Regional Municipality of Halton

New North Oakville Transportation Corridor and Crossing of Sixteen Mile Creek

Appendix I: Hydrogeological Assessment

Hydrogeological Assessment of Proposed New North Oakville Transportation Corridor

Prepared for
Totten Sims Hubicki Associates

Submitted by
Gartner Lee Limited

May, 2008

Gartner Lee

Hydrogeological Assessment of Proposed New North Oakville Transportation Corridor

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May, 2008

Reference: **GLL 40-875 / 80-318**

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May 1, 2008

Mr. Mike Delsey, P.Eng.
Vice President
Totten Sims Hubicki Associates
300 Water Street
Whitby, ON L1N 9J2

Dear Mr. Delsey:

Re: GLL 40875/80318 – Hydrogeological Assessment of Proposed New North Oakville Transportation Corridor

Gartner Lee Limited is pleased to present this hydrogeological assessment report for the proposed new transportation corridor in the north Oakville area. This report describes the geological setting and hydrogeological conditions of the study area and establishes a set of hydrogeological criteria for assessment of alternative routes for the corridor. As a result of the assessment, the preferred western route (W2) and eastern route (E1) for the corridor are identified from a hydrogeological perspective. We understand, however, the preferred western route has been selected to be W6 based on an overall evaluation of all engineering, social and environmental aspects.

Constraints and opportunities for selected or preferred routes are discussed and associated recommendations are provided in the report, including:

a) potential dewatering may be required for shallow water table conditions in surficial granular deposits along Route E1 between Trafalgar Road and Joshua's Creek and therefore, a drilling and groundwater monitoring programs are recommended to confirm the geology and groundwater conditions in the area to determine the need for dewatering and assess potential impacts and mitigation measures if required;

b) a pitted depression may be encountered during construction near the east end of Route E1 and therefore, it is recommended that a field inspection and monitoring of the depression feature be conducted to confirm its presence and current uses by local farmers or residents and assess its environmental significance; and

c) both bedrock and water table likely occur at shallow depths (less than 5 m) at the west end of Route W6. If road runoff is to be conveyed by roadside ditches, the water quality in shallow bedrock wells along Dundas Street

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West to the south of Route W6 would become vulnerable to contaminant migration from road construction and future maintenance (de-icing compounds). It is therefore recommended that a local well survey and water quality assessment be carried out to address potential road salt impacts on shallow bedrock wells along Dundas Street West and assess potential mitigation measures as well.

We trust this report meets with your requirements. Should you have any question on this report, please contact us.

Yours very truly,
GARTNER LEE LIMITED

Original letter signed and stamped

Steven J. Usher, M.Sc., P.Eng., P.Geo.
Consulting Engineer, Senior Hydrogeologist

SJU:pc
Attach.

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1. Hydrogeologic Objectives

As part of the Class Environmental Assessment (EA) for the new North Oakville Transportation Corridor the implications of the proposed works on the hydrogeologic setting must be considered. These considerations include potential effects on local aquifers, private wells, groundwater fed wetlands and groundwater fed streams. Therefore, the objectives of the hydrogeological assessment are as follows:

a) understand and demonstrate hydrogeological conditions of the study area;
b) establish hydrogeological criteria for route selection;
c) recommend the preferred route from a hydrogeological perspective; and
d) identify constraints and opportunities for the preferred route.

2. Methodology

The study area is located in the north Oakville area and bounded by Bronte Road on the west, Highway 407 on the north, Dundas Street on the south and 9th Line on the east, as shown in Figure 1.

This hydrogeological assessment was based on a desk-top study using all available published information for the study area including the Ontario Geologic Survey (OGS) geological mapping and the Ministry of the Environment (MOE) water well record database as well as historical consulting reports for the study area.

Geological cross-sections A-A' to G-G' (Figures 2 to 8) covering the entire study area, were prepared based on information from the MOE water well records. These cross-sections are intended to illustrate a conceptual understanding of the area in terms of the local geologic and hydrogeologic conditions. Based on this understanding, the preferred route was identified from a hydrogeological perspective and constraints and opportunities for the preferred route were also derived.

3. Existing Conditions

3.1 Geology

Regionally, the primary Quaternary deposit is the dense clayey silt till known regionally as the Halton Ground Moraine till plain. This plain is transected by the Trafalgar End Moraine till ridge. As described by the MNR (2003), Parish (2002) and Morrison Environmental (2001), the Trafalgar

Moraine runs generally west-northeast across the north Oakville area. The local geology in the area is well illustrated in the seven geological cross-sections A-A' to G-G' (Figures 2 to 8). The locations of these cross-sections are shown in Figure 1.

3.1.1 Halton Till Plain

The Halton Ground Moraine till plain is generally represented by the topographic relatively low area in the south part of the study area. Regionally, it extends as far north as the Niagara Escarpment. The Halton Till Plain is characterized by the surficial clayey silt till. It overlies a silt till/sandy silt till (thought to be the Newmarket Till) which in turn overlies the shale bedrock in the area. The thickness of the tills range from less than 5 m to the south of the study area to more than 15 m to the north of the area.

The top several metres of the Halton till are usually fractured and relatively weathered. Less extensive, thicker granular deposits (sand and gravel) are occasionally encountered in the till. More extensive, thin layers of sand and silty sand (usually less than 1 m thick) may occur in the upper part of the Halton Till in the area. These features are seen at the Halton Waste Management Site located north of Lower Baseline on the west side of Regional Road #25, as shown in Figure 1.

3.1.2 Trafalgar Moraine

The Trafalgar End Moraine till ridge is generally represented by the topographic relatively high area in the north part of the study area. It can be plainly seen on the north-south geologic cross-sections (Figures 4 to 8) as a place where the till thickens, causing a distinct topographic rise to the north. Based on the above cross-sections, the southern limit of the Trafalgar Moraine appears to be located on the north side of Burnhamthorpe Road between Bronte Road and Neyagawa Blvd., and on the south side of Burnhamthorpe Road between Neyagawa Blvd. and 9th Line. The approximate location of the south limit of the Trafalgar Moraine is shown on Figure 1. The crest of the moraine is located outside the study area to the north and runs west-northeast creating the topographic ridge between Burnhamthorpe Road and Lower Baseline.

The Trafalgar Moraine mainly consists of clayey silt till (Halton Till) in the area. The moraine overlies the shale bedrock of Queenston Formation. Sand and gravel deposits may be found locally on the bedrock surface beneath the moraine. Beach deposits (sand and silty sand) seem to often appear along the toe or south limit of the moraine till ridge. Deeper water lacustrine deposits (silt, sandy silt and clayey silt) may be found locally overlying the till or beach deposits in the area.

3.1.3 Overburden Thickness

It can be seen from the five north-south cross-sections (C-C' to G-G' or Figures 4 to 8) that the overburden is generally thicker to the north within the Trafalgar Moraine area and becomes thinner to the south of the moraine. Based on data from the MOE well records for the area, the overburden thickness in the Trafalgar Moraine area ranges between 5.5 m and 30.5 m with an average thickness of 14.2 m. The overburden thickness in the Halton Till Plain area south of the moraine, however, falls in the range from 0 to 14.3 m with an average thickness of only 4.7 m.

The overburden thickness (or depth to bedrock) is presented on the isopach map (Figure 9). This map was derived using a smooth technique in a GIS platform and is based on the MOE water well data for the area. In general, the estimated overburden thickness contour lines show that the bedrock is deeper (about 6 to 14 m) in the area north of the southern limit of the Trafalgar Moraine (halfway between Burnhamthorpe Road and Dundas Street) and much shallower (about 2 to 4 m) in the area to the south of it.

3.1.4 Bedrock Valleys

A deep, open bedrock valley occurs along the Sixteen Mile Creek in the study area. The red shale bedrock can be seen on steep slopes along the entire valley in the area. Cross-sections A-A’, B-B’ and D-D’ (Figures 2, 3 and 5) show that the 16-Mile Creek incises the bedrock in the area to a depth of about 25 to 30 m and that the floor of the bedrock valley is covered by several metres of clayey silt till. The valley floor was investigated by Thurber Engineering during a road widening project for Dundas Street in 2005. The investigation revealed that several metres of clayey silt till overly the shale bedrock beneath the valley floor.

There are other pre-historic valleys in the area that are infilled with sediment and not apparent on the surface. One such deep, buried bedrock valley exists in the area about 500 m west of Bronte Road and Dundas Street as shown in cross-section B-B’ (Figure 3). The buried bedrock valley appears to extend northwest – southeast and to be filled with at least 15 m of alluvial deposits (sand and gravel) at the bottom, which are in turn capped by the clayey silt till. Another example may underlie Joshua Creek to the east.

3.2 Hydrogeology

3.2.1 Water Table

Based on historical water level information from the MOE well records, the water table found across the area varied from about 3 m to 7 m below ground surface as shown in the cross-sections. In local areas such as near the east end of routes E1 to E3, the water table was found in sandy soils to be more shallow at about 2 m below grade. The water table will fluctuate seasonally, and is expected to rise during wet seasons (such as in the spring) and will decline over dry seasons (such as summer/early fall).

In general, the water table occurs in the Halton Till (Clayey Silt Till) in the study area. As shown on cross-sections F-F’ and G-G’ (Figures 7 and 8), however, the water table may occur below the bedrock surface to the south of Dundas Street where the overburden is thinner and more weathered overlying the shallow bedrock. It is apparent from cross-sections C-C’ to G-G’ (Figures 4 to 8) that the water table elevation declines in a similar fashion to the ground surface from the north to south.

3.2.2 Groundwater Flow

Groundwater flows under the hydraulic gradients imposed by the water table. There is both a vertical and a horizontal component to groundwater flow in this setting. Given the thin overburden, it is concluded that the bulk of the groundwater will move slowly downward as this is a regional groundwater recharge area. There will however be a component of horizontal groundwater flow laterally in the weathered till. This will occur primarily in the spring season when the water table inundates this weathered horizon. Horizontal groundwater flow is driven by the lateral hydraulic gradients imposed by the elevation of the water table. As the water table elevation declines very slowly to the south (Figures 4 to 8), the shallow groundwater flows generally in a southerly direction. Shallow groundwater, however, may flow easterly or westerly towards nearby tributaries or bedrock valleys or ponds that intercept the local water table.

Regionally, deep groundwater in the shale bedrock flows in a southerly direction towards the lake. The exception to this are the bedrock valleys that may attract a local component of flow.

3.2.3 Hydraulic Conductivity

Hydraulic conductivity (K) for Halton Till in the study area has been estimated from soil sample grain size data collected during a geotechnical investigation by Thurber Engineering in August 2005. The soil samples were taken from boreholes drilled for a road widening project for Dundas Street at the Sixteen Mile Creek. The grain size data from the borehole logs show that Halton Till in the area consists of silt and clay till, clayey silt till, silt till as well as clayey and sandy silt till. The K values for Halton Till in the area therefore fall in a wide range between $2x10^{-8}$ and $2x10^{-6}$ m/sec based on the Pucketts method for finer grained soils. The grain size data and calculations of K values for the Halton Till soils are presented in Table 1. Based on our own experience in the area the hydraulic conductivity can be even lower. For example values as low as 10^{-10} m/s were measured in the base soils of the nearby Halton Landfill north on Bronte Road.

3.3 Groundwater Supply

As discussed in Section 3.1, the overburden in the area consists of the low permeability Halton Till overlying the shale bedrock across the study area. Therefore there are few wells drawing water directly from this soil. Overburden aquifers (primarily sand) in the area are less extensive and occur only locally: either at surface; or within the till; or on the bedrock surface. The shale bedrock

Table 1 Calculations of Soil Hydraulic Conductivity (K) Using Soil Grain Size Data

Borehole No	Sample No	Sample Depth	Soil Description	Sieve/Hydrometer Analysis Results						Hydraulic Conductivity
				Gravel	Sand	Silt	Clay	Total		K (m/sec)
BH-1	SS # 4	3 - 3.6 m	Clayey Sandy Silt Till	5.0	24.0	48.0	23.0	100	%	4.6E-07
BH4	SS # 2	1.5 - 2.1 m	Clayey Silt Till	1	7	71	21	100	%	6.9E-07
BH4	SS # 4	3.0 - 3.2 m	Silt Till	0	4	78	18	100	%	1.2E-06
BH4	SS # 6	6.0 - 6.1 m	Silt Till	1	16	68	15	100	%	2.3E-06
BH5	SS # 4	2.3 - 2.9 m	Silt and Clay Till	0	2	59	39	100	%	2.0E-08
BH16	AS #1	5.1 - 5.4 m	Clayey Silt Till	1	9	59	31	100	%	9.6E-08

Notes: Grain size data from August 2005 geotechnical borehole logs by Thurber Engineering for Dundas St widening at Sixteen Mile Creek

Formula for calculation of K values:

Hydraulic Conductivity **K = 4.36*10^(-5)*e^(-0.1975*%Clay)**

%Clay = % of the total sample finer than 0.002 mm by weight

Formula from Pucketts Method for finer grained soils (sandy silt, silt, clayey silt to silty clay)

Reference: Groundwater and Vadose Zoen Monitoring, ASTM, STP1053, 1990 is a low yielding but extensive aquifer in the region. It was found that most water wells in the area extract groundwater from the bedrock. This is particularly the case in the area south of the Trafalgar Moraine where the overburden becomes much thinner than the Trafalgar Moraine.

The information of the MOE water wells in the area is summarized in Table 2. The data show that in the Trafalgar Moraine area about 88% of the total number of wells withdraw water from the bedrock. In the Halton Till Plain area south of the Trafalgar Moraine, however, fully 98% of water wells extract water from the bedrock due to the thinner overburden.

The data in Table 2 also show that a majority of water wells (about 87%) in the north Trafalgar Moraine area are deeper drilled wells (greater than 15 m). The deeper drilled wells, however, only account for about half of the total number of wells in the area south of the Trafalgar Moraine. Shallow water wells (less than 10 m) account for about 6% of wells on the Trafalgar Moraine and 18% of the total number on the Halton Till Plain to the south.

The water well information in Table 2 suggests that a significant portion of water wells in the area south of the Trafalgar Moraine are shallower bedrock wells (about 50% water wells less than 15 m and about 17.6% less than 10 m). The more shallow bedrock wells are more vulnerable to be affected by surface contamination (such as road salt) than deeper wells, particularly where overburden is less than 5 m thick.

3.4 Pitted Depressions

Pitted depressions are formed in the ground by the melting of buried ice blocks and subsequent collapse of the soil overlying the ice blocks. Pitted depressions are not necessarily located in low lying areas and are usually isolated from other surface water features. Pitted depressions are fed by direct precipitation, stormwater runoff if located in low lying areas, and groundwater if the pitted depressions are deep extending below the water table. If the pitted depression pond is deep, the local water table around it is expected to dip inwards to the pitted depression. Shallow groundwater flows slowly inward and discharges to the pitted depression to replenish loss due to open water evaporation in the pitted depression pond.

Pitted depressions are located mainly in the east part of the study area on the south slope of the Trafalgar Moraine near Burnhamthorpe Road and Highway 407 between Trafalgar Road and 9th Line Road (Figure 1). The larger pitted depression features are shown in the surficial geology map and small pitted depressions are identified on the air photos for the area taken in the spring of 2002. Two types of pitted depressions may exist, including:

1. *Warm pitted depressions* (or seasonal pitted depressions), which represent depressions in the ground that are mainly fed by surface water, when available; and

2. *Cold pitted depressions* (perennial pitted depressions) are usually deep and are partly fed by groundwater, provided there are permeable geologic pathways to do so.

Table 2 Summary of MOE Water Well Information

Well Type and Depth	Trafalgar Moraine Area		South of Trafalgar Moraine	
	No of Wells	% Wells	No of Wells	% Wells
Overburden Well	**16**	**11.2%**	**5**	**2.0%**
Bedrock Well	**127**	**88.8%**	**251**	**98.0%**
Total	**143**	100.0%	**256**	100.0%
Dug Well / Drilled Large Diameter Well	**36**	**25.2%**	**41**	**16.0%**
<5 m	1	0.7%	3	1.2%
5-10m	7	4.9%	33	12.9%
10-15m	9	6.3%	4	1.6%
15-20m	15	10.5%	0	0.0%
20-25m	4	2.8%	1	0.4%
Drilled Small Diameter Well	**107**	**74.8%**	**215**	**84.0%**
<5 m	0	0.0%	0	0.0%
5-10m	0	0.0%	10	3.9%
10-15m	2	1.4%	82	32.0%
15-20m	39	27.3%	80	31.3%
20-25m	34	23.8%	19	7.4%
25-30m	15	10.5%	9	3.5%
>30m	17	11.9%	15	5.9%

Notes:
the MOE well record database includes wells installed in the area since 1949 and updated to 1997
Dug Well / Large Diam. Drilled Well have a well diameter of about 762 mm or 914 mm.
Small diameter drilled wells have a well diameter of about 127 mm or 152 mm.

It appears that the pitted depressions in this area are warm pitted depressions, however they should be inspected and confirmed in the field. It is recommended that an inspection and limited monitoring of the pitted depressions be carried out to confirm their presence and nature as well as existing uses by local residents or farmers.

4. Assessment of Alternative Routes

4.1 Hydrogeological Criteria

The following hydrogeological criteria have been used to assess alternative routes for the Burnhamthorpe Road Realignment. The results of the assessment are summarized in the attached Tables 3 and 4.

4.1.1 Overburden

A great majority of water wells in the study area extract groundwater from the bedrock. This is because the overburden Halton Till (Clayey Silt Till) covering the entire study area is of low permeability and low yield, and the bedrock is a relatively better aquifer.

Overburden soil type and thickness are two important factors to consider. Low permeability soils and thick overburden are preferred for the following reasons:

Thick low permeability soils along the route will attenuate and impede movement of potential contaminants from the construction or the future road operation from migrating into nearby water wells thus, minimizing adverse effects on water quality in the wells.

Due to the fractured nature of the shale bedrock, it is relatively more permeable than the clayey silt till in the area. Fractured bedrock however does not exhibit a high storativity, and generally have large capture areas. Bedrock wells are more vulnerable to potential well level interference and contaminant migration from both the route construction and future road maintenance (road salt use). Therefore, the areas where shallow bedrock exists, such as to the south, would be least preferred.

The thick low permeability soil along the route will also minimize the effort for construction dewatering along the route, as well as minimize potential well level interference due to dewatering. If saturated sandy layers are encountered in the till during construction, they are most likely discontinuous and would not require significant dewatering efforts.

Table 3: Hydrogeological Assessment for Eastern Alternative Routes Between Neyagawa Blvd. And 9th Line Road

Hydrogeological Criteria	**Route E1**	**Route E2**	**Route E3**
Route Location	Trafalgar End Moraine - Till Ridge	Trafalgar End Moraine - Till Ridge	Halton Ground Moraine - Till Plain
Overburden			
Thickness (Depth to Bedrock)	13 - 18 m	11 - 13 m	3 - 5 m
Top 10 m Soil Type	Clayey Silt Till, Silt/Sandy Silt	Clayey Silt Till, Silt/Sandy Silt, Sand	Clayey Silt Till
Water Table			
Depth to Water Table	2 - 7 m	2 - 7 m	2 - 5 m
Nearby Water Wells			
Number of Wells	10	42	14
Type of Wells	9 Bedrock Wells, 1 Overburden Well	41 Bedrock Wells, 1 Overburden Well	All Bedrock Wells
Well Depth	All >15 m	3 Wells 5 -10 m	2 Wells 5 -10 m
		4 Wells 10 -15 m	3 Wells 10 -15 m
		35 Wells >15 m	9 Wells >15 m
Percentage of Shallow Wells (<15 m)	0%	17%	36%
Depression Features			
Number of Nearby Depressions	1	4	4
Type of Depressions	Unknown Cold or Warm	Unknown Cold or Warm	Unknown Cold or Warm
Groundwater Contribution to Streams	Ephemeral / Intermittent Streams May be Encountered. No Groundwater Baseflow	Intermittent Streams May be Encountered. Groundwater Baseflow Unlikely	Perennial Streams May be Encountered and May Have Groundwater Baseflow
East End of Routes	Extensive Shallow Sandy Layers with Shallow Water Table May be Encountered	Extensive Shallow Sandy Layers with Shallow Water Table May be Encountered	Extensive Shallow Sandy Layers with Shallow Water Table May be Encountered
Comments	**Most Preferred**		**Least Preferred**

Table 4: Hydrogeological Assessment for Western Alternative Routes Between Bronte Road And Neyagawa Blvd.

Hydrogeological Criteria	Route W1	Route W2	Route W3	Route W5	Route W6
Route Location	Halton Ground Moraine - Till Plain	East Section on Trafalgar End Moraine - Till Ridge and West Section on Halton Ground Moraine - Till Plain	Halton Ground Moraine - Till Plain	Halton Ground Moraine - Till Plain	Halton Ground Moraine - Till Plain
Overburden					
Thickness (Depth to Bedrock)	Majority <6 m	9 - 20 m	4 - 10 m	1.5 - 10 m	Majority <4 m
Top 10 m Soil Type	Clayey Silt Till	Clayey Silt Till	Clayey Silt Till	Clayey Silt Till	Clayey Silt Till
Water Table					
Depth to Water Table	3 - 7 m	3 - 7 m	3 - 7 m	3 - 7 m	3 - 7 m
Nearby Wells					
Number of Wells	12	12	27	27	12
Type of Wells	All Bedrock Wells	All Bedrock Wells	All Bedrock Wells	All Bedrock Wells	All Bedrock Wells
Well Depth	2 Wells 5-10 m	3 Wells 5-10 m	4 Wells 5-10 m	3 Wells 5-10 m	2 Wells 5-10 m
	4 Wells 10-15 m	3 Wells 10-15 m	7 Wells 10-15 m	7 Wells 10-15 m	4 Wells 10-15 m
	6 Wells >15 m	6 Wells >15 m	16 Wells >15 m	17 Wells >15 m	6 Wells >15 m
% Shallow Wells (<15 m)	50%	50%	41%	37%	50%
Depression Feature					
Number of Depressions	None	None	None	None	None
Type of Depressions	NA	NA	NA	NA	NA
Groundwater Contribution to Streams	Perennial Streams Will be Encountered. Sixteen Mile Creek May Have Groundwater Baseflow	Perennial Streams Will be Encountered. Sixteen Mile Creek May Have Groundwater Baseflow	Perennial Streams Will be Encountered. Sixteen Mile Creek May Have Groundwater Baseflow	Perennial Streams Will be Encountered. Sixteen Mile Creek May Have Groundwater Baseflow	Perennial Streams Will be Encountered. Sixteen Mile Creek May Have Groundwater Baseflow
West End of Routes	Bedrock Depth 1.5 - 6 m	Bedrock Depth 4 - 7 m	Bedrock Depth 4 - 7 m	Bedrock Depth 1.5 - 6 m	Bedrock Depth 1.5 - 6 m
Comments		**Most Preferred**			**Least Preferred**

The Trafalgar Moraine, is an end moraine forming a till ridge of clayey silt Halton Till. (It is important to understand that this feature is comprised of dense low permeability soils, unlike granular deposits such as the Oak Ridges Moraine.) As such, it is the preferred area for alternative routes from a hydrogeological perspective.

4.1.2 Water Wells

Shallow overburden wells are more susceptible to the influence of road contaminants. In the low permeability soils the well has to be proximal to the construction for there to be a risk of impact. Overburden wells more than 200 m away will experience little to no risk. Bedrock wells with greater than 6 m of clayey overburden will be well protected. If the road alignment falls in areas of shallow overburden, downgradient wells in the bedrock are also susceptible due to the discrete pathways in the bedrock that provide little attenuation of contaminants. For these reasons, proposed routes that run along the existing road (where wells are common) would be least preferred. In addition, routes to the south should also be avoided because the overburden is thinner and all wells are in bedrock

4.1.3 Depth to Water Table

Where the water table is shallow there is a greater risk to shallow wells. A deeper water table is preferred in any case, for road construction and future maintenance, as this may eliminate the need for dewatering during earth works. The water table is usually deeper in highland areas than in low-lying areas, and therefore the Trafalgar Moraine located in the northern highland area would be preferred from this perspective.

4.1.4 Pitted Depressions

As described in Section 3.4, pitted depressions are located mainly in the east part of the study area on the south slope of the Trafalgar Moraine near Burnhamthorpe Road and Highway 407 between Trafalgar Road and 9th Line Road (Figure 1). It appears that the pitted depressions in this area are warm pitted depressions, however they should be inspected and confirmed in the field.

A field inspection and limited monitoring of the pitted depressions should be carried out to confirm their presence and type as well as the existing use by local residents or farmers. In case cold pitted depressions are identified, their habitat and significance for aquatic life should be assessed. In general, the preferred route to be selected should not directly encounter pitted depressions and the existing functions of cold pitted depressions, if identified, should be maintained.

4.1.5 Groundwater Contribution to Streams

Some streams in nature are groundwater fed which provide unique coldwater habitat, whereas others are not and provide different habitat opportunities. There are three classifications of streams:

1. **Perennial**, which flow year round, every year, and are likely have some groundwater contribution (depending upon soil type);
2. **Intermittent**, which flow seasonally and may have some groundwater contribution (depending upon soil type), and;
3. **Ephemeral**, which only flow when there is runoff, and have no groundwater contribution.

In the geologic environment for this site there appears to be all three types, however the dense silty soil severely limits groundwater contributions. Where 16-Mile Creek intersects the fractured bedrock or sand lenses above the bedrock, there will be some groundwater inflow. Because of the low permeability surficial soils, route selection should focus to the north where the watercourses are mostly ephemeral.

4.2 Selection of Preferred Routes

The hydrogeological assessment of the alternative routes shown in Figure 1 has been summarized in Tables 3 and 4 in terms of the hydrogeological criteria discussed in Section 4.1. As the outcome of the assessment, Routes E1 and W2 are identified to be the most preferred route between Neyagawa Blvd. and 9th Line Road and between Bronte Road and Neyagawa Blvd., respectively. Further discussions on the selected preferred routes are provided below.

4.2.1 Eastern Routes E1 to E3

Route E1 is identified to be the preferred route for the eastern section of the proposed realigned Burnhamthorpe Road. The following are the four main reasons for the preferred route:

1. the greatest thickness (13 to 18 m) of the low permeability Halton Till to be encountered near surface along the route;
2. the least number of water wells (10) in the vicinity of the route;
3. the deepest water wells (all deeper than 15 m); and
4. no perennial stream to be encountered or no baseflow to streams to occur along the route.

Thicker low permeability soils along Route E1 will attenuate and impede movement of potential contaminants from the construction or the future road maintenance from migrating into nearby water wells thus minimizing adverse effects on water quality in the wells. Deeper wells usually provide better protection of well water quality than shallow wells. The thicker low permeability soils along Route E1 will also minimize the effort for construction dewatering and potential well interference due to dewatering[1].

Route E1 is located on the Trafalgar Moraine till ridge intercepting upstream sections of tributaries which are ephemeral and only flow when there is runoff, and have no groundwater contribution. Construction of Route E1, therefore, will not have an impact on groundwater baseflow to the tributaries.

By contrast, Route E3 is identified to be least preferred for the following reasons:

a) the least thickness (2 to 5 m) of the low permeability Halton Till to be encountered occurs near surface along the route;
b) the highest percentage of shallow bedrock wells (36% less than 15 m) in the vicinity of the route; and
c) perennial streams may be encountered and groundwater contribution to stream flow may take place along the route.

4.2.2 Western Routes W1 to W6

Route W2 is identified to be the preferred route for the western section of the proposed realigned Burnhamthorpe Road. Route W2 is located north of all other alternative routes and partly on the Trafalgar Moraine till ridge. The following are the main reasons for the preferred route:

a) the greatest depth (9 to 20 m) to bedrock or thickness of the low permeability overburden (Halton Till) along the route; and
b) the less number of water wells (12) in the vicinity of the route.

Due to the fractured nature of the shale bedrock, it is relatively more permeable than the clayey silt till (Halton Till) in the area. Bedrock wells are more vulnerable to potential well level interference and contaminant migration from both the route construction and future road maintenance (road salt use). Therefore, the areas where shallow bedrock exists (for example, Routes W1, W3, W4 W5 and W6), would be least preferred.

All other western alternative routes (W1, W3, W5 and W6) show similar low preferences based on the hydrogeological criteria mainly due to the shallower depths of bedrock (less than 10 m). Route W6 is identified to be the least preferred route attributed to the shallowest bedrock (majority less than 4 m) along the route, coupled with the proximity to wells on Dundas Street, compared to other routes.

1. *There will probably be little dewatering required for this construction, except for any buried drainage services or infrastructure requiring deep foundations.*

5. Discussions of Constraints and Opportunities

It is our understanding that the western and eastern preferred routes have been selected to be W6 and E1, respectively, based on an overall evaluation of all engineering, social and environmental aspects. From a hydrogeological perspective, however, the western preferred route should be W2 as discussed above. The following discussions involve not only Routes E1 and W2 but also W6.

5.1 Construction Dewatering

As shown in geological cross-section A-A' (Figure 2), surficial granular deposits (sand, silty sand/sandy silt, silt) along with shallow water table conditions may be encountered in the area on both sides of Burnhamthorpe Road between Trafalgar Road and Joshua's Creek. These conditions may require dewatering during construction of Route E1 if a service trench for the road is proposed to be incised below the local water table. A drilling and groundwater monitoring program should be carried out to confirm the geology and groundwater conditions in the area to determine the need for dewatering and assess potential impacts on local wells and streams as well as mitigation measures if required.

5.2 Pitted Depressions

It is noted from Figure 1, the preferred eastern Route E1 may encounter a pitted depression located on the north side of Burnhamthorpe Road. As well, there appear to be several pitted depressions located in the vicinity of the eastern sections of Routes E2 and E3. A field inspection and monitoring of these pitted depressions should be carried out to confirm their presence and current uses by local residents or farmers as well as assess their environmental significance. Potential impacts from the construction and future road maintenance on cold pitted depressions if identified, should be assessed.

5.3 Well Water Quality

As shown in cross-sections C-C' to F-F' (Figures 4 to 7), the shallow bedrock surface (less than 5 m) along with a shallow water table likely occur at the west end of Route W6 (Figure 4), the east end of Route W4 (Figure 5), the areas along Route E3 at 6th Line Road (Figure 6) and Trafalgar Road (Figure 7). The shale bedrock is usually more permeable due to fractures than the clayey silt till overburden. If road runoff is to be conveyed by roadside ditches in the shallow bedrock areas, the well water quality along Dundas Street West would become more vulnerable to contaminant migration from road construction and future maintenance (road salt use). It is therefore recommended that a local well survey and water quality assessment be carried out to address potential road salt impacts on shallow bedrock wells along Dundas Street West.

The opportunity to protect well water quality in the shallow bedrock areas is to collect road runoff by stormwater sewers that drain to downstream stormwater ponds for settling before being discharged to nearby tributaries.

6. Recommendations

The following recommendations are provided for your considerations:

a) The geology and groundwater conditions in the area on the north side of Burnhamthorpe Road between Trafalgar Road and 9th Line Road should be investigated to determine the need for dewatering during construction of service trenches if proposed, and to assess potential impacts on local wells and streams as well as mitigation measures if required.

b) The pitted depressions in the area on the north side of Burnhamthorpe Road between Trafalgar Road and 9th Line Road should be inspected and monitored to confirm their presence and current uses by local residents or farmers, as well as to assess their environmental significance. Potential impacts from the construction and future road maintenance on cold pitted depressions if identified, should be assessed as well.

c) A local well survey and water quality assessment should be carried out to assess potential road salt impacts on bedrock wells along Dundas Street West.

Report Prepared By:

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Senior Hydrogeologist

Original Report Signed and Sealed By:

Original report signed and stamped

Steven J. Usher, M.Sc., P.Eng., P.Geo.
Consulting Engineer, Senior Hydrogeologist

7. References

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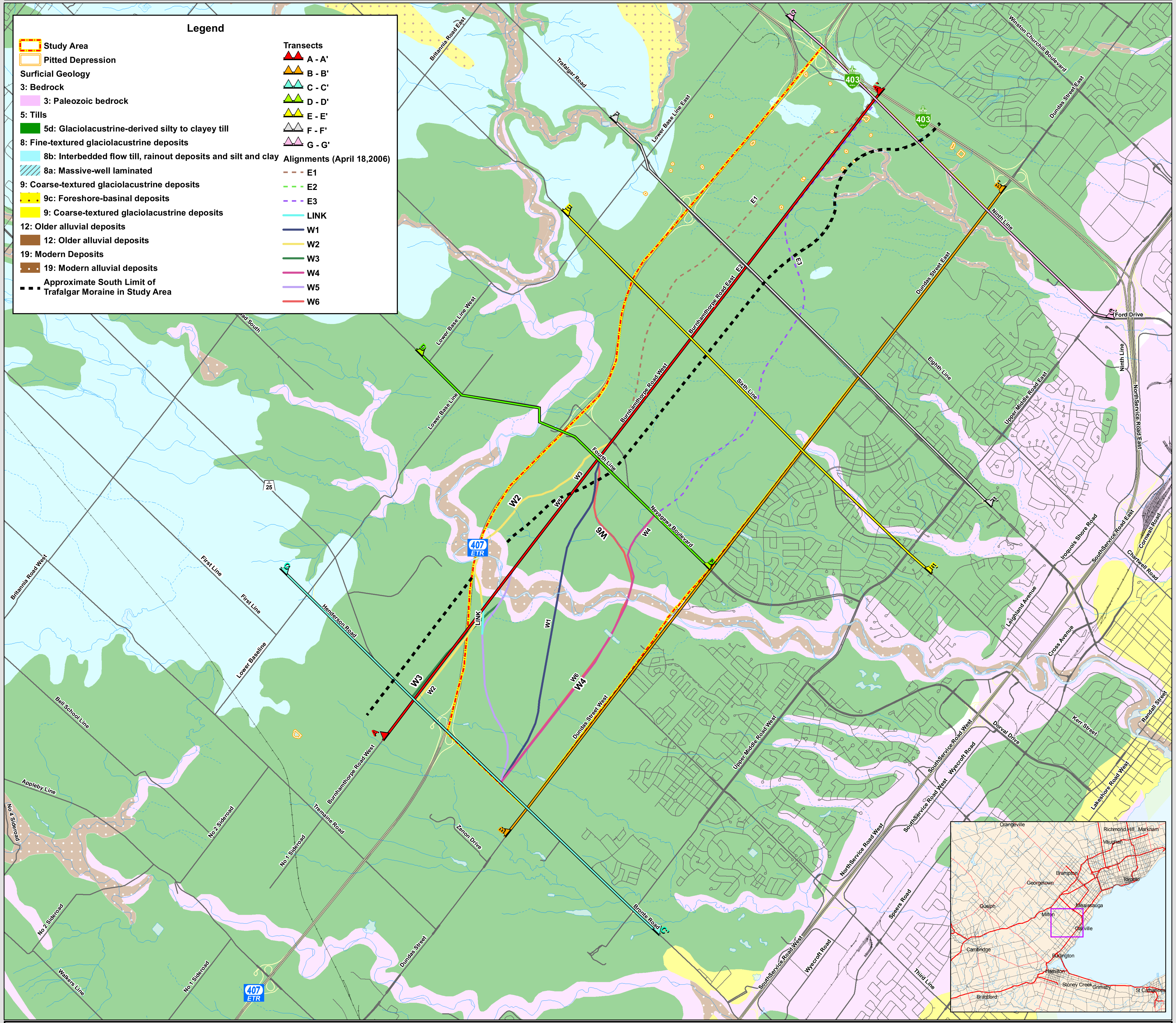
Figures

Figure 1: Surficial Geology

New North Oakville Transportation Corridor



Basemapping from OMNR
Projection: UTM NAD83 Zone 17

0 0.5 1 2 Kilometers

1:27,500

Surficial Geology

May 2008
Project 40875

Figure 1

Map Document: (N:\Projects\2004\40875\2006\Final\GIS\Spatial\40875SurficialGeology.mxd)
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LEGEND

- Sand/Silty Sand/Gravelly Sand
- Silt/Sandy Silt/Clayey Silt
- Clayey Silt/Clayey Silt Till
- Shale Bedrock

- 2650 — MOE Well No.
- Original Ground
- Inferred Stratigraphic Contact
- Static Water Level (m) at Well Completion
- Inferred Water Table
- Deepest Water Found
- 5 gpm — Pumping Rate (gallons per minute) during Well Test

Disclaimer

Cross-sections shown were derived from an interpretation of Ontario Ministry of the Environment Water Well records and intended to provide a conceptual understanding of the area only. Well location, elevation, and stratigraphic information presented should be considered as very approximate. These cross-sections are provided for general information only and should not, under any circumstances, be used to support engineering design work. Gartner Lee Limited accepts no responsibility for the accuracy of the information presented.

NOTES:

Location and elevation at boreholes are approximate and are to be used for interpretation purposes only. Stratigraphy between boreholes is inferred and may vary from that shown.

SCALES
HORIZONTAL 1:20,000
200m 0 400m 800m
5m 0 10m 20m
VERTICAL 1:500

New North Oakville
Transportation Corridor

GEOLOGICAL CROSS-SECTION A-A'
ALONG BURNHAMTHORPE ROAD

Designed By: YS	Drawn By: IRL/JEP
Checked By: SU	Approved By: –
Date Issued: APRIL 2008	Project No.: 40–875
Gartner Lee	FIGURE 2

LEGEND

Sand/Silty Sand/Gravelly Sand

Silt/Sandy Silt/Clayey Silt

Clayey Silt/Clayey Silt Till

Shale Bedrock

2650 — MOE Well No.

Original Ground

Inferred Stratigraphic Contact

Static Water Level (m) at Well Completion

Inferred Water Table

Deepest Water Found

5 gpm — Pumping Rate (gallons per minute) during Well Test

Disclaimer

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SCALES

HORIZONTAL 1:20,000

200m 0 400m 800m

5m 0 10m 20m

VERTICAL 1:500

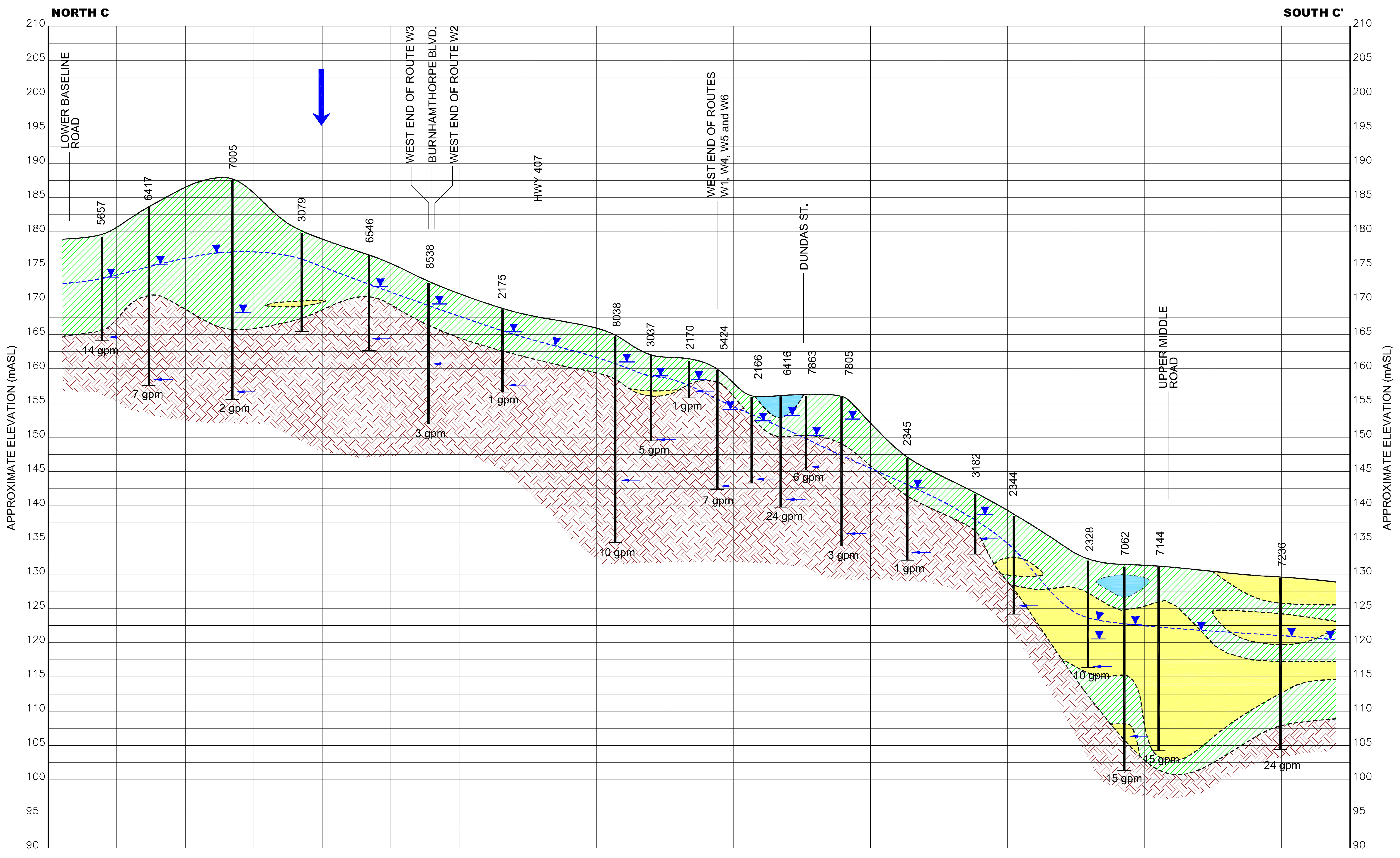
New North Oakville
Transportation Corridor

GEOLOGICAL CROSS-SECTION B-B'
ALONG DUNDAS ST.

Designed By: YS	Drawn By: IRL/JEP
Checked By: SU	Approved By: –
Date Issued: APRIL 2008	Project No.: 40–875

Gartner Lee

FIGURE 3



LEGEND

- Sand/Silty Sand/Gravelly Sand
- Silt/Sandy Silt/Clayey Silt
- Clayey Silt/Clayey Silt Till
- Shale Bedrock

- 2650 — MOE Well No.
- Original Ground
- Inferred Stratigraphic Contact
- Static Water Level (m) at Well Completion
- Inferred Water Table
- Deepest Water Found
- 5 gpm — Pumping Rate (gallons per minute) during Well Test
- Southern Limit of the Trafalgar Moraine

Disclaimer

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SCALES

HORIZONTAL 1:20,000 — 200m 0 400m 800m

VERTICAL 1:500 — 5m 0 10m 20m

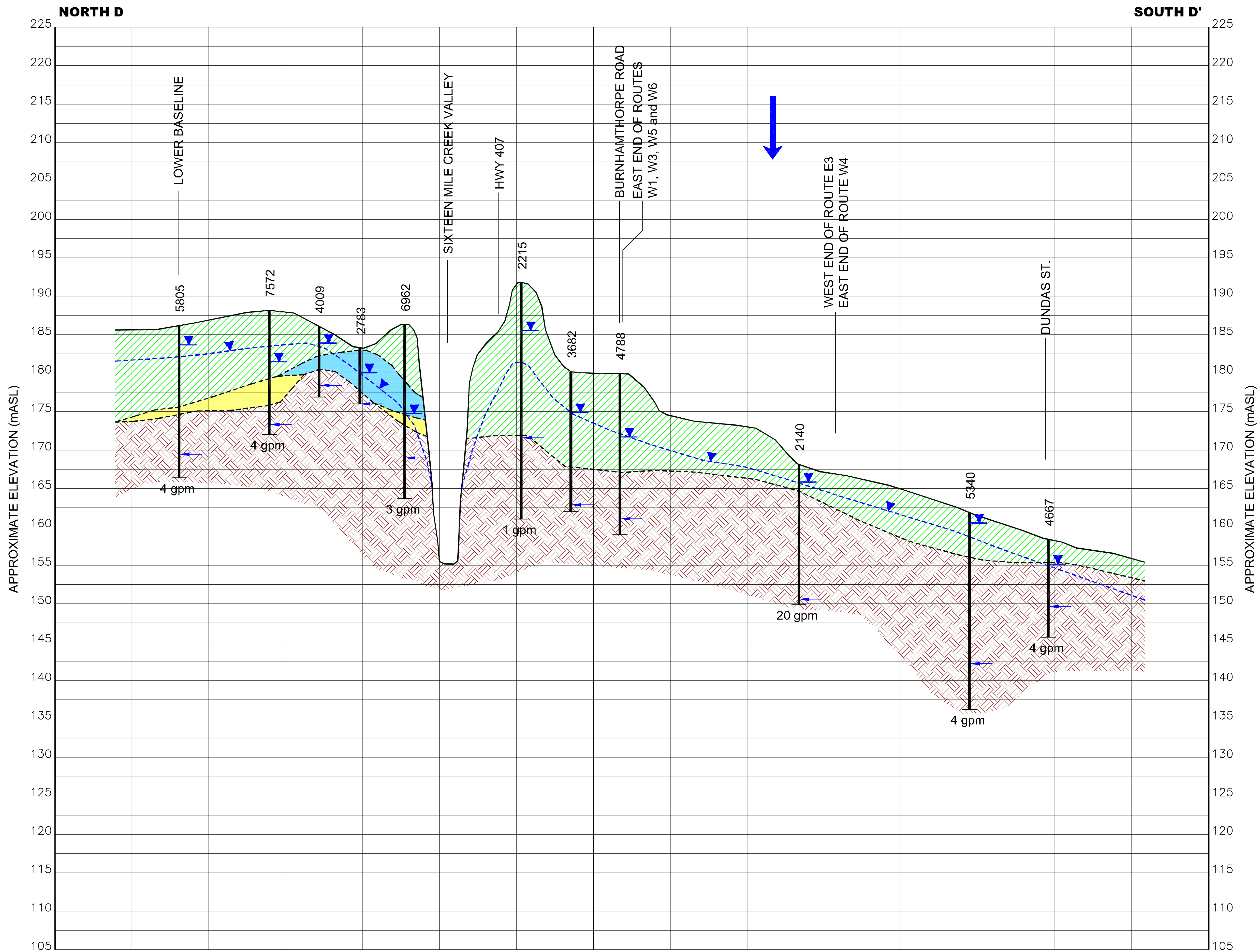
New North Oakville Transportation Corridor

GEOLOGICAL CROSS-SECTION C-C'
ALONG HWY #25 AND BRONTE ROAD

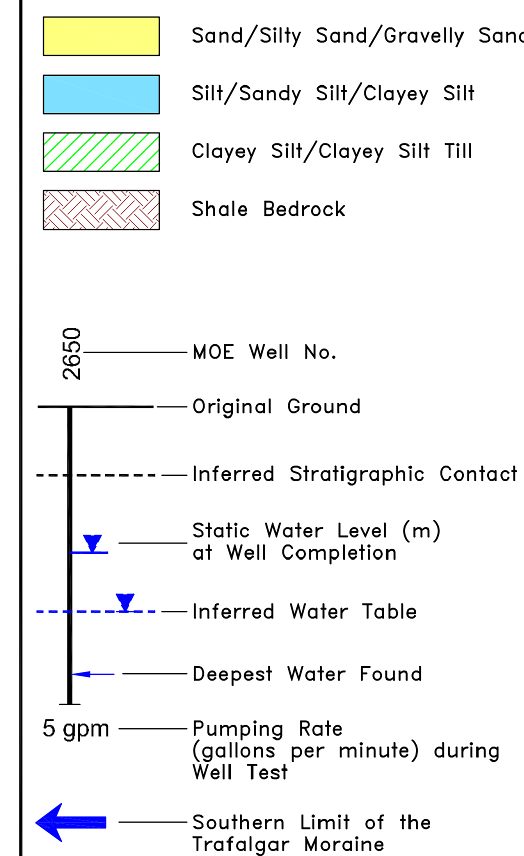
Designed By: YS	Drawn By: IRL/JEP
Checked By: SU	Approved By: –
Date Issued: APRIL 2008	Project No.: 40–875

Gartner Lee

FIGURE 4



LEGEND



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NOTES:

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SCALES

HORIZONTAL 1:20,000

200m 0 400m 800m

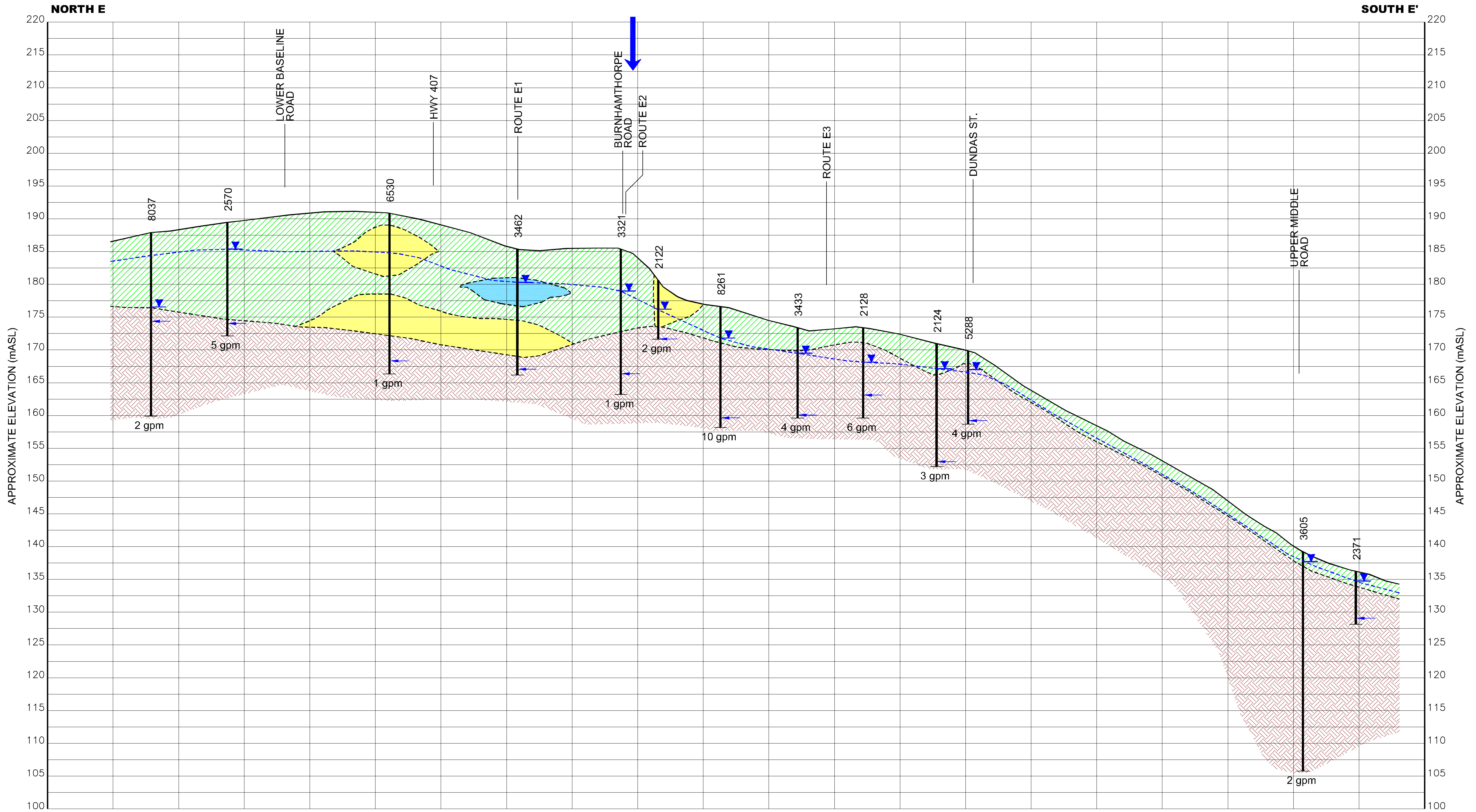
5m 0 10m 20m

VERTICAL 1:500

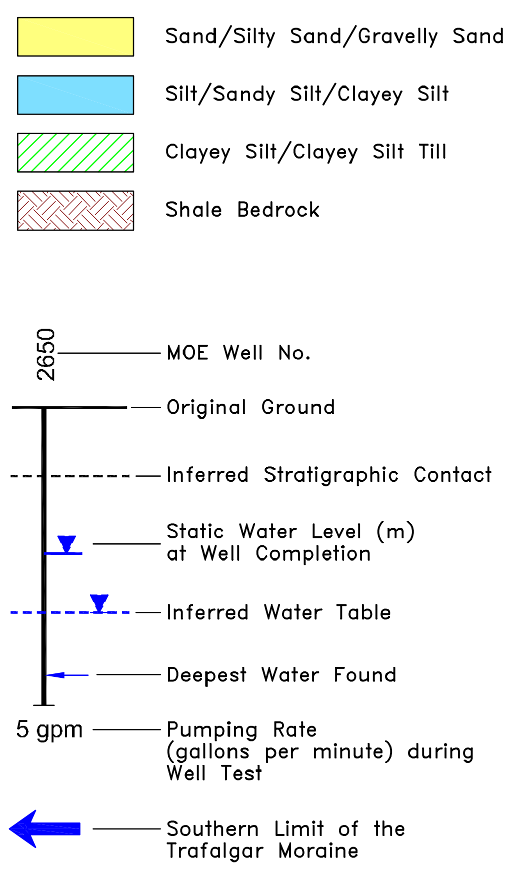
New North Oakville
Transportation Corridor

GEOLOGICAL CROSS-SECTION D-D'
ALONG NEYAGAWA BLVD.

Designed By: YS	Drawn By: IRL/JEP
Checked By: SU	Approved By: –
Date Issued: APRIL 2008	Project No.: 40–875
Gartner Lee	FIGURE 5



LEGEND



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SCALES

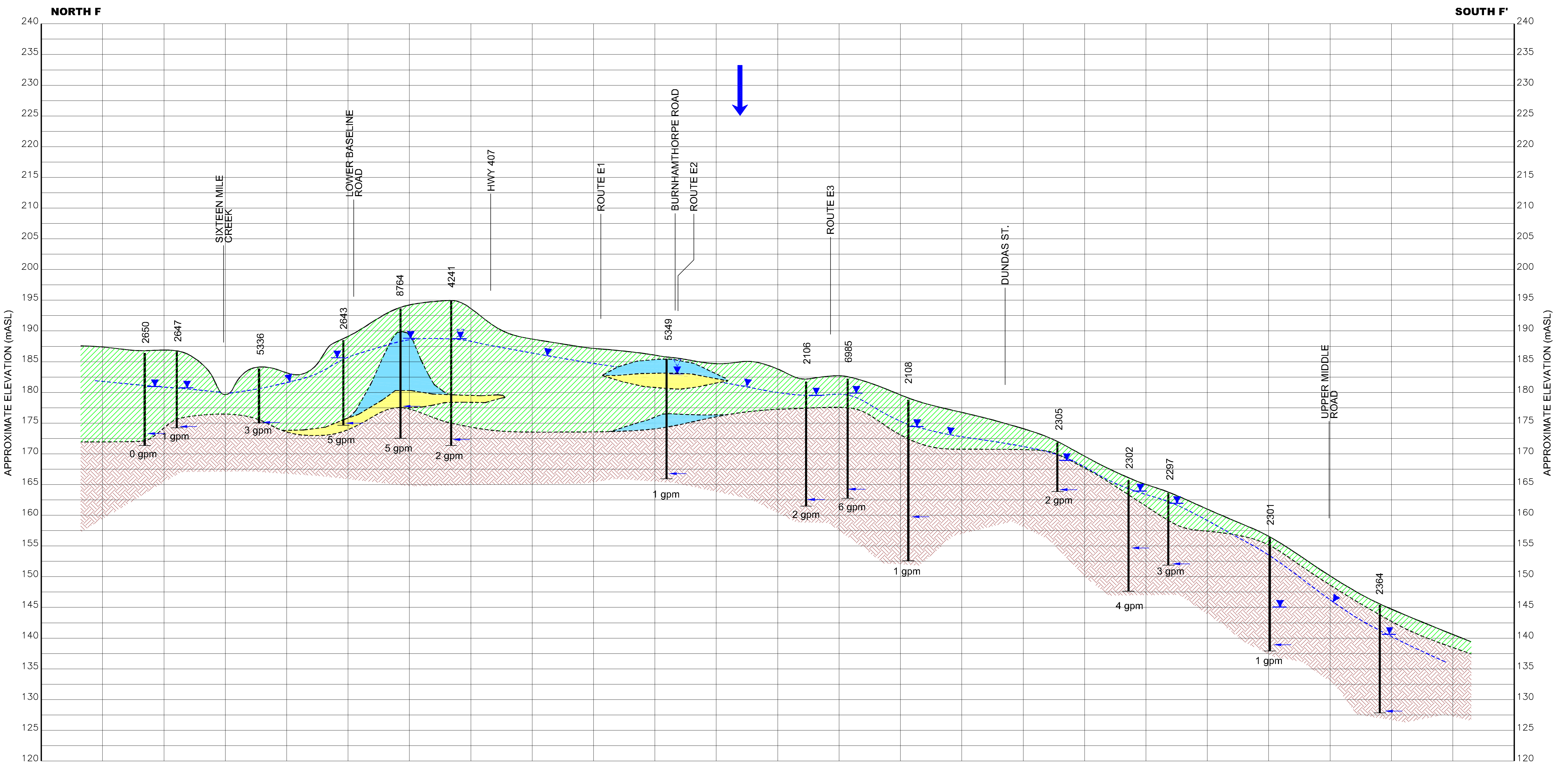
HORIZONTAL 1:20,000 (200m, 0, 400m, 800m)

VERTICAL 1:500 (5m, 0, 10m, 20m)

New North Oakville Transportation Corridor

GEOLOGICAL CROSS-SECTION E-E'
ALONG 6th LINE ROAD

Designed By: –	Drawn By: IRL/JEP
Checked By: –	Approved By: –
Date Issued: APRIL 2008	Project No.: 40–875
Gartner Lee	FIGURE 6



LEGEND

- Sand/Silty Sand/Gravelly Sand
- Silt/Sandy Silt/Clayey Silt
- Clayey Silt/Clayey Silt Till
- Shale Bedrock

2650 — MOE Well No.
— Original Ground
— Inferred Stratigraphic Contact
— Static Water Level (m) at Well Completion
— Inferred Water Table
— Deepest Water Found
5 gpm — Pumping Rate (gallons per minute) during Well Test
— Southern Limit of the Trafalgar Moraine

Disclaimer

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NOTES:

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SCALES

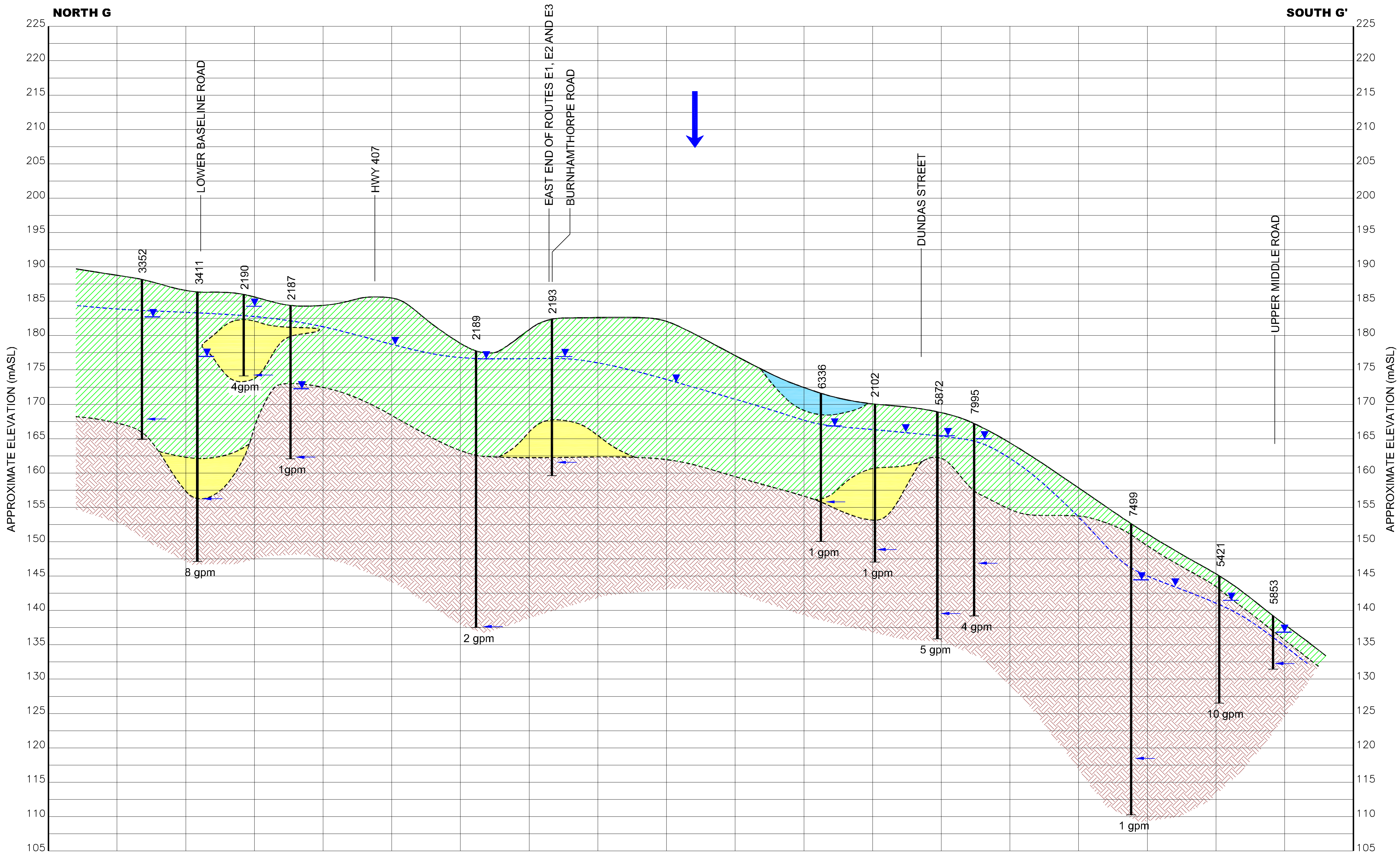
HORIZONTAL 1:20,000 — 200m 0 400m 800m

VERTICAL 1:500 — 5m 0 10m 20m

New North Oakville
Transportation Corridor

GEOLOGICAL CROSS-SECTION F-F'
ALONG TRAFALGAR ROAD

Designed By: YS	Drawn By: IRL/JEP
Checked By: SU	Approved By: –
Date Issued: APRIL 2008	Project No.: 40–875
Gartner Lee	FIGURE 7



LEGEND

Sand/Silty Sand/Gravelly Sand

Silt/Sandy Silt/Clayey Silt

Clayey Silt/Clayey Silt Till

Shale Bedrock

2650 MOE Well No.

Original Ground

Inferred Stratigraphic Contact

Static Water Level (m) at Well Completion

Inferred Water Table

Deepest Water Found

5 gpm Pumping Rate (gallons per minute) during Well Test

Southern Limit of the Trafalgar Moraine

Disclaimer

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SCALES

HORIZONTAL 1:20,000

200m 0 400m 800m

5m 0 10m 20m

VERTICAL 1:500

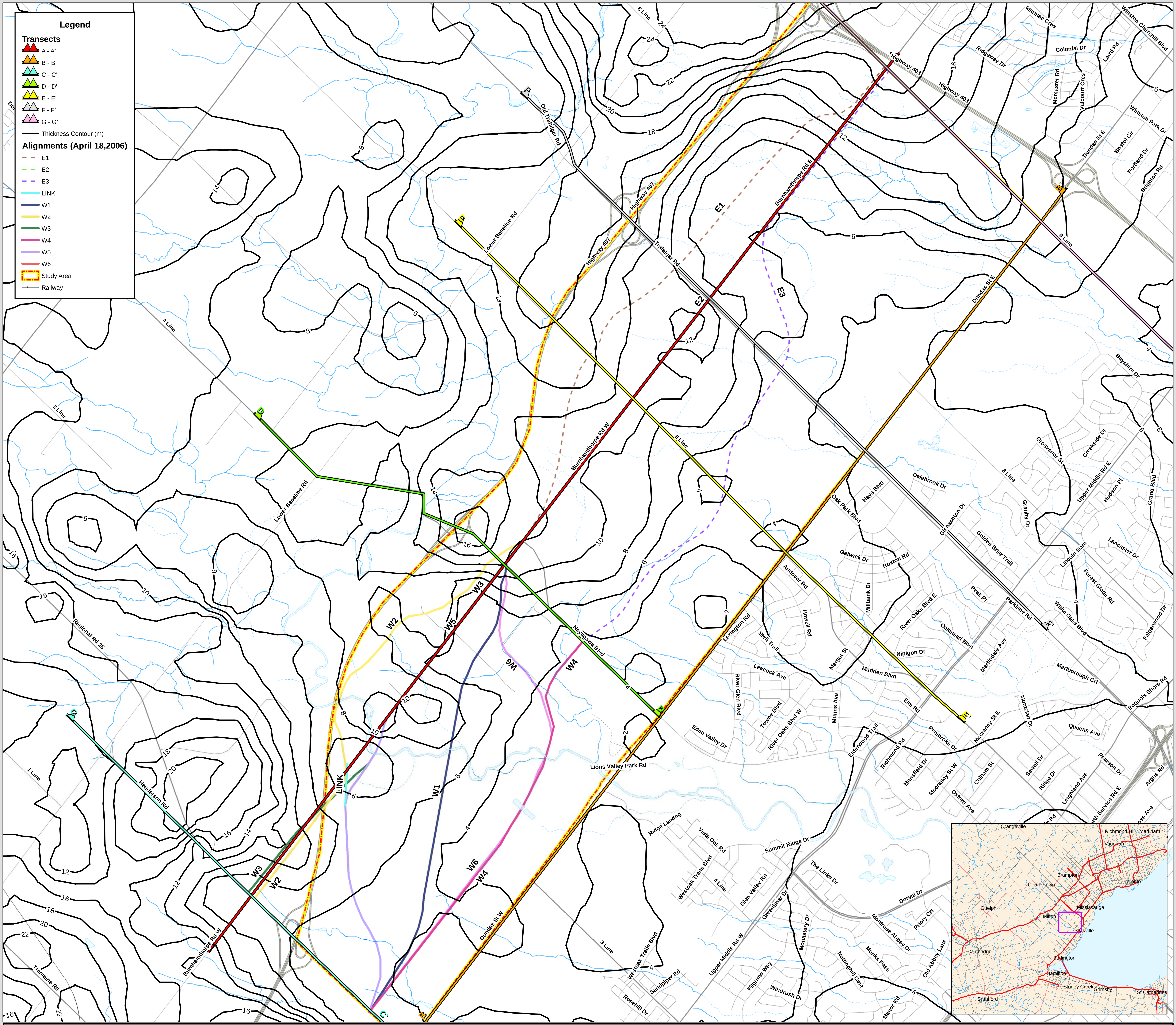
New North Oakville Transportation Corridor

GEOLOGICAL CROSS-SECTION G-G' ALONG 9TH LINE ROAD

Designed By: YS	Drawn By: JMC
Checked By: SU	Approved By: –
Date Issued: APRIL 2008	Project No.: 40–875
Gartner Lee	FIGURE 8

Figure 9: Overburden Thickness Contours

New North Oakville Transportation Corridor



Basemapping from OMNR
Projection: UTM NAD83 Zone 17

0 250 500 1,000 1,500 m

1:20,000

Overburden Thickness

May 2006
Project 40875

Figure 9

Map Document: (N:\Projects\2004\40875\2006\Final\GIS\Spatial\40875OverburdenThickness.mxd)
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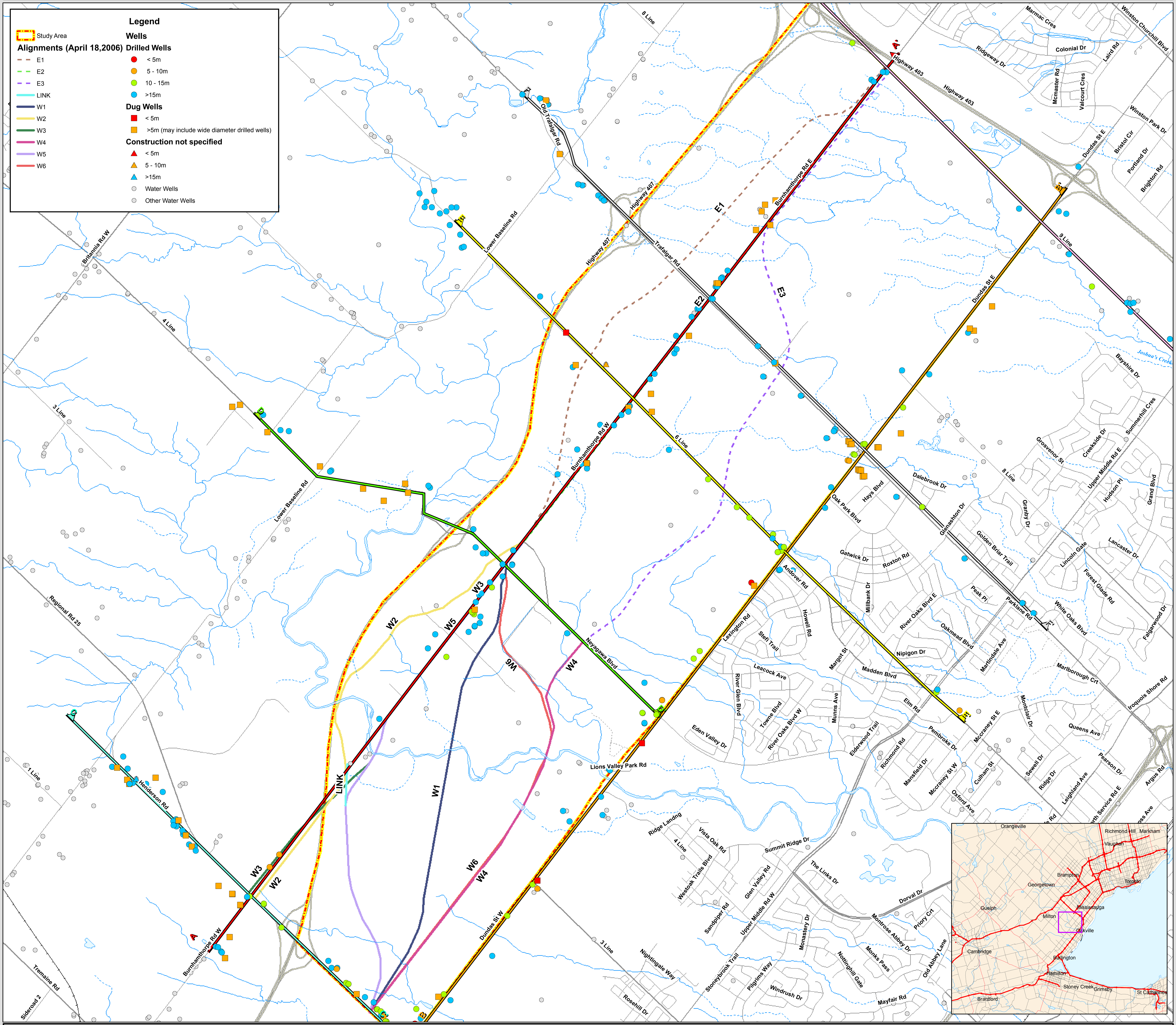
Figure 10: Well Location

New North Oakville Transportation Corridor



Basemapping from OMNR
Projection: UTM NAD83 Zone 17

0 250 500 1,000 1,500 m

1:20,000

Well Location

Gartner Lee

May 2006
Project 40875

Figure 10

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