REPORT

Norwegian GeoTest Sites (NGTS)

FIELD TEST RESULTS ØYSAND

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Summary

As part of the characterization of Øysand Sand site during NGTS project, two main reports are prepared: 1) a factual report (20160154-08-R) and 2) an interpretation report (20160154-09-R) (see figure in the next page). The present report (20160154-08-R) presents a factual summary of all in situ testing carried out for the NGTS project between 2016-2019.

Site specific tests and methods are described in the present report. Standard methods for laboratory and in situ tests that apply for all NGTS sites are detailed in the general reports NGTS Report 02 (20160154-02-R) and NGTS Report 03 (20160154-03-R), respectively.

NGTS – Øysand Research Site

VOLUME 1:	VOLUME 2:
FIELD OPERATIONS, PROCEDURES AND RESULTS, INCLUDING MEASURED AND DERIVED GEOTECHNICAL AND GEOPHYSICAL PARAMETERS	DATA INTERPRETATION AND EVALUATION OF REPRESENTATIVE GEOTECHNICAL AND GEOPHYSICAL PARAMETERS
NGTS REPORT NO.: 20160154-08-R	NGTS REPORT NO.: 20160154-09-R

Executive Summary (Volume 1)

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2. **Research site**: Geological setting. See associated Appendix and Tables for Log of Field Operations, Mapping and Coordinates.
3. **Field investigations**: Sub section for each In Situ Test. Contains Results (Measured and Derived). See corresponding Appendix and Tables for figures.
4. **Geotechnical Borehole Logs** with Soil Units, Summary of Geology, Soil Conditions and Soil Units.
5. **List of Symbols and Terms**
6. **References**

List of Appendix (figures and tables for field and laboratory test results)
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Review and reference page

Executive Summary (Volume 2)

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White background means current report.

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Review and reference page

1 Introduction

This report describes the work carried out at Øysand Sand Site as part of Research Council of Norway's (RCN) infrastructure project "Norwegian GeoTest Sites (NGTS)" (*Nasjonalt forsøksfelt*). NGTS projects has in total five sites. The present report summarizes the field work carried out at Øysand between 2016-2019. The laboratory work will be later presented in a set of publications as part of the Santiago Quinteros's PhD thesis.

1.1 Scope of work

During the first three years of the NGTS project (i.e. June 2016 to June 2019), resources are directed towards a full geotechnical characterization of the selected sites. This includes purchase of equipment and establishment of necessary site infrastructure for future use of the sites for in situ testing, including model testing, during the next 20 years. For example, installation of permanent in situ equipment (e.g. piezometers, thermistor strings and pressure cells), electricity and water supply to the site.

2 Øysand Research Site, Norway

The Øysand site is located about 15 km south-west from Trondheim, Norway. The sand deposit at Øysand originates from the Gaula River, a 150 km long river with an average discharge of 97 m^3/s which flows into the Trondheimsfjord and borders the site to the east, see Figure 2. An area of approximately 35,000 m^2, that is used mainly for agricultural purposes, is available for geotechnical investigations at Øysand. The deposit at the site consist of fluvial material, underlain by deltaic and marine sediments (Figure 1). While the depth to bedrock is unknown, a 1940s investigation made during the German occupation of Norway showed that the sediments extend to a depth of at least 80 m below ground level.

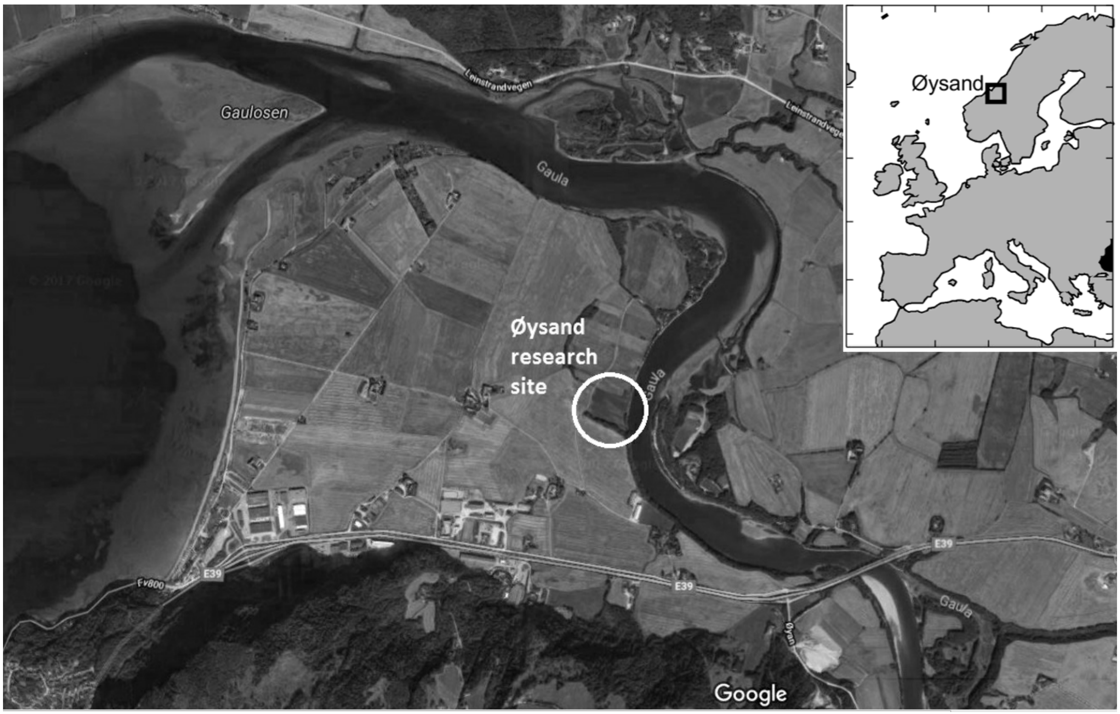

Figure 1. Location of the Øysand research site (modified from Google Maps 2017).

2.1 Topography of the site

The site topography comprises a practically flat surface that reposes around 2.7 m above sea level, except for a 7 m high ridge along the south part of the field. A road enables access throughout the year. Two farms are located about 500 m south-west of the site.

2.2 Geological setting and source material

Following deglaciation of the region approximately 10,300 years ago, the study area was subject to glacio-isostatic rebound and fall of relative sea-level. The highest relative sea level of the Øysand area is approximately 175 m.a.s.l. above the current sea level. Throughout the Holocene the mouth of the Gaula River continuously moved in a north-westwards direction in phase with delta progradation. The coarser deltaic and fluvial sediments deposited directly on the seafloor which consisted mostly of silts and clays (marine deposits). A quaternary geology map of the study presented in Figure 2 shows that the entire research site is located on a fluvial deposit reposing on thick deposits of marine clays.

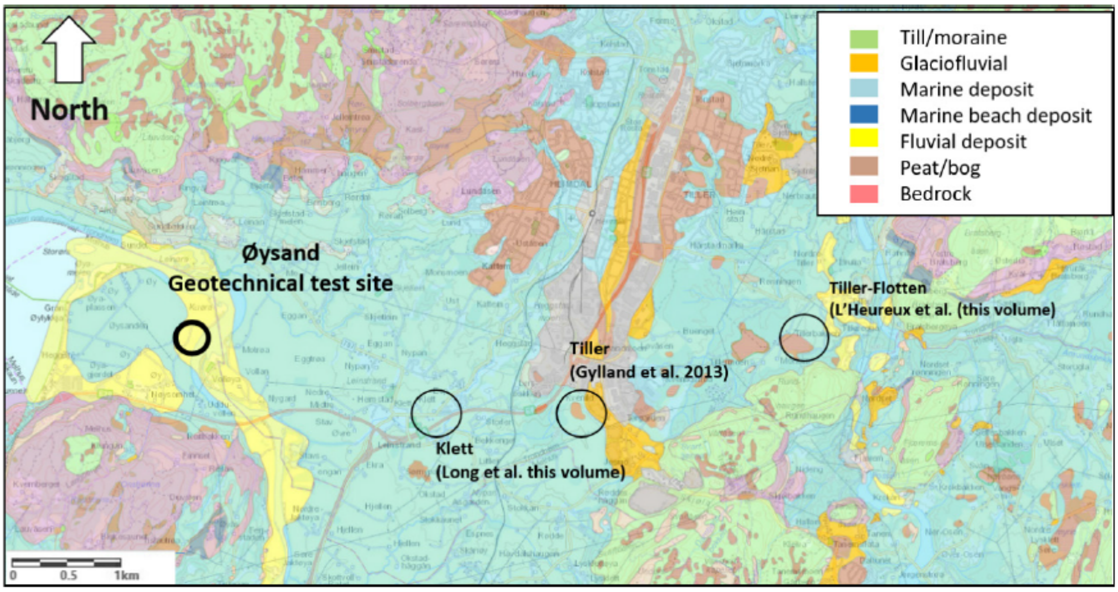

Figure 2. Geological map of Øysand peninsula (from Quinteros et al. 2019 and www.ngu.no).

Shoreline regression curves indicate that the study likely emerged from the sea about 1000–1500 years ago. Therefore, the deltaic sediments at Øysand are young. Following their emergence, the deltaic deposits were covered by coarser river deposits as the Gaula River meandered in the valley. Coarse sands and gravels are therefore expected to occur in the upper portion of the soil stratigraphy at Øysand.

The catchment area of the Gaula river is 3668 km^2 and is dominated by rocks from the Caledonian mountain range, including greenstone, amphibolite, tuff, and micaceous shales. The deposits found at Øysand today were produced by glacial erosion of the bedrock and fluvial erosion of marine and glacial deposits in the catchment. The major mineralogical components of the bedrock and glacial deposits in the catchment area are quartz, feldspars, illite and chlorite with the latter making up the main proportion of the clay fraction.

2.3 In situ testing and site investigations

A wide range of *in situ* tools, geophysical techniques, sampling techniques and laboratory tests have been used to assess the geological history and geotechnical properties of the sand deposits since 2016. A complete list of all geotechnical work, geophysical investigations, and laboratory tests performed at the site (including tests procedures, references and derived geotechnical parameters) is given in Table 1. The field test locations are shown in Figure 3. Appendix A presents some maps with the in situ testing and site investigations carried out at Øysand.The laboratory work will be presented later in a set of publications as part of the Santiago Quinteros's PhD thesis.

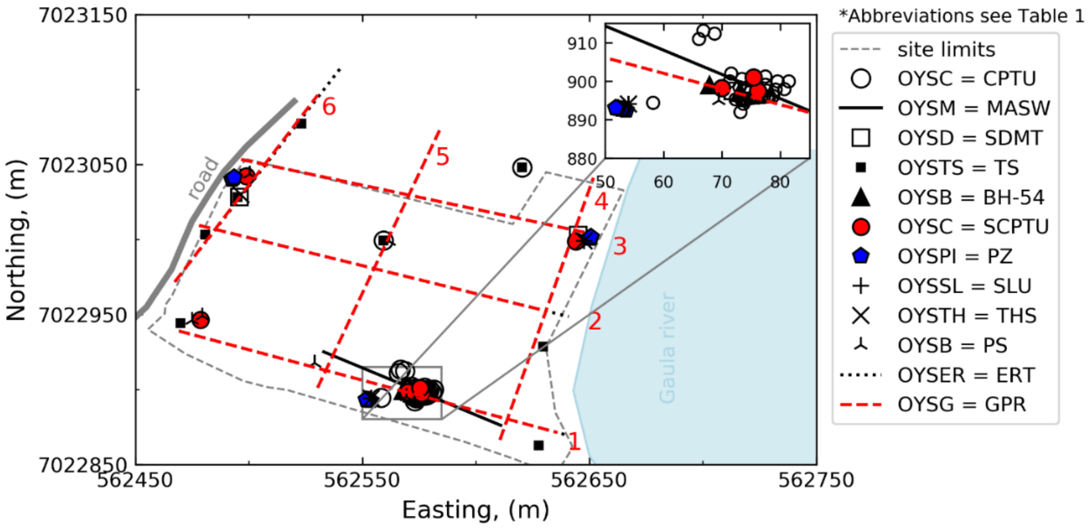

Figure 3. Location of field tests at Øysand research site.

Site characterization at Øysand includes geophysical and geotechnical methods and data. Geophysical tests included: Multichannel Analysis of Surface Waves (MASW), Electrical Resistivity Tomography (ERT), Ground Penetration Radar (GPR) and Self Polarization (SP). Geotechnical tests included: Total Soundings (TS), Cone Penetration Tests (CPTU), Seismic Cone Penetration Test (SCPTU), Seismic Dilatometer Tests (SDMT), Piezometers (Piezo), Thermistors Strings (THS), Slug test (SLU), Permeability tests using a NGI newly developed permeability probe and SPT tests. Soil was sampled using the Sonic Drill Sampler (SDS), the Geonor Push Piston Sampler (GPP), an open Push Piston Sampler (PPS), and the Japanese Gel Push Sampler (GPS). Sampling with an *in situ* ground freezing technique was conducted in April and May of 2019.

Table 1. Summary of geophysical and in situ tests performed at Øysand

Test	Abbreviation	Measured	Comment
Geophysical/non-intrusive			
Electrical resistivity tomography (ERT)	OYSER	Resistivity	by NGI[1]
Ground penetration radar (GPR)	OYSG	F_{DT}	by NGI
Multi-channel analysis of surface waves (MASW)	OYSM	v_p, ω	by APEX[2], and Reykjavik University
In situ			
Total sounding (TS)	OYSTS		
Cone penetration test (CPTU, SCPT)	OYSC	q_c, f_s, u_2, $v_{s,vh}$	
Swedish SPT sounding (Hejarsondering)	OYSSP	punches/0,2 m	
Seismic flat dilatometer (SDMT)	OYSD	P_0, P_1, I_D, K_D, E_D, v_{vh}	
Piezometers (PZ)	OYSPI	u, t	Pore pressure
Thermistor string (THS)	OYSTH	T, t	
Slug tests (SLU)	OYSSL	Pressure head	
NGI permeability probe (NGI-flow cone)	OYSC	Flow	
Sampling			
Geonor fixed piston composite (PS Ø 54 mm)	OYSB_PS54	-	2 BH, 12 tubes
Thin wall push piston sampler (PS, Ø 72 mm)	OYSB_PS72	-	4 tubes
Gel Push Sampler (GPS, Ø 72 mm)	OYSB_GPS	-	2 tubes
Ground freezing (Ø 100 mm)	OYSB_GF	-	April & May 2019

[1] NGI = Norwegian Geotechnical Institute, Oslo Norway
[2] APEX = Apex Geoservices, Wexford, Ireland
[3] NGU= Geological Survey of Norway, Trondheim, Norway (in Norwegian: Norges Geologiske Undersøkelse)

2.3.1 Ground water table (GWT)

A total of 16 electrical piezometers (Geotech PVT with built-in data loggers) are installed in clusters around the site. Their depths range from 5 to 20 m below ground level. The GWL is around 2 m below ground level. The groundwater pressure increases hydrostatically with depth, in general. However, locations near to the river are also affected by neap and spring tides from the nearby Trondheimsfjord, which occur every month and generate cyclic variations of about ± 10 kPa in the pore pressures and hence vertical and horizontal effective stresses. Appendix C presents results from electrical piezometers at Øysand.

3 Geophysical/non-intrusive

3.1 Electric Resistivity Tomography

A total of six profiles of ERT were performed on 10-11-12 April 2017. Three parallel profiles were carried out in the West North West - East South East (WWN-EES) direction and three parallel profiles were performed in the South West South - North East North (SSW-NNE) direction. Appendix A shows a location plan with the start and end point of each resistivity profile. Appendix D presents the results from the ERT survey.

3.2 Ground penetration radar (GPR)

A total of six profiles of GPR were performed on 10-11-12 April 2017. Three parallel profiles were carried out in the West North West - East South East (WWN-EES) direction and three parallel profiles were performed in the South West South - North East North (SSW-NNE) direction. Appendix A shows a location plan with the GPR profiles. Appendix E presents the results from the GPR survey.

3.3 MASW testing

NGI contracted APEX Geoservices Limited to conduct S-wave and P-wave velocities at the Øysand site using Multichannel Analysis of Surface Waves (MASW) and Seismic Refraction Profiling. The investigation was conducted in late October 2016. The full report is provided in Appendix F. MASW data were also acquired in 2018 at Øysand by the University of Reykjavik, Iceland. This data is to be presented in the frame of E.Á. Ólafsdóttir's PhD thesis.

4 In situ

In the early phase of the project, a set of in situ soundings were performed at different areas to find the most suitable test site at Øysand (Area 1-4; see Figure 4). Based on these results, on discussions with the landowner and for practical purposes, area 2 was selected at the most suitable test site at Øysand. In the following section, in situ results from all 4 areas are reported.

4.1 Total soundings

Four total soundings were conducted on potential research sites on the east bank of the river (Area 1 in Figure 4). Sixteen total soundings were conducted on potential research sites on the west bank of the river (Areas 2 to 4). Drilling depths were 25 m. The logs are shown in Appendix G. All total soundings were conducted using the NTNU all terrain drill rig. The calibration certificate of the load cell used is provided in Appendix G.

All four soundings in the east bank show the presence of a stiff layer 1 to 4 m thick in the top 7 m of the profile. The starting depth of these layers showed variability with location and significant flushing and hammering had to be used to penetrate them. At location OYSTS02 a stiff layer was also encountered at between 10 to 14 m depths. Above and below these layers softer soils (sands) were encountered.

On the west bank north of the cliff (Area 2), a stiff layer is observed at depths of 1.5 to 3 m with a variable thickness in the range of 4 to 7 m. At locations OYSTS10, OYSTS11 and OYSTS12, hammering and flushing were required to penetrate through sections of this layer. At locations OYSTS08 and OYSTS09 this layer was mostly penetrable with little hammering, but application of forces in excess of 20 kN was required. At locations OYSTS10 and OYSTS12 similar stiff layers were also encountered at 23 to 25 m depths. Below this layer softer soils were encountered to at least 23 m depth.

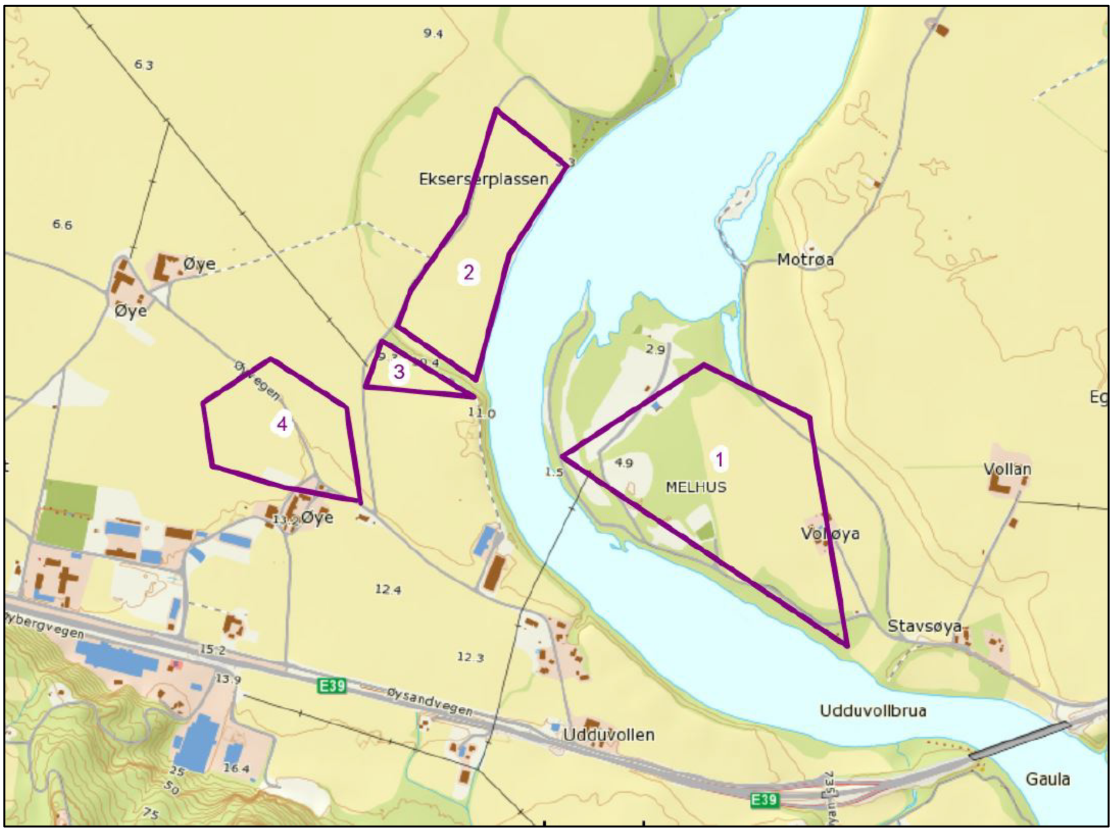

Figure 4. Map of region showing investigated areas (1 to 4) with total soundings. Area 2 corresponds to the selected test site at Øysand.

On the west bank south of the cliff (Area 3), a stiff layer was encountered at depths starting from about 6 m with a thickness ranging from 5 to 7 m. Above and below this layer are softer soils, or sands. At location OYSTS05, a stiff soil is also encountered at 22 m depth.

On the west bank near the farm (Area 4), a stiff layer is observed at location OYSTS15 between 2 and 5 m depth and at location OYSTS16 at 1.5 to 2 m and at 4.5 to 5.5 m. Below these zones the soil resistance is less and fairly uniform down to 20 m.

4.2 Cone Penetration Tests (CPTU & SCPTU)

Piezocone penetration tests were conducted at a total of 48 locations in the four areas given in Figure 4, mainly in area 2. To avoid damaging the cone, penetrations depths were selected based on the results of total soundings and predrilling and drilling through very stiff sublayers was in many cases adopted as required to avoid damaging the cone. The latter was required at locations OYSC03, OYSC07, OYSC09, OYSC41 and OYSC42, where two soundings were recorded per profile. The results of the tests are provided along with the calibration certificates in Appendix H.

On the east bank (Area 1), locations OYSC01 and OYSC03 were predrilled to a depth of 5 m and 4.5 m respectively. At location OYSC01 penetration down to about 15.5 m was achieved. At location OYSC03 two soundings were recorded with penetrations of 4.5 to 6.1 m and 7.0 to 12.8 m.

On the west bank north of the cliff (Area 2), locations OYSC09, OYSC10 and OYSC12, were predrilled to depths of 1 m, 8 m and 5 m respectively. At all these locations, penetration was terminated at about 21 m depth. It is noted that recorded pore water pressures were similar to the piezometric level.

On the west bank south of the cliff (location OYSC07), two soundings were recorded with penetrations of 1.5 m to 8 m and 10 m to 20 m (avoiding the stiff sublayer at 8 m). For convenience, the results of both soundings are combined in one profile in Appendix H.

On the west bank near the farm (Area 4), locations OYSC12, OYSC14 and OYSC16 were predrilled to depths of 5 m, 3 m and 5 m respectively. At all these locations, penetration was terminated at about 21 m depth.

The tests were generally performed according to NGTS Report 03. The methodology and results from the tests are documented in Appendix H. In addition, calibration certificates corresponding to each probe ID, probe specifications and available data to evaluate application class are attached in the same appendix. Not all tests are of application class 1, and some of the tests miss information necessary to determine the application class. For tests OYSC39 – OYSC42 too low penetration speed of 12 mm/s was used.

4.3 Seismic Dilatometer testing

Two seismic dilatometer tests have been conducted in Area 2.

Seismic dilatometer test (SDMT) were conducted at location OYSD01 on two separate days (Oct. 27 and Nov. 2). This was due to the existence of a harder layer (which was drilled through without testing) at a depth interval of 3.5 to 6.0 m. The total depth of testing was 18 m. A SDMT test was also conducted at location OYSD02 to a depth of 20 m. Predrilling was carried out to 6 m depth to penetrate the stiff top layer. The results of the SDMT field tests are provided in Appendix I.

The measured shear wave velocities showed good repeatability at all depths for location OYSD01. The highest measured velocity was 216 m/s at the top 1 m of soil. From 6.5 m to 17 m, the measured shear wave velocities were fairly consistent and ranged from 150 to 178 m/s. Similar results were obtained at location OYSD02 and is further documented in Appendix I.

4.4 Thermistor string (THS)

Three thermistor strings were installed. Unfortunately, they are not operative due to some malfunction of the equipment. Some data was collected before in the early stage of the project and it is summarized in Appendix J.

In general, data is collected from the thermistor string via NGI's Vista database and presented online with the following site: http://vistadv01.ngi.no/vdv/index.html

- Username: NGTS
- Password: NGTS2017

Historical data, real time display, and graphical output can be viewed under main functions on the top of the page for the selected site. Data can be downloaded under the information option.

4.5 Slug/Permeability tests

Falling head tests were performed in situ to determine the permeability of the soil. 4 tests were performed in borehole OYSSL01 and 5 tests were performed in borehole OYSSL02. The tests were done between 12 and 26 October 2017.

A casing was installed in the ground with the use of a Sonic drill rig. The rig applied a water pressure inside the casing during penetration in order to flush out excess soil from the casing. Installation was performed with enough vibration at 150 Hz and rotation to be able to penetrate the casing into the ground. The top of the casing was 10-20 cm above terrain at the end of the installation. After installation, the casing was filled with water. The water supply was stopped, and the sinking water level inside the casing was logged together with time by a logger already lowered into the casing. Also, the air pressure was logged to correct the water pressure measurements. The tests were generally terminated when the water column inside the casing reached an assumed equilibrium situation. The loggers used were Solinst Leveloggers.

The recorded water pressures, corrected for air pressure, versus time are presented in Appendix K.

Table 2. Summary of permeability tests.

Borehole	Depth of lower end of casing [m]	Depth of water pressure logger [m]	Comments
OYSSL01	7.59	7.34	
	9.19	8.94	
	12.18	11.93	
	16.73	16.48	
OYSSL02	6.06	5.81	It was found that there was an open cavity ending approximately 5 cm below lower end of casing at the beginning of the test.
	9.05	8.80	It was found that there was an open cavity ending approximately 8 cm below lower end of casing at the beginning of the test. The corrected water pressure did not reach a stable equilibrium. Pressure increased with time after lowest recorded water level.
	13.55	12.55	It was found that there was an open cavity ending approximately 15 cm below lower end of casing at the beginning of the test. After the test the cavity was found to be approximately 12 cm.
	16.56	15.56	It was found that there was an open cavity ending approximately 25 cm below lower end of casing at the beginning of the test.
	21.04	20.04	It was found that there was an open cavity ending approximately 27 cm below lower end of casing at the beginning of the test. The corrected water pressure did not reach a stable equilibrium. The test was terminated after 2 h 16 min since the water level had still not reached stable equilibrium.

4.6 NGI permeability probe (NGI – flow cone)

The NGI permeability flow cone, which has an add-on pumping system that allows water to flow into and out of the surrounding sediments while the CPTU test is performed, was also used at Øysand. NGI carried out the flow cone tests on September 25, 2018. To prevent damages to the equipment, it was decided to predrill through the gravelly top layer. A constant flow rate of 50 ml/min was applied during the cone penetration, which was started from 5.6 m below ground level (bgl) and ended at 13.83 m bgl. The cone penetration was paused at the five depths considered most optimal for stationary phase testing based on the cone penetration results. Most emphasis was on the excess pore pressure, but also the sleeve friction and cone resistance were considered to optimize the stationary phase testing. Table 3 provides test depths (filter center), number of tests at each depth and specified flow rates for the stationary phase testing.

Table 3. Summary of stationary phase testing

Depth (m)	No. of tests	Flow rate (ml/min)
6,16	5	100-300
6,88	5	100-300
9,30	3	12,3-24,6
11,42	8	16,4-400
13,01	4	8,2-100

Measured results: Penetration phase
Appendix L presents the measured cone resistance, qc, sleeve friction, fs, pore pressure behind cone, u2, and the pore pressure at flow filter center, uf, during the penetration phase. The figure includes best estimate in-situ pore pressure and the depths at which stationary phase tests were carried out. All parameters show variations with depth, which indicates a relatively layered soil profile. It is suggested that the local minimum pore pressures at flow filter location (e.g. 6.88 m bgl) correspond to layers with higher hydraulic conductivity (see Section 4.2). The local minimum pore pressures correspond well with three of the stationary phase test depths.

Measured results: stationary phase
Appendix L presents the pore pressure response at flow filter location 6.16 m bgl with time. Five tests with different flow rates were carried out at this depth. The pore pressure for the three first tests quickly reaches a peak before rapidly decreasing down to a pressure plateau. Although the specified flow rates for the first two tests are identical to the last two tests, the resulting pore pressure for the last two tests are lower, which implies a change in soil structure has occurred.

Appendix L shows the results from 6.88 m bgl. These results show a swift change in pressure until reaching the pressure plateau. After reaching the plateau, a steady increase in pore pressure with time can be observed. The results from the NGTS sand site suggest that the slope of the plateau depends on the specified flow rate. Figures 9 to 11 show the pore pressure response for the remaining tests where different test sequences were investigated.

More information is given in
Gundersen AS, Carotenuto P, Lunne T, et al. (2019) Field verification tests of the newly developed flow cone tool—In-situ measurements of hydraulic soil properties. *AIMS Geosciences* 5: 784–803.

4.7 Swedish SPT sounding (Hejarsondering)

A total of six Swedish SPT soundings (Hejarsondering) were performed at Øysand. The results are presented in Appendix N. This is one of the most widely used geotechnical survey methods in Sweden. The method is mainly used when piling foundations are relevant. The probing results are used for the evaluation of certain properties of the soil and in connection with piling for the assessment of impact conditions, reliability and required pile lengths. The standard recommended by the Swedish Geotechnical Association for Hejarsondering allows the use of solid bars as well as pipe rods with a diameter of 32 mm. During these tests, a conical shaped tip is beaten down in the ground with a weight in free fall.

The number of strokes or punches for a 0,2-meter drop is recorded. The test is used mainly in coarse-grained soil, moraine and clay moraine where CPTU cannot be operated as well as for determination of penetration depth for piles.

5 Sampling

Soil was sampled using the Sonic Drill Sampler (SDS), the Geonor Push Piston Sampler (GPP), an open Push Piston Sampler (PPS), and the Japanese Gel Push Sampler (GPS). Sampling with an *in situ* ground freezing technique was conducted in April and May 2019. Sample lists are presented in Appendix M for 3 boreholes (OYSB01, OYSB02 and OYSB09). The rest of the boreholes (OYSB14, OYSB15, OYSB21, OYSB22, OYSB23, OYSB24, OYSB10, OYSB12) will be reported as part of the PhD work of Santiago Quinteros.

6 List of symbols and terms

6.1 General

According to ISO/DIS 19901-8 (E):

a	net area ratio of the cone penetrometer
c_v	coefficient of consolidation
C_s	swelling index (for consolidation tests)
h_{sf}	height of reference point above seafloor
f_s	cone sleeve friction
G_{max}	initial shear modulus
I_L	liquidity index
I_P	plasticity index
i	inclination
K_o	coefficient of earth pressure at rest (= $\sigma'_{h0} / \sigma'_{v0}$)
m_v	coefficient of compressibility
p_0'	in situ vertical effective stress (=σ'_{v0})
q_c	cone penetration resistance
q_t	cone penetration resistance corrected for pore water pressure effects
s	vane blade thickness
$s_u = c_u$	undrained (undisturbed) shear strength of soil
s_{uC}	static triaxial compression undrained shear strength
s_{uD}	static DSS undrained shear strength
s_{uE}	static triaxial extension undrained shear strength
s_{ufv}	shear strength by vane testing
$s_{ufv,rem}$	remoulded shear strength by vane testing
$s_{ufv,res}$	residual shear strength by vane testing
S_t	soil sensitivity
u_2	pore pressure
V_p	compression wave velocity
V_s	shear wave velocity
v_{vh}	vertically (v) propagated, horizontally (h) polarized shear wave velocity
ξ	material damping ratio
z	height above seafloor for drilling mode *in situ* probe zero reference readings
γ'	submerged unit weight of soil
γ_m	material factor
ν	Poisson's ratio
σ	stress
σ'_{v0}	in situ vertical effective stress (= p_0')
σ'_{h0}	in situ horizontal effective stress
ϕ'	effective angle of internal friction

6.2 Units

According to ISO/DIS 19901-8 (E):

Units to be used may vary somewhat from one clause to another based on historical use. For example, a CPT cone cross-sectional area should be given in units of square millimetres (mm^2) as used today, and not for example in square metres (m^2). However, if there are no special historical reasons for deviating from the units listed below, then the units to be used are:

force	kN
moment	kNm
density	kg/m^3
unit weight	kN/m^3
stress, pressure, strength and stiffness	kPa*
coefficient of permeability	m/s
coefficient of consolidation	m^2/s*
penetration rate CPT	cm/s*

Rate of penetration is reported in mm/s.
Tip resistance, sleeve friction and pore pressure are reported in MPa.

6.3 Abbreviated terms

According to ISO/DIS 19901-8 (E):

BHA	bottom hole assembly
CCV	consolidated constant volume
CD	consolidated drained test
CPT	cone penetration test
CPTU	cone penetration test with pore-pressure measurement
CRS	controlled rate of strain
CT	computerized tomography
CU	consolidated undrained
DS	direct shear (box)
DGPS	differential global positioning system
DSS	direct simple shear
ERP	emergency response plan
FVT	field vane test
GIS	geographical information system
GNSS	global navigation satellite system
HAZID	hazard identification
HAZOP	hazard and operability study
HSE	health, safety and environment
HVAC	heating, ventilation and air conditioning
IL	incremental loading
LAT	lowest astronomical tide
LBL	long baseline
MSL	mean sea level
MSCL	multi-sensory core logging
OCR	over-consolidation ratio
PEP	project execution plan
PPE	personal protective equipment
QA	quality assurance
QC	quality control
RFID	radio-frequency identification
ROP	rate of penetration
ROV	remotely operated vehicle
RS	ring shear
SCPT	seismic CPT
SH	shear waves
SHANSEP	stress history and normalized soil engineering parameters
SIMOPS	simultaneous operations
SOW	scope of work
SRB	sulphate-reducing bacteria
SWL	safe working load
TC	triaxial compression
TE	triaxial extension
TOC	total organic content
UCT	unconfined compression test
USBL	ultra-short baseline
UU	unconsolidated-undrained

WGS	World Geographic System
VSP	vertical seismic profiling
YSR	yield stress ratio

Additional abbreviated terms:

ASTM	American Standard for Testing and Materials
CAD	Consolidated Anisotropic Drained
CAU	Consolidated Anisotropic Undrained
CPT	Cone Penetration Test
CPTU	Cone Penetration Test
CRSC	Constant Rate of Strain Consolidation
DIS	Draft International Standard
ISO	International Organization for Standardization
NGF	Norsk Geoteknisk Forening (Norwegian Geotechnical Society)
NS	Norsk Standard (Norwegian Standard)
PGA	Peak Ground Acceleration
PSV	Pseudo Velocity
UU	Unconsolidated Undrained

Coordinate table abbreviated terms:

ABBR/Group Name	Abbreviation definition Sampler & In situ test	Term in LOCA_ID-HOLE_ID
BH54C	54 mm composite sample borehole (with liner)	B
BH54	54 mm sample borehole (no liner)	B
BH72	72 mm sample borehole (no liner)	B
BH75	75 mm sample borehole (no liner)	B
BHSB	Sherbrooke block sample borehole (large)	B
BHSBm	Mini Sherbrooke block sample borehole	B
BHGPTr	Gel push Triple tube sampler	B
BHGPS	Gel push Static penetration	B
BHGUS	Gregory Undisturbed Fixed Piston Sample (GUS Sampler, manufactured by Acker Drill Company, PA)	B
BHDM	Dames and Moore Fixed Piston Sampler (DM Sampler, manufactured by GeoMatic, CA)	B
BG	Bag sample (unrelated to a BH)	BG
NA	Attempted test - no results reported	-
SCPTU-DIS	Seismic cone penetration tests with dissipation	C
CPTU-DIS	Cone penetration test with dissipation	C
RCPTU-DIS	Resistivity cone penetration test with dissipation	C
CPTU	Cone penetration test with pore pressure measurements	C

ABBR/Group Name	Abbreviation definition Sampler & In situ test	Term in LOCA_ID-HOLE_ID
CPT	Cone penetration test without pore pressure measurements	C
RCPTU	Resistivity cone penetration test	C
SCPTU	Seismic cone penetration tests	C
SDMT	Seismic dilatometer test	D
DMT	Dilatometer test	D
ERT	Electrical resistivity tomography	ER
MASW	Multichannel analysis of surface waves	M
SRefra	Seismic refraction	SRR
VSP	vertical seismic profiling	VP
SBP	Self boring pressuremeter test	P
EPCT	Earth pressure cell test (hydraulic, Glötzl)	EP
HFST	Hydraulic fracture stress test	H
FVT	Field vane	V
INC	Inclinometer	I
Piezo	Piezometer (Electric reading)	PI
StandP	Stand pipe	S
THS	Thermistor string	TH
RWS	Rotary weight sounding	RW
RCD	Rock control drilling	RC
SS	Simple Sounding	SS
RPS	Rotary pressure sounding	RP
TS	Total sounding	TS
SLU	Slug test	SL
PAC	Pack test	PA
XBseism	Crosshole seismic	XS
XBGPR	Crosshole GPR	XG
XBERT	Crosshole ERT	XE
DBseism	Downhole seismic	DS
DBGPR	Downhole GPR	DG
DBERT	Downhole ERT	DE
GPR	Ground penetrating radar	G
EM	Electromagnetic	E
SP	Self polarisation	SP
SRefle	Seismic reflection	SRL
HYP	Hydraulic piezometer (Manual reading)	HP
PS	Passive seismic	PS
SPLT	Screw-Plate Load Test	SPLT
WS	Weather station	WS

6.4 Classification system

6.4.1 Shear strength of clays or density of sands (ISO 14688-2:2004(E) and NGF (2011))

Undrained shear strength, $s_u = c_u$, of clays (in kPa)		Density index, I_D, of sands (in %)	
Extremely low	<10	Very loose	0 to 15
Very low	10 to 20	Loose	15 to 35
Low	20 to 40	Medium dense	35 to 65
Medium	40 to 75	Dense	65 to 85
High	75 to 150	Very dense	85 to 100
Very high	150 to 300		
Extremely high*)	>300		

*) Materials with shear strength greater than 300 kPa may behave as weak rock. Can be described according to ISO 14689-1

Note: In this report D_r is used for the relative density of sands, i.e. $I_D = D_r$.

6.4.2 Grain size distribution (ISO 14688-1:2002(E) and NGF (2011))

The grain size distribution is presented as percentages of the various grain sizes present in the soil as determined by sieving and sedimentation. The terms used to describe grain sizes are:

Soil fractions	Sub-fractions	Particle size (in mm)
Very coarse soil	Large boulder Boulder Cobble	> 630 200 to 630 63 to 200
Coarse soil	Gravel Coarse gravel Medium gravel Fine gravel	2 to 63 20 to 63 6.3 to 20 2.0 to 6.3
	Sand Coarse sand Medium sand Fine sand	0.063 to 2.0 0.63 to 2.0 0.2 to 0.63 0.063 to 0.2
Fine soil	Sand Coarse Sand Medium Sand Fine Sand	0.002 to 0.063 0.02 to 0.063 0.0063 to 0.02 0.002 to 0.0063
	Clay	≤ 0.002

6.4.3 Plasticity

The soil classification system used is described in NGF (2011).

Descriptions	I_p (%)
Low plasticity	< 10
Medium plasticity	10 – 20
High plasticity	> 20

6.4.4 Terms characterizing soil structure (NGI standard practice)

PARTING(S)	Horizontal inclusion(s) of different sediment type less than 3 mm thick
SEAM(S)	Horizontal inclusion(s) of different sediment type 3 mm to 75 mm thick
LAYER(S)	Horizontal inclusion(s) of different sediment type greater than 75 mm thick
POCKET(S)	Inclusion of different sediment type that is smaller than the diameter of the sample
BLOCKY	Containing discrete blocks of sediment set in a non-structured matrix
PSEUDO-BLOCKY	Block structures formed by intersecting fissures
PLATY	Containing discrete platelets with one dimension (vertical) limited and less than the other two
SLICKENSIDED	Having (inclined) planes of weakness that are slick and glossy in appearance
FISSURED	Containing small scale discontinuities in sediment fabric
LAMINATED	Composed of thin seams or partings of varying colour and texture
FOLIATED	Containing small scale laminar structure with no colour or textural variations
INTERLAYERED	Composed of alternate layers of different sediment types
WELL GRADED	Having a wide range of grain sizes. Similar to poorly sorted.
POORLY GRADED	Predominantly of one grain size. Similar to well sorted.

7 References

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NGI (2018) SCPT/SDMT seismic processing Technical note 20160154-02-TN, 14.06.2018

Olsen, L. and Sørensen, E. (1993) Øysand 1913 II, Quaternary map, 1:50.000, with descriptions (in Norwegian). Geological Survey of Norway.

Appendix A

MAPS

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Site extent

Site grid status cells
- Unauthorised
- Used
- Planned
- Available
- ERT_Lines

Groundinvestigations Type

BG, BH54, BH54C, BH72, BH75, BHGPS, BHGPTr, BHSB, BHSBm, BH100, CPT, CPTU, CPTU-DIS, RCPTU, RCPTU-DIS, SCPTU, SCPTU-DIS, DBERT, DBGPR, DBseism, FVT, EPCT, HFST, INC, PAC, Piezo, RCD, RPS, RWS, SBP, SDMT, SLU, SP, StandP, SS, THS, TS, VSP, XBERT, XBGPR, XBseism, NA, PS, MASW

NGTS - Øysand research site

Administration overview grid Øysand - aerial view
Grid 1.5 x 1.5
Site area: 10200sqm
Available cells: 3057

Spatial Reference:
ETRS 1989 UTM Zone 32N

Document No.	
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Figure No.	
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Date	Drawn by
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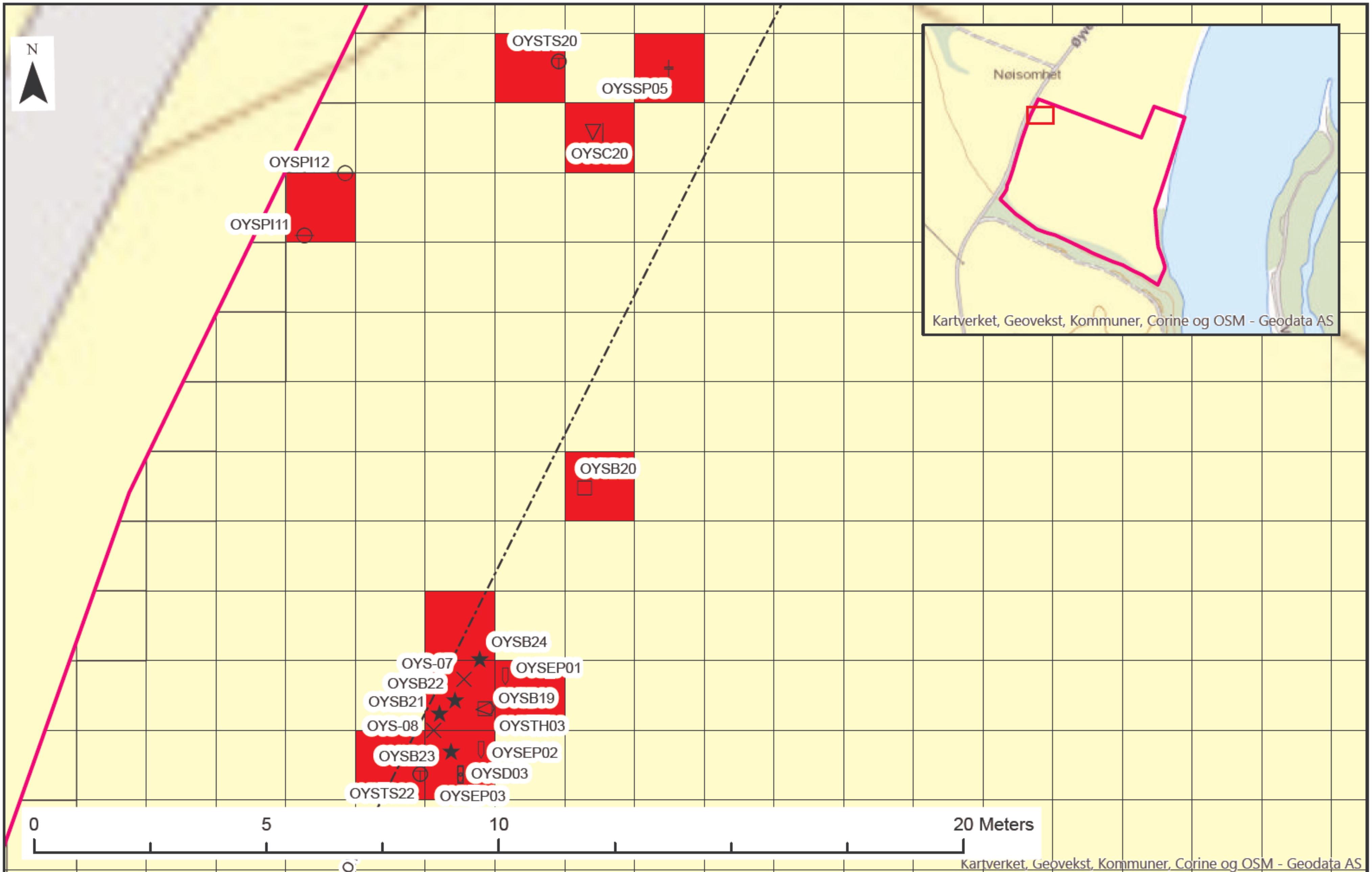
NGTS



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Site extent
Site grid
Site grid status cells
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Used
Planned
Available
EM_Lines

MASW_Lines
GPR_Lines
ERT_Lines
Groundinvestigations
BG
BH54
BH54C
BH72
BH75

BHGPS
BHGPTr
BHSB
BHSBm
BH100
CPT
CPTU
CPTU-DIS
RCPTU
RCPTU-DIS

SCPTU
SCPTU-DIS
DBERT
DBGPR
DBseism
FVT
EPCT
HFST
INC
PAC

Piezo
RCD
RPS
RWS
SBP
SDMT
SLU
SP
StandP
SS

THS
TS
VSP
XBERT
XBGPR
XBseism
NA
PS
MASW

NGTS - Øysand research site

Detailed grid with tests Øysand - topography view
Grid 1.5 x 1.5
Site area: 10200sqm
Available cells: 3057

Spatial Reference:
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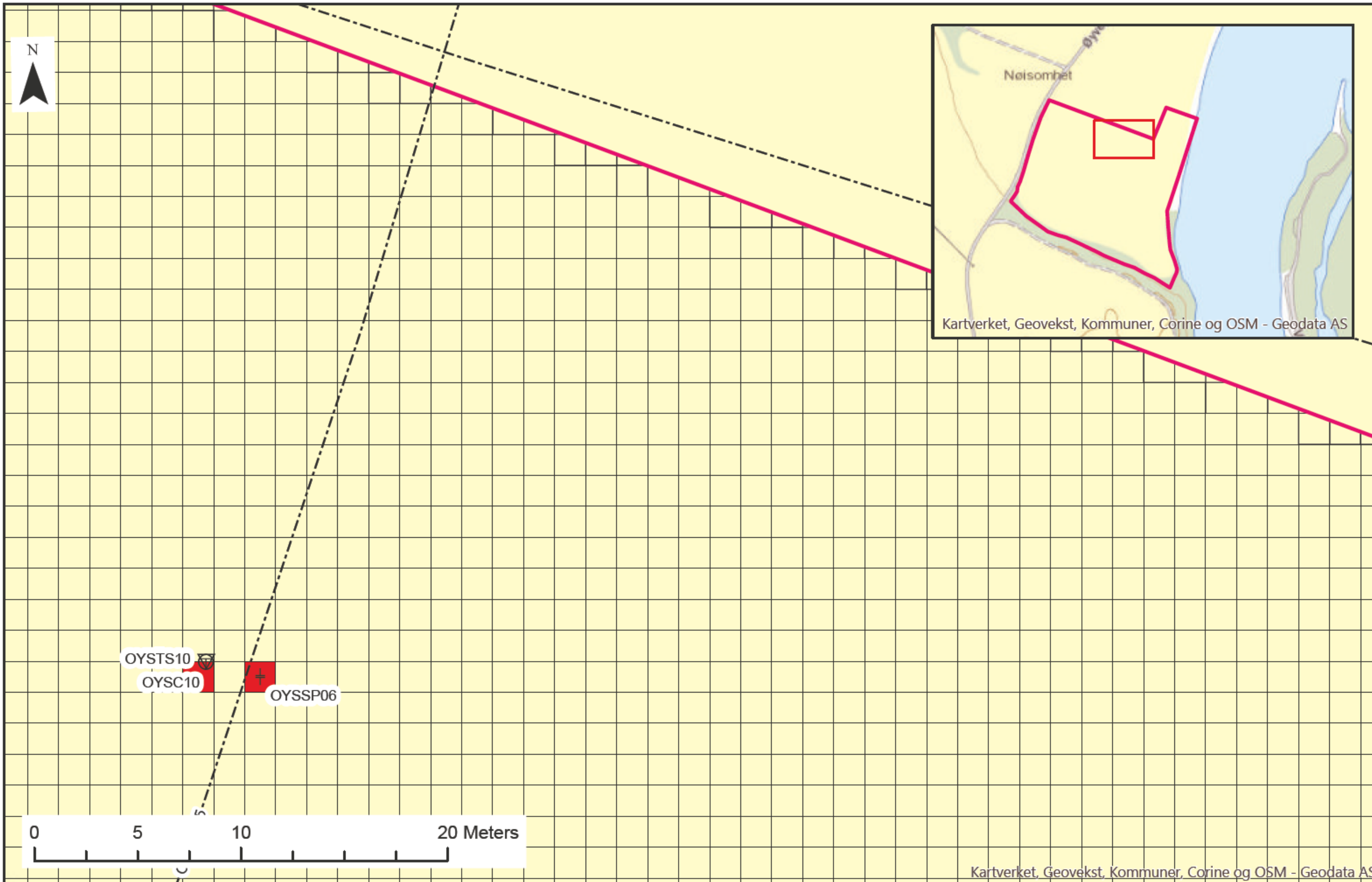

Site extent
Site grid

Site grid status cells
Unauthorised
Used
Planned
Available

EM_Lines
MASW_Lines
GPR_Lines
ERT_Lines

Groundinvestigations
BG
BH54
BH54C
BH72
BH75
BHGPS
BHGPTr
BHSB
BHSBm
CPT
CPTU
CPTU-DIS
RCPTU
RCPTU-DIS
SCPTU
SCPTU-DIS
DBERT
DBGPR
DBseism
FVT
EPCT
HFST
INC
PAC
Piezo
RCD
RPS
RWS
SBP
SDMT
SLU
SP
StandP
SS
THS
TS
VSP
XBERT
XBGPR
XBseism
NA
PS
MASW

NGTS - Øysand research site

Detailed grid with tests Øysand - topography view
Grid 1.5 x 1.5
Site area: 10200sqm
Available cells: 3057

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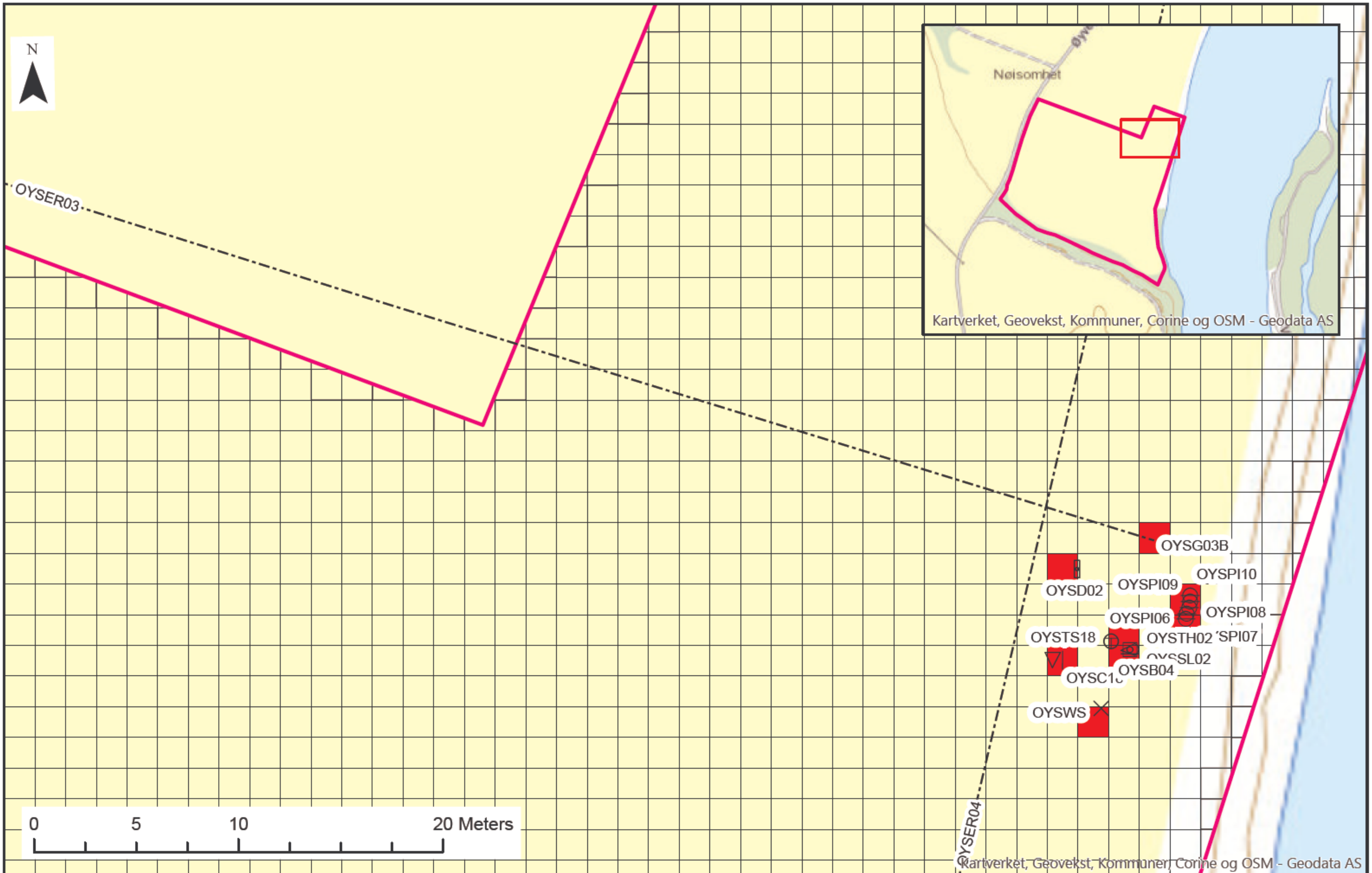

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MASW_Lines
GPR_Lines

ERT_Lines
Groundinvestigations
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BH54C
BH72
BH75
BHGPS
BHGPTr
BHSB
BHSBm

CPT
CPTU
CPTU-DIS
RCPTU
RCPTU-DIS
SCPTU
SCPTU-DIS
DBERT
DBGPR
DBseism
FVT
EPCT

HFST
INC
PAC
Piezo
RCD
RPS
RWS
SBP
SDMT
SLU
SP
StandP

SS
THS
TS
VSP
XBERT
XBGPR
XBseism
NA
PS
MASW

NGTS - Øysand research site

Detailed grid with tests Øysand - topography view
Grid 1.5 x 1.5
Site area: 10200sqm
Available cells: 3057

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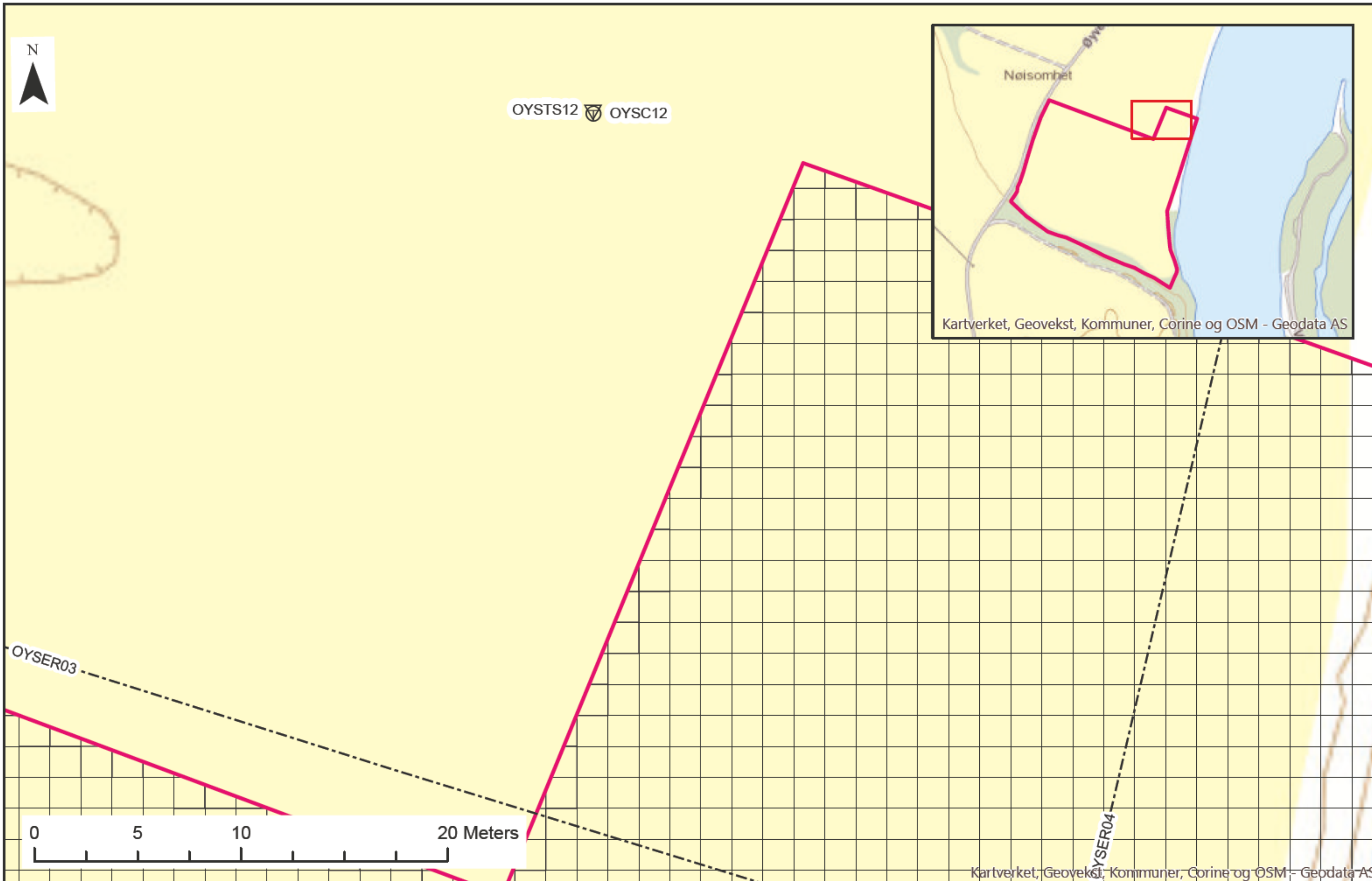

Site extent
Site grid
Site grid status cells
Unauthorised
Used
Planned
Available
EM_Lines
MASW_Lines
GPR_Lines
ERT_Lines

Groundinvestigations

BG, BH54, BH54C, BH72, BH75, BHGPS, BHGPTr, BHSB, BHSBm, CPT, CPTU, CPTU-DIS, RCPTU, RCPTU-DIS, SCPTU, SCPTU-DIS, DBERT, DBGPR, DBseism, FVT, EPCT, HFST, INC, PAC, Piezo, RCD, RPS, RWS, SBP, SDMT, SLU, SP, StandP, SS, THS, TS, VSP, XBERT, XBGPR, XBseism, NA, PS, MASW

NGTS - Øysand research site

Detailed grid with tests Øysand - topography view
Grid 1.5 x 1.5
Site area: 10200sqm
Available cells: 3057

Spatial Reference:
ETRS 1989 UTM Zone 32N

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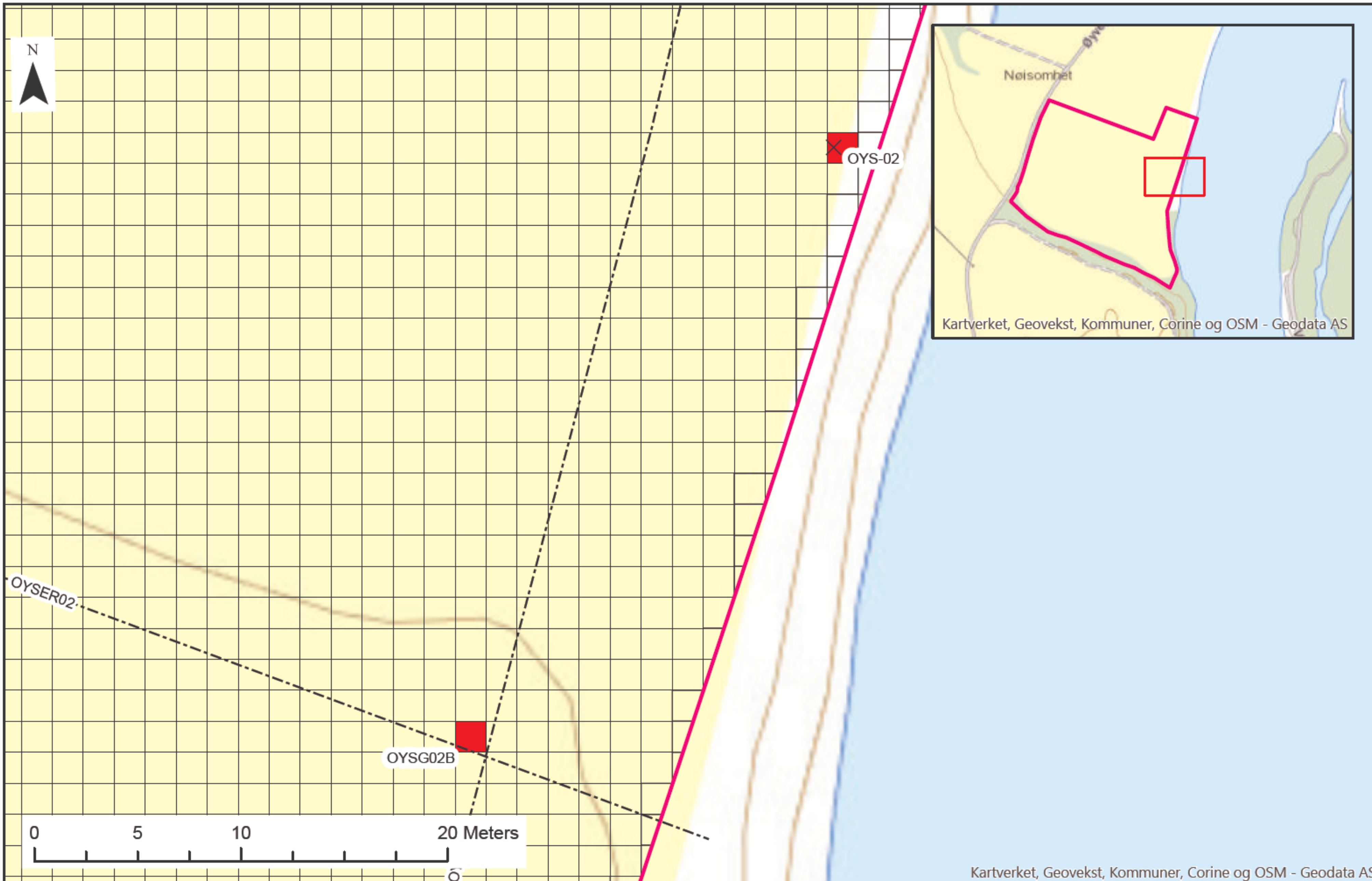

Site extent
Site grid

Site grid status cells
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Used
Planned
Available
EM_Lines
MASW_Lines
GPR_Lines
ERT_Lines

Groundinvestigations
BG, BH54, BH54C, BH72, BH75, BHGPS, BHGPTr, BHSB, BHSBm, CPT, CPTU, CPTU-DIS, RCPTU, RCPTU-DIS, SCPTU, SCPTU-DIS, DBERT, DBGPR, DBseism, FVT, EPCT, HFST, INC, PAC, Piezo, RCD, RPS, RWS, SBP, SDMT, SLU, SP, StandP, SS, THS, TS, VSP, XBERT, XBGPR, XBseism, NA, PS, MASW

NGTS - Øysand research site

Detailed grid with tests Øysand - topography view
Grid 1.5 x 1.5
Site area: 10200sqm
Available cells: 3057

Spatial Reference:
ETRS 1989 UTM Zone 32N

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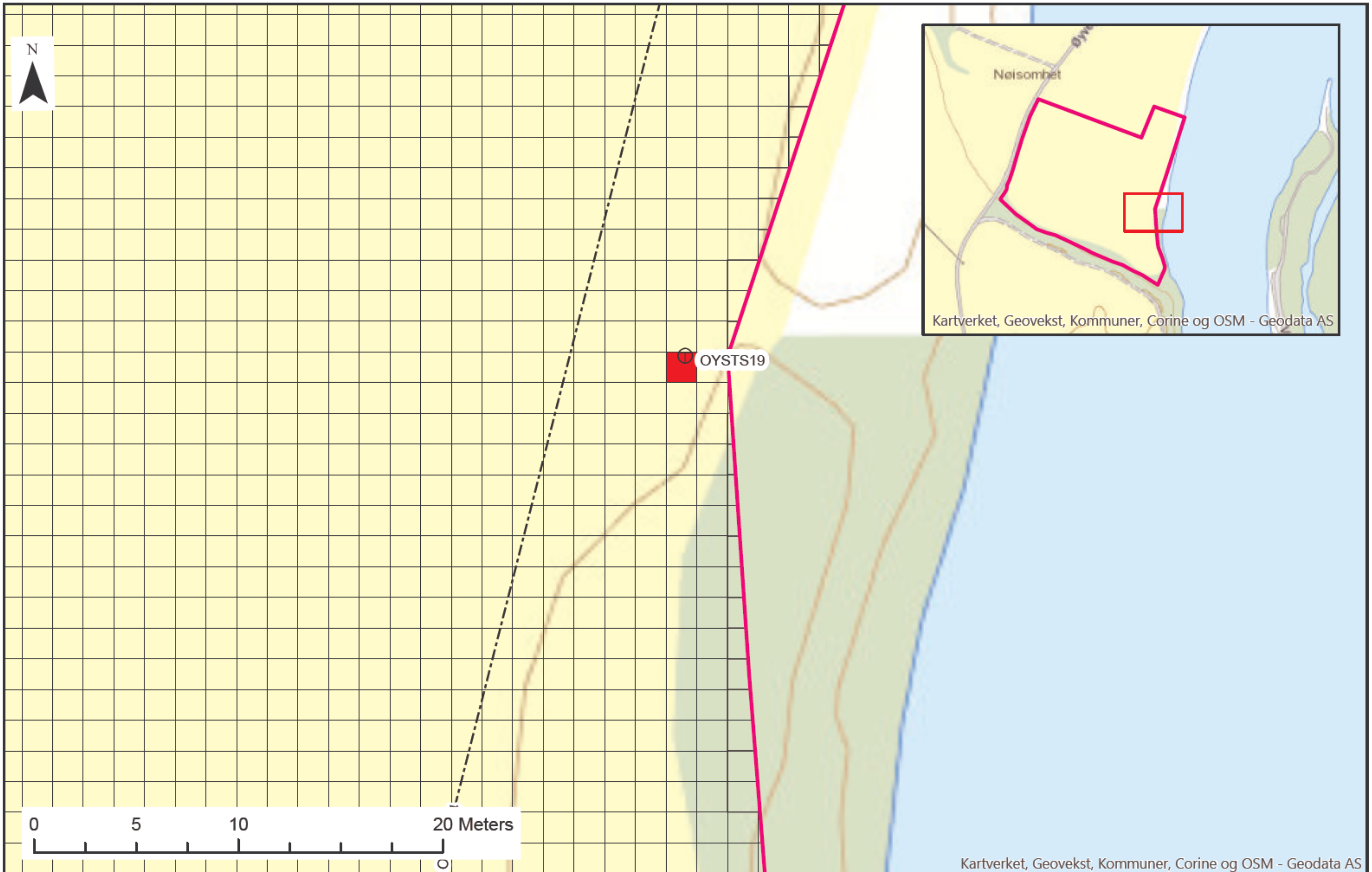

Site extent
Site grid
Site grid status cells
Unauthorised
Used
Planned
Available
EM_Lines
MASW_Lines
GPR_Lines
ERT_Lines

Groundinvestigations
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BH72
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NGTS - Øysand research site

Detailed grid with tests Øysand - topography view
Grid 1.5 x 1.5
Site area: 10200sqm
Available cells: 3057

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Figure No.
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2020-01-09

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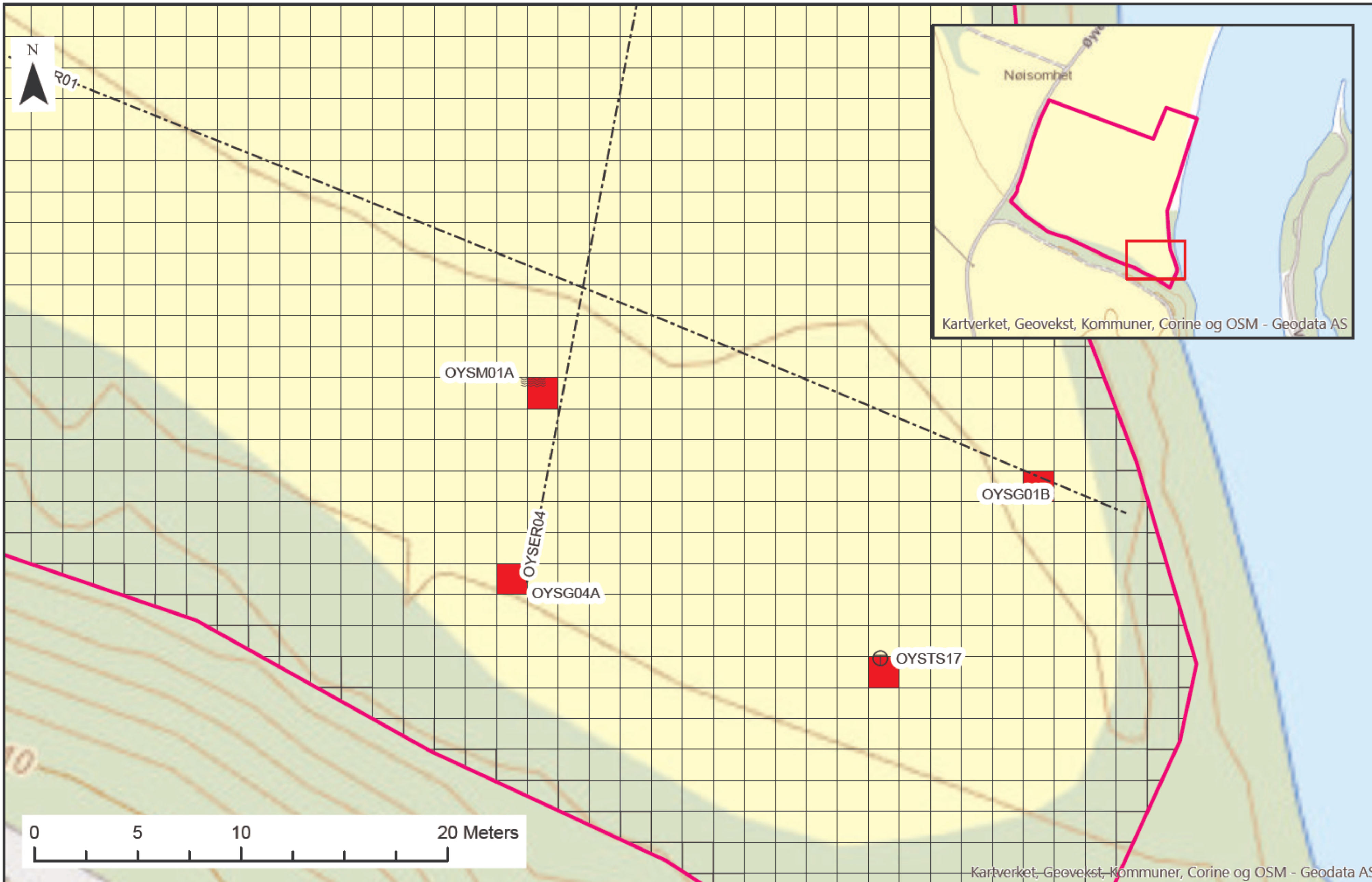

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MASW_Lines
GPR_Lines
ERT_Lines

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NGTS - Øysand research site

Detailed grid with tests Øysand - topography view
Grid 1.5 x 1.5
Site area: 10200sqm
Available cells: 3057

Spatial Reference:
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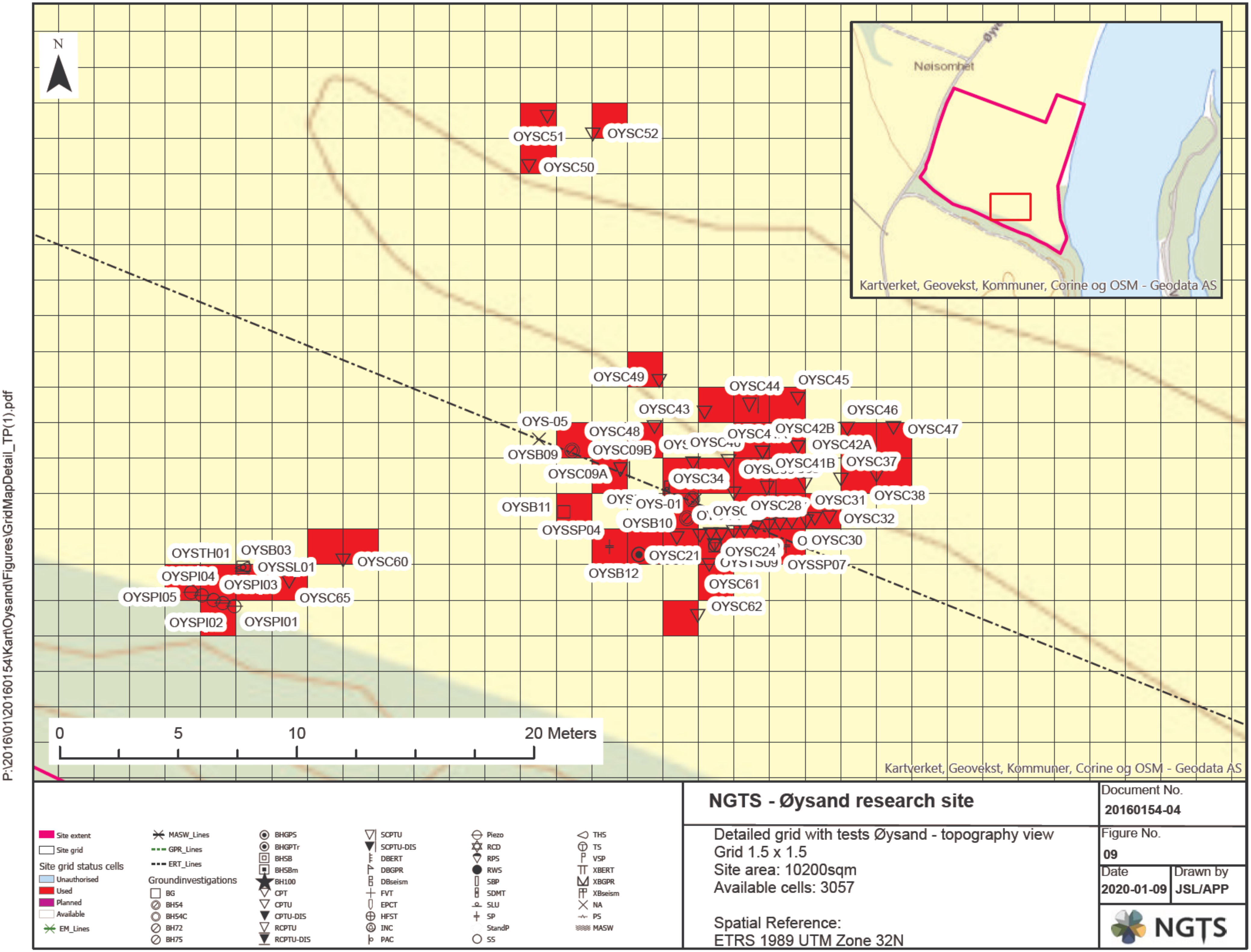

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Detailed grid with tests Øysand - topography view Grid 1.5 x 1.5 Site area: 10200sqm Available cells: 3057	Figure No. **09**	
	Date **2020-01-09**	Drawn by **JSL/APP**
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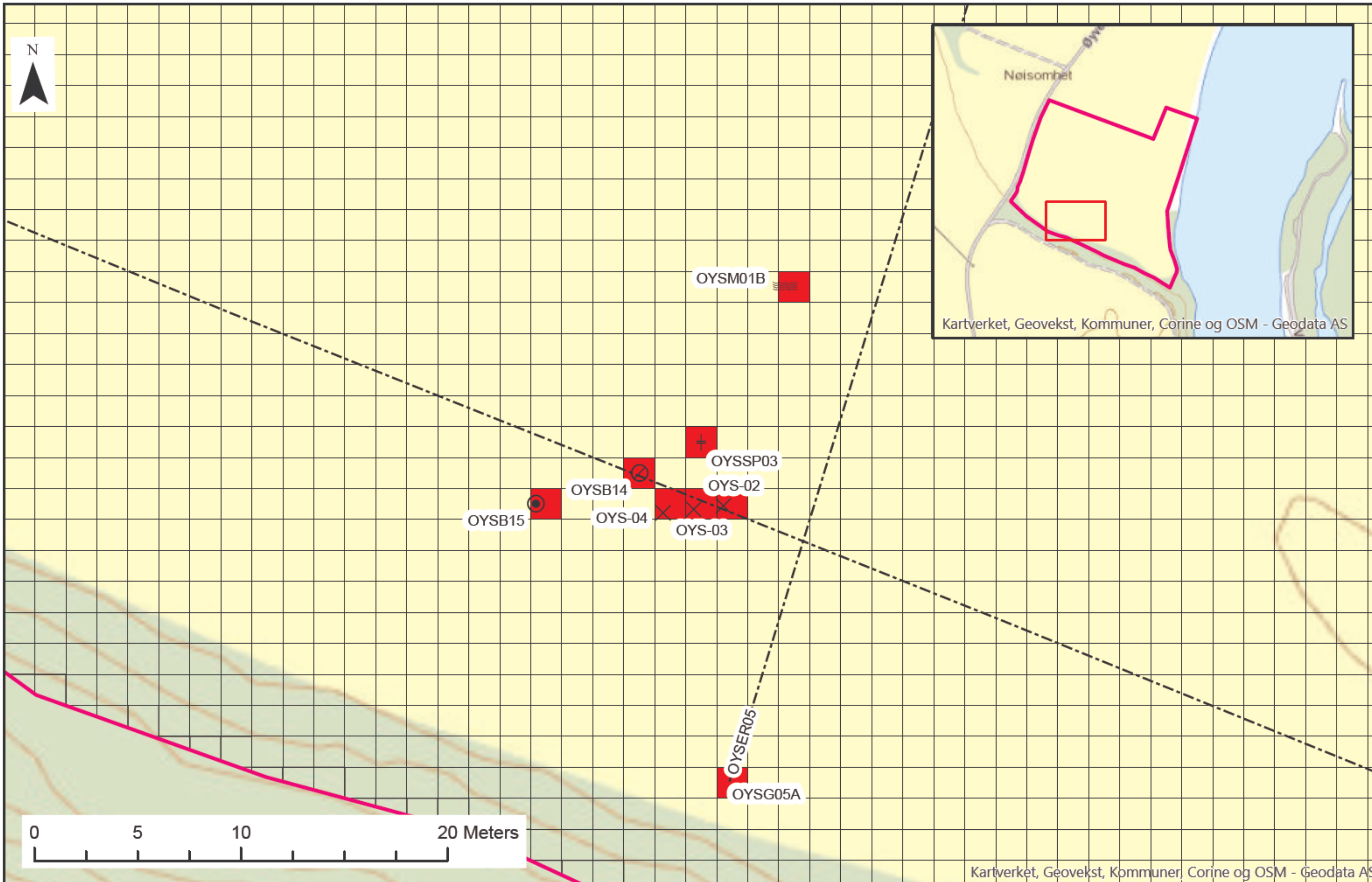

Site extent
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ERT_Lines
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BH75

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BHSB
BHSBm
BH100
CPT
CPTU
CPTU-DIS
RCPTU
RCPTU-DIS

SCPTU
SCPTU-DIS
DBERT
DBGPR
DBseism
FVT
EPCT
HFST
INC
PAC

Piezo
RCD
RPS
RWS
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StandP
SS

THS
TS
VSP
XBERT
XBGPR
XBseism
NA
PS
MASW

NGTS - Øysand research site

Detailed grid with tests Øysand - topography view
Grid 1.5 x 1.5
Site area: 10200sqm
Available cells: 3057

Spatial Reference:
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Figure No.
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2020-01-09

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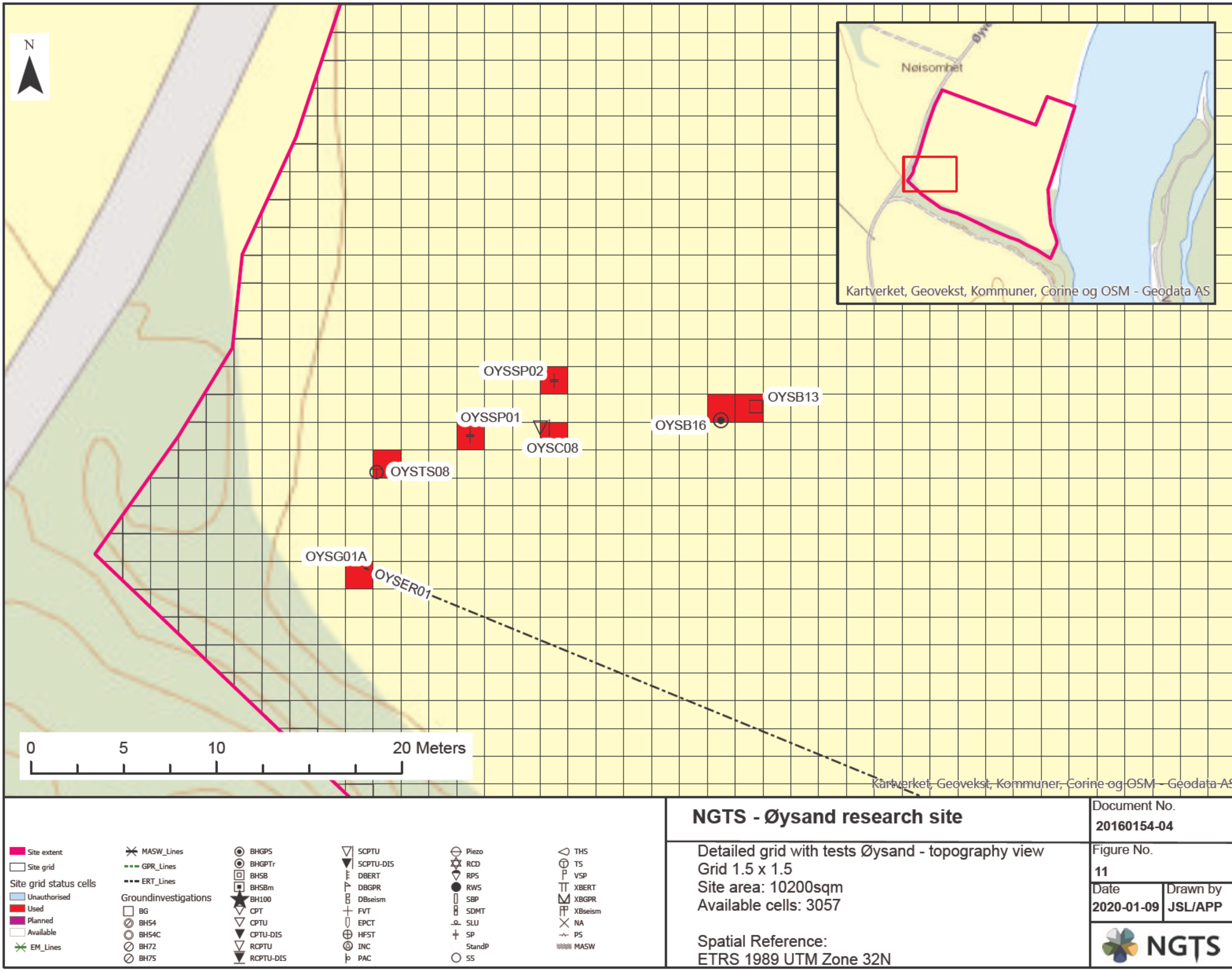

NGTS - Øysand research site

Detailed grid with tests Øysand - topography view
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Available cells: 3057

Spatial Reference:
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Document No.	20160154-04
Figure No.	11
Date	2020-01-09
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NGTS

Appendix B

COORDINATE TABLE

HEADING	Coordinate list
PROJ_ID	20160154
PROJ_NAME	National GeoTest Sites (NGTS)
PROJ_LOC	Oysand (OYS)
PROJ_CLNT	NGTS
PROJ_CONT	NGI
PROJ_END	NGI

LOCA_ID-HOLE_ID	ABBR	UTM	Datum	CM	Northing	Easting	Elevation surface	GPS Equipment ID	HDOP	VDOP	Field Equipment ID	Cone factor (a)	Depth to end of test	Depth to bedrock	DATE
-	-	-	-	-	m	m	m	-	m	m	-	-	m	m	YYYY-MM-YY
OYSBG01	BG	32	EUREF89	9°E	7022895,04	562573,89	2,74				Rig X	NA		NA	
OYSB01	BH54	32	EUREF89	9°E	7022884,05	562513,34	9,64				Rig X	NA		NA	
OYSB02	BH54C	32	EUREF89	9°E	7022897,01	562572,95	2,63				Rig X	NA		NA	
OYSC03A	CPTU	32	EUREF89	9°E	7022590,00	563071,00	3,00				4648	0,857	6,08	NA	2016-09-06
OYSC03B	CPTU	32	EUREF89	9°E	7022590,00	563071,00	3,00				4648	0,857	12,85	NA	2016-09-06
OYSC16	CPTU	32	EUREF89	9°E	7022703,83	562190,93	9,43				4648	0,857	20,52	NA	2016-10-03
OYSC14	CPTU	32	EUREF89	9°E	7022728,61	562276,28	9,78				4648	0,857	20,86	NA	2016-10-03
OYSC01	CPTU	32	EUREF89	9°E	7022812,00	562972,00	3,00				4648	0,857	15,21	NA	2016-09-07
OYSC07A	CPTU	32	EUREF89	9°E	7022884,05	562513,34	9,64				4648	0,857	8,15	NA	2016-09-07
OYSC07B	CPTU	32	EUREF89	9°E	7022884,05	562513,34	9,64				4648	0,857	20,02	NA	2016-09-27
OYSC02	CPTU	32	EUREF89	9°E	7022895,04	562573,89	2,74				4648	0,857	20,94	NA	2016-09-28
OYSC10	CPTU	32	EUREF89	9°E	7022999,19	562559,32	2,99				4648	0,857	20,53	NA	2016-09-28
OYSC12	CPTU	32	EUREF89	9°E	7023047,88	562620,49	2,90				4648	0,857	20,83	NA	2016-09-29
OYSM02A	MASW	32	EUREF89	9°E	7022720,00	562148,00	9,70				APEX	NA	0,00	NA	2016-11-02
OYSM02B	MASW	32	EUREF89	9°E	7022688,50	562234,00	9,60				APEX	NA	0,00	NA	2016-11-02
OYSM01A	MASW	32	EUREF89	9°E	7022876,00	562611,00	3,40				APEX	NA	0,00	NA	2016-11-02
OYSM01B	MASW	32	EUREF89	9°E	7022925,00	562533,00	3,70				APEX	NA	0,00	NA	2016-11-02
OYSD01	SDMT	32	EUREF89	9°E	7022897,43	562571,86	2,76							NA	2016-11-02
OYSTS03	TS	32	EUREF89	9°E	7022590,00	563071,00	3,00				Rig X	NA	25,02	NA	2016-09-06
OYSTS04	TS	32	EUREF89	9°E	7022608,00	563127,00	3,00				Rig X	NA	25,00	NA	2016-09-06
OYSTS02	TS	32	EUREF89	9°E	7022701,00	562939,00	4,00				Rig X	NA	25,02	NA	2016-09-06
OYSTS16	TS	32	EUREF89	9°E	7022703,83	562190,93	9,43				Rig X	NA	25,00	NA	2016-10-03
OYSTS14	TS	32	EUREF89	9°E	7022728,61	562276,28	9,78				Rig X	NA	25,00	NA	2016-09-29
OYSTS15	TS	32	EUREF89	9°E	7022790,05	562233,19	9,85				Rig X	NA	25,05	NA	2016-09-29
OYSTS01	TS	32	EUREF89	9°E	7022812,00	562972,00	3,00				Rig X	NA	25,02	NA	2016-09-05
OYSTS13	TS	32	EUREF89	9°E	7022823,41	562415,54	8,42				Rig X	NA	25,02	NA	2016-09-29
OYSTS07	TS	32	EUREF89	9°E	7022884,05	562513,34	9,64				Rig X	NA	25,08	NA	2016-09-07
OYSTS05	TS	32	EUREF89	9°E	7022895,00	562455,00	9,00				Rig X	NA	25,02	NA	2016-09-07
OYSTS09	TS	32	EUREF89	9°E	7022895,04	562573,89	2,74				Rig X	NA	25,02	NA	2016-09-27
OYSTS08	TS	32	EUREF89	9°E	7022944,07	562469,89	2,53				Rig X	NA	25,02	NA	2016-09-27
OYSTS10	TS	32	EUREF89	9°E	7022999,19	562559,32	2,99				Rig X	NA	25,02	NA	2016-09-28

PROJ_NAME	National GeoTest Sites (NGTS)
PROJ_LOC	Oysand (OYS)
PROJ_CLNT	NGTS
PROJ_CONT	NGI
PROJ_END	NGI

LOCA_ID-HOLE_ID	ABBR	UTM	Datum	CM	Northing	Easting	Elevation surface	GPS Equipment ID	HDOP	VDOP	Field Equipment ID	Cone factor (a)	Depth to end of test	Depth to bedrock	DATE
-	-	-	-	-	m	m	m	-	m	m	-	-	m	m	YYYY-MM-YY
OYSTS12	TS	32	EUREF89	9°E	7023047,88	562620,49	2,90				Rig X	NA	24,98	NA	2016-09-28
OYSTS11	TS	32	EUREF89	9°E	7023077,12	562523,24	2,93				Rig X	NA	25,02	NA	2016-09-28
OYSTS17	TS	32	EUREF89	9°E	7022862,65	562627,79	2,76				Rig X	NA	25,02	NA	2017-03-23
OYSTS18	TS	32	EUREF89	9°E	7022999,45	562646,80	3,22				Rig X	NA	25,02	NA	2017-03-23
OYSTS19	TS	32	EUREF89	9°E	7022928,55	562629,61	2,65				Rig X	NA	25,02	NA	2017-03-23
OYSB09	BH54	32	EUREF89	9°E	7022899,05	562567,87	2,69						20,00	NA	
OYSC08	SCPTU	32	EUREF89	9°E	7022946,42	562478,77	2,53				4648	0,857	20,96	NA	2017-04-03
OYSTS21	TS	32	EUREF89	9°E	7023003,14	562480,79	2,54				Rig X	NA	25,00	NA	2017-04-18
OYSTS20	TS	32	EUREF89	9°E	7023043,64	562498,06	2,73				Rig X	NA	25,02	NA	2017-04-18
OYSC20	SCPTU	32	EUREF89	9°E	7023042,11	562498,85	2,716				4648	0,857	20,01	NA	2017-04-19
OYSC09A	SCPTU	32	EUREF89	9°E	7022898,25	562569,98	2,77				4763	0,844	4,19	NA	2017-03-22
OYSC09B	SCPTU	32	EUREF89	9°E	7022898,25	562569,98	2,77				4763	0,844	20,01	NA	2017-03-22
OYSPI01	Piezo	32	EUREF89	9°E	7022892,48	562553,60	2,529						5,0	NA	2017-04-27
OYSPI02	Piezo	32	EUREF89	9°E	7022892,62	562553,14	2,513						9,0	NA	2017-04-27
OYSPI03	Piezo	32	EUREF89	9°E	7022892,74	562552,74	2,491						12,0	NA	2017-04-27
OYSPI04	Piezo	32	EUREF89	9°E	7022892,93	562552,25	2,483						15,0	NA	2017-04-27
OYSPI05	Piezo	32	EUREF89	9°E	7022893,05	562551,81	2,527						20,0	NA	2017-04-27
OYSPI06	Piezo	32	EUREF89	9°E	7023000,80	562650,52	3,336						5,0	NA	2017-04-27
OYSPI07	Piezo	32	EUREF89	9°E	7023000,52	562650,47	3,332						8,5	NA	2017-04-27
OYSPI08	Piezo	32	EUREF89	9°E	7023001,10	562650,63	3,266						10,0	NA	2017-04-27
OYSPI09	Piezo	32	EUREF89	9°E	7023001,37	562650,66	3,296						12,5	NA	2017-04-27
OYSPI10	Piezo	32	EUREF89	9°E	7023001,69	562650,68	3,296						18,0	NA	2017-04-27
OYSC18	SCPTU	32	EUREF89	9°E	7022998,49	562644,05	3,26				4648	0,857	20,00	NA	2017-04-20
OYSD02	SDMT	32	EUREF89	9°E	7023002,97	562645,16	3,09						20,00	NA	2017-05-02
OYSER01A	ERT	32	EUREF89	9°E	7022938,89	562469,20	2,53	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-10
OYSER01B	ERT	32	EUREF89	9°E	7022869,67	562639,67	3,08	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-10
OYSER02A	ERT	32	EUREF89	9°E	7023009,27	562478,13	2,84	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-10
OYSER02B	ERT	32	EUREF89	9°E	7022948,53	562640,97	3,18	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-10
OYSER03A	ERT	32	EUREF89	9°E	7023053,22	562496,63	1,93	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-10
OYSER03B	ERT	32	EUREF89	9°E	7023004,37	562648,91	2,13	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-10
OYSER04A	ERT	32	EUREF89	9°E	7022866,30	562610,67	2,65	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-11
OYSER04B	ERT	32	EUREF89	9°E	7023041,06	562651,84	3,12	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-11
OYSER05A	ERT	32	EUREF89	9°E	7022901,04	562530,31	2,41	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-11

PROJ_NAME	National GeoTest Sites (NGTS)
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PROJ_END	NGI

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-	-	-	-	-	m	m	m	-	m	m	-	-	m	m	YYYY-MM-YY
OYSER05B	ERT	32	EUREF89	9°E	7023072,56	562584,00	2,68	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-11
OYSER06A	ERT	32	EUREF89	9°E	7022971,54	562467,36	1,88	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-12
OYSER06B	ERT	32	EUREF89	9°E	7023113,65	562540,16	1,75	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-12
OYSG01A	GPR	32	EUREF89	9°E	7022938,89	562469,20	2,53	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-10
OYSG01B	GPR	32	EUREF89	9°E	7022871,21	562635,99	3,06	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-10
OYSG02A	GPR	32	EUREF89	9°E	7023009,27	562478,13	2,84	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-10
OYSG02B	GPR	32	EUREF89	9°E	7022953,03	562628,82	3,06	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-10
OYSG03A	GPR	32	EUREF89	9°E	7023053,22	562496,63	1,93	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-11
OYSG03B	GPR	32	EUREF89	9°E	7023004,37	562648,91	2,13	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-11
OYSG04A	GPR	32	EUREF89	9°E	7022866,30	562610,67	2,65	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-11
OYSG04B	GPR	32	EUREF89	9°E	7023041,06	562651,84	3,12	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-11
OYSG05A	GPR	32	EUREF89	9°E	7022901,04	562530,31	2,41	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-11
OYSG05B	GPR	32	EUREF89	9°E	7023072,56	562584,00	2,68	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-11
OYSG06A	GPR	32	EUREF89	9°E	7022971,54	562467,36	1,88	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-12
OYSG06B	GPR	32	EUREF89	9°E	7023096,29	562530,43	1,83	S-A 1	NR	NR	NGI	NA	0,00	NA	2017-04-12
OYSC21	CPTU	32	EUREF89	9°E	7022895,44	562573,26	2,61				C17190	0,783	25,45	NA	2017-09-21
OYSC22	CPTU	32	EUREF89	9°E	7022895,50	562573,70	2,62				C14251	0,776	25,31	NA	2017-09-21
OYSC23	CPTU	32	EUREF89	9°E	7022895,51	562574,18	2,63				S17176	0,76	25,75	NA	2017-09-21
OYSC24	CPTU	32	EUREF89	9°E	7022895,60	562574,69	2,62				S16299	0,7996	25,31	NA	2017-09-21
OYSC25	CPTU	32	EUREF89	9°E	7022895,70	562575,14	2,62				C14251	0,776	25,46	NA	2017-09-21
OYSC26	CPTU	32	EUREF89	9°E	7022895,81	562575,61	2,63				C17010	0,771	25,33	NA	2017-09-21
OYSC27	CPTU	32	EUREF89	9°E	7022895,86	562576,16	2,63				C17190	0,783	25,34	NA	2017-09-21
OYSC28	CPTU	32	EUREF89	9°E	7022895,92	562576,65	2,63				C14251	0,776	25,29	NA	2017-09-21
OYSC29	CPTU	32	EUREF89	9°E	7022896,01	562577,14	2,66				S16299	0,7996	25,35	NA	2017-09-21
OYSC30	CPTU	32	EUREF89	9°E	7022896,05	562577,73	2,66				S17176	0,76	24,92	NA	2017-09-21
OYSC31	CPTU	32	EUREF89	9°E	7022896,15	562578,11	2,65				C14251	0,776	24,32	NA	2017-09-21
OYSC32	CPTU	32	EUREF89	9°E	7022896,22	562578,72	2,66				C17010	0,771	25,30	NA	2017-09-21
OYS-01	NA	32	EUREF89	9°E	7022896,96	562573,05	2,60							NA	**2017-09-27**
OYSC34	CPTU	32	EUREF89	9°E	7022897,25	562574,71	2,65				MKj528	0,79	20,75	NA	2017-09-27
OYSC35	SCPTU	32	EUREF89	9°E	7022897,48	562576,16	2,65				MKj528	0,79	20,59	NA	2017-09-27
OYSC37	CPTU	32	EUREF89	9°E	7022897,82	562579,20	2,68				MKj528	0,79	20,77	NA	2017-09-28
OYSC38	CPTU	32	EUREF89	9°E	7022897,97	562580,71	2,68				MKj528	0,79	20,83	NA	2017-09-28
OYSC39	CPTU	32	EUREF89	9°E	7022898,50	562572,97	2,66				20759	0,69	25,90	NA	2017-09-28

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PROJ_CONT	NGI
PROJ_END	NGI

LOCA_ID-HOLE_ID	ABBR	UTM	Datum	CM	Northing	Easting	Elevation surface	GPS Equipment ID	HDOP	VDOP	Field Equipment ID	Cone factor (a)	Depth to end of test	Depth to bedrock	DATE
-	-	-	-	-	m	m	m	-	m	m	-	-	m	m	YYYY-MM-YY
OYSC40	CPTU	32	EUREF89	9°E	7022898,60	562574,46	2,70				20759	0,69	20,31	NA	2017-09-28
OYSC41A	CPTU	32	EUREF89	9°E	7022898,96	562575,89	2,69				20759	0,69	4,46	NA	2017-09-28
OYSC41B	CPTU	32	EUREF89	9°E	7022898,96	562575,89	2,69				20759	0,69	20,27	NA	2017-09-28
OYSC42A	CPTU	32	EUREF89	9°E	7022899,18	562577,38	2,70				20759	0,69	4,75	NA	2017-09-28
OYSC42B	CPTU	32	EUREF89	9°E	7022899,18	562577,38	2,70				20759	0,69	20,35	NA	2017-09-28
OYSSL01	SLU	32	EUREF89	9°E	7022894,11	562553,99	2,58							NA	
OYSSL02	SLU	32	EUREF89	9°E	7022999,02	562647,74	3,20							NA	
OYSTH01	THS	32	EUREF89	9°E	7022894,11	562553,99	2,58							NA	
OYSTH02	THS	32	EUREF89	9°E	7022999,02	562647,74	3,20							NA	
OYSB03	BG	32	EUREF89	9°E	7022894,11	562553,99	2,58							NA	
OYSB04	BG	32	EUREF89	9°E	7022999,02	562647,74	3,20							NA	
OYSC43	CPTU	32	EUREF89	9°E	7022900,64	562573,44	2,78				150912	0,75	25,70		2018-05-03
OYSC44	SCPTU	32	EUREF89	9°E	7022900,96	562575,40	2,86				180112	0,75	20,00		2018-05-03
OYSC45	CPTU	32	EUREF89	9°E	7022901,22	562577,41	2,82				180112	0,75	20,34		2018-05-04
OYSC50	CPTU	32	EUREF89	9°E	7022911,04	562566,05	2,74				4936	0,816	19,38		2018-05-31
OYSC51	CPTU	32	EUREF89	9°E	7022913,13	562566,82	2,72				4936	0,816	19,46		2018-05-31
OYSC52	CPTU	32	EUREF89	9°E	7022912,38	562568,75	2,72				4936	0,816	19,58		2018-05-31
OYS-02	NA	32	EUREF89	9°E	7022914,39	562530,01	2,46								
OYS-03	NA	32	EUREF89	9°E	7022914,23	562528,56	2,46								
OYS-04	NA	32	EUREF89	9°E	7022914,04	562527,10	2,42								
OYS-05	NA	32	EUREF89	9°E	7022899,53	562566,48	2,70								
OYSC60	CPTU	32	EUREF89	9°E	7022894,396	562558,20	2,40					0,824	19,84	NA	2018-09-24
OYSC61	CPTU	32	EUREF89	9°E	7022894,22	562573,65	2,62					0,824	19,84	NA	2018-09-24
OYSC62	CPTU	32	EUREF89	9°E	7022892,05	562573,18	2,61					0,824	13,82	NA	2018-09-25
OYS-06	NA	32	EUREF89	9°E	7022982,00	562647,00									2018-10-02
OYSSP01	SP	32	EUREF89	9°E	7022945,98	562474,9456									
OYSSP02	SP	32	EUREF89	9°E	7022948,98	562479,45									
OYSSP03	SP	32	EUREF89	9°E	7022917,48	562528,95									
OYSSP04	SP	32	EUREF89	9°E	7022894,98	562569,45									
OYSSP05	SP	32	EUREF89	9°E	7023043,48	562500,45									
OYSSP06	SP	32	EUREF89	9°E	7022998,48	562561,95									
OYSB14	BH72	32	EUREF89	9°E	7022915,98	562525,95									
OYSB15	BHGPS	32	EUREF89	9°E	7022914,48	562520,95									

PROJ_NAME National GeoTest Sites (NGTS)
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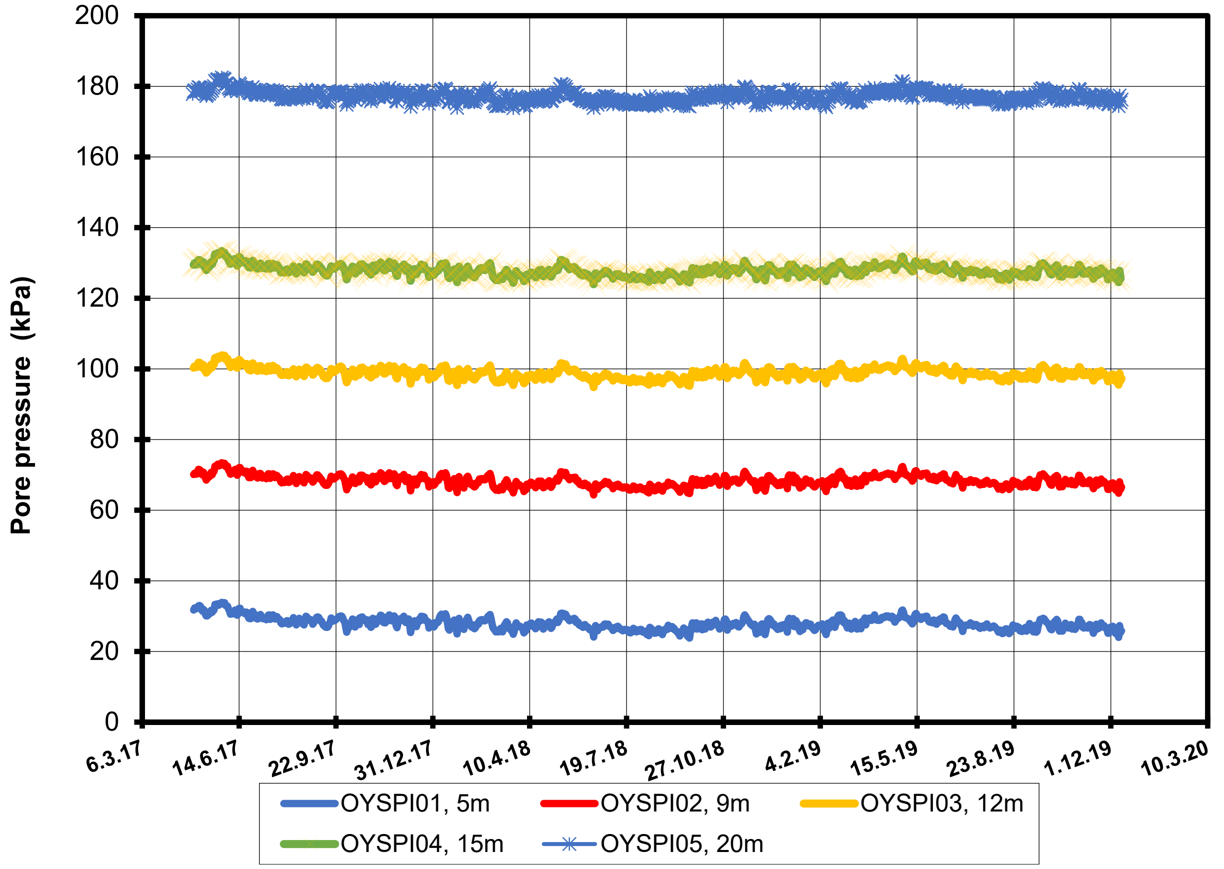
PROJ_CONT NGI
PROJ_END NGI

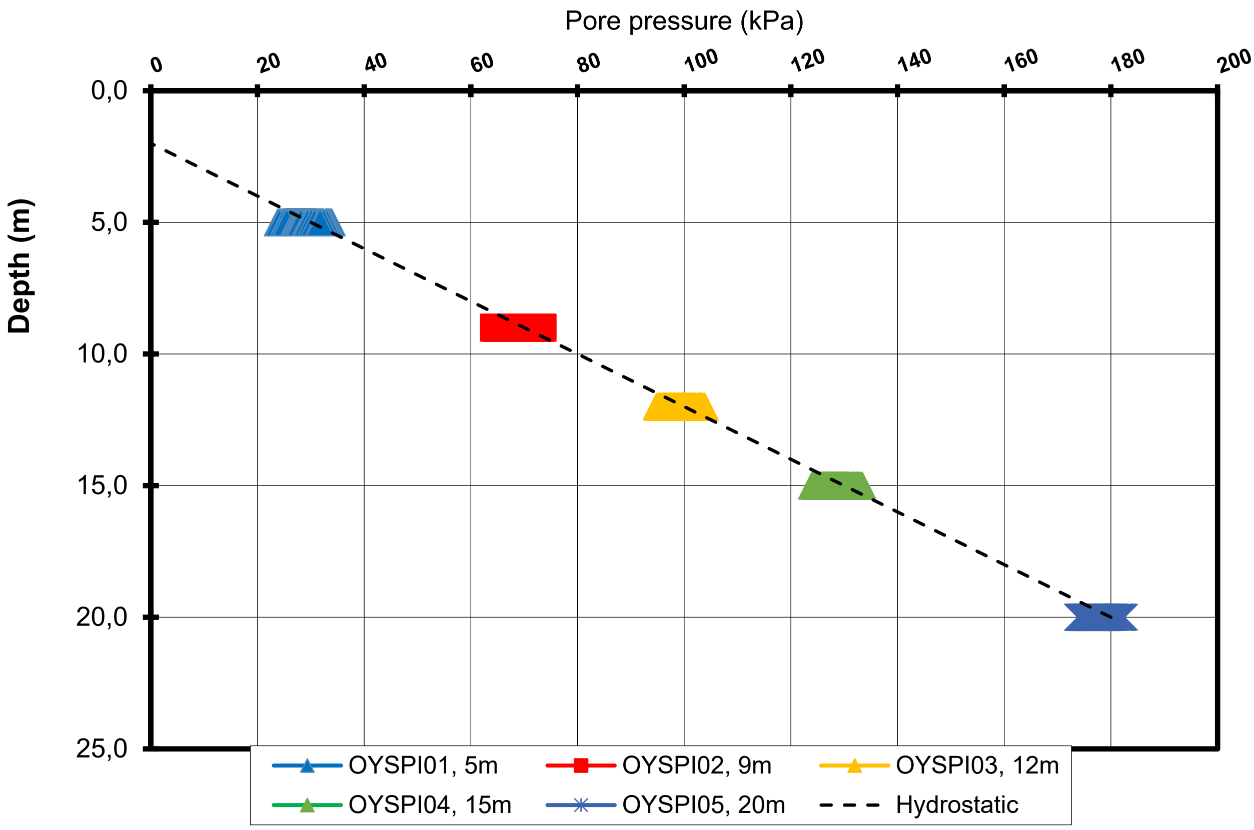
NGTS

LOCA_ID-HOLE_ID	ABBR	UTM	Datum	CM	Northing	Easting	Elevation surface	GPS Equipment ID	HDOP	VDOP	Field Equipment ID	Cone factor (a)	Depth to end of test	Depth to bedrock	DATE
-	-	-	-	-	m	m	m	-	m	m	-	-	m	m	YYYY-MM-YY
OYSB16	BHGPS	32	EUREF89	9°E	7022946,83	562488,43									
OYS-07	NA	32	EUREF89	9°E	7023030,33	562496,02									
OYS-08	NA	32	EUREF89	9°E	7023029,25	562495,37									
OYSB19	BG	32	EUREF89	9°E	7023029,70	562496,48									
OYSB20	BG	32	EUREF89	9°E	7023034,44	562498,63	2,42								
OYSB21	BH100	32	EUREF89	9°E	7023029,60	562495,50									
OYSB22	BH100	32	EUREF89	9°E	7023029,89	562495,84									
OYSC56	CPTU	32	EUREF89	9°E	7022895,36	562572,29						0,824			
OYSB23	BH100	32	EUREF89	9°E	7023028,79	562495,75									
OYSB24	BH100	32	EUREF89	9°E	7023030,774	562496,37									
OYSPI11	Piezo	32	EUREF89	9°E	7023039,87	562492,60	2,73						14,60		
OYSPI12	Piezo	32	EUREF89	9°E	7023041,22	562493,47	2,72						10,00		
OYSEP01	EPCT	32	EUREF89	9°E	7023030,40	562496,92									
OYSEP02	EPCT	32	EUREF89	9°E	7023028,82	562496,41									
OYSEP03	EPCT	32	EUREF89	9°E	7023028,28	562495,96									
OYSD03	SDMT	32	EUREF89	9°E	7023028,28	562495,96									
OYSTH03	THS	32	EUREF89	9°E	7023029,70	562496,48									
OYSTS22	TS	32	EUREF89	9°E	7023028,29	562495,09	2,76				NGI				2019-05-22
OYS-09	NA	32	EUREF89	9°E	7022996,16	562646,32	3,23								
OYSC65	CPTU	32	EUREF89	9°E	7022893,48	562555,94	2,54								
OYSSP07	SP	32	EUREF89	9°E	7022895,01	562576,90	2,77								
OYSPI13	Piezo	32	EUREF89	9°E	7022856,25	562581,16	9,65						4,50		
OYSPI14	Piezo	32	EUREF89	9°E	7022856,99	562579,61	9,59						8,55		
OYSPI15	Piezo	32	EUREF89	9°E	7023058,95	562487,53	2,95						10,00		
OYSPI16	Piezo	32	EUREF89	9°E	7023059,85	562485,85	2,94						4,70		
OYSB10	BH54	32	EUREF89	9°E	7022896,19	562572,71									
OYSB11	BG	32	EUREF89	9°E	7022896,47	562567,53									
OYSB12	BHGPS	32	EUREF89	9°E	7022894,68	562570,67									
OYSB13	BG	32	EUREF89	9°E	7022947,58	562490,29									

Appendix C

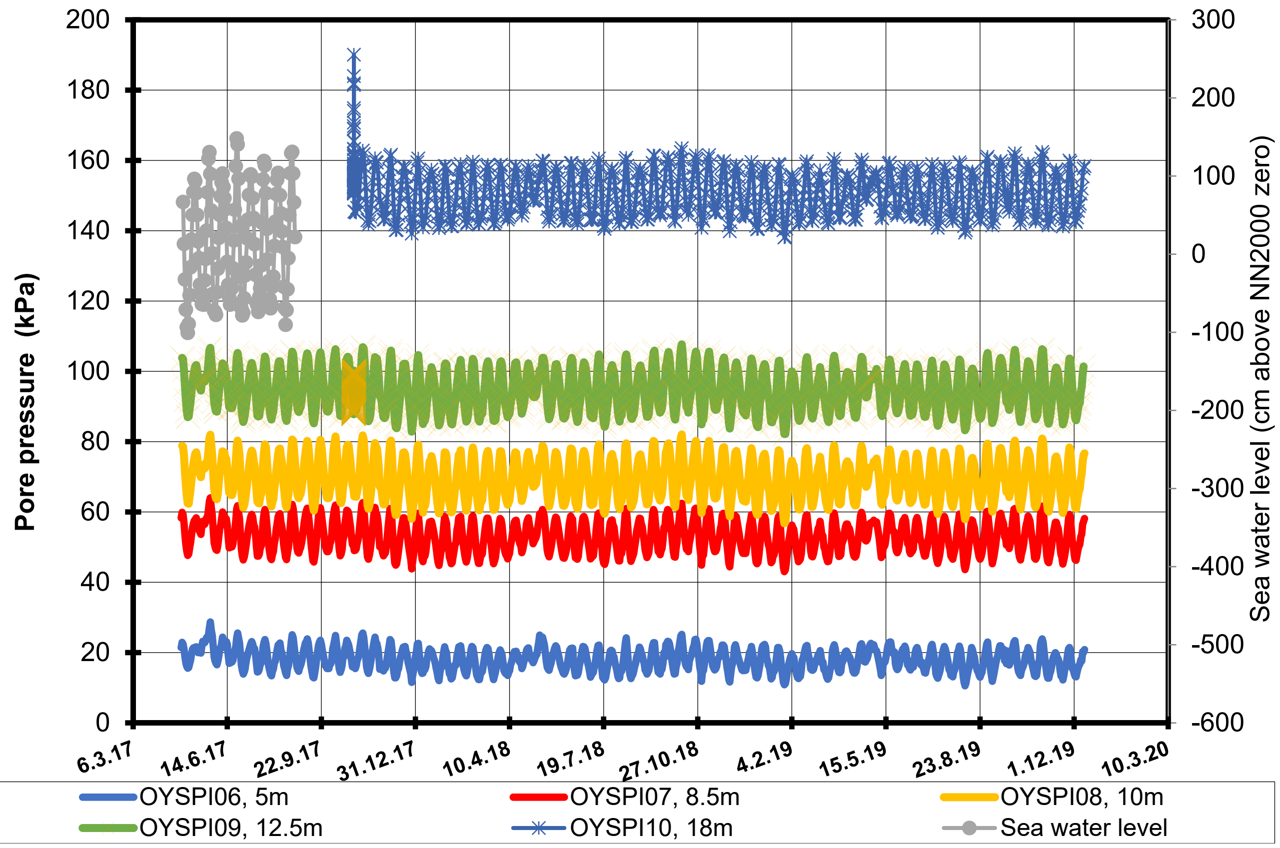
PIEZOMETER RESULTS

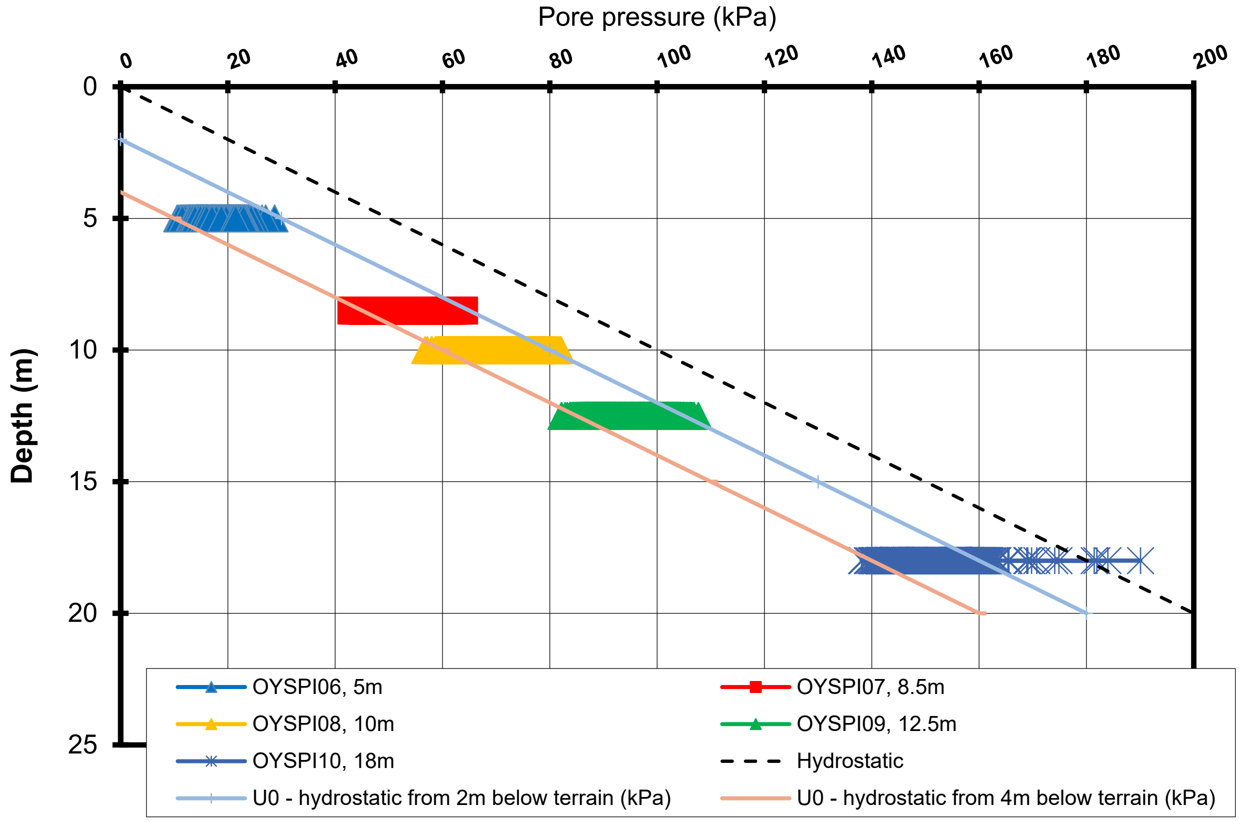




P:\2016\01\20160154\Fieldwork\Oysand\Piezo\OYSPI01-OYSPI05\[OYSPI01-OYSPI05.xlsx]Figur

NGTS - Øysand Research Site	Report No. 20160154-08-R	Figure No. 1
Results from electric porepressure measurements Borehole: OYSPI01, OYSPI02, OYSPI03, OYSPI04, OYSPI05 Elevation: 2,5 moh Installation date: 2017-04-27	Drawn by APP	Date 08.01.2020
	Control JSL	NGTS
	Approval JSL	





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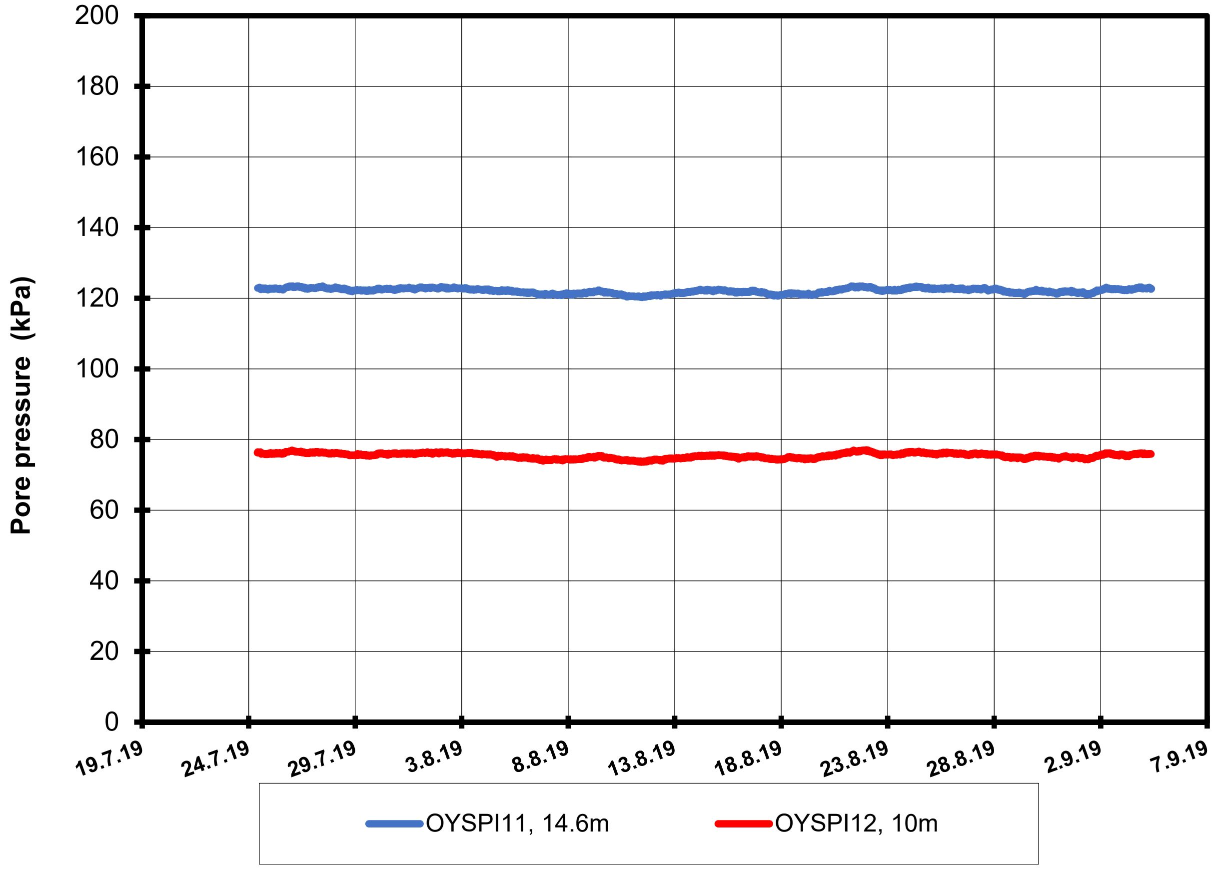
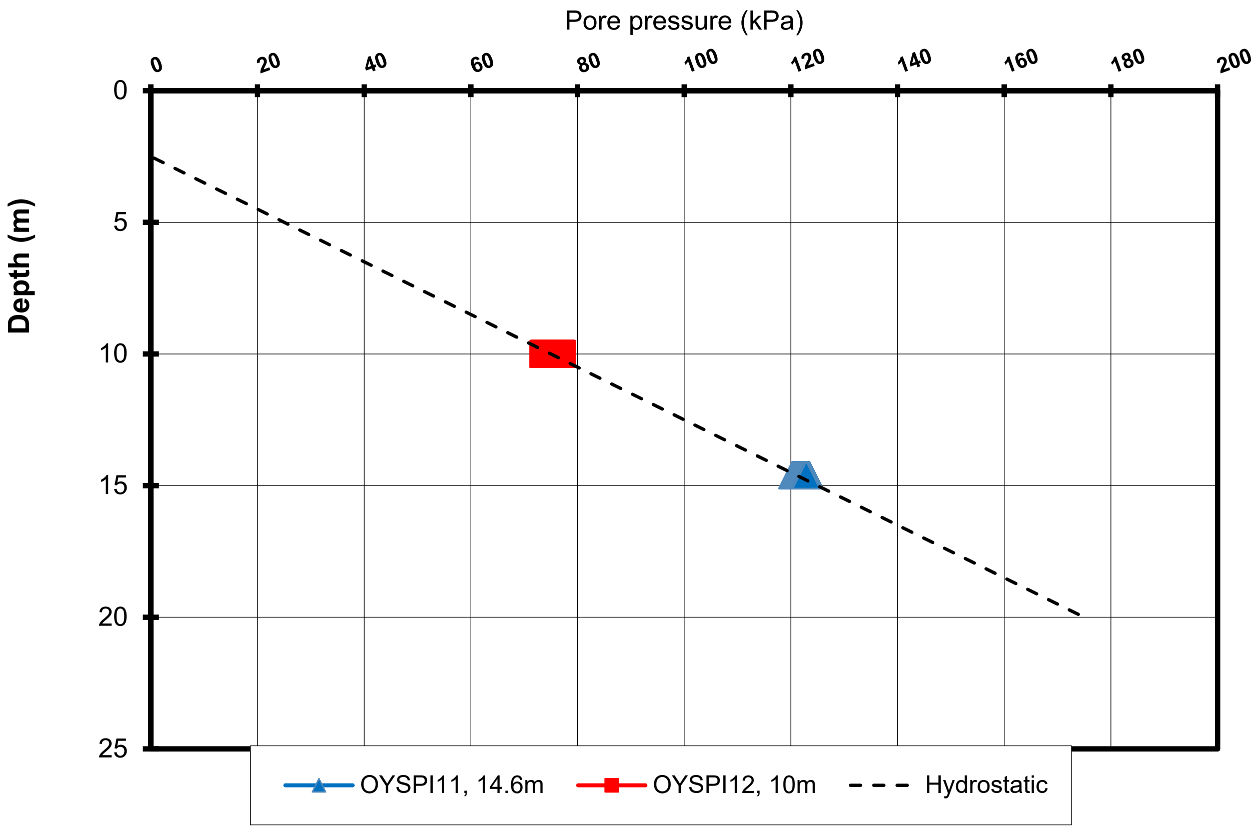
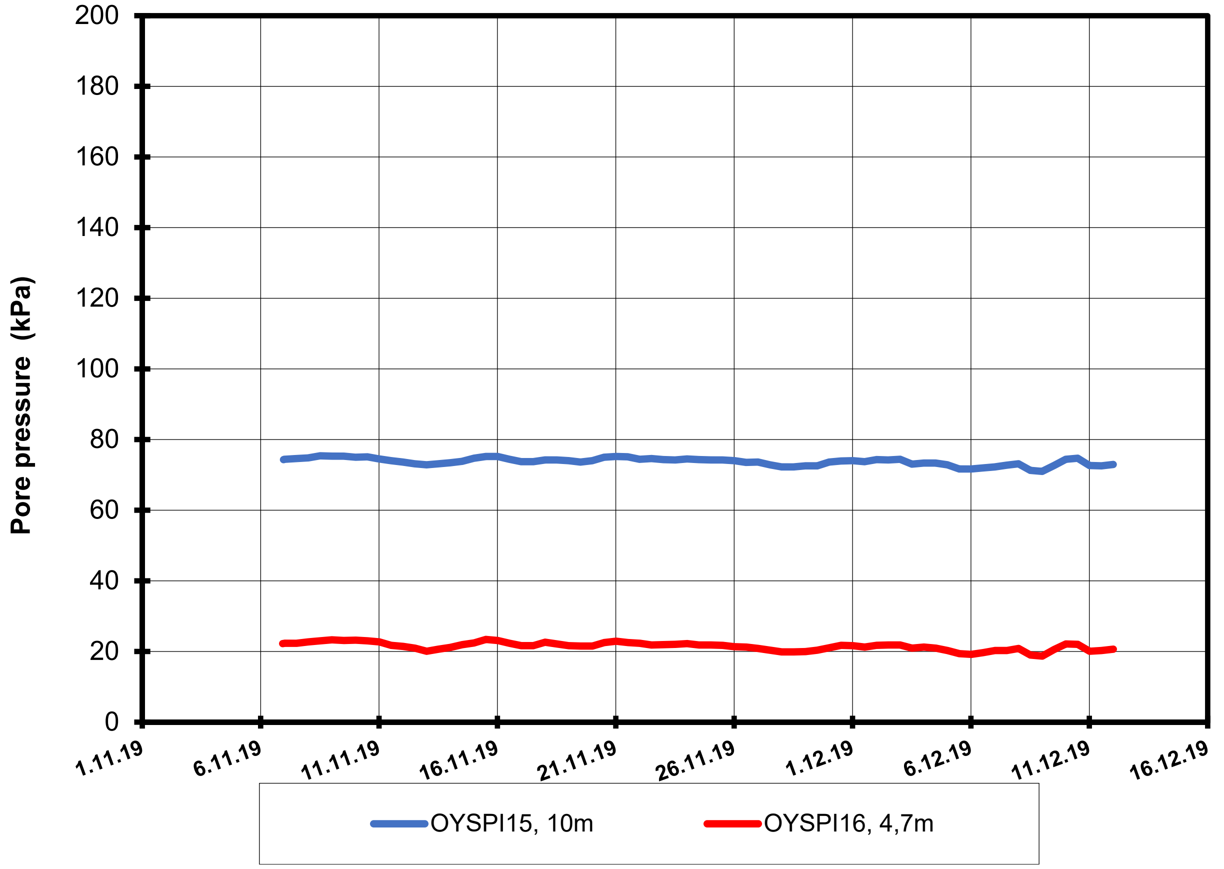
NGTS - Øysand Research Site	Report No. 20160154-08-R	Figure No. I2
Results from electric porepressure measurements Borehole: OYSPI06, OYSPI07, OYSPI08, OYSPI09, OYSPI10 Elevation: 3,3 moh Installation date: 2017-04-27	Drawn by Dry/APP	Date 08.01.2020
	Control JSL	NGTS
	Approval JSL	

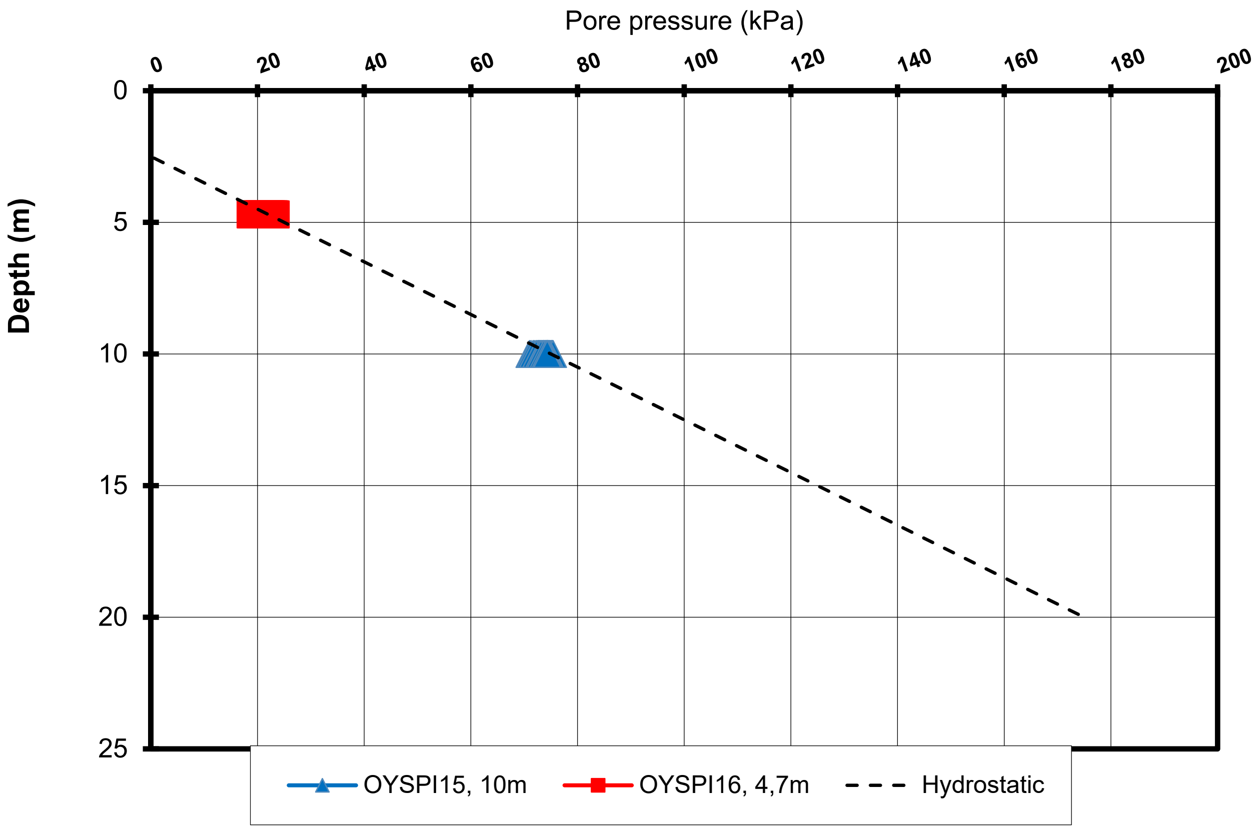




P:\2016\01\20160154\Fieldwork\Oysand\Piezo\OYSPI11-OYSPI12\[OYSPI11-OYSPI12.xlsx]Figur

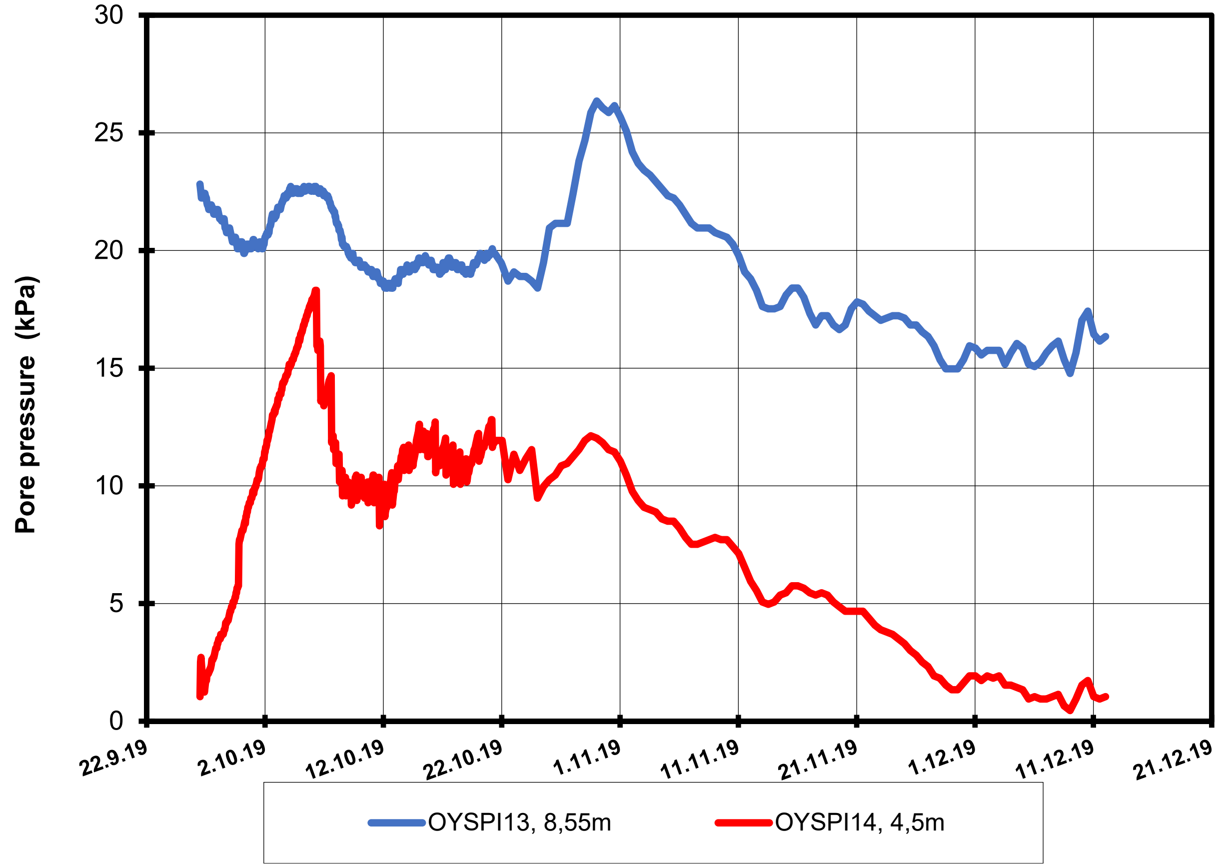
NGTS - Øysand Research Site	Report No. 20160154-08-R	Figure No. 3
Results from electric porepressure measurements Borehole: NGTS - Øysand Research Site Elevation: 2,7 moh Installation date: 2019-03-28	Drawn by APP	Date 08.01.2020
	Control JSL	NGTS
	Approval JSL	

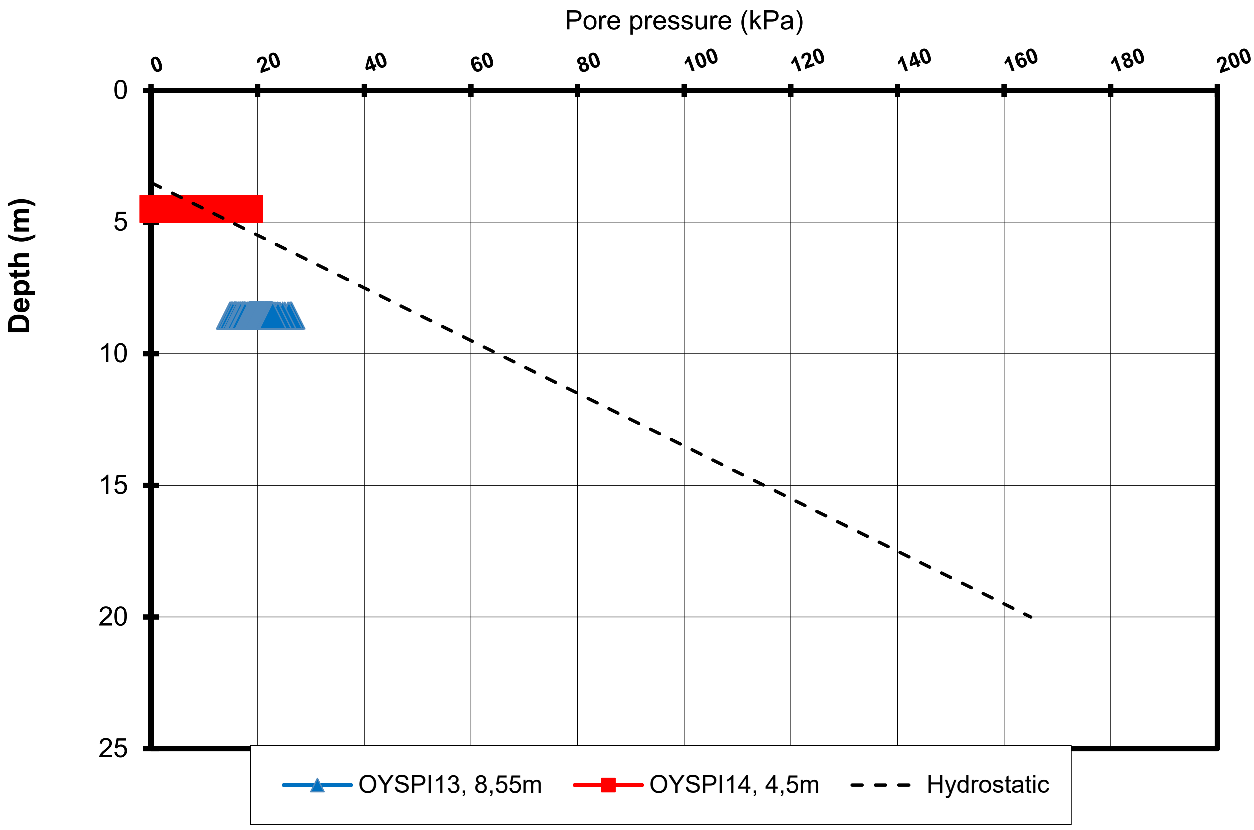




P:\2016\01\20160154\Fieldwork\Oysand\Piezo\OYSPI15-OYSPI16\[OYSPI15-OYSPI16.xlsx]Figur

NGTS - Øysand Research Site	Report No. 20160154-08-R	Figure No. 4
Results from electric porepressure measurements Borehole: OYSPI15, OYSPI16 Elevation: 3,0 moh Installation date: 2019-11-06	Drawn by APP	Date 09.01.2020
	Control JSL	
	Approval JSL	





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NGTS - Øysand Research Site	Report No. 20160154-08-R	Figure No. 5
Results from electric porepressure measurements Borehole: OYSPI13, OYSPI14 Elevation: 9,65-9,59 moh Installation date: 2019-09-26	Drawn by APP	Date 09.01.2020
	Control JSL	
	Approval JSL	

Appendix D

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY

Contents

D1 Methodology

Electrical Resistivity Tomography (ERT) is a near surface geophysical method that uses direct current to measure the earth's electrical resistivity. The current is injected into the subsurface through steel electrodes installed 10-20 cm into the ground, and the apparent resistivity distribution along a profile or area is measured. Using data processing and inverse modelling a two or three dimensional resistivity model of the subsurface can be derived.

A total of six profiles of ERT were performed on 10-11-12 April 2017. Three parallel profiles were carried out in the West North West - East South East (WWN-EES) direction and three parallel profiles were performed in the South West South - North East North (SSW-NNE) direction. Figure D1 shows a location plan with the start and end point of each resistivity profile. The official names are OYSER01 instead of E1 etc.

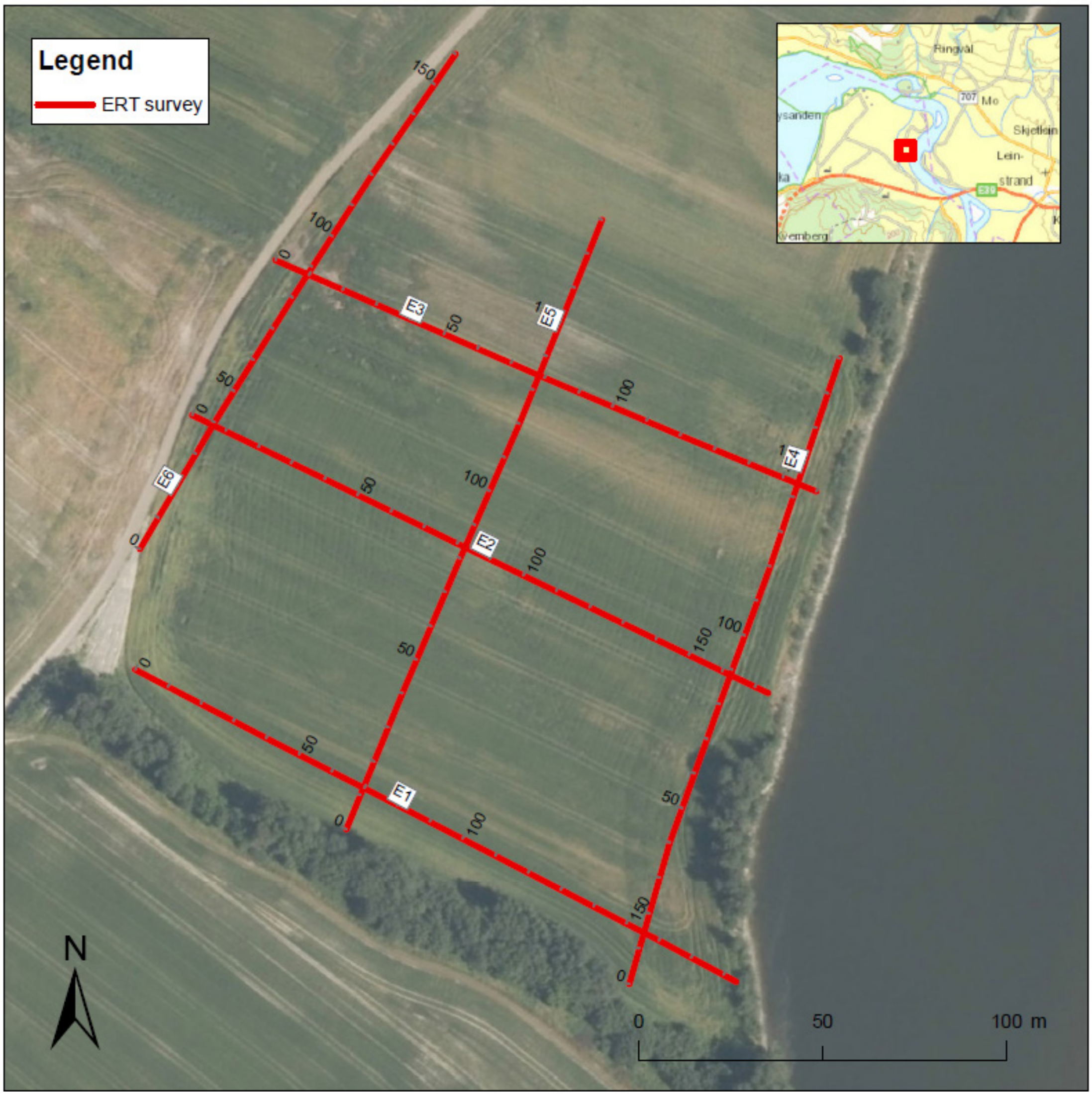


Figure D1 Overview map of the ERT survey

Acquisition

NGI uses a combined ERT and time domain induced polarization (IP) system, an ABEM Terrameter Lund System (www.guidelinegeo.com/abem-mala, 4 x 20 electrode cables, max array length 400m with 12-channel recording unit acquiring resistivity, IP windows and raw time series for advanced IP processing) (ABEM, 2016). It is robust, waterproof and designed for reliable operation in harsh environments. The multiple gradient array was chosen for the acquisition protocol, it has been designed for use in multichannel systems (Dahlin and Zhou, 2006) and is optimal for this instrument.

The electrode spacing is 2.0 m and the profile lengths range between 160 m and 184 m. In order to obtain position of the ERT profile, electrode positions were measured with a Differential Global Positioning System (DGPS) every 40 m. Table D1 presents the DGPS coordinates of start and end points of the resistivity profiles.

Table D1 Coordinates and elevation of start and end of survey lines. Projection: ETRS89 UTM32.

	East UTM32	North UTM32	Elevation
OYSER01 (E1) - 0m Start	562469,20	7022938,89	2,53
OYSER01 (E1) - 184m End	562639,67	7022869,67	3,08
OYSER02 (E2) - 0m Start	562478,13	7023009,27	2,84
OYSER02 (E2) - 174m End	562640,97	7022948,53	3,18
OYSER03 (E3) - 0m Start	562496,63	7023053,22	1,93
OYSER03 (E3) - 160m End	562648,91	7023004,37	2,13
OYSER04 (E4) - 0m Start	562610,67	7022866,30	2,65
OYSER04 (E4) – 180m End	562651,84	7023041,06	3,12
OYSER05 (E5) - 0m Start	562530,31	7022901,04	2,41
OYSER05 (E5) - 180m End	562584,00	7023072,56	2,68
OYSER06 (E6) - 0m Start	562467,36	7022971,54	1,88
OYSER06 (E6) - 160m End	562540,16	7023113,65	1,75

The acquisition was performed under heavy rain fall. Despite cautious handling, the instrument connectors got wet and it generated noisy voltage readings for one of the 12 channels. As a consequence the data quality weakened throughout the three acquisition days. Custom-made processing was then necessary to cull the noisy data points and retain enough data points for a successful resistivity inversion. We estimate that about 10 % of the resistivity data points were subsequently rejected. The quality of the IP data do not seem to be good enough to be of any use.

Processing
The raw data is inverted with software RES2DINV (RES2DINV, 2015) to obtain the model resistivity distribution. The following options are chosen for the inversion:

- import the topography data with UTM coordinates
- half unit cell spacing
- import the uncertainties on the voltage readings to weight the inversion process
- robust inversion (L2-norm) until iteration 7
- inspection of the residuals and rejection of outliers (~10 % of the data points)
- smooth inversion (L2-norm) using a flatness ratio filter of 0.5 until iteration 7
- the same colour and geometrical scales are used for the profiles
- there is no vertical exaggeration on the depth sections

D2 Results

All resistivity profiles are presented in Figures G2 to G7 with the same colour scale. The final RMS (root mean square of the misfit between the data and the models) is between 4.2% and 10.2%, which is considered good to fair.

On all profiles, the top 1-3 meters are marked by a resistive (ρ > 1000 Ωm) dry crust layer. This top layer thickens towards the NE. The layer below the dry crust shows resistivity values typical of silt and sand (64-512 Ωm). This layer does not seems to be uniform. Below 10-15 m depth, resistivities typical of clay (1-64 Ωm) are observed.

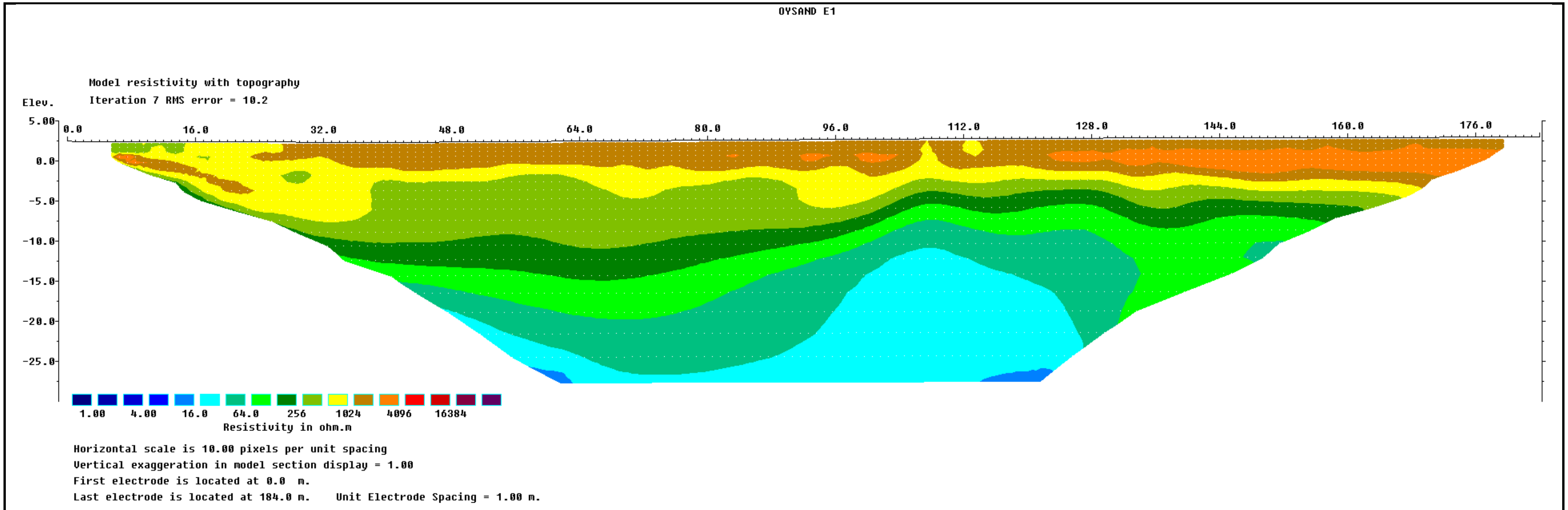
D3 References

[1] ABEM, 2016. Terrameter LS, User Manual, http://www.guidelinegeo.com/wp-content/uploads/2016/03/ABEM-Terrameter-LS-Toolbox-v2.0.1-User-Manual-1.pdf.

[2] Dahlin, T. and Zhou, B., 2006. Multiple gradient array measurements for multi-channel 2D resistivity imaging. Near Surface Geophysics, 4 (2), 213-123.

[3] RES2DINV, 2015. Geotomo Software. http://www.geoelectrical.com/, Window 7 Version 6.

[4] NGTS Report 03.



Norwegian GeoTest Sites- Øysand	Document no. 20160154-08-R	
ERT profile E1, from WWN to EES.	Figure no. G2	
	Date 2017-05-08	Drawn by SaB
	NGTS	

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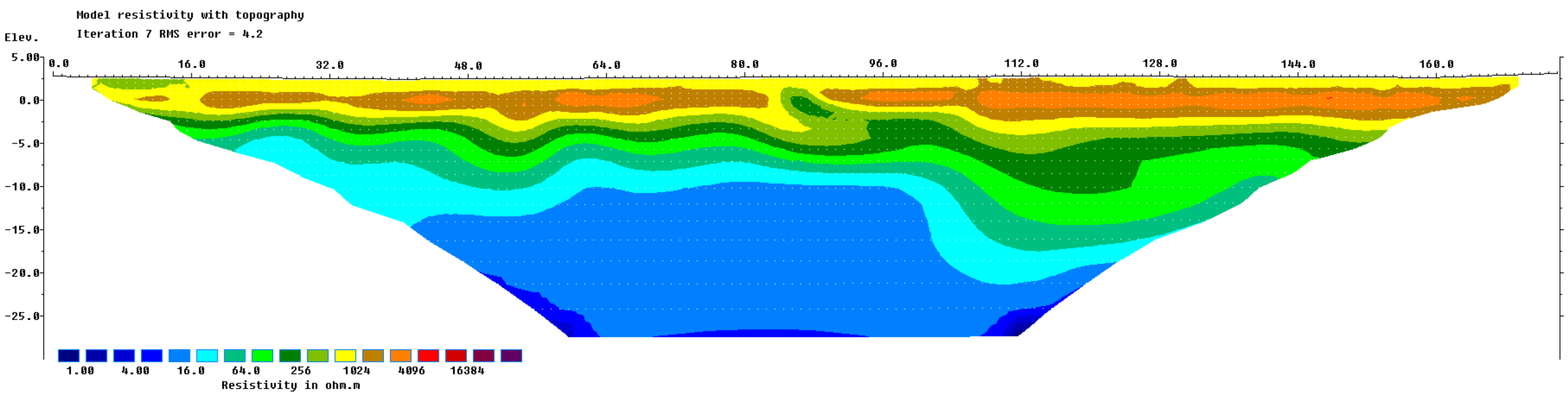
OYSAND E2



Horizontal scale is 10.00 pixels per unit spacing
Vertical exaggeration in model section display = 1.00
First electrode is located at 0.0 m.
Last electrode is located at 174.0 m. Unit Electrode Spacing = 1.00 m.

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Norwegian GeoTest Sites- Øysand	Document no. 20160154-08-R	
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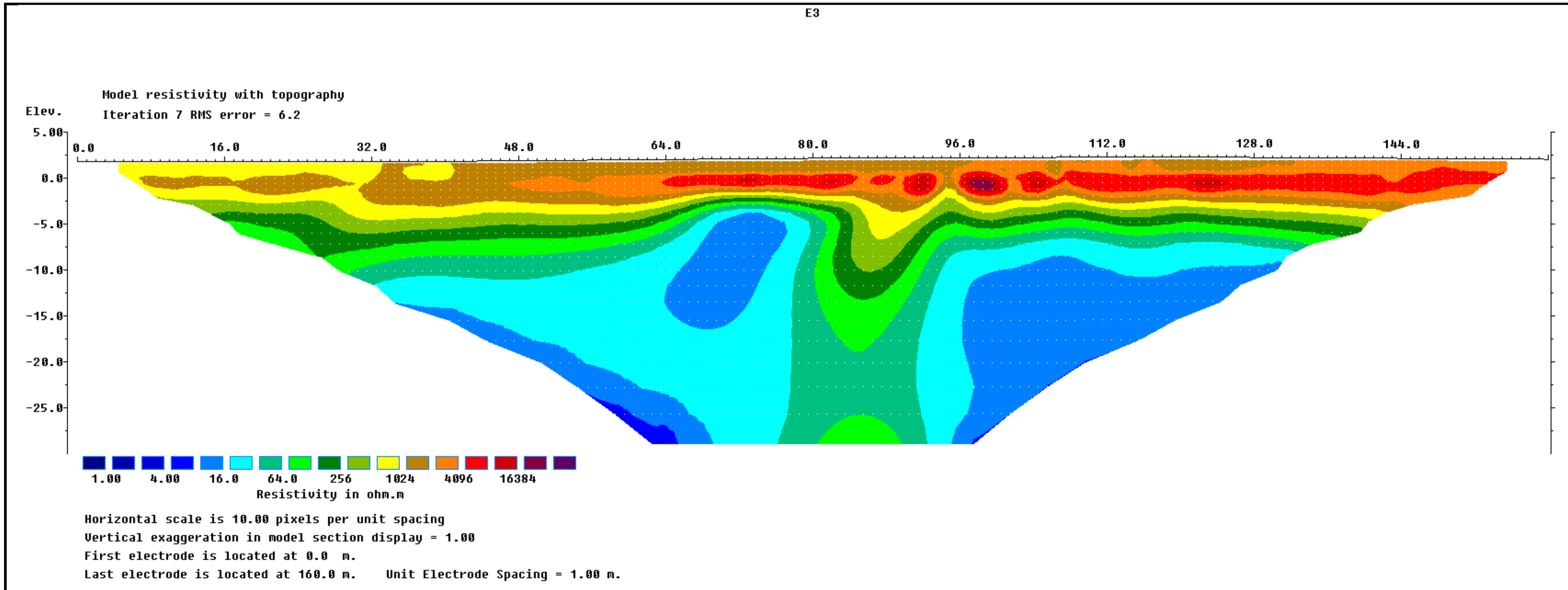
	Date 2017-05-08	Drawn by SaB
	NGTS	



Norwegian GeoTest Sites- Øysand	Document no. 20160154-08-R	
ERT profile E3, from WWN to EES.	Figure no. G4	
	Date 2017-05-08	Drawn by SaB
	NGTS	

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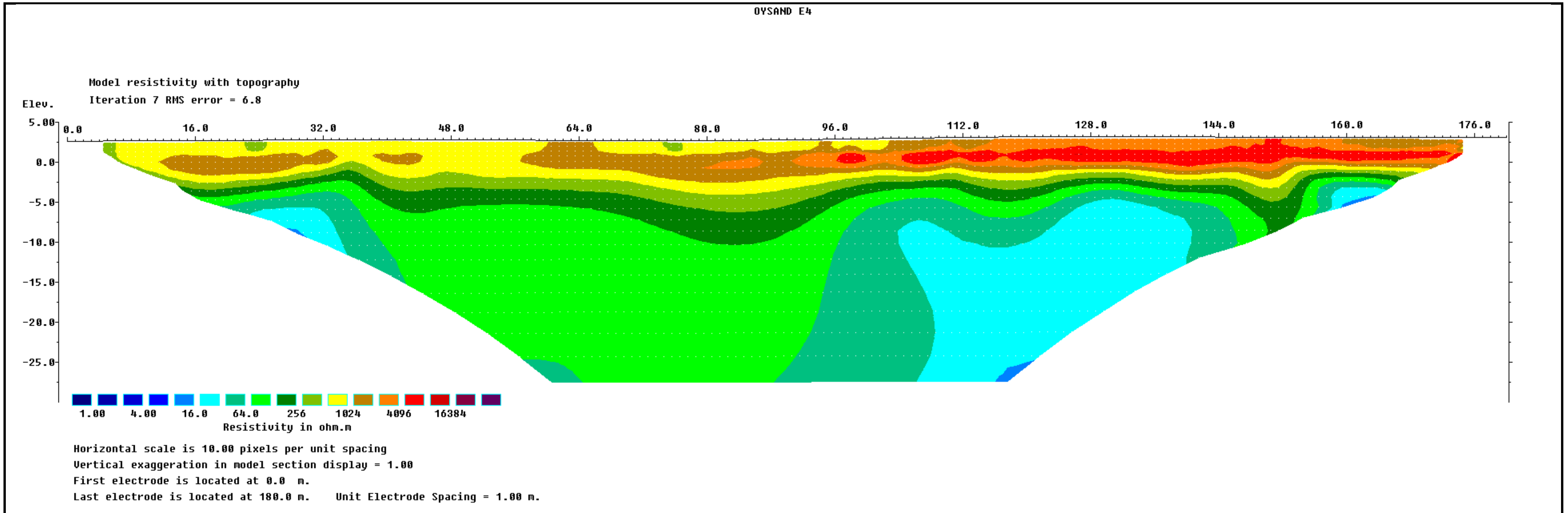

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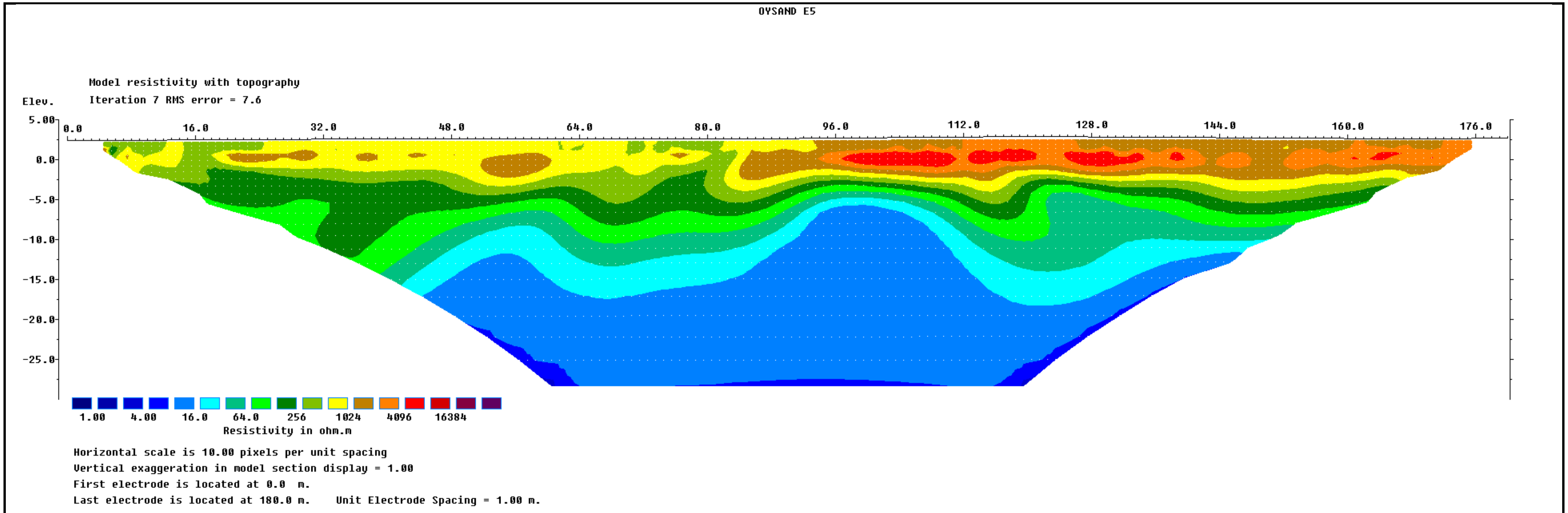
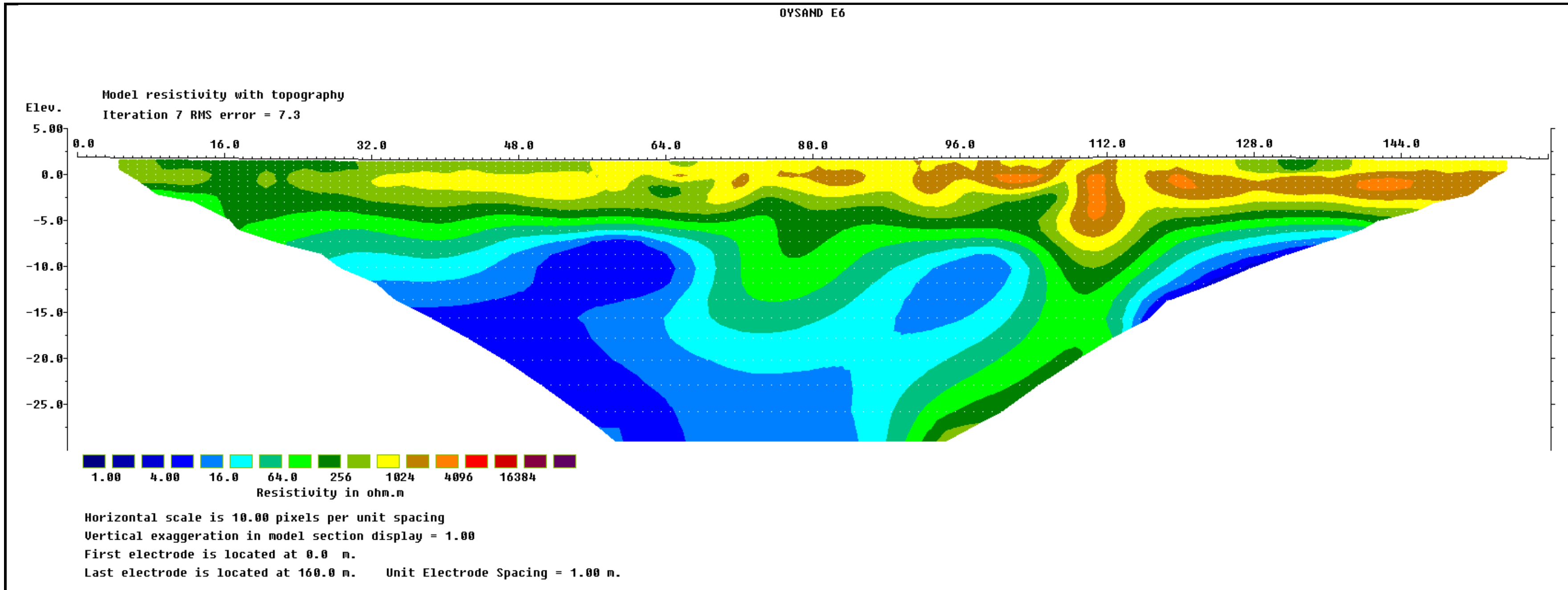
Norwegian GeoTest Sites - Øysand	Document no. 20160154-08-R	
ERT profile E4, from SSW-NNE.	Figure no. G5	
	Date 2017-05-08	Drawn by SaB
	NGTS	



Norwegian GeoTest Sites- Øysand	Document no. 20160154-08-R
ERT profile E5, from SSW-NNE.	Figure no. G6
	Date 2017-05-08 / Drawn by SaB
	NGTS



Norwegian GeoTest Sites- Øysand	Document no. 20160154-08-R
ERT profile E6, from SSW-NNE.	Figure no. G7
	Date 2017-05-08 / Drawn by SaB
	NGTS

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Appendix E

GROUND PENETRATING RADAR SURVEY

Contents

E1 Methodology

Ground Penetrating Radar (GPR) uses electromagnetic waves reflected on discontinuities (dielectric contrasts) after emission from radar antennas positioned along the earth's surface. These discontinuities correspond to changes of electromagnetic impedance $\eta = \mu c$ where μ is the magnetic permeability and $c = (1/\varepsilon\mu)^{1/2}$ is the velocity of electromagnetic waves, ε being the electric permittivity. The electromagnetic wave velocity c decreases in general with depth. As in seismic, the higher the frequency, the better the resolution, but the lower is the penetration depth. In addition, the penetration capacity is better in resistive materials (granite, dry sand, ice, etc.) than in conductive layers (clay, saturated soils, etc.).

Acquisition
NGI has developed a step-frequency radar instrument operating continuously over the frequency range from 10-210 MHz. The data from step-frequency systems is very different from conventional pulsed radar systems: the information is recorded in frequency domain with a real and imaginary part. Therefore the raw data must be converted to time domain. Both the emitting and receiving antennas were moved keeping a fixed distance (offset of 1.5m) between them.

A total of six profiles of GPR were performed on 10-11-12 April 2017. Three parallel profiles were carried out in the West North West - East South East (WWN-EES) direction and three parallel profiles were performed in the South West South - North East North (SSW-NNE) direction. Figure E1 shows a location plan with the GPR profiles. The official NGTS names are OYSG01 instead of G1 etc., as given in Table E1.

The profile lengths range between 140 m and 180 m. Profiles end-points were measured with a Differential Global Positioning System (DGPS). The distance along the GPR profiles was set by assuming a constant speed of walk during the acquisition. We did not include any elevation information in the header as the profiles are also assumed flat. Table H1 presents the DGPS coordinates of start and end points of the GPR profiles. The GPR profiles are aligned with the ERT profiles but OYSG01 (G1), OYSG02 (G2), and OYSG06 (G6) are slightly shorter than the ERT profiles.

Table E1 Coordinates of start and end of survey lines. Projection given in ETRS89 UTM32.

	East UTM32	**North UTM32**
OYSG01 (G1) - 0m Start	562469,20	7022938,89
OYSG01 (G1) - 180m End	562635,99	7022871,2
OYSG02 (G2) - 0m Start	562478,13	7023009,27
OYSG02 (G2) - 161m End	562628,82	7022953,0
OYSG03 (G3) - 0m Start	562496,63	7023053,22
OYSG03 (G3) - 160m End	562648,91	7023004,37
OYSG04 (G4) - 0m Start	562610,67	7022866,30
OYSG04 (G4) – 180m End	562651,84	7023041,06
OYSG05 (G5) - 0m Start	562530,31	7022901,04
OYSG05 (G5) - 180m End	562584,00	7023072,56
OYSG06 (G6) - 0m Start	562467,36	7022971,54
OYSG06 (G6) - 140m End	562530,43	7023096,29

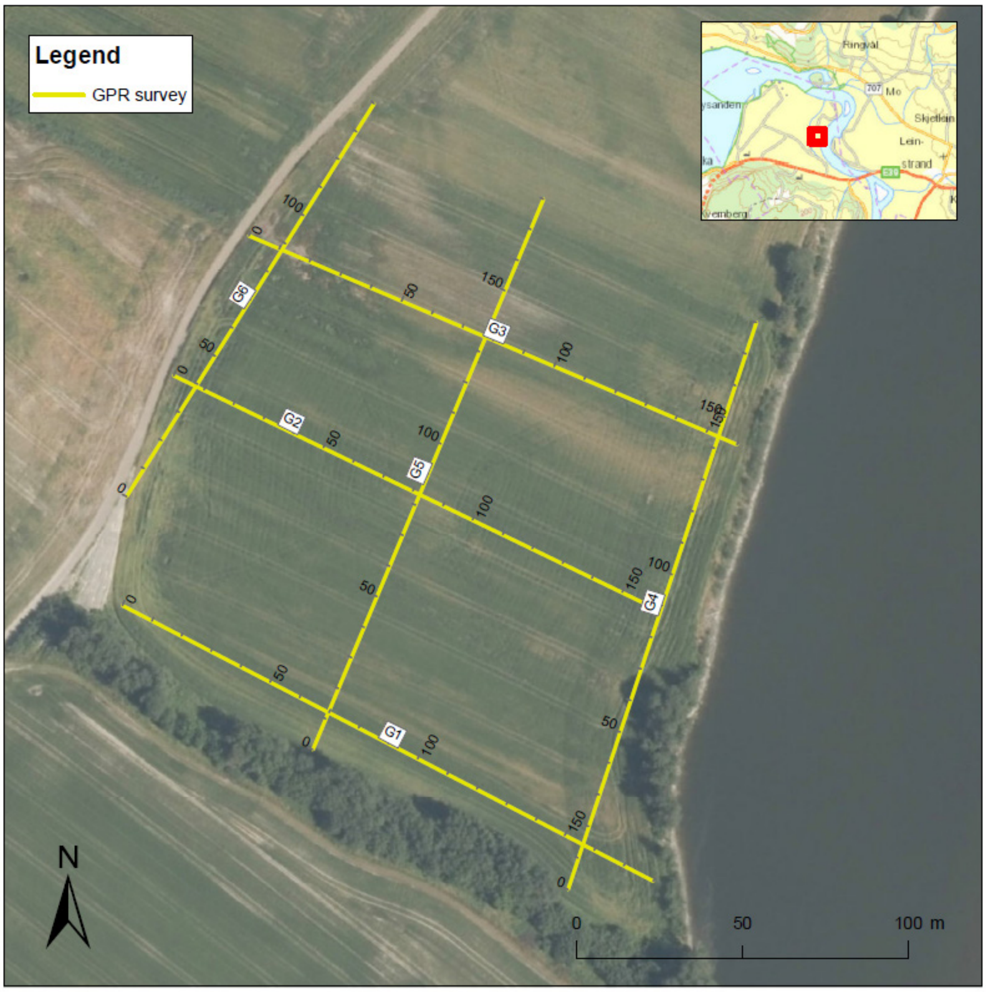

Figure E1 Overview map of the GPR survey

Processing

The time-domain data is processed with software Reflexw (www.sandmeier-geo.de/reflexw.html). We have applied a conventional processing flow in the *2D-dataanalysis* work package:

- *Remove:* remove unnecessary traces at the start and/or end of the profiles
- Set the trace coordinates in the *header* using the coordinated of the end-points and a *constant offset* between traces.
- *StaticCorrection/Move startime*: to adjust the zero time
- *1D-Filter/Dewow*: temporal filtering to remove very-low-frequency components (select a certain time window to calculate the mean, typically about one principal cycle – 8.6 ns)
- *Gain/Div. compensation* with **sqrt(t)* option
- *Mute:* cut the data after 210 ns to remove the multiple
- *2D-Filter/Background removal*

- Build a velocity model using diffraction hyperbolas. We obtained a fair fit with 0.13m/ns on a few hyperbolas.
- *Migration/Time-depth conversion/timedepth conversion:* convert to depth using the velocity picked with hyperbolas
- *Arithmetic Functions/Multiplication:* multiply the amplitude by a scalar (for example 1000) so that the profile can be plotted with a *plotscale* of 1 (necessary for the 3D visualization)
- We can use the option *pick/phase follower* to highlight the different layers

We can visualize the 6 profiles in a cube using the *3D-datainterpretation* work package:

- *Generate 3D-file from 2D-lines* with the option *use interpolation scheme for freely distributed 2D-lines*

E2 Results

All radargrams are presented in Figures E2 to E7 with the same 2D processing flow. They are migrated with a velocity of 0.13m/ns. It is worth mentioning that this velocity is a rough estimation and it would be possible to readjust it if one could calibrate the radargrams with the known depth of the certain layer.

For the time being, a preliminary interpretation can be derived for these profiles. The reflections show a layer of thin sediments above coarser sediments (gravel). The thickness of the thin top sediments is not uniform (0.5 to 2 m). The coarser layers seem to intersect each other. They appear coarser (rougher reflections and higher amplitudes) towards the river. This pattern is typical of braided rivers and fluvial deposit (Figure E8).

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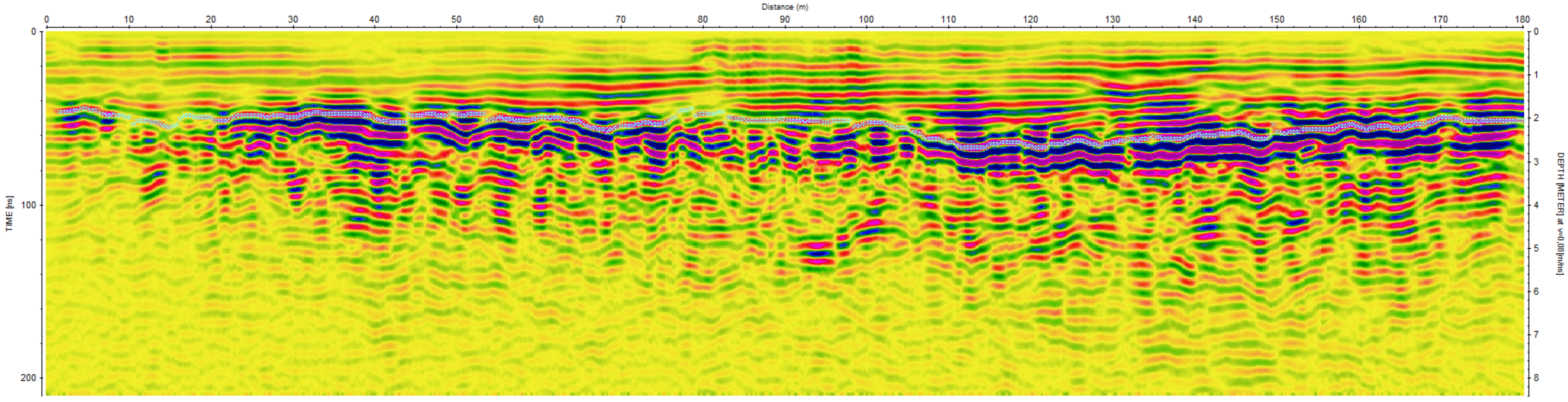

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Norwegian GeoTest Sites - Øysand	Document no. 20160154-08-R	
GPR profile OYSG01 (G1), from WWN to EES.	Figure no. E2	
	Date 2017-05-08	Drawn by SaB
	NGTS	

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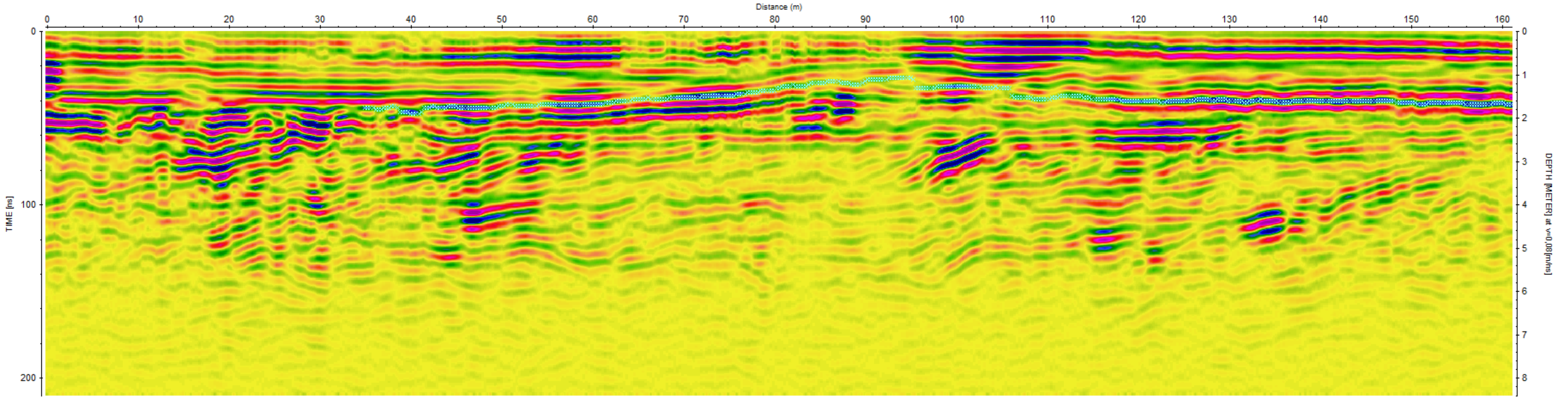

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Norwegian GeoTest Sites - Øysand	Document no. 20160154-08-R	
GPR profile OYSG02 (G2), from WWN to EES.	Figure no. E3	
	Date 2017-05-08	Drawn by SaB
	NGTS	

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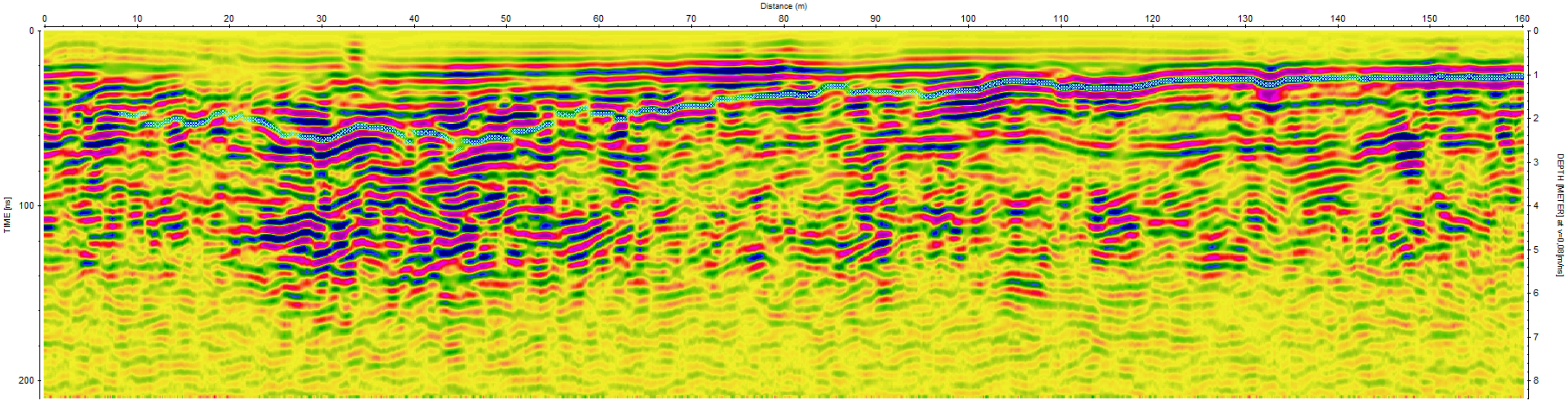

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Norwegian GeoTest Sites - Øysand	Document no. 20160154-08-R	
GPR profile OYSG03 (G3) from WWN to EES.	Figure no. E4	
	Date 2017-05-08	Drawn by SaB
	NGTS	

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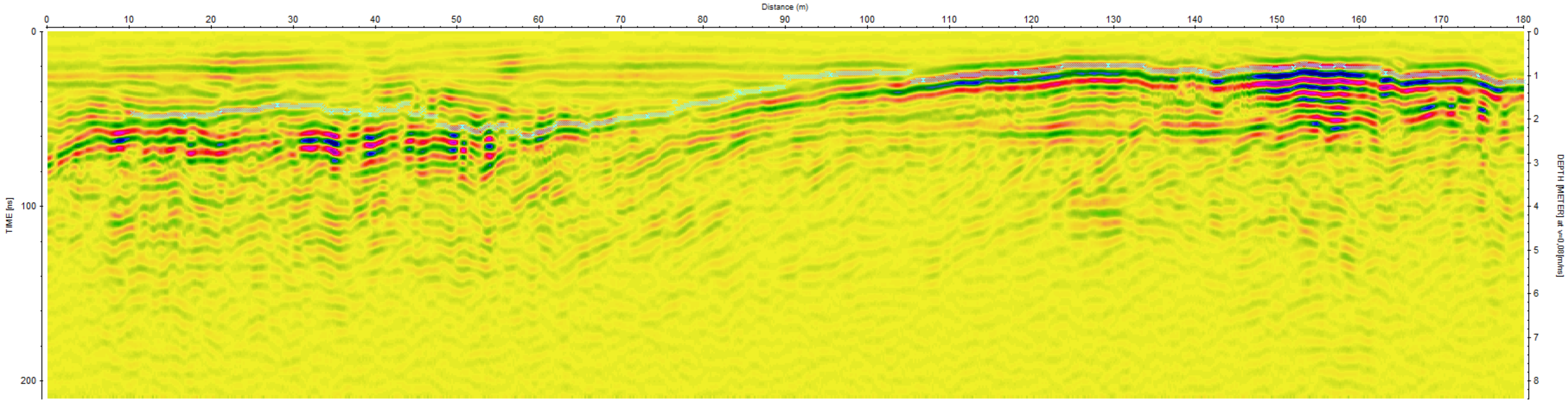

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Norwegian GeoTest Sites - Øysand	Document no. 20160154-08-R
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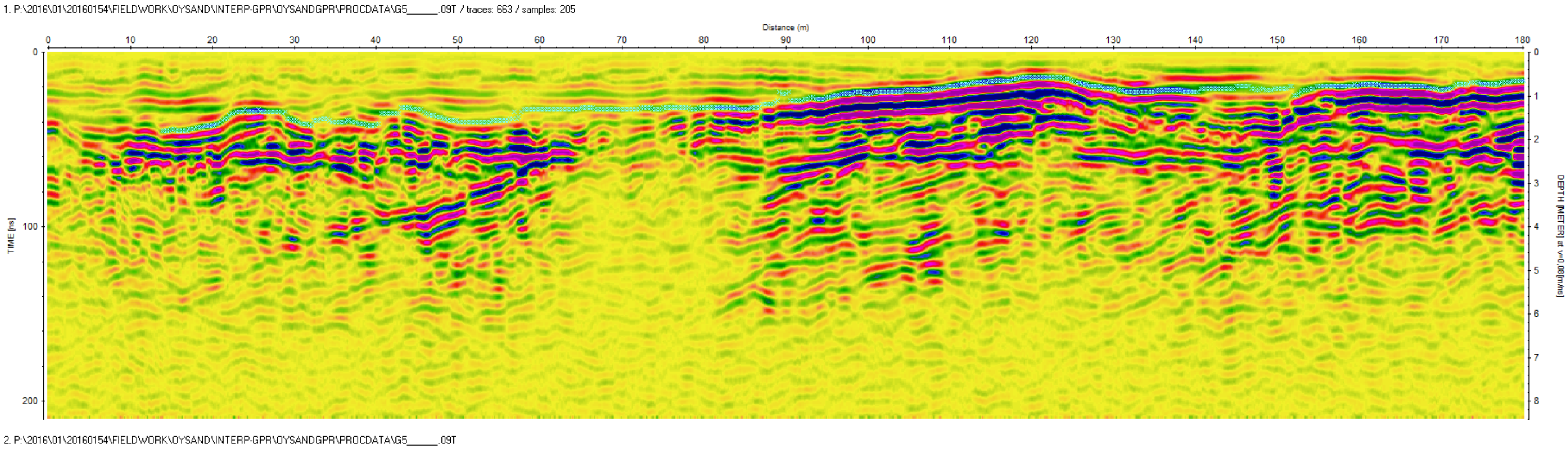
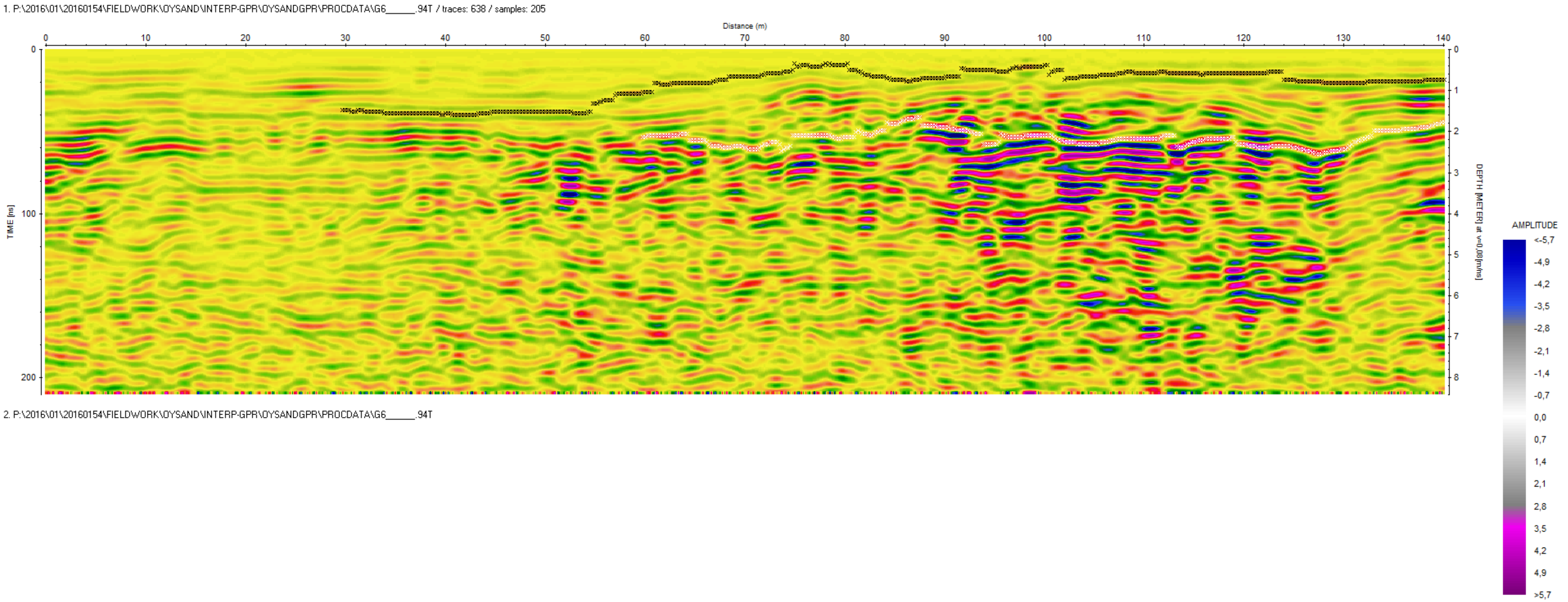
	Date: 2017-05-08 / Drawn by: SaB



Norwegian GeoTest Sites - Øysand	Document no. 20160154-08-R	
GPR profile OYSG05 (G5) from SSW-NNE.	Figure no. E6	
	Date 2017-05-08	Drawn by SaB
	NGTS	



Norwegian GeoTest Sites - Øysand	Document no. 20160154-08-R	
GPR profile OYSG06 (G6) from SSW-NNE.	Figure no. E7	
	Date 2017-05-08	Drawn by SaB
	NGTS	

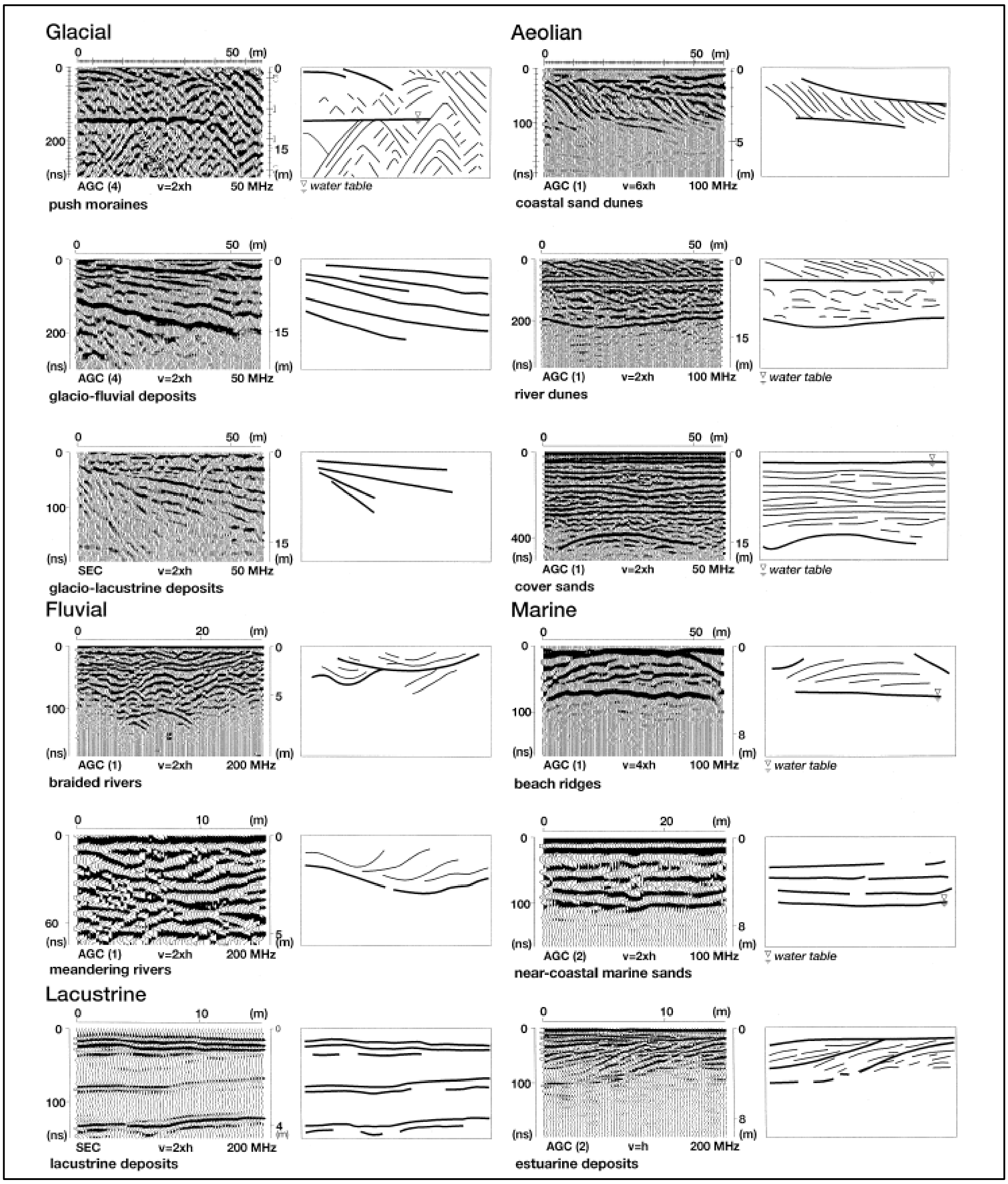


Figure E8 Characteristic reflection patterns from various sedimentary environments (from: Overmeeren, 1998).

The six radargrams are visualized in a 3D cube in Figure E9. We observe a good correlation at the intersection points.

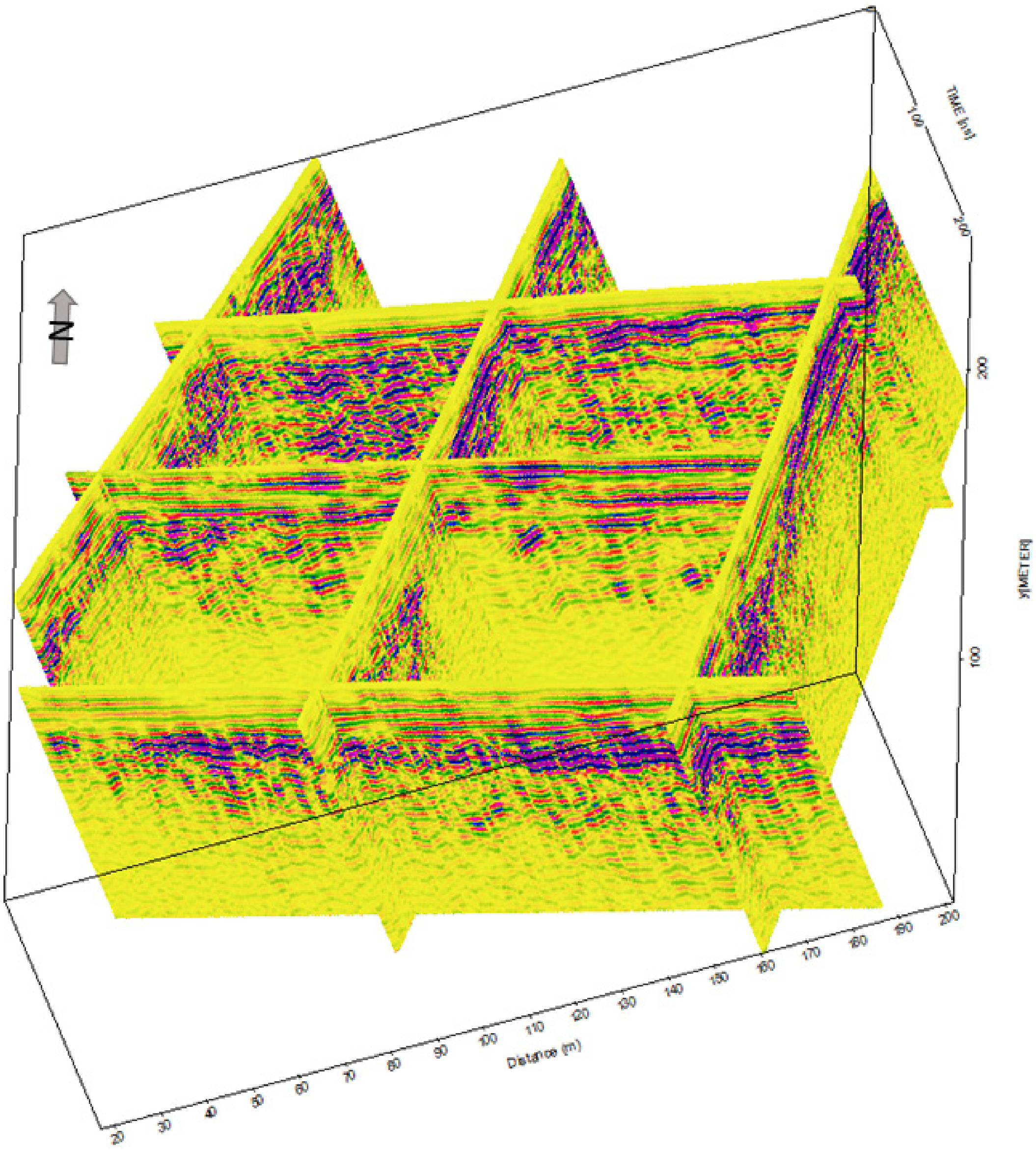


Figure E9: 3D visualisation of the GPR survey.

E3 References

Norsk geoteknisk forening. (n.d.). *Melding nr. 9. Veiledning for utførelse av totalsondering.*

Appendix F

MULTICHANNEL ANALYSIS OF SURFACE WAVES
& SEISMIC REFRACTION PROFILING

Contents

F1 Methodology

The Multi-channel Analysis of Surface Waves (MASW) (Park et al., 1998, 1999) utilizes Surface waves (Rayleigh waves) to determine the elastic properties of the shallow subsurface. Surface waves carry up to two/thirds of the seismic energy, but are usually considered as noise in conventional body wave reflection and refraction seismic surveys.

Seismic refraction profiling (SRP) measures the velocity of refracted seismic waves (P-waves) through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities. Readings are taken using geophones connected via multi-core cable to a seismograph.

F2 Results

Results are documented in the report by APEX geoservices below, dated 10th of November 2016.

F3 References

[E1] NGTS Report 03

AGL16239A_01

REPORT ON THE GEOPHYSICAL SURVEY AT OYSAND, NORWAY FOR THE NORWEGIAN GEOTECHNICAL INSTITUTE

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10TH NOVEMBER 2016

PRIVATE AND CONFIDENTIAL

THE FINDINGS OF THIS REPORT ARE THE RESULT OF A GEOPHYSICAL SURVEY USING NON-INVASIVE SURVEY TECHNIQUES CARRIED OUT AT THE GROUND SURFACE. INTERPRETATIONS CONTAINED IN THIS REPORT ARE DERIVED FROM A KNOWLEDGE OF THE GROUND CONDITIONS, THE GEOPHYSICAL RESPONSES OF GROUND MATERIALS AND THE EXPERIENCE OF THE AUTHOR. APEX GEOSERVICES LTD. HAS PREPARED THIS REPORT IN LINE WITH BEST CURRENT PRACTICE AND WITH ALL REASONABLE SKILL, CARE AND DILIGENCE IN CONSIDERATION OF THE LIMITS IMPOSED BY THE SURVEY TECHNIQUES USED AND THE RESOURCES DEVOTED TO IT BY AGREEMENT WITH THE CLIENT. THE INTERPRETATIVE BASIS OF THE CONCLUSIONS CONTAINED IN THIS REPORT SHOULD BE TAKEN INTO ACCOUNT IN ANY FUTURE USE OF THIS REPORT.

PROJECT NUMBER	AGL16239A		
AUTHOR	**CHECKED**	**REPORT STATUS**	**DATE**
EURGEOL SHANE O`ROURKE P.GEO., M.SC (GEOPHYSICS)	TONY LOMBARD M.SC (GEOPHYSICS)	V.01	10TH NOVEMBER 2016

CONTENTS

1. EXECUTIVE SUMMARY

APEX Geoservices Limited was requested by the Norwegian Geotechnical Institute to acquire S-wave and P-wave velocities at the Oysand test site, Norway.

The objectives of the investigation were to provide S-wave (shear-wave) and P-wave velocities at the locations specified by the client.

The investigation consisted of MASW Profiling (Multichannel Analysis of Surface Waves) and Seismic Refraction Profiling.

The shear wave velocities ranged from 150-217 m/s (average of 187 m/s) from 1.6-20.9m bgl.

The P-wave wave velocities ranged from 203-1894 m/s from 0-31m bgl.

2. INTRODUCTION

APEX Geoservices Limited was requested by the Norwegian Geotechnical Institute to acquire S-wave and P-wave velocities at the Oysand test site, Norway.

2.1 Survey Objectives

The objectives of the survey were to:

1. To provide S-wave values at the locations specified by the client.

2. To provide P-wave values at the locations specified by the client.

2.2 Site Background

The Oysand test site is located 15km south-west of Trondheim, Norway, at the estuary of the Guala River.

Apex Geoservices Ltd. carried out a series of 1D MASW (Multichannel Analysis of Surface Waves) and Seismic Refraction Profiles in the area to provide S-wave and P-wave values as part of the ongoing research.

The survey was carried out under the direction of the client, NGI, at two locations c.400m apart, denoted Area 1 and Area 2.

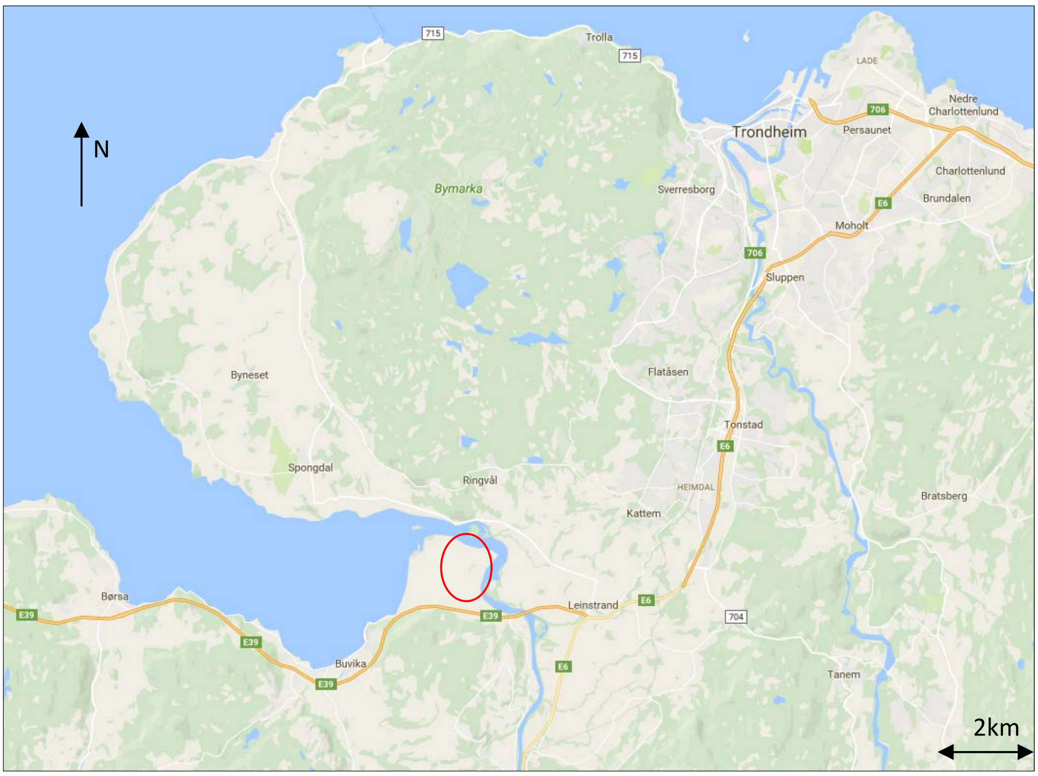


Fig.2.1. Oysand site Location (shown in red).

2.2.1 Topography

The topography for the survey area is generally flat, with elevation ranging from 3-10 mOD. The survey was carried out upon crop fields (Figs.2.2 and 2.3).

Fig.2.2. Area 1 survey location, for Profiles M1, S1 and S2.

Fig.2.3 Area 2 survey location, for Profiles M3, S3 and S4.

2.2.2 Bedrock & Sediments

Bedrock in the area is thought to be at a depth of c.90m bgl. The 1:250000 Sediments map (http://www.ngu.no/en/topic/datasets) for the area (Fig.2.4) describes the area as covered in fluvial deposition.

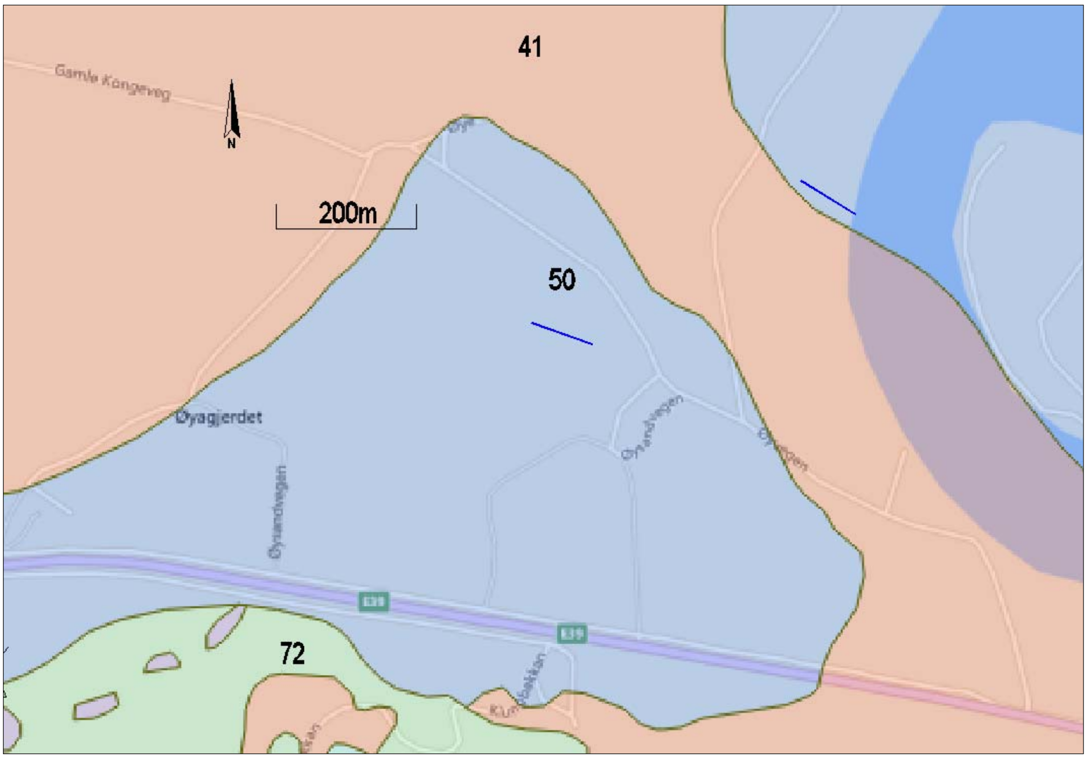


Fig.2.4. Sediments map for the survey area. Blue lines indicate 92m P-wave profiles.
41 = Hav-og fjordavsetning, sammenhengende dekke, ofte med stor mektighet.
50 = Elve- og bekkeavsetning (Fluvial avsetning).
72 = Forvitringsmateriale, usammenhengende eller tynt dekke over berggrunnen.

2.2.3 Site Investigation

A seismic dialatometer test (SDMT-2) at the location of Area 2 to the north-east showed shear wave velocities from 155-194 m/s from 6.5-17.0m bgl.

2.3 Survey Rationale

The **MASW** method is used to estimate shear-wave (S-wave) velocities in the ground material to indicate possible soft zones. Overburden material with an S-wave velocity of <175 m/s is generally classified as soft. The depth of investigation for this method will depend on the source type and geophone spacing. In this survey an effective depth of investigation of 2-20m bgl was achieved.

Seismic Refraction Profiling measures the velocity of refracted seismic waves (P-waves) through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities. Readings are taken using geophones connected via multi-core cable to a seismograph.

3. RESULTS & INTERPRETATION

Four seismic spreads (Profiles S1-S4) were recorded at Areas 1 and 2 (Drawing AGL16239A_01). Profiles S1 and S3 were 69m in length with a 3m geophone spacing and S2 and S4 were 92m in length with a 4m geophone spacing. Profiles S1 and S2 were centred at the location of the borehole and were recorded in Area 1. Profiles 3 and S4 were centred at the location of the borehole and recorded in Area 2. Passive MASW data was recorded for Profiles S2 and S4, however this did not yield any useable results.

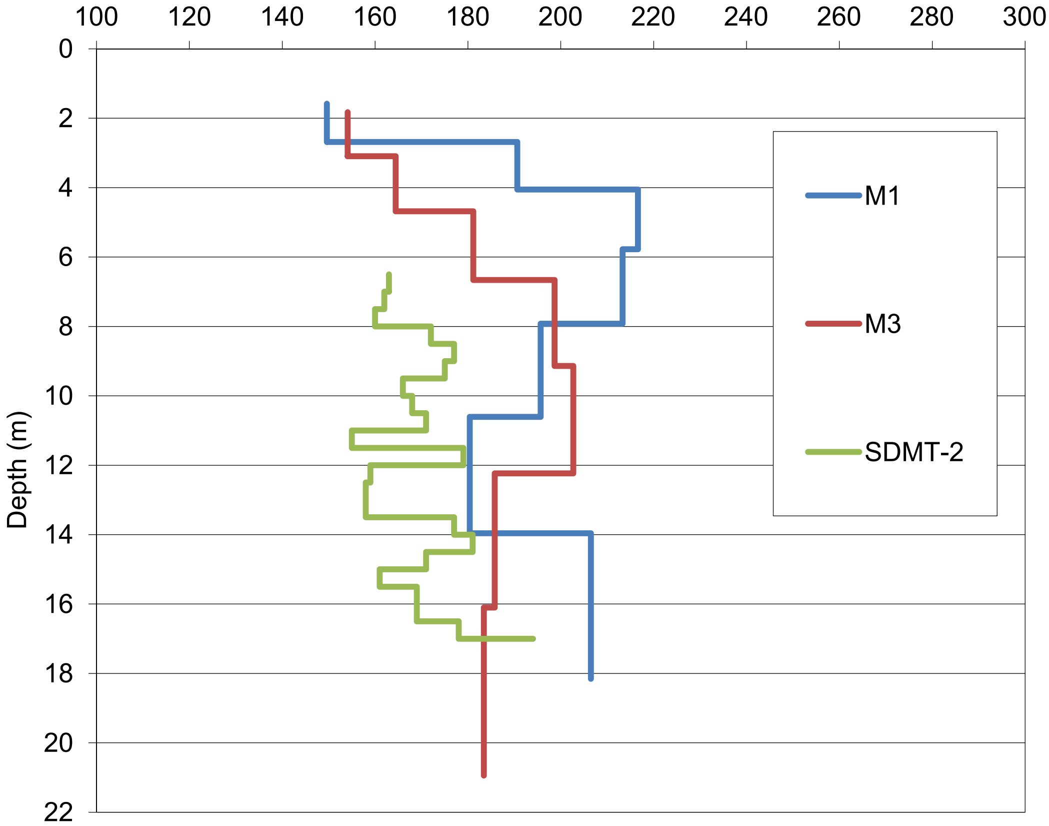
3.2 MASW Results

MASW processing was carried out on each of the Profiles S1-S4, with the most coherent dispersion curves selected for inversion. The resulting shear-wave velocity profiles (Vs) are denoted M1 for Area 1 and M3 for Area 2.

Fig. 3.1 depicts the Vs (shear-wave velocity) results. The individual Vs results for these profiles are shown in Appendix C.

Shear wave velocities ranged from 150-217 m/s (average of 187 m/s) from 1.6-20.9m bgl.

Fig.3.1 Shear wave Velocity, Vs (m/s)



3.2 Seismic Refraction Profiling

Profiles S2 (Area 1) and S4 (Area 2) were selected for P-wave processing with the following results (Appendix C).

The seismic data has outlined four velocity layers and has been generally interpreted on the following basis:

Layer	Seismic Velocity (m/s)	Average Seismic Velocity (m/s)	Thickness (m)	Interpretation	Stiffness/Rock Quality
1	203-288	253	1.0-1.6	Overburden	Soft/Loose
2	450-762	536	0.8-4.2	Overburden	Soft-Firm/Loose-Medium Dense
3	677-1018	910	0.4-6.9	Overburden	Firm/ Medium Dense
4	1622-1894	1775		Overburden	Stiff – very stiff / Dense – very dense

Layer 1 with a velocity of 203-288 m/s has been interpreted as soft/loose overburden which is 1.0-1.6m thick.

Layer 2 with a velocity of 450-762 m/s has been interpreted as soft-firm/loose-medium dense overburden which is 0.8-4.2m thick.

Layer 3 with a velocity of 677-1018 m/s has been interpreted as firm/medium dense overburden which is 0.4-6.9m thick.

Layer 4 with a velocity of 1622-1894 m/s has been interpreted as stiff-very stiff/dense-very dense overburden.

The overall depth of investigation of Profiles S2 and S4 is estimated at 31m bgl.

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5. APPENDIX A: DETAILED METHODOLOGY

5.1 MASW

5.1.1 Principles

The Multi-channel Analysis of Surface Waves (MASW) (Park et al., 1998, 1999) utilizes Surface waves (Rayleigh waves) to determine the elastic properties of the shallow subsurface. Surface waves carry up to two/thirds of the seismic energy but are usually considered as noise in conventional body wave reflection and refraction seismic surveys.

The penetration depth of surface waves changes with wavelength, i.e. longer wavelengths penetrate deeper. When the elastic properties of near surface materials vary with depth, surface waves then become dispersive, i.e. propagation velocity changes with frequency. The propagation (or phase) velocity is determined by the average elastic property of the medium within the penetration depth. Therefore the dispersive nature of surface waves may be used to investigate changes in elastic properties of the shallow subsurface.

The MASW method employs the multi-channel recording and processing techniques (Sheriff and Geldart, 1982) that have similarities to those used in a seismic reflection survey and which allow better waveform analysis and noise elimination. To produce a shear wave velocity (Vs) profile and a stiffness profile of the subsurface using Surface waves the following basic procedure is followed:

(i) A point source (eg. a sledgehammer) is used to generate vertical ground motions,

(ii) The ground motions are measured using low frequency geophones, which are disposed along a straight line directed toward the source,

(iii) the ground motions are recorded using either a conventional seismograph, oscilloscope or spectrum analyzer,

(iv) a dispersion curve is produced from a spectral analysis of the data showing the variation of surface wave velocity with wavelength,

(v) the dispersion curve in inverted using a modeling and least squares minimization process to produce a subsurface profile of the variation of Surface wave and shear wave velocity with depth,

(vi) a stiffness-depth profile (shear modulus, G) can be derived from elastic theory.

5.1.2 Data Collection

The recording equipment consisted of a Geode 24 channel digital seismograph, 24 no. 4.5hz vertical geophones and a 24 take-out cable, with a 3-4m geophone spacing. Fieldwork was carried out on the 20th October 2016. Weather conditions were generally good. Overall data quality was good.

1D MASW Profiles with a 3m and 4m geophone spacing were acquired in both areas. The data was acquired in both Active and Passive mode. In Active mode, the equipment comprised a 10kg hammer energy source with mounted trigger, with shots taken at various offsets at either end of each spread, with 2 sec. long records and a 0.25ms sample rate. A total of sixty active shots were taken at in each area.

In Passive mode, twenty 16 sec. records were recorded with a 1 sec. sample rate.

5.1.3 Data Processing

MASW processing was carried out using the SURFSEIS processing package developed by Kansas Geological Survey (KGS, 2000). SURFSEIS is designed to generate a shear wave (Vs) velocity profile.

SURFSEIS data processing involves three steps:

(i) Preparation of the acquired multichannel record. This involves converting the data file into the processing format.

(ii) Production of a dispersion curve from a spectral analysis of the data showing the variation of Raleigh wave phase velocity with wavelength. Confidence in the dispersion curve can be estimated through a measure of signal to noise ratio (S/N) which is obtained from a coherency analysis. Noise includes both body waves and higher mode surface waves. To obtain an accurate dispersion curve the spectral content and phase velocity characteristics are examined through an overtone analysis of the data.

(iii) Inversion of the dispersion curve is then carried out to produce a subsurface profile of the variation of shear wave velocity with depth.

5.1.4 Relocation

All data was referenced by the client using a Garmin GPS system with c.2m accuracy.

5.2 Seismic Refraction Profiling

5.2.1 Principles

The seismic refraction profiling method measures the velocity of refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities. Readings are taken using geophones connected via multi-core cable to a seismograph.

5.2.2 Data Collection

Two P-wave seismic spreads were recorded on the 20th October 2016 using a Geode high-resolution 24 channel digital seismograph with geophone spacings of 3 and 4m. The source of the seismic waves was a sledgehammer.

5.2.3 Data Processing

The recorded data was interpreted using the ray-tracing and intercept time methods, to acquire depths to layer boundaries and the P-wave velocities of these layers, using the FIRSTPIX and GREMIX programs.

GREMIX interprets seismic refraction data as a laterally varying layered earth structure. It incorporates the slope-intercept method, parts of the Plus-Minus Method of Hagedoorn (1959), Time-Delay Method, and features the Generalized Reciprocal Method (GRM) of Palmer (1980). Up to four layers can be mapped, one deduced from direct arrivals and three deduced from refractions. Phantoming of all possible travel time pairs can be carried out by adjusting reciprocal times of off shots.

5.2.4 Relocation

All data was referenced by the client using a Garmin GPS system with c.2m accuracy.

6. APPENDIX B: MASW RESULTS (S-WAVE)

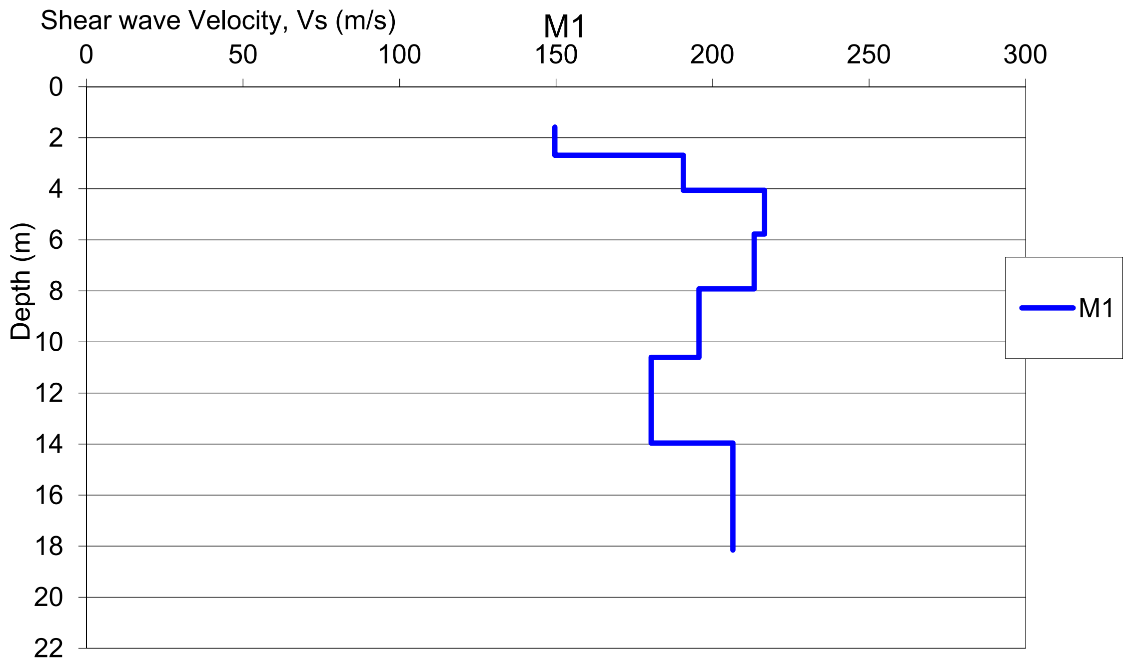
Table 6.1 depicts the interpreted shear wave velocities, and table 7.2 lists their locations in UTM 32N.

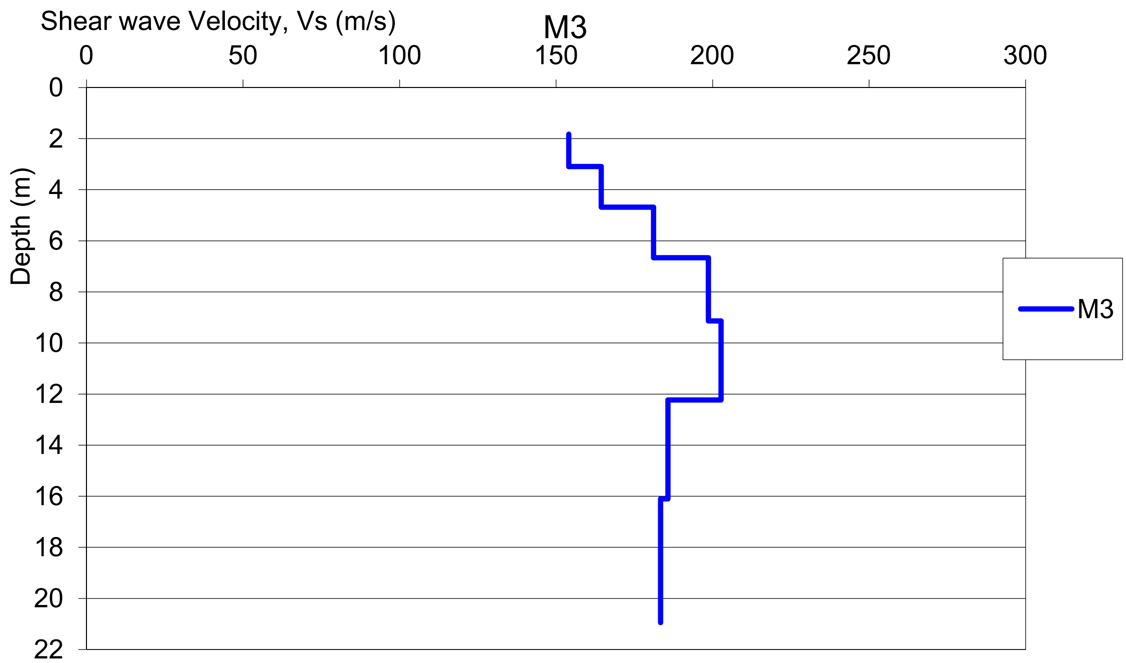
Table 6.1

M1		**M3**	
Depth m	**Vs m/s**	**Depth m**	**Vs m/s**
1.583	149.6	1.827	154.1
2.682	149.6	3.095	154.1
2.682	190.6	3.095	164.44
4.056	190.6	4.68	164.44
4.056	216.6	4.68	181.13
5.774	216.6	6.661	181.13
5.774	213.3	6.661	198.65
7.921	213.3	9.138	198.65
7.92	196	9.138	202.7
10.61	196	12.234	202.7
10.61	180	12.234	185.75
13.96	180	16.104	185.75
13.96	206	16.104	183.41
18.15	206	20.942	183.41

Table 6.2

	Easting	Northing
M1	562191.5	7022705
M3	562572.7	7022900


Shear wave Velocity, Vs (m/s)
M1
0
50
100
150
200
250
300
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
M1


Shear wave Velocity, Vs (m/s)
M3
0
50
100
150
200
250
300
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
M3

7. APPENDIX C: SEISMIC REFRACTION RESULTS (P-WAVE)

PROFILE	EAST	NORTH	STATION	PWAVE VELOCITY LAYER (m/s)				LAYER DEPTH (m)			LAYER ELEVATION (mOD)			
			(m)	1	2	3	4	1	2	3	1	2	3	4
S2	562148	7022720	0	285.7	484.9	677.0	1677.0	1.64	2.41	8.71	9.7	8.06	7.29	0.99
	562152	7022718.5	4	286.0	481.4	699.8	1670.7	1.6	2.73	9.15	9.7	8.1	6.97	0.55
	562156	7022717.5	8	286.2	477.9	722.7	1664.4	1.56	3.05	9.59	9.7	8.14	6.65	0.11
	562159	7022716	12	286.5	474.4	745.5	1658.1	1.52	3.36	10.01	9.68	8.16	6.32	-0.33
	562163	7022714.5	16	286.8	470.9	768.4	1651.9	1.47	3.66	10.42	9.63	8.16	5.97	-0.78
	562167	7022713	20	287.0	467.4	791.2	1645.6	1.43	3.96	10.82	9.6	8.17	5.64	-1.22
	562171	7022712	24	287.3	463.9	814.1	1642.6	1.39	4.25	10.53	9.6	8.21	5.35	-0.93
	562174	7022710.5	28	287.5	460.5	836.9	1642.6	1.35	4.54	10.17	9.6	8.25	5.06	-0.57
	562178	7022709	32	287.8	457.0	859.7	1642.6	1.3	4.82	10.51	9.6	8.3	4.78	-0.91
	562182	7022707.5	36	288.1	453.5	882.6	1642.6	1.26	5.1	10.34	9.6	8.34	4.5	-0.74
	562186	7022706.5	40	288.3	450.0	905.4	1642.6	1.22	5.37	9.85	9.6	8.38	4.23	-0.25
	562189	7022705	44	288.3	450.0	905.4	1642.6	1.22	5.37	9.57	9.6	8.38	4.23	0.03
	562193	7022703.5	48	287.4	451.9	891.8	1642.6	1.26	5.26	8.48	9.6	8.34	4.34	1.12
	562197	7022702	52	286.5	453.8	878.1	1694.2	1.29	5.14	8.93	9.6	8.31	4.46	0.67
	562201	7022701	56	285.6	455.6	864.4	1694.2	1.33	5.02	9.39	9.6	8.27	4.58	0.21
	562204	7022699.5	60	284.7	457.5	850.7	1694.2	1.37	4.9	9.51	9.6	8.23	4.7	0.09
	562208	7022698	64	283.7	459.4	837.1	1694.2	1.41	4.77	9.5	9.6	8.19	4.83	0.1
	562212	7022696.5	68	282.8	461.2	823.4	1694.2	1.44	4.65	10.11	9.6	8.16	4.95	-0.51
	562216	7022695.5	72	281.9	463.1	809.7	1655.0	1.48	4.52	10.28	9.6	8.12	5.08	-0.68
	562219	7022694	76	281.0	465.0	796.0	1655.0	1.52	4.39	10.44	9.6	8.08	5.21	-0.84
	562223	7022692.5	80	280.1	466.9	782.4	1655.0	1.55	4.26	10	9.6	8.05	5.34	-0.4
	562227	7022691.5	84	279.2	468.7	768.7	1644.0	1.59	4.13	10	9.6	8.01	5.47	-0.4
	562231	7022690	88	278.3	470.6	755.0	1633.0	1.62	4	10	9.6	7.98	5.6	-0.4
	562234	7022688.5	92	278.3	477.0	744.2	1622.0	1.62	4.09	9.89	9.6	7.98	5.51	-0.29

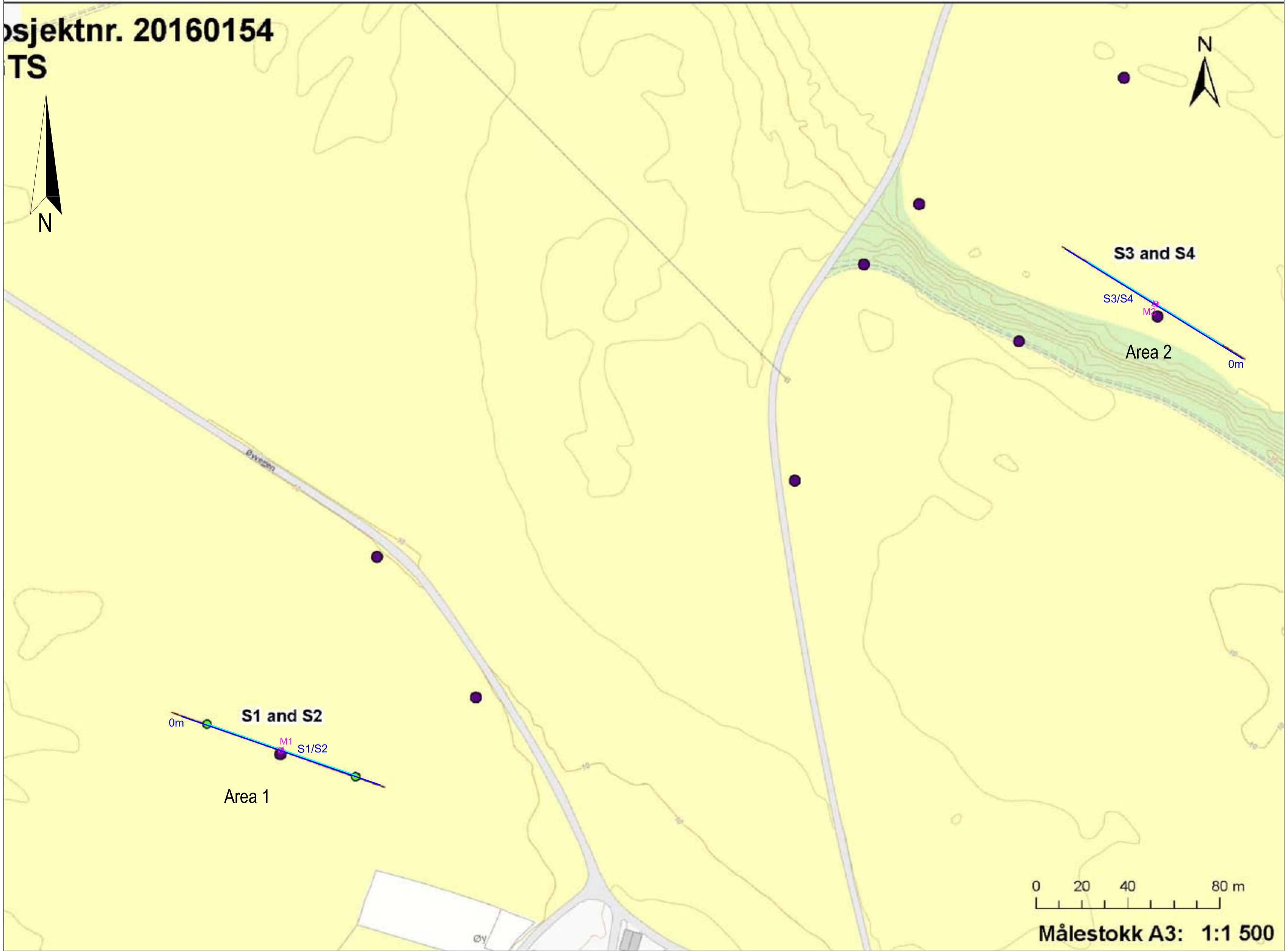
PROFILE	EAST	NORTH	STATION	PWAVE VELOCITY LAYER (m/s)				LAYER DEPTH (m)			LAYER ELEVATION (mOD)			
			(m)	1	2	3	4	1	2	3	1	2	3	4
S4	562611	7022876	0	202.5	761.9	1010.0	1891.0	1.47	2.8	4.22	3.4	1.93	0.6	-0.82
	562608	7022878	4	206.4	735.3	1010.8	1892.5	1.43	2.92	4.01	3.49	2.06	0.57	-0.53
	562604	7022880	8	210.2	708.8	1011.6	1894.1	1.39	3.02	3.79	3.57	2.18	0.55	-0.22
	562601	7022882.5	12	214.0	682.2	1012.5	1894.1	1.35	3.11	3.54	3.63	2.28	0.52	0.09
	562597	7022884.5	16	217.8	655.7	1013.3	1894.1	1.31	3.18	4.02	3.67	2.36	0.49	-0.35
	562594	7022886.5	20	221.6	629.1	1014.1	1894.1	1.26	3.23	4.62	3.71	2.45	0.48	-0.91
	562591	7022888.5	24	225.5	602.5	1014.9	1894.1	1.21	3.26	4.69	3.76	2.54	0.49	-0.93
	562587	7022891	28	229.3	576.0	1015.7	1894.1	1.16	3.28	5.38	3.8	2.64	0.52	-1.58
	562584	7022893	32	233.1	549.4	1016.6	1894.1	1.11	3.28	6.31	3.8	2.69	0.52	-2.51
	562581	7022895	36	236.9	522.9	1017.4	1894.1	1.05	3.27	6.21	3.8	2.75	0.53	-2.41
	562577	7022897	40	240.7	496.3	1018.2	1894.1	0.99	3.23	6.59	3.8	2.81	0.57	-2.79
	562574	7022899.5	44	240.7	496.3	1018.2	1894.1	0.99	3.23	6.72	3.8	2.81	0.57	-2.92
	562570	7022901.5	48	237.3	511.8	1016.5	1894.1	1.04	3.23	7.2	3.8	2.76	0.57	-3.4
	562567	7022903.5	52	233.8	527.3	1014.9	1894.1	1.08	3.22	7.41	3.8	2.72	0.58	-3.61
	562564	7022905.5	56	230.3	542.8	1013.2	1894.1	1.12	3.2	7.87	3.8	2.68	0.6	-4.07
	562560	7022908	60	226.8	558.3	1011.6	1894.1	1.16	3.17	8.95	3.8	2.64	0.63	-5.15
	562557	7022910	64	223.4	573.7	1009.9	1894.1	1.2	3.13	8.5	3.8	2.6	0.67	-4.7
	562553	7022912	68	219.9	589.2	1008.3	1894.1	1.24	3.09	8.68	3.77	2.53	0.68	-4.91
	562550	7022914	72	216.4	604.7	1006.6	1894.1	1.27	3.03	7.96	3.73	2.45	0.69	-4.24
	562547	7022916.5	76	213.0	620.2	1005.0	1894.1	1.3	2.97	7.24	3.7	2.4	0.73	-3.54
	562543	7022918.5	80	209.5	635.7	1003.3	1894.1	1.34	2.9	8.15	3.7	2.36	0.8	-4.45
	562540	7022920.5	84	206.0	651.2	1001.7	1886.4	1.36	2.82	7.06	3.7	2.34	0.88	-3.36
	562536	7022922.5	88	202.5	666.7	1000.0	1878.7	1.39	2.73	5.98	3.7	2.31	0.97	-2.28
	562533	7022925	92	202.5	666.7	1000.0	1871.0	1.39	2.73	5.98	3.7	2.31	0.97	-2.28

8. APPENDIX D: DRAWINGS

The information derived from the geophysical investigation is presented in the following drawings:

AGL16239A_01	Profile Locations	1:2500	@ A4
AGL16239A_02	P-Wave Profiles S2 & S4	1:1000	@ A4

INDEX MAP:



LEGEND:

SEISMIC REFRACTION PROFILE (4m Geophone Spacing)

SEISMIC REFRACTION PROFILE (3m Geophone Spacing)

M3 1D MASW PROFILE

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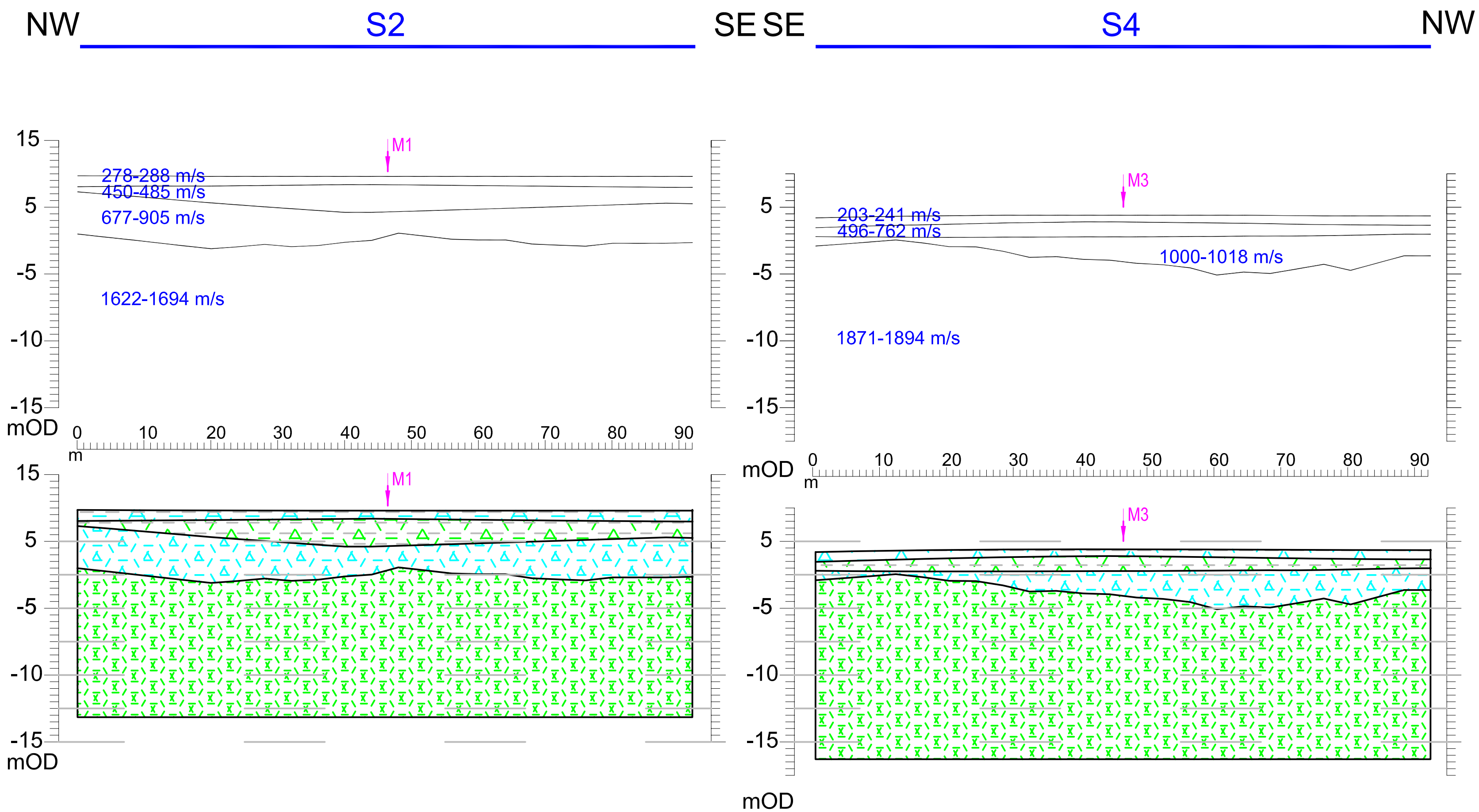
PROJECT:	OYSAND GEOPHYSICAL SURVEY
DRAWING No.:	AGL16239A_01 PROFILE LOCATIONS
DATE:	08.11.16
CLIENT:	NGI
SCALE:	1:2500 @ A4

Version:	Date:	Drawn By:	Checked:
1	08.11.16	SOR	TL



INDEX MAP:scale 1:5000@A4

LEGEND:

429-576 m/s P-WAVE VELOCITY LAYER

SOFT/LOOSE OVERBURDEN

SOFT-FIRM/LOOSE-MEDIUM DENSE OVERBURDEN

FIRM/MEDIUM DENSE OVERBURDEN

STIFF-VERY STIFF/DENSE-VERY DENSE OVERBURDEN

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PROJECT: OYSAND GEOPHYSICAL SURVEY

DRAWING No.: AGL16239A_01 P-WAVE PROFILES S2 & S4

DATE: 08.11.16

CLIENT: NGI

SCALE: 1:1000 @ A4

Version:	Date:	Drawn By:	Checked:
1	08.11.16	SOR	TL

Appendix G

TOTAL SOUNDINGS

Contents

Figures

G1 Methodology

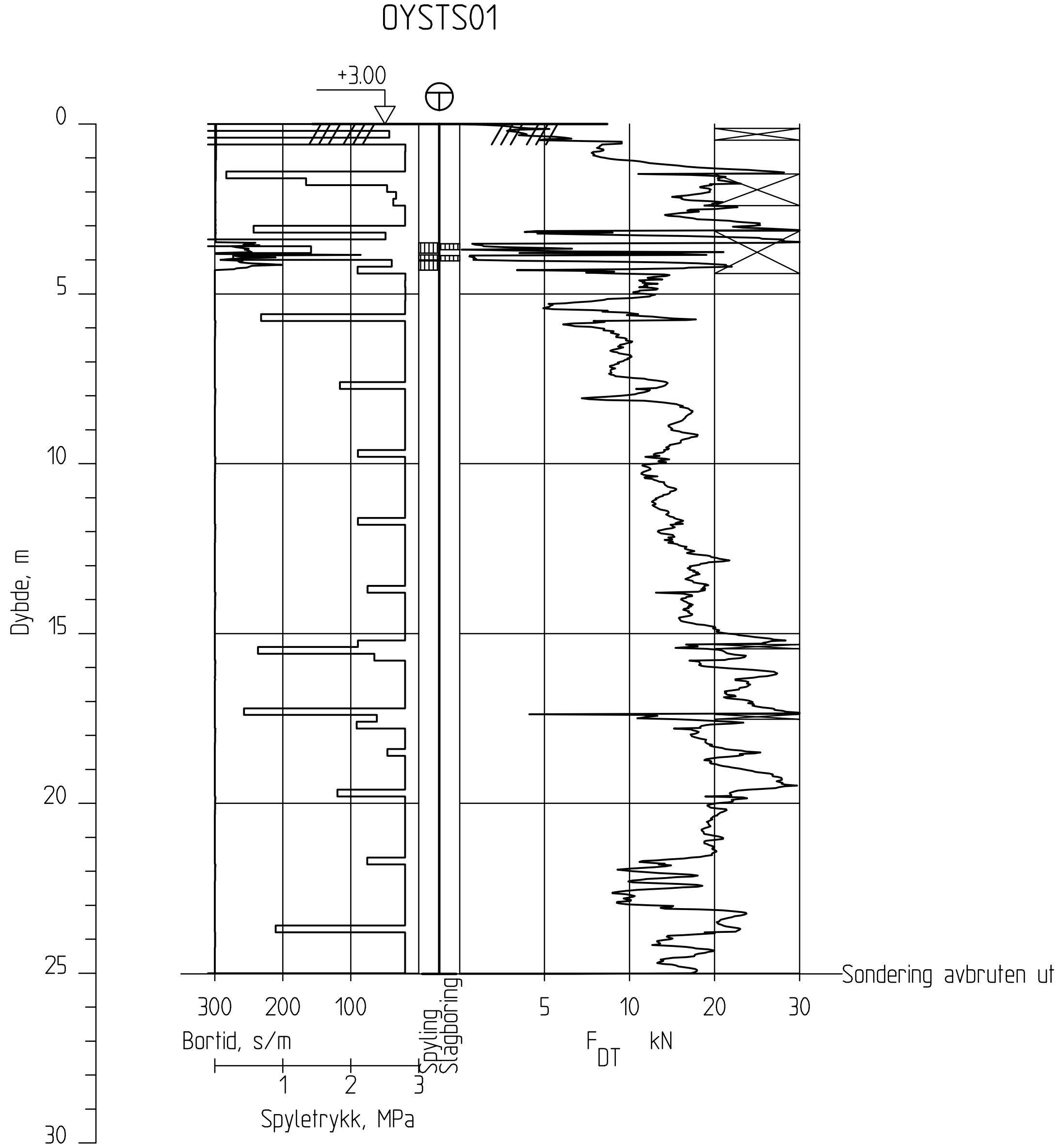
Total sounding is used to determine stratification in soils and to determine the depths to solid ground or bedrock. The method is considered to be a safe way to detect depth of bedrock by drilling 3 meters into the mountain. The results provide a basis for identifying soils and to assess the relative strength of the subsurface soils.

G2 Results

Figures B1 – B20 show the results of the total soundings.

G3 References

[B1] Norsk geoteknisk forening, "Veiledning for utførelse av totalsondering, Melding nr. 9".
[B2] NGTS Report 03



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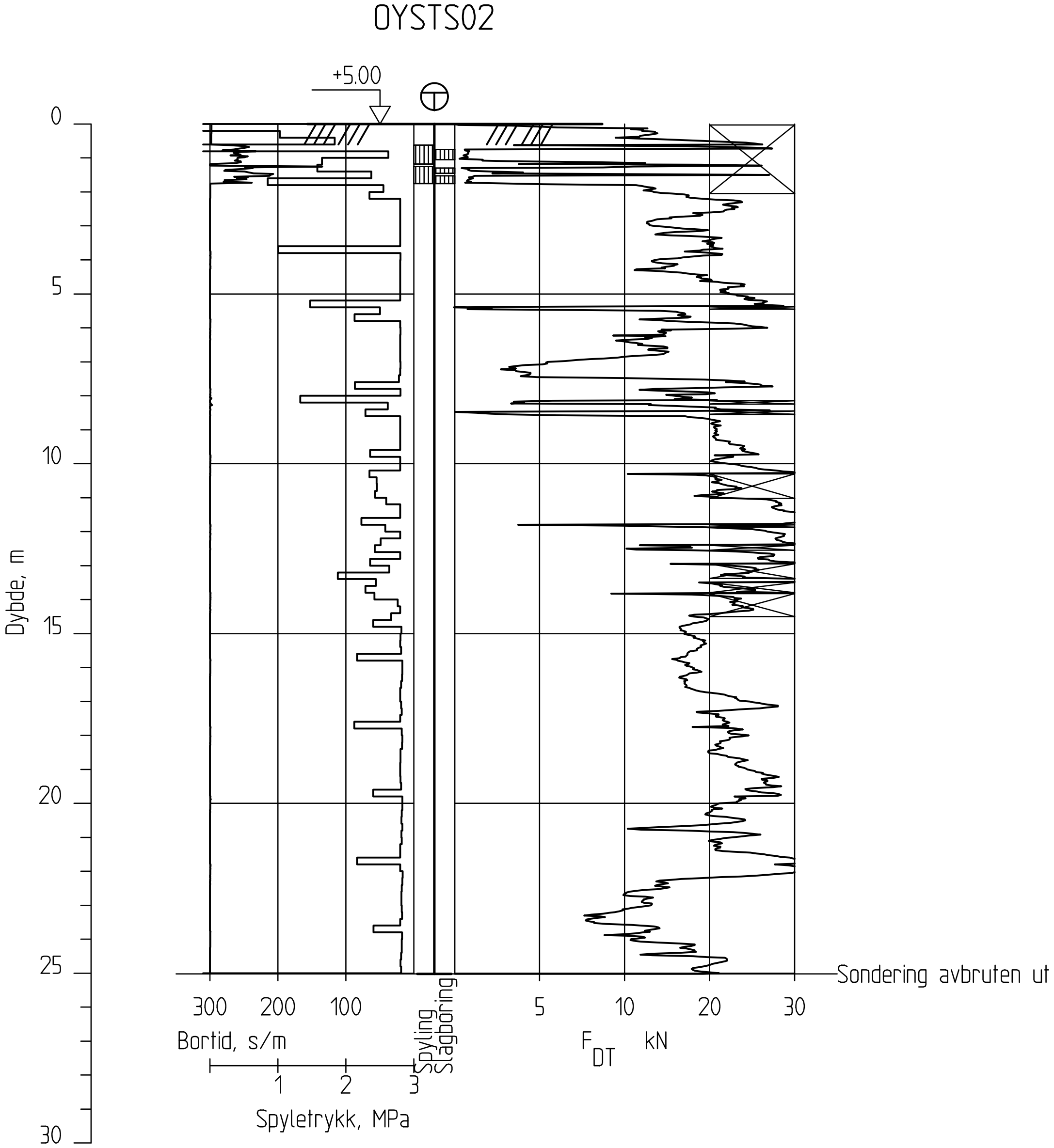

NGTS-Oysand

Rapport nr.
20160154-08-R

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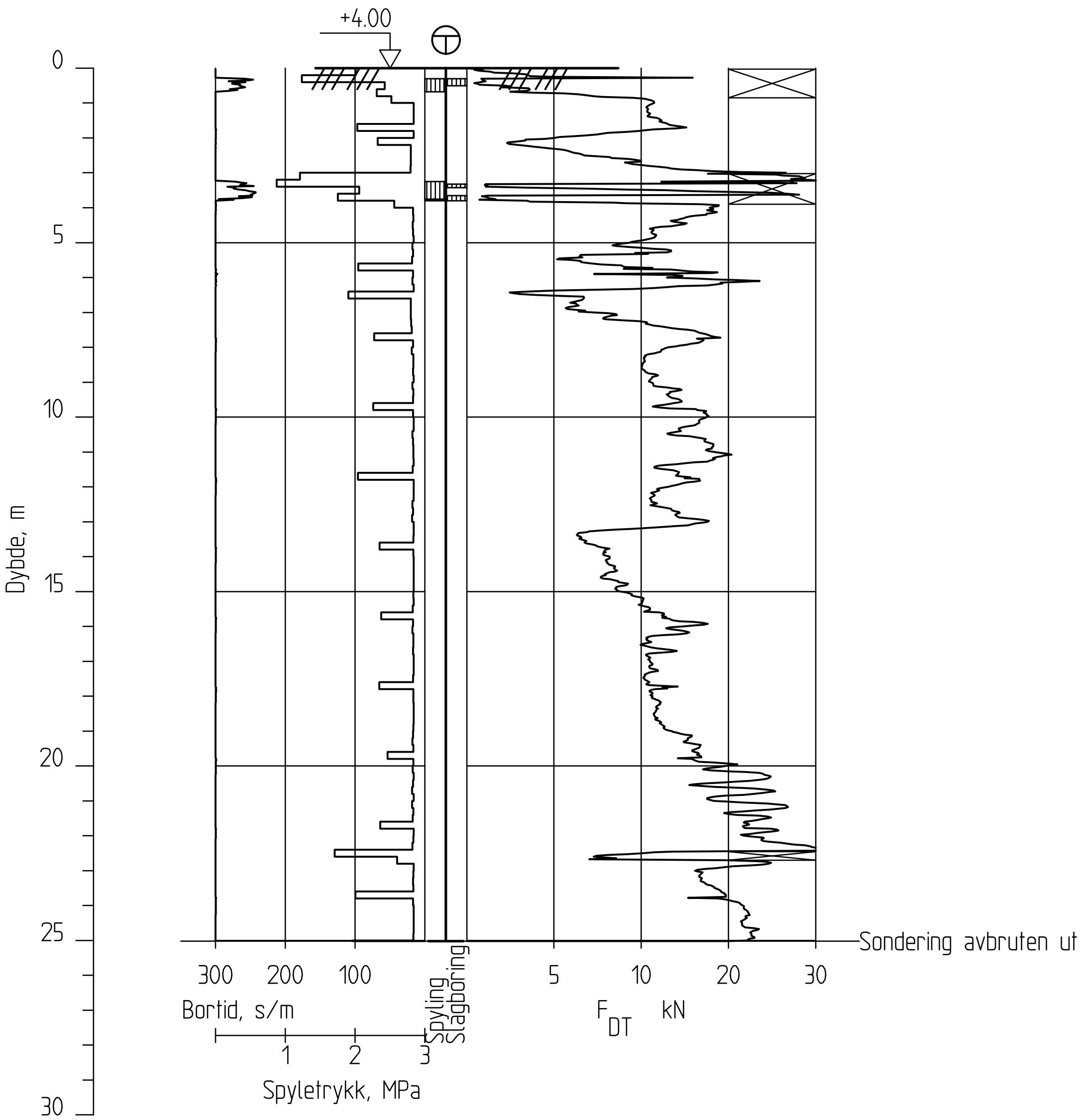

NGTS-Oysand

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Dato.
15.05.2017

Figur nr.
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AGu

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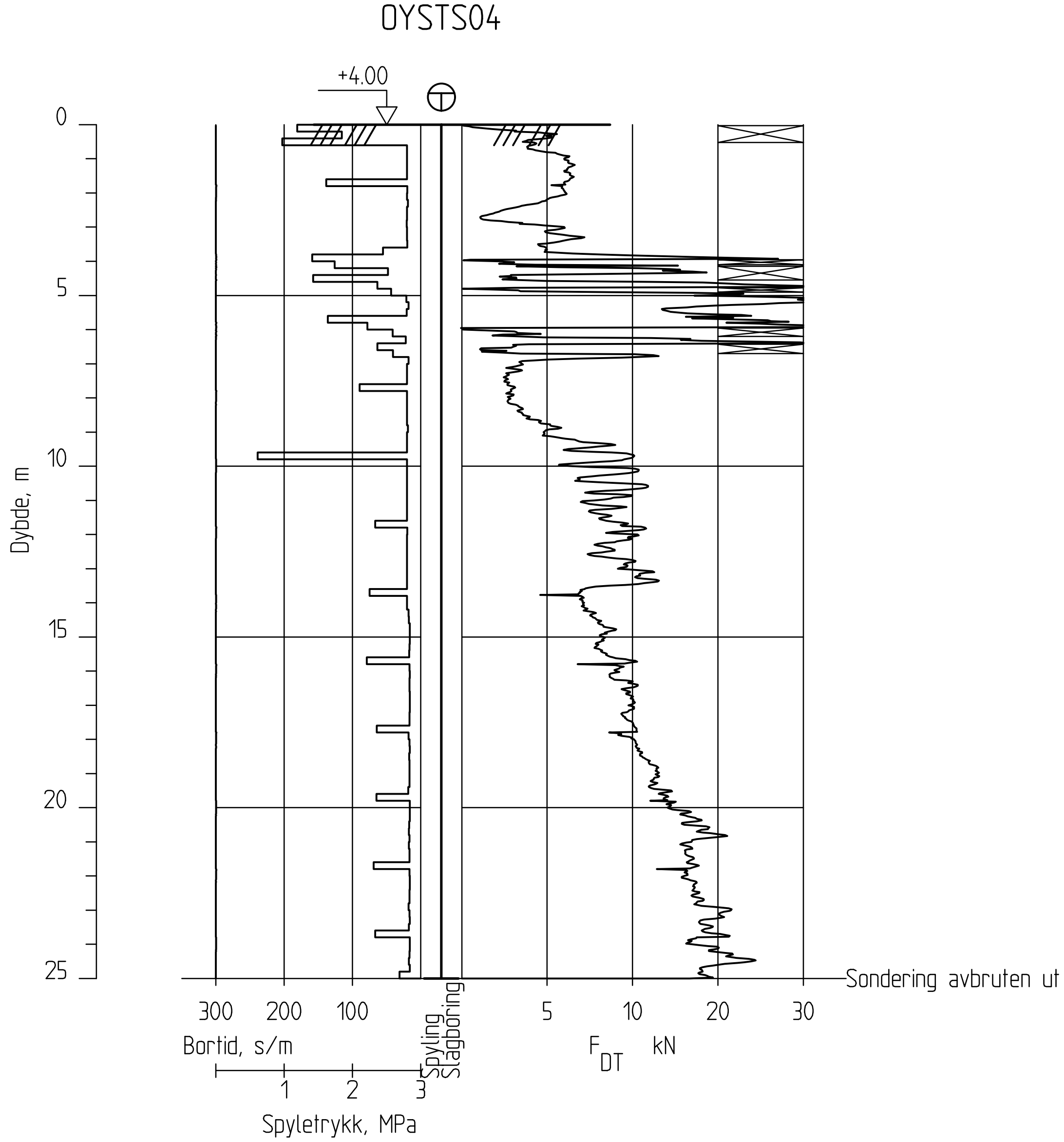

NGTS-Oysand

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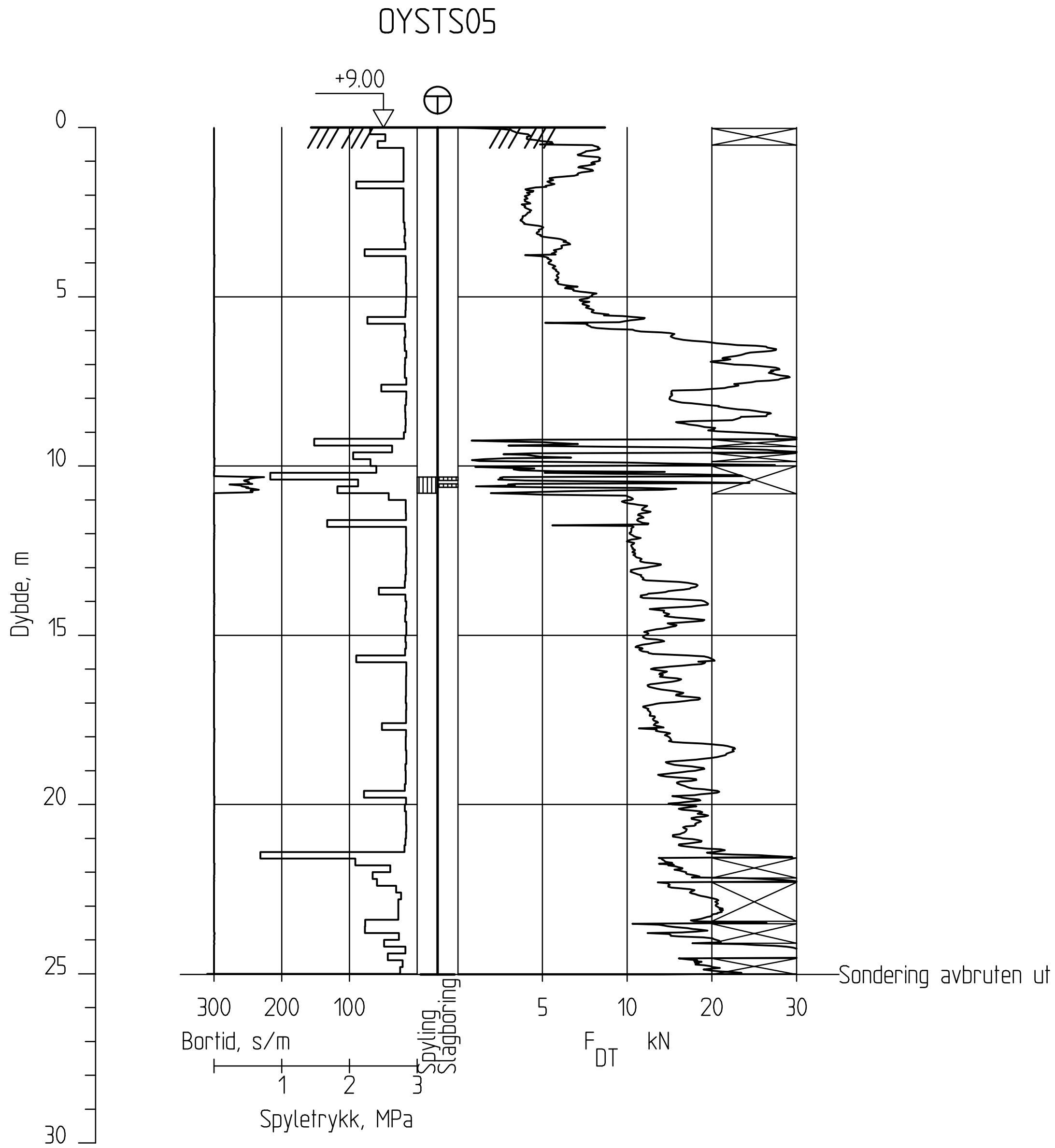

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Dato boret :07.09.2016

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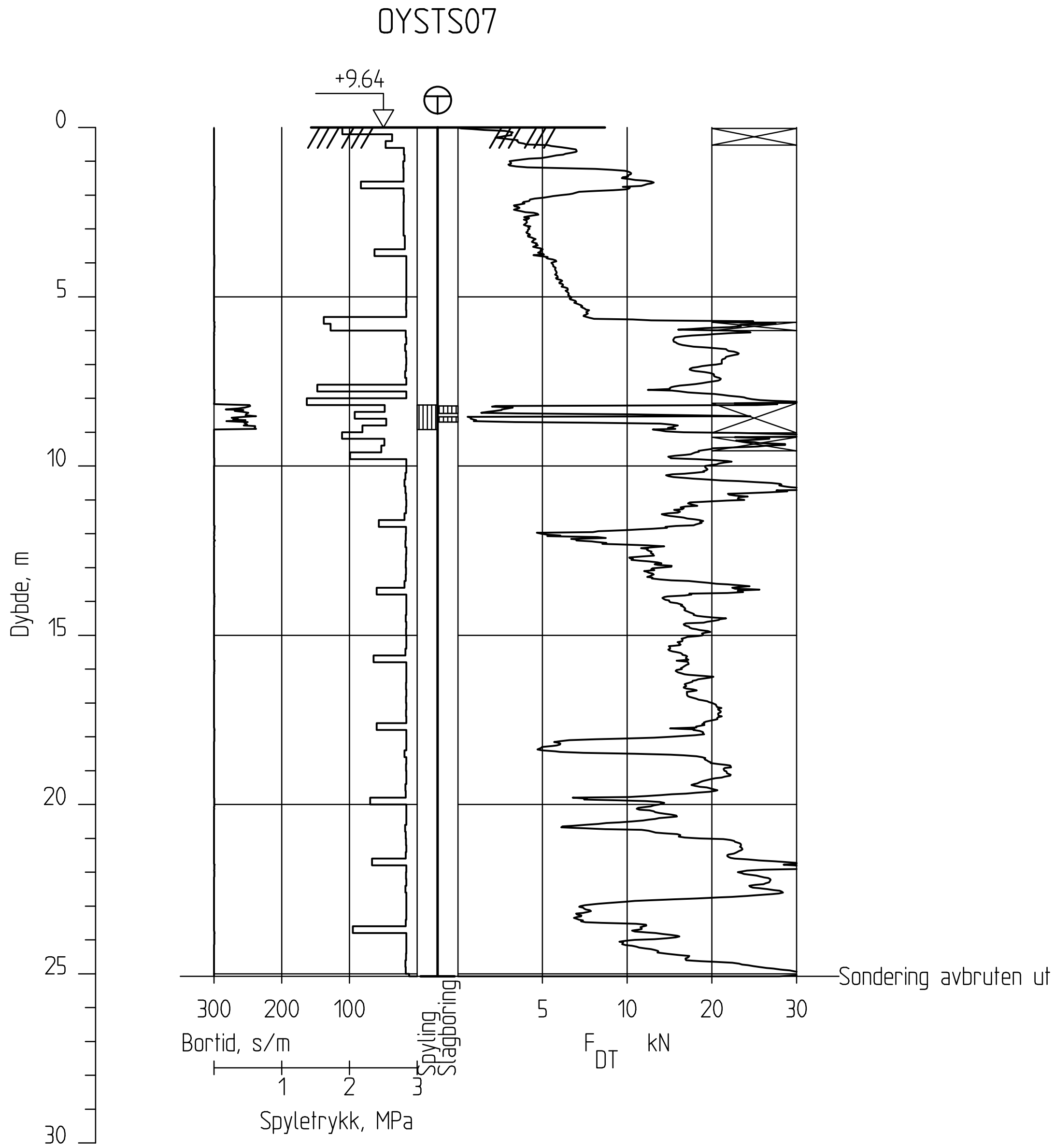

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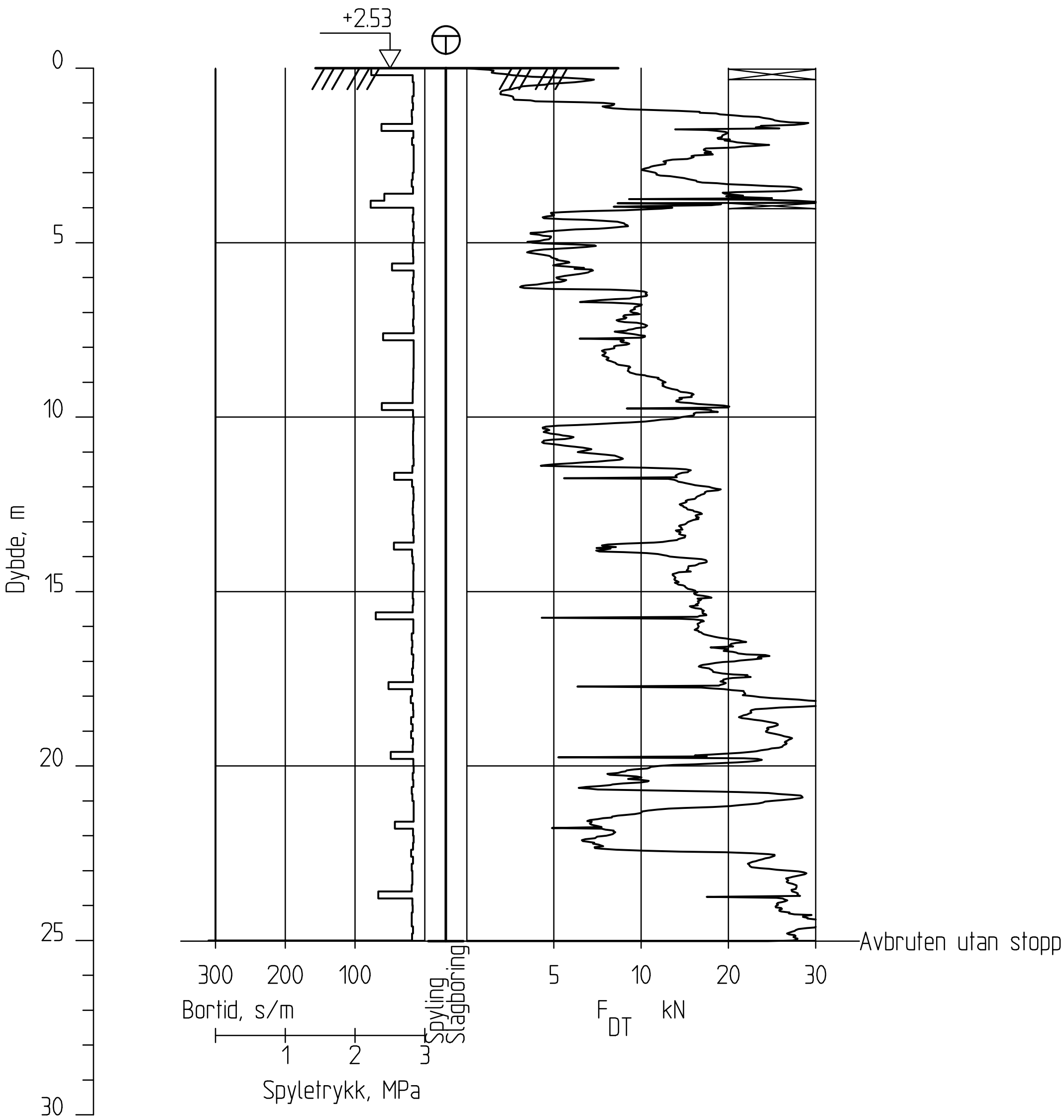
NGTS

OYSTS08



NGTS-Oysand

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Figur nr.	B7
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Kontr.	JSL
Godkj.	JSL

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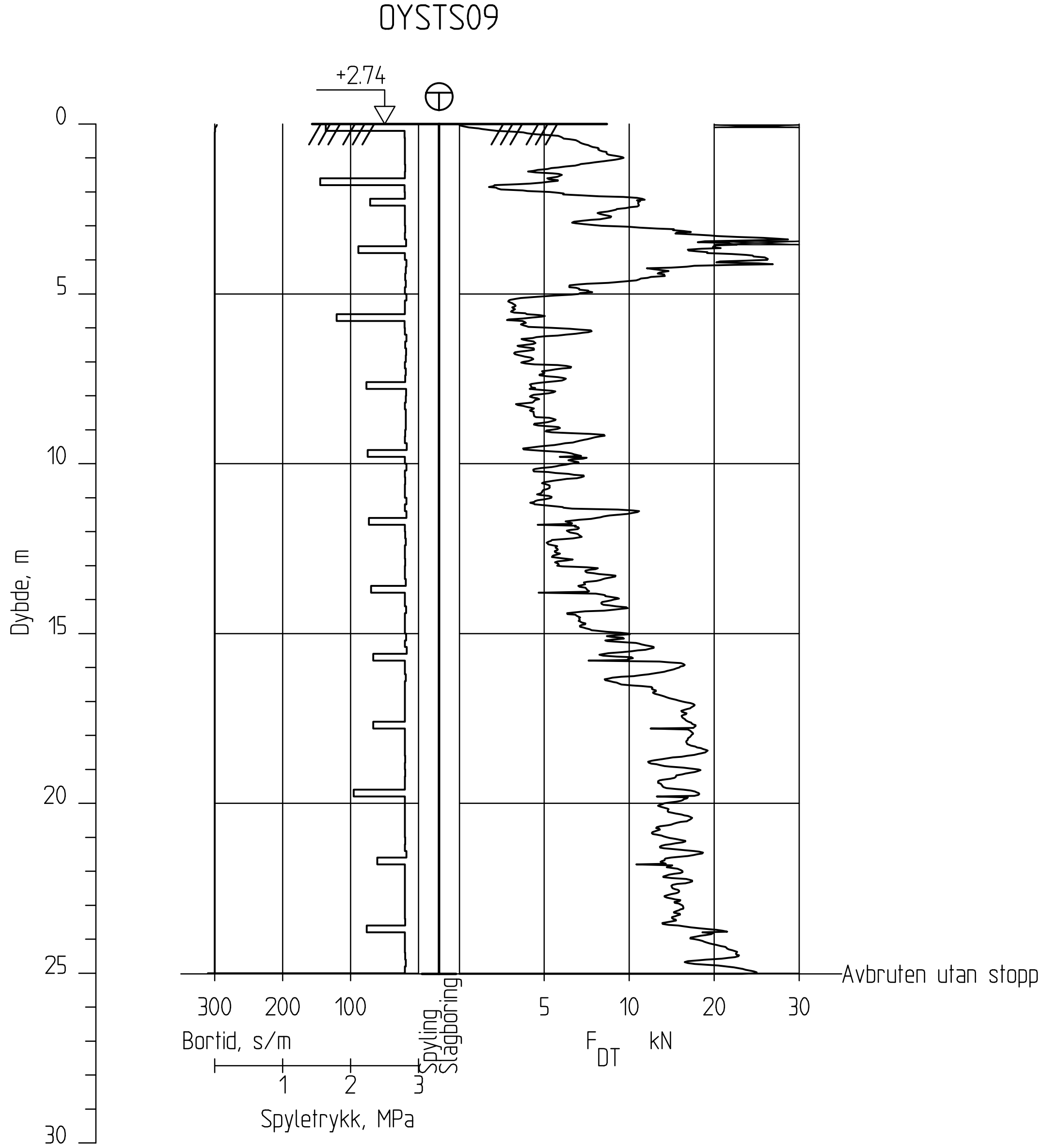

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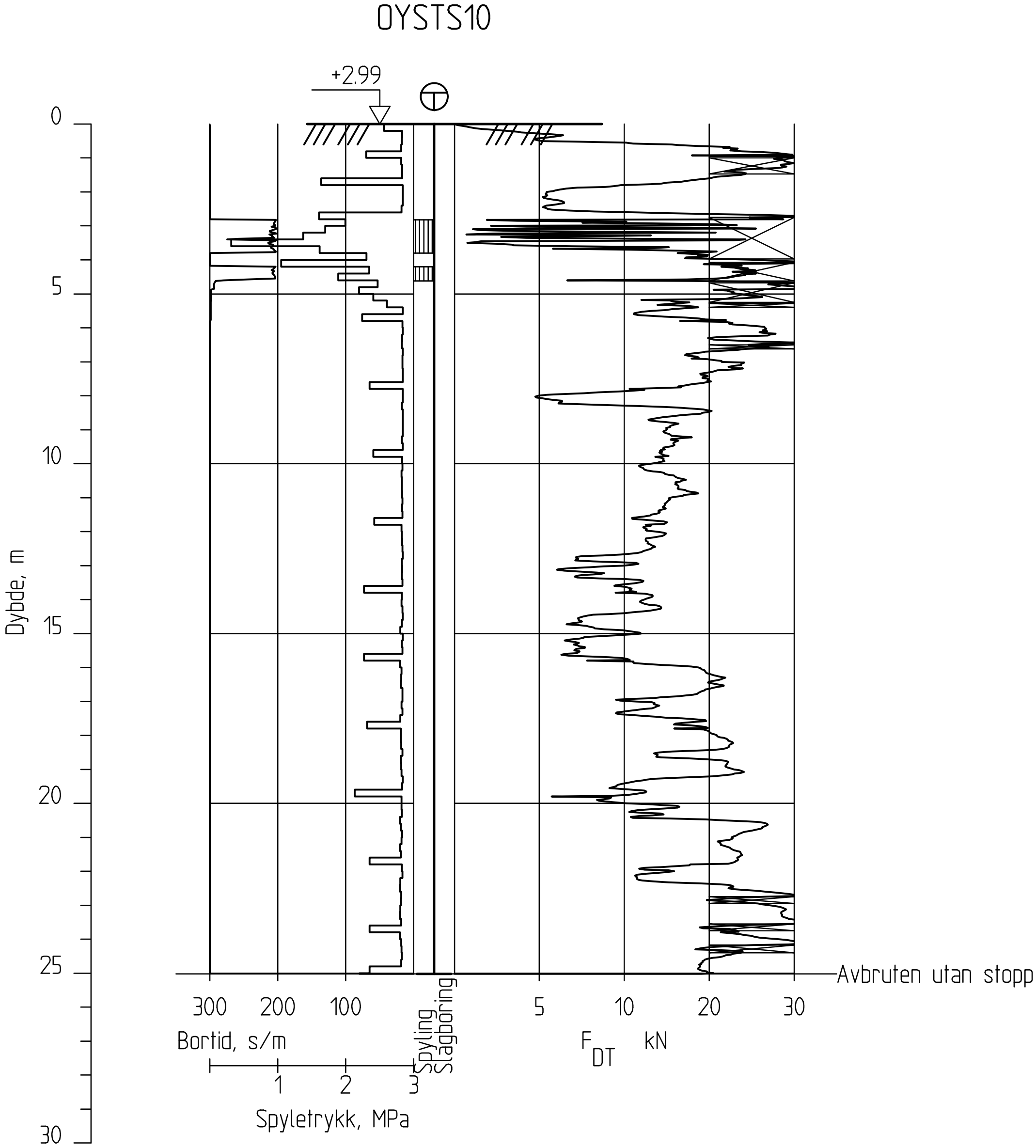

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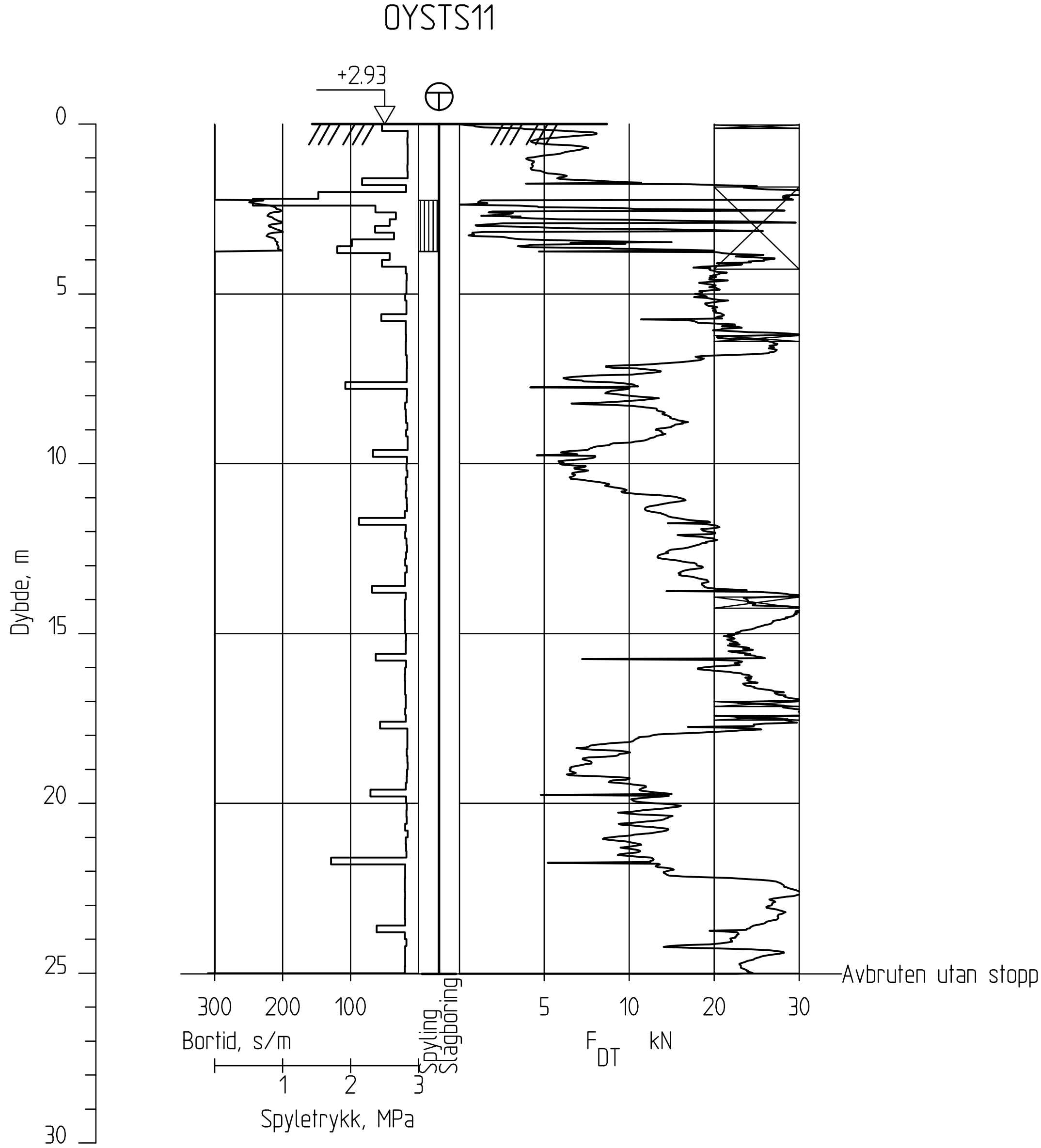

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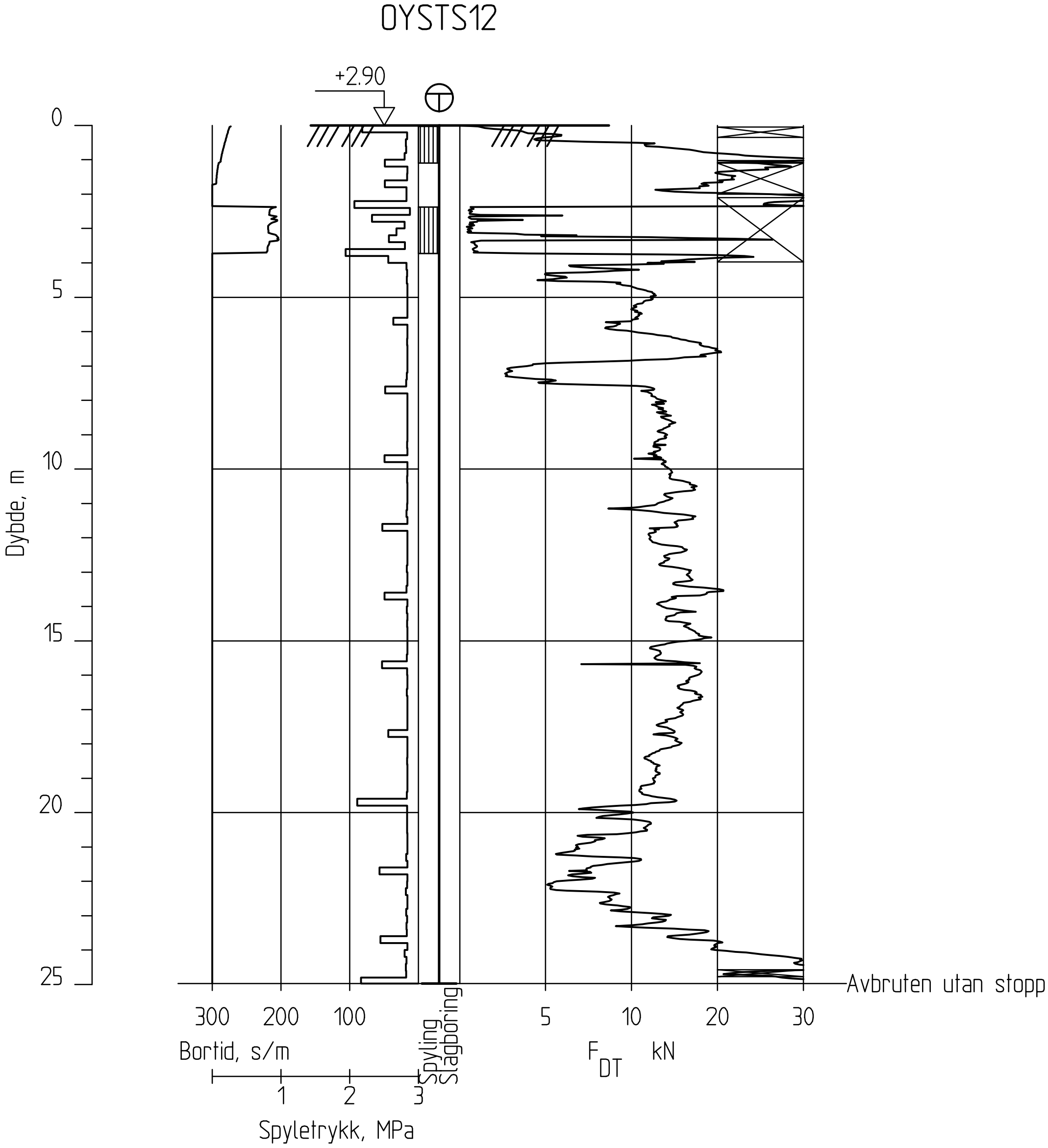

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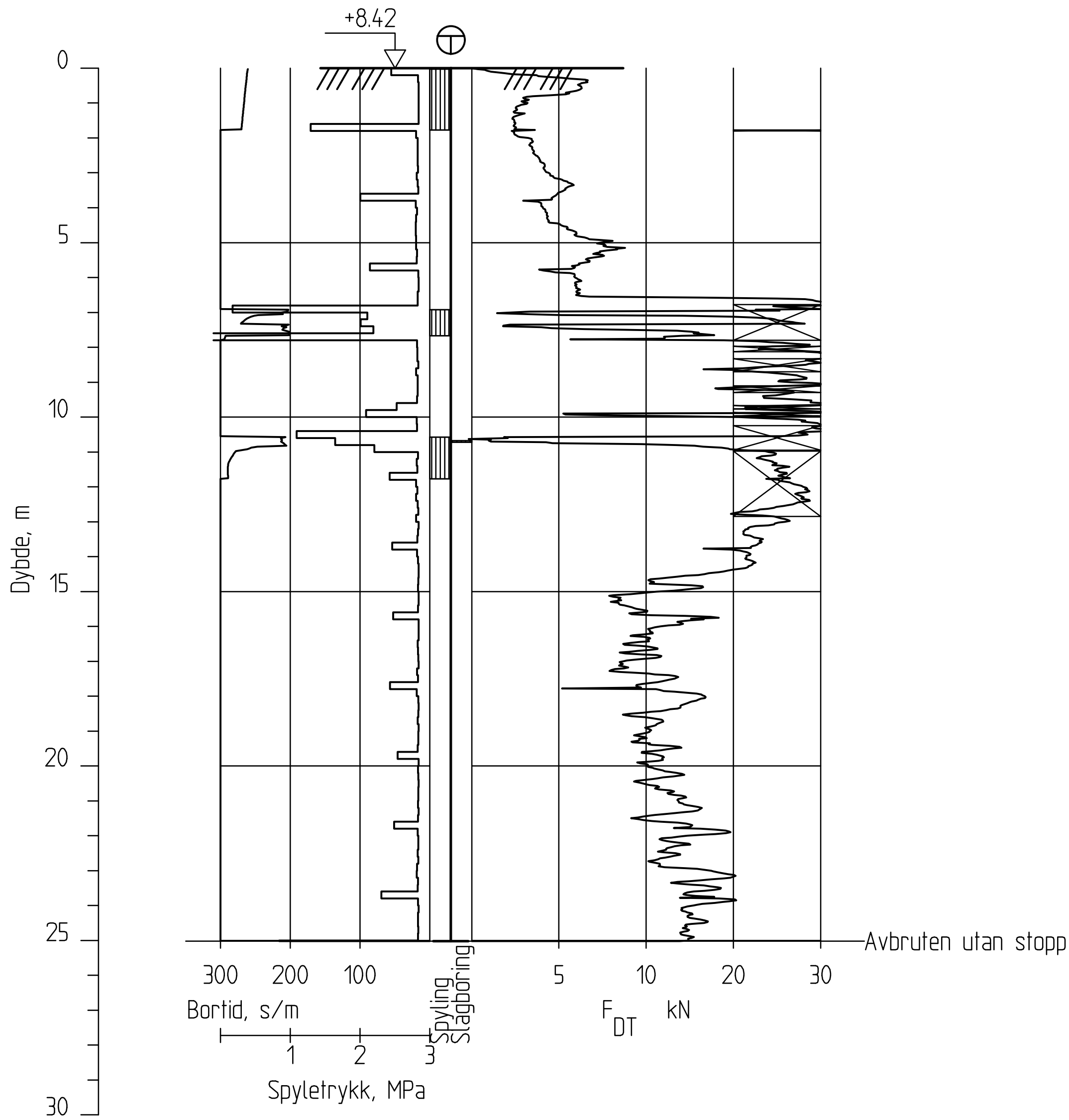

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Dato.	Figur nr.
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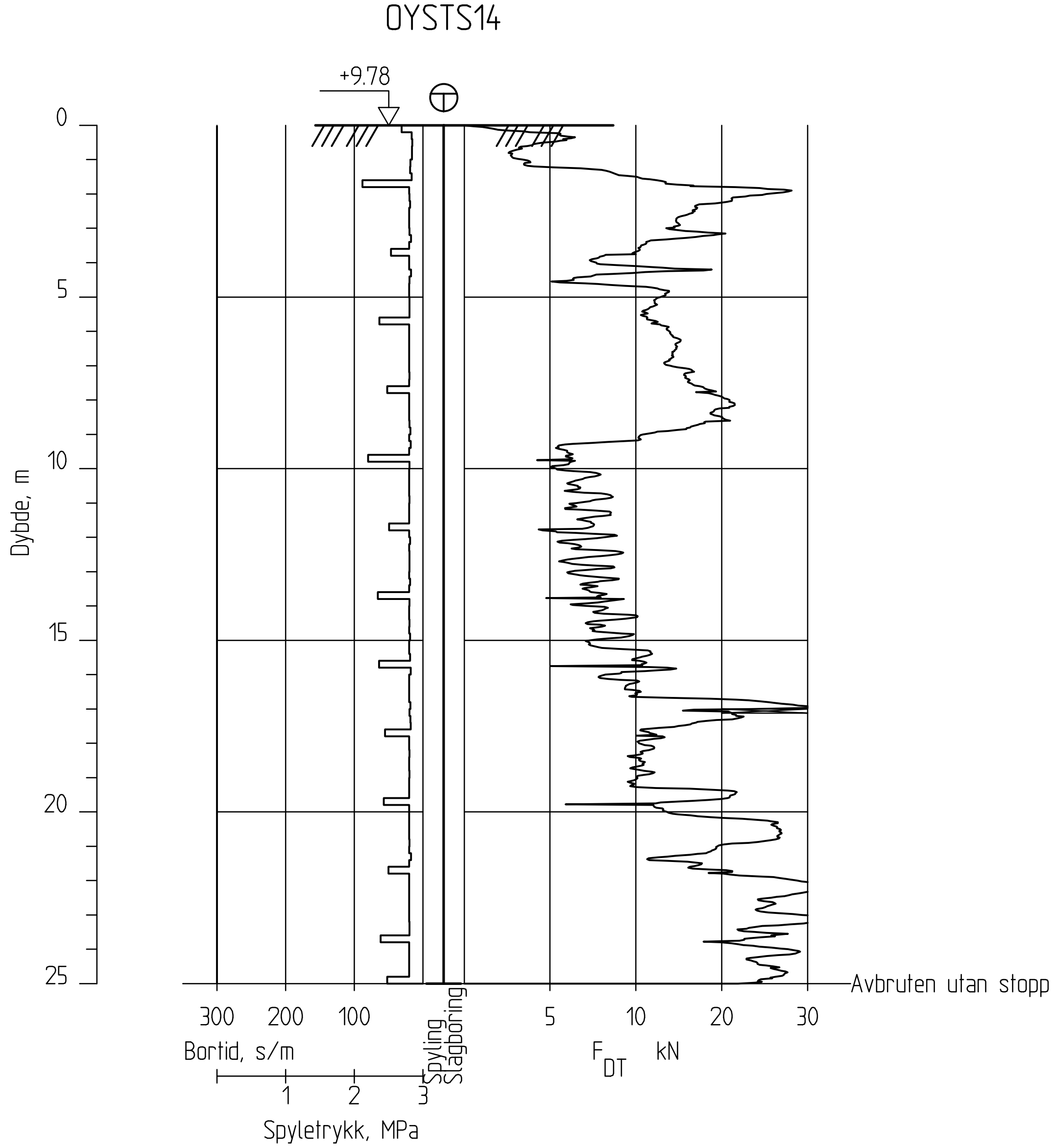

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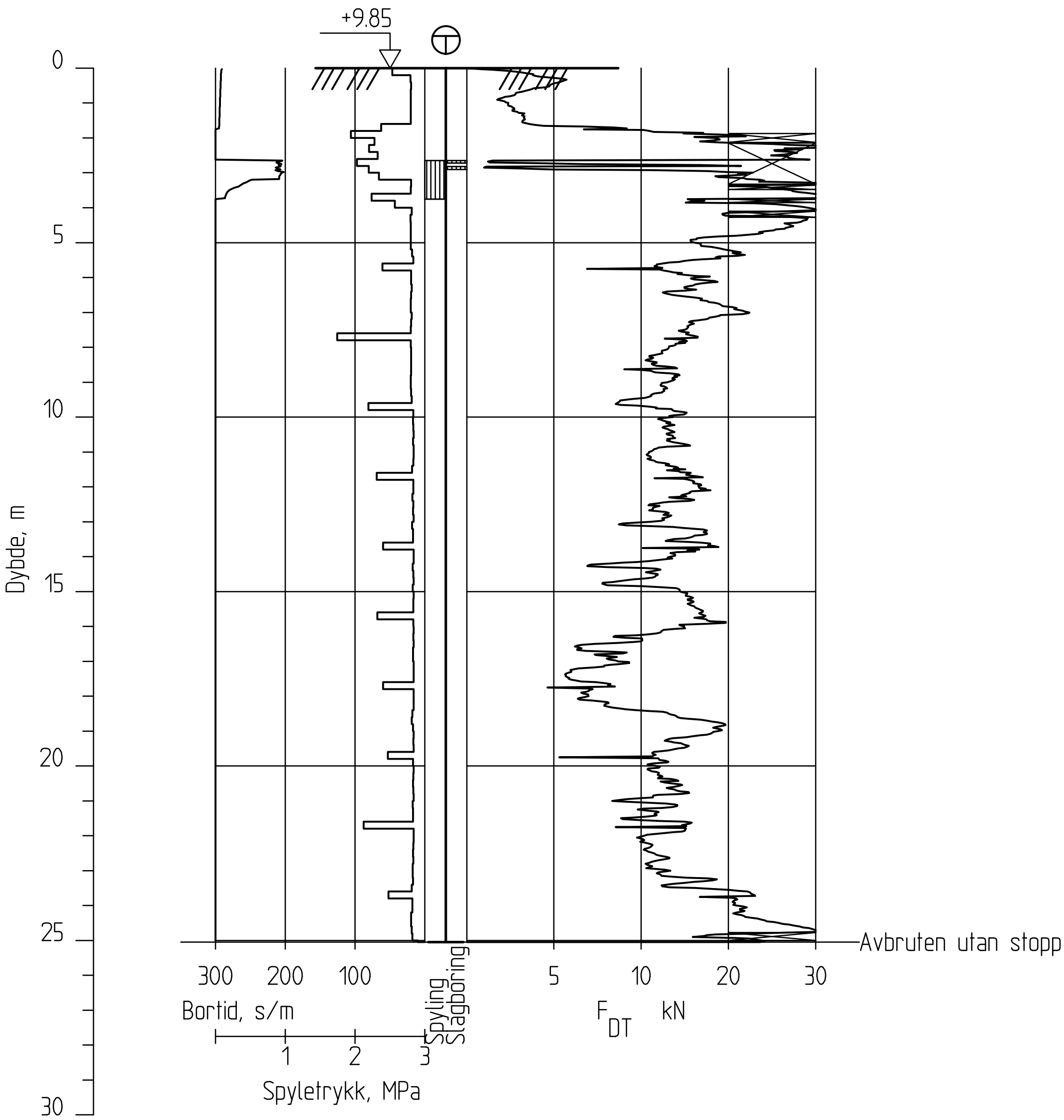

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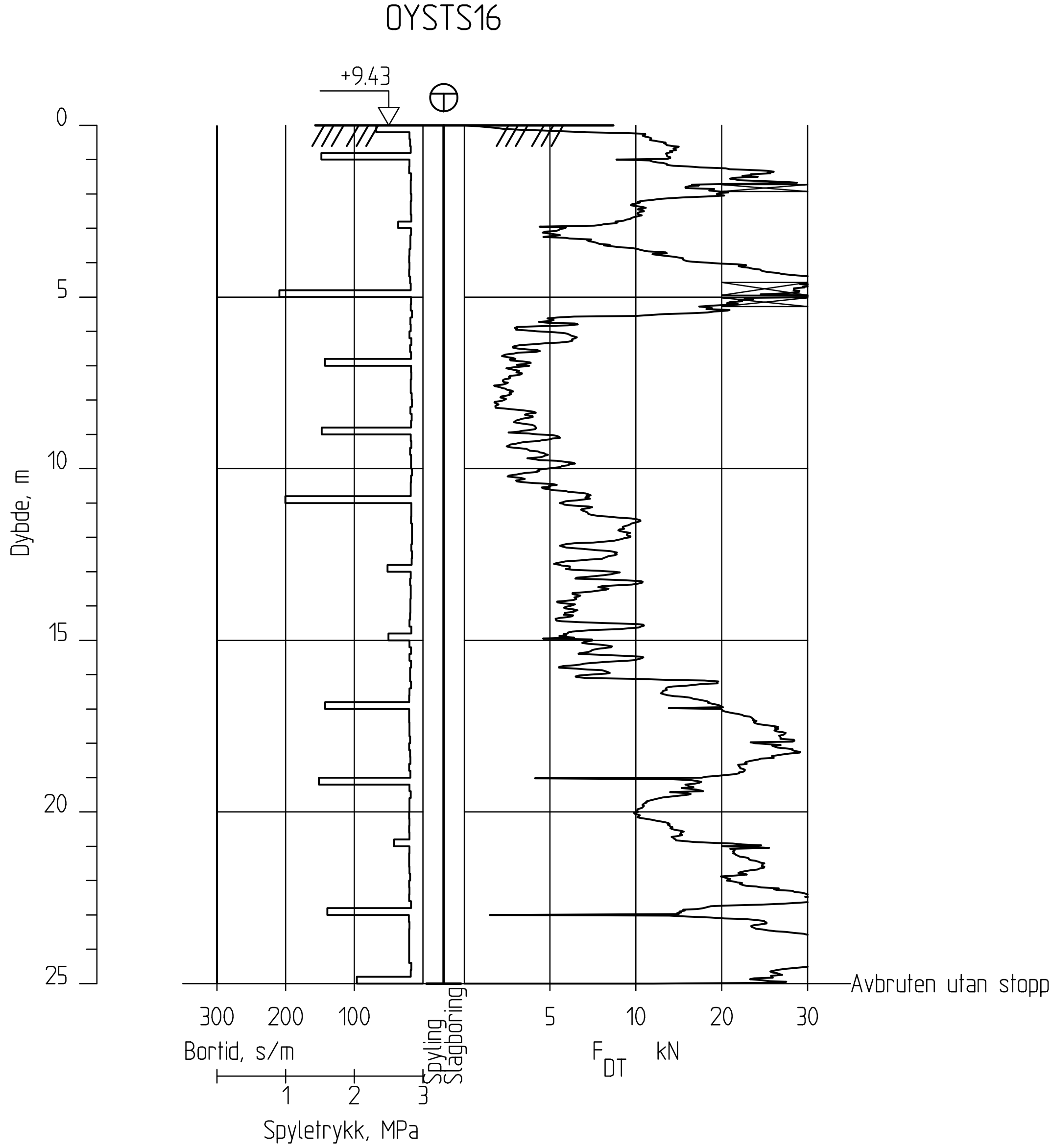

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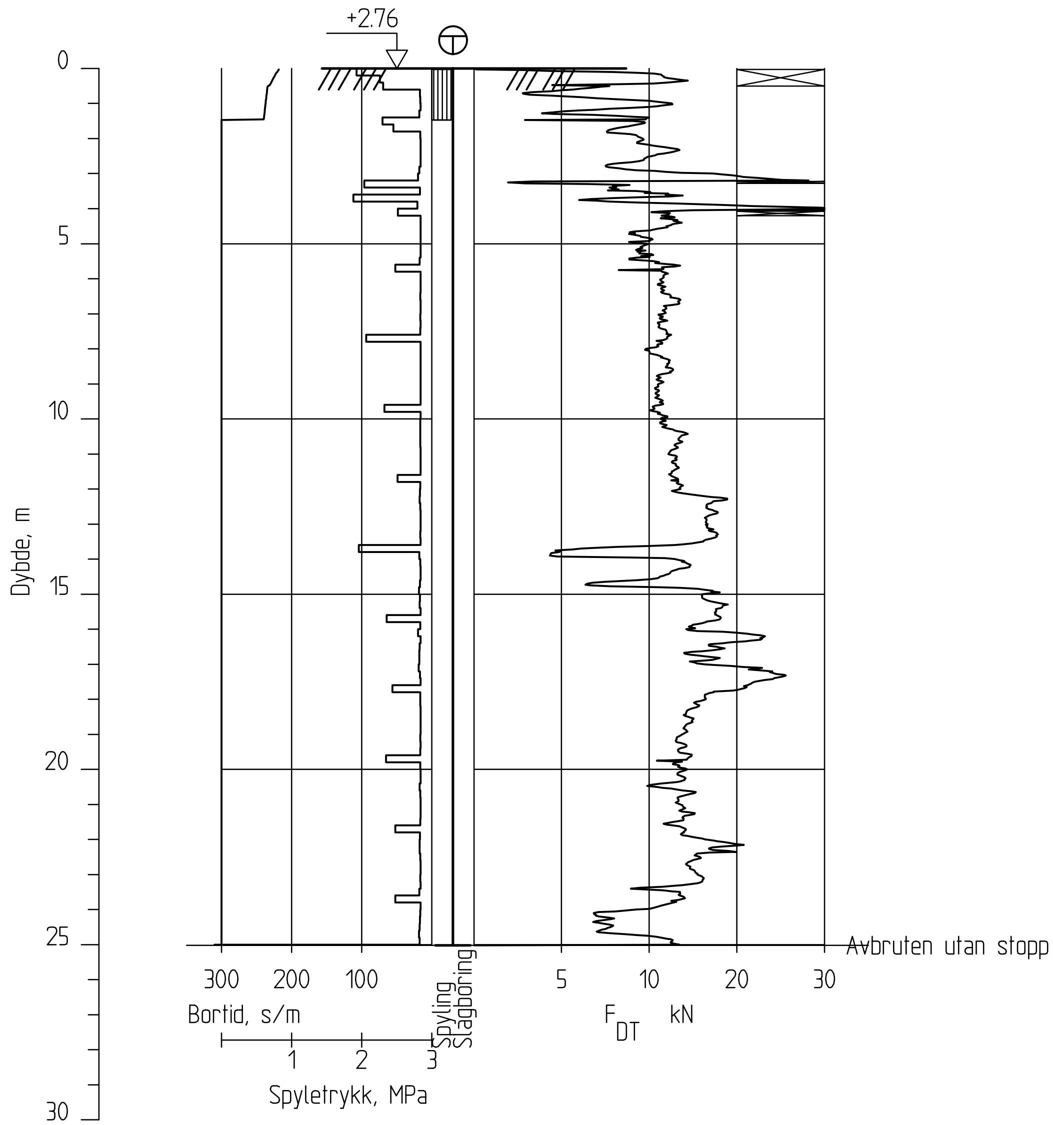

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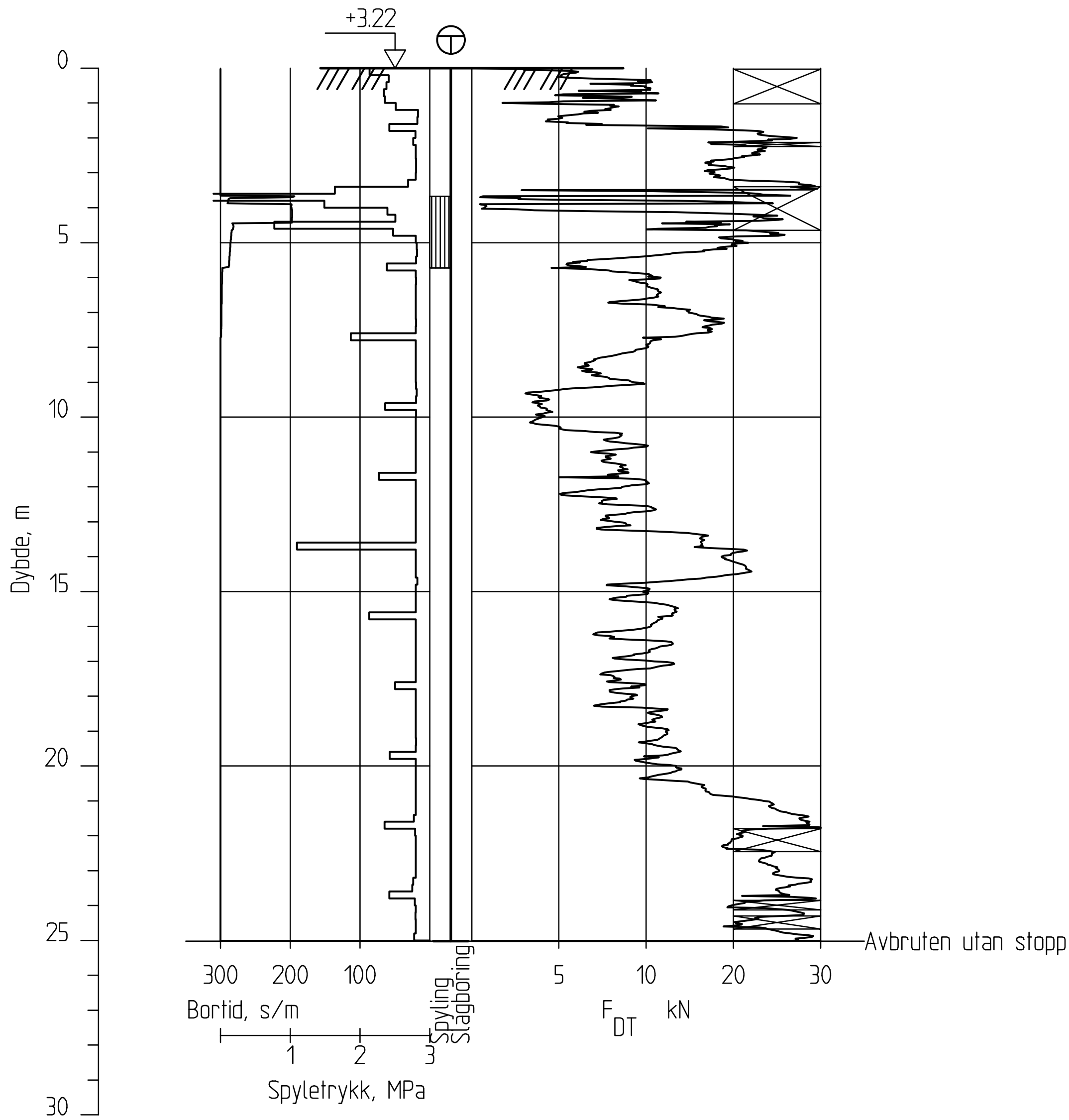

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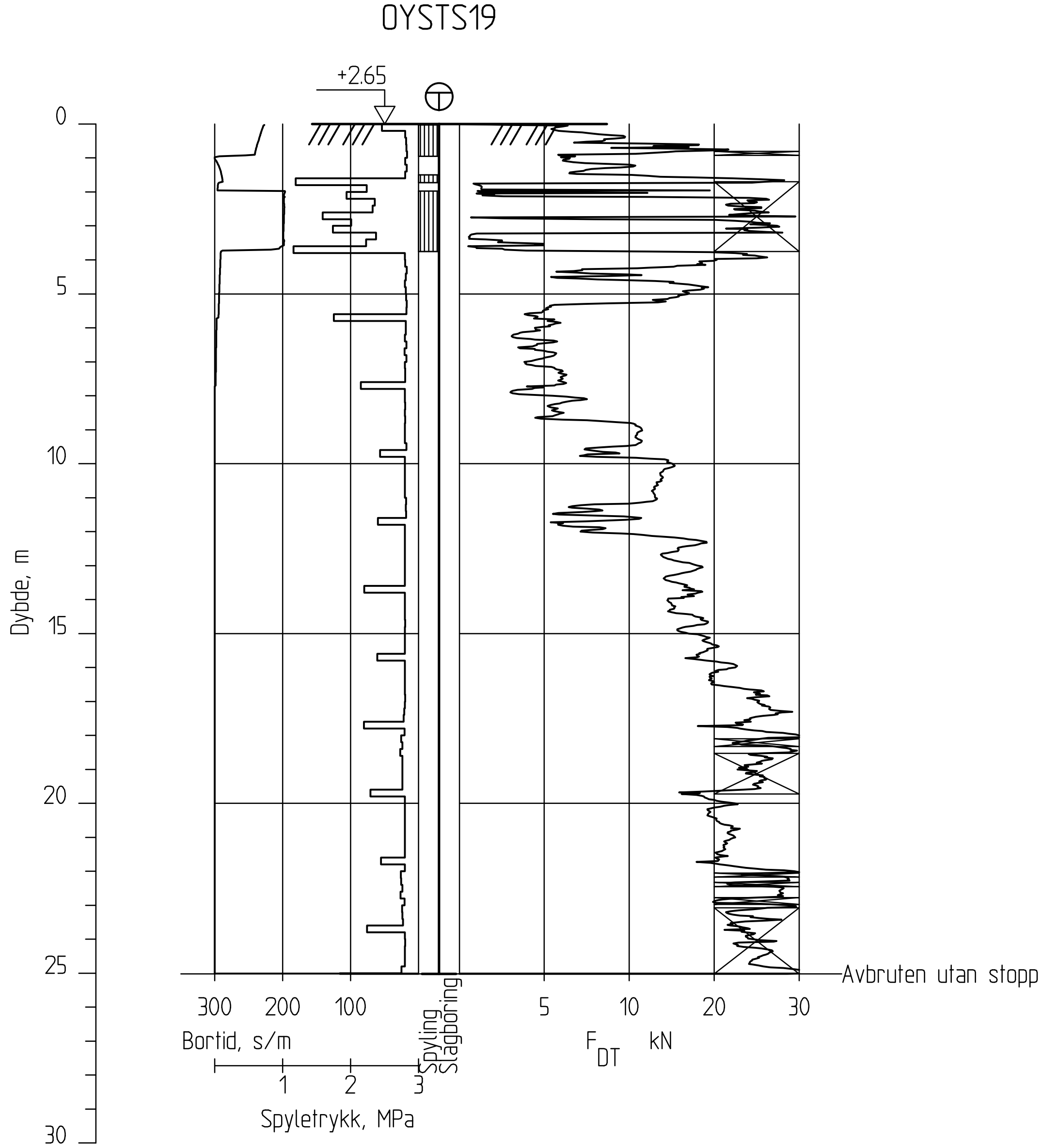

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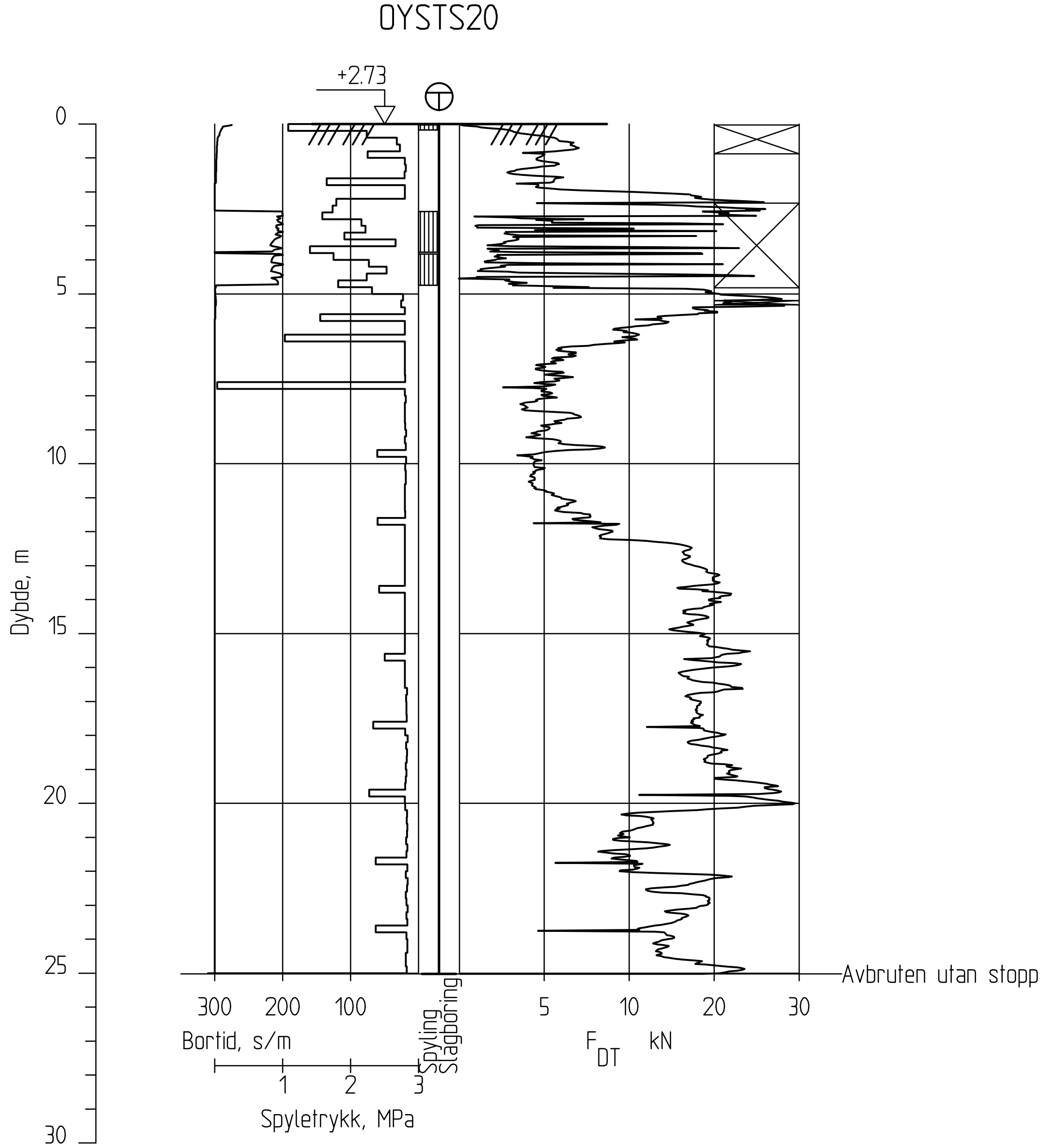

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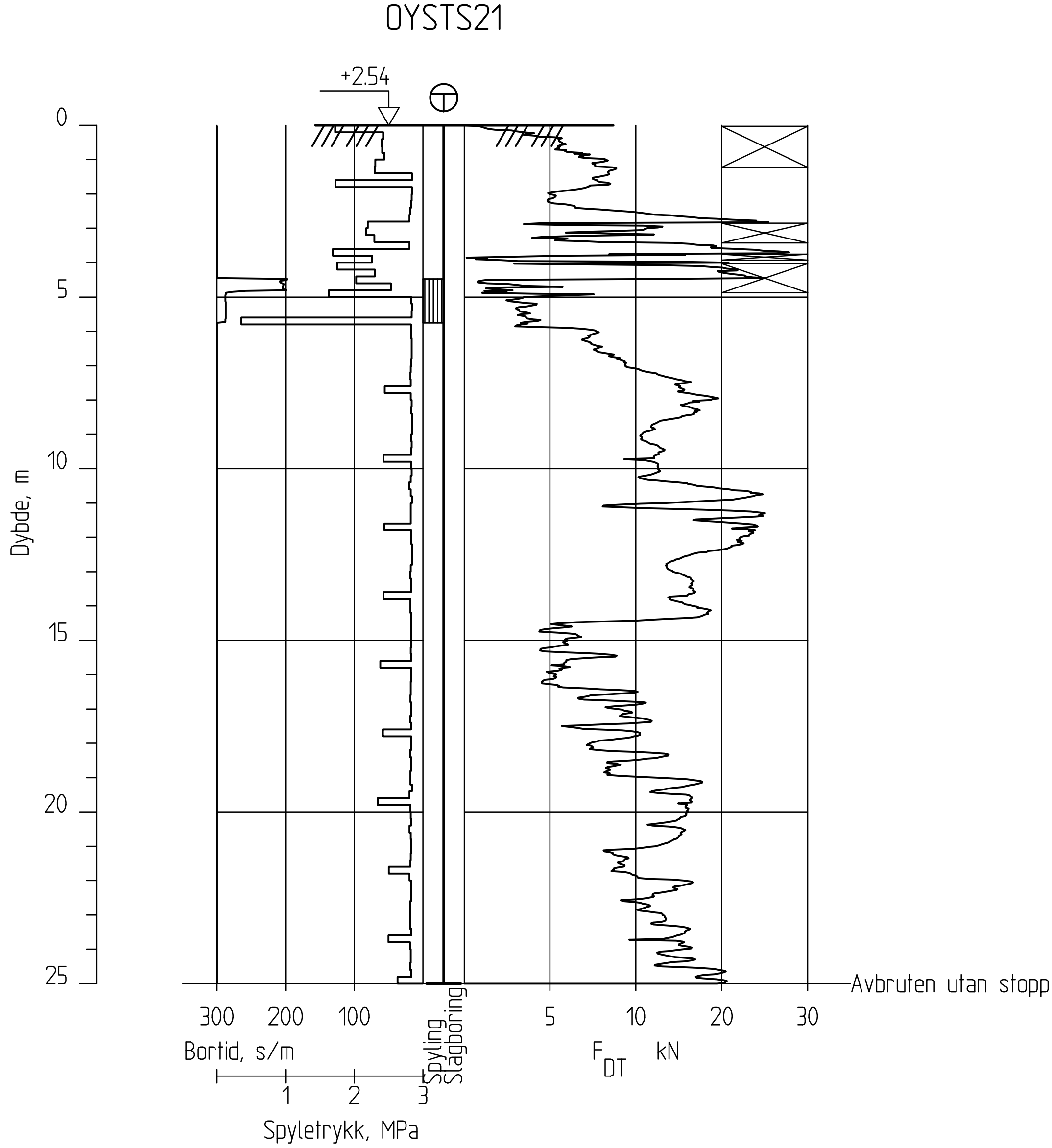

NGTS-Oysand

Totalsondering
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Dato boret :18.04.2017

Rapport nr.		
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Tegn. AGu	Kontr. JSL	Godkj. JSL

NGTS

Kalibreringsskjema.

GEOSAFE
SPESIALFIRMA I GEOTEKNISK FELTUTSTYR

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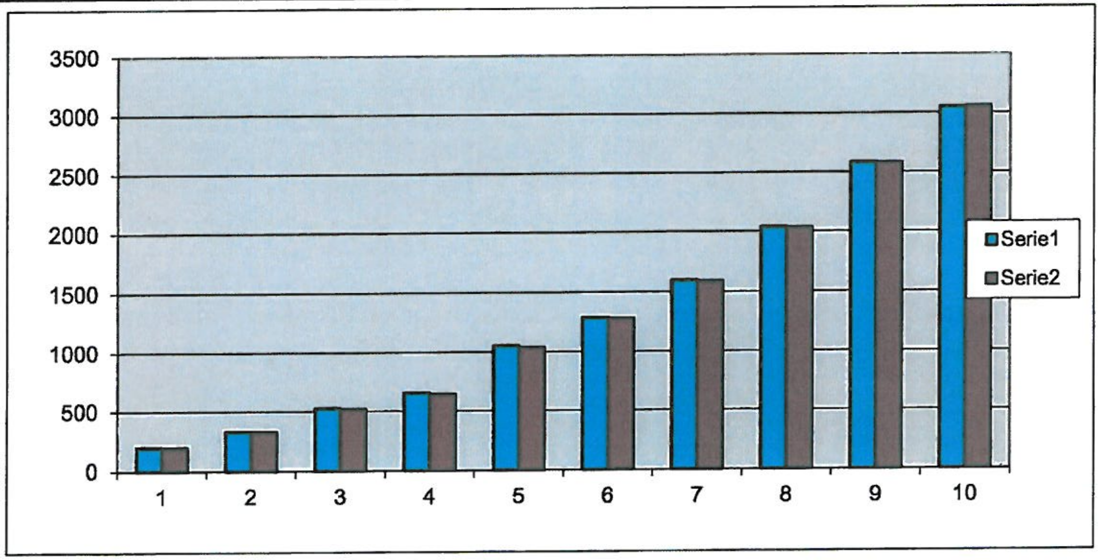


Attestert: Paul Venås

GeoSafe AS

Appendix H

PIEZOCONE PENETRATION TESTS & SEISMIC
PIEZOCONE PENETRATION TESTS

Contents

H1 Method

Cone Penetration Tests and Seismic Cone Penetration Tests are used for a more accurate determination of soil layering. The results may also be used to interpret approximate soil parameters.

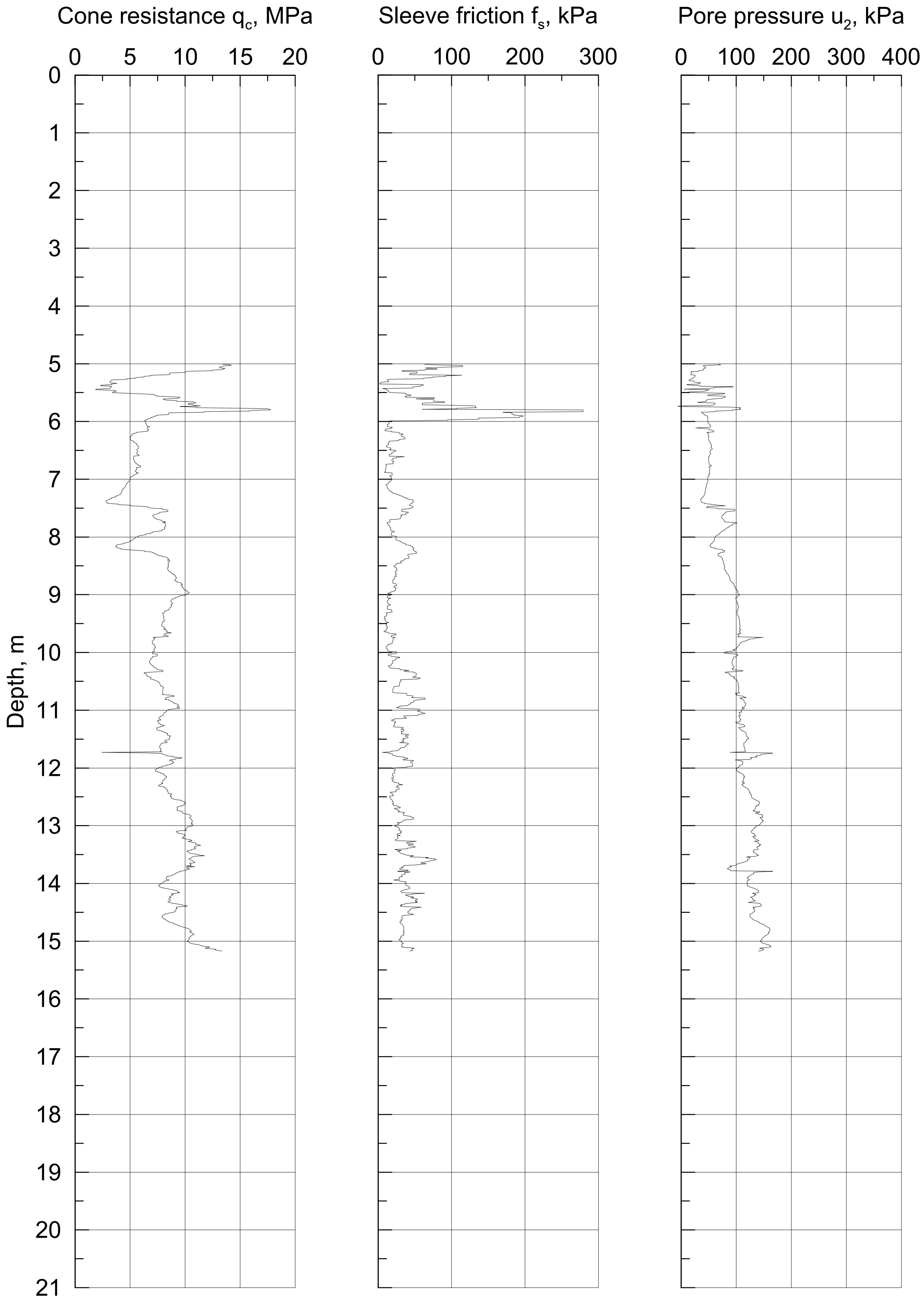
H2 Results

The results from the CPTU and SCPTU soundings are plotted in Figures C1 through C38.

H3 References

[1] Norsk Geoteknisk Forening, "Veiledning for utførelse av trykksondering - Melding nr. 5," 1982, Rev. nr. 3, 2010.

[2] Statens vegvesen, "Håndbok R211 - Feltundersøkelser," Statens vegvesen, 2014.



Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC01

Document No. 20160154-08-R	
Figure No. C1	
Date 2017-05-16	Drawn by AGu

NGTS

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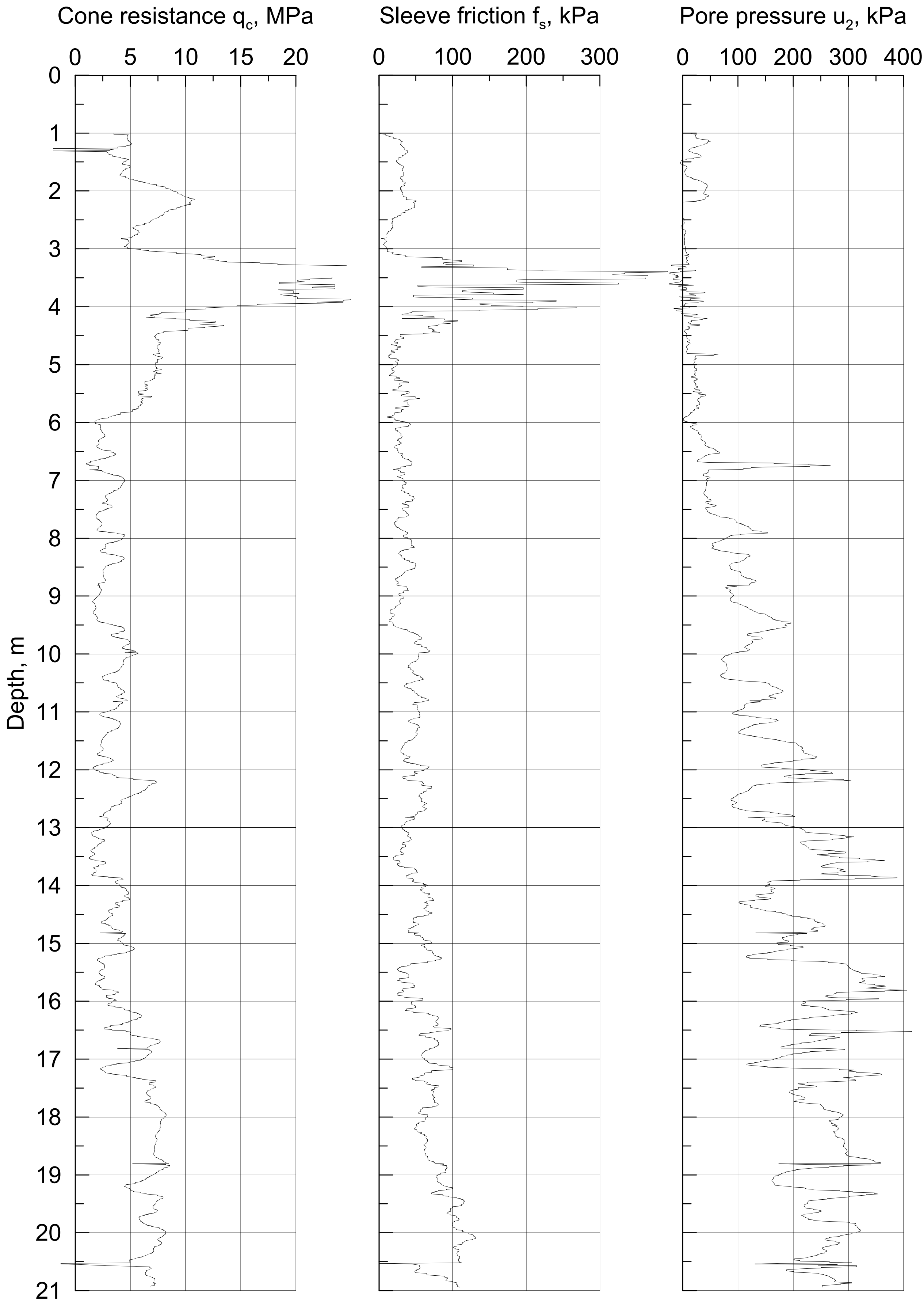

Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC02

Document No.	
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Date	Drawn by
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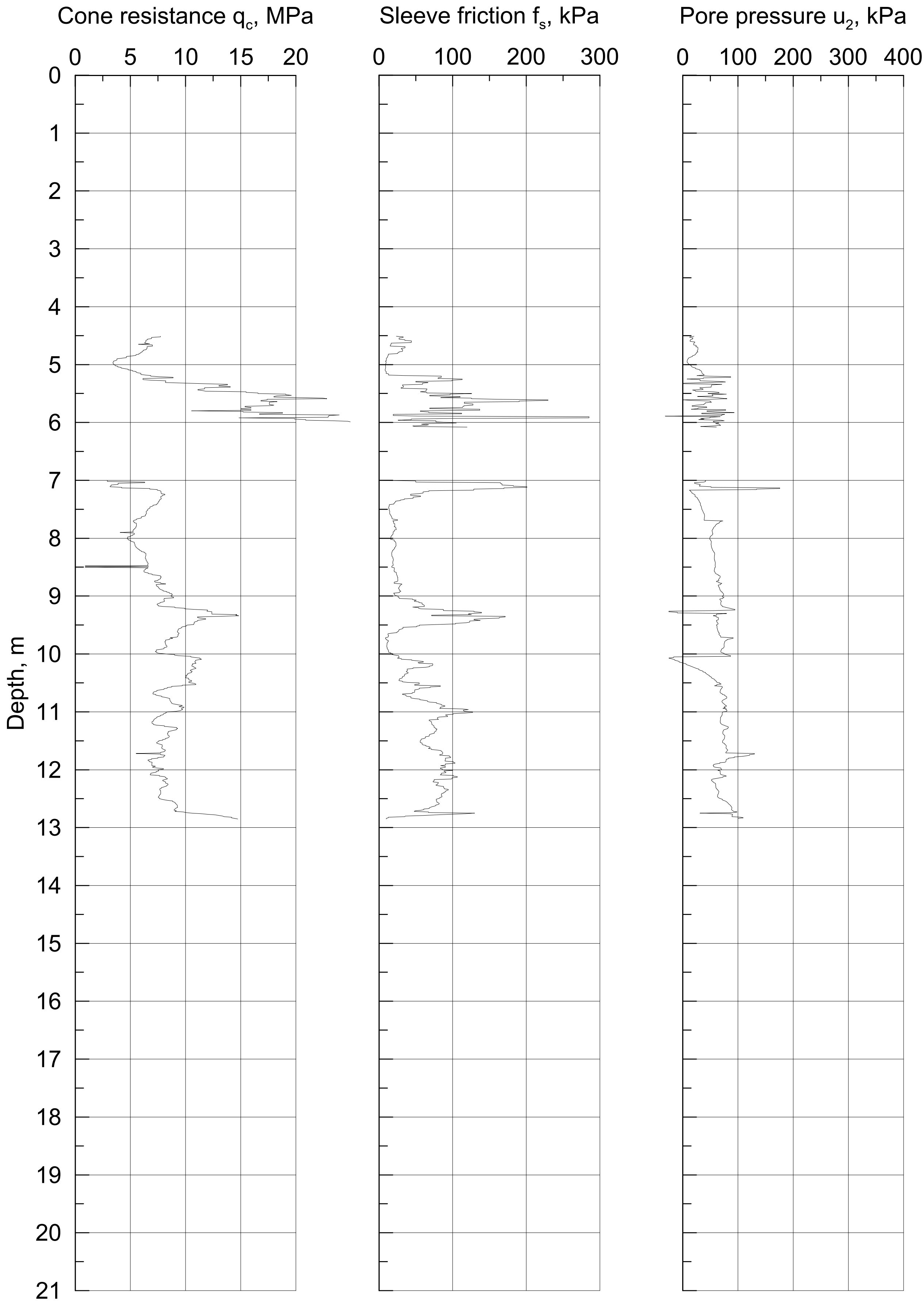

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Date/Rev.: 2015-01-21/01

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OYSC03	Date 2017-05-16 / Drawn by AGu
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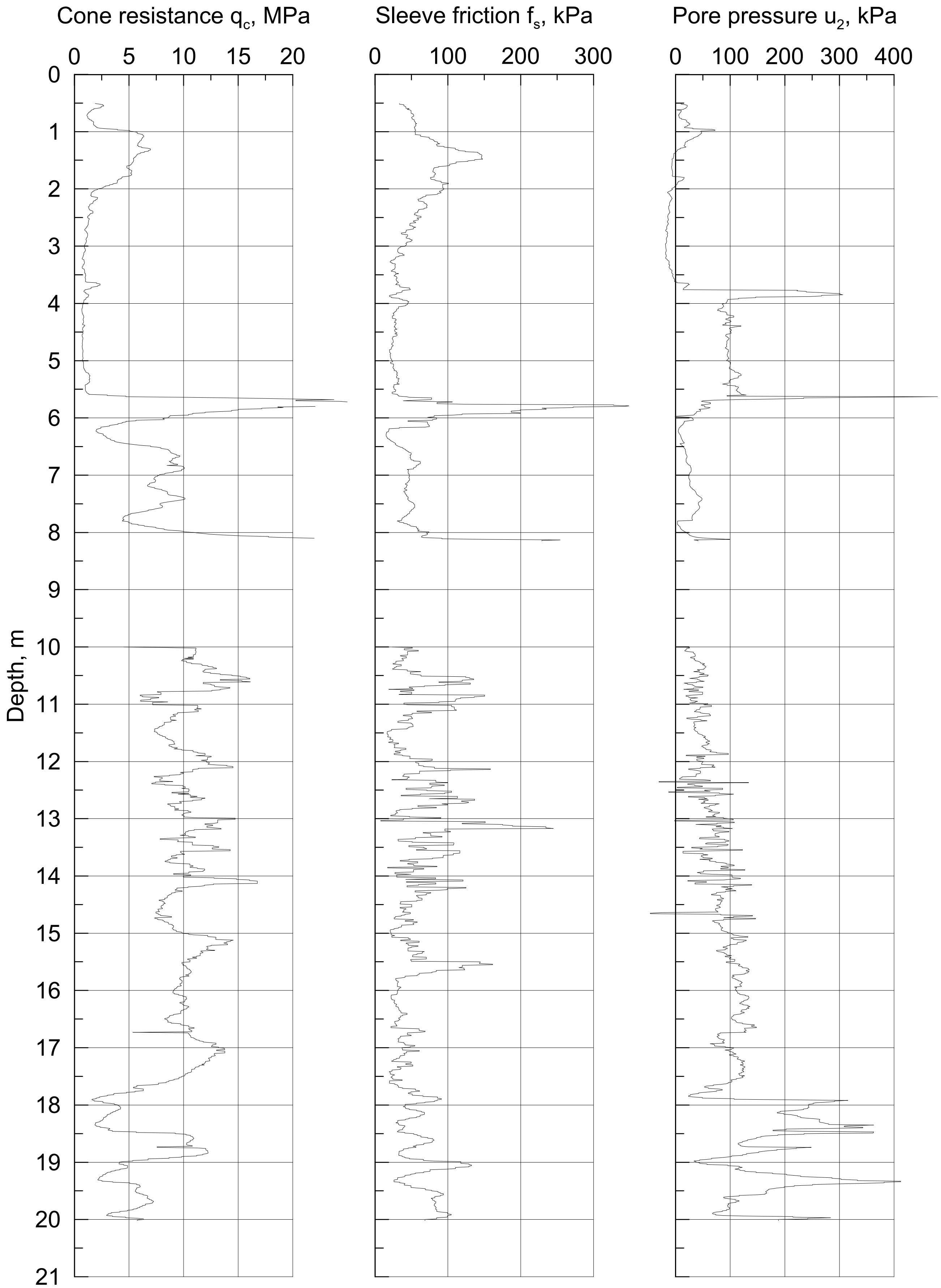

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Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
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OYSC07	Date 2017-05-16 / Drawn by AGu
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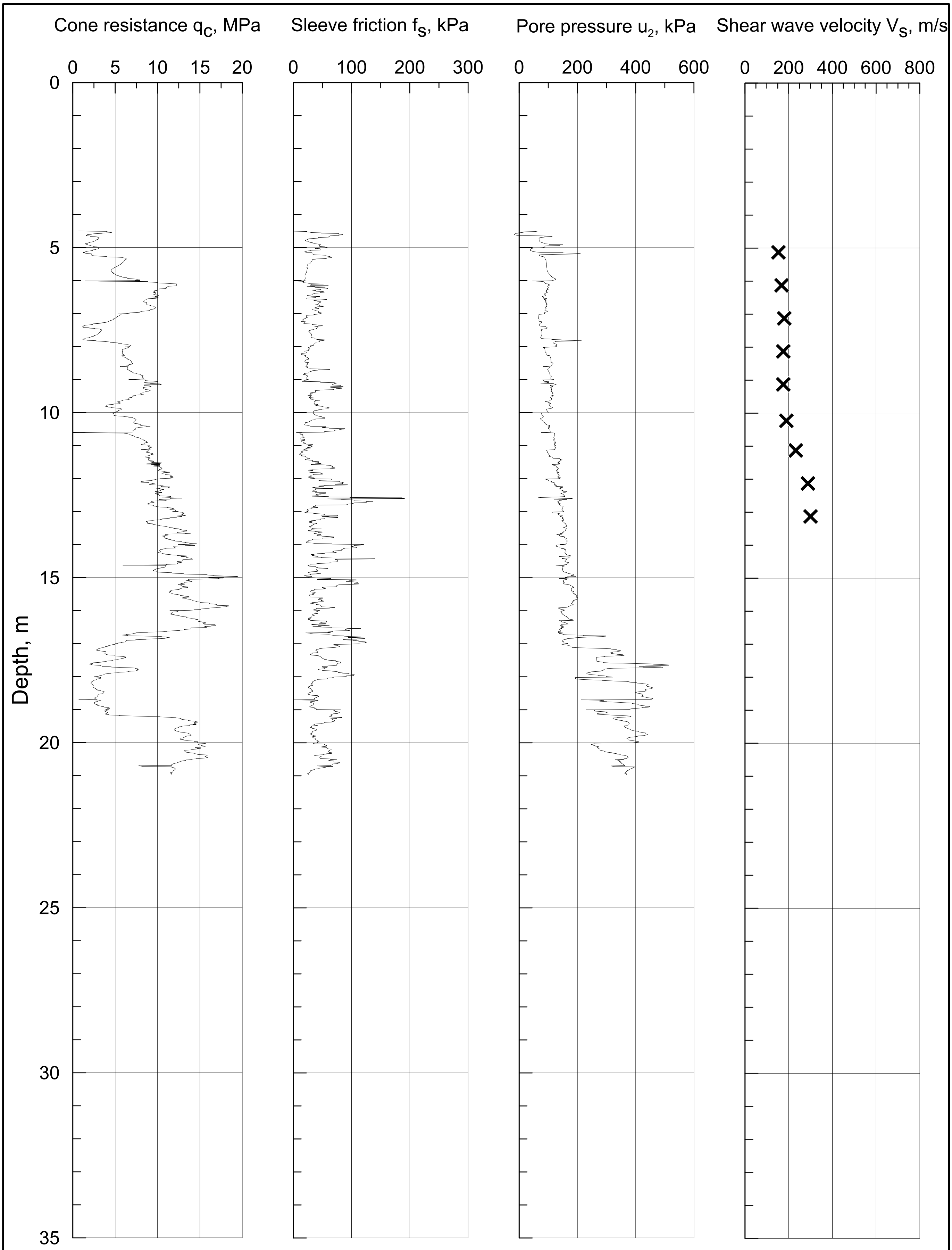

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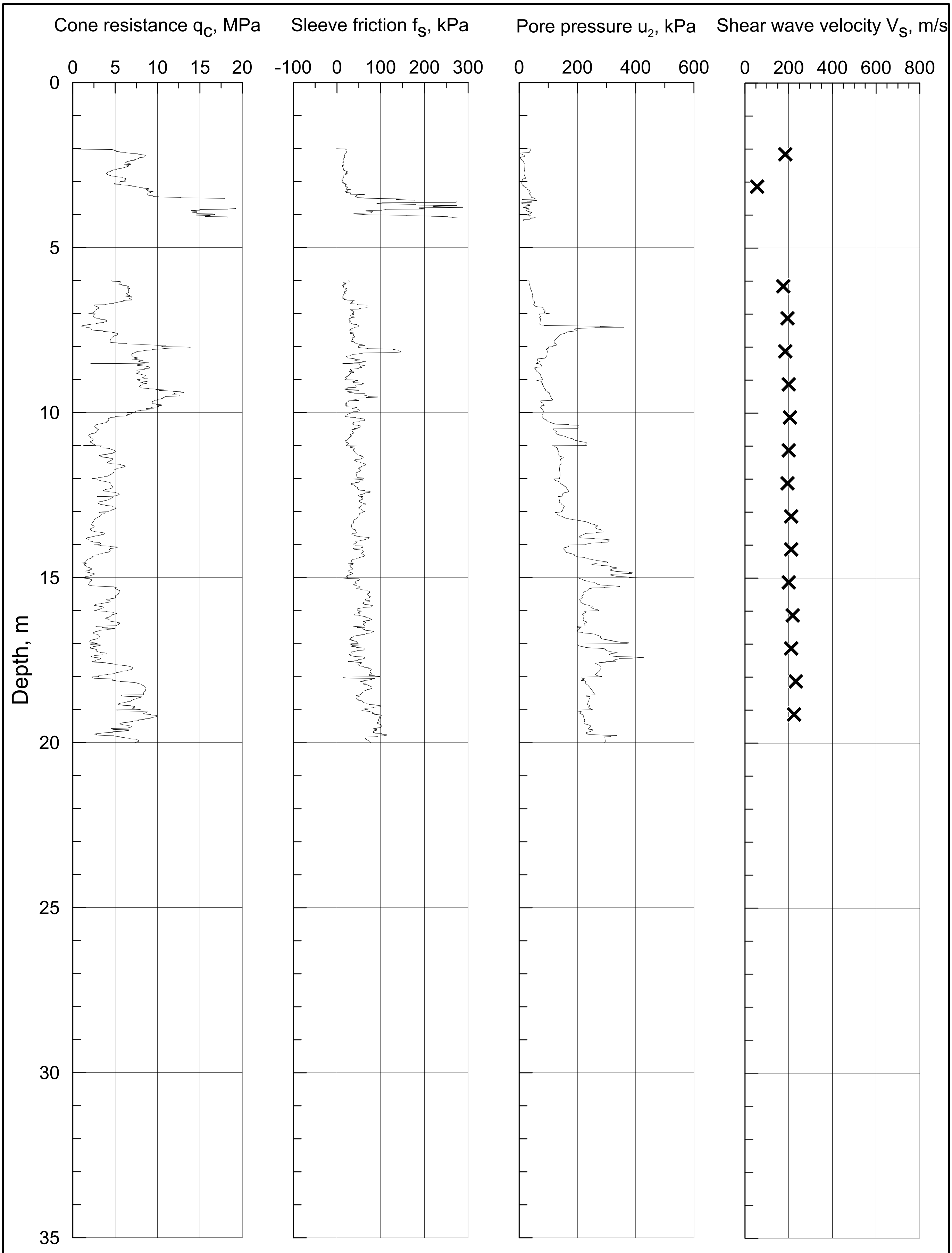
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

q_c, f_s, u_2 and V_s from SCPTU tests

OYSC08

Document No.	20160154-08-R
Figure No.	C5
Date	2019-03-12
Drawn by	AnL



Date/Rev.: 2015-01-21/01

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NGTS - Øysand Research Site	Document No. 20160154-08-R
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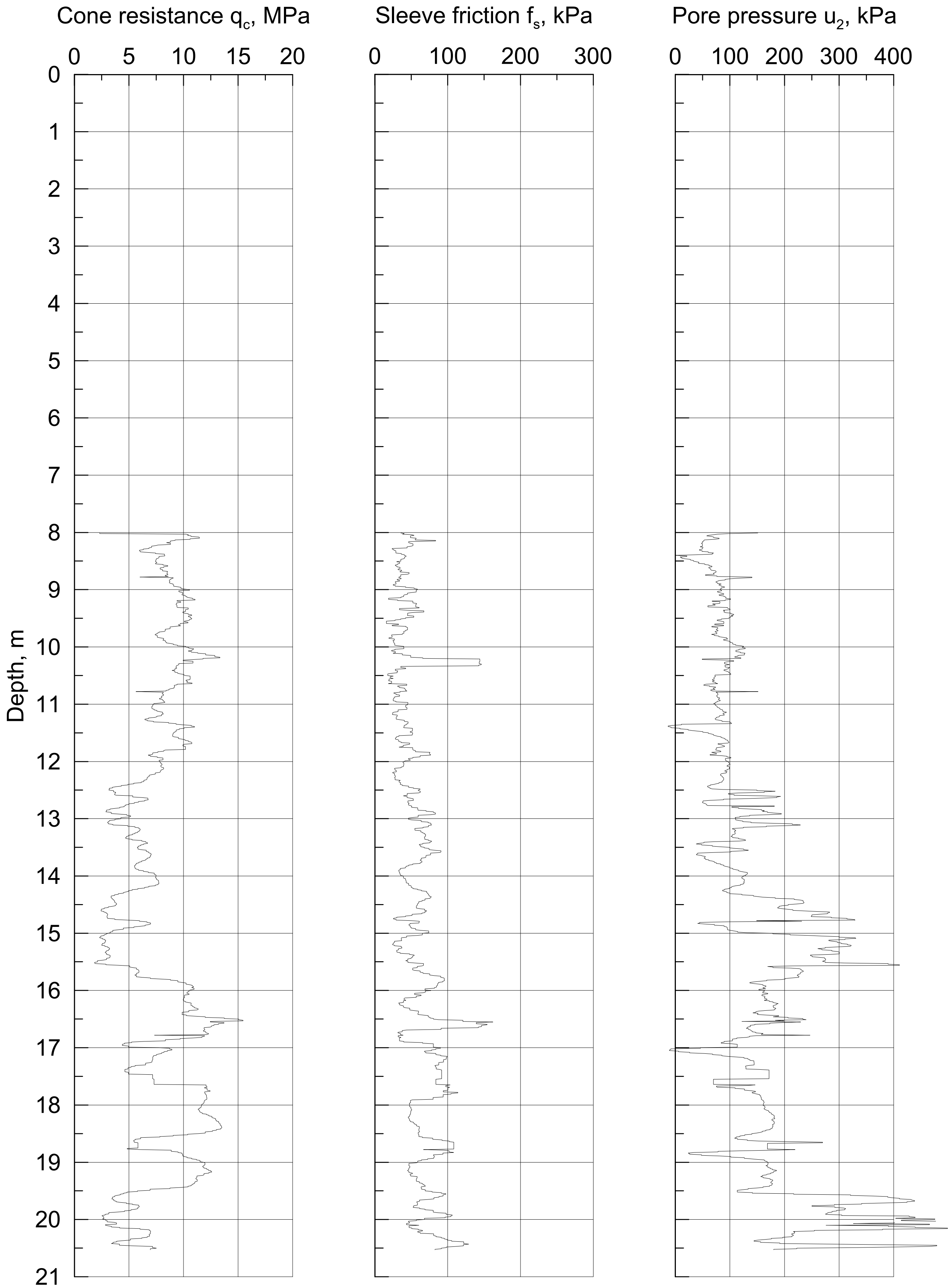
OYSC09	Date 2019-03-12 / Drawn by AnL

NGTS



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Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
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OYSC10	Date 2017-05-16 / Drawn by AGu
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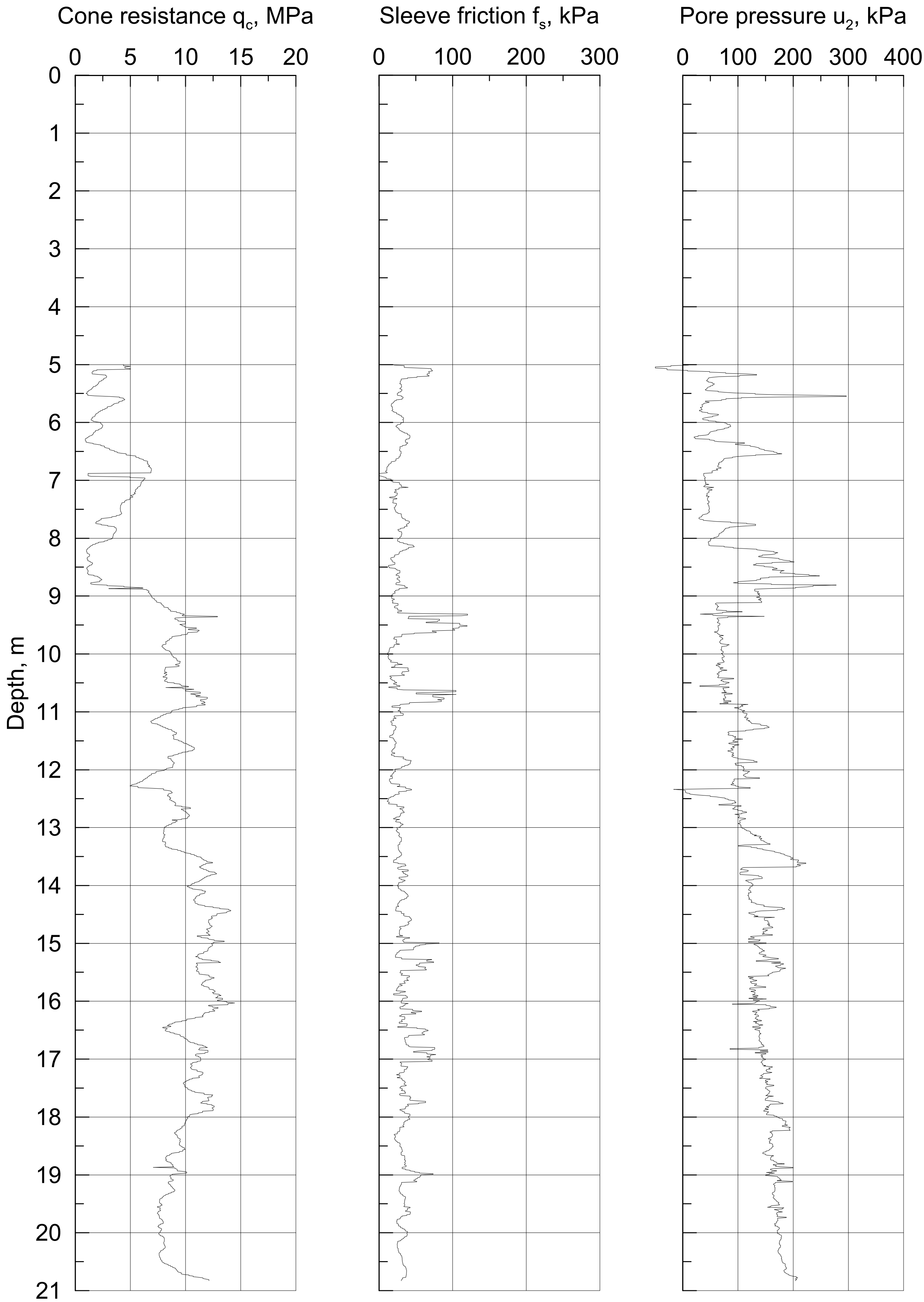

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Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
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	Date 2017-05-16 — Drawn by AGu
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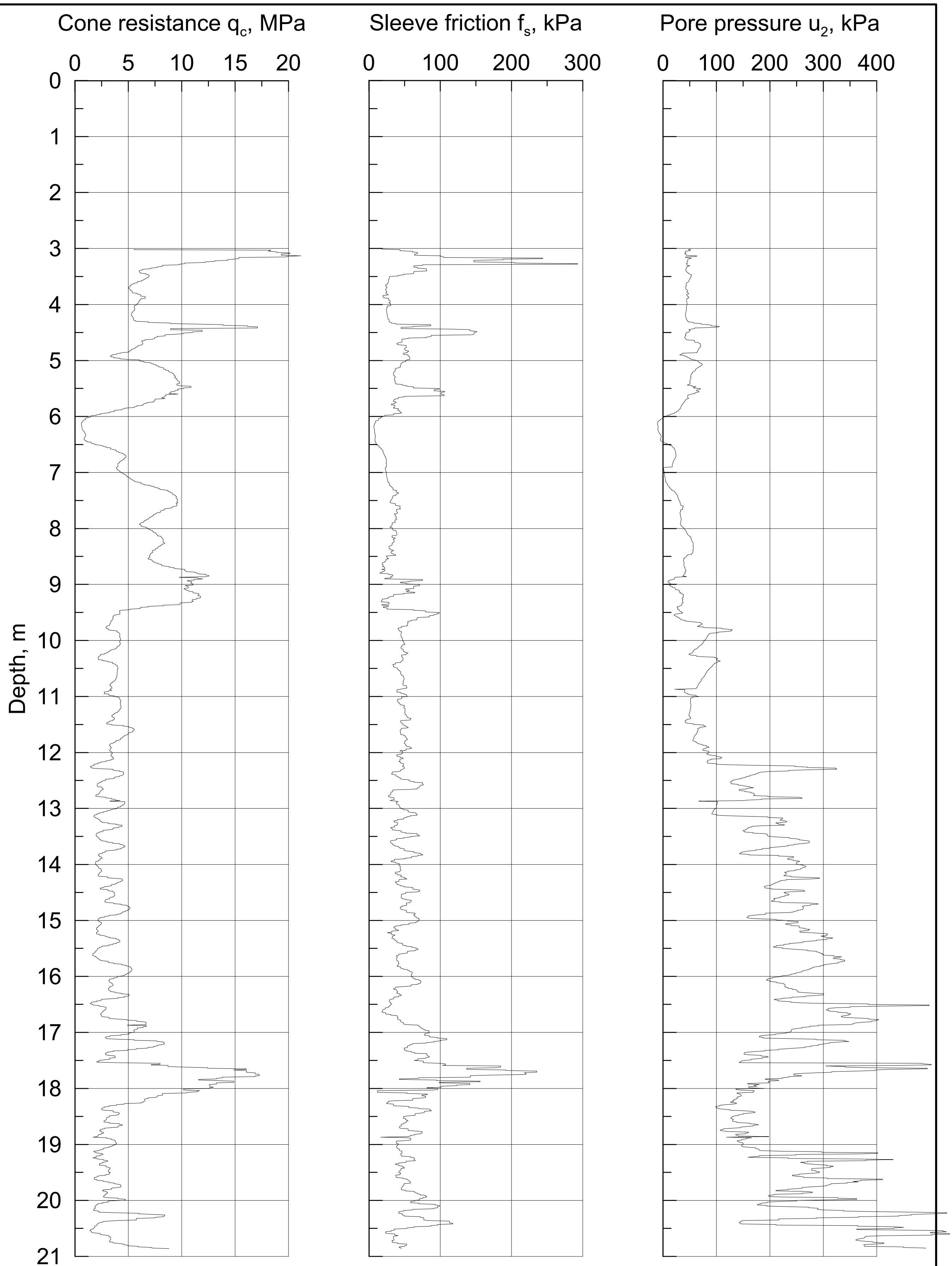

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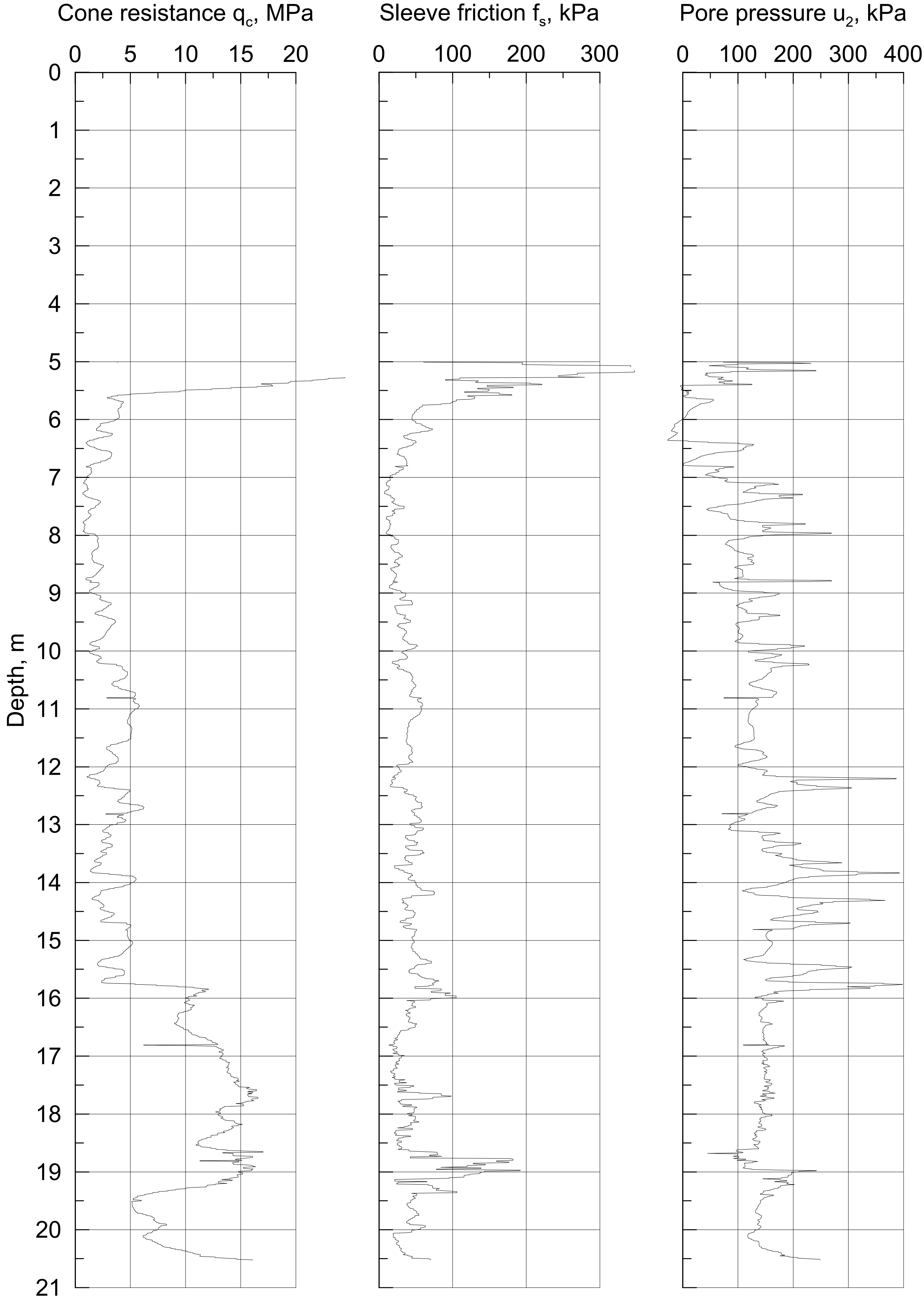

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Date/Rev.: 2015-01-21/01

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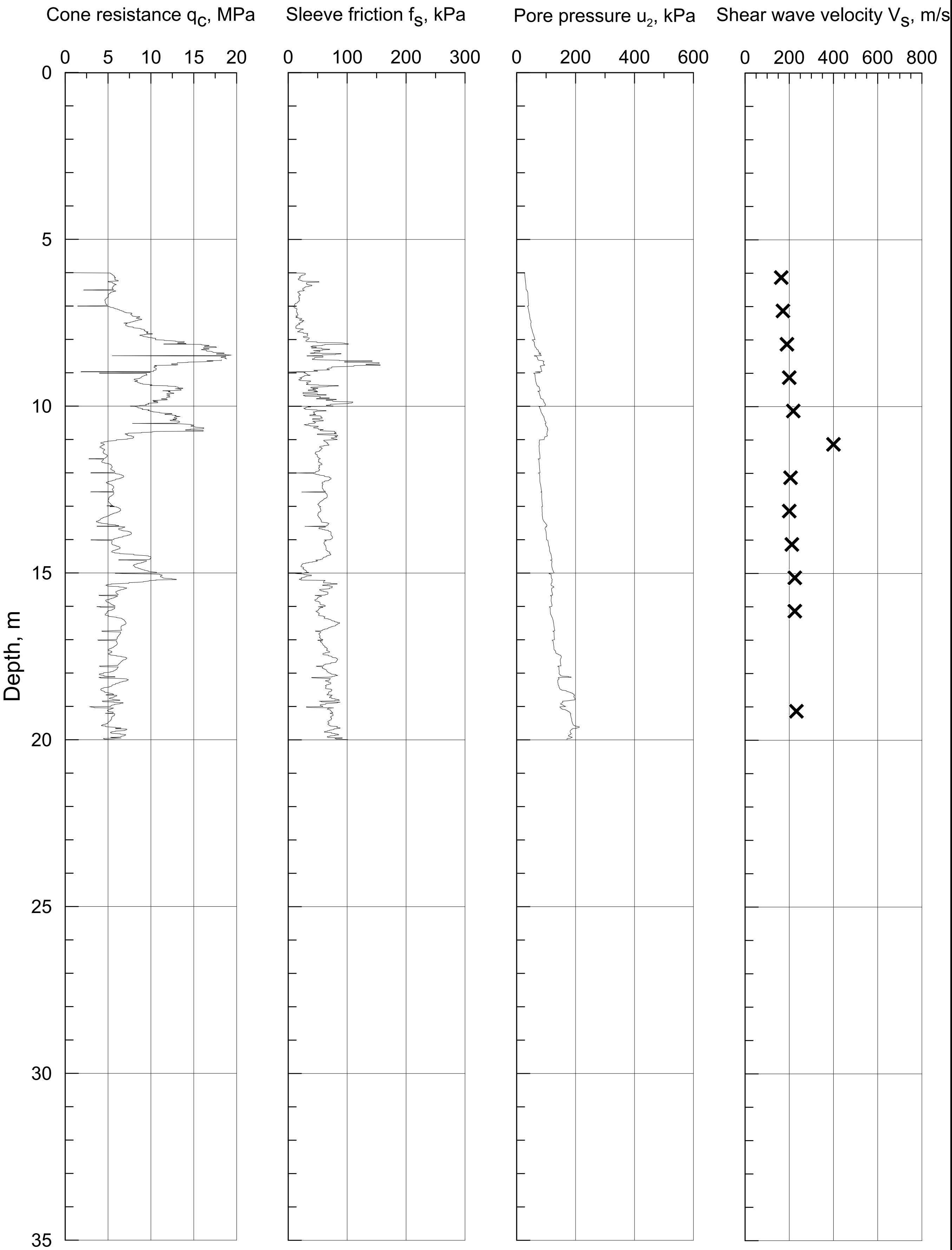

Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

q_c, f_s, u_2 and V_s from SCPTU tests

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Date	Drawn by
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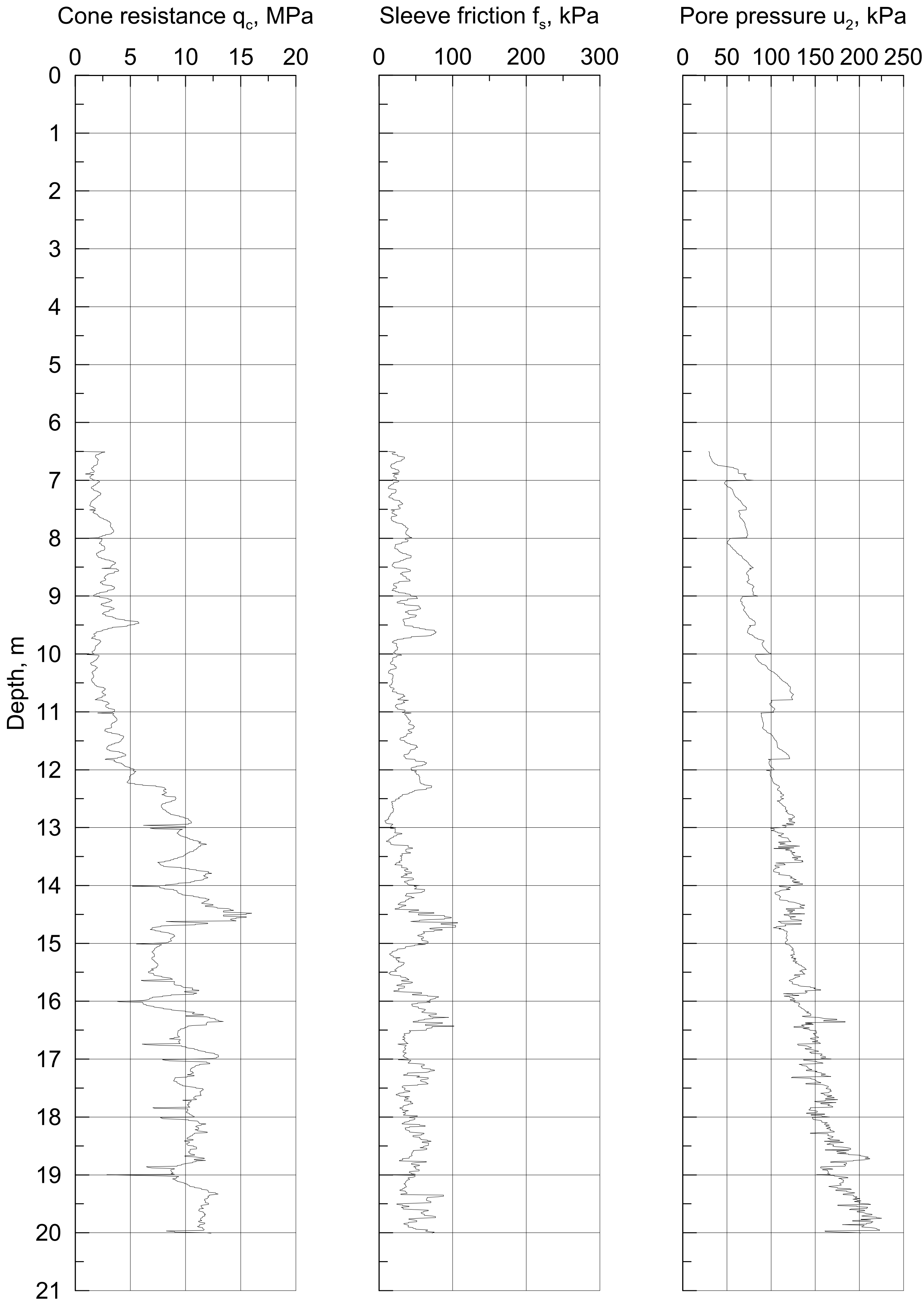


Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

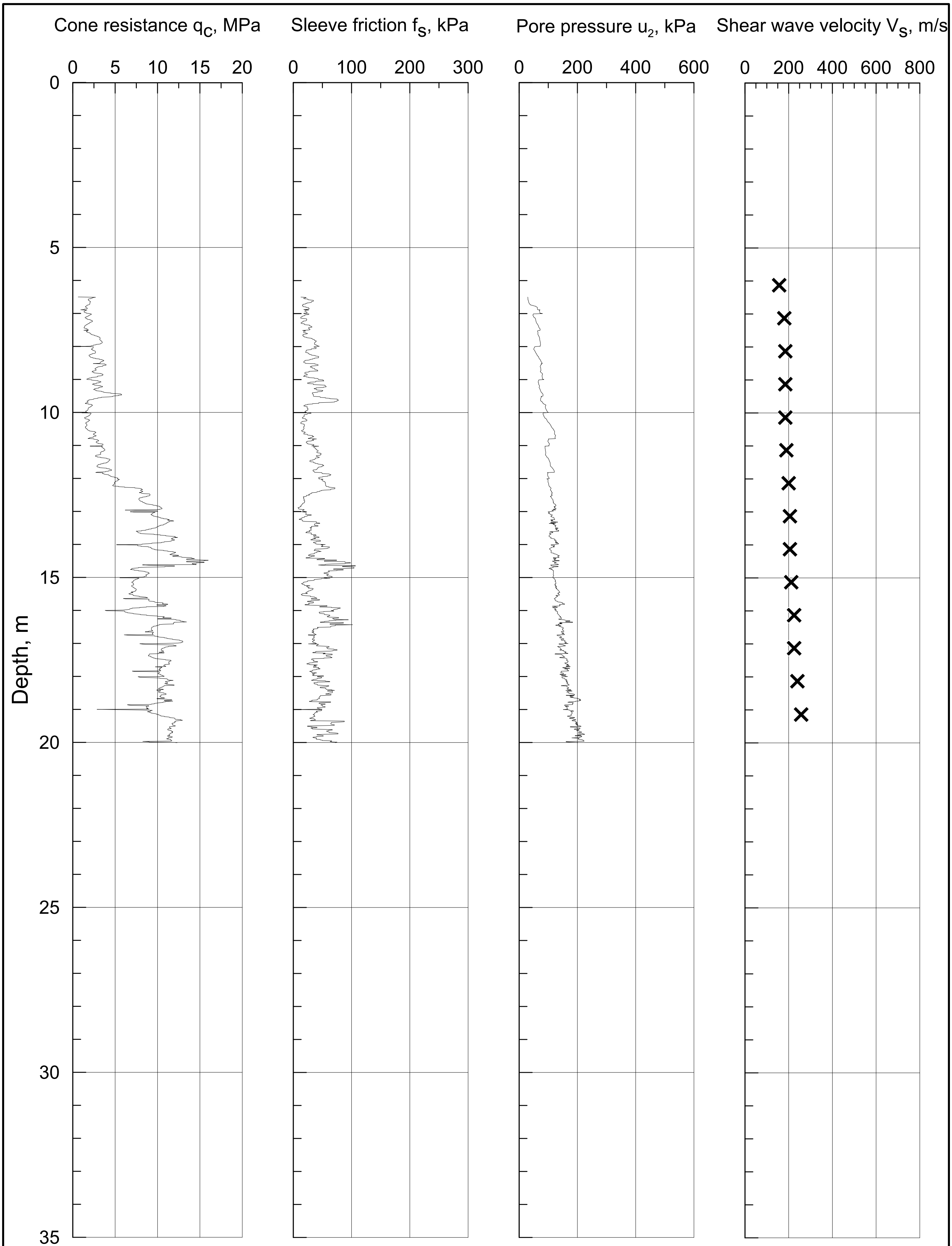
q_c, f_s and u_2 from CPTU tests

OYSC20

Document No. 20160154-08-R	
Figure No. 30.2000	
Date 2017-05-16	Drawn by AGu

NGTS

P:\2016\01\20160154\Leveranse dokumenter\Publikasjoner\ECSMGE 2019\Characterization Tiller site\FIGURE-C10_OYSC20_qc_fs_u2.grf



Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

q_c, f_s, u_2 and V_s from SCPTU tests

OYSC20

Document No.	20160154-08-R
Figure No.	C12
Date	2019-03-12
Drawn by	AnL

NGTS

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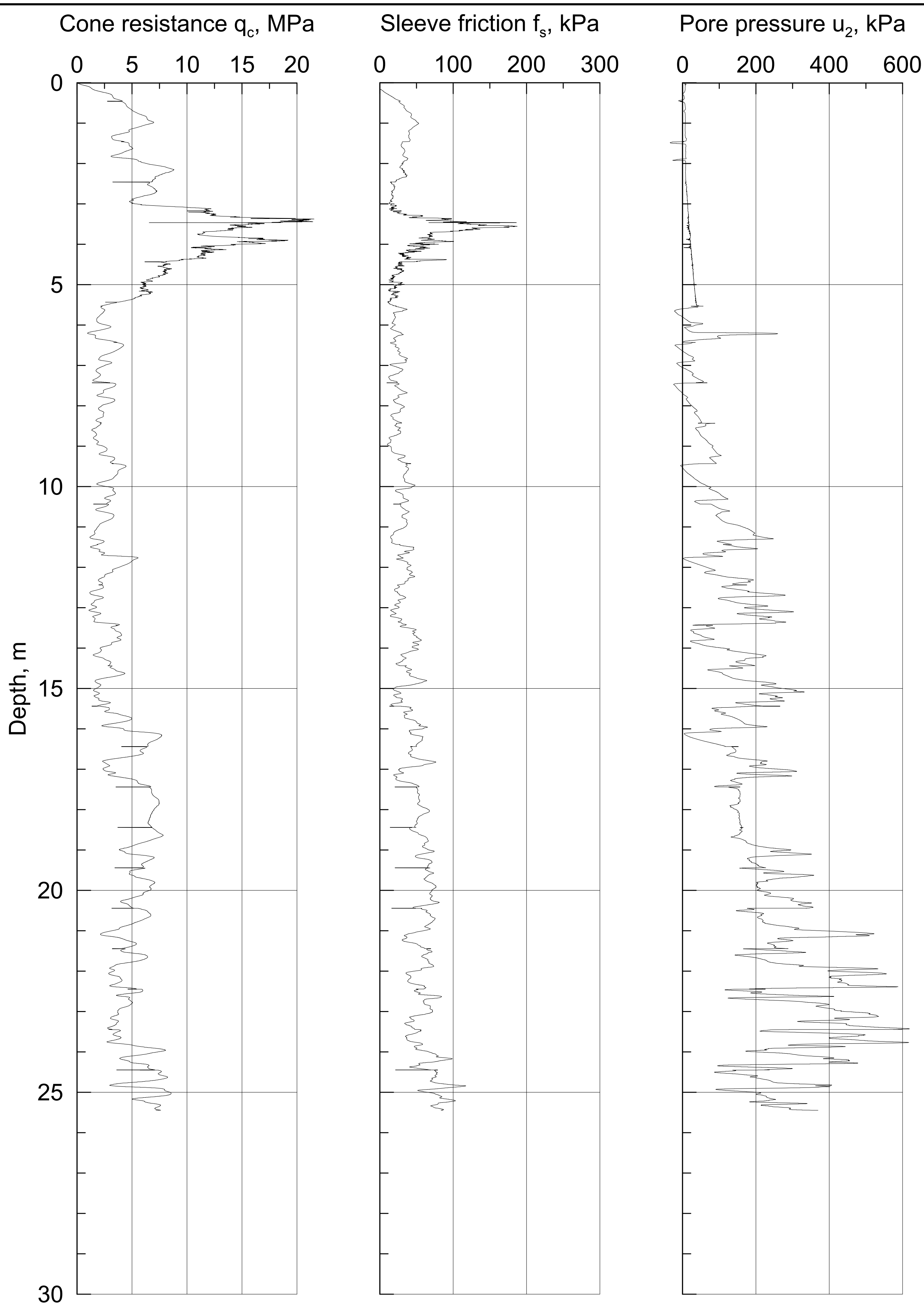
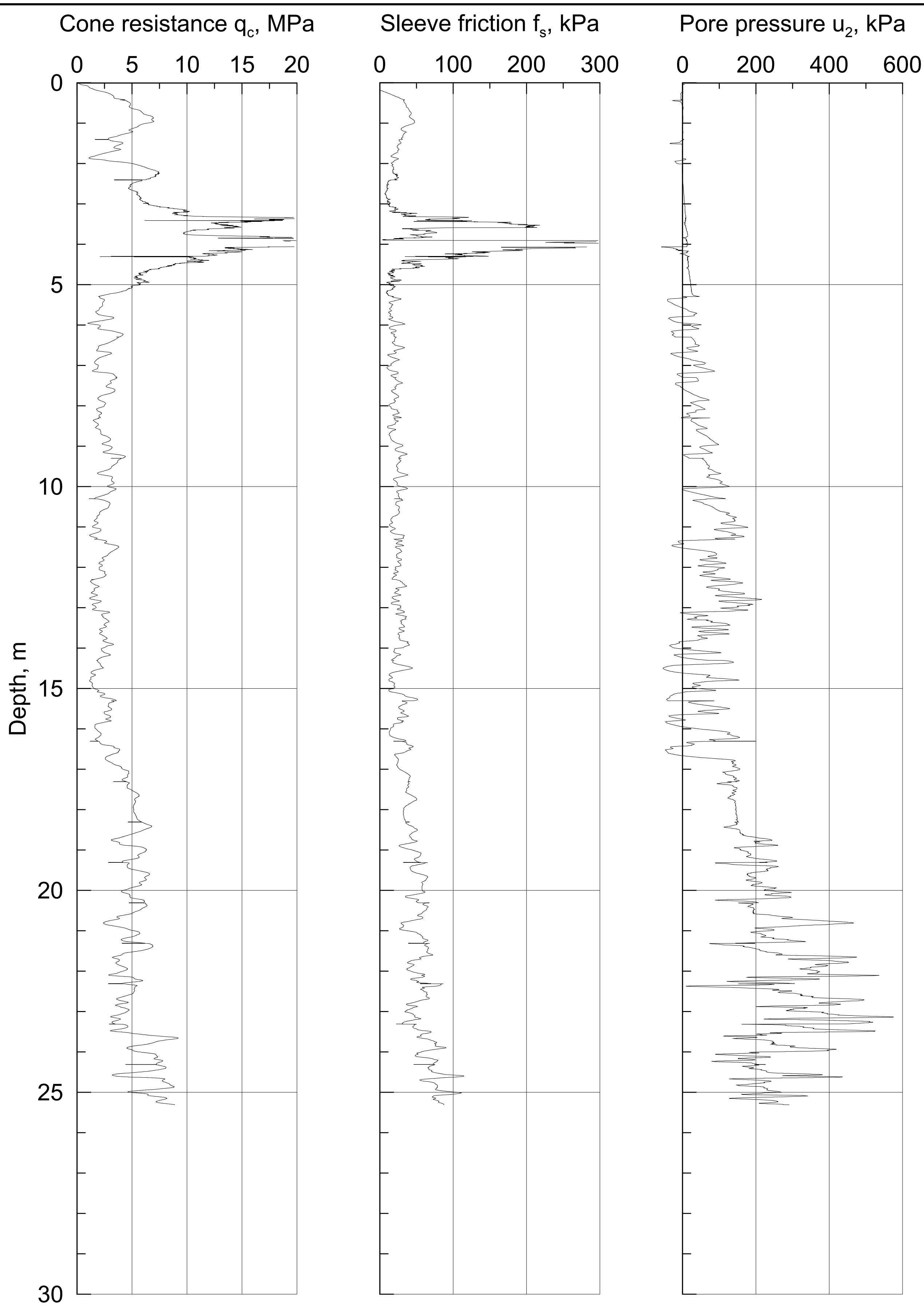


NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C13
	Date 2017-11-27 / Drawn by AnL
OYSC21	NGTS



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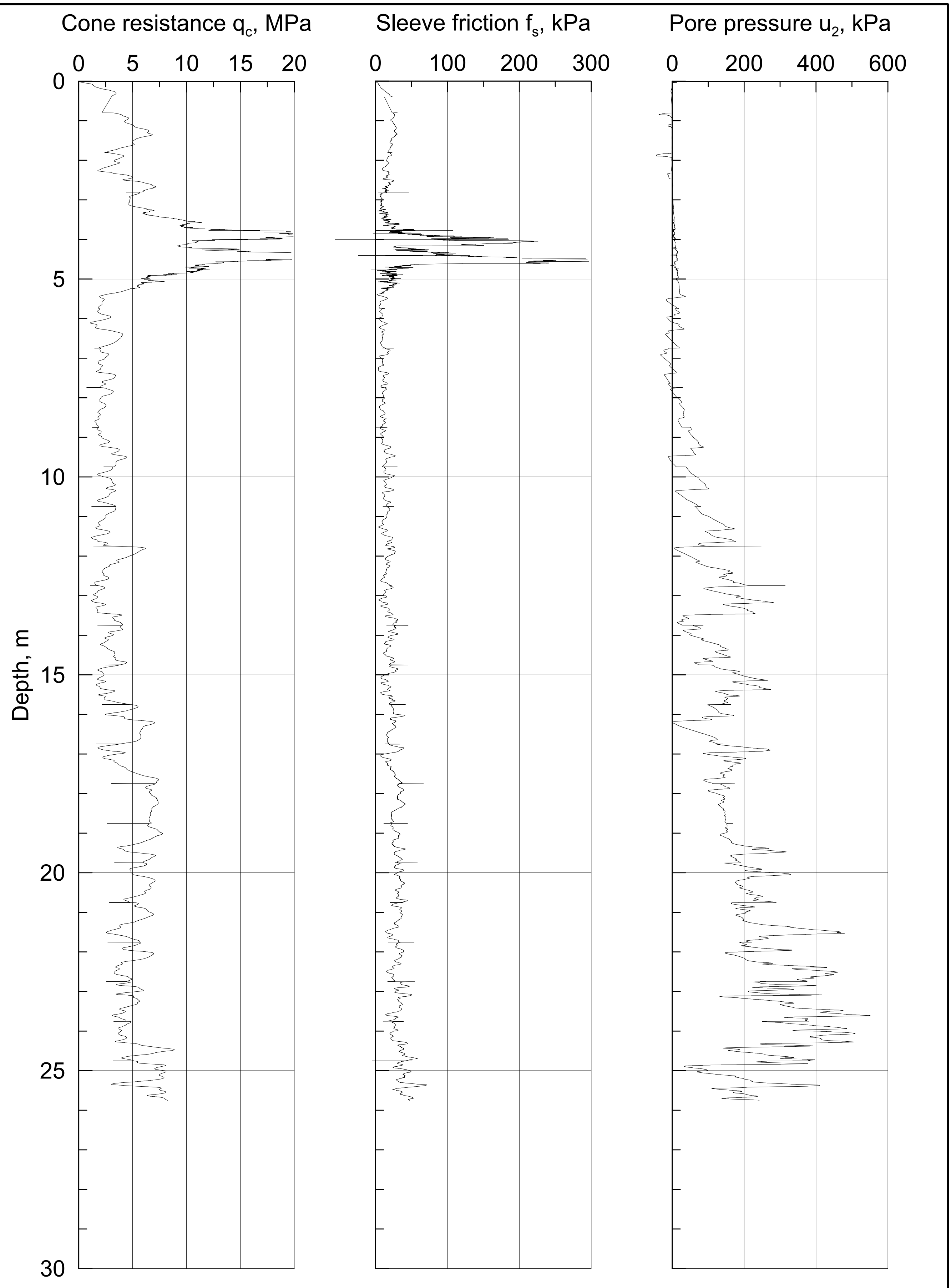
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C14
OYSC22	Date 2017-11-27 / Drawn by AnL

NGTS



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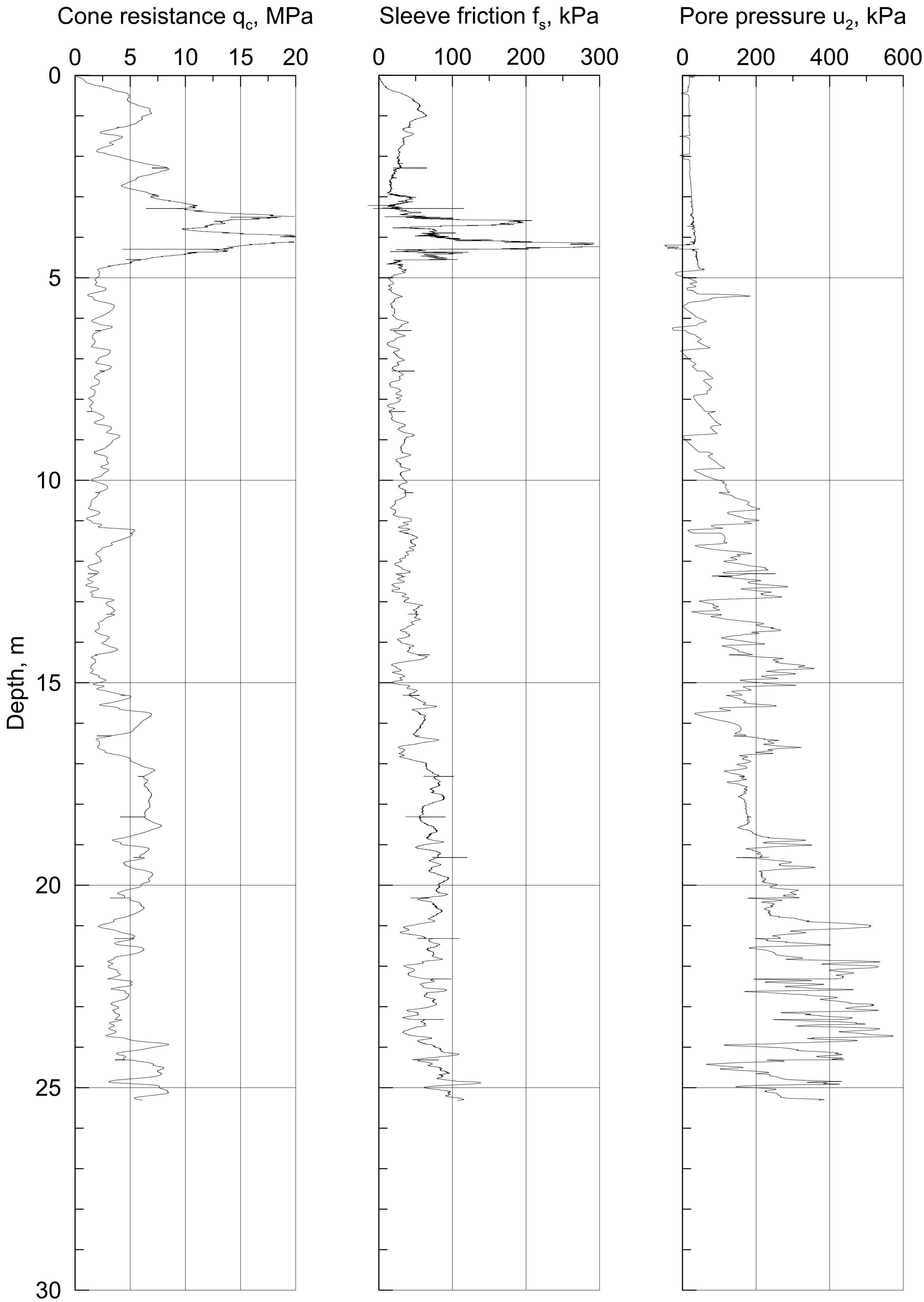
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C15
OYSC23	Date 2017-11-27 / Drawn by AnL

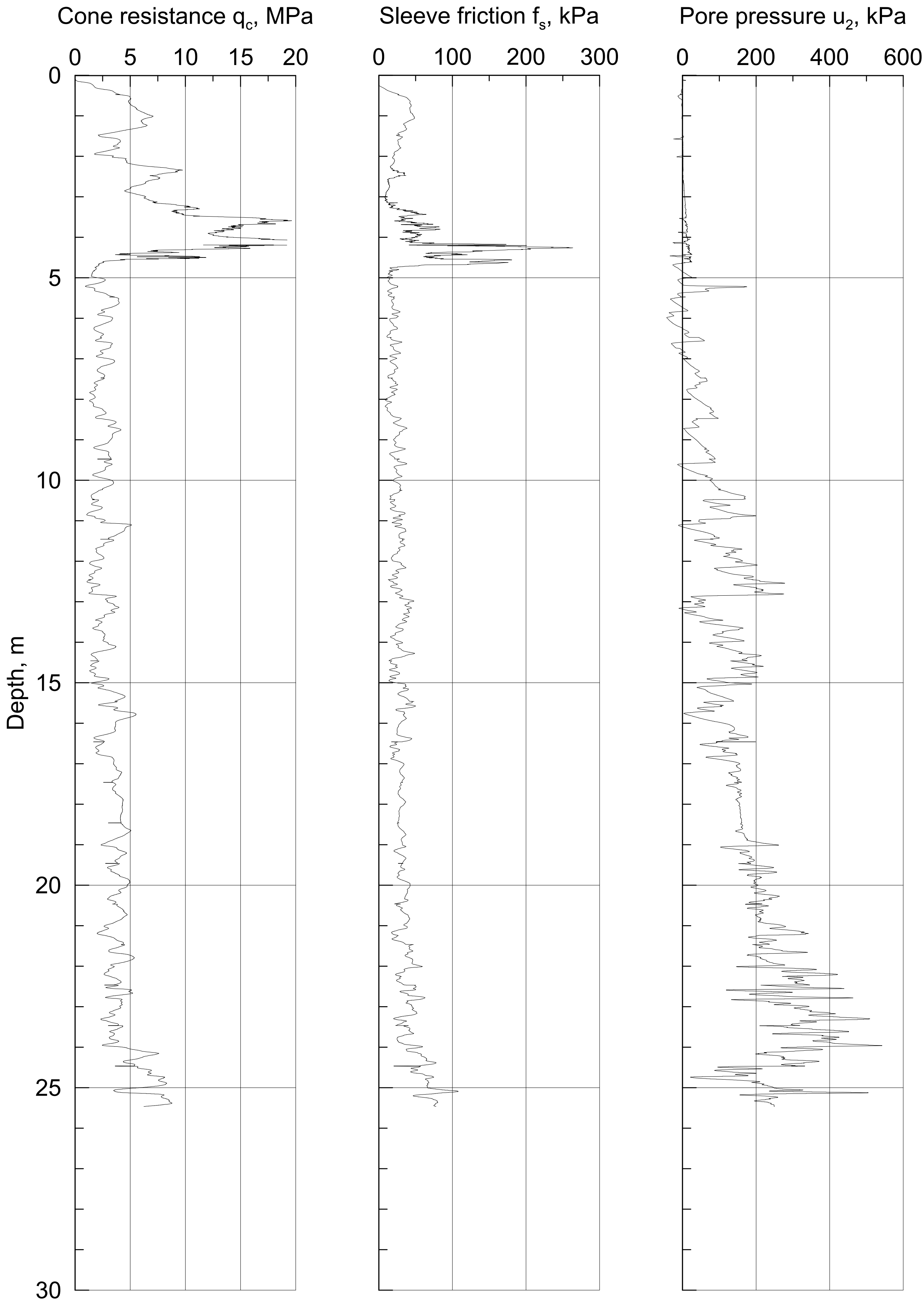
NGTS



Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R	
q_c, f_s and u_2 from CPTU tests	Figure No. C16	
OYSC24	Date 2017-11-27	Drawn by AnL

NGTS



Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC25

Document No.	20160154-08-R
Figure No.	C17
Date	2017-11-27
Drawn by	AnL

NGTS

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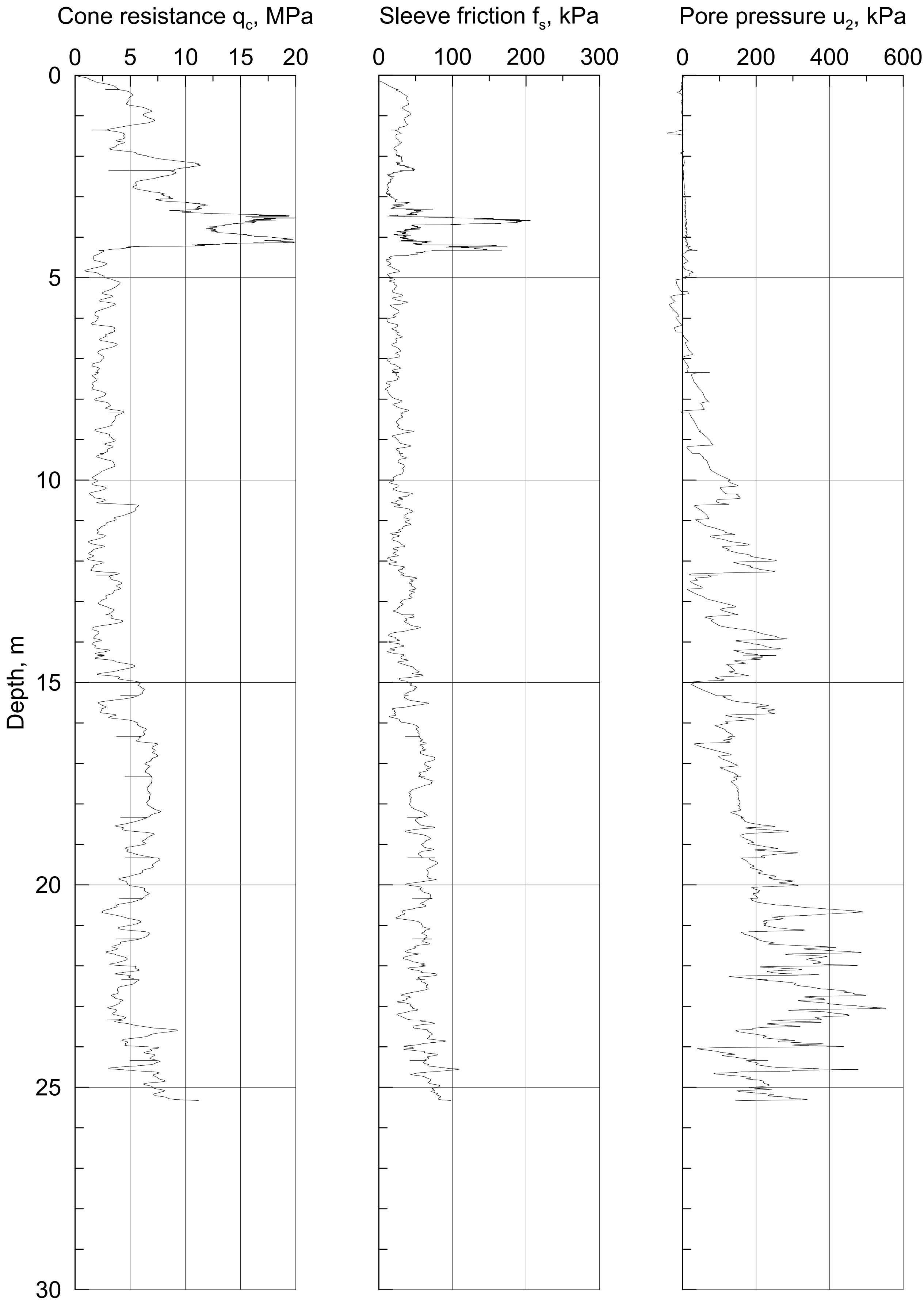

Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C18
	Date 2017-11-27
	Drawn by AnL
OYSC26	NGTS

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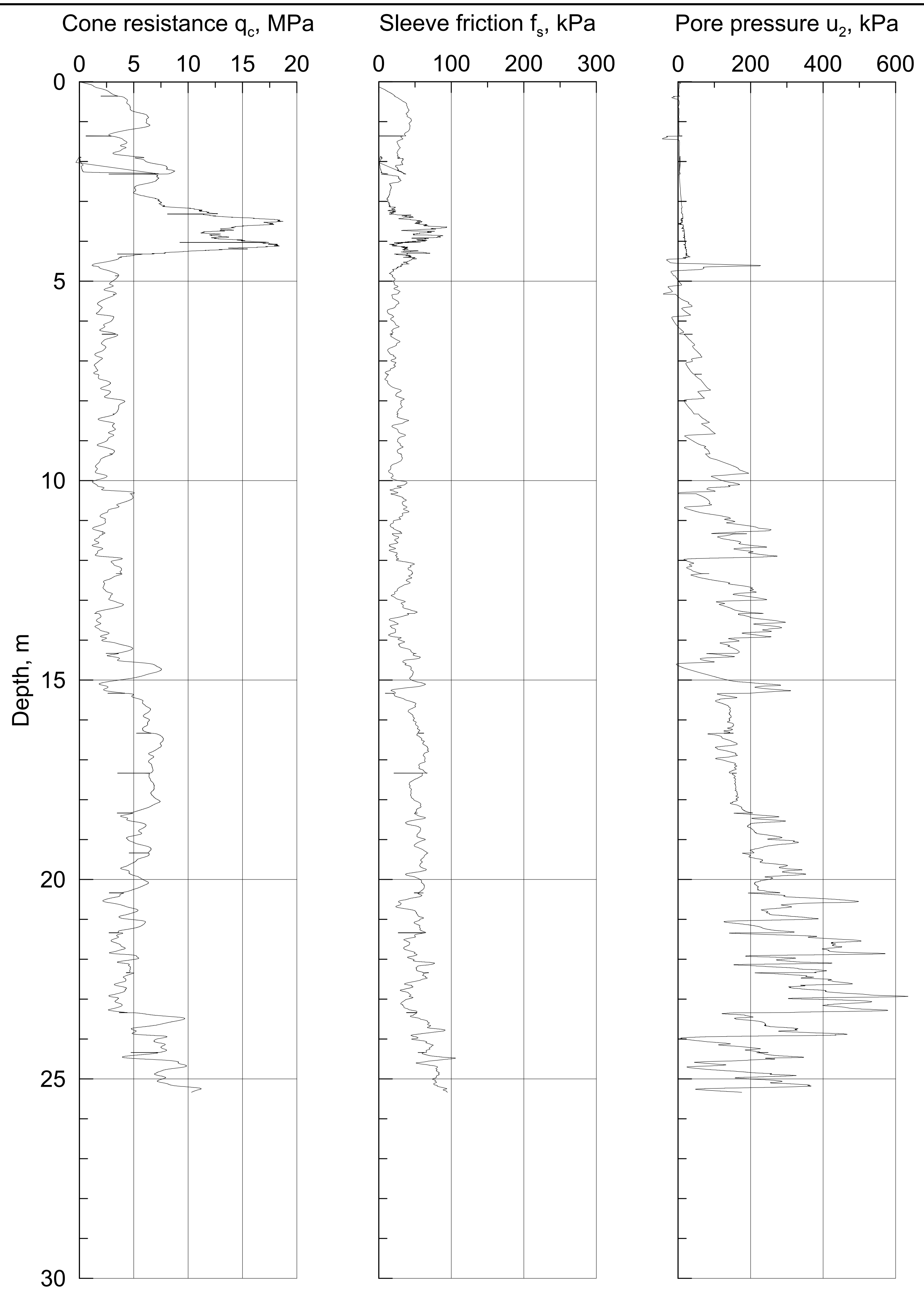

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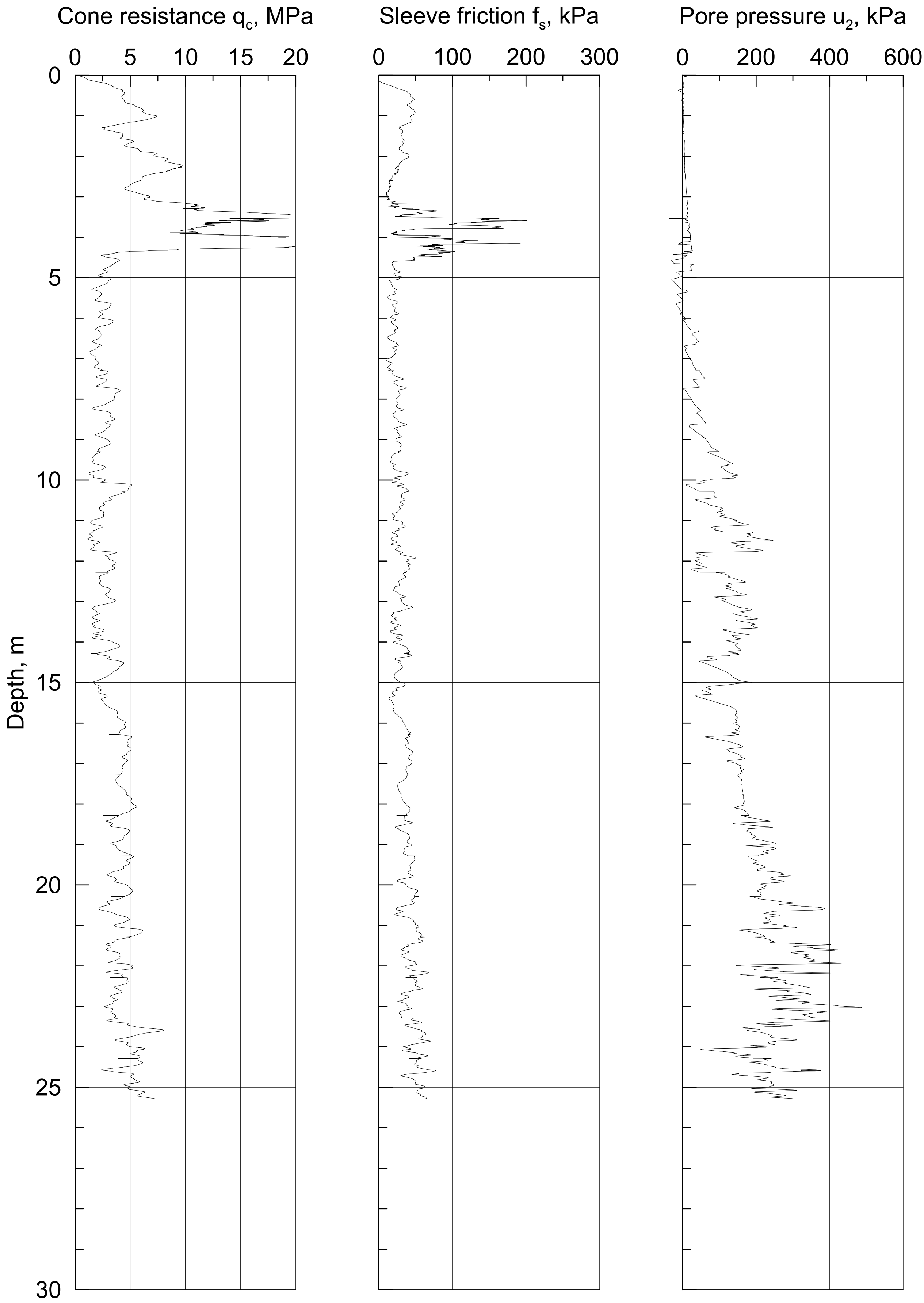
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C19
OYSC27	Date 2017-11-27 / Drawn by AnL

NGTS



Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC28

Document No.	20160154-08-R
Figure No.	C20
Date: 2017-11-27	Drawn by: AnL

NGTS

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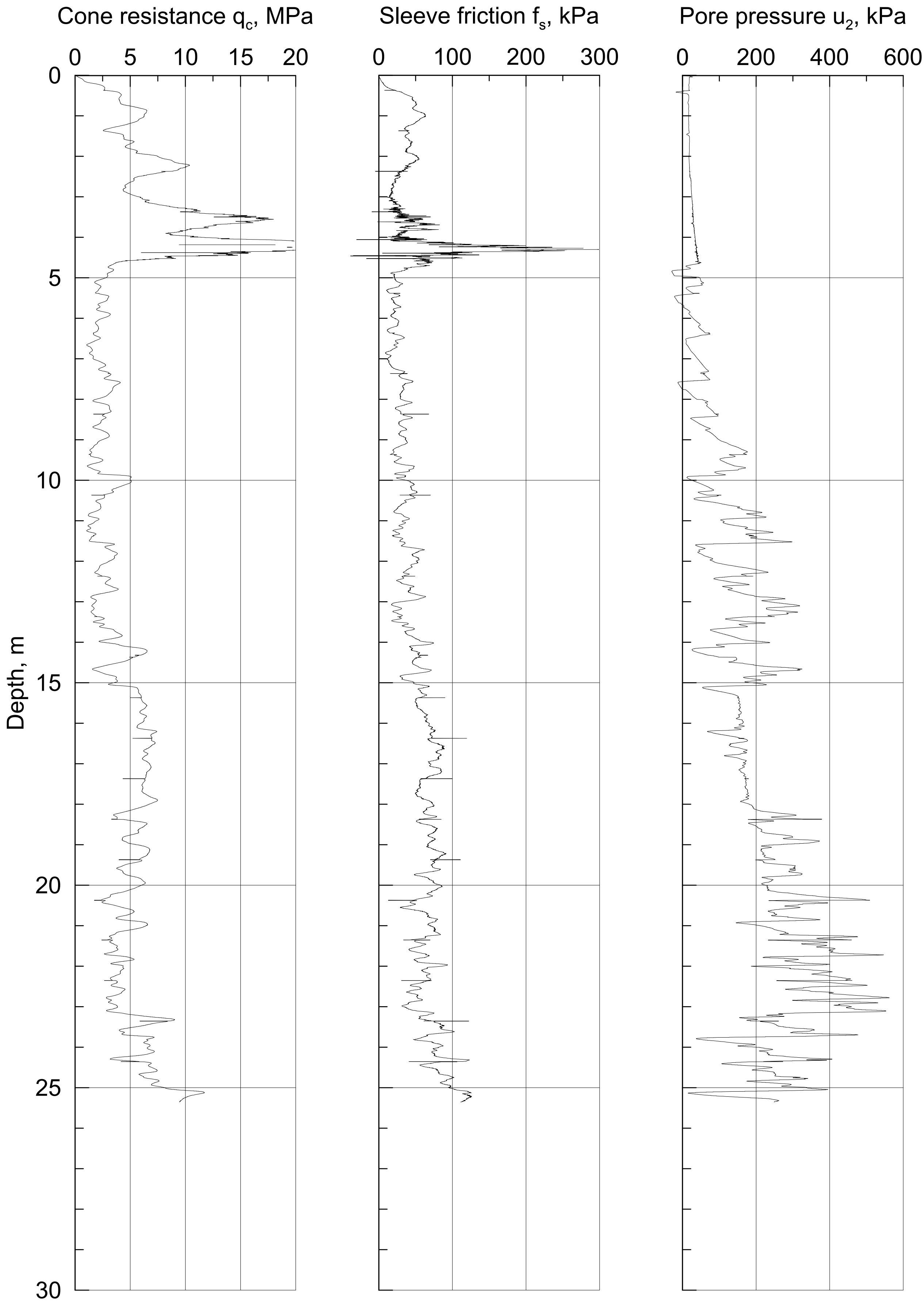

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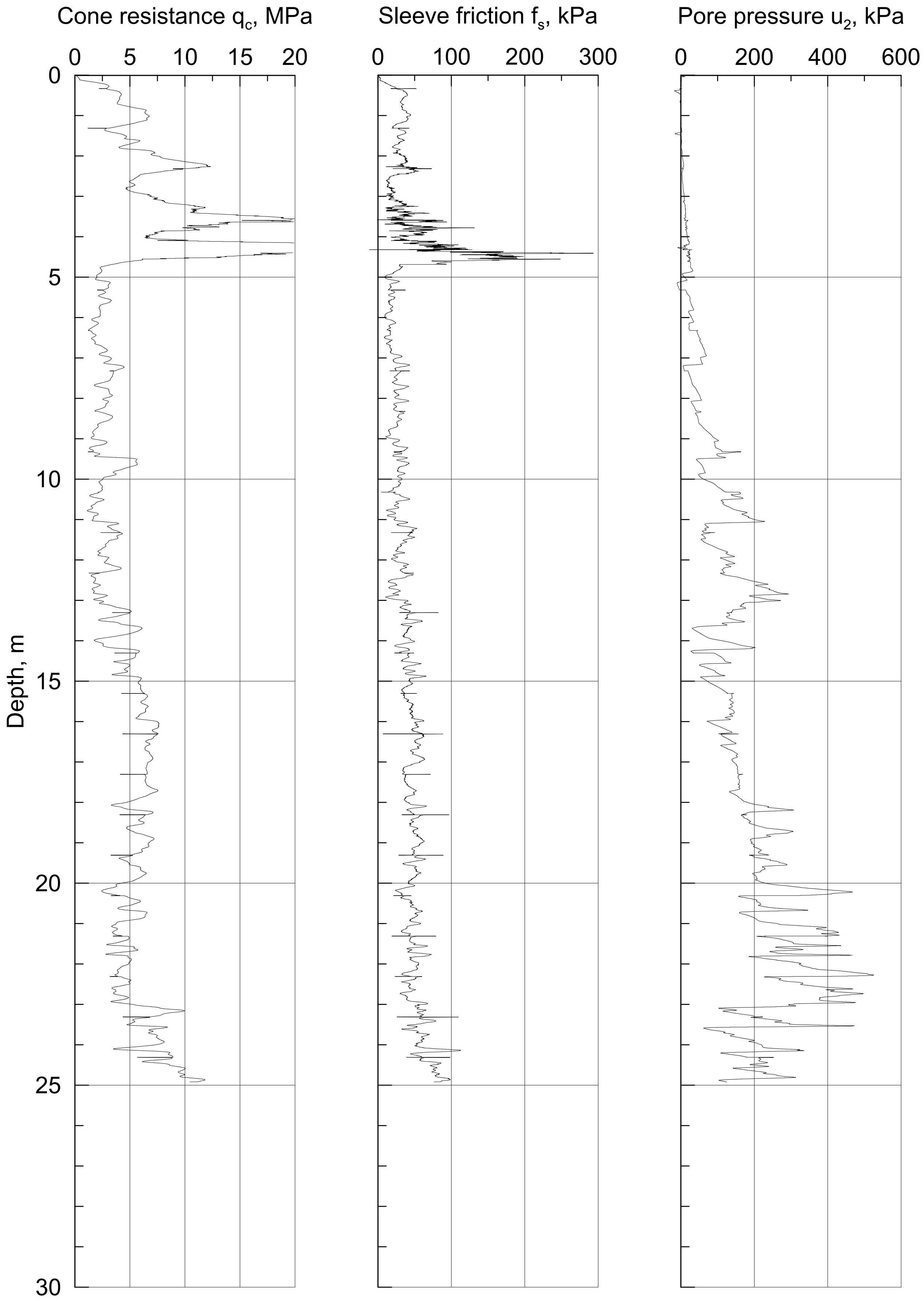
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C21
OYSC29	Date 2017-11-27 / Drawn by AnL

NGTS



Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC30

Document No. 20160154-08-R	
Figure No. C22	
Date 2017-11-27	Drawn by AnL

NGTS

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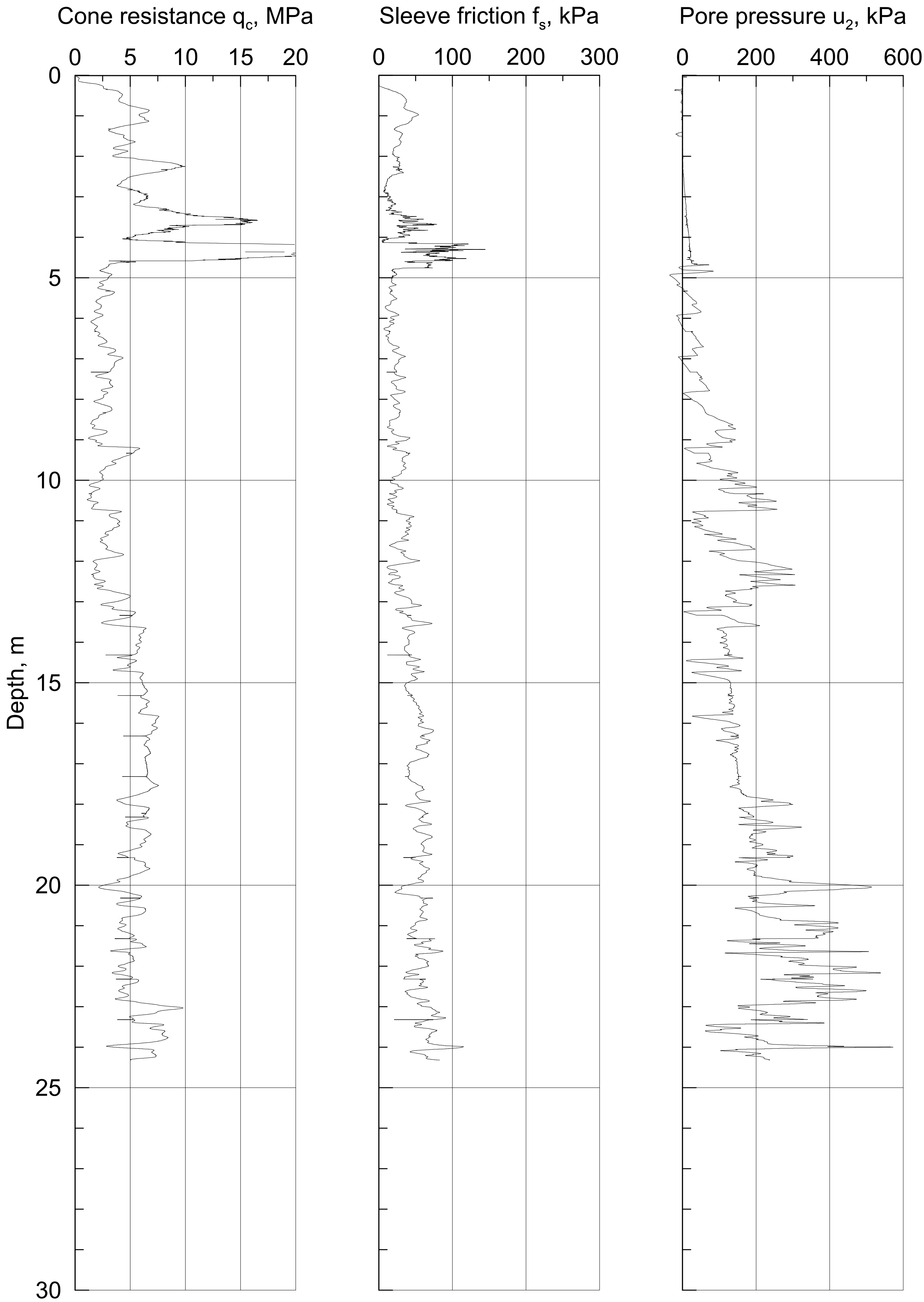

Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC31

Document No.	
20160154-08-R	
Figure No.	
C23	
Date	Drawn by
2017-11-27	AnL

NGTS

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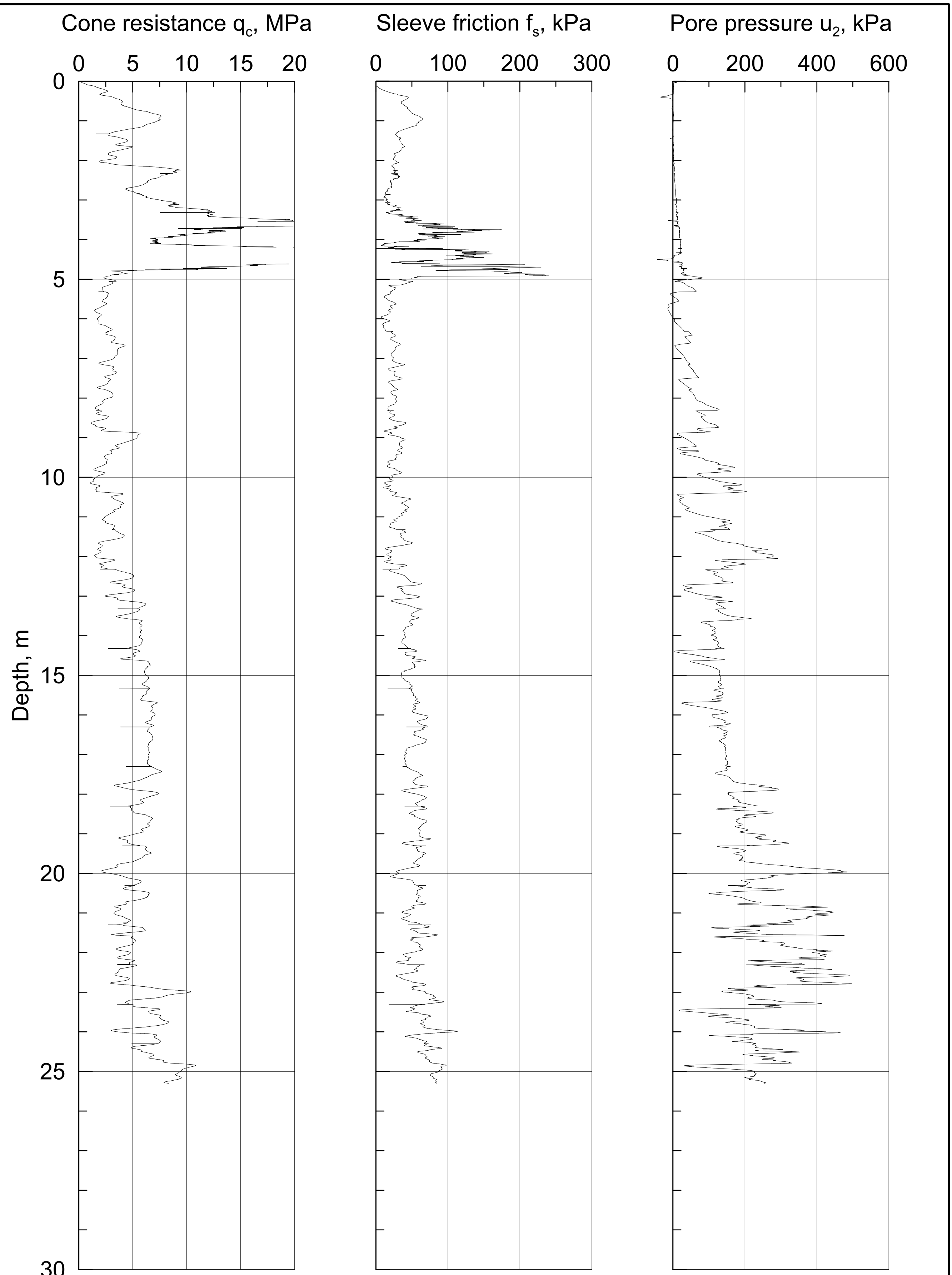
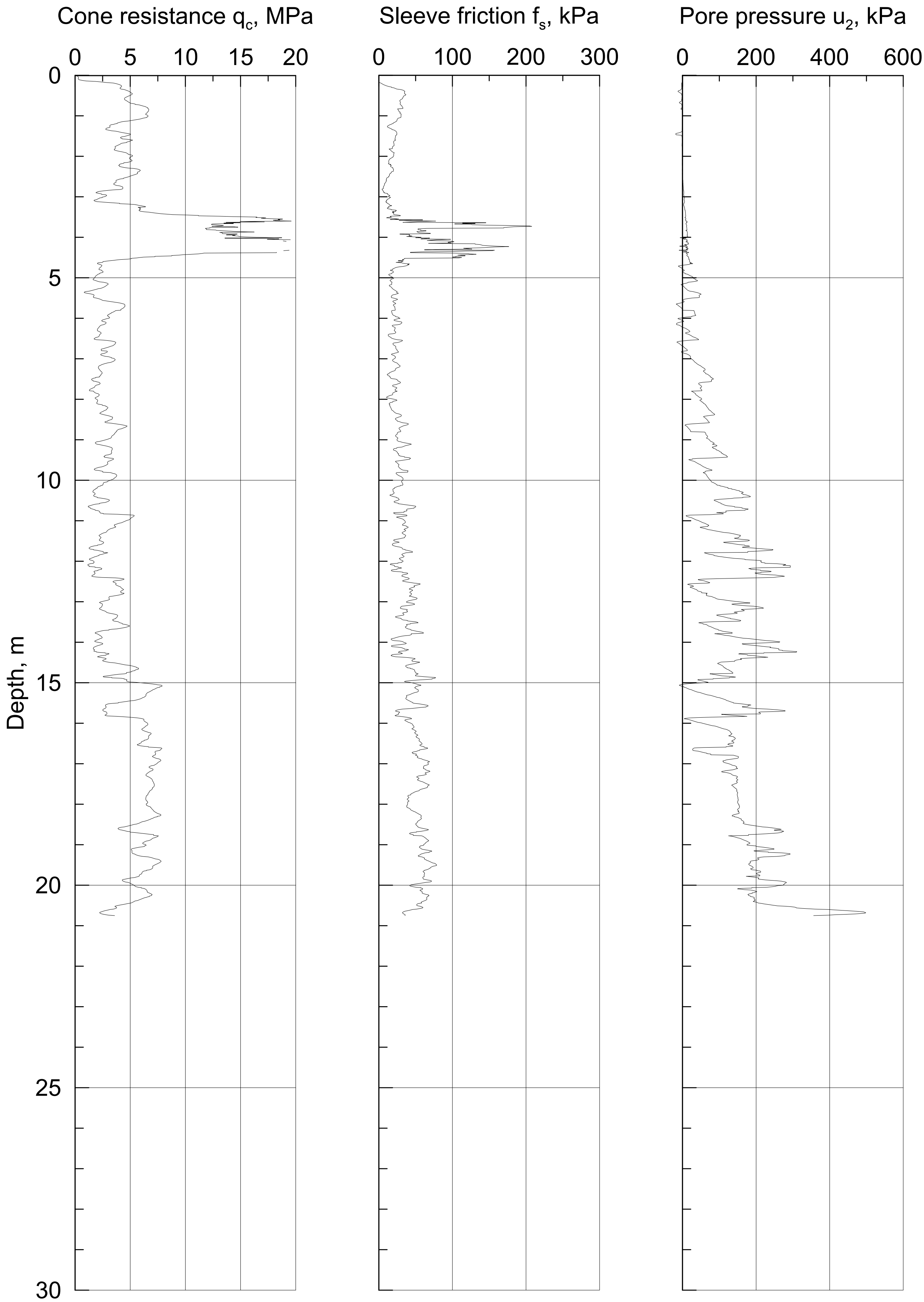


NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C24
OYSC32	Date 2017-11-27 / Drawn by AnL

NGTS



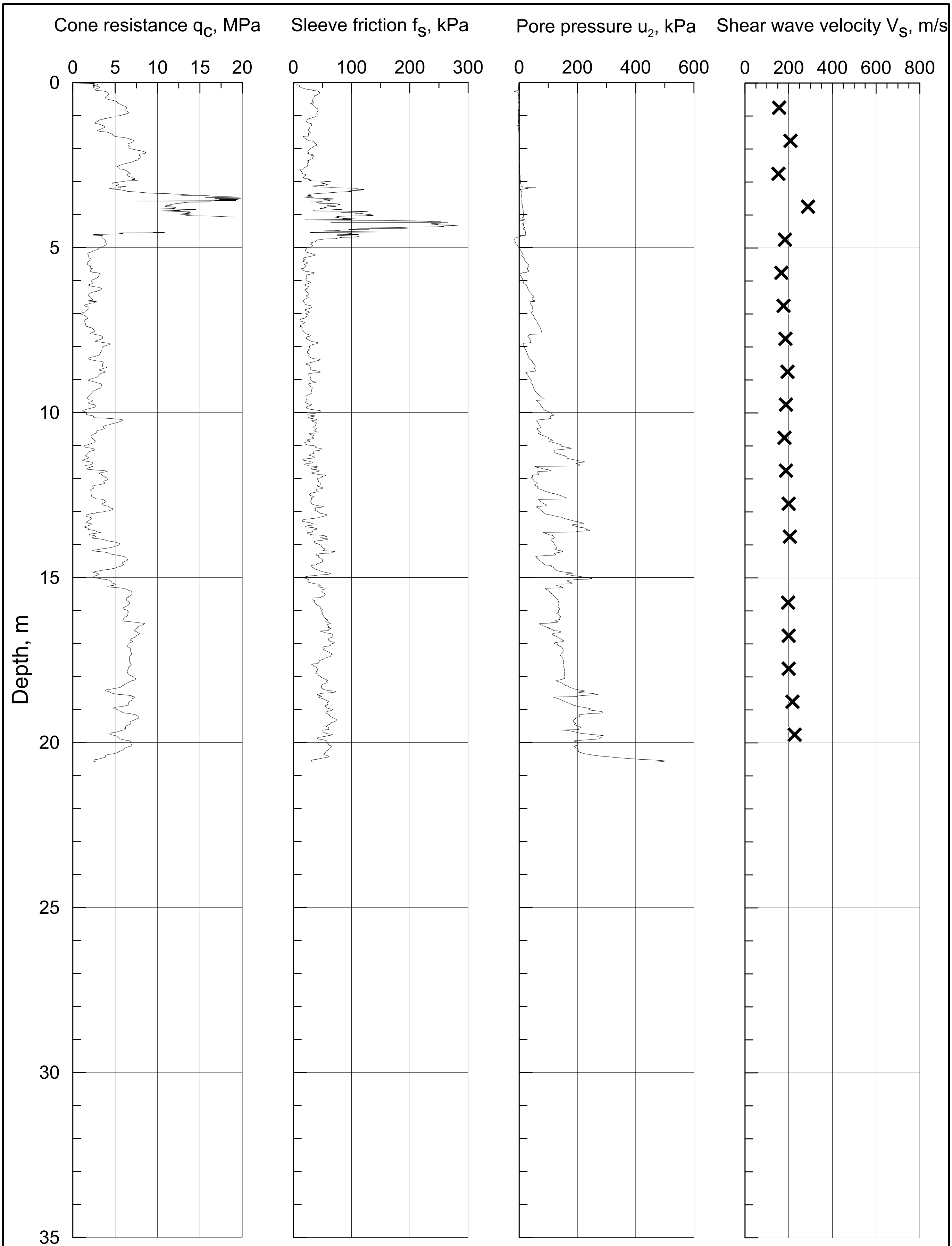
NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC34

Document No. 20160154-08-R	
Figure No. C25	
Date 2017-11-27	Drawn by AnL

NGTS



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Date/Rev.: 2015-01-21/01

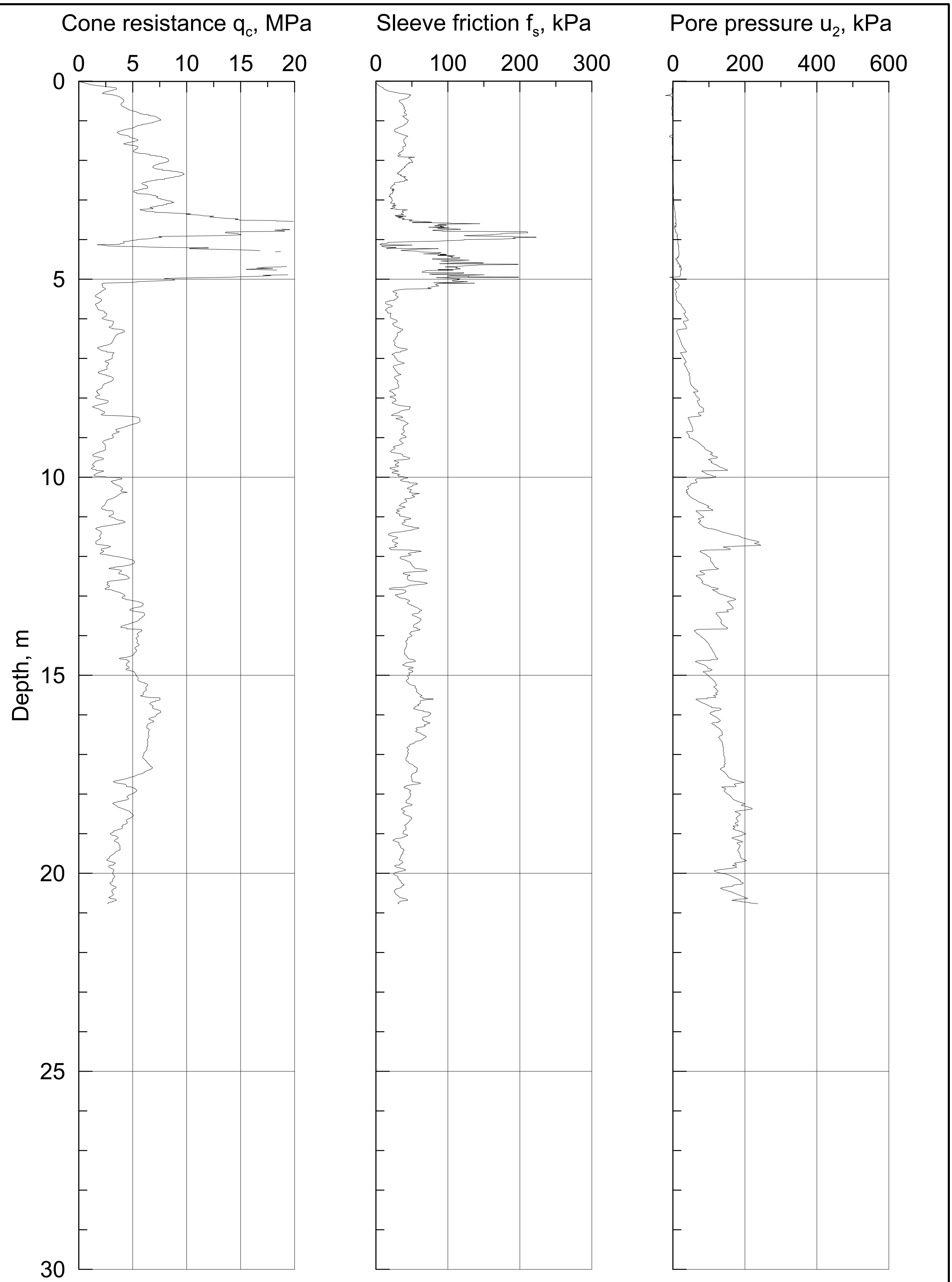
NGTS - Øysand Research Site

q_c, f_s, u_2 and V_s from SCPTU tests

OYSC35

Document No. 20160154-08-R	
Figure No. C26	
Date 2019-03-12	Drawn by AnL

NGTS



Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC37

Document No.	
20160154-08-R	
Figure No.	
C27	
Date	Drawn by
2017-11-27	AnL

NGTS

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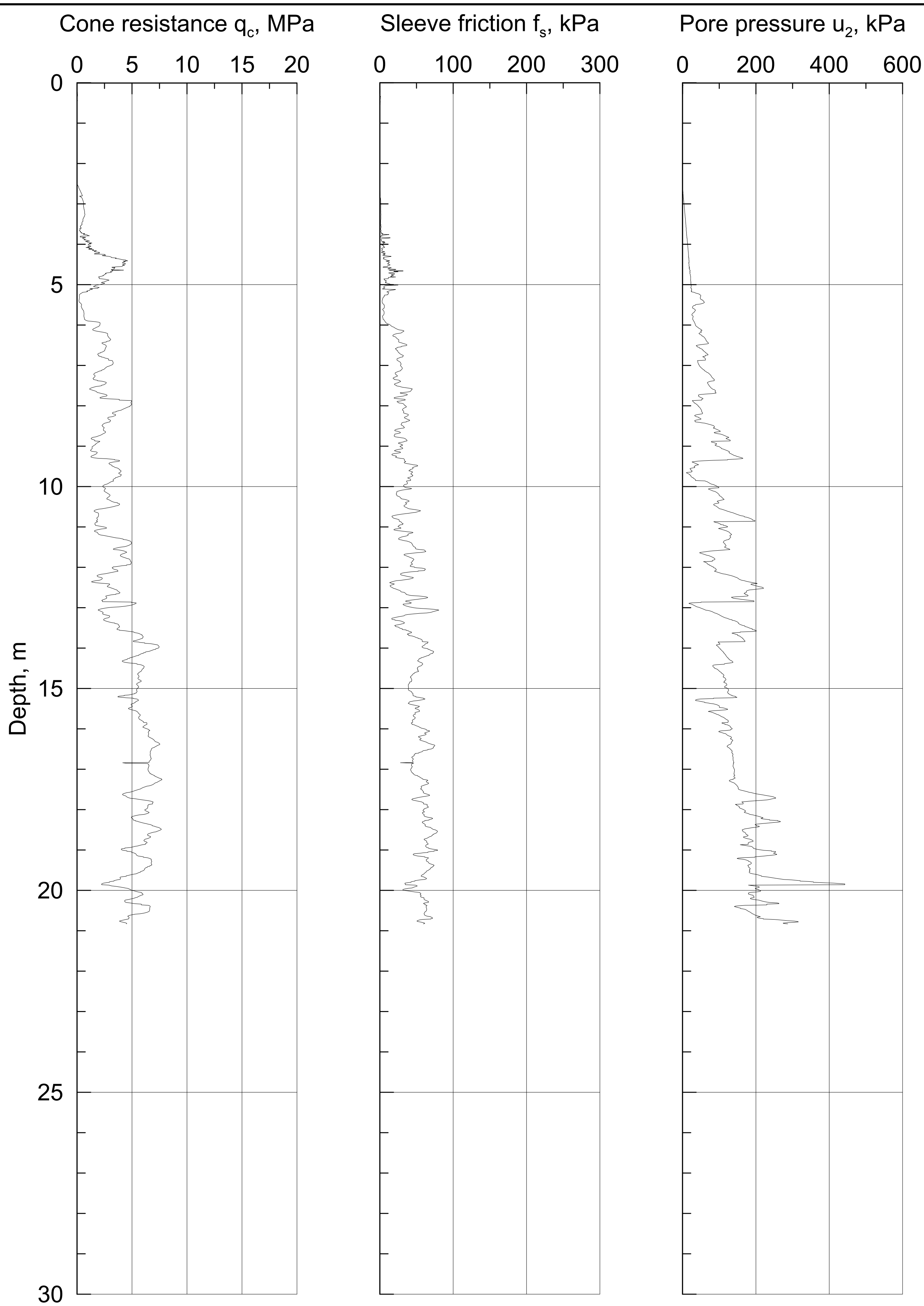

Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C28
OYSC38	Date 2017-11-27 / Drawn by AnL

NGTS

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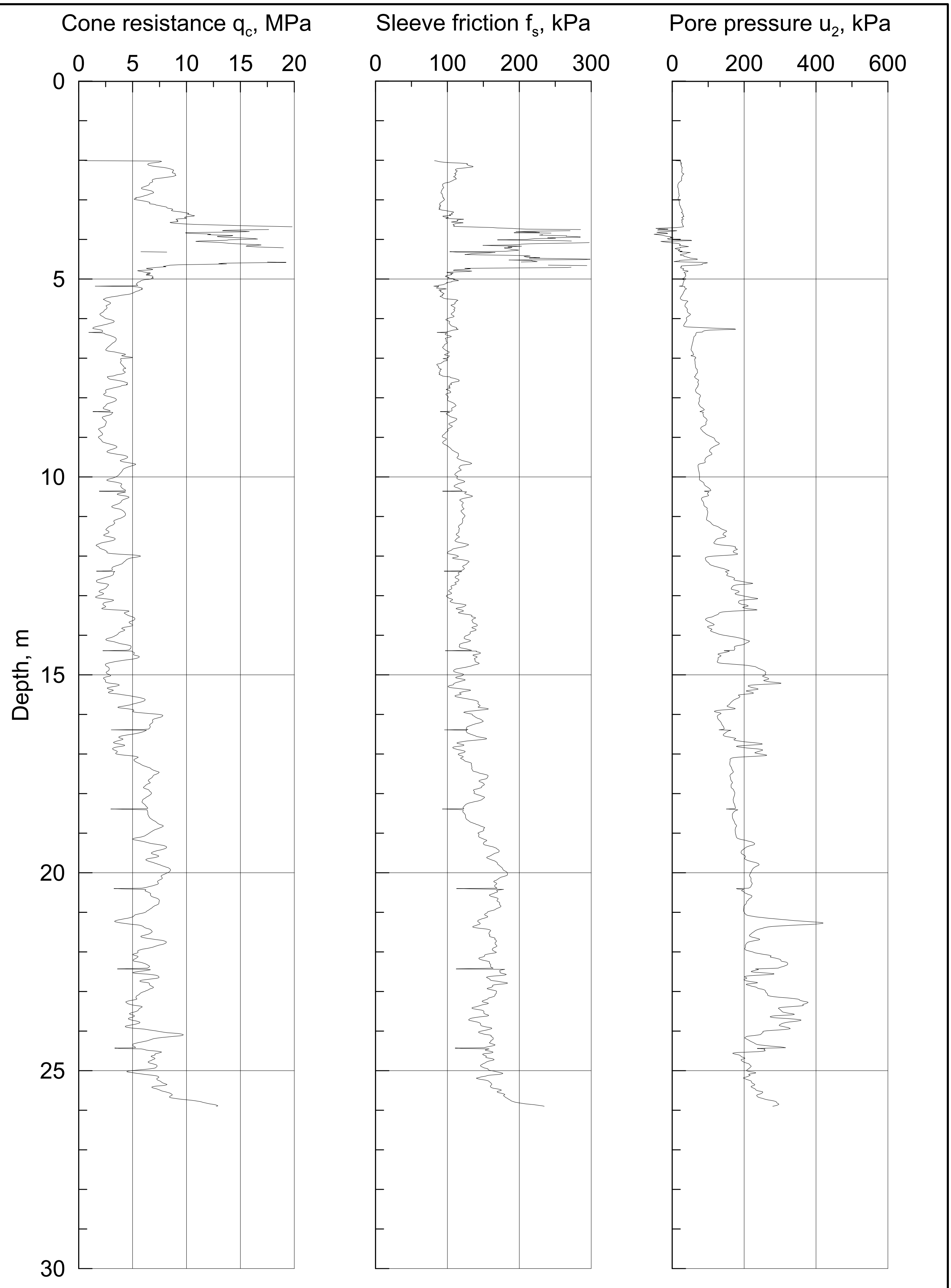

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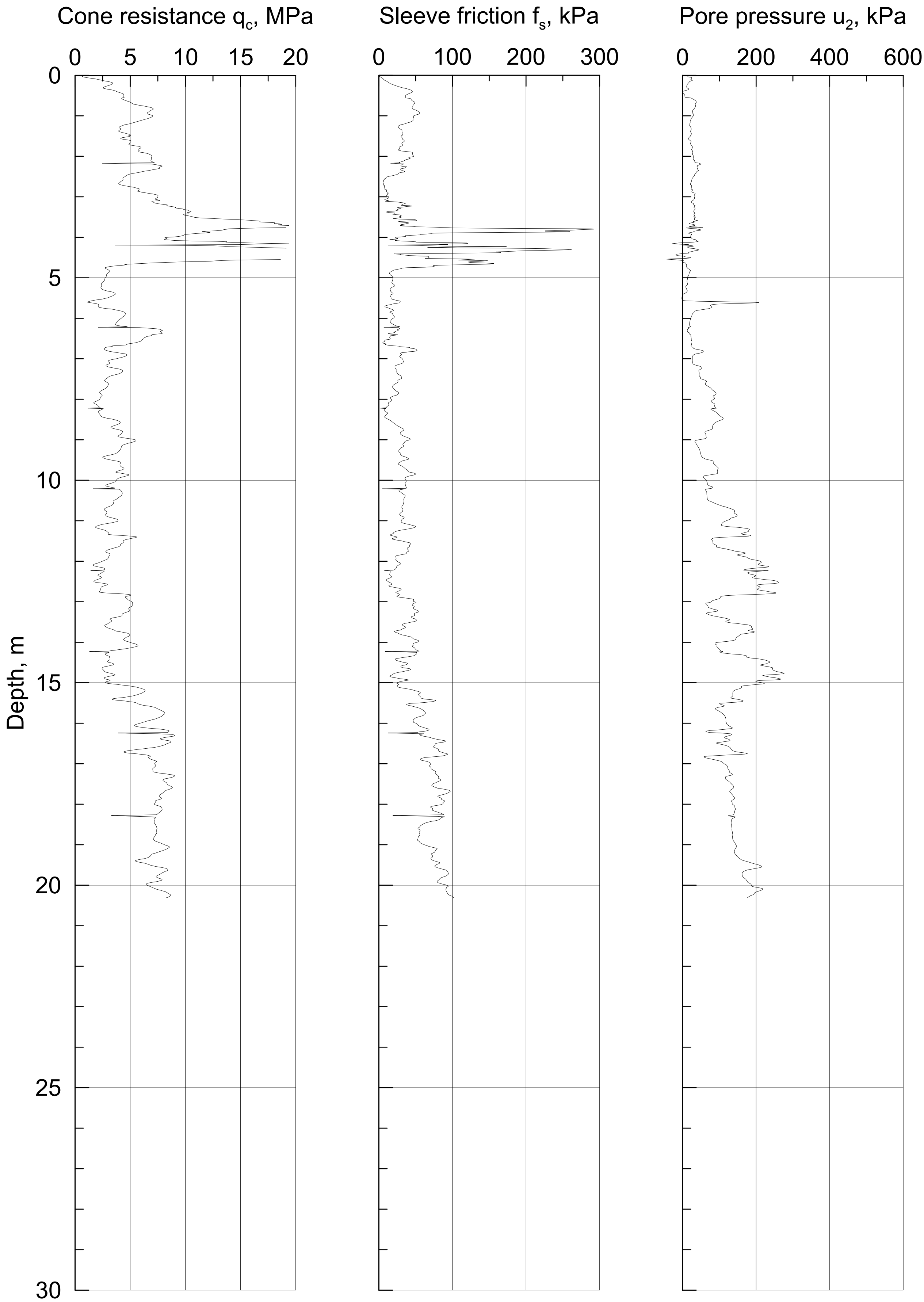
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R	
q_c, f_s and u_2 from CPTU tests	Figure No. C29	
OYSC39	Date 2017-11-27	Drawn by AnL
	NGTS	



NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC40

Document No. 20160154-08-R	
Figure No. C30	
Date 2017-11-27	Drawn by AnL

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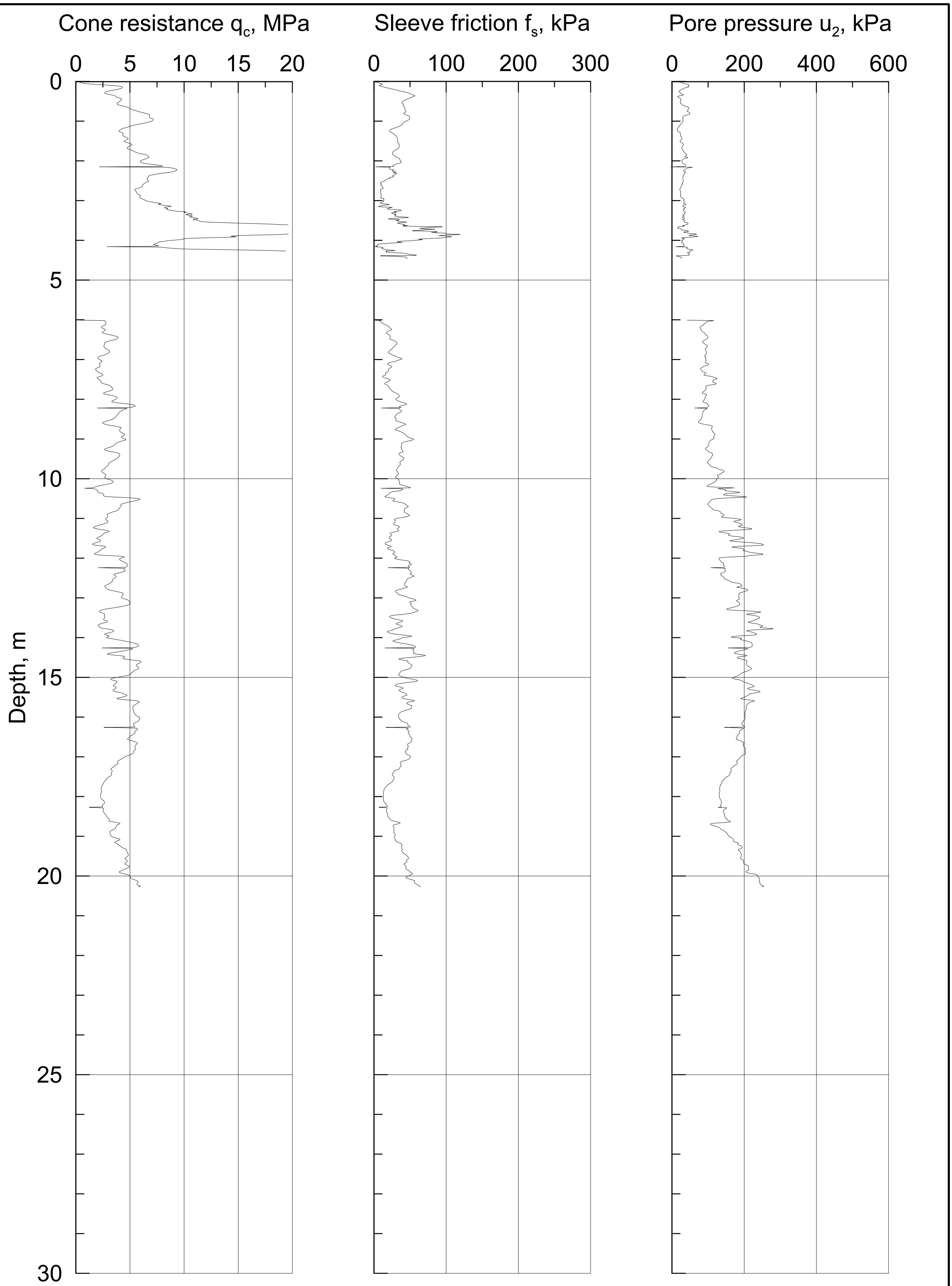

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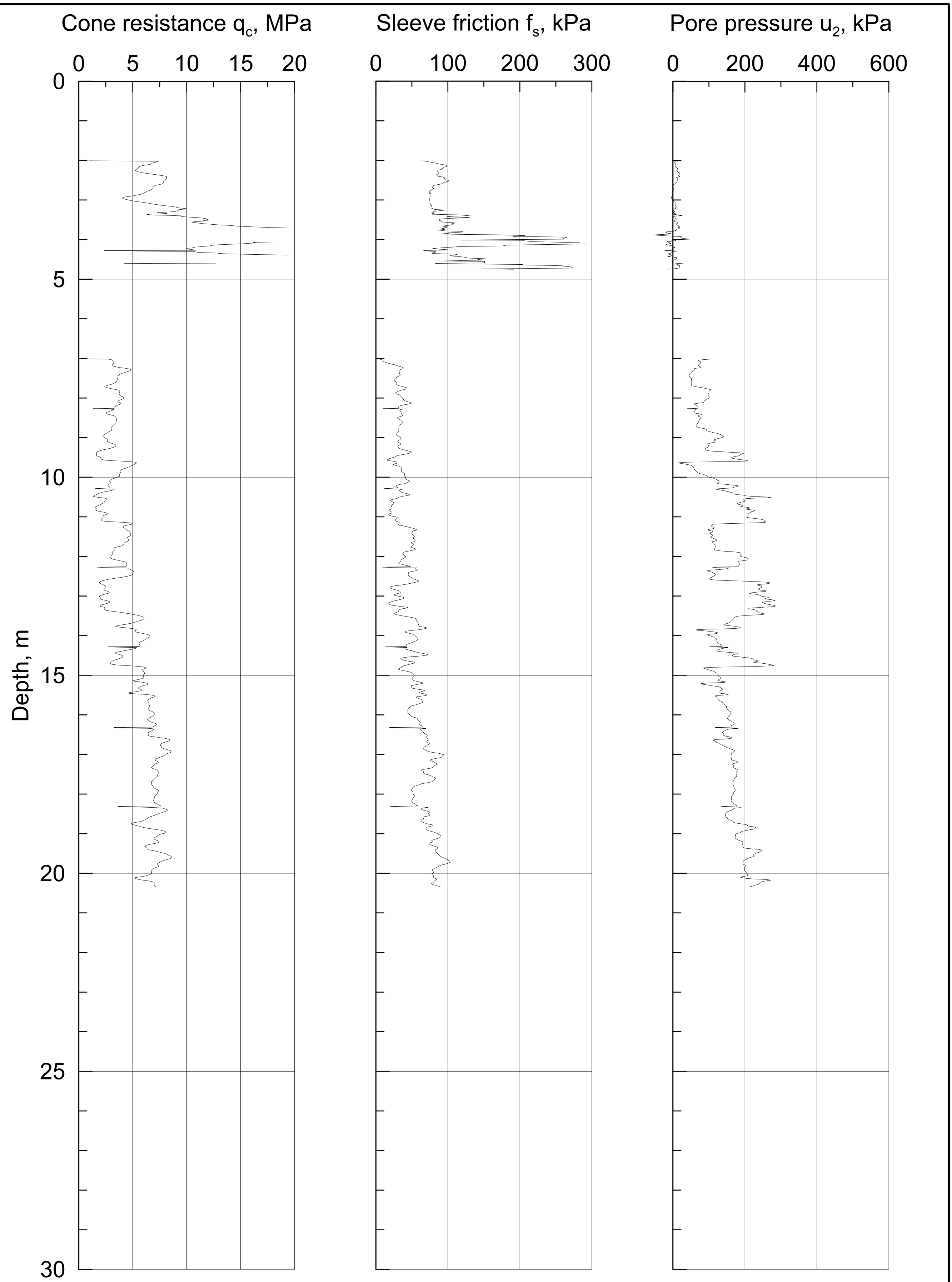
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C31
OYSC41	Date 2017-11-27 / Drawn by AnL

NGTS



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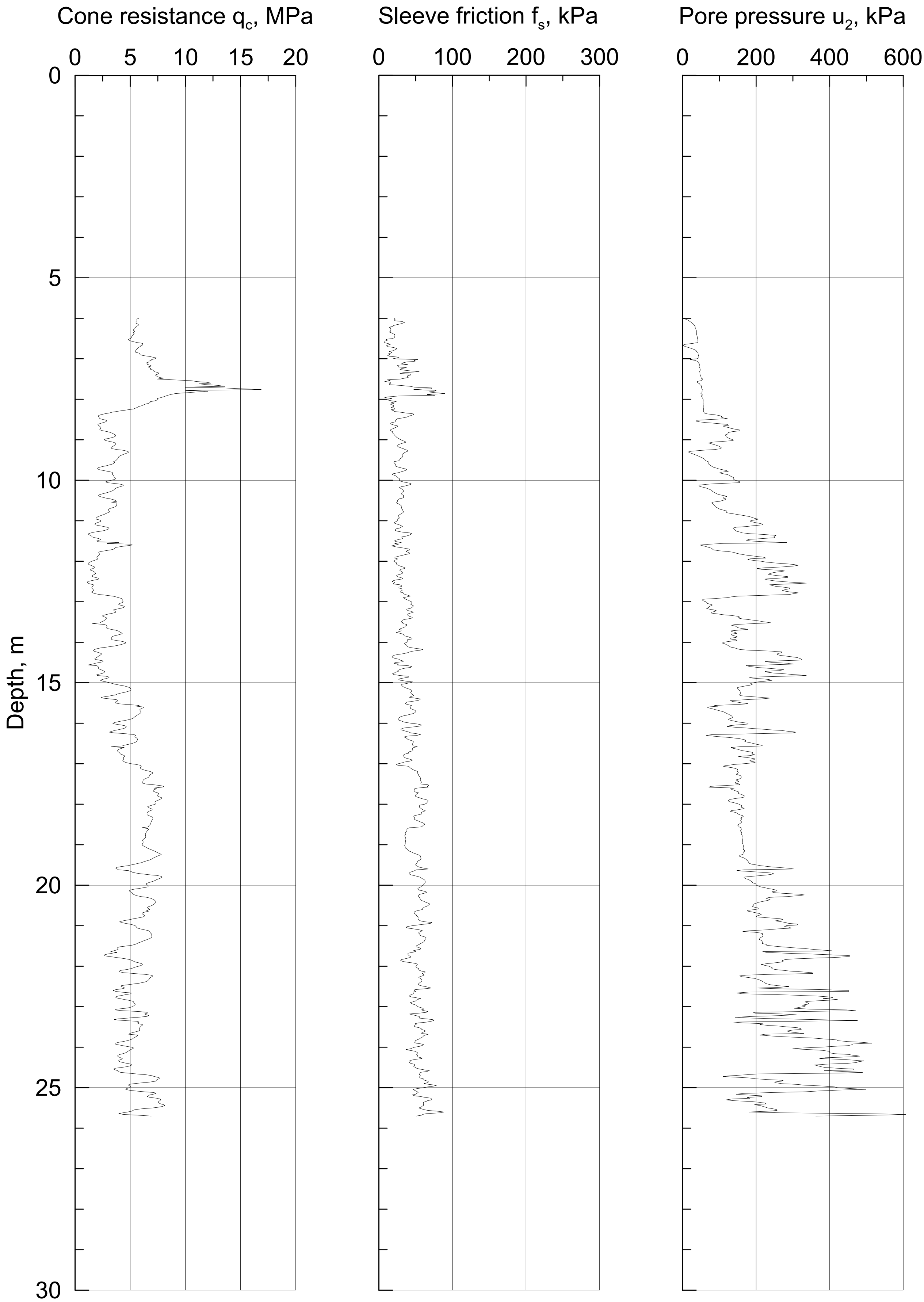
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C32
OYSC42	Date 2017-11-27 / Drawn by AnL

NGTS



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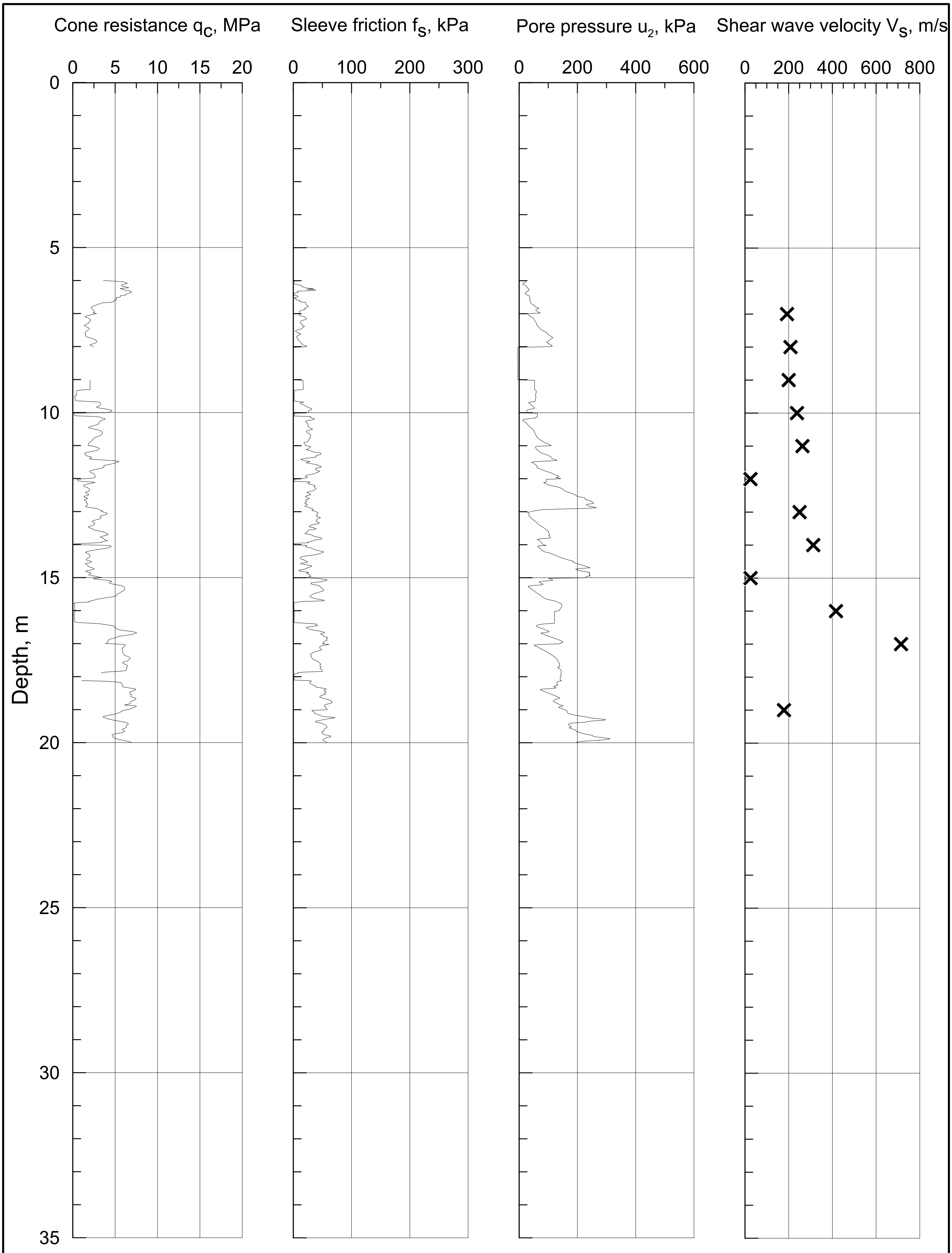
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C33
OYSC43	Date 2018-06-28 / Drawn by AnL

NGTS



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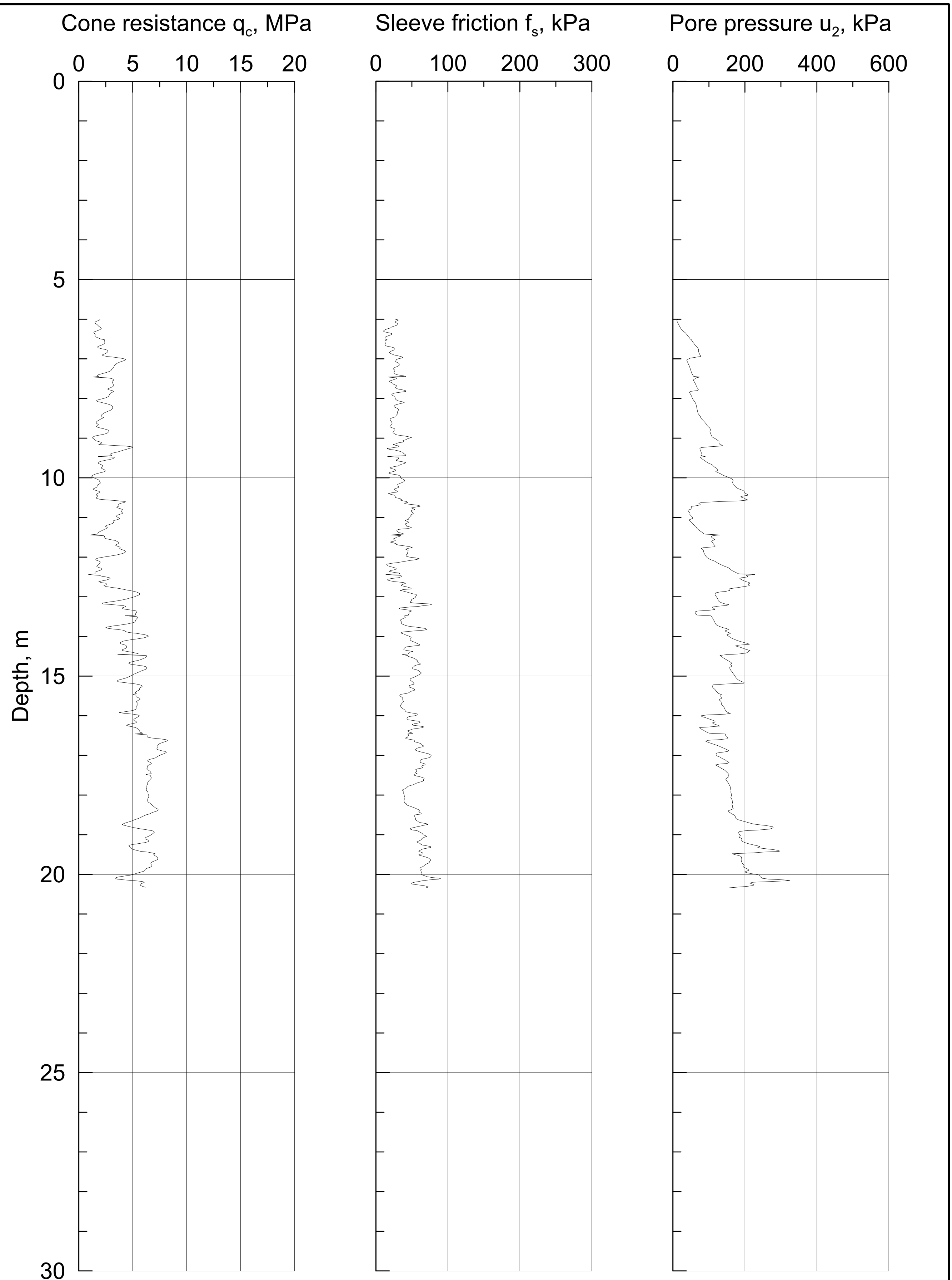
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R	
q_c, f_s, u_2 and V_s from SCPTU tests	Figure No. C34	
	Date 2019-03-12	Drawn by AnL
OYSC44	NGTS	



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Date/Rev.: 2015-01-21/01

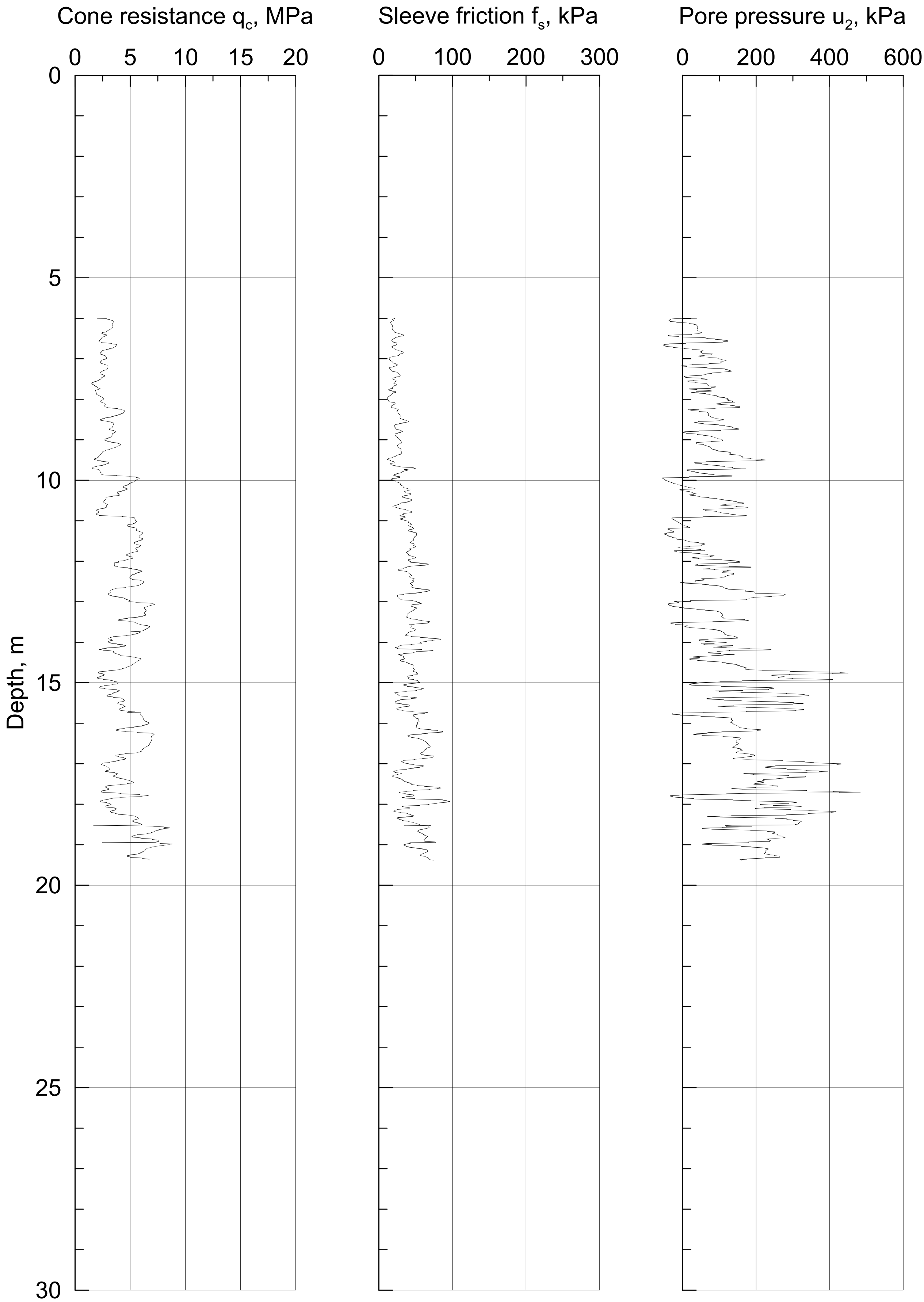
NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC45

Document No.	
20160154-08-R	
Figure No. C35	
Date 2018-06-28	Drawn by AnL

NGTS



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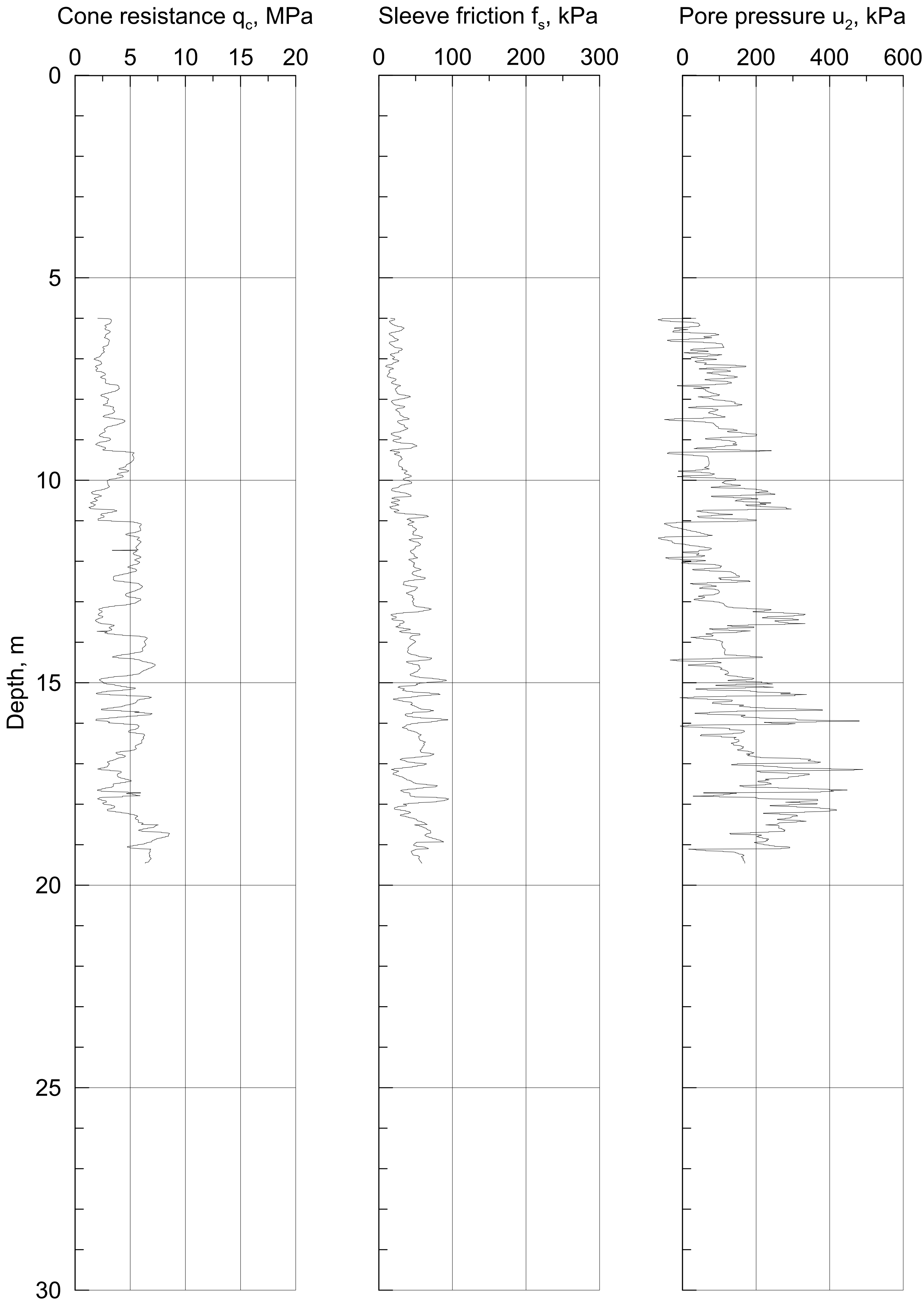
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C36
	Date 2018-06-28 / Drawn by AnL
OYSC50	NGTS



Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC51

Document No.
20160154-08-R

Figure No.
C37

Date
2018-06-28

Drawn by
AnL

NGTS

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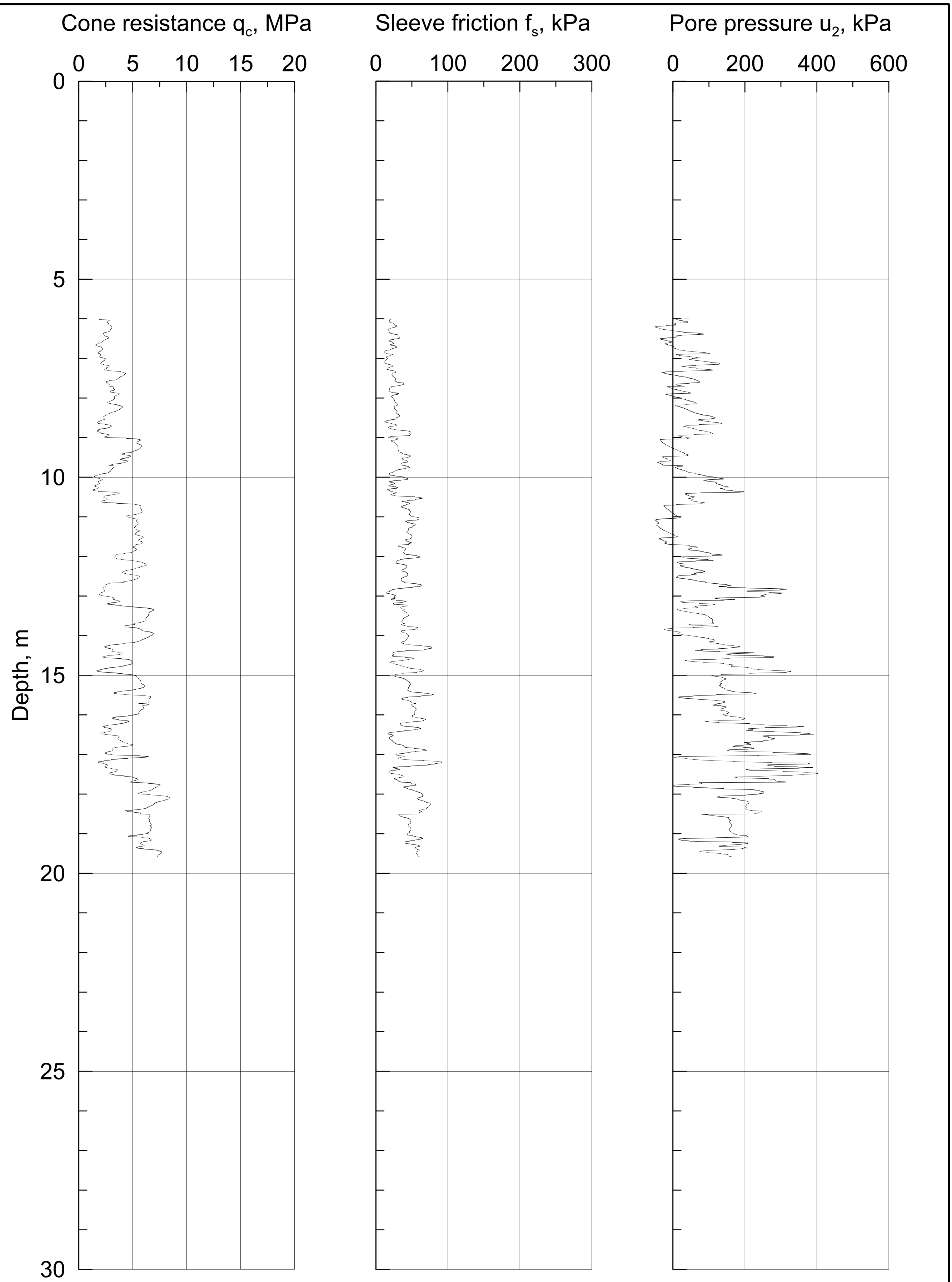

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Date/Rev.: 2015-01-21/01

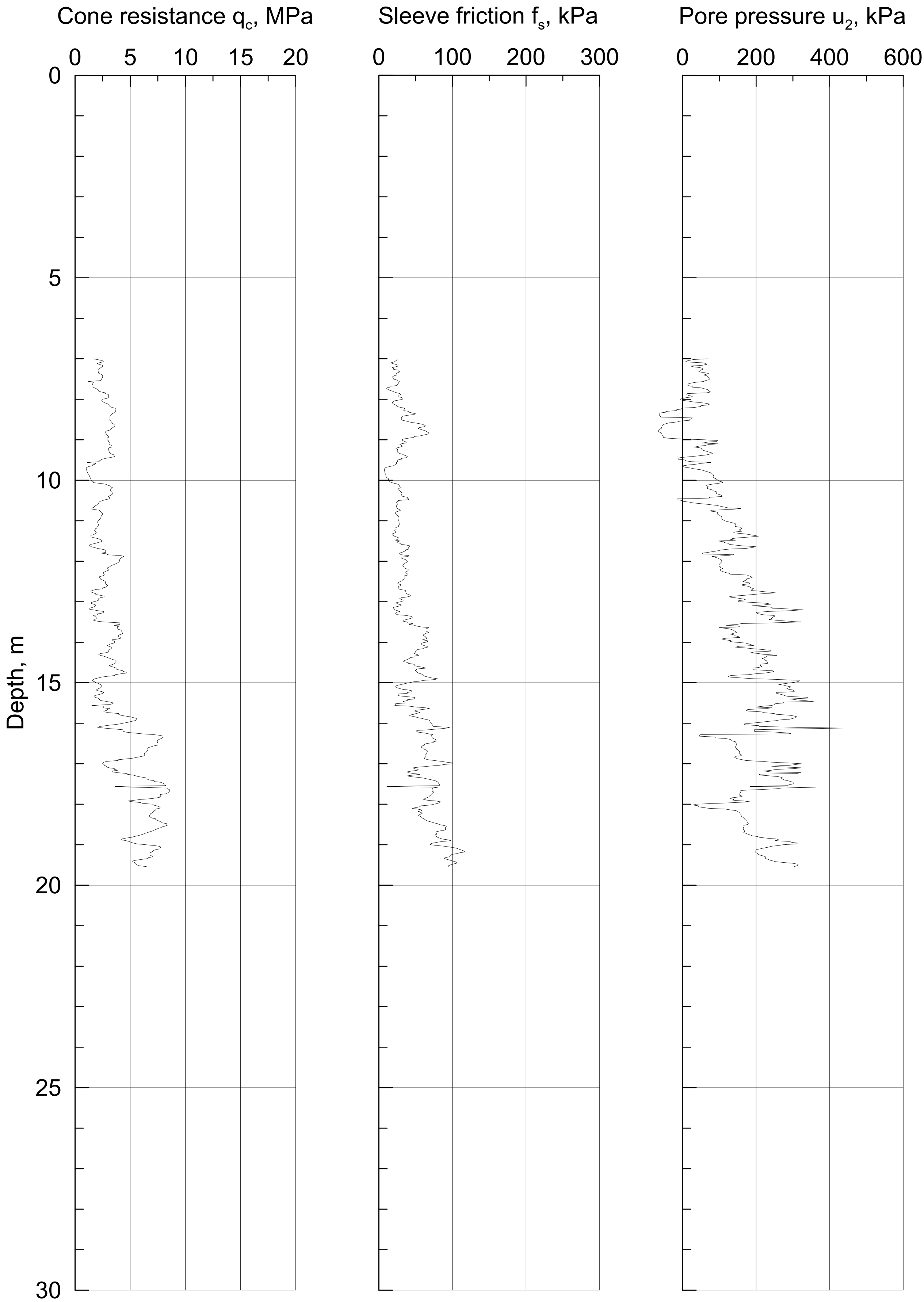
NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC52

Document No. 20160154-08-R	
Figure No. C38	
Date 2018-06-28	Drawn by AnL

NGTS



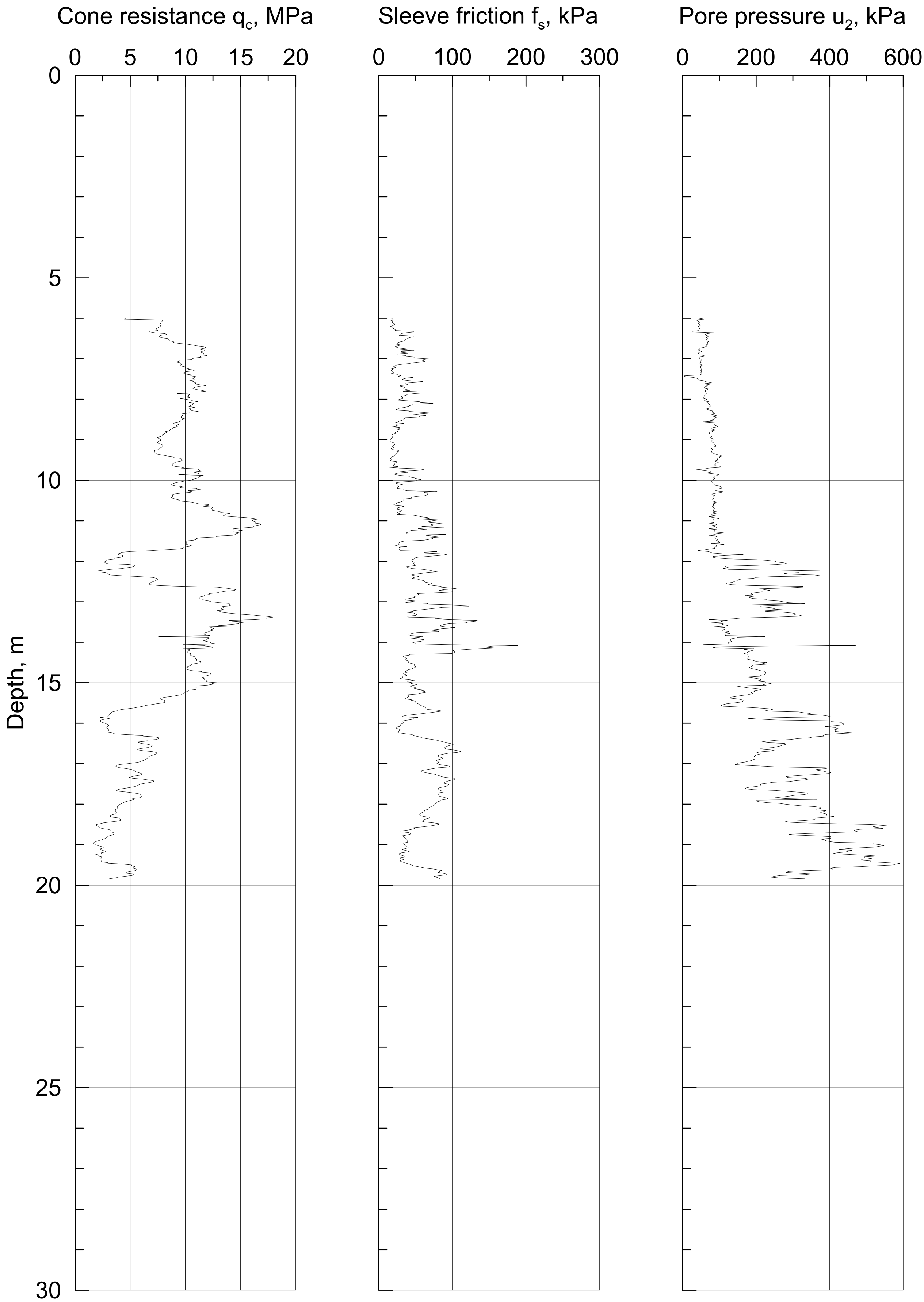
NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC56

Document No. 20160154-08-R	
Figure No. C39	
Date 2019-03-14	Drawn by AnL

NGTS



Date/Rev.: 2015-01-21/01

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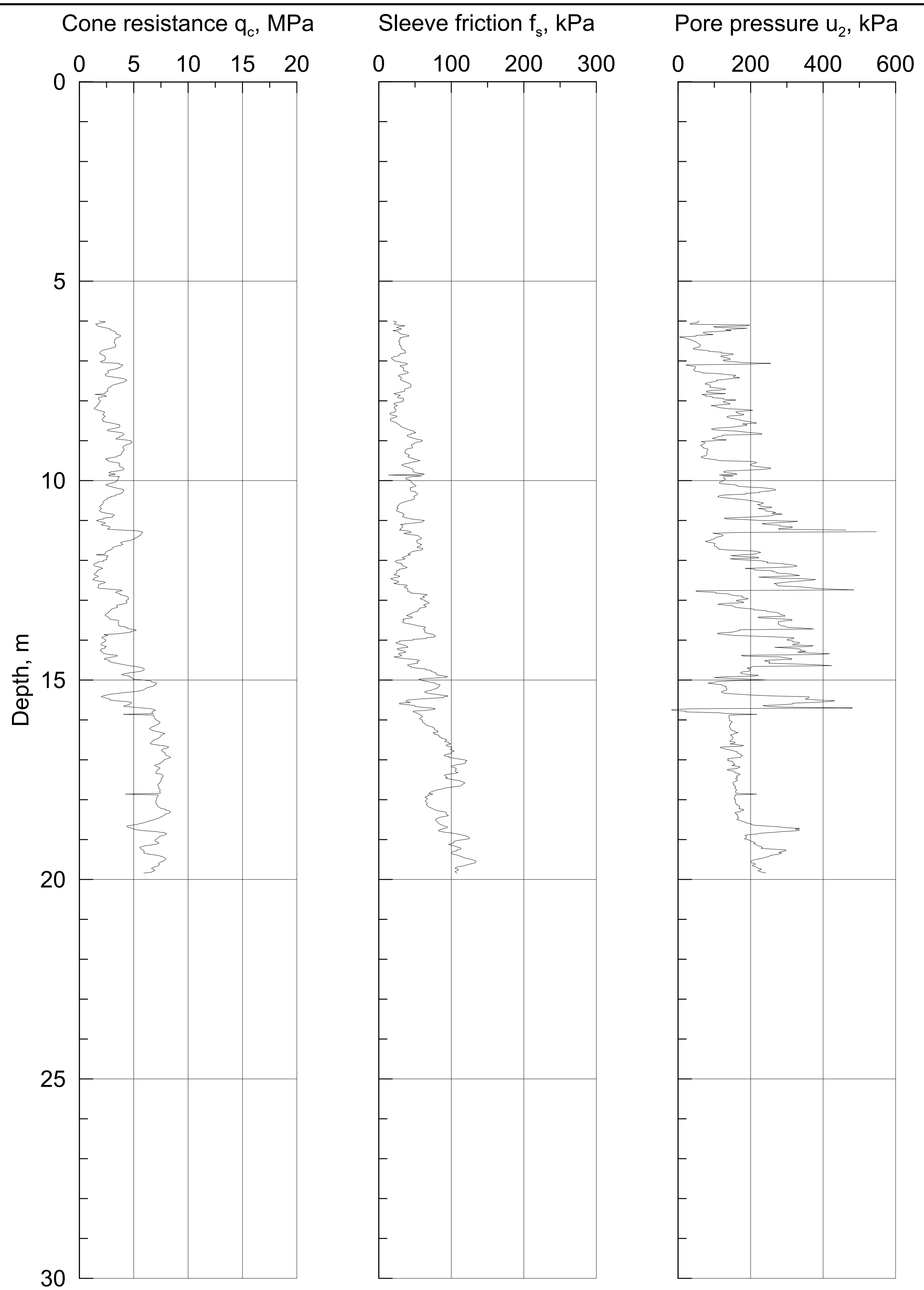
NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C40
OYSC60	Date 2019-03-14 / Drawn by AnL

NGTS



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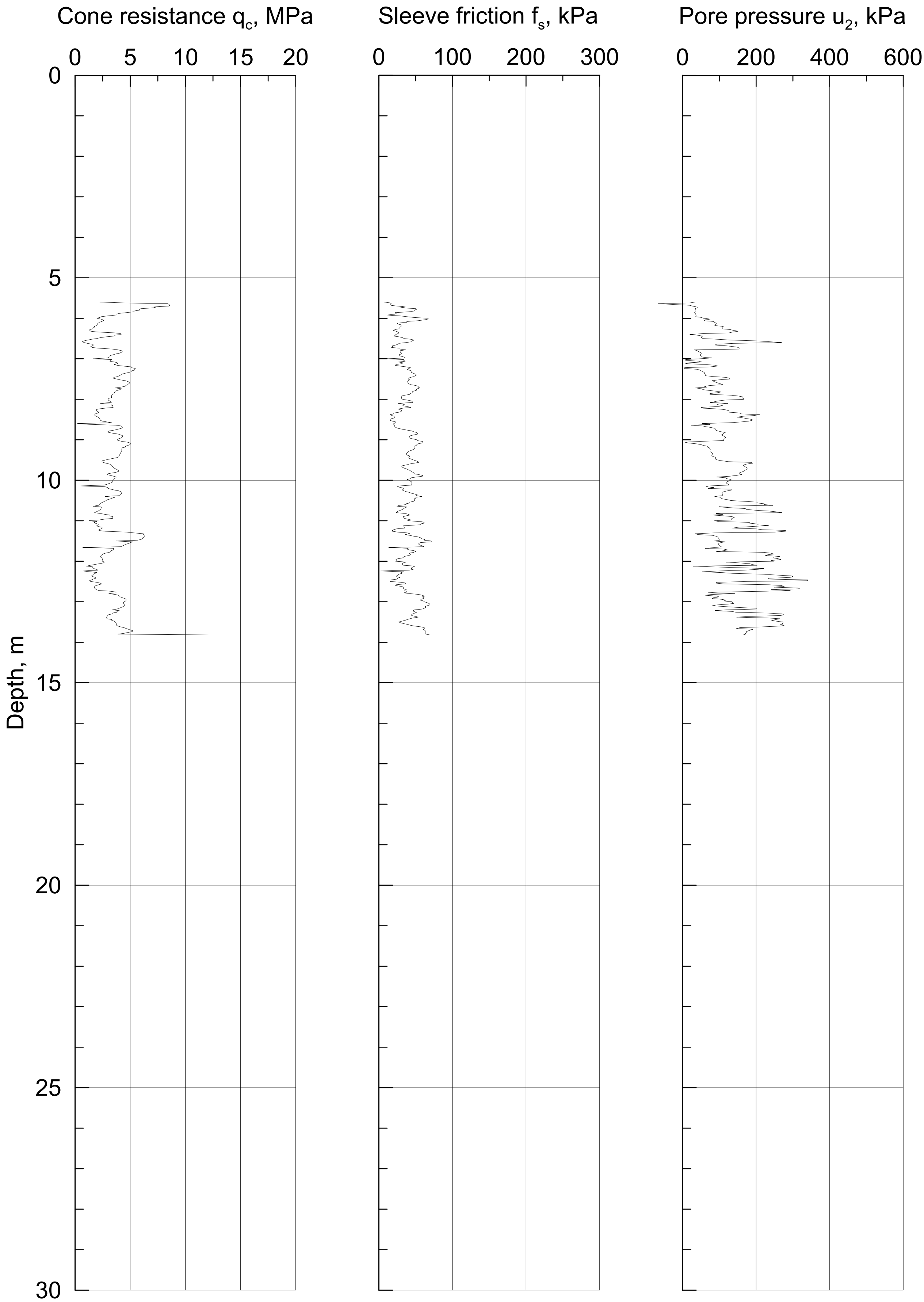
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R
q_c, f_s and u_2 from CPTU tests	Figure No. C41
OYSC61	Date 2019-03-14 / Drawn by AnL

NGTS



Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

q_c, f_s and u_2 from CPTU tests

OYSC62

Document No. 20160154-08-R	
Figure No. C42	
Date 2019-03-14	Drawn by AnL

NGTS

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GEOTECH

CERTIFICATE FOR CPT PROBE 4648

Probe No	4648
Date of Calibration	20130816
Replacement of	
Calibrated by	Joakim Tingström
File name	4648 20130816 133310.doc

Point Resistance — **Tip Area 10cm²**

Maximum Load	100	MPa
Range	100	MPa
Scaling Factor	**850**	
Resolution	0.8976	kPa
Area factor (a) at 1MPa	0.857	

ERRORS
Max. Temperature effect when not loaded 21.5424 kPa
Temperature range 0 –40 deg. Celsius.

Local Friction — **Sleeve Area 150cm²**

Maximum Load	0.5	MPa
Range	0.5	MPa
Scaling Factor	**4039**	
Resolution	0.0094	kPa
Area factor (b) at 1MPa	0	

ERRORS
Max. Temperature effect when not loaded 0.3102 kPa
Temperature range 0 –40 deg. Celsius.

Pore Pressure

Maximum Load	2.5	MPa
Range	2	MPa
Scaling Factor	**3488**	
Resolution	0.0219	kPa

ERRORS
Max. Temperature effect when not loaded 0.8541 kPa
Temperature range 0 –40 deg. Celsius.

Tilt Angle. — **Scaling Factor 1**

Range	0 - 40	Deg.

Temperature sensor. — **Scaling Factor 1**

Range	0 - 40	Deg. Celsius

BACK-UP MEMORY

CALIBRATION CERTIFICATE FOR CPT PROBE 4763

Probe No	4763
Date of Calibration	2016-05-11
Calibrated by	Joakim Tingström..................................
Run No	203
Test Class:	ISO 1

Point Resistance **Tip Area 10cm²**

Maximum Load	50	MPa
Range	50	MPa
Scaling Factor	**1603**	
Resolution	0,4759	kPa
Area factor (a)	0,844	

ERRORS
Max. Temperature effect when not loaded 17,124 kPa
Temperature range 0 –40 deg. Celsius.

Local Friction **Sleeve Area 150cm²**

Maximum Load	0,5	MPa
Range	0,5	MPa
Scaling Factor	**3679**	
Resolution	0,0104	kPa
Area factor (b)	0	

ERRORS
Max. Temperature effect when not loaded 0,59 kPa
Temperature range 0 –40 deg. Celsius.

Pore Pressure

Maximum Load	2	MPa
Range	2	MPa
Scaling Factor	**3449**	
Resolution	0,0221	kPa

ERRORS
Max. Temperature effect when not loaded 1,37 kPa
Temperature range 0 –40 deg. Celsius.

Tilt Angle. **Scaling Factor: 0,94**

Range	0 - 40	Deg.

Backup memory
Temperature sensor
Conductivity probe

Geomil equipment

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calibration certificate

DC15CFIIP.C17190 / 001

Cone number	DC15CFIIP.C17190	**Client**	Geomil internal production
Kind of cone	Compression		Westbaan 240
Calibration date	15-Sep-2017		2841 MC Moordrecht
Print date	16-Oct-2017		Netherlands

Channel 1

Channel 1	Cone resistance (q_c)
	$q_c = Q_c / A_c$
Range	0 ... 150 kN
A_c	1500 mm²
Zero load reading	7856941 digits
a-factor	0.783

Q_c Load (kN)	Eqv. q_c (MPa)	Output (Digits)
0	0	0
15	10	758923
30	20	1522560
45	30	2284766
60	40	3045579
75	50	3805039
90	60	4563185
105	70	5320057
120	80	6075695
135	90	6830137
150	100	7583424
135	90	6826468
120	80	6072456
105	70	5317698
90	60	4561975
75	50	3805073
60	40	3046773
45	30	2286860
30	20	1525117
15	10	761327
0	0	-4481

Zero load error	0.06 %
Max. linearity	0.18 %
Max. hysteresis	0.05 %

Channel 2

Channel 2	Local sleeve friction (f_s)
	$f_s = F_s / A_s$
Range	0 ... 22.5 kN
A_s	22500 mm²
Zero load reading	8439505 digits
b-factor	-0.001
Offset	97.6 mm

F_s Load (kN)	Eqv. f_s (MPa)	Output (Digits)
0.00	0.0	0
2.25	0.1	684216
4.50	0.2	1371789
6.75	0.3	2058214
9.00	0.4	2743463
11.25	0.5	3427502
13.50	0.6	4110302
18.00	0.8	5472057
20.25	0.9	6150951
22.50	1.0	6828480
20.25	0.9	6154962
18.00	0.8	5477802
13.50	0.6	4119074
11.25	0.5	3437238
9.00	0.4	2753573
6.75	0.3	2067946
4.50	0.2	1380223
2.25	0.1	690269
0.00	0.0	558

Zero load error	0.01 %
Max. linearity	0.34 %
Max. hysteresis	0.15 %

Channel 3

Channel 3	Pore pressure (u)
Range	0 ... 20 bar
Zero load reading	8446662 digits

Pressure (bar)	Eqv. u (MPa)	Output (Digits)
0	0.0	0
2	0.2	622138
4	0.4	1249510
6	0.6	1879556
8	0.8	2508221
10	1.0	3136594
12	1.2	3764657
14	1.4	4391379
16	1.6	5019904
18	1.8	5643446
20	2.0	6272129

Zero load error	0.02 %
Max. linearity	0.08 %

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calibration certificate

DC15CFIIP.C17190 / 001

Geomil equipment

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Channel 4 Inclination X	**Channel 5** Inclination Y	**Channel 6** None
Range -20 ... 20 °	**Range** -20 ... 20 °	

Angle (°)	Output (Digits)	Angle (°)	Output (Digits)
-20	-4667	-20	-4702
-15	-3368	-15	-3404
-10	-2070	-10	-2105
-5	-772	-5	-807
0	195	0	157
5	1825	5	1789
10	3123	10	3088
15	4421	15	4386
20	5719	20	5684

Calibration instrument(s)	**Certificate number(s)**	**Date(s)**
GSNCAL/822084350	2070856.06600.1	04-Sep-2017

Remark

We declare that the electrical cone with serial number DC15CFIIP.C17190 has been calibrated and that the specifications are according to the ISO 22476-1:2012 (Geotechnical investigation and testing – Field testing - Part 1: Electrical cone and piezocone penetration test).
The calibrations are traceable to national and international standards.

Date 15-Sep-2017
Calibrated by Joost Neugebauer

Date 15-Sep-2017
Approved by Jody Jansen

Signature

Signature

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calibration certificate

DC10CFIIP.C14251 / 001

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Cone number	DC10CFIIP.C14251	**Client**	Geomil internal production
Kind of cone	Compression		Westbaan 240
Calibration date	15-Sep-2017		2841 MC Moordrecht
Print date	16-Oct-2017		Netherlands

Channel 1	Cone resistance (q_c) $q_c = Q_c / A_c$	**Channel 2**	Local sleeve friction (f_s) $f_s = F_s / A_s$	**Channel 3**	Pore pressure (u)
Range	0 ... 50 kN	**Range**	0 ... 7.5 kN	**Range**	0 ... 20 bar
A_c	1000 mm²	**A_s**	15000 mm²		
Zero load reading	8853370 digits	**Zero load reading**	7785932 digits	**Zero load reading**	8027061 digits
a-factor	0.776	**b-factor**	0		
		Offset	80.1 mm		

Q_c Load (kN)	**Eqv. q_c (MPa)**	**Output (Digits)**	**F_s Load (kN)**	**Eqv. f_s (MPa)**	**Output (Digits)**	**Pressure (bar)**	**Eqv. u (MPa)**	**Output (Digits)**
0	0	0	0.00	0.00	0	0	0.0	0
5	5	595167	0.75	0.05	600568	2	0.2	616554
10	10	1191402	1.50	0.10	1219848	4	0.4	1240129
15	15	1787468	2.25	0.15	1841715	6	0.6	1865821
20	20	2383357	3.00	0.20	2465420	8	0.8	2491270
25	25	2979066	3.75	0.25	3090215	10	1.0	3118604
30	30	3574586	4.50	0.30	3715353	12	1.2	3745781
35	35	4169912	5.25	0.35	4340085	14	1.4	4372309
40	40	4765039	6.00	0.40	4963662	16	1.6	5001311
45	45	5359959	6.75	0.45	5585337	18	1.8	5625466
50	50	5954667	7.50	0.50	6204362	20	2.0	6248061
45	45	5360416	6.75	0.45	5596740			
40	40	4766534	6.00	0.40	4980769			
35	35	4172373	5.25	0.35	4361440			
30	30	3577890	4.50	0.30	3739550			
25	25	2983042	3.75	0.25	3115899			
20	20	2387786	3.00	0.20	2491286			
15	15	1792079	2.25	0.15	1866509			
10	10	1195878	1.50	0.10	1242366			
5	5	599140	0.75	0.05	619657			
0	0	843	0.00	0.00	6592			

Zero load error	0.01 %	**Zero load error**	0.11 %	**Zero load error**	0.01 %
Max. linearity	0.10 %	**Max. linearity**	0.34 %	**Max. linearity**	0.15 %
Max. hysteresis	0.08 %	**Max. hysteresis**	0.42 %		

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calibration certificate

DC10CFIIP.C14251 / 001

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Channel 4	Inclination X	Channel 5	Inclination Y	Channel 6	None
Range	-20 ... 20 °	**Range**	-20 ... 20 °		

Angle (°)	Output (Digits)	Angle (°)	Output (Digits)
-20	-4596	-20	-5526
-15	-3298	-15	-4228
-10	-2000	-10	-2930
-5	-702	-5	-1632
0	276	0	-744
5	1895	5	965
10	3193	10	2263
15	4491	15	3561
20	5789	20	4860

Calibration instrument(s)	Certificate number(s)	Date(s)
GSNCAL/822084350	2070856.06600.1	04-Sep-2017

Remark

We declare that the electrical cone with serial number DC10CFIIP.C14251 has been calibrated and that the specifications are according to the ISO 22476-1:2012 (Geotechnical investigation and testing – Field testing - Part 1: Electrical cone and piezocone penetration test). The calibrations are traceable to national and international standards.

Date	15-Sep-2017	**Date**	15-Sep-2017
Calibrated by	Joost Neugebauer	**Approved by**	Jody Jansen
Signature		**Signature**	

ISO 9001

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certificate_cal_001_v1

calibration certificate

DS10CFIIP.S17176 / 001

Geomil equipment
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Cone number	DS10CFIIP.S17176	**Client**	Geomil internal production
Kind of cone	Subtraction		Westbaan 240
Calibration date	15-Sep-2017		2841 MC Moordrecht
Print date	16-Oct-2017		Netherlands

Channel 1	Cone resistance (q_c) $q_c = Q_c / A_c$	**Channel 2**	Local sleeve friction (f_s) $f_s = F_s / A_s$	**Channel 3**	Pore pressure (u)
Range	0 ... 100 kN	**Range**	0 ... 100 kN	**Range**	0 ... 20 bar
A_c	1000 mm²	**A_s**	15000 mm²		
Zero load reading	7623146 digits	**Zero load reading**	7554737 digits	**Zero load reading**	8212984 digits
a-factor	0.76	**b-factor**	0.002		
		Offset	80.1 mm		

Q_c Load (kN)	**Eqv. q_c (MPa)**	**Output (Digits)**	**F_s Load (kN)**	**Eqv. f_s (MPa)**	**Output (Digits)**	**Pressure (bar)**	**Eqv. u (MPa)**	**Output (Digits)**
0	0	0	0	0.000	0	0	0.0	0
10	10	692677	10	0.667	710792	2	0.2	715133
20	20	1387394	20	1.333	1423525	4	0.4	1438947
30	30	2081296	30	2.000	2135310	6	0.6	2170393
40	40	2774358	40	2.667	2846138	8	0.8	2888594
50	50	3466554	50	3.333	3555998	10	1.0	3635534
60	60	4157859	60	4.000	4264878	12	1.2	4339022
70	70	4848245	70	4.667	4972769	14	1.4	5062640
80	80	5537689	80	5.333	5679659	16	1.6	5785605
90	90	6226163	90	6.000	6385538	18	1.8	6508129
100	100	6913643	100	6.667	7090395	20	2.0	7227065
90	90	6224832	90	6.000	6382755			
80	80	5536128	80	5.333	5676938			
70	70	4846764	70	4.667	4970502			
60	60	4156689	60	4.000	4263322			
50	50	3465852	50	3.333	3555272			
40	40	2774201	40	2.667	2846227			
30	30	2081686	30	2.000	2136061			
20	20	1388255	20	1.333	1424648			
10	10	693857	10	0.667	711864			
0	0	-925	0	0.000	-1304			

Zero load error	0.01 %	**Zero load error**	0.02 %	**Zero load error**	0.01 %
Max. linearity	0.14 %	**Max. linearity**	0.15 %	**Max. linearity**	0.30 %
Max. hysteresis	0.02 %	**Max. hysteresis**	0.04 %		

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calibration certificate
DS10CFIIP.S17176 / 001

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Channel 4	Inclination X	**Channel 5**	Inclination Y	**Channel 6**	None
Range	-20 ... 20 °	**Range**	-20 ... 20 °		

Angle (°)	**Output (Digits)**	**Angle (°)**	**Output (Digits)**
-20	-4982	-20	-5000
-15	-3684	-15	-3702
-10	-2386	-10	-2404
-5	-1088	-5	-1105
0	-136	0	-157
5	1509	5	1491
10	2807	10	2789
15	4105	15	4088
20	5404	20	5386

Calibration instrument(s)	**Certificate number(s)**	**Date(s)**
GSNCAL/822084350	2070856.06600.1	04-Sep-2017

Remark
We declare that the electrical cone with serial number DS10CFIIP.S17176 has been calibrated and that the specifications are according to the ISO 22476-1:2012 (Geotechnical investigation and testing – Field testing - Part 1: Electrical cone and piezocone penetration test).
The calibrations are traceable to national and international standards.

Date 15-Sep-2017
Calibrated by Joost Neugebauer

Date 15-Sep-2017
Approved by Jody Jansen

Signature

Signature

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calibration certificate

DS15CFIIP.S16299 / 001

Cone number	DS15CFIIP.S16299	**Client**	Geomil internal production
Kind of cone	Subtraction		Westbaan 240
Calibration date	15-Sep-2017		2841 MC Moordrecht
Print date	16-Oct-2017		Netherlands

Channel 1	Cone resistance (q_c)	**Channel 2**	Local sleeve friction (f_s)	**Channel 3**	Pore pressure (u)
	$q_c = Q_c / A_c$		$f_s = F_s / A_s$		
Range	0 ... 150 kN	**Range**	0 ... 150 kN	**Range**	0 ... 20 bar
A_c	1500 mm²	**A_s**	22500 mm²		
Zero load reading	8366299 digits	**Zero load reading**	8048019 digits	**Zero load reading**	8468774 digits
a-factor	0.7996	**b-factor**	-0.0004		
		Offset	97.6 mm		

Q_c Load (kN)	**Eqv. q_c (MPa)**	**Output (Digits)**	**F_s Load (kN)**	**Eqv. f_s (MPa)**	**Output (Digits)**	**Pressure (bar)**	**Eqv. u (MPa)**	**Output (Digits)**
0	0	0	0	0.000	0	0	0.0	0
15	10	764094	15	0.667	767668	2	0.2	621899
30	20	1528727	30	1.333	1535338	4	0.4	1250626
45	30	2292661	45	2.000	2302184	6	0.6	1880278
60	40	3055891	60	2.667	3068217	8	0.8	2509658
75	50	3818414	75	3.333	3833453	10	1.0	3138596
90	60	4580224	90	4.000	4597905	12	1.2	3769480
105	70	5341317	105	4.667	5361587	14	1.4	4397140
120	80	6101688	120	5.333	6124515	16	1.6	5025810
135	90	6861331	135	6.000	6886700	18	1.8	5651888
150	100	7620244	150	6.667	7648159	20	2.0	6280928
135	90	6862218	135	6.000	6886718			
120	80	6103156	120	5.333	6124191			
105	70	5343339	105	4.667	5361266			
90	60	4582718	90	4.000	4597815			
75	50	3821247	75	3.333	3833709			
60	40	3058877	60	2.667	3068822			
45	30	2295562	45	2.000	2303026			
30	20	1531252	30	1.333	1536194			
15	10	765901	15	0.667	768197			
0	0	729	0	0.000	739			

Zero load error	0.01 %	**Zero load error**	0.01 %	**Zero load error**	0.00 %
Max. linearity	0.15 %	**Max. linearity**	0.13 %	**Max. linearity**	0.10 %
Max. hysteresis	0.04 %	**Max. hysteresis**	0.01 %		

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calibration certificate

DS15CFIIP.S16299 / 001

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Channel 4	Inclination X	**Channel 5**	Inclination Y	**Channel 6**	None
Range	-20 ... 20 °	**Range**	-20 ... 20 °		

Angle (°)	Output (Digits)	Angle (°)	Output (Digits)
-20	-4912	-20	-5439
-15	-3614	-15	-4140
-10	-2316	-10	-2842
-5	-1018	-5	-1544
0	-72	0	-646
5	1579	5	1053
10	2877	10	2351
15	4175	15	3649
20	5474	20	4947

Calibration instrument(s)	Certificate number(s)	Date(s)
GSNCAL/822084350	2070856.06600.1	04-Sep-2017

Remark

We declare that the electrical cone with serial number DS15CFIIP.S16299 has been calibrated and that the specifications are according to the ISO 22476-1:2012 (Geotechnical investigation and testing – Field testing - Part 1: Electrical cone and piezocone penetration test).
The calibrations are traceable to national and international standards.

Date	15-Sep-2017	**Date**	15-Sep-2017
Calibrated by	Joost Neugebauer	**Approved by**	Jody Jansen
Signature		**Signature**	

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calibration certificate

DC10CFIIP.C17010 / 001

Geomil equipment

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Cone number	DC10CFIIP.C17010	**Client**	Geomil internal production
Kind of cone	Compression		Westbaan 240
Calibration date	15-Sep-2017		2841 MC Moordrecht
Print date	16-Oct-2017		Netherlands

Channel 1	Cone resistance (q_c)	**Channel 2**	Local sleeve friction (f_s)	**Channel 3**	Pore pressure (u)
	$q_c = Q_c / A_c$		$f_s = F_s / A_s$		
Range	0 ... 100 kN	**Range**	0 ... 15 kN	**Range**	0 ... 20 bar
A_c	1000 mm²	**A_s**	15000 mm²		
Zero load reading	7604956 digits	**Zero load reading**	8348955 digits	**Zero load reading**	8319072 digits
a-factor	0.771	**b-factor**	-0.007		
		Offset	80.1 mm		

Q_c Load (kN)	**Eqv. q_c (MPa)**	**Output (Digits)**	**F_s Load (kN)**	**Eqv. f_s (MPa)**	**Output (Digits)**	**Pressure (bar)**	**Eqv. u (MPa)**	**Output (Digits)**
0	0	0	0.0	0.0	0	0	0.0	0
10	10	695915	1.5	0.1	672623	2	0.2	578446
20	20	1393008	3.0	0.2	1345691	4	0.4	1163720
30	30	2089696	4.5	0.3	2018410	6	0.6	1750998
40	40	2785944	6.0	0.4	2690765	8	0.8	2336123
50	50	3481718	7.5	0.5	3362740	10	1.0	2921532
60	60	4176985	9.0	0.6	4034322	12	1.2	3507381
70	70	4871710	10.5	0.7	4705495	14	1.4	4092760
80	80	5565860	12.0	0.8	5376245	16	1.6	4678767
90	90	6259399	13.5	0.9	6046556	18	1.8	5261454
100	100	6952295	15.0	1.0	6716415	20	2.0	5843924
90	90	6254308	13.5	0.9	6045550			
80	80	5561602	12.0	0.8	5374875			
70	70	4868259	10.5	0.7	4704054			
60	60	4174313	9.0	0.6	4033027			
50	50	3479796	7.5	0.5	3361732			
40	40	2784741	6.0	0.4	2690110			
30	30	2089182	4.5	0.3	2018099			
20	20	1393150	3.0	0.2	1345638			
10	10	696680	1.5	0.1	672667			
0	0	-337	0.0	0.0	1645			

Zero load error	0.01 %	**Zero load error**	0.02 %	**Zero load error**	0.04 %
Max. linearity	0.08 %	**Max. linearity**	0.07 %	**Max. linearity**	0.10 %
Max. hysteresis	0.07 %	**Max. hysteresis**	0.02 %		

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calibration certificate

DC10CFIIP.C17010 / 001

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Channel 4	Inclination X	**Channel 5**	Inclination Y	**Channel 6**	None
Range	-20 ... 20 °	**Range**	-20 ... 20 °		

Angle (°)	**Output (Digits)**	**Angle (°)**	**Output (Digits)**	
-20	-4263	-20	-4175	
-15	-2965	-15	-2877	
-10	-1667	-10	-1579	
-5	-368	-5	-281	
0	651	0	749	
5	2228	5	2316	
10	3526	10	3614	
15	4825	15	4912	
20	6123	20	6211	

Calibration instrument(s)	**Certificate number(s)**	**Date(s)**
GSNCAL/822084350	2070856.06600.1	04-Sep-2017

Remark
We declare that the electrical cone with serial number DC10CFIIP.C17010 has been calibrated and that the specifications are according to the ISO 22476-1:2012 (Geotechnical investigation and testing – Field testing - Part 1: Electrical cone and piezocone penetration test).
The calibrations are traceable to national and international standards.

Date	15-Sep-2017	**Date**	15-Sep-2017
Calibrated by	Joost Neugebauer	**Approved by**	Kevin Janssens
Signature		**Signature**	

LLOYD'S REGISTER LRQA ISO 9001

Westbaan 240 | 2841 MC Moordrecht | The Netherlands | P.O. Box 450 | 2800 AL Gouda | The Netherlands
t: +31(0) 172 427 800 | f: +31(0) 172 427 801 | info@geomil.com | www.geomil.com

DC10 / DS10 Series

Specifications electrical (piezo)cone

Characteristics

Cone type
- Compression / Subtraction (*)

Parameters (CFII or CFIIP)
- Cone resistance
- Sleeve friction
- Pore pressure (optional)
- Inclination (XY)

Dimensions

Cross sectional area of cone (A_c)	:	1 000	mm²
Surface area of friction sleeve (A_s)	:	15 000	mm²
Total length	:	279	mm

Range & accuracy

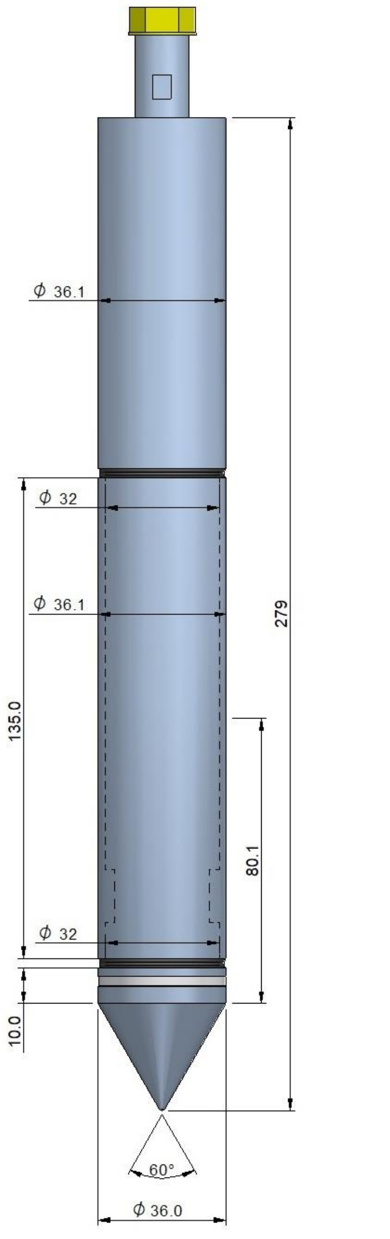
Cone resistance load cell			
Range	:	50 / 100*	MPa
Overload capacity	:	150	%
Net area ratio (a)	:	0.8	
Sleeve friction load cell			
Range	:	0.5 / 1.0*	MPa
Overload capacity	:	130	%
Cross sectional area bottom (A_{sb})	:	219	mm²
Cross sectional area top (A_{st})	:	219	mm²
Net area ratio (b)	:	0	
Offset of sleeve centre	:	80.1	mm
Pore pressure transducer			
Range	:	2.0	MPa
Burst pressure	:	150	%
Inclinometers			
Type	:	Dual accelerometer	
Range	:	- 20 … + 20	°

Temperature range

Operating temperature	:	- 10 … + 40	°C
Storage temperature	:	- 40 … + 60	°C

Notes

Down-hole signal conditioning and temperature compensation
Other load ranges available on request
Filter located in tip (u_1) or shoulder (u_2)
Wear resistant outer parts



a = A_n / A_c
A_n = cross sectional area of load cell
A_c = cross sectional area of cone

b = (A_{sb} − A_{st}) / A_s
A_{sb} = cross sectional area of friction sleeve bottom
A_{st} = cross sectional area of friction sleeve top
A_s = surface area of friction sleeve

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Bank Rabobank - Account no. 1350.49.229
IBAN NL78 RABO 0135 0492 29 - BIC RABONL2U
VAT no. NL812396212B01
Chamber of Commerce no. 2435053

DC15 / DS15 Series

Specifications electrical (piezo)cone

Characteristics

Cone type
- Compression / Subtraction (*)

Parameters (CFII or CFIIP)
- Cone resistance
- Sleeve friction
- Pore pressure (optional)
- Inclination (XY)

Dimensions

Cross sectional area of cone (A_c)	:	1 500	mm²
Surface area of friction sleeve (A_s)	:	22 500	mm²
Total length	:	319	mm

Range & accuracy

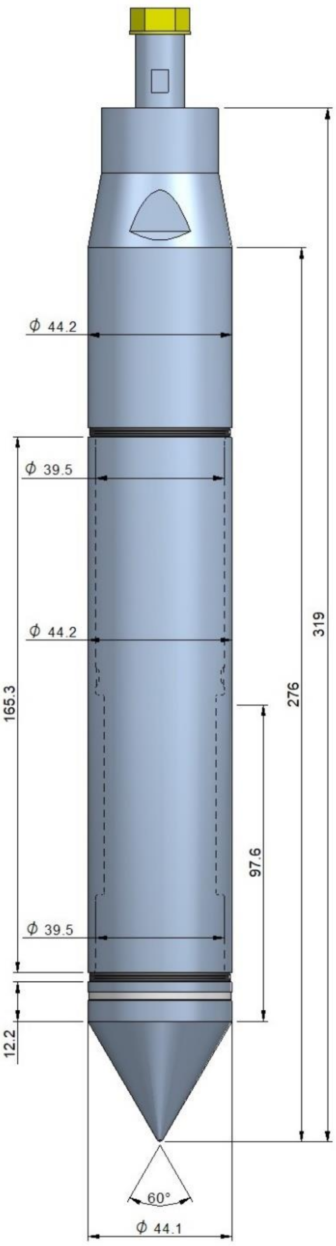
Cone resistance load cell			
Range	:	100	MPa
Overload capacity	:	150	%
Net area ratio (a)	:	0.8	
Sleeve friction load cell			
Design range	:	1.0	MPa
Overload capacity	:	130	%
Cross sectional area bottom (A_{sb})	:	309	mm²
Cross sectional area top (A_{st})	:	309	mm²
Net area ratio (b)	:	0	
Offset of sleeve centre	:	97.6	mm
Pore pressure transducer			
Range	:	2.0	MPa
Burst pressure	:	150	%
Inclinometers			
Type	:	Dual accelerometer	
Range	:	- 20 … + 20	°

Temperature range

Operating temperature	:	- 10 … + 40	°C
Storage temperature	:	- 40 … + 60	°C

Notes

Down-hole signal conditioning and temperature compensation
Other load ranges available on request
Filter located in tip (u_1) or shoulder (u_2)
Wear resistant outer parts
Cylindrical end piece available on request



a = A_n / A_c
A_n = cross sectional area of load cell
A_c = cross sectional area of cone

b = (A_{sb} − A_{st}) / A_s
A_{sb} = cross sectional area of friction sleeve bottom
A_{st} = cross sectional area of friction sleeve top
A_s = surface area of friction sleeve

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CONE CALIBRATION CERTIFICATE

N° Z045/17

Calibrated system *(Sistema tarato)* **:**

Serial number	**Mkj528**
Sensor	**TIP RESISTANCE**
Max. Capacity [MPa]:	**50**
Scaling Factor:	**184460**
Tip net area ratio (a_n):	**0,79**
Sleeve net ratio (b_n):	**0,00**

Addressee *(destinatario)* **:**

Pagani Geotecnical Equipment s.r.l.
loc. Campogrande n° 26
29010 Calendasco (Piacenza) ITALY

Applied load measurement system:
(Sistema di rilevamento del carico applicato)

Load cell:

Manufacturer	AEP transducers
Model	KAL 50 kN
Serial Number	33870

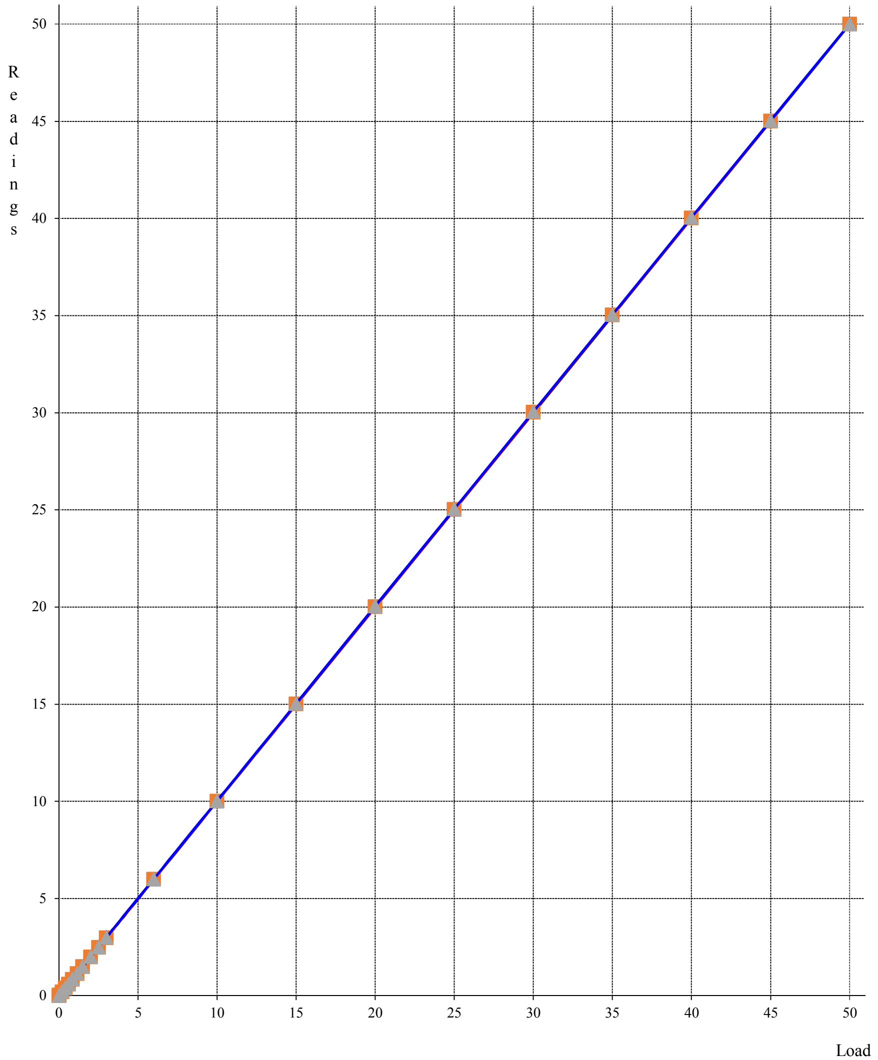
Power press:

Manufacturer	Easydur Italiana
Model	Aura 10T
Serial Number	29002

The measurement system is periodically checked in a SIT calibration center. *(Il sistema di rilevamento è sottoposto a verifica periodica presso un centro SIT)*

Last verification date:	27/02/2017
Certificate N.	LAT 052 1702374FSE
Temperature of calibration	22°C
Humidity	35%

Factory calibration in accordance with ASTM 05778-12



	Ascending		Descending	
	Load	Readings	Load	Readings
1	0,00	0,00	0,00	0,00
2	0,03	0,03	0,03	0,03
3	0,20	0,19	0,20	0,20
4	0,40	0,39	0,40	0,40
5	0,60	0,59	0,60	0,60
6	0,85	0,84	0,85	0,85
7	1,15	1,13	1,15	1,15
8	1,50	1,49	1,50	1,50
9	2,00	1,98	2,00	2,00
10	2,50	2,48	2,50	2,50
11	3,00	2,98	3,00	3,00
12	6,00	5,99	6,00	6,01
13	10,00	10,00	10,00	10,02
14	15,00	15,01	15,00	15,03
15	20,00	20,02	20,00	20,05
16	25,00	25,02	25,00	25,05
17	30,00	30,03	30,00	30,06
18	35,00	35,03	35,00	35,05
19	40,00	40,02	40,00	40,05
20	45,00	45,01	45,00	45,03
21	50,00	50,00	50,00	50,01

Unit: Mpa

Zero-load error:	=	0,000	% FSO
Zero-load thermal stability:	<=	1,000	% FSO
Nonlinearity:	=	0,056	% FSO
Hysteresis:	=	0,056	% FSO
Calibration error:	=	0,000	% MO
Apparent load:	=	0,240	% FSO

The adopted calibration procedure has been developed according to the suggestions given by Prof. Paul W. Mayne (Georgia Institute of technology) and Prof. Diego Lo Presti (University of Pisa)

Cone calibrated by ____________

Date of issue 08/04/2017

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CONE CALIBRATION CERTIFICATE
N° Z045/17

Calibrated system *(Sistema tarato)* **:**

Serial number	**Mkj528**
Sensor	**SLEEVE FRICTION**
Max. Capacity [kPa]:	**1600**
Scaling Factor:	**32064**

Addressee *(destinatario)* **:**

Pagani Geotecnical Equipment s.r.l.
loc. Campogrande n° 26
29010 Calendasco (Piacenza) ITALY

Applied load measurement system:
(Sistema di rilevamento del carico applicato)

Load cell:

Manufacturer	AEP transducers
Model	KAL 50 kN
Serial Number	33870

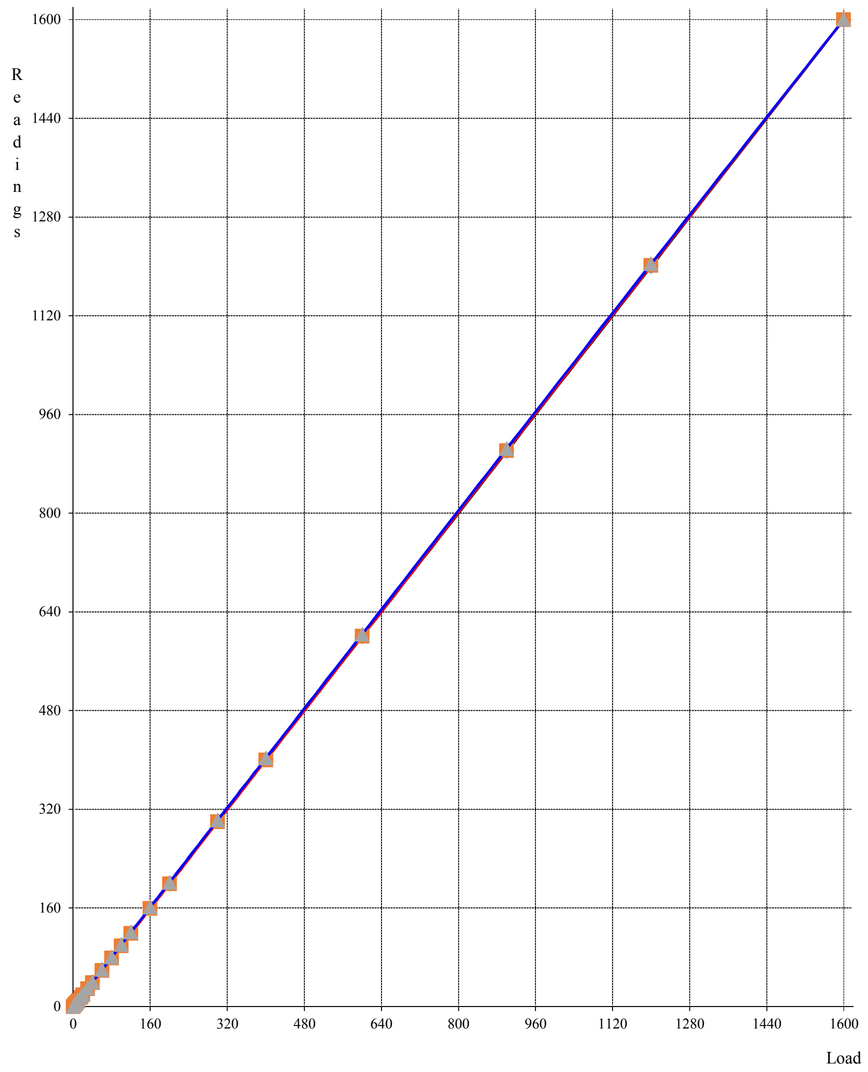
Power press:

Manufacturer	Easydur Italiana
Model	Aura 10T
Serial Number	29002

The measurement system is periodically checked in a SIT calibration center. *(Il sistema di rilevamento è sottoposto a verifica periodica presso un centro SIT)*

Last verification date:	27/02/2017
Certificate N.	LAT 052 1702374FSE
Temperature of calibration	22°C
Humidity	35%

Factory calibration in accordance with ASTM 05778-12



	Ascending		Descending	
	Load	Readings	Load	Readings
1	0,00	0,07	0,00	0,47
2	2,00	1,73	2,00	2,27
3	5,00	4,40	5,00	5,07
4	7,00	6,27	7,00	7,07
5	10,00	9,20	10,00	10,07
6	16,00	14,93	16,00	15,93
7	20,00	18,87	20,00	19,93
8	30,00	28,80	30,00	30,00
9	40,00	38,67	40,00	40,00
10	60,00	58,60	60,00	60,20
11	80,00	78,60	80,00	80,33
12	100,00	98,67	100,00	100,47
13	120,00	118,73	120,00	120,60
14	160,00	158,87	160,00	160,93
15	200,00	199,00	200,00	201,33
16	300,00	299,53	300,00	302,20
17	400,00	399,80	400,00	402,80
18	600,00	600,47	600,00	603,67
19	900,00	901,20	900,00	904,33
20	1200,00	1201,27	1200,00	1203,93
21	1600,00	1600,00	1600,00	1600,33

Unit: kPa

Zero-load error:	=	0,025	% FSO
Zero-load thermal stability:	<=	1,000	% FSO
Nonlinearity:	=	0,088	% FSO
Hysteresis:	=	0,200	% FSO
Calibration error:	=	0,000	% MO
Apparent load:	=	0,020	% FSO

The adopted calibration procedure has been developed according to the suggestions given by Prof. Paul W. Mayne (Georgia Institute of technology) and Prof. Diego Lo Presti (University of Pisa)

Cone calibrated by Claudio O.

Date of issue 08/04/2017

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CONE CALIBRATION CERTIFICATE
N° Z045/17

Calibrated system *(Sistema tarato)* **:**

Serial number	**Mkj528**
Sensor	**PORE PRESSURE**
Max. Capacity [kPa]:	**2500**
Scaling Factor:	**11012**
Sensor	**TILT ANGLE**
Max. Inclination [°]:	**20**
Scaling Factor:	**151154**

Addressee *(destinatario)* **:**
Pagani Geotecnical Equipment s.r.l.
loc. Campogrande n° 26
29010 Calendasco (Piacenza) ITALY

Applied load measurement system:
(Sistema di rilevamento del carico applicato)

Pressure Generator:

Manufacturer	AEP transducers
Model	GPM500

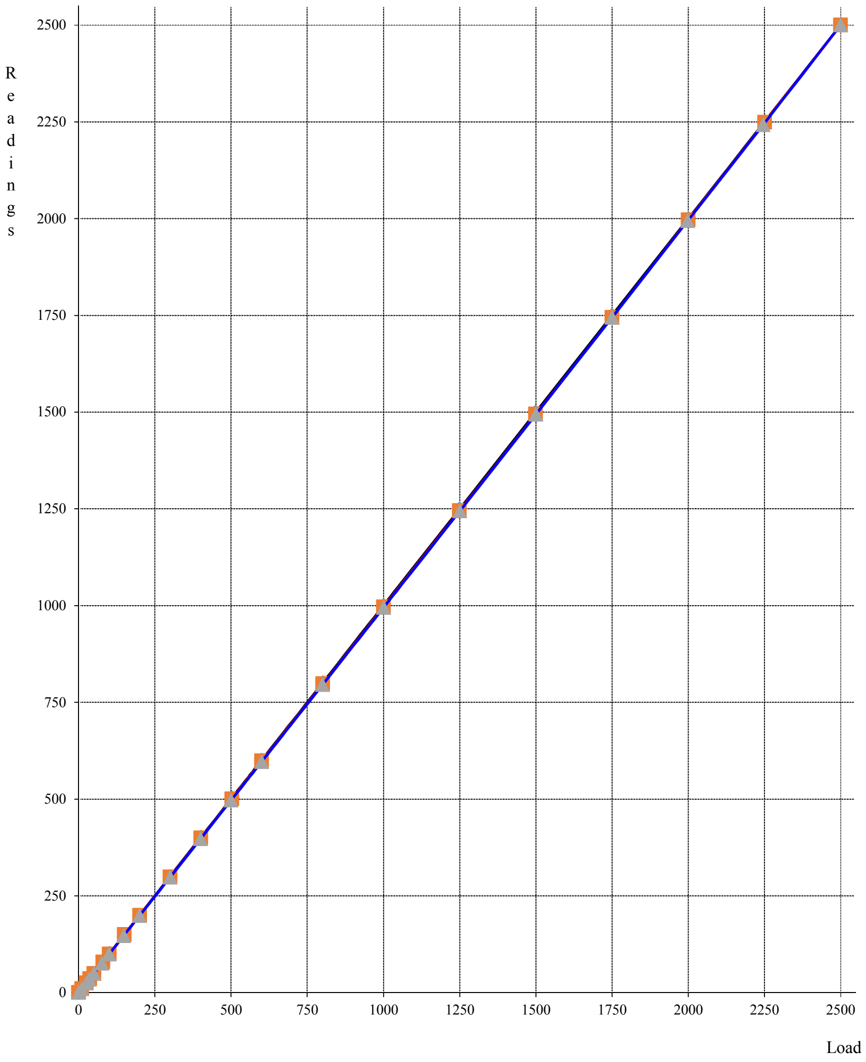
Digital Indicator:

Manufacturer	AEP transducers
Model	LAB DMM
Serial Number	301796

The measurement system is periodically checked in a SIT calibration center. *(Il sistema di rilevamento è sottoposto a verifica periodica presso un centro SIT)*

Last verification date:	25/01/2017
Certificate N.	LAT 093-9717P
Temperature of calibration	22°C
Humidity	35%

Factory calibration in accordance with ASTM 05778-12



	Ascending		Descending	
	Load	Readings	Load	Readings
1	0,00	0,00	0,00	0,00
2	10,00	10,00	10,00	9,90
3	25,00	24,90	25,00	24,60
4	36,40	36,00	35,00	34,30
5	50,00	49,30	50,00	49,30
6	80,00	79,00	76,20	75,80
7	101,00	100,00	100,00	99,60
8	150,00	149,70	147,60	146,90
9	200,00	199,50	199,80	198,60
10	300,00	299,10	300,00	298,20
11	401,00	399,70	400,00	397,60
12	502,80	500,80	500,00	496,90
13	600,80	598,60	600,00	596,30
14	801,00	797,80	800,00	795,30
15	1000,00	996,20	1000,60	995,20
16	1249,80	1245,50	1250,60	1244,70
17	1499,60	1494,90	1500,00	1494,50
18	1749,60	1744,70	1750,00	1744,80
19	1999,40	1996,80	1998,20	1994,30
20	2250,80	2249,00	2246,00	2242,70
21	2500,00	2500,10	2499,40	2500,10

Unit: kPa

Zero-load error:	=	0,000	% FSO
Nonlinearity:	=	0,196	% FSO

The adopted calibration procedure has been developed according to the suggestions given by Prof. Paul W. Mayne (Georgia Institute of technology) and Prof. Diego Lo Presti (University of Pisa)

Cone calibrated by Claudio C.

Date of issue 08/04/2017

Kalibreringscertifikat

Environmental Mechanics AB intygar att CPT sonden av typ Memocone, med det serienummer som anges nedan, har blivit kalibrerad i vårt laboratorie samt passerat vår kvalitetskontroll.

Serienummer:	20759	Visad last/crosstalk:	
Kalibreringsdatum:	07-mar-2016	Q när F lastas:	0.0 %FSO
Max tillåten belastning:	50 kN	F när Q lastas:	<0.3 %FSO
Area faktor:	a=0.69b=0.006	U när Q lastas (Q<=7MPa):	<0.2 %FSO

☑ ISO 22476-1 användningsklass 1 godkännande

☑ ASTM D 5778 godkännande

☐ ISO 22476-1 användningsklass 0 godkännande

Envi

Envi
Environmental Mechanics AB
Kungsgårdsgatan 7
S-441 57 Alingsås
SWEDEN

Johan Nil[illegible]

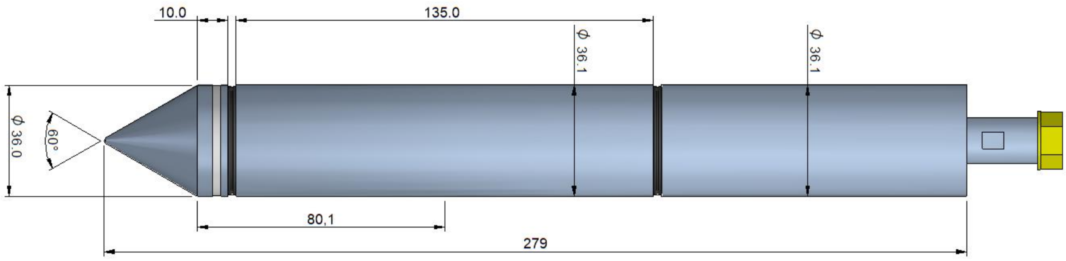
Test date	:	Thursday 21 September 2017
To	:	NGI
From	:	Geomil Equipment B.V.
Subject	:	CPTU at test site Øysand

General

Geomil performed several CPTU's at the Øysand testing site at Thursday 21th of September. Standard cones are used for these tests, 3 compression cones and 2 subtraction cones.

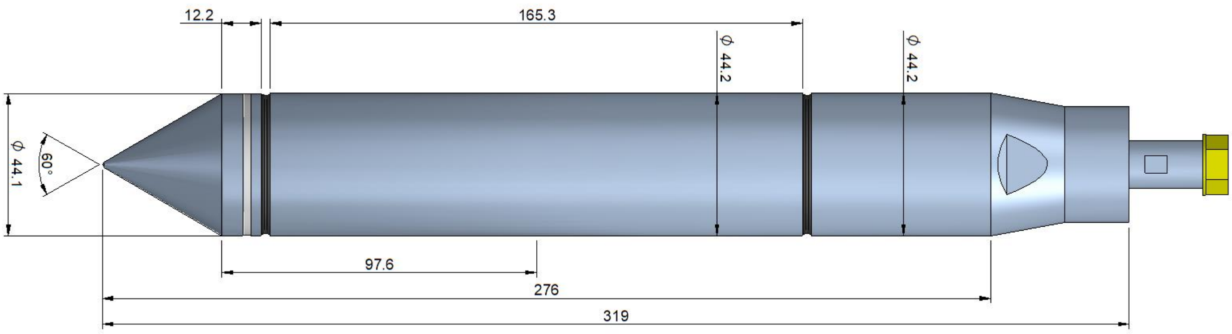
10 cm^2 cones with the following specifications:

Compression cone:	*C14251*	*Tip: 50 MPa*	*Sleeve: 500 kPa*	*Pore pressure (u2): 20 bar*
Compression cone:	*C17010*	*Tip: 100 MPa*	*Sleeve: 1000 kPa*	*Pore pressure (u2): 20 bar*
Subtraction cone:	*S17176*	*Tip: 100 MPa*	*Sleeve: 1000 kPa*	*Pore pressure (u2): 20 bar*



15 cm^2 cones with the following specifications:

Compression cone:	*C17190*	*Tip: 100 MPa*	*Sleeve: 1000 kPa*	*Pore pressure (u2): 20 bar*
Subtraction cone:	*S16299*	*Tip: 100 MPa*	*Sleeve: 1000 kPa*	*Pore pressure (u2): 20 bar*



Rig / CPT truck: Kodiak-180 (truck with leveling crawler set)
Push frame: 1m stroke (discontinuous)
Friction reducer: yes, with cams

Remarks

① During all test we had to be careful in the first few meters due to gravel/grit layers. This results in some speed reductions in these layers.

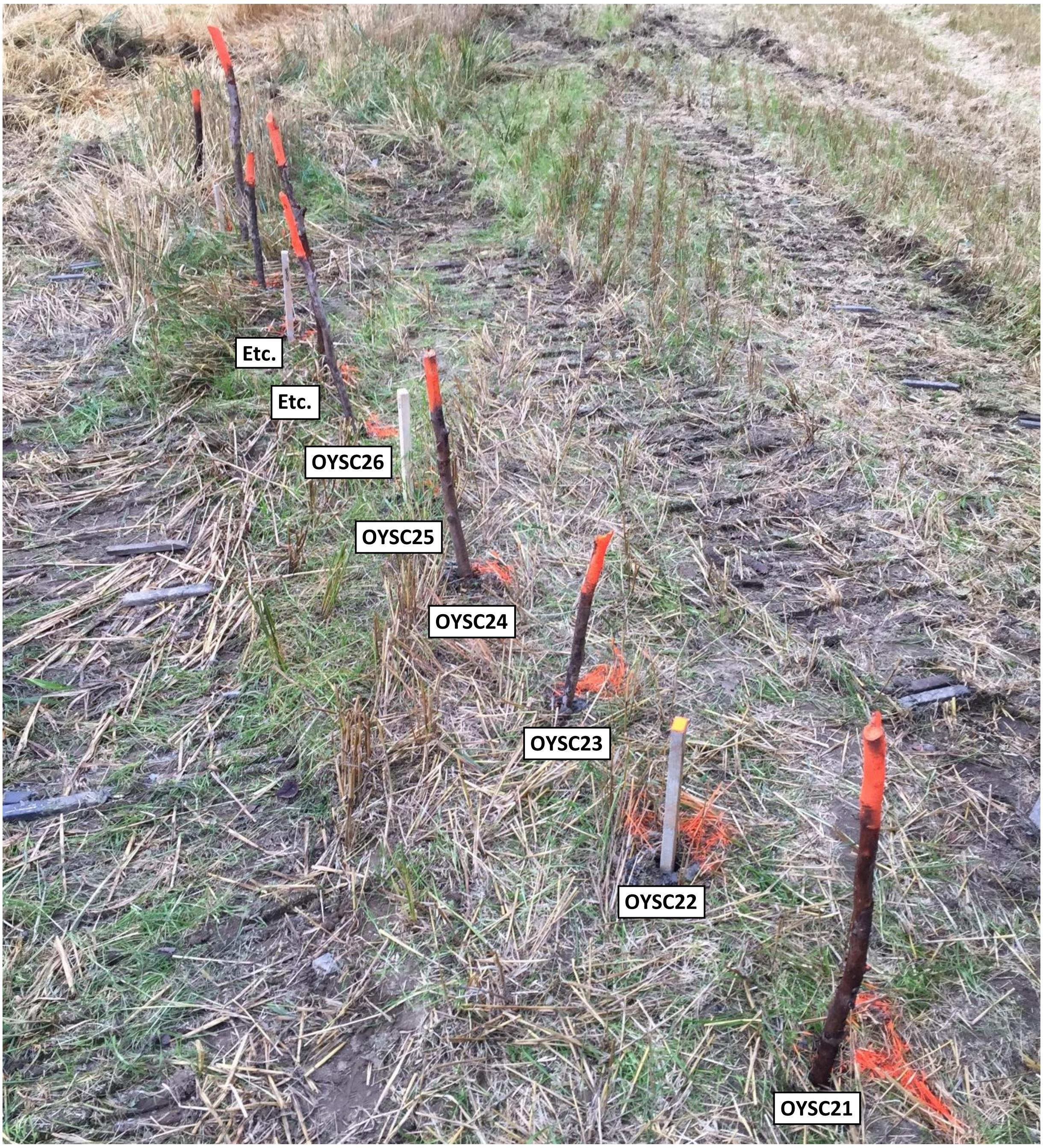
② Inclination is measured with an accelerometer in the cone. In the gravel/grit layers in first few meters the shock effect of touching stones has its effect on the (total) inclination data. With a shock, the x- and/or y-output can be larger than the real inclination of the cone is at that moment.

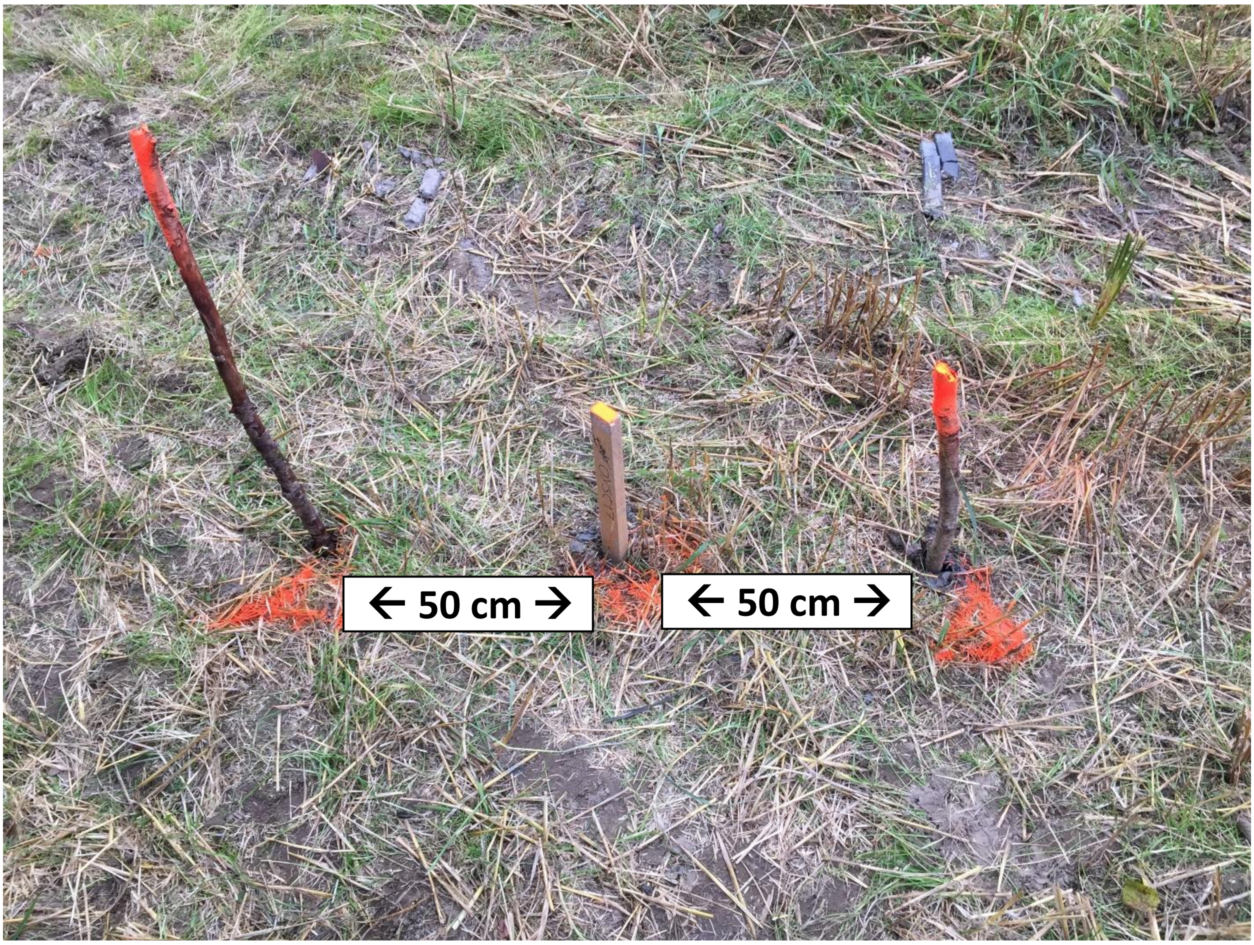
③ For all pore pressure tests (u2) the cones where de-aerated, installed with a brass filter and filled with silicon oil.

④ Data sheets:

- 1st sheet: RAW data
- 2nd sheet: Engineering data depth based
  0-readings taken into account, Rf ratio with lookup function (offset taken into account)
- 3rd sheet: Engineering data time based
  0-readings taken into account, Rf ratio with lookup function (offset taken into account)
- 4th sheet: Plots based on depth and time

Test locations Øysand




← 50 cm →
← 50 cm →

Date:28/10/2017

CPTu tests at Tiller and Øysand sites in Norway

Tiller site

The third and fourth National GeoTest Site (NGTS) in Norway are located near Trondheim city. Pagani team started to perform the tests in Tiller first (September /25, 26/ 2017) (Fig.1). The information available from NGI were (further information from NGI where added during the tests):

- Soil type: Quick clay
- Testing depth: approximately 25-30 meters
- Number of tests: 4 tests (3 CPTu and 1 SCPTu)

Fig.1: Test location at Tiller site

Instrumentations used from Pagani Geotechnical Equipment srl

The same instrumentation as explained in Ønsoy report has been used.

First day of testing

Weather condition: mainly sunny good to perform in situ tests.

The first CPTu test **TILC16**

The first CPTu test is **TILC16**.Piezocone serial number is MKj485[1].The penetration depth reached **31.71 m**, the penetration rate was 2cm/s as required from standards.

The Pagani rig anchored into the ground with helical augers of external diameter of 100mm, the anchoring depth was approximately 2.4 meters (Fig.2).

Before starting the test, the piezocone (with bronze filter mounted already) has been re-saturated for 15-20 minutes.

The second CPTu test **TILC14**

The second CPTu test is **TILC14 (31.71 m depth)**. Firstly, the rods and the piezocone were cleaned following the standard cleaning procedure at beginning of each piezocone test. The same procedures of anchoring and re-saturation of the filter, described above for the test **TILC16**, were used. Same piezocone as on **TILC16** were used.

The third CPTu test **TILC13**

The same piezocone (MKj485) and the same procedure as in TILC14 were used. The penetration depth reached **31.75 m**, the penetration rate was 2cm/s as required from standards.

Note 1: Before starting TILC16 (the first test of the day) accidentally, the MKj528 piezocone has been selected instead of MKj485. The attached TILC16 file has been re-scaled to the proper (scaling factors) of the correct used piezocone MKj485.

The Fig.2 shows Pagani team during an anchoring procedure with the helical augers

Fig.2: Operators at work

Second day of testing

Weather condition: mainly sunny good to perform in situ tests.

Requested one S-CPTu tests of 30 meters depth.

- Standard penetration rate
- Seismic tests at different depth intervals

S-CPTu test **TILC15**

Anchoring depth approximately 2.4 meters, auger diameter 100mm.

Before starting the test, the piezocone (with bronze filter) were re-saturated for 10-15 minutes. Piezocone serial number is MKj485 (calibration sheets are attached).

The seismic module has been mounted behind the piezocone. *The distance between piezocone tip and the first seismic sensor is 0.6m.*

Seismic tests were performed, firstly every 1 meter than every 2 meter.

Øysand site

Pagani team started to perform the tests in Øysand (September /27, 28/ 2017) Fig.3. The information available from NGI were (further information from NGI where added during the tests):

- Soil type: Sand, gravel layer at 4/5 m below ground
- Testing depth: approximately 20-25 meters
- Number of tests: 4 tests (3 CPTu and 1 SCPTu)

Fig.3: Test location at Øysand site

First day of testing

Weather condition: mainly sunny good to perform in situ tests.

Note: The test **Oysc33** was not included with the attached CPTu files. Reason why, is because when we start the test (after having difficulties on anchoring the machine) the piezocone got a high inclination at very beginning. Pagani Company decide to not consider that test and restart a new one. Anyway, if NGI would consider to check that test too (even if we think that is useless) we may send to you.

The first CPTu **Oysc34**

The first CPTu test is **Oysc34**.Piezocone serial number is MKj528.The penetration depth reached **20.75 m**, the penetration rate was 2cm/s as required from standards.

The Pagani rig anchored into the ground with helical augers of external diameter of 220mm, the anchoring depth was approximately 2.4 meters (Fig.3).

Before starting the test, the piezocone (with bronze filter mounted already) has been re-saturated for 15-20 minutes.

The second CPTu test **Oysc35**

The second CPTu test is **test Oysc35 (20.59 m depth)**. Firstly, the rods and the piezocone were cleaned following the standard cleaning procedure at beginning of each piezocone test. The same procedures of anchoring and re-saturation of the filter, described above for the test **Oysc34**, were used. Same piezocone as on **Oysc34** were used.

Seismic tests were performed, firstly every 1 meter than every 2 meter.

Second day of testing

Weather condition: mainly sunny good to perform in situ tests.

The first CPTu test **Oysc38**

The first CPTu test is **Oysc38**.Piezocone serial number is MKj528.The penetration depth reached **20.83 m**, the penetration rate was 2cm/s as required from standards.

The Pagani rig anchored into the ground with helical augers of external diameter of 220mm, the anchoring depth was approximately 2.4 meters (Fig.3).

Before starting the test, the piezocone (with bronze filter mounted already) has been re-saturated for 15-20 minutes.

The second CPTu test **Oysc37**

The second CPTu test is **test Oysc37 (20.77 m depth)**. Firstly, the rods and the piezocone were cleaned following the standard cleaning procedure at beginning of each piezocone test. The same procedures of anchoring and re-saturation of the filter, described above for the test **Oysc38**, were used. Same piezocone as on **Oysc38** were used.

Appendix I

SEISMIC DILATOMETER TESTS (SDMT)

Contents

Figures

I1 Method

The Seismic Dilatometer is the combination of the standard Flat Dilatometer (DMT) with a seismic module for measuring the shear wave velocity, V_s. A detailed description of the Flat Dilatometer Test is given in Marchetti, et al., 2001 [1] while the seismic measurement of shear wave velocity in connection with DMT is treated in detail by Marchetti, et al., 2008 [2].

I1.1 Flat dilatometer test

The DMT test involves driving a steel blade (dilatometer) into the ground, inflate the steel membrane to certain deformations and measure the corresponding pressures. At a given penetration depth, the measurements are done by inflating the membrane and making two or three readings:

1. The pressure required to disconnect (electrically) the membrane from the interior parts of the blade – A-pressure or "lift off"-pressure
2. The pressure required to move the center of the membrane 1.1 mm against the soil – B-pressure
3. Sometimes a third measurement is made corresponding to reconnection of the membrane with the interior parts of the blade – C-pressure

These readings are repeated at different penetration depths.

I1.2 Shear wave velocity measurements

To measure the shear wave velocity for low shear strains ($<10^{-4}$ %) at selected depths, the soil is accelerated at ground surface using an L-shaped shear beam and a sledgehammer. Dual receivers register the shear waves which is further used to calculate the average shear wave velocity within the depth interval of the receivers:

$$V_S = \frac{S_2 - S_1}{\Delta t}$$

Here S_1 and S_2 are the straight line distances between the center of the energy source to the upper and lower receivers respectively (see Figure I1). Δt is the difference in shear wave travel times from source to receivers.

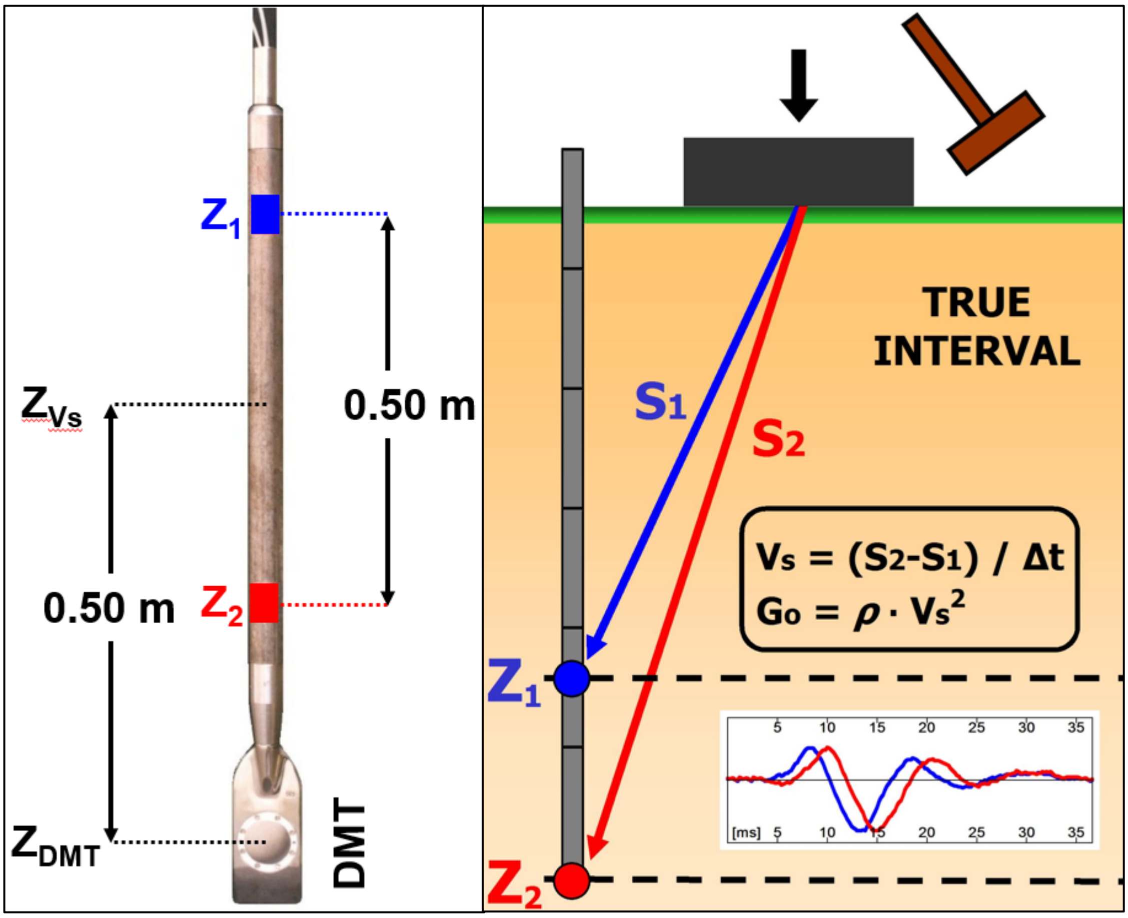


Figure I1 Dilatometer configuration. Z_1 and Z_2 are the locations of the shear wave velocity sensors.

I2 Equipment

NGI uses Cone Penetration equipment to penetrate the soil with the blade, but any common in-situ penetration tools can be used. The membrane of the blade is connected to a gas pressure unit on the surface which provides the pressure to inflate the steel membrane. The membrane works as an electrical switch signaling when specific deformations are reached.

The main part of the flat dilatometer consists of a flat stainless thin blade with a circular expandable steel membrane of 60 mm diameter on one side. The basic information about the configuration of the tests are given in [D3].

An external trigger is attached to the L-shaped shear beam not too close to the sledgehammer impact location. This sensor detects the impact and starts data acquisition. The configuration of the shear wave sensors can be seen in Figure I1. The average shear wave velocity is assigned automatically to Z_{Vs} by the SDMT software.

I3 Results

Two SDMT tests have been carried out (OYSD01 and OYSD02) at Øysand Research Site. Figures I2 and I3 illustrate the recorded and re-phased shear waves for test OYSD01 while recorded and re-phased shear waves obtained from test OYSD02 are demonstrated in Figure I4. Figures I5 to I12 demonstrate all shear wave results and flat dilatometer results from the two tests.

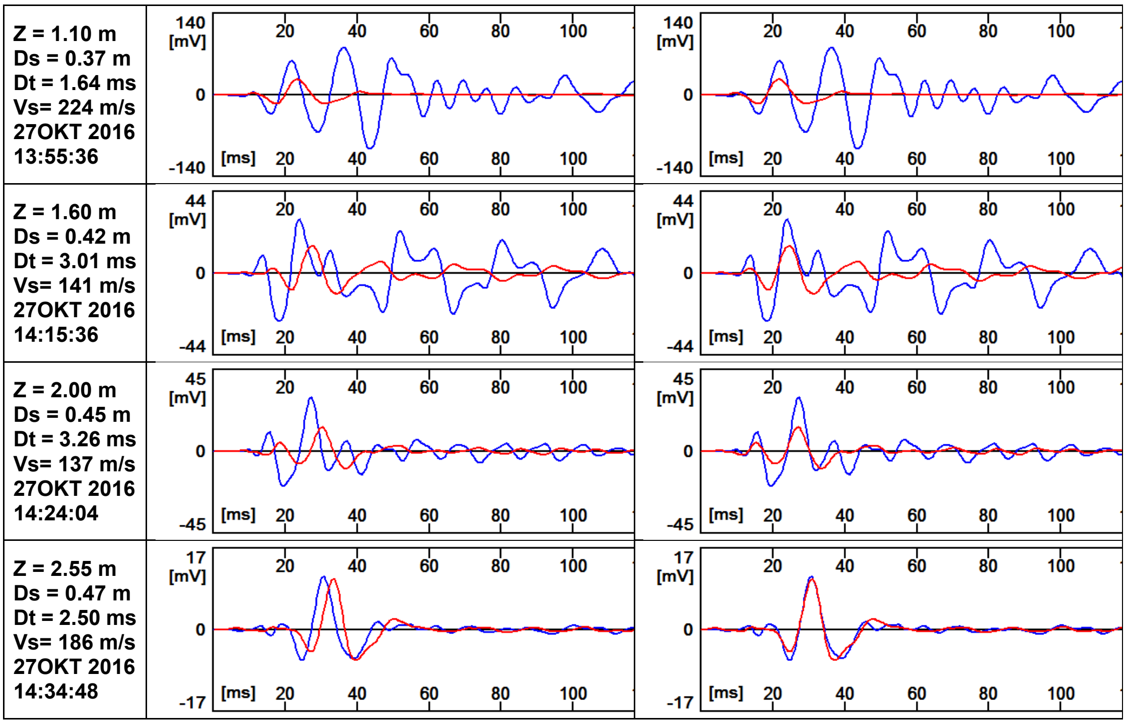
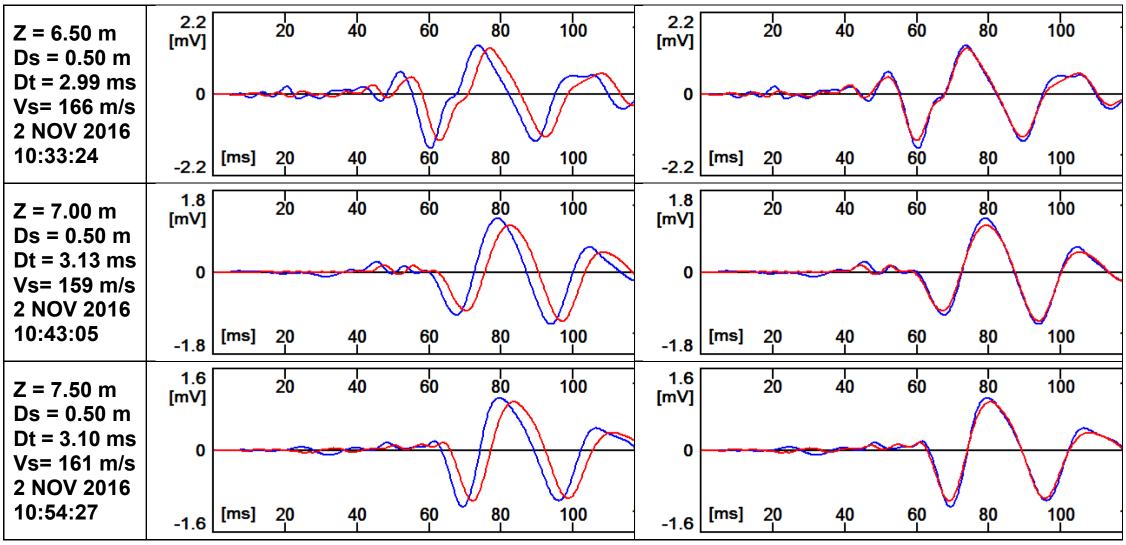
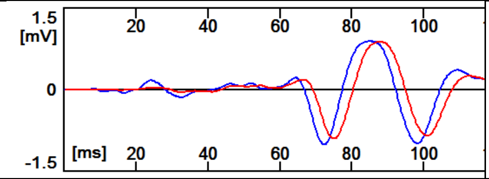
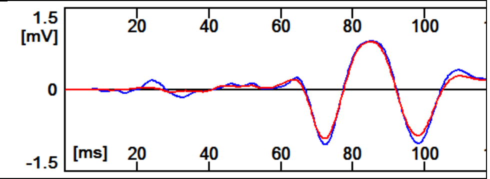


Figure I2 Recorded and re-phased shear waves – test OYSD01 – shallow depths

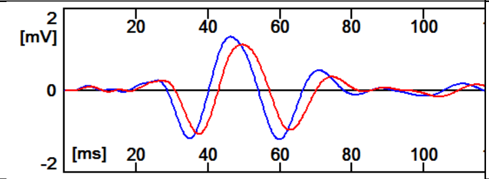


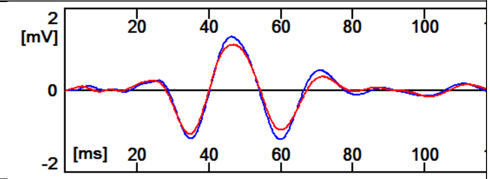
Z = 8.00 m
Ds = 0.50 m
Dt = 2.86 ms
Vs= 174 m/s
2 NOV 2016
11:03:17



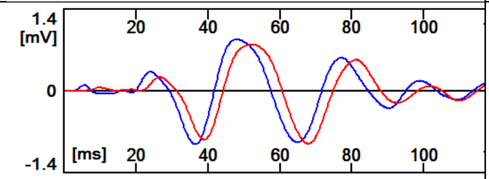


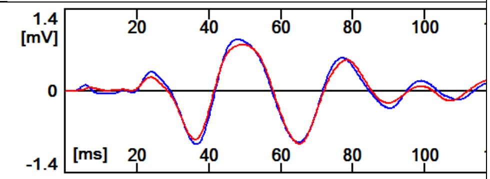
Z = 8.50 m
Ds = 0.50 m
Dt = 2.83 ms
Vs= 176 m/s
2 NOV 2016
11:13:42



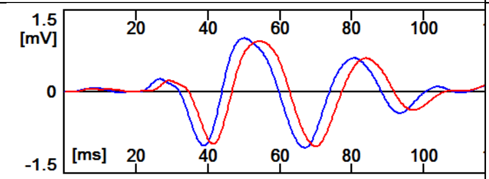


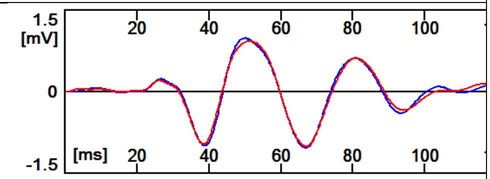
Z = 9.00 m
Ds = 0.50 m
Dt = 2.79 ms
Vs= 178 m/s
2 NOV 2016
11:39:43



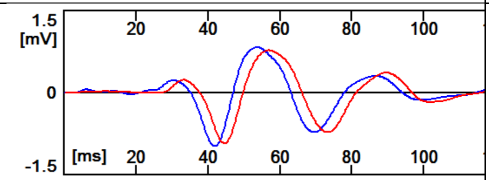


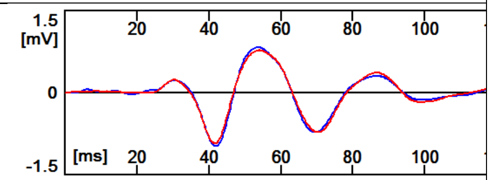
Z = 9.50 m
Ds = 0.50 m
Dt = 3.01 ms
Vs= 166 m/s
2 NOV 2016
11:45:49



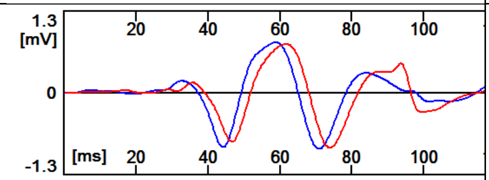


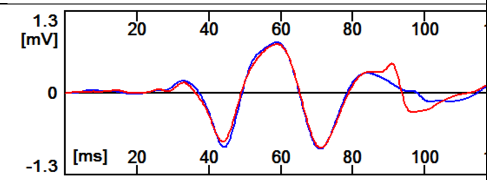
Z = 10.00 m
Ds = 0.50 m
Dt = 2.95 ms
Vs= 169 m/s
2 NOV 2016
11:50:01



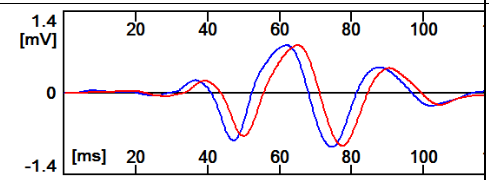


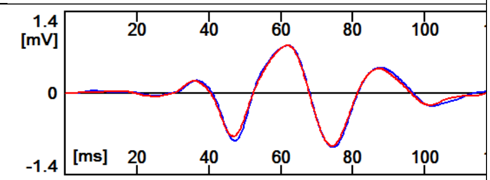
Z = 10.50 m
Ds = 0.50 m
Dt = 2.84 ms
Vs= 175 m/s
2 NOV 2016
12:35:39



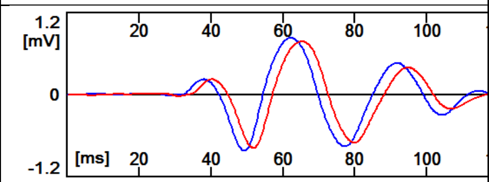


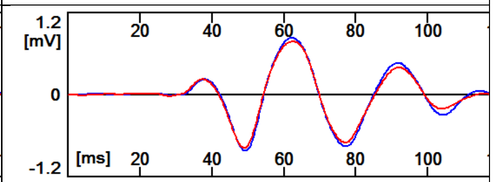
Z = 11.00 m
Ds = 0.50 m
Dt = 3.23 ms
Vs= 155 m/s
2 NOV 2016
12:42:05



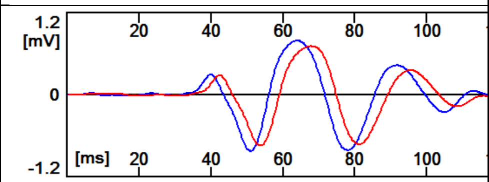


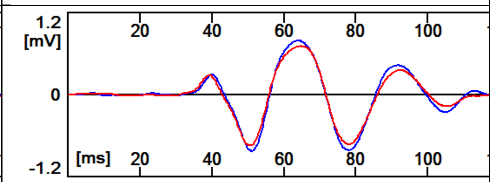
Z = 11.50 m
Ds = 0.50 m
Dt = 2.80 ms
Vs= 178 m/s
2 NOV 2016
12:47:49



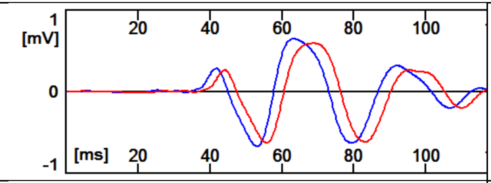


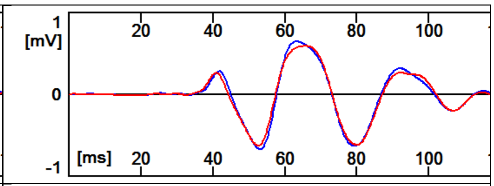
Z = 12.00 m
Ds = 0.50 m
Dt = 3.15 ms
Vs= 158 m/s
2 NOV 2016
12:51:38



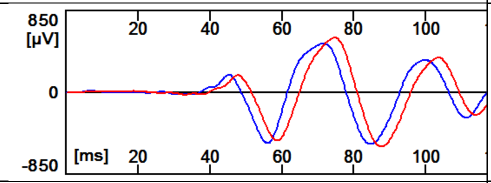


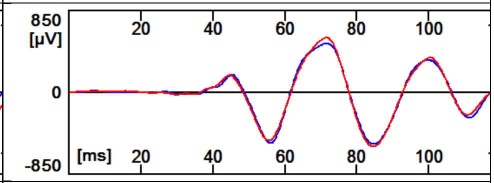
Z = 12.50 m
Ds = 0.50 m
Dt = 3.17 ms
Vs= 157 m/s
2 NOV 2016
12:55:44



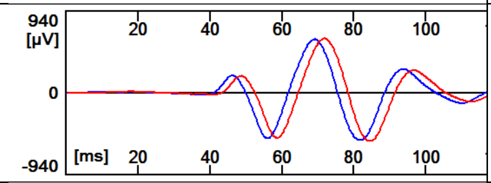


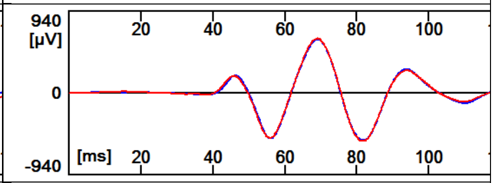
Z = 13.00 m
Ds = 0.50 m
Dt = 3.17 ms
Vs= 158 m/s
2 NOV 2016
12:59:46



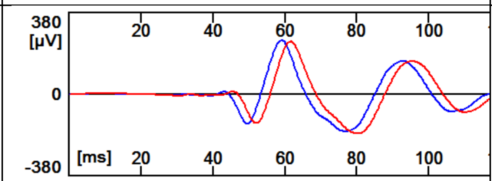


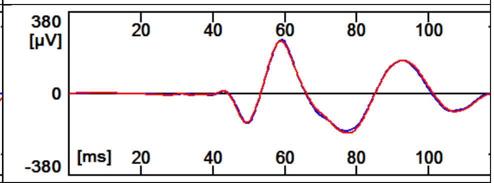
Z = 13.50 m
Ds = 0.50 m
Dt = 2.81 ms
Vs= 177 m/s
2 NOV 2016
13:06:48



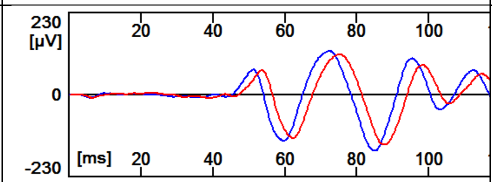


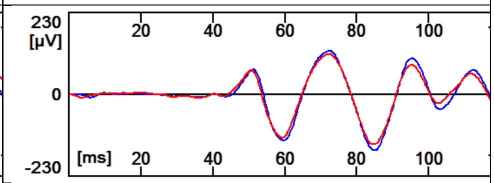
Z = 14.00 m
Ds = 0.50 m
Dt = 2.71 ms
Vs= 184 m/s
2 NOV 2016
13:10:31



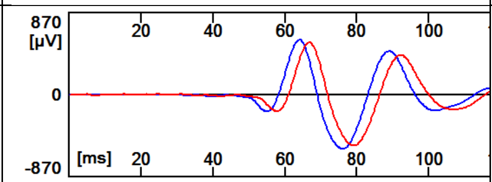


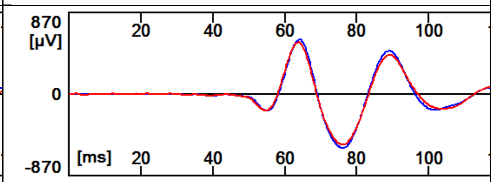
Z = 14.50 m
Ds = 0.50 m
Dt = 3.01 ms
Vs= 166 m/s
2 NOV 2016
13:21:08



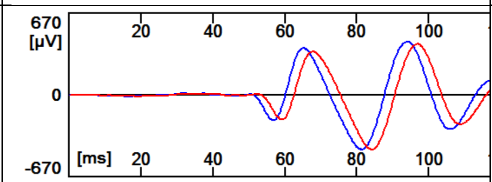


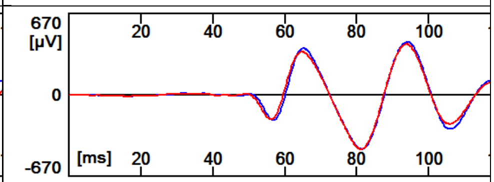
Z = 15.00 m
Ds = 0.50 m
Dt = 3.05 ms
Vs= 164 m/s
2 NOV 2016
13:25:23



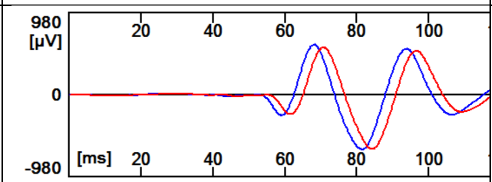


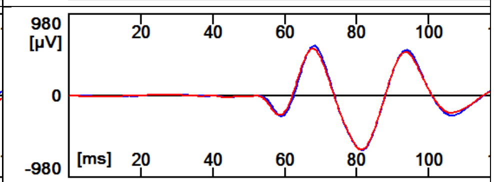
Z = 15.50 m
Ds = 0.50 m
Dt = 3.02 ms
Vs= 165 m/s
2 NOV 2016
13:33:47



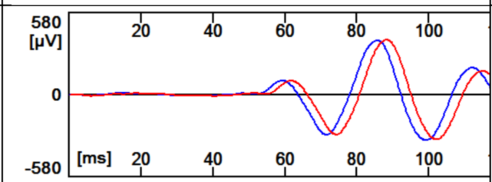


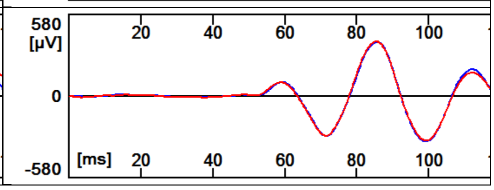
Z = 16.00 m
Ds = 0.50 m
Dt = 2.95 ms
Vs= 170 m/s
2 NOV 2016
13:37:34





Z = 16.50 m
Ds = 0.50 m
Dt = 2.84 ms
Vs= 176 m/s
2 NOV 2016
13:42:52





Z = 17.00 m
Ds = 0.50 m
Dt = 2.53 ms
Vs= 197 m/s
2 NOV 2016
13:50:09

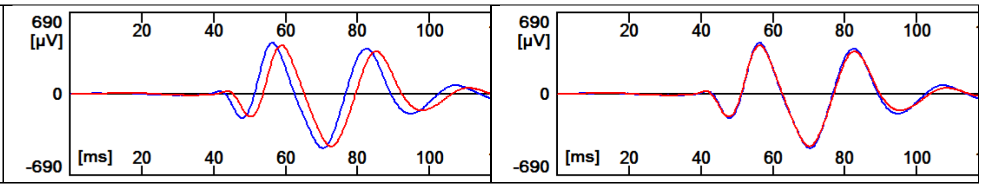
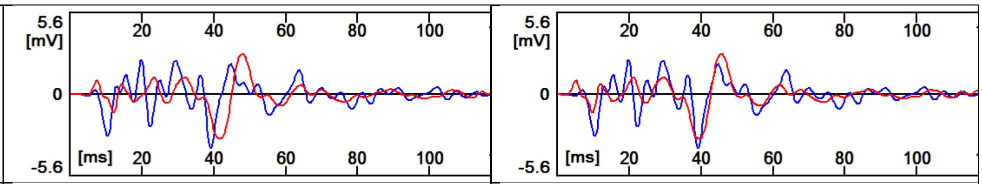
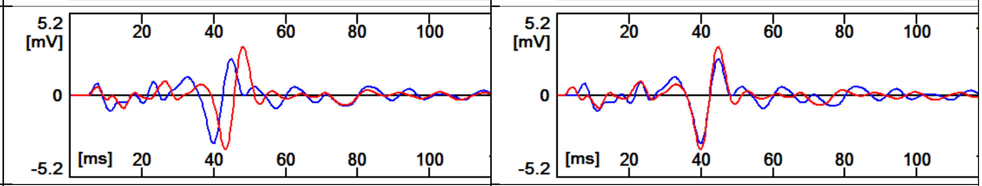


Figure I3 Recorded and re-phased shear waves – test OYSD01

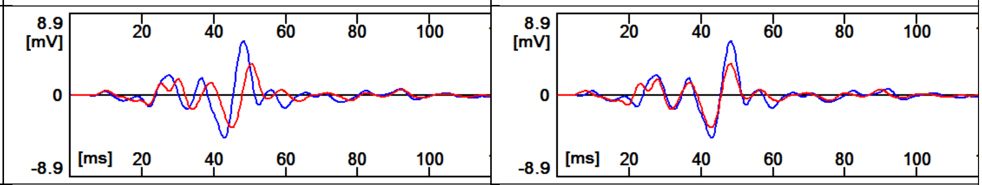
Z = 5.00 m
Ds = 0.50 m
Dt = 2.29 ms
Vs= 218 m/s
2 MAI 2017
13:31:36



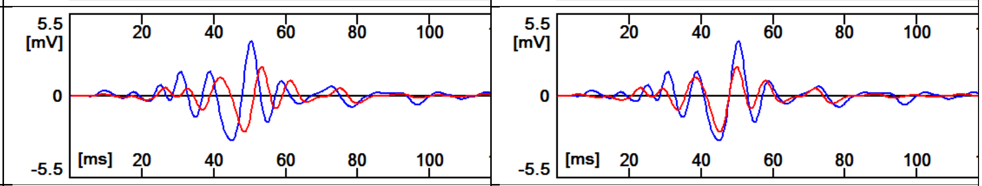
Z = 5.50 m
Ds = 0.50 m
Dt = 3.34 ms
Vs= 149 m/s
2 MAI 2017
13:44:13



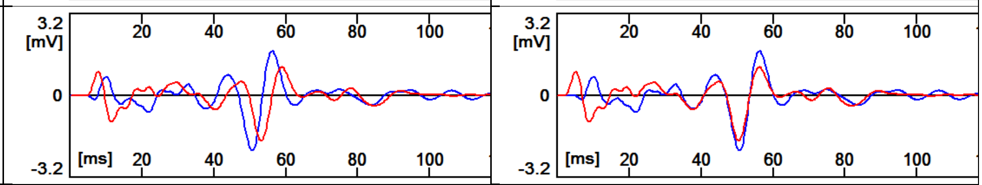
Z = 6.00 m
Ds = 0.50 m
Dt = 2.29 ms
Vs= 218 m/s
2 MAI 2017
13:49:43



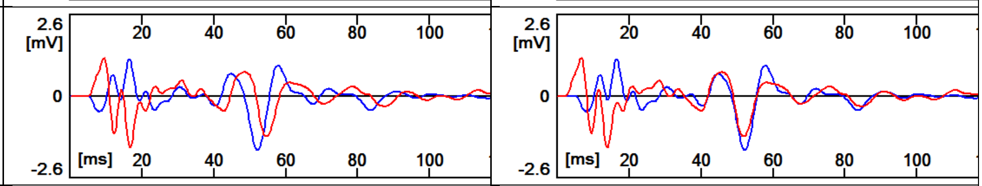
Z = 6.50 m
Ds = 0.50 m
Dt = 3.36 ms
Vs= 149 m/s
2 MAI 2017
14:02:04



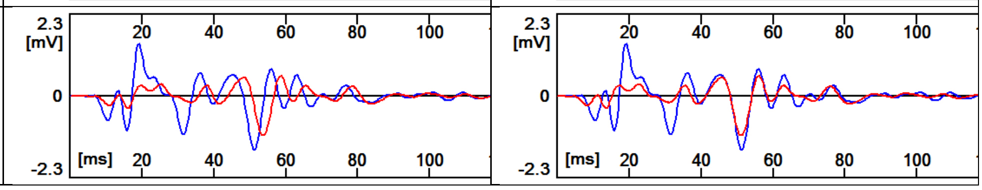
Z = 7.00 m
Ds = 0.50 m
Dt = 2.70 ms
Vs= 185 m/s
2 MAI 2017
14:14:06

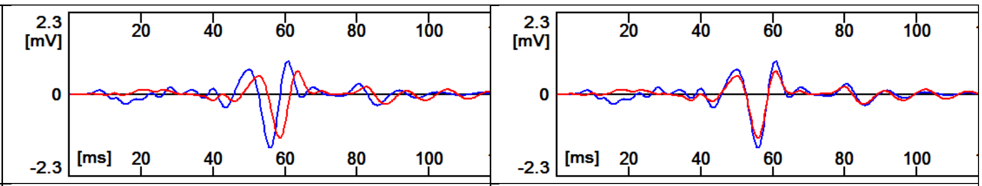
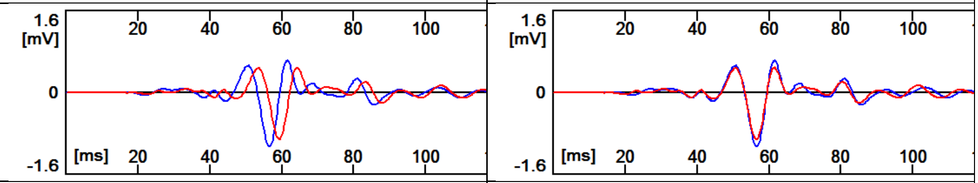
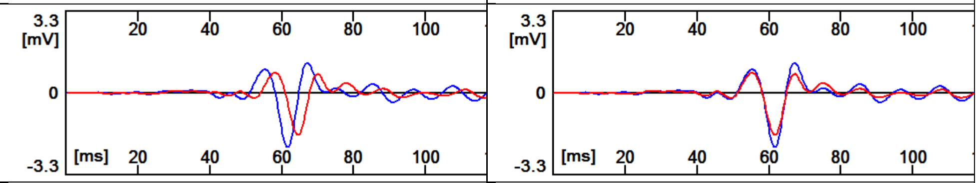
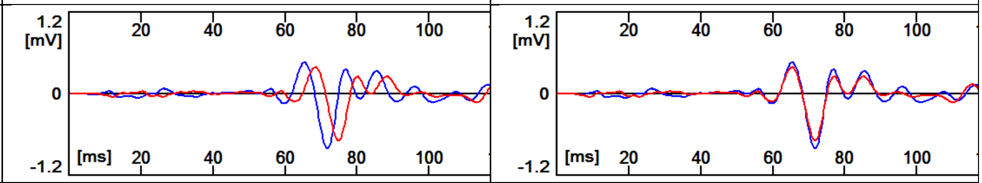
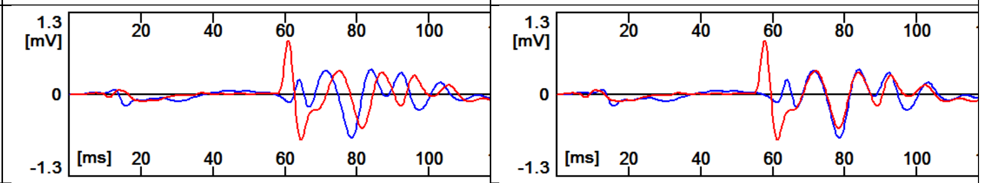
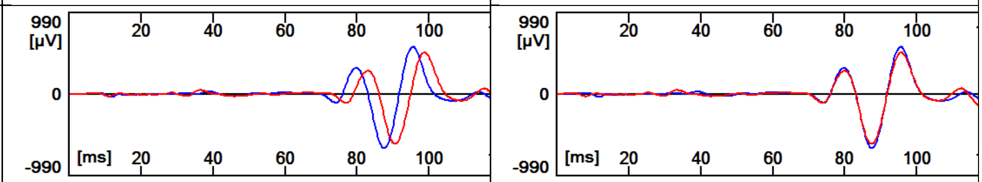
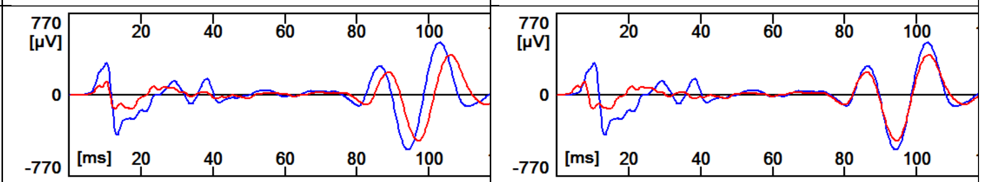
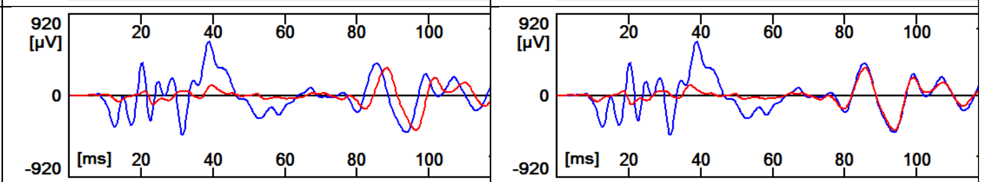
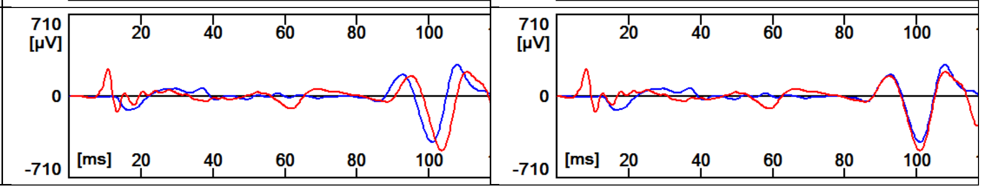


Z = 7.50 m
Ds = 0.50 m
Dt = 2.79 ms
Vs= 179 m/s
2 MAI 2017
14:41:58



Z = 8.00 m
Ds = 0.50 m
Dt = 2.54 ms
Vs= 196 m/s
2 MAI 2017
15:06:32



Z = 8.63 m **Ds = 0.50 m** **Dt = 2.70 ms** **Vs= 185 m/s** **2 MAI 2017** **15:33:42**	
Z = 9.00 m **Ds = 0.50 m** **Dt = 2.79 ms** **Vs= 179 m/s** **2 MAI 2017** **15:44:52**	
Z = 9.50 m **Ds = 0.50 m** **Dt = 2.87 ms** **Vs= 174 m/s** **2 MAI 2017** **16:13:08**	
Z = 11.50 m **Ds = 0.50 m** **Dt = 3.08 ms** **Vs= 162 m/s** **2 MAI 2017** **16:38:00**	
Z = 12.50 m **Ds = 0.50 m** **Dt = 3.15 ms** **Vs= 159 m/s** **2 MAI 2017** **16:45:59**	
Z = 13.50 m **Ds = 0.50 m** **Dt = 3.08 ms** **Vs= 162 m/s** **2 MAI 2017** **16:58:11**	
Z = 14.50 m **Ds = 0.50 m** **Dt = 2.69 ms** **Vs= 186 m/s** **2 MAI 2017** **17:10:35**	
Z = 15.50 m **Ds = 0.50 m** **Dt = 2.57 ms** **Vs= 194 m/s** **2 MAI 2017** **17:33:28**	
Z = 16.50 m **Ds = 0.50 m** **Dt = 2.65 ms** **Vs= 189 m/s** **2 MAI 2017** **17:45:35**	

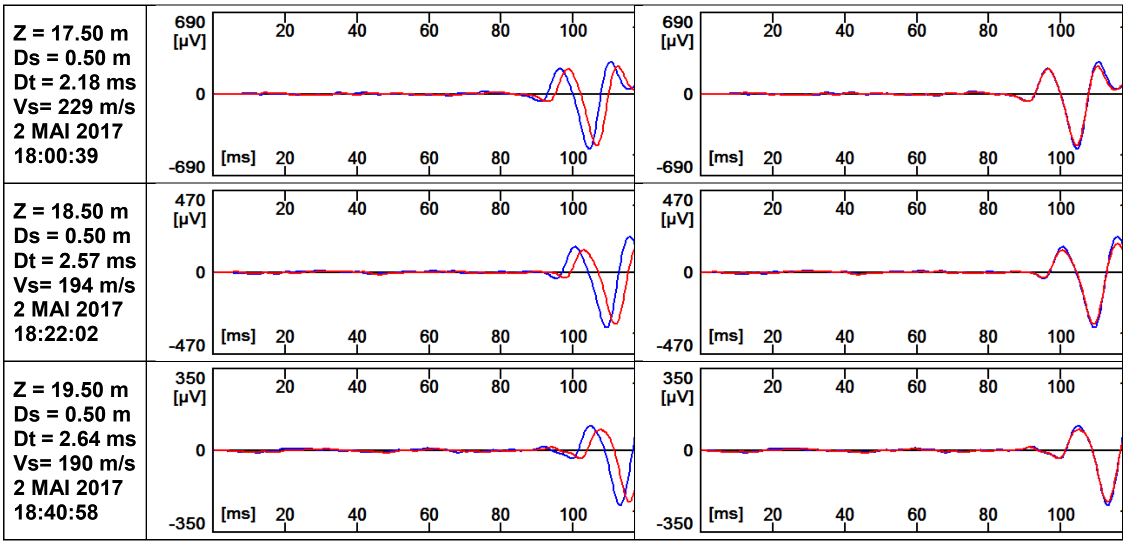


Figure I4 Recorded and re-phased shear waves – test OYSD02

I4 References

[1] S. Marchetti, P. Monaco, G. Totani and M. Calabrese, "The Flat Dilatometer Test (DMT) in Soil Investigations," ISSMGE, 2001.

[2] S. Marchetti, P. Monaco, G. Totani and D. Marchetti, "In Situ Tests by Seismic Dilatometer," ASCE Geotechnical Special Publication honoring Dr. John H. Schmertmann, New Orleans, 2008.

[3] International Organization for Standardization, "ISO 22476-11:2017(en) - Geotechnical investigation and testing - Field testing - Part 11: Flat dilatometer test," International Organization for Standardization, Geneva, 2017.

Depth	Measured Shear Wave Velocity (Vs)					Average Vs	Coeff. of Variation
	#1	#2	#3	#4	#5		
[m]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]
1.1	224	213	212	-	-	216	2.5
1.6	141	135	139	-	-	138	1.8
2.0	137	125	119	-	-	127	5.9
2.5	186	160	-	-	-	173	7.5
-	-	-	-	-	-	-	-
6.5	166	165	160	160	-	163	1.7
7.0	159	168	160	-	-	162	2.5
7.5	161	159	161	158	-	160	0.8
8.0	174	170	172	-	-	172	0.9
8.5	176	178	178	174	177	177	0.8
9.0	178	173	174	-	-	175	1.2
9.5	166	168	166	166	-	167	0.5
10.0	169	168	167	-	-	168	0.5
10.5	175	170	169	-	-	171	1.5
11.0	155	156	154	-	-	155	0.5
11.5	178	179	181	-	-	179	0.7
12.0	158	161	158	-	-	159	0.9
12.5	157	157	159	-	-	158	0.6
13.0	158	158	157	-	-	158	0.3
13.5	177	177	177	-	-	177	0.0
14.0	184	180	179	-	-	181	1.2
14.5	166	173	175	-	-	171	2.3
15.0	164	161	159	-	-	161	1.3
15.5	165	170	172	-	-	169	1.7
16.0	170	170	168	-	-	169	0.6
16.5	176	180	179	-	-	178	1.0
17.0	193	190	196	197	-	194	1.4
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
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-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-

National Geotest Site: Øysand (Sand Site)

Seismic Dilatometer Test

Test ID: OYSD01

Location: Øysand

Document No. 20160154-08-R

Figure No. D5

Date 07.06.2017

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Depth [m]	A [kPa]	B [kPa]	C [kPa]	P_0 [kPa]	P_1 [kPa]	P_2 [kPa]
1.4	261	831	-	252	766	-
1.6	363	1086	-	346	1021	-
1.8	398	1054	-	384	989	-
2.0	303	908	-	292	843	-
2.2	334	1137	-	313	1072	-
2.4	225	852	-	213	787	-
2.6	250	949	-	234	884	-
2.8	172	613	-	169	548	-
3.0	164	699	-	156	634	-
3.2	68	334	-	74	269	-
3.4	262	1143	-	237	1078	-
-	-	-	-	-	-	-
6.2	264	631	-	265	566	-
6.4	102	288	-	112	223	-
6.6	296	825	-	289	760	-
6.8	200	625	-	198	560	-
7.0	220	612	-	219	547	-
7.2	375	1041	-	361	976	-
7.4	325	953	-	313	888	-
7.6	260	926	32	246	861	47
7.8	273	881	32	262	816	47
8.0	149	754	-	138	689	-
8.2	284	788	-	278	723	-
8.4	289	910	-	277	845	-
8.6	232	607	-	232	542	-
8.8	293	970	-	278	905	-
9.0	488	1255	-	469	1190	-
9.2	380	1013	-	367	948	-
9.4	375	1033	-	361	968	-
9.6	309	815	53	303	750	68
9.8	268	542	-	273	477	-
10.0	272	663	-	271	598	-
10.2	331	826	-	325	761	-
10.4	385	1053	-	371	988	-
10.6	452	1255	-	431	1190	-
10.8	469	1171	-	453	1106	-
11.0	507	1175	-	493	1110	-
11.2	371	896	53	364	831	68
11.4	459	1200	70	441	1135	85
11.6	525	1307	-	505	1242	-
11.8	444	1093	-	431	1028	-
12.0	458	1208	-	440	1143	-
12.2	425	1072	-	412	1007	-

National Geotest Site: Øysand (Sand Site)

Document No.
20160154-08-R

Seismic Dilatometer Test

Figure No.
D6

Test ID: OYSD01

Location: Øysand

ΔA_{Before} = 15 kPa

ΔB_{Before} = 65 kPa

ΔA_{After} = 15 kPa

ΔB_{After} = 65 kPa

Date
07.06.2017

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AGu

NGTS

Depth [m]	A [kPa]	B [kPa]	C [kPa]	P_0 [kPa]	P_1 [kPa]	P_2 [kPa]
12.4	411	1069	-	397	1004	-
12.6	411	1036	-	399	971	-
12.8	417	1058	-	404	993	-
13.0	373	546	-	383	481	-
13.2	508	1068	-	499	1003	-
13.4	507	1239	-	489	1174	-
13.6	422	1065	-	409	1000	-
13.8	409	581	-	419	516	-
14.0	409	670	-	415	605	-
14.2	427	808	-	427	743	-
14.4	415	654	-	422	589	-
14.6	402	1154	-	383	1089	-
14.8	495	1148	-	481	1083	-
15.0	502	1155	-	488	1090	-
15.2	443	984	-	435	919	-
15.4	407	904	-	401	839	-
15.6	514	1311	-	493	1246	-
15.8	573	1435	-	549	1370	-
16.0	476	1204	112	459	1139	127
16.2	433	1094	-	419	1029	-
16.4	382	831	-	379	766	-
16.6	454	1105	-	440	1040	-
16.8	404	753	-	406	688	-
17.0	508	1315	-	487	1250	-
17.2	609	1540	-	581	1475	-
17.4	653	1583	-	626	1518	-
17.6	667	1587	-	640	1522	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-

National Geotest Site: Øysand (Sand Site)

Seismic Dilatometer Test

Test ID: OYSD01

Location: Øysand

ΔA_{Before} = 15 kPa

ΔB_{Before} = 65 kPa

ΔA_{After} = 15 kPa

ΔB_{After} = 65 kPa

Document No. 20160154-08-R

Figure No. D7

Date 07.06.2017

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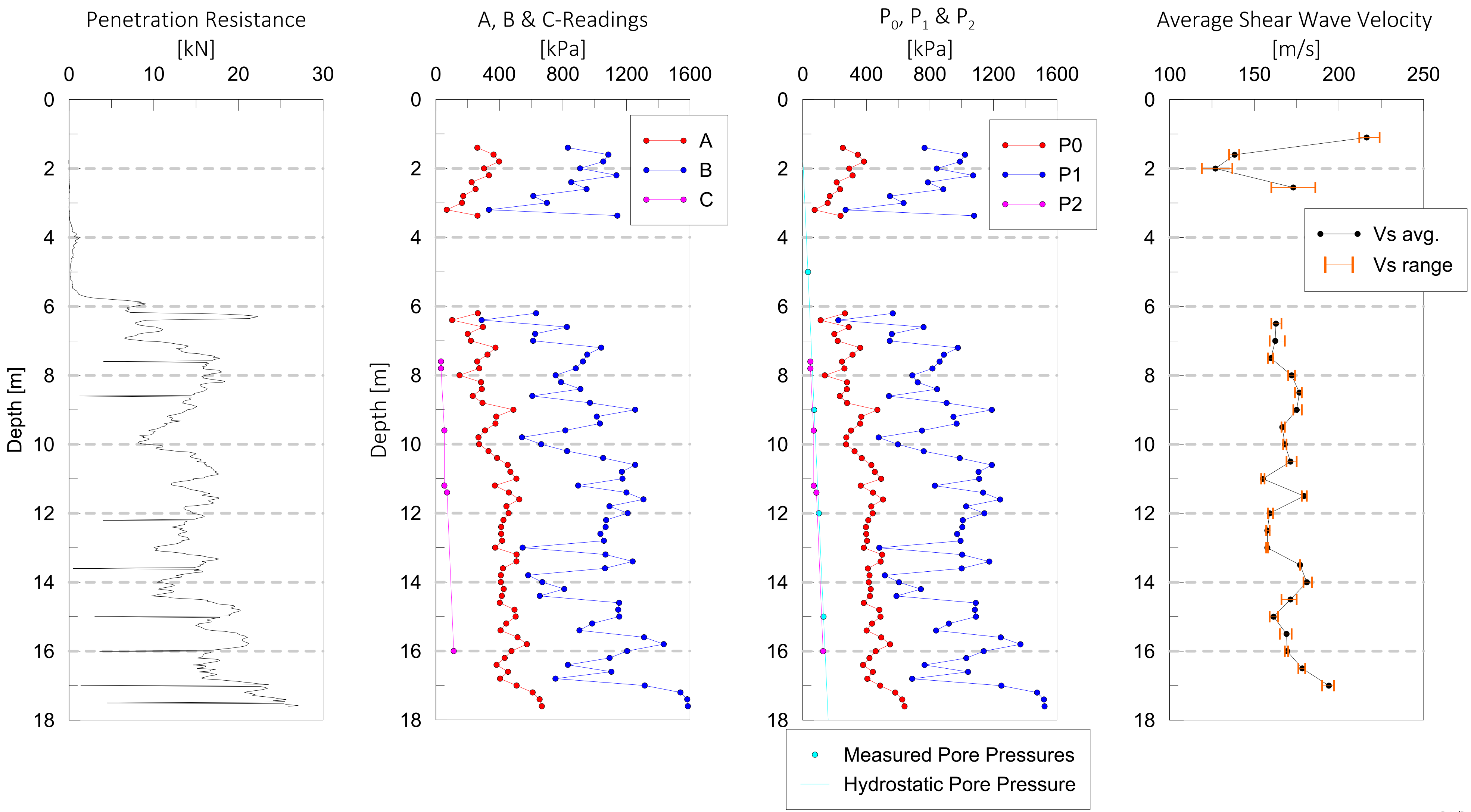

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Date/Rev.: 2015-01-21/01

Calibration Constants

ΔA_{Before} = 15 kPa ΔA_{After} = 15 kPa

ΔB_{Before} = 65 kPa ΔB_{After} = 65 kPa

National Geotest Site: Øysand (Sand Site)	Document No. 20160154-08-R	
Test Type: Seismic Dilatometer Test	Figure No. D8	
Test ID: OYSD01	Date 2017-06-08	Drawn by AGu
Location: Øysand	NGTS	

Depth	Measured Shear Wave Velocity (Vs)					Average Vs	Coeff. of Variation
	#1	#2	#3	#4	#5		
[m]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[m/s]	[%]
5.0	218	170	215	-	-	201	10.9
5.5	144	166	162	149	-	155	5.8
6.0	213	218	202	-	-	211	3.2
6.5	161	187	149	-	-	166	9.6
7.0	185	191	187	-	-	188	1.3
7.5	179	176	180	-	-	178	1.0
8.0	196	200	196	-	-	197	1.0
8.6	185	184	181	-	-	183	0.9
9.0	179	180	179	-	-	179	0.3
9.5	174	172	170	-	-	172	0.9
11.5	162	227	159	-	-	183	17.2
12.5	159	152	163	-	-	158	2.9
13.5	164	162	162	-	-	163	0.6
14.5	186	187	188	-	-	187	0.4
15.5	194	190	194	-	-	193	1.0
16.5	189	195	199	-	-	194	2.1
17.5	229	234	233	-	-	232	0.9
18.5	194	193	196	-	-	194	0.6
19.5	190	189	186	-	-	188	0.9
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
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-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-

National Geotest Site: Øysand (Sand Site)

Seismic Dilatometer Test

Test ID: OYSD02

Location: Øysand

Document No.	20160154-08-R
Figure No.	D9
Date	08.06.2017
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Depth [m]	A [kPa]	B [kPa]	C [kPa]	P_0 [kPa]	P_1 [kPa]	P_2 [kPa]
5.6	270	694	-	263	633	-
5.8	266	636	-	262	575	-
6.0	198	604	-	192	543	-
6.2	179	673	-	169	612	-
6.4	245	759	-	234	698	-
6.6	251	813	-	238	752	-
6.8	192	786	-	177	725	-
7.0	341	998	-	323	937	-
7.2	121	367	-	123	306	-
7.4	227	1265	-	190	1204	-
7.6	179	722	-	166	661	-
7.8	195	1172	-	161	1111	-
8.0	167	840	-	148	779	-
8.2	415	1173	-	392	1112	-
8.4	381	1027	-	363	966	-
8.6	364	997	-	347	936	-
8.8	243	572	-	241	511	-
9.2	345	1009	-	326	948	-
9.4	403	1125	-	382	1064	-
9.6	466	1252	-	441	1191	-
9.8	446	1206	-	423	1145	-
10.0	401	1152	-	378	1091	-
10.2	427	1218	-	402	1157	-
10.4	404	1118	-	383	1057	-
10.6	404	1155	-	381	1094	-
10.9	437	1163	-	415	1102	-
11.0	384	1008	-	367	947	-
11.2	430	1060	-	413	999	-
11.4	464	1139	-	445	1078	-
11.6	421	1144	-	399	1083	-
11.8	428	1206	-	404	1145	-
12.0	377	1048	-	358	987	-
12.2	357	939	-	343	878	-
12.4	450	1128	-	431	1067	-
12.6	442	1090	-	424	1029	-
12.8	371	990	-	355	929	-
13.0	475	1310	-	448	1249	-
13.2	489	1319	-	462	1258	-
13.4	419	1123	-	398	1062	-
13.6	448	1239	-	423	1178	-
14.0	517	1466	-	484	1405	-
14.2	411	1228	-	385	1167	-
14.4	283	1556	-	234	1495	-

National Geotest Site: Øysand (Sand Site)

Seismic Dilatometer Test

Test ID: OYSD02

Location: Øysand

ΔA_{Before} = 7 kPa

ΔB_{Before} = 78 kPa

ΔA_{After} = 15 kPa

ΔB_{After} = 45 kPa

Document No. 20160154-08-R

Figure No. D10

Date 08.06.2017

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Depth [m]	A [kPa]	B [kPa]	C [kPa]	P_0 [kPa]	P_1 [kPa]	P_2 [kPa]
14.6	461	1506	-	423	1445	-
14.8	368	1286	-	337	1225	-
15.0	471	1342	-	442	1281	-
15.2	193	793	-	178	732	-
15.4	226	927	-	206	866	-
15.6	235	733	-	225	672	-
15.8	191	1275	-	151	1214	-
16.0	531	1785	-	483	1724	-
16.2	551	1592	-	514	1531	-
16.4	642	1682	-	605	1621	-
16.6	509	1502	-	474	1441	-
16.8	565	1606	-	528	1545	-
17.0	588	1543	-	555	1482	-
17.2	641	1570	-	609	1509	-
17.4	634	1628	-	599	1567	-
17.6	619	1536	-	588	1475	-
17.8	525	1313	-	500	1252	-
18.0	541	1354	-	515	1293	-
18.2	562	1451	-	532	1390	-
18.5	533	1515	-	499	1454	-
18.6	613	1518	-	582	1457	-
18.8	637	1553	-	606	1492	-
19.0	628	1625	-	593	1564	-
19.2	598	1523	-	566	1462	-
19.4	545	1412	-	516	1351	-
19.6	634	1638	-	598	1577	-
19.8	751	1914	157	707	1853	168
20.0	717	1742	149	680	1681	160
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
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-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-

National Geotest Site: Øysand (Sand Site)

Seismic Dilatometer Test

Test ID: OYSD02

Location: Øysand

ΔA_{Before} = 7 kPa

ΔB_{Before} = 78 kPa

ΔA_{After} = 15 kPa

ΔB_{After} = 45 kPa

Document No. 20160154-08-R

Figure No. D11

Date 08.06.2017

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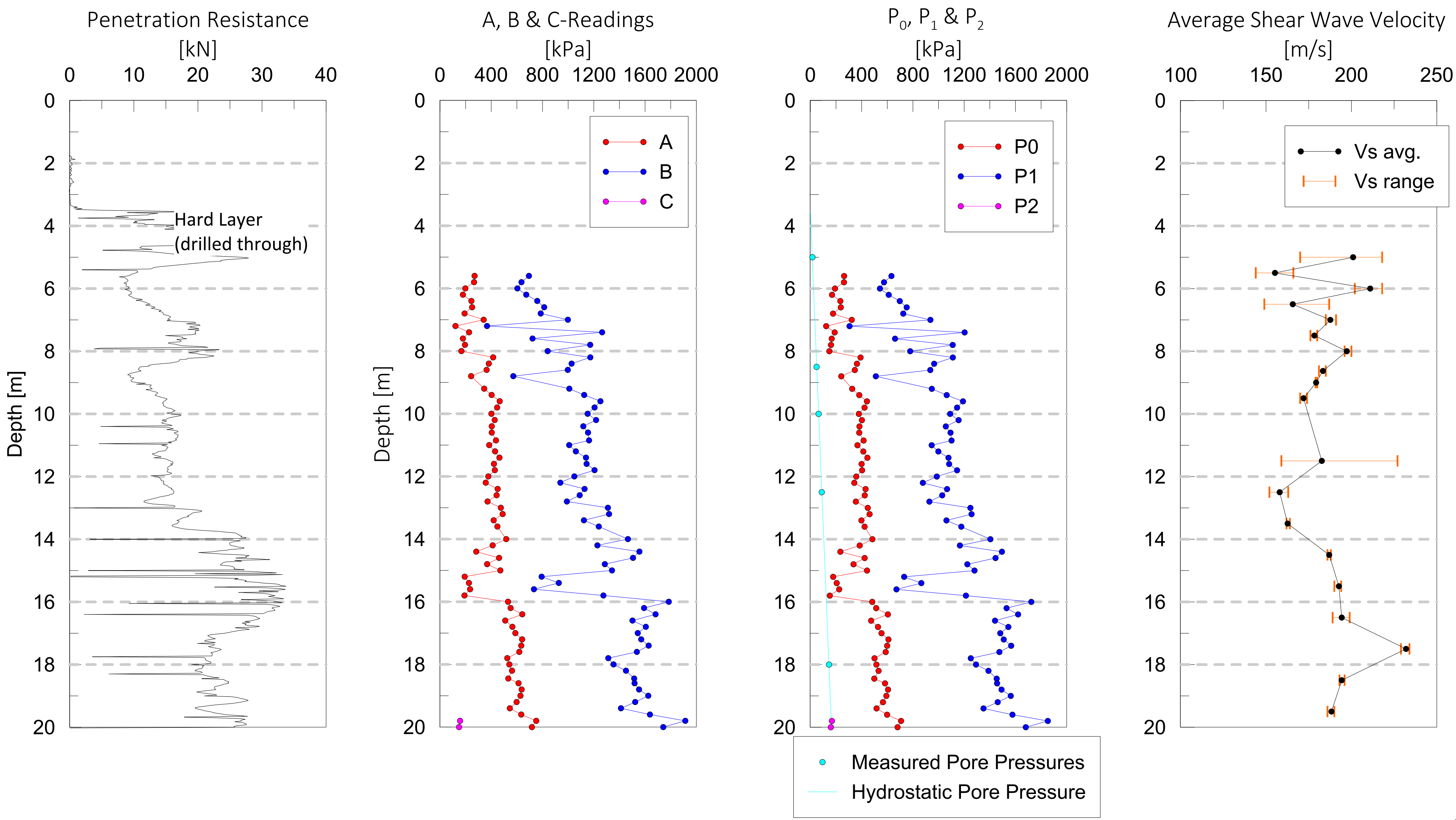
NGTS



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Date/Rev.: 2015-01-21/01

Calibration Constants

ΔA_{Before} = 7 kPa ΔA_{After} = 15 kPa

ΔB_{Before} = 78 kPa ΔB_{After} = 45 kPa

National Geotest Site: Øysand (Sand Site)

Test Type: Seismic Dilatometer Test

Test ID: OYSD02

Location: Øysand

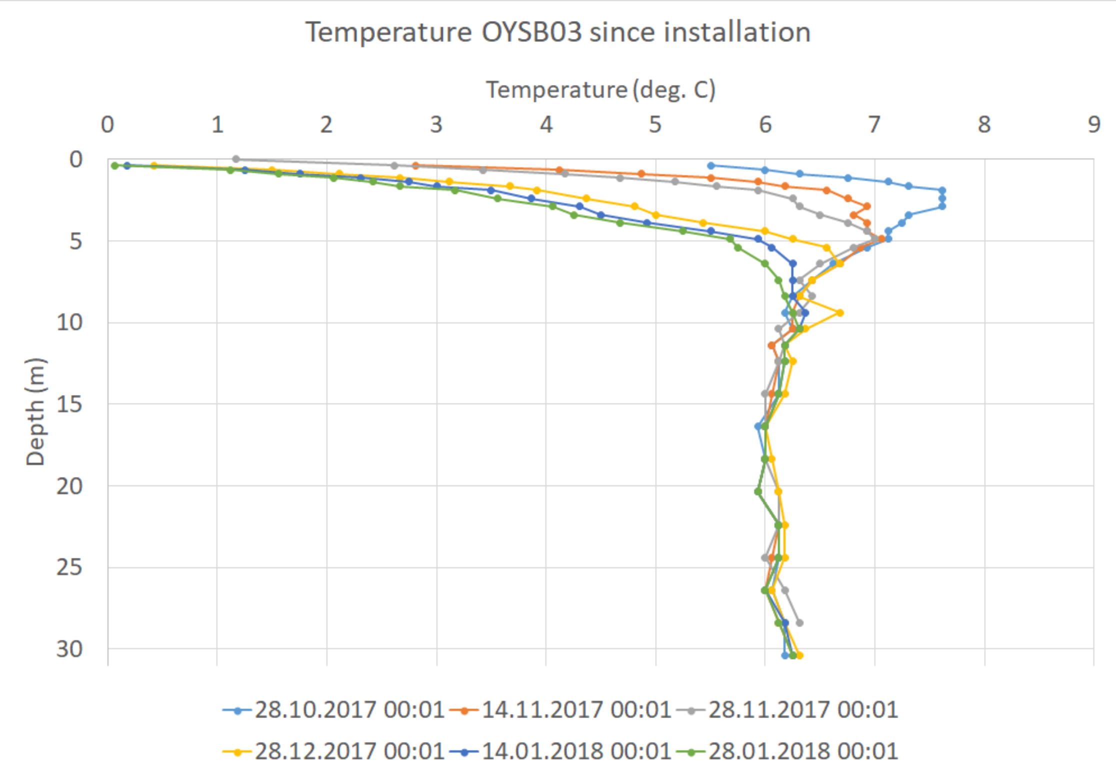
Document No.	20160154-08-R
Figure No.	D12
Date	2017-06-07
Drawn by	AGu

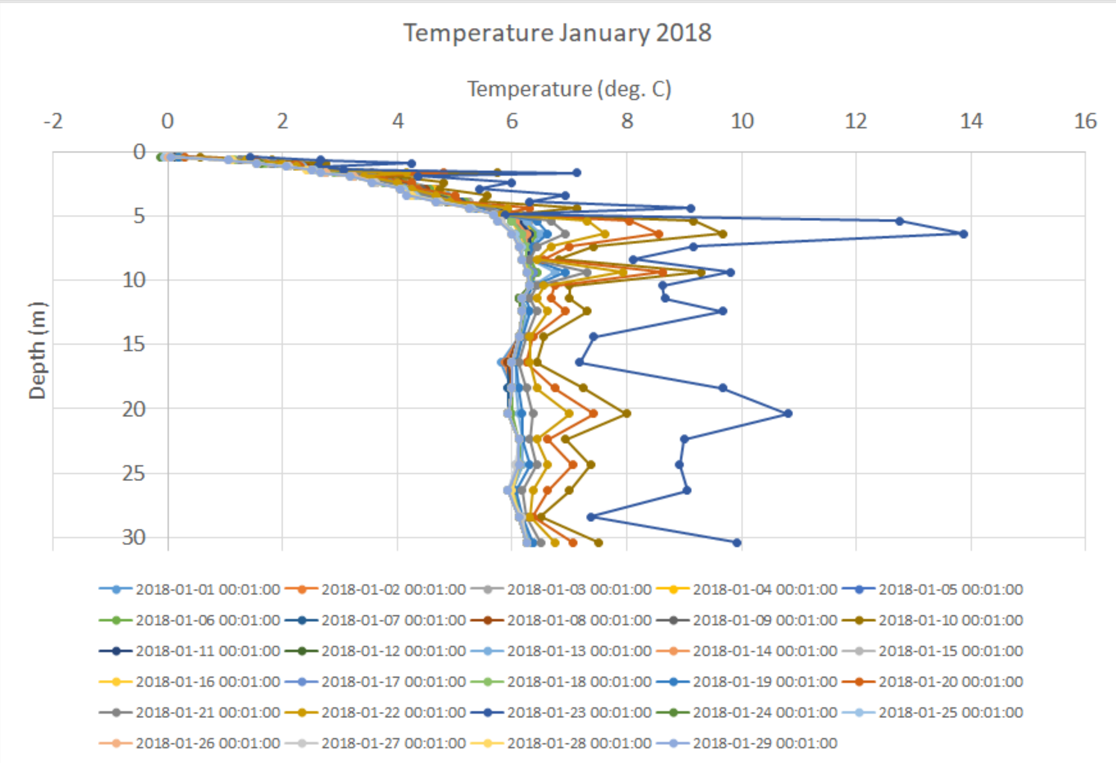
NGTS

Appendix J

THERMISTOR STRING

OYSTH01


Temperature OYSB03 since installation
Temperature (deg. C)
0 1 2 3 4 5 6 7 8 9
Depth (m)
0 5 10 15 20 25 30
28.10.2017 00:01
14.11.2017 00:01
28.11.2017 00:01
28.12.2017 00:01
14.01.2018 00:01
28.01.2018 00:01


Temperature January 2018
Temperature (deg. C)
-2 0 2 4 6 8 10 12 14 16
Depth (m)
0 5 10 15 20 25 30
2018-01-01 00:01:00
2018-01-02 00:01:00
2018-01-03 00:01:00
2018-01-04 00:01:00
2018-01-05 00:01:00
2018-01-06 00:01:00
2018-01-07 00:01:00
2018-01-08 00:01:00
2018-01-09 00:01:00
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2018-01-24 00:01:00
2018-01-25 00:01:00
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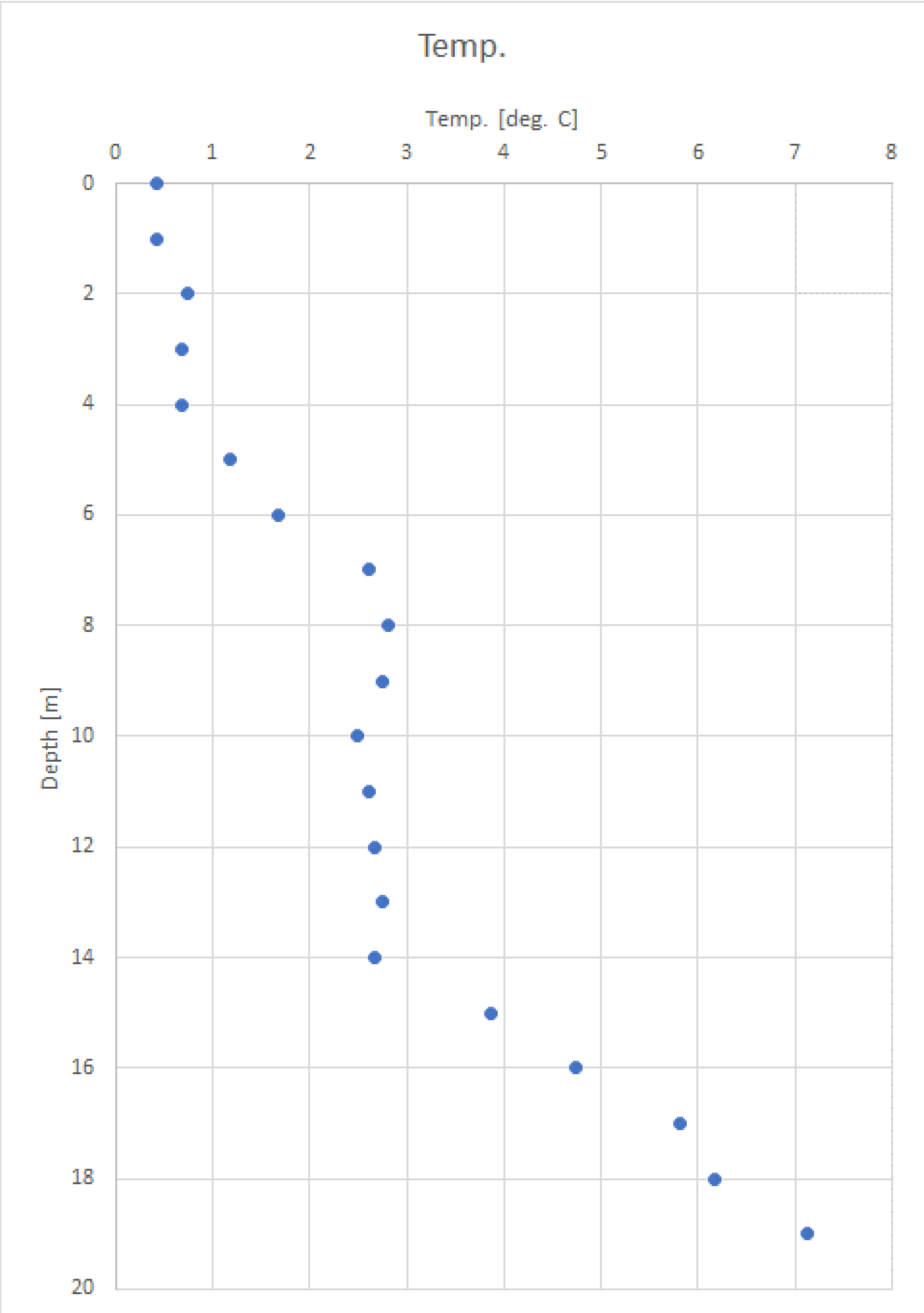
OYSTH02

No data available

OYSTH03

Date: 21.03.2018



Appendix K

PERMEABILITY TESTS

Contents

K1 Methodology

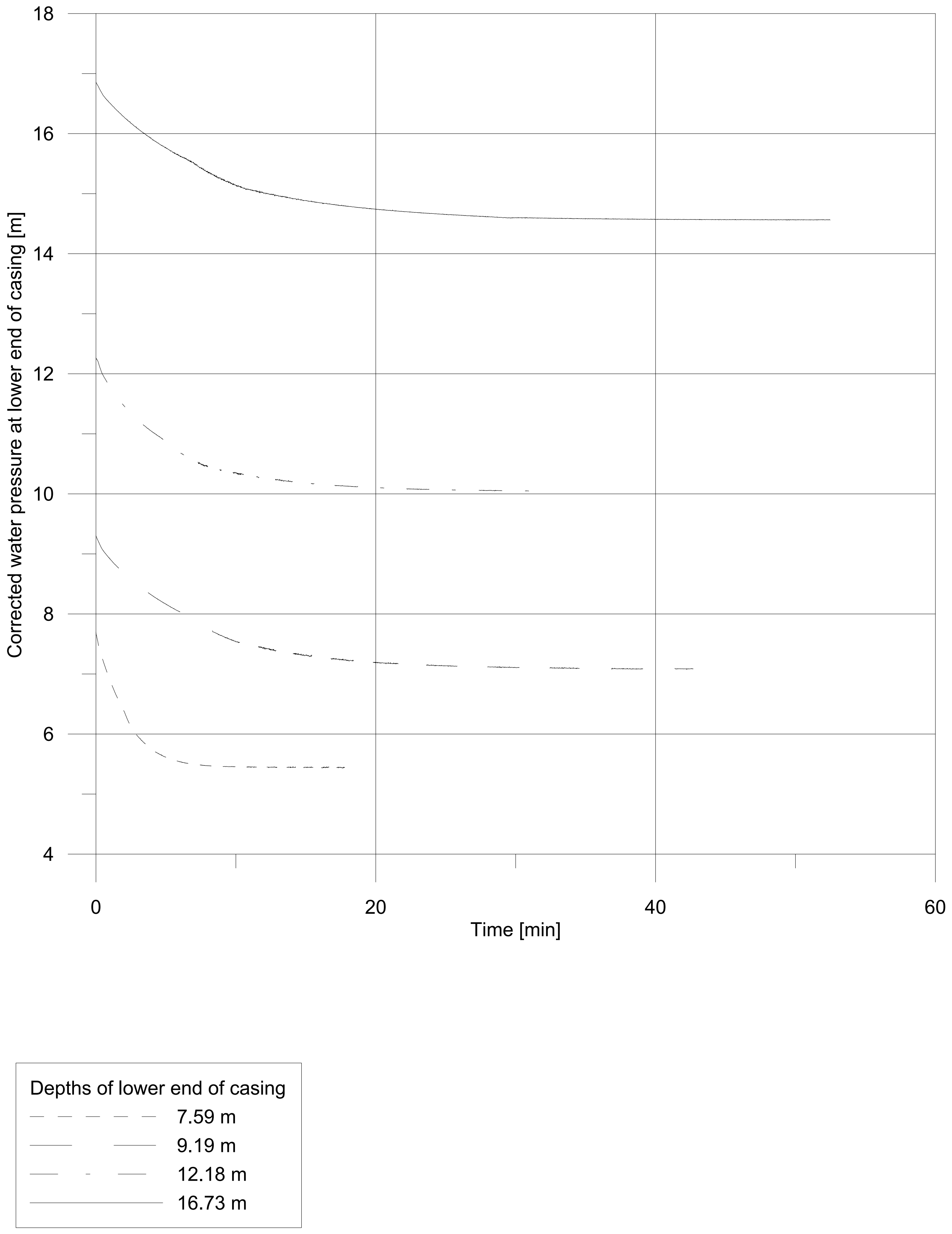
Falling head permeability tests may be used to determine the permeability of soil. A casing is installed in the ground, with top of casing 10-20 cm above terrain, and then filled with water. The water supply is stopped, and the sinking water level inside the casing is logged together with time. Also, the air pressure is logged in order to correct the water pressure measurements. The test is terminated when the water column inside the casing reaches equilibrium. From the corrected water pressure and time it is possible to calculate the permeability of the soil surrounding the lower end of the casing, for instance by the method described in [K1].

K2 Results

Figures M1 and M2 show water pressure corrected for air pressure versus time, for boreholes OYSSL01 and OYSL02, respectively.

K3 References

[K1] Demir, Z., & Narasimhan, T. N. (1994). Improved interpretation of Hvorslev tests. *Journal of Hydraulic Engineering*, *120*(4), 477-494.



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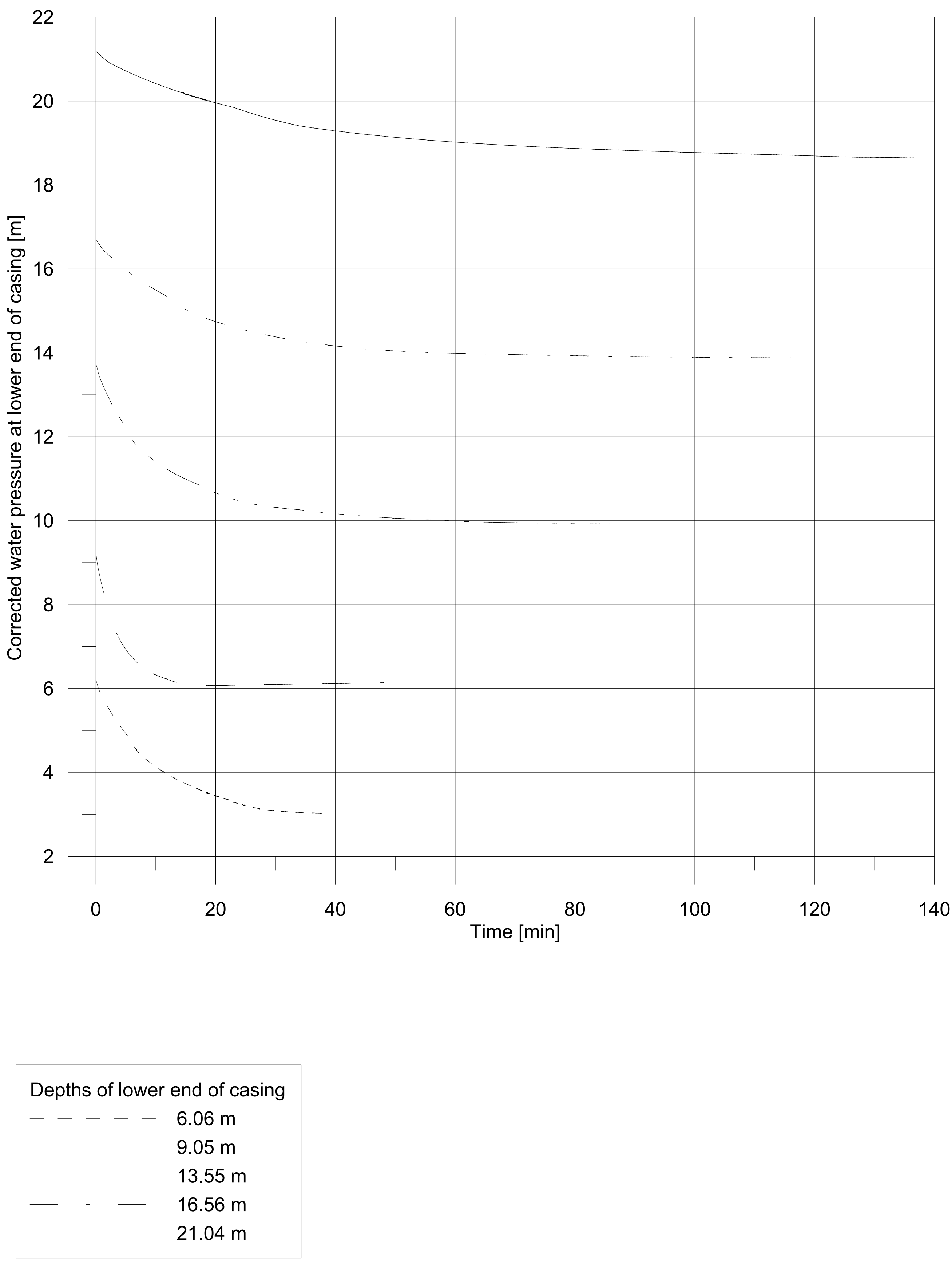
Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site	Document No. 20160154-08-R	
Water pressure corrected for air pressure versus time	Figure No. K1	
OYSSL01	Date 2019-03-13	Drawn by AnL
	NGTS	



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Date/Rev.: 2015-01-21/01

NGTS - Øysand Research Site

Water pressure corrected for air pressure versus time

OYSSL02

Document No.	
20160154-08-R	
Figure No.	
K2	
Date	Drawn by
2019-03-13	AnL

NGTS

Appendix L

NGI PERMEABILITY PROBE

All figures are taken from:
Gundersen A, Carotenuto P, Lunne T, Walta A, Sparrevik P. (2019). Field verification tests of the newly developed flow cone tool—In-situ measurements of hydraulic soil properties. AIMS Geosciences. 2019, 5 (4), 784-803.
https://www.aimspress.com/article/10.3934/geosci.2019.4.784

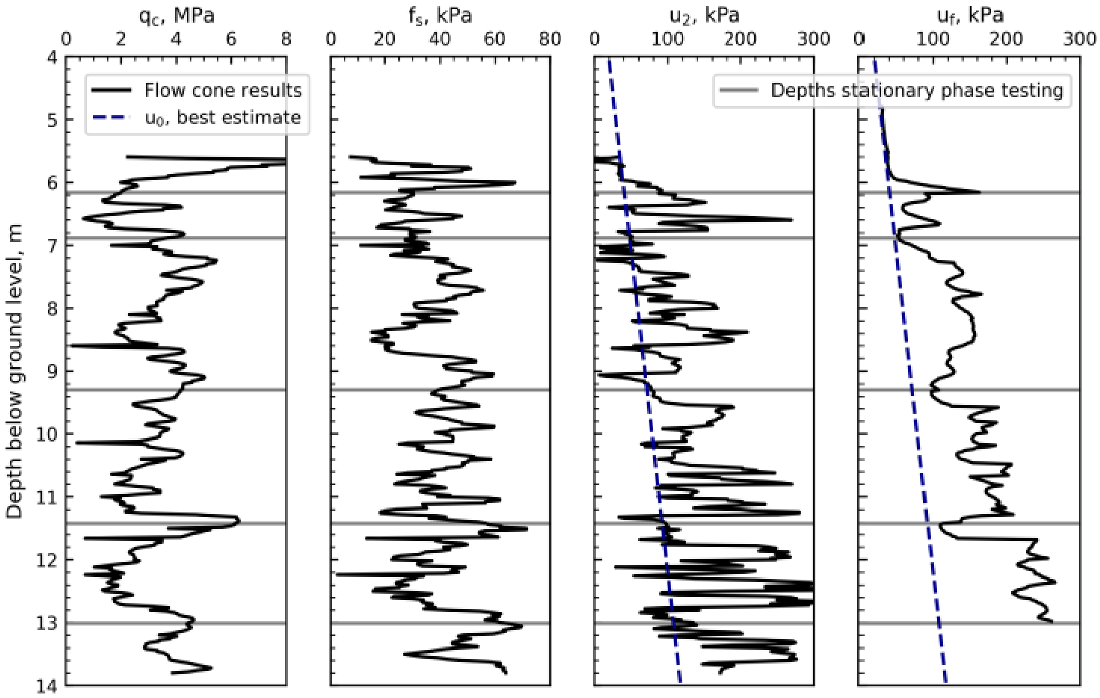

Figure 6. Results from the flow cone CPTU module.

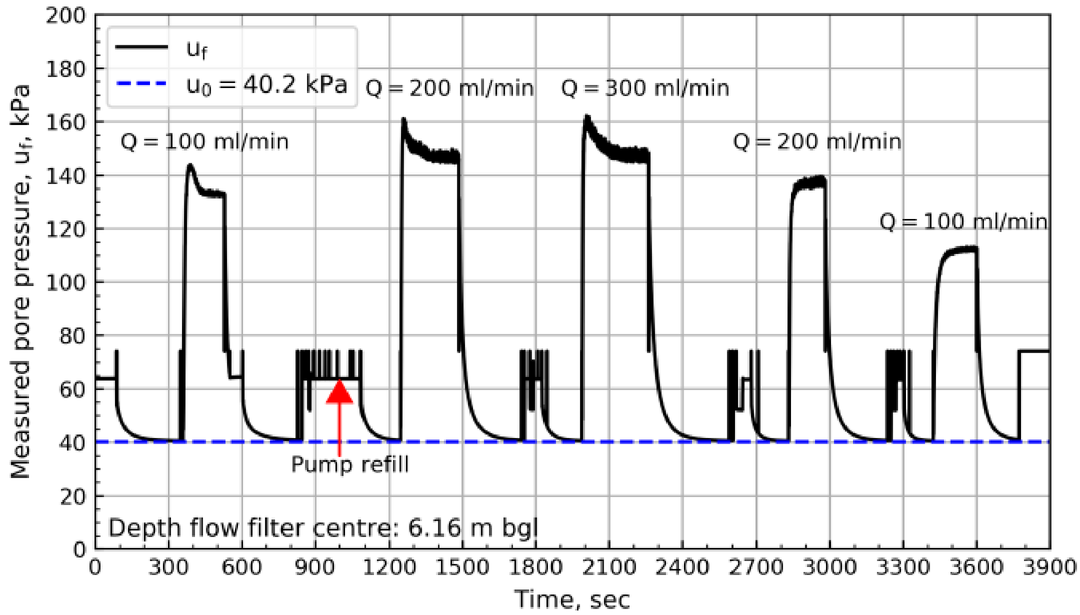

Figure 7. Measured pore pressure at flow filter location, u_f, during stationary phase testing at 6.16 m bgl. Interpretation of in-situ pore pressure, u_0, is included for reference.

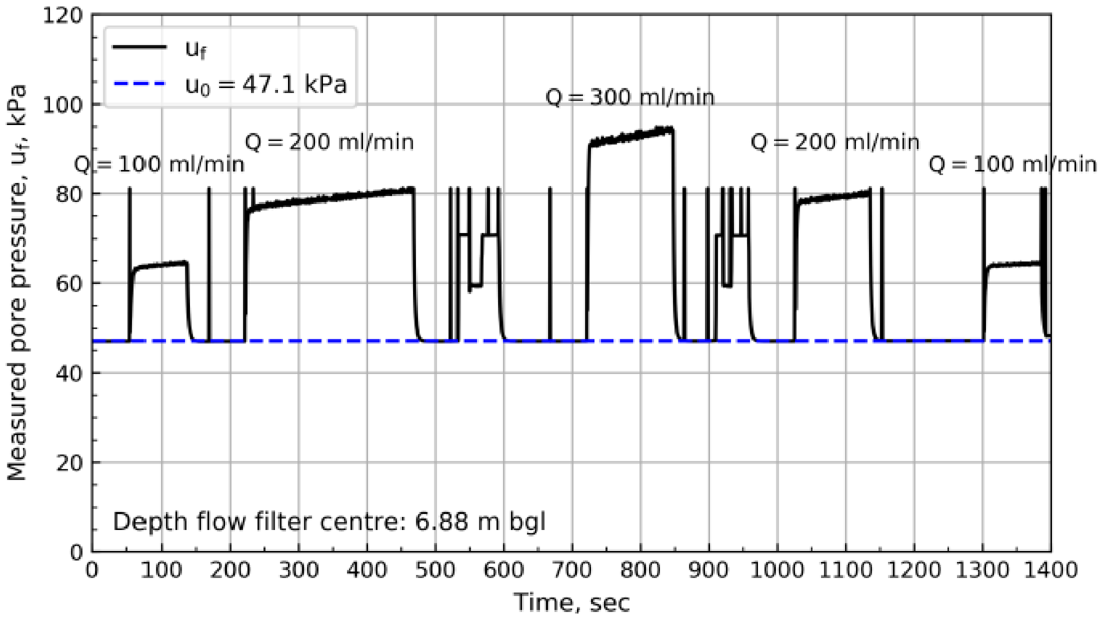

Figure 8. Measured pore pressure at flow filter location, u_f, during stationary phase testing at 6.88 m bgl. Interpretation of in-situ pore pressure, u_0, is included for reference.

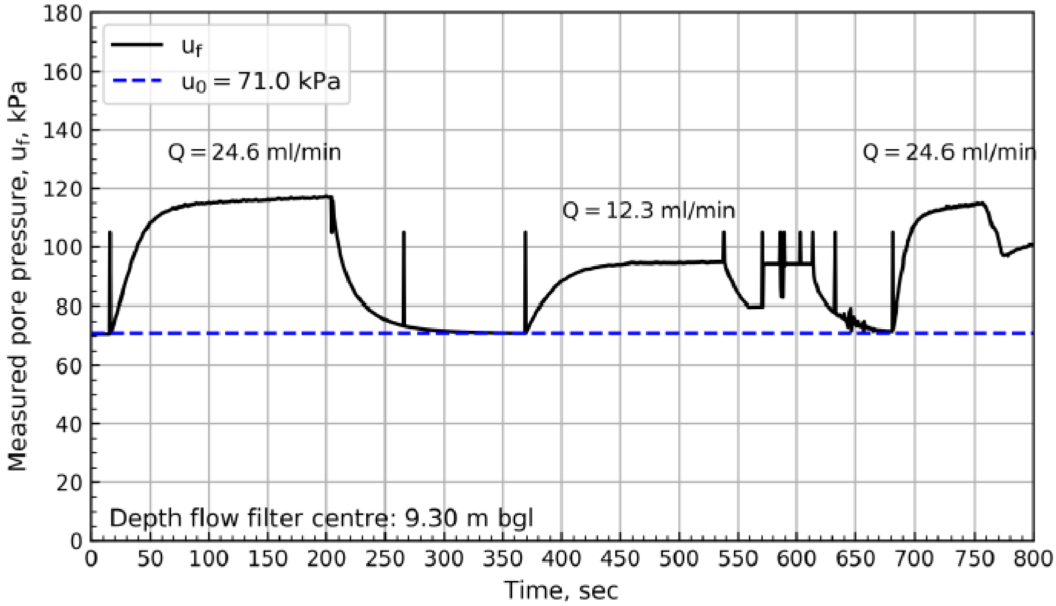

Figure 9. Measured pore pressure at flow filter location, u_f, during stationary phase testing at 9.30 m bgl. Interpretation of in-situ pore pressure, u_0, is included for reference.

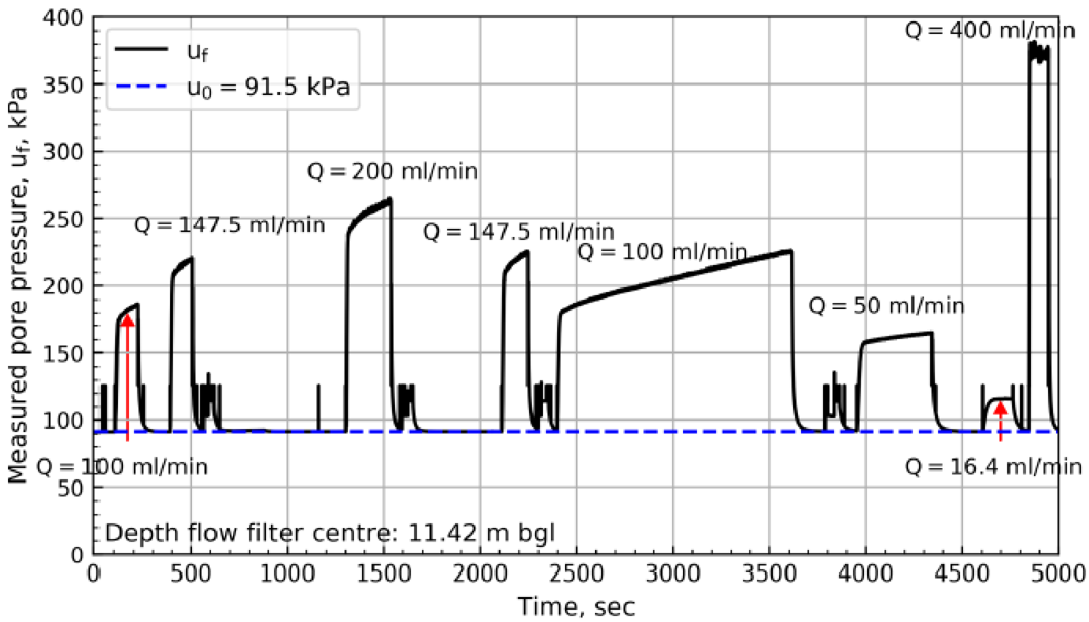

Figure 10. Measured pore pressure at flow filter location, u_f, during stationary phase testing at 11.42 m bgl. Interpretation of in-situ pore pressure, u_0, is included for reference.

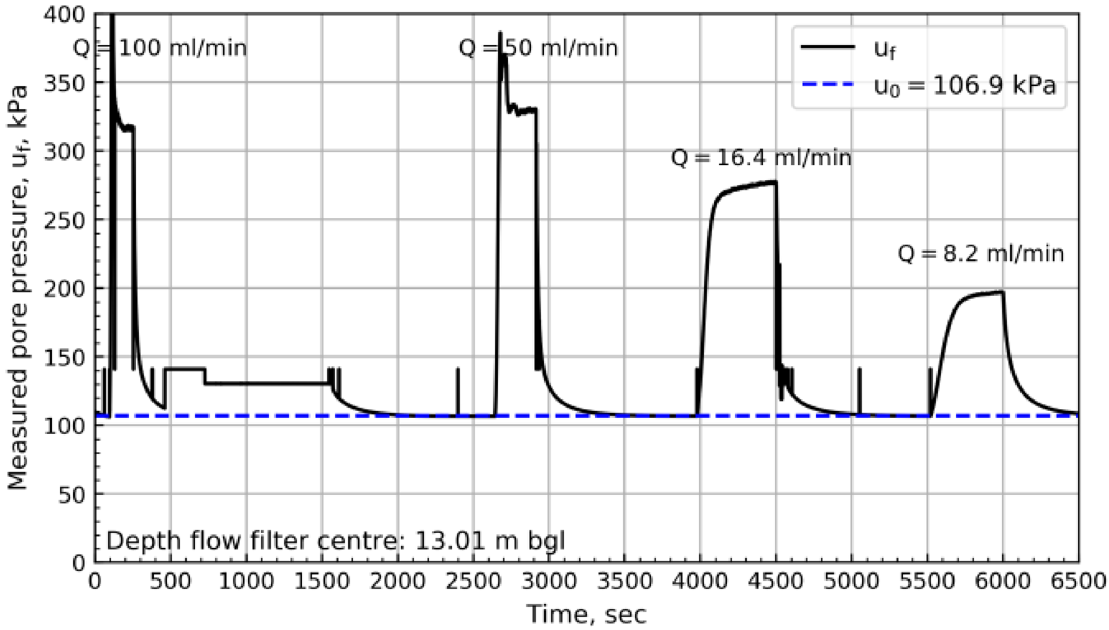

Figure 11. Measured pore pressure at flow filter location, u_f, during stationary phase testing at 13.01 m bgl. Interpretation of in-situ pore pressure, u_0, is included for reference.

Appendix M

SAMPLE LIST FROM BOREHOLES

GROUP	SAMP
HEADING	Sample list
PROJ_ID	20160154
PROJ_NAME	National GeoTest Sites (NGTS)
PROJ_LOC	Oysand (OYS)
PROJ_CLNT	NGTS
PROJ_CONT	NGI
PROJ_ENG	NGI
LOCA_ID	OYSB01
SAMP_TYPE	BH54
Full description	54 mm sample borehole (no liner) 54 mm with sand catcher and bag samples
SAMP_DATE	2016-09-27
LOCA_DRIL	HSA/Rok
Temperature	---

ISO Field classification: YES

SAMP_TOP	SAMP_BASE	SAMP_REF	SAMP_CLASS	Samples in lal	DREM_REM	
					predrilling	
6	7	Bag1	Sand	Next day		bag sample
7	8	1	Sand	Next day		

National GeoTest Sites (NGTS)

Description

Sample list

OYSB01

BH54

Document No. 20160154-08-R

Figure No. 1

Date 10.01.2020

Drawn by APP

NGTS

P:\2016\01\20160154\Fieldwork\Oysand\BH\[OYSB01.xlsx]Samplelist

GROUP	SAMP
HEADING	Sample list
PROJ_ID	20160154
PROJ_NAME	National GeoTest Sites (NGTS)
PROJ_LOC	Oysand (OYS)
PROJ_CLNT	NGTS
PROJ_CONT	NGI
PROJ_ENG	NGI
LOCA_ID	OYSB02
SAMP_TYPE	BH54
Full description	54 mm composite sample borehole (with liner) Bag samples
SAMP_DATE	2016-10-04
LOCA_DRIL	HSA/Rok
Temperature	---

ISO Field classification: YES

SAMP_TOP	SAMP_BASE	SAMP_REF	SAMP_CLASS	Samples in lab	DREM_REM	
					predrilling	
2	3	1	Sand	Next day		
4	5	bag1		Next day		bag sample
5	6	bag2	Gravel	Next day		bag sample
6	6,6	bag3	Gravel	Next day		bag sample
6,6	7	bag4	Sand	Next day		bag sample
7	8	bag5	Sand	Next day		bag sample
8	9	bag6	Sand	Next day		bag sample

National GeoTest Sites (NGTS)

Description

Sample list

OYSB02

BH54 Bag samples

Document No.	Figure No.	Date	Drawn by
20160154-08-R	2	10.01.2020	APP

NGTS

P:\2016\01\20160154\Fieldwork\Oysand\BH\[OYSB02.xlsx]Samplelist

GROUP	SAMP
HEADING	Sample list
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PROJ_LOC	Oysand (OYS)
PROJ_CLNT	NGTS
PROJ_CONT	NGI
PROJ_ENG	NGI
LOCA_ID	OYSB09
SAMP_TYPE	BH54
Full description	54 mm sample borehole (no liner) with sand catcher and bag samples
SAMP_DATE	2017-04-05
LOCA_DRIL	HSA/Rok
Temperature	---

ISO Field classification: NO

SAMP_TOP	SAMP_BASE	SAMP_REF	SAMP_CLASS	Samples in lal	DREM_REM
					predrilling
0	1	1		Next day	
1	2	2		Next day	
2	3	3		Next day	
3	4	4		Next day	
4	5	Bag1		Next day	bag sample
5	6	5		Next day	
6	7	6		Next day	
7	8	7		Next day	
8	9	8		Next day	
9	10	9		Next day	
10	11	10		Next day	
11	12	11		Next day	
12	13	12		Next day	
13	14	13		Next day	
14	15	14		Next day	
15	16	15		Next day	
16	17	16		Next day	
17	18	17		Next day	
18	19	18		Next day	
19	20	19		Next day	

National GeoTest Sites (NGTS)

Description

Sample list

OYSB09

BH54 with sand catcher and bag samples

Document No. 20160154-08-R

Figure No. 3

Date 10.01.2020

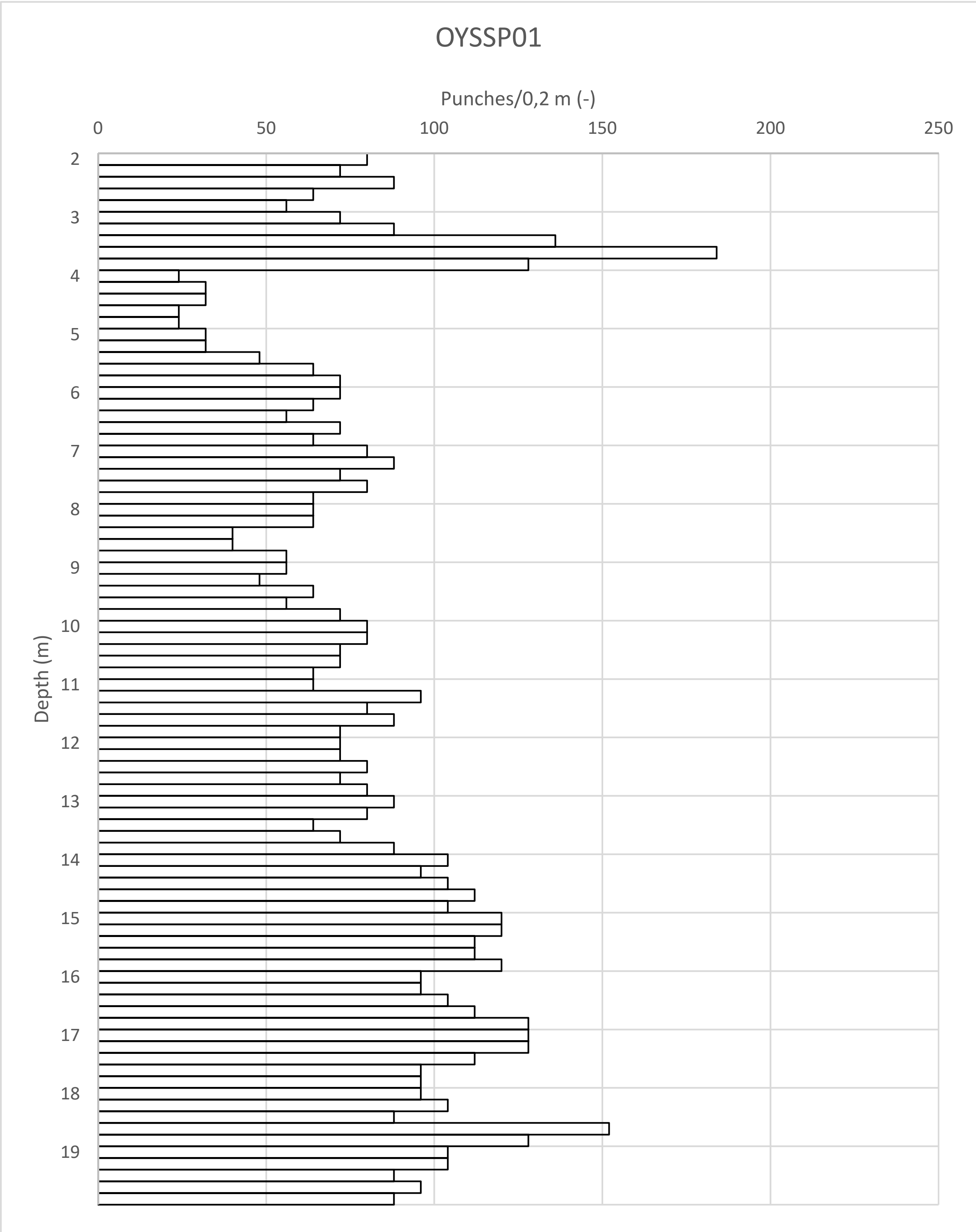
Drawn by APP

NGTS

P:\2016\01\20160154\CoordinateMaster\[NGTS_Coordinates_Oysand.xlsx]OYS

Appendix N

SWEEDISH SPT SOUNDING (HEJARSONDERING)
RESULTS



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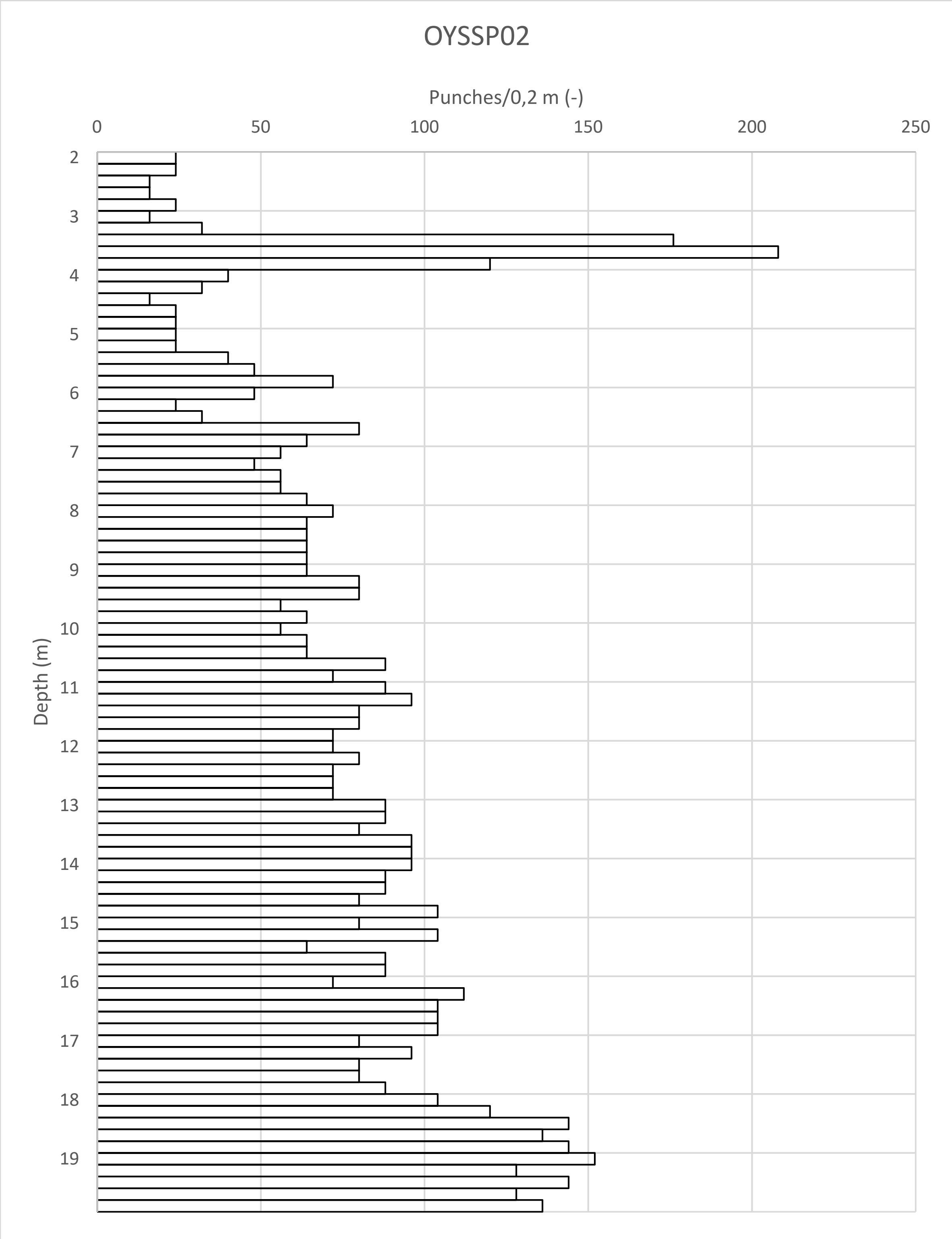
	Approval JSL	



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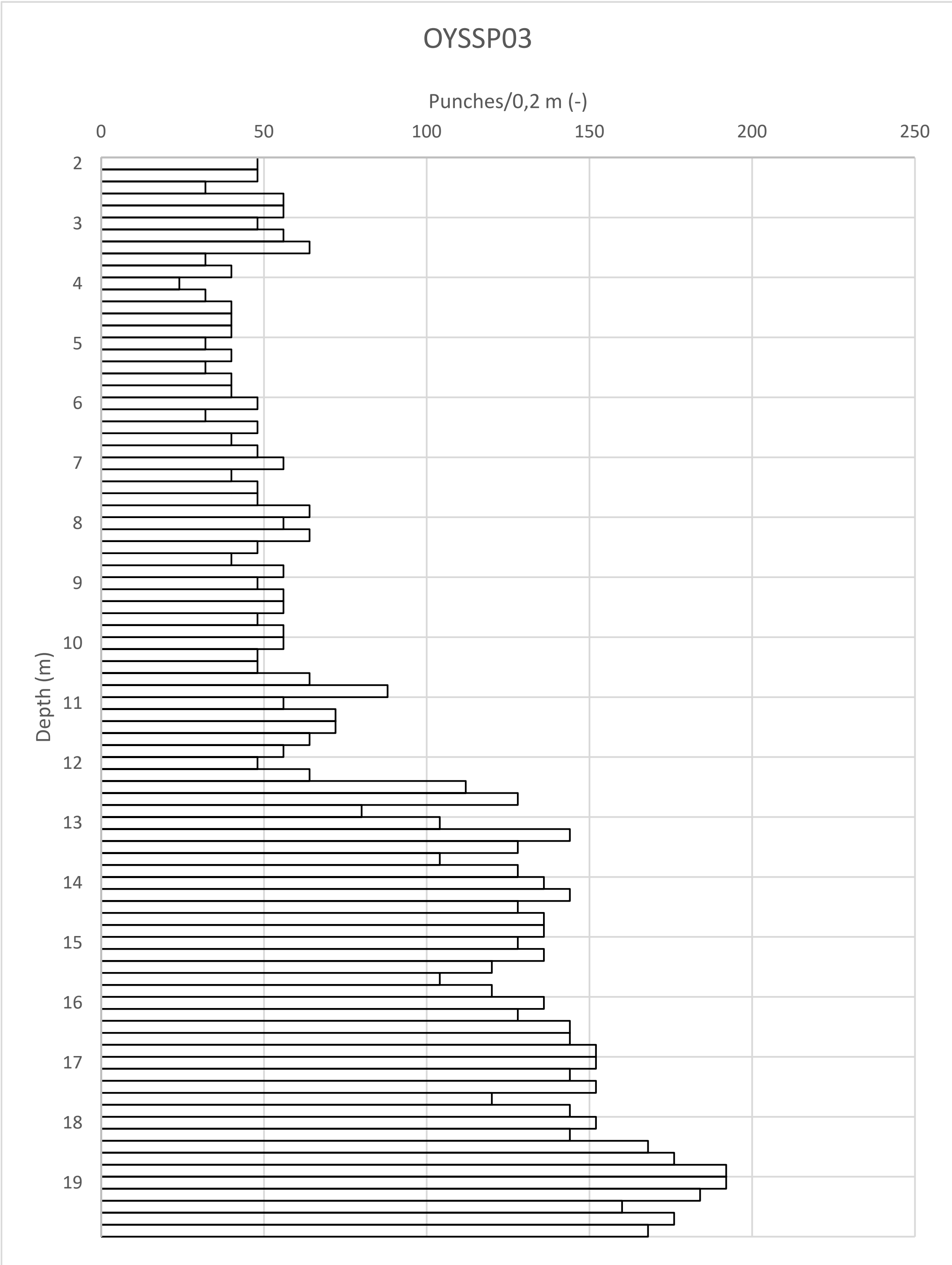

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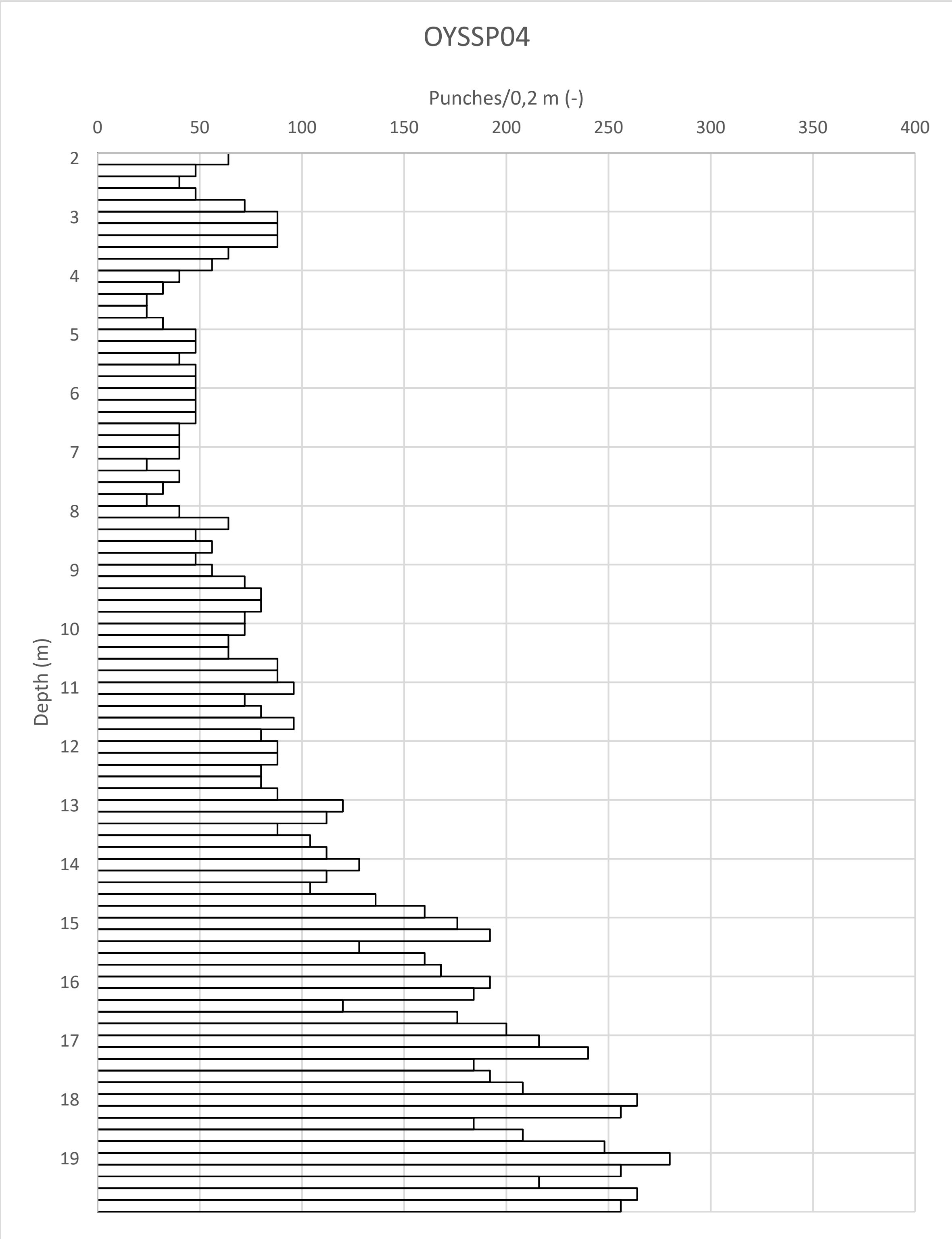

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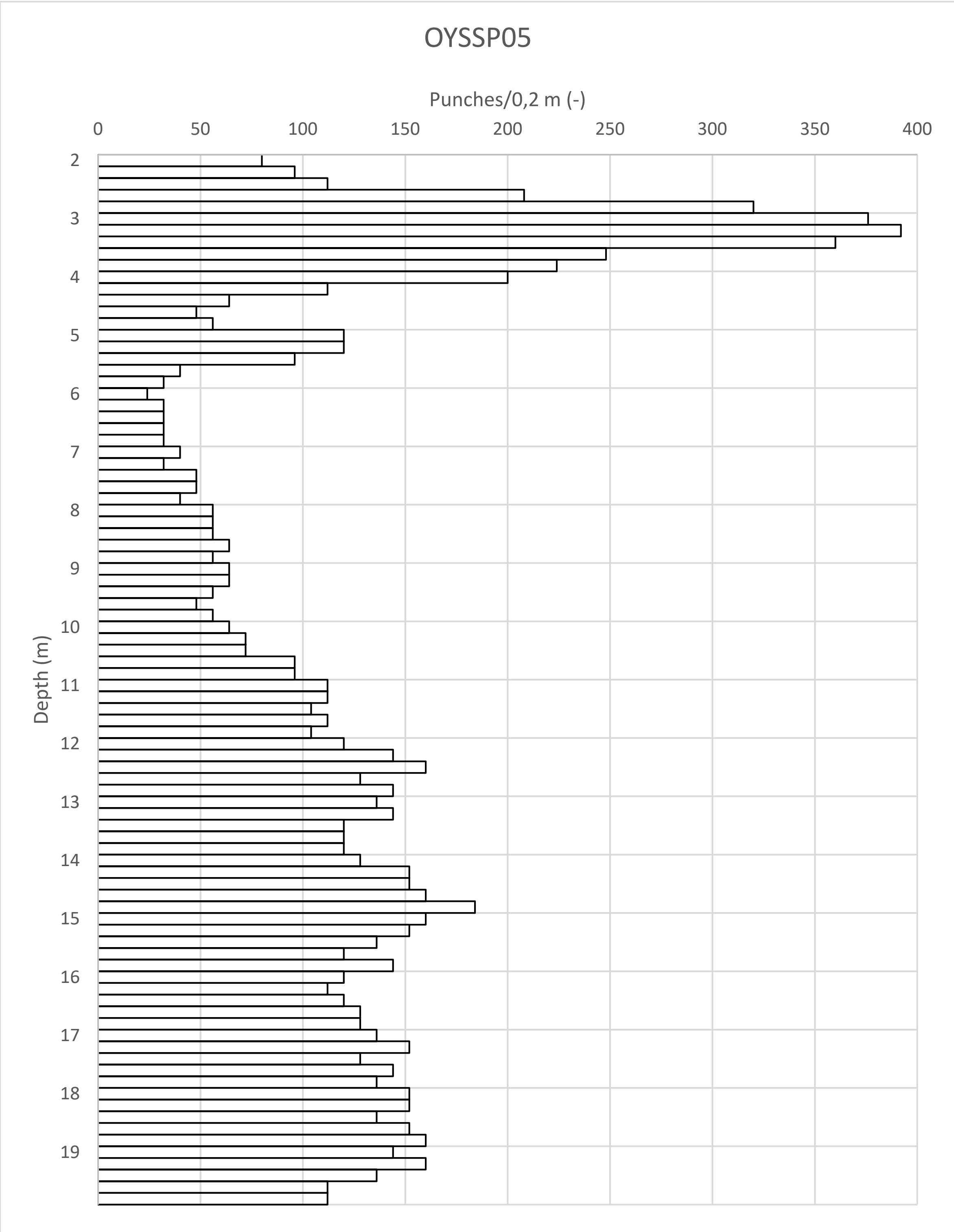
	Approval JSL	



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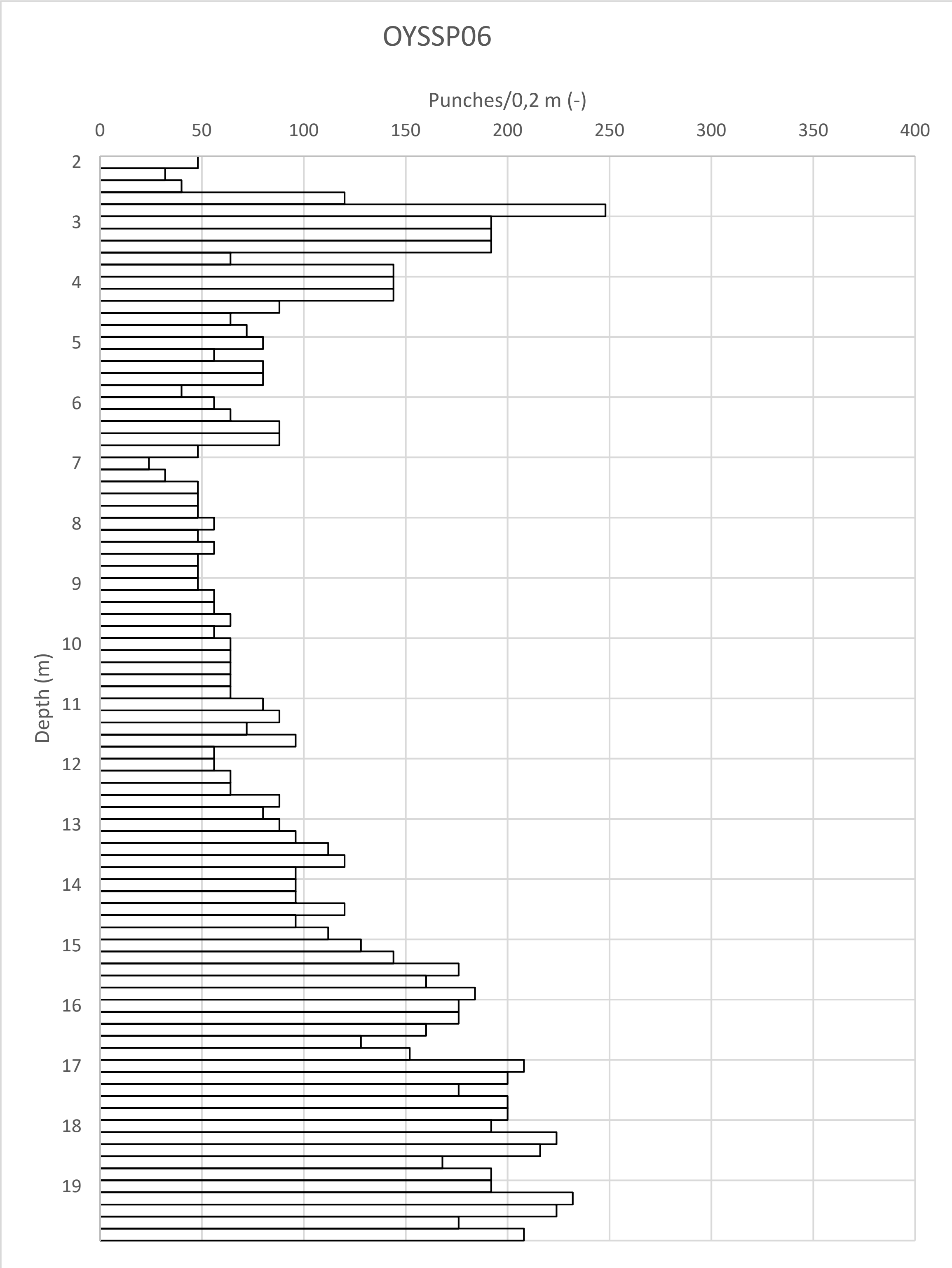

NGTS - Øysand Research Site	Report No. 20160154--08-R	Figure No. 6
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	Approval JSL	

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Kommune/*Municipality* Trondheim	**Feltnavn/*Field name*** -
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Kartblad/*Map*	**Felt, blokknr./*Field, Block No.*** -
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0	Original document	2020-01-10 Priscilla Paniagua	2020-01-10 Jean-Sebastien L'Heureux		

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