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LOCATION Moon River Bridge

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Trow

GEOCRES 31E-161

Foundation Investigation Report
Moon River Bridge
Southbound Lanes Bridge, Site 42-26S
W.P. 216-90-01
Highway 69, District 52
Huntsville, Ontario

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Trow

Preface

Work Project 216-90-01 is one of a series of projects for the four lane expansion of Highway 69. This project is located from 0.4 km south of the Musquash River, northerly 8.9 km to Tower Road, within the MTO Northern Region, District 52, Huntsville.

It is located in the former Townships of Gibson, Freeman and on the Whata Mohawk First Nation Lands in the present Township of Georgian Bay, District of Muskoka. This project includes:

- the construction of new Southbound Lanes
- rehabilitation of the existing highway to divided freeway standards to become the Northbound Lanes
- construction of a replacement bridge over the Musquash River for the Northbound Lanes
- construction of a bridge over the Musquash River for the Southbound Lanes
- construction of a diamond interchange at the intersection of Cranberry Marsh Road and Highway 69
- construction of a bridge over the Moon River for the Southbound Lanes
- construction of associated side roads resulting from the creation of the controlled access highway
- construction of a diamond interchange at the intersection of Cranberry Marsh Road and Highway 69

The following report comments on the foundation investigation and subsequent engineering recommendations for the Southbound Moon River Bridge.

Other associated Geotechnical, Foundation and Pavement Reports for this project include:

- Foundation Investigation Report, Approach Embankments, Southbound Lanes, Musquash River, MTO Foundation Section, March 1993
- Pavement Design report, Trow Consulting Engineers Ltd., January 1998
- Foundation Investigation Report, Musquash River, Northbound Lanes Replacement Bridge, Site 42-46N, Trow Consulting Engineers Ltd., January 1998
- Foundation Investigation, Musquash River, Southbound Lane Bridge, Site 42-465, MTO Foundation Section, March 1993
- Foundation Investigation Report, Cranberry Marsh Road Interchange, Site 42-318, Trow Consulting Engineers Ltd., January 1998

- Foundation Investigation Report, Moon River, Southbound Lane Bridge, Site 42-265, Trow Consulting Engineers Ltd., January 1998

Forthcoming reports include:

- Foundation Investigation Report, Muskoka Road 12 Interchange, Trow Consulting Engineers Ltd., Spring 1998.
- Supplemental Pavement Design Report, Trow Consulting Engineers Ltd., Spring, 1998.

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PART 1 Foundation Investigation

1.1 Introduction

This submission presents the results of a geotechnical investigation completed by Trow Consulting Engineers Ltd. (Trow) for the Moon River Bridge, WP 216-90-01, Highway 69, District 52, Gibson Township.

A new two lane, bridge consisting of either three or four spans has been proposed for the southbound lanes of Highway 69 at the Moon River crossing. This report applies to the proposed bridge structure and the approaches within approximately 20 metres of the bridge abutments between stations 25+400± to 25±545±.

1.2 Site Description and Geological Setting

1.2.1 Site Description

The site is located in the former Gibson Township (Lot 13, District of Muskoka) along Highway 69 at the Moon River between stations 25+400± and 25+545±. Figure 1 shows the site location plan. The existing Highway 69 consists of a two lane road which carries both north and southbound traffic across the Moon River on an existing simply supported through truss bridge.

A three span or four span bridge has been proposed to carry southbound traffic across the Moon River. The centreline of the new southbound Moon River Bridge is located approximately 35m west of the existing Moon River Bridge centreline. The north approach grades to the new bridge will be raised by up to 8 metres near the new north abutment and the existing grades for the south approach will be lowered by 1 to 2 metres.

The general terrain in the area of the proposed river crossing is moderately undulating consisting of rock outcrops of gneissic bedrock separated by intervening marshy zones and wooded areas. The Moon River is approximately 40 to 50 metres wide and flows west toward Georgian Bay and at the time of the initial investigation, the Moon River water level was found to fluctuate with an average approximate elevation of 202.3 m.

The north bank to the Moon River at the location of the proposed new bridge is approximately 5 m in height and sloped at a gradient of approximately 1.8 to 2 horizontal to 1 vertical. Photograph 1 shows the north bank of the Moon River and the north abutment of the existing Moon River Bridge. A small creek or tributary to the Moon River flows from north to south near the location of the proposed north abutment and pier. This creek drains a low lying marshy area which extends below the plan limits of the proposed north abutment and north approach embankment for the 3 span bridge option. Photograph 1 shows the creek outlet at the north bank of the Moon River and Photograph 2 shows the current creek alignment looking south toward the Moon River. To construct a new 3 span bridge at the site, the creek will be diverted and a concrete box culvert has been proposed to handle the creek flow. The location of the creek discharge point (waterfall), however, will remain unchanged due to environmental constraints.

The south bank of the Moon River at the location of the proposed new bridge is approximately 15 metres in height and sloped at a gradient which varies between 3.5 horizontal to 1 vertical and 2.5 horizontal to 1 vertical. Photograph 3 shows the south bank of the Moon River and the existing south abutment of the existing bridge.

Both the north and south banks are well vegetated with a mixture of young and mature trees (see Photographs 1, 2 and 3).

1.2.2 Geological Setting

According to OGS Maps 2544 and 2556, the site is located in what is known as the central gneiss belt. The bedrock at the site consists of Precambrian gneisses of metasedimentary origin. As previously noted, the topography in the area is undulating with frequent bedrock outcrops. As such, the surface soils in the area consist of intervening shallow organic deposits (peat, muck and marl), and glaciofluvial deposits consisting of gravel and sand including proglacial river and deltaic deposits.

1.3 Investigative Procedures

1.3.1 General

The field work for the proposed southbound Moon River Bridge was carried between November 11 and November 25, 1997, and between March 10 and March 20, 1998. The initial phase of the investigation consisted of Eight (8) boreholes, three (3) cone holes, and six (6) auger probe holes in total which were advanced at the site using equipment owned and operated by Master Soil Investigation Ltd. Drawing 1 (Appendix B) shows the site plan and the borehole, cone hole and auger probe locations. The borehole logs, cone logs and auger probe logs are attached in Appendix C.

An additional geotechnical investigation was conducted between March 10 and March 20, 1998, to further investigate the foundation and approach embankment alternatives for the north abutment. As previously noted, both three and four span options are being considered for the site. The additional field investigation for the Southbound Moon River Bridge consisted of sixteen (16) boreholes which were advanced at the site using equipment owned and operated by Longyear Canada Inc. The borehole logs are attached in Appendix C and Drawing 2 (Appendix B) shows the site plan and borehole locations for the additional field investigation. Table 1-1 below summarizes all boreholes, cone holes, and auger probe holes drilled at the Moon River site.

All field work was supervised by a member of Trow's engineering staff who directed the drilling and sampling operations, logged the factual borehole data, and retrieved soil and rock core samples for subsequent laboratory testing and identification. All borehole elevations were provided by Mr. P. Collie of Dennis Consultants, a division of R.V. Anderson (RVA), and are referenced to geodetic. The following is a discussion of the field procedures used for the boreholes drilled at the location of the bridge abutments and bridge piers, respectively.

Table 1-1 Summary of Boreholes

Borehole Number	Depth (m)	Location	Foundation Element
1	5.6	25+416.092	• South Abutment
2	8.4	25+442.159	• South Pier
3	5.9	25+486.190	• North Pier
4	5.0	25+523.830	• North Abutment - 3 Span Option • North Pier - 4 Span Option
5	11.8	25+529.099	• North Abutment - 3 Span Option • North Pier - 4 Span Option
6	3.7	25+485.456	• North Pier
7	6.6	25+444.030	• South Pier
8	1.3	25+419.637	• South Abutment
AP-1	7.6	25+525.859	• North Abutment
AP-2	0.9	25+506.789	• North Approach Embankment - 3 Span Option
AP-3	1.8	25+502.821	• North Approach Embankment - 3 Span Option
AP-4	1.4	25+414.261	• South Abutment
AP-5	2.5	25+400.642	• South Approach
AP-6	0.6	25+404.157	• South Approach
Cone - 1		25+535.333	• North Approach Embankment - 3 Span Option
Cone - 2		25+526.086	• North Abutment
Cone - 3		25+515.879	• North Approach Embankment - 3 Span Option
Additional Investigation - March 10 to March 20 (1998) - Drawing 2 Appendix B			
101	3.3	N/A	• New Culvert Alignment
102	5.2	N/A	• New Culvert Alignment

Table 1-1 Summary of Boreholes

Borehole Number	Depth (m)	Location	Foundation Element
103	9.2	N/A	• New Culvert Alignment
104	8.3	N/A	• New Culvert Alignment
105	1.9	N/A	• New Culvert Alignment
106	7.6	N/A	• New Culvert Alignment
107	2.4	N/A	• New Culvert Alignment
201	10.4	25+552.000	• North Abutment - 4 Span Option - 26 m Span
202	14.2	25+552.000	• North Abutment - 4 Span Option - 26 m Span
203	14.6	25+552.000	• North Abutment - 4 Span Option - 26 m Span
204	17.3	25+558.000	• North Abutment - 4 Span Option - 26 m Span
301	5.2	25+544.000	• North Approach Embankment
302	5.9	25+544.000	• North Approach Embankment
303	5.3	25+544.000	• North Approach Embankment
401	1.4	25+588.000	• North Approach Embankment
402	3.2	25+568.000	• North Approach Embankment

1.3.2 Field Investigation - North and South Bridge Abutments - Three Span Option

The geotechnical investigation for the proposed north and south bridge abutments for the three (3) span bridge option was carried out between November 19 and 25, 1997. The investigation consisted of four (4) boreholes which were advanced to depths ranging from 1.25 metres to 11.8 metres. Two (2) boreholes were drilled near each of the north (Boreholes 4 and 5) and south (Boreholes 1 and 8) abutments. In addition, three (3) auger probe holes were also drilled near each of the north (Auger Probe AP-1, AP-2 and AP-3) and south (Auger Probe AP-4, AP-5 and AP-6) approaches and three (3) cone holes were advanced near the north abutment and north approach. As previously noted, the borehole, cone hole and auger probe hole locations are shown on Drawing 1 in Appendix B. The subsurface logs are attached in Appendix C and Table 1-1 contains a summary of the boreholes advanced at the site.

The boreholes for the north and south abutments were advanced through the overburden soils using a truck mounted CME-55 drill rig equipped with hollow stem augers. Soil samples were obtained using a standard 51mm O.D. split spoon sampler in conjunction with Standard Penetration Tests (ASTM D1586) at approximately 0.75 metre and 1.5 metre intervals. The Standard Penetration N-values were recorded and used to provide an assessment of the relative denseness of the overburden soils at the site and the soil samples were used for identification and laboratory testing.

Field vane tests were conducted at selected depths to obtain an estimate of the undrained shear strength of the soft clayey soils encountered at the bridge site during the drilling program. In addition, shelby tube samples of the clayey soils were retrieved for subsequent laboratory consolidation testing.

Conventional rock coring techniques were used to advance the boreholes approximately 2.8 m, and 3.1 m into the underlying bedrock at Boreholes 1 and 5, respectively. Standard B-size core barrels and N-size casings were used and core samples of the bedrock were retrieved for rock quality determinations and classification purposes.

1.3.3 Field Investigation - North and South Bridge Piers - Three Span Option

The geotechnical investigation for the bridge piers was carried out between November 11 and 21, 1997, and consisted of four (4) boreholes which were advanced to depths ranging from 3.7 metres to 8.4 metres. Two (2) boreholes were drilled near each of the north (Boreholes 3 and 6) and south (Boreholes 2 and 7) piers as indicated on Drawing 1 (see Appendix B). The borehole logs are attached in Appendix C of this report and Table 1-1 contains a summary of the boreholes drilled at the site.

The boreholes for the north and south piers were advanced through the overburden soils using a D-25 (Deitric) drill rig equipped with hollow stem augers. Photograph 4 (Appendix A) shows the raft used to drill Borehole 6 at the location of the north pier. Soil samples were obtained using a standard 51mm O.D. split spoon sampler in conjunction with Standard Penetration Tests (ASTM D1586) at approximately 0.75 metre and 1.5 metre intervals when practical. The Standard Penetration N-values were recorded and used to provide an assessment of the relative denseness of the overburden soils at the site and the soil samples were used for identification and laboratory testing. At Boreholes 3, 6 and 7, B-size core barrels and N-size casings were used to advance the boreholes through the overburden soils and to retrieve soil samples below elevations 205.7 m, 202.8 m and 199.7 m, respectively.

Conventional rock coring techniques were used to advance Boreholes 2, 3, 6 and 7 approximately 3.1m, 2.0m, 1.8m and 1.7m into the underlying bedrock, respectively. Standard B-size core barrels and N-size casings were used and core samples of the bedrock for rock quality determinations and classification purposes.

1.3.4 Additional Field Investigation - North Approach and North Abutment

The additional geotechnical investigation for the north approach was carried out between March 10 and March 20, 1998, and consisted sixteen boreholes in total:

1. Three (3) boreholes (Boreholes 201 to 203, inclusive) were drilled at the proposed north abutment location for the optional 26 metre fourth span (see Drawing 2, Appendix B).

2. One (1) borehole (Borehole 204) was drilled at the proposed abutment location for the optional 32 metre fourth span.

3. Seven (7) boreholes (Boreholes 101 to 107, inclusive) were drilled along the proposed new culvert alignment.

4. Three (3) boreholes (Boreholes 301, 302 and 303) were drilled to retrieve shelby tube samples and to conduct field vane tests along the alignment of the north approach embankment for the three (3) span bridge option.

5. Two (2) boreholes (Boreholes 401 and 402) were drilled along the alignment of the north approach for the four (4) span bridge option.

Table 1-1 contains a summary of the boreholes drilled for the additional field investigation at the Moon River site.

The boreholes for the additional investigation were advanced through the overburden soils using either a track mounted or truck mounted CME-75 drill rig equipped with hollow stem augers. Soil samples were obtained using a standard 51mm O.D. split spoon sampler in conjunction with Standard Penetration Tests (ASTM D1586) at approximately 0.75 metre and 1.5 metre intervals when practical. The Standard Penetration N-values were recorded and used to provide an assessment of the relative denseness of the overburden soils at the site and the soil samples were used for identification and laboratory testing. B-size core barrels and B-size casing were used to advance Borehole 204 through the overburden soils.

To investigate the consolidation characteristics of the soft cohesive soils at the north approach area, two (2) 73mm I.D. thin wall shelby tube samples were retrieved from Boreholes 301 and 302 and three (3) 73mm I.D. thin wall shelby tube samples were retrieved from Borehole 303 for subsequent laboratory consolidation testing and laboratory vane shear testing. In addition to the shelby tube samples, three (3) field vane tests were conducted in Boreholes 301, 302 and 303 at elevations ranging from 205.3m in Borehole 303 to 203.2 m in Borehole 302.

Conventional rock coring techniques were used to core the bedrock at the site. Standard B-size core barrels and B-size casings were used to advance Boreholes 202, 203 and 204, respectively, 2.8 m, 4.0 m and 3.0 m into bedrock. The bedrock core samples were retrieved for rock quality determinations and classification purposes.

1.3.5 Laboratory

The soil samples which were obtained in the field were examined in the laboratory for further verification and classification. A laboratory testing program for select soil samples consisted of the following:

- Atterberg Limits
- Natural Moisture Contents
- Unit Weights
- Oedometer Consolidation (Horizontal and Vertical Orientations)
- Laboratory Vane

The laboratory test results are summarized on the attached Borehole Logs and are discussed further in Sections 1.4 and 2 of this report.

1.4 Subsurface Conditions

1.4.1 General

The results of the geotechnical investigation for the Moon River Bridge are summarized on the attached borehole logs, cone logs and auger probe logs in Appendix C. The following is a description of the subsurface conditions encountered during the field investigation. The subsurface soil conditions encountered at the site are also summarized in stratigraphical form on Drawings 3, 4, 5, 6 and 7 in Appendix B.

1.4.2 TOPSOIL

Topsoil was encountered in Boreholes 2, 5, 7, 401 and 401 at the site. The thickness of the topsoil varied from 200 mm at Borehole 5 to 100 mm at Borehole 7.

1.4.3 FILL

To drill Boreholes 1, 3 and 8, the ground around these boreholes was regraded using a small dozer. As a result, a surficial layer of fill 1.98m, 1.99m, and 1.25 m thick was encountered during drilling of Boreholes 1, 3, and 8, respectively. The fill was loose to compact silty sand with some gravel. Standard penetration N-values ranged from 11 for SS1 of Borehole 1 to 49 for SS1 of Borehole 3.

Boreholes 201, 202, 203 and 204 were advanced though an existing road embankment located approximately 60 to 70 metres north of the Moon River. As such, fill consisting of sand and blast rock with occasional cobble and boulder sizes was encountered in these boreholes. The thickness of the fill varied from 2.0 m at Borehole 201 to 5.3 metres at Borehole 203.

1.4.4 PEAT

A surficial layer of soft compressible fibrous peat was encountered between elevations 208.19 m and 207.43 m in Borehole 4.

1.4.5 Upper SILTY SAND to SAND (TILL)

An upper deposit of loose to compact silty sand to sand (till) with some gravel was encountered in Boreholes 1, 101, 102, 103, 104, 106, 107, 201, 202, 203, 401 and 402 at the site. This soil layer was found to overly clayey silt to silty clay at Boreholes 102, 103, 104, 106, 107, 201, 202, 203, 401 and 402 and was typically encountered at elevations greater than approximately 207 m. The thickness of this soil layer varied between 0.6m at Borehole 201 (El. 208.0 m to 207.4 m) and 3.3 m at Borehole 101 (El. 209.3 m to 206.0 m). The moisture content was found to vary between 10% and 12%.

1.4.6 SILTY CLAY to CLAYEY SILT (CL)

Stratified silty clay to clayey silt with thin silt layers or lenses was encountered in Boreholes 4, 5, 102, 103, 104, 106, 201, 202, 203, 204, 301, 302, 303, and 401.

This soil layer was found to be very soft to firm with an undrained shear strength, c_u, ranging from 18.0 kPa at elevation 204.2 m in Borehole 301 to 52 kPa at elevation 204.2 m in Borehole 5 and elevation 204.8m in Borehole 302. Figure 2 shows the undrained shear strength profile based on the results of field vane tests and laboratory vane tests for this soil.

The natural moisture content, w_n, ranged from a minimum of 26% for silty seams to a maximum of 60% for more cohesive samples. The average moisture content for the deposit was found to be in the order of 45% and the unit weight was measured to be approximately 16.1 kN/m^3.

Atterberg limits were measured in the laboratory for six (6) split spoon samples and 1 thin wall shelby tube sample. The test results are summarized on the attached borehole logs (Appendix C) and in Table 1-2 below. The majority of soil samples tested plot just above the A-line (see Figure 3) and are classified as low plasticity clays (CL) using the Unified Soil Classification System (USCS). However, one sample (SS-3, Borehole 104) is classified as an intermediate plasticity clay (CI) according to the USCS Classification System and one sample (SS-4, BH-5) is classified as a high plasticity silt (MH).

The thickness of the silty clay to clayey silt soil (CL) layer ranged from approximately 2.2 metres at Borehole 106 (El. 208.2 m to El. 205.9 m) to approximately 5 metres at Borehole 5 (El. 208.1 m to El. 203.1 m).

Table 1-2 Summary of Atterberg Limits.

Borehole No.	Sample	LL (Liquid Limit)	PL (Plastic Limit)	Plasticity Index
BH4	SS-4	30	18	12
BH5	SS-4	56	23	32
AP-1	TW-1	37	17	20
BH104	SS-3	45	22	23
BH203	SS-2	24	15	9
BH204	SS-6	24	16	8
BH202	SS-2	32	16	16

Figures 4 through 9, inclusive, show the results of an oedometer consolidation test conducted for several shelby tube samples recovered from the site. Table 1-3 below summarizes the results of the consolidation tests and Drawings 1 and 2 in Appendix C shows the site plan and location boreholes. The recompression index, C_r, for the clayey silt to silty clay deposit at the site was found to range between 0.02 to 0.07. The compression index, C_c, was found range from 0.32 to 0.81 and the measured preconsolidation pressure varied from 85 kPa for shelby tube sample TW-1 from Borehole AP-1 to 170 kPa for the sample obtained from Borehole 303. Referring to Table 1-3, it was generally found that the horizontal coefficient of consolidation was approximately two (2) times greater than the vertical coefficient of consolidation. The horizontal coefficient of consolidation was found to range between 8 and 15 m^2/yr in the overconsolidated stress range and between 2.6 and 7.5 m^2/yr in the normally consolidated stress range. The vertical coefficient of consolidation varied between 8 and 9 m^2/yr in the overconsolidated stress range and between 1.25 and 5 m^2/yr in the normally consolidated stress range.

Table 1-3 Summary of Consolidation Test Results.

TEST NO.	DEPTH (m)	BOREHOLE	σ'_p (kPa)	$C_V^{O/C}$ (m^2/yr)	$C_V^{N/C}$ (m^2/yr)	Cc	CR	ORIENTATION
1	3.0-3.6	AP-1	85	8.0	3.0	0.6	0.02	VERTICAL
2	4.0-4.6	BH303	170	9.0	1.25	0.8	0.07	VERTICAL
3	4.0-4.6	BH303	140	8.0	2.6	0.81	0.04	HORIZONTAL
4	3.0-3.6	BH301	100	9.0	5.0	0.32	0.02	VERTICAL
5	3.0-3.6	BH301	95	10.0	7.5	0.34	0.02	HORIZONTAL
6	4.6-5.2	BH302	130	15.0	4.8	0.46	0.05	HORIZONTAL

σ'_p - Preconsolidation Pressure

$C_V^{O/C}$ - Coefficient of Consolidation in the over consolidated stress range.

$C_V^{N/C}$ - Coefficient of Consolidation in the normally consolidated stress range.

C_C - Compression Index.

C_R - Recompression Index.

1.4.7 Lower SILTY SAND (TILL) - with GRAVEL and some COBBLES and BOULDERS

Silty sand (till) with gravel, cobbles and boulders(TILL) was found overlying bedrock in Boreholes 3, 4, 5, 6, 7, 102, 103, 104, 106, 201, 202, 203, and 204. Based on Standard Penetration Test N-values, this soil layer was generally found to be compact to very dense. N-values ranged from 13 blows/300mm for SS4 from Borehole 103 to 106 blows/300mm for SS5 from Borehole 202. Some occasional higher N-values were recorded in zones with more gravel and/or cobbles and boulders. B-size core barrels and N-size casing were used to advance Boreholes 3, 6 and 7 through zones containing hard to very hard boulders and cobbles (typically just above the bedrock surface). The moisture content of this overburden layer was found to range from 8.3% to 11.7%.

Grain size distributions were obtained for select soil samples taken from this layer at Boreholes 2 and 7. The results are presented on the attached borehole logs and are shown on Figures 10 and 11. This soil layer was found to be predominantly sand and was generally found to overly bedrock at the site with a thickness ranging from 0.75 m at Borehole 1 (El. 213.98m to 213.22m) to 5.2 m at Borehole 2 (El. 203.49 m to 198.31 m).

1.4.8 BIOTITE-HORNBLENDE GNEISS

The bedrock was cored at Boreholes 1, 2, 3, 5, 6, 7, 202, 203, and 204. RQD and core recovery was logged in the field and the cores were returned to Trow for identification and classification purposes. The bedrock at the site was found to be hard to very hard, predominantly light grey to greyish black medium to coarse grained, unweathered, strong, biotite-hornblende gneiss. RQD values ranged from 50% for rock core (RC) sample number 1 of Borehole 202 to 100%. Based on RQD values, the rock mass quality is fair to excellent.

Fractures were close to widely spaced and were generally found to occur in sets oriented at approximately 10° and 30° to 40° to the core axis.

In general, the bedrock elevation was found to be variable at the site ranging from 216.2 m at Borehole 8 to 198.5 m at Borehole 203. In particular, at the location of working point WP#1, the bedrock was found to dip sharply toward the northeast. Also, the bedrock was found to dip sharply toward the south between Borehole 402 and Borehole 204 (see Drawings 1 and 2 in Appendix B for Borehole locations).

1.5 Groundwater Conditions

Stabilized groundwater levels were measured in Borehole 1, 4 and 5 after the completion of drilling. The water level was found to be at elevation 214.7m at Borehole 1 (November 25, 1997), elevation 208.0 m at Borehole 4 (November 19, 1997) and 208.1 m at Borehole 5 (November 20, 1997). Borehole 3, was found to be dry after the completion of drilling (November 21, 1997). Based on the observed groundwater levels in Boreholes 1 and 4, the ground water table was found to be just below the ground surface (0.2-1 metres) at the location of the north abutment and approach, approximately 1.25 metres below the ground surface at the south abutment and slightly above the water level of the Moon River at the location of the bridge piers. The elevation of the water level of the Moon River at the time of the field investigation was approximately 202.3 m.

Part 2 Engineering Discussions and Recommendations

2.1 Foundation - Design

Since the soils overlying bedrock at the site are generally weak, spread footings founded on or within the overburden soils are not feasible considering the load and serviceability requirements for the abutments. To support the bridge loads, deep foundation units will be required at the north abutment for the three span bridge option (WP#4), the north abutment for the four span bridge option (WP#5), and the south pier (WP#2). Spread footings founded directly on bedrock are suitable for the north pier (WP#3) and south abutment (WP#1).

2.2 North Abutment (3 Span Option - WP#4), North Abutment (4 Span Option - WP#5) and South Pier (WP#2)

2.2.1 Piled Foundations

Driven piles are suitable for the foundations at the north abutment (WP#4) for the three span bridge option, the north abutment (WP#5) for the four span bridge option, and for the south pier (WP#2). For piles driven to end bear on bedrock or into the silty sand till (see Section 2.2.2 for discussion), the following Limit States design values may be assumed in accordance with the Ontario Highway Bridge Design Code (O.H.B.D.C.):

Table 2-1 Design Pile Capacities

	HP 310x79	HP 310x110
Factored Geotechnical Capacity at ULS	1150 kN	1600 kN
Ultimate Capacity for Hiley Formula	2475 kN	3450 kN

The geotechnical capacity at SLS does not apply to piles which end bear on bedrock.

Based on the attached borehole logs in Appendix C, Table 2-2 shows a summary of the interpreted end bearing elevation of each pile at the borehole locations. Drawing 5 in Appendix B shows an interpreted cross-sectional profile for the subsurface conditions at the south pier and north abutment (3 Span Option) and Drawing 6 shows an interpreted cross-sectional profile for the subsurface conditions at the north abutment (4 Span Option).

Table 2-2 Interpreted End Bearing Elevation for Pile Foundations - North Abutment and South Pier

Borehole Number	Location on Structure	End Bearing Elevation (m)
BH-4	North Abutment (WP#4) - 3 Span Option - Station 25+526.000 North Pier (WP#4) - 4 Span Option - Station 25+526.00	203.2 m
BH-5	North Abutment (WP#4) - 3 Span Option - Station 25+526.000 North Pier (WP#4) - 4 Span Option - Station 25+526.000	200.4 m
BH-2	South Pier (WP#2) - Station 25+444.000	198.3 m
BH-7	South Pier (WP#2) - Station 25+444.000	198.6 m
BH-201	North Abutment (WP#5)- 4 Span Option - Station 25+552.000	199.6 m
BH-202	North Abutment (WP#5)- 4 Span Option - Station 25+552.000	198.9 m
BH-203	North Abutment (WP#5)- 4 Span Option - Station 25+552.000	198.5 m

It should be noted that the elevations given in Table 2-2 above are approximate. Furthermore, based on the soil borings, the bedrock elevation at the location of the Moon River Bridge is variable and may change rapidly over a very short distances.

Also, it is anticipated that the north approach grades will be raised by approximately 8 metres immediately adjacent to the north bridge abutment for both the 3 span and 4 span options. The resulting net load increase applied to the overburden soils will be approximately 145 kPa (assuming a unit weight of 18.0 kN/m^3 for the approach embankment fill). Under these conditions, settlements of the approach embankments are expected near the abutments resulting from consolidation of the soft clayey subsurface soils, and consequently, down drag forces will be generated on the piles.

Since it will be difficult to control the consolidation settlements of the clayey silt to silty clay (CL) soils encountered at the north abutment for the three span bridge option (WP#4), it is recommended that the pile load capacities listed in Table 2-1 be reduced by 20% at the north abutment area to account for down drag forces on the piles. Down drag forces are not anticipated at the location of the south pier (WP#2).

In the event that a four span bridge is chosen for the site, down drag forces are not anticipated for piles driven at the north pier (WP#4). At the location of the north abutment for the four span bridge option (WP#5), the pile load capacities listed in Table 2-1 must be reduced by 5% to account for down drag forces on the piles. If the soft to firm clayey silt to silty clay soils are excavated and removed at this foundation location, down drag forces on the piles can be neglected.

The lateral load capacity of H-piles driven to bedrock at the site is expected to be small. As such, all lateral loads should be supported using battered piles.

2.2.2 Construction - Piles

All piles should be driven to bedrock. If piles should end above the bedrock surface within the silty sand till, pile driving should be controlled by the Hiley Formula as per MTO standards SS103-10 or SS103-11 using the ultimate pile capacities referred to in Table 2-1.

Given the variable bedrock elevations at the site, the potential for irregular steeply sloping bedrock is considered to be moderate to high and, consequently, problems may arise during pile seating. At some locations, the piles may have a tendency to skip over the bedrock surface resulting in alignment problems or deeper penetration. In the event that this occurs, somewhat longer piles may be required and in some cases piles may have to be added or replaced.

To minimize seating difficulties, rock injector points could be considered to facilitate proper seating. It is also recommended that, upon initial contact with the bedrock, the pile driving energy should be reduced and subsequently increased incrementally until the piles have been sufficiently seated.

2.3 South Abutment (WP#1) and North Pier (WP#3) - 3 Span Option

2.3.1 Spread Footing on Bedrock

A spread footing founded directly on the underlying bedrock is adequate for both the south abutment (WP#1) and north pier (WP#3). At the north pier location, this option may require temporary diversion of the creek (see Drawing 1) located adjacent to the north pier and abutment during construction. For spread footings founded directly on the unweathered to slightly weathered bedrock, the following Limit States design values may be assumed in accordance with the O.H.B.D.C. and subject to geotechnical inspection:

Table 2-3 Spread Footing Capacity on Bedrock

	Spread Footing
Factored Bearing Capacity at ULS	5000 kPa

The above Factored Bearing Capacity at ULS applies to spread footings placed directly on bedrock with a good Rock Mass Quality (RQD>75). The bearing capacity at SLS will not govern for a spread footing founded on bedrock since the loads required to produce unacceptable settlements of the structure will be much larger than the recommended values for the factored capacity at ULS unacceptable settlements of the structure will be much larger than the recommended values for the factored capacity at ULS

As per section 6-8.4.2 of the Ontario Highway Bridge design code, a reduction factor shall be applied to the Ultimate Bearing Resistance at ULS (5000 kPa) to account for the effects of inclined loading. Table 2-4 contains a summary of reduction factors for inclined loads.

Table 2-4 Reduction Factors to Account for the Effects of Inclined Loads on the Ultimate Bearing Resistance at ULS *

Ratio of Horizontal to Vertical Load	Reduction Factor
0.1	0.87
0.2	0.76
0.3	0.66
0.4	0.57

*As advised by MTO Foundation Section " Although the OHBDC provides resistance reduction due to inclined loadings for footing on bedrock, the OHBDC committee has decided that no such reduction will be required if the footing is constructed on bedrock."

Note: The structural engineer can refer to Figure 6-8.4.2 of the Ontario Highway Bridge Design Code for reduction factors corresponding to ratios of horizontal to vertical loads which are not listed above.

Table 2-5 summarizes the interpreted footing level elevations at the location of Boreholes 3 and 6 for the north pier and Boreholes 1 and 8 for the south abutment.

Table 2-5 Bearing Elevations for Spread Footings - North Pier and South Abutment.

Borehole Number	Location on Structure	End Bearing and Footing Base Elevations (m)
BH-1	South Abutment (WP#1) - Station 25+418.000	213.2 m
BH-8	South Abutment (WP#1) - Station 25+418.000	216.3 m
BH-3	North Pier (WP#3) - Station 25+485.000	204.3 m
BH-6	North Pier (WP#3) - Station 25+485.000	201.9 m

2.3.2 Spread Footing - Sliding Resistance and Footing Base Preparation

The computation of the sliding resistance for spread footings shall be carried out in accordance with of O.H.B.D.C. An unfactored friction angle, ϕ', of 32 degrees can be used for sliding along the bedrock and footing base.

If the factored resistance against sliding failure is inadequate based on friction, then the footing should be anchored into bedrock by means of keys, dowels or sockets. An unfactored coefficient of passive earth pressure, K_p', equal to 3.7 can be used for design of a passive resistance key. Given the hardness of the bedrock, sockets and keys will likely be impractical. Developing adequate resistance against sliding of spread footings founded on the sloping bedrock at the site will likely require dowels.

The elevations presented in Table 2-5 are for preliminary purposes and were estimated based on the factual borehole data. Interpolation between boreholes is approximate, and as such, actual footing elevations will depend on the conditions encountered in the field at the time of construction. The surface of all footing bases must be cleared of all loosened or fractured rock and inspected by a qualified geotechnical engineer to verify the Rock Mass Quality prior to placement of concrete.

Where a footing is constructed on sloping bedrock, the rock surface should be blasted to provide a step-like footing base.

2.4 Modulus of Horizontal Subgrade Reaction

Table 2-6 contains a summary of material types with corresponding modulus of horizontal subgrade reaction. The lateral resistance of organic soils will be negligible. These soils should be assumed to be very compressible.

Table 2-6 Material Types and Modulus of Subgrade Reaction.

Soil Type	Unit Weight (kN/m^3)	Friction Angle (degrees)	Horizontal Modulus of Subgrade Reaction, k, (kN/m^3)
Clayey Silt to Silty Clay (CL)	16.5	27	8,000
Native Silty Sand (till)	20.0	30	40,000
Granular 'A' Backfill	22.5	35	40,000
Granular 'B' Backfill	21.5	30	40,000
Rock Fill	18.0	35	40,000

2.5 Frost Cover

For pile caps, frost protection should consist of a minimum of 2 m of earth cover or equivalent insulation. Footings placed directly on bedrock do not require frost protection. Based on the preliminary grades, 2 metres of earth cover at the location of the south pier will require a significant excavation at or near the toe of the south slope. Insulation should be considered to provide adequate frost protection at this location to facilitate construction, to minimize the depth of excavation and to minimize the area of disturbance near the toe of the south slope. Insulation can be installed directly below the piles cap prior to construction of the cap and should extend at least 1 m laterally beyond the plan limits of the cap.

2.6 Backfill

Backfill to abutments or retaining walls should consist of free draining granular materials such as Granular 'A' and Granular 'B' or rock fill. Computation of earth pressures shall be in accordance with Section 6.7.4 of the Ontario Highway Bridge Design Code. Unfactored properties for backfill materials are provided in the following table:

Table 2-7: Material Types and Unfactored Properties.

Material	Friction Angle, ϕ', in Degrees	Coefficient of Active Earth Pressure (Ka)	Coefficient of Earth Pressure at Rest (Ko)	γ (kN/m^3)
Granular A	35 degrees	0.27	0.43	22.5
Granular B	30 degrees	0.33	0.5	21.2
Rock Fill	35 degrees	0.27	0.43	18.0
Light Weight Fill	35 degrees	0.27	0.43	11.5

For abutments or retaining walls founded on battered piles, the coefficient of earth pressure at-rest must be assumed for design purposes. If rock fill is used as backfill for abutments, processed rock fill should be used with a maximum nominal particle size of 100 mm.

2.7 Construction Considerations

2.7.1 Piles and Spread Footings

The settlements of properly constructed piles and spread footings founded on bedrock are expected to be negligible.

2.7.2 North Approach Embankment - 3 Span Option

The grades at the north abutment are to be raised by approximately 8 m based on the preliminary design grades provided to Trow. A subsurface profile at the location of the north approach embankment is shown on Drawing 4. In addition to raising the grades at the north approach, a concrete box culvert has been proposed for the creek located adjacent to the north pier and north abutment. It will be necessary to divert this creek through the approach embankment, and as a result, there is a potential for significant lateral and vertical movement of the box culvert due to the embankment loading.

In addition to the geometric conditions noted above, it is understood that the Moon River Bridge must be completed during the initial stages of the current project to provide a haul route for blast rock fill. As such, it is critical that the approaches be built within a 6 month timeframe. Also, a settlement tolerance of less than 25 mm± after the application of the pavement base coarse has been established for the north and south approaches to the Moon River Bridge. The following is a discussion of the expected settlements and deformations during construction and the alternatives for the north approach embankment.

A stability analysis has been performed for the north approach embankment using the undrained shear strength, c_u, profile shown in Figure 2. Based on the design grades provided to Trow and the shear strength properties of the clayey silt to silty clay (CL) deposit at the north abutment location, a stabilization berm will be required for the north approach embankment. Drawing 8 shows the preliminary north approach embankment geometry. The north approach embankment can be constructed in one (1) stage using rock fill. A 3.5 m high berm (fill to El. 212.5± m) must be provided for stability and the stabilization berm must extend a minimum of 6 m laterally beyond the primary embankment (see Drawing 8). The stabilization berm should extend along the west edge of the embankment, extend around to the forward slope area south of the north abutment and should be matched with the existing Moon River Bridge embankment at about the 212.5 m contour. Although a berm on the east edge of the new north approach embankment is not required, some in-filling between the northbound and southbound embankments may be required to provide proper drainage. The elevation of the top of the berm will be approximately 212.5 m.

Figure 12 shows the estimated range of centreline settlements (consolidation) for the north approach embankment. The upper bound settlements shown in Figure 12 correspond to worse case soil properties and the lower bound settlements correspond to best case soil properties. It is evident from Figure 12 that, 6 months after the construction of the embankment the total centreline settlements are in the order of 120mm± to 160mm±. (It has been estimated that the initial base coarse of pavement will be applied approximately 6 months following construction of the bridge approaches.) The remaining centreline settlements after the initial application of the pavement base coarse are expected to be within the range of 80mm± to 140mm±. This calculated settlement range exceeds the settlement criteria of less than 25mm± of settlement after the application of the pavement base coarse.

In addition to the settlement analysis shown in Figure 12, the asphalt was cored at station 25+525m± (Pavement Design Report, Trow Consulting Engineers Ltd., January 1998) just north of the existing Moon River Bridge north abutment. The asphalt core indicated that 140mm of additional asphalt has been placed at this location. It is assumed that the additional asphalt was required to offset the north approach embankment settlements and to maintain a smooth grade between the approach and bridge abutment. This provides some verification of the settlement analysis shown in Figure 12.

Given the settlement criterion noted above and the potential for long term embankment movements, two alternative schemes to control settlements to within the design parameters have been investigated for the north approach embankment. The two alternatives include (a) full or partial excavation of the clayey silt to silty clay soils at the location of the north approach embankment or (b) vertical sand drains. Full or partial excavation of the clayey soils at the site will require excavation to an elevation of 204.5m± (a depth of between 3 to 4 metres). This alternative will require a substantial excavation at the toe of the existing Moon River Bridge north approach embankment. Although the clayey soils at the north approach could be excavated in panels to limit movements of the existing north embankment, there is a high potential for excessive movements which may adversely affect the existing north embankment. As such, this option is not recommended.

Alternatively, vertical sand drains at 2.5 metre centre-to-centre spacings can be installed to improve drainage, to improve short term embankment stability and to accelerate the consolidation settlements of the clayey silt to silty clay deposit at the site. A granular 'B' working pad ~600 m thick will be required on the clay subgrade soils to permit sand drain installation and to facilitate drainage. This option is expected to have a similar cost to full or partial excavation of the clayey soils at the site, however, the potential for movements of the existing north approach embankment are minimized. Figure 13 shows the calculated centreline settlements for vertical sand drains at 2.5 m centre-to-centre spacing. As noted above for Figure 12, the upper bound settlement curve corresponds to worse case soil properties and the lower bound cure corresponds to best case soil properties. It is evident from Figure 13 that, 6 months after the construction of the embankment the total centreline settlements are in the order of 190mm± to 280mm±. (It has been estimated that the initial base coarse of pavement will be applied approximately 6 months following construction of the bridge approaches.) The remaining centreline settlements after the initial application of the pavement base coarse are expected to be within the range of 10mm± to 20mm±. This calculated settlement range meets the settlement criteria of less than 25mm± of settlement after the application of the pavement base coarse.

To account for the embankment settlements and to provide some preloading for the north embankment, the north approach embankment should be overbuilt by approximately 0.75 metres and allowed to consolidate for 6 months. The excess fill can be removed prior to placement of the asphalt base coarse. Construction of the north abutment foundation should not begin until 50% of the total consolidation settlements have accumulated. For preliminary planning purposes, this will require 1.5 to 2 months.

To summarize, provided that a stabilization berm and properly constructed vertical sand drains are provided for the north approach embankment, both embankment stability criteria and settlement criteria can be met. Full or partial excavation of the clayey soils at the site is not recommended given the potential impact on the approach embankment to the existing Moon River Bridge. Drawing 8 shows the proposed embankment and vertical sand drain layout. A non-standard special provision (NSSP) will be required for the sand drains, gradation of the sand and the sand drain installation.

Pore pressures and embankment movements should be monitored during construction. The monitoring should consist of 1 to 2 pneumatic piezometers and 2 to 3 settlement plates. Field data should be interpreted during construction to verify design assumptions, to establish suitable construction rates, and to gain a better understanding of the long term embankment performance and maintenance requirements.

2.7.2 North Approach Embankment - 4 Span Option

A fourth span to the Moon River Bridge has also been proposed for the Moon River Bridge. For this bridge option, the north abutment will be located 26m to 32 m north of WP#4 (see Drawing 1). A culvert will not be required for the creek located north of the Moon River, and as a result, there will be no long term maintenance costs associated with the culvert. The creek will also not require re-alignment. Drawing 4 shows a longitudinal profile of the subsurface soils north of the Moon River and Drawing 6 shows an interpreted cross sectional profile at the location of the north abutment for the four span bridge option. If the four span bridge option is selected for the Moon River Bridge, settlements of the approach embankment for the north abutment can be minimized by full removal of the soft to firm clayey silt to silty clay encountered in Boreholes 201, 202, 203, 401 and 402. Full removal of the clayey soils at this location is considered to be feasible given the reduced depth of the clayey silt to silty clay deposit and the reduced height of the existing Highway 69 road embankment. The soft to firm clayey silt to silty clay soils north of the proposed abutment for the 4 span bridge should be excavated in panels to minimize any potential movement of the existing road embankment located to the east.

Based on the attached borehole logs, full removal of the soft foundation soils under the plan limits of the north approach embankment will require excavation to: (i) an average Elevation of 203.4 m at Working Point WP#5, (ii) an Elevation of 204.5 m at Borehole 204, (iii) approximate El. 211 m at Borehole 401 and (iv) an Elevation of 208.0 m at Borehole 402.

If the four span bridge option is chosen, post construction settlements of the north approach embankment are expected to meet the settlement criteria discussed in Section 2.7.1 above provided that all soft compressible foundation soils (eg. clayey silt to silty clay and compressible organics) are excavated as discussed above. The majority of embankment settlements are expected to occur during construction.

It is understood that the grades adjacent to the north abutment for this bridge option will be raised to approximately 217.2 m immediately adjacent to the abutment. The resulting embankment height varies from approximately 7.5 m above original ground level at the north abutment area to approximately 4.2 metres above original ground level at Station 25+600. As such, the stability of the north approach embankment is expected to be adequate without stabilization berms provided the approach embankment is constructed on the silty sand and gravel (till) encountered below the clayey silt to silty clay soils at the site (eg. full removal of clayey silt to silty clay soils). 1.5H:1V side slopes are adequate for the approach embankment if rock fill is used to construct the embankment. A berm will likely be required at the forward slope of the north abutment to provide sufficient frost cover for the abutment pile cap.

2.7.3 North Approach - Proposed Concrete Box Culvert (Three Span Option)

It has been estimated that a concrete reinforced box culvert located along the current creek alignment will be subjected to approximately 200 to 300 mm± of vertical settlement if the existing creek alignment is unchanged. The lateral movements during consolidation are expected to be in the order of 100mm to 200 mm±. The alternative culvert alignment shown in Drawing 8 has been proposed to limit post construction movements of the culvert, to minimize the potential for washout of the north embankment and to allow access for post construction maintenance.

Based on the available soils and site information, it appears that diversion of the creek will involve excavation through some loose silty sand (till) and soft to firm clayey silt to silty clay. Drawing 7 shows an interpreted stratigraphical profile along the proposed new culvert alignment. Partial removal of the clayey silt to silty clay along the culvert alignment is recommended to limit post construction movements of the culvert. To prevent base heave and to limited settlements, the upper half of soft to firm clayey silt soils should be sub-excavated to an elevation of approximately 207.2 m. Well graded fine to medium sand (similar to concrete sand) should be used as bedding for the culvert and to bring foundation grades up to the underside of the culvert. To prevent undermining of the culvert and to limit the potential for water to flow below the culvert within the sand bedding, two to three concrete or clayey cut-off plugs should be constructed below the culvert. The plugs should extend through the sand bedding and should key into the underlying clayey soils.

Given the ground surface elevations at the proposed new culvert location, the net increase in vertical stress applied to the underlying clayey silt to silty clay soils is expected to be small since the overlying silty sand (till) soils will be excavated and replaced with a hollow concrete box structure. As such, movements of the culvert are also expected to be small.

2.7.4 Driven Piles

In addition to the settlement considerations (see Section 2.7.1 and 2.7.2), it will not be practical to drive piles through rock fill. As such, granular fill (Granular 'B') should be used in the north abutment area of both the three span bridge option and four span bridge option. At the location of the north abutment for the four span bridge option (WP#5), this will require excavation and removal of the existing blast rock fill road embankment located at Station 25+558±. The extent of the granular fill should be sufficient to accommodate battered piles (see Drawing 8) and a suitable non-woven geotextile should be placed as a separator between the rock fill and granular fill material. The non-woven geotextile should have a minimum mass of 230 g/m^2 (eg. Terrafix 360R).

2.8 Excavations

All excavations must be in accordance with the Occupational Health and Safety Regulations for Construction. Excavations through embankment fill and underlying clayey silt to silty clay (CL) foundation soils are expected. The native clayey silt to silty clay (CL) and peat soils may be classified as Type 4 soils. All fill materials identified in the borehole logs should be classified as Type 3 soils for excavations above the water table. The native silty sand till can be classified as a Type 2 soil for excavations above the water table and as a type 4 soil below the water table.

During excavation of the north and south abutments, it is anticipated that any water entering the excavations due to runoff and perched groundwater can be handled using conventional sump and pump techniques.

For the south pier, the type and extent of dewatering will depend on the water level elevation of the river at the time of construction. The water level is expected to fluctuate seasonally and construction should be scheduled during a period of low water levels if practical. If conditions during construction are similar to those encountered during the current geotechnical investigation, excavations at or slightly below the river level to El. 202. m± are expected for the south pier. As such, it is anticipated that groundwater and runoff entering the excavation can be handled using conventional sump and pump techniques. A temporary dyke constructed using clayey material or a cofferdam should be maintained adjacent to the river (if space permits and subject to environmental approval) to prevent river water from entering directly into the south pier excavation.

Based on the sloping bedrock elevations at Boreholes 3 (El. 204.3m) and 6 (201.9 m), portions of the north pier excavation will be below the river level. Temporary sheeting will likely be required adjacent to the river to prevent water from entering the north pier excavation.

In the event that water levels in the river are higher than the levels recorded during this investigation, temporary sheeting may also be required adjacent to the river at the south pier to prevent water from entering the pier excavation.

2.9 Erosion Protection/Scour

The forward slopes will require erosion protection at the abutments subject to establishing the design high water level elevation. This erosion protection will likely consist of rock rip rap. The extent and sizing of the protective rip rap will depend on the hydrology of the river, the final grading and the shape of the river channel both upstream and downstream of the bridge. In general, the protective rock rip rap should extend a minimum of 10 m upstream and downstream from the bridge centreline. For preliminary design purposes, at least 0.6 m of rock protection (minimum size of 0.03 m^3) should be placed on the river banks up to the elevation of the design high water level. The rock protection should also extend down the river banks to the toe of the forward slopes. A suitable nonwoven geotextile should be placed as a separator between the rock rip rap and underlying native soils. The non-woven geotextile should have a minimum mass of 230 g/m^2 (eg. Terrafix 360R) and must be anchored in a trench located immediately up slope of the rock protection to prevent the geotextile and rock from sliding down slope. This office can provide further assistance with respect to the anchor trench detail once the final rip rap configuration is known.

The north pier will not require scour protection as this pier will be founded directly on bedrock. Scour protection for the south pier is likely not necessary, however, scour requirements will depend on the river hydraulics and the estimated scour depth. This office will be available for further consultations in this regard once the bridge design has been finalized and the river hydraulics and scour depth assessed. This office should also be contacted to review the final design drawings for slope, channel or pier protection.

2.10 General

The information presented in this report is based on a limited investigation designed to provide information to support an overall assessment of the current geotechnical conditions at the site of the proposed Moon River Bridge. The conclusions presented in this report reflect site conditions existing at the time of the investigation. It is noted that the soil boundaries indicated on the borehole logs are inferred from discontinuous sampling and observations during drilling. These boundaries are intended to reflect transition zones for the purpose of geotechnical design and should not be interpreted as exact planes of geological change.

This report has been prepared by Sean Hinchberger and reviewed by S.E. Gonsalves. Eric Gonneau and Chi Ng coordinated the field investigation and Indulis Dumpus and Glenn Black performed the fieldwork.

We trust this report is satisfactory for your purposes. Should you have any questions, please do not hesitate to contact this office.

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EXPLANATION OF TERMS AND SYMBOLS

N VALUE - SANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO DRIVE A STANDARD 51-mm O.D. SPLIT SPOON SAMPLER 0.3 m 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 0.3 m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED AS 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*

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

N (BLOWS / 0.3 m)	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

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

STRESS AND STRAIN

u	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
$\varepsilon_1 \varepsilon_2 \varepsilon_3$	%	PRINCIPAL STRAINS
v	1	POISSON'S RATIO
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	COEFFICIENT 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	kg/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kg/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kg/m^3	BULK UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kg/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kg/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kg/m^3	UNIT WEIGHT OF SUBMERGED SOIL

e		VOID RATIO
n		POROSITY
w	%	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}	%	VOID RATIO IN LOOSEST STATE

e_{min}	%	VOID RATIO IN MOST DENSE 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	HYDRAULID GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

Figure 1: Site Location Plan - Moon River Bridge

January, 1998

BR-11546A/G

TROW CONSULTING ENGINEERS LTD.

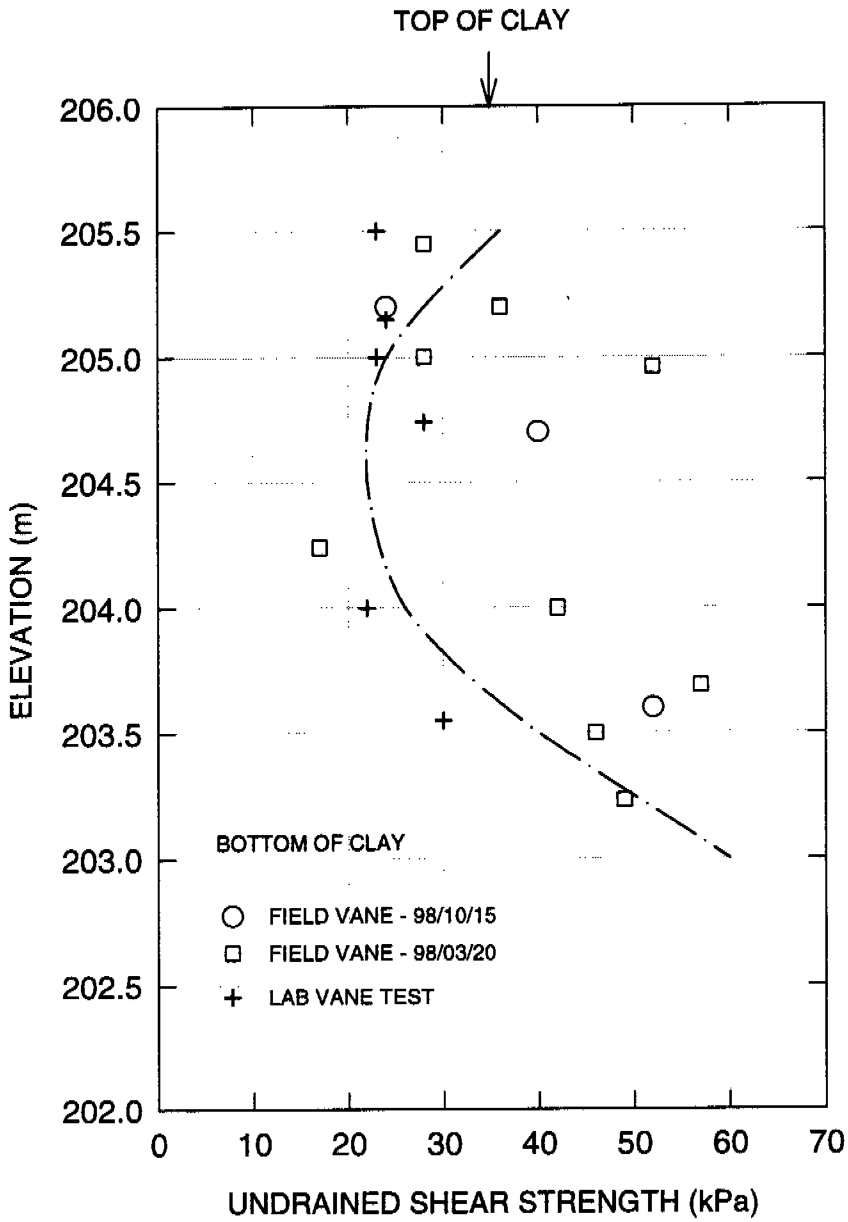


FIGURE 2 UNDRAINED SHEAR STRENGTH PROFILE
NORTH APPROACH - MOON RIVER BRIDGE.

TROW

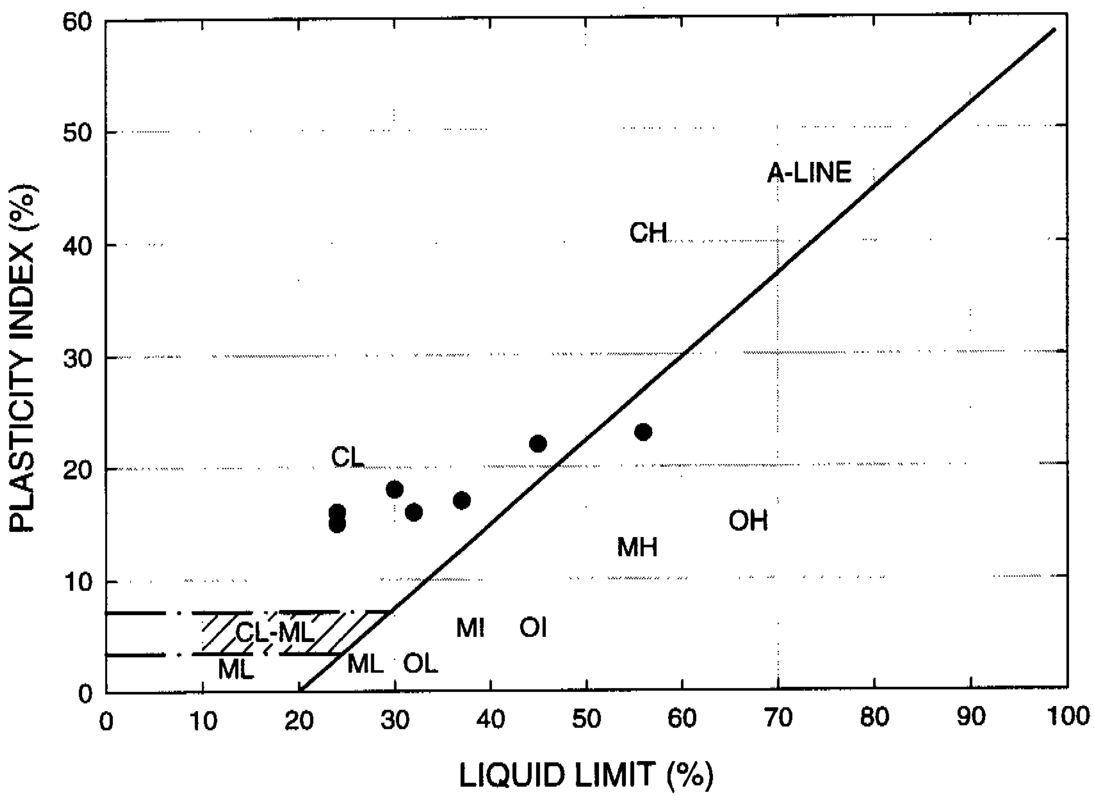
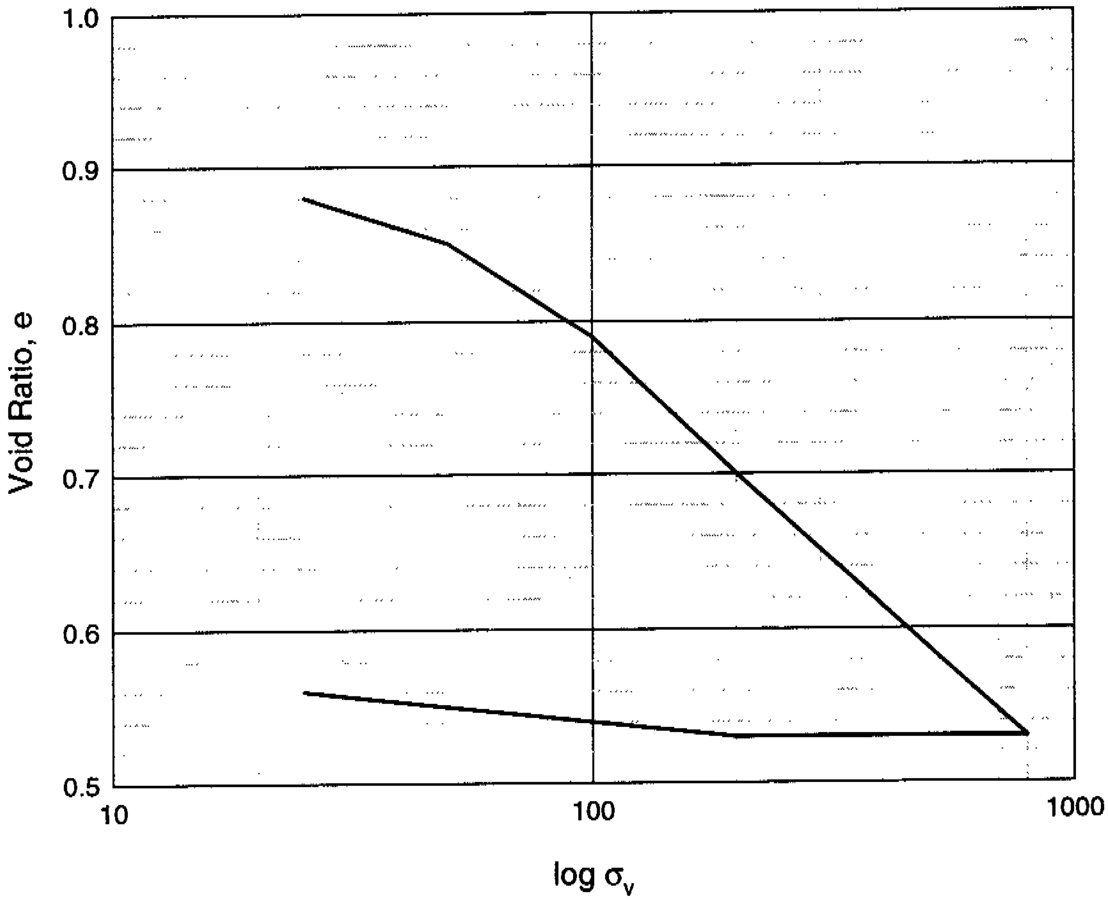


FIGURE 3 SUMMARY OF ATTERBERG LIMITS FOR CLAYEY SILT TO SILTY CLAY - MOON RIVER BRIDGE SITE

SOUTHBOUND MOON RIVER BRIDGE
W.P. 216-90-01

TROW

MOON RIVER BRIDGE
W.P. 216-90-01



BOREHOLE NO. AP-1
DEPTH 3.3m
MOISTURE CONTENT 32.6%
LIQUID LIMIT
PLASTIC LIMIT
PRECONSOL. PRESSURE 85kPa

SAMPLE DESCRIPTION

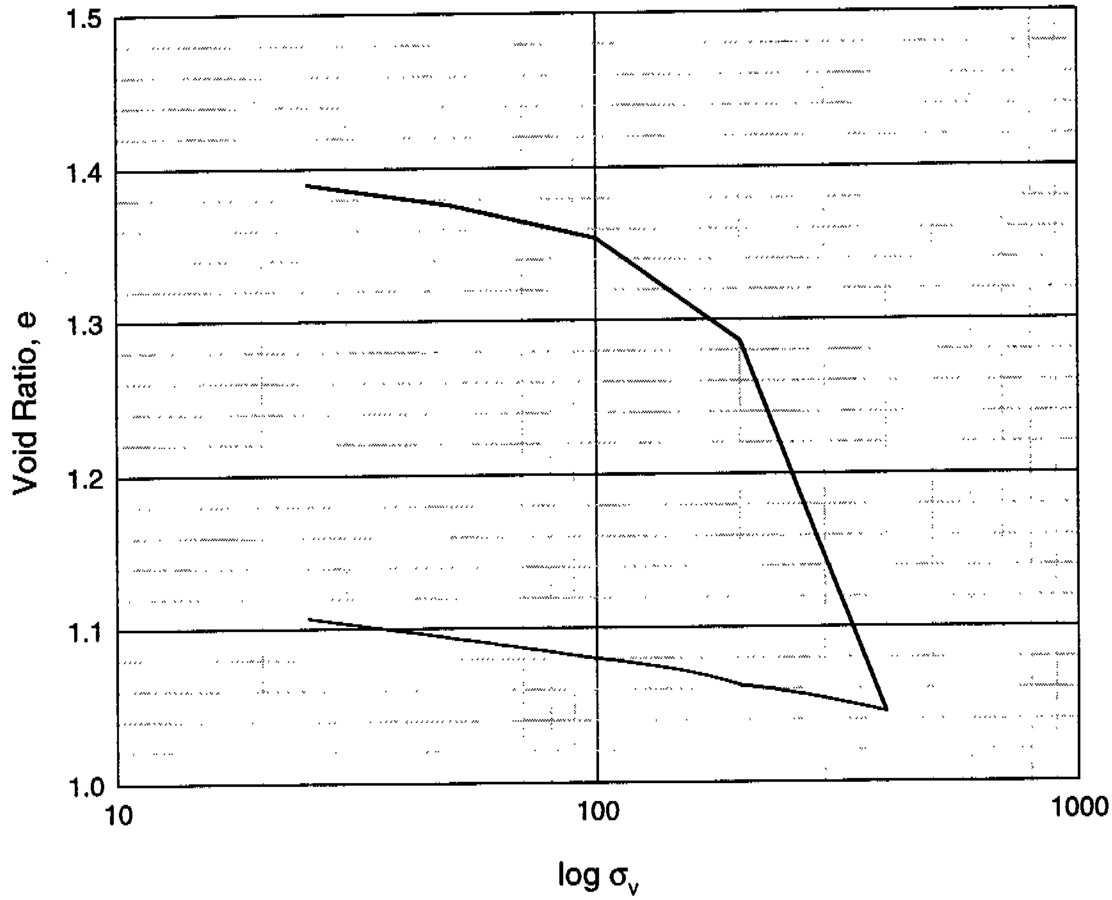
CLAYEY SILT TO SILTY CLAY (CL)
SOFT TO V. SOFT, BROWN, V. MOIST.
- VERTICAL SAMPLE -

C_C 0.6
C_R 0.32
INITIAL VOID RATIO 0.9

FIGURE 4 OEDOMETER CONSOLIDATION TEST RESULTS FOR SHELBY TUBE SAMPLE TW-1, BOREHOLE AP-1

TROW

MOON RIVER BRIDGE
W.P. 216-90-01



BOREHOLE NO. 303
DEPTH 4.3m
MOISTURE CONTENT 52.1%
LIQUID LIMIT
PLASTIC LIMIT
PRECONSOL. PRESSURE 170kPa

SAMPLE DESCRIPTION

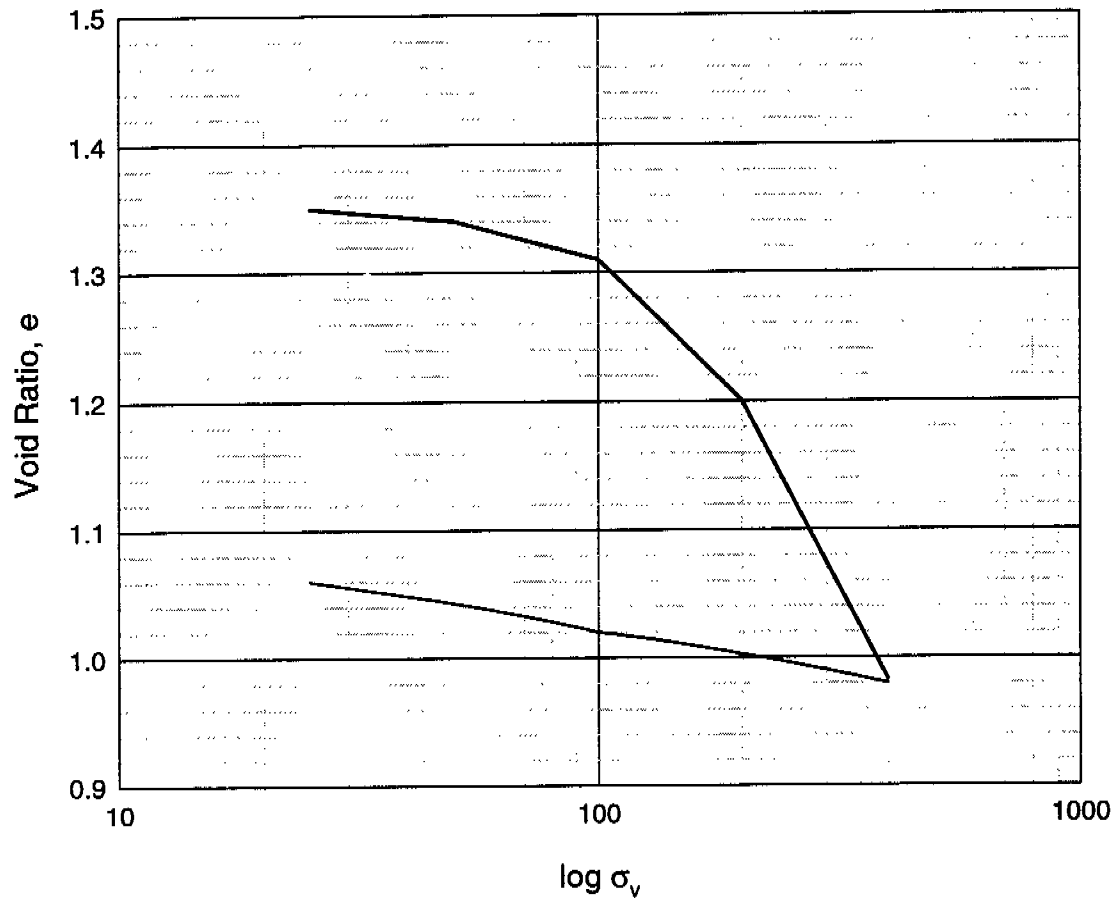
CLAYEY SILT TO SILTY CLAY (CL)
SOFT TO V. SOFT, BROWN, V. MOIST.

C_C 0.8
C_R 0.07
INITIAL VOID RATIO 1.4

FIGURE 5 OEDOMETER CONSOLIDATION TEST RESULTS FOR SHELBY TUBE SAMPLE TW2, BOREHOLE 303

TROW

MOON RIVER BRIDGE
W.P. 216-90-01



BOREHOLE NO. 303
DEPTH 4.3m
MOISTURE CONTENT 49.4
LIQUID LIMIT
PLASTIC LIMIT
PRECONSOL. PRESSURE 140

SAMPLE DESCRIPTION

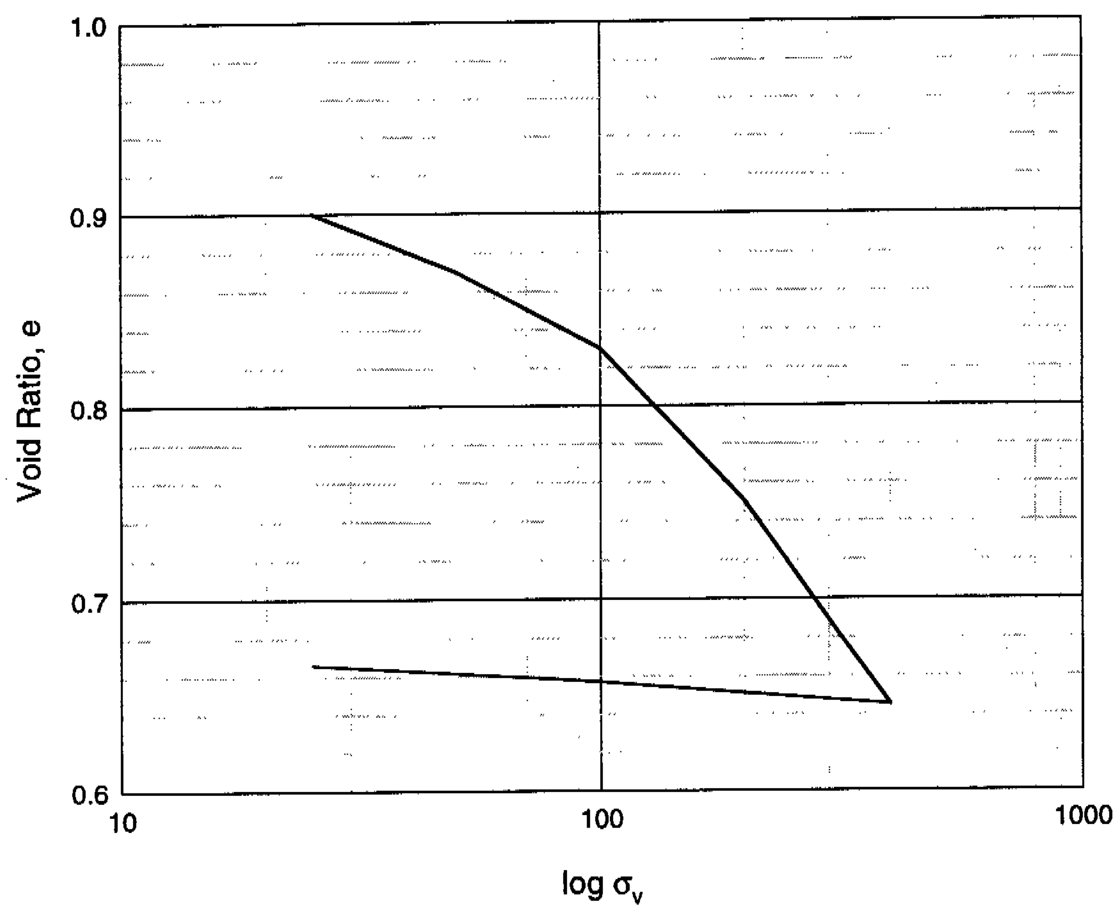
CLAYEY SILT TO SILTY CLAY (CL)
SOFT TO V. SOFT, BROWN, V. MOIST.
- HORIZONTAL SAMPLE -

C_C 0.8
C_R 0.04
INITIAL VOID RATIO 1.35

FIGURE 6 OEDOMETER CONSOLIDATION TEST RESULTS FOR SHELBY TUBE SAMPLE TW2, BOREHOLE 303

TROW

MOON RIVER BRIDGE
W.P. 216-90-01



BOREHOLE NO. 301
DEPTH 3.4m
MOISTURE CONTENT 32.6%
LIQUID LIMIT
PLASTIC LIMIT
PRECONSOL. PRESSURE 100kPa

SAMPLE DESCRIPTION

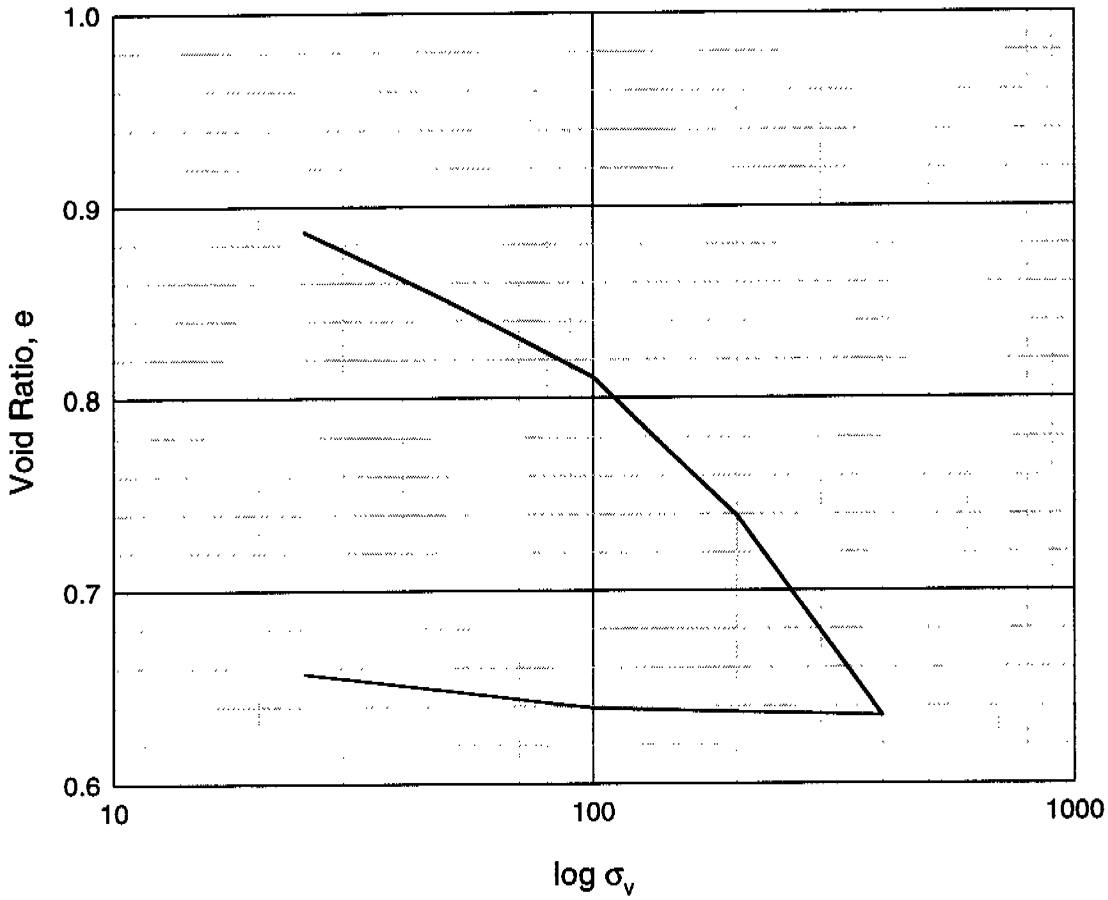
CLAYEY SILT TO SILTY CLAY (CL)
SOFT TO V. SOFT, BROWN, V. MOIST.
- VERTICAL SAMPLE -

C_C 0.32
C_R 0.02
INITIAL VOID RATIO 0.9

FIGURE 7 OEDOMETER CONSOLIDATION TEST RESULTS FOR SHELBY TUBE SAMPLE TW1, BOREHOLE 301

TROW

MOON RIVER BRIDGE
W.P. 216-90-01



BOREHOLE NO. 301
DEPTH 3.4m
MOISTURE CONTENT 33.6
LIQUID LIMIT
PLASTIC LIMIT
PRECONSOL. PRESSURE 95kPa

SAMPLE DESCRIPTION

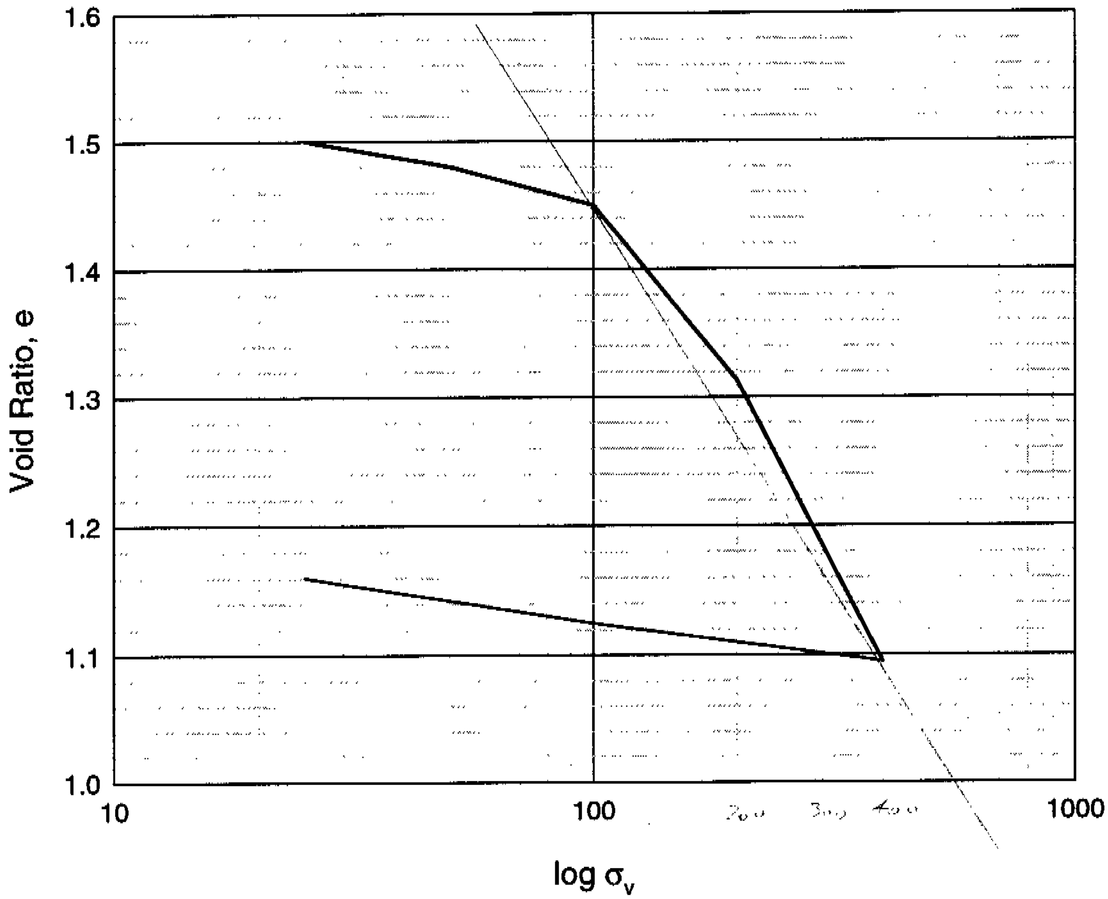
CLAYEY SILT TO SILTY CLAY (CL)
SOFT TO V. SOFT, BROWN, V. MOIST.
- HORIZONTAL SAMPLE -

C_C 0.34
C_R 0.02
INITIAL VOID RATIO 0.9

FIGURE 8 OEDOMETER CONSOLIDATION TEST RESULTS FOR SHELBY TUBE SAMPLE TW1, BOREHOLE 301

TROW

MOON RIVER BRIDGE
W.P. 216-90-01



BOREHOLE NO. 302
DEPTH 4.9m
MOISTURE CONTENT 56.3%
LIQUID LIMIT
PLASTIC LIMIT
PRECONSOL. PRESSURE 135kPa

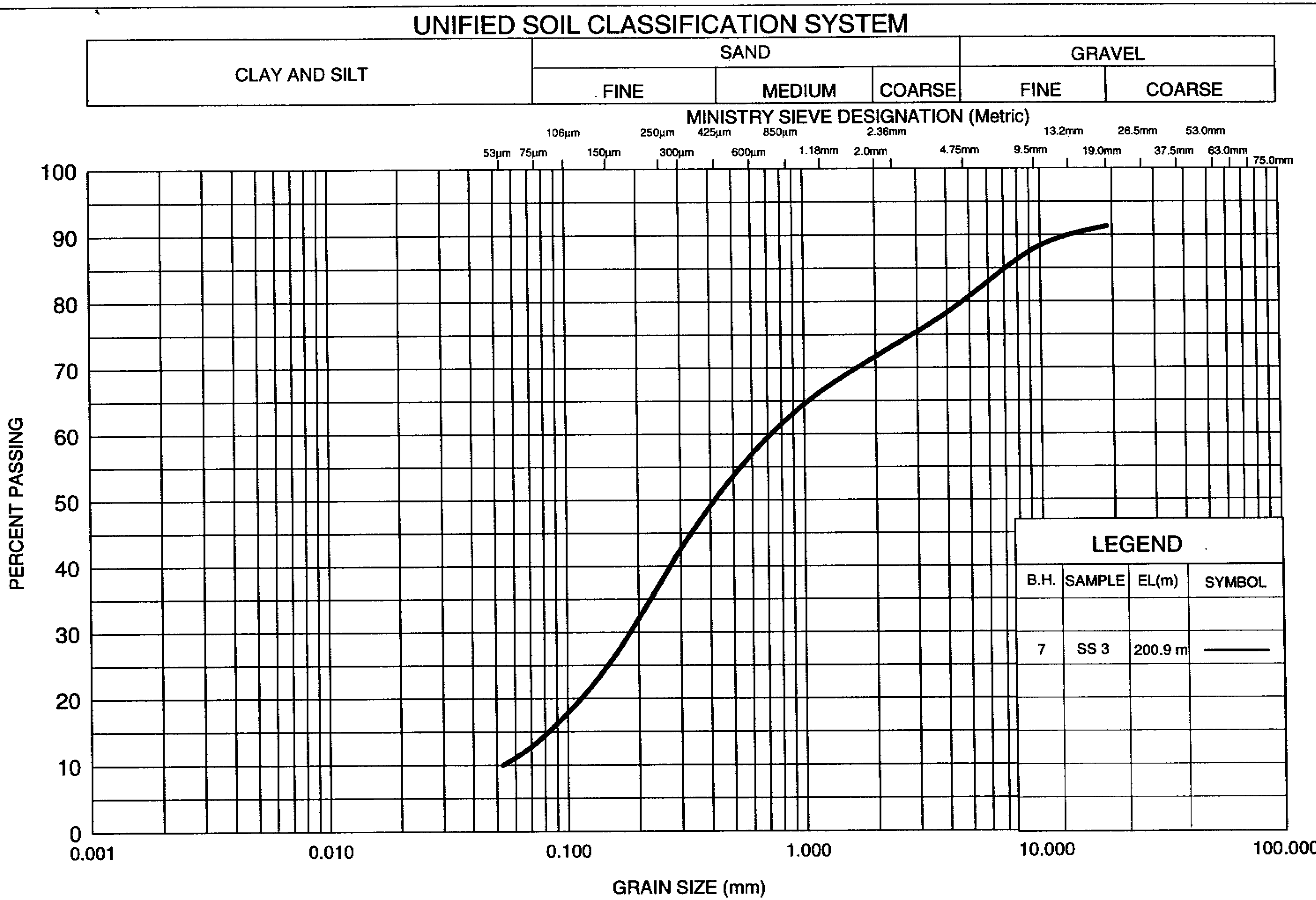
SAMPLE DESCRIPTION

CLAYEY SILT TO SILTY CLAY (CL)
SOFT TO V. SOFT, BROWN, V. MOIST.
- HORIZONTAL SAMPLE -

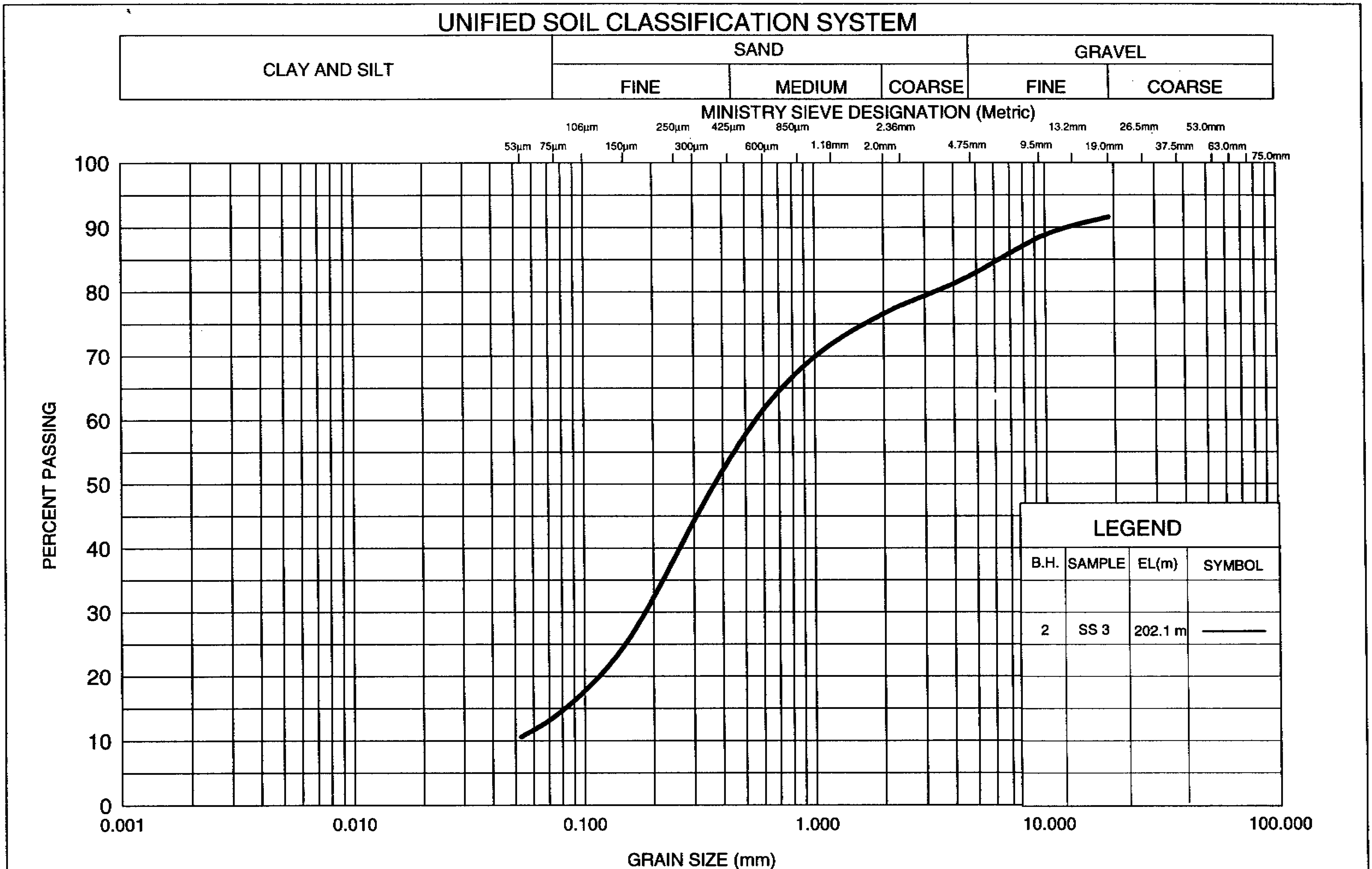
C_C 0.46 0.73
C_R 0.05
INITIAL VOID RATIO 1.5

FIGURE 9 OEDOMETER CONSOLIDATION TEST RESULTS FOR SHELBY TUBE SAMPLE TW2, BOREHOLE 302

TROW



Ministry of Transportation **METRIC**	**GRAIN SIZE DISTRIBUTION** B.H. 7 - SAMPLE 3: SAND - with some GRAVEL and SILT, brown, wet, loose (TILL).	**FIGURE 10** **W.P. 208-90-01**



Ministry of Transportation METRIC	**GRAIN SIZE DISTRIBUTION** B.H. 2 - SAMPLE 3: SAND - with some GRAVEL and SILT, brown, wet, loose (TILL).	FIGURE 11 W.P. 208-90-01

MOON RIVER BRIDGE
W.P. 216-90-01

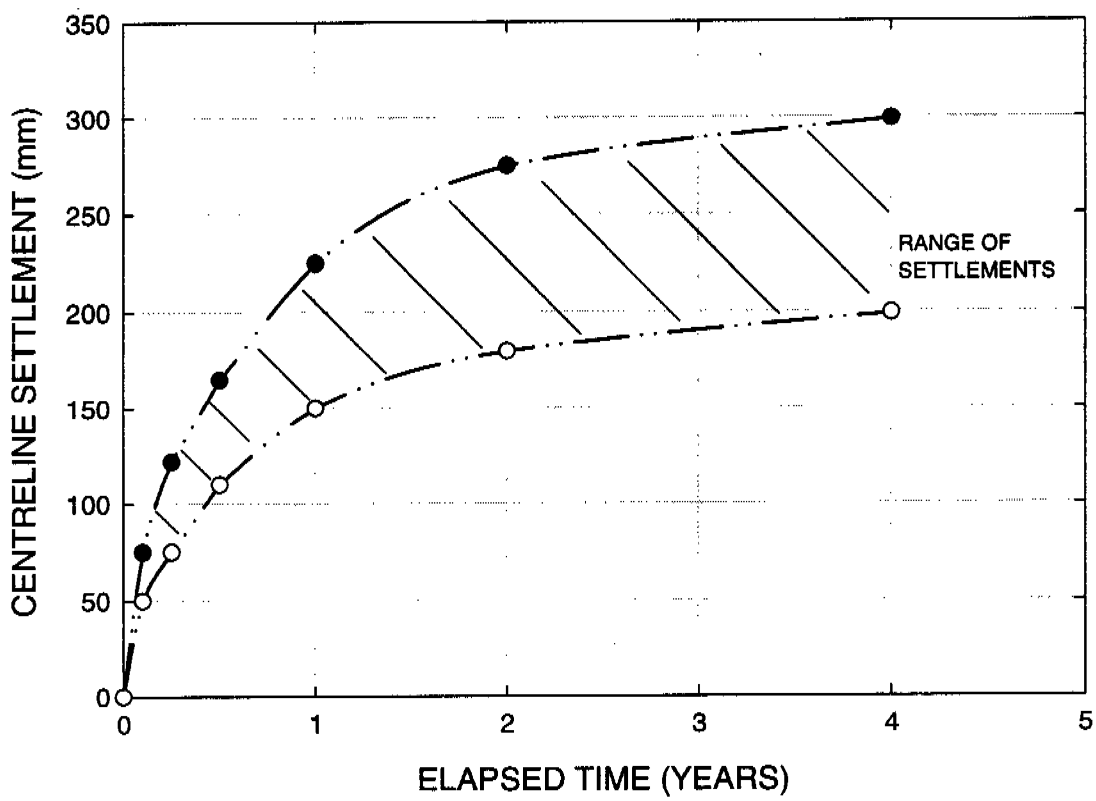


FIGURE 12 ESTIMATED SETTLEMENT RESPONSE FOR 8.5m EMBANKMENT HEIGHT

TROW

MOON RIVER BRIDGE
W.P. 216-90-01

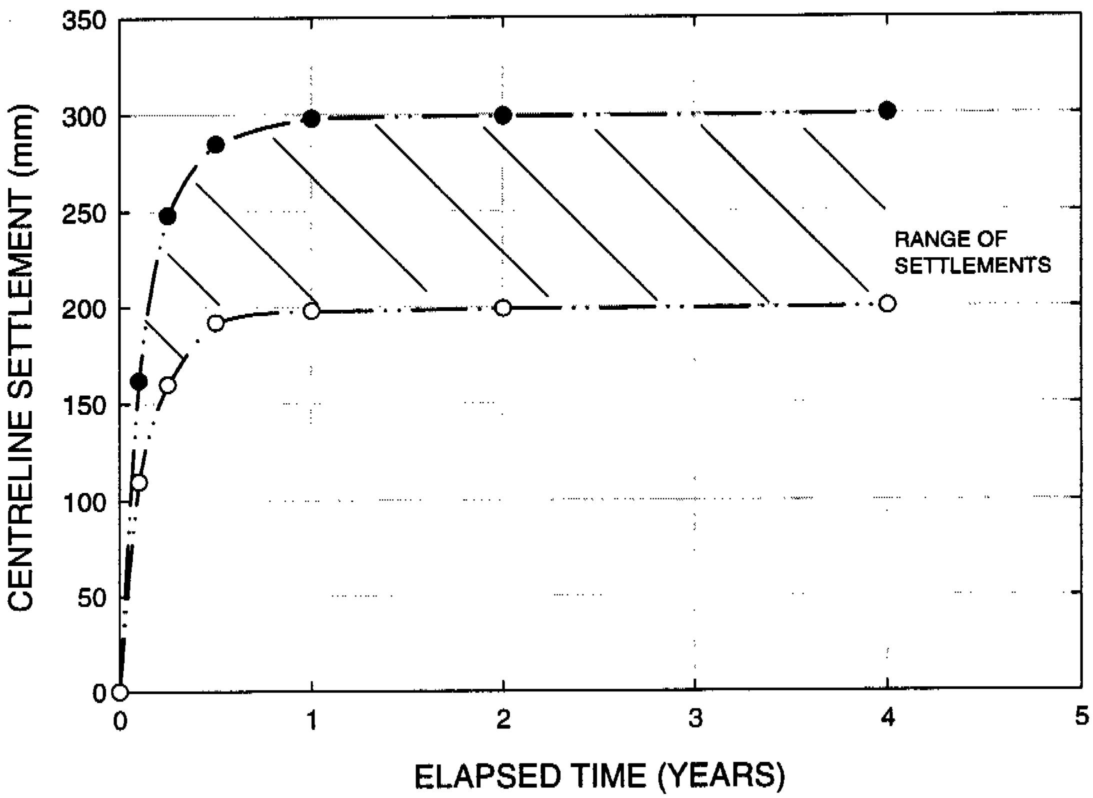


FIGURE 13 ESTIMATED SETTLEMENT RESPONSE FOR 8.5m EMBANKMENT HEIGHT WITH VERTICAL SAND DRAINS AT 2.5 m CENTRE TO CENTRE SPACING

TROW

Appendix A: PHOTOGRAPHS

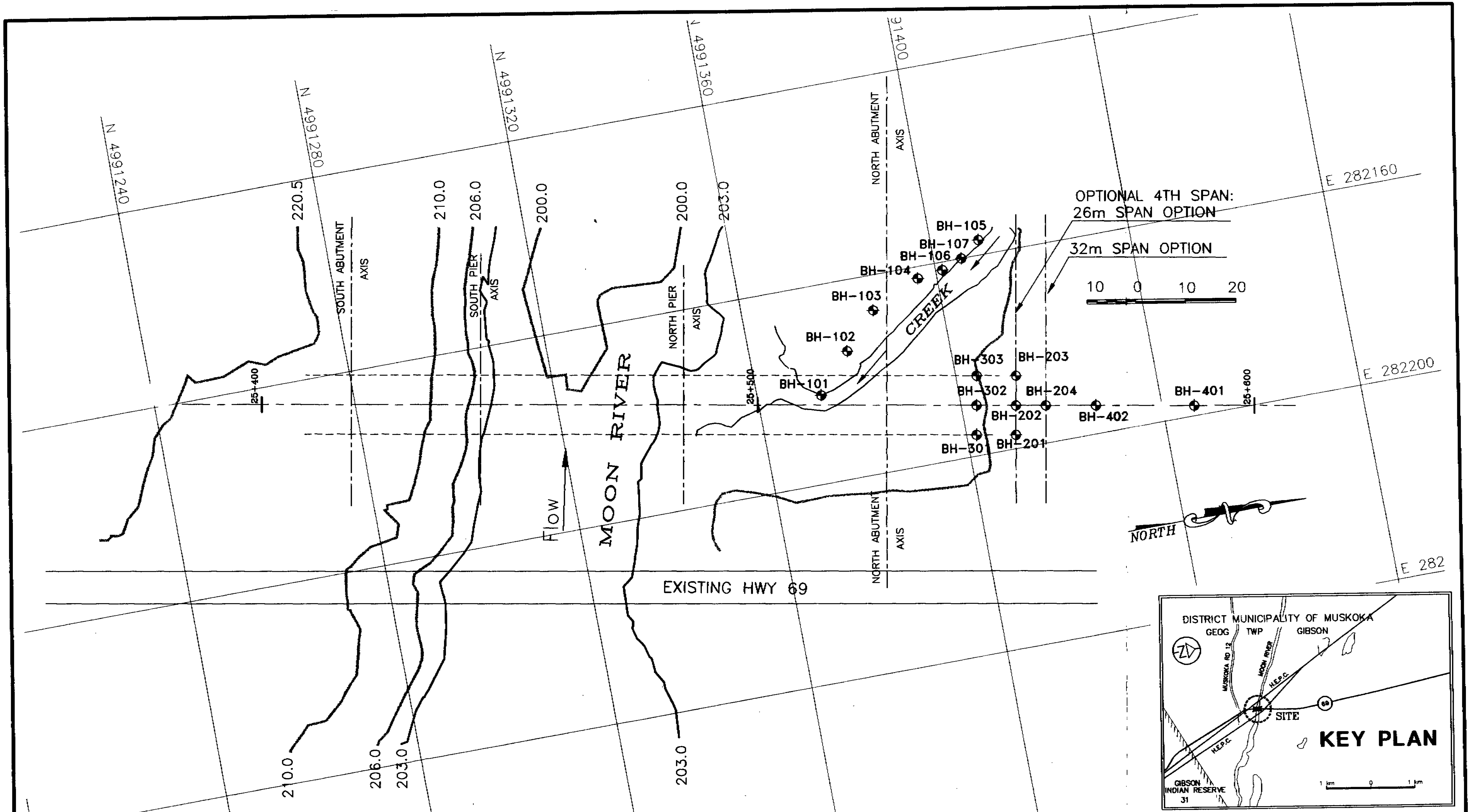
PHOTOGRAPH 1 North Bank of the Moon River.

PHOTOGRAPH 2 Creek adjacent to North Approach Embankment and Abutment

PHOTOGRAPH 3 South Bank of Moon River Bridge

PHOTOGRAPH 4 Raft and drill rig (D-25) used to advance boreholes for piers.

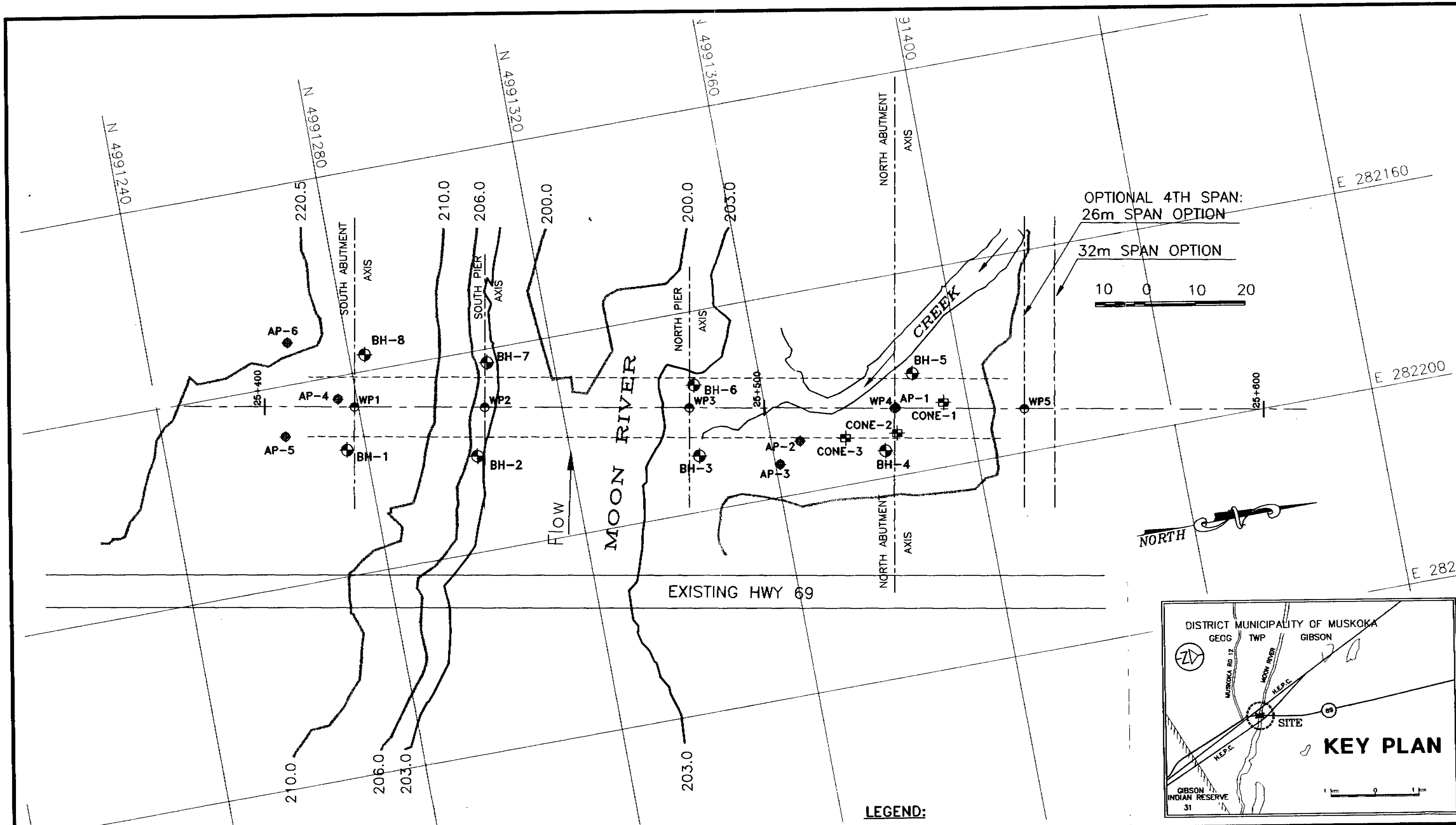
Appendix B: DRAWINGS



TROW CONSULTING ENGINEERS LTD.
BRAMPTON, ONTARIO

MOON RIVER BRIDGE-HWY 69
BOREHOLE LOCATION PLAN
ADDITIONAL SAMPLING &
NEW CULVERT ALIGNMENT
Toronto W.P. 216-90-01 ONTARIO

PROJECT NO.:	BR-11546-A/G
SCALE:	1:750
DRAWN BY:	S.S.
CHECKED BY:	S.H.
DATE:	OCT., 1998
DRAWING NO.:	2



LEGEND:

Symbol	Description
BH-6	BOREHOLE #
WP5	WORK POINT #
CONE-3	CONE #
AP-2	AUGER PROBE #

TROW CONSULTING ENGINEERS LTD.
BRAMPTON, ONTARIO

MOON RIVER BRIDGE
HWY 69
BOREHOLE LOCATION PLAN
W.P. 216-90-01
Toronto ONTARIO

PROJECT NO.:	BR-11546-A/G
SCALE:	1:750
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CHECKED BY:	S.H.
DATE:	OCT., 1998
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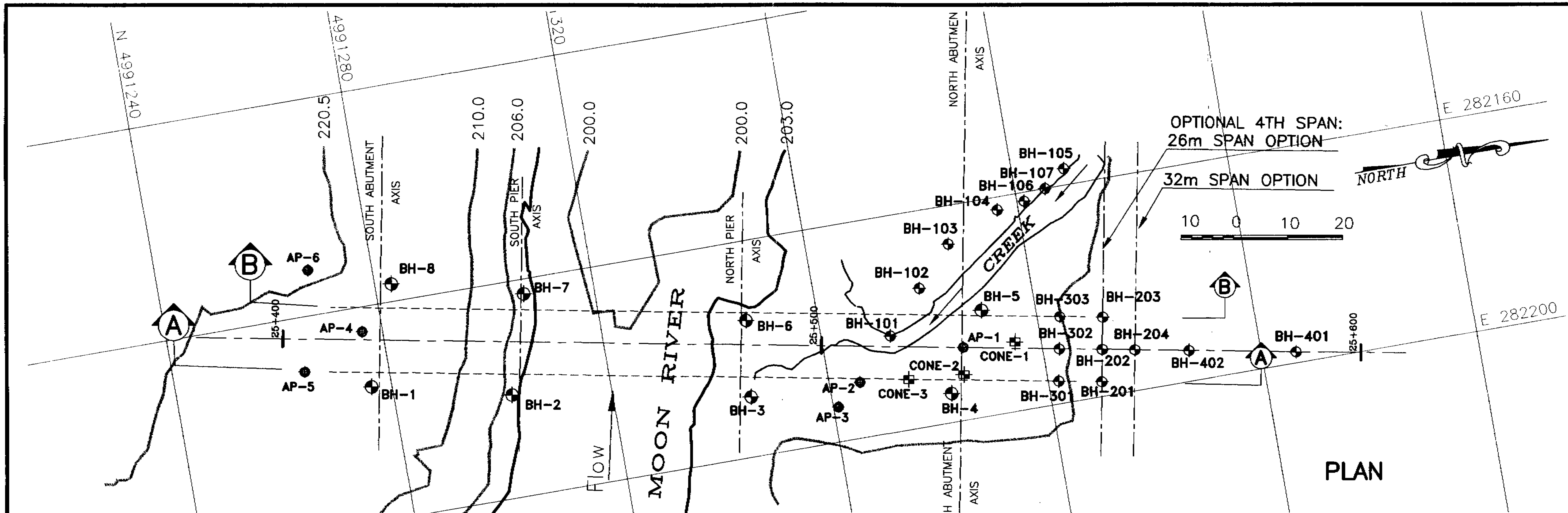
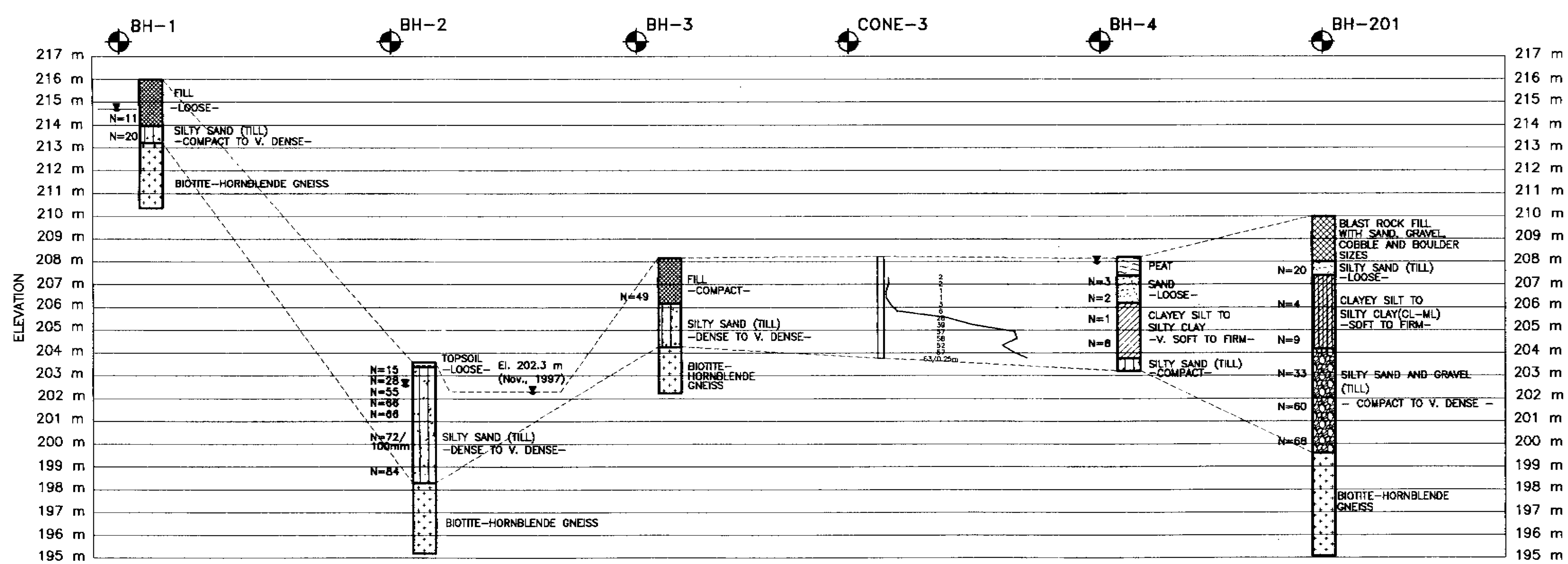




SECTION A–A

DO NOT SCALE HORIZONTAL DISTANCES IN PROFILE VIEW
FOR VERTICAL ELEVATION REFER TO THE PROFILE GRID.
FOR HORIZONTAL DISTANCES BETWEEN THE BORE LOGS
REFER TO THE PLAN VIEW

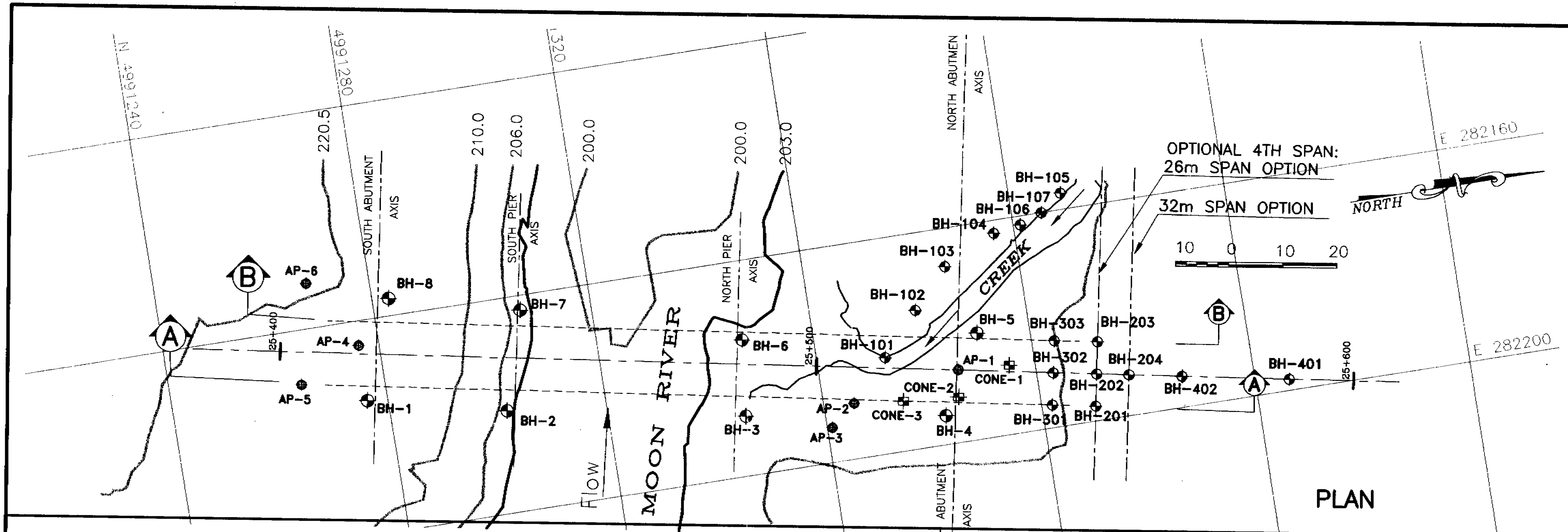
NOTE:

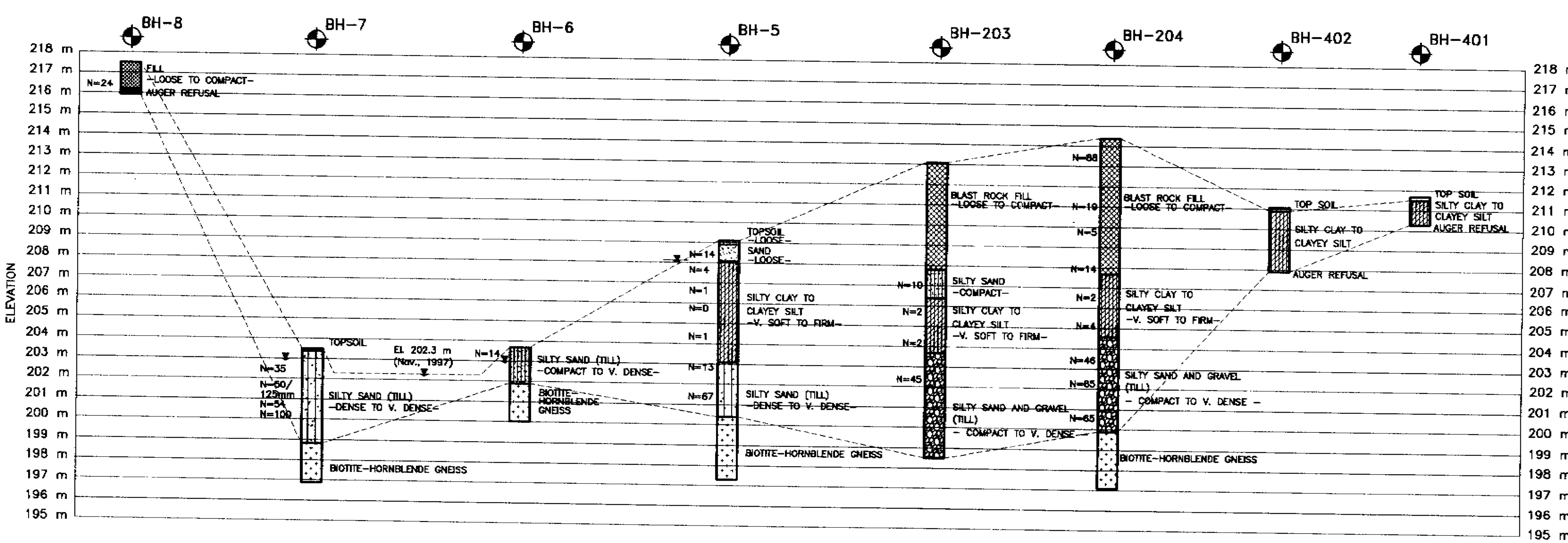
BOUNDARIES BETWEEN STRATA AT BOREHOLES ARE ESTIMATED FROM NON-CONTINUOUS SAMPLES. STRATA BOUDARIES BETWEEN BOREHOLES ARE PLOTTED TO AID IN THE INTERPRETATION OF GENERAL STRATIGRAPHY. ACTUAL BOUNDARIES WILL NOT EXACTLY CORRELATE WITH THOSE SHOWN.

TROW CONSULTING ENGINEERS LTD.
BRAMPTON, ONTARIO

MOON RIVER BRIDGE-HWY 69
SUBSURFACE PROFILES-SECTION A-A
W.P. 216-90-01
TORONTO ONTARIO

PROJECT NO.:	BR-11546-A/G
SCALE:	AS SHOWN
DRAWN BY:	S.S.
CHECKED BY:	S.H.
DATE:	OCT., 1998
DRAWING NO.:	3





SECTION B-B

DO NOT SCALE HORIZONTAL DISTANCES IN PROFILE VIEW
FOR VERTICAL ELEVATION REFER TO THE PROFILE GRID.
FOR HORIZONTAL DISTANCES BETWEEN THE BORE LOGS
REFER TO THE PLAN VIEW

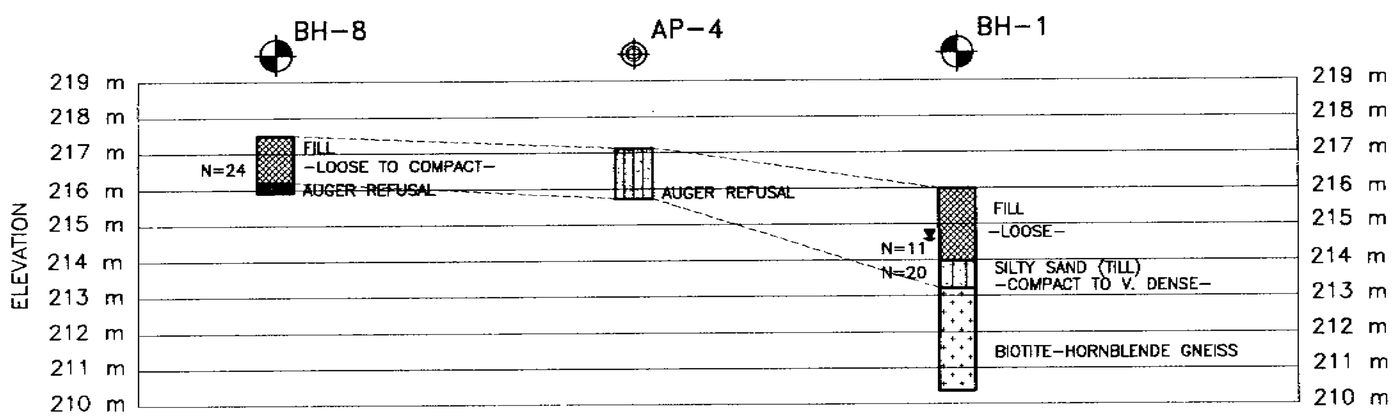
NOTE:

BOUNDARIES BETWEEN STRATA AT BOREHOLES ARE ESTIMATED FROM NON-CONTINUOUS SAMPLES. STRATA BOUDARIES BETWEEN BOREHOLES ARE PLOTTED TO AID IN THE INTERPRETATION OF GENERAL STRATIGRAPHY. ACTUAL BOUNDARIES WILL NOT EXACTLY CORRELATE WITH THOSE SHOWN.

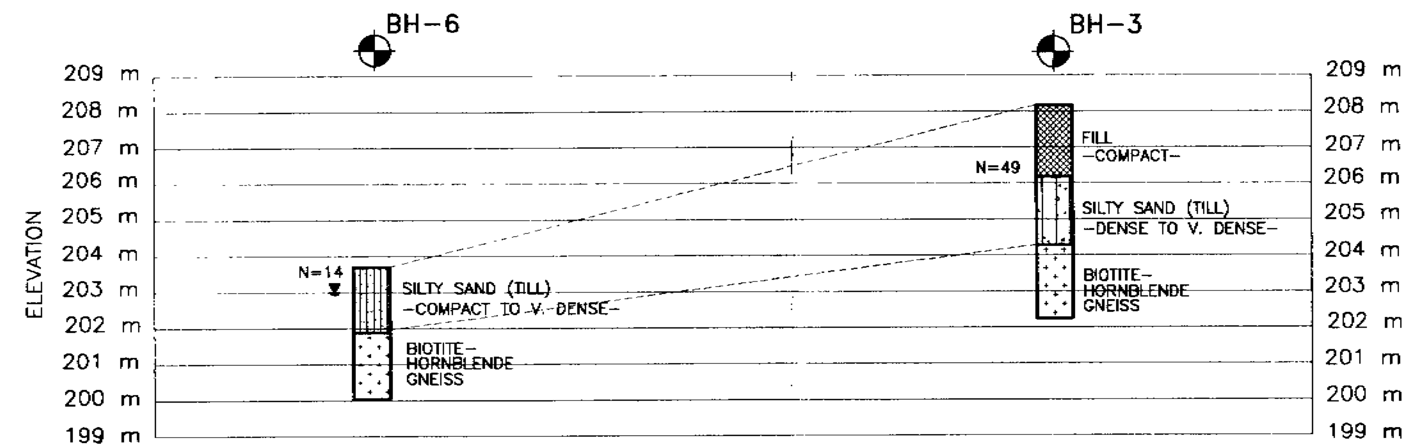
TROW CONSULTING ENGINEERS LTD.
BRAMPTON, ONTARIO

MOON RIVER BRIDGE-HWY 69
SUBSURFACE PROFILES-SECTION B-B
W.P. 216-90-01
TORONTO ONTARIO

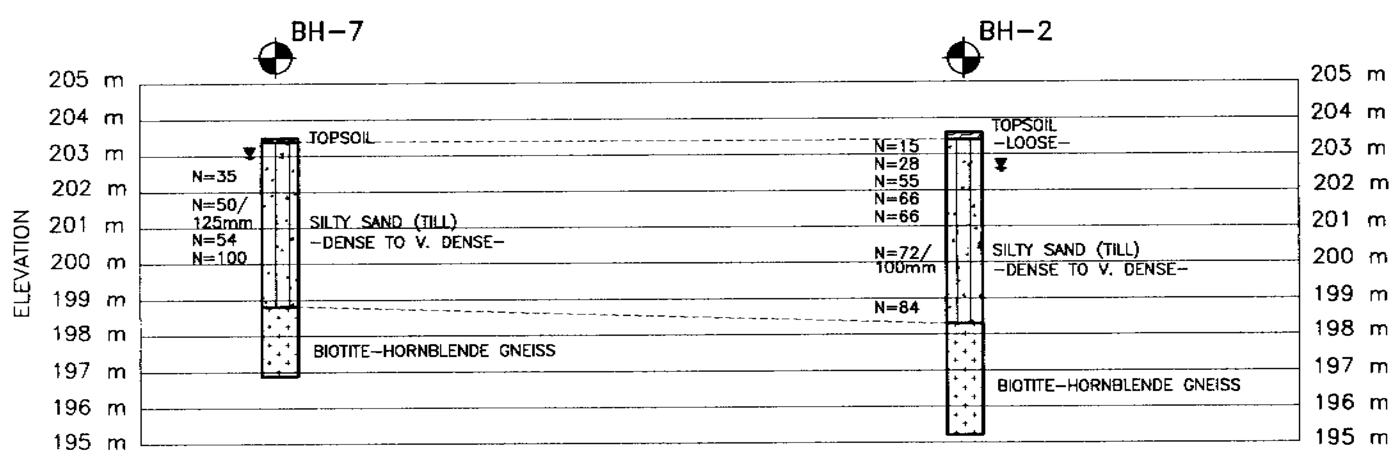
PROJECT NO.:	BR-11546-A/G
SCALE:	AS SHOWN
DRAWN BY:	S.S.
CHECKED BY:	S.H.
DATE:	OCT., 1998
DRAWING NO.:	4



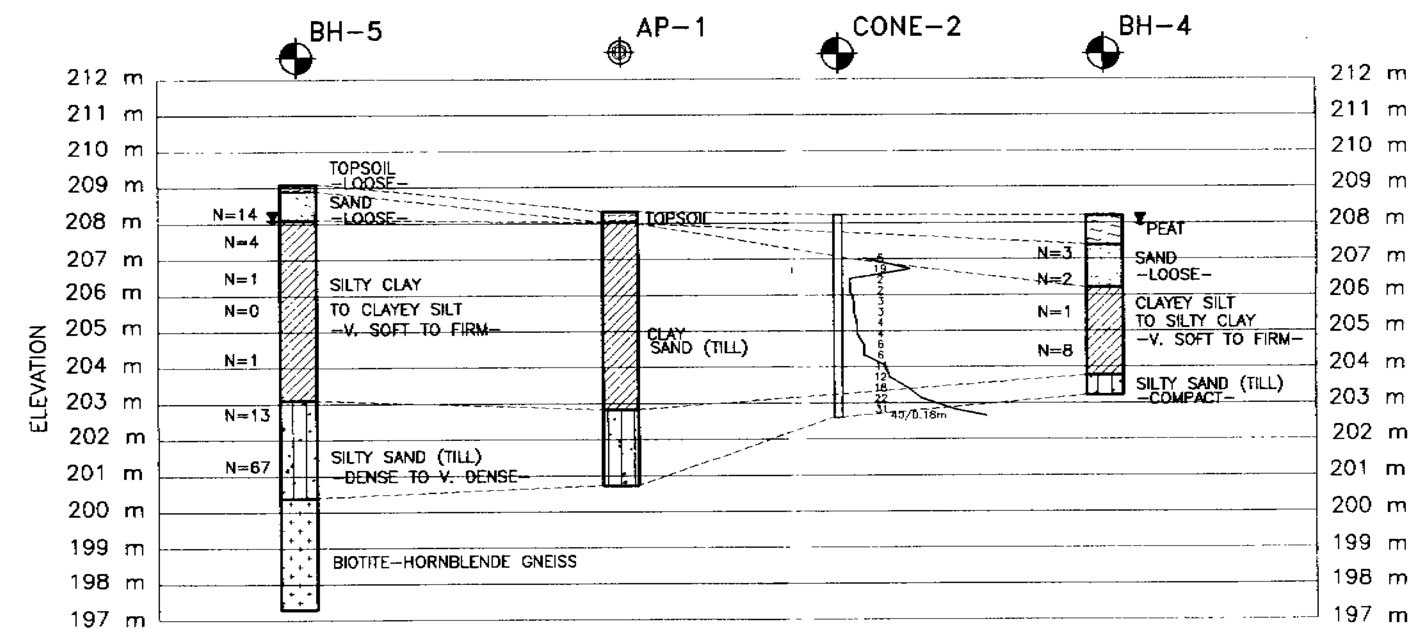
SOUTH ABUTMENT



NORTH PIER



SOUTH PIER



NORTH ABUTMENT

DO NOT SCALE HORIZONTAL DISTANCES IN CROSS SECTIONS.
FOR VERTICAL ELEVATION REFER TO THE CROSS SECTION GRID.
FOR HORIZONTAL DISTANCES BETWEEN THE BORE LOGS
REFER TO ONE OF THE PLAN VIEWS IN OTHER DRAWINGS.

NOTE:

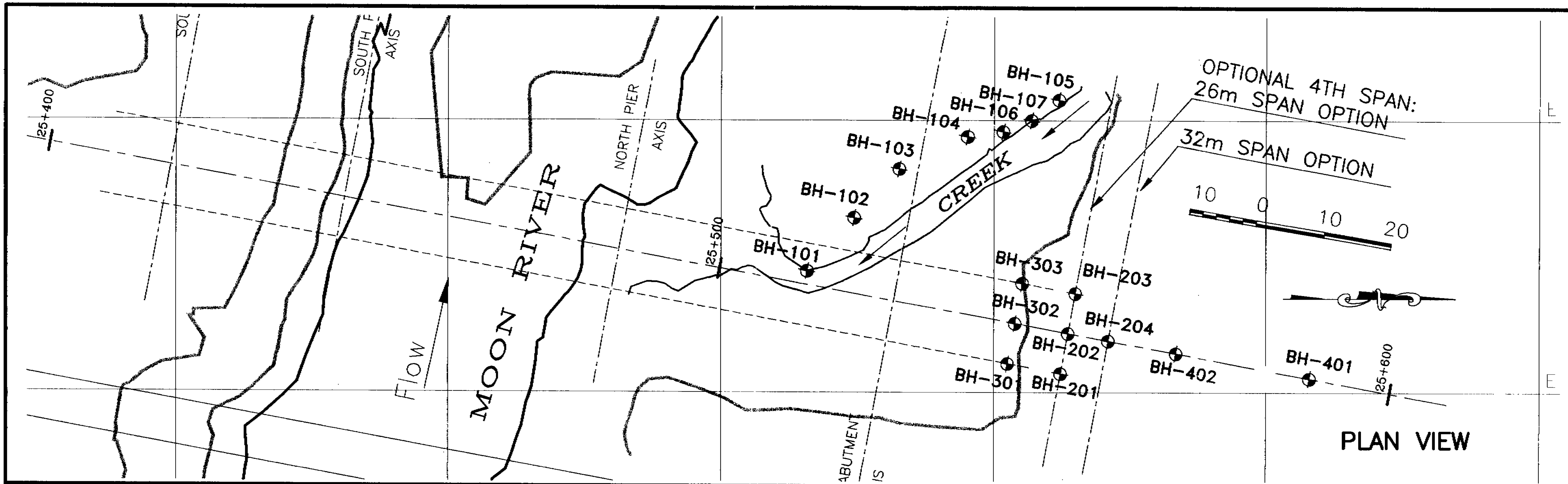
BOUNDARIES BETWEEN STRATA AT BOREHOLES ARE ESTIMATED FROM NON-CONTINUOUS SAMPLES. STRATA BOUDARIES BETWEEN BOREHOLES ARE PLOTTED TO AID IN THE INTERPRETATION OF GENERAL STRATIGRAPHY. ACTUAL BOUNDARIES WILL NOT EXACTLY CORRELATE WITH THOSE SHOWN.

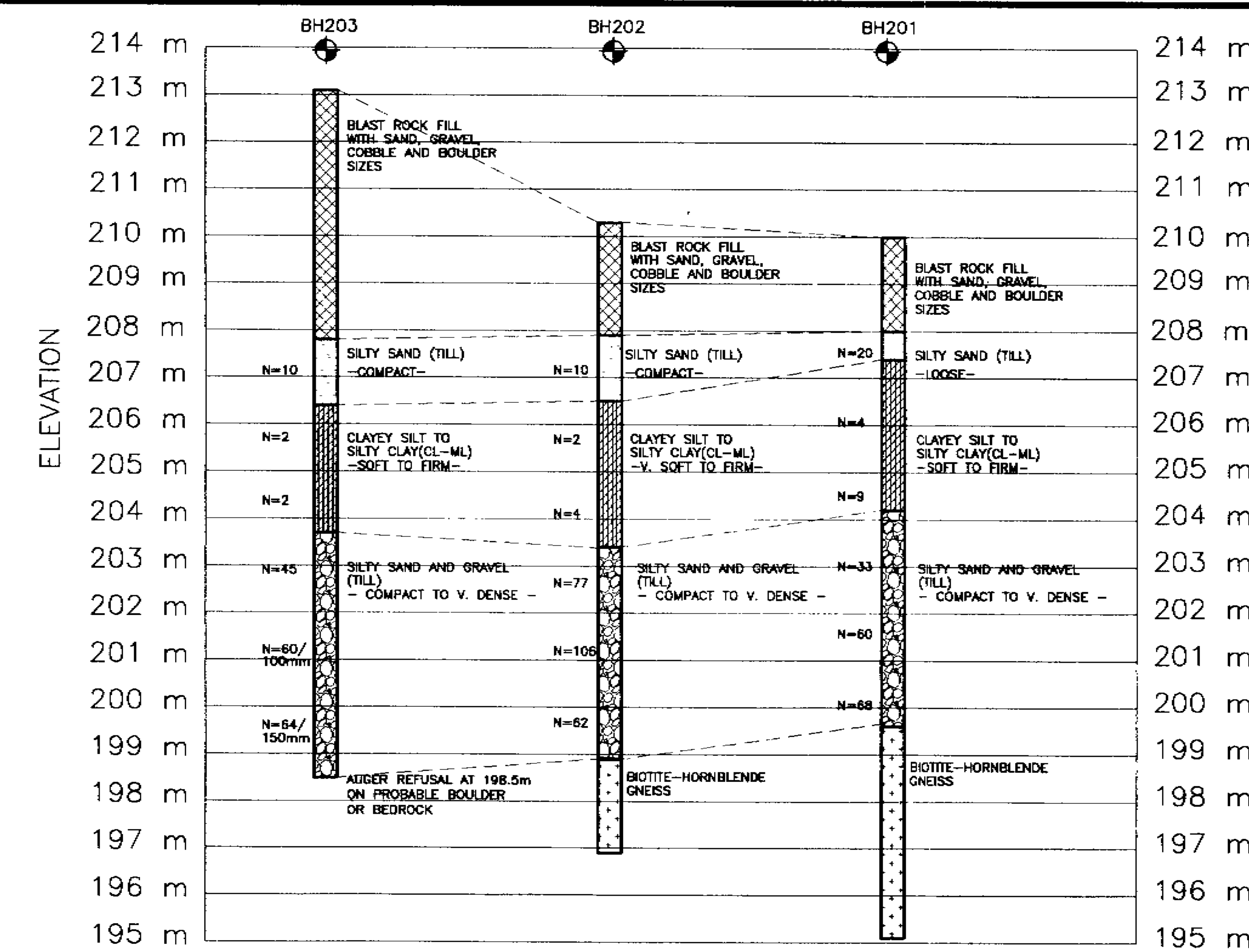
TROW CONSULTING ENGINEERS LTD.
BRAMPTON, ONTARIO

MOON RIVER BRIDGE
HWY 69
CROSS-SECTIONS
W.P. 216-90-01

TORONTO ONTARIO

PROJECT NO.:	BR-11546-A/G
SCALE:	AS SHOWN
DRAWN BY:	S.S.
CHECKED BY:	S.H.
DATE:	OCT., 1998
DRAWING NO.:	5





DO NOT SCALE HORIZONTAL DISTANCES IN PROFILE VIEW
FOR VERTICAL ELEVATION REFER TO THE PROFILE GRID.
FOR HORIZONTAL DISTANCES BETWEEN THE BORE LOGS REFER TO THE PLAN VIEW

NOTE:

BOUNDARIES BETWEEN STRATA AT BOREHOLES ARE ESTIMATED FROM NON-CONTINUOUS SAMPLES. STRATA BOUDARIES BETWEEN BOREHOLES ARE PLOTTED TO AID IN THE INTERPRETATION OF GENERAL STRATIGRAPHY. ACTUAL BOUNDARIES WILL NOT EXACTLY CORRELATE WITH THOSE SHOWN.

NORTH ABUTMENT
(4th SPAN OPTION)

PROFILE

TROW CONSULTING ENGINEERS LTD.
BRAMPTON, ONTARIO

CREEK TO MOON RIVER
HWY 69-NORTH ABUTMENT
OPTIONAL 26m 4TH SPAN PLAN-PROFILE
W.P. 216-90-01
Toronto ONTARIO

PROJECT NO.:	BR-11546-A/G
SCALE:	1:250
DRAWN BY:	S.S.
CHECKED BY:	S.H.
DATE:	OCT., 1997
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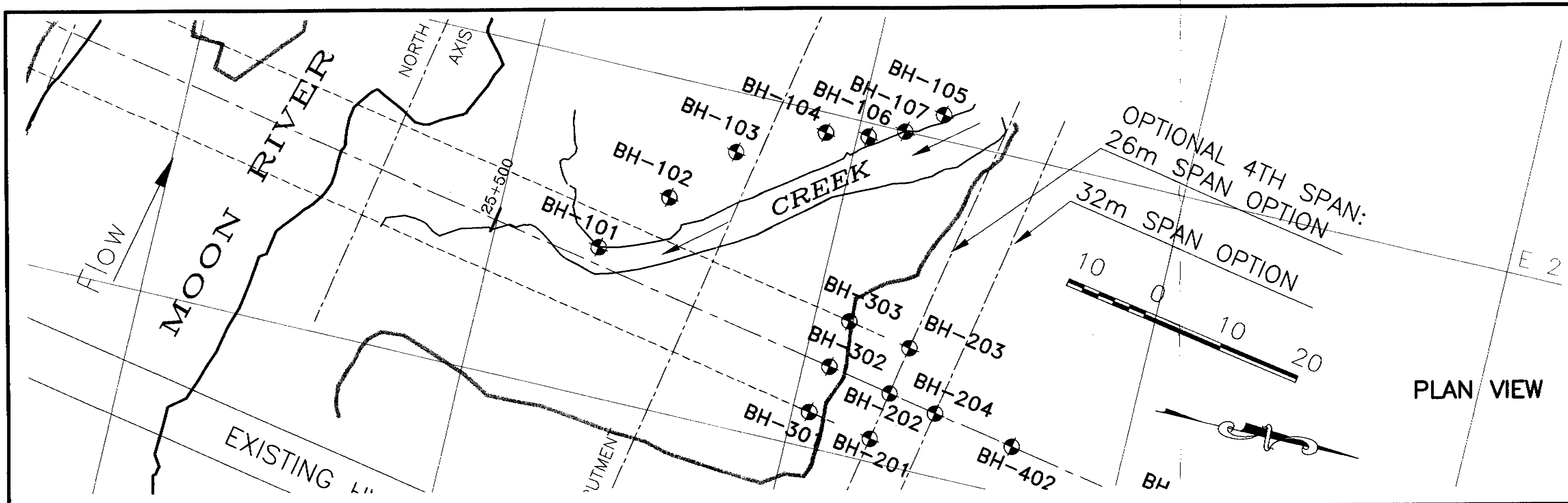
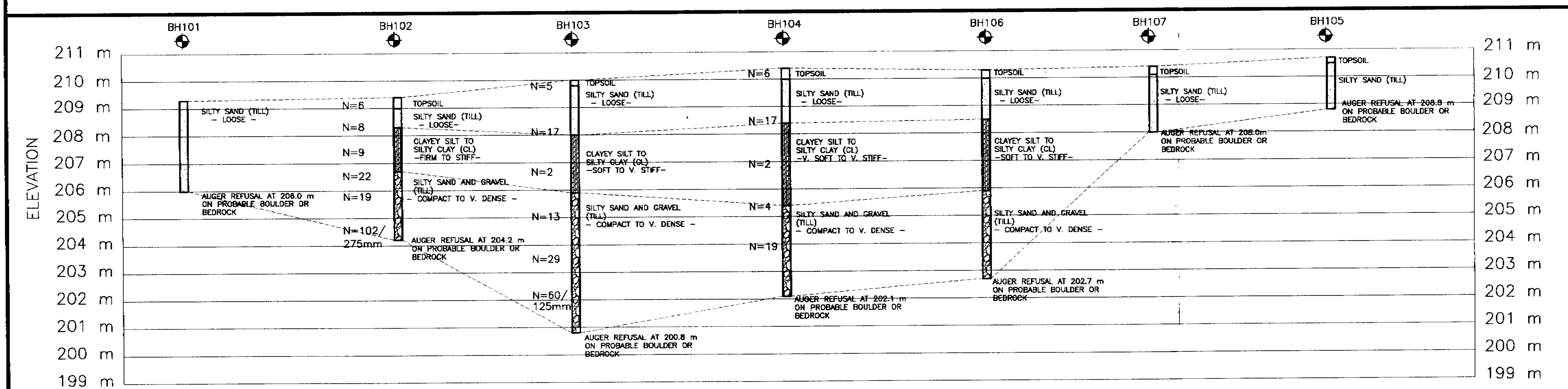




PROPOSED CULVERT ALIGNMENT

PROFILE

DO NOT SCALE HORIZONTAL DISTANCES IN PROFILE VIEW
FOR VERTICAL ELEVATION REFER TO THE PROFILE GRID.
FOR HORIZONTAL DISTANCES BETWEEN THE BORE LOGS
REFER TO THE PLAN VIEW

NOTE:

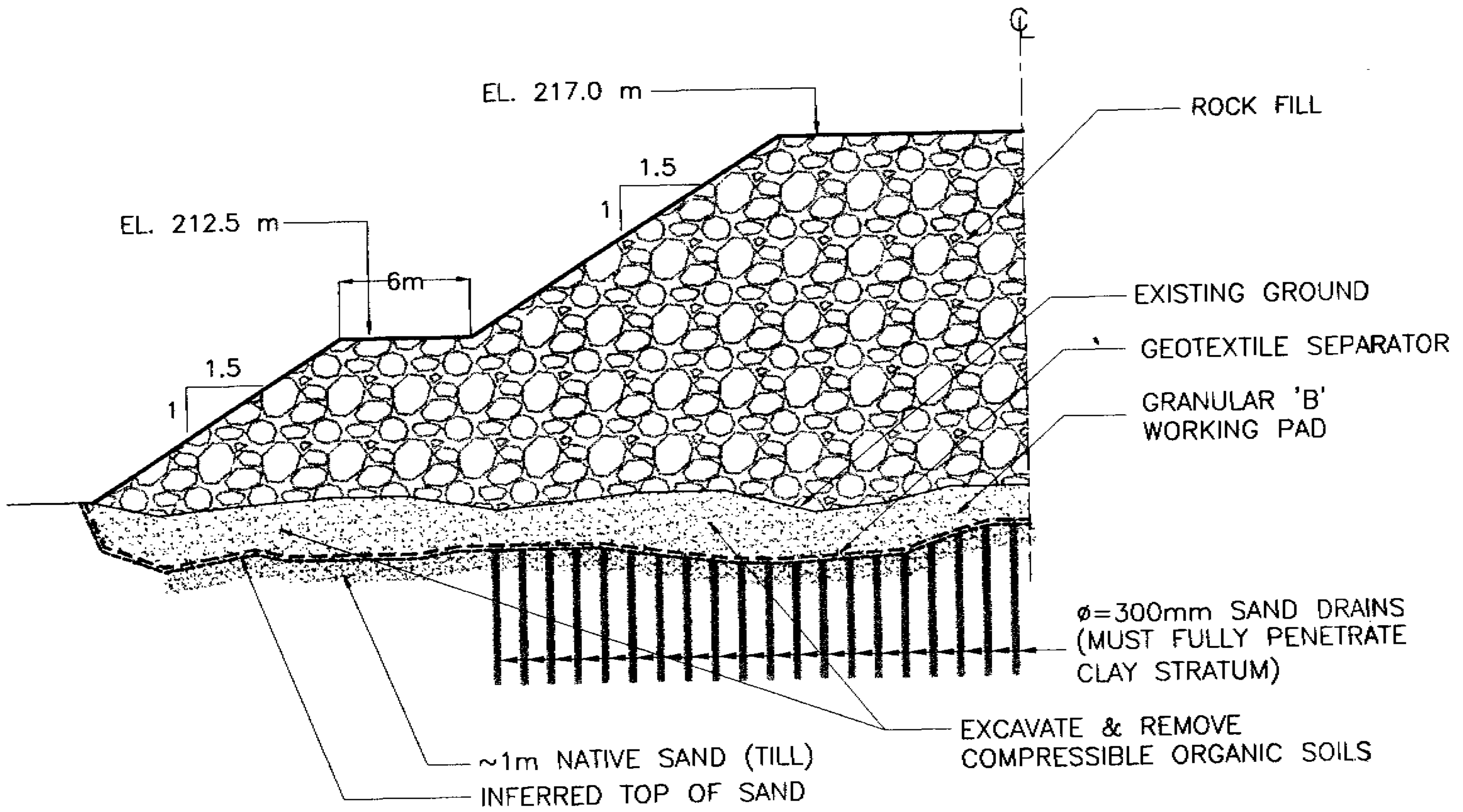
BOUNDARIES BETWEEN STRATA AT BOREHOLES ARE ESTIMATED FROM NON-CONTINUOUS SAMPLES. STRATA BOUNDARIES BETWEEN BOREHOLES ARE PLOTTED TO AID IN THE INTERPRETATION OF GENERAL STRATIGRAPHY. ACTUAL BOUNDARIES WILL NOT EXACTLY CORRELATE WITH THOSE SHOWN.

TROW CONSULTING ENGINEERS LTD.
BRAMPTON, ONTARIO

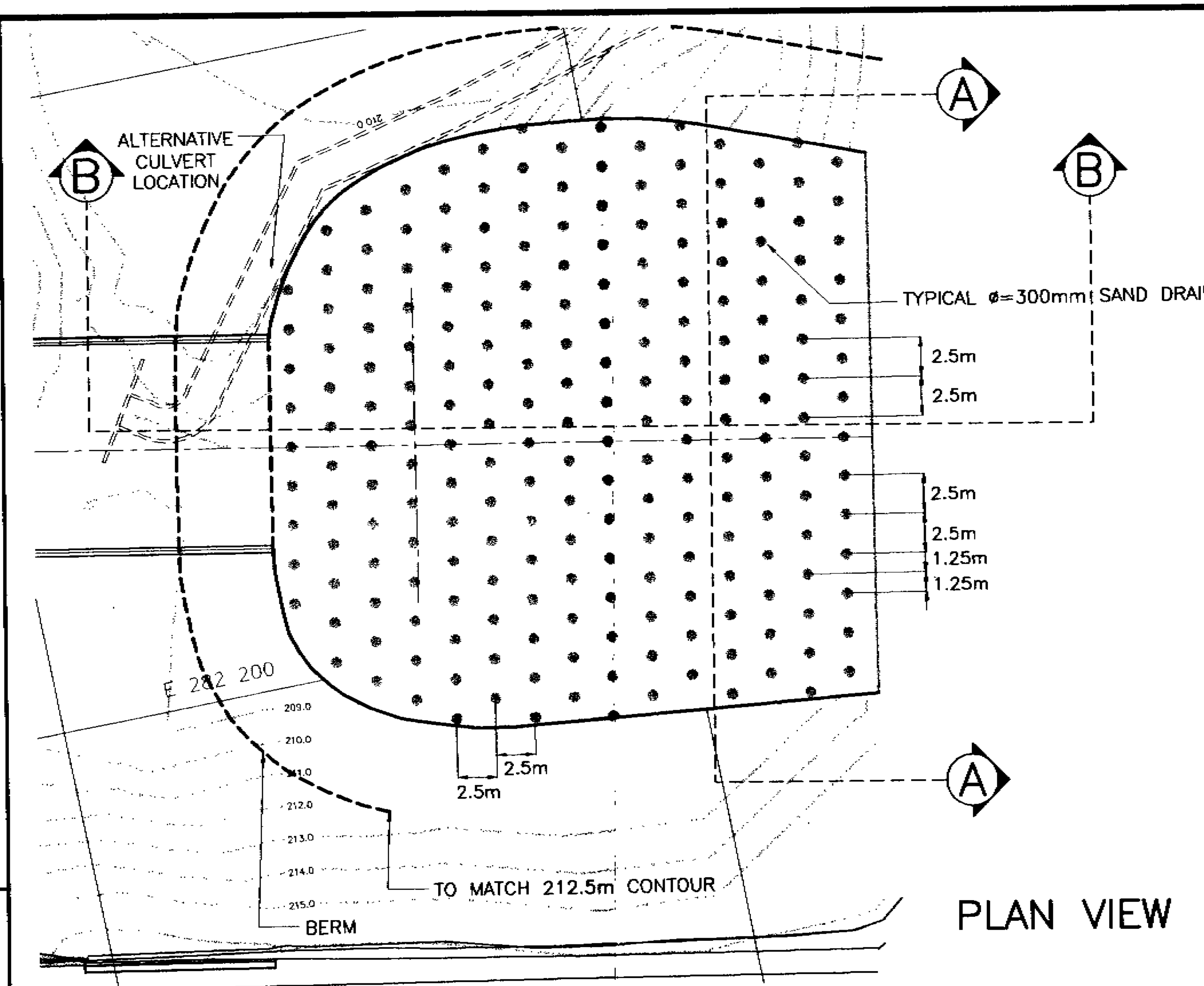
CREEK TO MOON RIVER
HWY 69-NORTH CULVERT
PLAN – PROFILE
W.P. 216-90-01

Toronto ONTARIO

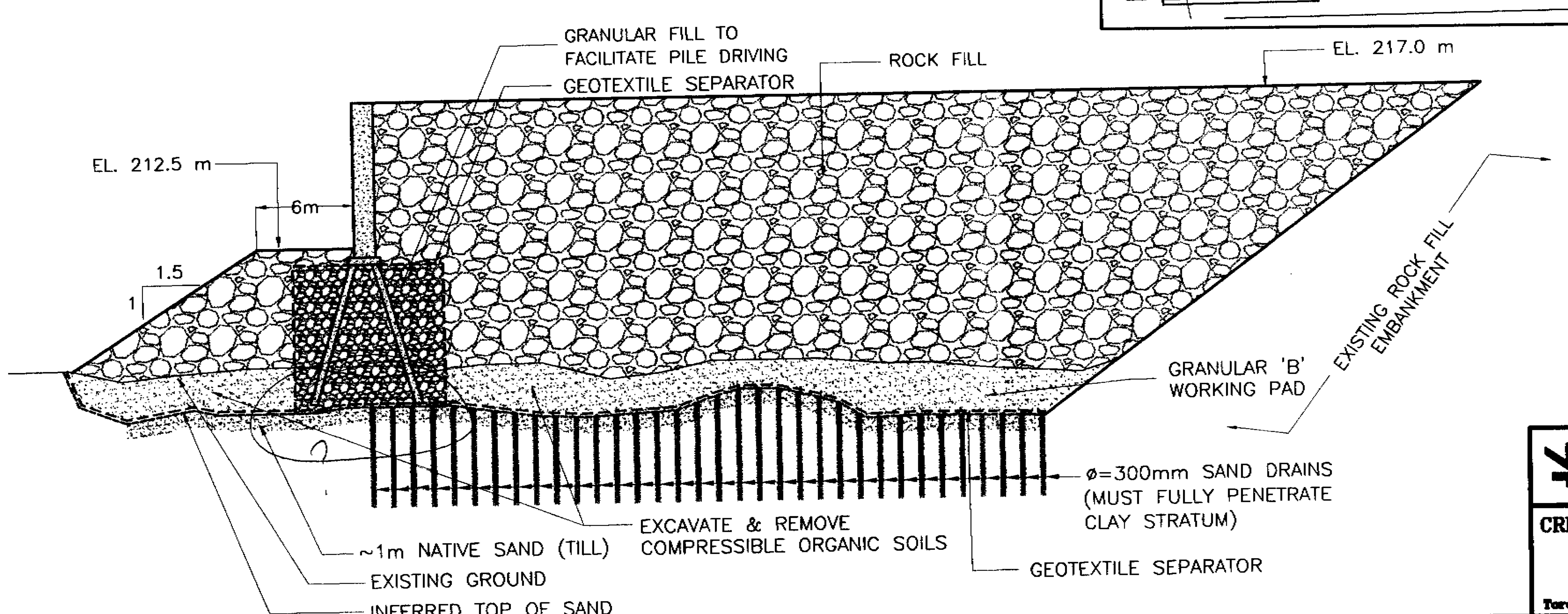
PROJECT NO.:	BR-11546-A/G
SCALE:	AS SHOWN
DRAWN BY:	S.S.
CHECKED BY:	S.H.
DATE:	OCT., 1998
DRAWING NO.:	7



SECTION A–A



SECTION B–B



TROW CONSULTING ENGINEERS LTD.
BRAMPTON, ONTARIO

CREEK TO MOON RIVER–HWY 69
EMBANKMENT GEOMETRY AND SAND DRAIN LAYOUT
W.P. 216–90–01
Toronto ONTARIO

PROJECT NO.:	BR–11546–A/G
SCALE:	AS SHOWN
DRAWN BY:	S.S.
CHECKED BY:	S.H.
DATE:	OCT., 1998
DRAWING NO.:	8

Appendix C: BOREHOLE, CONE AND AUGER PROBE LOGS

RECORD OF BOREHOLE 1

MOON RIVER BRIDGE

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION SOUTH ABUTMENT - 4 991 276.2N 282 175.0E
BOREHOLE TYPE SPT AND B SIZE CORE HOLLOW STEM AUGERS
DATE November 25, 1997

ORIGINATED BY I.D.
COMPILED BY S.H.
CHECKED BY C.N.

ELEV. / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — (20 40 60 80); SHEAR STRENGTH: Cu, KPa (UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE) (20 40 60 80)	PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl — WATER CONTENT (%) (20 40 60 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
216.0	GROUND SURFACE										
0.0	FILL - silty sandy and gravel, moist, loose.						215				
						▽					
			1	SS	11			⊗			
214.0 / 2.0	SILTY SAND - with gravel and cobbles, occ. boulders, grey, wet, compact to very dense. (TILL)						214				
			2	SS	20			⊗	○		
213.2 / 2.7	BIOTITE HORNBLENDE GNEISS - interlayered, pinkish to grey, fair to good rock mass quality, hard, fractures oriented at approximately 40 and 10 degrees to the core axis.						213				
			1	RC							REC 100% RQD 60%
							212				
			2	RC			211				REC 100% RQD 80%
210.4 / 5.6	END OF BOREHOLE										

MTOMOON HW69M 04/08/98

Trow

RECORD OF BOREHOLE 2
MOON RIVER BRIDGE

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION SOUTH PIER - 4 991 301.5N 282 180.9E
BOREHOLE TYPE SPT - B SIZE CORE HOLLOW STEM AUGERS
DATE November 11, 1997

ORIGINATED BY G.B.
COMPILED BY S.H.
CHECKED BY C.N.

ELEV. / DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	SPT N-Value	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (GR SA SI & CL)
203.6	GROUND SURFACE							
203.4 / 0.2	TOPSOIL - silt with organics, rootlets, leaves, dark brown, loose	1	SS	15				
	SILTY SAND - with gravel and cobbles, occ. boulders, grey, wet, dense to very dense. (TILL)	2	SS	28	▽			
		3	SS	55				24% 64% 12%
		4	SS	66				
		5	SS	66				
		6	SS	72		72/125mm		
		7	SS	84				
198.3 / 5.3	BIOTITE HORNBLENDE GNEISS - predominantly grey, with pinkish seams, excellent rock mass quality, hard, fractures oriented at 30 degrees to the core axis.	1	RC					REC 100% RQD 100%
		2	RC					REC 100% RQD 100%
		3	RC					REC 96% RQD 100%
195.3 / 8.4	END OF BOREHOLE							

Elevation scale (metres): 203, 202, 201, 200, 199, 198, 197, 196

SPT TEST (N-Value) ⊗; CONE PENETRATION TEST; SHEAR STRENGTH: Cu, KPa (○ UNCONFINED, ● QUICK TRIAXIAL, FIELD VANE, LAB VANE); PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl; UNIT WEIGHT kN/m³

Trow

RECORD OF BOREHOLE 3

MOON RIVER BRIDGE

METRIC

W.P. 216-90-01 | LOCATION NORTH PIER - 4 991 344.8N 282 189.1E | ORIGINATED BY I.D.

DIST 52 HWY 69 | BOREHOLE TYPE SPT - BQ CORE HOLLOW STEM AUGERS | COMPILED BY S.H.

DATUM GEODETIC | DATE November 21, 1997 | CHECKED BY S.E.G.

ELEV. / DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS/0.3m	ELEVATION SCALE (metres)	SPT TEST (N-Value)	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (GR SA (SI & CL))
208.2	GROUND SURFACE							
0.0	FILL - silty sand and gravel with roots, moist, compact.				208			
					207			
		1	SS	49		49		
206.2 / 2.0	SILTY SAND - with gravel and cobbles, occ. boulders, grey, wet, dense to very dense. (TILL)				206			
205.7 / 2.4	Boulders	1	CORE		205			
204.3 / 3.9	BIOTITE HORNBLENDE GNEISS - predominantly grey, with pinkish seams, good to excellent rock mass quality, hard, fractures oriented at 30 degrees to the core axis.	1	RC		204			REC 100% RQD 90%
		2	RC		203			REC 100% RQD 74%
		3	RC					REC 100%
		4	RC					REC 100% RQD 85%
202.2 / 5.9	END OF BOREHOLE NOTE: Borehole dry upon completion.							

Column headings (not filled in): GROUND WATER CONDITIONS; STRATA PLOT; CONE PENETRATION TEST; SHEAR STRENGTH: Cu, KPa (UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE) 20 40 60 80; PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl; UNIT WEIGHT kN/m³

MTOMOON HW69M 04/08/98

Trow

RECORD OF BOREHOLE 4

MOON RIVER BRIDGE

METRIC

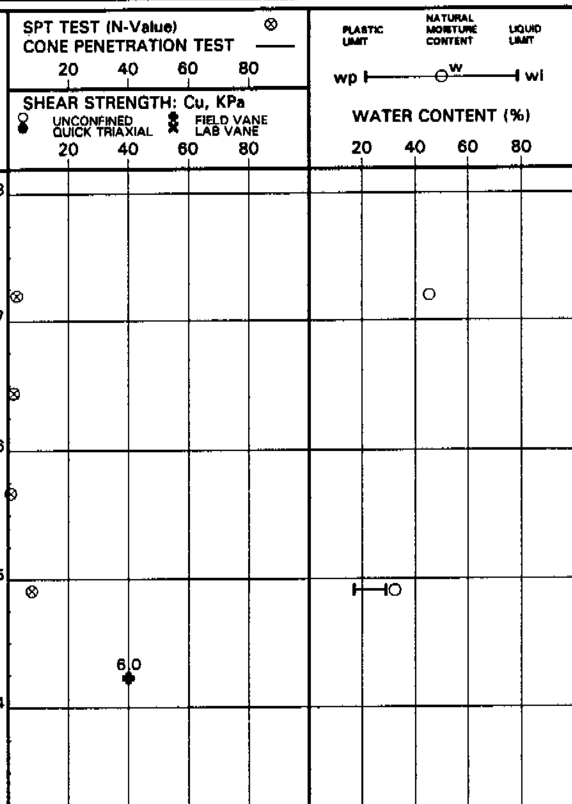
W.P. 216-90-01 | LOCATION NORTH ABUTMENT - 4 991 382.1N 282 194.6E | ORIGINATED BY I.D.

DIST 52 HWY 69 | BOREHOLE TYPE SPT - B SIZE CORE HOLLOW STEM AUGERS | COMPILED BY S.H.

DATUM GEODETIC | DATE November 19, 1997 | CHECKED BY S.E.G.

ELEV. DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)
208.2	GROUND SURFACE					
0.0	PEAT				▽	208
207.4 / 0.8	SAND - stratified, medium sand with organics, wet, loose.	1	SS	3		207
		2	SS	2		
206.2 / 2.0	SILTY CLAY to CLAYEY SILT (CL) - stratified with thin silt layers or lenses, redish brown to brown, moist, very soft to firm	3	SS	1		206
		4	SS	8		205
						204
203.8 / 4.4	SILTY SAND - with gravel and cobbles, occ. boulders, grey, wet, dense to very dense. (TILL)					
203.2 / 5.0	END OF BOREHOLE					

AUGER REFUSAL - PROBABLE BEDROCK OR BOULDER AT 4.97m



UNIT WEIGHT kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION: GR SA (SI & CL)

Trow

MTOMOON HW69M 04/08/98

RECORD OF BOREHOLE 5

MOON RIVER BRIDGE

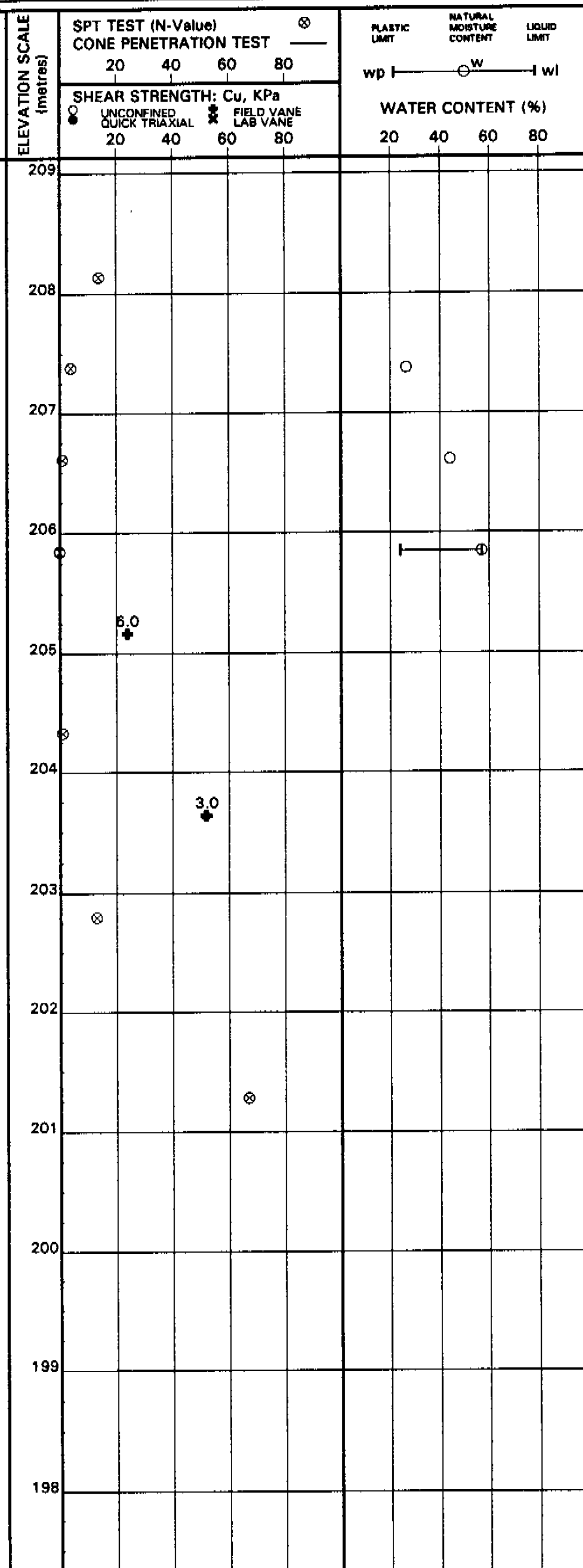
METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NORTH ABUTMENT - 4 991 390.2N 282 180.3E
BOREHOLE TYPE SPT - B SIZE CORE HOLLOW STEM AUGERS
DATE November 20, 1997

ORIGINATED BY I.D.
COMPILED BY S.H.
CHECKED BY S.E.G.

ELEV. / DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS/0.3m	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (GR SA (SI & CL))
209.1	GROUND SURFACE					
208.9 / 0.0	TOPSOIL - fine sand with organics, brown, loose.					
0.2	SAND - stratified fine and medium sand, grey, wet, loose.	1	SS	14		
208.1 / 1.1	SILTY CLAY to CLAYEY SILT (CL) - stratified with thin silt layers or lenses, redish brown to brown, moist, very soft to firm	2	SS	4		
		3	SS	1		
		4	SS	0	16.10	
		5	SS	1		
203.1 / 6.0	SILTY SAND - with gravel and cobbles, occ. boulders, grey, wet, dense to very dense. (TILL)	6	SS	13		
		7	SS	67		
200.4 / 8.7	BIOTITE HORNBLENDE GNEISS - dark grey with pinkish seams, fair to excellent rock mass quality, hard, fractures oriented at 10 to 50 degrees to the core axis.	1	RC			REC 100% RQD 70%
		2	RC			REC 100% RQD 100%
197.3 / 11.8	END OF BOREHOLE					



Trow

RECORD OF BOREHOLE 6

MOON RIVER BRIDGE

METRIC

W.P. 216-90-01 LOCATION NORHT PIER - 4 991 346.8N 282 174.7E ORIGINATED BY G.B.

DIST 52 HWY 69 BOREHOLE TYPE SPT - B SIZE CORE HOLLOW STEM AUGERS COMPILED BY S.H.

DATUM GEODETIC DATE November 17, 1997 CHECKED BY S.E.G.

ELEV. / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — (20 40 60 80); SHEAR STRENGTH: Cu, KPa (20 40 60 80)	WATER CONTENT (%) wp — w — wl (20 40 60 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
203.7	GROUND SURFACE										
0.0	SILTY SAND - with gravel and cobbles, occ. boulders, some decayed leaves and rootlets near surface, grey, wet, compact to very dense. (TILL)		1	SS	14	▽	203	⊗	○		
			2	CORE			202				
201.9 / 1.8	BIOTITE HORNBLENDE GNIESS - predominantly grey, with pinkish seams, good rock mass quality, hard, fractures oriented at 30 degrees to the core axis.	+	1	RC							REC 100%RQD 78.2%
		+	2	RC			201				REC 100%RQD 74.0%
200.0 / 3.7	END OF BOREHOLE						200				

MTOMOON HW69M 04/08/98

Trow

RECORD OF BOREHOLE 7

MOON RIVER BRIDGE

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION SOUTH PIER - 4 991 306.9N 282 162.7E
BOREHOLE TYPE SPT - B SIZE CORE HOLLOW STEM AUGERS
DATE November 13, 1997

ORIGINATED BY G.B.
COMPILED BY S.H.
CHECKED BY S.E.G.

Soil Profile

ELEV. / DEPTH	DESCRIPTION	STRATA PLOT
203.5	GROUND SURFACE	
203.4 / 0.1	TOPSOIL	
	SILTY SAND - with gravel and cobbles, occ. boulders, grey, wet, dense to very dense. (TILL)	till (circles and dots)
199.8 / 3.7	Boulders, cobbles.	circles and dots
198.6 / 4.9	BIOTITE HORNBLENDE GNEISS - predominantly grey, with pinkish seams, fair to good rock mass quality, hard, fractures oriented at 30 degrees to the core axis.	+
196.9 / 6.6	END OF BOREHOLE	

Samples

NUMBER	TYPE	BLOWS/0.3m	REMARKS & GRAIN SIZE DISTRIBUTION (GR SA (SI & CL))
1	SS	35	
2	SS	50	
3	SS	54	24% 64% 12%
4	SS	100	
1	CORE		
2	CORE		
3	CORE		
1	RC		REC 100% RQD 58%
2	RC		REC 80%
3	RC		REC 88% RQD 68%

GROUND WATER CONDITIONS: water level symbol (▽) at approx. elevation 203.

ELEVATION SCALE (metres): 203, 202, 201, 200, 199, 198, 197

SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — : 20 40 60 80 (sample 2: 50/125mm)

SHEAR STRENGTH: Cu, KPa — ○ UNCONFINED, ● QUICK TRIAXIAL, FIELD VANE, LAB VANE: 20 40 60 80

PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT: wp —○w— wl

WATER CONTENT (%): 20 40 60 80

UNIT WEIGHT kN/m³

Trow

RECORD OF BOREHOLE 8

MOON RIVER BRIDGE

METRIC

W.P. 216-90-01
DIST. 52 HWY 69
DATUM GEODETIC

LOCATION SOUTH ABUTMENT - 4 991 283.1N 282 156.7E
BOREHOLE TYPE SPT - B SIZE CORE HOLLOW STEM AUGERS
DATE November 25, 1997

ORIGINATED BY I.D.
COMPILED BY S.H.
CHECKED BY S.E.G.

ELEV. / DEPTH	SOIL PROFILE – DESCRIPTION	STRATA PLOT	SAMPLES – NUMBER	SAMPLES – TYPE	SAMPLES – BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — (20, 40, 60, 80); SHEAR STRENGTH: Cu, KPa (UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE) (20, 40, 60, 80)	PLASTIC LIMIT wp — NATURAL MOISTURE CONTENT w — LIQUID LIMIT wl; WATER CONTENT (%) (20, 40, 60, 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
217.5	GROUND SURFACE										
0.0	FILL - silty sand and gravel, moist, loose to compact.						217				
	AUGER REFUSAL - PROBABLE BEDROCK OR BOULDER AT 1.25 m		1	SS	24			⊗ (24)			
216.2 / 1.3	END OF BOREHOLE										

MTOMOON HW69M 04/08/98

Trow

RECORD OF BOREHOLE 101

METRIC

MOON RIVER

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NEW CULVERT ALIGNMENT - 4 991 367N 282 176E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 10, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

ELEV. DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — (20 40 60 80); SHEAR STRENGTH: Cu, KPa UNCONFINED QUICK TRIAXIAL / FIELD VANE LAB VANE (20 40 60 80)	PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl; WATER CONTENT (%) (20 40 60 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
209.3	GROUND SURFACE										
0.0	SILTY SAND - with some gravel, cobbles and boulders (TILL)						209				
							208				
							207				
206.0 / 3.3	AUGER REFUSAL AT 206.0 m ON PROBABLE BOULDER OR BEDROCK.						206				

MTOMOON MOON2 04/03/98

Trow

RECORD OF BOREHOLE 102

MOON RIVER

METRIC

W.P. 216-90-01 LOCATION NEW CULVERT ALIGNMENT - 4 991 372N 282 174E ORIGINATED BY G.B.

DIST 52 HWY 69 BOREHOLE TYPE AUGERS AND SPT CME55 COMPILED BY S.D.H.

DATUM GEODETIC DATE March 10, 1998 CHECKED BY S.E.G.

SPT TEST (N-Value) ⊗; CONE PENETRATION TEST —; SHEAR STRENGTH: Cu, KPa (UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE); WATER CONTENT (%): PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl

ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
209.4	GROUND SURFACE							
209.3 / 0.1	TOPSOIL SILTY SAND - some topsoil staining, occ. gravel, brown, loose.	1	SS	6		209		
		2	SS	8				
208.3 / 1.1	CLAYEY SILT TO SILTY CLAY (CL-CM) - brown to grey, moist to v. moist, firm to stiff					208		
		3	SS	9				
		4	SS	22		207		
206.7 / 2.7	SITLY SAND AND GRAVEL (SW-GW) - occ. cobbles, v. dense (TILL)	5	SS	19		206		
						205		
		6	SS	102				
204.2 / 5.2	AUGER REFUSAL AT 204.2 m ON PROBABLE BOULDER OR BEDROCK							

Plot annotation: 102/275 mm; 102

Trow

RECORD OF BOREHOLE 103

MOON RIVER

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NEW CULVERT ALIGNMENT 4 991 378N 282 170E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 10, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

ELEV. / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/0.3m	SPT (N-Value)	WATER CONTENT (%)
210.0	GROUND SURFACE					
209.9 / 0.1	TOPSOIL					
	SILTY SAND - reddish brown to brown, moist, loose.	1	SS	5	5	
		2	SS	17	17	~20
208.0 / 2.0	CLAYEY SILT TO SILTY CLAY (CL-CM) - brown to grey, moist, soft to very stiff.	3	SS	2	2	
205.9 / 4.1	SILTY SAND AND GRAVEL - with occasional cobbles, wet, compact, becomming very dense below 6.2 m.	4	SS	13	13	~13
		5	SS	29	29	
		6	SS	60	/125 mm	~11
200.8 / 9.2	AUGER REFUSAL AT 200.8 m ON PROBABLE BOULDER OR BEDROCK					

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (metres) 210–201; SPT TEST (N-Value) ⊗; CONE PENETRATION TEST; SHEAR STRENGTH: Cu, KPa (○ UNCONFINED, ● QUICK TRIAXIAL, FIELD VANE, LAB VANE) 20 40 60 80; PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl; WATER CONTENT (%) 20 40 60 80; UNIT WEIGHT kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)

Trow

RECORD OF BOREHOLE 104
MOON RIVER

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NEW CULVERT ALIGNMENT - 4 991 389N 282 168E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 10, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

ELEV. / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/0.3m
210.4	GROUND SURFACE			
210.3 / 0.1	TOPSOIL			
	SILTY SAND - some gravel, reddish brown to brown, moist, loose	1	SS	6
		2	SS	17
208.4 / 2.0	CLAYEY SILT TO SILTY CLAY (CL-ML) - brown to grey, moist to v. moist, very soft to v. stiff.	3	SS	2
		4	SS	4
205.4 / 5.0	SILTY SAND AND GRAVEL - occ. cobbles, grey to brown, compact becomming v. dense below 203.7 m.	5	SS	19
202.1 / 8.3	AUGER REFUSAL AT 203.7 m ON PROBABLE BOULDER OR BEDROCK			

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (metres) 210, 209, 208, 207, 206, 205, 204, 203; SPT TEST (N-Value) ⊗; CONE PENETRATION TEST —; 20 40 60 80; SHEAR STRENGTH: Cu, KPa ○ UNCONFINED ● QUICK TRIAXIAL ✕ FIELD VANE ✕ LAB VANE 20 40 60 80; PLASTIC LIMIT, NATURAL MOISTURE CONTENT, LIQUID LIMIT: wp ⊢—o w—⊣ wl; WATER CONTENT (%) 20 40 60 80; UNIT WEIGHT kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)

MTOMOON MOON2 04/03/98

Trow

RECORD OF BOREHOLE 105

MOON RIVER

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NEW CULVERT ALIGNMENT - 4 991 402N 282 166E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 11, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — (20, 40, 60, 80); SHEAR STRENGTH: Cu, KPa (UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE) (20, 40, 60, 80)	PLASTIC LIMIT wp — NATURAL MOISTURE CONTENT w — LIQUID LIMIT wl; WATER CONTENT (%) (20, 40, 60, 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION		
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m						GR	SA	(SI & CL)
210.7	GROUND SURFACE												
0.0	TOPSOIL over SAND AND GRAVEL FILL						210						
208.8 / 1.9	- possibly clayey silt near bedrock						209						
	AUGER REFUSAL AT 208.8 m ON PROBABLE BOULDER OR BEDROCK												

MTOMOON MOON2 04/03/98

Trow

RECORD OF BOREHOLE 106

MOON RIVER

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NEW CULVERT ALIGNMENT - 4 991 395N 282 167E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 19, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — 20 40 60 80; SHEAR STRENGTH: Cu, KPa (UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE) 20 40 60 80	PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl; WATER CONTENT (%) 20 40 60 80	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
210.3	GROUND SURFACE										
0.0	TOPSOIL over SILTY FINE SAND - brown, moist, possibly clayey silt						210				
							209				
208.2 / 2.1	CLAYEY SILT TO SILTY CLAY						208				
							207				
205.9 / 4.4	SILTY SAND AND GRAVEL - brown, moist						206				
							205				
							204				
							203				
202.7 / 7.6	AUGER REFUSAL AT 202.7 m ON PROBABLE BOULDER OR BEDROCK										

Trow

RECORD OF BOREHOLE 107

MOON RIVER

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NEW CULVERT ALIGNMENT - 4 991 399N 282 166E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 19, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

ELEV. DEPTH	DESCRIPTION (SOIL PROFILE)	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — 20 40 60 80; SHEAR STRENGTH: Cu, KPa ○ UNCONFINED ● QUICK TRIAXIAL ✕ FIELD VANE ✕ LAB VANE 20 40 60 80	PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl; WATER CONTENT (%) 20 40 60 80	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
210.4	GROUND SURFACE										
0.0	TOPSOIL over SILTY SAND						210				
							209				
208.0 2.4	AUGER REFUSAL AT 2.44 m ON PROBABLE BOULDER OR BEDROCK						208				

MTOMOON MOON2 10/08/98

Trow

RECORD OF BOREHOLE 201
MOON RIVER

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION ALTERNATIVE NORTH ABUTMENT LOCATION - 4 991 410N 282 197E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 11, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST —— : 20, 40, 60, 80
SHEAR STRENGTH: Cu, KPa — ○ UNCONFINED, ● QUICK TRIAXIAL, FIELD VANE, LAB VANE: 20, 40, 60, 80
PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT — wp ⊢—○w—⊣ wl — WATER CONTENT (%): 20, 40, 60, 80
UNIT WEIGHT kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION: GR SA (SI & CL)

ELEV. / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/0.3m	SPT remarks
210.0	GROUND SURFACE				
0.0	SAND AND BLAST ROCK FILL - brown, wet, loose				
208.0 / 2.0	SAND - fine to medium, with fine gravel, grey, wet, loose	1	SS	20	
207.4 / 2.6	CLAYEY SILT TO SILTY CLAY (CL-CM) - grey, very moist to moist, soft to firm	2	SS	4	
		3	SS	9	
204.2 / 5.8	SILTY SAND AND GRAVEL - occasional rock fragments, brown to grey, wet, compact to very dense, cobbles and boulders below 201.7 m.	4	SS	33	
		5	SS	60	/125 mm
		6	SS	68	/150 mm
199.6 / 10.4	AUGER REFUSAL AT 199.6 m ON PROBABLE BOULDER OR BEDROCK				

ELEVATION SCALE (metres): 210, 209, 208, 207, 206, 205, 204, 203, 202, 201, 200

Trow

RECORD OF BOREHOLE 202

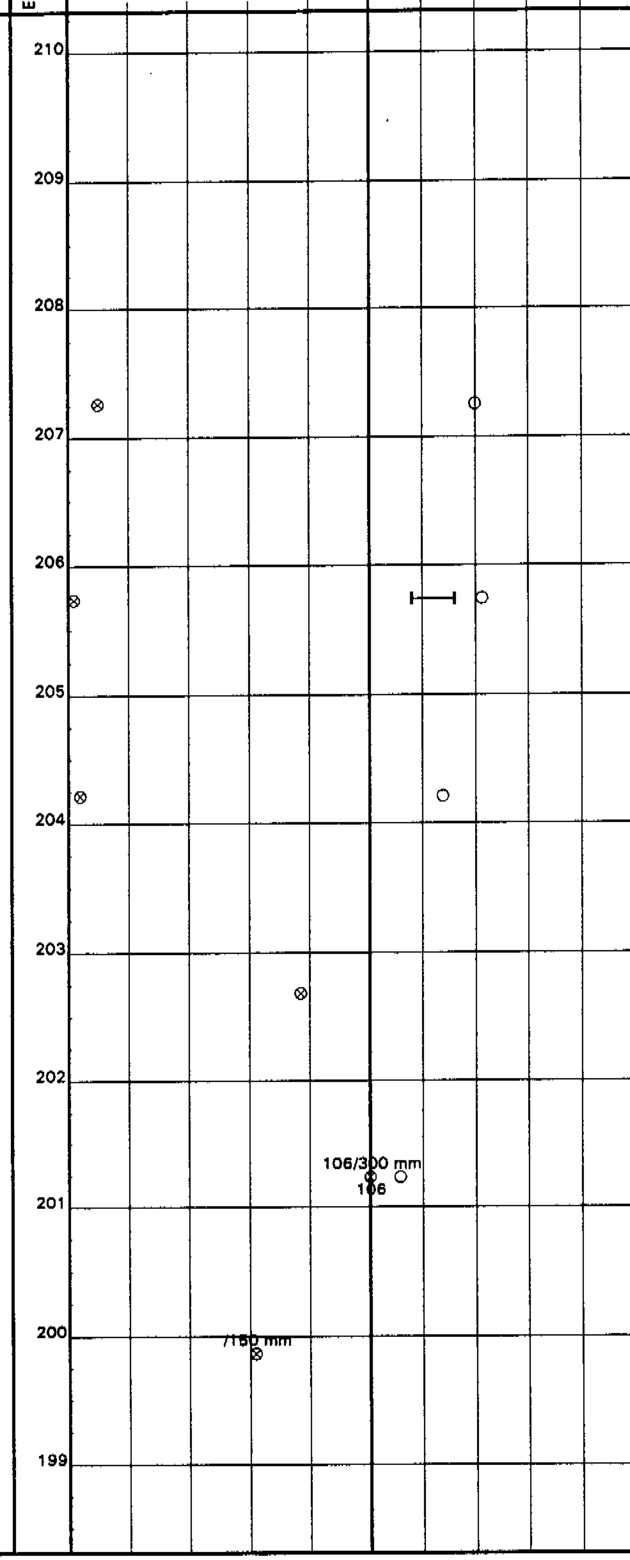
MOON RIVER

METRIC

W.P. 216-90-01	LOCATION ALTERNATIVE NORTH ABUTMENT LOCATION - 4 991 411N 282 191E	ORIGINATED BY G.B.	
DIST 52 HWY 69	BOREHOLE TYPE AUGERS AND SPT CME55	COMPILED BY S.D.H.	
DATUM GEODETIC	DATE March 12, 1998	CHECKED BY S.E.G.	

ELEV. / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/0.3m
210.3	GROUND SURFACE			
0.0	SAND and BLASTROCK FILL - occasional blast rock pieces, wood and organic matter, brown, moist, loose			
207.9 / 2.4	SILTY SAND AND GRAVEL - fine to medium sand, fine gravel, some organic material, grey, wet, loose	1	SS	10
206.5 / 3.8	CLAYEY SILT TO SILTY CLAY (CL-CM) - with silt seams, grey to grey-brown, very moist, very soft to firm	2	SS	2
		3	SS	4
203.4 / 6.9	SILTY SAND AND GRAVEL - with rock fragments, grey, wet, compact to very dense	4	SS	77
		5	SS	106
		6	SS	62
198.9 / 11.4	BIOTITE-HORNBLENDE GNEISS			

Column headings: STRATA PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (metres); SPT TEST (N-Value) ⊗; CONE PENETRATION TEST; SHEAR STRENGTH: Cu, KPa (UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE); PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl; WATER CONTENT (%); UNIT WEIGHT kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)



Trow

RECORD OF BOREHOLE 202

MOON RIVER

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION ALTERNATIVE NORTH ABUTMENT LOCATION - 4 991 411N 282 191E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 12, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

SOIL PROFILE: ELEV. DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — 20 40 60 80; SHEAR STRENGTH: Cu, KPa (UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE) 20 40 60 80	PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl; WATER CONTENT (%) 20 40 60 80	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION: GR SA (SI & CL)
210.3		+	1	RC							Rec 98% RQD 50%
		+					198				
		+	2	RC			197				Rec 100% RQD 64%
196.2 14.2	END OF BOREHOLE										

Trow

RECORD OF BOREHOLE 203

MOON RIVER

METRIC

W.P. 216-90-01
DIST 52   HWY 69
DATUM GEODETIC

LOCATION ALTERNATIVE NORTH ABUTMENT LOCATION - 4 991 412N 282 185E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 16, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

SPT TEST (N-Value) ⊗; CONE PENETRATION TEST —; SHEAR STRENGTH: Cu, KPa (○ UNCONFINED, ● QUICK TRIAXIAL, ✖ FIELD VANE, LAB VANE); WATER CONTENT (%): wp PLASTIC LIMIT, w NATURAL MOISTURE CONTENT, wl LIQUID LIMIT; UNIT WEIGHT kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION: GR SA (SI & CL)

ELEV. / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/0.3m
213.1	GROUND SURFACE			
0.0	SAND and BLASTROCK FILL - with occasional blast rock boulders, cobbles and large gravel, brown to grey, moist, loose to compact			
207.8 / 5.3	SILTY SAND - with occasional gravel, brown, wet, compact	1	SS	10
206.4 / 6.7	CLAYEY SILT TO SILTY CLAY (CL-CM) - with silt seams, grey to greyish brown, very moist, soft to firm	2	SS	2
		3	SS	2
203.7 / 9.4	SILTY SAND AND GRAVEL - grey, compact to very dense, with cobbles and boulders near bedrock surface, wet to very moist from ~9.4 to 14.6 m depth (TILL)	4	SS	45
		5	SS	60

Elevation scale (metres): 213, 212, 211, 210, 209, 208, 207, 206, 205, 204, 203, 202

/100 mm

Trow

RECORD OF BOREHOLE 203

METRIC

MOON RIVER

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION ALTERNATIVE NORTH ABUTMENT LOCATION - 4 991 412N 282 185E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 16, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) / SHEAR STRENGTH: Cu, KPa	WATER CONTENT (%)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
213.1						201				
						200				
		6	SS	64			/150 mm			
						199				
198.5 / 14.6	BIOTITE-HORNBLENDE GNEISS									
		1	RC			198				Rec 100% RQD 37%
						197				
		1	RC							Rec 100% RQD 63%
						196				
		1	RC							Rec 100% RQD 89%
						195				
194.5 / 18.6	END OF BOREHOLE									

MTOMOON MOON2 10/08/98

Trow

RECORD OF BOREHOLE 204

MOON RIVER

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION 32m NORTH ABUTMENT LOCATION - 4 991 417N 282 192E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 13, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

SOIL PROFILE

ELEV. / DEPTH	DESCRIPTION
214.4	GROUND SURFACE
0.0	SAND, GRAVEL AND BLAST ROCK FILL - occasional pieces of wood, grey and brown, moist, compact
207.7 / 6.7	CLAYEY SILT TO SILTY CLAY (CL-CM) - grey to greyish brown, very moist, soft to firm
204.6 / 9.8	SILTY SAND AND GRAVEL - grey, wet to moist, till-like near bedrock, compact to very dense, with cobbles and boulders near bedrock surface (TILL).

SAMPLES

NUMBER	TYPE	BLOWS/0.3m
1	SS	88
2	SS	19
3	SS	5
4	SS	14
5	SS	2
6	SS	4
7	SS	46

GROUND WATER CONDITIONS

ELEVATION SCALE (metres): 214, 213, 212, 211, 210, 209, 208, 207, 206, 205, 204, 203

SPT TEST (N-Value) ⊗
CONE PENETRATION TEST —
20 40 60 80

SHEAR STRENGTH: Cu, KPa
○ UNCONFINED ● QUICK TRIAXIAL
✖ FIELD VANE ✖ LAB VANE
20 40 60 80

PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT
wp ⊢——○w——⊣ wl
WATER CONTENT (%)
20 40 60 80

UNIT WEIGHT kN/m³

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

MTOMOON MOON2 10/08/98

Trow

RECORD OF BOREHOLE 204
MOON RIVER

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION 32m NORTH ABUTMENT LOCATION - 4 991 417N 282 192E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 13, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS/0.3m	ELEVATION SCALE (metres)	SPT TEST (N-Value)	REMARKS & GRAIN SIZE DISTRIBUTION
214.4		8	SS	65		/100 mm	
					202		
					201		
		9	SS	65		/125 mm	
					200		
199.9 14.5	BIOTITE-HORNBLENDE GNEISS						
		1	RC		199		Rec 100%RQD 77%
		2	RC		198		Rec 100%RQD 57%
		3	RC				Rec 100%RQD 91%
					197		
196.8 17.6	END OF BOREHOLE						

MTOMOON MOON2 10/08/98

Trow

RECORD OF BOREHOLE 301

METRIC

MOON RIVER

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION SAMPLE/VANE BOREHOLE - 4 991 400N 282 196E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 19, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

ELEV. / DEPTH	SOIL PROFILE – DESCRIPTION	STRATA PLOT	SAMPLE NUMBER	SAMPLE TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — / SHEAR STRENGTH: Cu, KPa (UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE)	WATER CONTENT (%) wp — w — wl	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
208.5	GROUND SURFACE										
0.0	NOT SAMPLED										
208.3 / 0.3	CLAYEY SILT TO SILTY CLAY (CL-CM) - grey to greyish brown, v. moist, soft to firm, some silt and fine sand seams (~100-200mm thick).	hatched					208				
							207				
							206				
			1	TW			205	Field vane 17.0			
								Field vane 8.0			
							204				
			2	TW				Field vane 2.2			
203.3 / 5.2											

Trow

RECORD OF BOREHOLE 302

MOON RIVER

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION SAMPLE/VANE BOREHOLE - 4 991 402N 282 190E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 19, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) / CONE PENETRATION TEST / SHEAR STRENGTH: Cu, KPa	WATER CONTENT (%)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
209.0	GROUND SURFACE						209				
0.0	NOT SAMPLED										
208.1 / 0.9	CLAYEY SILT TO SILTY CLAY (CL-CM) - grey to greyish brown, soft to firm, some silt and fine sand seams (~100-200mm thick).						208				
							207				
							206				
			1	TW			205	Field vane 13.0			
			2	TW			204	Field vane 11.5			
								Field vane 12.4			
203.1 / 5.9											

Legend: SPT TEST (N-Value) ⊗; CONE PENETRATION TEST —; SHEAR STRENGTH: UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE; PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl. Scales: 20 40 60 80.

MTOMOON MOON2 10/08/98

Trow

RECORD OF BOREHOLE 303

MOON RIVER

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION SAMPLE/VANE BOREHOLE - 4 991 403N 282 184E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 19, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

ELEV. DEPTH	SOIL PROFILE: DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) / CONE PENETRATION TEST; SHEAR STRENGTH: Cu, KPa	WATER CONTENT (%)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
208.7	GROUND SURFACE										
0.0	NOT SAMPLED										
208.1 0.6	CLAYEY SILT TO SILTY CLAY (CL-CM) - grey to greyish brown, v. moist, soft to firm, some silt and fine sand seams (~100-200mm thick).						208				
							207				
							206				
			1	TW			205	10.0			
			2	TW			204	5.0			
			3	TW				5.5			
203.4 5.3											

SPT / shear strength scale: 20 40 60 80. Legend: SPT TEST (N-Value) ⊗; CONE PENETRATION TEST —; UNCONFINED ○; QUICK TRIAXIAL ●; FIELD VANE ✚; LAB VANE ✖.

Water content: PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl; scale 20 40 60 80.

Trow

RECORD OF BOREHOLE 401

METRIC

MOON RIVER

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NORTH APPROACH - 4 991 486N 282 198E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 20, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — (20 40 60 80); SHEAR STRENGTH: Cu, KPa (UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE) (20 40 60 80)	PLASTIC LIMIT wp — NATURAL MOISTURE CONTENT w — LIQUID LIMIT wl; WATER CONTENT (%) (20 40 60 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION: GR SA (SI & CL)
211.7	GROUND SURFACE										
210.0 / 0.2	~150 mm TOPSOIL - roots, decayed matter, dark brown, moist over SILTY FINE SAND - red-brown, moist over CLAYEY SILT - brown, moist		1	AUGER			211				
210.4 / 1.4	AUGER REFUSAL AT 210.4 m ON PROBABLE BOULDER OR BEDROCK.										

Trow

RECORD OF BOREHOLE 402

MOON RIVER

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NORTH APPROACH - 4 991 428N 282 195E
BOREHOLE TYPE AUGERS AND SPT CME55
DATE March 20, 1998

ORIGINATED BY G.B.
COMPILED BY S.D.H.
CHECKED BY S.E.G.

ELEV. / DEPTH	SOIL PROFILE – DESCRIPTION	STRATA PLOT	SAMPLES – NUMBER	SAMPLES – TYPE	SAMPLES – BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — (20 40 60 80); SHEAR STRENGTH: Cu, KPa (○ UNCONFINED ● QUICK TRIAXIAL ✕ FIELD VANE ✕ LAB VANE) (20 40 60 80)	PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl – WATER CONTENT (%) (20 40 60 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION – GR SA (SI & CL)
211.1	GROUND SURFACE										
210.9 / 0.2	~150 mm TOPSOIL - roots, decayed matter, dark brown, moist over SILTY FINE SAND - red-brown, moist over CLAYEY SILT TO SILTY CLAY - brown, moist turning wet with depth		1	AUGER			211 / 210 / 209 / 208				
207.9 / 3.2	AUGER REFUSAL AT 207.9 m ON PROBABLE BOULDER OR BEDROCK.										

MTOMOON MOON2 04/03/98

Trow

RECORD OF BOREHOLE AP-1

MOON RIVER BRIDGE

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NORTH ABUTMENT - 4 991 405N 282 190E
BOREHOLE TYPE PROBE HOLE AUGERS
DATE November 20, 1997

ORIGINATED BY I.D.
COMPILED BY S.H.
CHECKED BY S.E.G.

ELEV. / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) / CONE PENETRATION TEST; SHEAR STRENGTH: Cu, KPa	WATER CONTENT (%) (wp, w, wl)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (GR SA SI & CL)
208.3	GROUND SURFACE										
0.0	TOPSOIL										
208.0 / 0.3	CLAY						208				
							207				
							206				
							205		wp–wl approx. 20–40 (above 205)		
							204				
							203				
202.9 / 5.5	SAND TILL - with gravel, cobbles and boulders, trace to some silt.						202				
	AUGER REFUSAL - PROBABLE BOULDER OR BEDROCK AT 7.55 m						201				
200.8 / 7.6	END OF BOREHOLE										

NOTES: Soil stratigraphy inferred from auger cuttings.

Trow

RECORD OF BOREHOLE AP-2

METRIC

MOON RIVER BRIDGE

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NORTH APPROACH - 4 991 380N 282 185E
BOREHOLE TYPE PROBE HOLE AUGERS
DATE November 20, 1997

ORIGINATED BY I.D.
COMPILED BY S.H.
CHECKED BY S.E.G.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST —— 20 40 60 80 / SHEAR STRENGTH: Cu, KPa ○ UNCONFINED ● QUICK TRIAXIAL ✕ FIELD VANE ✕ LAB VANE 20 40 60 80	PLASTIC LIMIT wp — NATURAL MOISTURE CONTENT w — LIQUID LIMIT wl / WATER CONTENT (%) 20 40 60 80	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
ELEV. / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m						
209.2	GROUND SURFACE										
0.0	SAND TILL - with gravel, trace to some silt AUGER REFUSAL - PROBABLE BEDROCK OR BOULDER AT 0.92 m						209				
208.3 0.9	END OF BOREHOLE NOTES: Soil stratigraphy inferred from auger cuttings.										

MTOMOON HW69M 04/08/98

Trow

RECORD OF BOREHOLE AP-3

MOON RIVER BRIDGE

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NORTH APPROACH - 4 991 380N 282 195E
BOREHOLE TYPE PROBE HOLE AUGERS
DATE November 20, 1997

ORIGINATED BY I.D.
COMPILED BY S.H.
CHECKED BY S.E.G.

SOIL PROFILE: ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — (20 40 60 80); SHEAR STRENGTH: Cu, KPa (UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE) (20 40 60 80)	PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl; WATER CONTENT (%) (20 40 60 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION: GR SA (SI & CL)
208.5	GROUND SURFACE										
0.0	SAND TILL - with gravel, some cobbles and boulders, trace to some silt.						208				
	AUGER REFUSAL - PROBABLE BOULDER OR BEDROCK AT 1.77 m						207				
206.7 1.8	END OF BOREHOLE										
	NOTES: Soil stratigraphy inferred from auger cuttings.										

Trow

RECORD OF BOREHOLE AP-4

MOON RIVER BRIDGE

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION SOUTH ABUTMENT - 4 991 268N 282 165E
BOREHOLE TYPE PROBE HOLE AUGERS
DATE November 25, 1997

ORIGINATED BY I.D.
COMPILED BY S.H.
CHECKED BY S.E.G.

ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — (20 40 60 80); SHEAR STRENGTH: Cu, KPa (○ UNCONFINED, ● QUICK TRIAXIAL, ✕ FIELD VANE, ✕ LAB VANE) (20 40 60 80)	PLASTIC LIMIT wp — NATURAL MOISTURE CONTENT w — LIQUID LIMIT wl; WATER CONTENT (%) (20 40 60 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
217.1	GROUND SURFACE										
0.0	SAND TILL - with gravel and occasional cobbles						217				
	AUGER REFUSAL - PROBABLE BOULDER OR BEDROCK AT 1.37 m						216				
215.8 / 1.4	END OF BOREHOLE										
	NOTES: Soil stratigraphy inferred from auger cuttings.										

MTOMOON HW69M 04/14/98

Trow

RECORD OF BOREHOLE AP-5

METRIC

MOON RIVER BRIDGE

W.P. 216-90-01 LOCATION SOUTH APPROACH - 4 991 230N 282 170E ORIGINATED BY I.D.

DIST 52 HWY 69 BOREHOLE TYPE PROBE HOLE AUGERS COMPILED BY S.H.

DATUM GEODETIC DATE November 25, 1997 CHECKED BY S.E.G.

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — 20 40 60 80; SHEAR STRENGTH: Cu, KPa ○ UNCONFINED ● QUICK TRIAXIAL ✕ FIELD VANE LAB VANE 20 40 60 80	PLASTIC LIMIT wp — NATURAL MOISTURE CONTENT w — LIQUID LIMIT wl; WATER CONTENT (%) 20 40 60 80	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
218.0	GROUND SURFACE						218				
217.8 0.2	TOPSOIL SAND TILL - with gravel, some cobbles, occ. boulders, trace to some silt.						217				
	AUGER REFUSAL - PROBABLE BOULDER OR BEDROCK AT 2.5 m						216				
215.5 2.5	END OF BOREHOLE NOTES: Soil stratigraphy inferred from auger cuttings.										

Trow

RECORD OF BOREHOLE AP-6

MOON RIVER BRIDGE

METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION SOUTH APPROACH - 4 991 240N 282 160E
BOREHOLE TYPE PROBE HOLE AUGERS
DATE November 25, 1997

ORIGINATED BY I.D.
COMPILED BY S.H.
CHECKED BY S.E.G.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST — (20 40 60 80); SHEAR STRENGTH: Cu, KPa — UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE (20 40 60 80)	PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl — WATER CONTENT (%) (20 40 60 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
ELEV. / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m						
221.1	GROUND SURFACE						221				
0.0	TOPSOIL										
220.8 / 0.3	SANDY LOAM WITH GRAVEL										
220.5 / 0.6	END OF BOREHOLE										
	AUGER REFUSAL - PROBABLE BOULDER OR BEDROCK AT 0.6 m										
	NOTES: Soil stratigraphy inferred from auger cuttings.										

Trow

RECORD OF CONE 1

MOON RIVER BRIDGE

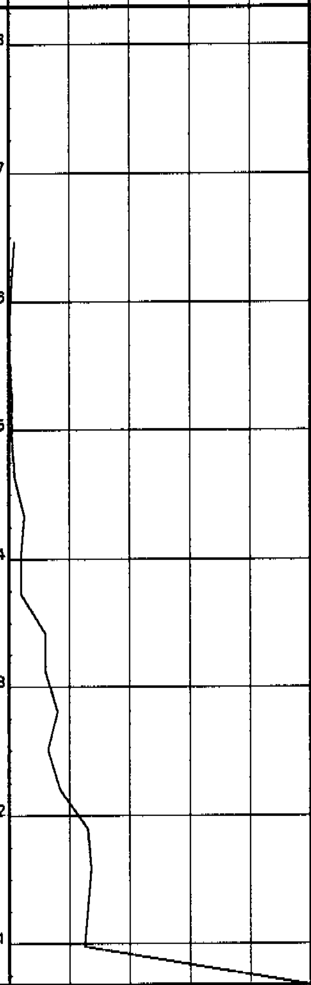
METRIC

W.P. 216-90-01
LOCATION NORTH APPROACH - 4 991 395.2N 282 187.1E
ORIGINATED BY I.D.

DIST 52 HWY 69
BOREHOLE TYPE CONE
COMPILED BY N.A.

DATUM GEODETIC
DATE November 20, 1997
CHECKED BY S.H.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST —— (20, 40, 60, 80); SHEAR STRENGTH: Cu, KPa (○ ● UNCONFINED, QUICK TRIAXIAL; FIELD VANE, LAB VANE) (20, 40, 60, 80)	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT: wp ⊢—○W—⊣ wl; WATER CONTENT (%) (20, 40, 60, 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (GR, SA, (SI & CL))
ELEV. / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m						
208.3	GROUND SURFACE										
0.0	SOIL NOT SAMPLED						208, 207, 206, 205, 204, 203, 202, 201				
200.7 / 7.6											



Trow

RECORD OF CONE 2
MOON RIVER BRIDGE

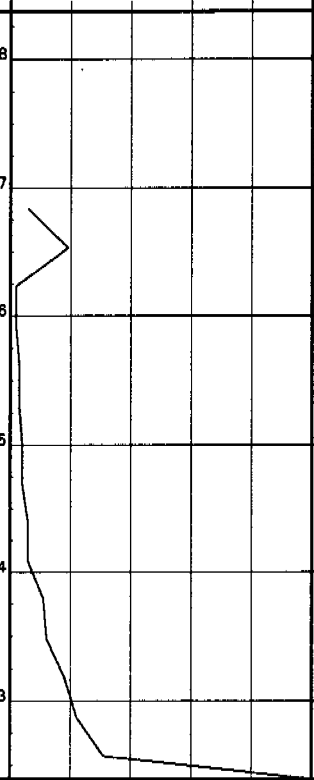
METRIC

W.P. 216-90-01
DIST 52 HWY 69
DATUM GEODETIC

LOCATION NORTH ABUTMENT - 4 991 384.9N 282 191.5E
BOREHOLE TYPE CONE
DATE November 20, 1997

ORIGINATED BY I.D.
COMPILED BY N.A.
CHECKED BY S.H.

SOIL PROFILE		SAMPLES				GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST —— (20, 40, 60, 80); SHEAR STRENGTH: Cu, KPa ● UNCONFINED ○ QUICK TRIAXIAL ✕ FIELD VANE ✕ LAB VANE (20, 40, 60, 80)	PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl; WATER CONTENT (%) (20, 40, 60, 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION GR SA (SI & CL)
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m						
208.4	GROUND SURFACE										
0.0	SOIL NOT SAMPLED						208, 207, 206, 205, 204, 203				
202.4 6.0											



MTOMOON HW69M 04/08/98

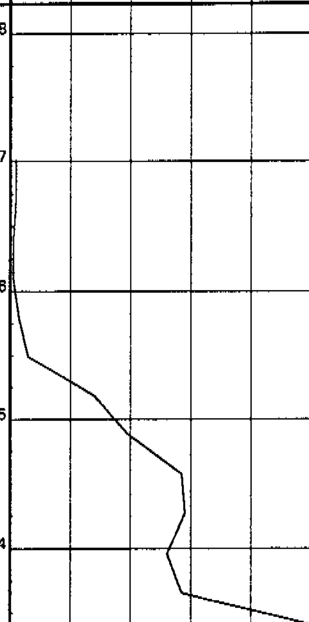
Trow

RECORD OF CONE 3
MOON RIVER BRIDGE

METRIC

W.P. 216-90-01	LOCATION NORTH APPROACH - 4 991 374.7N 282 190.7E	ORIGINATED BY I.D.
DIST 52 HWY 69	BOREHOLE TYPE CONE	COMPILED BY N.A.
DATUM GEODETIC	DATE November 20, 1997	CHECKED BY S.H.

SOIL PROFILE: ELEV. / DEPTH	SOIL PROFILE: DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) ⊗ / CONE PENETRATION TEST —— (20 40 60 80); SHEAR STRENGTH: Cu, KPa (UNCONFINED, QUICK TRIAXIAL, FIELD VANE, LAB VANE) (20 40 60 80)	PLASTIC LIMIT wp, NATURAL MOISTURE CONTENT w, LIQUID LIMIT wl; WATER CONTENT (%) (20 40 60 80)	UNIT WEIGHT kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION: GR SA (SI & CL)
208.2	GROUND SURFACE										
0.0	SOIL NOT SAMPLED						208				
							207				
							206				
							205				
							204				
203.4 / 4.8											



MTOMOON HW69M 04/14/98

Trow

memorandum

Ontario

To:	Paul Lecoarer, P. Eng. Senior Project Engineer Planning and Design Section Northern Region	1998 05 21
From:	Pavements and Foundations Section Room 223, Central Building Downsview, Ontario	
Re:	Review of Second Draft Foundations Report Moon River Bridge Southbound W.P. 216-90-01, Site 42-26S Hwy 69, District 52, Huntsville	

We have conceptually reviewed the second draft Foundation report dated April 23, 1998 produced by Trow Consulting engineers Ltd for R.V. Anderson Associates Ltd. to evaluate the performance of the Consultant. We have not reviewed the report in detail. The accuracy of the subsurface information and the technical recommendations remain the responsibility of the consultant. Earlier we had reviewed the first draft report dated January 16, 1998 and submitted our comments in a memo dated March 17, 1998 to Peter Stuart. In addition to the comments in our memo dated March 17, 1998 following are our comments on the second draft report.

- ✓ Page 14, Table 2-1: The axial capacity at SLS do not apply for piles on bedrock.
- ✓ Page 17, Table 2-4: Although, the OHBDC code talks for bearing resistance reduction due to inclined loading for footing on bedrock. The OHBDC committee has decided that no such reduction will be required if the footing is constructed on bedrock.
- ✓ Page 19, Section 2.5: For frost protection, details on how and where the insulation should be placed would be useful.
- ok Page 21 and Drawing No. 8: We are not sure how the sand drains will be installed through the rock fill.

- A Key Plan should be provided for the site locations.
- References of stations are given in the text. However, stations are not marked on the plan.
- The proposed grade is not shown on the profile.
- Groundwater elevation and river level should be shown on the profile and cross sections.

K. Ahmad, P. Eng
Foundation Engineer

For

T.C. Kim, P. Eng.
Senior Foundation Engineer

cc: P. Furst
D. Smith
T. Kazmierowski

From: Ken Ahmad
To: MTOHO1.TORHO2(Kim), MTONR.NORTHBAY(SmithDa)
Subject: WP 217-89-00, Hwy 69, Draft Foundation Design Report for Moon River Bridge Southbound -Reply

Dale:

We received the above-mentioned report this week. We are reviewing other reports, drawings and contract packages etc. in sequence as they were received. When we review the Moon River Bridge (shortly) we will look into your comments as well. We will send you a copy of our response.

Thanks

Ken

>>> Dale Smith 05/07/98 02:18pm >>>
Dear Tae,

I reviewed this draft report (forwarded to your office on April 29) and have the following comments/concerns:

1. Table 1.2 - field moisture content of these samples would be useful here.

2. Section 2.3.1 - This section indicates that Inclined Loading Reduction Factors are based on Figure 6-8.4.2 of the OHBDC. My understanding from the HoJo seminar with D. Becker in 1995 is that this figure does not apply to rock. For rock, reduction factors are determined based on an analysis taking into account the effect of fractures. Correct?

3. Section 2.5 - Refers to the use of insulation at the south pier pile cap, but no details on how and where the insulation should be placed are given.

4. Section 2.7.2 - Refers to subexcavation of the silty clay soils at the north approach in "panels" but there are no details given as to the width of the panels and whether they are to be excavated perpendicular to or parallel to the highway centreline. No alternatives (eg. sand drains) are discussed.

5. With respect to the borehole logs -

Bhs 2, 5, 7, 102, etc. have a problem in the upper left corner, under the Elev/Depth column.

The vane test results (see eg. BH 301) have a numeric value above the symbol. I believe it refers to remoulded strength but it could also be a sensitivity value. Clarification required.

I note that there are no grain size analyses of the silty clay.

6. At a progress meeting, the placing of rockfill on the soft to firm silty clay native soil was discussed. A concern was expressed with regard to the possibility of rockfill intrusion into the clay and resulting settlement/instability problems. Does foundations section have a position with respect to this concern?

MEMORANDUM

Ontario

Engineering Materials Office
Room 215, Central Building, Downsview
Tel. (416) 235-3731 Fax. (416) 235-5240

To: Peter Stuart
Senior Structural Engineer
Northern Region Planning and Design

Date: March 17, 1998

W.P. 216-90-01

From: Pavements and Foundations Section
Rm. 215, Central Building, Downsview

Subject: **Draft Foundation Report Review**
Moon River Bridge Southbound, Site 42-26S Highway 69

The above report was reviewed to determine the consultant's performance in providing the deliverables. The accuracy of the subsurface information and the adequacy and technical aspects for the recommendations remain the responsibility and liability of the consultant.

We have the following comments:

1. Drawings should indicate the location of the proposed culvert planned to divert the creek at the northern abutment. Water levels and a connected stratigraphical profile should be included in the drawings, this will be part of the contract package.
2. The size of rockfill should be controlled behind the north abutment. Rockfill placed immediately behind the retaining wall should not be greater than 300mm in size and be carefully placed so that no damage occurs to the structure.
3. While slopes of 1.5:1 are acceptable along the sides for the rockfill, the forward slope shown at the north abutment consists of granular material and should not have a slope steeper than 2:1. The consultant should review this.
4. In regards to the use of geogrids at the north abutment embankment, has full or partial depth removal of the underlying cohesive silty clay to clayey silt been considered. This may be cheaper and would improve the stability of the embankment.

If there are any questions please contact this office.

M. Michalek, P. Eng.
Foundation Engineer
For:
T. C. Kim, P. Eng.
Sr. Foundation Engineer

cc: T. Kazmierowski