Y/Ref. : EE520-170399
O/Ref. : F1626050-002

Geotechnical Investigation

PUBLIC SERVICES AND PROCUREMENT CANADA

Waterfalls Trail – Cap Tourmente National Wildlife Area

▶ MARCH 2017

FINAL REPORT

Geotechnical Investigation

Waterfalls Trail – Cap Tourmente National Wildlife Area

Presented to :

Mr. Marcel Thum, P.Eng.
Project Manager – Heritage Clients Services Team
PUBLIC SERVICES AND PROCUREMENT CANADA
3, Passage du Chien d'Or
Québec (QUÉBEC) G1R 3Z8

Prepared by :

Pascal Bouchard, Eng., n°OIQ 5017762
Project manager – Geotechnics

Approved by :

Ghislain Houde, Eng., n°OIQ 109938
Director

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Date : March 2017

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1 Introduction

1.1 Mandate and scope of work

Labo S.M. inc. services where retained by **Public Works and Government Services Canada (PWGSC)** to conduct a geotechnical investigation for the building project of anew recreational and tourist facilitie at the Cap Tourmente National Wildlife Area, located in Saint-Joachim.

The objective of this geotechnical investigation was to determine the nature and properties of the rock in place, to the extent that these characteristics affect the design and construction of the proposed facilities.

This report presents a description of the site and project, the methodology used during the field and laboratory works, the results obtained, as well as our conclusions and recommendations regarding:

- Type of anchoring to considered
- Design parameters of anchoring
- Monitoring during construction.

1.2 Site Location

The site is located within the boundaries of the Cap Tourmente National Wildlife Area, which is located in Saint-Joachim, Quebec. The work zone, which corresponds to a more or less steep cliff on the edge of the falls, is accessible via an old re-designed trail that joins the existing footpaths.

The construction sector consists of the upper landing of the cliff, an intermediate landing approximately 23 m below, and a third landing still 13 m lower. In all cases, the work areas are wooded and have uneven surfaces. The rock in the work areas is generally covered with a thin vegetal cover.

Based on the geological maps consulted trough the "**système d'information géominière du Québec** (**SIGÉOM**)" of the ministère de l'Énergie et des Ressources naturelles du Québec, several separate geological units are likely to be intercepted in the project area. The following figure, taken from **SIGÉOM**, illustrates the distribution of the various geological units, which are defined as follows:

1. Quaternary deposits consisting of sand, gravel, silt, till
2. Charnockitic migmatite and associated rocks of the charnockitic complex of Charlevoix
3. Utica calcareous shale
4. Fossiliferous micrite of the Deschambault Formation
5. Sandstone and conglomerate of the Trenton Group
6. Shale with sandstone laminates of the Lotbinière Formation.

Also, note that the site is intersected by several regional faults (lines in bold) oriented mainly east-west, or north-east / south-west.

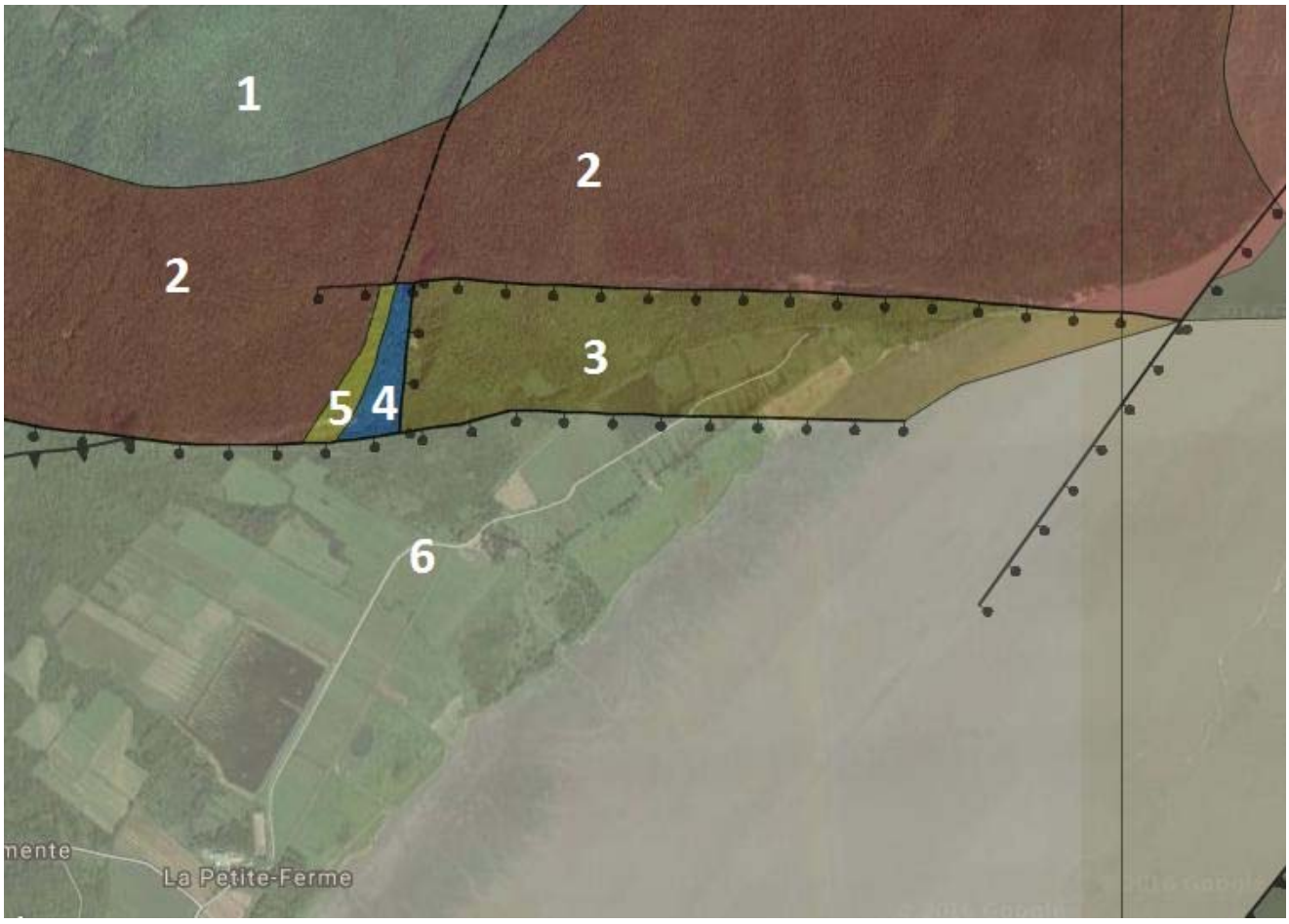


Figure 1 Geology of the area (from SIGEOM, 2016)

1.3 Project Description

According to the information provided by the client, the project consists of the development of a new footpath, belvederes and stairs in an zone of the Cap Tourmente National Wildlife Area currently not accessible to visitors. Given the topography of the sites in the study area, the projected structures (belvedere and staircases) will have to be anchored in the bedrock to ensure their stability. At the time of writing the final report, an overview of the proposed developments was provided to us by PWGSC in CAD format.

2 Method of Investigation

2.1 Field Work

Field investigations were carried out in 2016, between October 3 and 12. They consisted of the following work:

> Three (3) boreholes with rock sampling, identified BH-01-16 to BH-03-16, located on the upper, intermediate and lower landings.

All field work was carried out under the constant supervision of an experienced technologist. The information collected is presented in the boreholes reports included in Appendix B.

2.1.1 Boreholes Location

The boreholes were implanted on site by **Labo S.M. inc.** based on indication from **Environment Canada** staff and the constraints on site. For the boring needs, an easily accessible plane surface of rock was necessary to anchor the equipment.

No localization has been performed by our services for this project. However, boreholes BH-01-16 and BH-02-position 16 was identified by the surveyor mandated by **PWGSC** and was provided to us on a CAD drawing. For borehole BH-03-16, the location was not recorded. It was therefore positioned approximately on the provided drawing. In all cases, the elevation of the boreholes was interpolated from the contours indicated on the drawing.

The location of the boreholes are shown in the figure included in Appendix A.

2.1.2 Boring and Sampling

Drilling was carried out using a WEKA DK-32 and a CARDI T9-475 electric core drill. The boreholes reached a depth of between 2,1 m and 7,2 m. It should be noted that BH-01-16 was drilled vertically while boreholes BH-02-16 and BH-03-16 were drilled horizontally.

The Rock Quality Designation (RQD) was measured directly on site by the technologist assigned to the project and validated in the laboratory by the geotechnical engineer.

The following figure illustrates a typical installation for the borehole drilling.

Figure 2 Drilling of a horizontal borehole (BH-03-16)

2.2 Laboratory Testing

2.2.1 Geotechnical Analysis

The rock samples recovered from boreholes were sent to our laboratory and visually inspected by a geotechnical engineer in order to identify the stratigraphic profiles presented in the borehole reports. The tests shown in the following table were carried out on representative rock samples In order to determine the nature and some mechanical properties of the rock.

Table 1 Laboratory testing

Quantity	Analysis	Standard
2	Uniaxial Compressive strength on intact rock core specimen (dry conditioning)	ASTM D 7012

The results of the laboratory tests are presented in Appendix C. It should be noted that the tests were performed only on samples taken from boreholes BH-02-16 and BH-03-16. In the case of borehole BH-01-16, the recovered cores were toofractured to allow the realization of laboratory tests.

All recovered samples that were not used for laboratory testing will be kept until March 2017. After this time, they will be destroyed unless otherwise notified.

3 Results

3.1 Nature and Properties of Rock

The information collected during the field work and laboratory investigations is presented in the following paragraphs and summarized in Tables 2 and 3.

Rock

All boreholes were initiated from the rocky basement flush with the site, except BH-01-16 which was initiated on a 1,3 m thick gneiss block. As indicated earlier, BH-01-16 was drilled vertically while boreholes BH-02-16 and BH-03-16 were drilled horizontally.

The rock encountered is described as a granitic gneiss or a migmatite depending on the boreholes. Its color varies from pink to greenish gray. At vertical borehole (BH-01-16), the rock has an inclined foliation between 30 ° and 45 ° with respect to the axis of the core. As for horizontal boreholes (BH-02-16 and BH-03-16), the foliation is inclined between 45 ° and 70 ° with respect to the axis of the core, i.e. between 20 ° and 45 ° with respect to the vertical.

Discontinuities were noted at several locations along the samples taken. These discontinuities generally follow foliation and are referred to as very close to moderately spaced with spacing between 25 mm and 560 mm. The surfaces of the discontinuities generally show alteration in the form of rust.

At borehole BH-01-16, the quality of the rock mass is described as very poor with a RQD (Rock Quality Designation) of less than 25 % up to a depth of 7,2 m. On the basis of recovered cores, rock quality tends to increase from a depth of ± 7,0 m. We can not, however, confirm its true quality. For BH-02-16 and BH-03-16, the quality is fair to excellent with RQDs generally varying between 56 % and 100 %. However, a horizon with a 0 % RQD was encountered between 1,9 m and 2,1 m at the borehole BH-02-16. It should be noted that, when evaluating the RQD parameter, the cleavage or (unaltered) discontinuities are not considered.

The rock is described as hard to very hard with an estimated hardness between 5 and 7 on the scale of the Mohs Hardness Scale. Rock compressive strength, with values of 98,5 MPa and 160,0 MPa obtained fromlaboratory testing performed on representative samples, is rated as high to very high..

Table 2 Stratigraphy Summary

Borehole no	Surface elevation * (m)	Depth of granitic gneiss (m)		Depth of migmatite (m)	
		Poor quality	Fair to excellent quality	Poor quality	Fair to excellent quality
BH-01-16	88,00	0,0 to > 7,24	--	--	--
BH-02-16	67,00	--	0,0 to > 2,1	--	--
BH-03-16	39,25	--	--	--	0,0 to > 2,3

** Approximate elevation estimated from topographic survey provided by PWGSC*

Table 3 Laboratory tests Results

Borehole no	Sample no	Depth (m)	Conditioning	Uniaxial Compressive Strength (MPa)
BH-02-16	CR-4	1,45 – 1,65	Dry	160,0
BH-03-16	CR-3	2,08 – 2,31	Dry	98,5

4 Conclusions and recommendations

4.1 Project Summary and Site Conditions

This study is part of the project to build new recreational tourism facilities at the Cap Tourmente National Wildlife Area, including the development of a new hiking trail, belvedere and stairs on the mountainside. Due to the rugged topography of the site, it is projected to anchor the structures to the bedrock.

The results of the drilling campaign revealed that the rock is mainly composed of granitic gneiss or migmatite with a foliation oriented between 30 ° and 70 ° with respect to the axis of the core. At borehole BH-01-16, the quality of the rock mass is considered very bad. In the case of boreholes BH-02-16 and BH-03-16, the quality is fair to excellent. The rock hardness is estimated to be between 5 and 7 on the Mohs relative hardness scale, and its compressive strength is rated as high to very high.

4.2 Stability of the proposed structures

Given the topography of the site and the nature of the planned structures, several types of rock anchors can be considered for the construction of lookouts and stairs. Therefore the use of mechanical or chemical anchors (injected with cementitious slurry or resin) installed in the bedrock base can be considered. The final choice of the type of rock anchors to be used is the responsibility of the designer, as is the selection of the type of action (active or passive anchors). Given the particular conditions of the site and the proposed installation difficulties, it is strongly recommended to contact a specialized contractors in this field of work wich will be in the best position to evaluate the feasibility of the concept.

According to information obtained from various specialized companies, the use of simple anchors consisting of steel bars cemented in the rock mass with a cement grout could be considered. However, this solution is a first approach and should be further analyzed when the final concept (including anticipated loads and different constraints) is known. The design of the rock anchors (active or passive) shall take in account of the following four failure modes:

- Tendon tensile failure
- Grout-tendon bond or interface failure
- Rock-grout interface failure
- Rock mass failure.

The equations for calculating the required strength for each of the failure modes are presented in the following sections. In addition, physical and mechanical characteristics of the bedrock are presented in Section 4.3. The physical and mechanical characteristics of steel, which are required for certain calculations, must be obtained from suppliers.

In all cases, the calculations should be carried out by a qualified engineer in order to validate the formulas and parameters to be used for the needs of the project, and thus to optimize the chosen solution. The engineer must also specify the number, inclination and position of the various anchors required.

4.2.1 Tendon tensile failure

The ultimate tensile strength of the steel tendon is calculated as follows:

$$Q_{tu} = \sigma_{tu} * A_t$$

Where: σ_{tu} = ultimate tensile strength of the steel

A_t = cross-sectional area of steel in the tendon

4.2.2 Grout-tendon bond or interface failure

The ultimate shear strength that develops at the tendon-grout bond is calculated by the following equation:

$$Qtgu = 2\pi r_t \int_0^l \tau_{tgu}(z)\, dz$$

Where: r_t = radius of the steel tendon

l = length of tendon-grout bond

τ_{tgu} = shear resistance generated at distance z along the grout-tendon interface where $0 \leq z \leq l$

4.2.3 Rock-grout interface failure

Assuming that the shear resistance is distributed uniformly over the rock-grout bond, the ultimate shear resistance is given by the following equation:

$$Q_{rgu} = 2\pi r_g * l_{brg} * \tau_{rgu}$$

Where: r_g = outside radius of the grouted annulus around the tendon

l_{brg} = length of the rock-grout bond

τ_{rgu} = shear resistance generated at distance z along the rock-grout interface (assumed to be uniform along the bond)

4.2.4 Rock mass failure

In general, and considering an isolated rock anchor, the uplift force required to overcome the weight of the cone of rock may be calculated as:

$$Q_{ru} = \frac{1}{3}\pi\gamma * \tan^2\frac{\theta}{2}(D + \frac{L}{2})^3$$

Where: γ = unit weight of the rock (use full unit weight or submerged unit weight depending of the situation)

Θ = Cone angle (considering the apex located at mid-point of the grouted embedment length)

D = Depth from the surface to the top of the embedment length

L = Bond length

The uplift resistance available per unit length along a row of anchors is given by the following equation:

$$Q_{ru} = \frac{1}{2}\frac{\gamma}{s}(D + \frac{L}{2})^2 \tan\frac{\theta}{2}$$

Where: s = spacing of anchors along the row.

The formulas given above are taken from the article *Rock engineering design of post-tensioned anchors for dams - A Review* presented in **Journal of Rock Mechanics and Geotechnical Engineering**.

4.3 Design Parameters

Based on the results of on-site investigations and laboratory tests, the following design parameters can be used for the dimensioning of passive or active rock anchors:

<u>In the very poor to poor quality rock:</u>

The following values can be used for the entire rock encountered at borehole BH-01-16, even if a slight increase in quality is observed from ± 7,0 m.

> Rock density : 2,65

- Unit weight of rock γ : 26,0 kN/m^3
- Cone angle Θ : 60°
- Grout-rock bond (admissible) : 0,5 N/mm^2 (over the length of the anchor in poor quality rock)
- Grout-rock bond, τ_{rgu} (ultimate) : 1,5 N/mm^2 (over the length of the anchor in poor quality rock)
- Compressive strength of grout : minimum of 30 MPa at 28 days
- Compressive strength of rock : 98,5 MPa
- Factor of safety (admissible value): > 3,0.

<u>In the fair to excellent quality rock:</u>

The following values may be used for the entire rock encountered at boreholes BH-02-16 and BH-03-16

- Rock density : 2,65
- Unit weight of rock γ : 26.0 kN/m^3
- Cone angle Θ : 90°
- Grout-rock bond (admissible) : 0,9 N/mm^2 (on the length of the anchor)
- Grout-rock bond, τ_{rgu} (ultimate) : 2,7 N/mm^2 (on the length of the anchor)
- Compressive strength of grout : minimum of 30 MPa at 28 days
- Compressive strength of rock : 98,5 MPa
- Factor of safety (admissible value): > 3,0.

Regardless of the type of rock anchors (mechanical or chemical) and the mode of action (passive or active), on-site tests must be performed to ensure that the resistance values requested by the designer are met. The tests shall be carried out in accordance with ASTM D-4435 and ASTM D-4436 and according to the manufacturer's instructions.

4.4 Construction Monitoring

We recommend that the services of a specialised contractor in this type of work be retained to ensure that the work will be carried out in accordance with the applicable rules and regulations.

In addition, all manufacturers' specifications must be followedwhen installing the anchorages and when carrying out the various quality control tests.

5 Staff

The work on site was carried out by Andrew Cavanagh and, Jérôme Déry, technologists, and Jean François Rosa, junior engineer (OIQ member n °5066816) This report was written by Mr. Pascal Bouchard, engineer (OIQ member n°5017762), reviewed and approved by Mr. Ghislain Houde, engineer (OIQ member n°109938).

This report has been translate by Mrs. Katie St-Amand, M.Sc., geologist n°592 of the OGQ.

6 Limitations

The results of this geotechnical investigation are applicable only if considering the hypotheses and data collected during this study and the limits of the exploration techniques. Consequently, if the geotechnical conditions encountered during the construction phase of the project are different than those found in this study, they should be verified by a geotechnical engineer who will determine the effects of the new conditions on the project and, if needed, issue new recommendations.

All factual data, interpretations and recommendations found in this report pertain solely to the project which is the object of this investigation and do not apply to other projects or sites. This report was only prepared for the benefit of our client. We decline all responsibilities and obligations resulting from the use of this report by a third party. The consequences of any decision made by a third party based on this report are the third party's responsibility.

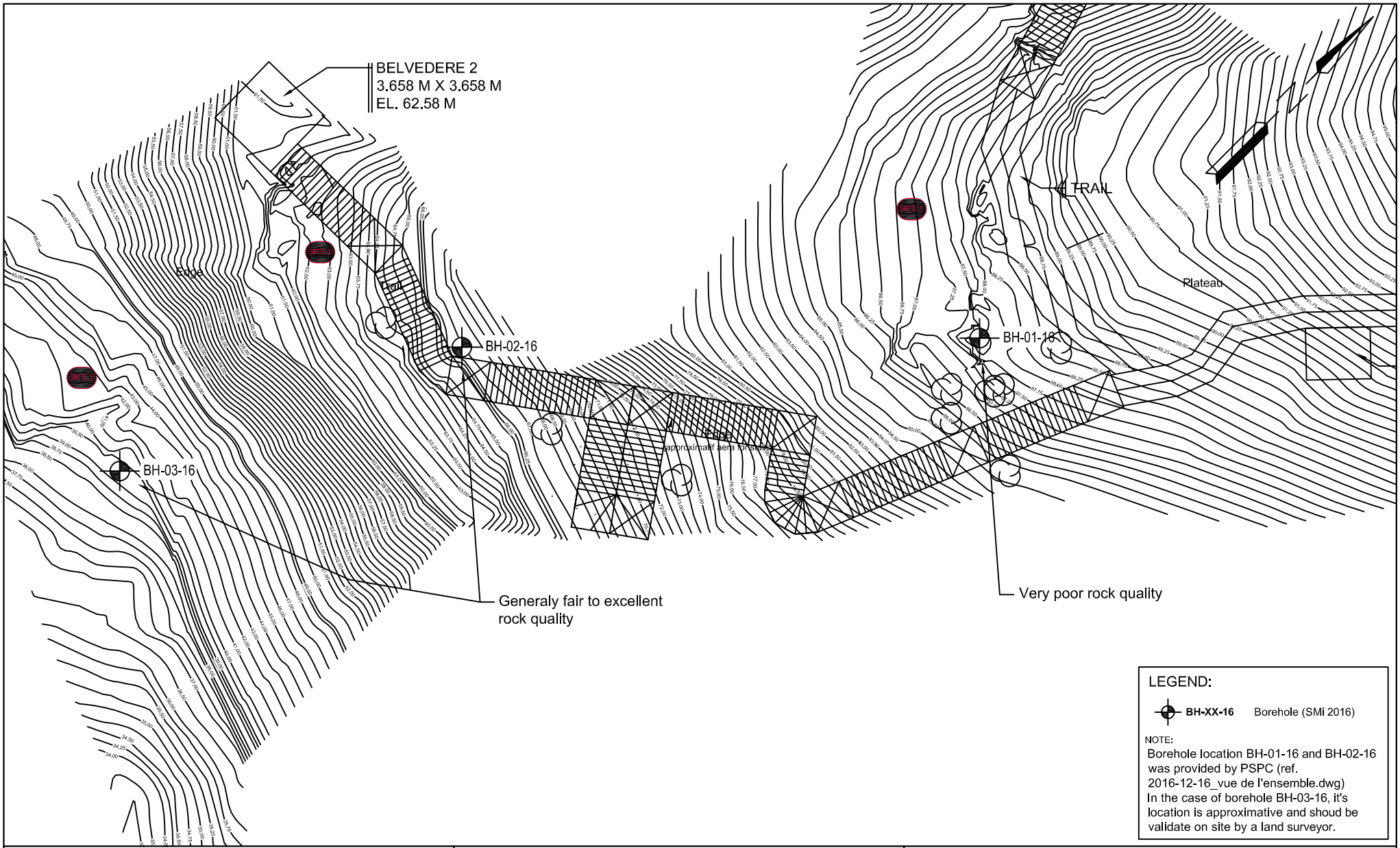
If changes were brought to the elevation, the location, the conception or the nature of the project, the conclusions and recommendations found in this report should not be considered valid until the impacts of the changes are reviewed and taken into account by Labo S.M. inc., and that the report's conclusions be modified or kept in writing. The realization of a complementary field investigation and report may be required.

APPENDIX A

SITE LOCATION
BOREHOLES LOCATION

SMi LABO S.M. INC. 1200, av. Saint-Jean-Baptiste, bur.116, Québec (Québec) G2E 5E8 Tél.: (418) 871-9330 - Téléc.: (418) 871-9343 www.groupesm.com	Project: Geotechnical Investigation - Waterfalls Trail Cap Tourmente National Wildlife Area Saint-Joachim (Quebec)	Title: Location site	
Drawn by: S. Bordeleau, tech.	Approuved by: Ghislain Houde, Eng.	Date: January 10th 2017	Discipline: Geotechnical
Scale: N/A	Client: Public Services and Procurement Canada	File no. : F1626050-002	Draw no.: F1626050002K001

cc8x11H



SMi LABO S.M. INC.
1200, av. Saint-Jean-Baptiste, bur.116, Québec (Québec) G2E 5E8
Tél.: (418) 871-9330 - Téléc.: (418) 871-9343
www.groupesm.com

Projet: Geotechnical Investigation - Waterfalls Trail
Cap Tourmente National Wildlife Area
Saint-Joachim (Quebec)

Title: Borehole location plan

Drawn by: S. Bordeleau, tech.	Approuved by: Ghislain Houde, Eng.	Date: January 10th 2017	Discipline: Geotechnical
Scale: 1:250	Client: Public Services and Procurement Canada	File no. : F1626050-002	Draw no.: F1626050002K002

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APPENDIX B

BOREHOLES REPORTS

Labo S.M. Inc.

BOREHOLE REPORT

Project: **Geotechnical Investigation - Waterfalls Trail**	Location: **Level #1**	Report # :	**BH-01-16**
	X:	Page:	**1 of 1**
Client: **Public Services and Procurement Canada (PSPC)**	Y:	Starting date:	**2016-10-03**
Site: **Cap Tourmente National Wildlife Area**	Type of survey: **BOREHOLE**	Technician:	**Andrew Cavanagh, techn.**
O./ref.: **F1626050002**	Equipment used: **Drill (WEKA DK-32 / CARDI T9-475)**	Depth:	**7.24m**
Figure: **F1626050002K002**	Casing: **BW** Split spoon or core size: **BX, BQ, TM casing 4.0"**	Elevation :	**m**

SAMPLING METHOD

SS	Split spoon
CSC	Continuous samping casing
CR	Diamond corer
TM	Thin-walled casing
TA	Auger
TS	Shelby casing
EM	Manual sampling

QUALITATIVE TERMS

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 TERMS

Trace	< 10 %
Some	10 - 20 %
Adjective(...uous)	20 - 35 %
and(ex: and sand)	> 35 %
First word	Dominant fraction

SYMBOLS

Nspt	Penetration index standard (BNQ 2501-140)
Ncorr	Corrected N for nonstandard diameter
Nc	Cone penetration index (BNQ 2501-145)
RQD	Rock quality designation (%)

GROUNDWATER LEVEL

	Date	Depth
Reading 1		m
Reading 2		m

Remark:

SAMPLE CONDITION

- Remoulded
- Intact (thin-walled casing)
- Lost
- Rock core

MECHANICAL PROPERTIES OF SOILS

COMPACITY	"N" Index	STIFFNESS	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

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

DISCONTINUITY SPACING

Extremely close	< 20 mm
Very close	20 - 60 mm
Close	60 - 200 mm
Moderately close	200 - 600 mm
Wide	600 - 2000 mm
Very wide	2000 - 6000 mm
Extremely wide	> 6000 mm

LAB TEST

AG	: Particle size analysis :
S	Sedimentometry
C	: Oedo. consolidation
W	: Water content
WL	: Liquid limit
Wp	: Plastic limit
VB	: Methylene blue
k	: Permeability
f'c	: Simple compression
MD	: Micro-deval
AC	: Chemical analysis

GRAPH

× : N (Stand. pen.)
▽ : Nd (Dyn. pen.):
■ Intact Cu
□ : Remoulded Cu
◆ : Intact Su
◇ : Remoulded Su

Wp W WL
20 40 60 80

DEPTH (m)	DEPTH (ft)	ELEVATION (m) / DEPTH (m)	SOILS AND ROCK DESCRIPTION	SYMBOL	CONDITION	TYPE AND #	CALIBER	RECUPERATION (%)	N - Nc - RQD	STANDARD PENTRATION TEST BLOW/150 mm	WATER LEVEL / WATER FLOW	REMARKS
		0.00										
		0.00	Block: Granitic gneiss; grey and pink.			CR-1	BQ	100	50			
						CR-2	BQ	100	100			
						CR-3	BQ	100	0			
						CR-4	BQ	100	0			
1						CR-5	BQ	58	58			
						CR-6	BQ	27	0			
		1.25	Rock: Granitic gneiss or Migmatite; grey and pink. Foliation orientation between 30° and 45° according to core axis. Discontinuities generally oriented according to foliation and spaced from±25 mm to ±150 mm. Alterations in the fractures. Estimated hardness between 5 and 7 on Mohs Hardness scale. Very fractured zones between 3,1 m and 5,9 m.			CR-7	BX	100	0			
	5					CR-8	BX	87	0			
2						CR-9	BX	75	0			
						CR-10	BX	89	22			
3	10					CR-11	BX	100	0			
						CR-12	BX	38	0			
4						CR-13	BX	23	0			
	15					CR-14	BX	33	0			
5						CR-15	BX	41	0			
6	20					CR-16	BX	69	0			
						CR-17	BX	81	24			
7												
		7.24	END OF BOREHOLE -									

General remarks: **Vertical borehole**

Checked by: **Pascal Bouchard, Eng.**

Date: **2016-11-05**

Labo S.M. Inc.

BOREHOLE REPORT

Project:	**Geotechnical Investigation - Waterfalls Trail**	Location:	**Level #2**	Report # :	**BH-02-16**
		X:		Page:	**1 of 1**
Client:	**Public Services and Procurement Canada (PSPC)**	Y:		Starting date:	**2016-10-07**
Site:	**Cap Tourmente National Wildlife Area**	Type of survey:	**BOREHOLE**	Technician:	**Andrew Cavanagh, techn.**
O./ref.:	**F1626050002**	Equipment used:	**Drill (WEKA DK-32 / CARDI T9-475)**	Depth:	**2.13m**
Figure:	**F1626050002K002**	Casing:	Split spoon or core size: **TM casing (4.0", 3.0")**	Elevation :	**m**

SAMPLING METHOD

SS	Split spoon
CSC	Continuous samping casing
CR	Diamond corer
TM	Thin-walled casing
TA	Auger
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EM	Manual sampling

QUALITATIVE TERMS

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Extremely wide	> 6000 mm

STRATIGRAPHY / SAMPLES / LAB/ IN SITU RESULTS

LAB TEST

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S Sedimentometry
C : Oedo. consolidation
W : Water content
WL : Liquid limit
Wp : Plastic limit
VB : Methylene blue
k : Permeability
f'c : Simple compression
MD : Micro-deval
AC : Chemical analysis

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◆ : Intact Su
◇ : Remoulded Su

Wp W WL
20 40 60 80

DEPTH (m)	DEPTH (ft)	ELEVATION (m) / DEPTH (m)	SOILS AND ROCK DESCRIPTION	SYMBOL	CONDITION	TYPE AND #	CALIBER	RECUPERATION (%)	N - Nc - RQD	STANDARD PENTRATION TEST BLOW/150 mm	WATER LEVEL / WATER FLOW	LAB TEST / IN SITU RESULTS	REMARKS
		0.00											
		0.00	Rock: Granitic gneiss; grey and pink. Foliation orientation from 45° to 70° according to core axis. Discontinuities oriented at 45° and spaced from ±230 mm to ±560 mm. Visible alterations in some fractures. Estimated hardness between 6 and 7 on the Mohs Hardness Scale.			CR-1		100	56				
1						CR-2		100	100				
	5					CR-3		100	100				
						CR-4		100	100			f'c=160,0 MPa	
2						CR-5		100	64				
						CR-6		100	0				
		2.13	END OF BOREHOLE -										
3	10												
4													
	15												
5													
6	20												
7													

General remarks: **Horizontal borehole**

Checked by: **Pascal Bouchard, Eng.**

Date: **2016-11-05**

Labo S.M. Inc.

BOREHOLE REPORT

Project: **Geotechnical Investigation - Waterfalls Trail**	Location: **Level #3**	Report # :	**BH-03-16**
	X:	Page:	**1 of 1**
Client: **Public Services and Procurement Canada (PSPC)**	Y:	Starting date:	**2016-10-12**
Site: **Cap Tourmente National Wildlife Area**	Type of survey: **BOREHOLE**	Technician:	**Andrew Cavanagh, techn.**
O./ref.: **F1626050002**	Equipment used: **Drill (CARDI T9-475)**	Depth:	**2.31m**
Figure: **F1626050002K002**	Casing: Split spoon or core size: **TM casing (4.0")**	Elevation :	**m**

SAMPLING METHOD

SS	Split spoon
CSC	Continuous samping casing
CR	Diamond corer
TM	Thin-walled casing
TA	Auger
TS	Shelby casing
EM	Manual sampling

QUALITATIVE TERMS

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 TERMS

Trace	< 10 %
Some	10 - 20 %
Adjective(...uous)	20 - 35 %
and(ex: and sand)	> 35 %
First word	Dominant fraction

SYMBOLS

Nspt	Penetration index standard (BNQ 2501-140)
Ncorr	Corrected N for nonstandard diameter
Nc	Cone penetration index (BNQ 2501-145)
RQD	Rock quality designation (%)

GROUNDWATER LEVEL

	Date	Depth
Reading 1		m
Reading 2		m

Remark:

SAMPLE CONDITION

- Remolded
- Intact (thin-walled casing)
- Lost
- Rock core

MECHANICAL PROPERTIES OF SOILS

COMPACITY	"N" Index	STIFFNESS	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

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

DISCONTINUITY SPACING

Extremely close	< 20 mm
Very close	20 - 60 mm
Close	60 - 200 mm
Moderately close	200 - 600 mm
Wide	600 - 2000 mm
Very wide	2000 - 6000 mm
Extremely wide	> 6000 mm

STRATIGRAPHY / SAMPLES / LAB/ IN SITU RESULTS

LAB TEST

AG : Particle size analysis :
S Sedimentometry
C : Oedo. consolidation
W : Water content
WL : Liquid limit
Wp : Plastic limit
VB : Methylene blue
k : Permeability
f'c : Simple compression
MD : Micro-deval
AC : Chemical analysis

GRAPH

× : N (Stand. pen.)
▽ : Nd (Dyn. pen.):
■ Intact Cu
□ : Remoulded Cu
◆ : Intact Su
◇ : Remoulded Su

Wp W WL
20 40 60 80

DEPTH (m)	DEPTH (ft)	ELEVATION (m) / DEPTH (m)	SOILS AND ROCK DESCRIPTION	SYMBOL	CONDITION	TYPE AND #	CALIBER	RECUPERATION (%)	N - Nc - RQD	STANDARD PENTRATION TEST BLOW/150 mm	WATER LEVEL / WATER FLOW	LAB TEST	GRAPH	REMARKS
		0.00												
0		0.00	Rock: Migmatite; pink to greenish grey. Inclined foliation between 45° and 60° according to core axis. Discontinuities oriented from 45° to 90° according to core axis and spaced between ±75 mm and ±560 mm. Fractures oriented at 60° according to core axis and spaced from ±480mm to ±710 mm. Alterations in the fractures. Few random fissures located between 1,8 m and 2,3 m. Estimated hardness between 5 and 7 on the Mohs Hardness Scale.			CR-1		100	66				
1						CR-2		92	28					
	5													
2						CR-3		100	100			f'c= 98,5 MPa		
		2.31	END OF BOREHOLE -											
3	10													
4														
	15													
5														
6	20													
7														

General remarks: **Horizontal borehole**

Checked by: **Pascal Bouchard, Eng.**

Date: **2016-11-05**

APPENDIX C

LABORATORY ANALYSES REPORTS

Laboratory report

Compressive Strength of Intact Rock Core Specimen

Compressive Strength and Elastic Moduli of Intact Rock Core Specimen - ASTM D 7012, Method C

LABO S.M. INC.

Report No.: 1604607
Laboratory No.: 16-10624
Borehole: BH-02-16
Sample: CR-4
Depth: 1.45 to 1.65m

File: **F1626050002**
Client: Public Service and Procurement Canada

Project: Geotechnical investigation-Waterfalls Trail-Cap Tourmente National Wildlife Area

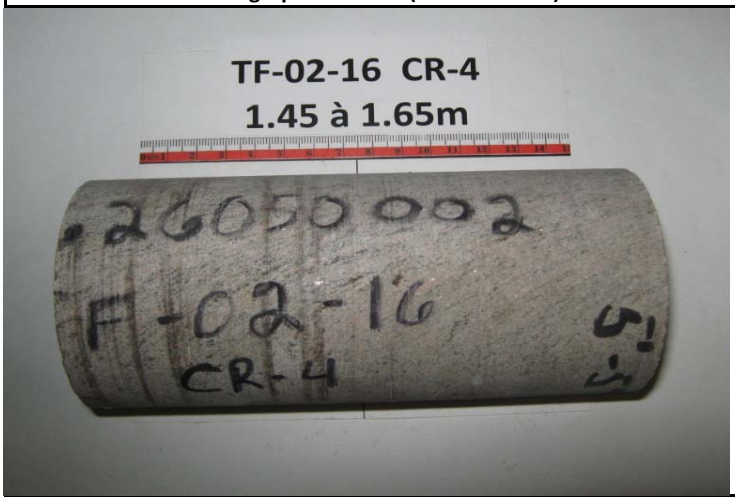
Conditionning:	Dry
Surface treatment:	Mecanically sand
Confinement temperature*:	22.7°C
Manipulator:	Marc Potvin
Date of analysis:	2016-10-25
Length mesuring apparatus:	GSM-403
Testing equipment:	GSM-350

Geologic description: Gneiss

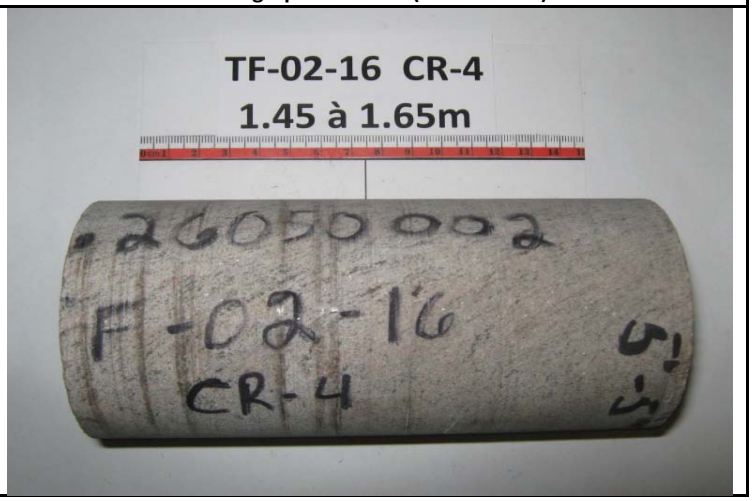
Orientation of stratification or bedding compared to loading axis: Horizontal

Result			Remarks
Average diameter	(mm)	70,76	Reach its point of rupture
Height	(mm)	148,37	
Height/Diameter Ratio		2,10	
Load	(kN)	629,10	
Compressive strenght	(MPa)	**160,0**	
Time to failure	(S)	6,4	
Loading rate	(kN/s)	98,3	
Volumic Mass	(kg/m^3)	2662	

Photograph or sketch (Before failure)



Photograph or sketch (After failure)



* If different from room temperature

Prepared by: Sylvie Daigle, Chef of laboratory Date

Verified by: Pascal Bouchard, Eng. Date

Laboratory report

Compressive Strength of Intact Rock Core Specimen

Compressive Strength and Elastic Moduli of Intact Rock Core Specimen - ASTM D 7012, Method C

LABO S.M. INC.

Report No.: 1604607
Laboratory No.: 16-10625
Borehole: BH-03-16
Sample: CR-3
Depth: 2.08 to 2.31m

File: **F1626050002**
Client: Public Service and Procurement Canada

Project: Geotechnical investigation-Waterfalls Trail - Cap Tourmente National Wildlife Area

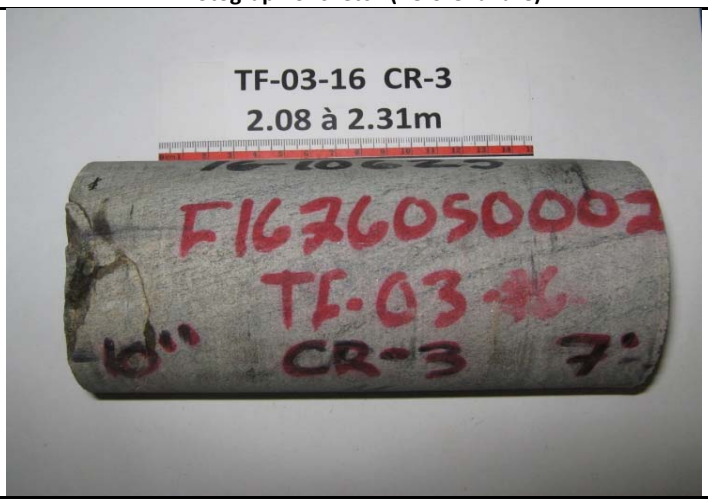
Conditionning:	Dry
Surface treatment:	Mecanically sand
Confinement temperature*:	22.7°C
Manipulator:	Marc Potvin
Date of analysis:	2016-10-25
Length mesuring apparatus:	GSM-403
Testing equipment:	GSM-350

Geologic description: Gneiss

Orientation of stratification or bedding compared to loading axis: Horizontal

Result			Remarks
Average diameter	(mm)	84,14	
Height	(mm)	174,1	
Height/Diameter Ratio		2,07	
Load	(kN)	547,70	
Compressive strength	(MPa)	**98,5**	
Time to failure	(S)	5,17	
Loading rate	(kN/s)	105,9	
Volumic Mass	(kg/m^3)	2656	

Photograph or sketch (Before failure)



Photograph or sketch (After failure)

* If different from room temperature

Prepared by: Sylvie Daigle, Chef of laboratory Date

Verified by: Pascal Bouchard, ing. Date

APPENDIX D

PHOTOGRAPHS

Photo 1 Borehole BH-01-16 (box 1 of 3)

Photo 2 Borehole BH-01-16 (box 2 of 3)

Photo 3 Borehole BH-01-16 (box 3 of 3)

Photo 4 Borehole BH-02-16 (box 1 of 2)

Photo 5 Borehole BH-02-16 (box 2 of 2)

Photo 6 Borehole BH-03-16 (box 1 of 3)

Photo 7 Borehole BH-03-16 (box 2 of 3)

Photo 8 Borehole BH-03-16 (box 3 of 3)

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