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A REPORT TO
SOPHIE'S LANDING GRIMSBY INC.

A GEOTECHNICAL INVESTIGATION FOR PROPOSED RESIDENTIAL DEVELOPMENT

165 LAKE STREET

TOWN OF GRIMSBY

REFERENCE NO. 2201-S023

SEPTEMBER 2023

DISTRIBUTION

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1.0 INTRODUCTION

In accordance with the Purchase Order 1002 dated January 7, 2022, from Mr. Sam Kerzner of Sophie's Landing Grimsby Inc., a geotechnical investigation was carried out at 165 Lake Street and a parcel of vacant land to the west, in the Town of Grimsby.

The purpose of this investigation was to identify the subsurface conditions and engineering properties of the disclosed soils for the design and construction of the proposed residential development. The geotechnical findings and resulting recommendations are presented in this Report.

In addition, a slope stability assessment was performed for a natural slope located to the north of the subject site in order to delineate the Long-Term Stable Top of Slope (LTSTOS) for the development.

2.0 SITE AND PROJECT DESCRIPTION

The Town of Grimsby is situated in an area where the Niagara Falls Moraine occurs. It consists of a variety of soils, with sand and silt being the predominant materials. The soils are often reddish in colour, which indicates remnants of Queenston shale bedrock glaciations.

The subject lot, comprising a total area of 12,846.36 m^2, consists of 165 Lake Street and a vacant land to the west. The site, fronting Lake Street, is located approximately 280 m west of Baker Road North, with the north property boundary abutting Lake Ontario. At the time of investigation, there was an existing residential dwelling with in-ground swimming pool and a septic system at 165 Lake Street and an abandon structure in the vacant lot. A natural slope, approximately 5.0 to 8.4 m in height, is located to the north of the site. The tableland is relatively flat with minor undulation.

According to the conceptual site plan provided, the site will be developed for a residential subdivision with private roadways and public amenities.

At the time of report preparation, the topographic plan of the site was not available; therefore, the slope stability analysis will be presented in a separate cover, when all necessary documents are provided.

3.0 FIELD WORK

The field work, consisting of five (5) sampled boreholes extending to the depths of 6.6 to 12.7 m, was carried out on January 24 and 25, 2022. The locations of the boreholes are shown on the Plan, Drawing No. 1.

The boreholes were advanced to the sampling intervals by a track-mounted, continuous-flight power-auger machine equipped for soil sampling. Standard Penetration Tests, using the procedures described on the enclosed “List of Abbreviations and Terms”, were performed at the sampling depths. The test results are recorded as the Standard Penetration Resistance (or ‘N’ values) of the subsoil. The relative density of the non-cohesive strata and the consistency of the cohesive strata are inferred from the ‘N’ values. Split-spoon samples were recovered for soil classification and laboratory testing.

Upon completion of borehole drilling and sampling, a monitoring well, 50 mm in diameter, was installed in Borehole 6 to facilitate groundwater monitoring for slope stability assessment. The depth and details of the monitoring well are shown on the respective Borehole Log.

The field work was supervised and the findings were recorded by a Geotechnical Technician. The ground elevation at each borehole was determined on the field using hand-held Global Navigation Satellite System equipment.

4.0 SUBSURFACE CONDITIONS

The boreholes were carried out in the open field. The borehole findings indicate that beneath the topsoil veneer and/or a layer of earth fill, the site is underlain by a silt deposit overlying a layer of silty clay till.

Detailed descriptions of the encountered subsurface soil conditions are presented on the Borehole Logs, Figures 1 to 5, inclusive. The revealed stratigraphy is plotted on the Subsurface Profile, Drawing No. 2. The engineering properties of the disclosed soils are discussed herein.

4.1 **Topsoil** (All Boreholes)

The revealed topsoil is approximately 15 cm in thickness at all borehole locations. Thicker topsoil layer may be contacted in areas beyond the borehole locations, especially in the low-lying and treed areas.

4.2 **Earth Fill** (All Boreholes)

A layer of earth fill was contacted below the topsoil veneer, extending to the depths of 0.6 to 2.3 m from the prevailing ground surface. It consists of a mixture of sand and silt, occasional topsoil and organics.

The recorded ‘N’ values, ranging from 3 to 20, with a median of 11 blows per 30 cm of penetration, indicated the earth fill was likely placed with some degrees of compaction.

One must be aware that the samples retrieved from boreholes may not be truly representative of the geotechnical and environmental quality of the earth fill, and do not indicate whether the topsoil beneath the earth fill was completely stripped. This should be further assessed by laboratory testing and/or test pits.

4.3 **Silt** (All Boreholes)

Native silt deposit was encountered in all boreholes beneath the earth fill, extending to the depths of 2.9 m to 7.0 m from the prevailing ground surface. Sand seams and layers are evident within the silt deposit, indicating that it is a lacustrine deposit. Grain size analysis was performed on 2 representative samples of silt and the results are plotted on Figure 6.

The recorded ‘N’ values range from 8 to 46, with a median of 16 blows per 30 cm of penetration, indicating the silt is loose to dense, generally compact in relative density. The natural water content values of the silt range from 14% to 24%, with a median of 18%, indicating very moist to wet conditions.

The engineering properties of the silt are listed below:

- Highly frost susceptible and highly water erodible.
- Semi-pervious to moderately low permeability, with an estimated coefficient of permeability of 10^{-4} to 10^{-6} cm/sec and a percolation time between 15 and 40 min/cm.

- The shear strength is derived from internal friction and is density dependent. Due to its dilatancy, the shear strength of the wet silt is susceptible to impact disturbance; i.e., the disturbance will induce a build-up of pore pressure within the soil mantle, resulting in reducing of shear strength.
- In excavation, the wet silt will slough, run with water seepage and boil with a piezometric head of 0.3 m.
- Moderate corrosivity to buried metal, with an estimated electrical resistivity of 4500 ohm·cm.

4.4 **Silty Clay Till** (All Boreholes)

The silty clay till was encountered below the silt deposit. All boreholes terminate within the till at depths between 6.6 m and 12.7 m below grade. The till consists of a random mixture of soils; the particle sizes range from clay to gravel, with the clay fraction exerting the dominant influence on its soil properties. Grain size analysis was performed on one representative sample of silty clay till and the result is plotted on Figure 7.

The recorded ‘N’ values range from 11 to 40 blows, with a median of 21 blows per 30 cm of penetration, indicating the silty clay till is stiff to hard, generally very stiff in relative density. Hard consistency can be resulted from the presence of occasional cobbles and boulders.

Atterberg Limit was performed on a representative soil sample. The resulting plastic limit, liquid limit are 18% and 30%, respectively, indicating low plasticity. The natural water content of the clay till samples ranged between 11% and 17%, with a median of 15%, indicating generally moist conditions.

The engineering properties of silty clay till are listed below:

- High frost-susceptible and low water erodibility.
- Low permeability, with an estimated coefficient of permeability of 10^{-7} cm/sec and percolation time of over 80 min/cm.
- The shear strength is primarily derived from consistency and augmented by the internal friction of the sand and silt.
- Moderately high corrosivity to buried metal, with an estimated electrical resistivity of 3000 ohm·cm.

4.4 Compaction Characteristics of the Revealed Soils

The obtainable degree of compaction is primarily dependent on the soil moisture and to a lesser extent, on the type of compactor used and the effort applied. As a general guide, the typical water content values of the revealed soils for Standard Proctor compaction are presented in Table 1.

Table 1 - Estimated Water Content for Compaction

Soil Type	Determined Natural Water Content (%)	Water Content (%) for Standard Proctor Compaction	
		100% (optimum)	Range for 95% or +
Existing Earth Fill	19 to 36 (median of 22)	14	10 to 18
Silt	14 to 24 (median of 18)	11	8 to 13
Silty Clay Till	11 to 17 (median of 15)	16	14 to 19

Based on the above findings, most of the in-situ soils are suitable for 95% or + Standard Proctor compaction. Where the soils are too wet, soil aeration will be required by spreading the soils thinly under a dry and warm weather. For reuse for structural backfilling, the existing earth fill should be segregated for the topsoil and deleterious material.

The lifts for compaction should be limited to 20 cm, or to a suitable thickness as assessed by test strips performed by the equipment which will be used at the time of construction.

5.0 GROUNDWATER CONDITION

The boreholes were checked for the presence of groundwater upon completion of drilling. The data is summarized in Table 2.

Table 2 – Groundwater Level Upon Completion of Drilling

Borehole No.	Ground Elevation (m)	Borehole Depth (m)	Groundwater Level on Completion	
			Depth (m)	Elevation (m)
1	83.1	8.1	6.1	77.0
2	83.7	6.6	5.2	78.5
3	82.4	6.6	5.2	77.2
4	83.5	6.6	1.8	81.7
5	83.2	12.7	Dry	-

Upon completion of drilling, the groundwater was recorded at the depths ranging from 1.8 to 6.1 m below the prevailing ground surface, or between EI. 77.0 m and El. 81.7 m. On May 30, 2022, approximately 5 weeks after the well installation, the groundwater level was measured at El. 75.7 m from the monitoring well. The water level readings represent the local groundwater regime and will be subject to seasonal fluctuation.

6.0 SLOPE STABILITY ASSESSMENT

A slope stability assessment was completed for the natural slope at the rear of the subject site. The objective was to establish the stable slope gradient to support the determination of the erosion hazard limit.

A natural slope, approximately 5.0 to 8.4 m in height with a slope gradient ranging from 1.3 to 1.6H:1V, is located to the north of the site, abutting the north shoreline of Lake Ontario. The tableland is relatively flat with minor undulation. The shoreline within the subject site is approximately 115 m in length.

Visual Inspection

Visual inspection to document the existing slope condition was carried out on May 30, 2022, and our observations were summarized as follows:

- Approximately 60 m in long of the shoreline appeared to be unprotected, while the remaining area appeared to be protected with stacked armour stone wall, concrete blocks and rubble revetment, continuing to the neighbouring properties.
- Active erosion including sloughing, groundwater seepage and sliding were evident along the slope surface within the unprotected area. Accumulated deposit of fine soil particles was observed at the toe of slope.
- Trees along the top of slope were generally upright.
- A beach was observed along the unprotected slope.

Slope Stability Analysis

Two (2) representative cross-sections (Cross-Sections A-A and B-B) were selected for the stability analysis and the locations are presented on Drawing No. 3. The slope profiles at the cross-sections were interpreted from the provided topographic survey plan and the subsurface profile of Borehole 5 was interpreted for the soil parameters in both cross-sections.

The slope sections were analyzed using the force-moment-equilibrium criteria of the Bishop Method using the effective soil shear strength parameters shown in Table 3. The recorded groundwater was incorporated into the analysis as a phreatic surface.

Table 3 – Soil Shear Strength Parameters

Soil Type	**Bulk Unit Weight γ (kN/m^3)**	**Effective Cohesion c' (kPa)**	**Effective Internal Friction Angle ϕ'**
Earth Fill	20.0	0	26°
Native Silt	21.0	0	30°
Native Silty Clay Till	22.0	5	31°

The resulting Factors of Safety (FOS) in existing conditions are presented on Drawing Nos. 4 and 5, and the resulting minimum FOS are summarized in the Table 4.

Table 4 – Slope Stability Analyses (Existing Conditions)

Cross Section	**Slope Height (m)**	**Slope Gradient**	**Factor of Safety (FOS)**	
			Local	**Global**
A-A	7.0	1.4H:1V	0.41	1.14
B-B	8.3	1.2 to 1.9H:1V	0.65	1.08

The resulting FOS at both cross-sections does not meet the Ontario Ministry of Natural Resources (OMNR) and Niagara Peninsula Conservation Authority (NPCA) guideline requirements for active land use (minimum FOS of 1.5).

A Shoreline Hazard Assessment, prepared by Shoreplan Engineering Limited dated July 2023, was provided for our review. A shoreline protection system designed for a service life of 50 years is proposed along the lakefront in the site.

In order to achieve FOS of 1.5 both locally and globally, Cross-Sections A-A and B-B were re-analyzed with the stable slope gradient. The analytical results are illustrated in Figures 6 and 7 and the details are presented in Table 5.

Table 5- Slope Stability Analyses (Geotechnically Stable Conditions)

Cross Section	Stable Slope Gradient	Factor of Safety (FOS)	
		Local	**Global**
A-A	Earth Fill – 3H:1V Native Silt – 2.5H:1V	1.51	1.52
B-B		1.50	1.52

Based on the above results, the slope is considered geotechnically stable with the stable slope gradients of 3.0H:1V and 2.5H:1V within the earth fill and the native silt deposit, respectively.

General Considerations

In order to prevent disturbance of the existing slope and to enhance the stability of the bank slope for the proposed development, the following geotechnical recommendations should be stipulated:

1. A vegetative cover on the slope must be maintained for protection against soil erosion by weathering. If, for any reason, the vegetative cover is stripped, it must be reinstated to its original, or better than its original, protective condition. Restoration with selected native plantings including deep rooting systems must be carried out after development to ensure bank stability. The bare slope surface must be adequately sodded or vegetated.
2. Surface water must be directed away from the slope or carried down the slope in suitable conduits. Grading of the land adjacent to the slope must be such that concentrated runoff is not allowed to drain onto the slope face. Landscaping features which may cause runoff to pond at the top of the slope, such as infiltration trenches, as well as saturating the crown of the bank, must not be permitted.
3. Additional fill and snow must not be piled near the top of slope.
4. Where development is carried out adjacent to the slope, there might be external factors to be considered in terms of potential human impact of improper land use. These include soil saturation from frequent watering to maintain landscaping features, stripping of topsoil or vegetation, dumping of loose fill, and material storage close to the top of slope; none of these should be permitted.

Provided that all the above recommendations are followed, the proposed development at the tableland should not have any adverse impact on the slope stability.

The above recommendations are subject to approval and requirements stipulated by NPCA.

7.0 DISCUSSION AND RECOMMENDATIONS

The investigation revealed that beneath the topsoil veneer and/or a layer of earth fill, the site is underlain by a generally compact silt deposit, overlying a generally very stiff silty clay till.

Upon completion of drilling, the groundwater was recorded at the depths of 1.8 to 6.1 m below the prevailing ground surface, or between EI. 77.0 m and 81.7 m. On May 30, 2022, the groundwater level was measured at El. 75.7 m from the monitoring well in Borehole 5. The water level readings represent the local groundwater regime and will be subject to seasonal fluctuation.

It is understood that the site will be developed for a residential subdivision with private roadways and public amenities. The geotechnical findings which warrant special consideration of the proposed development are presented below:

1. Topsoil can only be used for landscaping purposes; any surplus must be removed off-site.
2. The existing earth fill should be segregated for the topsoil and deleterious material, before reuse for structural backfilling.
3. Where additional fill is required for site grading, it may be economical to construct the pavement, building structures and underground services on engineered fill.
4. The native soils or engineered fill are considered suitable to support the proposed structure with conventional spread and strip footings. The foundation subgrade shall be inspected by a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer, to ensure that the revealed conditions are compatible with the foundation requirements.
5. In conventional basement construction, the basement should be provided with perimeter subdrains and should be founded at least 1.0 m above the highest recorded groundwater level.
6. A Class ‘B’ granular bedding, consisting of compacted 19-mm Crusher Run Limestone (CRL) or equivalent, is recommended for the construction of the underground services. In saturated soils, a Class ‘A’ concrete bedding is required.

The recommendations appropriate for the project described in Section 2.0 are based on the geotechnical findings of this investigation. One must be aware that the subsurface conditions may vary between boreholes. Should this become apparent during construction, a geotechnical engineer must be consulted to determine whether the following recommendations require revision.

7.1 Site Preparation

All existing structures must be demolished. The construction debris must be removed and the cavities must be properly backfilled prior to the development.

If the site is to be regraded with additional fill, it is economical to upgrade the existing fill and construct the pavement, building structures, and underground services on the engineered fill. The engineering requirements for a certifiable fill are presented below:

1. The existing earth fill should be removed and examined. Any topsoil and deleterious material must be segregated and removed before reuse for structural backfill.
2. Inorganic soils must be used for the engineered fill, they must be uniformly compacted in lifts of 20 cm thick to 100% Standard Proctor dry density (SPDD), up to the pre-grade level.
3. If imported fill is to be used, it should be inorganic soils, free of deleterious or any material with environmental issue (contamination). Any potential imported earth fill from off site must be reviewed for geotechnical and environmental quality by the appropriate personnel as authorized by the developer or agency, before being hauled to the site.
4. If the engineered fill is to be left over the winter months, adequate earth cover or equivalent must be provided for protection against frost action.
5. The engineered fill must extend over the entire graded area; the engineered fill envelope and finished elevations must be clearly and accurately defined in the field, and must be precisely documented by qualified surveyors.
6. The engineered fill must not be placed during the period from late November to early April when freezing ambient temperatures occur either persistently or intermittently. This is to ensure that the fill is free of frozen soils, ice and snow.
7. Where the fill is to be placed on a bank steeper than 1 vertical:3 horizontal, the face of the bank must be flattened for safe operation of the compactor and the required compaction can be obtained.

8. Where the ground is wet due to subsurface water seepage, an appropriate subdrain scheme must be implemented prior to the fill placement, particularly if it is to be carried out on sloping ground.
9. The fill operation must be inspected on a full-time basis by a technician under the direction of a geotechnical engineer.
10. The footing and underground services subgrade must be inspected by the geotechnical consulting firm that supervised the engineered fill placement. This is to ensure that the foundations are placed within the engineered fill envelope, and the integrity of the fill has not been compromised by interim construction, environmental degradation and/or disturbance by the footing excavation.
11. Any excavation carried out in certified engineered fill must be reported to the geotechnical consultant who supervised the fill placement in order to document the locations of excavation and/or to supervise reinstatement of the excavated areas to engineered fill status. If construction on the engineered fill does not commence within a period of 2 years from the date of certification, the condition of the engineered fill must be assessed for re-certification.
12. Despite stringent control in the placement of the engineered fill, variations in soil type and density may occur in the engineered fill. Therefore, the strip footings and the upper section of the foundation walls constructed on the engineered fill will require continuous steel reinforcement. The required number and size of reinforcing bars must be assessed by the structural engineer, by considering the uniformity as well as the thickness of the engineered fill beneath the foundations.
13. In sewer construction, the engineered fill is considered to have the same structural proficiency as a natural inorganic soil.

7.2 **Foundation**

The proposed structure can be supported on conventional spread and strip footings, founded onto the sound native soil or engineered fill. The recommended soil bearing pressures for the design of conventional footings are provided as follows:

- Maximum Allowable Soil Bearing Pressure at SLS = 150 kPa
- Factored Ultimate Soil Bearing Pressure at ULS = 250 kPa

The total and differential settlements of foundations designed for the bearing pressure at SLS are estimated to be within 25 mm and 20 mm, respectively.

The foundation subgrade should be inspected by the geotechnical engineer or a senior geotechnical technician to ensure that the revealed conditions comply with the foundation design requirements.

Footings exposed to weathering or in unheated areas should have at least 1.2 m of earth cover for protection against frost heave during the winter months.

If seepage or wet subgrade is encountered during excavation, the subgrade shall be protected by concrete mud-slab after the subgrade is inspected, to mitigate potential construction disturbance due to seepage and costly rectification of the bearing subsoil.

The foundations shall meet the requirements specified in the latest Ontario Building Code. The proposed structure shall be designed to resist an earthquake force using Site Classification 'D' (stiff soil).

7.3 **Basement and Slab-on-Grade Construction**

The basement floor of the proposed residences should be founded at a minimum separation of 1.0 m above the highest recorded groundwater level. The perimeter walls of the basement structures should be damp-proofed and provided with perimeter subdrains (Drawing No. 8). The subdrains should be encased in a fabric filter to protect them against blockage by silting. They should be connected to the positive outlet or sump pits where water can be removed. Where the basement is less than 1.0 m, but 0.5 m above the highest recorded groundwater level, the underfloor subdrain system should be installed. A vapour barrier should be provided between the concrete floor slab and the granular bedding. (Drawing No. 9).

The perimeter walls should be designed to sustain a lateral earth pressure calculated using the soil parameters stated in Section 6.8. Any applicable surcharge loads adjacent to the basement must also be considered in the wall design.

The subgrade for the basement slab should consist of sound natural soil or properly compacted inorganic earth fill. Where soft or wet subgrade is encountered, it must be subexcavated and replaced with on-site approved inorganic soil, compacted to at least 98% SPDD in lifts no more than 20 cm in thickness.

The basement floor should be constructed on a 20 cm thick granular bedding, consisting of 19-mm CRL or equivalent, compacted to 100% SPDD. Where underfloor subdrains are required, the granular bedding must be increased to 30 cm thick.

The external grading should be such that the surface runoff is directed away from the building foundations.

7.4 Underground Services

The subgrade for underground services shall consist of sound native soils or well-compacted inorganic earth fill. In areas where the subgrade consists of weak or badly weathered soils, it shall be removed and replaced with the bedding material and compacted to at least 98% SPDD.

A Class ‘B’ granular bedding, consisting of compacted 19-mm CRL or equivalent, is recommended for the construction of the underground services. In saturated or erodible soils, a Class ‘A’ concrete bedding is required.

The pipe joints into the catch basins and manholes shall be leak-proof, or wrapped tightly with waterproof membrane to prevent subgrade upfiltration through the joints. Openings to subdrains and catch basins shall be shielded by a fabric filter to prevent blockage by silting.

In order to prevent pipe floatation when the sewer trench is deluged with water, a soil cover with a thickness at least two times the diameter of the pipe should be in place at all times after completion of the pipe installation.

All metal fittings for the underground services shall be protected against soil corrosion. The in-situ soils have moderately high corrosivity to buried metal. In determining the mode of protection, an electrical resistivity of 3000 ohm·cm shall be used. However, this shall be verified by testing the soil along the pipe alignment at the time of construction.

7.5 Backfilling in Trenches and Excavated Areas

The on-site inorganic soils are generally suitable for use as trench backfill. The backfill should be compacted to at least 95% SPDD. In the zone within 1.0 m below the pavement subgrade or slab-on-grade construction, the material should be compacted to 98% SPDD with the water content 2% to 3% drier than the optimum. This is to provide the required stiffness for pavement and slab construction. In the lower zone, the compaction can be carried out on the wet side of the optimum; this allows a wider latitude of lift thickness.

In normal construction practice, the problem areas of ground settlement largely occur adjacent to manholes, catch basins, services crossings, foundation walls and columns. In areas which are inaccessible to a heavy compactor, imported sand backfill should be used with light weight vibratory compactor.

The narrow trenches should be cut at 1 vertical:2 or + horizontal so that the backfill can be effectively compacted. Otherwise, soil arching will prevent the achievement of proper compaction. The lift of each backfill layer should either be limited to a thickness of 20 cm, or the thickness should be determined by test strips.

One must be aware of the possible consequences during trench backfilling and exercise caution as described below:

- When construction is carried out in freezing winter weather, allowance should be made for these following conditions. Despite stringent backfill monitoring, frozen soil layers may inadvertently be mixed with the structural trench backfill. Should the in situ soils have a water content on the dry side of the optimum, it would be impossible to wet the soil due to the freezing condition, rendering difficulties in obtaining uniform and proper compaction. Furthermore, the freezing condition will prevent flooding of the backfill when it is required, such as when the trench box is removed. The above will invariably cause backfill settlement that may become evident in the first few years, depending on the depth of the trench which has been backfilled.
- In areas where the underground services construction is carried out during winter months, prolonged exposure of the trench walls will result in frost heave within the soil mantle of the walls. This may result in some settlement as the frost recedes, and repair costs will be incurred prior to final surfacing of the new pavement.
- To backfill a deep trench, one must be aware that future settlement is to be expected, unless the side of the cut is flattened to at least 1 vertical:1.5 + horizontal, and the lifts of the fill and its moisture content are stringently controlled; i.e., lifts should be no more than 20 cm (or less if the backfilling conditions dictate) and uniformly compacted to achieve at least 95% of the maximum Standard Proctor dry density, with the moisture content on the wet side of the optimum.
- It is often difficult to achieve uniform compaction of the backfill in the lower vertical section of a trench which is an open cut or is stabilized by a trench box, particularly in the sector close to the trench walls or the sides of the box. These sectors must be backfilled with sand. In a trench stabilized by a trench box, the void left after the

removal of the box will be filled by the backfill. It is necessary to backfill this sector with sand, and the compacted backfill must be flooded for 1 day, prior to the placement of the backfill above this sector, i.e., in the upper sloped trench section. This measure is necessary in order to prevent consolidation of inadvertent voids and loose backfill which will compromise the compaction of the backfill in the upper section.

- In areas where groundwater movement is expected in the subsoil and trench backfill, a concrete pipe bedding or anti-seepage collars should be provided.

7.6 Sidewalk and Landscaping Structures

The concrete sidewalk and landscaping structures in open areas will be subject to seasonal movement and they should be designed to be tolerable for frost heave. The finished grading must be designed such that it directs the surface water runoff away from the structures and prevent water ponding.

In areas where ground movement cannot be tolerated, the concrete slab must be constructed on free-draining granular material to 1.2 m in depth, compacted to 95% SPDD, with a subdrain for removal of any percolated groundwater at the bottom. Alternatively, the subgrade can be properly insulated with 50-mm Styrofoam, or equivalent.

7.7 Pavement Design

The recommended pavement design for roadway and parking is given in Table 6.

Table 6 - Pavement Design

Course	Thickness (mm)	OPS Specifications
Asphalt Surface	40	HL3
Asphalt Binder	50	HL8
Granular Base	150	Granular A or equivalent
Granular Sub-base	300	Granular B or equivalent

Prior to placement of the granular base and subbase, the subgrade shall be proof-rolled. Any weathered or soft subgrade shall be removed and replaced by properly compacted inorganic earth fill. In order to provide a stable subgrade surface for pavement construction, it is imperative that the subgrade within the 1.0 m zone below the underside of the granular base shall be compacted to 98% SPDD with water content 2% to 3% drier than the optimum. All the granular base shall be compacted to 100% SPDD.

The following measures shall be incorporated in the construction procedures and pavement design:

- Areas adjacent to the pavement shall be properly graded to prevent water ponding. Where surface runoff may drain onto the pavement, or water may seep into the granular base, a swale or intercept subdrain system shall be installed, if necessary.
- If the pavement is to be constructed during the wet season, thickening of the granular sub-base may be required to facilitate water drainage on site.
- Fabric filter-encased subdrain or stub drains will be required at the low areas. They shall be installed at 0.3 m below the underside of the granular sub-base and connected to a positive outlet for water drainage.

7.8 Soil Parameters

The recommended soil parameters for the project design are given in Table 7.

Table 7 - Soil Parameters

Unit Weight and Bulk Factor	**Unit Weight (kN/m^3)**		**Estimated Bulk Factor**	
	Bulk	**Submerged**	**Loose**	**Compacted**
Existing Earth Fill	20.0	10.0	1.20	1.00
Silt	21.0	11.0	1.20	1.00
Silty Clay Till	22.5	12.5	1.33	1.03
Lateral Earth Pressure Coefficients		**Active K_a**	**At Rest K_o**	**Passive K_p**
Compacted Earth Fill		0.40	0.50	2.50
Silt and Silty Clay Till		0.33	0.43	3.00
Coefficients of Friction				
Between Concrete and Granular Base			0.50	
Between Concrete and Sound Natural Soils			0.35	

7.9 Excavation

Excavation should be carried out in accordance with Ontario Regulation 213/91. For excavation purposes, the types of soils are classified in Table 8.

Table 8 - Classification of Soils for Excavation

Material	Type
Silty Clay Till	2
Earth Fill and Drained Silt	3
Saturated Silt	4

Based on the soil profile and borehole findings, the silt deposit is saturated. Where excavation extending into the silt stratum, dewatering will be required to lower the groundwater table at least 1.0 m below the bottom of excavation with closely spaced sumps. Where necessary, a hydrogeological study may be required to determine the volume and rate of dewatering.

Excavation into the hard till containing boulders may require extra effort and the use of a heavy-duty excavator. Boulders larger than 15 cm in size are not suitable for structural backfill and/or construction of engineered fill.

Prospective contractors would be requested to verify the in-situ subsurface conditions for soil cuts by digging test pits to 0.5 m below the anticipated depth of excavation. These test pits shall remain open for a few hours for assessment of the trench conditions.

8.0 LIMITATIONS OF REPORT

This report was prepared by Soil Engineers Ltd. for the account of Sophie's Landing Grimsby Inc., and for review by its designated consultants, financial institutions, and government agencies. Use of this report is subject to the conditions and limitations of the contractual agreement.

The material in the report reflects the judgment of Daric Yang, B.A.Sc. and Kin Fung Li, P.Eng., in light of the information available to it at the time of preparation. Any use which a Third Party makes of this report, or any reliance on decisions to be made based on it, is the responsibility of such Third Party. Soil Engineers Ltd. accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report.

SOIL ENGINEERS LTD.

Daric Yang, B.A.Sc.

Kin Fung Li, P.Eng.
DY/KFL

LICENSED PROFESSIONAL ENGINEER
Sept 15, 2023
K. F. LI
100169280
PROVINCE OF ONTARIO

LIST OF ABBREVIATIONS AND DESCRIPTION OF TERMS

The abbreviations and terms commonly employed on the borehole logs and figures, and in the text of the report, are as follows:

SAMPLE TYPES

AS	Auger sample
CS	Chunk sample
DO	Drive open (split spoon)
DS	Denison type sample
FS	Foil sample
RC	Rock core (with size and percentage recovery)
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

PENETRATION RESISTANCE

Dynamic Cone Penetration Resistance:

A continuous profile showing the number of blows for each foot of penetration of a 2-inch diameter, 90° point cone driven by a 140-pound hammer falling 30 inches.

Plotted as '—●—'

Standard Penetration Resistance or 'N' Value:

The number of blows of a 140-pound hammer falling 30 inches required to advance a 2-inch O.D. drive open sampler one foot into undisturbed soil.

Plotted as '○'

WH	Sampler advanced by static weight
PH	Sampler advanced by hydraulic pressure
PM	Sampler advanced by manual pressure
NP	No penetration

SOIL DESCRIPTION

Cohesionless Soils:

'N' (blows/ft)	Relative Density
0 to 4	very loose
4 to 10	loose
10 to 30	compact
30 to 50	dense
over 50	very dense

Cohesive Soils:

Undrained Shear Strength (ksf)	'N' (blows/ft)	Consistency
less than 0.25	0 to 2	very soft
0.25 to 0.50	2 to 4	soft
0.50 to 1.0	4 to 8	firm
1.0 to 2.0	8 to 16	stiff
2.0 to 4.0	16 to 32	very stiff
over 4.0	over 32	hard

Method of Determination of Undrained Shear Strength of Cohesive Soils:

x 0.0 Field vane test in borehole; the number denotes the sensitivity to remoulding

△ Laboratory vane test

☐ Compression test in laboratory

For a saturated cohesive soil, the undrained shear strength is taken as one half of the undrained compressive strength

METRIC CONVERSION FACTORS

1 ft = 0.3048 metres
1lb = 0.454 kg
1 inch = 25.4 mm
1ksf = 47.88 kPa

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JOB NO.: 2201-S023

LOG OF BOREHOLE: 1

FIGURE NO.: 1

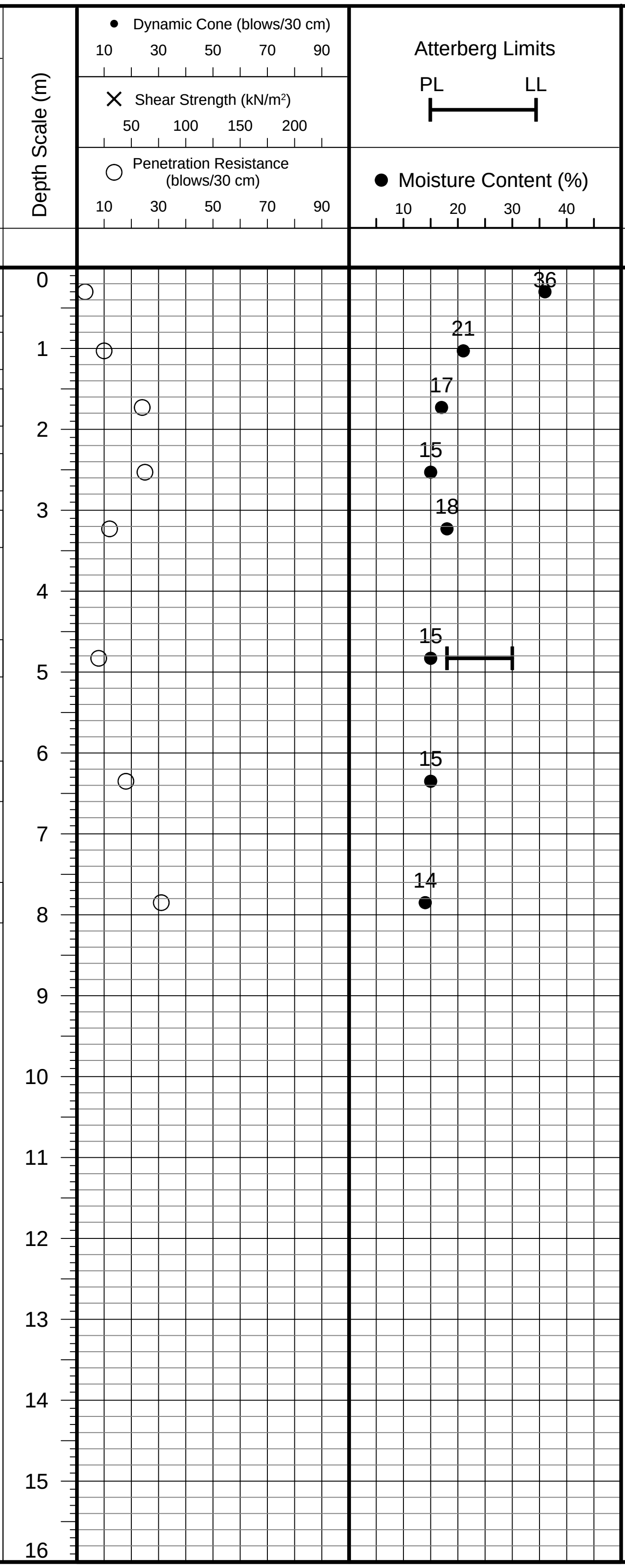
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger (Solid-Stem)

PROJECT LOCATION: 165 Lake Street, Town of Grimsby

DRILLING DATE: January 24, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
83.1	Ground Surface			
	15 cm TOPSOIL	1	DO	3
82.3 0.8	**EARTH FILL** Brown, sand and silt occ. gravel and topsoil inclusions	2	DO	10
	weathered	3	DO	24
	Loose to compact **SILT** some sand to sandy a trace to some clay brown / grey	4	DO	25
		5	DO	12
		6	DO	8
77.6 5.5	Grey, very stiff **SILTY CLAY TILL** low plasticity a trace of gravel occ. sand seams and layers and cobbles	7	DO	18
		8	DO	31
75.0 8.1	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ El. 77.0 m on completion of drilling

Soil Engineers Ltd.

JOB NO.: 2201-S023

LOG OF BOREHOLE: 2

FIGURE NO.: 2

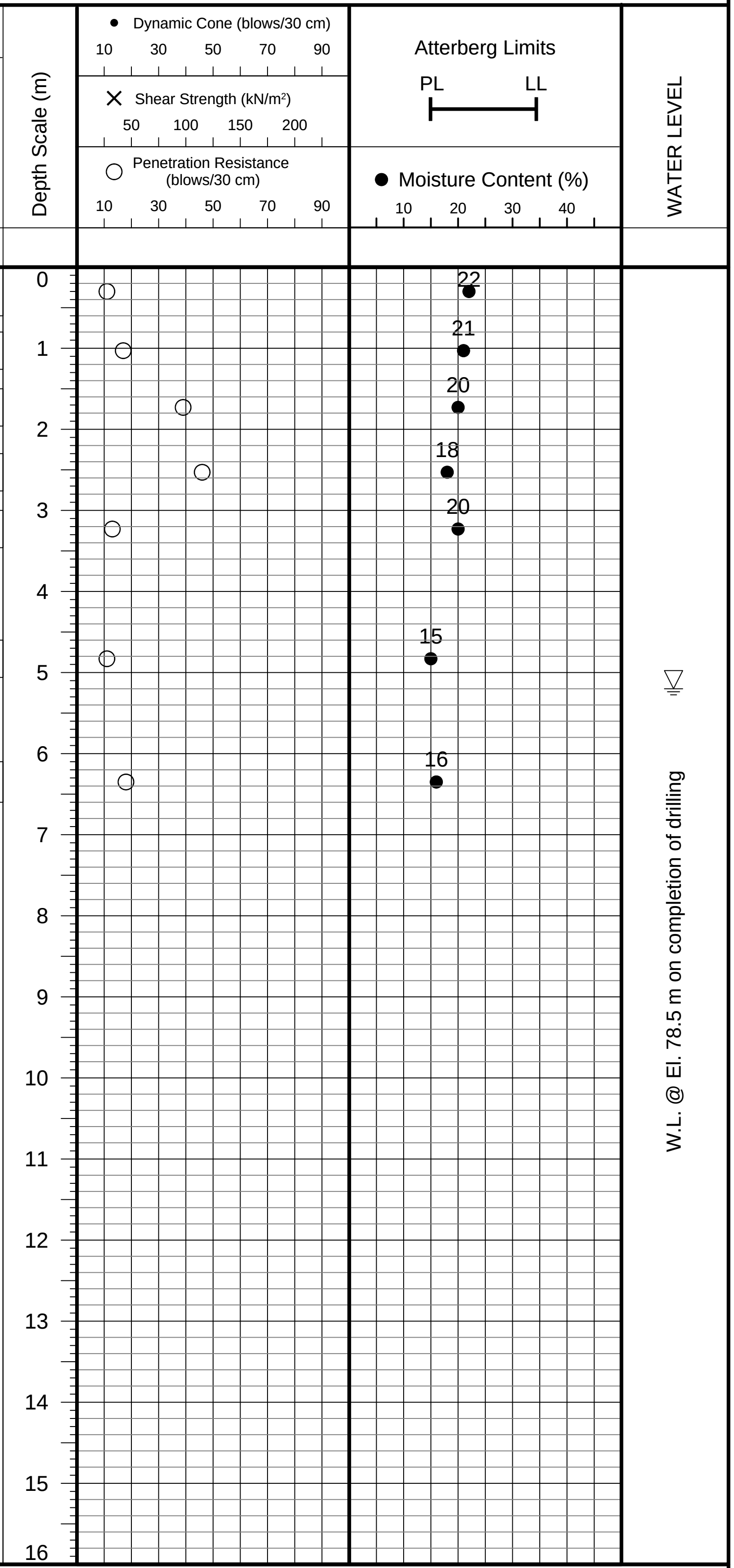
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger (Solid-Stem)

PROJECT LOCATION: 165 Lake Street, Town of Grimsby

DRILLING DATE: January 24, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
83.7	Ground Surface			
	15 cm TOPSOIL	1	DO	11
83.0 0.7	**EARTH FILL** Brown, sand and silt occ. gravel and topsoil inclusions	2	DO	17
	Brown, compact to dense **SILT** some sand to sandy a trace to some clay	3	DO	39
		4	DO	46
		5	DO	13
79.7 4.0	Grey, stiff to very stiff **SILTY CLAY TILL** low plasticity a trace of gravel occ. sand seams and layers	6	DO	11
		7	DO	18
77.1 6.6	**END OF BOREHOLE**			



W.L. @ El. 78.5 m on completion of drilling

Soil Engineers Ltd.

JOB NO.: 2201-S023

LOG OF BOREHOLE: 3

FIGURE NO.: 3

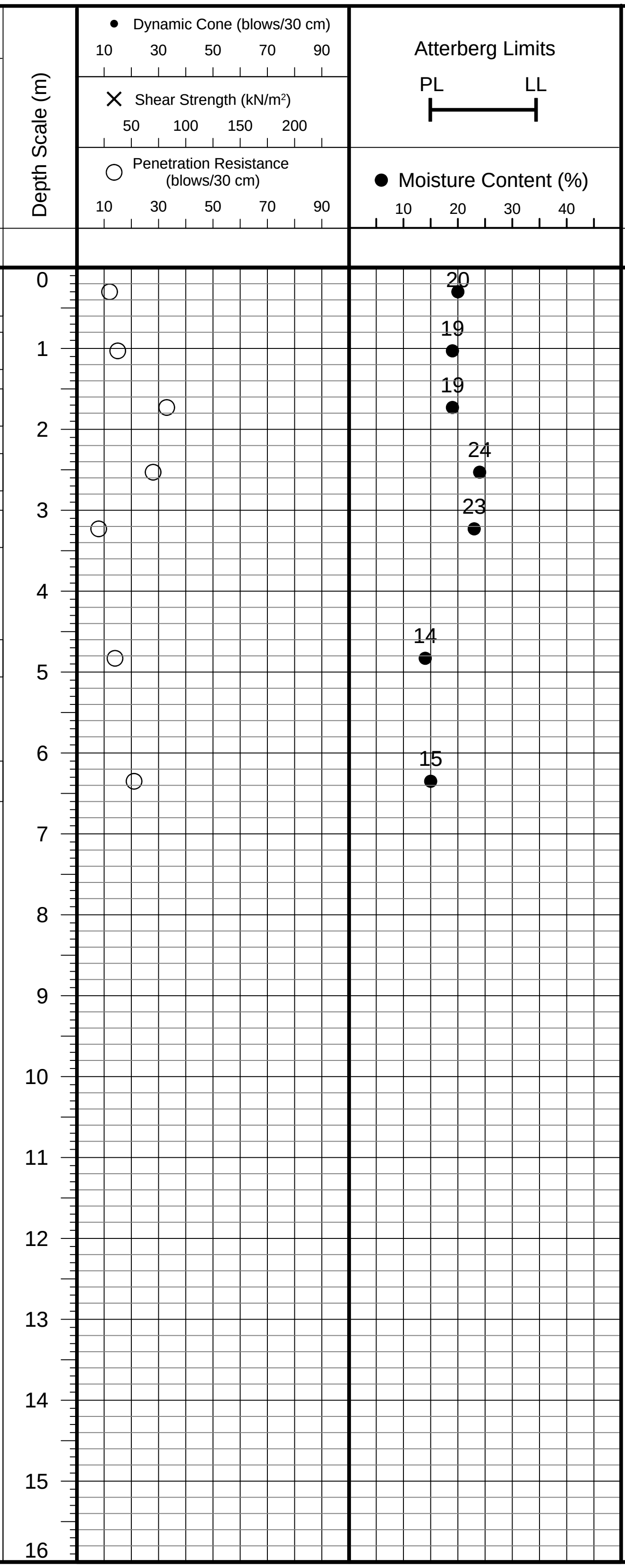
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger (Solid-Stem)

PROJECT LOCATION: 165 Lake Street, Town of Grimsby

DRILLING DATE: January 24, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
82.4	Ground Surface			
	15 cm TOPSOIL	1	DO	12
81.7 0.6	**EARTH FILL** Brown, sand and silt occ. gravel and topsoil inclusions	2	DO	15
	Brown, compact to dense **SILT** a trace of sand a trace to some clay	3	DO	33
		4	DO	28
		5	DO	8
78.4 4.0	Grey, stiff to very stiff **SILTY CLAY TILL** low plasticity a trace of gravel occ. sand seams and layers and cobbles	6	DO	14
		7	DO	21
75.8 6.6	**END OF BOREHOLE**			



WATER LEVEL

∇ W.L. @ El. 77.2 m on completion of drilling

JOB NO.: 2201-S023

LOG OF BOREHOLE: 4

FIGURE NO.: 4

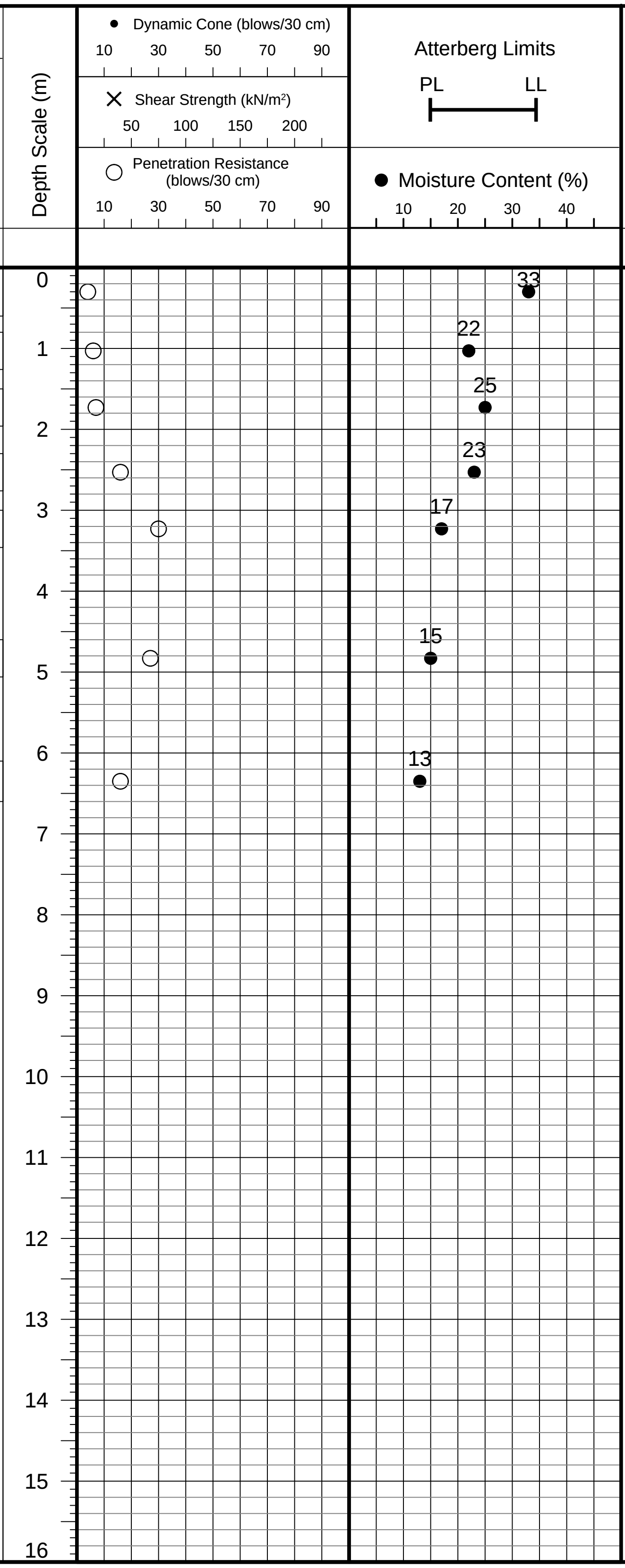
PROJECT DESCRIPTION: Proposed Residential Development

PROJECT LOCATION: 165 Lake Street, Town of Grimsby

METHOD OF BORING: Flight-Auger (Solid-Stem)

DRILLING DATE: January 24, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
83.5	Ground Surface			
	15 cm TOPSOIL	1	DO	4
	EARTH FILL Brown, sand and silt occ. gravel and topsoil inclusions	2	DO	6
		3	DO	7
81.2 2.3	Brown, compact **SILT** trace to some sand a trace of clay	4	DO	16
80.6 2.9	Grey, stiff to very stiff **SILTY CLAY TILL** low plasticity a trace of gravel occ. sand seams and layers and cobbles	5	DO	30
		6	DO	27
		7	DO	16
76.9 6.6	**END OF BOREHOLE**			



WATER LEVEL

▽ W.L. @ El. 81.7 m on completion of drilling

Soil Engineers Ltd.

JOB NO.: 2201-S023

LOG OF BOREHOLE: 5

FIGURE NO.: 5

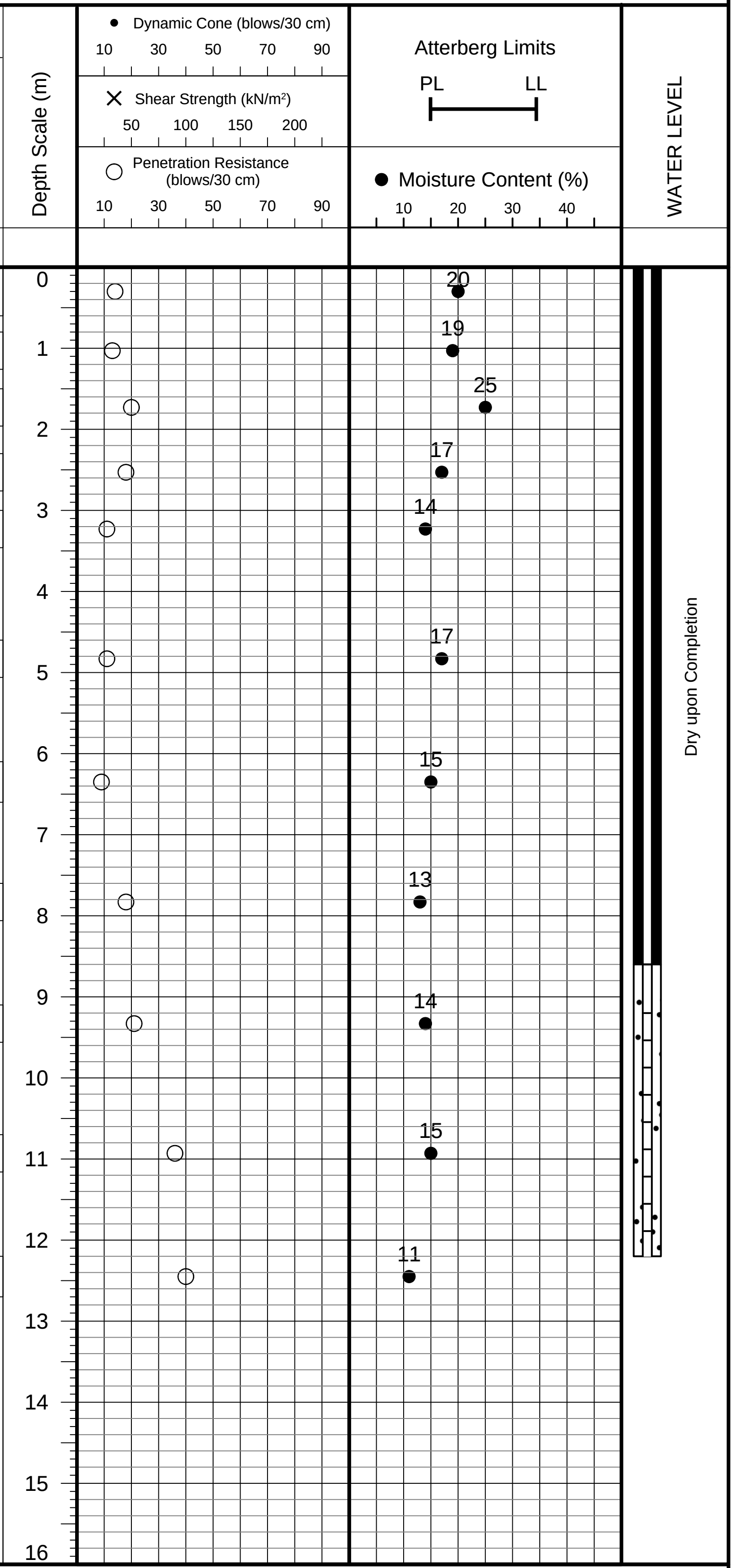
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger (Solid-Stem)

PROJECT LOCATION: 165 Lake Street, Town of Grimsby

DRILLING DATE: January 25, 2022

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
83.2	Ground Surface			
	15 cm TOPSOIL			
	EARTH FILL Brown, sand and silt occ. gravel and topsoil inclusions	1	DO	14
		2	DO	13
		3	DO	20
81.0 2.2	Loose to compact **SILT** some clay to clayey a trace of sand	4	DO	18
		5	DO	11
	brown grey			
		6	DO	11
		7	DO	9
76.2 7.0	Grey, very stiff to hard **SILTY CLAY TILL** low plasticity a trace of gravel occ. sand seams and layers, cobbles and boulders	8	DO	18
		9	DO	21
		10	DO	36
		11	DO	40
70.5 12.7	**END OF BOREHOLE** Installed 50 mm Ø monitoring well 12.2 m completed with 3.0 m screen Sand backfill from 8.6 to 12.2 m Bentonite seal from 0.0 m to 8.6 m Provided with a monument steel casing			



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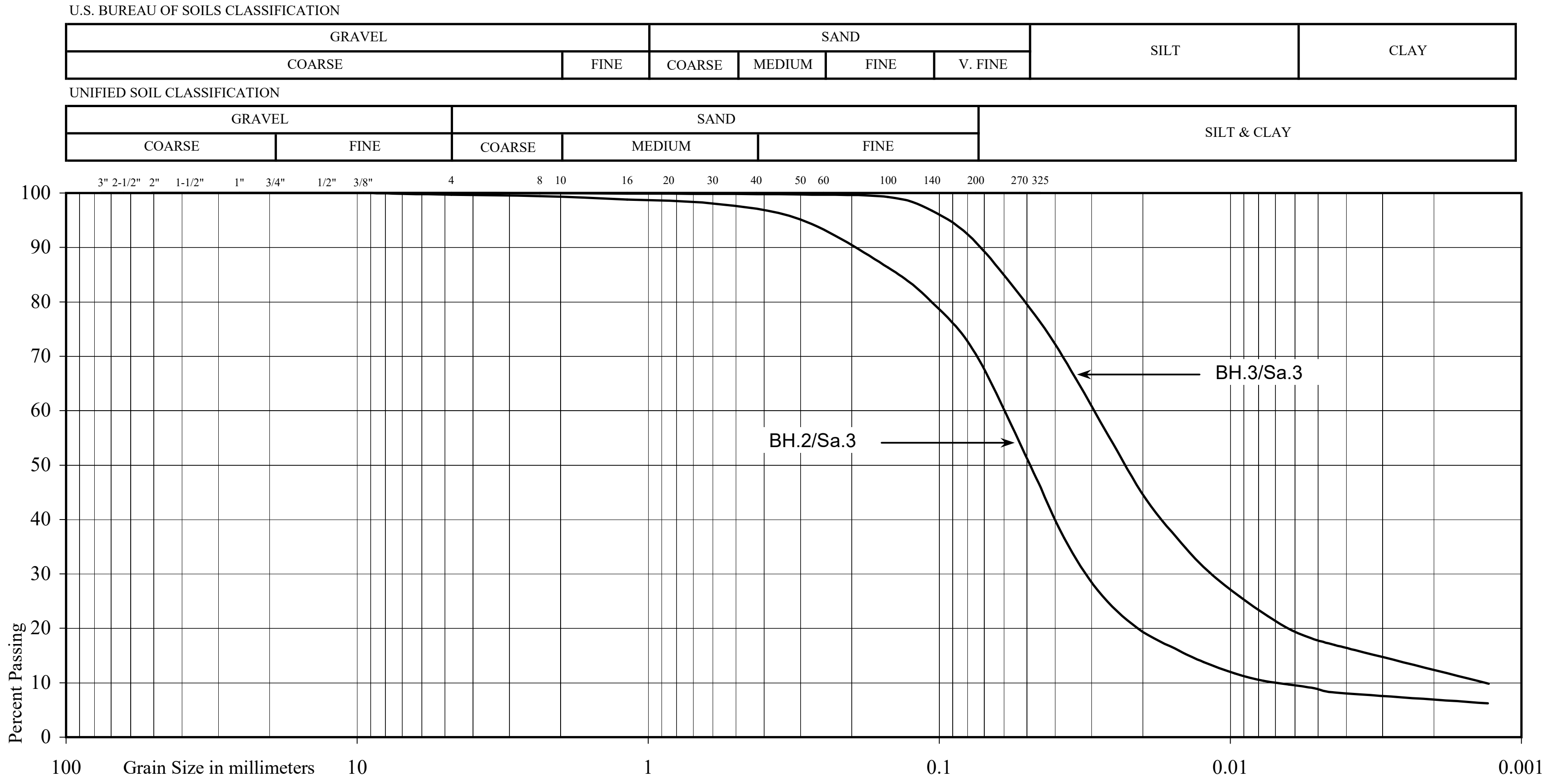
GRAIN SIZE DISTRIBUTION

Reference No: 2201-S023



Project:	Proposed Residential Development	
Location:	165 Lake Street, Town of Grimsby	
Borehole No:	2	3
Sample No:	3	3
Depth (m):	1.9	1.9
Elevation (m):	81.8	80.5

BH./Sa.	2/3	3/3
Liquid Limit (%) =	-	-
Plastic Limit (%) =	-	-
Plasticity Index (%) =	-	-
Moisture Content (%) =	20	19
Estimated Permeability (cm./sec.) =	10^{-4}	10^{-6}

Classification of Sample [& Group Symbol]: SILT
a trace of clay

Figure: 6

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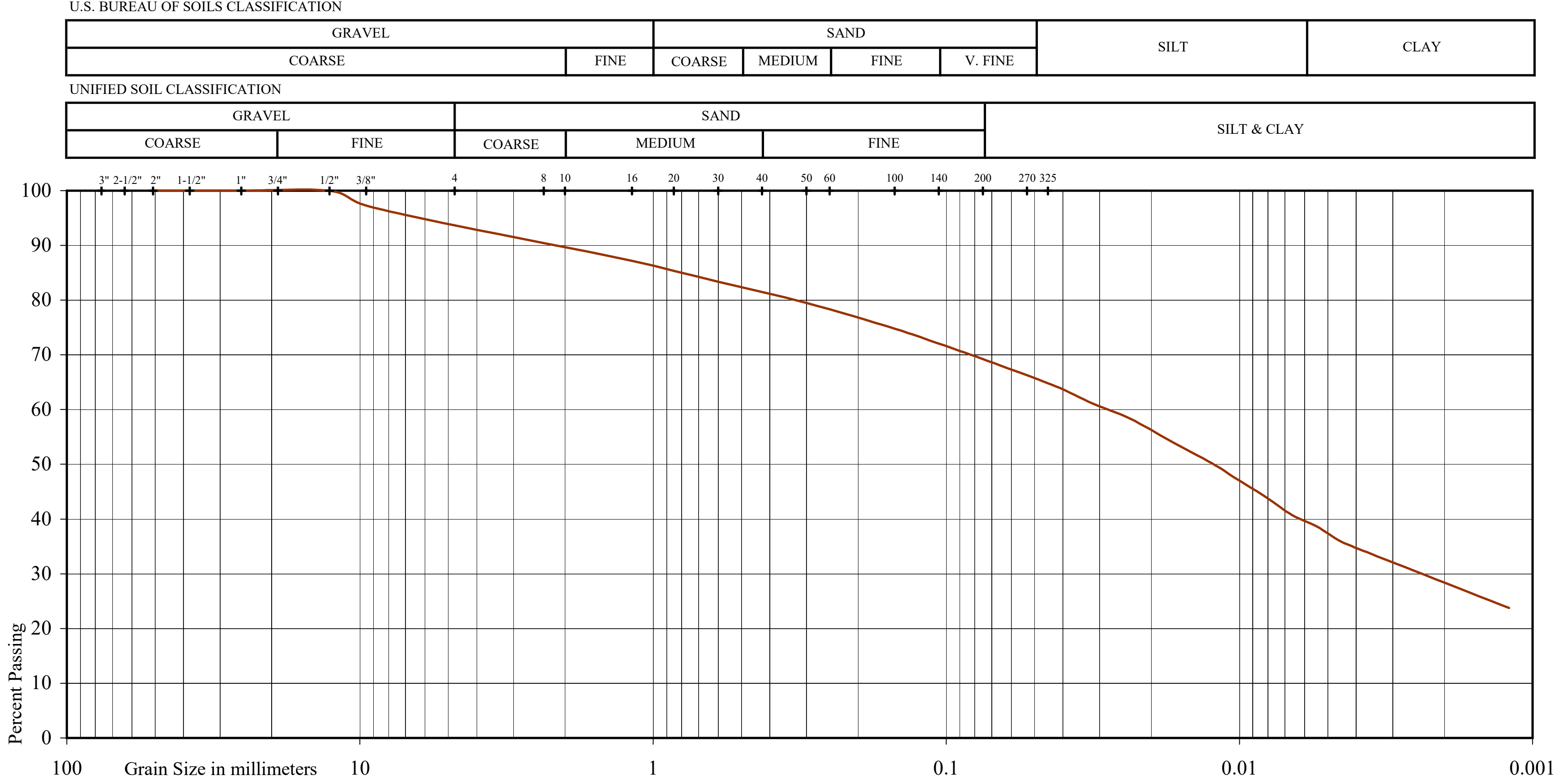
GRAIN SIZE DISTRIBUTION

Reference No: 2201-S023



Project: Proposed Residential Development

Location: 165 Lake Street, Town of Grimsby

Borehole No: 1

Sample No: 6

Depth (m): 4.7

Elevation (m): 78.4

Liquid Limit (%) = 30

Plastic Limit (%) = 18

Plasticity Index (%) = 12

Moisture Content (%) = 15

Estimated Permeability

(cm./sec.) = 10^{-7}

Classification of Sample [& Group Symbol]: SILTY CLAY TILL

a trace of gravel

Figure: 7

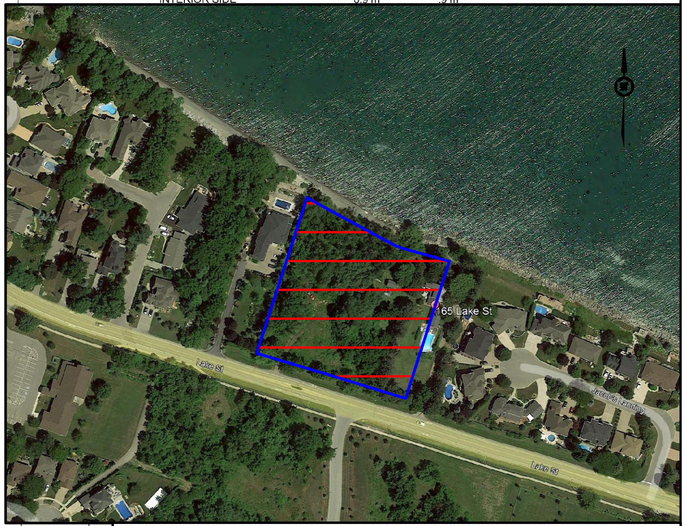
LEGEND

⊕	BOREHOLE/MONITORING WELL
⊕	BOREHOLE

SITE STATISTICS

ZONING: ND
TOTAL DWELLING COUNT = 32
SINGLE DETACHED DWELLINGS = 10
SEMI-DETACHED DWELLINGS = 22
PUBLIC ASSEMBLY BUILDING (CLUBHOUSE) = 1

	RM1	PROPOSED
LOT AREA	225 sq.m.	200.76 sq.m.
MIN. LOT FRONTAGE	7.5 m	8.4 m
MAX LOT COVERAGE	40%	107.77 sq.m. (54%)
MAX. HEIGHT PRINCIPAL BLDGS	10 m	9.4 m
SETBACKS		
FRONT	4.5 m	4.5 m
REAR	7.5 m	4.5 m
EXTERIOR SIDE	4.5 m	2.60 m
EXTERIOR SIDE (LAKE ST.)	4.5 m	3.30 m
INTERIOR SIDE	0.9 m	.9 m



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BOREHOLE LOCATION PLAN

SITE: 165 LAKE STREET, TOWN OF GRIMSBY

DESIGNED BY: J.F.
CHECKED BY: K.L.
DWG NO.: 1
SCALE: 1:750
REF. NO.: 2201-S023
DATE: August 2023
REV -

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SUBSURFACE PROFILE
DRAWING NO. 2
SCALE: AS SHOWN

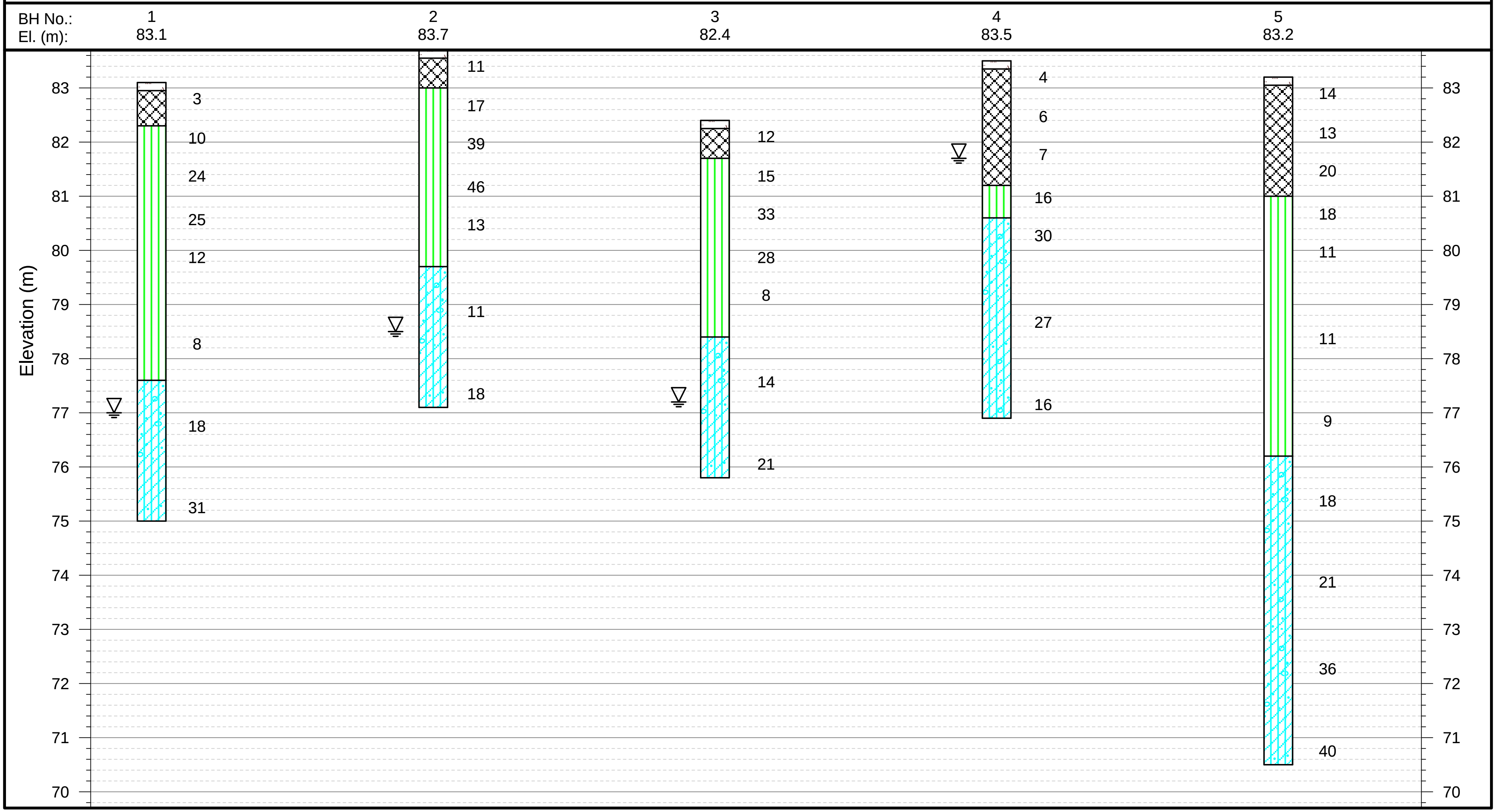
JOB NO.: 2201-S023
REPORT DATE: August 2023
PROJECT DESCRIPTION: Proposed Residential Development

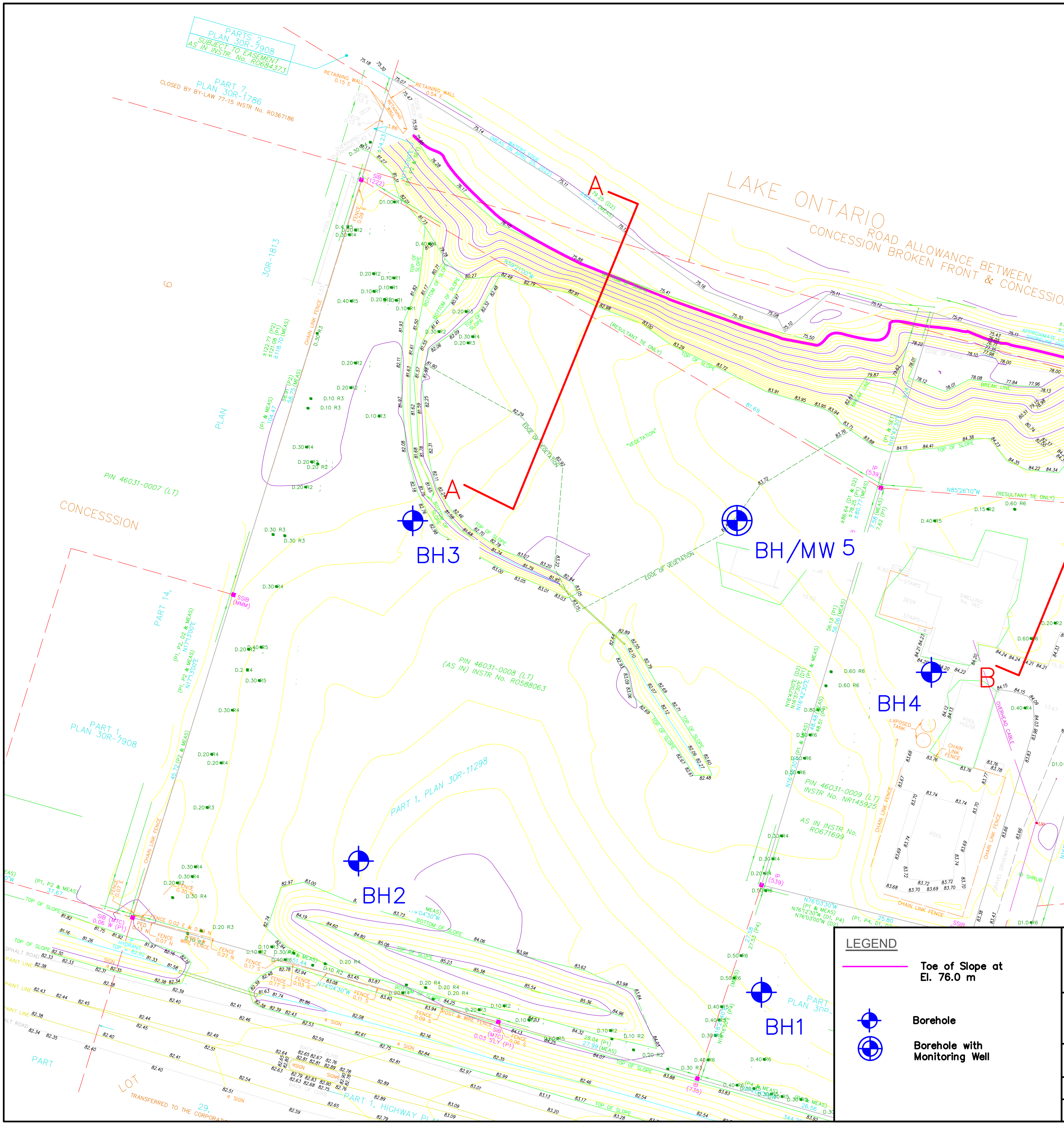
PROJECT LOCATION: 165 Lake Street, Town of Grimsby

LEGEND

▩ FILL ▥ SILT ▨ SILTY CLAY TILL ▤ TOPSOIL

▽ WATER LEVEL (END OF DRILLING)





NOTE:

Stable Slope Gradients:
Native Silt: 2.5H:1V, from Toe of Slope to El. 81.0m
Earth Fill: 3H:1V, from El. 81.0m to Top of Slope

LEGEND

Toe of Slope at El. 76.0 m

Borehole

Borehole with Monitoring Well

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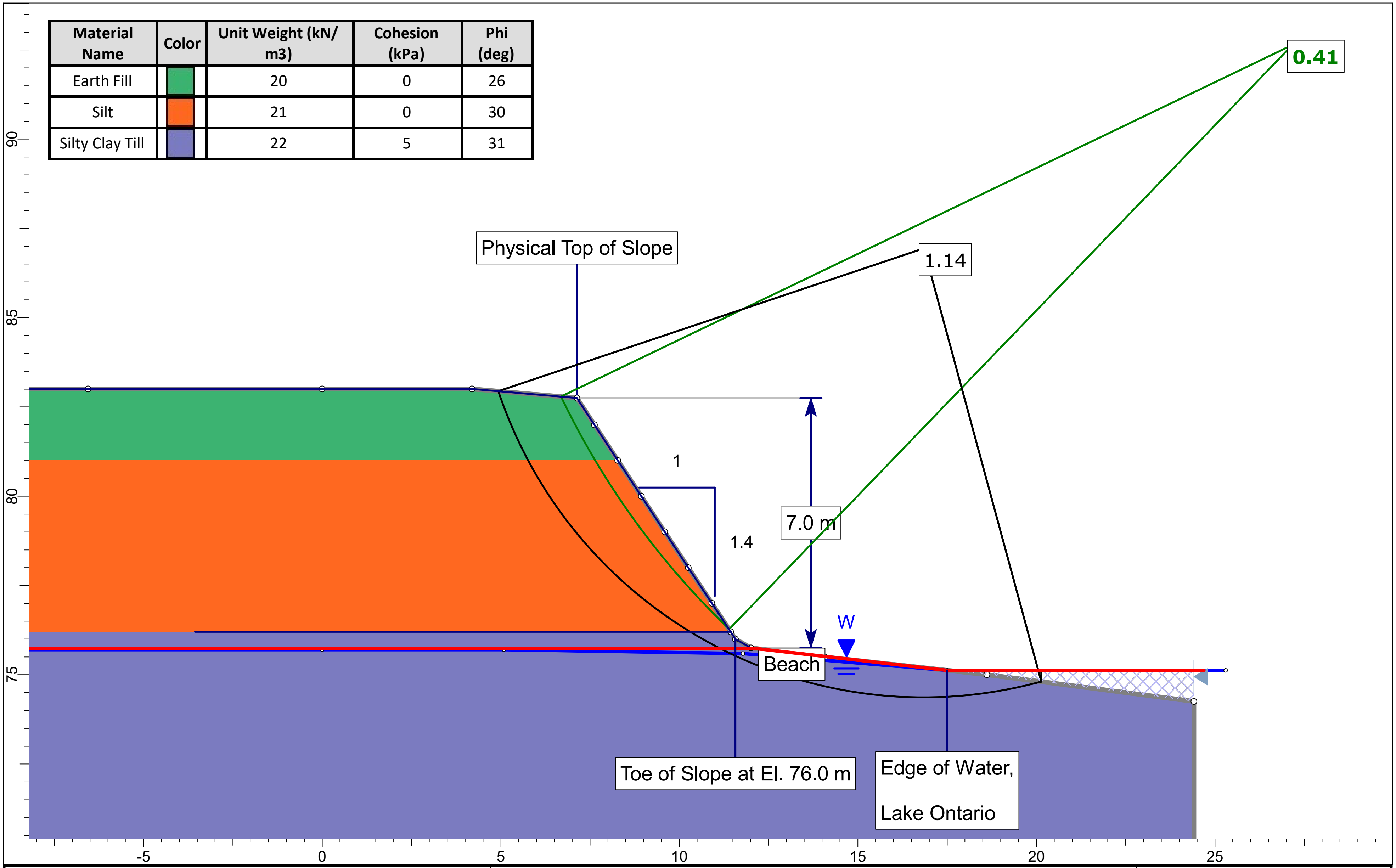
Cross-Section Location Plan

SITE: 165 Lake Street, Town of Grimsby

DESIGNED BY: D.Y.	CHECKED BY: K.L.	DWG NO.: 3
SCALE: 1:750	REF. NO.: 2201-S023	DATE: September 2023

REV



Material Name	Color	Unit Weight (kN/ m3)	Cohesion (kPa)	Phi (deg)
Earth Fill	🟩	20	0	26
Silt	🟧	21	0	30
Silty Clay Till	🟪	22	5	31

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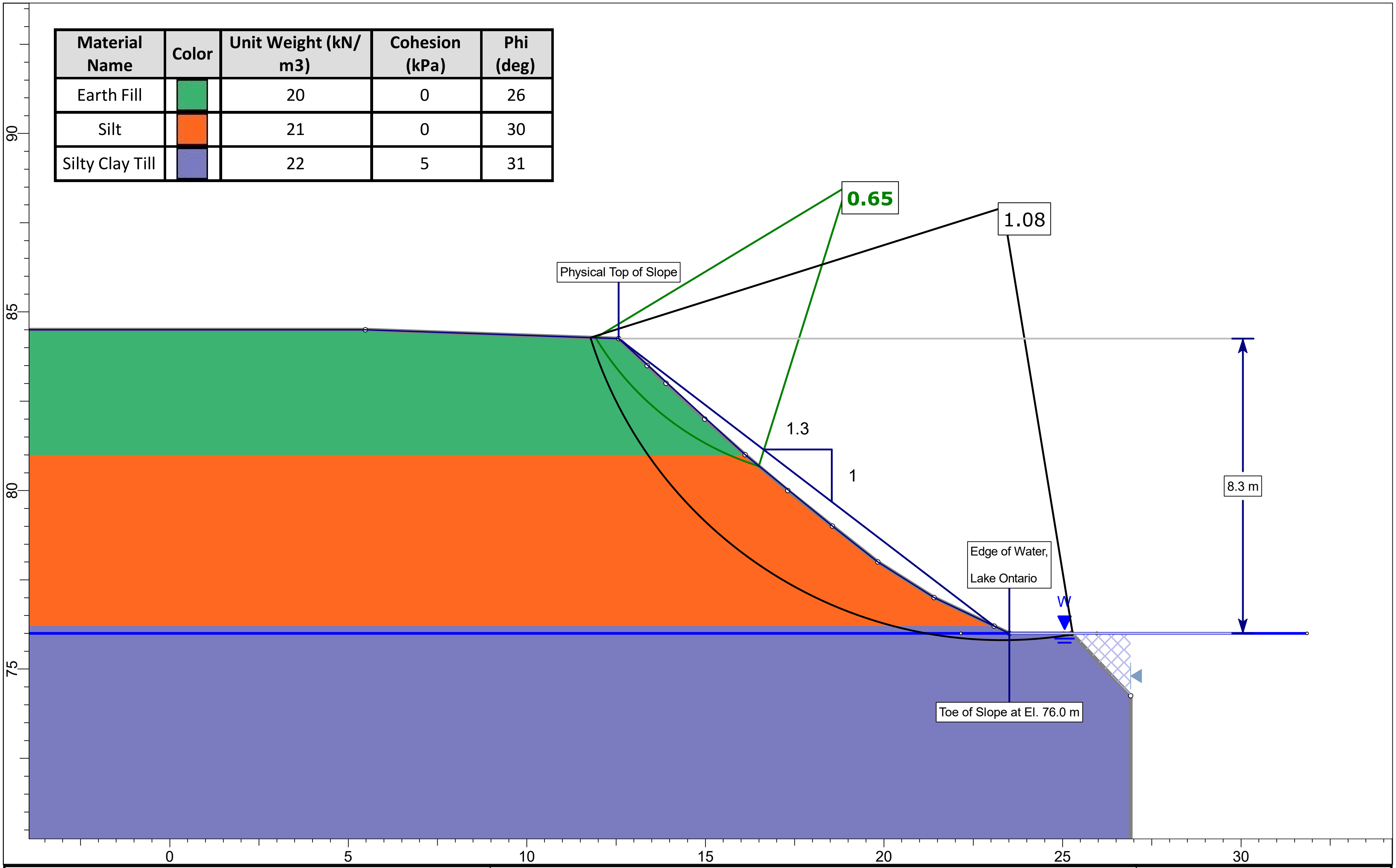
Project Title: Slope Stability Analysis Cross-Section A-A
Load Case: Existing Condition
Location: 165 Lake Street, Town of Grimsby
Drawn By: D.Y.
Checked By: K.L.
Scale: 1:150
Revision: 1
Date: August 2023
Reference No.: 2201-S023
Drawing No.



Material Name	Color	Unit Weight (kN/ m3)	Cohesion (kPa)	Phi (deg)
Earth Fill	🟩	20	0	26
Silt	🟧	21	0	30
Silty Clay Till	🟪	22	5	31

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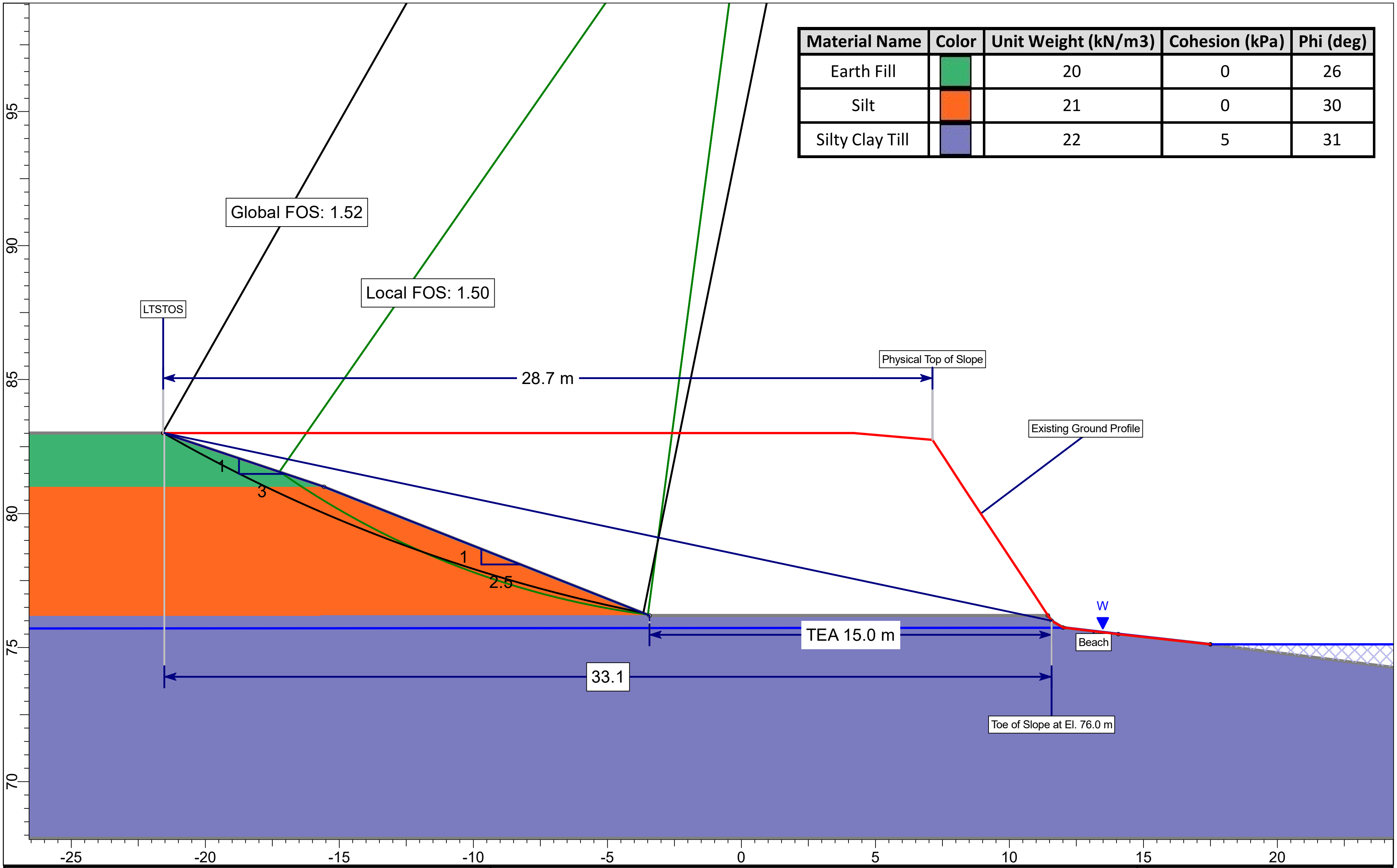
Project Title: Slope Stability Analysis Cross-Section B-B
Load Case: Existing Condition
Location: 165 Lake Street, Town of Grimsby
Drawn By: D.Y.
Checked By: K.L.
Scale: 1:150
Revision: 1
Date: August 2023
Reference No.: 2201-S023
Drawing No.:



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Earth Fill	🟩	20	0	26
Silt	🟧	21	0	30
Silty Clay Till	🟪	22	5	31

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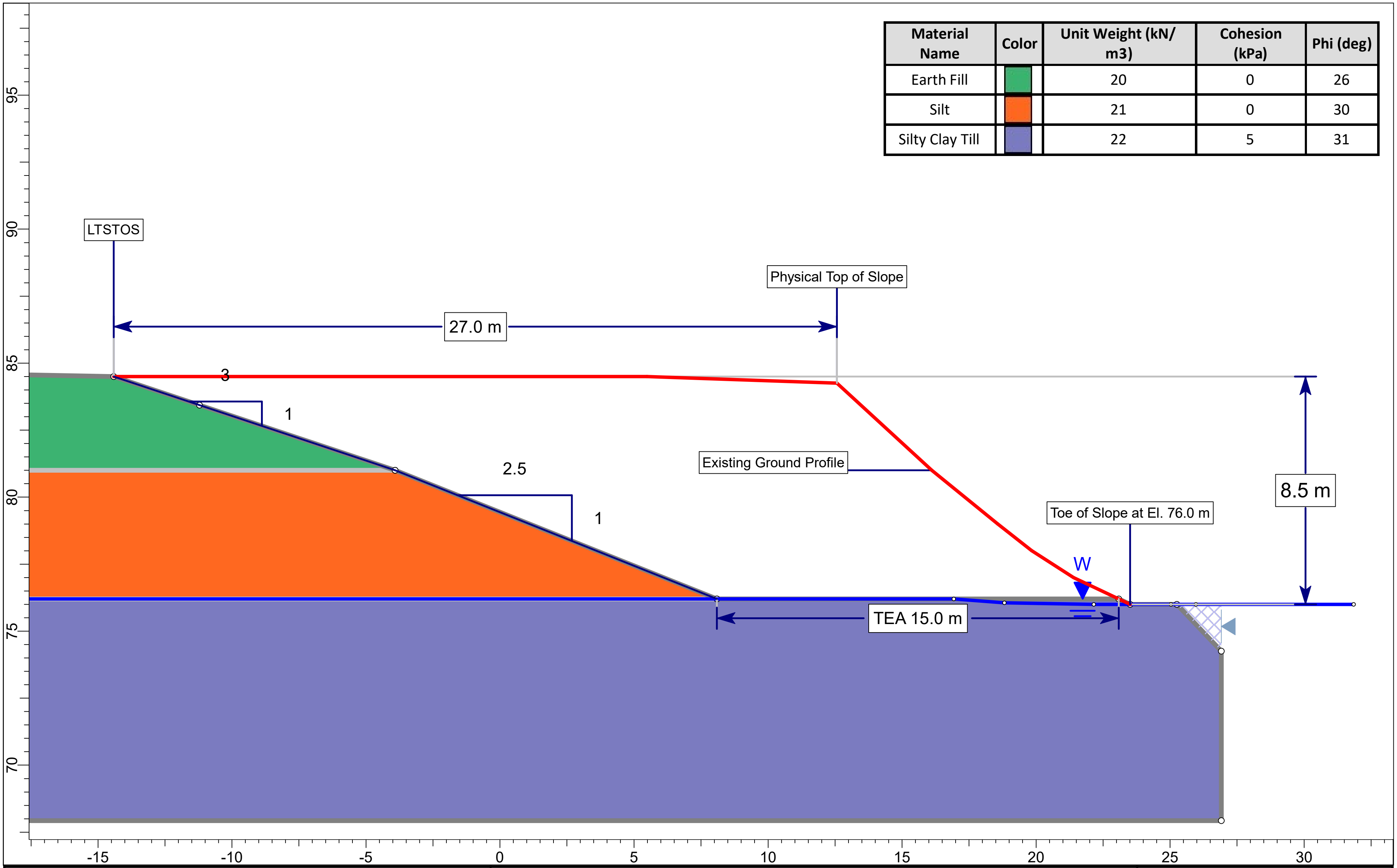
Project Title	Slope Stability Analysis Cross-Section A-A			Load Case	Stable Condition
Location	165 Lake Street, Town of Grimsby				
Drawn By	D.Y.	Checked By K.L.	Scale 1:200	Revision	1
Date	August 2023		Reference No. 2201-S023	Drawing No.	



Material Name	Color	Unit Weight (kN/m3)	Cohesion (kPa)	Phi (deg)
Earth Fill	🟩	20	0	26
Silt	🟧	21	0	30
Silty Clay Till	🟪	22	5	31

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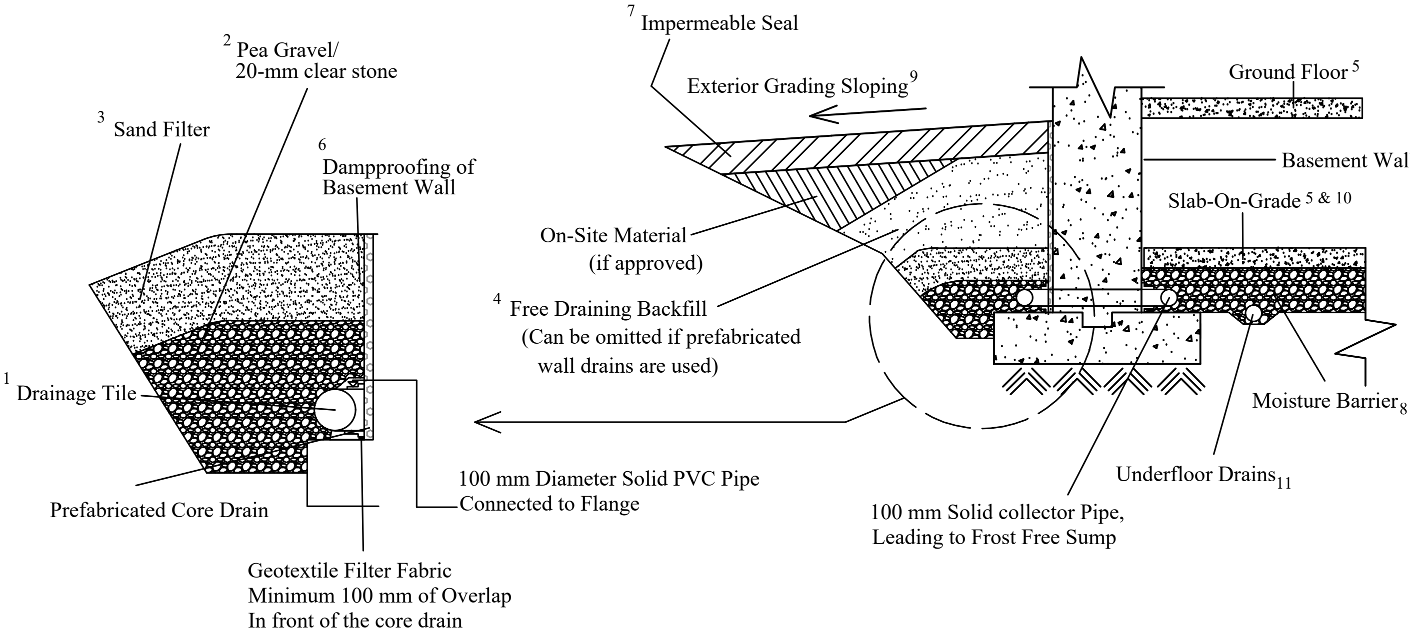
Project Title: Slope Stability Analysis Cross-Section B-B
Load Case: Existing Condition
Location: 165 Lake Street, Town of Grimsby
Drawn By: D.Y.
Checked By: K.L.
Scale: 1:200
Revision: 1
Date: August 2023
Reference No.: 2201-S023
Drawing No.: 7



NOTES:

1. **Drainage tile**: consists of 100 mm (4") diameter weeping tile or equivalent perforated pipe leading to a positive sump or outlet. Invert to be at minimum of 150 mm (6") below underside of basement floor slab.

2. **Pea gravel**: at 150 mm (6") on the top and sides of drain. If drain is not placed on concrete footing, provide 100 mm (4") of pea gravel below drain. The pea gravel may be replaced by 20 mm clear stone provided that the drain is covered by a porous geotextile membrane of Terrafix 270R or equivalent.

3. **Filter material**: consists of C.S.A. fine concrete aggregate. A minimum of 300 mm (12") on the top and sides of gravel. This may be replaced by an approved porous geotextile membrane of Terrafix 270R or equivalent.

4. **Free-draining backfill**: OPSS Granular 'B' or equivalent, compacted to 95% to 98% (maximum) Standard Proctor dry density. Do not compact closer than 1.8 m (6') from wall with heavy equipment. This may be replaced by on-site material if prefabricated wall drains (Miradrain) extending from the finished grade to the bottom of the basement wall are used.

5. **Do not backfill** until the wall is supported by the basement floor slab and ground floor framing, or adquate bracing.

6. **Dampproofing** of the basement wall is required before backfilling

7. **Impermeable backfill seal** of compacted clay, clayey silt or equivalent. If the original soil in the vicinity is a free-draining sand, the seal may be omitted.

8. **Moisture barrier**: 20-mm clear stone or compacted OPSS Granular 'A', or equivalent. The thickness of this layer should be 150 mm (6") minimum.

9. **Exterior Grade**: slope away from basement wall on all the sides of the building.

10. **Slab-On-Grade** should not be structurally connected to walls or foundations.

11. **Underfloor drains*** should be placed in parallel rows at 6 to 8 m (20'-25') centre, on 100 mm (4") of pea gravel with 150 mm (6") of pea gravel on top and sides. The invert should be at least 300 mm (12") below the underside of the floor slab. The drains should be connected to positive sumps or outlets. Do not connect the underfloor drains to the perimeter drains.

*Underfloor drains can be deleted where not required.

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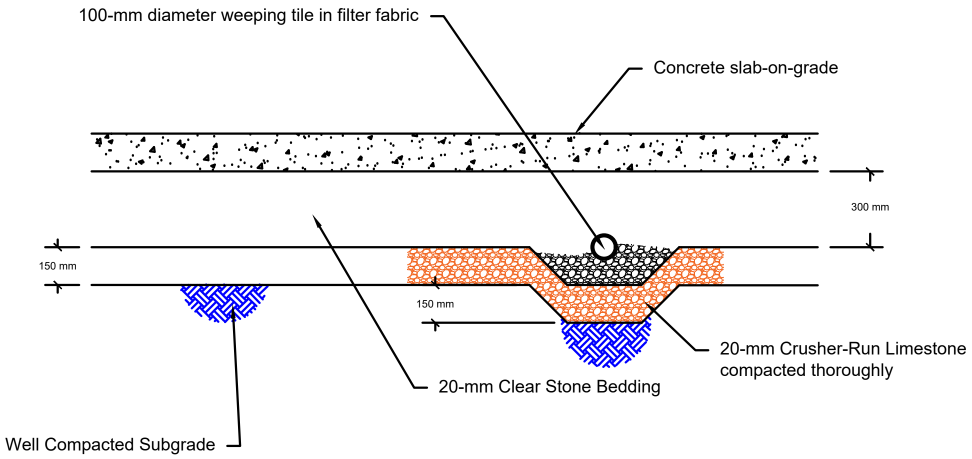
Details of Permanent Perimeter Drainage System

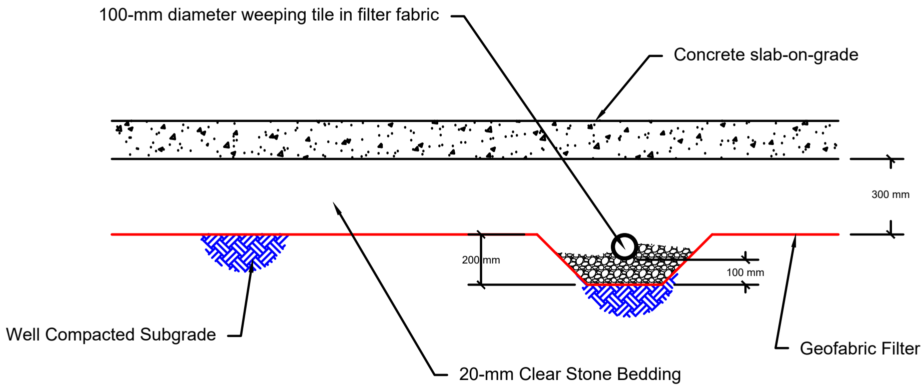
SITE 165 Lake Street, Town of Grimsby

DESIGNED BY D.Y. **CHECKED BY** K.L. **DWG NO.** 8

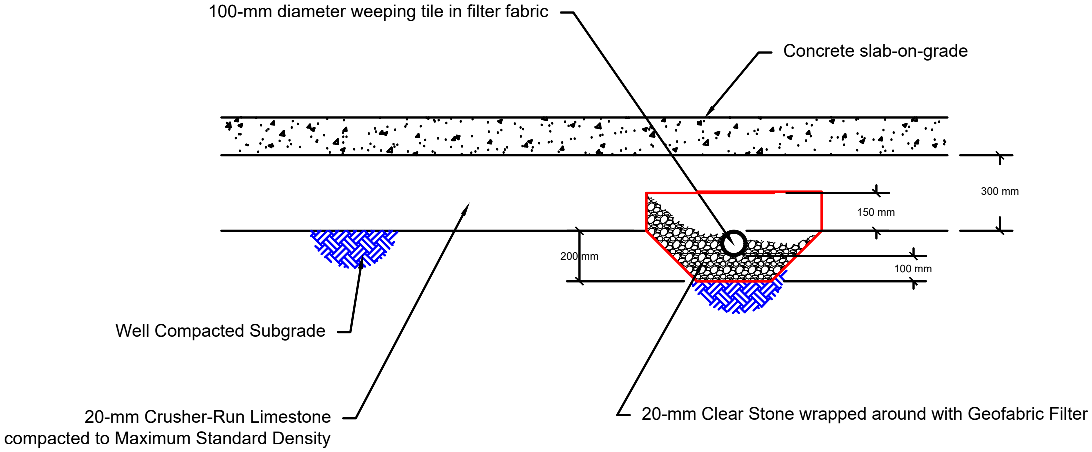
SCALE N.T.S. **REF. NO.** 2201-S023 **DATE** August 2023 **REV** -



Option 'A'



Option 'B'



Option 'C'

Note:

1. Weepers should be placed in 6 m grids, draining in a positive gradient towards an outlet or a sump pit for removal by pumping.
2. A 10-mil polyethylene sheet should be specified between the gravel bedding and concrete slab.

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Underfloor Subdrain Details

SITE: 165 Lake Street, Town of Grimsby

DESIGNED BY: D.Y.
CHECKED BY: K.L.
DWG NO.: 9
SCALE: N.T.S.
REF. NO.: 2101-S023
DATE: August 2021
REV -