

GEOCRES No. _____

DIST. CR REGION _____W.P. No. 312-97-00

CONT. No. _____

W. O. No. _____

STR. SITE No. _____

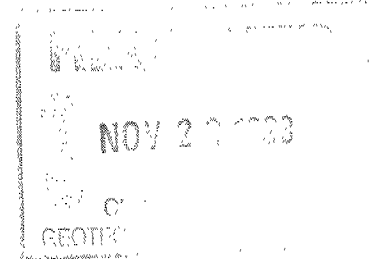
HWY. No. 58LOCATION Collier Rd. Ramp N/ENo of PAGES -OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS: _____

**Foundation Investigation and Design
Report - Slope Stability Analysis
Proposed Embankment Rehabilitation
N-E Ramp, Collier Road to
King's Highway 58, WP 312-97-00
City of Thorold, Region of Niagara**

Prepared for:

Ontario Ministry of Transportation
Pavements and Foundations Section
Foundations Group
Room 223, Central Building
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BRGE0050774A

November 18, 1998

Preface

Work project WP 312-97-00 involves the rehabilitation of Hwy58 from Hwy 406 easterly to Davis Drive including all interchange ramps at Collier Road, Pine Street and Davis Dr, but not including Thorold tunnel.

It is located in the City of St. Catharines and the Town of Thorold in the Regional Municipality of Niagara. The rehabilitation work includes:

- Repair failed joints and very severe cracks using full depth dowelled concrete.
- Spall and failed concrete repair using hot mix.
- Repair slight and moderate cracks with crack sealant.
- Repair severe cracks with hot mix.
- Subsealing cracks and joints indicated.
- Overlay concrete pavement with 50mm HDBC and 40mm DFC.

The following report comments on the foundation investigation and subsequent engineering for the slope stability of the N-E Ramp Collier Road to Kings Highway No. 58.

Other associated geotechnical and Pavement Report for the project includes:

- Pavement Design Report, Trow Consulting Engineers Ltd., November 10, 1998
BRGE0050774A

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PART 1 Foundation Investigation

1.1 Introduction

This submission presents the results of a foundation investigation completed by Trow Consulting Engineers Ltd. (Trow) for the proposed rehabilitation of Highway 58 between the Highway 406 interchange and Davis Drive in the Region of Niagara, Ontario. This report contains factual information (obtained from the field investigation) pertaining to the design of slope stabilization strategies. The report is prepared as a separate investigation and report - completed in conjunction with the Highway 58 evaluation.

1.2 Background and Site Description

1.2.3 Background

The subject site is located in the City of Thorold, in the Region of Niagara along Highway 58 at the Collier Road interchange (approximate Station 10+940 along Highway 58). The section of embankment which shows instability lies between N-E ramp Stations 0+400 and 0+450. Typical features associated with slope failure such as tension cracking at the crest of the slope and scarping along the length of the failed zone are apparent.

The embankment in this section was constructed as part of the original highway construction in the 1960's under Contract 66-58. The original design drawings indicate that to the east of the Collier Road interchange, the subsoil comprises silty clay which directly overlies dolomite and dolomitic limestone of the Goat Island formation.

The original construction drawings show that in the area immediately adjacent and to the south of the subject slope, a farm building and silo had existed, both since demolished (See Drawing 2). Also, the temporary detour for the construction of the overpass structure crossed over the area of the slope movements; details of this temporary construction are not known with certainty, but it may be assumed that the temporary road crossed the area near original grade, and that the affected portion of the highway and ramp embankment was constructed after the Collier overpass was completed. It is possible that different fill materials and methods may have been used during this construction.

1.2.2 Site Description

It is understood that the slope movement in this area has been an ongoing problem over some years, and that it is localized in nature. Other parts of the embankment are at similar inclinations but do not exhibit similar slope instability. At the crest of the slope in the subject area, an approximately 16m long crack exists through the paved shoulder, and typical slope

failure features are noticeable on the embankment face. The failure appears visually to be surficial in nature

Previous repair of the slope at the crest has been carried out as part of regular shoulder maintenance. This has included filling, re-contouring, re-paving of the surface and reinstatement of the crash barrier.

Data from recent topographic plans indicate that the slope inclination in the area of the failure is near 1 vertical to 2.2 horizontal.

1.3 Investigative Procedures

1.3.1 General

Part 1 of this report describes the investigative procedures adopted for the foundation assessment of the embankment to N-E Collier Road Ramp at the interchange to King's Highway 58. Properties of the overburden soils at the site were obtained by in situ and laboratory testing and procedures employed during the investigation are described below.

1.3.2 Field Investigation

The fieldwork for the investigation related to the embankment instability was carried out between August 13 and 14, 1998, and consisted of four (4) sampled boreholes (Boreholes 1 to 4) which were advanced to depths ranging from 6.25 m to 12.34 metres.

Two (2) boreholes were drilled at the bottom of the subject slope and two (2) were drilled near the crest of the slope. The borehole locations are shown on Drawing 2, in Appendix A. The borehole locations and elevations were determined by Trow Consulting Engineers Ltd. engineering staff and are referenced to ramp stationing and MTO geodetic datum (Bench Mark 625 = Elevation 185.801 m), respectively.

The boreholes were advanced through the overburden soils on the site using a track mounted CME-55 drill rig equipped with solid and hollow stem augers. Soil samples were obtained using a 51 mm 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.

All boreholes were advanced to practical refusal on assumed bedrock.

1.3.3 Laboratory

The laboratory testing program for selected soil samples consisted of the following:

- Natural Moisture Contents
- Unit Weight Determinations

The laboratory test results are summarized on the attached Borehole Logs 1 to 4, in Appendix A.

1.4 Subsurface Conditions

The borehole locations are shown on Drawing 2, in Appendix A and the subsurface information revealed from the boreholes near the slope location are summarized on the attached Borehole Logs 1 to 4, inclusive. Based on the borehole information, the following subsoil layers were encountered at this site:

- Topsoil;
- Shoulder Construction;
- Fill;
- Glacial Till;
- Bedrock.

A summary of the descriptions of the various soil strata encountered in the boreholes is presented below.

1.4.1 Topsoil

A thin veneer of topsoil, ranging in thickness from 50 to 100 mm, was encountered in Boreholes 1 and 2 at the base of the slope. The topsoil is generally of a silty nature, brown in colour and contains rootlets.

1.4.2 Shoulder Construction

At the boreholes drilled through the paved shoulder near the crest of the slope, the upper pavement construction comprises approximately 75 mm asphaltic concrete over approximately 150 mm crushed granular base material at Borehole 3. At Borehole 4 two layers of asphaltic concrete were encountered with a 75 mm thick layer of granular base sandwiched between. Beneath these upper pavement layers, the upper fill comprises loose to compact sand and gravel fill to a depth of approximately 0.7 m.

1.4.3 Fill

Beneath the topsoil in Boreholes 1 and 2, and beneath the upper shoulder construction in Boreholes 3 and 4, the general fill comprises clayey to sandy silt and silty clay with occasional gravel.

It is understood that the fill material was placed in a controlled fashion during construction of the main highway and the Collier Road interchange, and comprises native till materials excavated from the highway construction to the east - where the road extends down to the Thorold Tunnel.

The embankment fill in this area may be a slightly different material than indicated in the original borings from the 1960's (i.e., silty clay). There is a possibility that this small area may have been backfilled much later than the rest of the ramp, because of the Collier Road detour, and may therefore have comprised imported fill.

For the purposes of the slope analysis, based on the borehole data, the embankment fill was assumed to have the following properties (see Appendix B):

- Unit Weight, $\gamma = 19.5$ to 20.5 kN/m^3
- Effective Angle of Internal Friction, $\phi' = 30$ degrees

1.4.4 Glacial Till

The predominant subsoil unit beneath the site consists of moist, hard clayey silt to silty clay till extending from approximate elevation 177 m down to approximate elevation 172 m. The lower approximately 1 m to 2 m of this layer comprises soft to firm silty clay.

For the purposes of the slope analysis, based on the borehole data, the glacial till was assumed to have the following properties (see Appendix B):

- Unit Weight, $\gamma = 19.5$ to 20 kN/m^3
- Effective Angle of Internal Friction, $\phi' = 28$ degrees

1.4.3 Bedrock

The bedrock was not proven for this evaluation. All boreholes were drilled to practical refusal on the bedrock surface. Refusal levels ranged from 171.4 m to 172.5 m.

Bedrock in this area is known to comprise dolomite and dolomitic limestone of the Goat Island Formation.

1.5 Groundwater Conditions

Information regarding the groundwater levels at the site was obtained by measuring the water levels in the open boreholes after the completion of drilling. In addition, standpipe piezometers were installed in Boreholes 1 and 2 to allow monitoring of long-term conditions.

Free standing water was observed in Boreholes 1, 2, and 4. The water level was noted at between 6.1 m and 6.3 m depth (elevation 171.8 m to 172.2 m) in Boreholes 1 and 2, and near 11.3 m in Borehole 4 (elevation 173.6). Because of the low permeability of the native soils and fill, the water table had not recovered completely, and it is likely that these levels do not represent the stabilized water table. It is probable that much higher levels exist at different times of the year particularly during wet periods and that water may be perched in the embankment fills - depending on local slope geometry.

PART 2 Engineering Discussions and Recommendations

2.1 General

The following subsections address slope stability and construction considerations pertaining to the proposed embankment rehabilitation of the N-E ramp from Collier Road to King's Highway 58.

2.2 Slope Stability Considerations

2.2.1 General

A slope stability analysis was carried out on the affected area using subsoil data from the boreholes and survey information provided by the MTO. The analysis was carried out by calculating the Factor of Safety¹ against failure using the software SLOPE/W (from GeoSlope International). SLOPE/W is a computer program which calculates the Factor of Safety based on equilibrium methods using Bishop's Method of Slices.

2.2.2 Stability Analysis - Existing Condition

The results of the analysis are presented in Figures 1 to 3, in Appendix B, as summarized below.

a) Low Water Table Figure 1:

This situation assumes that the embankment is well drained and the stable water table is well below the base of the embankment. The Factor of Safety against failure of the slope is calculated as approximately 1.5, or stable.

b) High Water Table Figure 2:

This situation assumes that the embankment drainage is poor and the water table is near the surface. Such a situation could occur during wet periods in the spring and is likely exacerbated by poor drainage within the embankment fills. The Factor of Safety against failure of the slope in this case is near unity or failure. It is believed that this is the likely failure condition for the subject slope.

¹ The Factor of Safety is defined as the ratio of forces resisting failure to the forces promoting failure.

a) Mid-level Water Table Figure 1:

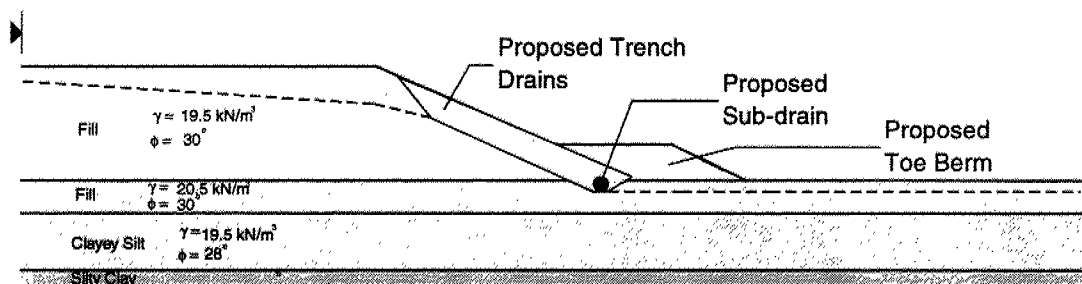
If the water table within the embankment is lowered to below mid-height, the slope is considered stable with a Factor of Safety against failure calculated at approximately 1.5.

These analyses indicate the embankment is not in danger of deep-seated, global failure. Considering all of the data available, it appears that the mode of failure of the slope is primarily surficial in nature, promoted by high groundwater conditions. The general embankment fill encountered in Boreholes 3 and 4 was found to be in good condition, but it is possible that the construction of slope flanks was not as rigorous and/or this zone of fill has been disturbed. Poor drainage within the embankment appears to have exacerbated the instability.

2.2.3 Stability Analysis - Proposed Rehabilitation

In order to effectively reduce the risk of slope failures in the future, it should be possible to increase the Factor of Safety by improving drainage and/or reducing the effective inclination of the slope by the placement of a toe berm, as shown in Figure 4 in Appendix B.

Two or three trench drains, at least 1.5 m deep, should be installed down the surface of the slope to promote drainage within the embankment fill, as detailed below. The drained water should be directed away - downstream to the west - by a sub-drain installed at the base of the existing slope. The trench drains and the subdrain should consist of full depth clear stone wrapped in filter cloth; where the trenches are exposed on the surface they should be protected with 100 mm to 200 mm rip rap.



The toe berm will provide a counter-balancing weight at the base of the slope, increasing the forces inhibiting failure. The berm should be approximately 2.0 m high and approximately 7 m wide from the base of the slope.

Such measures will increase the Factor of Safety to greater than 1.4, which should effectively treat the area against further instability.

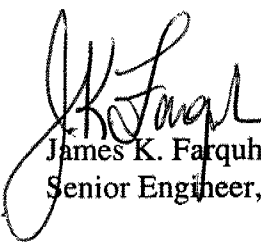
2.3 Closing Remarks


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 embankment rehabilitation at the Hwy. 58 - Collier Road Interchange. 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 James K Farquharson, P.Eng. and Eric Cheng, P.Eng., reviewed by Lloyd A. Gonsalves, P.Eng. Overview and approval was by Stan E. Gonsalves, P.Eng..

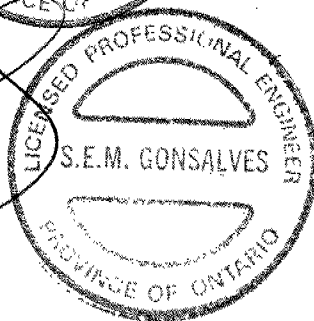
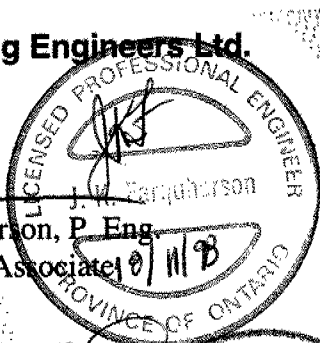
We trust this report is satisfactory for your purposes. Should you have any questions, please do not hesitate to contact this office.

Trow Consulting Engineers Ltd.

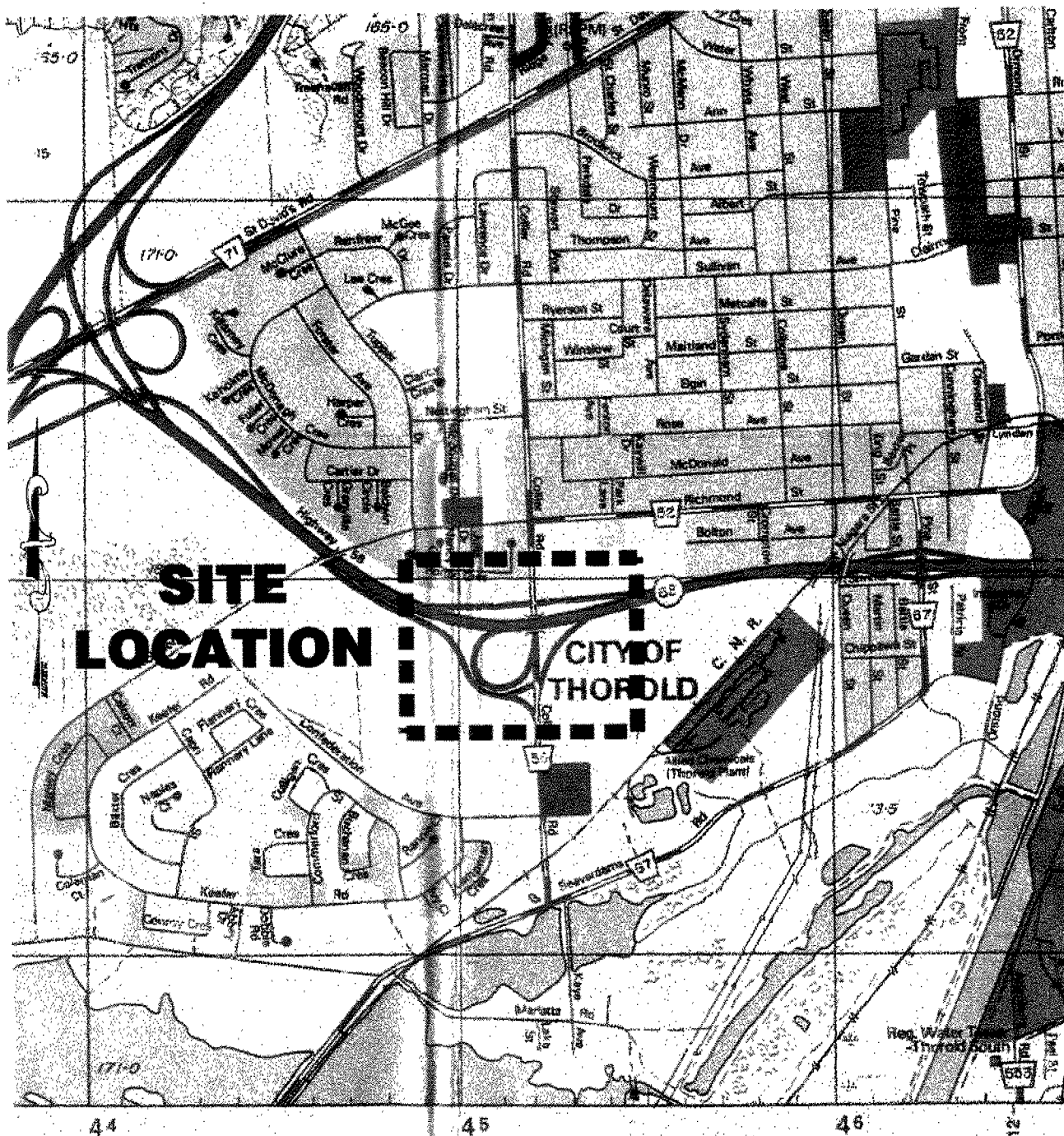

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Manager, Geotechnical Division


Stan E. Gonsalves, P.Eng.
Principal Engineer



Appendix A:
Key Plan, Borehole Location Plan
Section A-A & Borehole logs



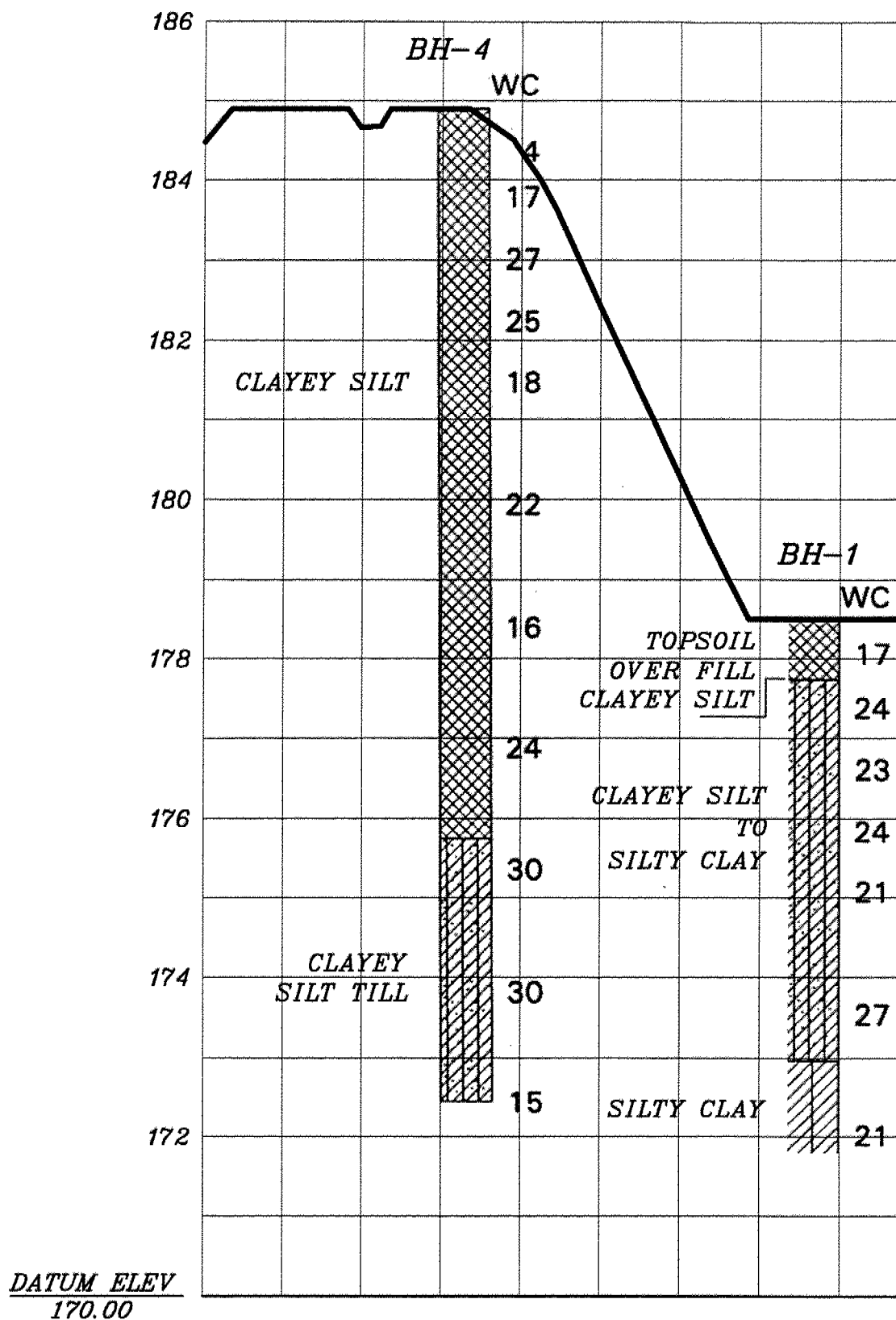
TROW CONSULTING ENGINEERS LTD.
BRAMPTON, ONTARIO

KEY PLAN
HWY. 58 & COLLIER ROAD
WP No.: 312-97-00

THOROLD

ONTARIO

PROJECT NO.:	BRGE0050774_A
SCALE:	NTS
DRAWN BY:	SS
CHECKED BY:	EC
DATE:	OCTOBER 2, 1998
DRAWING NO.:	1



TROW CONSULTING ENGINEERS LTD.

BRAMPTON, ONTARIO

SECTION A-A

THOROLD

ONTARIO

PROJECT NO.:	BRGE0050774_A
SCALE:	NTS - Vertical 5x exaggerated
DRAWN BY:	SS
CHECKED BY:	RC
DATE:	OCTOBER 2, 1998
DRAWING NO.:	3

RECORD OF BOREHOLE 1 Highway 58/Collier Road - N-E Ramp

1 OF 1

METRIC

W.P. 312-97-00

LOCATION Collier Ramp N-E Sta 0+420, ~22.0 m Rt. of C.L.

ORIGINATED BY N.A.

DIST Niagara HWY 58

BOREHOLE TYPE Solid Stem Auger/SPT

COMPILED BY N.A.

DATUM Geodetic

DATE August 13, 1998

CHECKED BY J.K.F.

SOIL PROFILE				SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) CONE PENETRATION TEST		PLASTIC LIMIT wp	NATURAL MOISTURE CONTENT w	LIQUID LIMIT wl	UNIT WEIGHT kN/m ³	WELL GRAPHICS/ PIEZOMETER DETAILS		
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m			20 40 60 80								
								SHEAR STRENGTH: Cu, MPa							WATER CONTENT (%)	
						UNCONFINED PENETROMETER 0.1	FIELD VANE LAB VANE 0.2									
178.1	GROUND SURFACE															
0.0	~ 50 mm Topsoil, over FILL - clayey silt, some gravel, topsoil inclusions, brown to dark brown, moist.		1	SPT	14		⊗				○			177.77		
177.32	CLAYEY SILT TO SILTY CLAY TILL - occasional pieces of limestone, brown/grey, moist, hard, becoming softer with depth		2	SPT	17		⊗				○			19.47		
0.75			3	SPT	21		⊗				○			20.32		
			4	SPT	16		⊗				○			19.79		
			5	SPT	19		⊗		▲		○			20.62		
			6	SPT	13		⊗	▲			○			19.36		
	- becoming firm to stiff with clay seams below ~4.5 m depth															
172.57	SILTY CLAY - occasional shale fragments, grey, moist, soft to firm.		7	SPT	6		⊗				○			171.36		
5.50																
171.36	ASSUMED LIMESTONE BEDROCK															
6.71	End of Borehole Auger refusal on assumed bedrock at 6.71 m depth.															

RECORD OF BOREHOLE 2 Highway 58/Collier Road - N-E Ramp

1 OF 1

METRIC

W.P. 312-97-00

LOCATION Collier Ramp N-E Sta 0+432, ~21.5 m Rt. of C.L.

ORIGINATED BY N.A.

DIST Niagara HWY 58

BOREHOLE TYPE Solid Stem Auger/SPT

COMPILED BY N.A.

DATUM Geodetic

DATE August 13, 1998

CHECKED BY J.K.F.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) CONE PENETRATION TEST				PLASTIC LIMIT wp	NATURAL MOISTURE CONTENT w	LIQUID LIMIT wl	WATER CONTENT (%)	UNIT WEIGHT kN/m ³	WELL GRAPHICS/ PIEZOMETER DETAILS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m			20	40	60	80						
178.3	GROUND SURFACE																
0.0	~100 mm Topsoil, over FILL - clayey silt, topsoil inclusions, trace to some gravel, rootlets, brown to dark brown, moist.		1	SPT	18		178	⊗				○				21.05	177.97
			2	SPT	16		177	⊗				○				19.40	
176.75	CLAYEY SILT TO SILTY CLAY TILL - some gravel sizes, brown, moist, hard in upper levels, becoming softer with depth		3	SPT	20		176	⊗				○				20.17	
1.52			4	SPT	19		175	⊗				○				19.69	
			5	SPT	16		174	⊗				○				19.34	
			6	SPT	11		173	⊗				○				19.97	
173.07	- occasional limestone and shale fragments, brown, moist, stiff below ~4.5 m depth		7	SPT	60		172	⊗				○					
5.20	SILTY CLAY - with pieces of limestone, brown, wet, soft to firm						171										
172.02	ASSUMED LIMESTONE BEDROCK						170										
6.25	End of Borehole Auger refusal on assumed bedrock at 6.25 m depth						169										

METRIC

CHECKED BY J.K.F.



RECORD OF BOREHOLE 3 Highway 58/Collier Road - N-E Ramp

2 OF 2

METRIC

W.P. 312-97-00 LOCATION Collier Ramp N-E Sta 0+412, ~5.0 m Rt. of C.L. ORIGINATED BY N.A.
DIST Niagara HWY 58 BOREHOLE TYPE Solid Stem Auger/SPT COMPILED BY N.A.
DATUM Geodetic DATE August 14, 1998 CHECKED BY J.K.F.

SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) CONE PENETRATION TEST				PLASTIC LIMIT wp	NATURAL MOISTURE CONTENT w	LIQUID LIMIT wl	UNIT WEIGHT kN/m³	WELL GRAPHICS/ PIEZOMETER DETAILS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE			20	40	60	80					
184.7															
			10	SPT	12	174	⊗	▲			○			19.43	
						173									
172.39 12.35	SILTY CLAY - with weathered rock fragments, brown, moist, soft to firm. ASSUMED LIMESTONE BEDROCK		11	SPT	60		▲	60/0 mm	⊗		○				
	End of Borehole Refusal to Sampler on Assumed Bedrock at 12.35 m depth														

RECORD OF BOREHOLE 4 Highway 58/Collier Road - N-E Ramp

1 OF 2

METRIC

W.P. 312-97-00

LOCATION Collier Ramp N-E Sta 0+424, ~5.0 m Rt. of C.L.

ORIGINATED BY N.A.

DIST Niagara HWY 58

BOREHOLE TYPE Solid Stem Auger/SPT

COMPILED BY N.A.

DATUM Geodetic

DATE August 14, 1998

CHECKED BY J.K.F.

SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) CONE PENETRATION TEST				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT				UNIT WEIGHT kN/m ³	WELL GRAPHICS/ PIEZOMETER DETAILS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER TYPE BLOWS/0.3m			20	40	60	80	wp	w	wl	WATER CONTENT (%)		
184.9	GROUND SURFACE														
0.0	~75 mm Asphaltic Concrete over ~75 mm Granular over ~50 mm Asphaltic Concrete over FILL - sand and gravel to ~0.75 m depth then clayey silt, brown, moist.		1 AUGER												
			2 SPT 11		184	⊗				○				21.05	
			3 SPT 6			⊗				○					
			4 SPT 6		183	⊗				○				19.14	
			5 SPT 7			⊗				○				19.48	
			6 SPT 11		182	⊗				○				20.88	
					181										
			7 SPT 15		180	⊗				○				19.58	
					179										
			8 SPT 14		178	⊗				○				20.81	
			9 SPT 15		177	⊗				○				19.44	
					176										
175.81															
9.10	CLAYEY SILT TILL - brown/grey, moist, firm to stiff.		10 SPT 7		175	⊗	▲			○				18.82	

RECORD OF BOREHOLE 4 Highway 58/Collier Road - N-E Ramp

2 OF 2

METRIC

W.P. 312-97-00

LOCATION Collier Ramp N-E Sta 0+424, ~5.0 m Rt. of C.L.

ORIGINATED BY N.A.

DIST Niagara HWY 58

BOREHOLE TYPE Solid Stem Auger/SPT

COMPILED BY N.A.

DATUM Geodetic

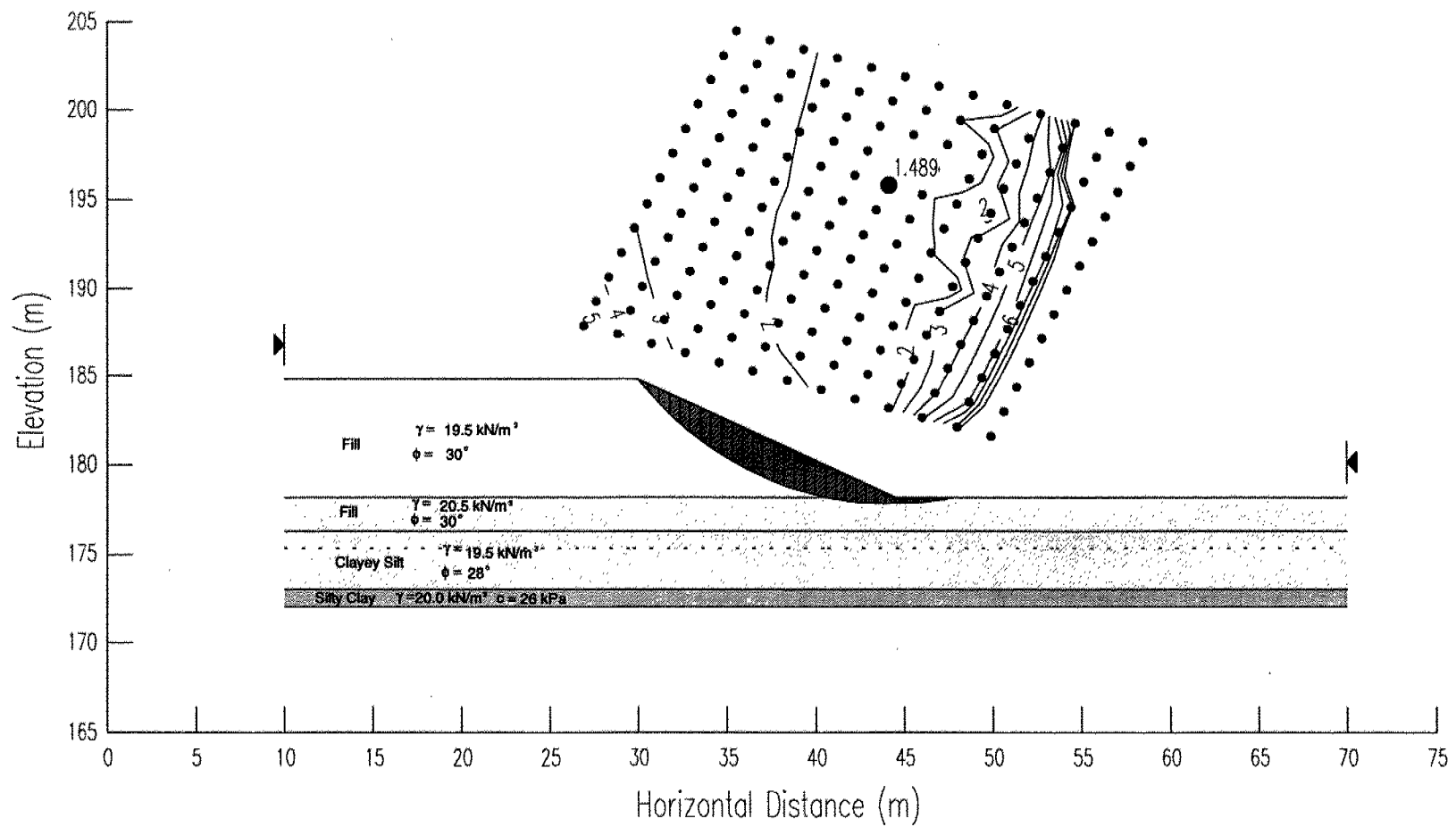
DATE August 14, 1998

CHECKED BY J.K.F.

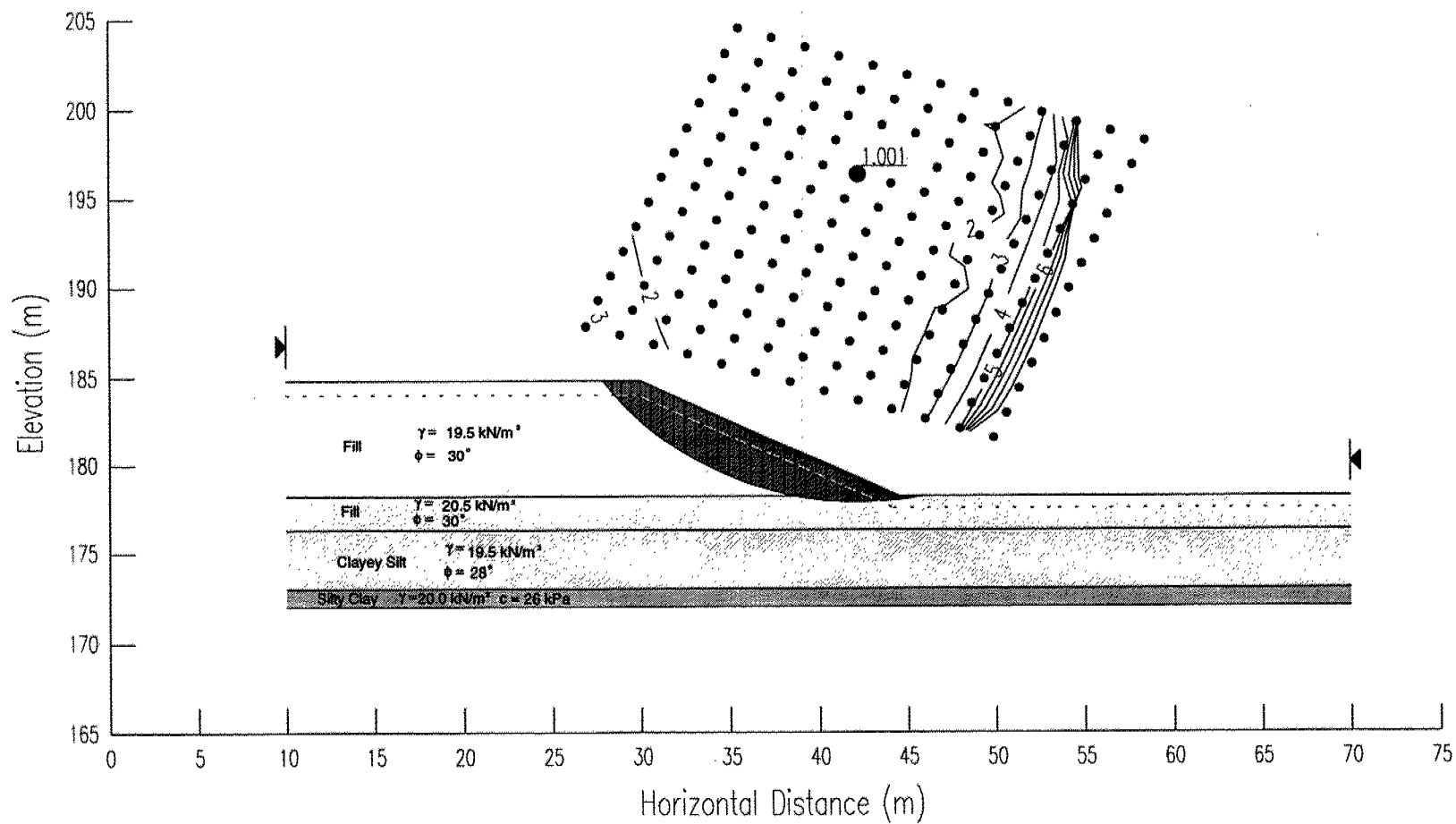
SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) CONE PENETRATION TEST				PLASTIC LIMIT wp	NATURAL MOISTURE CONTENT w	LIQUID LIMIT wl	UNIT WEIGHT kN/m³	WELL GRAPHICS/ PIEZOMETER DETAILS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE			20	40	60	80					
184.9															
			11	SPT	9		174							19.19	
							173								
122.53 12.38	-becoming hard below ~12.2 m depth End of Borehole Refusal to Sampler on Assumed Bedrock at 12.38 m depth		12	SPT	60					60/25 mm				21.87	

Appendix B: Slope Stability Analyses

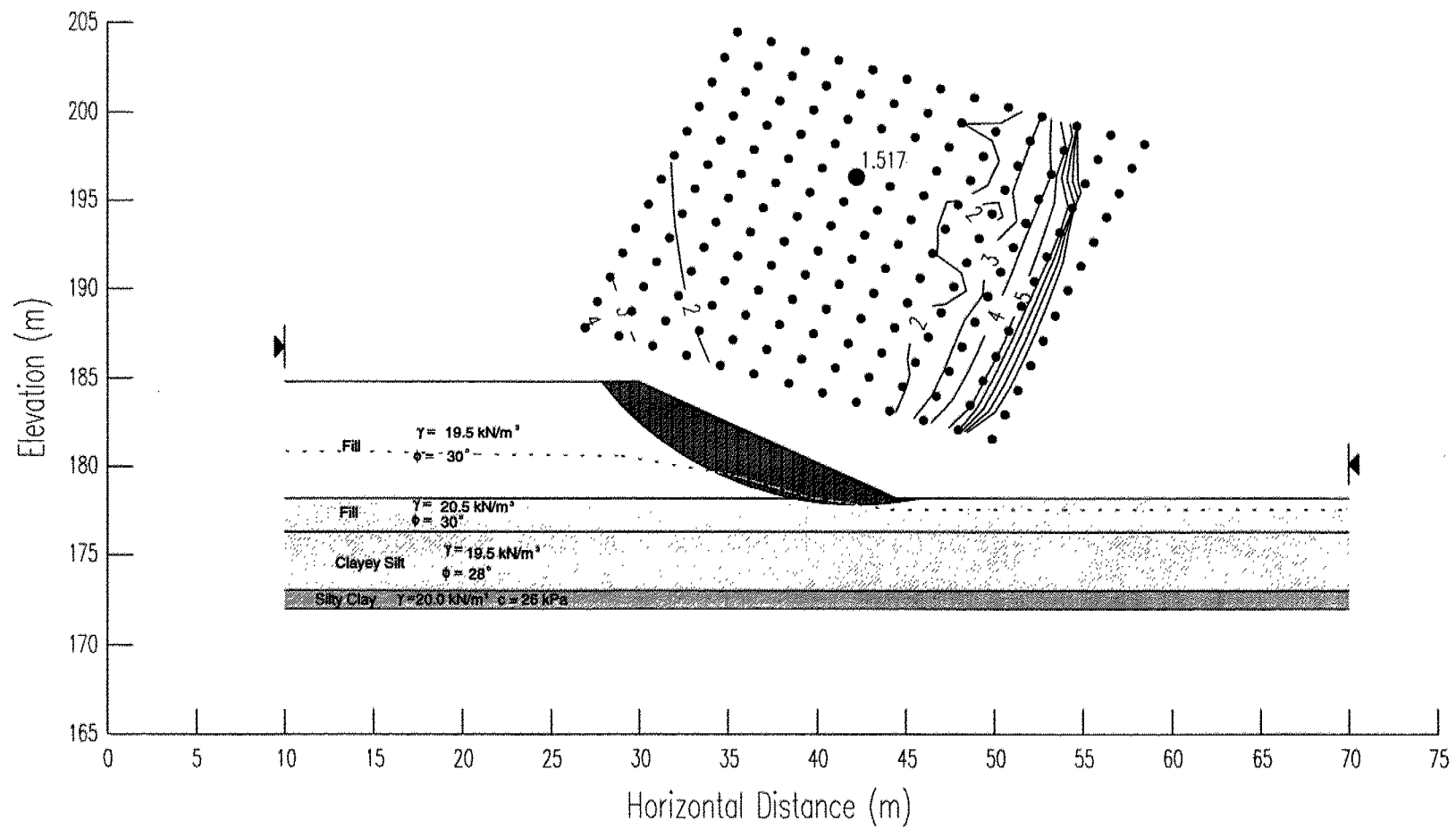
Highway 58 - Collier Road N-E Ramp
Figure 1



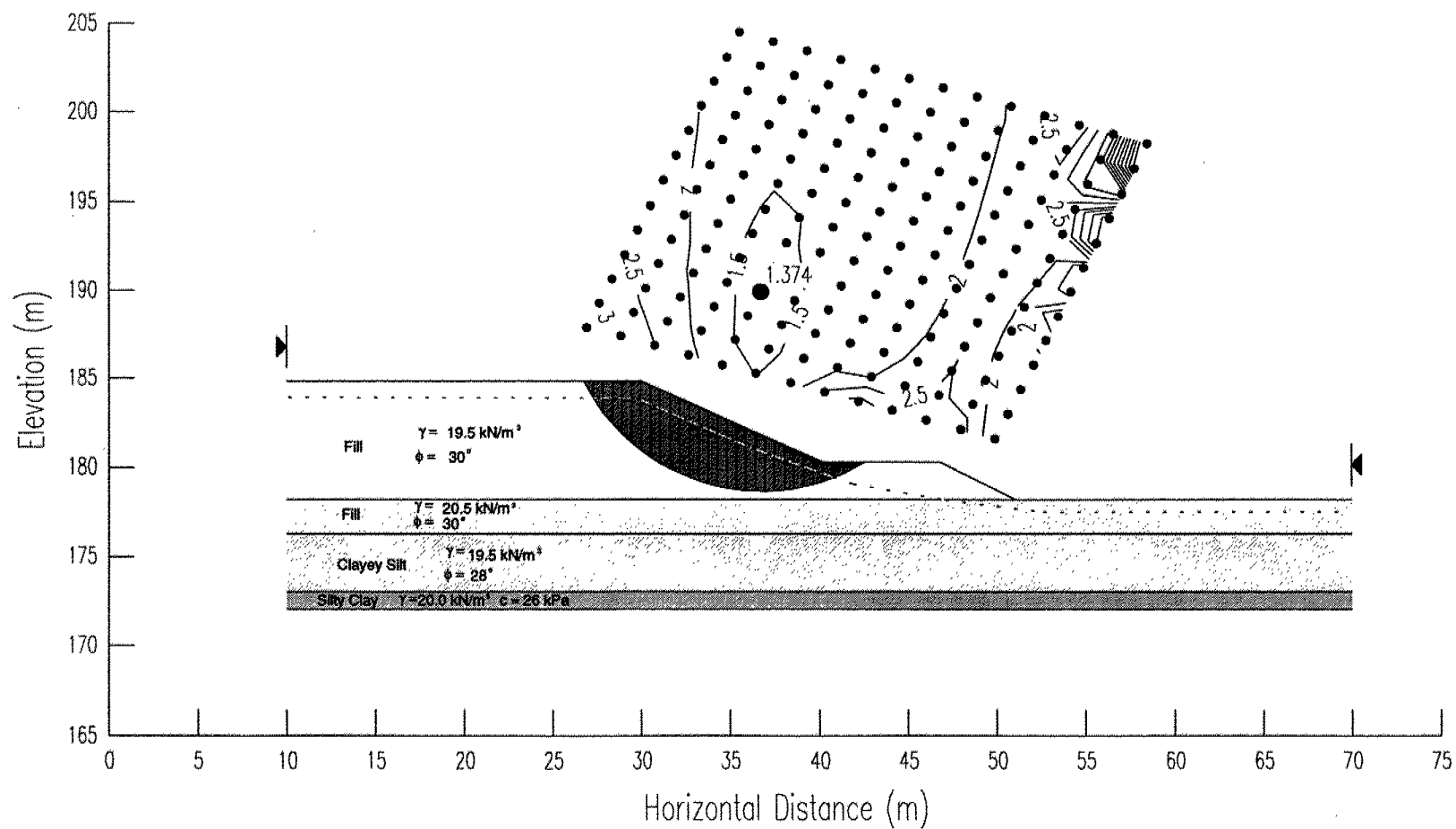
Highway 58 - Collier Road N-E Ramp
Figure 2



Highway 58 - Collier Road N-E Ramp
Figure 3



Highway 58 - Collier Road N-E Ramp
Figure 4



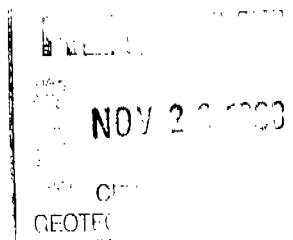
GEOCRES No. 30M3-218DIST. CR REGION W.P. No. 312-97-00CONT. No. W. O. No. STR. SITE No. HWY. No. 58LOCATION Hwy 58 N-E RAMP
FROM COLLIER RDPROPOSED EMBANKMENT REHAB.OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT. REMARKS:

GEOCRES 30M3-218

**Foundation Investigation and Design
Report - Slope Stability Analysis
Proposed Embankment Rehabilitation
N-E Ramp, Collier Road to
King's Highway 58, WP 312-97-00
City of Thorold, Region of Niagara**

Prepared for:

Ontario Ministry of Transportation
Pavements and Foundations Section
Foundations Group
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BRGE0050774A

November 18, 1998

Preface

Work project WP 312-97-00 involves the rehabilitation of Hwy58 from Hwy 406 easterly to Davis Drive including all interchange ramps at Collier Road, Pine Street and Davis Dr, but not including Thorold tunnel.

It is located in the City of St. Catharines and the Town of Thorold in the Regional Municipality of Niagara. The rehabilitation work includes:

- Repair failed joints and very severe cracks using full depth dowelled concrete.
- Spall and failed concrete repair using hot mix.
- Repair slight and moderate cracks with crack sealant.
- Repair severe cracks with hot mix.
- Subsealing cracks and joints indicated.
- Overlay concrete pavement with 50mm HDBC and 40mm DFC.

The following report comments on the foundation investigation and subsequent engineering for the slope stability of the N-E Ramp Collier Road to Kings Highway No. 58.

Other associated geotechnical and Pavement Report for the project includes:

- Pavement Design Report, Trow Consulting Engineers Ltd., November 10, 1998
BRGE0050774A

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PART 1 Foundation Investigation

1.1 Introduction

This submission presents the results of a foundation investigation completed by Trow Consulting Engineers Ltd. (Trow) for the proposed rehabilitation of Highway 58 between the Highway 406 interchange and Davis Drive in the Region of Niagara, Ontario. This report contains factual information (obtained from the field investigation) pertaining to the design of slope stabilization strategies. The report is prepared as a separate investigation and report - completed in conjunction with the Highway 58 evaluation.

1.2 Background and Site Description

1.2.3 Background

The subject site is located in the City of Thorold, in the Region of Niagara along Highway 58 at the Collier Road interchange (approximate Station 10+940 along Highway 58). The section of embankment which shows instability lies between N-E ramp Stations 0+400 and 0+450. Typical features associated with slope failure such as tension cracking at the crest of the slope and scarping along the length of the failed zone are apparent.

The embankment in this section was constructed as part of the original highway construction in the 1960's under Contract 66-58. The original design drawings indicate that to the east of the Collier Road interchange, the subsoil comprises silty clay which directly overlies dolomite and dolomitic limestone of the Goat Island formation.

The original construction drawings show that in the area immediately adjacent and to the south of the subject slope, a farm building and silo had existed, both since demolished (See Drawing 2). Also, the temporary detour for the construction of the overpass structure crossed over the area of the slope movements; details of this temporary construction are not known with certainty, but it may be assumed that the temporary road crossed the area near original grade, and that the affected portion of the highway and ramp embankment was constructed after the Collier overpass was completed. It is possible that different fill materials and methods may have been used during this construction.

1.2.2 Site Description

It is understood that the slope movement in this area has been an ongoing problem over some years, and that it is localized in nature. Other parts of the embankment are at similar inclinations but do not exhibit similar slope instability. At the crest of the slope in the subject area, an approximately 16m long crack exists through the paved shoulder, and typical slope

failure features are noticeable on the embankment face. The failure appears visually to be surficial in nature

Previous repair of the slope at the crest has been carried out as part of regular shoulder maintenance. This has included filling, re-contouring, re-paving of the surface and reinstatement of the crash barrier.

Data from recent topographic plans indicate that the slope inclination in the area of the failure is near 1 vertical to 2.2 horizontal.

1.3 Investigative Procedures

1.3.1 General

Part 1 of this report describes the investigative procedures adopted for the foundation assessment of the embankment to N-E Collier Road Ramp at the interchange to King's Highway 58. Properties of the overburden soils at the site were obtained by in situ and laboratory testing and procedures employed during the investigation are described below.

1.3.2 Field Investigation

The fieldwork for the investigation related to the embankment instability was carried out between August 13 and 14, 1998, and consisted of four (4) sampled boreholes (Boreholes 1 to 4) which were advanced to depths ranging from 6.25 m to 12.34 metres.

Two (2) boreholes were drilled at the bottom of the subject slope and two (2) were drilled near the crest of the slope. The borehole locations are shown on Drawing 2, in Appendix A. The borehole locations and elevations were determined by Trow Consulting Engineers Ltd. engineering staff and are referenced to ramp stationing and MTO geodetic datum (Bench Mark 625 = Elevation 185.801 m), respectively.

The boreholes were advanced through the overburden soils on the site using a track mounted CME-55 drill rig equipped with solid and hollow stem augers. Soil samples were obtained using a 51 mm 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.

All boreholes were advanced to practical refusal on assumed bedrock.

1.3.3 Laboratory

The laboratory testing program for selected soil samples consisted of the following:

- Natural Moisture Contents
- Unit Weight Determinations

The laboratory test results are summarized on the attached Borehole Logs 1 to 4, in Appendix A.

1.4 Subsurface Conditions

The borehole locations are shown on Drawing 2, in Appendix A and the subsurface information revealed from the boreholes near the slope location are summarized on the attached Borehole Logs 1 to 4, inclusive. Based on the borehole information, the following subsoil layers were encountered at this site:

- Topsoil;
- Shoulder Construction;
- Fill;
- Glacial Till;
- Bedrock.

A summary of the descriptions of the various soil strata encountered in the boreholes is presented below.

1.4.1 Topsoil

A thin veneer of topsoil, ranging in thickness from 50 to 100 mm, was encountered in Boreholes 1 and 2 at the base of the slope. The topsoil is generally of a silty nature, brown in colour and contains rootlets.

1.4.2 Shoulder Construction

At the boreholes drilled through the paved shoulder near the crest of the slope, the upper pavement construction comprises approximately 75 mm asphaltic concrete over approximately 150 mm crushed granular base material at Borehole 3. At Borehole 4 two layers of asphaltic concrete were encountered with a 75 mm thick layer of granular base sandwiched between. Beneath these upper pavement layers, the upper fill comprises loose to compact sand and gravel fill to a depth of approximately 0.7 m.

1.4.3 Fill

Beneath the topsoil in Boreholes 1 and 2, and beneath the upper shoulder construction in Boreholes 3 and 4, the general fill comprises clayey to sandy silt and silty clay with occasional gravel.

It is understood that the fill material was placed in a controlled fashion during construction of the main highway and the Collier Road interchange, and comprises native till materials excavated from the highway construction to the east - where the road extends down to the Thorold Tunnel.

The embankment fill in this area may be a slightly different material than indicated in the original borings from the 1960's (i.e., silty clay). There is a possibility that this small area may have been backfilled much later than the rest of the ramp, because of the Collier Road detour, and may therefore have comprised imported fill.

For the purposes of the slope analysis, based on the borehole data, the embankment fill was assumed to have the following properties (see Appendix B):

- Unit Weight, $\gamma = 19.5$ to 20.5 kN/m^3
- Effective Angle of Internal Friction, $\phi' = 30$ degrees

1.4.4 Glacial Till

The predominant subsoil unit beneath the site consists of moist, hard clayey silt to silty clay till extending from approximate elevation 177 m down to approximate elevation 172 m. The lower approximately 1 m to 2 m of this layer comprises soft to firm silty clay.

For the purposes of the slope analysis, based on the borehole data, the glacial till was assumed to have the following properties (see Appendix B):

- Unit Weight, $\gamma = 19.5$ to 20 kN/m^3
- Effective Angle of Internal Friction, $\phi' = 28$ degrees

1.4.3 Bedrock

The bedrock was not proven for this evaluation. All boreholes were drilled to practical refusal on the bedrock surface. Refusal levels ranged from 171.4 m to 172.5 m.

Bedrock in this area is known to comprise dolomite and dolomitic limestone of the Goat Island Formation.

1.5 Groundwater Conditions

Information regarding the groundwater levels at the site was obtained by measuring the water levels in the open boreholes after the completion of drilling. In addition, standpipe piezometers were installed in Boreholes 1 and 2 to allow monitoring of long-term conditions.

Free standing water was observed in Boreholes 1, 2, and 4. The water level was noted at between 6.1 m and 6.3 m depth (elevation 171.8 m to 172.2 m) in Boreholes 1 and 2, and near 11.3 m in Borehole 4 (elevation 173.6). Because of the low permeability of the native soils and fill, the water table had not recovered completely, and it is likely that these levels do not represent the stabilized water table. It is probable that much higher levels exist at different times of the year particularly during wet periods and that water may be perched in the embankment fills - depending on local slope geometry.

PART 2 Engineering Discussions and Recommendations

2.1 General

The following subsections address slope stability and construction considerations pertaining to the proposed embankment rehabilitation of the N-E ramp from Collier Road to King's Highway 58.

2.2 Slope Stability Considerations

2.2.1 General

A slope stability analysis was carried out on the affected area using subsoil data from the boreholes and survey information provided by the MTO. The analysis was carried out by calculating the Factor of Safety¹ against failure using the software SLOPE/W (from GeoSlope International). SLOPE/W is a computer program which calculates the Factor of Safety based on equilibrium methods using Bishop's Method of Slices.

2.2.2 Stability Analysis - Existing Condition

The results of the analysis are presented in Figures 1 to 3, in Appendix B, as summarized below.

a) Low Water Table Figure 1:

This situation assumes that the embankment is well drained and the stable water table is well below the base of the embankment. The Factor of Safety against failure of the slope is calculated as approximately 1.5, or stable.

b) High Water Table Figure 2:

This situation assumes that the embankment drainage is poor and the water table is near the surface. Such a situation could occur during wet periods in the spring and is likely exacerbated by poor drainage within the embankment fills. The Factor of Safety against failure of the slope in this case is near unity or failure. It is believed that this is the likely failure condition for the subject slope.

¹ The Factor of Safety is defined as the ratio of forces resisting failure to the forces promoting failure.

a) Mid-level Water Table Figure 1:

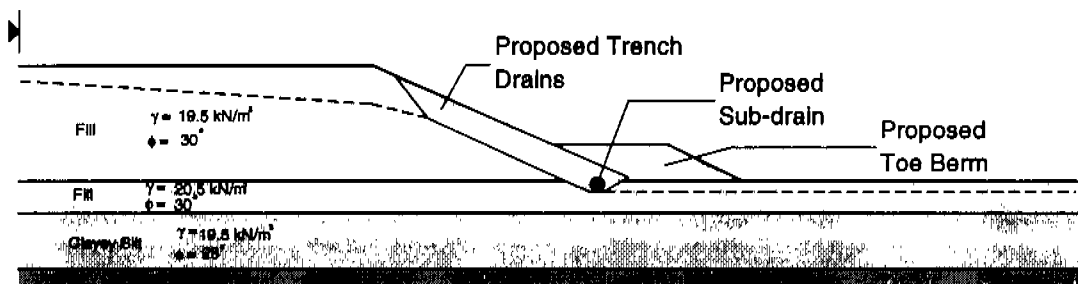
If the water table within the embankment is lowered to below mid-height, the slope is considered stable with a Factor of Safety against failure calculated at approximately 1.5.

These analyses indicate the embankment is not in danger of deep-seated, global failure. Considering all of the data available, it appears that the mode of failure of the slope is primarily surficial in nature, promoted by high groundwater conditions. The general embankment fill encountered in Boreholes 3 and 4 was found to be in good condition, but it is possible that the construction of slope flanks was not as rigorous and/or this zone of fill has been disturbed. Poor drainage within the embankment appears to have exacerbated the instability.

2.2.3 Stability Analysis - Proposed Rehabilitation

In order to effectively reduce the risk of slope failures in the future, it should be possible to increase the Factor of Safety by improving drainage and/or reducing the effective inclination of the slope by the placement of a toe berm, as shown in Figure 4 in Appendix B.

Two or three trench drains, at least 1.5 m deep, should be installed down the surface of the slope to promote drainage within the embankment fill, as detailed below. The drained water should be directed away - downstream to the west - by a sub-drain installed at the base of the existing slope. The trench drains and the subdrain should consist of full depth clear stone wrapped in filter cloth; where the trenches are exposed on the surface they should be protected with 100 mm to 200 mm rip rap.



The toe berm will provide a counter-balancing weight at the base of the slope, increasing the forces inhibiting failure. The berm should be approximately 2.0 m high and approximately 7 m wide from the base of the slope.

Such measures will increase the Factor of Safety to greater than 1.4, which should effectively treat the area against further instability.

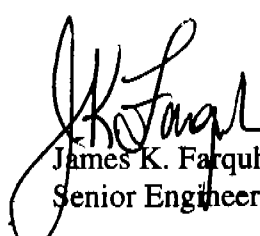
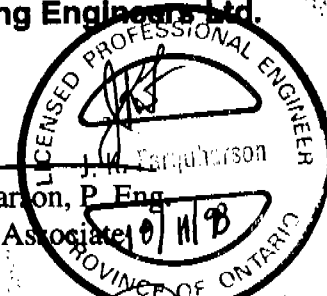
2.3 Closing Remarks


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 embankment rehabilitation at the Hwy. 58 - Collier Road Interchange. 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 James K. Farquharson, P.Eng. and Eric Cheng, P.Eng., reviewed by Lloyd A. Gonsalves, P.Eng. Overview and approval was by Stan E. Gonsalves, P.Eng..

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

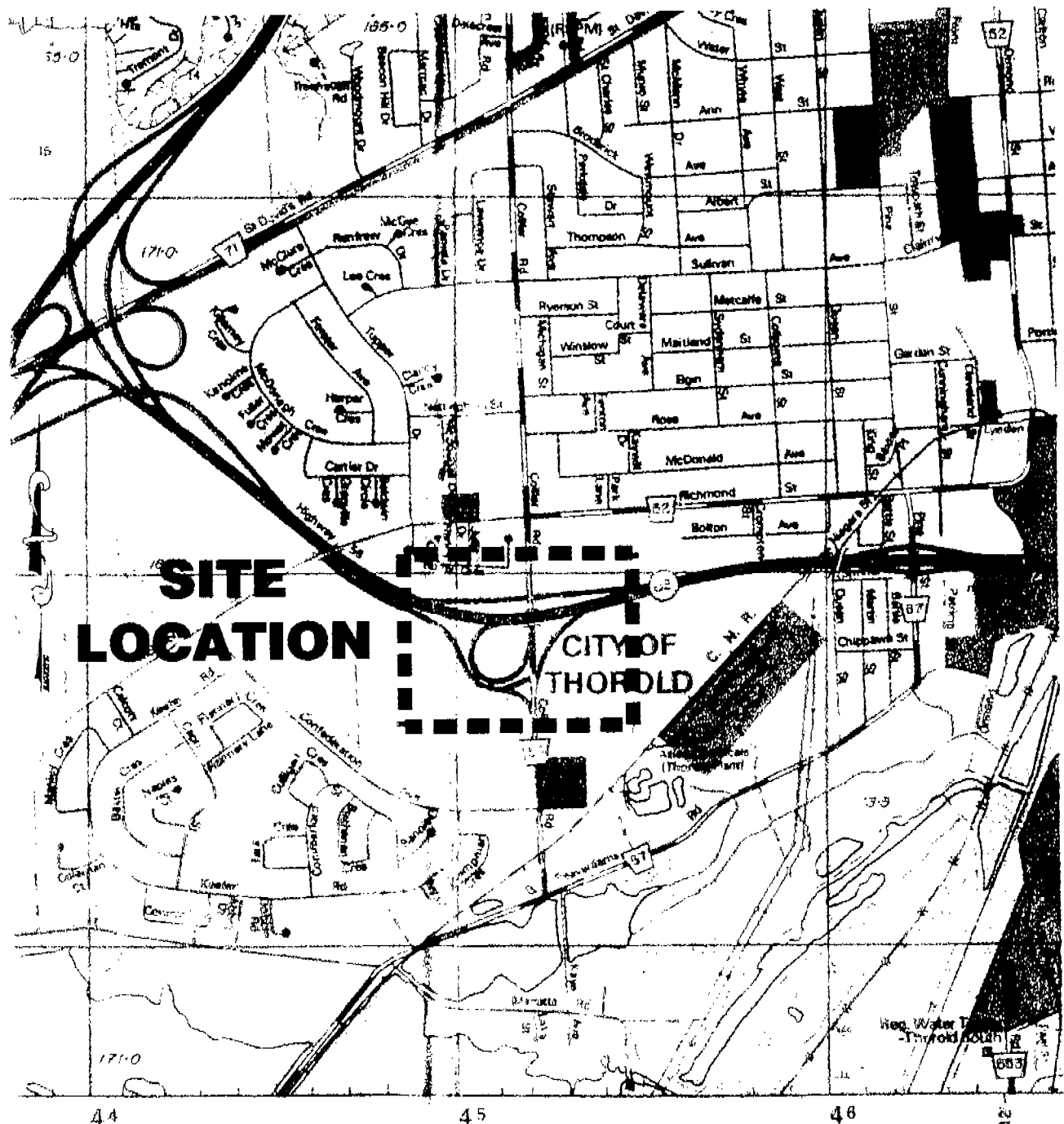
Trow Consulting Engineers Ltd.


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Appendix A:
Key Plan, Borehole Location Plan
Section A-A & Borehole logs



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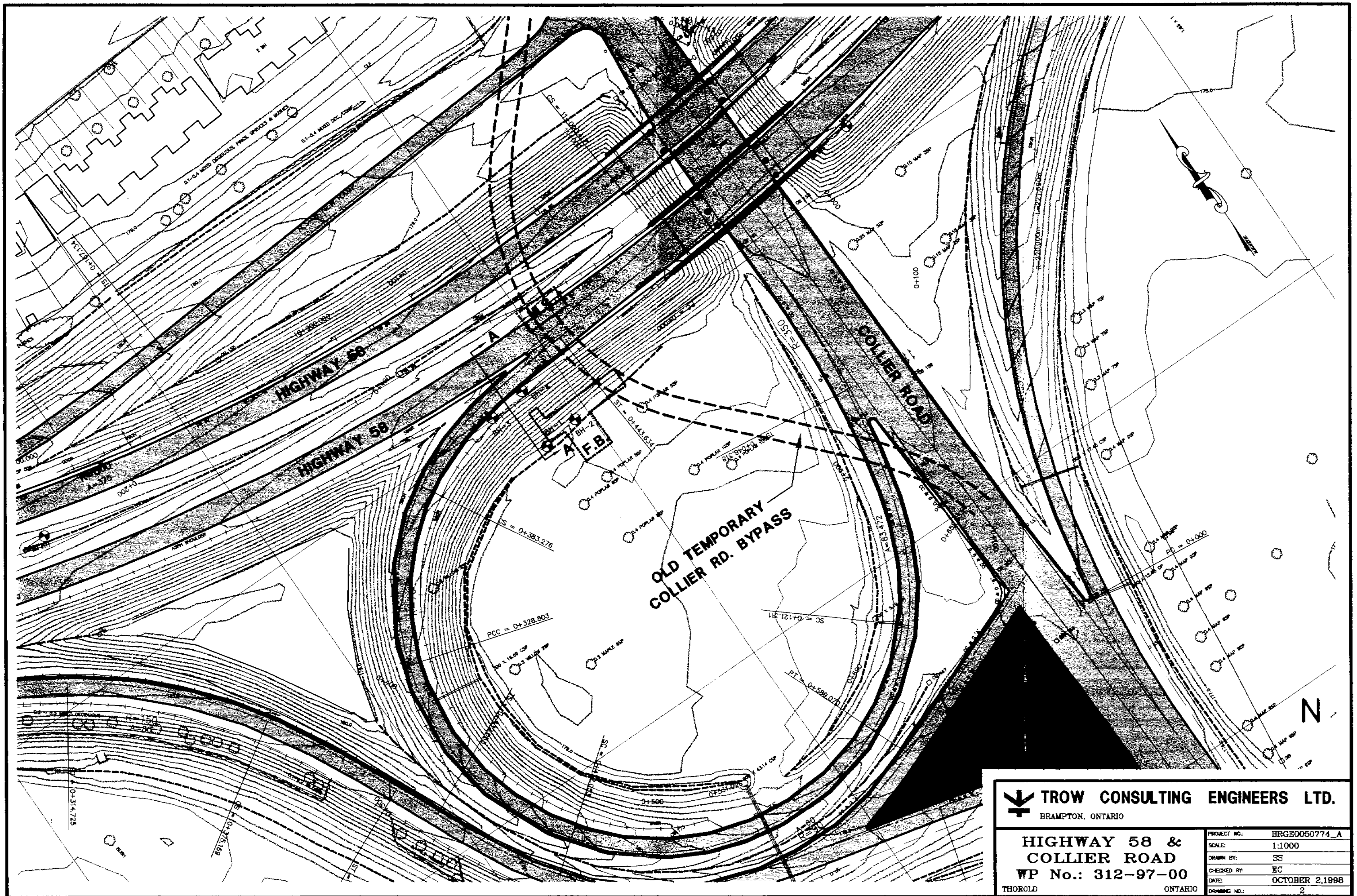
BRAMPTON, ONTARIO


KEY PLAN
HWY. 58 & COLLIER ROAD
WP No.: 312-97-00

THOROLD

ONTARIO

PROJECT NO.:	BRGE0050774_A
SCALE:	NTS
DRAWN BY:	SS
CHECKED BY:	EC
DATE:	OCTOBER 2, 1998
DRAWING NO.:	1




TROW CONSULTING ENGINEERS LTD.
 BRAMPTON, ONTARIO

HIGHWAY 58 & COLLIER ROAD
 WP No.: 312-97-00
 THOROLD ONTARIO

PROJECT NO.	BRGE0050774_A
SCALE	1:1000
DRAWN BY	SS
CHECKED BY	EC
DATE	OCTOBER 2, 1998
DRAWING NO.	2

RECORD OF BOREHOLE 1 Highway 58/Collier Road - N-E Ramp

1 OF 1

METRIC

W.P. 312-97-00

LOCATION Collier Ramp N-E Sta 0+420, ~22.0 m Rt. of C.L.

ORIGINATED BY N.A.

DIST Niagara HWY 58

BOREHOLE TYPE Solid Stem Auger/SPT

COMPILED BY N.A.

DATUM Geodetic

DATE August 13, 1988

CHECKED BY J.K.F.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) CONE PENETRATION TEST				PLASTIC LIMIT wp	NATURAL MOISTURE CONTENT w	LIQUID LIMIT wl	WATER CONTENT (%)	UNIT WEIGHT kN/m ³	WELL GRAPHICS/ PIEZOMETER DETAILS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m			SHEAR STRENGTH: Cu, MPa									
								UNCONFINED PENETROMETER	FIELD VANE LAB VANE	0.1	0.2						
178.1	GROUND SURFACE																
0.0	50 mm Topsoil over FILL - clayey silt, some gravel, topsoil inclusions, brown to dark brown, moist.		1	SPT	14											21.01	177.77
177.32																	
0.76	CLAYEY SILT TO SILTY CLAY TILL - occasional pieces of limestone, brown/grey, moist, hard, becoming softer with depth		2	SPT	17											19.47	
			3	SPT	21											20.32	
			4	SPT	16											19.79	
			5	SPT	19											20.62	
																	174.41
																	174.11
																	173.60
	- becoming firm to stiff with clay seams below 4.6 m depth		6	SPT	13											19.36	172.89
172.57																	
5.50	SILTY CLAY - occasional shale fragments, grey, moist, soft to firm.		7	SPT	6												171.36
171.36	ASSUMED LIMESTONE BEDROCK																
6.71	End of Borehole Auger refusal on assumed bedrock at 6.71 m depth.																

RECORD OF BOREHOLE 2 Highway 58/Collier Road - N-E Ramp

1 OF 1

METRIC

W.P. 312-97-00

LOCATION Collier Ramp N-E Sta 0+432, ~21.5 m Rt. of C.L.

ORIGINATED BY N.A.

DIST Niagara HWY 58

BOREHOLE TYPE Solid Stem Auger/SPT

COMPILED BY N.A.

DATUM Geodetic

DATE August 13, 1998

CHECKED BY J.K.F.

SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) CONE PENETRATION TEST		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT kN/m³	WELL GRAPHICS/ PIEZOMETER DETAILS	
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE			BLOWS/0.3m	20 40 60 80		wp — w — wl			
								SHEAR STRENGTH: Cu, MPa		WATER CONTENT (%)			
							UNCONFINED PENETROMETER	FIELD VANE LAB VALUE					
178.3 0.0	GROUND SURFACE												
	~100 mm Topsoil, over FILL - clayey silt, topsoil inclusions, trace to some gravel, rootlets, brown to dark brown, moist.		1	SPT	18						21.05	177.97	
			2	SPT	16						19.40		
176.76 1.52	CLAYEY SILT TO SILTY CLAY TILL - some gravel sizes, brown, moist, hard in upper levels, becoming softer with depth		3	SPT	20						20.17		
			4	SPT	19						19.69		
			5	SPT	16						19.34	178.07 174.76 174.15	
	- occasional limestone and shale fragments, brown, moist, stiff below ~4.5 m depth		6	SPT	11						19.97	173.64	
173.07 5.20	SILTY CLAY - with pieces of limestone, brown, wet, soft to firm												
172.02 6.28	ASSUMED LIMESTONE BEDROCK		7	SPT	60			60/125 mm				172.02	
	End of Borehole Auger refusal on assumed bedrock at 6.25 m depth												

RECORD OF BOREHOLE 3

Highway 58/Collier Road - N-E Ramp

1 OF 2

METRIC

W.P. 312-97-00

LOCATION Collier Ramp N-E Sta 0+412, ~5.0 m Rt. of C.L.

ORIGINATED BY N.A.

DIST Niagara HWY 58

BOREHOLE TYPE Solid Stem Auger/SPT

COMPILED BY N.A.

DATUM Geodetic

DATE August 14, 1998

CHECKED BY J.K.F.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) CONE PENETRATION TEST				PLASTIC LIMIT wp	NATURAL MOISTURE CONTENT w	LIQUID LIMIT wl	WATER CONTENT (%)	UNIT WEIGHT kN/m³	WELL GRAPHICS/ PIEZOMETER DETAILS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m			20	40	60	80						
184.7 0.0	GROUND SURFACE																
	75 mm Asphaltic Concrete over 150 mm Granular base over FILL - sand and gravel to ~0.7 m depth then CLAYEY SILT, with gravel, rootlets, brown to grey, moist, hard.		1	SPT	14		184										
			2	SPT	5		183									19.42	
			3	SPT	7		182									19.23	
			4	SPT	9		181										
			5	SPT	11		180									20.58	
			6	SPT	16		179										
			7	SPT	22		178									20.47	
			8	SPT	20		177									20.04	
176.24 8.50	CLAYEY SILT TO SILTY CLAY TILL - topsoil stains and oxidation, brown, moist, hard becoming firm.		9	SPT	17		176									19.99	
							175										

RECORD OF BOREHOLE 3

2 OF 2

METRIC

Highway 58/Collier Road - N-E Ramp

W.P. 312-97-00

LOCATION Collier Ramp N-E Sta 0+412, ~5.0 m Rt. of C.L.

ORIGINATED BY N.A.

DIST Niagara HWY 58

BOREHOLE TYPE Solid Stem Auger/SPT

COMPILED BY N.A.

DATUM Geodetic

DATE August 14, 1998

CHECKED BY J.K.F.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) CONE PENETRATION TEST				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT				UNIT WEIGHT kN/m³	WELL GRAPHICS/ PIEZOMETER DETAILS	
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS/0.3m			SHEAR STRENGTH: Cu, MPa				WATER CONTENT (%)						
								UNCONFINED PENETROMETER		FIELD VANE								
184.7								20	40	60	80	wp	w	wl	20	40	60	80
							174											
			10	SPT	12													
							173											
	SILTY CLAY - with weathered rock fragments, brown, moist, soft to firm. ASSUMED LIMESTONE BEDROCK		11	SPT	60													
172.35 12.35	End of Borehole Refusal to Sampler on Assumed Bedrock at 12.35 m depth																	

RECORD OF BOREHOLE 4 Highway 58/Collier Road - N-E Ramp

1 OF 2

METRIC

W.P. 312-97-00

LOCATION Collier Ramp N-E Sta 0+424, 5.0 m Rt. of C.L.

ORIGINATED BY N.A.

DIST Niagara HWY 58

BOREHOLE TYPE Solid Stem Auger/SPT

COMPILED BY N.A.

DATUM Geodetic

DATE August 14, 1998

CHECKED BY J.K.F.

SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) CONE PENETRATION TEST				PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT	WELL GRAPHICS/ PIEZOMETER DETAILS
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE			20 40 60 80								
							SHEAR STRENGTH: Cu, MPa								
							UNCONFINED PENETROMETER	FIELD VALUE	LAB VALUE						
GROUND SURFACE															
184.8	0.0	75 mm Asphaltic Concrete over 75 mm Granular over 50 mm Asphaltic Concrete over FILL - sand and gravel to 0.75 m depth then clayey silt, brown, moist.	1	AUGER											
			2	SPT	11										
			3	SPT	6		184							21.05	
			4	SPT	6		183							19.14	
			5	SPT	7		182							19.48	
			6	SPT	11		181							20.88	
			7	SPT	16		180							19.58	
			8	SPT	14		179							20.81	
			9	SPT	15		177							19.44	
175.81	9.10	CLAYEY SILT TILL - brown/grey, moist, firm to stiff.	10	BPT	7		176							18.82	
							175								

MT02 50774 11/09/98



RECORD OF BOREHOLE 4 Highway 58/Collier Road - N-E Ramp

2 OF 2

METRIC

W.P. 312-97-00

LOCATION Collier Ramp N-E Sta 0+424, ~5.0 m Rt. of C.L.

ORIGINATED BY N.A.

DIST Niagara HWY 58

BOREHOLE TYPE Solid Stem Auger/SPT

COMPILED BY N.A.

DATUM Geodetic

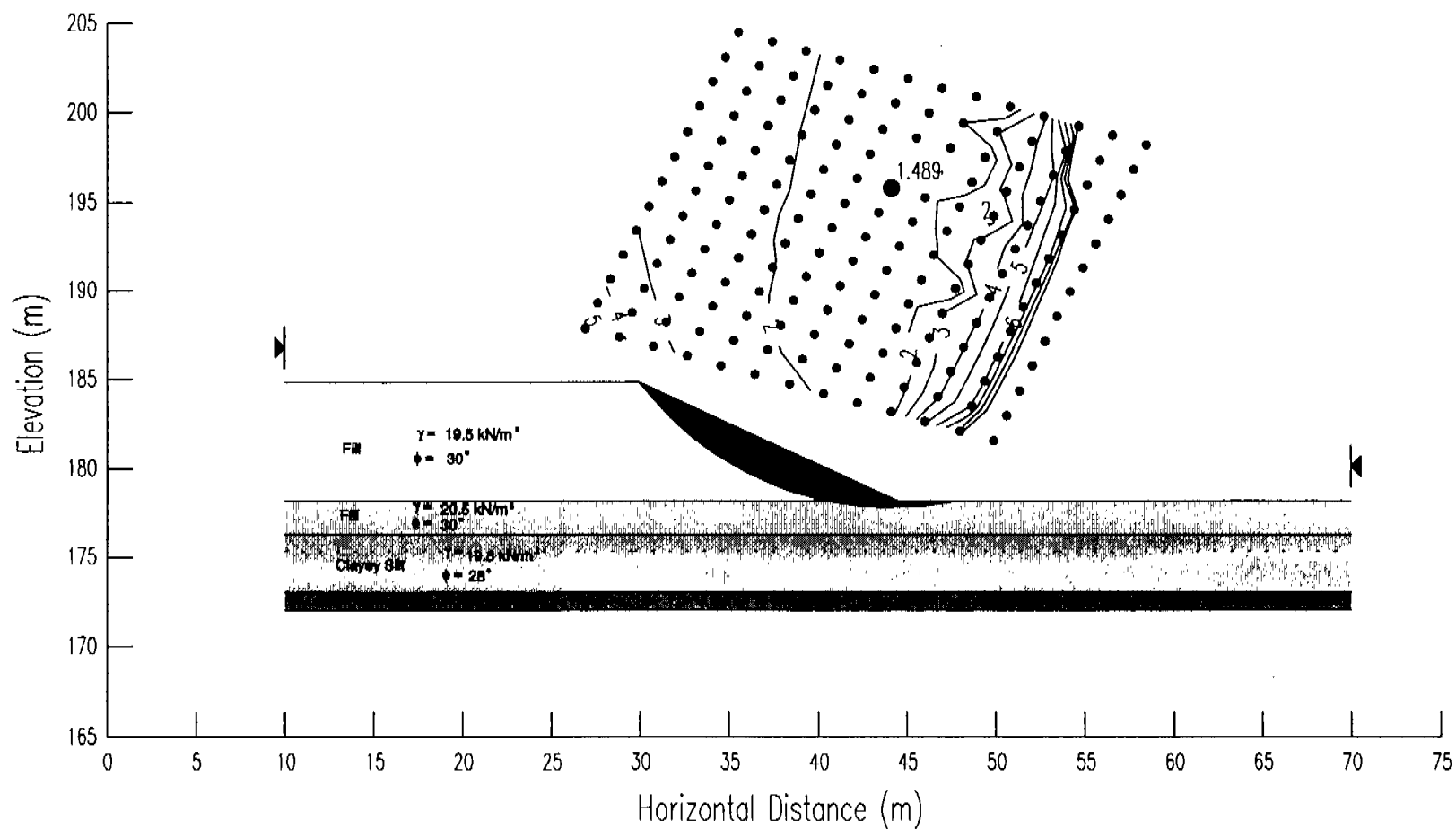
DATE August 14, 1998

CHECKED BY J.K.F.

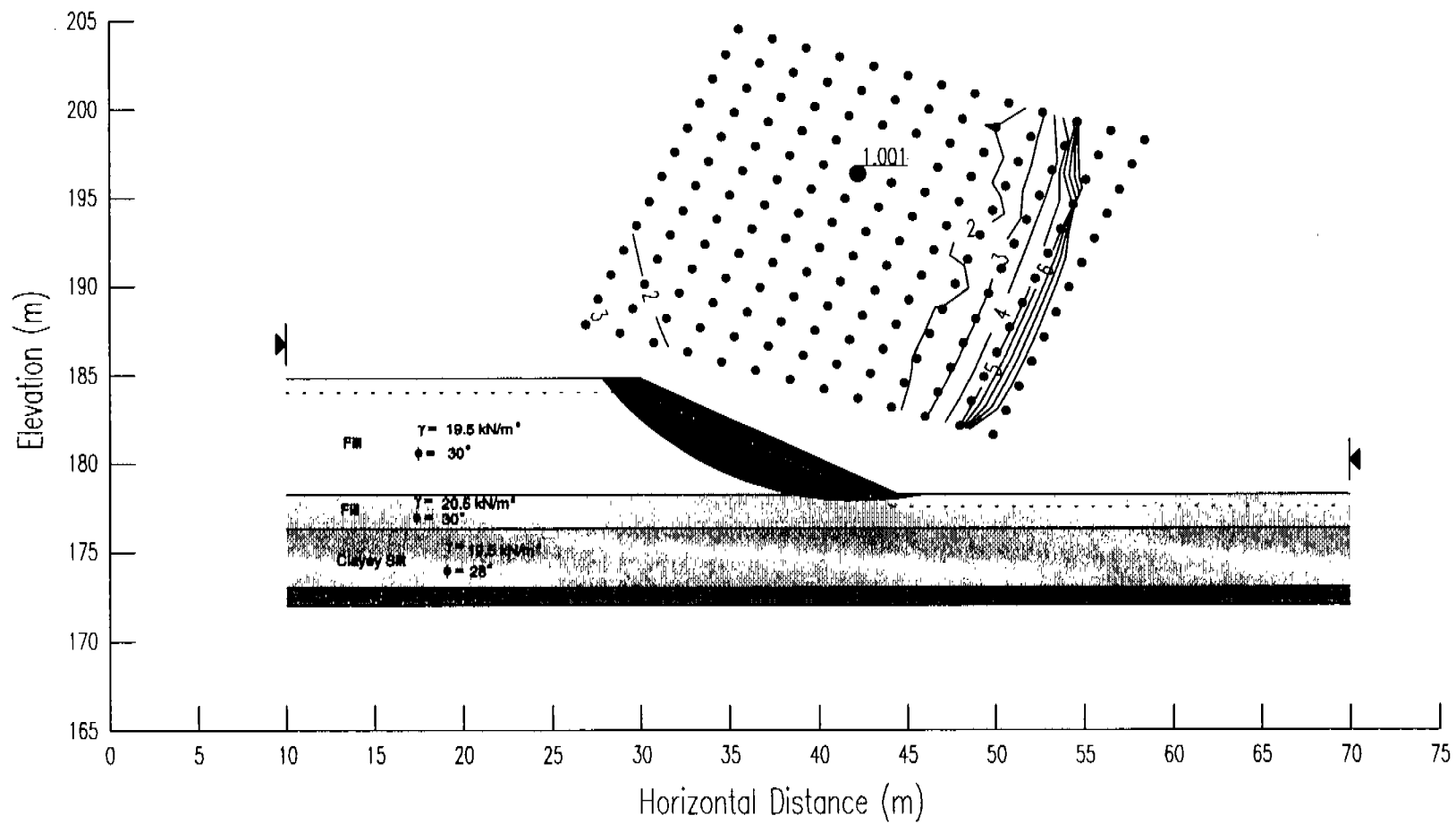
SOIL PROFILE			SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE (metres)	SPT TEST (N-Value) CONE PENETRATION TEST		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT kN/m³	WELL GRAPHICS/ PIEZOMETER DETAILS	
ELEV. DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE			BLOWS/0.3m	20 40 60 80		wp — w — wl				
								SHEAR STRENGTH: Cu, MPa		WATER CONTENT (%)				
184.9							UNCONFINED COMPRESSION PENETROMETER	FIELD VANE CUT VANE	0.1	0.2	20 40 60 80			
			11	SPT	9				174			19.19		
									173					
172.53 12.38	-becoming hard below ~12.2 m depth End of Borehole Refusal to Sampler on Assumed Bedrock at 12.38 m depth		12	SPT	60			60/25 mm C A				21.87		

Appendix B: Slope Stability Analyses

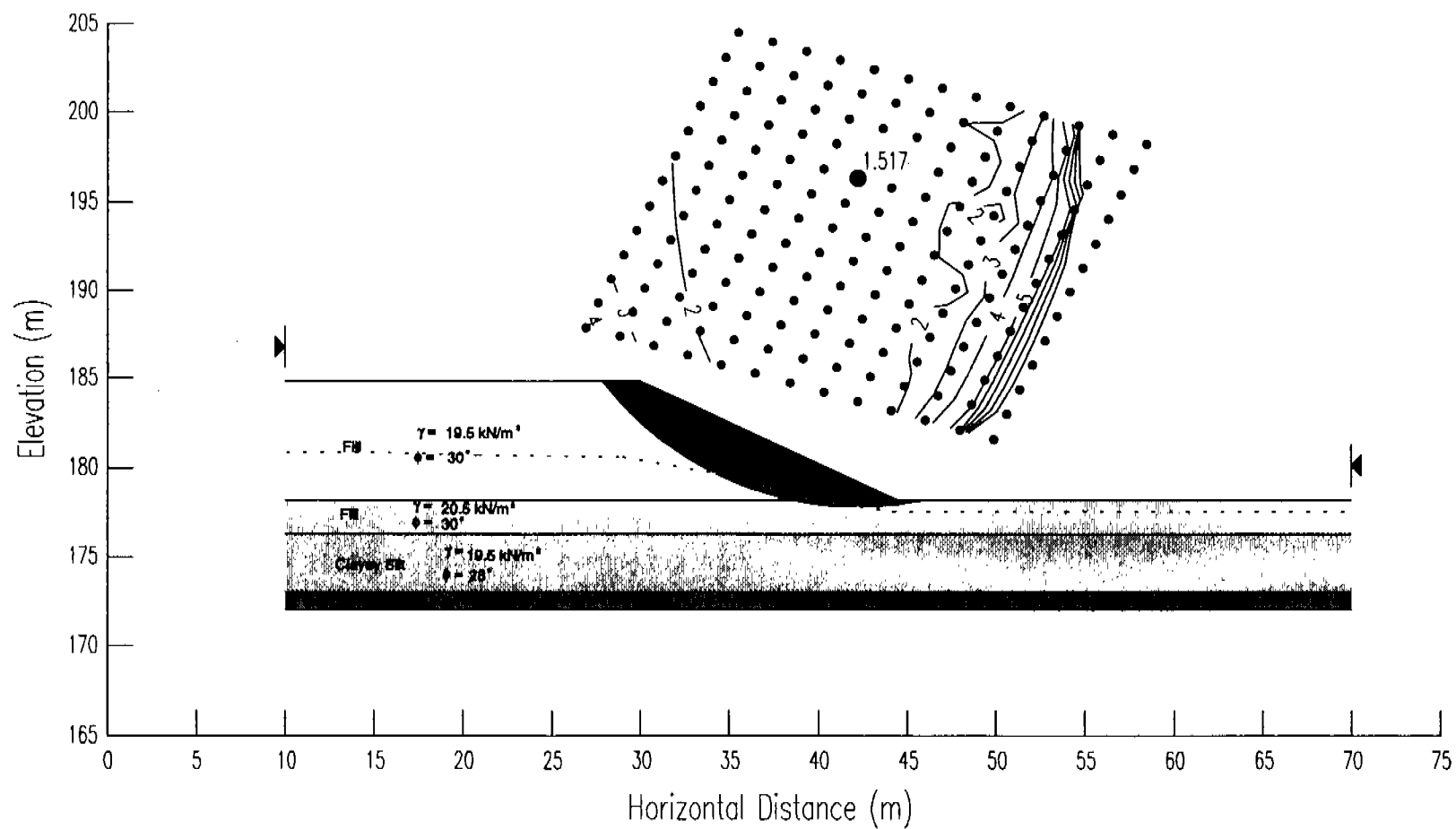
Highway 58 - Collier Road N-E Ramp
Figure 1



Highway 58 - Collier Road N-E Ramp
Figure 2



Highway 58 - Collier Road N-E Ramp
Figure 3



Highway 58 - Collier Road N-E Ramp
Figure 4

