

**ENGINEERING MATERIALS OFFICE
PAVEMENT & FOUNDATION DESIGN SECTION**

2000-11023
WO ~~990053-R~~ DIST 14
HWY Mun. STR SITE 47-62
Harley Twp.

Bear Creek Slip Failure

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GEOCRE 31M-45

DATE

OCT - 7 1982

FOUNDATION INVESTIGATION REPORT

For

W.O. 990053-R, Site 47-62

Bear Creek Bridge Slip Failure

Harley Twp., Lot 3, Conc. I/II

District 14, New Liskeard

INTRODUCTION:

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

The fieldwork was conducted during the period from 82 07 20-21 utilizing a continuous-flight auger machine equipped with 82 mm I.D. hollow-stem augers. This work consisted of 3 sampled boreholes/dynamic cone penetration tests.

SITE DESCRIPTION

The site is located on the Harley Twp. Conc. I/II road at Bear Creek Bridge, approximately 2.5 miles west of Hwy. 11.

Physiographically the site is located in the Cobalt Plain, a glacio-lacustrine plain of generally low local relief. At the site, the valley of Bear Creek lies approximately 15 feet below the plain and road.

At the time of the field investigation the slip failure extended from the east bridge abutment, approximately 75 feet east along the south half of the road. From discussions with neighbouring residents, and B. Peltier, Municipal Engineer, District #14, and field observations, it is our understanding that:

- the original bridge at this site was replaced in the early 1960's because of a slip failure
- the present failure occurred near the end of June, 1982
- the water level in Bear Creek is generally 3 feet higher in the spring

- the neighbouring fields are tiled and drain into the creek
- the wells in the area are artesian and also drain into the creek
- other slips have occurred along the creek bank
- the Township attempted to rebuild the road with limestone slabs and soil fill soon after the initial June 1982 failure but another slip failure was initiated by the construction
- the failure zone had slipped in a series of steps, encroaching on the river channel
- a vertical face had sheared away from the east abutment, exposing the piles.

SUBSURFACE CONDITIONS

General

The Record of Borehole Sheets (Appendix) illustrates the conditions at the borehole locations. The locations and elevations of the boreholes are shown in Drawing No. 990053-R.

The survey stations and elevations refer to a temporary benchmark (Sta. 0 + 00, elev. 100.00 feet) established at the south corner of the east abutment.

Generally, the overburden consists of a thick deposit of clay. The depth to bedrock is estimated at 200 feet. The surface material at the road, extending up to 7.0 feet in depth, is fill.

Fill Material

At BH #1, the road material consists of approximately 2.5 feet of limestone slabs, then silty sand fill containing some gravel and occasional layers of silty clay extending to a depth of 7.0 feet below the surface.

Clay

Clay of high plasticity (some silt) to clay of intermediate plasticity (with silt) constitutes the main deposit at this site.

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

	<u>Range</u>	<u>Average</u>	<u>Median</u>
Natural Moisture Content (w)	26.0-77.9%	59.9%	65.0%
Liquid Limit (W _L)	34.0-69.0%	55.5%	59.0%
Plastic Limit (W _p)	17.5-23.0%	21.3%	21.5%
Unit Weight (γ)	95.0-97.5 pcf	96.7 pcf	97.5 pcf
Shear Strength			
- field vane (undisturbed)	160-1000 psf	N/A	N/A
- field vane (remolded)	25-220 psf	N/A	N/A
- unconfined compression	197-404 psf	N/A	N/A

Additional laboratory testing was conducted to establish effective stress parameters:

$$c' = 429 \text{ psf}$$

$$\phi = 13^{\circ}$$

However, these stress parameters were adjusted for use in the effective stress stability analysis.

The shear strength of this deposit in the slip area generally increases with depth. The remolded shear strengths indicate sensitivities ranging from 2 to 13.

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

Groundwater

The groundwater was measured at elev. 84.5, approximately the same level as Bear Creek.

DISCUSSION AND RECOMMENDATIONS

Factors contributing to the slip failure include bank erosion and undercutting, and poor drainage.

These recommendations pertain to remedial measures for the stabilization of the slip failure.

The enclosed Figure 2 is a plan view illustrating the failure zone, the borehole locations and the recommended stabilization measures.

The enclosed Figure 3 is a X-section illustrating the recommended design for a typical section.

Design Data

- Refer to Figures 2 and 3.
- The creek channel should be relocated to accommodate the recommended stability treatment. The relocated creek channel should be designed so as to not create constrictions in water flow, especially in the vicinity of the bridge.
- The existing slope should be trimmed, or filled (with Granular "C"), as required to achieve the section illustrated in Figure 3A. From the edge of the road shoulder to the top of the berm surface (at elev. 91), the embankment should slope at 3:1; from the top of the berm surface to the bottom of the berm surface (at elev. 90), the embankment should slope at 20:1; from the bottom of the berm surface to the bottom of the river channel the embankment should slope at 3:1. The slope on the opposite side of the creek channel should be graded to 2:1 or flatter. The transition areas adjacent to the stability treatment should be graded into the existing contours at slopes of 3:1 or flatter.
- The drainage ditch immediately to the east of the failure zone (see Figure 2) should be relocated to accommodate the recommended geometry. Regardless of the location of the reconstructed creek channel, this ditch should be provided with a suitable drainage path to the creek.

- French drains (3 ft. in width) of Granular "A" should be constructed at 15 ft. intervals (C/L to C/L) from Sta. 0 + 00 to Sta. 0 + 60E inclusive. Refer to Figure 2 for a plan view of the drains; refer to Figure 3A for the excavation limit for the drains; refer to Figure 3B for a longitudinal section showing drain dimensions. Regardless of the location of the reconstructed creek channel, these drains should be provided with a suitable drainage path to the creek.
- Erosion protection, in the form of random rip rap (minimum blanket thickness = 2 ft.) should be placed on the lower slope of the stability treatment. The rip rap should extend a minimum of 6 ft. out along the creek bottom (see Figure 3A). The remaining stability treatment area and the adjacent transition zones should be protected by vegetation cover as soon as possible.
- As previously noted, Granular "A" should be used for the French drains, and Granular "C" should be used for the stability treatment embankment fill and the transition grading. The material excavated from the relocated creek channel is acceptable for use as fill outside of the stability treatment.

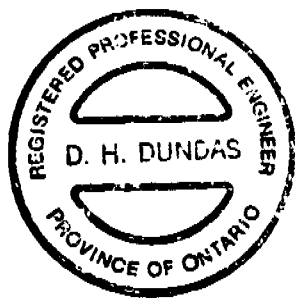
Construction Sequence

- 1) Relocate creek and drainage ditch.
- 2) Trim existing embankment in stability treatment area as required.
- 3) Construct stability treatment (including the French drains) below elev. 91.
- 4) Construct stability treatment (including the French drains) above elev. 91.
- 5) Grade stability treatment into adjacent contours.
- 6) Provide erosion protection.

- 7) Fill remaining depressions as required, providing suitable drainage paths to the relocated creek for the stability treatment and for the relocated ditch.

MISCELLANEOUS

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



D. H. Dundas

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

K. G. Selby

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

APPENDIX

RECORD OF BOREHOLE No 1

W O 990053-R LOCATION Sta. 0 + 35 E, o/s 3' Lt. & Twp. Rd. ORIGINATED BY D.D.
DIST 14 HWY 400 BOREHOLE TYPE Hollow Stem Auger & Cone Test COMPILED BY D.D.
DATUM Assumed DATE 82 07 20 CHECKED BY D.D.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100				
97.5	Ground Surface															
0.0	and boulders Silty Sand, occ. Silty Clay, Some Gravel		1	SS	14											
90.5	Loose to Compact (Fill)		2	SS	6											
7.0	Clay		3	SS	2											
	Some Silt		4	TV	PM											
			5	TV	PM											
			6	TV	PM											
			7	TV	PM											
			8	SS	PM											
			9	SS	PM											
	CH Very Soft to Firm		10	SS	PM											
	CI Firm		11	SS	PM											
			12	SS	PM											
			13	SS	PM											
14.5	End of Borehole															
83.0	Probable Clay															
	Some Silt															
-2.5	Continued															
100.0																

+3, x5: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 2

WO 990053-R LOCATION Sta. 0 + 30 E, o/s 45' St. E Twp. Rd. ORIGINATED BY D.D.
DIST 14 HWY Mun. BOREHOLE TYPE Hollow Stem Auger & Cone Test COMPILED BY D.D.
DATUM Assumed DATE 82 07 21 CHECKED BY D.D.

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES		20	40	60	80	100					
88.8	Ground Surface															
0.0	(CI) with Silt orig. ground surface		1	SS	5											
			2	TH	PH											
			3	SS	2											
	Clay (CH)															
	Some Silt		4	TH	PH											
			5	TH	PH											
	Very Soft to Firm		6	SS	PH											
			7	TH	PH											
			8	SS	PH											
45.8			9	SS	PH											
43.0	End of Borehole Probable Clay (CH) Some Silt															
38.8																
50.0	End of Cone Test															

+3, x5: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 3

W O 990053-R LOCATION Sta. 0 + 35 E, o/a 135' Rt. & Twp. Rd. ORIGINATED BY D.D.
 DIST 14 HWY Mun. BOREHOLE TYPE Hollow Stem Auger & Cone Test COMPILED BY D.D.
 DATUM Assumed Harley Twp. DATE 82 07 21 CHECKED BY D.D.

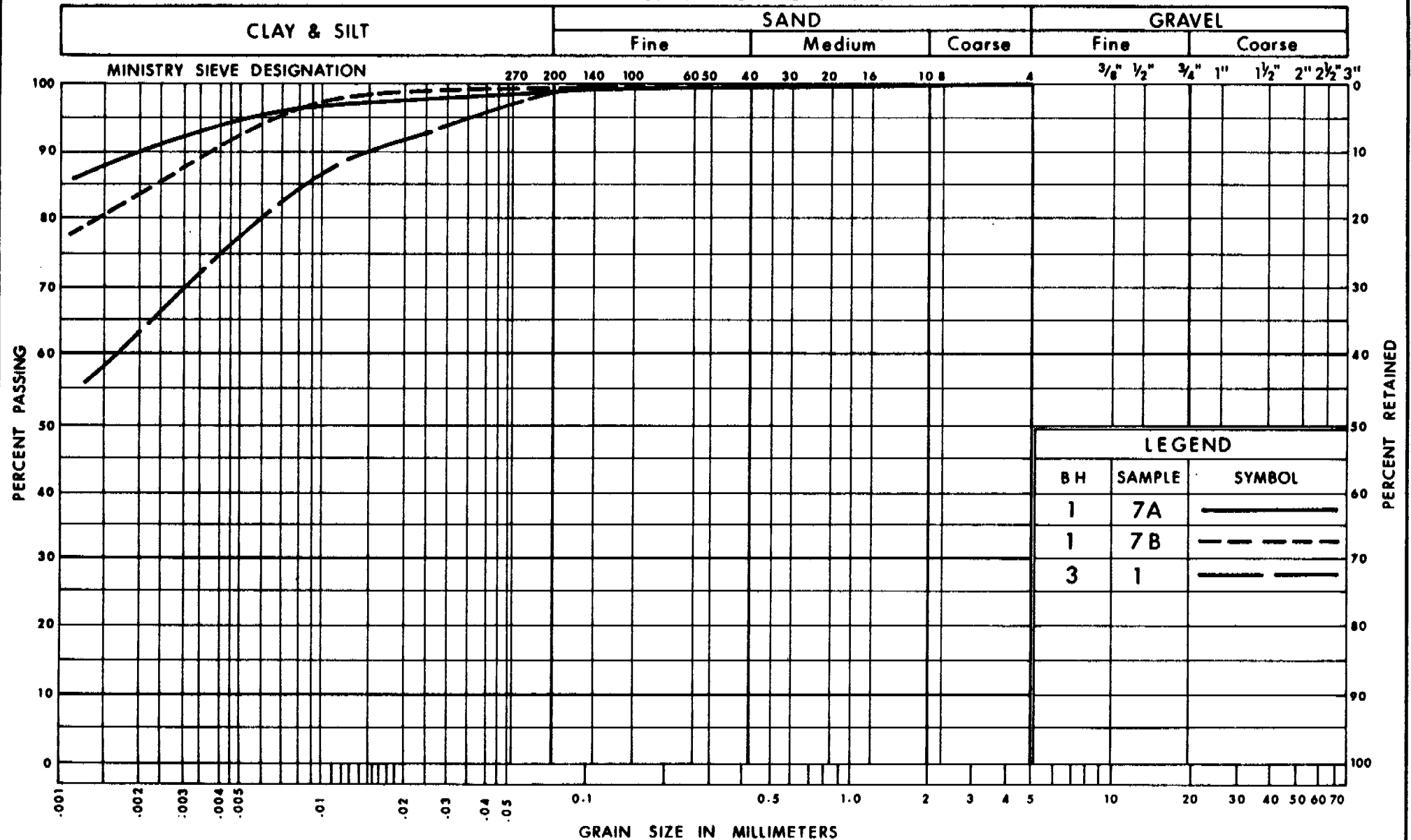
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
95.0	Ground Surface																
0.0	(CI) with silt		1	SS	25		90										0 0 39 61
	Clay (CH) Some Silt		2	SS	PM		80										
	Soft to Firm		3	SS	PM		70										
			4	SS	PM		60										
52.0			5	SS	PM												
43.0	End of Borehole Probable Clay (CH) Some Silt						50										
45.0																	
50.0	End of Cone Test																

+3, x5: Numbers refer to
Sensitivity

20
15
10
5 (% STRAIN AT FAILURE)

OFFICE REPORT ON SOIL EXPLORATION

UNIFIED SOIL CLASSIFICATION SYSTEM



Ministry of
Transportation and
Communications

GRAIN SIZE DISTRIBUTION
CLAY, WITH SOME SILT

FIG No 1

WO 990053 R

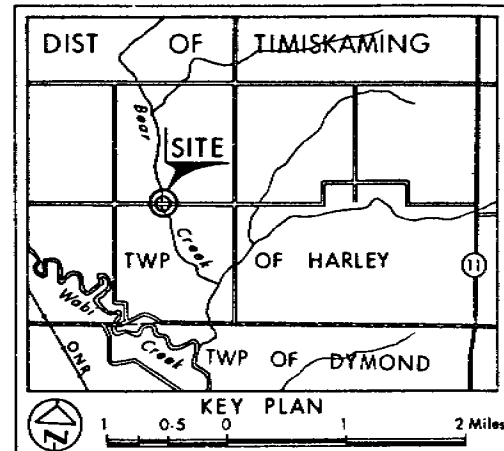
OVERSIZE DRAWING(S)

CONT No
WO No 990053-R



BEAR CREEK SLIP FAILURE
HARLEY TWP RD, LOT 3, CON 1 & 2
BORE HOLE LOCATIONS & SOIL STRATA

SHEET



LEGEND

- Bore Hole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊕ Bore Hole & Cone
- W' Blows/ft (Std Pen Test 350 ft lbs energy)
- CONE Blows/ft (60° Cone, 350 ft lbs energy)
- ↓ W.L. at time of investigation July 1982

No	ELEVATION	STATION	OFFSET
1	97.5	0+35 E	3' LT
2	88.8	0+30 E	45' RT
3	95.0	0+35 E	135' RT

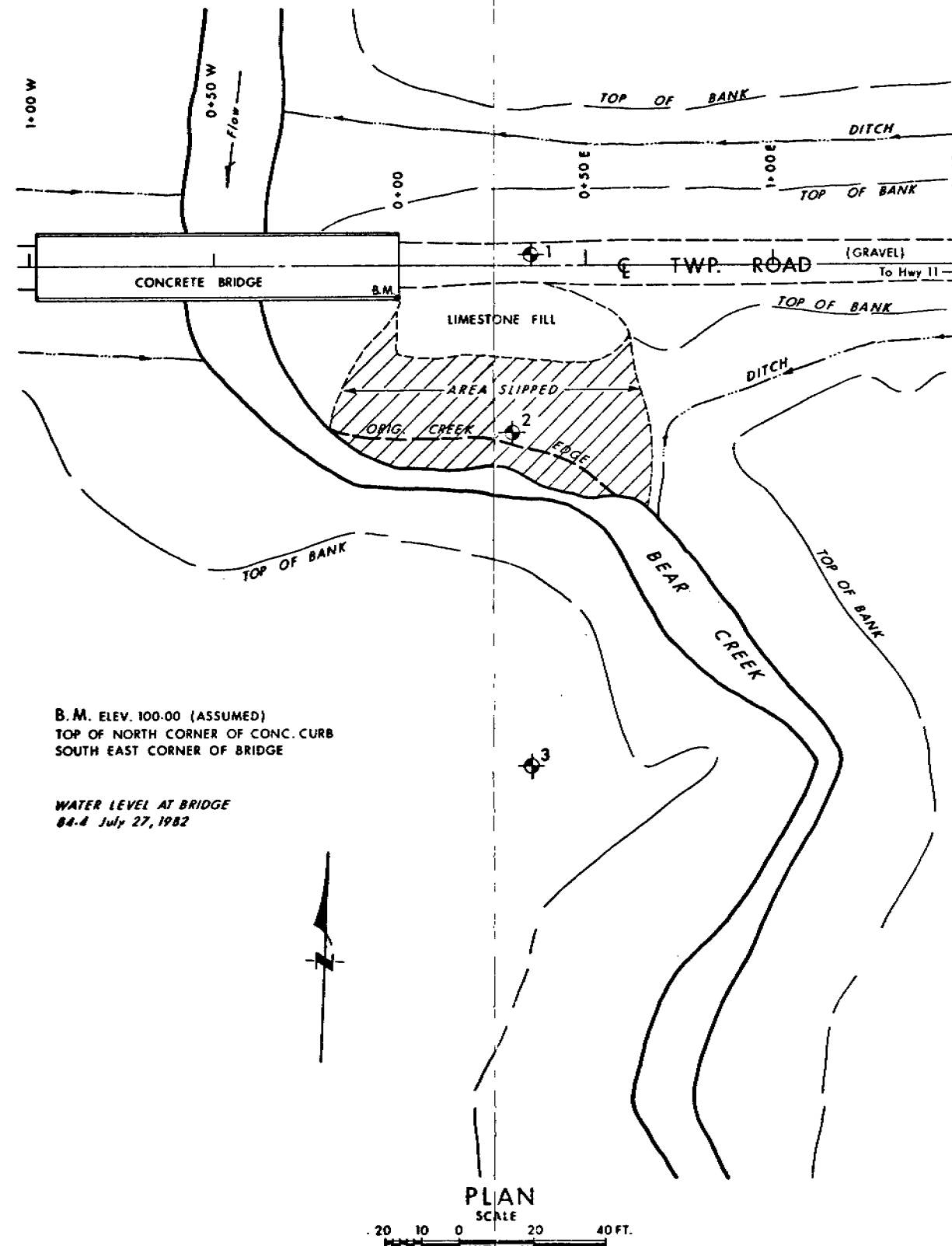
NOTE

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

REVISIONS	DATE	BY	DESCRIPTION

Geocres No 31M-45

HWY No HARLEY TWP RD DIST 14
SUBM'D D.D. CHECKED DATE Sept 30 82 SITE 47-62
DRAWN BY CHECKED APPROVED DWG 990053R-A



B.M. ELEV. 100.00 (ASSUMED)
TOP OF NORTH CORNER OF CONC. CURB
SOUTH EAST CORNER OF BRIDGE

WATER LEVEL AT BRIDGE
84.4 July 27, 1982

NOTE:

FOR SUBSOIL CONDITIONS REFER TO
RECORD OF BOREHOLE SHEETS.

EXPLANATION OF TERMS USED IN REPORT

'N' VALUE: AN INDICATOR OF SUBSOIL QUALITY. IT IS OBTAINED FROM THE STANDARD PENETRATION TEST (CSA STD. A119.1). SPT 'N' VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 2 INCH O.D. SPLIT-BARREL SAMPLER TO PENETRATE 12 INCHES INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WEIGHING 140 POUNDS, FALLING FREELY A DISTANCE OF 30 INCHES. FOR PENETRATIONS OF LESS THAN 12 INCHES 'N' VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. 'N' VALUES CORRECTED FOR OVERBURDEN PRESSURE ARE DENOTED THUS N_c .

DYNAMIC CONE PENETRATION TEST (CSA STD. A119.3): CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (2" O.D. 60 CONE ANGLE) DRIVEN BY 350 FT-LB IMPACTS ON 1/2" SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 12 INCH ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOIL QUALITY: SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSITY.

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

S_u (PSF)	0 - 250	250 - 500	500 - 1000	1000 - 2000	2000 - 4000	> 4000
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSITY: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF SPT 'N' VALUES AS FOLLOWS:

'N' (BLOW/FT)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCK QUALITY: 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 DRILLED IN THAT CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE NATURALLY FRACTURED CORE PIECES, 4" IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	2"	2" - 12"	1' - 3'	3' - 10'	> 10'
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS & SYMBOLS

LABORATORY TESTING

TRIAXIAL TESTS ARE DESCRIBED IN TERMS OF WHETHER THEY ARE CONSOLIDATED (C) OR NOT (U) ISOTROPICALLY (I) OR NOT (A) AND SHEARED DRAINED (D) OR UNDRAINED (U) WITH PORE PRESSURE MEASUREMENTS (BAR OVER SYMBOLS) EG. CUU = CONSOLIDATED ISOTROPIC UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENT UNLESS OTHERWISE SPECIFIED IN REPORT ALL TESTS ARE IN COMPRESSION

FIELD SAMPLING

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

EARTH PRESSURE TERMS

μ COEFFICIENT OF FRICTION
 δ ANGLE OF WALL FRICTION
 k_o COEFFICIENT OF EARTH PRESSURE AT REST
 k_A COEFFICIENT OF ACTIVE EARTH PRESSURE
 k_P COEFFICIENT OF PASSIVE EARTH PRESSURE
 i ANGLE OF INCLINATION OF SURCHARGE
 w SLOPE ANGLE-BACKFACE OF WALL
 β ANGLE OF SLOPE
 N, N_q, N_c BEARING CAPACITY FACTORS
 D_f DEPTH OF FOOTING
 B, L FOOTING DIMENSIONS

INDEX PROPERTIES

γ UNIT WEIGHT OF SOIL (BULK DENSITY)
 γ_w UNIT WEIGHT OF WATER
 γ_d UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
 γ' UNIT WEIGHT OF SUBMERGED SOIL
 G_s SPECIFIC GRAVITY OF SOLIDS
 e VOIDS RATIO
 e_o INITIAL VOIDS RATIO
 e_{max} e IN LOOSEST STATE
 e_{min} e IN DENSEST STATE
 D_r RELATIVE DENSITY = $\frac{e_{max} - e}{e_{max} - e_{min}}$
 n POROSITY
 w WATER CONTENT
 w_L LIQUID LIMIT
 w_P PLASTIC LIMIT
 w_S SHRINKAGE LIMIT
 I_p PLASTICITY INDEX = $w_L - w_P$
 I_L LIQUIDITY INDEX = $\frac{w - w_P}{w_L - w_P}$
 I_c CONSISTENCY INDEX = $\frac{w_L - w}{w_L - w_P}$
 A_c ACTIVITY = $\frac{I_p \text{ of soil}}{I_p \text{ of } 2\mu m \text{ Soil Fraction}}$
 O_m ORGANIC MATTER CONTENT
 S_r DEGREE OF SATURATION
 S SENSITIVITY = $\frac{S_u \text{ (undisturbed)}}{S_u \text{ (remoulded)}}$

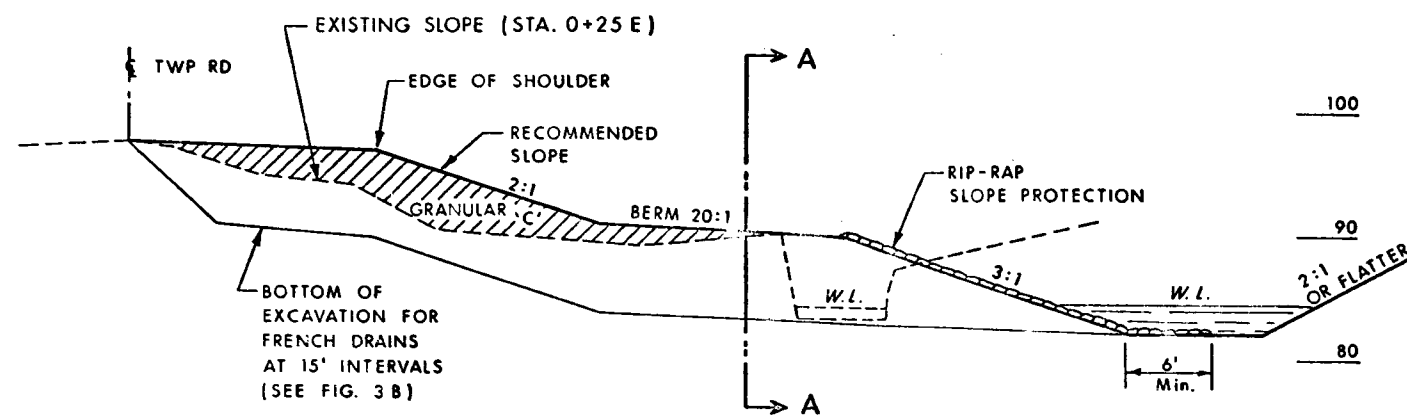
STRENGTH PARAMETERS

ϕ ANGLE OF SHEARING RESISTANCE
 τ_f PEAK SHEAR STRENGTH
 τ_R RESIDUAL SHEAR STRENGTH
 c COHESION INTERCEPT
 $\sigma_1, \sigma_2, \sigma_3$ NORMAL PRINCIPAL STRESSES
 u PORE WATER PRESSURE
 u_e EXCESS u
 r_u PORE PRESSURE RATIO
 q_u UNCONFINED COMPRESSIVE STRENGTH
 s_u UNDRAINED SHEAR STRENGTH
 ϵ LINEAR STRAIN
 γ SHEAR STRAIN
 ν POISSON'S RATIO
 E MODULUS OF ELASTICITY
 G MODULUS OF SHEAR DEFORMATION
 k_s MODULUS OF SUBGRADE REACTION
 m, n STABILITY COEFFICIENTS
 A, B PORE PRESSURE COEFFICIENTS

NOTE: EFFECTIVE STRESS PARAMETERS ARE DENOTED BY USE OF APOSTROPHE ABOVE THE SYMBOL, THUS:
 σ' = EFFECTIVE ANGLE OF SHEARING RESISTANCE;
 σ'_1 = EFFECTIVE NORMAL STRESS

HYDRAULIC TERMS

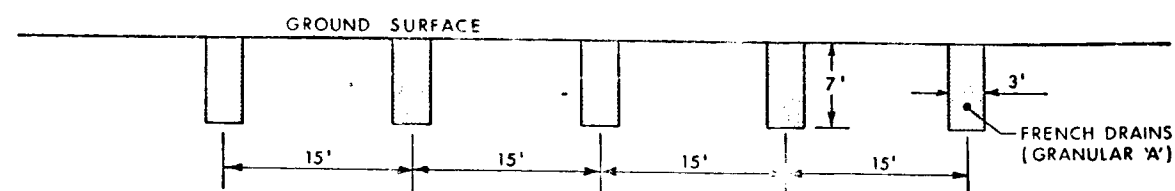
h HYDRAULIC HEAD OR POTENTIAL
 q RATE OF DISCHARGE
 v VELOCITY OF FLOW
 i HYDRAULIC GRADIENT
 j SEEPAGE FORCE PER UNIT VOLUME
 η COEFFICIENT OF VISCOSITY
 k COEFFICIENT OF HYDRAULIC CONDUCTIVITY
 k_h k IN HORIZONTAL DIRECTION
 k_v k IN VERTICAL DIRECTION
 α_v COEFFICIENT OF VOLUME CHANGE
 c_v COEFFICIENT OF CONSOLIDATION
 C_c COMPRESSION INDEX
 C_r RECOMPRESSION INDEX
 d DRAINAGE PATH DISTANCE
 T_v TIME FACTOR
 U DEGREE OF CONSOLIDATION
 O_c OVERCONSOLIDATION RATIO (OCR)



DESIGN FOR TYPICAL SECTION

Fig. 3A

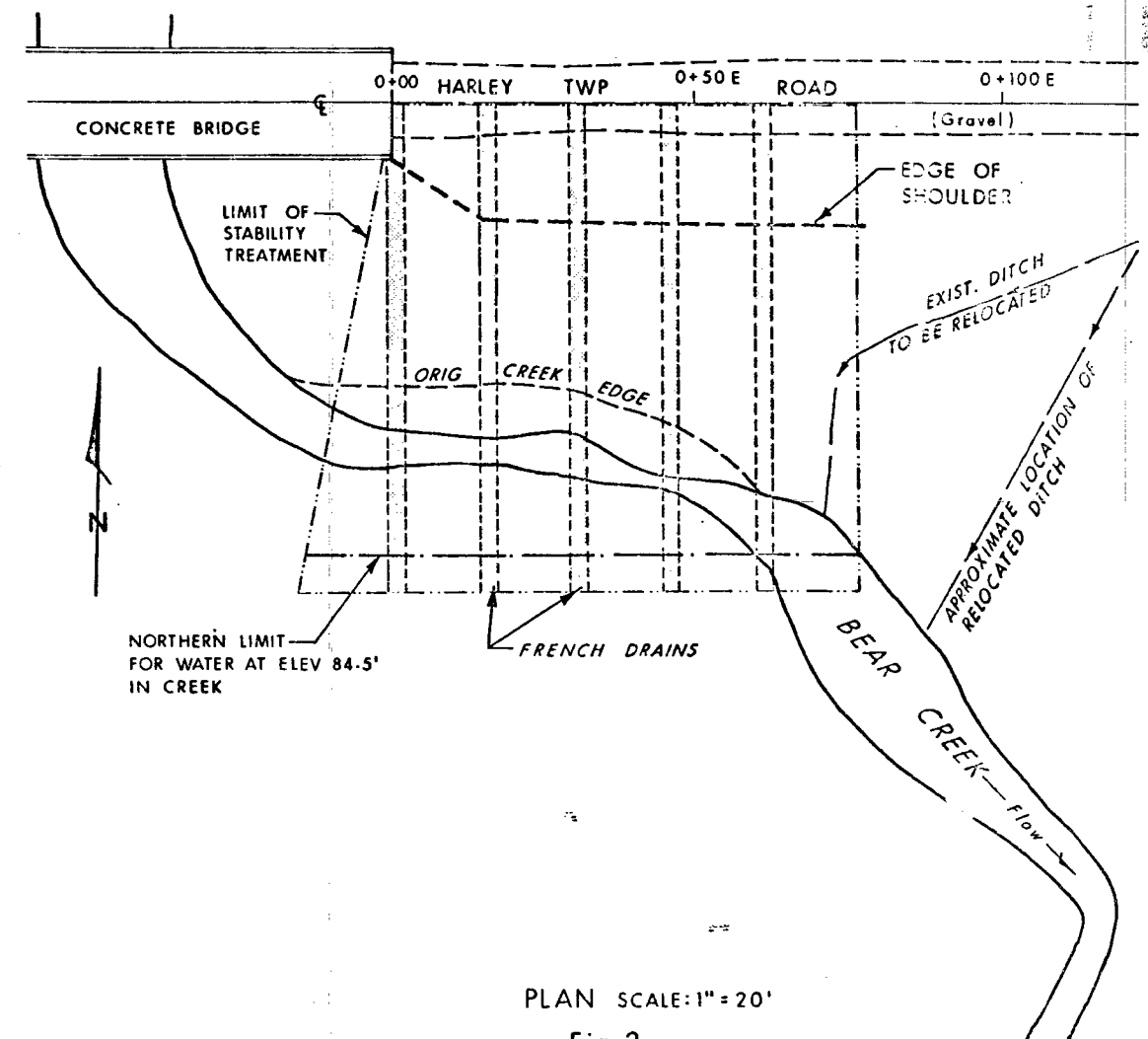
SCALE: 1" = 10'



LONGITUDINAL SECTION A-A

Fig. 3B

SCALE: 1" = 10'



PLAN SCALE: 1" = 20'

Fig. 2


 <p>Ministry of Transportation and Communications</p>	<p>BEAR CREEK SLIP FAILURE RECOMMENDED DESIGN</p>	
<p>DATE Oct 1, 1982</p>	<p>DIST. 14, TWP. OF HARLEY, LOT 3, CON 1 & 2 WO 990053 R</p>	<p>FIG No 2, 3A & 3B</p>

FIGURE 1

NO. 990053-R
SITE 47-62
SLIP FAILURE - BEAR CREEK BRIDGE
HARLEY TWP
DIST. 14

