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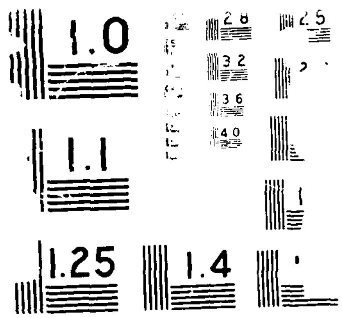
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US Army Corps of Engineers

RE-EVALUATION OF THE LOWER SAN FERNANDO DAM

Report 1

AN INVESTIGATION OF THE FEBRUARY 9, 1971 SLIDE

VOLUME II: APPENDIXES A-F

by

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US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

September 1989

Report 1 of a Series

GEOTECHNICAL LABORATORY

CONTENTS

NOTATIONS

The following symbols are used in this report:

Symbols and Abbreviations

Ac = area of triaxial test specimen after consolidation

a_{max} = maximum base rock acceleration

B_c = Skempton's pore pressure coefficient after consolidation

C = cone penetration test sounding prefix

c = cohesion intercept of a strength envelope

CR = clearance ratio of sampling tube = $\frac{ID - CE}{CE}$

where ID = inside diameter of tube
and CE = inside diameter of cutting edge

$C\overline{R}$ = consolidated undrained cyclic load triaxial test

$C\overline{R}\overline{R}$ = $C\overline{R}$ test followed by an $\overline{R}$ phase

D_{10} = diameter at which 10% of the soil is finer by weight

E = east

e_t = void ratio in sampling tube

e = void ratio

e_c = void ratio after consolidation

ES = exploration shaft

e_{1985} = in situ void ratio at time of sampling in 1985

e_{1971} = in situ void ratio immediately prior to 1971 San Fernando earthquake

F = force

F_a = maximum cyclic load applied in $C\overline{R}$ test

NOTATIONS
(continued)

FD = field density test

F_L = factor of safety against liquefaction susceptibility (equal to ratio of S_{us}/τ_d)

F_r = maximum load above anisotropic load felt by sample during cyclic loading in $C\overline{R}$ test

ft = feet

G = specific gravity of solids

G = shear modulus

g = acceleration due to gravity (32.2 feet per second)

G_{max} = shear modulus at very low strains

K_c = consolidation stress ratio = $\bar{\sigma}_{1c}/\bar{\sigma}_{3c}$

K_o = coefficient of lateral earth pressure, equal to $\bar{\sigma}_h/\bar{\sigma}_v$

k(t) = time history of average acceleration of sliding mass

kmax = maximum value of k(t)

ky = yield acceleration

LV = laboratory vane shear test; undrained

N = north

N = standard penetration test blowcount, blows/foot

NGVD = National Geodetic Vertical Datum; elevation

$\overline{p}$ = mean of minor and major effective principal stresses or vertical effective stress when used in the form c/p

q = one half of difference between major and minor principal stress; shear stress on plane inclined at 45° to major principal plane;

q_a = maximum applied q during $C\overline{R}$ test; summation of q_c and F_a/Ac

NOTATIONS
(continued)

q_c = q at completion of consolidation

q_p = q when peak shear stress is reached during triaxial test

q_r = maximum soil stress felt by sample during C$\overline{R}$ test; summation of q_c and F_r/Ac

q_s = q during steady state deformation

q_{us} = q during steady state deformation; undrained conditions

$\overline{R}$ = consolidated undrained, monotonically loaded triaxial test

S = south

S = degree of saturation

S = split-spoon sample boring number prefix

S = consolidated drained, monotonically loaded triaxial test

sec = seconds

S_{ds} = drained steady state shear strength

SSL = steady state line

S_{up} = peak undrained shear strength

S_{us} = undrained steady state shear strength

S_y = yield strength

t = time

t = tons

tsf = tons per square foot

TS = tripod tube sample number prefix

U = undisturbed sample boring number prefix

NOTATIONS
(continued)

U = undisturbed sample number prefix for fixed piston samples from borings

u_c = backpressure in triaxial test

V = volume

W = west

W = weight of sliding mass

α_s = slope of line through points representing steady state of deformation on stress path plot (q versus $\overline{p}$)

ΔV = change in volume

Δe = change in void ratio

δ = shear deformation

ϵ_a = axial strain

ϵ_s = axial strain when steady state deformation is reached during triaxial test

ϵ_p = axial strain when peak shear stress is reached during triaxial test

ϵ_{ec} = axial strain at end of cyclic loading in $C\overline{R}$ test (see Fig. F105)

ϵ_{rf} = axial strain at start of rapid failure in $C\overline{R}$ test (see Fig. 105)

ϵ_{tr} = triggering axial strain; axial strain required to trigger liquefaction failure

γ = shear strain

γ_t = total unit weight

γ_d = dry unit weight

γ_{dc} = dry unit weight at end of consolidation

γ_{tr} = triggering shear strain; shear strain required to trigger liquefaction failure

NOTATIONS
(concluded)

μ = Poisson's ratio

φ_s = friction angle at steady state of deformation in terms of effective stress

φ_p = maximum effective stress friction angle computed from a Mohr diagram

$\bar{\sigma}_h$ = horizontal effective stress

$\bar{\sigma}_1$ = major principal effective stress

$\bar{\sigma}_{1c}$ = major principal effective stress after consolidation

$\bar{\sigma}_{3ec}$ = minor principal effective stress at end of cyclic loading in CR test (see Fig. F105)

$\bar{\sigma}_{3s}$ = minor principal effective stress during steady state of deformation

$\bar{\sigma}_{3rf}$ = minor principal effective stress at start of rapid failure in CR test (see Fig. F105)

$\bar{\sigma}_3$ = minor principal effective stress

$\bar{\sigma}_{3c}$ = minor principal effective stress after consolidation

$\bar{\sigma}_f$ = effective normal stress on failure plane

$\bar{\sigma}_{fs}$ = effective normal stress on failure plane during steady state of deformation

$\bar{\sigma}_v$ = vertical effective stress

$\bar{\sigma}_o$ = octahedral effective stress; also contact stress between soil particles

τ = shear stress on failure plane

τ_d = driving shear stress on failure plane

APPENDIX A: SUBSURFACE EXPLORATION PROGRAM

APPENDIX A

SUBSURFACE EXPLORATION PROGRAM

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APPENDIX A

SUBSURFACE EXPLORATION PROGRAM

A.1 Purpose and Scope

The purpose of the exploration program was to characterize and obtain undisturbed samples of the sections of the dam which did not fail in 1971. Sampling was concentrated in the intact hydraulic fill shell on the downstream side of the dam.

The exploration program consisted of the following:

a. Six standard penetration test (SPT) borings performed by the Corps of Engineers Waterways Experiment Station (WES) between September 9 and 24, 1985.

b. Twelve cone penetration test soundings (CPT) performed by the Earth Technology Corporation (ERTEC) on September 18 and 19, 1985.

c. Six undisturbed sample borings performed by WES between September 25 and October 12, 1985.

d. Two groundwater observation wells installed by WES on September 25 and October 4, 1985.

e. One deep exploration shaft advanced by Zamborelli Drilling to obtain undisturbed samples, perform in situ density tests, and map sidewalls of the excavation.

An engineer from GEI was at the site during the investigation to coordinate and observe borings and soundings. Two engineers from GEI performed all geotechnical work in the exploration shaft.

The locations of all borings, soundings observation wells, and exploration shaft are shown in Fig. 5 of the main text. Their stations and elevations are presented in Table A1. Explorations were performed at 12 locations, Nos. 101 to 112, shown in Fig. 5. Borings and soundings are referenced to their location number. A description of the exploration shaft is presented in Appendix B.

The main purpose of the SPT borings and CPT soundings was to identify the various layers comprising the dam. The SPT and CPT data was used to identify locations and depths for undisturbed sampling from borings and exploration shaft.

A.2 Split-Spoon Sample (SPT) Borings

The SPT borings were performed to: 1) recover split-spoon samples to classify soils comprising the dam and foundation and 2) obtain standard penetration resistance values (N-values) of the various layers encountered. Six SPT borings (S101 through S105 and S111) were performed at the dam site. Detailed logs of these borings prepared by GEI are included at the end of this appendix.

Split-spoon samples were obtained every 5 feet in Boring S104. Intense stratification was observed in the split-spoon samples of the hydraulic fill in Boring S104, and it became evident that continuous sampling of the hydraulic fill in future borings would be necessary to define zonation within the hydraulic fill. Therefore, split-spoon samples in the remaining five SPT borings were obtained every 5 feet in the upper compacted fill, continuously in the hydraulic fill, and either continuously or at 5-foot intervals in the foundation soils. Each boring was advanced at least 5 feet into foundation material.

The SPT borings were drilled with a Failing 1500 truck-mounted drill rig using standard rotary wash boring techniques. Each borehole was advanced without casing, using N-rods and a 4-inch fishtail bit with deflectors which discharged the drilling mud upward. A bentonite drilling mud, maintained at the top of the borehole during the sampling and drilling operation, was used to stabilize the borehole. Split-spoon samples were taken using a 1-3/8-inch-I.D. sampling shoe attached to a 1½-inch-I.D. by 2.0-inch-O.D. split-barrel sampler. The split barrel had room for liners, but liners were not used. A 140-lb automatic trip hammer designed for a 30-inch free fall was used to drive the split-spoon sampler. The standard penetration test N-value used was taken from the second and third 6-inch interval of a 24-inch drive. The rate at which the blowcounts were delivered was approximately 30 to 40 blows per minute.

Stress wave energy measurements of the 140-lb trip hammer system were made by the U.S. Bureau of Reclamation (Farrar, 1986)[1]. The energy ratio of the hammer was found to be 72%.

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[1]List of References is presented at the end of the main text.

A.3 Cone Penetration Test (CPT) Soundings

Twelve CPT soundings (C101 to C112) were performed at the locations shown in Fig. 5. CPT sounding procedures and results are presented by the Earth Technology Corporation (1985).

The CPT soundings were conducted in general accordance with ASTM Specification D3441-79 using an electronic cone penetrometer. The cone tip and friction sleeve had outside diameters of 4.37 cm and a cross-sectional area of 15 sq cm.

A.4 Undisturbed Sample Borings

Undisturbed sample borings were performed to obtain undisturbed samples suitable for laboratory triaxial testing and void ratio measurements. Six undisturbed sample borings were performed at the site. Five undisturbed sample borings (U102 through U105 and U111) were located 5 feet east of the SPT borings with the same location numbers. One boring, U111A, was located 5 feet south of Boring S111. Logs of each of the undisturbed borings are presented at the end of this appendix.

Eighty fixed-piston tube samples were obtained in the six undisturbed sample borings. Data for each undisturbed fixed-piston sample is presented in Table A2.

The tube sample borings were advanced using the same equipment and drilling techniques as described in Section A.2. Each tube sample was obtained using a Hvorslev-type stationary fixed-piston sampler. Sampling tubes were 3.0-inch-O.D., 36-inch-long thin-walled galvanized coated steel tubes with a wall thickness of 1/16 inch. The cutting edge of each tube was machined and the clearance ratio, CR, of each tube was measured. Clearance ratio is defined and the values for each tube are presented in Table A.2. Clearance ratios of tubes ranged from 0.08 to 1.28% and averaged 0.6%.

The tube sampling procedure consisted of lowering the sampler to the bottom of the borehole with the actuating rods (attached to the fixed piston) inside the drill rods. The actuating rods were fixed to an independent frame that was set up over the borehole. The frame was supported on steel rods driven 2 feet into the ground. The sampler was pushed hydraulically in a smooth continuous motion until a pressure of 550 psi or 24 inches of penetration was reached. The penetration and any movements of the actuating rods and frame were carefully measured before and after each push. The tube was withdrawn from the bottom of the borehole in a smooth constant motion using hydraulic pressure to pull the tube at a rate of 1 inch per second or less for the first 2 feet. After the sampler was pulled free from the bottom of the borehole, withdrawal continued to the ground surface at a slow uniform rate no greater than 1 foot per second.

Special care was taken to avoid jarring or disturbing the tube samples during sampling, storage, and transportation. Each tube was held in a vertical position at all times from sampling in the field to arrival at GEI's laboratory in Winchester, Massachusetts. Precise measurements were made of sample penetration, sample recovery length, and any change in sample length during storage and transportation. Soil volume changes which occurred during the sampling operation, expressed as $\Delta V/V$, are summarized in Table A2. A large number of samples had very little volume change during sampling. No changes in sample length were recorded after storage and transportation to GEI's laboratory.

All undisturbed tube samples were brought to Futura Engineering Laboratories Inc., Santa Fee Springs, California for x-raying. A GEI engineer was present during x-raying to assist in handling the tubes.

A.5 Groundwater Observation Wells

Groundwater observation wells were installed at Locations 104 and 111 shown in Fig. 5. Groundwater observation well reports are presented at the end of this appendix. The following stabilized groundwater levels were recorded in each well:

Well No.	Date	Groundwater Elevation, NGVD, ft
CW104	10/17/85	1016.4
OW111	10/17/85	1011.3

Groundwater elevation in the exploration shaft, located 14 feet from OW111, was 1012.4 in December 1985.

TABLE A1 - SUMMARY OF BORING AND EXPLORATION SHAFT LOCATIONS AND ELEVATIONS
Lower San Fernando Dam - California

Number(1)	Station	Offset from Dam Centerline, ft	Ground Elevation (NGVD)
C101	16+45	68.8 S	1115.5
C102	16+50	54.0 N	1114.6
C103	9+40	132.0 S	1093.9
C104	9+40	73.1 S	1114.5
C105	9+40	23.4 S	1114.1
C106	5+90	73.1 S	1114.8
C107	16+45	23.4 S	1115.2
C108	12+85	132.0 S	1094.4
C109	12+85	73.1 S	1114.9
C110	12+85	23.4 S	1114.3
C111	5+90	132.0 S	1095.1
C112	5+90	23.4 S	1114.4
S101	16+40	68.8 S	1115.5
S102	16+40	54.0 N	1114.6
S103	9+35	132.0 S	1093.9
S104	9+35	73.1 S	1114.5
S105	9+35	23.4 S	1114.1
S111	5+85	132.0 S	1095.1
OW104	9+55	73.1 S	1114.5
OW111	5+95	132.0 S	1095.1
U102	16+35	54.0 N	1114.6
U103	9+30	132.0 S	1093.9
U104	9+30	73.1 S	1114.5
U105	9+30	23.4 S	1114.1
U111	5+80	132.0 S	1095.1
U111A	5+85	137.0 S	1095.1
ES111	5+85	120.0 S	1097.5

Note:

(1) C - Cone penetration test sounding
S - Split-spoon sample boring
OW - Observation well
U - Undisturbed sample boring
ES - Exploration shaft

Geotechnical Engineers Inc.

Project 85669
September 2, 1987

TABLE A2 - UNDISTURBED FIXED-PISTON SAMPLE DATA
Lower San Fernando Dam - California

Boring No.	Sample No.	Elevation(1) Top of Sample ft	Clearance(2) Ratio CR %	Penetration of Sampler P cm	Gross Recovery R cm	$\Delta V/V^{(3)}$ During Sampling %
U102	UF-1	1054.6	0.549	61.5	61.2	0.60
	UF-2	1052.6	0.509	61.0	60.6	0.36
	UF-3	1050.6	0.169	60.3	59.5	-1.00
	UF-4	1048.6	0.568	61.1	60.6	0.31
	UF-5	1046.6	0.494	60.3	59.9	0.32
U103	UF-1	1017.9	0.568	44.7	35.2	-20.36
	UF-2	1015.9	1.219	36.9	36.1	0.23
	UF-3	1013.9	0.925	59.6	58.4	-0.11
	UF-4	1011.9	0.941	60.1	59.5	0.87
	UF-5	1009.9	1.004	60.8	60.2	1.01
U104	UF-1	1046.8	0.596	61.3	60.7	0.20
	UF-2	1044.4	0.930	60.7	60.1	0.36
	UF-3	1042.5	0.642	60.7	59.6	-0.55
	UF-4	1040.5	0.665	61.0	60.0	-0.33
	UF-5	1033.5	0.766	60.2	57.4	-3.18
	UF-6	1031.5	0.797	60.2	58.7	-0.93
	UF-7	1024.5	0.660	55.8	53.4	-3.13
	UF-8	1022.5	0.582	59.8	58.8	-0.53
	UF-9	1020.5	0.741	55.8	55.7	1.31
	UF-10	1009.5	0.527	59.8	59.6	0.71
	UF-11	1007.5	0.288	43.4	41.2	-4.74
	UF-12	1005.5	0.247	24.6	23.9	-2.42
	UF-13	1003.5	0.743	57.6	56.0	-1.33
	UF-14	1001.5	0.623	60.5	60.1	0.58
U105	UF-1	1064.4	0.187	61.7	60.8	-1.09
	UF-2	1062.1	0.270	60.6	59.9	-0.62
	UF-3	1051.1	0.700	60.5	59.7	0.06
	UF-4	1049.1	0.656	61.2	60.5	0.16
	UF-5	1047.1	0.522	60.6	59.9	-0.12
	UF-6	1045.1	0.288	61.3	60.4	-0.90
	UF-7	1038.1	0.224	62.4	62.1	-0.03
	UF-8	1036.1	0.564	60.8	59.9	-0.37
	UF-9	1027.1	0.594	59.6	58.4	-0.85

Notes: See page 3

TABLE A2 - UNDISTURBED FIXED-PISTON SAMPLE DATA
Lower San Fernando Dam - California

Boring No.	Sample No.	Elevation(1) Top of Sample ft	Clearance(2) Ratio CR %	Penetration of Sampler P cm	Gross Recovery R cm	ΔV/V(3) During Sampling %
U105	UF-10	1025.1	1.054	62.1	60.8	-0.02
	UF-11	1022.1	0.196	59.6	59.0	-0.62
	UF-12	1020.1	0.439	61.0	59.8	-1.10
	UF-13	1018.1	0.564	60.9	59.8	-0.70
	UF-14	1016.1	0.169	60.4	59.7	-0.82
U111	UF-1	1071.1	0.425	60.8	53.3	-11.59
	UF-2	1069.1	0.330	61.4	52.0	-14.75
	UF-3	1047.1	0.320	63.1	63.3	0.96
	UF-4	1045.1	0.459	61.6	60.1	-1.54
	UF-5	1043.1	0.215	60.6	59.8	-0.90
	UF-6	1041.1	0.215	53.4	50.3	-5.40
	UF-7	1039.1	0.219	34.4	32.5	-5.11
	UF-8	1037.1	0.329	35.5	35.2	-0.19
	UF-9	1035.1	0.229	60.6	59.2	-1.86
	UF-10	1033.1	0.293	53.3	51.2	-3.38
	UF-11	1031.1	0.311	50.2	48.9	-1.98
	UF-12	1029.1	0.215	56.4	54.2	-3.49
	UF-13	1027.1	0.499	42.3	41.3	-1.39
	UF-14	1025.1	0.518	14.0	13.6	-1.85
	UF-15	1024.1	0.462	52.4	51.8	-0.13
	UF-16	1022.1	1.286	60.5	59.8	1.40
	UF-17	1020.1	0.082	51.0	50.0	-1.80
	UF-18	1018.1	0.408	60.6	60.1	-0.01
	UF-19	1016.1	1.183	61.3	60.3	0.71
	UF-20	1014.1	0.160	61.4	60.6	-0.99
	UF-21	1012.1	0.717	60.5	59.2	-0.74
	UF-22	1010.1	0.504	61.7	61.0	-0.14
	UF-23	1008.1	0.462	53.5	53.0	-0.02
U111A	UF-1	1047.1	0.490	60.8	61.1	1.48
	UF-2	1045.1	0.444	59.8	55.9	-5.69
	UF-3	1043.1	0.431	59.7	59.0	-0.32
	UF-4	1041.1	0.541	60.2	57.3	-3.78
	UF-5	1039.1	0.536	54.5	53.7	-0.41

Notes: See page 3

TABLE A2 - UNDISTURBED FIXED-PISTON SAMPLE DATA
Lower San Fernando Dam - California

Boring No.	Sample No.	Elevation(1) Top of Sample ft	Clearance(2) Ratio CR %	Penetration of Sampler P cm	Gross Recovery R cm	ΔV/V(3) During Sampling %
U111A	UF-6	1037.1	0.508	58.9	57.9	-0.70
	UF-7	1035.1	0.568	59.1	57.7	-1.26
	UF-8	1033.1	0.559	40.0	38.5	-2.67
	UF-9	1031.1	0.828	48.1	47.2	-0.24
	UF-10	1029.1	0.855	59.6	58.5	-0.16
	UF-11	1027.1	1.145	27.2	27.2	2.30
	UF-12	1025.1	1.116	24.7	24.1	-0.24
	UF-13	1024.1	0.800	49.2	48.6	0.37
	UF-14	1022.1	0.91	60.0	59.2	0.47
	UF-15	1020.1	0.550	56.1	53.9	-2.86
	UF-16	1018.1	1.186	60.2	59.7	1.54
	UF-17	1016.1	0.916	60.1	58.9	-0.19
	UF-18	1014.1	1.005	60.4	59.5	0.50
	UF-19	1012.1	0.824	60.6	59.5	-0.19
	UF-20	1010.1	0.620	59.3	58.4	-0.29
	UF-21	1008.1	0.710	61.1	60.6	0.60

Notes:

(1) Elevation Datum is NGVD.

(2) Clearance Ratio (CR) is defined as:

$$CR = \frac{ID-CE}{CE} \times 100\%$$

Where: ID = inside diameter of sampling tube
CE = diameter of cutting edge of sampling tube

(3) Change in volume during sampling ($\Delta V/V$) is computed as:

$$\Delta V/V = \left[\left(1+\frac{CR}{100}\right)^2 \times \frac{R}{P} - 1\right] \times 100 \text{ (in percent)}$$

Where: CR = clearance ratio of sample tube, defined above.
R = gross recovery
P = penetration length

Positive values indicate sample expansion; negative values indicate sample compression.

BORING LOCATION Sta 16+40, 68.8'S GROUND ELEVATION (NGVD) 1115.5 ft DATE START/FINISH 9/19/85 / 9/20/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 85.5 DRILLED BY F. Stewart WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NE 1) DATE - LOGGED BY J. R. Perkins DATE 9/19-20/85

S101

EL FT.	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
1115.5	0					Borehole advanced using standard rotary wash boring techniques with a bentonite drilling mud. Cleaned out borehole with a 4" fishtail bit with upward jetting.	
	1	S1	12 16 14 12	24	19		S1 - SILTY SAND, widely graded coarse to fine sand, ~25% nonplastic fines, ~15% gravel up to 1", brown (SM)
	2						
	3						
	4						
	5						
	6	S2	5 14 14 16	24	16		S2 - GRAVELLY SAND, widely graded coarse to fine sand, ~25% gravel up to 1", ~15% nonplastic fines, gray and brown (SW)
	7						
	8						
	9						
	10						
	11	S3	6 10 14 24	24	21		S3 - SILTY SAND, widely graded coarse to fine sand, ~25% nonplastic fines, ~10% gravel up to 1/2", brown and gray (SM)
	12						
	13						

BLOWS PER 6" - 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN - PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC - RECOVERY LENGTH OF SAMPLE
RQD - LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S - SPLIT SPOON SAMPLE
U - UNDISTURBED SAMPLES
US - SHELBY TUBE UD - DENISON
UF - FIXED PISTON UP - PITCHER
UO - OSTERBERG UG - GEI
▽ GROUNDWATER

NOTES

1) Groundwater levels not recorded because bentonite drilling mud used in borehole would produce inaccurate readings.

RE-EVALUATION OF THE STEEL IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC
WINCHESTER, MASSACHUSETTS

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 16+40, 68.8'S GROUND ELEVATION (NGVD) 1115.5 ft DATE START/FINISH 9/19/85 / 9/20/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 45.5 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY F.R. Perkins DATE 9/19-20/85

S101

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	13						
	14						
	15						
	16	S4	8 9 8 8	24	3		S4 - SANDY CLAY, sl. plastic fines, ~20% fine sand, brown (CL) Sample contained a 1" piece of gravel jammed in shoe.
	17						
	18						
	19						
	20						
	21	S5	5 5 7 9	24	14		S5 - SANDY CLAY, sl. to mod. plastic fines, ~15% fine sand, brown (CL) Occ. pockets of very dry gray clayey sand.
	22						
	23						
	24						
	25						
	26	S6	14 19 16 20	24	5		S6 - SAND, narrowly graded [illegible] ed. to fine sand, [illegible] % nonplastic fines, light brown (SP) [illegible] contained a [illegible] " piece of gravel [illegible] shoe.

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE — UD: DENISON
UF: FIXED PISTON — UP: PITCHER
UO: OSTERBERG — UG: GEL
GROUNDWATER

NOTES

See page 1.

RE-EVALUATION OF THE [illegible] IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 16+40, 68.8'S GROUND ELEVATION (NGVD) [illegible]15.5 ft DATE START/FINISH 9/19/85 / 9/20/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 85.5 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR 1) DATE - LOGGED BY J.R. Perkins DATE 9/19-20/85

S101

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	26–27	S6	14 19 16 20	24	5		S6 - See previous page.
	27–30						
	30–32	S7	10 12 14 20	24	15		S7 - SAND, narrowly graded med. to fine sand, mostly med., 3% coarse sand, 8% nonplastic fines, light brown (SP)
	32–35						
	35–37	S8	9 15 16 17	24	17		S8 - SAND, narrowly graded med. to fine sand, mostly fine, >10% nonplastic fines, light brown (SP-SM) Sample contained two thin sandy silt lenses.
	37–39						

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE — UD: DENISON
UF: FIXED PISTON — UP: PITCHER
UO: OSTERBERG — UG: GEL
▽ GROUNDWATER

NOTES

1) See Page 1

REEVALUATION OF [illegible] IN THE [illegible] DAM

GEOTECHNICAL ENGINEERS INC

DATE 3/[illegible]/86

PROJECT 85669

BORING LOCATION Sta 16+40, 68.8'S GROUND ELEVATION (NGVD) 1115.5 ft DATE START/FINISH 9/19/85 / 9/20/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 85.5 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/19-20/85

S101

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	39						
	40	S9	12 17 19 22	24	19		S9 SAND, narrowly graded fine sand, ~10% nonplastic fines, ~15% med. sand, brown (SP-SM) Sample contained three thin lenses of sandy silt.
	42–44						Approximate Interface - Rolled Fill / Hydraulic Fill
	45	S10	5 15 13 12	24	20		S10 SAND, narrowly graded med. to fine sand, ~10% nonplastic fines, brown (SP-SM) Sample contained three 1- to 2"-thick layers of stratified sandy clay to sandy silt.
	47	S11	8 5 14 20	24	19		S11-Top 3": SAND, widely graded coarse to fine sand, <5% fine gravel, <5% nonplastic fines, brown (SW) Next 5": SANDY SILT, non to sl. plastic fines, ~45% fine sand, stratified, dark olive brown (ML) Next 3": SILTY CLAY, mod. plastic fines, <5% fine sand, stratified, dark olive brown (CL) Bot 8": SAND, narrowly graded med. to fine sand, ~10% coarse sand, 5% nonplastic fines, light brown (SP)
	49	S12	11 15 15 14	24	19		S12-Top 8": SILTY SAND, narrowly graded fine sand, ~15% nonplastic fines, stratified (SM) Top 1/2 of section was brown and bottom 1/2 was gray. The above sections were separated by a 1/2"-thick layer of stratified sandy silt. Next 5": SAND, narrowly graded med. to fine sand, <5% nonplastic fines, light brown (SP) Bot 2": SANDY SILT, sl. plastic, stratified (ML)
	51–52	S13	13 10 13 14	24	14		S13-Top 5": SAND, narrowly graded fine sand, ~10% nonplastic fines, ~10% med. sand, olive gray (SP-SM) Next 2": SILTY CLAY and SANDY SILT, stratified (CL-ML) Next 4": SAND, widely graded coarse to fine sand, <5% nonplastic fines, olive gray (SW)

continued on next page

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE; UP: FIXED PISTON; UO: OSTERBERG; UD: DENISON; UP: PITCHER; UG: GEI
GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 16+40 68.8'S **GROUND ELEVATION (NGVD)** 1115.5 ft **DATE START/FINISH** 9/19/85 / 9/20/85

INCLINATION Vertical **BEARING** NA **TOTAL DEPTH (FT.)** 85.5 **DRILLED BY** F. Stewart, WES/COE

CASING ID Not used **CORE SIZE** NA **GROUNDWATER EL.** NR[1] **DATE** - **LOGGED BY** J. R Perkins **DATE** 9/19-20/85

S101

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	52–53	S13	13 10 13 14	24	14		S13-Bot 3": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, stratified, olive gray (SM)
	53–55	S14	8 13 12 10	24	16		S14: SAND, narrowly graded fine sand, ~10% nonplastic fines, ~10% med. sand, olive brown (SP-SM) Sample contained a 1/4" thick layer of stratified silty clay.
	55–57	S15	2 5 12 12	24	16		S15-Top 10": SANDY SILT, sl. plastic fines, ~35% fine sand, dark olive gray (ML) Bot 6": SAND, widely graded coarse to fine sand, ~10% nonplastic fines, ~10% gravel up to 1/2", brown (SW-SM)
	57–59	S16	6 11 16 13	24	14		S16-Top 2": SAND, widely graded coarse to fine sand, mostly med., ~5% nonplastic fines, brown (SW) Next 4": SILTY CLAY to SILTY SAND. Top of section consisted of stratified silty clay with fines content decreasing with depth to a silty fine sand containing ~25% nonplastic fines, dark olive gray (CL-SM) Bot 8": SAND, narrowly graded med. to fine sand, mostly med., <5% nonplastic fines, ~10% coarse sand, light gray (SP)
	59–61	S17	10 7 10 14	24	20		S17-Top 3": SILTY SAND, narrowly graded fine sand, ~15% nonplastic fines, ~10% med. sand, olive gray (SM) Next 4": SANDY CLAY, sl. to mod. plastic fines, ~15% fine sand, stratified, dark olive gray (CL) Bot 13": SILTY SAND, narrowly graded fine sand, 48% non co sl. plastic fines, dar olive (SM)
	61–63	S18	3 3 7 10	24	19		S18-Top 4": SILTY SAND, narrowly graded fine sand, ~15% nonplastic fines, dark olive (SM) Next 5": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, dark olive (CL) Q_p = 1.6, 1.7, 1.9 tsf Next 5": SANDY SILT, sl. plastic fines, ~40% fine sand, dark olive gray (ML) Bot 5": SILTY SAND, narrowly graded fine sand, ~35% non to sl. plastic fines, ~10% med. sand, dark gray (SM)
	63–65	S19	3 8 [illegible] 12	24	18		S19-Top 12": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, olive gray (SM) Sample contained layers of stratified silty clay up to 1/2" thick. Next 1": SAND, narrowly graded med. to fine sand, mostly med., <5% nonplastic fines, light brown (SP) Bot 5": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, dark olive brown (CL)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE UD: DENISON
UF: FIXED PISTON UP: PITCHER
UO: OSTERBERG UG: GEI
▽ GROUNDWATER

NOTES

[illegible] Page [illegible]

[illegible]EVAL[illegible] IN THE [illegible]OWER SA[illegible] FERNANDO DAM

GEOTECHNICAL ENGINEERS INC

DATE [illegible]

PROJECT [illegible]

BORING LOCATION Sta 16+40, 68.8'S GROUND ELEVATION (NGVD) 1125.5 ft DATE START/FINISH 9/19/85 / 9/20/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 95.5 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR 1) DATE ____ LOGGED BY J.R. Perkins DATE 9/19/85

S101

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN.	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	65–67	S20	2 5 7 10	24	19		S20 SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, very dark olive brown (CL) Occ. irregular pockets and lenses of silty fine sand. Q_p = 1.3, 1.3, 1.5 tsf, bottom to top
	67–69	S21	4 6 9 11	24	22		S21-Top 16": SANDY SILT, sl. plastic fines, ~45% fine sand, olive brown (SM-ML) Bot 6": SANDY CLAY, sl. to mod. plastic fines, ~20% fine sand, stratified, dark olive brown (CL) Occ. irregular pockets and lenses of silty fine sand.
	69–71	S22	4 7 10 13	24	24		S22 SANDY SILT, sl. plastic fines, ~30% fine sand, stratified, dark olive (ML) Occ. irregular pockets and lenses of silty fine sand.
	71–73	S23	WOR/5" 1/1" 12 18 19	24	18		S23-Top 7": SANDY CLAY, mod. plastic fines, <5% fine sand, stratified, very dark brown (CL) S_v = 0.5, 0.69 tsf Q_p = 1.0, 1.0 tsf
	73–75	S24	8 7 10 13	24	14		S24 SILTY CLAY, mod. plastic fines, <5% fine sand, stratified, dark olive (CL) Q_p = 2.1, 2.2, 2.2 tsf
	75–77	S25	6 6 8 12	24	24		S25 Similar to S24 (CL) Q_p = 1.8, 2.2, 2.2 tsf, bottom to top
	77–78	S26	9 10 13 20	24	24		S26-Top 6": SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, olive brown (SM) Next 12": SILTY CLAY, mod. plastic fines, <5% fine sand, stratified, dark olive brown (CL) Q_p = 1.8, 2.0, 2.1 tsf

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2 OIN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US - SHELBY TUBE; UP - FIXED PISTON; UO - OSTERBERG; UD - DENISON; UP - PITCHER; UG - GEI
GROUNDWATER

NOTES
1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC
DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 16+60, 68 R's GROUND ELEVATION (NGVD) 1115.5 ft DATE START/FINISH 9/19/85 / 9/20/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 85.5 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY T.R. Perkins DATE 9/19,20/85

S101

PG 7 OF 7

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	78						Approximate Interface - Hydraulic Fill / Alluvium
		S26	9 10 13 20	24	24		S26-Bot 6": SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, ~10% med. sand, blackish olive (SM)
	79	S27	9 45 50/1"	13	13		S27-Top 12": SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, ~10% med. sand, black (SM) Bot 1": Gravel
	80						
	81	S28	[illegible]	3	3		S28 SAND, narrowly graded fine sand, ~5% nonplastic fines, yellow-brown and gray (SP)
	82						
	83						
	84						
	85	S29	60	6	6		
							Bottom of Borehole - 85.5 ft
	86						
	87						
	88						
	89						
	90						
	91						

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE   UD: DENISON
UF: FIXED PISTON   UP: PITCHER
UO: OSTERBERG   UG: GEL
GROUNDWATER

NOTES

1) See Page 1

RE-EVALUATION OF THE [illegible] IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.
WINCHESTER, MASSACHUSETTS

DATE [illegible] 86
PROJECT 85669

BORING LOCATION [illegible] GROUND ELEVATION (NGVD) [illegible] DATE START/FINISH [illegible] / [illegible]

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) [illegible] DRILLED BY [illegible]

CASING ID Not used CORE SIZE NA GROUNDWATER EL [illegible] DATE [illegible] LOGGED BY [illegible] DATE [illegible]

S102

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
1114.6	0					Borehole advanced using standard rotary wash boring techniques with a bentonite drilling mud. Cleaned out borehole with a 4" fishtail bit with upward jetting.	
	1	S1	15 25 21 24	24	16		S1 - SILTY SAND, widely graded coarse to fine sand, mostly fine, <15% nonplastic fines, <10% gravel up to 1/2", brown (SM)
	2						
	3						
	4						
	5						
	6	S2	[illegible] 22	24	[illegible]		S2 - SILTY SAND, widely graded coarse to fine sand, mostly fine, <15% nonplastic fines, <5% gravel up to 3/4", brown (SM)
	7						
	8						
	9						
	10						
	11	S3	[illegible]	24	[illegible]		S3 - [illegible]
	12						

[illegible]

GROUNDWATER

BORING LOCATION Sta 16+40, 540'N GROUND ELEVATION (NGVD) [illegible] DATE START/FINISH 9/26/85 / [illegible]

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 26.0 DRILLED BY F. Stewart, -ES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR DATE - LOGGED BY [illegible] DATE [illegible]

S102

PG 2 OF 8

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	13						
	14						
	15						
	16	S4	10 15 14 16	24	8		S4 - GRAVELLY SAND, widely graded coarse to fine sand, ~20% gravel up to 3/4", ~10% nonplastic fines, gray and brown (SW-SM). Bottom of sample contained 2" of freshly broken gravel.
	17						
	18						
	19						
	20						
	21	S5	8 27 33 42	24	5		S5 - GRAVELLY SAND, widely graded coarse to fine sand, ~30% gravel up to 1 3/8", ~10% nonplastic fines, brown and gray (SW-SM)
	22						
	23						
	24						
	25	S6	8 15 [illegible] 22	24	9		S6 - GRAVELLY SAND, widely graded coarse to fine sand, ~2 % gravel up to 2", ~15% nonplastic fines, gray and brown (SM)

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE UD: DENISON
UF: FIXED PISTON UP: PITCHER
UO: OSTERBERG UG: GEL
GROUNDWATER

NOTES

[illegible] page [illegible]

REEVALUATION OF [illegible] ON THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE [illegible] 85

PROJECT [illegible]

BORING LOCATION Sta 16+40, 540'N GROUND ELEVATION (NGVD) 1114.6 DATE START/FINISH 9/16/85 / 9/17/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 36.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE [illegible]

S102

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	26–27	S6	8 15 22 22	24	9		S6 - See previous page.
	27–30						
	30–32	S7	9 13 20 22	24	9		S7 - SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, ~10% med. to coarse sand, brown (SM) Sample contained one 1" piece of gravel.
	32–35						
	35–37	S8	8 23 31 25	24	15		S8 - GRAVELLY SAND, widely graded coarse to fine sand, ~15% gravel up to 2", ~10% nonplastic fines, gray and brown (SW-SM)
	37–39						

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE; UP: FIXED PISTON; UO: OSTERBERG; UD: DENISON; UP: PITCHER; UB: BEI
GROUNDWATER

NOTES

1. See page [illegible]

RE-EVALUATION OF THE [illegible] IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE [illegible] 86

PROJECT 85669

BORING LOCATION Sta 16+40, 540'N	GROUND ELEVATION (NGVD) 1114.6	DATE START/FINISH 9/16/85 / 9/17/85	S102
INCLINATION Vertical BEARING NA	TOTAL DEPTH (FT.) 96.0	DRILLED BY F. Stewart, WES/COE	
CASING ID Not used CORE SIZE NA	GROUNDWATER EL. NR 1) DATE -	LOGGED BY J.R. Perkins DATE 9/16-17/85	PG 4 OF 8

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	39–40						Approximate Interface - Rolled Fill Hydraulic Fill
	40–42 (41)	S9	2 5 5 6	24	19		S9-Top 5": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, olive brown (SM) Gradual transition to next layer. Next 8": SANDY SILT, sl. plastic fines, ~45% fine sand, olive brown (ML) Bot 6": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, dark olive (CL) S_v = 0.66 tsf Q_p = 1.2 tsf
	42–44 (43)	S10	5 11 12 14	24	19		S10-Top 4": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, olive brown (CL) Next 1": SAND, widely graded coarse to fine sand, <5% nonplastic fines, brown (SW) Bot 14": SANDY CLAY, sl. plastic fines, ~45% fine sand, mottled black, brown and olive (CL) Portions of sample were dry and randomly mixed by color and clay content.
	44–46 (45)	S11	8 6 10 11	24	19		S11-Top 6": SANDY CLAY, sl. plastic fines, ~35% fine sand, mottled black, olive and brown (CL) Portions of sample were dry and randomly mixed by color and clay content. Next 5": SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, olive brown (CL) S_v = 0.46 tsf Q_p = 0.8 tsf Bot 7": Similar to top 6" (CL)
	46–48 (47)	S12	5 9 14 13	24	22		S12: SANDY CLAY, sl. plastic fines, ~20% fine sand, mottled black brown and olive (CL) Sample was randomly mixed by color and clay content. Sample contained pockets of dry clay.
	48–50 (49)	S13	6 9 11 13	24	19		S13: SANDY CLAY, sl. plastic fines, ~40% fine sand, mottled black, brown and olive (CL) Sample was randomly mixed by color and clay content. Sample contained pockets of dry clay.
	50–52 (51)	S14	[illegible] 7	24	21		S14-Top [illegible]": SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, light olive brown (SM) Occ. layers of silty clay up to 1/8" thick. Next 11": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, olive brown (CL) Occ. irregular lenses of silty fine sand. Bot 3": SILTY SAND, narrowly graded fine sand, ~15% nonplastic fines, dark olive brown (SM)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE — UD: DENISON
UF: FIXED PISTON — UP: PITCHER
UO: OSTERBERG — UG: GEL
GROUNDWATER

NOTES
1) See page [illegible]

REEVALUATION OF [illegible] IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC
DATE [illegible] 86
PROJECT 85669

BORING LOCATION Sta 16+40, 540'N	GROUND ELEVATION (NGVD) 1114.6	DATE START/FINISH 9-16-85 / 9-17-85	S102
INCLINATION Vertical BEARING NA	TOTAL DEPTH (FT) 96.0	DRILLED BY F. Stewart, [illegible]	
CASING ID Not used CORE SIZE NA	GROUNDWATER EL NR [illegible] DATE	LOGGED BY [illegible] Perrin DATE [illegible]	PG 5 OF 8

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	52–54	S15	4 4 8 8	24	24		S15-Top 5": SANDY CLAY, mod. plastic fines ~20% fine sand, stratified, olive brown (CL) Occ. lenses of silty fine sand. Next 6": SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, stratified, dark olive brown (SM) Next 11": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, olive brown (CL) Section contained a 2"-thick layer of silty fine sand at middle. Bot 2": SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, dark olive brown (SM)
	54–56	S16	2 5 6 9	24	24		S16-Top 6": SANDY CLAY, mod. plastic fines, ~15% very fine sand, stratified, olive brown (CL) Section contained one pocket of silty fine sand. Next 5": SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, stratified, olive brown (SM) Bot 3": SANDY CLAY, nonplastic fines, ~20% very fine sand, stratified, olive brown (CL)
	56–58	S17	3 8 10 14	24	24		S17-Top 10": SANDY CLAY, sl. to mod. plastic fines, ~20% very fine sand, stratified, olive brown (CL) Occ. layers of silty fine sand up to 2" thick. Next 11": SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, blackish gray (SM) Bot 3": SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, blackish gray (CL)
	58–60	S18	8 5 10 13	24	20		S18 Top 7": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, dark olive brown (SM) Next 10": SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, dark olive brown (CL) Bot 3": SAND, narrowly graded fine sand, ~10% nonplastic fines, olive brown (SP-SM)
	60–62	S19	[illegible] 12 13 12	24	21		S19-Top 4": SANDY SILT, sl. plastic fines, ~40% fine sand, dark olive gray (ML) Next 4": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, dark olive brown (CL) Bot 13": SAND, narrowly graded med. to fine sand, ~5% nonplastic fines, brown (SP)
	62–64	S20	[illegible]	24	15		S20-Top 3": Similar to bottom 3" of S19 (SP) Next 1.8": STRATIFIED SILTY CLAY (CL) Bot 12": SILTY SAND, narrowly graded fine sand, ~15% nonplastic fines, 10% med. sand, olive gray (SM)
	64–	S21	[illegible]	24	24		S21 SILTY SAND, narrowly graded fine sand, ~15% nonplastic fines, dark olive gray (SM) Sample contained three 2"-thick layers of stratified silty clay. Layers were located at the top, middle, and bottom sections of sample.

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE · UT: TENSION
UF: FIXED PISTON · P: PITCHER
UO: OSTERBERG · JB: BEI
▼ GROUNDWATER

NOTES
See Fig. [illegible]

[illegible] LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.
DATE [illegible] 86
PROJECT [illegible]

BORING LOCATION Sta 16+40, 540'N GROUND ELEVATION (NGVD) 1114.6 DATE START/FINISH [illegible] / [illegible] 85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 96.0 DRILLED BY F. Stewart, NES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NP[1] DATE - LOGGED BY J.R. Perkins DATE 9/[illegible] 85

S102

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	65	S21	3 3 6 8	24	24		S21 See previous page.
	66–67	S22	4 5 5 7	24	21		S22-Top 14": SILTY SAND, narrowly graded fine sand, ~50% nonplastic fines, dark olive gray (SM-ML) Bot 7": SANDY CLAY, sl. plastic fines, ~40% fine sand, stratified, dark olive gray (CL)
	68–69	S23	3 6 7 11	24	24		S23-Top 8": SANDY SILT, sl. plastic fines, ~40% fine sand, stratified, dark olive gray (ML) Bot 16": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, dark olive gray (CL). Occ. irregular pockets and lenses of silty fine sand. S_v = >1.0 tsf Q_p = 1.7, 1.8, 2.0 tsf
	70–71	S24	5 6 9 9	24	24		S24-Top 4": SANDY CLAY, sl. plastic fines, ~40% fine sand, dark olive gray (CL) Bot 20": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, dark olive gray (SM)
	72–73	S25	2 5 [illegible] 12	24	24		S25-Top 4": Similar to top 4" of S24 (CL) Bot 20": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, very dark olive (CL). Occ. irregular pockets and lenses of silty fine sand. S_v = >1.0 tsf Q_p = 1.5, 1.7, 1.5 tsf
	74–75	S26	2 [illegible] 7 8	24	24		S26 SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, very dark olive (CL) S_v = 0.76, 0.86, 0.90 tsf Q_p = 1.2, 1.2, 1.3 tsf
	76–77	S27	WOR [illegible]	24	24		S27 SANDY CLAY, sl. to mod. plastic fines, ~15% fine sand, stratified, dark olive brown (CL) S_v = [illegible].54, 0.60, 0.70 tsf Q_p = 0.9, [illegible], [illegible] tsf
	78						

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE
UF: FIXED PISTON
UO: OSTERBERG
UD: DENISON
UP: PITCHER
UG: GEI
▽ GROUNDWATER

NOTES

[illegible] page

[illegible]

[illegible] SANDY LAM

GEOTECHNICAL ENGINEERS INC

DATE [illegible] 86

PROJECT [illegible]

BORING LOCATION Sta 16+40, 540'N GROUND ELEVATION (NGVD) 1114.6 DATE START/FINISH 9/16/85 / 9/17/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 96.0 DRILLED BY F. Stewart, HFS/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE ___ LOGGED BY J.R. Perkins DATE 9/16-17/85

S102

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	78–80	S28	WOR/5", 1/1", 6, 7, 10	24	24		S28 SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, dark olive brown (CL) S_v = 0.81, 0.85, 0.93 tsf, top to bottom; Q_p = 1.5, 1.3, 1.3 tsf, top to bottom
	80–82	S29	WOR/5", 1/1", 5, 7, 10	24	24		S29 SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, dark olive brown (CL) S_v = 0.85, 0.93, 0.93 tsf; Q_p = 1.4, 1.4, 1.4 tsf
	82–84	S30	WOR, 7, 6, 9	24	24		S30 SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified dark olive brown (CL) S_v = 0.92, 0.98, 1.0 tsf, top to bottom; Q_p = 1.3, 1.4, 1.5 tsf, top to bottom
	84–86	S31	WOR, 6, 8, 10	24	24		S31 SANDY CLAY, mod. plastic fines, ~15% very fine sand, stratified, dark olive brown (CL)
	86–88	S32	5, 7, 9, 11	24	24		S32 SANDY CLAY, sl. plastic fines, ~20% very fine sand, stratified, dark olive brown (CL) Sample contained several lenses of silty fine sand. Sample contained two 2"-thick layers of silty fine sand.
	88–90	S33	5, 6, 9, 9	24	24		S33-Top 17": SILTY SAND, narrowly graded fine sand, ~35% non to sl. plastic fines, dark olive brown (SM) Section contained several stratified silty clay layers up to 1¼" thick. Bot 7": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, dark olive brown (CL)
	90–91	S34	5, 4, 5, 6	24	20		S34-Top 8": Similar to bottom 7" of S33 (CL)

Approximate interface - Hydraulic Fill / Alluvium

continued on next page

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE, UP: FIXED PISTON, UO: OSTERBERG, UD: DENISON, UP: PITCHER, UB: BEI
GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC

DATE 3/10/86

PROJECT 85669

BORING LOCATION Sta 16+40, 540'N GROUND ELEVATION (NGVD) 1114.6 DATE START/FINISH 9/16/85 / [illegible]

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 96.0 DRILLED BY E. Stewart WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR [illegible] DATE - LOGGED BY J.R. Perkins DATE 9/16-17/85

S102

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	91	S34	5 14 15 16	24	20		S34-Next 2": SILTY SAND, widely graded coarse to fine sand, ~20% nonplastic fines, ~10% gravel up to 1/2", olive blue (SM) Bot 10": GRAVELLY SILTY SAND, widely graded coarse to fine sand, ~20% gravel up to 1", ~15% nonplastic fines, brownish black (SW-SM)
	92						
	93						
	94						
	95	S35	36 90 50 [illegible]	24	20		S35 GRAVELLY SAND, widely graded coarse to fine sand, ~40% gravel up to 1 1/8", ~10% nonplastic fines, brown (SW-SM)
	96						Bottom of Borehole - 96.0 ft
	97						
	98						
	99						
	100						
	101						
	102						
	103						
	104						

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE UD: DENISON
UF: FIXED PISTON UP: PITCHER
UO: OSTERBERG UG: GEI

GROUNDWATER

NOTES

1) See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 132.0'S GROUND ELEVATION (NGVD) 1093.9 DATE START/FINISH 9/17/85 / 9/18/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 9?.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY T.R. Perkins DATE 9/17-18/85

S103

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
1093.9	0					Borehole advanced using standard rotary wash boring techniques with a bentonite drilling mud. Cleaned out borehole with a 4" fishtail bit with upward jetting.	
	1	S1	6 9 11 12	24	17		S1-Top 1": Bituminous Pavement. SANDY CLAY, sl. plastic fines, ~20% fine sand, brown (CL)
	2						
	3						
	4						
	5						
	6	S2	2 6 10 15	24	21		S2 Similar to S1 (CL)
	7						
	8						
	9						
	10						
	11	S3	5 11 [illegible] 10	24	15		S3-Top 4": Similar to S1 (CL) Bot 11" SAND, narrowly graded med. to fine sand, ~10% coarse sand and fine gravel, <5% nonplastic fines, brown (SP)
	12						
	13						

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN. TO DRIVE A 2 IN SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
UNDISTURBED SAMPLES
US: SHELBY TUBE
UP: FIXED PISTON
UO: OSTERBERG
UD: DENISON
UP: PITCHER
UG: GEI
GROUNDWATER

NOTES

1) Groundwater levels not recorded because bentonite drilling mud used in borehole would produce inaccurate readings.

REEVALUATION OF THE SLIDE IN THE WEST BANK EMBANKMENT DAM

GEOTECHNICAL ENGINEERS INC

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 132.0'S GROUND ELEVATION (NGVD) 1093.9 DATE START/FINISH 9/17/85 / 9/18/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 97.0 DRILLED BY C. Stevars, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR 1) DATE - LOGGED BY J.R. Perkins DATE 9/17-18/85

S103

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	13–15						
	15–17	S4	6 11 15 18	24	16		S4 SAND, narrowly graded fine sand, ~5% nonplastic fines, brown (SP)
	17–20						Approximate Interface - Rolled Fill Hydraulic Fill
	20–22	S5	14 17 10 12	24	18		S5-Top 8": SAND, narrowly graded fine sand, ~10% nonplastic fines, olive brown (SM-SP) Next 8": SANDY SILT, non to sl. plastic fines, ~45% fine sand, olive brown (ML) Bot 2": SAND, narrowly graded med. to fine sand, mostly fine, <5% nonplastic fines, brown (SP)
	22–25						
	25–26	S6	10 6 12 14	24	20		S6-Top 6": SAND, narrowly graded med. to fine sand, mostly med. ~10% coarse sand and fine gravel, <5% nonplastic fines, brown (SP) Next 6": SILTY SAND TO SILTY CLAY, fines content increases with depth (SM to CL)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE UD: DENISON
UF: FIXED PISTON UP: PITCHER
UO: OSTERBERG UG: GEL

▽ GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 132.0'S GROUND ELEVATION (NGVD) 1093.9 DATE START/FINISH 9/17/85 / 9/18/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 97.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/17-18/85

S103

EL FT	DEPTH FT.	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN IN.	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	26–27	S6	10 6 12 14	24	20		S6-Bot 8": Similar to top 6" (SP)
	27–29	S7	6 11 5 13	24	15		S7 SAND, narrowly graded med. to fine sand, mostly med., ~20% coarse sand and fine gravel, <5% nonplastic fines, brown (SP)
	29–31	S8	7 11 11 13	24	18		S8-Top 5": SAND, narrowly graded fine sand, ~5% nonplastic fines, brown (SP) Next 7": SAND, narrowly graded med. to fine, mostly med., ~10% coarse sand, <5% nonplastic fines, brown (SP) Next 2": SANDY SILT, sl. plastic fines, ~40% fine sand, olive gray (ML) Bot 5": Similar to top 5" (SP)
	31–33	S9	7 11 14 5	24	18		S9-Top 7": SAND, narrowly graded med. to fine sand, mostly med. ~10% coarse sand, <5% nonplastic fines, brown (SP) Next 4": SAND, narrowly graded fine sand, ~10% med. sand, <5% nonplastic fines, brown (SP) Bot 7": Similar to top 7" (SP)
	33–35	S10	4 8 9 12	24	20		S10-Top 3": SILTY CLAY, sl. to mod. plastic fines, ~10% fine sand, stratified, olive (CL) Next 10": SAND, widely graded coarse to fine sand, ~10% fine gravel, <5% nonplastic fines, brown (SW) Bot 7": SAND, narrowly graded med. to fine sand, <5% nonplastic fines, tan (SP)
	35–37	S11	WOR+H 12" 1 5" 3 7" 10	24	8		S11-Top 8": Wash Next 3": SAND, widely graded coarse to fine sand, mostly med., <5% nonplastic fines, brown (SW) Next 2": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, stratified, olive brown (SM) Bot 3": SAND, narrowly graded med. to fine sand, mostly med., <5% nonplastic fines, tan (SP)
	37–39	S12	7 [illegible] [illegible] [illegible]	24	13		S12-Top 3": SAND, narrowly graded med. to fine sand, ~10% coarse sand, <5% nonplastic fines, light brown (SP) Bot 10": SAND, narrowly graded fine sand, ~20% nonplastic fines, olive gray (SM)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
U(S): SHELBY TUBE   U(D): DENISON
U(F): FIXED PISTON   U(P): PITCHER
U(O): OSTERBERG   U(G): GEI
GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 132.0'S GROUND ELEVATION (NGVD) 1093.9 DATE START/FINISH 9/17/85 / 9/17/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 97.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL NR[1] DATE ____ LOGGED BY J.R. Perkins DATE 9/17-18/85

S103

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	39–41	S13	5 8 7 8	24	18		S13-Top 2": SAND, widely graded coarse to fine sand, ~10% gravel up to 1/2", ~5% nonplastic fines, olive brown (SW) Next 5": SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, dark olive brown (SM) Lower 1" of section contained a layer of stratified silty clay. Next 3": Similar to top 2" (SW) Next 4": Similar to SILTY SAND above (SM) Bot 4": Similar to top 2" (SW)
	41–43	S14	6 10 8 7	24	20		S14: Four 3"-thick layers of SILTY SAND gradually changing to SILTY CLAY. These four 3"-thick layers above are separated by three 2"-thick layers of SAND. Descriptions of each layer are as follows: SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, dark olive brown (SM) SILTY CLAY, sl. to mod. plastic fines, ~10% fine sand, stratified, dark olive brown (CL) SAND, widely graded coarse to fine sand, ~10% fine gravel, <5% nonplastic fines, olive brown (SW)
	43–45	S15	4 11 10 11	24	20		S15-Top 1": SAND, widely graded coarse to fine sand, ~10% fine gravel, <5% nonplastic fines, brown (SW) Next 3": SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, dark olive gray Next 3": SANDY SILT, sl. plastic fines, ~40% fine sand, stratified, dark olive black (ML) Next 8": Similar to top 1" (SW) Next 2": Stratified SILTY SAND and SANDY SILT. Bot 2": SAND, narrowly graded med. to fine sand, mostly med., <5% nonplastic fines, light brown (SP)
	45–47	S16	9 10 10 10	24	20		S16: LAYERED: SILTY SAND and SANDY SILT: SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, olive brown, layers up to 2" thick (SM) SANDY SILT, sl. plastic fines, ~40% fine sand, stratified dark olive brown, layers up to 1/2" thick (ML) Sample contained a 3"-thick layer of widely graded coarse to fine sand, located in middle of sample.
	47–49	S17	6 8 [illegible] 20	24	18		S17: SAND, narrowly graded fine sand, ~15% med. sand, ~5% nonplastic fines, light brown (SP) Sample contained two 1"-thick layers of stratified silty clay, located at top and bottom of sample. Sample also contained one 1"-thick layer of sandy silt, located at middle of sample.
	49–51	S18	11 13 13 15	24	22		S18-Top 7": SILTY SAND, narrowly graded fine sand, ~15% nonplastic fines, brown (SM) Section contained one 1/8"-thick lense of silty clay. Next 7": SAND, widely graded coarse to fine sand, mostly med. to fine, <5% nonplastic fines, brown (SW) Next 5": SILTY SAND, narrowly graded fine sand, ~50% nonplastic fines, dark olive (SM) Lower 1" of section consisted of stratified silty clay. Bot 3": SAND, narrowly graded med. to fine sand, <5% nonplastic fines, brown (SP)
	51–52	S19	10 11 19 19	24	17		S19-Top 3": SILTY SAND, narrowly graded fine sand, ~30% non to sl. plastic fines, dark olive (SM) Next 6": SAND, widely graded coarse to fine sand, <5% nonplastic fines, brown (SW)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE; UF: FIXED PISTON; UO: OSTERBERG; UD: DENISON; UP: PITCHER; G: GEL
▽ GROUNDWATER

NOTES
See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 132.0'S GROUND ELEVATION (NGVD) 1093.9 DATE START/FINISH 9/17/85 / 9/18/85

S103

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 97.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.P. Perkins DATE 9/17-18/85

EL FT	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN.	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	52	S19	10 11 19 19	24	17		S19-Next 2": SANDY SILT, sl. plastic fines, ~40% fine sand, stratified dark olive brown (ML) Bot 6": SAND, widely graded coarse to fine sand, <5% nonplastic fines, brown (SW)
	53–54	S20	3 20 14 9	24	20		S20-Top 4": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, olive brown (SM) Next 2": SANDY SILT, sl. plastic fines, ~40% fine sand, stratified, olive brown (ML) Next 9": SAND, widely graded coarse to fine sand, ~10% fine gravel, <5% nonplastic fines, brown (SW) Next 3": Similar to top 4" (SM) Bot 2": Similar to SANDY SILT above (ML)
	55–56	S21	18 14 19 26	24	18		S21-Top 3": SAND, widely graded coarse to fine sand, ~5% nonplastic fines, brown (SW) Next 7": SAND, narrowly graded med. to fine sand, <5% nonplastic fines, brown (SP) Next 4": SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, stratified, dark olive brown (SM) Bot 4": Similar to top 3" (SW)
	57–58	S22	22 18 18 13	24	20		S22-Top 15": SAND, widely graded coarse to fine sand, mostly med., ~5% fine gravel, <5% nonplastic fines, brown (SW) Next 4": SILTY SAND, narrowly graded fine sand, ~40% non to sl. plastic fines, olive brown (SM) Bot 1": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, dark olive brown (CL)
	59–60	S23	12 16 16 24	24	21		S23-Top 6": SAND, widely graded coarse to fine sand, mostly med. to fine, <5% nonplastic fines, brown (SW) Next 7": SAND, narrowly graded fine sand, ~10% nonplastic fines, olive gray (SP-SM) Bot 8": SAND, widely graded coarse to fine sand, <5% nonplastic fines, olive gray (SW)
	61–62	S24	8 13 24 19	24	21		S24-Top 7": SILTY SAND to SANDY SILT: SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, olive brown (SM) Gradually changes to SANDY SILT, sl. plastic fines, ~40% fine sand, stratified, olive brown (ML) Next 7": SAND, widely graded coarse to fine sand, <5% nonplastic fines, brown (SW) Bot 7": SAND, narrowly graded fine sand, ~5% nonplastic fines, brown (SP)
	63–64–65	S25	17 24 25 23	24	21		S25-Top 3": SAND, narrowly graded fine sand, ~10% nonplastic fines, brown (SP-SM) Next 8": SAND, widely graded coarse to fine sand, ~10% nonplastic fines, brown (SW-SM) Bot 10": Similar to top 3" (SP-SM)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE UD: DENISON
UF: FIXED PISTON UP: PITCHER
UO: OSTERBERG UG: GEI
▽ GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 132.0'S GROUND ELEVATION (NGVD) 1093.9 DATE START/FINISH 9/17/85 / 9/18/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 97.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/17-18/85

S103

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	65–67	S26	11, 11, 10, 28	24	22		S26-Top 8": SAND, narrowly graded fine sand, ~10% nonplastic fines, brown (SP-SM) Next 6": SILTY SAND, narrowly graded fine sand, ~25% non to sl. plastic fines, dark olive brown (SM) Bottom 1" of section contained a layer of stratified silty clay. Q_p = 1.05, 1.10 tsf Bot 8": SAND, widely graded coarse to fine sand, ~15% gravel up to 1.0" max., 10% nonplastic fines, brown (SM)
	67–69	S27	20, 28, 26, 22	24	20		S27-Top 10": SILTY SAND, widely graded coarse to fine sand, ~10% gravel up to 3/4", 20% nonplastic fines, brown (SM) Bot 10": SAND, narrowly graded fine sand, ~10% med. sand, ~5% nonplastic fines, brown (SP)
	69–71	S28	13, 19, 21, 26	24	22		S28-Top 2": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, dark olive brown (CL) Next 6": SAND, widely graded coarse to fine sand, mostly med., 15% g[illegible]l up to 3/4", <5% nonplastic fines, brown (SW) Next 9": SILTY [illegible]D, narrowly graded fine sand, ~30% nonplastic fines, ~10% med. sand, stratified, olive brown (SM) Bot 5": Similar to 6" sand layer above (SW)
	71–73	S29	13, 15, 14, 11	24	16		S29-Top 13": SAND, widely graded coarse to fine sand, ~10% fine gravel, ~10% nonplastic fines, brown (SW-SM) Section contained a 2"-thick layer of silty fine sand. Bot 3": SILTY SAND, narrowly graded fine sand, ~15% nonplastic fines, brown (SM)
	73–75	S30	8, 18, 20, 15	24	18		S30-Top 4": SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, dark brown (SM) Bottom 1" of section consisted of a stratified sandy silt. Next 13": SAND, widely graded coarse to fine sand, ~15% gravel up to [illegible] own (SW) Bot 1": SAND, narrowly graded fine sand, ~10% nonplastic fines, olive gray (SP-SM)
	75–77	S31	7, 12, 14, 13	24	18		S31-Top 3" SILTY CLAY, sl. to mod. plastic fines, ~10% fine sand, stratified, dark olive brown (CL) Next 9" SAND, widely graded, coarse to fine sand, ~10% nonplastic fines, <5% fine gravel, brown (SW-SM) Bot 6" SANDY SILT, nonplastic to sl. plastic fines, ~15% fine sand, mottled olive gray and brown (ML) Section appears to be dry.
	77–78	S32	6, 4, 10, [illegible]	24	20		S32-Top 12": SANDY SILT, non to sl. plastic fines, ~[illegible]% fine sand, dark olive brown, stratified (ML)

continued on next page

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
S: SHELBY TUBE D: DENISON
F: FIXED PISTON P: PITCHER
O: OSTERBERG G: GEL
▽ GROUNDWATER

NOTES
1. [illegible] page [illegible]

[illegible] IN THE WFR SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 132.0'S	GROUND ELEVATION (NGVD) 1093.9	DATE START/FINISH 9-[illegible]-85 / [illegible]-8-85	S103
INCLINATION Vertical BEARING NA	TOTAL DEPTH (FT) 97.0	DRILLED BY F. Stewart, WES/CCE	
CASING ID Not used CORE SIZE NA	GROUNDWATER EL NR[1] DATE -	LOGGED BY J.R. Perkins DATE 9-17-8-85	PG 7 OF 8

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	78–79	S32	6 4 10 11	24	20		S32-Bot 8": SAND, widely graded coarse to fine sand, ~10% nonplastic fines, brown (SW-SM)
	79–81	S33	8 13 16 19	24	17		S33: SAND, narrowly graded med. to fine sand, ~10% nonplastic fines, brown (SP-SM) Sample contained a 1-in. thick layer of stratified silty clay (CL)
	81–83	S34	10 15 17 15	24	17		S34: SAND, narrowly graded fine sand, ~10% nonplastic fines, brown (SP-SM)
	83–85	S35	8 10 15 19	24	17		S35: SILTY SAND, narrowly graded fine sand, ~15% nonplastic fines, brown (SM)
	85–87	S36	6 6 9 11	24	22		S36-Top 9": SILTY SAND, narrowly graded fine sand, ~15% nonplastic fines, brown (SM) Next 5": SILTY CLAY, mod. plastic fines, ~10% fine sand, brown (CL) Q_p = 1.3, 1.5 tsf S_v = 0.80 tsf Next 6": Similar to top 9" (SM) Bot 2": Similar to SILTY CLAY above (CL)
	87–89	S37	6 6 8 [illegible]	24	24		S37-Top 5": SILTY SAND, narrowly graded fine sand, ~15% nonplastic fines, brown (SM) Next 13": SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, dark brown (CL) Q_p = 2.2, 2.[illegible], 2.[illegible] tsf S_v = [illegible] tsf Approximate Interface - Hydraulic Fill Alluvium Next 5": SANDY SILT, sl. plastic fines, ~35% fine sand, black (ML) Bot 2": SILTY SAND, widely graded coarse to fine sand, ~20% nonplastic fines, black (SM)
	89–91	S38	11 22 [illegible] 17	24	20		S38: SILTY SAND, widely graded coarse to fine sand, [illegible] fine, ~25% nonplastic fines, olive and black (SM)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE, UF: FIXED PISTON, UO: OSTERBERG, UD: DENISON, UP: PITCHER, UB: BEI
▽ GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE ON THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3-10-86
PROJECT 85669

BORING LOCATION Sta 9+35, 132.0'S GROUND ELEVATION (NGVD) 1093.9 DATE START/FINISH 9/17/85 / 9/18/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 97.0 DRILLED BY F. Stewart WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL NR DATE - LOGGED BY R. Perkins DATE 9/17-18/85

S103

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	92						
	93						
	94						
	95						
	96	S39	[illegible]	24	22		S39 - SILTY SAND, narrowly graded med. to fine sand, mostly fine, ~35% non to sl. plastic fines, olive and brown (SM)
	97						Bottom of Borehole - 97.0 ft

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
UNDISTURBED SAMPLES
T: SHELBY TUBE D: DENISON
F: FIXED PISTON P: PITCHER
O: OSTERBERG U: OEI
GROUNDWATER

NOTES

NR: Not read

REEVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 73.1 S GROUND ELEVATION (NGVD) 1114.5 DATE START/FINISH 9/10/85 / 9/12/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 112.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not Used CORE SIZE NA GROUNDWATER EL NR DATE - LOGGED BY J.P. Perkins DATE 9/10-12/85

S104 PG 1 OF 9

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
1114.5	0					Borehole advanced using standard rotary wash boring techniques with a bentonite drilling mud. Cleaned out borehole with a 4" fishtail bit with upward jetting.	
	1	S1	25 27 18 18	24			S1 - SILTY SAND, widely graded coarse to fine sand, mostly fine, ~30% nonplastic fines, ~10% gravel up to 1/2" max., subangular, brown (SM)
	2						
	3						
	4						
	5						
	6	S2	9 9 15 22	24	19		S2 - SILTY SAND, widely graded coarse to fine sand, mostly fine, ~30% nonplastic fines, ~10% gravel up to 3/4", subangular, dark brown (SM)
	7						
	8						
	9						
	10						
	11	S3	8 [illegible] [illegible] 28	24	20		S3 - SILTY SAND, widely graded coarse to fine sand, ~30% slightly plastic fines, ~15% gravel up to 1/2", subrounded to subangular, dark brown (SM)
	12						
	13						

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE; UD: DENISON
UF: FIXED PISTON; UP: PITCHER
UO: OSTERBERG; UG: GEL
▽ GROUNDWATER

NOTES

Groundwater levels not recorded because bentonite drilling mud used in borehole would produce inaccurate readings.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 72 ↑ 5 GROUND ELEVATION (1114.5 DATE START/FINISH 9/10/85 / 9/12/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 117.0 DRILLED BY F. Stewart WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL na DATE - LOGGED BY J.R. Perkins DATE

S104

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	13						
	14						
	15						
	16	S4	6 14 17 19	24	19		S4 - SILTY SAND, widely graded coarse to fine sand, mostly med. to fine, ~30% slightly plastic fines, ~10% gravel up to 1.0", subrounded to subangular, dark brown (SM)
	17						
	18						
	19						
	20						
	21	S5	[illegible] 16 20	24	17		S5 - SILTY SAND, widely graded coarse to fine sand, mostly med. to fine, ~30% slightly plastic fines, ~10% gravel up to 2", subangular, top 6" dark brown, bottom 11" brown (SM)
	22						
	23						
	24						
	25						
	26	S6	[illegible]	24	6		S6 - SAND, narrowly graded med. to fine sand, <5% nonplastic fines, subrounded to subangular, light brown (SP). A 4" piece of gravel was wedged in sampler on top of sample.

BLOWS PER 6 IN: 140LB HAMMER FALLING 30 IN TO DRIVE A 2.0IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
S: SHELBY TUBE D: DENISON
F: FIXED PISTON P: PITCHER
O: OSTERBERG G: GEL
GROUNDWATER

NOTES

See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta. 9+35, 73.1?? GROUND ELEVATION (NGVD) 1114.5 DATE START/FINISH 9/10/85 / 9/12/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 117.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR 1) DATE - LOGGED BY J.R. Perkins DATE 9/10-12/85

S104

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	26	S6	4 3 14 20	24	6		S6 See previous page.
	27						
	28						
	29						
	30						
	31	S7	5 8 11 14	24	12		S7 SAND, narrowly graded med. to fine sand, mostly med., ~15% coarse sand and fine gravel up to 1/2", <3% nonplastic fines, subrounded to subangular, light tan (SP)
	32						
	33						
	34						
	35						
	36	S8	10 12 13 [illegible]	24	11		S8-Top 8": SAND, widely graded coarse to fine sand, ~10% gravel up to 3/8", <3% nonplastic fines, subrounded, brown (SW) Bot 3": SAND, widely graded coarse to fine sand, <5% nonplastic fines, subangular, reddish brown (SW). Sample contained two pieces of 1" gravel.
	37						
	38						
	39						

BLOWS PER 6": 140LB HAMMER FALLING 30" TO DRIVE A 2.0IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE — UD: DENISON
UF: FIXED PISTON — UP: PITCHER
UO: OSTERBERG — UG: GEI
▽ GROUNDWATER

NOTES

1) See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 73.1'S GROUND ELEVATION (NGVD) 1114.5 DATE START/FINISH 9/10/85 / 9/12/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 117.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NA[1] DATE - LOGGED BY J.S. Perkins DATE 9/10-12/85

S104

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	39–40						S9-Top 3": SILTY CLAY, mod. plastic fines, ~10% fine sand, laminated, dark gray (CL) Occ. irregular layers of silty fine sand to 1/4" thick.
	40						Approximate Interface - Rolled Fill / Hydraulic Fill
	40–42	S9	3 6 5 6	24			S9-Next 8": SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, laminated dark brownish gray (SM) Next 4": Similar to top 3" Next 4": Similar to SILTY SAND above (SM) Bot 5": (Top 3") SANDY SILT, slightly plastic fines, ~35% fine sand, dark gray (ML) (Bottom 2") SILTY CLAY, mod. plastic fines, <5% fine sand, laminated, dark gray (CL)
	45–47	S10	11 10 10 16	24	20		S10-Top 5": SAND, narrowly graded med. to fine sand, ~10% nonplastic fines, dark olive gray (SP) Next 9": (Top 2") SANDY SILT, sl. plastic fines, ~40% very fine sand, dark olive gray (ML) (Middle 6") SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, dark olive gray (SM) (Bottom 1") SILTY CLAY, mod. plastic fines, <5% fine sand, dark olive gray (CL) Bot 6": Similar to top 5" (SP)
	50–52	S11	5 9 9 7	24	15		S11-Top 5": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, dark olive gray (SM) Next 7": SAND, widely graded coarse to fine sand, <5% nonplastic fines, dark olive gray (SW) Bot 3": SANDY CLAY, sl. plastic fines, ~30% fine sand, dark olive gray (CL)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE UD: DENISON
UF: FIXED PISTON UP: PITCHER
UO: OSTERBERG UG: GEI
GROUNDWATER

NOTES

1. See page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 73.1'S GROUND ELEVATION (NGVD) 1114.5 DATE START/FINISH 9/10/85 / 9/12/85

S104

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 117.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.K. Perkins DATE 9/10-12/85

EL FT	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	52						
	53						
	54						
	55						
	56	S12	4 9 14 16	24	17		S12-Top 6": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, dark olive brown (SM) Bot 11": SAND, widely graded coarse to fine sand, <5% nonplastic fines, subangular, light olive brown (SW)
	57						
	58						
	59						
	60						
	61	S13	2 10 10 11	24	24		S13-Top 7": SILTY CLAY, mod. plastic fines, <5% fine sand, blackish brown, laminated (CL) Next 12": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, fine content decreases with depth, blackish brown (SM to SP) Bot 5": Similar to top 7" (CL)
	62						
	63						
	64						
	65						

BLOWS PER 6": 140LB HAMMER FALLING 30" TO DRIVE A 2.0IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE — UD: DENISON
UF: FIXED PISTON — UP: PITCHER
UO: OSTERBERG — UG: GEI

▽ GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.
WINCHESTER, MASSACHUSETTS

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 0+35, 71.1'S GROUND ELEVATION (NGVD) 1114.5 DATE START/FINISH 9/10/85 / 9/12/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 117.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/10-12/85

S104

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	65–67	S14	2, 5, 8, 8	24	22		S14 SANDY CLAY, mod. plastic fines, ~20% very fine sand, laminated, very dark brown (CL) Sample contained two 1" layers of silty fine sand located at the middle and top of sample. Q_p = 1.3, 1.5, 1.8 tsf; S_v = 0.86, 0.90 tsf
	70–72	S15	4, 7, 7, 10	24	24		S15-Top 6": SILTY CLAY, mod. plastic fines, ~10% very fine sand, laminated, very dark olive brown (CL) Q_p = 1.50, 1.60 tsf; S_v = 0.93, 0.95 tsf Next 12": SILTY SAND, narrowly graded fine sand, ~15% nonplastic fines, very dark olive brown (SM) Bot 6": SILTY CLAY, mod. plastic fines, ~10% very fine sand, laminated, very dark olive brown (CL) Occ. lenses of silty fine sand. Q_p = 1.50 tsf; S_v = 0.92 tsf
	75–77	S16	7, 6, 9, 14	24	19		S16-Top 2": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, very dark olive brown (SM) Next 4": SILTY CLAY, mod. plastic fines, <5% fine sand, laminated, very dark olive brown (CL) Next 7": SILTY SAND, narrowly graded fine sand, ~30% non to sl. plastic fines, very dark olive brown (SM) Next 4": Similar to SILTY CLAY above (CL) Q_p = 2.0 tsf; S_v = >1.0 tsf Bot 2": Similar to top 2" (SM)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE; UD: DENISON; UF: FIXED PISTON; UP: PITCHER; UO: OSTERBERG; UG: GEL
GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta. 9+35, 73.1'S GROUND ELEVATION (NGVD) 1114.5 DATE START/FINISH 9/10/85 / 9/12/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 117.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE ___ LOGGED BY J.R. Perkins DATE 9/10-12/85

S104

EL FT.	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN.	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	78						
	79						
	80						
	81	S17	5 19 21 20	24	17		S17-Top 7": SILTY CLAY, mod. plastic fines, <5% very fine sand, laminated, very dark olive brown (CL) Q_p = 1.2, 1.7 tsf S_v = 0.82, >1.0 tsf Bot 10": SAND, narrowly graded med. to fine sand, mostly fine, <5% nonplastic fines, brown (SP)
	82						
	83						
	84						
	85						
	86	S18	11 18 17 15	24	19		S18-Top 14": SILTY SAND, narrowly graded fine sand, ~45% nonplastic fines, dark olive brown (SM) Bot 5": SILTY SANDY CLAY, mod. plastic fines, ~15% very fine sand, stratified, several lenses and thin layers of silty fine sand, dark olive brown (CL)
	87						
	88						
	89						
	90						
	91	S19	4 6 11 17	24	24		S19-Top 16": SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, dark olive brown (SM) Sample contained three 1"-thick layers of stratified silty clay.

continued on next page

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE, UF: FIXED PISTON, UO: OSTERBERG, UD: DENISON, UP: PITCHER, UB: BEI
▽ GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 73.1'S GROUND ELEVATION (NGVD) 1116.5 DATE START/FINISH 9/10/85 / 9/12/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 117.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/10-12/85

S104

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	91–92	S19	4 5 11	24	24		S19-Next 5": SILTY CLAY, mod. plastic fines, ~5% very fine sand, stratified, dark olive brown (CL) S_v = 0.98, >1.0 tsf; Q_p = 1.8, 1.9, 2.2 tsf. Bot. 3": SAND, narrowly graded fine sand, ~5% nonplastic fines, brown (SP)
	92						
	93						
	94						
	95–97	S20	3 6 5 18	24	20		S20-Top 11": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, dark olive brown (SM). Next 6": SILTY CLAY, mod. plastic fines, ~5% fine sand, stratified, dark olive brown (CL) S_v >1.0 tsf; Q_p = 1.75, 2.0, 2.0 tsf. Bot 3": SAND, narrowly graded med. to fine sand, mostly fine, <5% nonplastic fines, brown (SP)
	98						
	99						
	100–102	S21	12 15 18 2?	24	17		S21: SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, olive brown (SM) Sample contained a 1"-thick layer of stratified silty clay.
	103						
	104						

BLOWS PER 6": 140LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE; UF: FIXED PISTON; UO: OSTERBERG; UD: DENISON; UP: PITCHER; UG: GEI
▽ GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.
WINCHESTER • MASSACHUSETTS

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, [illegible] GROUND ELEVATION (NGVD) 1114.5 DATE START/FINISH 9/10/85 / 9/12/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 117.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR DATE - LOGGED BY [illegible] DATE 9/10-12/85

S104

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	104						
	105						Approximate Interface - Hydraulic Fill / Alluvium
	106	S22	5 9 14 20	24	22		S22 - SANDY SILT, non to sl. plastic fines, ~35% fine - med sand, ~5% gravel up to ¼", blackish olive gray (ML)
	107						
	108						
	109						
	110						
	111	S23	12 17 18 25	24	22		S23 - Similar to S22 (ML)
	112						
	113						
	114						
	115						
	116	S24	9 14 15 23	24	18		S24- SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, olive gray and brown (SM)
	117						Bottom of Borehole - 117.0 ft

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE — UD: DENISON
UF: FIXED PISTON — UP: PITCHER
UO: OSTERBERG — UG: GEL
GROUNDWATER

NOTES
[illegible] ee page [illegible]

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 23.4'S GROUND ELEVATION (NGVD) 1114.1 DATE START/FINISH 9/12/85 / 9/16/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 117.0 DRILLED BY F. Stewart WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL Note* DATE - LOGGED BY J.R. Perkins DATE 9/12-16/85

S105

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
1114.1	0					Borehole advanced using standard rotary wash boring techniques with a bentonite drilling mud. Cleaned out borehole with a 4" fishtail bit with upward jetting.	
	1	S1	19 35 36 32	24	23		S1 - SILTY SAND, widely graded coarse to fine sand, mostly fine, ~30% nonplastic fines, <5% gravel, brown (SM)
	2						
	3						
	4						
	5						
	6	S2	9 14 25 24	24	21		S2 - SILTY SAND, widely graded coarse to fine sand, mostly fine, ~30% nonplastic fines, ~5% gravel up to 1/2", blackish brown (SM)
	7						
	8						
	9						
	10						
	11	S3	7 15 18 21	24	17		S3 - SANDY CLAY, sl. to mod. plastic fines, ~40% coarse to fine sand, ~15% gravel up to 1.0", brown and olive gray (CL)
	12						
	13						

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE   UD: DENISON
UF: FIXED PISTON   UP: PITCHER
UO: OSTERBERG   UG: GEL

▽ GROUNDWATER

NOTES

* Groundwater levels not recorded because bentonite drilling mud used in borehole would produce inaccurate readings.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC
WINCHESTER, MASSACHUSETTS

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta. 9+35, 21.4'S GROUND ELEVATION (NGVD) 1114.1 DATE START/FINISH 9/12/85 / 9/14/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 117.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/12-14/85

S105

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	13						
	14						
	15–17	S4	10 17 25 27	24	21		S4 - SILTY SAND, widely graded coarse to fine sand, mostly fine, ~30% non to sl. plastic fines, ~10% gravel up to 1/2", blackish gray (SM)
	18						
	19						
	20–22	S5	10 16 26 37	24	19		S5 - Similar to S4 (SM)
	23						
	24						
	25–26	S6	13 21 22 25	24	19		S6 - SILTY SAND, widely graded coarse to fine sand, ~30% nonplastic fines, ~10% gravel up to 1.0", blackish brown (SM)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE, UF: FIXED PISTON, UO: OSTERBERG, UD: DENISON, UP: PITCHER, UG: GEI
▽ GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 23.4'S GROUND ELEVATION (NGVD) 1114.1 DATE START/FINISH 9/12/85 / 9/14/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 117.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR 1) DATE - LOGGED BY J.R. Perkins DATE 9/12-14/85

S105

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	26–27	S6	13 21 2? 25	24	19		S6 - See previous page.
	30–32	S7	19 28 33 46	24	15		S7 - GRAVELLY SILTY SAND, widely graded coarse to fine sand, ~20% nonplastic fines, ~20% gravel up to 1¼", dark olive brown (SM)
	35–37	S8	24 16 20 100	24	14		S8 - GRAVELLY SILTY SAND, widely graded coarse to fine sand, ~20% gravel up to 1.0", ~20% nonplastic fines, dark olive brown (SM)

Depth scale: 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39

BLOWS PER 6 - 140 LB HAMMER FALLING 30 TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN - PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC - RECOVERY LENGTH OF SAMPLE
RQD - LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S - SPLIT SPOON SAMPLE
U - UNDISTURBED SAMPLES
US - SHELBY TUBE, UP - FIXED PISTON, UO - OSTERBERG, UD - DENISON, UP - PITCHER, UG - GEL
▽ GROUNDWATER

NOTES
1. See Page 1

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35 23.4'S GROUND ELEVATION (NGVD) 114.1 DATE START/FINISH 9/12/85 / 9/14/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 117.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/12-14/85

S105

EL FT	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	39						
	40–42	S9	31 44 28 33	24	0		S9 NO RECOVERY, suspect gravel in front of sampler while driving.
	45						Approximate Interface - Rolled Fill / Hydraulic Fill
	45–47	S10	4 9 11 8	24	12		S10-Top 5": SANDY CLAY, sl. to mod. plastic fines, ~35% coarse to fine sand, mostly fine, ~15% gravel up to 1/2", olive brown (CL). Bot 7": SAND, narrowly graded med. to fine sand, mostly med., ~10% coarse sand, <5% nonplastic fines, brown (SP). Tip of shoe contained a thin layer of silty clay.
	47–49	S11	4 4 4 5	24	15		S11 SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, very dark olive brown (CL) Q_p = 1.2, 1.1, 1.0 tsf; S_v = 0.66, 0.60, 0.60 tsf
	49–51	S12	2 3 5 6	24	24		S12 SANDY CLAY, sl. plastic fines, ~20% very fine sand, stratified, blackish olive Q_p = 1.2 tsf; S_v = 0.7 tsf
	51–52	S13	2 4 5 5	24	14		S13 SANDY CLAY, mod. plastic fines, ~20% very fine sand, blackish olive (CL) Occ. irregular pockets of silty fine sand. Sample contained a 1 1/4" piece of gravel at lower third.

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE UD: DENISON
UF: FIXED PISTON UP: PITCHER
UO: OSTERBERG UG: GEI
▽ GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.
WINCHESTER, MASSACHUSETTS

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 23.4'S GROUND ELEVATION (NGVD) [illegible] DATE START/FINISH 9/12/85 / 9/14/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 112.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/12-14/85

S105

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	52–53	S13	2, 4, 5, 5	24	14		S13 See previous page
	53–55	S14	3, 3, 5, 5	24	24		S14 SANDY CLAY, sl. plastic fines, ~25% fine sand, irregular stratification, blackish olive (CL) Q_p = 1.3 tsf, S_v = 0.72 tsf
	55–57	S15	2, 5, 8, 7	24	16		S15 SANDY CLAY, sl. plastic fines, ~25% very fine sand, stratified, blackish olive (CL)
	57–59	S16	4, 2, 4, 6	24	24		S16 SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, blackish olive (CL) Q_p = 0.8, 1.3, 1.5 tsf; S_v = 0.53, 0.73, 0.75 tsf
	59–61	S17	2, 3, 6, 7	24	24		S17-Top 23½": SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, blackish olive (CL) Q_p = 1.3, 1.6 tsf; S_v = 07.8, 0.73 tsf. Bot 1/2": SAND, narrowly graded fine sand, ~10% nonplastic fines, olive brown (SP-SM)
	61–63	S18	8, 14, [illegible]	24	15		S18-Top 5": SANDY CLAY, sl. plastic fines, ~25% fine sand, blackish olive (CL). Bot 10": SAND, narrowly graded fine sand, ~5% nonplastic, brown (SP)
	63–65	S19	[illegible]	24	18		S19-Top 5": SILTY CLAY, mod. plastic fines, ~15% fine sand, stratified dark olive brown (CL) Occ. pockets and lenses of silty fine sand. Next 8": SANDY SILT, non to sl. plastic fines, ~35% fine sand, dark olive brown (ML) Occ. layers of silty clay to 1/8" thick. Bot 5": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, ~5% med. to coarse sand, olive brown (SM)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
S: SHELBY TUBE; F: FIXED PISTON; O: OSTERBERG; D: DENISON; P: PITCHER; [illegible]
GROUNDWATER

NOTES
1) See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 23.4'S GROUND ELEVATION (NGVD) 1114.1 DATE START/FINISH 9/12/85 / 9/14/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 117.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/12-14/85

S105

EL FT	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	65–67	S20	7 5 5 7	24	20		S20-Top 5": SILTY SAND, narrowly graded fine sand, ~15% non plastic fines, ~5% med. to coarse sand, olive brown (SM) Bot 15": SANDY SILT-SILTY SAND, non to sl. plastic fines, ~50% fine sand, blackish olive (ML-SM)
	67–69	S21	1 4 6 9	24	24		S21-Top 17": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified blackish olive (CL) S_v = 0.90, 0.90 tsf Q_p = 1.50, 1.50 tsf Next 5": SANDY SILT, non to sl. plastic fines, ~45% fine sand, blackish olive (ML) Bot 2": Similar to top 17"(CL)
	69–71	S22	3 6 12 17	24	12		S22 SILTY SAND, narrowly graded fine sand. ~40% non to sl. plastic fines. blackish olive (SM) Entire length of sample disturbed. Piece of gravel in head of sampler.
	71–73	S23	6 6 9 19	24	19		S23-Top 5": SILTY SAND, narrowly graded fine sand ~30% nonplastic fines, very dark olive (SM) Next 7": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, very dark olive (CL) Next 2": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, very dark olive (SM) Next 2": SANDY CLAY, sl. plastic fines, ~35% fine sand, stratified, very dark olive (CL) Bot 3": SAND, narrowly graded fine sand, ~5% nonplastic fines, tan (SP)
	73–75	S24	2 4 [illegible] 8	24	24		S24-Top 5": SILTY CLAY, sl. plastic fines, ~30% fine sand, very dark olive (CL) Bot 19": SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified very dark olive (CL) S_v = 0.86, 0.91, 0.74 tsf top to bottom Q_p = 1.6, 1.6, 1.3 tsf top to bottom
	75–77	S25	2 5 8 9	24	24		S25 SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, very dark olive (CL) S_v = 0.56, 0.75, tsf top to bottom Q_p = 0.80, 1.60, tsf top to bottom
	77–78	S26	[illegible] 3 4 [illegible]	24	24		S26 SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, dark olive (CL) S_v = 0.74, 0.93, 0.93 tsf top to bottom Q_p = 0.90, 1.6, 1.5 tsf top to bottom

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE, UP: FIXED PISTON, UO: OSTERBERG, UD: DENISON, UP: PITCHER, U: [illegible]
▽ GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35 23.4'S GROUND ELEVATION (NGVD) 1114.1 DATE START/FINISH 9/12/85 / 9/14/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 117.0 DRILLED BY F. Stewart WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/12-14/85

S105

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN.	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	78, 79	S26	1 3 4 7	24	24		
	80, 81	S27	2 6 6 11	24	24		S27: SILTY CLAY, mod. plastic fines, ~10% fine sand, stratified, very dark olive (CL) S_v = 0.93, 0.91, 0.95 tsf top to bottom Q_p = 1.7, 1.7, 1.7 tsf top to bottom
	82, 83	S28	2 5 8 9	24	13		S28: SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, very dark olive (CL) Most of sample disturbed from piece of gravel.
	84, 85	S29	3 6 9 11	24	24		S29: SILTY CLAY, mod. plastic fines, ~10%, very fine sand, stratified, very dark olive (CL) Sample contained several irregular pockets and lenses of silty fine sand. S_v = 0.95, 0.95, 0.85 tsf top to bottom Q_p = 1.4, 2.0, 1.8 tsf top to bottom
	86, 87	S30	4 9 10 11	24	24		S30-Top 4": SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, very dark olive (CL) Next 6": SILTY SAND, narrowly graded fine sand, ~35% nonplastic fines, very dark olive (SM) Next 3": SILTY CLAY, similar to top 4" (CL) Next 2": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, very dark olive (SM) Bot 9": SILTY CLAY, similar to top 4" (CL)
	88, 89	S31	4 14 12 15	24	22		S31-Top 5": SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, very dark olive (CL) Next 1": SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, very dark olive (SM) Next 2": SILTY CLAY, similar to top 5" (CL) Next 7": SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, very dark olive (SM) Next 3": SILTY CLAY, similar to top 5" (CL) Bot 4": SILTY SAND, similar to top 7" layer above, except olive brown (SM)
	90, 91	S32	6 12 14 15	24	19		S32-Top 17": SANDY SILT, non to sl. plastic fines, ~30% fine sand, olive brown (ML) Bot 2": SILTY CLAY, mod. plastic fines, ~10%, very fine sand, stratified, olive brown (CL)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE UD: DENISON
UF: FIXED PISTON UP: PITCHER
UO: OSTERBERG UG: GEI
▽ GROUNDWATER

NOTES
1) See Page 1

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta. 9+35 23.4'S GROUND ELEVATION (NGVD) 1114.1 DATE START/FINISH 9/12/85 / 9/14/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 117.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/12-14/85

S105

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	91						
	92	S33	4 6 9 13	24	23		S33 SILTY CLAY, mod. plastic fines, ~5% very fine sand, stratified dark brown (CL) Occ. irregular pockets and lenses of silty fine sand. S_v = 1.0, 1.0 tsf top to bottom; Q_p = 1.5, 1.8 tsf top to bottom
	93						
	94	S34	4 6 9 11	24	8		S34 SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, dark brown (CL)
	95						
	96	S35	7 6 8 12	24	24		S35-Top 3": SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, dark brown (CL). Next 4": SILTY SAND, narrowly graded fine sand, ~40% non to sl. plastic fines, dark olive brown (SM). Bot 17": SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, dark brown (CL) Occ. irregular pockets and lenses of silty fine sand. S_v = 1.0, 0.86 tsf top to bottom; Q_p = 2.0, 1.7 tsf top to bottom
	97						
	98	S36	4 7 9 10	24	24		S36 SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, dark brown (CL) Occ. irregular pockets and lenses of silty fine sand. Lower half of sample contained a 4"-thick layer of SILTY FINE SAND with ~40% nonplastic fines (SM)
	99						
	100	S37	4 7 8 10	24	24		S37 SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, dark brown (CL) Several irregular pockets and lenses of silty fine sand. Q_p = 1.6, 1.6 tsf
	101						
	102	S38	4 10 [illegible] [illegible]	24	24		S38 SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, dark brown (CL) S_v = 0.95 tsf; Q_p = 1.6 tsf. Sample contained two 2"-thick layers at the top half and one 4"-thick layer at the bottom half. The layers consisted of SILTY SAND, narrowly graded fine sand, ~[illegible]% nonplastic fines, dark brown (SM)
	103	S39	[illegible]	24	24		S39 SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, very dark brown (CL) Occ. irregular pockets and lenses of silty fine sand.
	104						

continued on next page

BLOWS PER 6 IN.: 140 LB HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN./LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
S: SHELBY TUBE; F: FIXED PISTON; O: OSTERBERG; D: DENISON; P: PITCHER; G: GEI
GROUNDWATER

NOTES
1. [illegible] page

REEVALUATION OF THE [illegible] IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 9+35, 23.4'S	GROUND ELEVATION (NGVD) 1114.1	DATE START/FINISH 9/12/85 / 9/14/85	S105
INCLINATION Vertical BEARING NA	TOTAL DEPTH (FT.) 117.0	DRILLED BY F. Stewart, WES/COE	
CASING ID Not used CORE SIZE NA	GROUNDWATER EL. NR[1] DATE	LOGGED BY J.R. Perkins DATE 9/12-14/85	PG 9 OF 9

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	104	S39	5 9 9 10	24	24		S39 S_v = >1.0 tsf, Q_p = 1.7 tsf. Sample contained two 2"-thick layers of SILTY SAND, uniform fine sand, ~30% nonplastic fines, dark brown (SM). Layers were located at middle of sample.
	105						
	106	S40	4 [illegible] 11 12	24	24		S40 SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, dark brown (CL). Occ. lenses of silty fine sand. S_v = 1.0 tsf, Q_p = 2.1, 2.3, 2.4 tsf
	107						
	108	S41	4 12 12 13	24	24		S41 SILTY CLAY, mod. plastic fines, ~10% very fine sand, stratified, very dark brown (CL). Sample contained a 3"-thick layer of silty fine sand at middle of sample. S_v = >1.0 tsf, Q_p = 2.1, 2.2, 2.4 tsf
	109						S42-Top 6": SILTY CLAY, similar to S41 (CL)
							Approximate Interface - Hydraulic Fill / Alluvium
	110	S42	[illegible] 12 15 17	24	24		Bot 18": SILTY SAND, narrowly graded fine sand, ~40% nonplastic fines, ~10% med. to coarse sand, black (SM)
	111						
	112						
	113						
	114						
	115						
	116	S43	6 15 22 26	24	19		S43 SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, olive gray (SM)
	117						Bottom of Borehole - 117.0 ft

BLOWS PER 6 IN.: 140 LB HAMMER FALLING 30 IN. TO DRIVE A 2 IN. OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN./LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLE
US: SHELBY TUBE
UF: FIXED PISTON
UO: OSTERBERG
UD: DENISON
UP: PITCHER
UG: GEL

GROUNDWATER

NOTES

1) [illegible]

REEVALUATION OF THE FILL IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.
DATE 3/10/86
PROJECT [illegible]

BORING LOCATION Sta 5+35 132'S GROUND ELEVATION (NGVD) 1095.1 DATE START/FINISH 9/20/85 / 9/24/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 104.0 DRILLED BY Frank Stewart WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/20-24/85

EL FT.	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
1095.1	0					Borehole advanced using standard rotary wash boring techniques with a drilling mud. Cleaned out borehole with a 4" fishtail bit with upward jetting.	
	1	S1	11 15 14 15	24	3		S1 - SILTY CLAY, sl. plastic fines, ~30% med. to fine sand, brown (CL)
	2						
	3						
	4						
	5						
	6	S2	5 7 10 14	24	17		S2 - SANDY CLAY, sl. plastic fines, ~15% fine sand, brown (CL) Occ. irregular pockets of silty fine sand.
	7						
	8						
	9						
	10						
	11	S3	6 6 8 11	24	17		S3 - Similar to S2 (CL)
	12						
	13						

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE
UF: FIXED PISTON
UO: OSTERBERG
UD: DENISON
UP: PITCHER
UG: GEI
▽ GROUNDWATER

NOTES

1. Groundwater levels not recorded because bentonite drilling mud used in borehole would produce inaccurate readings.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta. 5+35, 132'S GROUND ELEVATION (NGVD) 1295.1 DATE START/FINISH 9/20/85 / 9/24/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 104.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/20-24/85

S111

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN.	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	13						
	14						
	15–17	S4	7 5 2 8	24			S4 — SAND, narrrowly graded fine sand, ~10% nonplastic fines, dark brown (SP-SM)
	18						
	19						Approximate Interface - Rolled Fill
	20–22	S5	7 9 14 16	24	19		Hydraulic Fill S5 — SAND, narrowly graded med. to fine sand, ~5% nonplastic fines, brown (SP) Sample contained a 1"-thick layer of stratified silty clay.
	22–24	S6	6 6 8 9	24	10		S6- Top 5": SILTY SAND, narrowly graded fine sand ~20% nonplastic fines, dark olive brown (SM) Next 1": SILTY CLAY, stratified (CL) Bot 4": SAND, widely graded coarse to fine sand, ~10% nonplastic fines, brown (SW-SM)
	24–26	S7	8 12 8 7	24	15		S7 — SAND, narrowly graded med. to fine sand, mostly med., ~10% coarse sand, <5% nonplastic fines, brown (SP) Bottom of sample contained a 1"-thick layer of grav, stratified silty fine sand.

BLOWS PER 6: 140 LB HAMMER FALLING 30" TO DRIVE A 2 O.IN. O.D. SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
ST: SHELBY TUBE · UD: DENISON
UF: FIXED PISTON · UP: PITCHER
UO: OSTERBERG · UG: GEL
∇ GROUNDWATER

NOTES

1) See Page 1.

RE-EVALUATION OF THE SLIDE IN THE SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta. 5+35 132'S GROUND ELEVATION (NGVD) 1095.1 DATE START/FINISH 9/20/85 / 9/26/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 104.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL NR DATE - LOGGED BY J.R. Perkins DATE 9-2[illegible]-85

S III

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	26						
	27	S8	11 15 5 [illegible]	24	15		S8 Top 9": SAND, widely graded coarse to fine sand, ~10% gravel up to ½", ~10% nonplastic fines, brown (SW - SM) Next 3": SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, stratified, dark olive gray (SM) Next 2": STRATIFIED SILTY CLAY (CL) Bot [illegible]": Similar to Silty Sand above (SM)
	28						
	29	S9	7 16 13 19	24	19		S9 SILTY SAND, widely graded coarse to fine sand, ~20% nonplastic fines, brown (SM). Sample contained a [illegible]-thick layer of stratified silty fine sand. Sample contained ~10% gravel.
	30						
	31	S10	10 [illegible]	24	16		S10-Top 5": SAND, narrowly graded med. to fine sand, ~10% nonplastic fines, ~10% coarse sand, stratified olive brown (SM-SP) Section contained a ½"-thick layer of stratified silty clay Next 6": SAND, widely graded coarse to fine sand, <5% nonplastic fines, brown (SW) Bot 5": SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, dark olive brown (SM)
	32						
	33	S11	6 [illegible] 12 11	24	16		S11-Top 4": SAND, widely graded coarse to fine sand, ~[illegible]% nonplastic fines, gray and brown (SW-SM) Next 2" STRATIFIED SANDY CLAY (CL) Next 6": SAND, widely graded coarse to fine sand, <5% nonplastic fines, brown (SW) Bot 4": SAND, narrowly graded fine sand, ~10% nonplastic fines, brown (SP-SM)
	34						
	35	S12	5 [illegible]	24	18		S12-Top 10": SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, stratified, dark olive gray (SM). Section contained two ¼"-thick layers of med. to fine sand. Section contained three layers of fine sandy silt layers of up to 2" thick. Bot 8": SAND, widely graded coarse to fine sand, mostly med., ~10% gravel up to ½", ~10% nonplastic fines, brown (SW-SM)
	36						
	37	S13	8 13 [illegible]	24	15		S13 SAND, widely graded coarse to fine sand, ~10% nonplastic fines, brown (SW-SM). Sample contained two ¼"-thick layers of stratified sandy silt.
	38						
		S14	8 [illegible]	24	[illegible]		
	39						

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE; UF: FIXED PISTON; UO: OSTERBERG; UD: DENISON; UP: PITCHER; UG: GEL
GROUNDWATER

NOTES
[illegible] See Page [illegible]

RE-EVALUATION OF THE [illegible] ON THE SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 5+35, 132'S	GROUND ELEVATION (NGVD) 1095.1	DATE START/FINISH 9/20-85 / 9/24/85	S111
INCLINATION Vertical BEARING NA	TOTAL DEPTH (FT.) 104.0	DRILLED BY F. Stewart, WES/COE	
CASING ID Not used CORE SIZE NA	GROUNDWATER EL. NR(1) DATE -	LOGGED BY L.R. Perkins DATE 9/20-24/85	PG. 4 OF 8

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	39 40	S14	8 10 11 12	24	17		S14-Top 4": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, brown (SM) Next 1": SANDY SILT, sl. plastic fines, ~35% fine sand, stratified, dark olive (ML) Bot 10": SAND, widely graded coarse to fine sand, ~10% nonplastic fines, brown (SW-SM) Section contained two 1/2"-layers of sandy silt
	41 42	S15	10 8 3 11	24	13		S15-Top 4": SAND, widely graded coarse to fine sand, ~10% gravel up 3/8", ~10% nonplastic fines, brown (SW-SM) Next 6": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, dark olive (SM) Section contained one 1/2"-thick layer of coarse to fine sand. Bot 6": SILTY SAND, similar to top 4". (SW-SM)
	43 44	S16	6 5 12 6	24	20		S16-Top 14": SILTY SAND, narrowly graded fine sand, ~25% nonplastic fines, dark olive (SM) Section contained three 2"-thick layers of coarse to fine sand located at top, middle and bottom of section. Bot 6": SANDY SILT, sl. plastic fines, ~40% fine sand, stratified, dark olive (ML)
	45 46	S17	4 10 9 11	24	17		S17-Top 5": SANDY SILT, sl. plastic fines, ~50% fine sand, stratified, dark olive (ML-SM) Occ. thin layers of silty clay. Next 6": SAND, widely graded coarse to fine sand, <5% nonplastic fines, brown (SW) Section contained one 1/2"-thick layer of silty fine sand. Bot 6": SAND, narrowly graded fine sand, ~10% nonplastic fines, 10% med. sand, brown (SP-SM)
	47 48	S18	5 10 6 8	24	16		S18 STRATIFIED SANDY CLAY, SILTY SAND and SANDY SILT, (top to bottom) Gradual transition from sandy clay to silty sand. Descriptions of each layer are as follows: SANDY CLAY sl. plastic fines, ~20% fine sand, stratified, dark olive (CL) SILTY SAND, narrowly graded fine sand, ~40% nonplastic fines, dark olive (SM) SANDY SILT, non to sl. plastic fines, ~40% fine sand, dark olive (ML)
	49 50	S19	10 12 [illegible] [illegible]	24	15		S19 Top 3": SANDY SILT, sl. plastic fines, ~30% fine sand, stratified, dark olive (ML) Bot 12": SAND, widely graded coarse to fine sand, mostly med. ~10% nonplastic fines, brown (SW-SM)
	51 52	S20	3 6 4 11	24	18		S20 Top 5": SANDY SILT, sl. plastic fines, ~35% fine sand, stratified, dark olive (ML) Next 3": SAND, widely graded coarse to fine sand, ~10% nonplastic fines, brown (SW-SM) Next 4": Similar to top 5" (ML) Next 4": SAND, narrowly graded fine sand, ~10% nonplastic fines, brown (SP) Bot [illegible]": Similar to 3" SAND layer above (SW-SM)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
(S) SHELBY TUBE (D) DENISON
(F) FIXED PISTON (P) PITCHER
(O) OSTERBERG (G) GEI
GROUNDWATER

NOTES
(1) See Page 1

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.
WINCHESTER • MASSACHUSETTS

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta. 5+35, 112'S	GROUND ELEVATION (NGVD) 1095.1	DATE START/FINISH 9/20/85 / 9/2-/85	S111
INCLINATION Vertical BEARING NA	TOTAL DEPTH (FT) 104.0	DRILLED BY F. Stewart, WES/COE	
CASING ID Not used CORE SIZE NA	GROUNDWATER EL. NE	DATE - LOGGED BY J.R. Perkins DATE 9/20-24/85	PG. 5 OF 8

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	52–54	S21	3 12 7 8	24	18		S21-Top 4": SANDY SILT, sl. plastic fines, ~40% fine sand, stratified, dark olive and dark brown (ML) Next 5": SAND, widely graded coarse to fine sand, ~10% fine gravel, 10% nonplastic fines, brown (SW-SM) Next 3": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, dark brown and dark gray (SM) Next 4": Similar to top 4" (ML) Bot 2": Similar to SAND above (SW-SM)
	54–56	S22	7 5 11 11	24	18		S22-Top 3": SAND, widely graded coarse to fine sand, mostly med., ~10% nonplastic fines, brown (SW-SM) Next 5": SANDY SILT, sl. plastic fines, ~45% fine sand at top of section decreasing to ~20% fine sand at bottom of section, stratified, brown (ML) Bot 10": SILTY SAND, narrowly graded fine sand, ~10% nonplastic fines, brown (SP-SM) Section contained two 1/2"-thick layers of coarse to fine sand.
	56–58	S23	8 12 15 11	24	19		S23 SAND, narrowly graded med. to fine sand, ~10% coarse sand, 10% nonplastic fines, stratified, olive brown (SP-SM)
	58–60	S24	10 13 18 16	24	15		S24 SAND, narrowly graded med. to fine sand, mostly fine, ~10% nonplastic fines, brown (SP-SM) Sample contained two 1/2"-thick layers of coarse to fine sand.
	60–62	S25	8 13 12 11	24	15		S25-Top 7": SAND, narrowly graded med. to fine sand, ~20% coarse sand and fine gravel, <5% nonplastic fines, brown (SP) Bot 8": SANDY SILT, non-plastic, ~40% fine sand sand, stratified, brown olive (ML)
	62–64	S26	11 12 20 25	24	18		S26 SAND, narrowly graded med. to fine sand, mostly fine, ~10% nonplastic fines, brown (SP-SM)
	64–65	S27	13 15 20 25	24	17		S27 SILTY SAND, narrowly graded med. to fine sand, ~20% nonplastic fines, brown (SM)

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2 OIN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN/LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE UD: DENISON
UF: FIXED PISTON UP: PITCHER
UO: OSTERBERG UB: BEI
GROUNDWATER

NOTES
1. See Page 1.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.
WINCHESTER, MASSACHUSETTS

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 5+35 132'S GROUND ELEVATION (NGVD) 1095.1 DATE START/FINISH 9/20/85 / 9/24/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 104.0 DRILLED BY F. Stewart, VES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY L.R. Perkins DATE 9/20-24/85

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	65–66	S27	13 15 20 25	24	17		S27 See previous page.
	66–68	S28	14 12 10 6	24	18		S28 SILTY SAND, narrowly graded fine sand ~30% nonplastic fines, brown and olive gray (SM)
	68–70	S29	22 38 28 27	24	14		S29-Top 8": SAND, widely graded coarse to fine sand, ~10% gravel up to 1/2", ~10% nonplastic fines, brown (SW-SM) Bot 6": Freshly broken weathered gravel
	70–72	S30	16 24 19 16	24	15		S30 SAND, widely graded coarse to fine sand, ~10% gravel up to 1/2", ~10% nonplastic fines, brown (SW-SM)
	72–74	S31	8 11 13 12	24	14		S31-Top 5": SANDY SILT, sl. plastic fines, ~50% fine sand, olive brown (ML-SP) Bot 9": SILTY SAND, narrowly graded med. to fine sand, ~20% nonplastic fines, ~10% coarse sand, brown (SM)
	74–76	S32	4 3 9 [illegible]	24	16		S32-Top 11": SILTY SAND, narrowly graded fine sand, ~40% nonplastic fines, brown (SM) Bot 5": SAND, narrowly graded fine sand, ~10% med. sand, ~10% nonplastic fines, brown (SP-SM)
	76–78	S33	10 13 15 12	24	14		S33[2] SAND, narrowly graded, med. to fine sand, ~30% nonplastic fines, brown (SP-SM)

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE
UF: FIXED PISTON
UO: OSTERBERG
UD: DENISON
UP: PITCHER
UG: GEL

GROUNDWATER

NOTES

1. See Page 1.

2. Sample described in Laboratory.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta. 5+35 132'S GROUND ELEVATION (NGVD) 1095.1 DATE START/FINISH 9/20/85 / 9/24/85		S111
INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 104.0 DRILLED BY E. Stewart WES/COE		
CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/20-24/85		PG. 7 OF 8

EL FT	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	SOIL AND ROCK DESCRIPTIONS
	78						
	79	S34	2 4 14 16	24	19		S34-Top 14": SILTY SAND, narrowly graded fine sand, ~35% sl. plastic fines, dark olive brown (SM) Bot 5": SAND, narrowly graded med to fine sand, ~5% nonplastic fines, brown (SP)
	80						
	81	S35	6 8 13 12	24	18		S35 2) SILTY SAND, narrowly graded med to fine sand, ~40% nonplastic fines, brown (SP-SM) *Sample contained one 3"-thick layer and one 1½"-thick layer of sl. plastic sandy silt.*
	82						
	83	S36	4 6 9 12	24	19		S36 2) SILTY SAND, widely graded coarse to fine sand, mostly fine, ~50% nonplastic fines, brown (SM)
	84						
	85	S37	8 12 9 10	24	20		S37 2) SAND, widely graded coarse to fine sand, ~40% nonplastic fines, dark brown (SM)
	86						
	87	S38	5 7 8 10	24	19		S38-Top 6": SILTY SAND, widely graded coarse to fine sand, ~20% nonplastic fines, ~10% gravel up ½", brown (SM) Next 7": SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, ~15% med. sand, brown (SM) Bot 6": SANDY SILT, sl. plastic fines, ~40% fine sand, dark olive brown (ML) S39-Top 6": SILTY CLAY, mod. plastic fines, ~10% very fine sand stratified, dark gray and dark brown (CL) Q_p = 2.3, 2.5, 2.8 tsf Approximate Interface - Hydraulic Fill / Alluvium
	88						
	89	S39	6 17 33 26	24	19		Next 8": SANDY CLAY, sl. plastic fines, ~30% coarse to fine sand, blackish gray (CL) Bot 5": GRAVELLY SAND, widely graded coarse to fine sand, ~15% gravel up to ½", ~5% nonplastic fines, dark gray (SW)
	90						
		S40	18 16 [illegible] 20	24	15		S40-Top 7": GRAVELLY SAND, widely graded coarse to fine sand, ~20% gravel up to 3/4", 5% nonplastic fines, olive (SW) Bot 8": SANDY SILT, sl. plastic fines, ~35% fine sand, ~5% med. sand, black (ML)
	91						

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED, %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE UD: DENISON
UF: FIXED PISTON UP: PITCHER
UO: OSTERBERG UG: GEI
▽ GROUNDWATER

NOTES
1. See Page 1.
2. Sample described in laboratory.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE 3/10/86
PROJECT 85669

BORING LOCATION Sta 5+35, [illegible] GROUND ELEVATION (NGVD) [illegible] DATE START/FINISH 9/20/85 / 9/26/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 104.0 DRILLED BY F. Stewart, [illegible] DATE — LOGGED BY J.R. Perkins DATE 9/20-2-85

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE -

S111

EL (FT)	DEPTH (FT)	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN IN	REC IN	REMARKS	SOIL AND ROCK DESCRIPTIONS
	91	S40	18 16 20 20	24	15		
	92–94	S41	6 7 15 17	24	24		S41 Top 12": SILTY SAND, narrowly graded fine sand, ~40% sl. plastic fines, 5% med. sand, black (SM) Bot 12": SANDY CLAY, med. plastic fines, ~25% very fine sand, black (CL) Several small pockets of gray silty sand.
	94–96	S42	5 10 13 16	24	21		S42 SANDY CLAY, sl. to mod. plastic fines, ~15% fine sand, ~5% med. sand, black (CL) Several small pockets of gray silty fine sand.
	96–98	S43	6 8 13 26	24	17		S43 SANDY CLAY, sl. to mod. plastic fines, ~20% med. to fine sand, mostly fine, olive gray (CL) Sand content decreases and plasticity increases with depth.
	98–100	S44	8 11 23 27	24	20		S44 SILTY SAND, narrowly graded fine sand, ~40% non to sl. plastic fines, brown and olive gray (SM) Fines content decreases with depth of sample.
	100–102	S45	26 33 34 40	24	16		S45-Top 8": SILTY SAND, narrowly graded fine sand, ~30% nonplastic fines, olive gray (SM) Bot 8": SILTY SAND, narrowly graded fine sand, ~20% nonplastic fines, olive brown (SM)
	102–104	S46	33 35 43 40	24	17		S46-Top 8": SAND, narrowly graded med. to fine sand, ~5% nonplastic fines, gray (SP) Section contained a [illegible]" piece of freshly broken gravel. Bot 9": SAND, widely graded coarse to fine sand, ~5% nonplastic fines, ~[illegible]% gravel up to ½", brown (SW)
	104						Bottom of Borehole - 104.0 ft

BLOWS PER 6": 140 LB HAMMER FALLING 30" TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE   UD: DENISON
UF: FIXED PISTON   UP: PITCHER
UO: OSTERBERG   UG: GEL

GROUNDWATER

NOTES

1. See Page 1.

RE-EVALUATION OF [illegible] IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE [illegible]

PROJECT [illegible]

BORING LOCATION Sta 16+35, 54.0'N GROUND ELEVATION (NGVD) 1114.6 DATE START/FINISH 10/8/85 / 10/8/85 **U102**

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 70.1 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL NR 1) DATE ___ LOGGED BY J.R. Perkins DATE 10/8/85 PG 1 OF 2

EL FT	DEPTH FT	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN	SAMPLE PEN CM	SAMPLE REC CM	REMARKS	SOIL AND ROCK DESCRIPTIONS
1114.6	0					2)	
	5						
	10						
	15						
	20						
	25						
	30						
	35						
	40						
	45						
	50						
	55						
	60	UP1	PUSH	61.5	[illegible]		UP1 - Bottom Trimmings, (CL) trimmed to (SP)
		UP2	PUSH	61	[illegible]		P2 - Bottom Trimmings (SW-SP)
		P3	[illegible]	[illegible]	[illegible]		P3 - Bottom Trimmings [illegible] trimmed to [illegible]

BLOWS PER 6 IN: [illegible] LB HAMMER FALLING 30 IN TO DRIVE A 2 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
[illegible] LENGTH OF SOUND CORES [illegible] IN / LENGTH CORED %
[illegible]
UNDISTURBED SAMPLES
T: SHELBY TUBE — D: DENISON
F: FIXED PISTON — P: PITCHER
O: OSTERBERG — C: CORE

GROUNDWATER

NOTES

1) Groundwater [illegible] not [illegible] used [illegible] produce inaccurate readings.
2) Boring advanced using [illegible] washboring or [illegible] with a bentonite drilling mud. [illegible] Backfilled boring with [illegible] cuttings.

[illegible]

GEOTECHNICAL ENGINEERS INC.

DATE 11-4-85
PROJECT 85669

BORING LOCATION Sta 16+35, 54.0'N GROUND ELEVATION (NGVD) [illegible]14.6 DATE START/FINISH 10/8/85 / 10/8/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) [illegible]0.1 DRILLED BY P. Stevers, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 10/8/85

U102

PG 2 OF 2

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN CM	REC CM	REMARKS	SOIL AND ROCK DESCRIPTIONS
1049.6	65	UF3	PUSH	[illegible]0.3	59.[illegible]		UF3 - See previous page.
		UF4	PUSH	61.1	60.6		UF4 - Bottom Trimmings, (CL).
		UF5	PUSH	60.3	59.9		UF5 - Bottom Trimmings, (ML-SM)
	70						Bottom of Borehole - 70.0'

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE 2 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES ÷ RUN LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
GROUNDWATER

NOTES

GEOTECHNICAL ENGINEERS INC

DATE [illegible] 85

PROJECT [illegible]

BORING LOCATION Sta 9+30, 132.0'S GROUND ELEVATION (NGVD) 1093.9 DATE START/FINISH 10/9/85 / 10/9/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 86.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL NR(1) DATE - LOGGED BY J.R. Perkins DATE 10/9/85

U103

PG 1 OF 1

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN CM	REC CM	REMARKS	SOIL AND ROCK DESCRIPTIONS
1093.9	0						
	77	UF1	PUSH	44.7	3?.2		UF1 - Bottom Trimmings, (SM).
	78	UF2	PUSH	36.9	36.?		UF2 - Bottom Trimmings, (SP).
	81	UF3	PUSH	59.6	58.4		UF3 - Bottom Trimmings, (SP).
	82	UF4	PUSH	60.1	59.5		UF4 - Bottom Trimmings, (SP-SW).
	84	UF5	PUSH	60.8	60.2		UF5 - Bottom Trimmings, (SP).
	86						Bottom of Borehole - 86.0'

BLOWS PER 6 IN.: 140 LB HAMMER FALLING 30 IN. TO DRIVE A 2 IN. OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE — UD: DENISON
UF: FIXED PISTON — UP: PITCHER
UO: OSTERBERG — UG: GEL
▽ GROUNDWATER

NOTES

1. Groundwater levels not recorded because bentonite drilling mud used in borehole would produce inaccurate readings.
2. Borehole advanced using standard rotary wash boring procedures with a bentonite drilling mud. Cleaned out borehole with a ... flange bit with ... and jetting ...

[illegible] WEBER SANFORD DAM

GEOTECHNICAL ENGINEERS INC.

DATE 11/4/85
PROJECT 85669

BORING LOCATION Sta 9+30, 73.1'S	GROUND ELEVATION (NGVD) 1114.5	DATE START/FINISH 10/5/85 / 10/6/85
INCLINATION Vertical BEARING NA	TOTAL DEPTH (FT) 115.0	DRILLED BY F. Stewart, WES/COE
CASING ID Not used CORE SIZE NA	GROUNDWATER EL NR (1) DATE -	LOGGED BY J.R. Perkins DATE 10/5-6/85

U104 PG. 1 OF 2

EL 1114.5 FT at DEPTH 0 FT

Depth scale (FT): 0, 5, 10, (break), 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100

SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN CM	REC CM	REMARKS	SOIL AND ROCK DESCRIPTIONS
UF1	PUSH	6[illegible].3	60.7		UF1 - Bottom Trimmings, (CL-ML).
UF2	PUSH	60.7	60.1		UF2 - Bottom Trimmings, (CL).
UF3	PUSH	60.7	59.6		UF3 - Bottom Trimmings, (CL).
UF4	PUSH	61.0	60.1		UF4 - Bottom Trimmings, (CL).
UF5	PUSH	60.2	57.4		UF5 - Bottom Trimmings, (SP).
UF6	PUSH	60.2	58.7		UF6 - Bottom Trimmings, (SP).
UF7	PUSH	55.8	53.4		UF7 - Bottom Trimmings, (SP).
UF8	PUSH	[illegible]	58.8		UF8 - Bottom Trimmings, (SP).
UF9	PUSH	55.8	55.8		UF9 - Bottom Trimmings, (CL).

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES 4 IN/LENGTH CORED %
S: SPLIT SPOON SAMPLE
UNDISTURBED SAMPLES
[illegible]
GROUNDWATER

NOTES

1. Groundwater levels not recorded because bentonite drilling mud used in borehole would produce inaccurate readings.
2. Borehole advanced using standard rotary wash boring procedures with a bentonite drilling mud. Cleaned out borehole with a [illegible] with upward jetting

REEVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC

DATE 11/4/85
PROJECT 85669

BORING LOCATION Sta 9+30, 73.1'S GROUND ELEVATION (NGVD) 1114.5 DATE START/FINISH 10/5/85 / 10/6/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 115.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NA DATE - LOGGED BY J.R. Perkins DATE 10/5-6/85

U104

PG 2 OF 2

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN CM	REC CM	REMARKS	SOIL AND ROCK DESCRIPTIONS
1014.5	100						
	105	UF10	PUSH	59.8	59.6		UF10 - Bottom Trimmings, (SM).
		UF11	PUSH	43.4	41.2		UF11 - Bottom Trimmings, (SM).
	110	UF12	PUSH	24.6	23.9		UF12 - Bottom Trimmings, (SW).
		UF13	PUSH	57.6	56.0		UF13 - Bottom Trimmings, (SM).
		UF14	PUSH	60.5	60.1		UF14 - Bottom Trimmings, (ML-CL).
	115						Bottom of Borehole - 115.0'
	120						

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE — UD: DENISON
UF: FIXED PISTON — UP: PITCHER
UO: OSTERBERG — UX: BEI

GROUNDWATER

NOTES

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.
WINCHESTER, MASSACHUSETTS

DATE 11/4/85
PROJECT 85669

BORING LOCATION	Sta 9+30, 23.4'S	GROUND ELEVATION (NGVD)	1114.1	DATE START/FINISH	10/6/85 / 10/8/85	U105
INCLINATION	Vertical	BEARING	NA	TOTAL DEPTH (FT)	100.0	
				DRILLED BY	F. Stewart, WES/COE	
CASING ID	Not used	CORE SIZE	NA	GROUNDWATER EL.	NR[1]	PG 1 OF 2
DATE	-	LOGGED BY	J.R. Perkins	DATE	10/6-8/85	

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN CM	REC CM	REMARKS	SOIL AND ROCK DESCRIPTIONS
1114.1	0						
	5						
	10						
	15						
	20						
	25						
	30						
	35						
	40						
	45						
	50						
		UF1	PUSH	61.7	60.8		UF1 - Bottom Trimmings, (CL).
		UF2	PUSH	60.6	59.9		UF2 - Bottom Trimmings, (CL).
	55						
	60						
		UF3	PUSH	60.5	[illegible]		UF3 - Bottom Trimmings, (SP).
	65						

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE — UD: DENISON
UF: FIXED PISTON — UP: PITCHER
UO: OSTERBERG — U(?): (BE)
▽ GROUNDWATER

NOTES

1) Groundwater levels not recorded because bentonite drilling mud used in borehole would produce inaccurate readings.

2) Borehole advanced using standard rotary wash boring procedures with a bentonite drilling mud. Cleaned out borehole with a 4" fishtail bit with upward jetting.

RE-EVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC

DATE 11/4/85
PROJECT 85669

BORING LOCATION Sta 9+30, 23.4'S	GROUND ELEVATION (NGVD) 1114.1	DATE START/FINISH 10/6/85 / 10/8/85	U105
INCLINATION Vertical BEARING NA	TOTAL DEPTH (FT.) 100.0	DRILLED BY F. Stewart, WES/COE	
CASING ID Not used CORE SIZE NA	GROUNDWATER EL. NR[1] DATE -	LOGGED BY J.R. Perkins DATE 10/6-8/85	PG 2 OF 2

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN	PEN CM	REC CM	REMARKS	SOIL AND ROCK DESCRIPTIONS
1049.1	65	UF4	PUSH	61.2	60.5		UF4 - Bottom Trimmings, (CL).
		UF5	PUSH	60.6	59.9		UF5 - Bottom Trimmings, ([illegible])
	70	UF6	PUSH	61.3	60.4		UF6 - Bottom Trimmings, (SP).
	75						
		UF7	PUSH	62.4	61.2		UF7 - Bottom Trimmings, (CL).
		UF8	PUSH	60.8	59.9		UF8 - Bottom Trimmings, (CL).
	80						
	85						
		UF9	PUSH	59.6	58.4		UF9 - Bottom Trimmings, (SM-SP).
	90	UF10	PUSH	62.1	60.8		UF10 - Bottom Trimmings, (SP).
		UF11	PUSH	59.6	59.0		UF11 - Bottom Trimmings, (CL).
	95	UF12	PUSH	61.0	59.8		UF12 - Bottom Trimmings, (CL).
		UF13	PUSH	60.9	59.8		UF13 - Bottom Trimmings, (CL).
		UF14	PUSH	60.4	59.7		UF14 - Bottom Trimmings, (ML).
	100						Bottom of Borehole - 100.0'

NOTES

BORING LOCATION Sta 5+80, 132.0'S GROUND ELEVATION (NGVD) 1095.1 DATE START/FINISH 9/26/85 / 10/3/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT) 88.8 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 9/26/85 10/3/85

UF11

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN CM	REC CM	REMARKS	SOIL AND ROCK DESCRIPTIONS
1095.1	0						
	25	UF1	PUSH	60.8	53.3		UF1 - Bottom Trimmings, (SM).
		UF2	PUSH	61.4	52.0		UF2 - Bottom Trimmings, (SW).
		UF3	PUSH	63.1	63.3		UF3 - Bottom Trimmings, (SW-SP).
		UF4	PUSH	61.6	60.[illegible]		UF4 - Bottom Trimmings, (ML-CL).
		UF5	PUSH	60.6	59.8		UF5 - Bottom Trimmings, (SW).
	55	UF6	PUSH	53.4	50.3		UF6 - Bottom Trimmings, (SP).
		UF7	PUSH	34.4	32.[illegible]		UF7 - Bottom Trimmings, (SW).
		UF8	PUSH	35.5	35.2		UF8 - Bottom Trimmings, (SP).
		UF9	PUSH	60.6	59.[illegible]		UF9 - Bottom Trimmings, (SP) trimmed to (CL).
		UF10	PUSH	53.3	51.2		UF10 - Bottom Trimmings, (SP).
	65	UF11	PUSH	50.[illegible]	48.[illegible]		UF11 - Bottom Trimmings, (SP).

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES > 4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
US: SHELBY TUBE; UD: DENISON; UF: FIXED PISTON; UP: PITCHER; UO: OSTERBERG; UG: GEL

▼ GROUNDWATER

NOTES

1) Groundwater levels not recorded because bentonite drilling mud used in borehole would produce inaccurate readings.

2) Borehole advanced using standard rotary wash boring procedures with a bentonite drilling mud. Cleaned out borehole with a [illegible] [illegible] [illegible] [illegible]

REEVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE [illegible]
PROJECT [illegible]

BORING LOCATION Sta 5+80, 132.0'S GROUND ELEVATION (NGVD) 1095.1 DATE START/FINISH [illegible] / 10/2/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 88.8 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR 1) DATE - LOGGED BY J.R. Perkins DATE 9/26/85 - 10/3/85

U111

PG. 2 OF 2

EL FT	DEPTH FT	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN CM	REC CM	REMARKS	SOIL AND ROCK DESCRIPTIONS
1030.1	65	UF11	PUSH	50.2	48.9		UF11 - See previous page.
		UF12	PUSH	56.4	54.2		UF12 - Bottom Trimmings, (SP).
		UF13	PUSH	42.3	41.3		UF13 - Bottom Trimmings, (SP).
	70	UF14	PUSH	[illegible]	[illegible]		UF14 - Did not save.
		UF15	PUSH	52.4	51.9		UF15 - Bottom Trimmings, (SP).
		UF16	PUSH	60.5	59.8		UF16 - Bottom Trimmings, (SM-ML).
	75	UF17	PUSH	51.0	50.0		UF17 - Bottom Trimmings, (SP).
		UF18	PUSH	60.6	60.1		UF18 - Bottom Trimmings, (ML).
	80	UF19	PUSH	61.3	60.3		UF19 - Bottom Trimmings, (ML-SM).
		UF20	PUSH	61.4	60.6		UF20 - Bottom Trimmings, (SP-SM).
		UF21	PUSH	60.5	59.2		UF21 - Bottom Trimmings, (SW).
	85	UF22	PUSH	61.7	61.0		UF22 - Bottom Trimmings, (SM).
		UF23	PUSH	53.5	53.0		UF23 - Bottom Trimmings, (ML).
	90						Bottom of Borehole - 88.8'
	95						
	100						

BLOWS PER 6 IN. - 140 LB HAMMER FALLING 30 IN. TO DRIVE A 2 IN. OD SPLIT SPOON SAMPLER
PEN - PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC - RECOVERY LENGTH OF SAMPLE
RQD - LENGTH OF SOUND CORES ... LENGTH CORED %
S - SPLIT SPOON SAMPLE
U - UNDISTURBED SAMPLES
S - SHELBY TUBE   UD - DENISON
F - FIXED PISTON   UP - PITCHER
UO - OSTERBERG   UG - GEL
GROUNDWATER

NOTES

GEOTECHNICAL ENGINEERS INC.

DATE 11/4/85
PROJECT 85669

BORING LOCATION Sta 5+85, 137.0'S GROUND ELEVATION (NGVD) 1095.1 DATE START/FINISH 10/10/85 / 10/11/85

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) [illegible] DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.P. Perkins DATE 10/10-11/85

U111A

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN CM	REC CM	REMARKS	SOIL AND ROCK DESCRIPTIONS
1095.1	0						
	5						
	10						
	15						
	20						
	25						
	30						
	35						
	40						
	45						
		UF1	PUSH	60.8	61.2		UF1 - Bottom Trimmings, (SP)
	50	UF2	PUSH	59.8	55.9		UF2 - Bottom Trimmings, (SP)
		UF3	PUSH	59.7	59.0		UF3 - Bottom Trimmings, (SP)
	55	UF4	PUSH	60.2	57.3		UF4 - Bottom Trimmings, (SP)
		UF5	PUSH	54.5	53.[illegible]		UF5 - Bottom Trimmings, (SP-SW).
		UF6	PUSH	[illegible]	[illegible]		UF6 - Bottom Trimmings, (SW).
	60	UF7	PUSH	[illegible]	[illegible]		UF7 - Bottom Trimmings, (SP).
		UF8	PUSH	[illegible]	[illegible]		UF8 - Bottom Trimmings, (SP).
	65	UF9	PUSH	[illegible]	[illegible]		UF9 - Bottom Trimmings, (SW).

BLOWS PER 6 IN: [illegible] HAMMER FA[illegible] [illegible] SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
[illegible] LENGTH OF SOUND CORES [illegible] LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
S: SHELBY TUBE — D: DENISON
[illegible] FIXED PISTON — [illegible]
O: OSTERBERG — [illegible]
GROUNDWATER

NOTES
1. Groundwater levels not recorded because bentonite drilling mud used in borehole would produce inaccurate readings.
2. Borehole advanced using standard rotary wash boring procedures with a bentonite drilling mud. Cleaned out borehole with a [illegible] [illegible] bit with upward jetting.

REEVALUATION OF THE [illegible] IN THE [illegible] SAN FERNANDO DAM

GEOTECHNICAL ENGINEERS INC.

DATE [illegible] 85
PROJECT [illegible]

BORING LOCATION Sta 5+85, 137.0'S GROUND ELEVATION (NGVD) 1095.1 DATE START/FINISH 10/10/85 / 10/11/85 **UIIIA**

INCLINATION Vertical BEARING NA TOTAL DEPTH (FT.) 89.0 DRILLED BY F. Stewart, WES/COE

CASING ID Not used CORE SIZE NA GROUNDWATER EL. NR[1] DATE - LOGGED BY J.R. Perkins DATE 10/10-11/85 PG 2 OF 2

EL FT	DEPTH FT	SAMPLE TYPE and NO	BLOWS PER 6 IN	PEN CM	REC CM	REMARKS	SOIL AND ROCK DESCRIPTIONS
1030.1	65						
		UF10	PUSH	59.6	58.5		UF10 - Bottom Trimmings, (SP).
		UF11	PUSH	27.2	27.2		UF11 - Bottom Trimmings, (SW).
	70	UF12	PUSH	54.7	54.1		UF12 - Bottom Trimmings, (SW/gravel).
		UF13	PUSH	59.2	58.6		UF13 - Bottom Trimmings, (SP-SM)
	75	UF14	PUSH	60.0	59.2		UF14 - Bottom Trimmings, (SM-ML)
		UF15	PUSH	56.1	53.9		UF15 - Bottom Trimmings, (SP-SW)
		UF16	PUSH	60.2	59.7		UF16 - Bottom Trimmings, (SM).
	80	UF17	PUSH	60.1	58.9		UF17 - Bottom Trimmings, (SP).
		UF18	PUSH	60.4	59.5		UF18 - Bottom Trimmings, (SW-SP).
		UF19	PUSH	60.6	59.5		UF19 - Bottom Trimmings, (SM-SP).
	85	UF20	PUSH	59.3	58.4		UF20 - Bottom Trimmings, (SP-SM).
		UF21	PUSH	61.1	60.6		UF21 - Bottom Trimmings, (SW-SM).
	90						Bottom of Borehole - 89.0'
	95						
	100						

BLOWS PER 6 IN: 140 LB HAMMER FALLING 30 IN TO DRIVE A 2.0 IN OD SPLIT SPOON SAMPLER
PEN: PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC: RECOVERY LENGTH OF SAMPLE
RQD: LENGTH OF SOUND CORES >4 IN / LENGTH CORED %
S: SPLIT SPOON SAMPLE
U: UNDISTURBED SAMPLES
GROUNDWATER

NOTES

REEVALUATION OF THE SLIDE IN THE LOWER SAN FERNANDO DAM

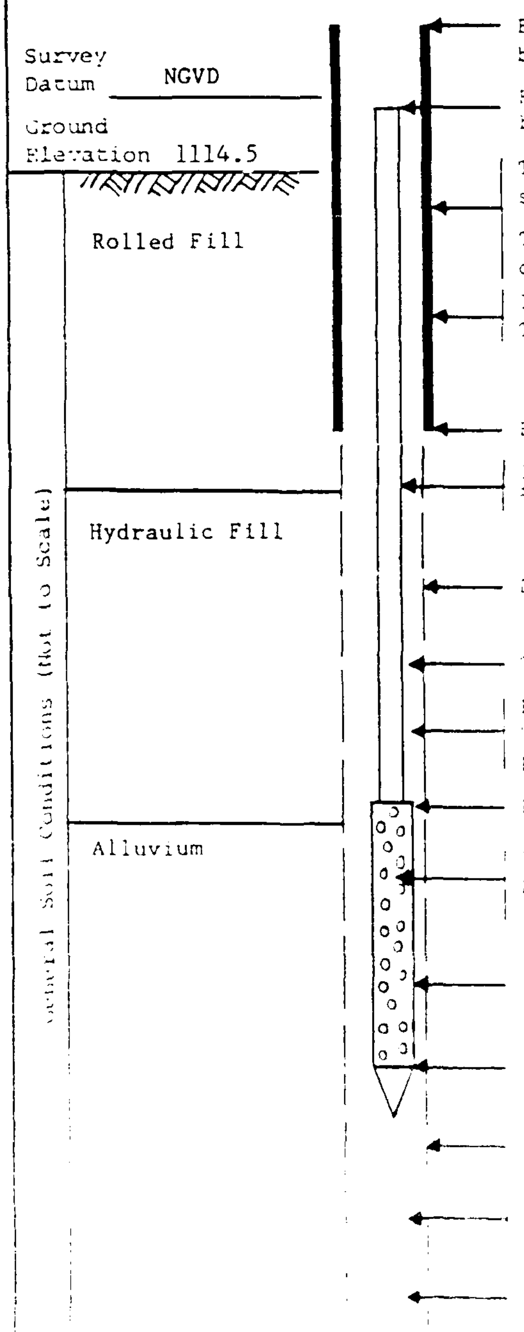
GEOTECHNICAL ENGINEERS INC.

DATE 11/4/85

PROJECT 85669

GROUNDWATER OBSERVATION WELL REPORT

Project	Lower San Fernando Dam	Page	1 of 1
Location	San Fernando Valley, California	Well No.	OW104
Client	WES/COE	Boring No.	OW104
Contractor	WES/COE Driller F. Stewart	Location	Sta 9+55
Inspected by	J. R. Perkins Date September 25, 1985		73.1' S
Checked by	T. O. Keller Date November 7, 1985	Proj. No.	85669



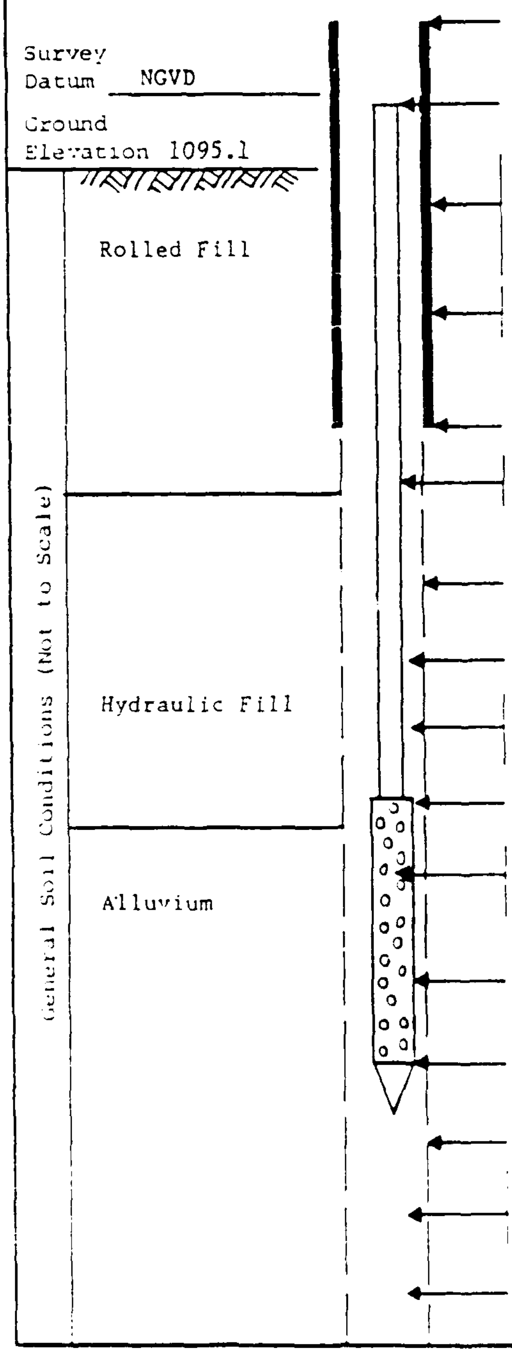
Elev. or length of surface casing above/below ground surface	0.1'
Elev. or length of riser pipe above/below ground surface	0
Thickness of surface seal below ground surface, if any	78.0'
Type of surface seal (indicate any additional seals)	cement grout
ID of surface casing	4.0"
Type of surface casing	steel pipe
Elev./depth bottom of casing	2.0'
ID and OD of riser pipe	1½"
Type of riser pipe	PVC
Diameter of borehole	4.0"
Type of backfill around riser pipe	cement grout
Elev./depth top of seal, if any	0
Type of seal	cement grout
Elev./depth bottom of seal	78.0'
Elev./depth top of pervious section	100.0'
Type of pervious section	PVC
Describe openings	slotted
ID and OD of pervious section	1½"
Type of backfill around pervious section	Ottawa sand
[illegible]	115.0'
[illegible]	117.0'
[illegible]	-
[illegible]	-
[illegible]	-
[illegible]	[illegible]

GROUNDWATER OBSERVATION WELL REPORT

Project	Lower San Fernando Dam	Page	1 of 1
Location	San Fernando Valley, California	Well No.	OW111
Client	WES/COE	Boring No.	OW111
Contractor	WES/COE — Driller: F. Stewart	Location	Sta 5+95, 132.0' S
Inspected by	J. R. Perkins — Date: October 4, 1985		
Checked by	T. O. Keller — Date: November 7, 1985	Proj. No.	85669

Survey Datum NGVD

Ground Elevation 1095.1



Elev. or length of surface casing above/below ground surface	-
Elev. or length of riser pipe above/below ground surface	1.5'
Thickness of surface seal below ground surface, if any	78.0'
Type of surface seal (indicate any additional seals)	cement grout
ID of surface casing	-
Type of surface casing	-
Elev./depth bottom of casing	-
ID and OD of riser pipe	1½"
Type of riser pipe	PVC
Diameter of borehole	4.0"
Type of backfill around riser pipe	cement grout
Elev./depth top of seal, if any	0
Type of seal	cement grout
Elev./depth bottom of seal	78.0'
Elev./depth top of pervious section	88.0'
Type of pervious section	PVC
Describe openings	slotted
ID and OD of pervious section	1½"
Type of backfill around pervious section	Ottawa sand
Elev./depth bottom of pervious section	93.0'
Elev./depth bottom of sand column	95.0'
Elev./depth top of seal, if any	-
Type of seal	-
Elev./depth bottom of seal	-
Type of backfill below pervious section, if any	Ottawa sand

APPENDIX B: EXPLORATION SHAFT

APPENDIX B

EXPLORATION SHAFT

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APPENDIX B

EXPLORATION SHAFT

B.1 Purpose and Scope

An exploration shaft was made through the downstream hydraulic fill shell of the dam to perform the following tasks at three separate levels in the dam:

a. Obtain undisturbed samples using GEI's tripod tube sampler.

b. Perform field density tests.

c. Obtain bag samples for laboratory testing.

d. Map the sidewalls of the excavation.

The exploration shaft was made at Location 111 as shown in Fig. 5 of the main text. The shaft was made at this location because N-values at the base of the hydraulic fill shell were more consistently low at this location than at other locations. The centerline of the shaft was located 12 feet north (upstream) of SPT boring S111.

The excavation and backfilling of the shaft was performed by Zamborelli Drilling Company, Inc. of Los Angeles, California. All sampling, testing, and mapping was performed by GEI from November 26 through December 20, 1985.

Explorations were performed in the shaft within Zones 2, 3, and 5 of the hydraulic fill shell shown in Fig. 9. The elevation ranges for explorations in each zone were as follows:

Zone	Exploration Elevation Range, ft
2	1047-1040
3	1034-1030
5	1016-1010

The ground surface elevation at the shaft location was El. 1097.5.

A total of 44 undisturbed tube samples were obtained from the shaft using GEI's tripod sampler. A total of [illegible]2 field density tests were performed using sand cone techniques. Approximately 2,500 pounds of bag samples were obtained from the shaft. Bag samples were obtained from the same layers in which tripod tube samples were taken and field density tests were performed. Bag samples from a particular layer were later mixed at GEI's laboratory to form batch mixes for laboratory testing.

B.2 Shaft Advancement Procedure

The shaft was excavated using a caisson drilling rig with a 6-foot-diameter auger. The sidewalls of the shaft were supported with 6-foot-diameter steel casing.

The excavation was advanced using an auger to approximately 1.5 feet above each sampling level. The casing was then lowered to the bottom of the excavation and fixed at the ground surface with two steel I-beams to prevent further penetration. The contractor hand excavated to within 2 to 3 inches of the desired sampling depth. While hand excavating to the top of the sampling level, one-quarter circles of plywood were placed on the bottom of the test shaft so as not to disturb the underlying layers. The last few inches were hand excavated by GEI's field engineers. A pilot excavation, one quarter of the shaft bottom area, was hand excavated approximately 1.0 foot below the sampling depth. This pilot excavation was used to identify soil layers prior to the start of sampling so that sampling and field density tests would be performed within a defined layer. Once the remaining three quarters of the shaft bottom was leveled and smoothed, sampling and field density testing was performed until the area was depleted. Details of tripod tube sampling and field density testing are presented in Sections B.3 and B.4, respectively. Hand excavating, sampling, and testing continued in approximately 1 foot vertical increments to the bottom of the sampling level.

When the bottom of the sampling level was reached, the sidewalls of the exposed layers below the casing were mapped. After all sampling and testing was completed, the casing was removed and the shaft was advanced with augers to the next sampling level.

[illegible] was encountered in the shaft at El. [illegible] approximately 12 inches above the bo[illegible] [illegible]

12-inch perforated steel casing that penetrated approximately 6 inches below the bottom of the drain. Inside the 12-inch perforated casing, a small submersible pump was used to remove the water.

After sampling, testing, and mapping were completed, the steel casing was removed and the test shaft backfilled with a 4,000 psi concrete mix to 1 foot below the ground surface. During the backfilling, the concrete mix was poured through a hopper connected to a 15-foot-long hose centered over the shaft.

B.3 Undisturbed Tripod Tube Sampling

Forty-four undisturbed tripod tube samples were obtained using GEI's tripod sampler. Tripod tube sample data is presented in Table B1. A photograph of the GEI tripod tube sampler is shown in Fig. B1. Sampling tubes were 3.0-inch O.D., 14-inch-long thin-walled galvanized steel tubes. Each tube was machined to have approximately zero clearance ratio, as defined in Table B1. Precise measurements showed that actual clearance ratios ranged from -0.01% to 0.01%.

All hand excavating and sampling was performed while standing on one-quarter circles of plywood so as not to disturb the underlying soils. The remaining three quarters of the soil surface was leveled prior to sampling and testing. The locations of tripod tube samples at each sampling level are shown in Figs. B2 to B4. An effort was made to obtain samples consisting of predominantly one soil type. This was done by starting the sampling at the top of a soil layer.

The tripod sampler shown in Fig. B1 was used to maintain the sampling tube in vertical alignment during advancement. The tube was advanced in increments of about 1/2-inch by using no more than light hand pressure. About 1/2 to 1 inch of soil around the periphery of the tube, below the cutting edge, was excavated prior to advancement of the tube. This pre-excavation allowed soil to easily peel away from the tube as it was advanced and minimized volume changes during sampling. Several hours of effort were required to obtain each sample.

Detailed measurements of tube penetration and soil recovery were made during advancement of the tube. These measurements are included in Table B1. Soil volume changes which occurred during sampling were computed based on these measurements.

B.4 Field Density Tests

Twelve field density tests were performed in the shaft using sand cone techniques. The test procedure was in accordance with ASTM D1556-82, "Density of Soil In Place by the Sand-Cone Method." A summary of field density test results is presented in Table B2.

At least one field density test was performed on each layer in which tripod tube samples were obtained (except one layer). An attempt was made to centrally locate each field density test with respect to the tube samples. The locations of field density tests are shown on the sampling location plans in Figs. B2 to B4. An effort was made to perform field density tests in one soil layer. However, virtually every layer encountered was intensely stratified. Representative samples of material were taken adjacent to the field density test locations for compaction testing in the laboratory.

B.5 Wall Mapping

Mapping of the exposed sidewalls below the casing was performed at each exploration level to document the stratification of the hydraulic fill.

Mapping was performed after tube sampling and field density testing because the largest amount of wall was exposed at that time. The upstream direction of the shaft was established and called north. Mapping started at the bottom of the casing and continued to the bottom of the sampled level.

Photographs of the excavation sidewalls were taken at each level of the shaft. Typical photographs at each level are shown in Figs. B5 to B7. These photos show the intense stratification present in the hydraulic fill shell.

TABLE B1 - UNDISTURBED TRIPOD TUBE SAMPLE DATA
Lower San Fernando Dam - California

ZONE 2

Sample	Elevation,(1) Top of Sample ft	Clearance(2) Ratio CR %	Cumulative Penetration P cm	Cumulative Recovery R cm	Total(3) ΔV/V %
TS101	1044.3	0.000	10.40 18.42	10.80 18.87	2.44
TS102	1044.3	-0.041	10.41 15.67	10.36 15.59	-0.59
TS103	1044.4	-0.032	6.90 15.97	7.08 16.14	1.00
TS104	1044.4	0.018	10.69 11.44	10.78 11.46	0.21
TS105	1044.5	-0.096	9.34 14.49	9.64 14.72	1.39
TS106	1044.4	0.036	8.98 16.53	8.99 16.69	1.04
TS107	1044.4	0.018	8.49 17.32	8.76 17.50	1.08
TS108	1043.0	-0.041	6.02 14.40	5.95 14.31	-0.71
TS109	1042.9	0.036	7.83 15.03	7.82 14.98	-0.26
TS110	1043.0	-0.077	[illegible] [illegible]	9.43 18.05	-0.81
TS111	1042.9	-0.018	10.48 16.61	10.34 16.40	-1.30
TS112	1042.4	-0.032	2.14 7.29 14.28	2.26 7.50 14.46	1.20

Notes: See page 5

Sample	Elevation,(1) Top of Sample ft	Clearance(2) Ratio CR %	Cumulative Penetration P cm	Cumulative Recovery R cm	Total(3) ΔV/V %
		Z O N E 2			
TS113	1042.3	-0.068	5.12	5.35	
			9.34	9.72	
			14.83	15.47	4.17
TS114	1042.4	-0.050	5.86	6.18	
			9.49	9.85	
			19.81	20.27	2.22
TS115	1041.2	-0.004	8.82	8.93	
			16.05	16.06	0.05
TS116	1041.1	-0.041	8.71	8.84	
			15.58	15.60	0.05
TS117	1041.1	-0.027	6.03	6.08	
			15.81	16.02	1.27
		Z O N E 3			
TS201	1032.5	-0.082	5.18	5.20	
			11.16	11.16	
			24.18	24.17	-0.21
TS202	1032.5	-0.027	8.37	8.37	
			13.56	13.56	
			23.51	23.40	-0.52
TS203	1032.5	-0.004	10.08	10.08	
			15.63	15.56	
			24.31	24.23	-0.34
TS204	1032.5	0	10.24	10.21	
			14.64	14.64	
			26.34	26.21	-0.49

Notes: See page 5

TABLE B1 - UNDISTURBED TRIPOD TUBE SAMPLE DATA
Lower San Fernando Dam - California

Z O N E 2

Sample	Elevation,(1) Top of Sample ft	Clearance(2) Ratio CR %	Cumulative Penetration P cm	Cumulative Recovery R cm	Total(3) ΔV/V %
TS205	1032.5	-0.050	12.11	12.05	
			20.10	19.95	
			28.91	28.79	-0.51
TS206	1032.5	-0.095	11.56	11.52	
			15.81	15.72	
			19.15	18.98	-1.08
TS207	1032.5	-0.055	9.27	9.28	
			19.72	19.76	
			28.79	28.79	-0.11
TS208	1031.1	0.027	6.64	6.67	
			14.57	14.58	
			17.01	17.00	0
TS209	1031.2	-0.046	8.67	8.67	
			15.36	15.28	
			17.11	17.10	-0.15
TS210	1031.2	-0.036	7.10	7.08	
			14.14	14.03	
			18.20	18.11	-0.57
TS211	1030.8	-0.055	7.30	7.41	
			11.55	11.57	
			13.41	13.48	0.41

Z O N E 3

Sample	Elevation,(1) Top of Sample ft	Clearance(2) Ratio CR %	Cumulative Penetration P cm	Cumulative Recovery R cm	Total(3) ΔV/V %
TS301	1015.2	0.009	6.18	6.18	
			11.69	11.72	
			13.8[illegible]	13.91	0.16
TS302	1014.0	-0.004	6.32	6.35	
			17.04	16.95	
			27.30	27.07	-0.85

Notes: See page 5

Z O N E 2

Sample	Elevation,(1) Top of Sample ft	Clearance(2) Ratio CR %	Cumulative Penetration P cm	Cumulative Recovery R cm	Total(3) ΔV/V %
TS303	1013.9	-0.018	9.39	9.42	
			15.97	15.93	
			19.94	19.84	
			23.01	22.83	-0.82
TS304	1014.0	-0.096	6.46	6.44	
			11.32	11.24	
			16.70	16.53	
			21.55	21.25	-1.58
TS305	1014.0	0.018	5.59	5.56	
			12.20	12.11	
			16.96	16.75	
			19.79	19.55	-1.18
TS306	1014.0	-0.018	5.73	5.76	
			13.82	13.78	
			21.91	21.82	
			27.20	27.12	-0.33
TS307	1014.0	0	6.18	6.16	
			12.57	12.58	
			19.28	19.21	
			23.43	23.32	-0.47
TS308	1014.1	0	8.10	8.09	
			14.62	14.55	
			20.40	20.27	
			21.55	21.41	-0.65
TS309	1014.1	0	7.99	8.02	
			14.02	13.96	
			22.06	21.91	
			26.51	26.31	-0.75
TS310	1013.1	0.009	7.61	7.49	
			12.55	12.37	
			21.30	21.00	
			25.45	25.09	-1.40

Notes: See page 5

TABLE B1 - UNDISTURBED TRIPOD TUBE SAMPLE DATA
Lower San Fernando Dam - California

ZONE 2

Sample	Elevation,[1] Top of Sample ft	Clearance[2] Ratio CR %	Cumulative Penetration P cm	Cumulative Recovery R cm	Total[3] ΔV/V %
TS311	1013.1	-0.014	3.78	3.74	
			12.48	12.28	
			19.22	18.87	-1.85
TS312	1013.2	-0.004	7.36	7.35	
			15.47	15.36	
			20.56	20.37	-0.93
TS313	1013.3	0.014	9.07	9.06	
			13.20	13.17	
			18.19	18.09	
			22.08	21.92	-0.70
TS314	1013.4	-0.018	9.96	9.78	
			15.76	15.53	
			17.68	17.42	-1.51
TS315	1012.4	0.009	8.28	8.37	
			12.27	12.33	
			15.31	15.33	0.15
TS316	1012.4	0.009	7.58	7.55	
			12.25	12.23	-0.15

Notes:

(1) Elevation datum is NGVD

(2) Clearance Ratio (CR) as defined as:

$$CR = \frac{ID-CE}{CE} \times 100\%$$

Where: ID = inside diameter of sampling tube
CE = diameter of cutting edge of sampling tube
Negative values indicates diameter of cutting edge is larger than inside diameter of sampling tube

(3) Change in volume during sampling (ΔV/V) is defined as:

$$\Delta V/V = \left[\left(1+\frac{CR}{100}\right)^2 \times \frac{R}{P} - 1\right] \times 100 \text{ (in percent)}$$

Where: CR = clearance ratio of sample tube, defined above.
R = gross recovery
P = penetration length
Positive values indicate sample expansion; negative values indicate sample compression.

TABLE B2 - SUMMARY OF FIELD DENSITY TESTS
PERFORMED IN EXPLORATION SHAFT
Lower San Fernando Dam

Field Density Test No.	Depth, Top of Layer	Elevation, Top of Layer	Field Measurements[1]			Estimated Δe Due to Swell	Estimated In situ Void Ratio in 1985
			Water Content	Dry Unit Weight, γ_d	Void Ratio		
	ft	ft, NGVD	%	pcf	(2)	(3)	(4)
101	53.2	1044.3	10.0	97.3	0.719	-0.017	0.702
102	54.6	1042.9	33.3	91.1	0.856	0	0.856
103	55.1	1042.4	8.2	108.0	0.542	-0.017	0.525
104	56.4	1041.1	16.1	95.8	0.746	-0.017	0.729
201	65.0	1032.5	14.8	93.3	0.785	-0.016	0.769
202	66.3	1031.2	12.7	94.9	0.762	-0.018	0.744
203	66.3	1031.2	13.2	93.9	0.781	-0.018	0.763
301	83.5	1014.0	26.2	98.6	0.702	-0.026	0.676
302	84.4	1013.1	27.4	96.7	0.736	-0.032	0.704
303	84.4	1013.1	26.0	98.1	0.711	-0.032	0.679
304	84.4	1013.1	27.9	95.8	0.752	-0.032	0.720
305	85.2	1012.3	23.8	100.7	0.667	-0.028	0.639

Notes:

1) Field density tests were performed using sand cone techniques, ASTM D1556. Density and water content measurements are for the fraction passing the No. 4 sieve.

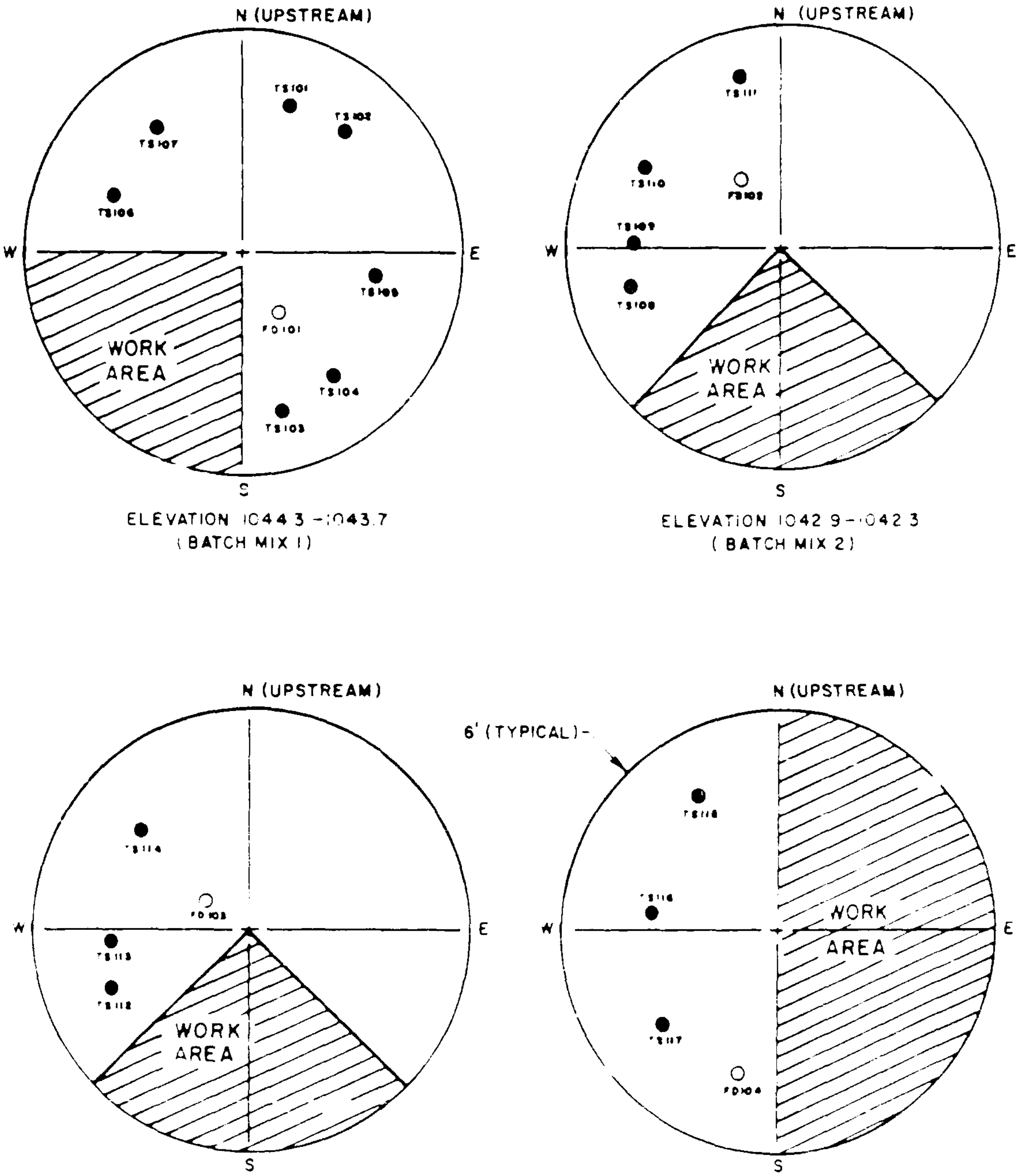
2) Void ratio based on specific gravity measurements of batch mix from the same elevation. Void ratio not corrected for swell at base of exploration shaft.

3) Void ratio changes due to swell of soils at the base of the exploration shaft were estimated using procedures described in Section 4.2.1 and Table 5 of the text.

4) Corrected for estimated swell at base of exploration shaft.

Tripod Tube Sample 303 Being Taken at a
Depth of 83.6 feet in the Exploration Shaft

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	PHOTOGRAPH OF GEI TRIPOD TUBE SAMPLER
GEOTECHNICAL ENGINEERS INC WINCHESTER, MASSACHUSETTS	Project [illegible]	Sep. [illegible] Fig. [illegible]



ELEVATION 1044.3 - 1043.7 (BATCH MIX 1)

ELEVATION 1042.9 - 1042.3 (BATCH MIX 2)

ELEVATION 1042.4 - 1041.8 (BATCH MIX 3)

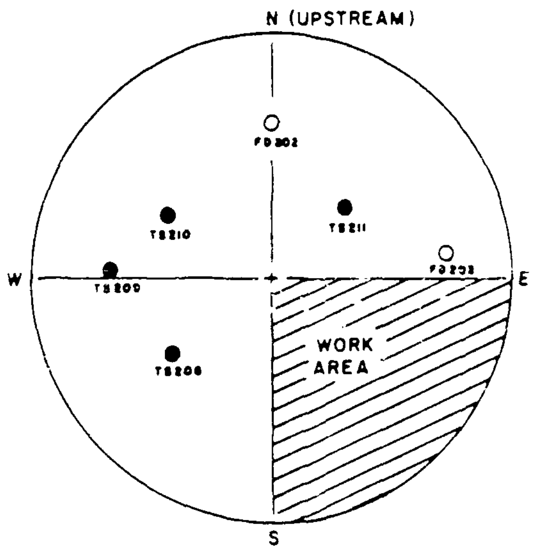
ELEVATION 1041.1 - 1040.5 (BATCH MIX 4)

LEGEND

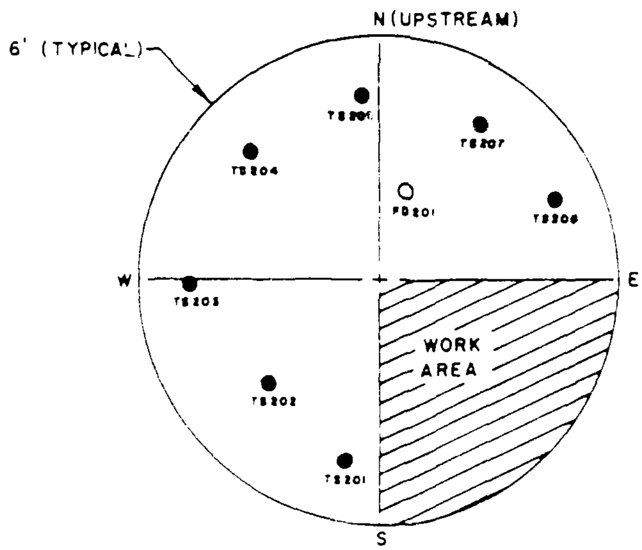
TS TRIPOD TUBE SAMPLE

FD FIELD DENSITY TEST

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	[illegible]AMPLE LOCATION PLAN - ZONE [illegible] IN EXPLORATION SHAFT
GEOTECHNICAL ENGINEERS INC WINCHESTER, MASSACHUSETTS	Project 85669	Sep. [illegible], 1987 Fig. [illegible]



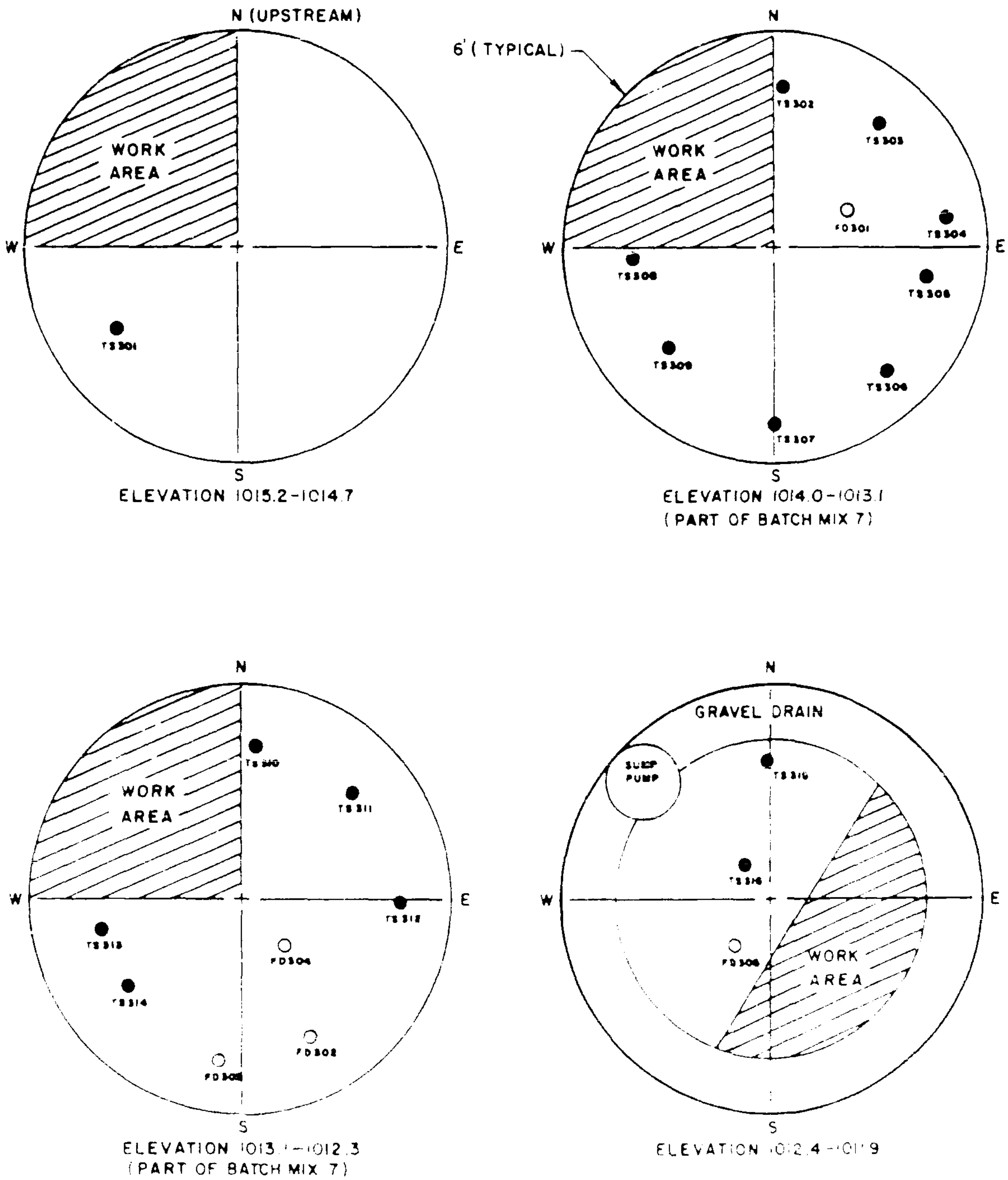
ELEVATION 1032.5–1031.6
(BATCH MIX 5)



ELEVATION 1031.2–1030.5
(BATCH MIX 6)

LEGEND
TS TRIPOD TUBE SAMPLE
FD FIELD DENSITY TEST

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SAMPLE LOCATION PLAN - ZONE 3 IN EXPLORATION SHAFT
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. B3



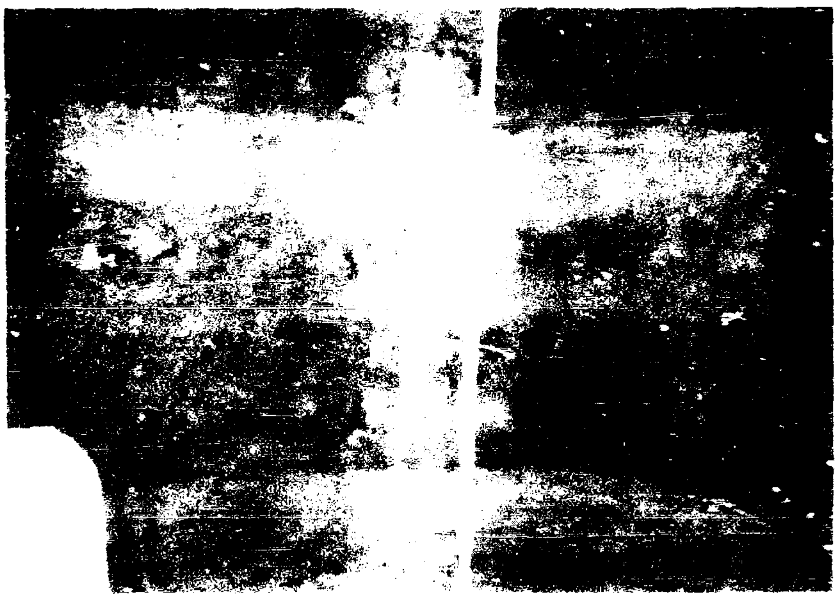
LEGEND

TS TRIPOD TUBE SAMPLE

FD FIELD DENSITY TEST

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SAMPLE LOCATION PLAN - ZONE 3 IN EXPLORATION SHAFT
GEOTECHNICAL ENGINEERS INC.	Project 85669	Sep. .. 1987 Fig. B4

— EL 1045.1'



— EL 1041.7'
NGVD

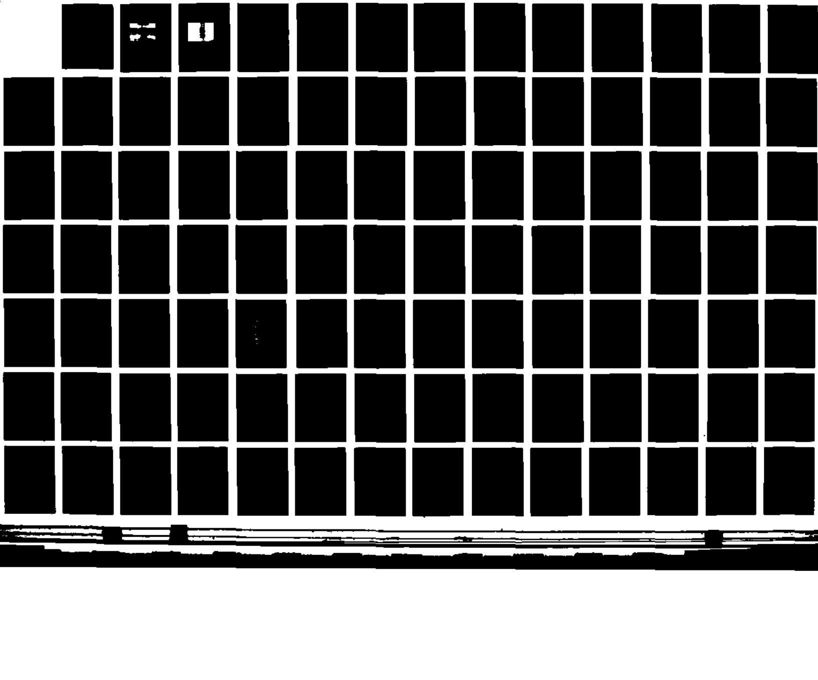
Downstream Wall of Exploration Shaft in Zone 2 of Hydraulic Fill Shell

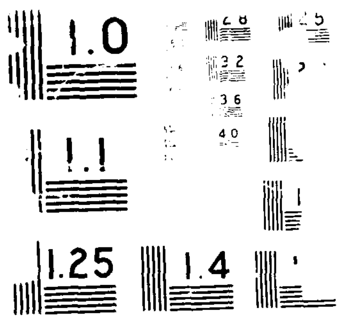
Darker layers correspond to sandy silts and clays, and lighter colored soils are sands and silty sands.

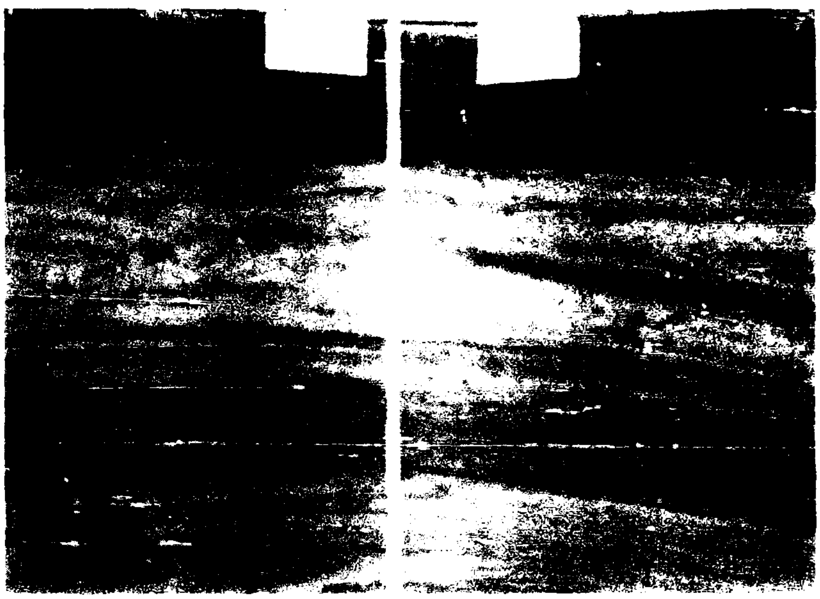
Army [illegible] Engineers [illegible], Mississippi	Reevaluation Lower San Fernando Dam San Fernando, [illegible]	[illegible] [illegible] SHAFT WALL - [illegible]
GEOTECHNICAL ENGINEERS IN[illegible]	[illegible]	[illegible]

[illegible]
INVESTIGATION OF T.. (U) GEI CONSULTANTS INC WINCHESTER
MA SEP 89

UNCLASSIFIED F/G 13/2 NL



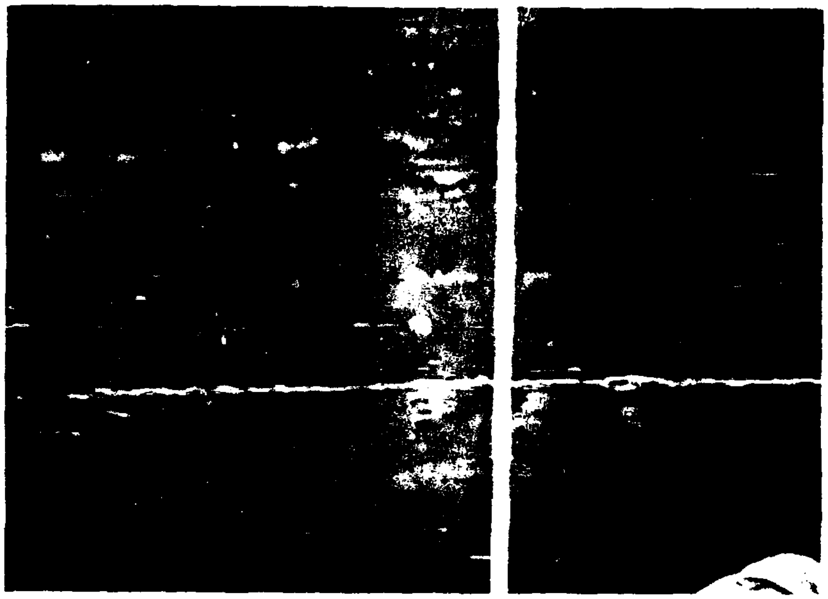

1.0
3.2
3.6
4.0
1.1
1.25
1.4



Downstream Wall of Exploration Shaft in Zone 3 of Hydraulic Fill Shell

Darker layers correspond to sandy silts and clays, and lighter colored soils are sands and silty sands.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of: Lower San Fernando Dam San Fernando, California	PHOTOGRAPH OF EXPLORATION SHAFT WALL - ZONE 3
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. B6



Downstream Wall of Exploration Shaft in Zone 5 of Hydraulic Fill Shell

Darker layers correspond to sandy silts and clays, and lighter colored soils are sands and silty sands.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	PHOTOGRAPH OF EXPLORATION SHAFT WALL - ZONE 5
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. B7

APPENDIX C: IN SITU VOID RATIO CHANGES OF CRITICAL LAYER

APPENDIX C

IN SITU VOID RATIO CHANGES OF CRITICAL LAYER

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APPENDIX C

IN SITU VOID RATIO CHANGES OF CRITICAL LAYER

C.1 Introduction

Undisturbed samples of the critical layer of the hydraulic fill shell on the downstream side of the dam were obtained in 1985. The void ratio and strength of these samples represent 1985 conditions. Thus it became necessary to estimate the void ratio changes that took place in the critical layer between the time of the earthquake in 1971 and the time of sampling in 1985. These void ratio changes were then used to estimate steady state strengths of the critical layer soils on the downstream side immediately before the 1971 earthquake. The 1971 void ratios of critical layer soils on the upstream side of the dam would be expected to be higher than the 1971 void ratios of the critical layer soils on the downstream side. This is because the critical layer on the upstream side was under a lower sustained effective stress due to the presence of the reservoir and the fact that the downstream slope was under additional load from the 1930 and 1940 berms. The estimated difference in void ratio between the upstream and downstream critical layers, in conjunction with strength data obtained for the downstream critical layer, were used to estimate the steady state strength of the upstream critical layer which actually participated in the 1971 flow slide.

The Los Angeles Department of Water and Power (LADWP) made detailed vertical and horizontal movement surveys of the embankment and groundwater observation well readings between 1929 and 1985. These excellent data were essential for estimating the void ratio changes which took place in the critical layer on the downstream side of the dam after the 1971 earthquake and for estimating differences between upstream and downstream void ratios.

The movement and observation well data were analyzed to develop a general understanding of the behavior of the downstream section of the dam prior to, during, and after the 1971 earthquake. Then the pertinent data were used to evaluate void ratio changes in the critical layer. The plots presented in the subsequent sections of this Appendix were prepared by GEI from the LADWP field survey sheets.

C.2 Movement and Settlement Data

C.2.1 General

The LADWP made detailed measurements of the vertical and horizontal movements of the dam starting in 1929. Five survey lines were established at the locations shown in Fig. C1. Vertical and horizontal movements of about 110 points were measured at least 6 times a year and sometimes 12 times a year up until the 1971 earthquake. Measurements were continued on a frequent basis for a period of about one year after the 1971 earthquake. The interval between measurements was reduced to one year starting in 1974.

Undisturbed samples of the critical layer on the downstream side of the dam were obtained at two locations: the exploration shaft and undisturbed sample borings at Location 111 and undisturbed sample boring at Location 103. Thus the movement data analyzed correspond to sections passing through these two locations.

C.2.2 Movements Measured Immediately After the 1971 Earthquake

Plots of vertical and horizontal movements at Stations 5+00 and 9+00 between December 30, 1970 (before the earthquake) and both February 13 and May 12, 1971 (after the earthquake) are shown in Figs. C2 and C3. These plots show that almost all of the movements measured in the three-month period following the earthquake occurred during the four-day period following the earthquake. The vertical and horizontal movements measured on February 13, 1971 were combined and are shown as vectors in Figs. C4 and C5 for Stations 5+00 and 9+00, respectively.

Examination of Figs. C2 through C5 indicates the following patterns of movement of the downstream slope as a result of the 1971 earthquake:

a. The downstream toe of the dam did not move appreciably as a result of the earthquake.

b. There was no bulging of the downstream slope.

c. Downstream of point 3 at Sta 5+00 and Sta 9+00, the horizontal components of the movements were in the downstream direction. Upstream of this point, and close to the scarp, horizontal movements were in the upstream direction, reflecting proximity to the scarp left by the upstream slide.

d. Downstream of point 5 at Sta 5+00 and point 6 at Sta 9+00, the rate of change of horizontal movements indicated horizontal compression, while upstream of these points, there was horizontal extension.

e. The settlements increased gradually in the upstream direction starting approximately from zero at the toe. However, they increased rapidly upstream of the point that separates horizontal compression from horizontal extension, i.e., point 5 at Sta 5+00 and point 6 at Sta 9+00, Figs. C2 and C3.

It can be concluded from the above observations that downstream of about points 5 and 6, the downstream section of the dam developed mainly a decrease in volume with relatively low shear strains. Upstream of these points, the dam developed increasingly large shear distortions near the scarp of the upstream slide.

A plot of vertical movements which occurred along the downstream berm road (122 feet south line) between December 30, 1970 and May 12, 1971 is shown in Fig. C6. Discussion of this plot is presented in Section C.4.

C.2.3 Long-Term Movements Prior to and After the 1971 Earthquake

Plots of vertical and horizontal movements vs. time for the measurement point located closest to the exploration shaft are shown in Figs. C7 and C8. This measurement point on the 122-foot south line, Sta 6+00, was only about 15 feet east of the shaft. The following are comments related to the vertical movement plot shown in Fig. C7:

a. The August 30, 1930 earthquake caused a little over 0.1 foot of settlement.

b. The relatively faster rate of settlement for the few years after the 1930 earthquake may be due to the effects of the 1930 earthquake, raising of the embankment to its final height and/or placement of the blanket on the downstream slope between 1929 and 1930.

c. Placement of the 1940 berm on the downstream slope caused settlement of about 0.12 feet between the time of placement and 1943.

d. The rate of settlement between about 1943 and the time of the 1971 earthquake was approximately constant at about 0.005 feet per year.

e. The 1971 earthquake caused a relatively large settlement to occur.

f. Settlements continued after the 1971 earthquake up to the time of soil sampling in 1985. Note that dam reconstruction was done in the upstream section of the dam, and thus had no effect on settlements on points along the downstream berm. These settlements are discussed in more detail later.

The horizontal movements of the same measurement points (Fig. C8) have the same pattern as the vertical movements, except after the 1971 earthquake. After the 1971 earthquake, with the reservoir empty, lateral movements essentially stopped whereas settlements continued. Note that the scatter is larger in the horizontal movement data than in the settlement data, reflecting more accuracy in the measurement of settlement.

Plots of vertical and horizontal movements vs. time for the measurement point located closest to Location 103 (Measurement Point at Sta 9+00 on the 122-foot South Line) are shown in Figs. C9 and C10. The vertical and horizontal movement data for this point follow the same pattern as that for the point located 300 feet east. This indicates that the behavior of the downstream slope was consistent over substantial horizontal distances.

Vertical movements vs. time for Points 16 and 24 on the 5+00 line are shown in Figs. C11 and C12. These points are located downstream of the exploration shaft. Point 16 is located on the berm over the toe of the original dam section. Point 24 is located at the toe of the dam. Point 16 indicates settlement after construction of the berm and significant settlement due to the 1971 earthquake. The vertical movement of Point 24 was essentially zero over the time it was monitored between 1949 and 1975, indicating negligible settlements of the foundation soils at the toe of the dam.

Expanded plots of settlement vs. time immediately after the 1971 earthquake for points near Locations 103 and 111 are shown in Fig. C13. These plots show that relatively large settlements occurred in the four days after the earthquake (February 9-13). The settlement rate decreased with time in the five months following the earthquake (up to about July 1, 1971). The settlement rate became approximately constant from July 1, 1971 to 1985 (Figs. C7 and C9).

C.3 Groundwater Data

The LADWP provided GEI with groundwater elevation measurements from numerous wells in the embankment. Two of these wells, 64I and 64J, are shown in Fig. C1. Well 64I was the closest to the exploration shaft location. The bottom of each well penetrated the 1971 phreatic surface by only a few feet as shown in Fig. C14. The tip of 64I was close to the boundary between Zones 1 and 2 of the hydraulic fill (see Figs. 9 and 10 in main text).

Groundwater elevations vs. time in Wells 64I and 64J are shown in Figs. C15 and C16. Data from each well is discussed below.

Well 64I - The bottom of this well was located at El. 1053, about 31 feet above the critical layer. Groundwater elevations in this well rose about 1 foot after the earthquake, but this rise occurred over a period of several weeks. The rise may be due to excess pore pressure generated as a result of earthquake shaking, but it is more likely due to the fact that after the failure, the reservoir was closer to the well for a short time after the failure.

The reservoir was essentially empty about 1.5 months after the earthquake. However, the groundwater level in Well 64I remained above its normal level for about 5 months after the earthquake (up to about June 1, 1971).

Groundwater levels in Well 64I decreased at a rate of about 1 foot/year until it became dry in November 1973. In 1985, the groundwater level in the exploration shaft, near Well 64I, was near the base of the embankment, as shown in Fig. C14.

Well 64J - The bottom of this well was located near the base of the hydraulic fill at about El. 1017. This elevation is close to the top of the critical layer. Water level in the well was about 3 feet higher than normal on the day after the earthquake. The water elevation decreased to its pre-earthquake level in a period of about one month. Water levels in 64J decreased at a faster rate than water levels in Well 64I, probably because of its proximity to the downstream drain.

C.4 Void Ratio Changes in Critical Layer Due to 1971 Earthquake

The 1971 earthquake caused generation of excess pore pressures in at least some of the soils in the downstream section of the dam located below groundwater level. The observations in Well 64I indicate that negligible pore pressures developed in Zones 1 and 2 of the hydraulic fill. The observations in Well 64J indicate that excess pore pressure did develop in the lower part of the hydraulic fill followed by reconsolidation after the earthquake. The reconsolidation is assumed to have manifested itself as settlements at the surface of the downstream slope and horizontal compression of the downstream section of the dam, except for the zone near the slide scarp which developed horizontal stretching.

For the purpose of our investigation, it is necessary to estimate the void ratio changes which took place after 1971 in the critical loose layer where undisturbed samples were taken. These changes would then be used to correct the 1985 void ratios of undisturbed samples to pre-1971 earthquake void ratios. Undisturbed samples were taken below the location of the berm road on the downstream slope. At this location, the downstream section of the dam was subjected to both vertical and horizontal compression. Virtually all of the horizontal movements occurred within about one month after the earthquake when there was still water in the reservoir. Subsequently, when the reservoir was empty, the horizontal movements stopped and only vertical movements were observed.

For analysis purposes, we considered separately two phases of the consolidation of the critical layer soils on the downstream side of the dam after the 1971 earthquake:

1. Consolidation due to dissipation of excess pore pressures generated during earthquake shaking, discussed in this section.

2. Consolidation due to the increase in effective stress caused by the permanent lowering of the reservoir (Section C.5).

The groundwater level at the location of the downstream berm road started dropping below its pre-earthquake level about five months after the earthquake (Fig. C15). This corresponds to the time when the settlement rate became approximately constant (Fig. C13). Therefore, settlements which occurred in the first five months after the earthquake probably are mainly due to dissipation of excess pore pressures generated by the earthquake, and those which occurred after that time can be assumed to be due to general groundwater lowering below pre-earthquake levels.

Void Ratio Changes at Location 111 - The settlement of the ground surface at Location 111 in the first five months after the earthquake was 0.46 foot (Fig. C13). Analyses were performed to estimate what part of the 0.46 foot of settlement occurred in the 15-foot-thick critical layer at the base of the hydraulic fill, so that the void ratio change of this layer could be estimated.

The volume change of each layer below groundwater level due to dissipation of pore pressure generated by cyclic loading is related to the maximum cyclic strain which occurred in the layer during cyclic loading. Castro (1987) has summarized laboratory test data relating the volumetric strain of saturated sand and silt samples to the maximum cyclic shear strain experienced by the samples (Fig. C17). The band labeled No. 3 in Fig. C17 represents data from tests performed on samples from Location 111 and reported in Appendix F, Section F.4.7. Castro (1987) has also summarized laboratory test data relating the volumetric strain of drained sands to the maximum cyclic shear strain experienced by the samples (Fig. C18).

The soil profile at Location 111 is shown in Fig. 9. Groundwater level prior to the earthquake was about El. 1060 at this location. For analysis of sands below groundwater level, the correlations between volumetric strain and cyclic shear strain shown in Fig. C19 were used. For sands above groundwater level, the hatched line in Fig. C18 was used.

The maximum cyclic shear strain in each layer of the soil profile which occurred during the 1971 earthquake was estimated using a SHAKE analysis. Details of the analysis are presented in Appendix E. A plot of maximum cyclic shear strain vs. depth is shown in Fig. E2. The maximum cyclic shear strain at the mid height of each zone of the soil profile based on the SHAKE analysis is presented in Table C1.

Each zone of the Location 111 soil profile (Fig. 9) was classified as loose, medium, or dense based on average N-values in the zones. The maximum cyclic shear strain and density classification of each zone was used to obtain a volumetric strain for the zone after reconsolidation using the correlations in Figs. C18 and C19. The thickness of each zone was multiplied by the computed volumetric strain in the zone to obtain settlements. The volumetric strain and computed settlement for each zone are presented in Table C1.

The summation of settlements of each zone for the above analyses was 0.51 foot which is very close to the measured value of 0.46 foot. The agreement in total settlement is somewhat fortuitous, since several interpretations of the correlations in Fig. C18 and C19 can be made. However, the more significant result is that about 49% of the 0.51 foot of computed settlement occurred in Zone 5, the critical layer. The above analyses was repeated using several positions for the loose, medium, and dense curves shown in Fig. C19. Computed settlements were different than 0.51 foot, but the percentage of the total settlement which occurred in Zone 5 was about 49% in all cases. Therefore, the actual height change of Zone 5 was about 49% of 0.46, or about 0.23 foot.

The void ratio change of Zone 5 soils due to dissipation of excess pore pressures after the earthquake was computed using the following equation (one-dimensional settlement):

$$\Delta e_1 = \frac{\Delta H_1}{H} (1+e_o)$$

where Δe_1 = void ratio change in Zone 5 due to dissipation of excess pore pressures

ΔH_1 = settlement of Zone 5 due to dissipation of excess pore pressures, equal to about 0.23 foot at Location 111

H = thickness of Zone 5, equal to 15 feet at Location 111

e_o = initial void ratio of soil in Zone 5

Computed values of Δe_1 for undisturbed samples from Location 111 are shown in Table 3 in the main text. For a typical initial void ratio of 0.7, the void ratio change, Δe_1, is equal to 0.026.

The above analysis neglects the horizontal compression developed in the hydraulic fill after the earthquake. An estimate of the horizontal compression in the critical layer was made, resulting in void ratio changes of 0.001 to 0.002. These void ratio changes result in changes in estimated in situ steady state strength of only a few percent and thus were neglected.

Void Ratio Changes at Location 103 - Void ratio changes, Δe_1, of Zone 5 soils at Location 103 were estimated using the same approach for estimating Δe_1 at Location 111. The estimated values of Δe_1 at Location 103 are also shown in Table 3 of the main text.

Settlements Near Abutments - Settlements along the 122-foot-south survey line (downstream berm road) which occurred as a result of earthquake shaking are shown in the upper part of Fig. C6. There is a consistent pattern of settlements between Stations 3+00 and 17+00. The settlement pattern approximately reflects the pattern of the ground surface elevation changes below the survey line.

The relatively large settlements in the vicinity of Station 2+00 are probably related to an historical problem in a gypsum foundation layer on the left abutment. Based on these historical records, dissolving of the gypsum by the reservoir water gradually developed paths (voids) for percolating water and resulted in excessive seepage through the east abutment. Grouting of these voids had been performed periodically to alleviate the seepage problem.

The survey line along the berm road is actually located a few feet upstream of the road on the slope of the embankment, presumably to prevent damage to the measurement points from traffic along the road (Fig. C1). However, near Station 18+00 to 21+00 the berm road starts to climb towards the right abutment and crosses the survey line. A possible explanation for the shape of the settlement profile between these stations, shown in Fig. C6, is that the measurement points at Stations 19+00 and 20+00 may have been disturbed by traffic along the berm road in the months following the earthquake when the crest road was no longer available for traffic. Note, however, that even though the shape of the settlement profile appears unusual, the average settlement in the Station 18+00 to 21+00 area is consistent with the results of an analysis of the type performed for Locations 103 and 111.

C.5 Void Ratio Changes in Critical Layer Due to Groundwater Lowering

The groundwater level at the location of the downstream berm road started dropping below its pre-earthquake level about five months after the earthquake (Fig. C15).

Groundwater well data indicate that groundwater levels at the location of the downstream berm road decreased at a slow rate after the reservoir had been completely emptied. This is consistent with settlement data which indicate that settlements at Locations 103 and 111 (berm road) occurred gradually for many years after the earthquake (Figs. C7, C9, C13).

Void Ratio Changes at Location 111 - The total settlement of the ground surface at this location which occurred from the time of the 1971 earthquake to the time of sampling in 1985 was 0.63 feet. About 0.46 feet of this settlement was due to consolidation as a result of the dissipation of excess pore pressures generated by the earthquake (Section C.4). The remaining 0.17 feet of settlement was due to consolidation which occurred as a result of groundwater lowering.

The soil profile at Location 111 is shown in Fig. 9. The settlement of each soil zone due to groundwater lowering is a function of the compressibility of the zone and the change in effective stress within the zone.

Consolidation curves from laboratory triaxial tests were used to determine the compression index of soil samples. These consolidation curves are presented in Appendix F, Figs. F70 and F71. Table C2 is a summary of compression index data for undisturbed samples from Zone 5, the critical layer, for different effective stress levels.

The increase in effective stress for each zone of the Location 111 soil profile was computed using the pre-earthquake and 1985 groundwater levels. Each soil zone was assigned a compression index on the basis of laboratory consolidation data and the average effective stress in the zone. Settlements of each zone were then computed using the change in effective stress and compression index for each zone. Table C3 presents a summary of settlement computations.

The total computed settlement of all soil zones at Location 111 for the above analysis was 0.20 feet. The computed settlement is close to the measured settlement of 0.17 feet. About 33% of the 0.20 feet of computed settlement occurred in Zone 5, the critical layer. Therefore, we estimate that the actual height change of Zone 5 was about 33% of 0.17 feet, or about 0.057 feet.

The void ratio change of Zone 5 soils due to groundwater lowering was computed using the following equation:

$$\Delta e_2 = \frac{\Delta H_2}{H} (1+e_o)$$

where Δe_2 = void ratio change in Zone 5 due to groundwater lowering

ΔH_2 = settlement of Zone 5 due to groundwater lowering, equal to about 0.057 feet at Location 111

H = thickness of Zone 5, equal to 15 feet at Location 111

e_o = initial void ratio of soil in Zone 5

Computed values of Δe_2 for undisturbed samples from Location 111 are shown in Table 3 in the main text. For a typical initial void ratio of 0.7, the void ratio change, Δe_2, is equal to 0.006.

Void Ratio Changes at Location 103 - Void ratio changes, Δe_2, of undisturbed samples from Location 103 were estimated using the same approach for estimating Δe_2 at Location 111. The estimated values of Δe_2 at Location 103 are shown in Table 3.

C.6 Void Ratio Difference Between Upstream and Downstream Critical Layer

Up to this point, all estimates of void ratio changes have reflected those which occurred in the critical layer on the downstream side between 1971 and 1985. These void ratio changes allow an estimate to be made of critical layer void ratios and strengths on the downstream slide of the dam just prior to the 1971 earthquake. It is reasonable to expect that void ratios of the upstream critical layer in 1971 were greater than those on the downstream side because of two factors:

1. Upstream soils had been under a lower sustained effective stress due to prolonged submergence prior to 1971.

2. Downstream soils had been subjected to higher effective stress due to the presence of the 1930 and 1940 berms.

Therefore, the 1971 steady state strengths of the critical layer soils on the upstream side of the dam would be less than the strengths on the downstream side.

Void Ratio Difference Due to Submergence

Historical records of the dam construction indicate that the crest of the dam was at El. 1088 NGVD in 1915 and that the reservoir was filled to within 5 feet of the crest at that time. The dam crest was raised gradually in 1916 and 1917 to about El. 1128. The records indicate that during these early years, while the dam was under construction, the reservoir was filled for summer irrigation use and was practically emptied during the winter season as a provision against unusual storms. Presumably, there was no longer a reason to empty the reservoir in the winter once the spillway was completed circa 1917.

No information was available on reservoir levels during most of the 1920s. However, there appears to be no reason why the reservoir should have been lowered during this period. Repairs to the upstream concrete facing were made in 1929. In order to repair the concrete facing, the reservoir had to be lowered to about El. 1050 in 1929.

Detailed records of reservoir elevation were available starting in 1930. These records indicate that the reservoir elevation was always above 1095 up until the 1971 earthquake with only one significant exception. This exception was a 4- to 5-month period in 1930 when the reservoir level dropped to El. 1076 and rose back to 1095.

The question arises as to whether the critical layer on the upstream side of the dam was ever subjected to an effective stress significantly greater than that corresponding to a fully submerged state. The most critical time for this would have been during lowering of the reservoir in the winter months circa 1915-1917 and during repairs in 1929. We believe that the upstream critical layer has not been subjected to effective stresses significantly greater than those corresponding to submerged conditions, as explained below.

The hydraulic fill process used to construct the dam no doubt caused the soil between the starter dikes to be saturated with a phreatic surface near the pond level at the crest of the dam. The reservoir filling in 1915 completely saturated the upstream slope. When the reservoir was lowered for a few months, drainage of water within the upstream slope started to occur. However, this drainage would occur very slowly as evidenced by the fact that the phreatic surface on the downstream side of the dam did not drop significantly in the 6 months after the upstream slope had failed in 1971 and the reservoir had been completely emptied.

The vertical effective stress in the upstream critical layer ($\bar{\sigma}_{v,us}$) at the location which mirrors the exploration shaft location (berm road) would be about 2.4 kg/cm^2 for submerged conditions. Below the downstream berm road, the vertical effective stress in the critical layer ($\bar{\sigma}_{v,ds}$) would be about 3.5 kg/cm^2 for a ground water depth of 35 feet. The following equation can be used to estimate the void ratio difference between the upstream and downstream critical layers due to the submergence effect:

$$\Delta e_{sub} = C_c \log_{10} \frac{\bar{\sigma}_{v,ds}}{\bar{\sigma}_{v,us}}$$

Using a value of C_c = 0.048 from Tables C2 and C3 results in a value of Δe_{sub} = 0.008.

Void Ratio Difference Due to 1930 and 1940 Berms

Berms on the downstream slope have caused consolidation stresses to be higher in the critical layer on the downstream side compared to the upstream side. The majority of the additional effective stress was caused by the large 1940 berm.

Using stress distribution equations, we estimate that the 1940 berm caused an increase in effective stress in the critical layer of about 0.58 kg/cm^2 at the location of the exploration shaft. Using a C_c = 0.048 as before, this increase in effective stress would cause a decrease in critical layer void ratio of about 0.003.

This void ratio change of 0.003 is corroborated by settlement measurements along the berm road (122 feet south line), shown in Fig. C7. The data indicates that the survey point adjacent to the exploration shaft settled about 0.12 feet as a result of primary consolidation which occurred in the few years following placement of the 1940 berm. Based on analysis similar to that described in Section C.5, we estimate that about 20% of the measured settlement was caused by consolidation of critical layer (Zone 5) soils. For a critical layer thickness of 15 feet and initial void ratio of 0.7, the backcalculated change in void ratio of critical layer soils is:

$$\Delta e_{berm} = \frac{0.12' \times 0.20}{15'} (1+0.7) = 0.003$$

This backcalculated value of 0.003 is the same as that estimated using the consolidation approach described previously.

Summary of Upstream/Downstream Void Ratio Difference

Void ratios are estimated to be higher in the upstream critical layer compared to the downstream layer by the following amounts:

		Δe
1.	Submergence effect	0.008
2.	Berm effect	0.003
	Total	0.011

Therefore, we added 0.011 to the estimated in situ void ratios of samples from the downstream critical layer to obtain void ratios for the upstream critical layer.

TABLE C1 - SUMMARY OF COMPUTED SETTLEMENTS IN SOIL ZONES AT LOCATION 111 DUE TO CYCLIC STRAINING AND DISSIPATION OF EXCESS PORE PRESSURES

Lower San Fernando Dam

Soil Zone	Above (A) or Below (B) Groundwater	Zone Thickness	Maximum Cyclic Shear Strain at Midheight of Zone[1)]	Average N-value in Zone[2)]	Layer Classification	$\frac{\Delta V}{V}$[3)]	Computed Settlement	Contribution to Computed Settlement
		ft	%	blows/ft		%	ft	%
Rolled Fill[4)]	A	6	0.14	7	Medium	0.13	0.008	2
1	A	15	0.22	20	Medium	0.18	0.027	5
1	B	6	0.35	22	Medium	0.18	0.011	2
2	B	15	0.75	17	Loose	0.57	0.085	17
3	B	11	1.00	28	Medium	0.53	0.058	11
4	B	6	0.80	42	Dense	0.36	0.022	4
5	B	15	3.50	18	Loose	1.65	0.247	49
Alluvium[5)]	B	8	2.00	>40	Dense	0.64	0.051	10
						Total	0.509	100

Notes:

1) Maximum shear strain based on SHAKE analysis, see Appendix E.
2) N-values measured in 1985 borings.
3) Volumetric strain of layers above groundwater based on Fig. C18 and below groundwater on Fig. C19.
4) Thickness of rolled fill is for sand portion only. The upper 14 feet of clay in this zone was assumed to have negligible volume change after cyclic loading. N-values are for sand portion only.
5) Thickness of alluvium taken as approximate total thickness of sand layers only. Clay layers in the alluvium were assumed to have negligible volume change after cyclic loading. N-values for the alluvium are for sand layers only.

TABLE C2 - SUMMARY OF COMPRESSION INDICES UNDISTURBED SAMPLES FROM ZONE 5 Lower San Fernando Dam

Triaxial[1] Test No.	COMPRESSION INDEX, C_c [2] At Isotropic Consolidation Stress, $\bar{\sigma}_o$ kg/cm^2 = 1	2	4	6	7	8	12
$\bar{R}1$	0.021	0.033	0.046	-	-	-	-
$\bar{R}5$	0.018	0.030	0.046	0.055	-	-	-
$\bar{R}6$	0.026	0.041	0.051	-	-	0.063	-
$\bar{R}7$	0.024	0.036	0.057	-	-	0.066	-
$\bar{R}8$	0.030	0.047	0.068	-	-	0.085	-
$\bar{R}12$	0.018	0.033	0.045	-	-	0.061	0.065
$\bar{R}13$	0.026	0.045	0.061	-	-	0.084	0.113
$\bar{R}14$	0.025	0.039	0.054	-	-	0.083	0.106
$\bar{R}15$	0.036	0.058	-	-	-	0.100	0.128
$\bar{R}16$	0.017	0.031	0.051	-	-	0.080	0.099
$\bar{R}17$	0.028	0.043	0.055	-	-	0.086	0.091
$\bar{R}18$	0.038	0.053	0.075	-	-	0.109	0.119
$\bar{R}19$	0.019	0.027	0.036	-	-	0.039	0.039
$\bar{R}20$	0.017	0.032	0.050	-	0.065	-	0.074

Notes:

1) Consolidation curves for triaxial tests are presented in Appendix F.

2) Compression Index, C_c, = $\Delta e/\Delta \log \bar{\sigma}_o$.

TABLE C3 - SUMMARY OF COMPUTED SETTLEMENTS IN SOIL ZONES AT LOCATION III DUE TO GROUNDWATER LOWERING

Lower San Fernando Dam

Soil Zone Below Groundwater	Zone Thickness, H	Effective Stress at Midheight of Zone[1]			Compression[2] Index, C_c	Computed[3] Settlement	Contribution to Computed Settlement
	ft	$\bar{\sigma}_{1971}$ kg/cm^2	$\bar{\sigma}_{1985}$ kg/cm^2	$\Delta\bar{\sigma}$ kg/cm^2		ft	%
1 to 4	40	1.66	2.07	0.41	0.042	0.095	48
5	15	2.19	3.16	0.97	0.048	0.067	33
Alluvium	10	2.41	3.43	1.02	0.042	0.038	19
					Total	0.200	100

Notes:

1) Effective stress is equal to the octahedral stress, or two-thirds vertical effective stress for $K_o = 0.5$.

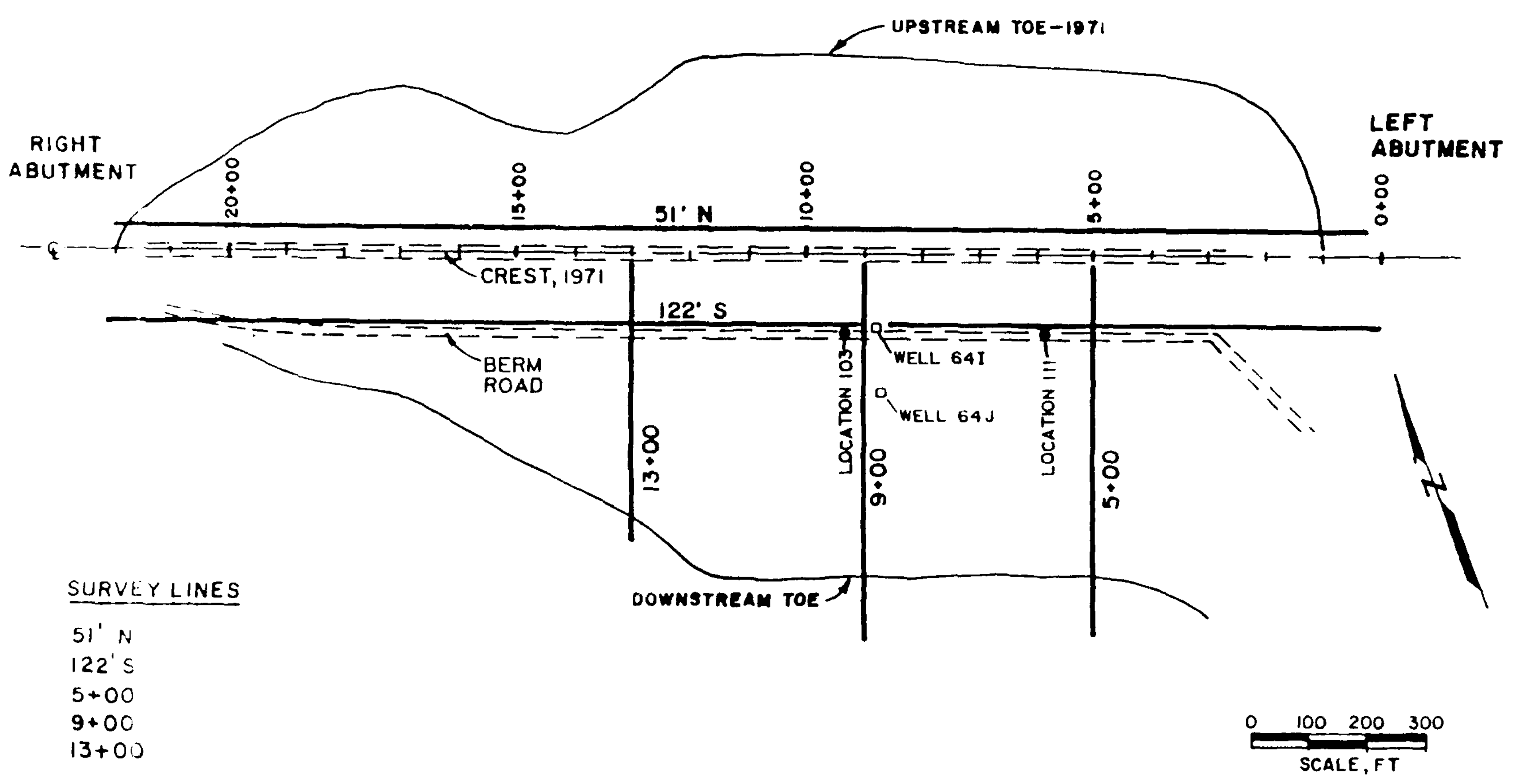
2) Compression Index, C_c, based on laboratory triaxial test data. C_c data for Zone 5 is shown in Table C2. C_c for alluvium zone was estimated.

3) Settlement equals = $\frac{C_c}{1+e_o} H \log_{10} \frac{\bar{\sigma}_{1985}}{\bar{\sigma}_{1971}}$.

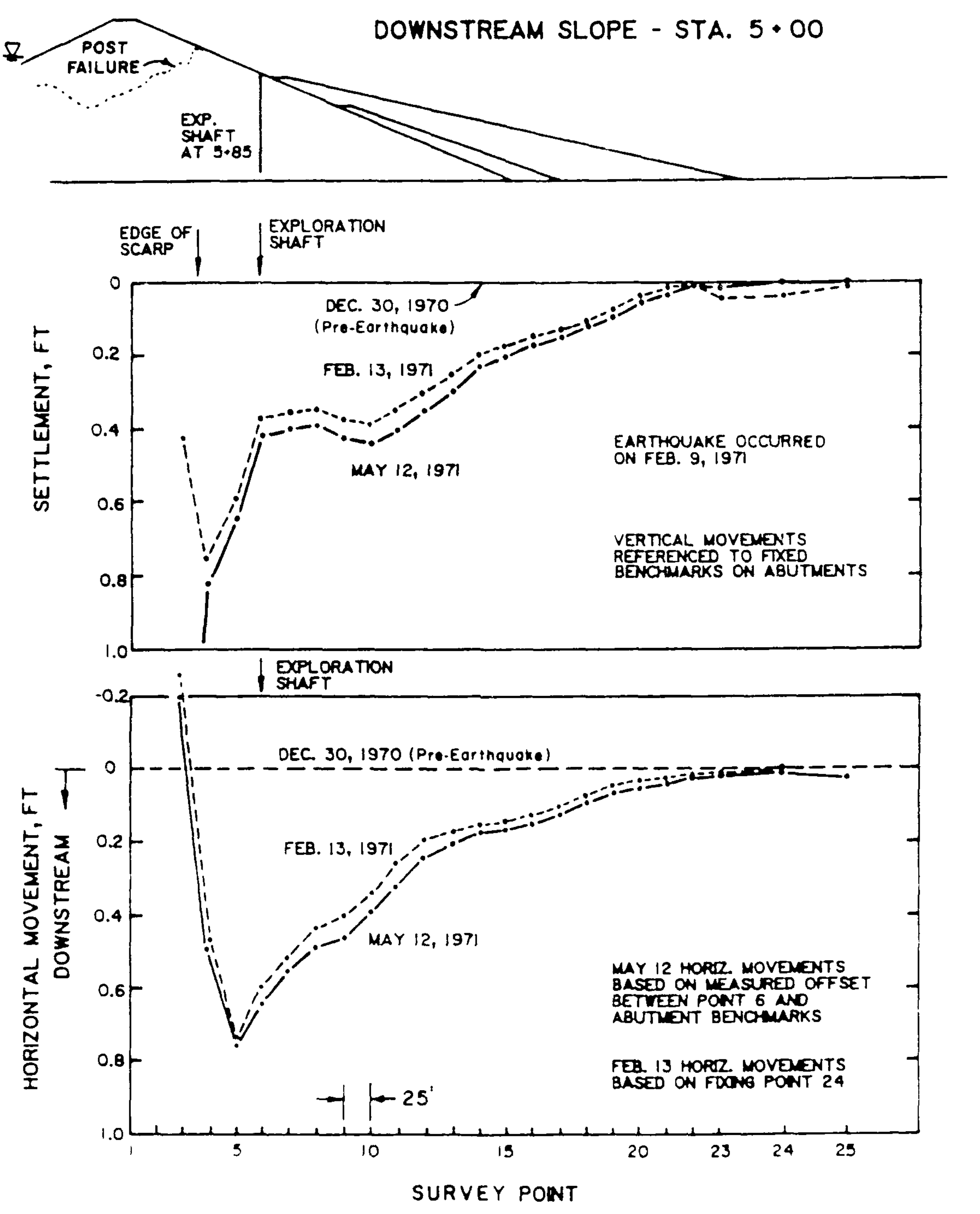
An initial void ratio, e_o, equal to 0.7 was used.

Geotechnical Engineers Inc.

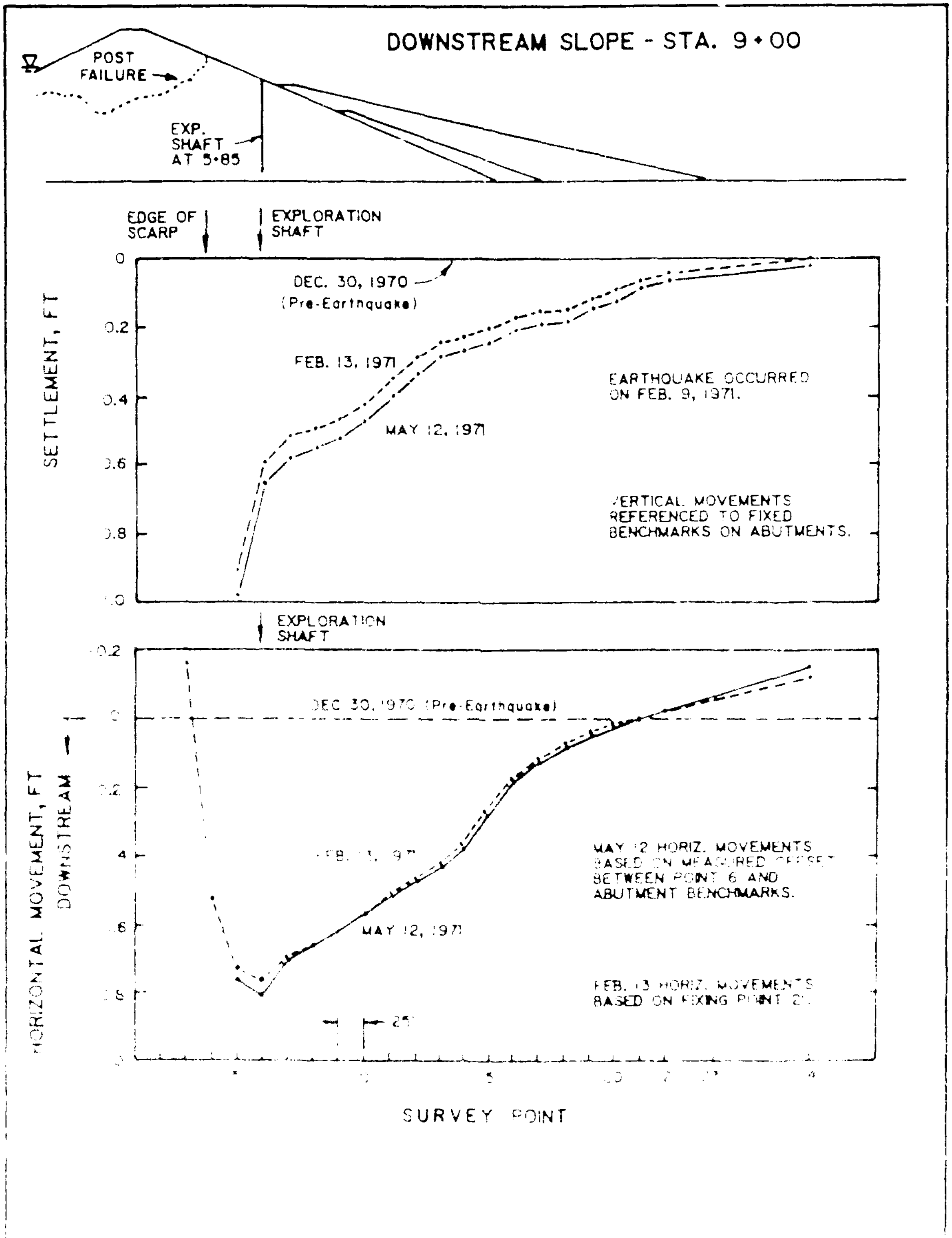
Project 85669
September 2, 1987

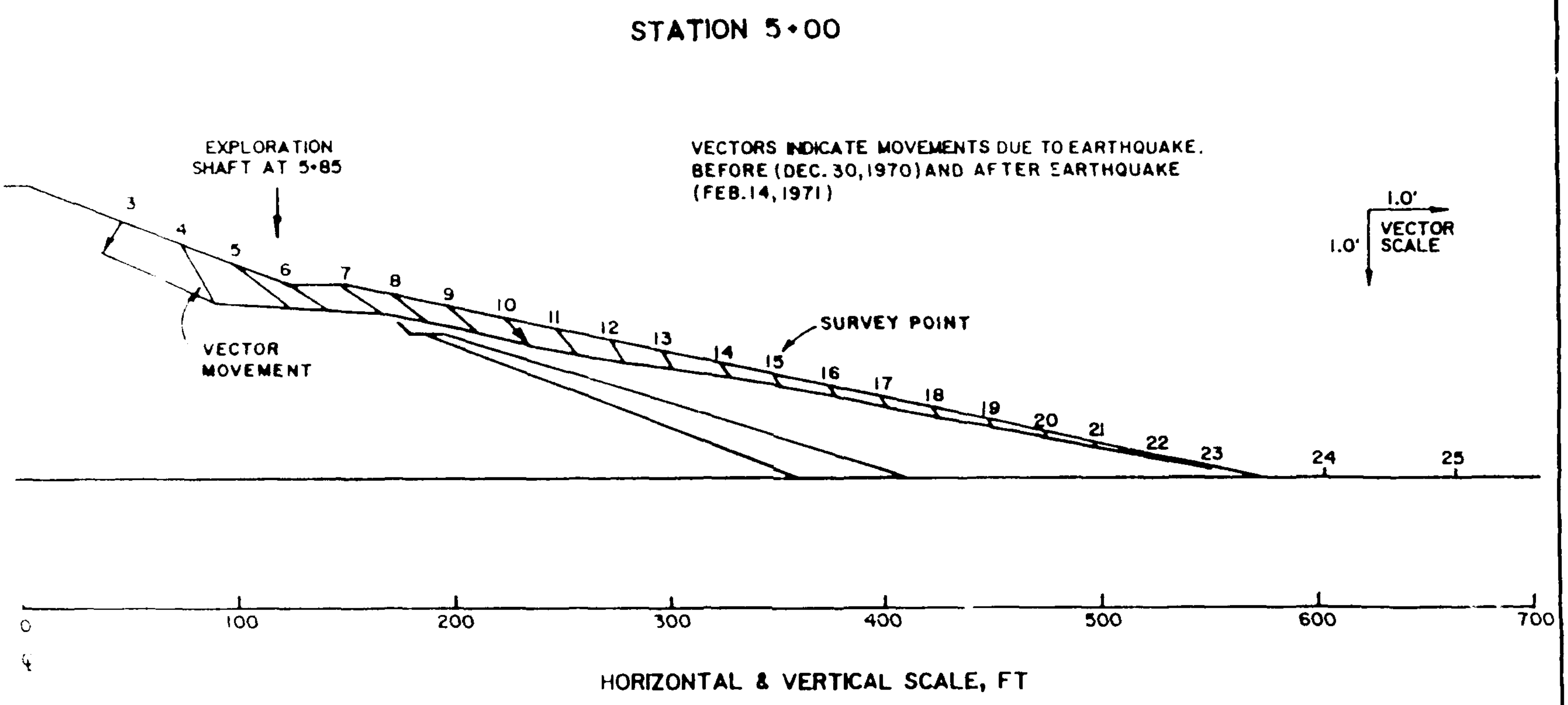


Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	PLAN VIEW OF SURVEY LINES
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Project 85669	August 14, 1987 Fig. C1

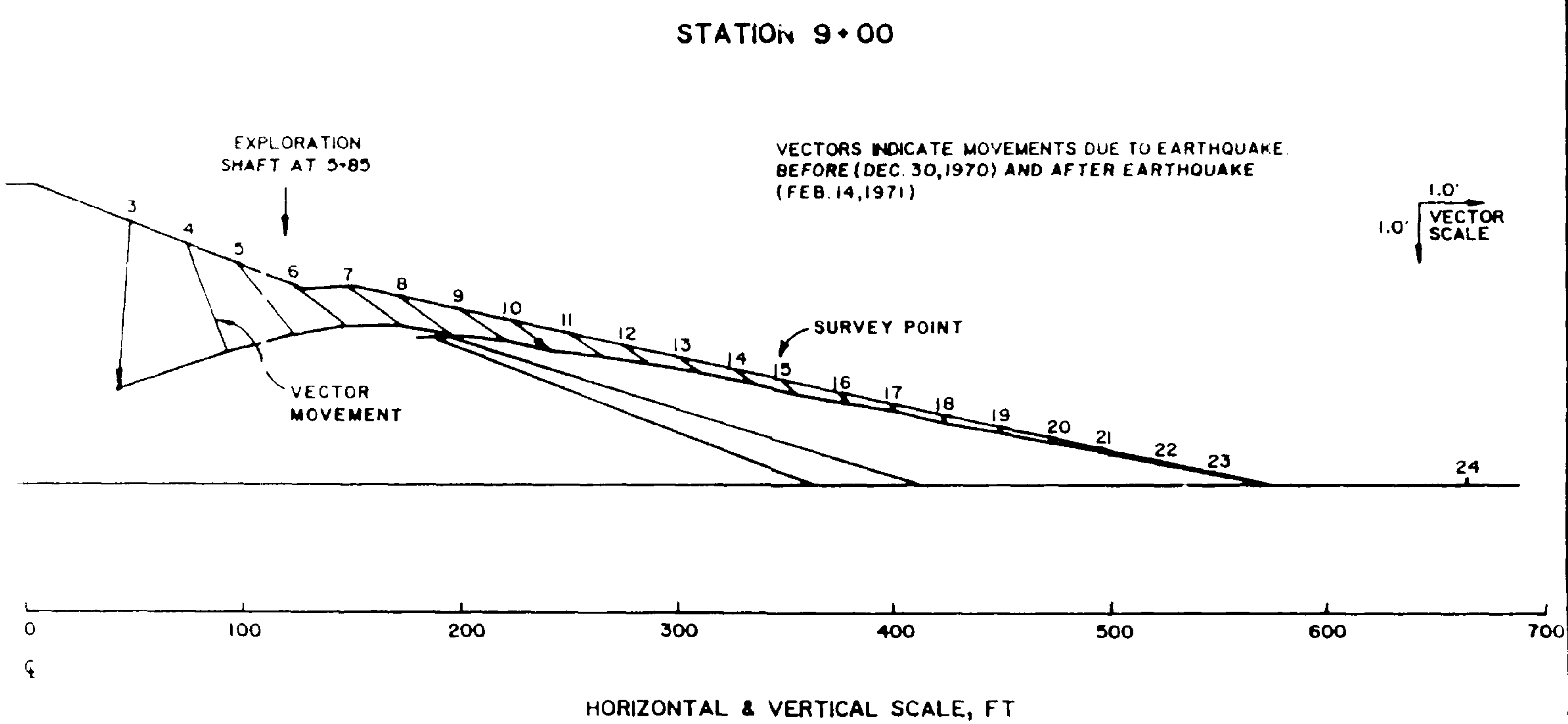


Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	HOR. MOVEMENT AND SETTLEMENT-DOWNSTREAM SLOPE-STATION 5+00
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Project 85669	August 14, 1987 Fig. C2

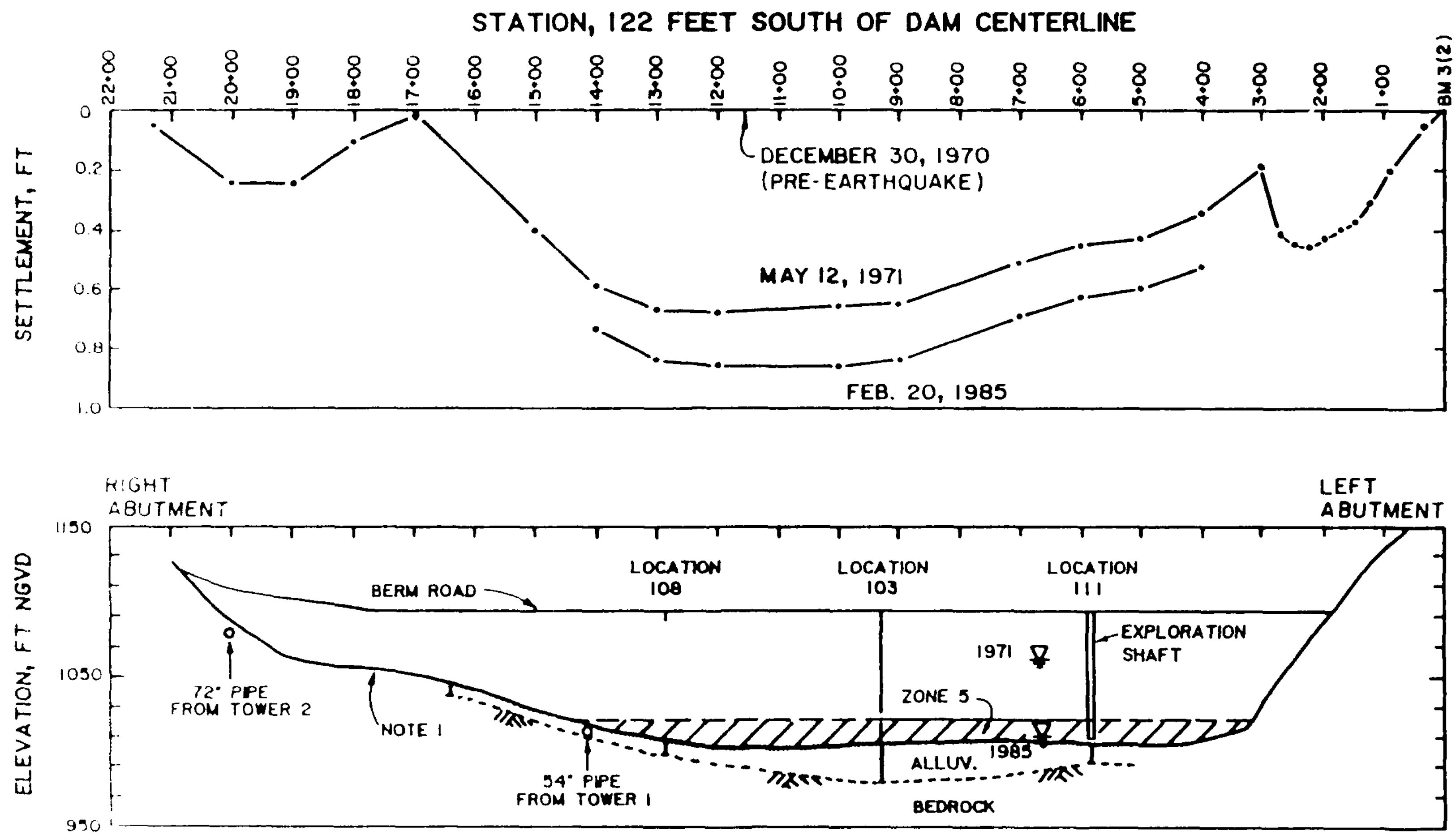

DOWNSTREAM SLOPE - STA. 9+00
POST FAILURE
EXP. SHAFT AT 5+85
EDGE OF SCARP
EXPLORATION SHAFT
DEC. 30, 1970 (Pre-Earthquake)
FEB. 13, 1971
MAY 12, 1971
EARTHQUAKE OCCURRED ON FEB. 9, 1971.
VERTICAL MOVEMENTS REFERENCED TO FIXED BENCHMARKS ON ABUTMENTS.
SETTLEMENT, FT
EXPLORATION SHAFT
DEC. 30, 1970 (Pre-Earthquake)
HORIZONTAL MOVEMENT, FT
DOWNSTREAM
MAY 12 HORIZ. MOVEMENTS BASED ON MEASURED OFFSET BETWEEN POINT 6 AND ABUTMENT BENCHMARKS.
MAY 12, 1971
FEB. 13 HORIZ. MOVEMENTS BASED ON FIXING POINT 21
25'
SURVEY POINT



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando California	VECTOR MOVEMENTS OF SURVEY POINTS ON DOWN- STREAM SLOPE STATION 5+00
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	August 14, 1987 Fig. C4



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	VECTOR MOVEMENTS OF SURVEY POINTS ON DOWN- STREAM SLOPE STATION 9+00
GEOTECHNICAL ENGINEERS INC	Project 85669	August 14 1987 Fig. C5

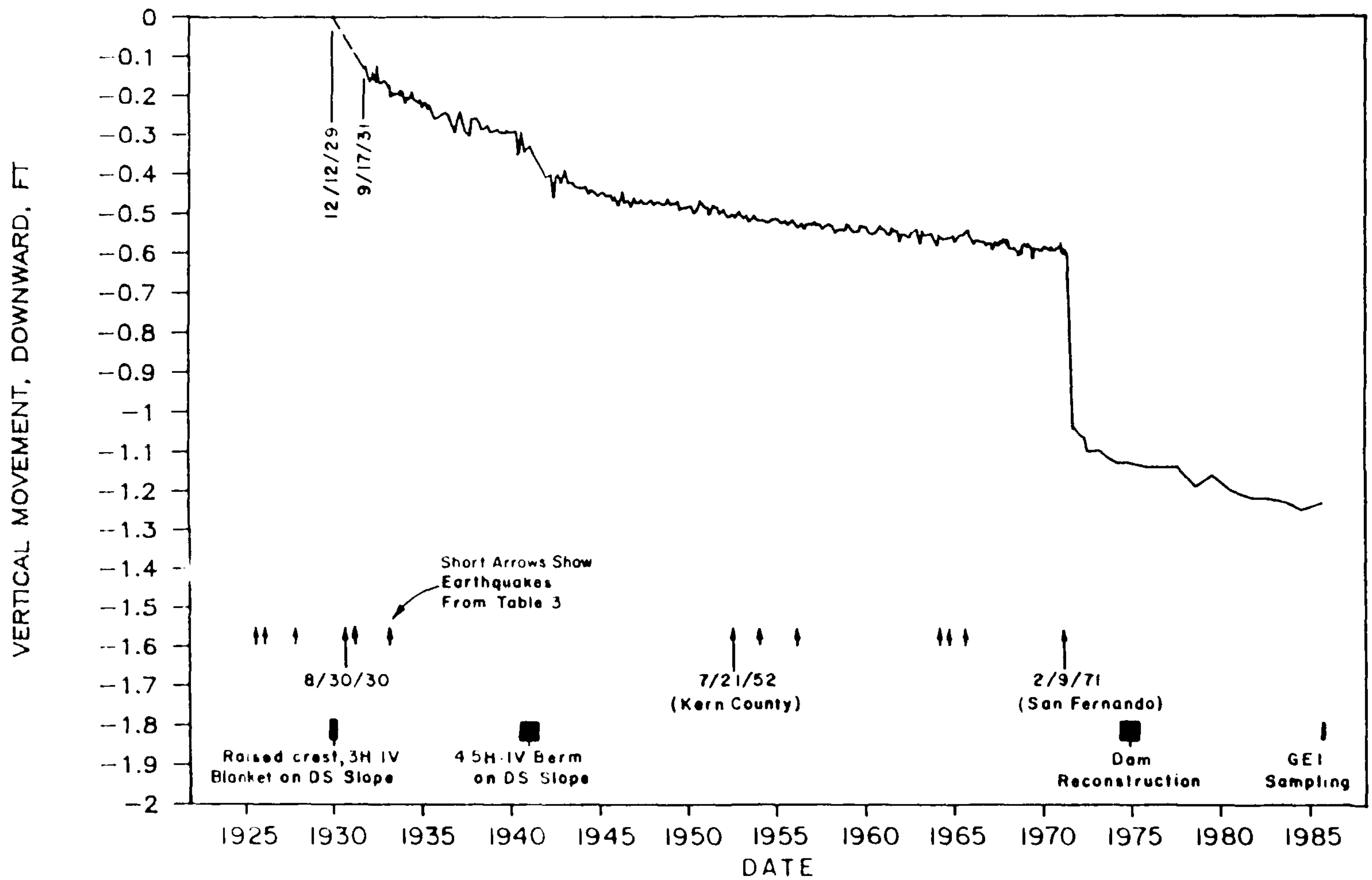


NOTES:

1) GROUND SURFACE TOPOGRAPHY FROM APRIL, 1916 PLAN DRAWING PROVIDED BY LADWP.

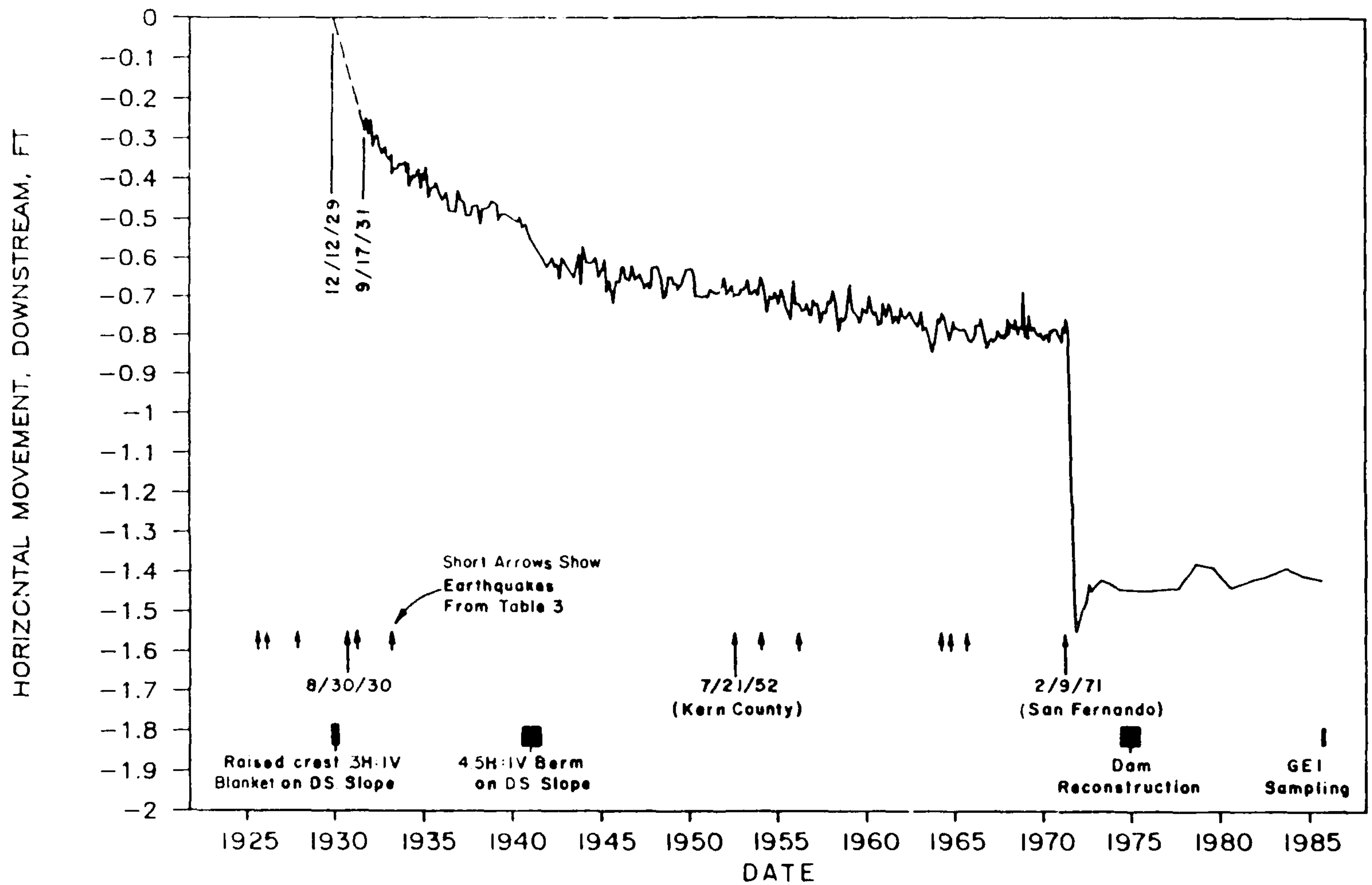
2) STABLE BENCH MARK 3 LOCATED AT STA 0+00, 280 FT DOWNSTREAM OF CENTERLINE.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SETTLEMENT PLOT AND PROFILE ALONG 122 FEET SOUTH SURVEY LINE
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	August 14, 1987 Fig. C6



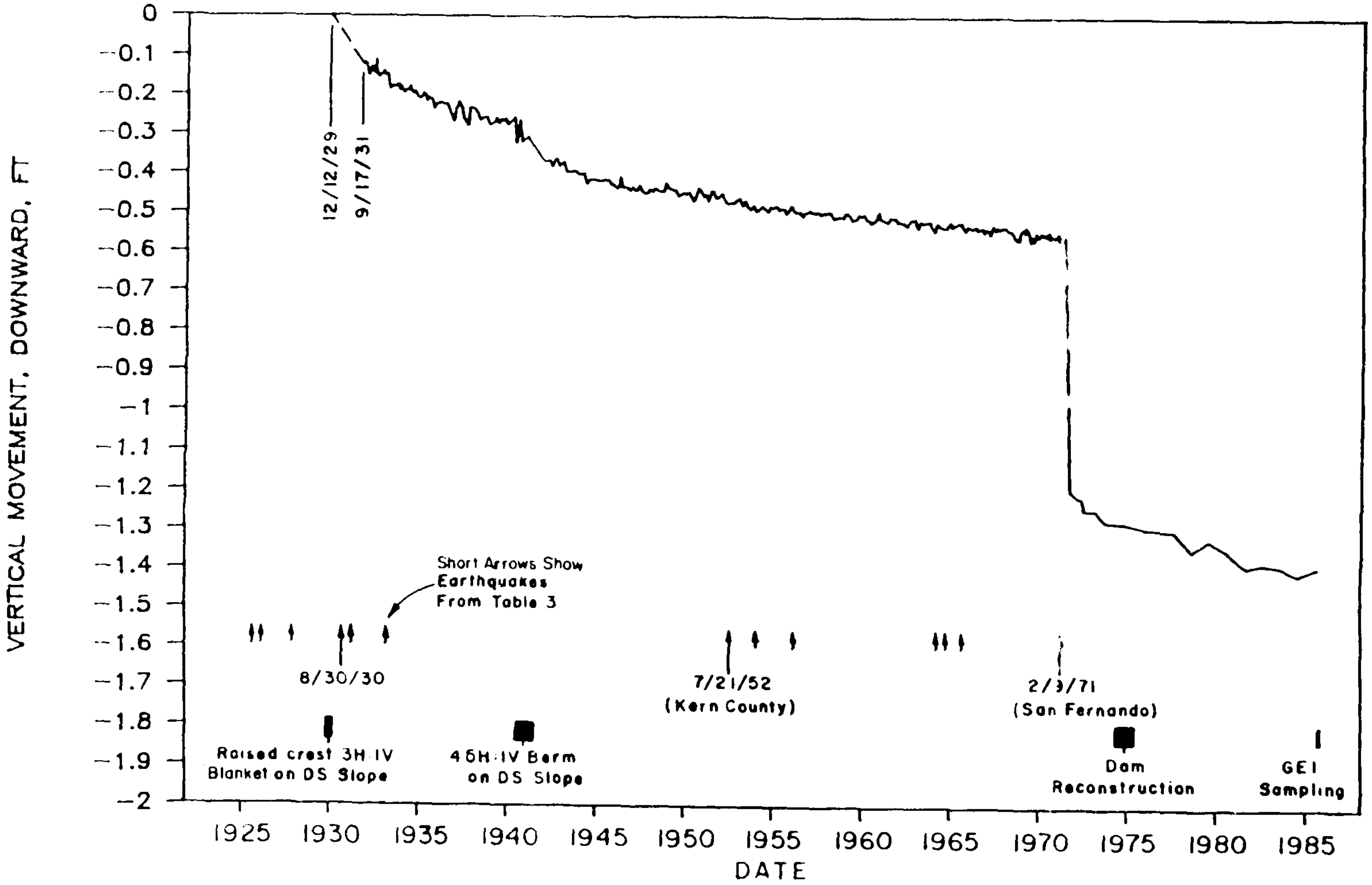
Dam Initially Constructed – 1916
Post 1971 Earthquakes not shown.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	VERTICAL MOVEMENT VS. TIME-SURVEY POINT AT 122 FEET SOUTH STATION 6+00
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	August 14, 1987 Fig. C7



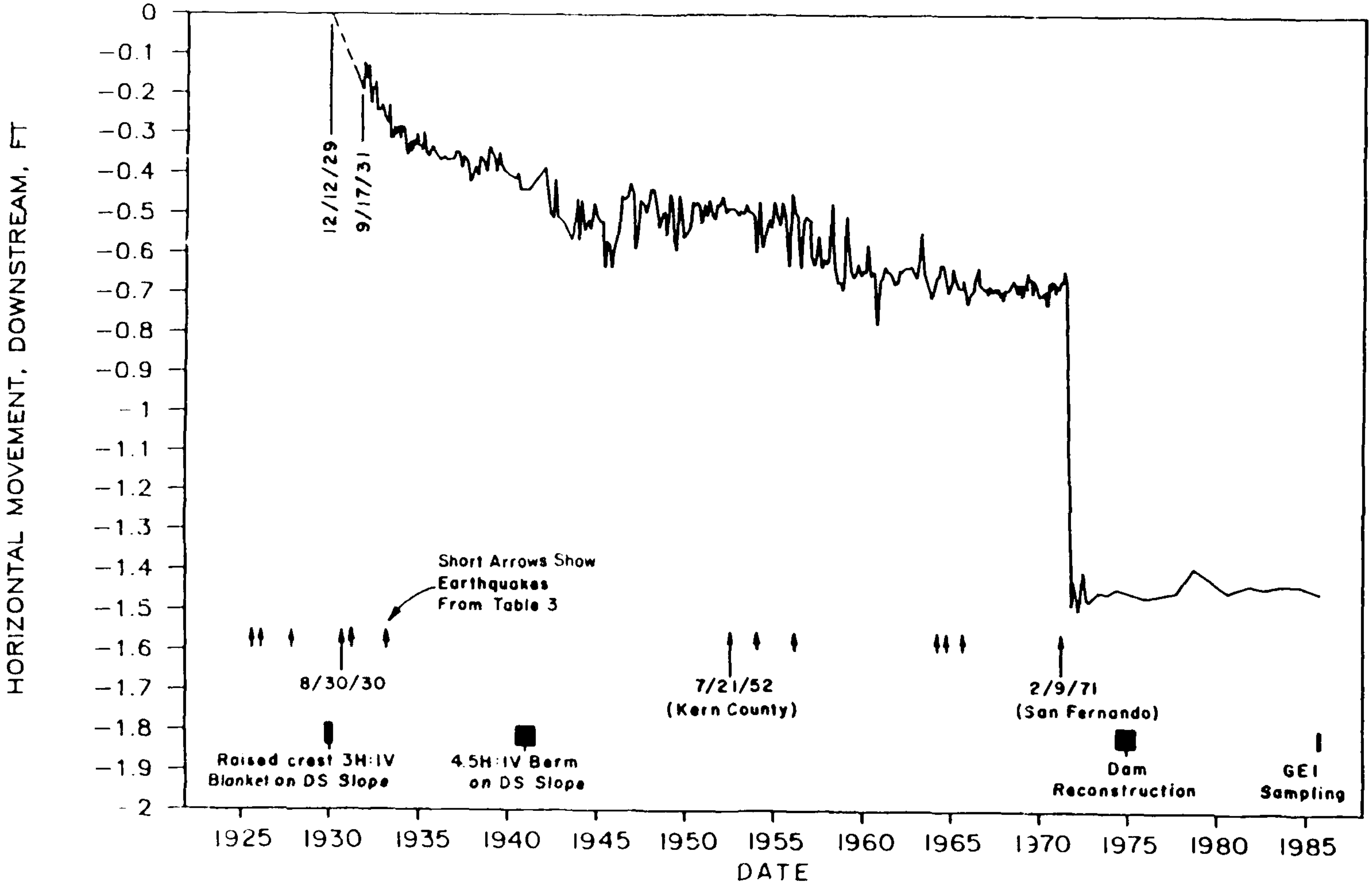
Dam Initially Constructed - 1916
Post 1971 Earthquakes not shown

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	HORIZONTAL MOVEMENT VS. TIME-SURVEY POINT AT 122 FEET SOUTH STATION 6+00
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	August 14, 1987 Fig. C8



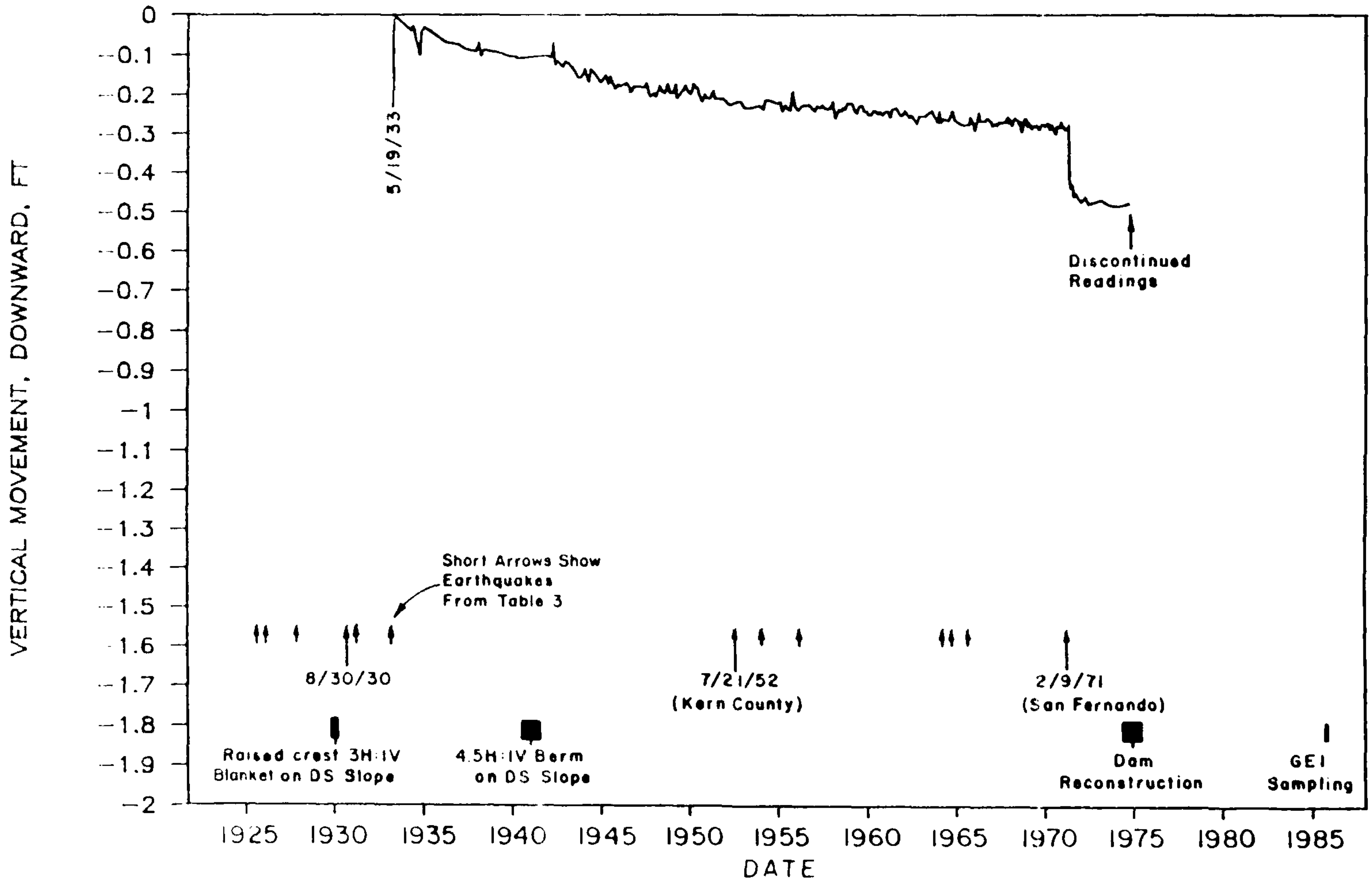
Dam Initially Constructed - 1916
Post 1971 Earthquakes not shown

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando California	VERTICAL MOVEMENT VS. TIME-SURVEY POINT AT 122 FEET SOUTH STATION 9+00
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	August 14, 1987 Fig. C9



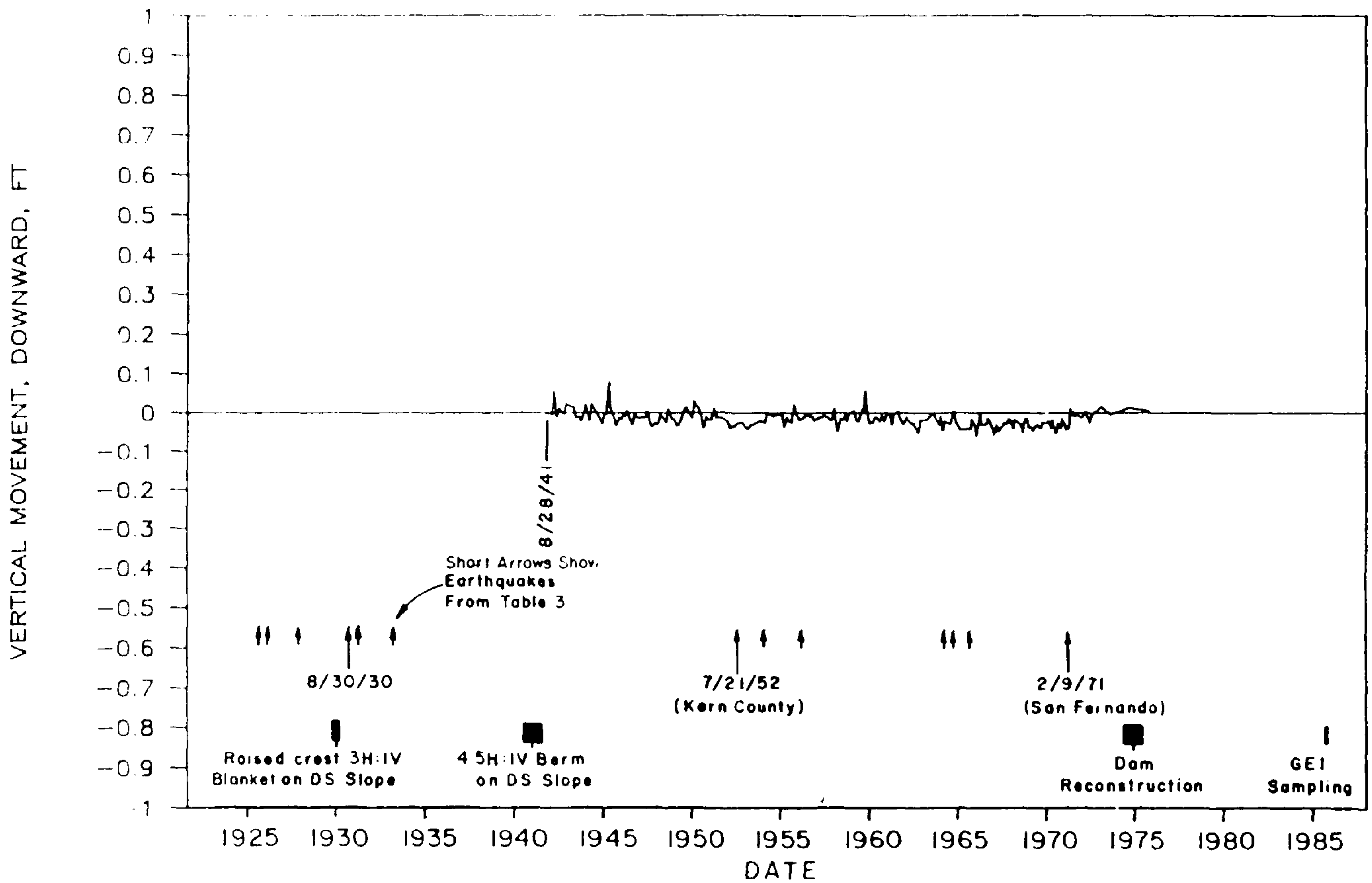
Dam Initially Constructed–1916
Post 1971 Earthquakes not Shown

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	HORIZONTAL MOVEMENT VS. TIME-SURVEY POINT AT 122 FEET SOUTH STATION 9+00
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	August 14, 1987 Fig. C10



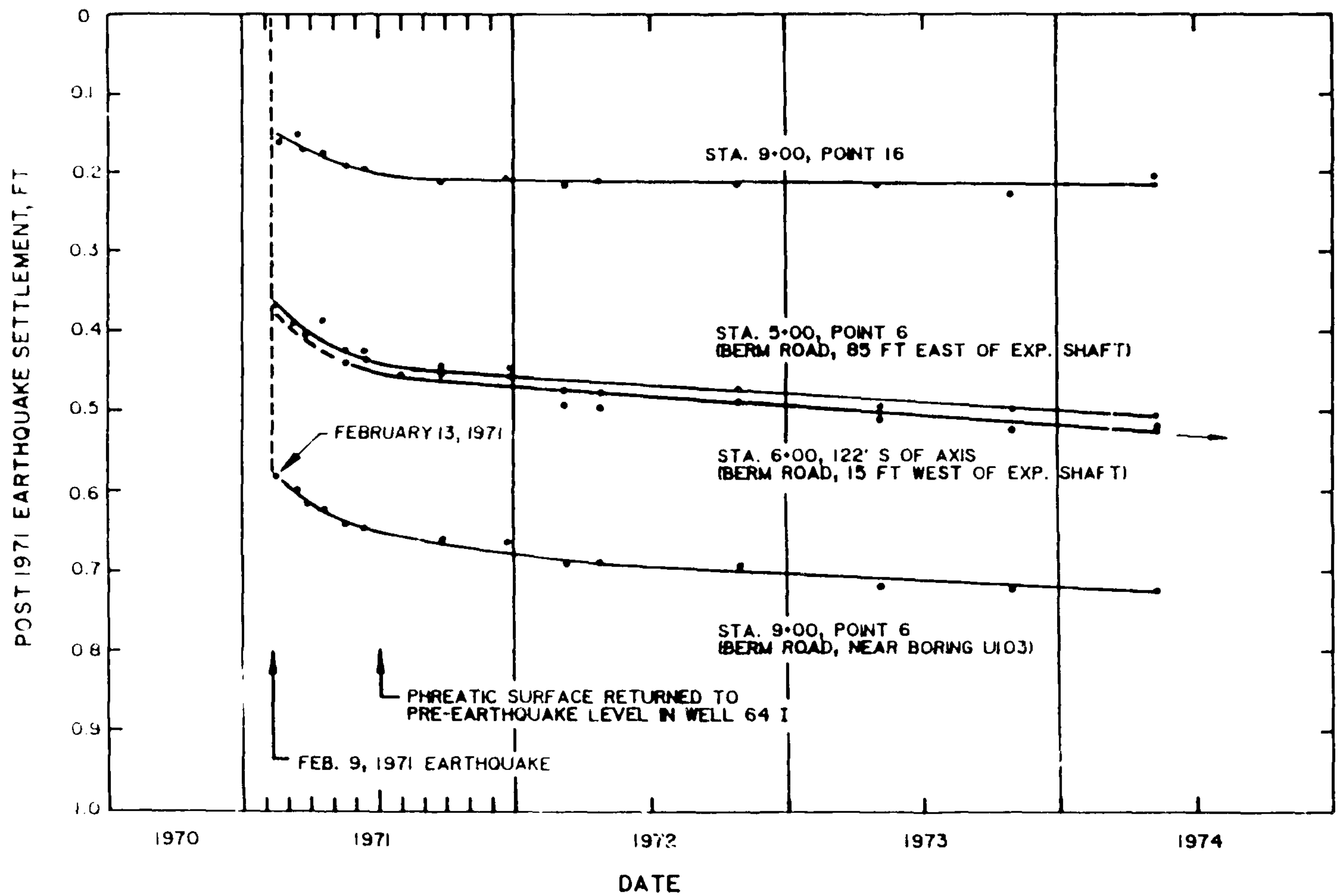
Dam Initially Constructed - 1916
Post 1971 Earthquakes not Shown

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	VERTICAL MOVEMENT VS. TIME-SURVEY POINT 16 ON STATION 5+00 LINE
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	August 14, 1987 Fig. C11

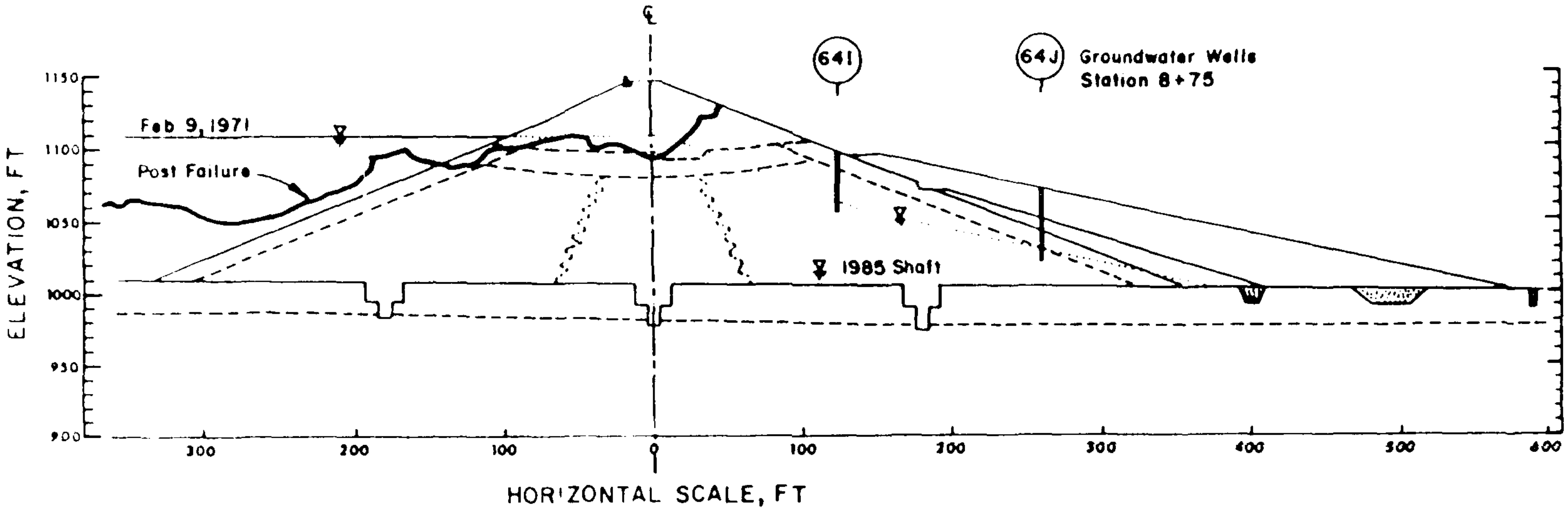


Dam Initially Constructed—1916
Post 1971 Earthquakes not Shown

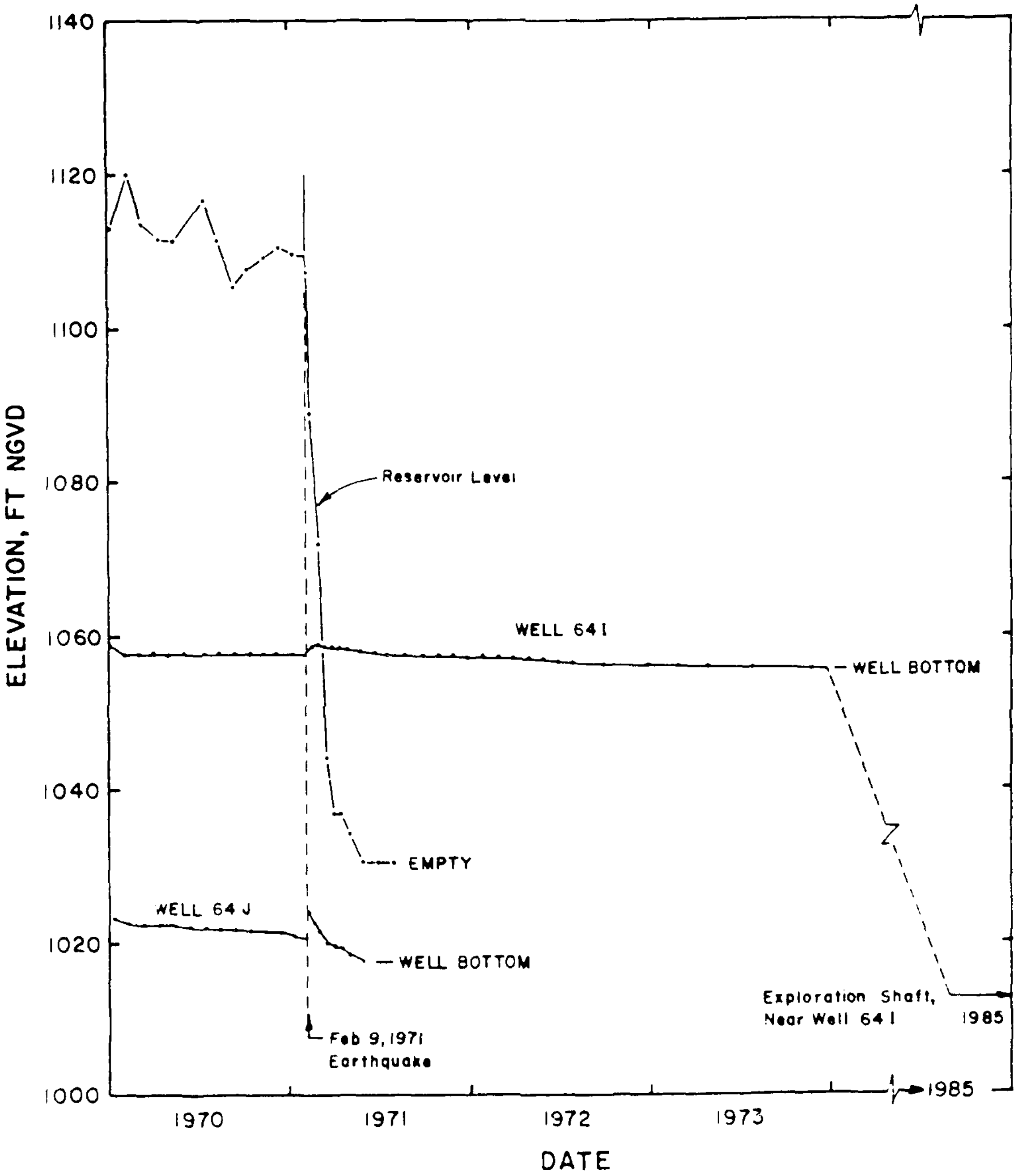
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	VERTICAL MOVEMENT VS. TIME-SURVEY POINT 24 ON STATION 5+00 LINE
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	August 14, 1987 Fig. C12



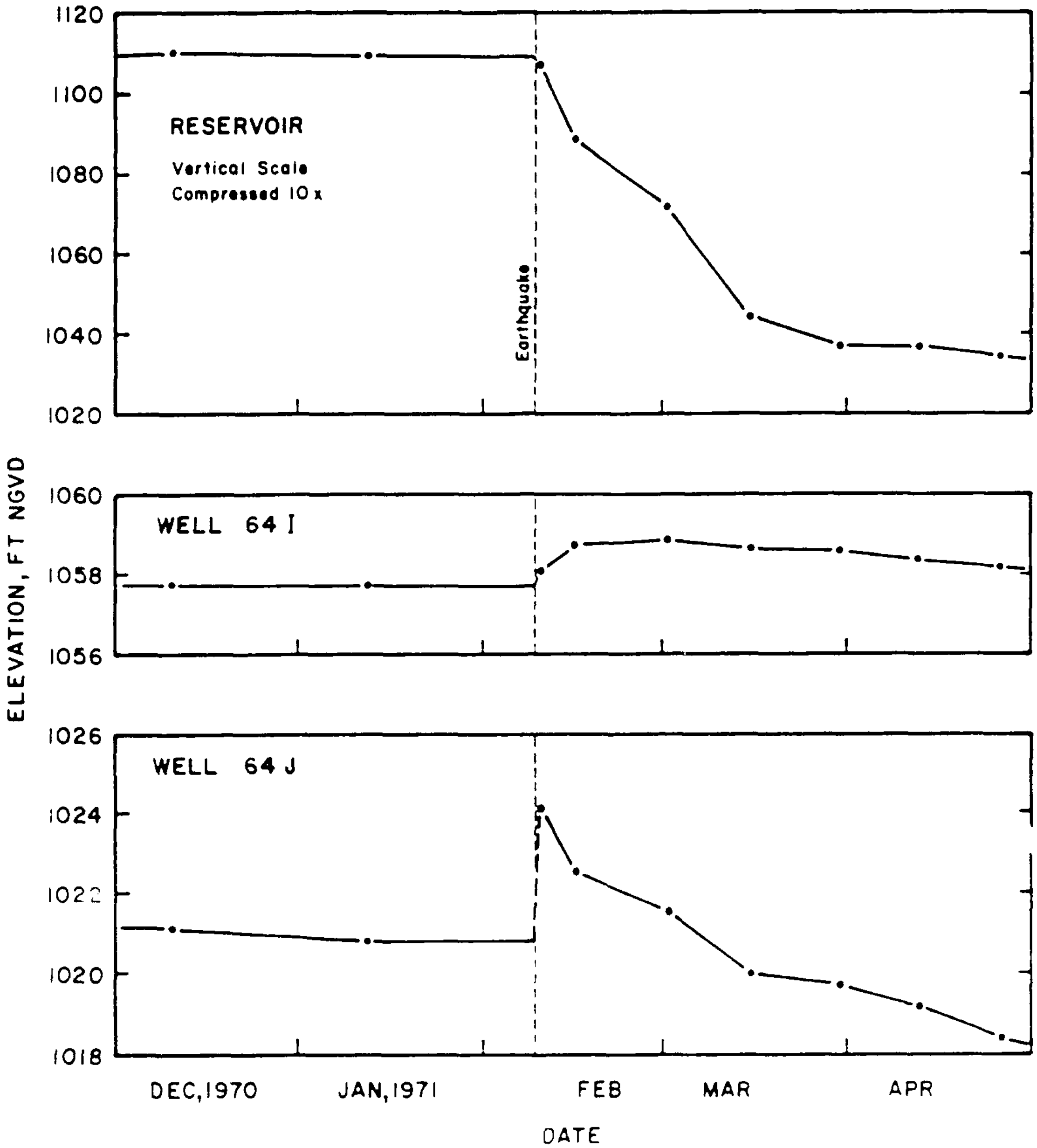
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SETTLEMENT VS. TIME FOR SURVEY POINTS ON DOWNSTREAM SLOPE
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	August 14, 1987 Fig. C13



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	CROSS SECTION OF DAM AT LOCATION OF WELLS 64I AND 64J
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. C14

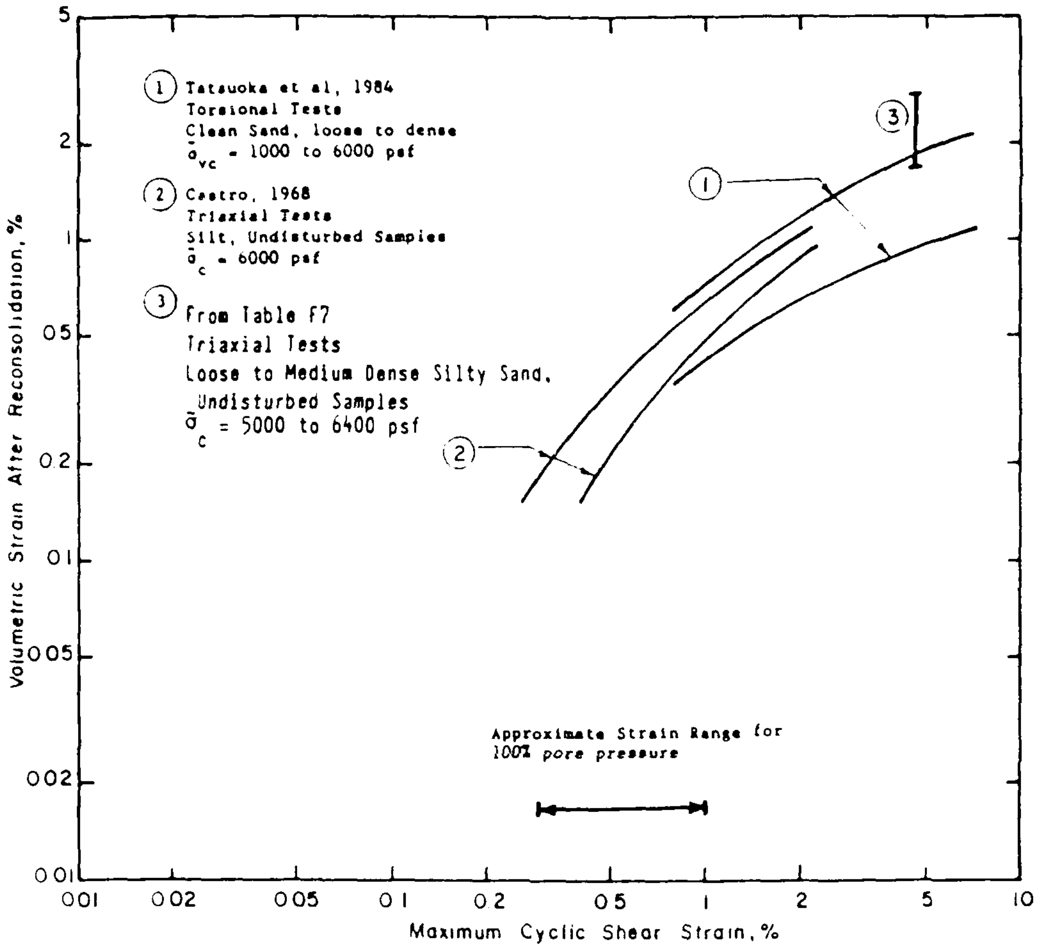


Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GROUNDWATER ELEVATIONS IN WELLS VS. TIME - 1970 - 1973
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. C15



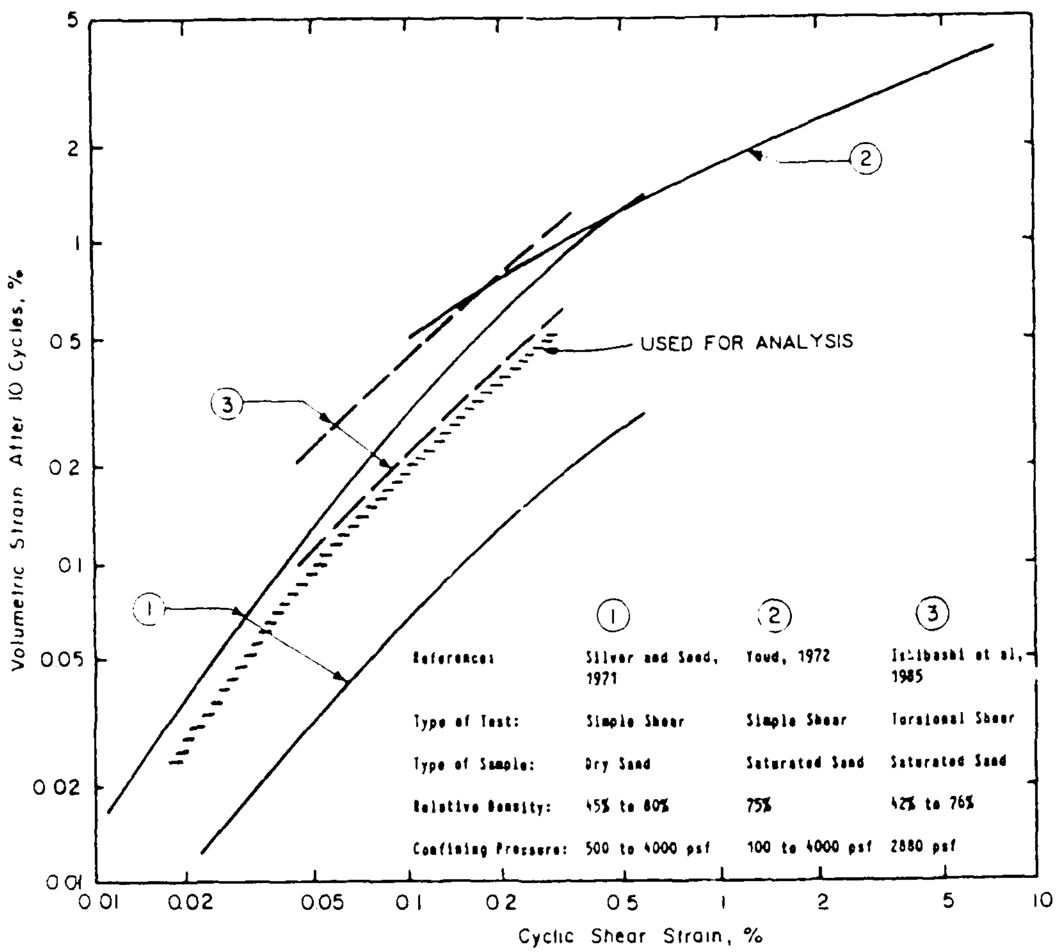
NOTE: WATER ELEVATIONS IN WELLS ARE PLOTTED TO A DIFFERENT SCALE THAN RESERVOIR ELEVATION.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GROUNDWATER ELEVATIONS IN WELLS VS. TIME - DEC. 1970 to APR. 1971
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. 316



After Castro, 1987
(modified)

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	VOLUME CHANGES OF SATURATED SANDS & SILTS AFTER CYCLIC LOADING - UNDRAINED CONDITIONS
GEOTECHNICAL ENGINEERS INC	Project 85669	Sep. [illegible], 1987 Fig. F17

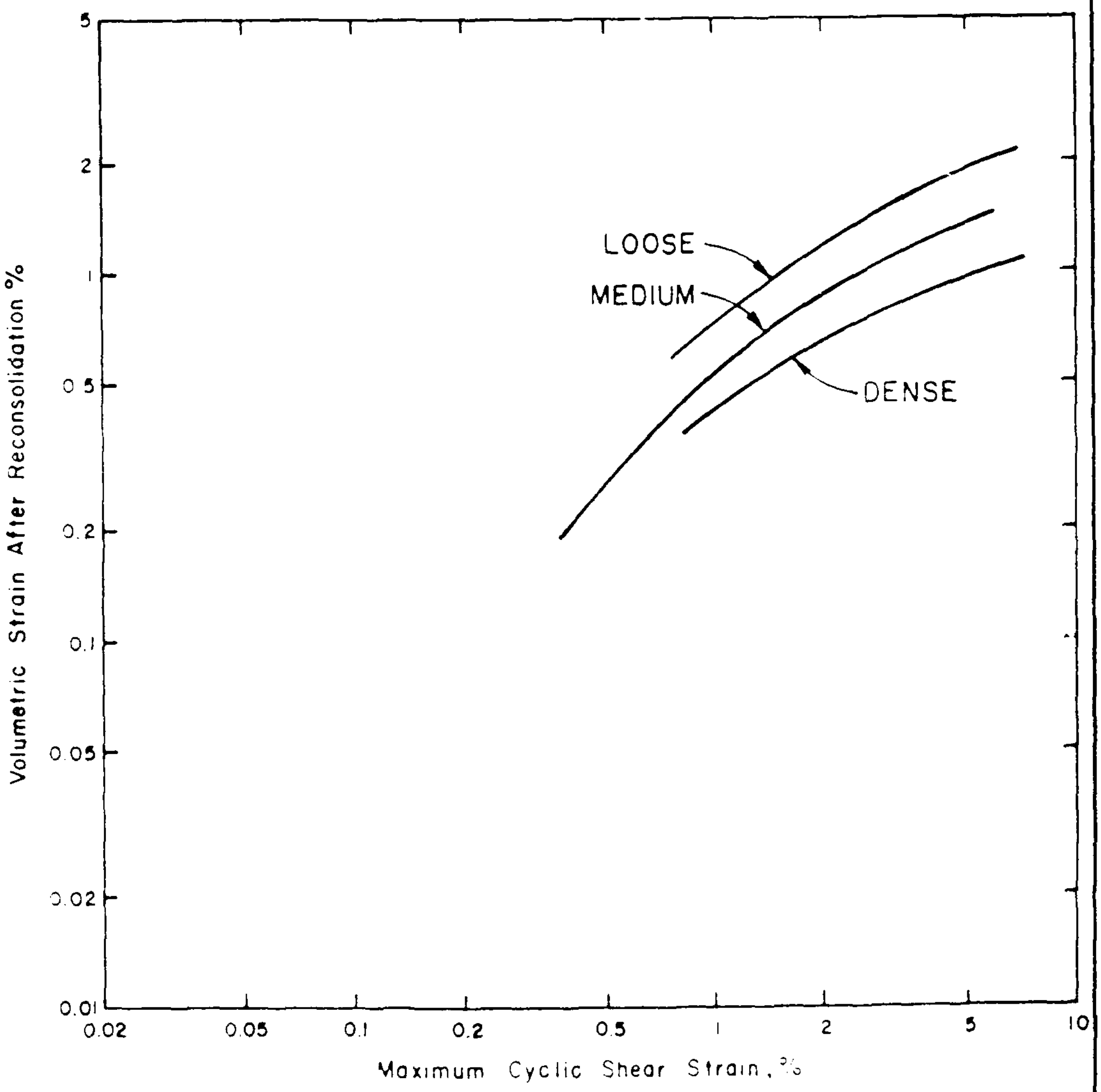


	(1)	(2)	(3)
Reference:	Silver and Seed, 1971	Youd, 1972	Ishibashi et al, 1985
Type of Test:	Simple Shear	Simple Shear	Torsional Shear
Type of Sample:	Dry Sand	Saturated Sand	Saturated Sand
Relative Density:	45% to 80%	75%	42% to 76%
Confining Pressure:	500 to 4000 psf	100 to 4000 psf	2880 psf

Note: Volumetric strain after 3 cycles was used in the analysis. The volumetric strain after 3 cycles is approximately 50% of the volumetric strain after 10 cycles.

After Castro, 1987

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	VOLUME CHANGES OF SANDS UNDER CYCLIC LOADING - DRAINED CONDITIONS
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. C18



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	VOLUME CHANGES OF SATURATED SOILS AFTER CYCLIC LOADING - USED FOR ANALYSES
GEOTECHNICAL ENGINEERS INC	Project 85669	Sep. 2, 1987 Fig. C19

APPENDIX D: STATIC AND PSEUDOSTATIC STABILITY ANALYSES

APPENDIX D

STATIC AND PSEUDOSTATIC STABILITY ANALYSES

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STATIC AND PSEUDOSTATIC STABILITY ANALYSES

D.1 Static Stability Analyses

D.1.1 Introduction

One of the steps in evaluating the liquefaction susceptibility of the dam is to determine the in situ driving shear stress in the critical soil layer (Section 4.6.1 of the main text). This section of the appendix describes stability analyses performed to determine the driving stress in the critical layer on the upstream side of the dam, as well as in the critical layer on the downstream side.

The computer program SSTAB2 (Wright, 1974) was used to analyze the slopes of the dam. The program uses a Spencer method of analysis in which the interslice forces are assumed to be inclined and parallel. The method satisfies all conditions of static equilibrium. Sliding wedges and circular arc failure surfaces were used in the analyses. Wedge failures were more critical than circular failures, so results of the wedge analyses were used. A manual search was performed to find the most critical wedge.

The driving shear stress in the critical layer is equal to the minimum shear resistance the layer must have to maintain stability of the slope, assuming fully mobilized strengths in other layers. The fully mobilized strengths are those that would act while deformations of the slope were occurring and would be available to resist a massive flow slide. The strength of the critical layer (c = strength, $\phi = 0$) is varied in the analysis until the factor of safety of the slope is equal to 1.0.

A cross section through the dam prior to the 1971 failure is shown in Fig. 2 of the main text. The simplified geometry used for performing stability analyses is shown in Fig. D1. The mobilized strengths of layers used in the analysis are presented in Table D1. A discussion of strengths used in the analyses is presented below.

Rolled Fill Cap and Ground Shale Layer - The rolled fill cap and ground shale layer, Layer 1 in Fig. D1, were judged to be slightly dilative based on soil descriptions and blowcounts in these layers. The mobilized strengths in these layers were varied using a friction angle of either 30° or 35°. These layers may have had slightly higher strengths below the groundwater due to dilation at the beginning of shear deformations, but dissipation of negative pore pressures would have reduced their strengths to drained values.

Clayey Core - The clayey core was assumed to act undrained during the failure. A laboratory vane shear test was performed on an undisturbed sample of the clayey core obtained from Boring U105 (Appendix F, Section F.5). The test was performed on a sample obtained below the 1985 groundwater level, and thus the sample is probably normally consolidated to the 1985 stresses

A plot of vane shear strength vs. vane displacement is shown in Fig. F116. This plot shows that large vane displacements were required to reduce the strength of the clay sample to its steady state strength. Thus the strength available in the field to resist the initial movements of a flow slide is the peak undrained strength, S_{up}. The strength used in stability analyses was varied from a high corresponding to $S_{up}/\bar{p} = 0.3$ to a low corresponding to $S_{up}/\bar{p} = 0.2$. The peak strength of the laboratory vane specimen corresponded to a c/p ratio, $S_{up}/\bar{p}$, equal to about 0.3 for 1985 conditions. Note that the resistance mobilized at a vane displacement of about 1 cm corresponded to an $S_{up}/\bar{p}$ ratio of about 0.16 and that the steady state strength corresponded to an $S_{us}/\bar{p}$ ratio of about 0.09.

A limited number of torvane shear strength measurements of the upper part of the clayey core were made soon after the 1971 failure (Seed, 1973). These measurements indicated an $S_{up}/\bar{p}$ ratio of about 0.3 which is consistent with the 1985 measurements of clay strength.

The clayey core was divided into three zones as shown in Fig. D1. The strength at the mid-height of each zone was used in the analyses.

Starter Dikes - Starter dikes used in the hydraulic filling process can be seen in construction photographs. Some compaction of these dikes resulted from equipment traffic. Because of the low confining pressures in the starter dike zone, it is likely that the soils in the dikes were dilative. The starter dikes were assigned a mobilized strength corresponding to drained conditions. The friction angle for the starter dikes was varied between 30° and 35°. As discussed in Section 5.7 of the main text, the toe of the starter dike on the upstream side of the dam may have dilated significantly and resisted initial flow slide movements with an undrained strength higher the the drained strength. Subsequent drainage of negative pore pressures in the toe dike would have reduced its strength from its undrained value towards its drained value which then could have allowed the flow slide to continue. This scenario points out the need to use the drained strengths of dense, dilative layers when evaluating susceptibility to a liquefaction flow slide.

1929-1930 Blanket and 1940 Berm - The engineering properties of these layers are not well known. Records indicate that they were apparently compacted to some degree during placement. The mobilized strengths of these layers were assumed to correspond to a drained friction angle of 40°.

Hydraulic Fill Shells - The upstream and downstream hydraulic fill shells were assumed to act undrained during the failure.

D.1.2 Static Stability Analysis of Upstream Slope

The critical failure surface through the upstream slope based on our stability analyses is shown in Fig. D1. The majority of the failure surface through the upstream hydraulic fill shell passes through the base of the shell, the location of the critical layer. Analyses were performed for two cases. Case A was based on lower bound values of the mobilized strengths varied in the analyses and Case B was based on upper bound values (Table D1). The driving shear stress, τ_d, through the critical layer on the upstream side of the dam was computed to be the following:

	Driving Shear Stress τ_d, kg/cm^2
Case A	0.53
Case B	0.44
Average	0.48

We believe that a driving shear stress of 0.48 kg/cm^2 is a reasonable value to use for evaluating the liquefaction susceptibility of the critical layer on the upstream side of the dam.

D.1.3 Static Stability Analysis of Downstream Slope

The critical failure surface through the downstream slope based on our stability analyses is shown in Fig. D2. Stability analyses were performed for the same two cases described in the previous section. The majority of the failure surface through the downstream hydraulic fill shell passes through the base of the shell, the location of the critical layer. The driving shear stress, τ_d, through the critical layer on the downstream side of the dam was computed to be the following:

	Driving Shear Stress τ_d, kg/cm^2
Case A	0.41
Case B	0.24
Average	0.33

We believe that a driving shear stress of 0.33 kg/cm^2 is a reasonable value to use for evaluating the liquefaction susceptibility of the critical layer on the downstream side of the dam for the prefailure condition.

Stability analysis of the downstream slope were also performed using the geometry of the dam immediately after the 1971 failure. The geometry used in the analysis was based on that shown in the upper part of Fig. 3. For the post-failure condition, the driving shear stress through the critical layer on the downstream side of the dam was computed to be 0.22 kg/cm^2 $\pm$ 0.06 kg/cm^2.

D.2 Pseudostatic Stability Analysis

The purpose of the pseudostatic stability analyses was to determine yield accelerations to be used for estimating strains with a Newmark-type analysis for various earthquake intensities. The strain estimates were then compared with the strains required to trigger liquefaction.

The shear stresses present along the base of the critical wedge for an upstream failure, prior to the earthquake, were related to the drained strengths for all soils. The earthquake stresses represented by a horizontal force acting on the critical wedge will cause additional shear stresses along the base of the wedge, and for a sufficiently large horizontal force, yielding of the soils will occur. The yielding that is relevant to the triggering of liquefaction is that of the Zone 5 hydraulic fill soils. These soils reach a peak strength at very small strains and liquefaction is triggered if yielding causes an accumulation of shear strain of 0.5% or larger. The question arises as to how much additional resistance is mobilized in the other soils along the base of the wedge under the small strains needed to trigger liquefaction. Two assumptions were made for the strengths used in the pseudostatic stability analyses to obtain upper and lower bounds for the yield acceleration, as shown in Table D2. The two assumptions are as follows:

a. the shear strengths in all soils are equal to the pre-earthquake mobilized shear strengths, except for the critical soil in which yielding is assumed to occur at the peak undrained strength (1,700 psf); and

b. the applicable shear strengths are equal to the peak drained strength in the rolled fill cap and ground shale layer and equal to the peak undrained strength in the clayey core, starter dike, and Zone 5 of the hydraulic fill shell (critical soil).

For cases a. and b. the computed yield accelerations of the upstream slope were 0.05 and 0.07 g, respectively.

TABLE D1 - SOIL PROPERTIES USED IN STABILITY ANALYSES TO DETERMINE IN SITU DRIVING SHEAR STRESSES
Lower San Fernando Dam

Soil	Layer[1] No.	Total Unit Weight, pcf	Case A - Lower Bound		Case B - Upper Bound	
			c psf	φ degrees	c psf	φ degrees
Rolled Fill Cap and Ground Shale Layer	1	120	0	30	0	35
Clayey Core[2]	2	120	1300	0	1970	0
	3	120	1600	0	2400	0
	4	120	1900	0	2830	0
Starter Dikes	5	120	0	30	0	35
1929-1930 Blanket	6	120	0	40	0	40
1940 Berm	7	120	0	40	0	40
Upstream Hydraulic Fill Shell	8	120	Note 3	0	Note 3	0
Downstream Hydraulic Fill Shell	9	120	Note 4	0	Note 4	0

Notes:

1) See Fig. D1 for dam geometry and layer numbers used in stability analyses.

2) Case A corresponds to $c/\overline{p} = 0.2$ and Case B corresponds to $c/\overline{p} = 0.3$.

3) The strength in this zone was varied until the factor of safety of the potential upstream failure surface equaled 1.0.

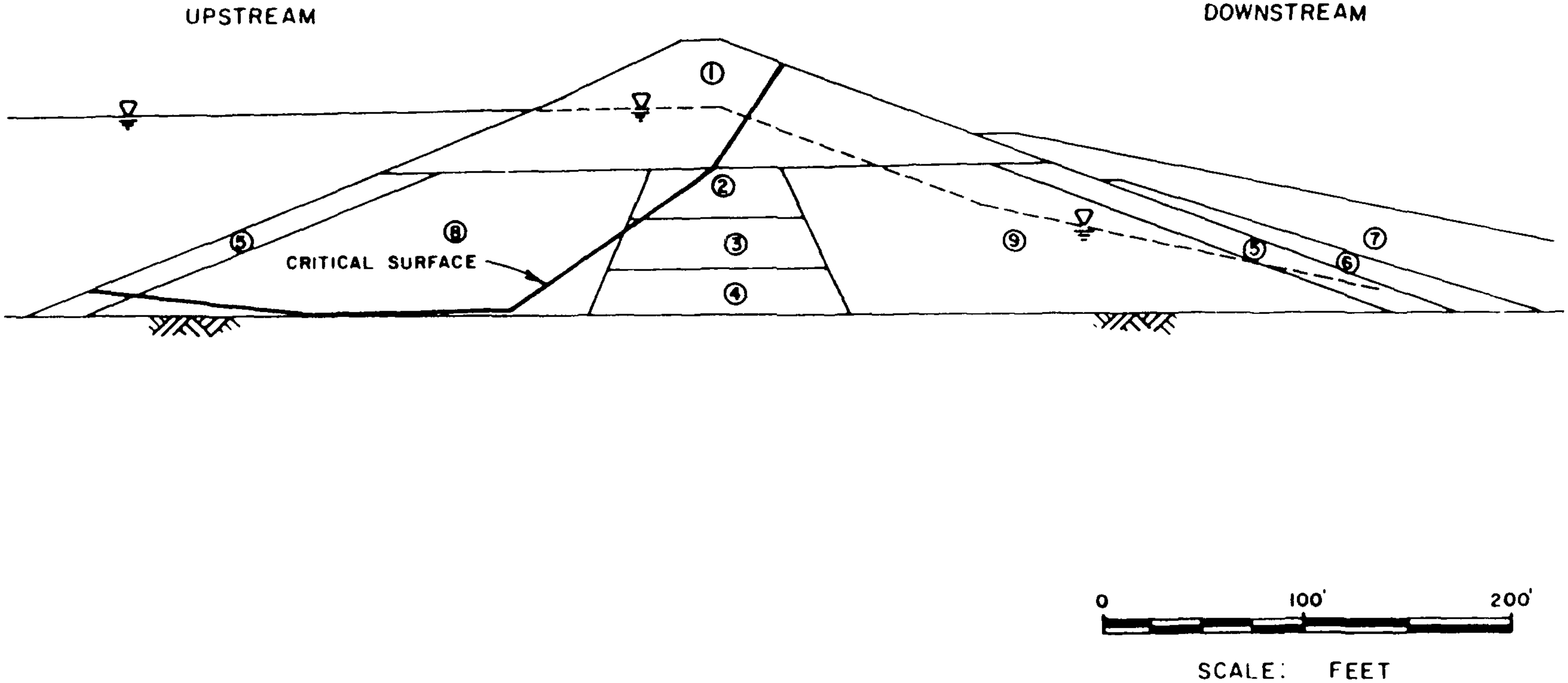
4) The strength in this zone was varied until the factor of safety of the potential downstream failure surface equaled 1.0.

TABLE D2 - SOIL PROPERTIES USED IN PSEUDOSTATIC STABILITY ANALYSES TO DETERMINE YIELD ACCELERATIONS OF UPSTREAM SLOPE
Lower San Fernando Dam

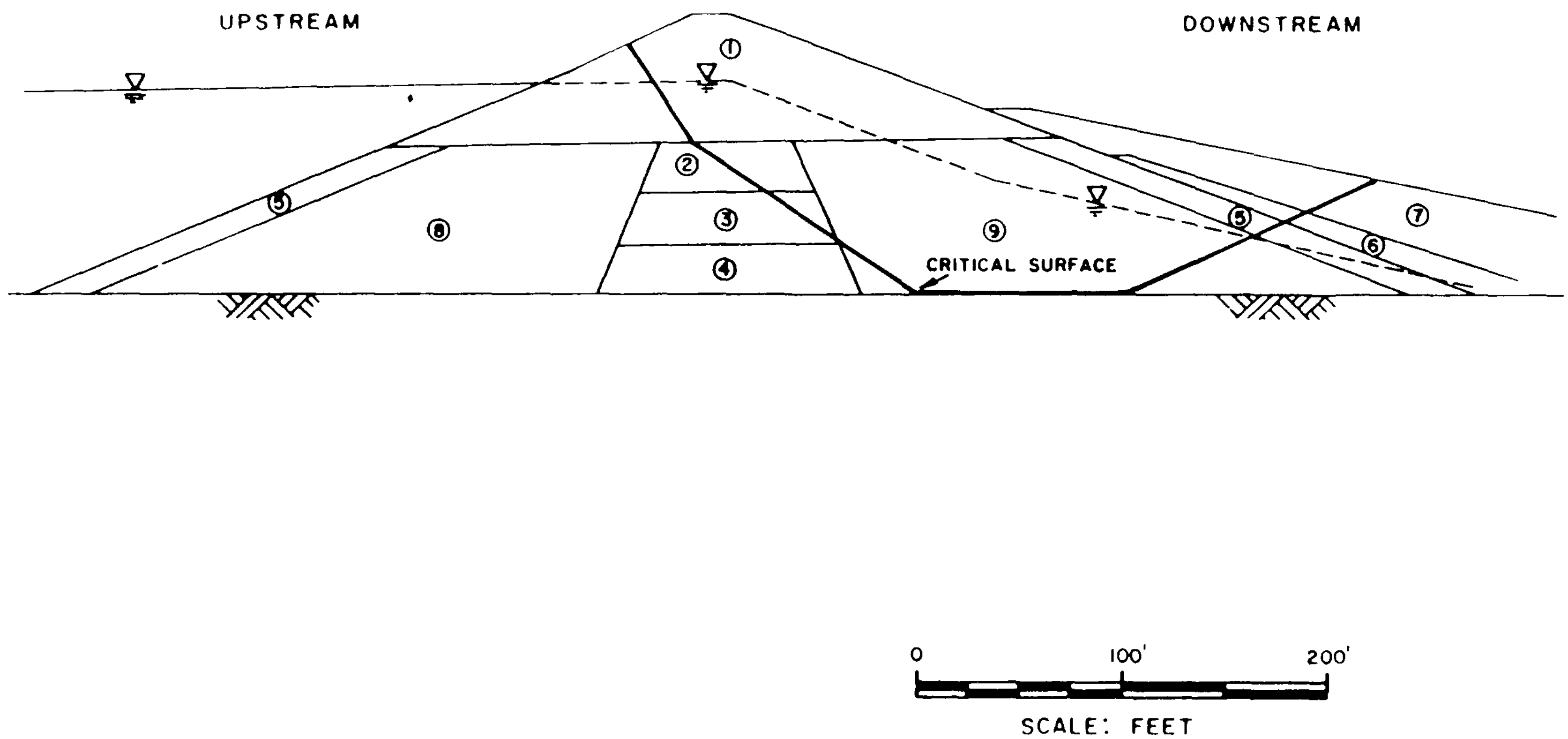
Soil	Layer[1] No.	Total Unit Weight, pcf	Yield Strength, S_y psf	
			Case A	Case B
Rolled Fill Cap and Ground Shale Layer	1	120	400	700
Clayey Core	2	120	1,400	1,600
Starter Dike	5	120	100	3,400
Upstream Hydraulic Fill Shell	8	120	1,700	1,700

Note:

1) See Fig. D1 for dam geometry and layer numbers used in stability analyses.



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	CRITICAL FAILURE SURFACE THROUGH UPSTREAM SLOPE
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. D1



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	CRITICAL FAILURE SURFACE THROUGH DOWNSTREAM SLOPE
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. D2

APPENDIX E: SHAKE ANALYSES

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SHAKE ANALYSES

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SHAKE ANALYSES

E.1 General

The computer program SHAKE (Schnabel et al, 1972) involves a one-dimensional analysis in which the soil profile is modeled as a series of horizontal layers, and the vertical propagation of shear waves is considered.

SHAKE analyses were performed on soil profiles through the downstream and upstream hydraulic fill shells of the dam.

E.2 Soil Profile Through Downstream Shell

A SHAKE analysis was performed using the soil profile at Location 111 to determine the maximum cyclic shear strain in each layer of the soil profile which occurred during the 1971 earthquake (see Appendix C, Section C.4). The soil profile at Location 111 is shown in Fig. 9 of the main text. The groundwater level for the SHAKE analysis was assumed to be its 1971 elevation, or about 35 feet below ground surface at Location 111.

The input parameters for the SHAKE analysis of the Location 111 soil profile are shown in Table E1. Values of maximum soil modulus coefficient $(K_2)_{max}$, for each layer of the hydraulic fill shell were estimated on the basis of corrected 1985 N-values as explained in Table E1. The N-values prior to the 1971 earthquake would be somewhat less than the 1985 values. We did not try to predict 1971 N-values for the purpose of estimating maximum soil modulus coefficients because we felt this level of refinement in estimating the coefficients was unwarranted.

Earthquake time histories of acceleration were input at the surface of the bedrock layer. The earthquake time history was that obtained from a seismoscope located on the right abutment. The motion in the direction normal to the axis of the dam was used. The record, developed by R. F. Scott (Seed, et al 1973) is shown in Fig. E1.

A plot of maximum cyclic shear strain vs depth developed from the SHAKE analyses is shown in Fig. E2.

E.3 Soil Profile Through Upstream Shell

SHAKE analysis were performed on a soil profile through the upstream hydraulic fill shell to determine time histories of stresses applied to the potential sliding mass on the upstream slope. Stresses from the SHAKE analyses were used to define time histories of acceleration as discussed in Section 5.5 of the main text.

The soil profile used for SHAKE analyses of the upstream shell was taken to be the same as that observed at Location 111 through the downstream shell, except that the groundwater level was placed at the ground surface due to the presence of the reservoir.

The input parameters for SHAKE analyses of the upstream soil profile are shown in Table E2. Values of maximum soil modulus coefficient, $(K_2)_{max}$, for each layer were taken to be the same as those estimated for the downstream slope. The shear moduli of layers in the upstream profile are less than shear moduli in the downstream profile due to the lower effective overburden stresses.

Earthquake time histories of acceleration were input at the surface of the bedrock layer. The earthquake time history was that developed by R. F. Scott (Fig. E1). The accelerations in the record were scaled to obtain several earthquake time histories with various peak accelerations for use in SHAKE analyses as described in Section 5.5 of the main text.

TABLE E1 - SUMMARY OF INPUT PARAMETERS FOR SHAKE ANALYSIS OF LOCATION 111 SOIL PROFILE - DOWNSTREAM SLOPE
Lower San Fernando Dam

Layer[1)]	Thick-ness	Total Unit Weight	$(N_1)_{60}$ [2)]	$\bar{\sigma}_m$ [3)]	$(K_2)_{max}$ [4)]	G_{max} [4)]
	ft	pcf	blows/ft	psf		psf x 10^6
Dense Fill	20	120	-	780	52	1.45
Zone 1 above groundwater	15	120	22	2140	56	2.59
Zone 1 below groundwater	6	120	22	2840	56	2.98
Zone 2	15	120	15	3230	49	2.79
Zone 3	11	120	20	3720	54	3.29
Zone 4	6	120	30	4040	62	3.94
Zone 5	15	120	11	4430	44	2.93
Alluvium	12	120	-	4940	52[5)]	3.65

Notes:

1) Soil profile is that shown in Fig. 9 with groundwater level 35 feet below ground surface.

2) $(N_1)_{60}$ is 1985 measured N-value in layer corrected for overburden pressure, using 60% of the theoretical free-fall hammer energy transferred to drill rods instead of the measured 72%, and liner effects as described in Seed, 1985.

3) $\bar{\sigma}_m$ is the 1971 octahedral effective stress at the midheight of the layer, equal to $0.65\bar{\sigma}_v$.

4) Maximum soil modulus coefficient, $(K_2)_{max}$, and maximum shear modulus, G_{max}, based on relationships between these parameters and $(N_1)_{60}$ and $\bar{\sigma}_m$ suggested by Seed, et al (1986). Attenuation curves for Damping Ratio and Shear Modulus based on Seed and Idriss (1970) for cohesionless soils. Input earthquake record is that shown in Fig. E1.

5) Value of $(K_2)_{max}$ for alluvium same as that used in Seed, et al (1973) for upper alluvium.

TABLE E2 - SUMMARY OF INPUT PARAMETERS FOR SHAKE ANALYSIS OF SOIL PROFILE THROUGH UPSTREAM SLOPE
Lower San Fernando Dam

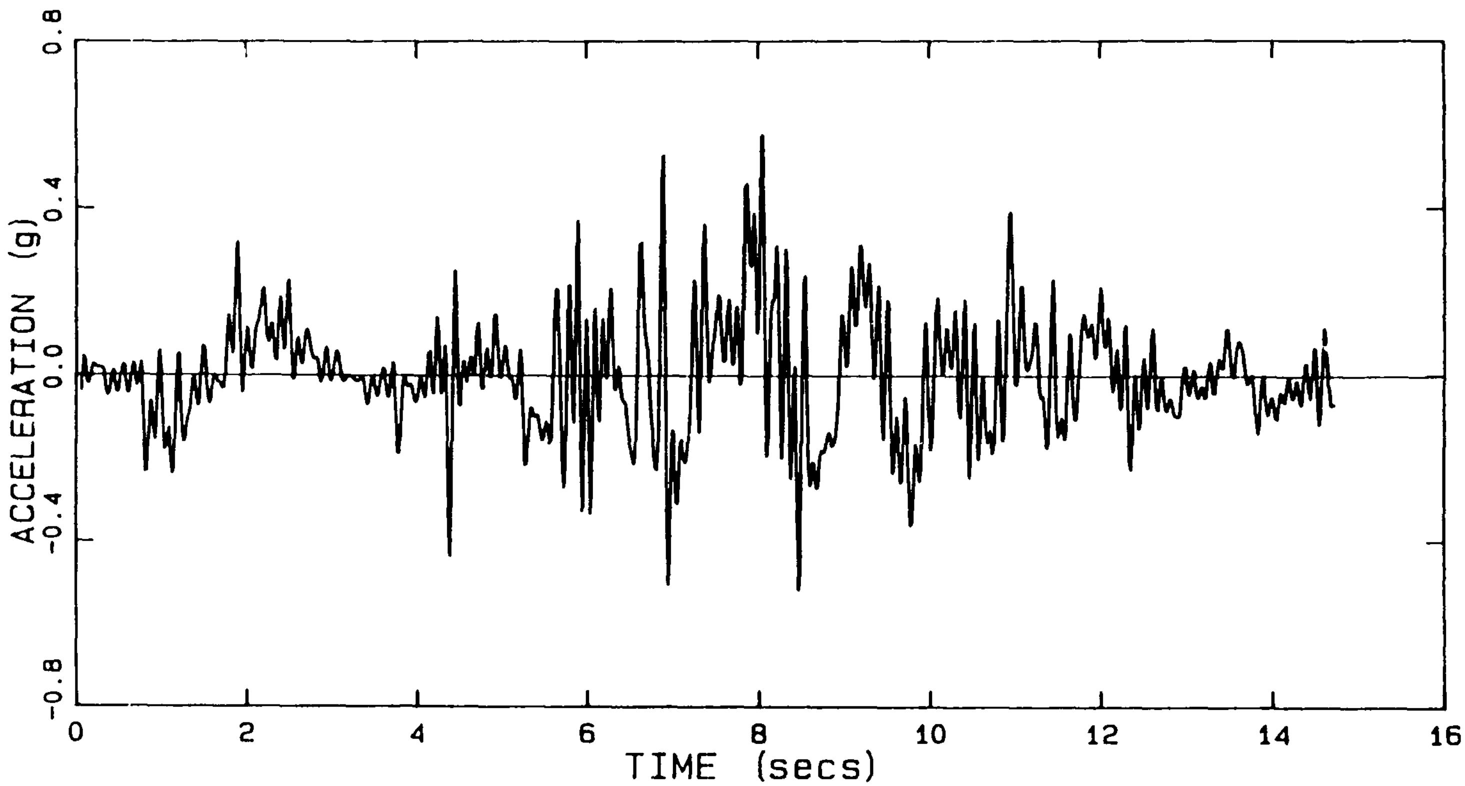
Layer[1)]	Thick-ness ft	Total Unit Weight pcf	$\bar{\sigma}_m$ [2)] psf	$(K_2)_{max}$ [3)]	G_{max} [3)] psf x 10^6
Dense Fill	20	120	380	52	1.02
Zone 1	21	120	1170	56	1.91
Zone 2	15	120	1860	49	2.11
Zone 3	11	120	2360	54	2.62
Zone 4	6	120	2690	62	3.21
Zone 5	15	120	3090	44	2.45
Alluvium	12	120	3610	52	3.12

Notes:

1) Soil profile is that shown in Fig. 9 except that a groundwater level at the ground surface was used.

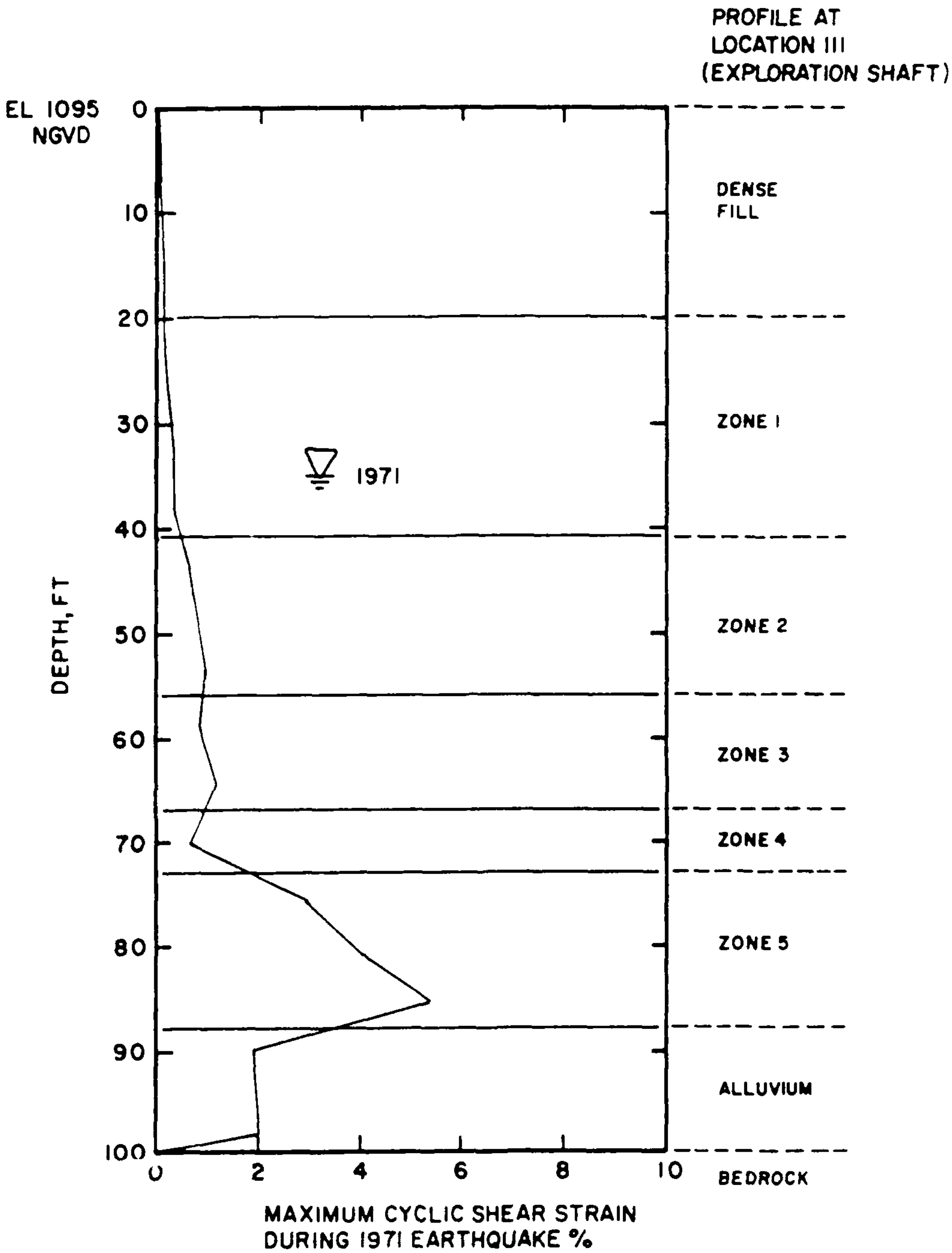
2) $\bar{\sigma}_m$ is the 1971 octahedral stress at the midheight of the layer, equal to $0.65\bar{\sigma}_v$.

3) Maximum soil modulus coefficient, $(K_2)_{max}$, the same as those in Table E1. Maximum shear modulus, G_{max}, based on $\bar{\sigma}_m$ and $(K_2)_{max}$. Attenuation curves for Damping Ratio and Shear Modulus based on Seed and Idriss (1970) for cohesionless soil.



After R. F. Scott's interpretation of record from seismoscope on right abutment of dam. Motion normal to axis of dam. Refer to Seed, et al, 1973.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	ACCELERATION TIME HISTORY AT DAM SITE - 1971 SAN FERNANDO EARTHQUAKE
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. E1



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	MAXIMUM CYCLIC SHEAR STRAIN VS. DEPTH
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. E2

APPENDIX F: LABORATORY TESTING PROGRAM

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LABORATORY TESTING PROGRAM

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APPENDIX F

LABORATORY TESTING PROGRAM

F.1 Introduction

Laboratory tests were performed on the following types of soil samples from Lower San Fernando Dam:

Source	Sample Type
Borings	Split-spoon samples Undisturbed fixed piston samples
Exploration Shaft	Undisturbed tripod tube samples Batch mixes formed from bag samples

Laboratory tests included index tests, monotonically and cyclically loaded triaxial tests, and vane shear tests. A list of all laboratory tests performed on each sample is presented in Table F1.

F.2 Preparation of Batch Mixes

Seven batch mixes were prepared from bag samples obtained from the exploration shaft. The individual bag samples used to form each batch mix are presented in Table F2, as well as the elevation range from which the bag samples were taken. An attempt was made to form batch mixes which would represent a particular soil layer encountered in the shaft.

Individual bag samples used to form a particular batch mix were combined on a large mixing board in the laboratory. The mixture was worked with a shovel until the soil was homogeneous. All laboratory tests of batch mixes were performed on the fraction passing the No. 4 sieve.

F.3 Index Tests

The following types of index tests were performed: specific gravity, compaction, Atterberg limits, mineralogical analysis, and grain size analyses. Results of index tests are summarized in Table F2 and discussed separately below.

F.3.1 Specific Gravity Determinations

Specific gravity tests were performed on each of the seven batch mix samples. Results of specific gravity tests are presented in Table F2. The measured specific gravities were used to calculate void ratios of triaxial test specimens.

F.3.2 Compaction Tests

Laboratory compaction tests were performed on each of the seven batch mix samples. The tests were performed in accordance with ASTM Procedure D1557-78, Method A. Results of the compaction tests are shown in Figs. F1 through Fig. F7.

F.3.3 Atterberg Limits Determination

One Atterberg limit test was performed on the minus No. 40 fraction of Batch Mix 7. The results of this test are as follows:

Liquid Limit = 24
Plastic Limit = 20
Plasticity Index = 4

Based on these results, the minus No. 40 fraction of Batch Mix 7 has a Unified Soil Classification of ML.

F.3.4 Mineralogical Analysis

A mineralogical analysis of a sample of Batch Mix 7 was performed for GEI by Resource Engineering Incorporated of Waltham, Massachusetts using reflected light microscopy. The following results were reported:

Mineral Type	Volume %
Quartz	67
Feldspar	15
Clays	10
Opaques	5
Other	3

The shape of most of the mineral grains was described as angular or blocky, and equiaxis with very few exhibiting a platy structure. No organic materials were found in the sample.

F.3.5 Grain Size Analyses

Grain size analyses were performed on the following samples:

No. of Tests	Sample Type
10	Split-spoon samples
21	Undisturbed samples
7	Batch mix samples

Grain size curves of all samples tested are presented in Figs. F8 to F49. Grain size analyses of triaxial test specimens were performed on a representative portion of the failure zone of the specimens. In some cases, two grain size analyses were performed on a triaxial test specimen to classify two obviously different layers in the specimen.

Grain size curves of undisturbed samples from Zone 5 of the hydraulic fill shell (critical layer) are plotted together in Fig. 11. Batch Mix 7 from the same zone is also shown in Fig. 11.

F.4 Triaxial Tests

F.4.1 General

The following triaxial tests were performed as a part of this study:

20 Isotropically consolidated, undrained triaxial, monotonic compression ($\overline{R}$) tests on undisturbed samples.

10 Isotropically consolidated, undrained triaxial, monotonic compression ($\overline{R}$) tests on remolded samples of Batch Mix 7.

2 Isotropically consolidated, drained triaxial, monotonic compression (S) tests on remolded samples of Batch Mix 7.

9 Anisotropically consolidated, undrained triaxial, monotonic compression ($\overline{R}$) tests on remolded samples of Batch Mix 7.

5 Anisotropically consolidated, undrained triaxial, cyclic load followed by monotonic compression ($C\overline{RR}$) tests on undisturbed

specimens; the consolidation phase of these tests included an unloading cycle to measure swelling properties.

11 Anisotropically consolidated, undrained triaxial, cyclic load ($C\overline{R}$) tests on remolded samples of Batch Mix 7.

Specimen preparation techniques are discussed below in Section F.4.2, followed by discussions of the individual test results in Sections F.4.3 through F.4.7.

F.4.2 Specimen Preparation

F.4.2.1 Undisturbed Tube Samples

The general procedure followed for preparing undisturbed tube samples for triaxial testing was as follows:

1. The distance from the ends of the tube to the soil surfaces at both ends of the tube were measured. These distances were compared to measurements of the same distance recorded just after the tube was taken in the field. Differences between the two sets of measurements were used to determine void ratio changes during sample shipment. In this investigation, no changes in sample length were measured during shipment.

2. The X-ray of the undisturbed tube sample selected for testing was examined to identify soil layers within the tube. Triaxial tests were performed on samples which appeared from the X-ray to be one soil layer within the tube. The section of tube for testing was identified and marked for cutting, leaving about 2 cm on each end of the section for trimming.

3. The tube was secured vertically in a chain vise, and stiffening rings placed adjacent to the cut locations. The purpose of the rings was to prevent the tube from deforming during cutting and thus to reduce stresses on the soil during cutting.

4. The tube cutter was positioned at the desired cut location and then turned slowly while applying gentle pressure. The distance from the top of tube to the soil was measured before and after cutting to determine if soil length changes occurred during cutting. A typical cut required about 15 to 20 minutes. In this investigation, little to no volume changes took place during cutting.

5. To promote saturation and easier sample extrusion, the bottom section of the tube was placed in a water bath, allowing water to be drawn to the top by capillarity. The bottom was protected by a piece of filter paper and a porous stone during saturation, with only the porous stone coming in contact with the water.

6. After saturation, the sample was trimmed to the desired test length in the tube, and measurements of the sample length recorded for determining the void ratio of the sample in the tube.

7. A membrane was placed on a membrane stretcher and the sample extruded directly into the membrane. Extrusion was performed with the tube in a vertical position.

8. The sample was placed on the bottom platen of the triaxial cell, the top cap was placed on the sample, and a vacuum of about 15 inches of mercury applied to the sample. Lubricated end platens were used for virtually all triaxial tests so that the smallest sample height could be used. This increased the probability that the triaxial test specimen would be essentially of one soil type.

9. The diameter and height of the sample were measured, the triaxial cell assembled, and the cell filled with water.

10. The vacuum was locked into the sample by closing the drainage lines, and the cell

pressure was increased to 0.5 kg/cm^2. The drainage lines were opened, releasing the vacuum and bringing the pore water pressure to atmospheric.

The sample was then ready for backpressure saturation and consolidation as discussed in Section F.4.2.3 below.

F.4.2.2 Remolded Samples

Triaxial tests were performed on remolded samples of Batch Mix 7. Only the fraction passing the No. 4 sieve was used for testing. The soil was passed through either a No. 10 or No. 40 sieve prior to testing to break lumps of soil.

Three methods were used to form samples of Batch Mix 7 for triaxial testing. The first method consisted of compacting the samples at a water content of about 7%. After compaction, the samples were saturated by flowing water through the samples from the bottom to the top, and then using backpressure saturation to achieve full saturation. This method required high backpressures to achieve proper saturation.

The second method involved placing the sample as a slurry at a water content ranging from 30 to 38%. This method was used for tests $\overline{R}104$ and $\overline{R}105$. Samples formed in this manner were found to be very soft and difficult to handle, and required long consolidation times at low consolidation pressures.

The third method was the most practical and was used for the majority of the triaxial tests on remolded samples. Samples were compacted in a mold at water contents typically between 3 and 4%. The following is a detailed summary of this procedure:

1. A confining membrane was secured in a sample mold and stretched smooth by applying a vacuum between the mold and the membrane. The mold was placed around the bottom platen of the triaxial cell. The diameter and height of the mold with the membrane in place was measured.

2. Using a target void ratio, known mold dimensions, and the water content of the batch mix, the required weight of soil for the test was weighed and mixed with CO_2.

3. Samples were compacted to target void ratios in layers between 1.35 and 1.5 cm thick by static pressure from a tamper. The top of each layer was scarified prior to the addition of the next layer.

4. When the desired sample height was reached, the top platen was placed on the sample and the membrane stretched over the platens. A small vacuum was applied to the sample, and the mold removed. Lubricated end platens were used for almost all tests.

5. After removing the mold, air within the sample was displaced by flowing CO_2 through the sample. The CO_2 entered the bottom of the sample under atmospheric pressure, and was pulled through the sample by a vacuum. The drainage line to the bottom of sample was then closed.

6. Sample dimensions were measured with the vacuum still applied. The cell was assembled and filled with water, and a small cell pressure of about 0.1 kg/cm^2 applied.

7. The vacuum was locked into the sample by closing the valve to the top drainage line. De-aired distilled water was then slowly introduced to the bottom of the sample. Water was drawn upward through the sample under the gradient imposed by the locked in vacuum. The rate of inflow was carefully controlled to prevent surges of water inflow.

8. When the distilled water reached the top of the sample and appeared in the top drainage line the sample was ready for backpressure saturation and consolidation. The drainage lines were opened, releasing the vacuum and bringing

the pore water pressure to atmospheric, while the cell pressure was increased from 0.1 to 0.5 kg/cm^2.

F.4.2.3 Backpressure Saturation and Consolidation

Backpressure saturation and isotropic consolidation was performed using a regulated air pressure system, with air over water interfaces. Graduated burettes having capacities of 60 ml were used to measure volume change from either the top or bottom drainage lines.

The air regulating system used allowed simultaneous increase of cell pressure and back-pressure. Starting from a confining pressure of 0.5 kg/cm^2 and a backpressure of 0.0 kg/cm^2, the pressures were increased in increments of 0.5 or 1.0 kg/cm^2, with drainage lines open. Measurements of the pore pressure coefficient, B, were performed during incremental increases in cell pressure and backpressure until the measured B-coefficient was approximately 0.95 or greater.

Upon completion of saturation, samples were isotropically consolidated to the desired effective stress. Volume and height changes were monitored during each increment of consolidation stresses.

When necessary, anisotropic consolidation loads were applied prior to shear. The required load was calculated based on the desired anisotropic stress and the estimated area after isotropic consolidation. Anisotropic loads were applied using either a dead load system, air pressure in a triaxial cell top with a built in air piston, or by loading the sample at a slow strain rate in a load frame. In all cases, the load was monitored by a load cell mounted beneath the soil sample.

At the completion of consolidation, the samples were loaded either monotonically or cyclically. After loading the samples were reconsolidated to their original isotropic stresses, (for undrained tests). The drainage lines were closed, and the triaxial cell dismantled. The final water content was then measured, using one half of the specimen for undisturbed tests and the whole sample for remolded samples. The final water content, final weight of solids, and specific gravity were then used to calculate the void ratios during shear and consolidation.

F.4.3 $\bar{R}$ Tests - Undisturbed Samples

Twenty $\bar{R}$ tests ($\bar{R}1$ through $\bar{R}20$) were performed on either undisturbed tripod tube samples from the exploration shaft, or on undisturbed fixed piston tube samples from borings. The purpose of the tests was to provide data for determining the in situ undrained steady state shear strength of the soils.

Results of $\bar{R}$ tests on undisturbed samples are summarized in Table F3, and summary plots for the individual tests are presented on Figs. F50 through F69. Triaxial consolidation curves for samples from Zone 5 are presented in Fig. F70, and consolidation curves for all other undisturbed samples are shown in Fig. F71. Descriptions of undisturbed samples after triaxial testing are presented in Table F8.

Conventional end platens were used for the first five $\bar{R}$ tests ($\bar{R}1$ through $\bar{R}5$). The remainder of the tests were performed using lubricated end platens. The reason for choosing lubricated ends was to minimize the number of layers within a given test specimen. The height-to-diameter ratio for the conventional end samples ranged from about 2.1 to 2.3, while the lubricated end platen tests were performed using a height-to-diameter ratio of about 1.5.

The drainage lines to the specimens were closed at the conclusion of consolidation and the samples sheared in monotonic compression. All of the tests were performed in a strain controlled loading device. Pore pressure changes, applied load, and axial deformation were monitored throughout the tests. Axial strain rates were chosen to allow pore pressure equalization during shear. Axial strain rates ranged from about 0.21 to 0.76 %/min.

The samples were typically sheared to an axial strain of about 25%. Test $\bar{R}11$ and $\bar{R}12$ were stopped at lower strains because the applied loads had reached or exceeded the capacity of the load cells.

The drainage lines were opened at the conclusion of shearing to allow excess pore pressures to dissipate. The volume change during reconsolidation was recorded, and the drainage lines were again closed. The triaxial cell was dismantled and the sample was cut vertically. One half of the sample was used for water content determination, and the remaining half was photographed and visually classified. A representative portion of the sample in the failure zone of the specimen was selected for grain size analysis.

F.4.4 $\overline{R}$ Tests - Remolded Samples, Isotropically Consolidated

Ten $\overline{R}$ tests, ($\overline{R}$101 through $\overline{R}$110), were performed on isotropically consolidated remolded samples of Batch Mix 7. The samples were prepared using three procedures, as discussed in Section F.4.2.2 above. The purpose of the tests was to develop the steady state line for Batch Mix 7.

Results of these tests are summarized in Table F4, and summary plots for the individual tests are presented in Figs. F72 through F81.

The shearing procedure for these tests was essentially identical to that used for undisturbed samples. Pore pressures, load, and axial deformation were measured continuously while the samples were sheared at slow strain rates to allow pore pressure equalization. The strain rates ranged from about 0.07 to 2 %/min.

The steady state condition was not reached in Test $\overline{R}$104, one of the samples prepared as a slurry. The value of $\bar{\sigma}_f$ at the end of this test was plotted in Fig. 15 and an arrow shown next to the data point to indicate that $\bar{\sigma}_{fs}$ was not reached.

The procedure for reconsolidating the sample and measuring the water content at the end of the test was similar to the procedure for the $\overline{R}$ tests on undisturbed samples, except that the entire sample was used for the water content determination.

A plot of q vs $\overline{p}$ for all isotropically consolidated $\overline{R}$ tests on Batch Mix 7 samples is shown in Fig. F84. This plot shows that the steady state friction angle of Batch Mix 7 was consistently 34° for values of $\overline{p}$ less than about 13 kg/cm^2. The friction angle decreased slightly at higher effective stresses.

The steady state lines for Batch Mix 7 (Figs. 15 and 17, in terms of $\bar{\sigma}_{fs}$ and S_{us}, respectively) were determined on the basis of the measured values of $\bar{\sigma}_{3s}$ and a steady state friction angle of 34°. The corresponding relationships are:

$$\bar{\sigma}_{fs} = \left(\frac{\cos^2\varphi}{1-\sin\varphi}\right)\bar{\sigma}_{3s} = 1.56\ \bar{\sigma}_{3s} \text{ for } \varphi = 34°$$

$$S_{us} = \left(\frac{\sin\varphi\cos\varphi}{1-\sin\varphi}\right)\bar{\sigma}_{3s} = 1.05\ \bar{\sigma}_{3s} \text{ for } \varphi = 34°$$

$$S_{us}/\bar{\sigma}_{fs} = \tan\varphi$$

F.4.5 S Tests - Remolded Samples

Two S tests (S1 and S2) were performed on isotropically consolidated remolded samples of Batch Mix 7. The purposes of the tests were to provide additional data for developing the steady state line, and to demonstrate the independence of test type on the steady state strength of a soil. Results of these tests are presented in Table F4 and individual test results are shown in Figs. F82 and F83.

Both S tests were performed using lubricated end platens, and were set up following the same general procedure discussed in Section F4.2.2. The samples were sheared under conditions of controlled strain at a rate slow enough to allow pore pressure dissipation. Measurements of applied load, axial strain, and volume change were measured during shear.

The minor principal stress was decreased during shear in an attempt to keep the effective stress on the failure plane constant throughout the test. The effective stress on the failure plane varied somewhat during shear as shown by the stress paths in Figs. F82 and F83. The samples were contractive throughout shear, and the void ratios were essentially constant at the end of the test.

F.4.6 $\bar{R}$ Tests - Remolded Samples, Anisotropically Consolidated

Nine $\bar{R}$ tests ($\bar{R}$201 through $\bar{R}$209) were performed on anisotropically consolidated remolded samples of Batch Mix 7. The main purposes of these tests were to determine peak strengths and strains and to investigate their variation with strain rate. In addition, five of the tests reached a steady state condition and provided additional data for defining the steady state line of Batch Mix 7. Results of these tests are summarized in Table F5, and summary plots for the individual tests are shown in Figs. F85 through F93.

The samples were prepared as discussed in Section F.4.2.2 above. Both lubricated end platens and conventional end platens were used as shown in Table F5.

Anisotropic stresses were applied at the end of isotropic consolidation. This was done by applying an axial load with a dead load frame or an air piston.

The samples were tested at strain rates that can be considered either slow (<1%/min.), medium (about 30 to 50%/min.), or fast (from 3800 to 4900%/min.). The slow and medium strain rate tests were performed under conditions of controlled strain. Fast strain rates were achieved by instantaneously applying a large compression pulse to the load piston attached to the top of the sample. Test results were recorded on a strip chart recorder, and the strain rate reported in Table F5 was measured from the record. The strain rate at the beginning of the test tended to vary, until the sample had passed its peak strength. Thereafter the sample tended to deform at a relatively constant velocity. Strain rates reported on Table F5 are based on the constant velocity portion of the test.

F.4.7 C$\overline{RR}$ Tests - Undisturbed Samples

Five triaxial tests (C$\overline{RR}$1 through C$\overline{RR}$5) were performed on undisturbed samples primarily to obtain reconsolidation characteristics of the soil after being subjected to cyclic loading. The tests are designated C$\overline{R}$ to indicate cyclic loading under undrained conditions and $\overline{R}$ to indicate monotonic loading after cyclic loading. The following procedure was followed:

Phase	Procedure
a	Anisotropically consolidate specimen to the approximate in situ stresses at the sample location prior to the 1971 earthquake.
b	Close drainage to specimen and cyclically load specimen to a maximum cyclic axial strain (single amplitude) of about 3%. Restrictors were placed on the load

piston so that cyclic strains would not exceed 3%.

c Open drainage to specimen and measure the decrease in void ratio caused by dissipation of excess pore pressure in specimen.

d Anisotropically consolidate specimen to the approximate in situ stresses at the sample location in 1985.

e Decrease consolidation stress to $\bar{\sigma}_{1c} = \bar{\sigma}_{3c} = 0.1$ kg/cm^2.

f Isotropically consolidate specimen to $\bar{\sigma}_{3c} = 8.0$ kg/cm^2.

g Shear the specimen in undrained monotonic compression.

Undisturbed samples ranged from a slightly silty, widely graded sand to a clayey silt. Grain size curves of samples tested are presented in Figs. F45 to F49. Descriptions of individual samples after triaxial testing are presented in Table F8.

Plots of void ratio e vs $\bar{\sigma}_3$ for each test are presented in Figs. F94 to F98. These plots show void ratio changes which occurred during each of the phases described above.

A summary of Phases a through c is presented in Table F7. During cyclic loading, $\bar{\sigma}_3$ decreased from initial values ranging from 2.5 to 3.2 kg/cm^2 to final values ranging from about 0.1 to 0.3 kg/cm^2. Drainage after cyclic loading caused void ratios to decrease in the range of 0.027 to 0.048.

Phase "e" was performed to obtain data on the amount of swelling caused by a decrease in consolidation stress. A plot of swelling coefficient ($\Delta e / \Delta \log \bar{\sigma}_0$) vs initial void ratio is shown in Fig. 13.

Samples were reconsolidated to $\bar{\sigma}_{3c}$ = 8 kg/cm^2 prior to the $\bar{R}$ phase. Results of the $\bar{R}$ phase are presented in Table F3 and data plots for individual $\bar{R}$ tests are presented in Figs. F99 to F103.

F.4.8 $\overline{CR}$ Tests - Remolded Samples

Eleven cyclic triaxial tests ($\overline{CR}$101 through $\overline{CR}$111) were performed on anisotropically consolidated remolded samples of Batch Mix 7. The tests are referred to as $\overline{CR}$ tests to indicate that a cyclic axial load was applied, and that the samples were undrained during shear. Results of these tests are summarized in Table F6, and summary plots of the individual tests are shown in Figs. F106 through F115.

The purpose of these tests was to determine the minimum axial strain required to trigger specimen failure after undrained cyclic loading. The consolidation stresses were chosen such that the ratio of undrained steady state shear strength to driving shear stress on the failure plane would be as close as possible to 0.54, the same as the factor of safety against a liquefaction flow slide, S_{us}/τ_d, through the critical layer (Zone 5) on the upstream side of the dam in 1971. Because of the sample preparation and consolidation procedures used, we typically achieved laboratory $S_{us}/\tau d$ ratios of 0.60 to 0.70.

It was desired to apply cyclic transient loads that would not be available to drive the failure. Only the static (consolidation) anisotropic loads would drive the failure. A loading apparatus was developed that allowed application of triangular shaped axial compression pulses. A schematic diagram of the loading apparatus is shown in Fig. F104. The anisotropic load (Lc) was applied to the sample by adding dead load to the hanger system beneath the sample. At the conclusion of consolidation, the drainage lines to the specimen were closed. The cyclic load (F_a) was then applied by imparting blows to the spring/cushion system above the sample using a hand-held sledge hammer. The stiffness of the spring/cushion system resulted in triangular spikes lasting about 0.03 to 0.05 seconds.

The force applied to the loading yoke was monitored using a load cell mounted beneath the spring/cushion system. The load applied to the soil was measured using the load cell mounted below the soil sample. Axial strain was measured using DCDT's mounted on the load piston, and pore pressure was monitored using standard pore pressure transducers. All measurements were recorded on a strip chart recorder.

A typical strip chart record, from test CR111, is shown in Fig. F105. The record has been redrawn to show axial strain (ϵ_a) instead of deformation, and effective minor principal stress ($\bar{\sigma}_3$) instead of pore pressure. The applied cyclic force F_a is the force applied over and above the anisotropic consolidation load L_c. The total soil force F_r is the load resisted by the soil at any point in time, and therefore includes the anisotropic load and any additional load imparted to the soil by the cyclic loading.

As shown in Fig. F105, the applied cyclic force for test $\overline{C}$R111 greatly exceeded the available soil resistance, (i.e. a force of approximately 36 kg was applied to the loading yoke, while the soil could resist only about 19 kg more than the consolidation load). Therefore the sample yielded and accumulated axial strain. Two load cycles of approximately equal magnitude were applied in the test.

The axial strain at the end of cyclic loading for test $\overline{C}$R111 was about 0.47%. After cycling had stopped the sample continued to creep under constant load to a strain of 1.05%. At that point the creep rate accelerated and the sample underwent rapid failure.

The significance of the axial strain at the end of cycling, and at the start of rapid failure can be seen by observing the stress-strain curve for anisotropically consolidated specimens loaded monotonically at slow strain rates. The axial strain at peak for the strain controlled tests averaged about 0.1%. Therefore, the strain at the end of cycling during test $\overline{C}$R111 had exceeded the strain to peak. However, during the strain controlled tests the available soil resistance at strains of up to about 1% was greater than the consolidated shear stress. Therefore, during the cyclic test, when the accumulated strain had reached about 1%, the driving shear stress exceeded the soil resistance, and the sample failed rapidly.

F.5 Laboratory Vane Shear Test

One laboratory vane shear test was performed on an undisturbed sample of the clayey core (Sample UF14C from Boring U105). This sample was located below groundwater level at the time of sampling in 1985.

The laboratory vane was 1.27 cm in diameter and 1.27 cm in height. The vane rotation rate was 19 degrees/second.

Results of the vane shear test are presented in Fig. F116, which includes a plot of vane shear strength vs displacement of the periphery of the vane.

TABLE F1 - LIST OF LABORATORY TESTS
Lower San Fernando Dam

Boring No. or Exploration Shaft(ES)	Sample No.	Depth (Elevation)[1] to Top of Test Specimen ft	Grain Size Curve Fig. No.	Specific Gravity Table No.	Compaction Test Fig. No.	Engineering Properties Tests[2] Test No.	Engineering Properties Tests[2] Table No.	Engineering Properties Tests[2] Fig. No.
S101	S7	30.0 (1085.5)	F8	-	-	-	-	-
S101	S17	59.9 (1055.6)	F9	-	-	-	-	-
S102	S22	66.0 (1048.6)	F10	-	-	-	-	-
S103	S18	50.2 (1043.7)	F11	-	-	-	-	-
S104	S27	67.0 (1026.9)	F12	-	-	-	-	-
S104	S18	85.0 (1029.5)	F13	-	-	-	-	-
S104	S22	105.0 (1009.5)	F14	-	-	-	-	-
S105	S32	89.0 (1025.1)	F15	-	-	-	-	-
S111	S9	28.0 (1067.1)	F16	-	-	-	-	-
S111	S25	61.0 (1034.1)	F17	-	-	-	-	-
[illegible]	UF3B	80.4 (1014.7)	F43	-	-	$\overline{R}19$	F3	F68
	UF3C	80.9 (1013.0)	F32	-	-	$\overline{R}8$	F3	F57
[illegible]	UF10C	89.8 (1024.3)	F33	-	-	$\overline{R}9$	F3	F58
	UF14C					LV1		F116
[illegible]	UF8B	58.4 (1036.7)	F49	-	-	$CR\overline{R}5$	F3, F7	F98, F103
	UF23B	87.7 (1007.4)	F42	-	-	$\overline{R}18$	F3	F67
[illegible]	UF9B	64.4 (1030.7)	F48	-	-	$CR\overline{R}4$	F3, F7	F97, F102
	UF14D	74.5 (1020.6)	F38	-	-	$\overline{R}14$	F3	F63
	UF16D	78.5 (1016.6)	F39	-	-	$\overline{R}15$	F3	F64
	UF19A	83.3 (1011.8)	F44	-	-	$\overline{R}20$	F3	F69
	UF19C	84.3 (1010.8)	F29	-	-	$\overline{R}5$	F3	F54
	UF20D	86.5 (1008.6)	F40	-	-	$\overline{R}16$	F3	F65
	UF21A	87.1 (1008.0)	F41	-	-	$\overline{R}17$	F3	F66

Notes: See page 2.

TABLE F1 - LIST OF LABORATORY TESTS
Lower San Fernando Dam

Boring No./ or Exploratory Shaft(ES)	Sample No.	Depth (Elevation)[1] to Top of Test Specimen ft	Grain Size Curve Fig. No.	Specific Gravity Table No.	Compaction Test Fig. No.	Engineering Properties Tests[2] Test No.	Engineering Properties Tests[2] Table No.	Engineering Properties Tests[2] Fig. No.
ES	TS102	53.2 (1044.3)	F28	-	-	$\overline{R}$4	F3	F53
	TS103	53.2 (1044.3)	F35	-	-	$\overline{R}$11	F3	F60
	TS112	55.1 (1042.4)	F47	-	-	$\overline{CRR}$3	F3, F7	F96, F101
	TS116	56.4 (1041.1)	F27	-	-	$\overline{R}$3	F3	F52
	TS203	65.0 (1032.5)	F26	-	-	$\overline{R}$2	F3	F51
	TS207A	65.0 (1032.5)	F34	-	-	$\overline{R}$10	F3	F59
	TS302	83.5 (1014.0)	F25	-	-	$\overline{R}$1	F3	F50
	TS306A	83.5 (1014.0)	F46	-	-	$\overline{CRR}$2	F3, F7	F94, F99
	TS306B	84.4 (1013.1)	F31	-	-	$\overline{R}$7	F3	F56
	TS309A	83.4 (1014.1)	F30	-	-	$\overline{R}$6	F3	F55
	TS309B	83.8 (1013.7)	F45	-	-	$\overline{CRR}$1	F3, F7	F95, F100
	TS314	84.1 (1013.4)	F37	-	-	$\overline{R}$13	F3	F62
	TS315	85.1 (1012.4)	F36	-	-	$\overline{R}$12	F3	F61
Batch Mix 1[3]		53.2 (1044.3)	F18	F2	F1	-	-	-
2		54.6 (1042.9)	F19	F2	F2	-	-	-
3		55.1 (1042.4)	F20	F2	F3	-	-	-
4		56.4 (1041.1)	F21	F2	F4	-	-	-
5		65.0 (1032.5)	F22	F2	F5	-	-	-
6		66.3 (1031.2)	F23	F2	F6	-	-	-
7[4]		83.5 (1014.0)	F24	F2	F6	$\overline{R}$101-$\overline{R}$110	F4	F72-F81
						S1, S2	F4	F82, F83
						$\overline{R}$201-$\overline{R}$209	F5	F85-F93
						$\overline{CR}$101-$\overline{CR}$111	F6	F104-F115

Notes:
1) Elevation datum is NGVD.
2) See text of Appendix F for definitions of engineering property test prefixes: $\overline{R}$, $\overline{CR}$, $\overline{CRR}$, S, LV.
3) See Table F2 for description of batch mixes.
4) See Section F3.3 of text for Atterberg Limit Determinations and Section F3.4 of text for Mineralogical Analyses.

TABLE F2 - SUMMARY OF BATCH MIX SAMPLES FORMED FROM BAG SAMPLES TAKEN FROM EXPLORATORY SHAFT
Lower San Fernando Dam - California

Batch Mix No.	Elevation Range, NGVD	Bag Samples Forming Mix	Soil Description			Specific Gravity	Maximum Dry Unit Weight, ASTM D1557[2)]
			USCS Symbol	% Passing[1)] No. 200 Sieve	C_u		pcf
1	1044.3 to 1043.7	BS 102, 103, 104	SM	14.1	3.6	2.68	104.0
2	1042.9 to 1042.3	BS 105, 106, 107	ML, ML-CL	87.8	>30	2.71	113.5
3	1042.4 to 1041.8	BS 108, 109, 110	SP-SM	10.6	4.9	2.67	110.5
4	1041.1 to 1040.5	BS 112, 113, 114	SM	20.9	3.8	2.68	104.5
5	1032.5 to 1031.6	BS 201, 202, 203 204, 205	SM	37.5	6.1	2.67	104.8
6	1031.2 to 1030.5	BS 207, 208, 209 210	SM	30.7	4.2	2.68	103.5
7	1014.0 to 1012.3	BS 301, 302, 304 305, 306, 308 309, 311	SM-ML	50.5	31.5	2.69	115.9

Notes:

1) The percent passing the No. 200 sieve is based on the minus No. 4 sieve fraction.

2) ASTM D1557, Method A was used. Only the minus No. 4 sieve fraction is used for this method.

TABLE [illegible] - $\overline{R}$ TESTS ON UNDISTURBED SPECIMENS

Lower San Fernando Dam

Test No.	Sample No.	Depth (ft)	[illegible] (2)	Dry Unit Weight (Void Ratio): In Tube After Sampling in Field	In Triaxial Cell: Initial	In Triaxial Cell: End of Shear	Effective Consolidation Stress $\bar{\sigma}_{3c} = \bar{\sigma}_{1c}$	At Peak: Shear Stress q_p (3)	At Peak: Axial Strain ϵ_p	At Peak: Friction Angle φ_p	At Steady State: Shear Stress q_s (3)	At Steady State: Effective Minor Principal Stress $\bar{\sigma}_{3s}$	At Steady State: Axial Strain ϵ_s	At Steady State: Shear Strength S_{us} (4)	At Steady State: Friction Angle φ_s	Back Pressure u_c	Pore Pressure Coefficient B_c (5)	Axial Strain Rate
			pcf	pcf	pcf	pcf	kg/cm²	kg/cm²	%	deg	kg/cm²	kg/cm²	%	kg/cm²	deg	kg/cm²		%/min
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100.? ([illegible])	4.0	2.98	14.3	34.7	2.98	2.25	19.3	2.45 (2.36)	34.7	6.0	0.9?	0.31
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.?3	19.?	35.?	5.47	4.38	24.6	4.56	33.8	12.0	0.97	0.33
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.?3	21.?	34.9	7.49	5.86	25.0	6.20	34.1	1?.0	0.95	0.32
[illegible]	[illegible]	[illegible] (44.5)	[illegible]	[illegible]	[illegible]	[illegible]	6.0	> 5.36	> 25.0	32.8	5.36	> 4.55	> 25.0	> 4.51	32.8	8.?	0.9?	0.34
[illegible]	[illegible]	94.3 ([illegible])	101.3 (0.657)	101.5 (0.654)	103.4 (0.624)	105.6 (0.590)	6.0	4.76	19.9	33.7	4.76	3.82	19.9	3.96 (4.01)	33.7	8.0	0.98	0.34
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] (0.718)	[illegible]	104.6 (0.615)	8.0	3.91	20.6	34.5	3.86	3.04	25.0	3.20 (3.20)	34.6	7.0	1.0	0.47
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] (0.656)	8.0	3.15	14.1	34.1	3.02	2.47	24.4	2.52 (2.59)	33.5	7.0	0.9?	0.47
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.0	4.3?	25.2	34.5	4.30	3.29	25.2	3.54 (3.46)	34.5	7.?	0.9?	0.45
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	106.0 ([illegible])	8.0	3.85	19.9	33.1	3.81	3.34	25.0	3.22	32.2	7.0	0.97	[illegible]
[illegible]	[illegible]	[illegible]	[illegible] (0.791)	[illegible] (0.795)	95.1 ([illegible])	[illegible] (0.707)	8.0	5.33	21.8	33.7	5.32	4.47	25.0	4.47	32.9	7.0	0.97	0.47
[illegible]	[illegible]	[illegible] (44.5)	[illegible]	[illegible] (0.714)	[illegible]	103.? (0.642)	12.0	8.44	14.6	34.8	8.32	[illegible]	16.4	6.86	34.2	7.0	0.94	0.47
[illegible]	[illegible]	[illegible]	[illegible]	101.5 ([illegible])	[illegible]	[illegible] (0.589)	12.0	7.56	17.9	33.6	7.51	[illegible]	19.8	6.31 (6.66)	[illegible]	7.0	1.0	0.47
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	103.4 (0.625)	12.0	4.31	19.9	33.8	4.12	3.51	24.4	3.47 (3.69)	[illegible]	7.0	1.0	0.48
[illegible]	[illegible] #14	[illegible]	[illegible]	97.4 ([illegible])	[illegible]	102.7 (0.655)	12.0	5.43	24.4	31.6	5.23	5.07	32.0	4.68 (5.33)	31.3	4.0	0.95	0.36

[illegible]

[illegible]

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September 2, 1987

TABLE 5 – $\bar{R}$ TESTS ON UNDISTURBED SPECIMENS
Lower San Fernando Dam

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Effective Consolidation Stress $\bar{\sigma}_{3c} = \bar{\sigma}_1$ kg/cm²	At Peak: Shear Stress q_p (3) kg/cm²	At Peak: Axial Strain ϵ_p %	At Peak: Friction Angle φ_p deg	At Steady State: Shear Stress q_s (3) kg/cm²	At Steady State: Effective Minor Principal Stress $\bar{\sigma}_{3s}$ kg/cm²	At Steady State: Axial Strain ϵ_s %	At Steady State: Shear Strength S_{us} (4) kg/cm²	At Steady State: Friction Angle φ_s deg	Back Pressure u_c kg/cm²	Pore Pressure Coefficient B_c (5)	Axial Strain Rate %/min
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.0	4.66	19.6	32.9	4.64	3.93	21.5	3.90 (4.13)	32.8	5.0	0.96	0.36
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.0	[illegible]	11.6	33.3	4.09	3.36	11.6	3.42 (3.53)	33.3	6.0	0.96	0.47
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.0	5.56	19.4	33.2	5.49	4.68	25.0	4.55 (4.92)	32.7	7.0	0.95	0.48
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.86	18.6	32.0	4.81	4.34	23.9	4.09 (4.56)	31.7	6.0	0.98	0.11
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.0	8.43	25.0	34.0	8.43	6.64	25.0	6.99 (6.98)	34.0	13.0	0.96	0.45
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.0	5.94	16.4	34.4	5.92	4.65	20.1	4.90 (4.89)	34.1	7.0	0.94	0.47
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.0	7.28	22.4	34.2	7.22	5.86	27.4	6.02 (6.16)	33.5	5.0	0.97	0.76
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.0	6.45	21.5	34.1	6.37	5.14	24.4	5.40 (5.40)	33.6	5.0	0.97	0.75
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.0	> 9.93	> 6.2	> 37.7	> 9.91	> 6.30	> 6.23	> 7.84	–	7.0	0.99	0.75
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.0	6.24	22.7	33.2	6.11	5.30	25.0	5.16	32.4	8.0	0.95	0.75
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.0	12.56	[illegible]	36.0	12.13	9.11	24.3	9.96	34.8	8.0	0.95	0.68

Notes:

(1) Elevation datum is NGVD.
(2) Void ratio prior to correction due to swell at base of exploration shaft.
(3) Shear stress on the 45° plane
(4) S_{us} = undrained steady state shear strength = $q_s \cos \varphi_s$ based on measured q_s and φ_s. Values in parentheses equal 1.051 $\bar{\sigma}_{3s}$ derived from the geometry of the Mohr's circle and steady state friction angle of 34° measured for Batch Mix 7 from Zone 5 of the hydraulic fill shell.
(5) B_c is the B-value of the specimen after back pressure saturation.

[illegible]

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September 2, 1987

TABLE F4 - $\overline{R}$ AND S TESTS ON BATCH MIX 7
ISOTROPIC CONSOLIDATION
Lower San Fernando Dam

Test No.	Dry Unit Weight [illegible]	[illegible]	[illegible]	Effective Consolidation Stress $\overline{\sigma}_{1c}$ $\overline{\sigma}_{3c}$ (kg/cm²)	At Peak: Shear Stress q_p (1) (kg/cm²)	At Peak: Axial Strain ϵ_p (%)	At Peak: Friction Angle ϕ_p (deg)	At Steady State: Shear Stress q_s (1) (kg/cm²)	At Steady State: Effective Minor Principal Stress $\overline{\sigma}_{3s}$ (σ_{ts}) (2) (kg/cm²)	At Steady State: Axial Strain ϵ_s (%)	At Steady State: Shear Strength S_{us} (3) (kg/cm²)	At Steady State: Friction Angle ϕ_s (deg)	Back Pressure u_o (kg/cm²)	Pore Pressure Coefficient B (4)	Axial Strain Rate (%/min)
[illegible]	[illegible]	[illegible]	[illegible]	12.[illegible]	4.35	24.7	35.1	4.35	3.22 (5.02)	[illegible]	3.55 (3.38)	35.1 (3.39)	6.0	0.96	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	2.0	1.24	25.4	34.9	1.24	0.93 (1.45)	25.[illegible]	1.22 (0.98)	34.9 (0.98)	11.0	0.98	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.91	[illegible]	19.4	0.68	0.57 (0.89)	8.2	0.58 ([illegible])	32.2 ([illegible])	16.0	0.94	[illegible]
[illegible]	[illegible]	[illegible]	111.	6.[illegible]	> 3.48	> 25.2	33.5	> 3.48	> 2.82 (54.40)	> 25.2	> 2.90 (52.96)	33.5	13.0	0.93	0.073
[illegible]	[illegible]	[illegible]	[illegible]	2.[illegible]	> 0.89	> 28.2	35.7	> 0.89	> 0.63 (50.98)	> 28.2	> 0.51 (50.66)	35.6	7.5	0.98	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	2.0	[illegible]	9.84	18.1	0.31	0.24 (0.37)	20.1	0.28 (0.25)	33.6	5.0	0.95	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	8.	1.71	[illegible]	18.3	1.42	1.26 (1.96)	10.9	1.12 (1.32)	33.9	[illegible]	0.97	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	32.	9.72	30.1	31.3	10.6	9.72 (15.23)	30.1	9.[illegible] ([illegible])	31.3	7.0	1.00	1.43
[illegible]	[illegible]	[illegible]	[illegible]	23.	5.6[illegible]	27.3	33.6	5.6	4.55 (7.09)	27.3	4.20 ([illegible])	27.3	9.0	0.97	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	12.0	[illegible]	26.8	33.5	3.29	2.62 (4.16)	26.8	2.74 ([illegible])	33.5	7.0	0.96	[illegible]

[illegible]

TABLE E4 – $\bar{R}$ AND S TESTS ON BATCH MIX 7
ISOTROPIC CONSOLIDATION
Lower San Fernando Dam

Test No.	Dry Unit Weight (Void Ratio) [illegible]	In Triaxial Cell: Initial Under Vacuum	In Triaxial Cell: End of Shear	Effective Consolidation Stress $\bar{\sigma}_{3c}$	At Peak: Shear Stress q_p (1)	At Peak: Axial Strain ϵ_p	At Peak: Friction Angle φ_p	At Steady State: Shear Stress q_s (1)	At Steady State: Effective Minor Principal Stress $\bar{\sigma}_{3s}$ ($\bar{\sigma}_{fs}$) (2)	At Steady State: Axial Strain ϵ_s	At Steady State: Shear Strength S_{ds} (9)	At Steady State: Friction Angle φ_s	Back Pressure	Pore Pressure Coefficient B_c (3)	Axial Strain Rate
	pcf	pcf	pcf	kg/cm²	kg/cm²	%	deg	kg/cm²	kg/cm²	%	kg/cm²	deg	kg/cm²		%/min
[illegible]	[illegible]	[illegible]	[illegible]	2.0	1.55	28.4	35.2	1.55	1.14 (7) (1.78)	28.4	1.27 (1.20)	35.0	7.0	0.97	0.5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.43	19.2	31.0	7.43	7.0 (8) (10.91)	19.2	6.37 (7.36)	31.0	6.0	0.97	0.5

[illegible]

- [illegible] specimens
- Lubricated end platens.

Notes:

(1) [illegible] on the 45° plane.

(2) [illegible] effective stress on the specimen failure plane based on φ_s = 34°.

(9) S_{ds} [illegible] steady state shear strength [illegible] $\cos \varphi_s$. Values in parentheses equal 1.051 $\bar{\sigma}_{fs}$, derived from the geometry of the Mohr's circle and φ_s = 34°.

(3) [illegible] is the B-value of the specimen after back pressure saturation.

[illegible]

[illegible]

(7) [illegible] to keep approximately constant effective stress on 34° plane.

(8) [illegible] to keep approximately constant effective stress on 34° plane [illegible], then readjusted to $\bar{\sigma}_3$ = 7.0 kg/cm².

(9) [illegible] steady state shear strength [illegible]. Values in parentheses equal 1.051 $\bar{\sigma}_{fs}$, derived from the geometry of the Mohr's circle and φ_s = 34°.

[illegible]

ANISOTROPIC CONSOLIDATION

Lower San Fernando Dam

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	At Peak: Shear Stress, (2) kg/cm²	At Peak: Axial Strain, %	At Steady State: Shear Stress, (2) kg/cm²	At Steady State: Effective Minor Principal Stress, $\bar{\sigma}_{3s}$ ($\bar{\sigma}_{fs}$) kg/cm²	At Steady State: Axial Strain, ϵ_s %	At Steady State: Shear Strength, S_{us} (3) kg/cm²	At Steady State: Friction Angle, ϕ_s deg	Back Pressure kg/cm²	Pore Pressure Coefficient (5)	Maximum Axial Strain Rate %/min.	$\frac{S_{us}}{q_c \cos\phi_s}$ (8)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(6)	-	0.72(4)	-	[illegible]	0.92	[illegible]	[illegible]
[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.70 (1.09)	15.0	0.80 (0.74)	35.6	4.50	[illegible]	48	0.89
[illegible]	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(6)	-	0.28(4)	-	[illegible]	[illegible]	[illegible]	0.69
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(6)	-	0.25(4)	-	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.29 (0.45)	18.0	0.28 (0.30)	33.5	[illegible]	[illegible]	[illegible]	0.73
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(6)	-	0.44(4)	-	[illegible]	[illegible]	[illegible]	1.14
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.64	[illegible]	[illegible]	0.41 (0.62)	25.0	0.49 (0.42)	[illegible]	[illegible]	[illegible]	34	[illegible]
[illegible]	-	[illegible]	[illegible]	[illegible]	.63	0.18	0.53	0.41 (0.64)	[illegible]	0.44 (0.43)	34.5	[illegible]	[illegible]	[illegible]	1.04
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.13	0.30	0.24 (0.37)	24.0	0.25 (0.25)	33.7	2.50	[illegible]	[illegible]	[illegible]

[illegible]

(1) [illegible]

(2) [illegible] ... derived from the geometry of the [illegible]

(3) [illegible] steady state ... strength ... void ratio ... and steady state [illegible]

(6) Sample did not reach steady state condition.

(7) Upper 1 cm of specimen accidentally densified during setup; void ratio presented is average for specimen and is higher than void ratio in shear zone of specimen.

(8) $q_c\cos\phi_s$ = driving shear stress on specimen failure plane, ϕ_s = 34°.

Project 85654
January 15, 1988

TABLE [illegible] – [illegible]R TESTS ON BATCH MIX 7

Lower San Fernando Dam

Test No.	Void Ratio at [illegible]	Effective Consolidation Pressure	[illegible] Initial Shear Stress (1)	Maximum Applied Cyclic Load (2)	Maximum Applied Stress (3)	Maximum [illegible] Load Resisted by Cell (3)	Maximum Cell Stress (3)	Number of Load Cycles Applied	Effective Minor Principal Stress at End of Cyclic Loading (4) $\bar{\sigma}_{3c}$	Accumulated Axial Strain at [illegible] of Cyclic Loading (4) ϵ_{ac}	Time from End of Cyclic Loading to Start of Rapid Failure (5)	Axial Strain at Start of Rapid Failure (5) ϵ_{rf}	Effective Minor Principal Stress at Start of Rapid Failure (5) $\bar{\sigma}_{3rf}$	Effective Minor Principal Stress at 20% Axial Strain (6)	Undrained Steady State Shear Strength (7) S_{us}	$\frac{S_{us}}{q_c \cos\varphi_s}$
		kg/cm²	kg/cm²	kg	kg/cm²	kg	kg/cm²		kg/cm²	%	min	%	kg/cm²	kg/cm²	kg/cm²	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	-	19.7	(10)	0.77	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.42	8.11	(11)	(11)	(11)	[illegible]	0.33	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	107	0.56	16.5	(9)	(9)	(9)	-	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.23	19	0.52	1.85	0.07	2.31	0.46	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.85	5	0.43	5.74	(11)	(11)	(11)	[illegible]	[illegible]	0.64
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.76	5	[illegible]	1.26	0.07	1.85	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]															
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.74	5	[illegible]	[illegible]	42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.75	0.47	6.3	1.35	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

(8) ϵ_a not measured during this test.

(9) Rapid failure did not occur during this test.

(10) Sample strained from 0.25% to 19.7% during third [illegible] cycle. Loads applied with air piston.

(11) Rapid failure began during cyclic loading; [illegible] was [illegible] after start of rapid failure.

(12) Loads applied with air piston system in this test, [illegible] not measured.

Project 85667

September 2, 1987

[illegible] – [illegible] OF VOLUMETRIC STRAINS
AFTER UNDRAINED CYCLIC LOADING
CRR TESTS 1 THROUGH 5
Lower San Fernando Dam

[illegible]	[illegible]	[illegible]	Effective Consolidation Stress		e_c[1]	No. of Load Cycles Applied[2]	Maximum Cyclic Strain (3)	Cumulative Axial Strain After Cyclic Loading	Δe[4]	ΔV[5]/V
		[illegible]	$\bar{\sigma}_{1c}$	$\bar{\sigma}_{3c}$						
		[illegible]	kg/cm²	kg/cm²			%	%		%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.648	[illegible].5	3.07	3.[illegible]	0.0[illegible]	2.91
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.6[illegible]	3.5	3.[illegible]	3.[illegible]	[illegible]	2.36
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.5[illegible]	[illegible].5	2.98	3.6	[illegible]	1.74
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.[illegible]	3.5	3.05	3.6	[illegible]	2.11
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11.5	2.86	3.6	0.038	2.52

[illegible]

[illegible] ... specimens, [illegible] end platens.

[illegible] ... refer to sections of the tube, [illegible]

[illegible] ... loading.

[illegible] ... After cycling, sample came to rest [illegible] ... the sample.

[illegible] ... equal to one half of measured [illegible]

[illegible] ... completion of [illegible]

Project 8[illegible]
September [illegible], 1987

TABLE F8 - DESCRIPTION OF TRIAXIAL TEST SPECIMENS - UNDISTURBED SAMPLES
Lower San Fernando Dam

Triaxial Test No.	Boring No. or Exploration Shaft(ES)	Sample No.	Sample Length After Testing cm	Sample Descriptions		Remarks
$\overline{R}1$	ES	TS302	13.0	Stratified silty fine sand, fine sandy silt, and silt. Layers typically 0.5 to 2 mm thick, >50 layers.		
$\overline{R}2$	ES	TS203	12.5	Top 5 cm:	Stratified silty fine sand.	Specimen bulged at Clayey Silt. Grain size analyses performed on a) 1.5 cm silt portion and b) 2 cm fine sand portion.
				Next 1.5 cm:	Clayey Silt.	
				Next 2 cm:	Predominantly fine sand.	
				Bot. 4 cm:	Stratified silty fine sand and fine sandy silt.	
$\overline{R}3$	ES	TS116	12.5	Top 3 cm:	Sand, widely graded.	Grain size analyses on Bot. 9.5 cm.
				Bot. 9.5 cm:	Stratified fine sand, silty fine sand, and fine sandy silt. Some sandy layers contain occasional coarse-medium sand particles. Layers typically 0.5 to 2 mm thick, >50 layers.	
$\overline{R}4$	ES	TS1C2	11.0	Top 9 cm:	Stratified very fine sand and silty fine sand. Layers typically <1 mm thick, >50 layers.	Grain size analyses on Top 9 cm.
				Bot. 2 cm:	Silt.	

TABLE F8 - DESCRIPTION OF TRIAXIAL TEST SPECIMENS - UNDISTURBED SAMPLES
Lower San Fernando Dam

Triaxial Test No.	Boring No. or Exploration Shaft(ES)	Sample No. *	Sample Length After Testing cm	Sample Descriptions	Remarks
$\overline{R}5$	U111A	UF19C	11.5	Stratified very fine sand, silty fine sand, and fine sandy silt. Top 7 cm is intensely stratified. Middle 2 cm contains silt lenses and occasional coarse-medium sand. Bottom 5 cm contains occasional fine gravel, coarse-medium sand, and is less stratified.	
$\overline{R}6$	ES	TS309A	8.3	Stratified fine sand, silty fine sand, and fine silt. Occasional medium sand. Middle 3 cm is predominantly silty fine sand.	
$\overline{R}7$	ES	TS306B	8.5	Top 7 cm: Stratified fine sand, silty fine sand, and fine sandy silt. Layers typically <0.5 mm thick, >50 layers. Bot. 1.5 cm: Silt.	Grain size analyses on Top 7 cm.
$\overline{R}8$	U103	UF3C	8.9	Silty fine sand to sandy silt. Two 5 mm thick layers of fine sand at top. Numerous 0.5 to 1 mm laminae of very fine sand.	
$\overline{R}9$	U105	UF10C	8.3	Clayey, sandy silt. Sand is fine grained. Several lenses of fine sand up to about 5 mm in diameter.	Grain size analyses on Top 8 cm.

TABLE F8 - DESCRIPTION OF TRIAXIAL TEST SPECIMENS - UNDISTURBED SAMPLES
Lower San Fernando Dam

Triaxial Test No.	Boring No. or Exploration Shaft (ES)	Sample No.	Sample Length After Testing cm	Sample Descriptions	Remarks
R10	ES	TS207A	9.0	Top 8 cm: Silty, fine sand with several laminae of siltier sand about 2 cm from top. Bot. 1 cm: Silt.	Grain size analyses on Top 8 cm.
R11	ES	TS103	9.5	Silty fine to medium sand. Mostly fine sand. Occasional pieces of fine gravel and coarse sand. Sand is subangular.	
R12	ES	TS315	9.0	Stratified silt, fine sandy silt, silty fine sand, and fine sand. Layers typically 0.5 to 2 mm thick, >50 layers.	
R13	ES	TS314	8.0	Stratified silt and fine sandy silt. Numerous 0.5 to 2 mm thick laminae of very fine sand. Estimate >50 layers.	
R14	U111A	UF14D	7.2	Stratified fine sand, silty fine sand, sandy silt, and silt. Sandier layers predominate in top 2 cm. Swirl patterns evident in bottom 6 cm.	Grain size analyses on bottom 6 cm.
R15	U111A	UF16D	8.2	Stratified fine sand, silty fine sand, sandy silt, and silt. Occasional coarse-medium sand particle. Layers typically 0.5 to 2 mm thick, >50 layers.	

AD-A214 749   RE-EVALUATION OF THE LOWER SAN FERNANDO DAM REPORT 1 AN   3/4
INVESTIGATION OF T..(U) GEI CONSULTANTS INC WINCHESTER
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UNCLASSIFIED   F/G 13/2   NL

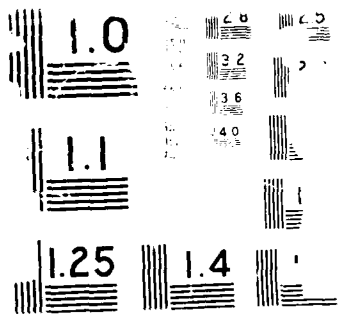
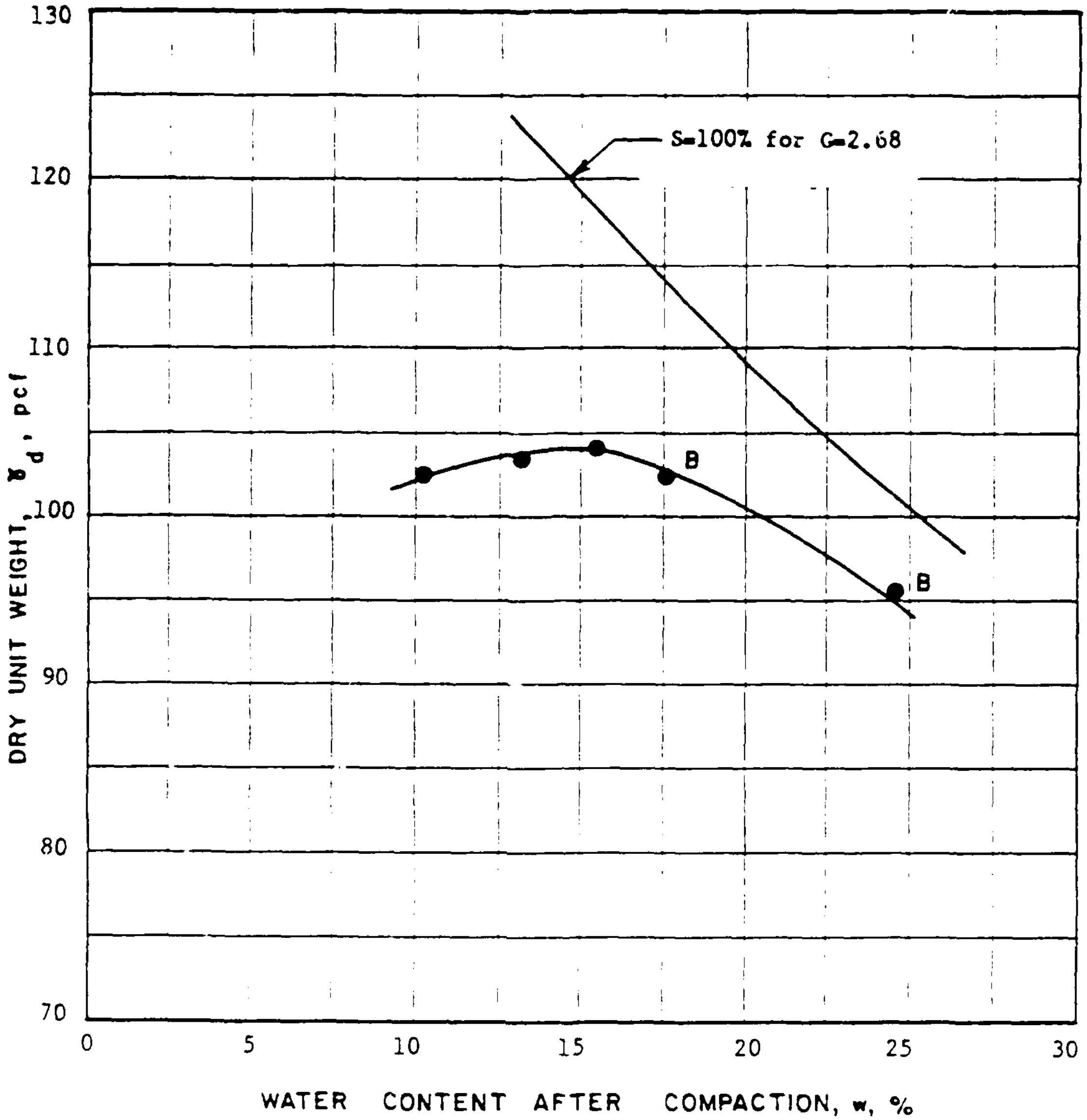

1.0
1.1
1.25
1.4
3.2
3.6
4.0

TABLE F8 - DESCRIPTION OF TRIAXIAL TEST SPECIMENS - UNDISTURBED SAMPLES
Lower San Fernando Dam

Triaxial Test No.	Boring No. or Exploration Shaft(ES)	Sample No.	Sample Length After Testing cm	Sample Descriptions	Remarks
$\overline{R}$16	U111A	UF20D	7.2	Silty fine sand. Occasional lenses of silt. Occasional medium sand particle. Relatively little stratification.	
$\overline{R}$17	U111A	UF21A	7.7	Fine sandy silt at top grading to silty fine sand at bottom. Top contains inclusions of silt about 1 to 1.5 cm in size. Faint stratification evident.	Grain size analyses did not include silt inclusions.
$\overline{R}$18	U111	UF23B	7.5	Top 2.5 cm: Stratified silty fine sand. Mid. 2.5 cm: Stratified clayey silt. Bot. 2.5 cm: Intensely stratified silty fine sand and sandy silt.	Grain size analyses on Mid. 2.5 cm.
$\overline{R}$19	U103	UF3B	8.6	Silty fine sand. Top 2 cm contains medium sand and occasional coarse sand. Relatively little stratification.	
$\overline{R}$20	U111A	UF19A	8.5	Silty fine sand. Occasional coarse-medium sand. Faint stratification.	
$C\overline{RR}$1	ES	TS309B	6.0	Top 2 cm: Stratified silty sand and sandy silt. Layers typically 0.5 mm thick. Mid. 2 cm: Predominantly silty sand. Bot. 2 cm: Predominantly sandy silt.	

TABLE F8 - DESCRIPTION OF TRIAXIAL TEST SPECIMENS - UNDISTURBED SAMPLES
Lower San Fernando Dam

Triaxial Test No.	Boring No. or Exploration Shaft(ES)	Sample No.	Sample Length After Testing cm	Sample Descriptions	Remarks
CRR2	ES	TS306A	7.3	Stratified silty fine sand and fine sandy silt. Mostly silty sand, several very fine sand laminae. Layers typically 0.5 to 2 mm thick.	
CRR3	ES	TS112	8.6	Sand, widely graded. Mostly fine sand. About 8% silt.	
CRR4	U111A	UF9B	8.0	Top 2 cm: Silt to Clayey Silt. Occasional fine sand laminae. Two clay laminae <0.5 mm thick. Bot. 6 cm: Stratified silty fine sand and fine sandy silt.	Specimen failed in top portion. Grain size analyses on Top 2 cm.
CRR5	U111	UF8B	8.7	Sand, widely graded. Mostly fine-medium sand. About 11% silt.	



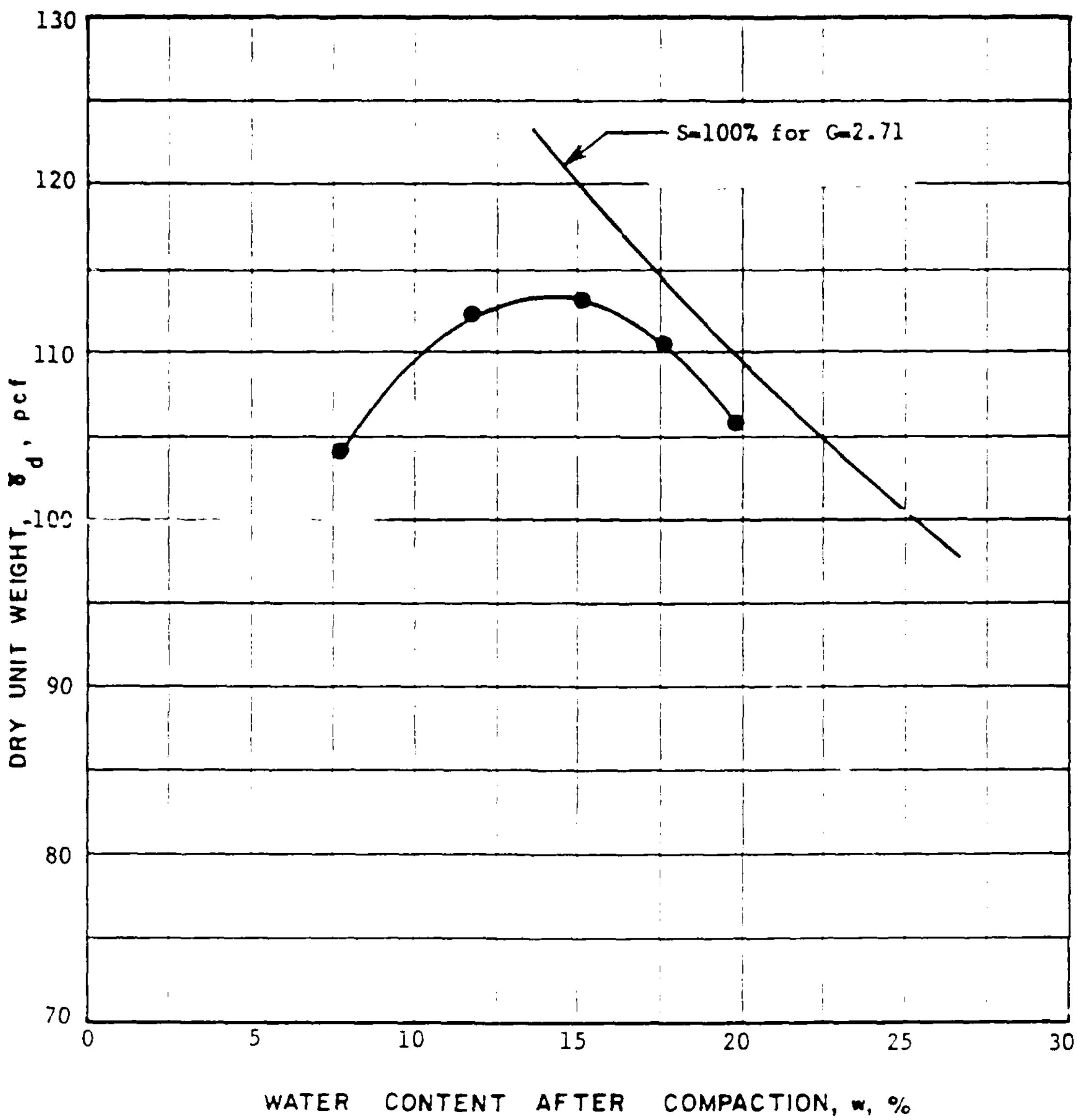
SOURCE OF SOIL: Exploratory Shaft

SOIL DESCRIPTION: Batch Mix 1; Bag Samples BS102, BS103, BS104; Silty Sand (SM)

COMPACTION PROCEDURE: ASTM D1557-78, Method A

NOTE: "B" indicates bleeding of water from base of compaction mold during compaction.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	COMPACTION CURVE BATCH MIX 1
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Project 85669	Feb. 20, 1986 Fig. F1



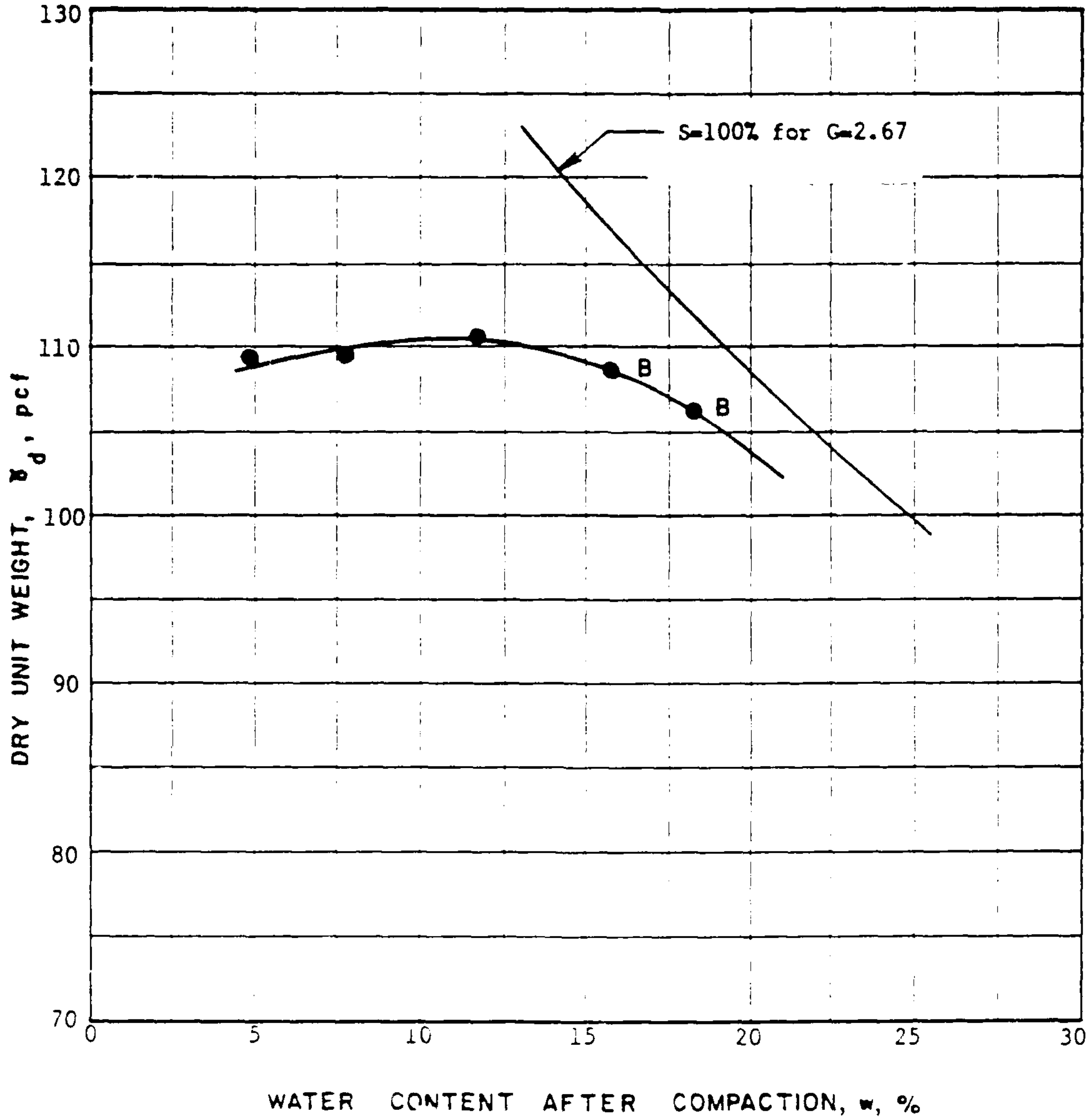
SOURCE OF SOIL : Exploratory Shaft

SOIL DESCRIPTION : Batch Mi... Bag Samples BS105, BS106, BS107;
SILT (ML-C...

COMPACTION PROCEDURE: ASTM D1557-78, Method A

NOTE: "B" indicates bleeding of water from base of compaction mold during compaction.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	COMPACTION CURVE BATCH MIX 2
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Feb. 20, 1986 Fig. F2



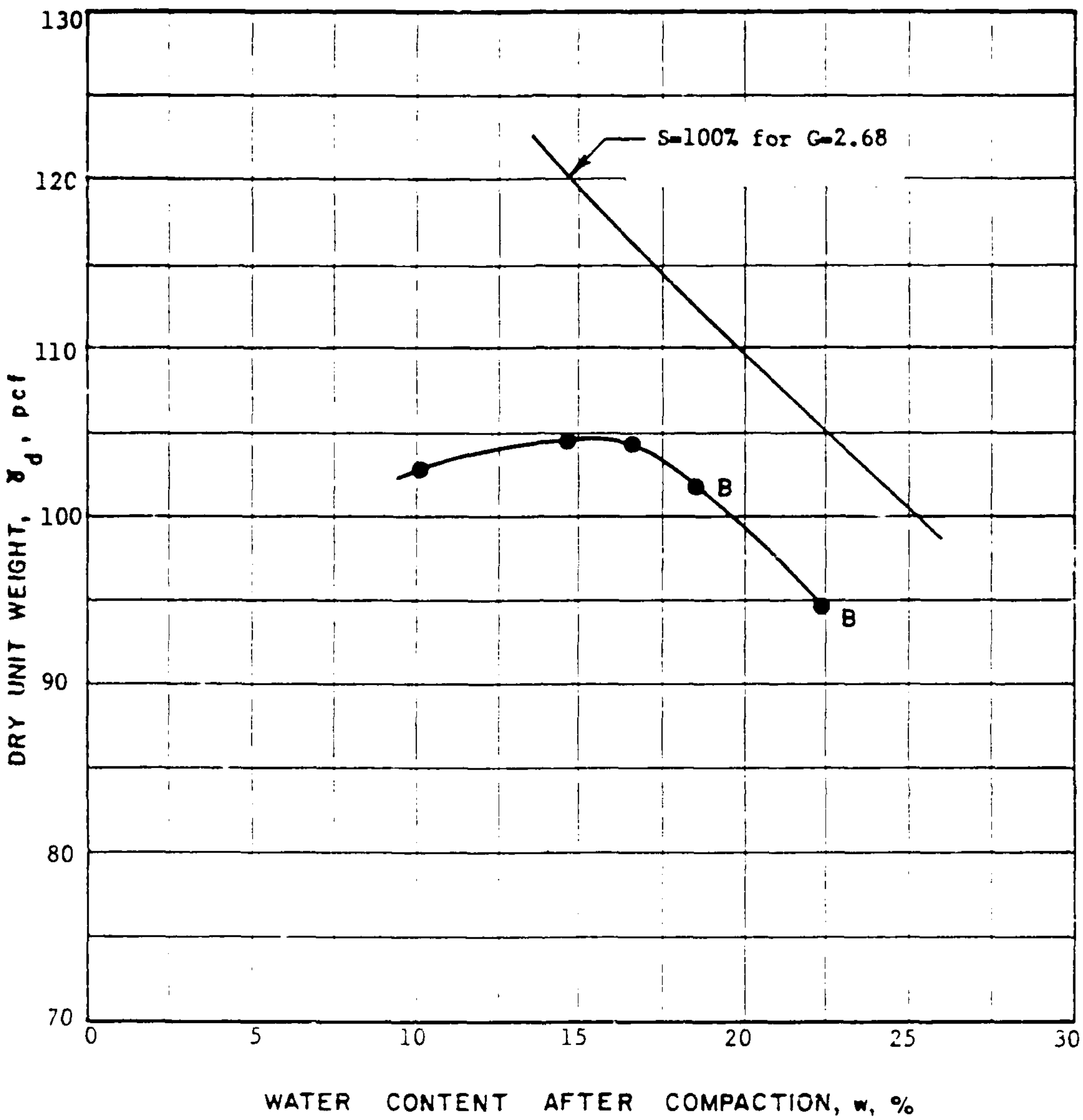
SOURCE OF SOIL : Exploratory Shaft

SOIL DESCRIPTION : Batch Mix 3; Bag Samples BS108, BS109, BS110; Sand and Silty Sand (SP-SM)

COMPACTION PROCEDURE : ASTM D1557-78, Method A

NOTE: "B" indicates bleeding of water from base of compaction mold during compaction.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	COMPACTION CURVE BATCH MIX 3
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Feb. 20, 1986 Fig. F3



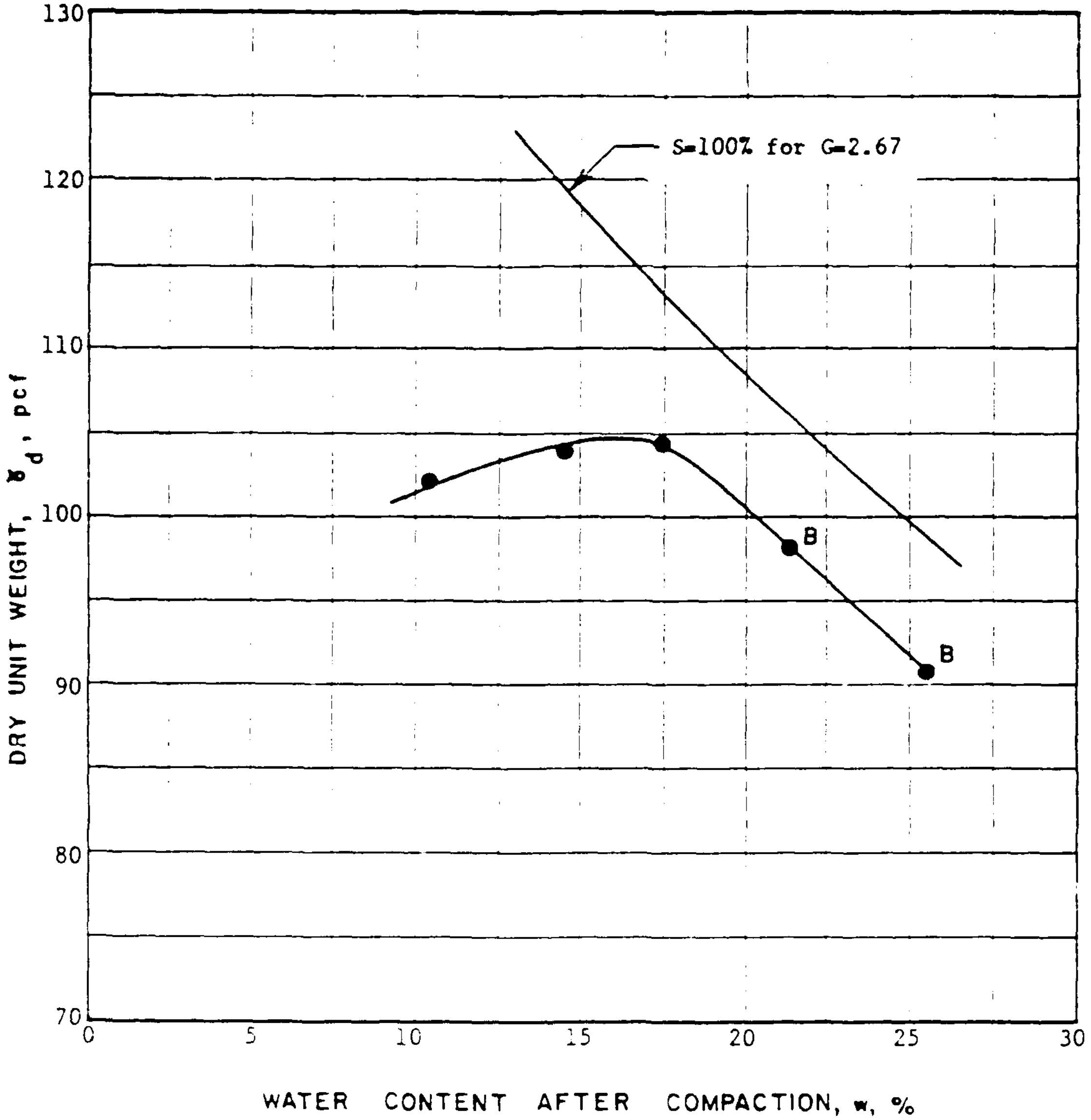
SOURCE OF SOIL: Exploratory Shaft

SOIL DESCRIPTION: Batch Mix 4; Bag Samples BS112, BS113, BS114; Silty Sand (SM)

COMPACTION PROCEDURE: ASTM D1557-78, Method A

NOTE: "B" indicates bleeding of water from base of compaction mold during compaction.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	COMPACTION CURVE BATCH MIX 4
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Project 85669	Feb. 20, 1986 Fig. F4



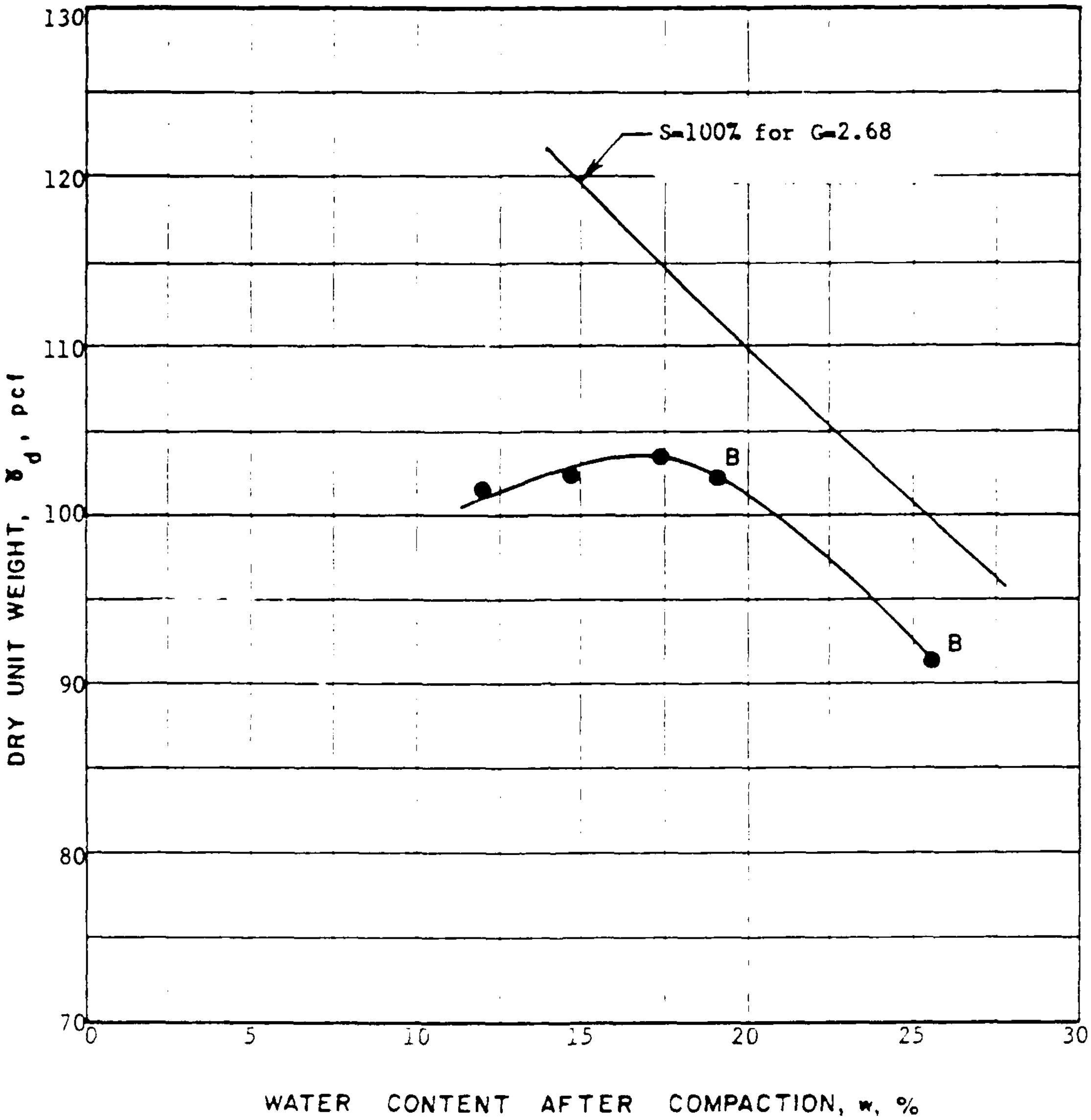
SOURCE OF SOIL : Exploratory Shaft

SOIL DESCRIPTION : Batch Mix 5; Bag Samples BS201 through BS205; Silty Sand (SM)

COMPACTION PROCEDURE : ASTM D1557-78, Method A

NOTE: "B" indicates bleeding of water from base of compaction mold during compaction.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	COMPACTION CURVE BATCH MIX 5
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Feb. 20, 1986 Fig. F5



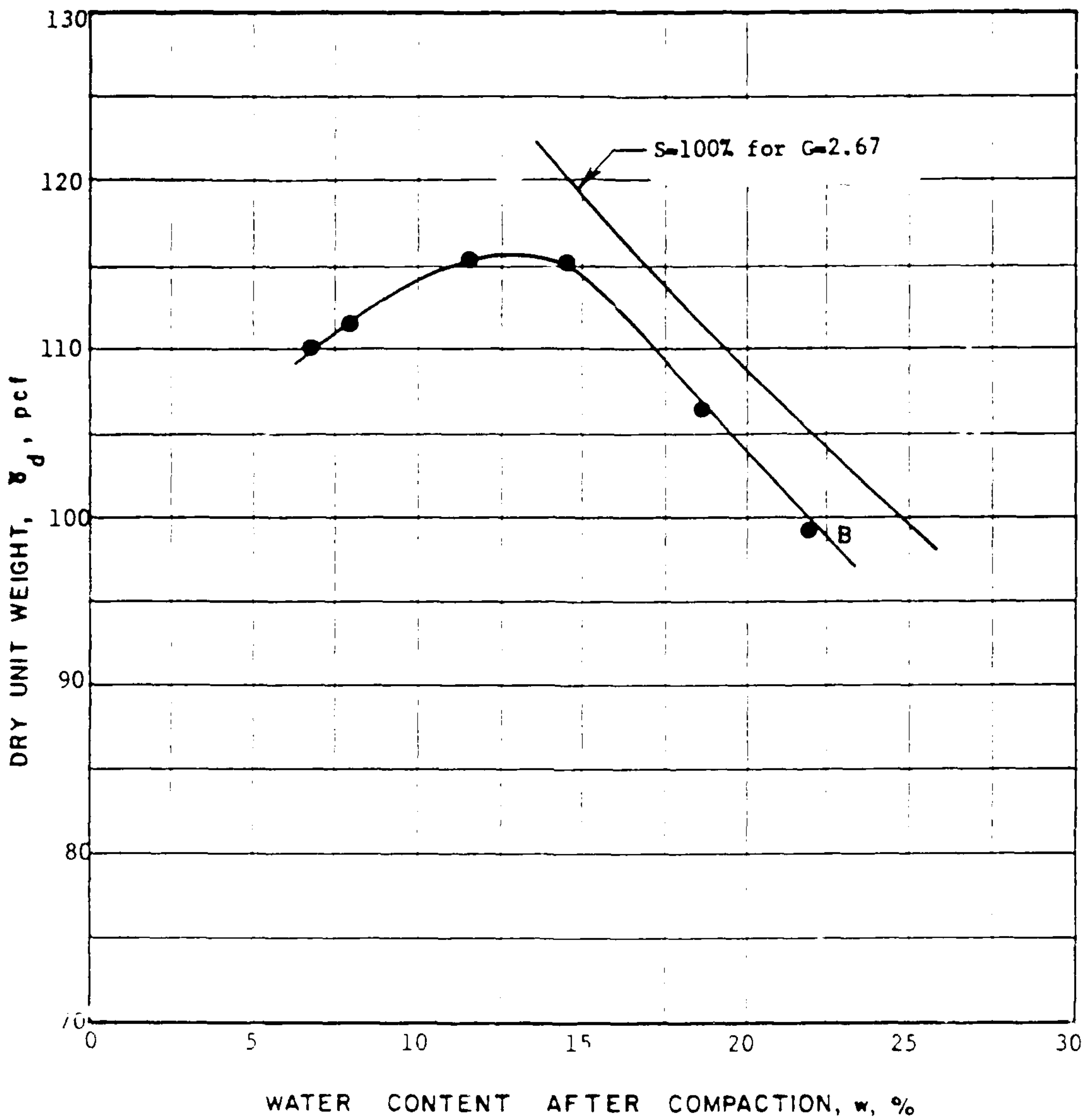
SOURCE OF SOIL: Exploratory Shaft

SOIL DESCRIPTION: Batch Mix 6; Bag Samples BS207 through BS210; Silty Sand (SM)

COMPACTION PROCEDURE: ASTM D1557-78, Method A

NOTE: "B" indicates bleeding of water from base of compaction mold during compaction.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	COMPACTION CURVE BATCH MIX 6
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Feb. 20, 1986 Fig. F6



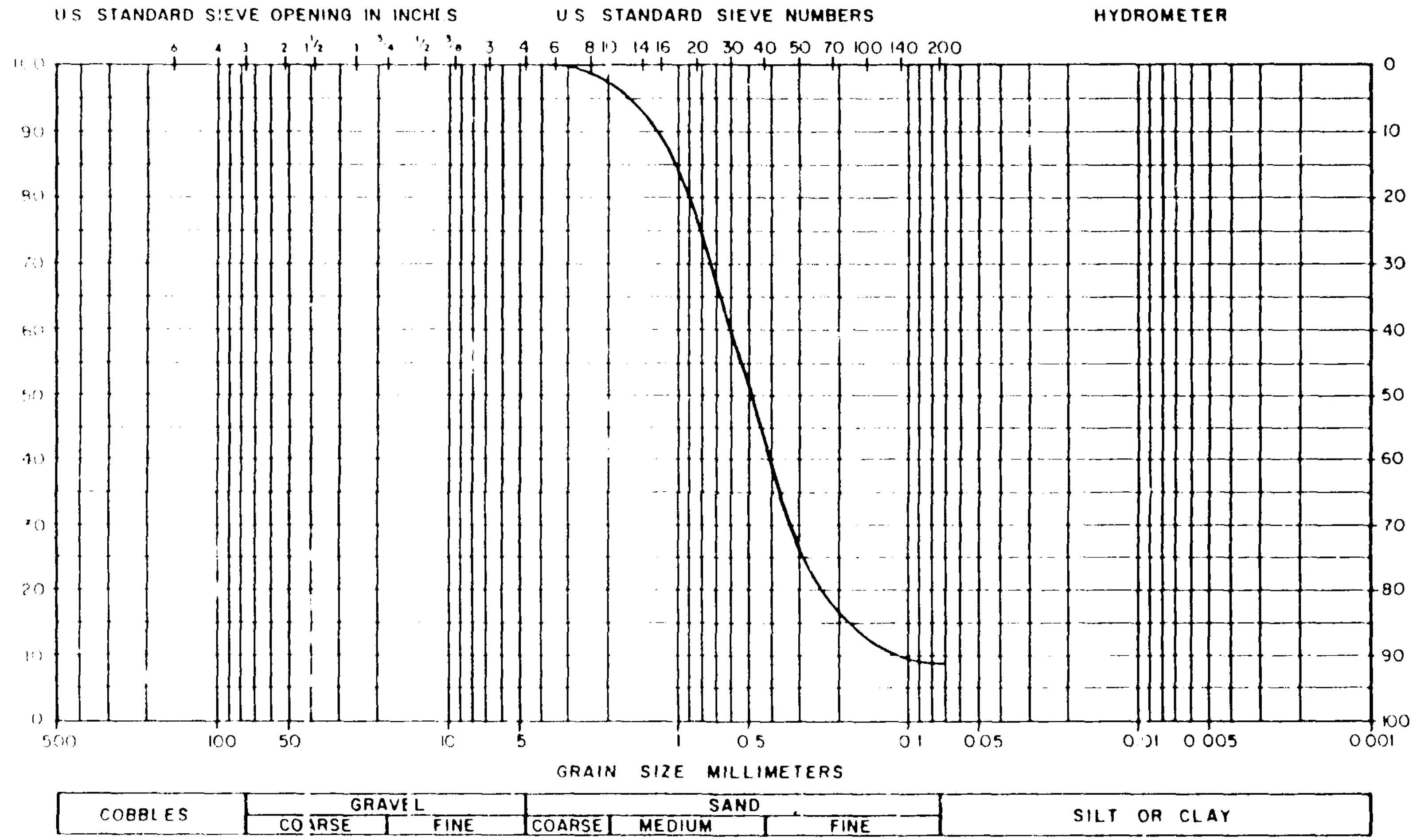
SOURCE OF SOIL: Exploratory Shaft

SOIL DESCRIPTION : Batch Mix 7; Bag Samples BS301, BS302, BS304, BS305, BS306, BS308, BS309, BS311; Sandy Silt (ML)

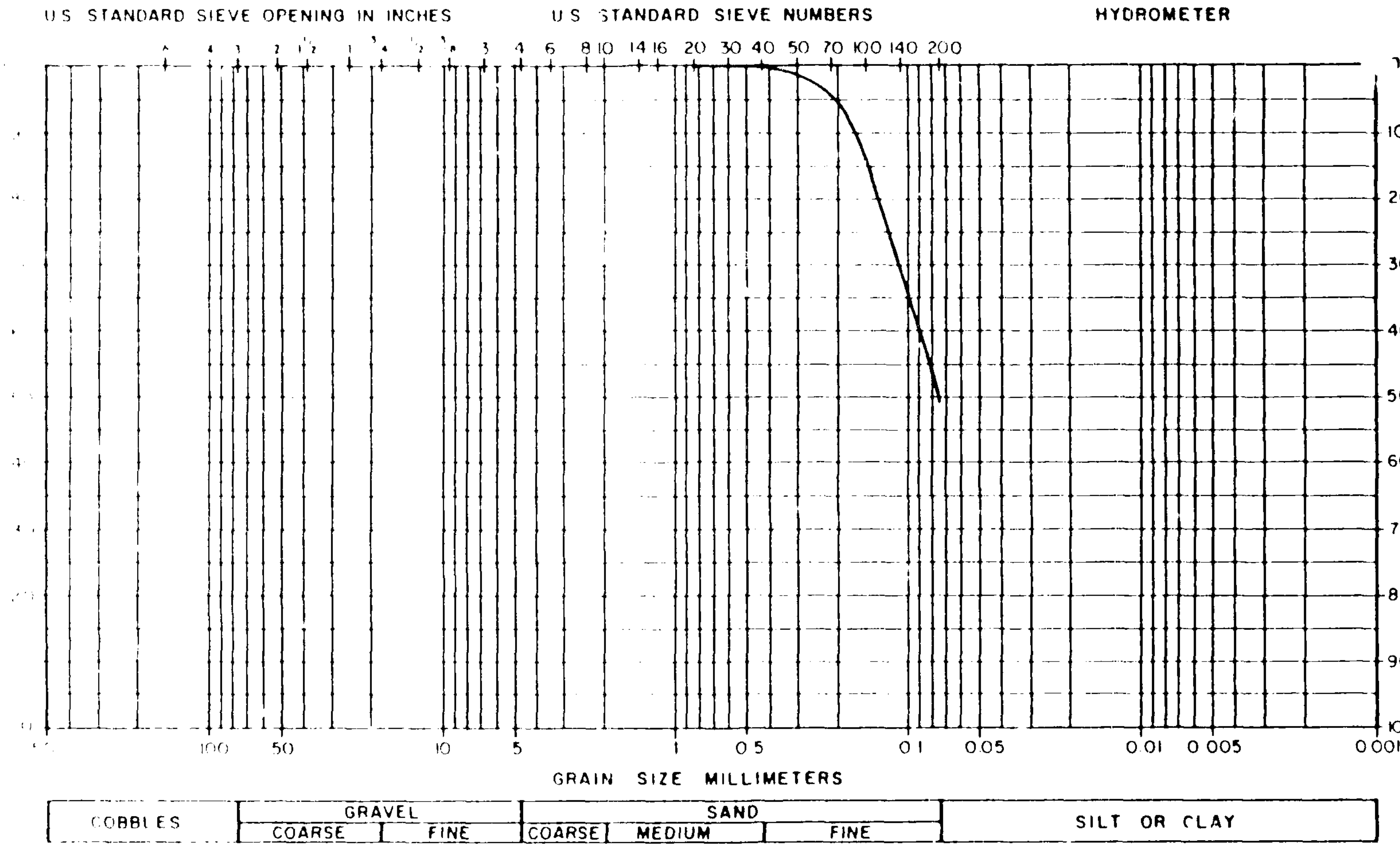
COMPACTION PROCEDURE : ASTM D1557-78, Method A

NOTE: "B" indicates bleeding of water from base of compaction mold during compaction.

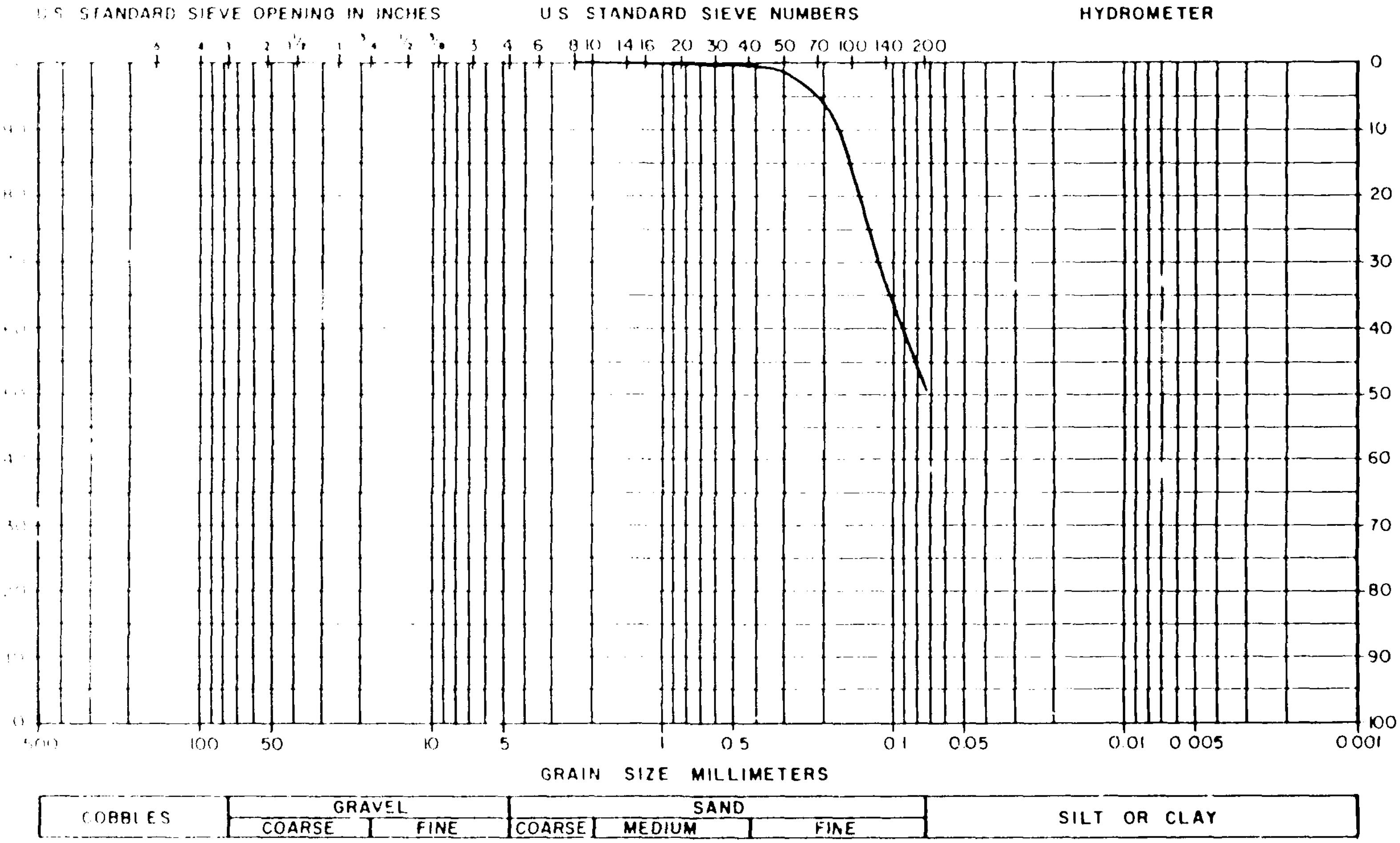
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	COMPACTION CURVE BATCH MIX 7
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Feb. 20, 1986 Fig. F7



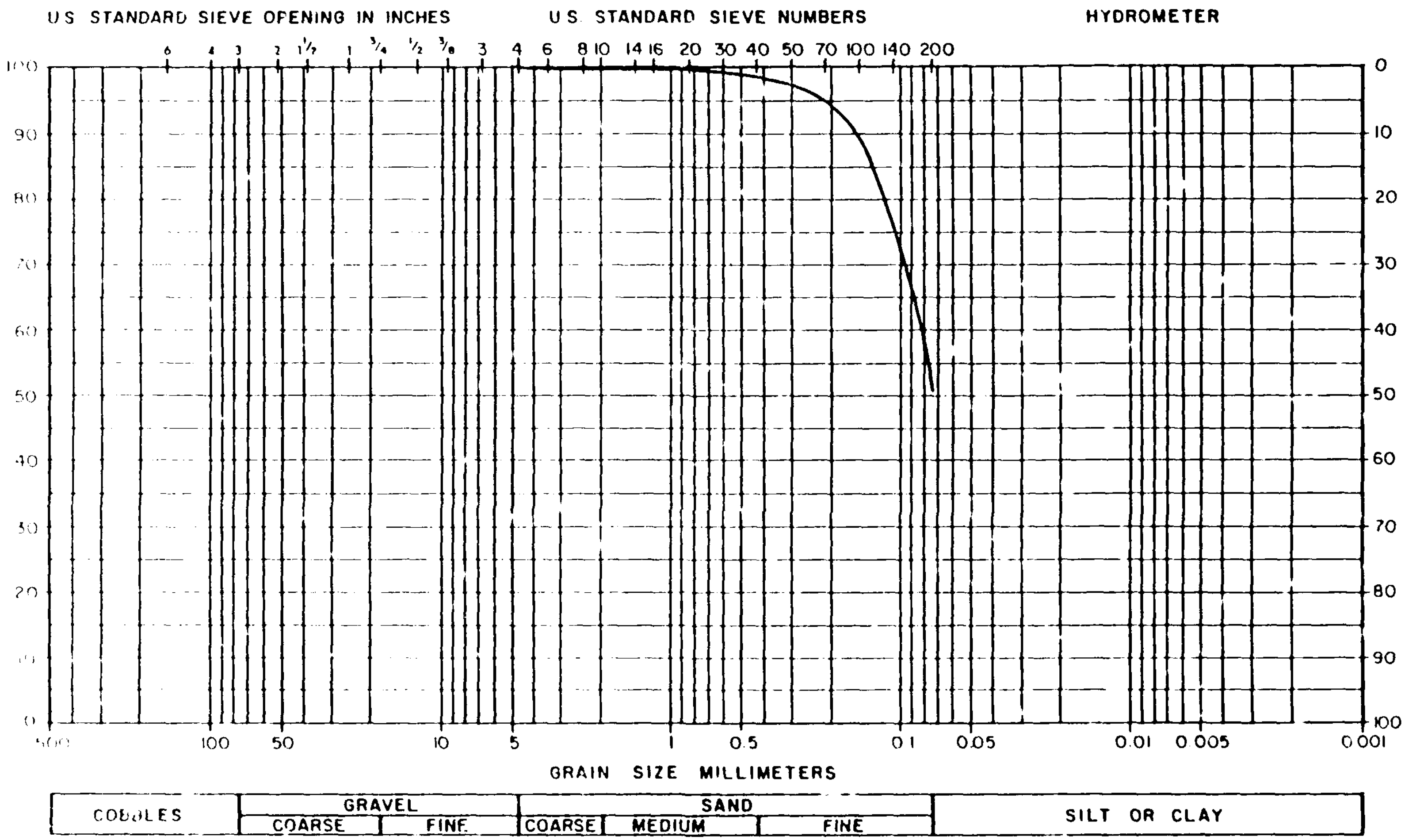
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING S101 SAMPLE S7
GEOTECHNICAL ENGINEERS INC	Project 85669	Sep. 2, 1987 Fig. F8



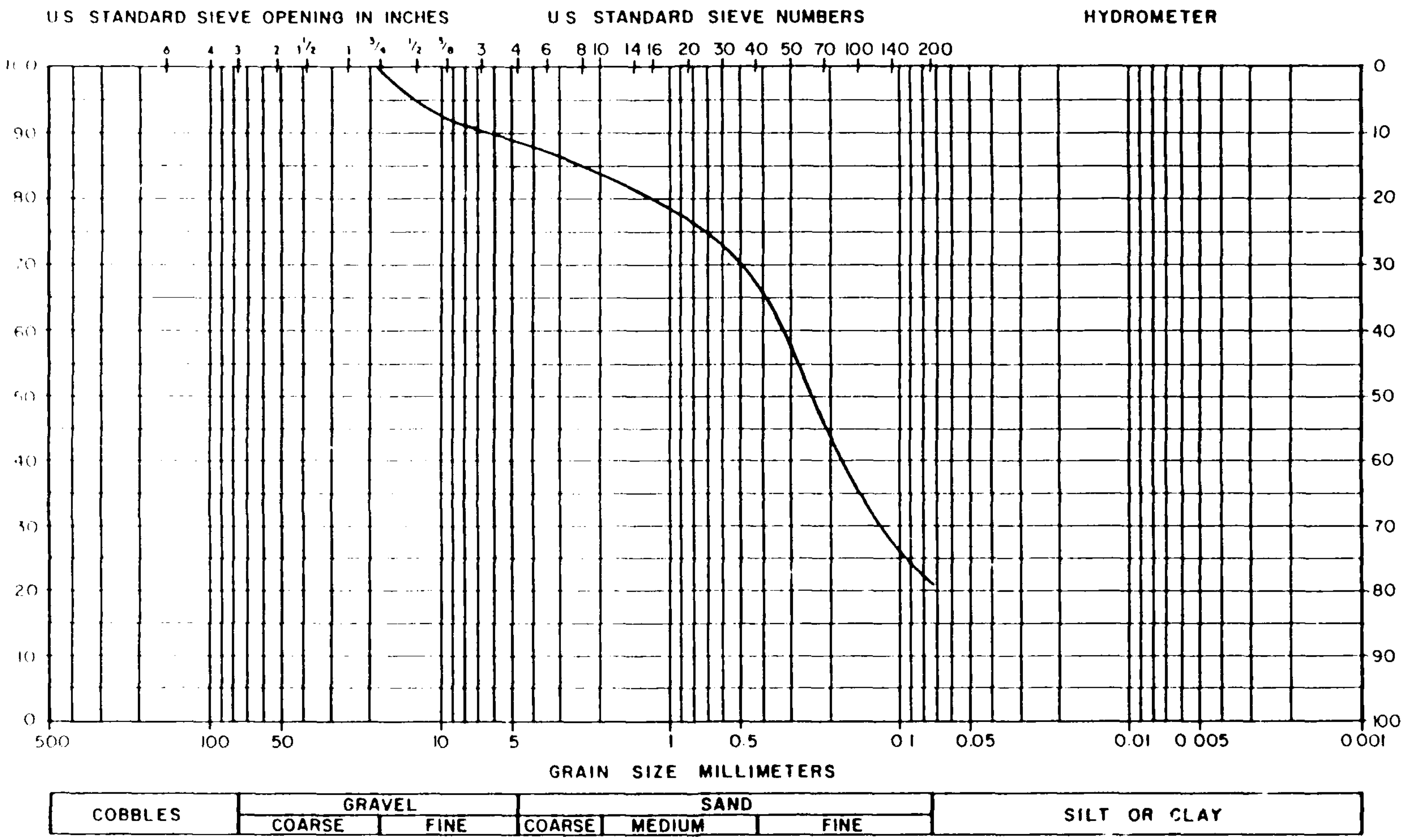
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING S101 SAMPLE S17 BOTTOM 13 INCHES
GEOTECHNICAL ENGINEERS INC	Project 85669	Sep. 2, 1987 Fig. F9



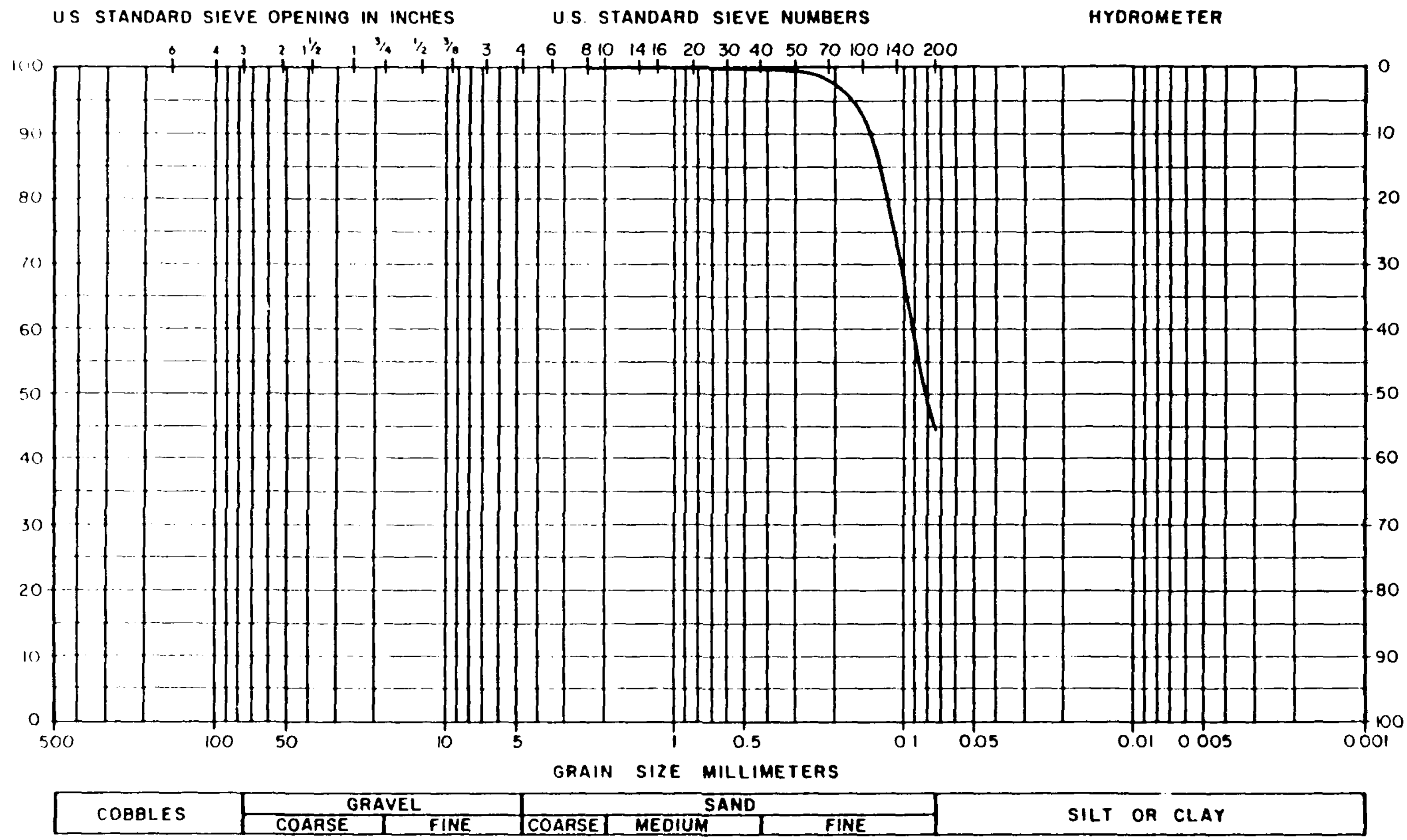
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING S102 SAMPLE S22 TOP 14 INCHES
GEOTECHNICAL ENGINEERS INC	Project 85669	Sep. 2, 1987 Fig. F10



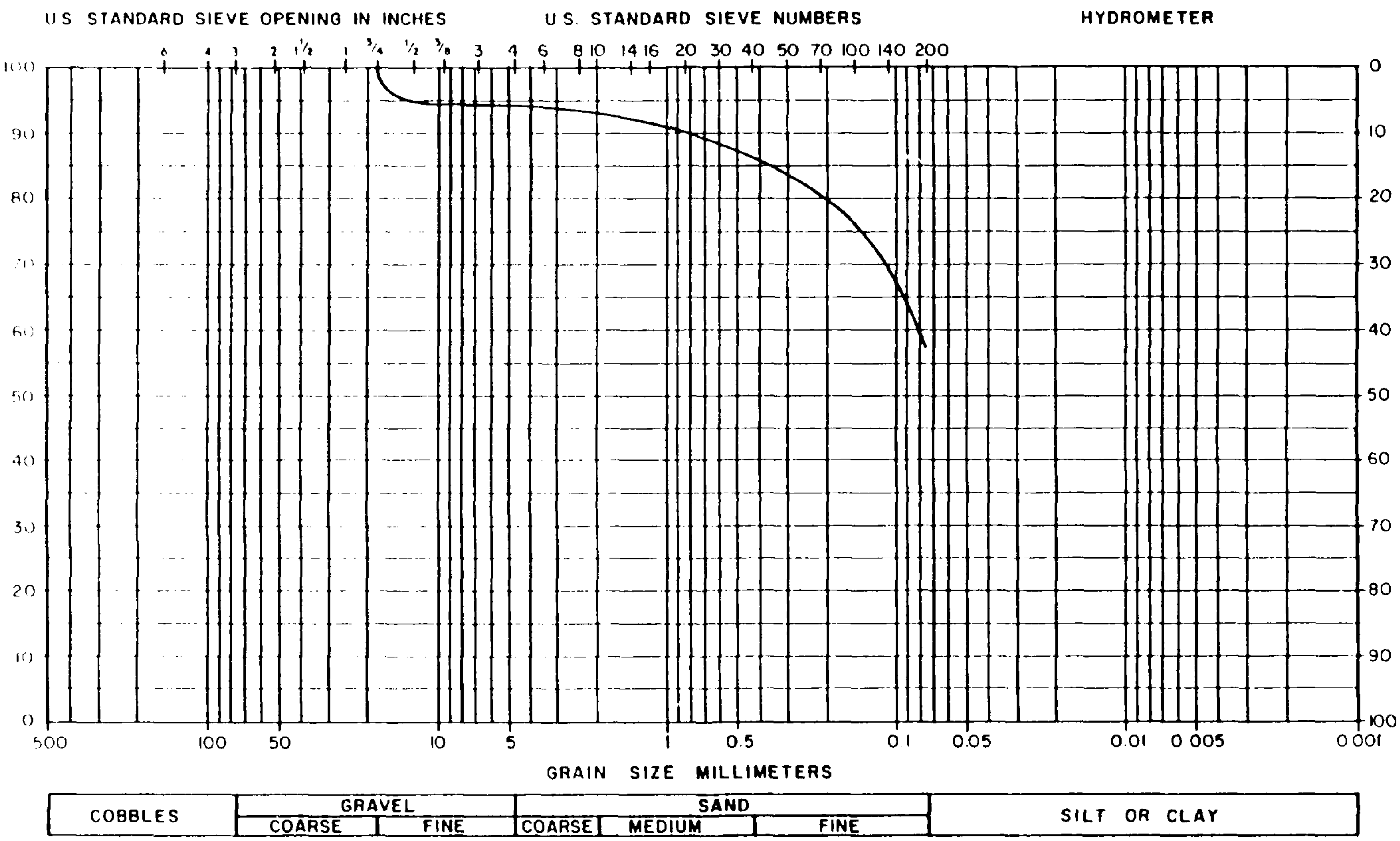
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING S103 SAMPLE S18 MIDDLE 5 INCHES
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. F11



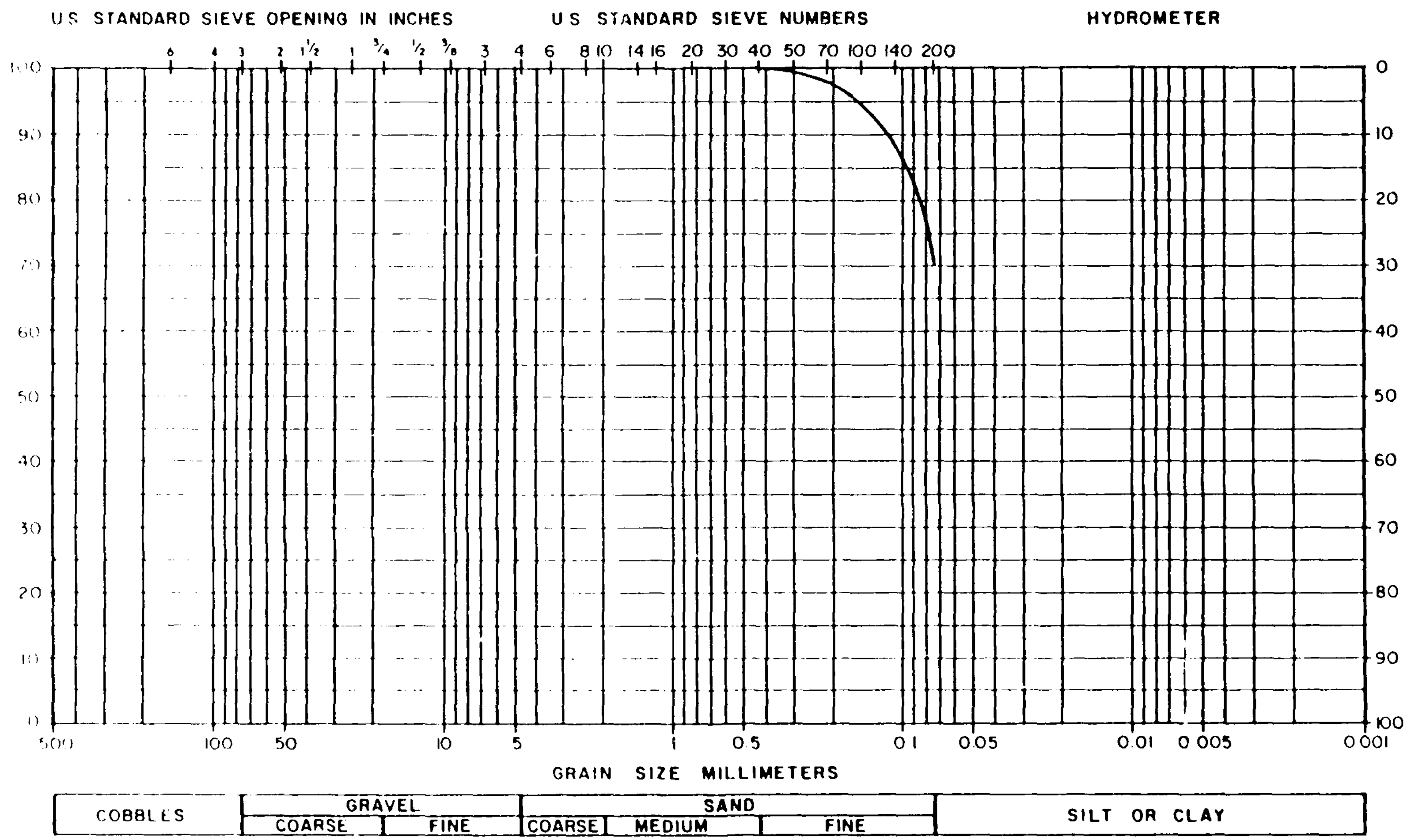
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING S103 SAMPLE S27 TOP 10 INCHES
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. F12



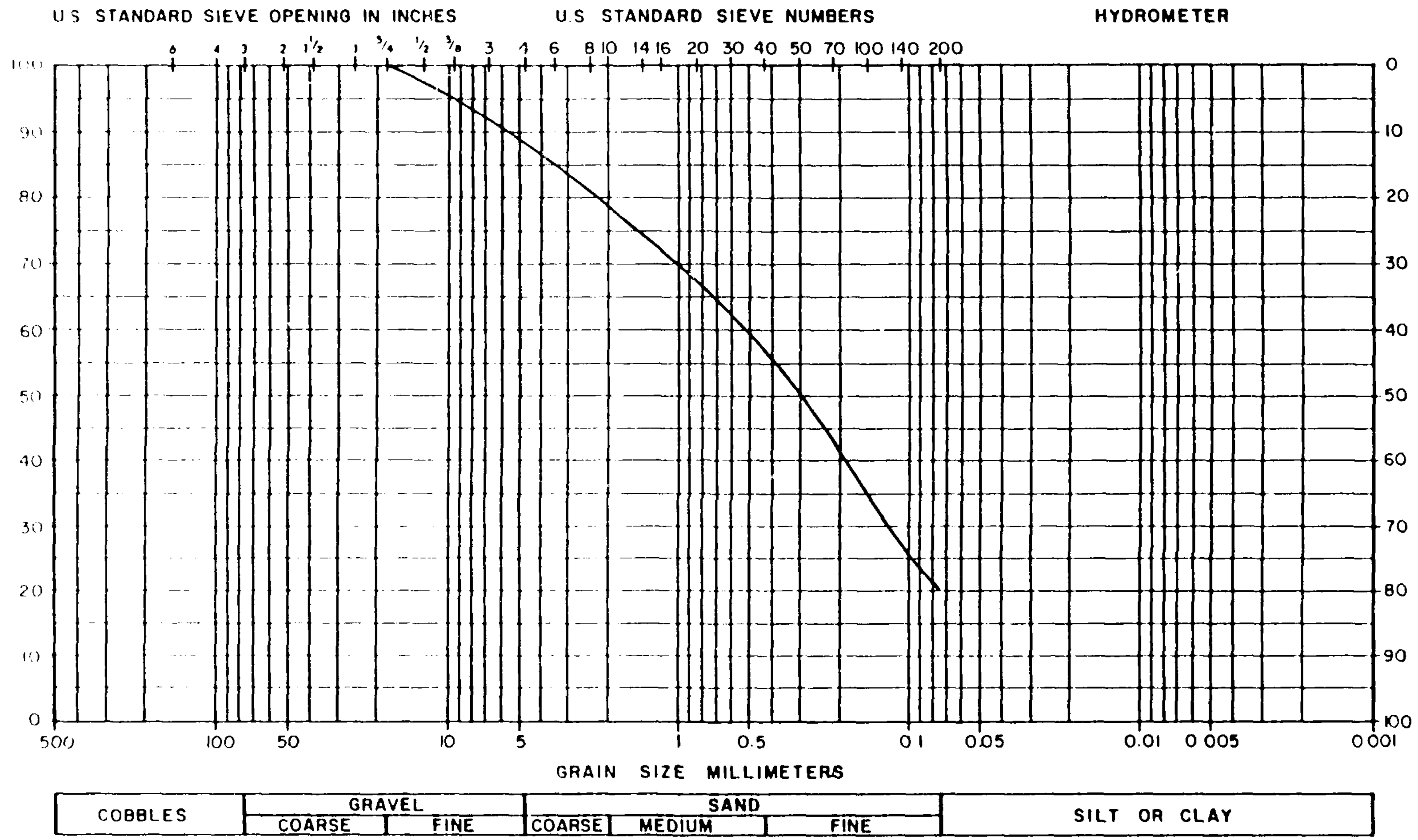
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING S104 SAMPLE S18 TOP 14 INCHES
GEOTECHNICAL ENGINEERS INC	Project 85669	Sep. 2, 1987 Fig. F13



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING S104 SAMPLE S22
GEOTECHNICAL ENGINEERS INC	Project 85669	Sep. 2, 1987 Fig. F14



Army Corps of Engineers Vicksburg, Mississippi GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Re-evaluation of Lower San Fernando Dam San Fernando, California Project 85669	GRAIN SIZE CURVE BORING S105 SAMPLE S32 TOP 17 INCHES Sep. 2, 1987 Fig. F15



Army Corps of Engineers
Vicksburg, Mississippi

GEOTECHNICAL ENGINEERS INC
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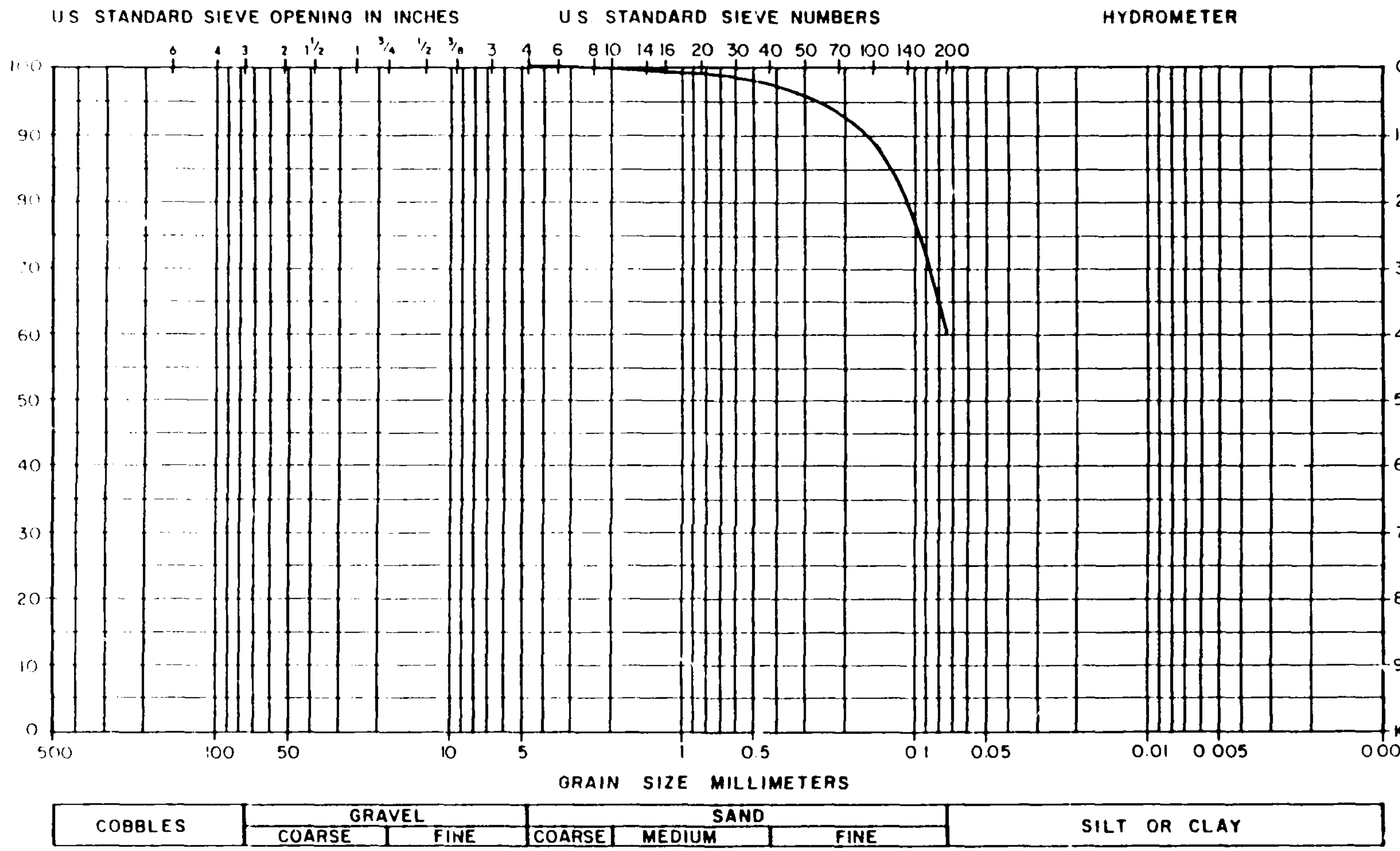
Re-evaluation of
Lower San Fernando Dam
San Fernando, California

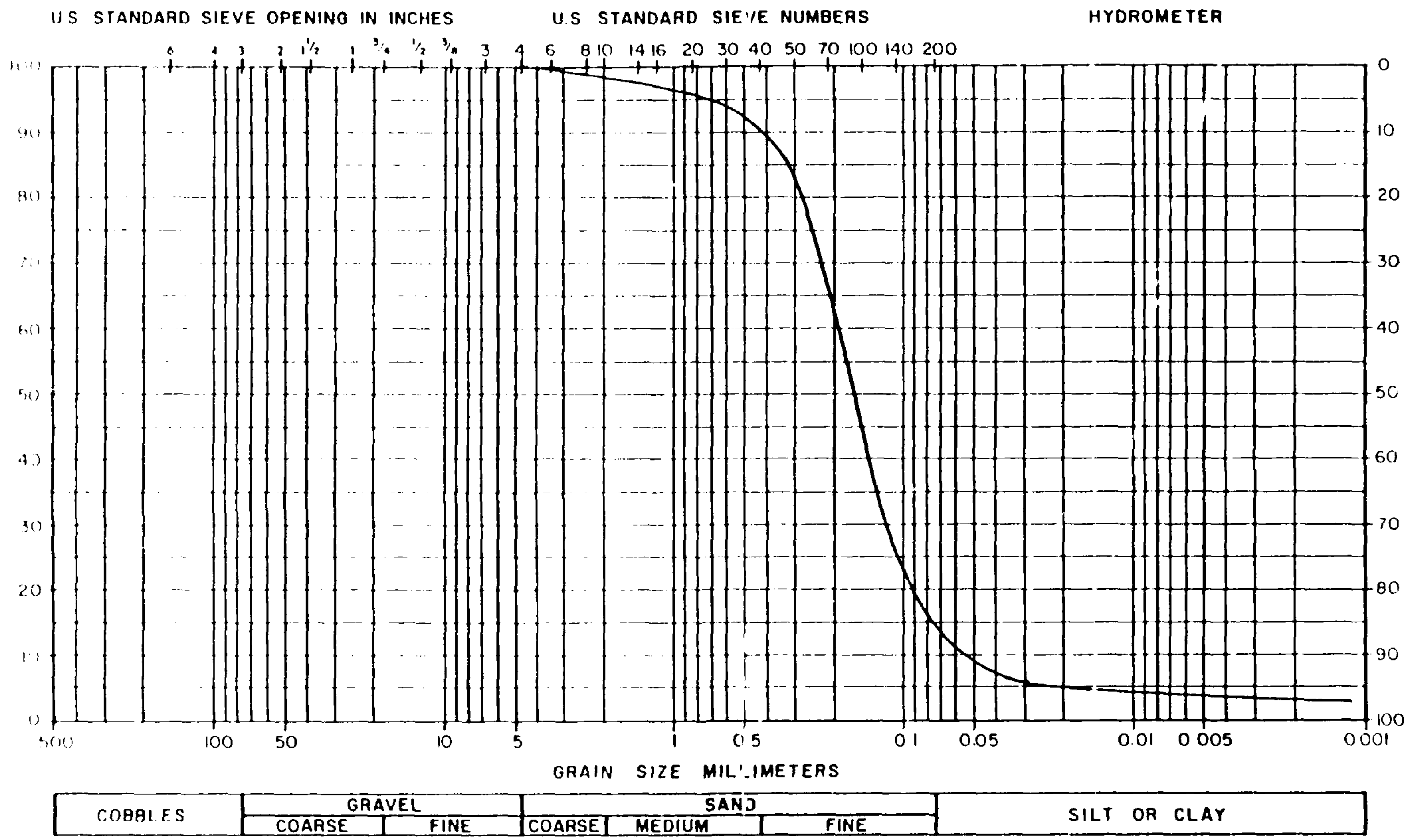
Project 85669

GRAIN SIZE CURVE
BORING S111
SAMPLE S9

Sep. 2, 1987 Fig. F16

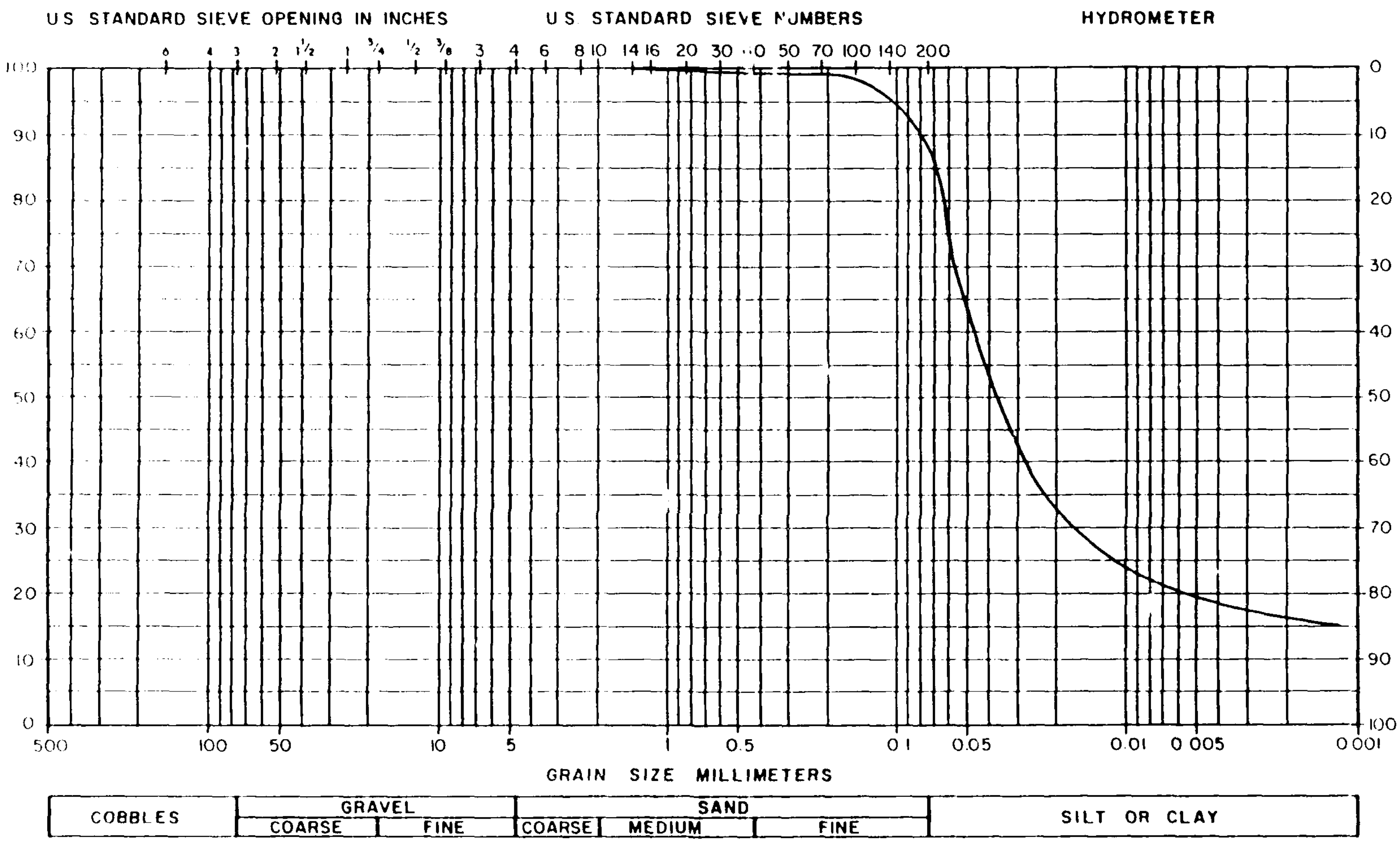


Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING S111 SAMPLE S25 BOTTOM 8 INCHES
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. F17



NOTE: 4.2% of the total sample was retained on the No. 4 sieve. The maximum particle size was 1-in.

Army Corps of Engineers Vicksburg, Mississipi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BATCH MIX 1 FRACTION PASSING NO 4. SIEVE
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Feb. 20, 1986 Fig. F18



Army Corps of Engineers
Vicksburg, Mississippi

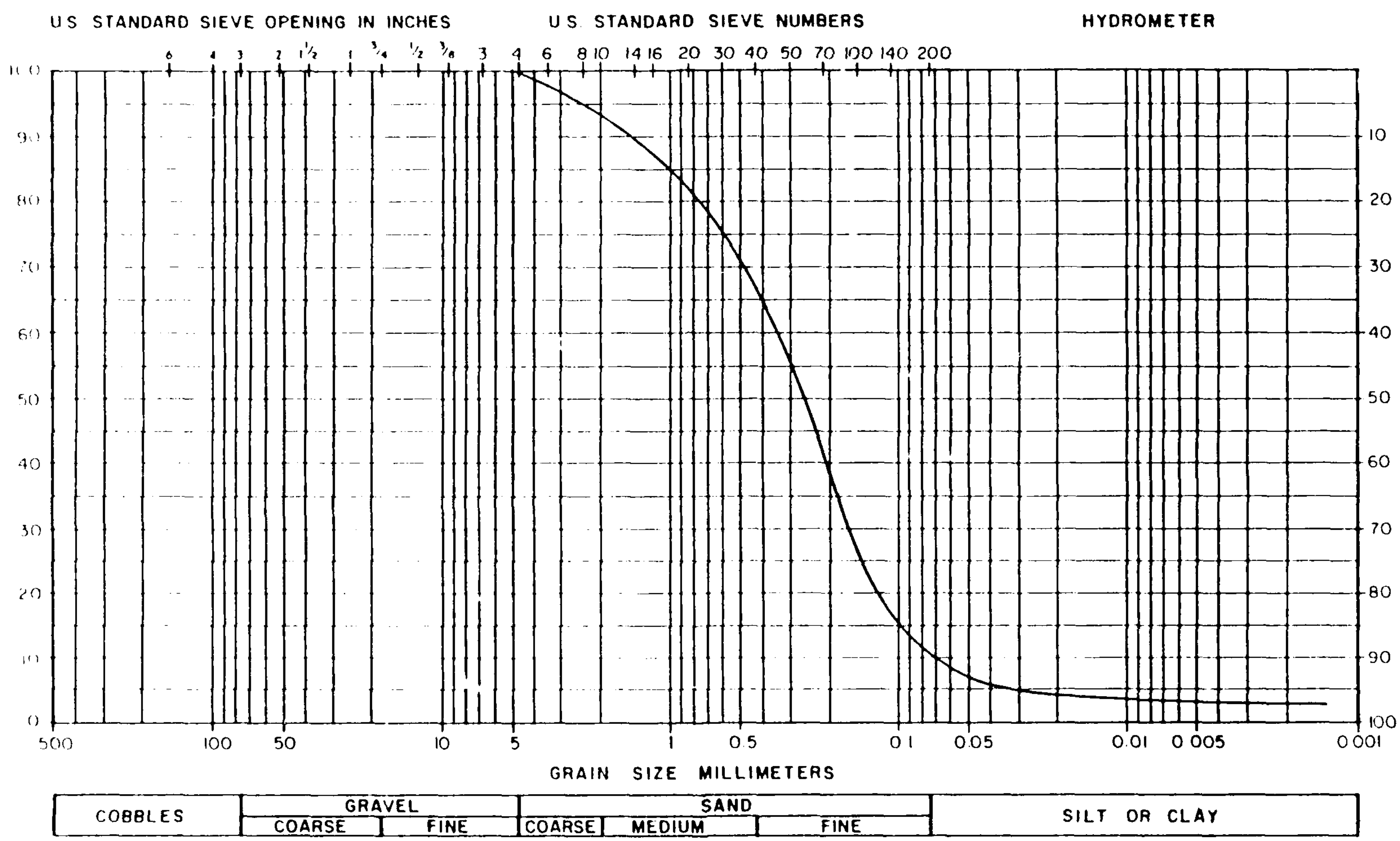
GEOTECHNICAL ENGINEERS INC
WINCHESTER • MASSACHUSETTS

Re-evaluation of
Lower San Fernando Dam
San Fernando, California

Project 85669

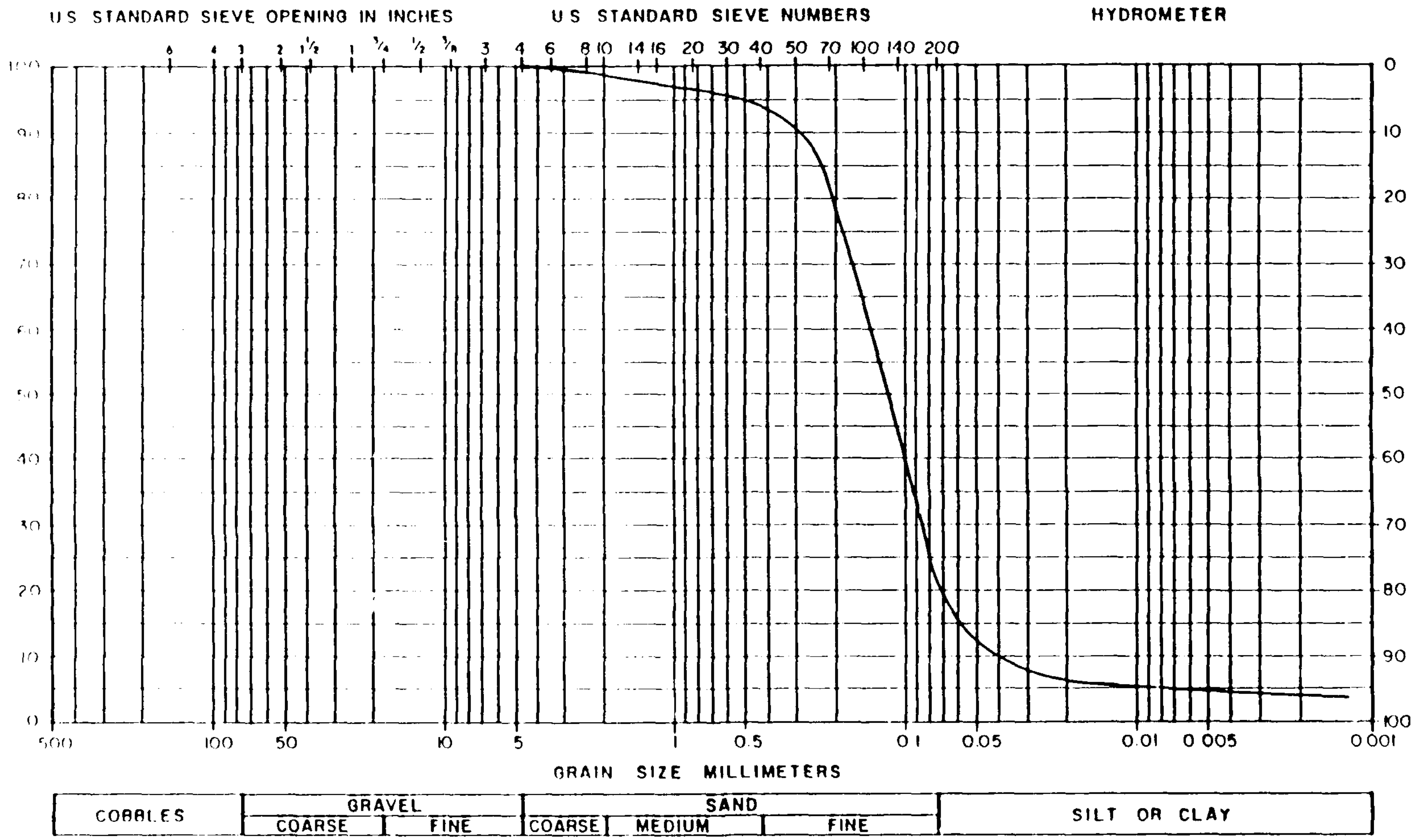
GRAIN SIZE CURVE
BATCH MIX 2

Feb. 20, 1986 Fig. F19



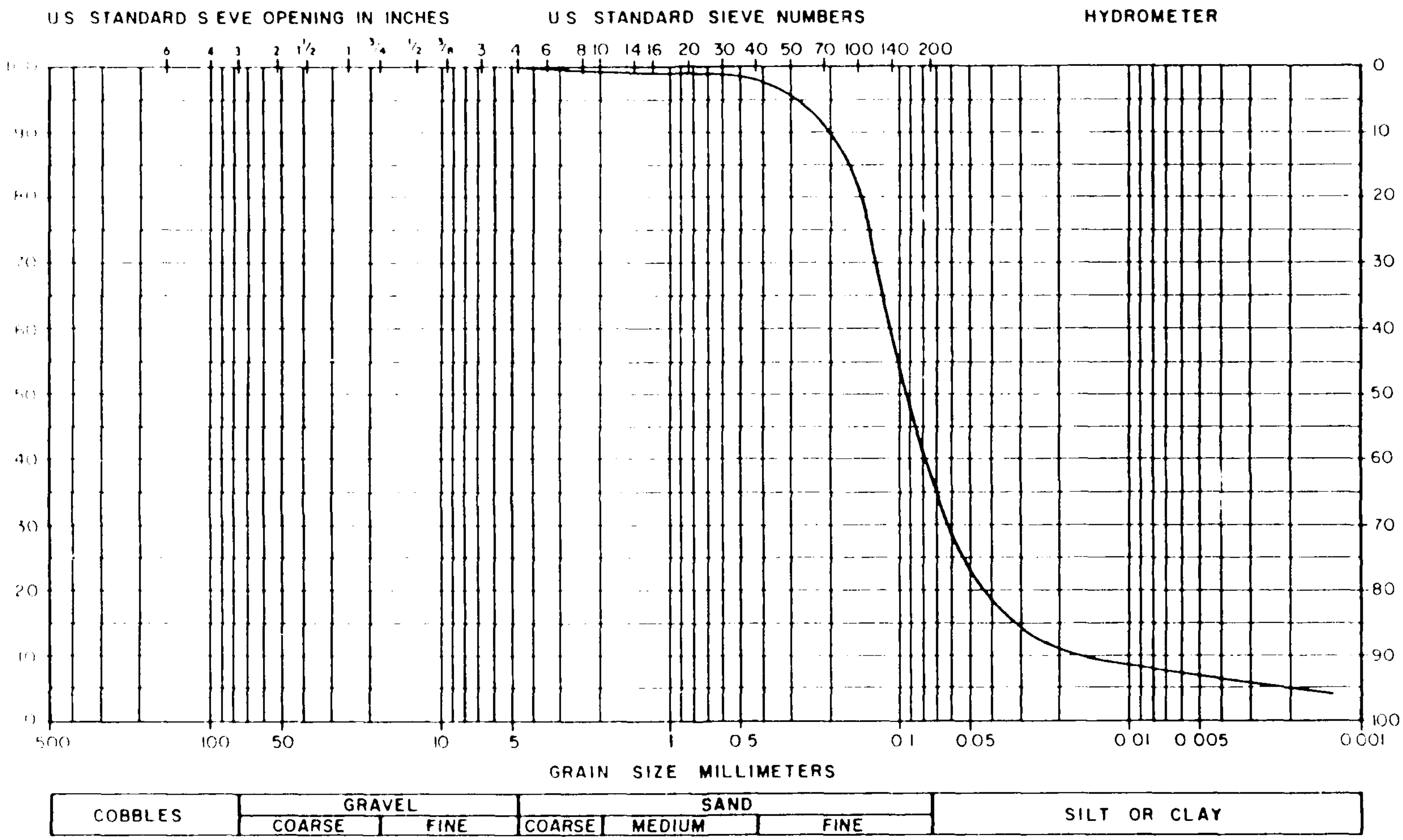
NOTE: 4.7% of the total sample was retained on the No. 4 sieve. The maximum particle size was 1 1/2-in.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BATCH MIX 3 FRACTION PASSING NO. 4 SIEVE
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Feb. 20, 1986 Fig. F20



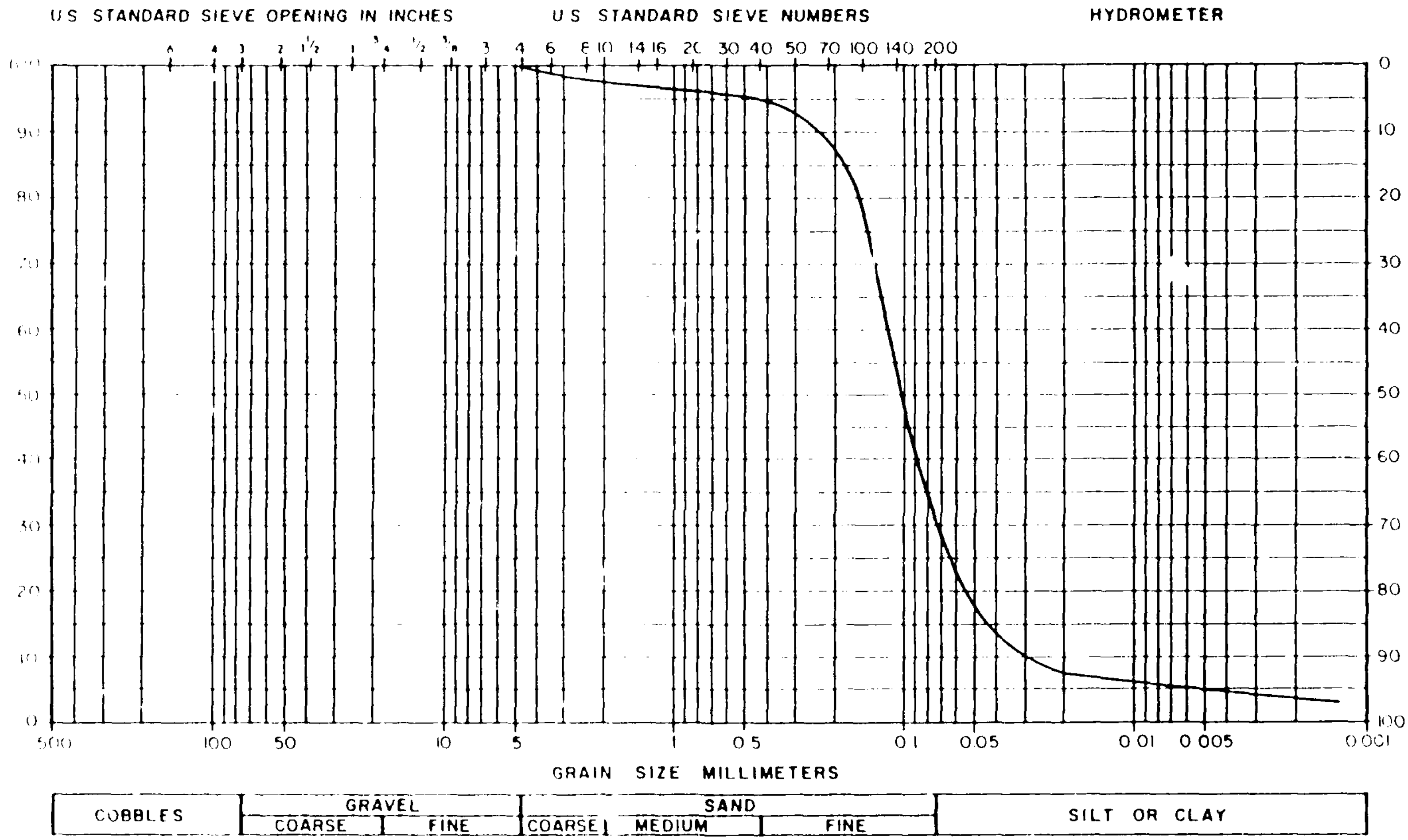
NOTE: 0.8% of the total sample was retained on the No. 4 sieve. The maximum particle size was 1-in.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BATCH MIX 4 FRACTION PASSING NO. 4 SIEVE
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Feb. 20, 1986 Fig. F21



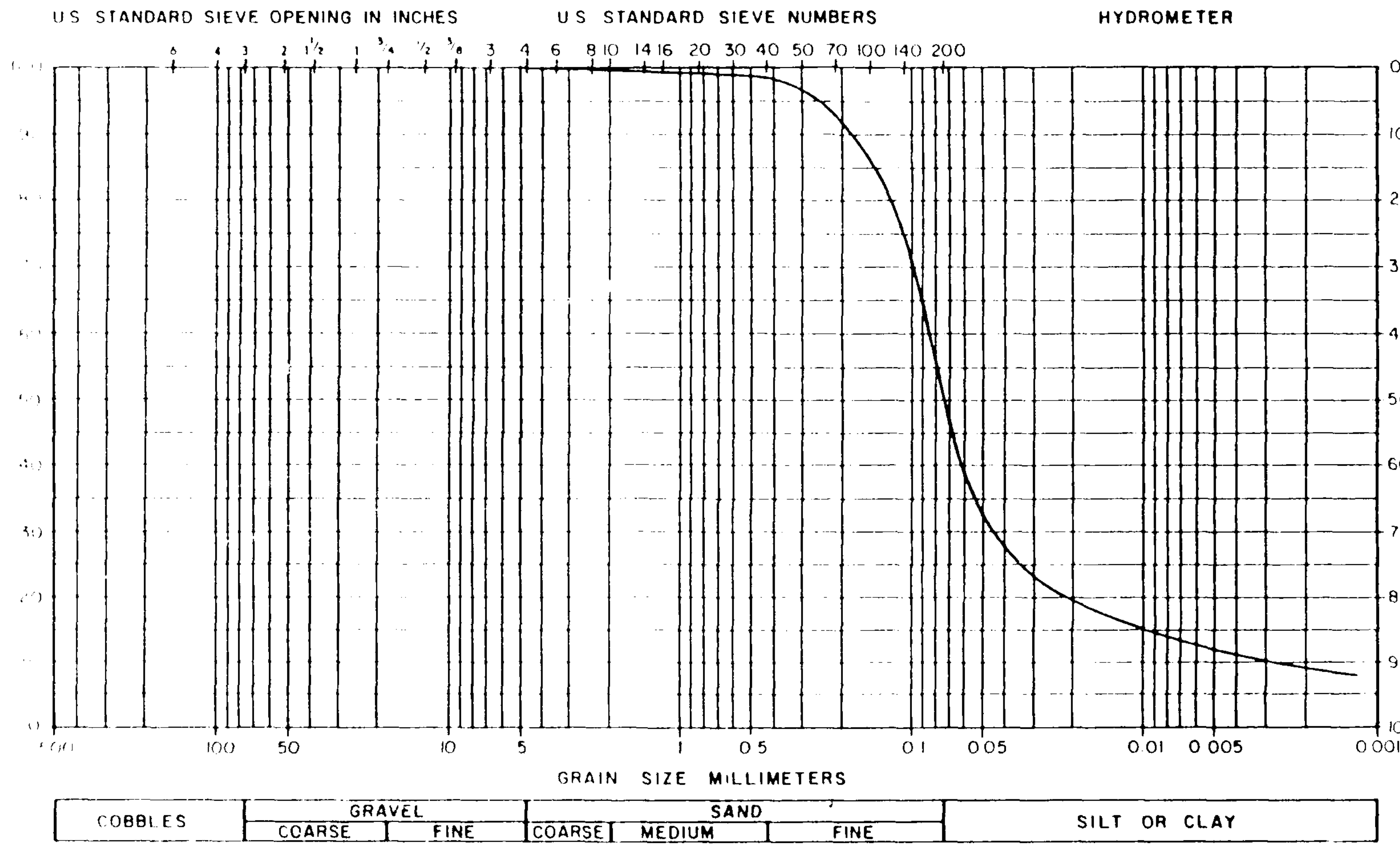
NOTE: 1.5% of the total sample was retained on the No. 4 sieve. The maximum particle size was 1/2-in.

Army Corps of Engineers Vicksburg, Mississippi GEOTECHNICAL ENGINEERS INC	Re-evaluation of Lower San Fernando Dam San Fernando, California Project 85669	GRAIN SIZE CURVE BATCH MIX 5 FRACTION PASSING No. 4 SIEVE Feb. 20, 1986 Fig. F22



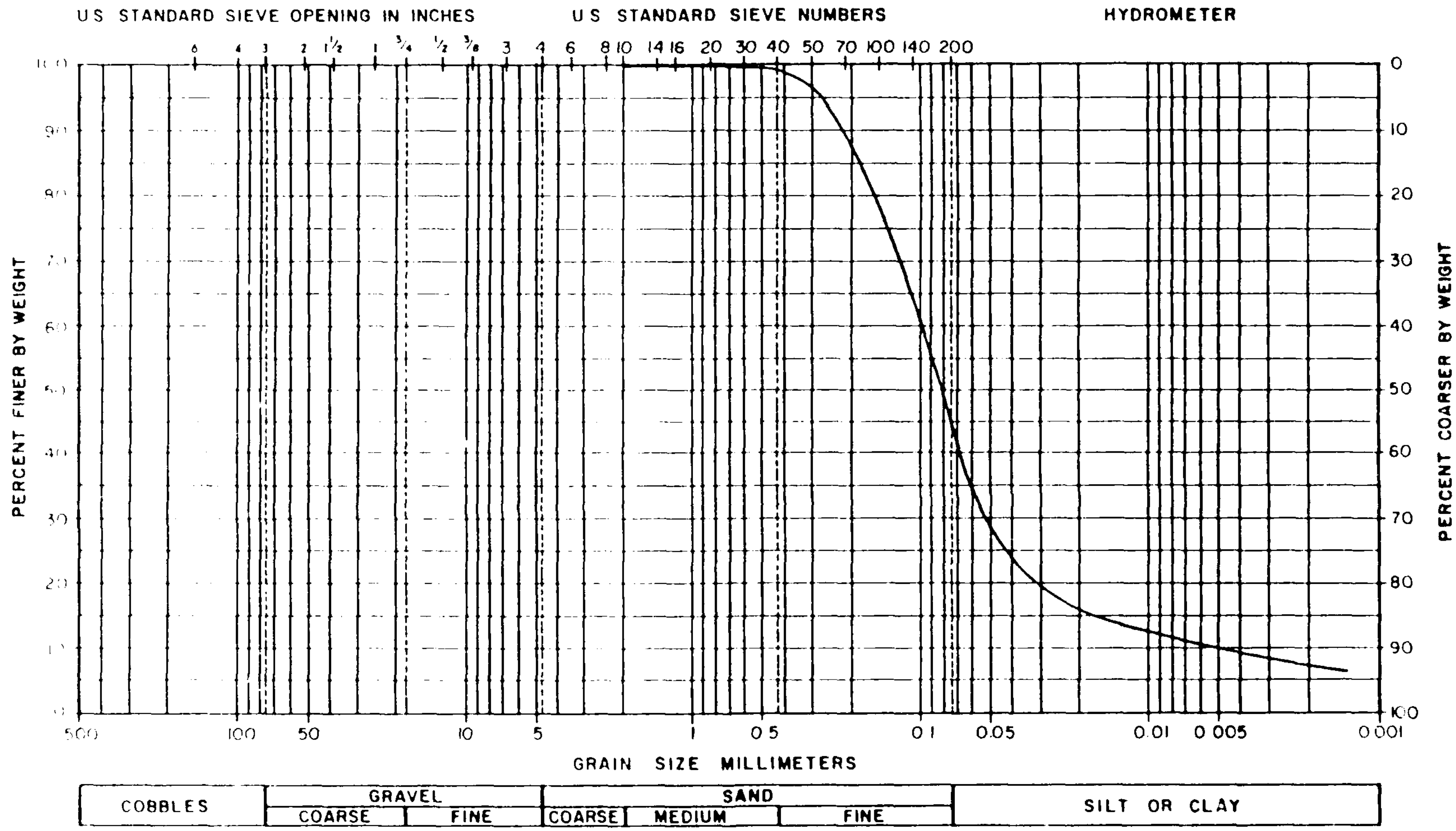
NOTE: 1.1% of the total sample was retained on the No. 4 sieve. The maximum size was 1-in.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BATCH MIX 6 FRACTION PASSING No. 4 SIEVE
GEOTECHNICAL ENGINEERS INC	Project 85669	Feb. 20, 1986 Fig. F23

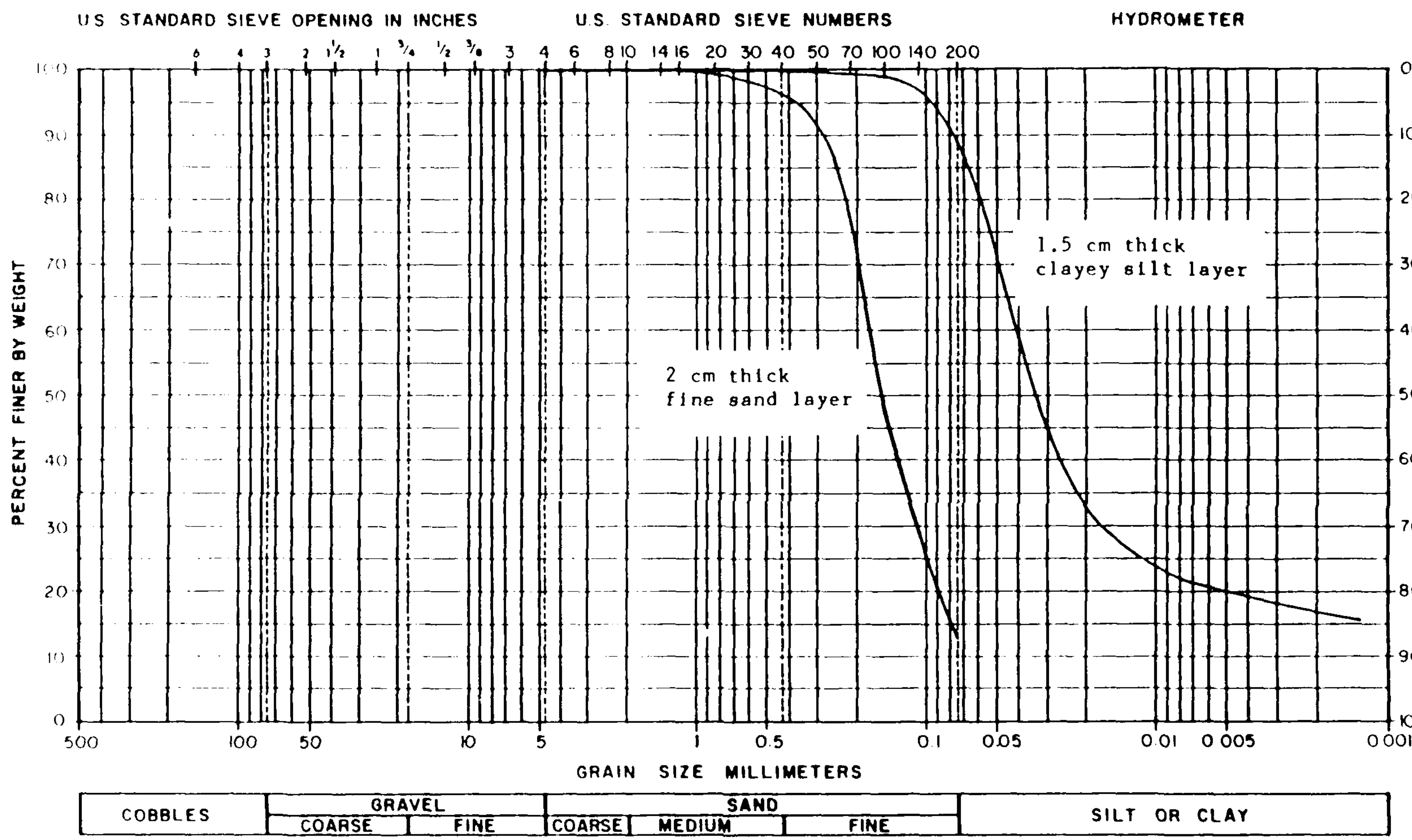


NOTE: 0.6% of the total sample was retained on the No. 4 sieve. The maximum particle size was 3/8-in.

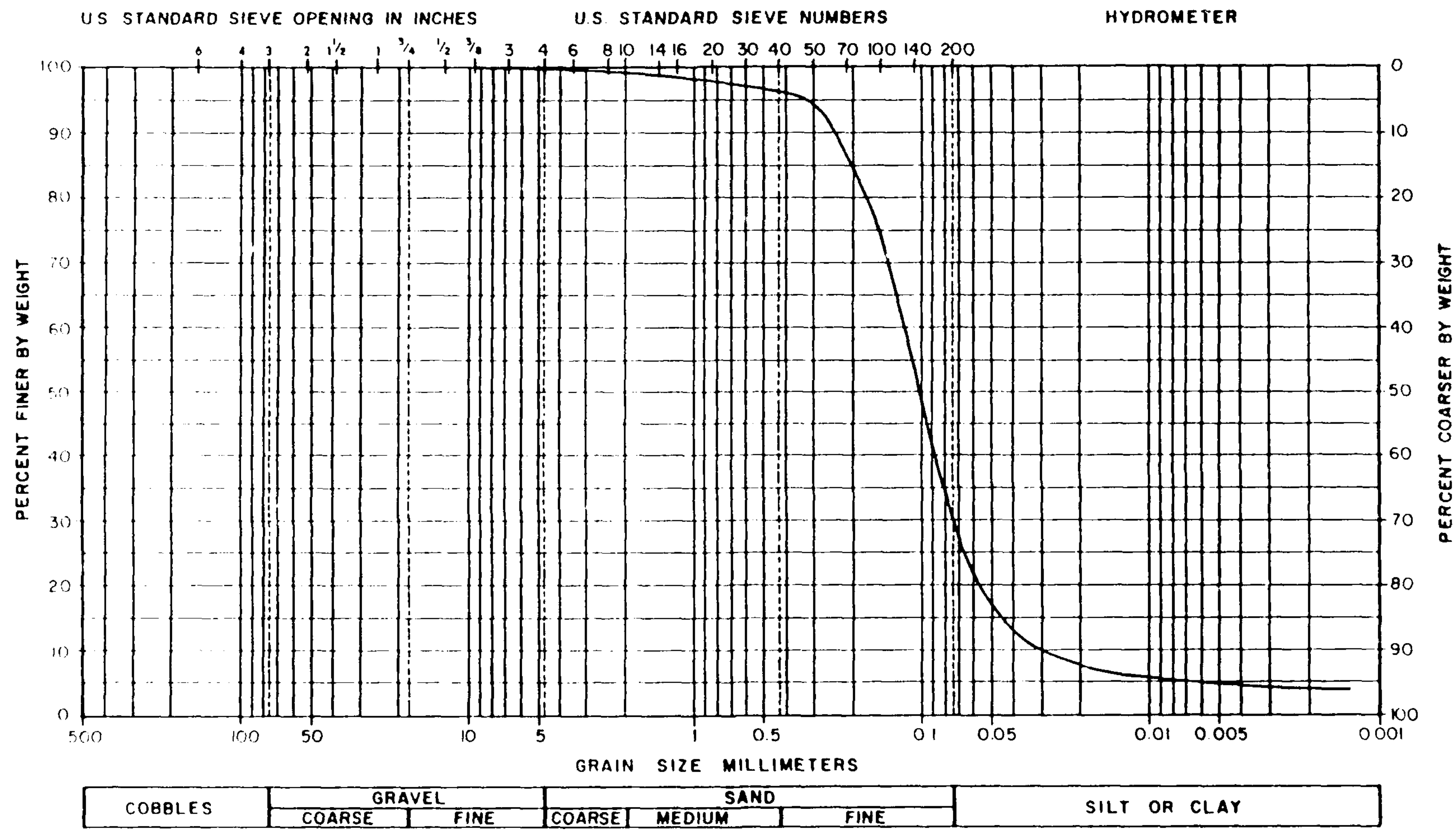
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BATCH MIX 7 FRACTION PASSING No. 4 SIEVE
GEOTECHNICAL ENGINEERS INC	Project 85669	Feb. 20, 1986 Fig. F24



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS302 FROM TEST R̄1
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F25

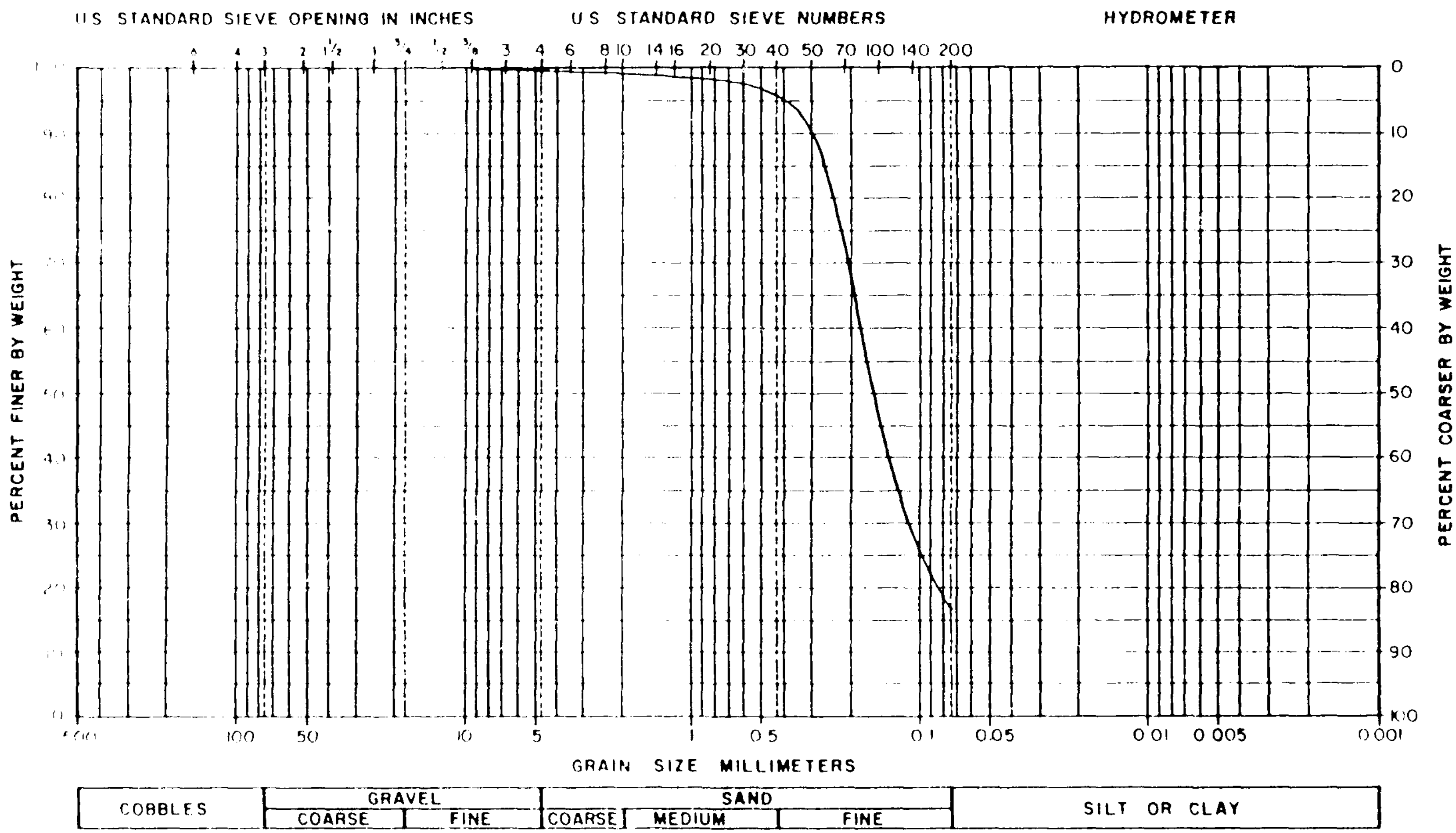


Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS203 FROM TEST R2
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F26



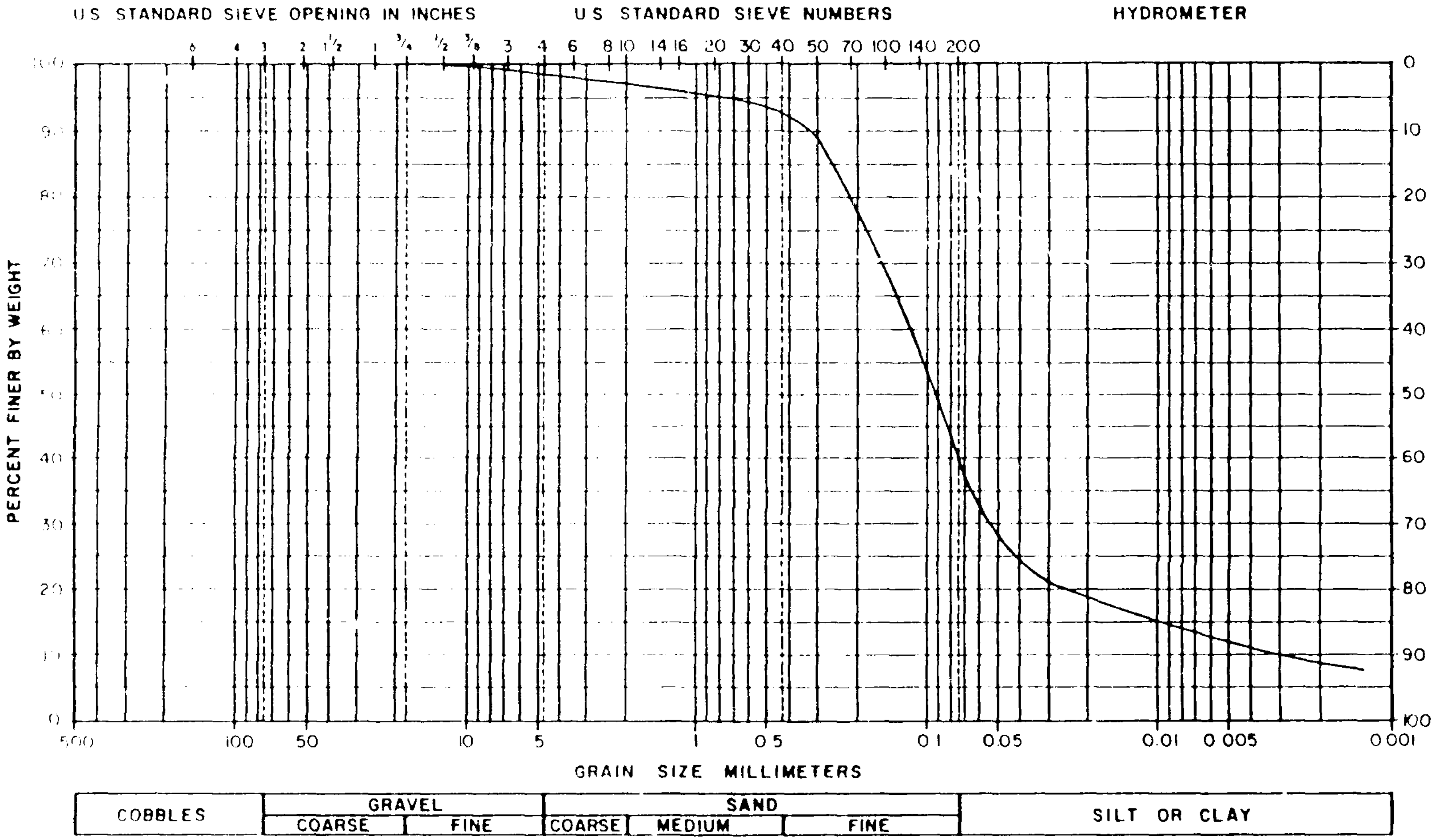
Grain size analyses performed on bottom 9.5 cm of sample.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS1J6 FROM TEST R3
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F27

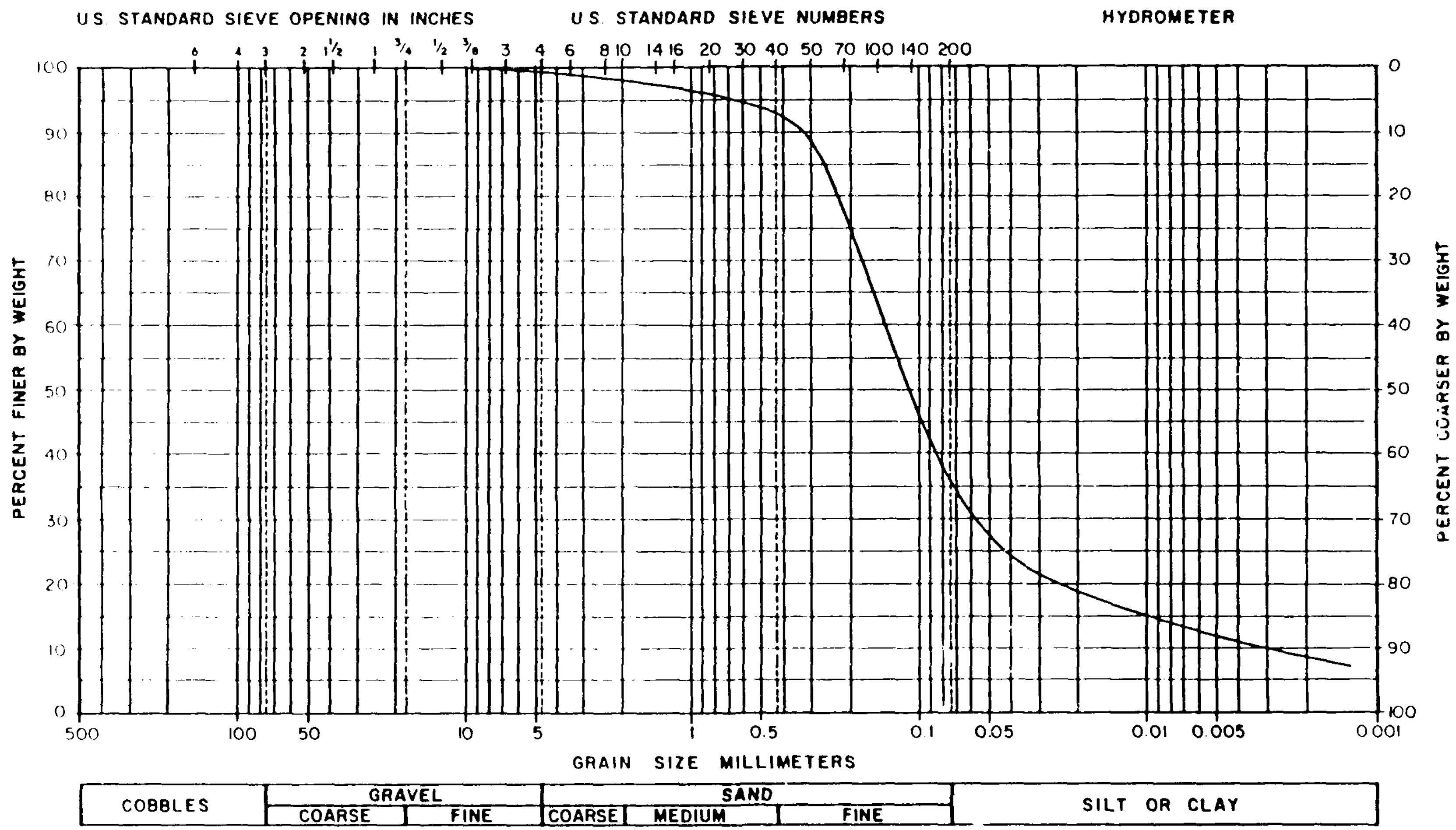


Grain size analyses performed on top 3 cm of sample.

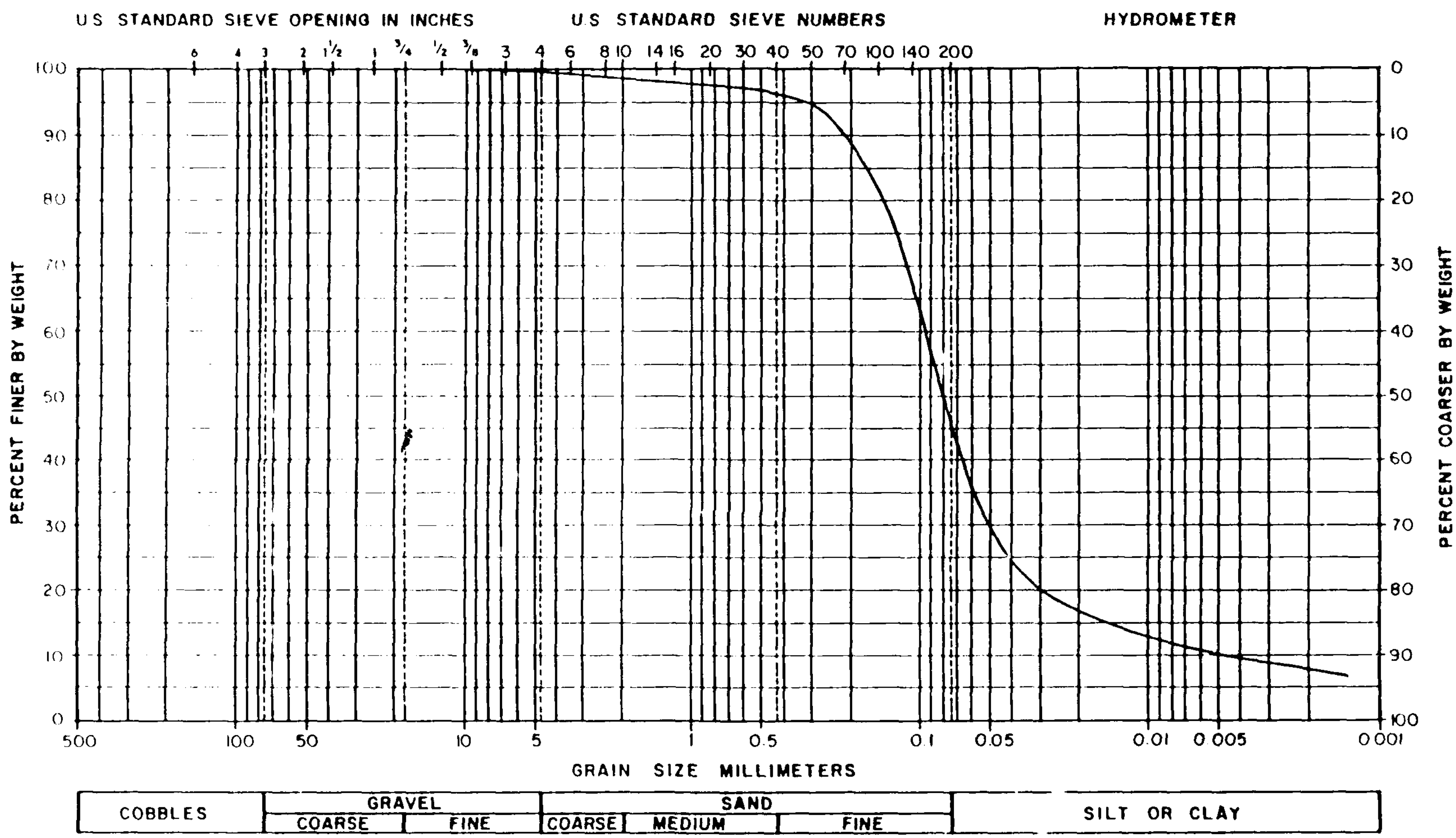
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS102 FROM TEST R4
GEOTECHNICAL ENGINEERS INC	Project 85669	Sept. 2, 1987 Fig. F28



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING U111A SAMPLE UF19C FROM TEST R5
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F29

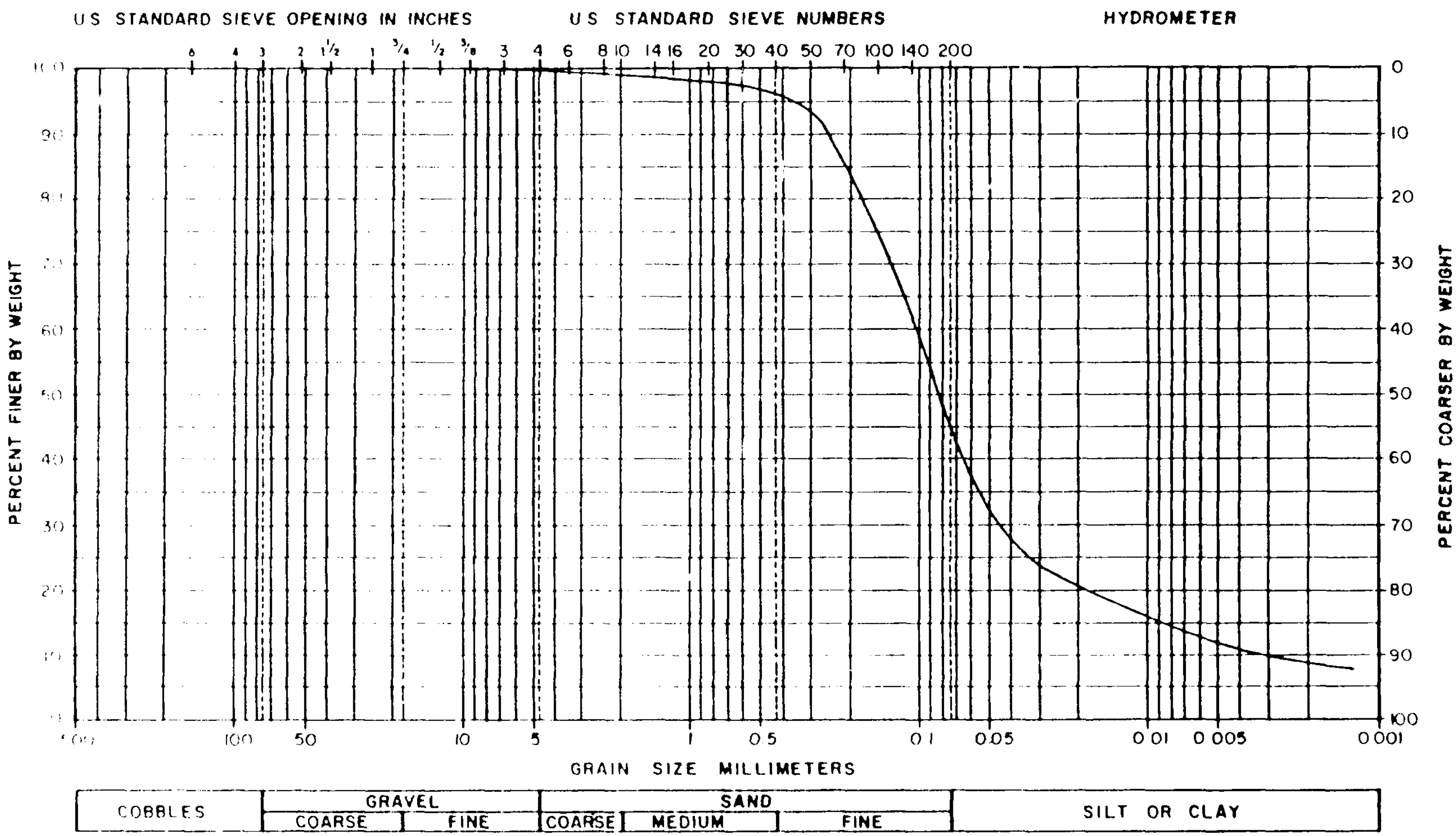


Army Corps of Engineers Vicksburg, Mississippi GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Re-evaluation of Lower San Fernando Dam San Fernando, California Project 85669	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS309A FROM TEST R6 Sept. 2, 1987 Fig. F30

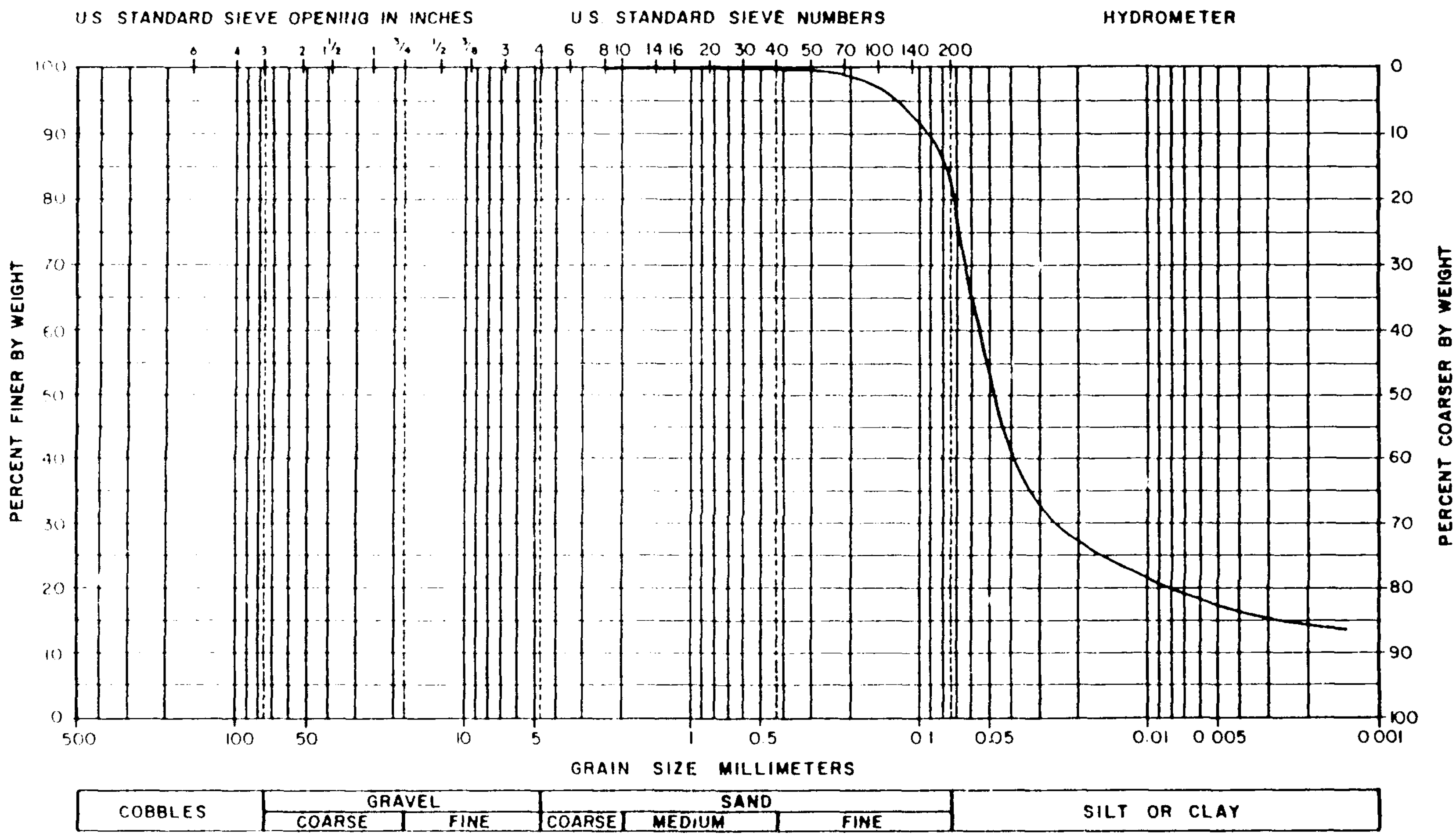


Grain size analyses performed on top 7 cm of sample.

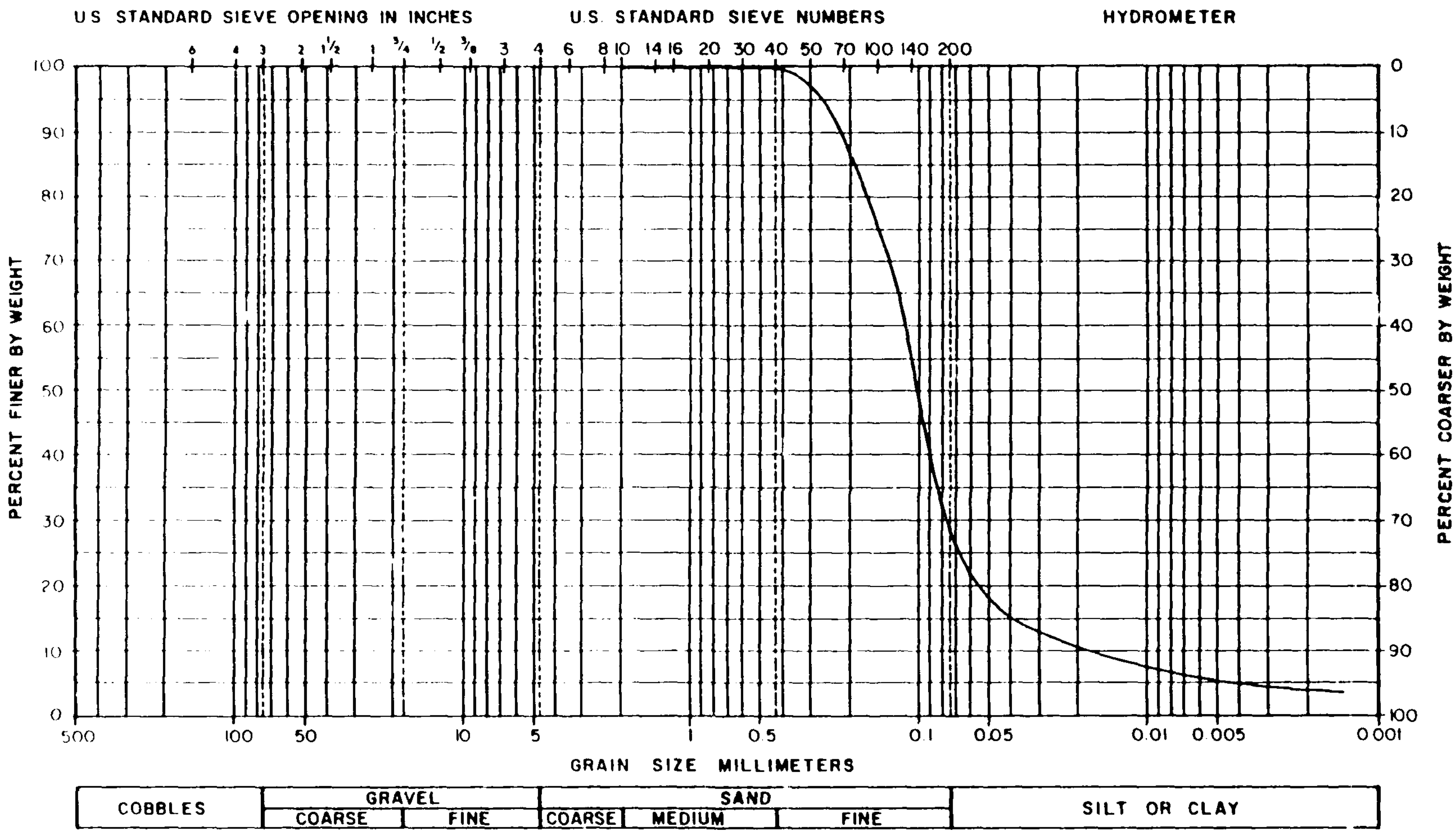
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS306B FROM TEST R7
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F31



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING U103 SAMPLE UF3C FROM TEST R8
GEOTECHNICAL ENGINEERS INC	Project 85669	Sept. 2, 1987 Fig. F32

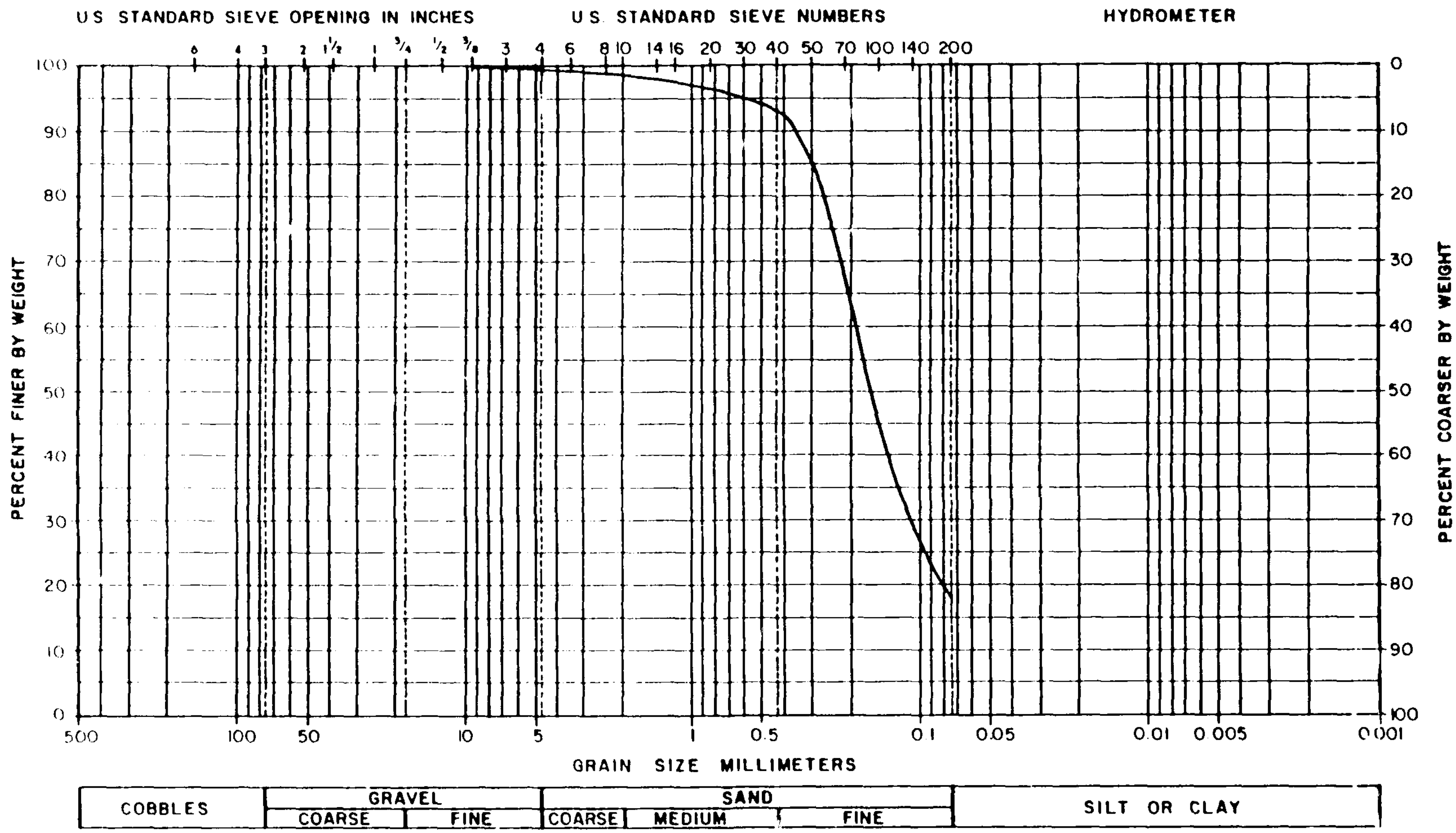


Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING U105 SAMPLE UF10C FROM TEST R̄9
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F33

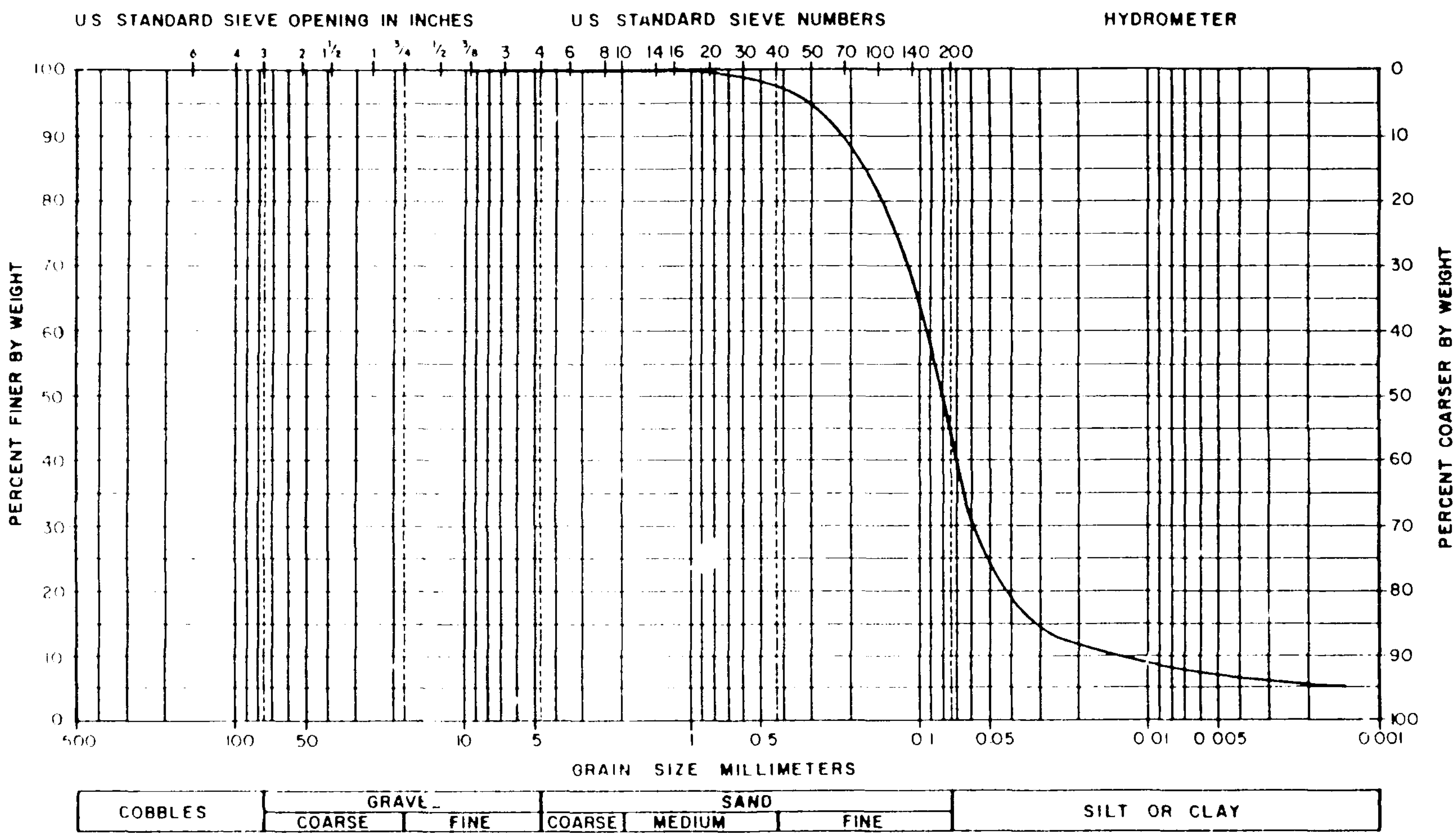


Grain size analyses performed on top 8 cm of sample.

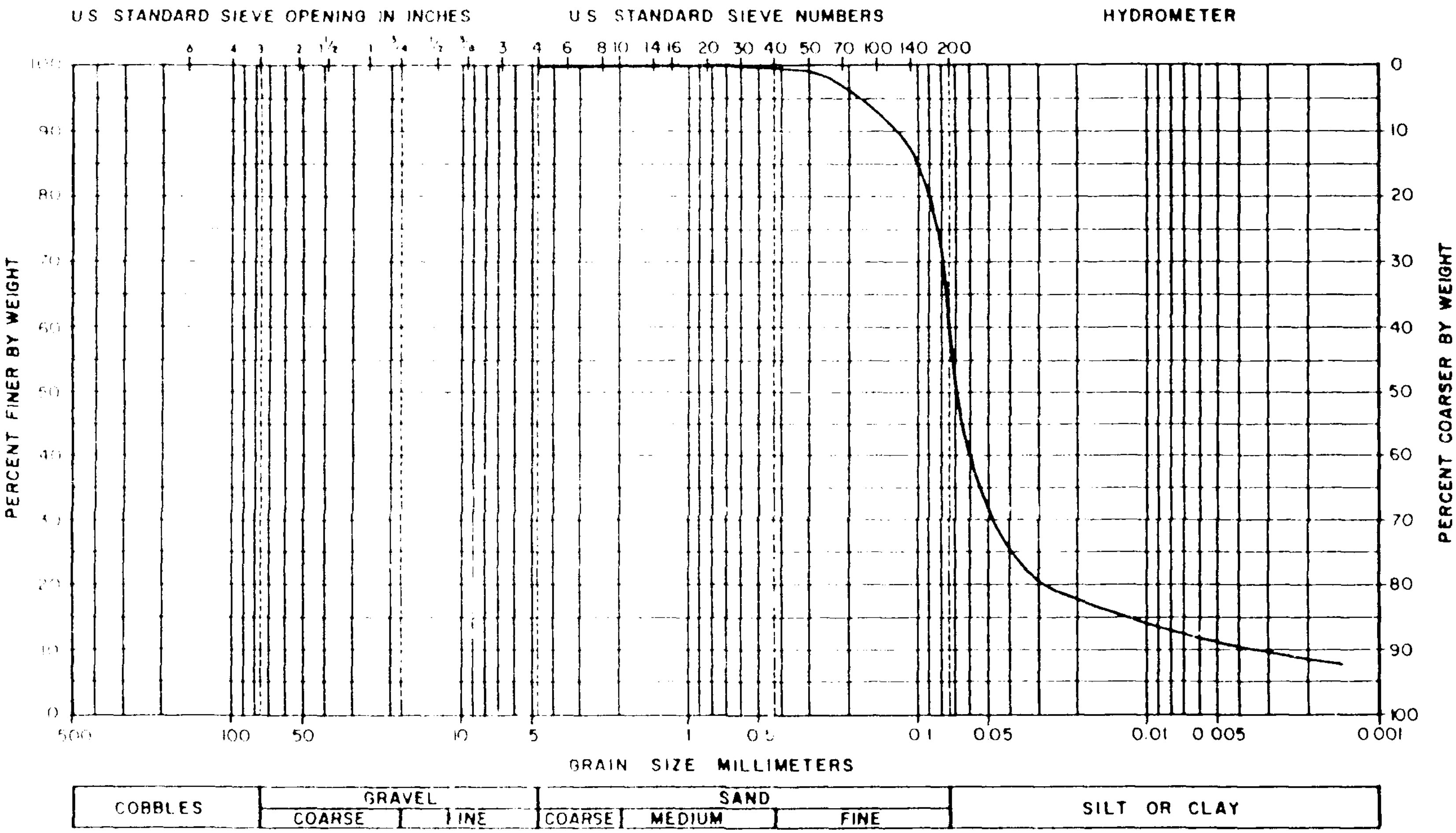
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS207A FROM TEST R10
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F34



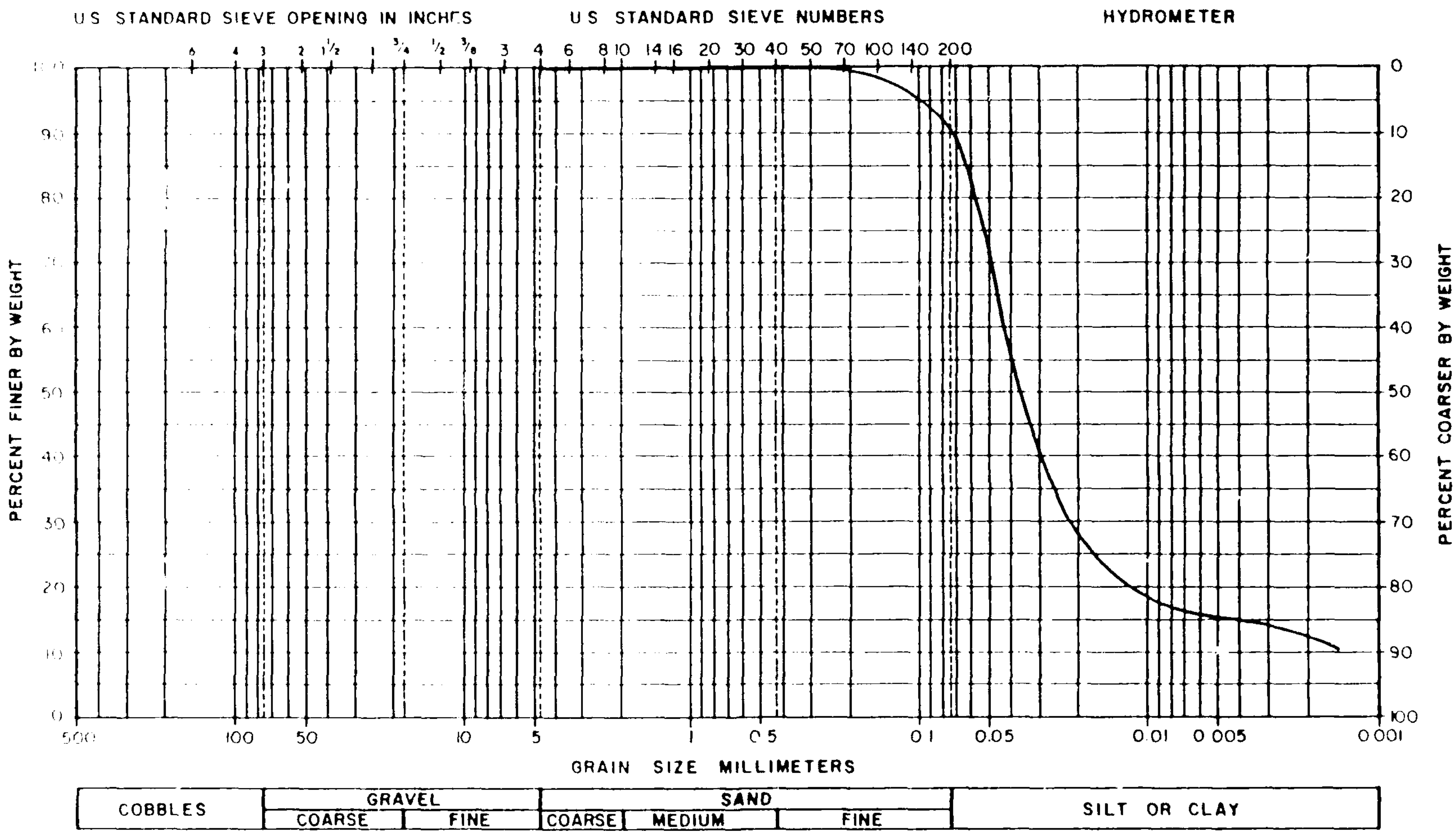
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS103 FROM TEST R11
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F35



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS315 FROM TEST R12
GEOTECHNICAL ENGINEERS INC WINCHESTER, MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F36

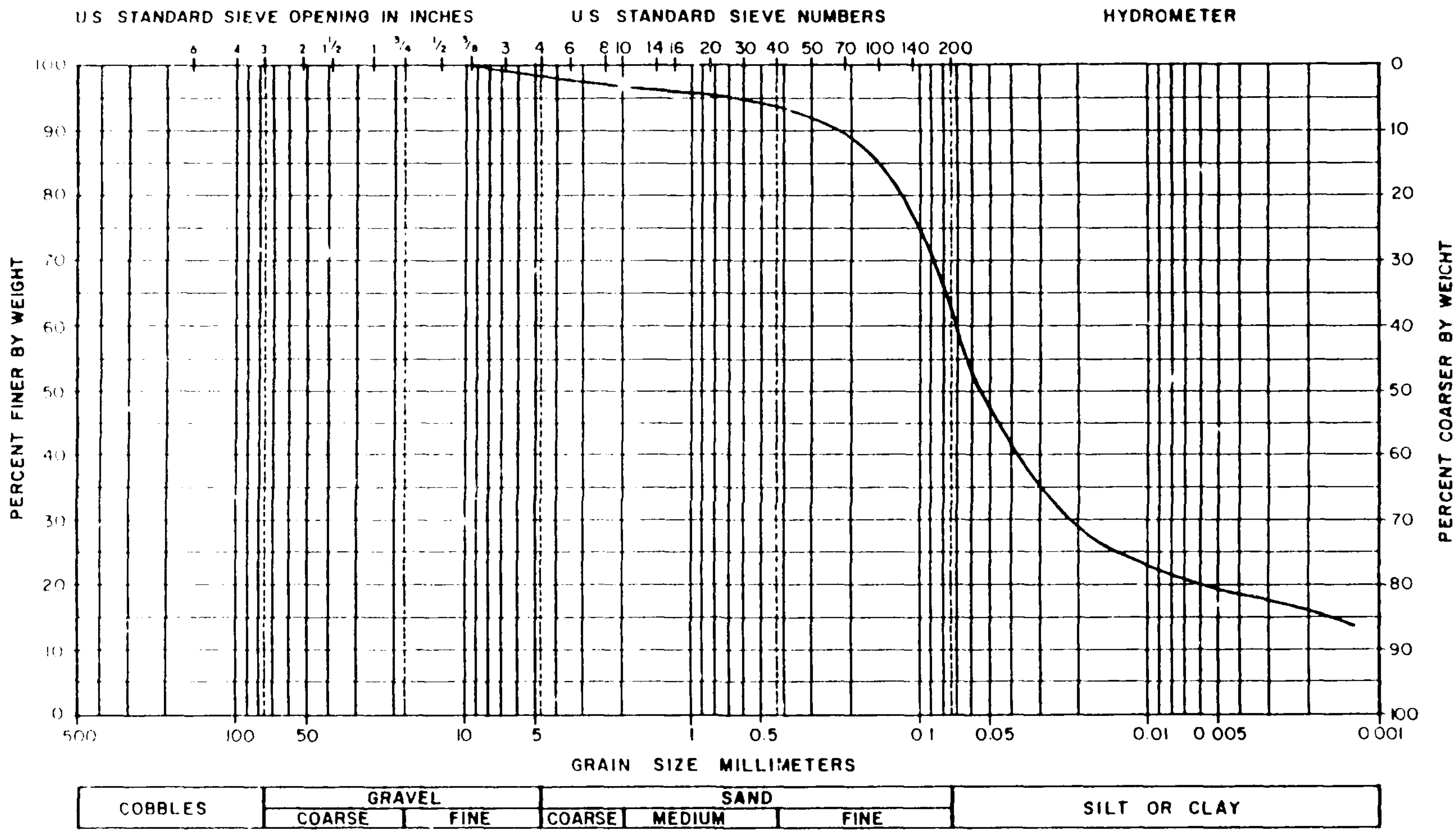


Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS314 FROM TEST R̄13
GEOTECHNICAL ENGINEERS INC	Project 85669	Sept. 2, 1987 Fig. F37

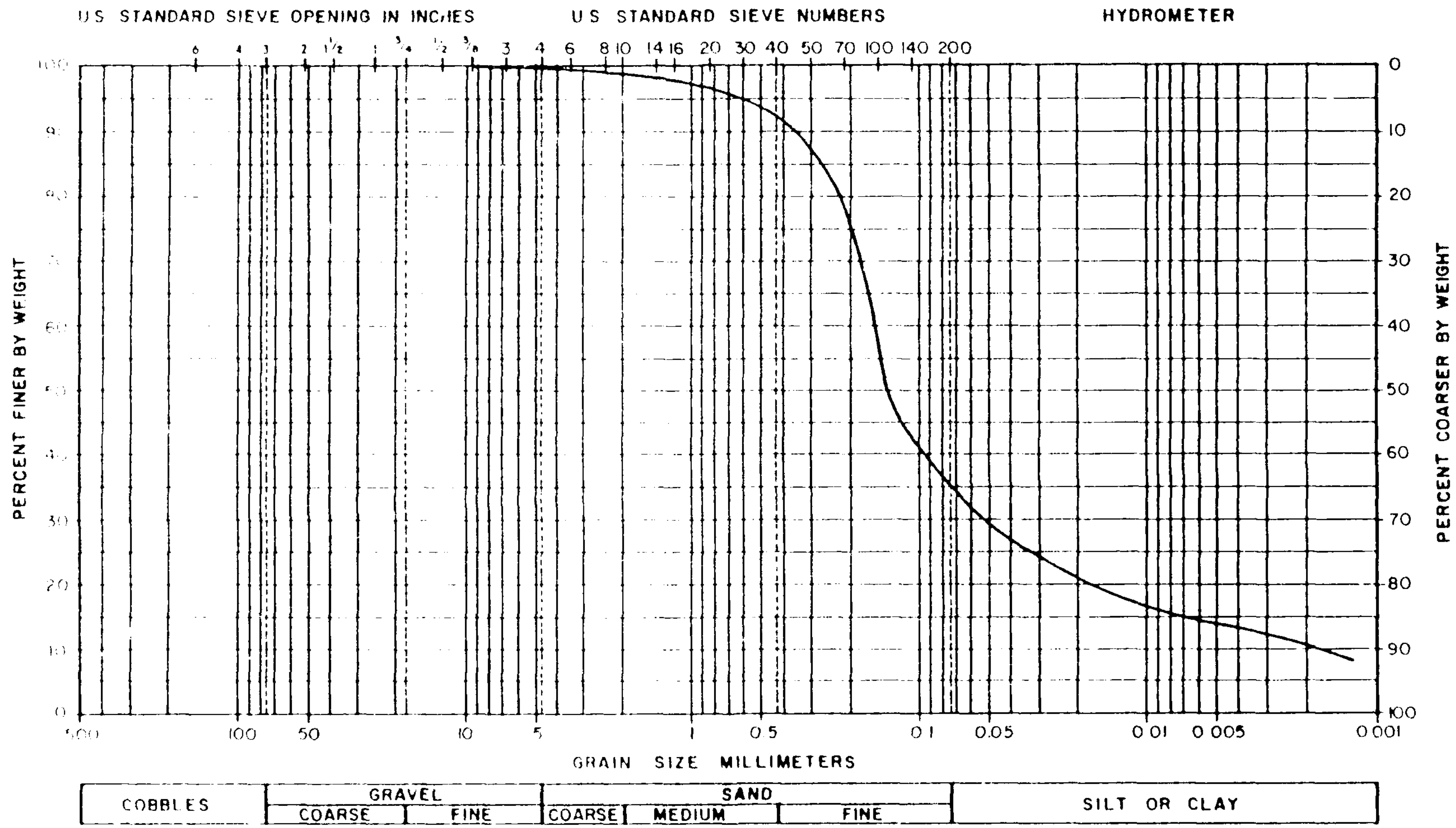


Grain size analyses performed on bottom 6 cm of sample.

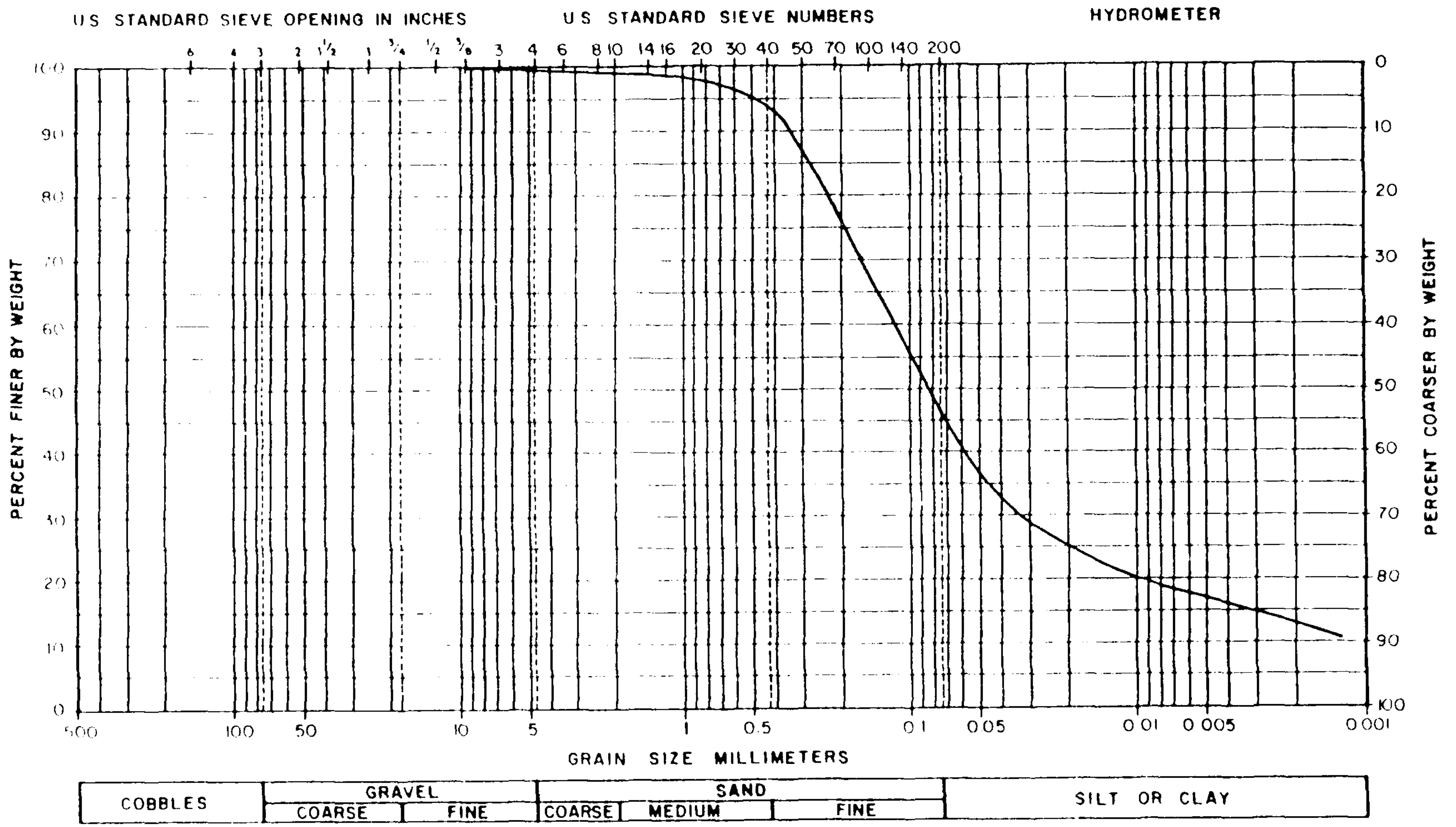
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING U111A SAMPLE UF14D FROM TEST R14
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F38



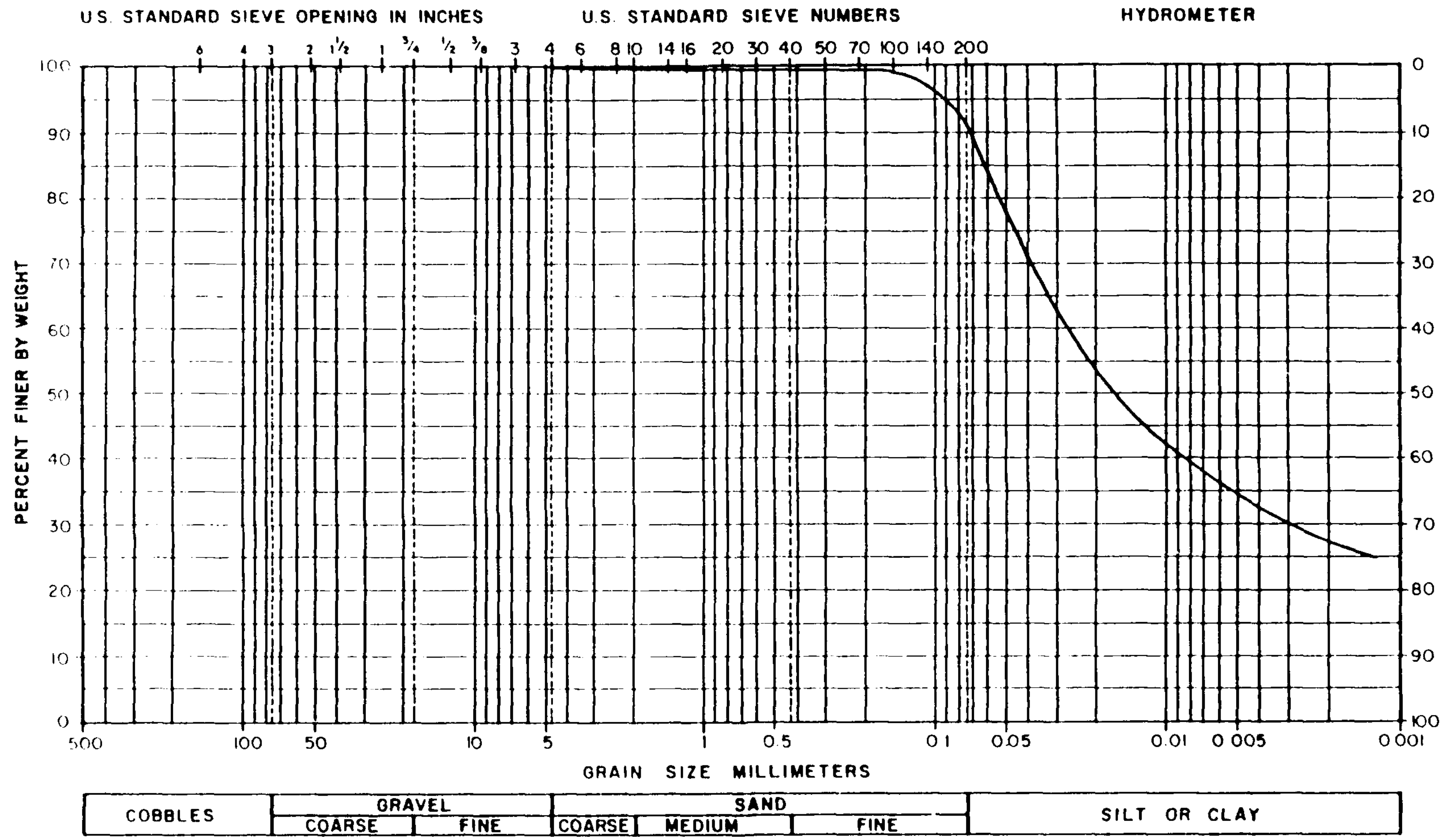
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING U111A SAMPLE UF16D FROM TEST $\bar{R}15$
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F39



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING U111A SAMPLE UF20D FROM TEST R̄16
GEOTECHNICAL ENGINEERS INC	Project 85669	Sept. 2, 1987 Fig. F40

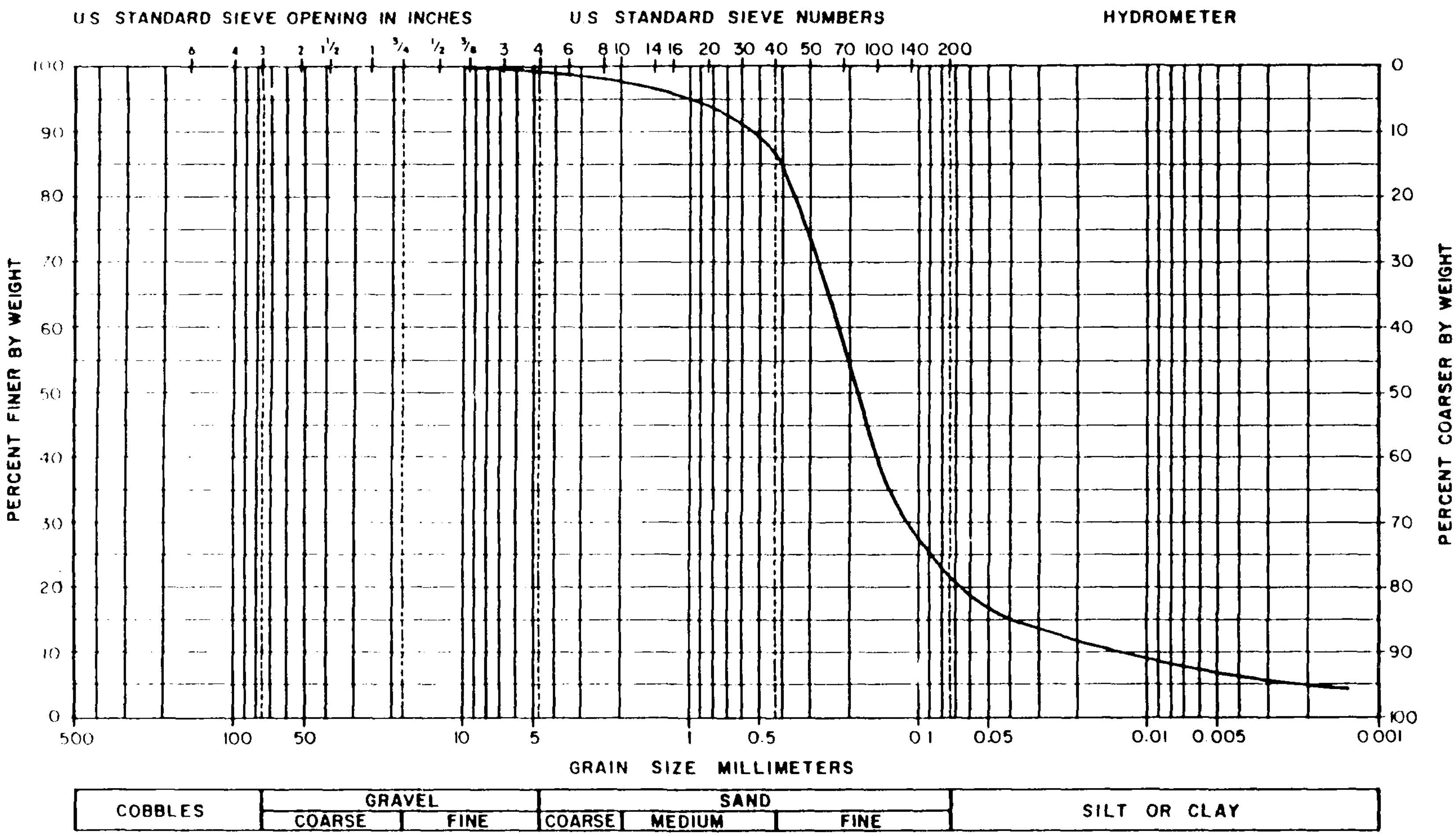


Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING U111A SAMPLE UF21A FROM TEST R17
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F41

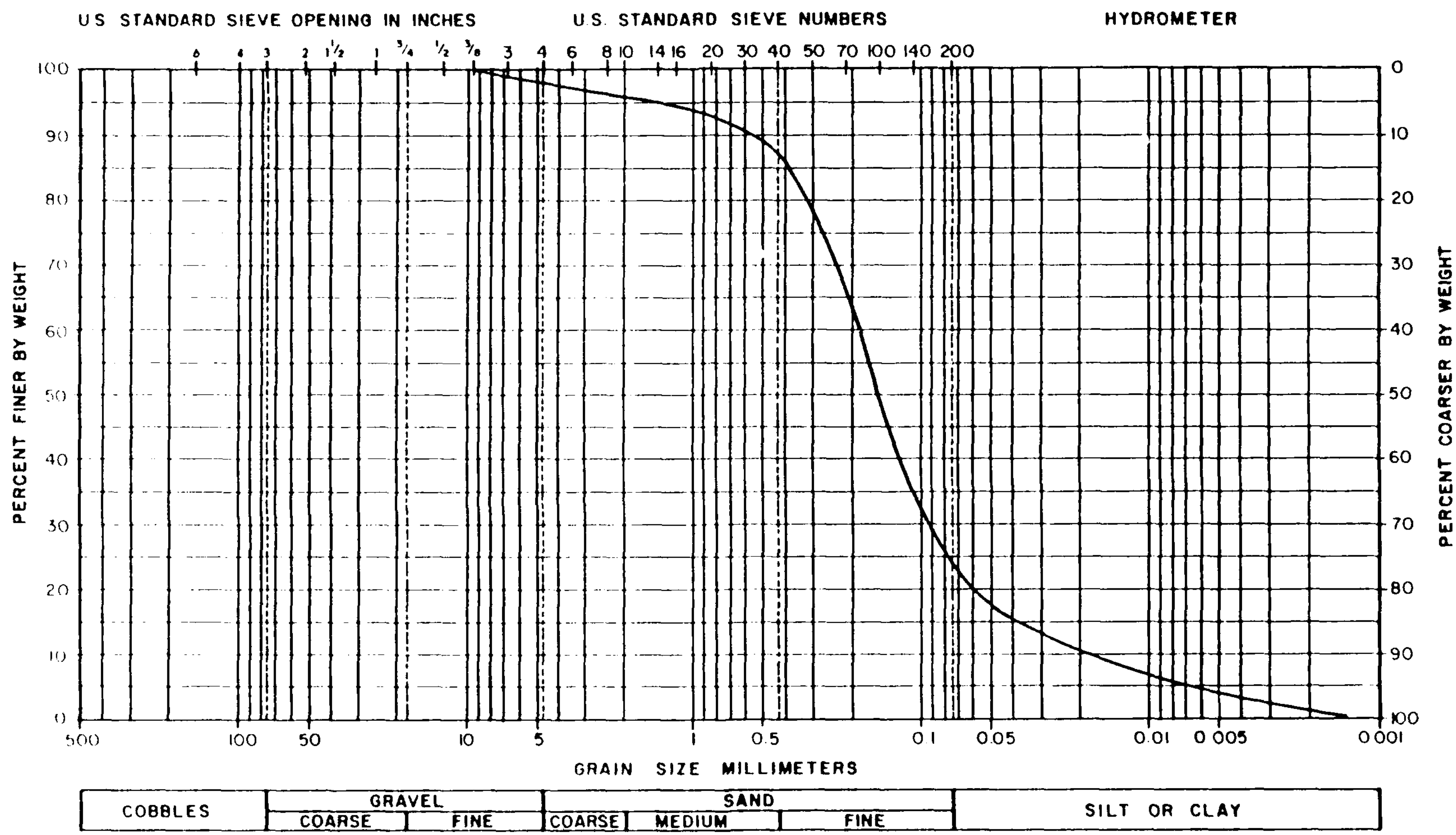


Grain size analyses performed on middle 2.5 cm of sample.

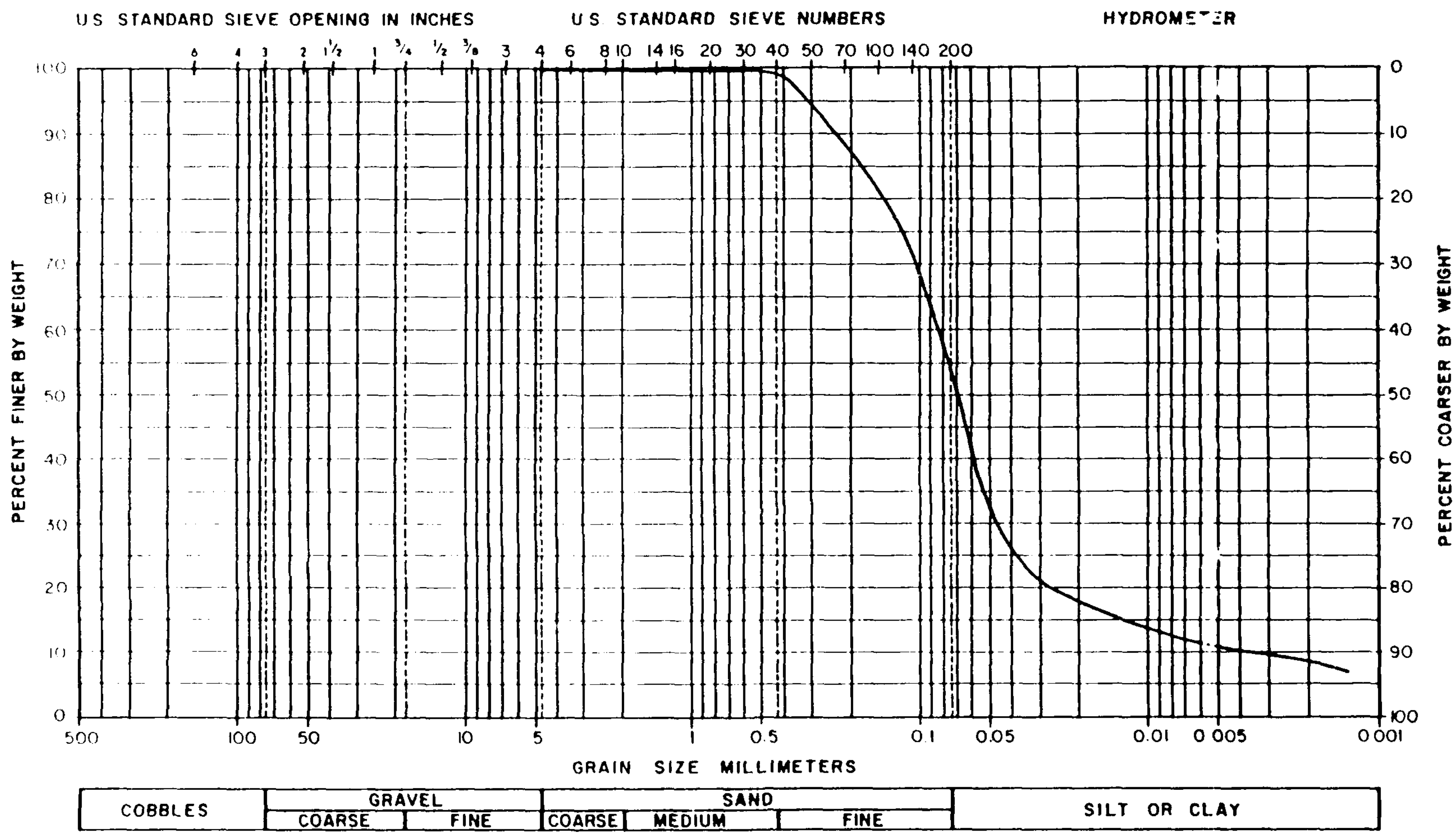
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING U111 SAMPLE UF23B FROM TEST R18
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F42



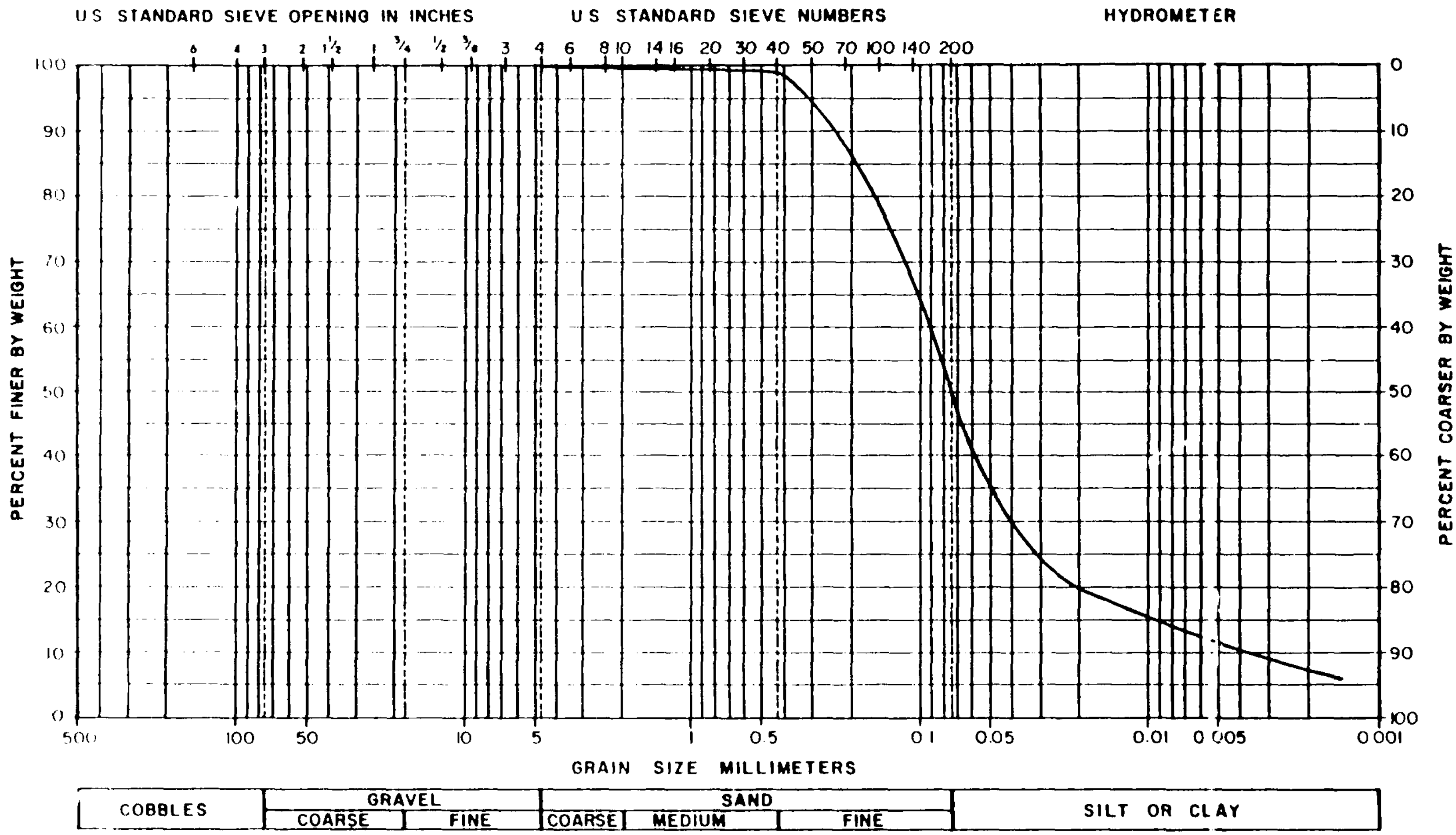
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING U103 SAMPLE UF3B FROM TEST R19
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F43



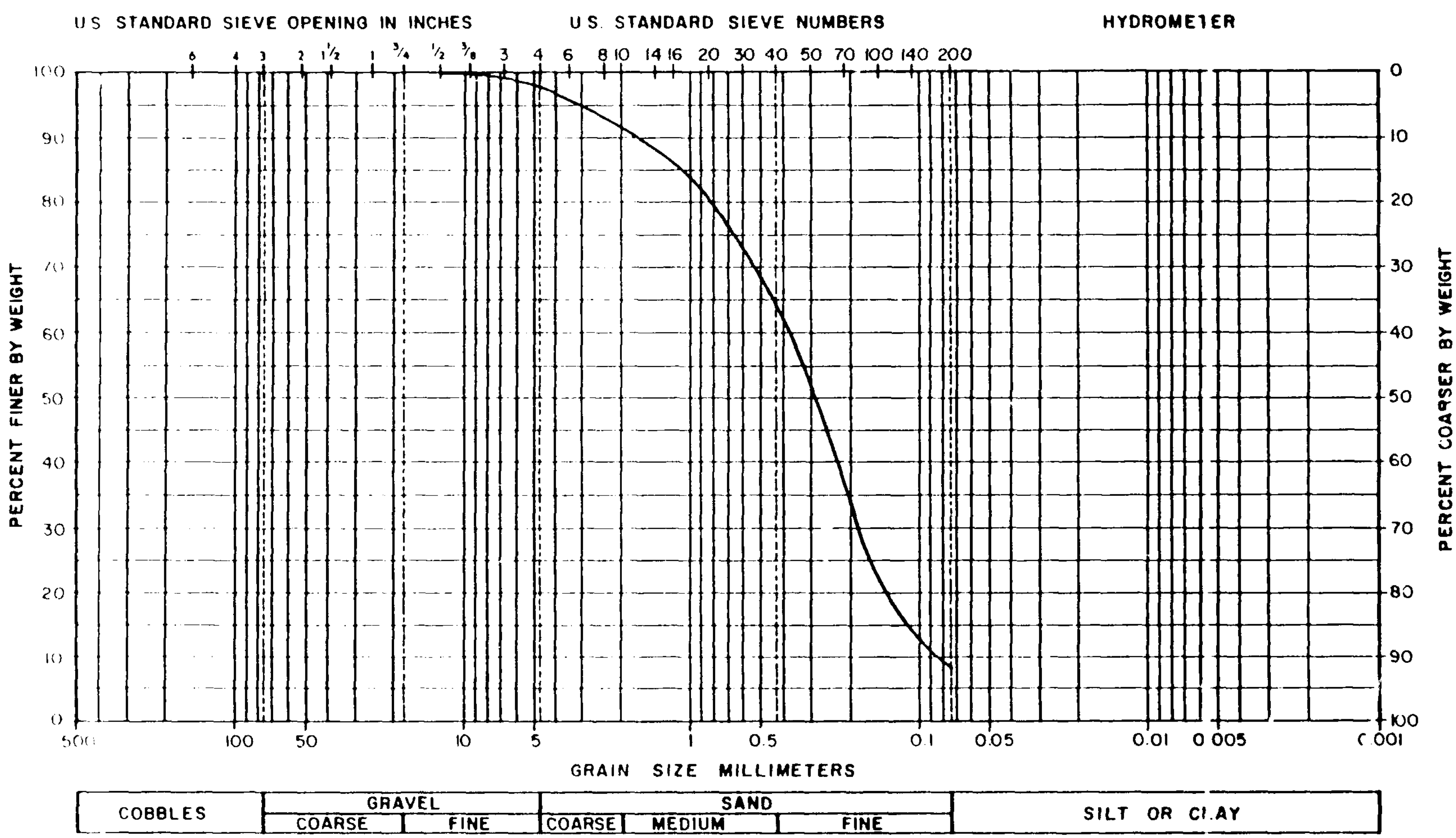
Army Corps of Engineers Vicksburg, Mississippi GEOTECHNICAL ENGINEERS INC	Re-evaluation of Lower San Fernando Dam San Fernando, California Project 85669	GRAIN SIZE CURVE BORING U111A SAMPLE UF19A FROM TEST R̄20 Sept. 2, 1987 Fig. F44



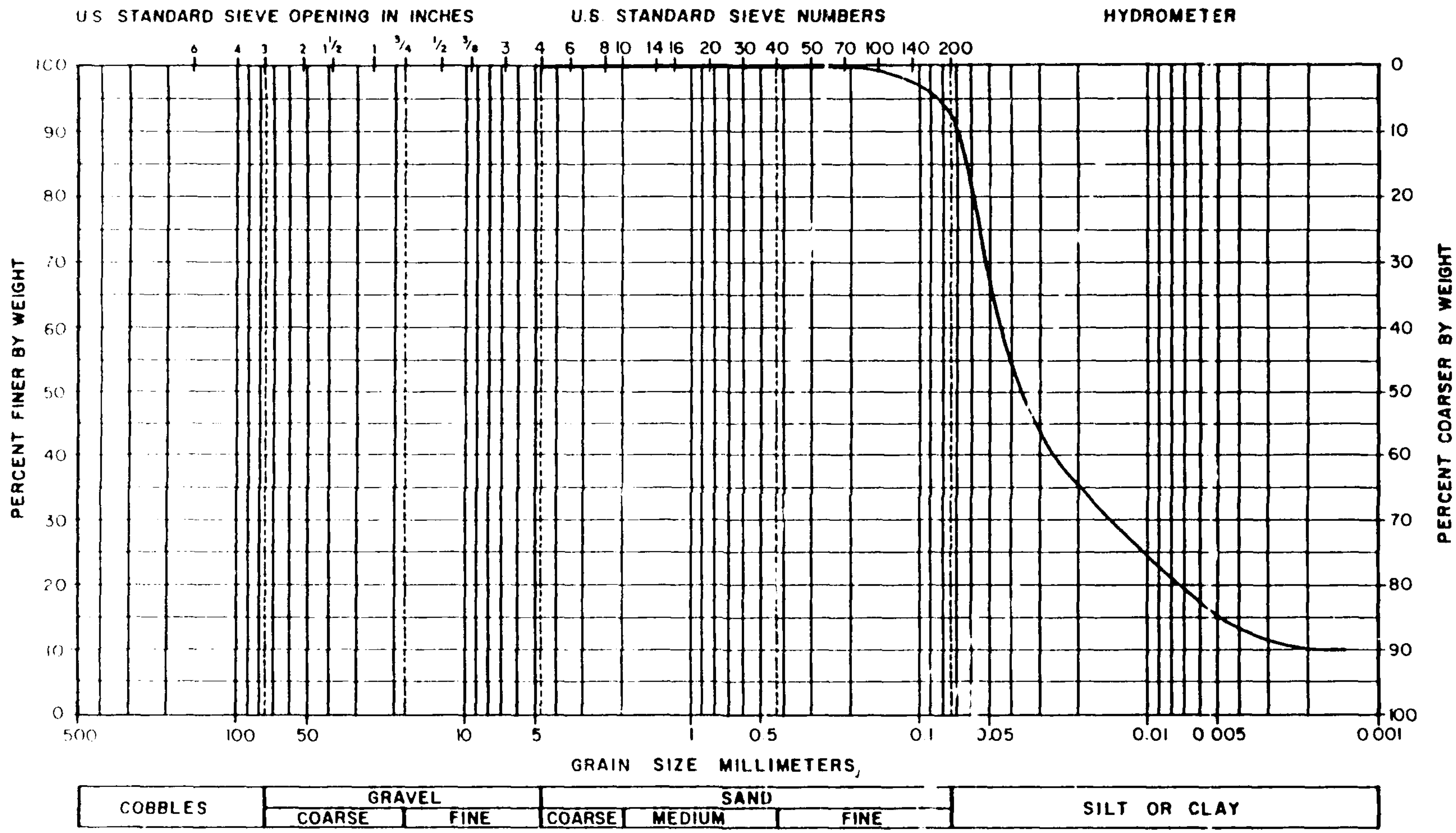
Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS309B 'ROM TEST CRR1
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F45



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS306A FROM TEST CRR2
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F46

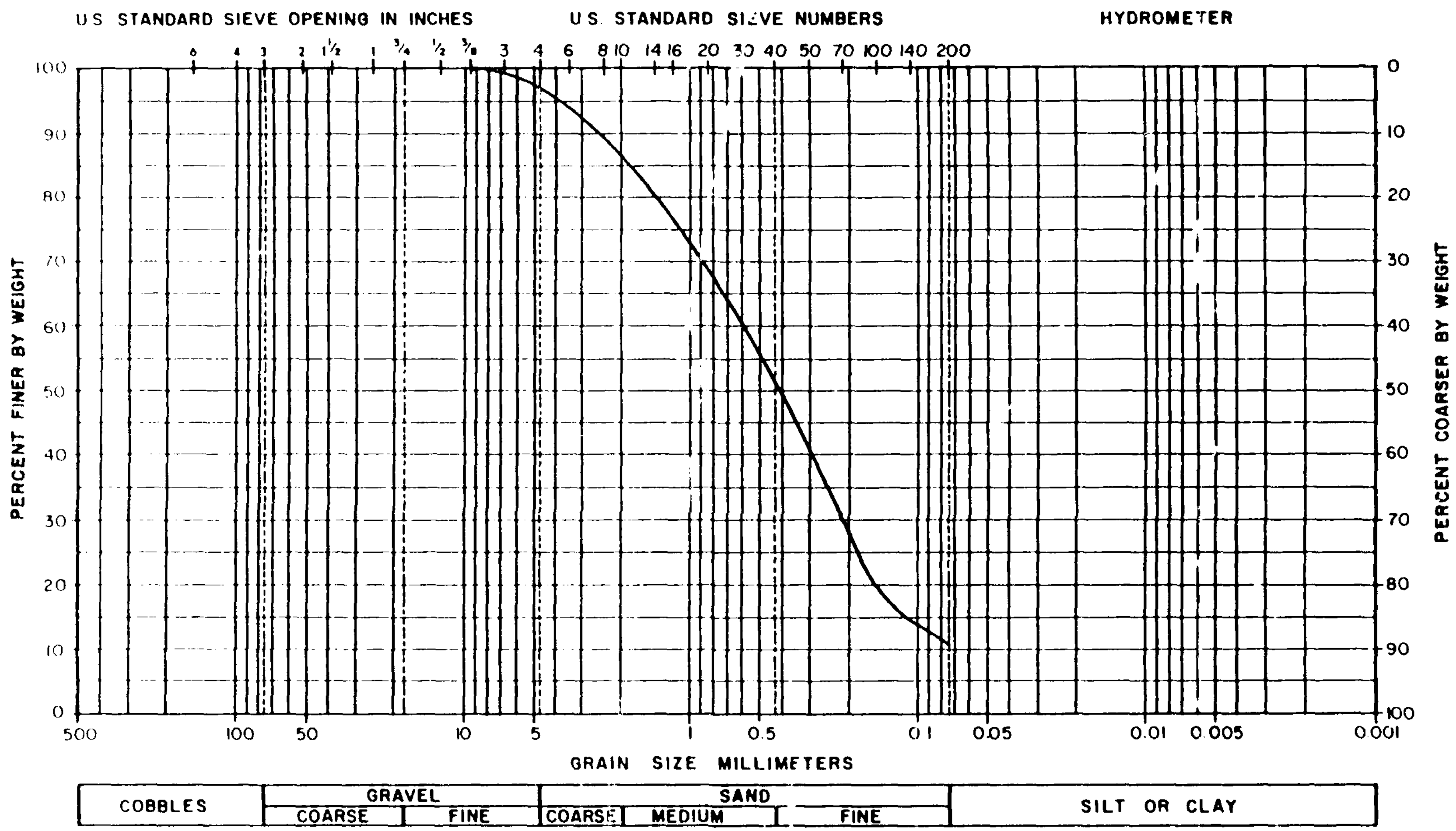


Army Corps of Engineers Vicksburg, Mississippi GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE EXPLORATORY SHAFT SAMPLE TS112 FROM TEST CRR3
	Project 85669	Sept. 2, 1987 Fig. F47

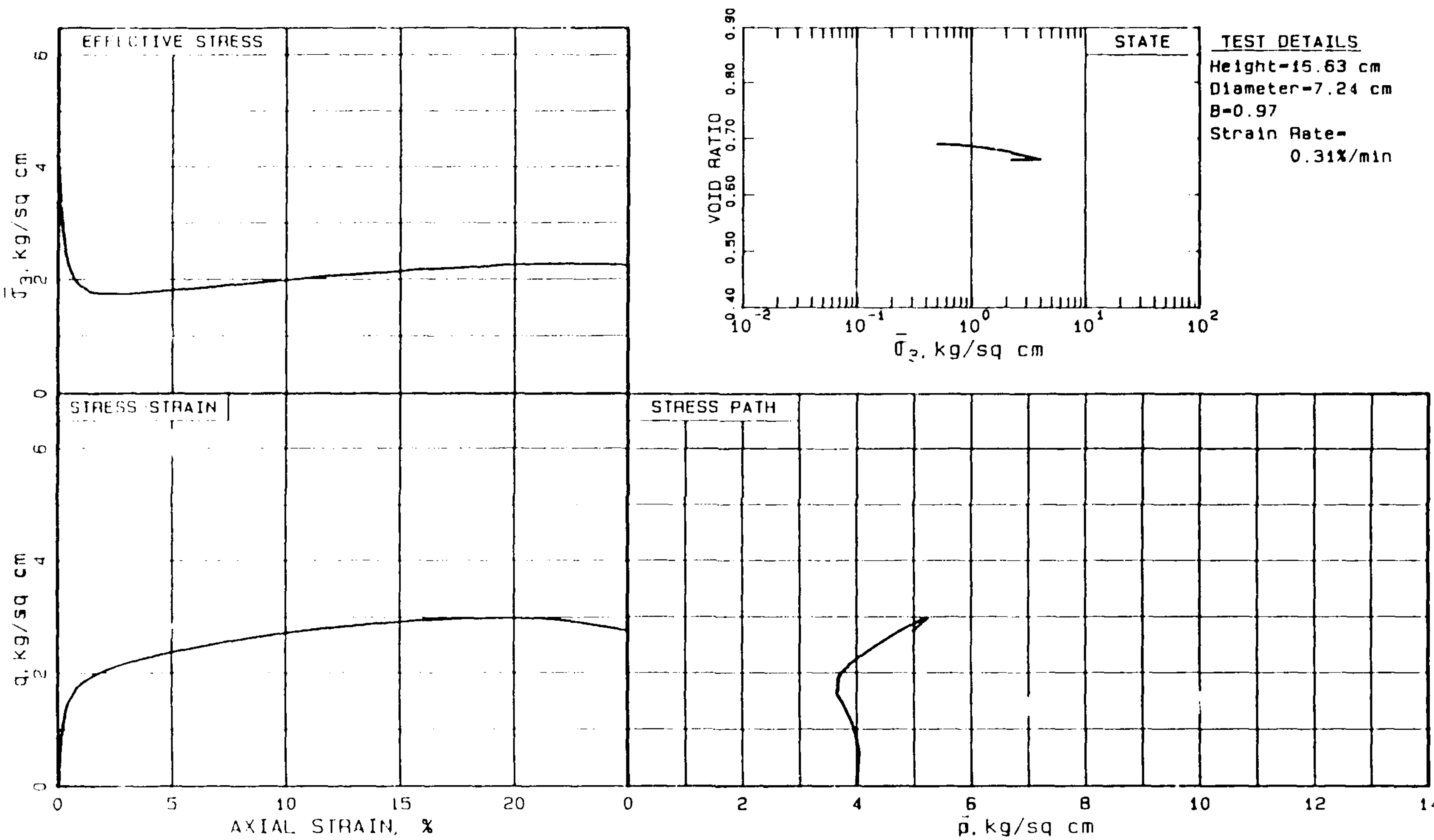


Grain size analyses performed on top 2 cm of sample.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING U111A SAMPLE UF9B FROM TEST CRR4
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F48



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	GRAIN SIZE CURVE BORING U111 SAMPLE UF8B FROM TEST CRR5
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F49



TEST DETAILS
Height=15.63 cm
Diameter=7.24 cm
B=0.97
Strain Rate=
0.31%/min

SOIL	Exp. Shaft	Sample TS302	STATE	$\bar{\sigma}_{3c}$=4.0 kg/sq cm	e_c=0.667
Top Depth 83.5 ft		El 1014.0 ft		K_c =1.0	γ_{dc}=100.7 pcf
Silty Sand, Stratified, 45% fines.					
STRUCTURE			LOADING		
Undisturbed Tripod Tube Sample.			Undrained Axial Monotonic Compression.		

R1
LOWER SAN FERNANDO DAM
PROJECT 85669 22 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
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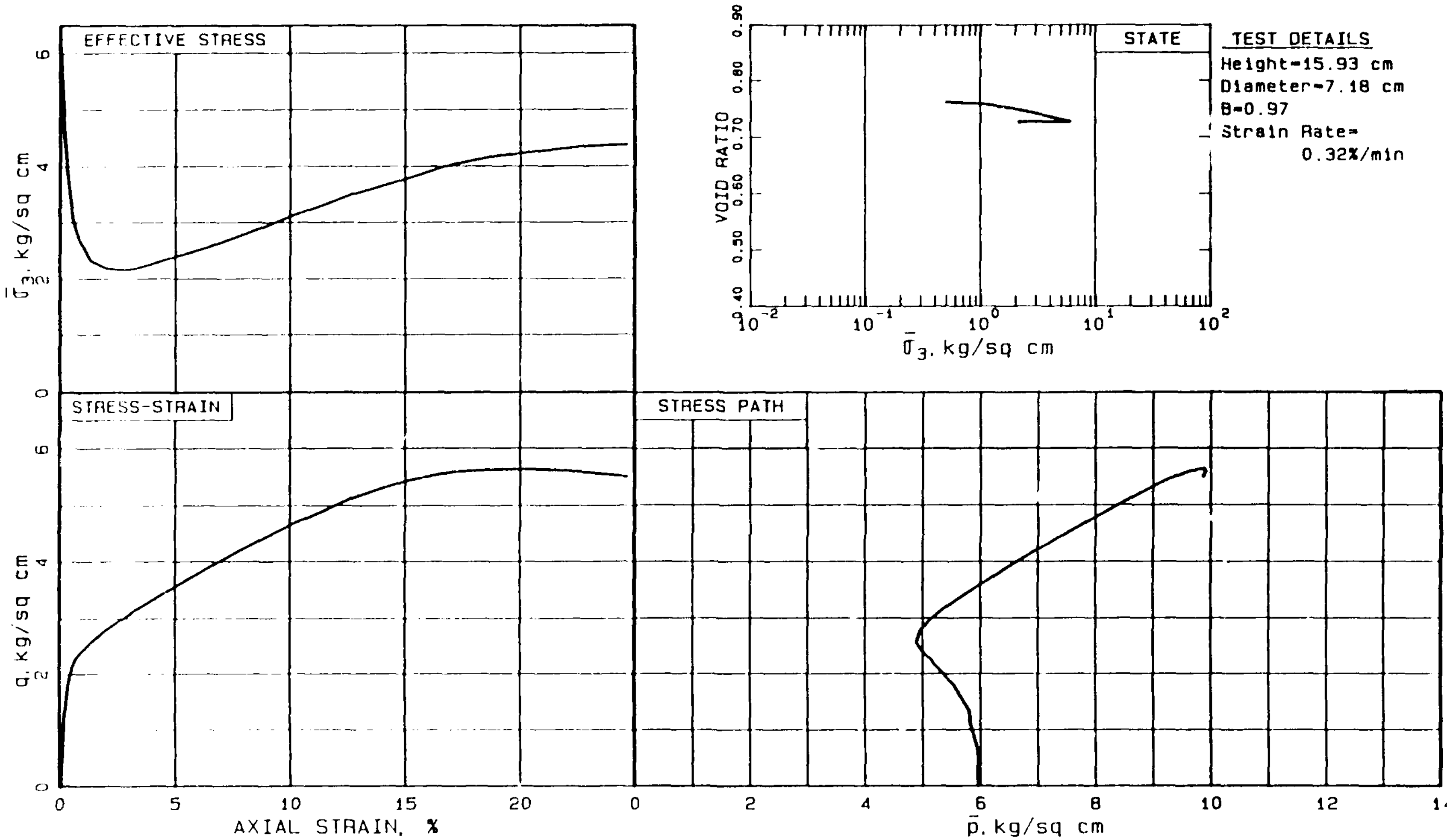
Fig. F50



SOIL	Exp. Shaft	Sample TS203
Top depth 65.0 ft		El 1032.5 ft
Silty Sand with 12 mm Silt Layer.		
STRUCTURE		
Undisturbed Tripod Tube Sample.		

STATE		
	$\bar{\sigma}_{3c}$=6.0 kg/sq cm	e_c=0.726
	K_c =1.0	γ_{dc}=96.4 pcf
LOADING		
Undrained Axial Monotonic Compression.		

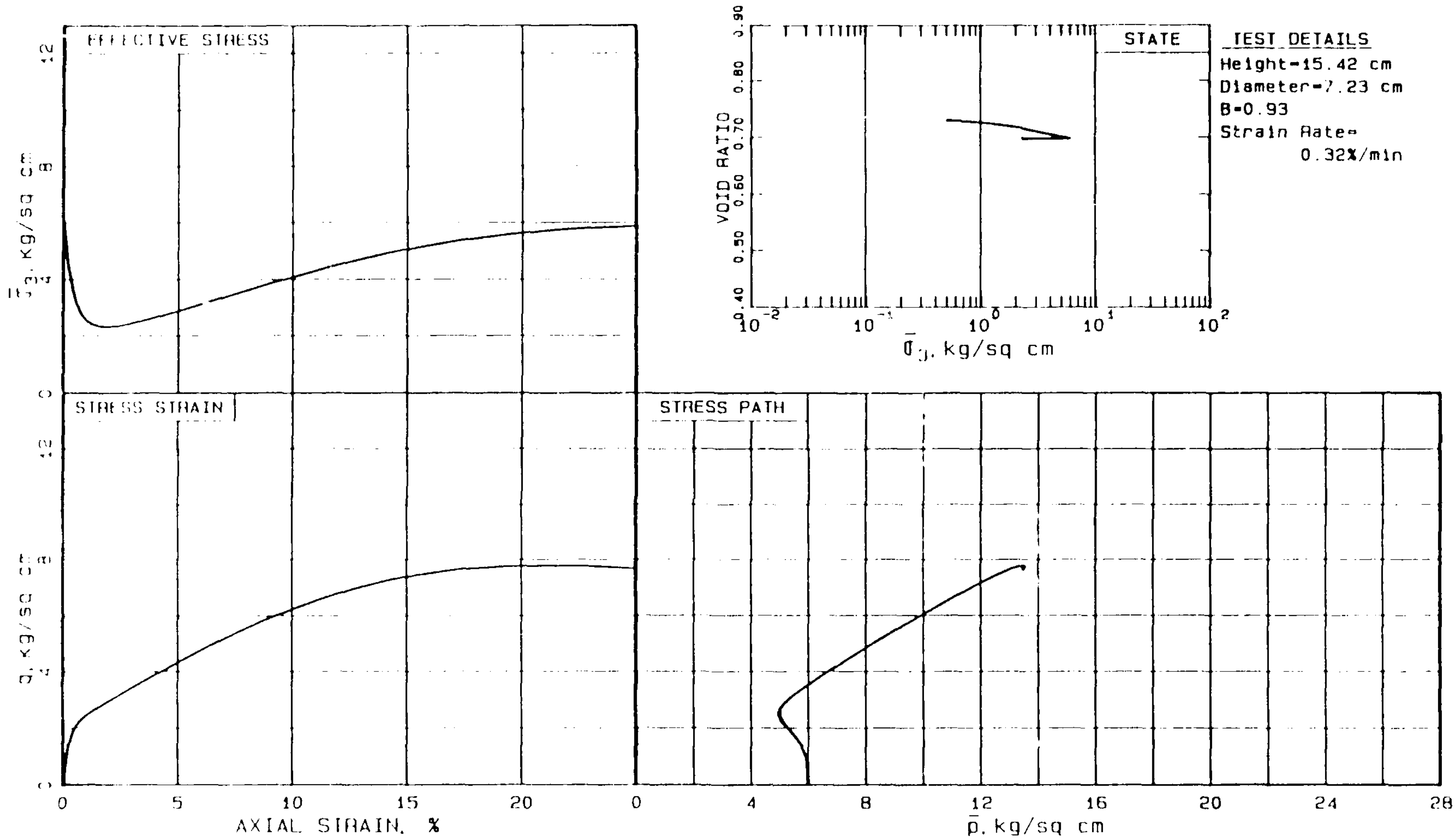
R2

LOWER SAN FERNANDO DAM

PROJECT 85669 22 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS

Fig. F51



SOIL	Exp. Shaft	Sample TS116
Top depth 56.4 ft		El 1041.1 ft
Silty Sand, Stratified, 31% fines.		

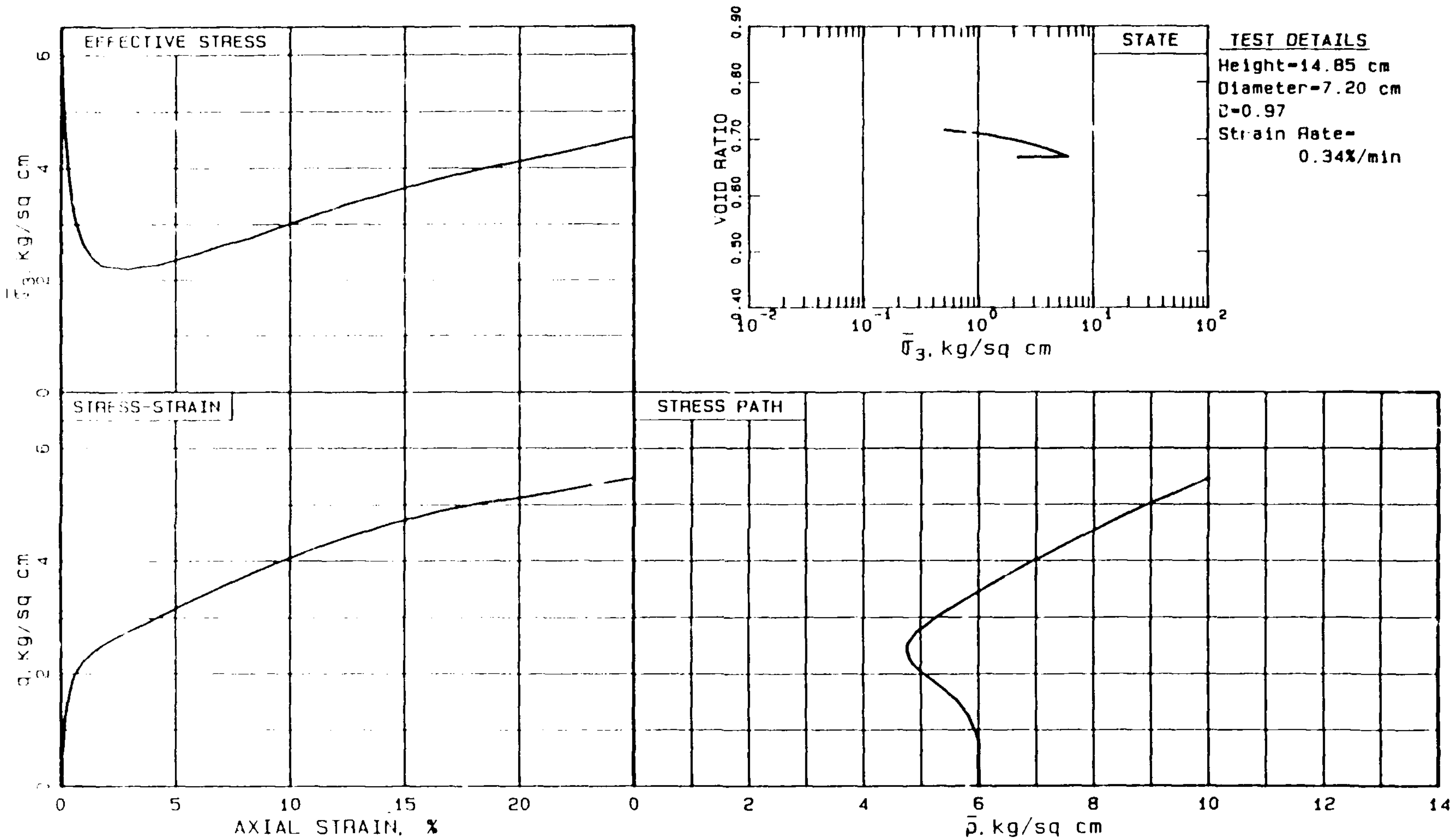
STRUCTURE: Undisturbed Tripod Tube Sample.

STATE: $\bar{\sigma}_{3c}$ =6.0 kg/sq cm e_c =0.697 K_c =1.0 γ_{dc}=98.5 pcf

LOADING: Undrained Axial Monotonic Compression.

R3
LOWER SAN FERNANDO DAM
PROJECT 85669 22 JANUARY 1987

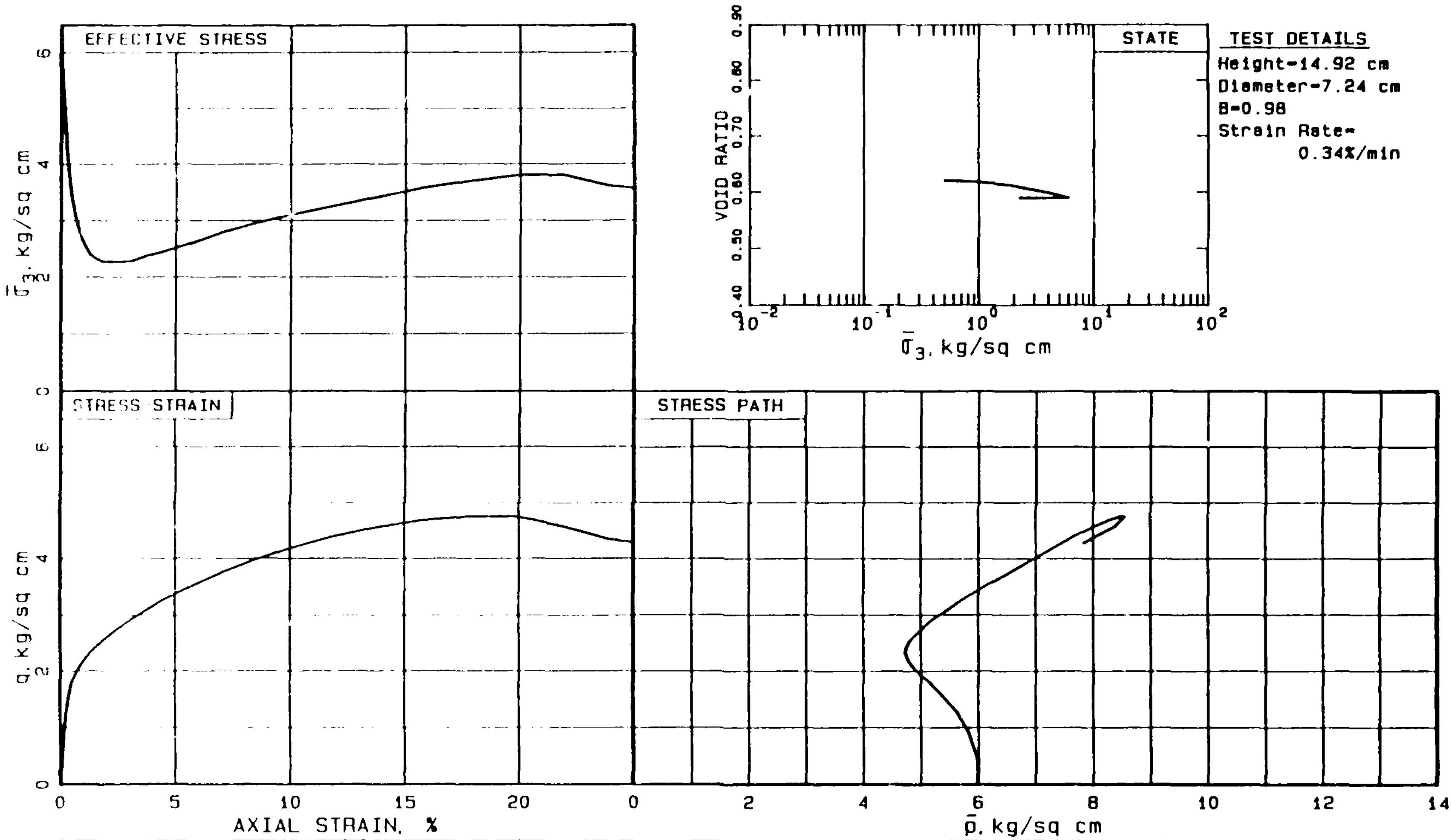
GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



SOIL	Exp. Shaft	Sample TS102	STATE	$\bar{\sigma}_{3c}$=6.0 kg/sq cm	e_c=0.667
Top depth 53.2 ft		El 1044.3 ft		K_c =1.0	γ_{dc}=100.3 pcf
Silty Sand with 2 cm Silt Layer.					
STRUCTURE			LOADING		
Undisturbed Tripod Tube Sample.			Undrained Axial Monotonic Compression.		

R4
LOWER SAN FERNANDO DAM
PROJECT 85669 22 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



TEST DETAILS
Height=14.92 cm
Diameter=7.24 cm
B=0.98
Strain Rate=
0.34%/min

SOIL	Boring U111A	Sample UF19C
Top Depth 84 3 ft		El 1010.8 ft
Silty Sand, Stratified, 40% fines.		

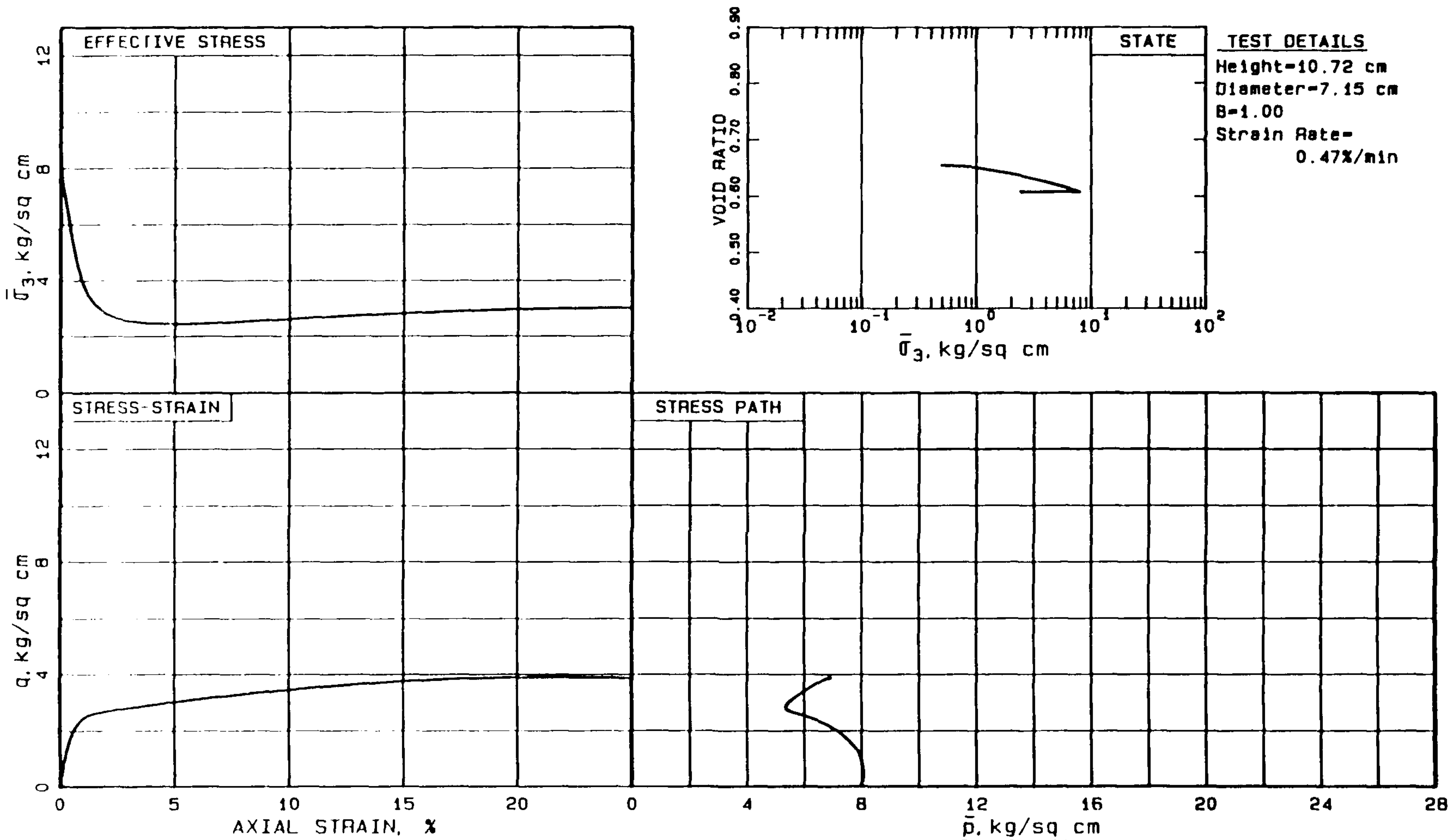
STRUCTURE
Undisturbed Fixed Piston Tube Sample.

STATE
$\bar{\sigma}_{3c}$=6.0 kg/sq cm e_c=0.590
K_c =1.0 γ_{dc}=105.6 pcf

LOADING
Undrained Axial Monotonic Compression.

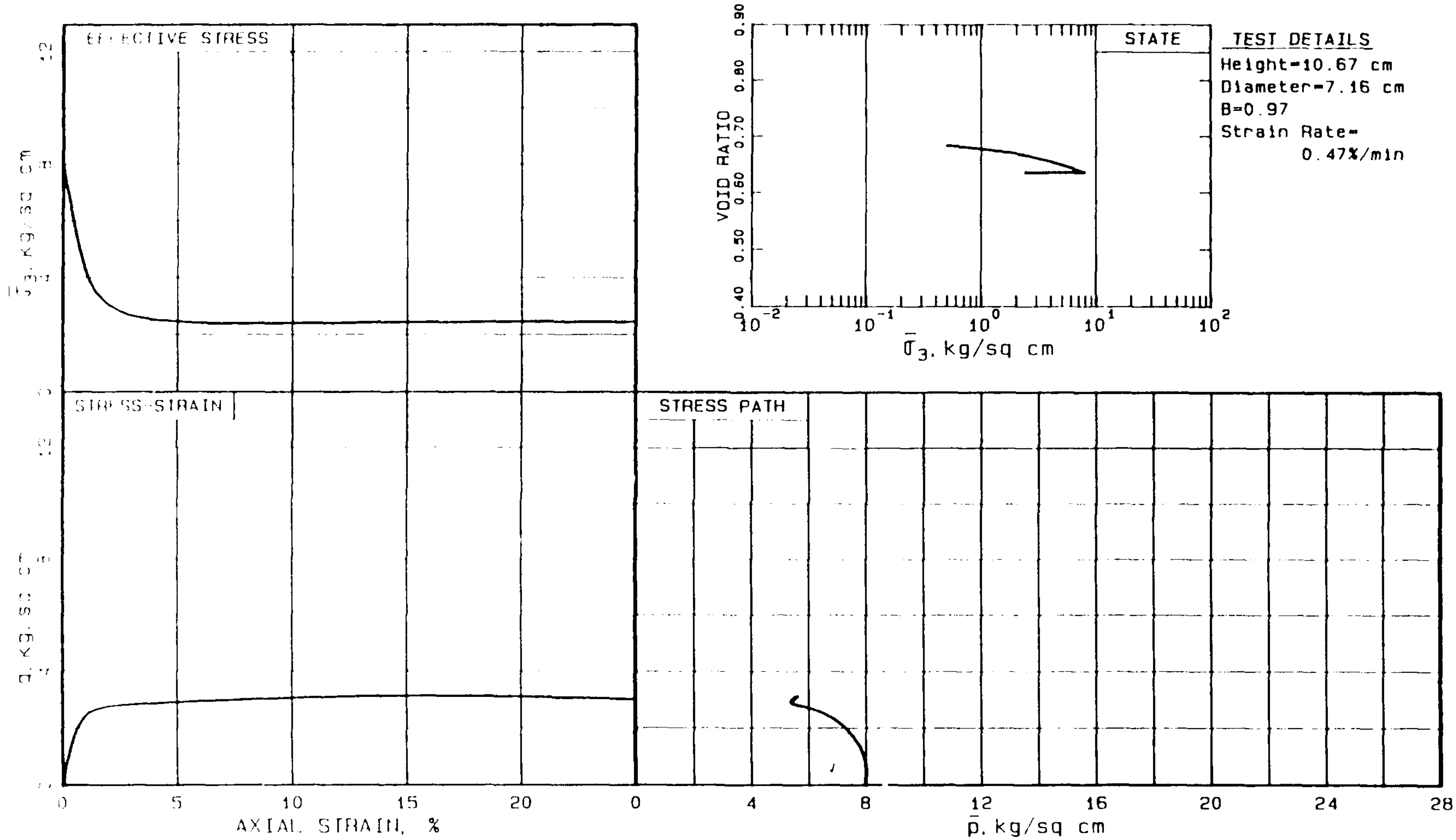
R5
LOWER SAN FERNANDO DAM
PROJECT 85669 22 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



SOIL Exp. Shaft Sample TS309A Top Depth 83.4 ft El 1014.2 ft Silty Sand, Stratified, 36% fines.	STATE $\bar{\sigma}_{3c}$=8.0 kg/sq cm e_c=0.605 K_c =1.0 γ_{dc}=104.6 pcf	R6 LOWER SAN FERNANDO DAM PROJECT 85669 22 JANUARY 1987
STRUCTURE Undisturbed Tripod Tube Sample.	LOADING Undrained Axial Monotonic Compression.	GEOTECHNICAL ENGINEERS INC. WINCHESTER - MASSACHUSETTS

Fig. F55



SOIL | Exp. Shaft | Sample TS306B
Top Depth 84.4 ft | El 1013.1 ft
Silty Sand, Stratified, 44% fines.

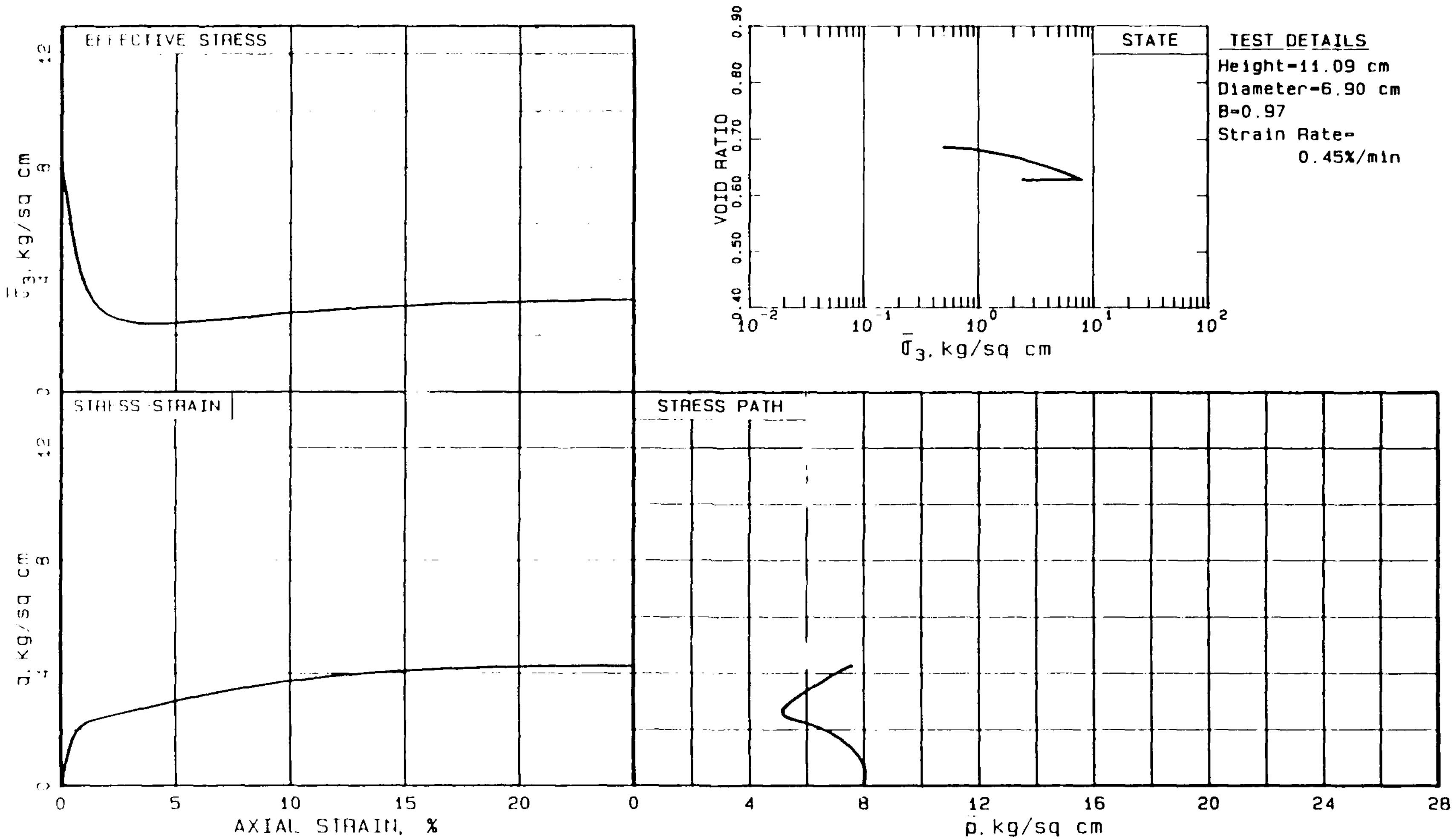
STRUCTURE
Undisturbed Tripod Tube Sample.

STATE
$\bar{\sigma}_{3c}$=8.0 kg/sq cm e_c=0.636
K_c =1.0 γ_{dc}=102.6 pcf

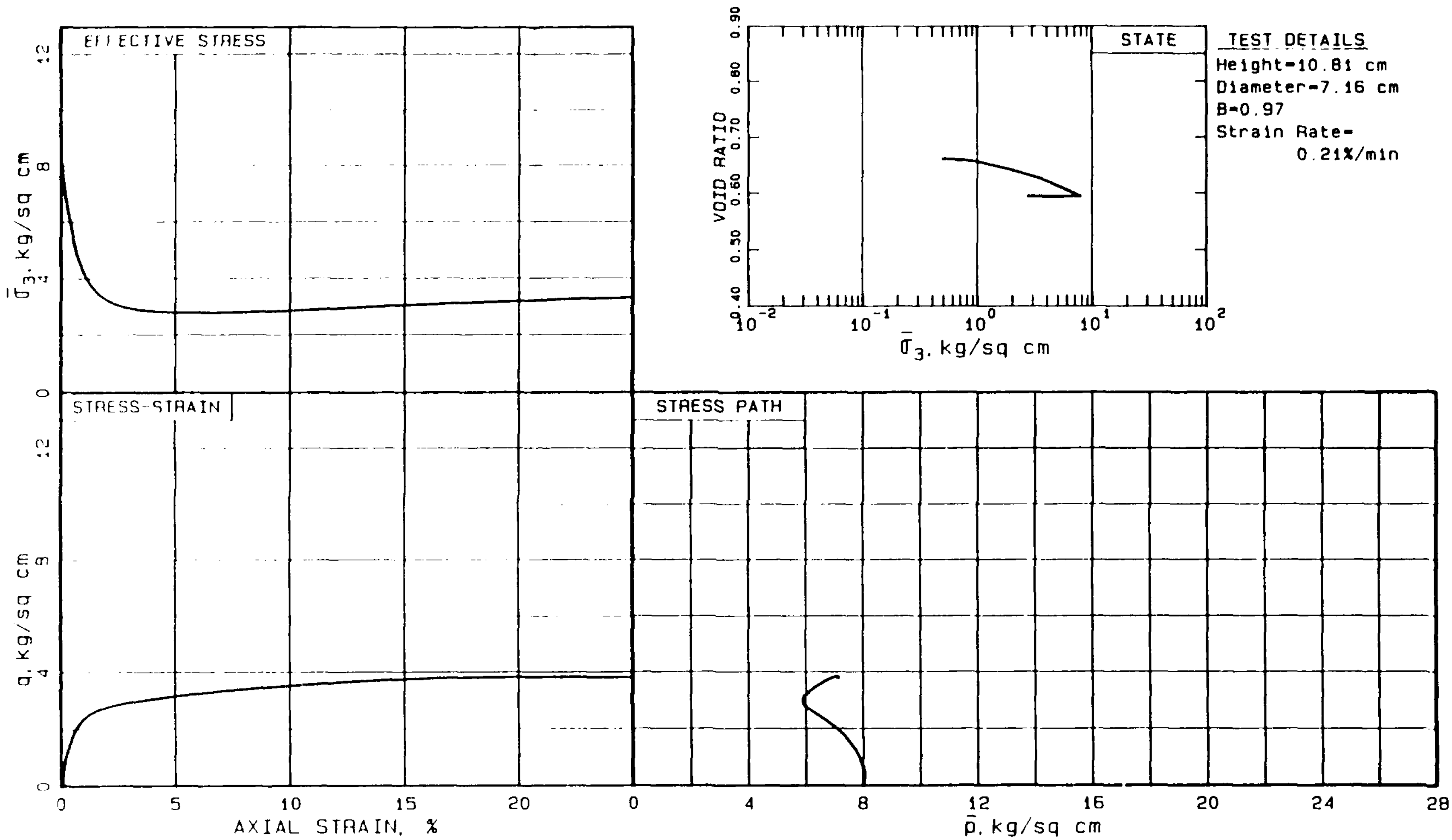
LOADING
Undrained Axial Monotonic Compression.

R7
LOWER SAN FERNANDO DAM
PROJECT 85669 22 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



SOIL: Boring U103 Sample UF3C Top depth 80.9 ft El 1013.0 ft Silty Sand, Stratified, 47% fines.	STATE: $\bar{\sigma}_{3c}$=8.0 kg/sq cm e_c=0.626 K_c =1.0 γ_{dc}=103.2 pcf	R8 LOWER SAN FERNANDO DAM PROJECT 85669 22 JANUARY 1987
STRUCTURE: Undisturbed Fixed Piston Tube Sample.	LOADING: Undrained Axial Monotonic Compression.	GEOTECHNICAL ENGINEERS INC. WINCHESTER - MASSACHUSETTS



SOIL Boring U105 Sample UF10C
Top depth 89.8 ft El 1024.3 ft
Sandy Silt, Stratified.

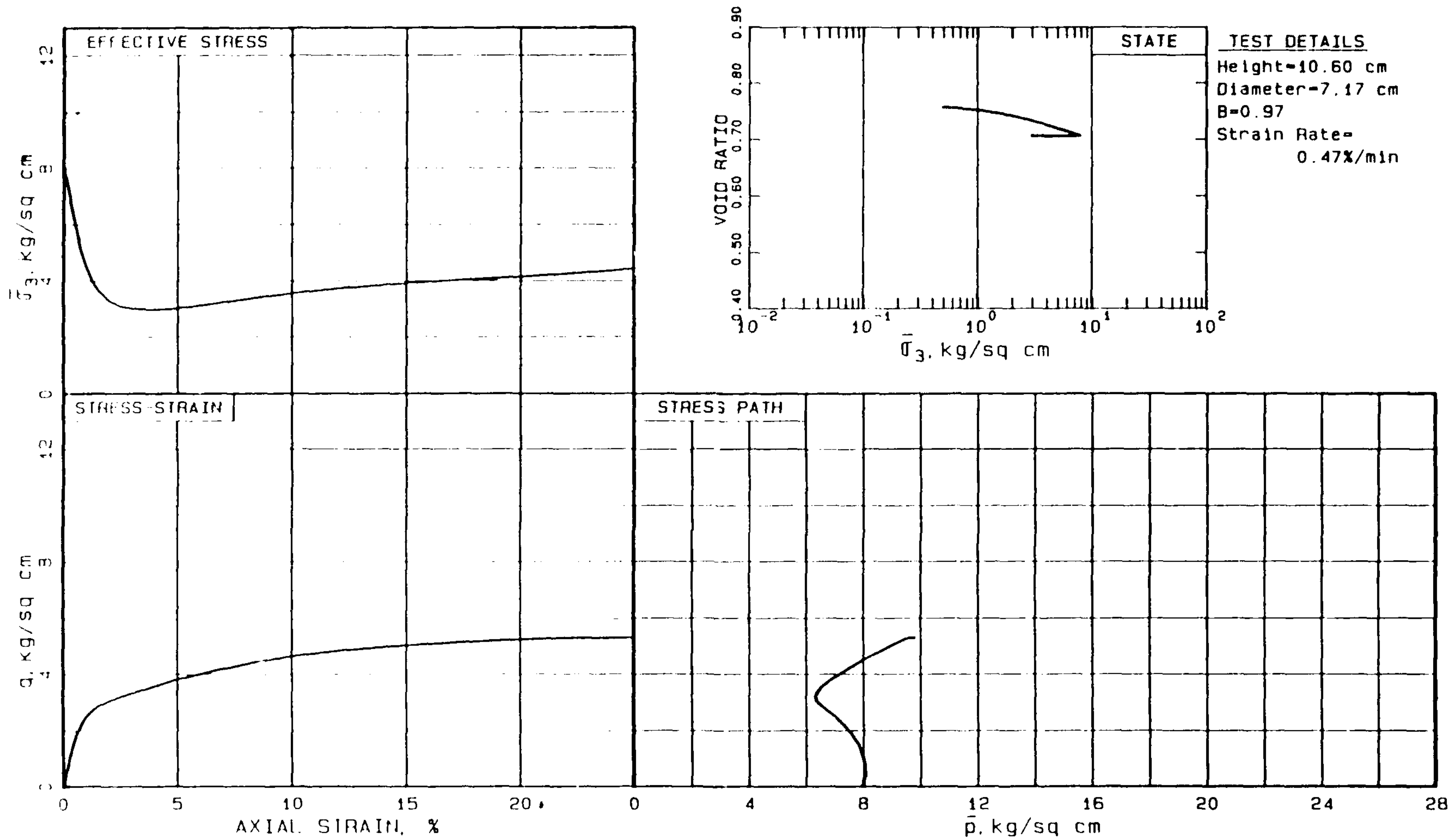
STRUCTURE
Undisturbed Fixed Piston Tube Sample.

STATE $\bar{\sigma}_{3c}$ =8.0 kg/sq cm e_c =0.595
K_c =1.0 γ_{dc} =106.0 pcf

LOADING
Undrained Axial Monotonic Compression.

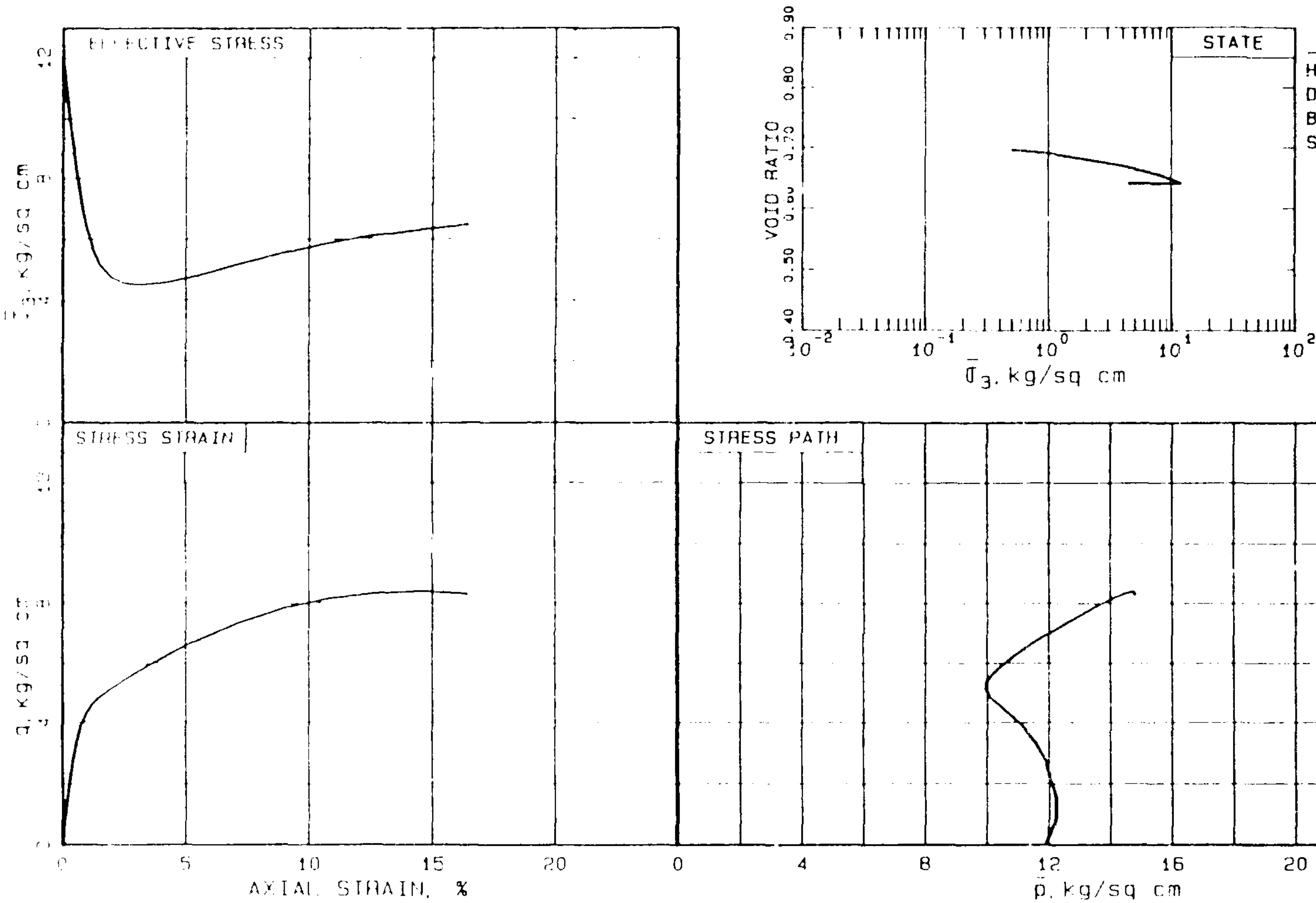
R9
LOWER SAN FERNANDO DAM
PROJECT 85669 22 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



SOIL Exp. Shaft Sample TS207A Top depth 65.0 ft El 1032.5 ft Silty Sand, 29% fines.	STATE $\bar{\sigma}_{3c}$=8.0 kg/sq cm e_c=0.707 K_c =1.0 γ_{dc}=98.0 pcf	R10 LOWER SAN FERNANDO DAM PROJECT 85669 22 JANUARY 1987
STRUCTURE Undisturbed Tripod Tube Sample.	LOADING Undrained Axial Monotonic Compression.	GEOTECHNICAL ENGINEERS INC. WINCHESTER - MASSACHUSETTS

Fig. E59



TEST DETAILS

Height=10.68 cm
Diameter=7.21 cm
B=1.00
Strain Rate=
0.47%/min

SOIL		
Fxp. Shaft	Sample TS103	
Top depth 53.2 ft	El 1044.3 ft	
Silty Sand, 19% fines		

STRUCTURE: Untrimmed Triped Tube Sample

STATE: $\bar{\sigma}_{3c}$=12.0 kg/sq cm e_c=0.642
K_c =1.0 γ_{dc}=103.0 pcf

LOADING: Undrained Axial Monotonic Compression

R11
LOWER SAN FERNANDO DAM
PROJECT 85669 22 JANUARY 1987

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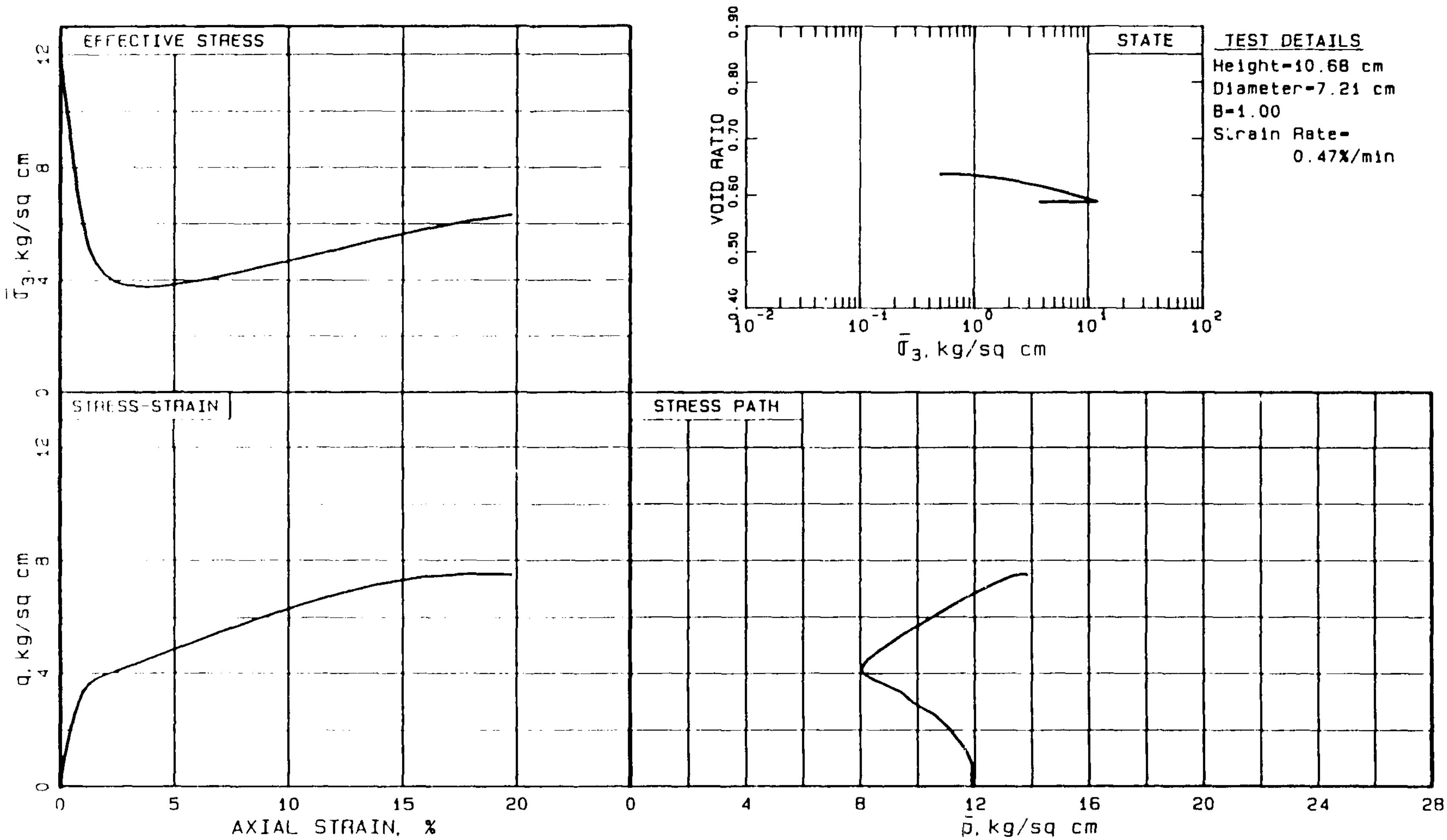
WINCHESTER · MASSACHUSETTS



SOIL	Exp. Shaft	Sample TS315
Top depth 85.1 ft		El 1012.4 ft
Silty Sand, Stratified, 46% fines.		
STRUCTURE		
Undisturbed Tripod Tube Sample.		

STATE	$\bar{\sigma}_{3c}$=12.0 kg/sq cm e_c=0.589
	K_c =1.0 γ_{dc}=105.6 pcf
LOADING	
Undrained Axial Monotonic Compression.	

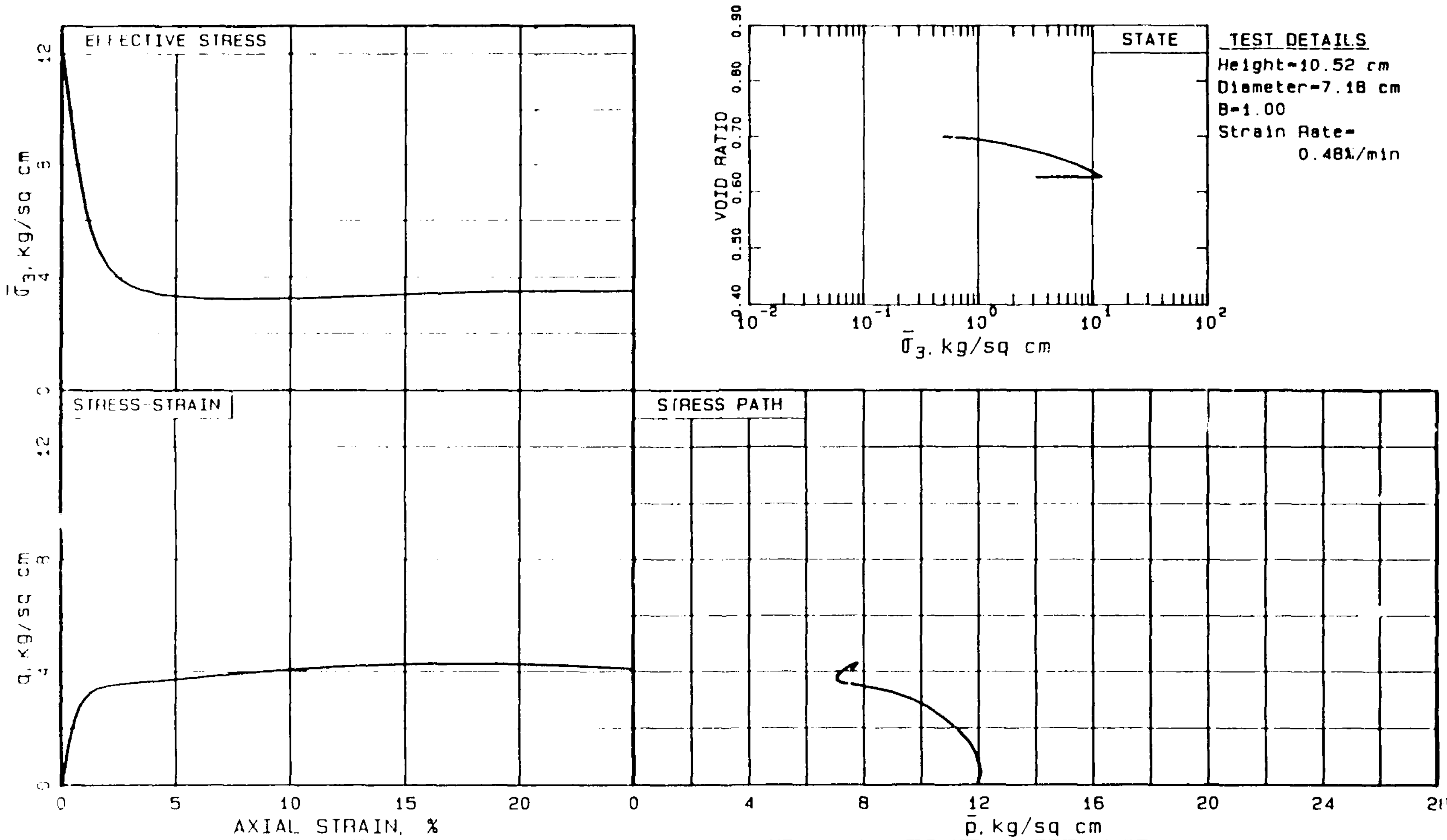
R12

LOWER SAN FERNANDO DAM

PROJECT 85669 22 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS

Fig. F61



SOIL	Exp. Shaft	Sample TS314
Top depth 84.1 ft		El 1013.4 ft
Sandy Silt, Stratified, 69% fines.		
STRUCTURE		
Undisturbed Tripod Tube Sample.		

STATE	$\bar{\sigma}_{3c}$=12.0 kg/sq cm	e_c=0.625
	K_c =1.0	γ_{dc}=103.3 pcf
LOADING		
Undrained Axial Monotonic Compression.		

R13
LOWER SAN FERNANDO DAM
PROJECT 85669 22 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
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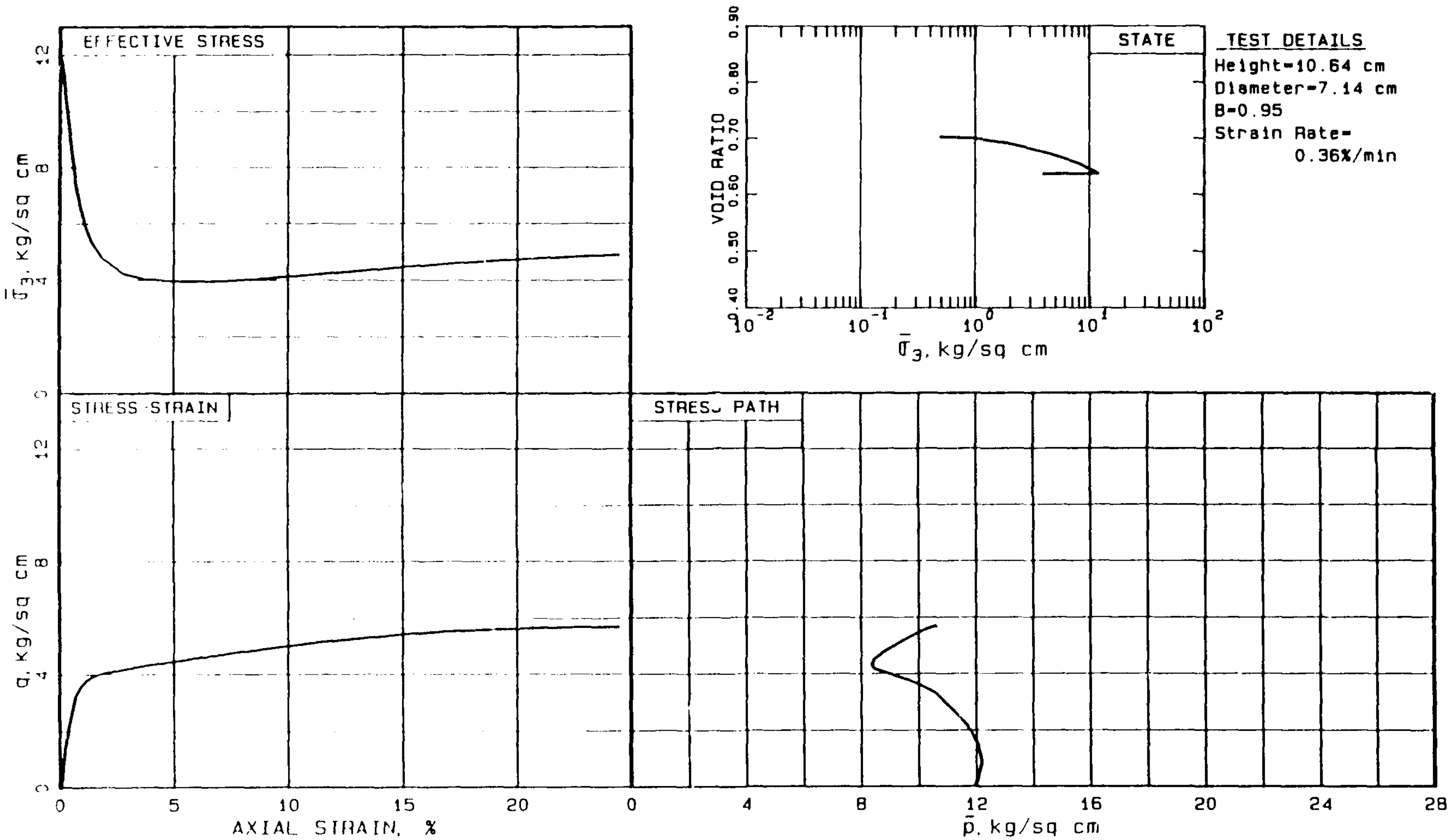
Fig. F62



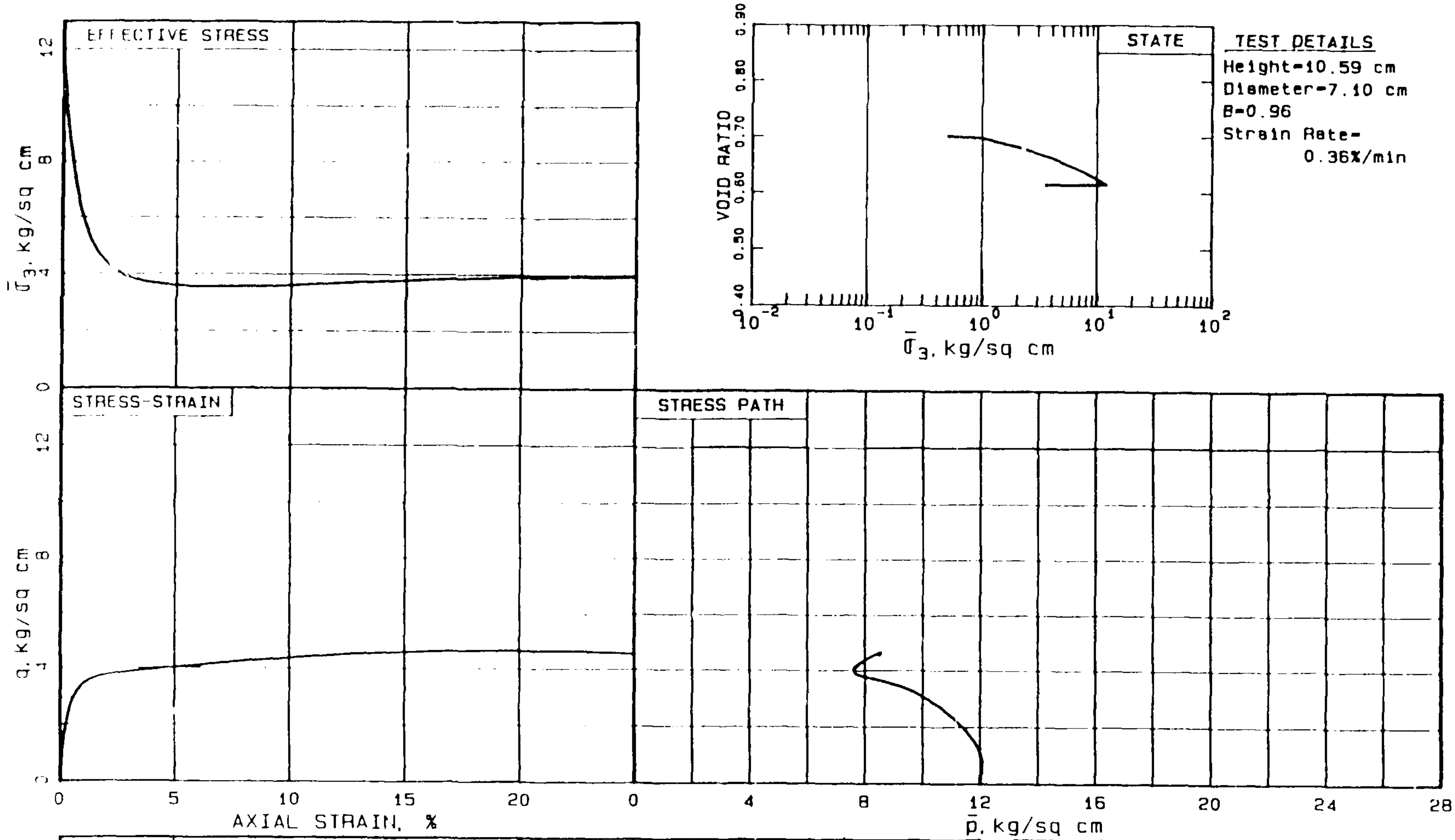
TEST DETAILS
Height=10.64 cm
Diameter=7.14 cm
B=0.95
Strain Rate=
0.36%/min

SOIL	Boring U111A Sample UF14D Top depth 74.5 ft El 1020.6 ft Silt, Stratified.	STATE	$\bar{\sigma}_{3c}$=12.0 kg/sq cm e_c=0.635 K_c =1.0 γ_{dc}=102.7 pcf
STRUCTURE	Undisturbed Fixed Piston Tube Sample.	LOADING	Undrained Axial Monotonic Compression.

R14
LOWER SAN FERNANDO DAM
PROJECT 85669 22 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS

Fig. 263



SOIL	Boring U111A Sample UF16D
	Top depth 78.5 ft El 1016.6 ft
	Sandy Silt, Stratified, 36% Sand.
STRUCTURE	Undisturbed Fixed Piston Tube Sample.

STATE	$\bar{\sigma}_{3c}$=12.0 kg/sq cm e_c=0.617
	K_c =1.0 γ_{dc}=103.8 pcf
LOADING	Undrained Axial Monotonic Compression.

R15

LOWER SAN FERNANDO DAM

PROJECT 85669 22 JANUARY 1987

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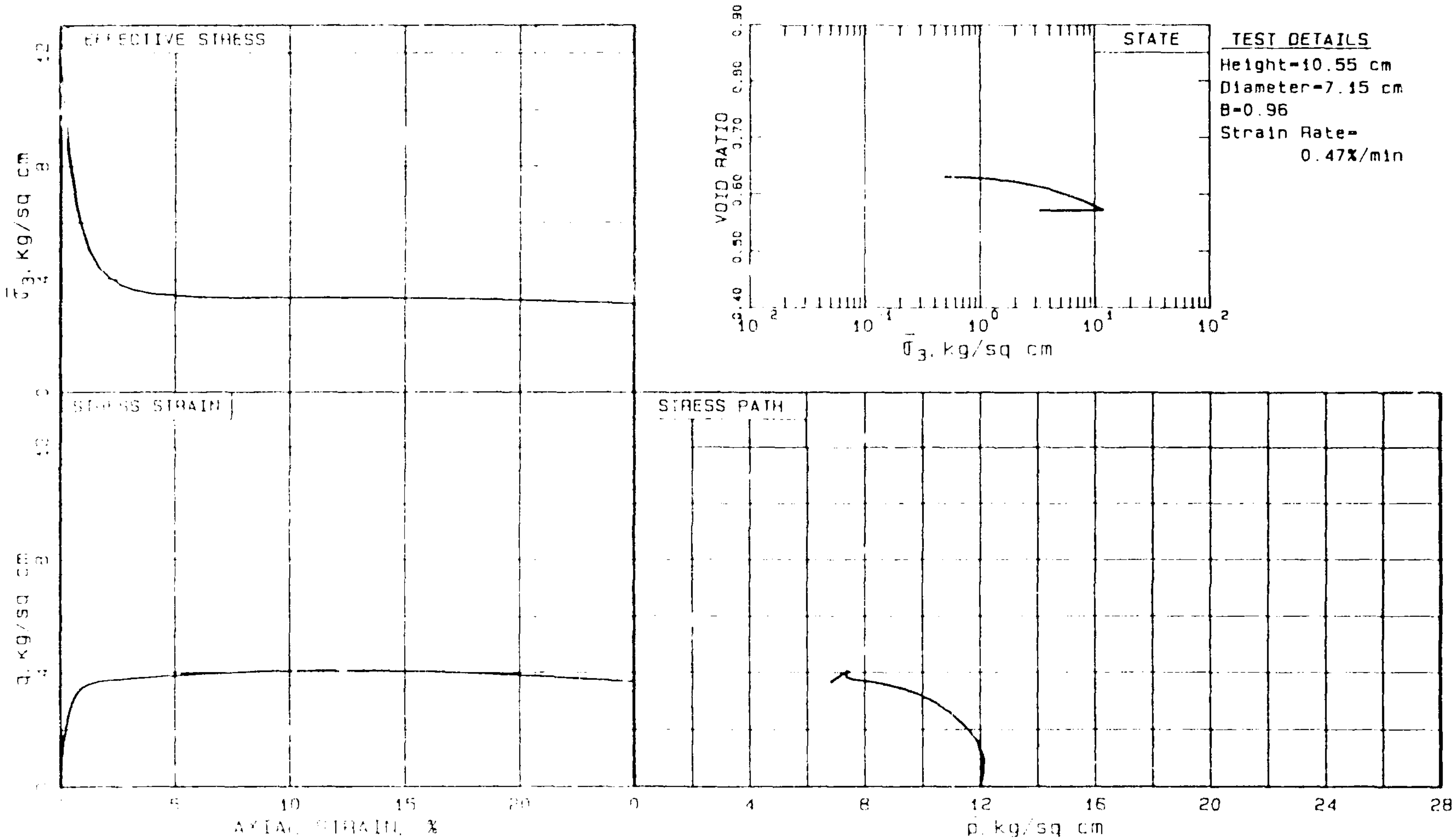

Boring U111A Sample UF200
Depth 86.5 ft El 1008.6 ft
Silty Sand, 35% fines

Undisturbed Fixed Piston Tube Sample

STATE $\bar{\sigma}_{3c}$ =12.0 kg/sq cm e_c =0.558
K_c =1.0 γ_{dc} =107.0 pcf

LOADING
Undrained Axial Monotonic Compression

R16
LOWER SAN FERNANDO DAM
PROJECT 85669 22 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
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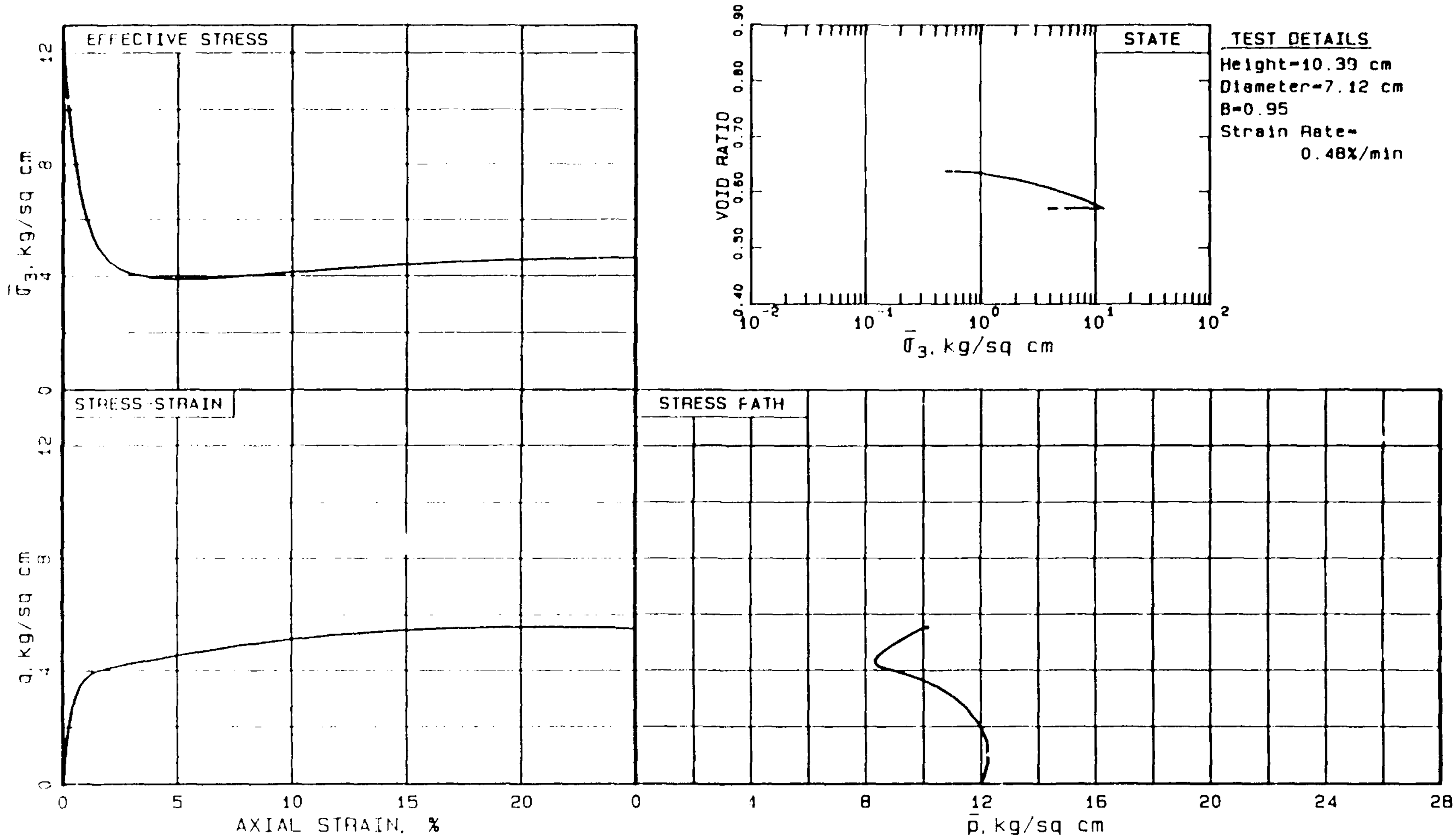

TEST DETAILS
Height=10.39 cm
Diameter=7.12 cm
B=0.95
Strain Rate= 0.48%/min

SOIL	Boring U111A Sample UF21A Top depth 87.1 ft El 1008.0 ft Silty Sand, 46% fines.	STATE	$\bar{\sigma}_{3c}$=12.0 kg/sq cm e_c=0.567 K_c =1.0 γ_{dc}=107.1 pcf
STRUCTURE	Undisturbed Fixed Piston Tube Sample	LOADING	Undrained Axial Monotonic Compression

R17
LOWER SAN FERNANDO DAM
PROJECT 85669 22 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
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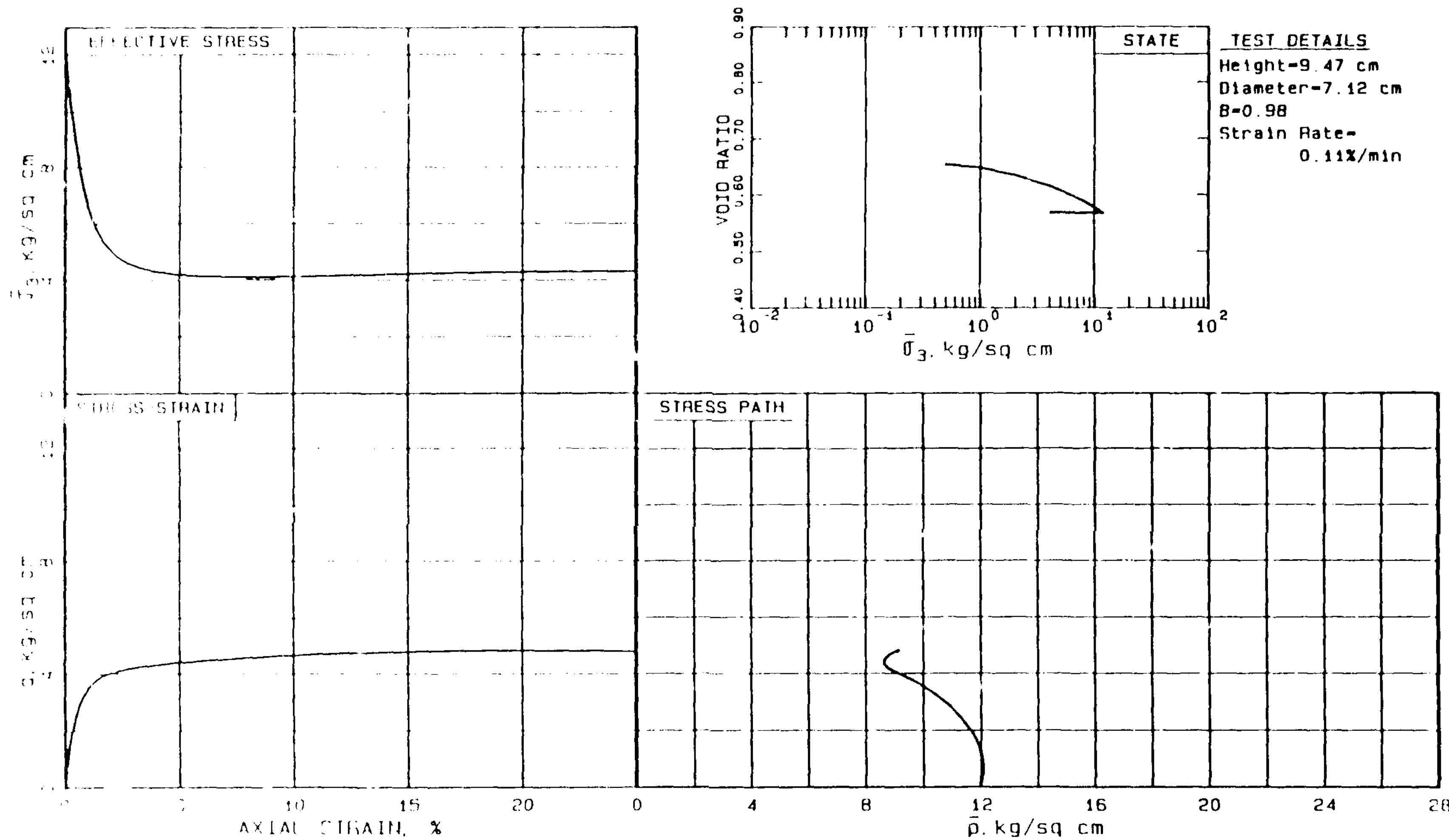


SOIL | Boring U111 Sample UF238
Top depth 87.7 ft El 1007.4 ft
Silt and Stratified Silty Sand

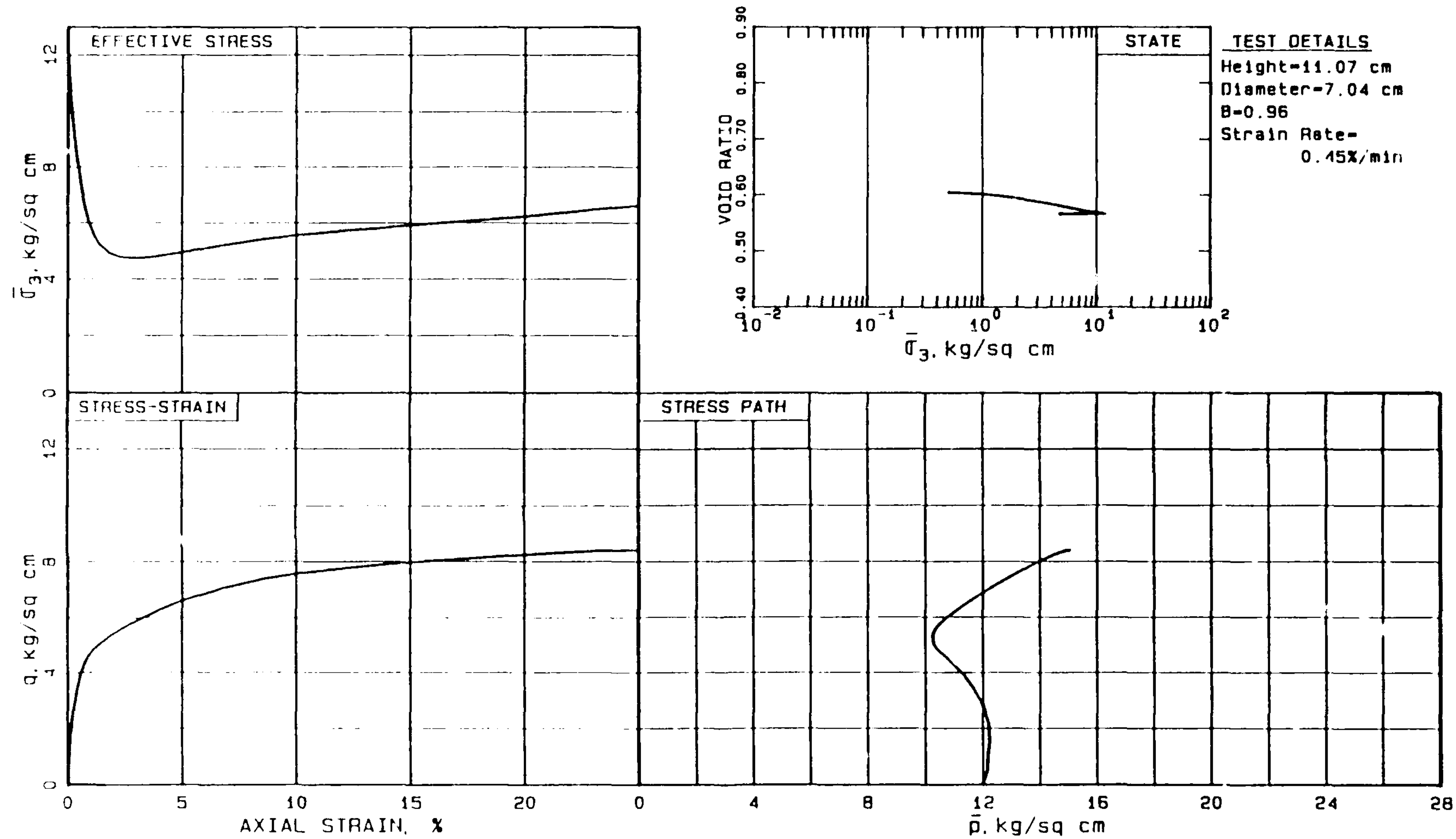
STRUCTURE
Undisturbed Fixed Piston Tube Sample

STATE | $\bar{\sigma}_{3c}$=12.0 kg/sq cm e_c=0.560
K_c =1.0 γ_{dc}=107.6 pcf

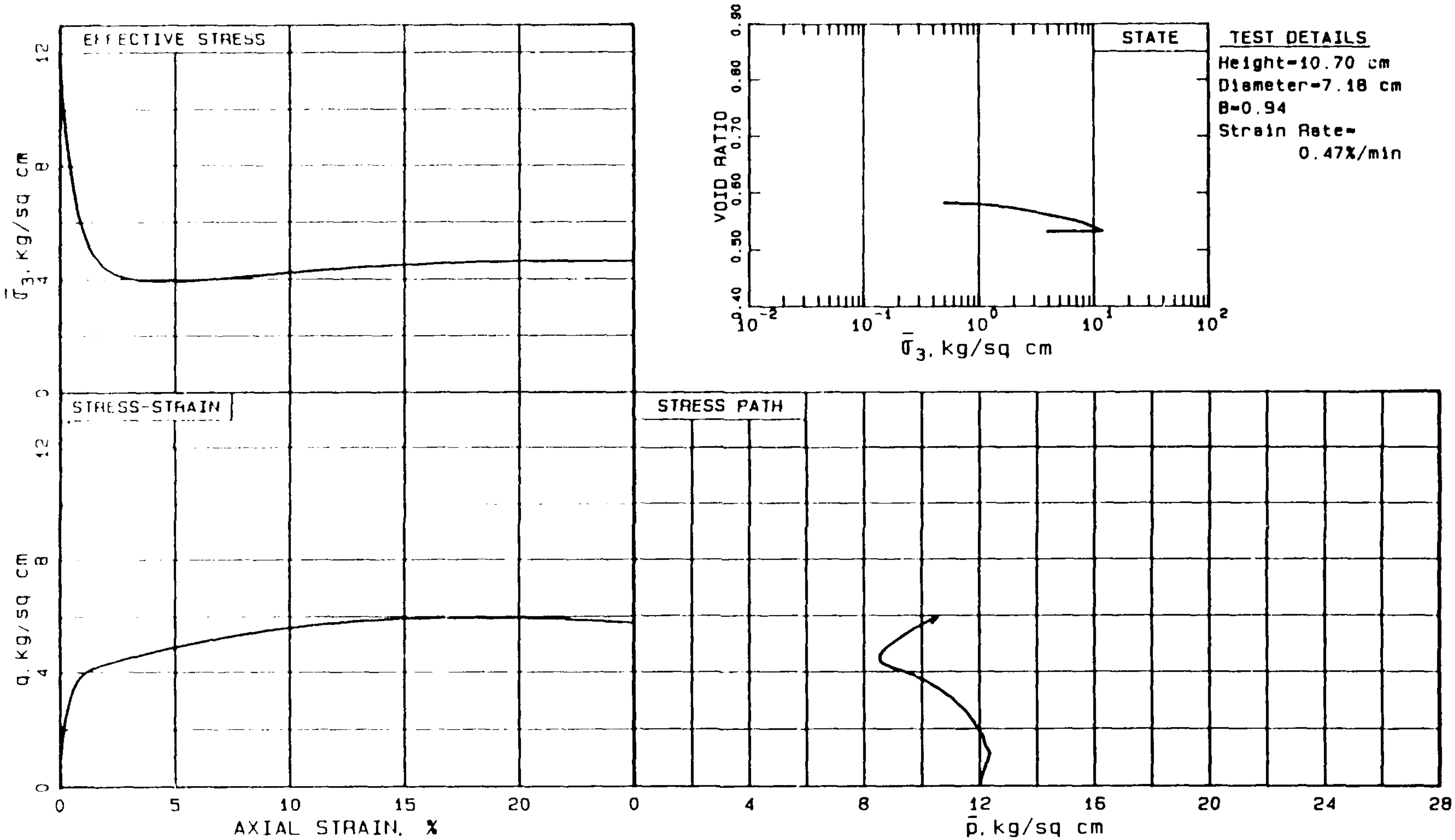
LOADING
Undrained Axial Monotonic Compression

R18
LOWER SAN FERNANDO DAM
PROJECT 85669 22 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS

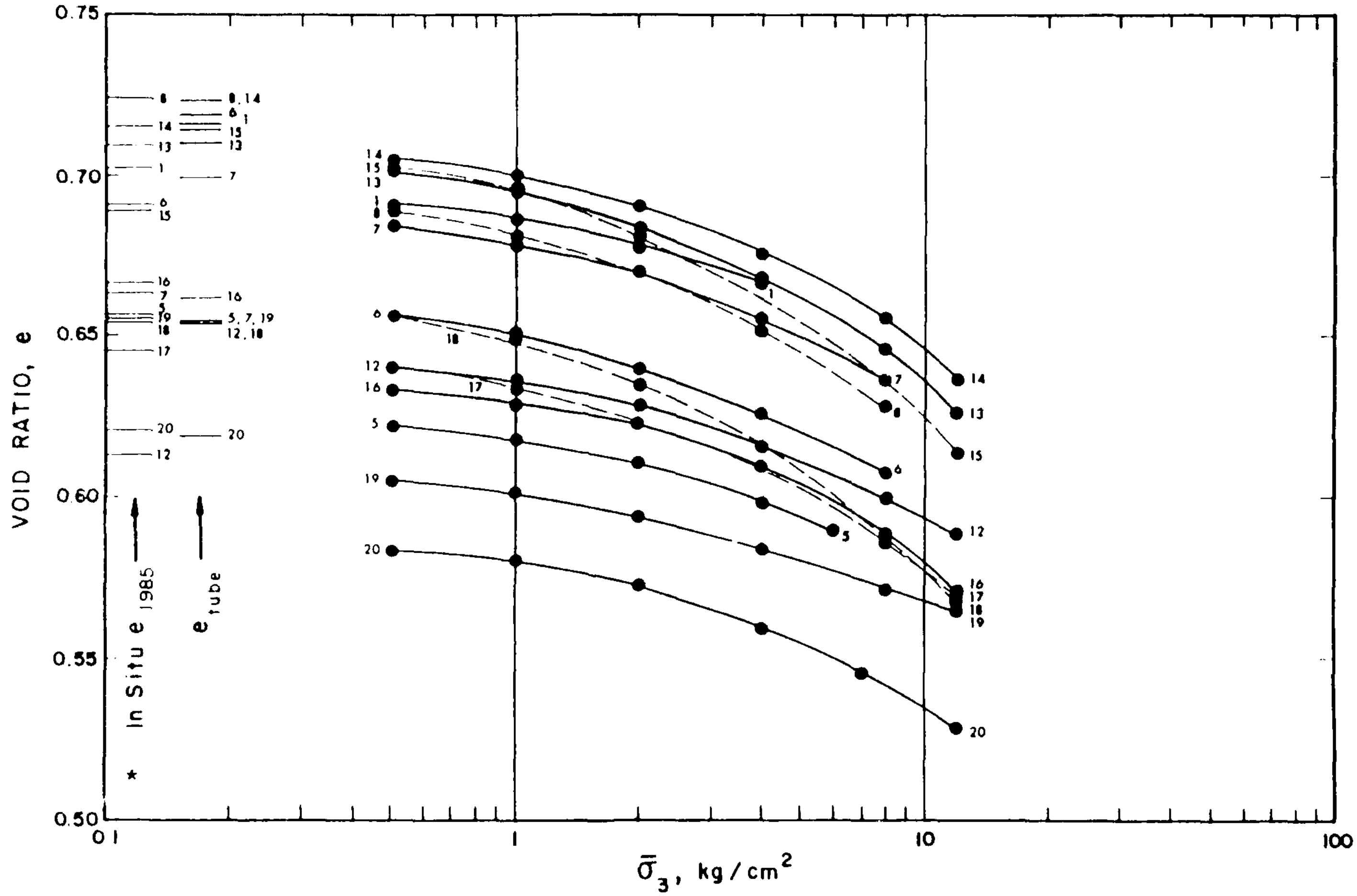


SOIL	Boring U103 Sample UF3B Top depth 80.4 ft El 1014.7 ft Silty Sand, 22% fines.	STATE	$\bar{\sigma}_{3c}$=12.0 kg/sq cm e_c=0.563 K_c =1.0 γ_{dc}=107.4 pcf	R19 LOWER SAN FERNANDO DAM PROJECT 85669 22 JANUARY 1987
STRUCTURE	Undisturbed Fixed Piston Tube Sample.	LOADING	Undrained Axial Monotonic Compression.	GEOTECHNICAL ENGINEERS INC. WINCHESTER - MASSACHUSETTS



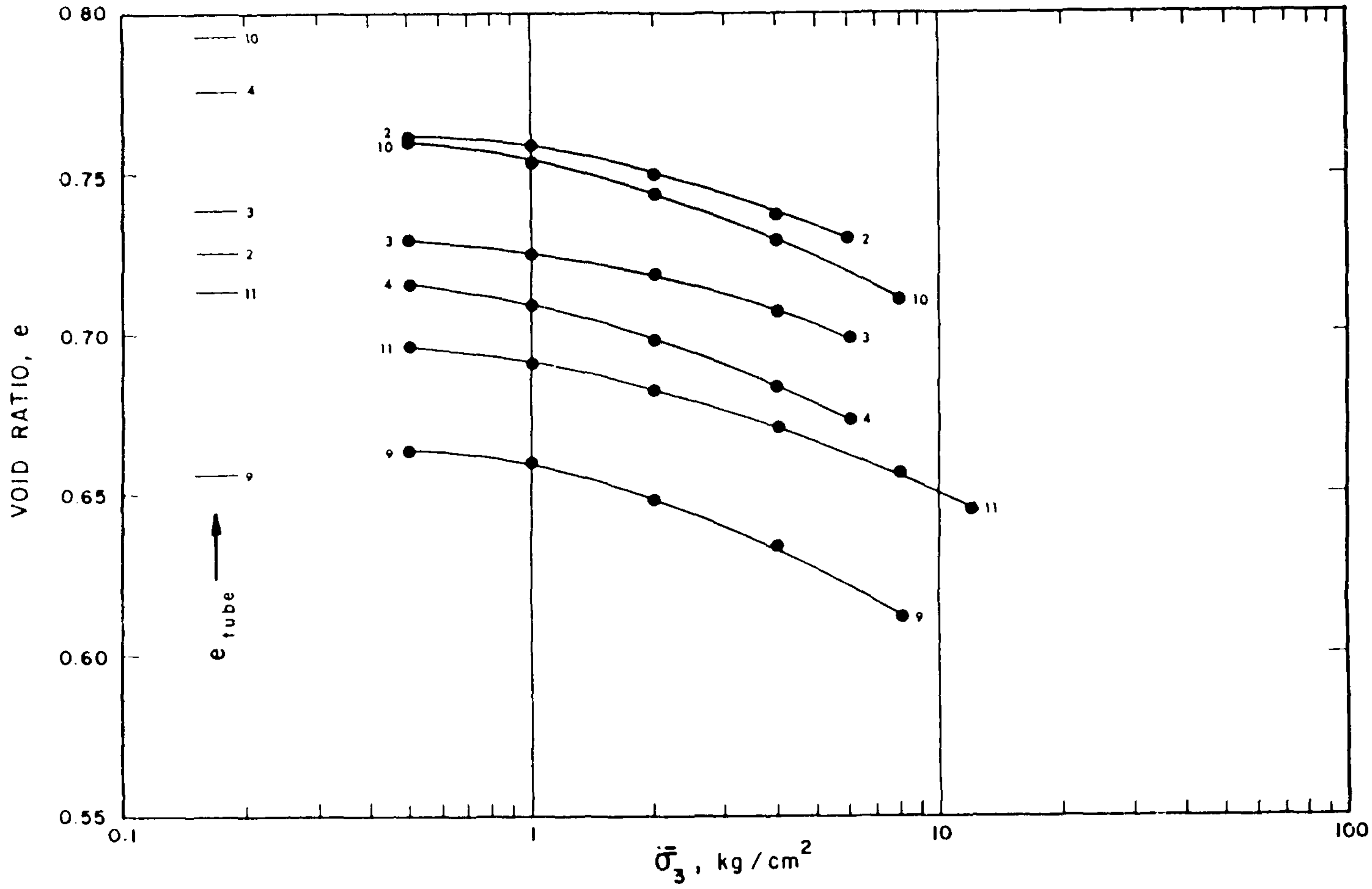
TEST DETAILS
Height=10.70 cm
Diameter=7.18 cm
B=0.94
Strain Rate=
0.47%/min

SOIL — Boring U111A Sample UF19A Top depth 83.3 ft El 1011.8 ft Silty Sand, 27% fines.	STATE — $\bar{\sigma}_{3c}$=12.0 kg/sq cm e_c=0.532 K_c =1.0 γ_{dc}=109.6 pcf	R20 LOWER SAN FERNANDO DAM PROJECT 85669 22 JANUARY 1987
STRUCTURE — Undisturbed Fixed Piston Tube Sample.	LOADING — Undrained Axial Monotonic Compression.	GEOTECHNICAL ENGINEERS INC. WINCHESTER - MASSACHUSETTS

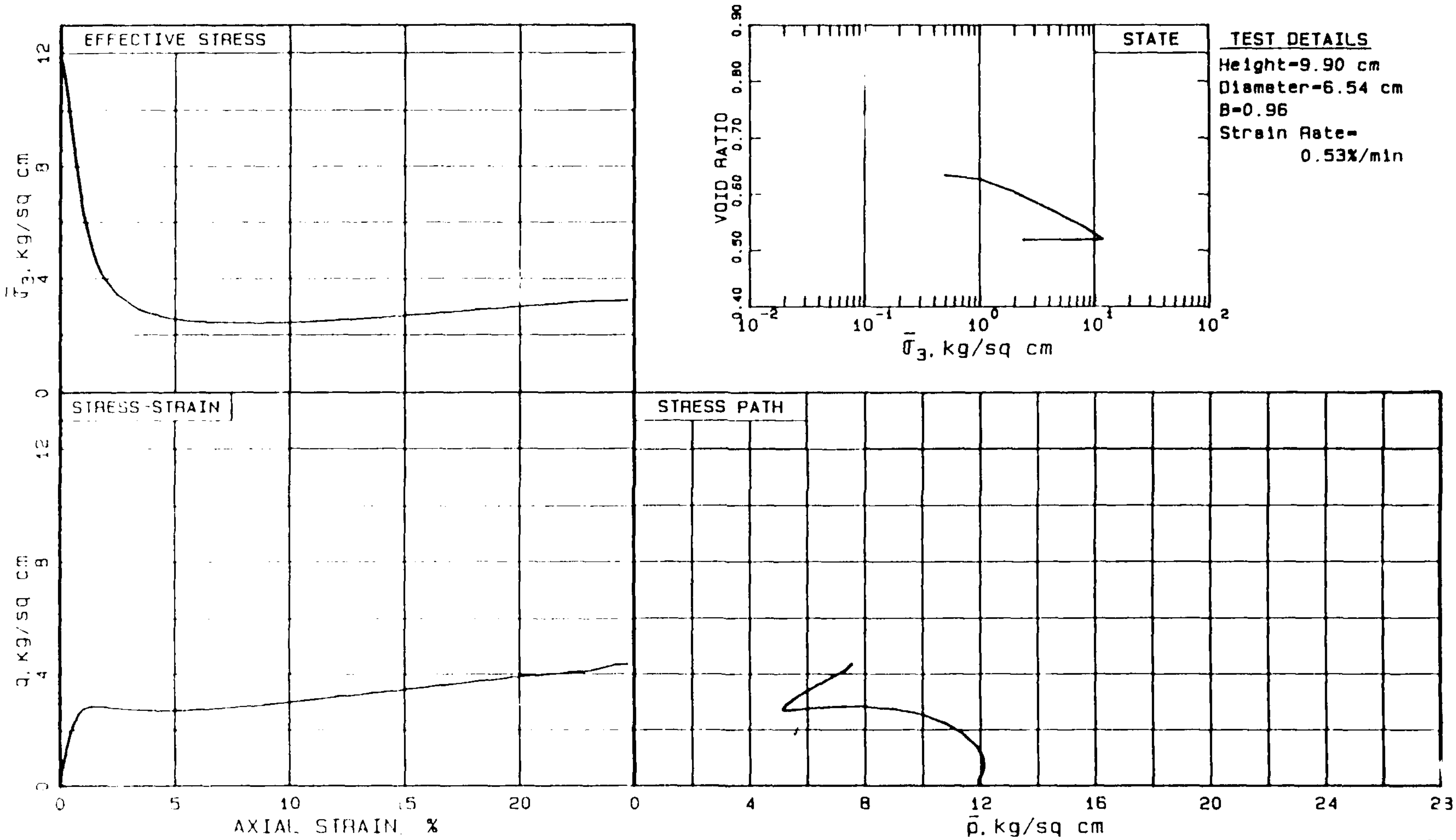


*prior to correction for swell of exploration shaft samples.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	CONSOLIDATION CURVES UNDISTURBED SAMPLES FROM HYDRAULIC FILL ZONE 5
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F70



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	CONSOLIDATION CURVES UNDISTURBED SAMPLES HYDRAULIC FILL ZONES 2 AND 3
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F71



SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.	STATE	$\bar{\sigma}_{3c}$=12.0 kg/sq cm e_c=0.522 K_c =1.0 γ_{dc}=110.3 pcf
STRUCTURE	Remolded. Compacted moist at 7% water content in 7 layers. Soil passed through No. 4 sieve.	LOADING	Undrained Axial Monotonic Compression.

R101
LOWER SAN FERNANDO DAM
PROJECT 85669 5 FEBRUARY 1987

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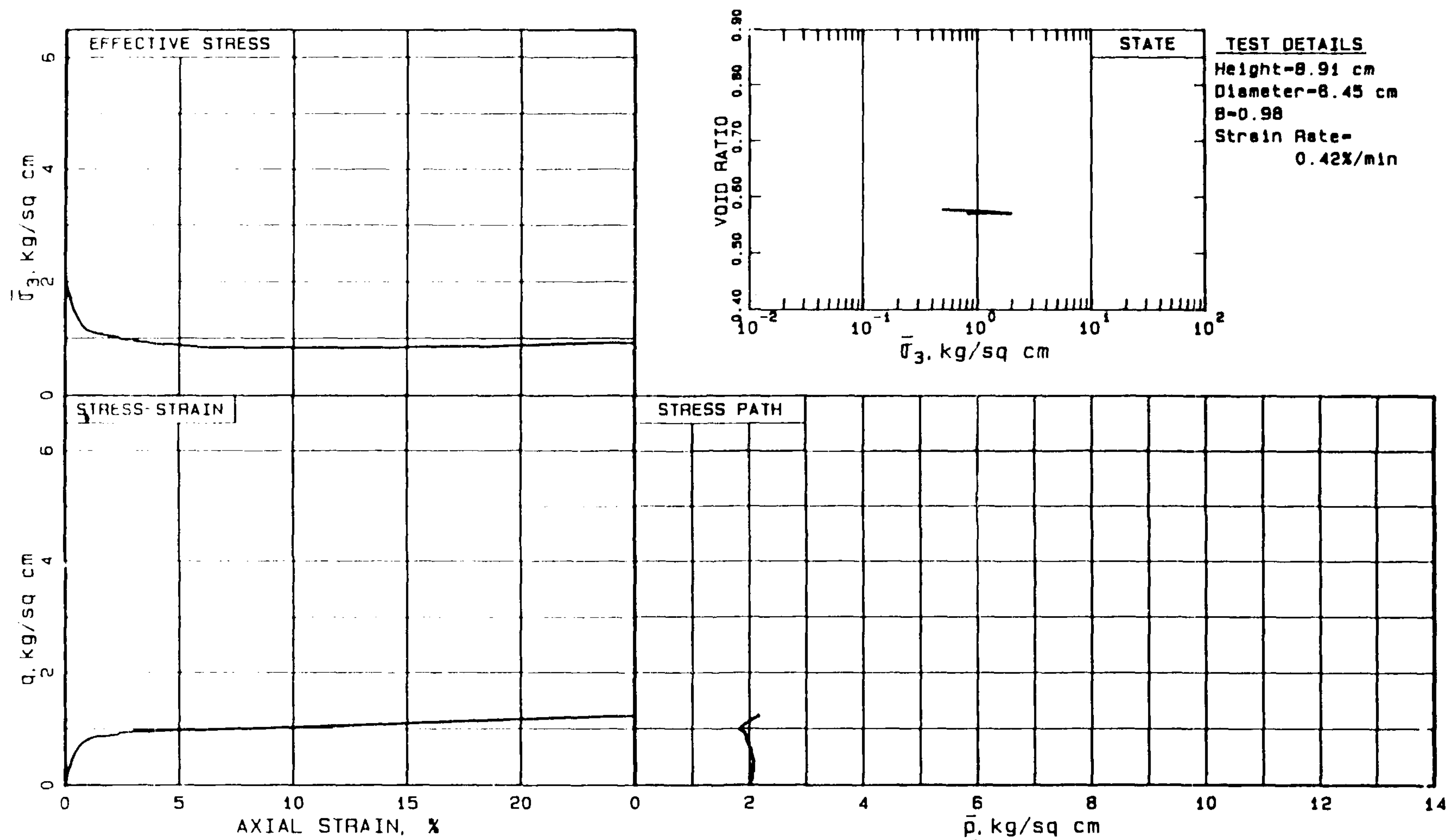
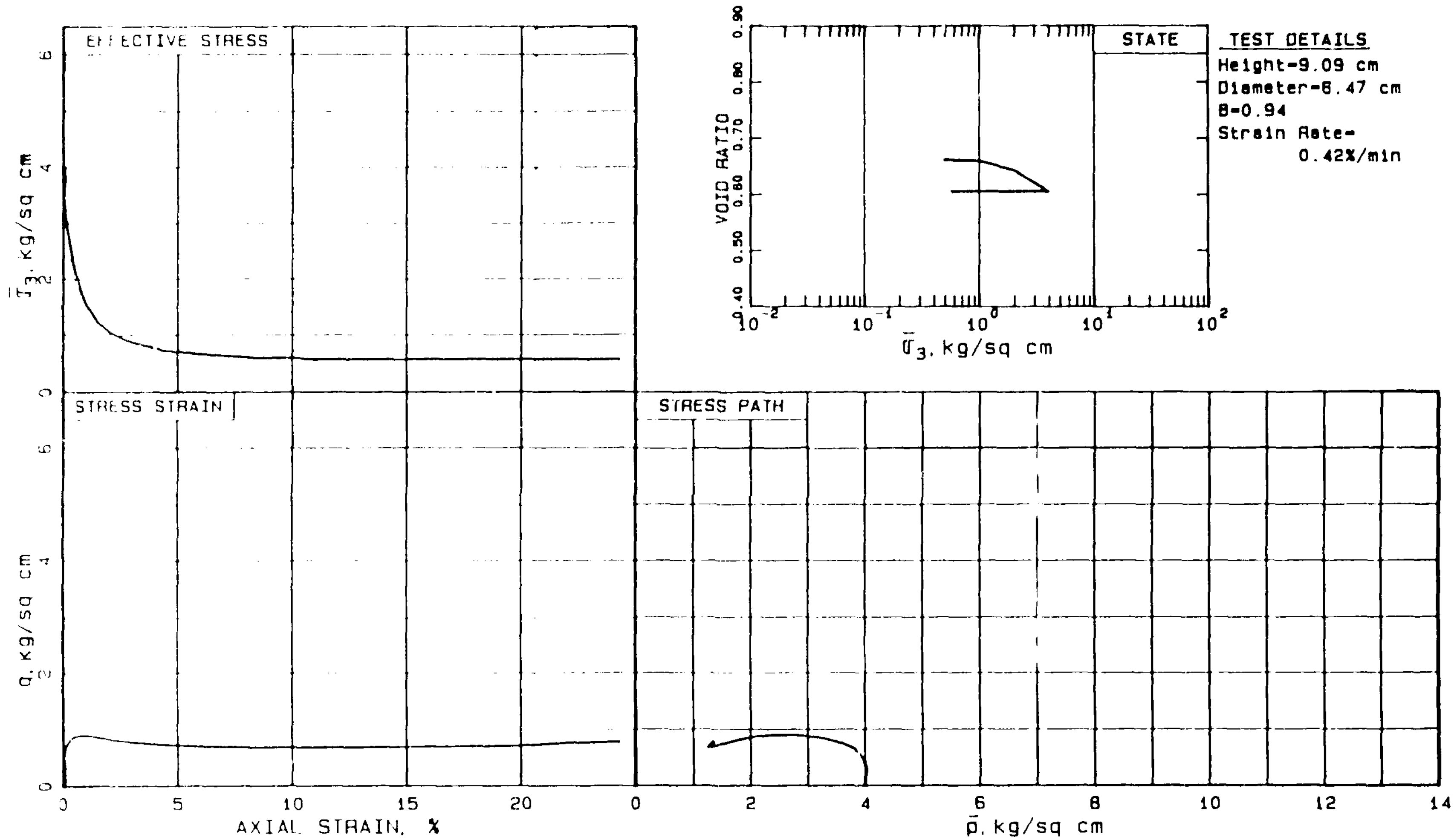


TEST DETAILS
Height=8.91 cm
Diameter=8.45 cm
B=0.98
Strain Rate= 0.42%/min

SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.	STATE	$\bar{\sigma}_{3c}$=2.0 kg/sq cm e_c=0.576 K_c =1.0 γ_{dc}=106.5 pcf
STRUCTURE	Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.	LOADING	Undrained Axial Monotonic Compression.

R102
LOWER SAN FERNANDO DAM
PROJECT 85669 5 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



SOIL: Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.

STRUCTURE: Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.

STATE: $\bar{\sigma}_{3c}$=4.0 kg/sq cm e_c=0.605

K_c =1.0 γ_{dc}=104.6 pcf

LOADING: Undrained Axial Monotonic Compression.

R103

LOWER SAN FERNANDO DAM

PROJECT 85669 5 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.

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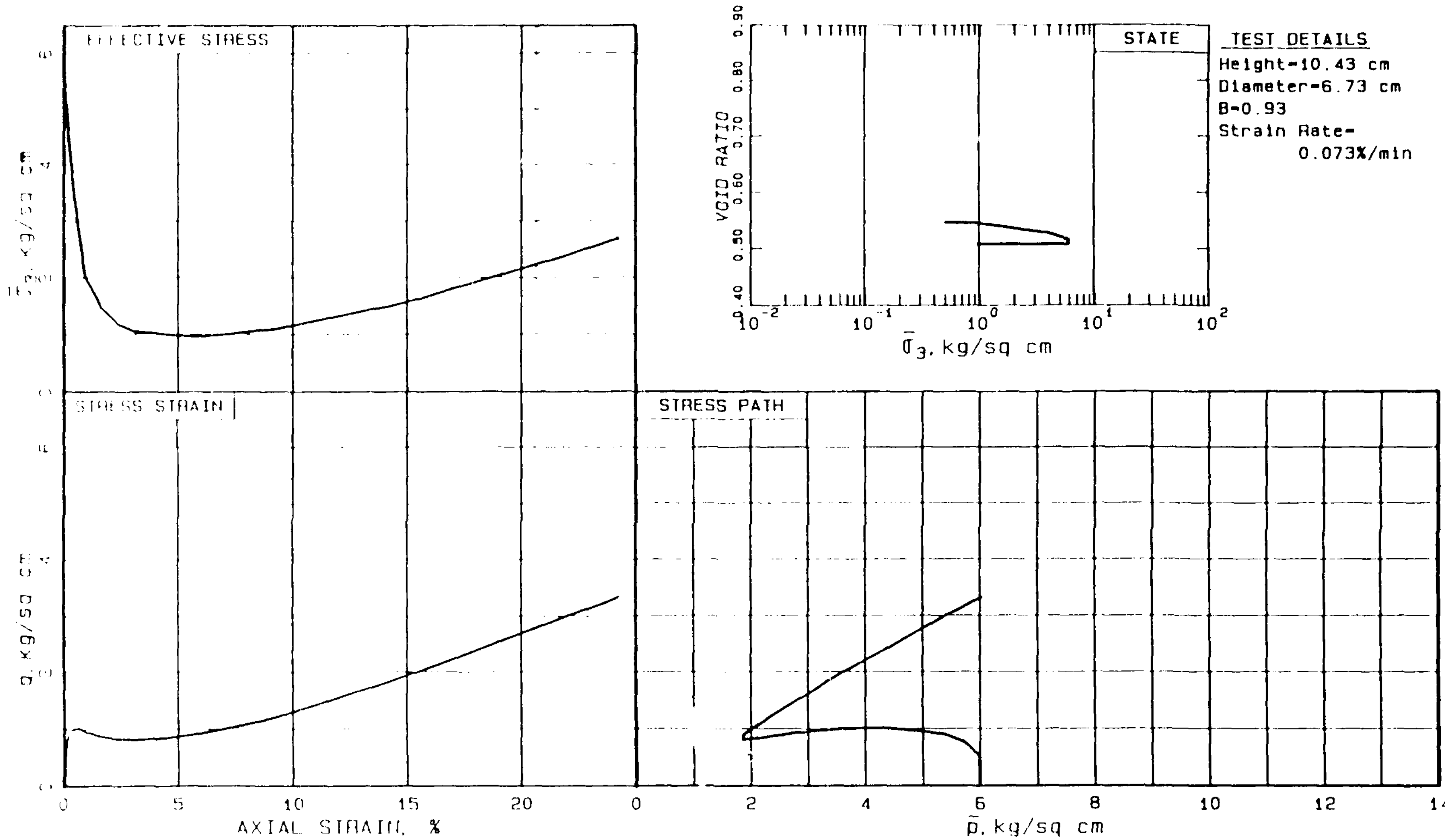
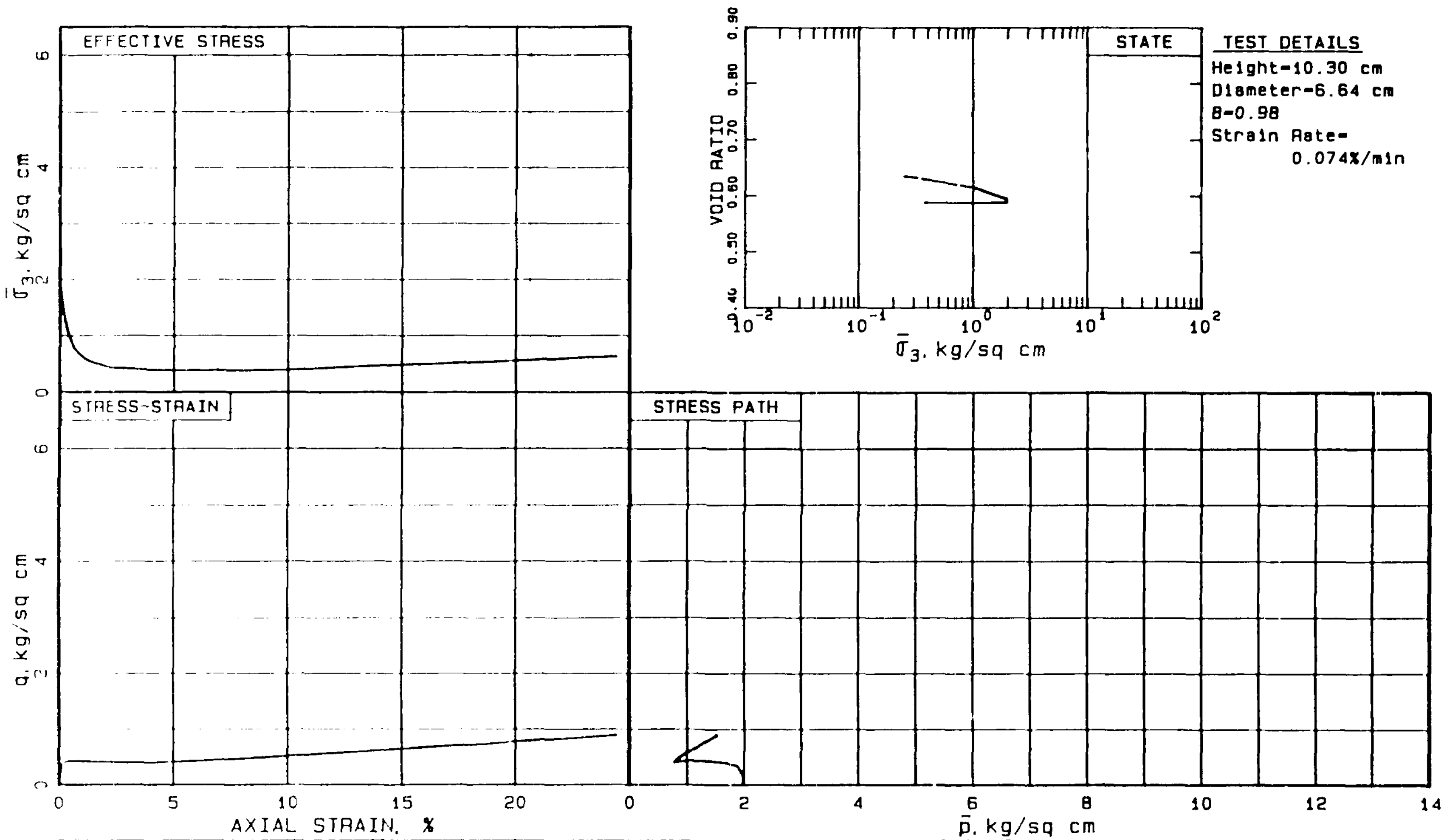


TEST DETAILS
Height=10.43 cm
Diameter=6.73 cm
B=0.93
Strain Rate=
0.073%/min

SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines	STATE	$\bar{\sigma}_{3c}$=5.0 kg/sq cm e_c=0.512 K_c =1.0 γ_{dc}=111.0 pcf
STRUCTURE	Remolded. Placed as a slurry at a water content of 30%	LOADING	Undrained Axial Monotonic Compression

R104
LOWER SAN FERNANDO DAM
PROJECT 85663 5 FEBRUARY 1987

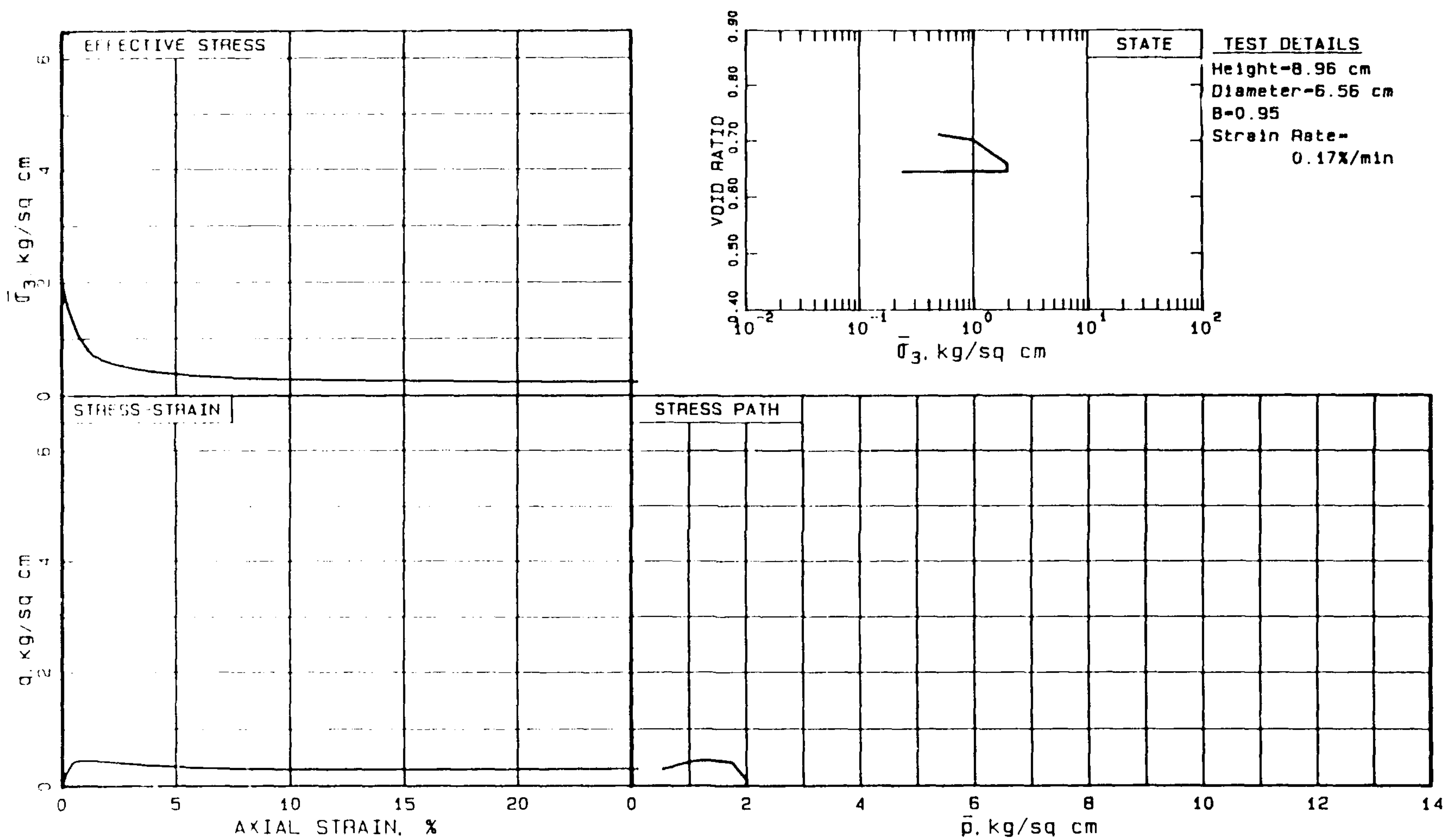
GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.
STRUCTURE	Remolded. Placed as a slurry at a water content of 38%.
STATE	$\bar{\sigma}_{3c}$=2.0 kg/sq cm e_c=0.592 K_c =1.0 γ_{dc}=105.5 pcf
LOADING	Undrained Axial Monotonic Compression.

R105
LOWER SAN FERNANDO DAM
PROJECT 85669   5 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



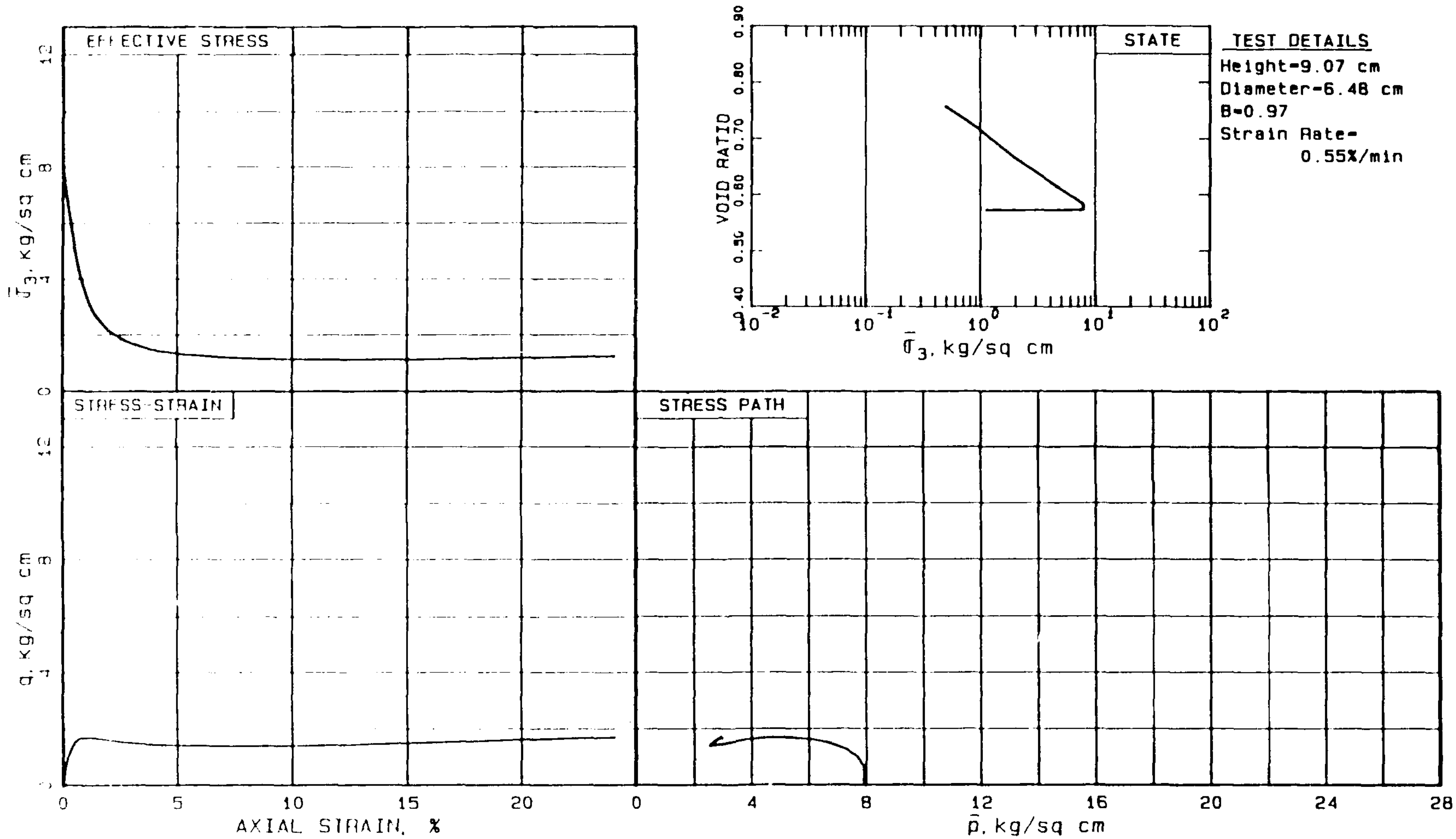
TEST DETAILS

Height=8.96 cm
Diameter=6.56 cm
B=0.95
Strain Rate=
0.17%/min

SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.
STRUCTURE	Remolded. Compacted moist at 3% water content in 8 layers. Soil passed through No. 40 sieve.
STATE	$\bar{\sigma}_{3c}$=2.0 kg/sq cm e_c=0.651 K_c =1.0 γ_{dc}=101.7 pcf
LOADING	Undrained Axial Monotonic Compression.

R106
LOWER SAN FERNANDO DAM
PROJECT 85669 5 FEBRUARY 1987

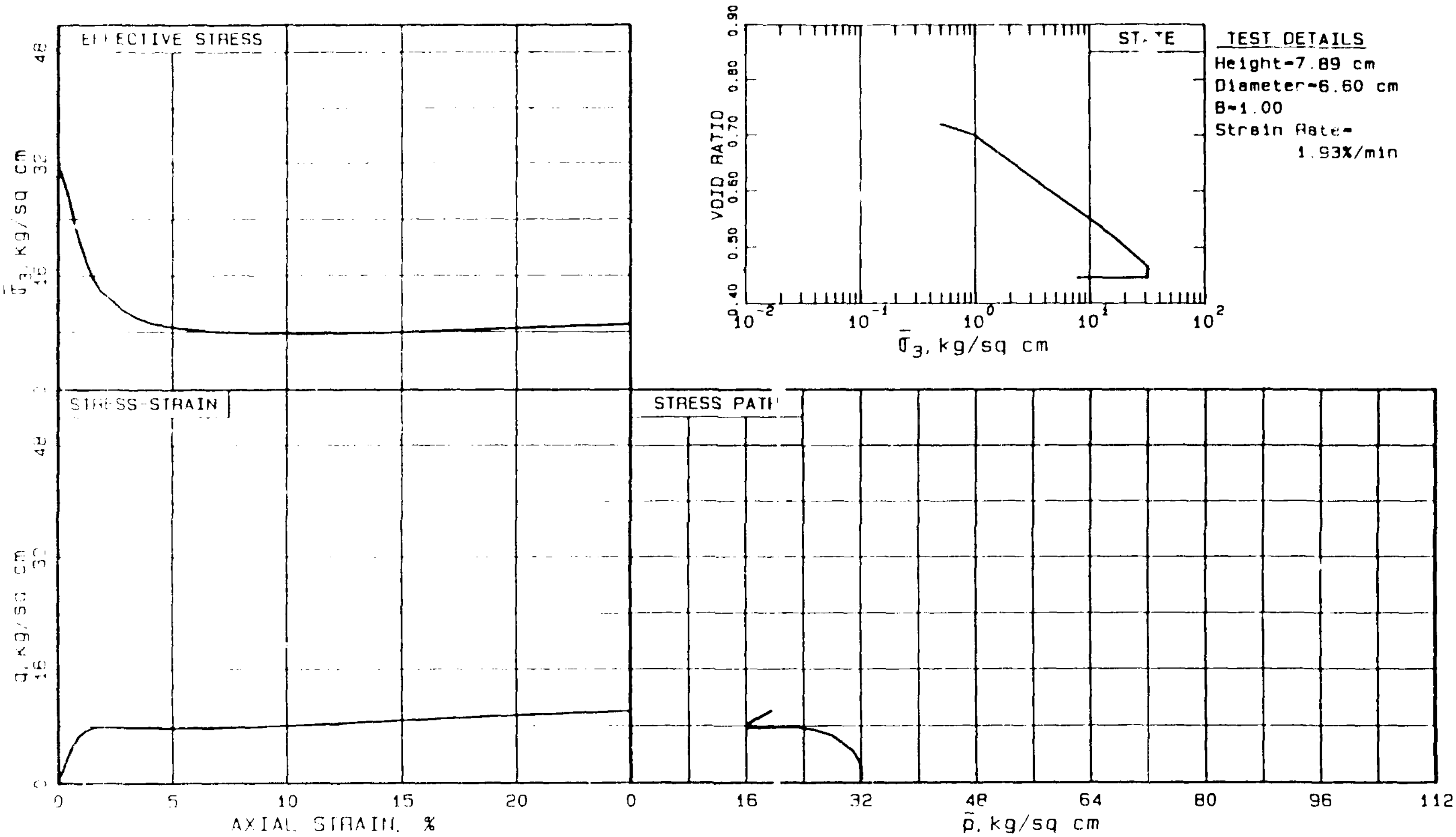
GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.
STRUCTURE	Remolded. Compacted moist at 3% water content in 8 layers. Soil passed through No. 40 sieve.
STATE	$\bar{\sigma}_{3c}$=8.0 kg/sq cm e_c=0.578 K_c =1.0 γ_{dc}=106.4 pcf
LOADING	Undrained Axial Monotonic Compression.

R107
LOWER SAN FERNANDO DAM
PROJECT 35669 5 FEBRUARY 1987

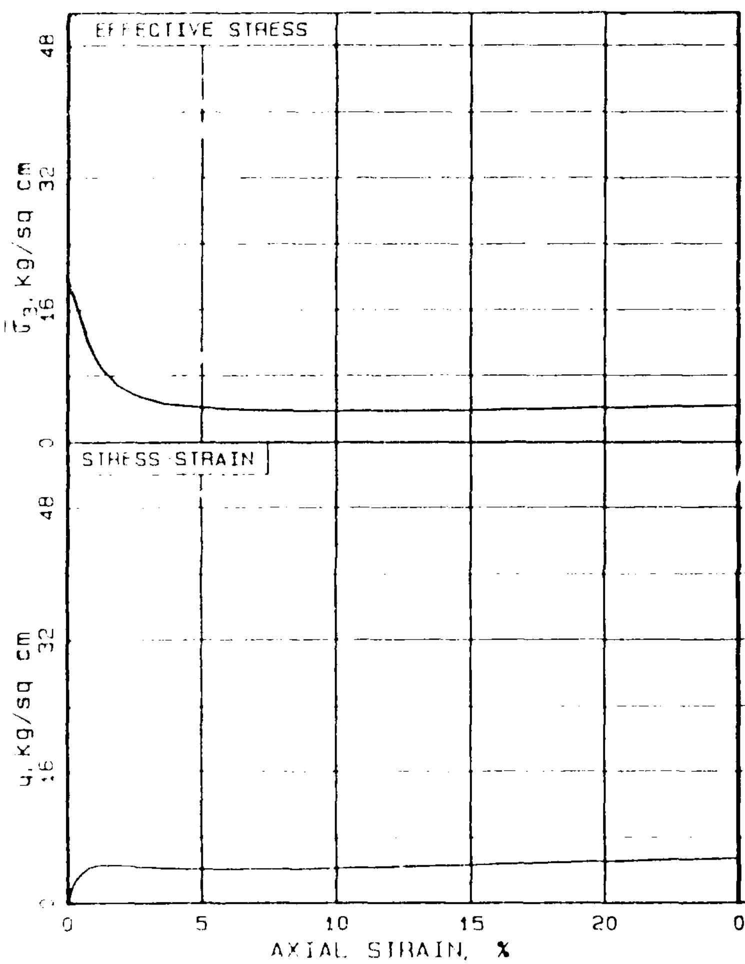
GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS

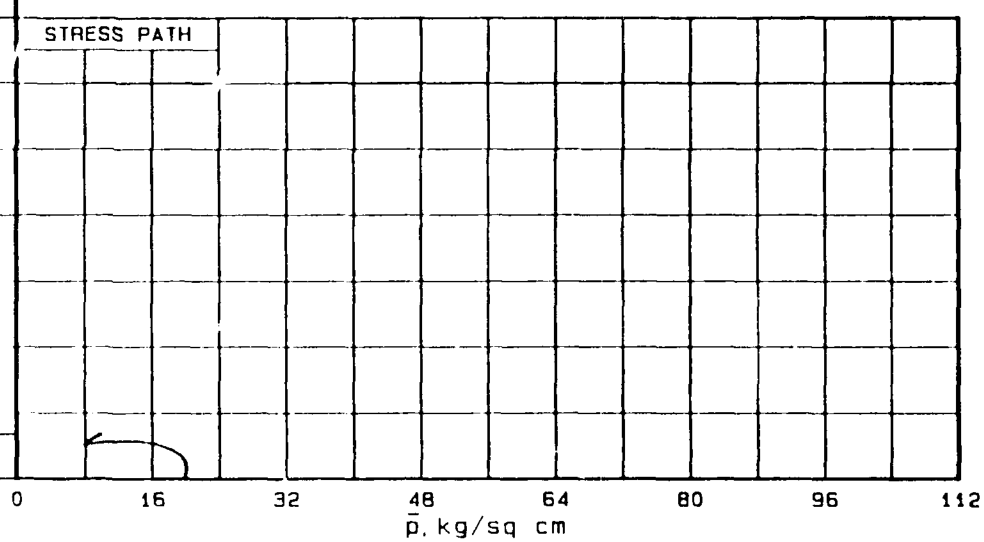


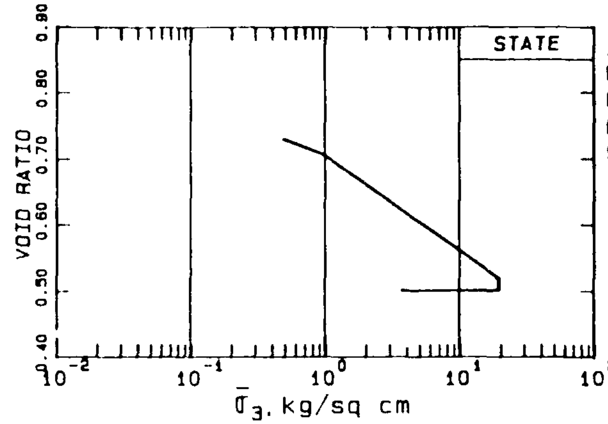
SOIL — Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines	STATE — $\bar{\sigma}_{3c}$=32.0 kg/sq cm e_c=0.451 K_c =1.0 γ_{dc}=115.7 pcf
STRUCTURE — Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve	LOADING — Undrained Axial Monotonic Compression.

R108
LOWER SAN FERNANDO DAM
PROJECT 85669 5 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS







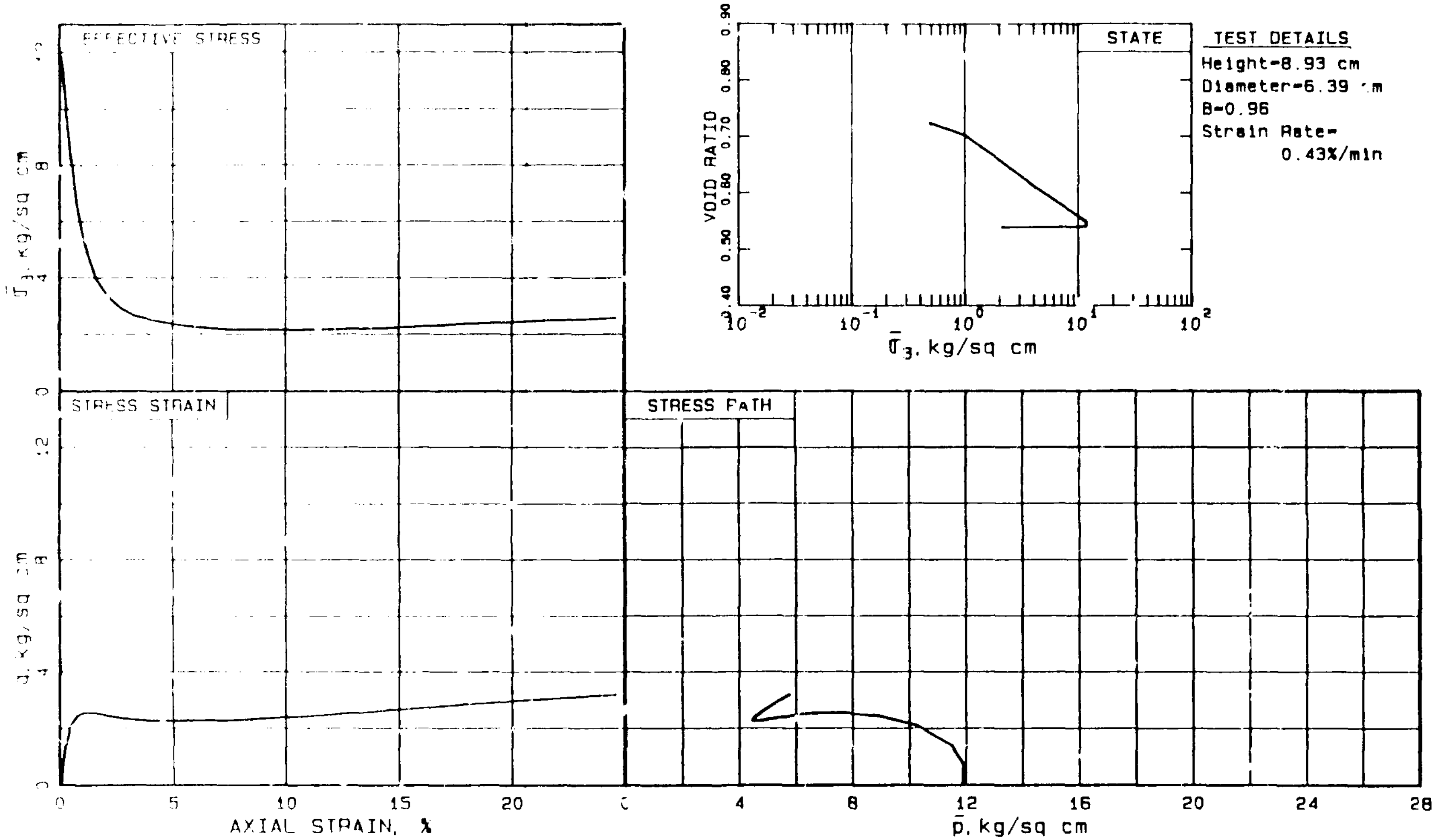
TEST DETAILS

Height=8.88 cm
Diameter=6.32 cm
B=0.97
Strain Rate=
0.86%/min

SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.
STRUCTURE	Remolded. Compacted moist at 5% water content in 8 layers. Soil passed through No. 40 sieve.
STATE	$\bar{\sigma}_{3c}$=20.0 kg/sq cm e_c=0.506 K_c =1.0 γ_{dc}=111.5 pcf
LOADING	Undrained Axial Monotonic Compression.

R109
LOWER SAN FERNANDO DAM
PROJECT 85669 5 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



SOIL	Batch Mix 7. Silty fine sand with 50 5% slightly plastic fines.
STRUCTURE	Remolded. Compacted moist at 3% water content in 8 layers. Soil passed through No. 40 sieve.
STATE	$\bar{\sigma}_{3c}$=12.0 kg/sq cm e_c=0.543 K_c =1.0 γ_{dc}=108.8 pcf
LOADING	Undrained Axial Monotonic Compression.

R110

LOWER SAN FERNANDO DAM

PROJECT 85669 5 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.
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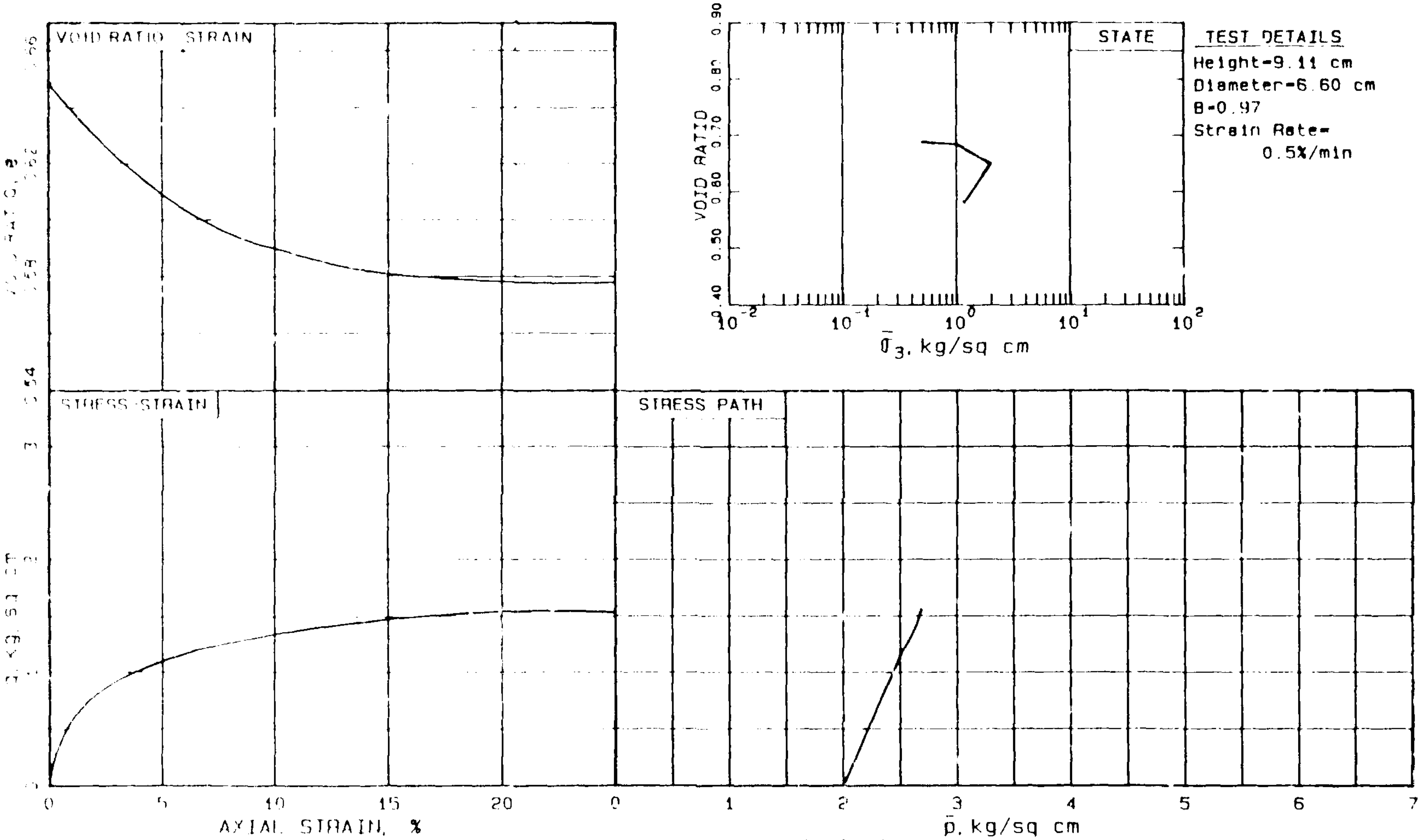
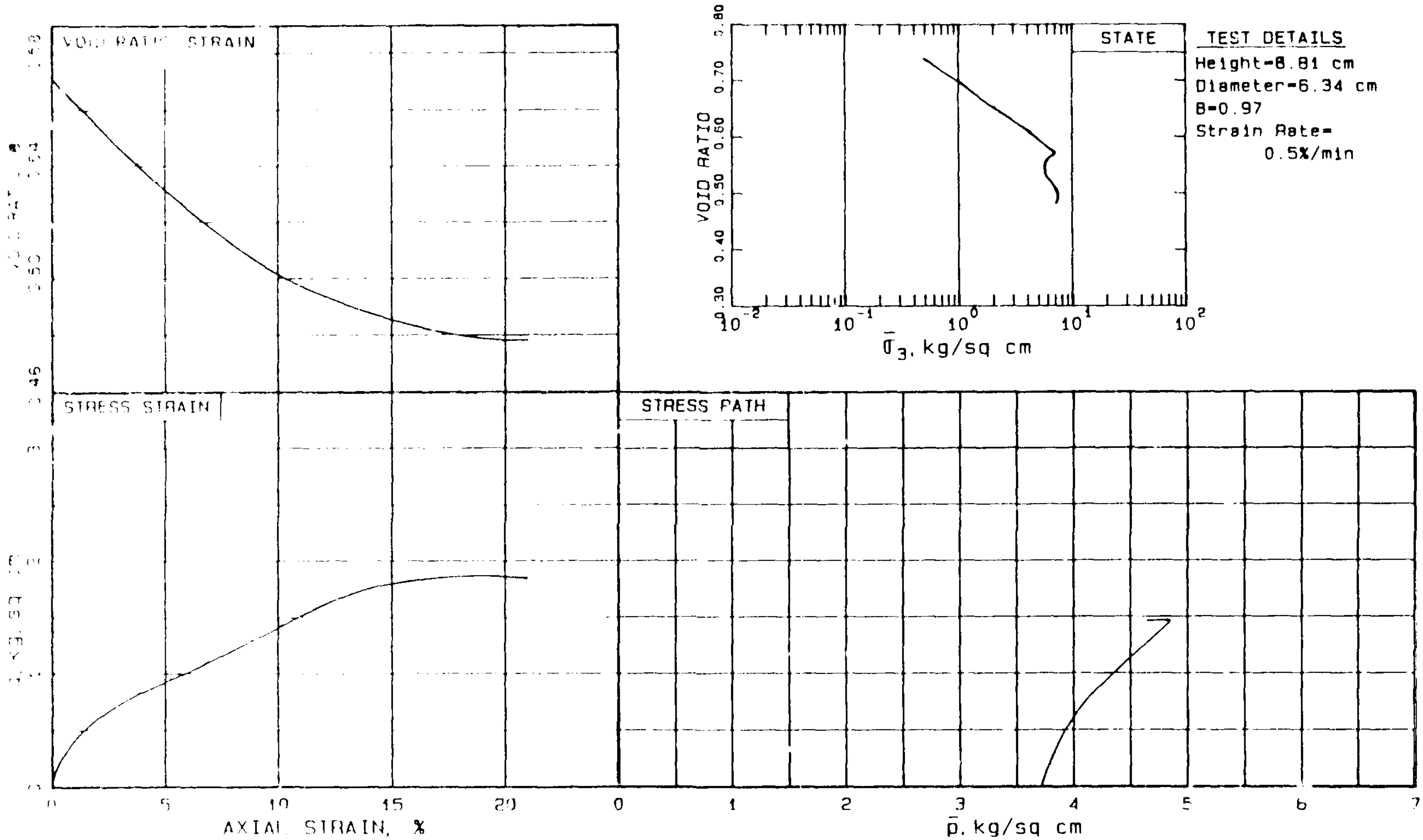


TEST DETAILS
Height=9.11 cm
Diameter=6.60 cm
B=0.97
Strain Rate=
0.5%/min

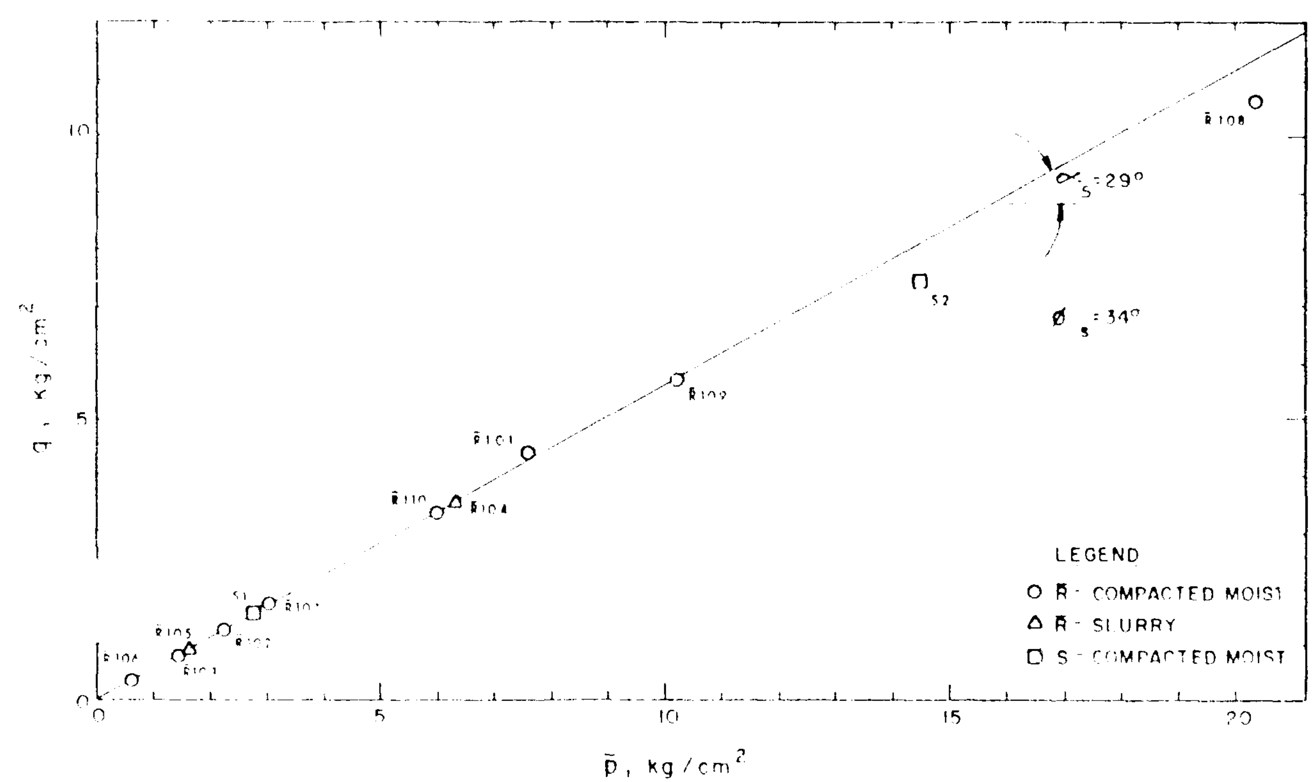
SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.	STATE	$\bar{\sigma}_{3c}$=2.0 kg/sq cm e_c=0.650 K_c =1.0 γ_{dc}=101.7 pcf
STRUCTURE	Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.	LOADING	Drained Axial Monotonic Compression

S1
LOWER SAN FERNANDO DAM
PROJECT 85669 5 FEBRUARY 1987

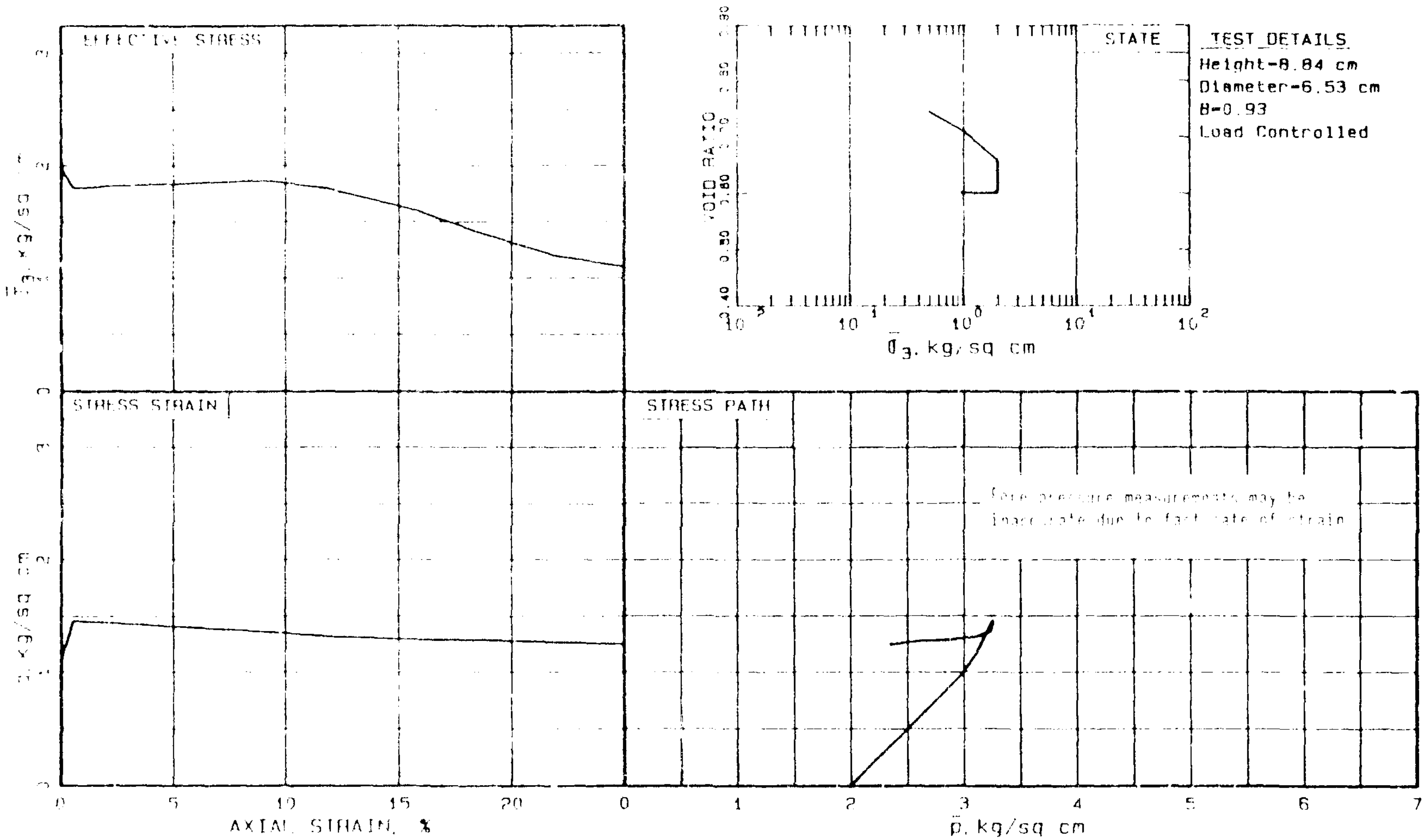
GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



SOIL Batch Mix 7 Silty fine sand with 50.5% slightly plastic fines	STATE $\bar{\sigma}_{3c}$=7.0 kg/sq cm e_c=0.572 K_c =1.0 γ_{dc}=106.7 pcf	S2 LOWER SAN FERNANDO DAM PROJECT 85669 5 FEBRUARY 1987
STRUCTURE Remolded Compacted moist at 4% water content in 8 layers Soil passed through No. 40 sieve.	LOADING Drained Axial Monotonic Compression.	GEOTECHNICAL ENGINEERS INC. WINCHESTER - MASSACHUSETTS

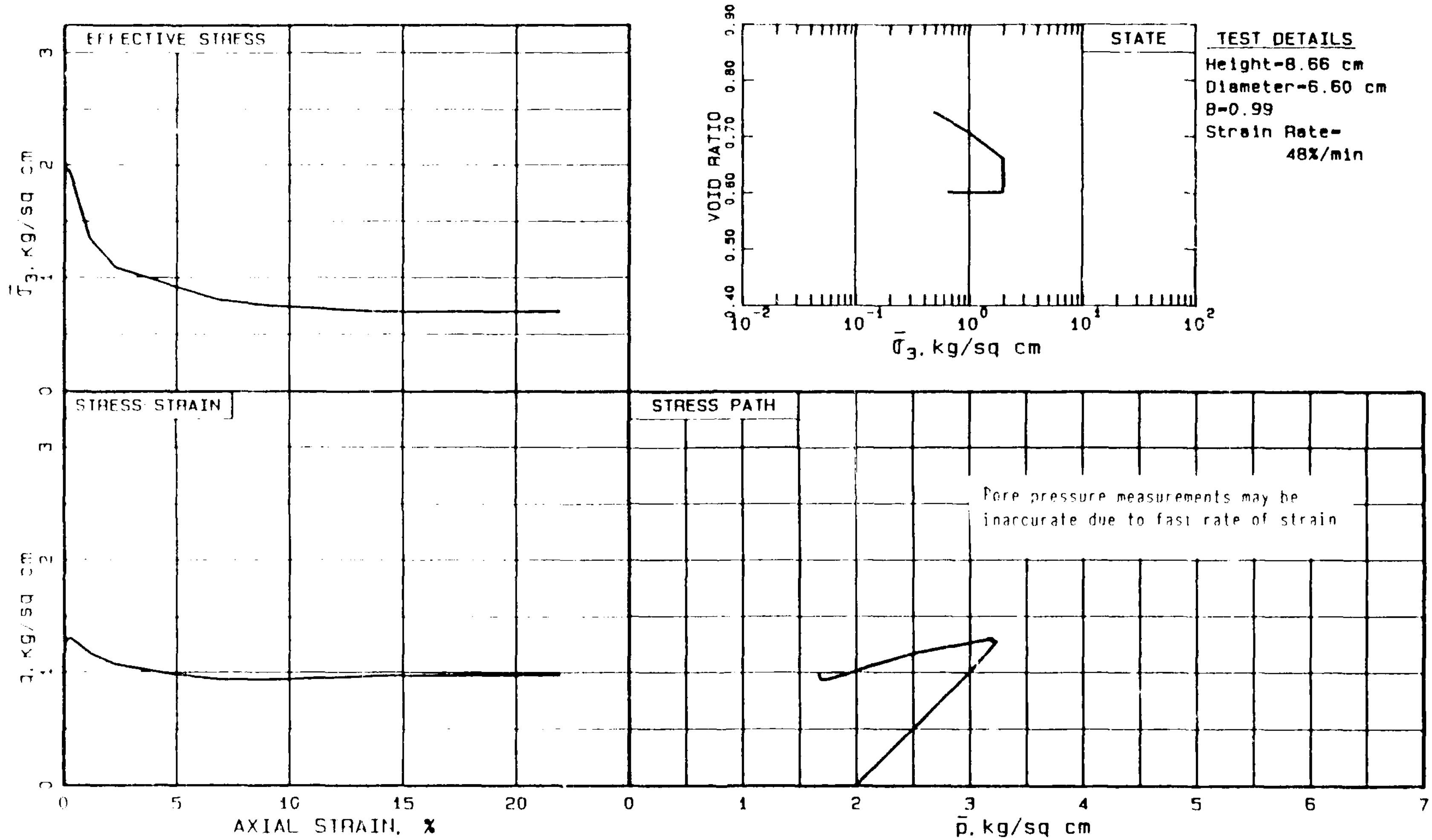


Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	q VS $\bar{p}$ AT STEADY STATE FROM ISOTROPIC $\bar{R}$ AND S TESTS ON BATCH MIX 7
Φ GEOTECHNICAL ENGINEERS INC	Project 85669	Sept. 2, 1987 Fig. F84



SOIL	Batch Mix 7 Silty fine sand with 50.5% slightly plastic fines	STATE	$\bar{\sigma}_{3c}$=2.0 kg/sq cm e_c=0.601 K_c =2.0 γ_{dc}=104.8 pcf
STRUCTURE	Remolded Compacted moist at 4% water content in 8 layers Soil passed through No. 40 sieve.	LOADING	Undrained Axial Monotonic Compression

R201
LOWER SAN FERNANDO DAM
PROJECT 85669 10 FEBRUARY 1987
GEOTECHNICAL ENGINEERS INC. WINCHESTER - MASSACHUSETTS



SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.
STRUCTURE	Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.
STATE	$\bar{\sigma}_{3c}$=2.0 kg/sq cm e_c=0.601 K_c =2.0 γ_{dc}=104.9 pcf
LOADING	Undrained Axial Monotonic Compression.

R202
LOWER SAN FERNANDO DAM
PROJECT 85669 10 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.
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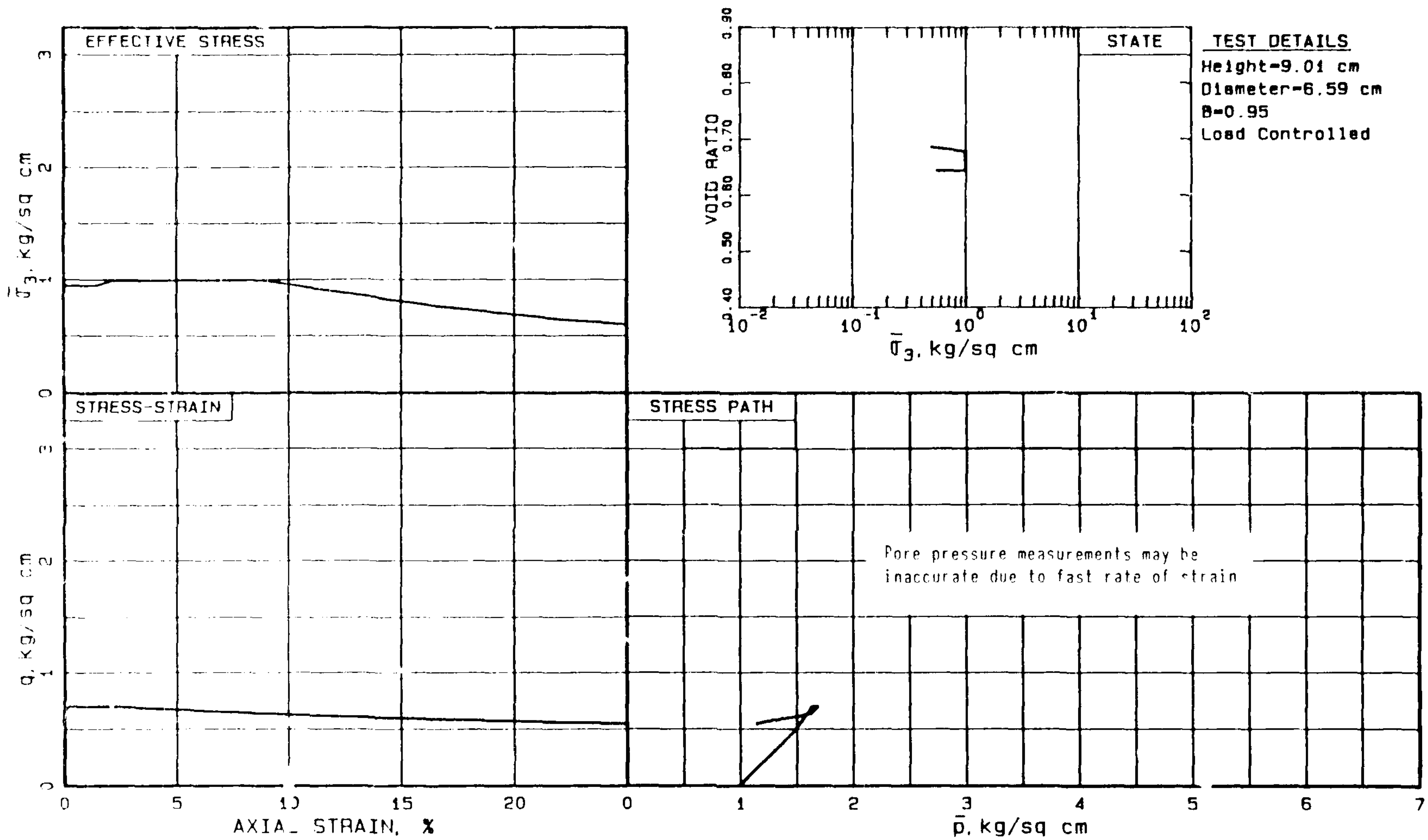

TEST DETAILS
Height=9.01 cm
Diameter=6.59 cm
B=0.95
Load Controlled

SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.	STATE	$\bar{\sigma}_{3c}$=1.0 kg/sq cm e_c=0.644 K_c =2.0 γ_{dc}=102.1 pcf
STRUCTURE	Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.	LOADING	Undrained Axial Monotonic Compression.

R203
LOWER SAN FERNANDO DAM
PROJECT 85669 10 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.
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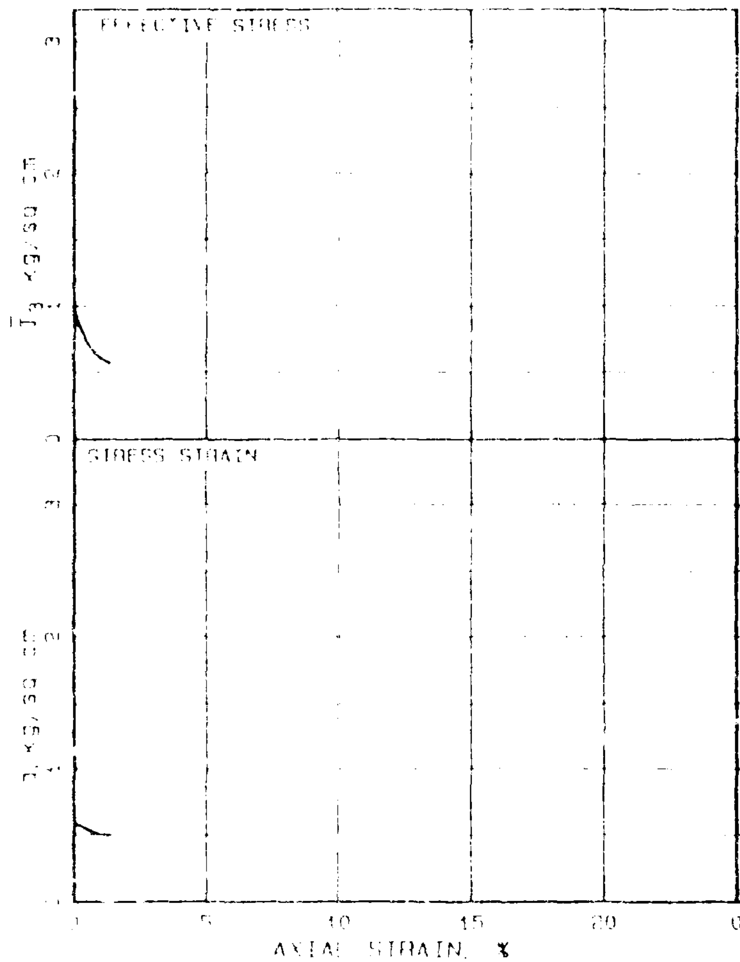
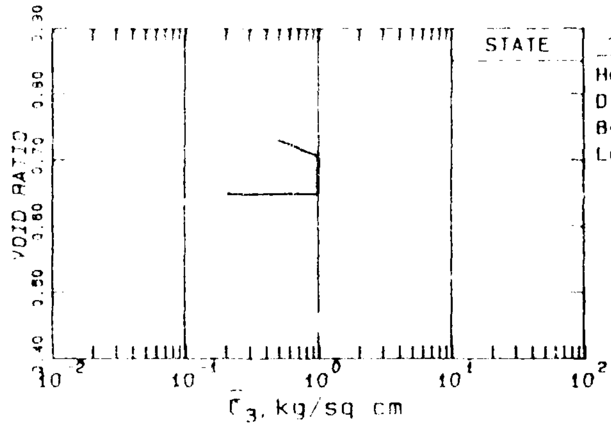
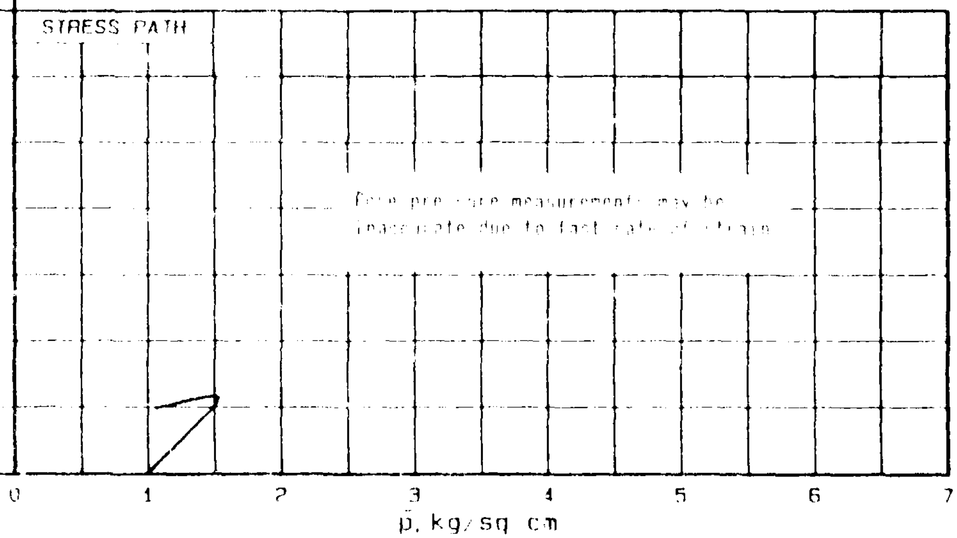




TEST DETAILS

Height=8.56 cm
Diameter=6.77 cm
B=1.00
Load Controlled



SOIL	Batch Mix 7 Silty fine sand with 50.5% slightly plastic fines
STRUCTURE	Remolded Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve
STATE	$\bar{\sigma}_{3c}$=1.0 kg/sq cm e_c=0.649 K_c =2.0 γ_{dc}=101.8 pcf
LOADING	Undrained Axial Monotonic Compression

R204
LOWER SAN FERNANDO DAM
PROJECT 85669   10 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.
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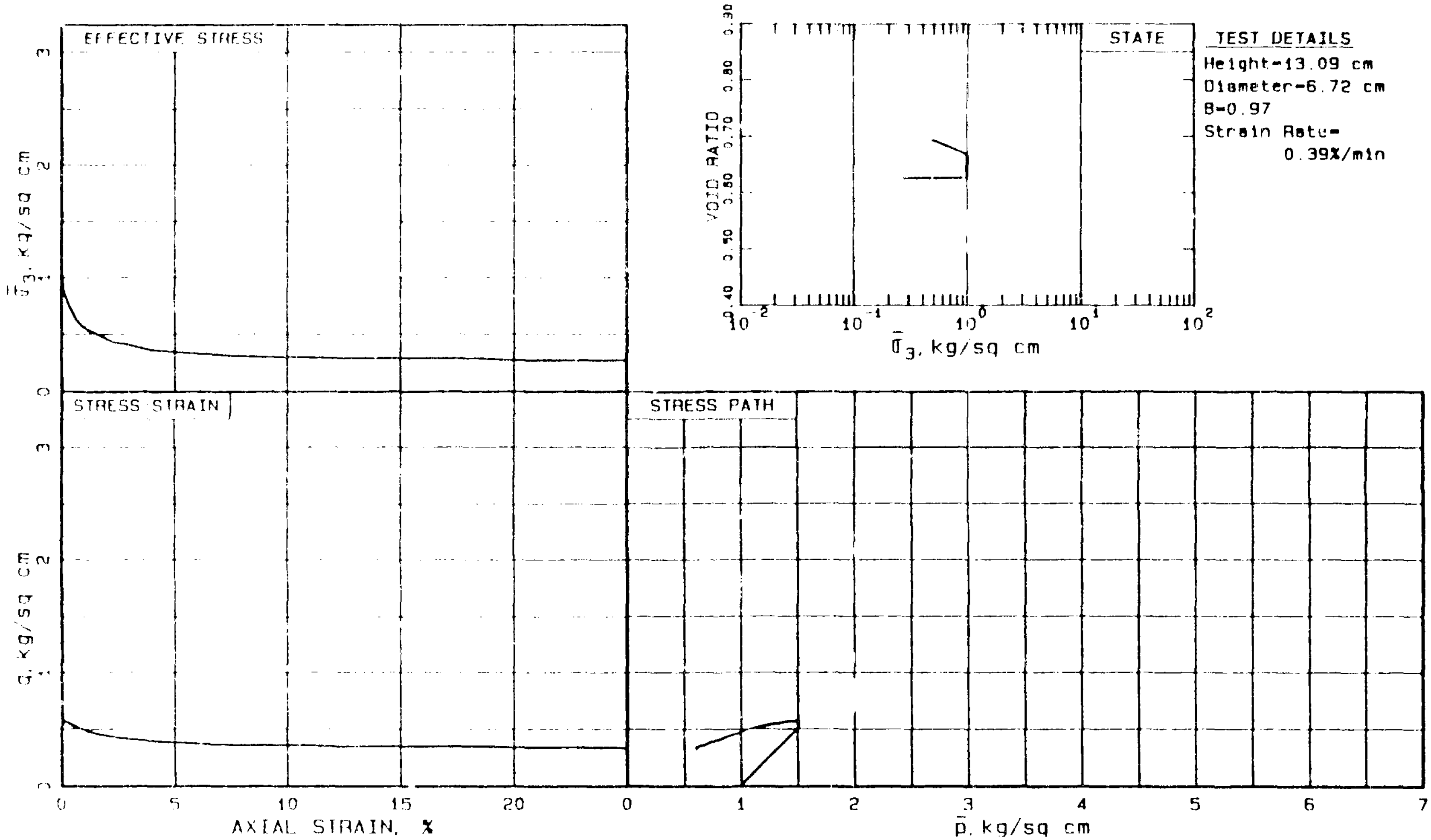

TEST DETAILS
Height=13.09 cm
Diameter=6.72 cm
B=0.97
Strain Rate=
0.39%/min

SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.
STRUCTURE	Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 4 sieve.
STATE	$\bar{\sigma}_{3c}$=1.0 kg/sq cm e_c=0.627 K_c =2.0 γ_{dc}=103.2 pcf
LOADING	Undrained Axial Monotonic Compression.

R205
LOWER SAN FERNANDO DAM
PROJECT 85669 10 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.
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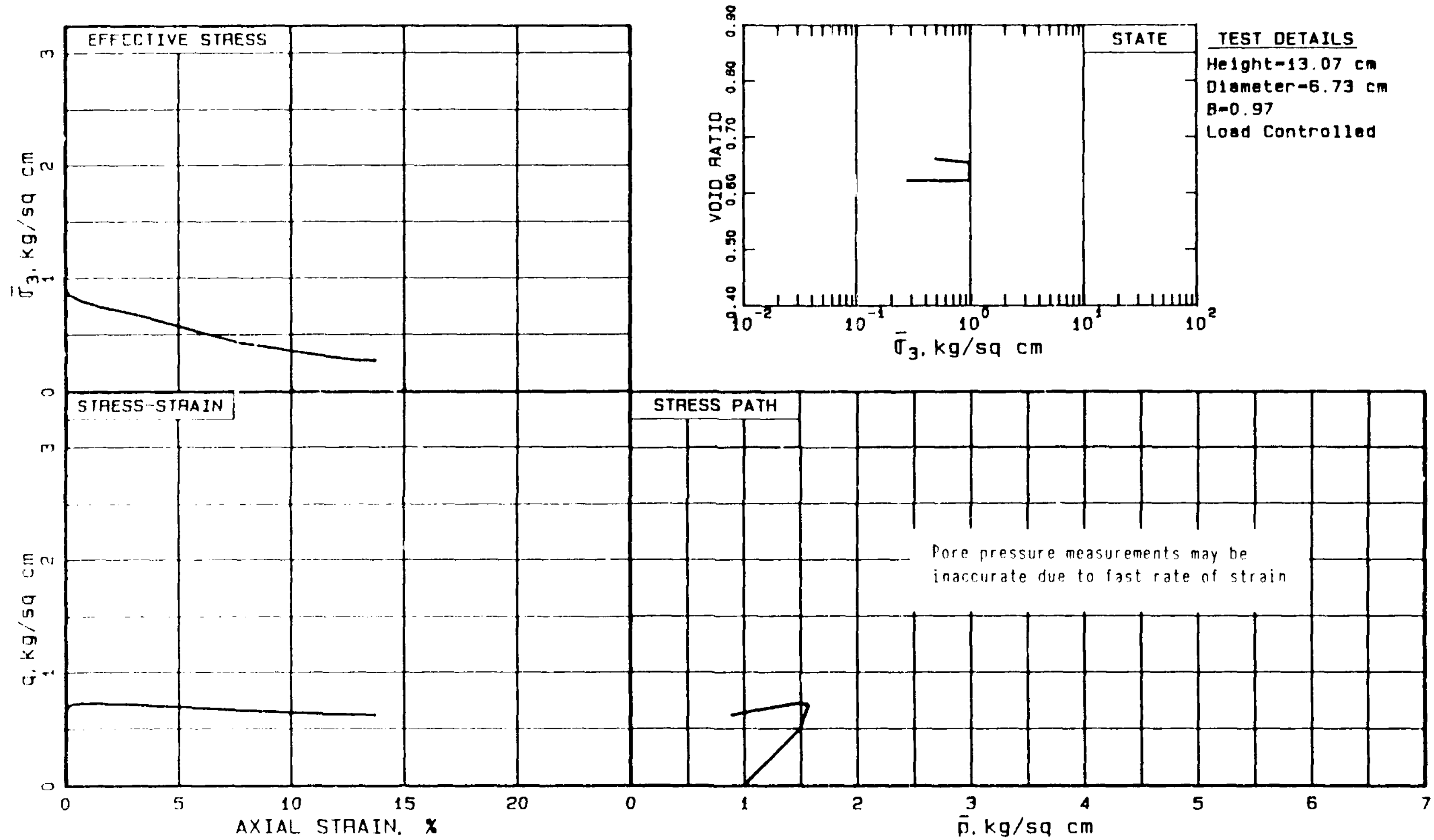

SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.
STRUCTURE	Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 4 sieve.
STATE	$\bar{\sigma}_{3c}$=1.0 kg/sq cm e_c=0.623 K_c =2.0 γ_{dc}=103.4 pcf
LOADING	Undrained Axial Monotonic Compression.

R206

LOWER SAN FERNANDO DAM

PROJECT 85669 10 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.

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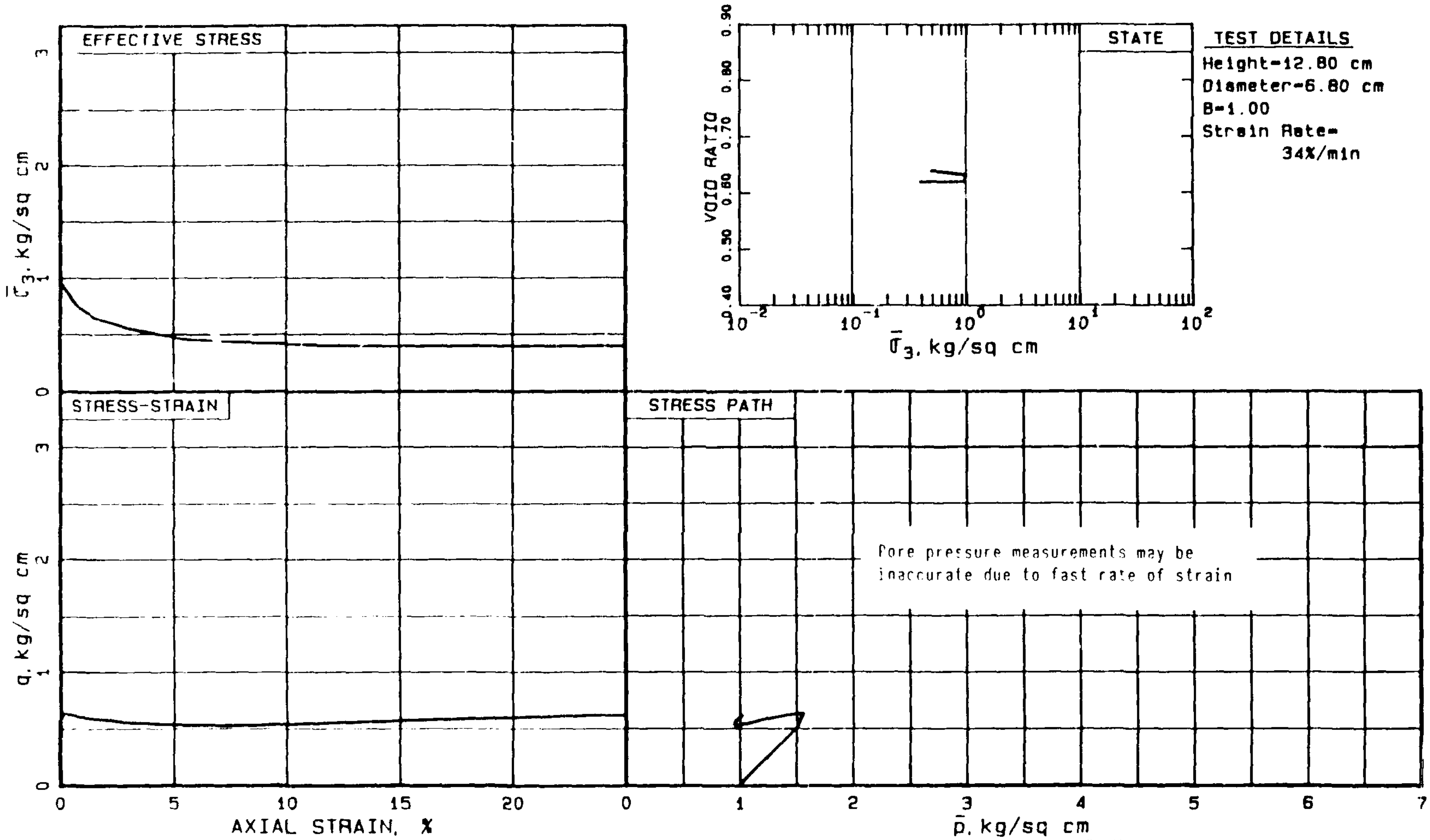


SOIL Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.

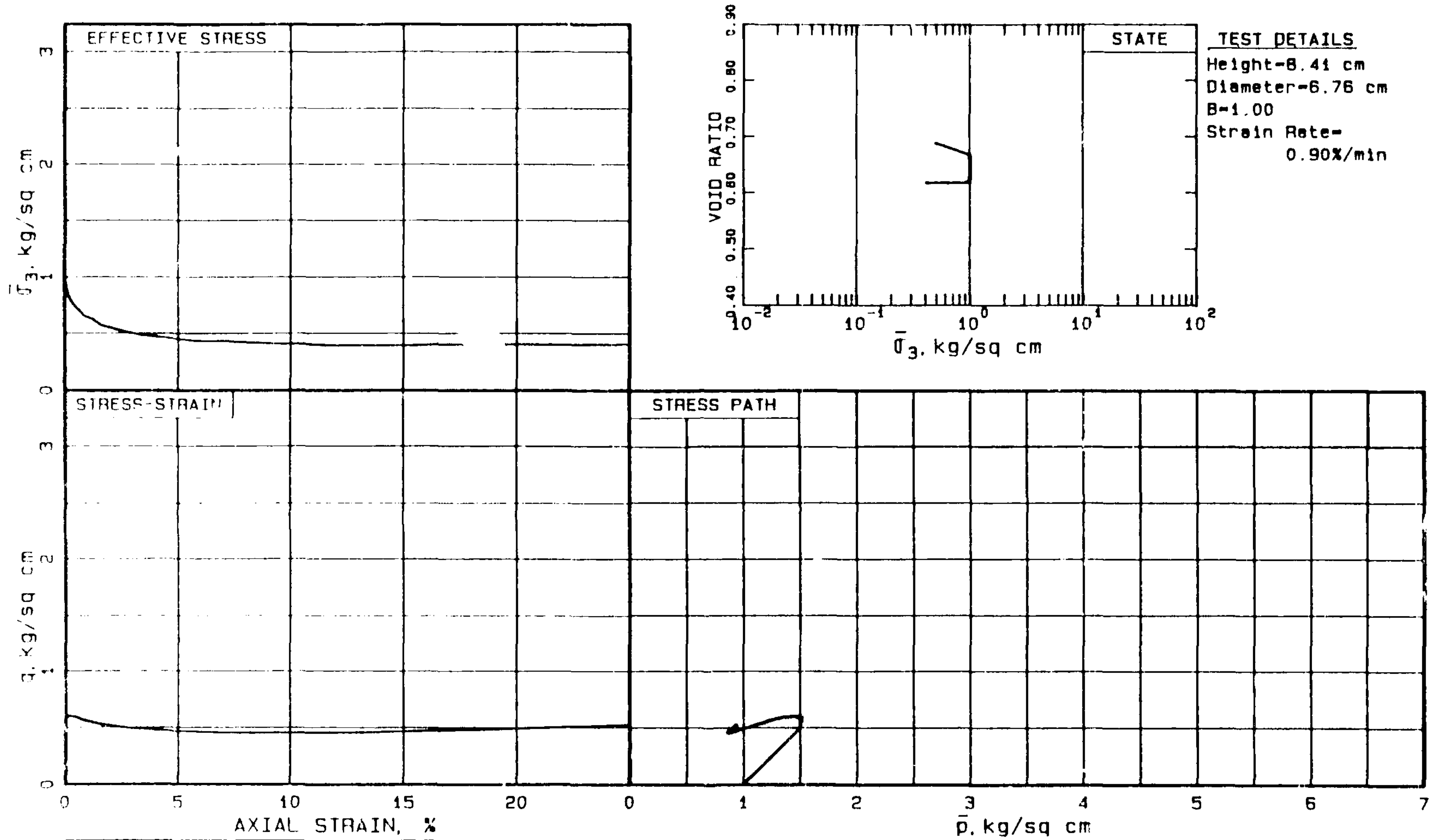
STRUCTURE *Remolded.* Compacted moist at 4% water content in 8 layers. Soil passed through No. 4 sieve.

STATE $\bar{\sigma}_{3c}$=1.0 kg/sq cm e_c=0.620
K_c =2.0 γ_{dc}=103.6 pcf

LOADING Undrained Axial Monotonic Compression.

R207
LOWER SAN FERNANDO DAM
PROJECT 85669 10 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



SOIL | Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.

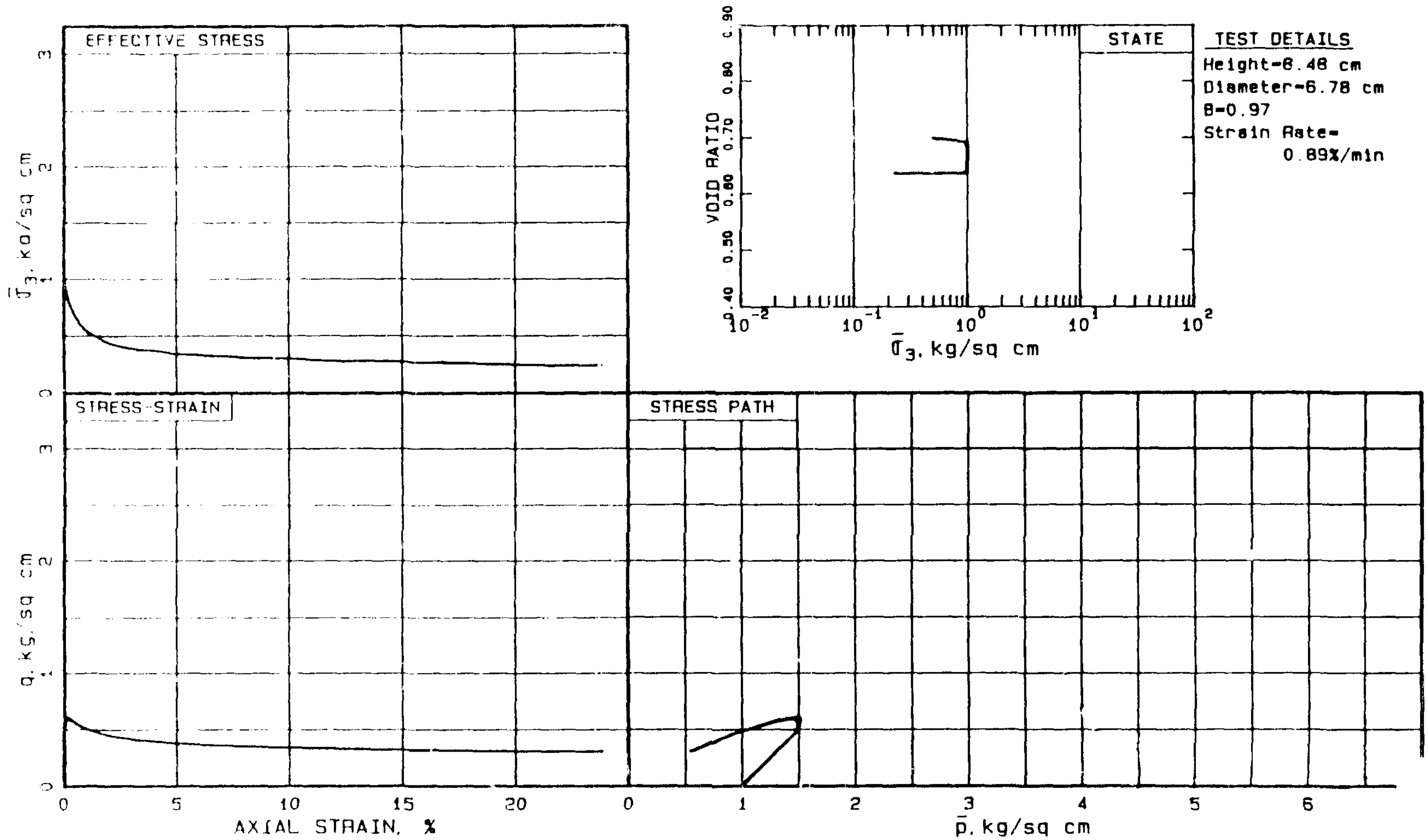
STRUCTURE | Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 4 sieve.

STATE | $\bar{\sigma}_{3c}$=1.0 kg/sq cm e_c=0.617
K_c =2.0 γ_{dc}=103.8 pcf

LOADING | Undrained Axial Monotonic Compression.

R208
LOWER SAN FERNANDO DAM
PROJECT 85669 10 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



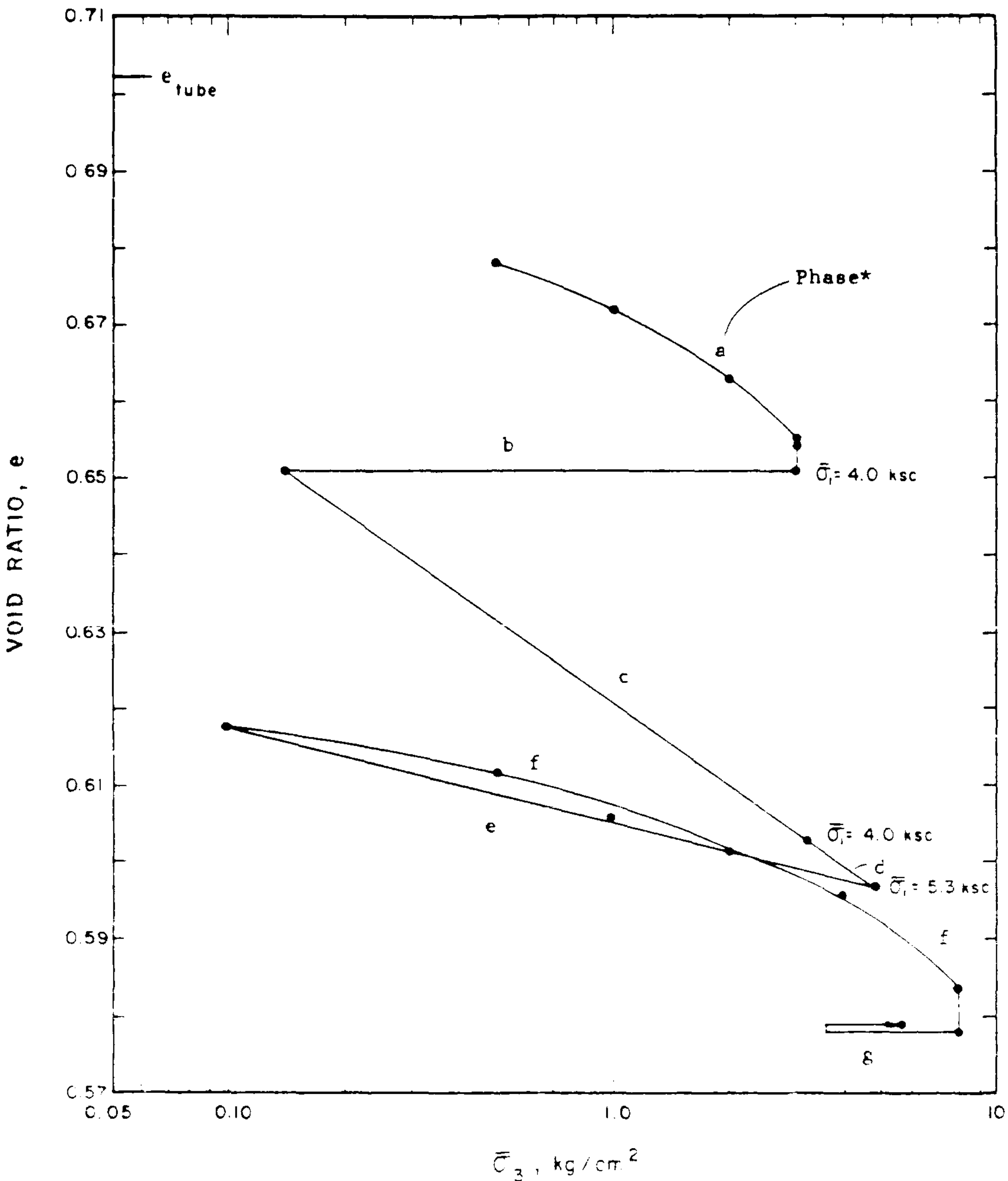
TEST DETAILS

Height=8.48 cm
Diameter=6.78 cm
B=0.97
Strain Rate= 0.89%/min

SOIL	Batch Mix 7. Silty fine sand with 50.5% slightly plastic fines.	STATE	$\bar{\sigma}_{3c}$=1.0 kg/sq cm e_c=0.637 K_c =2.0 γ_{dc}=102.5 pcf
STRUCTURE	Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.	LOADING	Undrained Axial Monotonic Compression.

R209
LOWER SAN FERNANDO DAM
PROJECT 85669   10 FEBRUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS



*See text of Appendix for explanation of Phases.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY OF VOID RATIO CHANGES - TEST CRE1 EXPLORATORY SHAFT SAMPLE TS309B
GEOTECHNICAL ENGINEERS INC WINCHESTER, MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F94

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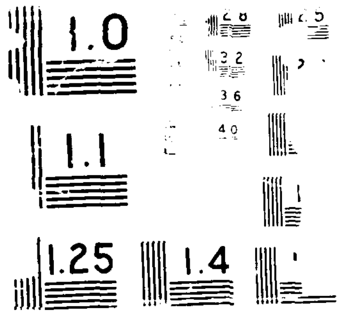
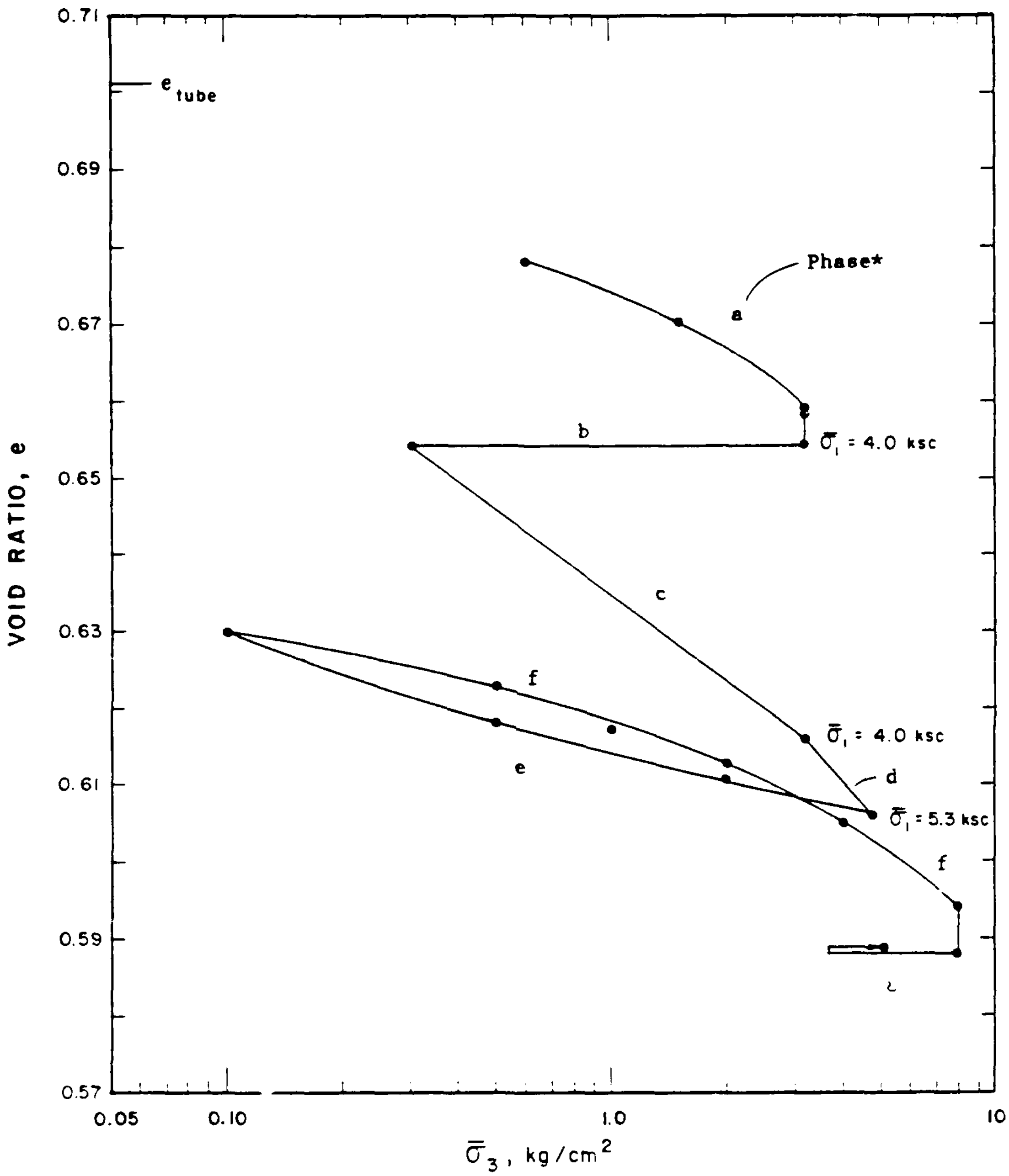
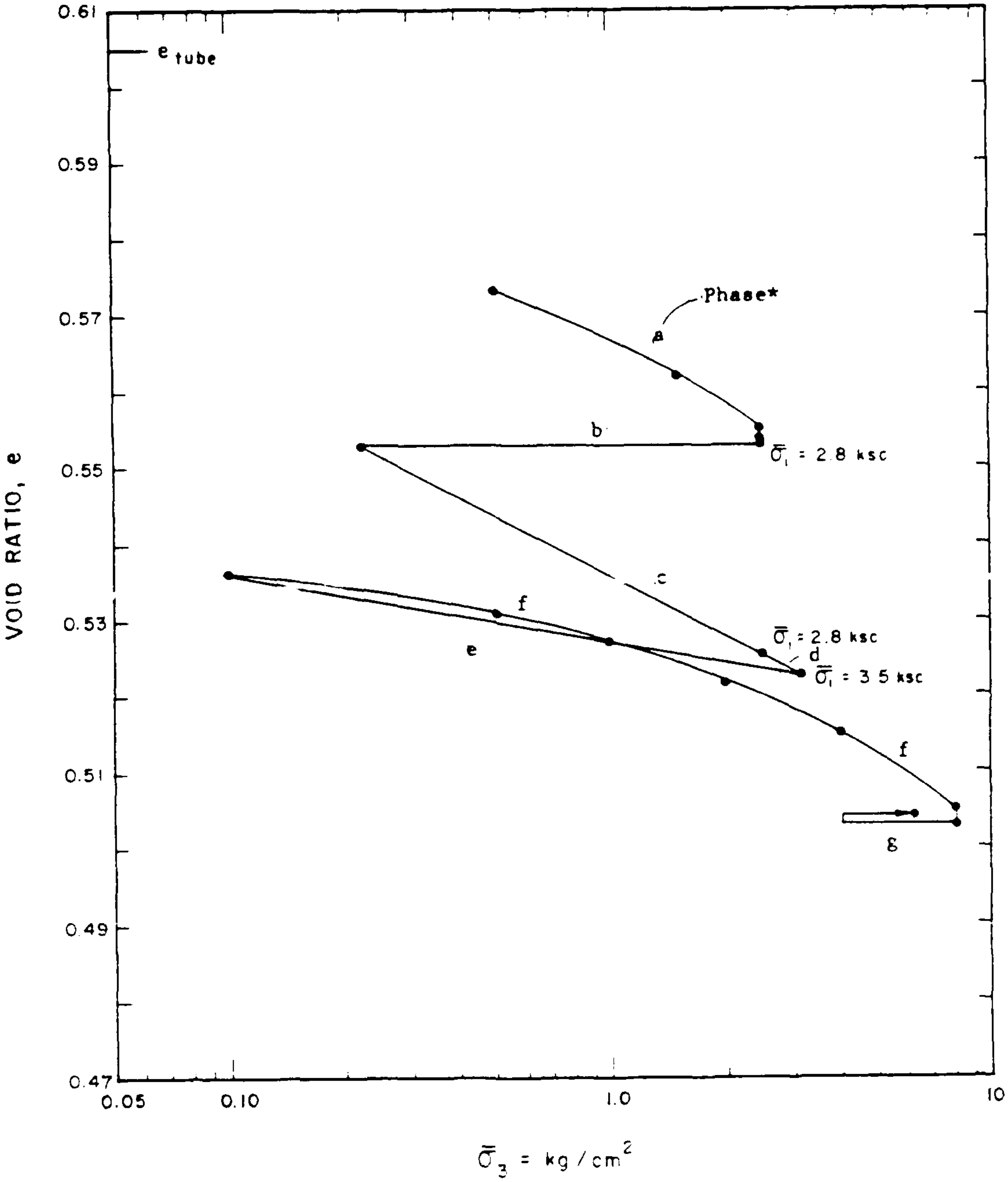

1.0
1.1
1.25
1.4



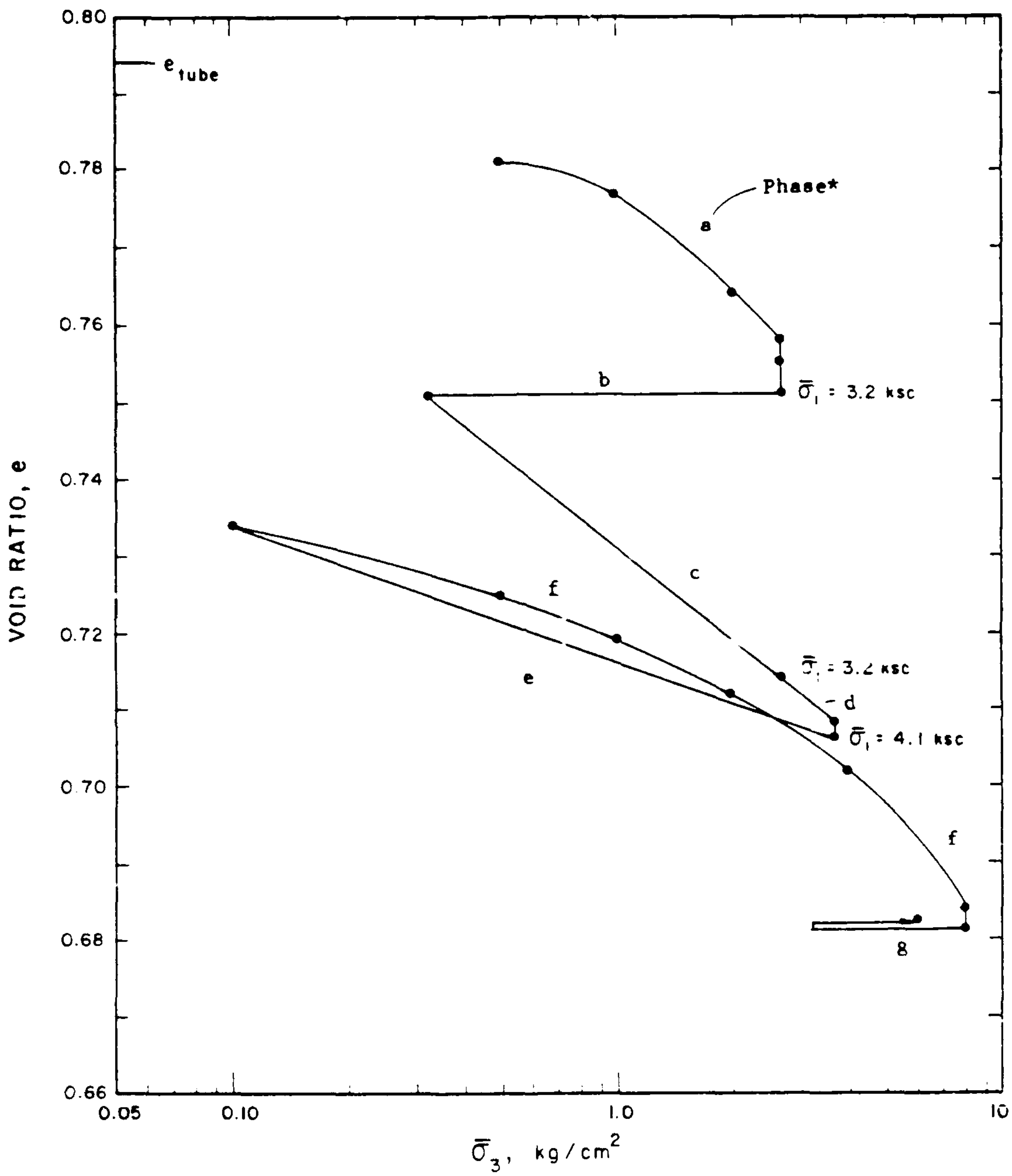
*See text of Appendix for explanation of Phases.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY OF VOID RATIO CHANGES - TEST CRR2 EXPLORATORY SHAFT SAMPLE TS306A
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F95



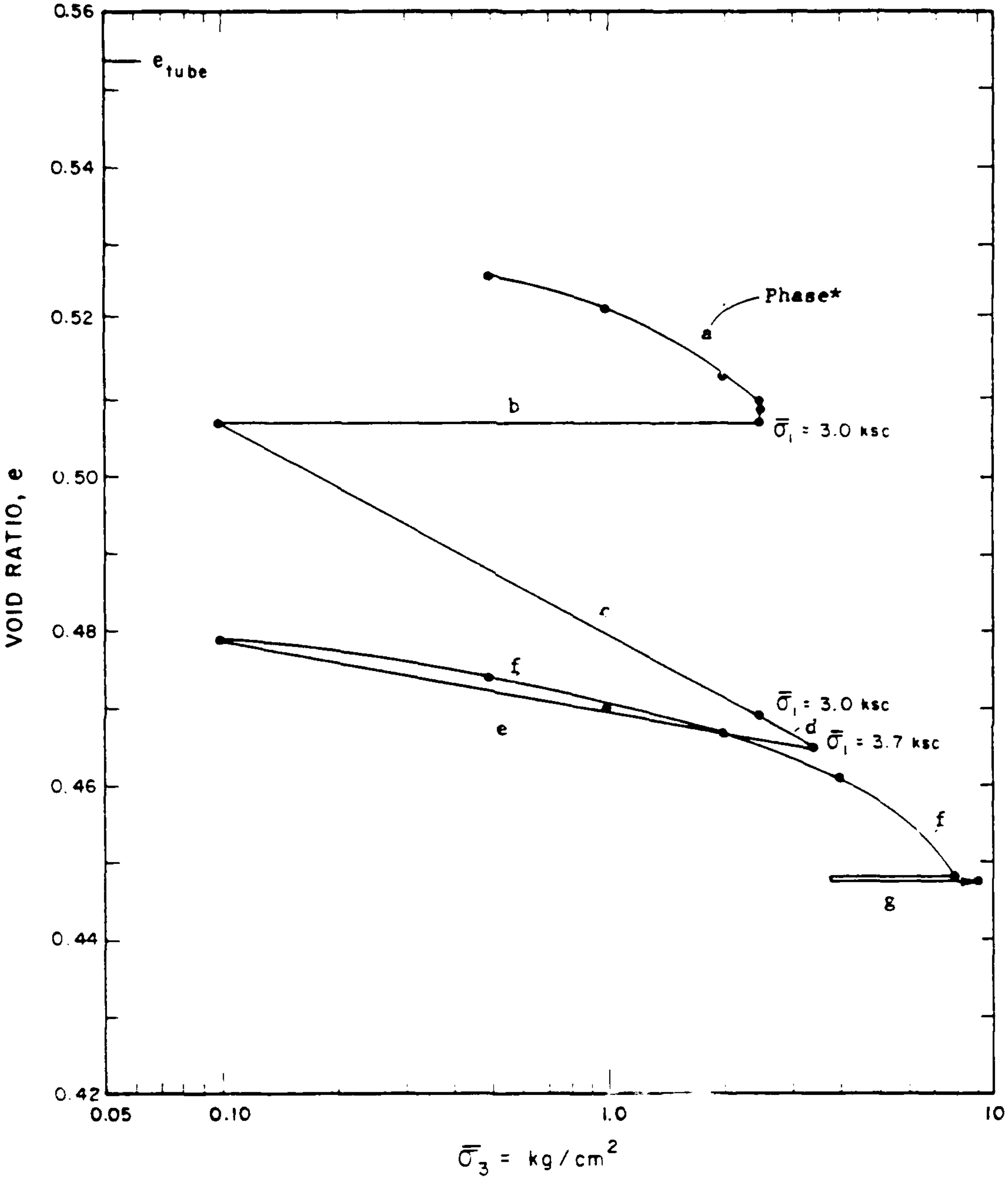
*See text of Appendix for explanation of Phases.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY OF VOID RATIO CHANGES - TEST CRR3 EXPLORATORY SHAFT SAMPLE TS112
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F96



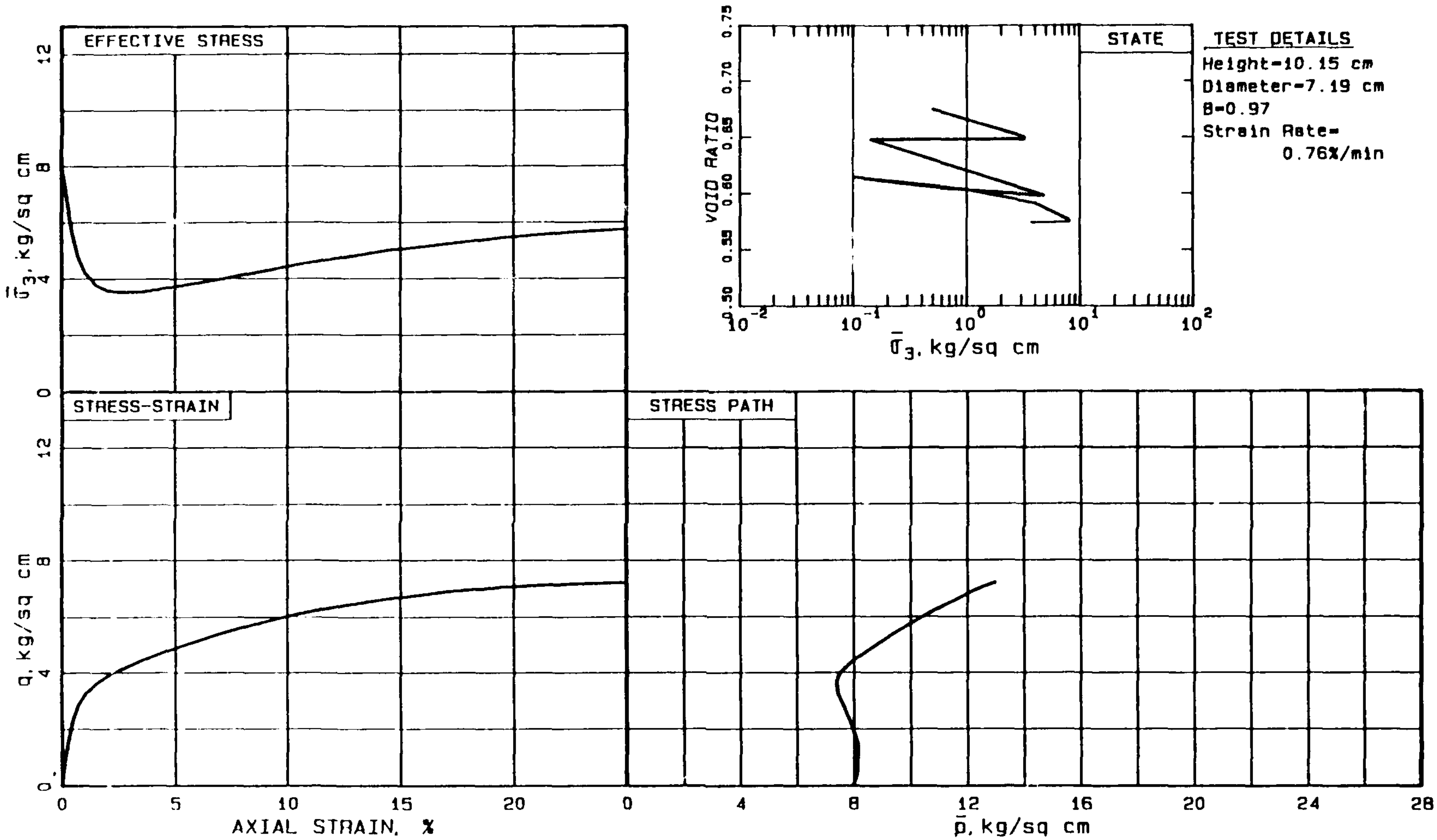
*See text of Appendix for explanation of Phases.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY OF VOID RATIO CHANGES - TEST CRR4 BORING U11iA SAMPLE UF9F
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F97



*See text of Appendix for explanation of Phases.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY OF VOID RATIO CHANGES - TEST CRR5 BORING U111 SAMPLE UF8B
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F98



TEST DETAILS
Height=10.15 cm
Diameter=7.19 cm
B=0.97
Strain Rate= 0.76%/min

SOIL	Exp. Shaft	Sample TS309B
Top Depth 83.8 ft		El 1013.7 ft
Sandy Silt, Stratified, 44% Sand.		

STRUCTURE
Undisturbed Tripod Tube Sample.

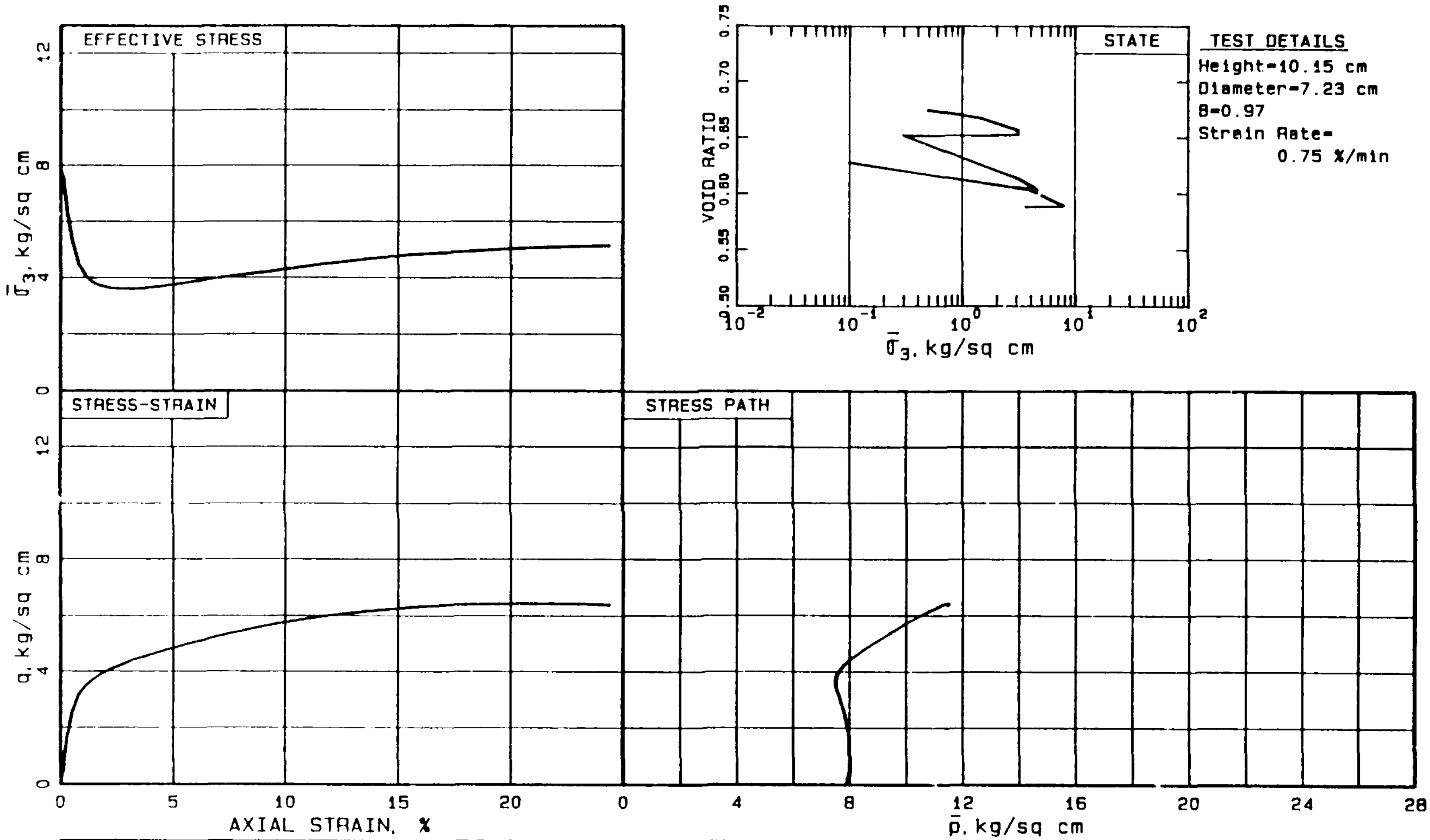
STATE
$\bar{\sigma}_{3c}$=8.0 kg/sq cm e_c=0.578
K_c =1.0 γ_{dc}=106.4 pcf

LOADING
Undrained Axial Monotonic Compression.

C9-R-1
LOWER SAN FERNANDO DAM
PROJECT 85669 30 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS

Fig. F99



SOIL	Exp. Shaft	Sample TS306A
Top Depth 83.5 ft		El 1014.0 ft
Silty Sand, Stratified,		49% fines.

STRUCTURE
Undisturbed Tripod Tube Sample.

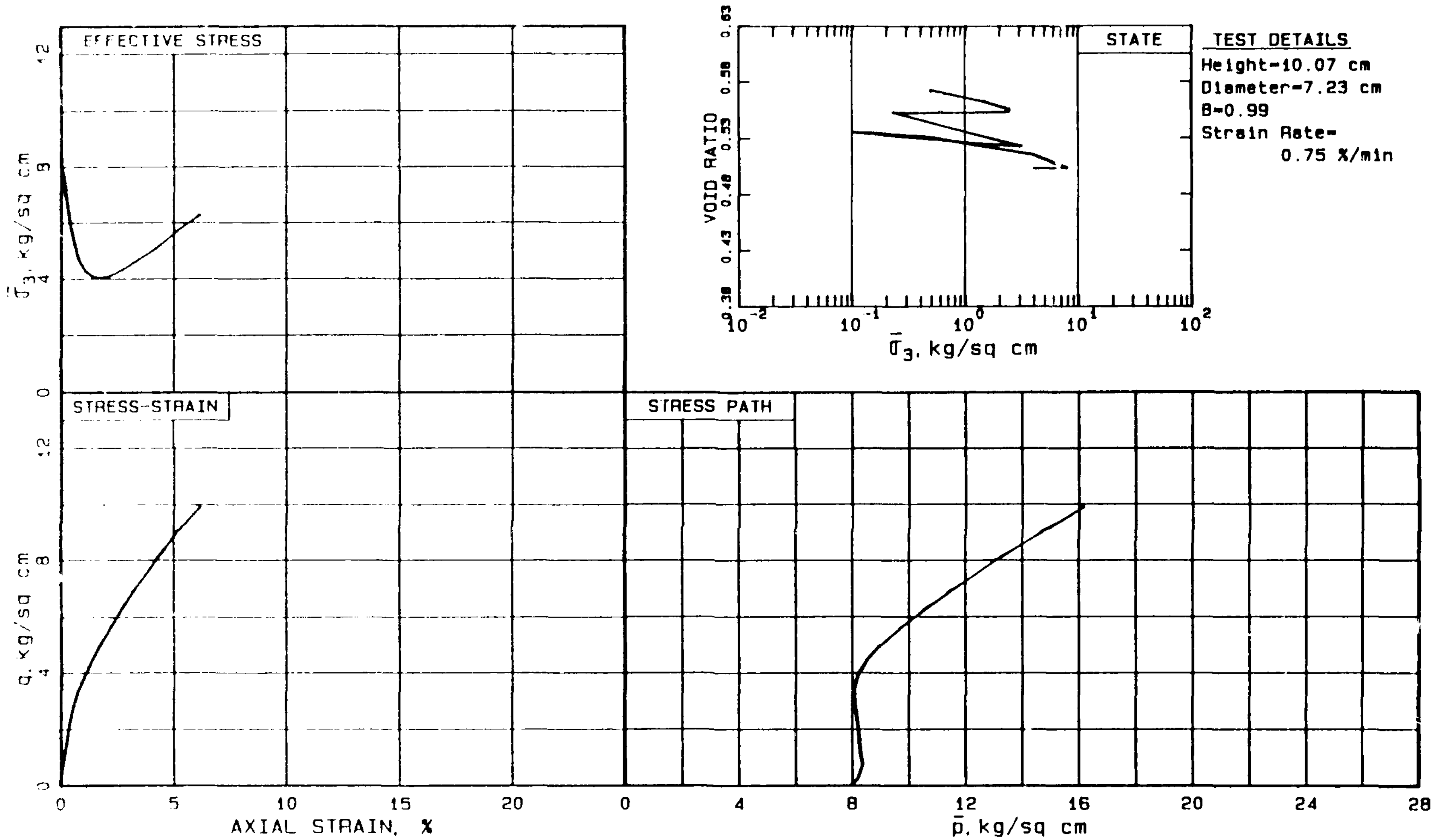
STATE
$\bar{\sigma}_{3c}$=8.0 kg/sq cm e_c=0.590
K_c =1.0 γ_{dc}=105.6 pcf

LOADING
Undrained Axial Monotonic Compression.

CR-R-2
LOWER SAN FERNANDO DAM
PROJECT 85669 30 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS

Fig. F10C



SOIL	Exp. Shaft	SAMPLE TS112	STATE	$\bar{\sigma}_{3c}$=8.0 kg/sq cm	e_c=0.503
Top Depth 55.1 ft		El 1042.4 ft		K_c =1.0	γ_{dc}=110.8 pcf
Widely Graded Sand.					
STRUCTURE			LOADING		
Undisturbed Tripod Tube Sample.			Undrained Axial Monotonic Compression.		

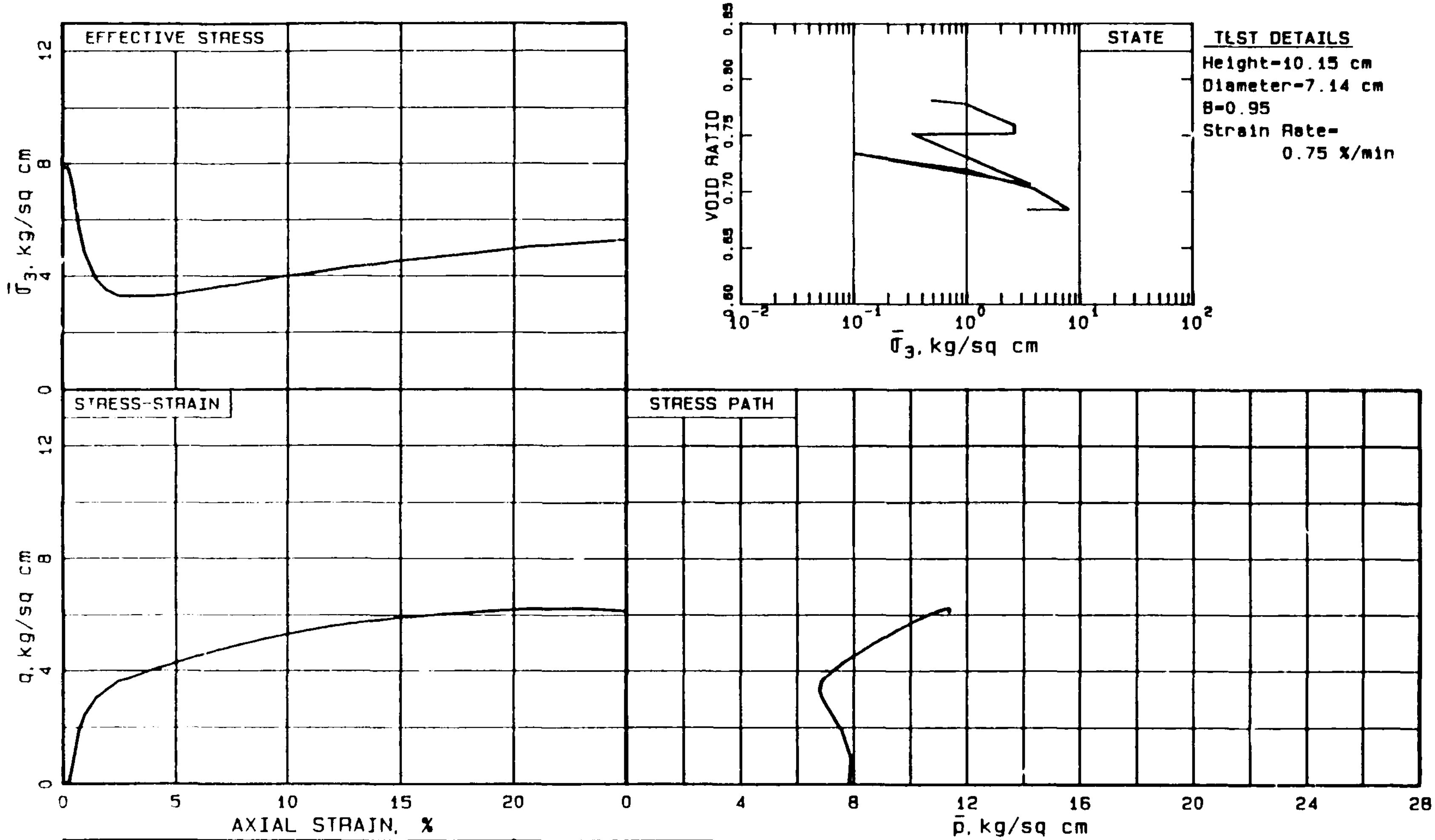
CR-R-3

LOWER SAN FERNANDO DAM

PROJECT 85669 30 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.

WINCHESTER - MASSACHUSETTS



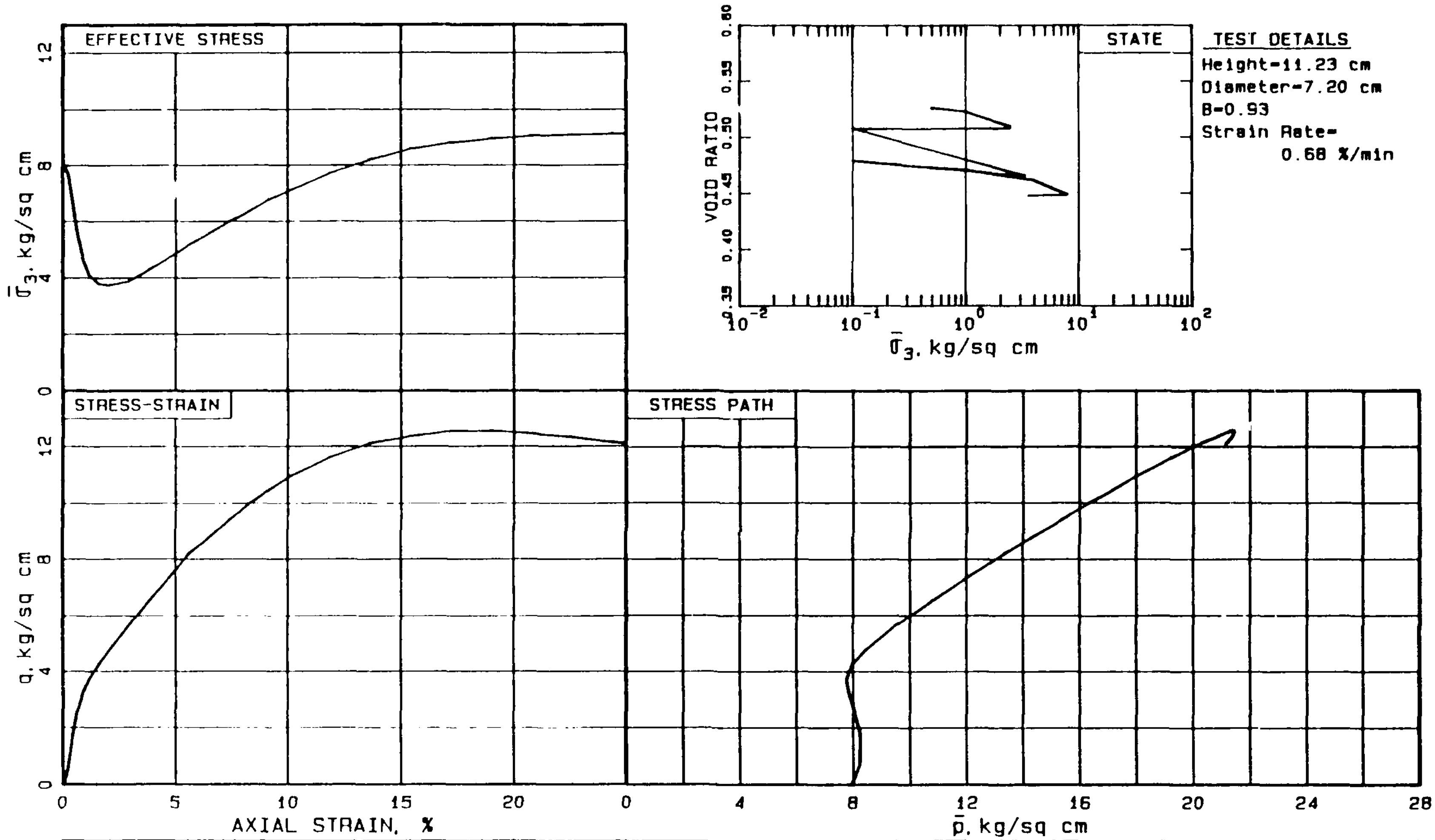
TEST DETAILS
Height=10.15 cm
Diameter=7.14 cm
B=0.95
Strain Rate=
0.75 %/min

SOIL	Boring U111A Sample UF9B
	Top Depth 64.4 ft El 1030.7 ft
	Sand, Silty Sand, and Silt.
STRUCTURE	Undisturbed Fixed Piston Tube Sample.

STATE	$\bar{\sigma}_{3c}$=8.0 kg/sq cm e_c=0.681
	K_c =1.0 γ_{dc}=99.1 pcf
LOADING	Undrained Axial Monotonic Compression.

CR-R-4
LOWER SAN FERNANDO DAM
PROJECT 85669 30 JANUARY 1987

GEOTECHNICAL ENGINEERS INC.
WINCHESTER - MASSACHUSETTS

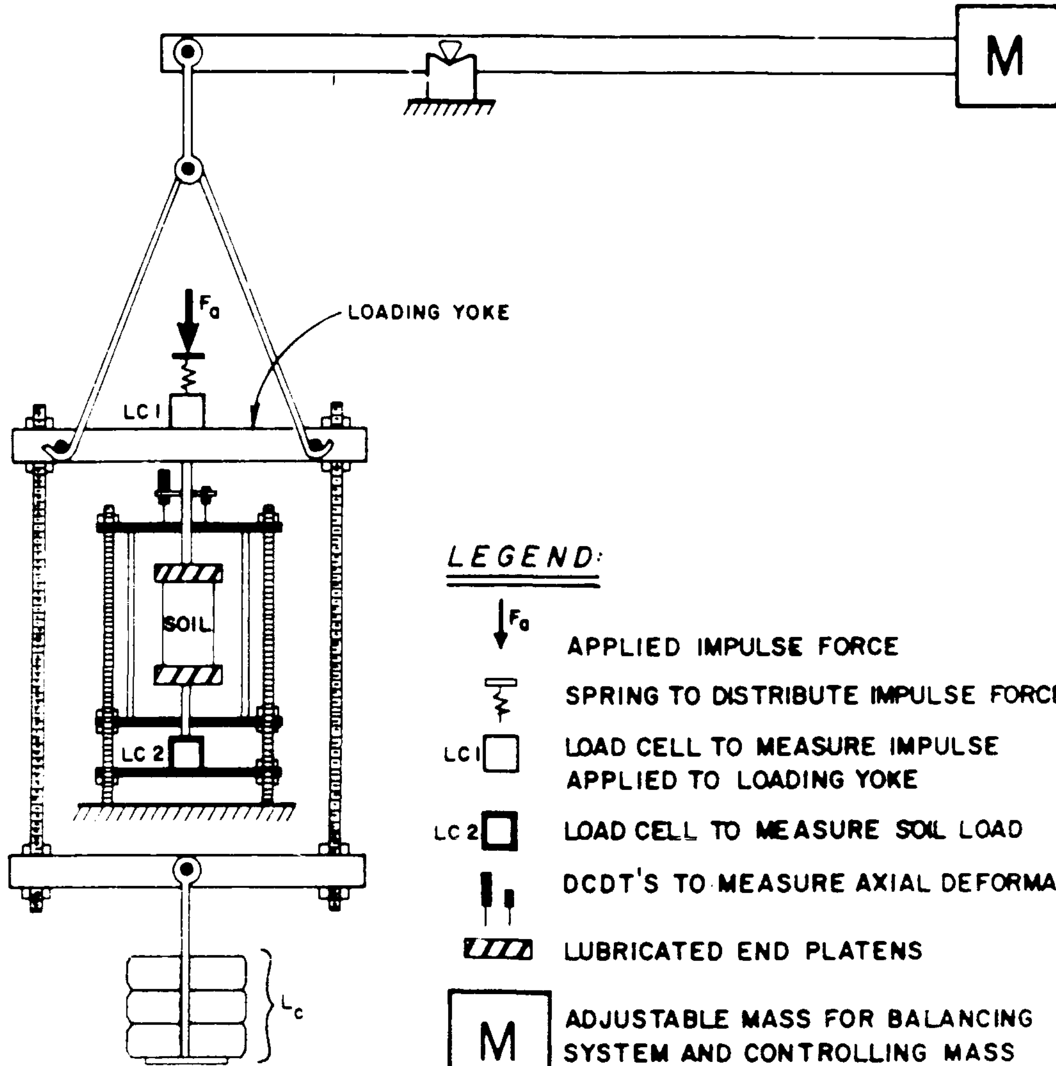


TEST DETAILS

Height=11.23 cm
Diameter=7.20 cm
B=0.93
Strain Rate= 0.68 %/min

SOIL	STATE	
Boring U111 Sample UF88 Top Depth 58.4 ft El 1036.7 ft Widely Graded Sand.	$\bar{\sigma}_{3c}$=8.0 kg/sq cm e_c=0.448 K_c =1.0 γ_{dc}=115.1 pcf	CR-R-5 LOWER SAN FERNANDO DAM PROJECT 85669 30 JANUARY 1987
STRUCTURE	**LOADING**	
Undisturbed Fixed Piston Tube Sample.	Undrained Axial Monotonic Compression.	GEOTECHNICAL ENGINEERS INC. WINCHESTER - MASSACHUSETTS

Fig. F103



LEGEND:

- F_a APPLIED IMPULSE FORCE
- SPRING TO DISTRIBUTE IMPULSE FORCE
- LC 1 LOAD CELL TO MEASURE IMPULSE APPLIED TO LOADING YOKE
- LC 2 LOAD CELL TO MEASURE SOIL LOAD
- DCDT'S TO MEASURE AXIAL DEFORMATION
- LUBRICATED END PLATENS
- M ADJUSTABLE MASS FOR BALANCING SYSTEM AND CONTROLLING MASS MOMENT OF INERTIA
- L_c DEAD WEIGHT SYSTEM FOR APPLYING ANISOTROPIC CONSOLIDATION STRESSES

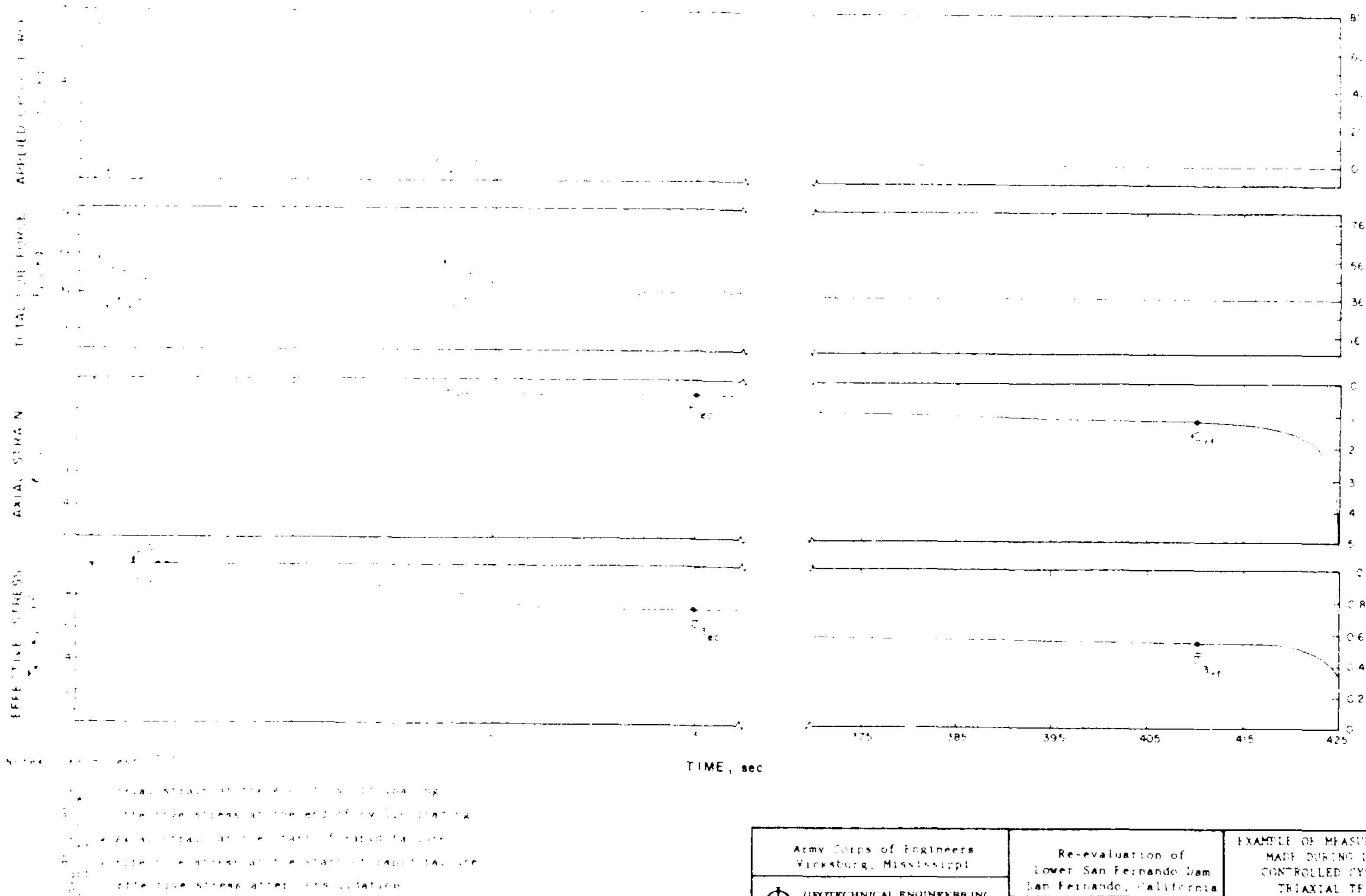
NOTE:

THE FOLLOWING ARE NOT SHOWN:

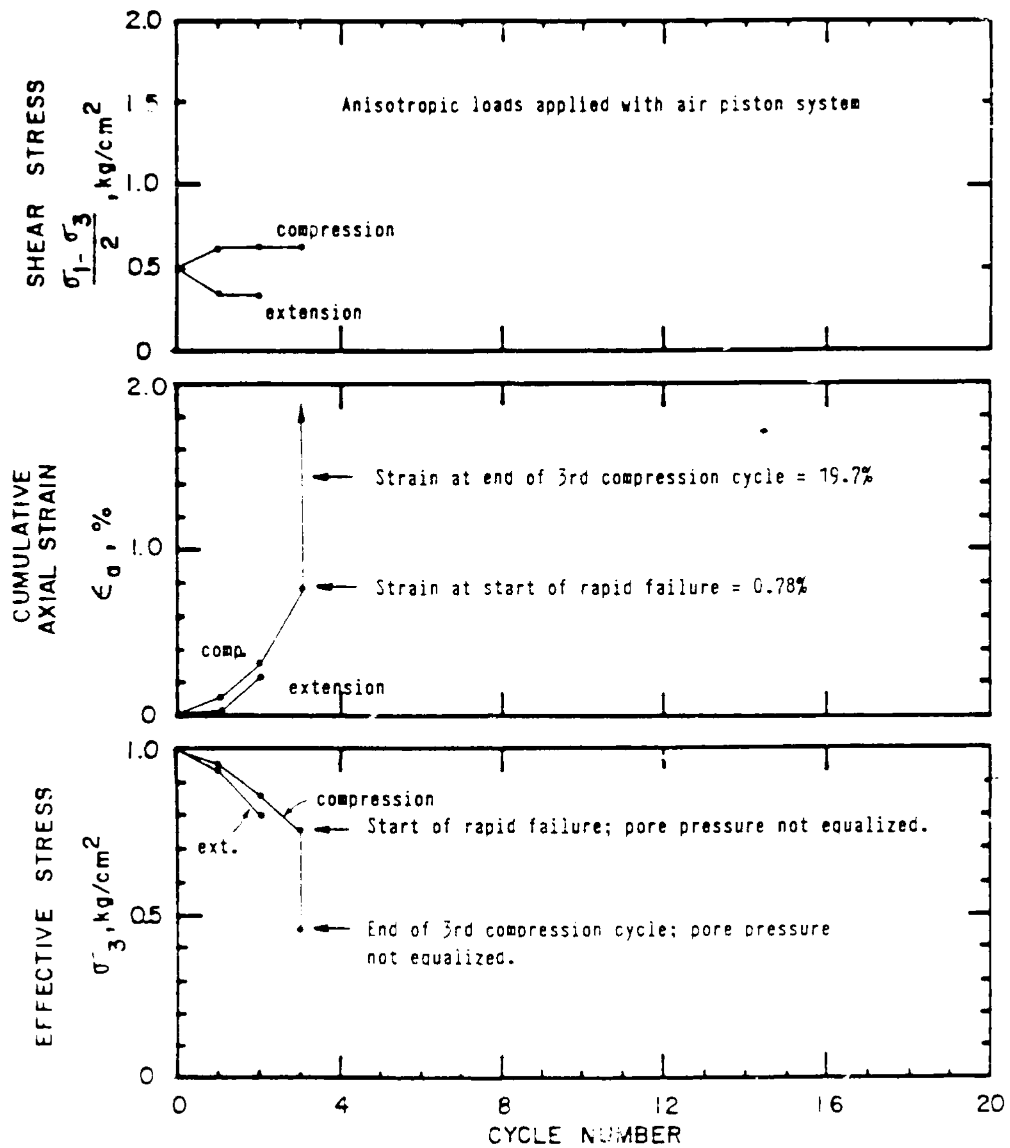
1. Air Pressure Regulating System
2. Back Pressure and Cell Pressure Lines
3. Pore Pressure Transducer
4. Volume Change Measurement System
5. Strip Chart Recorder

NOT TO SCALE

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SCHEMATIC DIAGRAM OF LOAD CONTROLLED CYCLIC DEVICE
GEOTECHNICAL ENGINEERS INC.	Project 85669	Sept. 2, 1987 Fig. F104



Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	EXAMPLE OF MEASUREMENTS MADE DURING LOAD CONTROLLED CYCLIC TRIAXIAL TEST
GEOTECHNICAL ENGINEERS INC	Project 85669	Sept. 2, 1987 Fig. F10



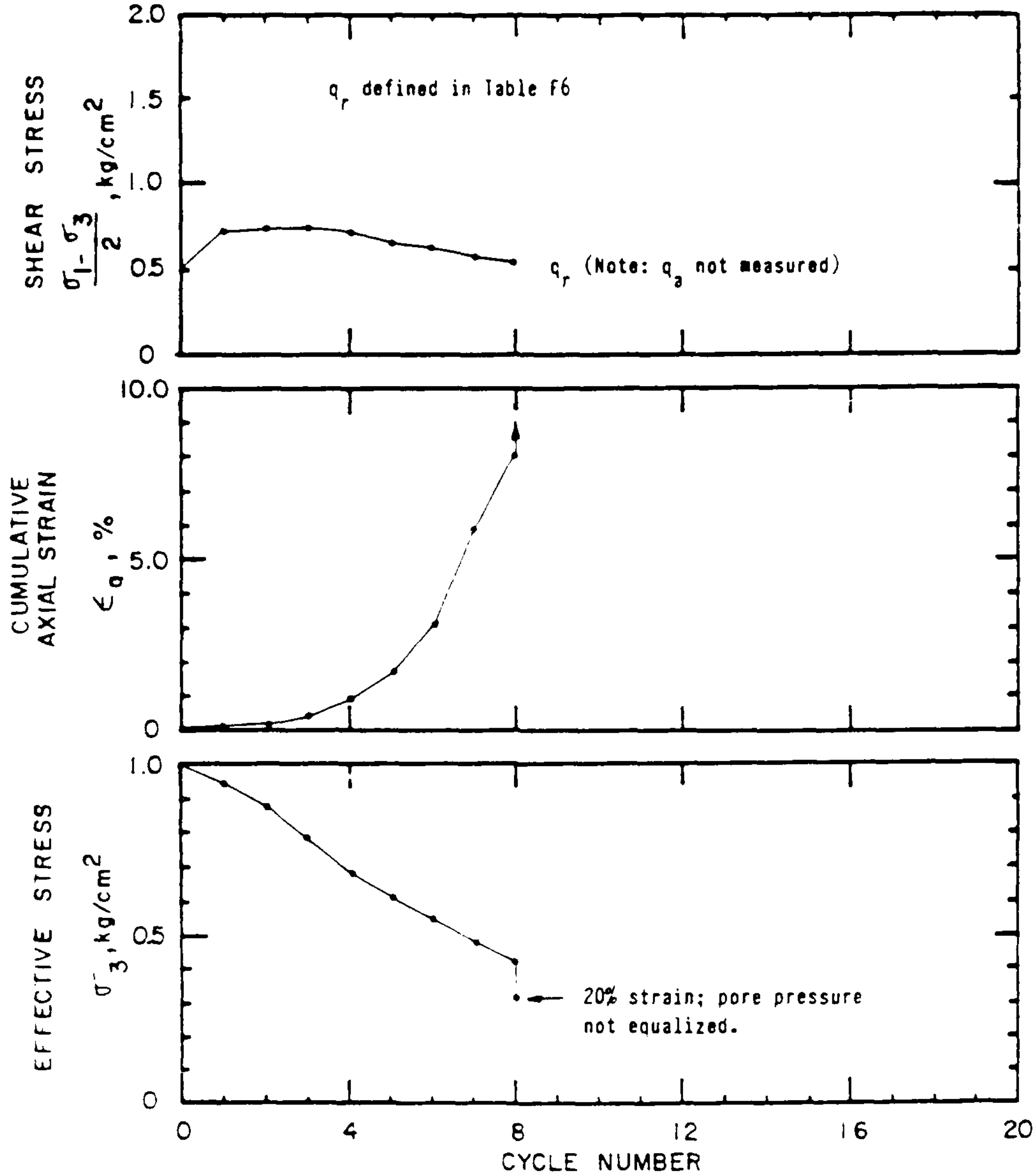
SOIL: Batch Mix 7. Silty Fine Sand with 50.5% slightly plastic fines.

STRUCTURE: Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.

STATE: $\bar{\sigma}_{1c}$ = 2.00 kg/cm^2 $\quad e_c$ = 0.646
$\bar{\sigma}_{3c}$ = 1.00 kg/cm^2 $\quad \gamma_{dc}$ = 102.0 pcf

LOADING: Undrained Cyclic Axial Compression. Air Piston Load Application System

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY PLOTS CYCLIC TRIAXIAL TEST CR101
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F106



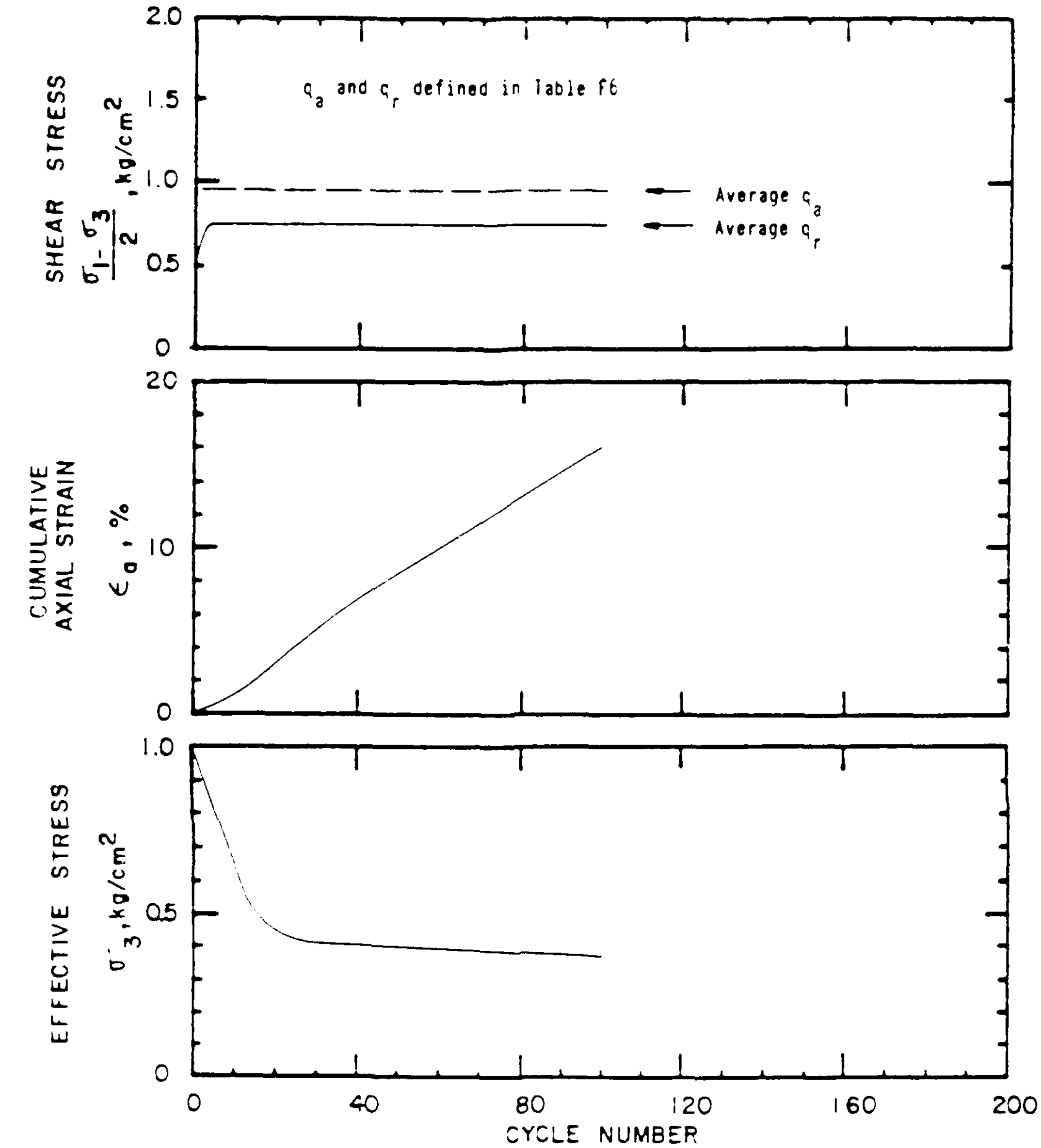
SOIL: Batch Mix 7. Silty Fine Sand with 50.5% slightly plastic fines.

STRUCTURE: Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.

STATE: $\bar{\sigma}_{1c}$ = 2.03 kg/cm^2 e_c = 0.636
$\bar{\sigma}_{3c}$ = 1.00 kg/cm^2 γ_{dc} = 102.6 pcf

LOADING: Undrained Cyclic Axial Compression.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY PLOTS CYCLIC TRIAXIAL TEST CR102
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F107



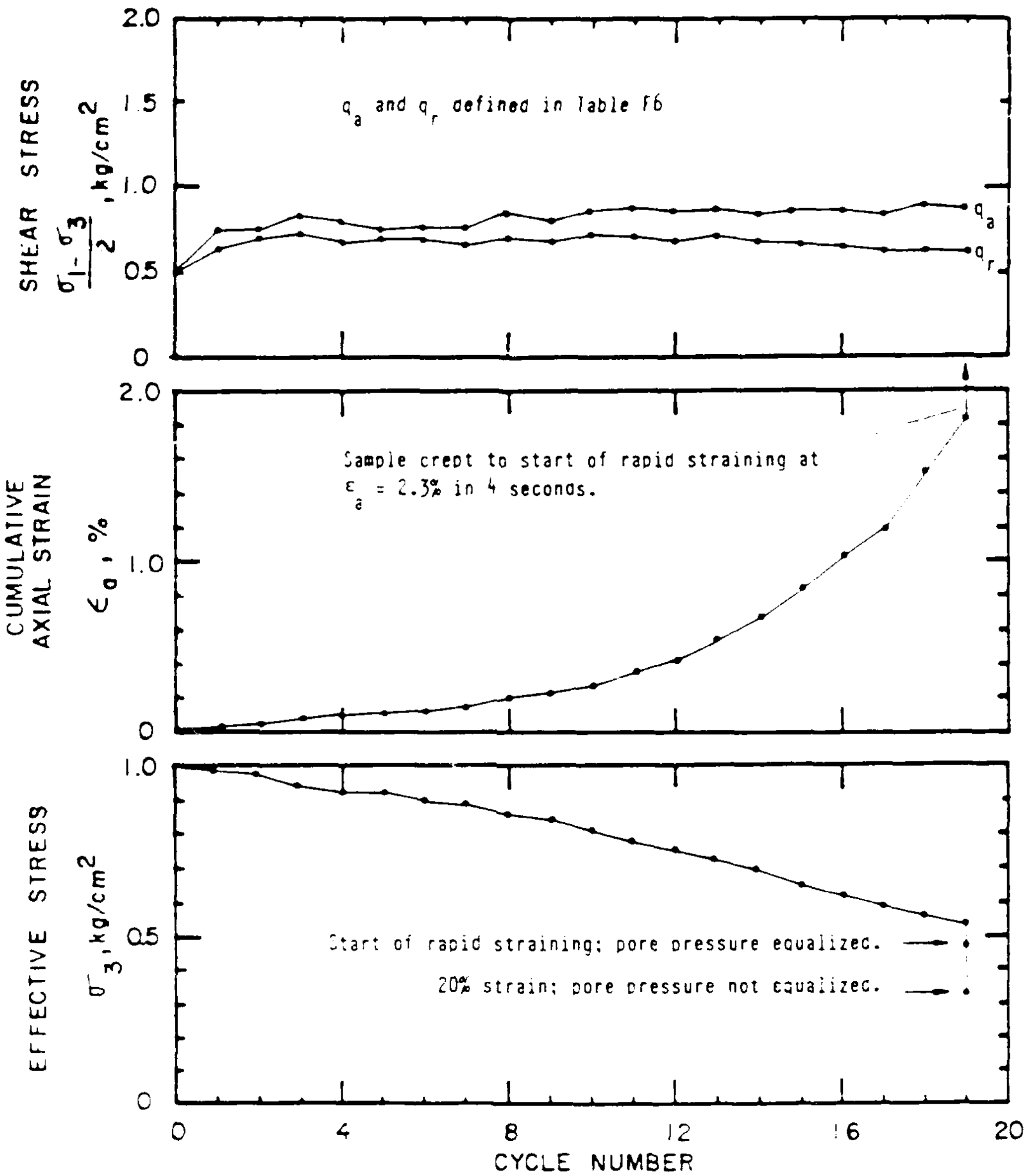
SOIL: Batch Mix 7. Silty Fine Sand with 50.5% slightly plastic fines.

STRUCTURE: Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.

STATE: $\bar{\sigma}_{1c}$ = 2.05 kg/cm² e_c = 0.593
$\bar{\sigma}_{3c}$ = 1.00 kg/cm² γ_{dc} = 105.4 pcf

LOADING: Undrained Cyclic Axial Compression.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY PLOTS CYCLIC TRIAXIAL TEST CR103
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F108



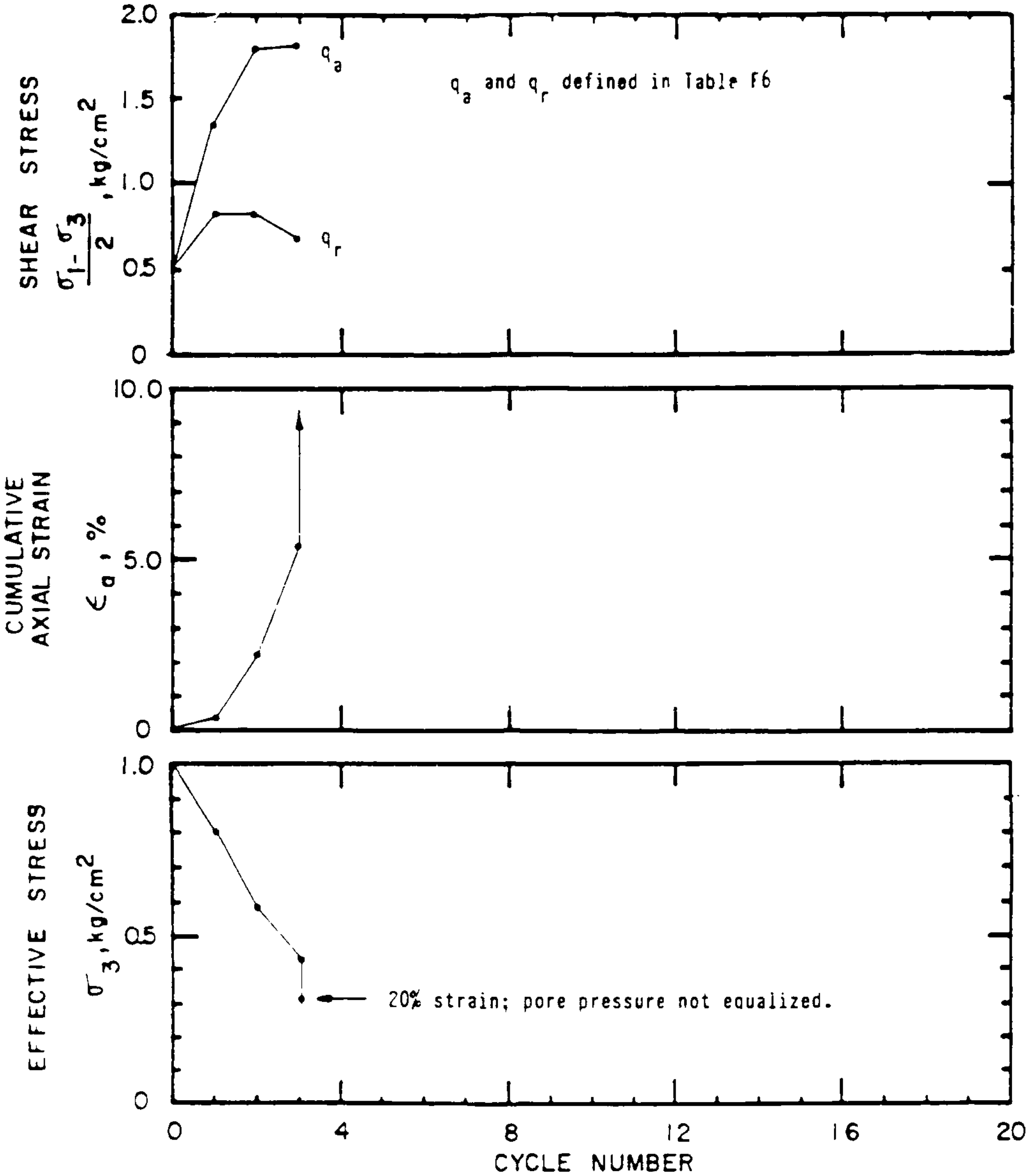
SOIL: Batch Mix 7. Silty Fine Sand with 50.5% slightly plastic fines.

STRUCTURE: Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.

STATE: $\bar{\sigma}_{1c}$ = 2.00 kg/cm² e_c = 0.640
$\bar{\sigma}_{3c}$ = 1.00 kg/cm² γ_{dc} = 102.4 pcf

LOADING: Undrained Cyclic Axial Compression.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY PLOTS CYCLIC TRIAXIAL TEST CR104
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F109



SOIL: Batch Mix 7. Silty Fine Sand with 50.5% slightly plastic fines.

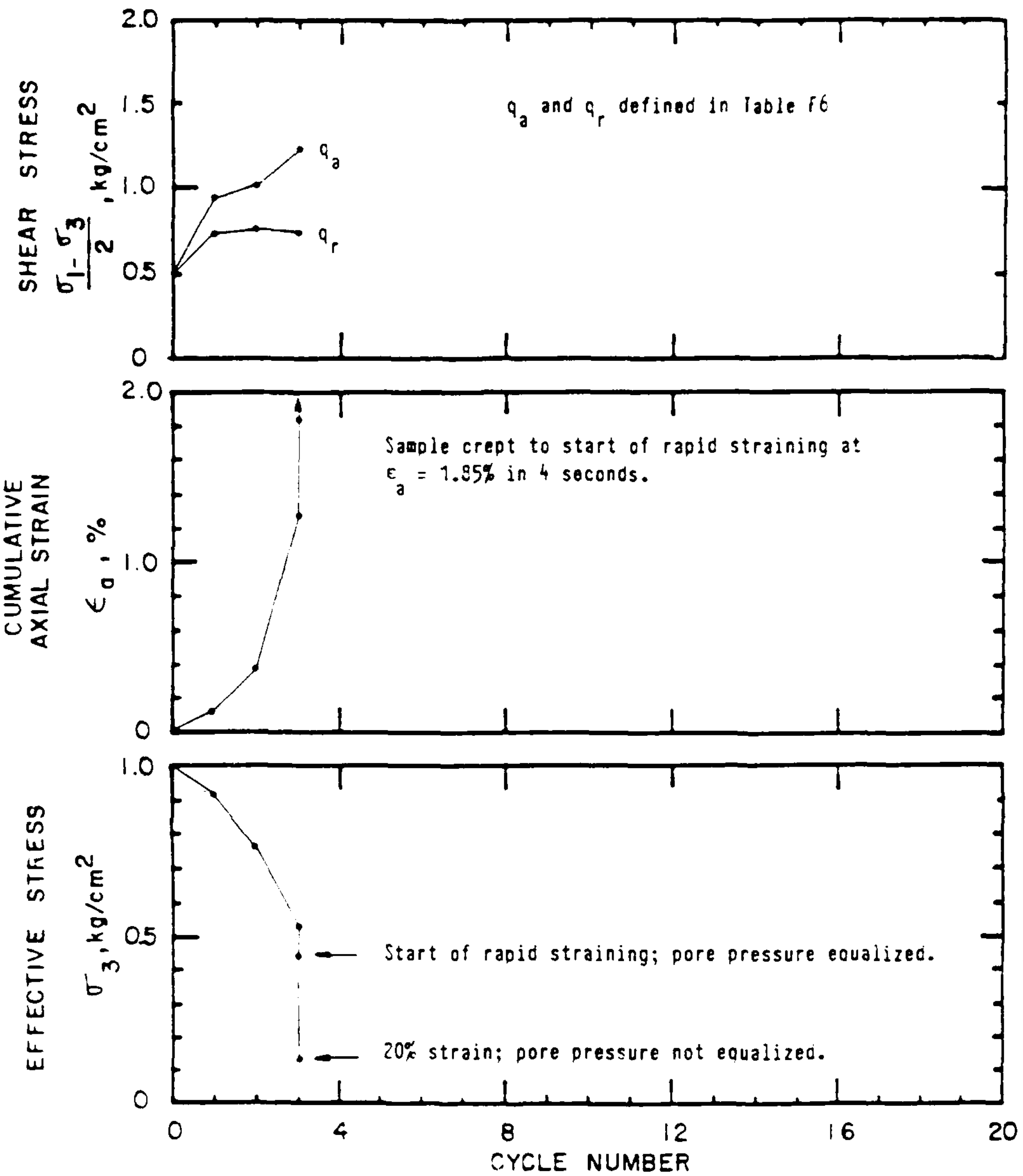
STRUCTURE: Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.

STATE: $\bar{\sigma}_{1c}$ = 2.01 kg/cm^2 $\quad e_c$ = 0.647

$\bar{\sigma}_{3c}$ = 1.00 kg/cm2 $\quad \gamma_{dc}$ = 101.9 pcf

LOADING: Undrained Cyclic Axial Compression.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY PLOTS CYCLIC TRIAXIAL TEST CR105
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F110



SOIL: Batch Mix 7. Silty Fine Sand with 50.5% slightly plastic fines.

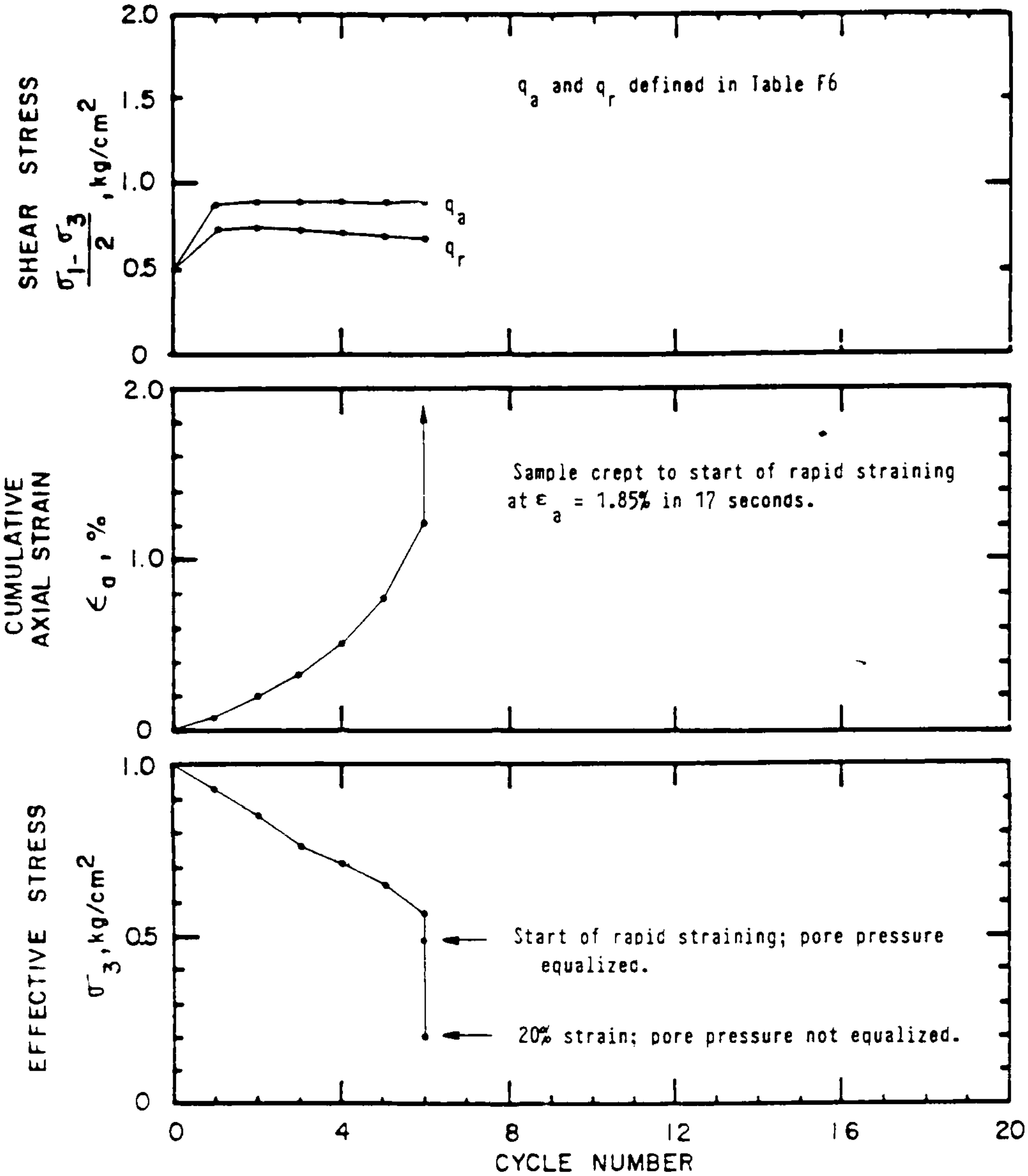
STRUCTURE: Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.

STATE: $\bar{\sigma}_{1c}$ = 2.00 kg/cm^2 e_c = 0.643

$\bar{\sigma}_{3c}$ = 1.00 kg/cm^2 γ_{dc} = 102.2 pcf

LOADING: Undrained Cyclic Axial Compression.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY PLOTS CYCLIC TRIAXIAL TEST CR106
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F111



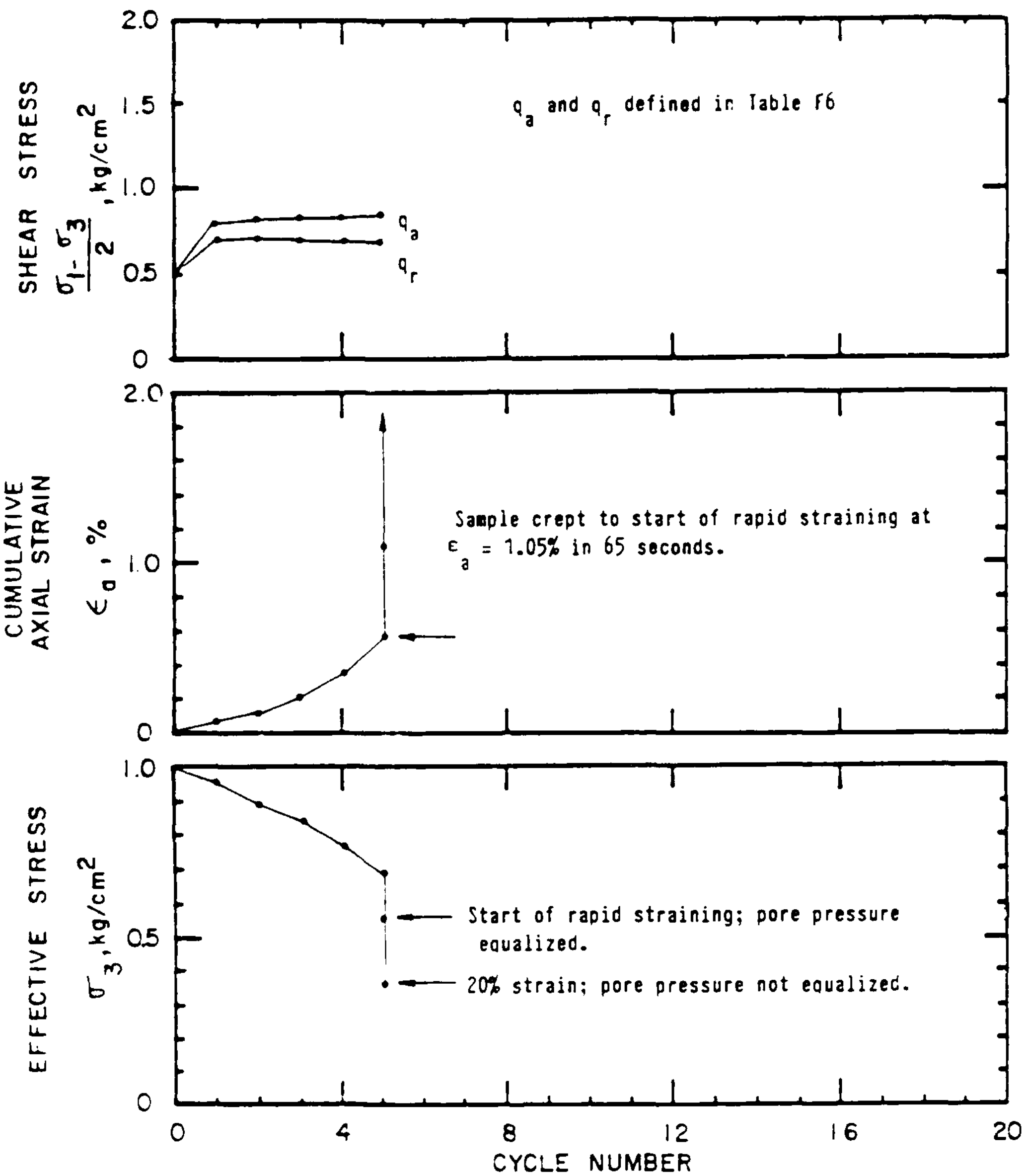
SOIL: Batch Mix 7. Silty Fine Sand with 50.5% slightly plastic fines.

STRUCTURE: Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.

STATE: $\bar{\sigma}_{1c} = 2.00$ kg/cm^2 $e_c = 0.649$
$\bar{\sigma}_{3c} = 1.00$ kg/cm^2 $\gamma_{dc} = 101.8$ pcf

LOADING: Undrained Cyclic Axial Compression.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY PLOTS CYCLIC TRIAXIAL TEST CR108
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F112



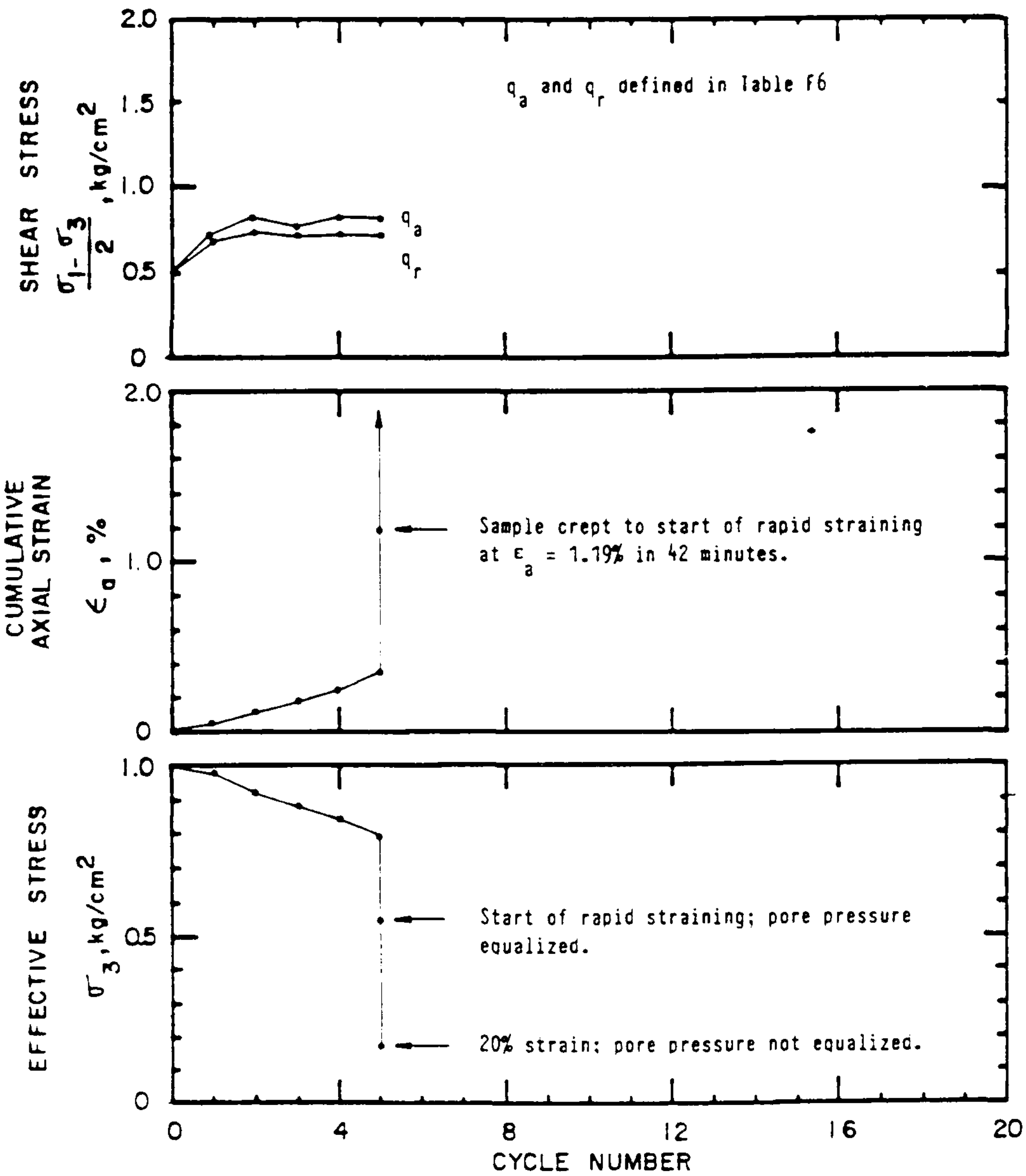
SOIL: Batch Mix 7. Silty Fine Sand with 50.5% slightly plastic fines.

STRUCTURE: Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.

STATE: $\bar{\sigma}_{1c}$ = 2.01 kg/cm^2 e_c = 0.645
$\bar{\sigma}_{3c}$ = 1.00 kg/cm^2 γ_{dc} = 102.0 pcf

LOADING: Undrained Cyclic Axial Compression.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY PLOTS CYCLIC TRIAXIAL TEST CR109
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F113



SOIL: Batch Mix 7. Silty Fine Sand with 50.5% slightly plastic fines.

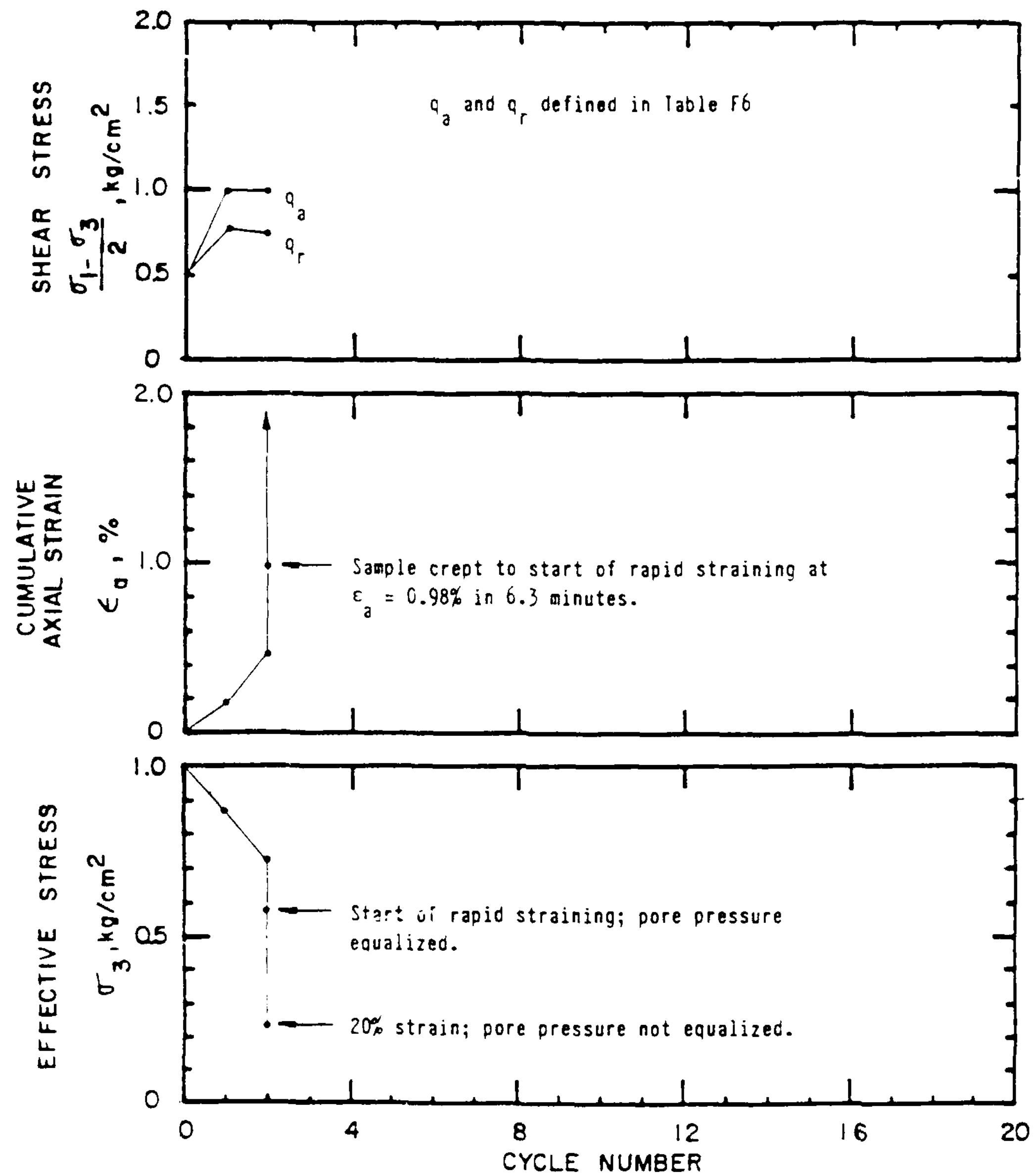
STRUCTURE: Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.

STATE: $\bar{\sigma}_{1c}$ = 2.00 kg/cm^2 e_c = 0.651

$\bar{\sigma}_{3c}$ = 1.00 kg/cm^2 γ_{dc} = 101.7 pcf

LOADING: Undrained Cyclic Axial Compression.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY PLOTS CYCLIC TRIAXIAL TEST CR110
GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F114



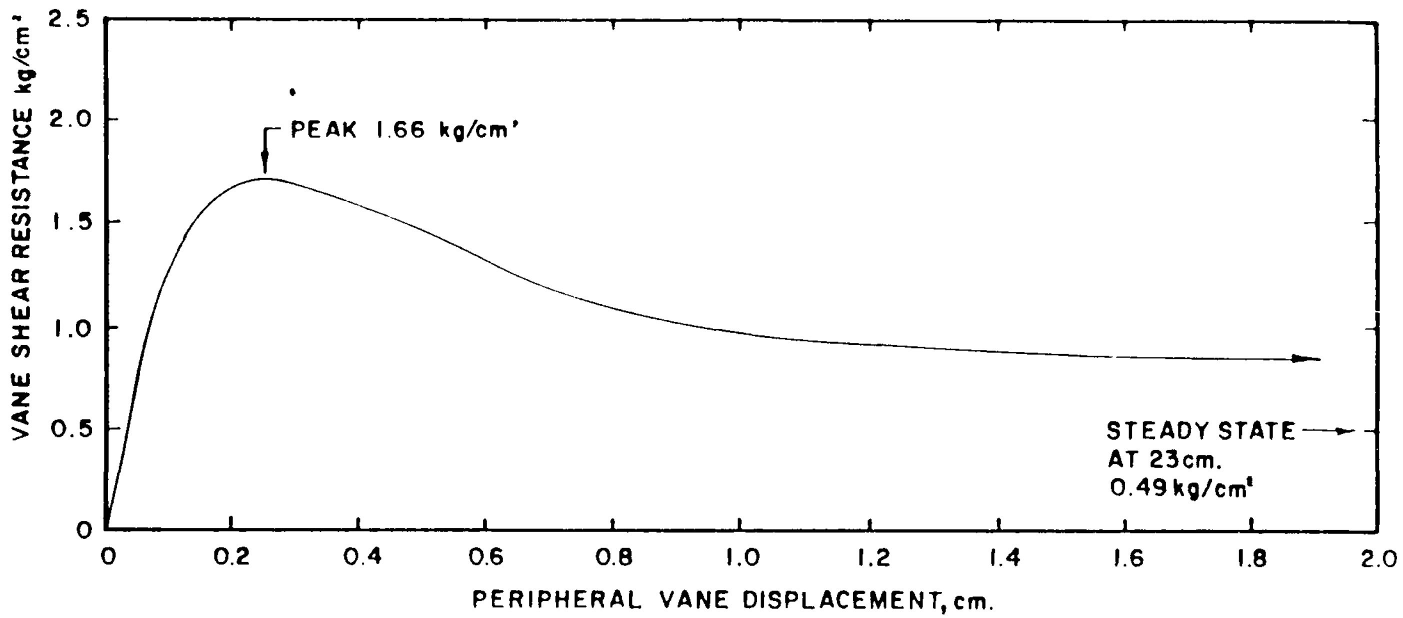
SOIL: Batch Mix 7. Silty Fine Sand with 50.5% slightly plastic fines.

STRUCTURE: Remolded. Compacted moist at 4% water content in 8 layers. Soil passed through No. 40 sieve.

STATE: $\bar{\sigma}_{1c}$ = 2.00 kg/cm² e_c = 0.646
$\bar{\sigma}_{3c}$ = 1.00 kg/cm² γ_{dc} = 102.0 pcf

LOADING: Undrained Cyclic Axial Compression.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SUMMARY PLOTS CYCLIC TRIAXIAL TEST CR111
GEOTECHNICAL ENGINEERS INC. WINCHESTER • MASSACHUSETTS	Project 85669	Sept. 2, 1987 Fig. F115



SOIL:	Boring U105, Sample UF14C, Depth 99.6 ft, El. 1014.5 ft, Silty Clay
STRUCTURE:	Undisturbed Tube Sample
STATE:	Water Content 24.0%
LOADING:	Vane inserted 2.5 cm into open end of specimen while specimen was still in sampling tube. Undrained vane shear.
DETAILS:	Vane size: 1.27 cm diameter, 1.27 cm long. Rotation Rate: 19.1°/sec. Peripheral Vane Displacement Rate: 0.21 cm/sec.

Army Corps of Engineers Vicksburg, Mississippi	Re-evaluation of Lower San Fernando Dam San Fernando, California	SHEAR RESISTANCE VS. PERIPHERAL VANE DISPLACEMENT TEST LV1
Φ GEOTECHNICAL ENGINEERS INC WINCHESTER • MASSACHUSETTS	Project 85669	Sep. 2, 1987 Fig. F116

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