GNWT Response to:
GoC NRCan IR#6 (ID20)
Topic
Design/Engineering

Comment
Information on baseline terrain conditions and sensitivity, geotechnical and permafrost conditions, ground thermal conditions are required for adequate design of the highway and granular resources, impact assessment, effects of climate change on the project, and the implementation of mitigation techniques. Information on baseline terrain conditions and sensitivity along the proposed route is required to determine design parameters for the highway and for impact assessment, and to ensure impacts of the project on the environment as well as the impact of the environment on the project are minimized. Baseline information on geotechnical and permafrost conditions is required for adequate design of the highway and for characterizing potential borrow sites. This information is also required for assessment of potential impacts and implementation of mitigation techniques. Information on ground thermal conditions is required for adequate design of the highway, assessment of impacts associated with the highway and granular resource extraction and also for determining the effects of climate change on the project. The Proponent has indicated that results from geotechnical drilling will be incorporated into the final road design. At present, however, no information is available in regards to terrain sensitivity, overburden thickness, geotechnical and permafrost conditions, or ground thermal regimes.

Recommendation
Please provide any additional information on the geotechnical conditions presently known along the proposed roadway corridor, now that geotechnical drilling has been completed. If reports are incomplete, please provide borehole locations, depths drilled, and initial drilling results, if known.

GNWT Response
The contractor is working on the drat geotechnical report for the roadway alignment and will be submitted to the public registry once it is available. As per our June 29, 2017 response, INF is currently conducting geotechnical investigations at 13 preferred prospects. Once the geotechnical investigations are complete and the final reports have been produced, actual quality and quantity of granular materials available at each source will be known. Additionally, Table 1. TASR Alignment Borehole Coordinates, provides 65 borehole coordinates along the alignment, that were identified and surveyed. Further details of drilling results will be supplied to the public registry when completed.

Table 1: TASR Alignment Borehole Coordinates

TASR Alignment					
Borehole #	Station	UTM Zone 11		Lat/Long	
		X	Y	Latitude	Longitude
1	0+500	526042.69	6928000.49	62° 28' 55.9"	-116° 29' 41.2"
2	1+000	525548.12	6928073.12	62° 28' 58.4"	-116° 30' 15.7"
3	1+500	525057.59	6928169.94	62° 29' 1.6"	-116° 30' 49.9"
4	3+000	523575.08	6928244.96	62° 29' 4.4"	-116° 32' 33.4"
5	4+500	522106.56	6928549.35	62° 29' 14.5"	-116° 34' 15.8"
6	6+000	520616.92	6928389.72	62° 29' 9.7"	-116° 35' 60.0"
7	7+500	519128.13	6928206.72	62° 29' 4.1"	-116° 37' 44.0"
8	9+000	517889.67	6928930.64	62° 29' 27.7"	-116° 39' 10.2"
9	10+500	516731.72	6929884.13	62° 29' 58.7"	-116° 40' 30.8"
10	12+000	515453.01	6930619.16	62° 30' 22.6"	-116° 41' 59.9"
11	13+500	514143.57	6931312.87	62° 30' 45.2"	-116° 43' 31.2"
12	15+000	512930.94	6932195.78	62° 31' 13.9"	-116° 44' 55.8"
13	16+500	511718.31	6933078.69	62° 31' 42.6"	-116° 46' 20.3"
14	18+000	510501.59	6933955.9	62° 32' 11.1"	-116° 47' 45.3"
15	19+500	509953.14	6935339.27	62° 32' 55.8"	-116° 48' 23.3"
16	21+000	509467.55	6936754.11	62° 33' 41.6"	-116° 48' 57.0"
17	22+500	508978.46	6938172.14	62° 34' 27.5"	-116° 49' 31.0"
18	24+000	508492.05	6939588.66	62° 35' 13.3"	-116° 50' 4.8"
19	25+500	508005.67	6941007.61	62° 35' 59.2"	-116° 50' 38.7"
20	27+000	508170.88	6942461.11	62° 36' 46.1"	-116° 50' 26.9"
21	28+500	508536.34	6943915.91	62° 37' 33.1"	-116° 50' 1.0"
22	30+000	508497.74	6945389.67	62° 38' 20.7"	-116° 50' 3.4"
23	31+500	508258.19	6946870.42	62° 39' 8.6"	-116° 50' 20.0"
24	33+000	508024.73	6948352.11	62° 39' 56.5"	-116° 50' 36.1"
25	34+500	507811.47	6949836.87	62° 40' 44.5"	-116° 50' 50.8"
26	36+000	507599.42	6951321.81	62° 41' 32.5"	-116° 51' 5.5"
27	37+500	507328.25	6952791.53	62° 42' 20.0"	-116° 51' 24.3"
28	39+000	507662.4	6954242.59	62° 43' 6.9"	-116° 51' 0.6"
29	40+500	508252.22	6955596.84	62° 43' 50.6"	-116° 50' 18.8"
30	42+000	508547.48	6957040.66	62° 44' 37.2"	-116° 49' 57.8"
31	43+500	508765.12	6958524.69	62° 45' 25.1"	-116° 49' 42.2"
32	45+000	509394.06	6959845.91	62° 46' 7.8"	-116° 48' 57.6"

Borehole #	Station	UTM Zone 11		Lat/Long	
		X	Y	Latitude	Longitude
33	46+500	509426.43	6961210.38	62° 46' 51.8"	-116° 48' 55.0"
34	48+000	508721.37	6962527.99	62° 47' 34.5"	-116° 49' 44.5"
35	49+500	508142.14	6963885.81	62° 48' 18.4"	-116° 50' 25.1"
36	51+000	508218.31	6965334.12	62° 49' 5.2"	-116° 50' 19.5"
37	52+500	508287.31	6966832.27	62° 49' 53.6"	-116° 50' 14.4"
38	54+000	508069.95	6968306.74	62° 50' 41.3"	-116° 50' 29.5"
39	55+500	507674.34	6969752.87	62° 51' 28.0"	-116° 50' 57.2"
40	57+000	506928.45	6970967.15	62° 52' 7.3"	-116° 51' 49.8"
41	58+500	506725.67	6972376.37	62° 52' 52.9"	-116° 52' 3.9"
42	60+000	506651.77	6973823.12	62° 53' 39.6"	-116° 52' 8.9"
43	61+500	506858.05	6975308.27	62° 54' 27.6"	-116° 51' 54.1"
44	63+000	506876.92	6976802.56	62° 55' 15.9"	-116° 51' 52.6"
45	64+500	506951.46	6978224.79	62° 56' 1.8"	-116° 51' 47.1"
46	66+000	506307.78	6979523.88	62° 56' 43.8"	-116° 52' 32.5"
47	67+500	505522.08	6980797.46	62° 57' 25.0"	-116° 53' 28.1"
48	69+000	504790.59	6982107.01	62° 58' 7.4"	-116° 54' 19.9"
49	70+500	504108.92	6983436.38	62° 58' 50.4"	-116° 55' 8.2"
50	72+000	503911.42	6984923.28	62° 59' 38.4"	-116° 55' 22.1"
51	73+500	503712.11	6986409.98	63° 0' 26.5"	-116° 55' 36.1"
52	75+000	503506.25	6987895.7	63° 1' 14.5"	-116° 55' 50.6"
53	76+500	503280.96	6989344.5	63° 2' 1.3"	-116° 56' 6.5"
54	78+000	502808.33	6990766.48	63° 2' 47.2"	-116° 56' 40.1"
55	79+500	502335.14	6992189.71	63° 3' 33.2"	-116° 57' 13.7"
56	81+000	501567.87	6993439.35	63° 4' 13.6"	-116° 58' 8.3"
57	82+500	501383.29	6994923.63	63° 5' 1.6"	-116° 58' 21.4"
58	84+000	501190.65	6996410.14	63° 5' 49.6"	-116° 58' 35.1"
59	85+500	501224.12	6997890.13	63° 6' 37.4"	-116° 58' 32.7"
60	87+000	501584.43	6999201.6	63° 7' 19.8"	-116° 58' 6.9"
61	88+500	501765.09	7000685.42	63° 8' 7.8"	-116° 57' 54.0"
62	90+000	501627.33	7002178.89	63° 8' 56.0"	-116° 58' 3.7"
63	91+500	501126.9	7003536.86	63° 9' 39.9"	-116° 58' 39.5"
64	93+000	500286.26	7004779.14	63° 10' 20.0"	-116° 59' 39.5"
65	93+780	499845.11	7005422.1	63° 10' 40.8"	-117° 0' 11.1"

GNWT Response to:
MVEIRB IR#10

Topic
Equitable Distribution of Employment Benefits

Comment
The Tłı̨chǫ Government and Community Government of Whatì have proposed mitigation #4 (mobilization of the Career Development and Economic Development Officers) to prepare the local workforce for project related job opportunities (PR#96 p9). While the exact number and types of jobs required for the construction and operations phases for the project is unknown, many of the positions will revolve around historically male-dominated trades and occupations. Table 1-3 from PR#96 outlines the current labour supply numbers for the anticipated equipment requirements.

Recommendation
1. Please provide a breakdown by gender of the current labour supply numbers in Table 1-3 of PR#96.
2. What specific strategies does the GNWT have in place to ensure active and equitable participation for women in the employment opportunities related to the project?

GNWT Response
The Tłı̨chǫ Government has provided input for the response for the first part of this IR (Part 1) since the table was developed and submitted by the TG to the Review Board in PR#96.

The GNWT has responded to Part 2 of the IR with GNWT-specific initiatives for employment benefits for women. The Tłı̨chǫ Government responded to strategies for ensuring equitable employment for women in IR 9.

Part 1

Below is a breakdown of gender supply based on PR#96 table 1-3. We note that men hold the majority of the positions, which reflects the general characteristics of tradespeople in construction jobs. That being said, the Tłı̨chǫ Government is committed to ensuring women's equitable participation in, and benefit from, projects that are operating in their territory.

It should be noted that the Community Government of Whati (CGW) trained four women as Heavy Equipment Operators (HEO) last year. The CGW plans to continue this training program for women this year as well, contingent on secured funding.

Table 1: Equipment Needs and Labour Supply by Gender

Anticipated equipment list for construction of proposed TASR Equipment	Size	Community Labour Supply Numbers			
		Behchokǫ̀	*Whatì*	*Gamètì*	*Wekweètì**
Tracked Dozers	D3 through to D9	107 men 9 women	7 men 0 women	n/a	n/a
Hydraulic Excavators (wheeled & Tracked)	E70 through to 2458		2 men 0 women	n/a	n/a
Motor Graders	Various	48 men 5 women	13 men 0 women	8 people total *(Mostly men, some women with HEO experience)*	n/a
Loaders (wheeled and tracked)	Various	26 men 0 women	17 men 0 women	n/a	n/a
Compaction Equipment		16 men 10 women	5 men 0 women	n/a	n/a
Rotary Drills	Various	92 men 14 women	1 man 0 women	n/a	n/a
Gravel Crushing Plants (Cone and Jaw)	Various	6 men 0 women	Not applicable		
Single axle, Tandem axle and Tri axle Haul Trucks	Various-water tankers, sewage tanks, rock, gravel, sanding trucks and plow trucks	47 men 1 woman	18 men 2 women	10 men 2 women	n/a
Tractor Trailers	Various	15 men 4 women	4 men 0 women	n/a	n/a
Rock Trucks	Various	26 men 1 women	8 men 0 women	n/a	n/a
Tractor Mowing Machines	Various	Na	Na	n/a	n/a
Water Trucks	Various	Single axle vehicle, see above			
Fuel Tankers	Various to 40,000 litres				
Pile Drivers	Various	na	1 man 0 women	n/a	n/a
Service Vehicles	Various-pickup trucks, utility service trucks, flat decks, snowmobiles, quads, etc.	33 men 5 women	Lots of individuals could fill these positions – people with Class 5 and recreational vehicle licenses. Count not available but could fill positions		
Tree	Various	42 men	45 men	13 men	Approx. 10

Anticipated equipment list for construction of proposed TASR Equipment	Size	Community Labour Supply Numbers			
		Behchokǫ̀	***Whatì***	***Gamètì***	***Wekweètì****
Harvesters/Mulchers		4 women	5 women	2 women	total
Cranes	Various	Information not available for the region			
Various small equipment (rock pickers, soil cultivators, post hole drills, post drivers, water pumps, rig maps, tampers, compressors, jack hammers, etc.	Various	63 men 11 women	14 men 0 women	12 men 2 women	0 men 0 women
Temporary Construction/Work Camp Facilities	150 person camps	157 men 11 women	55 men 0 women	n/a	7 total
Generators	Various	Not applicable			

*For Wekweètì, available labour supply by gender is tracked differently than the other three communities. A summary of the community labour supply for employment related to the construction of the TASR, according to gender, is described below in Table 2:

Table 2: Wekweètì Equipment Needs and Labour Supply by Gender

Employment type relevant to the construction of the TASR *(Wekweètì residents only; count includes persons currently in training)*	**Total Labour Supply**	**Currently Employed**
HEO	38 (32 men, 6 women)	21 (16 men, 5 women)
General Labour	38 (34 men, 4 women)	19 (17 men, 2 women)
Water delivery	25 (24 men, 1 woman)	13 (13 men, 0 women)
Sewage / waste services	25 (24 men, 1 woman)	13 (13 men, 0 women)
Drill Blasting	4 (4 men, 0 women)	4 (4 men, 0 women)
Bridge construction	4 (0 men, 4 women)	2 (0 men, 2 women)
Transportation (long haul trucking)	21 (21 men, 0 women)	13 (13 men, 0 women)
Light equipment	11 (11 men, 0 women)	8 (8 men, 0 women)
Wildlife monitoring	24 (23 men, 1 women)	8 (8 men, 0 women)

Additional demographic statistics of the available labour force supply in the community of Wekweètì includes:

- Nine women over the age of 50 are in the workforce, 7 of whom are currently employed;
- One woman who works in the mines and is currently employed;
- Eighteen women with young children are in the workforce, 14 of whom are currently employed; and
- Four women under age 50 (without children) who are in the workforce, two of whom are currently employed.

Part 2
The following is a summary of specific strategies that the GNWT has in place to ensure active and equitable participation for women regarding employment opportunities. These strategies include preferential hiring, training programs and workplace safety.

Local/Northern employment and training are high priorities with the GNWT. Regarding specific strategies to ensure active and equitable participation of women, the GNWT's affirmative action policy states that resident women have priority status on competitions for management and non-traditional jobs. A variety of training opportunities are available for northerners, including women:

- Small community employment support:
    - Provides wage subsides to employers in small NWT communities who offer training in the workplace to unemployed individuals for 12 – 52 weeks, and applies to the community of Whati.
- Apprenticeship Training-on-the-Job program:
    - Helps northerners take part in apprenticeship training by providing wage subsidies to employers who train them towards journeyperson certification.
- Training-on-the-Job program:
    - This program helps employment insurance participants take part in skills development opportunities by providing wage subsidies to employers who offer them training in the workplace.

In regards to the TASR, employment statistics will be collected by Project Co. as specified in the TASR project agreement and submitted to the GNWT. The number of women employed can be included in statistics collected and submitted, in order for the GNWT to track the number of northern, local and women employed with the project.

Women's safety in the workplace is an issue the GNWT takes seriously. The GNWT's Harassment Free and a Respectful Workplace Policy to address safety in the workplace.

Geotechnical Recommendation Report Proposed Arch Culvert Crossing #10a Station 48+208

Geotechnical Investigation,
Proposed Tlicho All-Season Road,
Northwest Territories

Stantec

Prepared for:
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Project No. 144902448

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1.0 PROJECT DESCRIPTION AND BACKGROUND

Project Description

Acting under the authorization of Tlicho Engineering and Environmental Services Ltd. (Tlicho), Stantec Consulting Ltd. (Stantec) carried out a geotechnical investigation in support of the arch culvert planned at 'Crossing #10a' along the proposed Tlicho All Season Access Road (TASR). The purpose of the investigation was to characterize the subsurface conditions and provide geotechnical comments and recommendations to assist with arch culvert design and site development.

The investigation was carried out in general accordance with Stantec's proposal dated January 12, 2017, as part of an overall geotechnical program by Tlicho for the Government of the Northwest Territories (GNWT) along the proposed 94 km TASR alignment extending from the Yellowknife Highway (Highway 3) to the Settlement of Whati on the south shore of Lac La Martre (RFP Event ID: EV000000001132). The scope of work outlined in the GNWT Request for Proposal includes the geotechnical investigation and design of the 94 km long TASR corridor, four bridges and three structural culverts. Tlicho was responsible for management and execution of the overall project and team as the Prime Contractor, with Stantec acting as sub-consultant providing geotechnical engineering and technical services to the project, including:

- Provision of geotechnical field personnel to log subsurface conditions during drilling operations at eighty-one (81) geotechnical boreholes in accordance with the RFP:
  - Thirteen (13) boreholes at the four (4) proposed major bridge crossings:
    - Crossing #8, Station 40+400 - Duport River Crossing
    - Crossing #9, Station 45+175 - (unnamed)
    - Crossing #14, Station 69+666 - James River Crossing
    - Crossing #15, Station 85+397 - La Martre River
  - Three (3) boreholes at the three (3) proposed major bridge culvert crossings:
    - Crossing #5, Station 16+532
    - Crossing #6, Station 19+427
    - Crossing #10a, Station 48+208
  - Sixty-five (65) boreholes to observe the subsurface conditions along the road alignment;
- Installation and reading of thermistors;
- Borehole layout and as-drilled survey;
- Completion of a laboratory testing program on the recovered borehole samples as specified in the RFP; and
- Geotechnical engineering assessment and reporting on the field and laboratory findings in two reports (Geotechnical Data Report and Geotechnical Recommendations Report) for each crossing location and for the overall roadway alignment.
  - These documents should be read in conjunction with the Statement of General Conditions, Appendix A.

This geotechnical recommendation report has been prepared specifically for the proposed Arch Culvert Crossing No. 10a on the Tlicho All Season Road at Station 48+208. This report should be read in conjunction with the Stantec Geotechnical Data Report titled "Geotechnical Data Report Proposed Arch Culvert Crossing #10a Station 48+208". The Geotechnical Data Report documents the results from the investigation completed for the arch culvert.

Background - Proposed Structure

An arch culvert is proposed at Crossing No. 10a on the Tlicho All Season Road alignment at Station 48+208. The preliminary structure design consists of a metal arch structure supported on granular pad foundation and a geosynthetic reinforced soil (GRS) backfill to construct the arch culvert. The height and width of the metal arch structure will be 1.91 m and 3.66 m, respectively. The total length of the arch culvert will be 16.2 m.

The Preliminary General Layout drawing for the proposed arch culvert is presented on Drawing No. 2 in Appendix B. The General Layout drawing is based on the Tlicho All Season Road Predesign Report and was designed by DOT Structures and drawn/drafted by DOT Technical Services. GNWT DOT was responsible for the precise station location and arch culvert dimensions. The proposed arch culvert will facilitate water flow beneath the Tlicho All Season Road from west to east. The road embankment has proposed side slopes of approximately 2H:1V. The finished road top surface of the highway is approximately 3.6 m higher than the ground surface. The general layout drawing is conceptual, and it will be revised at the final design stage.

Key approximate elevations associated with the proposed arch culvert are as follows:

Finished Road top Elevation:	279.28 m (at Centreline)
Proposed Invert Elevation:	275.98 m inlet
	275.34 m outlet
Proposed Obvert Elevation:	277.89 m inlet
	277.25 m outlet
Design Streambed Elevation:	275.23 m inlet
	274.59 m outlet
Existing Ground Elevation	275.98 m inlet
	275.36 m outlet
Design Water Level (obvert of pipe):	277.8 m

2.0 GEOTECHNICAL DESIGN RECOMMENDATIONS

The design and analysis approach for this report is based on the Canadian Standards Association (CSA), 2014 Canadian Highway Bridge Design Code (CHBDC) and assumes that the structures are classified as a Buried Structure (CSA S6-14 Section 7). The analysis approach assumes a force-based design (FBD) and elastic static analysis (ESA) methods for the structural design.

2.1 GEOTECHNICAL DESIGN PARAMETERS

Based on the Geotechnical Data report, the subsurface stratigraphy at the site consisted of root mat at the surface over peat, which was underlain by sand with varying amounts of silt, clay and gravel. Cobbles were also inferred in the sand.

For design purposes, the soil model provided in Table 2.1 will be used. The soil model is based on the soil properties encountered in the boreholes from the field investigation. The design methodology assumes that permafrost is present at the culvert location (Section 2.3.1). The parameters in Table 2.1 are for unfrozen soils. The use of unfrozen soil parameters for bearing capacity design of the culvert foundation is a conservative approach, if the soils are frozen. Design parameters for the proposed embankment fill are also provided.

The "degree of site and prediction model understanding for the native soils" has been assessed as "Typical Understanding" as per Section 6.5 of the Commentary on CSA S6-14, Canadian Highway Bridge Design Code (CHBDC), (S6, 1-14).

Table 2.1: Generalized Soil Profile at Arch Culvert Crossing No. 10a

Approximate Depth (m)		Soil Type	Design Parameters				Design Temperature Profile
From	To		γ (kN/m³)	ϕ' (°)	c' (kPa)	E (MPa)	
-	0	Embankment Fill (Pit run fill) See Section 2.4	21	32	-	50	Seasonal Freeze Thaw
0	-	Structural Gravel Pad (structural backfill, see Table 3.1)	21	35	-	50	
0	1.0	Peat	16	12	-	5	
1.0	2.0	Silty, Clayey Sand (Dense)	20	30	2	35	
2.0	4.0	Silty, Clayey Sand (Dense)	20	30	2	35	-0.1 to 0 °C
4.0	-	Inferred Bedrock	26.5	-	-	-	-

Notes: (1) depth is referenced from existing ground surface, i.e. depth is zero at ground surface

(2) γ = total unit weight, ϕ' = soil friction angle, c' = effective cohesion, E = soil/rock modulus

(3) A design water level at elevation 277.8 m will be used (obvert of pipe). Effective unit weights (γ') should be used below the groundwater level.

(4) The depths provided in the above table reflect a generalization of the borehole data to incorporate the most significant aspects of the geotechnical design and are not based on any specific location.

2.2 SEISMIC DESIGN CONSIDERATIONS

2.2.1 Site Class

It is recommended that Site Class C, very dense soil and soft rock, as defined in CHBDC (CHBDC, 2014) Section 4.4.3 be used in the seismic design for this site. The energy-corrected weighted harmonic mean penetration resistance, $\overline{N}_{60}$, values were used to assess the seismic site classification for this site are as follows.

Depth Below Culvert	Soil	$\overline{N}_{60}$
0 to 4 m	Silty, Clayey Sand	> 50
4 to 30 m	Glacial Till or Bedrock	100

Notes:
(1) An energy-corrected penetration resistance $\overline{N}_{60}$ of 100 was used below 4 m depth due to auger refusal at a depth of 3.96 m below ground surface on inferred bedrock or very dense, clayey, silty sand with cobbles and boulders (glacial till).

2.2.2 Peak Ground Acceleration (PGA)

Seismic hazard values for this site were obtained from Natural Resources Canada (2015 National Building Code). Table 2.2 summarizes the parameters based on a 2475-year return period to be used in forced based design.

Table 2.2: Peak Ground Acceleration Data

PGA	$S_a(0.2)$	PGA_{ref}	Site Adjusted PGA	Site Class
0.030 g	0.052 g	0.0240 g	0.0300 g	C

The 2015 NBC Seismic Hazard calculation sheet that corresponds to this site is provided in Appendix C.

2.2.3 Vertical Acceleration Ratio (A_v)

CSA S6-14 Section 7.5.5.1 indicates that for the design of buried structures the vertical component of an earthquake, expressed as the vertical acceleration ratio, A_v, effectively increases the unit weight of the soil from γ to γ (1+A_v). The vertical acceleration ratio, A_v, is to be two-thirds of the Site Adjusted PGA value for the site. The recommended A_v value for this project is 0.02 g.

2.2.4 Liquefaction Potential

The potential for soil liquefaction was evaluated by comparing the cyclic stress ratio (CSR) caused by the design earthquake with the soil resistance expressed in terms of the cyclic resistance ratio (CRR). The evaluation follows the analysis methodology suggested by Idriss and Boulanger (2008) and is based on the following:

- The blow count data from boreholes.
- A Site Adjusted PGA of 0.03 g.
- An earthquake magnitude M_w of 5.84, which is based on a Seismic Hazard Deaggregation calculated by the Canadian Hazards Information Service. A copy of the deaggregation result is provided in Appendix C (Geological Survey of Canada, 2017).

The analysis indicates a factor of safety against liquefaction of over 2.0, and therefore earthquake induced liquefaction is not considered a concern at this site.

2.3 FOUNDATION RECOMMENDATIONS

2.3.1 Frost Consideration

Based on the available thermistor temperature data recorded for borehole BH17-42C, we are unable to confirm if permafrost was present at this site. For design purposes, it may be conservative and precautionary to assume permafrost is present. The depth of the seasonal freeze thaw zone (active layer) was estimated to be 2 m based on the thermistor temperature data for BH17-42C, as summarized in Table 2.1, although it is difficult to estimate the depth of the active layer using temperature data collected in winter. An estimate of the active layer thickness should be done using temperature data or shallow physical probing collected in early/late fall.

The native clayey, silty sand deposit present at the culvert site is classified as SM-SC and consists of more than 25% silt and 14% clay size particles. Hence, the native clayey, silty sand soil is classified as F4 based on U.S. Corps of Engineers Frost Design Soil Classification (Canadian Foundation Engineering Manual, 2006). The F4 classification indicates that the native soil is highly susceptible to frost heave in the presence of a high groundwater table and freezing ground temperatures and will cause movement of the arch culvert and embankment. The culvert foundation will require frost protection as discussed in the next section.

2.3.2 Foundation Type and Geotechnical Resistance

A gravel pad foundation constructed from well-graded crushed aggregate structural backfill is considered suitable for foundations of the proposed arch structure. The recommended grading specification for structural backfill is provided in Section 3.1.

A minimum of 0.6 m wide rigid steel plate should be placed directly below the feet of the metal arch structure to distribute the local stress concentration and reduce bearing stress. The steel plate should be rigidly connected to the feet of the arch structure. Alternately, a concrete pad can be considered in place of the rigid steel plate. The rigid steel plate or the concrete pad should be embedded to a minimum depth of 0.3 m into the gravel pad foundation.

The gravel pad foundation should have a minimum width of 1.5 m. As discussed in the above section, the native clayey, silty sand soil is classified as highly susceptible to frost heave. Hence, the non-frost susceptible gravel pad foundation is recommended to extend to the estimated seasonal freeze thaw zone of 2 m below the exposed ground surface.

The geotechnical resistances for the above recommended foundation type is provided in Table 2.3. The bearing stress at the base of the arch structure should be limited to the geotechnical resistances of the gravel pad foundation.

Table 2.3: Recommended Factored Geotechnical Resistances

Structure	Approximate Foundation Elev. (m)	Width of Rigid Steel Plate or Concrete Pad (m)	Factored Resistance at ULS (kPa) $\phi_{gu} = 0.5$	Factored Reaction at SLS (kPa) $\phi_{gs} = 0.8$
Arch Culvert	275.67	0.6	125	1,000
		0.8	140	880
		1.0	155	780

Notes:

(1) A minimum embedment depth of **0.3 m** is required for the rigid steel plate or concrete pad into the gravel pad foundation.

(2) The Geotechnical Resistances were estimated assuming a consequence classification of "Typical Consequence" with a consequence factor equal to 1.0 in accordance with Section 6.5 and Table 6.1 of CHBDC, 2014.

(3) In accordance with Section 6.9 and Table 6.2 of the CHBDC, 2014, a resistance factor of 0.5 has been applied to calculate the factored geotechnical resistance at Ultimate Limit States (ULS).

(4) The geotechnical reaction at Serviceability Limit States (SLS) typically corresponds to a maximum settlement of 25 mm. In accordance with Section 6.9 and Table 6.2 of CHBDC, 2014, a geotechnical resistance factor of 0.8 has been applied to calculate the factored geotechnical reaction at SLS. Additional settlement due to thaw consolidation associated with degradation of existing permafrost (Section 2.6) is anticipated.

2.3.3 Subgrade Preparation

Deleterious materials such as root mat and a peat layer were encountered in the borehole BH17-42C drilled at the proposed arch culvert location. The thickness of the deleterious materials was approximately 0.82 m.

All the layers of deleterious materials and very loose native silty sand layer should be excavated from the proposed arch culvert footprint. The lateral extent of such excavation should include all deleterious material within the influence zone of the arch culvert. The exposed subgrade after removal of deleterious material should be examined by a qualified geotechnical inspector to confirm that the soils are consistent with those observed in the boreholes and to ensure that there is no loose or deleterious material left. Any loose, disturbed, or organic material identified during the inspection will require removal to the satisfaction of the geotechnical inspector. The working surface subgrade should be protected from disturbance and freezing in winter construction. As noted above, additional excavation may be required to address frost heave mitigation issues.

2.4 EMBANKMENT DESIGN

2.4.1 General

The embankment at the arch culvert location will consist of a GRS backfill for the arch culvert and a road embankment over the GRS backfill. The road embankment will extend beyond the GRS backfill along the road profile, and will be constructed with pit run fill at a side slope of 2H:1V.

Based on the Preliminary General Layout Plan, the roadway profile at the arch culvert location will be raised above the existing ground profile by up to approximately 3.6 m.

The potential presence of fine-grained thaw sensitive soils including the organic soil, sandy silt and the clay increase the potential for thaw related settlement and subsidence (CSA, 2010) if permafrost is present. If permafrost is present, and the embankment thickness is greater than about 1.5 m, then the permafrost will be aggraded into the embankment, in the short term (Wolfe, 1998). In the longer term, the permafrost level may recede downward to the original level due to long-term climate warming. Thus, thaw settlement is likely to be less of an issue under the main part of the embankment. However, it may be an issue at the toe of the embankment slopes where the embankment fill thickness is less than 1.5 m. Additionally, snow tends to build up at the toe of the embankment and acts as an insulator, resulting in warming of the embankment toe. Both vertical and horizontal movements could develop and could impact the performance of the road embankment. Seasonal maintenance of the impacted infrastructure and ground surface should be carried out.

The following sections provide recommendations for the design and construction of the embankment at the arch culvert location.

2.4.2 Embankment Construction

All the layers of root mat, peat, and any other deleterious materials should be excavated and removed from beneath the footprint of the embankment. The exposed subgrade after excavation should be examined and approved by a qualified geotechnical inspector prior to backfilling.

A non-woven geotextile such as Terrafix 270R or approved equivalent should be placed directly on the subgrade and should extend 6 m laterally into the embankment footprint from the toe of embankment.

The road embankment should be constructed with pit run fill placed in lifts no thicker than 150 mm and compacted to at least 95% Standard Proctor Maximum Dry Density (SPMDD). Pit run fill should consist of well-graded sand and gravel with less than 10% fines (clay and silt size particles). Soil gradation testing of the fill should be carried out and reviewed by a geotechnical engineer prior to delivery to site. All fill should be placed and compacted when air temperatures are consistently above freezing. No fill should be placed and compacted that is frozen or at freezing temperatures.

The GRS backfill for the arch culvert should be constructed as per the GRS manufacturer specifications. The complete design of the GRS including the dimensions, material types and other specifications should be provided by the GRS manufacturer, and reviewed by the geotechnical engineer of record for the project. We recommend the backfill material for the GRS meet or exceed the specifications outlined in Section 3.1. The CHBDC specifications should be compared with the manufacturer specifications for GRS arch culvert, and whichever specification is more stringent should govern.

2.4.3 Embankment Settlement

The settlement of the embankment has been assessed based on the following mechanisms; self-weight settlement of embankment fill, thaw settlement of the seasonal freeze / thaw layer and underlying permafrost, and the elastic settlement of underlying unfrozen soil layers.

Table 2.4 summarizes the embankment settlement estimated at borehole location BH17-42C. The analysis predicts about 43 mm of settlement.

Table 2.4: Estimated Embankment Settlement

Settlement Mechanisms	Borehole Location
	BH17-42C
Self-weight Settlement of Embankment Fill[1] (mm)	36
Thaw Settlement of Frozen Soil[2] (mm)	Negligible
Elastic Settlement of Unfrozen Soil[3] (mm)	7
Total Settlement	43

Notes:

1) Estimate assumes fill placement during temperatures above 0°C. Estimate assumes self-weight settlement equal to 1% of the embankment fill height.
2) Estimate assumes the seasonal freeze thaw layer are frozen during fill placement and a maximum depth of 4 m. Unit thaw settlement was assessed based on statistical method proposed by the modified Nixon and Ladanyi (1978) equation (Andersland and Ladanyi,1994), and compared with thaw strain values estimated from figures by Hanna et al. (1978).
3) Elastic settlement of unfrozen soil was calculated using Settle3D program by Rocscience (Rocscience, 2009) using soil design parameters and soil stratigraphy noted in Table 2.1. The estimate assumes that the peat has been removed and replaced with pit run fill.

Andersland and Ladanyi (1994) note that where variations of subsurface conditions (soil type and moisture content and ice content) and variable thaw progression beneath the embankment occur, significant differential settlements can be anticipated. Such subsurface conditions may exist at the arch culvert location. The differential movements arising from the variable subsurface condition and thaw progression could impact the performance of the arch culvert and road embankment. Seasonal maintenance of the impacted infrastructure may be required. Monitoring of the culvert and embankment is also recommended to periodically evaluate their performance and determine the need and scope of maintenance.

To mitigate embankment deformation related to self-weight settlement and related processes we recommend the following:

- Placing embankment fills during summer.
- Over building the embankment by approximately 0.3 m to 0.5 m.

In addition, monitoring of the embankment performance will assist in identifying potential performance issues. Monitoring may comprise:

- Monitoring the embankment for a period of 2 years. Monitoring should include mapping of cracks, measurement of crack apertures (if present), observations on the condition of the embankment slope and toe of slope.
- Installing multibead thermistor cables in the subgrade to monitor changes in the geothermal regime.
- The monitoring observations should be reviewed by a geotechnical engineer. After completion of monitoring the embankment could be re-graded to final grades.

2.4.4 Stability of Slopes

A global stability analysis of a 2H:1V embankment slope as shown on the Preliminary General Layout drawing was carried out. Both static and conventional pseudo-static limit equilibrium slope stability analysis methods were applied using the program Slope/W (Geo-Slope, 2012) and the design parameters noted in Table 2.1.

The analysis assumes that the peat layer will be removed from beneath the footprint of the embankment and replaced with pit run fill and the embankment will be constructed with pit run fill.

The pseudo-static stability analysis of the embankment slope considered seismic loading of 0.015, which is one-half of the Site Adjusted Peak Ground Acceleration (PGA).

The slope stability evaluation results indicate that the estimated factor of safety against critical failure is 1.5 for static conditions using a design high water level at elevation 277.8 m. The factor of safety against critical failure meets the required target value of 1.1 (seismic) for highway embankments.

2.5 EROSION AND SCOUR PROTECTION

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. All slopes within 3 m of the culvert inlet and outlet should be surfaced with rip-rap at least 300 mm thick placed on a non-woven filter fabric such as Terrafix

270R or approved equivalent; the rip-rap should extend up the slope to 0.3 m above the design high water level. Rip-rap aprons are shown on the Preliminary General Layout Plan at the culvert inlet and outlet. Where embankment construction includes earth fill, normal slope vegetation should be established as soon as possible after completion of the embankment fills in order to control surficial erosion.

The contractor should provide silt fences and erosion control blankets, as required, throughout the duration of the construction to prevent silt/sediment from running off the site.

2.6 CLIMATE CHANGE SENSITIVITY AND PERMAFROST DEGRADATION RISK

The 2010 CSA Technical Guide titled "Infrastructure in Permafrost: A Guideline for Climate Change Adaption" provides guidance on assessing the potential impacts of climate change on infrastructure in permafrost. As per Table 5.2 in CSA (2010), seasonal mean temperature change under moderate (A1B) green-house gas scenarios, the mean annual temperatures for the Arctic Sector C1 are projected to be 1.3 °C (2011-2040), 2.7 °C (2041-2070), and 3.7 °C (2071 – 2100) respectively. A warming climate could cause a change in depth of the active soil layer (where present). A deepened active layer can also initiate thaw settlement of underlying native soil, which will negatively impact the performance of embankments.

Based on CSA (2010), the sensitivity of the site to climate change was assessed as "high" and the consequence of permafrost degradation is assessed to be "minor" assuming the organic soil is removed and replaced with crushed aggregate below the culverts. The assessed site sensitivity and consequence suggests a risk level of "B" (moderate risk), which suggests a semi-quantitative analysis should be completed.

Long-term monitoring of the culvert, embankment, and the thermistors should be carried out as part of the evaluation of the long-term performance of the culvert and embankment. If the existing thermistors cannot be maintained during construction, a new multibead thermistor should be installed to a depth of 15 m to provide long-term ground temperature monitoring.

2.7 CEMENT TYPE AND CORROSION PROTECTION

One sample of the native soil was submitted to Maxxam Analytics in Edmonton for analysis of pH, water soluble sulphate and chloride concentrations, and resistivity. The testing was completed to determine the potential for deterioration of concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel used in buried infrastructure. The analysis results are summarized in Table 4.1 in the Geotechnical Data Report.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. The soluble sulphate concentrations for the sample was 0.021%. Soluble sulphate concentrations less than 0.1 % generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. Type GU (General Use) Portland Cement can therefore be suitable for use in concrete at this site, if applicable.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH value was 8.16, which is within the normal range for soil pH of 5.5 to 9.0. The pH level of the tested soil does not indicate a highly corrosive environment. The resistivity result was 7 Ohm-m, which suggests a severe degree of corrosiveness for steel. The chloride content was 0.00084% (8.4 ppm), which indicate a non-corrosiveness for steel. The test results provided in Table 4.1 in the Geotechnical Data Report may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

3.0 CONSTRUCTION CONSIDERATIONS

3.1 EXCAVATION AND BACKFILLING

Temporary side slopes for open cut excavations should have a gradient of 1H:1V or flatter, sloped from the bottom of the excavation.

Excavation and backfill for the culvert structure should be carried out in accordance with Section 7, Buried Structures of the 2014 CHBDC. Based on this guideline, some of the specifications, but not limited to, for the proposed arch culvert are outlined below. The CHBDC specifications should be compared with the manufacturer specifications for GRS arch culvert, and whichever governs should be considered.

- The 2014 CHBDC states that the structural backfill in single-conduit structure shall extend transversely on each side beyond the spring lines of the conduit to the smaller of 5 m and half the bottom width of the arch culvert, but not less than the height of arch culvert, for structure constructed in trench in which the natural soil is less stiff than the engineered soil. Hence, for the proposed arch culvert with bottom width of 3.66 m and height of 1.91 m, the structural backfill should extend to a minimum distance of 1.91 m beyond the bottom edges of the arch structure on each side.
- The 2014 CHDBC states that the structural backfill in single-conduit structure shall extend vertically up to the minimum depth of cover required by Clause 7.6.4.1 of CHDBC. Hence, for the proposed arch culvert with bottom width of 3.66 m and height of 1.91 m, the minimum depth of cover of the structural backfill is evaluated to be 0.6 m.
- The 2014 CHDBC states that the material for structural backfill shall be boulder free and shall be selected from the Group I or II soils specified in Table 7.4 of the CHDBC, with required compaction as per Table 7.5 of the CHDBC. The backfill shall be placed and compacted in layers not exceeding 200 mm of compacted thickness, with each layer compacted to the required density prior to the addition of the next layer. The difference in levels of structural backfill on the two sides of a conduit at any transverse section shall not exceed 200 mm. The structural backfill within 300 mm of the conduit walls shall be free of stones exceeding 75 mm in any dimension. Heavy equipment shall not be allowed within 1 m of the conduit walls. The structural backfill adjacent to the conduit wall and to within the frost penetration depth shall be free of frost-susceptible soils.

Bedding, leveling and GSR fill material for the arch culvert should consist of structural backfill meeting the grading specifications outlined in Table 3.1.

Table 3.1: Aggregate Specifications for Structural Backfill

Class 25 mm Aggregate		Percent Passing
Percent Passing Metric Sieve (CGSB 8-GP-2M) mm	25.000	100
	20.000	82-97
	16.000	70-94
	12.500	
	10.000	52-79
	8.000	
	5.000	35-64
	1.250	18-43
	0.630	12-34
	0.315	8-26
	0.160	5-18
	0.080	2-8
% FRACTURE BY WEIGHT (2 FACES)	ALL +5.000	60+
PLASTICITY INDEX (PI)		Non-plastic
L.A. ABRASION LOSS PERCENT MAX.		50

Note: Aggregate specifications for structural backfill adapted from the Alberta Transportation Standard Specification for Highway Construction, Table 3.2.3.1 Specification for Aggregate (Alberta Transportation, 2013).

3.2 REUSE OF EXCAVATED MATERIAL

The native material in the vicinity of the project site consists of root mat, peat and clayey, silty sand with cobbles.

The clayey, silty material is highly susceptible to frost heave as discussed in Section 2.6, and hence will not be suitable as backfill for the proposed arch culvert. The native clayey, silty sand soil may be used for embankments if properly processed and compacted and only where potential frost heaving will not negatively impact the performance of the culvert or roadway. Other native soils may be used for landscaping purposes only.

3.3 TEMPORARY CONSTRUCTION DEWATERING

Groundwater was encountered at the depth of 2.6 m in the borehole BH17-42C during the investigation. Fluctuations in the groundwater due to seasonal changes or in response to a particular precipitation event should be anticipated.

Depending on the time of year of construction, installation of the arch culvert may require excavation below the groundwater level. Control of groundwater during construction may be required. The groundwater level should be lowered to at least 0.5 m below the subgrade level of the culvert and the subcut for the granular pad material.

The native soils within the anticipated depth of excavation have a low to moderate hydraulic conductivity, in the order of 10^{-3} to 10^{-5} cm/s. Significant groundwater flow should be anticipated within unfrozen organic soil and peat layers. Dewatering of the culvert excavation using conventional sump and pump techniques should be adequate. If high groundwater levels are present during construction, cofferdams enclosing the work area may be used as required.

For reference, the results of the grain size distribution tests (and Unified Soil Classifications) completed on the predominant soil strata encountered in the boreholes have been compared to the grain size curves and soil types referenced in Supplementary Standard SB-6 of the 2012 Ontario Building Code (OBC). The OBC has been used as a guideline to estimate the likely range in the coefficient of permeability of the soils encountered in the investigation. It is noted that the industry typically refers to "hydraulic conductivity" rather than "coefficient of permeability" in this respect. The terms are often considered interchangeable, but for purposes of this report the values provided are in the form of "length/time" (cm/sec) and are therefore considered strictly applicable to "hydraulic conductivity", and hence "hydraulic conductivity" is used herein.

Based on the comparison conducted, the following values are provided:

Unfrozen Soil Type	Estimated Hydraulic Conductivity	Comment
Silty Sand (SM)	10^{-3} to 10^{-5} cm/sec	Medium to Low Permeability
Clayey Sand (SC)	10^{-2} to 10^{-3} cm/sec	Medium to Low Permeability

The OBC states, in part, that "it must be emphasized that, particularly for fine-grained soils, there is no consistent relationship (between coefficient of permeability and soils of various types) due to the many factors involved". Such factors as structure, mineralogy, density (compactness or consistency), plasticity, and organic contents of the soil can have a large influence on the hydraulic conductivity; variations in excess of an "order of magnitude" are common place in this respect.

4.0 DESIGN UNCERTAINTIES

A primary uncertainty for the design of this culvert structure is the variability of foundation conditions. This includes the potential presence of buried massive ice under the culvert location. The geotechnical drilling program was not able to penetrate to significant depths due to auger refusal. Such refusal may be caused by many factors including encountering bedrock, or well-bonded permafrost soils. Experience on the reconstruction of Highway 3 between Behchoko and Yellowknife found that many culvert crossings were underlain by massive ice, which negatively impacted the performance of the road embankment and culvert. To address the potential for the presence of massive ice at this culvert site several recommendations are provided to the Client for their consideration:

- Conducting an additional geotechnical program at the time of construction consisting of test pits or additional drilling using a more powerful drill than what was used for the initial geotechnical program.
- Conducting a geophysical survey along the road alignment to provide additional information on the subsurface conditions at depth.
- Developing a construction contingency plan for the presence of massive ice, prior to construction, so that the plan is in place and can be readily implemented should the need arise.

5.0 DESIGN REVIEW AND CONSTRUCTION MONITORING

Stantec Consulting Ltd. should review the design details, specifications and drawings prior to construction. Quality assurance and construction monitoring should be provided during construction in order to confirm that the contractor is following the recommendations in this Report. Long-term monitoring should be completed to monitor for settlement and performance of the culverts and embankments.

6.0 CLOSURE

A soil investigation is a limited sampling of a site. The recommendations given herein are based on information gathered at the specific borehole locations. Should any conditions at the site be encountered that differ from those at the borehole locations, we request that we be notified immediately in order to assess the additional information and its effects on the above recommendations. Use of this report is subject to the Statement of General Conditions provided in Appendix A. It is the responsibility of Tlicho Engineering & Environmental Services Ltd., who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd. should any of these not be satisfied. The Statement of General Conditions addresses the following:

- Use of the report
- Basis of the report
- Standard of care
- Interpretation of site conditions
- Varying or unexpected site conditions
- Planning, design or construction

We trust the information presented herein meets your present requirements. Should you have any questions or require additional information, please do not hesitate to contact us.

This report has been prepared by Abraham Mineneh and reviewed by Christopher McGrath and Jim Oswell.

Respectfully submitted,

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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 Consulting Ltd. 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 Consulting Ltd.'s 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 Consulting Ltd. 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 Consulting Ltd. 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 Consulting Ltd. 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 Consulting Ltd. will not be responsible to any party for damages incurred as a result of failing to notify Stantec Consulting Ltd. that differing site or sub-surface conditions are present upon becoming aware of such conditions.

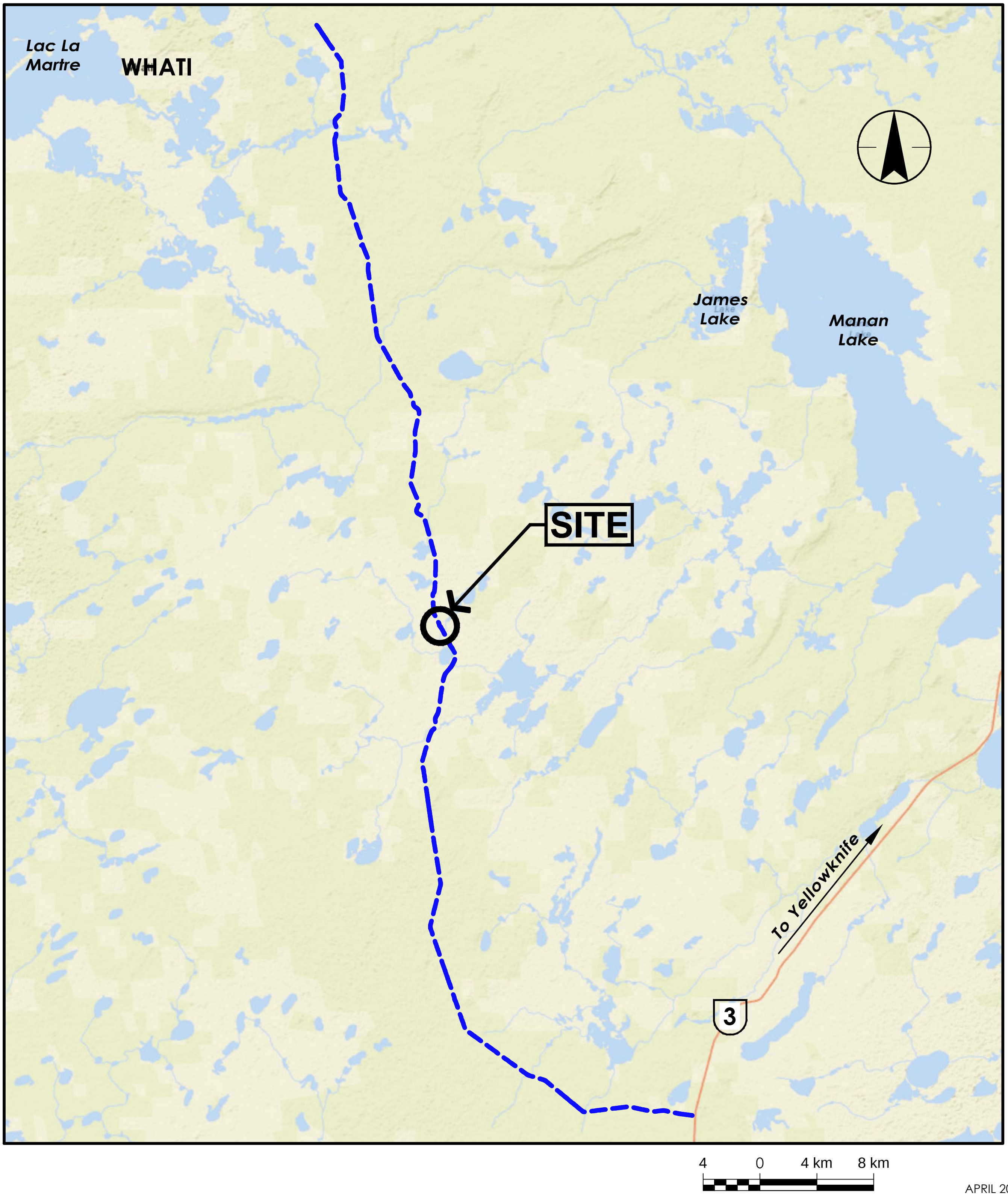
PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project 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 Consulting Ltd. cannot be responsible for site work carried out without being present.

APPENDIX B

Drawing No. 1 – Key Plan

Drawing No. 2 – General Layout and Borehole Location Plan

Site Photos



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2017/05/23 1:10 PM By: Pinnell, Brian

APRIL 2017
Project No. 144902448

Stantec

400 - 1331 Clyde Avenue
Ottawa, ON, Canada K2C 3G4
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LEGEND

PROPOSED ALIGNMENT

NOTES

IMAGERY: ESRI ©2017.

Client/Project

TLICHO ENGINEERING & ENVIRONMENTAL SERVICES LTD.

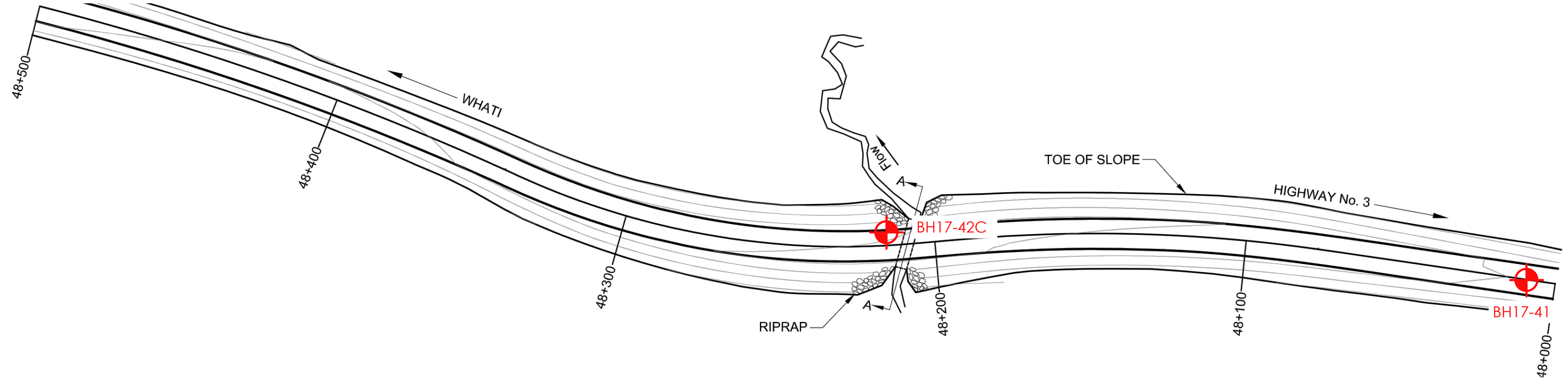
GEOTECHNICAL INVESTIGATION
BRIDGE CROSSING #10a, NWT

Drawing No.

1

Title

KEY PLAN



SITE PLAN
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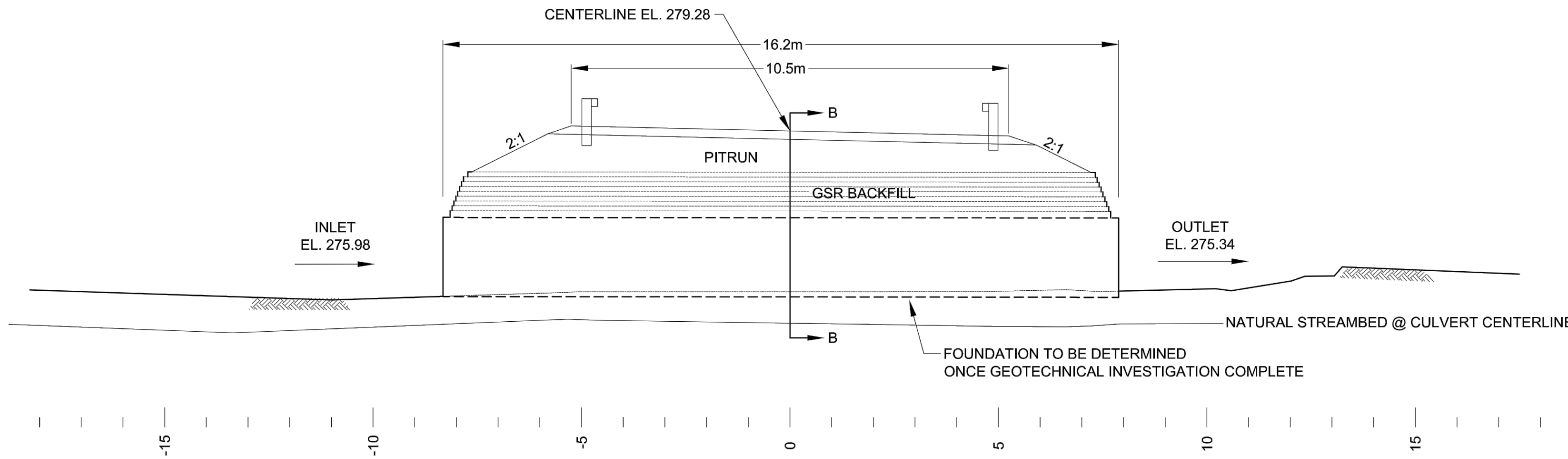
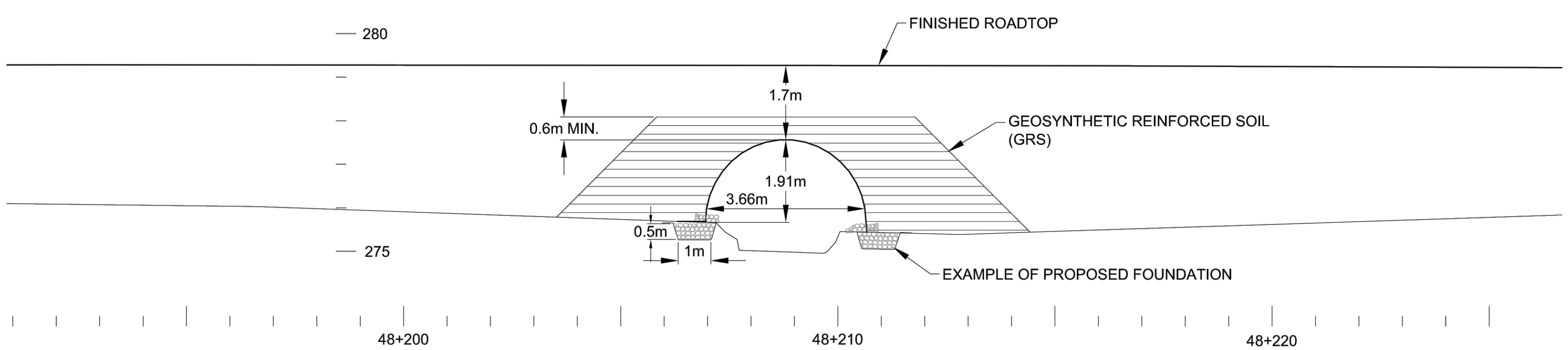
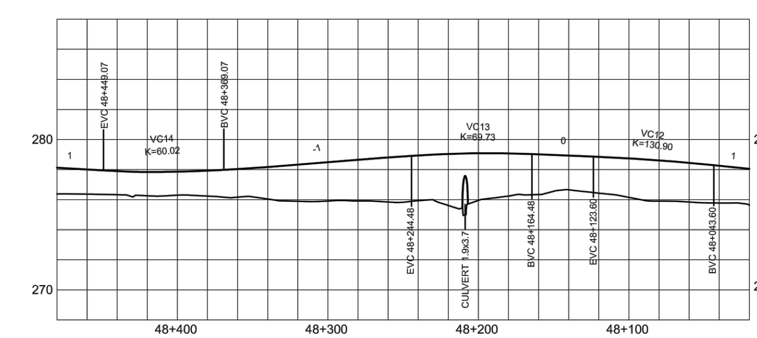


CULVERT PROFILE A-A @ 48+208.8
1:150

PLAN
1:10,000



SECTION B-B
1:150



ROADWAY PROFILE
H 1:5,000 V 1:500

APRIL 2017
PROJECT No. 144902448

T:\1449XXX\144902448 Ontario\From Ontario\Crossing 10a\144902448_C10a_General Layout.dwg
2017/05/23 1:32 PM By: Pinnell, Brian

Stantec

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LEGEND

APPROXIMATE BOREHOLE LOCATION

NOTES

1. DRAWING PROVIDED BY DOT TECHNICAL SERVICES (TASR-04-16 (CROSSING#10a).

Client/Project

TLICHO ENGINEERING & ENVIRONMENTAL SERVICES LTD.
GEOTECHNICAL INVESTIGATION
CROSSING #10a CULVERT, NWT

Drawing No.
2

Title

GENERAL LAYOUT AND BOREHOLE LOCATION PLAN

Photo No. 1: BH17-41 Looking Roadside

Photo No. 2: BH17-41 Looking Along Road

Photo No. 3: BH17-41 Looking Roadside

Photo No. 4: BH17-41 Looking Along Road

Photo No. 5: BH17-42C Looking Toward Borehole

Photo No. 6: BH17-42C Closer View of Thermistor Cables and PVC Pipe

Photo No. 7: BH17-42C Looking Roadside

Photo No. 8: BH17-42C Looking Roadside

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APPENDIX C

NBC Seismic Hazard Calculation Sheet
Seismic Hazard Deaggregation

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

April 20, 2017

Site: 62.5482 N, 116.8059 W User File Reference: Tlicho All Season Road, Northwest Territories

Requested by: , Stantec Consulting Ltd.

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	**Sa(0.2)**	Sa(0.3)	**Sa(0.5)**	**Sa(1.0)**	**Sa(2.0)**	**Sa(5.0)**	**Sa(10.0)**	**PGA (g)**	**PGV (m/s)**
0.040	0.056	**0.052**	0.044	**0.040**	**0.033**	**0.021**	**0.0072**	**0.0034**	**0.030**	**0.034**

Notes. Spectral (Sa(T), where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s. Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. ***These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.***

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.0025	0.011	0.020
Sa(0.1)	0.0040	0.016	0.029
Sa(0.2)	0.0057	0.018	0.029
Sa(0.3)	0.0070	0.018	0.027
Sa(0.5)	0.0076	0.019	0.026
Sa(1.0)	0.0065	0.016	0.023
Sa(2.0)	0.0040	0.010	0.015
Sa(5.0)	0.0014	0.0035	0.0049
Sa(10.0)	0.0008	0.0016	0.0023
PGA	0.0023	0.0089	0.016
PGV	0.0059	0.015	0.022

References

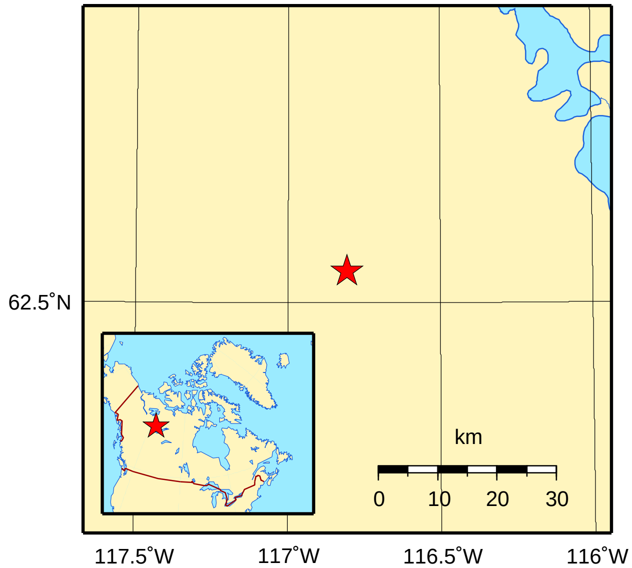
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites *www.EarthquakesCanada.ca* and *www.nationalcodes.ca* for more information

Aussi disponible en français



Natural Resources Canada
Ressources naturelles Canada
Canada

Seismic Hazard Deaggregation

calculated by the Canadian Hazards Information Service

INFORMATION: *EarthquakesCanada.nrcan.gc.ca*

Eastern Canada (613) 995-5548 Western Canada (250) 363-6500

Requested by: Zach Popper, Stantec

2017/04/21

For site Tlicho All Season Road, NT at 62.548 N 116.806 W

For ground motion parameter peak ground acceleration (PGA)

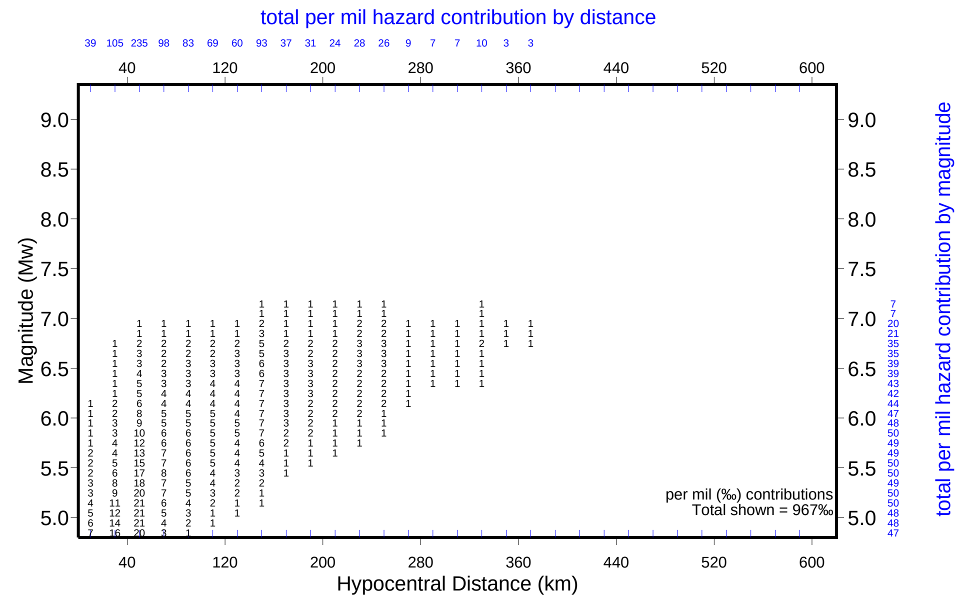
at a probability of 0.000404 per annum, seismic hazard = 0.030 g

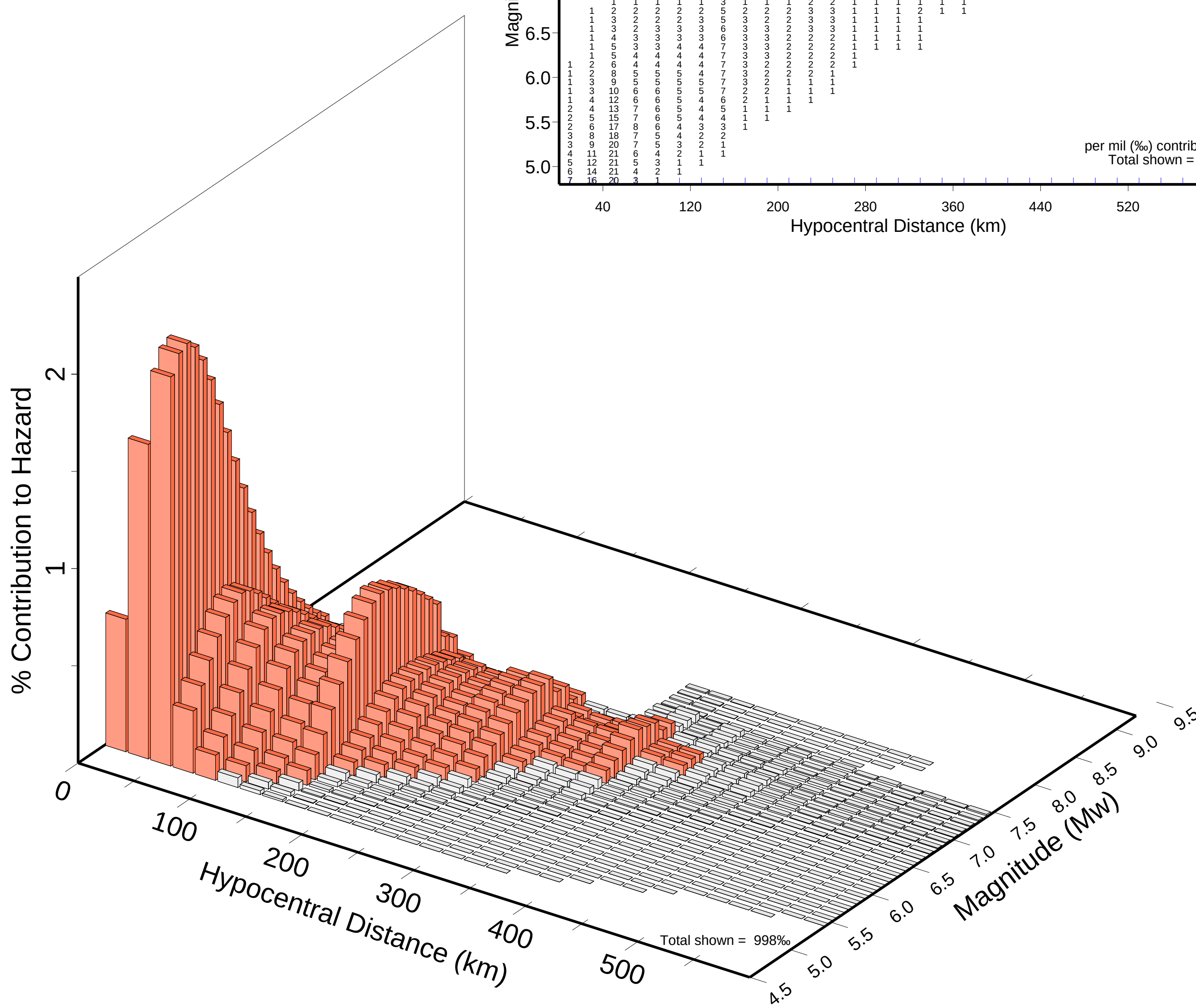
Mean magnitude (Mw) 5.84 Mean distance 112 km

Mode magnitude (Mw) 5.050 Mode distance 50 km

Deaggregation of mean hazard

Model: WArctic_g2015clC.model





Aussi disponible en francais