were apparently due to dielectric influence of the distilled water without of sufficient cure-time of allow "dissolution" and equillbrium of conductive clay minerals or chemical electrolyte salts.

RESISTIVITY V.S. CORROSION TABLE E-2

TABLE E-2

RESISTIVITY VS. CORROSION POTENTIAL

Specific Conductivity, cm/ohm	Specific Resistivity, cm/ohm	Expected Corrosion Attack
$>10^{-3}$	<1,000	very strongly aggressive
10^{-3} -3.3 x 10^{-4}	1,000 -3,000	strongly aggressive
3.3 x 10^{-4} -2 x 10^{-4}	3,000 - 5,000	aggressive
2 x 10^{-4} -10^{-4}	5,000 - 10,000	moderately aggressive
10^{-4} -5 x 10^{-5}	10,000 - 20,000	slightly aggressive
$<10^{-5}$	>20,000	virtually nonaggressive

TEST METHOD FOR RESISTIVITY

State Department of Highways and Public Transportation

Materials and Tests Division

METHOD OF TEST FOR THE RESISTIVITY OF SOILS MATERIAL

Scope

This test method outlines the procedure for obtaining the resistivity of soil and aggregate materials. Resistivity (ohm-cm) varies directly with the moisture content of the material until the minimum resistivity is obtained. This minimum resistivity value is defined as the resistivity of the material. Resistivity is an important factor in considering the use of metal pipe, earth-reinforcing strips and other metal items in earthwork.

Sample

Secure a representative sample of the total material of sufficient size to yield approximately 1300 grams of material passing the No. 8 mesh sieve. Test Method Tex-100-E should be followed in sizing and selecting a representative size.

Apparatus

1. Portable resistivity meter. Vibroground Model 293 or equal.

2. Small box with inside dimensions of 4 inches x 6 inches x 1-3/4 inches (see Figure 2).

3. Straightedge.

4. Drying pans, mixing pans, trowel and small scoop.

5. A No. 8 Standard U.S. Sieve meeting the requirements of Test Method Tex-907-K.

6. 200 ml graduated beaker.

7. A balance with a minimum capacity of 1500 grams which meets the requirements of Test Method Tex-901-K, Class II-D.

8. See Figure 1 for equipment set-up.

Materials

Distilled or demineralized water.

Procedure

1. Select a representative sample of the material to be tested for resistivity.

2. Dry the sample to constant weight in an oven at a temperature of 140° ± 9°F and allow to cool at room temperature.

3. Soils that form hard lumps or contain aggregates will be crushed to pass the No. 8 sieve.

4. The sample will be reduced by a sample splitter or quartering cloth to make a soil sample of approximately 1300 grams. Weigh sample to nearest 0.5 gram.

5. Place the wires from one clip on the left of the meter dial and the wires from the other clip on the right.

6. Fill the soil box with the well-mixed dry soil, compact lightly with fingers and level off the top with a straightedge. Connect the resistivity meter to the side terminals of the box. Place switch in Adj. position during preliminary adjustments. For maximum sensitivity place the switch in Read position. Read and record the resistance, in ohms, on the data sheet (page 3).

7. Empty the soil back into the mixing pan and add 100 ml of distilled or demineralized water at room temperature and mix until all the water is dispersed uniformly through the soil. Fill the soil box by lightly hand-compacting the wet soil, making sure that the soil completely fills the box. Level off the top of the hand-compacted sample with a straightedge. Connect the resistivity meter to the box (as in Step 6). Read and record the resistance on the data sheet.

8. Repeat the above procedure, using the same sample, adding distilled or demineralized water in increments of 50 ml for sandy soils and 100 ml for clayey soils. Insure that each addition of water is dispersed evenly through the sample. The resistivity readings should decrease for several readings before an increase is noted. The lowest resistivity reading before an increase will be the reading to use for calculating the resistivity of the soil, as shown on the data sheet (page 3). The resistivity for sandy soils is generally higher than for clayey soils. The sandy soils may contain higher levels of soluble salts and not always increase after several decreasing readings. For sandy soils the reading used to calculate the resistivity value will be when total saturation occurs. This is when water is observed rising to the surface during compaction of the sample.

Calculations

Resistivity (in ohm-cm) = Box Factor X Resistance.

$$\text{Soil Box Factor} = \frac{A}{D}\ \text{cm}$$

A = Area of one electrode

D = Distance between electrodes

$$\text{S.B.F.} = \frac{6'' \times 1.75'' \times 2.54\ \frac{\text{cm}}{\text{in.}}}{4''}$$

S.B.F. = 6.67 cm

NOTES:

1. The dial reading is resistance in ohms and is measured between the two electrodes that are separated by 4 inches of soil in this procedure.

2. Resistivity varies with temperature; therefore, it is important that the soil and added moisture be at uniform room temperature when mixed and tested.

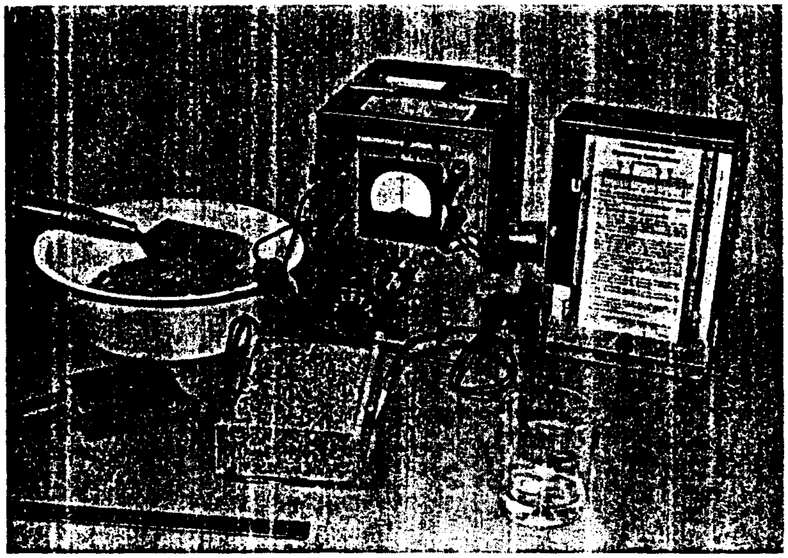


Figure 1

Project: ____________________ Date: ____________________

Location: ____________________ By: ____________________

Soil Type: ____________________

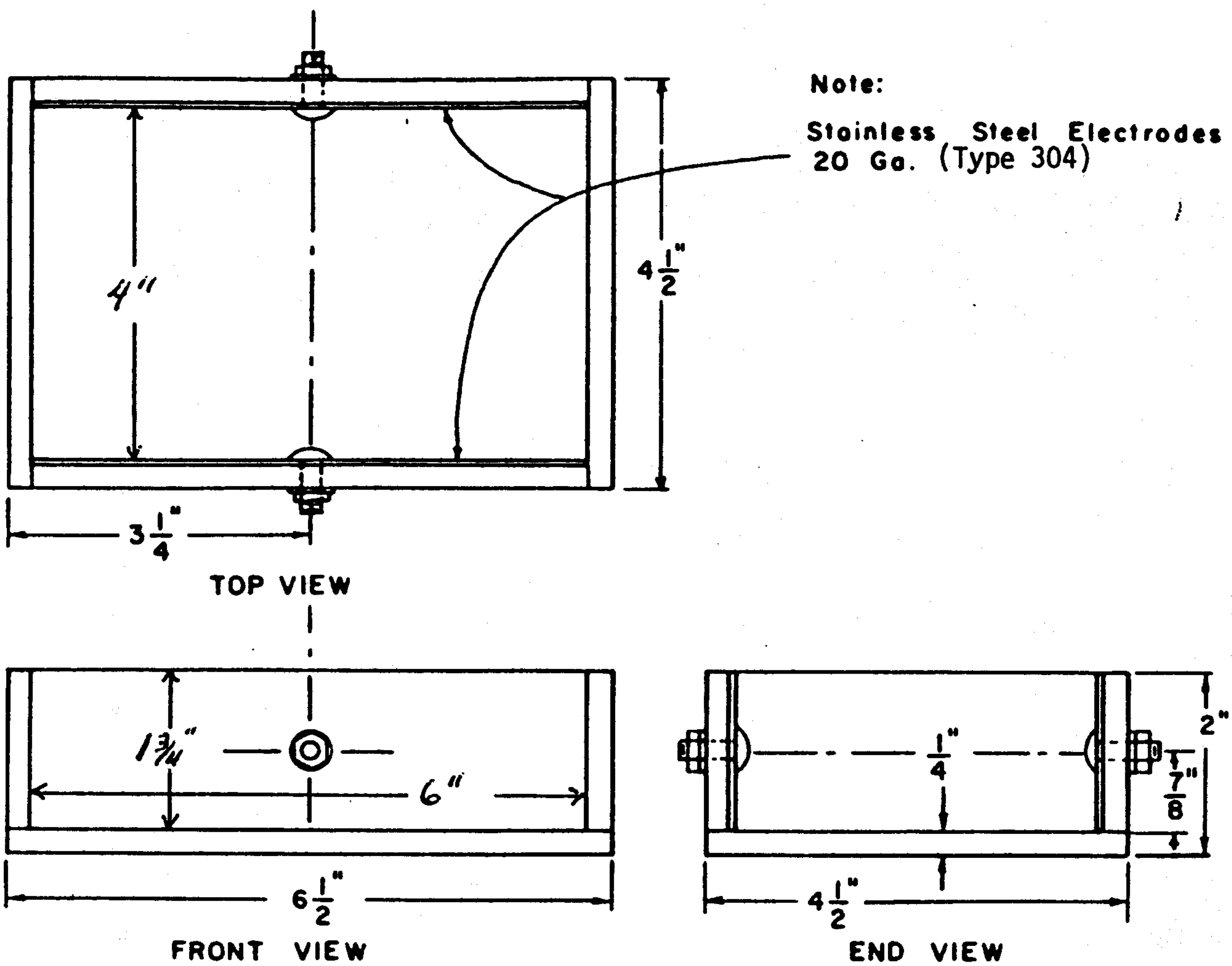
Laboratory Number	Location	Depth (ft)	Weight Soil (g)	Water Added (ml)	Multi-plier	Dial Reading	Resis-tance (ohms)
Example #1	SH 000	3-6	1300	0	10^4	1.0	10000
				150	10^4	1.0	10000
				150	10^4	.57	5700
				150	10^4	.33	3300
				150	10^4	.23	2300*
				150	10^4	.24	2400

*Minimum resistance reading

Resistivity (ohm-cm) = Box Factor X Resistance

R = 6.67 X 2300*

R = 15,341 ohm-cm



Soil Box For Laboratory Resistivity Determination

Material: 1/4" Plastic

Bottom - 1 Pc. 6 1/2" × 4 1/2" × 1/4"

Ends - 2 Pcs. 4 1/2" × 1 3/4" × 1/4"

Sides - 2 Pcs. 6" × 1 3/4" × 1/4"

Electrode - 2 Pcs. 20 Ga. Stainless Steel 6" × 1 3/4"

2 Ea. No. 8-32 × 3/4" Round Head Stainless Steel or Brass Machine Screw with Rubber Washer and Stainless Steel or Brass Washer and Nut.

Figure 2