Geotechnical Investigation, Proposed Cultural Centre, Cambridge Bay, Nunavut

Client:
Pitquhirnikkut Ilihautiniq / Kitikmeot Heritage Society

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Cambridge Bay, Nunavut

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Date Submitted:
January 13, 2023

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Executive Summary

A geotechnical investigation was undertaken at the site of the proposed Cultural Centre to be located on Lot 50, Block 13 in the Hamlet of Cambridge Bay, Nunavut. This work was authorized by Pitquhirnikkut Ilihautiniq / Kitikmeot Heritage Society.

It is proposed to construct a Cultural Campus dedicated to the documentation, revitalization, and mobilization of Inuinnait knowledge. The proposed facility would comprise of one 1200 square feet building and outdoor activities areas with construction planned during the summer / fall of 2022.

The purpose of the investigation was to establish geotechnical and groundwater conditions at the site and to make recommendations for the design of building foundations from a geotechnical perspective including climate conditions and anticipated changes in building site conditions due to climate warming, drainage of melt water, slope stability, foundation washout and water ponding on the southeast portion of the property. Impact of construction on local surface and groundwater conditions, and recommendations for any drainage measures are also required.

The investigation comprised of drilling eight boreholes at the site to depths varying between 4 m and 10 m with an air track drill. Soil and bedrock cuttings retrieved were sampled at 1 m depth intervals, visually examined, logged, identified, and preserved in plastic bags. A representative portion of each sample was placed in a plastic bag and weighed on-site for moisture content determination. Multi-bead thermistor strings were installed in Boreholes 2 and 5 for monitoring ground temperature.

Samples were examined in the EXP laboratory in Ottawa by a senior geotechnical engineer and borehole logs prepared. Laboratory testing consisted of performing moisture content tests on all the samples and Atterberg Limit, grain size analyses, and limited chemical tests on selected soil samples.

The investigation revealed that the surficial soil at the site is sand and gravel an/or sub-glacial till which extends to a depth of 2.0 m to 4.0 m. The till is a heterogenous mixture of clay, silt, sand, and gravel with cobbles and boulders. The sand and gravel and the till are likely underlain by shale bedrock in Boreholes 1 to 3 to 6 m to 7 m depths. The shale bedrock in Boreholes 1 to 3 and the sand and gravel / till in the other boreholes are likely underlain by weathered to sound dolomite or dolomitic limestone bedrock to the entire depth investigated, i.e., 4 m to 10 m depth.

All the boreholes were dry on completion of the fieldwork.

It is considered that there are three foundation options feasible for the site. The first option is to found the proposed structure on end bearing piles socketed either in shale and weathered dolomite / dolomitic limestone bedrock or in sound dolomite to dolomitic limestone bedrock with a structural floor slab which is also supported on piles. Alternatively, the proposed structure may be founded on shallow spread and strip footings set on in an inground well compacted engineered fill bed underlain by insulation and thermosyphons. The third option is to found the structure in above ground engineered fill pad supporting an elevated floor slab with air space between the underside of the building and the engineered fill pad. Although the first option would result in greater upfront costs, in the long run it may be more cost effective compared to the second option. The reason for this is that the second option would require constant temperature monitoring and maintenance. It would also be more susceptible to human error. The third option will be the most economical but would require an elevated floor slab with airspace underneath.

The site has been classified as **Class "C"** for seismic site response in accordance with the requirements of Section 4.1.8.4 of the National Building Code of Canada, 2015. The on-site soils are also not susceptible to liquefaction during a seismic event.

Available information indicates that average temperature projections for Canada for the late century (2081-2100) range in an increase of 1.8^{o} C for low emission scenario to 6.3^{o} C for high emission scenario. Over the past three decades, there has been a decline in the Canadian land and marine areas covered with snow and ice. However, only small changes are projected for northern Canada in the future in spite of the climate changes because winter temperatures will remain sufficiently cold.

Climate warming will result in an increase in the mean annual precipitation of 7 percent under low emission scenario. As the temperature rises, there will be a shift from snow to rain in the spring and fall seasons. Changes in climate are expected to lead a change in events such as wildfires, drought, and floods. This would result in increased quantities of surface and sub-surface water flows.

The rise in sea level in the Cambridge Bay area for the next 90 years has been projected to range from -25 cm (local sea level fall) to +45 cm (local sea level rise).

The climate warming may have the following impact on the subject site:

(1) Landscape hazards due to climate warming will likely pose a low risk on the site at locations investigated as the overburden is relatively thin. If greater thickness of overburden and ice are encountered elsewhere on the site, relative degree of infrastructure risk may increase.

(2) The presence of thermokarst ponds, ice wedges and ground subsidence in areas of surface water ponding would indicate that varying quantities of excess ice occur in the overburden. Excess ice presents a potential hazard to infrastructure stability.

(3) Climate warming will necessitate continual attention to drainage issues and may require re-assessment of the routing, investigation and volume capacity of the on-site drainage systems.

1.0 Introduction

A geotechnical investigation was undertaken at the site of the proposed Cultural Centre to be located on Lot 50, Block 13 in the Hamlet of Cambridge Bay, Nunavut (Figure 1). This work was authorized by Pitquhirnikkut Ilihautiniq / Kitikmeot Heritage Society.

Pitquhirnikkut Ilihautiniq / Kitikmeot Heritage Society is developing a new cultural campus dedicated to the documentation, revitalization, and mobilization of Inuinnait knowledge. The project, titled Nunamiutuqaq (Building from the Land), bridges traditional principles of Inuit architecture with cutting-edge technologies and materials to revitalize Inuit traditions of building in harmony with the Arctic landscape. The proposed facility would comprise of one 1200 square feet building and outdoor activities areas with construction planned during the summer / fall of 2022.

The geotechnical investigation was undertaken to:

1) Establish geotechnical, groundwater, and permafrost conditions at the site;
2) Determine the active layer thickness;
3) Discuss surficial and bedrock geology of the site;
4) Make preliminary recommendations regarding the most suitable type of foundations, founding depth and the Serviceability Limit State (SLS) bearing pressure and factored geotechnical resistance at Ultimate Limit State (ULS) of the founding stratum;
5) Discuss floor slab construction of the proposed buildings;
6) Provide site classification for seismic site response;
7) Discuss subsurface concrete requirements and soil corrosivity;
8) Comment on site grading requirements;
9) Discuss excavation and slope stability conditions;
10) Comment on backfill requirements, suitability of on-site soils for backfilling purposes, and availability of construction materials;
11) Discuss site drainage; and,
12) Recommend pavement structure for proposed roadways and parking lots.

The comments and recommendations given in this report are based on the assumption that the above-described design concept will proceed into construction. If changes are made either in the design phase or during construction, this office must be retained to review these modifications. The result of this review may be a modification of our recommendations, or it may require additional field or laboratory work to check whether the changes are acceptable from a geotechnical viewpoint.

2.0 Cambridge Bay Climate and Conditions

Cambridge Bay is located between Dease Strait and Queen Maud Gulf on the southeast coast of Victoria Island, part of the Artic Archipelago. It is a transportation and administrative centre for the Kitikmeot Region. To the north of the community is Ferguson Lake which flows into Wellington Bay via the Ekalluk River.

Cambridge Bay has a polar climate with no month having an average temperature of 10^{o} C (50^{o} F) or higher. It has never recorded a temperature above freezing between October 31 and April 19. During the summer months, the temperature shortly rises above freezing for a few months before dipping back down for another 9 months of winter. Average annual rainfall and snowfall are 72 mm and 80 cm respectively.

The freezing and thawing indices for Cambridge Bay are 5703 C degree days and 629 C degree days respectively.

Cambridge Bay road network reaches about 15 km to the northeast to Iqaluktuuttiaq, 15 km to the north and 10 km to the west. Community infrastructure extends 3 km north to the water supply lake and almost 4 km to the west to the end of the airport runway beyond which the gravel road extends another 6 km toward a large gravel pit and a number of houses and cabins.

3.0 Site Geology

3.1 Site Surficial Geology

A review of the available geological information was undertaken. It indicates that the predominant overburden at the site is till which comprises of a wide range of clast sizes and includes varying proportions of boulders, cobbles, sand, silt and clay suspended in an unconsolidated matrix of mud or sand. In places, it is interbedded (or underlain by) sand and gravel. Its thickness varies from 1 m to 15 m. It was mainly deposited sub-glacially (i.e., directly underlying an ice mass and in close contact with the underlying ice). Fluting is present locally where drift is thin (1-2 m). Drumlines and drumlinoids occur where the drift is thick (10-15 m). The area north of town and west (including the airport and Distant Early Warning [DEW] line station) is covered by up to 5 m thick till blanket (Figure 3).

Based on the field observations Smith and Forbes [1] have suggested that local till thicknesses are in the order of 1 m to 3 m. A prominent esker ridge (up to 6 m high) runs for approximately 10 km along the valley of Fresh Water Creek. Uvayuq Road (formerly known as Mount Pelly Road) follows the esker eastward. The esker is formed of fine to medium sand with little gravel.

3.2 Site Bedrock Geology

The bedrock at the site comprises of Arctic Platform dolostone, dolomitic limestone, or limestone, with smaller proportions of sandstone, siltstone and shale. The bedrock is exposed along the eastern and western shores of the bay, at the mouth of Fresh Water Creek, along the shores of Kangiqhuk, and in quarries to the west and north sides of the hamlet (Figure 4).

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[1] Smith, I.R., and Forbes, D.L., 2014. Reconnaissance assessment of landscape hazards and potential impacts of future climate change in Cambridge Bay, western Nunavut. Summary of Activities, 2013, Canadian-Nunavut Geoscience Office, pages 159-170

4.0 Procedure

The field work for the geotechnical investigation was undertaken on May 15, 2022, and was supervised on a full-time basis by a geotechnician.

The field work consisted of drilling eight (8) boreholes (BH1 to BH8, inclusive) to a depth of 4 m to 10 m using an air track drill. The locations of the boreholes are shown on Site Plan, Figure 2.

Bulk soil samples were obtained from the boreholes at 1 m depth intervals. These samples were visually examined for textural classification, logged, preserved in plastic bags, and identified.

On completion of drilling, multi-bead thermistors were installed in Boreholes BH2 and BH5 to 10 m depth. Thermistor beads were installed in the borehole at 0.5 m to 2 m depth intervals.

The locations and elevations of the boreholes were established by representatives of EXP and have been presented o Table 1.

Table 1: Locations and Elevations of Boreholes

Borehole #	Eastings	Northings	Elevation (m)
1	498313.5	7667662.2	5.64
2	498323.5	7667658.9	5.19
3	498307.1	7667656.0	6.27
4	498314.4	7667649.6	6.38
5	498306.2	7667671.7	5.64
6	498329.5	7667648.6	5.09
7	498342.1	7667648.0	4.13
8	498301.2	7667637.3	8.40

The elevations of the boreholes refer to the geodetic datum.

On completion of the field work, all soil samples were transported to the EXP laboratory in the city of Ottawa, Ontario. All the soil samples were examined in the laboratory by a senior geotechnical engineer and borehole were prepared. The engineer also assigned laboratory testing which consisted of performing natural moisture content tests on all the samples and grain size analysis, Atterberg Limit, pH, sulphate, chloride and electrical conductivity tests on selected samples.

5.0 Site Description

The site is located on Lot 50, Block 13, in the Hamlet of Cambridge Bay, Nunavut. It is located in the northwest quadrant of the intersection of Okalik and Natik Streets. Okalik Street is located on an approximately 3 m high ridge. Crushed 19 mm stone has been pushed over the edge of the north shoulder of the road resulting in a shallow road shoulder. The site slopes down in the north and east directions so that the resultant down gradient is in the northeast direction. The ground surface elevations at the site vary from Elevation 8.87 m at the southwest corner to Elevation 2.16 m, approximately, at the northeast corner, resulting in a relief of approximately 6.7 m. The ground surface elevations at the borehole locations (in the construction area) vary from Elevation 4.1 m to Elevation 8.4 m.

A creek is located approximately 25 m north of the site and traverses in the easterly direction. The bottom of the creek is covered with snow and ice during the winter moths and is used by Ski-doos. At the time of the geotechnical investigation, wet areas were noted on both sides of the creek during snowfall / snow melt. However, the water level was lower than the site level. The entire area is covered with grass and tundra. The Canadian High Arctic Research Station (CHARS) is located north of the creek.

Boreholes 1, 2, 3 and 5 were covered with a thin snow cover underlain by approximately 100 mm thick layer of tundra. Boreholes 4, 6 and 7 were covered with 300 mm to 450 mm of snow underlain by approximately 100 mm of tundra. These locations were frozen at the surface. Borehole 8 was located close to the edge of the north shoulder of Okalik Street and encountered approximately 1.5 m of sand and gravel fill.

6.0 Subsurface Soil Description

A detailed description of the subsurface soil and groundwater conditions determined from the boreholes are given on the attached Borehole, Figures 5 to 12 inclusive. The borehole logs and related information depict subsurface conditions only at the specific locations and times indicated. Subsurface conditions and water levels at other locations may differ from conditions at the locations where sampling was conducted. The passage of time also may result in changes in the conditions interpreted to exist at the locations where sampling was conducted. Boreholes were drilled to provide representation of subsurface conditions as part of a geotechnical exploration program and are not intended to provide evidence of potential environmental conditions.

It should be noted that the soil boundaries indicated on the borehole logs are inferred from discontinuous sampling and observations during drilling. These boundaries are intended to reflect approximate transition zones for the purpose of geotechnical design and should not be interpreted as exact planes of geological change. The “Note on Sample Descriptions” preceding the borehole logs form an integral part of this report and should be read in conjunction with this report.

A review of Figures 5 to 12 indicates that the soil stratigraphy at the site is fairly consistent. It comprises of a layer of till or sand and gravel underlain by bedrock, as detailed below.

6.1 Tundra

The site is covered with approximately 100 mm thick layer of tundra except in Borehole 8.

6.2 Fill

The surficial soil encountered in Borehole 8 was crushed sand and gravel road shoulder fill which extends to a depth of 1.5 m approximately (Elevation 6.9 m). The natural moisture content of the fill varied from 2.6 precent to 4.1 percent. It comprises of 4 percent clay and silt, 41 percent sand, and 55 percent gravel (Figure 11).

6.3 Sand and Gravel

The fill is in Borehole 8 and the tundra in all the other boreholes except Boreholes 5 and 6 are underlain by a layer of sand and gravel with cobbles and boulders which extends to a depth of 2.0 m to 4.0 m (Elevation 1.64 to 4.9 m). This stratum comprises of 3 to 4 percent clay and silt, 45 to 63 percent sand, and 33 to 52 percent gravel (Figures 12 to 14). Its moisture content varies from 3.4 percent to 12.1 percent.

6.4 Till

The sand and gravel in Borehole 3 and the tundra in Boreholes 5 and 6 are underlain by till which extends to a depth of 2.5 m to 4.0 m (Elevation 1.64 m to 2.59 m). The till is a heterogeneous mixture of clay, silt, sand and gravel with cobbles and boulders. The results of the grain size analysis performed on this stratum are given on Figures 15 to 17. A review of these figures indicates that the till comprises of 16 to 32 percent clay and silt, 50 to 60 percent sand, and 18 to 32 percent gravel. The moisture content of the till varies from 2.6 to 18.7 percent.

6.5 Possible Shale Bedrock

The sand and gravel in Boreholes 1 and 2 and the till in Borehole 3 are underlain by possible shale bedrock which extends to a depth of 7.0 m to 8.0 m (Elevation -1.81 m to 0.27 m). Rock chips retrieved indicate that the bedrock is thinly laminated and is dark grey in colour. The bedrock drilling was relatively easy, indicating that it is soft rock. The moisture content of rock powder and chips retrieved varied from 2.8 percent to 6.1 percent.

6.6 Possible Dolomite or Dolomitic Limestone Bedrock

The shale bedrock in Boreholes 1 to 3, the till in Boreholes 5 and 6, and the sand and gravel in Boreholes 4, 7 and 8 are underlain by possible dolomite or dolomitic limestone bedrock which extends to the entire depth investigated in all the boreholes, i.e., 4.0 m to 10 m depth (Elevation 4.81 to 3.4 m). The dolomite or dolomitic limestone bedrock is weathered in the upper levels and becomes sound with depth. The moisture content of the bedrock varied from 1.0 to 6.9 percent.

Table 2: Summary of Laboratory Test Results

Borehole #	Sample Depth (m)	Atterberg Limit Test Results			Grain Size Analyses Results (%)		
		Plastic Limit (%)	Liquid Limit (%)	Plastic Index (%)	Clay & Silt	Sand	Gravel
2	1.0 – 1.3	Non-plastic	Non-plastic	Non-plastic	4	49	47
3	3.0 – 3.3	Non-plastic	Non-plastic	Non-plastic	17	60	23
4	2.0 – 2.3	Non-plastic	Non-plastic	Non-plastic	4	63	33
5	1.0 – 1.3				32	50	18
6	1.0 – 1.3	Non-plastic	Non-plastic	Non-plastic	16	52	32
8	1.0 – 1.3				4	41	55
8	3.0 – 3.3				3	45	52

6.7 Groundwater

All the boreholes were dry on completion and were backfilled. At the time of drilling, the soil was frozen from the ground surface. The active layer thickness is reported to be less than 1 m thick. Therefore, it is anticipated that a shallow perched water table would be encountered at the site during the short summer season between snow melt and refreeze.

7.0 Soil Salinity

The salinity of the on-site soil was calculated by conducting limited conductivity tests on selected soil samples. The results have been tabulated on Table 3.

Table 3: Salinity of On-site Soils

Borehole #	Sample Depth (m)	Salinity in Parts per Thousand (ppt)
2	1.0 – 1.3	1.24
	5.0 – 5.3	2.27
	8.0 – 8.3	2.11
3	3.0 – 3.3	2.57
	6.0 – 6.3	1.08
4	2.0 – 2.3	0.71
5	1.0 – 1.3	0.65
	9.0 – 9.3	1.61
6	1.0 – 1.3	1.41

A review of the above table indicates that the salinity of the soil varies from 0.41 parts per thousand (ppt) to 2.57 ppt. On this basis, the soil is considered low in salinity. Certificate of Laboratory Analysis is attached as Appendix B.

8.0 Ground Temperature

Thermistors were installed in Boreholes 2 and 5 to determine the ground temperature. Readings were taken between May 17 and June 15, 2022. Some of the readings have been tabulated on Tables 4(a) and 4(b). Additional readings were collected by Qillaq travel from the thermistor installed in Bore No. 5 and forwarded to exp during the period between October 2022 and January 2023 and the results are presented in table 4c.

Table 4(a): Ground Temperature Readings Taken in Borehole 2 Between May 18 and June 15, 2022

BH-02 - May 18 2022			BH-02 - May 25, 2022			BH-02 - June 11, 2022			BH-02 - June 15, 2022		
Bulb	Depth	Temp (ºC)	Bulb	Depth	Temp (ºC)	Bulb	Depth	Temp (ºC)	Bulb	Depth	Temp (ºC)
1	-0.5	-8.1	1	-0.5	-6.9	1	-0.5	-2.9	1	-0.5	-2.5
2	-1.0	-11.3	2	-1.0	-9.1	2	-1.0	-5.2	2	-1.0	-4.7
3	-1.5	-13.0	3	-1.5	-10.5	3	-1.5	-6.9	3	-1.5	-6.3
4	-2.0	-13.9	4	-2.0	-11.8	4	-2.0	-8.3	4	-2.0	-7.7
5	-2.5	-14.3	5	-2.5	-12.8	5	-2.5	-9.7	5	-2.5	-9.2
6	-3.0	-14.2	6	-3.0	-13.2	6	-3.0	-10.7	6	-3.0	-10.2
7	-4.0	-13.3	7	-4.0	-13.0	7	-4.0	-11.8	7	-4.0	-11.5
8	-5.0	-11.6	8	-5.0	-11.7	8	-5.0	-11.5	8	-5.0	-11.3
9	-6.0	-10.2	9	-6.0	-10.4	9	-6.0	-10.6	9	-6.0	-10.6
10	-8.0	-9.1	10	-8.0	-9.2	10	-8.0	-9.5	10	-8.0	-9.5
11	-10.0	-8.7	11	-10.0	-8.8	11	-10.0	-8.9	11	-10.0	-9.0

Table 4(b): Ground Temperature Readings Taken in Borehole 5 Between May 18 and June 13, 2022

BH-05 - May 18, 2022			BH-05 - May 25, 2022			BH-05 - June 9, 2022			BH-05 - June 13, 2022		
Bulb	**Depth**	**Temp (ºC)**	**Bulb**	**Depth**	**Temp (ºC)**	**Bulb**	**Depth**	**Temp (ºC)**	**Bulb**	**Depth**	**Temp (ºC)**
1	-0.5	-7.0	1	-0.5	-6.1	1	-0.5	-1.7	1	-0.5	-1.5
2	-1.0	-10.4	2	-1.0	-8.8	2	-1.0	-4.8	2	-1.0	-4.2
3	-1.5	-12.6	3	-1.5	-10.5	3	-1.5	-7.0	3	-1.5	-6.4
4	-2.0	-13.7	4	-2.0	-11.8	4	-2.0	-8.6	4	-2.0	-8.0
5	-3.0	-14.3	5	-3.0	-13.1	5	-3.0	-10.7	5	-3.0	-10.1
6	-4.0	-13.5	6	-4.0	-13.3	6	-4.0	-12.0	6	-4.0	-11.6
7	-6.0	-10.6	7	-6.0	-10.8	7	-6.0	-10.9	7	-6.0	-10.9
8	-8.0	-9.2	8	-8.0	-9.3	8	-8.0	-9.6	8	-8.0	-9.6
9	-10.0	-8.8	9	-10.0	-8.9	9	-10.0	-9.1	9	-10.0	-9.1

Table 4(c): Ground Temperature Readings Taken in Borehole 5 Between October 7, 2022, and January 5, 2023

		Oct. 07, 2022	Oct. 19, 2022	Nov. 1, 2022	Nov. 15, 2022	Nov. 24, 2022	Nov. 30, 2022	Dec. 08, 2022	Dec. 22, 2022	Jan. 05, 2023
Bulb	**Depth**	**Temp (ºC)**	**Temp (ºC)**	**Temp (ºC)**	**Temp (ºC)**	**Temp (ºC)**	**Temp (ºC)**	**Temp (ºC)**	**Temp (ºC)**	**Temp (ºC)**
1	-0.5	0.2	0.0	-0.4	-4.0	-6.1	-7.4	-9.9	-11.6	-14.1
2	-1.0	-0.1	-0.2	-0.3	-2.6	-4.3	-5.3	-7.4	-9.3	-11.6
3	-1.5	-1.0	-1.0	-1.0	-2.0	-3.4	-4.3	-5.8	-8.0	-10.0
4	-2.0	-1.9	-1.8	-1.8	-2.0	-2.9	-3.6	-4.8	-6.8	-8.7
5	-3.0	-3.5	-3.3	-3.2	-3.1	-3.3	-3.5	-4.0	-5.5	-7.0
6	-4.0	-5.5	-5.3	-5.1	-4.9	-4.8	-4.8	-4.8	-5.3	-6.1
7	-6.0	-8.1	-8.0	-7.7	-7.5	-7.4	-7.3	-7.2	-7.0	-7.0
8	-8.0	-9.1	-9.0	-8.8	-8.7	-8.6	-8.6	-8.4	-8.3	-8.6
9	-10.0	-8.6	-9.2	-9.1	-9.0	-9.0	-8.9	-8.8	-8.8	-8.6

9.0 Permafrost and Active Layer Thickness

Cambridge Bay has a polar climate with freezing temperatures for 9 moths of the year. As a result, the thickness of the active layer has been reported as less than 1 m below which the ground and bedrock remain frozen year-round. Smith and Forbes have reported that there is little evidence for the presence of excess ground ice in the Cambridge Bay built up area but there are indications of excess ice in areas around the DEW line station and in isolated areas east of the airport. Evidence of massive ground ice and excess ice is found in low lying areas surrounding ponds. The absence of ground ice features in the Cambridge Bay region generally indicates thin cover of sediment overlying the bedrock. In addition, coarse nature of the sediment and the regional slope has facilitated drainage of the overburden.

10.0 Site Grading

The grades proposed at the site were not available at the time of writing this report. Topographic survey of the site indicates that the elevation of the Okalik Street varies from Elevation 10.1 m at the west property boundary to Elevation 2.72 m at the east property boundary. Elevations of Natik Street vary from Elevation 3.22 m at the intersection of Okalik Street and Natik Street to Elevation 2.25 m close to the north property boundary of the site. Site elevations vary from Elevation 8.87 m at the southwest corner to Elevation 2.16 m at the northeast corner. The resultant downslope at the site is from the southwest corner of the site to the northeast corner. In the area of the proposed development, the ground surface elevations vary from Elevation 5.19 m to Elevation 8.40 m. The site is located approximately 1.5 to 2.0 m below the road level. It is therefore anticipated that approximately 1.5 m to 2.0 m of fill will be placed at the site to raise the grade. The following procedure is recommended for site grading.

It is recommended that all the tundra should be stripped from the area to be filled. The exposed subgrade should then be proof rolled with a highway type roller in the presence of geotechnical personnel if construction is undertaken during summer months. Any soft pockets identified should be sub-excavated and the excavation backfilled with engineered fill conforming to gradation requirements of Table 5. It should be compacted to 100 percent Standard Proctor Maximum Dry Density (SPMDD). Granular fill conforming to the gradation requirements of Table 5 should then be placed in 300 mm lift thicknesses and each lift compacted to 100 percent Standard Proctor Maximum Dry Density. In-place density tests should be performed on each lift to ensure that the specified depth of compaction is being achieved. The placement and compaction of the fill can in this manner be undertaken to the proposed grade. The sides of the granular pad should be sloped at an inclination of 3H:1V or flatter to blend with the existing grade. The finished grade of the granular pad should be sloped in the southwest to northeast direction to maintain the current surface water drainage direction.

11.0 Foundation Considerations

The investigation has revealed that the geotechnical conditions at the site comprise of surficial sand and gravel and till which extend to 2.0 m to 4.0 m depth. These soils are underlain by possible shale bedrock in Boreholes 1 to 3 to 6 m to 7 m depth. The shale and overburden in the other boreholes are underlain by possible dolomite or dolomitic limestone bedrock which extends to the entire depth investigated, i.e., 4.0 m to 10.0 m depth. The bedrock is weathered in upper levels and becomes sound with depth. The proposed structure is to be located in the vicinity of Boreholes 1 to 4 inclusive. In these boreholes, the bedrock is likely present at a depth of 2 m to 4 m below the existing ground surface. However, it is noted that the shale bedrock is a relatively soft rock compared to dolomite or dolomitic limestone.

It is considered that there are three foundation options available for the site. These are:

(1) Rock socketed end bearing pile foundation with the floor slab also supported on piles.

(2) Spread footings set in an inground engineered fill pad at shallow depth underlain by rigid insulation and thermosyphons with a slab-on-grade floor.

(3) Spread footings set in localized pits at a shallow depth in an above ground engineered fill pad with adjustable steel posts supporting an elevated structure on columns and beams with a minimum of 0.6 m of airspace between the foundation beams and the granular bed.

It is noted that Option 1 would result in the greatest front-end costs. However, this option has the advantage that post construction foundation maintenance costs will be minimal. Option 2 would require lower front-end costs but it has the disadvantage that regular ground temperature monitoring and maintenance of the thermosyphons would be required during the life expectancy of the structure. Option 3 is the most cost effective as far as the front-end costs are concerned. However, it has the disadvantage that regular monitoring of settlements of the building and adjustment of the steel posts will be required as the structure settles or heaves. If regular monitoring and adjustment of the structure is not undertaken, it may heave and/or settle differentially, resulting in twisting and cracking of the structure.

11.1 End Bearing Piles

It is considered that the proposed structure may be founded on rock socketed end bearing piles with a floor slab also supported on end bearing piles. The shale bedrock is a somewhat softer rock compared to dolomite or dolomitic limestone and dolomite and/or dolomitic limestone bedrock is weathered in the upper levels. It is considered that one option would be to found the proposed structure on end bearing piles in shale and weathered limestone bedrock. This approach would result in shorter piles although the pile capacity will be lower. In this case it is likely that the piles can be founded at a depth of 2 m to 3 m below the surface of the shale or weathered limestone bedrock. The other option is to found the piles in sound dolomite or dolomitic bedrock at an estimated depth of 9 m to 10 m below the existing ground surface. However, the actual founding level would have to be established in the field by qualified geotechnical personnel experienced with arctic drilling techniques. Round Hollow Structural Sections (HSS) are recommended as opposed to pipe casings.

Since the piles will be socketed into bedrock, settlement is anticipated to be negligible and the factored geotechnical resistance at Ultimate Limit State (ULS) will govern the design. Steel piles installed in shale or weathered dolomite or dolomitic limestone bedrock according to the recommendations herein may be designed on the basis of a factored geotechnical resistance at ULS of 5 MPa over the full base area of the grouted pile. In addition to end bearing, the bond between the grout and the bedrock may also be taken into consideration for design. The factored bond stress between the grout and the bedrock may be taken as 1.0% of the unconfined compressive strength of the grout. Assuming the minimum unconfined compressive strength of the grout will be 30 MPa, the factored bond stress will be 300 kPa. This bond will resist compression or tension loads.

Steel piles installed in sound dolomite or dolomitic limestone bedrock may be designed on the basis of factored geotechnical resistance at Ultimate Limit State (ULS) of 10 MPa over full base area of the grouted piles. In additional, the bond between the grout and bedrock may be taken as 1.5 percent of the unconfined compressive strength of the grout. Assuming the maximum unconfined compressive strength of the grout will be 30 MPa, the factored bond stress will be 450 kPa.

It is recommended that as a somewhat conservative approach, a design active layer thickness of 2.0 m be used for the site. The upper portion of the piles within the design 2.0 m active zone should be covered with heavy grease and wrapped with polyethylene sheets coated with heavy grease to reduce seasonal uplift forces. Even with this precaution the piles should be designed to resist an ultimate frost-jacking force of 150 kPa through the active zone. Therefore, based on the use of 30 MPa grout, the piles should be grouted at least 1.0 m into the competent bedrock at the site if the piles are founded on sound dolomite or dolomitic limestone bedrock.

It is noted that the bearing capacity of the piles may be reduced by improper seating of the pile on the bedrock or by poor bond at the grout/pile interface. Therefore, it is considered imperative that the pile boreholes are cleaned properly so that the piles are set directly on the bedrock.

If the piles are to be installed when the active layer is not fully frozen, accumulation of the groundwater in the pile holes will cause problems during pile installation. Water in the pile holes will make it difficult for the drilling equipment to properly clean the holes. In addition, water may cause the boreholes to cave-in making pile installation and quality control very difficult. The pile borings may be cased in order to reduce groundwater seepage and cave-in of the holes. However, it may still be difficult to obtain a clean and dry hole where boulders are encountered. It is noted that if a clean and dry hole is not achieved during installation of the piles, it may be necessary to reduce the pile bearing capacity. If grout installation to the bottom of the borehole is carried out in the wet, then the grout should be tremied to the bottom to avoid dispersion and dilution.

The portion of the pile to be grouted should be free of paint, lacquer, oil, dirt or excessive rust to ensure good bonding. Therefore, a non-lacquered HSS section should be specified for the piles.

The piles should be installed in pre-drilled oversize holes at least 25 mm diameter larger than the pile diameter. The pile holes should be cleaned out completely. Immediately after cleaning the socket, the socket should be filled with an approved fast setting arctic grout, with accelerating and water reducing agents, such as, SIKA ARCTIC 100 or equivalent. The procedure for mixing, handling and installing the grout should be in accordance with the manufacturer's recommendations.

The piles should be placed through the grout and vibrated to the rock socket base. The piles should be installed open-ended. Measurements should be taken during pile installation to verify that the piles are being seated on bedrock. The pile should be supported within the hole, using bracing at ground surface for plumb piles or down hole centralizers for inclined piles for a period of 24 hours to allow setting of the grout. Loads should not be applied to the pile for at least three days after installation. After the grout has set, the remaining annular space between the pile and the hole should be filled with sand slurry made with fresh potable water and saline free sand to the final grade. The fines content of the sand should not exceed 12 percent and the maximum particle size should be limited to one-half of the annulus spacing. Drill cuttings would not be suitable for this purpose. Dry drill cuttings may be used for filling the inside of the piles.

Test cylinders of the proposed grout should be cast and stored on-site for several days prior to being transported to a laboratory for testing of the compressive strength.

For lateral load design purposes, the upper 2.0 m of the piles should also be considered as unsupported.

11.2 Spread and Strip Footings on Inground Engineered Fill Pad with Insulation and Thermosyphons

The alternative to end bearing piles is to found the proposed structure on spread and strip footings on an inground engineered fill pad with insulation and thermosyphons. This foundation option would require that all the existing fill, topsoil and underlying natural soil are sub-excavated to a minimum depth of 2 m and the excavation backfilled with engineered fill.

11.2.1 Building Foundation

This option would require that the floor slab of the building is set on top of an inground engineered fill pad at least 2 m thick (subject to change depending on results of geothermal analysis) which should extend at least 2 m beyond the perimeter of the structure. The portion of the Styrofoam insulation which will extend 2 m beyond the perimeter of the structure should be sloped downward to prevent groundwater flow within the engineered fill structure.

The proposed structure may be founded on spread and strip footings set in the engineered fill pad at shallow depth. The floor slab and the footings should be underlain by rigid insulation of required thickness as determined by geothermal analysis and should extend a minimum of 2 m beyond the perimeter of the structure. The insulation should be underlain by thermosyphons. Details of the engineered fill pad thickness and the type and thickness of insulation required would be determined by a geothermal analysis which is currently in progress.

For preliminary design, footings set on the well compacted and prepared engineered fill pad may be designed for Serviceability Limit State (SLS) bearing pressure of 150 kPa and factored geotechnical structure at Ultimate Limit State of 225 kPa. It is noted that the SLS and ULS bearing pressure will be affected by the type of insulation used. Dow Chemical, a manufacture of polystyrene foam insulation, recommends that the long-term static loads on their extruded polystyrene insulation should be limited to 33 percent of the ultimate compressive strength of the insulation and dynamic loads should be limited to 20 percent of the ultimate compressive strength of the insulation. The ultimate compressive strength of Dow Chemical's Highload 40, 60 and 100 extruded polystyrene insulations may be taken as 275 kPa (40 psi), 415 kPa (60 psi) and 690 kPa (100 psi), respectively. The designer should ensure that foundation design complies to the specifications and recommendations of the manufacturer of the type of insulation used.

The thermosyphon design is a proprietary activity by the manufacturer. It is therefore recommended that a qualified thermosyphon manufacturer should be retained to provide site specific engineering design.

11.2.2 Granular Pad Construction

Excavation for construction of the engineered fill pad should extend at least 2 m below the underside of the floor slab and to a sufficient depth to remove all fill and debris from the site. It should extend at least 2 m beyond the parameter of the structure and should therefore be sloped at an inclination of 1H:1V or flatter depending on site conditions at the time of construction. The exposed subgrade should then be proof-rolled with a highway type roller in the presence of geotechnical personnel if construction is undertaken during summer months. Any soft pockets identified should be sub-excavated and the excavations backfilled with engineered fill (conforming to gradation requirements of Table 5) compacted to 100 percent Standard Proctor Maximum Dry Density (SPMDD). Construction of the granular pad may then proceed.

From a geotechnical perspective, the engineered fill used to construct the engineered fill pad should consist of frost stable sand and gravel, preferably conforming to the gradation given on Table 5. The engineered fill should be placed in lifts compatible with the compaction equipment and each lift compacted to 100 percent SPMDD. In-place density tests should be performed on each lift to ensure that the specified degree of compaction has been achieved. Consideration should be given to placement of a thick (50 mm thick) sand bedding layer below the ESP Styrofoam insulation. This will reduce the opportunity for coarse ground particles to puncture the EPS.

It should be noted that thermosyphons system is a proprietary design and therefore construction of the pad and material specification should also comply to the requirements of the design-build engineer.

Table 5: Gradation Requirements of Engineered Fill

Sieve Size	Percentage Passing
25.0 mm	100
19.0 mm	75 – 100
9.5 mm	50 – 85
4.75 mm	35 – 65
2.0 mm	25 – 50
0.42 mm	15 – 30
0.075 mm	5 - 10

The EPS should be placed in layers with joints off-set from the layer above and below. This will reduce the opportunity for vertical thermal currents to form. EPS insulations are susceptible to degradation in the presence of hydrocarbons. If there is any likelihood that hydrocarbons may penetrate the concrete slab-on-grade, a suitable impermeable barrier should be installed between the EPS and the concrete floor.

The presence of subsurface water flow under the structure may render the insulation slab design ineffective. If there is access to groundwater, frost heaving may occur. Steps must be taken to limit or prevent this completely using drainage ditch and/or placement of impervious layers.

Construction of the engineered fill pad in winter or freezing temperatures typically results in poor short and long-term performance of the pad. If winter construction is anticipated, EXP should be notified so that appropriate fill specifications and construction procedures may be evaluated.

11.3 Spread Footings on Above Ground Engineered Fill Pad Supporting an Elevated Structure

The third option is to support the proposed structure on spread footings set in localized pits at a minimum depth of 0.5 m below the surface of a 2.0 m thick above ground engineered fill pad supporting an elevated structure on adjustable steel columns and beams. The granular pad should extend at least 3 m beyond the perimeter of the structure in all directions and should thereafter be sloped at an inclination of 2H:1V in all directions. This option would require that a minimum of 0.6 m of airspace is provided between the underside of the grade beams and the surface of the engineered fill pad. This space should not be boarded or used for storage purposes. The floor slab of the structure may be constructed with timber or steel.

The following procedure is recommended for the construction of the engineered fill pad.

All the tundra / topsoil should be stripped from the area of the granular bed. The exposed surface should be proof rolled. Any soft or loose areas encountered should be sub-excavated and replaced with free draining sand and gravel fill conforming to the gradation requirements of Table 5. The fill should be compacted to 100 percent Standard Proctor Maximum Dry Density (SPMDD). Construction of the granular pad may then proceed. Engineered fill conforming to the gradation requirements of Table 5 should then be placed in lifts compatible with the compaction equipment used and each lift compacted to 100 percent SPMDD. In-place density tests should be performed on each lift to ensure that the specified degree of compaction has been achieved.

The footings of the structure should be set at a minimum depth of 0.5 m below the surface of the engineered fill pad in localized pits. The backfill in the pits should be compacted to 100 percent SPMDD. A Serviceability Limit State bearing pressure of 150 kPa and factored geothermal resistance at Ultimate Limit State of 225 kPa may be used to design the footings. It is noted that in time, the permafrost is expected to build into the engineered fill pad.

11.4 Proposed General and Loading Pads

It is noted that general and loading pads are to be constructed as part of the proposed development. It is not known if concrete slabs will be located on top of these pads. These pads may consist of 1.5 m high elevated engineered fill. The sides of the granular pads should be sloped at an inclination of 3H:1V. Materials to be stored on the pads should be set back at least 2 m from the crest of side slopes. All the topsoil / tundra should be stripped from the area of the granular pad. The exposed surface should be proof rolled. Any soft areas encountered should be sub-excavated and replaced with free draining sand and gravel fill compacted to 100 percent Standard Proctor Maximum Dry Density. Free draining sand and gravel fill should then be placed in 300 mm thicknesses and each lift compacted to 100 percent of SPMDD. The fill should preferably meet the gradation requirements of Table 5. The placement and compaction of the fill may be undertaken in this manner to the final grade.

12.0 Site Classification and Seismic Site Response

Cambridge Bay has a polar climate with freezing temperatures for nine months of the year. As a result, the thickness of the active layer has been reported less than 1 m below which the ground and bedrock remain frozen year-round. The frozen soil is hard. Therefore, the site has been classified as Class 'C' for seismic site response in accordance with the requirements of Section 4.1.8.4 of the National Building Code of Canada, 2015. The on-site soils are also considered non-liquefiable during a seismic event.

13.0 Subsurface Concrete Requirements

Selected chemical tests were performed on some of the soil samples to determine subsurface concrete requirements and corrosion potential of on-site soils. The test results are given on Table 6.

Table 6: Results of Chemical Tests on Soil Samples

Borehole #	Depth (m)	pH	Sulphates (%)	Chlorides (%)	Electrical Resistivity (ohm-cm)
BH2	1.0 – 1.3	8.34	0.1480	0.0449	515
BH2	5.0 – 5.3	8.21	0.1250	0.1210	282
BH2	8.0 – 8.3	7.35	0.2700	0.0406	310
BH3	3.0 – 3.3	8.59	0.0728	0.1890	249
BH3	6.0 – 6.3	8.47	0.1060	0.0356	592
BH4	2.0 – 2.3	8.64	0.0886	0.205	901
BH5	1.0 – 1.3	8.47	0.0628	0.0239	980
BH5	9.0 – 9.3	8.05	0.1600	0.0480	398
BH6	1.0 – 1.3	8.69	0.0260	0.0158	1580
Threshold Value		< 5.0	> 0.1	> 0.04	< 700

A review of the above table indicates that the concentration of water-soluble sulphates in the subsoil at the site varies from 0.026 to 0.27 percent. This concentration of sulphates would have a moderate to severe degree of sulphate attack on sub-surface concrete. The concrete should be designed according to the requirements of CSA A23.1.

The concentration of chlorides in the subsoil also exceeds the threshold value. The subsurface concrete should meet the requirements of CSA A23.1.

The resistivity tests indicate that the soil at the site is corrosive to very corrosive to subsurface steel. It is therefore recommended that a corrosion specialist should be consulted to provide mitigative measures if steel is to be buried below ground at the site, e.g., end bearing piles.

Certificate of Laboratory Analysis is attached as Appendix A.

14.0 Pavement Structure for Roadways and Parking Areas

It has been assumed that roadways and parking lots will be gravel surfaced. The pavement structure for the proposed roads and parking lots may consist of 200 mm of granular base conforming to gradation requirements of type 1 soil of Table 7. It should be underlain by 700 mm of select granular sub-base conforming to gradation requirements of Type 2 of Table 7. All the tundra should be stripped from the roadways and parking lot areas. The exposed surface should be thoroughly compacted. Any soft areas identified should be sub-excavated and replaced with sand and gravel fill compacted to 100 percent SPMDD. The sub-base may then be placed in lift thicknesses compatible with the type of compaction used and each compacted to 100 percent SPMDD. Two hundred millimetres of base should then be placed and compacted to 100 percent SPMDD.

Table 7: Recommended Gradation for Type 1, Type 2 and Select Subgrade Material

Property	ASTM Test Method	Type 2 (Sub-Base)	Type 1 (Base)	Select Subgrade Material General Backfill
Gradation (sieve/% passing)				
150 mm	C136			100
75 mm	C136	100		
37.5 mm	C136			
25.0 mm	C136	50 – 100	100	50 – 100
19.0 mm	C136	-	75 – 100	
9.5 mm	C136	-	50 – 85	
4.75 mm	C136	20 – 55	35 – 65	20 – 100
2.0 mm	C136		25 – 50	
0.425 mm	C136	5 – 35	15 – 30	
0.300 mm	C136	-		5 – 95
0.150 mm	C136	-		2 – 65
0.075 mm	C117	5 – 10	5 – 10	0 – 25
Crushed Content (%) min.	-	60	60	
Plasticity Index (%) max.	D4318	NP	NP	-
Abrasion Loss (%) max.	C131	50	45	-
Flat or Elongated Particles (%) Max.	D4791	15	15	-

15.0 Excavations

It is anticipated that 1 m to 2 m of fill will be placed at the site to raise the grade. Therefore, excavations for the installation of services, etc., would extend to a maximum depth of 1 m to 2 m below the existing ground surface. Since the depth of the active layer thickness is approximately 1 m, the excavations will extend through wet sand to the underlying frozen ground. Excavations at the site below the groundwater table are expected to slough and may eventually stabilize at a slope of 2H:1V to 3H:1V from the bottom of the excavation. Any seepage of surface or subsurface water into the excavations may be collected in perimeter ditches and removed by pumping.

Many geologic materials deteriorate rapidly upon exposure to meteorological elements. Unless otherwise specifically indicated in this report, walls and floors of excavations must be protected from moisture, desiccation, and frost action throughout the course of construction.

Although this investigation has estimated the groundwater levels at the time of the fieldwork, and commented on dewatering and general construction problems, conditions may be present which are difficult to establish from standard boring and excavating techniques and which may affect the type and nature of dewatering procedures used by the contractor in practice. These conditions include local and seasonal fluctuations in the groundwater table, erratic changes in the soil profile, thin layers of soil with large or small permeabilities compared with the soil mass, etc. Only carefully controlled tests using pumped wells and observation wells will yield the quantitative data on groundwater volumes and pressures that are necessary to adequately engineer construction dewatering systems.

16.0 Backfilling Requirements and Suitability of the On-Site Soils for Backfilling Purposes

The on-site soils to be excavated are anticipated to consist of sand and gravel fill or till with cobbles and boulders. The sand and gravel and the till may be used for backfilling service trenches, etc., provided that it is compactable, i.e., its moisture content is within 2 percent of the optimum moisture content. It should be compacted to 100 percent SPMDD.

Fill required to raise the site grades should be placed in 300 mm lifts and each lift compacted to at least 95 percent of the SPMDD. Material required for the construction of the engineered fill pad and the pavement structure should also be compacted to 100 percent of the SPMDD.

17.0 Site Drainage

As indicated previously, satisfactory performance of the foundation system is contingent on eliminating or minimizing surface and subsurface water flow under the structure. It is therefore imperative that drainage ditches are located upgradient of the structure to divert the flow of any sub-surface water under the structure. Drainage ditches filled with gravel should be located along the west, south and east sides of the engineered fill pad to intercept the subsurface water during spring and summer seasons. The drainage ditches should extend at least 1.5 m below the original ground surface to pick up subsurface flow of water. The drainage ditches should be suitably outletted. Alternatively, the ditches should be backfilled with well compacted clay fill to provide a cut-off and prevent subsurface flow of water under the structure. All down spouts from the building should be directed to discharge at least 2 m from the perimeter of the building or preferably be collected and discharged in perimeter drainage ditches.

It is recommended that the finished grade around the buildings should be sloped away from the structure at a grade of at least two percent to prevent ponding of the surface water around the foundations of the structures.

18.0 Climate Conditions, Projected Climate Conditions, and Anticipated Changes in Building Site Conditions

18.1 Existing and Projected Climate Conditions

A literature review of CCCR 2019[2] indicates that Canada's climate has warmed and will warm further in the future. Past and future warming in Canada is about twice the magnitude of global warming. Northern Canada has warmed and will continue to warm at even more than double the global rate. Annual average temperature over northern Canada increased by 2.3^{o} C since 1948. Annual average temperature projections for Canada for the late century (2001-2100) range from an increase of 1.8^{o} C for low emission scenario and 6.3^{o} C for high emission scenario compared to the reference period 1986-2005. Over the past three decades, there has been a decline in the Canadian land and marine areas covered with snow and ice and permafrost temperatures have increased. Only small changes are projected for northern Arctic Canada because winter temperatures will remain sufficiently cold in spite of overall warming.

Because of climate warming, scientists have projected that future mean annual precipitation in Canada will increase by 7 percent under low emission scenario. As temperature rises, there will be a shift from snow to rain in the spring and fall seasons. The changes in climate are expected to lead to a change in events such as wildfires, drought, and floods. This would result in increased quantities of surface and sub-surface water flows.

The global sea level is rising. It rose about 1.8 ± 0.5 mm per year from 1961 to 20003. Various scenarios adapted by James et al (2011)[3] projects for the rise in sea level in Cambridge Bay for the next 90 years to range from -25 cm (local sea level fall) to +45 cm (local sea level rise). They conclude that the most probable amount will be somewhere between -15 and + 30 cm.

18.2 Anticipated Changes in Site Conditions

Smith and Forbes have indicated that potential climate warming may affect the Cambridge Bay landscape in the following manner.

(1) Landscape hazards in the Cambridge Bay area appear to pose a low risk since most of the Hamlet is located on a thin veneer of land and glacial sediment overlying bedrock. In areas where there is a greater thickness of sediment, and ice content, relative degrees of infrastructure risk may increase.

(2) The presence of thermokarst panels, ice wedges and ground subsidence in areas of surface water ponding indicate that varying quantities of excess ice occur in the overburden in the Cambridge Bay area. Excess ice presents a potential hazard to infrastructure stability. In some cases, it can be mitigated through engineering and design measures.

(3) The coarse-grained gravel rich materials used to construct roads and building pads in the Cambridge Bay area are an asset to the region's infrastructure stability as they are less prone to washouts from flooding during spring melts.

(4) Climate warming will also necessitate continual attention to drainage issues and may require re-assessment of the routing, investigation and volume capacity of drainage network with each step of community developments.

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[2] Environment and Climate Change Canada, Government of Canada. Canada's Changing Climate Report, CCCR 2019

[3] James, T.S., Forbes, D.L., Dyke, A.S., and Mate, D.J., 2011. Sea-level Projections for Five Pilot Communities of the Canada-Nunavut Climate Change Partnership; Geological Survey of Canada, Open File 6715, page 23

19.0 Design Review and Foundation Monitoring

It is recommended that a geotechnical review of the foundation drawings and specifications should be undertaken by this office to ensure that recommendations made in the report have been properly interpreted.

It is recommended that installation of the foundations at the site should be monitored by qualified geotechnical personnel. The monitoring would comprise supervision of installation of the piles and/or engineered fill to ensure that the specified degree of compaction is achieved. The footing pads should be reviewed to ensure that they are set on undisturbed engineered fill free of snow, ice, etc., or on undisturbed frozen ground.

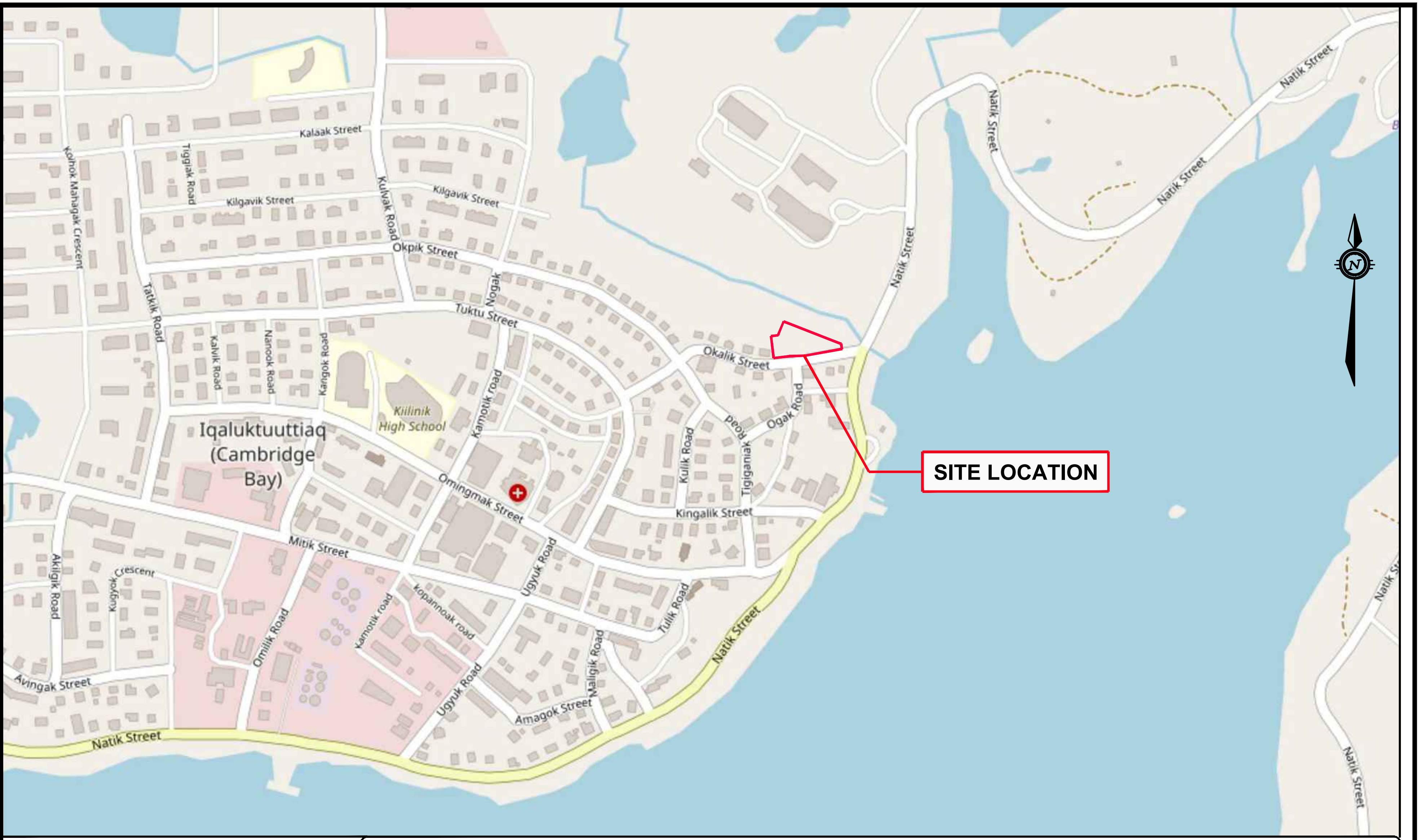
If the building is founded on end bearing piles, it will be important to ensure that all the loose material has been removed from the bottom of pile holes and that the pile will be founded on bedrock.

20.0 General Closure

The comments given in this report are intended only for the guidance of design engineers. The number of boreholes required to determine the localized underground conditions, between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc., would be much greater than has been carried out for design purposes. Contractors bidding on our undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

The information contained in this report in no way reflects on the environmental aspects of the soils. The environmental report for this project should be referred to for any environmental concerns at the site.

FIGURES



0 50m 100m 300m

HORIZONTAL 1:7,500

EXP Services Inc. www.exp.com
t: +1.613.688.1899 | f: +1.613.225.7337
2650 Queensview Drive, Suite 100
Ottawa, ON K2B 8H6, Canada

DATE		
JUNE 2022		
DESIGN	CHECKED	
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DRAWN BY		
AS		

GEOTECHNICAL INVESTIGATION

KITIKMEOT HERITAGE SOCIETY - OKALIK STREET, CAMBRIDGE BAY, NU

SITE LOCATION PLAN

project no.
OTT-22009219-A0

scale
1:7,500

FIG 1

Filename: E:\OTT\OTT-22009219-A0\60 Execution\65 Drawings\22009219-A0_GEO.dwg
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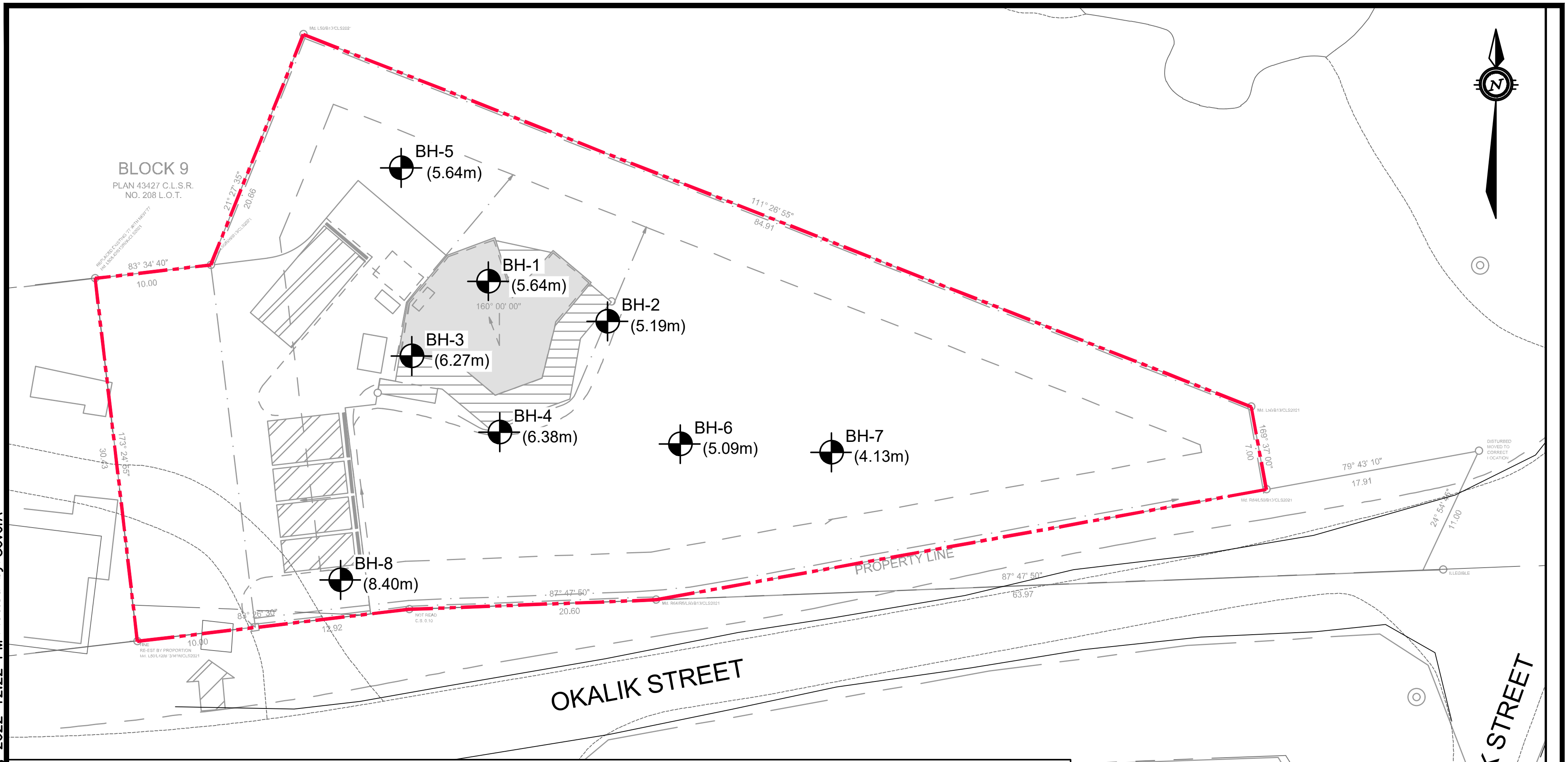

GENERAL NOTES:

1. THE BOUNDARIES, ROCK, AND SOIL TYPES HAVE BEEN ESTABLISHED ONLY AT BOREHOLE LOCATIONS. BETWEEN BOREHOLES THEY ARE ASSUMED AND MAY BE SUBJECT TO CONSIDERABLE ERROR.
2. SOIL SAMPLES AND ROCK CORES WILL BE RETAINED IN STORAGE FOR THREE MONTHS AND THEN DESTROYED UNLESS THE CLIENT ADVISES THAT AN EXTENDED TIME PERIOD IS REQUIRED.
3. ASPHALT QUANTITIES SHOULD NOT BE ESTABLISHED FROM THE INFORMATION PROVIDED AT THE BOREHOLE LOCATIONS.
4. BOREHOLE ELEVATIONS SHOULD NOT BE USED TO DESIGN BUILDING(S) OR FLOOR SLABS OR PARKING LOT(S) GRADES.
5. THIS DRAWING FORMS PART OF THE REPORT PROJECT NUMBER AS REFERENCED AND SHOULD BE USED ONLY IN CONJUNCTION WITH THIS REPORT.

LEGEND

— · · —	SITE BOUNDARIES
⊕ BH-1	BOREHOLE NUMBER AND LOCATION (ORIGINAL GROUND ELEVATION)

0 5m 10m 20m

HORIZONTAL 1:500

EXP Services Inc. www.exp.com
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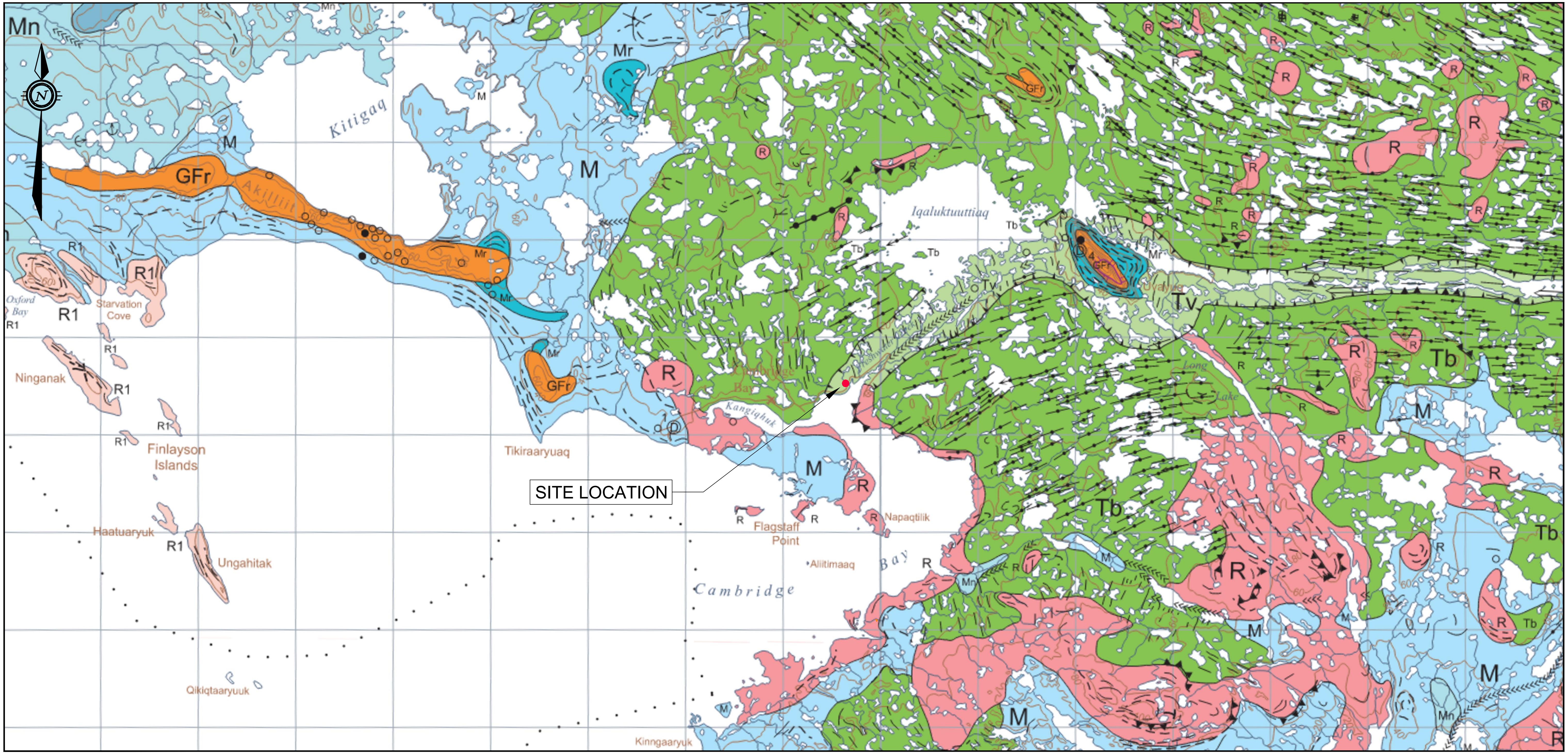
2650 Queensview Drive, Suite 100
Ottawa, ON K2B 8H6, Canada

DATE JUNE 2022		GEOTECHNICAL INVESTIGATION KITIKMEOT HERITAGE SOCIETY - OKALIK STREET, CAMBRIDGE BAY, NU	project no. OTT-22009219-A0
DESIGN IT	CHECKED IT		scale 1:500
DRAWN BY AS		BORHOLE LOCATION PLAN	FIG 2

Filename: E:\OTT\OTT-22009219-A0\60 Execution\65 Drawings\22009219-A0_GEO.dwg
Last Saved: Jun 29, 2022 10:35 AM Last Plotted: Jun 29, 2022 12:22 PM Plotted by: SeverA



LEGEND:

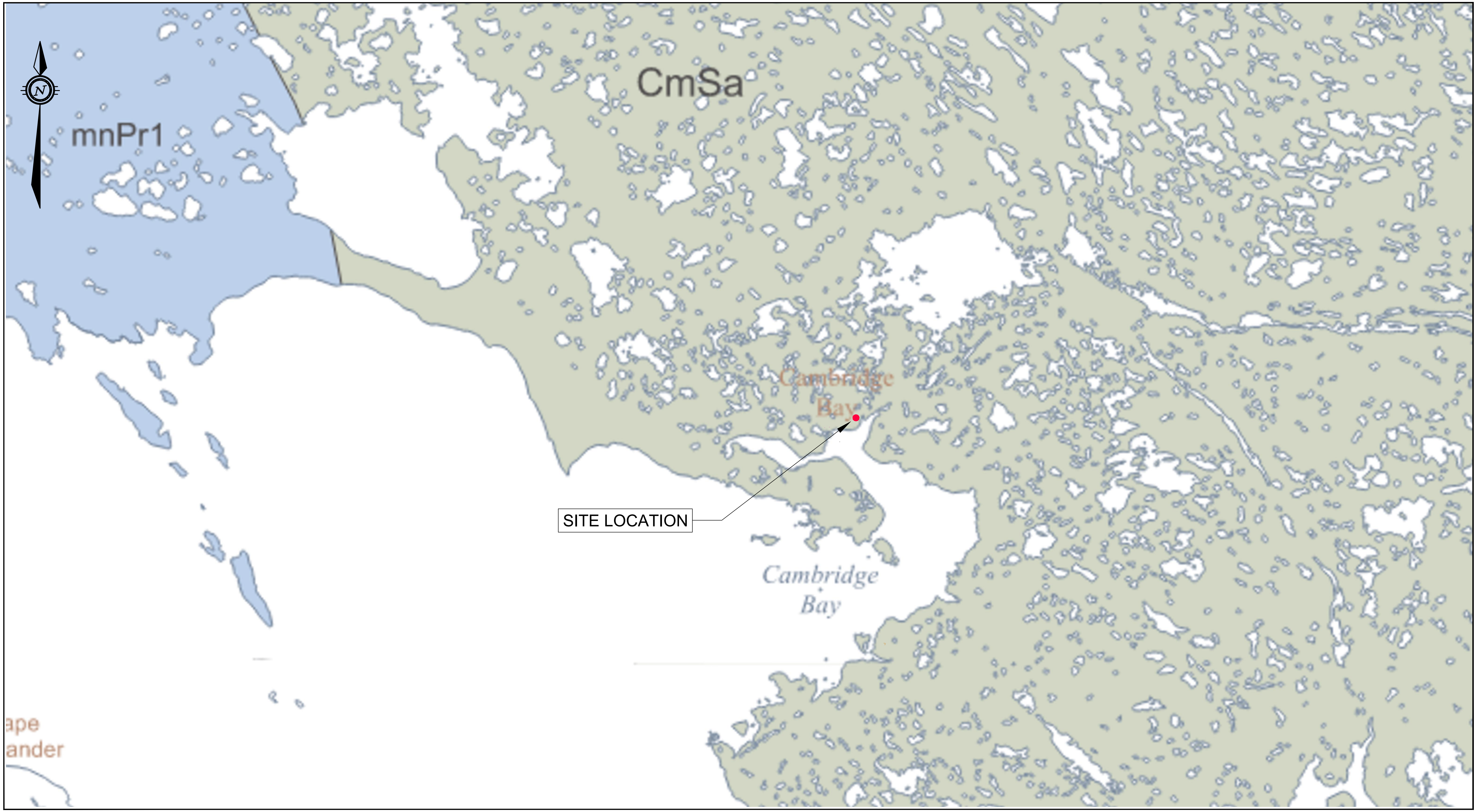
Mr	BEACH SEDIMENTS: GRAVEL AND GRAVELLY SAND; 1 - 4 m THICK; LITTORAL SEDIMENTS OCCUR AS FLIGHTS OF RAISED STRANDLINES; LOCALLY DISTURBED BY ICE PUSH
Mn	NEARSHORE SEDIMENTS: SILT TO SANDY SILT, LOCALLY STONEY; 1-5 m THICK; OVERLIE GLACIOMARINE SEDIMENT; SUBLITTORAL SEDIMENTS OCCUR OFFSHORE FROM DELTAS ADN BEACH TERRCES; FORM A VENEER SCOURED BY DRIFTING ICE.
M	MARINE SEDIMENTS, UNDIFFERENTIATED: COMPLEX OF SILT AND SANDY SILT ON BEDROCK, DIAMICTON, OR LOCALLY, GRAVEL; DISCONTINUOUS VENEER 1 - 3 m THICK
Tv	TILL VENEER: THIN, PATCHY DIAMICTON, MAY INCLUDE STRATIFIED SEDIMENTS; 1 m THICK OR LESS; DEPOSITED SUBGLACIALLY; GROUND MORAINE COMMONLY BEDROCK CONTROLLED; MAY REMAIN IN MELTWATER SCOUR AREAS DEFINED BY TUNNEL CHANNELS
Tb	TILL BLANKET: MASSIVE DIAMICTON; IN PLACES INTERBEDDED WITH (OR UNDERLAIN BY) SAND AND GRAVEL; 1 - 15 m THICK; MAINLY DEPOSITED SUBGLACIALLY; GROUND MORAINE; FLUTINGS PRESENT LOCALLY WHERE DRIFT IS THIN (1 - 2 m); DRUMLINS AND DRUMLINOIDS OCCUR WHERE DRIFT IS THICK (10 - 15 m)
GFr	ESKER SEDIMENTS: GRAVEL, SAND, MINOR SILT AND CLAY; 10 - 20 m THICK; GLACIOFLUVIAL SEDIMENTS OCCUR AS SHARP-CRESTED AND FLAT-TOPPED ESKERS; DEPOSITED SUBGLACIALLY OR WITH ICE CONTROL
R	UNDIFFERENTIATED BEDROCK: SANDSTONE, SILTSTONE, SHALE, AND CARBONATE; PRECAMBRIAN OR CAMBRIAN

0 2km 4km 8km
HORIZONTAL 1:200,000

exp Services Inc.
100-2650 Queensview Drive
Ottawa, ON K2B 8H6
www.exp.com

DESIGN I.T.	KITIKMEOT HERITAGE SOCIETY OKALIK STREET, CAMBRIDGE BAY, NU	SCALE 1:200,000
DRAWN G.C./A.S.		SKETCH NO
DATE JUNE 2022	SURFICIAL GEOLOGY	FIG 3
FILE NO OTT-22009219-A0		

Filename: E:\OTT\OTT-22009219-A0\60 Execution\65 Drawings\22009219-A0 FIG 3 Surficial.dwg
Last Saved: Jun 29, 2022 11:55 AM Last Plotted: Jun 29, 2022 12:24 PM Plotted by: SeverA



LEGEND:

CmSa	ARCTIC PLATFORM: DOLOSTONE, DOLOMITIC LIMESTONE, LIMESTONE; MINOR SANDSTONE, SHALE, INTRACLAST CONGLOMERATE, BRECCIA; NEARSHORE AND INTERTIDAL TO SUPRATIDAL
mnPr1	RAE: DOLOSTONE, DOLOSILTITE, QUARTZ ARENITE, MINOR LITHIC ARENITE, INTRACLAST CONGLOMERATE; CLASTIC SHELF, OFFSHORE PLATFORM AND FLUVIAL-DELTAIC

0 2km 4km 8km

HORIZONTAL 1:200,000

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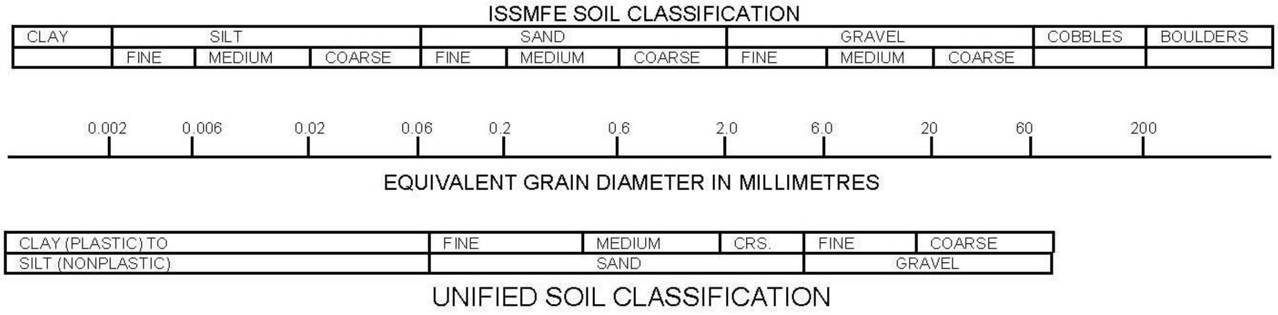
DESIGN I.T.	KITIKMEOT HERITAGE SOCIETY OKALIK STREET, CAMBRIDGE BAY, NU	SCALE 1:200,000
DRAWN G.C./A.S.		SKETCH NO
DATE JUNE 2022	BEDROCK GEOLOGY	FIG 4
FILE NO OTT–22009219–A0		

Filename: E:\OTT\OTT–22009219–A0\60 Execution\65 Drawings\22009219–A0 FIG 4 Bedrock.dwg
Last Saved: Jun 29, 2022 12:18 PM Last Plotted: Jun 29, 2022 12:29 PM Plotted by: SeverA

Notes On Sample Descriptions

1. All sample descriptions included in this report follow the Canadian Foundations Engineering Manual soil classification system. This system follows the standard proposed by the International Societv for Soil Mechanics and Foundation Engineering. Laboratory grain size analyses provided by **exp** Services Inc. also follow the same system. Different classification systems may be used by others; one such system is the Unified Soil Classification. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually. Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems.



2. Fill: Where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc., none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

3. Till: The term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Log of Borehole BH-01

Project No: OTT-22009219-A0

Figure No. 5

Project: Proposed Cultural Centre. Proposed Kitikmeot Heritage Society. New Cultural Campus.

Page. 1 of 1

Location: Lot 50, Block 13, Cambridge Bay, Nunavut

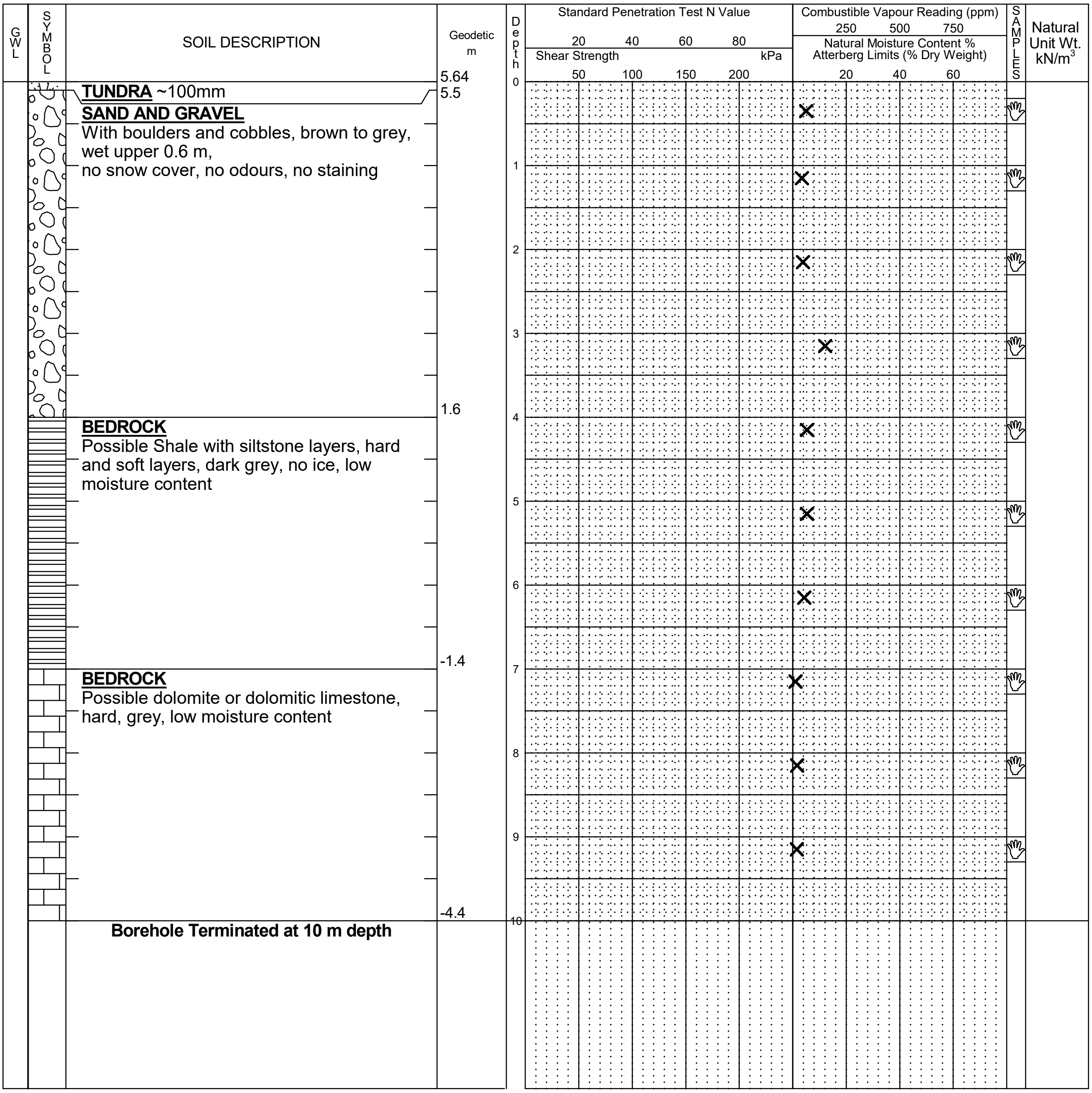
Date Drilled: 'May 15, 2022

Drill Type: Air Track

Datum: Geodetic

Logged by: S.B.   Checked by: S.K.A

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◫	Natural Moisture Content	✕
SPT (N) Value	○	Atterberg Limits	├─○
Dynamic Cone Test	───	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲



TUNDRA ~100mm

SAND AND GRAVEL
With boulders and cobbles, brown to grey, wet upper 0.6 m,
no snow cover, no odours, no staining

BEDROCK
Possible Shale with siltstone layers, hard and soft layers, dark grey, no ice, low moisture content

BEDROCK
Possible dolomite or dolomitic limestone, hard, grey, low moisture content

Borehole Terminated at 10 m depth

NOTES:

1. Borehole data requires interpretation by EXP before use by others
2. Borehole backfilled upon completion
3. Field work supervised by an **exp** representative.
4. See Notes on Sample Descriptions
5. Log to be read with EXP Report OTT-22009219-A0

WATER LEVEL RECORDS

Date	Water Level (m)	Hole Open To (m)
Upon Completion	dry	10.0

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %

Log of Borehole **BH-02**

Project No: OTT-22009219-A0

Figure No. 6

Project: Proposed Cultural Centre. Proposed Kitikmeot Heritage Society. New Cultural Campus.

Page. 1 of 1

Location: Lot 50, Block 13, Cambridge Bay, Nunavut

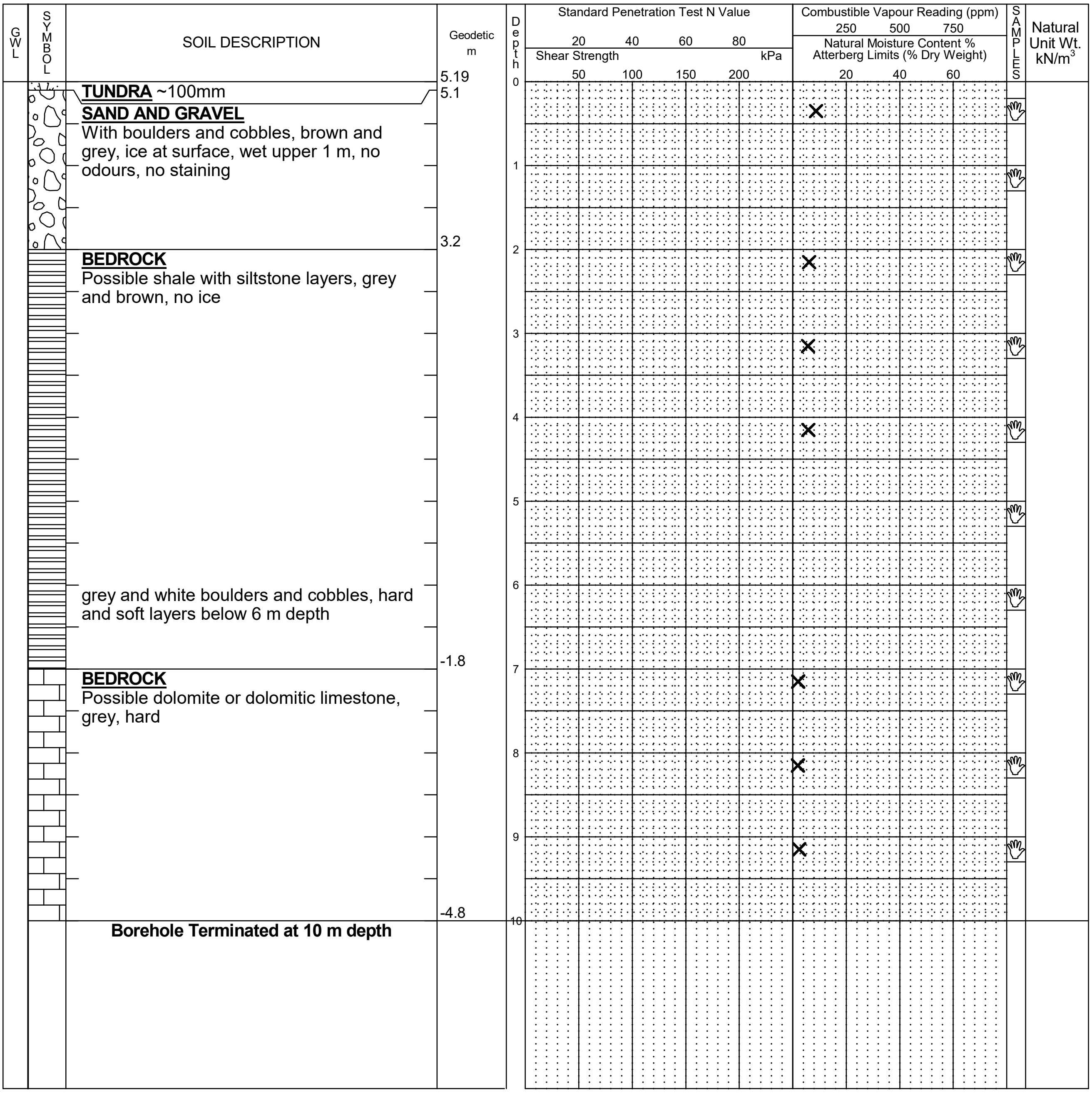
Date Drilled: 'May 15, 2022

Drill Type: Air Track

Datum: Geodetic

Logged by: S.B. Checked by: S.K.A

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◫	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	├─○
Dynamic Cone Test	───	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲



Geodetic m	Soil Description
5.19	
5.1	**TUNDRA** ~100mm
	SAND AND GRAVEL With boulders and cobbles, brown and grey, ice at surface, wet upper 1 m, no odours, no staining
3.2	**BEDROCK** Possible shale with siltstone layers, grey and brown, no ice grey and white boulders and cobbles, hard and soft layers below 6 m depth
-1.8	**BEDROCK** Possible dolomite or dolomitic limestone, grey, hard
-4.8	**Borehole Terminated at 10 m depth**

NOTES:

1. Borehole data requires interpretation by EXP before use by others
2. Multi-bead thermistor string installed to 10.0 m depth upon completion
3. Field work supervised by an **exp** representative.
4. See Notes on Sample Descriptions
5. Log to be read with EXP Report OTT-22009219-A0

WATER LEVEL RECORDS

Date	Water Level (m)	Hole Open To (m)
Upon Completion	dry	10.0

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %

Log of Borehole BH-03

Project No: OTT-22009219-A0

Figure No. 7

Project: Proposed Cultural Centre. Proposed Kitikmeot Heritage Society. New Cultural Campus.

Page. 1 of 1

Location: Lot 50, Block 13, Cambridge Bay, Nunavut

Date Drilled: 'May 15, 2022

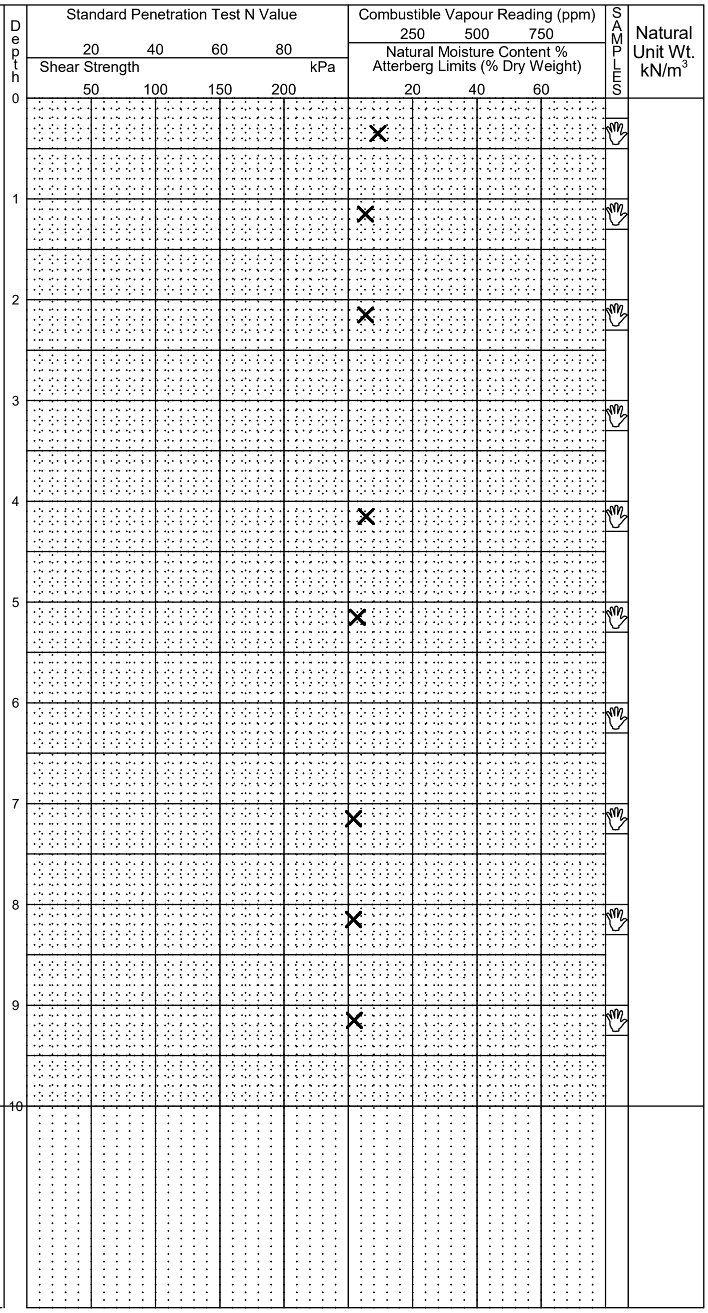
Drill Type: Air Track

Datum: Geodetic

Logged by: S.B. Checked by: S.K.A

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◧	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	├─○
Dynamic Cone Test	—	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲

GWL	SOIL DESCRIPTION	Geodetic m
		6.27
	TUNDRA ~100mm	6.2
	SAND AND GRAVEL With boulders and cobbles, brown to grey, wet upper 0.6 m, no snow cover, no odours, no staining	
		4.3
	TILL Heterogeneous mixture of clay, silt, sand, and gravel, with cobbles and boulders, brown to grey, moist	
		2.3
	BEDROCK Possible shale with sandstone layers, grey to white, hard and soft layers, no ice	
		0.3
	BEDROCK Possible dolomite or dolomitic limestone with shale layers, grey	
		-3.7
	Borehole Terminated at 10 m depth	



NOTES:

1. Borehole data requires interpretation by EXP before use by others
2. Borehole backfilled upon completion
3. Field work supervised by an **exp** representative.
4. See Notes on Sample Descriptions
5. Log to be read with EXP Report OTT-22009219-A0

WATER LEVEL RECORDS

Date	Water Level (m)	Hole Open To (m)
Upon Completion	dry	10.0

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %

Log of Borehole BH-04

Project No: OTT-22009219-A0

Figure No. 8

Page. 1 of 1

Project: Proposed Cultural Centre. Proposed Kitikmeot Heritage Society. New Cultural Campus.

Location: Lot 50, Block 13, Cambridge Bay, Nunavut

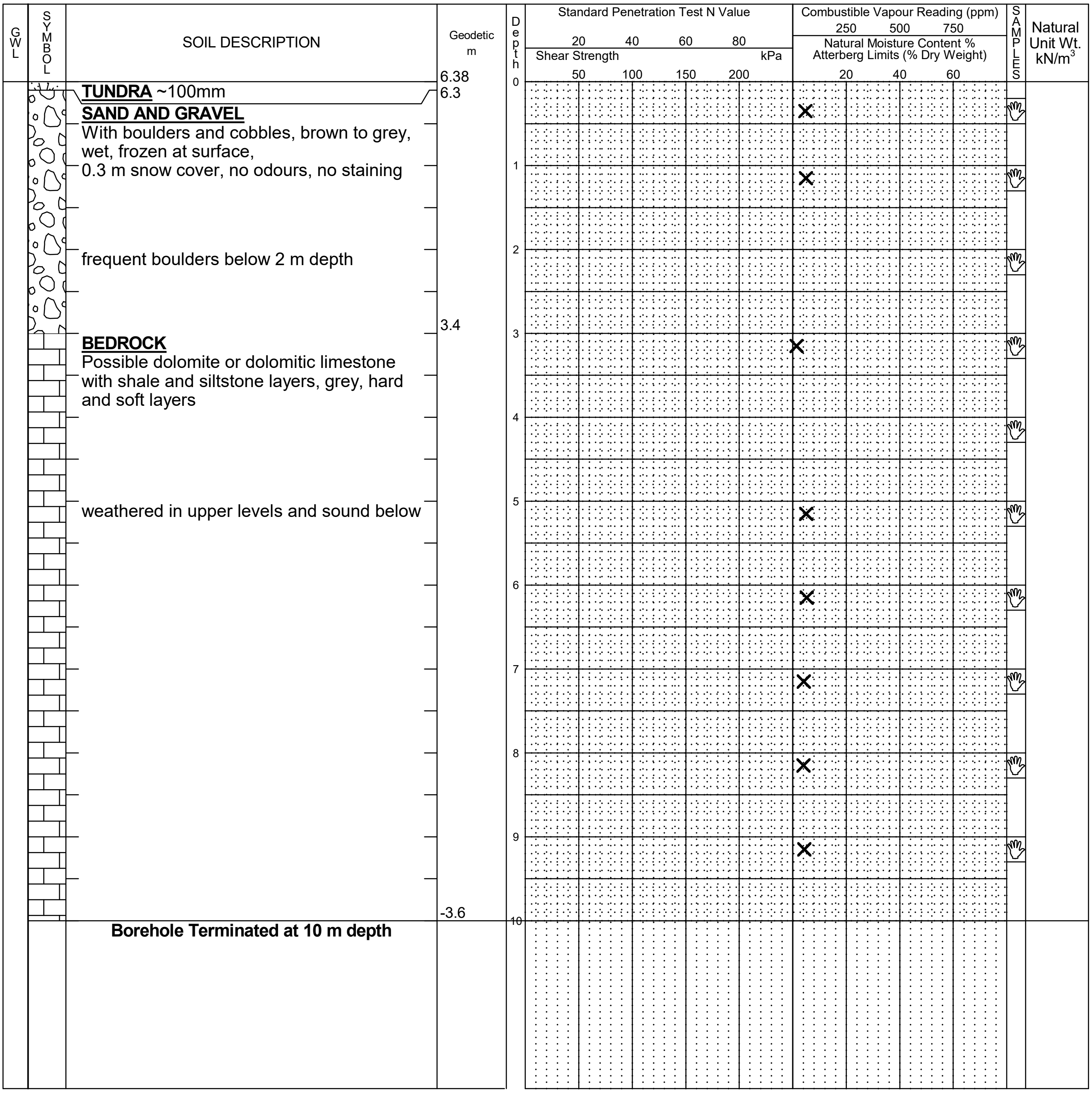
Date Drilled: 'May 15, 2022

Drill Type: Air Track

Datum: Geodetic

Logged by: S.B. Checked by: S.K.A

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◧	Natural Moisture Content	✕
SPT (N) Value	○	Atterberg Limits	⊢○
Dynamic Cone Test	—	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲



Geodetic m	SOIL DESCRIPTION
6.38 6.3	**TUNDRA** ~100mm
	SAND AND GRAVEL With boulders and cobbles, brown to grey, wet, frozen at surface, 0.3 m snow cover, no odours, no staining
	frequent boulders below 2 m depth
3.4	**BEDROCK** Possible dolomite or dolomitic limestone with shale and siltstone layers, grey, hard and soft layers
	weathered in upper levels and sound below
-3.6	**Borehole Terminated at 10 m depth**

NOTES:

1. Borehole data requires interpretation by EXP before use by others
2. Borehole backfilled upon completion
3. Field work supervised by an **exp** representative.
4. See Notes on Sample Descriptions
5. Log to be read with EXP Report OTT-22009219-A0

WATER LEVEL RECORDS

Date	Water Level (m)	Hole Open To (m)
Upon Completion	dry	10.0

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %

Log of Borehole BH-05

Project No: OTT-22009219-A0

Project: Proposed Cultural Centre. Proposed Kitikmeot Heritage Society. New Cultural Campus.

Location: Lot 50, Block 13, Cambridge Bay, Nunavut

Figure No. 9

Page. 1 of 1

Date Drilled: 'May 15, 2022

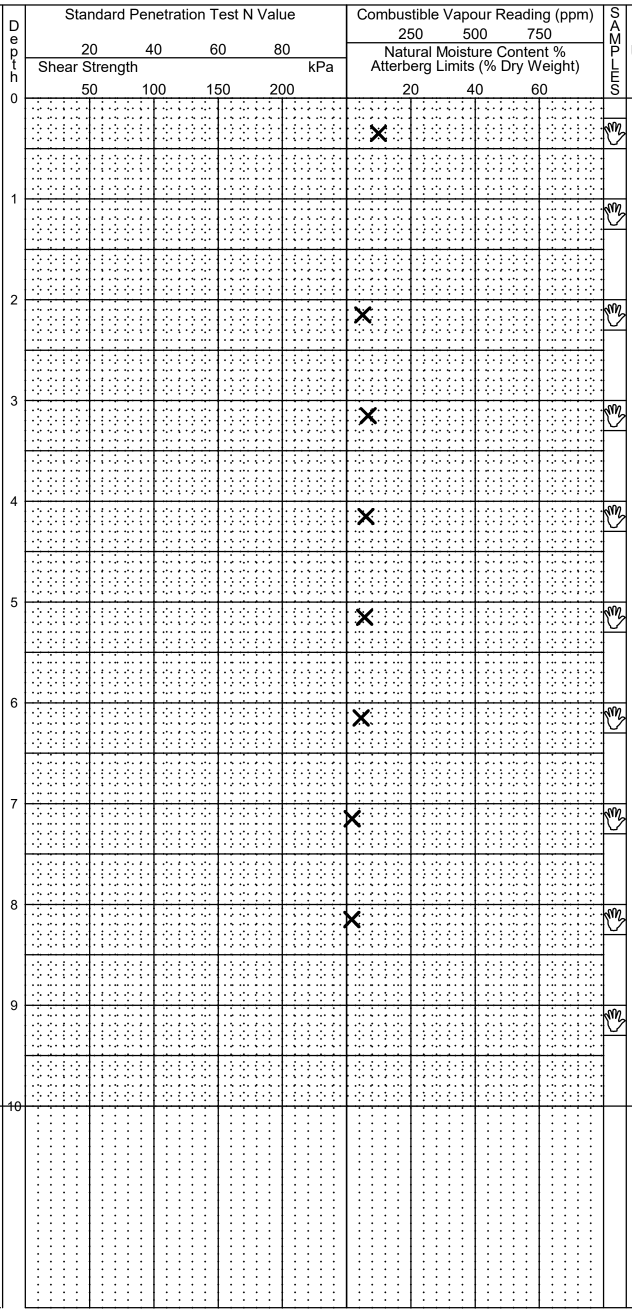
Drill Type: Air Track

Datum: Geodetic

Logged by: S.B. Checked by: S.K.A

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	▥	Natural Moisture Content	✕
SPT (N) Value	○	Atterberg Limits	├─○
Dynamic Cone Test	───	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■	Shear Strength by Penetrometer Test	▲
Shear Strength by Vane Test	+ S		

GWL	SYMBOL	SOIL DESCRIPTION	Geodetic m	Depth
			5.64	0
		TUNDRA ~100mm	5.5	
		TILL Heterogeneous mixture of clay, silt, sand, and gravel, with cobbles and boulders, brown to grey, moist		
		BEDROCK Possible dolomite or dolomitic limestone with shale layers, weather in upper levels, sound below 7 m depth	1.6	
			-4.4	10
		Borehole Terminated at 10 m depth		



Natural Unit Wt. kN/m³

NOTES:
1. Borehole data requires interpretation by EXP before use by others
2. 19 mm thermistor pipe installed to 10.0 m depth upon completion
3. Field work supervised by an **exp** representative.
4. See Notes on Sample Descriptions
5. Log to be read with EXP Report OTT-22009219-A0

WATER LEVEL RECORDS

Date	Water Level (m)	Hole Open To (m)
Upon Completion	dry	10.0

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %

Log of Borehole BH-06

Project No: OTT-22009219-A0

Figure No. 10

Project: Proposed Cultural Centre. Proposed Kitikmeot Heritage Society. New Cultural Campus.

Page. 1 of 1

Location: Lot 50, Block 13, Cambridge Bay, Nunavut

Date Drilled: 'May 15, 2022

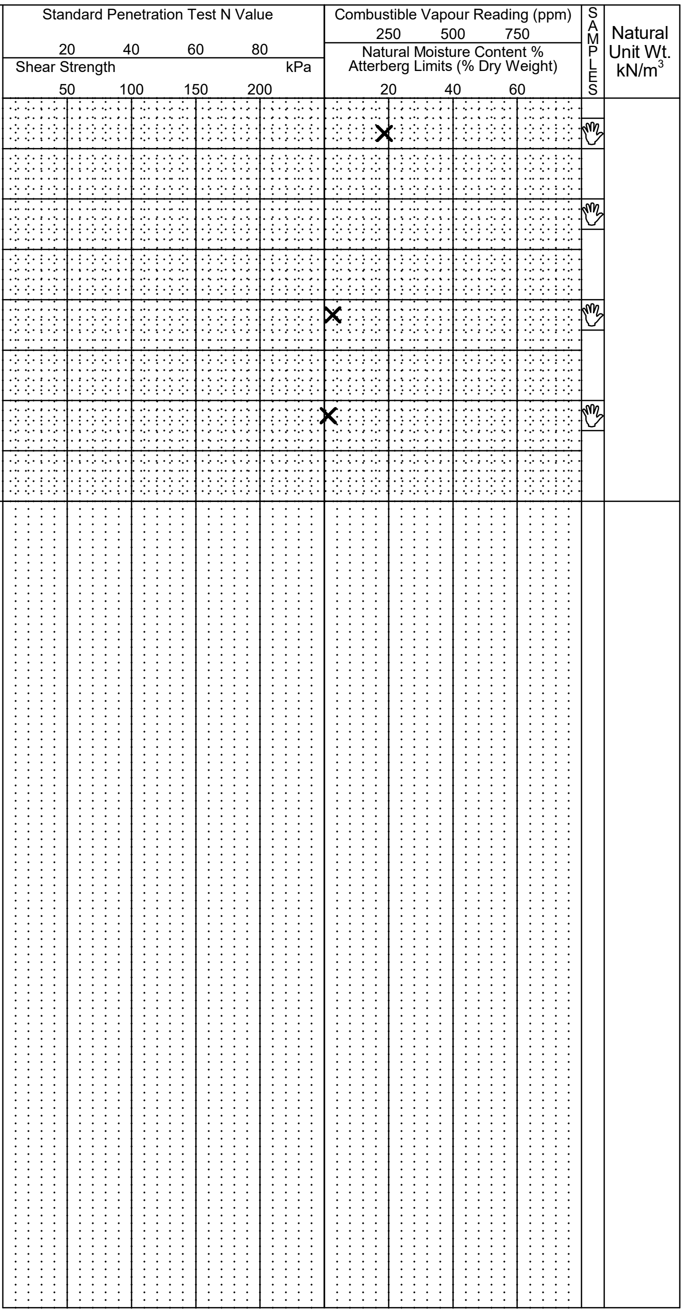
Drill Type: Air Track

Datum: Geodetic

Logged by: S.B. Checked by: S.K.A

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◧	Natural Moisture Content	✕
SPT (N) Value	○	Atterberg Limits	├─○
Dynamic Cone Test	──	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲

GWL	SYMBOL	SOIL DESCRIPTION	Geodetic m	Depth
			5.09	0
		TUNDRA ~100mm	5.0	
		TILL Sand and gravel, some clay and silt, with boulders and cobbles, dark to light brown, wet at surface, 0.5 m snow cover, no odours, no staining		1 2
		BEDROCK Possible dolomite or dolomitic limestone, grey	2.6	3
			1.1	4
		Borehole Terminated at 4 m depth		



NOTES:

1. Borehole data requires interpretation by EXP before use by others
2. Borehole backfilled upon completion
3. Field work supervised by an **exp** representative.
4. See Notes on Sample Descriptions
5. Log to be read with EXP Report OTT-22009219-A0

WATER LEVEL RECORDS

Date	Water Level (m)	Hole Open To (m)
Upon Completion	dry	4.0

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %

Log of Borehole BH-07

Project No: OTT-22009219-A0

Project: Proposed Cultural Centre. Proposed Kitikmeot Heritage Society. New Cultural Campus.

Location: Lot 50, Block 13, Cambridge Bay, Nunavut

Figure No. 11

Page. 1 of 1

Date Drilled: 'May 15, 2022

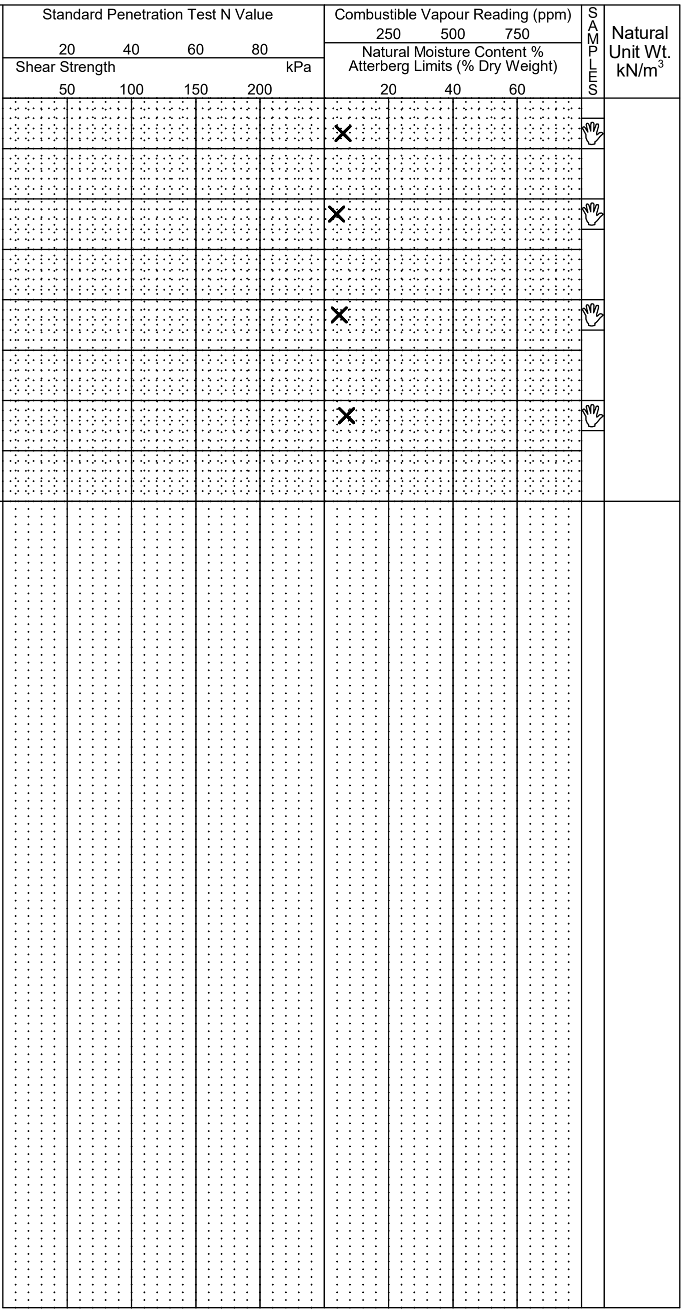
Drill Type: Air Track

Datum: Geodetic

Logged by: S.B. Checked by: S.K.A

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◨	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	⊢○
Dynamic Cone Test	—	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲

GWL	SYMBOL	SOIL DESCRIPTION	Geodetic m	Depth
			4.13	0
		TUNDRA ~100mm	4.0	
		SAND AND GRAVEL With boulders and cobbles, dark to light brown, ice at surface, no odours, no staining		1
		BEDROCK Possible dolomite or dolomitic limestone, weathered to sound with depth, grey, damp	2.1	2
				3
		Borehole Terminated at 4 m depth	0.1	4



NOTES:

1. Borehole data requires interpretation by EXP before use by others
2. Borehole backfilled upon completion
3. Field work supervised by an **exp** representative.
4. See Notes on Sample Descriptions
5. Log to be read with EXP Report OTT-22009219-A0

WATER LEVEL RECORDS

Date	Water Level (m)	Hole Open To (m)
Upon Completion	dry	4.0

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %

Log of Borehole BH-08

Project No: OTT-22009219-A0

Figure No. 12

Project: Proposed Cultural Centre. Proposed Kitikmeot Heritage Society. New Cultural Campus.

Page. 1 of 1

Location: Lot 50, Block 13, Cambridge Bay, Nunavut

Date Drilled: 'May 15, 2022

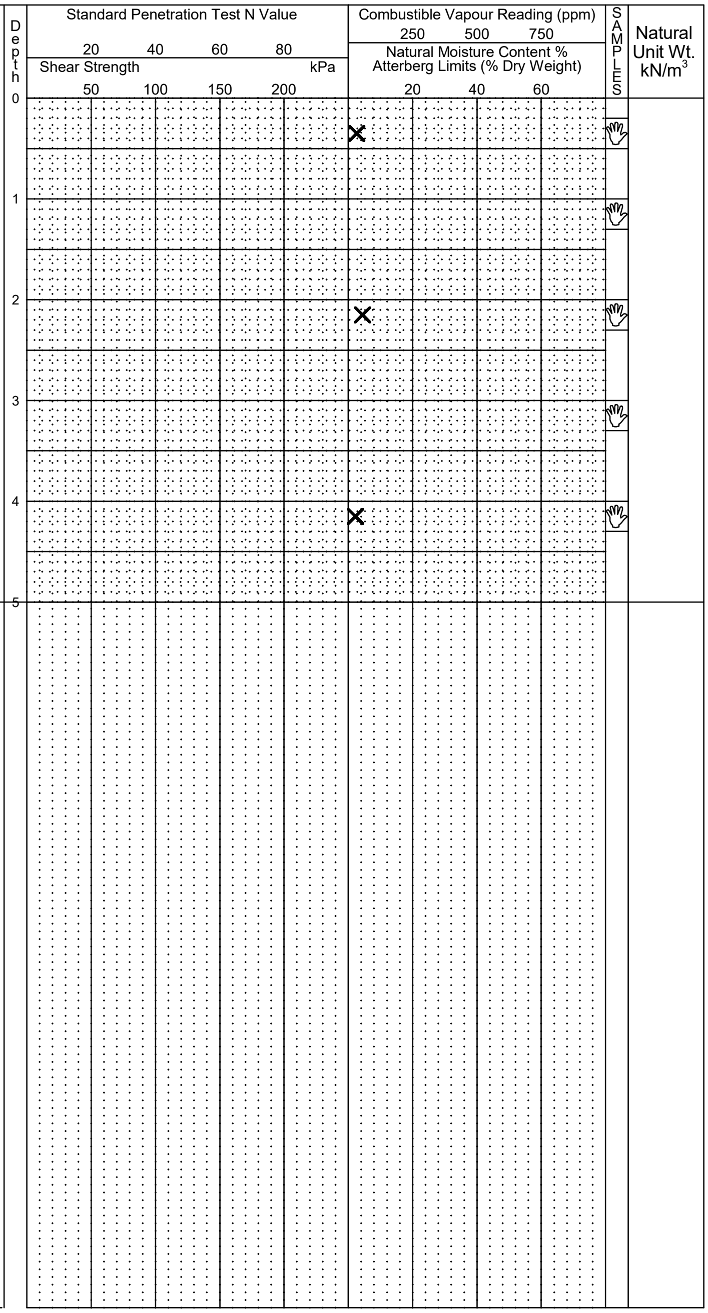
Drill Type: Air Track

Datum: Geodetic

Logged by: S.B. Checked by: S.K.A

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◫	Natural Moisture Content	✕
SPT (N) Value	○	Atterberg Limits	├─○
Dynamic Cone Test	──	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■	Shear Strength by Penetrometer Test	▲
Shear Strength by Vane Test	+ S		

GWL	SYMBOL	SOIL DESCRIPTION	Geodetic m
	☒	**FILL** Crushed sand and gravel shoulder of roadway, brown, frozen, 0.5 m snow removed for drill access	8.4
	○	**SAND AND GRAVEL** With boulders and cobbles, brown to grey, damp, no odours, no staining	6.9
	▦	**BEDROCK** Possible dolomite or dolomitic limestone, layered, soft to hard drilling, brown to grey, damp	4.9
		Borehole Terminated at 5 m depth	3.4



NOTES:

1. Borehole data requires interpretation by EXP before use by others
2. Borehole backfilled upon completion
3. Field work supervised by an **exp** representative.
4. See Notes on Sample Descriptions
5. Log to be read with EXP Report OTT-22009219-A0

WATER LEVEL RECORDS

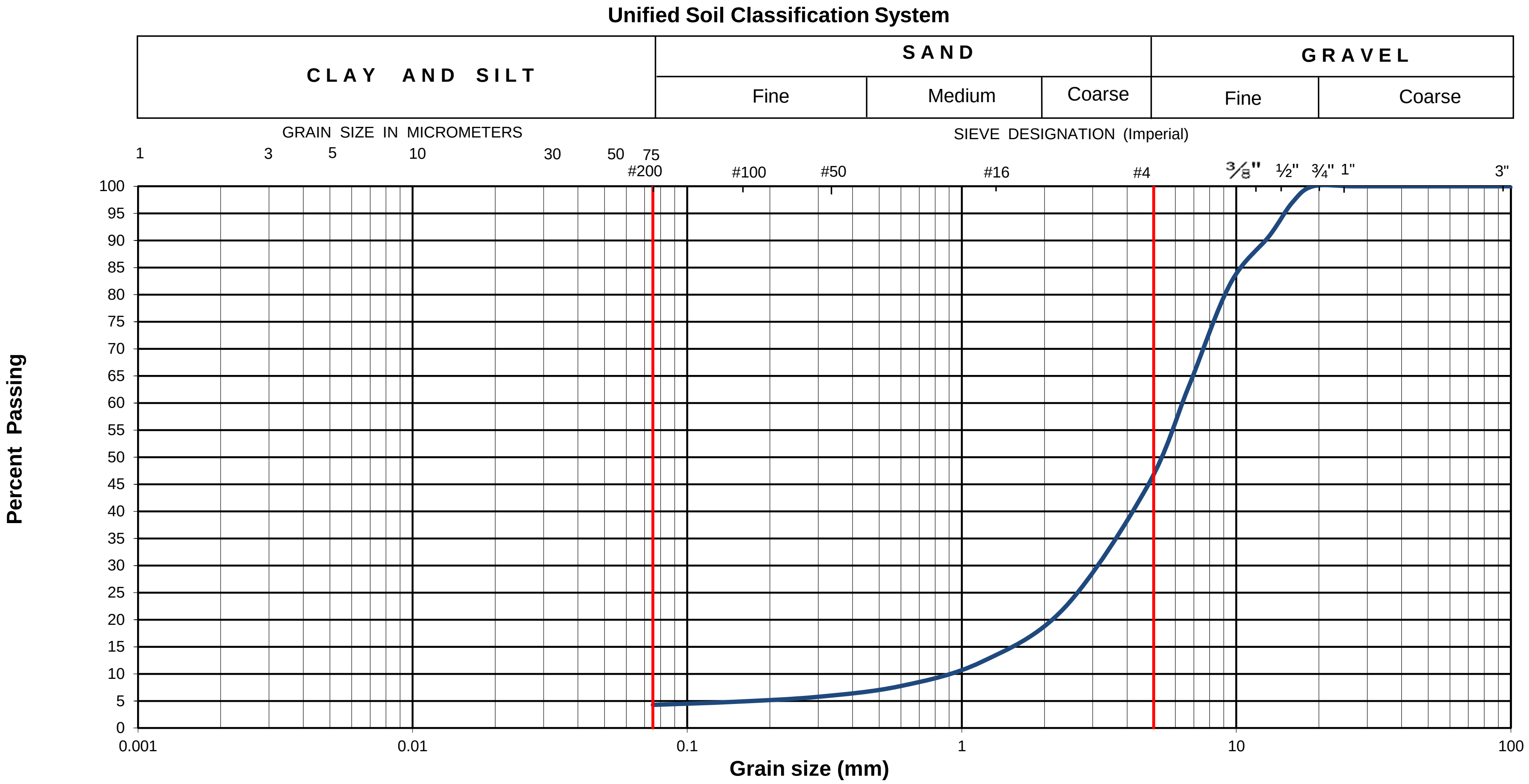
Date	Water Level (m)	Hole Open To (m)
Upon Completion	dry	5.0

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %

EXP Services Inc.
100-2650 Queensview Drive
Ottawa, ON   K2B 8H6

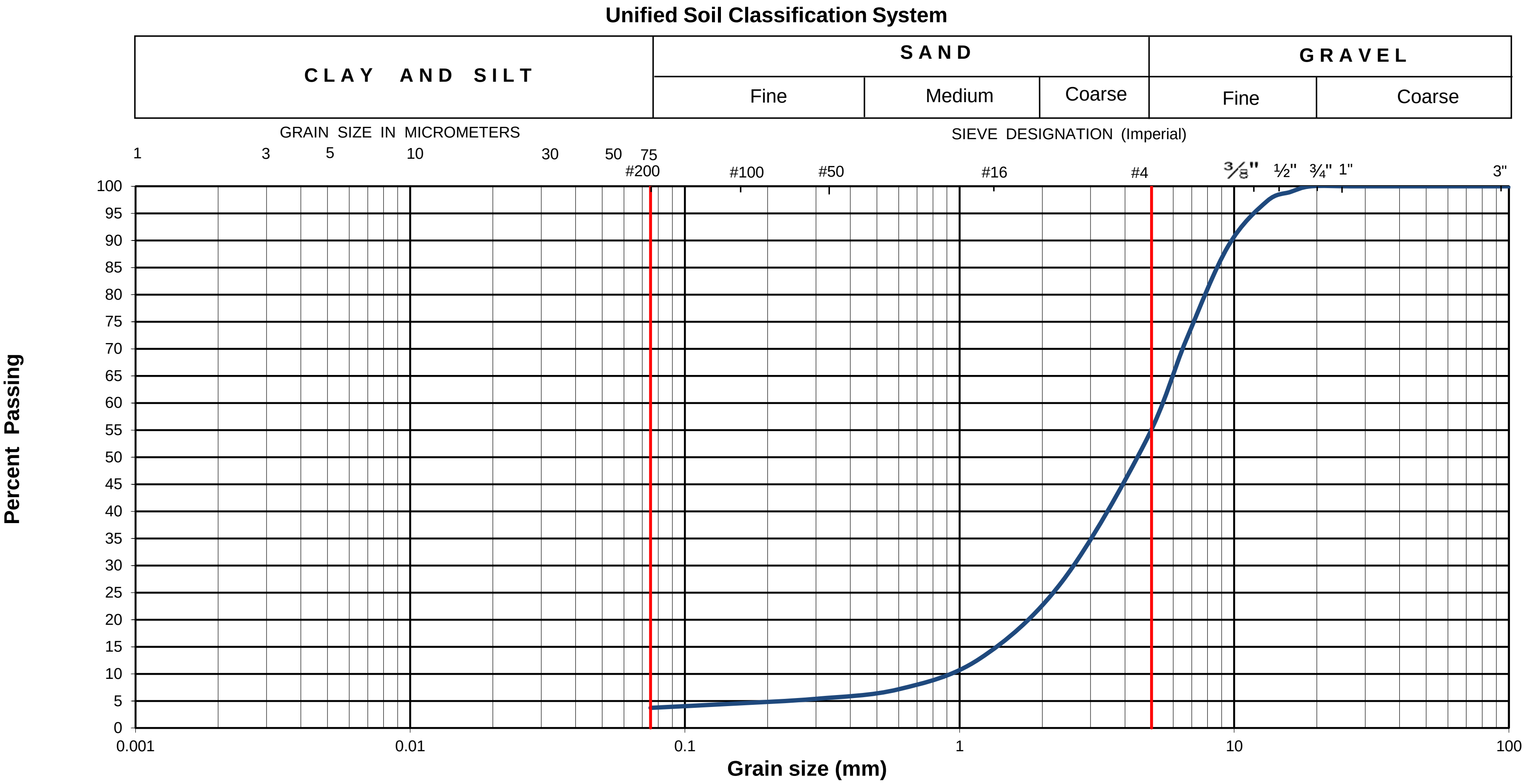
Grain-Size Distribution Curve
Method of Test For Sieve Analysis of Aggregate
ASTM C-136



EXP Project No.:	**OTT-22009219-A0**	**Project Name :**	**Geotechnical Investigation - Proposed New Cultural Campus**						
Client :	**himikkut Ilihautiniq / Kitikmeot Heritage S**	**Project Location :**	**Lot 50, Block 13, Cambridge Bay, NU**						
Date Sampled :	**May 16, 2022**	**Borehole No:**	**BH 8-2**	**Sample:**	**0**			**Depth (m) :**	**1.0-1.3**
Sample Composition :		**Gravel (%)**	**55**	**Sand (%)**	**41**	**Silt & Clay (%)**	**4**	**Figure :**	**13**
Sample Description :	**Well Graded Gravel with Sand (GW)**								

EXP Services Inc.
100-2650 Queensview Drive
Ottawa, ON K2B 8H6

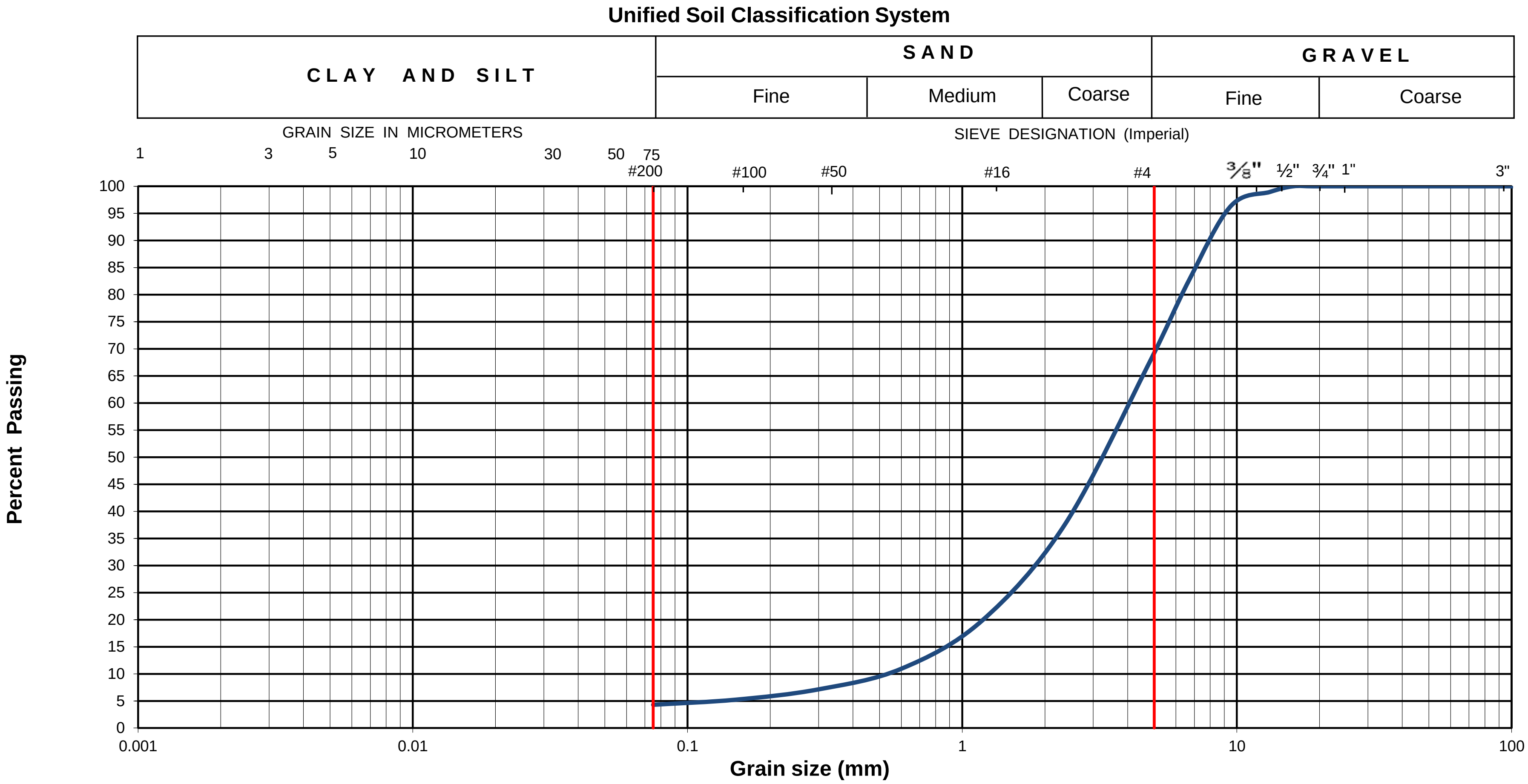
Grain-Size Distribution Curve
Method of Test For Sieve Analysis of Aggregate
ASTM C-136



EXP Project No.:	**OTT-22009219-A0**	**Project Name :**	**Geotechnical Investigation - Proposed New Cultural Campus**						
Client :	**himikkut Ilihautiniq / Kitikmeot Heritage S**	**Project Location :**	**Lot 50, Block 13, Cambridge Bay, NU**						
Date Sampled :	**May 16, 2022**	**Borehole No:**	**BH 2-2**	**Sample:**	**0**			**Depth (m) :**	**1.0-1.3**
Sample Composition :		**Gravel (%)**	**47**	**Sand (%)**	**49**	**Silt & Clay (%)**	**4**	**Figure :**	**14**
Sample Description :	**Well Graded Sand with Gravel (SW)**								

EXP Services Inc.
100-2650 Queensview Drive
Ottawa, ON   K2B 8H6

Grain-Size Distribution Curve
Method of Test For Sieve Analysis of Aggregate
ASTM C-136



EXP Project No.:	**OTT-22009219-A0**	**Project Name :**	**Geotechnical Investigation - Proposed New Cultural Campus**						
Client :	**himikkut Ilihautiniq / Kitikmeot Heritage S**	**Project Location :**	**Lot 50, Block 13, Cambridge Bay, NU**						
Date Sampled :	**May 16, 2022**	**Borehole No:**	**BH 4-3**	**Sample:**	**0**	**Depth (m) :**	**2.0-2.3**		
Sample Composition :		**Gravel (%)**	**33**	**Sand (%)**	**63**	**Silt & Clay (%)**	**4**	**Figure :**	**15**
Sample Description :	**Well Graded Sand with Gravel (SW)**								

Grain-Size Distribution Curve
Method of Test For Sieve Analysis of Aggregate
ASTM C-136

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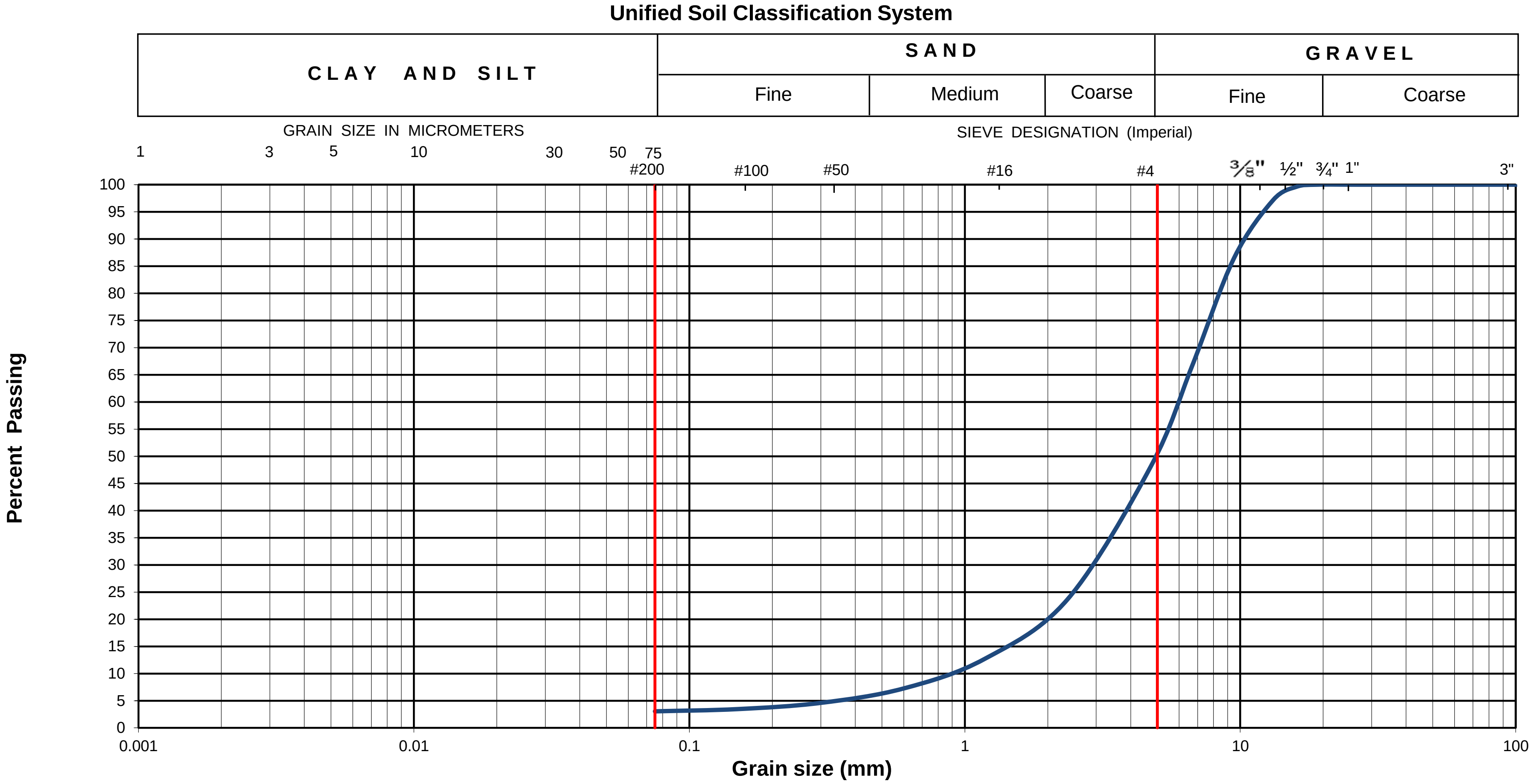
Ottawa, ON K2B 8H6



EXP Project No.:	OTT-22009219-A0	**Project Name :**	Geotechnical Investigation - Proposed New Cultural Campus						
Client :	himikkut Ilihautiniq / Kitikmeot Heritage S	**Project Location :**	Lot 50, Block 13, Cambridge Bay, NU						
Date Sampled :	May 16, 2022	**Borehole No:**	BH 8-4	**Sample:**	0			**Depth (m) :**	3.0-3.3
Sample Composition :		**Gravel (%)**	52	**Sand (%)**	45	**Silt & Clay (%)**	3	**Figure :**	16
Sample Description :	Well Graded Gravel with Sand (GW)								

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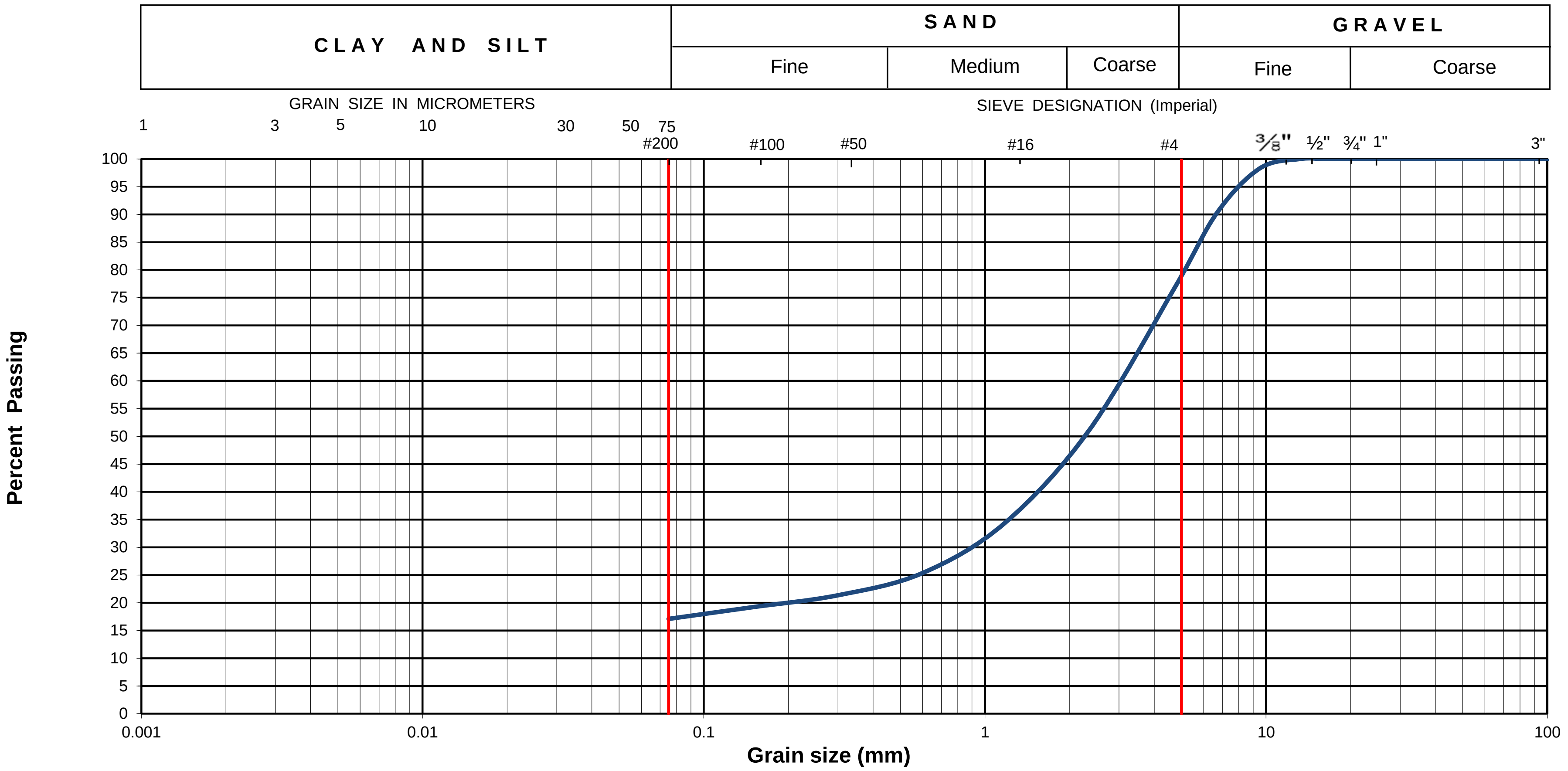
Grain-Size Distribution Curve
Method of Test For Sieve Analysis of Aggregate
ASTM C-136

Unified Soil Classification System



EXP Project No.:	**OTT-22009219-A0**	**Project Name :**	**Geotechnical Investigation - Proposed New Cultural Campus**						
Client :	**himikkut Ilihautiniq / Kitikmeot Heritage S**	**Project Location :**	**Lot 50, Block 13, Cambridge Bay, NU**						
Date Sampled :	**May 16, 2022**	**Borehole No:**	**BH 3-4**	**Sample:**	**0**			**Depth (m) :**	**3.0-3.3**
Sample Composition :		**Gravel (%)**	**23**	**Sand (%)**	**60**	**Silt & Clay (%)**	**17**	**Figure :**	**17**
Sample Description :	**Silty Sand with Gravel (SM)**								

Grain-Size Distribution Curve
Method of Test For Particle Size Analysis of Soil
ASTM C-136/ASTM D422

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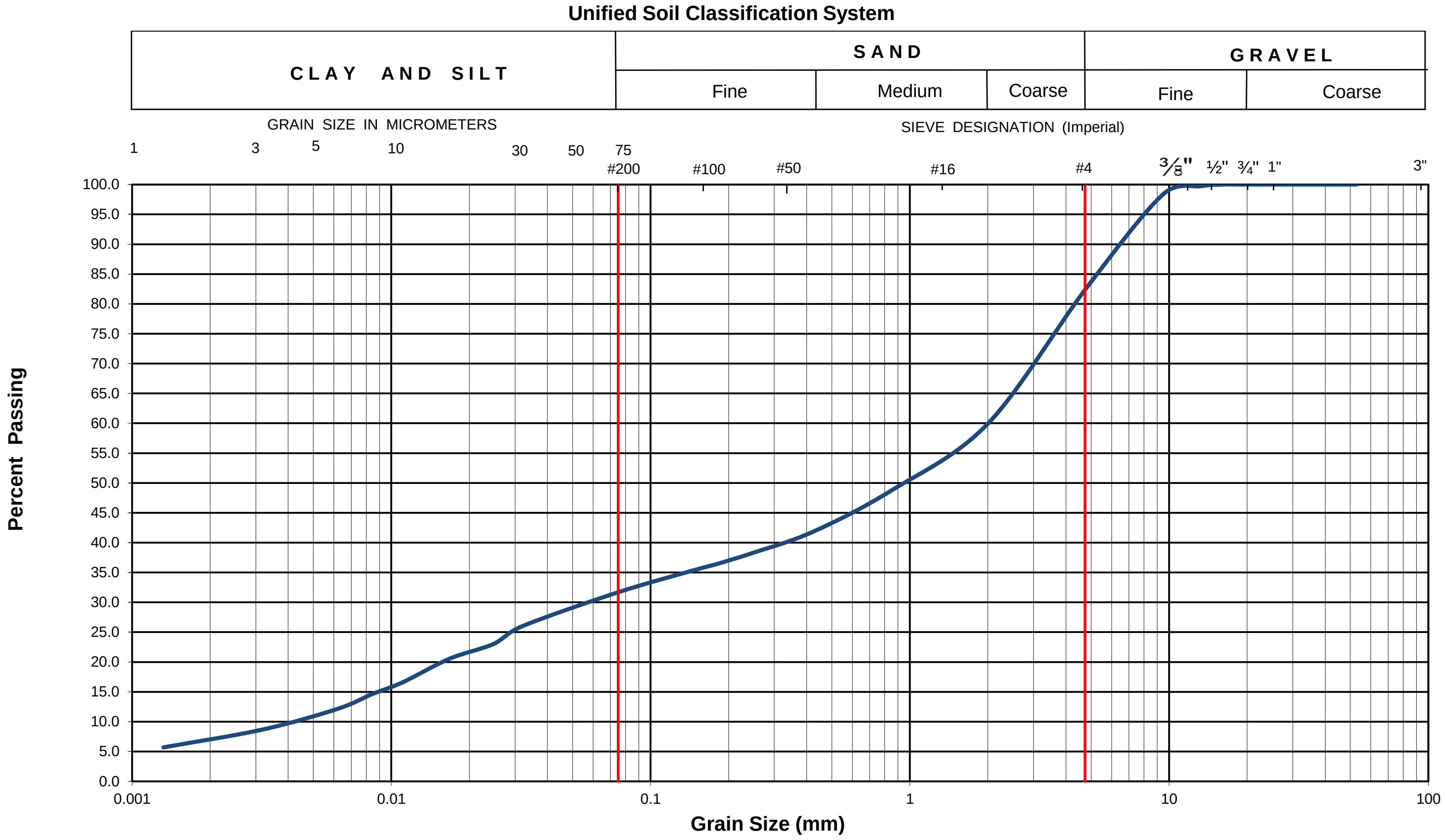
Ottawa, ON K2B 8H6



EXP Project No.:	**OTT-22009219-A0**	**Project Name :**	**Geotechnical Investigation - Proposed New Cultural Campus**						
Client :	**Pitqunimikkut Ilinautiniq / Kitikmeot Hertiage Society**	**Project Location :**	**Lot 1004 CLSR 79787, Cambridge Bay, NU**						
Date Sampled :	**May 16, 2022**	**Borehole No:**	**BH 5-2**	**Sample No.:**	**0**			**Depth (m) :**	**1.0-1.3**
Sample Description :		**% Silt and Clay**	**32**	**% Sand**	**50**	**% Gravel**	**18**	**Figure :**	**18**
Sample Description :	**Silty Sand with Gravel (SM)**								

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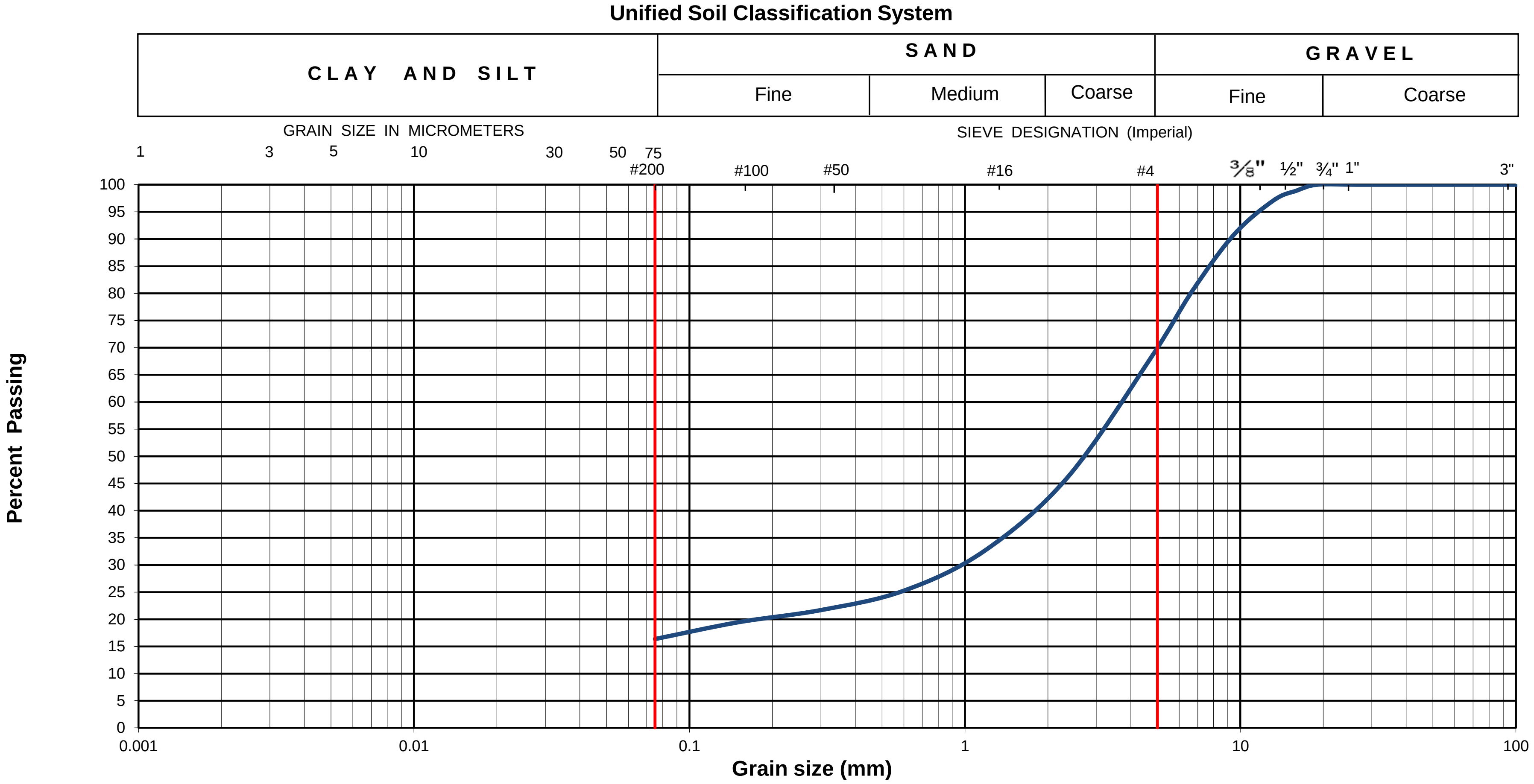
Ottawa, ON K2B 8H6

Grain-Size Distribution Curve
Method of Test For Sieve Analysis of Aggregate
ASTM C-136



EXP Project No.:	**OTT-22009219-A0**	**Project Name :**	**Geotechnical Investigation - Proposed New Cultural Campus**						
Client :	**himikkut Ilihautiniq / Kitikmeot Heritage S**	**Project Location :**	**Lot 50, Block 13, Cambridge Bay, NU**						
Date Sampled :	**May 16, 2022**	**Borehole No:**	**BH 6-2**	**Sample:**	**0**	**Depth (m) :**	**1.0-1.3**		
Sample Composition :		**Gravel (%)**	**32**	**Sand (%)**	**52**	**Silt & Clay (%)**	**16**	**Figure :**	**19**
Sample Description :	**Silty Sand with Gravel (SM)**								

APPENDIX A: LABORATORY TEST CERTIFICATE

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
http://www.agatlabs.com

CLIENT NAME: EXP SERVICES INC
2650 QUEENSVIEW DRIVE, UNIT 100
OTTAWA, ON   K2B8H6
(613) 688-1899

ATTENTION TO: SURINDER AGGARWAL

PROJECT: OTT-2201448-A0

AGAT WORK ORDER: 22T905042

SOIL ANALYSIS REVIEWED BY: Jacky Zhu, Spectroscopy Technician

DATE REPORTED: Jun 15, 2022

PAGES (INCLUDING COVER): 5

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

Notes

Disclaimer:

- *All work conducted herein has been done using accepted standard protocols, and generally accepted practices and methods. AGAT test methods may incorporate modifications from the specified reference methods to improve performance.*
- *All samples will be disposed of within 30 days after receipt unless a Long Term Storage Agreement is signed and returned. Some specialty analysis may be exempt, please contact your Client Project Manager for details.*
- *AGAT's liability in connection with any delay, performance or non-performance of these services is only to the Client and does not extend to any other third party. Unless expressly agreed otherwise in writing, AGAT's liability is limited to the actual cost of the specific analysis or analyses included in the services.*
- *This Certificate shall not be reproduced except in full, without the written approval of the laboratory.*
- *The test results reported herewith relate only to the samples as received by the laboratory.*
- *Application of guidelines is provided "as is" without warranty of any kind, either expressed or implied, including, but not limited to, warranties of merchantability, fitness for a particular purpose, or non-infringement. AGAT assumes no responsibility for any errors or omissions in the guidelines contained in this document.*
- *All reportable information as specified by ISO/IEC 17025:2017 is available from AGAT Laboratories upon request.*

Member of: Association of Professional Engineers and Geoscientists of Alberta (APEGA)
Western Enviro-Agricultural Laboratory Association (WEALA)
Environmental Services Association of Alberta (ESAA)

AGAT Laboratories is accredited to ISO/IEC 17025 by the Canadian Association for Laboratory Accreditation Inc. (CALA) and/or Standards Council of Canada (SCC) for specific tests listed on the scope of accreditation. AGAT Laboratories (Mississauga) is also accredited by the Canadian Association for Laboratory Accreditation Inc. (CALA) for specific drinking water tests. Accreditations are location and parameter specific. A complete listing of parameters for each location is available from www.cala.ca and/or www.scc.ca. The tests in this report may not necessarily be included in the scope of accreditation. Measurement Uncertainty is not taken into consideration when stating conformity with a specified requirement.

Certificate of Analysis

AGAT WORK ORDER: 22T905042

PROJECT: OTT-2201448-A0

CLIENT NAME: EXP SERVICES INC

ATTENTION TO: SURINDER AGGARWAL

SAMPLING SITE:

SAMPLED BY:EXP

Corrosivity Package

DATE RECEIVED: 2022-06-08

DATE REPORTED: 2022-06-15

			SAMPLE DESCRIPTION:	BH 1 S2 1.0-1.45M	BH 1 S6 5.0-5.45M	BH 1 S10 9.0-9.45M	BH 2 S5 4.0-4.45M	BH 2 S8 7.0-7.45M	BH 4 S3 2.0-2.45M	BH 4 S5 4.0-4.45M	BH 6 S5 4.0-4.45M
			SAMPLE TYPE:	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil
			DATE SAMPLED:	2022-05-16	2022-05-16	2022-05-16	2022-05-16	2022-05-16	2022-05-16	2022-05-16	2022-05-16
Parameter	**Unit**	**G / S**	**RDL**	**3951018**	**3951082**	**3951083**	**3951084**	**3951085**	**3951086**	**3951087**	**3951088**
Chloride (2:1)	µg/g		2	461	1790	820	1410	2130	820	2230	2040
Sulphate (2:1)	µg/g		2	505	897	1180	775	1050	376	923	964
pH (2:1)	pH Units		NA	7.88	8.18	8.55	8.50	8.24	8.17	8.28	8.23
Electrical Conductivity (2:1)	mS/cm		0.005	1.21	3.88	2.46	3.25	4.90	1.61	4.90	4.59

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

3951018-3951088 EC, pH, Chloride and Sulphate were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil). Resistivity is a calculated parameter.

Analysis performed at AGAT Toronto (unless marked by *)

Certified By:

NIANDONG ZHU

Quality Assurance

CLIENT NAME: EXP SERVICES INC | **AGAT WORK ORDER: 22T905042**
PROJECT: OTT-2201448-A0 | **ATTENTION TO: SURINDER AGGARWAL**
SAMPLING SITE: | **SAMPLED BY:EXP**

Soil Analysis

RPT Date: Jun 15, 2022			DUPLICATE			Method Blank	REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD		Measured Value	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper	Recovery	Acceptable Limits Lower	Acceptable Limits Upper
Corrosivity Package															
Chloride (2:1)	3951018	3951018	461	468	1.5%	< 2	92%	70%	130%	97%	80%	120%	102%	70%	130%
Sulphate (2:1)	3951018	3951018	505	519	2.7%	< 2	98%	70%	130%	100%	80%	120%	NA	70%	130%
pH (2:1)	3951018	3951018	7.88	8.04	2.0%	NA	98%	80%	120%						
Electrical Conductivity (2:1)	3951018	3951018	1.21	1.10	9.5%	< 0.005	91%	80%	120%						

Comments: NA signifies Not Applicable.
pH duplicates QA acceptance criteria was met relative as stated in Table 5-15 of Analytical Protocol document.
Duplicate NA: results are under 5X the RDL and will not be calculated.
Matrix spike: Spike level < native concentration. Matrix spike acceptance limits do not apply.

Certified By: Niandong Zhu

ASSOCIATION OF THE CHEMICAL PROFESSION OF ONTARIO
CHARTERED
NIANDONG ZHU
CHEMIST

Method Summary

CLIENT NAME: EXP SERVICES INC **AGAT WORK ORDER: 22T905042**

PROJECT: OTT-2201448-A0 **ATTENTION TO: SURINDER AGGARWAL**

SAMPLING SITE: **SAMPLED BY:EXP**

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Chloride (2:1)	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	modified from SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	modified from EPA 9045D and MCKEAGUE 3.11	PH METER
Electrical Conductivity (2:1)	INOR-93-6075	modified from MSA PART 3, CH 14 and SM 2510 B	PC TITRATE

AGAT Laboratories

5835 Coopers Avenue
Mississauga, Ontario L4Z 1Y2
Ph: 905.712.5100 Fax: 905.712.5122
webearth.agatlabs.com

Laboratory Use Only

Work Order #: 22T905042

Cooler Quantity: 1 large one-bag - no ice / packs

Arrival Temperatures: 22.1 | 22.0 | 22.0
2.6 | 3.8 | 5.1

Custody Seal Intact: ☐Yes ☐No ☐N/A

Notes: Bagged Ice

Chain of Custody Record

If this is a Drinking Water sample, please use Drinking Water Chain of Custody Form (potable water consumed by humans)

Report Information:

Company: EXP
Contact: Surinder Aggarwal
Address: 2650 Queensview Drive Suite 100
Ottawa ON K2B 8H6
Phone: 613-688-1899 Fax:
Reports to be sent to:
1. Email: Surinder.Aggarwal@exp.com
2. Email:

Regulatory Requirements:

(Please check all applicable boxes)

☐ Regulation 153/04
Table ______ *Indicate One*
☐Ind/Com
☐Res/Park
☐Agriculture
Soil Texture *(Check One)*
☐Coarse
☐Fine

☐ Excess Soils R406
Table ______ *Indicate One*
☐ Regulation 558
☐ CCME

☐ Sewer Use
☐Sanitary ☐Storm
______ *Region*
☐ Prov. Water Quality Objectives (PWQO)
☐ Other
______ *Indicate One*

Is this submission for a **Record of Site Condition?** ☐ Yes ☐ No

Report Guideline on *Certificate of Analysis* ☐ Yes ☐ No

Turnaround Time (TAT) Required:

Regular TAT (Most Analysis) ☒ 5 to 7 Business Days

Rush TAT (Rush Surcharges Apply)

☐ 3 Business Days ☐ 2 Business Days ☐ Next Business Day

OR Date Required (Rush Surcharges May Apply): ______

Please provide prior notification for rush TAT
**TAT is exclusive of weekends and statutory holidays*

For 'Same Day' analysis, please contact your AGAT CPM

Project Information:

Project: OTT-22014485-A0
Site Location: Shop + Office Cambridge Bay NU
Sampled By: ExP
AGAT ID #: ______ PO: ______

Please note: If quotation number is not provided, client will be billed full price for analysis.

Invoice Information:

Bill To Same: Yes ☒ No ☐

Company:
Contact:
Address:
Email:

Sample Matrix Legend

B	Biota
GW	Ground Water
O	Oil
P	Paint
S	Soil
SD	Sediment
SW	Surface Water

Sample Identification	Date Sampled	Time Sampled	# of Containers	Sample Matrix	Comments/ Special Instructions	Field Filtered - Metals, Hg, CrVI, DOC Y / N	O. Reg 153 Metals & Inorganics	O. Reg 153 Metals - ☐ CrVI, ☐ Hg, ☐ HWSB	O. Reg 153 BTEX, F1-F4 PHCs Analyze F4G if required ☐ Yes ☐ No	PAHs	Total PCBs ☐ Aroclor	VOC	O. Reg 558 Landfill Disposal Characterization TCLP: TCLP: ☐M&I ☐VOCs ☐ABNs ☐B(a)P ☐PCBs	O. Reg 406 Excess Soils SPLP Rainwater Leach SPLP: ☐Metals ☐VOCs ☐SVOCs	O. Reg 406 Excess Soils Characterization Package pH, ICPMS Metals, BTEX, F1-F4	Salt - EC/SAR	pH	SO4	Chloride	Elec Conductivity				Potentially Hazardous or High Concentration (Y/N)
BH 1 s2 1.0-1.45m	May 16/22	AM PM	1														✓	✓	✓	✓				
BH 1 s6 5.0-5.45m	↓	AM PM	↓														↓	↓	↓	↓				
BH 1 s10 9.0-9.45m		AM PM																						
BH 2 s5 4.0-4.45m		AM PM																						
BH 2 s8 7.0-7.45m		AM PM																						
BH 4 s3 2.0-2.45m		AM PM																						
BH 4 s5 4.0-4.45m		AM PM																						
BH 6 s5 4.0-4.45m		AM PM															✓	✓	✓	✓				
		AM PM																						
		AM PM																						
		AM PM																						

Samples Relinquished By (Print Name and Sign):	Date	Time	Samples Received By (Print Name and Sign):	Date	Time	
			C. Griffith	JUN 07 2022	15h40	'22 JUN 8 9:56 AM
CC to Puro	JUN 07 2022	16h00	Anthony Dasilva			Page ______ of ______
						Nº: T114966

LIST OF DISTRIBUTION

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Sophie Pantin pantinsophie@gmail.com