ENGINEERING CONSULTING SERVICES

VOLUME 6 - APPENDIX

APPENDIX 6.1.2 – PRELIMINARY GEOTECHNICAL INVESTIGATION – NEMASKA ACCESS ROAD

FEASIBILITY STUDY FINAL REPORT PHASE I

Consultant Reference: LGA-1-GN-F-FRN-RT-0006_00_6.1.2
2023-03-31

Stantec ▮ DESFOR ▮ SYSTRA
with subconsultant KPMG

LA GRANDE ALLIANCE FEASIBILITY STUDY – PHASE I

PRELIMINARY GEOTECHNICAL INVESTIGATION – NEMASKA ACCESS ROAD

February 22, 2023

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LA GRANDE ALLIANCE FEASIBILITY STUDY – PHASE I
PRELIMINARY GEOTECHNICAL INVESTIGATION – NEMASKA ACCESS ROAD

Revision	Description	Author		Quality Check		Independent Review	
00	Final Report	TC	15/02/23	RH	16/02/23	AED	16/02/23

LA GRANDE ALLIANCE FEASIBILITY STUDY – PHASE I
PRELIMINARY GEOTECHNICAL INVESTIGATION – NEMASKA ACCESS ROAD

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1.0 Introduction

1.1 General

La Grande Alliance refers to the Memorandum of Understanding (MOU) on the Cree-Québec Sustainable Infrastructure Program in Eeyou Istchee Baie-James, signed between the Cree Nation Government (CNG) and the Government of Québec on February 17, 2020. The purpose of the MOU is to provide a framework for Cree local and regional entities to work closely with relevant Québec government ministries to connect, develop and protect the territory of the Eeyou Istchee Baie-James region of northern Québec in an inclusive and participatory manner. The main objective of La Grande Alliance is to build a promising program for the strategic, predictable, and sustainable development of the territory over a 30-year time horizon.

Infrastructure development is a major component of *La Grande Alliance*. The program aims at improving and building major transportation infrastructure on the territory, including the implementation of a railway alongside the Billy-Diamond Highway to Whapmagoostui, where the construction of a deep-water port is being considered. The current program is divided into three phases. Phase I being carried out by Vision Eeyou Istchee Consortium, focusing on the feasibility design of the following infrastructures:

- Upgrade of the existing access roads between the Billy-Diamond Highway (BDH) and the Cree communities of Waskaganish, Eastmain and Wemindji;
- Upgrade of the existing access road between the *Route du Nord* and the community of Nemaska;
- New railway along the Billy-Diamond Highway (BDH) between the town of Matagami and KM 257 of the same highway (Rupert River Bridge);
- Recommissioning of the railway line from Grevet (Lebel-sur-Quévillon) to Chapais (approximately 225 km);
- Construction of transfer areas along the Billy-Diamond Highway and Grevet-Chapais line corridors, specifically the area at KM 257;
- Upgrade of the *Route du Nord*, and;
- Construction of a secondary access road to the Cree Nation of Mistissini.

The location of the infrastructures listed above is shown on Figure 1.

Limitations associated with this report and its contents are provided in the Statement of General Conditions included in Appendix A.

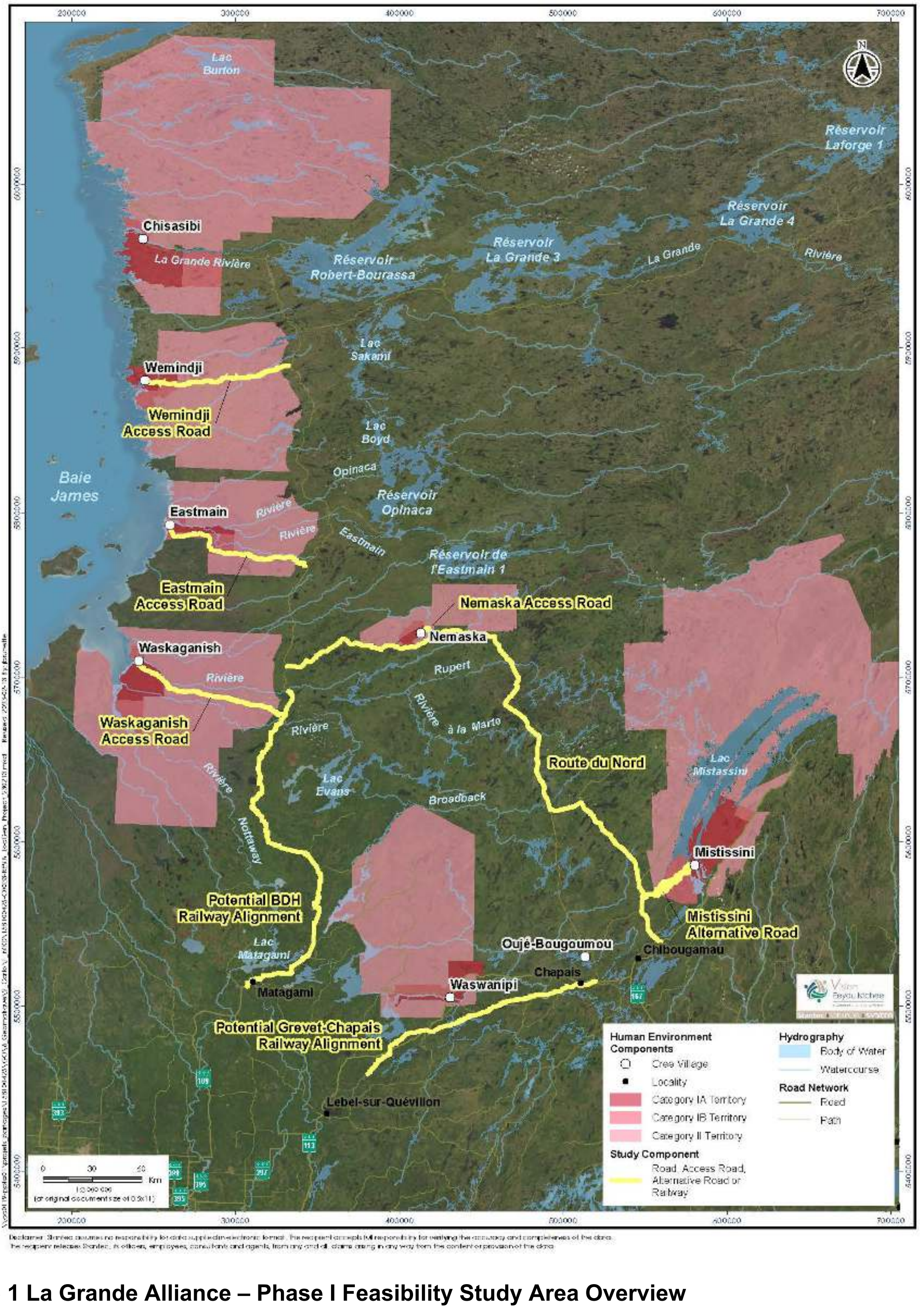

Figure 1 La Grande Alliance – Phase I Feasibility Study Area Overview

1.2 Scope of Work and Objective

As part of the Feasibility Study, the scope of work included carrying out a Preliminary Geotechnical Investigation for each of the transportation infrastructure corridors listed in Section 1.1 of this report.

The current report focuses on the gravel road portion of the existing access road between the *Route du Nord* and the Cree community of Nemaska, (the “Site”).

The preliminary geotechnical investigation was carried out to determine the site characteristics with regards to the nature and properties of granular roadbed materials in place, organic soil deposits, and the native mineral soils. The information gathered during this investigation was used to estimate the baseline in-situ conditions at the Site that feeds the Feasibility Study for the upgrading of the Nemaska Access Road.

1.3 Site and Description

The project consists of the upgrading (geometry, drainage, paving, etc.) of the access road between the *Route du Nord* and the Cree community of Nemaska.

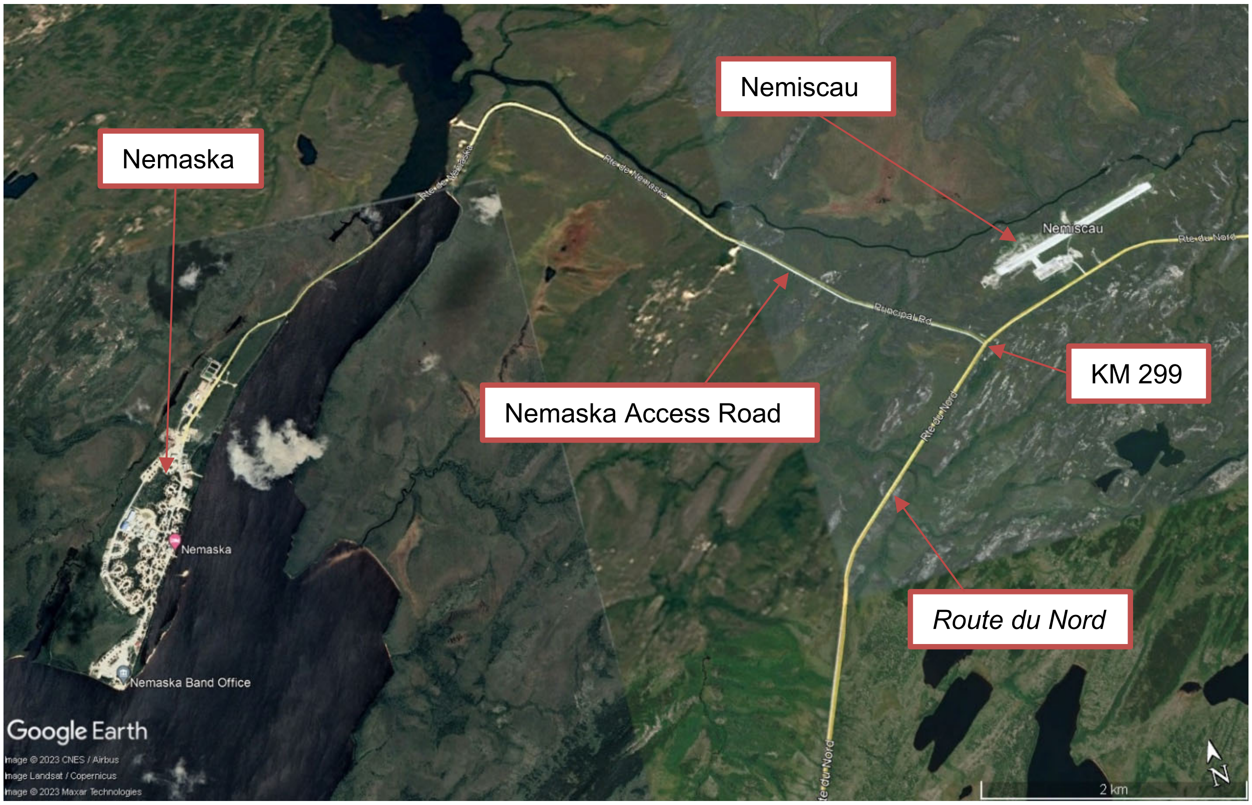

Figure 2 Access Road from BDH to Nemaska (Google Earth)

The Site consists of a gravel road that connects the community of Nemaska to KM 299 of the *Route du Nord*. The road is about 10 km long, and the last 4 km at the north end is paved. This road is essentially composed of granular fill placed directly on the former topsoil and/or peat surface layer. Within the gravel section, the surface course is maintained annually by placing of new gravel and reprofiling the surface as required.

The geodetic elevations range from el. ≈230 m in the village of Nemaska to el. ≈255 m at the *Route du Nord* intersection. A key plan showing the location of the Site is presented in Figure 2 and in Appendix B.

1.4 Geomorphology

During the Late Wisconsin Glaciation (24,000 to 8,000 years before present (BP)), the James Bay region was covered by the Laurentide ice sheet. During this glaciation, large amounts of materials were transported and subsequently deposited as till (morainal deposits) across the landscape. Following the ice melt, the marine transgression of the Tyrrell Sea occurred around 7,900 BP (Hardy 1977). Glaciomarine silt and clay accumulated in the low-lying areas and coarser deposits accumulated along the former Tyrrell Sea shorelines. Locally, marine clays cover the glaciolacustrine sediments of Lake Ojibway, which are usually 10 to 15 m thick (Hardy 1982). Peat bogs and fens have accumulated over the glacial and non-glacial deposits, especially over poorly drained glaciomarine and morainal (till) deposits.

According to the *Système d'information géominière* of Quebec (SIGÉOM), the community access road to Nemaska mostly sits on sand (≈38%), till (≈21%), peatland (≈10%) and the remaining 31% is crossing over Champion Lake before entering the Cree community of Nemaska; Figure 3 on next page illustrates this distribution along the access road. Note that the SIGÉOM legend is a genesis legend used to map a deposit according to its deposition process; it has been converted to the textural deposit legend used for the LGA project. Also, the SIGÉOM legend maps only the first metre of soil and does not consider the deeper deposits. Table 1 provides the equivalent group symbols used in the SIGÉOM system and LGA project mapping.

Table 1 Converted Legend from SIGÉOM to the Project Mapping

SIGÉOM Legend	LGA Project Legend
-Subaquatic outwash sediment (Gs) -Coastal and pre-coastal glaciomarine sediment (MGb)	Sand (S)
Frontal moraine sediment (GxT)	Gravelly sand (S-SG)
Deep-water fine-grained marine sediment (MGa)	Silty Clay (CM)
Undifferentiated organic sediment (O)	Peatland (Pt)
Rock (R)	Rock (R)
Undifferentiated till (T)	Till (T)

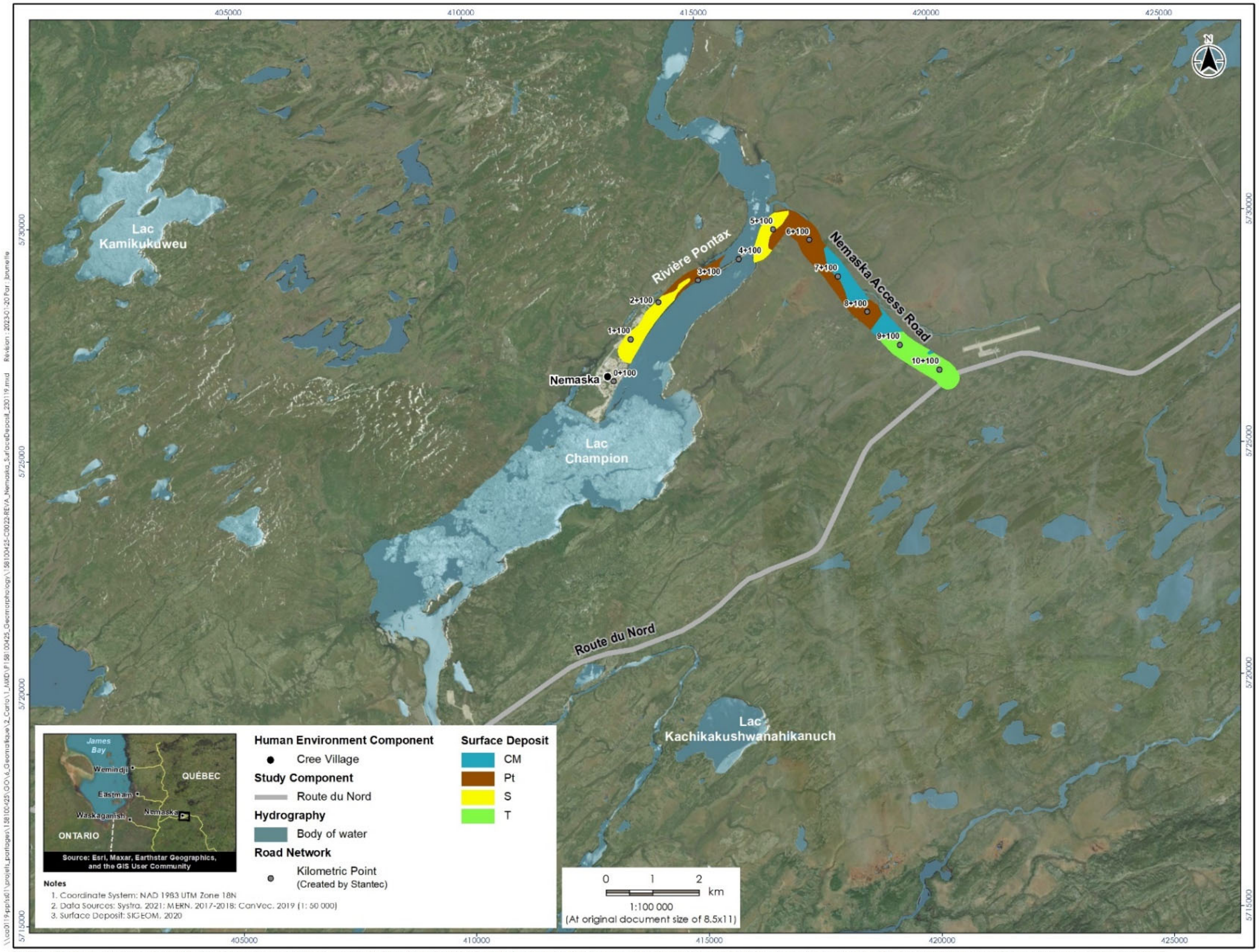

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Figure 3 Mapping of the Nemaska Access Road

2.0 Method of Investigation

2.1 Utility Locates

A request was filed by Stantec to Info-excavation to identify underground public utilities present in the vicinity of the work site. Where present, all identified utilities were marked on the ground prior to the execution of the field work. For this Site, the work was carried out directly on the roadway, which had no underground infrastructure and public utilities.

2.2 Health and Safety

The Stantec employees who participated in this project familiarized themselves with all the relevant Stantec Safe Work Practices (SWPs) prior to the beginning of any fieldwork. In addition, Stantec's pre-job Health and Safety Checklist, that identifies any health and safety risks, was filled out and signed by all the participants in the fieldwork, including the subcontractors. The goal of this document is to identify any potential dangers in order to prevent accidents and injuries from occurring. No health and safety incidents occurred while Stantec was present at the Site.

2.3 Geotechnical Field Investigation

Four (4) boreholes, identified BH22-46 to BH22-49, were drilled on June 29, 2022, as part of the investigation. The boreholes were drilled to obtain representative information on the geotechnical properties of the granular materials and soils in place. They were advanced using a truck-mounted drill rig operated by *Downing Drilling Ltd*. under the constant supervision of an experienced Stantec technician. The borehole reports are presented in Appendix C.

Traffic management was provided by *Sécurité Mahican* from Mashteuiatsh. A traffic management plan was prepared which included reducing traffic flow to a single lane near the investigation area following a pre-established signage plan.

At each borehole, the soils were initially sampled from the surface using a 63 mm external diameter split spoon sampler (*N* size sampler). Subsequently, the soils were sampled at regular intervals using a 610 mm long and 51 mm external diameter split spoon sampler (*B* size sampler) and the Standard Penetration Tests (SPTs) was performing as defined in ASTM D-1586. The soils collected each split-spoon samplers were examined and described, and the soil recovery measured and recorded.

The SPT test consists of counting the numbers of blows required to drive a *B* size sampler 12 in. (305 mm) into a soil by means of a 140 lb (63.5 kg) mass falling a height of 30 in. (762 mm). The blow count is referred to as the N-value of the soil, which is a description of its state of compactness.

All geotechnical soil samples recovered from the boreholes were placed in moisture-proof bags, appropriately labelled, and returned to our laboratory for detailed geotechnical classification and testing, as discussed further below.

2.4 Site Survey

The borehole locations were selected by a geomorphologist in order to obtain a representative characterization of the *in-situ* conditions with regard to low points, culverts, streams and peat bogs. The boreholes were generally positioned at regular intervals of 3 km to 5 km, and the locations were confirmed in advance by the team carrying out the Feasibility Study of the project.

The boreholes were positioned on Site using a 3-m precision GPS. Where the borehole drilled at a different location than initially targeted, the new coordinates were recorded by the field technician.

No geodetic elevations were measured. All the boreholes were carried out directly on the gravel surface course of the road. All depths mentioned in this report refer to the surface of the road at the time of the works « metre below ground surface (mbgs) ».

For the purpose of this study, borehole BH22-46 corresponds to the junction of the paved and gravel road at the *north-west* end near Nemaska and borehole BH22-49 corresponds to the last borehole at the *south-east* of the road, near the *Route du Nord* intersection.

The geodetic coordinates at each borehole location are presented below and are shown in Appendix B.

Table 2 Borehole Coordinates

Borehole	X	Y
	Geodetic Coordinates U18	
BH22-46	416 897	5 729 910
BH22-47	417 700	5 729 079
BH22-48	418 263	5 728 341
BH22-49	418 955	5 727 603

2.5 Laboratory Testing

All collected samples returned to our laboratory were subjected to a detailed visual examination and additional classification by a geotechnical engineer. The following geotechnical laboratory tests were performed on selected samples:

Table 3 Geotechnical Laboratory Tests

Laboratory tests	Standards	Number of tests
Grain-size distribution by mechanical sieve (coarse soil fraction)	BNQ 2501-025	12

The results of the laboratory tests are discussed in the text of this report and are presented in Appendix D.

The soil samples will be stored for a period of 12 months after issuing of the final report. Samples will then be discarded unless otherwise directed.

3.0 Subsurface Conditions

3.1 Subsurface Stratigraphy

The borehole reports depict conditions at specific locations and on the dates indicated. Subsurface soil and groundwater conditions at locations away from the boreholes could vary from those indicated on the borehole reports.

It should be noted that the term "depth" always refers to the surface of the road at the time of the works (mbgs), as defined in subsection 2.4.

Soil classification was based on the procedures described in ASTM D2487 (Standard Practice for Classification of Soils for Engineering purposes (Unified Soil Classification System)) and ASTM D2488 (Standard Practice for Description and Identification of Soils, Visual-Manual Procedure). The subsurface stratigraphy summary is presented in the following table.

Table 4 Subsurface Stratigraphy Summary

Borehole	Stratigraphy (Depth, m)		
	Surface Course	Granular Fill	Native Granular Deposit
BH22-46	0.00 -- 0.44	0.44 -- 1.22	1.22 -- 1.83
BH22-47	0.00 -- 0.61	0.61 -- 1.22	1.22 -- 1.83
BH22-48	0.00 -- 0.51	--	0.51 -- 1.83
BH22-49	0.00 -- 0.43	0.43 -- 1.22	1.22 -- 1.83

The subsurface conditions observed, and the results of the field and laboratory testing, are presented on the borehole reports included in Appendix C.

3.1.1 Surface Course

A surface course was encountered in all boreholes with a thickness ranging from 430 mm to 610 mm. The surface course generally consisted of a brown sand and gravel to gravelly sand with traces of silt.

Four (4) representative samples of the surface course layer were selected for grain size distribution testing. The laboratory test results are summarized in the following table and the detailed results are included in Appendix D.

Table 5 Laboratory Test Results – Surface Course

Borehole	Sample	Depth (m)	Fines (%)	Sand (%)	Gravel (%)
BH22-46	SS-01A	0.00 – 0.44	8.1	52.6	39.3 (1)
BH22-47	SS-01	0.00 – 0.61	8.7	62.5	28.8 (1)
BH22-48	SS-01A	0.00 – 0.51	9.3	55.3	35.4 (1)
BH22-49	SS-01A	0.00 – 0.43	9.9	54.6	35.5 (1)
Note (1): No compliance with MG 20b (5% < Fines < 11%) and (40% < Gravel < 65%) in accordance with BNQ 2560-114 standard.					

Typically, MG 20b material is recommended and used as a surface course for gravel roads. MG 20b contains more fine particles than an MG 20, and thus provides a greater surface stability. According to the BNQ 2560-114 standard Travaux de génie civil - Granulats, in addition to the requirements on the intrinsic properties of a material used in a surface course, an MG 20b must contain between 5 and 11% of fine particles, and between 40 and 65% of gravel. In the current investigation, out of 4 samples considered representative of the in-place surface course, no samples met these requirements.

In general, the material in place and used as a surface course contain good proportion of fine particles but not enough of coarse particles (gravel) to meet the standards of BNQ 2560-114 as a surface course material.

3.1.2 Granular Fill

A granular fill was found underneath the surface layer, at a depth ranging from 0.43 m to 0.61 m below ground surface (mbgs). This layer has a thickness ranging from 610 mm to 790 mm, and essentially consisted of a brown grey to brown sand with some silt and gravel to a silty sand with some gravel.

Standard Penetration Test N-values measured in this granular fill ranged between 9 and 20, indicating that the fill is in a loose to compact state.

Four (4) representative samples of this granular fill were selected for grain size distribution tests. The laboratory test results are summarized in the following table and the detailed results are included in Appendix D.

Table 6 Laboratory Results – Granular Fill

Borehole	Sample	Depth (m)	Fines (%)	Sand (%)	Gravel (%)
BH22-46	SS-01B	0.44 – 0.61	14.1 (1)	81.5	4.4
BH22-46	SS-02B	0.82 – 1.22	24.9 (1)	62.8	12.3
BH22-47	SS-02	0.61 – 1.22	21.6 (1)	65.9	12.5
BH22-49	SS-02	0.60 – 1.22	18.1 (1)	66.3	15.6
Note (1): No compliance with MG 112 (0% < Fines < 10%) and (0% < Gravel < 88%) in accordance with BNQ 2560-114 standard.					

The granular fill encountered at the site is similar to the native granular deposit described in Section 3.1.3 and is not sufficiently coarse to be considered as a subbase layer for the future developments. It should be considered as part of the roadway subgrade.

Typically, a material of type MG 112 is recommended and used as a subbase under the surface course, in the case of a gravel road. According to the BNQ standard 2560-114 Travaux de génie civil - Granulats, in addition to the requirements on the intrinsic properties of a material used as a sub-base layer, MG 112 must contain between 0 and 10% of fine particles and between 0 and 88% of gravel. In the current investigation, all of the samples considered representative of the granular fill in place do not meet these requirements.

In general, the material in place, and apparently used as a subbase layer under the surface course, contains a high proportion of fine particles and does not meet the standards of BNQ 2560-114 as a subbase material. This material would be qualified by MTQ as an SM-coarse, or a silty sand with fewer than 30% of fine particles, which is a good quality subgrade soil.

3.1.3 Native Granular Deposit

A native granular deposit was encountered in some boreholes at a depth ranging from 0.51 m to 1.22 m below ground surface (mbgs). This native granular deposit generally consisted of a brown silty sand with some to traces of gravel.

Standard Penetration Test N-values measured in this soil ranged between 4 and 22, indicating that this native granular deposit is in a very loose to compact state.

Four (4) representative samples of the native granular deposit were selected for grain size distribution tests. The laboratory test results are summarized in the following table.

Table 7 Laboratory Results – Native Granular Deposit

Borehole	Sample	Depth (m)	Fines (%)		Sand (%)	Gravel (%)	USCS
			Clay	Silt			
BH22-46	SS-03	1.22 – 1.83	24.9		65.8	9.3	SM
BH22-47	SS-03	1.22 – 1.83	26.2		66.0	7.8	SM
BH22-48	SS-02	0.61 – 1.22	24.7		56.8	18.5	SM
BH22-49	SS-03	1.22 – 1.83	26.5		57.8	15.7	SM

The detailed laboratory test results are included in Appendix D.

This material would be qualified by MTQ as an SM-coarse, or a silty sand with fewer than 30% of fine particles, which is a good quality subgrade soil.

All boreholes ended within this native granular deposit at a depth of 1.83 m below ground surface (mbgs).

3.2 Groundwater

No standpipe or piezometer was installed in the boreholes during this investigation. Visual observations of water conditions in boreholes were noted during fieldwork, on June 29, 2022. This information is provided in the borehole reports in Appendix C.

Groundwater levels can be expected to fluctuate during periods of heavy precipitation associated with seasonal weather trends, specific rainfall events, site use, adjacent site use, and construction activity. Therefore, it is possible that the groundwater levels will be different during the planned work.

4.0 Discussions and Recommendations

This section provides engineering input related to the geotechnical design aspects of the upgrading of the Nemaska access road based on our interpretation of the available subsurface information described herein, and our understanding of the project requirements.

The discussion and recommendations presented in the following sections are to provide the designers with functional information for planning and preliminary design purposes only. A detailed geotechnical investigation and design report, complete with additional boreholes, will be required prior to or during the final design stage of the project.

4.1 Project Description

The Site consists of the gravel road portion of the access road that connects the community of Nemaska to KM 299 of the *Route du Nord*. The total access road has a length of about 10 km, of which the last 4 km at the north end is paved and excluded from the Site discussed in this report.

The access road is essentially made up of granular fill placed directly on natural soil, topsoil and/or peat. The surface course of the gravel road is maintained annually by adding additional granular fill and reprofiling, as required. The geodetic elevation ranges from el. ≈230 m in the village of Nemaska to el. ≈255 m at the *Route du Nord* intersection.

The preliminary geotechnical investigation was carried out to estimate the baseline *in-situ* conditions at the Site that will influence the Feasibility Study for the upgrading of the Nemaska Access Road. The following sections outline the geotechnical and material concerns and requirements that will influence the feasibility and the design of the project.

This report discusses rehabilitation design methods which may be considered for the preliminary design of the gravel portion of the access road to Nemaska, while referring to certain typical concepts applicable in a northern environment. It provides guidance to the designer in modifying or amending current practices, considering the specific context of the project. A list of relevant elements to consider when selecting a rehabilitation method and carrying out a preliminary design is also provided.

4.2 Methods of Rehabilitation

Despite the northern context in which the improvement work for the Nemaska access road is to be carried out, all the usual rehabilitation/improvement methods can be considered by the client. However, some of these require additional precautions and/or adjustments due to the climatic conditions and the geographical remoteness of the site, the quantity and quality of the existing roadway gravels in place, as well as the availability of borrow materials to be used for construction.

The choice of the roadway rehabilitation method should consider both the initial construction costs and the maintenance and repair costs, in the medium and long term, depending on the design life span of the rehabilitated structure. The design should consider the traffic volume and type, both current and projected, while considering future developments in the region (transportation of wood, granular materials, resources, major mine or industry start-ups, construction and operation of electrical substations, wind farms, etc.) When establishing the traffic hypotheses and rehabilitation method, the projected heavy truck traffic, especially the type of heavy trucks and their purpose, will be a critical input parameter that will govern the design approach. The nature of the truck traffic will have a considerable impact on the design of the rehabilitation method.

When selecting a rehabilitation method, the advantages and disadvantages of each method should be analyzed. A summary of the main viable methods considered applicable to this project is presented in the following paragraphs. The most common methods for road construction in northern and remote areas are hot mix asphalt paving, surface treatment, and gravel surfacing.

4.2.1 Paved Surface

Rigid and semi-rigid pavements are known to perform well when subjected to intense heavy traffic loading but there are some limitations to their use in cold climates which restricts their applicability; these include concrete pavements and hot mix asphalt pavements with a concrete base or a chemically stabilized base. Their relatively high initial cost and their sensitivity to differential soil movements are two main reasons making these pavements unsuitable in cold areas where traffic volumes are low, and soils are sensitive to frost action (Doré & Zubeck 2009).

The present study will therefore focus on the use of hot mix asphalt as the pavement surface type, commonly used for high traffic roads in Quebec. This surface type has proven itself in the past and over time, and comprehensive design and construction standards have been developed by the MTQ, making the design and its application quite simplistic. Many design guidelines and tools also exist that indicate that a maximum service life of 25 years can be achieved if all design and construction criteria are met. The application of a paved surface course greatly improves the pavement's performance, the user's comfort, and tire traction, making the infrastructure much safer. The finished paved road surface allows for good lateral surface water drainage and for the elimination of dust.

4.2.2 Surface Treatment

While chip seals and coatings are used widely as surface treatments in warm climates, bituminous surface treatment (BST) is used extensively in the Yukon and Canada as a low-cost highway surface course (MacLeod 1989). Alaskans have been using the same type of treatment since 1987, calling it asphalt surface treatment (AST). The AST and BST consist of a thin layer of asphalt binder, typically high float asphalt emulsion, covered with well-graded aggregate. The advantage of surface treatment versus gravel roads are dust control, improved surface drainage, reduced water infiltration, and reduced maintenance. Furthermore, the dust-free surface and improved driving surface, come without the costly capital outlays required for hot-mix pavements (Doré & Zubeck 2009).

This type of pavement is a low-cost option, but it is intended for low-volume roads and rural areas. Moreover, this option does not offer the same structural capacity as an asphalt pavement. In the case of heavy trucking and heavy haulage traffic, the underlying granular structure must be improved (in terms of quality and quantity) prior to paving. Therefore, the surface treatment does not provide any structural contribution, unlike asphalt pavement. A deep and adequate granular structure must be provided.

Since 1967, the use of surface treatments on MTQ roadways has been limited to about 15 projects, most of them located in northern regions. The common practice is to lay a double, in some cases triple, surface treatment over the existing granular base. The cost varies depending on the year of construction, number of layers, length, and location of the project, but is about half that of conventional asphalt (DGLC 2017).

Compared to a road with a gravel surface, the application of a surface treatment increases the roadbed's life span, improves user comfort and tire traction, eliminates the dust problem when heavy vehicles pass by, and allows for the painting of permanent pavement markings for safer driving conditions.

When compared to a paved surface, the main disadvantages of using surface treatment are the shorter lifespan (less than 10 years) and the lack of structural capacity (compensated by the use of thicker granular materials or of geogrid to increase the overall strength). According to the CIO of Oujé-Bougoumou, surface treated roads appear to cause premature wear of vehicle tires.

4.2.3 Gravel Surface

Gravel surface roads are the most common roadway types in cold regions. Moreover, this is how the current road is built. While it has the lowest capital cost to construct, the maintenance costs are typically higher than that for paved roads. Gravel roads require periodic grading and dust mitigation works. Gravel surface roads may be treated with dust control palliative measures (such as calcium chloride), asphalt emulsions or proprietary blends (Doré & Zubeck 2009).

4.3 Chosen Rehabilitation Method

Considering that the surface treatment approach would offer a shorter lifespan and therefore, a faster return to periodic maintenance, the feasibility study identified the construction of a roadway with a standard paved surface as the preferred option. In addition to providing a user-friendly surface and increased traffic safety, this option offers the best service life, provided that all the design inputs mentioned in this study are optimally considered.

This option reduces the quantity of granular material, not easily available in the area, required for initial construction and required for maintenance throughout the design service life. Also, it allows for the use of existing materials as subbase materials, upon which a new granular base layer can be constructed; in contrast, the surface treatment option would involve the placement of significantly more granular material to obtain the required pavement strength, resulting in a major increase in the existing roadway profile height. In addition, this method will limit the use of geogrids which can have a significant impact on project costs and schedules.

4.4 Design Consideration

4.4.1 Traffic Design Parameters

Based on the available data, the following traffic parameter assumptions were considered for the structural design of the new pavement.

- Classification: local road, resource access
- AADT (2022) : 250 vehicles per day
- Annual traffic growth: 3%
- Projected AADT (2027): 290 vehicles per day
- Percent heavy vehicles: 15%.
- Corrected AADT (heavy vehicles + traffic growth): 634 vehicles per day
- Design life: 25 years
- Truck Factor (TF): 1.2 (default value from Chaussée2)
- Lifetime traffic demand (total aggressiveness): 285,000 ESAL

Where:

  - AADT is the average annual daily traffic.
  - ESAL is the equivalent single axel load of 8 160 kg (18,000 lb).
  - TF is the average number of ESALs per truck applicable to the heavy vehicles.

It is recommended that a comprehensive traffic data analysis be carried out, including an updated traffic count. The traffic analysis should be able to anticipate the volume and especially the type of heavy vehicles that will have to circulate on the roadway once it is paved, considering their future use and the various industries/activities that will be developed in the region. Also, it is possible that one roadway will be used more than another over its expected life span (e.g.: lumber or mining material carriers loaded in one direction only). In such a case, it could be considered using different traffic data (and therefore a different design) for one lane rather than another.

The following examples of heavy traffic which could ultimately be applicable to the road are provided to underline the importance of defining an appropriate truck traffic projection at the final design stage.

- If 75-ton high efficiency log trucks were to be used on the roadway, their truck factor (TF) values would range of 7.0 to 10.0, compared to the TF value of 1.2 used above. Hypothetically, this could result in the blended heavy vehicle truck traffic TF value of 5.0, then the total design loading would increase to 1.71 million ESALs.
- If non-standard vehicles such as 220-ton lumber haulers were to be used on the roadway, they would have to be analyzed separately because their truck factor (TF) values would increase up to 300; this would imply that each pass of a 220-ton lumber hauler would impose the same damage as 30 passes of a 75-ton high efficiency log truck or 250 passes of the average truck currently considered in the design.

4.4.2 Frost Penetration and Transitions

According to the statistical data available from the Weather Network, the Mean Freezing Index in Degree-Day Celsius is approximately 2193 °C.days for Matagami and 2186 °C.days for Moosonee in Ontario. Based on the simplified frost penetration depth calculation method (Brown, 1964), it is anticipated that a frost penetration of approximately 3.0 m could be anticipated at the site.

According to Table 1.10-1 *Profondeur de transition en fonction de l'indice de gel* (Transition Depth by Frost Index) in MTQs document *Tome II – Construction routière*, a transition depth "P" of 2.0 m is applicable for a mean freezing index of greater than 1700 °C·days and for a local road. This depth should be measured from the final pavement profile. Thus, to remedy the inconveniences associated with the differential frost heave behaviour of soils and rock, it will be important to provide transitions that will allow for a longitudinally gradual surface heave that will not affect the comfort and safety of users. The transitions will be applicable in areas with soils of varying degrees of frost susceptibility, in areas undergoing total rehabilitation, during road widening, during construction of a new structure with road realignment, and in the vicinity of structures and culverts. Longitudinal and transverse transitions shall be carried out in accordance with the requirements of Standard Drawings 016 to 023 provided in *Tome II – Construction routière*.

4.4.3 Choice of Materials in Northern Context

Considering the northern context of the Site, a certain flexibility regarding the choice of granular materials may be required. It will be necessary to consider the availability of these materials and the necessary effort to obtain the required grain-size distribution and normally required aggregate physical properties (crushing, screening, transportation, stockpiling, etc.). As previous discussed, the traffic volume and anticipated trucks must be determined and taken into account when considering the project.

For example, if the pavement was to remain unpaved (no overlay), the use of large, processed gravels such as MG 80 or MG 56 material could be required in areas that will be heavily used by heavy traffic. The feasibility of this approach would have to consider the properties of the aggregates in place and their context of use.

4.4.4 Organic Soil Consideration

According to Section 11.11.1 of MTQs provincial standard specifications, the *Cahier des charges et devis généraux* (CCDG, 2022), when preparing and stabilizing the subgrade of a roadway, unsuitable materials such as organic soils must be excavated and replaced to at least 1 m below the top of the subbase layer and to at least 300 mm below the subgrade line. Soils accepted by the Ministry for this type of soils shall have a maximum organic matter content of 3.0%.

Since a 300 mm resurfacing thickness is planned and the granular material in place meets the requirements of a MG 112 subbase, the future top of subbase is considered to correspond to the existing gravelled road surface. Therefore, during the design stage, it will be necessary to ensure that the organic soils are located at a minimum depth of 1 m below the existing road surface.

Of the 4 boreholes drilled as part of this investigation, no organic soil was encountered under the road embankment. Otherwise, it is recommended to treat the segments where the thickness of granular material is insufficient separately. To compensate for the poor performance of the surface pavement in the presence of these unsuitable soils being too close to the surface, the subbase could be reinforced with geogrids, or its thickness could be increased before the proposed base gravel layer is placed.

4.4.5 Subbase Design and Protection Against Frost Heave

In roadways, the thickness of the subbase layer is determined according to the soil types which forms the supporting subgrade, directly below the subbase, present within the entire frost penetration depth. At the site, the frost penetration depth being about 3.0 m and the subgrade soil types to be considered while selecting the subbase thickness are the following:

- Granular materials (soils consisting of 20.0% or less fine particles, GM, GC);
- Native granular deposit or granular fill in place (SM-coarse, SC);
- Native cohesive deposit (SM fin, clay crust, MH, CH, ML, ML-CL).

For this project, the subbase shall consist of natural or recycled aggregates (MR) of MG 112 size. The characteristics of the granular and recycled materials used as subbase shall meet the requirements of BNQ 2560-114 *Travaux de génie civil – Granulats* (Civil Engineering Works – Aggregates) and BNQ 2560-600 *Granulats – Matériaux recyclés fabriqués à partir de résidus de béton, d'enrobés bitumineux et de briques – Classification et caractéristiques* (Aggregates - Recycled Materials Made from Concrete Residues, Bituminous Asphalt and Brick - Classification and Characteristics).

Table 2.5-1 of *Tome II – Construction Routières* presents the subbase thicknesses of natural or recycled MG 112 aggregates according to the road classification, frost index and subgrade soil conditions. For the project, given that the subgrade soils vary greatly in their frost index from one area to another, this table recommends a subbase thickness ranging from 300 mm (GM, GC, in fill) to 700 mm (SM-coarse, SC, in cut).

If there were presence of fine soils (SM fin, clay crust, MH, CH ou CL) in the subgrade (not detected in the boreholes of the present preliminary geotechnical investigation), the table 2.5-1 rather propose a subbase thickness ranging from 600 mm (in fill) to 1 050 mm (in cut).

Since it is planned to construct a granular overlay on the roadway with material suitable for a base gravel (MG 20) and considering that the material in place and apparently used as a subbase layer under the surface course contains a high proportion of fine particles and does not meet the standards of BNQ 2560-114 as a subbase material (see section 3.1.2), the future subbase will only consist of the surface course. The table below illustrates the measured thickness of existing granular material which will constitute the future subbase for each of the boreholes drilled as part of this investigation.

Table 8 Thickness of Existing Granular Material to be Used as the Future Subbase

Borehole	Existing Granular Material (mm)	Borehole	Existing Granular Material (mm))
BH22-46	440	BH22-48	510
BH22-47	610	BH22-49	430

In general, the thickness of the existing surfacing granular material (the future subbase) which has a minimum thickness of 430 mm at the borehole location, plus 300 mm proposed for the resurfacing, will provide satisfactory frost protection according to the recommendations provided above. Thus, frost heave should remain below the 70 mm tolerance threshold for a local road as required by the MTQ design approach. It should be noted that the thickness of the subbase in place will not provide complete frost protection, which would require a minimum thickness of 3.0 m for the entire road; rather the proposed design assumes that the frost penetration will extend into the subgrade and that the resulting frost heave will be limited to about 70 mm. The additional costs required to increase this thickness does not appear to be justified considering the benefits that this would bring. However, this pavement structure will provide sufficient partial protection for satisfactory performance in the northern region. Thus, in certain sectors, the appearance of frost-related deterioration is possible following the installation of the foundation and the pavement but should be of low severity, particularly if the recommended transition treatments recommended in Section 4.4.2 are followed.

It should also be noted that the use of extruded polystyrene thermal insulation could be considered in excavated areas with subgrade soils highly susceptible to frost heaving and where the thickness of granular material in place is too low to provide adequate frost protection. In these cases, the thermal insulation should conform to Standard 14301 *Polystyrène pour construction routière* (Polystyrene for Road Construction) and be sized according to Table 2.5-1 *of Tome II – Construction routière*. The insulation should be installed over the existing MG 112 layer (existing granular materials) and the overlying material should consist of MG 20 or MG 112 with more than 30% retained particles on the 5 mm sieve, in addition to the proposed base gravel thickness.

Considering that the number of boreholes carried out within the current investigation is limited, it is recommended that an additional investigation be carried out to reduce the spacing between boreholes. This will ensure that the limits of the varying subgrade soils are better determined, mainly in existing in cut areas where the profile was lowered from the natural grade, in peat bog areas, or in areas with highly frost susceptible fine soils.

4.4.6 Base Course Design

For this project, the base course should consist of an MG 20a natural or recycled aggregate (MR) since an asphalt-surfaced road is planned. If the surface treatment option is selected, the base course required would still be an MG 20a as the MG 20b is preferred for gravel surfaces only.

The characteristics of granular and recycled materials used as a foundation must meet the requirements of the BNQ 2560-114 and BNQ 2560-600 standards discussed above.

Table 2.5-2 in *Tome II – Construction Routière* presents the natural or recycled MG 20 aggregate base course thicknesses according to the corrected projected AADT (which includes up to 10% of heavy vehicles) and according to the road classification. For the project, this table recommends a minimum thickness of 200 mm (local roads, corrected projected AADT between 500 and 1000).

It should be noted that heavy traffic has a significant influence on the minimum thickness of base material required, especially when the pavement is heavily loaded or when the heavy traffic is unevenly distributed over the lanes, such as in the case of logging or quarrying operations or a borrow pit. Therefore, since the volume and nature of the heavy traffic that will travel on the roadway is still uncertain at this time, it is recommended that a minimum layer of 300 mm of MG 20a material be placed as the base course layer. This additional thickness will also facilitate the placing and profiling of the gravel base course prior to paving.

4.4.7 Pavement Design

Table 2.5-3 of *Tome II – Construction Routière* presents the asphalt thicknesses to be placed according to the corrected projected AADT (taking into account heavy vehicles), the road classification and the study area. For the Site, this table recommends a minimum thickness of 80 mm of asphalt (local roads, projected AADT between 500 and 1000, north zone). For a thickness of 80 mm, a single layer of ESG-14 is allowed. ESG-14 is the recommended option for a single layer of asphalt and when heavy vehicles are present (very good support capacity and rutting resistance).

During the engineering and future design phases, it is recommended that an analysis of the projected traffic volume, type of heavy vehicles and their use is carried out. It should be noted that the number of heavy vehicles and their blended Truck Factor (TF) is the most important parameter to determine the required thickness of the asphalt layer and can considerably vary the required thickness of asphalt to be placed. Also, if only one layer of asphalt is to be placed, the maximum thickness allowed is 80 mm; for a thicker hot-mix design, two lifts of asphalt would be required.

For example, if the estimated number of heavy vehicles of 15% were to increase to 30% or if the estimated blended average truck factor of 1.2 TF were to increase to 4.5 TF, then the asphalt thickness required would be in the order of 100 mm, with two layers of asphalt (60 mm of ESG 14 + 40 mm of ESG 10). According to the Table 2.5-4 of *Tome II – Construction Routière,* for heavily used roads (logging, quarrying, etc.), the total hot-mix thickness should not be less than 110 mm.

Paving earlier than October 24 is recommended for a single lift paving course with a thickness greater than or equal to 50 mm. Bitumen must meet the requirements of Table 4101-1 of standard 4101 of the MTQ document *Tome VII – Matériaux*. The aggregates used to manufacture bituminous mixes must meet the particle size requirements of standards NQ 2560-114 and 4202 of the MTQ document *Tome VII – Matériaux*.

4.5 Drainage

It is recommended that existing culverts be inspected to verify their condition and sizes. If necessary, additional culverts should be installed to ensure proper drainage of the roadway.

It is recommended that existing ditches be cleaned and dug (if necessary), particularly in areas where the roadway was constructed in a cut cross-section; these areas appear to have shallow ditches that do not extend to the bottom of the existing granular layers. Ditch clean out or deepening should be carried out to ensure that the bottom of the ditches is at least 300 mm lower than the subgrade line. Standard Drawing 025 in Chapter 1 of *Tome II – Construction routière* of the MTQ shows the required drainage details for the pavement structure.

Surface drainage and drainage of the granular base and subbase layers (containing less than 10% of fine particles) must be ensured in order to allow a satisfactory performance, including uniform frost heaving, of the pavement structure.

The longitudinal and transverse surface profile must also be designed with an adequate slope (2%) to allow the evacuation of surface water to ditches designed for this purpose.

The longitudinal and transverse profile of the surface of the bituminous mix must also be designed with an adequate slope to allow the shedding of surface water towards manholes and catch basins fitted out for this purpose.

4.6 Roadway Widening

Roadway widening may be required in the case of problematic curves. In such cases, it is recommended that a geotechnical investigation be carried out in the widening area. A roadway widening on organic or fine compressible soils could cause a differential behaviour between the two roadway structures, which would result in major deterioration of the surface pavement, or even structural instability of the roadway.

If new fill sections or reprofiling of the existing roadway embankments are planned, a slope stability analysis should be carried out taking into account the nature of underlying soils and determining the appropriate slope geometry that will ensure the stability of the road embankments.

4.7 Raising of Road Embankment

If the roadway platform is to be raised significantly (more than 2 m) to correct the profile, the affected areas will require an intrusive geotechnical investigation to properly manage the potential stability or settlement risks. This will be specifically relevant in areas with organic soils or fine compressible soils.

4.8 Maintenance

In addition to the routine maintenance of the paved road (snow removal, deicing, and traction sanding), it is recommended that the pavement condition be inspected yearly to locate specific areas that will require preventive and corrective measures to ensure the longevity of the roadway. When required, the preventive procedures should be carried out before pavement deterioration commences. Cracks which appear within the paved surface should be sealed on the year of their appearance. Corrective measures could include some surface treatments, pavement overlays, repair of drainage systems, and local failures.

If the results of future pavement condition surveys suggest a requirement for a major rehabilitation treatment in specific areas, strength measurement tools such as a falling weight deflectometres (FWD) and continuous thickness measurement tools such as ground-penetrating radar (GPR) scans could be used to assess the conditions before selecting an appropriate treatment method. The data collected would be analyzed by a pavement engineer to determine the cause of the problem and to find the most suitable maintenance and/or rehabilitation method.

The potential of unanticipated future major rehabilitation requirements will depend greatly on the nature of the heavy truck traffic that will ultimately use the access road.

4.9 Recommended Level of Inspection and Testing

In order to ensure compliance with the design and to confirm assumptions made in this report and by the designers, construction observation, inspection and testing by a geotechnical engineer, as described below, are recommended.

All exposed soils should be inspected by a geotechnical engineer prior to the placement of granular materials. Such inspections are necessary to confirm the expected consistency and nature of the subgrade soils, to ensure that all soft spots have been identified and remediated and that the drainage of surface water has been ensured by the contractor. Subgrade inspections should be carried out to verify nature of the soil subgrade and the granular structure.

All sources of granular materials imported on site should be sampled, tested, and reviewed by a geotechnical engineer.

The placement of granular materials should be observed and tested by geotechnical personnel using nuclear density gauge to ensure all compaction requirements and optimal moisture content are achieved during construction.

4.10 Recommendations for Future Investigations

As mentioned in the previous section 4.4.1, a traffic analysis is recommended prior to the engineering design phases of the project to adjust the design and preliminary recommendations made in this geotechnical report in support of the feasibility report.

Also, future geotechnical studies will be required to refine the currently available geotechnical information for, but not limited to, the following:

- Complementary subgrade investigation on the existing road, including an overall reduction in the borehole spacing, following the *MTQ guideline Guide de planification et réalisation des études de reconnaissance de sols* – this could include approximately four to five boreholes per km of roadway.
- Geotechnical, stability and settlement analyses of the area where a major increase in the profile is proposed.
- Geotechnical investigation for areas of road realignment, widening, or total reconstruction.
- Additional geotechnical investigations for all new structures and culverts, as well as for those requiring major foundation rehabilitation (partial or total reconstruction).

5.0 References

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APPENDICES

Appendix A Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Experts-conseils and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec Experts-conseils present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec Experts-conseils is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Experts-conseils at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec Experts-conseils must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec Experts-conseils will not be responsible to any party for damages incurred as a result of failing to notify Stantec Experts-conseils that differing site or sub-surface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Experts-conseils, sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Experts-conseils cannot be responsible for site work carried out without being present.

Appendix B Figure

Stantec
Stantec Experts-conseils ltée
100, Alexis-Nihon boulevard, door 110
Saint-Laurent, Quebec H4M 2N6
Tel: 514.739.0708
Fax: 514.739.8499
www.stantec.com

Important note :
All dimensions shown in this figure are approximate and the user is responsible for checking them. Stantec should be notified of any errors or omissions as soon as possible.

Legend :

⊕ BH22-xx   Borehole 2022 (Stantec)

Geodesic coordinates (UTM-18)

Borehole N°	East (m)	North (m)
BH22-46	416897	5729910
BH22-47	417700	5729079
BH22-48	418263	5728341
BH22-49	418955	5727603

Graphic scale :

0 25 50 75 100 125 m

Scale : 1/2500

Source :
© Image from Google Earth 2023

Client :
Cree Development Corporation

Project :
La Grande Alliance - Feasibility Study, Phase I
Preliminary Geotechnical Investigation

Location :
Nemaska Access Road (Quebec)

Figure title :
Borehole Location

Project N° : 158100425.500.710.2	Draft by : S. Veillette, tech.
Date : 2023-01-31	Verified by : T. Coulaux, ing.
Drawing n° : 01	Page : 1 de 1

V:\01216\active\158100425\dessins\6.Figures et logs\Access-Road_500.710.2\Roadway\158100425.500.710.2-01.dwg   PRINTED: Fév 16, 2023

Paper size : 11x17

Appendix C Borehole Reports

BOREHOLE REPORT

Project:	La Grande Alliance - Feasibility Study - Phase I Preliminary Geotechnical Investigation	Coordinate :	Geo. System : UTM Zone: 18	Borehole :	**BH22-46**
		X :	416 897	Page :	1 of 1
Project No.:	158100425.500.710.2	Y :	5 729 910	Start date :	2022-06-29
Client:	Cree Development Corporation	Type of borehole :	Hollow Stem Auger	Inspector :	S. Pelletier, tech.
Site:	Nemaska Access Road	Equipment :	CME	Depth :	1,83 m
		Sampling type :	B, N		
		Corer :	Figure :		

SAMPLE TYPE

SS	Split spoon
CS	Continuous sampling
DC	Diamond rock core
AS	Auger
TW	Thin wall sampler
ST	Shelby tube
MA	Manual sample

QUALITATIVE TERMINOLOGY

Clay	< 0.002 mm
Silt	0.002 - 0.08 mm
Sand	0.08 - 5 mm
Gravel	5 - 80 mm
Cobbles	80 - 200 mm
Boulders	> 200 mm

QUANTITATIVE TERMINOLOGY

Traces	< 10 %
Some	10 - 20 %
Adjective (...y)	20 - 35 %
and (ex: and gravel)	> 35 %
Main word	Dominant fraction

SYMBOLS

N	Standard penetration value (ASTM D 1586)
Nc	Dynamic cone penetration value (BNQ 2501-145)
RQD	Rock Quality Designation (%)

GROUNDWATER

	Date	Depth
Reading 1		m
Reading 2		m

Remarks :

SAMPLE STATE

☒	Remoulded
▨	Intact (thin wall sampler)
■	Lost
◧	Core (diamond rock core)

MECHANIC CHARACTERISTICS OF SOILS

COMPACTION	INDEX "N"	CONSISTENCY	Cu OR Su (kPa)
Very loose	0 - 4	Very soft	< 12
Loose	4 - 10	Soft	12 - 25
Compact	10 - 30	Firm	25 - 50
Dense	30 - 50	Stiff	50 - 100
Very dense	> 50	Very stiff	100 - 200
		Hard	> 200

ROCK QUALITY DESIGNATION

QUALIFICATIVE	RQD
Very poor	< 25 %
Poor	25 - 50 %
Fair	50 - 75 %
Good	75 - 90 %
Excellent	90 - 100 %

JOINTS SPACING

Very tight	< 20 mm
Tight	20 - 60 mm
Close	60 - 200 mm
Moderately spaced	200 - 600 mm
Spaced	600 - 2000 mm
Very spaced	2000 - 6000 mm
Wide	> 6000 mm

STRATIGRAPHY

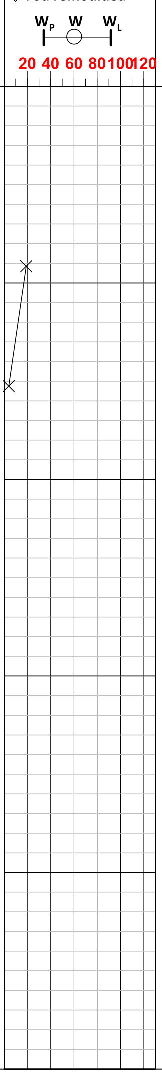
SAMPLES

TESTS

GA : grain size analysis
H : hydrometer test
C : consolidation
W : water content
W_L : liquid limit
W_P : plastic limit
Dr : specific gravity
k : permeability
f'c : compressive str.
OM : organic matter
CA : chemical analyses
SAV : soil agressivity value

☒ : N (standard pen.)
▽ : Nc (dyn. pen.)
■ : Cu intact
☐ : Cu remoulded
◆ : Su intact
◇ : Su remoulded

DEPTH (m)	DEPTH (ft)	DEPTH (m)	DESCRIPTION OF SOILS AND ROCK	SYMBOL	STATE	TYPE N°	SUB - SAMPLE	CALIBER	RECOVERY (%)	N - RQD	Standard penetration test BLOWS/150mm	WATER LEVEL / WATER INFLOW	TESTS	REMARKS
		0,00	Surface course : Brown moist SAND and GRAVEL with traces of silt.		☒	SS-01	A	N	66		4-10-12-13		GA	
		0,44	Granular fill : Grey moist SAND with some silt and traces of gravel.				B						GA	
					☒	SS-02	A	B	75	19	13-9-10-3			
1		0,82	Brown moist Silty SAND with some gravel, compact.				B						GA	
	5	1,22	Native granular deposit : Brown moist Silty SAND with traces of gravel, very loose.		☒	SS-03		B	51	4	3-2-2-2		GA	
2		1,83	END OF BOREHOLE											
3	10													
4														
	15													



General remarks: **Boreholes positionned on Site with a handheld GPS of 3 m precision**

Verified by :
T. Coulaux, ing.
Date : 2023-02-15

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Stantec

BOREHOLE REPORT

Project:	**La Grande Alliance - Feasibility Study - Phase I** **Preliminary Geotechnical Investigation**	Coordinate :	**Geo. System : UTM Zone: 18**	Borehole :	**BH22-47**
		X :	**417 700**	Page :	**1 of 1**
Project No.:	**158100425.500.710.2**	Y :	**5 729 079**	Start date :	**2022-06-29**
Client:	**Cree Development Corporation**	Type of borehole :	**Hollow Stem Auger**	Inspector :	**S. Pelletier, tech.**
Site:	**Nemaska Access Road**	Equipment :	**CME**	Depth :	**1,83 m**
		Sampling type :	**B, N**		
		Corer :		Figure :	

SAMPLE TYPE

SS	Split spoon
CS	Continuous sampling
DC	Diamond rock core
AS	Auger
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ST	Shelby tube
MA	Manual sample

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and (ex: and gravel)	> 35 %
Main word	Dominant fraction

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RQD	Rock Quality Designation (%)

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	Date	Depth
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Reading 2		m

Remarks :

SAMPLE STATE

☒	Remoulded
▨	Intact (thin wall sampler)
■	Lost
◧	Core (diamond rock core)

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		Hard	> 200

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Fair	50 - 75 %
Good	75 - 90 %
Excellent	90 - 100 %

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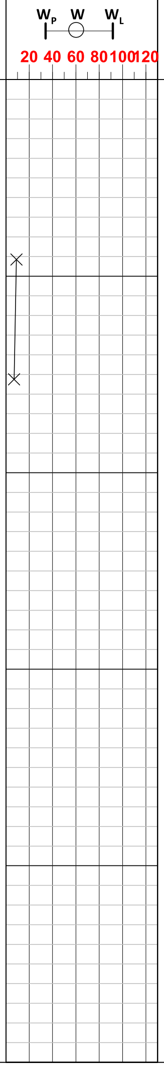
Tight	20 - 60 mm
Close	60 - 200 mm
Moderately spaced	200 - 600 mm
Spaced	600 - 2000 mm
Very spaced	2000 - 6000 mm
Wide	> 6000 mm

STRATIGRAPHY / SAMPLES / TESTS

DEPTH (m)	DESCRIPTION OF SOILS AND ROCK	SYMBOL	STATE	TYPE N°	SUB - SAMPLE	CALIBER	RECOVERY (%)	N - RQD	Standard penetration test BLOWS/150mm	WATER LEVEL / WATER INFLOW	TESTS	REMARKS
0,00	Surface course : Brown moist Gravelly SAND with traces of silt.		☒	SS-01		N	48		5-12-61-36		GA	
0,61	Granular fill : Grey moist Silty SAND with some gravel, loose.		☒	SS-02		B	41	9	6-4-5-4		GA	
1,22	Native granular deposit : Grey moist to saturated Silty SAND with traces of gravel, loose.		☒	SS-03		B	51	7	4-4-3-3		GA	
1,83	END OF BOREHOLE											

GA : grain size analysis
H : hydrometer test
C : consolidation
W : water content
W_L : liquid limit
W_P : plastic limit
Dr : specific gravity
k : permeability
f'c : compressive str.
OM : organic matter
CA : chemical analyses
SAV : soil agressivity value

× : N (standard pen.)
▽ : Nc (dyn. pen.)
■ : Cu intact
□ : Cu remoulded
◆ : Su intact
◇ : Su remoulded



General remarks:	**Boreholes positionned on Site with a handheld GPS of 3 m precision**	Verified by :	**T. Coulaux, ing.**
		Date :	**2023-02-15**

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BOREHOLE REPORT

Project: **La Grande Alliance - Feasibility Study - Phase I**
Preliminary Geotechnical Investigation

Project No.: **158100425.500.710.2**

Client: **Cree Development Corporation**

Site: **Nemaska Access Road**

Coordinate : **Geo. System : UTM Zone: 18**
X : **418 263**
Y : **5 728 341**
Type of borehole : **Hollow Stem Auger**
Equipment : **CME**
Sampling type : **B, N**
Corer :
Figure :

Borehole : **BH22-48**
Page : **1 of 1**
Start date : **2022-06-29**
Inspector : **S. Pelletier, tech.**
Depth : **1,83 m**

SAMPLE TYPE

SS	Split spoon
CS	Continuous sampling
DC	Diamond rock core
AS	Auger
TW	Thin wall sampler
ST	Shelby tube
MA	Manual sample

QUALITATIVE TERMINOLOGY

Clay	< 0.002 mm
Silt	0.002 - 0.08 mm
Sand	0.08 - 5 mm
Gravel	5 - 80 mm
Cobbles	80 - 200 mm
Boulders	> 200 mm

QUANTITATIVE TERMINOLOGY

Traces	< 10 %
Some	10 - 20 %
Adjective (...y)	20 - 35 %
and (ex: and gravel)	> 35 %
Main word	Dominant fraction

SYMBOLS

N	Standard penetration value (ASTM D 1586)
Nc	Dynamic cone penetration value (BNQ 2501-145)
RQD	Rock Quality Designation (%)

GROUNDWATER

	Date	Depth
Reading 1		m
Reading 2		m

Remarks :

SAMPLE STATE

☒	Remoulded
▨	Intact (thin wall sampler)
■	Lost
◧	Core (diamond rock core)

MECHANIC CHARACTERISTICS OF SOILS

COMPACTION	INDEX "N"
Very loose	0 - 4
Loose	4 - 10
Compact	10 - 30
Dense	30 - 50
Very dense	> 50

CONSISTENCY	Cu OR Su (kPa)
Very soft	< 12
Soft	12 - 25
Firm	25 - 50
Stiff	50 - 100
Very stiff	100 - 200
Hard	> 200

ROCK QUALITY DESIGNATION

QUALIFICATIVE	RQD
Very poor	< 25 %
Poor	25 - 50 %
Fair	50 - 75 %
Good	75 - 90 %
Excellent	90 - 100 %

JOINTS SPACING

Very tight	< 20 mm
Tight	20 - 60 mm
Close	60 - 200 mm
Moderately spaced	200 - 600 mm
Spaced	600 - 2000 mm
Very spaced	2000 - 6000 mm
Wide	> 6000 mm

STRATIGRAPHY

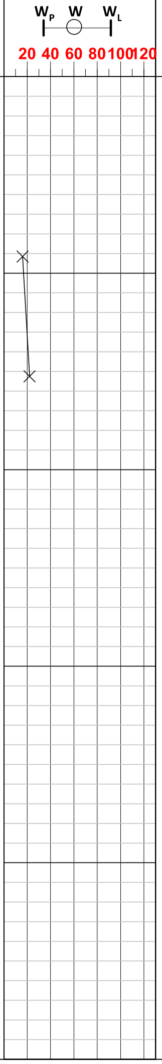
SAMPLES

TESTS

GA : grain size analysis
H : hydrometer test
C : consolidation
W : water content
W_L : liquid limit
W_P : plastic limit
Dr : specific gravity
k : permeability
f'c : compressive str.
OM : organic matter
CA : chemical analyses
SAV : soil agressivity value

☒ : N (standard pen.)
▽ : Nc (dyn. pen.)
■ : Cu intact
☐ : Cu remoulded
◆ : Su intact
◇ : Su remoulded

DEPTH (m)	DESCRIPTION OF SOILS AND ROCK	STATE	TYPE N°	SUB - SAMPLE	CALIBER	RECOVERY (%)	N - RQD	Standard penetration test BLOWS/150mm	WATER LEVEL / WATER INFLOW	TESTS	REMARKS
0,00	Surface course : Brown moist SAND and GRAVEL with traces of silt.	☒	SS-01	A	N	67		10-22-21-19		GA	
0,51	Native granular deposit : Grey moist Silty SAND with some gravel, compact.			B							
		☒	SS-02		B	56	16	10-7-9-10		GA	
		■	SS-03		B	0	22	14-13-9-14			
1,83	END OF BOREHOLE										



General remarks: **Boreholes positionned on Site with a handheld GPS of 3 m precision**

Verified by : T. Coulaux, ing.
Date : 2023-02-15

BOREHOLE REPORT

Project:	**La Grande Alliance - Feasibility Study - Phase I** **Preliminary Geotechnical Investigation**	Coordinate :	**Geo. System : UTM Zone: 18**	Borehole :	**BH22-49**
		X :	**418 955**	Page :	**1 of 1**
Project No.:	**158100425.500.710.2**	Y :	**5 727 603**	Start date :	**2022-06-29**
Client:	**Cree Development Corporation**	Type of borehole :	**Hollow Stem Auger**	Inspector :	**S. Pelletier, tech.**
Site:	**Nemaska Access Road**	Equipment :	**CME**	Depth :	**1,83 m**
		Sampling type :	**B, N**		
		Corer :	Figure :		

SAMPLE TYPE

SS	Split spoon
CS	Continuous sampling
DC	Diamond rock core
AS	Auger
TW	Thin wall sampler
ST	Shelby tube
MA	Manual sample

QUALITATIVE TERMINOLOGY

Clay	< 0.002 mm
Silt	0.002 - 0.08 mm
Sand	0.08 - 5 mm
Gravel	5 - 80 mm
Cobbles	80 - 200 mm
Boulders	> 200 mm

QUANTITATIVE TERMINOLOGY

Traces	< 10 %
Some	10 - 20 %
Adjective (...y)	20 - 35 %
and (ex: and gravel)	> 35 %
Main word	Dominant fraction

SYMBOLS

N	Standard penetration value (ASTM D 1586)
Nc	Dynamic cone penetration value (BNQ 2501-145)
RQD	Rock Quality Designation (%)

GROUNDWATER ▽

	Date	Depth
Reading 1		m
Reading 2		m

Remarks :

SAMPLE STATE

☒	Remoulded
▨	Intact (thin wall sampler)
■	Lost
◧	Core (diamond rock core)

MECHANIC CHARACTERISTICS OF SOILS

COMPACTION	INDEX "N"	CONSISTENCY	Cu OR Su (kPa)
Very loose	0 - 4	Very soft	< 12
Loose	4 - 10	Soft	12 - 25
Compact	10 - 30	Firm	25 - 50
Dense	30 - 50	Stiff	50 - 100
Very dense	> 50	Very stiff	100 - 200
		Hard	> 200

ROCK QUALITY DESIGNATION

QUALIFICATIVE	RQD
Very poor	< 25 %
Poor	25 - 50 %
Fair	50 - 75 %
Good	75 - 90 %
Excellent	90 - 100 %

JOINTS SPACING

Very tight	< 20 mm
Tight	20 - 60 mm
Close	60 - 200 mm
Moderately spaced	200 - 600 mm
Spaced	600 - 2000 mm
Very spaced	2000 - 6000 mm
Wide	> 6000 mm

STRATIGRAPHY

SAMPLES

TESTS

GA : grain size analysis
H : hydrometer test
C : consolidation
W : water content
W_L : liquid limit
W_P : plastic limit
Dr : specific gravity
k : permeability
f'c : compressive str.
OM : organic matter
CA : chemical analyses
SAV : soil agressivity value

× : N (standard pen.)
▽ : Nc (dyn. pen.)
■ : Cu intact
☐ : Cu remoulded
◆ : Su intact
◇ : Su remoulded

W_P W W_L

20 40 60 80 100 120

DEPTH (m)	DESCRIPTION OF SOILS AND ROCK	SYMBOL	STATE	TYPE N°	SUB - SAMPLE	CALIBER	RECOVERY (%)	N - RQD	Standard penetration test BLOWS/150mm	WATER LEVEL / WATER INFLOW	TESTS	REMARKS
0,00	Surface course : Brown moist SAND and GRAVEL with traces of silt.	☒	☒	SS-01	A	N	54		9-20-18-17		GA	
0,43	Granular fill : Grey moist SAND with some silt and gravel, compact.	▨			B							
			☒	SS-02		B	66	20	12-10-10-11		GA	
1,22	Native granular deposit : Grey moist Silty SAND with some gravel, compact.		☒	SS-03		B	54	13	7-7-6-8		GA	
1,83	END OF BOREHOLE											

Depth scale: 1, 2, 3, 4 (m); 5, 10, 15 (ft)

General remarks:	**Boreholes positionned on Site with a handheld GPS of 3 m precision**	Verified by :	**T. Coulaux, ing.**
		Date :	**2023-02-15**

Appendix D Laboratory Test Results

Stantec
2273 Michelin Street,
Laval QC, H7L 5B8

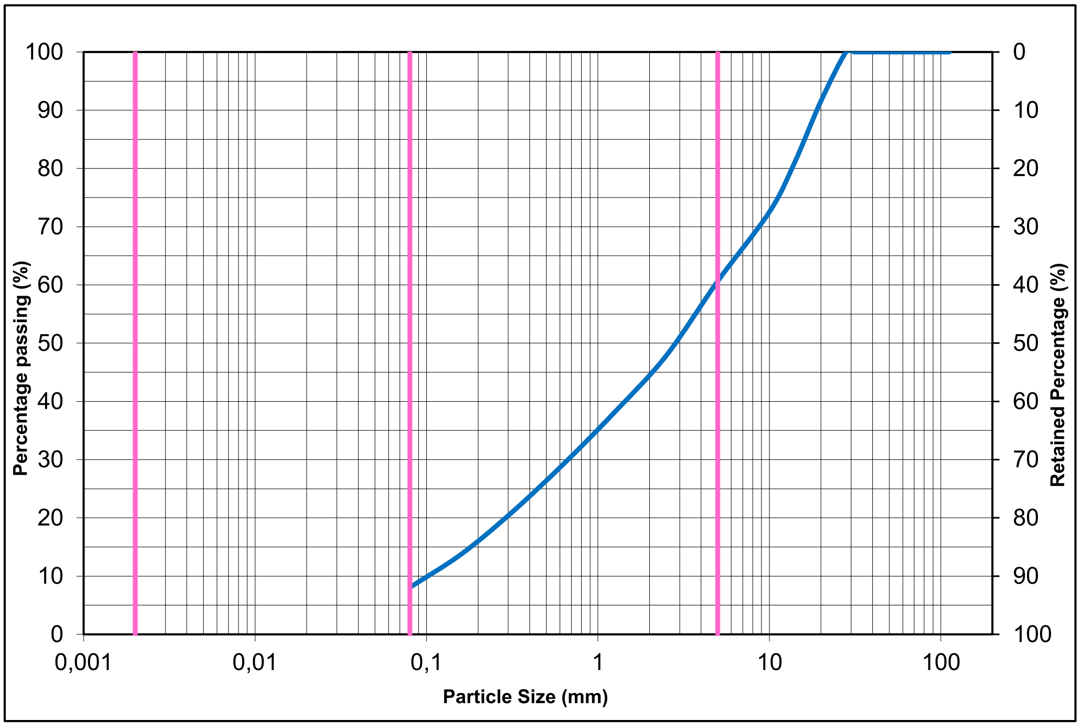
LABORATORY TESTING REPORT

Client : Cree Development Corporation
Project : LGA - Nemaska Access Road (Qc)
Sampled by : Sylvain Pelletier
Sampling Date : June 29, 2022

Project No : 158100425.500.710.2
Sample No : BH22-46 SS-01A
Depth : 0,00 - 0,44m
Material Description : Sand and Gravel, traces of fine particles

Grain Size Analysis (BNQ 2501-025)

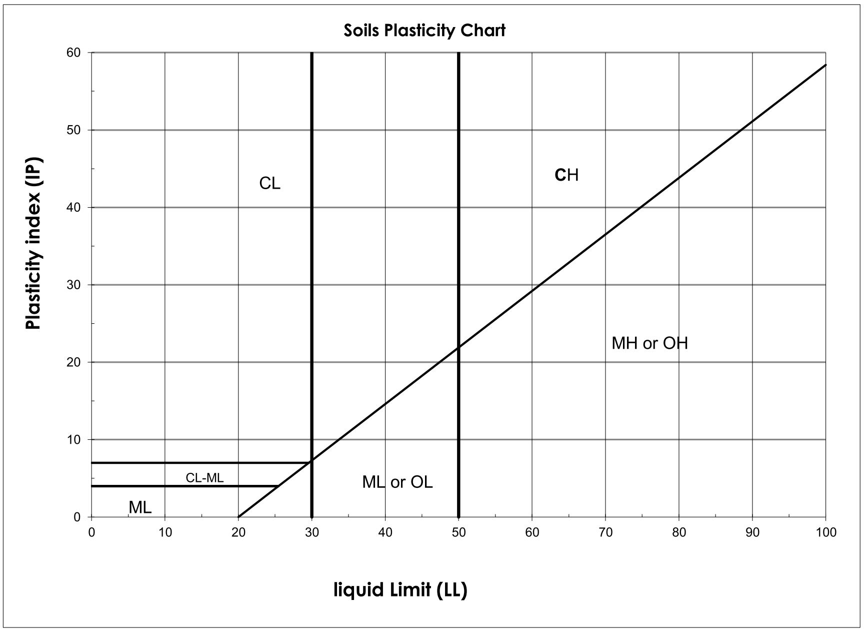
Openings Dimensions	Cumulative Results
mm	%
112	100
80,0	100
56,0	100
40,0	100
31,5	100
28,0	100
20,0	92
14,0	81
10,0	73
5,00	61
2,50	48
1,25	38
0,630	29
0,315	21
0,160	14
0,080	8,1



% Gravel : 39,3 % Sand : 52,6 % Fine particles : 8,1

Other tests

Test / Standard	Results



Remarks :

Prepared by : Benoit Cyr, Geo.

Date : October 25, 2022

Stantec
2273 Michelin Street,
Laval QC, H7L 5B8

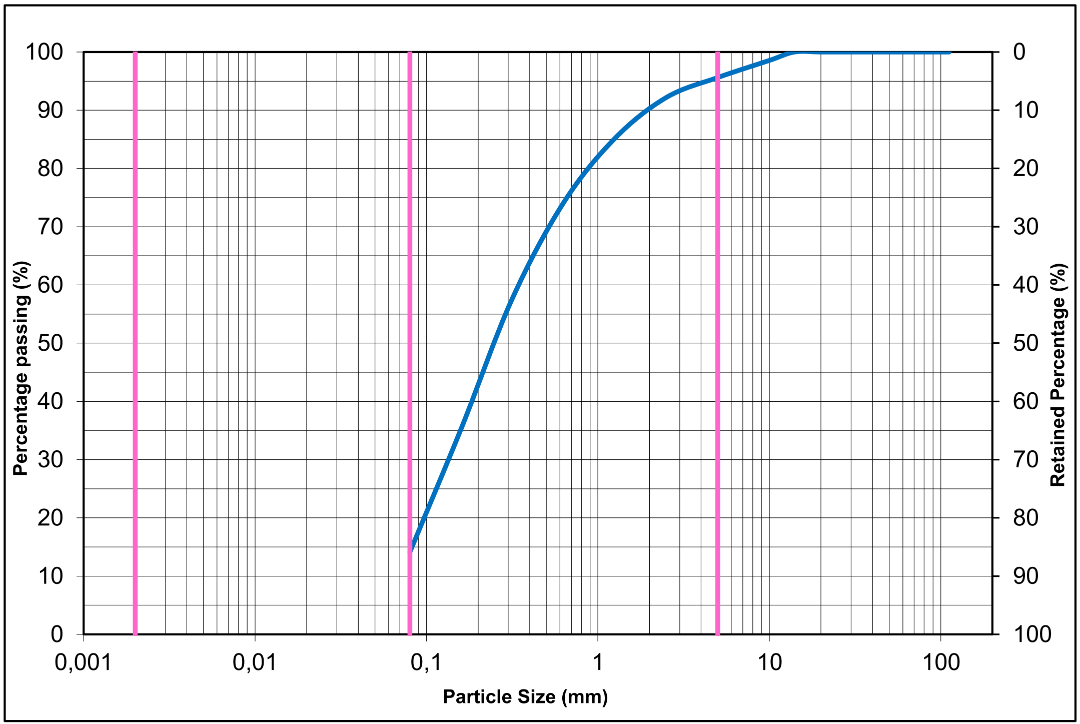
LABORATORY TESTING REPORT

Client : Cree Development Corporation
Project : LGA - Nemaska Access Road (Qc)
Sampled by : Sylvain Pelletier
Sampling Date : June 29, 2022

Project No : 158100425.500.710.2
Sample No : BH22-46 SS-01B
Depth : 0,44 - 0,61m
Material Description : Sand, some fine particles, traces of Gravel

Grain Size Analysis (BNQ 2501-025)

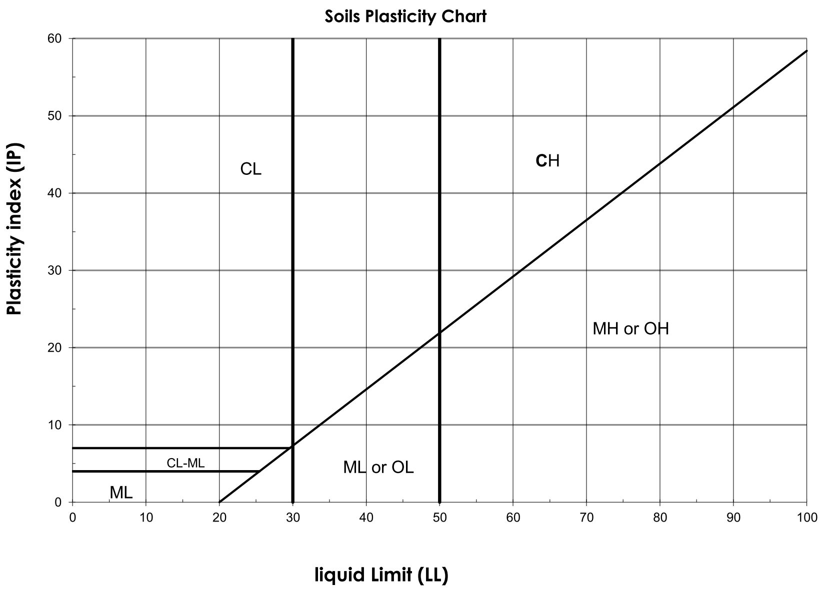
Openings Dimensions	Cumulative Results
mm	%
112	100
80,0	100
56,0	100
40,0	100
31,5	100
28,0	100
20,0	100
14,0	100
10,0	99
5,00	96
2,50	92
1,25	85
0,630	74
0,315	58
0,160	35
0,080	14,1



% Gravel : 4,4 % Sand : 81,5 % Fine particles : 14,1

Other tests

Test / Standard	Results



Remarks :

Prepared by : Benoit Cyr, Geo. BA

Date : October 25, 2022

Stantec
2273 Michelin Street,
Laval QC, H7L 5B8

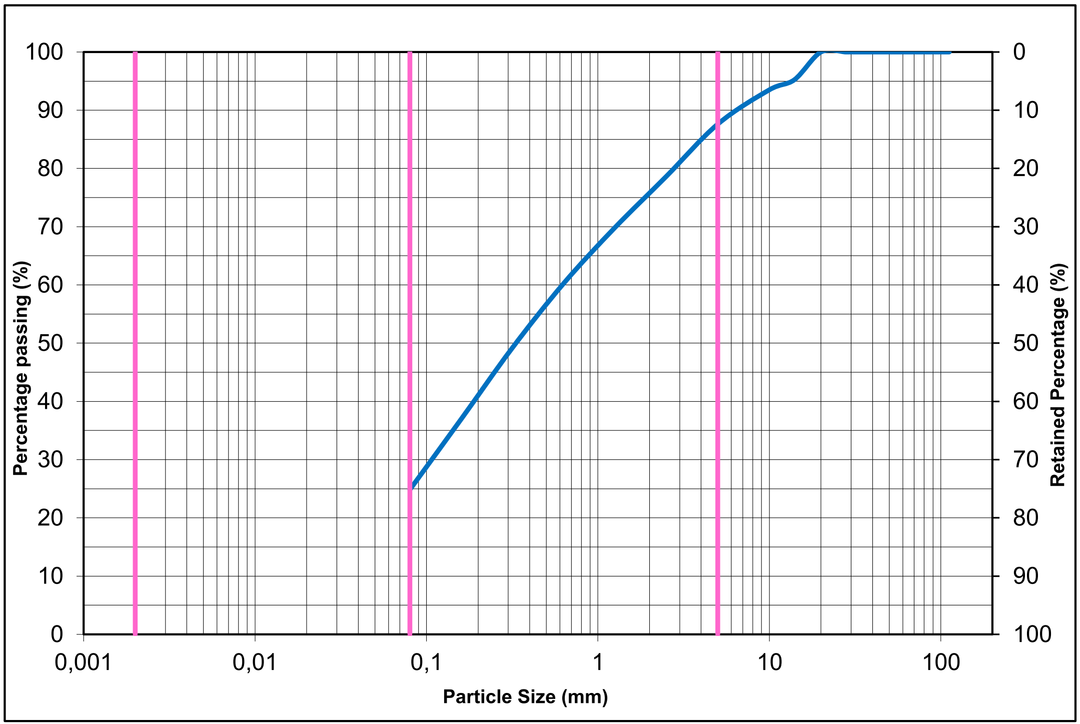
LABORATORY TESTING REPORT

Client : Cree Development Corporation
Project : LGA - Nemaska Access Road (Qc)
Sampled by : Sylvain Pelletier
Sampling Date : June 29, 2022

Project No : 158100425.500.710.2
Sample No : BH22-46 SS-02B
Depth : 0,82 - 1,22m
Material Description : Silty Sand, some Gravel

Grain Size Analysis (BNQ 2501-025)

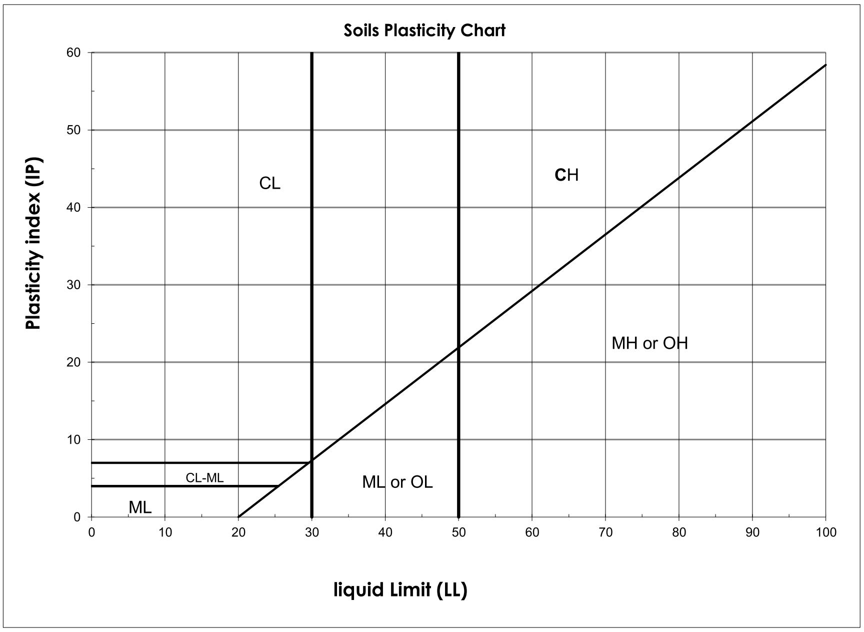
Openings Dimensions	Cumulative Results
mm	%
112	100
80,0	100
56,0	100
40,0	100
31,5	100
28,0	100
20,0	100
14,0	95
10,0	94
5,00	88
2,50	79
1,25	70
0,630	60
0,315	49
0,160	37
0,080	24,9



% Gravel : 12,3 % Sand : 62,8 % Fine particles : 24,9

Other tests

Test / Standard	Results



Remarks :

Prepared by : Benoit Cyr, Geo.

Date : October 25, 2022

Stantec
2273 Michelin Street,
Laval QC, H7L 5B8

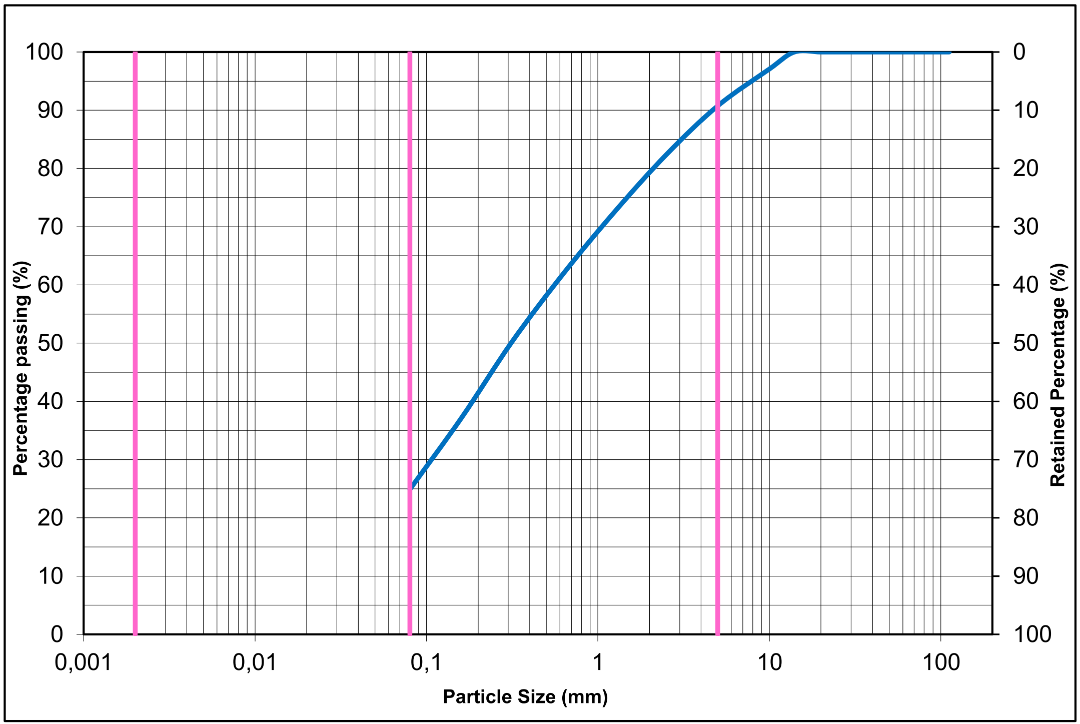
LABORATORY TESTING REPORT

Client : Cree Development Corporation
Project : LGA - Nemaska Access Road (Qc)
Sampled by : Sylvain Pelletier
Sampling Date : June 29, 2022

Project No : 158100425.500.710.2
Sample No : BH22-46 SS-03
Depth : 1,22 - 1,83m
Material Description : Silty Sand, traces of Gravel

Grain Size Analysis (BNQ 2501-025)

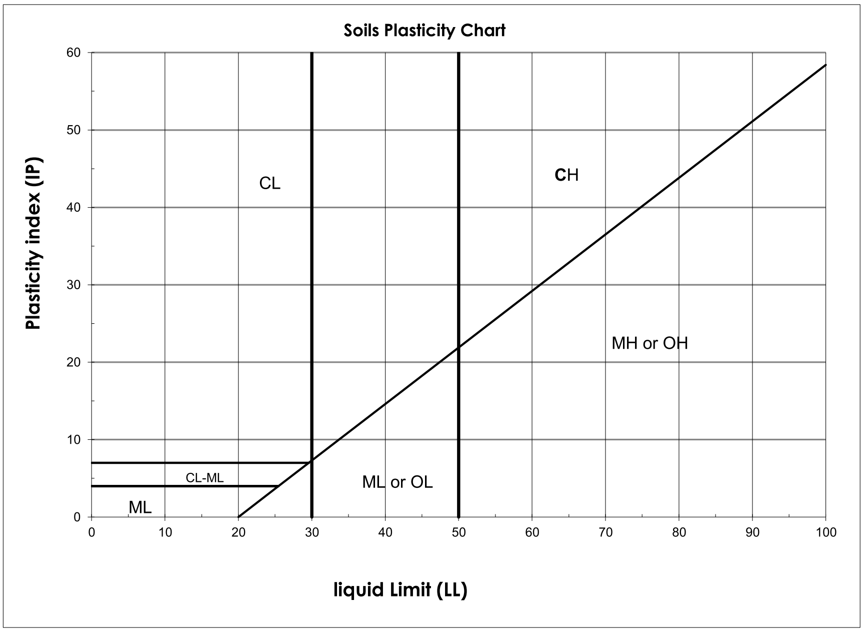
Openings Dimensions	Cumulative Results
mm	%
112	100
80,0	100
56,0	100
40,0	100
31,5	100
28,0	100
20,0	100
14,0	100
10,0	97
5,00	91
2,50	82
1,25	73
0,630	62
0,315	50
0,160	37
0,080	24,9



% Gravel : 9,3 % Sand : 65,8 % Fine particles : 24,9

Other tests

Test / Standard	Results



Remarks :

Prepared by : Benoit Cyr, Geo.

Date : October 25, 2022

Stantec

2273 Michelin Street,
Laval QC, H7L 5B8

LABORATORY TESTING REPORT

Client : Cree Development Corporation

Project : LGA - Nemaska Access Road (Qc)

Sampled by : Sylvain Pelletier

Sampling Date : June 29, 2022

Project No : 158100425.500.710.2

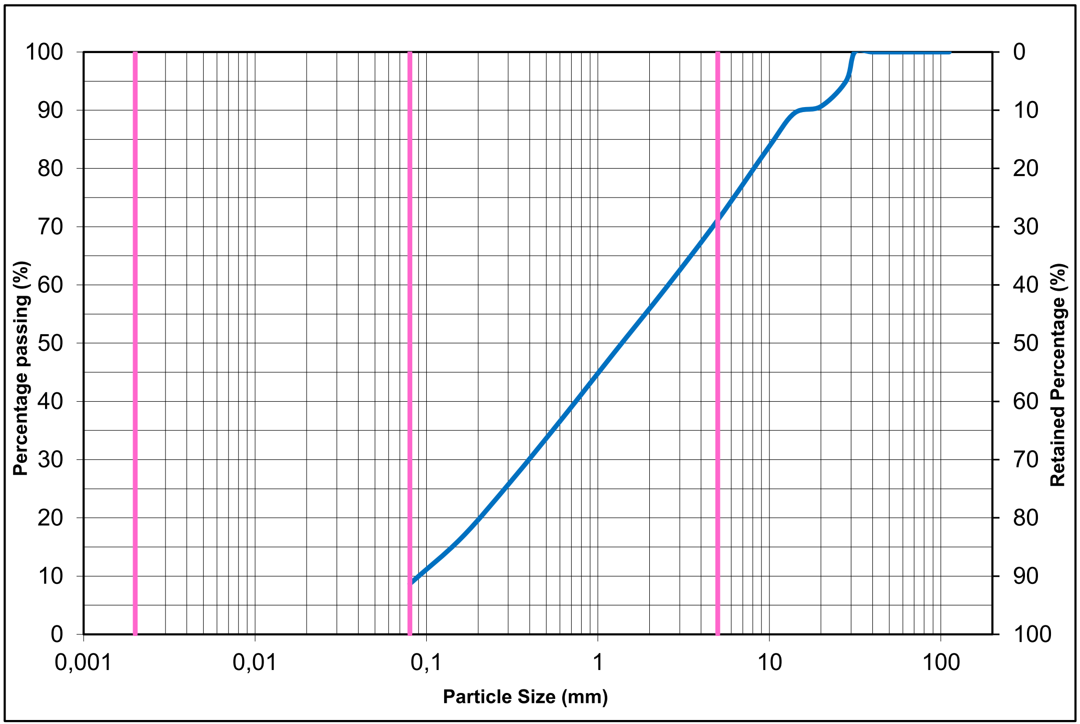
Sample No : BH22-47 SS-01

Depth : 0,00 - 0,61m

Material Description : Gravely Sand, traces of fine particles

Grain Size Analysis (BNQ 2501-025)

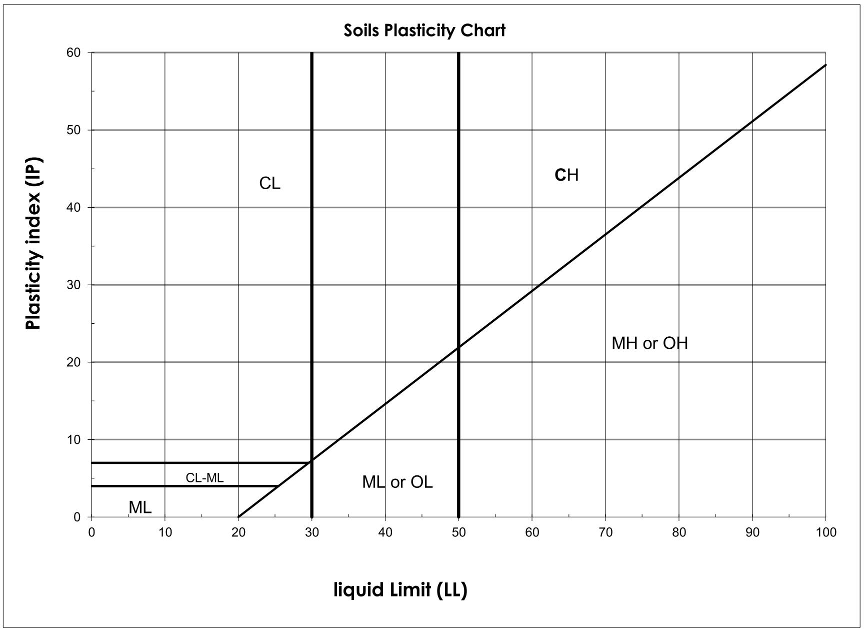
Openings Dimensions	Cumulative Results
mm	%
112	100
80,0	100
56,0	100
40,0	100
31,5	100
28,0	95
20,0	91
14,0	89
10,0	84
5,00	71
2,50	60
1,25	48
0,630	37
0,315	26
0,160	17
0,080	8,7



% Gravel : 28,8 % Sand : 62,5 % Fine particles : 8,7

Other tests

Test / Standard	Results



Remarks :

Prepared by : Benoit Cyr, Geo.

Date : October 25, 2022

Stantec
2273 Michelin Street,
Laval QC, H7L 5B8

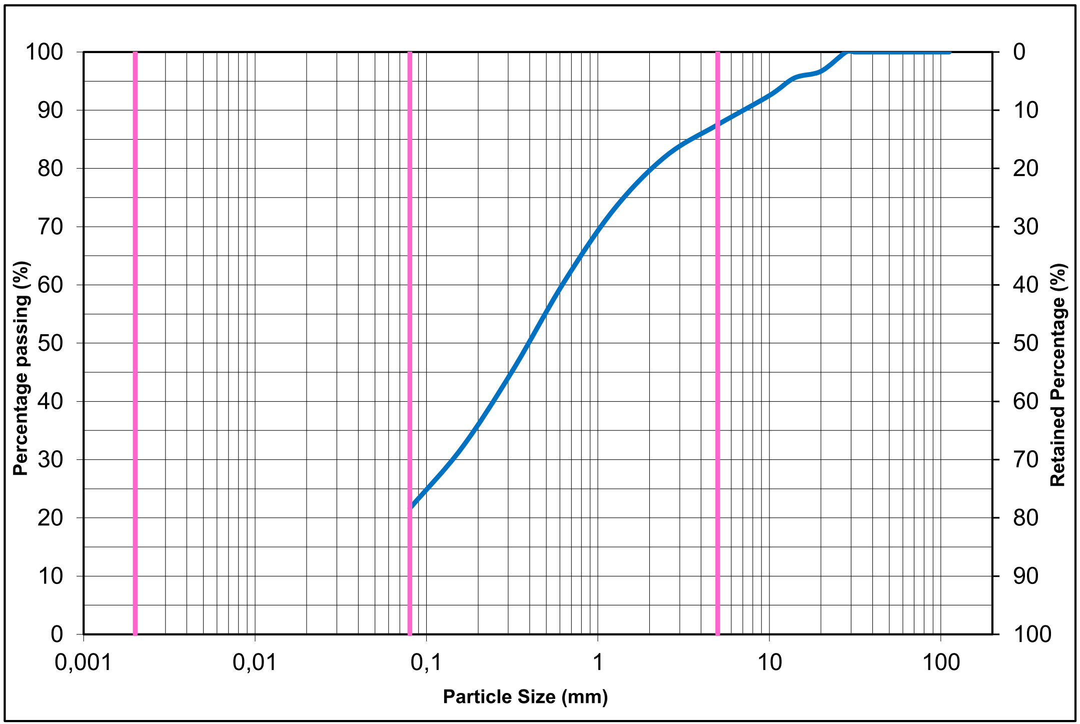
LABORATORY TESTING REPORT

Client : Cree Development Corporation
Project : LGA - Nemaska Access Road (Qc)
Sampled by : Sylvain Pelletier
Sampling Date : June 29, 2022

Project No : 158100425.500.710.2
Sample No : BH22-47 SS-02
Depth : 0,61 - 1,22m
Material Description : Silty Sand, some Gravel

Grain Size Analysis (BNQ 2501-025)

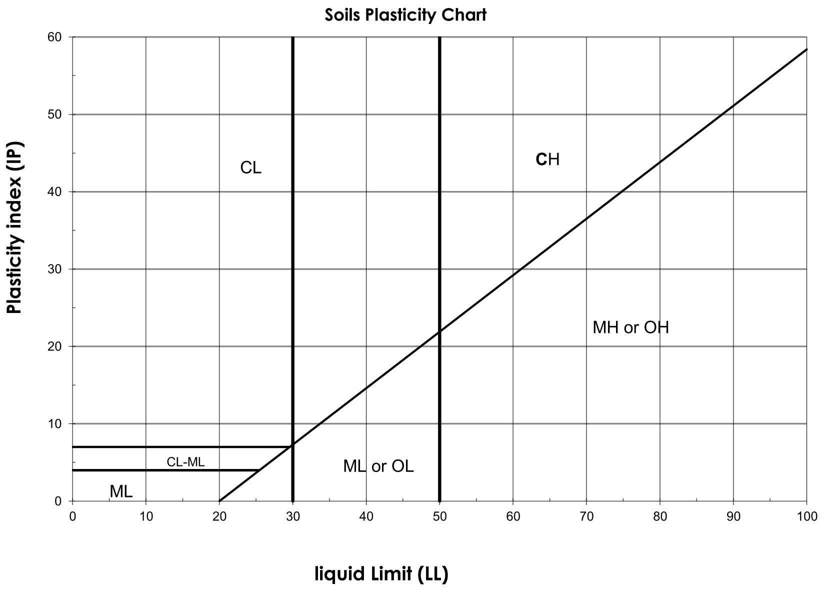
Openings Dimensions	Cumulative Results
mm	%
112	100
80,0	100
56,0	100
40,0	100
31,5	100
28,0	100
20,0	97
14,0	96
10,0	93
5,00	88
2,50	82
1,25	73
0,630	60
0,315	45
0,160	32
0,080	21,6



% Gravel : 12,5 % Sand : 65,9 % Fine particles : 21,6

Other tests

Test / Standard	Results



Remarks :

Prepared by : Benoit Cyr, Geo.

Date : October 25, 2022

Stantec

2273 Michelin Street,
Laval QC, H7L 5B8

LABORATORY TESTING REPORT

Client : Cree Development Corporation

Project : LGA - Nemaska Access Road (Qc)

Sampled by : Sylvain Pelletier

Sampling Date : June 29, 2022

Project No : 158100425.500.710.2

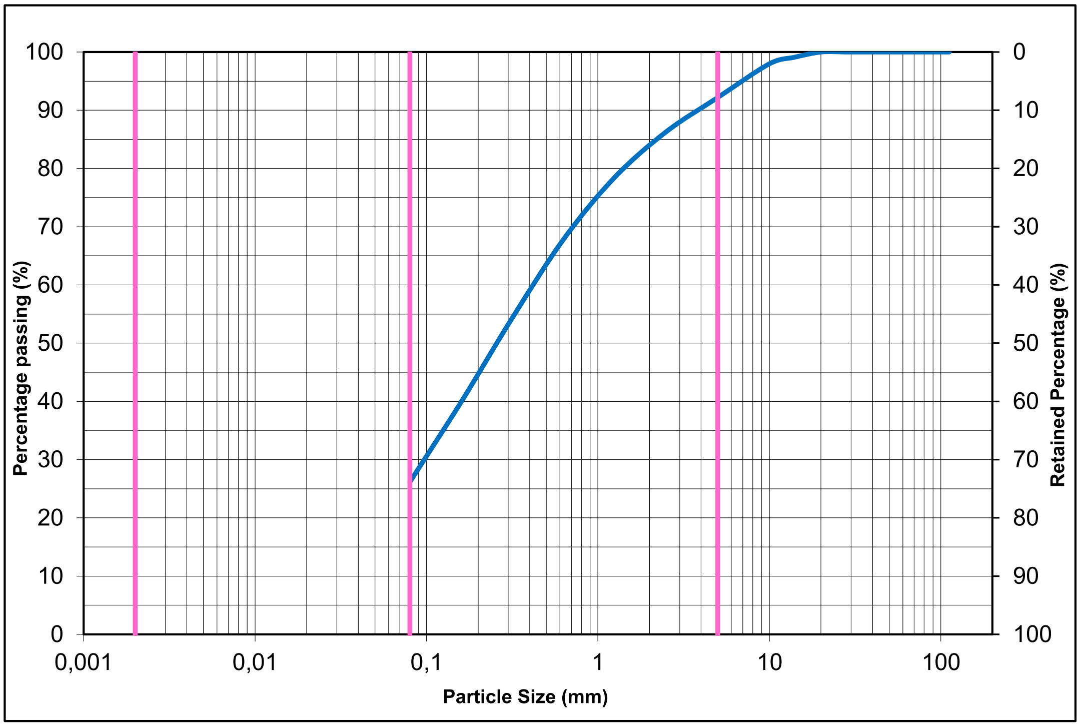
Sample No : BH22-47 SS-03

Depth : 1,22 - 1,83m

Material Description : Silty Sand, traces of Gravel

Grain Size Analysis (BNQ 2501-025)

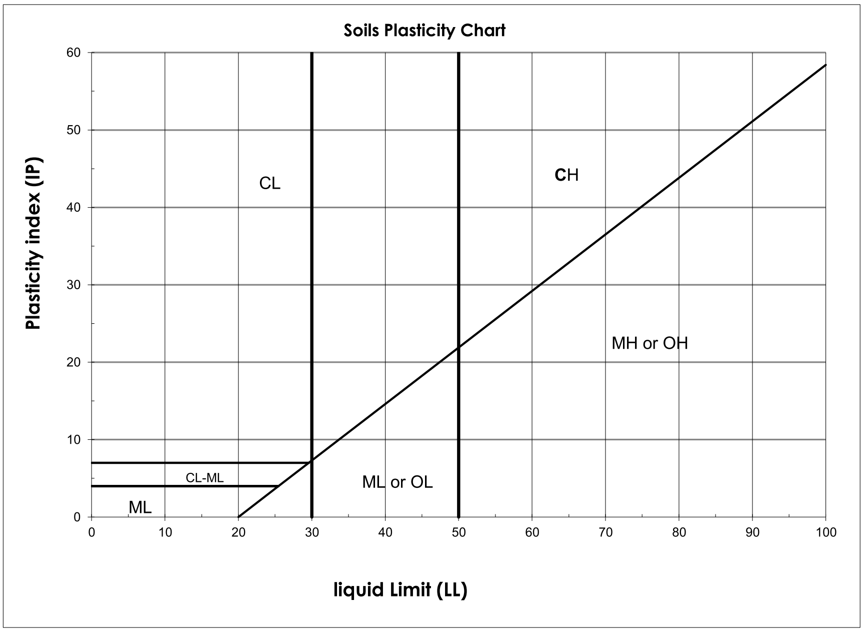
Openings Dimensions	Cumulative Results
mm	%
112	100
80,0	100
56,0	100
40,0	100
31,5	100
28,0	100
20,0	100
14,0	99
10,0	98
5,00	92
2,50	86
1,25	78
0,630	68
0,315	54
0,160	40
0,080	26,2



% Gravel : 7,8 % Sand : 66,0 % Fine particles : 26,2

Other tests

Test / Standard	Results



Remarks :

Prepared by : Benoit Cyr, Geo.

Date : October 25, 2022

Stantec
2273 Michelin Street,
Laval QC, H7L 5B8

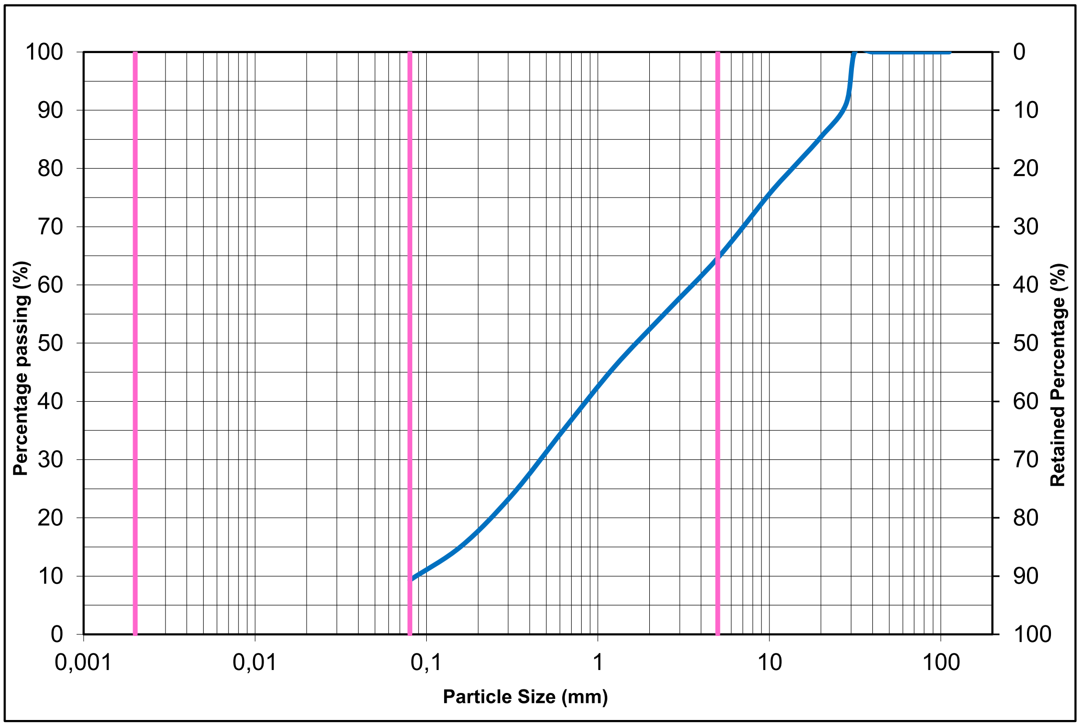
LABORATORY TESTING REPORT

Client : Cree Development Corporation
Project : LGA - Nemaska Access Road (Qc)
Sampled by : Sylvain Pelletier
Sampling Date : June 29, 2022

Project No : 158100425.500.710.2
Sample No : BH22-48 SS-01A
Depth : 0,00 - 0,51m
Material Description : Sand and Gravel, traces of fine particles

Grain Size Analysis (BNQ 2501-025)

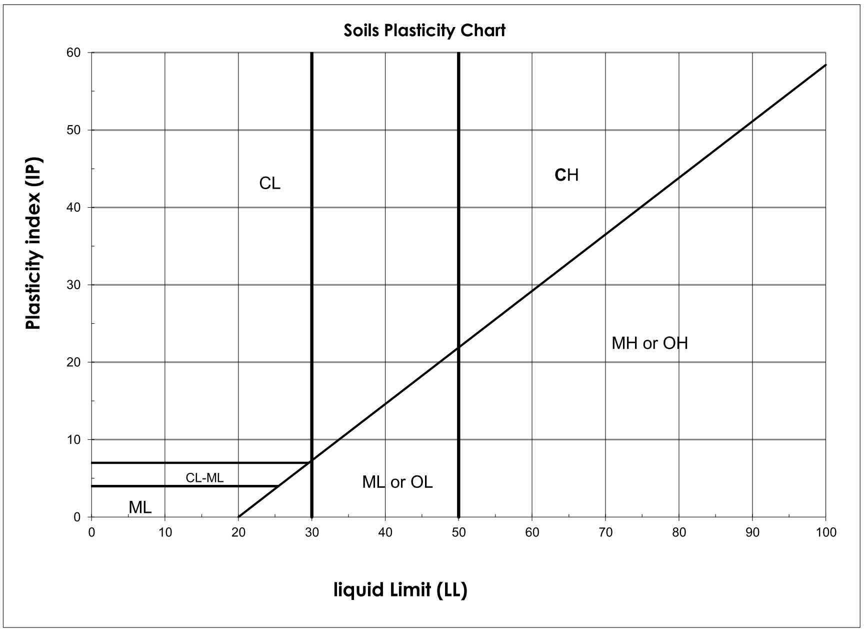
Openings Dimensions	Cumulative Results
mm	%
112	100
80,0	100
56,0	100
40,0	100
31,5	100
28,0	91
20,0	85
14,0	80
10,0	76
5,00	65
2,50	55
1,25	46
0,630	35
0,315	24
0,160	15
0,080	9,3



% Gravel : 35,4 % Sand : 55,3 % Fine particles : 9,3

Other tests

Test / Standard	Results



Remarks :

Prepared by : Benoit Cyr, Geo.

Date : October 25, 2022

Stantec
2273 Michelin Street,
Laval QC, H7L 5B8

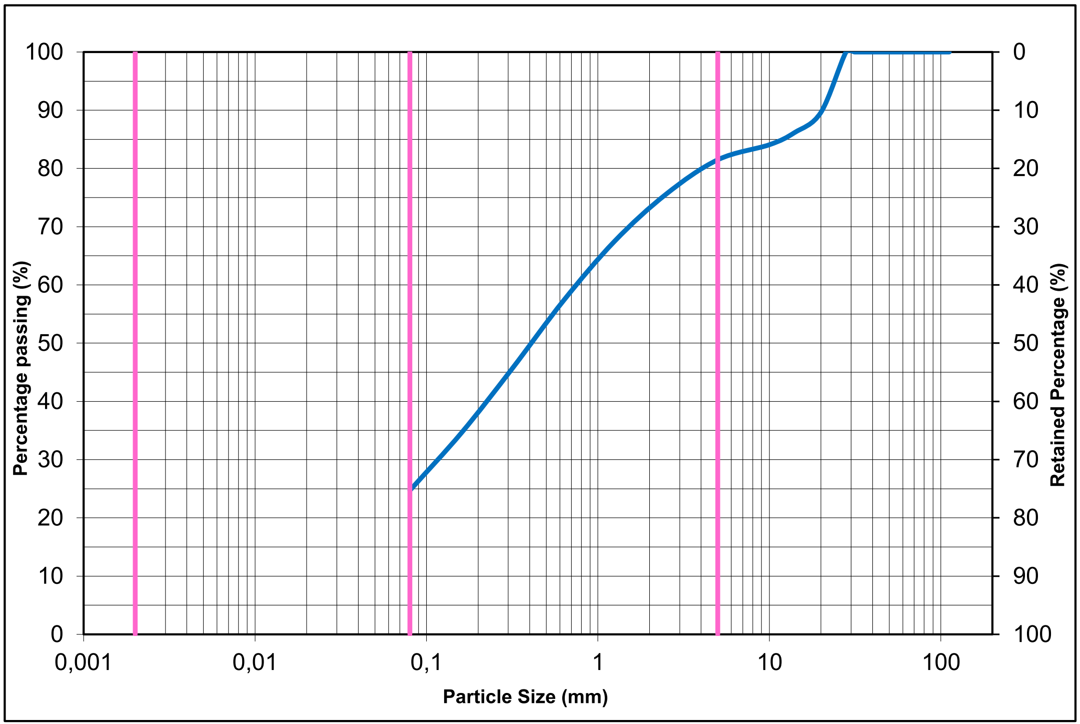
LABORATORY TESTING REPORT

Client : Cree Development Corporation
Project : LGA - Nemaska Access Road (Qc)
Sampled by : Sylvain Pelletier
Sampling Date : June 29, 2022

Project No : 158100425.500.710.2
Sample No : BH22-48 SS-02
Depth : 0,61 - 1,22m
Material Description : Silty Sand, some Gravel

Grain Size Analysis (BNQ 2501-025)

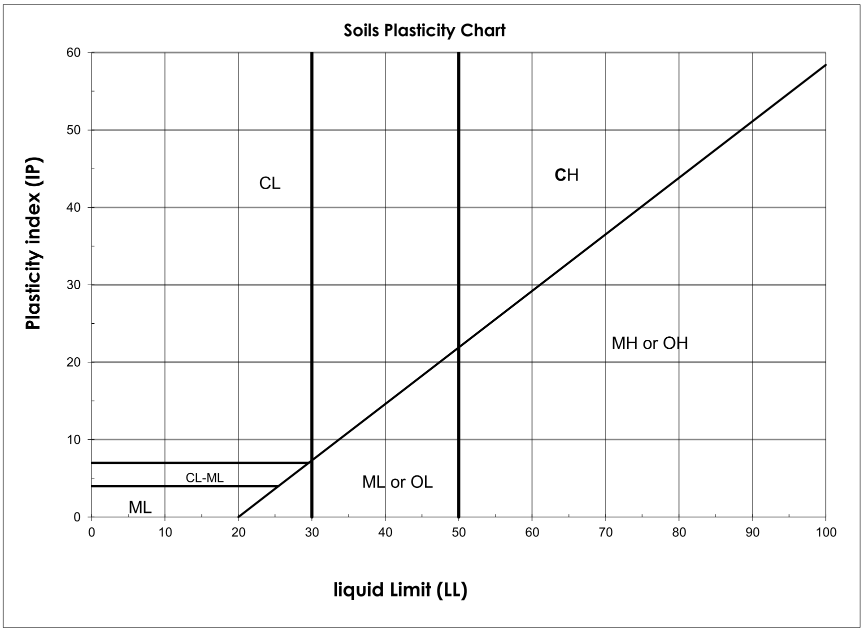
Openings Dimensions	Cumulative Results
mm	%
112	100
80,0	100
56,0	100
40,0	100
31,5	100
28,0	100
20,0	90
14,0	86
10,0	84
5,00	81
2,50	76
1,25	67
0,630	57
0,315	46
0,160	35
0,080	24,7



% Gravel : 18,5 % Sand : 56,8 % Fine particles : 24,7

Other tests

Test / Standard	Results



Remarks :

Prepared by : Benoit Cyr, Geo.

Date : October 25, 2022

Stantec
2273 Michelin Street,
Laval QC, H7L 5B8

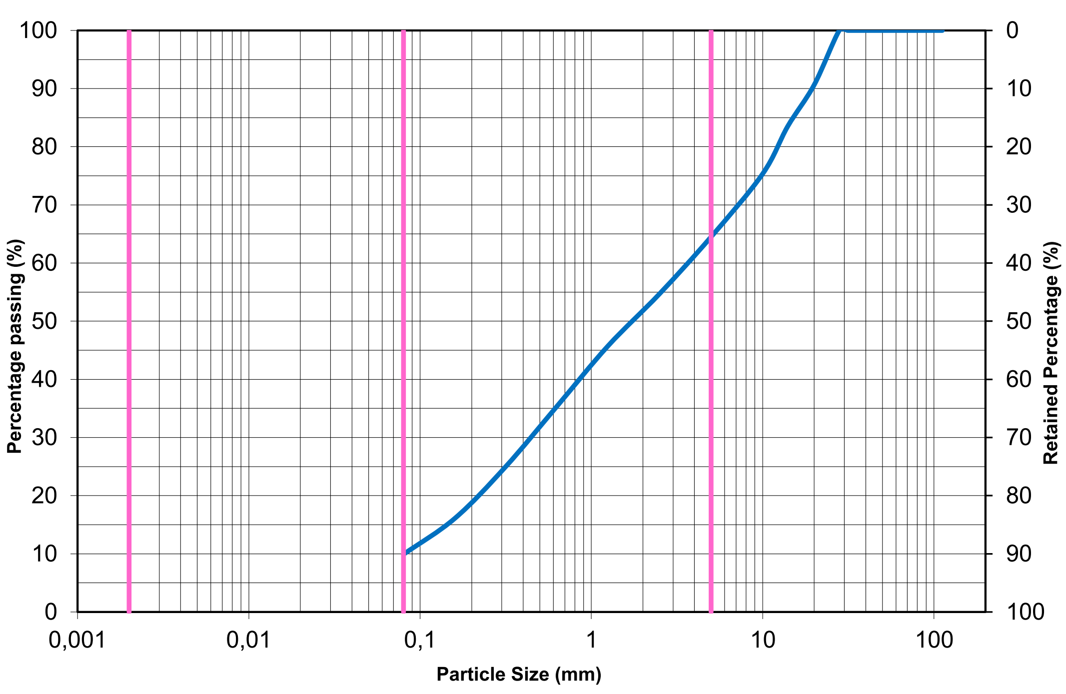
LABORATORY TESTING REPORT

Client : Cree Development Corporation
Project : LGA - Nemaska Access Road (Qc)
Sampled by : Sylvain Pelletier
Sampling Date : June 29, 2022

Project No : 158100425.500.710.2
Sample No : BH22-49 SS-01A
Depth : 0,00 - 0,43m
Material Description : Sand and Gravel, traces of fine particles

Grain Size Analysis (BNQ 2501-025)

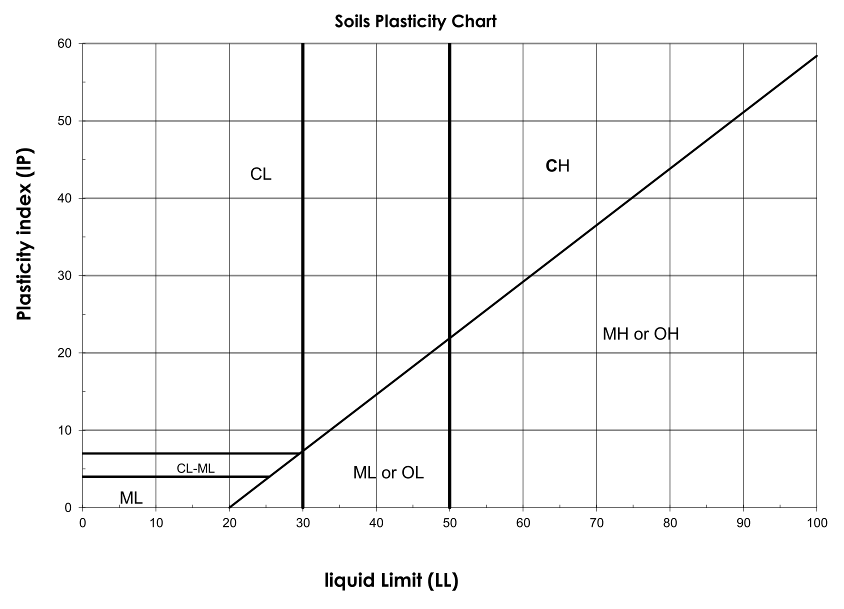
Openings Dimensions	Cumulative Results
mm	%
112	100
80,0	100
56,0	100
40,0	100
31,5	100
28,0	100
20,0	91
14,0	83
10,0	75
5,00	65
2,50	55
1,25	46
0,630	35
0,315	25
0,160	16
0,080	9,9



% Gravel : 35,5 % Sand : 54,6 % Fine particles : 9,9

Other tests

Test / Standard	Results



Remarks :

Prepared by : Benoit Cyr, Geo.

Date : October 25, 2022

Stantec

2273 Michelin Street,
Laval QC, H7L 5B8

LABORATORY TESTING REPORT

Client : Cree Development Corporation

Project : LGA - Nemaska Access Road (Qc)

Sampled by : Sylvain Pelletier

Sampling Date : June 29, 2022

Project No : 158100425.500.710.2

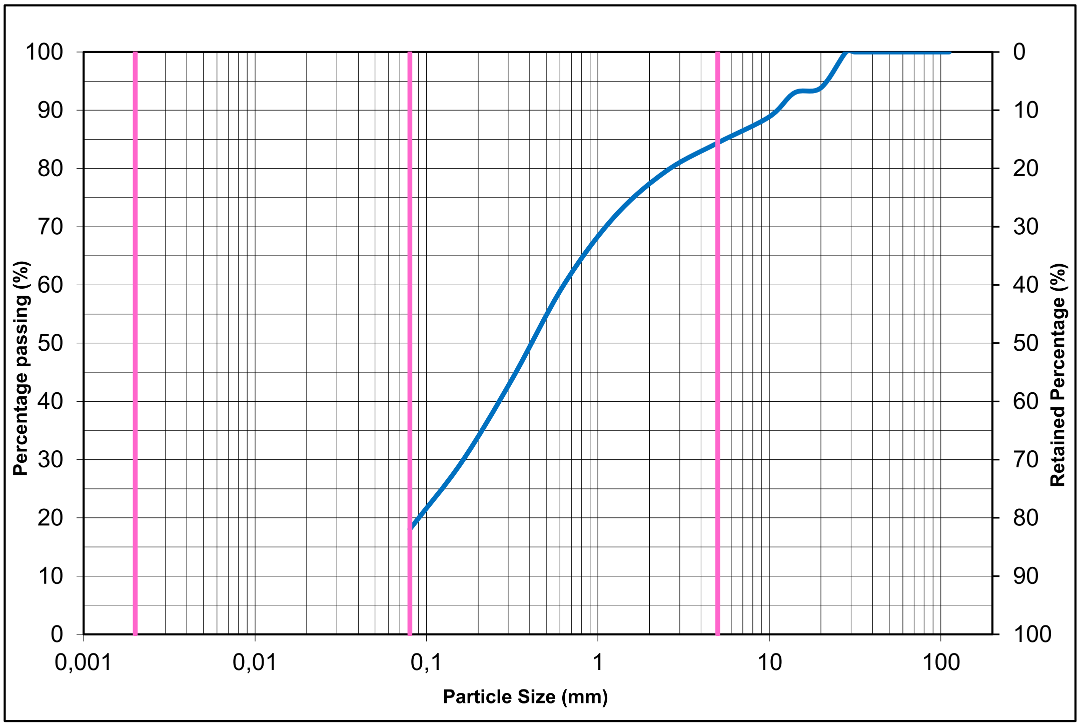
Sample No : BH22-49 SS-02

Depth : 0,61 - 1,22m

Material Description : Sand, some fine particles, some Gravel

Grain Size Analysis (BNQ 2501-025)

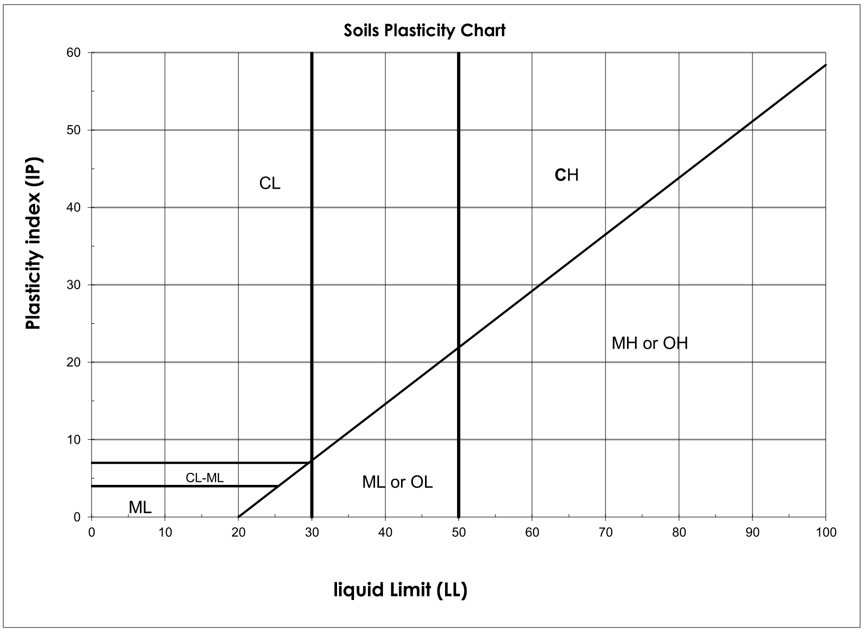
Openings Dimensions	Cumulative Results
mm	%
112	100
80,0	100
56,0	100
40,0	100
31,5	100
28,0	100
20,0	94
14,0	93
10,0	89
5,00	84
2,50	80
1,25	72
0,630	60
0,315	44
0,160	30
0,080	18,1



% Gravel : 15,6 % Sand : 66,3 % Fine particles : 18,1

Other tests

Test / Standard	Results



Remarks :

Prepared by : Benoit Cyr, Geo.

Date : October 25, 2022

Stantec
2273 Michelin Street,
Laval QC, H7L 5B8

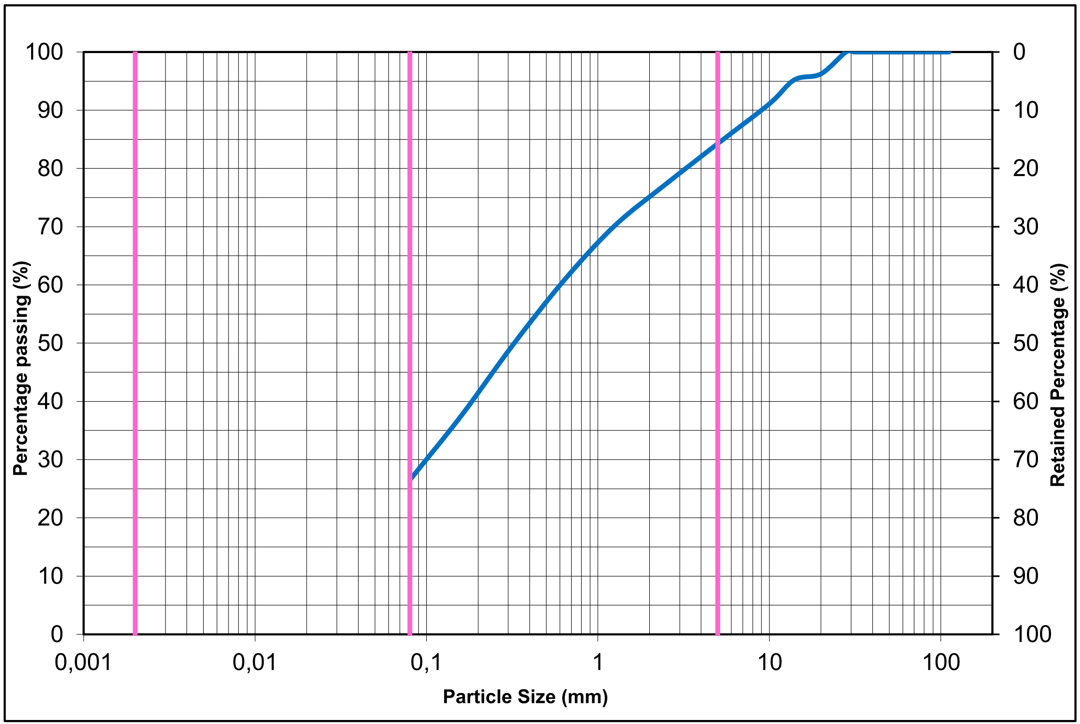
LABORATORY TESTING REPORT

Client : Cree Development Corporation
Project : LGA - Nemaska Access Road (Qc)
Sampled by : Sylvain Pelletier
Sampling Date : June 29, 2022

Project No : 158100425.500.710.2
Sample No : BH22-49 SS-03
Depth : 1,22 - 1,83m
Material Description : Silty Sand, some Gravel

Grain Size Analysis (BNQ 2501-025)

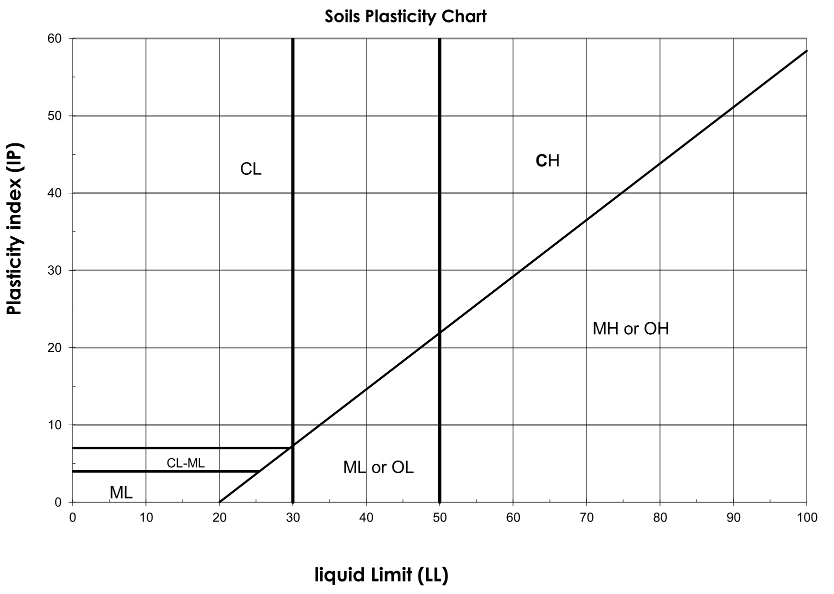
Openings Dimensions	Cumulative Results
mm	%
112	100
80,0	100
56,0	100
40,0	100
31,5	100
28,0	100
20,0	96
14,0	95
10,0	91
5,00	84
2,50	77
1,25	70
0,630	61
0,315	49
0,160	38
0,080	26,5



% Gravel : 15,7 % Sand : 57,8 % Fine particles : 26,5

Other tests

Test / Standard	Results



Remarks :

Prepared by : Benoit Cyr, Geo. BC

Date : October 25, 2022