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Report

Impact of changing climate on infrastructure in Longyearbyen: stability of foundations on slope terrain – Case study

Field report – geotechnical investigations

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Rock and Soil Mechanics
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ABSTRACT
SINTEF Building and Infrastructure is performing a study funded by Svalbard Environmental Protection Fund, Longyearbyen Lokalstyre and Store Norske Boliger AS. The project is named "Impact of changing climate on infrastructure in Longyearbyen: stability of foundations on slope terrain – case study". A part of this project is to collect information of subsoil properties. This report describes the soil investigations performed in spring 2017 in a slope in Longyearbyen.

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APPENDICES

1 Introduction

SINTEF Building and Infrastructure is performing a study funded by Svalbard Environmental Protection Fund, Longyearbyen Lokalstyre and Store Norske Boliger AS. The project is named "Impact of changing climate on infrastructure in longyearbyen: stability of foundations on slope terrain – case study". A part of this project is to collect information of subsoil properties. This report describes the soil investigations performed in spring 2017 in a slope in Longyearbyen.

2 Background

The last years exhibit record-breaking values of air temperatures and amount of precipitation in Svalbard. Several severe events caused by environmental hazards took place in Longyearbyen in the last decade and for the last year in particular. One may relate such events as manifestation of a changing climate.

Increase in air temperatures leads to degradation of permafrost. Consequences of permafrost degradation consist in increased thickness of the active layer, warming of permafrost at depth, and permafrost thawing. One can expect that the latter phenomena will lead to decrease of bearing capacity of foundations based on permafrost.

It is therefore relevant to assess how existing foundations in Longyearbyen will withstand to projected climate change. For this purpose, soil investigations must be performed to establish input parameters for detailed analyses of foundation behaviour of buildings on slope terrain.

3 Location

The drilling campaign took place at Svalbard in Longyearbyen (see Figure 1). The location of the soil investigation was uphill house No.16 in road 232 as shown in Figure 2. Detailed location of boreholes is shown in Figure 3.

Figure 1 Overview map of the Svalbard Archipelago (/ 1/).

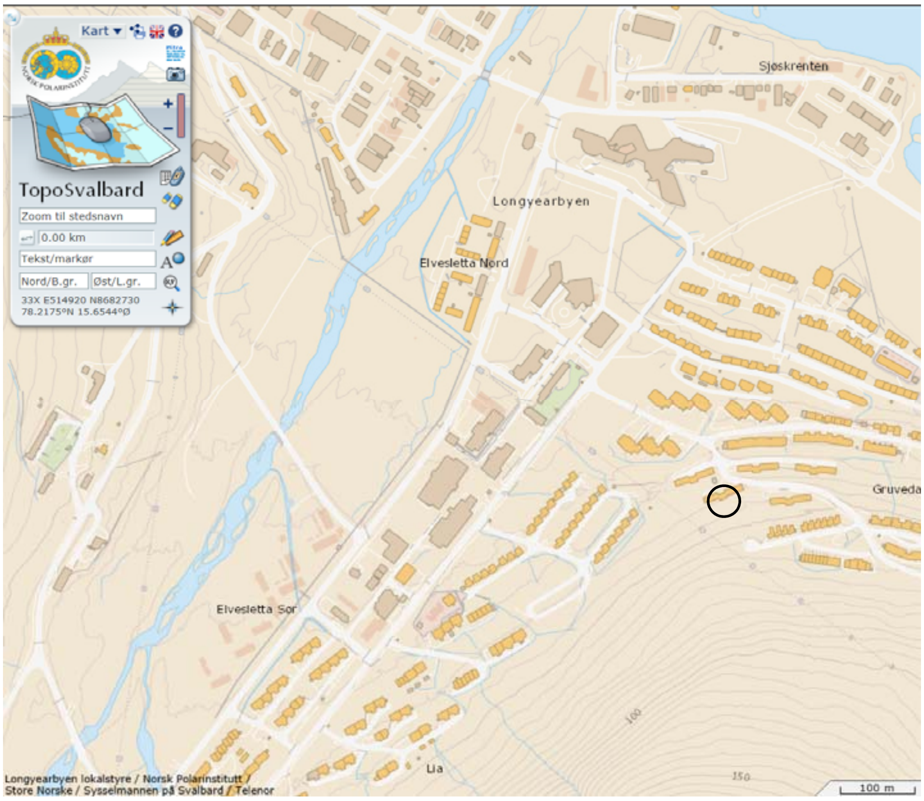

Figure 2 Location of the site in Longyearbyen (/ 2/).

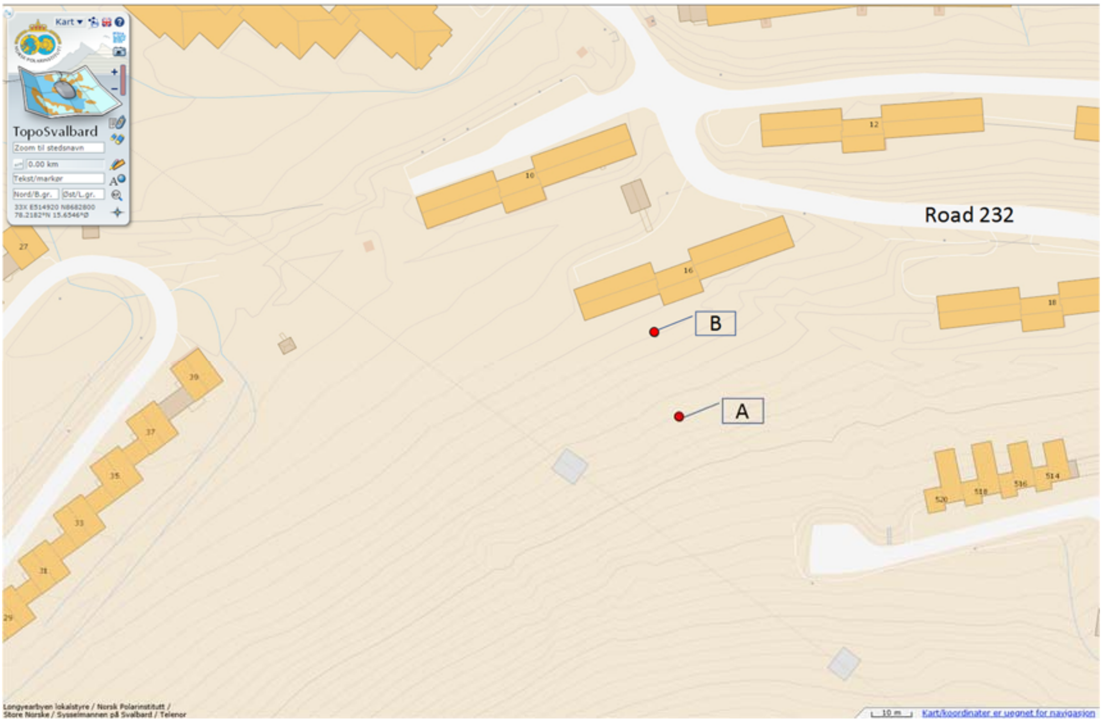

Figure 3 Detailed location of boreholes close to building no.16 in road 232 (/ 2/).

4 Methods and equipment

4.1 Drillrig

Field work is performed with SINTEFs custom built Geotech 504 drilling rig. The drilling rig can be disassembled to make it easy to transport in parts with helicopter if necessary. The drilling rig is equipped for different types of drilling and sounding, cone penetration testing, permafrost coring and conventional piston sampling. The drilling rig in operation in Longyearbyen slope is shown in Figure 4.

Figure 4 Drilling with Geotech 504.

4.2 Total sounding

The standard method for total soundings, as specified by the Norwegian Road Authorities (NPRA 2014, / 3/), is performed by rotating a drill bit into the ground at constant rotation and speed of penetration while recording the soil resistance. Increased rotation speed, flushing and drill hammer is used to penetrate hard layers or rocks. In frozen soils, the resistance is too high to facilitate the required penetration rate, i.e. increased rotation is used at all time and valuable information is lost. Based on this, a modification to the total sounding procedure has been developed by SINTEF (/ 4/ and / 5/) which allows for obtaining detailed information of the soil profile while maintaining the effectiveness of sounding. The modified total sounding is performed with constant force while logging the penetration rate. Hammering and flushing (in permafrost with air) is performed continuously.

5 Soil investigations

Two boreholes have been drilled with the SINTEF drilling rig in Longyearbyen, Svalbard (see Figure 5). Total sounding has been performed in both boreholes down below the rock interface. Auger sampling has been performed in borehole A and samples have been collected in the following intervals: [0- 0,3m], [0,3-0,6m], [0,6-0,9m], [0,9-1,1m], [1,1-1,3m], [1,2-1,3m], [1,2-1,45m], [1,45-1,65m], [1,65-1,75m]. From the total sounding, samples were collected for every meter.

The samples were kept in sealed plastic bags in a freezing room, to keep their properties and to avoid moisture loss. Different laboratory tests were carried out on these samples to make the soil classification possible.

Casing was installed in borehole A for installation of thermistor string.

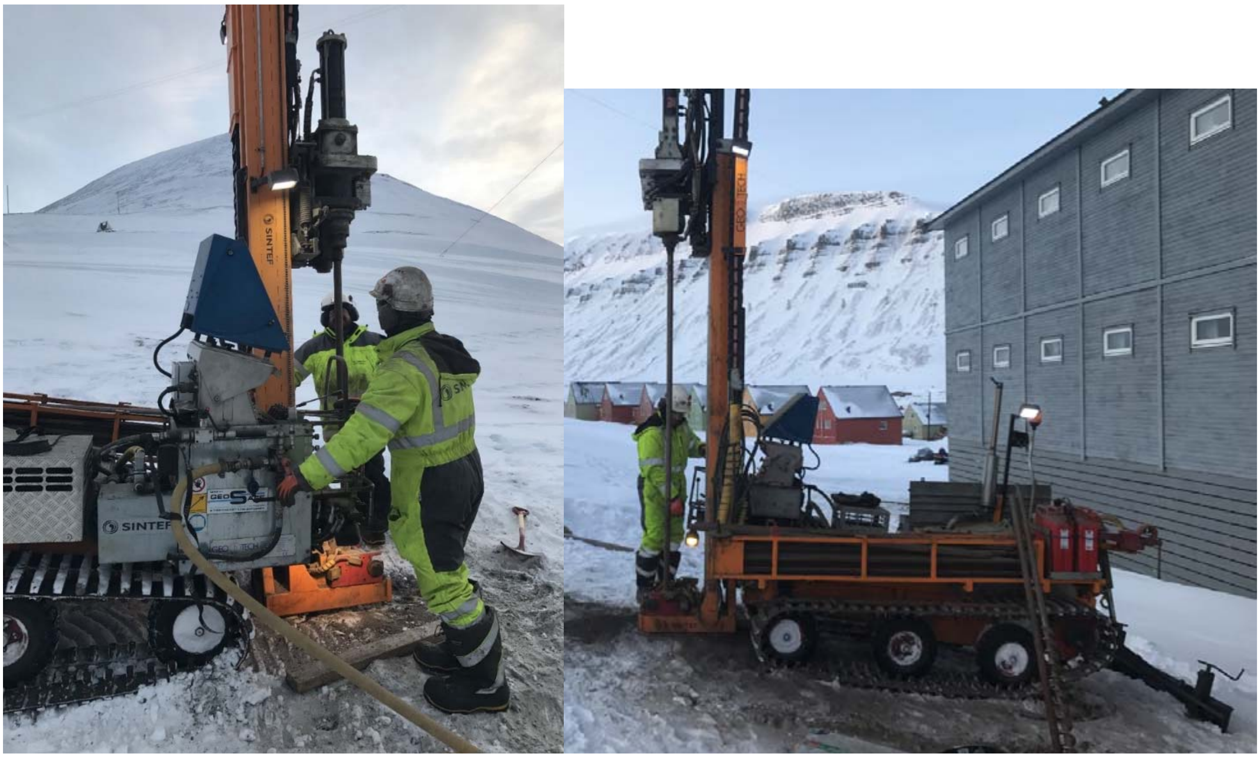

Figure 5 a) Drilling at borehole A. b) Drilling at location B.

6 Borehole information

The coordinates for the boreholes has been geodetic surveyed.

Borehole	Drilled depth	Heigth	Latitude	Longitude	UTM 33	UTM 33
	m	m.a.s.l.	degrees	degrees	East	North
A	7,82	45,5	78.2182600	015.6560400	514953.35	8682811.51
B	9,40	40,7	78.2180800	015.6562600	514958.58	8682791.48

Casing installed for thermistor installation in borehole A.

7 Total sounding results

The results from the total sounding is presented in Figure 6 and Figure 7. Bedrock was discovered at 6,35m depth at location 16A and at 4,6 m depth at location 16B.

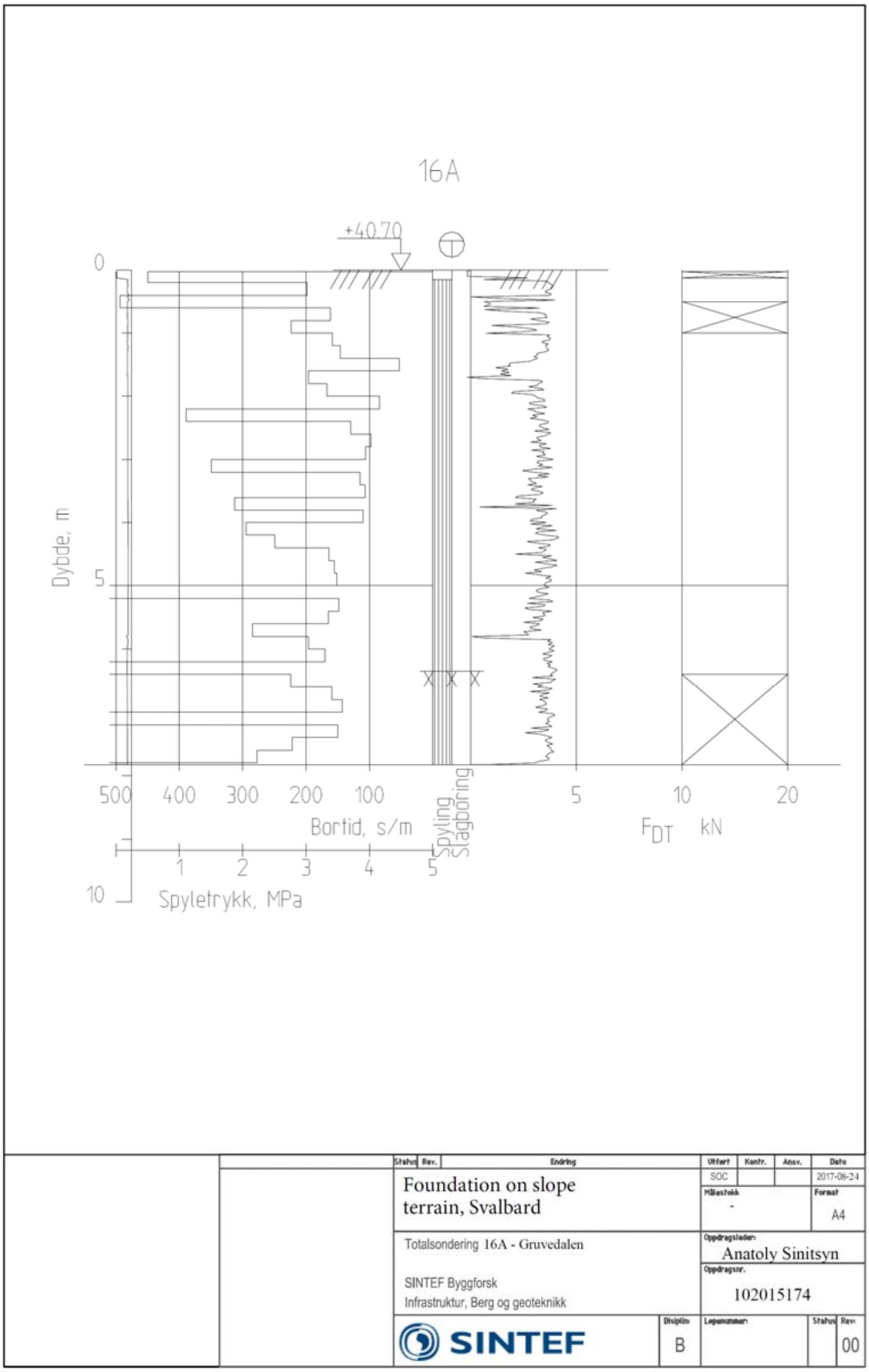

Figure 6 Result from total sounding in borehole 16A.

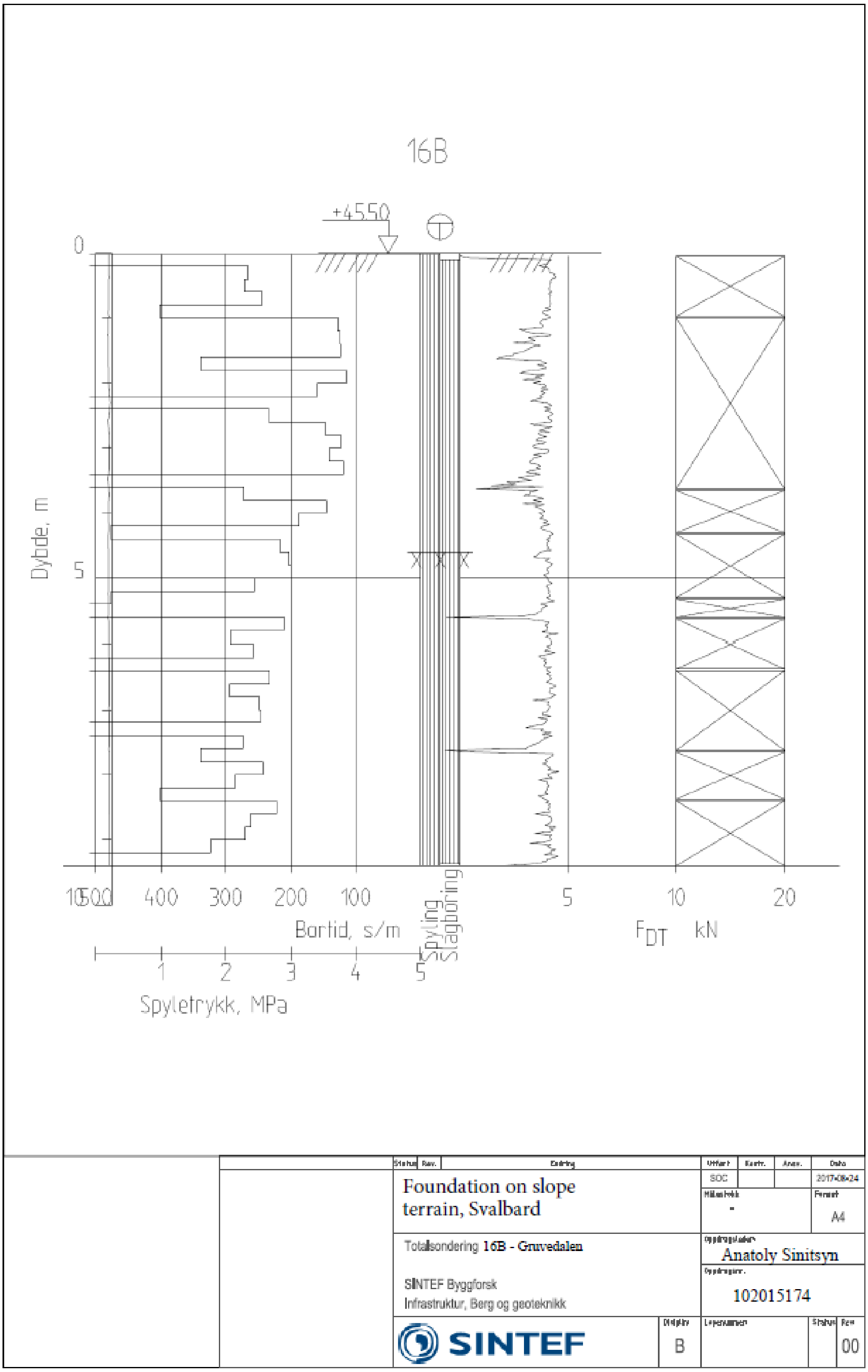

Figure 7 Result from total sounding in borehole 16B.

8 Laboratory work

The laboratory work has been performed in connection with a master student project / 6/.

8.1 Grain size

The particle-size distribution for the three tested samples is presented in Figure 8. Wet-sieving is performed for particles down to a grain size of 0,074 mm, and hydrometer analyses has been performed on the part of the sample smaller than 0,074 mm.

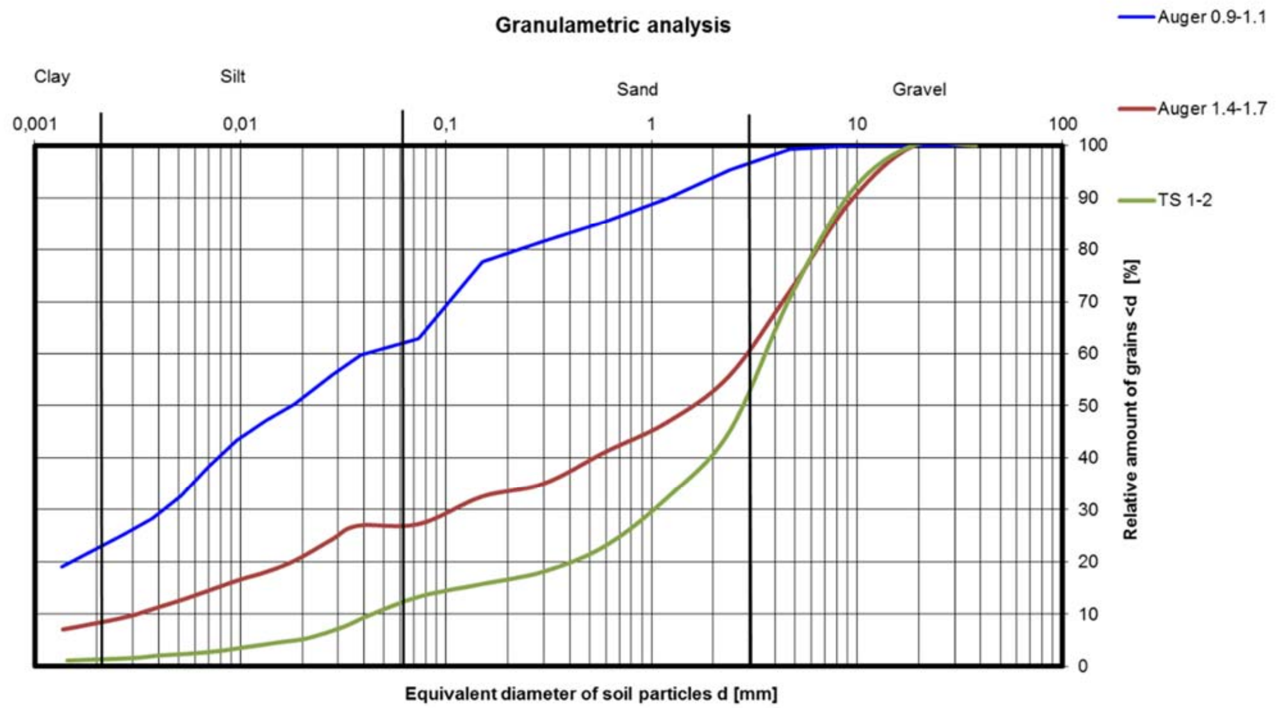

Figure 8 Grain-size distribution of auger samples from borehole 16A.

The particle-size distribution is used to give a description of the soil as shown in Table 1.

Table 1 Description of soil based on percentage of soil types from grain size tests.

Sample type	Sample depth (m)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Description
Auger	0,9-1,1	4	33	40	23	**Clay**, silty sandy
Auger	1,4-1,7	39	34	19	8	Gravelly, sandy, silty and clayey material
Cuttings from total sounding	1-2	46	42	11	1	Gravelly, sandy and silty material

8.2 Water content

The geotechnical water content in a soil mass can be determined by:

$$w = \frac{M_w}{M_s} \cdot 100\%$$

Where M_w = mass of water, and M_s = mass of dried solids.

The water content can be determined from samples collected from the ground. In this project water content has been determined on auger samples (down to 1,75m depth), and drill cuts collected during total sounding (down to 8 m depth). The results from water content analyses from auger samples are shown in Figure 9. The water content determined on drill cut samples from total soundings does not give reliable values since water may have escaped during the drilling process with use of air flushing.

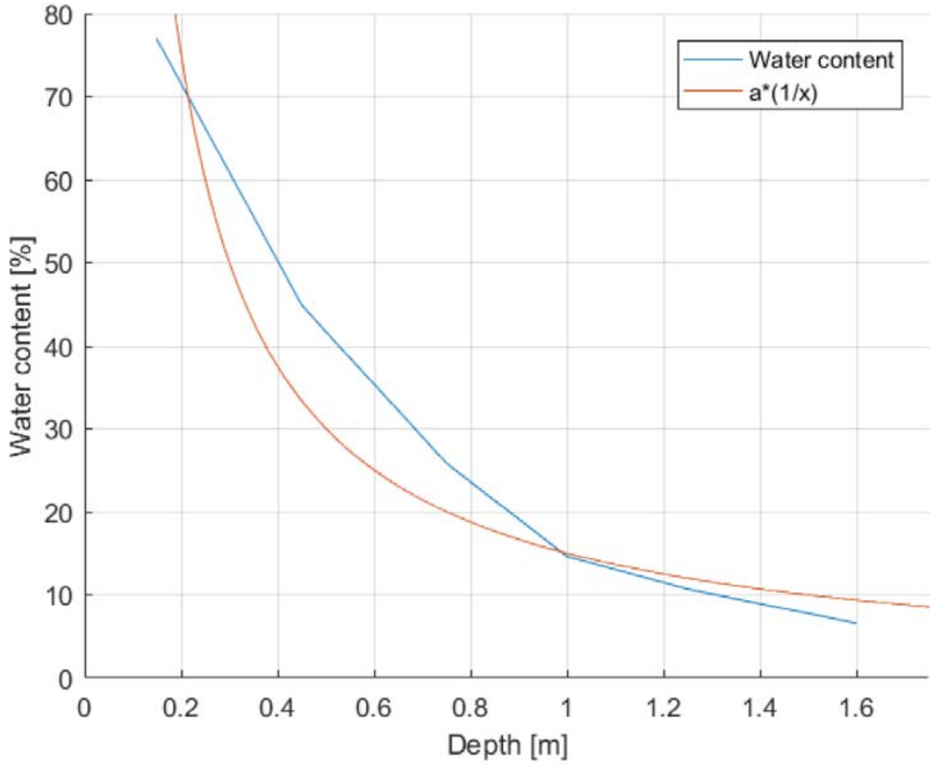

Figure 9 Water content (%) of soil from auger sampling.

The water content distribution with depth can be approximated by the curve $w = a \cdot \frac{1}{z}$ with a=15 (z=depth).

9 Thermistor installation and readings

A thermistor string was installed in a 50 mm diameter plastic casing in Borehole A on October 26th 2017. Prior to installation the thermistor string was calibrated in-house at ambient room temperature and in a bath of ice cubes and water (0º C). Readings of temperature from the thermistor string in the "air-filled" casing was performed on November 1st, and is shown in Figure 10.

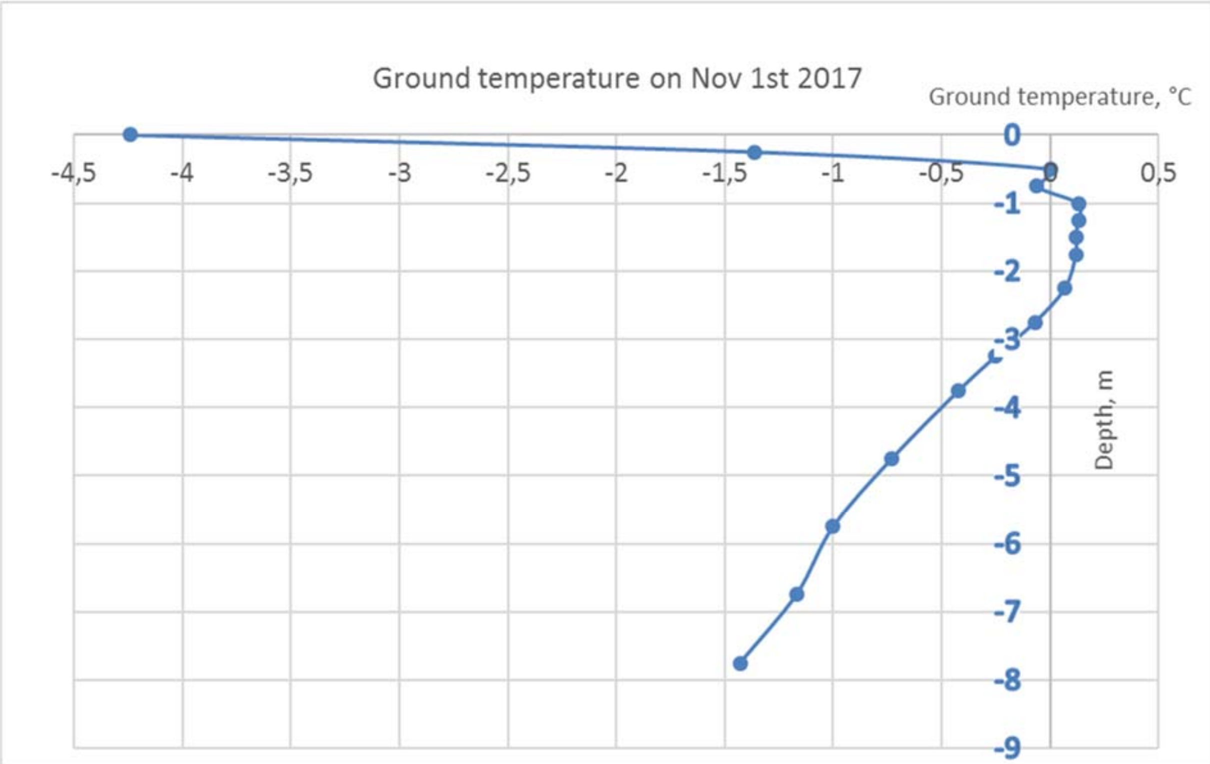

Figure 10 Ground temperatures at location A.

Thermistor readings signalise that the active layer thickness is approximately 2,5 m, and permafrost temperature at the deepest sensor (-7.75 m) is only -1.5 °C.

10 References

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