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GEOTECHNICAL ENGINEERING INVESTIGATION

on

Roosevelt Irrigation District Canal
Station 20+50 to Station 24+00
Phoenix, Arizona

for

Simons, Li & Associates
P.O. Box 1816
3555 Stanford Road
Ft. Collins, Colorado

524 North Sixth Avenue
Tucson, Arizona 85705
(602) 623-7774

DESERT
EARTH
ENGINEERING

Registered Professional Engineer (Civil)
CERTIFICATE NO.
10296
ROBERT L.
SOGGE
Date Signed 1/30/86
ARIZONA, U.S.A.

January 30, 1986
84-210B

CONSULTING GEOTECHNICAL ENGINEERS

A109.945

January 30, 1985
84-210B

Simons, Li & Associates
P.O. Box 1816
3555 Stanford Road
Ft. Collins, Colorado 80522

ATTN: Noel Bormann

RE: Geotechnical Engineering Report
RID Canal Station 11+00 to Station 24+00
Phoenix, Arizona

Introduction

This report is supplementary to Desert Earth Engineering reports on the Roosevelt Irrigation District Canal dated October 23, 1984 and November 22, 1985. This report discusses the use of vertical drains to accelerate consolidation of the clay-filled waste pit between Stations 21+00 and 24+00 of the flume alignment. Such consolidation will be necessary to provide stability to an embanked channel passing over the waste pits.

This report is a revision of our report dated December 18, 1985. Specific points addressed by the revision are as follows:

1) Assumption of horizontal permeability equal to twice the vertical permeability
2) Discussion of stability of clay pit related to cohesive strength
3) Reduction and possible elimination of secondary consolidation through use of a surcharge
4) Disruption of sand drains by differential movement.
5) Discrepancies in consolidation-time theories

DESERT EARTH ENGINEERING

524 North Sixth Avenue
Tucson, Arizona 85705
(602) 623-7774

Field Investigation

Number of Test Borings: 5

Location: See Site Plan, Fig. 1

Date Drilled: November 20, 1985

Subsurface soils were sampled using a CME-55 drill rig equipped with split spoon and ring samplers. Boring logs containing descriptions of the materials encountered in the subsurface investigation of the site are presented in Appendix A. Continuous penetrometer testing was used to locate the bottom of the waste pit. The penetration resistance values are included on the boring logs.

A soil profile for the project site is presented in Fig. 2. This soil profile is transverse to the canal alignment and shows the approximate side slope of the filled waste pit at Station 21+40. All evidence indicates that this profile is consistent from Station 21+00 to Station 24+00.

Laboratory Test Results

Selected samples taken in the field investigation were tested in the laboratory for grain size, Atterberg Limits, consolidation, and permeability. Estimates of shear strength for several samples are tabulated in Appendix B. These numbers were derived from needle penetrometer testing of undisturbed ring samples. Shear strength values given by Western Technologies Inc. are included for comparison.

The material found in the clay pit was very consistent. The results of Desert Earth's consolidation testing and those of WTI's consolidation tests are very similar; therefore only three consoldation tests were performed. These tests were conducted up to approximately 3 KSF as this was the

anticipated overburden pressure to be exerted by the final proposed configuration. This anticipated configuration consisted of a final embankment height of 15 feet as per our phone conversation with Noel Bormann.

Summary of Laboratory Testing Results (Complete Results are given in Appendix B)

Gradation and Plastic Index Tests

Boring No.	Depth (ft)	% Passing #200 Sieve	LL	PI	USCS Symbol
B-13	14-15.5	99	77	51	CH
B-13	34-35	99	80	53	CH

Consolidation Characteristic of Soil Subjected to Saturation

Boring No.	Depth (ft)	Surcharge Pressure (psf)	Consolidation %
B-13	24-25	2800	19.1
B-17	14-15	3000	13.1
B-18	14-15	1400	9.8

The unusual upward concave portion of the consolidation test performed on material from B-13 at 24-25 feet may be the result of premature removal of the sample from the test apparatus. Values for C_c were not calculated from this section of the curve.

Consolidation Parameters

Compression Index $C_c = .7$

Coefficient of Vertical Consolidation $C_{vv} = 0.043\ ft^2/day$

Coefficient of Horizontal Consolidation $C_{vh} = .0862\ ft^2/day$

Coefficient of Permeability $k = 1 \times 10^{-4}\ ft/day = 3.5 \times 10^{-8}\ cm/sec$

Sand drain diameter = 1 ft
Sand drain spacing = 5 ft

Conclusions and Recommendations

Our field and laboratory testing shows the waste pit to be filled with a uniform, very plastic, saturated clay. This clay is unconsolidated and, under the expected loading, has a settlement potential of up to 20%. This could lead to total settlements of up to 5 feet for overburden placed above the clay layer.

Because of the low permeability of the clay, settlement will be dependent on dissipation of pore-water pressure over time. Laboratory testing indicates that 90% of primary consolidation will occur 8-12 years after placement of the overburden.

Consolidation of the clay can be greatly accelerated through the use of vertical drains. The effectiveness of these drains is a function of both the drain diameter and the drain spacing, with the drain spacing having the greater effect. The analyses performed by Desert Earth Engineering is based upon a drain diameter of 1 foot. A graph of percent consolidation versus time for three different spacings is presented in Fig. 3.

The analysis performed by Desert Earth Engineering was based on radial drainage theory developed by Barron in 1948 and Richardt in 1957. This analyses assumed equal vertical strains at the surface of the clay layer. For this analysis it was also assumed that the coefficient of horizontal permeability k_h is twice the vertical coefficient k_v. This assumption is slightly conservative as values as high as $k_h = 3$ to $5\ k_v$ are often encountered. This assumption was made necessary by the difficulty of retrieving undisturbed samples taken horizontally into the clay layer. Also assumed in this analysis was a well radius reduction factor of 1/2 to account for smear as proposed by Leonards (1962). This analysis also assumed a constant initial pore water pressure throughout the clay mass. A double drained, homogeneous soil mass was also assumed.

This analysis is limited to consolidation properties of saturated, cohesive soils and does not include the effects of elastic settlement. However, any sand layers subject to elastic settlements in this clay deposit are small and should not affect the settlement or drain performance significantly.

As per phone conversations between Noel Bormann of Simons, Li & Associates and Donald Tharp of Desert Earth Engineering, the performance of sand drains was analysed for 1-foot-diameter drains spaced 5 feet on center in a triangular pattern. Our analysis indicates that the time required to achieve 95% consolidation is approximately 50 days for this configuration.

The differential settlement to be anticipated after achieving 95% consolidation for the proposed channel configuration without having placed the surcharge was calculated for three vertical sections. The first section analyzed was longitudinally along the channel centerline from the eastern to the western limits of the pit. Our analysis indicates that the total differential settlement to be anticipated along this section is approximately

5 1/2 inches. This is composed of an additional primary consolidation of 3 inches to be expected over a period of 5 to 6 months, and an additional secondary consolidation of 2 1/2 inches to be anticipated over a period of approximately 10 years.

Similar differential settlements may be anticipated for the second section analyzed which was taken perpendicular to the canal centerline at the center of the pit, extending from 20 feet south of the centerline to 150 feet north of the centerline.

A third section across the center of the pit from 20 feet south to 150 feet north of the centerline was analyzed for a clay depth of 15 feet. Differential settlements across this section would be approximately 1/2 of those listed above.

This analysis assumes that no additional settlement will occur in the sand material which borders the clay pit, preceding the 50 day period required to achieve 95% consolidation. It also assumes that a uniform rate of consolidation across the clay pit will occur. This analysis was also based upon an average clay depth of 35 feet which was obtained from borings which were drilled to the full depth of the clay. The actual WTI borings drilled near the center of this stretch at Stations 22+60 and 23+60 stopped before fully penetrating this layer. Prediction of secondary consolidation is difficult at best and some degree of uncertainty is inherent in any analysis. One of these uncertainties is the degree that secondary consolidation will be affected by organic content of the soil. Although an organic component was reported in the soils sampled by Western Technologies, the effect of this organic component should not significantly change the secondary consolidation predictions calculated for this project since some secondary consolidation behavior, due to organic matter, should have been reflected in the results of

our laboratory testing for primary consolidation.

Because uncertainties exist in the prediction of secondary consolidations, Desert Earth Engineering recommends that after the sand drains are installed, a surcharge of 10 feet of additional engineered fill be placed on the 15 foot high embankment and that this total of 25 feet of fill be allowed to achieve 95% of primary consolidation before the upper 10 feet is removed. Our analysis indicates that under this 10 foot surcharge approximately 72% consolidation would be necessary to eliminate primary consolidation under the load remaining after the surcharge is removed. This corresponds to a time of approximately 20 days. To virtually eliminate both primary and secondary consolidation under the loads imposed by the final proposed channel configuration, approximately 95% consolidation would be required under the proposed 10 foot surcharge. This corresponds to a time of approximately 50 days. Detailed calculations for these values are presented in Appendix C.

To assure that 95% of primary settlement has occurred in the projected time period, a monitoring program will be required. This monitoring program could consist of a series of benchmarks placed on the fill. Settlement versus time readings may then be recorded in the field and a chart of settlement versus time readings may be compiled. Achievement of 95% consolidation may then be verified by comparing the readings obtained in the field with those obtained from laboratory testing.

All above calculations are based on radial drainage theory using a sand drain diameter of 12 inches. Consolidation times calculated using this theory are much lower than when calculated using Hansbro's theoretical formula for wick drains. The main difference between these two theories is that the conventional radial drainage theory assumes Darcian flow of pore water while Hansbro's theory validly assumes non-Darcian flow. Nevertheless, the Hansbro

equation given by Amerdrain is in part empirical and should not govern design in this case.

A second factor contributing to the discrepancy between calculated consolidation times using the two theories is drain diameter. The radial-drainage theory times are based on a sand-drain diameter of 12 inches, whereas Amerdain suggests using a fabric wick equivalent-diameter of 50 mm (2 inches). If the 2-inch diameter is used in the conventional calculations, consolidation times are slightly longer.

Both of the factors discussed above yield longer, and therefore, more conservative, consolidation times for given degrees of consolidation. Various theories for prediction times of consolidation typically give a large range of results. Prediction of the actual settlement to be expected is much more accurate. We consider the predicted times given in this report to be reliable; actual consolidation in the field should be carefully monitored so that settlement can be plotted against time. This will give the best check of when enough consolidation has occurred to allow construction of the flume channel without the threat of settlement-caused damage.

A system of adequate drainage must also be provided to conduct water from the drains horizontally away from the site. This may be accomplished by the use of French drains filled with permeable soil or with filter fabric. Once this system of drainage is installed, placement of the overburden may begin.

Further testing will be required to assess the stability of the embankment after consolidation is completed. Consolidated undrained triaxial compression tests should be conducted to provide an assessment of the stability of the clay material. Such tests should be conducted on samples consolidated to the level anticipated in the field and then sheared in an undrained manner to get the shear strength. The consolidation level at which

these tests should be run can either be predicted or tests can be run on actual samples taken in the field after various levels of consolidation have occurred. A slope stability computer program can then be run using the strength obtained from the shear tests to evaluate the stability of the material in the field and a determination can then be made of whether or not a stabilizing berm is required.

Ralph Pattison of Desert Earth Engineering inspected the portion of the alignment from Station 11+00 to Station 18+00 on December 6, 1985. Comments relating to this inspection are given in Appendix D.

We thank you for working with us on this project. If we can be of further help, please call.

Submitted By:

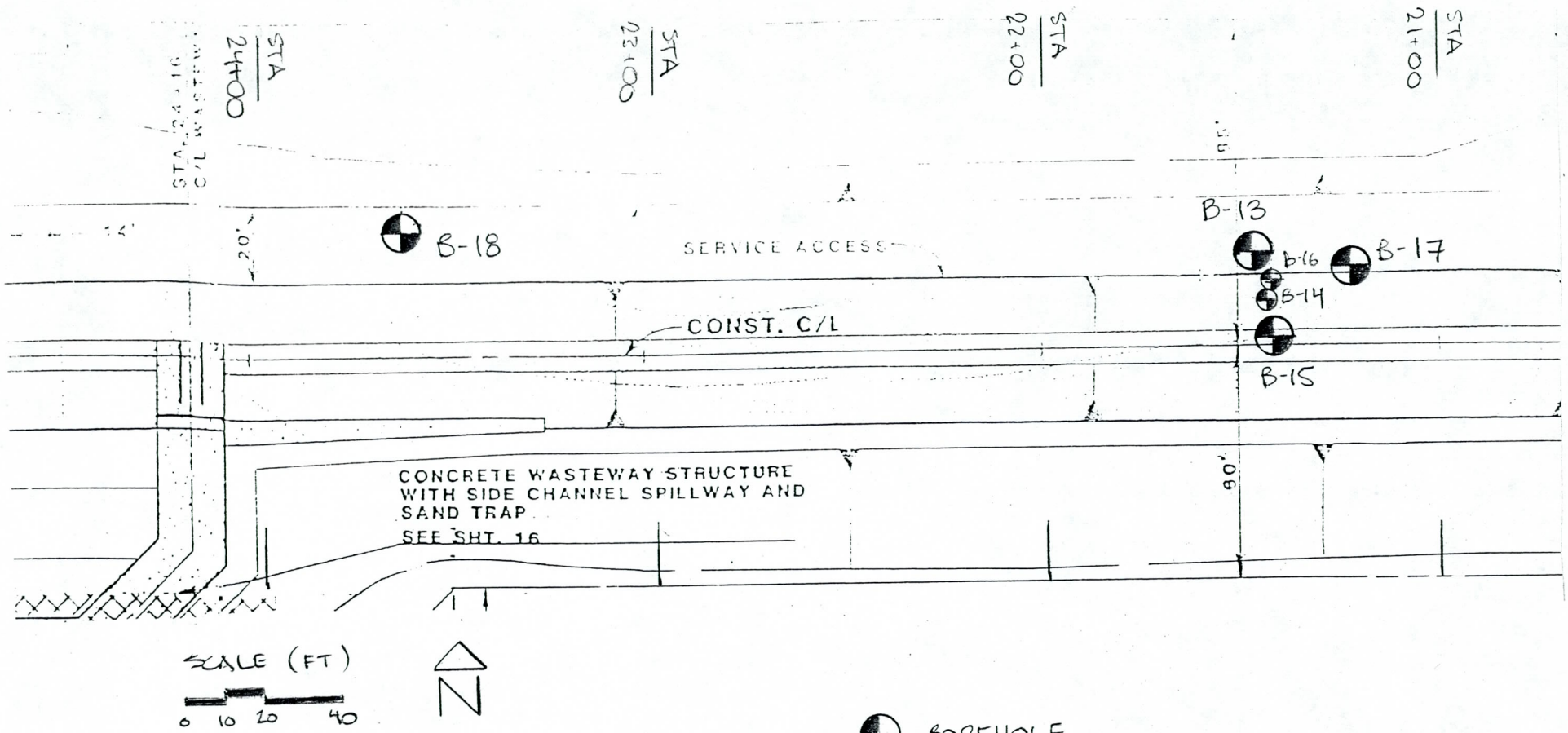
Ralph Pattison, B.S.C.E.

Registered Professional Engineer (Civil) CERTIFICATE NO. 10296 ROBERT L. SOGGE Date Signed 1/30/86 ARIZONA, U.S.A.

R. L. Sogge, P.E.

RLS/ajt

Copies: (1) Addressee
(1) Simons, Li & Associates
Tucson, Arizona
ATTN: John Lynch



BOREHOLE

PENETROMETER PROBE

BOREHOLE LOCATIONS

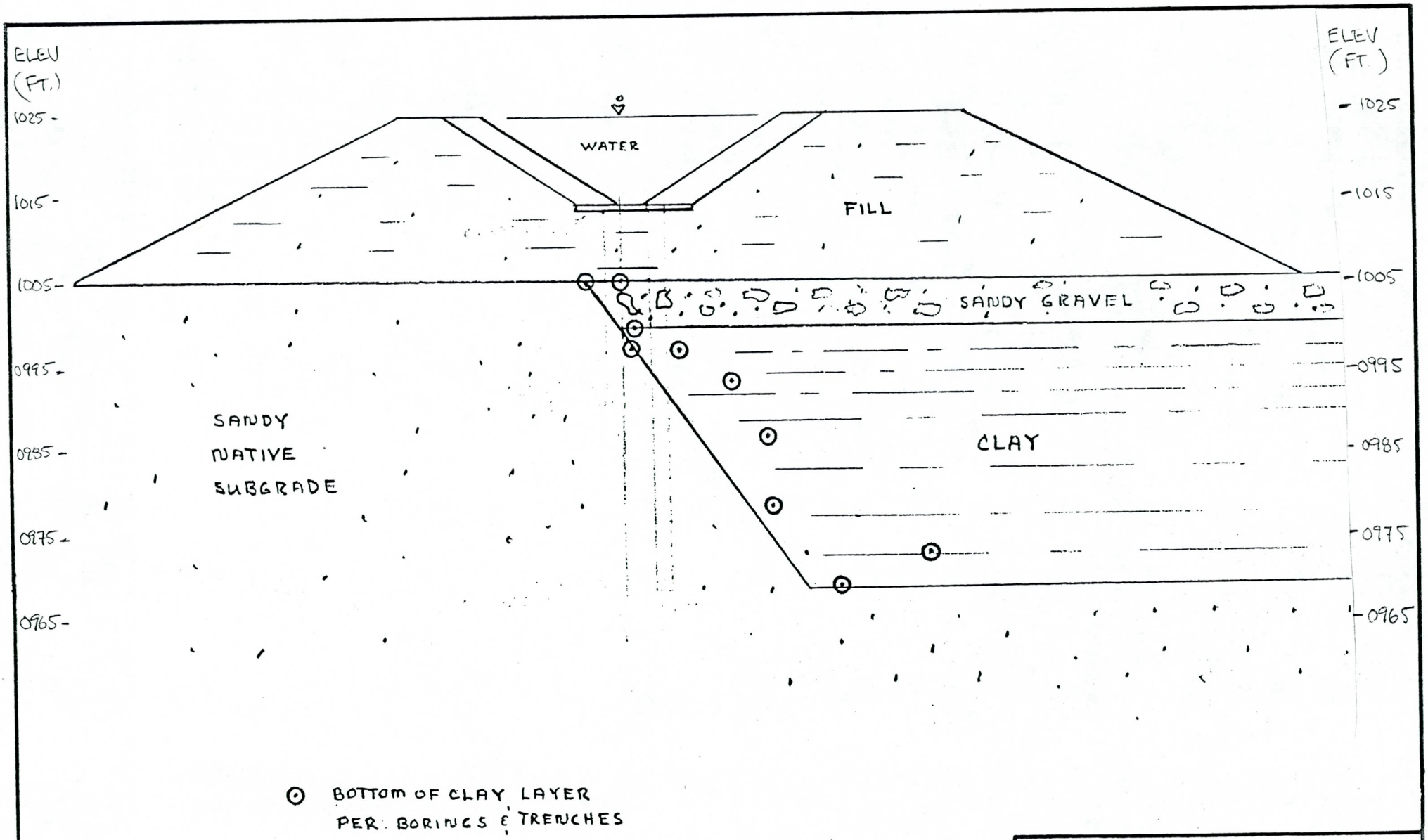
ROOSEVELT IRRIGATION DISTRICT CANAL

STATION 21+00 TO STATION 24+00

Desert Earth Engineering
consulting geotechnical engineers

Drawn by:	Date	Checked by:	Date
RMP	18DEC85	RJ	12/18/85

Sheet of	Job No.	Figure No.
	84-210B	1



⊙ BOTTOM OF CLAY LAYER PER BORINGS & TRENCHES

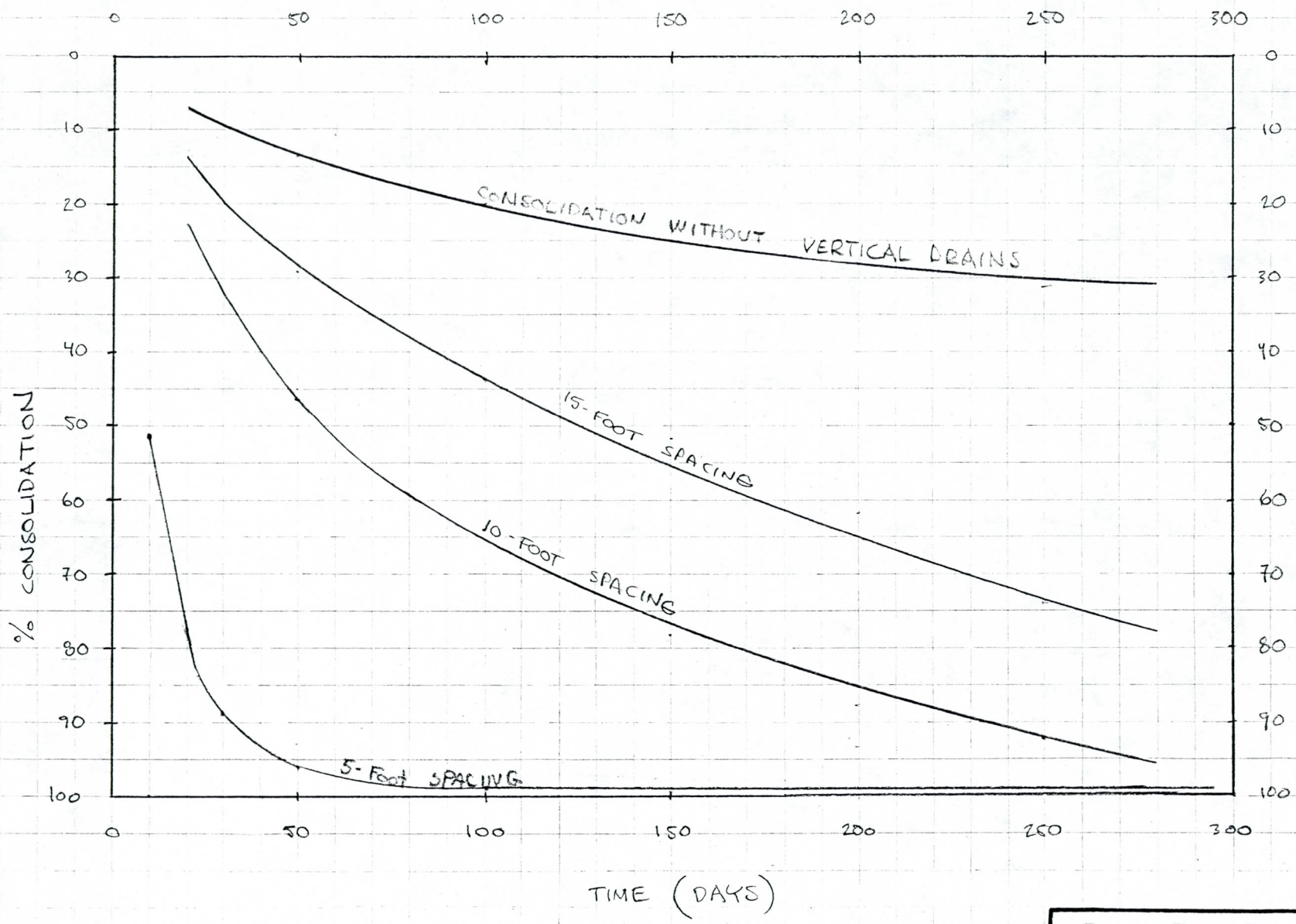
SOIL PROFILE

ROOSEVELT IRRIGATION DISTRICT CANAL

STA 21+00 TO STA 24+00

Desert Earth Engineering
consulting geotechnical engineers

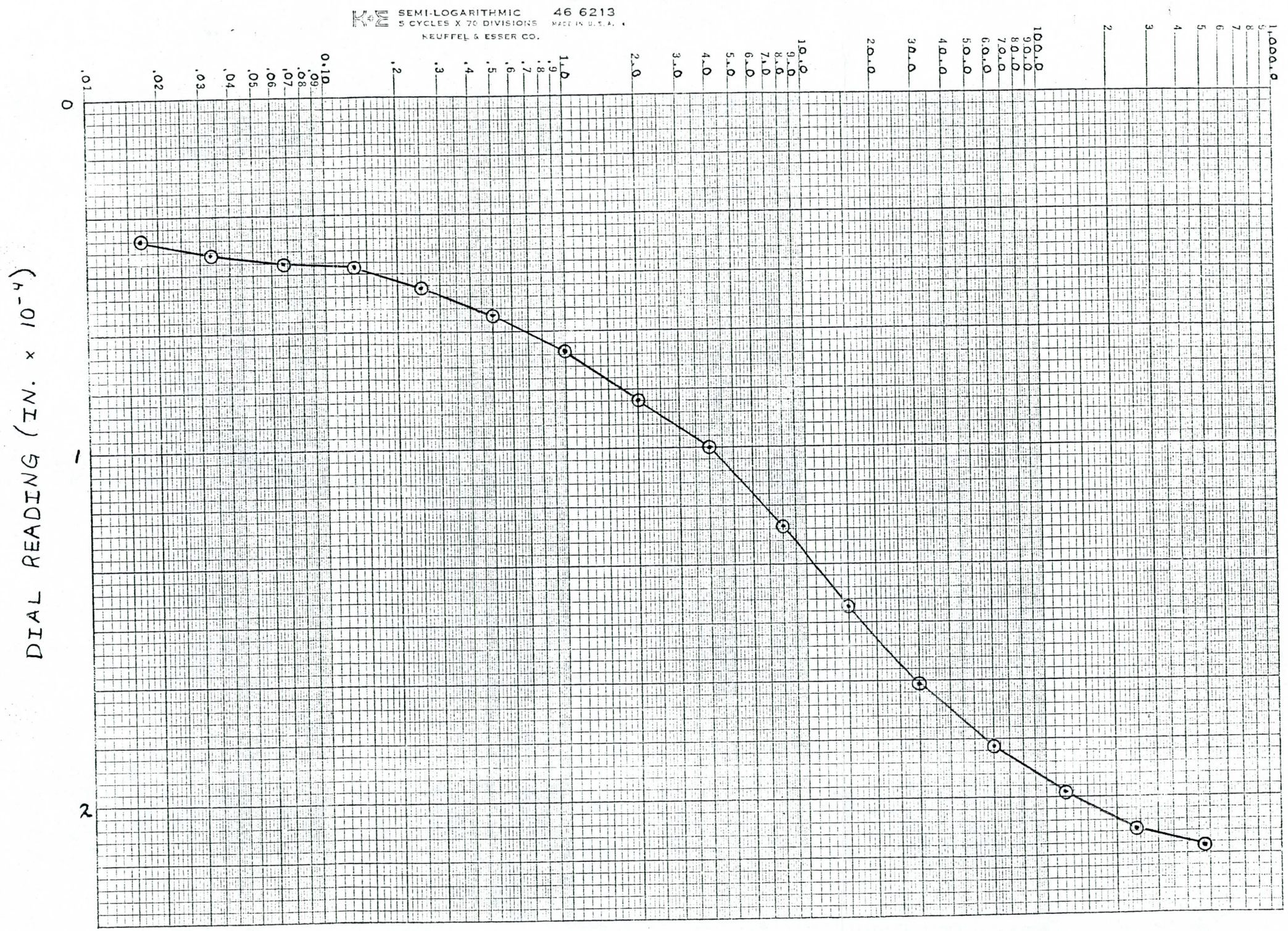
Drawn by:	Date	Checked by:	Date
RMP	18 DEC 85	RYJ	12/18/85
Sheet of	Job No. 84-210B	Figure No. 2	



EFFECT OF VERTICAL DRAINS ON CLAY PIT

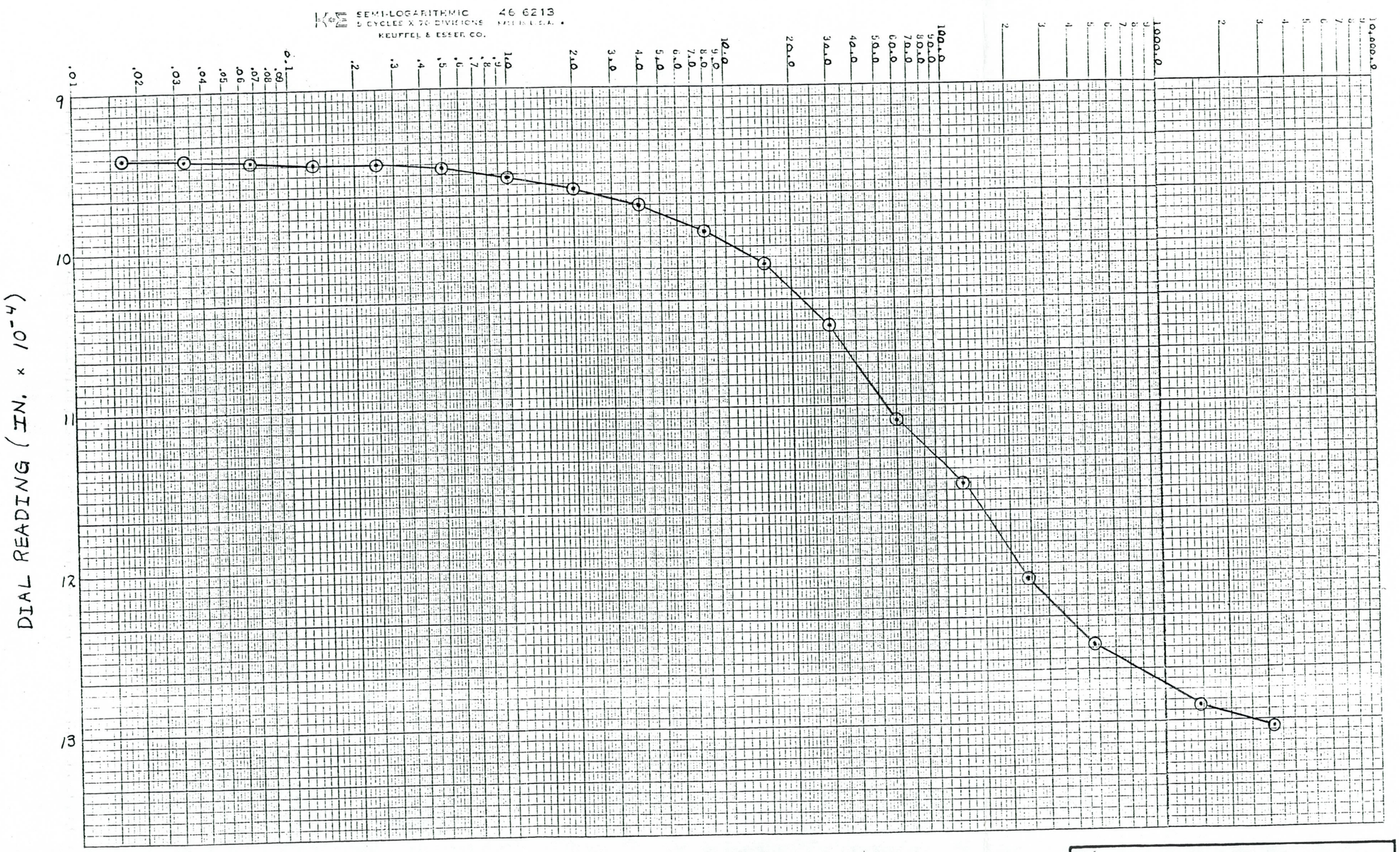
ROOSEVELT IRRIGATION DISTRICT CANAL

Desert Earth Engineering consulting geotechnical engineers			
Drawn by: RMP	Date 18DEC85	Checked by: RYA	Date 12/18/85
Sheet of	Job No. 85-210B	Figure No. 3	



Time Rate of Consolidation
B-17 @ (14-15 ft)
500 psf

Desert Earth Engineering consulting geotechnical engineers			
Drawn by: JH	Date 1/7/86	Checked by: DT	Date 1/7/86
Sheet 1 of 1	Job No. 84-210B	Figure No. 4	



Time Rate of Consolidation
B-17 @ (14-15 ft)
3000 psf

Desert Earth Engineering consulting geotechnical engineers			
Drawn by: JH	Date 1/7/86	Checked by: DT	Date 1/7/86
Sheet 1 of 1	Job No. 84-210B	Figure No. 5	

APPENDIX A

Soil Boring Logs

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
84-210B	Simons, Li & Assoc.	RID

LOCATION OF BORING

Sta. 21+47 24 ft N of CL

DRILLING METHOD & EQUIPMENT: CME-55 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer and Ring Sampler

CASING DEPTH:

BORING NO. B-13

SHEET 1 OF 2

ENGINEER RMP

TIME:

DATE 20 Nov 85

DATUM: ELEVATION 1005

SURFACE CONDITIONS

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULL-NOSE BLOWS/FT	WATER LEVEL	
			0			Gray and Brown SAND, ROCK and COBBLES
			1			
			2			
			3			Some clay
			4			
			5			
			6			(CH) Brown CLAY with trace sand; saturated, very plastic, soft
			7			
SS	18/0	9/8/8	8			
			9			
			10			
			11			
			12			
			13			
			14			(CH) CLAY
SS	18/18	1/1/1	15			
			16			
			17			
			18			
			19			
RS	12/0	3/3	20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
84-210B	Simons, Li & Assoc.	RID

LOCATION OF BORING

DRILLING METHOD & EQUIPMENT: CME-55 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer and Ring Sampler

CASING DEPTH

BORING NO. B-13

SHEET 2 OF 2

ENGINEER RMP

TIME

DATE 20 Nov 85

DATUM

ELEVATION

SURFACE CONDITIONS

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULL-NOSE BLOWS/FT	WATER LEVEL	
			20			(CH) Brown CLAY; saturated, very plastic, soft
			21			
			22			
			23			
			24			
RS	12/6	2/1	25			
			26			
			27			
			28			
			29			
SS	18/24	2/2/2	30			
			31			
			32			
			33			
			34			
SS	18/18	4/12/16	35			(SM) Brown SAND with trace silt; moist, medium dense, nonplastic
			36			
			37			Bottom of hole at 35.5 ft
			38			
			39			
			40			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
84-210B	Simons, Li & Assoc.	RID

LOCATION OF BORING

Sta. 21+44 12 ft N of CL

DRILLING METHOD & EQUIPMENT: CME-55 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer and Ring Sampler

CASING DEPTH:

BORING NO. B-14

SHEET 1 OF 1

ENGINEER RMP

TIME:

DATE 20 Nov 85

DATUM: ELEVATION 1004

SURFACE CONDITIONS

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULL-NOSE BLOWS/FT	WATER LEVEL	
			0			Gray and Brown SAND, GRAVEL and COBBLES
			1			
			2			
			3			
			4			
			5			Bottom of overburden layer 5.0 ft
			6			Bullnose penetration only, 6 ft to 14 ft
			7	5		
			8	6		
			9	9		
			10	9		
			11	11		
			12	22		
			13	37		
			14	44		
			15			Bottom of hole at 14.0 ft
			16			
			17			
			18			
			19			
			20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
84-210B	Simons, Li & Assoc.	RID

LOCATION OF BORING

Sta. 21+42 2 ft N of CL

DRILLING METHOD & EQUIPMENT: CME-55 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer and Ring Sampler

CASING DEPTH:

BORING NO.: B-15

SHEET: 1 OF 1

ENGINEER: RMP

TIME:

DATE: 20 Nov 85

DATUM: ELEVATION 1003

SURFACE CONDITIONS:

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULL-NOSE BLOWS/FT	WATER LEVEL	
			0			Gray and Brown SAND, GRAVEL and COBBLES
			1			
			2			
			3			Clean Brown SAND with trace gravel; moist, medium dense, clasts are rounded
			4			
SS	18 / 18	4/5/7	5			
			6			
			7			
			8			
			9			
SS	18 / 18	12/15/14	10			
			11			
			12			Bottom of hole at 10.5 ft
			13			
			14			
			15			
			16			
			17			
			18			
			19			
			20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
84-210B	Simons, Li & Assoc.	RID

LOCATION OF BORING

Sta. 21+43 15 ft N of CL

DRILLING METHOD & EQUIPMENT: CME-55 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer and Ring Sampler

CASING DEPTH

BORING NO.: B-16

SHEET: 1 OF 1

ENGINEER: RMP

TIME

DATE: 20 Nov 85

DATUM

ELEVATION

SURFACE CONDITIONS

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULL-NOSE BLOWS/FT	WATER LEVEL	
			0			Gray and Brown SAND, GRAVEL and COBBLES
			1			
			2			
			3			
			4			
			5			
			6			
			7			(CH) Brown CLAY; saturated, very plastic, soft
			8			
			9			
RS	12 / 0	5/6	10			Bullnose penetration only, 10 ft to 18 ft
			11	8		
			12	8		
			13	6		
			14	9		
			15	11		
			16	16		
			17	17		
			18	24		
			19			Bottom of hole at 18.0 ft
			20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
84-210B	Simons, Li & Assoc.	RID

LOCATION OF BORING

Sta. 21+21 20 ft N of CL

DRILLING METHOD & EQUIPMENT: CME-55 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer and Ring Sampler

CASING DEPTH:

BORING NO. B-17

SHEET 1 OF 2

ENGINEER RMP

TIME:

DATE 20 Nov 85

DATUM: ELEVATION 1003

SURFACE CONDITIONS

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULL-NOSE BLOWS/FT	WATER LEVEL	
			0			Gray and Brown SAND, GRAVEL and COBBLES
			1			
			2			
			3			
			4			Some clay
			5			
			6			
			7			(CH) Brown CLAY; saturated, very plastic, soft
			8			
			9			
SS	18 / 12	3/2/4	10			(SM) Brown SAND with some silt
			11			
			12			
			13			(CH) CLAY interlayered with (SM) SAND with some silt; saturated, soft
			14			
RS	12 / 12	2/3	15			(CH) CLAY
			16			
			17			
			18			
			19			Some layers with trace organics
SS	18 / 18	½/½/½	20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
84-210B	Simons, Li & Assoc.	RID

LOCATION OF BORING

DRILLING METHOD & EQUIPMENT: CME-55 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer and Ring Sampler

CASING DEPTH

BORING NO. B-17

SHEET 2 OF 2

ENGINEER RMP

TIME

DATE 20 Nov 85

DATUM

ELEVATION

SURFACE CONDITIONS

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULL-NOSE BLOWS/FT	WATER LEVEL	
			20			(CH) CLAY
			21			
			22			
			23			
RS	12/12	3/3	24			
			25			
			26			GRAVELLY
			27			
			28			
			29			(GW) Brown SANDY GRAVEL with some clay
SS	18/18	9/8/5	30			
			31			
			32			
			33			
			34			(GW) Brown SANDY GRAVEL with trace clay; very dense, angular to subangular
SS	12/12	33/47	35			
			36			Bottom of hole at 35.0 ft
			37			
			38			
			39			
			40			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
84-210B	Simons, Li & Assoc.	RID

LOCATION OF BORING

Sta. 23+60 35 ft N of CL

DRILLING METHOD & EQUIPMENT: CME-55 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer and Ring Sampler

CASING DEPTH:

BORING NO. B-18

SHEET 1 OF 3

ENGINEER RMP

TIME:

DATE 20 Nov 85

DATUM: ELEVATION 1009

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULL-NOSE BLOWS/FT	WATER LEVEL	SURFACE CONDITIONS
			0			Gray and Brown SAND, GRAVEL and COBBLES
			1			
			2			
			3			
			4			
			5			
			6			
			7			(CH) CLAY
			8			
			9			Some cobbles, 7 ft to 14 ft
			10			
			11			
			12			
			13			
			14			(CH) CLAY
RS	12 / 12	2/4	15			
			16			
			17			
			18			
			19			
			20			

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
84-210B	Simons, Li & Assoc.	RID

LOCATION OF BORING

DRILLING METHOD & EQUIPMENT: CME-55 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer and Ring Sampler

CASING DEPTH

BORING NO. B-18

SHEET 2 OF 3

ENGINEER RMP

TIME

DATE 20 Nov 85

DATUM

ELEVATION

SURFACE CONDITIONS

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULL-NOSE BLOWS/FT	WATER LEVEL
			20		
			21		
			22		
			23		
			24		
			25	1	
			26	1	
			27	1	
			28	2	
			29	2	
			30	2	
			31	2	
			32	3	
			33	3	
			34	4	
			35	5	
			36	5	
			37	6	
			38	7	
			39	7	
			40	8	

Bullnose penetration only, 24 ft to 45 ft

DESERT EARTH ENGINEERING

JOB NO.	CLIENT	LOCATION
84-210B	Simons, Li & Assoc.	RID

LOCATION OF BORING

DRILLING METHOD & EQUIPMENT: CME-55 Drill Rig equipped with 6 5/8" OD 3 1/4" ID hollow-stem continuous flight augers

SAMPLING METHOD: Split-spoon Penetrometer and Ring Sampler

CASING DEPTH

BORING NO.: B-18

SHEET: 3 OF 3

ENGINEER: RMP

TIME

DATE: 20 Nov 85

DATUM

ELEVATION

SURFACE CONDITIONS

SAMPLER TYPE	INCHES DRIVEN / INCHES RECOVERED	BLOWS/6" SAMPLER	DEPTH IN FEET	BULL-NOSE BLOWS/FT	WATER LEVEL
			40	8	
			41	10	
			42	10	
			43	11	
			44	32	
			45		
			46		
			47		
			48		
			49		
			50		
			51		
			52		
			53		
			54		
			55		
			56		
			57		
			58		
			59		
			60		

Bottom of hole at 45.0 ft

APPENDIX B

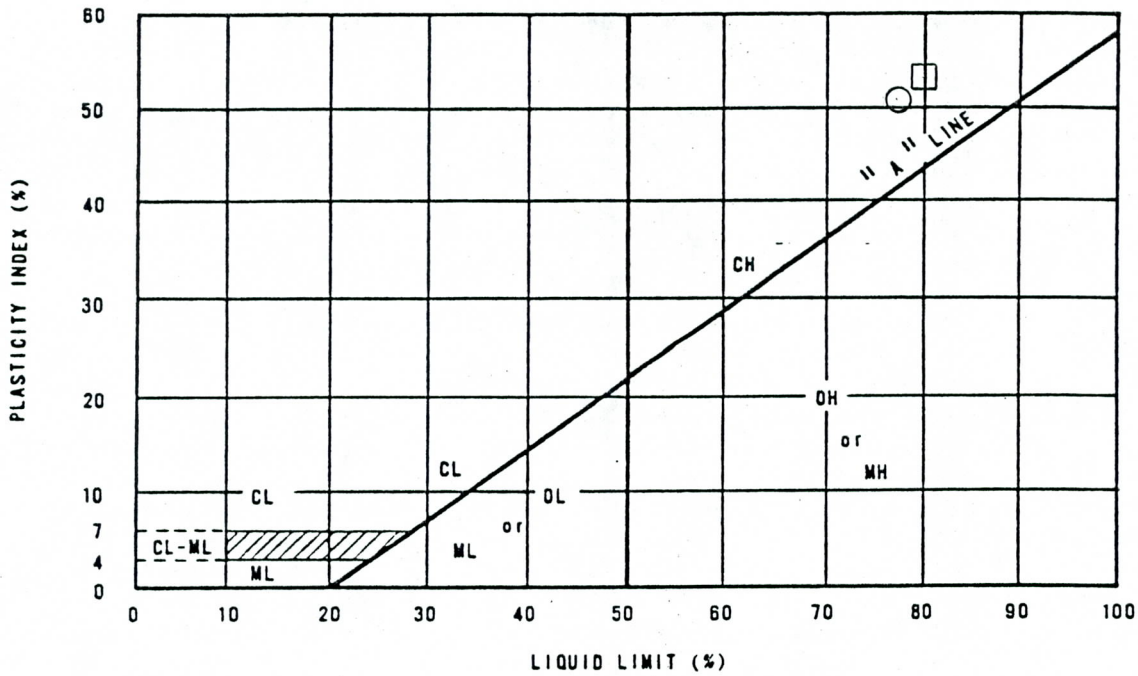
Laboratory Results

JOB 84-210B

DATE 18 Dec 85

BY RMP

PLASTICITY CHART



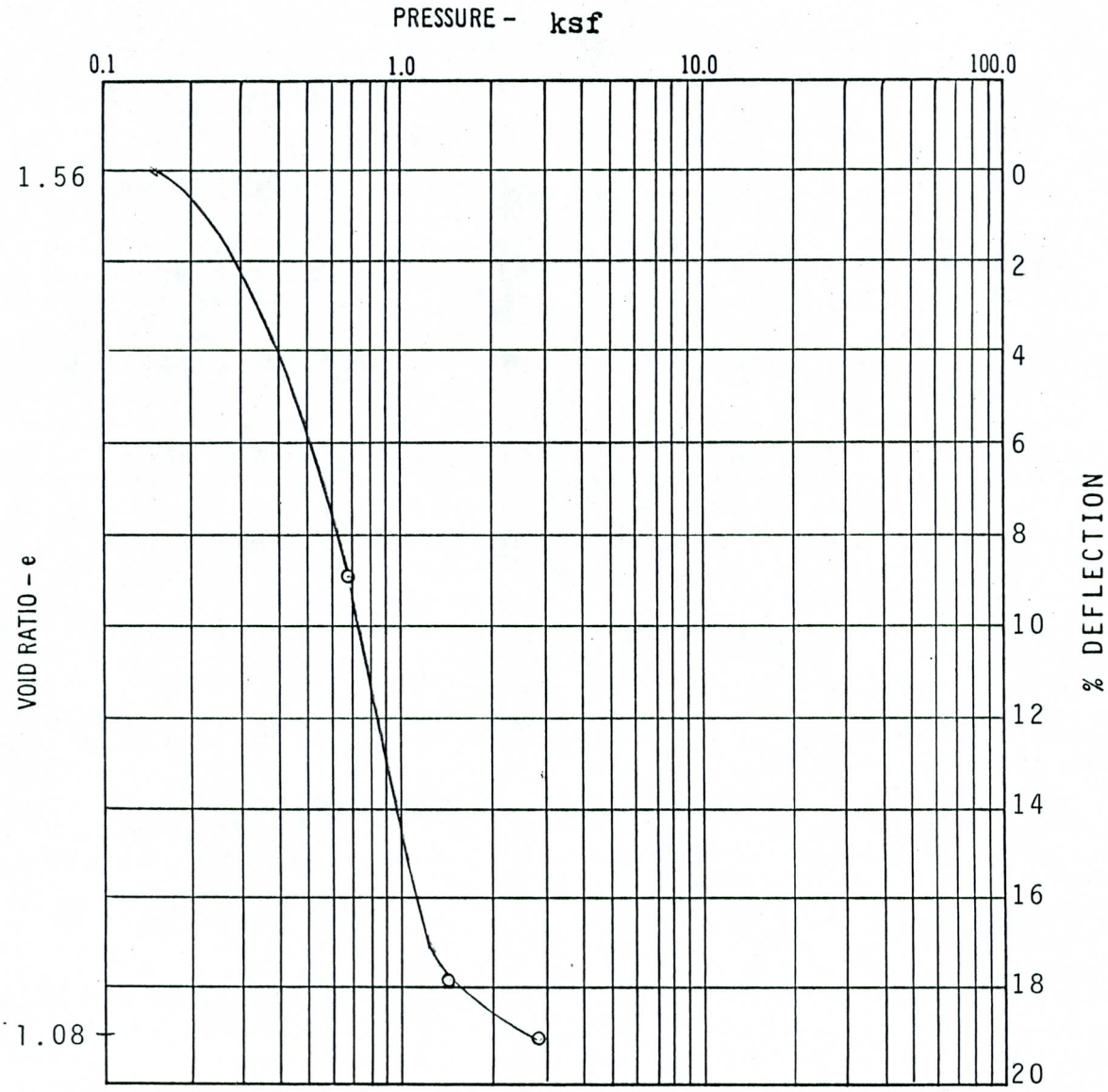
PLASTICITY DATA

KEY SYMBOL	HOLE NO	DEPTH (feet)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	UNIFIED SOIL CLASSI-FICATION SYMBOL	% PASSING # 200
○	B-13	14-15.5	77	51	CH	99
□	B-13	34-35	80	53	CH	99

desert earth engineering

JOB NO. 84-210B BY RMP DATE 11 Dec 85

CONSOLIDATION TEST DATA



DESCRIPTION OF SAMPLE: (CH) Brown CLAY					
BORING: B-13		DEPTH: 24-25		ELEVATION: 0981	
MOST PROBABLE PRECONSOLIDATION STRESS (KSF) SHOWN THUS: P_c ↓			EXISTING OVERBURDEN STRESS (KSF) SHOWN THUS: P_o ↓		
COMPRESSION INDEX (C_c)		.676	SWELLING INDEX (C_s)		
MOISTURE CONTENT %	INITIAL	62.5	VOID RATIO	INITIAL - e_o	1.56
	FINAL	39.8		FINAL - e_F	1.08
DRY DENSITY (PCF.)	INITIAL	65.7	DEGREE OF SATURATION %	INITIAL	SAT
	FINAL	81.2		FINAL	SAT

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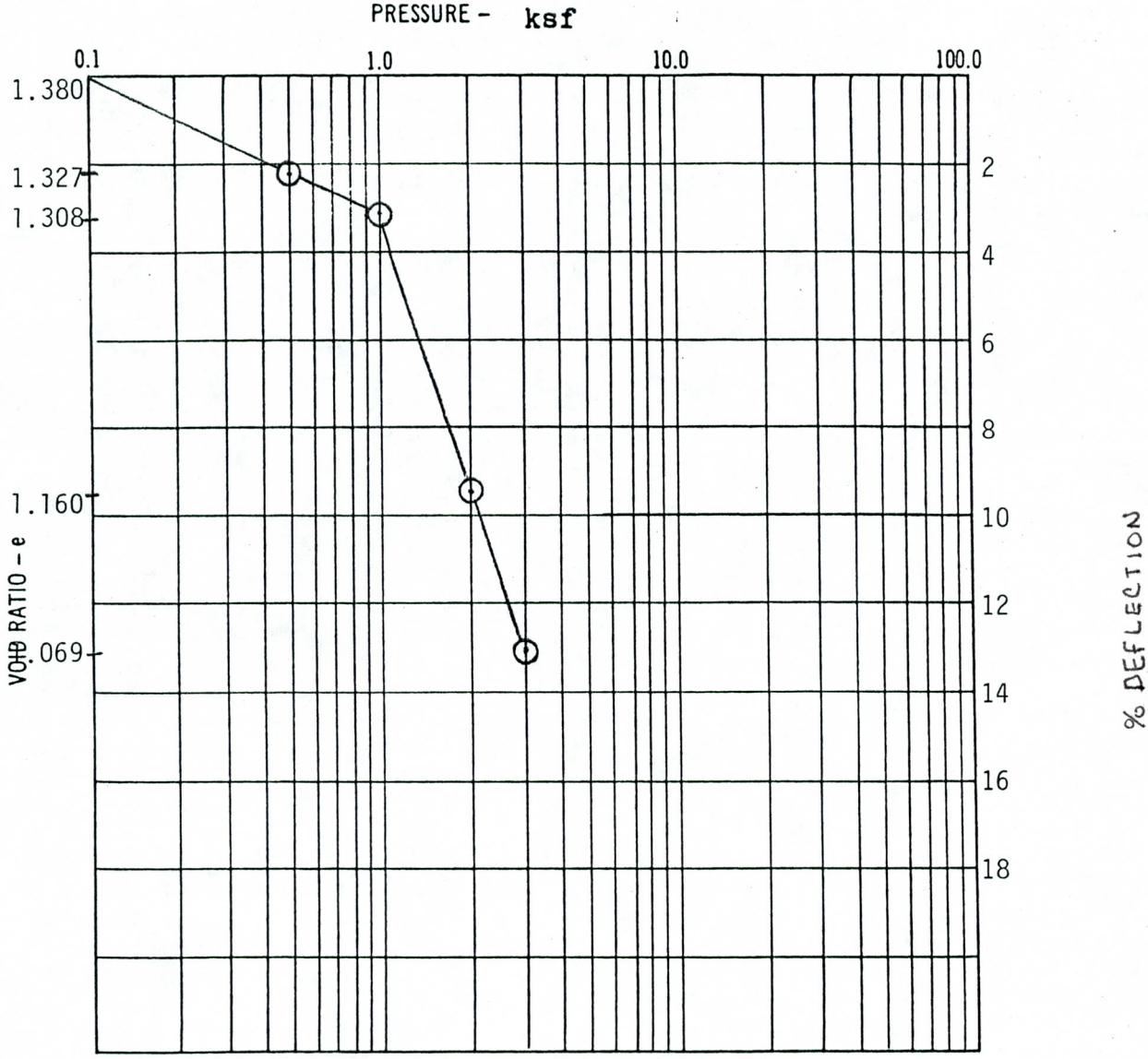
CONSOLIDATION TEST DATA



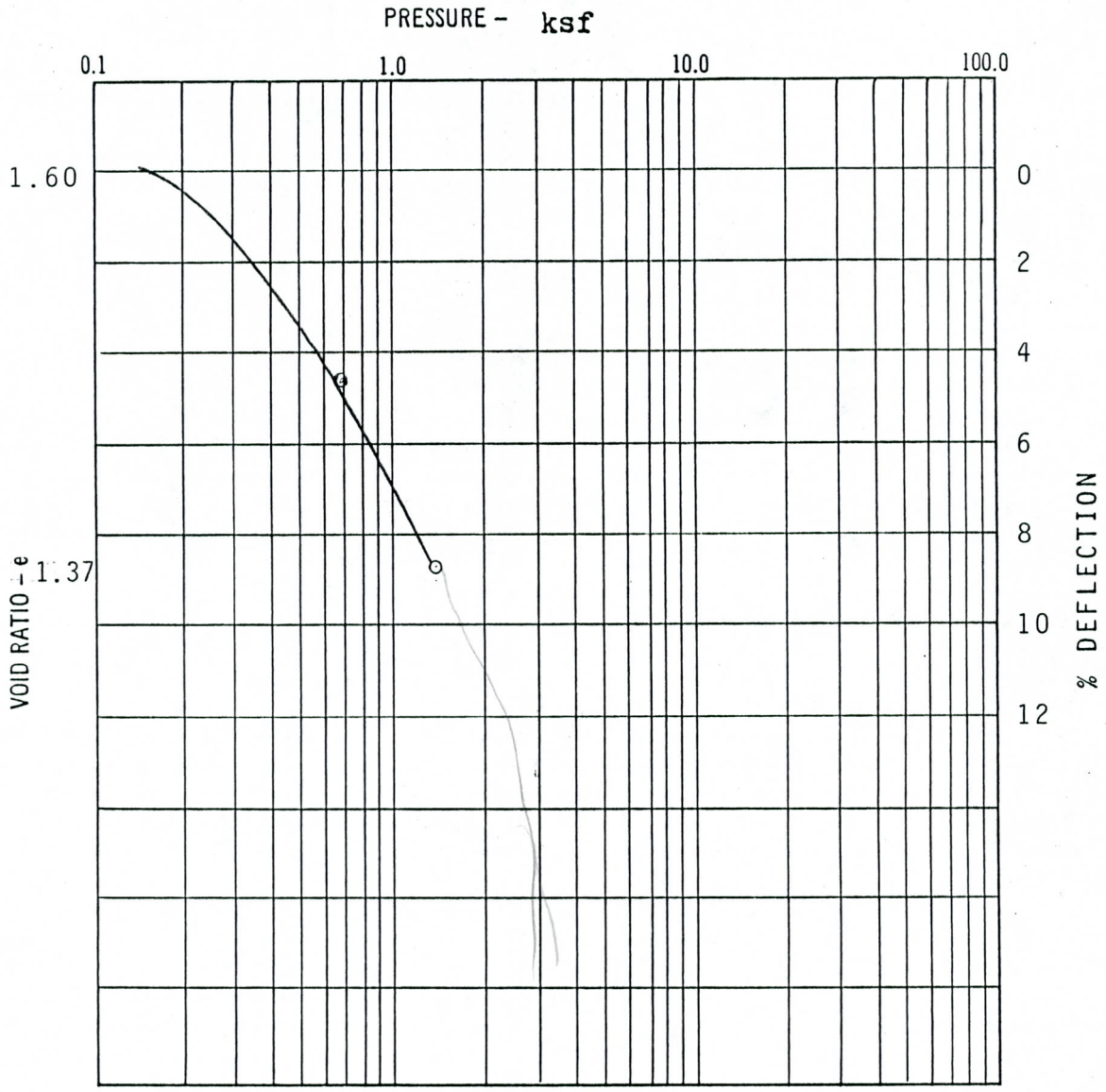
JOB NO. 84-210B BY TPB DATE 6 Jan 86

DESCRIPTION OF SAMPLE: Brown CLAY with trace sand (CH)					
BORING: B-17		DEPTH: 14.0-15.0		ELEVATION:	
MOST PROBABLE PRECONSOLIDATION STRESS (KSF) SHOWN THUS: P_c ↓			EXISTING OVERBURDEN STRESS (KSF) SHOWN THUS: P_o ↓		
COMPRESSION INDEX (C_c)			SWELLING INDEX (C_s)		
MOISTURE CONTENT %	INITIAL	56.0	VOID RATIO	INITIAL - e_o	1.380
	FINAL	62.2		FINAL - e_F	1.069
DRY DENSITY (PCF.)	INITIAL	69.5	DEGREE OF SATURATION %	INITIAL	90.1
	FINAL	79.9		FINAL	100.0

desert earth engineering

JOB NO. 84-210B BY RMP DATE 18 Dec 85

CONSOLIDATION TEST DATA



DESCRIPTION OF SAMPLE: (CH) Brown CLAY					
BORING: B-18		DEPTH: 14-15		ELEVATION: 0995	
MOST PROBABLE PRECONSOLIDATION STRESS (KSF) SHOWN THUS: P_c			EXISTING OVERBURDEN STRESS (KSF) SHOWN THUS: P_o		
COMPRESSION INDEX (C_c)			SWELLING INDEX (C_s)		
MOISTURE CONTENT %	INITIAL	54.2	VOID RATIO	INITIAL - e_o	1.60
	FINAL	50.7		FINAL - e_F	1.37
DRY DENSITY (PCF.)	INITIAL	64.9	DEGREE OF SATURATION %	INITIAL	91.7
	FINAL	71.1		FINAL	SAT

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SUMMARY OF SHEAR STRENGTH DETERMINATION

Firm	Boring (No.)	Depth (ft)	UCS (psf)	C (psf)
WTI	B-1	5-8	420	210
WTI	B-2	14-17	360	180
WTI	B-3	5-8	1,200	600
DEE	B-13	24-25	250	125
DEE	B-17	14-15	920	460
DEE	B-17	24-25	840	420
DEE	B-18	14-15	1,120	560

APPENDIX C

Calculations

CALCULATION COVER SHEET

Job No. 84-210B

No. of Sheets 6

PROJECT: Roosevelt Irrigation District Canal
Station 20+50 to Station 24+00

FEATURE: Sand drain performance

ITEM: Time of Consolidation
Differential Settlement
Effect of Overburden Placement on Settlement

SOURCE OF DATA:

Western Technologies Report Number 2155J020-E
Results of Desert Earth Engineering Laboratory Testing on Materials

REFERENCES:

Foundation Engineering Handbook
by Hans F. Winterkorn and Hsai-Yang Fang Ph.D
Foundation Analysis and Design
by Joseph E. Bowles
Soil Mechanics
By T. William Lambe and Robert V. Whitman

Calculation By: Donald Tharp and Ralph Pattison

Date: January 8, 1986

desert earth engineering

WICK-DRAIN CONSOLIDATION TIME
(HANSBRO)

84-210B
27 JAN 86
RMP

$$t = \frac{\alpha}{\lambda} D^2 \sqrt{D g \rho_w / \Delta \bar{u}_0} \left(\frac{1}{\sqrt{1-\bar{U}_n}} - 1 \right)$$

$\alpha = f\left(\frac{D}{d}\right) = (\text{for 5-ft spacing}) = \frac{5\,ft}{50\,mm} = \frac{60\,in}{2\,in} = f(30) = .32$

$D = 5'$

$d = 2''$

$\lambda = \frac{KM}{g \rho_w} = \frac{K}{m_v g \rho_w} =$

$m_v = \frac{a_v}{1+e_0} = \frac{.072\ ft^2/kip}{2.5} = .0288\ ft^2/kip$

$K_v = 1 \times 10^4\ ft/day$

TRY GRAPH

$c_v = .043\ ft^2/day = 15.7\ ft^2/year$

$t = 6$ months $\quad \bar{U} = 95$

Fig 1 $\quad f_2 = 0.14$ yrs

$f_2 c_v = 0.14\,yr\ 15.7\ ft^2/yr = 2.2\ ft^2$

$\Delta u_v = 25 \times 130 + 15 \times 100 = 4750$

Calculate C_{vh} :

$$C_{vh} = \frac{k_h (1+e_o)}{a_v \gamma_w}$$

$$C_{v_v} = \frac{(1\times10^{-4})(2.60)}{(.072)(.0624)} = .0431 \text{ ft}^2/\text{day}$$

$$C_{vh} = \frac{(2\times10^{-4})(2.6)}{(.072)(.0624)} = .0862 \text{ ft}^2/\text{day}$$

$e_o = 1.567$

$$C_c = \frac{e_1 - e_2}{\log \frac{\sigma_2}{\sigma_1}} = \frac{1.36 - 1.00}{\log \frac{7.2}{2.2}}$$

$= 0.7$

check to see if close :

$C_c = 0.009(LL-10) =$

$= 0.009(77-10) = 0.6$ ✓

Radial Consolidation Calculations
Roosevelt Irrigation District
85-210b 11/2/86 pg 1 of 3
RMP

Evaluate a_v (see figure 1)

$$a_v = \frac{e_1 - e_2}{P_1 - P_0} = \text{Coeff of compressibility}$$

from WTI B-2 @ (14'-17')

$P_0 = 2.2$ KSF $\quad e_1 = 1.36$
$P_1 = 7.2$ KSF $\quad e_2 = 1.00$

e values from $1+e = \frac{\gamma_w G_s}{\gamma_D}$

$\gamma_w = 62.4$ pcf, $\gamma_D = 63.2$, $G_s = 2.70$

$$a_v = \frac{1.36 - 1.00}{7.2 - 2.2} = .072 \text{ ft}^2/\text{kip}$$

Evaluate k_h

$\bar{C}_v = (.0048 + .0038)/2 = .0043$ in^2/min

from D.E.E. test (see figure 2)

$$C_v = \frac{k_v}{\gamma_w m_v}$$

$$m_v = \frac{a_v}{1+e_1} = \frac{.072}{2.36} = .0305 \text{ ft}^2/\text{kip}$$

$$k_v = \frac{.0043 \text{ in}^2}{\text{min}} \times \frac{62.4 \text{ lb}}{\text{ft}^3} \times \frac{.0305 \text{ ft}^2}{\text{kip}}$$

$$k_v = \frac{.0082 \text{ in}^2 \text{ lb}}{\text{min ft kip}} \times \frac{1 \text{ ft}^2}{144 \text{ in}^2} \times \frac{1 \text{ kip}}{1000 \text{ lb}} \times \frac{1440 \text{ min}}{1 \text{ Day}}$$

$k \approx .1\times10^{-4}$ ft/day $\approx 3.5\times10^{-8}$ cm/sec

assume: $2k_v = k_h$ ⇒ slightly conservative

Calculate T_h & T_v for Various times (t)

$$T_h = \frac{C_{vh}\, t}{(\delta e)^2}$$

$C_{vh} = .0862\ ft^2/day$

$$T_v = \frac{C_v\, t}{H^2}$$

$C_v = .0431\ ft^2/day$

assume H = 15.5 ft
clay depth = 31 ft

t = 50 days :

T_h = .69

T_v = .01

t = 100 days ;

T_h = 1.38

T_v = .02

t = 150 days :

T_h = 2.07

T_v = .027

t = 30 days

T_h = .414

T_v = .005

t = 15 days

T_h = .207

T_v = .003

t = 10 days

T_h = .138

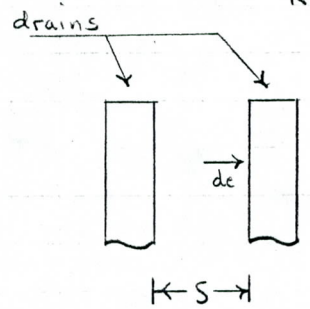
T_v = .002

t = 5 days

T_h = .069

T_v = .001

Radial Consolidation Calculations
Roosevelt Irrigation District
85-210 B 1/2/86 pg 2 of 3
RMP



de = ½ S

de = horizontal drainage path

for wells 5 ft on center de = 2.5

Well Diameter Ratio : (n)

$$n = \frac{de}{R_w}$$ assume R_w = 0.25 ft

This assumption to account for smear as per Leonards (1962)

$$n = \frac{2.5}{.25}$$

n = 10

Calculate $\bar{u}_{RZ}$

(consolidation due to both vertical & radial drainage)

$$\bar{u}_{RZ} = 1 - (1 - u_R)(1 - u_Z)$$

Read u_r from Table 4.9
Read u_z from Table 4.7

$t = 50$ days

$\left.\begin{array}{l} u_R = .96 \\ u_Z = .11 \end{array}\right\}$ $\bar{u}_{RZ} = 1 - (1 - .96)(1 - .11) = 96.4\%$

$t = 100$ days

$\left.\begin{array}{l} u_R = .99 \\ u_Z = .16 \end{array}\right\}$ $\bar{u}_{RZ} = 1 - (1 - .99)(1 - .16) = 99.2\%$

$t = 150$ days

$\left.\begin{array}{l} u_R = .995 \\ u_Z = .19 \end{array}\right\}$ $\bar{u}_{RZ} = 1 - (1 - .995)(1 - .19) = 99.6\%$

$t = 30$ days

$\left.\begin{array}{l} u_R = .875 \\ u_Z = .08 \end{array}\right\}$ $\bar{u}_{RZ} = 1 - (1 - .875)(1 - .08) = 88.5\%$

$t = 15$ days

$\left.\begin{array}{l} u_R = .65 \\ u_Z = .06 \end{array}\right\}$ $\bar{u}_{RZ} = 1 - (1 - .65)(1 - .06) = 67\%$

$t = 10$ days

$\left.\begin{array}{l} u_R = .50 \\ u_Z = .04 \end{array}\right\}$ $\bar{u}_{RZ} = 1 - (1 - .50)(1 - .04) = 52\%$

$t = 5$ days

$\left.\begin{array}{l} u_R = .30 \\ u_Z = .02 \end{array}\right\}$ $1 - (1 - .3)(1 - .02) = 31.4\%$

To eliminate primary consol. Part I

$$\bar{u}_{RZ} = \frac{\log\left(1+\frac{P_f}{P_o}\right)}{\log\left[\left(1+\frac{P_f}{P_o}\left(1+\frac{P_s}{P_f}\right)\right)\right]}$$

$$\bar{u}_{RZ} = \frac{.3297}{.4615} = 71.4\%$$

This will eliminate primary consolidation under final load.

Part II

To eliminate secondary consol as well

$$\bar{u}_{RZ} = \frac{\left[1 - C_\alpha \log\frac{t_{sec}}{t_p}\right]\log\left(1+\frac{P_f}{P_o}\right) + \frac{C_\alpha}{C_c}(1+e_o)\log\frac{t_{sec}}{t_p}}{\log\left[\left(1+\frac{P_f}{P_o}\left(1+\frac{P_s}{P_f}\right)\right)\right]}$$

$$\bar{u}_{RZ} = 95\%$$

∴ @ 95 % consol ≈ 30 days the 10' overburden may be removed and no additional settlement will occur

Roosevelt Irrigation District
Overburden Stress Calcs.
84-210B 1/3/86 pg 1 of 1

Assume: 15 foot high embankment when finished

P_o = existing effective overburden pressure

P_f = load imposed by final structure

P_s = load imposed by surcharge

gravel layer

$P_o = (4)(125) + (20)(120-62.4) = 1{,}652$ psf

(assume clay 40 ft deep)

$P_f = (15)(125) = 1{,}875$ psf

(assume 15 ft high embankment)

$P_s = (10)(125) = 1250$ psf

(assume 10 foot surcharge)

for part 2:

assume: $\frac{\text{time for secondary consol}}{\text{time for primary consol}} = 10$

assume: $\frac{C_\alpha}{C_c} = .0058$

assume: $C_c = 0.7$ from WTI B-2@14-17'

∴ $C_\alpha = .0041$ from DEE B-17@14-15'

$e_o = 1.567$ from WTI B-2@14-17'

Longitudinal Centerline

Roosevelt Irrigation District
Differential Settlement Calcs
Section 1 Longitudinal ℄ sta 24+00 to 20+50
85-210b 11/6/85 pg 1 of 1

What is differential after achieving 95% settlement?

How much additional settlement?
Primary Consolidation

Total Settlement $(\Delta H) = m_v \Delta p H = \varepsilon H$

$\Delta p = (19)(125) + 35/2\,(102-62.4) = 3068$ psf

ε @ $\Delta p = 3068 \approx 14\%$ WTI B-2@(14-17)

$\Delta H = (.14)(35) = 4.9 \approx 5$ ft

After Achieving 95% consolidation
5% left to go in primary

Additional Primary Settlement = (5)(12)(.05) = 3 inches

Alternate Settlement Calculation

$\Delta H = (H / 1+e_o)\,\Delta e$

$\Delta H = (35/2.567)(1.567-1.207) = 4.9$ ✓

Additional Secondary Consolidation

$C_\alpha = \dfrac{\Delta \varepsilon}{\log t_2/t_1} = \dfrac{.0014}{\log 53/24} = .0041$

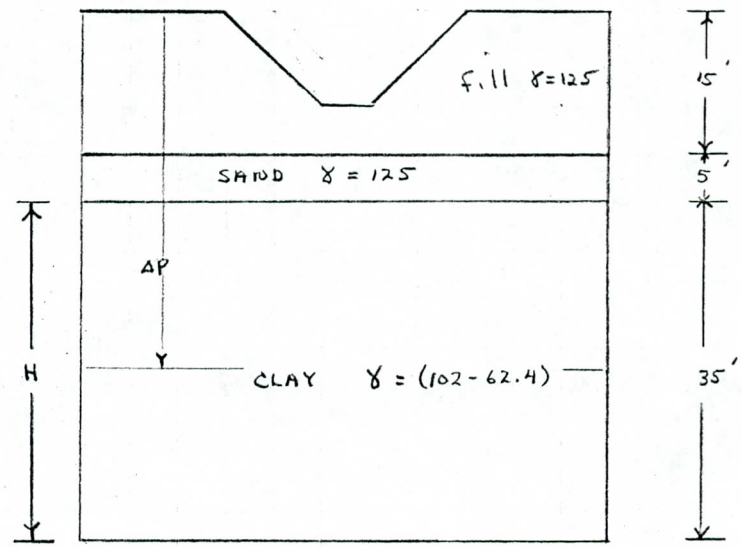
$\Delta e = -C_\alpha \log t_2/t_1$

$\Delta e = -.0041 \log \dfrac{(10)(365)(24)(60)}{4000} = -.0128$

$\Delta H = (H/1+e_o)(\Delta e)$

$\Delta H = (35/2.207)(.0128) = .2028$ ft

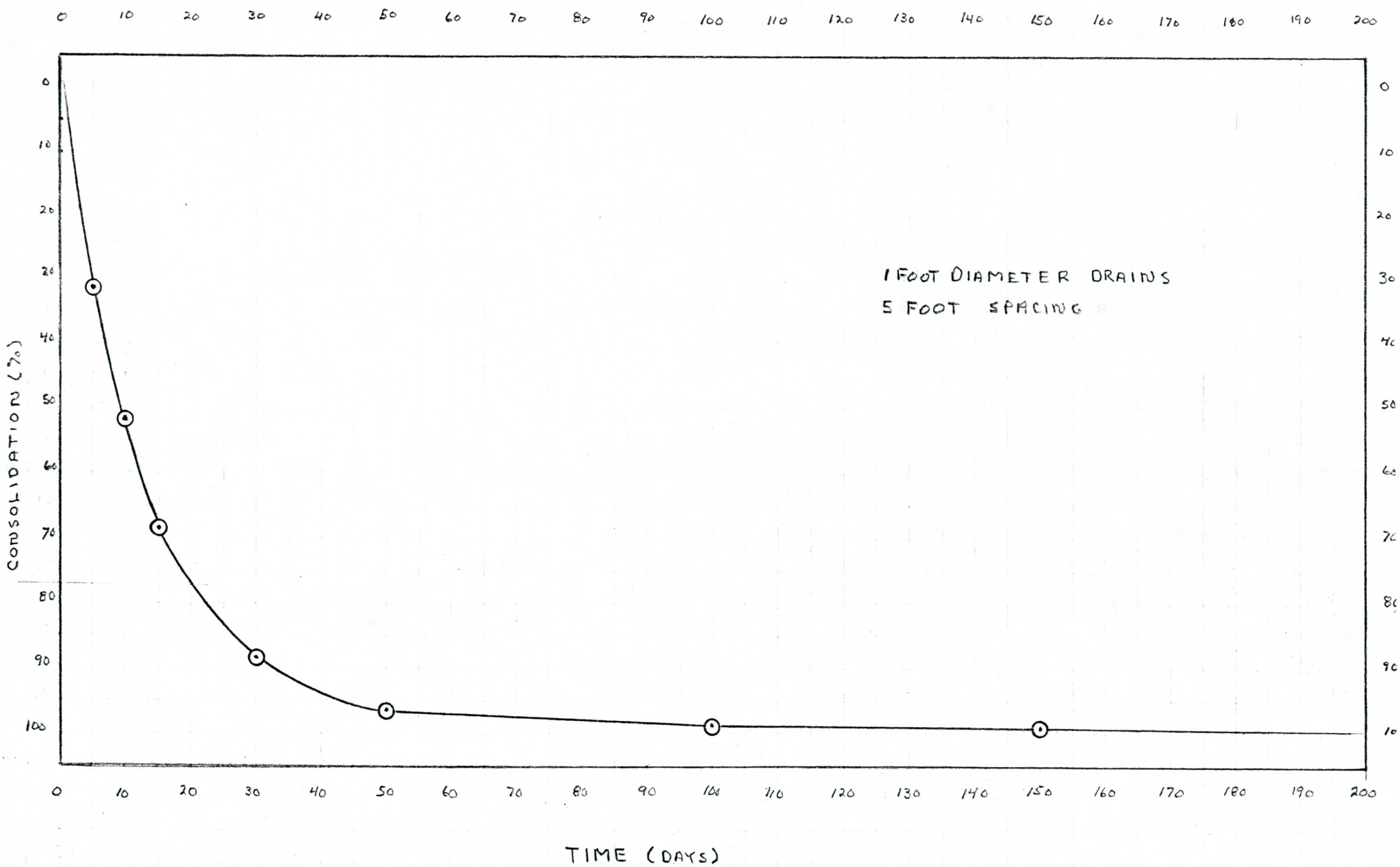
$= 2.4$ inches



Here t_2 = 10 years
t_1 = 4000 minutes

see time rate of consol 3000psf B-17 @ 14-15 ft

Here $e_o = e_{100\%\ primary} = 1.207$



TIME VS CONSOLIDATION
FOR SAND DRAINS ON 5 FOOT CENTERS

APPENDIX D

Comments on Station 11+00

To Station 18+00

APPENDIX D

COMMENTS ON STATION 11+00 TO STATION 18+00

Further problems at the site have been encountered in the area of the water-filled waste pond between Stations 11+00 and 18+00. These problems were discussed in an informal meeting between Ralph Pattison of Desert Earth Engineering and Kent Hamm of Western Technologies Incorporated on December 6, 1985.

Construction problems in the area of the water-filled waste pit seem to be primarily related to the inability to provide an adequate dewatering system for the pond. Furthermore, a soft clay or silt layer at the bottom of the pond, 2-9 feet thick, aggravates the difficulty of bringing construction equipment onto the site. The depth of this layer was determined by WTI personnel by pushing a probe down from a boat in the pond. These probes indicate that, at its maximum depth about 110 feet north of the alignment centerline, this layer starts about 4 feet below the water surface (Elevation 1001.5) and is about 9 feet thick.

According to Mr. Hamm it has been the experience of contractors that, during placement of backfill in the waste pond, this extremely soft layer forms a mud wave which impinges on the property of the gravel yard and poses a danger to their pumps. This is one of the factors that makes the construction of a dike necessary for dewatering the pond difficult.

As an alternative to dewatering we propose that fill be pushed out slowly from the south end of the pond, so that construction equipment may be supported. If necessary, clay pushed out ahead of this fill may then be removed with equipment supported on the fill. When the entire canal right-of-way has been so covered several random test borings should be made to assess

the condition of waste material below the pad. If no problems are exposed by these borings, treatment of the site may continue as planned and specified in our report of October 23, 1984. If a problem is encountered, the worst case will be the presence of clay. If necessary this can be meliorated through the use of vertical drains as planned for the clay pit between Stations 21+00 and 24+00.