GEOTECHNICAL INVESTIGATION

PROPOSED TOWNHOUSE DEVELOPMENT

233 UPPER QUEEN STREET, THORNDALE, ON

LDS PROJECT NO. GE-00630

FEBRUARY 24, 2022

Submitted to:

RAND DEVELOPMENTS
1304 SANDBAR STREET
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Appendices

1. INTRODUCTION

LDS Consultants Inc. (LDS) has been retained by RAND Developments to conduct a Geotechnical Assessment for proposed townhouse development located at municipal number (MN) 233 Upper Queen Street, Thorndale, ON. The subject site is located along the south side of Upper Queen Street, east of Agnes Street. A Key Plan showing the site location is provided on Figure 1, below.

Figure 1: Key Plan

1.1 Site Description

A review of aerial photographs dating back to 2006 indicates that the site is occupied by a single residential dwelling, with a garage structure, at the north end of the property, while the rest area of the property is grass-covered and vacant. The site is irregular in shape. From a topographical perspective, the ground surface exhibits a gradual relief of approximately 2 m, sloping down from north to south. The subject site is bordered by residential lands and community baseball court to the south, east and west, Upper Queen Street to the north.

1.2 Terms of Reference

It is understood that the proposed townhouse development will consist of 41 units, within the subject site. This geotechnical report has been prepared for the purposes of providing geotechnical comments and recommendations to support the design and construction of the proposed buildings.

This report provides a summary of the borehole findings (documenting soil and groundwater conditions at the site). The report provides geotechnical comments and recommendations for the proposed development, including: site preparation (including the removal of existing building, the re-use of excavated materials as engineered fill, structural fill, and service trench backfill), temporary excavations (including maximum slope inclinations, excavation support and lateral earth pressures), groundwater control (including the need for a Permit to Take Water or Environmental Activity and Sector Registry submission), foundation design (including soil bearing capacity, subgrade preparation, and potential settlements), slab-on-grade construction (including modulus of subgrade reaction), foundation drainage and backfilling, seismic design considerations, site servicing (including re-use of onsite soils in service trenches), pavement design (including pavement component thickness for local roads, and reinstating service connections which extend into the municipal right-of-way) and excess soil management discussion.

The report also provides preliminary information about the characterization of the hydrogeological setting for the site, including: characterization of the hydrologic and hydrogeological setting, a summary of MECP well records within 100 m of the site, stormwater management considerations (including factored soil infiltration rates and a discussion of limitations which result from soil and/or shallow groundwater conditions), a discussion of the potential effects on shallow groundwater at the site, as it relates to the proposed construction.

This report is provided on the basis of the terms noted above, and on the assumption that the design will follow applicable codes and standards. The site investigation and recommendations provided in this report follow generally accepted practice for geotechnical consultants in Ontario. The format and content of this report has been guided to address specific client needs. LDS has provided engineering guidelines for the geotechnical design and construction at the site.

If there are any changes in the design features as a result of municipal review and approval, LDS should be afforded the opportunity to review such changes to confirm that geotechnical requirements remain appropriate to support the design.

Laboratory testing, where applicable, follows ASTM or CSA Standards.

2. INVESTIGATION PROGRAM

2.1 Review of Published Information

2.1.1 Review of Geological Mapping

Select geological mapping and publications were reviewed for the purposes of reviewing regional characteristics for soil conditions in the area. Findings are summarized below, for reference.

Physiography & Quaternary Geology

Physiographic mapping for Southwestern Ontario *(Chapman, L.J. and Putnam, D.F. 2007. Physiography of Southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 228)*, identifies that subject site is located within the Physiographic Region known as the Stratford Till Plain. The site is located at the boundary area between spillways and undrumlinized till plains, and as such, the subgrade soils are expected to be comprised of silt and silt till deposits, with intermittent wet sand and sandy silt layers.

Quaternary geology mapping *(Ontario Geological Survey 2000. Quaternary geology, seamless coverage of the Province of Ontario; Ontario Geological Survey, Data Set 14---Revised)* indicates that the study area consists of Tavistock Till including sandy silt to silt matrix and Glaciofluvial Outwash deposits including gravel and sand.

Bedrock Geology

Bedrock geology mapping for Southwestern Ontario *(Ontario Geological Survey. 1:250 000 scale, Bedrock Geology of Ontario. Ontario Geological Survey, Miscellaneous Release Data 126, Revised 2006)* indicates that bedrock in the general area consists of limestone, dolostone and shale from the Dundee Formation.

Geological publications and well records in the area indicate that the bedrock surface is approximately below 19 to 23 m of overburden soils in the vicinity of the site. Bedrock was not encountered during the fieldwork for this investigation.

2.1.2 UTRCA Generic Regulation

In May 2006, Ontario Regulation 157/06 came into effect in the Upper Thames River Conservation Authority (UTRCA) watershed, which locally implements the Generic Regulation (Development, Interference with Wetlands and Alterations to Shoreline and Watercourses). This regulation replaces the former Fill, Construction and Alteration to Waterways regulations, and is intended to ensure public safety, prevent property damage and social disruption, due to natural hazards such as flooding and erosion. Ontario Regulation 157/06 is implemented by the local Conservation Authority, by means of permit issuance for works in or near watercourses, valleys, wetlands, or shorelines, when required.

The site is <u>not</u> located within the UTRCA Regulated Lands, therefore development of the subject property is not expected to require a Section 28 permit or other approvals from the UTRCA.

2.1.3 Source Water Protection Mapping

Where proposed developments are being planned, it is important to determine the presence of Significant Groundwater Recharge Areas and High Vulnerability Aquifers in the area. These areas are protected under the Clean Water Act (2006). In general, Significant Groundwater Recharge Areas are defined as areas where water seeps into an aquifer from rain and melting snow, supplying water to the underlying aquifer. A highly vulnerable aquifer occurs where the subsurface material offers limited protection from contamination resulting from surface activities.

LDS has reviewed the MECP Source Water Protection Information to determine whether the site is located in any identified areas of source water concern, as they relate to local groundwater quality (current to June 16, 2021). The property is located within the Upper Thames River Source Protection Area, and the following observations are noted for the site:

- The Property is <u>not</u> located in any of the following designated areas listed in the MECP Source Protection mapping:
  - Wellhead Protection Area, Wellhead Protection Area E (GUDI), Wellhead Protection Area Q1 or Wellhead Protection Area Q2;
  - Intake Protection Zone or Intake Protection Zone Q;
  - Significant Groundwater Recharge Area;
  - Highly Vulnerable Aquifer;
  - Issue Contributing Area; and,
  - Event Based Area.

The above comments are demonstrated on Drawing 1, in Appendix A.

2.1.4 MECP Well Record Review

A review of local well records available through the Ministry of Environment, Conservation, and Parks (MECP) for this area was carried out to review the water levels recorded in the nearby wells. Drawings C1 and C2 in Appendix C shows the location of the wells (with corresponding Well Registration No.) which are in close proximity (within 100 m) of the site.

The water supply wells noted in the records are set in the intermediate (15 to 30 m depth) and deep (more than 30 m depth) overburden aquifers. Static water level in the water supply wells is reported at depths ranging from 2.1 m to 10.7 m.

One well record is identified as an observation wells, and three well abandonment records (Wells 7048800, 7052246 and 7121020) are included in the well records. In general, the observation well and abandoned holes are recorded at varying depths (from less than 15 m depth to deeper than 30 m depth) within the well records.

The water supply wells and observation wells are summarized in the following table, for reference.

Table 1: MECP Well Record Summary

MECP Well ID	Registration Year	Well Type	Depth of Well (m)	Depth Water Found (m)	Static Water Level (m)	Pump Rate (L/min)
Water Supply Wells						
4105033	23-Jun-70	Domestic	22.86	22.56	3.05	37.85
4104105	23-Oct-47	Domestic	34.75	2.13	2.13	30.28
4105977	14-Aug-72	Domestic	32.00	32.00	3.05	30.28
4111362	12-Aug-88	Domestic	35.05	34.75	4.88	37.85
4110221	21-May-85	Domestic	35.66	35.66	3.66	37.85
4110071	03-Aug-84	Livestock	30.78	30.78	3.35	34.07
4114790	25-Oct-01	Domestic	31.39	31.39	3.66	45.42
4114800	30-Oct-01	Domestic	32.61	32.61	4.27	45.42
4115429	23-Sep-03	Domestic	31.39	31.39	10.67	45.42
4110070	24-Aug-84	Domestic	28.96	24.38	3.96	37.85
4110499	03-Jun-86	Domestic	31.70	31.70	4.88	26.50
Observation Wells						
7176180	08-Dec-11	Monitoring	6.9	3.1	*NR*	*NR*
NR: Not recorded						

2.2 Field Program

LDS field staff and the drilling contractor carried out a Safety Meeting prior to drilling at the site, which included a review of the underground utility locates completed through Ontario-One-Call and with a private locator, in preparation for the drilling program.

LDS carried out a field program consisting of five (5) boreholes (denoted as BH1 through BH5), drilled on January 20th, 2022. The boreholes were advanced at the site by a local drilling-contractor, using a track-mounted drill-rig. The boreholes were advanced to depths ranging from 5.0 to 6.6 m below existing grade (m bgs).

Within the boreholes, Standard Penetration Tests (SPTs) were performed to assess the compactness of the underlying soils and to obtain representative samples. The SPT testing was carried out using a 63.5 kg drop hammer, falling from a height of 0.76 m. The fieldwork was supervised by a member of LDS' technical staff. During the drilling, the stratigraphy in the boreholes was examined and logged in the field by LDS geotechnical personnel. All samples recovered from the site were returned to LDS for detailed examination and selective testing. During collection, all samples were assessed from a visual and olfactory perspective to determine if there were any obvious signs of contamination or environmental impact. No discernible impacts were identified in the collected samples. Short-term groundwater level observations within the open boreholes and the natural moisture contents of recovered soil samples were recorded on the borehole logs.

Ground surface elevations at the borehole locations were surveyed by LDS using a Trimble R10 GPS rover. The location of the boreholes is summarized below, and illustrated on Drawing 2, in Appendix A. It should be noted that the elevations at the as-drilled borehole locations were not provided by a professional surveyor and should be considered to be approximate. Contractors performing any work referenced to the borehole elevations should confirm the borehole elevations for their work.

Table 2: Borehole Locations (UTM 17T)

Location	Northing, m N	Easting, m E	Ground Surface Elevation (m asl)
BH1	4772239.68	488317.32	286.10
BH2	4772221.94	488357.50	286.32
BH3	4772168.37	488350.93	285.41
BH4	4772122.10	488396.36	285.35
BH5	4772119.77	488346.38	284.67

The depth to groundwater seepage and short-term water level measurements were obtained prior to backfilling the boreholes. Boreholes were backfilled with a mixture of bentonite chips and cuttings, to restore holes back to level conditions with the ground surface.

Monitoring wells were installed in three of the boreholes (BH2 to BH4) to allow for monitoring the stabilized groundwater level at the site. Wells are comprised of a 50 mm diameter CPVC pipe, with a slotted and filtered screen. Details of monitoring well construction are provided on the attached borehole logs. The screens on each well are mill-slotted, with a slot spacing of 0.5 mm, and were backfilled with Type 2 Silica Sand. Above the screened depth, the annular space was backfilled with a bentonite slurry, up to ground surface. The wells have been equipped with lockable caps. The monitoring wells have been registered with the Ministry of Environment, Conservation, and Parks (MECP), in accordance with Ontario Regulation (O.Reg.) 903.

Table 3 (below) summarizes the well construction details.

Table 3: Well Construction Details

Borehole	Ground Surface Elevation, m	Well Installation Depth, m	Screened Length, m	Screened Strata
BH2/MW	286.32	4.57	1.52	Silt Till, some sand inclusions
BH3/MW	285.41	6.10	3.05	Silt Till / Sand and Gravel
BH4/MW	285.35	4.57	1.52	Silt Till, some sand inclusions

The depth to groundwater seepage and short-term water level measurements were obtained prior to backfilling the remaining boreholes. Boreholes were backfilled with a mixture of bentonite chips and cuttings, to restore holes back to level conditions with the ground surface.

2.3 Geotechnical Laboratory Testing

All samples recovered from the site were returned to LDS for detailed examination and selective testing. Routine moisture content determinations were carried out on select samples. One (1) grain size analysis was carried out on a select sample. The results are presented on the borehole logs provided in Appendix B.

Collected soil samples will be disposed of, following the issuance of the Geotechnical Report, unless prior arrangements have been made for longer term storage.

3. SUMMARIZED CONDITIONS

3.1 Borehole Findings

A total of five (5) boreholes were advanced at the site to examine soil and shallow groundwater conditions. The borehole locations are shown on Drawing 2, in Appendix A. In general, soils observed in the boreholes consisted of topsoil and fill materials overlying native sandy silt and silt till with sand and gravel layers. General descriptions of subsurface conditions are summarized in the following sections. Borehole logs are provided in Appendix B, for reference. It should be noted that boundaries of soil indicated in the borehole logs are inferred from non-continuous sampling and observations during drilling. These boundaries reflect transition zones for the purposes of geotechnical design and should not be interpreted as exact planes of geological change.

Topsoil

Topsoil with thicknesses ranging from 150 mm to 250 mm was encountered surficially in all boreholes. The topsoil consisted of dark brown silty loam. The topsoil was in a moist state at the time of the fieldwork, based on visual and tactile examination.

It should be noted that topsoil quantities noted above are based on information provided at the borehole locations only, and may vary in areas with existing vegetation and tree cover. If required, a more detailed analysis (involving additional shallow test pits) is recommended to accurately quantify the amount of topsoil to be removed for construction purposes.

Fill Materials

Fill materials consisting of sandy silt were encountered underlying the topsoil in Boreholes BH1 and BH2, and extended to a depth of 1.4 m bgs. The fills are in a loose state of compactness, based on Standard Penetration Test (SPT) N-values ranging from 6 to 7 blows per 0.3 m of split-spoon sampler penetration. Based on the field visual inspection, the fill materials were moist to wet. Moisture content determinations conducted on the recovered sample yielded 11.9 to 21.2 percent.

Sandy Silt

A layer of sandy silt deposit was encountered below the topsoil in Boreholes BH3 to BH5, and extended to a depth of 1.4 m bgs. The sandy silt was described as brown in colour, and contained a trace of clay and gravel. The SPT N-values range from 5 to 11 blows per 0.3 m of split spoon sampler penetration, indicating a loose to compact state of compactness. Based on the field visual inspection, the sandy silt was moist to wet. Moisture content determinations conducted on recovered samples range between 14.2 and 24.3 percent.

Silt Till

The predominant soil at the site is silt till, encountered below fill materials and sandy silt soil in all boreholes. The silt till extended to terminal depths ranging from 5.0 to 6.6 m bgs. The silt till was described as brown to grey in colour, and contained some sand and a trace of clay and gravel. The SPT N-values range from 11 to over 50 blows per 0.3 m of split spoon sampler penetration, indicating a compact to very dense state of compactness. Based on the field visual inspection, the till was moist. Moisture content determinations conducted on recovered samples range between 6.0 and 16.2 percent.

Sand and Gravel

Sand and gravel deposit was encountered within the silt till in Borehole BH3, and extended to a depth of 4.0 m bgs. Standard Penetration Test (SPT) N-value yielded 73 blows per 0.3 m of split-spoon sampler penetration, indicating a very dense state of compactness. Based on the field visual inspection, the sand and gravel was moist to saturated. Moisture content determinations conducted on recovered sample yielded 8.0 percent. One sample of the sand and gravel deposit was submitted for gradation analyses. The results are summarized in Table 4 below and are also shown graphically in Appendix B.

Table 4: Results of Gradation Analysis, Sand and Gravel

Sample ID	Unified Soil Classification		
	% Fines (Silt & Clay)	% Sand	% Gravel
BH3 SA4	17.6	46.0	36.4

3.2 Estimate of Soil Hydraulic Conductivity

The hydraulic conductivity of a soil depends on a number of factors, including particle size distribution, degree of saturation, compactness, adsorbed water (which depends on clay content). The heterogeneous nature of glacial deposits can also contribute to variations in soil permeability where the soil composition may include localized areas with increased fine material or sandy material which can influence soil permeability at different points within the soil strata.

The soil permeability of the select sand sample was assessed by the methods of correlation of hydraulic conductivity and factored infiltration rates based on the results of gradation analyses on the collected sample.

Grain Size Analyses

Based on the gradation results of the predominantly sandy soils presented in Section 3.1, the following values for saturated hydraulic conductivity have been determined for the sandy soils encountered across the site. Hazen's method was used to correlate the grain size analysis to the hydraulic conductivity of the sand soils. This correlation is based on the following relationship:

$$k \text{ (cm/s)} = C(d_{10})^2$$

where, d_{10} is the diameter (size measured in mm) at which 10% of the sample passes; and,
C is an empirical coefficient (average value of 1.0).

Table 5: Hydraulic Conductivity and Factored Infiltration Rates from Hazen's Method

Sample ID	Sample Composition			Parameter		
	% Silt & Clay	% Sand	% Gravel	D_{10} (mm)	Saturated Hydraulic Conductivity (m/sec)	Factored Infiltration Rate (mm/hr)
BH3 SA4	17.6	46.0	36.4	0.03	9.0 $\times 10^{-6}$	28

The natural water-bearing sand and gravel soil has a saturated hydraulic conductivity in the range of 10^{-5} to 10^{-6} m/s, based on the above results.

The infiltration rates displayed in Table 5 have been calculated using correlation from TRCA/CVC Low Impact Development Stormwater Management Planning and Design Guide protocol which references *Ontario Ministry of Municipal Affairs and Housing (OMMAH). 1997. Supplementary Guidelines to the Ontario Building Code 1997. SG-6 Percolation Time and Soil Descriptions. Toronto, Ontario.* A Factor of Safety of 2.5 has been applied, in accordance with TRCA/CVC Low Impact Development Stormwater Management Planning and Design Guide protocol.

Onsite Verification During Construction

A number of factors can influence the actual soil permeability and infiltration rate onsite during the site grading activities, including cut-fill activities, and the use of onsite or imported materials to achieve design grades. It is recommended that geotechnical inspection of materials which are used onsite and field testing during the construction phase of the project be carried out to confirm that infiltration rates which have been used for design purposes are appropriate to the actual site conditions.

3.3 Shallow Groundwater Conditions

All boreholes were observed open and dry upon completion of drilling. Stabilized water level measurements were recorded in the monitoring wells installed across the site on January 25th and February 23rd, 2022, and are summarized in the following table.

Table 6: Stabilized Groundwater Observations

Monitoring Well	Ground Surface Elev. (m, asl)	Depth to Groundwater (m, bgs) *Groundwater Elevation (m, asl)*	
		January 25th, 2022	February 23rd, 2022
BH2/MW	286.32	1.01 *285.31*	0.21 *286.11*
BH3/MW	285.41	0.70 *284.71*	0.11 *285.30*
BH4/MW	285.35	0.89 *284.46*	0.16 *285.19*

The groundwater flow direction interpreted from the water level measurements collected by LDS indicates a shallow groundwater flow direction towards the south.

Based on the predominant soil conditions encountered in the boreholes, shallow groundwater is present within the sandy soils and weathered soils near surface during the monitoring period, with the water being perched above the silt till soils. This groundwater may be seasonal in nature, with water being present during wet periods, and spring conditions. Lower sand and gravel soils also appear to contain the shallow groundwater.

It should be anticipated that shallow groundwater levels will vary in response to climatic or seasonal conditions, and, as such, may differ at the time of construction. During wet periods (heavy rains and melt periods), it is anticipated that surface water infiltration into the weathered soils near surface occurs, and causes the temporary presence of groundwater at shallow depths, resulting in nominal groundwater seepage from open excavations.

4. GEOTECHNICAL COMMENTS AND DISCUSSION

Based on the site plan provided, it is understood that a total of 41 townhouses are proposed at the subject site.

The boreholes generally revealed a layer of topsoil and fill materials overlying competent natural sandy silt and silt till deposits.

Shallow groundwater levels were recorded in the monitoring wells at depths ranging from 0.1 to 1.0 m bgs, corresponding to Elevations between 286.1 m asl and 284.5 m asl. It should be anticipated that shallow groundwater will vary in response to climatic or seasonal conditions, and, as such, may differ at the time of construction. During wet periods (heavy rains and melt periods), it is anticipated that surface water infiltration into the weathered soils near surface occurs, and causes the temporary presence of groundwater at shallow depths, resulting in nominal groundwater seepage from open excavations. During the drier summer months, infiltrated surface water which provides a source for shallow groundwater is expected to be less pronounced.

The following sections of this report provide geotechnical comments and recommendations to assist with design and construction of the proposed residential development, including: site preparation (including the removal of existing building, the re-use of excavated materials as engineered fill, structural fill, and service trench backfill), temporary excavations (including maximum slope inclinations, excavation support and lateral earth pressures), groundwater control (including the need for a Permit to Take Water or Environmental Activity and Sector Registry submission), foundation design (including soil bearing capacity, subgrade preparation, and potential settlements), slab-on-grade construction (including modulus of subgrade reaction), foundation drainage and backfilling, seismic design considerations, site servicing (including re-use of onsite soils in service trenches), pavement design (including pavement component thickness for local roads, and reinstating service connections which extend into the municipal right-of-way) and excess soil management discussion.

4.1 Site Preparation

4.1.1 Building Demolition and Removal

The subject site is currently occupied by a single residential dwelling. It is anticipated that the existing structures on site will be removed prior to the site grading activities.

Based on the age of the existing buildings, it is possible that hazardous buildings materials and/or designated substances may be present. Owner requirements are set forth by the Ontario Ministry of Labour (MOL) under Ontario Regulation (O.Reg.) 490/09: Designated Substances; Section 30(1) of the Ontario Occupational Health and Safety Act (OHSA); and Section 10 of O.Reg. 278/05: Designated Substance – Asbestos on Construction Projects and in Buildings and Repair Operations, as amended. It is recommended to complete a Designated Substances Survey / Hazardous Building Materials Survey (DSS/HMS) for the Site building prior to demolition to identify any hazardous substances within the premises and to provide guidance on how to handle/maintain any such products during the demolition.

It is recommended that the building foundations (including foundation walls, footings and floor slabs), be completely removed from the site, in order to prevent these becoming “hard points” under future buildings and thus cause excessive differential settlements.

The existing septic tanks is located south of the existing garage, which should be removed in their entirety. Septic tanks should be pumped out by licensed contractors, prior to being removed from the site.

4.1.2 Site Grading Activities

Based on existing site conditions, it is expected that some site grading activities may be required. Vegetation removal and topsoil stripping is anticipated throughout the area to be developed. In general, this is expected to require the removal of 150 mm to 250 mm of surficial topsoil. Thicker topsoil areas may be present between the borehole locations, and where local depressions are present at the site.

Surficial topsoil may be stockpiled on site for possible re-use as landscaping fill. In the event that material is disposed of offsite, testing of the material for transport should conform to MECP Guidelines and requirements.

As a general rule of thumb, for a balanced cut-fill site, the site grades are typically raised about 1 m. As such, the depth the shallow groundwater observed in the boreholes would generally be expected to be at or below a typical underside of footing level. As site grading design details are established, this can be checked to help ensure that shallow groundwater conditions will not adversely impact building foundations.

Prior to placement of engineered fill or new building foundations, existing fill and topsoil, vegetation and otherwise deleterious materials should be removed. Once complete, the exposed subgrade should be thoroughly proof-rolled and inspected by geotechnical field staff from LDS. If loose or otherwise unstable soils are detected in the exposed subgrade, localized sub excavation may be required to remove unsuitable soils. These areas should be restored with approved compactible fill material, placed in accordance with the engineered fill requirements noted below.

It is noted that fill material containing building debris is generally not expected to be suitable for re-use onsite, except where landscaping (non-structural) fill may be needed. Offsite disposal of these soils will require analytical testing, in accordance with MECP Guidelines and classification requirements for transport and disposal. The testing requirements for disposal will depend on the requirements outlined by the receiver.

If encountered, any existing or abandoned underground services which cross beneath the new building footprint should be removed, rerouted and/or relocated, as appropriate. Boreholes were located away from existing services, therefore the fill material associated with trench backfill within existing services trenches, if encountered, may require further site assessment to determine its suitability to be re-used onsite.

In areas which engineered fill is to be placed to raise grades (to restore former building areas, or where unstable soils have been removed), the exposed subgrade soils should be reviewed approved by the geotechnical consultant following topsoil stripping.

In accordance with the Ontario Building Code (Section 4.2.4.15), foundations may be set on fill material provided that it can be demonstrated that the fill is capable of safely supporting the building and that detrimental movement of the building will not occur. In this regard, it is recommended that any fill material placed in future building footprints be engineered and verified through an inspection and testing program. Engineered fill should consist of suitable, compactable, inorganic soils, which are free of topsoil, organics and miscellaneous debris. For best compaction results, the fill material should have a moisture content within about 3 percent of optimum, as determined by Standard Proctor testing.

The placement of the engineered fill should be monitored by the geotechnical consultant to verify that suitable materials are used, and to confirm that suitable levels of compaction are achieved. The engineered fill material should be placed in maximum 300 mm (12 inch) thick lifts and uniformly compacted to 100 percent Standard Proctor Maximum Dry Density (SPMDD). Additional notes regarding engineered fill placement are provided on Drawing 3, in Appendix A.

The existing natural subgrade soils, comprised of silty soils, may be suitable for re-use as engineered fill. The possible re-use of onsite soils should be subject to review and approval by the geotechnical consultants.

In the event that a water supply well is encountered, it should be decommissioned in accordance with the Regulations outlined in O.Reg. 903. This same regulation applies to the decommissioning of monitoring wells, when they are no longer required.

4.2 Excess Soil Management Considerations

In December of 2019, the Ministry of Environment, Conservation, and Parks (MECP) released a new regulation under the Environmental Protection Act, titled “On-Site and Excess Soil Management” to support improved management of excess construction soil. Due to Covid-19, full implementation of this regulation has been delayed, however, on January 1, 2021, Phase 1 of the new Excess Soil Regulation (O. Reg. 406/19) implementation came into effect, and Phase 2 of the Regulation was implemented on January 1, 2022.

Excess soil is defined as material that was generated during construction activities at a Site but will not be needed for grading, fill, or other purposes and therefore needs to be transported off-Site. The regulation requires a project leader to comply with specific requirements before removing excess soil from a project area. Generally, these requirements include:

- Preparation of an Assessment of Past Uses Report which is similar to a Phase One Environmental Site Assessment for the source site, to evaluate the presence of potentially contaminating activities which may have resulted in the potential for impacted soil or groundwater conditions to be present at the source site;
- Preparation and implementation of a Sampling and Analysis Plan which outlines the suggested sample locations and sampling intervals, analytical sample testing parameters, and sampling frequency;
- Preparation of a Soil Characterization Report, following the soil sampling and analytical testing;

- Preparation of an Excess Soil Destination Assessment Report which identifies where excess soils can be disposed offsite, including a review of Beneficial Reuse Sites, if the developer and/or their contractor have a potential re-use site being considered; and,
- Development and implementation of a tracking system.

Soil testing should reflect the highest concentration of contaminants of potential concern (as determined by the QP) on site. In order to adequately characterize the excess soil, the regulation prescribes a minimum number of samples to be collected, depending on soil volume excavated, as well as a minimum list of parameters to be analyzed for. The new requirements on number of samples and minimum sample parameters are summarized in the following tables.

Table 7: Minimum Number of Samples

<table>
<tr><th rowspan="2">Volume Threshold</th><th colspan="2">Minimum number of samples for Bulk Soil Analysis</th><th rowspan="2">Minimum number of samples of Leachate Analysis</th></tr>
<tr><th>Small Volume Projects</th><th>Volume Independent Projects</th></tr>
<tr><td>≤350 m3</td><td>≥ 3 samples</td><td>-</td><td>-</td></tr>
<tr><td>≤350 m3 to <600 m3</td><td rowspan="4">-</td><td>≥ 3 samples</td><td>≥ 3 samples</td></tr>
<tr><td>>600 m3 to <10,000 m3</td><td>≥1 sample for each additional 200 m^3 within threshold limits</td><td rowspan="3">3 samples + 10% of Bulk Soil samples collected</td></tr>
<tr><td>>10,000 m3 to <40,000 m3</td><td>≥1 sample for each additional 450 m^3 within threshold limits</td></tr>
<tr><td>>40,000 m3</td><td>≥1 sample for each additional 2,000 m^3 beyond threshold limit</td></tr>
</table>

Table 8: Minimum Analytical Requirements

Parameters to be analyzed	Surface (Topsoil) and Subsurface Soils
Metals (including Hydrides)	✓
Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX)	✓
Petroleum Hydrocarbons (PHCs) F1 – F4	✓
pH, EC, SAR	✓
Leachate Analysis	See Note 1
Notes 1. Leachate analysis is conditional on contaminant of potential concern being identified by the QP, the volume of excess soil exceeding 350m^3 and applicable standards	

The above notes the minimum sampling requirements; based on past site uses the QP may require additional sample parameters to be added to the above listed. Furthermore, O. Reg. 406/19 may have other implications on proposed soil management activities (such as guidelines of receiving site and temporary soil storage sites) that are not noted above.

In the event that the Assessment of Past Uses does not identify any potentially contaminating activities within predominantly residential sites, the QP may determine that no sampling or testing is required under the Regulation. However, due diligence screening may still be advised and receiving sites may specify their own testing requirements outside of those specified in the regulation.

The onus is on the Excess Soil Source Site to carry out environmental soil quality testing for the removal and transport of their excess soils. The Source Site is required to have a Qualified Person (QP) complete a Soil Characterization Report (SCR) summarizing the soil testing results, which can be provided to the Beneficial Re-Use (receiver) Site for review to confirm the quality of materials which is being proposed to be imported to the site. There are significant efforts and costs associated with analytical testing of soils and preparation of the required documents, for which the Source Site may look to Beneficial Re-use Sites to share some of the cost.

In the event that the site requires imported fill material to achieve design grades, the site would be characterized as a Beneficial Re-Use Site. As such, a Qualified Person (QP) will need to be retained to prepare an Excess Soil Destination Assessment Report (ESDAR), which outlines the geotechnical requirements for beneficial reuse of imported materials onsite along with the environmental soil quality criteria (including the applicable O.Reg. 153/04 Site Condition Standards) for material which is appropriate to be accepted at the Site. In this case, material meeting the O.Reg. 406/19 Table 2.1 Site Condition Standards, Residential/Parkland/Institutional Land Use (or better) is general considered appropriate for this site.

LDS can assist further during construction to ensure that handling and disposal of excess soils from the site follow the regulatory requirements under the Excess Soils Regulation.

4.3 Excavations and Groundwater Control

4.3.1 Excavations

Excavations for the proposed buildings and site services are generally expected to extend into the native silty soil and silt till deposit, or possible engineered fill material, depending on final site grades. Site servicing depths are generally expected to be in the range of 4 m maximum depth.

All work associated with design and construction relative to excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). Based on the results of the geotechnical investigation and in accordance with Section 226 of Ontario Regulation 213/91, the fill materials and native loose to compact silty soils can be classified as Type 3 Soil above the groundwater table and as Type 4 Soil below the groundwater table. The natural silt till can be classified as Type 2 Soil above the groundwater table and as Type 3 Soil below the groundwater table. For excavations which extend through or terminate in Type 2 soil, temporary excavation side slopes must be cut near vertical in the bottom 1.2 m, and sloped back at an inclination of 1H:1V above that level. For excavations which extend through or terminate in Type 3 soil, temporary excavation side slopes must be cut back at a maximum inclination of 1H:1V from the base of the excavation. For excavations which extend through or terminate in Type 4 soil, temporary excavation side slopes must be at a maximum inclination of 3H:1V from the base of the excavation. For excavations through multiple soil types, the side slope geometry is governed by the soil with the highest number Type designation.

In the event that construction occurs in seasonally wet conditions or when frozen soil conditions are present, care will be required to maintain safe excavation side slopes, and suitable excavation bases. The contractor should use a reasonable effort to direct surface run-off away from open excavations.

The silty soils are susceptible to disturbance from construction equipment, and as such, it is recommended that construction equipment and vibration be strictly controlled over the exposed subgrade. The use of excavators and excavation equipment which can work on a constructed fill mat is recommended. Some consolidation of the loose subgrade soils which may remain in place should be anticipated.

In the event that if any materials will be disposed of offsite, testing of the materials for transport should conform to MECP Guidelines and requirements.

4.3.2 Excavation Support

Unsupported open cut excavations can be utilized at the site where space permits. If space restrictions at the site do not allow for conventional open cut without risk of undermining, or where excavation sizes are to be limited, the use of adequate bracing or shoring may be required. In the natural subgrade soils, bracing will not normally be required if the structures are behind a 45-degree line drawn up from the near edge of the excavation.

If the construction excavation side slopes recommended above cannot be maintained due to lack of space or close proximity of other structures, an engineered excavation support system must be used. Minimum support system requirements for steeper excavations are stipulated in Sections 234 through 242 of the Act and Regulations. The shoring system must be designed to be internally (overturning, and sliding) and externally stable (slope stability/base heave).

A prefabricated trench box may be used provided that it is designed (by a professional engineer) to withstand the soil and hydrostatic loading (if applicable).

Based on the field and laboratory testing during the present geotechnical investigation and our experience with similar soils, the following soil parameters are recommended for the design of the engineered shoring system.

Table 9: Soil Parameters for Shoring Design

Soil	φ	γ (kN/m^3)	K_a	K_o	K_p
Loose to Compact Sandy Silt	28	19.5	0.36	0.53	2.78
Compact to Very Dense Silt Till	28	19.5	0.36	0.53	2.78
Very Dense Sand and Gravel / Compact Granular Fill Granular ‘B’ (OPSS 1010)	32	22.0	0.31	0.47	3.25

In the event that imported fill material is present near the excavation which vary materially from the above soils, the geotechnical consultant should review the soil conditions to confirm the design parameters.

4.3.3 Groundwater Control

Shallow groundwater levels were recorded in the monitoring wells at depths ranging from 0.1 to 1.0 m bgs, corresponding to Elevations between 286.1 m asl and 284.5 m asl. Depending on the timing of construction, it is anticipated that seasonal conditions may cause variations in the perched shallow groundwater level.

Conventional groundwater control methods are generally expected to be suitable for shallow excavations which remain above the groundwater table at the site, to address surface water infiltration and minor shallow groundwater seepage for excavations which do not extend below the stabilized groundwater table.

However, where excavations extend below the stabilized groundwater level in water-bearing sand and gravel soils, more significant construction dewatering measures are anticipated to provide adequate groundwater control to lower the groundwater table and to allow for safe excavations. The water-bearing sand layers encountered at the site were observed at variable depths. As such, the use of trench liner boxes in open cut excavations may be helpful in limiting the amount of groundwater seepage into open excavations.

Soil permeability values in the natural sandy/silty subgrade soils are expected to be in the range of 10^{-5} to 10^{-6} m/s, based on the laboratory testing (presented in Section 3.2). This information is provided to assist with determining appropriate construction dewatering methods.

Regardless, groundwater control measures at the site should help to maintain stable excavated slopes; reduce saturated soil conditions to allow for possible reuse of excavated material; and provide a dry and stable base for excavations and construction operations.

For substantial excavations which extend into saturated sandy soils below the groundwater table, a system of well points is typically installed along or around an excavation. Specific dewatering requirements for this site should be reviewed when design grades, and servicing design levels are identified.

A Dewatering Plan should be submitted by excavating contractors involved in site servicing work for the subdivision. To assist in preparation of the dewatering plan, consideration should be given to carrying out a series of pre-tender test pits for contractors to obtain a better appreciation of the behaviour of excavations and to confirm dewatering requirements. Contractors (including specialist dewatering contractors) who might be involved in the job should witness these test pits.

If excavations are expected to encroach upon the stabilized groundwater table, it is recommended that at a minimum, that work should not proceed with open cut excavations without having an Environmental Activity Sector Registry (EASR) submission in place. This will allow water taking in excess of 50,000 litres per day, up to 400,000 litres per day.

Preparation of the Construction Dewatering and Discharge Plan requires information from the contractor carrying out the excavation work, and the contractor responsible for providing groundwater control. The construction methodology, including details for the typical length and depth of service trenches, information about excavation support or cut-off systems (such as trench liner boxes) which may be utilized, and the method of groundwater control which will be utilized. This information is included, to inform the discussion which is provided in the Dewatering Plan, which is expected to include discussion on potential impacts to soil settlement, impact to existing groundwater users and surface water features, along with consideration for extreme weather events.

The Discharge Plan will identify the discharge location for pumped water, including sediment and erosion control measures which will be utilized where water is contained onsite in surface water features, or where filtering of discharge water is planned, for water being outletted to municipal infrastructure.

In the event that positive groundwater control is required which will require a higher water taking volume (greater than 400,000 L/day), a Permit to Take Water (PTTW) may be required. Some of the factors which directly contribute to the volume required for a Permit to Take Water include the following:

- Localized variations in soil conditions;
- Seasonal influences on stabilized water table;
- Design depth for excavations;
- Length and staging to advance continuous open-cut excavations (i.e.: excavations for site servicing); and,
- Methodology and experience of the contractor.

A detailed hydrogeological assessment from a quantitative point of view will be required to estimate the quantity of water to be removed, when additional information is available for the site. The hydrogeological assessment should also include calculations for the zone of influence, identify potential impacts to existing structures, and identify potential qualitative and quantitative impacts to nearby properties which rely on the shallow groundwater table as a potable water source. Details regarding volume monitoring, water quality analyses and method / location of discharge water will also be required as part of the Permit to Take Water submission.

4.3.4 Seasonal Groundwater Monitoring

The existing wells at the site may be used for ongoing/future groundwater monitoring. Seasonal variations in the groundwater level are anticipated at the site. In this regard, consideration should be given to establishing a program of manual groundwater measurements or installation of dataloggers in select wells to provide a continuous record of seasonal groundwater levels that can be used to assist in the detailed design of the proposed residential development. LDS would be pleased to assist in providing a scope and budget for this work.

4.4 Building Design and Construction

The following geotechnical comments and recommendations are provided for the proposed townhouse development. However, it should be noted that the detailed design of the proposed development is not available at the time preparing this report. Therefore, the following recommendations should be further reviewed once more information is available.

4.4.1 Foundation Design

For design of footings on the competent natural subgrade soils below 1.2 m below existing grades or supported on engineered fill, the following allowable bearing pressures (net stress increase) can be used for design of footings:

- Serviceability Limit States (SLS) 150 kPa (~3000 psf)
- Ultimate Limit States (ULS) 225 kPa (~4700 psf)

All footings exposed to seasonal freezing conditions should be protected from frost action by at least 1.2 m (4 ft.) of soil cover or equivalent insulation.

Excessive differential settlements can occur where the subgrade support material types differ below the underside of continuous strip footings, (i.e., natural glacial till to engineered fill). As such, where strip footings transition from one material to another the transition between the materials should be suitably sloped or benched to mitigate differential settlements. It is recommended that the following transition precautions to mitigate/accommodate potential differential settlements be considered, and incorporated into the design, subject to review by the structural engineer:

- For strip footings, the transition zones should be adequately reinforced with additional reinforced steel lap lengths or widened footings;
- Steel reinforced poured concrete foundation walls; and
- Control joints throughout the transition zone(s).

Individual spread footings should generally be spaced a minimum distance of 1.5 times the largest footing width apart from each other to avoid stress bulb interaction between footings. This assumes the footings are at the same elevation.

The natural subgrade soils may be susceptible to disturbance by construction activities, especially during adverse weather conditions or when water seepage from excavation sidewalls are present. Consequently, after the founding surfaces have been exposed, the soils should be thoroughly recompacted to provide a uniform base, suitable to provide the bearing capacity noted above. Consideration should be given to placing concrete foundations as soon as possible following excavation and subgrade inspection.

Footings at different elevations should be located such that the higher footings are set below a line drawn up at 10 horizontal to 7 vertical from the closest edge of the lower footing. It is important that servicing excavations which encroach on the building foundations are checked to ensure that they do not undermine the building foundations.

Verification of the footing base conditions should be undertaken by the geotechnical engineer at the time of excavation. Provided that the stability of the soils exposed at the founding level is not compromised as a result of construction activity, precipitation, cold weather conditions, etc., and the design bearing pressures are not exceeded, the total and differential settlements of footings are expected to be less than 25 mm and 19 mm, respectively.

It should be noted that the recommended bearing capacities have been calculated by based on the observations of the soil and groundwater conditions within the borehole program at the site. Where variations occur between the borehole locations, and during construction of the new buildings, site verification by the LDS' geotechnical engineer is recommended to confirm soil conditions and verify soil bearing capacity.

4.4.2 Slab-on-Grade Construction

Concrete floors for the proposed buildings may be constructed using conventional concrete poured slab techniques, following the review and approval of the subgrade soils.

In preparation for the construction of the floor slab, any unstable soils should be removed and/or recompacted to ensure that founding soils which will support the floor slab are suitable. In the event that the exposed subgrade soils are wet they will exhibit a greater sensitivity to disturbance. Structural fill placed below the concrete floor slab should be comprised of inorganic soils, placed and compacted in uniform lifts, to a minimum of 98 percent SPMDD.

Care should be taken to protect the subgrades below the floor slabs during construction, by limiting construction traffic on the prepared subgrade soils. In addition, if the exposed subgrade soils are exposed to inclement weather conditions (i.e. rain, snow, freezing conditions), some remedial works may be required to remove wet, soft, or disturbed soils prior to stone and concrete placement

A moisture barrier, consisting of a minimum 200 mm thick of uniformly compacted 19 mm clear stone is recommended over the approved subgrade. For design purposes, the modulus of subgrade reaction (k) can be taken as 45 MPa/m, for the compacted stone over approved subgrade soils. An alternate configuration of compacted granular material such as OPSS 1010 Granular A may also be considered for the moisture barrier. If alternative materials are proposed for use onsite, the minimum level of compaction and overall design thickness of the moisture barrier layer should be reviewed by the geotechnical consultant.

The water-to-cement ratio of the concrete utilized in the floor slab should be strictly controlled to minimize shrinkage of the slab. Adequate joints and / or the use of fibre reinforcement may be considered by the designer to help control cracking. The sawcut depth for control joints should be ¼ of the slab thickness. The use of super plasticizers should be considered to reduce shrinkage and increase workability of the concrete.

During construction, concrete sampling and testing is recommended to ensure that concrete mix design requirements are satisfied.

4.4.3 Foundation Drainage and Backfill

In general, the existing native soils excavated from the building footprints (from above the stabilized water level) are generally expected to be suitable for re-use as foundation wall backfill. The materials to be re-used as foundation wall backfill should be within three percent of optimum moisture content for best compaction results. If the weather conditions are very wet during construction, site review by the geotechnical consultant may be advised to confirm the suitability of onsite soils for reuse.

In the event that excavated materials contain topsoil, organics or otherwise unsuitable material, such materials should be stockpiled separately, and limited to re-use where settlements can be tolerated.

It is recommended that heavy compaction equipment be restricted within 0.5 m of the wall. Backfill should be brought up evenly on both sides of the foundation walls which have not been designed to resist lateral earth pressures.

The near-surface soils may be susceptible to frost effects, which can impact hard landscaping adjacent to the building. At locations where the proposed building is expected to have exterior entrances, care should be taken in detailing the exterior slabs and/or sidewalks providing insulation, drainage and non-frost susceptible backfill to maintain flush transitions in cold weather conditions.

A review of the grading plan should be conducted to confirm that building foundations will be set above the stabilized groundwater level. If this can be confirmed, no special water-proofing measures are required. Foundations should be provided with damp-proofing and foundation drainage tiles, in accordance with standard Ontario Building Code (OBC) requirements. Shallow groundwater may be present at/near the design underside of footing elevation, where wet soils are present. The addition of subfloor drains, connected to the sump pump may be advised. Site review by the geotechnical consultant can assist in this regard. Consideration may be given to enhanced damp-proofing measures (such as subfloor drains), where there is reasonable concern that the basement level may conflict with the high groundwater level on an intermittent basis.

Exterior perimeter foundation drains are not required where the finished floor elevation is set at least 150 mm above the exterior grade, or where the exterior grade is positively sloped away from the structures to promote surface water run-off and reduce groundwater infiltration adjacent to foundation walls.

Any discharge which is directed into municipal infrastructure will be subject to municipal approvals and/or permitting, and must adhere to sewer discharge by-laws.

4.4.4 Concrete Recommendations

CSA A.23-1.04 provides minimum requirements for concrete, including Exposure Class, maximum water to cement ratios, allowable air entrainment, slump, temperature requirements, etc. The design of the building foundations should have regard to the above referenced standard, and should be reviewed by the designer for conformance to CSA standards.

Concrete sampling and testing for foundations and concrete slabs (in accordance with CSA A23.1-04) is recommended.

4.5 Seismic Design Considerations

Subsoil and groundwater information at the Site have been examined in relation to Section 4.1.8.4 of the Ontario Building Code (OBC) 2012. The subsoils expected below the proposed buildings will generally consist of loose to compact silty soils and compact to very dense silt till deposit encountered within the boreholes.

Table 4.1.8.4.A. Site Classification for Seismic Site Response in OBC 2012 indicated that to determine the site classification, the average properties in the top 30 m are to be used. The Site Classification recommendation is based on the available information as well as our interpretation of conditions at and below the boreholes, and based on a review of geological mapping, and our knowledge of the soil conditions in the area.

Based on the above assumptions, interpretations in combination with the known local geological conditions, the Site Class for the proposed development is classified as "C" as per Table 4.1.8.4.A, Site Classification for Seismic Site Response, OBC 2012. In the event that a higher Site Classification is being sought by the structural design engineer, additional deep boreholes and / or multichannel analysis of surface waves (MASW) testing would be required to determine if the soil conditions below the current depth of exploration can support a higher Site Classification.

4.6 Site Services

Subgrade soils beneath new services are generally expected to consist of compact silt till and silty soil deposits. No bearing problems are anticipated for flexible or rigid pipes founded on the natural loose to dense soil deposits. However, localized base improvement along the trench bottom may be required for excavations which terminate in wet or loose subgrade soils. The extent of base improvement or stabilization is best determined in the field during construction, with consultation from LDS' geotechnical engineer.

4.6.1 Pipe Bedding

For services supported on competent native deposits, the bedding should conform to Municipal and OPS Standards. Bedding aggregate should be compacted to a minimum 95 percent SPMDD. Water and sewer lines installed outside of heated areas should be provided with a minimum 1.2 m of soil cover for frost protection.

A well graded stone layer may be used in service trenches as bedding below the spring line of the pipe if necessary, to provide stabilization to the excavation base in wet subgrade soils, where encountered. Geotextile may be considered for wrapping the pipe and to limit movement of fines from surrounding soils into the bedding material. Potential locations for use of stone bedding can be identified through site inspection during construction and will vary across the site due to seasonal conditions and variations in perched groundwater conditions.

Due to the presence of shallow groundwater conditions at the site, it is anticipated that some servicing pipes may encounter and extend down into the stabilized groundwater level. Trench plugs / clay collars may be considered at strategic manhole locations to help reduce groundwater transfer through bedding materials. As such, seepage collars can be installed strategically at manhole locations to slow down the groundwater transfer through bedding materials. Clay collar/plug must be constructed of plastic low-permeability soil with moisture content within 3 percent of the optimum moisture as determined by the Standard Proctor test method. The height of the clay collar should extend above the pipe bedding and cover material (and at least 600 mm above the pipe). The location and frequency of collars use can be best assessed during the early stage of construction, by a geotechnical engineer.

4.6.2 Trench Backfill

Requirements for backfill in service trenches, etc. should also conform to Municipal and OPS Standards. A program of in-situ density testing is recommended to ensure that satisfactory levels of compaction are achieved. Based on the results of this investigation, excavated material for trenches will generally consist of sandy silt and silt till. Select portions of this inorganic material may be used for construction backfill provided that reasonable care is exercised in handling the material. In this regard, the material should be within 3 percent of the optimum moisture as determined by the Standard Proctor density test. Stockpiling of material for prolonged periods of time should be avoided. This is particularly important if construction is carried out in wet, adverse weather. Backfilling operations during cold weather should avoid inclusions of frozen lumps of material, snow and ice. The following table outlines the recommended levels of compaction within the trench backfill:

Table 10: Trench Backfill Compaction Requirements

Scenario	Minimum Recommended Compaction Level	Soil Moisture Content
More than 1 m below underside of granular subbase, and in landscaped areas	95% SPMDD	Within +/- 5% of optimum moisture
Less than 1 m below underside of granular subbase	98% SPMDD	Within +/- 3% of optimum moisture

Soils excavated from below the stabilized groundwater table may be too wet for re-use as backfill, unless adequate time is allowed for drying, or if material is blended with approved dry fill; otherwise, it may be stockpiled onsite for re-use as landscape fill, or disposed of off-site, testing of the material for transport should conform to MECP Guidelines and requirements.

Normal post-construction settlement of the compacted trench backfill should be anticipated, with the majority of such settlement taking place within about 6 months following the completion of trench backfilling operations. This settlement may be compensated for, where necessary, by placing additional granular material prior to asphalt paving. Alternatively, if the asphalt binder course is placed shortly following the completion of trench backfilling operations in these areas, any settlement that may be reflected by subsidence of the binder asphalt should be compensated for by placing an additional thickness of binder asphalt or by padding.

4.7 Pavement Design

The development will be accessed with an internal road network, accessing Upper Queen Street at the north end of the site. The exposed subgrade soils within the roadways are expected to be comprised of re-compacted soils of silty textures. The road subgrade should be thoroughly proof-rolled and reviewed by the geotechnical consultant. In the event that loose or soft areas are noted, additional work may be required to sub excavate and replace unstable soils with suitable compactable material. In general terms, subgrade soils supporting site pavements should be compacted to a minimum level of 98 percent SPMDD.

The recommended pavement structure provided in this report is based on the natural subgrade soils encountered in the boreholes or suitably re-compacted soils, as described previously.

Provided that the preceding recommendations are followed, the pavement thickness design requirements given in the following table are recommended for the anticipated subgrade conditions and traffic loading on the internal network of local roads.

Table 11: Pavement Design Recommendations

Pavement Component	Pavement Component Thicknesses		Specified Compaction Levels
	Local Roads	Restoration to Upper Queen Street	
Asphaltic Concrete	35mm HL 3 45mm HL 8	40mm HL 3 50mm HL 8	Min. 97% Bulk Relative Density (BRD)
Granular A Base	150 mm	150 mm	100% SPMDD
Granular B Subbase	300 mm	450 mm	100% SPMDD

A thicker granular subbase (up to 450 mm) may be warranted for the local roads where site roads will be used for construction access when only a portion of the pavement structure is in place. The design thicknesses noted above are not intended to support heavy and concentrated construction traffic.

Where local roads connect to existing pavements, subgrade levels and pavement components should be tapered to match / tie-into existing pavement structures to minimize differential settlements at the transition from existing to new pavement.

It is recommended that a program of inspection and materials testing (including laboratory analyses and compaction testing) be carried out during construction to confirm that geotechnical requirements are satisfied.

- Samples of both the Granular 'A' and Granular 'B' aggregates should be checked for conformance to OPSS 1010 prior to use on site, and during construction.
- The asphaltic concrete paving materials should conform to the requirements of OPSS 1150. The asphalt should be placed in accordance with OPSS 310.
- Specified compaction levels are identified in the table, above. Alternatively, to the specified compaction range noted in the above table for asphalt compaction, a compaction level of 97 percent of the bulk relative density (BRD) is also an appropriate measure for asphalt compaction.

Good drainage provisions will optimize pavement performance. The finished pavement surface should be free of depressions and should be sloped (preferably at a minimum grade of two percent) to provide effective surface drainage. Surface water should not be allowed to pond adjacent to the outside edges of pavement areas.

The sandy subgrade soils, if encountered, have good natural drainage and therefore pavement subdrains are generally not anticipated. Otherwise, short (3.0 m long) subdrains are recommended at each catchbasin location to intercept excess subsurface moisture and prevent subgrade softening. The subdrains should be comprised of 150 mm perforated pipe set in stone and wrapped in geotextile (Terrafix 270 R or equivalent).

4.8 Curbs and Sidewalks

The concrete for any new exterior curbs and sidewalks should be proportioned, mixed placed and cured in accordance with the requirements of OPSS 353, OPSS 1350 and the Municipality. During cold weather, the freshly placed concrete should be covered with insulating blankets to protect against freezing.

The following concrete specifications are required for curb and gutter, and sidewalk design and construction:

- 28-day compressive strength: 30 MPa
- Air entrainment: 5-7 percent; and,
- Maximum Slump: 75 mm.

The subgrade for the sidewalks should consist of undisturbed natural soil or well compacted fill. A minimum 100 mm thick layer of compacted (minimum 98 percent SPMDD) Granular 'A' is recommended below sidewalk slabs. Sidewalks have a minimum thickness of 125 mm and a width of 1.50 m, and are expected to follow road grades with a minimum gradient of 0.5% and a maximum gradient of 8.0%.

4.9 Sediment and Erosion Control Considerations

Sediment and erosion control measures will be required around the perimeter of the site and at catch basin/manhole structures which are in the work area and susceptible to impacts from the construction activities onsite. It is important to ensure that the sediment control measures are installed properly, and in accordance with the design drawings. If deficiencies are identified in its performance through regular inspection, enhancements beyond the recommended design may be required. The following outlines some general mitigation measures are suggested as best management practice:

- Establish controlled construction entrance/exit points, incorporating the use of mud-mats to help control the amount of loose soil being carried offsite from construction vehicles;
- Prevent wind-blown dust;
- Install perimeter ESC measures such as silt around temporary soil stockpiles;
- Build-up boulevard areas to help limit sediment-laden stormwater run-off (from open or partially constructed areas) from discharging into catch basins and stormwater infrastructure, and regular inspection and maintenance of silt bags/geotextile filters installed in catch basins;
- Monitor discharge water (for water quality – turbidity) from stormwater run-off and construction dewatering activities;
- Re-establish vegetative cover in disturbed areas. In areas which are susceptible to erosion; and,

Maintain perimeter silt fence (and other perimeter ESC measures) in place until vegetative cover is established.

4.10 Geotechnical Inspection and Testing

An effective inspection and testing program is an essential part of construction monitoring. The Inspection and Testing Program may include the following items:

- Subgrade examination prior to engineered fill placement;
- Inspection and materials testing during engineered fill placement (full-time monitoring is recommended) and site servicing works, including soil sampling, laboratory testing, and compaction testing;
- Footing base confirmations for any foundations constructed on engineered fill;
- Inspection and testing during construction of site pavements including compaction testing and laboratory testing;
- Concrete sampling and testing for curbs and sidewalks; and,
- Inspection and materials testing for base and surface asphalt.

The Municipality may require inspection and testing records for servicing tie-ins to verify that project specifications have been satisfied for site servicing connections and road repairs, if required.

5. HYDROGEOLOGICAL DISCUSSION

5.1 Hydrogeologic Setting

As discussed in Section 3.3, shallow water level measurements were recorded in the monitoring wells at depths ranging from 0.1 to 1.0 m bgs, corresponding to Elevations between 284.5 m asl and 286.1 m asl. The groundwater flow direction interpreted from the water level measurements collected by LDS indicates a shallow groundwater flow direction towards the south.

It is important to note that shallow groundwater will vary in response to climatic or seasonal conditions, and, as such, may differ depending on the seasonal conditions. Shallow groundwater in unconfined aquifers can be significantly influenced by exceptional and/or sustained rainfall events.

The following preliminary discussion is provided to identify potential development impacts which can be associated with the urbanization of a site, as is expected with the proposed residential development which is planned for this property.

5.2 Preliminary Impact Assessment

5.2.1 Impacts to Natural Features

LDS is not aware of any sensitive natural features such as woodlands, wetlands or surface water features which are present in the immediate area of the site. As such, the proposed site development is not expected to have a significant ecological impact. No significant surface water features are located in proximity to the Site. The zone of influence for construction dewatering is expected to be limited to area immediately surrounding the open excavation. Given the localized nature of the groundwater control currently anticipated for the Site, no impact to surface water features is anticipated as a result of construction dewatering activities.

5.2.2 Impacts to Local Water Supply Wells

The water supply wells noted in the MECP well record within 100 radius from the site are set in the intermediate and deep overburden aquifer. Typical site servicing depths and excavations for building foundations are expected to be well above the intermediate and deep overburden aquifers. From a quantitative standpoint, temporary construction dewatering will not result in the alterations in the water level within those aquifers.

5.2.3 Impacts from Construction Equipment

Construction activities at the site are generally not expected to impact the general chemistry or bacteriological properties of the unconfined intermediate and deep overburden aquifers. However, the possibility exists that a spill or uncontrolled release of fuel or associated material could occur during construction, which could have a direct impact to surface water and shallow groundwater conditions.

A Best Management Practice (BMP) and spill contingency plan (including a spill action response plan) should be in place for fuel handling, storage and onsite equipment maintenance activities. It is recommended that there be a designated equipment fuelling areas located away from the wetland, and implementing a spill contingency plan (including a spill action response plan) for fuel handling, storage and onsite equipment maintenance activities to minimize the risk of contaminant releases as a result of the proposed construction activities.

It is important to note that if a spill (possible incident) is related to the contractor's activities, the contractor is responsible to report the incident to the Spills Action Centre, and/or notify the local MECP office. Depending on the type of incident, water sampling and quality testing may be warranted to document the extent of the impact. Scoping for the required testing will depend on the incident report.

5.2.4 Impacts from Uncontrolled Erosion / Sediment Discharge

Surface water quality can be detrimentally impacted by uncontrolled erosion and sediment discharge from the site. As such, it is imperative that an adequate Sediment and Erosion Control Strategy be established for the site during the construction phase of the development. In addition to implementing sediment and erosion controls during construction, regular inspection and maintenance will also be necessary to ensure that sensitive receptors are not negatively impacted during construction.

Sediment and erosion control measures will be required to limit sediment discharge towards the natural features. It is important to ensure that the sediment control measures are installed properly, and in accordance with the design drawings. If deficiencies are identified in its performance through regular inspection, enhancements beyond the recommended design may be required.

The following table summarizes general mitigation measures are suggested as best management practices to limit foreseeable events where contamination or negative impacts to hydrologic features at the site may be possible. As construction work progresses at the site, regular maintenance and additional sedimentation measures may be required to limit the effect of siltation of run-off water in localized areas.

Table 12: Construction BMPs

Practice / Task	During Site Grading	During Site Servicing	During Building & Pavement Construction	Following Construction
Measures to Protect Off-Site Sediment Release				
Establish controlled construction entrance/exit points, incorporating the use of mud-mats to help control the amount of loose soil being carried offsite from construction vehicles	✓	✓		
Prevent wind-blown dust.	✓	✓	✓	
Installing perimeter ESC measures such as silt fence and/or silt sock around temporary soil stockpiles, with dedicated points of access clearly marked onsite.	✓	✓		
Build-up boulevard areas to help limit sediment-laden stormwater run-off (from open or partially constructed areas) from discharging into catchbasins and stormwater infrastructure, and regular inspection and maintenance of silt bags/geotextile filters installed in catchbasins.			✓	✓
Measures to Protect Natural Features				
Monitoring of discharge water (for water quality – turbidity) from stormwater run-off and construction dewatering activities.	✓	✓	✓	
Delineate work areas to limit construction activities encroaching into the natural heritage features and setback areas, to prevent unnecessary vegetation removal.	✓	✓	✓	
Dedicated fuel storage and equipment fuelling areas located away from natural or otherwise sensitive features. Contractors should have an emergency spills management plan.	✓	✓		
Re-establishing vegetative cover in disturbed areas. In areas which are susceptible to erosion, additional measures may include the use of sod, hydroseeding, or mulch to protect the exposed subgrade soils.	✓	✓	✓	✓
Maintain perimeter silt fence (and other perimeter ESC measures) in place until disturbed areas and lots are sodded/seeded, and vegetative cover has become established.			✓	✓

While active construction dewatering occurs at the site, a program which includes turbidity monitoring is recommended, to confirm that the quality of discharge water will not have adverse impacts to sensitive receptors. In the event that water discharged from the site is considered to have an elevated turbidity level, associated construction activities should be halted until remedial measures can be implemented. Such measures may include enhanced or more robust sediment and erosion control measures, incorporating pooling areas and measures that will reduce suspended solids, temporary storage measures to prevent off-site discharge.

5.4 Low Impact Development Considerations

Consideration should be given to identify stormwater management options which allow secondary infiltration or reduced run-off under post-development conditions, to be incorporated into the stormwater management design. LID (Low Impact Development) strategies help to mitigate the impacts of increased runoff and stormwater pollution by managing runoff as close to its source as possible, by incorporating site features which enhance post-development infiltration, evapotranspiration, filtration and detention of stormwater. These practices can help to reduce contaminants in runoff, and can reduce the volume and intensity of stormwater flows.

The infiltration capacity of a soil depends on a number of factors, including particle size distribution, degree of saturation, compactness, adsorbed water (which depends on clay content). The heterogeneous nature of glacial deposits can also contribute to variations in soil permeability where the soil composition may include localized areas with increased fine material or sandy material which can influence soil permeability at different points within the soil strata.

Based on the permeability results presented in Section 3.2, the natural water-bearing sandy soils have a saturated hydraulic conductivity in the range of 10^{-5} to 10^{-6} m/s, with factored infiltration rates of approximately 28 mm/hr.

Where low permeability soils are present (such as natural silt till, or imported silty/clayey soils), the use of infiltration-based features may not be effective. LID measures which extend the retention time for surface water run-off, provide increased evapotranspiration opportunities and to help moderate and potentially reduce run-off volumes, may be considered appropriate.

It is also important to note that the presence and effective depth of sandy soils may be altered by site grading activities at the site. The stormwater management strategy at the site will need to consider site grading activities at the site, which may alter the near-surface soil conditions, as a result of cut-fill activities to accommodate design grades.

Prior to finalizing the design of any LID features being considered at the site, consideration should also be given to potential shallow groundwater contaminants which may be present in the area. The introduction of additional groundwater into areas with existing contaminants may result in changes in the existing contaminant plume. Coordination with the environmental consultant will be required to identify if mobilization of groundwater contaminants is a concern.

Field confirmation of soil permeability and effective infiltration rates in the natural or reconstructed subgrade soils will need to be undertaken to confirm soil suitability for any infiltration-based LID measures which are considered at the site.

5.5 Well Decommissioning

Monitoring wells associated with the preparation of this report have been installed at the site, to document stabilized groundwater conditions. When the monitoring wells are determined to be no longer required, the wells should be properly decommissioned in accordance with Ontario Regulation 903. This regulation identifies that only certified and qualified well drilling technicians are permitted to direct the decommissioning work for existing wells.

Decommissioning a well which is no longer in use helps to ensure the safety of those in the vicinity of the well, prevents surface water infiltration into an aquifer via the well, prevents the vertical movement of water within a well, conserves aquifer yield and hydraulic head and can potentially remove a physical hazard.

6. QUALIFICATIONS OF ASSESSORS

This assessment was prepared by Mr. Andy Chen, P.Eng. who has been trained in conducting geotechnical assessments, including detailed slope stability analysis. Mr. Chen is a licensed professional engineer in the Province of Ontario. He obtained a Master of Engineering in Civil and Environmental Engineering from Western University in 2014. He has been practicing geoscience services under the Guideline of Professional Engineers Providing Geotechnical Engineering Services under the Professional Engineers Act in Ontario, and has over six (6) years of experience in the consulting engineering field, focusing on residential developments, industrial and commercial buildings, municipal infrastructures and slope stability analyses.

This assessment was reviewed by Mrs. Rebecca Walker, P. Eng., QP, who has been thoroughly trained in conducting geotechnical and hydrogeological assessments. Mrs. Walker is a licensed professional engineer in the Province of Ontario. She obtained a Bachelor of Applied Science in Geological Engineering from Queen’s University in 1998 and is a Qualified Person (QP) registered with MECP. She has been practicing geoscience services under the Guideline of Professional Engineers Providing Geotechnical Engineering Services under the Professional Engineers Act in Ontario. Mrs. Walker has over 20 years of direct experience in the geotechnical and hydrogeological consulting industry. Over 3,800 projects have been completed under her supervision. Mrs. Walker is also a recognized expert in the industry and has testified as an expert witness in Local Planning Appeal Tribunal (formerly Ontario Municipal Board) hearings and Municipal Councils related to groundwater hydrogeology and geotechnical matters for land development and construction. She has been retained for many projects, both directly and indirectly (as a subconsultant) by local municipalities as a hydrogeological and geotechnical consultant.

7. CLOSING

The geotechnical recommendations provided in this report are applicable to the project described in the text. LDS would be pleased to provide a review of design drawings and specifications to ensure that the geotechnical comments and recommendations provided in this report have been accurately and appropriately interpreted.

It is important to note that the geotechnical investigation involves a limited sampling of the subsurface conditions at specific borehole locations. The conclusions and recommendations presented in this report reflect site conditions existing at the time of the investigation and a review of available information which has been presented in the report. Should subsurface conditions be encountered which vary materially from those observed in the boreholes, we recommend that LDS be consulted to review the additional information and verify if there are any changes to the geotechnical recommendations.

The comments given in this report are intended to provide guidance for design engineers. Contractors making use of this report are responsible for their construction methods and practices, and should seek confirmation or additional information if required, to ensure that they understand how subsurface soil and groundwater conditions may affect their work.

No portion of this report may be used as a separate entity. It is intended to be read in its entirety.

We trust this satisfies your present requirements. If you have any questions or require anything further, please feel free to contact our office.

Respectfully Submitted,

LDS CONSULTANTS INC.

LICENSED PROFESSIONAL ENGINEER
Feb 23, 2022
R.A. WALKER
PROVINCE OF ONTARIO

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APPENDIX A

DRAWINGS AND NOTES

Latitude: **43.10198** Longitude: **-81.14311**
UTM Zone: **17**
Easting: **488354.72** Northing: **4772149.43**
Upper Tier Municipality: **COUNTY OF MIDDLESEX**
Lower Tier Municipality: **MUNICIPALITY OF THAMES CENTRE**
Township Concession and Lot: **NISSOURI CON 3 LOT 15**
Assessment Parcel Address: **233 UPPER QUEEN ST**
Assessment Roll #: **3926031020090000000**
MECP District: **London**
MECP Region: **Southwestern**

Source Protection Details for Location

Source Protection Area: **Upper Thames River**
View Source Protection Plan
Wellhead Protection Area: **No**
Wellhead Protection Area E (GUDI): **No**
Intake Protection Zone: **No**
Issue Contributing Area: **No**
Significant Groundwater Recharge Area: **No**
Highly Vulnerable Aquifer: **No**
Event Based Area: **No**
Wellhead Protection Area Q1: **No**
Wellhead Protection Area Q2: **No**
Intake Protection Zone Q: **No**

Information is current as of: **February 18, 2022**

SOURCE:
Base drawing from Ontario Ministry of the Environment, Conservation and Parks Protection Information Atlas, as current as February 18, 2022

PROJECT NAME

Geotechnical Investigation

PROJECT LOCATION

233 Upper Queen Street
Thorndale, ON

DRAWING NAME

Source Water Protection Map

SCALE	PROJECT NO.
As Shown	GE-00630
DATE	**DRAWING NO.**
February 2022	1

Location	Northing, m N	Easting, m E	Ground Surface Elevation (m asl)
BH1	4772239.68	488317.32	286.1
BH2	4772221.94	488357.5	286.32
BH3	4772168.37	488350.93	285.41
BH4	4772122.1	488396.36	285.35
BH5	4772119.77	488346.38	284.67

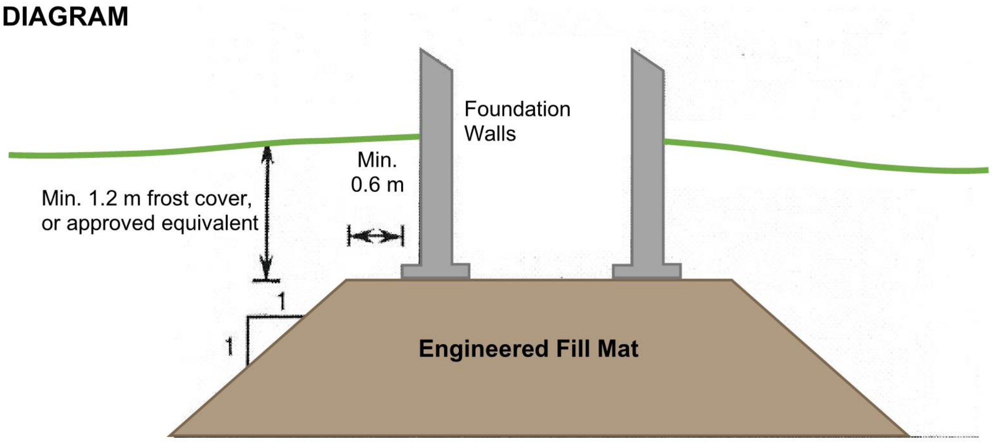
LDS

Legend
- BOREHOLE LOCATION
- MONITORING WELL LOCATION

Project Name	Project Location	Project Drawing	Scale	Project No
GEOTECHNICAL INVESTIGATION	223 UPPER QUEEN STREET THORNDALE, ONTARIO	BOREHOLE PLAN	1:500	GE-00630
			Date: FEB 2022	Drawing #: 2

ENGINEERED FILL PLACEMENT

SCHEMATIC DIAGRAM



NOTES:

1. The area must be stripped of all topsoil contaminated fill material, and other unsuitable soils, and proof rolled. Soft spots must be dug out. The stripped natural subgrade must be examined and approved by the geotechnical consultant.
2. In areas where engineered fill is placed on a slope, the fill should be benched into the approved subgrade soils.
3. Material used for engineered fill must be free of topsoil, organics, frost and frozen material, and otherwise unsuitable or compressible soils, as determined by a Geotechnical Engineer. Any material proposed for use as engineered fill must be examined and approved prior to use onsite.
4. Engineered fill should be placed in maximum 300 mm thick lifts, and uniformly compacted to 100% Standard Proctor dry density. For best compaction results, engineered fill should be within 3 percent of its optimum moisture content, as determined by the Standard Proctor density test.
5. Full time geotechnical monitoring, inspection and in-situ density (compaction) is required during placement of the engineered fill.
6. Site grades should be maintained during area grading activities to promote drainage, and to minimize ponding of surface water on the engineered fill mat. Rutting by construction equipment should be kept to a minimum, where possible. Additional work to ensure suitability of engineered fill may be required if fill is placed in inclement weather conditions.
7. The fill must be placed such that the specified geometry is achieved. Refer to schematic diagram for minimum requirements. Environmental protection may be required, such as frost protection during construction, and after the completion of the engineered fill mat.
8. An allowable bearing pressure of 145 kPa (3000 psf) may be used provided that all conditions outlined above, and in the Geotechnical Report are adhered to.
9. These guidelines are to be read in conjunction with the Geotechnical Report prepared by LDS.
10. For foundations set on engineered fill, footing enhancement and/or concrete reinforcing steel placement may be recommended. The footing geometry and extent of concrete reinforcing steel will depend on site specific conditions. In general, consideration may be given to having a minimum strip footing width of 500 mm (20 inches), containing nominal steel reinforcement.

LDS	PROJECT NAME Geotechnical Investigation	PROJECT NO. GE-00630
	PROJECT LOCATION 233 Upper Queen Street, Thorndale, ON	DRAWING NO. 3