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G.I.-30 SEPT. 1976

GEOCRES No. 31G-58

DIST. 9 REGION

W.P. No. 35-66-19

CONT. No.

W. O. No.

STR. SITE No.

HWY. No. 138

LOCATION BOUNDARY MUNICIPAL DRAIN
& Hwy 138

No. OF PAGES -

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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS, ONTARIO

MEMORANDUM

TO: Mr. J. E. Callaghan, (2)
District Engineer,
District #9,
Ottawa, Ontario.

FROM: Foundations Office,
Design Services Branch,
West Bldg., Downsview.

ATTENTION:

DATE: February 7, 1973.

OUR FILE REF.

IN REPLY TO

FEB 16 1973

SUBJECT:

FOUNDATION INVESTIGATION REPORT
For
Settlement of Corrugated Steel Pipe Culvert
Boundary Municipal Drain and
Hwy. #138 (Station 26+56)
County of Stormont
District No. 9 (Ottawa)
W.O. 72-11147 -- W.P. 35-66-0519

Enclosed please find our complete foundation investigation report for the above-mentioned project. We believe you will find the factual data contained in the report to be sufficient for your purposes.

The recommendations contained in the report were given verbally to Mr. J. A. Cruickshank on January 18, 1973, by Mr. M. Devata, Supervising Foundations Engineer, in order that remedial measures for the culvert failure could be proceed with the minimum of delay. If further problems arise in connection with this project, please contact this Office.

MD/ao

Encl.

cc: E. J. Orr
A. Rutka
A. J. Percy
T. C. Kingsland
E. R. Saint
G. A. Wrong
B. J. Giroux
B. A. Singh

Foundations Files
Documents ✓

A. G. Stermac
A. G. Stermac,
PRINCIPAL FOUNDATIONS ENGINEER.

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FOUNDATION INVESTIGATION REPORT
For
Settlement of Corrugated Steel Pipe Culvert
Boundary Municipal Drain and
Hwy. #138 (Station 26+56)
County of Stormont
District No. 9 (Ottawa)
W.O. 72-11147 -- W.P. 35-66-~~66~~19

1. INTRODUCTION:

A foundation investigation was carried out by this Office for the underpass structure at the crossing of Hwy. #417 and Hwy. #138, in the County of Prescott. A foundation report was submitted for this structure (Report No. W.J. 70-F-11, dated April 24, 1970). The aforementioned municipal drain will have to cross the south approach embankment to this structure at about Station 26+56. A 218 feet long 66 inch diameter corrugated steel pipe culvert was installed at this location in June and July of 1971. Recommendations pertaining to the installation of the culvert were provided by personnel from the Materials Section, Eastern Region.

Visual observations carried out by District Construction personnel, following placement of the culvert, have indicated that it has settled considerably. It was felt that from a hydrological point of view the culvert is unacceptable.

An on-site meeting was held on December 20, 1972, to inspect the culvert. In attendance were Messrs. J. A. Cruickshank, Construction Engineer, District #9 (Ottawa), and M. Devata, Supervising Foundations Engineer. At this meeting it was agreed

to carry out a study to determine the causes of the settlement as well as make recommendations pertaining to the remedial measures necessary to rectify the culvert distress. This study has been carried out by the Foundations Office.

This report presents all the factual information obtained from the recent investigation at this culvert site, together with our assessment of the causes of the culvert settlement. In addition, possible remedial measures are recommended.

2. DESIGN AND CONSTRUCTION DETAILS:

a) Structure Approach Embankments:

Fills up to 22 feet in height were to be placed to form the approaches to this structure. The subsoil conditions in this area are as follows: thin surficial deposits (topsoil or peat) underlain by a 21 to 35 feet thick stiff to soft clay stratum, which in turn is followed by glacial till then bedrock. In the critical areas along the approaches the topsoil and peat were subexcavated and backfilled with granular material in compliance with the recommendations made by the Materials Section, Eastern Region.

Berms were required in order to ensure the stability of the approach fill sections; berm details were given in the foundation report. In addition, the underlying compressible clay stratum would consolidate over a period of time due to the applied fill loading. It was estimated that the maximum total amount of settlement beneath the 22 feet high south approach would be of the order of 2-1/2 to 3 feet. In order to minimize post-construction maintenance problems it was decided to accelerate the settlement by surcharging the approaches with 5 feet of fill. These surcharges were to be left in place for a period of 18 months prior to their removal and the eventual construction of the structure.

The fill used to construct the approaches was locally available material, which was composed of either i) a granular to cohesive glacial till, or ii) silty sand.

In situ testing carried out by district personnel indicates that the in-place bulk density of the fill varies from 140 to 145 p.c.f.

Construction Sequence in Vicinity of Culvert

<u>Dates</u>	<u>Details</u>	<u>Remarks</u>
July 7 to 22/71	Embankment Constructed to Top of Surcharge (El. 237.2)	Approx. 24' Fill
Aug. 6/71	Surcharge Partially Removed (El. 235.8)	Surcharge Partially Removed after failure of North Approach
Aug. 6/72	Top of Embankment (El. 234.4)	Embankment Settled 1.4' Between Aug. '71 and Aug. '72.
Sept./72	Embankment Unloaded to earth grade level (El. 230.8)	

b) Placement of Culvert:

Prior to placing fill along the south approach the 66 inch diameter culvert was installed. According to available information all topsoil was removed from the vicinity of the culvert and it was placed on a 2 foot thick bed of compacted sand with some silt. In addition, the culvert was provided with a 1-1/2' camber in order to allow for the differential settlement expected along its length, due to the consolidation of the underlying clay stratum. The placement elevations of the culvert were as follows:

<u>Location</u>	<u>Obvert Elevation</u>
West End	215.0
Ø	216.5
East End	215.0

3. FIELD INVESTIGATION:

a) Results of Boring Programme:

A total of nine boreholes were put down between January 10 and 17, 1973, using a C.M.E. 75 equipped with hollow

stem augers. Six of these borings were put down along the centre line of the culvert in order to establish the present obvert elevation of the culvert. At the remaining boring locations samples of the fill and sensitive clay stratum were obtained in order to determine the vertical and lateral extent, as well as the engineering properties of these deposits. Detailed logs are being prepared for each borehole. Further, the locations of the boreholes are shown on Drawing No. W.O. 72-11147A along with an inferred stratigraphical profile along the centre line of the culvert.

A number of observations can be made based on the boring programme. These are listed below:

- i) The topsoil and organic material has been removed within the critical areas.
- ii) No voids were encountered in the fill, with the exception of a 1/2 foot deep surface cavity 10 feet to the right of the centre-line along the culvert. The results of the standard penetration testing carried out indicate that the fill has been subjected to an acceptable compactive effort.
- iii) The culvert which was convex in shape is now concave, being lowest in the centre. The settlement along the culvert is presented in the table to follow.

Settlement of Culvert (Station 26+56)

Offset	Obvert Elevation		Settlement (ft)
	Initial (July, 1971)	Jan. 1972	
75' Lt. (on berm)	215.0	214.6	0.4
55' Lt. (on berm)	215.5	214.5	1.0
17' Lt. (top of embankment)	216.1	212.5	3.6
Ø (top of embankment)	216.5	212.5	4.0
10' Rt. (top of embankment)	216.3	213.0	3.3

- iv) The three borings put down adjacent to the culvert indicated that the clay stratum, at these points, had undergone consolidation; the magnitude was similar to that presented in the above table.

b) Inspection Inside Culvert:

On January 11, 1973, a diver from The Laurentian Trading Post, Ottawa, entered the culvert from the west end. The diver made the following observations:

- i) The culvert is concave in shape. At either end the water level is approximately 33 inches below the obvert which is at about elevation 214.7. In the centre, however, there was only about 10 inches of freeboard.
- ii) There is approximately 1 foot of silt covering the bottom of the culvert.
- iii) 16 feet from the west end the joint had separated.
- iv) 50 feet from the west end the culvert is still round.
- v) At centre-line the joint has separated approximately 6 inches. The west side of the joint is 6 inches lower than the east. The top of the pipe is flat at this location. The pipe is elliptical in shape being approximately 60 inches high and 68 inches wide. A 6 inch high pile of stones is present beneath the break.
- vi) 50 feet right of the centre line the pipe had a normal circular cross-section.

4. REASONS FOR CULVERT SETTLEMENT:

Beneath the centre line of the fill the culvert at Station 26+56 has settled approximately 4 feet. However, beneath the berms the culvert has settled only from 1/2 to 1 foot. The borings put down immediately south of the culvert have indicated that the subsoil in this area has settled a corresponding amount. Based on these observations it is inferred that the differential settlement along the culvert is due to the time dependent consolidation of the parent compressible clay stratum caused by the approach fill loading.

Settlement plates have been installed at Station 27+75 where the profile grade of the top of surcharge was at elevation 239. After removal of the surcharge the top of earth grade is at elevation 233, which corresponds to heights above the existing ground surface of 26 feet and 20 feet, respectively. Between July, 1971, and January, 1973, the clay stratum, at this location, has settled approximately 3 feet; i.e., 1 foot less than what has occurred at the culvert.

The upper few feet of the clay stratum, in the immediate vicinity of the drain channel, may have been in a softened condition due to weathering processes. Further, the upper zone of the sensitive clay may have been remoulded by the construction operations associated with the installation of the culvert. The additional settlement at the culvert location could be due to either or both of these possibilities.

It should be noted that the clay stratum, beneath the south approach fill, is still consolidating. The settlement, however, is occurring at a much slower rate than it was in the period immediately after the fill placement.

5. RECOMMENDED REMEDIAL MEASURES:

As discussed previously the culvert at Station 26+56 has settled differentially due to the consolidation of the underlying parent cohesive stratum. Beneath the centre-line of the fill the settlement is of the order of 4 feet, while beneath the berm the culvert has settled anywhere from 1/2 to 1 foot. From a hydrological point of view the existing profile of the culvert is unsatisfactory and will have to be improved.

One solution would be to remove the existing culvert and install a new one with a more acceptable profile grade. The excavation to expose the culvert will be about 22 feet deep. In order to ensure the stability of the temporary side slopes they should be cut no steeper than 1:1. If steeper slopes are required, then the excavation should be sheeted in accordance with the provisions set for in the Trench Excavators Act.

Once the existing culvert is removed it will be necessary

to add fill in order to realize the revised profile grade. This fill will act as a bedding for the new culvert. It is recommended that this fill be composed of Granular 'A' material which should be well compacted in 6 inch lifts. The select fill bedding should extend 2 feet on either side of the culvert. Further, well compacted Granular 'A' material should extend a minimum of 2 feet above the top of the culvert. Above this level any acceptable locally available earth material can be used as backfill, provided it is properly compacted.

The parent cohesive stratum is still consolidating; the time-rate, however, is now slower than it was when the fill was initially placed in July, 1971. In order to account for the magnitude of differential settlement expected in the future it is recommended that the culvert be provided with an 18 inch camber. Specifically the elevation of the centre of the culvert should be 18 inches higher than that at the exit and 12 inches higher than the entrance.

As an alternative consideration should be given to diverting the municipal drain in a southerly direction in order to cross the south approach at a point where the fill height is of the order of 10 to 12 feet. The advantages of this solution are:

- i) The settlement of the clay stratum is less in this area since the loading is much less.
- ii) The depth of excavation needed is minimized.

A culvert in such a location should be underlain by at least 2 feet of Granular 'A' material. The vertical and lateral extent of the Granular 'A' material around and above the culvert should be similar to that discussed for the first solution. The culvert should be provided with a 9 inch camber in order to allow for future consolidation settlement of the parent cohesive stratum.

If this scheme is adopted the existing culvert should be completely plugged with earth fill.

The foregoing recommendations concerning remedial measures were given by M. Devata to J. A. Cruickshank on

January 8, 1973, verbally. This report confirms the verbal recommendations.

6. MISCELLANEOUS:

The field work for this project was carried out during the period of January 10 to 17, 1973, under the supervision of Mr. B. T. Darch, Senior Foundations Engineer, who also wrote this report. This report was reviewed by Mr. M. Devata, Supervising Foundations Engineer.

The equipment used was owned and operated by the F. E. Johnston Drilling Company Limited, Ottawa.

B. T. Darch, P. Eng.

B. T. Darch, P. Eng.

M. Devata

M. Devata, P. Eng.

BTD/ao



APPENDIX I

DESIGN SERVICES BRANCH

FOUNDATION OFFICE

RECORD OF BOREHOLE NO C-1 & C-1A

JOB W.O. 72-11147 LOCATION Hwy. 138 - Station 26 + 43 o/s 6' LT.- c-1 ORIGINATED BY B.T.D.
 W.P. 35-66-05/9 BORING DATE January 10, 11, & 12, 1973 COMPILED BY B.T.D.
 DATUM Geodetic BOREHOLE TYPE Continuous Flight Hollow Stem Auger CHECKED BY [Signature]
C-1A - Vane Borehole Only

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F.					WATER CONTENT %				
							O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE					W_P W W_L				
230.6	Top Of Embank					200	400	600	800	1000					GR.SA.SI.CL.	
0.0	FILL															
	Clayey silt with sand & gravel		1	SS	21											
	or		2	SS	42											
	Het. Mix. of silt sand & gravel, trace of glacial till, (brown)		3	SS	29											
	compact to dense or		4	SS	24	220										
	very stiff to hard		5	SS	41											
	Silty Sand (brown)		6	SS	27											
			7	SS	19											
			8	SS	34											
			9	SS	19	210										
205.6	Loose to Compact		10	SS	10											
			11	SS	8											
25.0	Desicated Zone Firm		12	3"TW	PM											
	CLAY		13	SS	1											
	Trace of sand, (sensitive) grey		14	3"TW	PM	200										
			15	SS	-											
			16	2"TW	PM											
			17	SS	-											
			18	2"TW	PM											
			19	SS	-											
189.6	Soft to Firm		20	2"TW	PM	190										
41.0	Het. Mix. of silt sand & gravel with some clay, glacial till. Compact to dense or very stiff		21	SS	16											
	to hard.		22	SS	21											
179.6			23	SS	36	180										
51.0	End of Borehole															
						170										

▼ 211.5

In Open
BH

Jan. 11, 1973

OFFICE REPORT ON SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO C-2

JOB W.O. 72-11147

LOCATION Hwy. #138 - Station 26+26, o/s 13' RT

ORIGINATED BY B.T.D.

W.P. 35-66-05/9

BORING DATE January 12 & 15, 1973

COMPILED BY B.T.D.

DATUM Geodetic

BOREHOLE TYPE Continuous Flight Hollow Stem Auger

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT ——— w_L PLASTIC LIMIT ——— w_p WATER CONTENT — w w_p — w — w_L WATER CONTENT %			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F.									
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE									
230.0	Top of Embank						200	400	600	800	1000					GR.SA.SI.CL.
0.0	FILL Sand with some Gravel Compact		1	SS	18	220										<div>▼ 210.5</div> <div>W.L. In Open BH Jan. 15, 1973</div>
	FILL Clayey silt with Sand & Gravel Glacial Till Brown		2	SS	26											
			3	SS	18											
			4	SS	5	210										
208.5	Very stiff to stiff		5	SS	1	200										
21.5	CLAY Trace of Sand, (Sensitive) grey		6	3"TW	PM											
			7	2"TW	PM											
						190										
190.0	Soft to Firm		8	SS	17											
40.0	Clayey Silt with Sand & Gravel		9	SS	11											
184.0	Glacial Till, Very Stiff															
46.0	End of Borehole					180										

▼ 210.5

W.L. In
Open BH
Jan. 15,
1973


OFFICE REPORT ON SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE N^oC-3

JOB W.O. 72-11147 LOCATION Along ϕ of Existing Culvert Station 26+56, 0/s 10' RT ORIGINATED BY BTD
 W.P. 35-66-05/9 BORING DATE January 15, 1973 COMPILED BY BTD
 DATUM Geodetic BOREHOLE TYPE Continuous Flight Hollow Stem Auger CHECKED BY [Signature]

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT		LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W		BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F. ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE		WATER CONTENT % W_P W W_L			
230.2	Top of Embankment					230						
0.0	Embankment Fill					220						
213.0												
17.2	End of Borehole Top of Culvert					210						

OFFICE REPORT ON SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO C-4

JOB W.O. 72-11147

LOCATION Station 26+56, ϕ of Existing CulvertORIGINATED BY BTD

W.P. 35-66-05/9

BORING DATE January 15, 1973

COMPILED BY BTDDATUM GeodeticBOREHOLE TYPE Continuous Flight Hollow Stem AugerCHECKED BY OP.

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT		LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w		BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F. ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE		WATER CONTENT % w_p w w_L			
230.9	Top of Embankment					230						
0.0	Embankment	X				220						
	Fill											
212.5												
18.4	End of Borehole Top of Culvert					210						

OFFICE REPORT ON SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO C-5

Station 26+56, 0/s 17' LT

JOB W.O. 72-11147

LOCATION Along \varnothing of Existing Culvert

ORIGINATED BY BTD

W.P. 35-66-05/9

BORING DATE January 15, 1973

COMPILED BY BTD

DATUM Geodetic

BOREHOLE TYPE Continuous Flight Hollow Stem Auger

CHECKED BY BTD

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT				LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F. \circ UNCONFINED + FIELD VANE \bullet QUICK TRIAXIAL x LAB VANE				w_p	w	w_L		
230.7	Top of Embankment					230									
0.0	Embankment														
	Fill					220									
212.5															
18.2	End of Borehole Top of Culvert					210									

OFFICE REPORT ON SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO C-6

JOB W.O. 72-11147

LOCATION Along \varnothing of Existing Culvert, Station ²⁶⁺⁵⁶ o/s 55' LT

W.P. 35-66-05/9

BORING DATE January 16, 1973

ORIGINATED BY BTD

DATUM Geodetic

BOREHOLE TYPE Continuous Flight Hollow Stem Auger

COMPILED BY BTDCHECKED BY CP

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT				LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w				BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F. \circ UNCONFINED + FIELD VANE \bullet QUICK TRIAXIAL x LAB VANE				WATER CONTENT % w_p w w_L					
222.4	Top Berm															
0.0	Embankment Fill					220										
214.5																
7.9	End of BH Top of Culvert					210										

OFFICE REPORT ON SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE N^oC-7

JOB W.O. 72-11147

LOCATION Along ϕ of Existing Culvert Station 26+56. o/s 63' LT.W.P. 35-66-05/9BORING DATE January 16, 1973ORIGINATED BY BTDCOMPILED BY BTDDATUM GeodeticBOREHOLE TYPE Continuous Flight Hollow Stem AugerCHECKED BY [Signature]

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT		LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W		BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F. ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE		WATER CONTENT % W_P W W_L			
221.8	Top of Berm											
220.0	Embankment Fill	X				220						
214.5		X										
7.3	End of Borehole Top of Culvert					210						

OFFICE REPORT ON SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO C-8

JOB W.O. 72-11147 LOCATION Along ∇ of Existing Culvert Station 26+56, o/s 75' LT. ORIGINATED BY BTD
 W.P. 35-66-05/9 BORING DATE January 16, 1973 COMPILED BY BTD
 DATUM Geodetic BOREHOLE TYPE Continuous Flight Hollow Stem Auger CHECKED BY [Signature]

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT				LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W W_P W W_L WATER CONTENT %				BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F. ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE									
221.0	Top of Berm															
0.0	Embankment	X				220										
214.6	Fill	X														
6.4	End of Borehole Top of Culvert					210										

OFFICE REPORT ON SOIL EXPLORATION

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO C-9

JOB W.O. 72-11147

LOCATION Hwy. # 138- Station 26+35, 0/s 65' LT

ORIGINATED BY BTD

W.P. 35-66-05 19

BORING DATE January 16 & 17, 1973

COMPILED BY BTDDATUM GeodeticBOREHOLE TYPE Continuous Flight Hollow Stem AugerCHECKED BY [Signature]

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT ——— W_L PLASTIC LIMIT ——— W_P WATER CONTENT ——— W W_P ——— W ——— W_L WATER CONTENT %			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		SHEAR STRENGTH P.S.F. ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 200 400 600 800 1000									
221.5	Top of Berm															GR.SA.SI.CL.
0.0	FILL					220										
	clayey silt with sand & gravel		1	SS	18											
	glacial till		2	SS	26											
	very stiff		3	SS	32											
210.2	sand with some silt compact to dense		4	SS	12	210										
11.7	top soil		5	SS	14											
	desicated zone		6	SS	PM											
	very stiff to firm		7	SS	PM											
	Clay, trace of sand		8	2"TW	PM											
	sensitive grey															
	Soft to Firm					200										
192.3			9	2"TW	PM											
			10	SS	105	190										
29.2	End of Borehole probably glacial till															

OFFICE REPORT ON SOIL EXPLORATION

ABBREVIATIONS & SYMBOLS USED IN THIS REPORTPENETRATION RESISTANCE

'N'=STANDARD PENETRATION RESISTANCE : - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES INTO THE SUBSOIL, DRIVEN BY MEANS OF A 140 POUND HAMMER FALLING FREELY A DISTANCE OF 30 INCHES.

DYNAMIC PENETRATION RESISTANCE : - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 2 INCH, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS, 12 INCHES INTO THE SUBSOIL, THE DRIVING ENERGY BEING 350 FOOT POUNDS PER BLOW.

DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS :-

<u>CONSISTENCY</u>	<u>c LB./SQ. FT.</u>	<u>DENSENESS</u>	<u>'N' BLOWS / FT.</u>
VERY SOFT	0 - 250	VERY LOOSE	0 - 4
SOFT	250 - 500	LOOSE	4 - 10
FIRM	500 - 1000	COMPACT	10 - 30
STIFF	1000 - 2000	DENSE	30 - 50
VERY STIFF	2000 - 4000	VERY DENSE	> 50
HARD	> 4000		

TERMS TO BE USED IN DESCRIBING SOILS:-

TRACE < 10% , SOME 10-25% , WITH 25-40% , > 40% SILTY, SANDY, GRAVELLY, CLAYEY ETC.

TYPE OF SAMPLE

S.S.	SPLIT SPOON	T.W.	THINWALL OPEN
W.S.	WASHED SAMPLE	T.P.	THINWALL PISTON
S.T.	SLOTTED TUBE SAMPLE	O.S.	OESTERBERG SAMPLE
A.S.	AUGER SAMPLE	F.S.	FOIL SAMPLE
C.S.	CHUNK SAMPLE	R.C.	ROCK CORE

P.H. SAMPLE ADVANCED HYDRAULICALLY

P.M. SAMPLE ADVANCED MANUALLY

SOIL TESTS

U	UNCONFINED COMPRESSION	L.V.	LABORATORY VANE
UU	UNCONSOLIDATED UNDRAINED TRIAXIAL	F.V.	FIELD VANE
CIU	CONSOLIDATED ISOTROPIC UNDRAINED TRIAXIAL	C	CONSOLIDATION
CID	" " DRAINED "	S	SENSITIVITY
CAU	" ANISOTROPIC UNDRAINED "		
CAD	" " DRAINED "		

ABBREVIATIONS & SYMBOLS USED IN THIS REPORT

SOIL PROPERTIES

γ	UNIT WEIGHT OF SOIL (BULK DENSITY)
γ_s	UNIT WEIGHT OF SOLID PARTICLES
γ_w	UNIT WEIGHT OF WATER
γ_d	UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
γ'	UNIT WEIGHT OF SUBMERGED SOIL
G	SPECIFIC GRAVITY OF SOLID PARTICLES $G = \frac{\gamma_s}{\gamma_w}$
e	VOID RATIO
n	POROSITY
w	WATER CONTENT
S_r	DEGREE OF SATURATION
w_L	LIQUID LIMIT
w_p	PLASTIC LIMIT
I_p	PLASTICITY INDEX
w_s	SHRINKAGE LIMIT
I_L	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$
I_c	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$
e_{max}	VOID RATIO IN LOOSEST STATE
e_{min}	VOID RATIO IN DENSEST STATE
I_D	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
	RELATIVE DENSITY D_r IS ALSO USED
h	HYDRAULIC HEAD OR POTENTIAL
q	RATE OF DISCHARGE
v	VELOCITY OF FLOW
i	HYDRAULIC GRADIENT
k	COEFFICIENT OF PERMEABILITY
j	SEEPAGE FORCE PER UNIT VOLUME
m_v	COEFFICIENT OF VOLUME CHANGE = $\frac{-\Delta e}{(1+e)\Delta\sigma}$
c_v	COEFFICIENT OF CONSOLIDATION
C_c	COMPRESSION INDEX = $\frac{\Delta e}{\Delta \log_{10} \sigma}$
T_v	TIME FACTOR = $\frac{c_v t}{d^2}$ (d, DRAINAGE PATH)
U	DEGREE OF CONSOLIDATION
τ_f	SHEAR STRENGTH
c'	EFFECTIVE COHESION INTERCEPT
ϕ'	EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION
c_u	APPARENT COHESION
ϕ_u	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
μ	COEFFICIENT OF FRICTION
S_t	SENSITIVITY

GENERAL

π	= 3.1416
e	BASE OF NATURAL LOGARITHMS 2.7183
$\log_e \sigma$ OR $\ln \sigma$	NATURAL LOGARITHM OF σ
$\log_{10} \sigma$ OR $\log \sigma$	LOGARITHM OF σ TO BASE 10
t	TIME
g	ACCELERATION DUE TO GRAVITY
V	VOLUME
W	WEIGHT
M	MOMENT
F	FACTOR OF SAFETY

STRESS AND STRAIN

u	PORE PRESSURE
σ	NORMAL STRESS
σ'	NORMAL EFFECTIVE STRESS ($\bar{\sigma}$ IS ALSO USED)
τ	SHEAR STRESS
ϵ	LINEAR STRAIN
γ	SHEAR STRAIN
ν	POISSON'S RATIO (μ IS ALSO USED)
E	MODULUS OF LINEAR DEFORMATION (YOUNG'S MODULUS)
G	MODULUS OF SHEAR DEFORMATION
K	MODULUS OF COMPRESSIBILITY
η	COEFFICIENT OF VISCOSITY

EARTH PRESSURE

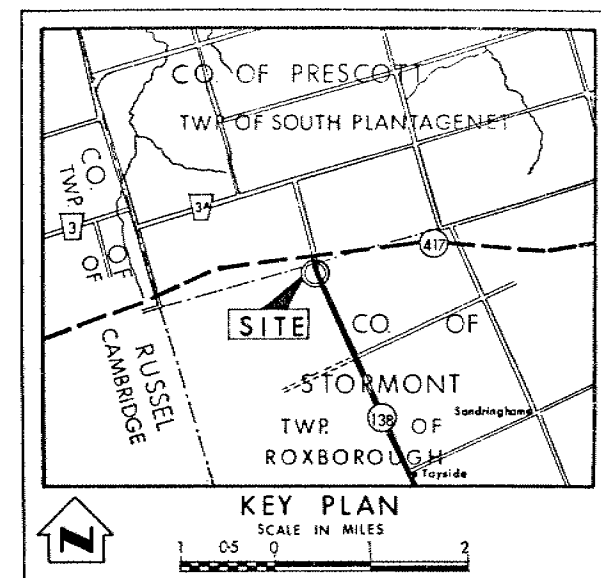
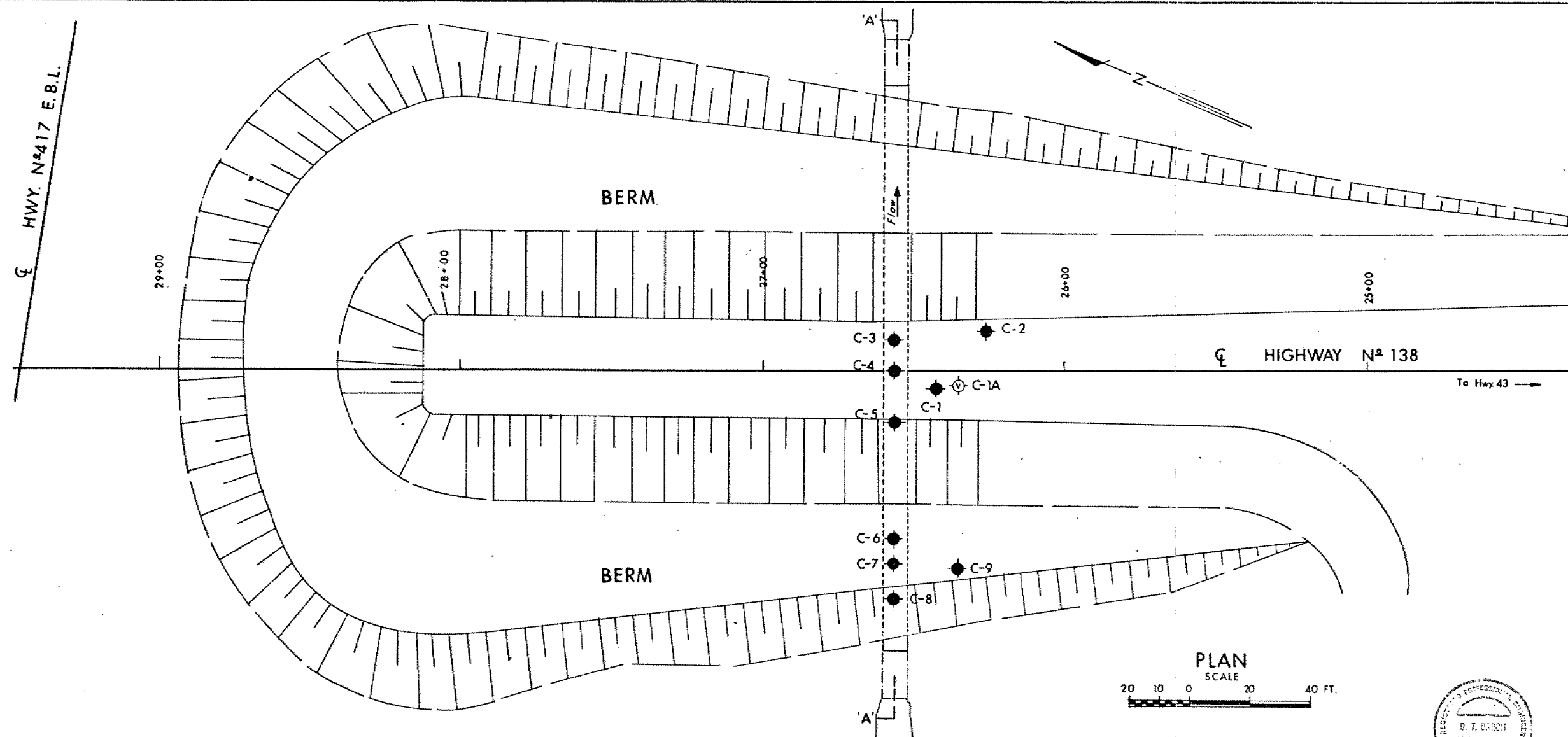
d	DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE
δ	ANGLE OF WALL FRICTION
K	DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS
K_0	COEFFICIENT OF EARTH PRESSURE AT REST

FOUNDATIONS

B	BREADTH OF FOUNDATION
L	LENGTH OF FOUNDATION
D	DEPTH OF FOUNDATION BENEATH GROUND
N	DIMENSIONLESS COEFFICIENT USED WITH A SUFFIX APPLYING TO SPECIFIC GRAVITY, DEPTH AND COHESION ETC. IN THE FORMULA FOR BEARING CAPACITY
k_s	MODULUS OF SUBGRADE REACTION

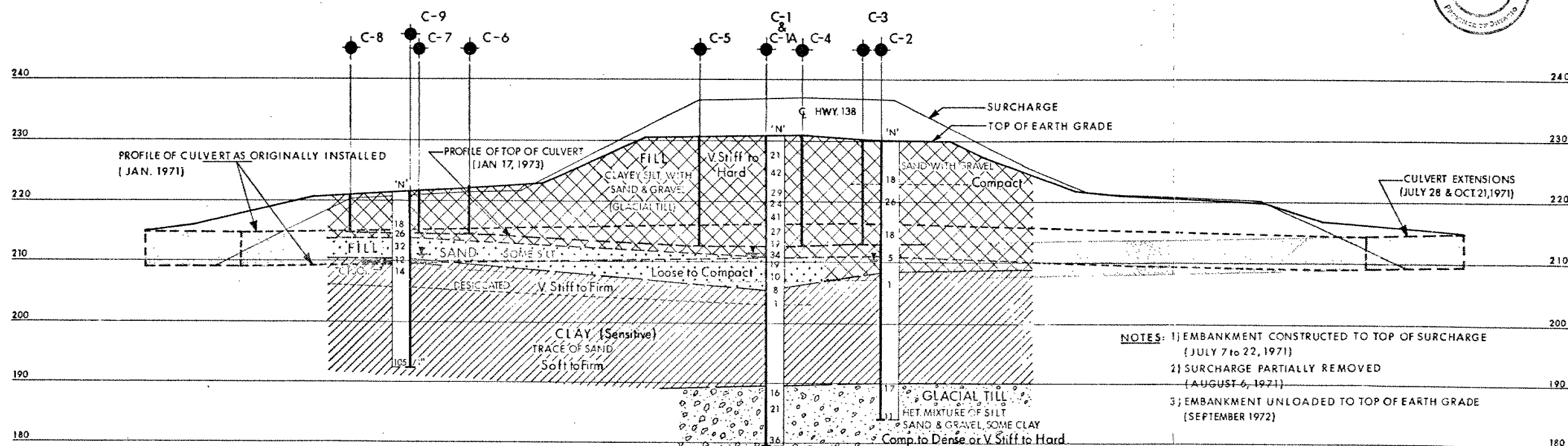
SLOPES

H	VERTICAL HEIGHT OF SLOPE
D	DEPTH BELOW TOE OF SLOPE TO HARD STRATUM
β	ANGLE OF SLOPE TO HORIZONTAL



LEGEND			
	Bore Hole		
	Cone Penetration Test		
	Bore Hole & Cone Test		
	Water Levels established at time of field investigation, JAN. 1973		
	Vane Test		

NO.	ELEVATION	STATION	OFFSET
C-1	230.6	26+43	6' LT.
C-1A	230.6	26+35	5' LT.
C-2	230.0	26+26	13' RT.
C-3	230.2	26+56	10' RT.
C-4	230.9	26+56	CL
C-5	230.7	26+56	17' LT.
C-6	222.4	26+56	55' LT.
C-7	221.8	26+56	63' LT.
C-8	221.0	26+56	75' LT.
C-9	221.5	26+35	65' LT.



- NOTES: 1) EMBANKMENT CONSTRUCTED TO TOP OF SURCHARGE (JULY 7 to 22, 1971)
2) SURCHARGE PARTIALLY REMOVED (AUGUST 6, 1971)
3) EMBANKMENT UNLOADED TO TOP OF EARTH GRADE (SEPTEMBER 1972)

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

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS - ONTARIO
DESIGN SERVICES BRANCH - FOUNDATIONS DEPT.

BOUNDARY MUNICIPAL DRAIN
(STATION 26+56)

HIGHWAY NO. 138 DIST. NO. 9
CO. STORMONT
TWP. ROXBOROUGH LOT 12 & 13 CON. 10

BORE HOLE LOCATIONS & SOIL STRATA

SUBMIT BTD	CHECKED	WP NO. 35-66-19	DRAWING NO.
DRAWN F.L.	CHECKED	WO NO 72-11147	72-11147A
DATE FEB. 9, 1973	SITE NO.	BRIDGE DRAWING NO.	
APPROVED	CONT. NO.		

PRINCIPAL FOUNDATION ENGINEER