REPORT ON
FOUNDATION INVESTIGATION AND DESIGN
PROPOSED CULVERT EXTENSIONS
HIGHWAY 401 AT HIGHWAY 77
(STATION 13+897, TILBURY NORTH)
HIGHWAY 401 AT TREMBLAY CREEK
(STATION 10+025, TILBURY WEST)
G.W.P. 61-00-00
PURCHASE ORDER NO. 3005-A-000301
GEOCRES NO. 40J2-58

Submitted

To

ERES Consultants

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Review Principal

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1.0 INTRODUCTION

This report presents the results of a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the detailed design and construction of the proposed extensions to two culverts located on Highway 401 at Highway 77 and at Tremblay Creek, respectively. This work is part of the project involving reconstruction and widening of 10.6 km of Highway 401 from 1.2 km west of Highway 77 to 1.0 km east of Essex County Road 42 in Southwestern Ontario.

The purpose of this investigation was to determine the subsurface conditions at the existing culvert inlet and outlet locations and, based on this and other available data, to provide foundation recommendations for the design of the culvert extensions or replacement. Comments are also provided on construction issues which may affect design.

Prior to this investigation, relevant foundation investigation references available from the GEOCRES system for the general vicinity of the sites have been consulted. Particular reference is made to the following documents in the preparation of this report.

- Peto MacCallum Ltd. titled “Foundation Investigation and Design Report for Highway 77 Underpass, G.W.P. 60-00-00, Site 6-104, Highway 401, Comber, Ontario", PML Ref. 01TF072E, September 2002, GEOCRES No. 40J2-46 (Reference 1).

- Department of Highways, Ontario Report titled "Hwy. 401 Revision Crossing Hwy. 2, 1 Mile West of Tilbury", W.P. 159-58, April 1959, GEOCRES No. 59-F-11, (Reference 2).

2.0 SITE AND PROJECT DESCRIPTION

The first culvert is located on Highway 401 at Station 13+897, just west of the underpass structure at Highway 77 within the Town of Lakeshore, Township of Tilbury West, Essex County, Ontario. The second culvert is located on Highway 401 at Station 10+025, at Tremblay Creek about 1 km west of the Gracie Road underpass structure within the Town of Lakeshore, Township of Tilbury West, Essex County, Ontario. Both sites are situated within the MTO District 31 and their locations are shown on Drawing 19-2005-16-3.

The general vicinity of the sites is lightly vegetated with grass and occasional shrubs and trees. The original terrain is relatively flat-lying with the bridges and approaches being the prominent features on site.

The existing culvert at Highway 77 is a 1.5 m wide by 1.5 m high open footing concrete structure. It is understood that the currently proposed design plan calls for an extension of the culvert by 4 m at both ends, or possible replacement of the structure.

The existing culvert at Tremblay Creek is a 5.5 m wide by 1.8 m high open footing concrete structure. We understand that it is proposed to extend the culvert by 3 m at both ends.

3.0 INVESTIGATION PROCEDURES

3.1 Field Investigation

The borehole investigation program at the two sites were carried out from December 3 to 5, 2002, inclusive, when 4 sampled boreholes, numbered 02-40 and 02-41 (Highway 77 culvert), 02-50 and 02-51 (Tremblay Creek culvert), were drilled and sampled near the inlet and outlet locations of the culverts. All four boreholes were drilled and sampled to 8.2 m depth below the existing ground surface.

The approximate locations of all four boreholes are shown on Drawing 19-2005-16-3. The investigation was carried out using track and truck mounted drill rigs supplied and operated by specialist drilling contractors.

In the boreholes, all soil samples were obtained with a 50 mm outside diameter split spoon sampler driven in accordance with the Standard Penetration Test (SPT). It was not possible to carry out any field vane test due to the stiffness of the silty clay till foundation soils. Pocket penetrometer readings were obtained on selected cohesive samples for qualitative strength correlation purposes. Groundwater conditions in the open boreholes were observed throughout the drilling operations. One standpipe piezometer was installed in each of the Boreholes 02-40 and 02-50 to permit longer term groundwater level monitoring.

The field work was supervised on a full-time basis by one of our field technicians who located the boreholes in the field, cleared borehole locations of underground utilities, directed the drilling, sampling and in-situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in appropriately labelled containers and transported back to Thurber’s laboratory in Oakville for further examination and testing.

Upon completion of drilling, the boreholes were backfilled with drill cuttings. Once the last set of piezometer readings was taken, the piezometers were decommissioned with cement and bentonite.

All as-drilled borehole locations were established in the field by Thurber's drilling supervisor in relation to surface features on site. The ground surface elevations and plan co-ordinates (northings and eastings) at the borehole locations have been estimated based on plans and profiles originated from MTO and forwarded to Thurber by ERES (MTO Drawings titled "Pre-Engineering", GWP 60-00-00B prepared by J.D. Barnes Ltd.). Results of the field sampling and testing are presented on Drawing 19-2005-16-3 and on the Records of Boreholes in Appendix A.

3.2 Laboratory Testing

Geotechnical laboratory testing consisted of natural moisture content, visual classification and description of all soil samples in accordance with the current MTO standards. Grain size distribution analysis and Atterberg Limits tests were conducted on selected samples. Results of these tests are presented in Appendices A, B and C.

4.0 GENERAL SITE GEOLOGY AND SUBSURFACE STRATIGRAPHY

4.1 General Site Geology

Based on published geological information, the general area of the project is located within the physiographic sub-region named Essex Clay Plain of the St. Clair Clay Plains. This is a till plain with lacustrine clay deposits which settled in the depressions while the knolls were lowered by wave action of past glacial lakes. The till deposits consist mainly of a silty clay to clayey silt matrix. Below the extensive till deposits lies bedrock of the Dundee Formation (Chapman and

Putnam, “The Physiography of Southern Ontario”, Third Edition, Ontario Geological Survey, 1984). The bedrock reportedly consists of limestone, dolostone and shale.

4.2 Subsurface Stratigraphy

This section contains generalized summary of the subsurface conditions at this site. The detailed subsurface soil and groundwater conditions encountered in the boreholes are presented on the Records of Borehole sheets in Appendix A.

In general, the subsurface conditions encountered in the boreholes consist of a deposit of silty clay till. Topsoil overlies the till at some locations. Groundwater levels at 5.9 m and 3.3 m depths were measured in piezometers installed in two selected boreholes.

4.2.1 Topsoil

Topsoil was encountered in Boreholes 02-40 and 02-41. At the borehole locations, topsoil thickness varied between 75 mm and 100 mm.

4.2.2 Silty Clay Till

A deposit of silty clay till was encountered below the topsoil or at ground surface in all four boreholes drilled during this investigation. This deposit was not fully penetrated in any of these boreholes.

The upper zone of the silty clay till is dessicated and is brown to mottled brown and grey in colour. The stiff crust extends below this upper zone into the underlying grey portion of the till, and is generally greater than 6 m in thickness. Correlations with SPT ‘N’ values which typically varied from 14 blows to greater than 32 blows, and with pocket penetrometer test results, indicated that the crust has a typically very stiff to hard consistency. The upper 0.6 m of the till was apparently disturbed by past activities on site and had a generally firm consistency as indicated by SPT ‘N’ values of between 6 blows and 9 blows. No successful field vane test was carried out within this crust due to its stiffness. Below the crust is the main body of the grey silty clay till. Correlation with SPT ‘N’ values, ranging between 22 blows and 16 blows, and pocket penetrometer results, indicated that this grey till has a typically very stiff consistency. In Borehole 02-51, however, ‘N’ values of 12 blows were obtained near the bottom of the hole indicating that the till became stiff with depth.

Atterberg limits tests carried out on selected samples of this till yielded liquid limits varying from 36% to 38%, and corresponding plasticity indices varying from 17% to 19%. Figures B1 shows Atterberg limits test results plotted on a plasticity chart which indicated that this till has a medium plasticity (group symbol of CI). Figure C1 shows grain size distribution curves of selected samples indicating clay contents of 48% to 49%. Measured moisture contents of samples of the till ranged between approximately 19% and 22%.

4.2.3 Groundwater Conditions

During drilling, no free water was observed in any of the open boreholes. One piezometer was installed at the bottom of each of the Boreholes 02-40 and 02-50. Piezometric levels of 5.9 m depth (Elevation 175.6 m) and 3.3 m depth (Elevation 174.2 m) were measured in Boreholes 02-40 and 02-50, respectively, on January 9, 2003.

It should be noted that groundwater levels are subject to seasonal fluctuations and may also be influenced by the water level in the creek.

5.0 FOUNDATION EVALUATION AND RECOMMENDATIONS

5.1 General

This section of the report presents the foundation recommendations for the design and construction of the proposed extension to both culverts, and possible replacement of the Highway 77 culvert. It is understood that these extensions are required to accommodate the proposed widening of the Highway 401 embankment.

It is understood that the proposed works include the following :

Highway 77 Culvert (Station 13+897)

- extending the existing concrete open footing culvert, 1.5 m wide by 1.5m high, by 4 m at both the inlet and the outlet ends,

- possibility of replacing the entire culvert.

Tremblay Creek Culvert (Station 10+025)

- extending the existing concrete open footing culvert, 5.5 m wide by 1.8 m high, by 3 m at both the inlet and the outlet.

At both locations, the road embankment is in the order of 1 m over the top of the existing culvert, and in the order of 2 m to 2.5 m immediately adjacent to the box.

5.2 Culvert Foundations

Boreholes 02-40 and 02-41 at the Highway 77 culvert, and Boreholes 02-50 and 02-51 at the Tremblay Creek culvert indicated that the foundation silty clay till has a typically very stiff to hard consistency, with the exception of the upper 0.6 m of firm zone. It is recommended that the culvert footings for the extension be founded within the very stiff to hard till and below the depth of frost penetration of 1.2 m. The actual founding level also depends on hydrologic, hydraulic and other requirements.

Based on the MTO Drawings titled “Pre-Engineering”, GWP 60-00-00B prepared by J.D. Barnes Ltd., it is estimated that the existing footings are founded at approximately Elevation 181 m at Highway 77, and at approximately Elevation 177.5 m at Tremblay Creek. These elevations must be confirmed during detailed design. It is recommended that the new footings be founded at the respective founding elevations of the existing footings such that the latter will not be undermined.

Given the very stiff to hard consistency of the founding till and the anticipated light loading at the footing base (culvert self weight and road fill above culvert), the footings for the culvert or any headwalls, if required, may be designed for a factored geotechnical resistance at Ultimate Limit States (ULS) of 350 kPa and a geotechnical resistance at Serviceability Limit State (SLS) of 250 kPa.

Relatively low road embankments (in the order of 2 m) exist at the culvert locations. Provided that the new footings are properly designed and constructed as recommended in this report, the total and differential foundation settlements will be less than 25 mm and 15 mm, respectively. Such settlements are expected to be completed by the end of construction.

The culvert should be designed to resist frost forces, lateral earth pressures, weight of embankment fill above the roof, and traffic loadings. The design should also include the provision of soil cover of 1.2 m, or its thermal equivalent, to the footings for frost protection purposes.

5.3 Lateral Earth Pressures and Backfilling

Backfill to the culvert should consist of free-draining, non-frost susceptible granular materials such as Granular A or B (with less than 5% passing the No. 200 sieve) conforming to OPSS 1010 (Special Provision 110F13) requirements. Reference should be made to the backfill arrangements stipulated in OPSD 803.01 or OPSD 803.02, as appropriate. Excavated silty clay till materials are not suitable for backfilling adjacent to culvert walls. All fills should be placed in loose lifts not exceeding 200 mm thick and be compacted to 98 % of its SPMDD at a placement moisture content within 2% of the optimum value. The backfill should be placed and compacted in simultaneous equal lifts on both sides of the culvert, and the top of backfill elevation should be the same on both sides of the culvert at all times. Heavy compaction equipment should not be used adjacent to the walls and roofs of the culverts.

The culvert walls may be designed based on the following lateral pressure distribution :

$$p = K ((H + q)$$

where
- p = lateral earth pressure acting at any depth, kPa
- H = depth below finished road surface, m
- q = surcharge pressure, kPa
- K = earth pressure coefficient (see table below)

The following table lists the unfactored earth pressure coefficients that may be assumed for design.

Conditions Behind Wall	Earth Pressure Coefficient (K)			
	OPSS Granular A $\phi = 35°$; $\gamma = 22$ kN/m^3		OPSS Granular B, Type I $\phi = 30°$; $\gamma = 21$ kN/m^3	
	Horizontal Ground Behind Wall	Ground Sloping at 2H : 1V Behind Wall	Horizontal Ground Behind Wall	Ground Sloping at 2H : 1V Behind Wall
"Active" Coefficient, K_a	0.27	0.40	0.33	0.54
"At-Rest" Coefficient, K_0	0.43	0.62	0.50	0.76

If the wall design allows lateral yielding (non rigid frame structure), active earth pressures may be used. If the wall design does not allow lateral yielding (rigid frame structure), at-rest earth pressures should be assumed.

Additional lateral pressure must be added to account for compaction induced stresses. The additional pressure must be computed in accordance with Figure 6.9.3 of the Canadian Highway Bridge Design Code (CHBDC, 2000).

5.4 Embankment Stability

The width of the highway embankment will be extended in conjunction with the culvert extensions. Provided that the foundation subgrade is properly prepared as recommended in this report, a widened embankment ranging between 2 m and 2.5 m in overall height (about 1 m cover above the existing culverts), with a slope inclination of 2 H : 1 V, should be stable.

5.5 Culvert Replacement at Highway 77

It is understood that consideration is also given to replacing the culvert at Highway 77. Foundation and lateral earth pressure design for the new culvert may be carried out as outlined in Sections 5.2 and 5.3. Reference should also be made to OPSD 803.06 for backfill requirements.

Some elastic rebound of the foundation till will take place upon excavation of the overlying road fill and removal of the old culvert. Recompression is also anticipated upon installation of the replacement culvert and the placement of backfill. Since there is no extra loading on the foundation soil, no additional settlement will be induced. All vertical foundation movements associated with this unloading and reloading cycle is expected to complete by the end of construction.

5.6 Excavation, Shoring and Groundwater Control

In general, surface vegetation, topsoil, organic deposits, disturbed or otherwise loose/soft soils and other deleterious materials should be stripped from the subgrade in the vicinity of the culvert inlet and outlet areas, and under the new embankment footprint. Excavation for culvert footing construction will mainly involve the upper, firm, zone of the silty clay till and creek deposits.

All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and safety Act (OHSA), its regulations and other applicable regulations. For the purposes of assessing slope inclination and excavation support requirements in compliance with OHSA, the following soil types would apply to the subsurface stratigraphy encountered at the borehole locations :

Embankment Fills (existing)	Type 3
Creek Deposits (loose/soft sands, silts, clays)	Type 4
Silty Clay Till (native)	Type 2

Conventional excavation equipment should be suitable for all soil excavations at this site.

Surface water inflow into the footing excavations should be expected. Some form of groundwater control, in conjunction with temporary creek diversion, will be required to maintain dry footing excavations. Pumping from properly filtered sumps should be adequate to maintain reasonably dry excavations. Surface run-off should be diverted away from any excavation at all times.

Temporary shoring may be required to retain the embankment fills adjacent to the inlet and outlets areas. Based on available subsurface information, a shoring system consisting of steel soldier H-piles with timber lagging may be considered. The expression and geotechnical design values presented in Section 5.3 may be used for shoring design. For evaluation of passive toe resistance in front of the soldier piles, a passive earth pressure coefficient, K_p, value of 3.0 may be assumed. A submerged unit weight, γ_{sub} , of 10 kN/m^3 should be used where the soldier pile toe extends below the groundwater table.

Any shoring system required must be designed by a licensed Professional Engineer experienced in such designs.

Decisions regarding dewatering, shoring methods and sequencing should be made by the contractor and submitted to the Contract Administrator for information and review purposes.

5.7 Erosion Control

Erosion protection should be provided at the culvert inlet and outlet areas. It is recommended that a clay seal or a cut-off wall be used to minimize the potential of erosion in the inlet area. A clay seal should have a minimum compacted thickness of 0.3 m and should extend above the high water level. The material used for the clay seal should conform to the requirements stipulated in OPSS 1205. Alternatively, a concrete cut-off wall may be used to serve a similar purpose.

Design of schemes of erosion protection to the stream bed in the inlet and outlet areas may depend on hydrologic, hydraulic and/or other concerns. Typically, rip-rap (rock) protection should be provided to these areas. The rip-rap layer should cover all surfaces on the embankment slopes with which creek water is likely to be in contact.

Vegetation cover should be established on all exposed earth slopes to protect the embankment fill against surficial erosion. Reference may be made to OPSS 572 for more detailed requirements.

5.8 Construction Considerations

Temporary diversion of the creek, in conjunction with properly implemented sump pumping, is essential to maintaining reasonably dry excavations for foundation construction.

Care must be exercised during excavation to avoid disturbing the founding subgrade. When the excavation reaches the required elevation, the subgrade should be inspected and approved by qualified geotechnical personnel appointed by the Contract Administrator.

Temporary shoring systems should be properly designed and implemented to retain the adjacent road embankment such that potential movement of the fill can be minimized.

5.9 Construction Sequencing

Detailed construction scheduling information was not available at the time of preparation of this report. Based on the foundation considerations discussed above and our understanding of the proposed scope of work, we envisage preliminary construction sequencing as outlined below :

Culvert Extensions at Highway 77 and Tremblay Creek

1. Relocate utilities as required.
2. Temporarily divert the creek.
3. Install temporary shoring systems as required.
4. Strip and excavate in the embankment toe area to create sufficient space for the proposed works. In plan, the excavation base should extend at least 1 m beyond the perimeter of the culvert footprint. Excavated clean, inorganic, silty clay till and granular materials may be stockpiled on site for re-use on site.
5. Construct clay seal or concrete cut-off at inlet area.
6. Construct culvert extension on properly prepared and inspected subgrade.
7. Backfill around and above the culvert using approved granular materials. Materials should be placed and compacted uniformly on both sides.
8. Place fill for road embankment widening.
9. Complete rip-rap and other stream bed treatment procedures in both inlet and outlet areas.
10. Lower portions of the shoring wall may be left in place provided that they do not interfere with any of the erosion protection works and final embankment slopes.
11. Reinstate road embankment and re-vegetate as required; resume creek flow.

Culvert Replacement at Highway 77 (optional)

Complete replacement of the existing culvert with a new culvert will require several stages of carefully planned traffic diversion schemes. Construction sequence will be addressed should this option be adopted in the final design.

5.10 Construction Inspection and Testing

Subgrade inspection and field density testing should be carried out by qualified geotechnical personnel during all excavation and fill placement operations to confirm that the foundation recommendations are correctly implemented and material specifications are met.

DIST NO. 31,HWY.401
GWP NO. 61-00-00

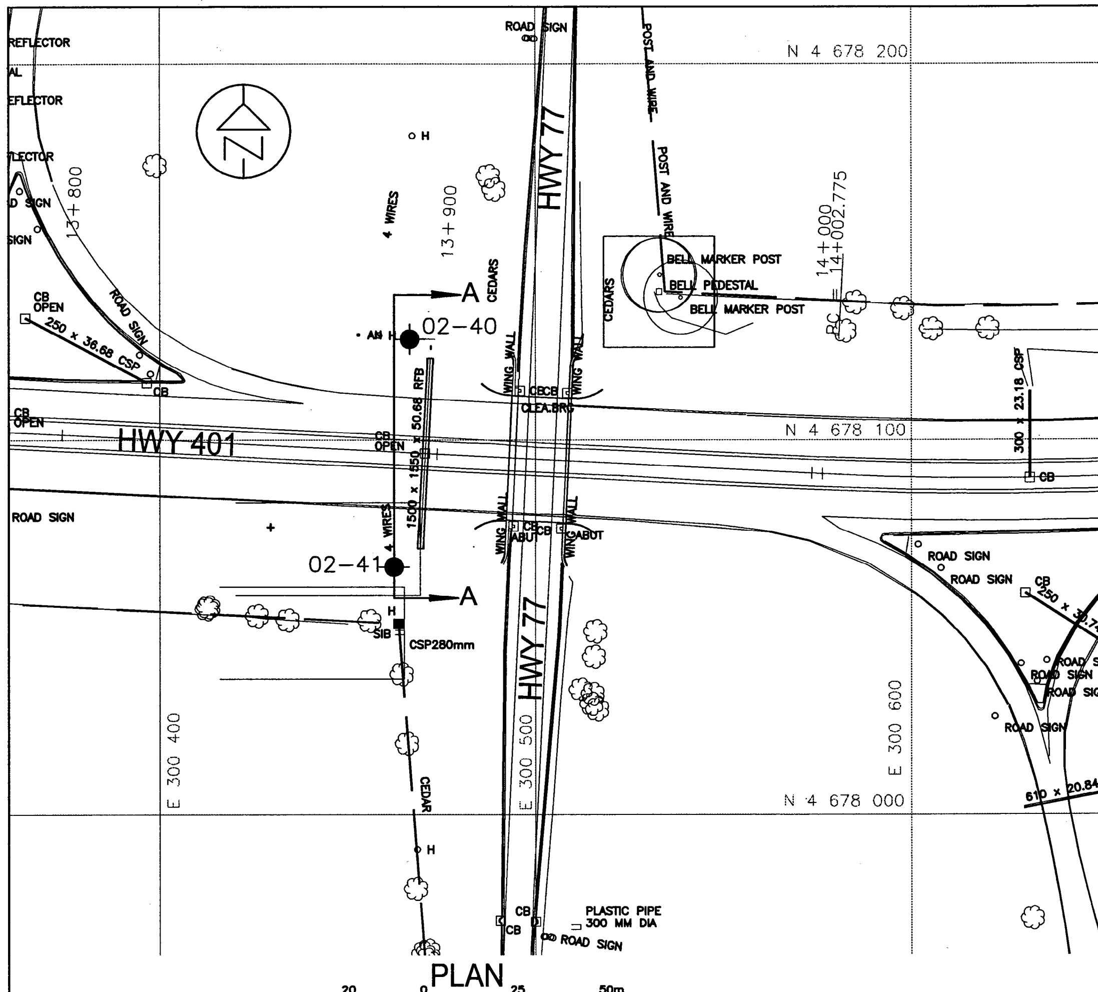
HWY 77 CULVERT (TILBURY WEST)
TREMBLAY CREEK (TILBURY NORTH)
BORE HOLE LOCATION & SOIL STRATA

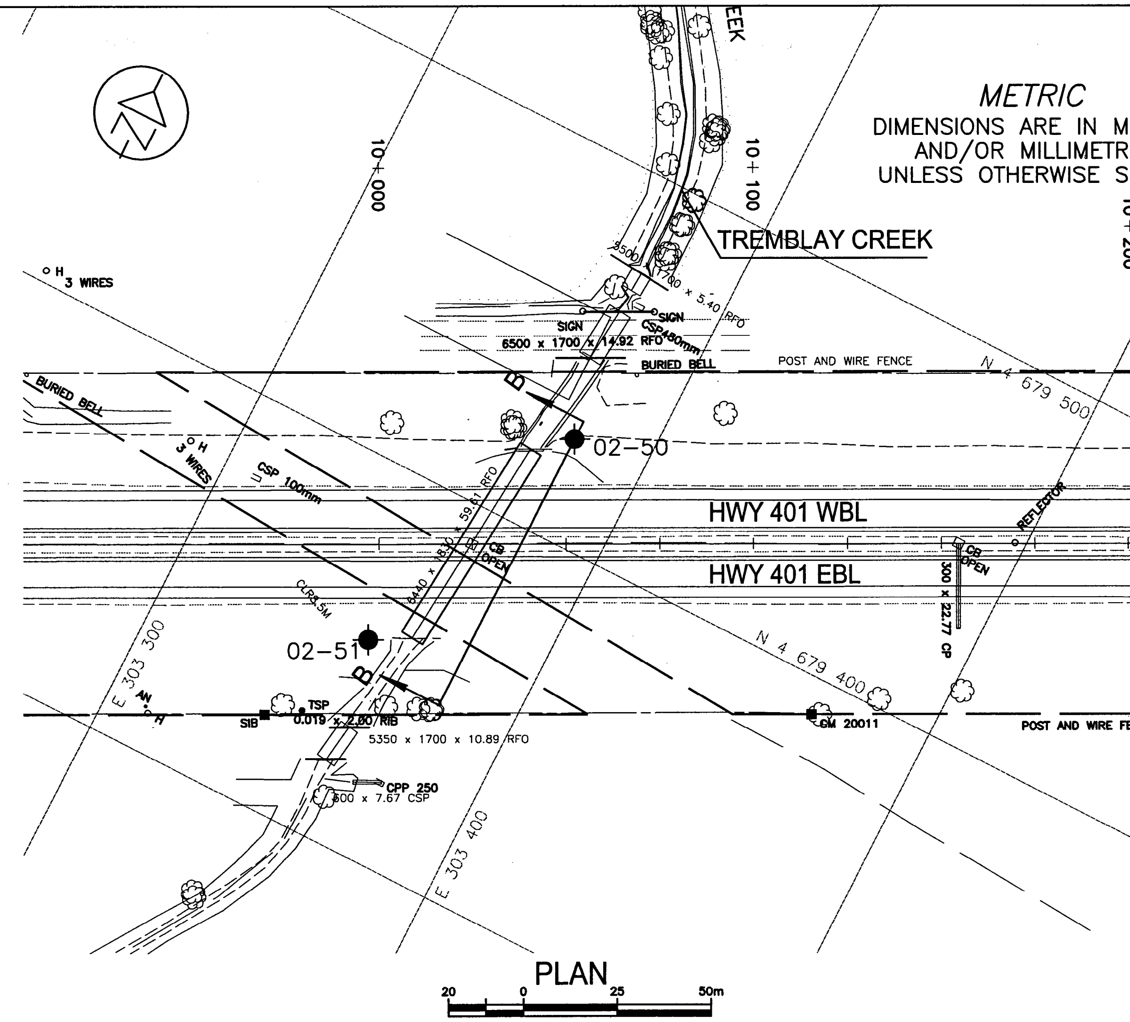
SHEET

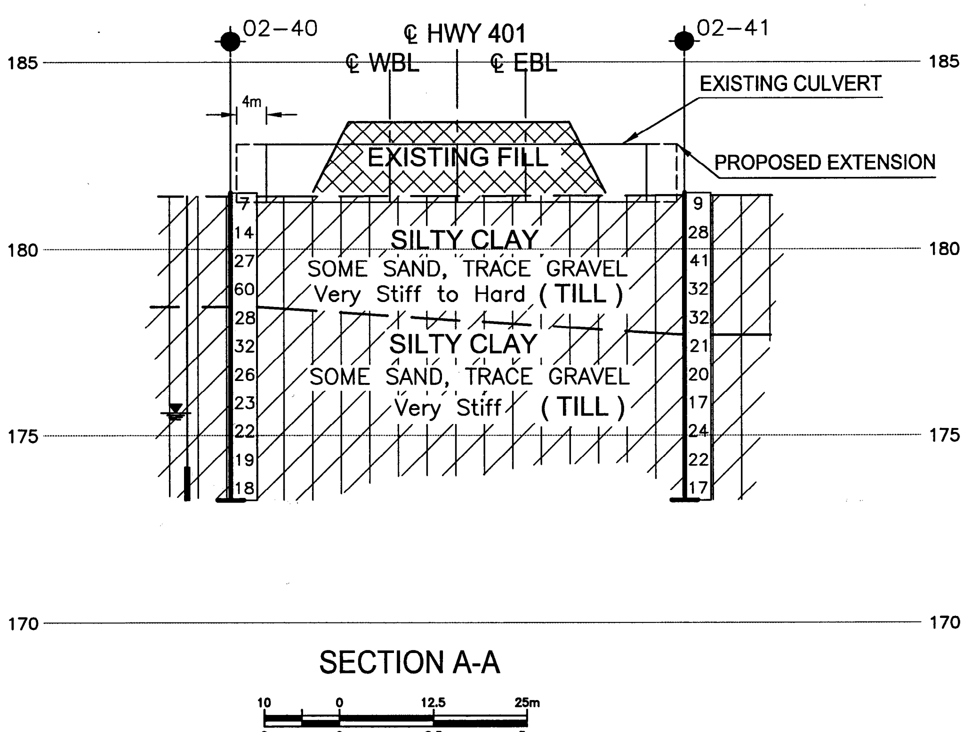
ERES CONSULTANTS
A Division of Applied Research Associates, Inc.

THURBER ENGINEERING LTD.

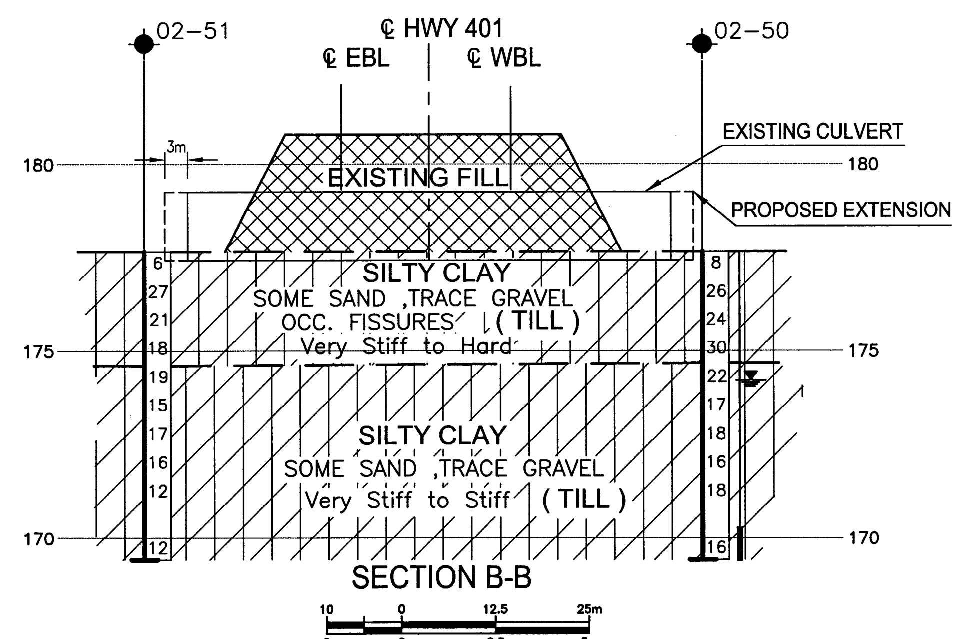
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN



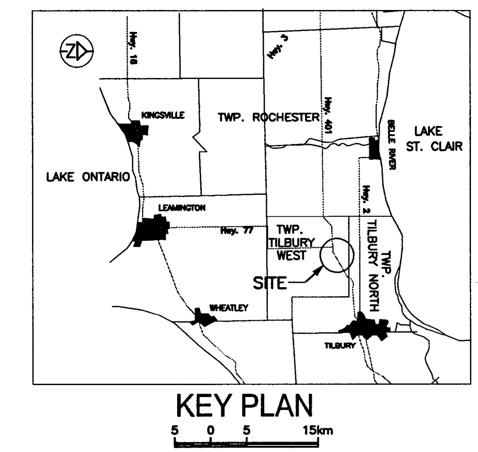




SECTION A-A



SECTION B-B



KEY PLAN

LEGEND

●	Bore Hole
⊕	Dynamic Cone penetration Test (cone)
◆	Bore Hole & Cone
N	Blow / 0.3m (std pen Test,475 J / blow)
CONE	Blows /0.3m (60° Cone ,475J/blow)
PH	Pressure, Hydraulic
▼	WL on January 9, 2003
⊻	Head Artesian Water
┃	Piezometer

NO	ELEVATION	NORTHING	EASTING
02-40	181.5	4678127	300467
02-41	181.5	4678066	300462
02-50	177.6	4679427	303380
02-51	177.6	4679355	303355

— NOTE —

The boundaries between soil strata have been established only at Bore hole locations . Between Bore Holes the boundaries are assumed from geological evidence .

REVISIONS		
MAR.2003	SP	FINAL
DEC.2002	SP	ISSUED AS DRAFT FOR REVIEW
DATE	BY	DESCRIPTION

DESIGN SP	CHK PKC	CHBDC 2000	LOAD	DATE MAR.2003
DRAWN SS	CHK SP	SITE	STRUCT	DWG. 19-2005-16-3