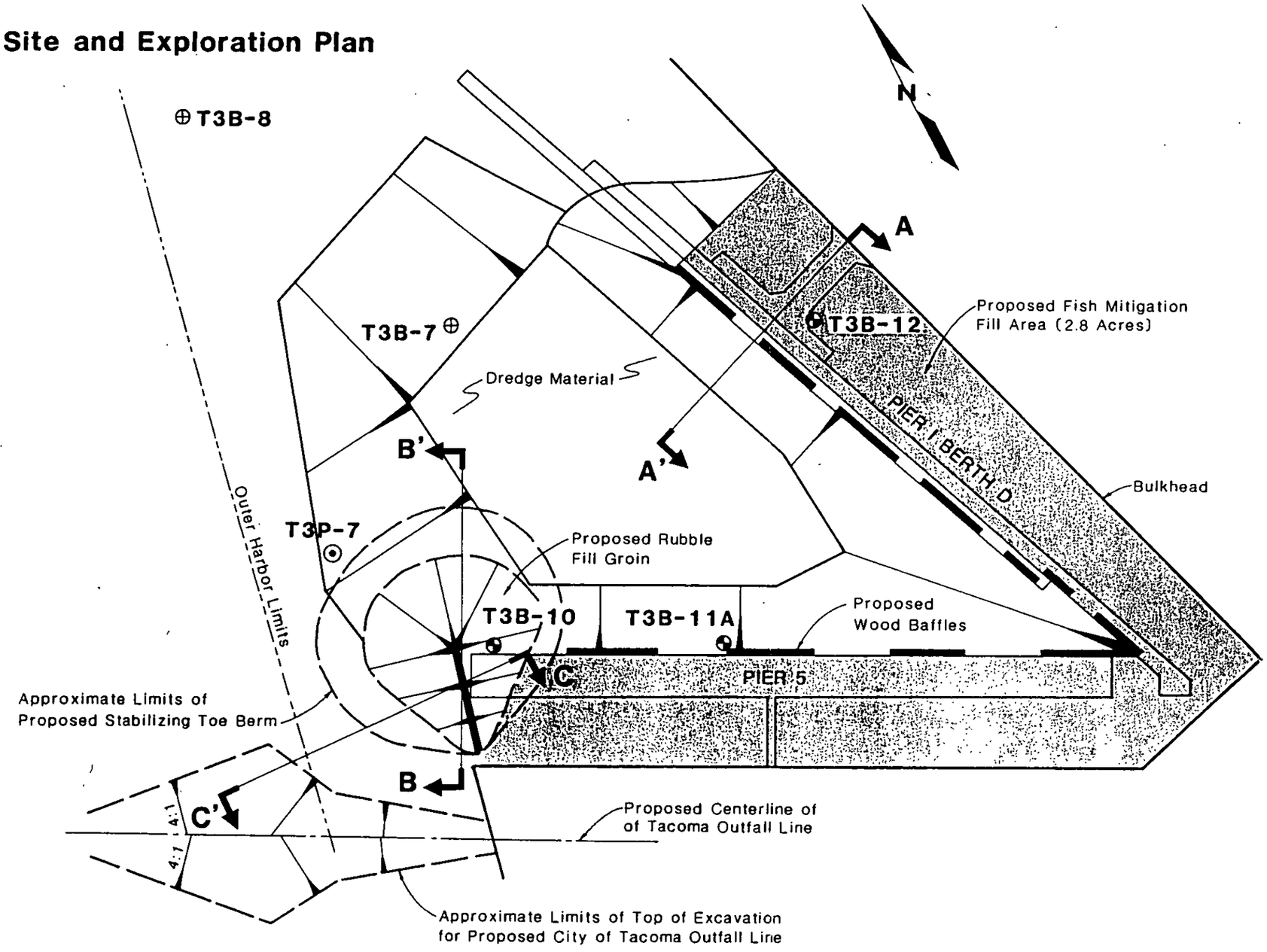
HARTCROWSER

Earth and Environmental Technologies

Subsurface Explorations and Geotechnical Engineering Study Terminal 3 Fish Mitigation Fill (Piers 5 and 1D) Port of Tacoma, Washington

J-1682-01

Site and Exploration Plan



A A' Cross Section Location and Designation

Exploration Location and Number

T3B-10	Hart Crowser Boring, Current Study
T3B-8	Previous Hart Crowser Boring, (J-1680/1681)
T3P-7	Previous Hart Crowser Probe, (J-1680/1681)

Note: Drawing adapted from drawings entitled "Terminal 3 Development - Fish Mitigation Area Site Plan" (6 sheets), dated 1/20/87, prepared by ABAM Engineers.

0 100 200
Scale in Feet

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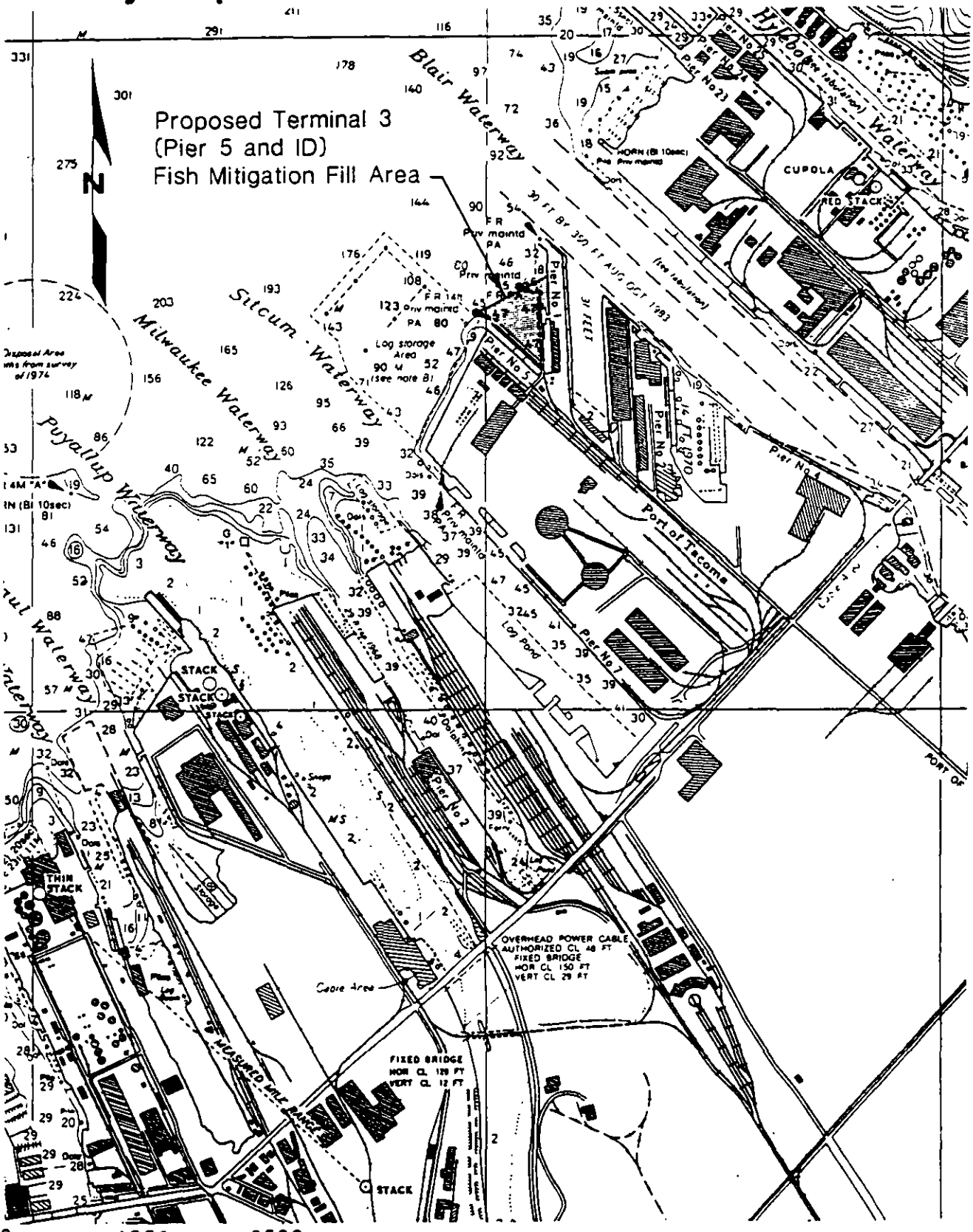
Figure 2

Vicinity Map-Terminal 3 Fish Mitigation Fill (Piers 5 and 1D)



0 1250 2500

Scale in Feet

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Figure 1

APPENDIX A
FIELD EXPLORATIONS

The program of subsurface explorations for this project included completion of three borings. In addition, three explorations (two borings and one cone penetration test) were completed in the area during a previous exploration program for the Terminal 3 Development project. The results of both exploration programs are presented on the exploration logs within this Appendix. The exploration logs are a representation of our interpretation of the drilling, sampling, and testing information. The depth where the soils or characteristics of the soils changed is noted. The change may be gradual. Soil samples recovered in the explorations were visually classified in the field in general accordance with the method presented on Figure A-1. A legend for the field exploration logs defining symbols and abbreviations utilized is also presented on Figure A-1.

The exploration locations are presented on Figures 2 and 3. The explorations were located in the field by hand taping or pacing from existing physical features. The approximate ground surface (mudline) elevation at the exploration locations, as presented on the exploration logs, are interpreted from elevations presented on drawing No. EP 4143-15 entitled "Terminal 3 and 4 Wharf Construction", provided by ABAM Engineers and the Port of Tacoma. The location and elevation of the explorations should be considered accurate to the degree implied by the method used.

Auger Borings

A total of three hollow-stem auger borings, designated T3B-10, T3B-11A, and T3B-12, were drilled from February 24 to February 26, 1987. The borings were completed to depths ranging from 42.5 to 49 feet below the mudline. The borings were advanced with a truck-mounted drill rig under subcontract to Hart Crowser, Inc. using a 3-3/8-inch inside diameter hollow-stem

auger. The drill rig was positioned on Piers 1D and 5 structures so that the drilling was accomplished offshore over the edge of the piers. The drilling was accomplished under the continuous observation of an engineering geologist from our firm. Detailed field logs were prepared of each boring. Samples were obtained on 2-1/2 to 5-foot depth intervals using the Standard Penetration Test (SPT) procedure and thin-walled Shelby tubes.

The Standard Penetration Test procedure as described in ASTM D 1587, was used to obtain disturbed samples. A standard 2-inch outside diameter, split-spoon sampler is driven into the soil a distance of 18 inches using a 140-pound hammer, free-falling 30 inches. The number of blows required to drive the sampler the last 12 inches is the Standard Penetration Resistance. This resistance, or blow count, provides a measure of the relative density of granular soils and consistency of cohesive soils. The blow counts are plotted on the boring logs at the respective sample depths. Samples were recovered from the split-barrel sampler, field classified and placed in water-tight jars and taken to our laboratory for further testing. The Standard Penetration Test is a useful quantitative tool from which density/consistency is determined. The results must be used in conjunction with other tests and engineering judgment.

If the high penetration resistance encountered in very dense materials precluded driving the total 18-inch sample interval, the penetration resistance for the partial penetration is entered on logs as follows: if the total penetration is greater than 6 inches and less than 18 inches, then the noted blow count is the sum of the number of blows completed after the first 6 inches of penetration, over the number of inches driven in excess of the first 6 inches. For example, a blow count series of 12 for 6 inches, 30 for 6 inches, and 50 for 3 inches, would be recorded as 80/9 inches. A blow count series of 32 for 6 inches and 50 for 4 inches would be reported as 50/4 inches. In the case where total penetration is less than 6 inches, the total number of blows and penetration are indicated.

In fine-grained soils, a 3-inch diameter thin-walled steel (Shelby) tube sampler was pushed hydraulically below the auger to obtain a relatively undisturbed sample for classification and testing. The tubes were sealed in the field and taken to our laboratory for extrusion and classification.

The boring logs are presented on Figures A-2 through A-4.

Two borings, T3B-7 and T3B-8, and one cone penetration test probe, T3P-7 were accomplished for a previous exploration program for the Port of Tacoma Terminal 3 project in October, 1986. The borings were accomplished using a SINCO 5000 rotary wash drill rig mounted on a barge. The probe was accomplished using the same drill rig equipped with an electric cone penetrometer. All explorations were accomplished under the continuous observation of a Hart Crowser geotechnical engineer. Details of the exploration methods were presented in Hart Crowser report No. J-1680/1681, dated October, 1986. Logs of the borings and probe are presented on Figures A-5 and A-6 and A-8. Figure A-7 presents a key to the electric cone penetrometer.

Key to Exploration Logs

Sample Descriptions

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance. Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 - 4	Very soft	0 - 2	<0.125
Loose	4 - 10	Soft	2 - 4	0.125 - 0.25
Medium dense	10 - 30	Medium stiff	4 - 8	0.25 - 0.5
Dense	30 - 50	Stiff	8 - 15	0.5 - 1.0
Very dense	>50	Very stiff	15 - 30	1.0 - 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptible moisture, probably above optimum

Minor Constituents

	Estimated Percentage
Not identified in description	0 - 5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Legends

Sampling

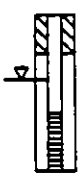
BORING SAMPLES

- Split Spoon
- Shelby Tube
- Cuttings
- Core Run
- * No Sample Recovery
- P Tube Pushed, Not Driven

TEST PIT SAMPLES

- Grab (Jar)
- Bag
- Shelby Tube

Ground Water Observations



- Surface Seal
- Ground Water Level on Date (ATD) At Time of Drilling
- Observation Well Tip or Slotted Section
- Ground Water Seepage (Test Pits)

Test Symbols

GS	Grain Size Classification
CN	Consolidation
TUU	Triaxial Unconsolidated Undrained
TCU	Triaxial Consolidated Undrained
TCD	Triaxial Consolidated Drained
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits

Water Content in Percent
Liquid Limit
Natural
Plastic Limit

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Figure A-1

APPENDIX B
LABORATORY TESTING PROGRAM

A laboratory testing program was performed for this study to evaluate the basic index and geotechnical engineering properties of the site soils. Laboratory tests were performed on both disturbed and relatively undisturbed samples. The laboratory tests performed and the procedures followed are outlined below.

Soil Classification

Soil samples recovered in the explorations were visually classified in the field and then taken to our laboratory where the classifications were verified in a relatively controlled environment. Visual-manual field and laboratory observations include density/consistency, moisture condition, grain size and plasticity estimates.

The classifications of selected samples were checked by performing laboratory tests such as Atterberg limits determinations and grain size analyses. Classifications were made in general accordance with the Unified Soil Classification (USC) System, ASTM D 2487, as presented on Figure B-1.

Water Content Determinations

Water contents were determined for most samples recovered in the explorations in general accordance with ASTM D 2216 as soon as possible following their arrival in our laboratory. The results of these tests are plotted at the respective sample depth on the exploration logs. In addition, the water contents of samples subjected to other testing have been determined and are presented on the exploration logs as well as with the various test results which follow in this appendix.

Atterberg Limits (AL)

Atterberg limits determinations were accomplished for selected fine-grained soil samples. The liquid limit and plastic limit were determined in general accordance with ASTM D 423 and ASTM D 424, respectively. The results of the Atterberg limits analyses and the plasticity characteristics are summarized on the Plasticity Chart, Figure B-2, which relates the plasticity index (liquid limit minus the plastic limit) to the liquid limit. The results of the Atterberg limits tests are shown graphically on the boring logs as well as where applicable on figures presenting various other test results.

Grain Size Analysis (GS)

Grain size analyses were performed on representative samples in general accordance with ASTM D 422. The wet sieve analysis method was used which determines the size distribution greater than the U.S. No. 200 mesh sieve. The results of the tests are presented as curves on Figure B-3 plotting percent finer by weight versus grain size.

200-Wash

Three samples were subjected to a modified grain size classification known as a 200-wash. The samples were "washed" through the No. 200 mesh sieve to determine the relative percentages of coarse and fine-grained material in the samples. The tests were performed in general accordance with ASTM D 1140. The results are presented as a single point plotted on the No. 200 sieve line on Figure B-3. That point represents the percentage of the sample finer than the No. 200 sieve.

Pocket Penetrometer (PP) and Torvane (TV)

The pocket penetrometer and torvane procedures provide quick approximate tests of the consistency (undrained shear strength) of a cohesive soil sample. The pocket penetrometer device consists of a calibrated spring

mechanism which measures penetration resistance of a 1/4-inch-diameter steel tip over a given distance. The penetration resistance is correlated to the unconfined compressive strength of the soil, which is typically twice the undrained shear strength of a saturated, cohesive soil.

The torvane device consists of a 1-inch-diameter plate with eight equally spaced and radially arranged 1/4-inch vanes. The vanes are pressed into the soil and the device is rotated. The vanes force a shear failure to take place over the area of the face of the plate, and the resistance at failure as measured by a calibrated spring is correlative to the undrained shear strength of the sample tested. The results of the pocket penetrometer and torvane tests are presented on the exploration logs.

Triaxial Unconsolidated Undrained Compression Test (TUU)

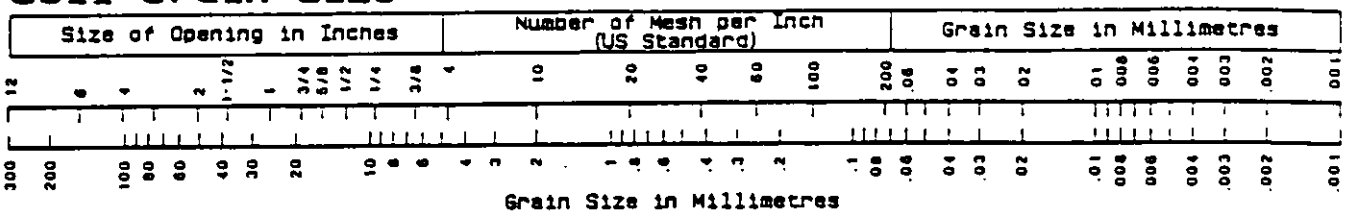
The triaxial unconsolidated undrained compression test is a method used to estimate the undrained shear strength of the soil. The test was performed in general accordance with ASTM D 2850. A relatively undisturbed fine-grained sample was trimmed to a length of about 5-1/2 to 6 inches, encased in a rubber membrane and placed in the triaxial cell. An all-around confining pressure was applied hydraulically, but the sample was not allowed to consolidate, and no back pressure was applied. An axial load was then applied at a constant strain rate to the sample without allowing drainage from the specimen. The stress-strain behavior was recorded until failure occurred. The failure stress was generally taken as the maximum load on the sample or the load recorded at 20 percent strain, whichever was greater. The test results plotted in terms of axial strain versus deviator stress are presented on Figures B-4 and B-5. The shear strength is considered to be one-half the maximum stress difference.

As noted on Figure B-5, test results for two samples, S-2 and S-4, from boring T3B-10 are believed to be invalid due to possible drainage of water from the sample prior to testing. The density and consistency of the material in the Shelby tube indicated a significantly lower shear strength

than measured in the triaxial cell. Therefore, we feel the shear strengths obtained from these two tests do not represent in-situ conditions.

Unified Soil Classification (USC) System

Soil Grain Size



COBBLES	GRAVEL	SAND	SILT and CLAY
Coarse-Grained Soils			Fine-Grained Soils

Coarse-Grained Soils

G W	G P	G M	G C	S W	S P	S M	S C
Clean GRAVEL <5% fines		GRAVEL with >12% fines		Clean SAND <5% fines		SAND with >12% fines	
GRAVEL >50% coarse fraction larger than No. 4				SAND >50% coarse fraction smaller than No. 4			
Coarse-Grained Soils >50% larger than No. 200 sieve							

G W and S W $\left(\frac{D_{60}}{D_{10}}\right)>4$ for G W, >6 for S W & $1\leq\left(\frac{(D_{30})^2}{D_{10}\times D_{60}}\right)\leq 3$

G P and S P Clean GRAVEL or SAND not meeting requirements for G W and S W

G M and S M Atterberg limits below A Line with PI <4

G C and S C Atterberg limits above A Line with PI >7

* Coarse-grained soils with percentage of fines between 5 and 12 are considered borderline cases requiring use of dual symbols.

D_{10}, D_{30}, and D_{60} are the particle diameter of which 10, 30, and 60 percent, respectively, of the soil weight are finer.

Fine-Grained Soils

M L	C L	O L	M H	C H	O H	Pt
SILT	CLAY	Organic	SILT	CLAY	Organic	Highly Organic Soils
Soils with Liquid Limit <50%			Soils with Liquid Limit >50%			
Fine-Grained Soils >50% smaller than No. 200 sieve						

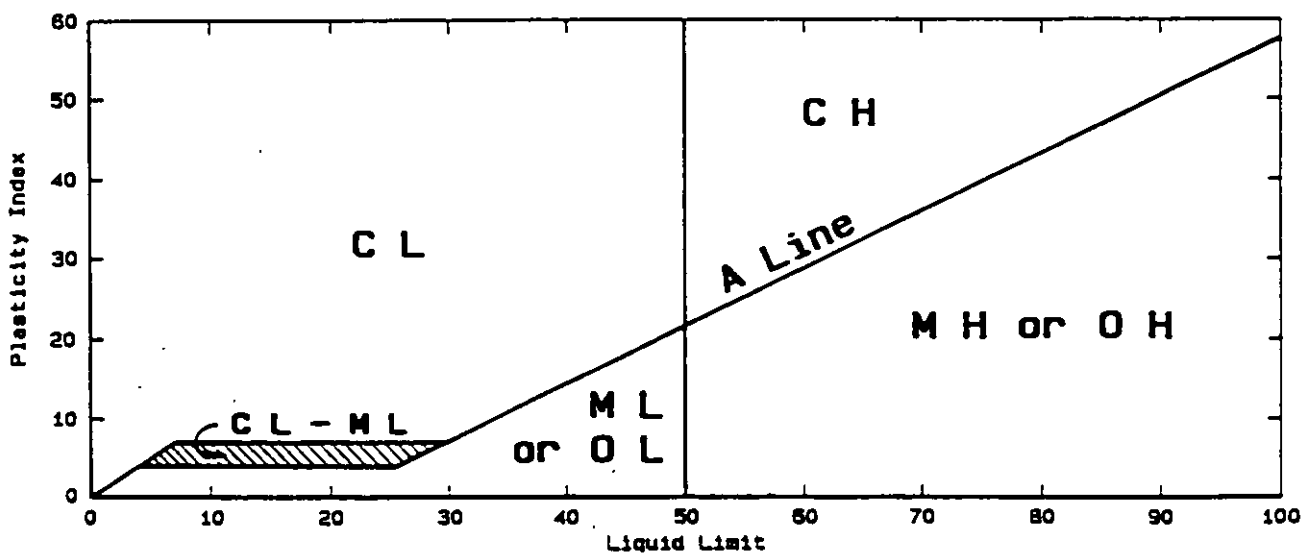


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Figure B-1

Boring Log T3B-10

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet -35 (MLLW)

Depth in Feet

Chemical odor noted in samples from mudline to about 10-foot-depth.

Very soft, wet, black, clayey SILT with abundant shells.

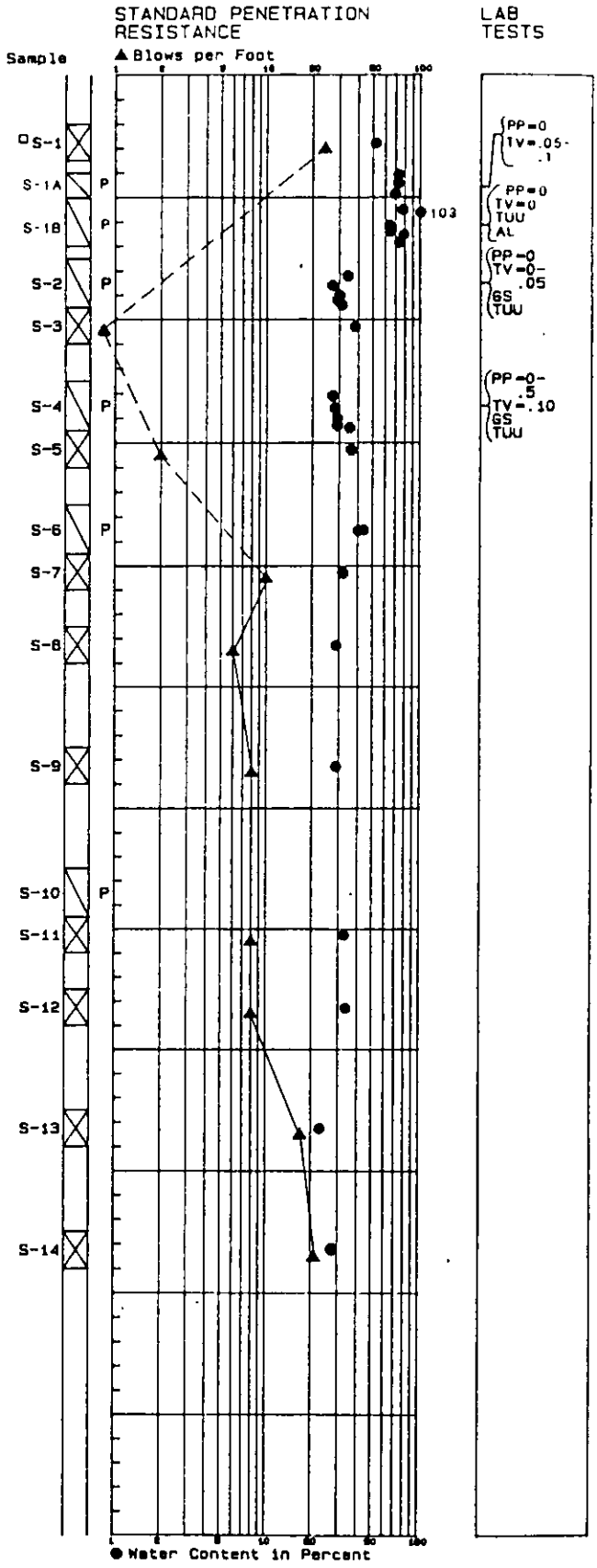
Very loose, wet, black, very silty SAND with silt seams.

Loose to medium dense, wet, dark gray, slightly silty to silty SAND.

Medium stiff, wet, gray, sandy SILT.

Medium dense, wet, gray, silty SAND.

Bottom of Boring at 49.0 Feet.
Completed 2/24/87.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

□ HIGH BLOW COUNT DUE TO DEBRIS IN SAMPLE TIP.

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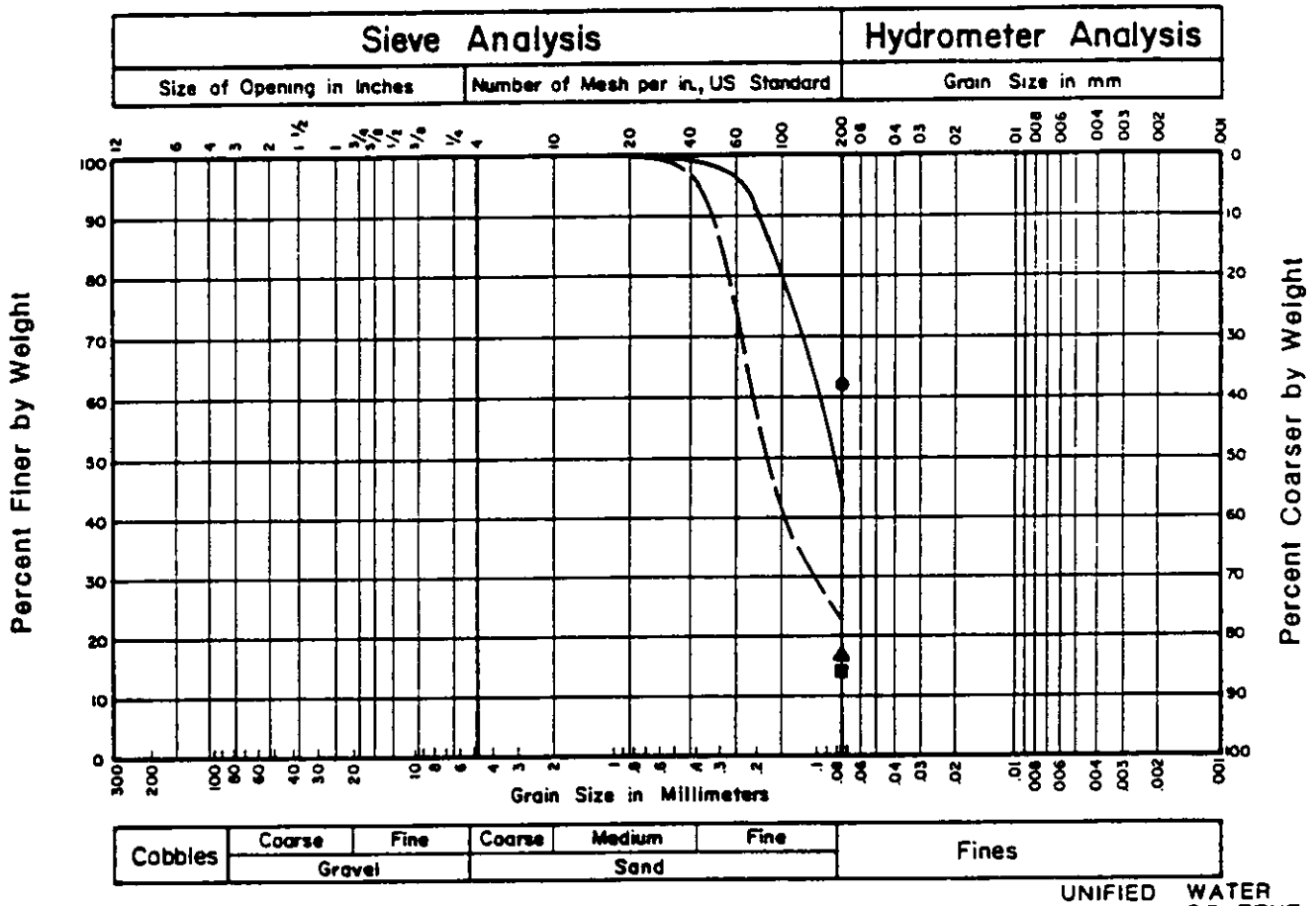
Figure A-2

Grain Size Classification



LINE SYMBOL	BORING NUMBER	SAMPLE NUMBER	DEPTH IN FEET	CLASSIFICATION	UNIFIED SOIL CLASS.	WATER CONTENT PERCENT
———	T3B-10	S-2	8.7-9.2	Very silty, fine SAND	SM	30
●	T3B-10	S-3	9.5-11.0	Very sandy SILT		38
— —	T3B-10	S-4	13.8-14.3	Silty fine SAND	SM	29
▲	T3B-10	S-5	14.5-16.0	Silty SAND		36
■	T3B-10	S-7	19.5-21.0	Silty SAND		32

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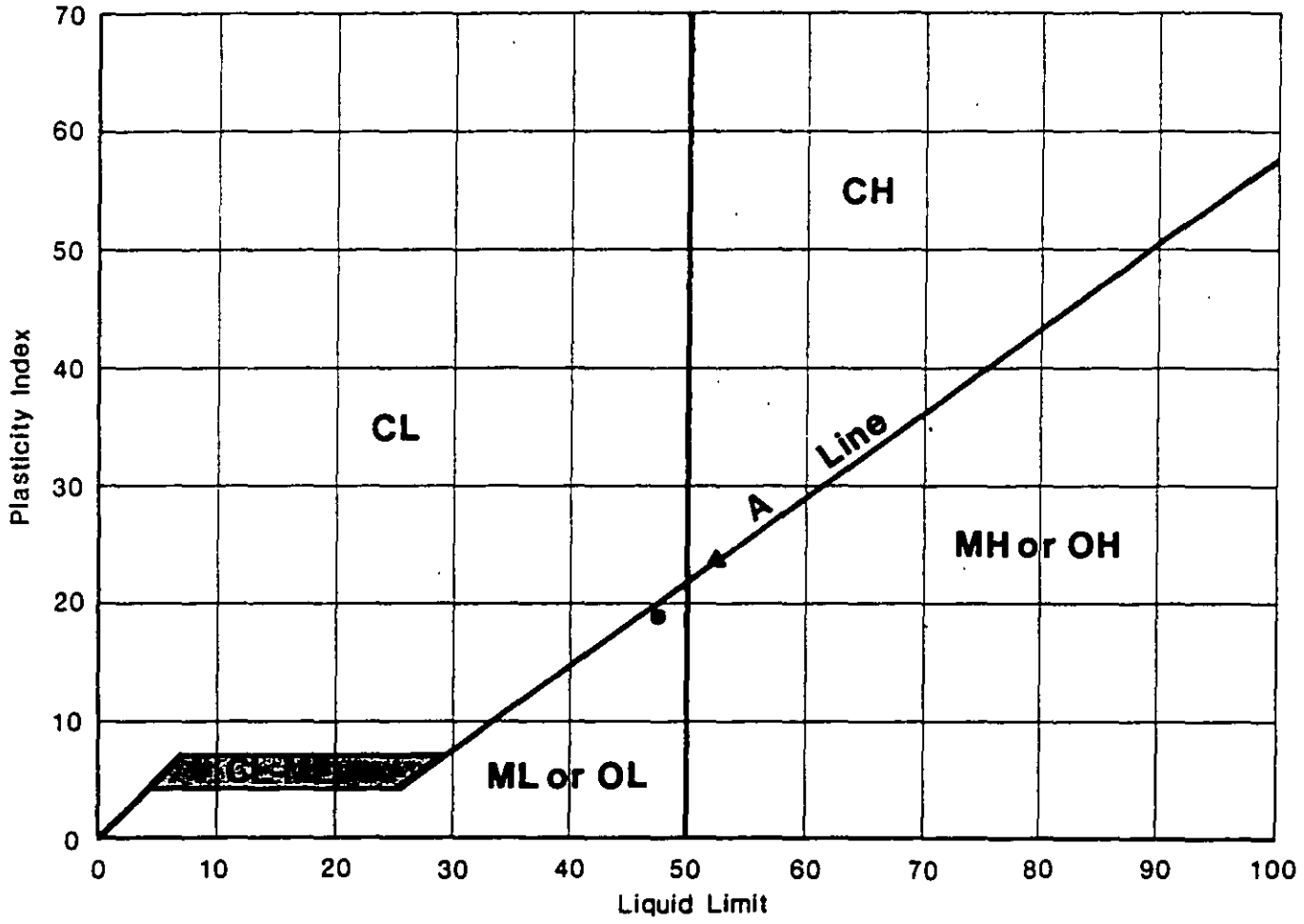
Figure B-3

Plasticity Chart



SYMBOL	BORING NUMBER	SAMPLE NUMBER	DEPTH IN FEET	WATER CONTENT IN PERCENT NAT.	L.L.	P.L.	P.I.	CLASSIFICATION	USC
●	T3B-10	S-1B	6.4-4.9	79	48	29	19	Clayey SILT	ML
▲	T3B-12	S-1	1.5-2.0	63	52	30	22	Silty CLAY	CH

L.L. LIQUID LIMIT
P.L. PLASTIC LIMIT
P.I. PLASTICITY INDEX
USC UNIFIED SOIL CLASSIFICATION

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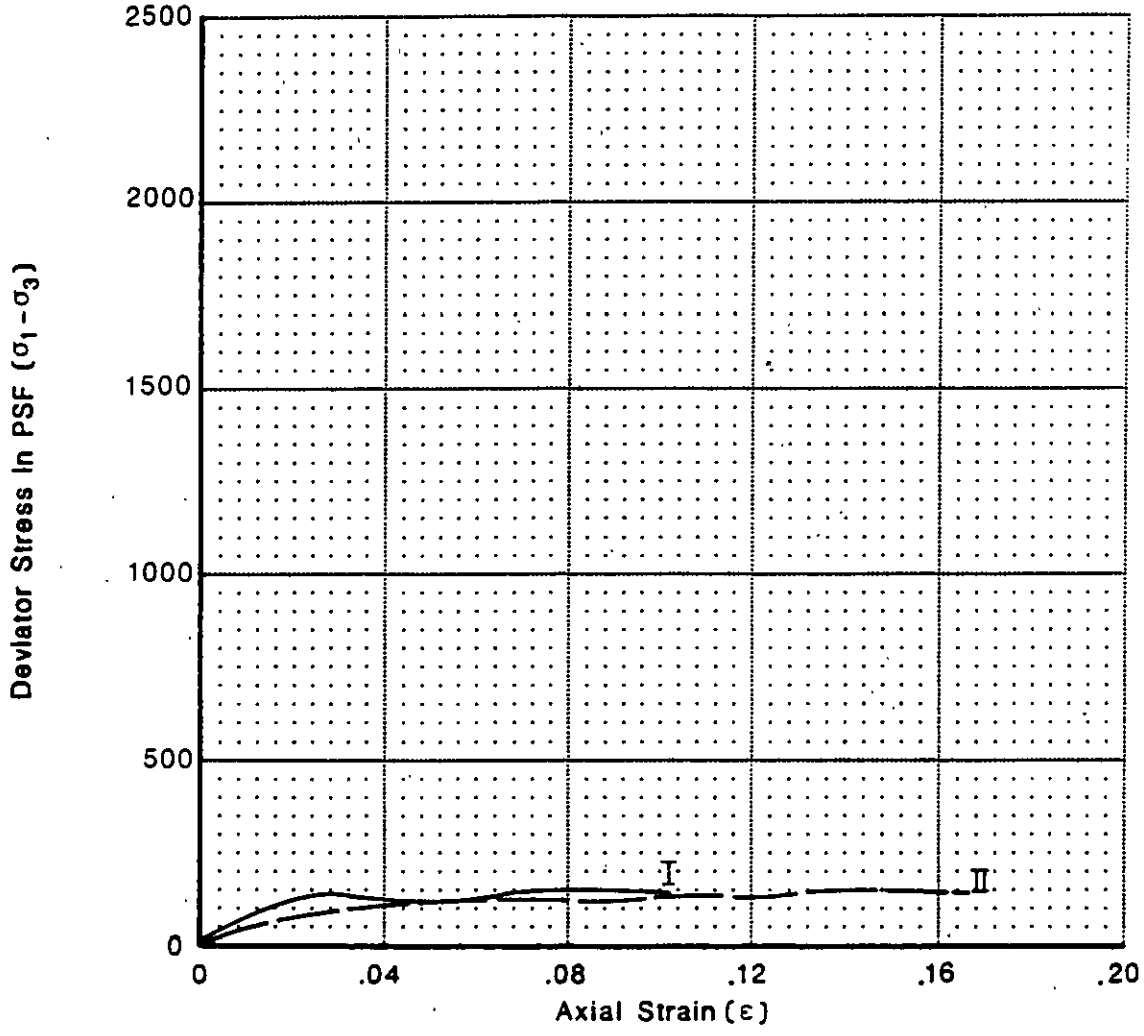
Figure B-2

Triaxial Compression Tests
Unconsolidated, Undrained



TEST NUMBER	EXPLOR NUMBER	SAMPLE NUMBER	DEPTH IN FEET	U.S.C.	DESCRIPTION
I	T3B-10	S-1B	6.4-4.9	ML	Clayey SILT
II	T3B-12	S-1	1.5-2.0	CH	Silty CLAY w/shells & slag

TEST NUMBER	WATER CONTENT IN PERCENT NAT.	L.L.	P.L.	P.I.	WET UNIT WEIGHT IN PCF	PRESSURE IN PSI CELL	BACK	SHEAR STRENGTH (S_u) IN PSF	STRAIN AT FAILURE (ε_f)
I	73	48	29	19	96	5	0	70	.07
II	63	52	30	22	102	0.8	0	80	.13

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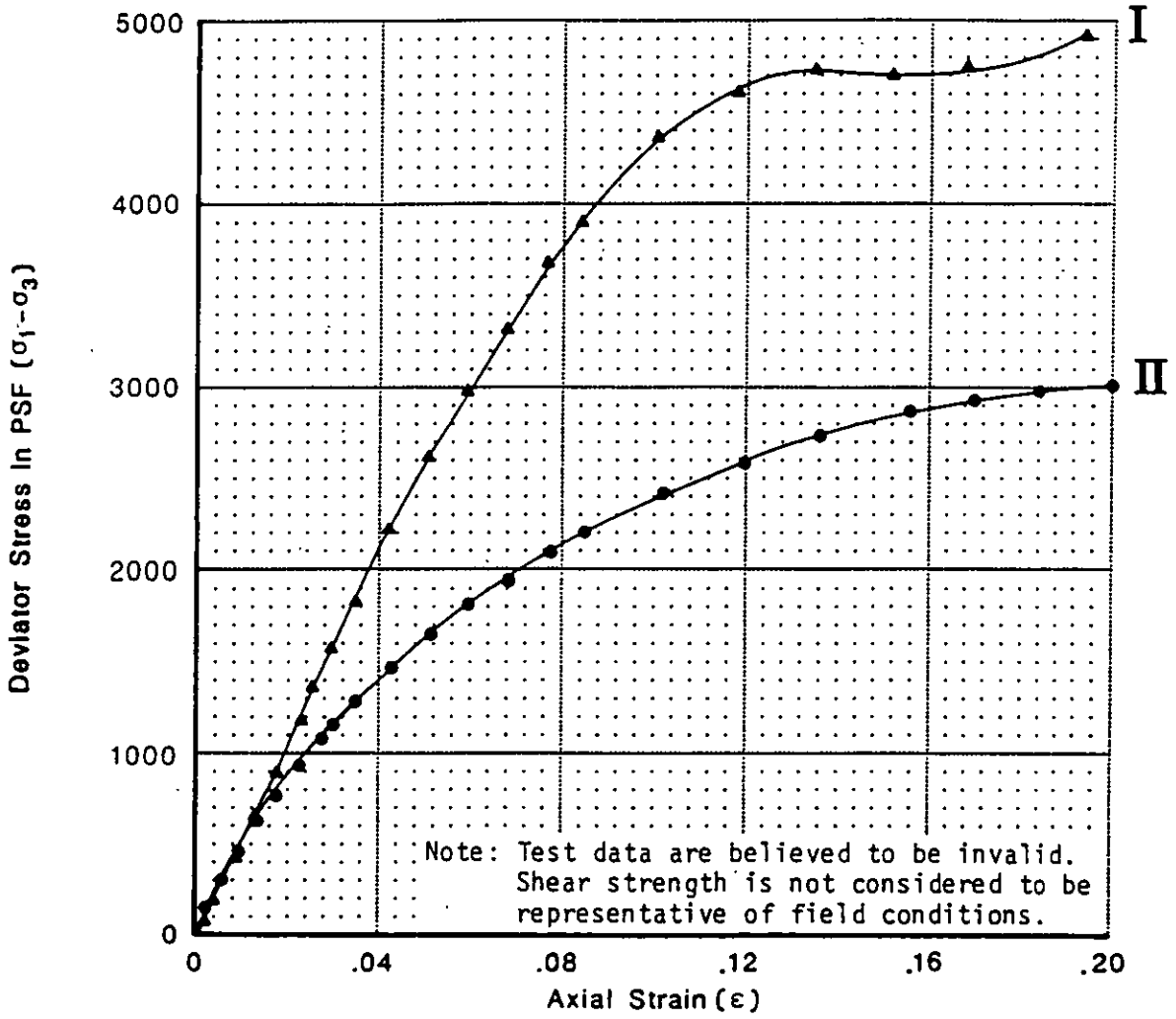
Figure B-4

Triaxial Compression Tests
Unconsolidated, Undrained



TEST NUMBER	EXPLOR NUMBER	SAMPLE NUMBER	DEPTH IN FEET	U.S.C.	DESCRIPTION
I	T3B-10	S-2	8.7-9.2	SM	Very silty fine SAND
II	T3B-10	S-4	13.8-14.3	SM	Silty fine SAND

TEST NUMBER	WATER CONTENT IN PERCENT NAT.	L.L.	P.L.	P.I.	WET UNIT WEIGHT IN PCF	PRESSURE IN PSI CELL	BACK	SHEAR STRENGTH (S_u) IN PSF	STRAIN AT FAILURE (ε_f)
I	31				119	5	0	2430	.20
II	29				115	7.5	0	1490	.20

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Figure B-5

Boring Log T3B-11A

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet -36 (MLLW)

Chemical odor noted in samples from mudline to about 10 feet below.

Very soft, wet, black, clayey SILT with shells.

Loose to medium dense, wet, black, silty SAND grading to slightly silty SAND with occasional silt seams.

Medium stiff, wet, gray, slightly sandy SILT.

Loose to medium dense, wet, gray, silty SAND.

Strong chemical odor noted while drilling.

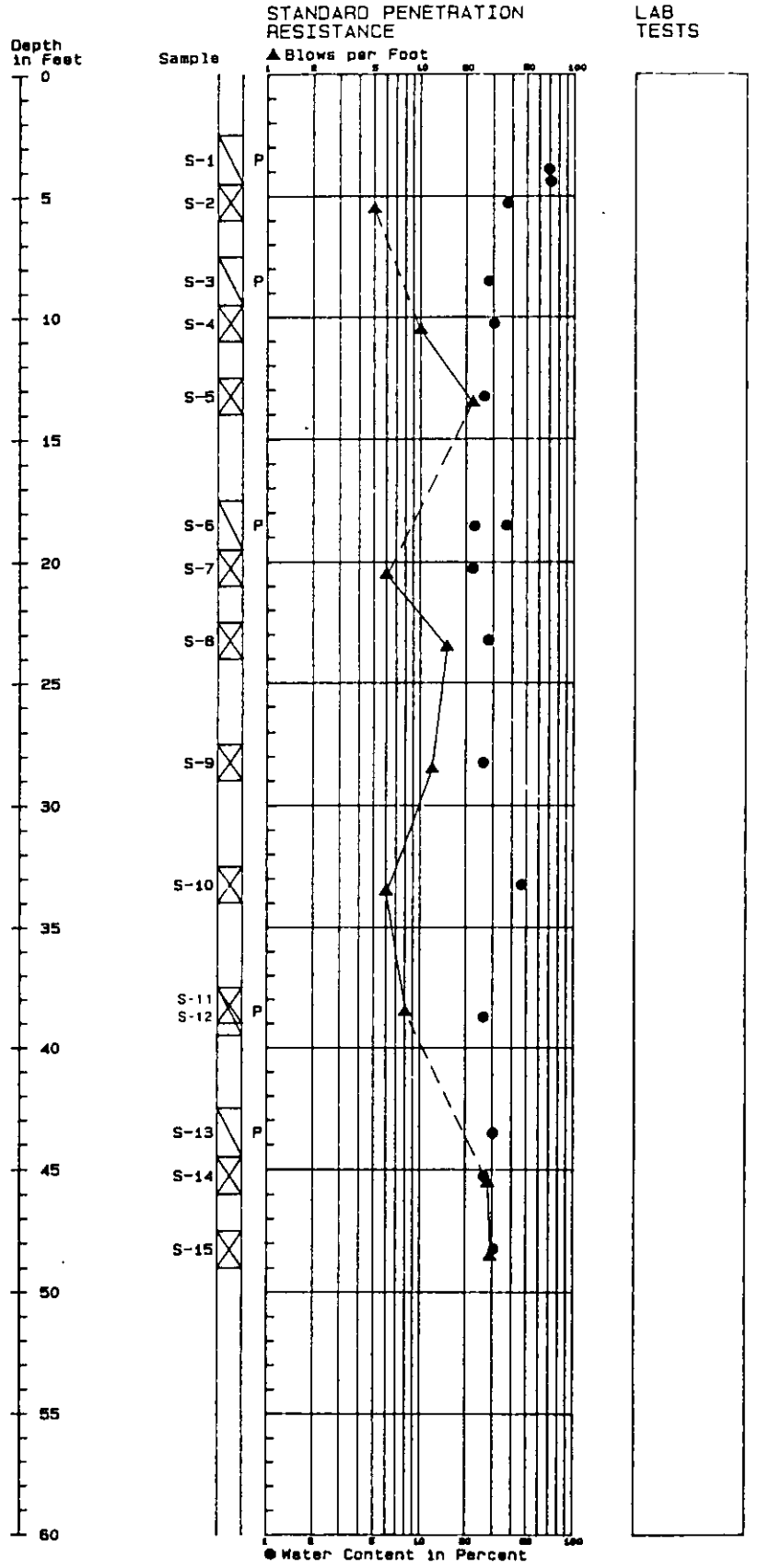
Medium dense, wet, gray SAND.

Medium stiff, wet, gray, clayey SILT

Stiff to very stiff, wet, gray, slightly sandy to sandy SILT.

Bottom of Boring at 49.0 Feet. Completed 2/25/87.

Note: A tube was attempted for S-11 with no recovery. A standard penetration test was then taken (S-12) in same zone. The blow count for S-12 may not be representative of actual soil conditions.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Soil descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Ground water level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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Figure A-3

Boring Log T3B-12

SOIL DESCRIPTIONS

Ground Surface Elevation in Feet -22 (MLLW)

Strong chemical odor noted in samples from mudline to bottom of boring.

- Very soft, wet, black, clayey SILT with shells and slag debris. Wire rope noted throughout zone.

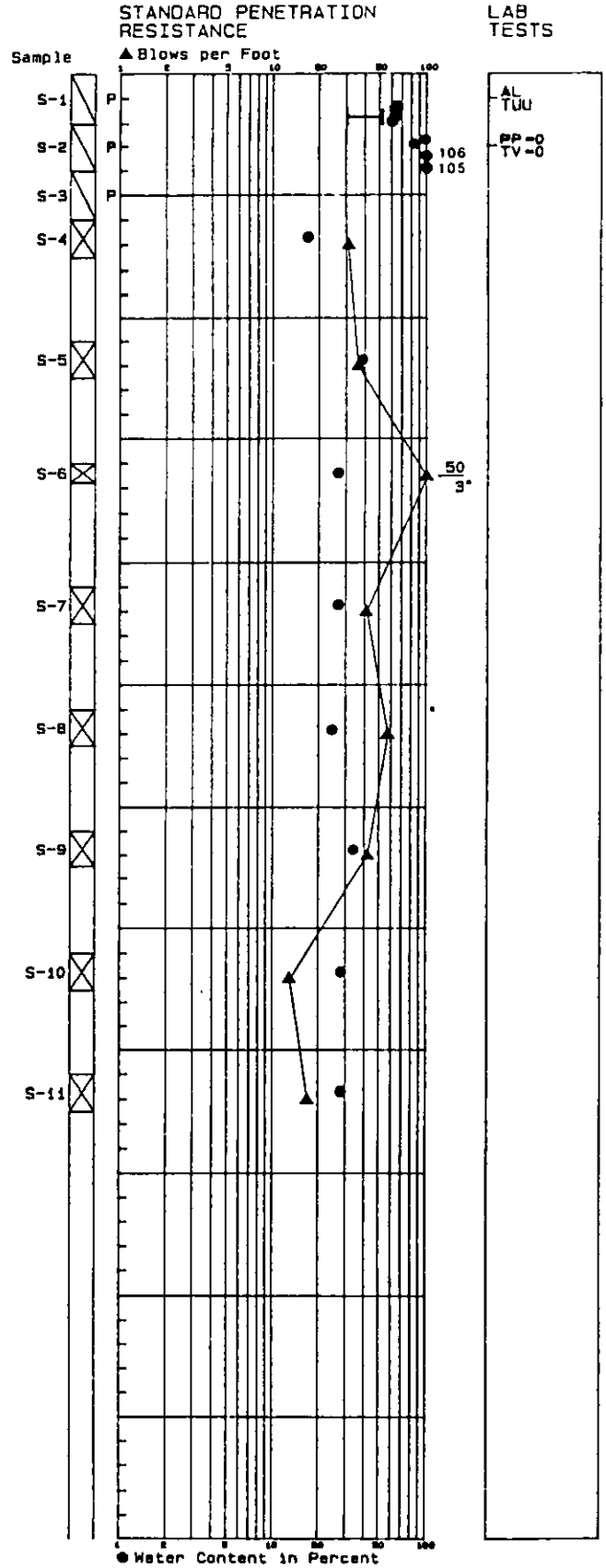
Dense, wet, dark gray, slightly silty SAND with some gravel. (FILL?)

Hard, wet, dark gray, sandy SILT. (FILL?)

Dense, wet, dark gray, slightly silty to silty, fine SAND with occasional wood fragments, roots and wire fragments. (FILL?)

Medium dense, wet, gray, slightly silty SAND.

Bottom of Boring at 42.5 Feet. Completed 2/21/87.



1. Refer to Figure A-1 for explanation of descriptions and symbols.
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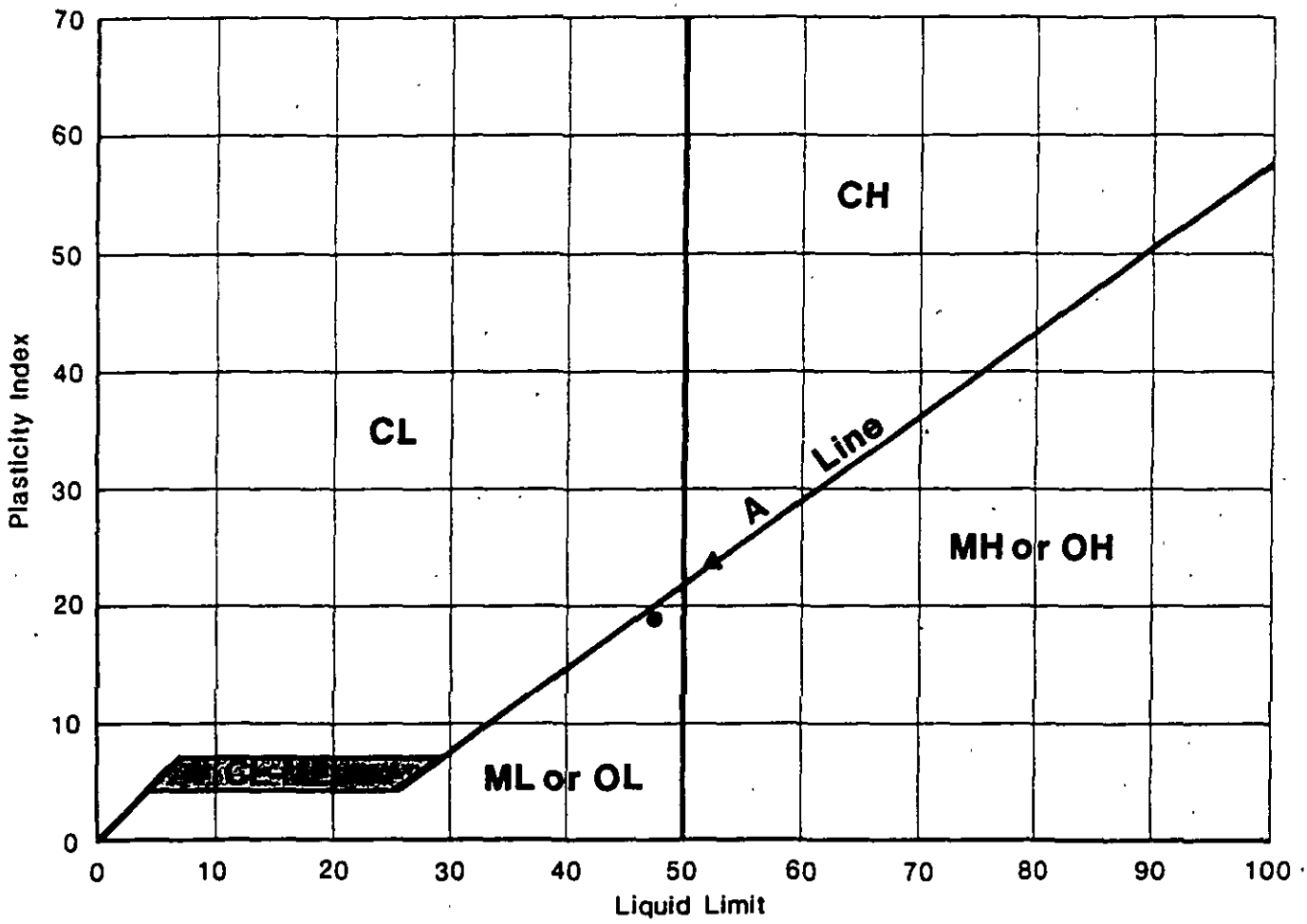
Figure A-4

Plasticity Chart



SYMBOL	BORING NUMBER	SAMPLE NUMBER	DEPTH IN FEET	WATER CONTENT IN PERCENT NAT.	L.L.	P.L.	P.I.	CLASSIFICATION	USC
●	T3B-10	S-1B	6.4-4.9	79	48	29	19	Clayey SILT	ML
▲	T3B-12	S-1	1.5-2.0	63	52	30	22	Silty CLAY	CH

L.L. LIQUID LIMIT
P.L. PLASTIC LIMIT
P.I. PLASTICITY INDEX
USC UNIFIED SOIL CLASSIFICATION

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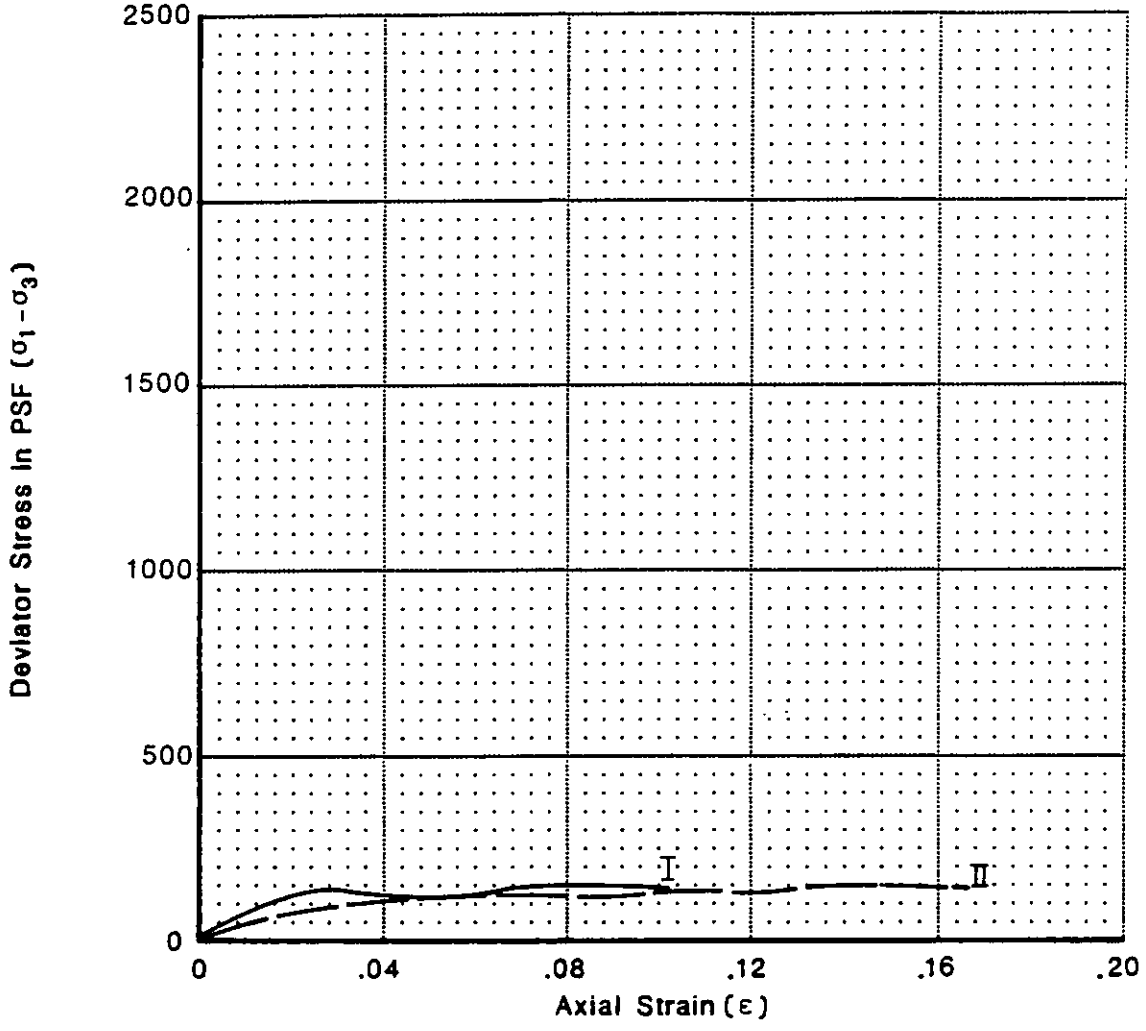
Figure B-2

Triaxial Compression Tests
Unconsolidated, Undrained



TEST NUMBER	EXPLOR NUMBER	SAMPLE NUMBER	DEPTH IN FEET	U.S.C.	DESCRIPTION
I	T3B-10	S-1B	6.4-4.9	ML	Clayey SILT
II	T3B-12	S-1	1.5-2.0	CH	Silty CLAY w/shells & slag

TEST NUMBER	WATER CONTENT IN PERCENT NAT.	L.L.	P.L.	P.I.	WET UNIT WEIGHT IN PCF	PRESSURE IN PSI CELL	BACK	SHEAR STRENGTH (S_u) IN PSF	STRAIN AT FAILURE (ε_f)
I	73	48	29	19	96	5	0	70	.07
II	63	52	30	22	102	0.8	0	80	.13

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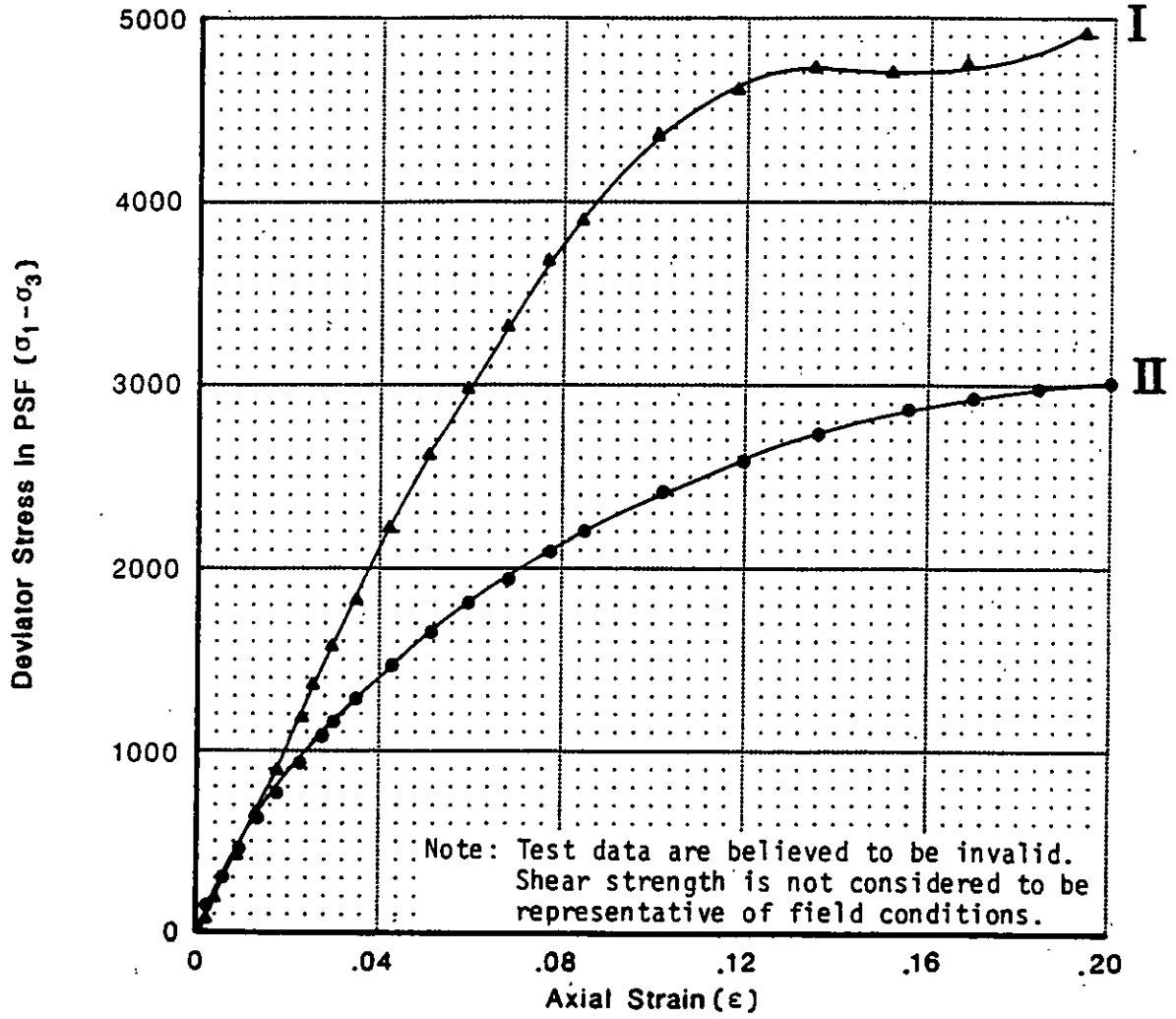
Figure B-4

Triaxial Compression Tests
Unconsolidated, Undrained



TEST NUMBER	EXPLOR NUMBER	SAMPLE NUMBER	DEPTH IN FEET	U.S.C.	DESCRIPTION
I	T3B-10	S-2	8.7-9.2	SM	Very silty fine SAND
II	T3B-10	S-4	13.8-14.3	SM	Silty fine SAND

TEST NUMBER	WATER CONTENT IN PERCENT NAT.	L.L.	P.L.	P.I.	WET UNIT WEIGHT IN PCF	PRESSURE IN PSI CELL	BACK	SHEAR STRENGTH (S_u) IN PSF	STRAIN AT FAILURE (ε_f)
I	31				119	5	0	2430	.20
II	29				115	7.5	0	1490	.20

J-1682-01 March 1987
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Figure B-5