



May 13, 2016

## FOUNDATION INVESTIGATION AND DESIGN REPORT

**PATROL YARD STRUCTURE  
MUNICIPALITY OF DYSART PATROL YARD  
HIGHWAY 118, WEST OF HALIBURTON  
ASSIGNMENT NO. 16, AGREEMENT NO. 5013-E-0034  
MINISTRY OF TRANSPORTATION, ONTARIO**

**Submitted to:**

Ministry of Transportation, Ontario  
Pavements and Foundations Section  
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REPORT



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# **PART A**

**PATROL YARD STRUCTURE  
MUNICIPALITY OF DYSART PATROL YARD  
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MINISTRY OF TRANSPORTATION, ONTARIO**



## **1.0 INTRODUCTION**

Golder Associates Ltd. (Golder) has been retained by The Ministry of Transportation, Ontario (MTO), Northeastern Region to provide foundation engineering services for a proposed sand/salt stockpile storage structure at the Municipality of Dysart Patrol Yard, located west of Haliburton on Highway 118 in the Geographic Township of Dysart. This work has been carried out as Retainer Assignment #16 under Agreement #5013-E-0034.

The purpose of this investigation is to establish the subsurface conditions at the proposed Patrol Yard structure by methods of borehole drilling, in situ testing and laboratory testing on selected samples. The location of the structure was provided to Golder as a hand sketch by the MTO and the corners were staked in the field by MTO as indicated on Drawing 1.

## **2.0 SITE DESCRIPTION AND BACKGROUND INFORMATION**

The proposed storage structure will be 8.5 m wide by 11.0 m long in plan dimensions and will be located within a cleared area in the existing Patrol Yard.

In general, the topography in the area of the proposed structure is flat. Overall, within the Patrol Yard property, the ground surface slopes down from the highway along the south perimeter of the yard to the north. The municipal garage and offices are located in the southern portion of the patrol yard with entrances at about the highway grade. The stockpile storage structure is to be located in the northern portion of the yard, about 6 m below the grade of the existing municipal garage and offices. Various materials stockpiles and other existing structures are present in the general area of the new stockpile storage facility.

A review of published geological information for the project area (OGS, 2013)<sup>1</sup> indicates that the site is located within an area of coarse textured glaciolacustrine deposit, primarily consisting of sand and gravel with minor amounts of clay and silt. The site borders on areas classified as a bedrock drift complex which consists of exposed bedrock or bedrock covered by a thin layer of surficial glacial till or stratified deposit (OGS, 2013)<sup>1</sup>. Based on published geologic information (OGS, 2000)<sup>2</sup> the bedrock in the area is classified as early felsic plutonic rock consisting of derived gneisses and migmatites.

A search of MTO's Geocres database for relevant geotechnical information and a review of a Foundation Investigation and Design Report prepared for the MTO by exp Services Inc. (exp) titled Slope Instability, Highway 118, 0.5 km North of Haliburton County Road 121 District 52, Huntsville, dated April 10, 2013, GEOCREs No. 31E-326, indicates that subject area of exp's report is located on the shores of Head Lake about 2.3 to 2.6 km southeast of the Municipality of Dysart Patrol Yard. In this report, the native material encountered in boreholes drilled within the Highway 118 right of way consist of non-cohesive deposits of sand, silt and gravel, with occasional cobbles and boulders inferred from drilling progress or encountered during drilling. According to exp's report, bedrock was encountered or inferred from auger refusal at depths ranging from 2.4 m to 8.1 m below ground surface (bgs). The report shows groundwater conditions in the open boreholes drilled on the highway embankment ranging from dry to 1.8 m below ground surface upon completion of drilling, while for those boreholes drilled at the toe of slope the water level was taken as the water level elevation observed in Head Lake. The report indicates that stabilized water levels measured in two monitoring wells installed within the embankment of Highway 118 range from 3.9 m to 5.6 m bgs.

<sup>1</sup> Ontario Geologic Survey. 2003. Surficial Geology of Southern Ontario. Ontario Ministry of Northern Development and Mines. Miscellaneous Release –Data 128, Revised.

<sup>2</sup> Ontario Geologic Survey. 2000. 1:250,000 Scale Bedrock Geology of Ontario. Ontario Ministry of Northern Development and Mines. Miscellaneous Release – Data 126, Revision 1.



A detailed description of the subsurface conditions at the structure location within the Municipal Patrol Yard is presented in Section 4.0.

### **3.0 INVESTIGATION PROCEDURES**

#### **3.1 Foundation Investigation**

The investigation for the storage structure was carried out on March 8, 2016, during which time a total of four boreholes (BH16-1 to BH16-4) were advanced within the footprint of the proposed structure. The locations of the boreholes are shown on Drawing 1 and the coordinates are provided on the Record of Borehole sheets in Appendix A and in the table below.

The field investigation was carried out using a buggy-mounted CME 550 drill rig supplied and operated by Landcore Drilling of Chelmsford, Ontario. The boreholes were advanced through the soil using 108 mm inner diameter hollow-stem augers. Soil samples were obtained at depth intervals of 0.75 m and 1.5 m, using a 50 mm O.D. split-spoon sampler driven by an automatic hammer and carried out in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586, Standard Test Method for Standard Penetration Test). The boreholes were advanced with augers to depths ranging between 6.7 m and 8.9 m bgs. In three boreholes, dynamic cone penetration tests (DCPT) were conducted from the bottom of the boreholes to depths ranging from 10.4 m to 11.3 m bgs. All boreholes were backfilled with bentonite and cuttings upon completion in accordance with Ontario Regulation 903 Wells (as amended).

The groundwater conditions and water levels in the open boreholes were observed during the drilling operations and are described on the Record of Borehole sheets provided in Appendix A.

The fieldwork was observed by a member of our engineering and technical staff, who located the boreholes, arranged for the clearance of underground services using Ontario One Call and a private locator, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and cared for the soil samples. The samples were identified in the field, placed in appropriate containers, labelled and transported to our Whitby Geotechnical Laboratory where the samples underwent further visual examination and laboratory testing. All of the laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, and grain size distribution) were carried out on selected samples. The results of the laboratory testing on samples from the boreholes are presented on the Record of Borehole sheets and shown on Figures B1 to B4 are included in Appendix B.

Representatives of MTO outlined the location of the structure in the field using stakes. Our staff located the boreholes close to the four corners of the staked footprint of the structure as best could be delineated prior to drilling and measured the boreholes to easily identifiable known points. The UTM coordinates of the as-drilled borehole locations were recorded with a handheld GPS (accuracy to  $\pm 5$  m) using NAD 83 datum. The borehole coordinates were subsequently converted into MTM NAD 83 in AutoCAD. Borehole elevations were surveyed by a member of our technical staff in reference to a temporary bench mark (TBH) consisting of the top of the floor slab at the northeast core of the entrance doorway of the existing municipal garage and office building which was taken as Elevation 100.0 m local datum. The borehole locations given in the Record of Borehole sheets and shown on Drawing 1 are positioned relative to MTM NAD 83 northing and easting coordinates and the elevations are referenced to the surface of the garage and office floor slab. The borehole locations, ground surface elevations and drilled borehole and DCPT depths are as follows:



## FOUNDATION REPORT – PATROL YARD STRUCTURE MUNICIPALITY OF DYSART PATROL YARD, HIGHWAY 118

Borehole	Location (MTM NAD 83)		Ground Surface Elevation* (m)	Borehole Depth (m)	DCPT Depth (m)
	Northing	Easting			
BH16-1	4992380.6	381177.5	94.4	6.7	10.4
BH16-2	4992383.7	381170.5	94.3	6.7	11.3
BH16-3	4992374.8	381165.4	94.2	6.7	11.0
BH16-4	4992370.7	381171.3	93.8	8.9**	-

\*Elevation is referenced to the top of floor slab of the municipal garage and office (relative to Elevation 100.0 m local datum).

\*\*Hollow Stem Augers and SPT sampler were advanced to refusal in BH16-4.

## 4.0 SUBSURFACE CONDITIONS

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are provided on the Record of Borehole sheets contained in Appendix A. The results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ tests (i.e., SPT 'N'-values) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

### 4.1 Subsoil Conditions

In general, the subsurface conditions encountered at the site consist of gravelly sand fill with trace organics, some cobbles exposed at surface, underlain by a deposit of generally compact orange/brown sand, trace to some gravel. The sand deposit is underlain by a deposit of brown/grey to grey, very loose to compact silt and sand, which in turn is underlain by a stratum of dense sandy silt and gravel till at one borehole location; the till deposit contains cobbles and/or boulders as inferred from observations of drilling progress. Sampling in three boreholes was terminated in the silt and sand deposit and DCPT were completed from the sampling depth to determine the depth to refusal and inferred approximate thickness of the deposit. One borehole was terminated within the sandy silt and gravel deposit due to auger and SPT refusal. A more detailed description of the soil deposits encountered in the boreholes is provided below.





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Deposit/Layer Description	Boreholes	Deposit Thickness (m)	Deposit Surface Elevation <sup>1</sup> (m)	'N'-Values (blows)	Laboratory Testing <sup>1</sup>
				Consistency or Relative Density	
<b>(FILL) Gravelly Sand</b> , trace organics; some cobbles <sup>2</sup> ; brown to grey; Frozen to moist	16-1 to 16-4	0.2 – 0.5	94.4 – 93.8	n/a	w = 8% – 17% 1 – MH (Fig. B1)
				<b>Frozen</b>	
<b>Sand</b> , trace to some gravel, some silt, trace clay; orange-brown to brown; moist to wet	16-1 to 16-4	0.9 – 4.3	94.1 – 93.6	N = 7 to 31	w = 11% - 28% 4 – MH (Fig. B2)
				<b>Loose to Dense</b>	
<b>Silt and Sand</b> , trace clay, layered, brown/grey to grey; wet <sup>3</sup>	16-1 to 16-4	3.6 (BH16-4) – >5.3 (potentially to >8.0 m by DCPT) <sup>3</sup>	93.0 – 89.3	N = 0 (weight of hammer) to 31 <sup>4</sup>	w = 23% - 32% 6 – MH (Fig. B3)
				<b>Very Loose to Compact</b>	
<b>Sandy Silt and Gravel (Till)</b> , grey; wet	16-4	>0.8	85.7	N = 50/0.03	w = 12% - 15% 1 – MH (Fig. B4)
				<b>Very Dense</b>	

### Where:

N = SPT 'N'-value; number of blows for 0.3 m of penetration unless otherwise noted

w = Natural Moisture Content (%)

MH = Combined Sieve and Hydrometer analysis

### Notes:

<sup>1</sup>Elevations are referenced to the top of floor slab of the municipal garage and office (assumed to be Elevation 100.0 m).

<sup>2</sup>Cobbles were observed at ground surface.

<sup>3</sup>SPT Sampling in Boreholes 16-1, 16-2, and 16-3 was terminated in the silt and sand stratum. The deposit thickness reported is inferred from results of the DCPTs completed from the bottom of the boreholes and is not be reflective of in-situ conditions.

<sup>4</sup>Typically the 'N'-values decreased with depth. The 'N'-value of 31 blows per 0.3 m of penetration as recorded at the base of the deposit in Borehole 16-4 and is associated in part with the underlying sandy silt and gravel till deposit.

## 4.2 Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. Water levels may vary depending on the time of year and precipitation events. Groundwater elevations as encountered in the boreholes may not be representative of static groundwater levels since the groundwater levels in the boreholes may not have stabilized on completion of drilling. Furthermore, groundwater elevations will vary depending on seasonal fluctuations, precipitation and local soil permeability.





## FOUNDATION REPORT – PATROL YARD STRUCTURE MUNICIPALITY OF DYSART PATROL YARD, HIGHWAY 118

Borehole	Depth to Groundwater (mbgs)	Groundwater Elevation (m)*
BH16-1	1.3	93.1
BH16-2	1.8	92.5
BH16-3	1.7	92.5
BH16-4	1.6	92.2

\* Elevations are referenced to the top of floor slab of the municipal garage and office (relative to be Elevation 100.0 m local datum).

### 5.0 CLOSURE

This Foundation Investigation Report was prepared by Mr. David Marmor E.I.T., and the technical aspects were reviewed by Ms. Sarah E.M. Poot, P.Eng., a senior geotechnical engineer and Associate of Golder. Mr. Jorge M.A. Costa, P.Eng., a Senior Consultant of Golder and Designated MTO Foundations Contact for Golder, conducted an independent quality control review of this report.



## Report Signature Page

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# PART B

FOUNDATION DESIGN REPORT  
PATROL YARD STRUCTURE  
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## **6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS**

This section of the report provides foundation design recommendations for the proposed patrol yard storage structure to be constructed adjacent to Highway 118, west of Haliburton, Ontario. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the foundation investigation at the site.

The interpretation and recommendations presented are intended to provide the designers with sufficient information to assess the feasible foundation alternatives and to design the proposed structure foundations. Where comments are made on construction, they are provided in order to highlight those aspects which could affect the design of the project, and for which special provisions or operational constraints may be required in the Contract Documents. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods, scheduling and the like.

### **6.1 General**

Based on the information provided in the Terms of Reference for this work, the proposed storage structure will be 8.5 m wide by 11 m long in plan dimensions. Based on design drawings for similar structures provided by the MTO and correspondence with MTO, it is understood that the storage structure will have a maximum height of about 4.9 m to the bottom of the roof trusses; the structure will be constructed with 1.2 m high, cast-in-place concrete walls along the perimeter supporting pre-engineered timber or steel walls and roof, and will have a concrete floor. Based on the proposed use of the structure Golder has assumed that it will be unheated.

The existing ground surface at the structure location varies between Elevation 93.8 m and 94.4 m, local datum. Elevation is referenced to the top of the floor slab of the existing municipal garage and office (taken as Elevation 100.0 m). The ground surface at Boreholes BH16-1 to 16-3 ranges from Elevation 94.4 m to 94.2 m, and at Borehole BH16-4, which was advanced within a slight depression at the site, is Elevation 93.8 m. The assumed finished top of floor will be at the level of the current ground surface, at about Elevation 94.2 m (local datum). To achieve this finished grade requires the placement of engineered fill within the general area of Borehole BH16-4 to provide a level floor slab for the structure.

In general, the subsurface conditions encountered at the site consist of up to 0.5 m of gravelly sand fill at the ground surface underlain by an approximately 0.9 to 4.3 m thick deposit of generally compact sand, in turn underlain by a very loose to compact deposit of silt and sand, which in turn is underlain by a stratum of very dense sandy silt and gravel till, in places. The unstabilized groundwater level was measured at depths between 1.3 m between 1.8 m below ground surface, or between Elevations 93.1 m and 92.2 m, respectively.

### **6.2 Foundations**

Based on the subsurface conditions at this site and previous experience with similar structures, deep foundations are not considered to be a practical foundation option for the proposed structure. We recommend that the sand/salt storage structure be supported on shallow foundations comprised of strip/spread footings founded on/within the native compact sand deposit and/or the compact upper portion of the silt and sand deposit. The strip footings may either be constructed with the founding elevation below the depth of frost penetration or above the frost penetration depth, to avoid a deeper excavation, provided that adequate insulation is utilized to protect the founding subgrade from the effects of frost penetration. Construction of footings founded below the frost



penetration depth will require dewatering as the excavation will extend below the groundwater level. Both options for foundation elevations are considered in this report and recommendations are provided below.

If the geotechnical resistances provided below for strip/spread footings are not sufficient for the design of the structure and a deep foundation option is required, additional boreholes extending to refusal would be required.

### 6.2.1 Footing Elevation

Strip or spread footings may be founded below the depth of frost penetration, or above the depth of frost penetration on suitable insulation to provide for appropriate frost protection of the founding subgrade. The following founding elevations for the underside of strip or spread footings are recommended for design. These founding elevations should be checked relative to the adjacent grades to ensure that the recommended cover for each option below the lowest surrounding final grade is achieved to provide adequate protection against frost penetration and protection to the insulation from construction equipment/traffic (see Section 6.2.4).

Options	Maximum (Highest) Footing Founding Elevation	Founding Stratum	Depth Below Existing Grade at Borehole Locations
Option 1 (below frost penetration depth)	92.4 m	Compact Sand to Compact Silt and Sand	1.4 m to 2.0 m – must provide at least 1.8 m of soil cover by placing additional soil in low areas
Option 2 (above frost penetration depth)	93.6 m (Subgrade Level at Elevation 93.3 m)	Frost Protection Insulation over Compact Sand	0.2 m to 0.8 m - must provide at least 0.6 m of cover over insulation in exterior areas

### 6.2.2 Geotechnical Resistance

Strip or spread footings placed on the properly prepared subgrade (compact sand/compact silt and sand, or on insulation) at the design elevations given in Section 6.2.1, should be designed based on the factored geotechnical axial resistances at Ultimate Limit States (ULS) and geotechnical reactions at Serviceability Limit States (SLS) for 25 mm of settlement, given below. Settlement of the footings under the loading from the stockpile, which will happen after footing construction, should also be considered as discussed in Section 6.5.2.

Foundation Elevation	Footing Width (m)	Factored Geotechnical Axial Resistance at ULS (kPa)	Geotechnical Reaction at SLS (for 25 mm settlement) (kPa)
92.4 m	1	350	75
	2	375	50
93.6 m	1	175	90
	2	200	60



The ULS resistance and the settlement are dependent on the footing size, depth of embedment, configuration and applied loads. The geotechnical resistances should, therefore, be reviewed if the selected footing width or founding elevation differs from those given above. In addition, the geotechnical resistances are provided for loads applied perpendicular to the surface of the footings; where applicable, inclination of the load should be taken into account in accordance with Chapter 10 of the Canadian Foundation Engineering Manual (CFEM) 4<sup>th</sup> Edition, 2006 and the National Building Code of Canada (NBCC) and its Commentary, 2010 .

The footing subgrade should be inspected by a Quality Verification Engineer following excavation, in accordance with OPSS 902 (Excavating and Backfilling - Structures) to check that the founding elevation is reached and that all unsuitable material, including organic or loose/soft material, has been removed. If the conditions at the time of construction are wet, from rainfall, snow or groundwater, the founding soils may be susceptible to disturbance and if the concrete for the footings cannot be poured immediately after excavation and inspection, it is recommended that concrete working slab be placed on the prepared subgrade within four hours of its inspection and approval. A Non-Standard Special Provision (NSSP) for the working slab should be included in the Contract Documents; an example is provided in Appendix C.

### **6.2.3 Resistance to Lateral Loads**

Resistance to lateral forces/sliding resistance between the base of the concrete footings and the proposed founding material should be calculated in accordance with Chapter 24 of the CFEM (2006). The coefficient of friction,  $\tan \delta$ , for cast-in-place concrete footings on the properly prepared subgrade soils or working slab (see Section 6.6) is provided below. These values assume that construction is carried out in dry conditions. These values represent unfactored values and the appropriate factors should be applied as outlined in the NBCC, 2010.

<b>Founding Elevation (Local Datum)</b>	<b>Founding Stratum</b>	<b>Footing Type</b>	<b><math>\tan \delta</math> (Navfac, 1986)</b>
92.4 m	Compact Sand to Compact Silt and Sand	Cast-in-place	0.32
93.6 m	Sand Fill over Frost Protection Insulation over Compact Sand	Cast-in-place	0.40

The following information is provided concerning the structural design of the perimeter walls in the event that the perimeter walls are required to support unbalanced lateral earth pressures resulting from the sand/salt stockpiles being piled against the walls. The structural support of the buildings walls to resist induced loadings from the portion of sand/salt stockpiles placed against the walls inside the building will likely have to be supported by concrete buttresses constructed along the outside of the building. The design of the walls to resist such lateral loads may be based on the geotechnical design parameters (for a triangular lateral earth pressure distribution) as follows:

- Unit weight of sand/salt stockpile material ( $\gamma$ ) = 21 kN/m<sup>3</sup>;
- Height of stockpiled material against the wall (1.2 m at maximum capacity) plus height of sloping material above the wall (assumed to be 3.8 m at maximum capacity at a slope of 1.5H:1V);
- Lateral earth pressure coefficient ( $K_0$ ) = 0.46 (uncorrected for sloping pile); and



- Coefficient of friction between concrete footing and founding stratum ( $\mu$ ) =  $\tan \delta$  (as above).

#### **6.2.4 Frost Protection**

The native soils at the footing founding elevation are considered frost susceptible. All footings founded at Elevation 92.4 m should be provided with a minimum of 1.8 m of soil cover for frost protection (OPSD 3090.101, Foundation Frost Penetration Depths for Southern Ontario). In addition, the bearing soil and fresh concrete should be protected from freezing during cold weather construction.

For footings founded at elevation of 93.6 m, frost protection should be provided by the installation of insulation on the subgrade below the footings to minimize the potential for damage due to frost action. A 75 mm thick layer of rigid polystyrene foam insulation (i.e. Styrofoam SM or equivalent) should be placed at the underside of the footings and extend a minimum of 1.8 m from the edges of the footings. The insulation should consist of Styrofoam High-Load 60 or equivalent with a minimum compressive strength of 415 kPa. The insulation beyond the outside edges of the footings should be provided with at least 0.6 m of soil cover. The insulation should be supported on a bedding layer a minimum of 150 mm of OPSS.PROV 1010 (Aggregates) Granular 'A' compacted to not less than 100 per cent of the material's standard Proctor maximum dry density (SPMDD). A 75 mm thickness layer of sand fill, meeting the specifications of OPSS.PROV 1004 (Aggregates – Miscellaneous) for Winter Sand, or OPSS.PROV 1002 (Aggregate - Concrete) for Fine Aggregate should be placed between insulation and the footing pad to provide a levelling surface for the casting/placing of the footings. A conceptual drawing of the floor slab and foundation details including insulation is, shown on Drawing 2, attached.

### **6.3 Seismic Site Classification**

According to Table 4.1.8.4 A of the Ontario Building Code (2012), the project site is classified as Class E for the observed properties and thickness of the native soils. The four values for the Gravenhurst area of the Spectral Response Acceleration [ $S_a(T)$ ] for different periods and the Peak Ground Acceleration (PGA) can be obtained from the National Building Code of Canada (2010). The design values of acceleration-based site coefficient ( $F_a$ ) and velocity-based site coefficient ( $F_v$ ) for the project site should be calculated in accordance with Tables 4.1.8.4 B and C, respectively, of the Ontario Building Code (2012). Should higher site class designations be required, additional investigation to measure the seismic site response will be required.

### **6.4 Floor Slab**

It is understood that the sand/salt storage structure will have a concrete floor slab which would be supported on the native soil deposits or engineered fill over the native soils. Golder has assumed that the finished floor level will match the existing ground surface at approximate Elevation of 94.2 m local datum. The concrete floor slab should be supported on a minimum thickness of 150 mm of OPSS.PROV 1010 (Aggregates) Granular 'A' compacted to not less than 100 per cent of the material's standard Proctor maximum dry density (SPMDD) as outlined in OPSS 501 (Construction Specification for Compacting).

The floor slab should not be structurally connected to the concrete walls or footings. Joints should be installed within the floor slab to allow it to move and account for differential settlement as discussed further in Section 6.5.2.

Where the interior ground floor slab is at or above the level of the exterior final grade, no perimeter drainage at the footing level is required, however, based on our experience with similar structures, a permanent sub-floor drainage system may be required to collect salt-bearing water and convey it to a holding tank. If required, the





drainage system could consist of a system of floor drains and collection pipes draining to designated holding tanks for treatment and/or disposal. To minimize introducing contamination into the native soils by run-off water or infiltration containing concentrations of salt, a barrier should be installed below the sand/salt storage area. Consideration could be given to the use of a compacted low-permeability clay (i.e., bentonite) liner or geosynthetics (i.e., geosynthetic clay liner or a geomembrane). The use of a geomembrane has the advantage over compacted clay products in terms of improved performance of the barrier and floor slab system. Details of the geomembrane installation and specifications, collection/drainage pipe type, network layout and size, and quality control/assurance procedures should be provided by the designer of the drainage collection system. Geotechnical recommendations related to the installation of the geomembrane/drainage system are provided below.

The geomembrane, if required, should be installed on a minimum 75 mm thick layer of sand fill, meeting the specifications of OPSS.PROV 1004 (Aggregates – Miscellaneous) for Winter Sand, or OPSS.PROV 1002 (Aggregate - Concrete) for Fine Aggregate placed over the subgrade, to protect the geomembrane from angular gravel/cobble pieces that may be contained in the existing subsoil. If a geomembrane is utilized as a component of the low-permeability system under the floor slab, then a 300 mm thick layer of sand fill should be placed directly on top of the geomembrane to protect it from the overlying concrete floor slab. A conceptual drawing of the floor slab and foundation details including the geomembrane is presented on Drawing 2.

Care must be taken when placing the sand on top of the geomembrane, during spreading and compacting the sand which should be carried out using a low ground-pressure bulldozer (maximum ground pressure of 35 kPa). The sand cover should be compacted to at least 95 per cent of the material's standard Proctor maximum dry density. A minimum 300 mm thick separation distance must be maintained between the bulldozer tracks and the top of the geomembrane. Truck traffic should be restricted to temporarily thickened areas of the cover soil layer by providing a minimum separation distance of 900 mm between truck tires and the underlying geomembrane. An example NSSP for placement and compaction of soils above the geomembrane is included in Appendix C.

## **6.5 Stability and Settlement Analysis**

### **6.5.1 Stability**

Stability analyses have been performed for the maximum height of the sand/salt storage pile equal to 3.8 m, using the commercially available program SLOPE/W produced by Geo-Slope International Ltd (Version 7.23). Effective stress parameters were employed in the analysis, based on the results of the Standard Penetration Tests tempered by engineering judgment based on precedent experience in similar soils. The following summarizes the strength parameters and unit weights employed for the different materials.

<b>Material</b>	<b>Unit Weight (kN/m<sup>3</sup>)</b>	<b>Strength Parameters</b>
Stockpiled Sand/Salt Material	21	$c' = 0$ kPa $\phi' = 33^\circ$
Interface Between Stockpile and Floor Slab	21	$c' = 0$ kPa $\phi' = 29^\circ$
Concrete Floor Slab	24	$c' = 3,000$ kPa $\phi' = 0^\circ$



<b>Material</b>	<b>Unit Weight (kN/m<sup>3</sup>)</b>	<b>Strength Parameters</b>
Engineered Fill Underlying Concrete Floor Slab	21	$c' = 0 \text{ kPa}$ $\phi' = 33^\circ$
Geomembrane	19	$c' = 0 \text{ kPa}$ $\phi' = 16^\circ$
Compact sand	20	$c' = 0 \text{ kPa}$ $\phi' = 33^\circ$
Compact to very loose silt and sand	18	$c' = 0 \text{ kPa}$ $\phi' = 29^\circ$

Note: The internal friction angle for the geomembrane is based on information provided by Layfield Geosynthetics.

The stability analyses assume that all topsoil and native soils containing organics have been removed prior to construction, the concrete side walls in the sand/salt storage area have a minimum founding depth of 0.6 m below finished ground surface, sand/salt is piled to a maximum height of 1.2 m up the sides of the perimeter walls, the stockpiled material and concrete floor slab interface has a minimum internal angle of friction of 29 degrees, the concrete floor slab is 150 mm thick, the proposed geomembrane and sand interface has a minimum internal angle of friction of 16 degrees, and that there is a minimum thickness of 450 mm of free draining granular material between the concrete floor slab and the geomembrane liner (comprised of 150 mm of Granular 'A' and 300 mm of sand cover over the geomembrane). The results of the stability analyses are as follows:

- A factor of safety greater than 1.5 is obtained for a deep-seated, global type failure surface that could impact the stability of the sand/salt storage structure, for an approximately 3.8 m high stockpile, the height of which is governed by the angle of repose of the stockpiled material. The results from a selected stability analysis is presented on Figure 1.
- As the side slopes of the stockpile are governed by the angle of repose of the stockpile material and the height of the pile is dependent on the height of the perimeter walls against which it is placed, the stability of the pile was assessed for the approximate maximum height of placement for the condition of an unrestrained front slope as shown on Figure 2; the stockpile will "fail" surficially and slough to the angle of repose if material is placed to a greater height. A factor of safety greater than 1.3 is obtained for the stockpiled sand sliding along the concrete floor slab when the height of stockpile is about 3.8 m.

### **6.5.2 Settlement**

Settlement analysis has been performed for the sand/salt stockpile loading, assuming a maximum stockpile height of 3.8 m using the commercially available program Settle<sup>3D</sup> (Version 2.016) produced by Rocscience Inc. as well as hand calculations. Based on the generally cohesionless nature of the soils at the site, long-term consolidation settlements are not anticipated.

The elastic compression of the very loose to compact subsoils under the sand/salt stockpile loading has been modelled using elastic moduli of deformation based on the measured SPT 'N'-values and correlations proposed by Bowles (1984). The properties used to calculate settlement are shown in the table below:



<b>Material</b>	<b>Unit Weight (kN/m<sup>3</sup>)</b>	<b>Elastic Modulus E (MPa)</b>
Compact sand	21	25
Compact to very loose silt and sand	18	10 decreasing with depth to 4
Very dense silty sand and gravel (Till)	21	50

The stockpile loadings have been assumed based on a maximum sand/salt pile height of approximately 3.8 m at the centre and 1.2 m along the side walls. The estimated settlement under the stockpile ranges from about 35 mm to 65 mm at the centre and 20 mm to 40 mm at the edges of the stockpile resulting, in differential settlement between the edge of the building and the center of the building ranging from 15 mm to 45 mm. The settlement is considered elastic and will occur during stockpile loading (i.e., after the footings have been constructed). The design of the footings should consider the settlement under the full stockpile loading that will occur after construction.

## **6.6 Site Preparation and Engineered Fill Construction**

Any fill materials required within the building envelope should consist of suitable material placed/compacted to engineered fill standards. All topsoil, if encountered and any portions of the cohesionless deposits that are loose/disturbed or contain organics and/or other deleterious materials are not considered to be suitable for the subgrade support of building foundations, floor slabs, or as engineered fill materials. The exposed subgrade should be proof-rolled under the supervision of experienced geotechnical personnel. Any softened/loosened or poorly performing areas of the subgrade soils should be sub-excavated and replaced with engineered fill comprised of free-draining material, such as OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B, Type I or Type II.

The prepared area should encompass the limits of any engineered fill. The engineered fill limits are defined such that the fill extends to at least 1 m beyond the outside edge of the founding level of any footing (if removal of unsuitable material is required from under the footing footprint) or other settlement-sensitive area and then downward and outward at a slope of one horizontal to one vertical (1H:1V).

Following proof-rolling and approval of the subgrade, engineer-approved fill should be placed in accordance with OPSS 501 (Compacting) and SP105S21. Within the building footprints, the fill should be compacted to 100 per cent of the material's standard Proctor maximum dry density. Filling should continue until the design subgrade elevation is achieved, with full-time inspection and in-situ density testing carried out by a qualified geotechnical engineering firm during placement of engineered fill beneath the structure and settlement-sensitive areas.

As discussed in Sections 6.2 (Foundations) and 6.5 (Stability and Settlement Analysis), the geotechnical recommendations provided for the design of shallow foundations, assessment of stability, and for mitigation of settlement due to the sand/salt pile loadings are based on the use of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type II fill for the support of the concrete floor slab.

The final surface of the engineered fill should be protected as necessary from construction traffic, and should be sloped to provide positive drainage for surface water during the construction period. If the engineered fill materials will be left exposed (i.e., uncovered) during periods of freezing weather, consideration should be given to placing an additional soil cover above final subgrade to provide for frost protection.



## **6.7 Construction Considerations**

### **6.7.1 Temporary Excavations and Groundwater Control**

All excavations must be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. The excavations will extend to depths between about 1 m and 2 m below ground surface, depending on the footing founding elevation. Based on observations in the boreholes during drilling, the water level is expected to be as high as Elevation 93.1 m (local datum) (i.e. at a depth of between about 1.3 and 1.8 m below ground surface). For foundations founded at Elevation 93.6 m (local datum), the base of excavations and the installation of frost protection insulation are expected to be placed at Elevation 93.3 m (local datum), which is essentially at or slightly above the groundwater level. However, the base of excavations for foundations founded below the frost depth at, Elevation 92.4 m, are expected to be below the groundwater level at this site. The excavation for the floor slab and installation of engineered fill and geomembrane is expected to extend to Elevation 93.5 m, which is above the groundwater level.

The surficial fill and native soils above the groundwater level at this site are classified as Type 3 soil according to OHSA. The native soils below the water table would be classified as Type 4 soil unless a suitable dewatering system is installed to lower the water level below the base of the excavation. Temporary excavations above the water table may be made with side slopes no steeper than 1H:1V. Where excavations extend below the groundwater table at the site, the temporary side slopes will have to be formed at 3H:1V unless proper groundwater control is implemented.

Given the gradation of the native deposits of sand and silt and sand below the groundwater table and the need to lower the water level by up to 0.7 m below the highest level for footings founded below the depth of frost penetration depth, active dewatering will likely be required to maintain the stability of the excavation and install the footings for excavations below the adjacent water table. Groundwater control measures will likely extract more than 50,000 L/day of water but likely less than 400,000 L/day. Under recently introduced changes to the Environmental Protection Act by the Ontario Ministry of the Environment and Climate Change ("MOECC"), water taking for construction site dewatering for volumes greater than 50,000 L/day but less than 400,000 L/day qualify for the Environmental Activity Section Registry (EASR). Under the ESAR, a Permit to Take Water is not required for water taking for construction site dewatering for volumes less than 400,000 L/day, however an application for an EASR would be required, including a water taking report and discharge plan.

The contractor should be made aware that, based on anticipated excavations depths, excavations in sand and silt to sand soils below the groundwater table will likely require pro-active groundwater controls (which may need to take the form of installation of well points) to help ensure the stability of slopes and bases of the proposed excavations, in addition to pumping from sumps. It should be noted that the water levels in this area may fluctuate depending on the time of year. It is recommended that excavations for foundations be carried out in late summer when water levels are anticipated to be lower. An example of NSSP concerning dewatering of the native soils during excavation and foundation construction is attached in Appendix C.

If steeper side slopes are necessary, temporary excavation support will be required. Temporary excavation support should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). The lateral movement of the temporary shoring system should meet Performance Level 2 as specified in OPSS.PROV 539.



### **6.7.2 Obstructions**

Although boulders were not encountered during the drilling operation cobbles were observed present on ground surface and encountered within the surficial fill deposit at the site and the potential exists that both cobbles and/or boulders are present within the native site soils at greater depth. Conventional excavation equipment should be suitable for the majority of excavation through the on-site soils.

### **6.7.3 Summary of Recommended NSSPs**

As noted in the preceding discussions, it is recommended that the following Non-Standard Special Provisions (NSSPs) be provided in the Contract Documents to address geotechnical aspects of excavation and foundation construction at this site:

- NSSP regarding placement of a concrete working slab on the foundation subgrade immediately following inspection of the prepared subgrade, to protect the sand/silt soils from disturbance.
- NSSP for supply and installation of sand fill above the geomembrane, and to warn the Contractor of restricted construction activities above the geomembrane.
- NSSP concerning dewatering of the native soils during excavation and foundation construction.

## **7.0 CLOSURE**

This report was prepared by Mr. David Marmor, E.I.T. and the technical aspects were reviewed by Ms. Sarah E. M. Poot, P.Eng., a senior geotechnical engineer and Associate with Golder. Mr. Jorge M. A. Costa, P.Eng., Golder's Designated MTO Contact for Foundations for this assignment and Senior Consultant with Golder, conducted an independent quality control review of the report.



## Report Signature Page

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\\Golder.gds\gal\Whitby\Active\_2014\1181- Geotechnical & Pavement\14-1181-0014 MTO EOI 5013-E-0034 NER Retainer\Assignment 16\Report\final\14-1181-0014-16000 Final RPT May 13, 2016 FIDR Patrol Yard Structure.docx



## REFERENCES

- Bowles, J.E., 1984. *Physical and Geotechnical Properties of Soils*, Second Edition. McGraw Hill Book Company, New York.
- Canadian Foundation Engineering Manual (CFEM). 2006. Fourth Edition. Canadian Geotechnical Society.
- National Building Code of Canada (NBCC). 2010. National Research Council of Canada.
- Occupational Health and Safety Act and Regulation for Construction Projects, 2014.
- Ontario Building Code (OBC). 2012. O.Reg. 332/12, Building Code Act, 1992. Ministry of Municipal Affairs and Housing.
- Ontario Geologic Survey. 2003. *Surficial Geology of Southern Ontario*. Ontario Ministry of Northern Development and Mines.
- Ontario Geologic Survey. 2000. *Bedrock Geology, Seamless Coverage of the Province of Ontario*. Ontario Ministry of Northern Development and Mines.
- Unified Facilities Criteria, U.S. Navy. 1986. *NAVFAC Design Manuals 7.01 and 7.02. Soil Mechanics, Foundation and Earth Structures*. Alexandria, Virginia.

### ASTM International

- ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

### Commercial Software

- GeoStudio (Version 7.23) by Geo-Slope International Ltd.
- Settle 3D (Version 3.014) by Rocscience Inc.

### Ontario Provincial Standard Drawings

- OPSD 3090.101 Foundation, Frost Penetration Depths for Southern Ontario

### Ontario Provincial Standard Specifications

- OPSS.PROV 501 Construction Specification for Compacting
- OPSS. PROV 539 Construction Specification for Temporary Protection Systems
- OPSS 902 Construction Specification for Excavating and Backfilling - Structures
- OPSS.PROV 1002 Material Specification for Aggregates – Concrete
- OPSS.PROV 1004 Material Specification for Aggregates – Miscellaneous
- OPSS.PROV 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

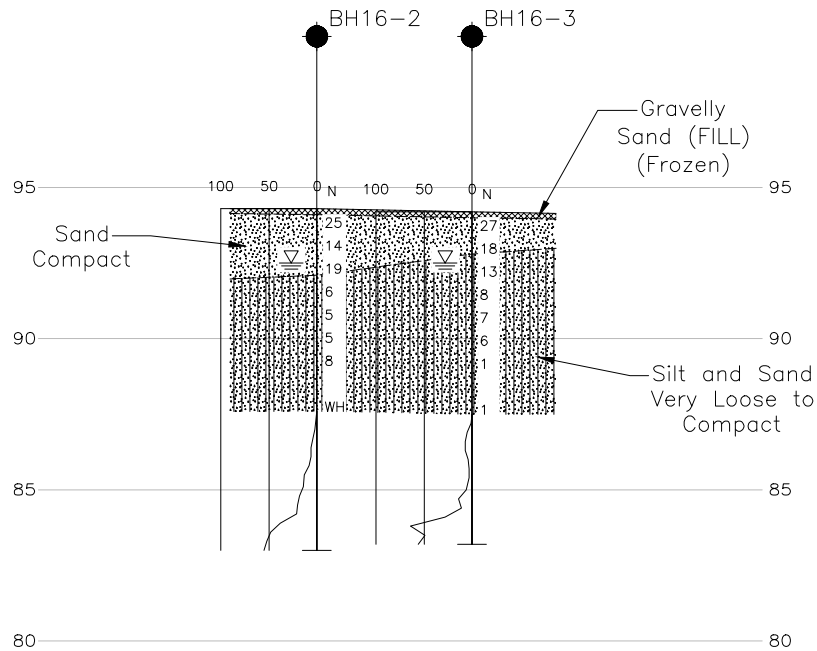
### Ontario Water Resources Act

- Ontario Regulation 903/90 Wells: O. Reg. 468/10 Amendment to Ontario Regulation 903

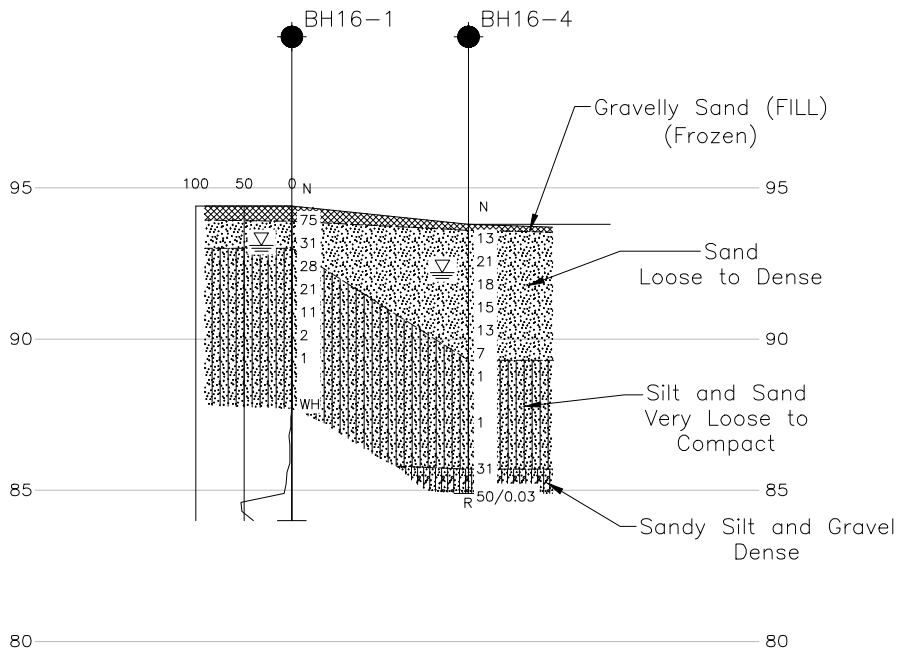




PLAN  
SCALE  
5 0 5 10 m



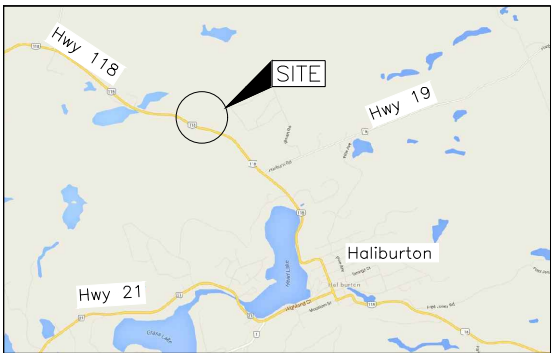
A-A'  
1  
HORIZONTAL SCALE  
5 0 5 10 m  
VERTICAL SCALE  
2.5 0 2.5 5 m



B-B'  
1  
HORIZONTAL SCALE  
5 0 5 10 m  
VERTICAL SCALE  
2.5 0 2.5 5 m

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

CONT No. .  
WP No. .  
HIGHWAY 118 PATROL YARD  
MUNICIPALITY OF DYSART  
BOREHOLE LOCATIONS AND SOIL  
STRATA



KEY PLAN  
SCALE  
1 0 1 2 km

LEGEND

- Borehole - Current Investigation
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated  
(Std. Pen. Test, 475 j/blow)
- R Refusal
- WL upon completion of drilling

BOREHOLE CO-ORDINATES			
No.	LOCAL DATUM ELEVATION	NORTHING	EASTING
BH16-1	94.4	4992380.6	381177.5
BH16-2	94.3	4992383.7	381170.5
BH16-3	94.2	4992374.8	381165.4
BH16-4	93.8	4992370.7	381171.3

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

Elevation is relative to Elevation=100 m local datum.

REFERENCE

Image ©2016 DigitalGlobe  
2015 DigitalGlobe satellite imagery supplied by GoogleEarth Pro.®



NO.	DATE	BY	REVISION
Geocres No. 31E-362			
HWY. 118	PROJECT NO. 14-1181-0014		DIST. .
SUBM'D.	CHKD. DM	DATE: 5/13/2016	SITE: .
DRAWN: TB	CHKD. SEMP	APPD. JMAC	DWG. 1

CONT No.  
WP No.

---

HIGHWAY 118 PATROL YARD  
MUNICIPALITY OF DYSART  
COMCEPTUAL FOOTING AND FLOOR  
SLAB DESIGN

**SHEET**

Ground Elev. 94.2 m

Founding Elev. 92.4 m

1.8 m (min)

Floor Slab

Granular Pad

Sand Fill (if required)

Geomembrane (if required)

Native Soil

150 mm

300 mm

75 mm

The diagram illustrates a cross-section of a foundation and floor slab assembly. A vertical wall is shown on the left, resting on a foundation. The foundation is composed of a 1.8 m wide base layer of granular pad, a 0.6 m (min) thick layer of styrofoam insulation, and a 1.8 m wide base layer of granular pad. The ground level is at 94.2 m, and the founding elevation is at 93.6 m. The floor slab is shown on the right, resting on a granular pad. The floor slab is 150 mm thick. The granular pad is 300 mm thick. The floor slab is supported by a 75 mm thick sand fill (engineered granular fill acceptable if geomembrane not required) and a 150 mm thick sand fill. The floor slab is also supported by a 75 mm thick sand fill. The floor slab is shown on the right, resting on a granular pad. The floor slab is 150 mm thick. The granular pad is 300 mm thick. The floor slab is supported by a 75 mm thick sand fill (engineered granular fill acceptable if geomembrane not required) and a 150 mm thick sand fill. The floor slab is also supported by a 75 mm thick sand fill.

SCALE

0.5 0 0.5 1 m

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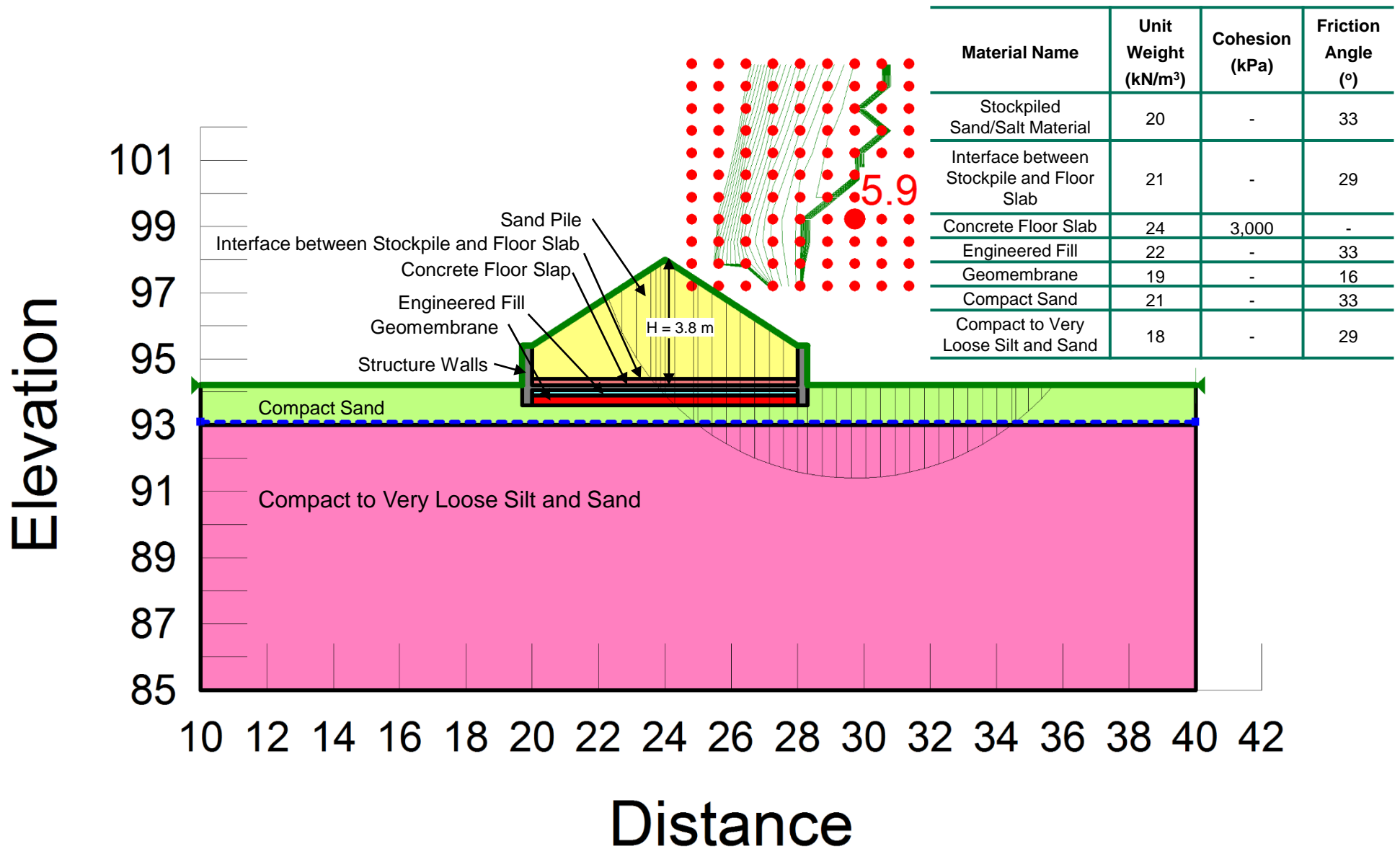
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-	-	-	-
NO.	DATE	BY	REVISION
Geocres No. _____			
HWY. 118		PROJECT NO. 14-1181-0014	DIST. _____
SUBM'D.	CHKD. DM	DATE: 5/11/2016	SITE: _____
DRAWN: TB	CHKD. SEMP	APPD. JMAC	DWG. 2



## Stability Analysis Global Stability

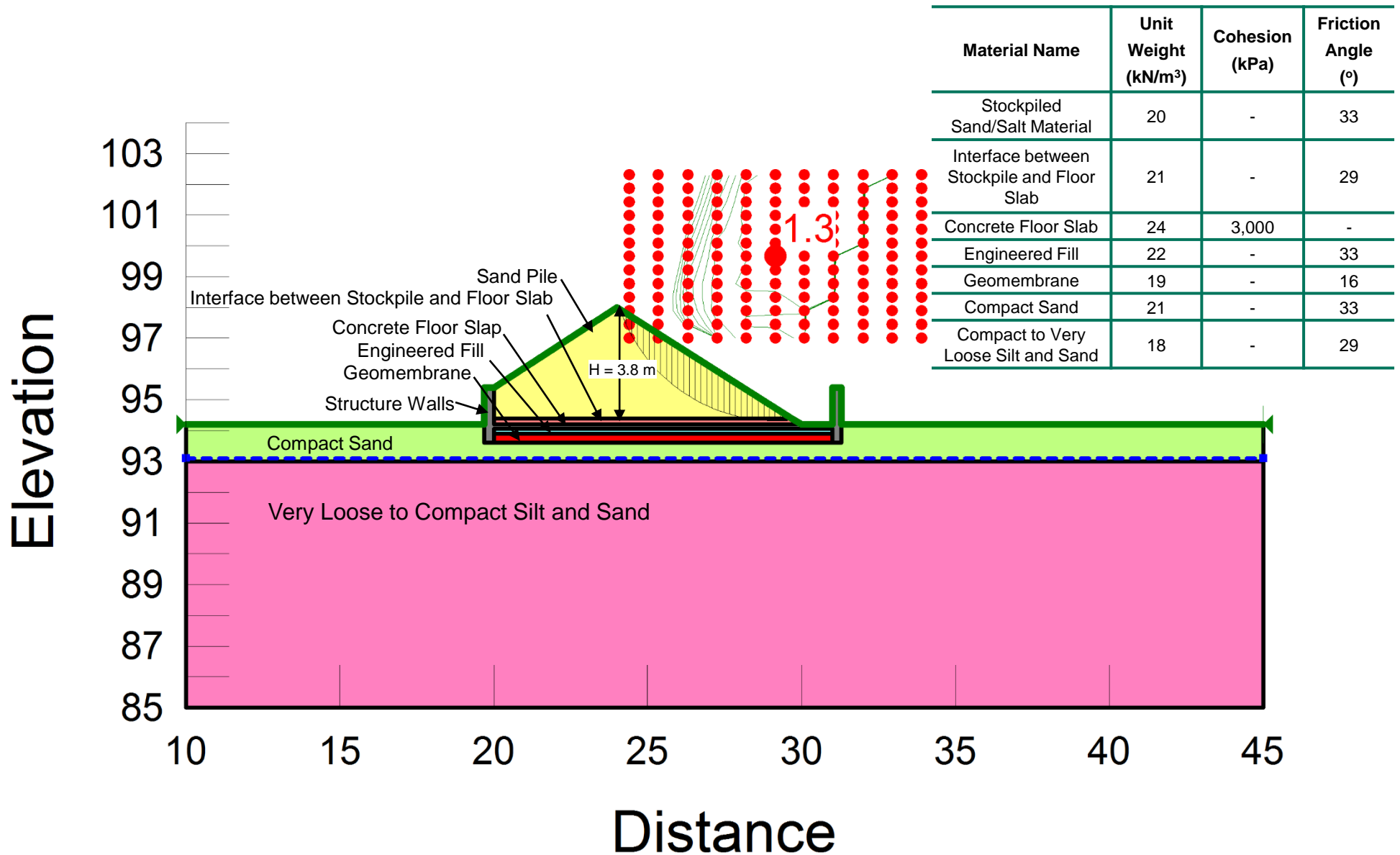
Figure 1





# Stability Analysis Stockpile Stability

Figure 2





# APPENDIX A

## Record of Boreholes



## LIST OF SYMBOLS

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

### I. GENERAL

$\pi$	3.1416
$\ln x$ ,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

### III. SOIL PROPERTIES

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

### (a) Index Properties (continued)

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

### (b) Hydraulic Properties

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

### (c) Consolidation (one-dimensional)

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

### (d) Shear Strength

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

\* Density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1  
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$



## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

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

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), $N$ :

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

#### Dynamic Cone Penetration Resistance; $N_d$ :

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

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

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive (Cohesionless) Soils

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

#### (b) Cohesive Soils Consistency

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

### IV. SOIL TESTS

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

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

### V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



1 OF 1 **METRIC**

DATUM	GEODETIC	DATE	March 8, 2016	CHECKED BY	SEMP
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+3, ×3: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

[illegible]

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

[illegible]

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

PROJECT		14-1181-0014 / 16000		<b>RECORD OF BOREHOLE No BH16-4</b>		1 OF 1 <b>METRIC</b>															
G.W.P.		LOCATION		N 4992370.7; E 381171.3		ORIGINATED BY JJL															
DIST		HWY 11		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers		COMPILED BY DM															
DATUM GEODETIC		DATE		March 8, 2016		CHECKED BY SEMP															
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%) W <sub>p</sub> — W — W <sub>L</sub>			γ	GR	SA	SI	CL	
93.8	GROUND SURFACE							20	40	60	80	100	20	40	60						
0.0	Gravelly sand, trace organics (FILL)		1A	SS	13									○							
0.2	Brown to grey Frozen		1B												○						
	SAND, some silt, trace gravel, trace clay																				
	Loose to compact		2	SS	21										○						
	Orange/brown																				
	Moist to wet																				
			3	SS	18										○						
	Becoming grey/brown below 2.6 m depth.		4A	SS	15										○						
			4B												○						
		5	SS	13									○								
		6	SS	7									○								
89.3																					
4.5	SILT and SAND, trace clay, layered		7	SS	1									○							
	Very loose to compact																				
	Grey																				
	Wet																				
			8	SS	1									○							
			9A	SS	31									○							
			9B											○							
85.7																					
8.1	Sandy SILT and GRAVEL, trace clay													○							
	(TILL)																				
	Very dense																				
	Grey																				
	Wet																				
84.9														○							
8.9	Cobbles and/or boulders inferred from observation of drilling progress.																				
	END OF BOREHOLE SPLIT-SPOON AND AUGER REFUSAL																				
	Note:  1. Water level at a depth of 1.6 m below ground surface (Elev. 92.2 m) upon completion of drilling.																				

SUD-MTO 001 14-1118-0014 ASS(GN16.GPJ GAL-MISS.GDT 22/04/16 DATA INPUT:



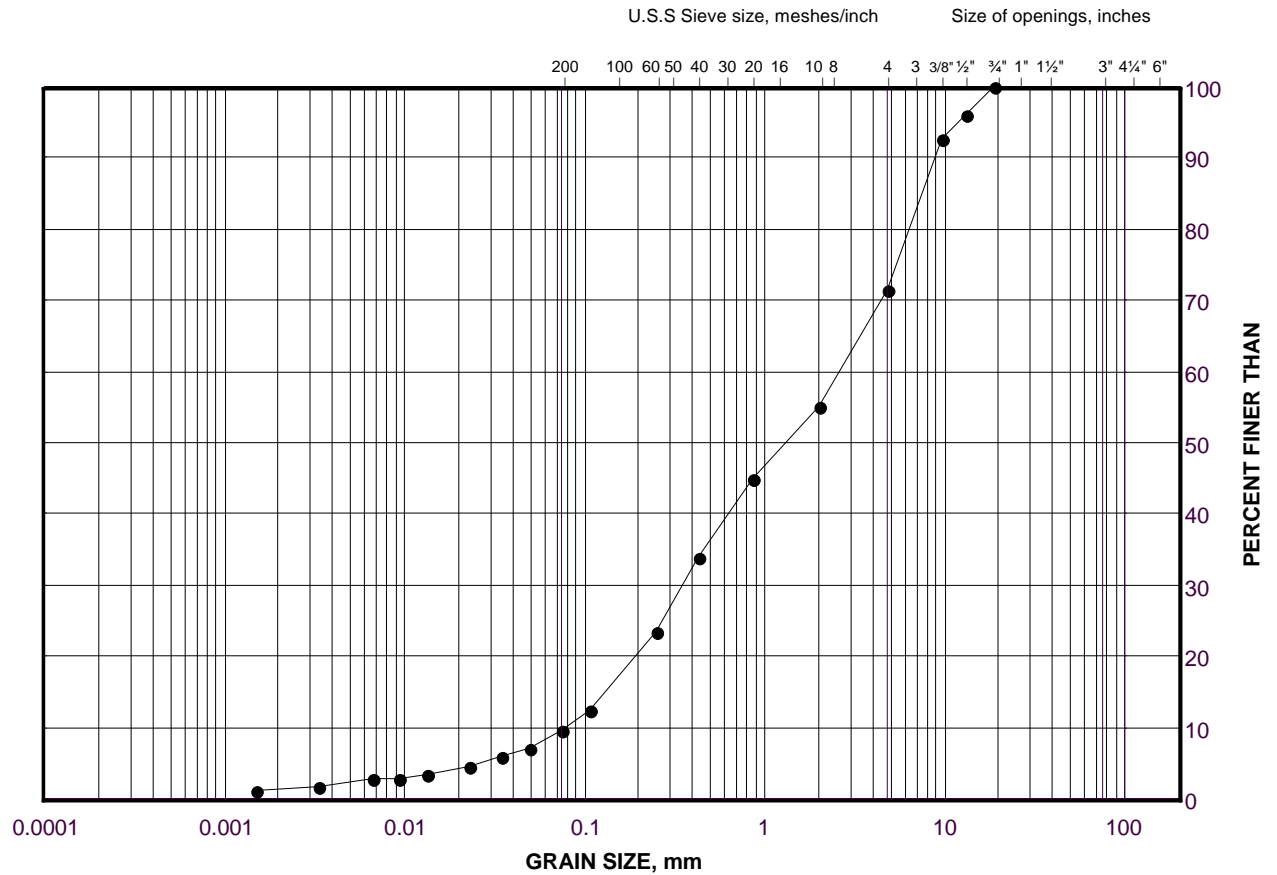
# APPENDIX B

## Laboratory Tests Results

# GRAIN SIZE DISTRIBUTION

Gravelly Sand (FILL)

FIGURE B1



SILT AND CLAY SIZES			FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED			SAND SIZE			GRAVEL SIZE		SIZE

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	16-1	1A	94.2

Project Number: 14-1181-0014 (16 000)

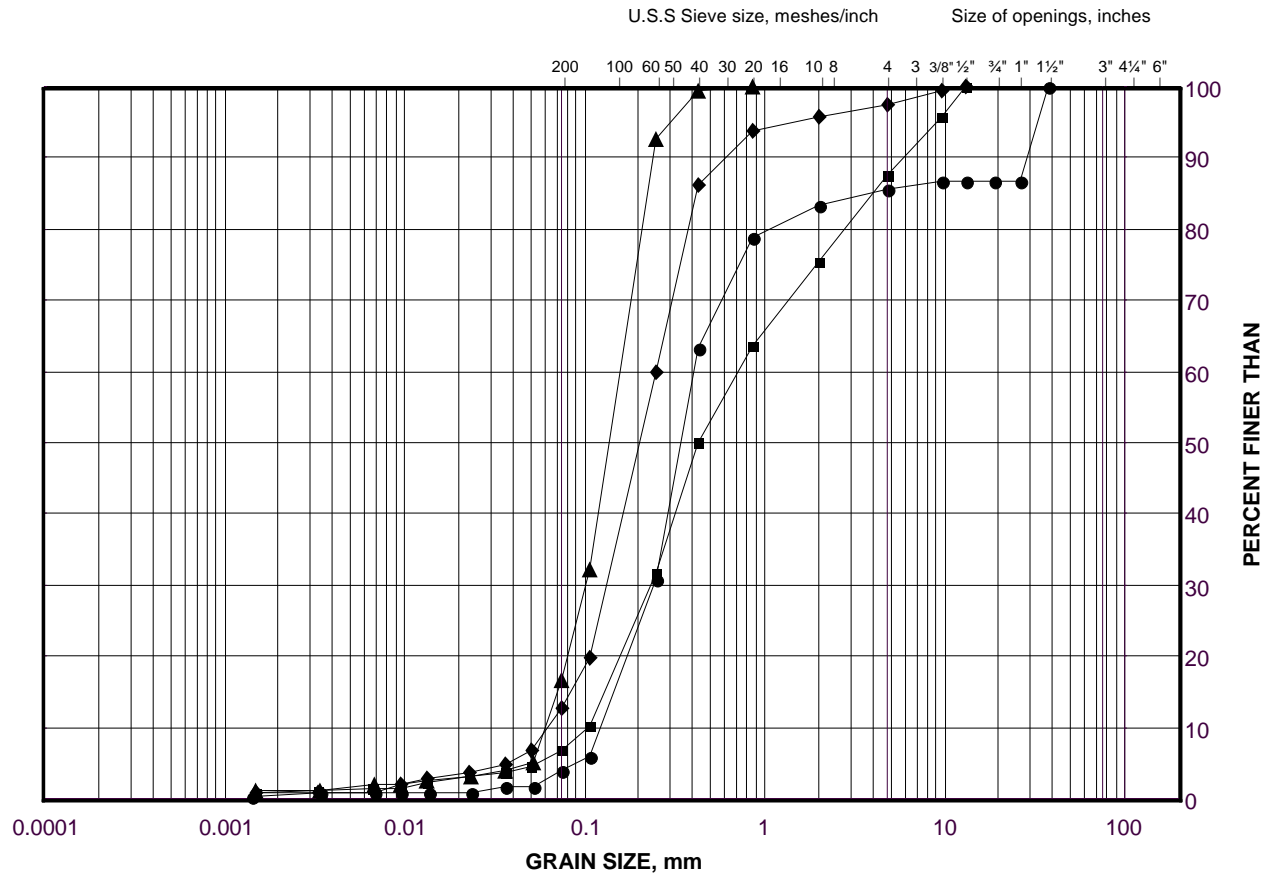
Checked By: SEMP

**Golder Associates**

Date: 14-Apr-16

# GRAIN SIZE DISTRIBUTION SAND

FIGURE B2



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	16-3	2	93.1
■	16-1	2	93.3
◆	16-4	3	92.0
▲	16-4	6	84.7

Project Number: 14-1181-0014 (16 000)

Checked By: SEMP

**Golder Associates**

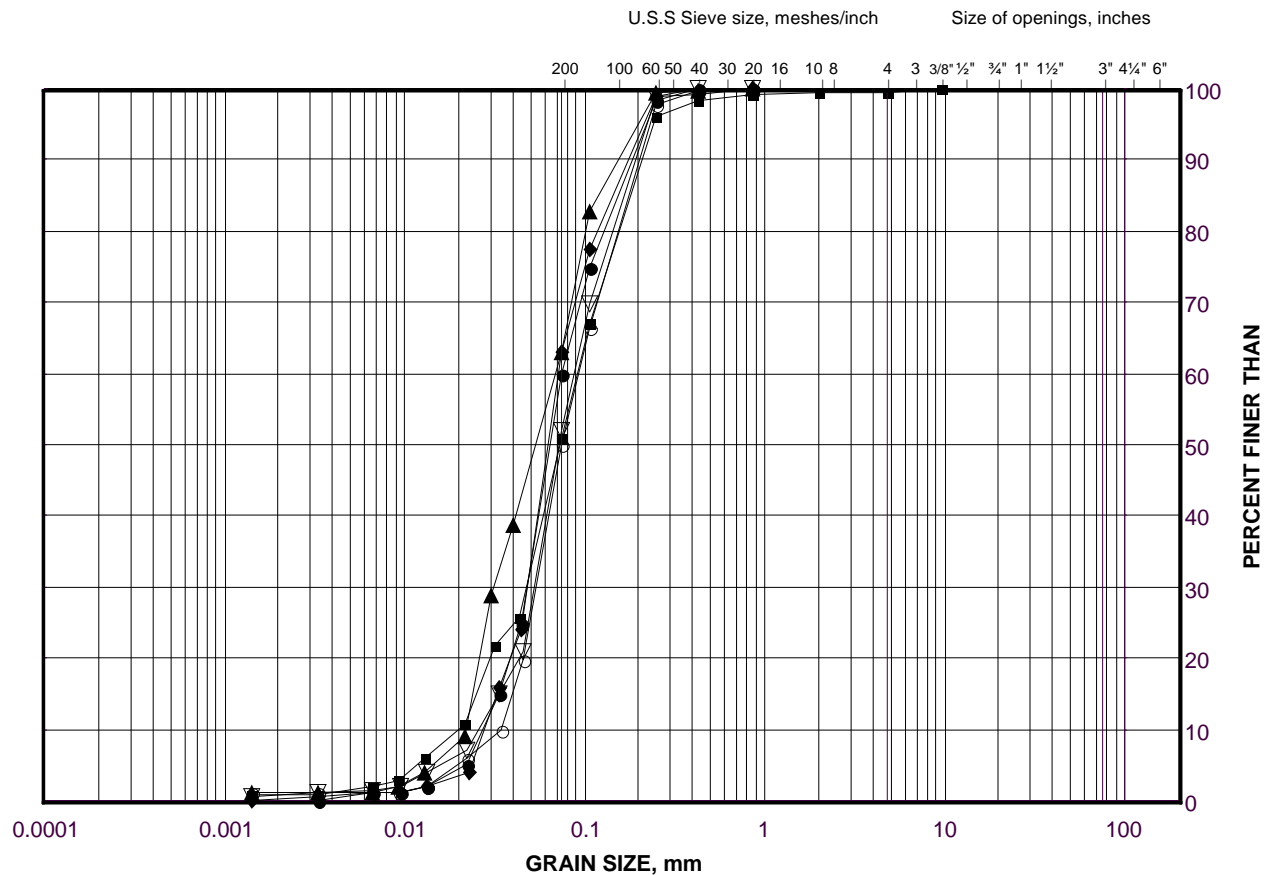
Date: 14-Apr-16



# GRAIN SIZE DISTRIBUTION

SILT and SAND

FIGURE B3



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	16-3	3	92.4
■	16-1	3	92.6
◆	16-2	4	91.7
▲	16-1	5	91.0
▽	16-3	7	89.3
○	16-2	7	89.4

Project Number: 14-1181-0014 (16 000)

Checked By: SEMP

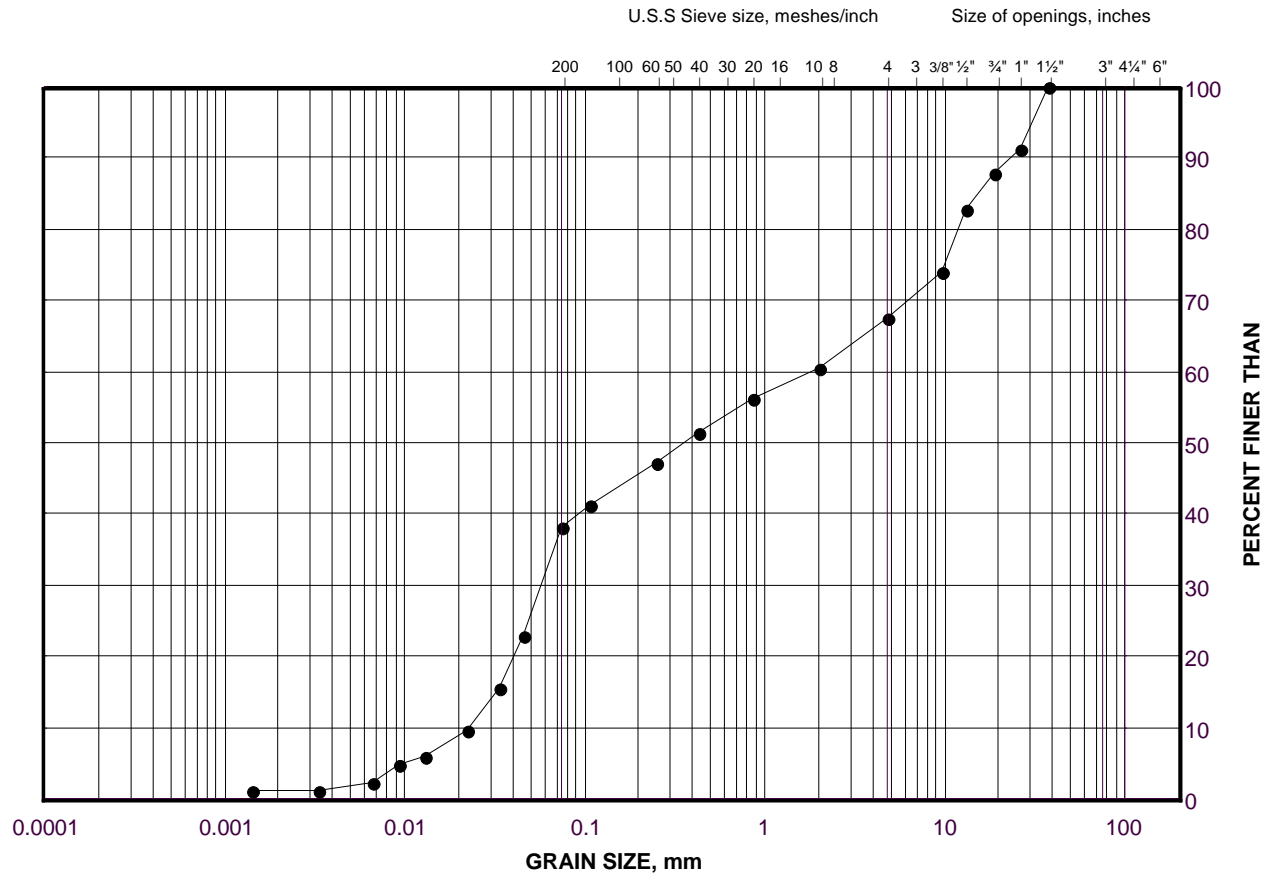
**Golder Associates**

Date: 14-Apr-16

# GRAIN SIZE DISTRIBUTION

Sandy Silt and Gravel (TILL)

FIGURE B4



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

## LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	16-4	9B	85.6

Project Number: 14-1181-0014 (16 000)

Checked By: SEMP

**Golder Associates**

Date: 22-Apr-16



# APPENDIX C

## Non-Standard Special Provisions

## **WORKING SLAB - Item No.**

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### Special Provision

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#### **1.0 SCOPE**

This Special Provision covers the requirements for the supply and placement of a concrete working slab under structure foundations.

#### **2.0 REFERENCES**

This Special Provision refers to the following standards, specifications or publications:

##### **Ontario Provincial Standard Specifications, Construction**

OPSS 902      Excavating and Backfilling - Structures

#### **3.0 DEFINITIONS - Not Used**

#### **4.0 DESIGN AND SUBMISSION REQUIREMENTS - Not Used**

#### **5.0 MATERIALS**

Concrete for working slabs shall have a minimum 28 day strength of 20 MPa.

#### **6.0 EQUIPMENT - Not Used**

#### **7.0 CONSTRUCTION**

##### **7.01 Excavation**

Excavation for the working slab shall be according to OPSS 902.

##### **7.02 Protection of Founding Soil**

Following inspection and approval of the prepared subgrade, a working slab with a minimum thickness of 100 mm shall be placed on the foundation subgrade as specified in the Contract Documents.

##### **7.03 Protection of Founding Bedrock**

The surface of the footing founding rock shall be exposed, cleaned and any loose or fractured parts removed so that sound rock is exposed. The working slab shall be placed on the exposed cleaned sound founding rock surface as specified in the Contract Documents.

Thickness of the mass concrete pad shall depend on the slope and irregularities in the exposed founding rock surface. A nominal thickness and a footprint plan view area has been specified on the Contract Documents

##### **7.04 Dewatering**

Dewatering shall be carried out according to OPSS 902.

**8.0                      QUALITY ASSURANCE - Not Used**

**9.0                      MEASUREMENT FOR PAYMENT - Not Used**

**10.0                    BASIS OF PAYMENT**

**10.01                  Working Slab - Item**

Payment at the Contract price for the above tender item shall be full compensation for all labour, Equipment and Material to do the work.

## **SAND FILL (COVER SOIL) ABOVE GEOMEMBRANE – Item No.**

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### **Non-Standard Special Provision**

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#### **Scope of Work**

The scope of work for the above noted tender item includes the supply and placement of sand fill above the geomembrane. This specification is also to alert the contractor that specialized equipment or construction techniques are required for placing and compacting all fill materials above the geomembrane.

#### **Materials**

Sand fill placed directly above and below the geomembrane will meet OPSS.PROV 1004 (Aggregates - Miscellaneous) Winter Sand, or OPSS.PROV 1002 (Aggregate – Concrete) Fine Aggregates.

At least two weeks prior to delivery of the cover soil to the site, the Contractor shall submit to the Contract Administrator the results of a grain size distribution analysis (sieve and hydrometer) performed on a representative sample of the cover soil material.

The source and quality of the sand fill material must be approved by the Contract Administrator prior to delivery of the material to site.

#### **Construction**

The Contractor must submit a list of equipment and proposed methods for placement of the sand fill (cover soil) above the geomembrane to the Contract Administrator at least two weeks prior to commencement of work. If equipment and/or methods prove unsatisfactory, the Contractor will implement changes required to ensure proper completion of work.

The sand fill must be spread with a low ground-pressure bulldozer or equivalent (maximum ground pressure of 35 kPa). A minimum of 300 mm separation distance must be maintained between the bulldozer tracks and the top of the geomembrane. The compacted density of the cover soil shall be great than or equal to 95% of the Standard Proctor Maximum Dry Density.

Truck traffic will be restricted to temporarily thickened areas of the cover soil layer providing a minimum separation distance of 900 mm between the truck tires and the underlying geomembrane.

Vary the bulldozer traffic path and operate equipment with care and under controlled speed, keeping turning radii as large as possible.

Repair any damage (i.e. tears, punctures) to the geomembrane liner caused during placement of the cover soil layer. The liner repair work shall involve uncovering the damaged areas and patching to a minimum distance of 1 m all around the tear or puncture.

**Construction Quality Assurance**

Samples of the sand fill received at the site will be taken for analysis of grain size distribution by the CQA Consultant. The sampling frequency will be one sample per 25 m<sup>3</sup> of cover soil received at the site or one sample if the source changes. The results of the analysis shall meet the requirements given in this specification. Material not meeting the project specification must be removed from the site by the Contractor at no cost to the Owner.

The CQA Consultant will inspect the placement of the cover soil, with particular attention given to the thickness of the cover soil layer and the action of the spreading and hauling equipment on the construction surface.

The CQA Consultant will check the thickness of the cover soil layer and carry out testing for percent compaction using a Nuclear Density Gauge at a minimum frequency of 1 test per 50 m<sup>2</sup>.

**Basis of Payment**

Payment at the contract price for the above noted tender item includes full compensation for all labour, equipment and materials to do the required work.

**DEWATERING FOR EXCAVATIONS – Item No.**

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Non-Standard Special Provision

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**Scope**

The contractor shall be alerted that the soils at the Municipality of Dysart Patrol Yard site consist of water-bearing sand and silt to sand. Foundation elements requiring construction below the groundwater level must be carried out in the dry. The excavation shall be kept stable during the work.

It should be noted that water levels within the area are known to fluctuate. As a result, it is recommended that excavation for the foundations or any other element be performed in mid to late summer.

**Basis of Payment**

Payment at the contract price for the above tender item shall be full compensation for all labour, equipment and materials required to do the work.



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