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DIST. 14 REGION

W.P. No.

CONT. No.

W. O. No. 14-70003

STR. SITE No.

HWY. No. MUNICIPAL

LOCATION SIDEROAD SLIP FAILURE

(BEAUCHAMP TWP. LOT 2, CON IV)

No of PAGES - 1

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

ENGINEERING MATERIALS OFFICE
PAVEMENT & FOUNDATION DESIGN SECTION

WO 14-70003-R DIST 14

HWY Mun. STR SITE N/A

Beauchamp Twp. Lot 2, Conc. IV Slip Failure

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FOUNDATION INVESTIGATION REPORT

For

W.O. 14-70003-R; Site N/A

Sideroad Slip Failure

Beauchamp Twp., Lot 2, Conc. IV

District 14, New Liskeard

INTRODUCTION:

This report summarizes the results of the foundation investigation for the above-noted road failure.

The fieldwork was conducted during the period from 83 07 14-28, utilizing a continuous flight auger machine equipped with 82 mm I.D. hollow-stem augers. This work consisted of 7 sampled boreholes/dynamic cone penetration tests.

SITE DESCRIPTION

The site is located approximately 1.4 km north of the Conc. III/IV road on the Lot 2/3 sideroad in Beauchamp Twp. (approximately 6.5 km west of Hwy. 11).

Physiographically the site is located in the Colbolt Plain, a glaciolacustrine plain of generally low local relief.

At this site, the sideroad crosses a tributory of Eventurel Creek. The creek flows to the east through an 18±m long, 4.3±m diameter CSP culvert. The road surface is 5.4±m above the culvert invert level.

At the time of the field investigation, the slip failure extended along the east side of the road affecting up to 4.5±m (width) of the northbound lane. Refer to Drawing No. 1470003-R-A for specific failure location details.

Based on site inspections and discussions with Mr. O. Allen (Township Maintenance, Dist. 14) it is our understanding that:

- the existing culvert was installed in approximately 1969.
- the culvert was seated at the creek invert level that existed at that time

- since installation of the culvert, the invert elevation of the downstream creek channel has been cut 3±m lower, within a distance of 20±m from the culvert
- there are numerous progressive slip failures along the downstream creek channel
- small cracks were evident along the road surface, near the eventual failure zone, as early as 1982.
- on 83 05 27, the initial slip failure occurred
- an attempt to backfill the road surface portion of the slip failure was made on 83 05 27
- on 83 05 28, the slip dropped 3±m, and was eventually backfilled
- at the time of the field investigation the slip was 0.5±m below the road surface
- the water depth in the creek may reach 2±m in the spring. At the time of the field investigation the creek water was estimated at 0.15 m
- on 83 06 09 and 83 07 14 (before the field investigation) shallow surface ponding was evident in the area directly below the failure zone, even after a long period of dry weather conditions
- the culvert inlet was undercut at least 0.15 m at the time of the field investigation. Otherwise, the culvert appeared to be in good condition

SUBSURFACE CONDITIONS

General

The Record of Borehole Sheets, (Appendix) illustrate the conditions at the borehole locations. The locations and elevations of the boreholes are shown on Drawing No. 1470003-R-A.

The survey stations and elevations refer to temporary benchmarks established by our field personnel. (Sta. 00+000, Elev. 100.00 m).

Generally, the sequence of overburden materials, from the surface downwards is as follows:

- 2 m of silty clay
- 11 m of varved clay
- 7 m of silt
- then silty sand

The road embankment is composed of approximately 2 m of fill.

Road Embankment Fill Material

At BH#6 and #7, up to 2.1 m of silty sand, containing traces of gravel and clay and occasional pockets ofsilty clay (CL) was encountered.

The denseness of this material ranges from very loose to loose.

Silty Clay (CL) to Clay (CH); some sand, trace organics

This deposit is the surface material in the valley, where it extends to elev. 95±m. It also lies directly beneath the road embankment fill where it extends to elev. 97 to 98 m. The thickness of this very soft to stiff material ranges from 0.9 to 2.1 m.

Physical properties of the material, as determined from field and laboratory tests, are summarized as follows:

	Range	Average	Median
Natural Moisture Content (w)	22.5 - 29.5%	25.3%	24.0%
Liquid Limit (w_L)	38.0 - 52.5%	45.3%	45.5%
Plastic Limit (w_p)	17.5 - 24.0%	21.3%	22.5%

Figure 1 illustrates a typical grain size distribution for this material.

Varved Clay

This material underlies the silty clay to clay and extends for approximately 11 m to elevation 84±m.

The deposit consists of regular alternating layers of clay of low plasticity (2 cm thickness) and clay of intermediate to high plasticity (1 cm thickness), generally containing over 50% silt and traces of sand. The consistency of the deposit ranges from soft to firm, generally increasing with depth.

Physical properties of the material, as determined from field and laboratory tests, are summarized as follows:

	Range	Average	Median
Natural Moisture Content (w)	34.0 - 59.5%	43.1%	41.8%
Liquid Limit (w_L)	24.0 - 55.5%	33.6%	29.5%
Plastic Limit (w_p)	16.0 - 20.5%	17.8%	17.0%
Shear Strength			
- field vane (undisturbed)	17 - 62 kPa	N/A	N/A
- field vane (remoulded)	2 - 18 kPa	N/A	N/A
- unconfined compression	15 - 19 kPa	N/A	N/A
Unit Weight (γ)	17.1 - 17.4 kN/m^3	17.2 kN/m^3	17.2 kN/mx3

The sensitivity of this material ranges from 2 to 12.

Laboratory tests to determine the effective stress parameters provided the following results:

- normally consolidated condition; $c' = 0$ kPa
  $\phi' = 33-34°$

- overconsolidated condition; $c' = 5-8$ kPa
  $\phi' = 31-33°$

The effective stress parameters were modified to $c' = 5$ kPa, $\phi' = 27°$ for the purposes of the stability analyses.

Figure 2 illustrates a typical grain size distribution for this material.

Physical properties, as determined for each varve, are summarized below.

	CL Varve	CI/CH Varve
Natural Moisture Content (w)	27.5%	62.5%
Liquid Limit (w_L)	25.5 - 27.0%	62.5 - 70.5%
Plastic Limit (w_p)	20.0 - 21.5%	23.0 - 26.0%

Silt (ML); some clay, trace sand

This deposit underlies the varved clay, and extends for an estimated 7 m to elev. 76.8±m. The material is generally slightly plastic. Its consistency ranges from very soft to firm.

Physical properties of the material, as determined from field and laboratory tests, are summarized below:

Natural Moisture Content (w)	38.5%
Shear Strength	
- field vane (undisturbed)	36 kPa
- field vane (remoulded)	14 kPa

Figure 3 illustrates a typical grain size distribution for this material.

Silty Sand to Sandy Silt; trace clay

This material underlies the silt. The denseness of this deposit was determined as very loose - probably due to the artesian groundwater conditions encountered.

Figure 4 illustrates a typical grain size distribution for this material.

Groundwater

Measured groundwater elevations were quite variable but the groundwater level was estimated at 93 m (0.5 to 1.0 metres above the creek level).

Artesian conditions were observed in one hole below elev. 74.5 m. The static head level was 0.3 m above ground level.

DISCUSSION AND RECOMMENDATIONS

The road embankment slip failure was a result of progressive failures of the slopes adjacent to the creek and downstream from the culvert.

The creek slope failures were caused by lowering of the creek channel invert and undercutting of the creek banks.

In order to stabilize the road embankment, it is necessary to first stabilize the creek slopes.

The proposed design illustrated in Figures 5, 6 and 7 is intended as a guide. The hydrologic aspects have been discussed with Mr. J. Carter, Sr. Hydrology Engineer, Drainage and Hydrology Section.

Please submit your final design drawings and a complete description of the proposed cohesive fill (for reclaiming the creek bed) to this office for our review.

If there are any questions, please do not hesitate to contact this office.

Creek Embankment Design Details

- Refer to Figures 5 and 6.
- Complete creek bed construction under dry conditions.
- The creek should be straightened, graded and channelled for approximately 50 m downstream from the culvert outlet (refer to Drawing 1470003-R-A).
- Construct the creek bed to the geometry illustrated in Figures 5 and 6 using suitable cohesive fill (till), suitably compacted. Note that we have only estimated the width of the creek channel bottom.
- Protect the cohesive material with a minimum 0.15m thick Granular A blanket and a minimum 0.3 m thick blanket of random rip-rap, as illustrated in Figures 5 and 6. Angular rip-rap would be preferable, especially in those areas near the culvert outlet. Random rip-rap (min. thickness 0.3 m) is also required on the creek slopes as illustrated in the figures.

- Use gabion baskets to line critical portions of the channel slopes and to act as energy dissipaters as illustrated in Figures 5 and 6. The backfill to the gabions near the culvert should be cohesive material.
- Use a Granular 'A' layer (0.15 m min. thickness) to prevent any loss of creek bed material through the energy dissipater at the downstream end of the channel treatment, as illustrated in Figure 5.
- The channel treatment may require periodic maintenance.
- At the culvert inlet and outlet, ensure that the backfill material is properly placed and compacted.
- At the culvert inlet, construct a seal of cohesive material (min. thickness 0.6 m) to prevent any future undermining or seepage. The seal should extend for a minimum of 2 m on each side of the culvert inlet, and from the high water level down the embankment and at least 2 m along the stream channel. (Refer to Figure 7). Benches should be placed in the existing slopes to facilitate placement of the cohesive fill.

Road Embankment Design Details

- Construct the road embankment to the geometry illustrated in Figures 5 and 6.
- On the north side of the culvert construct a 5 m wide berm at elev. 97.8 m along the east side of the road from the culvert to Sta. 0+60±. The berm surface should slope down 0.3 m across its 5 m width to facilitate drainage. The berm should be constructed of suitable embankment material.
- The slopes adjacent to the creek should be graded into the channel treatment at 3:1.
- Other slopes should be graded into the existing contours at 2:1.
- Place a pad (0.3 m min. thickness) of Granular 'A' beneath the plan area of the proposed berm.
- Construct a 0.6 m deep trench as illustrated on Drawing No. 1470003-R-A, and backfill with Granular 'A'. It is suggested that this trench be excavated and immediately backfilled in sections no longer than 5 m. This drain should extend into the creek.
- The berm and transition areas should be protected by vegetation cover as soon as possible after construction.

Construction Sequence

The construction sequence is very important in order to maintain the stability of the road.

Following is our recommended sequence:

(1) Construct drain/trench to creek.

(2) Divert stream water in order to construct channel treatment in the day.

(3) Repair culvert backfill where necessary and construct culvert inlet seal.

(4) Construct stream channel treatment.

(5) Return stream flow to completed channel.

(6) Place Granular 'A' pad below proposed berm.

(7) Construct berm.

(8) Construct remaining portions to achieve recommended road embankment geometry.

(9) Provide required vegetation cover.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of Mr. C.S. McLorg, Student Specialist. The report was written by Mr. McLorg and Mr. D.H. Dundas, Project Foundations Engineer and reviewed by Mr. K.G. Selby, Senior Foundations Engineer. The equipment used was owned and operated by Atcost Soil Drilling Limited.

C.S. McLorg,
Student Specialist Engineering

D.H. Dundas, P. Eng.,
Project Foundations Engineer

K.G. Selby, P. Eng.,
Senior Foundations Engineer

APPENDIX

Ministry of Transportation and Communications
Ontario

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 1 METRIC

WO 14-70003R LOCATION Sta. 0 + 44, 15 m RT of Control Line ORIGINATED BY CM
DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM
DATUM Relative DATE 83 07 14-15 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (10 20 30 40 50)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
97.0	Ground Surface										
0.0	and sand		1	SS	3		96				0 16 34 50
	Silty Clay (GL) to Clay (CH) some sand, trace organics Soft to Firm		2	SS	4						
94.9			3	SS	5						
			4	SS	6						
2.1			5	SS	2		94				
	Varved Clay alternating layers of CL (thickness 2 cm) and CH to CI (thickness 1 cm) and/some silt trace sand		6	TW	PH					17.1	Varved CL/CH 0 0 56 44
			7	SS	2		92				Effective Stress Parameters C' (kPa) ϕ' (o) O.C. 5 34 N.C. 0 33
			8	SS	2						
	Soft to Firm		9	TW	PM		90			17.4	Varved CL/CH 0 0 76 24 0 1 15 84
			10	SS	2		88				
			11	SS	2		86				
	Stiff		12	TW	PH						
84.2											
12.8	End of Borehole						84				
	Probable Silt (slighlty plastic ML)						82				
78.4							80				
18.6	End of Cone Test										

+3, x5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 2 METRIC

WO 14-70003R LOCATION Sta. 0 + 48, 25 m RT of Control Line ORIGINATED BY CM
DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM
DATUM Relative DATE 83 07 18 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (10 20 30 40 50)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
96.0	Ground Surface										
0.9 / 95.1	Silty Clay (CL) to Clay (CH) some sand, trace organics Very soft to soft		1	SS	2	* Artesian Head to Elev 96.3	96				
0.9			2	SS	1			+3			0 1 22 77
	Very Soft						94	+2			
			3	SS	2			+4			
	Varved Clay alternating layers of CL (thickness 2 cm) and CH to CI (thickness 1 cm) and/some silt trace sand Soft to Firm		4	SS	3		92				
			5	TW	PH			+4 +5 +3		17.2	0 0 63 37 Effective Stress Parameters C' ø' (kPa) (o) O.C. 8 33 N.C. 0 31
			6	SS	2		90	+4			
			7	SS	2			+4			
			8	TW	PH		88	+5 +4 +5 +3			
			9	SS	2		86				
	Stiff		10	SS	4			+5			0 0 67 33
84.1											
11.9			11	SS	1		84	+2			0 0 89 11
	Silt (slightly plastic ML) some clay trace sand Very Soft to Firm							+2			
			12	SS	3		82				
			13	SS	5						
			14	SS	7		80				
			15	SS	6		78				
76.8											
19.2	Silty Sand to Sandy Silt trace clay very loose		16	SS	1	Artesian Condition Encountered	76				0 43 55 2
74.7											
21.3	End of Borehole Probable Silty Sand						74				
							72				
							70				
							68				
65.2							66				
30.8	End of Cone Test										

+3, x5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 3 METRIC

WO 14-70003R LOCATION Sta. 0 + 39, 29 m RT of Control Line ORIGINATED BY CM
DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM
DATUM Relative DATE 83 07 19 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE) (10 20 30 40 50)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT Wl — WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
96.0	Ground Surface										
0.0 / 94.8	Silty Clay (CL) to Clay (CH) some sand, trace organics Very Soft		1	SS	1						
1.2	Varved Clay alternating layers of CL (thickness 2 cm) and CH to CI (thickness 1 cm) and/some silt trace sand Very Soft to Firm		2	SS	2		94	+4			
			3	SS	2			+3			
			4	SS	2		92	+5			
			5	SS	2			×5			
			6	SS	2		90	+5			
			7	SS	1			×5			
			8	SS	2		88	+4			
			9	SS	2		86	+4			
84.4			10	SS	2			+2			
11.6 / 82.9	Silt (slightly plastic ML) some clay, trace sand Soft to Firm		11	SS	4		84	×2			
13.1 / 80.4	End of Borehole Probable Silt (slightly plastic ML)						82				
15.6	End of Cone Test										

+3, ×5 : Numbers refer to Sensitivity

20 / 15 ○ 5 (%) STRAIN AT FAILURE / 10

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 4 — METRIC

WO 14-70003R | LOCATION Sta. 0 + 40, 15 m RT of Control Line | ORIGINATED BY CM
DIST 14 | HWY Municipal | BOREHOLE TYPE Hollow Stem Auger, Cone Test | COMPILED BY CM
DATUM Relative | DATE 83 07 19 - 20 | CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
97.0	Ground Surface						
0.0	Silty Clay (CL) to Clay (CH) some sand, trace organics Firm to Stiff		1	SS	8		96
			2	SS	5		
			3	SS	5		
94.9			4	SS	7		
2.1			5	SS	3		94
			6	SS	2	▼	
	Varved Clay alternating layers of CL (thickness 2 cm) and CH to CI (thickness 1 cm) and/some silt trace sand Soft to Firm		7	SS	2		
			8	SS	3		92
			9	SS	2		
			10	SS	2		90
			11	SS	3		88
	Stiff		12	SS	2		86
84.5							
12.3			13	SS	3		
83.9	Silt *						84
13.1	End of Borehole						
	Probable Silt (slightly plastic ML)						82
81.5							
15.5	End of Cone Test						
	* (slightly plastic ML) some clay trace sand Soft to Firm						

DYNAMIC CONE PENETRATION RESISTANCE PLOT — 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
10 20 30 40 50

PLASTIC LIMIT W_P | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W_L
WATER CONTENT (%)

UNIT WEIGHT γ

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

+3 +5 +6 +5 +6 +4 +3 +5 2

+3, ×5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 5 METRIC

WO 14-70003R LOCATION STA. 0 + 52, 34 m RT of Control Line ORIGINATED BY CM
DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM
DATUM Relative DATE 83 07 20 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa: ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE	WATER CONTENT (%)		GR SA SI CL
96.6	Ground Surface							10 20 30 40 50	20 40 60		
0.0	Silty Clay (CL) to Clay (CH) some sand, trace organics		1	SS	5		96				
95.1	Soft to Firm		2	SS	2			+3			
1.5			3	SS	2			+3			
			4	SS	2		94				
	Varved Clay alternating layers of CL (thickness 2 cm) and CH to CI (thickness 1 cm) and/some silt trace sand		5	SS	2			+12			0 0 63 37
			6	SS	1		92	+7			
								+6			
			7	SS	2		90	+5			
			8	SS	3			+4			
			9	SS	2		88	+5			
			10	SS	2		86				
84.7											
11.9	Silt (slightly plastic ML) some clay, trace sand Soft to Firm		11	SS	4		84	+2			
83.5											
13.1	End of Borehole										
	Probable Silt (slightly plastic ML)						82				
81.1											
15.5	End of Cone Test										

$+^{3}$, $\times^{5}$: Numbers refer to Sensitivity

15 ◇ 5 (%) STRAIN AT FAILURE (20 / 10)

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 6

METRIC

W O 14-70003R LOCATION Sta. 0 + 38, 6 m RT of Control Line ORIGINATED BY CM

DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM

DATUM Relative DATE 83 07 20 - 21 CHECKED BY

SOIL PROFILE ELEV/DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS
100.8	Ground Surface					
	Silty Sand trace gravel and clay occ. silty clay (CL) pockets Loose (Fill Material)		1	SS	8	
			2	SS	5	
			3	SS	9	
98.7			4	SS	7	
2.1	Silty Clay (CL) to Clay (CH) some sand, trace organics Firm		5	SS	7	
			6	SS	7	
96.9			7	SS	6	
3.9			8	SS	3	
	Varved Clay alternating layers of CL (thickness 2cm) and CH to CI (thickness 1 cm) and/some silt trace sand		9	SS	2	
			10	SS	4	
			11	SS	4	▼
			12	SS	5	
	Soft to Firm Stiff		13	SS	3	
			14	SS	5	
87.7						
13.1	End of Borehole					
	Probable Varved Clay					
85.2						
15.6	End of Cone Test					

ELEVATION SCALE

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
10 20 30 40 50

PLASTIC LIMIT W_P | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W_L
WATER CONTENT (%)
20 40 60

UNIT WEIGHT γ

REMARKS & GRAIN SIZE DISTRIBUTION (%)

	GR	SA	SI	CL
	0	15	50	35
	0	0	65	35

$+^3$, $\times^5$: Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 7 METRIC

WO 14-70003R LOCATION Sta. 0 + 43, 6 m RT of Control Line ORIGINATED BY CM
DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM
DATUM Relative DATE 83 07 21 CHECKED BY

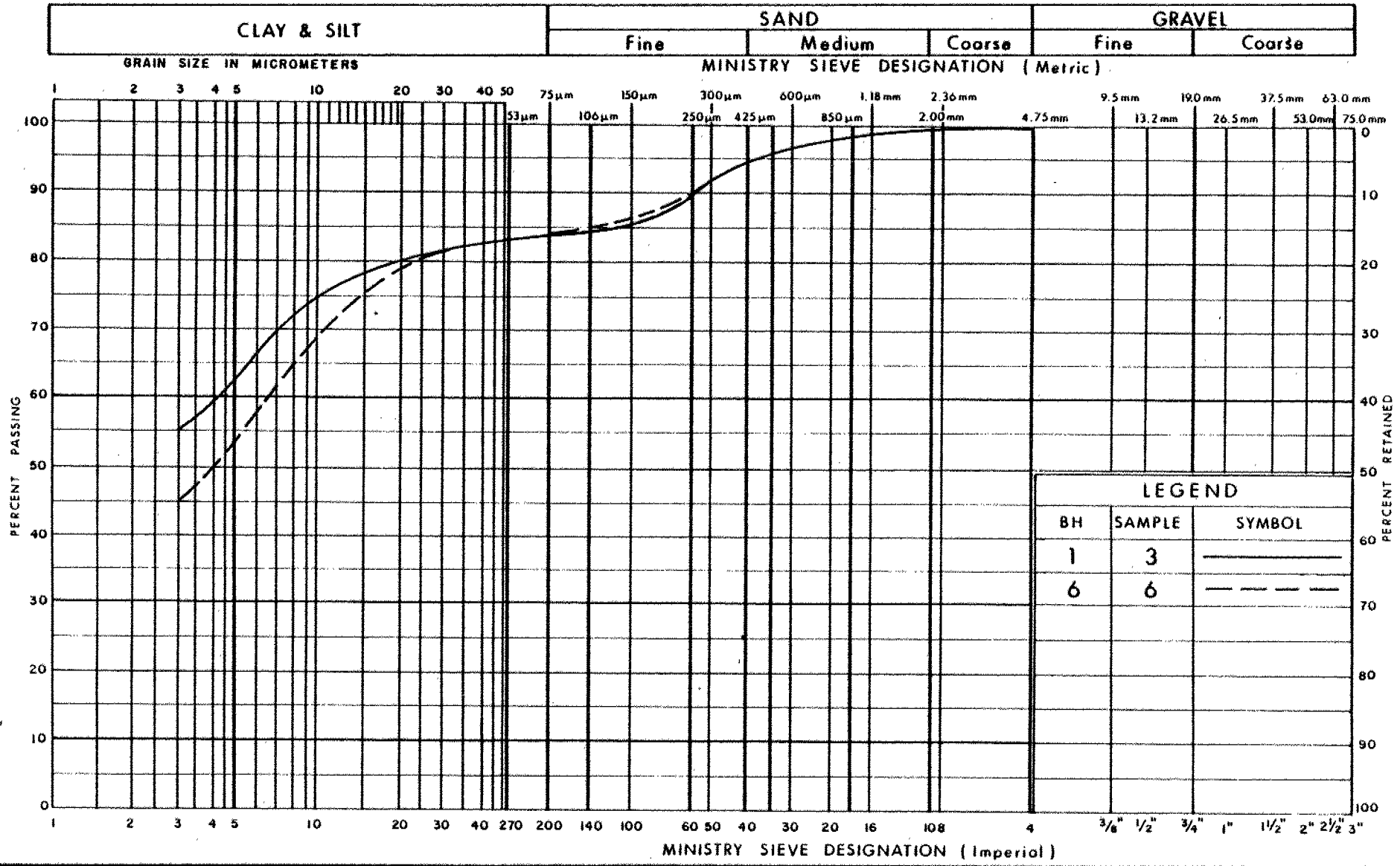
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE, 10 20 30 40 50)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.6	Ground Surface										
0.0	Silty sand, trace gravel and clay occ. silty clay (CL) pockets Very loose to loose (Fill Material)		1	SS	5	Dry	100				
			2	SS	3						
98.8			3	SS	3						
1.8	Silty Clay (CL) to Clay (CH) some sand, trace organics Soft to Firm		4	SS	6						
97.9			5	SS	4		98				
2.7			6	SS	3						
	Varved Clay alternating layers of CL (thickness 2 cm) and CH to CI (thickness 1 cm) and/some silt trace sand Soft to Firm		7	SS	2			+8			
			8	SS	2		96	+3			
			9	SS	2			+7			
			10	SS	2		94	+4			
93.3								+4			
7.3	End of Borehole										
	Probable Varved Clay						92				
91.2											
9.4	End of Cone Test										

$+^3$, $\times^5$: Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

UNIFIED SOIL CLASSIFICATION SYSTEM



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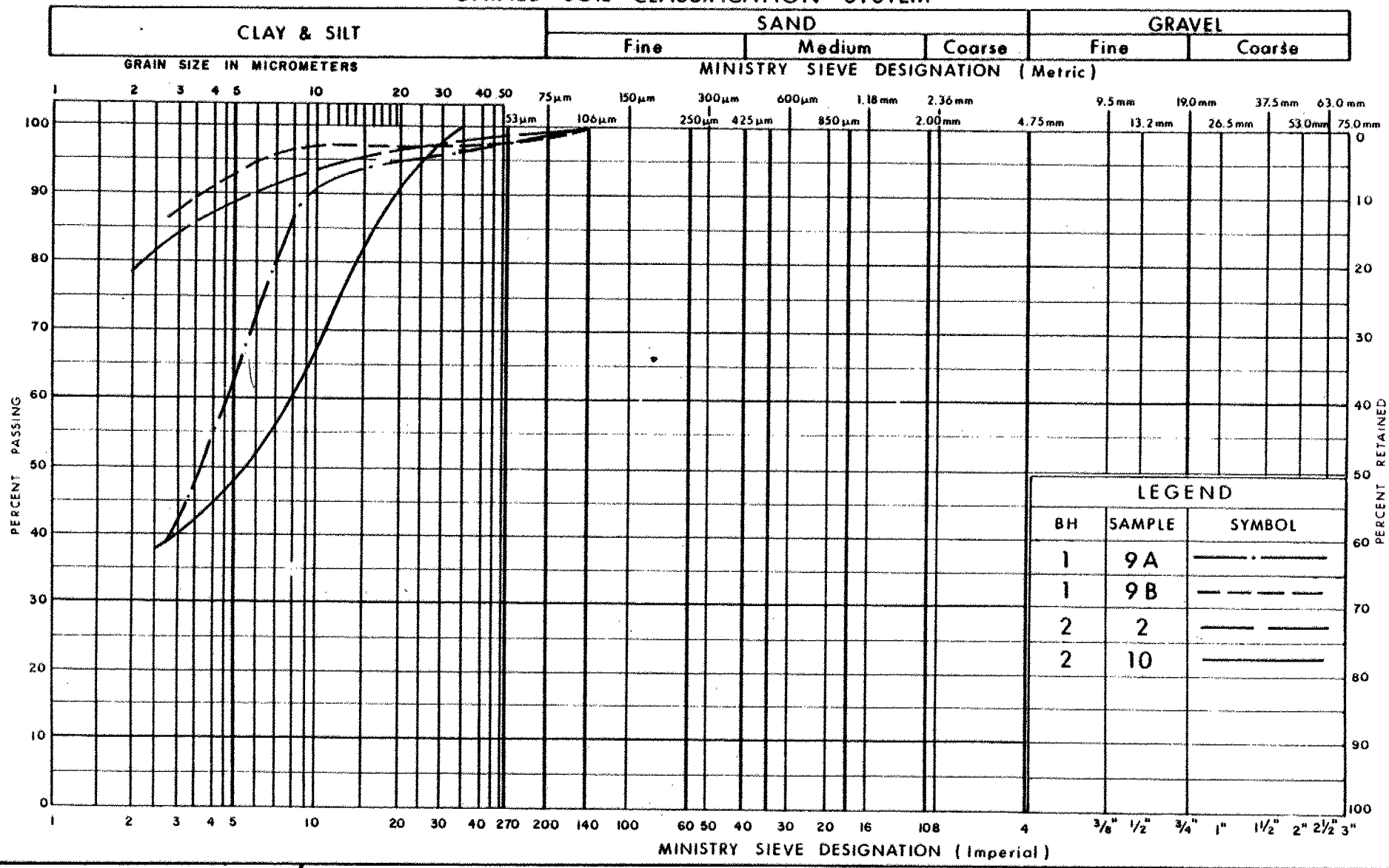
GRAIN SIZE DISTRIBUTION
SILTY CLAY TO CLAY
SOME SAND , TRACE ORGANICS

FIG No 1
WO 14 - 70003 - R

UNIFIED SOIL CLASSIFICATION SYSTEM



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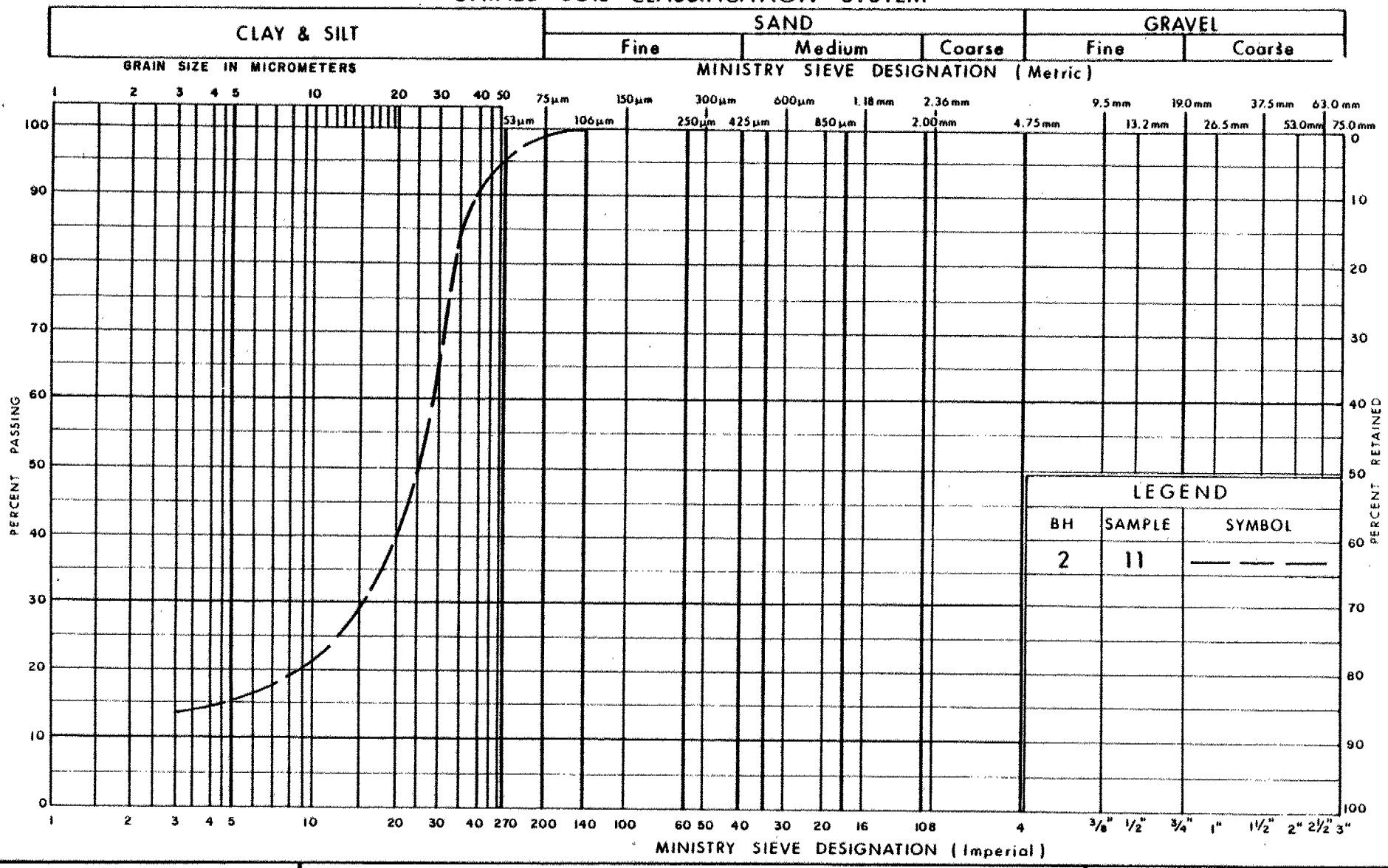
GRAIN SIZE DISTRIBUTION
VARVED CLAY

FIG No 2
WO 14-70003-R

UNIFIED SOIL CLASSIFICATION SYSTEM



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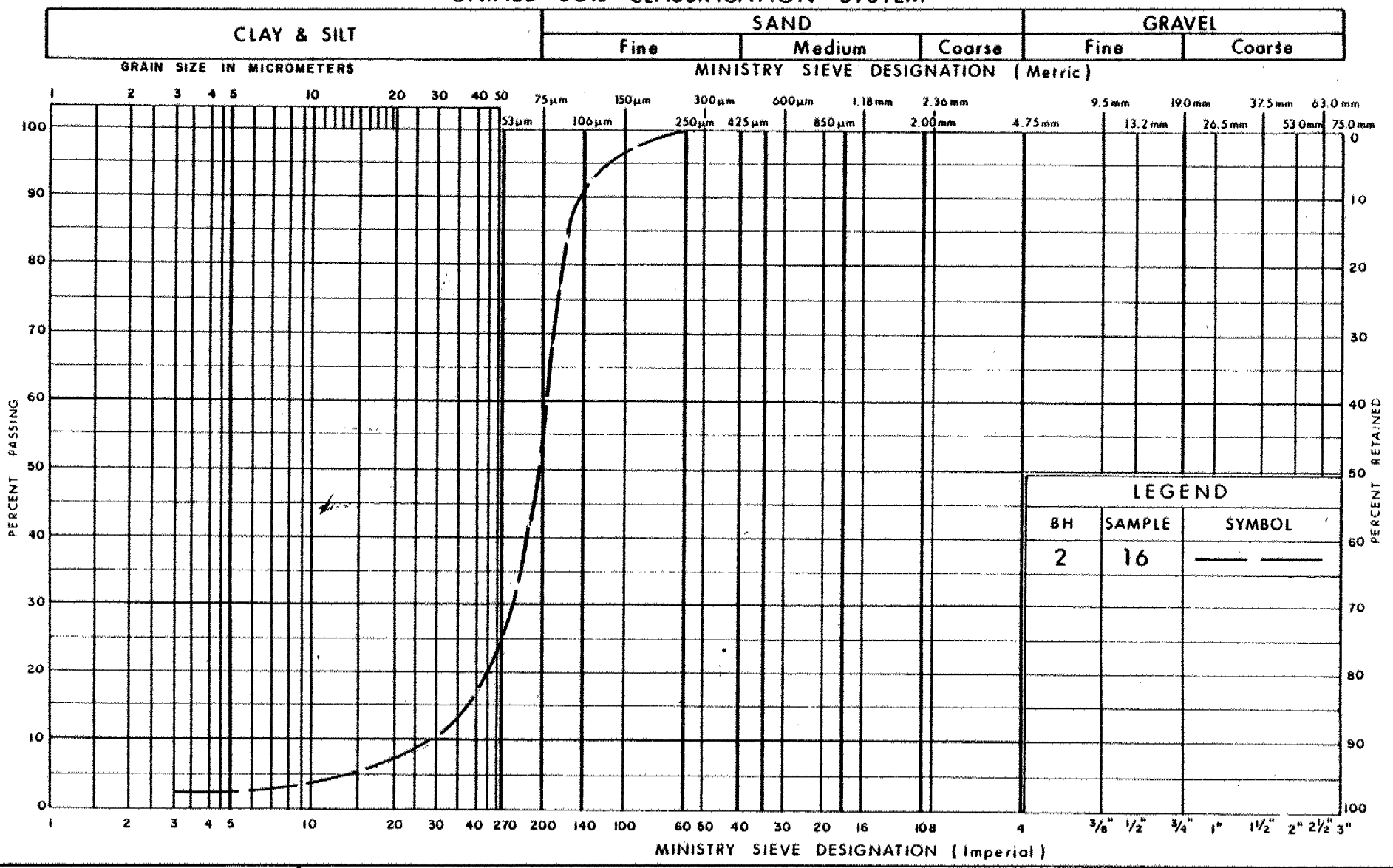
GRAIN SIZE DISTRIBUTION

SILT SOME CLAY, TRACE CLAY

FIG No 3

WO 14-70003-R

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION
SILTY SAND TO SANDY SILT
TRACE CLAY

FIG No 4
WO 14-70003-R

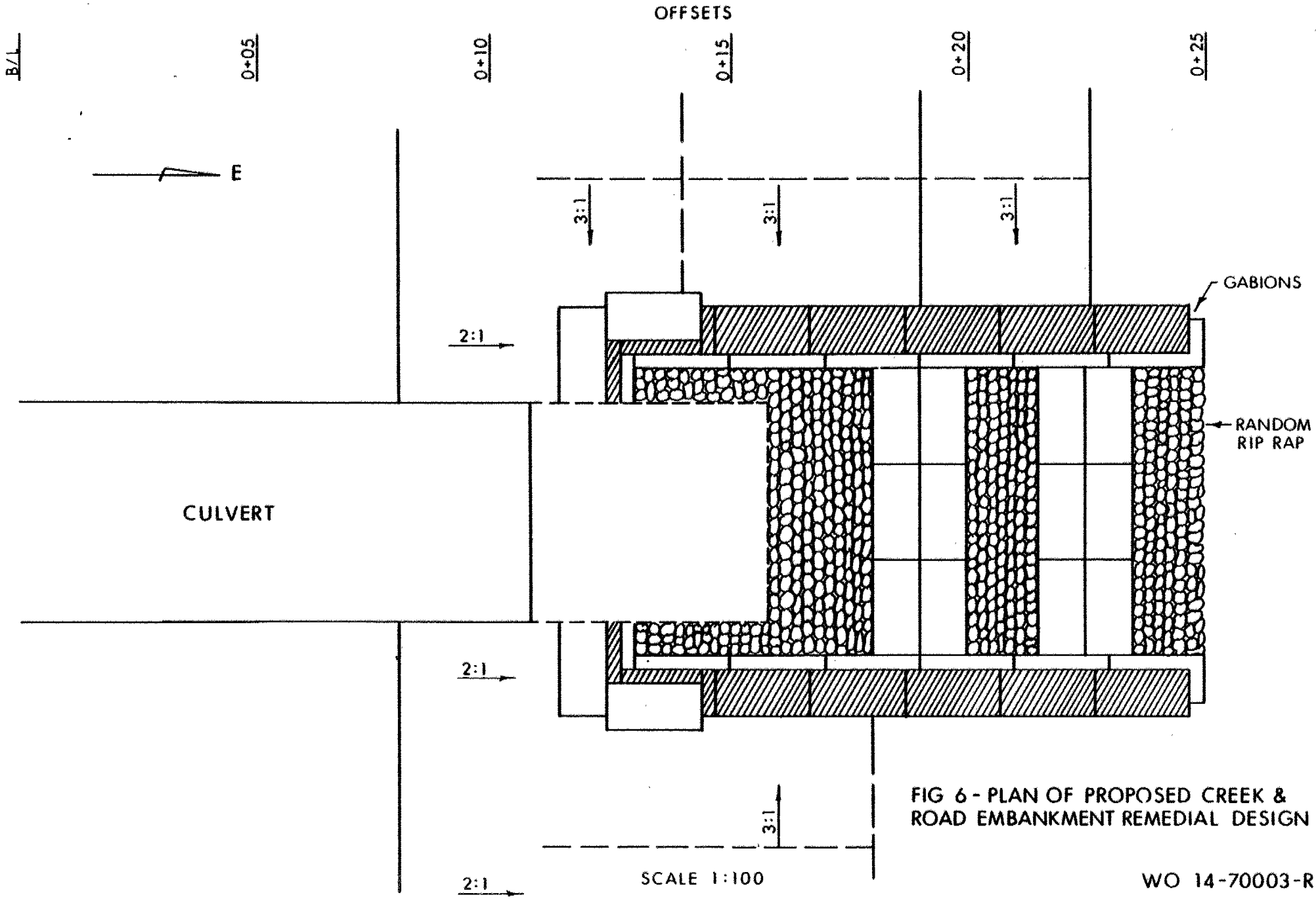
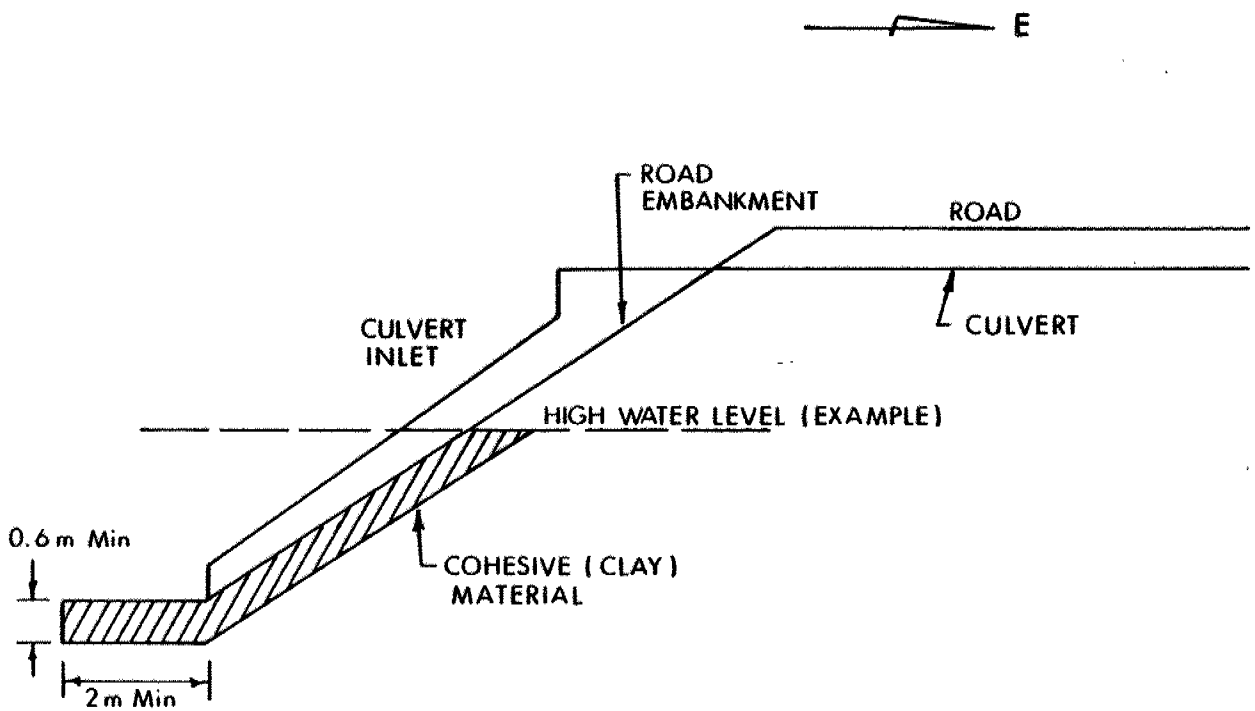


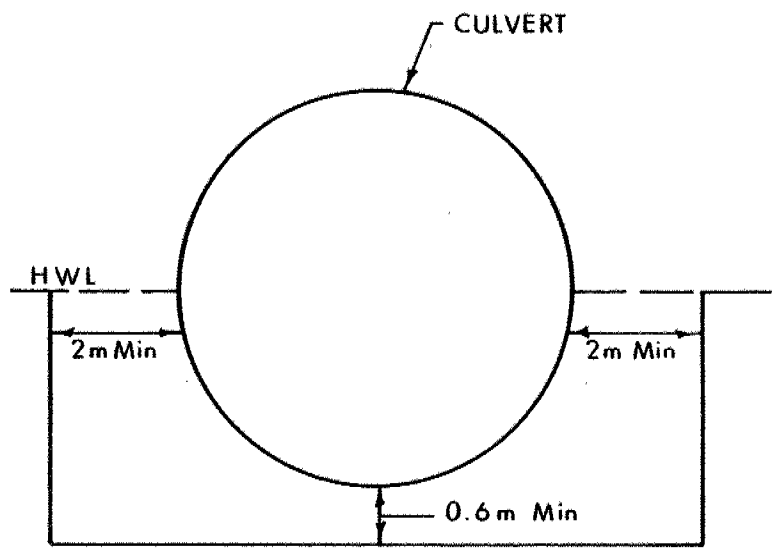
FIG 6 - PLAN OF PROPOSED CREEK & ROAD EMBANKMENT REMEDIAL DESIGN

WO 14-70003-R



NTS

a) Longitudinal Section



NTS

b) Front View

FIG 7 - CULVERT INLET SEAL

WO 14-70003-R

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS $\bar{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	>200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

R Q D (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	>3m
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

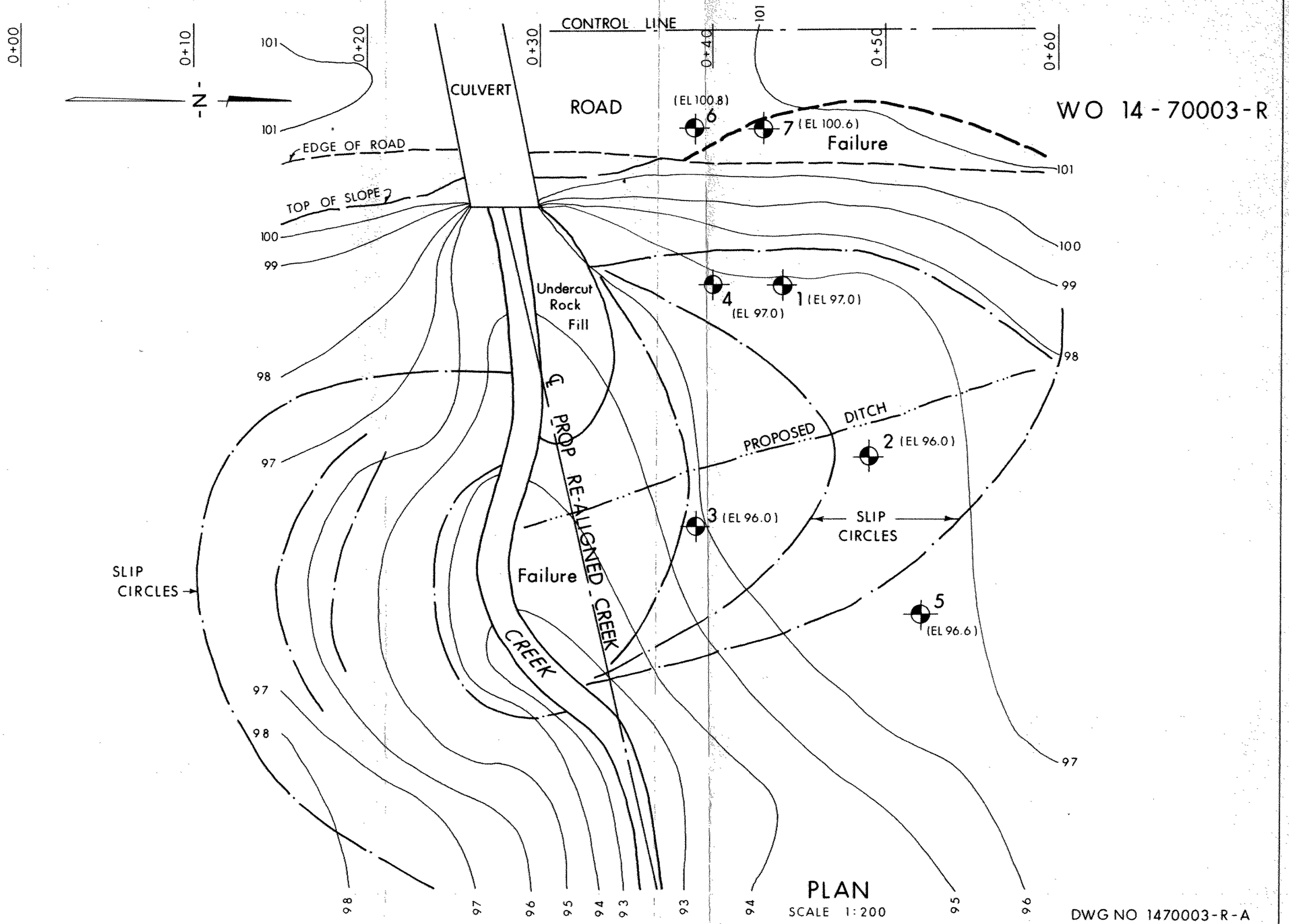
m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL

e	1, %	VOID RATIO
n	1, %	POROSITY
w	1, %	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_p	%	PLASTIC LIMIT
w_s	%	SHRINKAGE LIMIT
I_p	%	PLASTICITY INDEX = $w_L - w_p$
I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$
I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$
e_{max}	1, %	VOID RATIO IN LOOSEST STATE
e_{min}	1, %	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_U	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

WO 14-70003-R



PLAN

SCALE 1:200

DWG NO 1470003-R-A

ENGINEERING MATERIALS OFFICE
PAVEMENT & FOUNDATION DESIGN SECTION

WO 14-70003-R DIST 14

HWY Mun. STR SITE N/A

Beauchamp Twp. Lot 2, Conc. IV Slip Failure

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GEOCRES 31M-48

DATE OCT 18 1983

FOUNDATION INVESTIGATION REPORT

For

W.O. 14-70003-R; Site N/A

Sideroad Slip Failure

Beauchamp Twp., Lot 2, Conc. IV

District 14, New Liskeard

INTRODUCTION:

This report summarizes the results of the foundation investigation for the above-noted road failure.

The fieldwork was conducted during the period from 83 07 14-28, utilizing a continuous flight auger machine equipped with 82 mm I.D. hollow-stem augers. This work consisted of 7 sampled boreholes/dynamic cone penetration tests.

SITE DESCRIPTION

The site is located approximately 1.4 km north of the Conc. III/IV road on the Lot 2/3 sideroad in Beauchamp Twp. (approximately 6.5 km west of Hwy. 11).

Physiographically the site is located in the Colbolt Plain, a glaciolacustrine plain of generally low local relief.

At this site, the sideroad crosses a tributory of Eventurel Creek. The creek flows to the east through an 18±m long, 4.3±m diameter CSP culvert. The road surface is 5.4±m above the culvert invert level.

At the time of the field investigation, the slip failure extended along the east side of the road affecting up to 4.5±m (width) of the northbound lane. Refer to Drawing No. 1470003-R-A for specific failure location details.

Based on site inspections and discussions with Mr. O. Allen (Township Maintenance, Dist. 14) it is our understanding that:

- the existing culvert was installed in approximately 1969.
- the culvert was seated at the creek invert level that existed at that time

- since installation of the culvert, the invert elevation of the downstream creek channel has been cut 3±m lower, within a distance of 20±m from the culvert
- there are numerous progressive slip failures along the downstream creek channel
- small cracks were evident along the road surface, near the eventual failure zone, as early as 1982.
- on 83 05 27, the initial slip failure occurred
- an attempt to backfill the road surface portion of the slip failure was made on 83 05 27
- on 83 05 28, the slip dropped 3±m, and was eventually backfilled
- at the time of the field investigation the slip was 0.5±m below the road surface
- the water depth in the creek may reach 2±m in the spring. At the time of the field investigation the creek water was estimated at 0.15 m
- on 83 06 09 and 83 07 14 (before the field investigation) shallow surface ponding was evident in the area directly below the failure zone, even after a long period of dry weather conditions
- the culvert inlet was undercut at least 0.15 m at the time of the field investigation. Otherwise, the culvert appeared to be in good condition

SUBSURFACE CONDITIONS

General

The Record of Borehole Sheets, (Appendix) illustrate the conditions at the borehole locations. The locations and elevations of the boreholes are shown on Drawing No. 1470003-R-A.

The survey stations and elevations refer to temporary benchmarks established by our field personnel. (Sta. 00+000, Elev. 100.00 m).

Generally, the sequence of overburden materials, from the surface downwards is as follows:

- 2 m of silty clay
- 11 m of varved clay
- 7 m of silt
- then silty sand

The road embankment is composed of approximately 2 m of fill.

Road Embankment Fill Material

At BH#6 and #7, up to 2.1 m of silty sand, containing traces of gravel and clay and occasional pockets ofsilty clay (CL) was encountered.

The denseness of this material ranges from very loose to loose.

Silty Clay (CL) to Clay (CH); some sand, trace organics

This deposit is the surface material in the valley, where it extends to elev. 95±m. It also lies directly beneath the road embankment fill where it extends to elev. 97 to 98 m. The thickness of this very soft to stiff material ranges from 0.9 to 2.1 m.

Physical properties of the material, as determined from field and laboratory tests, are summarized as follows:

	Range	Average	Median
Natural Moisture Content (w)	22.5 - 29.5%	25.3%	24.0%
Liquid Limit (w_L)	38.0 - 52.5%	45.3%	45.5%
Plastic Limit (w_p)	17.5 - 24.0%	21.3%	22.5%

Figure 1 illustrates a typical grain size distribution for this material.

Varved Clay

This material underlies the silty clay to clay and extends for approximately 11 m to elevation 84±m.

The deposit consists of regular alternating layers of clay of low plasticity (2 cm thickness) and clay of intermediate to high plasticity (1 cm thickness), generally containing over 50% silt and traces of sand. The consistency of the deposit ranges from soft to firm, generally increasing with depth.

Physical properties of the material, as determined from field and laboratory tests, are summarized as follows:

	Range	Average	Median
Natural Moisture Content (w)	34.0 - 59.5%	43.1%	41.8%
Liquid Limit (w_L)	24.0 - 55.5%	33.6%	29.5%
Plastic Limit (w_p)	16.0 - 20.5%	17.8%	17.0%
Shear Strength			
- field vane (undisturbed)	17 - 62 kPa	N/A	N/A
- field vane (remoulded)	2 - 18 kPa	N/A	N/A
- unconfined compression	15 - 19 kPa	N/A	N/A
Unit Weight (γ)	17.1 - 17.4 kN/m^3	17.2 kN/m^3	17.2 kN/mx3

The sensitivity of this material ranges from 2 to 12.

Laboratory tests to determine the effective stress parameters provided the following results:

- normally consolidated condition; $c' = 0$ kPa
  $\phi' = 33-34°$

- overconsolidated condition; $c' = 5-8$ kPa
  $\phi' = 31-33°$

The effective stress parameters were modified to $c' = 5$ kPa, $\phi' = 27°$ for the purposes of the stability analyses.

Figure 2 illustrates a typical grain size distribution for this material.

Physical properties, as determined for each varve, are summarized below.

	CL Varve	CI/CH Varve
Natural Moisture Content (w)	27.5%	62.5%
Liquid Limit (w_L)	25.5 - 27.0%	62.5 - 70.5%
Plastic Limit (w_p)	20.0 - 21.5%	23.0 - 26.0%

Silt (ML); some clay, trace sand

This deposit underlies the varved clay, and extends for an estimated 7 m to elev. 76.8±m. The material is generally slightly plastic. Its consistency ranges from very soft to firm.

Physical properties of the material, as determined from field and laboratory tests, are summarized below:

Natural Moisture Content (w)	38.5%
Shear Strength	
- field vane (undisturbed)	36 kPa
- field vane (remoulded)	14 kPa

Figure 3 illustrates a typical grain size distribution for this material.

Silty Sand to Sandy Silt; trace clay

This material underlies the silt. The denseness of this deposit was determined as very loose - probably due to the artesian groundwater conditions encountered.

Figure 4 illustrates a typical grain size distribution for this material.

Groundwater

Measured groundwater elevations were quite variable but the groundwater level was estimated at 93 m (0.5 to 1.0 metres above the creek level).

Artesian conditions were observed in one hole below elev. 74.5 m. The static head level was 0.3 m above ground level.

DISCUSSION AND RECOMMENDATIONS

The road embankment slip failure was a result of progressive failures of the slopes adjacent to the creek and downstream from the culvert.

The creek slope failures were caused by lowering of the creek channel invert and undercutting of the creek banks.

In order to stabilize the road embankment, it is necessary to first stabilize the creek slopes.

The proposed design illustrated in Figures 5, 6 and 7 is intended as a guide. The hydrologic aspects have been discussed with Mr. J. Carter, Sr. Hydrology Engineer, Drainage and Hydrology Section.

Please submit your final design drawings and a complete description of the proposed cohesive fill (for reclaiming the creek bed) to this office for our review.

If there are any questions, please do not hesitate to contact this office.

Creek Embankment Design Details

- Refer to Figures 5 and 6.
- Complete creek bed construction under dry conditions.
- The creek should be straightened, graded and channelled for approximately 50 m downstream from the culvert outlet (refer to Drawing 1470003-R-A).
- Construct the creek bed to the geometry illustrated in Figures 5 and 6 using suitable cohesive fill (till), suitably compacted. Note that we have only estimated the width of the creek channel bottom.
- Protect the cohesive material with a minimum 0.15m thick Granular A blanket and a minimum 0.3 m thick blanket of random rip-rap, as illustrated in Figures 5 and 6. Angular rip-rap would be preferable, especially in those areas near the culvert outlet. Random rip-rap (min. thickness 0.3 m) is also required on the creek slopes as illustrated in the figures.

- Use gabion baskets to line critical portions of the channel slopes and to act as energy dissipaters as illustrated in Figures 5 and 6. The backfill to the gabions near the culvert should be cohesive material.
- Use a Granular 'A' layer (0.15 m min. thickness) to prevent any loss of creek bed material through the energy dissipater at the downstream end of the channel treatment, as illustrated in Figure 5.
- The channel treatment may require periodic maintenance.
- At the culvert inlet and outlet, ensure that the backfill material is properly placed and compacted.
- At the culvert inlet, construct a seal of cohesive material (min. thickness 0.6 m) to prevent any future undermining or seepage. The seal should extend for a minimum of 2 m on each side of the culvert inlet, and from the high water level down the embankment and at least 2 m along the stream channel. (Refer to Figure 7). Benches should be placed in the existing slopes to facilitate placement of the cohesive fill.

Road Embankment Design Details

- Construct the road embankment to the geometry illustrated in Figures 5 and 6.
- On the north side of the culvert construct a 5 m wide berm at elev. 97.8 m along the east side of the road from the culvert to Sta. 0+60±. The berm surface should slope down 0.3 m across its 5 m width to facilitate drainage. The berm should be constructed of suitable embankment material.
- The slopes adjacent to the creek should be graded into the channel treatment at 3:1.
- Other slopes should be graded into the existing contours at 2:1.
- Place a pad (0.3 m min. thickness) of Granular 'A' beneath the plan area of the proposed berm.
- Construct a 0.6 m deep trench as illustrated on Drawing No. 1470003-R-A, and backfill with Granular 'A'. It is suggested that this trench be excavated and immediately backfilled in sections no longer than 5 m. This drain should extend into the creek.
- The berm and transition areas should be protected by vegetation cover as soon as possible after construction.

Construction Sequence

The construction sequence is very important in order to maintain the stability of the road.

Following is our recommended sequence:

(1) Construct drain/trench to creek.

(2) Divert stream water in order to construct channel treatment in the ~~day~~. dry.

(3) Repair culvert backfill where necessary and construct culvert inlet seal.

(4) Construct stream channel treatment.

(5) Return stream flow to completed channel.

(6) Place Granular 'A' pad below proposed berm.

(7) Construct berm.

(8) Construct remaining portions to achieve recommended road embankment geometry.

(9) Provide required vegetation cover.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of Mr. C.S. McLorg, Student Specialist. The report was written by Mr. McLorg and Mr. D.H. Dundas, Project Foundations Engineer and reviewed by Mr. K.G. Selby, Senior Foundations Engineer. The equipment used was owned and operated by Atcost Soil Drilling Limited.

C.S. McLorg,
Student Specialist Engineering

D.H. Dundas, P. Eng.,
Project Foundations Engineer

K.G. Selby, P. Eng.,
Senior Foundations Engineer

APPENDIX

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 1 METRIC

WO 14-70003R LOCATION Sta. 0 + 44, 15 m RT of Control Line ORIGINATED BY CM
DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM
DATUM Relative DATE 83 07 14-15 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT Wl	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 10 20 30 40 50	WATER CONTENT (%) 20 40 60	kN/m³	GR SA SI CL
97.0	Ground Surface										
0.0	and sand		1	SS	3						
	Silty Clay (CL) to Clay (CH) some sand, trace organics Soft to Firm		2	SS	4						
			3	SS	5						0 16 34 50
94.9			4	SS	6						
2.1			5	SS	2						
	Varved Clay alternating layers of CL (thickness 2 cm) and CH to CI (thickness 1 cm) and/some silt trace sand Soft to Firm		6	TW	PH	▼				17.1	Varved CL/CH 0 0 56 44 Effective Stress Parameters C' (kPa) ø' (o) O.C. 5 34 N.C. 0 33
			7	SS	2						
			8	SS	2						
			9	TW	PH					17.4	Varved CL/CH 0 0 76 24 0 1 15 84
			10	SS	2						
			11	SS	2						
	Stiff		12	TW	PH						
84.2											
12.8	End of Borehole										
	Probable Silt (slighlty plastic ML)										
78.4											
18.6	End of Cone Test										

$+^3$, $\times^5$: Numbers refer to Sensitivity

20 / 15 ◇ 5 / 10 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 2 METRIC

WO 14-70003R LOCATION Sta. 0 + 48, 25 m RT of Control Line ORIGINATED BY CM
DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM
DATUM Relative DATE 83 07 18 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (o UNCONFINED, • QUICK TRIAXIAL, + FIELD VANE, x LAB VANE) (10 20 30 40 50)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT Wl / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
96.0	Ground Surface										
0.9 / 95.1	Silty Clay (CL) to Clay (CH) some sand, trace organics Very soft to soft		1	SS	2	* Artesian Head to Elev 96.3	96	+3			0 1 22 77
0.9	Very Soft		2	SS	1		94	+2			
			3	SS	2			+4			
	Varved Clay alternating layers of CL (thickness 2 cm) and CH to CI (thickness 1 cm) and/some silt trace sand Soft to Firm		4	SS	3		92	+4		17.2	0 0 63 37 Effective Stress Parameters C' Ø' (kPa)(o) O.C. 8 33 N.C. 0 31
			5	TW	PH			+5 +3			
			6	SS	2		90	+4			
			7	SS	2			+4			
			8	TW	PH		88	+5 +4 +5 +3			
			9	SS	2		86	+5			
	Stiff		10	SS	4						0 0 67 33
84.1											
11.9	Silt (slightly plastic ML) some clay trace sand Very Soft to Firm		11	SS	1		84	+2 +2			0 0 89 11
			12	SS	3		82				
			13	SS	5						
			14	SS	7		80				
			15	SS	6		78				
76.8											
19.2	Silty Sand to Sandy Silt trace clay very loose		16	SS	1	Artesian Condition Encountered	76				0 43 55 2
74.7											
21.3	End of Borehole Probable Silty Sand						74				
							72				
							70				
							68				
65.2							66				
30.8	End of Cone Test										

+3, x5 : Numbers refer to Sensitivity

20 / 15 5 (%) STRAIN AT FAILURE / 10

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 3 METRIC

WO 14-70003R LOCATION Sta. 0 + 39.29 m RT of Control Line ORIGINATED BY CM
DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM
DATUM Relative DATE 83 07 19 CHECKED BY

SOIL PROFILE ELEV/DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa 10 20 30 40 50 (O UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL — WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
96.0	Ground Surface										
0.0 / 94.8	Silty Clay (CL) to Clay (CH) some sand, trace organics Very Soft		1	SS	1						
1.2	Varved Clay alternating layers of CL (thickness 2 cm) and CH to CI (thickness 1 cm) and/some silt trace sand Very Soft to Firm		2	SS	2		94	+4			
			3	SS	2			+3			
			4	SS	2			+5			
			5	SS	2		92	+5			
			6	SS	2			+5			
			7	SS	1		90	+3			
			8	SS	2			+4			
			9	SS	2		88	+4			
			10	SS	2		86	+4			
84.4								+2			
11.6 / 82.9	Silt (slightly plastic ML) some clay, trace sand Soft to Firm		11	SS	4		84	+2			
13.1 / 80.4	End of Borehole Probable Silt (slightly plastic ML)						82				
15.6	End of Cone Test										

+3, ×5 : Numbers refer to Sensitivity

15 ◇ 20/10 5 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 4 METRIC

WO 14-70003R LOCATION Sta. 0 + 40, 15 m RT of Control Line ORIGINATED BY CM
DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM
DATUM Relative DATE 83 07 19 - 20 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 10 20 30 40 50	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT Wl — WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
97.0	Ground Surface										
0.0	Silty Clay (CL) to Clay (CH) some sand, trace organics Firm to Stiff		1	SS	8		96				
			2	SS	5						
			3	SS	5						
94.9			4	SS	7						
2.1			5	SS	3						
			6	SS	2		94	+3			
	Varved Clay alternating layers of CL (thickness 2 cm) and CH to CI (thickness 1 cm) and/some silt trace sand Soft to Firm		7	SS	2			+5			
			8	SS	3		92	+6			
								+5			
			9	SS	2						
							90	+6			
			10	SS	2						
								+4			
			11	SS	3		88	+3			
	Stiff		12	SS	2		86	+5			
84.5											
12.5	Silt *		13	SS	3		84	2			
83.9											
13.1	End of Borehole Probable Silt (slightly plastic ML)						82				
81.5											
15.5	End of Cone Test										
	* (slightly plastic ML) some clay trace sand Soft to Firm										

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 5

METRIC

WO 14-70003R LOCATION STA. 0 + 52, 34 m RT of Control Line ORIGINATED BY CM

DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM

DATUM Relative DATE 83 07 20 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS
96.6	Ground Surface					
0.0	Silty Clay (CL) to Clay (CH) some sand, trace organics		1	SS	5	
			2	SS	2	
95.1	Soft to Firm					
1.5	Varved Clay alternating layers of CL (thickness 2 cm) and CH to CI (thickness 1 cm) and/some silt trace sand		3	SS	2	
			4	SS	2	
			5	SS	2	
			6	SS	1	
			7	SS	2	
			8	SS	3	
			9	SS	2	
			10	SS	2	
84.7						
11.9	Silt (slightly plastic ML) some clay, trace sand Soft to Firm		11	SS	4	
83.5						
13.1	End of Borehole Probable Silt (slightly plastic ML)					
81.1						
15.5	End of Cone Test					

ELEVATION SCALE

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
10 20 30 40 50

PLASTIC LIMIT W_p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W_L
WATER CONTENT (%)
20 40 60

UNIT WEIGHT γ

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL
0 0 63 37

+3, x5 : Numbers refer to Sensitivity

20
15 ⊹ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
Ontario

RECORD OF BOREHOLE No 6

METRIC

W O 14-70003R LOCATION Sta. 0 + 38, 6 m RT of Control Line ORIGINATED BY CM
DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM
DATUM Relative DATE 83 07 20 - 21 CHECKED BY

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.8	Ground Surface						
	Silty Sand trace gravel and clay occ. silty clay (CL) pockets Loose (Fill Material)		1	SS	8		
			2	SS	5		
			3	SS	9		
98.7			4	SS	7		
2.1	Silty Clay (CL) to Clay (CH) some sand, trace organics Firm		5	SS	7		
			6	SS	7		0 15 50 35
96.9			7	SS	6		
3.9			8	SS	3		
	Varved Clay alternating layers of CL (thickness 2cm) and CH to CI (thickness 1 cm) and/some silt trace sand		9	SS	2		
			10	SS	4		0 0 65 35
			11	SS	4		
			12	SS	5		
	Soft to Firm Stiff		13	SS	3		
			14	SS	5		
87.7							
13.1	End of Borehole						
	Probable Varved Clay						
85.2							
15.6	End of Cone Test						

ELEVATION SCALE: 100, 98, 96, 94, 92, 90, 88, 86

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE; 10 20 30 40 50

PLASTIC LIMIT Wp — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ

+2, +4, +6, +5, +7, +5, +6, +6

$+^3$, $\times^5$: Numbers refer to Sensitivity

20 / 15 ◇ 5 (%) STRAIN AT FAILURE / 10

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation and Communications
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RECORD OF BOREHOLE No 7 METRIC

WO 14-70003R LOCATION Sta. 0 + 43, 6 m RT of Control Line ORIGINATED BY CM
DIST 14 HWY Municipal BOREHOLE TYPE Hollow Stem Auger, Cone Test COMPILED BY CM
DATUM Relative DATE 83 07 21 CHECKED BY

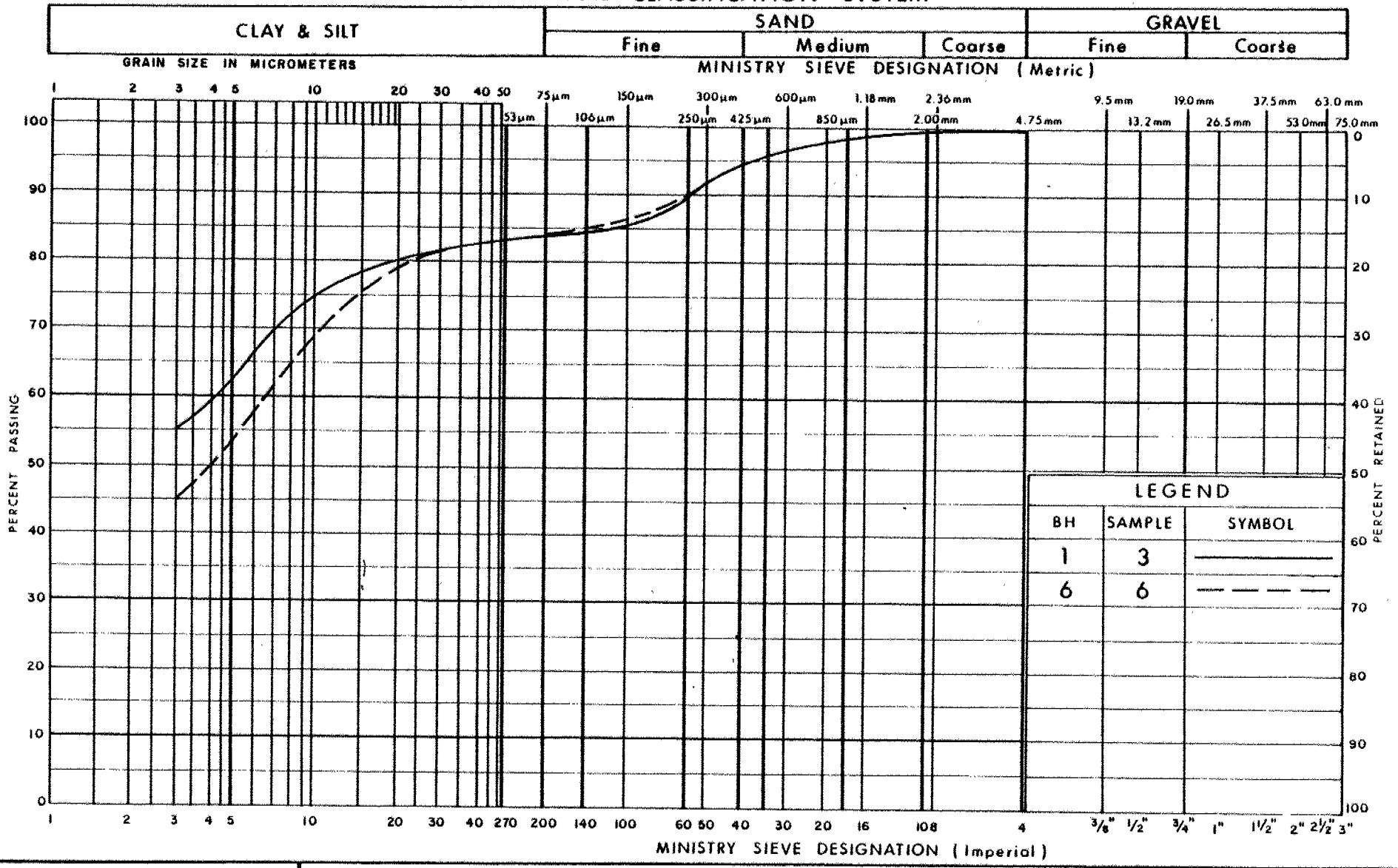
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 10 20 30 40 50	PLASTIC LIMIT Wp / NATURAL MOISTURE CONTENT W / LIQUID LIMIT WL / WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
100.6	Ground Surface										
0.0	Silty sand, trace gravel and clay occ. silty clay (CL) pockets Very loose to loose (Fill Material)		1	SS	5	Dry	100				
			2	SS	3						
98.8			3	SS	3						
1.8	Silty Clay (CL) to Clay (CH) some sand, trace organics Soft to Firm		4	SS	6						
97.9			5	SS	4						
2.7			6	SS	3		98				
	Varved Clay alternating layers of CL (thickness 2 cm) and CH to CI (thickness 1 cm) and/some silt trace sand Soft to Firm		7	SS	2			+8			
							96	+3			
			8	SS	2			+7			
			9	SS	2			+4			
			10	SS	2		94	+4			
93.3											
7.3	End of Borehole										
	Probable Varved Clay						92				
91.2											
9.4	End of Cone Test										

$+^3$, $\times^5$: Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

UNIFIED SOIL CLASSIFICATION SYSTEM



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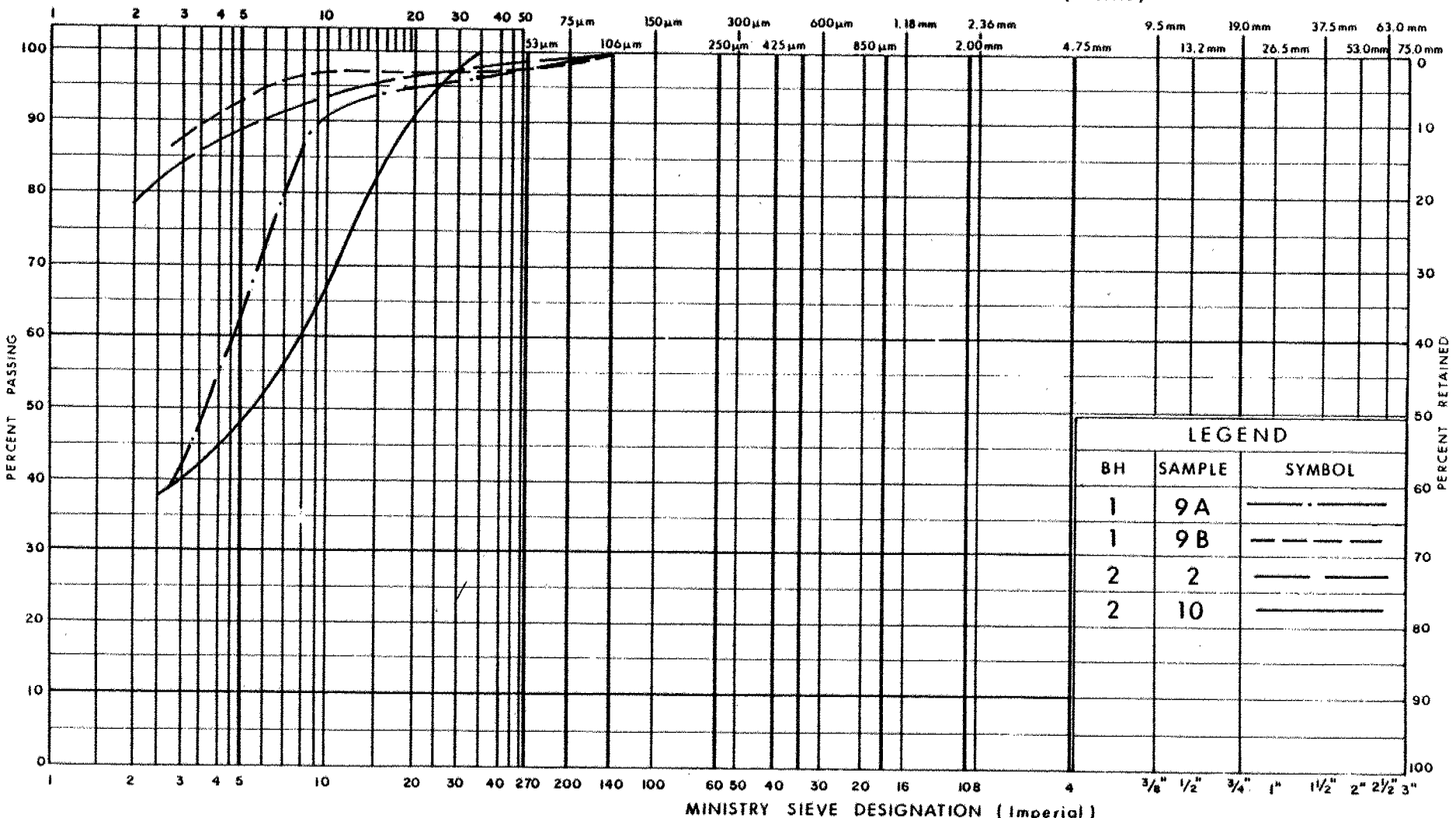
GRAIN SIZE DISTRIBUTION
SILTY CLAY TO CLAY
SOME SAND , TRACE ORGANICS

FIG No 1
WO 14 - 70003 - R

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



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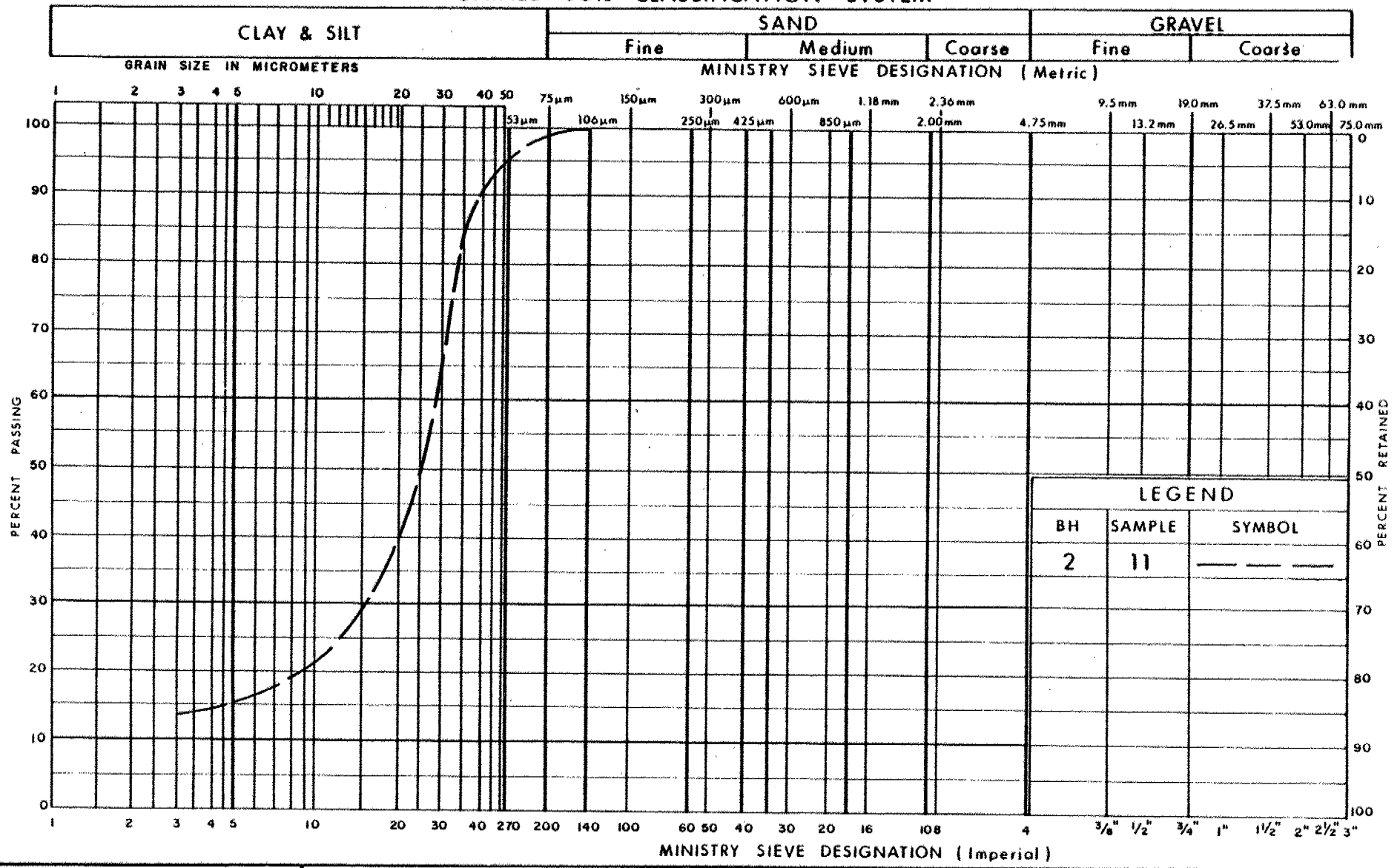
GRAIN SIZE DISTRIBUTION
VARVED CLAY

FIG No 2
WO 14-70003-R

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION

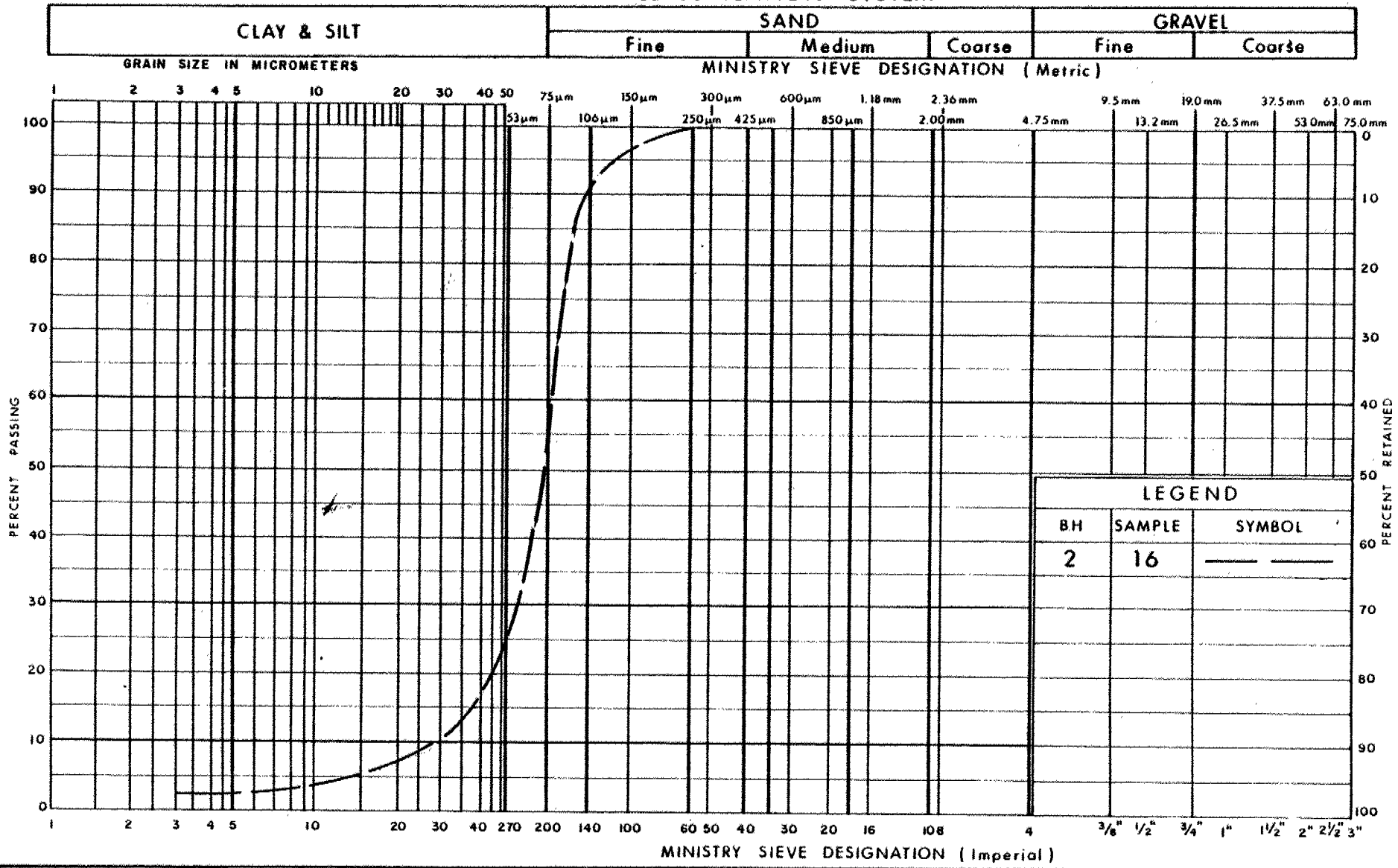
SILT SOME CLAY, TRACE CLAY

FIG No 3

WO 14-70003-R

78 12 M

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION
SILTY SAND TO SANDY SILT
TRACE CLAY

FIG No 4
WO 14-70003-R

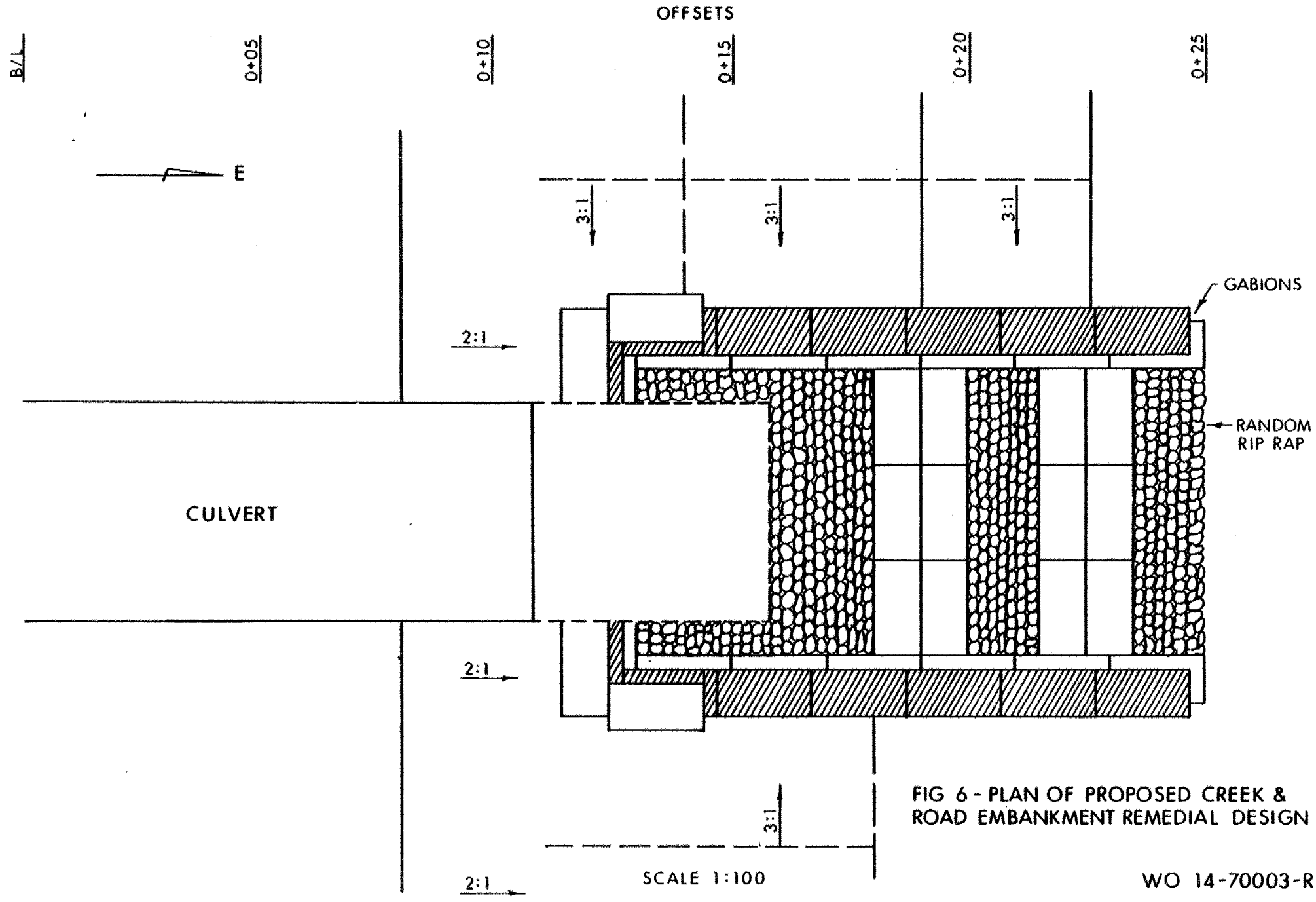
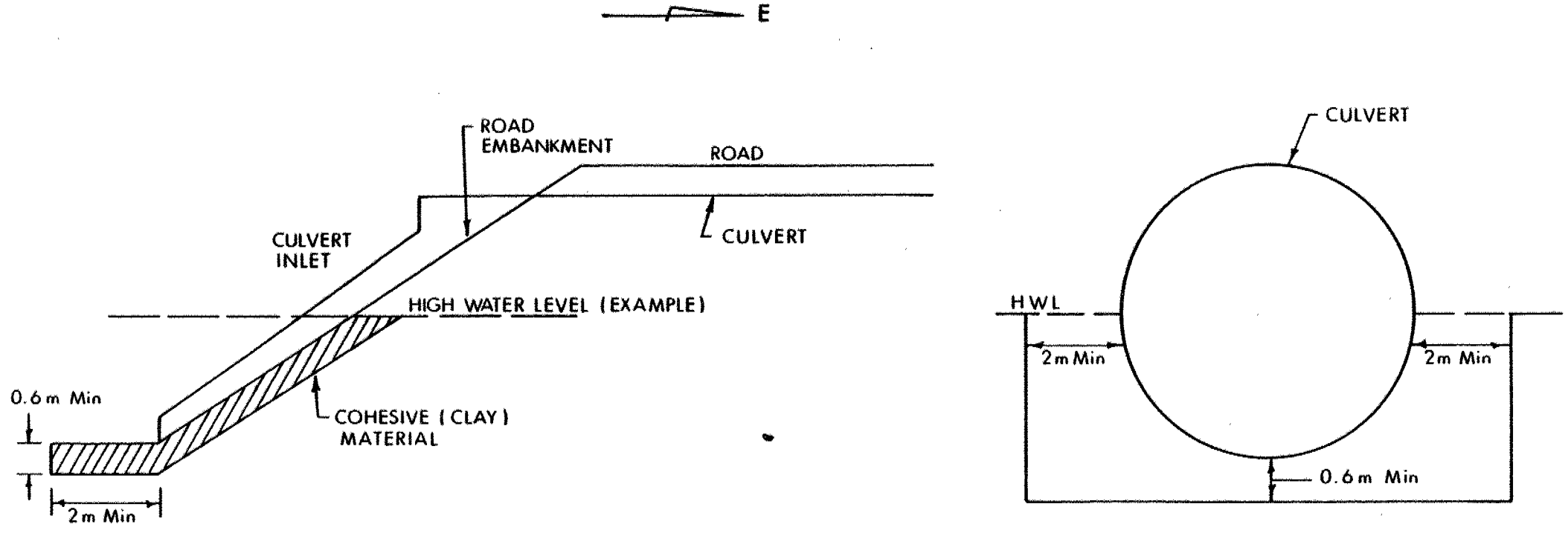


FIG 6 - PLAN OF PROPOSED CREEK & ROAD EMBANKMENT REMEDIAL DESIGN

WO 14-70003-R



NTS

a) Longitudinal Section

NTS

b) Front View

FIG 7 - CULVERT INLET SEAL

WO 14-70003-R

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS $\bar{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

R Q D (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

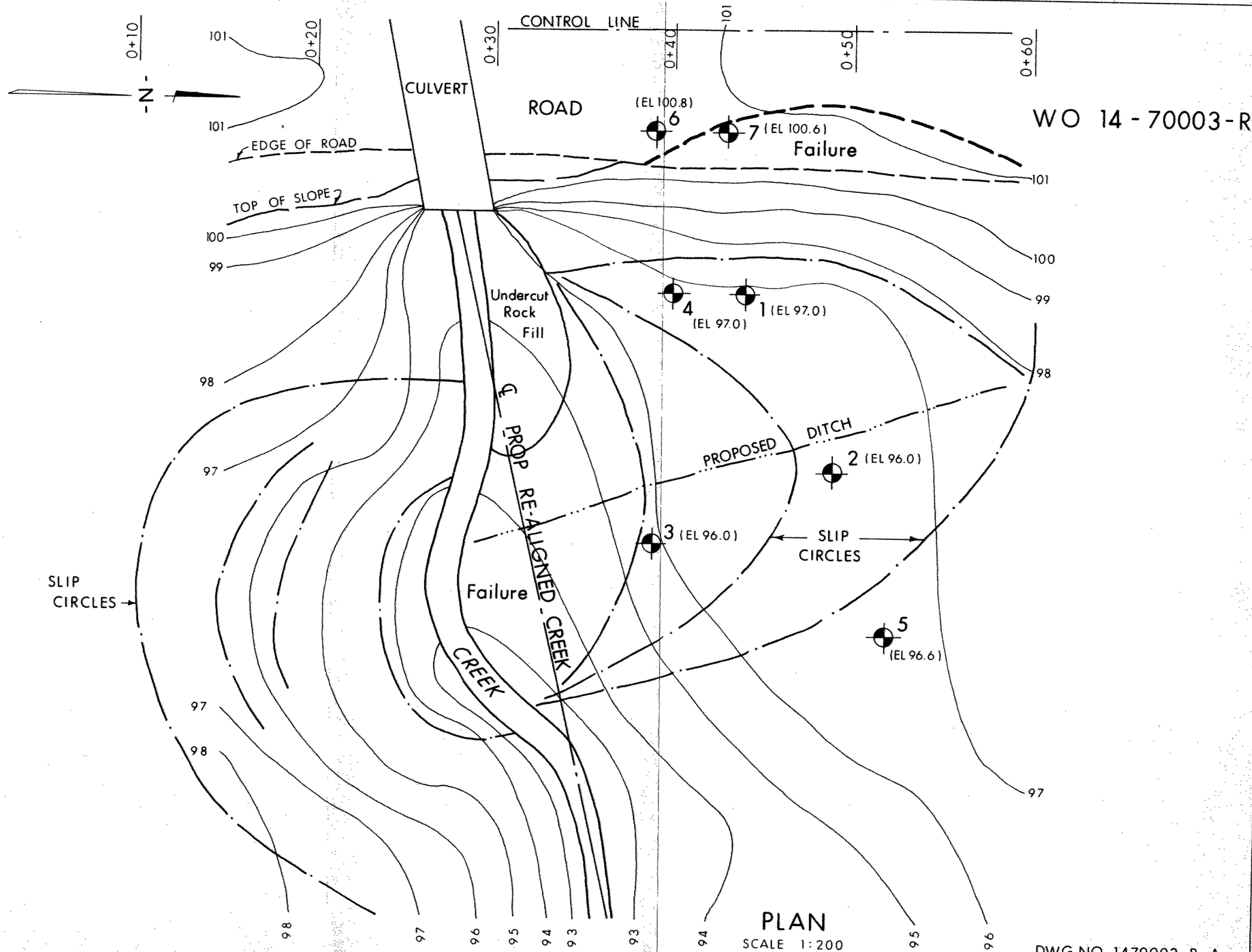
MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1,%	VOID RATIO	e_{min}	1,%	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1,%	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1,%	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_U	1	UNIFORMITY COEFFICIENT
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_S	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL				k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	j	kN/m^3	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL	e_{max}	1,%	VOID RATIO IN LOOSEST STATE			

WO 14-70003-R



PLAN
SCALE 1:200

DWG NO 1470003-R-A

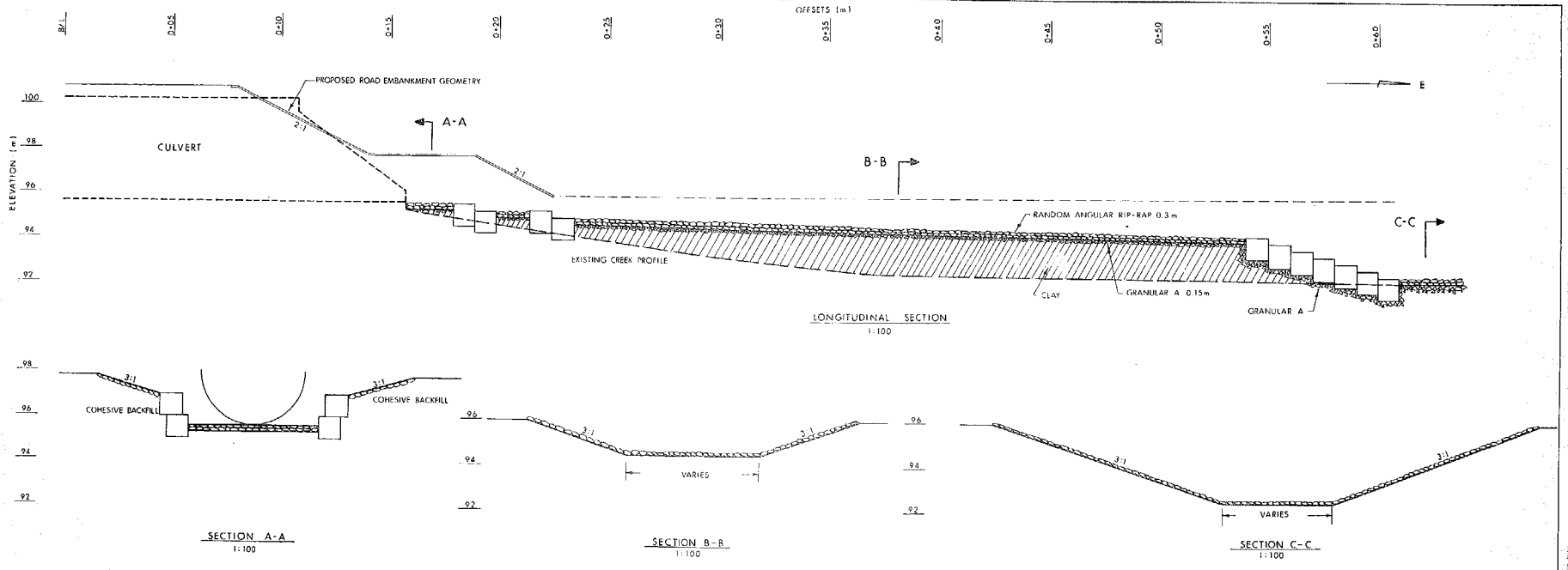


FIG 5 - LONGITUDINAL PROFILE OF PROPOSED CREEK & ROAD EMBANKMENT REMEDIAL DESIGN

WO 14-70003-R

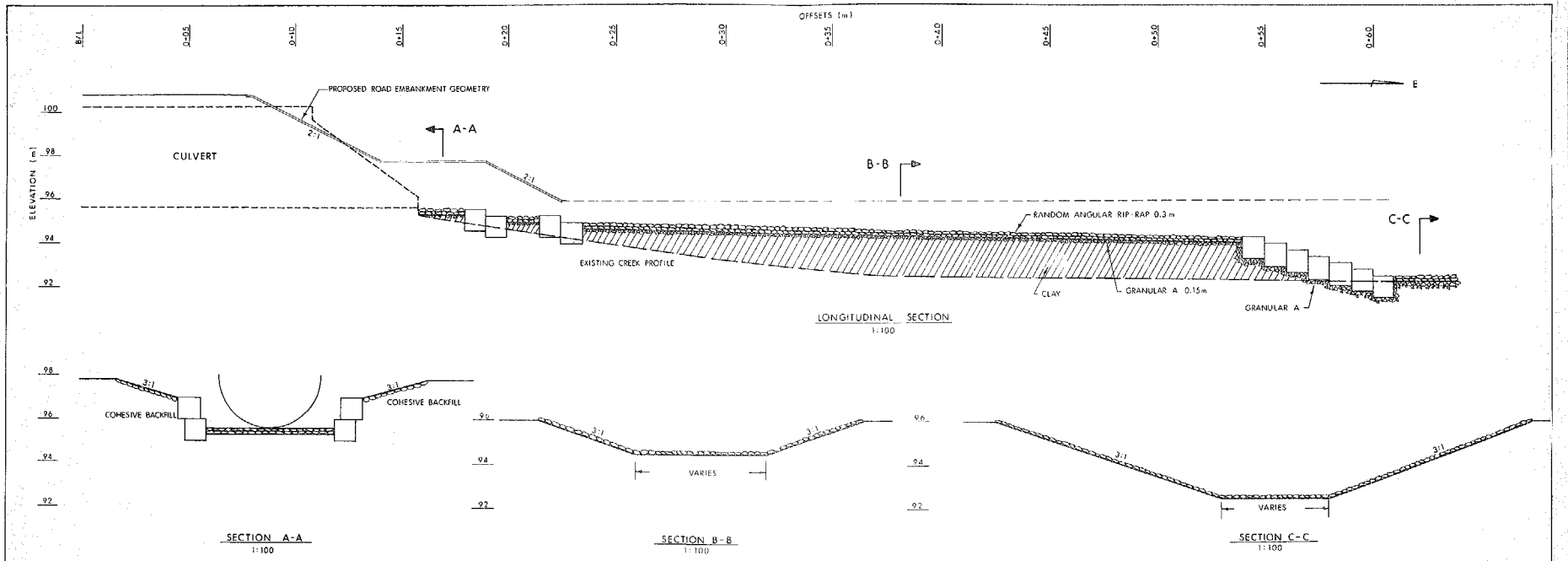


FIG 5 - LONGITUDINAL PROFILE OF PROPOSED CREEK & ROAD EMBANKMENT REMEDIAL DESIGN

WO 14-70003-R