

Northern Climate ExChange

# Final Report: Dempster Highway Permafrost Assessment

March 2014



**Northern Climate ExChange**  
YUKON RESEARCH CENTRE • Yukon College

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## GENERAL DESCRIPTION OF THE PROJECT MAJOR ACHIEVEMENTS

### DESIGN OF SITES FOR INSTRUMENTATION

A draft for the design of sites for instrumentation was given to Highways and Public Works (HPW) on September 6<sup>th</sup>, 2013. The document included descriptive texts and diagram of the sites configuration and instrumentation. The document was reviewed and altered at HPW's request to meet further requirements. Alteration included reducing the number of boreholes from 4 to 3 per site; the depth of the boreholes from 10 to 8 m, and elimination of the sat-link communication capability. HPW produced a tender document including the design of the sites and the instrumentation requirement that was used in the call for tenders for drilling.

The final design of sites for instrumentation is provided in Annex A.

### REVIEW DRILLING CONTRACTS

Only one contractor, Midnight Sun Drilling Inc., answered to the call for proposals. The drilling contracts were not provided by HPW for review.

### BOREHOLE DRILLING AND ON-SITE LOGGING

**LOCATION ONE:** Located at km 124.0 of the Dempster Highway (Chapman Lake). Three sites were drilled on location from November 26<sup>th</sup> to November 29<sup>th</sup>, on the left hand side of the road (west side):

S1-Toe: located at the toe of the embankment (N64.90316 W138.27801). This site was drilled down to 28ft (8.53 m). The soil appeared to be coarse, gravelly, and unfrozen. Cuttings were collected during the drilling process (9 sample bags), but no frozen cores were retrieved. The borehole was instable and caving; no pvc tubing was installed.

S1-Field: located in the field (N64.90321 W138.27828). This site was drilled down to 28ft (8.53 m). The soil was frozen down to 3.5 m, cores were collected down to this depth (5 samples). Below, the soil reverted to gravelly, apparently unfrozen condition; and cuttings were collected during (5 sample bags). The borehole was sufficiently stable to allow pvc tubing to be installed.

S1-Road: located on the road (N64.90315 W138.27767). This site was drilled down to 33 ft (10.0 m). below the Embankment, 1.8 m thick, the soil appeared to be coarse, gravelly, and unfrozen. Cuttings were collected during the drilling process (8 sample bags), but no frozen cores were retrieved. The borehole was instable and caving; no pvc tubing was installed.

**LOCATION TWO:** Located at km 421.0 of the Dempster Highway. Three sites were drilled on location from December 1<sup>th</sup> to December 2<sup>th</sup>, on the right hand side of the road (East side):

S2-Toe: located at the toe of the embankment (N66.70089 W136.35854). This site was drilled down to 29ft (8.84 m). The soil appeared to be fine sediment with level of gravel. The cores were mostly frozen, but may have been altered by the drilling process as, often, length of the cores were inconsistent with the depth provided by the driller. Thirteen (13) samples were collected. The borehole was stable, and pvc tubing was installed.

S2-Field: located in the field (N66.70092 W136.35819). This site was drilled down to 28ft (8.53 m). The soil appeared to be fine sediment with level of gravel. The cores were mostly frozen, yet discrepancies exist between length and depth of the some of the cores. Fourteen (14) samples were collected. The borehole was stable, and pvc tubing was installed.

S2-Road: located on the road (N66.70093 W136.35862). This site was drilled down to 33 ft (10.0 m). Below the Embankment, 8 ft thick (2.44 m), the soil appeared to be organic grading to silt or clay, ice-rich, with gravelly levels. Nineteen (19) samples were collected. The borehole was stable, and pvc tubing was installed.

**LOCATION THREE:** Located at km 8.5 of the Dempster Highway as per NWT's km posts (8.5 km north of Yukon NWT border). Three sites were drilled on location from December 3<sup>th</sup> to December 4<sup>th</sup>, on the Left hand side of the road (West side):

S3-Road: located on the road (N67.10919 W136.08800). This site was drilled down to 27.5 ft (8.4 m), reaching bedrock. Below the Embankment, tentatively 8 ft thick (4.0 m), fine organic soil occurs with the presence of wedge ice. Deeper, at about 6.8 m, the soil appeared to be weathered schist grading into bedrock with depth. Fifteen (15) samples were collected. Fifteen (15) samples were collected. The borehole was stable, and pvc tubing was installed.

S3-Toe: located at the toe of the embankment (N67.10924 W136.08825). This site was drilled down to 20ft (6.1 m), reaching bedrock. The soil appeared to be fine sediment from ground surface to 2.4 m approximately, and then soil evolves into schist debris, probably weathered bedrock. Thirteen (13) samples were collected. The borehole was stable, and pvc tubing was installed.

S3-Field: located in the field (N67.10929 W136.08854). This site was drilled down to 10.5 ft (3.2 m), reaching bedrock. After fine sediment, coarse material was encountered around 2 m, grading into weathered bedrock, and then bedrock. Five (5) samples were collected. The borehole was stable, and pvc tubing was installed.

**LOCATION FOUR:** Located at km 51.5 of the Dempster Highway as per NWT's km posts (51.5 km north of Yukon NWT border). Three sites were drilled on location from December 4<sup>th</sup> to December 5<sup>th</sup>, on the Left hand side of the road (North side):

S4-Toe: located at the toe of the embankment (N67.24103 W135.26304). This site was drilled down to 27 ft (8.23 m). The soil consisted in ice-rich silt with erratic bed of gravel. The cores were frozen (13 cores in total), but Discrepancy exist between core length and depth due to decompression induced by the drilling process. The borehole was stable, and pvc tubing was installed.

S4-Field: located in the field (N67.24115 W135.26290). This site was drilled down to 27.5 ft (8.4 m). The soil consisted in ice-rich silt with erratic bed of gravel. The cores were frozen (12 cores in total), but yet discrepancy exist between core length and depth. The borehole was stable, and pvc tubing was installed.

S4-Road: located in the road embankment (N67.24092 W135.26307). This site was drilled down to 33 ft (10.06 m). After 2 m of embankment, the soil still consisted in ice-rich silt with erratic bed of gravel. The cores were frozen (16 cores in total), but yet discrepancy exist between core length and depth. The borehole was stable, and pvc tubing was installed.

## **CORE STORAGE**

The cores were brought back to Whitehorse by December 6<sup>th</sup> 2013. They were stored and locked in the walk-in freezer, inside the Yukon Research Centre (YRC) compound.

## **CORE LOGGING**

The core logging activities took place from February 3<sup>rd</sup> to 17<sup>th</sup>. The cores were logged and pictures were taken from the least altered and most representative samples. Selected cores were sawed in half using a rock saw to allow better view of the geocryological features. Once logged, the most adequate samples were selected for soil testing, and the cores were given to EBA for analysis.

The logs of the cores and pictures of geocryological features are provided in Annex B.

## **ISSUES, AREAS OF CONCERN OR RISK FACTORS THAT MAY AFFECT COMPLETION OF THE PROJECT AS PER ORIGINAL PLANS AND PROPOSED MITIGATION STRATEGIES AFFECTING THE SCHEDULE IF ANY**

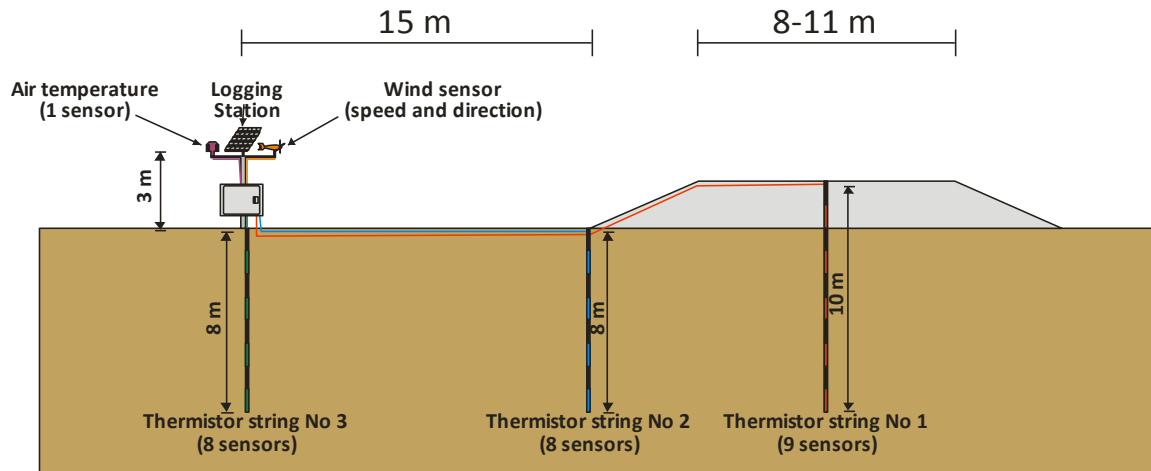
The drilling and coring activities were originally intended to occur early November 2013. However, the drilling ended up taking place in early December, due to the late agreement between HPW and the Drilling Company. This delay significantly altered the original schedule, and resulted in personnel working in harsher weather conditions. Core description and logging was also postponed to early February as time did not allow this to take place in Whitehorse following the drilling activities. The short 5-day notice given by HPW did not allow NCE to rent the most adequate vehicle for the field work. A flat-deck truck was the only vehicle available for rental, and therefore cores had to be transported by towed trailer, which was also inadequate for the load. As a result we experienced trailer and

truck problems (trailer wheel axle broke off due to load). Repairs will be included in the finances associated with this project budget. Other than those listed above, no noticeable issues occurred during the logging of the cores.

## **HIGHLIGHTS OF COMMUNICATION ACTIVITIES OF THE PROJECT**

To date, no communication activities have occurred other than assessment and discussion with the drillers during field activities on an informal and regular basis. During the field work, daily e-mail and phone call to up-date and report about work progress to Muhammad Idrees took place.

## ANNEX A: FINAL DESIGN OF SITES FOR INSTRUMENTATION



### DRILLING AND INSTRUMENTATION SITES

#### *PROPOSED DRILLING AND INSTRUMENTATION SITES*

##### Yukon Sites

The following two sites are located on the Yukon side of the Dempster Highway:

Location One: Proposed drilling and instrumentation location one (1) is located at km 124.0 of the Dempster Highway (Chapman Lake), the GPS coordinates of the location are W0628765 and N7199997. The borehole shall be drilled on the left-hand side. Thickness of the embankment is small and access to the location is easy.

Location Two: Proposed drilling and instrumentation location two (2) is located at km 421.0 of the Dempster Highway, the GPS coordinates of the location are W0439925 and N7398707. The borehole shall be drilled on the right-hand side. Thickness of the embankment is approximately 2.0 meters and access to the location is easy. Ice lenses are evident on the surface.

##### NWT Sites

The following two sites are located in the NWT side of the Dempster Highway:

Location Three: Proposed drilling and instrumentation location three (3) is located at km 8.5 of the Dempster Highway as per NWT's km posts (8.5 meters north of Yukon NWT border); the GPS coordinates of the location are 67° 6.552' N and 136° 5.274' W. The borehole shall be drilled on the left-hand side. Thickness of the embankment is approximately 1.5 meters and access to the location is easy.

Location Four: Proposed drilling and instrumentation location four (4) is located at km 51.5 of the Dempster Highway as per NWT's km posts (51.5 meters north of Yukon NWT border), the GPS coordinates of the location are 67° 14.447' N and 135° 15.788' W. The borehole shall be drilled on the left-hand side. Thickness of the embankment is approximately 1.5 meters on RHS and 1.0 meter on left-hand side, Access to the location is easy.

*Note: Above proposed locations are approximate only. Actual locations will be laid out in the field by the Engineer before the start of the work to facilitate assess.*

## **SUPPLY AND INSTALLATION OF INSTRUMENTATIONS**

### ***THERMISTOR CABLES***

Three thermistor cables shall be supplied, installed and connected with data logger at each location to measure the ground temperatures at different depths meeting the following criteria:

- a) Each thermistor string shall be made up of twisted pairs with temperature sensor shielded within jacket of polyurethane. Each thermistor cable shall be able to fit in 25mm diameter casings. The thermistor cable shall be strong enough to withstand the stresses caused by the moving traffic or settlement due to thermal movement or permafrost thaw. The thermistor cable shall have resistance against silicon oil, bentonite, silt, sand and gravel.
- b) The thermistor cable one (1), installed at the centre of the road shall have 38.0 m length with 28.0 m lead length and nine temperature sensors located at the depth of 0.2 m, 1.0 m, 1.5 m, 2.0 m, 3.0 m, 4.5 m, 6 m, 8.0 m and 10.0 m below the road top.
- c) The thermistor cable two (2), installed at the toe of the embankment shall have 26.0 m length with 18.0 m lead length and eight temperature sensor located at the depth of 0.2 m, 1.0 m, 1.5 m, 2.0 m, 3.0 m, 4.5 m, 6.0 m, and 8.0 m below the existing ground.
- d) The thermistor cable three (3), installed at 15 m from the toe of the embankment shall have 11.0 m length with 3.0 m lead length and eight temperature sensor located at the depth of 0.2 m, 1.0 m, 1.5 m, 2.0 m, 3.0 m, 4.5 m, 6.0 m, and 8.0 m below the existing ground.
- e) All the thermistor sensors shall be able to accurately record temperatures ranging from -50°C to +70°C with interchangeability tolerance of  $\pm 0.1^\circ\text{C}$  from 0.0°C to 70°C and  $\pm 0.2^\circ\text{C}$  below 0°C or better. The temperature survival range for the thermistor cables shall be -50°C to +100°C and typical thermometric drift for 100 months shall be  $<0.01^\circ\text{C}$  @ 0°C and  $<0.02^\circ\text{C}$  @ 25°C or better.
- f) Use Steinhart and Hart equation to calculate temperature to fit to the range of 0 to 70°C with maximum error of 0.03°C at 50°C.



### ***AIR TEMPERATURE PROBE***

One air temperature and humidity probe with white color RM Young Radiation Shield 10 Plate Threaded (without plug), shall be supplied, installed and connected with data logger at each location to measure the air temperature and relative humidity meeting the following criteria:

- a) The cable for air temperature probe shall have enough length to mount on three meter high post with data logger. The temperature probe shall be equipped with a radiation and wind shield, to limit the solar radiation loading and has to withstand severe winter/summer outdoor conditions. Each probe shall come with a polyethylene filter that protects its sensor from fine dust and particles and minimizes water absorption and retention. White color wind shield shall be naturally aspirated 10-plate radiation shield allowing air to pass freely through the shield and keeping the probe at or near ambient temperature.
- b) Each temperature shall be equipped with sensor mounting adapter threaded 15.5 mm diameter drilled and split.
- c) The probe shall use an advanced capacitive sensor to measure relative humidity.
- d) Temperature probe shall be able to accurately record temperatures ranging from -50°C to +70°C with interchangeability tolerance of + 0.2°C from 0.0°C to 70°C and + 0.5°C @50°C or better. The temperature survival range for the thermistor cables shall be -50°C to +100°C and typical thermometric drift for 100 months shall be <0.01°C @ 0°C and <0.02°C @ 25°C or better.
- e) The temperature probe shall be compatible with all kinds of the data loggers.
- f) Use Steinhart and Hart equation to calculate temperature to fit to the range of 0 to 70°C with maximum error of 0.03°C at 50°C.

### ***WIND MONITOR***

The wind sensor or anemometer measures wind speed and wind direction. One wind monitor with mounting arm shall be supplied and installed and connected with data logger at each location meeting the following criteria:

- a) Each wind sensor shall have enough cable length to attach with the data logger.
- b) The design of wind monitor shall be such to prevent ice buildup allowing the sensor to provide accurate measurements in harsh arctic conditions, rugged enough to work in very harsh environment, and shall be compatible with all kinds of data loggers.
- c) Wind monitor shall be capable of operating in a temperature range of -50°C to +50°C, assuming non rimming conditions and measuring wind speed of 0 to 100 m/s within an accuracy of  $\pm 0.3$  m/s or 1% of the reading, starting threshold of 1.0 m/s, distance constant of 2.7 meters (63% Accuracy), resolution of 0.1 m/s or better and output AC voltage (3 pulses per revolution, 90 Hz or 1800 rpm) 8.8 m/s.

- d) Wind monitor shall be capable of measuring wind direction in the range of 0 to 360° within an accuracy of  $\pm 0.5^\circ$ , starting threshold of 1.1 m/s at 10° displacement, damping ratio of 0.3, damped natural wavelength of 7.4 m, un-damped natural wavelength of 7.2 m, and output analog DC voltage from potentiometer—resistance 10kohms; linearity 0.25%; life expectancy 50 million revolutions.
- e) Each wind monitor shall be equipped with mounting rod which will include 6 feet cross arm, 10" mount pipe, one 3/4" x 3/4" Crossover to connect mount pipe to the cross arm and one 1" x 3/4" Crossover to connect the sensor to the mount pipe.

#### **DATA LOGGER**

The Contractor shall supply and install one manual download data logger at each location meeting the following criteria:

- a) The data logger system shall capable of recording the input data from 28 sensors: 25 ground temperature sensors, one air temperature sensor and 1-2 wind sensors.
- b) Each Data logger shall be compatible with nearly all available sensors, including thermocouples, SDI-12 sensors, and 4 to 20 mA sensors.
- c) Each Data logger shall have minimum of three years manufacturer's warranty.
- d) Each data logger shall have manual download system with capabilities of converting into automated download through GOES Satellite System if required in future; data logger also shall have serial communications with serial sensors and devices supported via I/O port pairs; flexible power and communication options making it ideal for remote locations; 4-MB memory which can be expanded with add-on memory systems; support PakBus, Modbus, SDI-12, and DNP3 protocols; compatible with channel expansion peripherals allowing to expand the system; program with LoggerNet, PC400, or ShortCut; communicate via various options: TCP/IP, email, FTP, and web server; gas Discharge Tube (GDT) protected inputs; battery-backed SRAM and clock that ensure data, programs, and accurate time are maintained while data logger is disconnected from the main power source; program and control on site with addition of keyboard and display unit; and contain custom ASIC chip that expands pulse count, control port, and serial communications capabilities. The format of the data download from the data logger shall be electronic file compatible with Excel worksheet.
- e) Each Data Logger shall have following specification:
  - i. Maximum Scan Rate: 100 Hz;
  - ii. 16 single-ended or 8 differential individually configured Analog Inputs;
  - iii. Two Pulse Counters;
  - iv. Switched Excitation Channels: 3 voltage;
  - v. Digital Ports1: 8 I/Os or 4 RS-232 COM2;

- vi. Communications/Data Storage Ports: 1 CS I/O, 1 RS-232, 1 parallel peripheral;
  - vii. Switched 12 Volt: 1;
  - viii. Input Voltage Range:  $\pm 5$  Vdc;
  - ix. Analog Voltage Accuracy:  $\pm(0.06\%$  of reading + offset),  $0^{\circ}$  to  $40^{\circ}\text{C}$ ;
  - x. Analog Resolution:  $0.33\ \mu\text{V}$ ;
  - xi. A/D Bits: 13;
  - xii. Temperature Range, Standard  $-25^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$ , Extended  $-55^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ ;
  - xiii. Memory: 2 MB Flash (operating system), 4 MB (CPU usage, program storage, and data storage);
  - xiv. Power Requirements: 9.6 to 16 Vdc;
  - xv. Current Drain: 0.7 mA typical; 0.9 mA max. (sleep mode), 1 to 16 mA typical (w/o RS-232 communication), 17 to 28 mA typical (w/RS-232 communication); and
  - xvi. Protocols Supported: PakBus, Modbus, DNP3, FTP, HTTP, XML, POP3, SMTP, Telnet, NTCIP, NTP, SDI-12, and SDM.
- f) Each data logger shall be equipped with following accessories:
- i. One 32 Channel Multiplexer w/o enclosures compatible with the data logger, capable of operating under similar conditions as of data logger and supporting many types of sensors including thermistors, potentiometers, strain gages, vibrating wires, reflectometers, and soil moisture blocks;
  - ii. Two finished four conductor cables with enough lead length to connect with the system;
  - iii. One Data Logger Support Software: the Contractor shall provide the necessary software to design the data acquisition System, download the data from the logger to a computer using either 1- a flash memory or physical cable connection, and convert the data files in a format exploitable under Microsoft Excel functional under Windows operating system or MAC operating system.
  - iv. Three Resistor Assembly – 1k ohm 0.1% precision Capacity;

- v. One White UV Stabilized Water Tight Fiberglass Enclosure (16 inch x 18 inch in dimension including the installation kit) which can house a data logger, power supply, at least one peripheral, and multiplexer. The Enclosure shall be severe weather resistant, made of fiberglass reinforced polyester with door gasket, external grounding lug, stainless steel and lockable hasps. The Enclosure shall be shipped with supply kit that consists of desiccant, a humidity indicator card, cable ties, wire tie tabs, putty, grommets, screws, and PVC coupling.

Alternatively 1.25 to 2 mm thick stainless steel enclosure will be allowed if fiberglass enclosure is not available with Ingress Protection up to Nema 4X or IP 65, having gasket material of polyurethane silicone and can withstand temperature of -50°C; the stainless steel enclosure shall be padded with 3-4 mm thick adhesive foam tape; covered of aluminum foil to increase the thermal insulation; fittings, such as plastic boards, will allow fastening the various components of the system in the enclosure. the enclosure will have enough internal storage space to position several desiccant packets that will pull out moisture to prevent rust and corrosion of the electronic devices;

- vi. One Enclosure Mount Kit for tower and mast mount including hardware;
- vii. One number Sealed Rechargeable Lead Acid Battery with enough lead length to connect with unregulated solar panel or wall charger and system, providing a 12-Vdc with a nominal rating of 26Ah, or more if required, w/PS 100 connector, and fused 5A. The rechargeable battery will be trickle-charged from external solar panel but the battery life will provide sufficient power to maintain the system functional for at least one year without the solar panel, should the solar panel break. A regulator shall be used to connect the sealed rechargeable battery with the solar panel. The regulators will control the current flowing and ensure that the battery keeps alimentering the system adequately. Its characteristics will depend on the types of battery and solar panel used; and
- viii. One Plastic Outdoor Enclosure Battery Case with lockable pole mount. The Battery Enclosure shall be water tight capable of mounting on pole. The Enclosure shall be strong and durable enough to withstand severe weather conditions for many years.

### **50 WATT SOLAR PANEL**

The Contractor shall provide and install one 50 watt solar panel at each location having enough cable length to connect with the batteries. The solar panel will be equipped with mounting kit and hardware to easily mount on the tripod, pole or tower. The solar panel shall be photovoltaic power sources capable of recharging batteries in very cold environment.

### ***MOUNTING TRIPOD WITH FLOATING BASE***

The Contractor shall provide one mounting tripod at each location to mount all enclosures at a height of least one meter above the ground surface and the air temperature and wind sensors at a height of three meters above the ground. The mounting shall also carry the solar panel and should have room for future installation of satellite antenna. The mounting tripod shall have the following specifications:

- a) The mounting tripod and floating base shall be strong and heavy enough to withstand heavy winds and weight of wild animals like bear if they climb, without tipping. The mounting tripod shall be properly anchored into permafrost. The permafrost may become unstable or uneven so the contractor shall provide a footing strong enough to remain stable for extended period of time.
- b) If wooden mounting shall be used then the Contractor shall make the mounting with treated 8 inch x 8 inch wooden planks as shown in the drawings. Steel shall be galvanized if used for the mounting tripod.
- c) The Contractor shall submit the design of the mounting tripod to the Engineer for approval at least two weeks prior to supply and installation.

### ***NOTES***

Any other instrument and accessories not mentioned here but required to properly operate and download the data from the thermistor cables, wind monitor, and air temperature probe.

The Contractor shall calibrate all the instruments before installation in accordance with manufacturer's recommendations.

## **ANNEX B: CORE LOGS AND PLATES**

This document presents the core logs, including a photo plate displaying pictures of the geocryologic features of the core.

The first column of the log represents permafrost features based on observed sedimentary and ground ice feature. Sedimentary features are black and white, whereas ground ice features are shown in blue tones. Darker blue tones are used for seemingly ice-richer samples. All observations are only visual and therefore subjective. Soil tests are necessary to validate the observations. The depths have to be considered with caution.

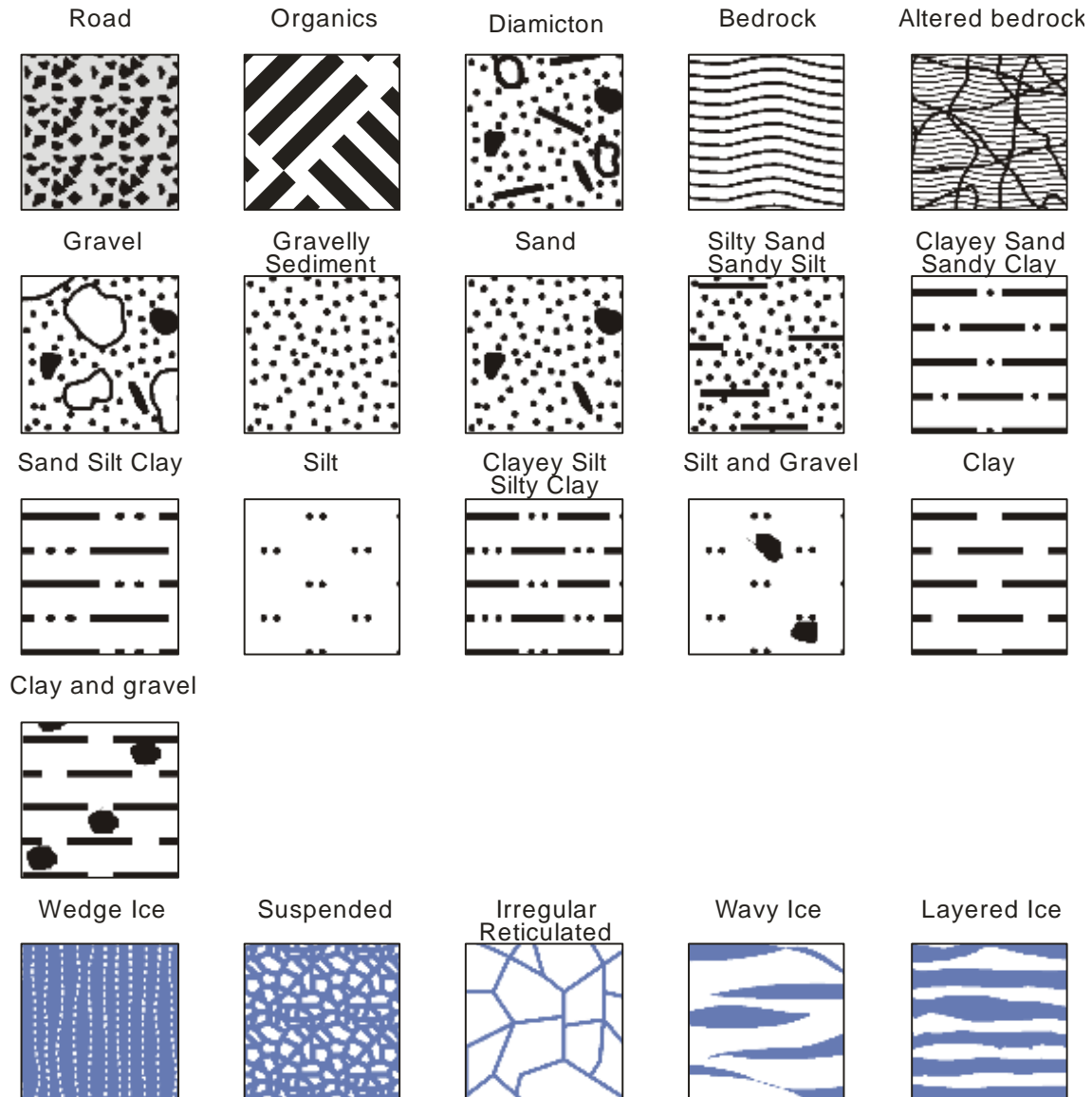
The second column indicates the sample number, which also corresponds to the field number identified on the photos.

The third column indicates the nature of soil testing ordered for specific samples. A camera icon is present to specify when a sample was photographed, and is shown in the following photo plate.

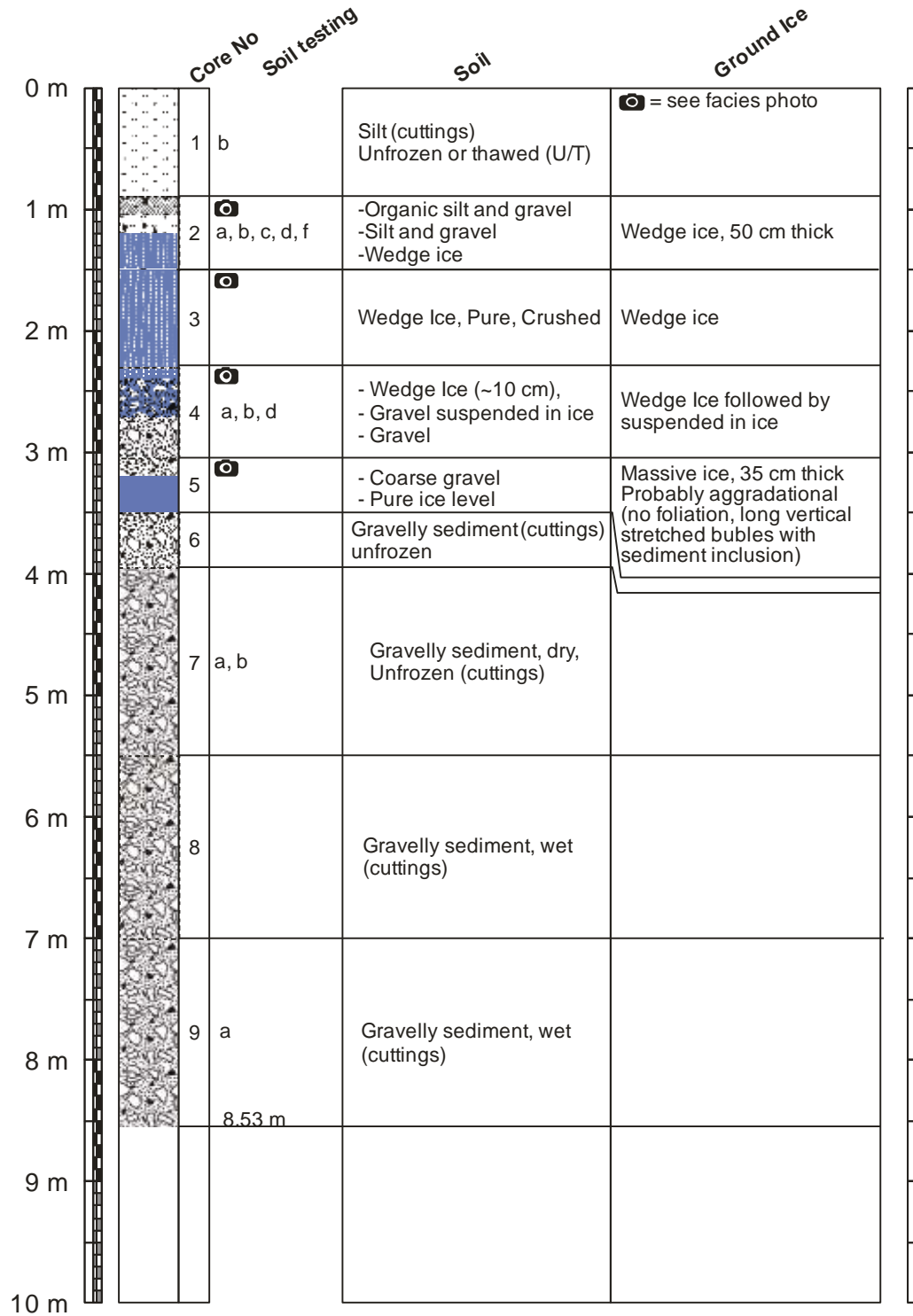
The fourth column provides a description of the sedimentary features.

The fifth column provides a description of the ground-ice features.

## Sedimentary and ground-ice patterns

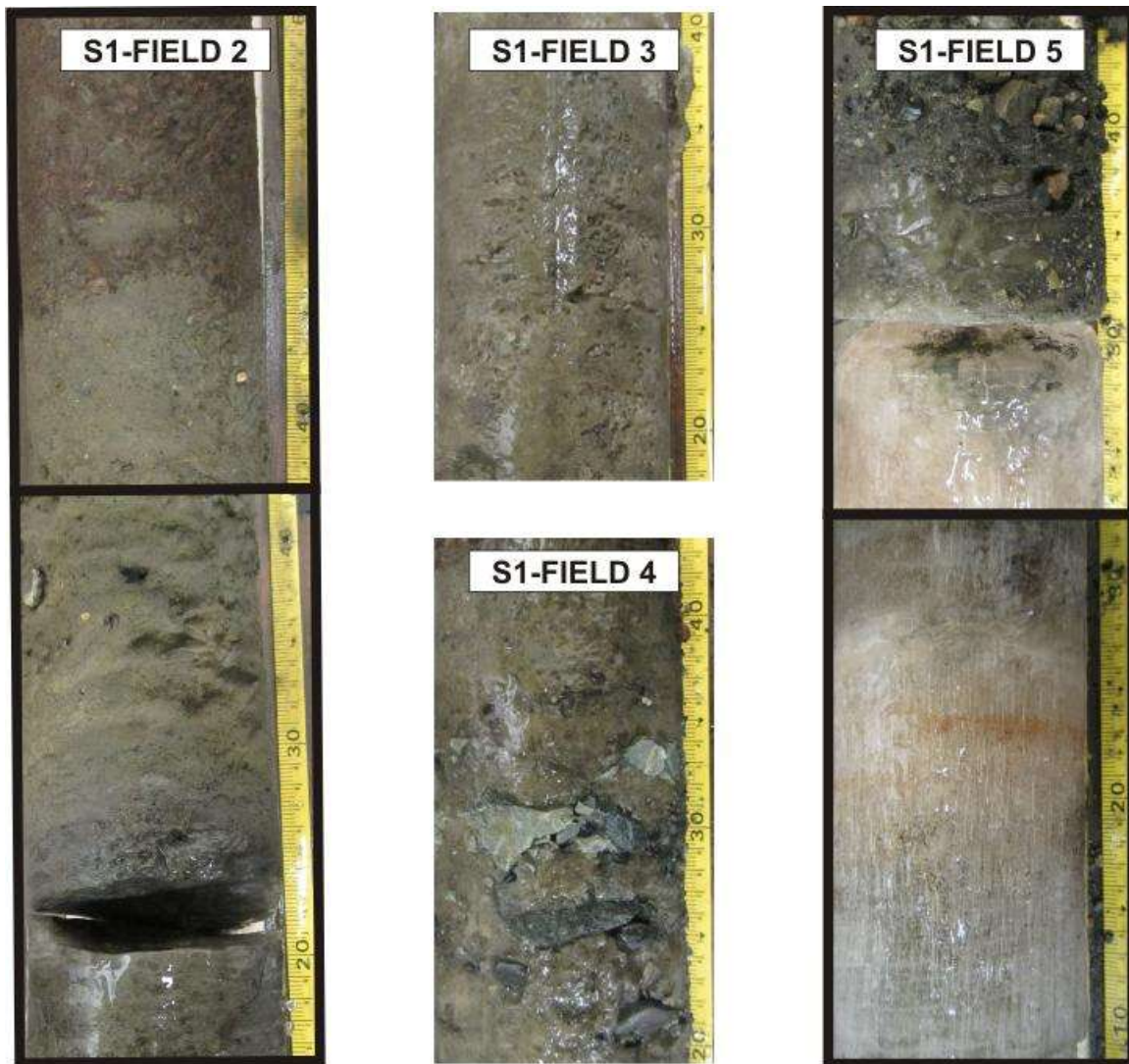


S1-FIELD



Type of Soil testing:  
a) Moisture content;  
b) Sieve analyses  
c) Atterberg limits;  
d) Excess ice content with bulk density;  
e) Thermal conductivity (not performed);  
f) Organic content.





**Permafrost features for Site 1 under the Field.**

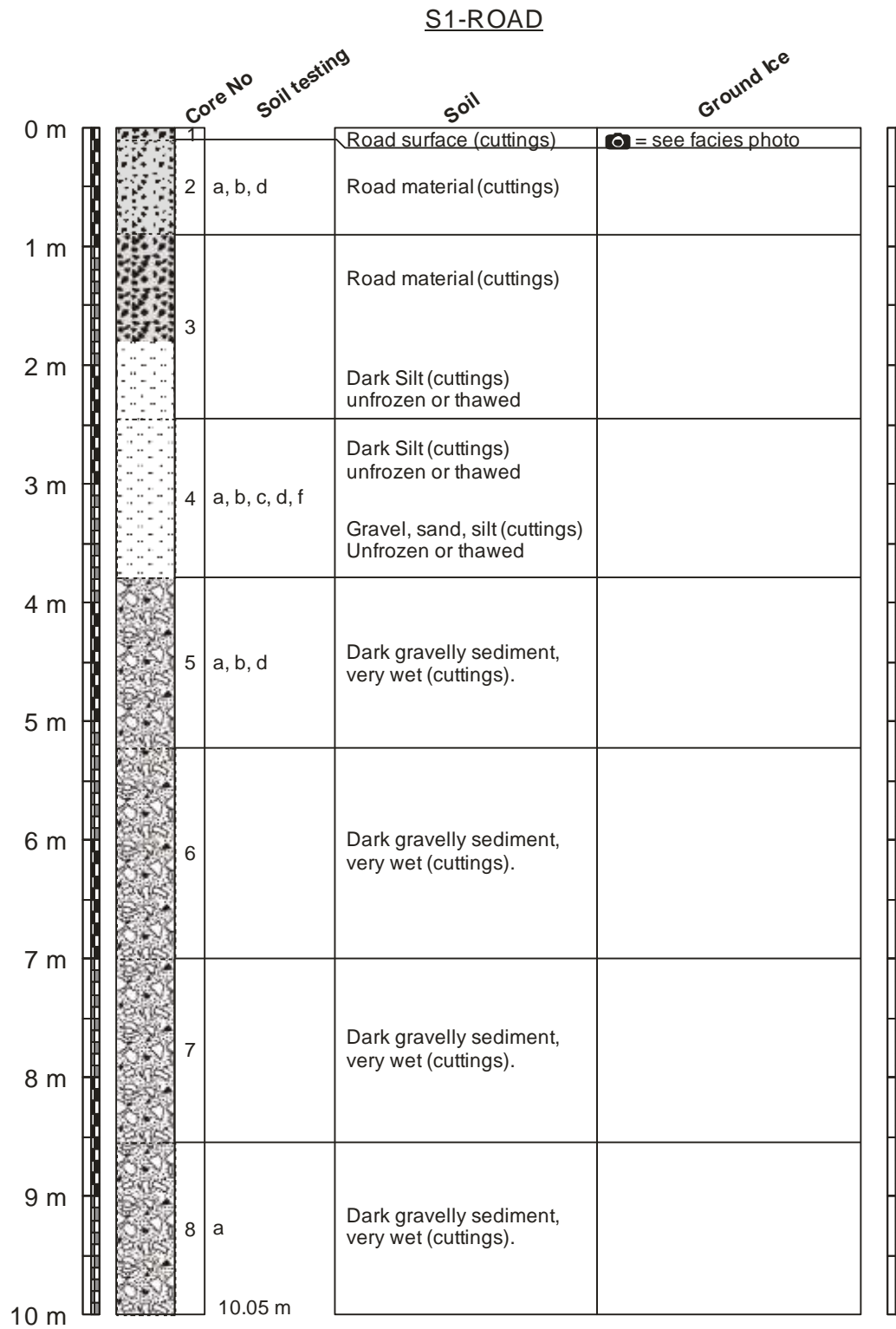
S1-TOE

	Core No	Soil testing	Soil	Ground Ice
0 m	1	b	Dark Silt (cuttings) Unfrozen or thawed (U/T)	📷 = see facies photo
1 m	2	a, b, c, d, f	Dark silt with gravel, and organic levels	No visible excess ice
	3		Gravel (cuttings) (U/T)	
2 m	4	a, b, d	Gravelly sediment: Gravel in dark silt (cuttings) (U/T)	
3 m	5		Gravelly sediment: Gravel in dark silt (cuttings) (U/T)	Wedge Ice followed by suspended in ice
4 m	6		Gravelly sediment: Gravel in dark silt (U/T) (cuttings)	
5 m				
6 m	7		Gravelly sediment: Gravel in dark silt (U/T) Maybe less coarse (cuttings)	
7 m	8	a, b	Gravelly sediment: Gravel in dark silt (U/T) (cuttings)	
8 m	9		Gravelly sediment: Gravel in dark silt (cuttings) (U/T)	
		8.53 m		
9 m				
10 m				

Type of Soil testing:  
a) Moisture content;  
b) Sieve analyses  
c) Atterberg limits;  
d) Excess ice content with bulk density;  
e) Thermal conductivity (not performed);  
f) Organic content.



**Permafrost features for Site 1 under the toe of the Embankment.**



Type of Soil testing:  
a) Moisture content;  
b) Sieve analyses  
c) Atterberg limits;  
d) Excess ice content with bulk density;  
e) Thermal conductivity (not performed);  
f) Organic content.

S2-FIELD

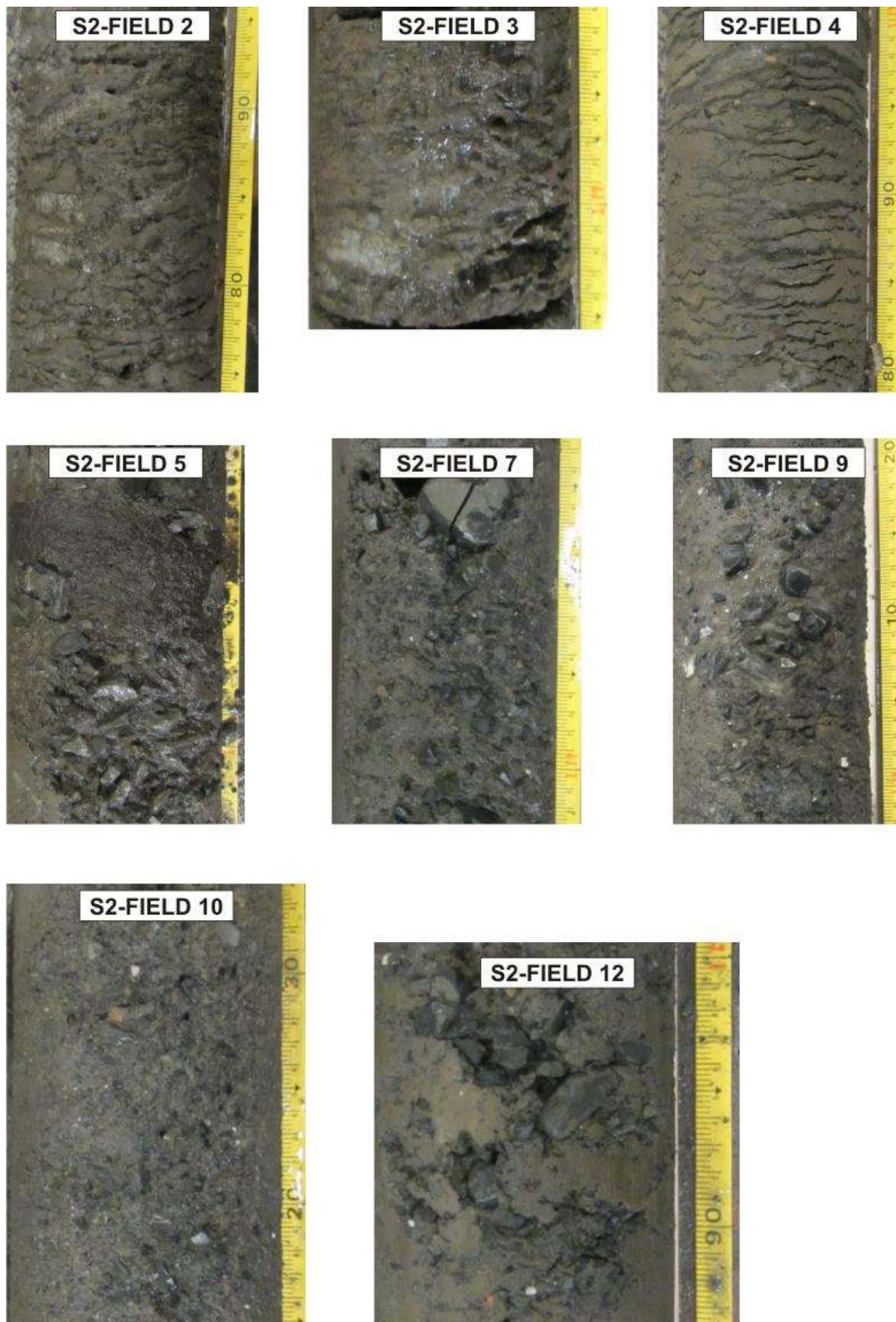
	Core No	Soil testing	Soil	Ground Ice
0 m	1	b	Brown, organic silt Unfrozen (cuttings)	☉ = see facies photo
1 m	2	☉ a, b, c, d	Brown diamicton- Peat layer @ top	Ice-rich: suspended
	3	☉	Brown diamicton	Ice-rich: suspended
2 m	4	☉ a, b, c, d, f	Brown diamicton - organics (putrid odor - muck)	Ice-rich: layered to suspended
3 m	5	☉ a, b, d	Diamicton: gravel in brown silt - organics (putrid odor - muck)	Ice associated with organics
	6		Diamicton	Ice-poor
4 m	7	☉	Diamicton	Visible cement ice
	8		Diamicton	Ice-poor
5 m	9	☉ a, b, d	Diamicton	Ice-poor
6 m	10	☉	Diamicton	Ice-poor - thin ice layer @ base
	11		Diamicton	Ice-poor
7 m	12	☉	Diamicton	
	13	a, b, d	Diamicton - Angular Schist debris in fine matrix (cuttings)	
8 m	14		Diamicton - Fine material and gravel(cuttings)	
	8.53 m			
9 m				
10 m				

Note: A Diamicton is a very poorly sorted terrigenous sediment consisting of sand or larger size particles that are suspended in a mud matrix.

Type of Soil testing:  
a) Moisture content;  
b) Sieve analyses  
c) Atterberg limits;

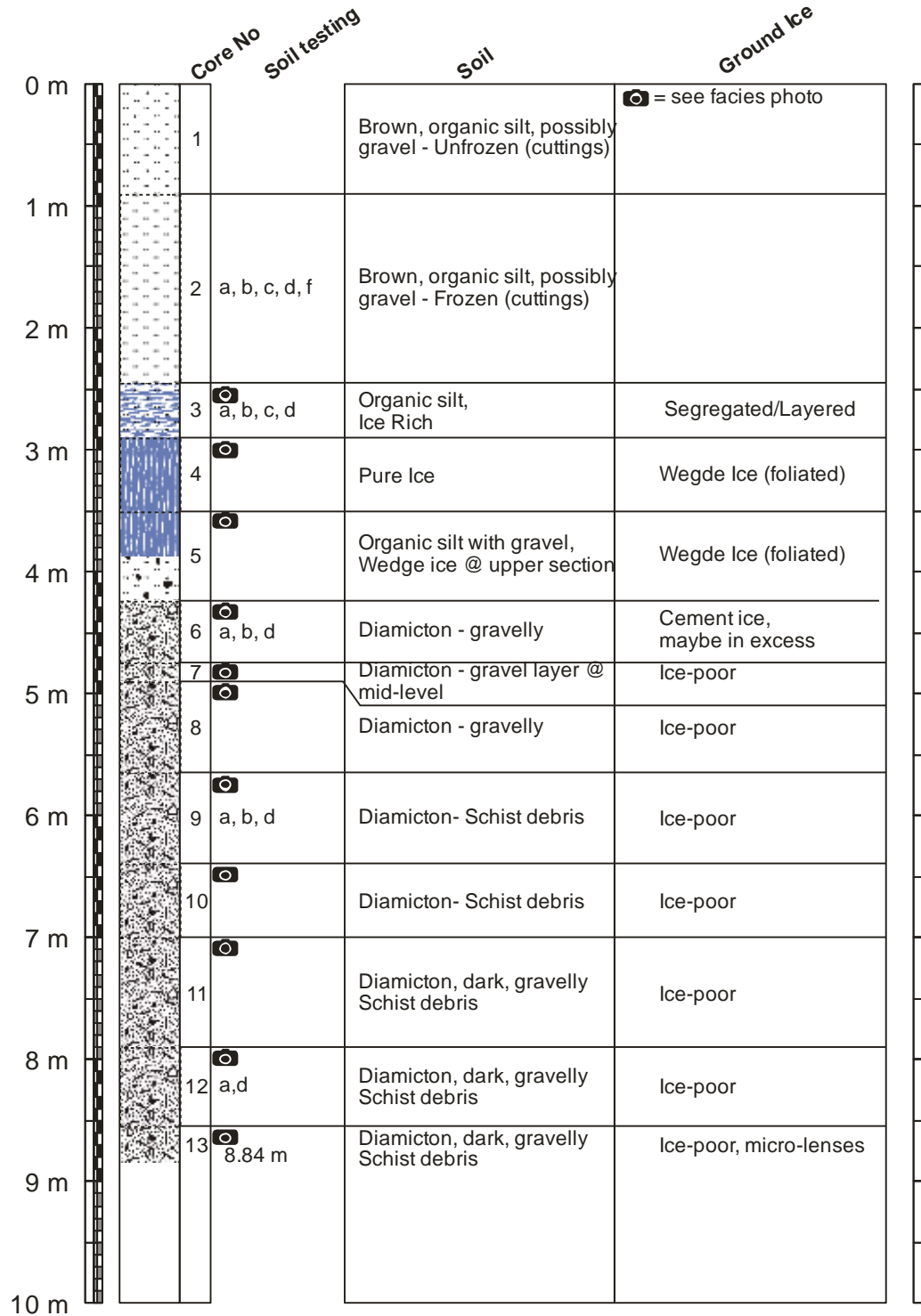
d) Excess ice content with bulk density;  
e) Thermal conductivity (not performed);  
f) Organic content.





**Permafrost features for Site 2 under the Field.**

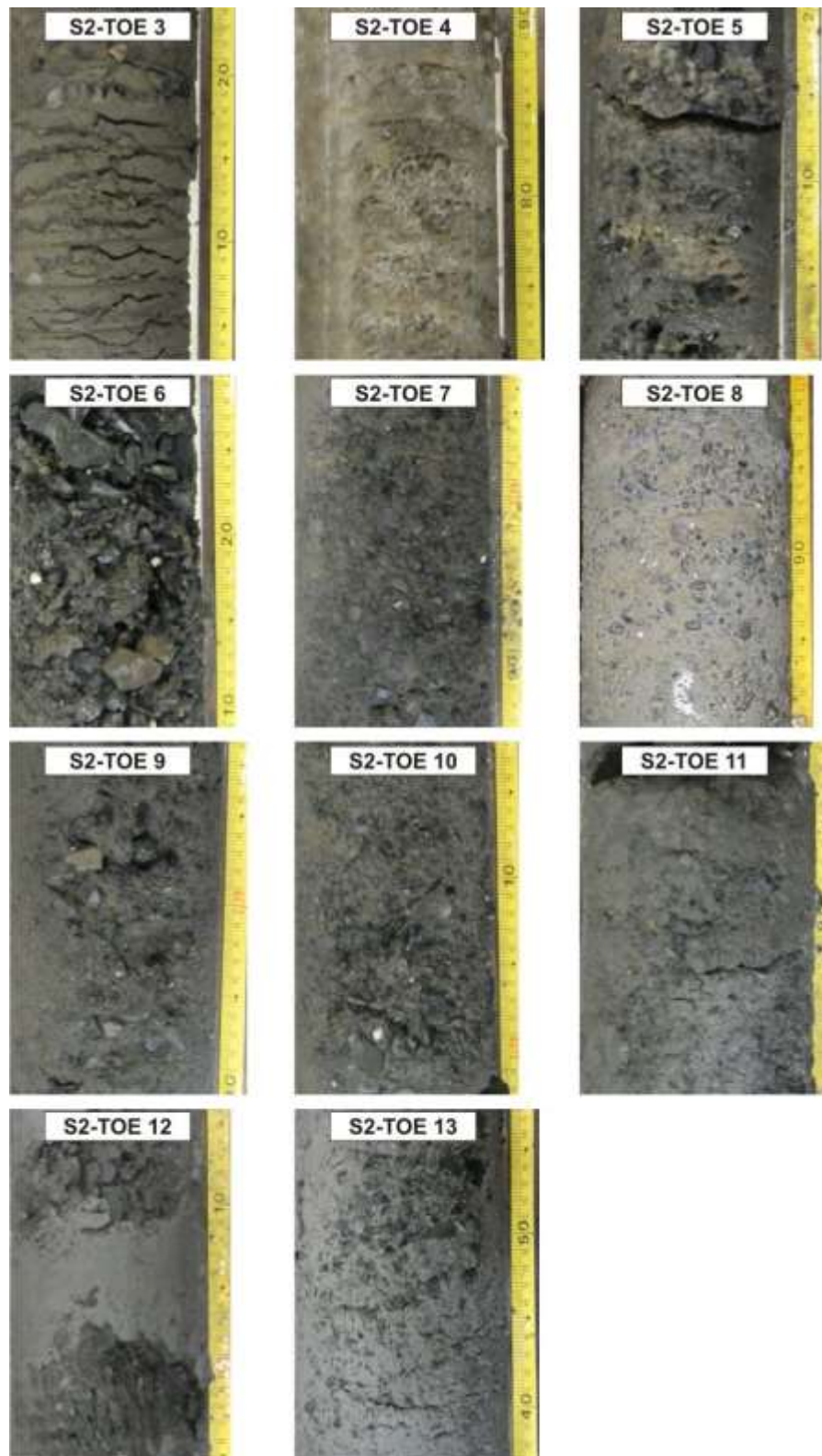
S2-TOE



Note: A Diamicton is a very poorly sorted terrigenous sediment consisting of sand or larger size particles that are suspended in a mud matrix.

Type of Soil testing:  
a) Moisture content;  
b) Sieve analyses  
c) Atterberg limits;

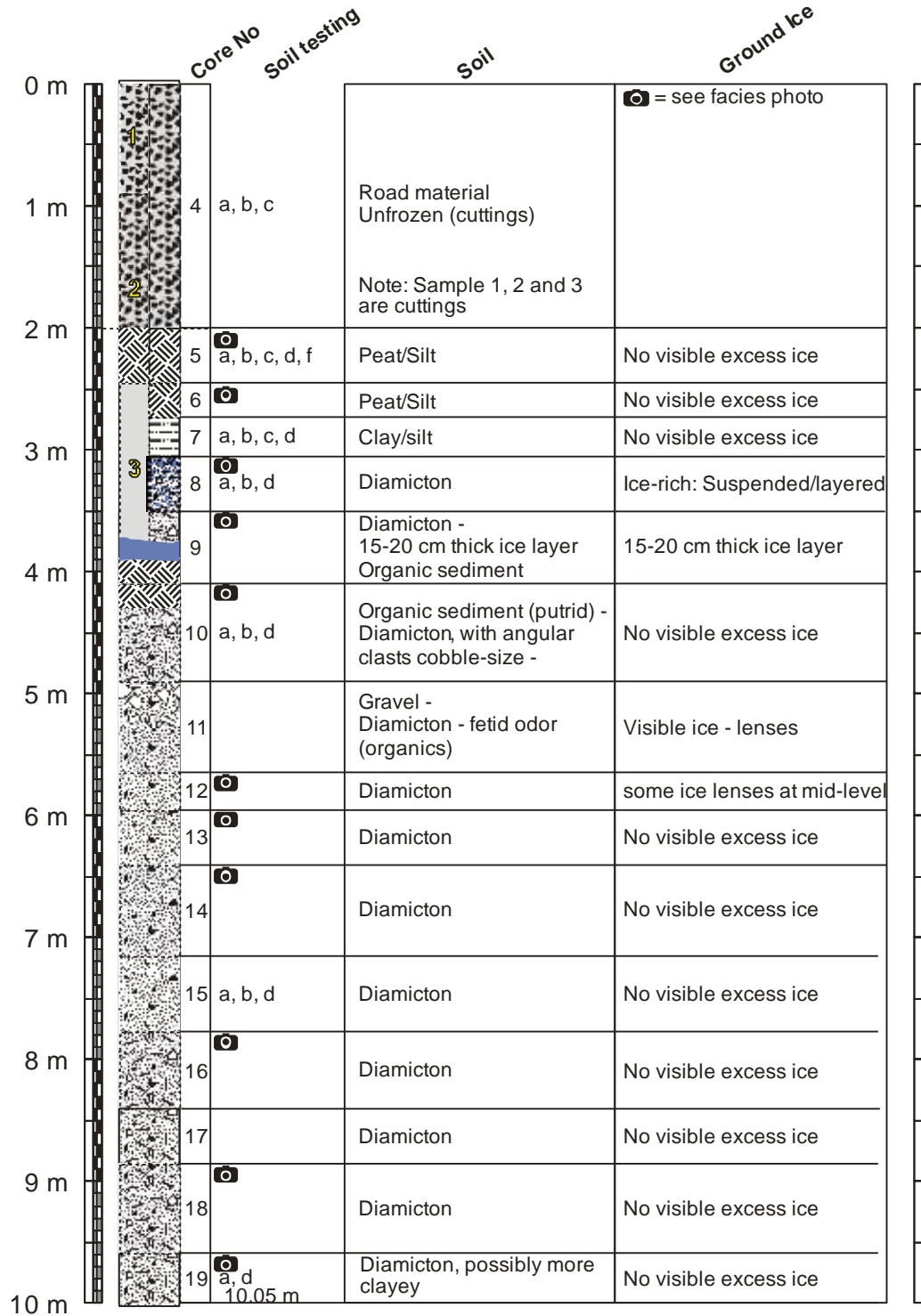
d) Excess ice content with bulk density;  
e) Thermal conductivity (not performed);  
f) Organic content.



**Permafrost features for Site 2 under the toe of the Embankment.**



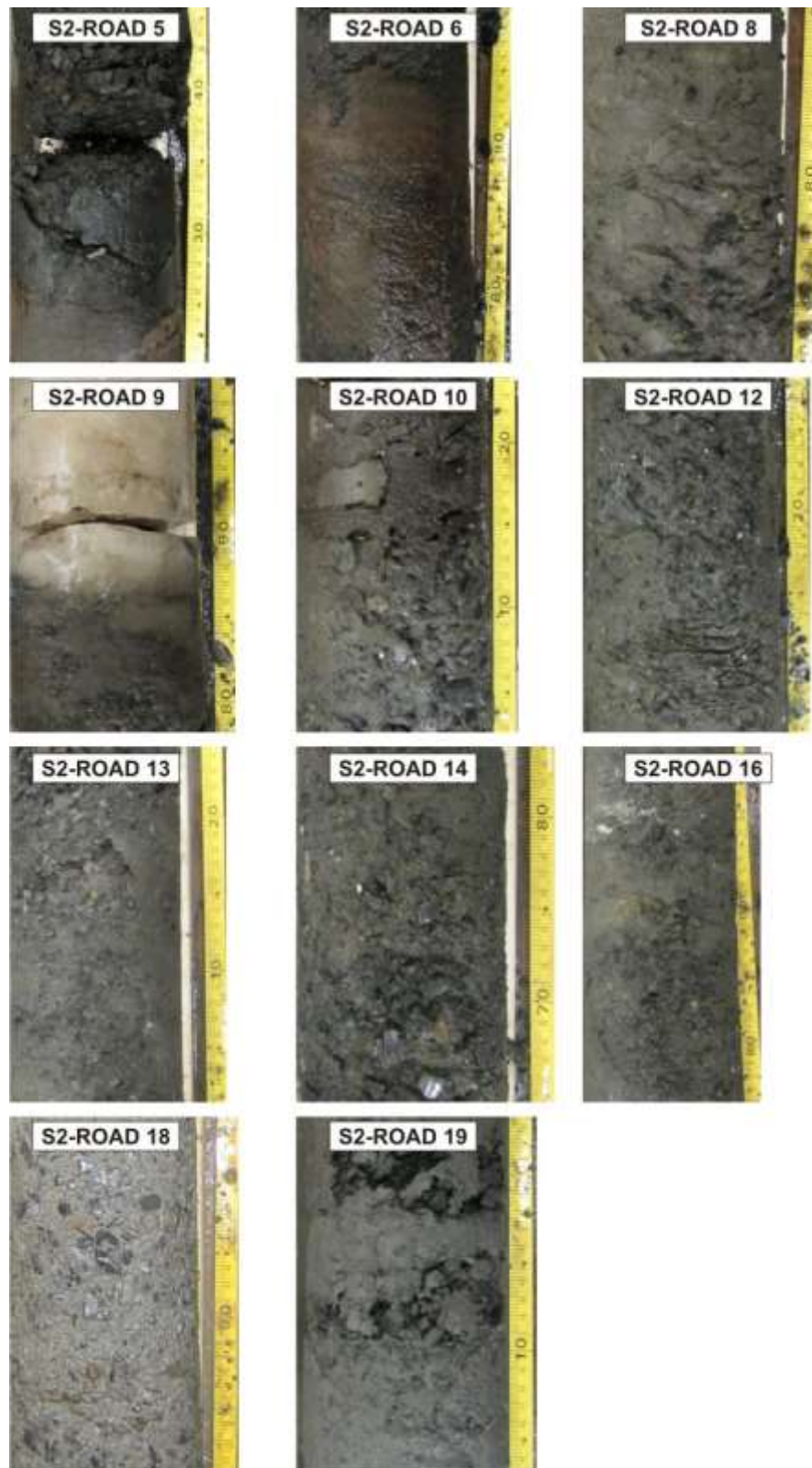
S2-ROAD



Note: A Diamicton is a very poorly sorted terrigenous sediment consisting of sand or larger size particles that are suspended in a mud matrix.

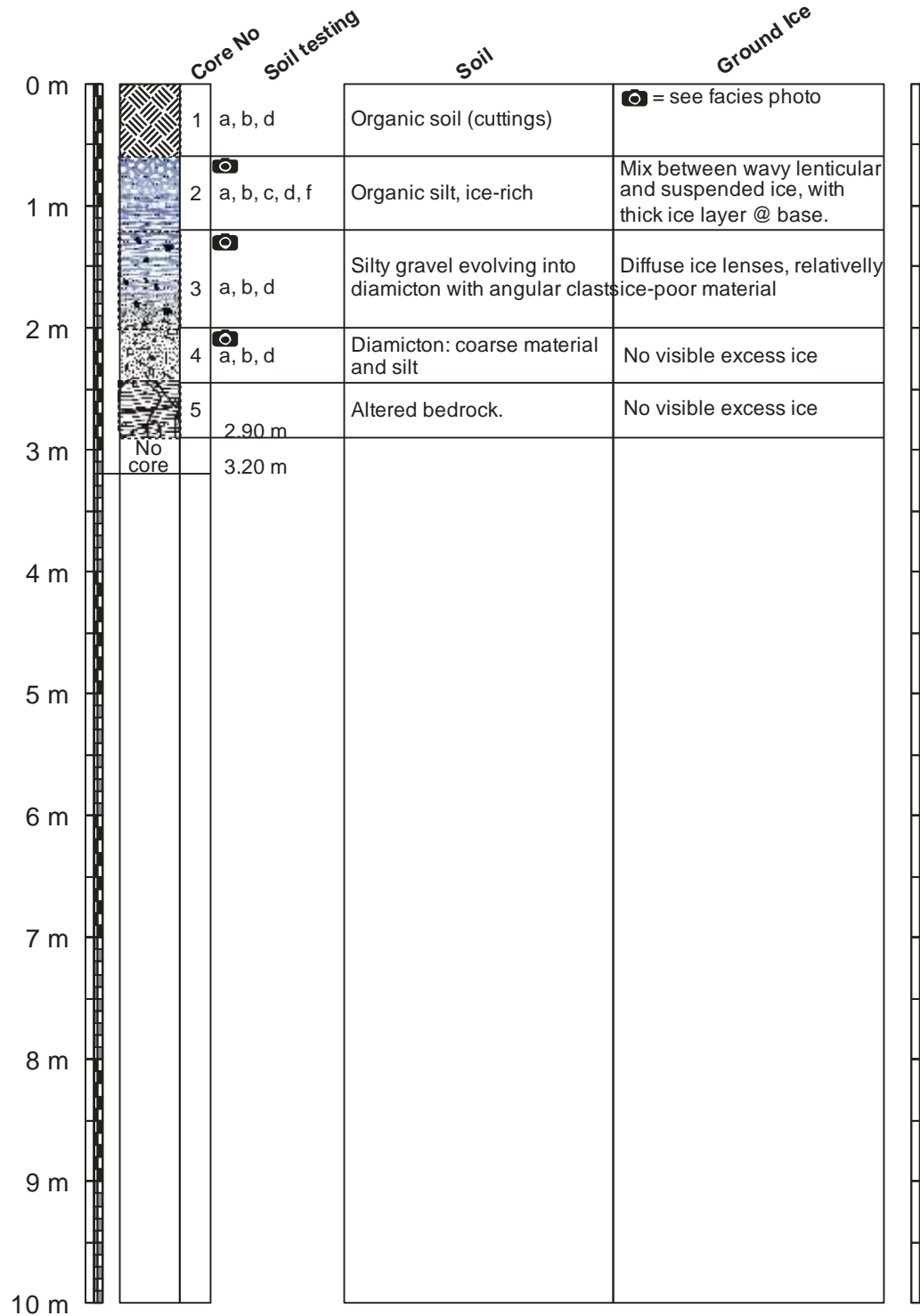
Type of Soil testing:  
a) Moisture content;  
b) Sieve analyses  
c) Atterberg limits;

d) Excess ice content with bulk density;  
e) Thermal conductivity (not performed);  
f) Organic content.



Permafrost features for Site 2 under the road.

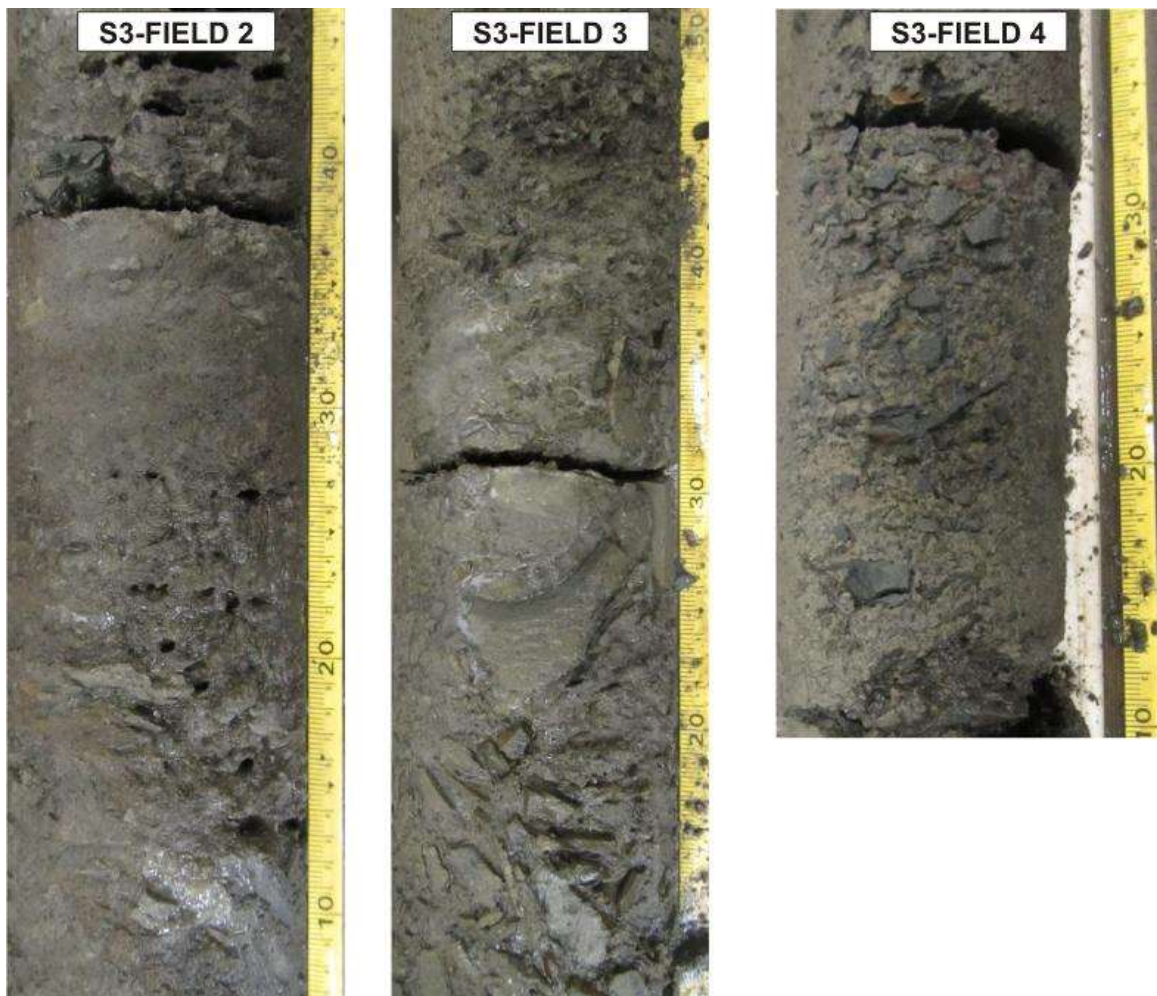
S3-FIELD



Note: A Diamicton is a very poorly sorted terrigenous sediment consisting of sand or larger size particles that are suspended in a mud matrix.

Type of Soil testing:  
a) Moisture content;  
b) Sieve analyses  
c) Atterberg limits;

d) Excess ice content with bulk density;  
e) Thermal conductivity (not performed);  
f) Organic content.



**Permafrost features for Site 3 under the Field.**

S3-TOE

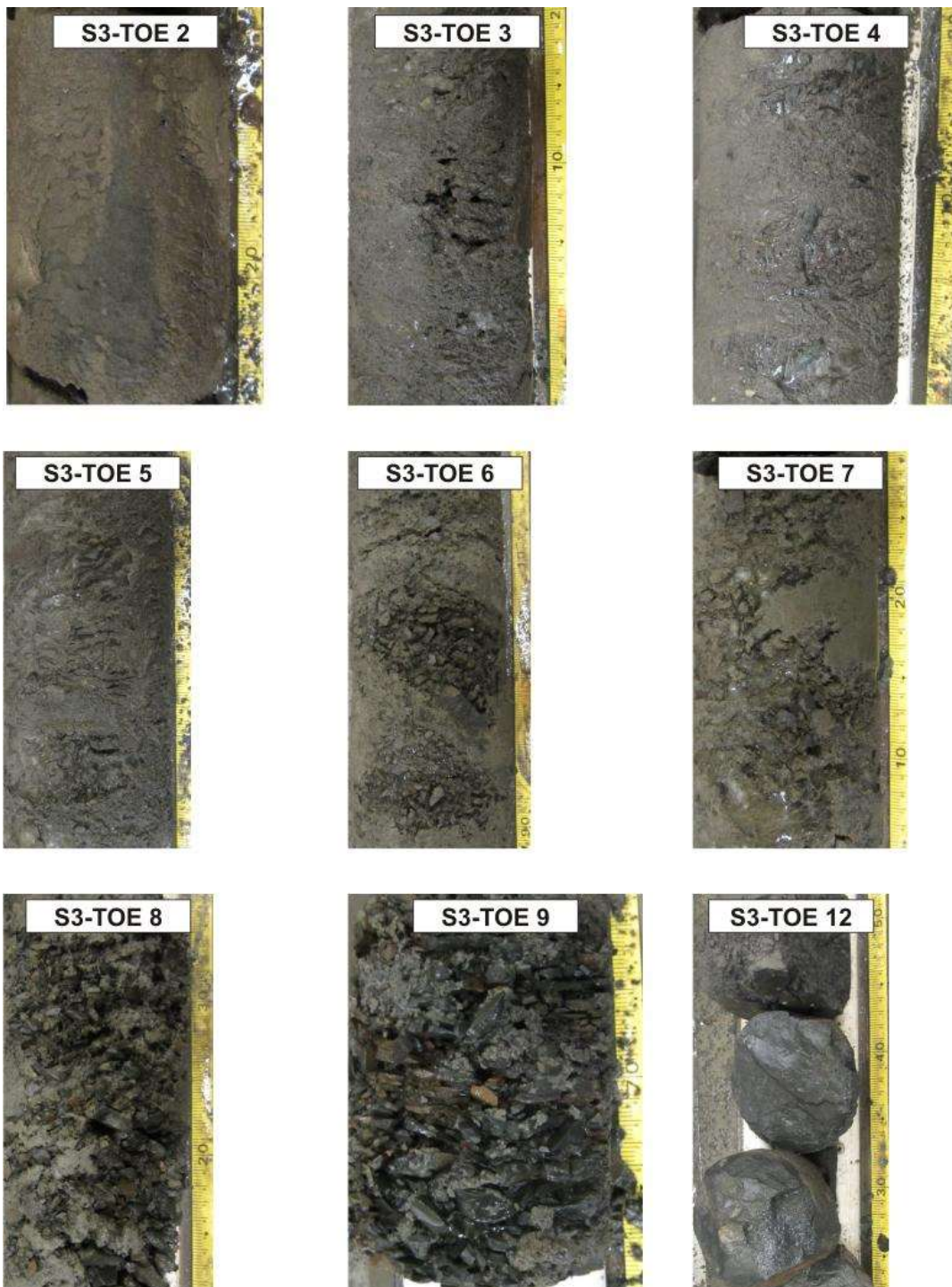
	Core No	Soil testing	Soil	Ground Ice
0 m	1		Organic soil (cuttings)	☒ = see facies photo
	2	a, b, c, d, f	Silt - to clean	No visible excess ice
1 m	3		Silt and organics	Layered/lensed ice
	4		Silt and organics	Layered/lensed ice
2 m	5	a, b, d	Silt and organics	Layered/lensed ice
	6		Diamicton with schist debris in silty matrix	Layered to suspended ice
	7		Diamicton with schist debris in silty matrix; cobbles	Layered to suspended ice
3 m	8	a, b, d	Diamicton: Schist debris in silty matrix.	No visible excess ice
	9		Diamicton from weathered bedrock, or slope deposit.	No visible excess ice
4 m	10		Diamicton from weathered bedrock, or slope deposit.	No visible excess ice
	11		Diamicton from weathered bedrock, or slope deposit.	No visible excess ice
5 m	12		Bedrock, altered.	No visible excess ice
6 m	13	a, d 5.94 m 6.10 m	Bedrock, altered.	No visible excess ice
7 m				
8 m				
9 m				
10 m				

Note: A Diamicton is a very poorly sorted terrigenous sediment consisting of sand or larger size particles that are suspended in a mud matrix.

Type of Soil testing:  
a) Moisture content;  
b) Sieve analyses  
c) Atterberg limits;

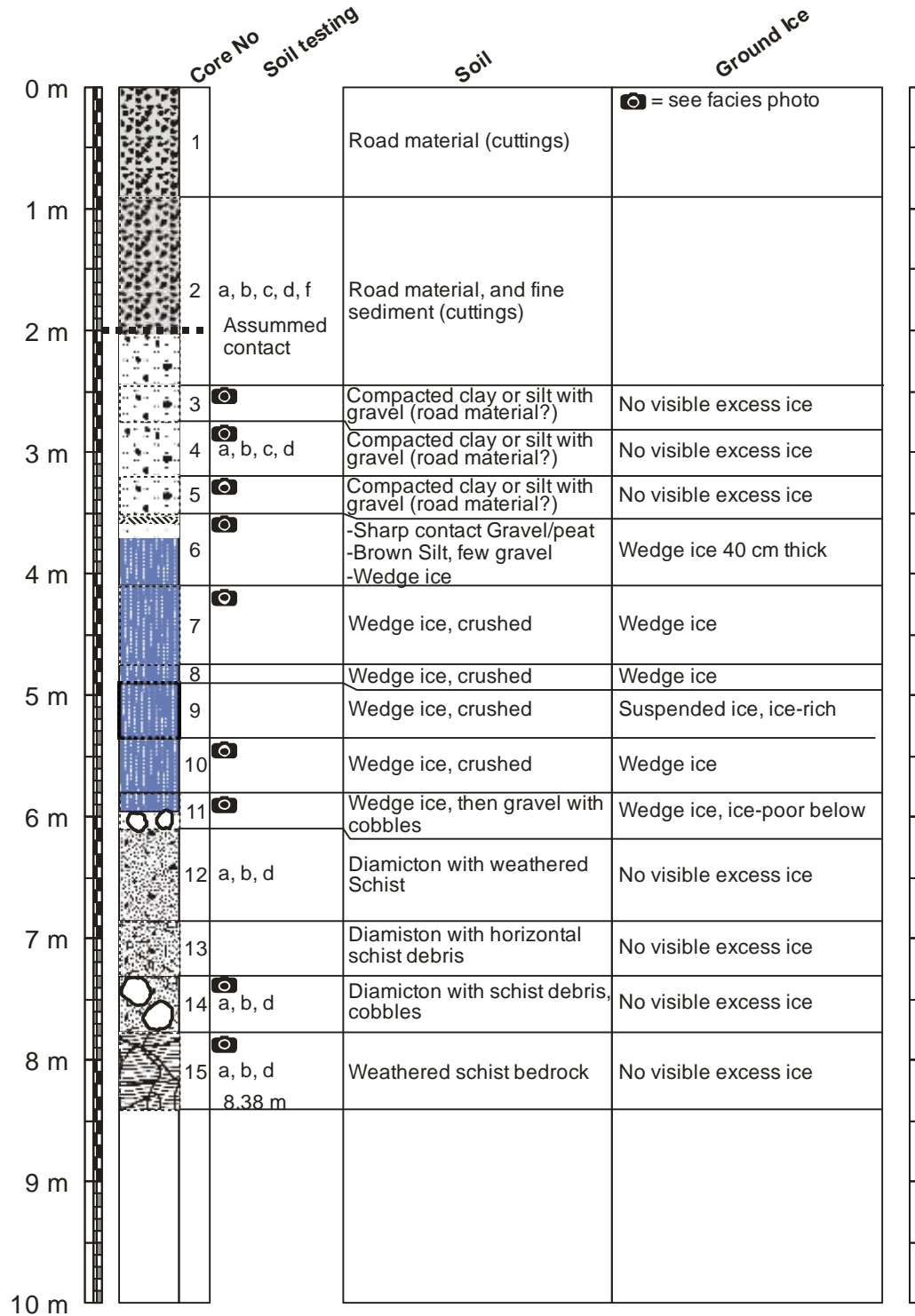
d) Excess ice content with bulk density;  
e) Thermal conductivity (not performed);  
f) Organic content.





**Permafrost features for Site 3 under the toe of the Embankment.**

S3-ROAD



Note: A Diamicton is a very poorly sorted terrigenous sediment consisting of sand or larger size particles that are suspended in a mud matrix.

Type of Soil testing:  
a) Moisture content;  
b) Sieve analyses  
c) Atterberg limits;

d) Excess ice content with bulk density;  
e) Thermal conductivity (not performed);  
f) Organic content.



Permafrost features for Site 3 under the road.



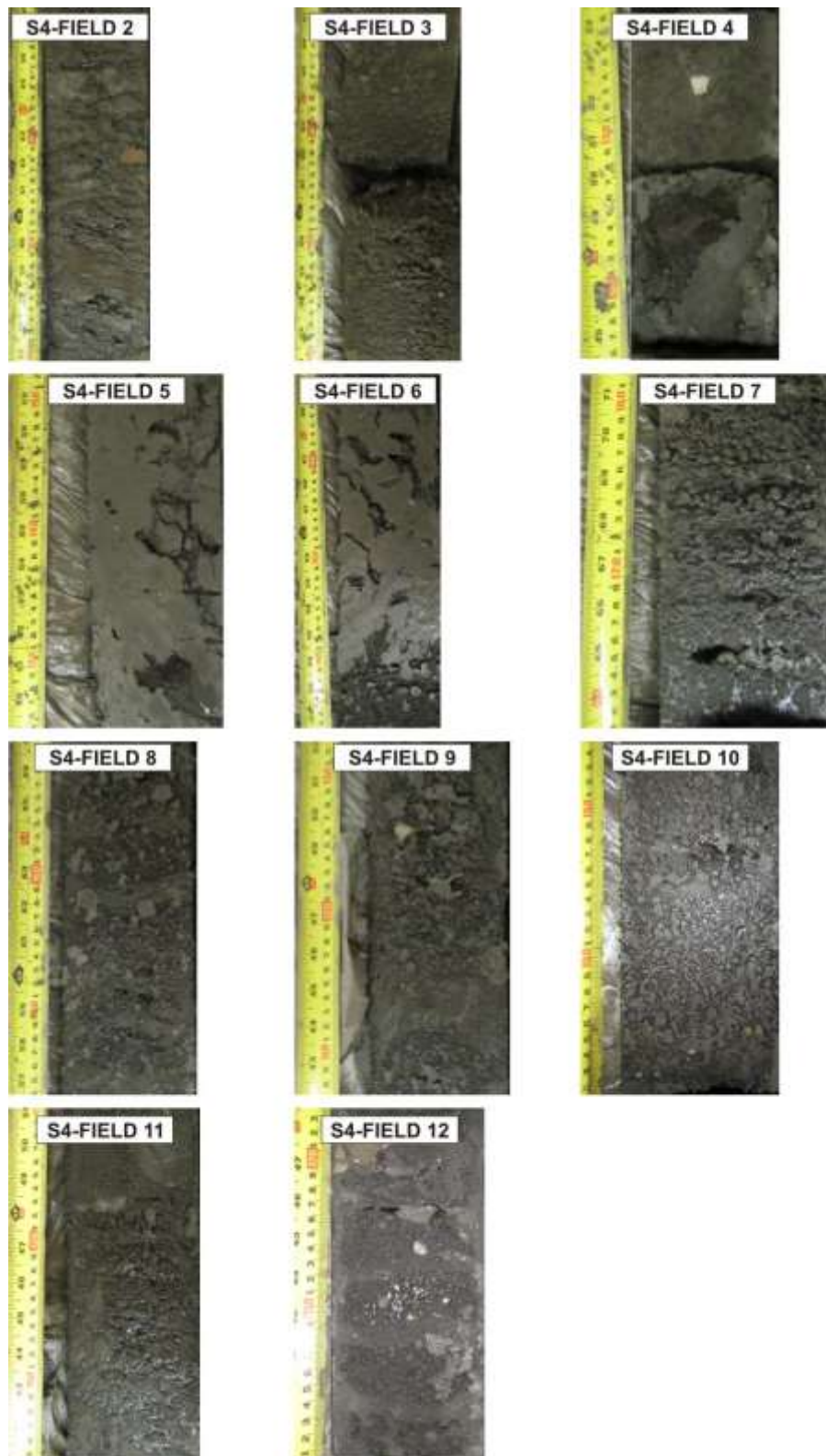
S4-FIELD

	Core No	Soil testing	Soil	Ground Ice
0 m	1	a, b, c, d, f	Silty clay with organics (cuttings)	☉ = see facies photo
1 m	2	☉	Silt	-10 cm ice layer at top; followed by to suspended ice
	3	☉ a, b, c, d	Silt	Suspended followed by layered ice
2 m	4	☉ a, b, c, d	Clay	Few ice
	5	☉	Clay	Few ice
3 m	6	☉	Clay	Few ice
4 m	7	☉ a, b, d	Silt with gravel	Suspended ice, ~1 cm or less cluster
5 m	8	☉	Silt with gravel	Suspended ice, ~1 cm or less cluster
6 m	9	☉	Silt with gravel	Suspended ice, ~1 cm or less cluster
	10	☉ a, b, c	Silt	Suspended ice, bigger cluster, more developed
7 m	11	☉ a, b, d	Silt	Suspended ice, ~1 cm or less cluster
8 m	12	☉ a, b, d 8.38 m	Silt with gravel	Suspended ice, less developed
9 m				
10 m				

Note: A Diamicton is a very poorly sorted terrigenous sediment consisting of sand or larger size particles that are suspended in a mud matrix.

Type of Soil testing:  
a) Moisture content;  
b) Sieve analyses  
c) Atterberg limits;

d) Excess ice content with bulk density;  
e) Thermal conductivity (not performed);  
f) Organic content.



**Permafrost features for Site 4 under the Field.**

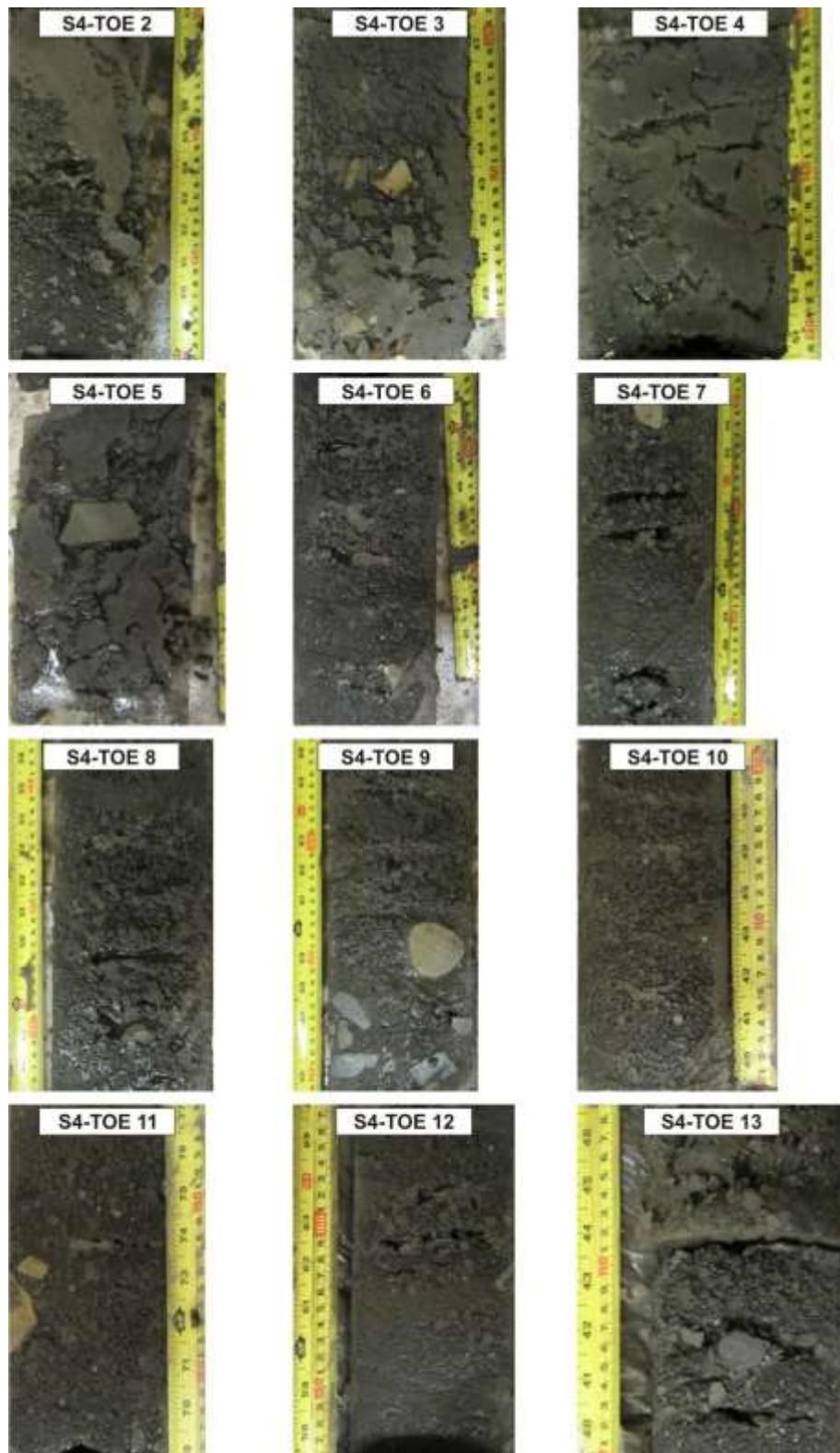
S4-TOE

	Core No	Soil testing	Soil	Ground Ice
0 m	1	a, b, c, d	Brown Silt (cuttings)	☉ = see facies photo
	2	☉	-Clay, relatively ice-rich	Suspended ice
1 m	3	a, b, c, d, f	-Clay, relatively ice-rich	Suspended ice
	4	☉	-Clay, relatively ice-poor	Suspended ice, poorly developed
2 m	5	☉	-Clay, less ice -Silt with gravel, more ice	Suspended ice, ~1 cm or less cluster
	6	a, b, d	Gravelly silt	Ice rich; suspended
3 m	7	☉	Gravelly silt	Ice rich; suspended
	8	a, d	Gravelly silt	Ice rich; suspended
4 m	9	☉	Gravelly silt	Ice rich; suspended
	10	☉	Gravelly silt	Ice rich; suspended
5 m	11	☉	Gravelly silt	Ice rich; suspended
	12	a, d	Gravelly silt	Ice rich; suspended
6 m	13	☉	Gravelly silt	Ice rich; suspended
		8.23 m		
7 m				
8 m				
9 m				
10 m				

Note: A Diamicton is a very poorly sorted terrigenous sediment consisting of sand or larger size particles that are suspended in a mud matrix.

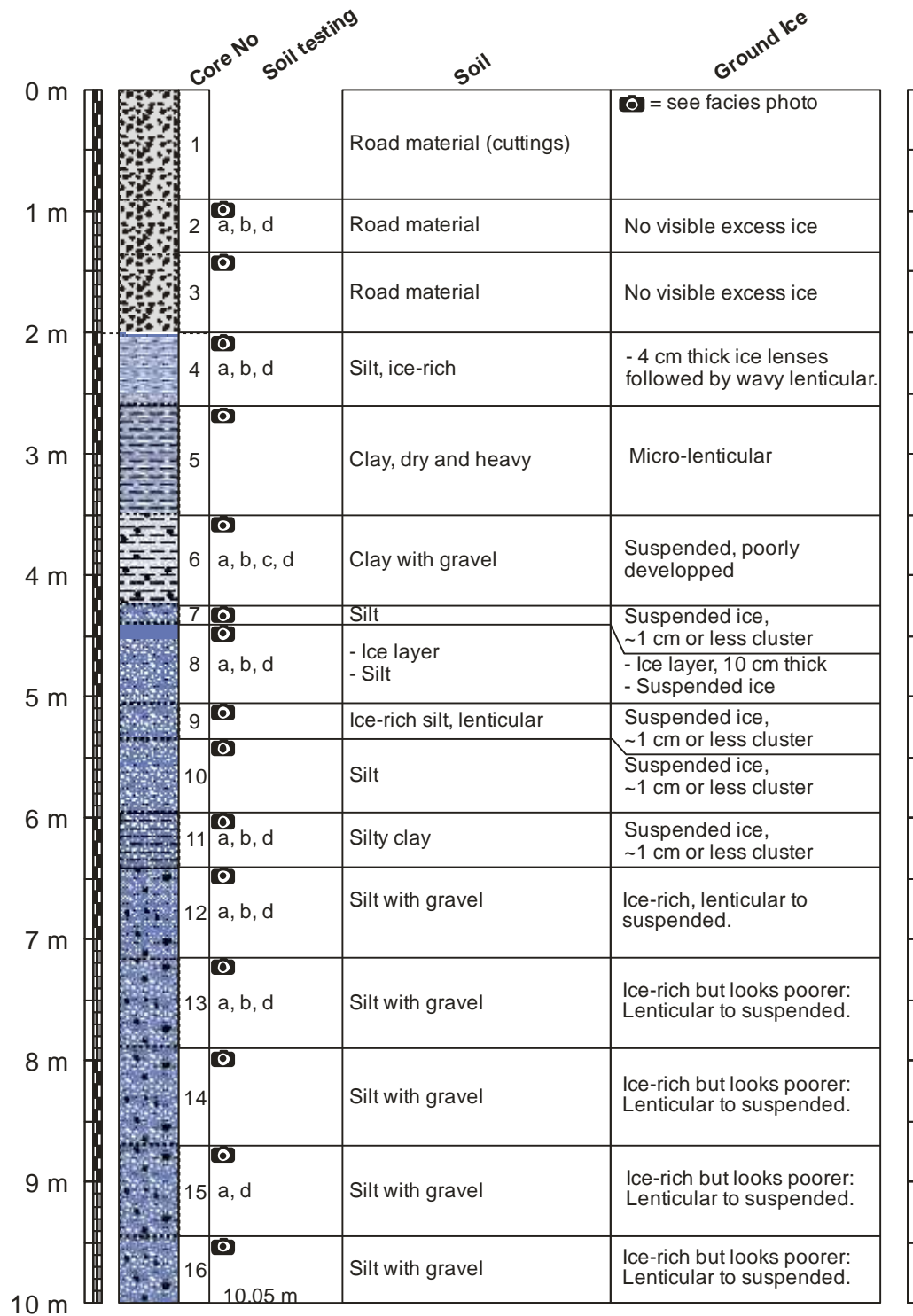
Type of Soil testing:  
a) Moisture content;  
b) Sieve analyses  
c) Atterberg limits;

d) Excess ice content with bulk density;  
e) Thermal conductivity (not performed);  
f) Organic content.



**Permafrost features for Site 4 under the toe of the Embankment.**

S4-ROAD

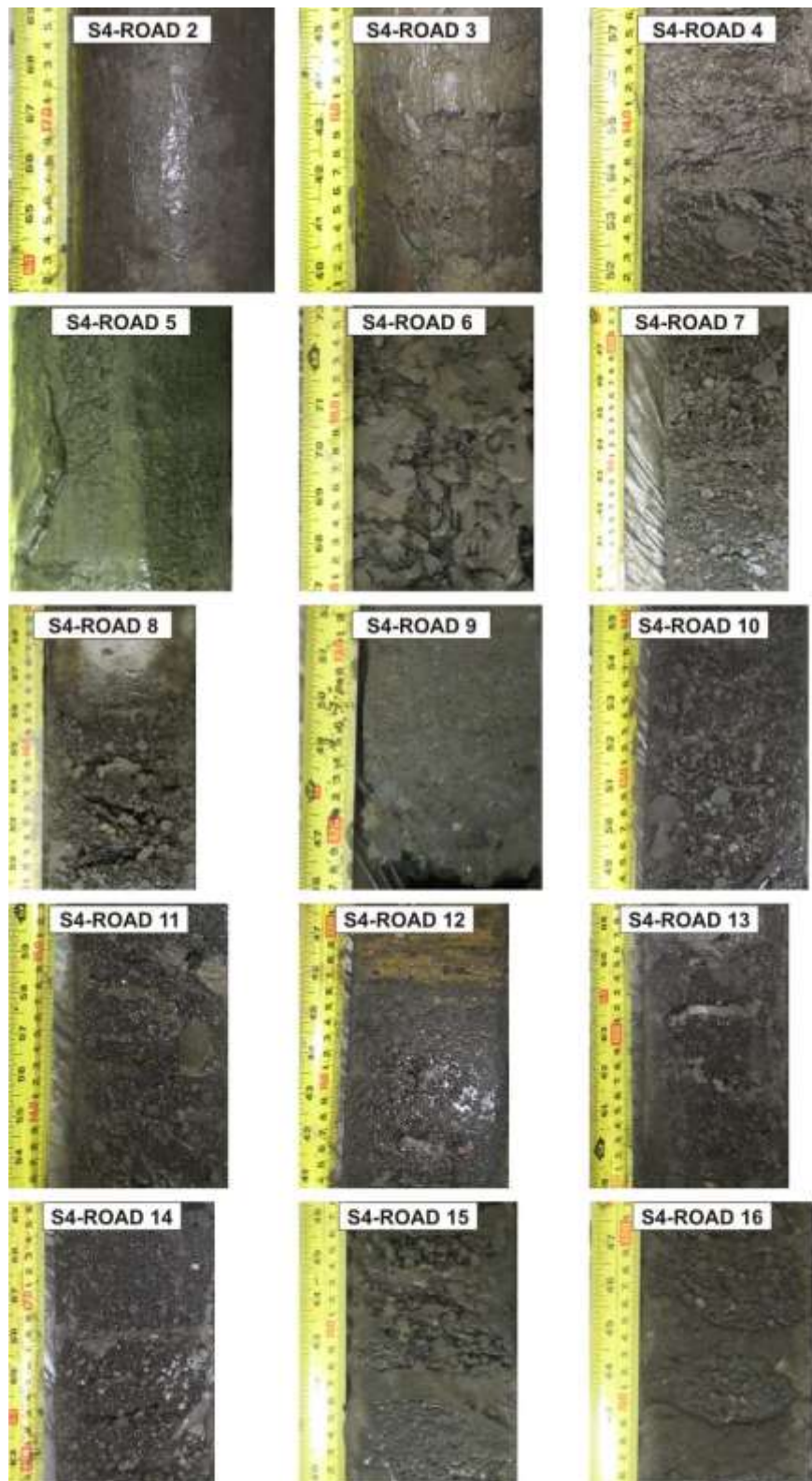


Note: A Diamicton is a very poorly sorted terrigenous sediment consisting of sand or larger size particles that are suspended in a mud matrix.

Type of Soil testing:  
a) Moisture content;  
b) Sieve analyses  
c) Atterberg limits;

d) Excess ice content with bulk density;  
e) Thermal conductivity (not performed);  
f) Organic content.





Permafrost features for Site 4 under the road.