March 2012

FOUNDATION INVESTIGATION AND DESIGN REPORT

Retaining Walls
Culvert Site 12-397/C, Geographic Township of Stephen
Culvert Site 12-400/C and Station 10+194, Geographic Township of Hay
Highway 21 Rehabilitation
From Grand Bend North Limits, Northerly 7.8 km
To 0.1 km North of Hendrick Road
GWP 3952-01-00, Purchase Order No. 3010-E-0026
Ministry of Transportation, Ontario – West Region

Submitted to:

Mr. Kevin Welker, P.Eng., Partner
Dillon Consulting Limited
130 Dufferin Avenue, Suite 1400
London, Ontario
N6A 5R2

REPORT

Report Number: 11-1132-0014-2000-R04

Geocres No. 40P5-19

Distribution:

8 Copies - Dillon Consulting Limited
2 Copies - Golder Associates Ltd.

Table of Contents

APPENDICES

PART A

FOUNDATION INVESTIGATION REPORT

RETAINING WALLS
CULVERT SITE 12-397/C, GEOGRAPHIC TOWNSHIP OF STEPHEN
CULVERT SITE 12-400/C AND STATION 10+194, GEOGRAPHIC TOWNSHIP OF HAY
HIGHWAY 21 REHABILITATION
FROM GRAND BEND NORTH LIMITS, NORTHERLY 7.8 KM
TO 0.1 KM NORTH OF HENDRICK ROAD
GWP 3952-01-00, PURCHASE ORDER NO. 3010-E-0026
MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION

1.0 INTRODUCTION

Golder Associates Ltd. (Golder Associates) has been retained by Dillon Consulting Limited (Dillon) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out the foundation investigations as part of the detail design work for GWP 3952-01-00, the rehabilitation of Highway 21, within the project limits.

This report was prepared for the new retaining walls at the following locations:

- Ratz Drain Culvert, Site 12-397/C – new walls at all four corners;
- Turnbull Creek Culvert, Site 12-400/C – replacement of failed wall at southeast corner; and
- Non-Structural Culvert, Station 10+194 – new walls at all four corners.

The purpose of the foundation investigation is to determine the subsurface conditions at the location of the proposed structure replacement by drilling boreholes and carrying out in situ testing and laboratory testing on selected samples. The Terms of Reference for the scope of work are outlined in the MTO's Request for Proposal and in Golder Associates' proposal P0-1132-0014 dated March 28, 2011 and our letter dated July 20, 2011. The work was carried out in accordance with our Quality Control Plan for Foundations Engineering dated May 2011.

Dillon provided Golder Associates with preliminary drawings for this project in digital format.

2.0 SITE DESCRIPTION

2.1 General

The project area for the Highway 21 rehabilitation is located north of Grand Bend, Ontario. The site extends 7.8 kilometres north from the Grand Bend north limits to 0.1 kilometres north of Hendrick Road. New retaining walls are proposed at the following locations:

- Ratz Drain Culvert, Site 12-397/C, Geographic Township of Stephen;
- Turnbull Creek Culvert, Site 12-400/C, Geographic Township of Hay; and
- Non-Structural Culvert, Station 10+194, Geographic Township of Hay.

The locations of the project and the subject culverts are shown on the Key Plan, Figure 1.

This section of Highway 21 is currently a two-lane undivided highway oriented generally north-south.

Ratz Drain Culvert is a concrete, rigid frame, box culvert 3.66 metres wide, 1.83 metres high and 28.6 metres long with an invert elevation of about 180.7 metres. Turnbull Creek Culvert is a concrete, rigid frame, box culvert 3.66 metres wide, 3.05 meters high and 37.8 metres long with an invert elevation of about 181.7 metres. The culvert has a drop spillway through the length of the culvert. The non-structural culvert at Station 10+194 is a concrete box culvert 1.22 metres wide, 1.22 metres high and 29.40 metres long with an invert elevation of about 186.4 metres.

Land use in the vicinity of the sites is primarily rural agricultural and residential. The adjacent topography is generally flat.

Site photographs are provided in Appendix B.

2.2 Site Geology

This project lies within the physiographic region of Southwestern Ontario known as the Huron Slope[1]. The soils generally consist of till formed from a brown calcareous clay, containing a minimum of pebbles and boulders.

Based on the Ontario Division of Mines Preliminary Map P.974 entitled "Quaternary Geology, Grand Bend Area, Southern Ontario", the sites lie in an area of primarily St. Joseph clayey silt till.

[1] L.J. Chapman and D.F. Putnam: The Physiography of Southern Ontario, Third Edition. Ontario Geological Survey, Special Volume 2, 1984.

The Geologic Survey of Canada Map 1263A entitled "Geology, Toronto-Windsor Area, Ontario" indicates that the subcropping bedrock in the area of the sites is limestone and shale of the Hamilton group of Middle Devonian age. Based on the Ontario Division of Mines Preliminary Map P.265 entitled "Bedrock Topography Series, Grand Bend Area, Southern Ontario", the bedrock surface in this area subcrops at about elevations 156 to 160 metres or some 28 to 32 metres below ground surface.

3.0 INVESTIGATION PROCEDURES

The field investigation at these sites was carried out between September 28 and 29, 2011. The table below summarizes the coordinates, ground surface elevations and depths of the boreholes:

Borehole	Location (m)		Ground Surface Elevation	Borehole Depth
	Northing	Easting	(m)	(m)
Non-Structural Culvert at Station 10+194				
24	4 799 935	366 719	188.46	5.49
25	4 799 938	366 704	188.87	5.94
Ratz Drain Culvert (Site 12-397/C)				
30	4 798 031	365 589	184.09	6.71
31	4 798 027	365 574	184.10	6.71
Turnbull Creek Culvert (Site 12-400/C)				
32	4 801 064	367 383	187.80	5.33
32A	4 801 070	367 386	187.82	10.52
33	4 801 058	367 394	182.35	2.44

The boreholes were drilled using a truck mounted power auger supplied and operated by a specialist drilling contractor. Borehole 33 was drilled using manual equipment by members of our geotechnical engineering staff. Samples of the overburden were typically obtained at depth intervals of 0.75 metres using 50 millimetre outside diameter split spoon sampling equipment in accordance with the Standard Penetration Test procedures (ASTM D1586). Non-standard penetration testing and sampling was carried out in the manually drilled borehole. The penetration testing was carried out using a 31.5 kilogram manual hammer. The driving resistances have been adjusted to approximate N values.

The samplers used in the investigations limit the maximum particle size that can be sampled and tested to about 40 millimetres. Therefore, particles or objects that may exist within the soils that are larger than this dimension will not be sampled or represented in the grain size distributions. Larger particle sizes, including cobbles and boulders, are known to be present in the glacial till deposits as discussed in the text of this report.

Groundwater conditions in the boreholes were observed throughout the drilling operations. A standpipe was installed in borehole 30 as indicated on the corresponding Record of Borehole sheet. The boreholes were backfilled in accordance with current regulations, MTO recommended procedures and Ontario Regulation 903 (as amended).

The field work was supervised on a full-time basis by an experienced member of our engineering staff who arranged for underground utility locates, directed the drilling, sampling and in situ testing operations, logged the boreholes and cared for the samples obtained. The soil samples were identified in the field, placed in labelled containers and transported to Golder's London laboratory for further examination and testing. Index and classification tests, consisting of water content determinations, grain size distribution analyses and Atterberg limits determinations, were carried out on selected samples. The results of the field and laboratory testing are given on the Record of Borehole sheets and in Appendix A.

The as-drilled borehole locations and ground surface elevations are shown on the Record of Borehole sheets and on Drawings 1 to 3.

4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the in situ and laboratory testing carried out on selected samples, are given on the attached Record of Borehole sheets following the text of this report and in Appendix A. The stratigraphic boundaries shown on the Record of Borehole sheets are inferred from non-continuous sampling and observations of drilling resistance and represent transitions between soil types rather than exact planes of geological change. Subsurface conditions will vary between and beyond the borehole locations.

The locations and elevations of the boreholes are shown on Drawings 1 to 3. A detailed description of the subsurface conditions encountered in the boreholes is provided on the Record of Borehole sheets and is summarized below.

4.2 Non-Structural Culvert, Station 10+194

Boreholes 24 and 25 were advanced to determine the subsurface conditions for the design of the replacement retaining walls at all four corners of the non-structural culvert at Station 10+194. The borehole locations are presented on Drawing 2.

4.2.1 Topsoil

A 0.4 metre thick layer of topsoil was encountered at the ground surface in borehole 24.

4.2.2 Fill

A 0.3 metre thick layer of crushed sand and gravel fill was encountered at the ground surface in borehole 25 overlying a 1.0 metre thick layer of sand fill. The sand fill had an N value, as determined in the standard penetration testing, of 12 blows per 0.3 metres.

Layers of soft to stiff clayey silt fill were encountered beneath the topsoil in borehole 24 and beneath the sand fill in borehole 25. The clayey silt fill was 0.8 to 2.1 metres thick and had N values of 2 to 12 blows per 0.3 metres.

4.2.3 Clayey Silt Till

A stratum of firm to hard clayey silt till was encountered beneath the clayey silt fill in boreholes 24 and 25 at elevations 186.0 and 186.7 metres. Both of the boreholes were terminated in the clayey silt till after exploring it for 3.1 to 3.8 metres.

The clayey silt till had N values of 6 to 34 blows per 0.3 metres and water contents of 14 per cent. The clayey silt till is of low plasticity based on four Atterberg limits determinations carried out on samples obtained during standard penetration testing. The plastic limits ranged from 14 to 15 per cent, the liquid limits ranged from 28 to 30 per cent and the plasticity indices ranged from 13 to 15 per cent. The Atterberg limits data for the clayey silt till are presented on Figure A-3.

Grain size distribution curves for samples of the clayey silt till recovered from the standard penetration testing are presented on Figure A-2.

Although not specifically encountered in the boreholes, the presence of cobbles and boulders should be anticipated throughout the clayey silt till deposit.

4.2.4 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling. Both of the boreholes remained dry during drilling.

On September 28, 2011, the water level in the watercourse was at about elevation 186.5 metres at the outlet.

Based on the above, the inferred groundwater level is at elevation 186 metres.

The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring melt conditions.

4.3 Ratz Drain Culvert, Site 12-397/C

Boreholes 30 and 31 were advanced to determine the subsurface conditions for the design of the new retaining walls at all four corners of the Ratz Drain Culvert. The borehole locations are shown on Drawing 3.

4.3.1 Fill

Boreholes 30 and 31 encountered crushed sand and gravel fill at the ground surface. The crushed sand and gravel fill was 0.3 to 0.4 metres thick.

Layers of highly variable fill were encountered beneath the crushed sand and gravel fill in boreholes 30 and 31. The variable fill consisted of sand, silty sand, sandy silt, silt, topsoil and clayey silt. The fill layers were 3.0 to 4.1 metres thick, had N values of 1 to 16 blows per 0.3 metres, with water contents of 16 to 89 per cent.

A grain size distribution curve for a sample of the sand fill is presented on Figure A-1 in Appendix A.

4.3.2 Organic Silt

A 2.0 metre thick layer of organic silt was encountered beneath the fill in borehole 31 at elevation 180.9 metres. The organic silt had N values of weight of hammer to 2 blows per 0.3 metres and water contents of 50 to 127 per cent.

4.3.3 Topsoil

A 0.5 metre thick layer of buried topsoil was encountered beneath the fill in borehole 30 at elevation 179.7 metres. The topsoil had an N value of 7 blows per 0.3 metres and a water content of 24 per cent.

4.3.4 Silty Fine Sand

A 0.2 metre thick layer of silty fine sand was encountered beneath the buried topsoil in borehole 30. The silty fine sand had a water content of 13 per cent.

4.3.5 Clayey Silt Till

A stratum of stiff to very stiff clayey silt till was encountered beneath the silty fine sand in borehole 30 and beneath the organic silt in borehole 31 at elevation 178.9 metres. Both of the boreholes were terminated in the clayey silt till after exploring it for 1.5 metres.

The clayey silt till had N values of 11 to 20 blows per 0.3 metres and water contents of 15 and 18 per cent. The clayey silt till is of low plasticity based on two Atterberg limits determinations carried out on samples obtained during standard penetration testing. The plastic limits were 14 and 16 per cent, the liquid limits were 27 and 29 per cent and the plasticity indices were 13 per cent. The Atterberg limits data for the clayey silt till are presented on Figure A-3.

Grain size distribution curves for samples of the clayey silt till recovered from the standard penetration testing are presented on Figure A-2.

Although not specifically encountered in the boreholes, the presence of cobbles and boulders should be anticipated throughout the clayey silt till deposit.

4.3.6 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling. A standpipe was installed in borehole 30. Installation details are provided on the corresponding Record of Borehole sheets following the text of this report. A summary of the encountered and measured groundwater levels is provided in the following table:

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Elevation (m)	Installation	Measured Groundwater Elevation (m)	
				Sep. 29, 2011	Oct. 21, 2011
30	184.09	181.19	Standpipe	180.97	181.32
31	184.10	181.11	-	-	-

Groundwater was encountered in the boreholes at a depth of 2.9 metres or elevations 181.1 to 181.2 metres.

On September 29, 2011, the water level in the Ratz Drain was at about elevation 180.6 metres at the inlet.

On October 21, 2011, the water level in the standpipe installed in borehole 30 was about 2.8 metres below ground surface or at about elevation 181.3 metres.

The above-noted water levels are not considered to be representative of the long-term, stabilized groundwater conditions. Based on the measured and encountered groundwater levels, the inferred groundwater level is at elevation 181 metres. The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring melt conditions.

4.4 Turnbull Creek Culvert, Site 12-400/C

Boreholes 32, 32A which were located in the northeast corner due to site access restrictions and 33 were advanced to determine the subsurface conditions for the design of the replacement retaining wall at the southeast corner of Turnbull Creek Culvert. The borehole locations are presented on Drawing 1.

4.4.1 Fill

Boreholes 32 and 32A encountered crushed sand and gravel fill at the ground surface. The crushed sand and gravel fill was 0.4 metres thick.

Layers of variable fill were encountered beneath the crushed sand and gravel fill in boreholes 32 and 32A. The variable fill consisted of sand and clayey silt with trace gravel and topsoil. Borehole 32 encountered practical auger refusal due to concrete at a depth of 5.3 metres. Two additional boreholes drilled immediately adjacent to borehole 32 also encountered practical auger refusal at a depth of 5.4 metres. Where fully penetrated in borehole 32A, the fill layers were 5.6 metres thick. The fill had N values of weight of hammer to 9 blows per 0.3 metres. The sand fill had a water content of 13 per cent.

A grain size distribution curve for a sample of the sand fill is provided on Figure A-1.

4.4.2 Topsoil

A 0.4 metre thick layer of topsoil was encountered at the ground surface in borehole 33.

4.4.3 Clayey Silt Till

A stratum of firm to very stiff clayey silt till was encountered beneath the topsoil in borehole 33 and beneath the clayey silt fill in borehole 32A at elevations 181.7 and 181.9 metres. Both of the boreholes were terminated in the clayey silt till after exploring it for 2.1 to 4.6 metres.

The clayey silt till had N values of 7 to 17 blows per 0.3 metres and water contents of 16 to 19 per cent. The clayey silt till is of low plasticity based on three Atterberg limits determinations carried out on samples obtained during standard penetration testing. The plastic limits ranged from 14 to 16 per cent, the liquid limits were 28 per cent and the plasticity indices ranged from 12 to 14 per cent. The Atterberg limits data for the clayey silt till are presented on Figure A-3.

Grain size distribution curves for samples of the clayey silt till recovered from the standard penetration testing are presented on Figure A-2.

Although not specifically encountered in the boreholes, the presence of cobbles and boulders should be anticipated throughout the clayey silt till deposit.

4.4.4 Groundwater Conditions

Groundwater conditions were observed during and on completion of drilling and sampling. A summary of the encountered groundwater levels is provided in the following table:

Borehole	Ground Surface Elevation (m)	Encountered Groundwater Elevation (m)	Installation
32	187.80	183.99	-
32A	187.82	Dry	-
33	182.35	181.68	-

Groundwater was encountered in boreholes 32 and 33 at depths of 3.8 and 0.7 metres or elevations 181.7 and 184.0 metres, respectively. Borehole 32A remained dry during drilling.

On September 29, 2011, the water level in Turnbull Creek was at about elevation 182.0 metres at the culvert inlet.

The above-noted water levels are not considered to be representative of the long-term, stabilized groundwater conditions. Based on the encountered groundwater levels, the inferred groundwater level is at elevation 182 metres. The groundwater levels are expected to fluctuate seasonally and are expected to be higher during periods of sustained precipitation or during spring melt conditions.

5.0 MISCELLANEOUS

This investigation was carried out using equipment supplied and operated by Henderson Drilling Inc., who is an Ontario Ministry of Environment licensed well contractor. The field operations were supervised by Mr. Michael Arthur under the direction of Mr. David J. Mitchell.

The laboratory testing was carried out at Golder Associates' London laboratory under the direction of Mr. Chris M. Sewell. The laboratory is an accredited participant in the MTO Soil and Aggregate Proficiency Program and is certified by the Canadian Council of Independent Laboratories for testing Types C and D aggregates. This report was prepared by Mr. Tyson Pitt, P.Eng. under the direction of the Team Leader, Mr. Philip R. Bedell, P.Eng. This report was reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

ORIGINAL SIGNED

Tyson Pitt, P.Eng.
Project Engineer

Philip R. Bedell, P.Eng.
Senior Consultant

ORIGINAL SIGNED

Fintan J. Heffernan, P.Eng.
MTO Designated Contact

TP/PRB/FJH/ly/cr

n:\active\2011\1132-geo\1132-0000\11-1132-0014 dillon - gwp 3952-01-00 - hwy 21\ph 2000 - foundations\rpts\r04 - retaining walls\1111320014-2000-r04 mar 8 12 (final) parts a&b retaining walls.docx

PART B

FOUNDATION DESIGN REPORT

RETAINING WALLS
CULVERT SITE 12-397/C, GEOGRAPHIC TOWNSHIP OF STEPHEN
CULVERT SITE 12-400/C AND STATION 10+194, GEOGRAPHIC TOWNSHIP OF HAY
HIGHWAY 21 REHABILITATION
FROM GRAND BEND NORTH LIMITS, NORTHERLY 7.8 KM
TO 0.1 KM NORTH OF HENDRICK ROAD
GWP 3952-01-00, PURCHASE ORDER NO. 3010-E-0026
MINISTRY OF TRANSPORTATION, ONTARIO - WEST REGION

6.0 ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides our recommendations on the foundation aspects of the design of the new retaining walls at the following locations on Highway 21:

- Ratz Drain Culvert, Site 12-397/C, Geographic Township of Stephen;
- Turnbull Creek Culvert, Site 12-400/C, Geographic Township of Hay; and
- Non-Structural Culvert, Station 10+194, Geographic Township of Hay.

The recommendations are based on our interpretation of the factual data obtained from the boreholes advanced during the investigation at these sites. The interpretation and recommendations are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the proposed culvert foundations. As such, where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The new retaining walls could consist of reinforced soil system (RSS) walls, gravity walls or concrete cantilever walls. It is understood that the proposed walls will be about 1 to 3 metres high.

6.2 Foundations

The subsurface conditions encountered during the investigation generally consisted of surficial topsoil or fill underlain by layers of clayey silt till.

Based on the results of the foundation investigation, the new retaining walls may be founded on the native undisturbed clayey silt till at or below the following elevations:

Culvert Site	Invert Elevation (m)	Highest Founding Elevation (m)
Ratz Drain Culvert, Site 12-397/C	180.7	178.8
Turnbull Creek Culvert, Site 12-400/C	181.7	181.7
Non-Structural Culvert, Station 10+194	186.4	186.0

Alternatively, provided that all topsoil, fill and any loose organic and wet or deleterious materials are subexcavated from the entire area of the proposed retaining walls, the new retaining walls at Ratz Drain may be founded on unshrinkable fill (U Fill) or lean concrete.

6.2.1 Geotechnical Resistances

The firm to hard clayey silt till is suitable for support of the proposed new retaining walls. A factored geotechnical resistance at Ultimate Limit States (ULS) of 200 kilopascals and a geotechnical resistance at Serviceability Limit States (SLS) of 150 kilopascals may be used for design purposes. A factored geotechnical resistance at ULS of 100 kPa and a geotechnical resistance at SLS of 75 kPa may be used for design purposes for the new Ratz Drain retaining walls founded on U Fill or lean concrete. The SLS value corresponds to 25 millimetres of settlement.

Alternatively, an RSS wall footing designed with the geotechnical resistances given above may be founded on a 0.3 metre thick layer of compacted Granular A constructed on the surface of the clayey silt till. The Granular A should extend 0.5 metres beyond the edge of the footing.

6.2.2 Frost Protection

All footings should be provided with a minimum of 1.2 metres of soil cover or thermal equivalent for frost protection purposes.

6.3 Lateral Earth Pressures for Design

Lateral pressures acting on the retaining walls will depend on the type and method of placement of the backfill materials, the nature of the soil behind the backfill, the freedom of lateral movement of the structure and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the walls in accordance with the current CHBDC. It should be noted that these design recommendations and parameters assume full removal of the existing poor quality fill and level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope as described in this report.

- Select free-draining granular fill meeting the specifications of OPSS Granular A or Granular B Type III, but with less than 5 per cent passing the No. 200 sieve, should be used as backfill behind the retaining walls. Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill. Other aspects of the granular backfill requirements with respect to subdrains and frost taper should be in accordance with OPSD 803.010.

- The granular fill may be placed either in a zone with a width equal to at least 1.2 metres behind the back of the stem (Case (a) from Commentary on CHBDC Figure C6.20) or within the wedge-shaped zone defined by a line drawn at a maximum slope of 1 horizontal to 1 vertical extending up and back from the rear face of the foundation (Case (b) from Commentary on CHBDC Figure C6.20).

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the wall stem, in accordance with CHBDC Figure C6.6. Compaction equipment should be used in accordance with OPSS 501. Other surcharge loadings should be accounted for in the design, as required.

- For walls backfilled using granular materials as noted above, the following parameters (unfactored) may be assumed:

	GRANULAR A	GRANULAR B (Type III)
Fill unit weight:	22 kN/m^3	21 kN/m^3
Coefficients of static lateral earth pressure:		
'active' or unrestrained, K_a	0.27	0.31
'at rest' or restrained, K_o	0.43	0.47

- If the wall support allows lateral yielding (unrestrained structure), active earth pressures may be used in the geotechnical design of the structure. The granular fill should be placed in a wedge shaped zone with a width equal to at least 1.2 metres at the footing level against a cut slope which begins at the footing level and extends upwards at a maximum inclination of 1 horizontal to 1 vertical.

- If the wall support does not allow lateral yielding (which is typically the case for a rigid concrete box culvert), at-rest earth pressures should be assumed for geotechnical design. The granular fill should be placed in a zone with a width equal to at least 1.2 metres behind the culvert walls.

- Resistance to lateral forces (i.e. sliding resistance) for a cast-in-place wall footing with a concrete working slab may be based on the unfactored angle of friction between the clayey silt till and the concrete. The factored horizontal geotechnical resistance, H_{ri}, should be based on CHBDC 6.7.5 as follows:

$$H_{ri} = 0.8A'c' + 0.8V\tan\delta > H_f$$

Where:

A'	-	effective contact area, square metres
c'	=	0 kilopascals
δ	=	30 degrees (clayey silt till)
V	-	unfactored vertical force, kilonewtons
H_f	-	factored horizontal load, kilonewtons

The unfactored coefficient of passive pressure for the portion of the culvert wall below the ground surface may be taken as 3.0 based on an unfactored effective angle of internal friction, ϕ', of 32 degrees. In general, it is recommended that the frictional resistance of the top 1 metre of soil in front of any wall be ignored due to disturbance caused by frost action.

6.4 Backfill

Select, free draining granular fill, in accordance with OPSS Granular A or Granular B, Type III gradation specifications should be used as backfill immediately adjacent to the retaining wall. All granular backfill should be placed in maximum 200 millimetre thick loose lifts and uniformly compacted to at least 95 per cent of standard Proctor maximum dry density (SPMDD). Heavy compaction equipment, however, should not be used within the lateral distance behind any structure equal to the current height of the fill above the base of the structure.

A proprietary RSS wall should be designed by the supplier and constructed in accordance with their specifications. The geotechnical aspects of the global stability of the detailed retaining wall design should be reviewed prior to construction.

The recommended geotechnical design parameters for the RSS wall are as follows:

Unit weight of granular backfill	22 kN/m^3
Unit weight of water	9.8 kN/m^3
Active earth pressure coefficient, K_a (based on horizontal ground)	0.3
Coefficient of friction between granular backfill and founding soils	0.28

6.5 Construction Considerations

Care should be taken during construction to avoid disturbance of the subgrade prior to constructing foundations for the retaining walls. All topsoil, organics and soft or loose soils should be removed from below the proposed founding elevation and wasted or reused as landscaping fill, as required. Subgrade preparation should be performed and monitored in accordance with OPSS 902.

The cleaned excavation base should be inspected by a geotechnical Quality Verification Engineer (QVE) and a working slab placed immediately after inspection to protect the founding materials. It is recommended that the footing excavation be carried out such that the final 0.5 metres of excavation is completed with the QVE on site. A Non Standard Special Provision (NSSP) should be added to the Contract Documents specifying protection of the founding soil through use of a working slab below cast-in-place footings.

6.6 Excavations and Temporary Cut Slopes

Excavations will extend through the existing Highway 21 embankment fill and into the underlying clayey silt till. Contractors should also be prepared for the presence of cobbles and boulders within the till.

It is anticipated that the excavations will extend below the inferred groundwater level elevations of 181 and 182 metres at the Ratz Drain Culvert and Turnbull Creek Culvert sites, respectively. Excavations for the non-structural culvert at Station 10+194 are not anticipated to extend below the groundwater level. It is considered that groundwater can be controlled by pumping from properly constructed and filtered sumps located at the base of the excavations. A Permit To Take Water is not considered necessary at this time. Sumps should be maintained outside of the actual foundation limits.

Surficial water seepage into the excavations should be expected and will be heavier during periods of sustained precipitation. Surface water runoff should be directed away from the excavations at all times. The existing culvert flows will need to be diverted/piped during construction. The appropriate NSSP should be included in the contract documents to alert the contractor about the need for adequate control of surface and groundwater flows.

Temporary open cut slopes within the fill materials should be maintained no steeper than 1 horizontal to 1 vertical and localized sloughing and ground movements should be expected. All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. The fill and any cohesionless materials below the groundwater level would be classified as Type 3 soils. The cohesionless materials above the groundwater level and clayey silt till would be classified as Type 2 soils.

6.6.1 Staging and Temporary Roadway Protection

It is understood that a single lane is to remain open to traffic during construction. Therefore, construction of the new retaining walls may need to be conducted in stages using open cut construction and a signalized single lane.

Temporary support systems could consist of soldier piles and lagging or steel sheet piles. A soldier pile and lagging system is preferred for constructability. The temporary shoring will have maximum heights of about 5.3, 6.1 and 2.9 metres above the excavation bases at Ratz Drain Culvert, Turnbull Creek Culvert and the Non-Structural Culvert at Station 10+194, respectively.

Excavation support systems should be designed and constructed in accordance with OPSS 539 and the design should limit the lateral movement of the temporary shoring system to meet Performance Level 2. The contractor is responsible for the complete detailed design of the protection system.

The design of a braced soldier sheet pile wall or a pile and lagging wall should be based on a rectangular earth pressure distribution using the design parameters given below. Where the support to the wall is provided by anchors or rakers, the wall design should be based on a triangular earth pressure distribution using the design parameters given below. The raker/anchor support must be designed to accommodate the loads applied from pressures and surcharge pressures from area, line or point loads as well as the impact of sloping ground behind the system. Passive toe restraint to the soldier piles may be determined using a triangular pressure distribution acting over an equivalent width equal to three times the pile socket diameter.

The unfactored triangular earth pressure distribution (p in kN/m^2; increasing with depth) can be calculated as follows:

$p = K_a (\gamma H + q)$

where H = the height of the excavation at any point in metres

K_a = active coefficient of earth pressure

γ = soil unit weight

q = surcharge for traffic and other loading

For a braced system, the unfactored rectangular earth pressure distribution (p in kN/m^2; constant with depth), can be calculated as follows:

$p = 0.65 K_a (\gamma H + q)$

where H = the total height of the excavation

K_a = active coefficient of earth pressure

γ = soil unit weight

q = surcharge for traffic and other loading

The support systems may be designed using the following parameters:

Soil Type	Coefficient of Earth Pressure			Internal Angle of Friction (degrees)	Unit Weight (kN/m^3)
	Active, K_a	At Rest, K_o	Passive, K_p		
Fill	0.33	0.50	3.0	30	19
Organic Silt	0.36	0.53	2.8	28	15
Clayey Silt Till	0.31	0.47	3.3	32	19

The earth pressure coefficients identified above may be applied assuming a horizontal ground surface behind the retaining structure. Where the ground surface behind the retaining structure is sloped, the earth pressure coefficients provided in the table above must be increased. Contractors should be prepared for the presence of cobbles and boulders within the till strata and the appropriate NSSP should be provided.

7.0 MISCELLANEOUS

This report was prepared by Mr. Tyson Pitt, P.Eng. under the direction of the Team Leader, Mr. Philip R. Bedell, P.Eng. This report was reviewed by Mr. Fintan J. Heffernan, P.Eng., the Designated MTO Contact and Quality Control Auditor for this assignment.

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED

Tyson Pitt, P.Eng.
Project Engineer

ORIGINAL SIGNED

Philip R. Bedell, P.Eng.
Senior Consultant

ORIGINAL SIGNED

Fintan J. Heffernan, P.Eng.
MTO Designated Contact

TP/PRB/FJH/ly/cr

n:\active\2011\1132-geo\1132-0000\11-1132-0014 dillon - gwp 3952-01-00 - hwy 21\ph 2000 - foundations\rpts\r04 - retaining walls\1111320014-2000-r04 mar 8 12 (final) parts a&b retaining walls.docx

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split spoon sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; N_d:

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60º cone attached to “A” size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure
PM: Sampler advanced by manual pressure
WH: Sampler advanced by static weight of hammer
WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm^2 pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils

Consistency	c_u,s_u kPa	c_u,s_u psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I. General

π	3.1416
ln x,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\ \sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
v	poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma$-u)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1+\sigma_2+\sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s/\rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_l	liquid limit
w_p	plastic limit
l_p	plasticity index $= (w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p)/I_p$
I_C	consistency index $= (w_l - w)/I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e)/(e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_a	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	over-consolidation ratio $= \sigma'_p/\sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = tan δ
c'	effective cohesion
c_u,s_u	undrained shear strength (ϕ = 0 analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 + \sigma_3)/2$ or $(\sigma'_1 + \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 + \sigma_3)$
S_t	sensitivity

Notes:
1. $\tau = c' + \sigma' \tan \phi'$
2. shear strength = (compressive strength)/2

* density symbol is ρ. Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 24

METRIC

PROJECT 11-1132-0014
W.P. 3952-01-00 LOCATION N 4799935.3 ;E 366718.6 ORIGINATED BY MA
DIST HWY 21 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY WDF
DATUM GEODETIC DATE September 28, 2011 CHECKED BY

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
188.46	GROUND SURFACE				
0.00	TOPSOIL, sandy				
188.09	Brown				
0.37	FILL, clayey silt, some sand, trace gravel, trace topsoil Soft Brown and Black	1	SS	4	
		2	SS	2	
186.78 1.68	FILL, clayey silt, some sand, trace gravel Stiff Brown	3	SS	12	
186.02 2.44	CLAYEY SILT TILL, some sand, trace gravel Stiff to Hard Brown becoming Grey at about elev. 184.5m	4	SS	30	1 16 48 35
		5	SS	30	
		6	SS	23	1 17 48 34
		7	SS	14	
182.97 5.49	END OF BOREHOLE Borehole dry during drilling on Sept. 28, 2011.				

Elevation scale: 188, 187, 186, 185, 184, 183

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 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

+3, ×3: Numbers refer to Sensitivity   ○ 3% STRAIN AT FAILURE

LDN_MTO_06 11-1132-0014-2000.GPJ LDN_MTO.GDT 02/11/11

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 25

METRIC

PROJECT 11-1132-0014
W.P. 3952-01-00
LOCATION N 4799938.1 ;E 366704.1
ORIGINATED BY MA
DIST HWY 21
BOREHOLE TYPE POWER AUGER, HOLLOW STEM
COMPILED BY WDF
DATUM GEODETIC
DATE September 28, 2011
CHECKED BY

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
188.87	GROUND SURFACE									
0.00	FILL, sand and gravel, crushed; Brown									
188.53 / 0.34	FILL, sand, fine to medium, trace silt, trace gravel; Compact; Brown	1	SS	12	188					
187.50 / 1.37	FILL, clayey silt, some sand, trace gravel, trace topsoil; Firm; Brown	2	SS	6	187					
186.74 / 2.13	CLAYEY SILT TILL, some sand, trace gravel; Firm to Hard; Brown becoming Grey at about elev. 183.7m	3	SS	6	186					
		4	SS	14		plotted	4	15	48	33
		5	SS	34	185					
		6	SS	23	184	plotted	4	15	46	35
		7	SS	17	183					
182.93 / 5.94	END OF BOREHOLE Borehole dry during drilling on Sept. 28, 2011.									

Column headings: SOIL PROFILE (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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 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

+³, ×³: Numbers refer to Sensitivity ○³% STRAIN AT FAILURE

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 30

METRIC

PROJECT	11-1132-0014				
W.P.	3952-01-00	LOCATION	N 4798031.1 ;E 365589.3	ORIGINATED BY	MA
DIST	HWY 21	BOREHOLE TYPE	POWER AUGER, HOLLOW STEM	COMPILED BY	WDF
DATUM	GEODETIC	DATE	September 29, 2011	CHECKED BY	

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
184.09	GROUND SURFACE					
0.00	FILL, sand and gravel, crushed Brown					
183.72 / 0.37	FILL, sand, fine to medium, trace silt Compact Brown	1	SS	13		
		2	SS	11		
181.96 / 2.13	FILL, silty sand, some gravel Brown					
181.62 / 2.47	FILL, sandy silt, some topsoil, trace clay Very Loose Brown	3	SS	3		
181.19 / 2.90	FILL, sand, fine to medium, some gravel, trace silt Loose Brown	4	SS	5	o	24 73 (3)
180.28 / 3.81	FILL, silt, some clay, trace organic material, with peat layers Very Loose Grey	5	SS	1	89	
179.67 / 4.42	TOPSOIL, silty Very Loose Black	6	SS	7	o	
179.15 / 4.94	SILTY FINE SAND, some gravel Loose Grey				o	
5.18	CLAYEY SILT TILL, some sand, trace gravel Stiff to Very Stiff Grey	7	SS	11	Wp—o—WL	1 15 46 38
		8	SS	17		
177.38 / 6.71	END OF BOREHOLE					

Ground water conditions: Cuttings (184–183.3); Grout (182.5–181.3); Caved Material (181.3–180.3); Standpipe (180.3–179.2); Granular Bentonite (179.2–178.6); Cuttings (178.6–177.4). Water levels marked at approx. elev. 181.32 and 180.97.

Elevation scale: 184, 183, 182, 181, 180, 179, 178

Groundwater encountered at about elev. 181.19m during drilling on Sept. 29, 2011.

Water level in Standpipe at elev. 180.97m on Sept. 29, 2011.

Water level in Standpipe at elev. 181.32m on Oct. 21, 2011.

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (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

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 31

METRIC

PROJECT 11-1132-0014

W.P. 3952-01-00 LOCATION N 4798027.3 ;E 365574.0 ORIGINATED BY MA

DIST HWY 21 BOREHOLE TYPE POWER AUGER, HOLLOW STEM COMPILED BY WDF

DATUM GEODETIC DATE September 29, 2011 CHECKED BY

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	WATER CONTENT / REMARKS	GR SA SI CL
184.10	GROUND SURFACE						
0.00	FILL, sand and gravel, trace silt, crushed						
0.27	Brown FILL, sand, fine to medium, some gravel, trace silt Compact Brown	1	SS	16			
182.67 1.43	FILL, topsoil, silty, trace gravel Very Loose Black	2	SS	3			
181.97 2.13	FILL, clayey silt, some sand, trace gravel Firm Brown	3	SS	4	▽ (elev. 181.11)		
181.20 2.90	FILL, silty sand, some gravel, trace organic material						
180.87 3.23	Very Loose Brown ORGANIC SILT, with fibrous peat layers Very Loose Brown and Grey	4	SS	2		50	
		5	SS	WH		127	
		6	SS	2		108	
178.92 5.18	CLAYEY SILT TILL, some sand, trace gravel Stiff to Very Stiff Grey	7	SS	12			1 14 47 38
		8	SS	20			
177.39 6.71	END OF BOREHOLE Groundwater encountered at about elev. 181.11m during drilling on Sept. 29, 2011.						

Column headings: SOIL PROFILE; SAMPLES; STRAT PLOT; ELEVATION SCALE (184, 183, 182, 181, 180, 179, 178); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 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

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 32

METRIC

PROJECT 11-1132-0014
W.P. 3952-01-00
LOCATION N 4801063.5 ;E 367382.5
ORIGINATED BY MA
DIST ___ HWY 21
BOREHOLE TYPE POWER AUGER, HOLLOW STEM
COMPILED BY WDF
DATUM GEODETIC
DATE September 29, 2011
CHECKED BY ___

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
187.80	GROUND SURFACE							
0.00	FILL, sand and gravel, crushed Brown							
187.43 / 0.37	FILL, clayey silt, some sand, trace gravel, trace topsoil Soft to Firm Brown					187		
		1	SS	7				
		2	SS	3		186		
185.67 / 2.13	FILL, sand, fine to medium, trace to some gravel, trace organic material Very Loose to Loose Brown							
		3	SS	9		185		
		4	SS	5			○ (approx. 13)	15 65 10 10
					∇	184		
		5	SS	3				
		6	SS	WH		183		
182.47 / 5.33	END OF BOREHOLE Practical Auger refusal (Concrete) Borehole moved 2.0m north of original location - refusal at 5.39m Borehole moved 5.2m north of original location - refusal at 5.39m Borehole moved 7.2m north of original location - See Record of Borehole 32A Groundwater encountered at about elev. 183.99m during drilling on Sept. 29, 2011.							

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 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

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 32A

METRIC

PROJECT	11-1132-0014				
W.P.	3952-01-00	LOCATION	N 4801069.7 ;E 367386.1	ORIGINATED BY	MA
DIST		HWY 21	BOREHOLE TYPE: POWER AUGER, HOLLOW STEM	COMPILED BY	WDF
DATUM	GEODETIC	DATE	September 29, 2011	CHECKED BY	

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	PLASTIC LIMIT W_P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W_L	GR	SA	SI	CL
187.82	GROUND SURFACE										
0.00	FILL, sand and gravel, crushed Brown										
187.45 / 0.37	FILL, clayey silt, some sand, trace gravel, trace topsoil Soft to Firm Brown										
185.69 / 2.13	FILL, sand, fine to medium, trace to some gravel, trace organic material Very Loose to Loose Brown										
184.77 / 3.05	FILL, clayey silt, some sand, trace gravel, trace topsoil Soft Grey	7	SS	3							
181.88 / 5.94	CLAYEY SILT TILL, some sand, trace gravel Firm to Stiff Grey	8	SS	11	✓	✓	✓	2	14	43	41
		9	SS	13							
		10	SS	10	✓	✓	✓	1	11	43	45
		11	SS	8							
		12	SS	8							
		13	SS	7							
177.30 / 10.52	END OF BOREHOLE Borehole dry during drilling on Sept. 29, 2011.										

Upper 3.1m of stratigraphy has been inferred from Borehole 32, observations of auger material and drilling resistance.

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (187 to 178); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL.

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

Golder Associates
London, Ontario

RECORD OF BOREHOLE No 33

METRIC

PROJECT 11-1132-0014

W.P. 3952-01-00 LOCATION N 4801057.6 ;E 367394.3 ORIGINATED BY DV

DIST HWY 21 BOREHOLE TYPE MANUAL, UNCASED COMPILED BY WDF

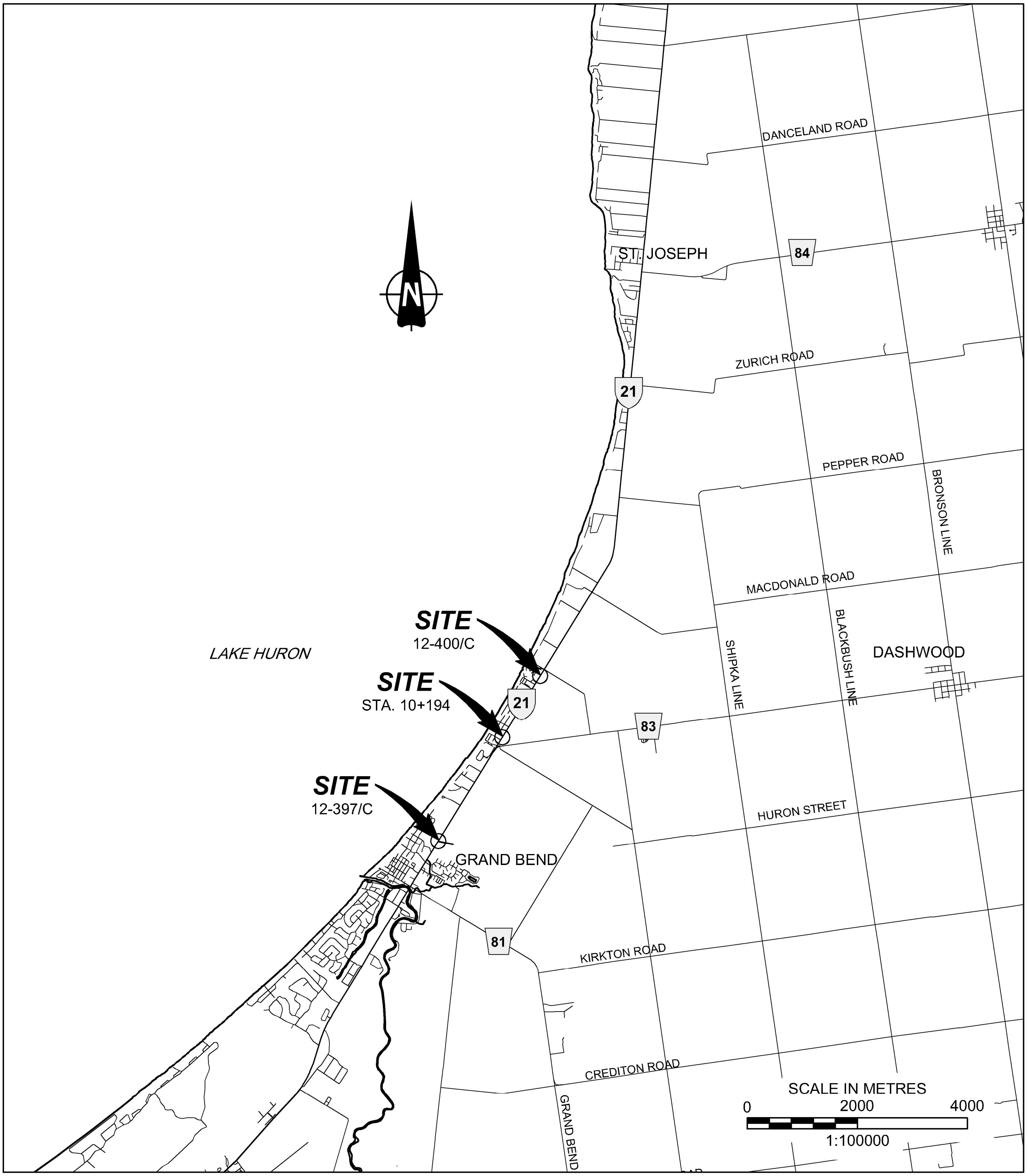
DATUM GEODETIC DATE September 29, 2011 CHECKED BY

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%) (PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
182.35	GROUND SURFACE										
0.00	TOPSOIL, sandy Brown										
181.98 0.37	CLAYEY SILT TILL, some sand, trace gravel Firm to Very Stiff Grey					∇	182				
			1	SS	7						
							181				
			2	SS	12				plotted		2 12 44 42
			3	SS	17						
179.91 2.44	END OF BOREHOLE Groundwater encountered at about elev. 181.68m during drilling on Sept. 29, 2011.						180				

NOTE: Blows/0.3m using non-standard hammer are Approximate Standard Penetration N Value Only, Refer to accompanying text.

Legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE

+3, ×3: Numbers refer to Sensitivity ○3% STRAIN AT FAILURE



Drawing file: 1111320014-2000-F04001.dwg Mar 01, 2012 - 12:00pm

REFERENCE

DRAWING BASED ON CLIENT SUPPLIED INFORMATION AND CANMAP STREET FILES v2008.4

NOTE

THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ACCOMPANYING TEXT.

PROJECT

RETAINING WALLS
HIGHWAY 21 REHABILITATION
GWP 3952-01-00

TITLE

KEY PLAN

Golder Associates
LONDON, ONTARIO

PROJECT No.	11-1132-0014		FILE No. 1111320014-2000-F04001	
			SCALE AS SHOWN	REV. 0
CADD	WDF	Oct. 31/11	**FIGURE 1**	
CHECK				

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

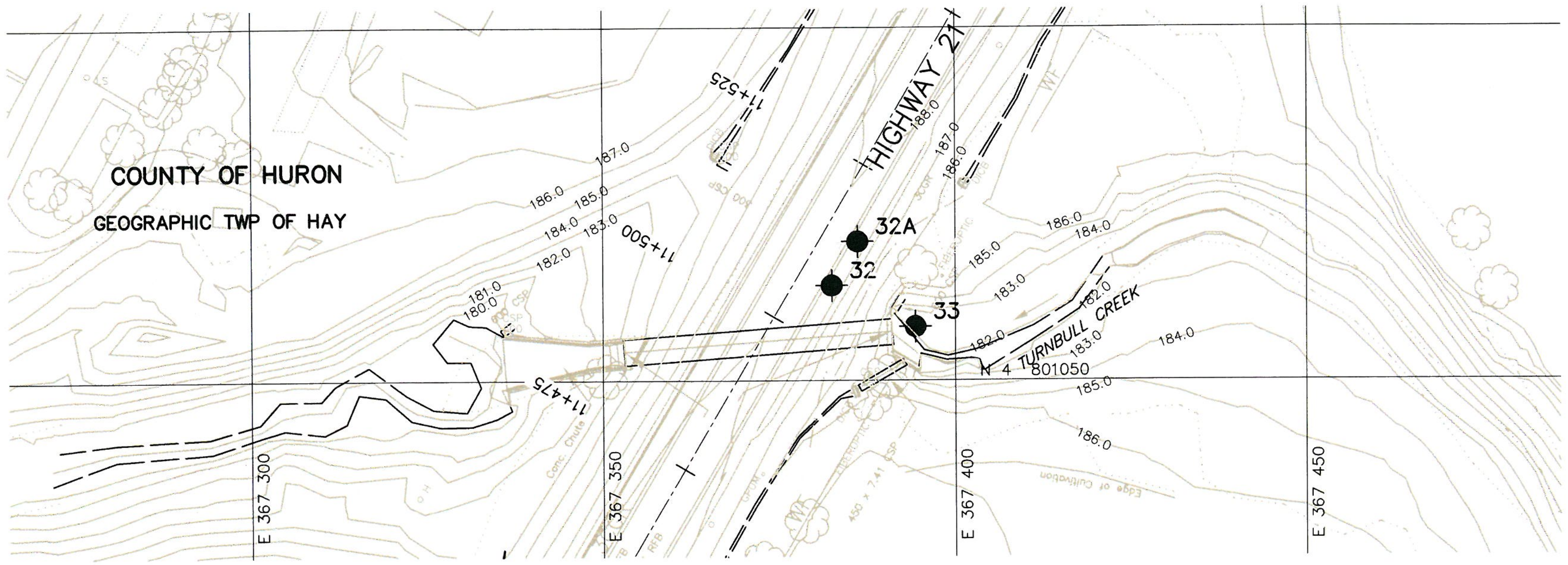
CONT No. 2012-3009
WP No. 3952-01-00

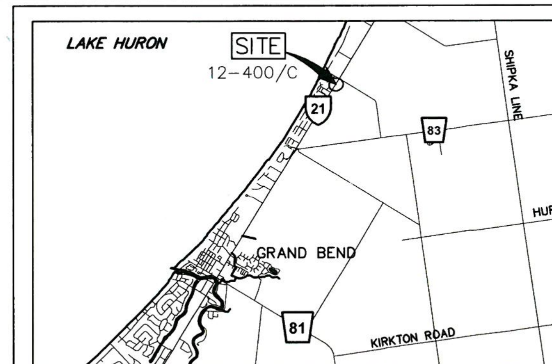
SHEET

RETAINING WALLS
TURNBULL CREEK CULVERT
HIGHWAY 21 REHABILITATION
BOREHOLE LOCATIONS

Golder Associates Ltd.
LONDON, ONTARIO, CANADA

PLAN (12-400/C)





KEY PLAN

SCALE 1.5 0 1.5 km

LEGEND

Borehole – Current Investigation

No.	ELEVATION	CO-ORDINATES MTM ZONE 11	
		NORTHING	EASTING
32	187.80	4 801 063.5	367 382.5
32A	187.82	4 801 069.7	367 386.1
33	182.35	4 801 057.6	367 394.3

REGISTERED PROFESSIONAL ENGINEER F.J. HEFFERNAN PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER T.N.S.PITT 100132967 PROVINCE OF ONTARIO

NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

The boundaries between soil strata have been established only at borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base plans provided in digital format by Dillon Consulting Limited.

NO.	DATE	BY	REVISION

Geocres No. 40P5-19			
HWY. 21		PROJECT NO. 11-1132-0014	DIST.
SUBM'D. TP	CHKD.	DATE: JAN. 27/12	SITE: 12-400/C
DRAWN: WDF/AMG	CHKD.	APPD.	DWG. 1

PLOT DATE: March 09, 2012
FILENAME: N:\active\2011\1132-Geo\1132-0000\11-1132-0014 DILLON - GWP 3952-01-00 - HWY 21\Drafting\AutoCAD files\1111320014-2000-D0401.dwg

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

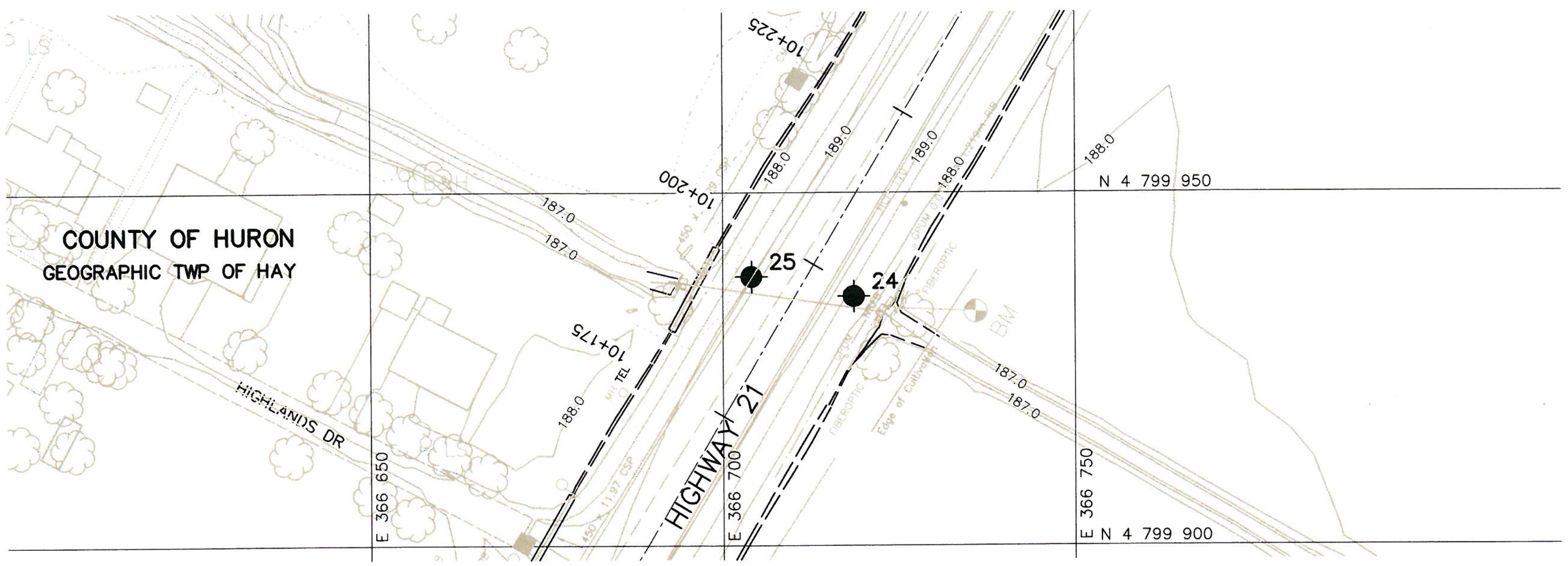
CONT No. 2012–3009
WP No. 3952–01–00

SHEET

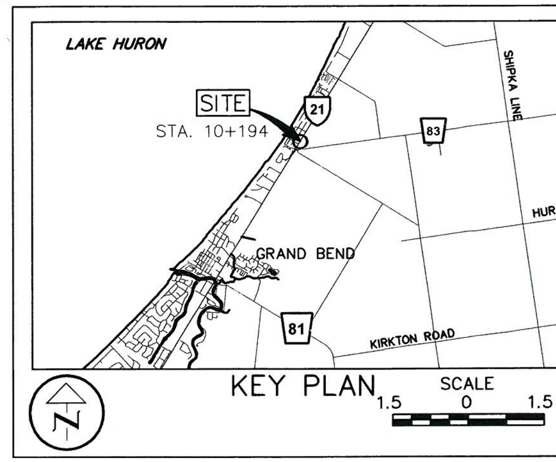
RETAINING WALLS
NON–STRUCTURAL CULVERT, STA. 10+194
HIGHWAY 21 REHABILITATION
BOREHOLE LOCATIONS

Golder Associates Ltd.
LONDON, ONTARIO, CANADA

PLAN (STA. 10+194)



SCALE
20 0 10 20 m



KEY PLAN
SCALE 1.5 0 1.5 km

LEGEND

Borehole – Current Investigation

No.	ELEVATION	CO–ORDINATES MTM ZONE 11	
		NORTHING	EASTING
24	188.46	4 799 935.3	366 718.6
25	188.87	4 799 938.1	366 704.1

REGISTERED PROFESSIONAL ENGINEER F.J. HEFFERNAN PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER T.N.S.PITT 100132967 PROVINCE OF ONTARIO

NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

The boundaries between soil strata have been established only at borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base plans provided in digital format by Dillon Consulting Limited.

NO.	DATE	BY	REVISION

Geocres No. 40P5–19

HWY. 21		PROJECT NO. 11–1132–0014	DIST.
SUBM'D. TP	CHKD.	DATE: JAN. 27/12	SITE:
DRAWN: AMG	CHKD.	APPD.	DWG. 2

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

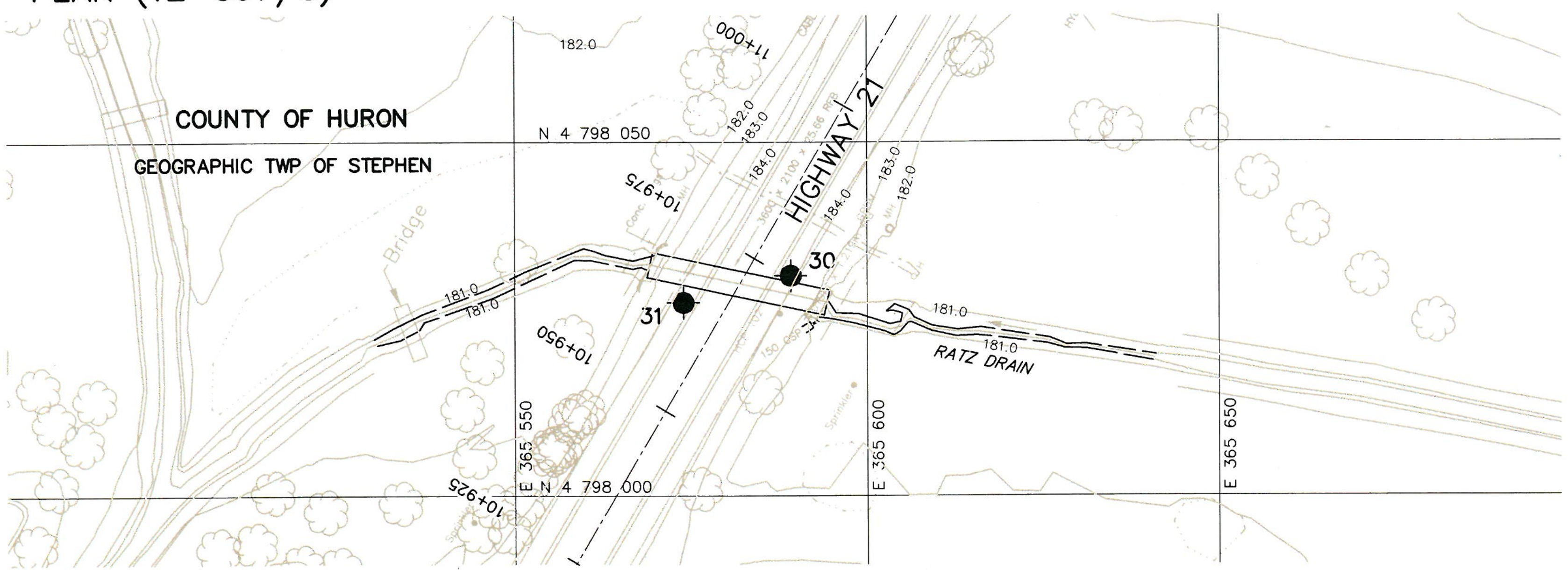
CONT No. 2012–3009
WP No. 3952–01–00

SHEET

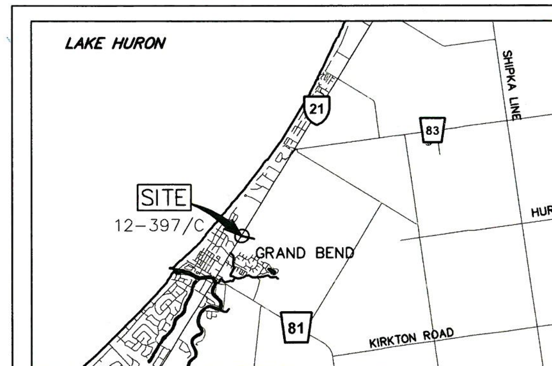
RETAINING WALLS
RATZ DRAIN CULVERT
HIGHWAY 21 REHABILITATION
BOREHOLE LOCATIONS

Golder Associates Ltd.
LONDON, ONTARIO, CANADA

PLAN (12–397/C)



SCALE
20 0 10 20 m

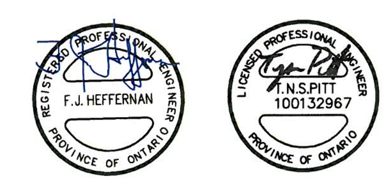


KEY PLAN
SCALE
1.5 0 1.5 km

LEGEND

Borehole – Current Investigation

No.	ELEVATION	CO-ORDINATES MTM ZONE 11	
		NORTHING	EASTING
30	184.09	4 798 031.1	365 589.3
31	184.10	4 798 027.3	365 574.0



NOTES

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

The boundaries between soil strata have been established only at borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REFERENCE

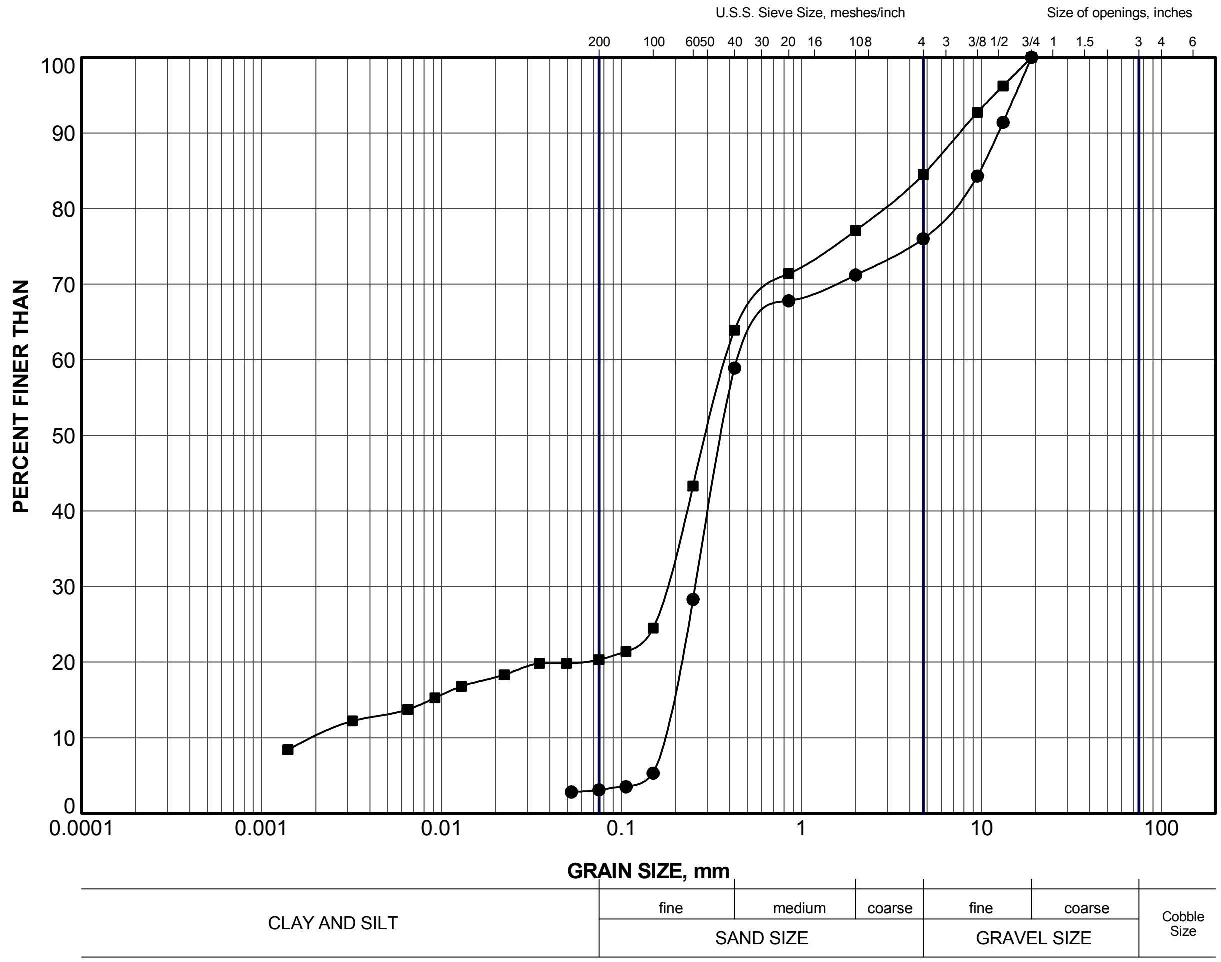
Base plans provided in digital format by Dillon Consulting Limited

NO.	DATE	BY	REVISION

Geocres No. 40P5–19			
HWY. 21		PROJECT NO. 11–1132–0014	DIST.
SUBM'D. TP	CHKD.	DATE: JAN. 27/12	SITE: 12–397/C
DRAWN: AMG	CHKD.	APPD.	DWG. 3

APPENDIX A

Laboratory Test Data



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	30	4	180.8
■	32	4	184.5

PROJECT

RETAINING WALLS
HIGHWAY 21 REHABILITATION
GWP 3952-01-00

TITLE

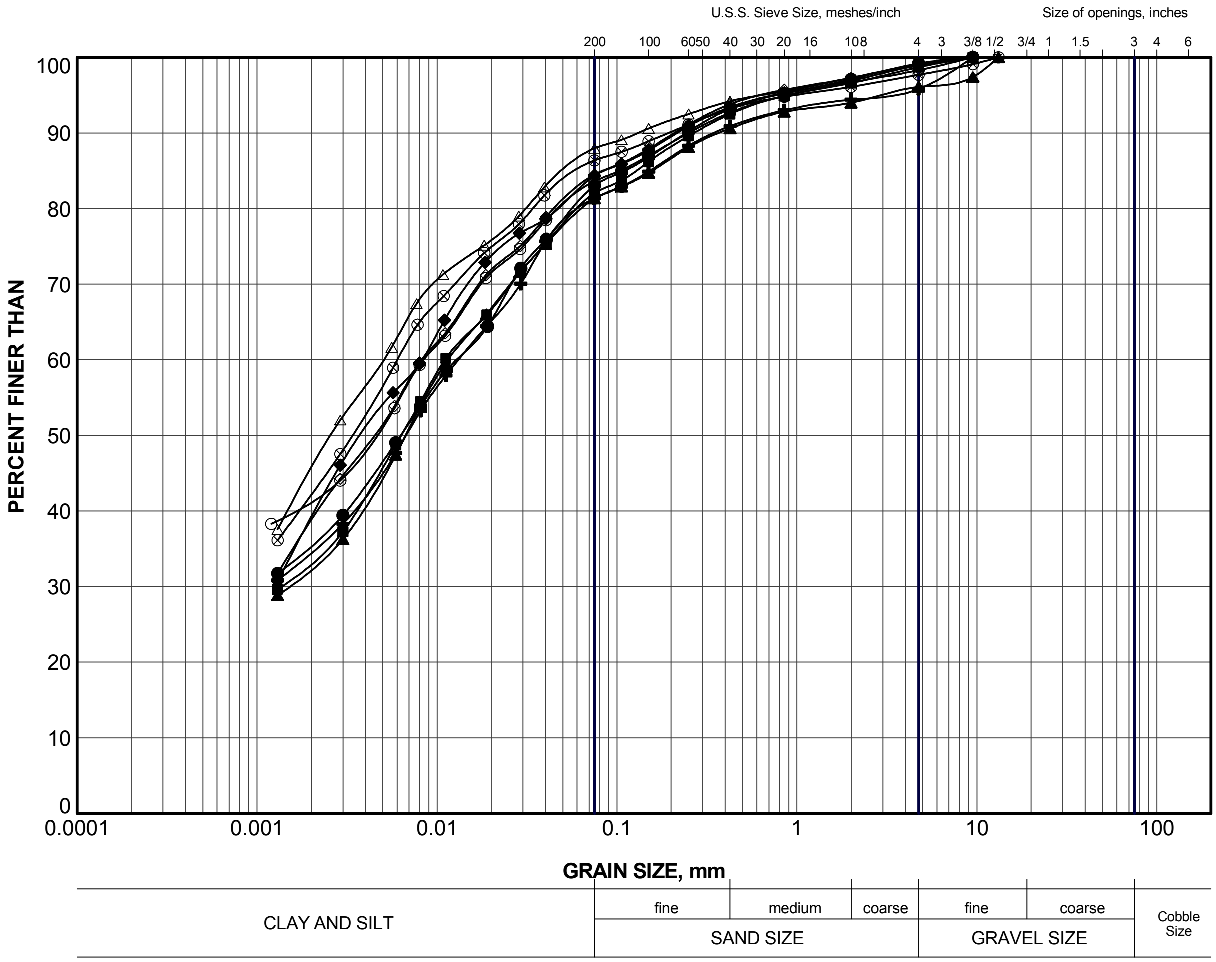
GRAIN SIZE DISTRIBUTION

FILL, sand

Golder Associates
LONDON, ONTARIO

PROJECT No.		11-1132-0014	FILE No. 1111320014-2000-F040A1	
			SCALE N/A	REV.
DRAWN	WDF	Nov 01/11	**FIGURE A-1**	
CHECK				

LDN_MTO_GSD GLDR_LDN.GDT



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	24	4	185.6
■	24	6	184.1
▲	25	4	185.6
✚	25	6	184.1
◆	30	7	178.5
◇	31	7	178.5
○	32A	8	181.5
△	32A	10	180.0
⊗	33	2	180.6

PROJECT

RETAINING WALLS
HIGHWAY 21 REHABILITATION
GWP 3952-01-00

TITLE

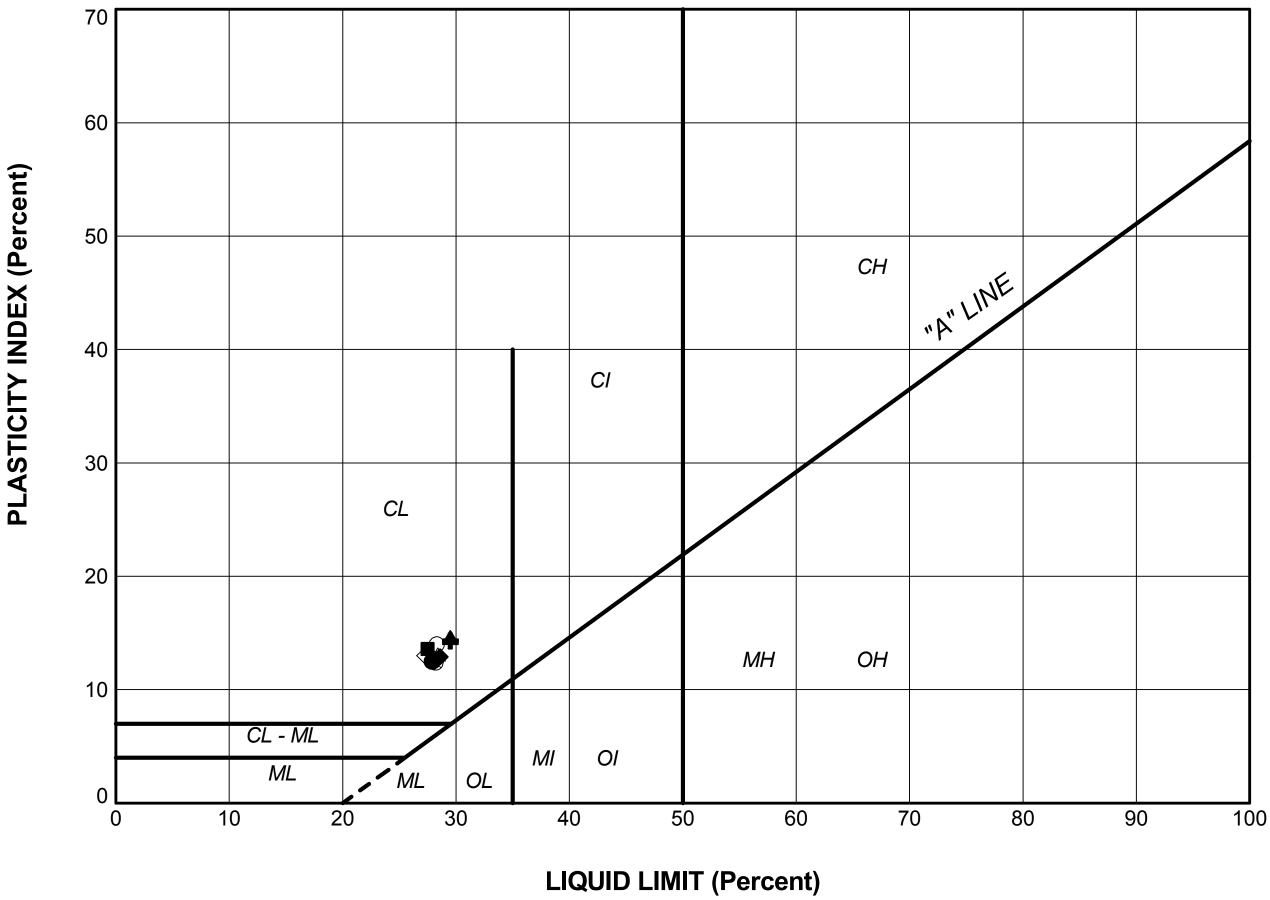
GRAIN SIZE DISTRIBUTION

CLAYEY SILT TILL

PROJECT No.	11-1132-0014	FILE No. 1111320014-2000-F040A2	
		SCALE N/A	REV.
DRAWN	WDF	Nov 01/11	FIGURE A-2
CHECK			

Golder Associates
LONDON, ONTARIO

LDN_MTO_GSD GLDR_LDN.GDT



SOIL TYPE
C = Clay
M = Silt
O = Organic

PLASTICITY
L = Low
I = Intermediate
H = High

LEGEND

SYMBOL	BOREHOLE	SAMPLE	LL(%)	PL(%)	PI
●	24	4	27.9	15.4	12.5
■	24	6	27.5	13.9	13.6
▲	25	4	29.5	14.9	14.6
✚	25	6	29.5	15.2	14.3
◆	30	7	28.6	15.7	12.9
◇	31	7	27.2	14.2	13.0
○	32A	8	28.3	14.3	14.0
△	32A	10	28.4	15.3	13.1
⊗	33	2	28.2	15.8	12.4

PROJECT
RETAINING WALLS
HIGHWAY 21 REHABILITATION
GWP 3952-01-00

TITLE
PLASTICITY CHART
CLAYEY SILT TILL

Golder Associates
LONDON, ONTARIO

PROJECT No.		11-1132-0014	FILE No. 1111320014-2000-F040A3	
			SCALE N/A	REV.
DRAWN	WDF	Nov 01/11	**FIGURE A-3**	
CHECK				

LDN_MTO_PI GLDR_LDN.GDT

APPENDIX B

Site Photographs

Photograph 1: Non-Structural Culvert, Sta. 10+194 (east).

Photograph 2: Non-Structural Culvert, Sta. 10+194 (west).

Photograph 3: Ratz Drain, inlet (east).

Photograph 4: Ratz Drain, outlet (west).

Photograph 5: Turnbull Creek Culvert, southeast retaining wall.

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

Africa	+ 27 11 254 4800
Asia	+ 852 2562 3658
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Ltd.
309 Exeter Road, Unit #1
London, Ontario, N6L 1C1
Canada
T: +1 (519) 652 0099

Golder Associates