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GEOCRES No. 31M-55

DIST. 17 REGION

W.P. No. 61-87-00

CONT. No.

W. O. No.

STR. SITE No.

HWY. No. 11

LOCATION HWY 11, TWP OF STRATHCONA  
(SOUTH OF TEMAGAMI)  
3 CULVERT EXTENSIONS

=====

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:



Ministry  
of  
Transportation

*FILE*

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## **FOUNDATION DESIGN SECTION**

**foundation  
investigation and  
design report**

**ENGINEERING MATERIALS OFFICE**  
**FOUNDATION DESIGN SECTION**

WP 61-87-00 DIST 54  
HWY 11 STR SITE -

Concrete Culvert Extensions  
Proposed Widening of Highway 11

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GEOCRES 31M-55

DATE MAR 15 1995

# FOUNDATION INVESTIGATION REPORT

for

Concrete Culvert Extensions  
Proposed Widening of Highway 11

W.P. 61-87-00

District 54, Sudbury

## INTRODUCTION

This report summarizes the information obtained from the foundation investigation carried out at three culvert sites along Highway 11. The locations of the culverts are shown on Figure 1 and described as follows:

Culvert No. 1, Sta. 11+227.7, Strathcona Township

Culvert No. 2, Sta. 14+389.8, Strathcona Township

Culvert No. 3, Sta. 18+926.1, Strathcona Township

The investigation was carried out upon the request of the Northern Region Structural Section for culvert extensions required for the proposed widening of Highway 11. The existing culverts are of non-rigid frame with open footings. The field work was carried out between 94 11 14 and 94 11 17. The work consisted of one (1) sampled borehole each at culvert locations 1 and 3, along with one (1) hand augered hole at culvert no. 3. Culvert no. 2 was inaccessible to the track mounted drill rig. However, the bedrock surface was determined by hand augering at the existing culvert inlet and visual inspection at three other locations along the proposed extension alignment. Dynamic cone penetration test was performed adjacent to the borehole advanced at culvert no. 1 location.

## SITE DESCRIPTION

All the three sites are located to the east of Highway 11, within approximately 2 to 9 kms south of Temagami, in the township of Strathcona, District of Nipissing.

According to the Northern Ontario Engineering Geology Terrain Study published by the Ministry of Natural Resources, the sites are located in an area of shallow bedrock knobs with organic terrain or ground moraine as the subordinate landform. The soil mantle above bedrock is predominantly peat or glacial till material.

Culvert no. 1 carries water from a swamp across the highway to Herridge Lake via a creek. The immediate area of the culvert inlet is swampy. The area surrounding the swamp is heavily wooded. The size of the culvert is 3.65 m X 1.52 m and the concrete face of the inlet has deteriorated with exposed rebars. There is no apparent signs of settlements at the culvert location although a transverse crack was noted on the

pavement near the culvert. The existing embankment slopes are  $2 \pm m$  high and standing at a gradient of about 2H:1V. Both the existing highway pavement and embankment appear to be in good shape in the vicinity of the culvert. There is no apparent land use outside the highway corridor.

Culvert no. 2 carries water from Little Lowell Lake across the highway to Diversion Lake. The existing highway embankment is  $10 \pm m$  high and composed of rock fill with rock blocks up to  $1 \pm m$  in size. The size of the culvert is 1.83 m X 1.83 m and the culvert appears to be in a good shape. A beaver dam is found about 3 to 4 meters from the inlet of the culvert and is damming up water to  $1 \pm m$  high. Massive rock outcrop can be found along the shore. The toe of the embankment is densely wooded. The existing rock fill slope is standing at 1.25H:1V to 1.5H:1V. Majority of the slope surface is barren. Some erosion gullies can be found near the top of the slope. There are longitudinal cracks on the pavement and shoulder of the highway at this location. There is no apparent land use outside the highway corridor.

Culvert no. 3 carries water from a swampy area across the highway to Jessie Lake. The culvert is 3.05 m X 1.52 m in size. The concrete at both ends of the culvert has deteriorated badly with exposed rebars. Looking through the opening, the culvert appears to be sagging in the transverse direction. There was a beaver dam about 4.5 m from the culvert inlet. Water was flowing rapidly over the beaver dam in a westerly direction. Exposed rock cuts can be found about 12 m south of the culvert. The area beyond the north side of the culvert becomes quite swampy. The highway embankment consisting of granular fill is about 1 m high on the south side of the culvert and increases to about 2 m to the north, standing at 1.5H:1V approximately. The pavement is generally in good shape with only a transverse crack about 3-4 m south of the culvert. Rock blocks were found alongside the creek and on the creek bed. At the time of the investigation, the water level is about 800 mm below the top of the culvert and water is about 600 mm deep at the culvert inlet. There is no apparent land use outside the highway corridor.

## INVESTIGATION PROCEDURES

Soil data and inherent properties were obtained by insitu and laboratory testing. The procedures employed are discussed below:

### Field

The field investigation work for the three culvert extensions was carried out between 94 11 14 and 94 11 17 and consisted of two sampled boreholes and one dynamic cone penetration test. Hand augering was also performed at two locations.

The two boreholes were advanced at culvert nos. 1 and 3 using conventional hollow stem augering techniques with a track mounted continuous flight auger machine. BH 11 was supplemented by a dynamic cone penetration test performed adjacent to it. The sampling program consisted of disturbed samples taken by split spoon sampler in accordance with Standard Penetration Test (ASTM D1586). Standard Penetration ('N') values were recorded for assessment of the denseness of the non-cohesive material encountered. Bedrock was cored at both hole locations. Wire line rock coring techniques were applied in retrieving rock core samples for rock quality determination and classification purposes. Standard NW core barrels and casings were used. All subsoil samples were identified in the field and returned to the laboratory for further examination and appropriate testing.

Culvert no. 2 lies beneath a 10 ±m rock fill embankment and is inaccessible to the track mounted machine. Even with a diamond drill and a raft, a large crane would have to be mobilized to lower the equipment down to the lake. With the numerous rock blocks lying on the lake bed around the culvert extension location, there would have been problem in setting the casings in the water. Accordingly, no drilling was carried out. Massive rock outcrops are evident about 9 m from the culvert. Bedrock is expected to be at the lake bed covered by some rock blocks from the fill slope. Hand augering was carried out at the existing culvert inlet to determine the probable rock surface. The elevations of the bedrock surface at 9, 10 and 12 m from the culvert were also determined by visual inspection.

BH 31 was advanced on the south side of the creek at culvert no. 3 location. As observed in the field, bedrock appeared to be dipping down from the exposed rock cut to the south of the culvert towards the swampy area to the north of the culvert. Accordingly, it was decided that the bedrock be probed on the north side of the culvert. However, due to the soft ground to the north, the drill rig could not advance to the north side of the culvert. Probing was therefore carried out by hand augering. Probable bedrock level was determined by auger refusal.

The field work at all the three sites was carried out at or very close to the free water surface. Water in the boreholes was therefore right at the surface. All boreholes were backfilled upon completion of the field work.

Surveying required to ascertain borehole locations and elevations was carried out by the Northern Region Survey and Plans Section.

#### Laboratory

The laboratory testing on selected soil samples consisted of the following:

- Grain Size Distribution

- Natural Moisture Content

Laboratory results are given in the following section of this report and are illustrated on Record of Borehole sheets included in the Appendix.

## SUBSURFACE CONDITIONS

### General

The Record of Borehole sheets in the Appendix illustrate the subsurface conditions at the borehole locations. The locations of the boreholes at each culvert site are shown on Figures 2 to 4.

At culvert no. 1 location, the subsurface stratigraphy as revealed in BH 11 comprises a 2 m thick organic peat layer overlying a 1.7 m thick non-cohesive glacial till deposit. Bedrock was encountered at 3.7 m depth (El. 314.6 m).

At culvert no. 2 location, no drilling was carried out. Hand augering at BH 21 location indicated probable bedrock at El. 324.1 m, some 0.5 m below the water surface. At the end of the proposed culvert extension, bedrock outcrops can be found above the water surface. Bedrock surface elevation was also determined at three locations which are at 9, 10 and 12 m from the culvert inlet. The elevations are El. 325.6, 326.6 and 326.7 m respectively.

At culvert no. 3 location, the subsurface stratigraphy as revealed in BH 31 comprises a 0.9 m thick of rock fill overlying bedrock at El. 303.6 m. Hand augering at BH 32 location indicated probable bedrock surface at El. 303.7 m.

Following are the specific descriptions of the material encountered in the investigation.

### Peat

This organic layer was contacted in BH 11. It basically consists of black organics with wood fibres and has a very soft consistency. The natural moisture content determined from laboratory testing carried out on one of the samples is very high, at 450.5%.

### Heterogeneous Mixture of Silt, Sand and Gravel

This non-cohesive deposit was encountered in BH 11 underlying the peat layer. Based

on the SPT 'N' values which range from 3 to 14 blows/0.3 m, the denseness of the material is very loose to compact. Laboratory testing carried out on a representative sample indicates a natural moisture content of 11% and a grain size distribution of 24% gravel, 40% sand and 36% silt and clay.

### Rockfill

This fill layer was contacted at the surface in BH 31. It basically consists of the blasted rock fragments that were pushed in during construction of the highway. Traces of sandy silt and organics are also found in the sample.

### Bedrock

Bedrock was cored in BH 11 at culvert no. 1 location from 3.66 to 6.12 m depth. It is a strong slightly weathered to unweathered Granite with interlayered Pegmatite and Meta-volcanic of the Superior Province. Core recoveries obtained are 100% and Rock Quality Designations range from 74 to 100%.

Bedrock was also cored in BH 31 at culvert no. 3 location from 0.91 to 3.10 m depth. It is a strong slightly weathered to unweathered Meta-volcanic of the Superior Province. Core recoveries obtained range from 96 to 100% and Rock Quality Designations range from 0 to 100%.

Rock cores from the field were examined and classified by MTO petrographer, D. Williams. Detailed descriptions of the rock are attached in the Appendix.

### Groundwater

During the time of the investigation, the water level in the creek was at El. 317.9 m at culvert no.1. At culvert no. 2, a beaver dam was damming up water about 3 to 4 m from the existing culvert inlet. The water level between the beaver dam and the culvert was at El. 324.6 m and it was at El. 325.6 m behind the dam. At culvert no. 3, the water level was at El. 304.6 m. Seasonal fluctuations in water levels are expected.



## DISCUSSION AND RECOMMENDATIONS

### General

Due to the proposed widening of Highway 11, it is required to extend the existing culvert at three site locations on the east side of the highway. The existing culverts are of non-rigid frame with open footings. Based on the assumed configurations from Planning and Design Section, the required length of culvert extension varies from 4 to 12 m. The thickness of fill above the culvert extension is approximately 2 m, 8 m and 1 m for culvert nos. 1 to 3 respectively.

### Foundation

#### Culvert no. 1 -

According to the investigation results, the bedrock at this location is overlain by a 2 m thick peat layer and a 1.7 m thick non-cohesive glacial till stratum. The till layer is in a loose state. It is recommended to support the culvert extension on shallow footings founded on the till stratum at El.  $316.0 \pm m$ . This depth would generally be sufficient to provide a 2 m earth cover for the required frost protection. For footings founded on the till material, the following design capacities are recommended as per O.H.B.D.C.:

Factored Bearing Capacity at U.L.S. = 350 kPa  
Bearing Capacity at S.L.S. = 150 kPa

The recommended design bearing capacity at S.L.S. corresponds to an estimated settlement of up to 23 mm due to compression of the loose wet non-cohesive till material. Majority of the settlement will occur on completion of culvert construction and placement of fill above it. The structural joint at the new/existing culvert interface should be designed to accommodate this movement.

#### Culvert no. 2 -

No drilling was done at culvert #2 location. However, bedrock is estimated to be at El.  $324.0 \pm m$  at the existing culvert inlet based on hand augering. Massive rock outcrops can be found above the water surface. Bedrock surface elevations were determined to be at El.  $325.5 \pm m$  at 9 m from the existing culvert and at El.  $326.5 \pm m$  from 10 m to 12 m. It is envisaged that bedrock is close to the lake bed between the existing culvert and the rock outcrop mentioned above, although no probing was carried out due to the water

depth (about 1 m) and obstructions from beaver dam and the rock fill lying at the lake bed. The exact rock profile has to be determined during construction. It is believed that some rock excavation has to be carried out. For footings founded on bedrock, the following design capacities are recommended in accordance with the O.H.B.D.C.:

Factored Bearing Capacity at U.L.S. = 10,000 kPa  
Bearing Capacity at S.L.S. does not govern

For shallow footings founded on rock, no frost protection is required. The founding surface should be formed reasonably flat. If rock surface is dipping at an angle across the footing area below the proposed founding elevation, it should preferably be benched or roughened and the overexcavation be filled with mass concrete to the required elevation. The sliding resistance between concrete and bedrock may be calculated using an unfactored value of 35°, provided the bedrock surface is generally rough. The sliding resistance can be increased by means of rock dowels.

#### Culvert no. 3 -

According to the investigation results, bedrock exists near the ground surface at El. 303.5 ±m. It is recommended that the extension of the culvert be founded on bedrock. Depending on the proposed elevation of the culvert, some rock excavation may be required. For shallow footings founded on bedrock, no frost protection is required. The following design capacities are recommended in accordance with O.H.B.D.C.:

Factored Bearing Capacity at U.L.S. = 10,000 kPa  
Bearing Capacity at S.L.S. does not govern

#### Construction Considerations

##### Culvert no. 1 -

The non-cohesive glacial till stratum is susceptible to disturbance under unbalanced hydrostatic heads. For the construction of the culvert, prior creek diversion and advance dewatering will be required to draw the water level down below the footing elevation before excavation is carried out. Conventional method of oversized excavation with sump pumping in perimeter ditches may be used. However, if this method cannot draw the water table down to a satisfactory level due to the relatively high permeability of the till layer, interlocking sheetpiles can be driven around the perimeter of the proposed extension down to bedrock as cut-off walls. Excavation and dewatering can be carried out within the sheetpile cofferdam. Since the sheetpiles are driven to bedrock, no piping problem is envisaged. However, the stability of the cofferdam has to be checked and strutting may be required to support the cofferdam. Once the structure extension is

completed and backfilling done, the sheetings can be extracted. It is not known where the existing footings are founded at. It is probable that they are founded within the till stratum. Where excavation comes close to the existing culvert, precautionary measures should be taken to prevent undermining of the existing footings. Although the flow of water was slow as observed during the investigation, it may be prudent to protect the footings from scouring with rip raps.

#### Culvert no. 2 -

As discussed before, no drilling was carried out at this site due to access problems. The bedrock elevation at both ends of the proposed extension was determined by hand augering and visual observation. In general, the actual bedrock profile along the extension has to be determined during construction. After removal of the existing beaver dam, it is envisaged that a steel caisson (box) can be employed for temporary works. The gaps between the steel caisson and the bedrock have to be sealed and the area inside dewatered for the construction of footings. Any irregularities of the bedrock level can either be trimmed or filled with concrete to the required footing founding elevations. It is believed that the existing footings are founded on bedrock. However, excavation should not be taken below the existing footing base to avoid undermining of the footings.

#### Culvert no. 3 -

The creek has to be temporarily diverted prior to construction. A steel caisson can be used to contain the area for dewatering. Bedrock appears to be reasonably flat at this location. Any irregularities in bedrock profile along the extension can either be trimmed or filled with concrete to the required elevations. It is envisaged that the existing footings are founded on bedrock. However, excavation should not be taken below the existing footing base to avoid undermining of the footings.

#### Approach Slopes

All organic material should be removed prior to placement of fill for the approach slopes. Only relatively free draining granular material should be used under water. The existing slopes should be benched in accordance with OPSD 208.01 to receive the new fill. For culverts 1 and 3, earth slopes should be constructed at 2H:1V and rock fill slopes at 1.5:1V or flatter. The maximum slope height is about 4 m. For culvert 2, rock fill should be used. Rock fill can be constructed at a gradient of 1.25H:1V or flatter up to 6 m and with a 2 m berm every 6 m up to a maximum height of 12 m.

For earth fill slopes, slope protection by means of vegetation cover should be established as soon as possible after formation of the slopes. Culvert inlet treatment in the form of rip-raps or stone-pitching is recommended to prevent erosion and scouring. This is not

required in the case of rock fill.

### Backfill

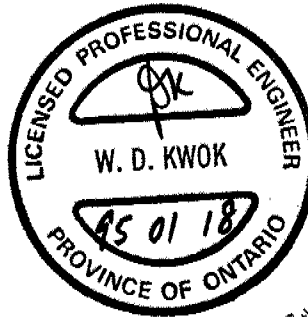
Backfill to culvert walls should consists of granular material in accordance with MTO Standard Special Provision No. 109F03 (92 03). It is envisaged that rock fill will be used at culvert no. 2. Computation of earth pressure shall be in accordance with Section 6.7.4 of the O.H.B.D.C. Unfactored properties for backfill materials are provided as follows:

<u>Material</u>	$\phi$	$\gamma$
Granular 'A'	35°	22.8 kN/m <sup>3</sup>
Granular 'B'	30°	21.2 kN/m <sup>3</sup>
Rockfill	35°	18.0 kN/m <sup>3</sup>

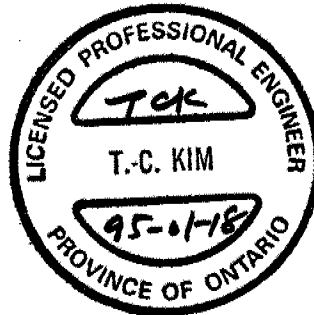
MISCELLANEOUS

The field work for this investigation was carried out under the joint supervision of D. Kwok, Project Foundation Engineer and D. Duke, Pavement Design and Evaluation Engineer. The equipment was owned and operated by Dominion Soil Investigation Inc. Bedrock was examined and classified by MTO petrographer D. Williams.

This report was prepared by D. Kwok, reviewed and approved by T. Kim, Senior Foundation Engineer.



  
D. Kwok, P. Eng.  
Project Foundation Engineer



  
T. Kim, P. Eng.  
Senior Foundation Engineer

## **APPENDIX**

# RECORD OF BOREHOLE No 11

1 OF 1

METRIC

W.P. 61-87-00 LOCATION Ste. 11+217.3 o/s 17.1 m Rt. C.L. of Hwy 11 ORIGINATED BY DK  
DIST 54 HWY 11 BOREHOLE TYPE Cone Test, H.S. Auger, NW Core Barrel COMPILED BY DD  
DATUM Geodetic DATE 94 11 17 CHECKED BY TK

SOIL PROFILE			SAMPLES			GROUND WATER ↓ CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES								
318.3	Ground Surface												
0.0	Black Organics Fibrous Very Soft (Peat)		1	SS	0		318						
316.3			2	SS	14		317					w=450.5	
2.0	Heterogeneous Mixture of Sand, Silt and Gravel Grey Very Loose		3	SS	3		316						24 40 (36)
314.6			4	SS	5		315						
3.7			5	RC	REC	100%	314						RQD 74%
			6	RC	REC	100%	313						RQD 88%
	Bedrock		7	RC	REC	100%							RQD 100%
312.2													
6.1	End of Borehole												
	* 94 11 17												

# RECORD OF BOREHOLE No 21

1 OF 1

METRIC

W.P. 61-87-00 LOCATION Sta 14+389.8 o/s 14.6 m Rt along skew of culvert ORIGINATED BY DK  
 DIST 54 HWY 11 BOREHOLE TYPE Hand-auger COMPILED BY DD  
 DATUM Geodetic DATE 94 11 17 CHECKED BY TK

SOIL PROFILE			SAMPLES			GROUND WATER • CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100									
324.6	Water Surface																
0.0																	
324.1																	
0.5	End of Borehole  • 94 11 17  ** Auger refusal on Probable Bedrock	**															



# RECORD OF BOREHOLE No 31

1 OF 1

METRIC

W.P. 61-87-00 LOCATION Sta. 18+924.4 o/s 12.2 m Rt. C.L. of Hwy 11 ORIGINATED BY DK  
DIST 54 HWY 11 BOREHOLE TYPE S.S. Auger, NW Core Barrel COMPILED BY DD  
DATUM Geodetic DATE 94 11 15 - 94 11 16 CHECKED BY TK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40					
304.5	Ground Surface													
0.0	Broken Rock Fragments trace of Sandy Silt and Organics Olive Green (Rock Fill)		1	SS	80	/23cm								
303.6			2	RC	REC	100%								
0.9			3	RC	REC	96%								
	Bedrock		4	RC	REC	100%								
301.4			5	RC	REC	100%								
3.1	End of Borehole													
	• 94 11 15													

# RECORD OF BOREHOLE No 32

1 OF 1

METRIC

W.P. 61-87-00 LOCATION Sta. 18+926.7 e/s 8.3 m Rt. C.L. of Hwy 11 ORIGINATED BY DK  
 DIST 54 HWY 11 BOREHOLE TYPE Hand-auger COMPILED BY DD  
 DATUM Geodetic DATE 94 11 15 CHECKED BY TK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100	w <sub>p</sub>	w	w <sub>L</sub>		
304.8	Ground Surface																
0.0	Broken Rock Fragments with Organics (Rock Fill)																
303.7																	
1.1	End of Borehole Probable Bedrock																
	* 94 11 15																

# ROCK CORE DESCRIPTION

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Page 1 of 1

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
11	5	3.66-4.19	100	74	3.66-6.12	<b>GRANITE</b> , yellowish grey to moderate orange pink to moderate reddish orange, with interlayered moderate orange pink <b>PEGMATITE</b> (8%) and dark greenish grey to greenish black <b>META-VOLCANIC</b> (6%); coarse grained; strong; unweathered to slightly weathered; fractures wide to close spaced, dipping to flat, undulating to planar, smooth to rough.
	6	4.19-4.60	100	88		
	7	4.60-6.12	100	100		
31	2	0.91-1.07	100	0	0.91-3.10	<b>META-VOLCANIC</b> (agglomeratic), light greenish grey to dark greenish grey; fine grained; strong; unweathered to slightly weathered; fractures moderate to close spaced, near vertical to flat, undulating to planar, smooth to rough.
	3	1.07-1.68	96	92		
	4	1.68-2.49	100	100		
	5	2.49-3.10	100	100		

\*CR = CORE RECOVERY

\*RQD = ROCK QUALITY DESIGNATION

*Note: Depths are approximated where core recovery is less than 100%*  
 Logged by: DAW, Soils and Aggregates Section

## 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 (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	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

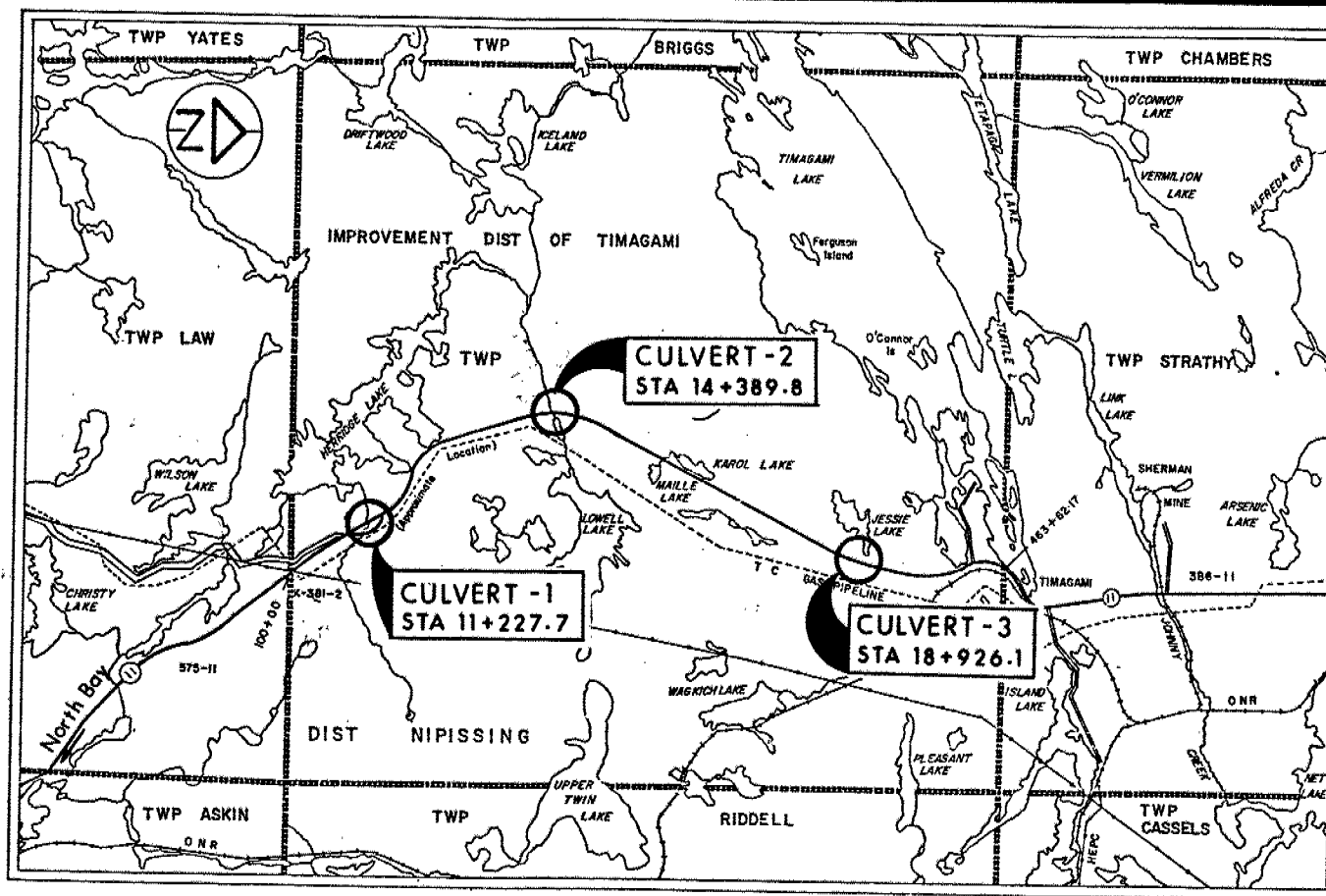
$u_w$	kPa	PORE WATER PRESSURE
$r_u$	1	PORE PRESSURE RATIO
$\sigma$	kPa	TOTAL NORMAL STRESS
$\sigma'$	kPa	EFFECTIVE NORMAL STRESS
$\tau$	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
$\epsilon$	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS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

### MECHANICAL PROPERTIES OF SOIL

$m_v$	kPa <sup>-1</sup>	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	m <sup>2</sup> /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_t$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	kg/m <sup>3</sup>	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	$e_{min}$	1, %	VOID RATIO IN DENSEST STATE
$\gamma_s$	kN/m <sup>3</sup>	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	$I_D$	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
$\rho_w$	kg/m <sup>3</sup>	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
$\gamma_w$	kN/m <sup>3</sup>	UNIT WEIGHT OF WATER	$S_r$	%	DEGREE OF SATURATION	$D_n$	mm	n PERCENT - DIAMETER
$\rho$	kg/m <sup>3</sup>	DENSITY OF SOIL	$w_L$	%	LIQUID LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\gamma$	kN/m <sup>3</sup>	UNIT WEIGHT OF SOIL	$w_p$	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
$\rho_d$	kg/m <sup>3</sup>	DENSITY OF DRY SOIL	$w_s$	%	SHRINKAGE LIMIT	q	m <sup>3</sup> /s	RATE OF DISCHARGE
$\gamma_d$	kN/m <sup>3</sup>	UNIT WEIGHT OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
$\rho_{sat}$	kg/m <sup>3</sup>	DENSITY OF SATURATED SOIL	$I_L$	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
$\gamma_{sat}$	kN/m <sup>3</sup>	UNIT WEIGHT OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
$\rho'$	kg/m <sup>3</sup>	DENSITY OF SUBMERGED SOIL	$e_{max}$	1, %	VOID RATIO IN LOOSEST STATE	j	kn/m <sup>3</sup>	SEEPAGE FORCE
$\gamma'$	kN/m <sup>3</sup>	UNIT WEIGHT OF SUBMERGED SOIL						



KEY PLAN  
SCALE  
1km 0 1km

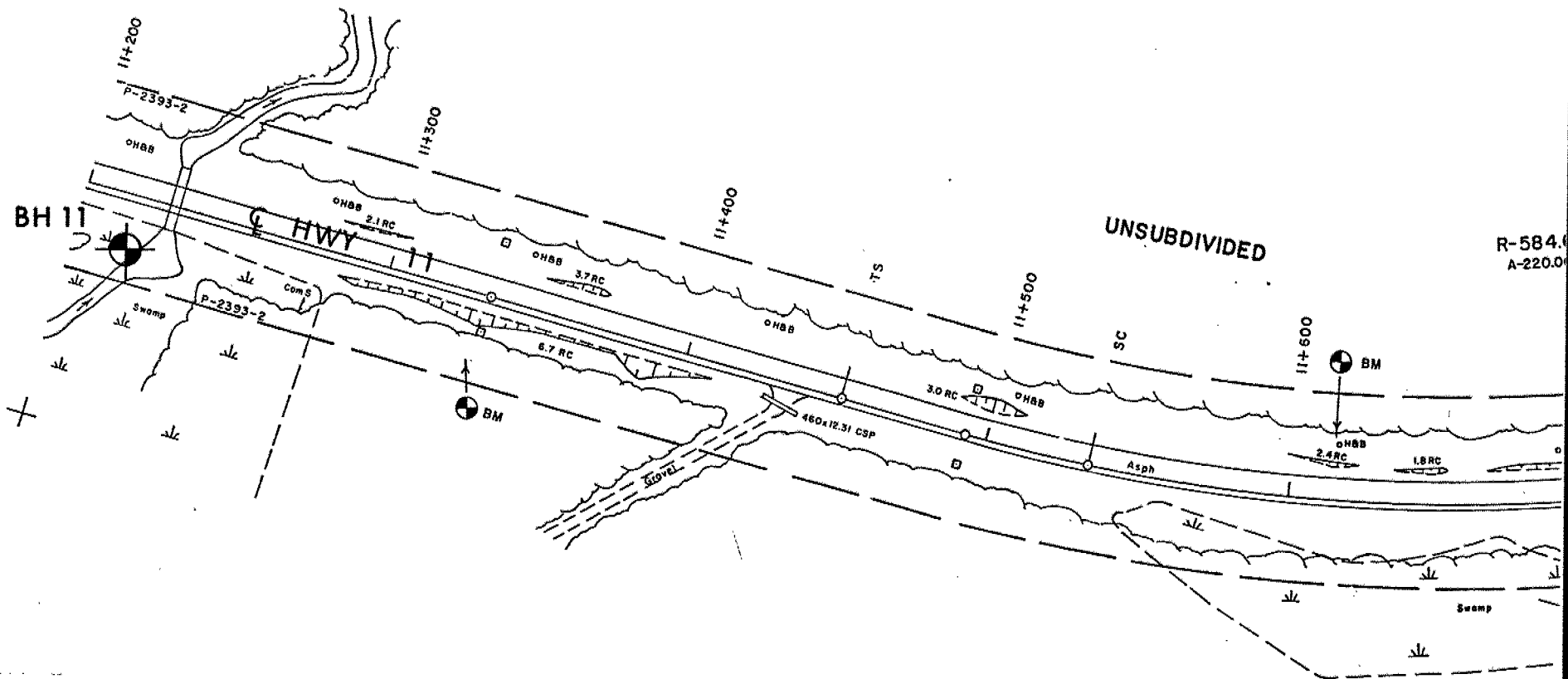
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Dist 54

Figure No 1



## CULVERT No 1



### NOTE:

For Subsoil information  
refer to Record of  
Borehole Sheets.

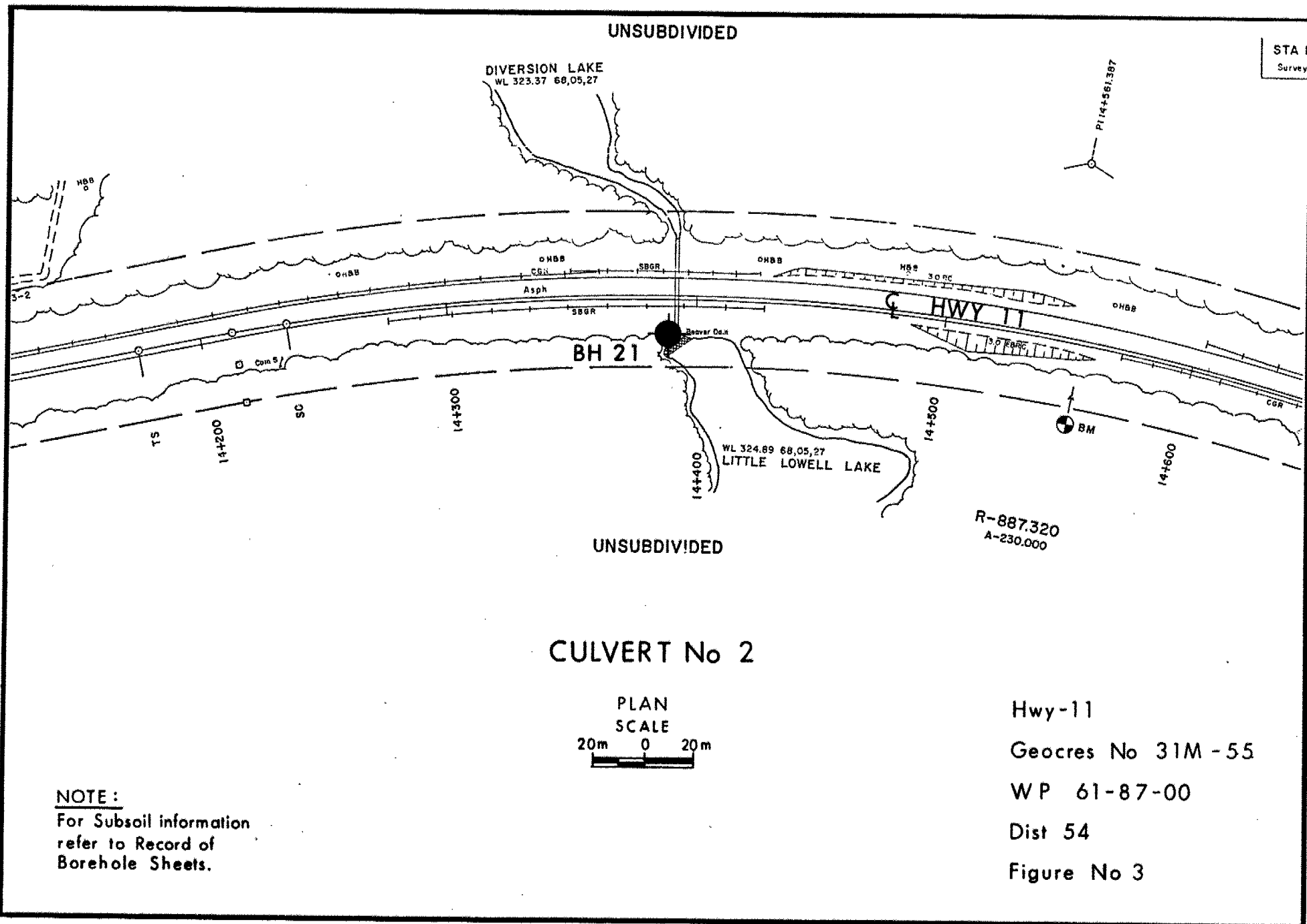
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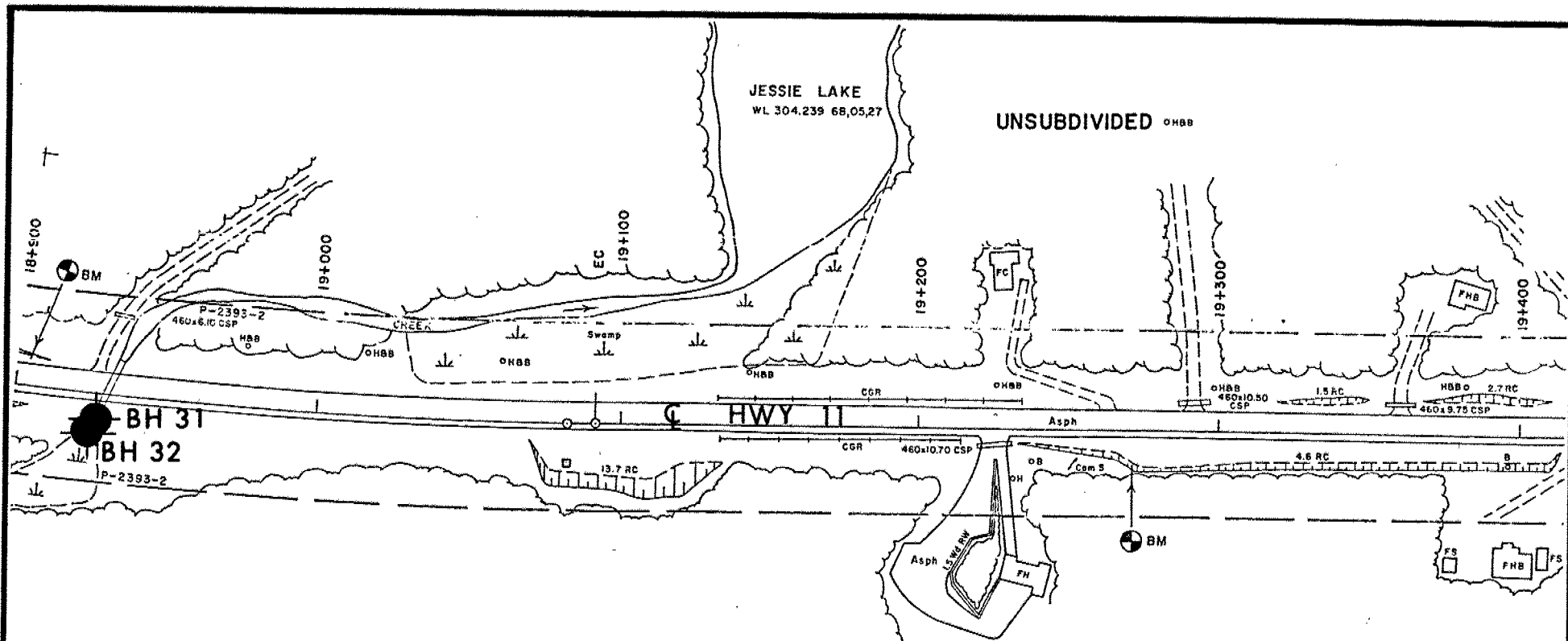
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Dist 54

Figure No 2





## CULVERT No 3



### NOTE :

For Subsoil information  
refer to Record of  
Borehole Sheets.

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Figure No 4