Job No. 78/5041

GEOLOGIC AND SOIL ENGINEERING REPORT
LAGOON EMBANKMENT EVALUATION
CHERRYVALE, KANSAS

PREPARED FOR

NATIONAL ZINC COMPANY
BARTLESVILLE, OKLAHOMA 74003

June 9, 1978

PREPARED BY

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LAGOON EMBANKMENT EVALUATION
CHERRYVALE, KANSAS
GEOLOGY AND SITE CONDITIONS

The site of existing lagoon is located near the northwest limits of Cherryvale, Kansas in the N 1/2, Sec. 8, T32S, R17E.

The lagoon embankment, which has a maximum height of about 15 feet, presently ponds approximately 20± surface acres of water. This embankment was originally constructed in the late 1940's to entrap and pond contaminated surface runoff from the zinc plant property. The impoundment was designed to be an evaporating lagoon; however, to satisfactorily perform this function the embankment was subsequently modified several times by both increasing the height and constructing a new dike to enlarge the storage area. We were informed by personnel from the National Zinc Company that the existing impoundment has performed satisfactorily as an evaporating lagoon. We were also informed that several areas of seepage noted in the lower portion of the dike along the west downstream side have occurred since the embankment first impounded water.

The subject site is located within the Osage Cuestas section of the Osage Plains physiographic province, which is characterized by rolling, steep-sided hills that are dissected by intermittent streams with flat alluvial valleys. Specifically this site is on a drainage tributary

of Drum Creek which is in turn a tributary of the Verdigris River. The upper bedrock in this area is composed of limestones and shales of the Dennis Limestone formation of upper Pennsylvanian geologic age. In Borings 1 through 6 the Winterset limestone and Stark shale members of the Dennis Limestone formation were encountered. In each of these borings the upper portion of the Winterset limestone (surface bedrock) was found to be broken, weathered and containing seepage water perched above the underlying hard and relatively unweathered bedrock materials. The Winterset was encountered as high as elevation 80.6 feet (datum this survey) in Boring 6 to as low as elevation 75.6 feet (datum this survey) in Boring 2. Where penetrated, the thickness of the Winterset varied from 2.5 to 9.0 feet.

The soils encountered in the embankment portion of this site consist of medium and high plasticity (CL & CH) silty clay fill overlying the natural silty clay and sandy clay mantle soils which occur above the Winterset limestone. A thin topsoil zone was encountered below the fill in most borings and the entire embankment is capped with approximately one foot of cinder and brick used as a road bed. At the test hole locations the natural mantle soils, including topsoil zone, vary in thickness from 3 to 10 feet above bedrock. Geologic and Surface Profiles at the locations of Borings 1 through 4 are shown on the enclosed Figure Numbers 11 through 14 respectively.

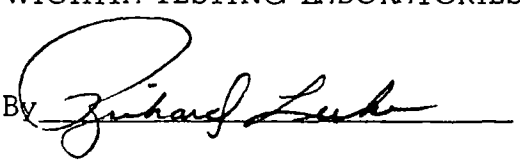
The boring locations are shown on the enclosed Figure No. 1. The boring logs (Figures 2 through 10) present data obtained in this exploration. The logs include the surface elevation; depths and elevations of major changes in the character of the subsurface materials; visual descriptions of the materials in accordance with the Unified Soil Classification System; groundwater data; penetration resistance recorded in 0.5 ft. increments of depth; and the location of undisturbed soil samples.

The elevations shown on the Boring Logs were referenced to the floor level at the west entrance to the Filter House Building. This benchmark was assigned an elevation of 100.00 feet.

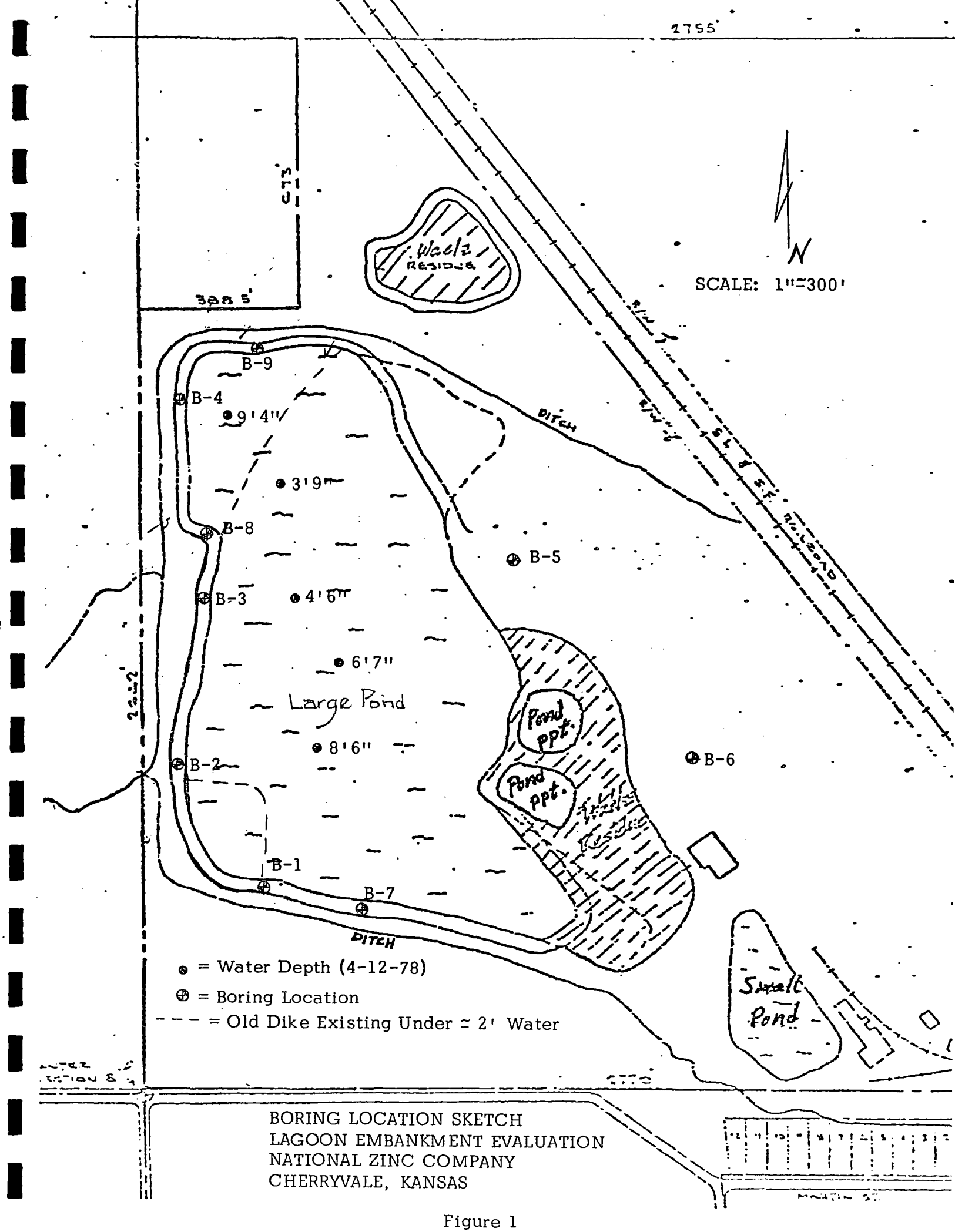
Observation wells were constructed by a licensed well driller at the location of Borings 1 through 4. The well driller was instructed to place one well point using PVC plastic pipe, through the embankment soils and into the underlying bedrock at each of these locations. In addition, near the location of Boring 2, one observation well was to be placed in the embankment fill above natural soils approximately 12 feet below grade. It is our understanding that the purpose of these observation wells is for National Zinc Company and/or the Kansas State Department of Health and Environment to monitor the seepage water level and quality.

Submitted By:

WICHITA TESTING LABORATORIES

By 

Richard L. Luke
Engineering Geologist



BORING LOCATION SKETCH
LAGOON EMBANKMENT EVALUATION
NATIONAL ZINC COMPANY
CHERRYVALE, KANSAS

Figure 1

WICHITA TESTING LABORATORIES
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Wichita , Kansas

BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger	Standard Penetration Test			Boring No. 1
Undisturbed Soil Sampler: 3-in.o.d. thin-walled tube	140-lb. Hammer	30-in. Fall	2-in.o.d. Split-barrel Sampler	Sheet 1 of 1
w=Moisture Content, % D=Dry Density, pcf	Penetration Resistance: N=Blows per foot			Date: 4-11-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
91.7	0		Fill: cinders, brick, tile, etc.; loose.			
90.7	1	CH	Fill: silty clay; dark yellowish brown mottled with very dark brown and grayish brown; wet; med. plasticity; stiff.	1		W=23.6 D=101.5
					6	
					7	N=13
					6	
86.2	5.5		As above but saturated in seams.			
85.2	6.5	CH	Silty Clay: very dark gray and dark grayish brown; wet to saturated in seams; high plasticity; medium stiff to stiff. (possible fill)			Water Level @ 8.0' (Elev. 83.7) After 24 Hours
84.2	7.5	CL				
82.7	9	CH	Silty Clay: very dark gray; minor organics; saturated; med. plasticity; medium stiff. (old topsoil zone)	2		W=27.1 D=94.5
					2	
			Silty Clay: dark yellowish brown; saturated; high plasticity; medium stiff.		2	N=7
					5	
79.2	12.5		As above but some limestone gravel.			
				3		W=33.4 D=87.6
76.2	15.5		Limestone: broken and weathered.			
75.2	16.5		Limestone: light gray and hard. (possible Winterset Limestone)			
73.7	18		Shale: dark gray to gray; hard. (possible Stark Shale)			
			Coal Seam			
71.7	20					

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Figure 2

Drilled By: William R. Giesel

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Materials Engineers
Wichita, Kansas

BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger	Standard Penetration Test			Boring No. 2
Undisturbed Soil Sampler: 3-in. o.d. thin-walled tube	140-lb. Hammer	30-in. Fall	2-in. o.d. Split-barrel Sampler	Sheet 1 of 2
w=Moisture Content, % / D=Dry Density, pcf	Penetration Resistance: N=Blows per foot			Date: 4-11-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
92.1	0		Fill: cinders, brick, tile, etc.; loose.			
91.1	1	CH & CL	Fill: silty clay; very dark grayish brown, dark yellowish brown and reddish brown; wet; medium and high plasticity; stiff.	4		W=25.5 D=98.6
89.1	3		As above but saturated in seams.		3 4 5	N=9
84.1	8	▽	Very wet to saturated.	5		Water Level @ 7.7' (Elev. 84.4) After 24 Hours
					2 4 5	N=9 W=32.1 D=90.3
				6		W=30.2 D=94.9
78.6	13.5	CL	Silty Clay: some organics; very dark gray; very wet to saturated; medium plasticity; medium stiff. (old topsoil)		1 2 3	N=5
77.1	15	CH	Silty Clay: dark yellowish brown; saturated; high plasticity; medium stiff.	7		W=27.3 D=94.9
75.6	16.5		Limestone: weathered and broken.			
73.1	19		Limestone: hard; light yellowish brown. (possible Winterset Limestone)			

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Figure 3

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BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger	Standard Penetration Test			Boring No. 2
Undisturbed Soil Sampler: 3-in.o.d. thin-walled tube	140-lb. Hammer	30-in. Fall	2-in.o.d. Split-barrel Sampler	Sheet 2 of 2
w=Moisture Content, % D=Dry Density, pcf	Penetration Resistance: N=Blows per foot			Date: 4-18-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
72.1	20		Limestone: as before; but shaley; dark gray and hard.			
70.6	21.5		Shale: dark gray with thin limestone stringers. (possible Stark Shale)			
67.1	25					

Figure 3a

Drilled By: William R. Giesel

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Wichita , Kansas

BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger	Standard Penetration Test			Boring No. 3
Undisturbed Soil Sampler: 3-in. o.d. thin-walled tube	140-lb. Hammer	30-in. Fall	2-in.o.d. Split-barrel Sampler	Sheet 1 of 2
w=Moisture Content, % D=Dry Density, pcf	Penetration Resistance: N=Blows per foot			Date: 4-11-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
91.3	0		Fill: cinders, brick, clay tile, etc.			
90.3	1	CH	Fill: silty clay; dark yellowish brown, grayish brown, reddish brown and gray; wet; high plasticity; stiff to medium stiff with depth.	8		W=25.5 D=94.8
87.3	4	CL	Fill: silty clay; very dark brown and yellowish brown; wet with saturated seams; medium plasticity; medium stiff.	9	2 2 3	N=5 W=28.5 D=95.5 Water Level @ 7.7' (Elev. 83.6) After 24 Hours
83.8	7.5					
83.3	8	CL CH	Silty Clay: very dark gray with some organics; wet; medium plasticity; med. stiff to stiff. (old topsoil zone)	10		W=24.3 D=98.0
82.3	9		Silty Clay: dark gray with lime concretions; wet; high plasticity; medium stiff to stiff.		3 4 4	N=8
80.3	11	CH	As above but dark yellowish brown. Gravelly Clay: 20% fine to medium gravel (chert); dark yellowish brown; wet; high plasticity; stiff.	11		W=22.4 D=107.6
77.8	13.5		Limestone: dark yellowish brown; broken and weathered. (possible Winterset Limestone)			
74.8	16.5		Limestone: light yellowish brown; fossiliferous; medium hard. (Winterset Limestone)			

Figure 4 Drilled By: William R. Giesel

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WICHITA TESTING LABORATORIES
Materials Engineers
Wichita , Kansas

BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger	Standard Penetration Test			Boring No. 3
Undisturbed Soil Sampler: 3-in.o.d. thin-walled tube	140-lb. Hammer	30-in. Fall	2-in.o.d. Split-barrel Sampler	Sheet 2 of 2
w=Moisture Content, % D=Dry Density, pcf	Penetration Resistance: N=Blows per foot			Date: 4-11-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
71.3	20		Limestone: gray; hard.			
69.3	22		Shale: dark gray (possible Stark Shale)			
68.3	23		Calcareous			
67.8	23.5		Shale as before.			
66.3	25					

Figure 4a

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Materials Engineers
Wichita , Kansas

BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger		Standard Penetration Test		Boring No. 4
Undisturbed Soil Sampler: 3-in.o.d. thin-walled tube		140-lb. Hammer	30-in. Fall	2-in.o.d. Split-barrel Sampler	Sheet 1 of 2
w=Moisture Content, %	D=Dry Density, pcf	Penetration Resistance: N=Blows per foot			Date: 4-11-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
92.1	0		Fill: cinders, brick, clay, tile, etc.			
91.1	1	CL	Fill: silty clay; dark yellowish brown, gray and reddish brown; wet; medium plasticity; medium stiff.	12		W=25.4 D=97.9
88.1	4	CH& CL	Fill: silty clay; very dark gray and dark gray; wet to saturated in seams; high and medium plasticity; medium stiff.		2 3 5	N=8
84.6	7.5	CH w/ CL ▽	Silty Clay: dark yellowish brown with iron stains; wet to very wet; high plasticity; with medium plasticity zones; medium stiff.	13		W=25.7 D=96.9
					2 3 4	Water Level @ 9.5' (Elev. 82.6') After 24 Hours N=7
				14		W=27.1 D=92.8
80.1	12	CH	Gravelly Clay: 20 to 25% fine to medium gravel; dark yellowish brown; very wet; high plasticity; stiff.		4 5 5	N=10
77.6	14.5		As above but saturated.			
76.6	15.5		Limestone: broken and weathered.			
75.1	17		Limestone: light gray; hard. (possible Winterset Limestone)			
72.1	20					

Figure 5

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Wichita , Kansas

BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger	Standard Penetration Test			Boring No. 4
Undisturbed Soil Sampler: 3-in. o.d. thin-walled tube	140-lb. Hammer	30-in. Fall	2-in. o.d. Split-barrel Sampler	Sheet 2 of 2
w = Moisture Content, % / D = Dry Density, pcf	Penetration Resistance: N = Blows per foot			Date: 4-11-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
72.1	20		As before.			
71.1	21		Limestone: sandy and shaley; dark gray.			
63.1	29		Shale: fissile; black; hard. (possible Stark Shale)			
62.1	30					

Figure 5a

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Wichita , Kansas

BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger	Standard Penetration Test			Boring No. 5
Undisturbed Soil Sampler: 3-in.o.d. thin-walled tube	140-lb. Hammer	30-in. Fall	2-in.o.d. Split-barrel Sampler	Sheet 1 of 2
w=Moisture Content, % D=Dry Density, pcf	Penetration Resistance: N=Blows per foot			Date: 4-11-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
94.1	0		Fill: Cinders.			
90.1	4	▽	As above but saturated.			Water @ 4.0' After Drilling. (perched in cinders above silty clay)
87.6	6.5	CL	Silty Clay: very dark grayish brown; very wet; low to medium plasticity; medium stiff.			
86.1	8	CH	Silty Clay: brownish gray with olive yellow and iron staining; very wet; medium to high plasticity; medium stiff.			
82.1	12		As above but yellowish brown with light gray to gray mottling; iron stain; 10 to 15% coarse sand; stiff.			
78.1	16		As above but with 15 to 25% gravel.			
77.1	17		Limestone: yellowish brown; weathered; medium hard.			
75.1	19		Limestone: yellowish brown to light gray; hard.			

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Figure 6

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Materials Engineers
Wichita , Kansas

BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger		Standard Penetration Test		Boring No. 5
Undisturbed Soil Sampler: 3-in. o.d. thin-walled tube		140-lb. Hammer	30-in. Fall	2-in.o.d. Split-barrel Sampler	Sheet 2 of 2
w=Moisture Content, %	D=Dry Density, pcf	Penetration Resistance: N=Blows per foot			Date: 4-11-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
74.1	20		Limestone: as before.			
72.6	21.5		Limestone: shaley; medium hard.			
71.1	23		Limestone: hard.			
68.1	26		Shale: dark gray; hard.			
			Calcareous			
64.1	30					

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Figure 6a

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WICHITA TESTING LABORATORIES
Materials Engineers
Wichita , Kansas

BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger		Standard Penetration Test		Boring No. 6
Undisturbed Soil Sampler: 3-in. o.d. thin-walled tube		140-lb. Hammer	30-in. Fall	2-in. o.d. Split-barrel Sampler	Sheet 1 of 2
w=Moisture Content, %	D=Dry Density, pcf	Penetration Resistance: N=Blows per foot		Date: 4-12-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
94.1	0		Fill: cinders and ash with brick and tile rubble; saturated @ 3.0'; loose.			Water @ 3.9' After Drilling (Perched above silty clay)
89.6	4.5	CH	Silty Clay: very dark gray; traces of fine sand; very wet; medium to high plasticity; medium stiff.			
88.1	6		As above but olive gray, gray and yellowish brown mottled.			
85.6	8.5	CH	Silty Clay: yellowish brown mottled with light gray to gray; very wet; high plasticity; medium stiff to stiff.			
82.1	12		As above with 20 to 25% limestone gravel; stiff.			
80.6	13.5		Limestone: yellowish brown; broken and weathered. (possible Winterset Limestone)			
78.6	15.5		Limestone: light gray; hard. (Winterset Limestone)			
77.6	16.5		As above but broken in part.			
74.6	19.5		Limestone: hard. (Winterset Limestone)			

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Figure 7

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Materials Engineers
Wichita , Kansas

BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger	Standard Penetration Test			Boring No. 6
Undisturbed Soil Sampler: 3-in. o.d. thin-walled tube	140-lb. Hammer	30-in. Fall	2-in.o.d. Split-barrel Sampler	Sheet 2 of 2
w=Moisture Content, % D=Dry Density, pcf	Penetration Resistance: N=Blows per foot			Date: 4-12-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
74.1	20		Limestone: as before.			
72.6	21.5		Shale: gray and light gray; sandy; high plasticity; hard. (possible Stark Shale)			
69.1	25					

Figure 7a

Drilled By: William R. Giesel

WICHITA TESTING LABORATORIES
Materials Engineers
Wichita, Kansas

BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger	Standard Penetration Test			Boring No. 7
Undisturbed Soil Sampler: 3-in.o.d. thin-walled tube	140-lb. Hammer	30-in. Fall	2-in.o.d. Split-barrel Sampler	Sheet 1 of 1
w=Moisture Content, % D=Dry Density, pcf	Penetration Resistance: N=Blows per foot			Date: 4-12-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
(Est.) 92.0	0		Fill: cinders, brick, tile, etc.; loose.			
90.5	1.5	CH	Fill: silty clay; dark yellowish brown mottled with very dark brown; wet; high plasticity; stiff.			
86.0	6	CL	Silty Clay: very dark gray; wet; medium plasticity; medium stiff. (old topsoil zone)			
85.0	7	CH	Silty Clay: dark gray; wet; high plasticity; medium stiff to stiff.			
84.0	8		As above but dark yellowish brown.			
76.0	16					
75.5	16.5		Weathered Limestone			

Figure 8

Drilled By: Richard L. Luke

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WICHITA TESTING LABORATORIES
Materials Engineers
Wichita , Kansas

BORING LOG

PROJECT
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger	Standard Penetration Test		Boring No. 8
Undisturbed Soil Sampler: 3-in. o.d. thin-walled tube	140-lb. Hammer	30-in. Fall	2-in. o.d. Split-barrel Sampler	Sheet 1 of 1
w=Moisture Content, % D=Dry Density, pcf	Penetration Resistance: N=Blows per foot		Date: 4-12-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
(est.) 92.0	0		Fill: cinders.			
91.0	1	CH	Fill: silty clay; dark brown mottled with dark yellowish brown and reddish brown; wet; high plasticity; stiff.			
88.0	4	CH	Fill: silty clay; gray; yellowish brown and dark gray; very wet; high plasticity; stiff.			
85.0	7	CL	Silty Clay: very dark gray; very wet; medium to high plasticity; medium			
84.0	8	CH	stiff. (old topsoil zone)			
85.0	9	CH	Silty Clay: dark gray; very wet; high plasticity; medium stiff to stiff.			
			Silty Clay: dark yellowish brown; very wet; high plasticity; stiff.			
78.5	13.5		Weathered Limestone.			
78.0	14					

Figure 9

Drilled By: Richard L. Luke

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WICHITA TESTING LABORATORIES
Materials Engineers
Wichita, Kansas

BORING LOG

PROJECT

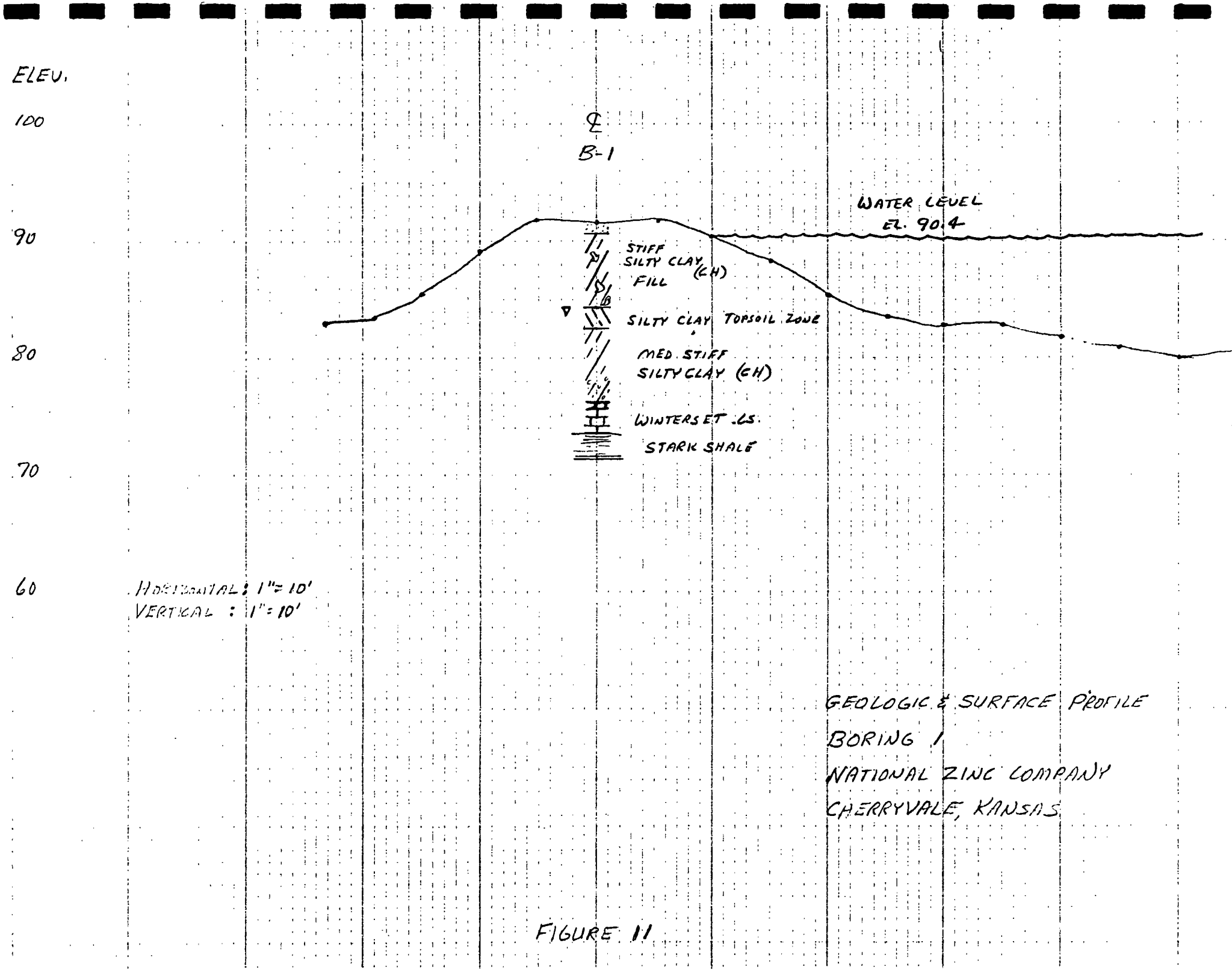
Lagoon Embankment Evaluation
National Zinc Company
Cherryvale, Kansas

Boring Method: 6-in. continuous flight auger	Standard Penetration Test			Boring No. 9
Undisturbed Soil Sampler: 3-in. o.d. thin-walled tube	140-lb. Hammer	30-in. Fall	2-in. o.d. Split-barrel Sampler	Sheet 1 of 1
w=Moisture Content, % D=Dry Density, pcf	Penetration Resistance: N=Blows per foot			Date: 4-12-78

Elevation	Depth	Group Symbol	Description of Materials	Sample No.	Blows	Remarks
(Est.) 92.0	0		Fill: cinders, brick, tile, etc.; loose.			
91.0	1	CH	Fill: silty clay; dark yellowish brown, brown and grayish brown; wet; high plasticity; stiff.			
88.0	4	CL	Silty Clay: very dark gray to dark gray with some organics; saturated; medium plasticity; soft to medium stiff. (old topsoil zone)	15		W=30.5 D=90.6
87.0	5	CH	Silty Clay: dark gray; very wet; high plasticity; medium stiff.			
85.5	6.5		As above but dark yellowish brown and stiff.			
77.0	15		Saturated.			
76.5	15.5		Weathered Limestone.			
76.0	16					

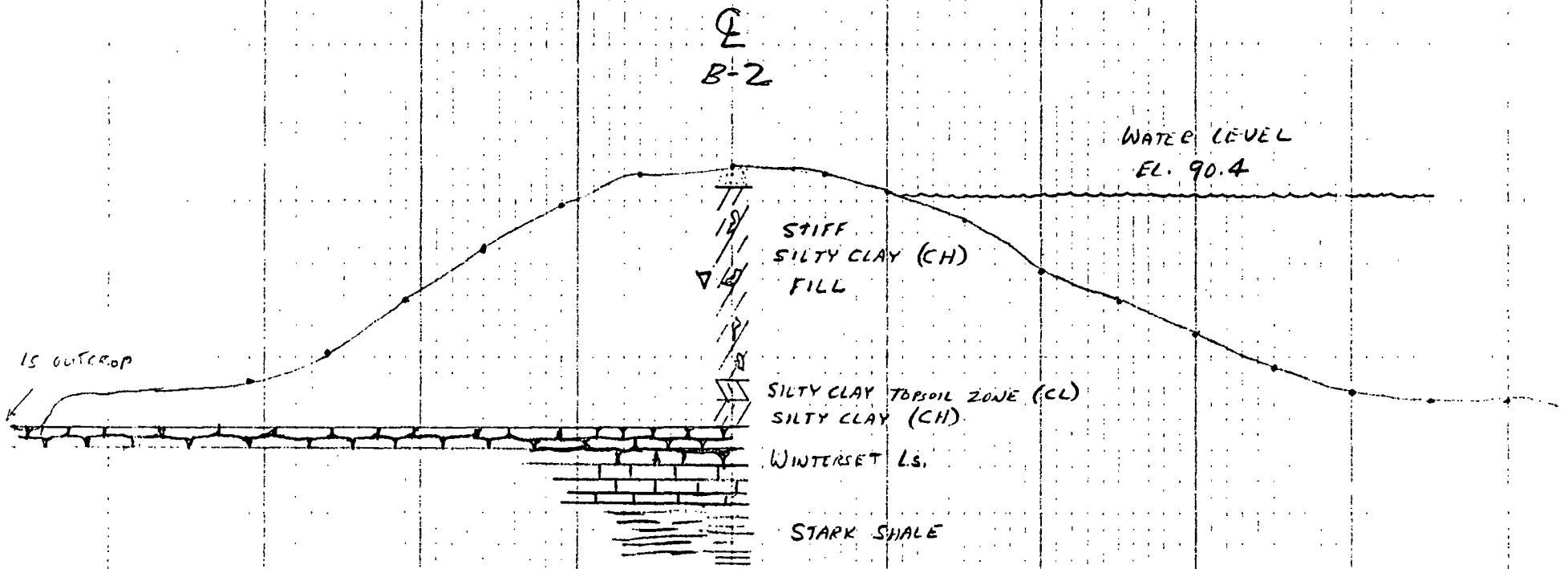
Figure 10

Drilled By: Richard L. Luke



GEOLOGIC & SURFACE PROFILE
BORING 1
NATIONAL ZINC COMPANY
CHERRYVALE, KANSAS

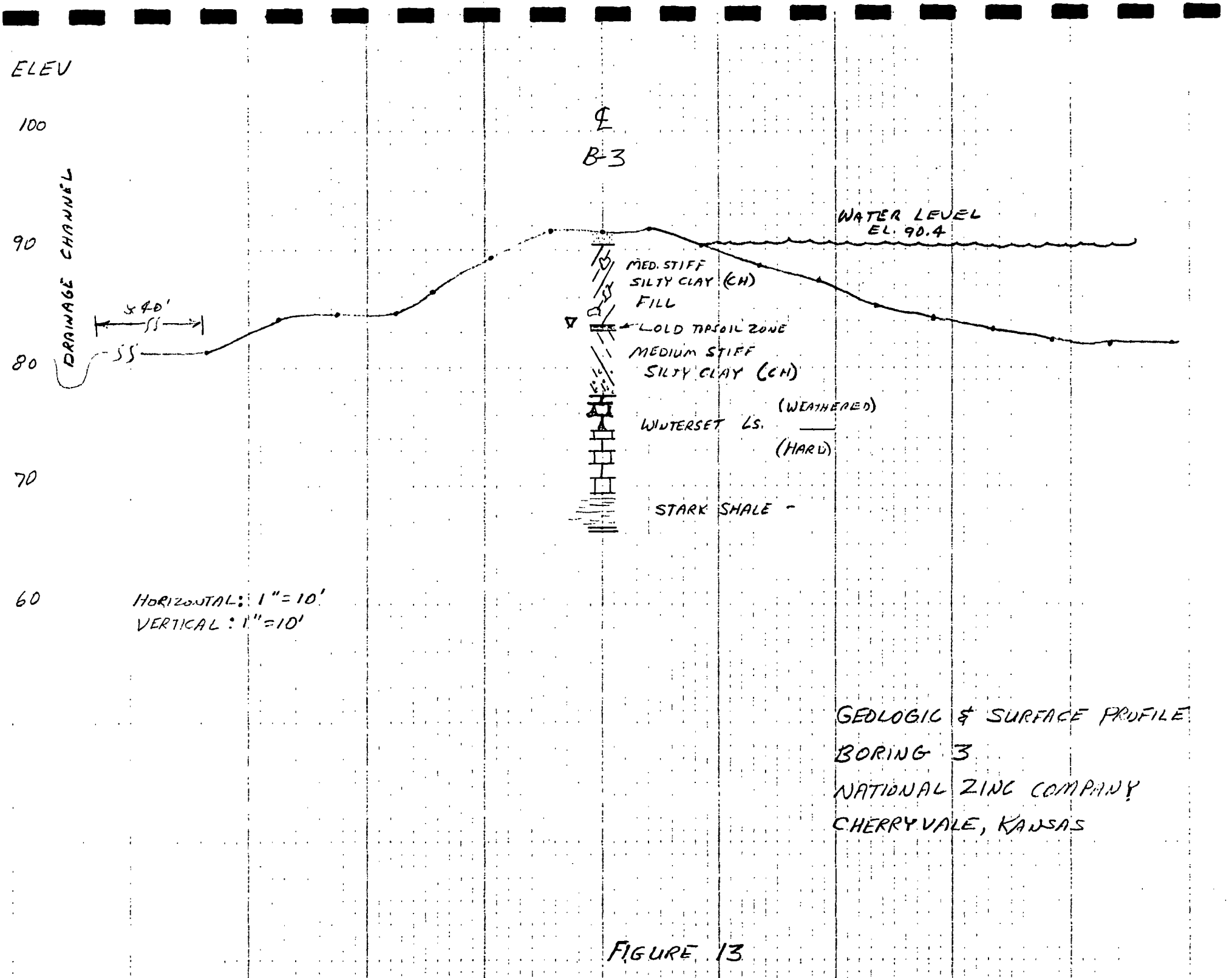
FIGURE 11



HORIZONTAL: 1"= 10'
VERTICAL : 1"=10'

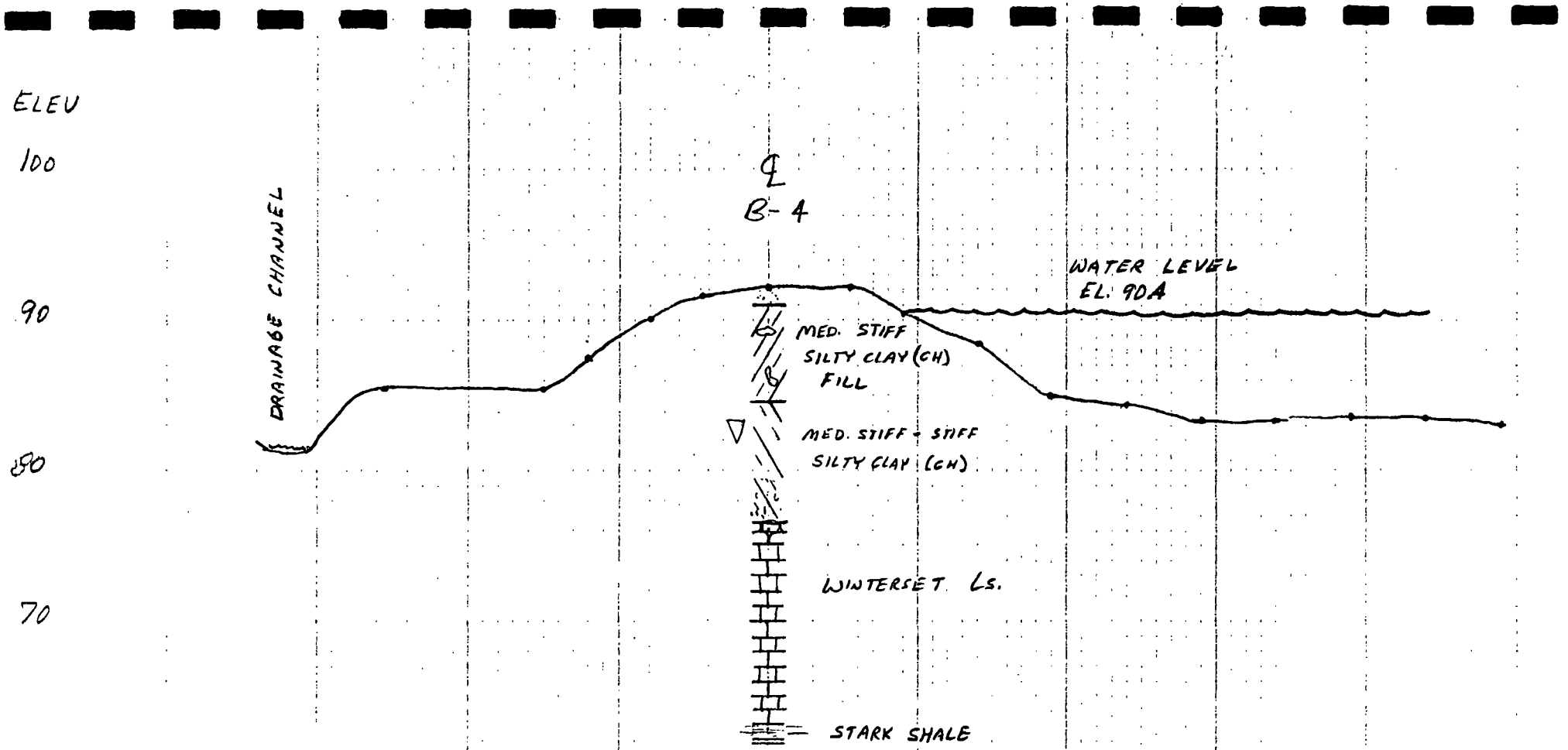
GEOLOGIC & SURFACE PROFILE
BORING 2
NATIONAL ZINC COMPANY
CHERRYVALE, KANSAS

FIGURE 12



GEOLOGIC & SURFACE PROFILE
BORING 3
NATIONAL ZINC COMPANY
CHERRYVALE, KANSAS

FIGURE 13



GEOLOGIC & SURFACE PROFILE
BORING 4
NATIONAL ZINC COMPANY
CHERRYVALE, KANSAS

FIGURE 14

SOILS ENGINEERING REPORT
LAGOON EMBANKMENT EVALUATION
CHERRYVALE, KANSAS

I. INTRODUCTION

This is a report of subsurface and soil conditions for the existing wastewater lagoon at National Zinc Company plant near Cherryvale, Kansas. The lagoon has been used as a sedimentation basin to collect contaminated surface runoff from the plant area. The wastewater lake was designed as an evaporating lagoon. Numerous height and area additions have been constructed subsequent to initial construction to provide adequate storage.

This investigation was authorized by a contract between National Zinc Company and Wichita Testing Laboratories, dated April 3, 1978.

The purpose of this investigation was to provide an evaluation of the stability of the lagoon embankment as it exists.

Since no guidelines were designated for evaluating the existing embankment we used Soil Conservation Service criteria (Earth Dams and Reservoirs, SCS Technical Release No. 60) in our stability analysis. The embankment stability analysis was made utilizing Class (a) dam criteria. It should be noted that our investigation does not include a flood routing study.

II. FOUNDATION CHARACTERISTICS

1. Bedrock. Limestones and shales of upper Pennsylvanian geologic age underlie the lagoon. The bedrock is believed to be the upper portion of the Dennis Limestone, a member of the Kansas City group. The upper few feet of the limestone bedrock was generally weathered and broken at the boring locations. Residual gravelly clays and silty clay colluvium mantle the bedrock beneath the lagoon embankment. Some seepage was noted at the toe of the embankment at various locations along the west and southwest sides of the wastewater lagoon.

2. Classification. The naturally occuring soils above the bedrock have medium to high plasticity and medium stiff to stiff consistency. Liquid limit (ASTM: D-423) values of 40, 47, 53 and 45 and plasticity indices (ASTM: D-424) of 20, 28, 31 and 26 were obtained for Lab.Sample Nos. 2, 10, 11 and 13 respectively. Based on laboratory tests a visual inspection of the natural soils were classified as gravelly and silty clay (CL and/or CH) according to the Unified Classification System.

3. Density. Six undisturbed samples of the natural foundation soil above the bedrock were obtained using 3 and 5 inch diameter shelby tube samplers. The in situ dry densities varied from 1.49 to 1.72 gm/cc and the soil moisture contents varied from 22.4 to 27.3 percent.

4. Shear Strength. Consolidated-undrained (CU and $\overline{CU}$) triaxial tests were made on 1.4 inch diameter test specimens trimmed from Lab. Sample No. 7. The test specimens were saturated by backpressure prior to consolidation and shearing. Measurement of pore pressure response gave B parameters of 0.98 to 1.00. The total stress shear parameters interpreted from the test data for Lab Sample No. 7 are $\phi = 13.8^{o}$ with c = 540 psf. The effective stress parameters are interpreted to be $\phi = 32.0$ and c = 0 psf.

5. Permeability. Falling head permeability tests were made on four undisturbed samples of the natural foundation soils beneath the embankment. The permeability rate was determined for each sample at a confining pressure of 0.5 KSF. Permeability rates of 3.4×10^{-5}, 4.6×10^{-8}, 2.1×10^{-4} and 5.3×10^{-8} cm/sec were obtained for Lab. Sample Nos. 2, 10, 11 and 13 respectively. Using an average permeability value of 6×10^{-5}, the seepage beneath the maximum section of the embankment (near Boring No. 2) was calculated to be about 0.14 cubic feet per day per lineal foot of embankment. Using the dimensions of this maximum section for the effective length of the embankment (assumed to be 2000 feet), the total quantity of seepage beneath the embankment is calculated to be about 280 cubic feet per day.

As can be seen from the laboratory test data, the permeability rates of the foundation soils can vary greatly. The weathered, broken portions of the limestone can also be highly pervious. The seepage rates will differ greatly at various locations beneath the embankment. The actual total quantity of seepage beneath the embankment may be from 200 to possibly 500 cubic feet per day.

6. Dispersion. The results of the dispersion tests on Lab. Sample Nos. 2, 10, 11 and 13 indicated dispersions of 33, 30, 6 and 37 respectively. These values indicate the foundation soils are low to non-dispersive.

III. EXISTING EMBANKMENT MATERIALS

1. Classification. Seven samples of material from the existing embankment were tested in the laboratory for classification in accordance with the Unified Soil Classification System. The liquid limits ranged from 39 to 60 and the plasticity indices varied from 19 to 42 for the embankment samples. The embankment materials were classified as silty clay and as CL and/or CH.

2. Density. Seven relatively undisturbed samples of the embankment material were obtained for inspection and laboratory testing. The insitu dry densities of these samples ranged from 1.45 to 1.63 gm/cc and their moisture contents varied from 23.6 to 32.1%

3. Shear Strength. A triaxial shear test (CU and $\overline{CU}$) was performed on specimens trimmed from Lab. Sample No. 6. The test specimen was saturated by backpressure prior to consolidation and shearing. Measurement of pore pressure response gave B parameters of 0.97 to 0.99. The total stress shear parameters interpreted from the test data are $\phi = 22.7^{\circ}$ with c = 330 psf. The effective stress parameters for the sample are interpreted to be $\phi = 28.0^{\circ}$ and c = 300 psf.

4. Permeability. Falling head permeability tests were made on two undisturbed samples of material from the existing embankment. The permeability rate was determined for each undisturbed sample at a confining pressure of 0.5 KSF. Permeability rates of 1.3×10^{-8} and 1.2×10^{-7} cm/cc were obtained for Lab. Sample Nos. 5 and 8. Assuming the average laboratory permeability value of 7×10^{-8} cm/sec represents the permeability rate of the entire embankment, then seepage through the dam is expected to be less than 0.000475 cubic feet per day per linear foot of dam. Using the dimension of the maximum section, an average permeability rate of 7×10^{-8} cm/sec and an assumed total embankment length of 2000 feet, the total quantity of seepage through the embankment is calculated to be about 1 cubic foot per day. Although not indicated by our investigation the embankment may have some zones of more permeable materials and actual quantities of seepage through the embankment may be considerably greater than the calculated quantity.

5. Dispersion. The results of the dispersion tests on Lab. Sample Nos. 5 and 8 from the embankment indicated dispersions of 33 and 22 respectively.

IV. SLOPE STABILITY ANALYSIS

Computer analyses of slope stability were performed using the modified Swedish circle method for steady seepage conditions at the maximum section of the lagoon embankment (near Boring No. 2). In our analyses we assumed a downstream slope of 1.7 from the top of the embankment (about elevation 92.0) to the top of the natural ground surface (about elevation 79.6). The embankment section used in our analyses had a top width of 12 feet. We also used a 2:1 slope for the upstream slope (the side facing the lagoon). We made our analyses assuming that a theoretical phreatic surface would develop at the water level in the lagoon (at elevation 90.4 resulting in 1.6 feet of freeboard) and would extend to the toe of the downstream slope (about elevation 79.6). Effective stress shear parameters ($\overline{CU}$) were used for steady seepage analysis.

The safety factors for both normal and earthquake conditions were determined for the maximum section as described above. A safety factor of 1.46 was obtained for static conditions using a total of 184 trial arcs. This factor of safety met the 1.4 minimum requirement (SCS, TR-60). A factor of safety of 1.16 was obtained for earthquake conditions in a static analysis, assuming a horizontal acceleration of 0.10 g. This met the 1.0 minimum factor of safety requirement (SCS, TR-60).

The maximum section showing slope configurations, phreatic surface, soil contacts and the theoretical failure surface are shown graphically on the enclosed "Slope Stability Analysis - Embankment Cross-Section".

As can be seen from the enclosed embankment cross-section the actual phreatic surface is substantially lower (as much as 3 feet) than the theoretical phreatic surface. This indicates that portions of the limestone bedrock are very permeable and act as a drainage blanket in lowering the phreatic surface.

V. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on the field and laboratory test data obtained from this investigation and on current Soil Conservation Service criteria, we conclude that the National Zinc Company waste water lagoon has adequate slope stability for the existing slope configurations and lake level. As stated in the introduction to this report, we did not conduct a flood routing study.

RECOMMENDATIONS

(1) We recommend an in-depth hydrology study made to determine the potential for overtopping the lagoon embankment.

(2) At the time of this investigation the lagoon water level was at elevation 90.4 which provides only 1.6 feet of freeboard at the maximum section. We concur with the State of Kansas Department of Health and Environment suggestion in their letter to National Zinc Company dated January 31, 1978 stating that the plant area be graded so as to divert all uncontaminated storm water runoff from entering the subject lagoon system.

(3) Seepage does not appear critical at the present time; however, timely observations, measurements, and analysis of data are recommended as a safeguard for future continued use of the lagoon. The seepage quantities could be determined economically by constructing weirs. The seepage quantities could then be monitored by studying the weir readings taken periodically. Tests of the dissolved and suspended solids in the seepage water could be monitored for indications of leaching or piping. The seepage water in the installed observation wells could be similarly tested and monitored. Pump-in or pump-out tests of the observation wells could also provide useful information.

If the quantity of seepage beneath the embankment is considered excessive at any time it may be controlled by pressure grouting through the embankment or possibly by application of bentonite to the reservoir surface. A cement grout appears preferable over other forms of chemical grout. Bentonite could be applied to those sections of the reservoir where seepage is to be controlled. This may be accomplished by broadcasting pelleted bentonite over the water surface.

If you have questions concerning this report, please give us a call at your convenience.

Submitted By:

WICHITA TESTING LABORATORIES

By Kent J. Schwieger

Kent J. Schwieger, P.E.

825 "J" Street

WESTERN LABORATORIES
Materials Engineers

Lincoln, Nebraska

LAB. SAMPLE NUMBER	FIELD NUMBER	LOCATION AND DESCRIPTION	DEPTH Feet	FIELD CLASSIFICATION	MECHANICAL ANALYSIS GRAIN SIZE DISTRIBUTION EXPRESSED AS PERCENT FINER BY DRY WEIGHT																	ATTERBERG LIMITS		UNIFIED CLASSIFICATION	SOLUBLE SALTS %	DISPERSION %	MOISTURE - DENSITY RELATIONSHIPS ☐ STANDARD ☐ MODIFIED			UNDISTURBED SAMPLE DATA		G_s	SPECIAL TESTS	
					FINES					SAND						GRAVEL																
					0.001 m m	0.005	0.02	0.05	#200 0.074	#100 0.149	#50 0.297	#40 0.42	#20 0.84	#10 2.0	#4 4.76	3/8" 9.525	1/2" 12.7	3/4" 19.05	1" 25.4	1 1/2" 38.1	3" 76.2 m m	L.L.	P.I.				CURVE NO	MAX γ_d p c f	w_o %	γ_d g/cc	w_n %		Triaxial	Perm.
1	1	Boring No. 1	2.0-3.5	CL	23	32	62	86	92	96	97	98	99	100								39	19	CL						1.63	23.6			
2	2	Boring No. 1	8.0-9.5	CL	16	29	57	87	96	98	99	100										40	20	CL		33				1.51	27.1			X
4	4	Boring No. 2	2.0-3.5	CH	16	31	63	84	89	93	96	97	98	100								53	30	CH						1.58	25.5			
5	5	Boring No. 2	7.0-8.5	CL	22	39	63	91	96	99	99	100										43	23	CL		33				1.45	32.1			X
6	6	Boring No. 2	12.0-13.5	CH	40	54	76	90	94	98	100											60	42	CH						1.45	30.2		X	
7	7	Boring No. 2	15.5-16.5	CH	15	38	60	72	76	82	87	89	95	99	100							52	32	CH						1.52	27.3		X	
8	8	Boring No. 3	2.0-3.5	CH	18	37	63	83	88	92	95	96	98	100								54	34	CH		22				1.52	25.5			X
9	9	Boring No. 3	5.0-6.5	CH	36	52	73	87	92	96	99	100										54	31	CH						1.53	28.5			
10	10	Boring No. 3	7.0-8.5	CL	27	37	63	88	95	98	99	100										47	28	CL		30				1.57	24.3			X
11	11	Boring No. 3	12.0-13.5	CH	25	45	65	77	81	87	90	92	95	100								53	31	CH		6				1.72	22.4			X
12	12	Boring No. 4	2.0-3.5	CL	10	34	61	90	94	98	99	99	100									45	27	CL						1.57	25.4			
13	13	Boring No. 4	7.0-8.5	CL	21	43	64	89	95	99	99	100										45	26	CL		37				1.55	25.7			X
14	14	Boring No. 4	10.0-11.5	CH	21	43	66	85	91	97	98	99	99	100								54	35	CH						1.49	27.1			

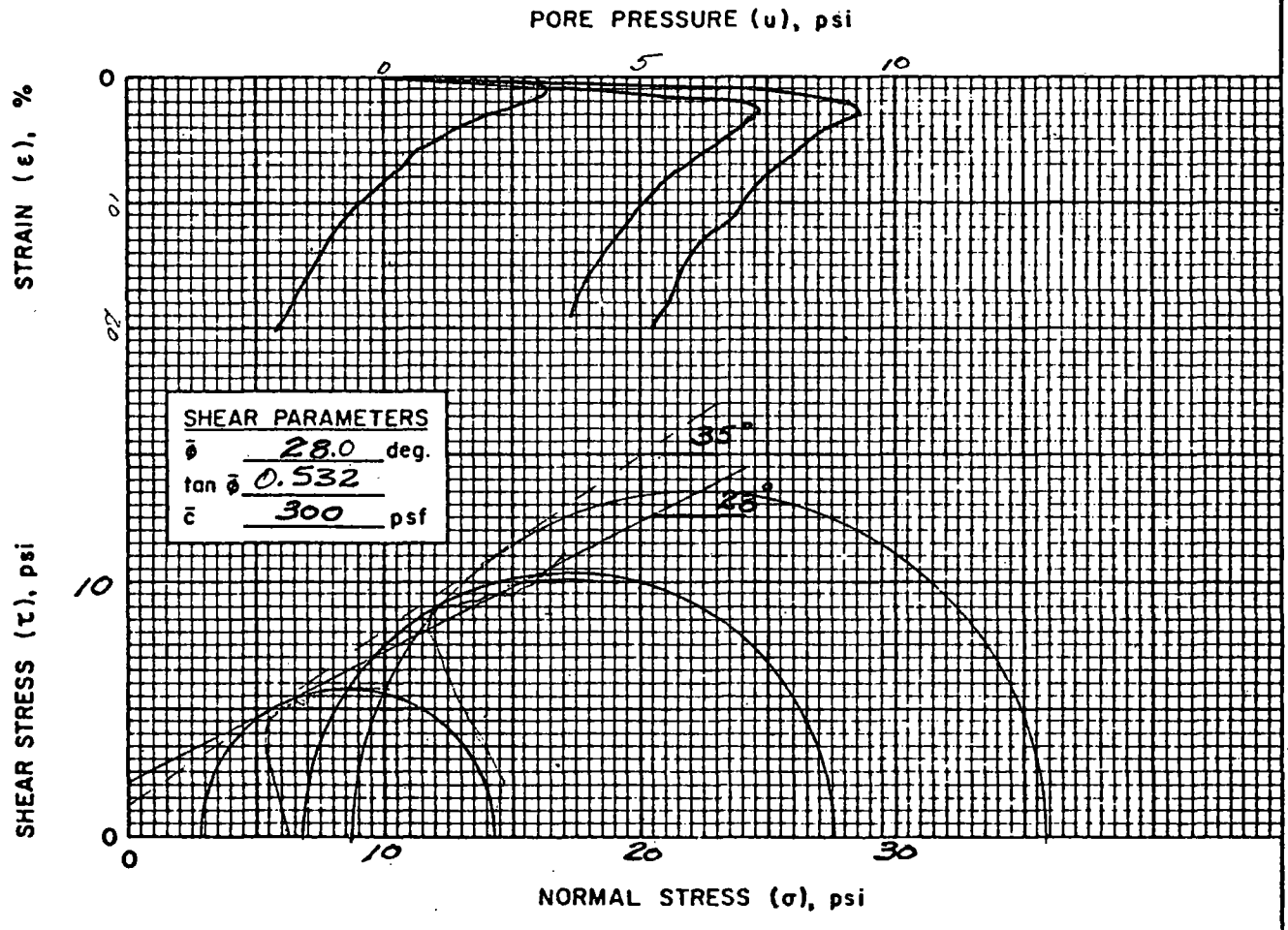
LABORATORY NO. 6

MATERIALS TESTING REPORT	WESTERN LABORATORIES *Materials Engineers*	TRIAXIAL SHEAR TEST with pore pressure measured

PROJECT and STATE: National Zinc Co — SAMPLE LOCATION: & Embankment @ B-2

TYPE OF SAMPLE: Undisturbed — TESTED AT: Lincoln, NE — APPROVED BY: — DATE: 5/5/78

MINOR PRINCIPAL STRESS, σ_3 (psi)	PORE PRESSURE, u (psi)	EFFECTIVE MINOR PRINCIPAL STRESS, $\bar{\sigma}_3$ (psi)	DEVIATOR STRESS, $\sigma_1 - \sigma_3$ (psi)	FAILURE CRITERIA	AXIAL STRAIN AT FAILURE, ε (%)
6.2	3.3	2.9	11.3	$\frac{\bar{\sigma}_1}{\bar{\sigma}_3}$	1.00
14.1	7.3	6.8	20.8		2.69
17.8	9.1	8.7	27.2		3.37



REMARKS: Envelope based on vector curves

LABORATORY NO. 7

MATERIALS TESTING REPORT	WESTERN LABORATORIES *Materials Engineers*	TRIAXIAL SHEAR TEST

PROJECT and STATE: NATIONAL ZINC Co.

SAMPLE LOCATION: & Embankment @ B-2

FIELD SAMPLE NO.: 7

DEPTH: 15.7'-16.4'

GEOLOGIC ORIGIN:

TYPE OF SAMPLE: UNDISTURBED

TESTED AT: LINCOLN, NEBR.

APPROVED BY:

DATE: 5-4-78

INDEX TEST DATA

USCS _____; LL _____; PI _____

% FINER (mm): 0.002 _____; 0.005 _____; 0.074 (#200) _____

G_s (-#4) _____; G_s (+#4) _____

STANDARD: γ_d MAX. _____ pcf; w_o _____ %

MODIFIED: γ_d MAX. _____ pcf; w_o _____ %

SPECIMEN DATA

HEIGHT 3.0 "; DIAMETER 1.4 "

MATERIALS TESTED PASSED _____ SIEVE

METHOD OF PREPARATION Trimmed from an undisturbed Core

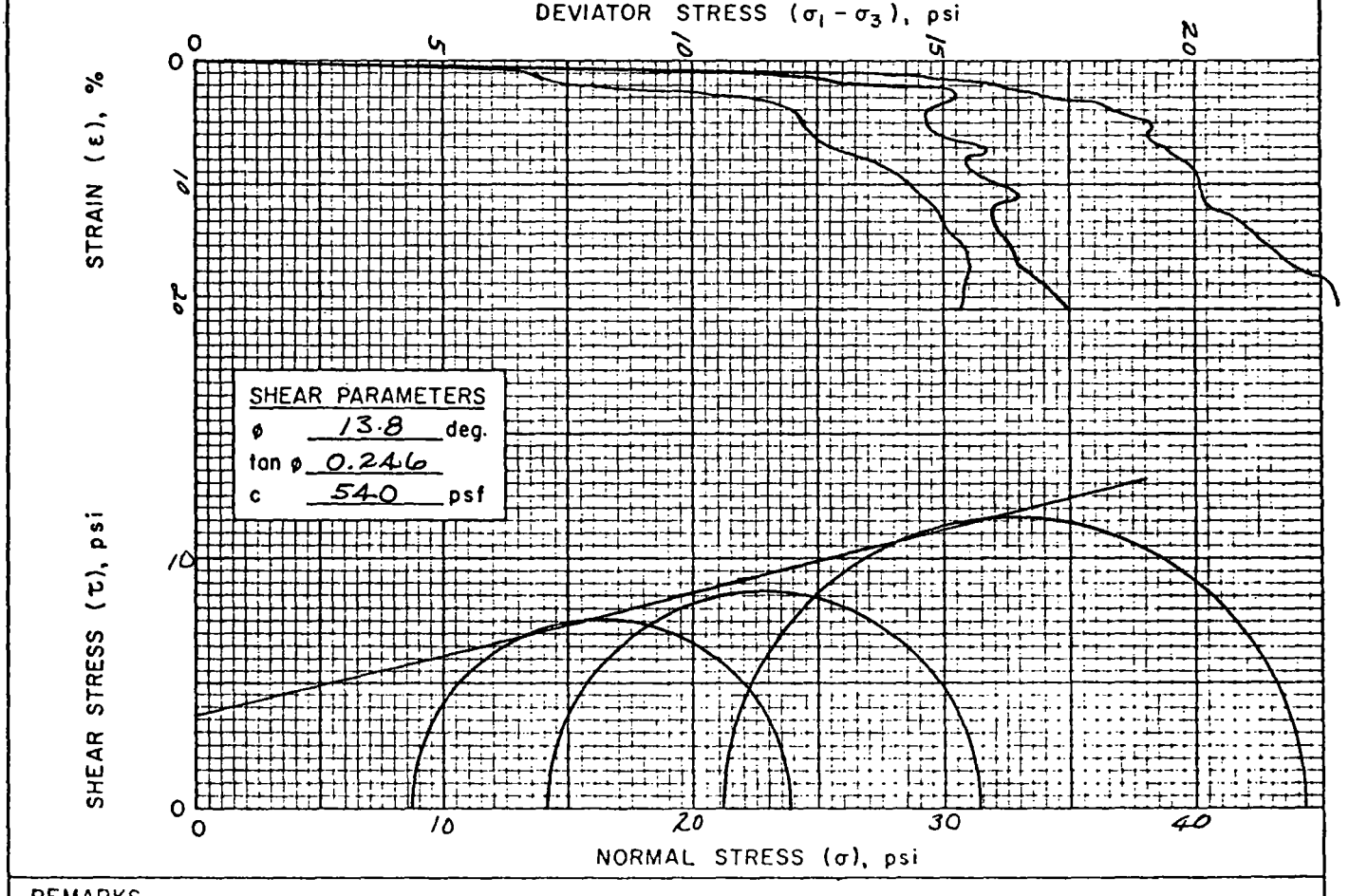
MOLDING MOISTURE _____ %

MOLDED AT _____ % OF γ_d MAXIMUM

TYPE OF TEST

- UU ☐
- CU ☐
- $\overline{CU}$ ☒
- CD ☐

DRY DENSITY		B Parameter	MOISTURE CONTENT, %			TIME OF CONSOLIDATION (hrs.)	MINOR PRINCIPAL STRESS σ_3 (psi)	DEVIATOR STRESS $\sigma_1 - \sigma_3$ (psi)	AXIAL STRAIN AT FAILURE, ε (%)
INITIAL pcf ☒ g/cc ☐	CONSOLIDATED pcf ☒ g/cc ☐		START OF TEST	DEG. OF SAT. AT START OF TEST	END OF TEST				
96.7	103.0	.98	27.3	100.8	26.7	17	8.7	15.5	16.72
94.9	100.6	1.00	27.3	96.5	24.5	15	14.1	17.5	20.16
92.9	96.9	.99	27.3	91.9	27.0	17	21.1	23.1	20.14



REMARKS

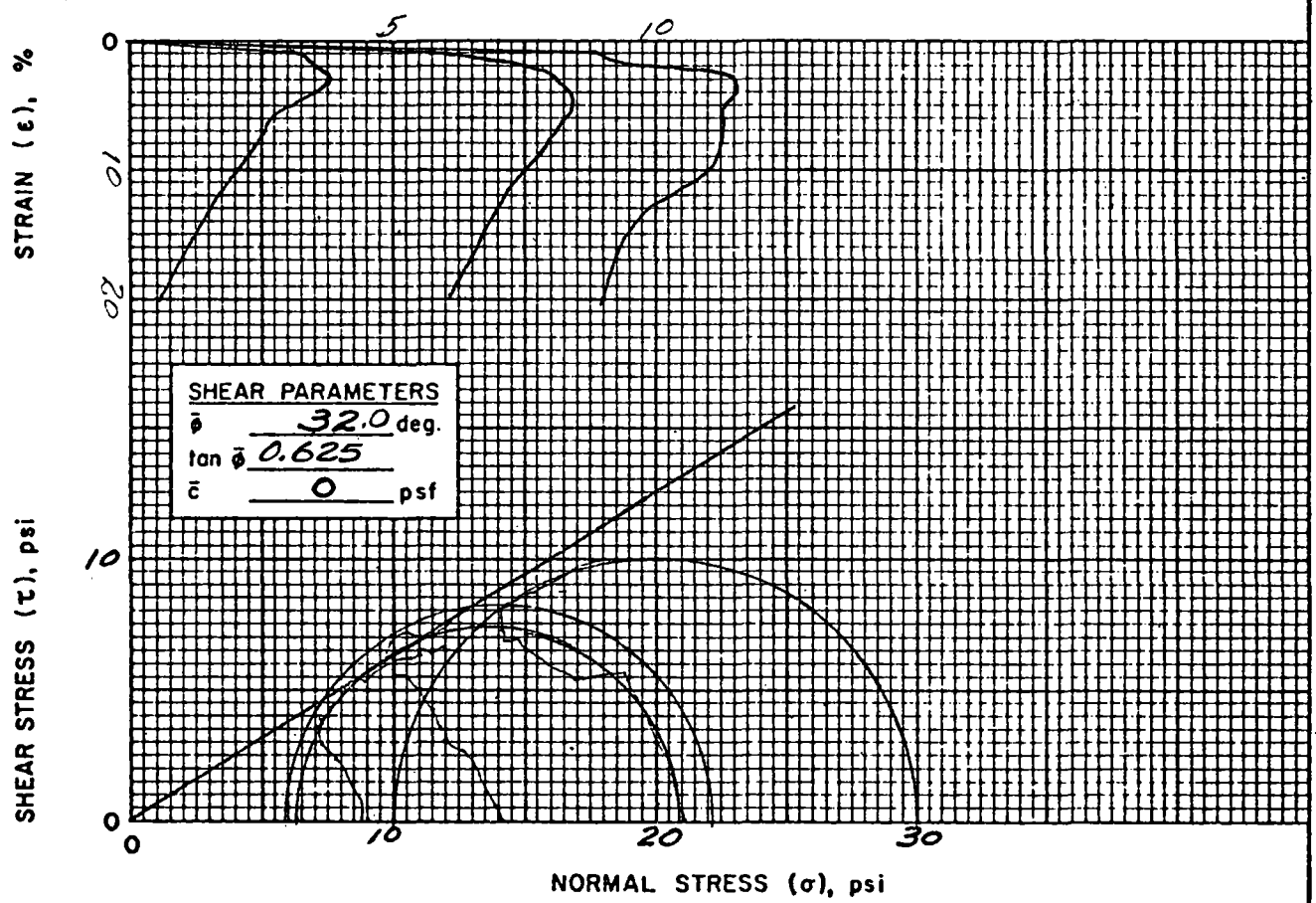
LABORATORY NO. 7

MATERIALS TESTING REPORT	WESTERN LABORATORIES *Materials Engineers*	TRIAXIAL SHEAR TEST with pore pressure measured

PROJECT and STATE: National Fire Pa | SAMPLE LOCATION: & Embankment @ B-2

TYPE OF SAMPLE: Undisturbed | TESTED AT: Lincoln, NE | APPROVED BY: | DATE: 3/4/78

MINOR PRINCIPAL STRESS, σ_3 (psi)	PORE PRESSURE, u (psi)	EFFECTIVE MINOR PRINCIPAL STRESS, $\bar{\sigma}_3$ (psi)	DEVIATOR STRESS, $\sigma_1 - \sigma_3$ (psi)	FAILURE CRITERIA	AXIAL STRAIN AT FAILURE, ε (%)
8.7	2.3	6.4	14.4	$\frac{\bar{\sigma}_1}{\bar{\sigma}_3}$	9.36
14.1	8.2	5.9	16.1		6.40
21.1	11.1	10.0	19.9		8.06

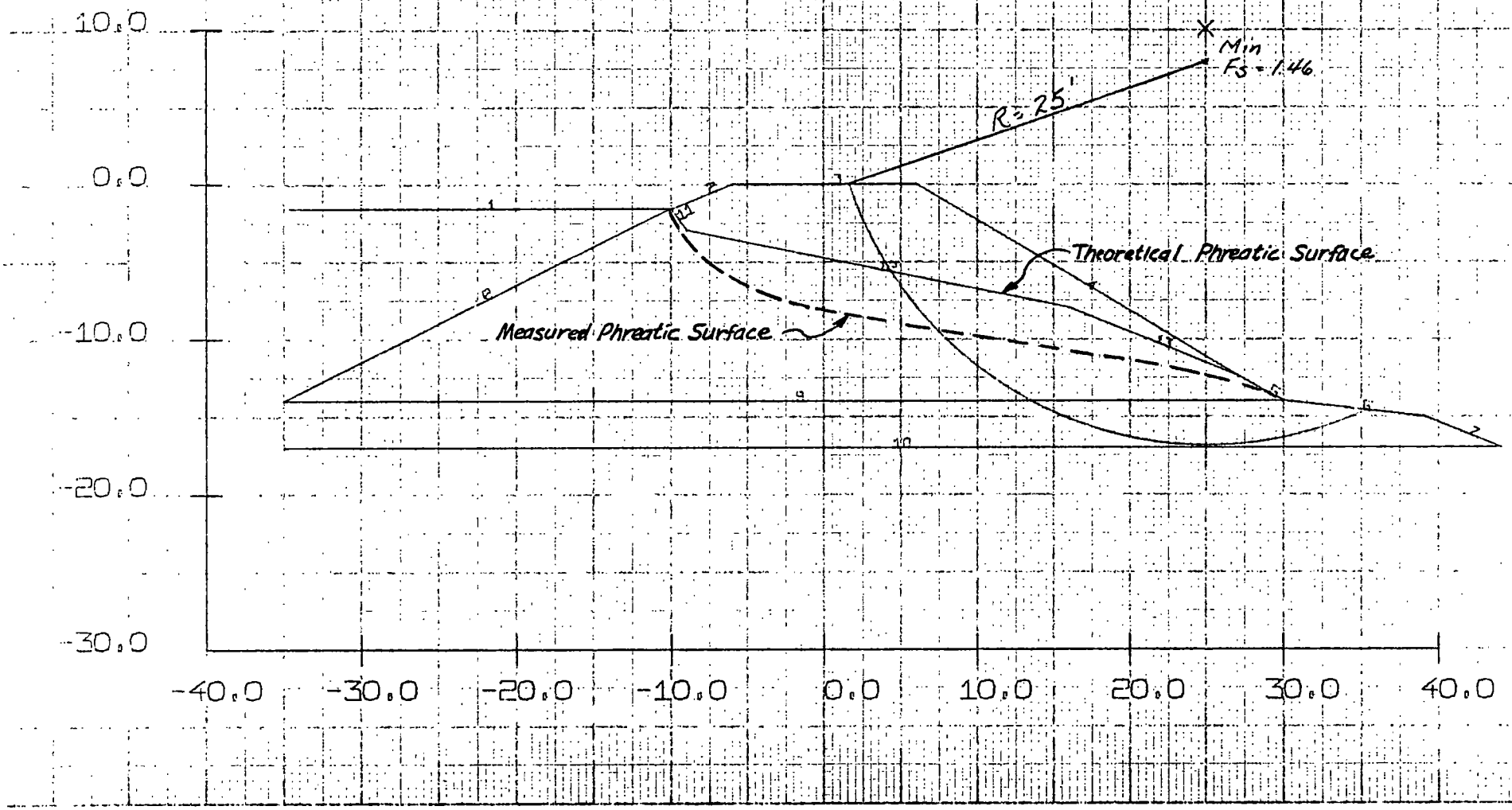


REMARKS: Envelope based on vector curves

SLOPE STABILITY ANALYSIS
EMBANKMENT CROSS-SECTION

NATIONAL ZINC COMPANY - MAXIMUM SECTION JOB NO. 78/5041

Near Hole B-2



LABORATORY NO. 6

MATERIALS TESTING REPORT	WESTERN LABORATORIES *Materials Engineers*	TRIAXIAL SHEAR TEST

PROJECT and STATE: NATIONAL ZINC Co.
SAMPLE LOCATION: @ Embankment @ B-2
FIELD SAMPLE NO.: 6
DEPTH: 12.8' - 13.2'
GEOLOGIC ORIGIN:
TYPE OF SAMPLE: UNDISTURBED
TESTED AT: LINCOLN, NEBR
APPROVED BY:
DATE: 5-5-78

INDEX TEST DATA

USCS _____; LL _____; PI _____
% FINER (mm): 0.002 _____; 0.005 _____;
0.074 (#200) _____
G_s (-#4) _____; G_s (+#4) _____
STANDARD: γ_d MAX. _____ pcf; w_o _____ %
MODIFIED: γ_d MAX. _____ pcf; w_o _____ %

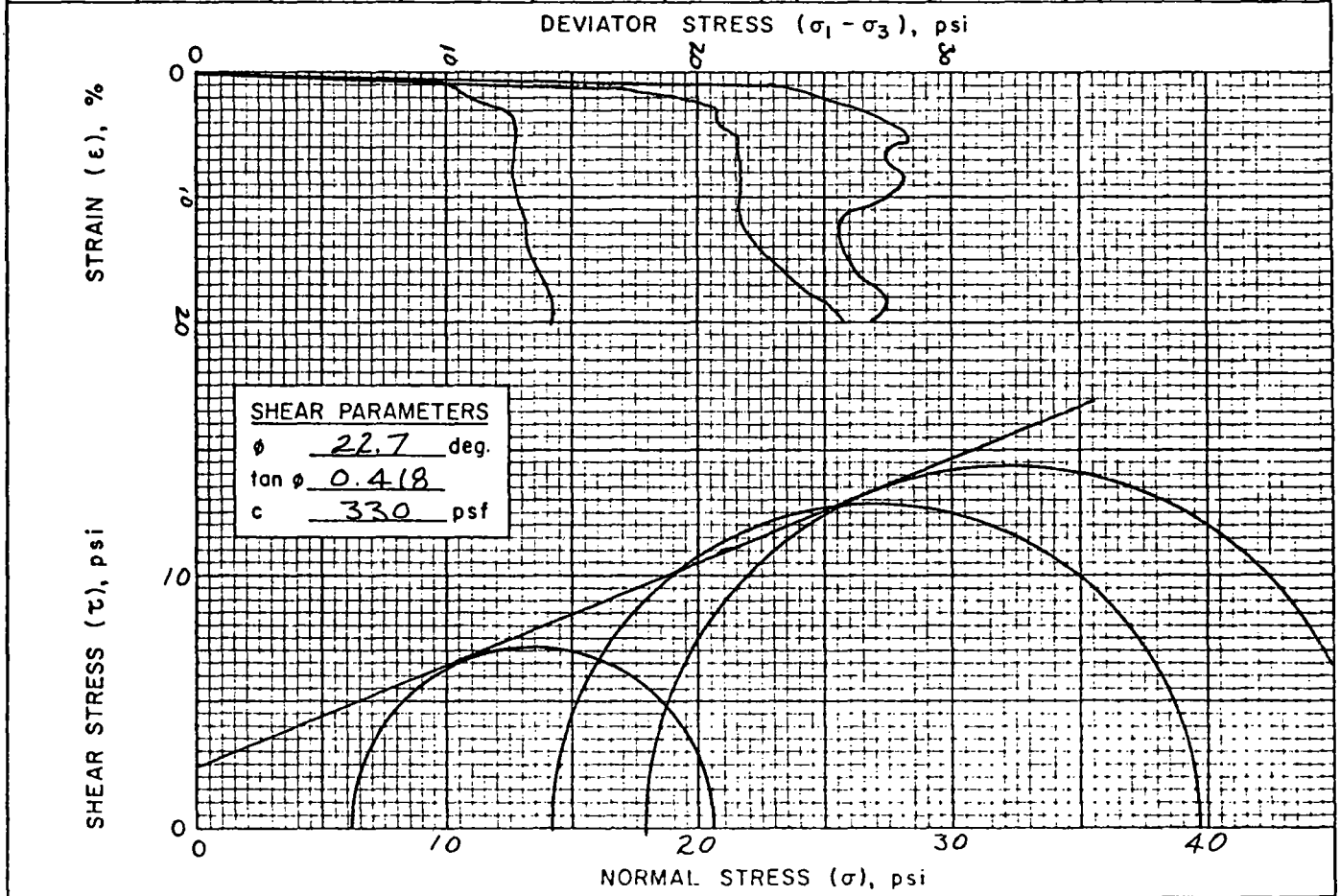
SPECIMEN DATA

HEIGHT 3.0 "; DIAMETER 1.4 "
MATERIALS TESTED PASSED _____ SIEVE
METHOD OF PREPARATION Trimmed from an undisturbed core
MOLDING MOISTURE _____ %
MOLDED AT _____ % OF γ_d MAXIMUM

TYPE OF TEST

UU ☐
CU ☐
$\overline{CU}$ ☒
CD ☐

DRY DENSITY		B	MOISTURE CONTENT, %			TIME OF	MINOR	DEVIATOR	AXIAL
INITIAL pcf ☒ g/cc ☐	CONSOLIDATED pcf ☒ g/cc ☐	Parameter	START OF TEST	DEG. OF SAT. AT START OF TEST	END OF TEST	CONSOLIDATION (hrs.)	PRINCIPAL STRESS σ_3 (psi)	STRESS $\sigma_1 - \sigma_3$ (psi)	STRAIN AT FAILURE, ε (%)
89.9	93.2	.98	30.8	96.2	33.9	15	6.2	14.4	19.40
89.4	88.8	.99	30.8	95.2	34.1	15	14.1	25.7	20.14
92.3	96.9	.97	29.0	96.4	33.9	16	17.8	28.5	5.39



REMARKS