Technical Memorandum

Date: March 27, 2012

Subject: Permanent Remediation of Cut Slope Instabilities on Highway 89 near 5th Line, Essa Township.
W.O. 2012-11010
GEOCRES No. 31D-537

1. INTRODUCTION

MERO Pavements and Foundations Section was requested by Central Region (CR) Geotechnical Section on March 6th, 2012 to provide recommendations for the embankment instabilities that occurred at the westbound embankment of Highway (Hwy) 68, approximately 100m east of 5th Line intersection.

Mr Dave Theissler from CR contract office contacted MTO Foundation office and indicated that there is a slope instability issue on the westbound embankment of Hwy 89 near 5th Line intersection (See Figure 1) in the township of Essa.

According to the background given to us, the slope was cut in April/May 2010 originally; the cut material was sandy with large seams of silt running through it. Once the silt was exposed to the air, the water began to escape and the earth material began seeping out of the slope. As time was of the essence a decision was made by the Ministry to stabilize the slope by means of installing rip rap underlain by geotextiles in these areas. These areas were large and extensive enough that virtually the entire slope was covered. The treatment was successful and has remained stable until recently. On March 5th, Dave Theissler was notified about the problem and made a site visit. The material from the slope had washed out and filled the ditch so that it was at the same elevation as the asphalt on Highway 89. The ditch, which runs towards the river, crosses under the township road and connects to another ditch which outlets directly into the river. There is a silt fence at the ultimate outlet into the river. Subsequently, the contractor was called to the site on March 5th afternoon and they controlled the silt flow by means of hydro vacuuming, and placing sand bags on top of the slope.

MTO Foundations office received a request from the CR to visit the site on March 6th and conducted a site visit on the subsequent day (March 7th) by Alper Turan, Project Foundation Engineer. Alper Turan met with Dave Theissler (MTO CR) and contractor' representatives in the site and received an introduction to the problem and conducted a walk-over. The following are observations that are made during our site visit.

The slope instabilities took place in a cut section of the slope in the area of Essa 5th Line and Highway 89 for the section along the Highway from about Station 16+300 to Station 16+400. The slope is approximately 10 m high and constructed in cut. The cut slope is constructed with a 2 m wide mid-height berm. The slope inclination is 2:1 from the toe to the mid-height berm and 2.5:1 from the mid-height berm to the crest. The lower portion of the slope is covered using geotextile and riprap. The bold lines in Figure 1 depict the extent of riprap application. No drainage ditches exist on the crest of the slope. It was observed that the farm land beyond the crest of the slope was gently sloping towards the cut slope. The Nottawasaga River is the lowest point in the area from a drainage

perspective. The slope instability was observed to be approximately 75 m east of the intersection of Highway 89 and 5th line, which coincides with the middle of the portion where riprap is present. The location of instability is approximately shown with dotted lines in Figure 1. Figures 2 to 4 show some views from the slope instability. Sand bags had been placed to control the run-off from the slope by the contractor after the incidence took place. However, they were not observed to efficiently control the run off (see Figure 5).

2. EVALUATION

The following provides the evaluation of the slope instability.

2.1. Subsurface Conditions

The subsurface conditions in the cut slope are given in "The Foundation Report – HWY 89 Nottawasaga River Bridge & Retaining Wall and Cut Slope at Essa 5th Line". The following subsections summarize the subsurface information given in the foundation report in the cut slope area. Figure 6 gives a cross-section of the cut slope with the representative subsurface conditions. Appendix-A show the borehole plan for the cut slope and the logs for BH 09-1 and BH 09-2.

2.1.1. Top Soil

A 0.3 m thick deposit of topsoil was encountered at the ground surface in Borehole 09-1.

2.1.2. Fill

Fill consisting of silty sand, some gravel, trace organic matter was encountered in Borehole 09-2 at the ground surface and extends to a depth of 0.8 m below ground surface (i.e.Elevation 210.9 m).

2.1.3. Sandy Silt

A deposit of sandy silt was encountered immediately below the topsoil at the location of Borehole 09-1 and extends to a depth of 4.7 m below ground surface (i.e. Elevation 216.2 m). The thickness of this deposit is 4.4 m. Measured SPT "N" values within the sandy silt deposit range from 4 blows to 23 blows per 0.3 m of penetration, indicating a loose to compact relative density. The lower "N" values were encountered within the upper 2 m of the deposit below the existing ground surface. The deposit was found to contain trace to some clay. The water contents on five samples selected in this deposit range between 15 percent and 18 percent.

2.1.4. Silty Clay and Clayey Silt

Deposits of silty clay and clayey silt were encountered underlying the deposits of sandy silt in Borehole 09-1 and underlying the fill in Borehole 09-2, at Elevation 216.2 m and Elevation 210.9 m, respectively. In Borehole 09-1, the silty clay deposit extends to a depth of 5.6 m below ground surface (i.e. Elevation 215.3 m). In Borehole 09- 2, the clayey silt deposit extends to a depth of 1.4 m below ground surface (i.e. Elevation 210.3 m). The thickness of this deposit is 0.9 m in Borehole 09-1 and 0.6 m in Borehole 09-2.

A measured SPT "N" value within the silty clay deposit was 16 blows per 0.3 m of penetration indicating a very stiff consistency. An SPT "N" value of 4 blows per 0.3 m of penetration was measured within the clayey silt deposit in Borehole 09-2, indicating a firm consistency. Water contents on a selected sample of the silty clay and clayey silt deposit were about 23 percent. The

liquid limits are about 32 percent and 37 percent, the plastic limits are about 16 percent and 20 percent, and the corresponding plasticity indices are about 16 percent and 17 percent. These results indicate that these deposits consist of clayey silt and silty clay of low to intermediate plasticity.

2.1.5. Silty Sand

A deposit of silty sand was encountered underlying the silty clay deposit in Borehole 09-1 at Elevation 215.3 m. The silty sand deposit is 5.7 m thick and extends to Elevation 209.6 m. Measured SPT "N" values within the silty sand deposit range from 43 blows per 0.3 m of penetration to 113 blows for 0.3 m of penetration, indicating a dense to very dense relative density. The water contents of the silty sand deposit range from about 6 percent to 14 percent.

2.1.6. Silt and Sand to Silt

Deposits of silt and sand to silt were encountered underlying the silty sand deposit at depths of 11.3 m below ground surface in Borehole 09-1 and 1.4 m below ground surface in Borehole 09-2. Borehole 09-1 was terminated within the silt and sand deposit at a depth of 15.9 m below the existing ground surface (i.e. Elevation 205.1 m). Borehole 09-2 was terminated within a silt deposit at a depth of 5.2 m below the existing ground surface (i.e. Elevation 206.5 m). Measured SPT "N" values within these deposits range from 20 blows per 0.3 m of penetration to 128 blows for 0.3 m of penetration, indicating a compact to very dense relative density. The silt and sand deposit was found to contain trace clay. The silt deposit was found to contain some clay. The water contents of the silt and sand deposit range from about 13 percent to 16 percent, and the measured water contents of the silt deposits range from about 16 percent to 19 percent. Atterberg limits tests carried out on two samples of the silt deposit indicate that the silt is non-plastic.

2.2. Groundwater Conditions

The foundation report indicates that the groundwater seepage was observed at a depth of 1.5 m below ground surface during drilling of Boreholes 09-1 and 09-2. The groundwater level in the monitoring well installed in Borehole 09-1 was measured on May 8, 2009 at a depth of 10 m below the present ground surface (i.e. Elevation 210.9 m). The water level observed in the open Borehole 09-2 upon completion of drilling was at a depth of 2.1 m below ground surface (i.e. Elevation 209.6 m). The groundwater levels are depicted on the cut slope cross-section given in Appendix A. Generally, the groundwater seeps through the slope at approximately mid height, probably transferred through more permeable seams in the soil.

2.3. Surficial Erosion

The foundation report indicated that the surficial failures could be observed on the upper portion of the existing 2H:1V slope about 25 m to 30 m east of Borehole 09-2. The report indicated that similar slope instabilities are expected to occur in the slope and recommends the construction of the upper portion of the slope with 2.5:1 inclination. The foundation report also recommended the construction of an interceptor ditch on top of the upper slope to minimize the surface flow over the slope and control surficial erosion.

2.4. Conclusion

Based on our field observations and the review of the foundation investigation and design report, it is our opinion that the slope instabilities are surficial in nature and global stability of the cut slopes are not compromised. The instabilities stem from pore pressures from seepage that intercepts the

cut slope aggravated by uncontrolled surface runoff on the slope. It was observed during our site visit that the interceptor ditch was not constructed as shown in contract drawings (See Figure 6). The geotextiles that cover the lower portion of the cut slope are believed to be clogged by silty material which potentially contributed to instabilities by raising the ground water table and increasing the pore pressures acting against the slope.

3. REMEDIATION STRATEGY

3.1. Temporary Remediation

The construction of the interceptor ditch on the crest of cut slope as per the contract drawings are recommended during the site visit. The interceptor ditch is also a part of the permanent remediation.

3.2. Permanent Remediation

The permanent remediation strategy for the cut slope comprises three steps;

- Construction of interceptor ditch on the slope crest as shown in contract drawings
- The clearing of the disturbed material at the location of failure and reinstating the slope to original design geometry.
- The construction of armoured vertical ditches and removal of geotextiles/riprap at these locations.

3.2.1. Interceptor Ditch

The foundation report recommended that the construction of an interceptor ditch on top of the upper slope is necessary in order to minimize the surface flow over the slope and control surficial erosion. Thus, construction of interceptor ditches as shown in contract drawings are recommended as the first step. The details of the interceptor ditch are provided in contract package. The minimum dimensions of the interceptor ditch are given in Figure 7.

3.2.2. Reinstating the Slope

At the instabilities, the disturbed soil shall be cleared before reinstating the slope to original design geometry. The soil shall be excavated to a minimum of 1m beyond the horizontal limits of failure and to a minimum of 500mm below the vertical extent of failure. Hypothetical lines that represent the line of failure and the line of clearing are depicted in Figure 8. The slope shall be rebuilt using granular A fill material in steps or if lifts not exceeding 500mm and compacted after each step or lift with an appropriate sized static roller (see OPSS 1004: Material Specification for Aggregates – Miscellaneous). Reconstruction shall proceed from bottom to top and granular material shall extend to base of overlying topsoil. Geotextiles-riprap cover shall not be reinstated at repaired sections. The reinstated sections shall be covered with a minimum 600 mm topsoil with appropriate seeding and mulching/protection. The East-West extent of the repair sections shall include the areas, where sloughing and erosion exist (which may be only one massive location unless others have occurred since the noted site visit) .Please refer to Figure 9 for illustration.

3.2.3. Construction of Armored Vertical Ditches and Local Replacement of Geotextile/Riprap.

After reinstating the slope to original geometry as shown in Figure 8, vertical armoured ditches shall be constructed at three locations as shown in Figure 10 by re-excavation of trenches. The depth of the ditch shall be minimum 1m from the slope design surface and a minimum of 2m wide. The trenches shall be filled with Rip-Rap R-10 grading aggregate fill. The existing drainage ditch at the toe of the cut slope shall also be armoured with Rip-Rap R-10 grading aggregates (minimum thickness 300mm). All Rip-Rap R-10 grading aggregates shall be placed using rock protection construction method from the bottom up (i.e. machine place and random manner and without geotextile separator). Compaction is not required. Refer to the following Ontario Provincial Standard Specifications for construction method and material selection:

OPSS 511: Construction Specification for Rip Rap, Rock Protection and Gravel Sheeting
OPSS 1004: Material Specification for Aggregates - Miscellaneous

The construction of armoured vertical ditches shall be performed at three locations in total with one at the center of the repaired area and one at 30m to the east and west of the centreline. The geotextiles underlying the riprap is considered to be clogged and resulting in a raise in ground water table. However, the removal of the entire geotextile-riprap zone is considered impractical. Thus, geotexile shall be removed at the locations of the armoured vertical ditches. This operation shall proceed as follows:

- Excavate drainage ditches removing geotextiles/riprap
- Backfill with R-10 aggregate
- Connect vertical drains to toe drain
- Connect vertical drains to interceptor ditch last through channels in order to avoid flooding from runoff during construction

If you have any questions, please do not hesitate to contact us.

Prepared by
Alper Turan, P.Eng.
Project Foundations Engineer

Reviewed by
Dave Dundas, P. Eng.
Senior Foundations Engineer

Figure 1: Location of Cut Slope Instability

Figure 2: Slope Instability from the crest, towards south.

Figure 3: Slope Instability from the mid-height berm, towards north.

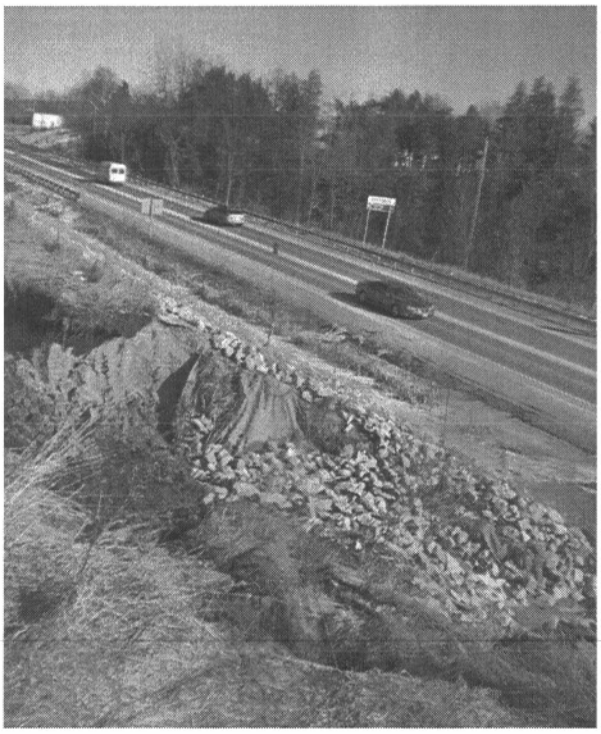


Figure 4: Slope Instability, towards south-east.

Figure 5: Sand bags placed after the instability took place.

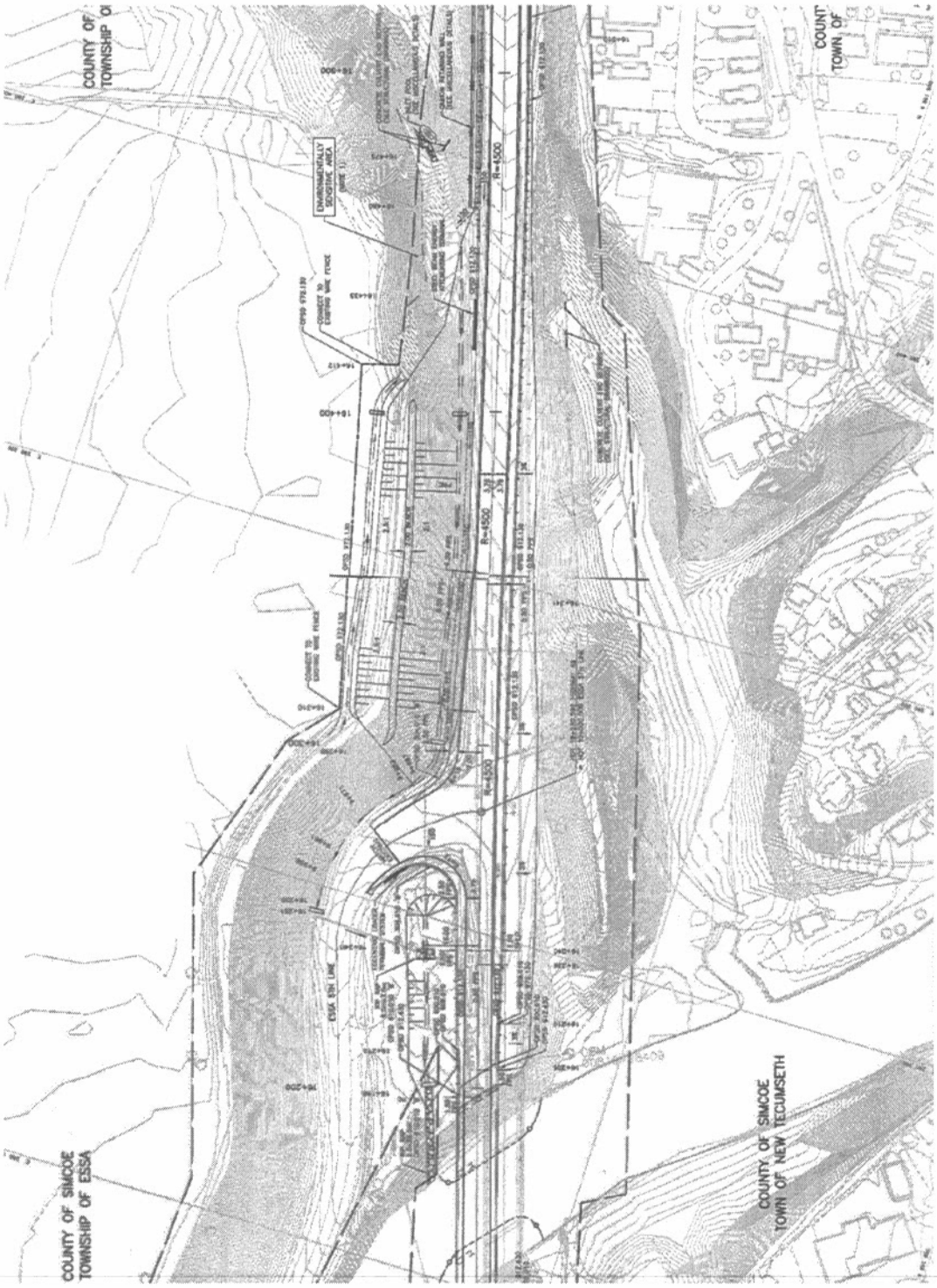


Figure 6: Cut slope general arrangement.

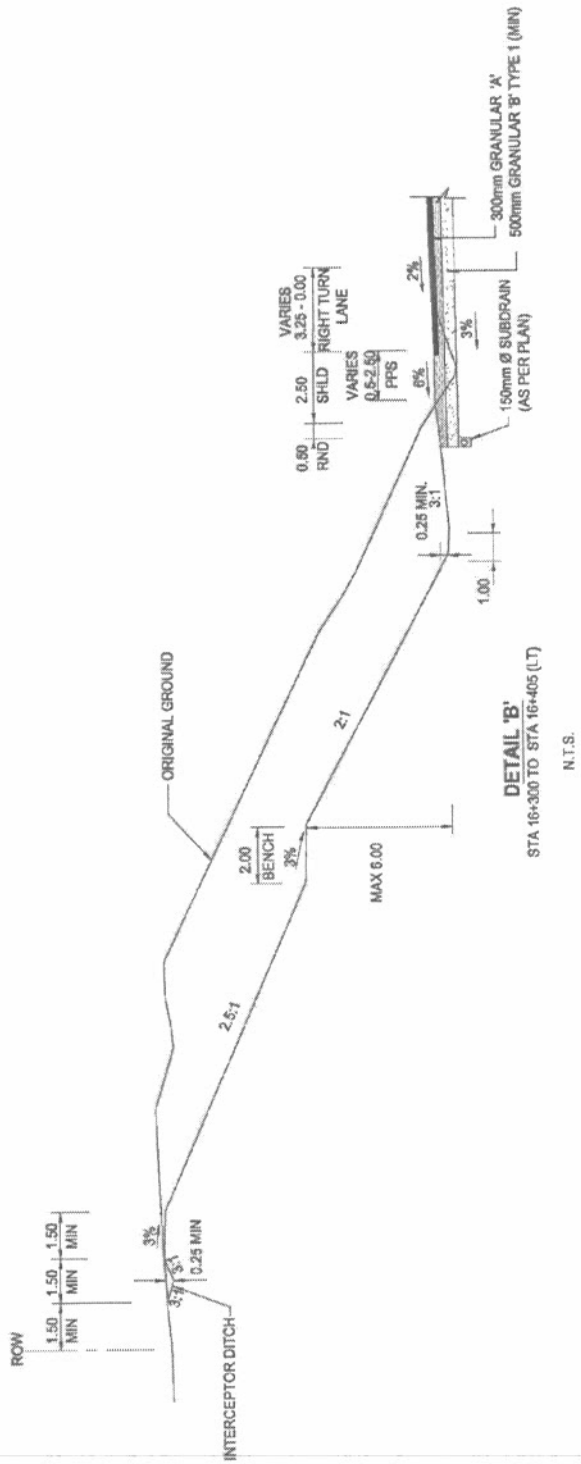


Figure 7. Design geometry of cut slope and interceptor ditch.

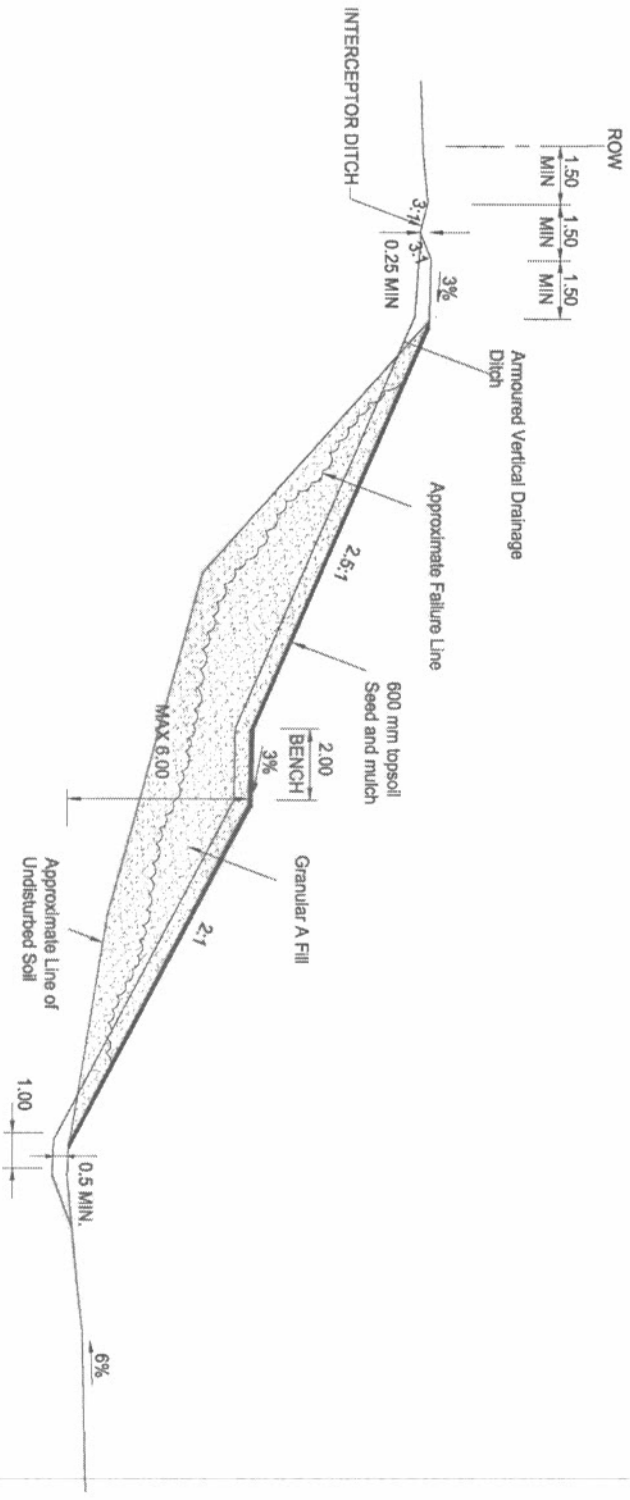


Figure 8. Repair of the failed sections.

Figure 9. Depression zones west of the failed area.

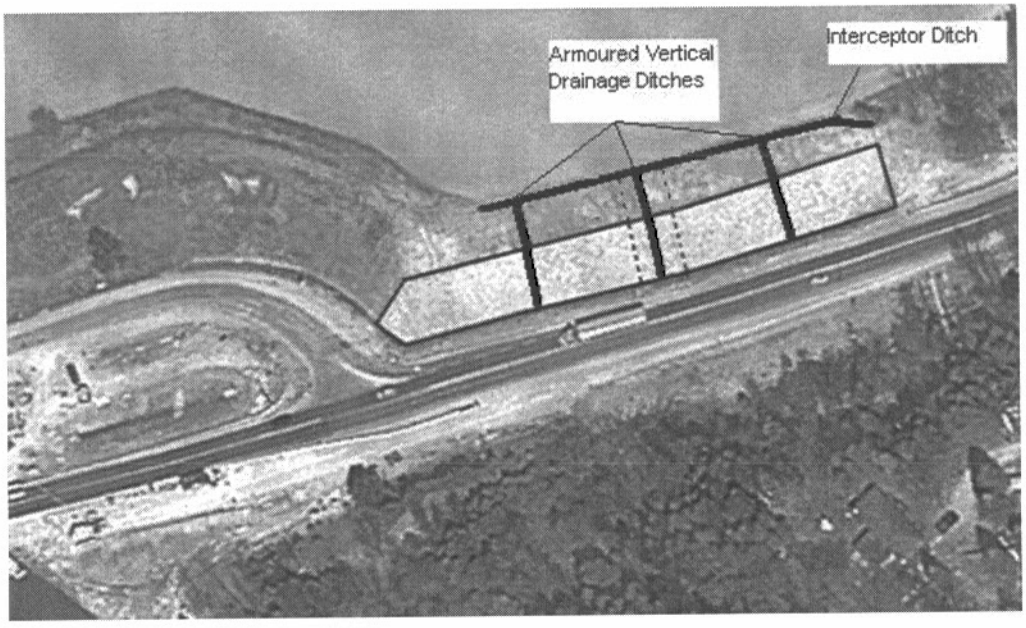
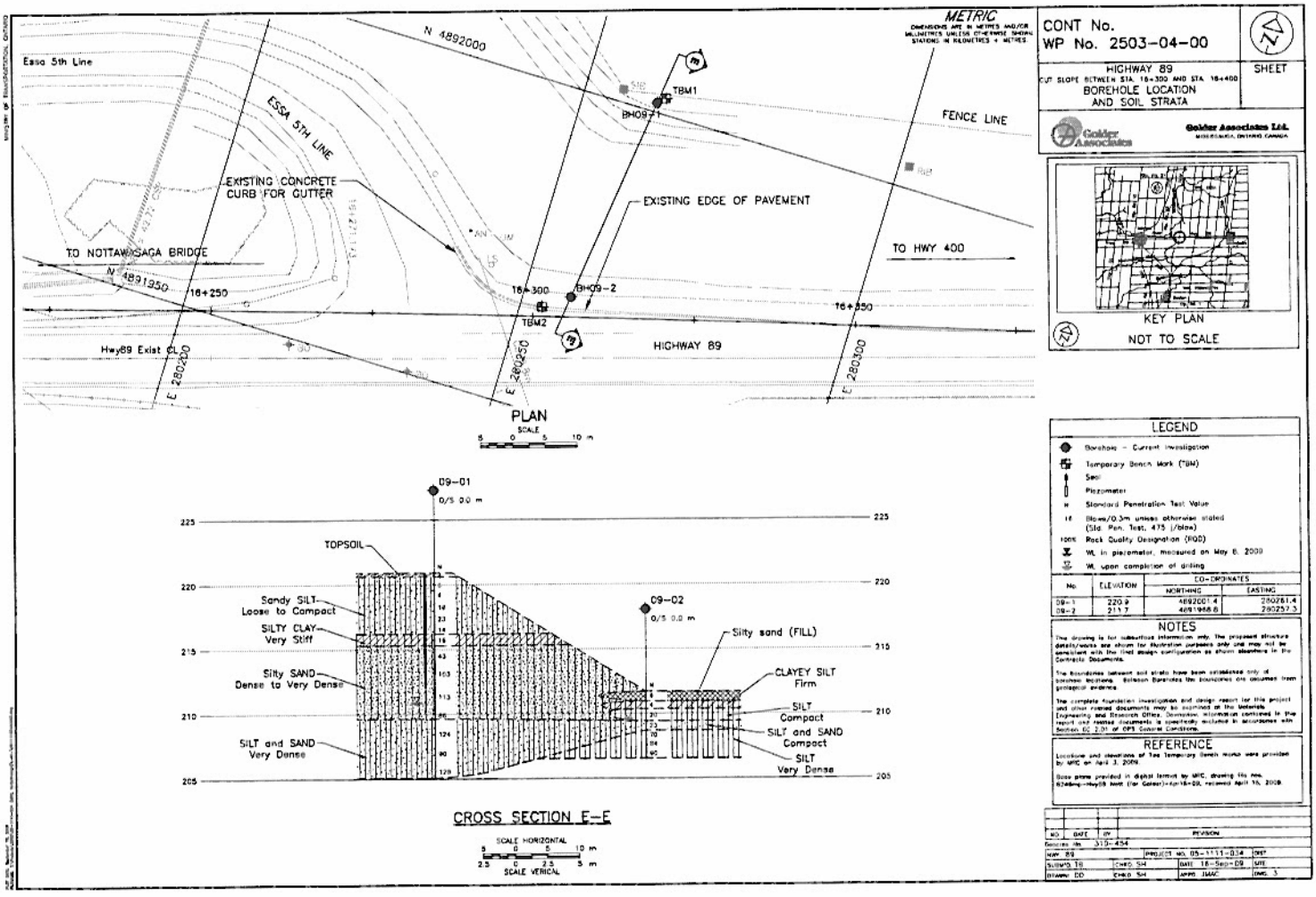


Figure 10. Locations of armoured vertical drainage ditches.

Figure 10. Intermittent replacement of geotextiles-riprap with granular toe berm.

APPENDIX A – SUBSURFACE INFORMATION


METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN
STATIONS IN KILOMETRES + METRES
CONT No.
WP No. 2503-04-00
HIGHWAY 89
CUT SLOPE BETWEEN STA. 16+300 AND STA. 16+400
BOREHOLE LOCATION AND SOIL STRATA
SHEET
Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA
Essa 5th Line
ESSA 5TH LINE
N 4892000
TBM1
BH09-1
FENCE LINE
EXISTING CONCRETE CURB AND GUTTER
EXISTING EDGE OF PAVEMENT
TO NOTTAWASAGA BRIDGE
TO HWY 400
N 4891950
16+250
16+300
BH09-2
16+350
TBM2
HIGHWAY 89
Hwy89 Exist CL
E 280200
E 280250
E 280300
PLAN
SCALE
5 0 5 10 m
KEY PLAN
NOT TO SCALE
09-01
0/S 0.0 m
09-02
0/S 0.0 m
225
220
215
210
205
TOPSOIL
Sandy SILT
Loose to Compact
SILTY CLAY
Very Stiff
Silty SAND
Dense to Very Dense
SILT and SAND
Very Dense
Silty sand (FILL)
CLAYEY SILT
Firm
SILT
Compact
SILT and SAND
Compact
SILT
Very Dense
CROSS SECTION E-E
SCALE HORIZONTAL
5 0 5 10 m
2.5 0 2.5 5 m
SCALE VERICAL
LEGEND
Borehole - Current Investigation
Temporary Bench Mark (TBM)
Seal
Piezometer
N Standard Penetration Test Value
N Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 J/blow)
100% Rock Quality Designation (RQD)
WL in piezometer, measured on May 8, 2009
WL upon completion of drilling
No. | ELEVATION | CO-ORDINATES NORTHING | EASTING
09-1 | 220.9 | 4892001.4 | 280261.4
09-2 | 211.7 | 4891968.8 | 280257.3
NOTES
The drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contract Documents.
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.
The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office. Therefore, information contained in the report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.
REFERENCE
Locations and elevations of the Temporary Bench marks were provided by MTC on April 3, 2009.
Base plans provided in digital format by MTC, drawing file nos. 624dtmg-Hwy89 base (for Golder)-Apr16-09, received April 16, 2009.
NO. | DATE | BY | REVISION
Geocres No. 31D-454
HWY 89
PROJECT NO. 05-1111-0034
DIST
SUBMITTED
CHKD. SH
DATE 18-Sep-09
SITE
DRAWN DD
CHKD. SH
APPD. JMAC
DWG. 1

Golder Associates

RECORD OF BOREHOLE No 09-1

1 OF 2 **METRIC**

PROJECT 05-1111-034 | W.P. 2503-04-00 | DIST Central HWY 89 | DATUM Geodetic

LOCATION N 4892001.4 ;E 280261.4 | BOREHOLE TYPE D-50 Track-mounted Power Auger, 210 mm O.D. Hollow Stem Augers | DATE April 9, 2009

ORIGINATED BY TB | COMPILED BY SH | CHECKED BY JMC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): o UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
220.9	GROUND SURFACE										
0.0 / 220.6	TOPSOIL										
0.3	Sandy SILT, trace to some clay Loose to compact Brown Moist to wet		1	SS	4		220				
			2	SS	6						
			3	SS	4		219				0 28 62 10
			4	SS	16						
			5	SS	23		218				
			6	SS	14						
216.2							217				
4.7	SILTY CLAY, trace sand Very stiff Grey/brown Moist		7	SS	16						0 2 51 47
215.3							216				
5.6	Silty SAND, trace clay Dense to very dense Brown to grey Moist		8	SS	43		215				
			9	SS	103		214				
			10	SS	113		213				
	- Orange brown between 10.67 m and 11.28 m depth		11	SS	86		212				0 68 30 2
209.6							211				
11.3	SILT and SAND, trace clay Very dense Grey Moist to wet		12	SS	124		210				
			13	SS	90		209				
							208				
							207				0 43 55 2
							206				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No 09-1

2 OF 2 **METRIC**

PROJECT 05-1111-034
W.P. 2503-04-00
DIST Central HWY 89
DATUM Geodetic
LOCATION N 4892001.4 E 280261.4
BOREHOLE TYPE D-50 Track-mounted Power Auger, 210 mm O.D. Hollow Stem Augers
DATE April 9, 2009
ORIGINATED BY TB
COMPILED BY SH
CHECKED BY JMC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE; ● QUICK TRIAXIAL × REMOULDED; 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	— CONTINUED FROM PREVIOUS PAGE —										
205.1	SILT and SAND, trace clay Very dense Grey Moist to wet		14	SS	128				o		
15.9	END OF BOREHOLE						205				

Notes:

1. Groundwater seepage at a depth of 1.5 m (Elevation 219.4 m).
2. Groundwater level at a depth of 3.9 m (Elevation 217.0 m) upon completion of drilling.
3. Groundwater level measured in monitoring well on May 8, 2009 at a depth of 10.0 m below ground surface (Elevation 210.9 m).

$+^3$, $\times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 09-2

1 OF 1 **METRIC**

PROJECT 05-1111-034 | LOCATION N 4891968.8 ;E 280257.3 | ORIGINATED BY TB

W.P. 2503-04-00 | BOREHOLE TYPE D-50 Track-mounted Power Auger, 108 mm O.D. Solid Stem Augers | COMPILED BY SH

DIST Central HWY 89 | DATE April 9, 2009 | CHECKED BY JMC

DATUM Geodetic

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
211.7	GROUND SURFACE										
0.0	Silty sand, some gravel, trace organic matter (FILL) Loose Brown Moist		1	SS	6						
210.9 0.8	CLAYEY SILT, trace gravel, trace sand Firm Grey Moist		2	SS	4		211				
210.3 1.4	SILT, some sand, some clay Compact Grey Wet		3	SS	20	▽	210		o	NP	0 17 69 14
209.4 2.3	SILT and SAND Compact Grey Wet		4	SS	23		209				
208.7 3.0	SILT, some clay, trace sand Very dense Grey Moist to wet		5	SS	70		208		o		
			6	SS	84						
206.5			7	SS	90		207		o	NP	0 3 83 14
5.2	END OF BOREHOLE										

Notes:

1. Groundwater seepage at a depth of 1.5 m (Elevation 210.2 m).

2. Groundwater level at a depth of 2.1 m (Elevation 209.6 m) upon completion of drilling.

$+^3, \times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE