

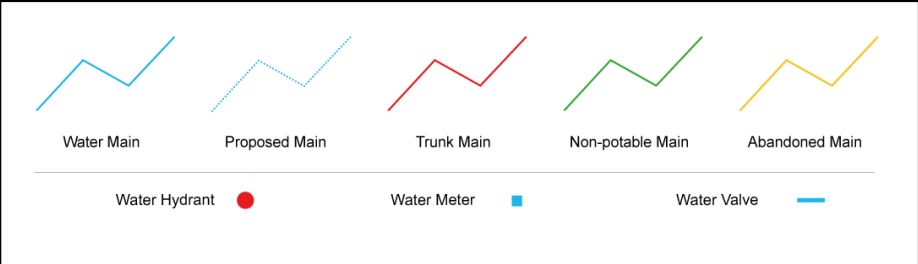


(c) Crown copyright and database rights 2020 Ordnance Survey 100031673 Date: 03/12/20 Scale: 1:1250 Map Centre: 511780,103082 Data updated: 16/11/20 Our Ref: 464960 - 1 Clean Water Plan A3

The positions of pipes shown on this plan are believed to be correct, but Southern Water Services Ltd accept no responsibility in the event of inaccuracy. The actual positions should be determined on site. This plan is produced by Southern Water Services Ltd (c) Crown copyright and database rights 2020 Ordnance Survey 100031673. This map is to be used for the purposes of viewing the location of Southern Water plant only. Any other uses of the map data or further copies is not permitted.

WARNING: BAC pipes are constructed of Bonded Asbestos Cement.

WARNING: Unknown (UNK) materials may include Bonded Asbestos Cement.

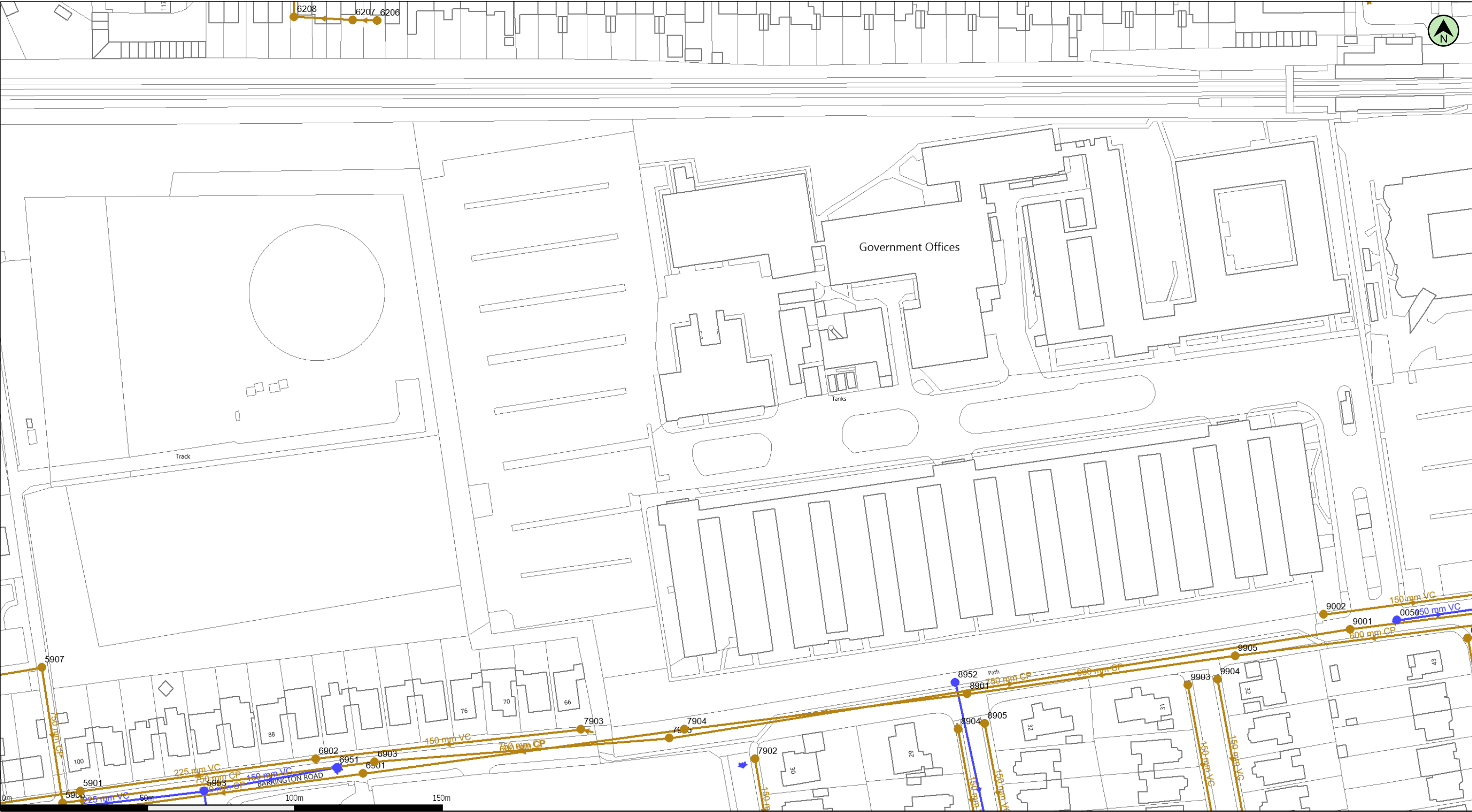


alex.band@soiltechnics.net

STS5226

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Foul Gravity Sewer	Combined Gravity Sewer	Culverted Water Course or Treated Effluent	Surface Water Gravity Sewer
Rising Main, Vacuum or Syphon	Combined Outfall	Surface Water Outfall	Surface Water Inlet
Combined Pumping Station	Surface Water Pumping Station	Foul Pumping Station	Foul Manhole
Water Treatment Works	Section 104 Area	Building Over Agreement Area	Combined Manhole
			Surface Water Manhole
			Side Entry Manhole, Decaration Chamber, Dummy Manhole or Surface Water Soakaway

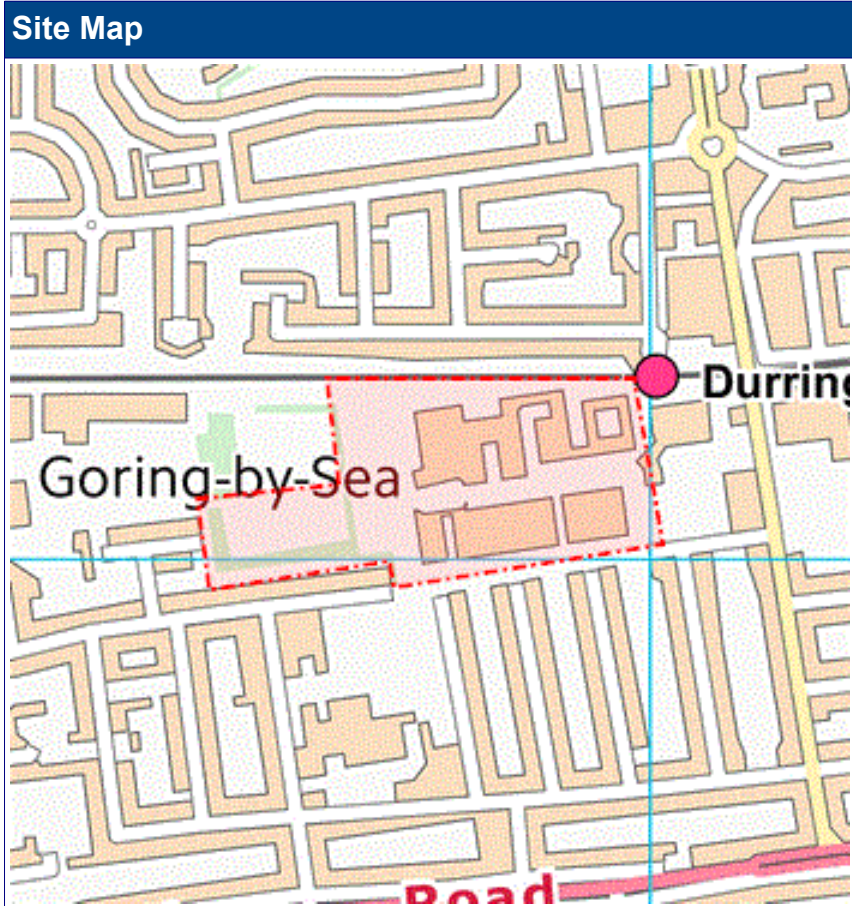
alex.band@soiltechnics.net
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Enquirer			
Name	Miss Alexa Band	Phone	
Company	Soiltechnics	Mobile	Not Supplied
Address	Cedar Barn White Lodge Walgrave Northamptonshire NN6 9PY		
Email			

Enquiry Details			
Scheme/Reference	STS5226		
Enquiry type	Initial Enquiry	Work category	Development Projects
Start date	04/12/2020	Work type	Commercial/industrial
End date	04/12/2020	Site size	77202 metres square
Searched location	XY= 511851, 103106	Work type buffer*	25 metres
Confirmed location	511802 103077		
Site Contact Name	Not Supplied	Site Phone No	Not Supplied
Description of Works			

* The WORK TYPE BUFFER is a distance added to your search area based on the Work type you have chosen.



Asset Owners

Terms and Conditions. Please note that this enquiry is subject always to our standard terms and conditions available at www.lineasearchbeforeudig.co.uk ("Terms of Use") and the disclaimer at the end of this document. Please note that in the event of any conflict or ambiguity between the terms of this Enquiry Confirmation and the Terms of Use, the Terms of Use shall take precedence.

Notes. Please ensure your contact details are correct and up to date on the system in case the LSBUD Members need to contact you.

Validity and search criteria. The results of this enquiry are based on the confirmed information you entered and are valid only as at the date of the enquiry. It is your responsibility to ensure that the Enquiry Details are correct, and LineasearchbeforeUdig accepts no responsibility for any errors or omissions in the Enquiry Details or any consequences thereof. LSBUD Members update their asset information on a regular basis so you are advised to consider this when undertaking any works. It is your responsibility to choose the period of time after which you need to resubmit any enquiry but the maximum time (after which your enquiry will no longer be dealt with by the LSBUD Helpdesk and LSBUD Members) is 28 days. If any details of the enquiry change, particularly including, but not limited to, the location of the work, then a further enquiry must be made.

Asset Owners & Responses. Please note the enquiry results include the following:

1. "LSBUD Members" who are asset owners who have registered their assets on the LSBUD service.
2. "Non LSBUD Members" are asset owners who have not registered their assets on the LSBUD service but LSBUD is aware of their existence. Please note that there could be other asset owners within your search area.

Below are three lists of asset owners:

1. **LSBUD Members who have assets registered within your search area. ("Affected")**
 - a. These LSBUD Members will either:
 - i. Ask for further information ("Email Additional Info" noted in status). The additional information includes: Site contact name and number, Location plan, Detailed plan (minimum scale 1:2500), Cross sectional drawings (if available), Work Specification.
 - ii. Respond directly to you ("Await Response"). In this response they may either send plans directly to you or ask for further information before being able to do so, particularly if any payments or authorisations are required.
2. **LSBUD Members who do not have assets registered within your search area. ("Not Affected")**
3. **Non LSBUD Members who may have assets within your search area.** Please note that this list is not exhaustive and all details are provided as a guide only. It is your responsibility to identify and consult with all asset owners before proceeding.

National Grid. Please note that the LSBUD service only contains information on National Grid's Gas above 7 bar asset, all National Grid Electricity Transmission assets and National Grid's Gas Distribution Limited above 2 bar asset.

For National Grid Gas Distribution Ltd below 2 bar asset information please go to www.beforeyoudig.nationalgrid.com

LSBUD Members who have assets registered on the LSBUD service within the vicinity of your search area.

List of affected LSBUD members

Asset Owner	Phone/Email	Emergency Only	Status
ESP Utilities Group	01372227560	01372227560	Await response
SGN	08009121722	0800111999	Await response
UK Power Networks	08000565866	08000565866	Await response

LSBUD Members who do not have assets registered on the LSBUD service within the vicinity of your search area. Please be aware that LSBUD Members make regular changes to their assets and this list may vary for new enquiries in the same area.

List of not affected LSBUD members

AWE Pipeline	Balfour Beatty Investments Limited	BOC Limited (A Member of the Linde Group)
BP Exploration Operating Company Limited	BPA	Carrington Gas Pipeline
CATS Pipeline c/o Wood Group PSN	Cemex	Centrica Storage Ltd
Chrysaor Production (UK) Limited	CLH Pipeline System Ltd	CNG Services Ltd
Concept Solutions People Ltd	ConocoPhillips (UK) Teesside Operator Ltd	Diamond Transmission Corporation
DIO (MOD Abandoned Pipelines)	DIO (MOD Live Pipelines)	Drax Group
E.ON UK CHP Limited	EirGrid	Electricity North West Limited
ENI & Himor c/o Penspen Ltd	EnQuest NNS Limited	EP Langage Limited
ESSAR	Esso Petroleum Company Limited	Fulcrum Pipelines Limited
Gamma	Gas Networks Ireland (UK)	Gateshead Energy Company
Gigaclear Ltd	Gtt	Heathrow Airport LTD
Humbly Grove Energy	IGas Energy	INEOS FPS Pipelines
INEOS Manufacturing (Scotland and TSEP)	INOVYN ChlorVinyls Limited	INOVYN Enterprises Limited
Intergen (Coryton Energy or Spalding Energy)	Jurassic Fibre Ltd	Mainline Pipelines Limited
Manchester Jetline Limited	Manx Cable Company	Marchwood Power Ltd (Gas Pipeline)
Melbourn Solar Limited	Murphy Utility Assets	National Grid Gas (Above 7 bar), National Grid Gas Distribution Limited (Above 2 bar) and National Grid Electricity Transmission
Northumbrian Water Group	NPower CHP Pipelines	NYnet Ltd
Oikos Storage Limited	Ørsted	Perenco UK Limited (Purbeck Southampton Pipeline)
Petroineos	Phillips 66	Portsmouth Water
Premier Transmission Ltd (SNIP)	Redundant Pipelines - LPDA	RWE - Great Yarmouth Pipeline (Bacton to Great Yarmouth Power Station)
RWEnpower (Little Barford and South Haven)	SABIC UK Petrochemicals	Scottish and Southern Electricity Networks
Scottish Power Generation	Seabank Power Ltd	SES Water
Shell	Shell NOP	SSE Enterprise Telecoms
SSE Generation Ltd	SSE Utility Solutions Limited	Tata Communications (c/o JSM Construction Ltd)
Total (Colnbrook & Colwick Pipelines)	Total Finaline Pipelines	Transmission Capital
	University of Cambridge Granta Backbone	

Uniper UK Ltd

Network

Vattenfall

Veolia ES SELCHP Limited

Veolia ES Sheffield Ltd

Wales and West Utilities

West of Duddon Sands Transmission Ltd

Western Power Distribution

Westminster City Council

Zayo Group UK Ltd c/o JSM Group Ltd

The following Non-LSBUD Members may have assets in your search area. It is **YOUR RESPONSIBILITY** to contact them before proceeding. Please be aware this list is not exhaustive and it is your responsibility to identify and contact all asset owners within your search area.

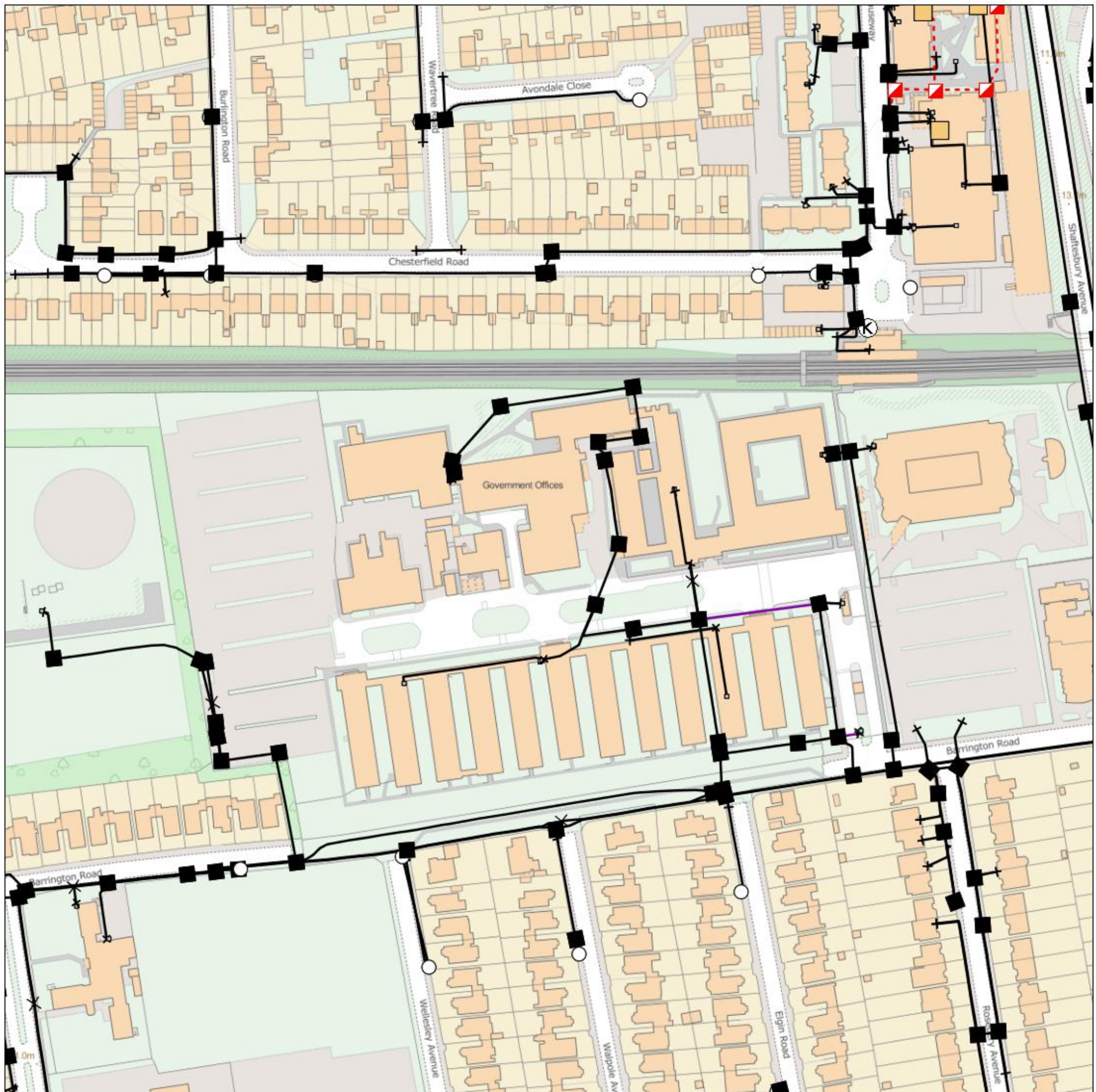
Non-LSBUD members (Asset owners not registered on LSBUD)			
Asset Owner	Preferred contact method	Phone	Status
BT	https://www.swns.bt.com/pls/mbe/welcome.home	08000232023	Not Notified
CenturyLink Communications UK Limited	plantenquiries@instalcom.co.uk	02087314613	Not Notified
CityFibre	asset.team@cityfibre.com	033 3150 7282	Not Notified
Colt	plantenquiries@catelecomuk.com	01227768427	Not Notified
Energetics Electricity	plantenquiries@lastmile-uk.com	01698404646	Not Notified
ENGIE	nrswa.uk@engie.com	01293 549944	Not Notified
GTC	https://pe.gtc-uk.co.uk/PlantEnqMembership	01359240363	Not Notified
KPN (c/-Instalcom)	kpn.plantenquiries@instalcom.co.uk	n/a	Not Notified
Mobile Broadband Network Limited	mbnlplantenquiries@turntown.com	01212 621 100	Not Notified
Sky UK Limited	nrswa@sky.uk	02070323234	Not Notified
Sota	SOTA.plantenquiries@instalcom.co.uk		Not Notified
Southern Water	www.digdat.co.uk	08452700212	Not Notified
Utility assets Ltd	assetrecords@utilityassets.co.uk		Not Notified
Verizon Business	osp-team@uk.verizonbusiness.com	01293611736	Not Notified
Virgin Media	http://www.digdat.co.uk	08708883116	Not Notified
Vodafone	osm.enquiries@atkinsglobal.com	01454662881	Not Notified

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Maps by email Plant Information Reply



IMPORTANT WARNING

Information regarding the location of BT apparatus is given for your assistance and is intended for general guidance only. No guarantee is given of its accuracy. It should not be relied upon in the event of excavations or other works being made near to BT apparatus which may exist at various depths and may deviate from the marked route.



openreach

CLICK BEFORE YOU DIG

FOR PROFESSIONAL FREE ON SITE ASSISTANCE PRIOR TO COMMENCEMENT OF EXCAVATION WORKS INCLUDING LOCATE AND MARKING SERVICE

email cbyd@openreach.co.uk

ADVANCE NOTICE REQUIRED
(Office hours: Monday - Friday 08.00 to 17.00)
www.openreach.co.uk/cbyd

Accidents happen

If you do damage any Openreach equipment please let us know by calling 0800 023 2023 (opt 1 + opt 1) and we can get it fixed ASAP

KEY TO BT SYMBOLS

	Planned	Live	Change Of State	+	Hatchings	
PCP			Split Coupling	×	Built	
Pole			Duct Tee	▲	Planned	
Box			Building		Inferred	
Manhole			Kiosk	K	Duct	
Cabinet			Other proposed plant is shown using dashed lines. BT Symbols not listed above may be disregarded. Existing BT Plant may not be recorded. Information valid at time of preparation. Maps are only valid for 90 days after the date of publication.			
	Pending Add	In Place	Pending Remove	Not In Use		
Power Cable						
Power Duct				N/A		

BT Ref : TVZ03348H

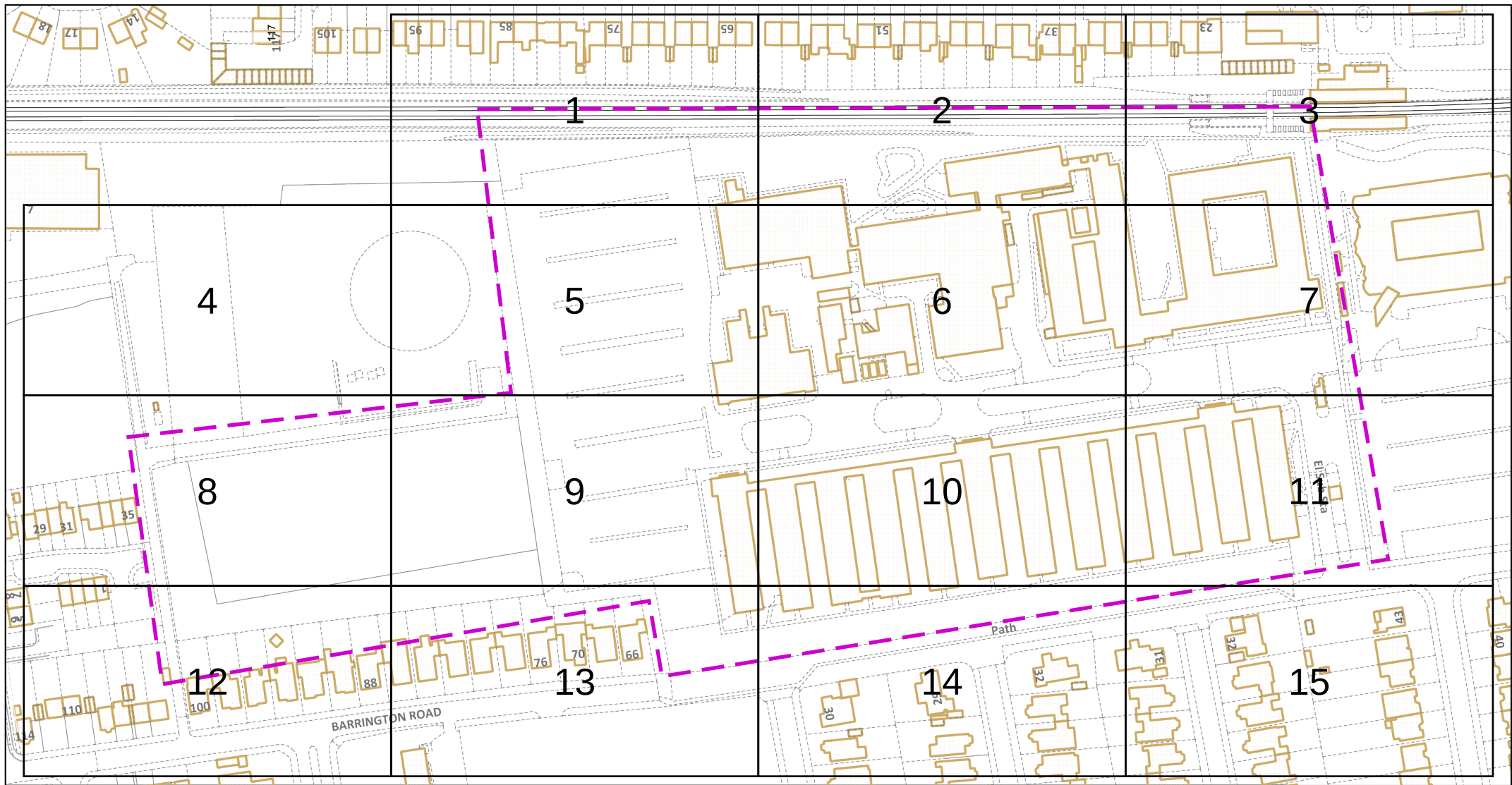
Map Reference : (centre) TQ1185103106

Easting/Northing : (centre) 511851,103106

Issued : 03/12/2020 15:35:04

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Dig Sites Area: Line:

The quality and accuracy of any print will depend on your printer, your computer and its print settings. Measurements scaled from this plan may not match measurements between the same points on the ground.

This plan must be used with the attached 'Symbols' document.

Date Requested: 03/12/2020

Job Reference: 20712204

Site Location: 511422 102818

Requested by:

Miss Alexa Band

Your Scheme/Reference:

STS5226

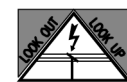
Scale: 1:2050 (When plotted at A4)

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4. This plan has been provided to you on the basis of the terms of use set out in the covering letter that accompanies this plan. If you do not accept and/or do not understand the terms of use set out in the covering letter you must not use the plan and must return it to the sender of the letter.
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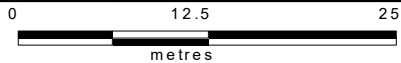
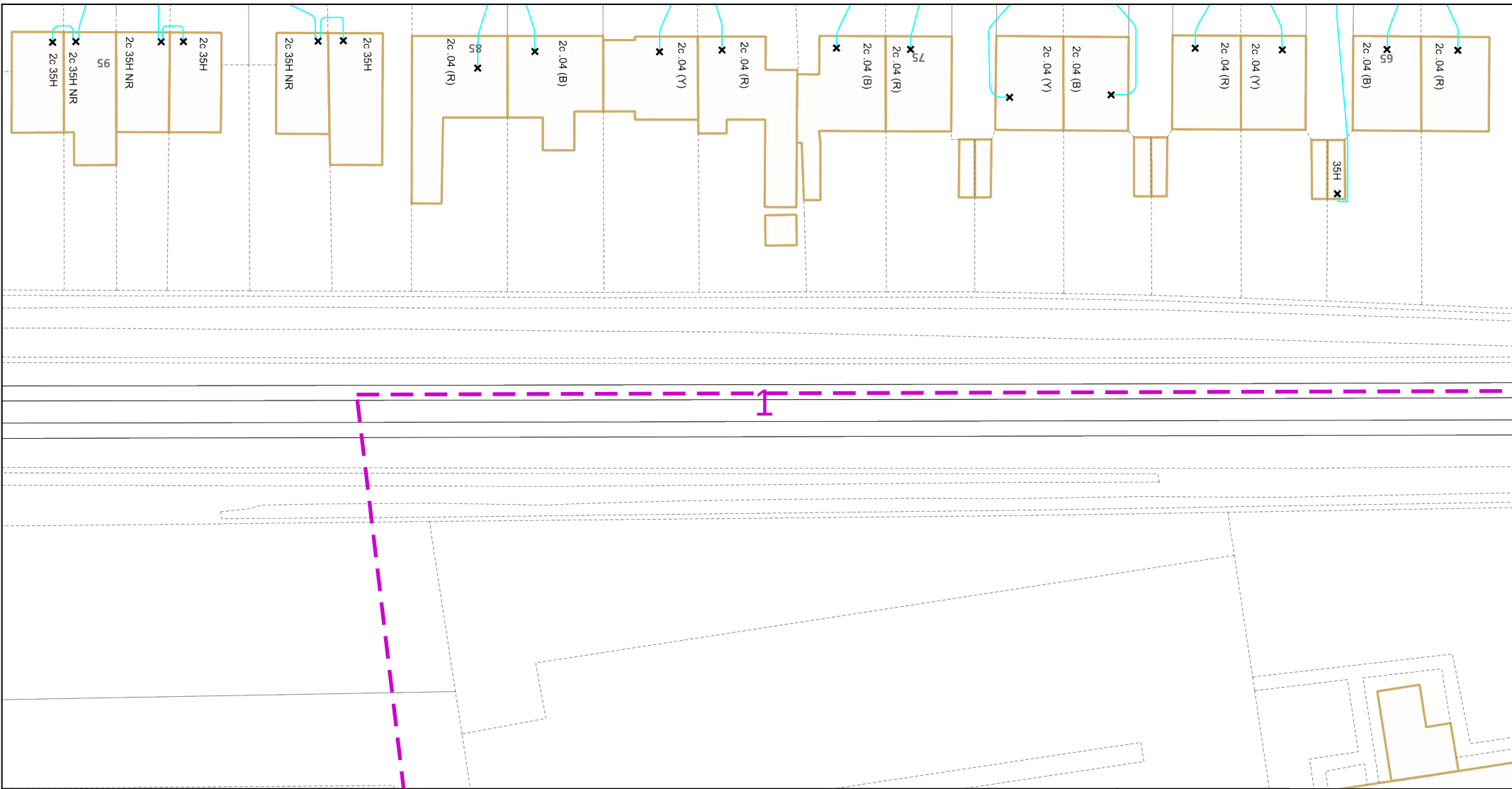


IF IN DOUBT - ASK! PHONE
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URGENTLY



ALWAYS LOOK UP
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Refer to HSE Guidance
note GS6

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Site Location: 511422 102818

Requested by: Miss Alexa Band

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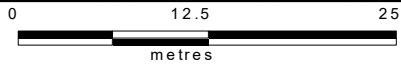
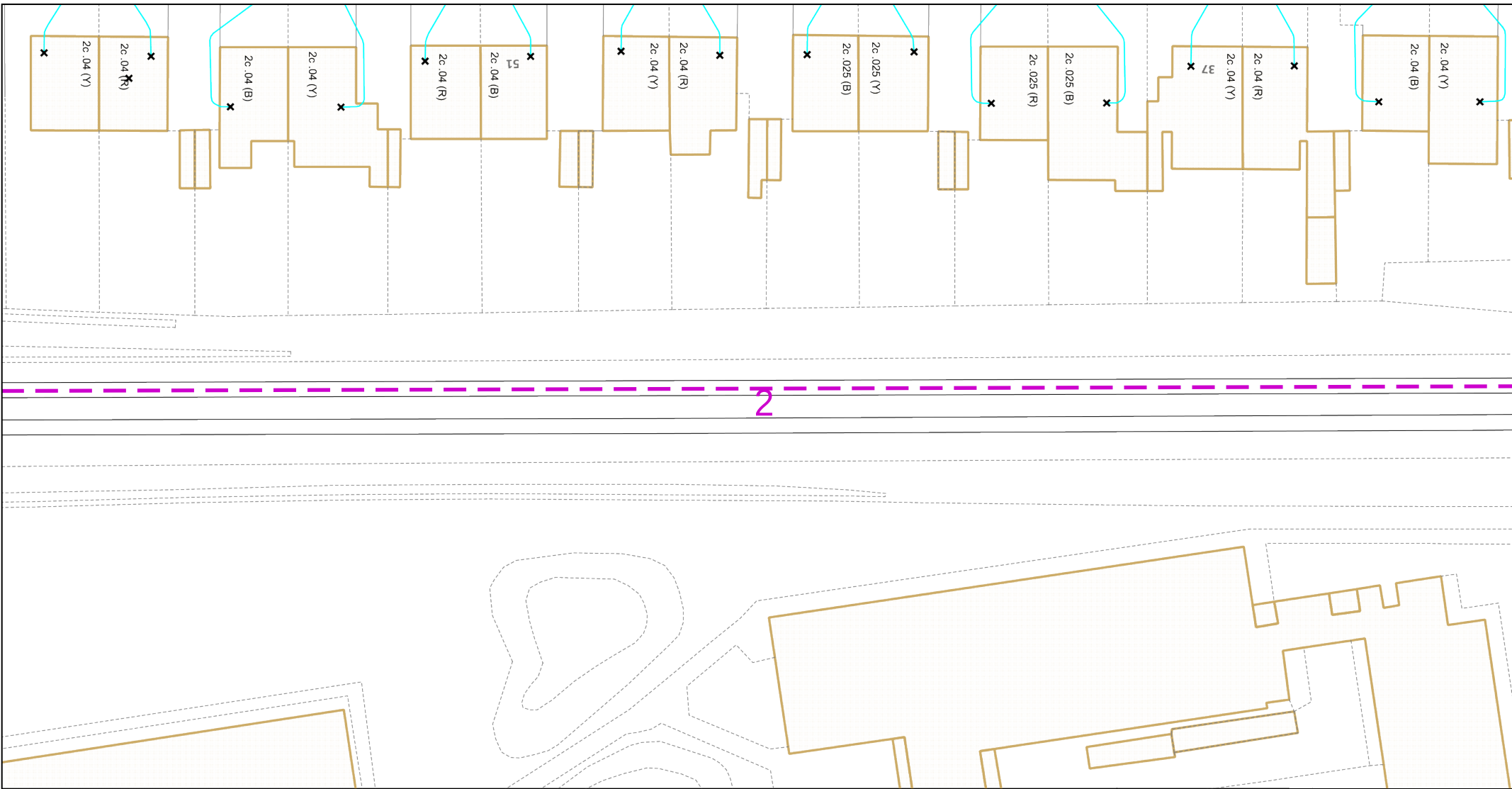


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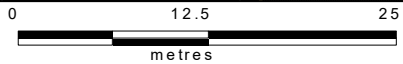
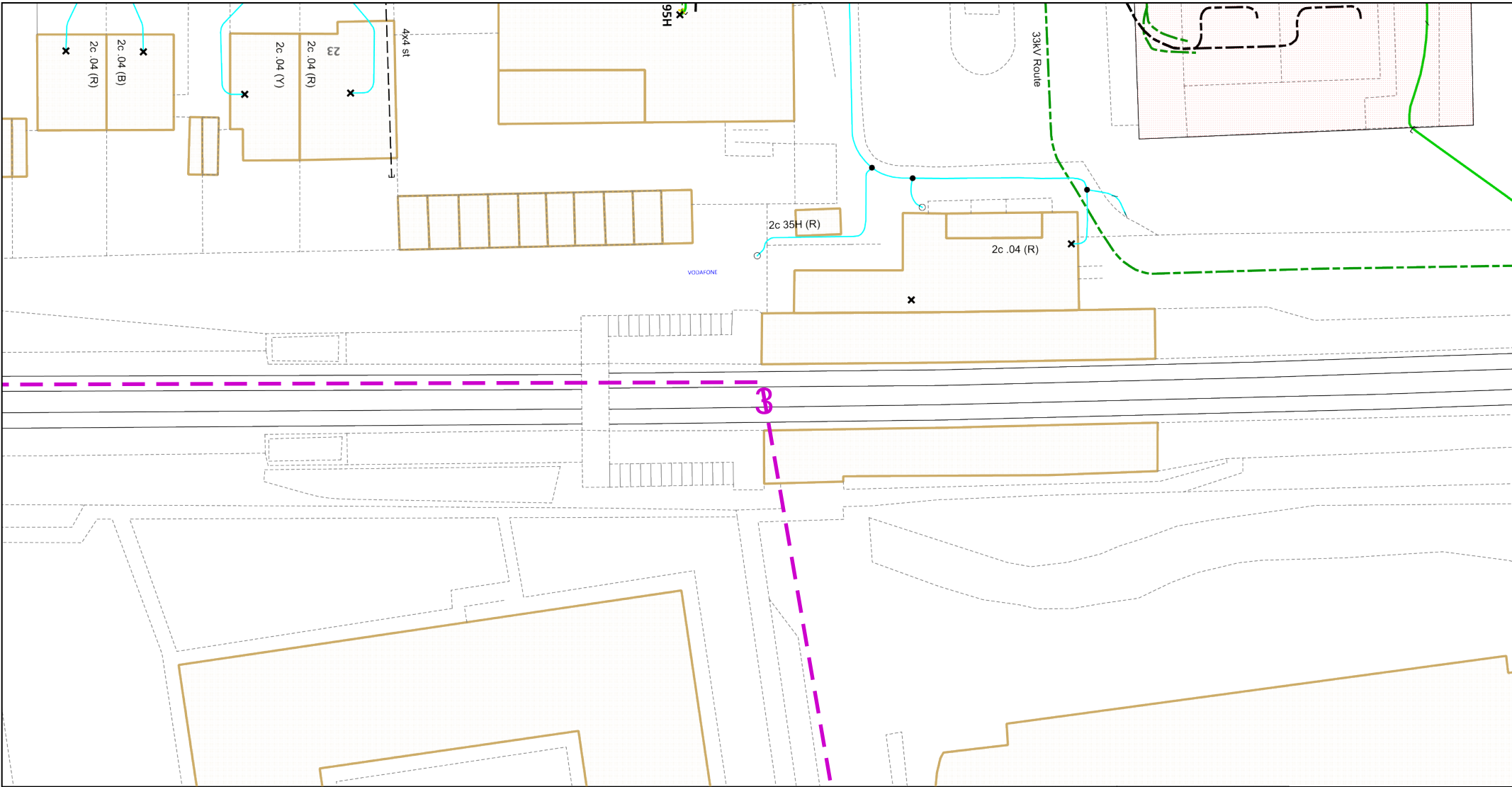


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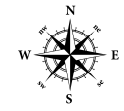
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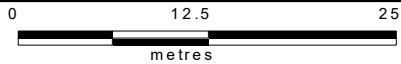
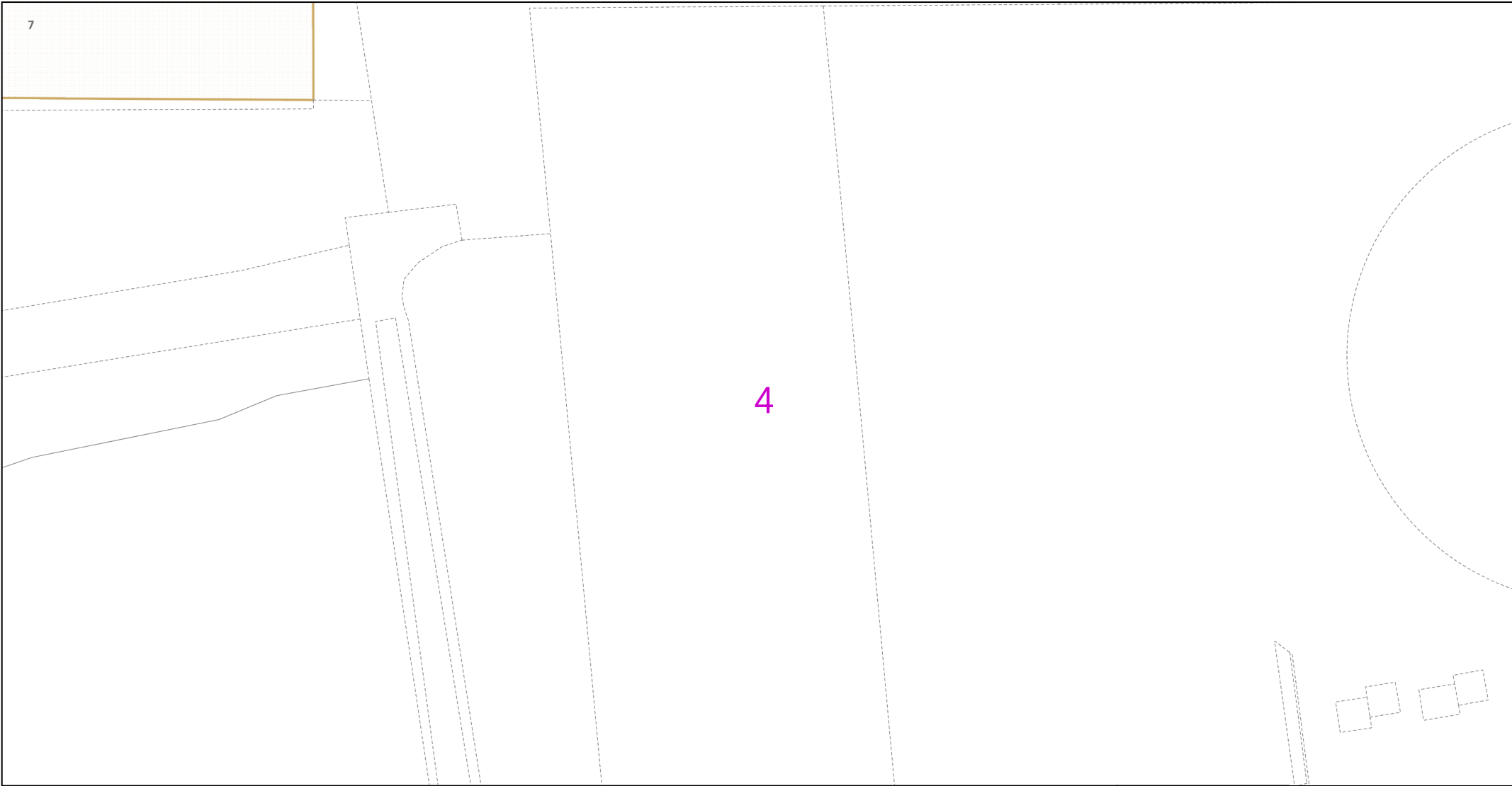


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Dig Sites Area:  Line: 

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Date Requested: 03/12/2020
Job Reference: 20712204
Site Location: 511422 102818
Requested by: Miss Alexa Band

Your Scheme/Reference:
STS5226
Scale: 1:500 (When plotted at A4)

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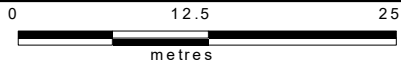
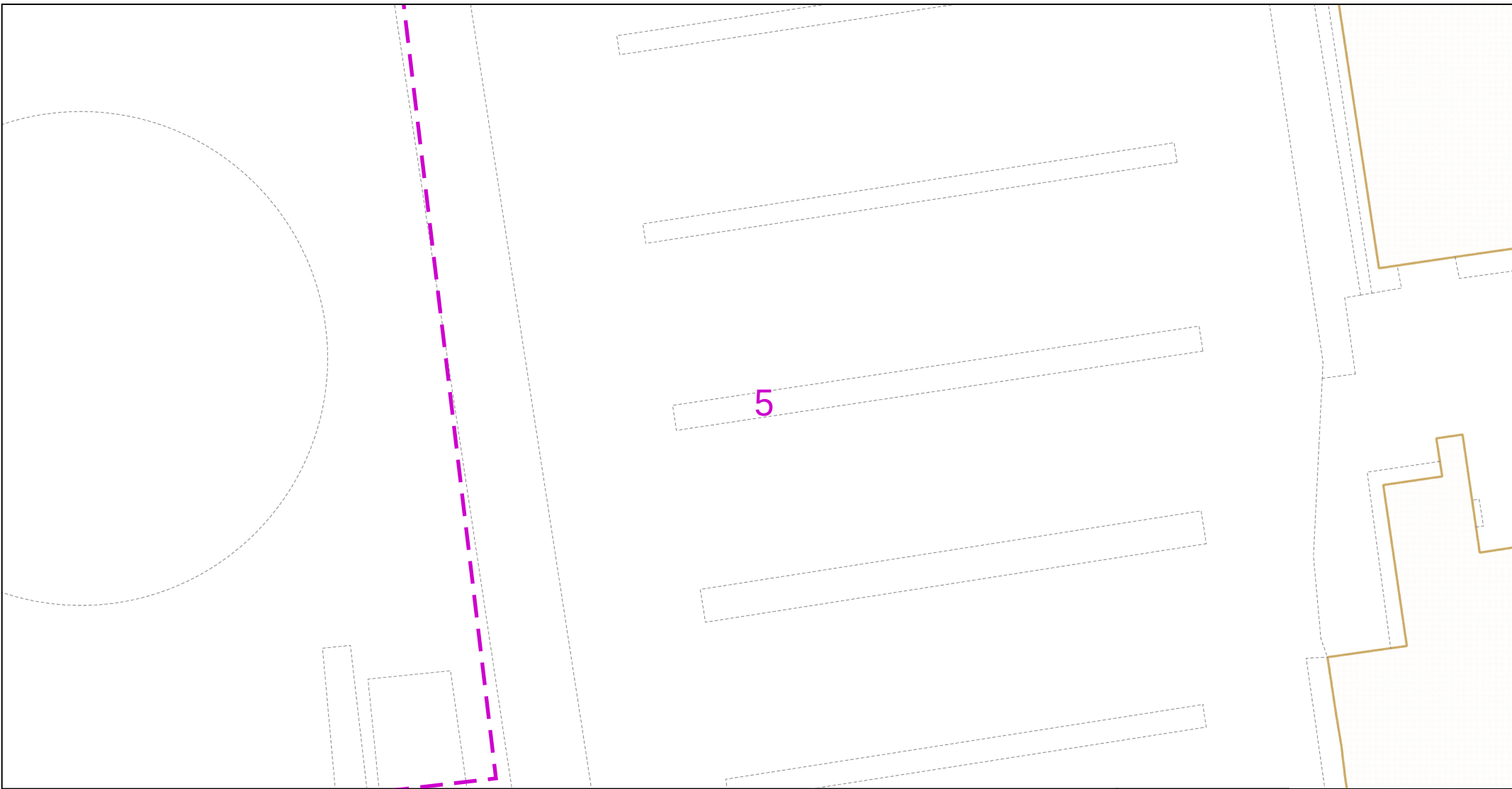


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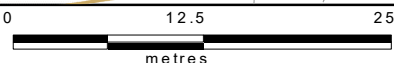
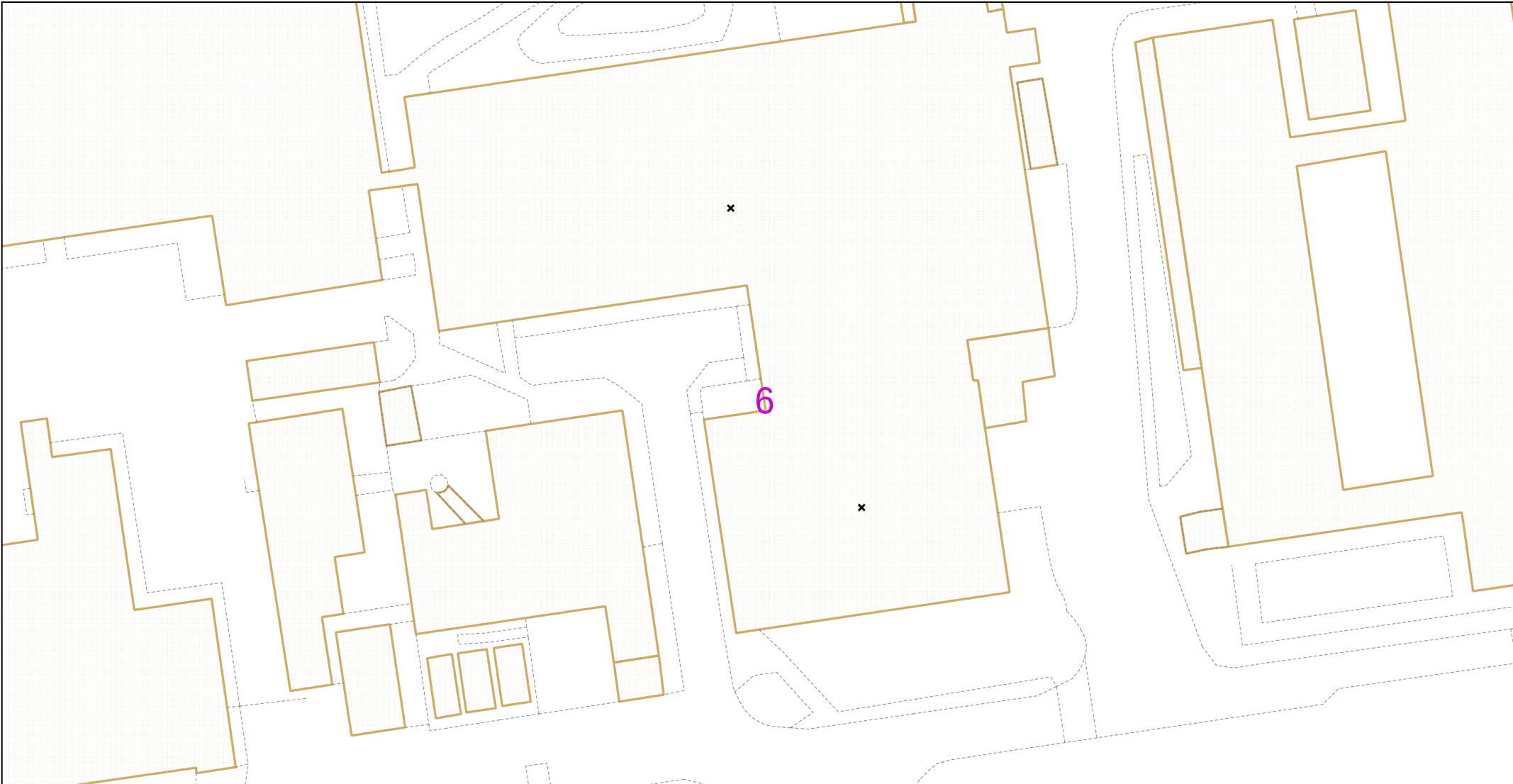
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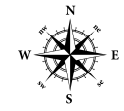
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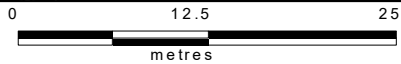
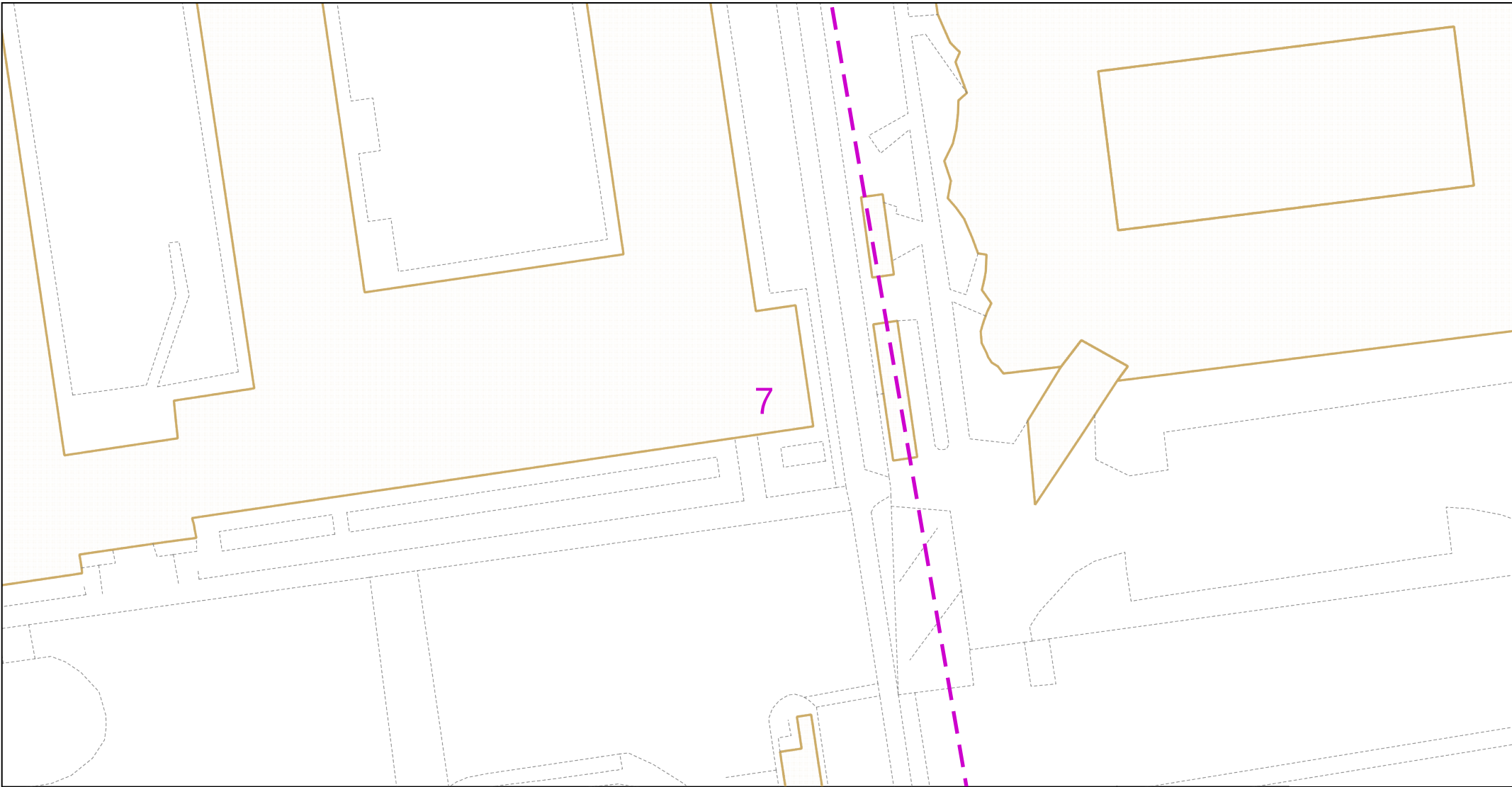


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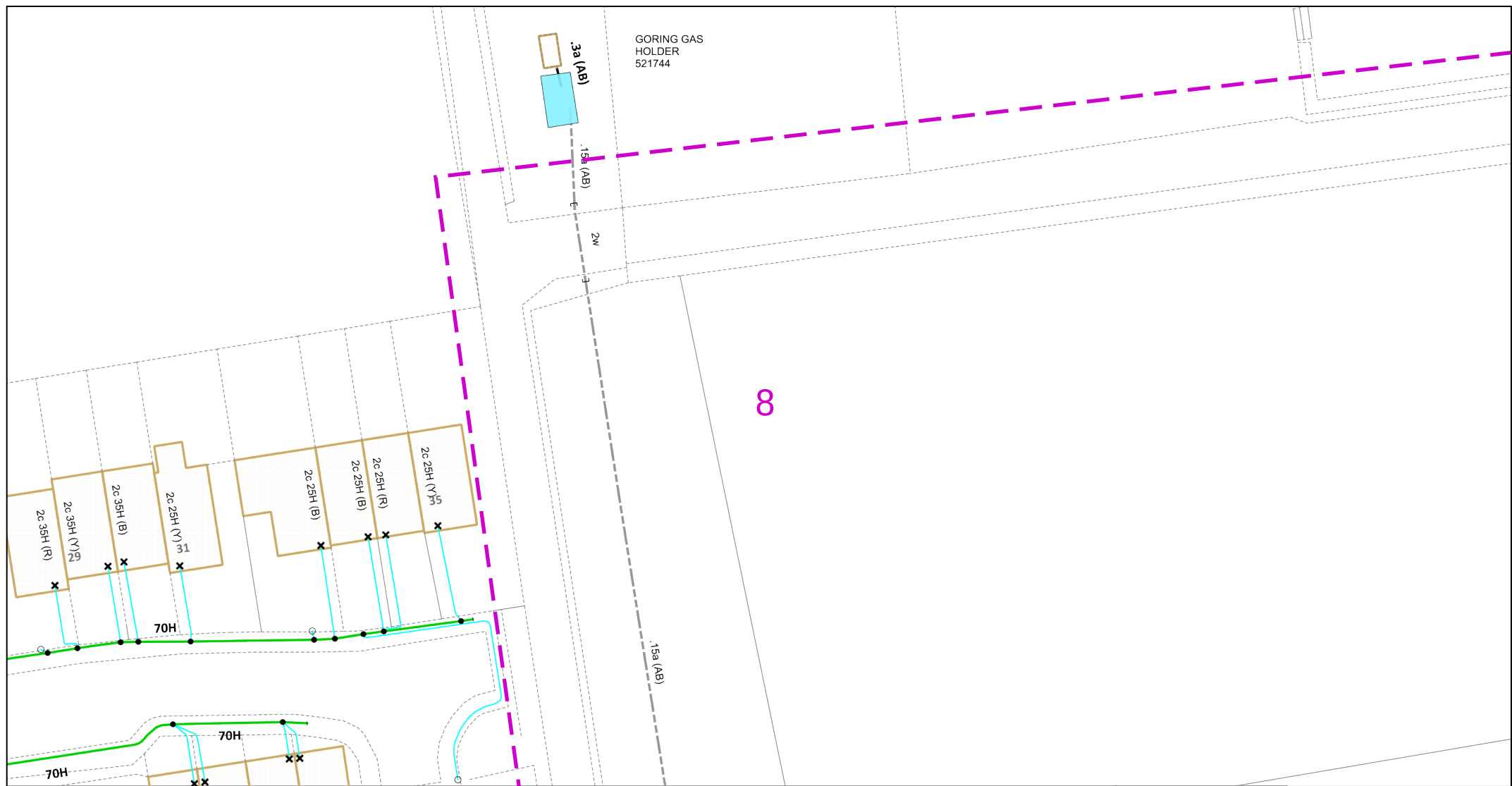


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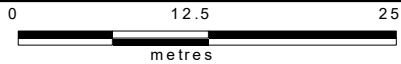
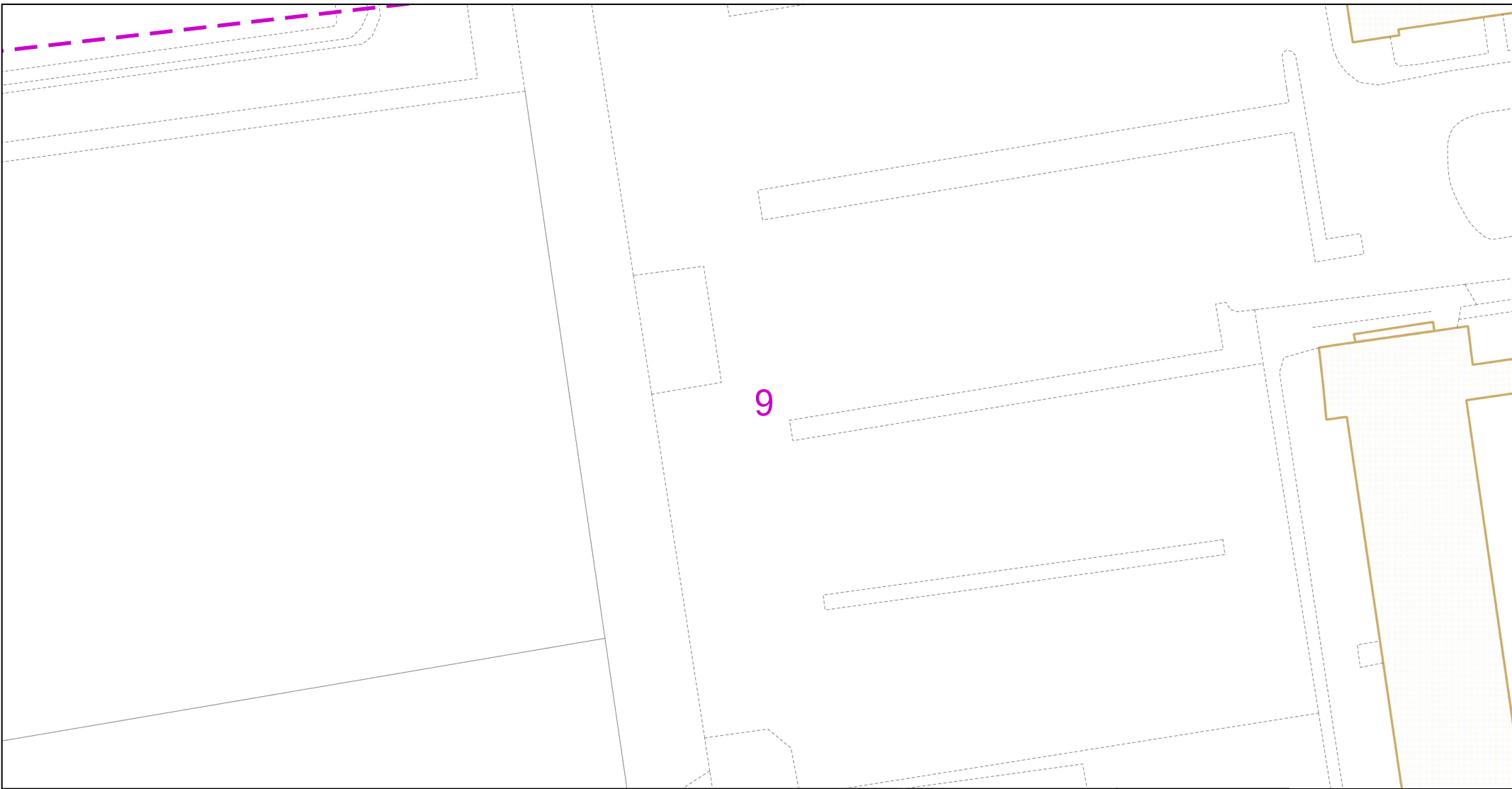


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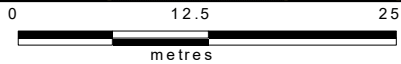
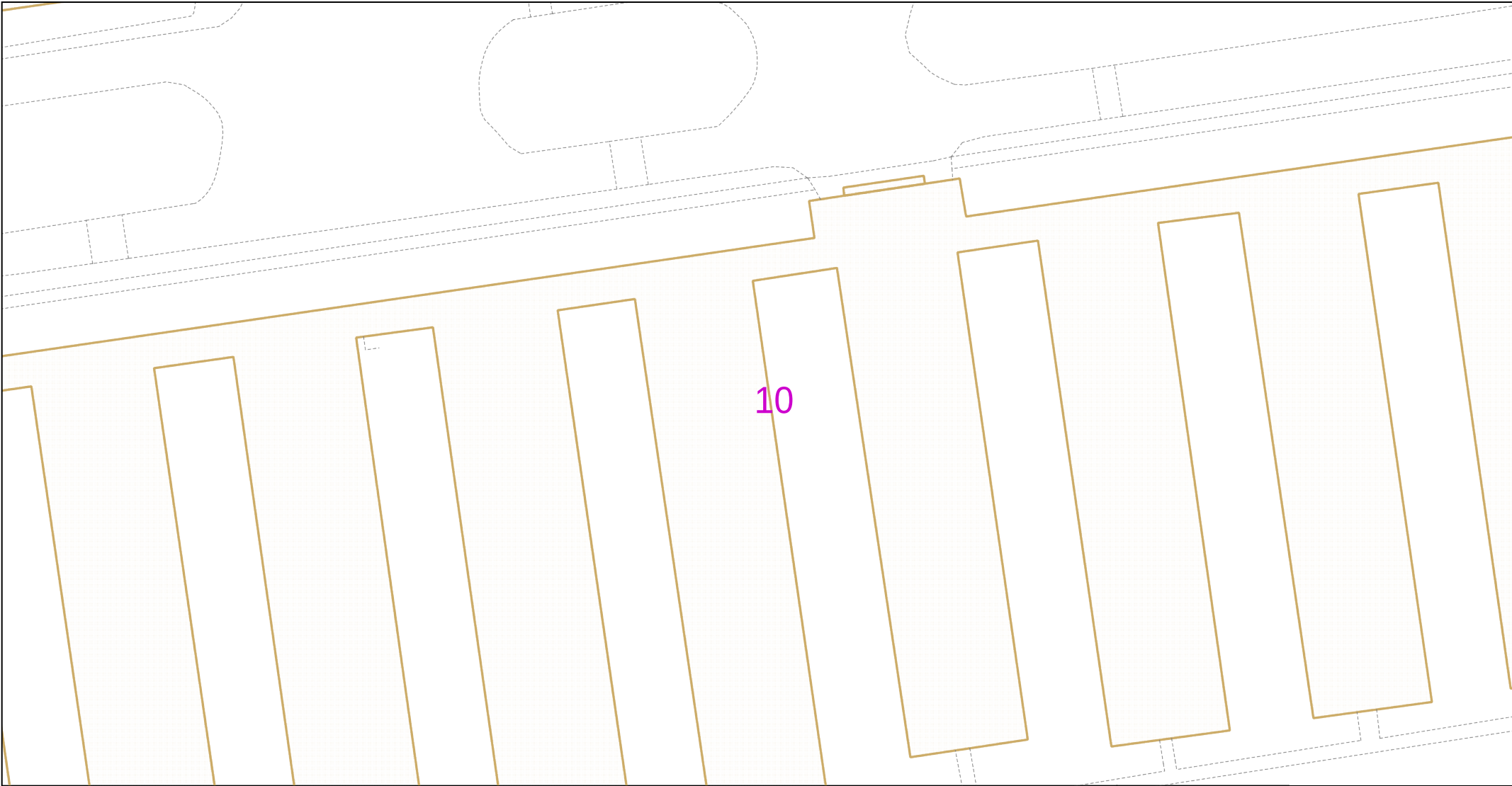


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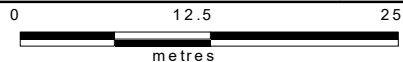
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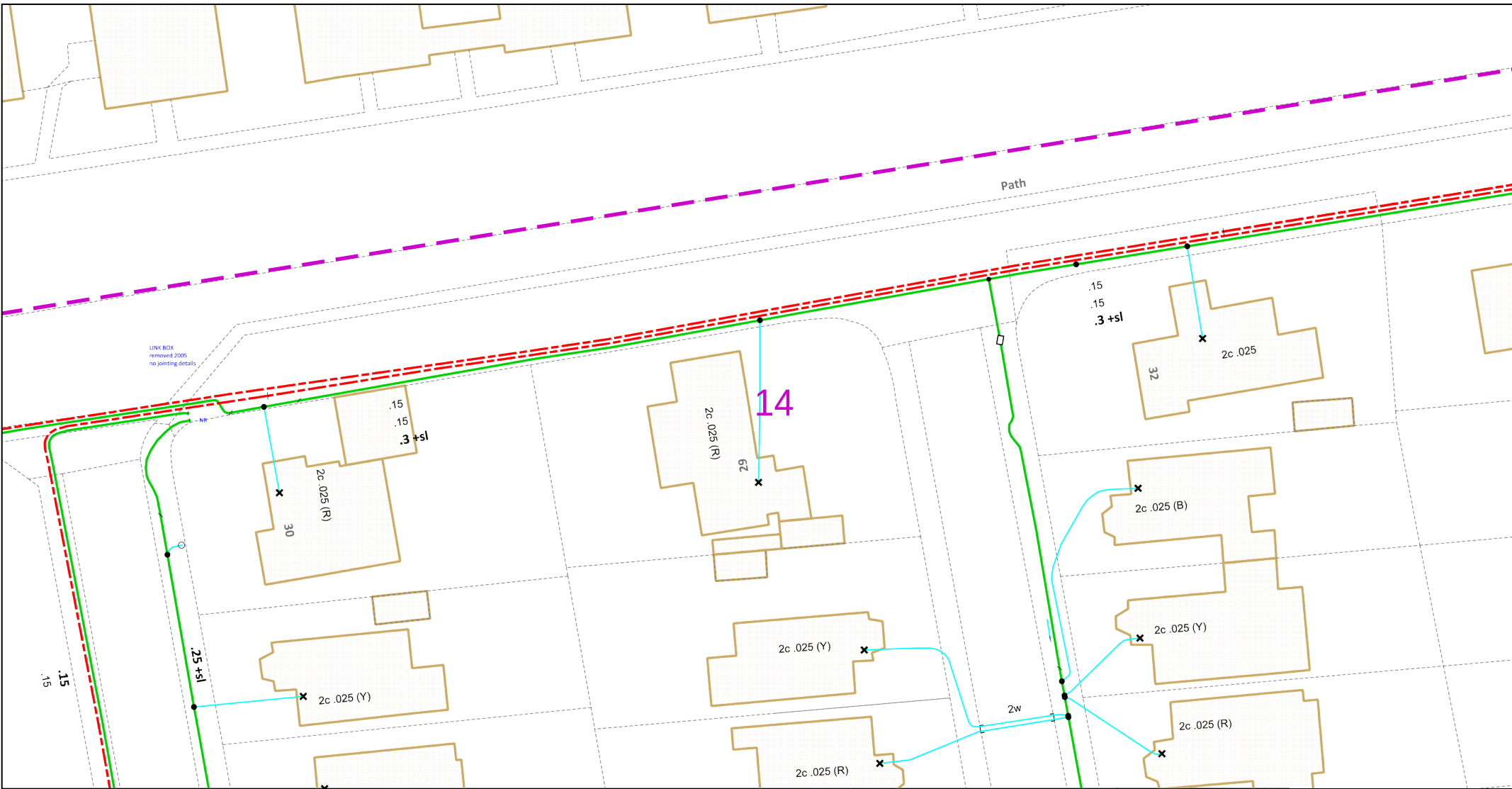
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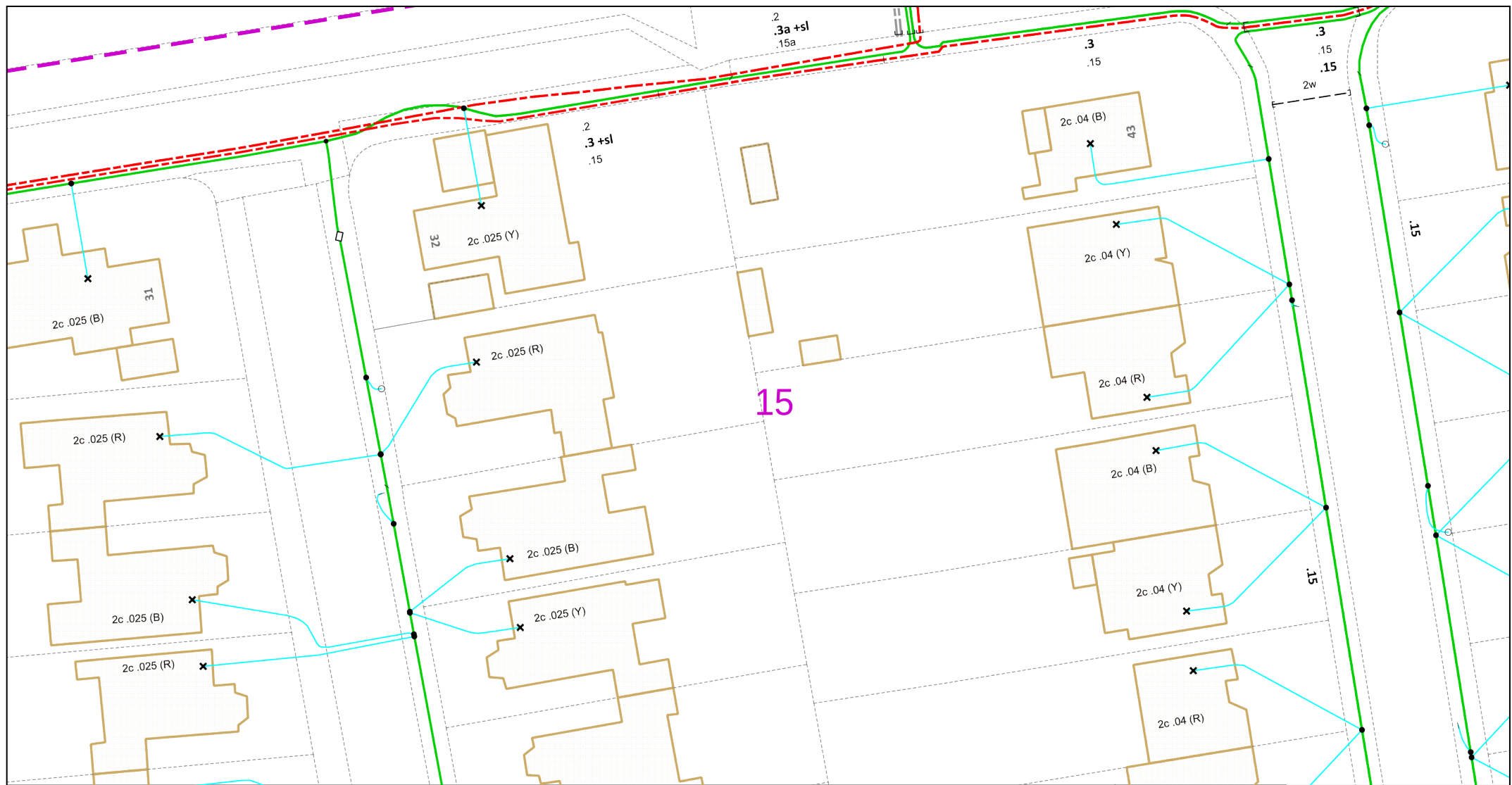


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0 12.5 25 metres Dig Sites Area: Line:		The quality and accuracy of any print will depend on your printer, your computer and its print settings. Measurements scaled from this plan may not match measurements between the same points on the ground.					
This plan must be used with the attached 'Symbols' document. Date Requested: 03/12/2020 Job Reference: 20712204 Site Location: 511422 102818 Requested by: Miss Alexa Band Your Scheme/Reference: STS5226 Scale: 1:500 (When plotted at A4)		1. The position of the apparatus shown on this drawing is believed to be correct but the original landmarks may have been altered since the apparatus was installed. 2. The exact position of the apparatus should be verified - use approved cable avoidance tools prior to excavation using suitable hand tools. 3. It is essential that trial holes are carefully made avoiding the use of mechanical tools or picks until the exact location of all the cables have been determined. 4. It must be assumed that there is a service cable into each property, lamp column and street sign, etc. 5. All cables must be treated as being live unless proved otherwise by UK Power Networks. 6. The information proved must be given to all people working near UK Power Networks plant and equipment. Do not use plans more than 3 months after the issue date for excavation purposes. 7. Please be aware that electric cables/lines belonging to other owners of licensed electricity distribution systems may be present and it is your responsibility to identify their location. 8. Please be aware the Low Voltage Overhead power lines are not currently displayed for the Eastern Region via this service, if you require records on the location of these please contact our Plan Provision team directly via plans@ukpowernetworks.co.uk.		1. UK Power Networks does not warrant that the information provided to you is correct. You rely upon it at your own risk. 2. UK Power Networks does not exclude or limit its liability if it causes the death of any persons or causes personal injury to a person. 3. Subject to paragraph 2 UK Power Networks has no liability to you in contract, in tort (including negligence), for breach of statutory duty or otherwise for any loss, damage, cost, claims, demands, or expenses that you or any third party may suffer or incur as a result of using the information provided whether for physical damage to property or for any economic loss (including without limitation loss of profit, loss of opportunity, loss of savings, loss of goodwill, loss of business, loss of use) or any special or consequential loss or damage whatsoever. 4. This plan has been provided to you on the basis of the terms of use set out in the covering letter that accompanies this plan. If you do not accept and/or do not understand the terms of use set out in the covering letter you must not use the plan and must return it to the sender of the letter. 5. You are responsible for the security of the information provided to you. It must not be given, sold or made available upon payment of a fee to a third party. 6. Please Note: The Overview map does not display UK Power Networks electricity network and should not be used for the location of UK Power Networks assets. For detail of the electricity network please view the relevant page as highlighted in the Overview map.		UK Power Networks IF IN DOUBT - ASK! PHONE 0800 056 5866 EMERGENCY - If you damage a cable or line Phone 0800 783 8838 (24hrs) URGENTLY ALWAYS LOOK UP BEFORE YOU START WORK Refer to HSE Guidance note GS6	
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Date Requested: 03/12/2020

Job Reference: 20712204

Site Location: 511422 102818

Requested by: Miss Alexa Band

Your Scheme/Reference:

STS5226

Scale: 1:500 (When plotted at A4)

1. The position of the apparatus shown on this drawing is believed to be correct but the original landmarks may have been altered since the apparatus was installed.
2. The exact position of the apparatus should be verified - use approved cable avoidance tools prior to excavation using suitable hand tools.
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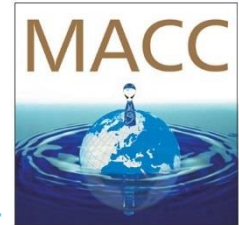


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MACC International Ltd, Camilla Court, Nacton, Ipswich, Suffolk, IP10 0EU, UK

Alexa Band
Receptionist
Soiltechnics Ltd
Email 1st Instance: Alexa.Band@soiltechnics.net

Your Reference:

Our Reference: JM/3536/600

Date: 08/12/2020

Unexploded Ordnance Preliminary Risk Review
Inland Revenue, Durrington Bridge House, Barrington Road, Worthing,
West Sussex, BN12 4XH

MACC International Ltd (MACC) has conducted a preliminary risk review for the site footprint. The review has drawn on open source and in-house information, references have been provided where available (See Annex A). The review has been conducted to provide Soiltechnics Ltd with a review of the risk which may be posed by UXO while conducting investigations on the site.

This document has been produced in the United Kingdom by MACC International Limited and has been provided solely as an aid in decision making. It is not intended to be used by any person for any purpose other than that specified. Any liability arising out of use by a third party of this document for purposes not wholly connected with the above shall be the responsibility of that party, who shall indemnify MACC International Limited against all claims, costs, damages and losses arising out of such use.

Worthing suffered a moderate level of enemy bombing during WWII and records were found to indicate that at least one HE bomb strike was recorded on adjacent land to the west of the site. Whilst considering the history of the site and the level of post-war development, the following conclusions have been reached:

- It is considered that there is a credible likelihood of encountering UXO on the plot.
Consequently, the UXO risk is considered to be Medium within the site boundary.
- Therefore, it is recommended that:
 1. All site personnel are provided with a UXO Safety Awareness Talk before intrusive works are commenced.
 2. All intrusive investigations into post war un-worked ground should be supported by specialist EOD services.

I trust this document has provided you with sufficient information to meet your immediate needs, should you require anything further, please do not hesitate to contact me.

Yours Sincerely



John Morrison
Operations Manager

Unexploded Ordnance Preliminary Risk Review

Site location 	Site Address: Inland Revenue, Durrington Bridge House, Barrington Road, Worthing, West Sussex, BN12 4XH Grid Reference: 511873, 103092 
Scope of Intended works	Preliminary review of the risk that may be posed by UXO to geotechnical investigations.
History	Wartime Use: The site footprint was largely undeveloped land within an industrial site during WWII. Post War Development: The site footprint and surrounding area has undergone significant post-war development.
Wartime History	Enemy Bombing: Records were found to indicate several HE bomb strikes within the vicinity of Durrington Station (located adjacent to the site to the north-east) during WWII. Most notably, at least one HE bomb struck a gasholder located adjacent to the site to the west. Heavy-Aircraft Guns: No guns were recorded to have been positioned on site. The nearest Heavy Anti-Aircraft Gun Sites were located approximately 5.6km to the south-west and 6km south-west of the site footprint. Military Use: There was a military presence in the surrounding area during WWII including a Ground Controlled Interception (GCI) radar approximately 800m north of the site which operated to locate and track enemy aircraft. However, no records were found to indicate military use within the site footprint or immediate surrounding area.
Unexploded Ordnance (UXO) Finds	No records were found to confirm a UXO find within the site footprint.

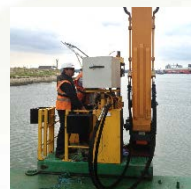
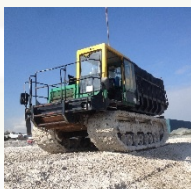
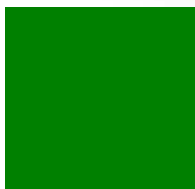
BARRINGTON ROAD, WORTHING

SOIL INVESTIGATION

CPT REPORT

**Cone penetration testing
Magnetometer testing
Parameter interpretation**

Project ref.: P-107644-7



PROJECT:	Barrington Road, Worthing
-----------------	---------------------------

CLIENT:	Soiltechnics
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FIELDWORK

CPT rig(s)	18.0-tonne track-truck mounted CPT unit (UK22)
Date fieldwork started	19 th January 2021
Date fieldwork completed	19 th January 2021
Lankelma's representative	Emma Stickland
Client's representative	Georgie Lodge

REPORT

Status	Revision	Action	Date	Name
Revised	00	Completed	25/01/21	Chris Player
		Checked	25/01/21	Joseph Hobbs
		Approved	25/01/21	Joseph Hobbs
Final	01	Completed	26/01/21	Chris Player
		Checked	26/01/21	Joseph Hobbs
		Approved	26/01/21	Joseph Hobbs

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1 INTRODUCTION

At the request of Soiltechnics, a soils investigation was carried out on project *Barrington Road, Worthing*.

Site location:

(In the general region of)

HMRC Building
Barrington Road
Worthing
BN12 4XH

2 DISCLAIMER

The investigation information, raw data and interpretations provided in this report are for the sole benefit of the Client identified at the front of the report.

Lankelma has exercised reasonable skill and care in the fieldwork and preparation of this report. This report has been completed based on information available to Lankelma at the time of preparation. The measurement and interpreted data in this report do not constitute recommendations for design purposes. An appropriately qualified person must review and interpret the data given in this report, together with any assumptions we have made that affect the data, before using the data for design or recommendation. Lankelma accepts no responsibility for the accuracy or suitability of any assumptions, derived soil parameters, soil classification descriptions or soil layer boundaries contained in this report.

3 COMPLETED WORKS

- 6 nr. combined magnetometer-cone penetration tests with pore pressure measurement (CPTu)
- Factual report including point data interpretation of selected parameters

Appendix A *Summary Tables* contains tabulated details of the works completed together with analysis results where applicable.

4 FIELDWORK GENERAL

Fieldwork was performed with an 18.0-tonne track-truck mounted CPT unit (UK22) equipped with a 17.5-tonne capacity hydraulic ram set.

The Client was responsible for the positioning and re-survey of all investigative locations.

The target depth for the investigation was until cone refusal was reached. Table 1 details the final test depths and reasons for test termination (*refusal factor*). Where penetration refusal was encountered the termination depth was advised to, and agreed with, the Client's on-site representative.

5 CONE PENETRATION TESTS

Cone penetration testing was carried out in general accordance with BS ISO 22476-1:2012.

Penetrometer measurements included cone tip resistance, friction sleeve resistance and dynamic pore water pressure sampled at a 10 mm resolution.

Penetrometers were calibrated in accordance with BS8422:2003 and ASTM E74-13a, and penetrometers with down-hole digitisation and incorporating load cell temperature sensors were calibrated in accordance with ISO 376:2011. The BS8422:2003 calibration provides a single calibration uncertainty value as a percentage of full-scale output (FSO), while ISO 376:2011 calibrations provide an uncertainty value for each calibration force or pressure and extends to the very low range (tip pressure ≥ 0.06 MPa) required to quantify uncertainty in low strength soils. The management of calibration records is in accordance with ISO 10012. Copies of all calibration certificates for the cones used are provided in Appendix B.

The piezometer filter element was in the u_2 position and was vacuum saturated. The pore pressure system was saturated with de-aired 1000 cSt glycerine oil.

5.1 GLOSSARY OF CPT TERMS AND SYMBOLS

SYMBOLS & ABBREVIATIONS

B_q	Pore pressure ratio. The net pore pressure normalized with respect to the net cone resistance: $B_q = (u_2 - u_0) / (q_t - \sigma_v)$
F_r	Normalised friction sleeve resistance: $F_r = f_s / (q_c - \sigma_v)$
f_s	Friction sleeve resistance. The total frictional force acting on the friction sleeve, F_s , divided by its surface area A_s : $f_s = F_s / A_s$.
G	Shear modulus
g	Gravitational constant: $g = 9.81 \text{ m/s}^2$
G_0	Small strain shear modulus
G_s	Specific gravity of solids
HOC	Heavily overconsolidated
I_c	Soil Behaviour Type Index
LOC	Lightly overconsolidated
NC	Normally consolidated
OC	Overconsolidated

q_c	Cone resistance. The total force acting on the cone Q_c , divided by the projected area of the cone, A_c : $q_c = Q_c / A_c$.
Q_t	Normalised cone resistance (Method 1): $Q_t = (q_c - \sigma_v) / \sigma'_v$
q_t	Corrected tip resistance. The cone tip resistance q_c corrected for pore water pressure effects on the cone shoulder.
q_{t-net}	Net cone resistance: $q_{t-net} = q_t - \sigma_v$. Where q_t is unavailable q_c is applied.
q_{t1}	Normalised cone resistance (Method 2): $q_{t1} = (q_t) / (\sigma'_v)^{0.5}$
R_f	Friction ratio The ratio, expressed as a percentage, of the sleeve friction, f_s , to the cone resistance, q_c , both measured at the same depth: $R_f = (f_s / q_c) \cdot 100$
SBT or SBTn	Soil behaviour type classification
u_0	Equilibrium pore pressure
u_2	Pore pressure. Dynamic pore pressure measured at the shoulder position (u_2) during penetration dissipation tests. $u_2 = \Delta u_2 + u_0$
Δu_2	Excess pore pressure. $\Delta u_2 = u_2 - u_0$
V_s, V_p	Shear wave velocity, V_s, and pressure wave velocity, V_p. Measured with use of a seismic receiver.
z	Depth below ground level. Depth below ground level as penetration length without correction for inclination, or true depth after correction for inclination.
<u>Greek</u>	
γ	Unit weight of soil
γ_w	Unit weight of water
ρ	Volumetric mass density (or specific mass) of soil: $\rho = \gamma / g$
σ_v	Total overburden stress
σ'_v	Effective overburden stress
σ_{atm} , or, P_a	Reference atmospheric stress: $\sigma_{atm} = 101.3 \text{ kPa}$

TERMS

Cone or 'tip': The conical tip of the cone penetrometer.

Friction sleeve: The section of the cone penetrometer upon which the sleeve friction is measured, located behind the cone tip.

Piezocone: A cone penetrometer with a pore pressure sensor (u_2 / u_1)

Seismic cone: A cone penetrometer with a seismic receiver incorporated inside or behind.

Dynamic pore pressure: The pore pressure measured during penetration (u_2 / u_1) .

Soil behaviour type, or 'SBT': Soil classification scheme or classified soil type according to Robertson (1990, 2016) often abbreviated to SBT or according to normalised cone parameters SBTn.

Rod string: The series of hollow tube push rods that transmit force to the penetrometer.

5.2 CPT DATA REDUCTION AND PRESENTATION

The CPT results are presented in Appendix C. The corrected cone resistance (q_t), local side friction (f_s), dynamic pore water pressure (u_2), friction ratio (R_f) and inclination are all presented against depth and elevation in accordance BS ISO 22476-1:2012. CPT data and the associated derived geotechnical parameters are included in the 4.0 data file provided.

The cone tip and sleeve force measurements were converted to pressure using the nominal dimensions of the penetrometer.

For piezocone tests the corrected tip resistance (or 'total tip resistance') was calculated according to the formula

$$q_t = q_c + u_2 \times (1 - a)$$

Where a is the 'area ratio' and $(1 - a)$ is the proportion of cross-sectional area between the cone tip and cone body where pore pressures (positive or negative) can act to add or subtract from the total external axial force on the tip. The difference between measured and corrected values is largest in low strength collapsible soils with large excess pore pressures. The percentage adjustment is described by the curves in the following chart for $a = 0.8$:

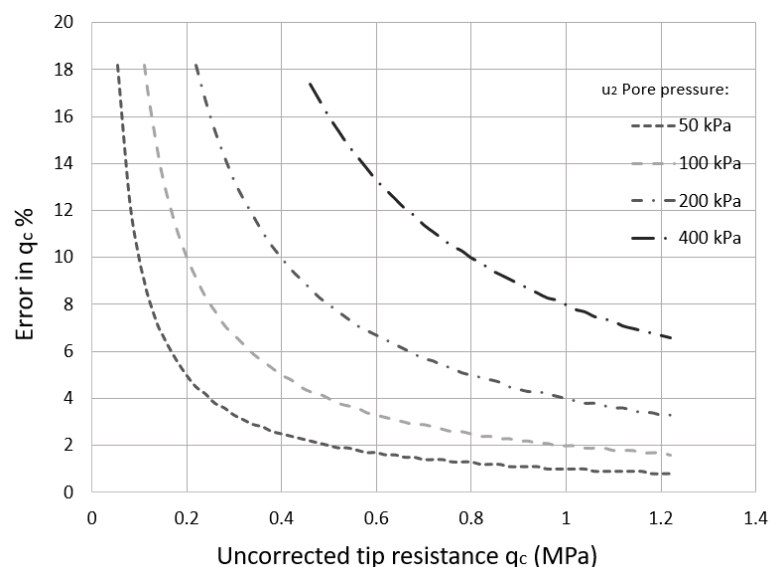


Figure 5-1 Uncorrected tip with measured tip resistance

Penetration length readings were corrected for inclination and sleeve readings were depth corrected for the dimensional offset between cone tip and sleeve during post processing. Rod spikes (artefacts of the pause for push rod addition) were filtered from the cone tip and sleeve data. The data was re-sampled from 10 mm resolution to 20 mm to reduce the size of the data set to a more manageable size for end users. A 20 mm resolution is well within the intrinsic influence zone of the cone tip measurement and the loss of meaningful resolution is negligible.

The raw data are presented in Appendix C. For piezocone tests q_t is reported on all logs, and q_c only appears in the digital AGS data.

Geotechnical parameters appropriate for drained and undrained cone penetration conditions were derived for corresponding drained and undrained derived soil behaviour types (SBTs) respectively, however, to account for uncertainty in the SBT correlation with drainage behaviour, all parameters were derived over a range of transitional soils within the range $2.4 < I_c < 2.7$ (see section 6.3).

In general, the engineering parameters derived for fine grain soils (undrained) are suitable for soils of both silicate and carbonate composition, whereas parameters derived for coarse soils are intended for non-cemented predominantly silicate composition.

5.3 IN-SITU STRESS CONDITIONS

An estimate of the equilibrium pore pressure and total and effective vertical stress states is required for derivation of many parameters obtained from the CPT and dissipation test.

The total vertical stress with depth was calculated as the sum of the calculated soil unit weight above a given depth. See section 5.4 for information on the empirical estimate of soil unit weight.

The depth of the phreatic surface applied in the calculation of effective stress was taken as equal to the groundwater level(s) provided by the Client.

Note: The term phreatic surface is used here, however when it is based on piezocone measurements it is assumed that the piezometric level (under hydrostatic conditions) and phreatic surface coincide. The phreatic or piezometric surface reported is intended to provide information about the assumed pore pressure distribution and may not represent the true position of the groundwater table or perched water bodies. Complex groundwater pressure distributions will be applied if they are observed from the measurements and are sufficiently well defined.

5.4 SOIL UNIT WEIGHT

The soil unit weight was estimated using the following method proposed by Robertson (2010).

$$\frac{\gamma}{\gamma_w} = 0.27 \log(R_f) + 0.36 (\log(q_t/R_f)) + 1.236$$

Throughout pre-drilled zones (inspection pits or drill-out) the soil unit weight was assumed as 17 kN/m³.

For depths where the friction sleeve measurement falls below zero, the friction sleeve was substituted with an artificial nominal 1.0 kPa resistance for the purpose of obtaining an approximate soil unit weight necessary for estimation of total vertical stress over the entire profile.

5.5 SOIL BEHAVIOUR TYPE

The soil behaviour type (SBT) was interpreted using the Robertson (1990) classification system based on the normalised cone resistance (Q_t) and normalised friction sleeve resistance (F_r) for silicate soils.

While the classification based on normalised parameters is considered more accurate, particularly for NC soils exceeding a depth of 15 m, the classification is often significantly in error (artificially granular/drained) at very shallow depth ($< 1-3$ m). The error at shallow depth is associated with the potentially large difference between the estimated vertical effective stress (applied in normalisation) and the unknown horizontal stress influencing penetration resistance.

Robertson (2010) proposed a non-normalised version of the 1990 chart which uses dimensionless cone resistance (q_c/Pa) and friction ratio, R_f . The classification according to this chart can be more reliable at shallow depth and has been plotted as an approximate SBT index (discussed below) for comparison to the normalised classification.

The SBT chart is provided in Appendix B – *General Information*, titled ‘CPT Soil Behaviour Type Chart’.

It should be noted that the SBT classification provides the general soil ‘type’ which typically provides a similar CPT measurement range of q_c and f_s . Correspondingly, it will also show biased towards the soil fraction that dominates the mechanical behaviour. While the repeatability and behavioural bias of the SBT is usually beneficial, the classification is not always an appropriate substitute for classification based on grain-size distribution and plasticity.

The layer boundaries are manually interpreted based on broad changes in SBT classification or variance with depth. Once layer boundaries are defined, the SBT zones classified within each layer are listed together with the corresponding percentage of data points within the layer. The modal classification is reported in full, with abbreviated short descriptions for all secondary zones, for example - ‘*Clays – clay to silty clay [74%]; *Silt mixtures [20%]*’, where the asterisk represents an abbreviation of the full description ‘*Silt mixtures – clayey silt to silty clay*’. It is important to consider that the classification zone boundaries do not exist in reality and small shifts in the cone response can lead multiple classifications within layers of relatively uniform behaviour; especially were the layer data plot close to a triple junction and/or has spurious spikes or very thin layers. Therefore, some system to limit the number of classified zones is usually necessary for clarity in the plot. The logic used by Lankelma for each layer is:

For $LT \geq 1$, $C = 85$

For $0.5 \leq LT < 1$, $C = 75$

For $0 < LT < 0.5$, $C = 65$

Where

C = Minimum % SBT zone classification coverage within the layer

LT = Layer thickness (m)

For layers having a thickness of less than 1 m then 10% of data at the top and bottom of the layer are excluded to limit the effect of transition zone data (mobilised resistance influenced by overlying or underlying strata) being included in the classification.

The continuous SBT index I_c should be used to assess the classification distribution and variation not accounted for by the layer description.

An alternative to this system is to classify each data point using coloured bars. However, the zones where the classification is known to be incorrect (e.g. very thin layers, transition zones) are left included and may be misinterpreted.

The results are presented in Appendix D.

5.6 SOIL BEHAVIOUR TYPE INDEX - I_c

The main trend in soil behaviour type (SBT) variation can be expressed by a continuous index, I_c , proposed by Robertson and Wride (1998) based on a similar index proposed by Jefferies and Davies (1993). The index provides a continuous profile of SBT variation with depth for end-user analysis of soil units and variation within units.

The equivalent non-normalised version, as proposed by Robertson (2010), is provided for comparison.

The basis of I_c and its approximation of the original chart classification zones may be seen from Appendix B figure 'CPT Soil Behaviour Type Chart'. The method does not identify zones 1 (*sensitive fine grained*) or zones 8 & 9 (*overconsolidated or cemented*).

Normalised SBT index I_c (Robertson and Wride, 1998):

$$I_c = [(3.47 - \log Q_t)^2 + (\log F_r + 1.22)^2]^{0.5}$$

Non-normalised SBT index I_c (Robertson, 2010):

$$I_c = \left[\left(3.47 - \log \left(\frac{q_c}{\sigma_{atm}} \right) \right)^2 + (\log R_f + 1.22)^2 \right]^{0.5}$$

The normalised version of I_c is generally more accurate, while the non-normalised version is intended for compatibility with the non-normalised Robertson's (2010) SBT chart and may be more accurate at shallow depths in overconsolidated soils.

The results are presented in Appendix D.

5.7 RELATIVE DENSITY

The relative density of sands was calculated based on an empirical relationship proposed by Jamiolkowski *et al.* (2001) based on a large database of undisturbed frozen samples and calibration chamber tests. The expected accuracy may be evaluated from the figures presented below.

$$D_r = 100 \left[0.268 \cdot \ln \left(\frac{q_t / \sigma_{atm}}{\sqrt{\sigma_{v0}' / \sigma_{atm}}} \right) - k \right]$$

k = Compressibility dependant constant can be taken as -0.675 for medium compressibility (applied value in our interpretation), ≤ 1 for high compressibility and ≥ 2 for compressible sands.

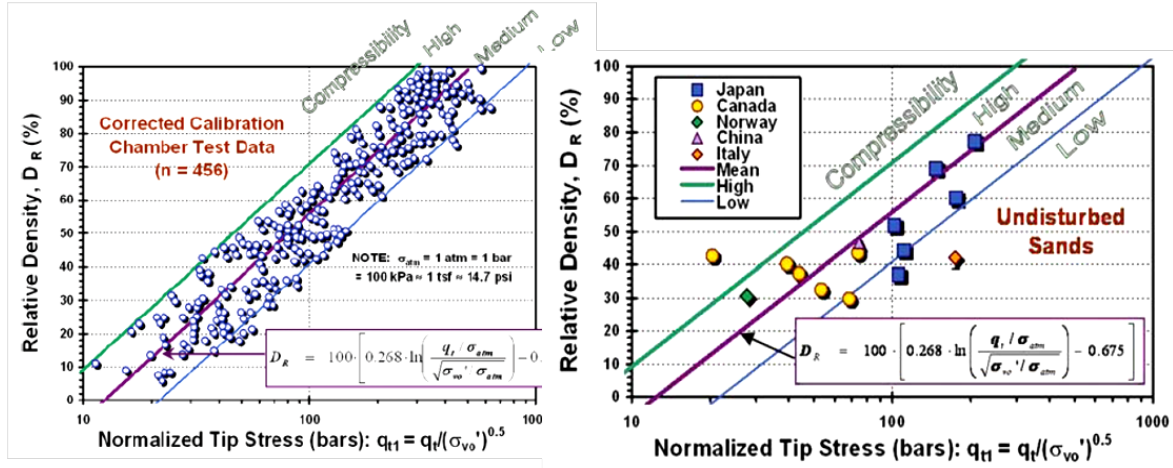


Figure 5-2 Relative density with normalised tip stress and sand compressibility from calibration chamber tests (left) and undisturbed frozen samples (right). Jamiolkowski *et al.* (2001). Reproduced from Mayne (2007).

The results are presented in Appendix E- *Standard interpretation results (set 2)*.

5.8 UNDRAINED SHEAR STRENGTH

The undrained shear strength s_u is usually estimated as a factor of net tip resistance (Lunne *et al.*, 1981):

$$s_u = \frac{q_c - \sigma_{v0}}{N_k}$$

Where N_k is an empirical cone factor which varies with soil type, stress history, structure/fabric, plasticity, and the mode of shear.

Mayne and Peuchen (2018) performed and evaluation of 407 high-quality triaxial compression tests with net tip resistance to proposed N_{kt} factors with regression analysis details for five categories of clays shown in Table 1.

Table 1 Summary of CAUC s_u versus q_{net} for clays. Reproduced from Mayne and Peuchen (2018).

Clay Group	Number of sites	Nr Data	Correlation Coefficient r^2	Factor N_{kt}	Mean Pore Pressure Parameter B_q
Offshore NC-LOC	17	115	0.98	12.32	0.51
Onshore NC-LOC	30	191	0.867	12	0.53
Sensitive NC-LOC	5	43	0.507	10.33	0.84
OC Intact	5	36	0.862	13.57	0.49
OC Fissured	5	22	0.393	22.47	-0.01
All clays	62	407	0.923	13.33	0.55

Alternatively, a variable N_{kt} factor can be estimated for the profile as a function of the pore pressure parameter B_q , applicable for B_q values of > -0.01 . The following equation proposed by Mayne and Peuchen is based on the same database evaluation:

$$N_{kt} = 10.5 - 4.6 \cdot \ln(B_q + 0.1)$$

Where the pore pressure parameter B_q is the ratio of excess pore pressure to net tip resistance:

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{v0}}$$

The N_{kt} estimate has a standard error of 2.4 N_k and correlation coefficient of 0.645.

The estimate based on B_q is presented as 's_u5' on the parameter plots and is only suitable for tests that have a high-quality pore pressure data, often indicated by a positive, repeatable, and dynamic response.

Note: N_{kt} (with subscript 't') indicates a N_k factor that has been established using the corrected tip resistance q_t . N_{kt} can be applied to the uncorrected tip resistance q_c (non-piezcone tests) but results in a slightly lower estimate of s_u depending on the correction magnitude ($q_c - q_t$) in lower strength soils.

Undrained shear strengths corresponding to selected values of N_k are presented on the plots of Appendix D. 's_u3' on the logs ($N_k = 15$) has been included as a reference for comparison to traditionally reported N_k values of 15 and 20.

5.9 OVERCONSOLIDATION RATIO

The preconsolidation stress σ'_p was calculated based on the method proposed by Mayne et al (2009):

$$\sigma'_p = k \cdot (q_t - \sigma_{v0})^{m'}$$

$$OCR = \sigma'_p / \sigma'_{v0}$$

Mayne et al found that the trend with mean grain size followed a power law through the addition of exponent m' and that its value can be estimated by relation to soil behaviour type index I_c :

$$m' = 1 - \frac{0.28}{1 + \frac{I_c}{2.65}}^{25}$$

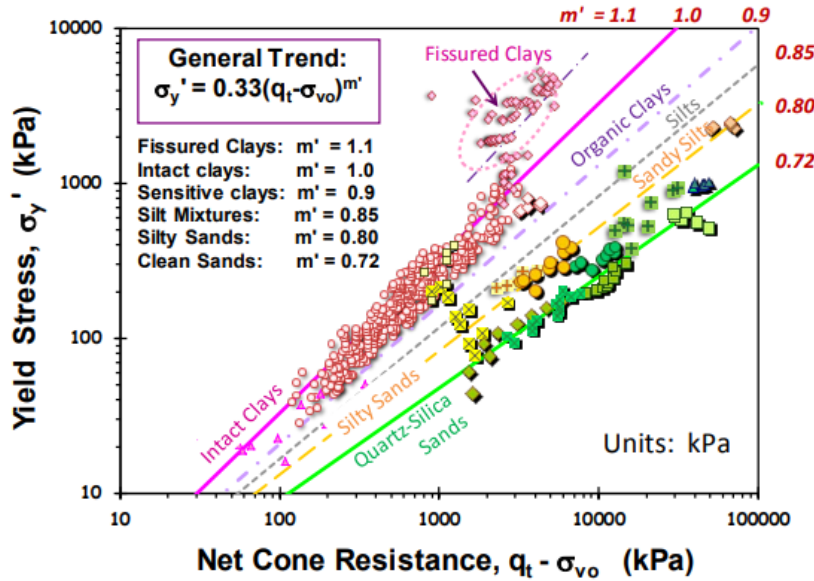


Figure 5-3 Preconsolidation stress with net cone resistance power law, reproduced from Mayne (2014).

An additional σ'_p and OCR was calculated for $m' = 1.1$ to reflect the upper trend for over consolidated fissured clays not captured by the correlation with I_c .

5.10 SPT N60 VALUES

Equivalent SPT N60 values, defined as the non-normalised SPT blow count over a 30 cm interval, were derived for two correlations.

Method 1 - Jefferies and Davies (1993) cited in Lunne *et al.* (1997)

$$N_{60} = \frac{q_t}{8.5 \cdot \sigma_{atm} \cdot \left(1 - \frac{I_c}{4.6}\right)}$$

Method 2 - Robertson (2012)

$$\frac{\left(\frac{q_t}{p_a}\right)}{N_{60}} = 10^{(1.268 - 0.2817 I_c)}$$

The correlations are intended for clays, silts and sands and not for carbonates or cemented geo-materials.

The results are presented in Appendix D.

5.11 FRICTION ANGLE

Sands

The peak friction angle of granular materials was calculated using the Kulhawy and Mayne (1990) method. The relationship is based on a calibration chamber database from 24 sands of varying mineralogy.

$$\phi' = 17.6 + 11.0 \cdot \log(q_{t1})$$

Where:

ϕ' = Peak friction angle (degrees)

q_{t1} = stress normalised cone resistance =

$$\left(\frac{q_t}{\sigma_{atm}} \right) / \left(\frac{\sigma_{v0'}}{\sigma_{atm}} \right)^{0.5}$$

The presence of compressible minerals tends to reduce tip resistance resulting in lower estimate of friction angle, while very coarse (sand) or larger grain size tends to increase tip resistance resulting in higher estimate. High k_0 conditions also result in an overestimate of friction angle.

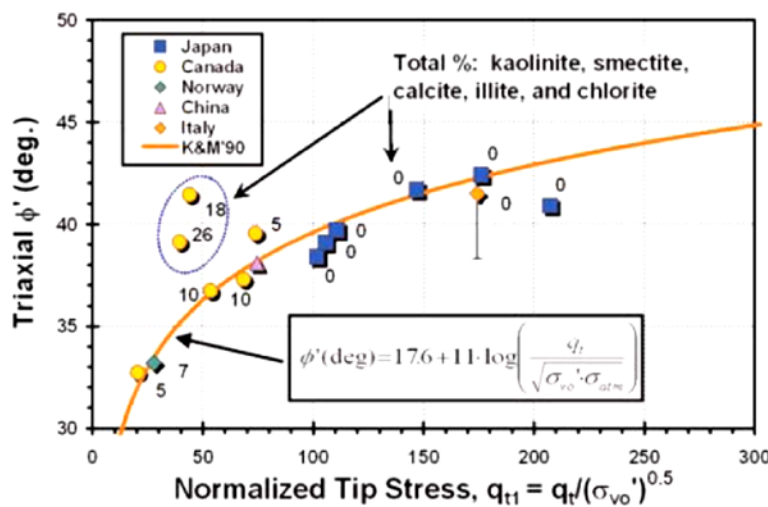


Figure 5-4 Peak triaxial friction angle from undisturbed sands with normalised cone resistance.

Fine grained soils

The effective friction angle for fine grained soils was calculated based on the Senneset *et al.* (1988, 1989) method by applying the approximate closed form solution by Mayne & Campanella (2005) as a direct function of the pore pressure parameter B_q and normalised tip resistance Q . The method is applicable where $0.1 < B_q < 1.0$ and $20^\circ < \phi' < 45^\circ$ and generally appropriate for non-cemented normally consolidated to lightly overconsolidated soils.

$$\phi' = 29.5^\circ B_q^{0.121} [0.256 + 0.336 B_q + \log Q]$$

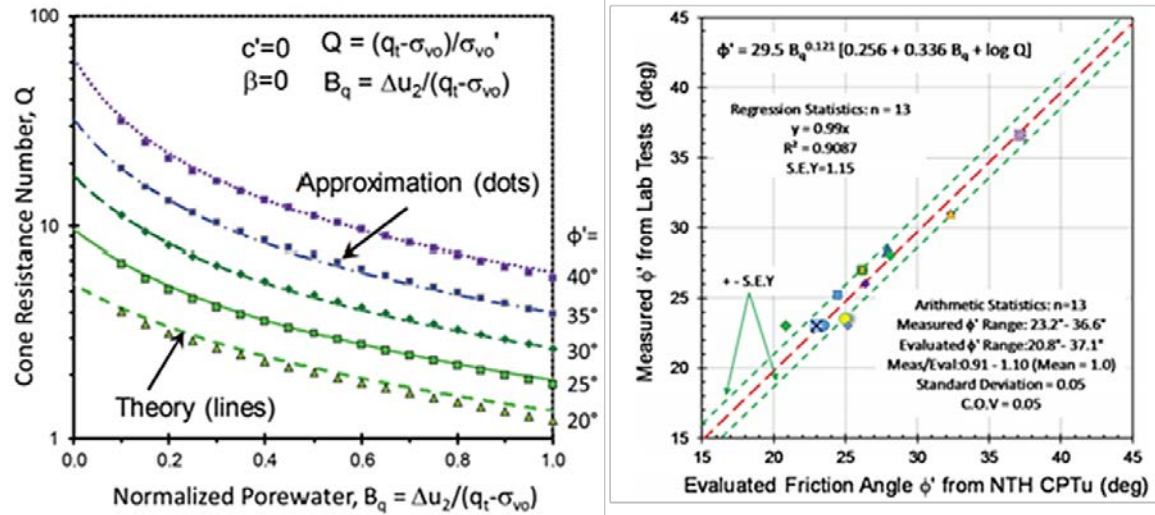


Figure 5-5 [Left] Theoretical curves with function approximation (dots) overlay [Right] calibration data from geotechnical centrifuge tests for a variety of soils. Redrawn from Ouyang & Mayne (2018).

The results are presented in Appendix E.

5.12 COEFFICIENT OF VOLUME CHANGE

Coefficient of volume change m_v defined as the inverse of the constrained modulus M , is evaluated for all soil types using the constrained modulus method proposed by Mayne (2006) cited in Mayne (2007) applicable to the present state of vertical effective stress up to the pre-consolidation stress.

$$m_v = \frac{1}{M}$$

Where:

$$M = \alpha \cdot (q_t - \sigma_v)$$

$$\alpha = 5$$

An alpha factor of 8.25 reported by Kulhawy & Mayne (1990) for fine grained soils appears to provide a better fit through the data for intact non-organic clays, reducing to around 1 to 2 for organic plastic clays.

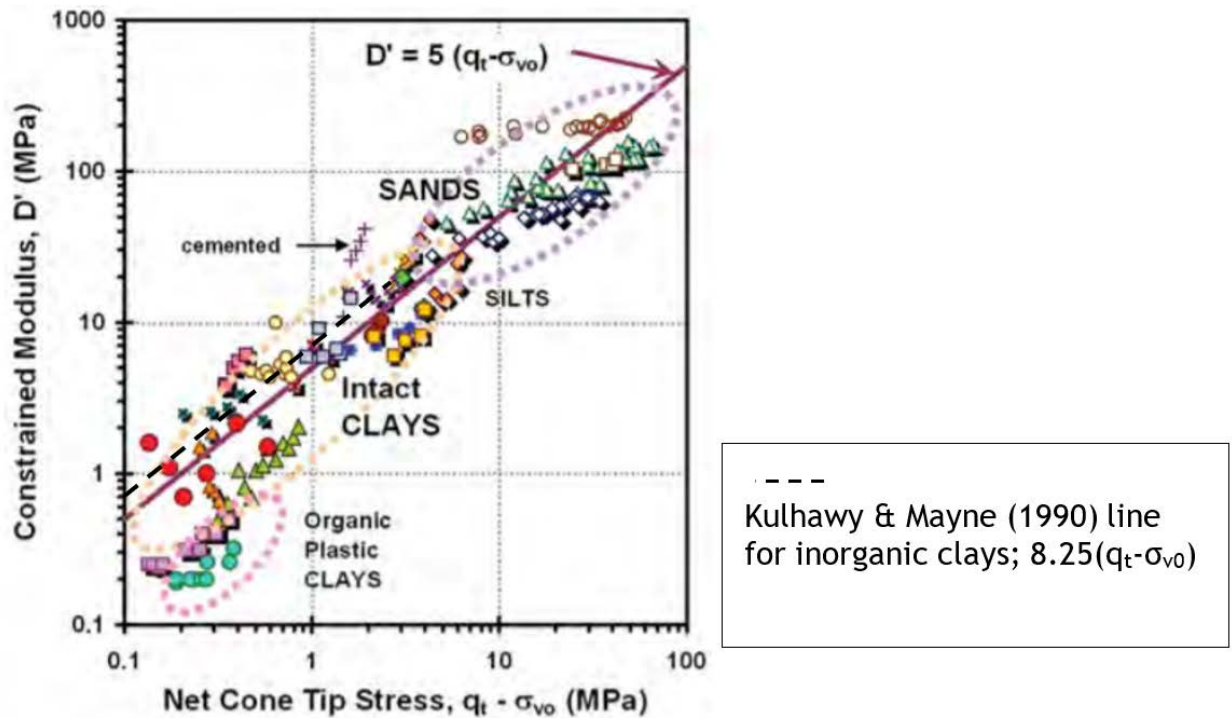


Figure 5-6 Constrained modulus of Mayne (2006). Annotated/redrawn from NCHRP Synthesis 368 (2007).

The results are presented in Appendix D.

5.13 YOUNG'S MODULUS

The Young's modulus E' at 25% mobilised shear strength (FOS = 4) was calculated according to the method proposed by Robertson (2009):

$$E' = \alpha(q_t - \sigma_v)$$

Where:

$$\alpha = 0.015(10^{0.55Ic+1.68})$$

The method described by Robertson may be adapted to estimate E' for loading at different percentages of yield stress.

The results are presented in Appendix E.

6 CPT INTERPRETATION NOTES

Provided below is a non-exhaustive set of notes on interpretation of the acquired CPT data with reference to examples within the dataset where appropriate.

DRAINED AND UNDRAINED SOIL BEHAVIOUR

Geotechnical parameters appropriate for drained and undrained cone penetration conditions are derived for drained and undrained soil behaviour types (SBTs) respectively, however, to help mitigate the uncertainty in the SBT correlation with drainage behaviour, all parameters are derived over the Soil Behaviour Type range $2.4 < I_c < 2.7$. For partially drained conditions, error will be introduced within derived parameters.

Piezcone dynamic pore pressure and dissipation tests may be used to identify drainage conditions. Dissipation t_{50} values exceeding 50 seconds indicate undrained penetration behaviour based on the findings of Kim *et al.* (2008).

In partially drained materials the friction sleeve resistance may rise significantly immediately following a pause in penetration due to consolidation and increased effective stress on the friction sleeve.

DYNAMIC PORE PRESSURE u_2 (CPTu)

While the piezo system is saturated before use, testing through unsaturated soils may result in some degree of desaturation leading to a less accurate and more 'sluggish' pore pressure response. Desaturation can also occur during penetration due to suction pressure during dilative shear at the cone shoulder. Dissipation tests that are undertaken following desaturation are likely to have a more pronounced initial rise and some degree of error will be present in the analysis.

If the system becomes desaturated it may re-saturate at higher excess pressures later in the test as gas dissolves under pressure. The pore pressure response in saturated contractive soils should normally have a dynamic 'peaky' appearance.

The tip resistance in lower strength contractive soils without pore pressure measurement in the u_2 position is likely to be significantly lower (up to 20%, typically ~10%) than the equivalent corrected tip resistance depending on the magnitude of excess pore pressure generated during penetration.

CONE TIP AND SLEEVE OFFSET

The accuracy of the SBT over thin layers and at layer boundaries is sensitive to offset error in the friction ratio often resulting in sharp peaks or troughs at boundaries. The friction ratio is often inaccurate in heavily disturbed soils with a 'blocky' macro fabric. The last ~8 cm of data is also not included in the SBT material description as no friction sleeve measurements are recorded.

FRICTION SLEEVE DATA

There are two common causes of friction sleeve measurement issues; 1) unequal pore pressure acting on the sleeve end areas as the sleeve passes through materials of different permeability and hence excess pore pressure Δu_2 , often resulting in a negative/positive spike, and 2) Accuracy limitations and temperature effects in very low strength or sensitive soils. The latter can often be mitigated by temperature stabilisation during the test and at the time of zero output measurement.

CONE TYPE

The reference cone type has a 10 cm² projected cone tip area and 150 cm² friction sleeve area, however it is common to use a larger 15 cm² cone with a 225 cm² friction sleeve area for improved sensitivity, temperature stability, damage prevention and penetration depth potential due to the higher bending strength. Use of a 15 cm² cone does however require higher penetration force (reaction force) for a given penetration pressure and produces more pronounced transition zones and thin layer effects (larger failure zone).

TRANSITION ZONES AND THIN LAYER EFFECTS

During penetration at the boundary between soils of contrasting stiffness, a transition zone is often evident prior to mobilisation of the true soil stiffness. These should be cautiously ignored in assessment of soil behaviour type and parameter evaluation. Where the stiff layer is thin (<~0.75 m) mobilised resistance may be significantly less than that of an equivalent thick layer. The effect for thin low stiffness layers is less significant. Procedures for thin-layer effect correction are provided by Robertson and Wride (1998).

GRAVELS

The presence of gravel or larger clasts in a soil is often characterised by short peaks in the CPT tip and sleeve readings, possibly with associated inclinometer 'shake' and/or short sharp reductions in pore water readings due to dilation effects. Frequent gravels in soft or loose soils may generate localised erroneous friction ratio values.

7 MAGNETOMETER TESTING

A combined CPT/magnetometer was used at prescribed locations to provide the data for on-site mitigation of UXO risk.

The magnetometer used in the Lankelma magcone system comprises a Bartington Instruments 3-axis flux gate magnetometer that is capable of measuring disturbances in the Earth's field of less than 1 part in a million. Buried ferrous items, such as UXO, result in localized distortions of the magnetic field. The detection radius of the works undertaken was dependent upon the level of magnetic field distortion noise and the size of the ferrous object(s) of interest. The magnetometer data was reviewed in real-time. As such no data had been processed or provided in this report.

The magnetometer probe was pushed into the soil using a standard CPT rig up to a maximum applied force of 15 Tonnes.

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APPENDICES

APPENDIX A SUMMARY TABLES

Table 2 CPT summary

Location ID	Stroke number	Final depth (m)	Cone ID	Piezocone test	Pre-drilled (m)	Pre-drilling details	Rig	Primary refusal factor	Applied zero values: qc, fs, u2	Tip zero drift (kPa)	Sleeve zero drift (subtraction) (kPa)	Piezo zero drift (kPa)	Nr dissipation tests	Raw File Name	Easting (m)	Northing (m)	Elevation (m)	Remarks
CPT01	1	12.90	S15-CFIPM(100).1431	YES	1.2	IP-BF	UK22	Lateral support	pre, pre, pre	-18.4	1.6	-1.3		107644--UK22-190121-LP71.L05				
CPT02	1	10.52	S15-CFIPM(100).1431	YES	1.2	IP-BF	UK22	Lateral support	pre, pre, pre	-82.4	-0.4	0.3		107644--UK22-190121-LP71.L01				
CPT03	1	9.32	S15-CFIPM(100).1431	YES	1.2	IP-BF	UK22	Lateral support	pre, pre, pre	1	-0.9	-5		107644--UK22-190121-LP71.L02				
CPT04	1	13.60	S15-CFIPM(100).1431	YES	1.2	IP-BF	UK22	Lateral support	pre, pre, pre	-42.6	-0.3	3.8		107644--UK22-190121-LP71.L04				
CPT05	1	5.02	S15-CFIPM(100).1431	YES	1.2	IP-BF	UK22	Lateral support	pre, pre, pre	19.2	2.2	-4.3		107644--UK22-190121-LP71.L03				
CPT06	1	9.16	S15-CFIPM(250).841	YES	1.2	IP-BF	UK22	Lateral support	pre, pre, pre	-42	-1.7	-9.6		107644--UK22-190121-LP71.L06				

CPT test plots are presented in Appendix C.

APPENDIX B GENERAL INFORMATION

LIST OF FIGURES

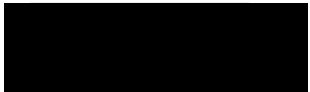
Cone calibration certificate: S15-CFIIP.1431

Data sheet: 18.0-tonne track-truck mounted CPT unit (UK22)

CPT soil behaviour type chart

Instrument:	Digital-Geopoint-S15-150kN-5MPa	Location:	Lankelma Calibration Laboratory
Serial number:	DS15-CFIIPM.1431	Temperature (°C):	22.2
Manufacturer:	Geopoint	Temperature change (°C):	0.22
Calibration standard:	Conforms to ISO 376:2011 & ISO 22476-1:2012	Calibration engineer:	A Harman
ISO 22476-1:2012 application class:	Class 1	Calibration re-verification date:	03/12/2020
Date of calibration:	03/08/2020	Calibration verification completed:	pass
Calibration expiry:	02/02/2021		

This calibration certificate is valid for 6 months, with a verification of the calibration being performed between 2 and 4 months from the date of calibration.

Calibration signed and dated by: 	Calibration checked and dated by: 	Calibration verification signed and dated by: 
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REFERENCE INSTRUMENTS	SERIAL NUMBER	UNCERTAINTY OF RECORDED VALUE	CALIBRATION DATE
AM DSCC-100kN Load Cell	51998	0.02%	12/07/2019
AM DSCCHA-5kN Load Cell	61065	0.05%	12/07/2019
Omega MMG750V	502273	0.01%	25/07/2019
Keithley 3706A Multimeter	4067652	24ppm	16/07/2019
STM Inclinator	05-1810	0.05°	15/07/2019
Digitron 2024T Thermometer	5709263686	0.5°C	29/07/2019

The calibration tests were made in the Lankelma force standards machine. The applied forces of which are within an uncertainty of:
± 0.050 % of nominal value from 0.5kN up to 10kN, then 0.02% of nominal from 10kN up to 100kN.

MEASUREMENTS

- The forces applied, and the resulting deflections are given in Tables 1. No corrections for temperature have been applied to these results.
 - The cone was loaded to full range 3 times for no less than 1 minute before calibration and after each rotation.
 - The cone was calibrated in low and high range using two reference load cells. The low range calibration consisted of a maximum load of 5kN with 4 sets of increasing forces and 2 sets of decreasing forces. The high range calibration consisted of a maximum load of 100kN with 3 sets of increasing forces and 2 sets of decreasing forces.
 - The difference in deflection for each applied force with rotation is the relative reproducibility error b , shown as a percentage of the recorded value and in units of pressure MPa. The uncertainty relating to the difference in deflection for increasing forces against decreasing forces is the reversibility uncertainty U_{rev} , shown as a percentage of the recorded value and in units of pressure MPa.
 - For each application of force, the coefficients of a linear and third order equation relating the estimate of the mean deflection as a function of the applied calibration force were calculated. Table 2.
 - The combined expanded uncertainty of deflection U for each force is shown as a percentage of the recorded value and in units of pressure MPa.
 - The coefficients of a third order equation relating a given applied force to the estimate of the mean deflection were also calculated. The coefficients are given in Table 3.
 - In use the forces acting on the sleeve load cell element are a combination of tip resistance and sleeve friction, with the tip resistance from the tip load cell element being subtracted to give the sleeve friction value. The resultant error values for differing tip and sleeve values are shown in Table 4.
- * The combined expanded uncertainties shown are to $k=2$ with a 95% coverage factor.

The calibration uncertainty is the uncertainty in the force value calculated from the interpolation equation at any deflection.

At each calibration point a combined standard uncertainty uc is calculated from the readings obtained during the calibration.

$$uc = \sqrt{\sum_{i=1}^8 u_i^2}$$

and

$$U = k \times uc$$

where

- u_1 is the standard uncertainty associated with the applied calibration force.
- u_2 is the standard uncertainty associated with the reproducibility of the calibration results.
- u_3 is the standard uncertainty associated with the repeatability of the calibration results.
- u_4 is the standard uncertainty associated with the resolution and noise of the system.
- u_5 is the standard uncertainty associated with the creep of the instrument.
- u_6 is the standard uncertainty associated with the drift in zero output.
- u_7 is the standard uncertainty associated with temperature of the instrument.
- u_8 is the standard uncertainty associated with interpolation best fit of the linear or 3rd order polynomial equation.

Symbols and their designations

Symbol	Designation
Ref LC	Reference load cell with calibration force in kN
cts	Counts. Base digital cone units.
0.1N	Interpolated digital cone units from counts
b	Relative reproducibility error
U_{rev}	Reversibility uncertainty
Uc	Combined standard uncertainty
Uc_{sub}	Combined standard uncertainty including sleeve subtraction
U	Combined expanded uncertainty
$k=2$	95% uncertainty coverage factor

CONE END RESISTANCE CALIBRATION

Table 1-a.

Low range calibration									High range calibration								
Ref LC (kN)	Tip change in output (cts)				Reproducibility error <i>b</i>		Reversibility error <i>U_{rev}</i>		Ref LC (kN)	Tip change in output (cts)			Reproducibility error <i>b</i>		Reversibility error <i>U_{rev}</i>		
	1 0°	2 120°	3 240°	4 240°						1 0°	2 120°	3 240°					
0.100	1.163E+05	1.165E+05	1.161E+05	1.161E+05	0.000	0.33			5.000	5.776E+06	5.775E+06	5.780E+06	0.003	0.09			
0.500	5.774E+05	5.787E+05	5.799E+05	5.780E+05	0.001	0.44			10.000	1.154E+07	1.154E+07	1.154E+07	0.000	0.01			
1.000	1.156E+06	1.159E+06	1.157E+06	1.157E+06	0.001	0.22			15.000	1.730E+07	1.730E+07	1.730E+07	0.002	0.02			
1.500	1.734E+06	1.735E+06	1.734E+06	1.734E+06	0.001	0.05			20.000	2.308E+07	2.307E+07	2.307E+07	0.001	0.01			
2.000	2.313E+06	2.312E+06	2.314E+06	2.313E+06	0.001	0.10			30.000	3.462E+07	3.462E+07	3.462E+07	0.004	0.02			
2.500	2.891E+06	2.890E+06	2.893E+06	2.893E+06	0.001	0.08			40.000	4.616E+07	4.617E+07	4.616E+07	0.006	0.02			
3.000	3.470E+06	3.470E+06	3.471E+06	3.471E+06	0.001	0.04			50.000	5.770E+07	5.770E+07	5.769E+07	0.008	0.02			
3.500	4.049E+06	4.049E+06	4.051E+06	4.050E+06	0.001	0.05			60.000	6.922E+07	6.913E+07	6.921E+07	0.052	0.13			
4.000	4.627E+06	4.628E+06	4.630E+06	4.629E+06	0.002	0.08			80.000	9.223E+07	9.221E+07	9.220E+07	0.017	0.03			
5.000	5.784E+06	5.787E+06	5.788E+06	5.787E+06	0.002	0.06			100.000	1.152E+08	1.152E+08	1.151E+08	0.020	0.03			
4.000	4.624E+06	4.625E+06			0.000	0.02	0.001	0.03	80.000	9.227E+07	9.227E+07		0.001	0.00	-0.016	-0.03	
3.500	4.046E+06	4.045E+06			0.000	0.01	0.001	0.05	60.000	6.929E+07	6.929E+07		0.001	0.00	-0.036	-0.09	
3.000	3.467E+06	3.467E+06			0.000	0.02	0.001	0.05	50.000	5.777E+07	5.777E+07		0.001	0.00	-0.024	-0.07	
2.500	2.887E+06	2.888E+06			0.000	0.03	0.001	0.06	40.000	4.624E+07	4.624E+07		0.001	0.00	-0.024	-0.09	
2.000	2.308E+06	2.309E+06			0.001	0.04	0.001	0.09	30.000	3.469E+07	3.469E+07		0.003	0.01	-0.022	-0.11	
1.500	1.730E+06	1.731E+06			0.001	0.08	0.001	0.12	20.000	2.313E+07	2.313E+07		0.002	0.02	-0.017	-0.13	
1.000	1.154E+06	1.155E+06			0.001	0.10	0.001	0.17	15.000	1.734E+07	1.734E+07		0.001	0.01	-0.013	-0.13	
0.500	5.763E+05	5.767E+05			0.000	0.07	0.001	0.16	10.000	1.156E+07	1.156E+07		0.002	0.03	-0.007	-0.10	
0.100	1.151E+05	1.156E+05			0.000	0.43	0.000	0.56	5.000	5.777E+06	5.775E+06		0.001	0.03	0.000	-0.01	

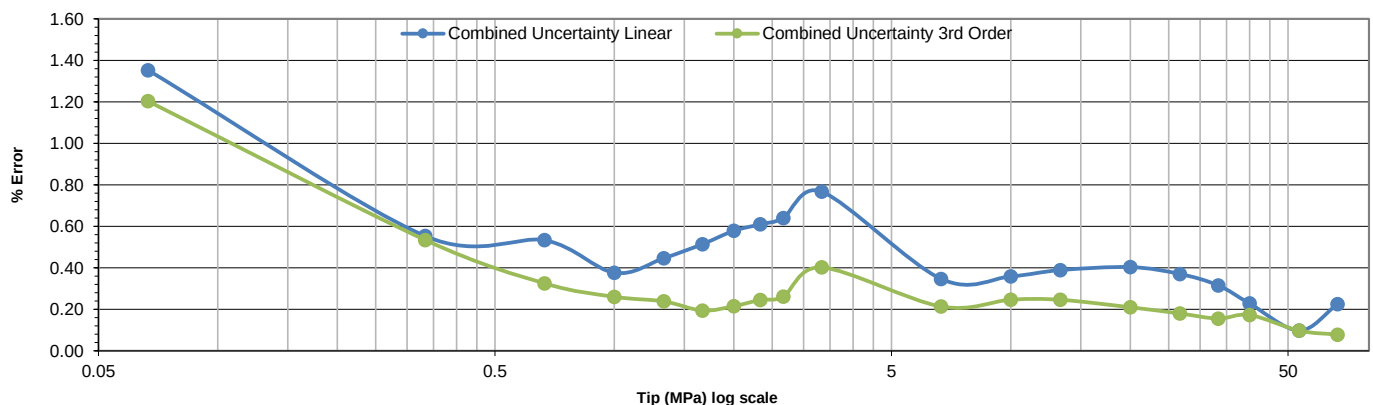
Table 2-a.

Low range calibration								High range calibration							
Reference output		Linear equation			3rd order equation			Reference output		Linear equation			3rd order equation		
Ref Load Cell Nom. (MPa)	Ref Load Cell (0.1N)	Cone output (0.1N)	Expanded uncertainty <i>U</i> *		Equation output (0.1N)	Expanded uncertainty <i>U</i> *		Ref Load Cell Nom. (MPa)	Ref Load Cell (0.1N)	Cone output (0.1N)	Expanded uncertainty <i>U</i> *		Equation output (0.1N)	Expanded uncertainty <i>U</i> *	
0.067	1000	1009	0.001	1.90	1007	0.001	1.51	3.333	50000	50105	0.014	0.43	50005	0.006	0.17
0.333	5000	5019	0.003	0.85	5009	0.002	0.59	6.667	100000	100071	0.013	0.19	99874	0.019	0.28
0.667	10000	10037	0.005	0.81	10017	0.003	0.41	10.000	150000	150079	0.015	0.15	149788	0.030	0.30
1.000	15000	15042	0.006	0.56	15012	0.002	0.24	13.333	200000	200140	0.022	0.17	199762	0.034	0.26
1.333	20000	20061	0.008	0.60	20021	0.004	0.28	20.000	300000	300303	0.043	0.22	299782	0.033	0.17
1.667	25000	25079	0.011	0.65	25029	0.005	0.27	26.667	400000	400399	0.057	0.21	399791	0.035	0.13
2.000	30000	30103	0.014	0.68	30042	0.006	0.31	33.333	500000	500436	0.064	0.19	499816	0.036	0.11
2.333	35000	35127	0.017	0.72	35057	0.008	0.35	40.000	600000	600121	0.049	0.12	599581	0.072	0.18
2.667	40000	40143	0.019	0.72	40063	0.009	0.34	53.333	800000	799850	0.047	0.09	799827	0.048	0.09
3.333	50000	50189	0.026	0.77	50089	0.013	0.40	66.667	1000000	998941	0.150	0.23	1000029	0.052	0.08
2.667	40000	40112	0.015	0.56	40031	0.005	0.18	53.333	800000	800321	0.058	0.11	800301	0.056	0.11
2.333	35000	35088	0.012	0.50	35017	0.003	0.14	40.000	600000	600979	0.134	0.33	600441	0.066	0.16
2.000	30000	30072	0.010	0.48	30012	0.002	0.12	33.333	500000	501095	0.147	0.44	500475	0.068	0.20
1.667	25000	25046	0.006	0.38	24996	0.002	0.12	26.667	400000	401040	0.140	0.53	400432	0.061	0.23
1.333	20000	20026	0.004	0.29	19985	0.003	0.20	20.000	300000	300882	0.118	0.59	300361	0.051	0.25
1.000	15000	15011	0.002	0.19	14981	0.003	0.28	13.333	200000	200599	0.081	0.61	200220	0.032	0.24
0.667	10000	10011	0.002	0.26	9991	0.002	0.24	10.000	150000	150416	0.057	0.57	150125	0.019	0.19
0.333	5000	5000	0.001	0.26	4990	0.002	0.48	6.667	100000	100245	0.033	0.50	100047	0.010	0.14
0.067	1000	1000	0.001	0.81	998	0.001	0.89	3.333	50000	50102	0.015	0.45	49999	0.005	0.16

Table 3-a. Third order equation

For a given cone indicated output of D (0.1N units), the corrected applied force	a0 = 0.00000	Maximum tip zero drift during the calibration (MPa) =	0.001
F (in 0.1N units) is calculated from :	a1 = 0.99800	Maximum load cell zero drift during the calibration (MPa) =	0.000
F = (a3 x D³) + (a2 x D²) + (a1 x D) + a0	a2 = -4.23201E-11	Factor used to convert from counts to 0.1N units =	0.0086737
	a3 = 3.14261E-15	Maximum tip full scale reading (MPa) =	100.00
		Tip resolution (Pa) =	66.7
		Tip area (cm²) =	15
		Tip area ratio =	0.807

COMBINED EXPANDED UNCERTAINTY TIP



SLEEVE FRICTION CALIBRATION

Table1-b.

Low range calibration									High range calibration								
Ref LC (kN)	Sleeve change in output (cts)				Reproducibility error b		Reversibility error U_{rev}		Ref LC (kN)	Tip change in output (cts)				Reproducibility error b		Reversibility error U_{rev}	
	1 0°	2 120°	3 240°	4 240°	kPa	%	kPa	%		1 0°	2 120°	3 240°		kPa	%	kPa	%
0.100	1.186E+05	1.183E+05	1.196E+05	1.196E+05	0.049	1.10			5.000	5.930E+06	5.926E+06	5.934E+06		0.282	0.13		
0.500	5.928E+05	5.937E+05	5.963E+05	5.943E+05	0.129	0.58			10.000	1.185E+07	1.184E+07	1.185E+07		0.109	0.02		
1.000	1.187E+06	1.189E+06	1.187E+06	1.188E+06	0.078	0.18			15.000	1.777E+07	1.776E+07	1.776E+07		0.239	0.04		
1.500	1.780E+06	1.781E+06	1.780E+06	1.781E+06	0.029	0.04			20.000	2.369E+07	2.369E+07	2.369E+07		0.242	0.03		
2.000	2.374E+06	2.372E+06	2.375E+06	2.376E+06	0.117	0.13			30.000	3.555E+07	3.554E+07	3.554E+07		0.355	0.03		
2.500	2.968E+06	2.967E+06	2.970E+06	2.970E+06	0.101	0.09			40.000	4.740E+07	4.739E+07	4.738E+07		0.459	0.03		
3.000	3.563E+06	3.562E+06	3.564E+06	3.564E+06	0.082	0.06			50.000	5.924E+07	5.923E+07	5.922E+07		0.650	0.03		
3.500	4.157E+06	4.156E+06	4.159E+06	4.158E+06	0.106	0.07			60.000	7.107E+07	7.097E+07	7.104E+07		3.876	0.15		
4.000	4.750E+06	4.750E+06	4.754E+06	4.753E+06	0.118	0.07			80.000	9.469E+07	9.466E+07	9.465E+07		1.712	0.05		
5.000	5.940E+06	5.941E+06	5.942E+06	5.943E+06	0.095	0.04			100.000	1.182E+08	1.182E+08	1.182E+08		2.049	0.05		
4.000	4.748E+06	4.748E+06			0.022	0.01	0.049	0.03	80.000	9.472E+07	9.470E+07			0.634	0.02	-0.835	-0.02
3.500	4.154E+06	4.153E+06			0.059	0.04	0.072	0.05	60.000	7.113E+07	7.112E+07			0.364	0.01	-2.174	-0.08
3.000	3.560E+06	3.560E+06			0.005	0.00	0.054	0.04	50.000	5.930E+07	5.930E+07			0.009	0.00	-1.413	-0.06
2.500	2.965E+06	2.964E+06			0.015	0.01	0.063	0.06	40.000	4.746E+07	4.746E+07			0.081	0.00	-1.369	-0.08
2.000	2.370E+06	2.371E+06			0.031	0.04	0.062	0.07	30.000	3.561E+07	3.560E+07			0.245	0.02	-1.267	-0.10
1.500	1.776E+06	1.777E+06			0.041	0.06	0.076	0.12	20.000	2.374E+07	2.374E+07			0.128	0.01	-1.009	-0.11
1.000	1.185E+06	1.185E+06			0.003	0.01	0.069	0.16	15.000	1.780E+07	1.780E+07			0.015	0.00	-0.717	-0.11
0.500	5.912E+05	5.911E+05			0.004	0.02	0.045	0.20	10.000	1.186E+07	1.186E+07			0.011	0.00	-0.309	-0.07
0.100	1.174E+05	1.180E+05			0.023	0.52	0.017	0.39	5.000	5.924E+06	5.928E+06			0.136	0.06	0.043	0.02

Table 2-b.

Low range calibration								High range calibration							
Reference output		Linear factor output			3rd order equation			Reference output		Linear factor output			3rd order equation		
Ref Load Cell Nom. (kPa)	Ref Load Cell (0.1N)	Cone output (0.1N)	Expanded uncertainty U^* kPa	%	Equation output (0.1N)	Expanded uncertainty U^* kPa	%	Ref Load Cell Nom. (kPa)	Ref Load Cell (0.1N)	Cone output (0.1N)	Expanded uncertainty U^* kPa	%	Equation output (0.1N)	Expanded uncertainty U^* kPa	%
4	1000	1004	0.051	1.15	1005	0.055	1.25	220	50000	50105	1.005	0.46	50004	0.387	0.18
22	5000	5021	0.219	0.99	5013	0.164	0.75	441	100000	100093	0.995	0.23	99891	1.119	0.13
44	10000	10035	0.325	0.74	10017	0.180	0.41	661	150000	150108	1.197	0.18	149811	1.820	0.14
66	15000	15042	0.387	0.59	15013	0.164	0.25	881	200000	200172	1.729	0.20	199787	2.053	0.12
88	20000	20059	0.539	0.61	20020	0.229	0.26	1322	300000	300341	3.196	0.24	299811	1.984	0.08
110	25000	25080	0.724	0.66	25031	0.314	0.29	1762	400000	400443	4.143	0.24	399826	2.069	0.06
132	30000	30105	0.943	0.71	30045	0.434	0.33	2203	500000	500474	4.521	0.21	499846	2.201	0.05
154	35000	35130	1.163	0.75	35059	0.566	0.37	2643	600000	600157	3.372	0.13	599612	4.595	0.09
176	40000	40148	1.317	0.75	40067	0.625	0.35	3524	800000	799874	3.084	0.09	799851	3.160	0.04
220	50000	50198	1.782	0.81	50096	0.929	0.42	4405	1000000	998942	9.954	0.23	1000034	3.499	0.04
176	40000	40119	1.063	0.60	40039	0.372	0.21	3524	800000	800281	3.614	0.10	800260	3.492	0.05
154	35000	35094	0.844	0.55	35024	0.255	0.17	2643	600000	600941	8.523	0.32	600398	4.015	0.08
132	30000	30078	0.699	0.53	30019	0.195	0.15	2203	500000	501075	9.615	0.44	500448	4.269	0.10
110	25000	25049	0.451	0.41	25000	0.116	0.11	1762	400000	401014	9.040	0.51	400396	3.756	0.11
88	20000	20029	0.277	0.31	19990	0.148	0.17	1322	300000	300860	7.653	0.58	300329	3.092	0.12
66	15000	15013	0.136	0.21	14984	0.160	0.24	881	200000	200574	5.113	0.58	200188	1.816	0.10
44	10000	10010	0.107	0.24	9992	0.089	0.20	661	150000	150392	3.506	0.53	150094	1.025	0.08
22	5000	4995	0.072	0.33	4987	0.125	0.57	441	100000	100214	1.942	0.44	100012	0.477	0.05
4	1000	994	0.059	1.33	995	0.054	1.23	220	50000	50073	0.737	0.33	49972	0.437	0.10

Table 3-b. Third order equation

For a given cone indicated output of D (0.1N units), the corrected applied force F (in 0.1N units) is calculated from : $F = (a_3 \times D^3) + (a_2 \times D^2) + (a_1 \times D) + a_0$	$a_0 =$	2.67691	Maximum sleeve zero drift during the calibration (kPa) =	0.104
	$a_1 =$	0.99791	Maximum load cell zero drift during the calibration (kPa) =	0.008
	$a_2 =$	1.12378E-10	Factor used to convert from counts to 0.1N units =	0.0084496
	$a_3 =$	3.07069E-15	Physical strength limited maximum sleeve reading (MPa) =	1.333
			Sleeve resolution (Pa) =	4.4
			Sleeve area (cm²) =	227
			Sleeve area ratio =	1.000

COMBINED EXPANDED UNCERTAINTY SLEEVE

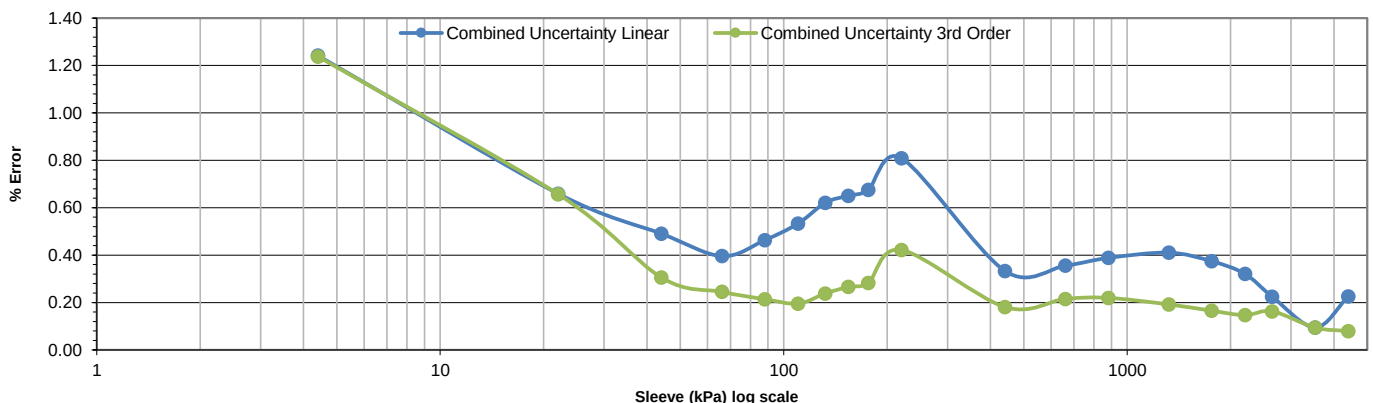


Table 4-b Sleeve friction - tip subtraction combined standard uncertainty U_{c_sub}

		Sleeve linear equation subtraction error (%)										Sleeve 3rd order equation subtraction error (%)							
		Sleeve kPa →										Sleeve kPa →							
		4	22	44	66	110	154	220	661			4	22	44	66	110	154	220	661
Tip MPa ↓	0.07	1.9	0.6	0.4	0.3	0.3	0.4	0.4	0.2	Tip MPa ↓	0.07	1.8	0.6	0.3	0.2	0.1	0.2	0.2	0.1
	0.33	3.7	0.9	0.5	0.4	0.4	0.4	0.4	0.2		0.33	3.6	0.9	0.5	0.3	0.2	0.2	0.3	0.1
	0.67	5.7	1.4	0.8	0.5	0.5	0.5	0.5	0.2		0.67	3.8	1.0	0.5	0.3	0.2	0.2	0.3	0.1
	1.00	6.4	1.5	0.8	0.6	0.5	0.5	0.5	0.2		1.00	4.4	1.1	0.5	0.4	0.2	0.2	0.3	0.1
	1.67	13.7	2.9	1.6	1.1	0.8	0.7	0.7	0.3		1.67	5.5	1.3	0.6	0.4	0.3	0.3	0.3	0.1
	2.33	22.7	4.7	2.5	1.7	1.1	1.0	0.8	0.3		2.33	9.6	2.1	1.0	0.7	0.5	0.4	0.4	0.2
	3.33	40.0	8.2	4.2	2.8	1.8	1.5	1.2	0.4		3.33	21.2	4.4	2.2	1.5	0.9	0.7	0.6	0.2
	10.00	54.2	11.1	5.6	3.8	2.4	1.9	1.5	0.5		10.00	35.3	7.3	3.6	2.4	1.5	1.1	0.9	0.3
	13.33	78.4	15.9	8.0	8.3	3.4	2.5	2.8	0.8		13.33	47.2	9.6	4.8	4.1	2.0	1.5	1.1	0.4

PORE PRESSURE CALIBRATION

Table1-c.

Ref PR (kPa)	PWP change in output (cts)			Reproducibility error b		Reversibility error U_{rev}	
	1 0°	2 120°	3 240°				
100	2.119E+07	2.124E+07	2.130E+07	0.5	0.49		
200	4.240E+07	4.250E+07	4.256E+07	0.7	0.37		
400	8.482E+07	8.490E+07	8.506E+07	1.2	0.29		
600	1.272E+08	1.273E+08	1.274E+08	0.9	0.15		
800	1.695E+08	1.696E+08	1.697E+08	1.3	0.16		
1000	2.117E+08	2.119E+08	2.120E+08	1.2	0.12		
1500	3.172E+08	3.173E+08	3.175E+08	1.4	0.10		
2000	4.225E+08	4.227E+08	4.228E+08	1.6	0.08		
2500	5.276E+08	5.279E+08	5.280E+08	1.9	0.08		
3000	6.326E+08	6.329E+08	6.330E+08	1.7	0.06		
2500	5.283E+08	5.286E+08		1.1	0.04	-2.0	-0.08
2000	4.237E+08	4.238E+08		0.7	0.03	-3.2	-0.16
1500	3.181E+08	3.185E+08		2.1	0.14	-2.9	-0.19
1000	2.125E+08	2.127E+08		0.7	0.07	-2.3	-0.23
800	1.701E+08	1.703E+08		1.2	0.15	-1.8	-0.22
600	1.277E+08	1.278E+08		0.6	0.09	-1.4	-0.23
400	8.527E+07	8.535E+07		0.4	0.09	-1.2	-0.31
200	4.263E+07	4.274E+07		0.5	0.26	-0.6	-0.32
100	2.139E+07	2.135E+07		0.2	0.19	-0.4	-0.42

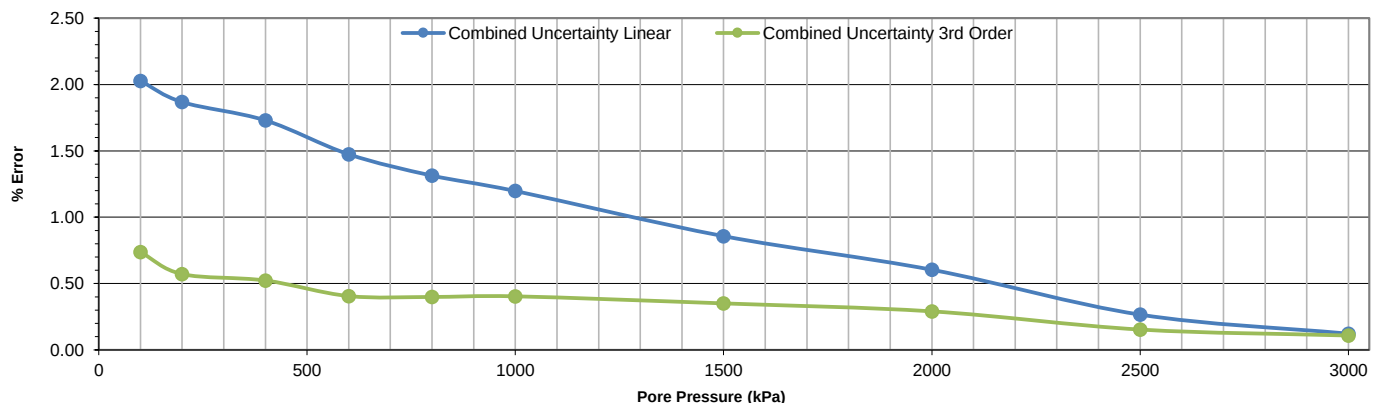
Table 2-c.

Reference output		Linear factor output			3rd order equation		
Ref Pressure (kPa)	Ref Pressure (0.1Pa)	Cone output (0.1Pa)	Expanded uncertainty U^* kPa	%	Equation output (0.1N)	Expanded uncertainty U^* kPa	%
100	1000000	1006840	1.446	1.45	996982	0.759	0.76
200	2000000	2013654	2.814	1.41	1995941	1.050	0.52
400	4000000	4025082	5.155	1.29	3993636	1.693	0.42
600	6000000	6032858	6.687	1.11	5990273	2.262	0.38
800	8000000	8037822	7.715	0.96	7986634	3.071	0.38
1000	10000000	10040881	8.370	0.84	9983575	3.748	0.37
1500	15000000	15039783	8.267	0.55	14977743	5.014	0.33
2000	20000000	20033047	7.100	0.36	19980800	4.666	0.23
2500	25000000	25015591	3.954	0.16	24986968	3.578	0.14
3000	30000000	29991462	3.673	0.12	29999629	3.258	0.11
2500	25000000	25045428	9.344	0.37	25016987	4.098	0.16
2000	20000000	20084475	17.059	0.85	20032402	6.957	0.35
1500	15000000	15086234	17.451	1.16	15024219	5.505	0.37
1000	10000000	10077220	15.579	1.56	10019826	4.331	0.43
800	8000000	8065900	13.298	1.66	8014609	3.315	0.41
600	6000000	6054528	11.003	1.83	6011836	2.610	0.43
400	4000000	4043137	8.682	2.17	4011579	2.493	0.62
200	2000000	2023113	4.656	2.33	2005330	1.236	0.62
100	1000000	1012926	2.608	2.61	1003018	0.716	0.72

Table 3-c. Third order equation

For a given cone indicated output of D (0.1N units), the corrected applied force	$a_0 = -1343.13908$	Maximum PWP zero drift during the calibration (kPa) =	0.73
F (in 0.1N units) is calculated from :	$a_1 = 0.99121$	Maximum reference zero drift during the calibration (kPa) =	0.166
$F = (a_3 \times D^3) + (a_2 \times D^2) + (a_1 \times D) + a_0$	$a_2 = 3.28348E-10$	Factor used to convert from counts to 0.1Pa units =	0.0473942
	$a_3 = -8.26557E-19$	Maximum PWP full scale reading (kPa) =	5000
		PWP resolution (Pa) =	0.1

COMBINED EXPANDED UNCERTAINTY PORE PRESSURE



INCLINATION CALIBRATION

Ref Inclination (°C)	Cone inclination output	
	X Inc (cts)	Y Inc (cts)
-25	-23775	-25343
0	399	798
25	24776	26357

Ref Inclination (°)	Cone inclination output	
	X Inc (°)	Y Inc (°)
-25	-24.9	-25.3
0	0.0	0.0
25	25.1	24.7

	X inc	Y inc
Factor used to convert from counts to 0.1m° units =	10.298389	9.67077137
Inclination error (°) =	0.1	0.3



UK22 Track-truck

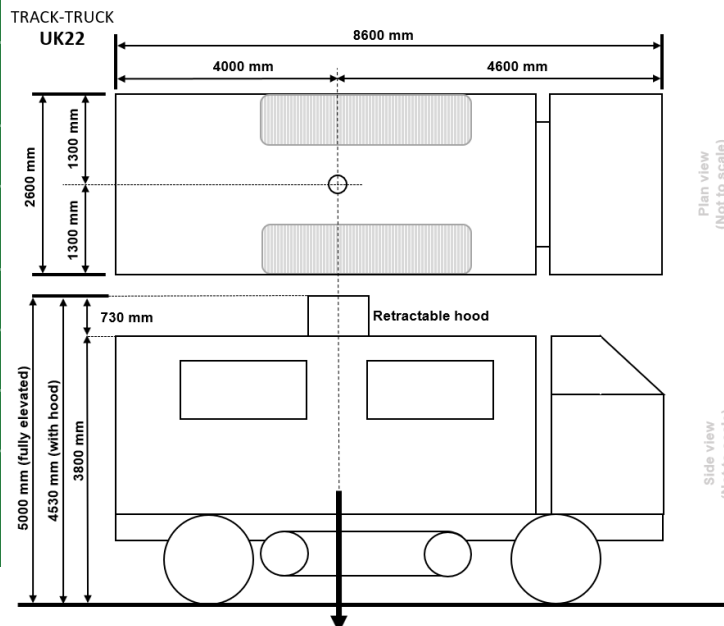


Rig weight	18 T
Max. operating ram capacity	200 kN
Max. travelling speed	4 km/h (tracking)
Track material	Composite
Track length	2800 mm
Track width	650 mm
Jack plate dimensions	Tracks act as jacks
Jack arrangements	1nr. on each side
Max. ground bearing pressure	76 kPa
Max. testing gradient	10 degrees
Max. traversing gradient	30 degrees (operator assessed)
Clamp arrangement	Automatic hydraulic
Ram stroke	1250 mm
Max. casing size	55 mm
Typical production	100 m+ of standard CPTu testing per day (depending on conditions and access)

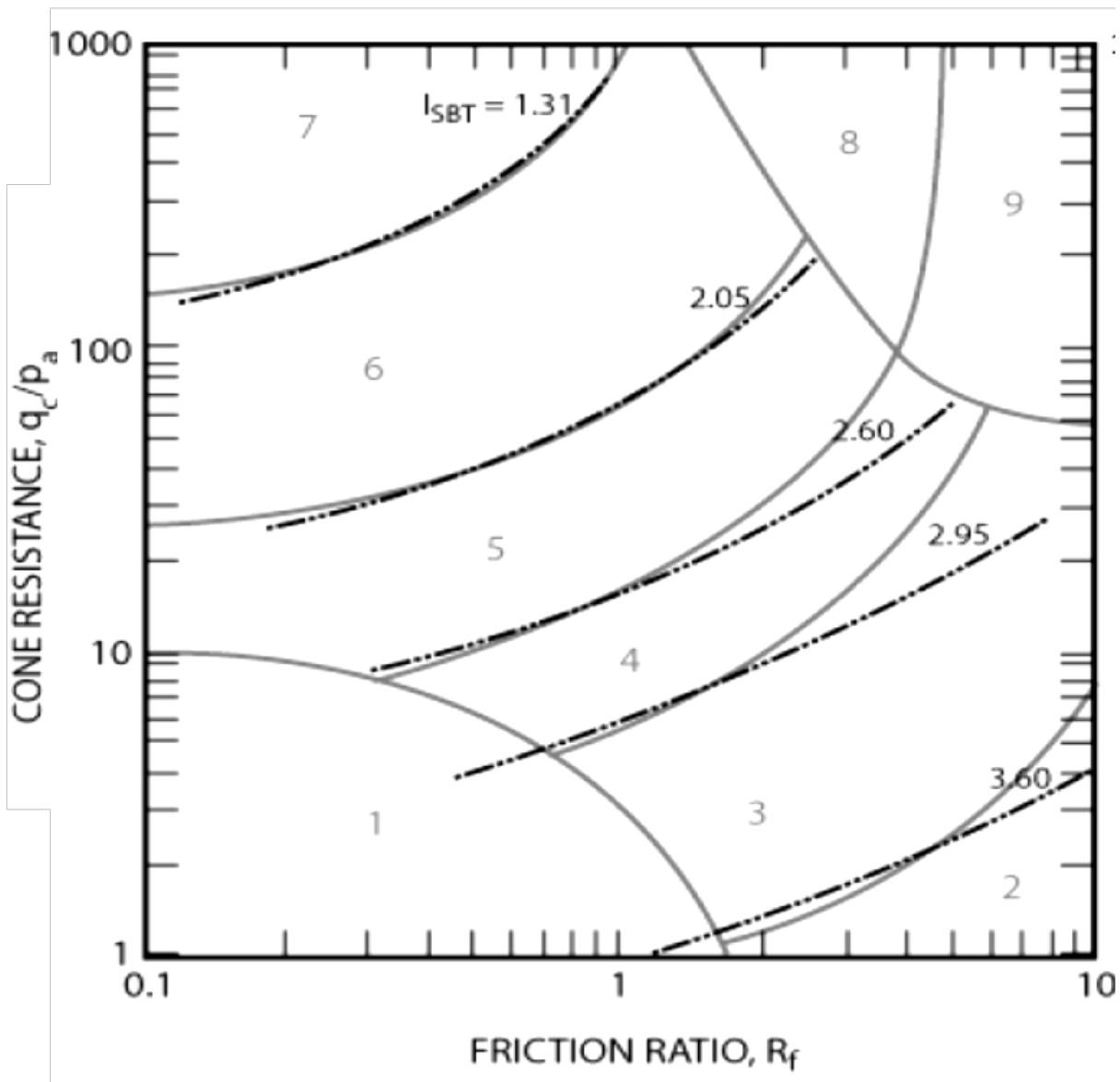
The versatile track-truck is suitable for most geotechnical sites. The rig is driven to site as a self-contained HGV with composite tracks that can be deployed to cope with soft or uneven terrain.

Remote-controlled tracking to assist with manoeuvring onto location.

Complies with Euro 6 emission standards for use in London's low emissions zones (LEZ).



CPT SOIL BEHAVIOUR TYPE CHART



Non-normalised SBT chart by Robertson *et al.* (2010) based on dimensionless cone resistance (q_c/p_a) and friction ratio, R_f , showing contours of SBT index I_{SBT} (denoted I_c on the test plots). The chart is also applicable to normalised tip and sleeve values Q_t and F_r .

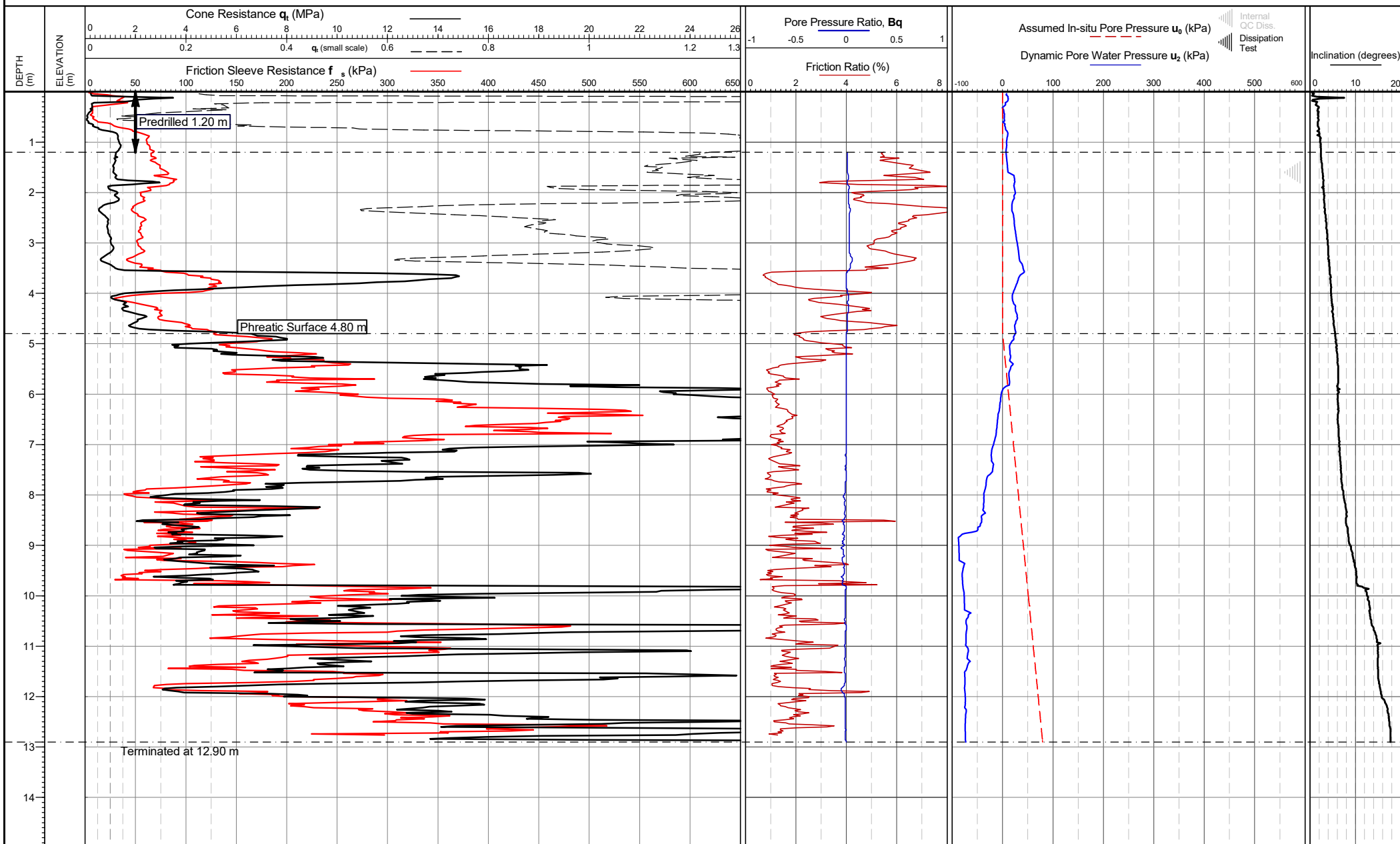
Zone	Soil Behaviour Type (SBT)	
1	Sensitive fine-grained	6 Sands - clean sand to sandy silt
2	Clay – organic soil	7 Dense sand to gravelly sand
3	Clays - clay to silty clay	8 Stiff sand to clayey sand*
4	Silt mixtures - clayey silt to silty clay	9 Stiff fine grained*
5	Sand mixtures – silty sand to sandy silt	*Heavily overconsolidated or cemented

Note zones 8 and 9 appear as 'Stiff sand to clayey sand – HOC or cemented' and 'Stiff fine grained – HOC or cemented' within the soil unit descriptions of plots in Appendix D.

APPENDIX C CONE PENETRATION TEST RESULTS

RAW DATA PLOTS

Plots are provided for all locations



Cone area (mm²): 1500
Cone ID: S15-CFIPM(100).1431
Operator: Gary Connor
Rig Used: UK22
Date of test: 19/01/2021 14:34:00

Zero drift (Pre/post test)
 q_0 (kPa): -18.4
 f_0 (kPa): 1.6 ($f_{s, drift} - q_{0, drift}$)
 u_2 (kPa): -1.3

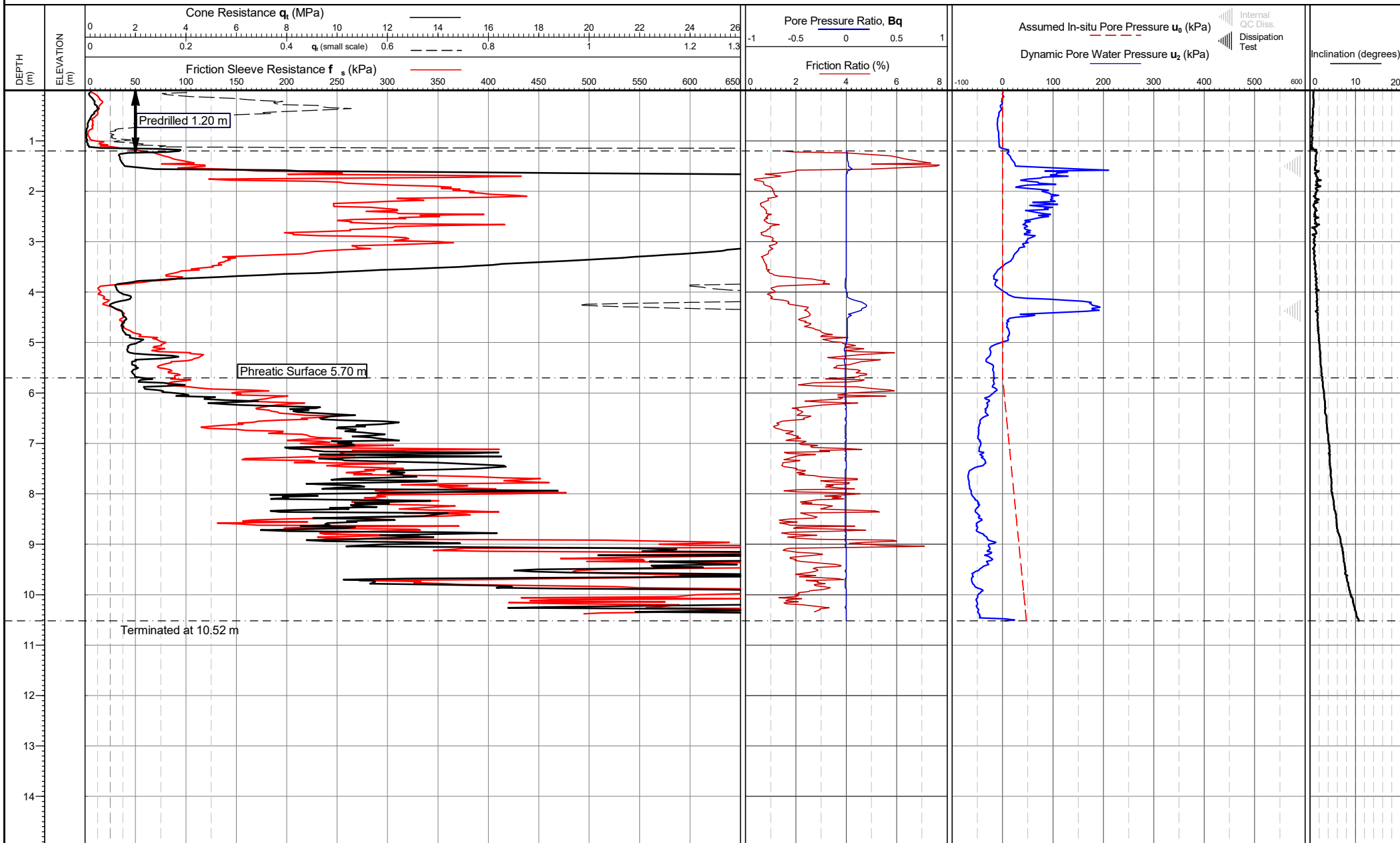
Location: West Sussex, UK
Coordinates: ,
Elevation:
Coordinate system:

Remarks:
*Phreatic surface origin: Observation from nearby client borehole records: BH01
Termination Remark: Lateral support

Date of plot:
26-01-21
Checked by:
Chris Player

Lankelma Project Ref:
P-107644-7

TEST ID: CPT01



Cone area (mm²): 1500
Cone ID: S15-CFIPM(100).1431
Operator: Gary Connor
Rig Used: UK22
Date of test: 19/01/2021 09:49:00

Zero drift (Pre/post test)
 q_0 (kPa): -82.4
 f_0 (kPa): -0.4 ($f_{s,drift} - q_{c,drift}$)
 u_2 (kPa): 0.3

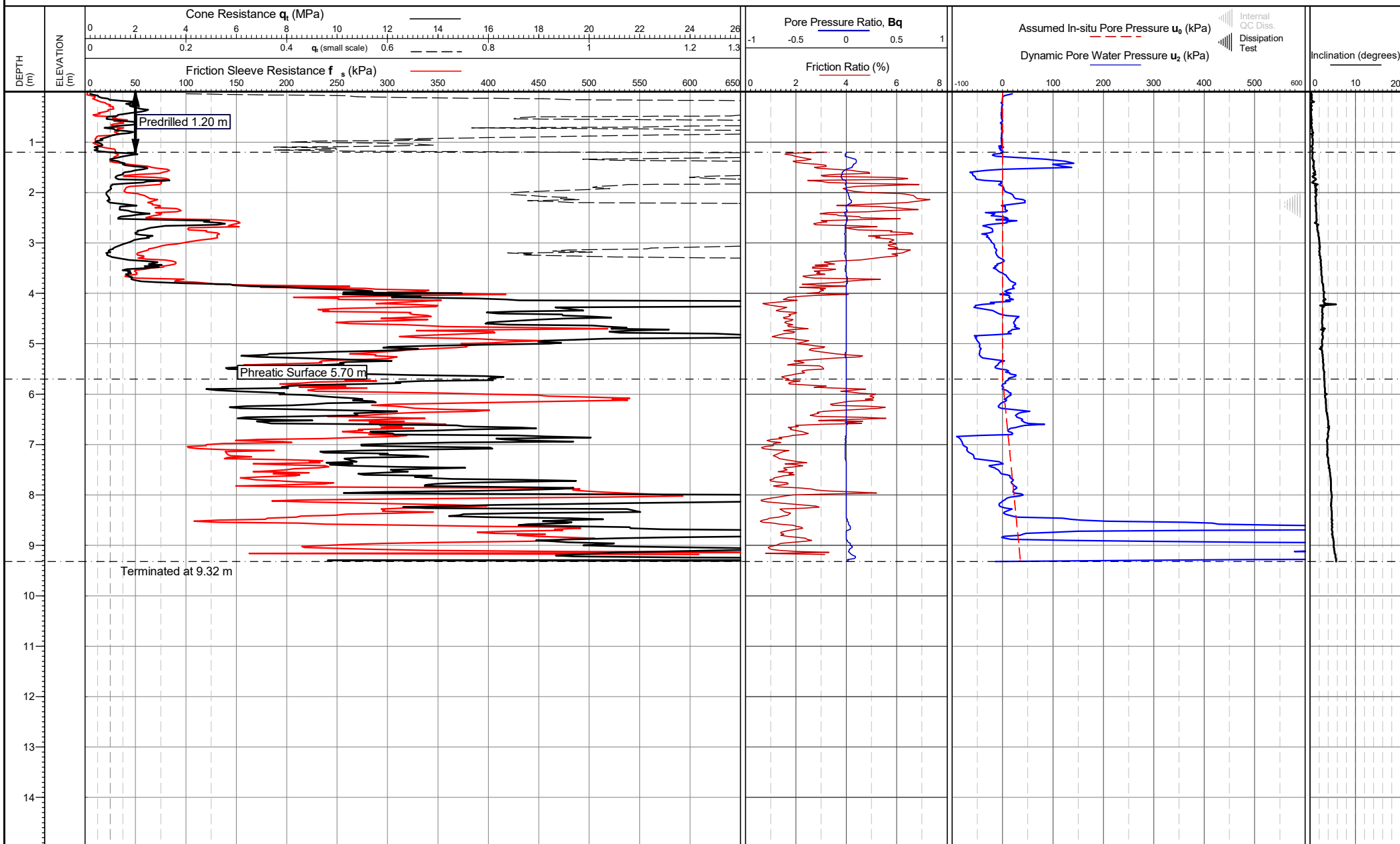
Location: West Sussex, UK
Coordinates: ,
Elevation:
Coordinate system:

Remarks:
*Phreatic surface origin: Average measured piezometric depth from other location(s)
Termination Remark: Lateral support

Date of plot:
26-01-21
Checked by:
Chris Player

Lankelma Project Ref:
P-107644-7

TEST ID: CPT02



Cone area (mm²): 1500
Cone ID: S15-CFIPM(100).1431
Operator: Gary Connor
Rig Used: UK22
Date of test: 19/01/2021 10:58:00

Zero drift (Pre/post test)
 q_0 (kPa): 1.0
 f_0 (kPa): -0.9 ($f_{s, drift} - q_{c, drift}$)
 u_2 (kPa): -5.0

Location: West Sussex, UK
Coordinates: ,
Elevation:
Coordinate system:

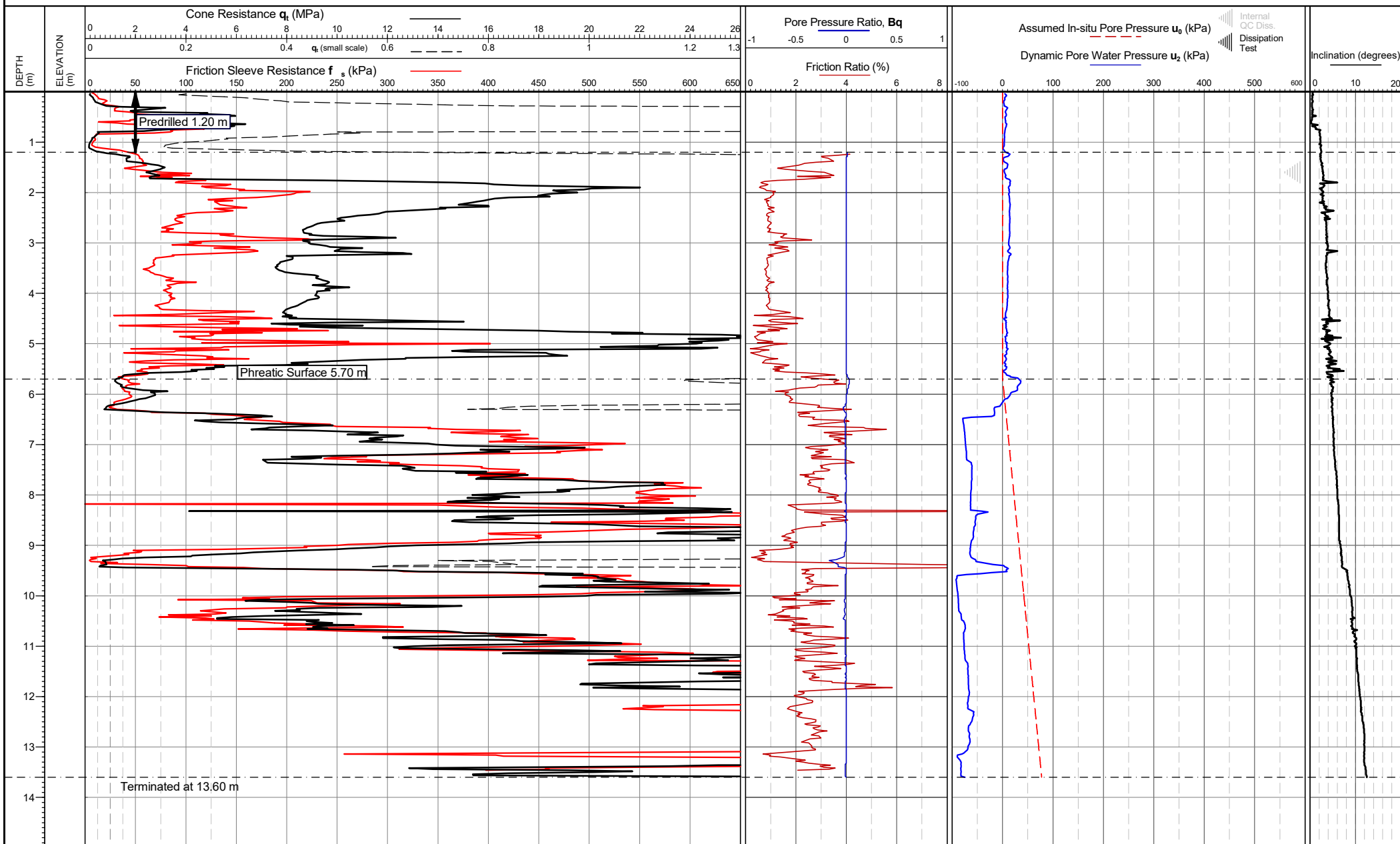
Remarks:
*Phreatic surface origin: Average measured piezometric depth from other location(s)
Termination Remark: Lateral support

Date of plot:
26-01-21
Checked by:
Chris Player

Lankelma Project Ref:
P-107644-7

TEST ID: CPT03

Page 1 of 1



Cone area (mm²): 1500
 Cone ID: S15-CFIPM(100).1431
 Operator: Gary Connor
 Rig Used: UK22
 Date of test: 19/01/2021 13:44:00

Zero drift (Pre/post test)
 q_0 (kPa): -42.6
 f_0 (kPa): -0.3 ($f_{s, drift} - q_{0, drift}$)
 u_2 (kPa): 3.8

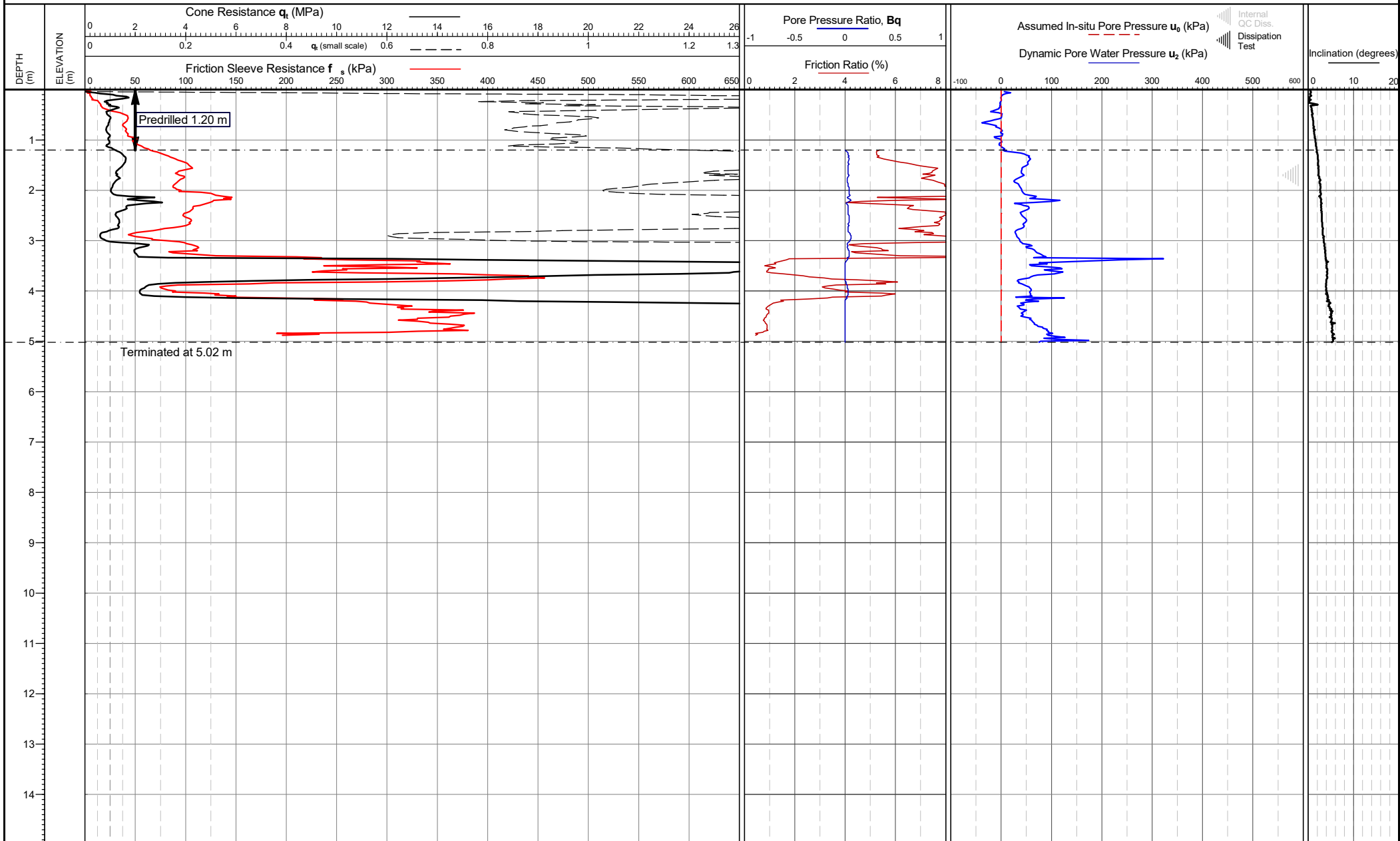
Location: West Sussex, UK
 Coordinates: ,
 Elevation:
 Coordinate system:

Remarks:
 *Phreatic surface origin: Average measured piezometric depth from other location(s)
 Termination Remark: Lateral support

Date of plot:
 26-01-21
 Checked by:
 Chris Player

Lankelma Project Ref:
 P-107644-7

TEST ID: CPT04



Cone area (mm²): 1500
Cone ID: S15-CFIPM(100).1431
Operator: Gary Connor
Rig Used: UK22
Date of test: 19/01/2021 12:16:00

Zero drift (Pre/post test)
 q_0 (kPa): 19.2
 f_0 (kPa): 2.2 ($f_{s, drift} - q_{0, drift}$)
 u_2 (kPa): -4.3

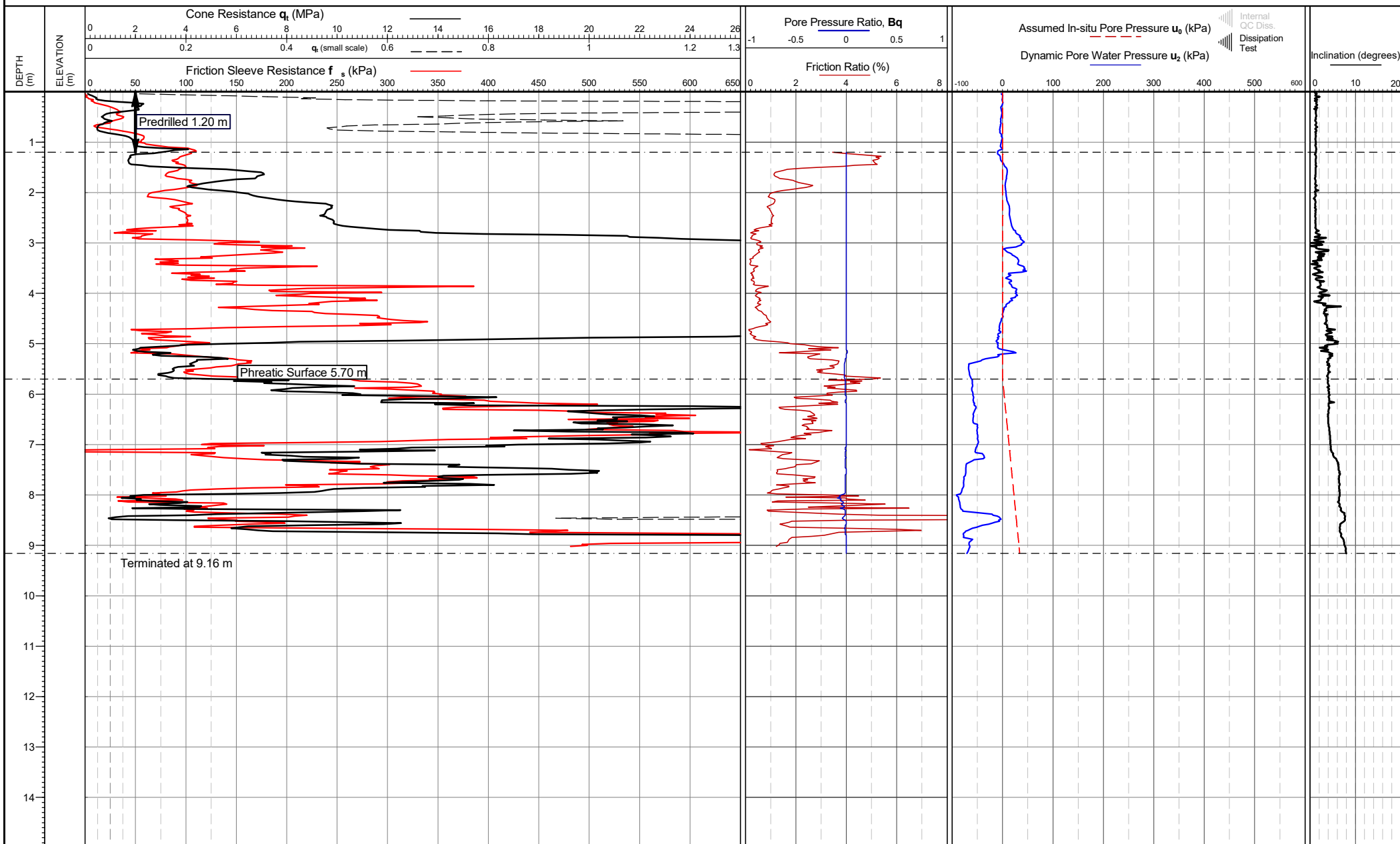
Location: West Sussex, UK
Coordinates: ,
Elevation:
Coordinate system:

Remarks:
*Phreatic surface origin: Observation from nearby client borehole records: BH03
Termination Remark: Lateral support

Date of plot:
26-01-21
Checked by:
Chris Player

Lankelma Project Ref:
P-107644-7

TEST ID: CPT05



Cone area (mm²): 1500
Cone ID: S15-CFIPM(250).841
Operator: Gary Connor
Rig Used: UK22
Date of test: 19/01/2021 15:25:00

Zero drift (Pre/post test)
 q_0 (kPa): -42.0
 f_s (kPa): -1.7 ($f_{s, drift} - q_{0, drift}$)
 u_2 (kPa): -9.6

Location: West Sussex, UK
Coordinates: ,
Elevation:
Coordinate system:

Remarks:
*Phreatic surface origin: Average measured piezometric depth from other location(s)
Termination Remark: Lateral support

Date of plot:
26-01-21
Checked by:
Chris Player

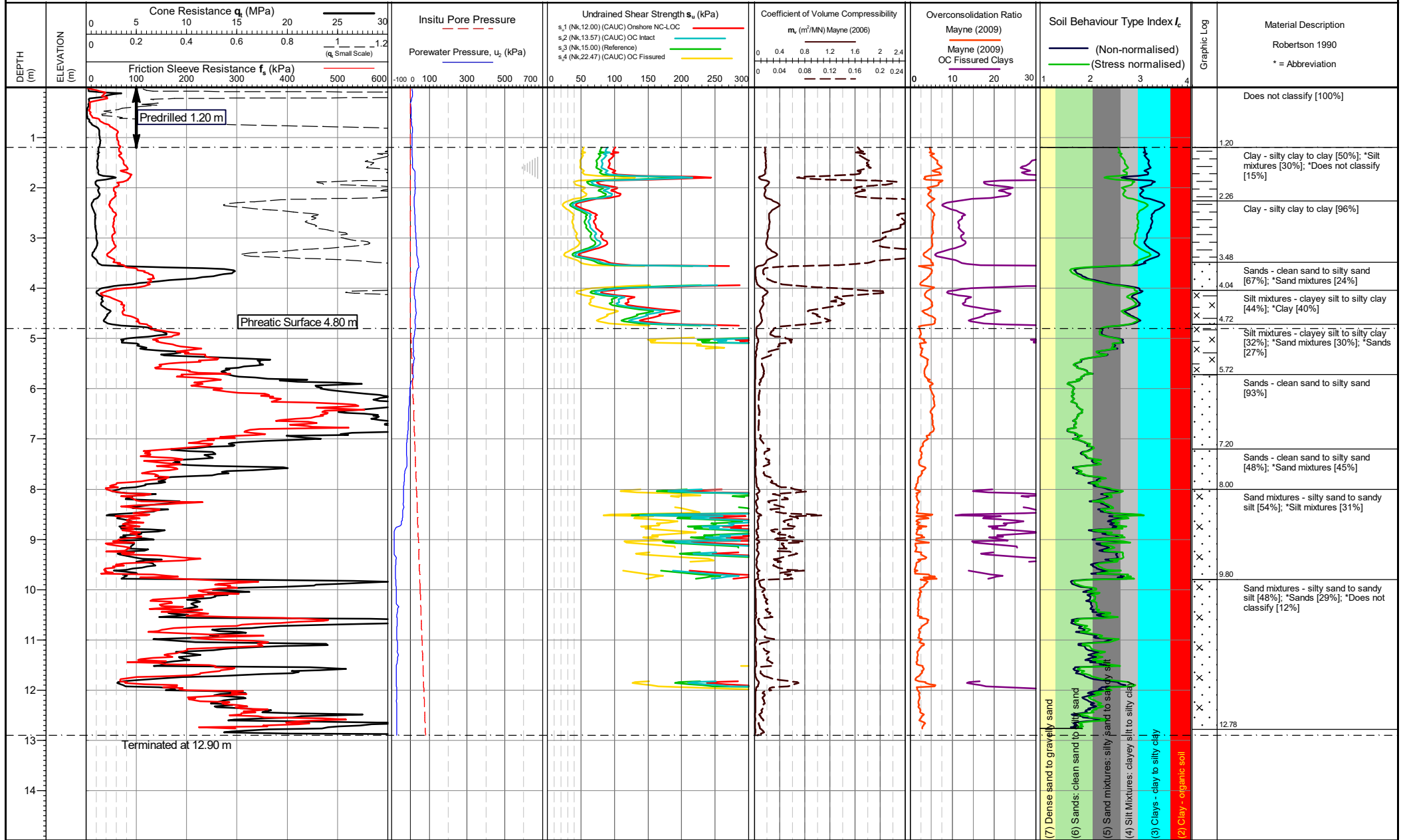
Lankelma Project Ref:
P-107644-7

TEST ID: CPT06

APPENDIX D INTERPRETATION RESULTS - SET 1

**UNDRAINED SHEAR STRENGTH
COEFFICIENT OF VOLUME CHANGE
OVERCONSOLIDATION RATIO
SOIL BEHAVIOUR TYPE (SBT) DESCRIPTIONS**

Plots are provided for all locations



Cone area (mm²):1500
ConeID: S15-CFIPM(100).1431
Operator: Gary Connor
Rig Used: UK22
Date of test: 19/01/2021 14:34:00

Location: West Sussex, UK
Coordinates: ,
Elevation:
Coordinate system:

Remarks: *Phreatic surface origin: Observation from nearby client borehole records: BH01

Termination Remark:
Lateral support

Internal QA Diss.
Dissipation Test
Penetration
Pause (<1cm/s)

Both drained and undrained parameters are calculated for mixed SBTs = Ic 2.40-2.70. See report text for methods and discussion of parameter evaluation.

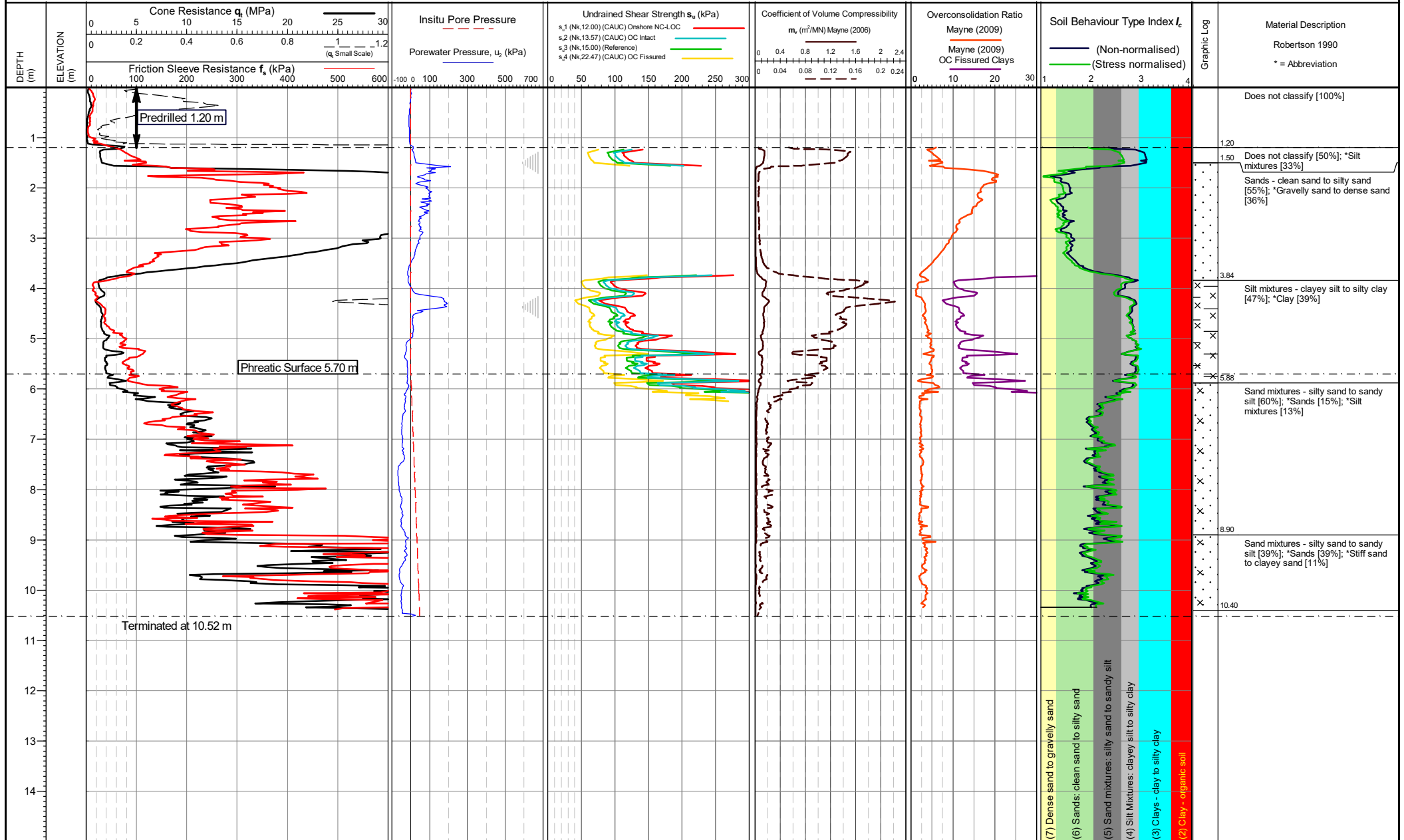
Date of plot:
26-01-21

Checked by:
Chris Player

Lankelma Project Ref:
P-107644-7

TEST ID: CPT01

Page 1 of 1



Cone area (mm²):1500
 ConeID: S15-CFIPM(100).1431
 Operator: Gary Connor
 Rig Used: UK22
 Date of test: 19/01/2021 09:49:00

Location: West Sussex, UK
 Coordinates: ,
 Elevation:
 Coordinate system:

Remarks: *Phreatic surface origin: Average measured piezometric depth from other location(s)

Termination Remark:
 Lateral support

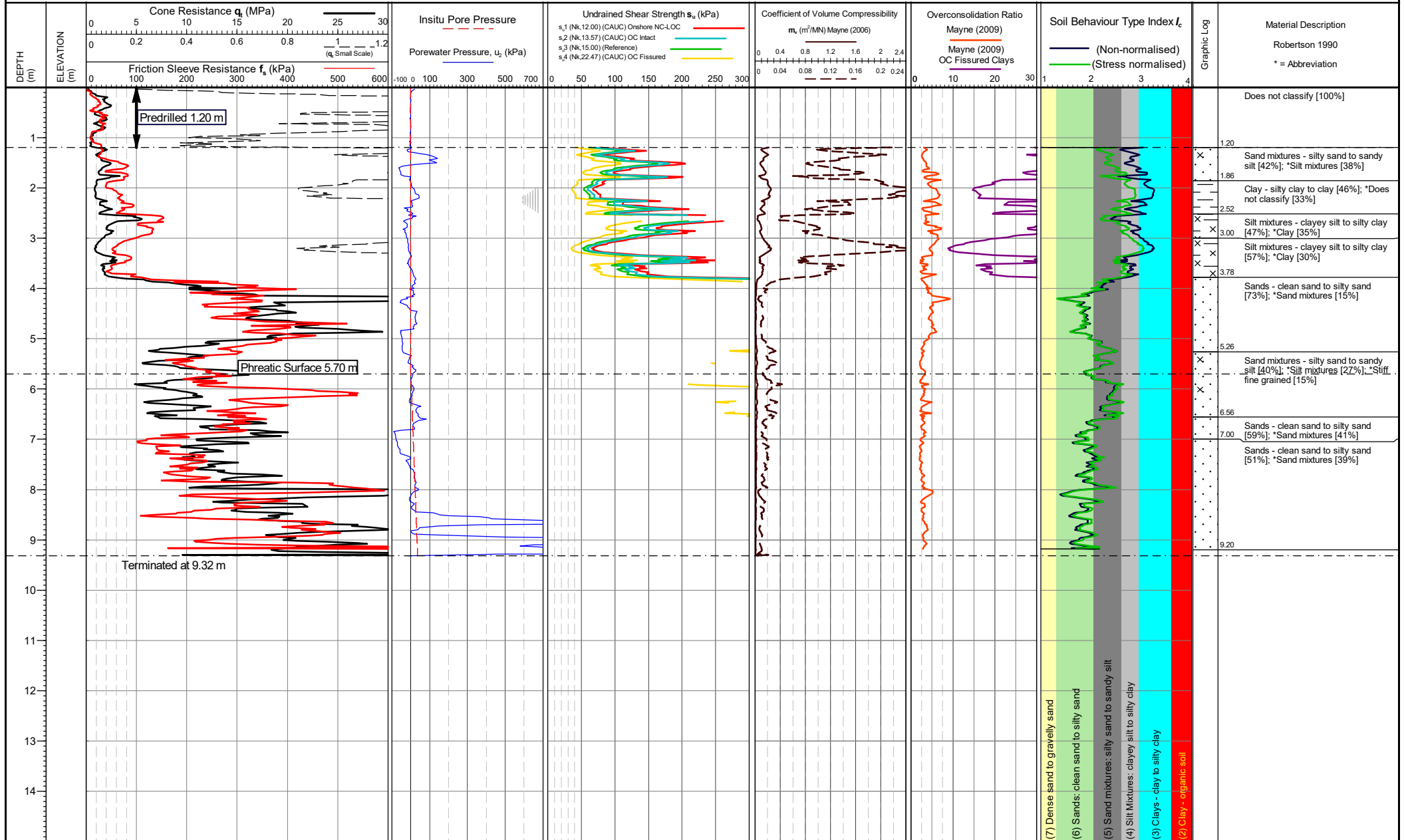
Internal QA Diss.
 Dissipation Test
 Penetration
 Pause (<1cm/s)

Both drained and undrained parameters are calculated for mixed SBTs = I_c 2.40-2.70. See report text for methods and discussion of parameter evaluation.

Date of plot: 26-01-21
 Checked by: Chris Player

Lankelma Project Ref: P-107644-7

TEST ID: CPT02



Cone area (mm²):1500
ConeID: S15-CFIPM(100).1431
Operator: Gary Connor
Rig Used: UK22
Date of test: 19/01/2021 10:58:00

Location: West Sussex, UK
Coordinates: ,
Elevation:
Coordinate system:

Remarks: *Phreatic surface origin: Average measured piezometric depth from other location(s)

Termination Remark:
Lateral support

Internal QA Diss.
Dissipation Test
Penetration
Pause (<1cm/s)

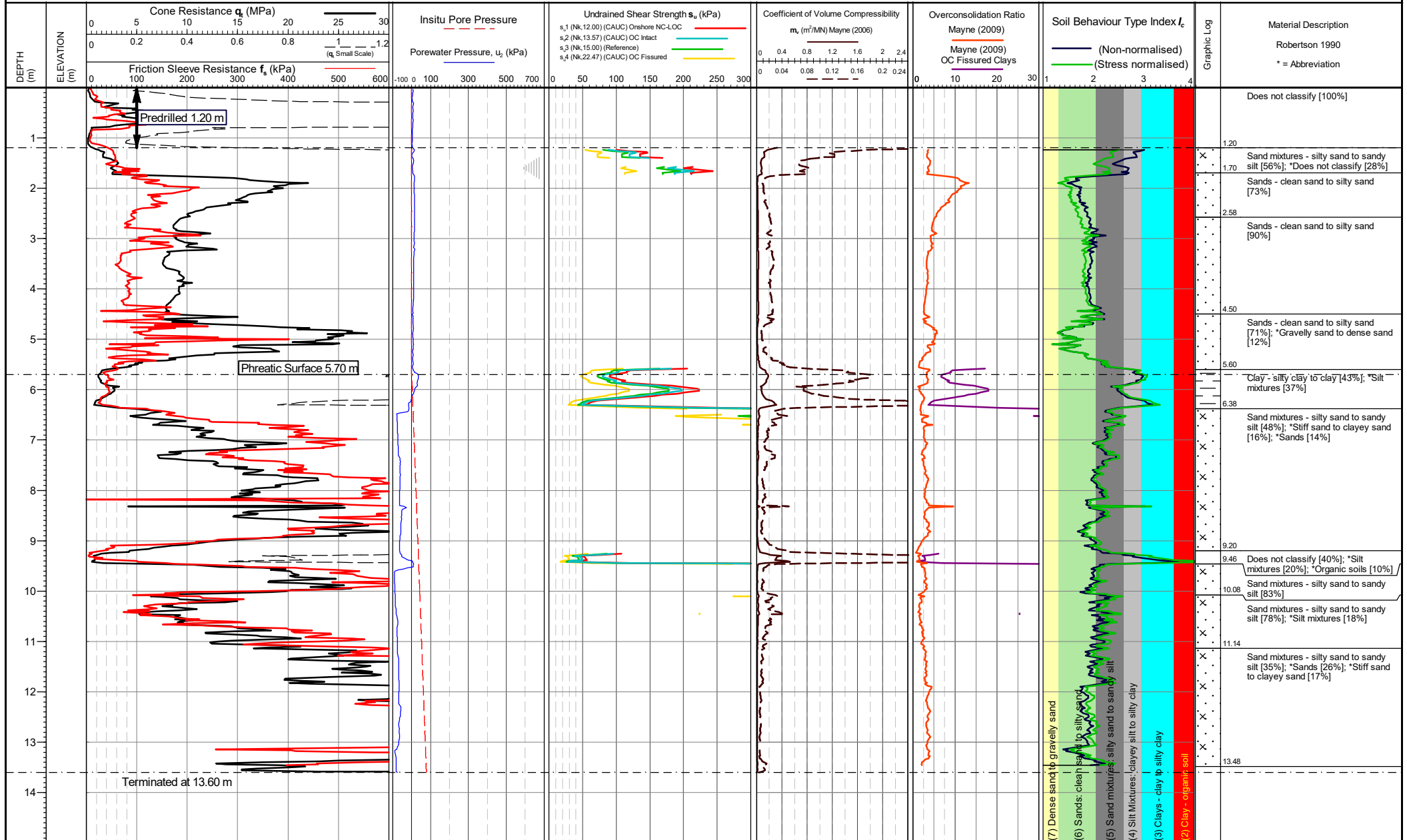
Both drained and undrained parameters are calculated for mixed SBTs = I_c 2.40-2.70. See report text for methods and discussion of parameter evaluation.

Date of plot:
26-01-21

Checked by:
Chris Player

Lankelma Project Ref:
P-107644-7

TEST ID: CPT03



Cone area (mm²): 1500
 ConeID: S15-CFIPM(100).1431
 Operator: Gary Connor
 Rig Used: UK22
 Date of test: 19/01/2021 13:44:00

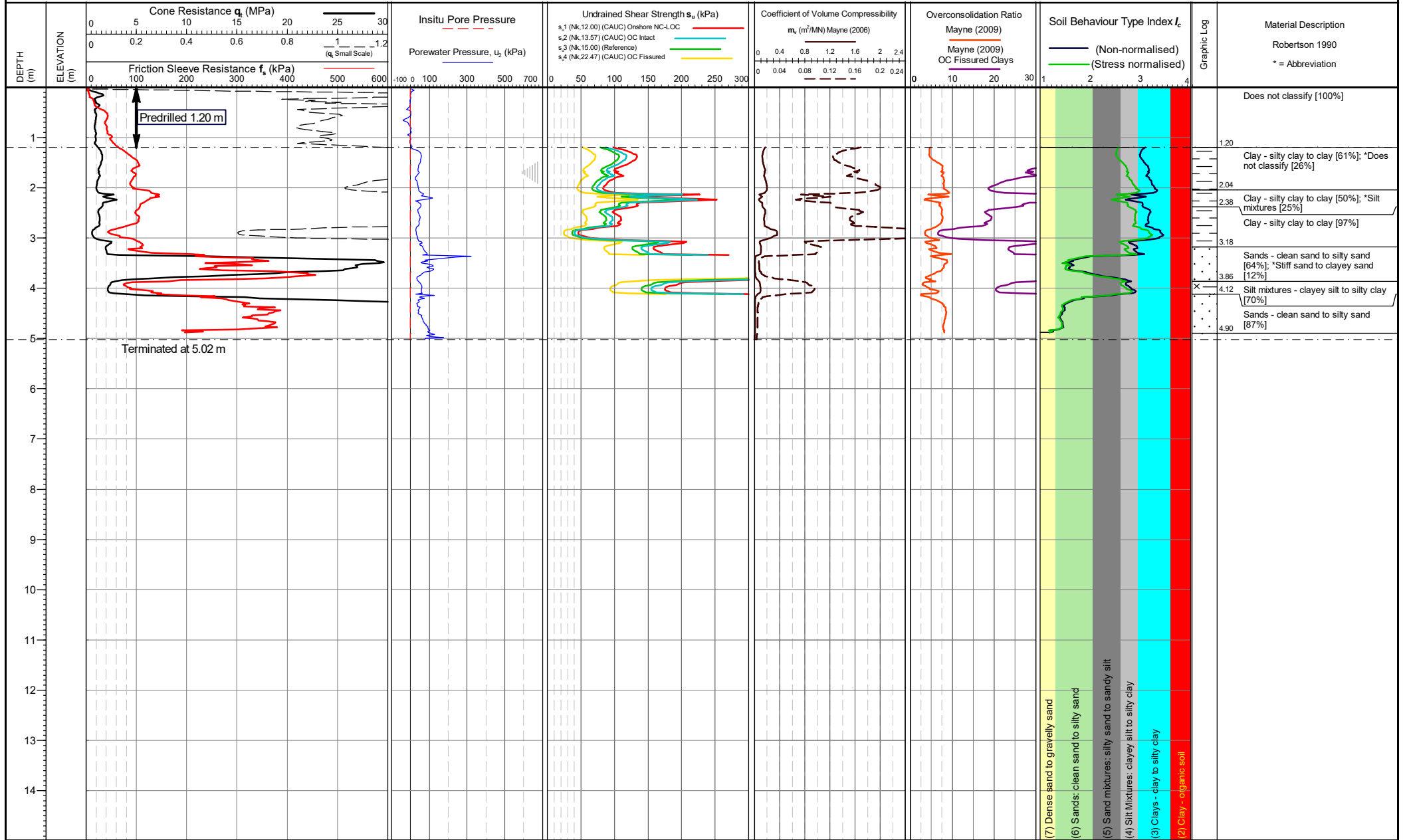
Location: West Sussex, UK
 Coordinates: ,
 Elevation:
 Coordinate system:

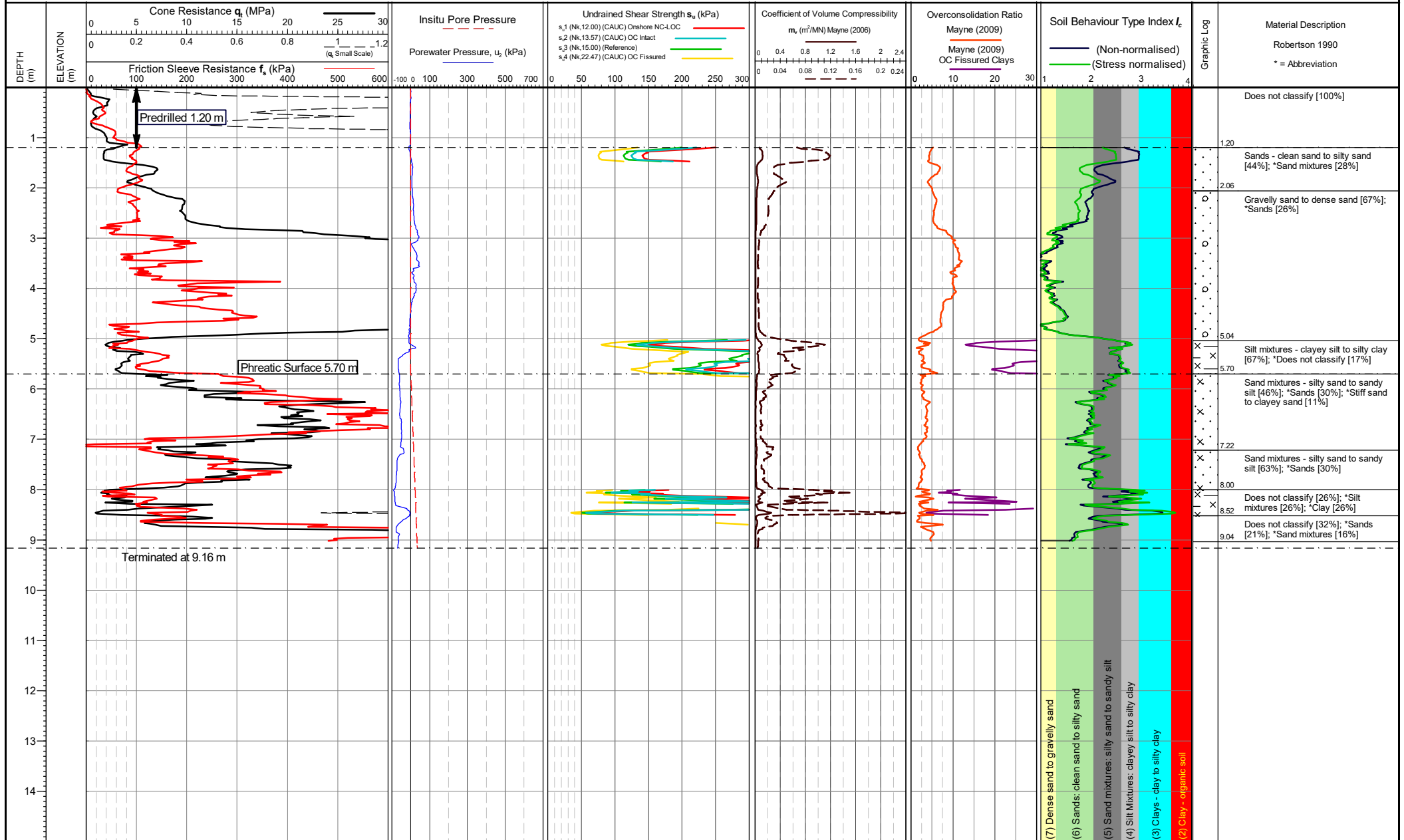
Remarks: *Phreatic surface origin: Average measured piezometric depth from other location(s)
 Termination Remark:
 Lateral support

Internal QA Diss.
 Dissipation Test
 Penetration
 Pause (<1cm/s)
 Both drained and undrained parameters are calculated for mixed SBTs = I_c 2.40-2.70. See report text for methods and discussion of parameter evaluation.

Date of plot: 26-01-21
 Lankelma Project Ref: P-107644-7
 Checked by: Chris Player

TEST ID: CPT04





Cone area (mm²):1500
 ConeID: S15-CFIPM(250).841
 Operator: Gary Connor
 Rig Used: UK22
 Date of test: 19/01/2021 15:25:00

Location: West Sussex, UK
 Coordinates: ,
 Elevation:
 Coordinate system:

Remarks: *Phreatic surface origin: Average measured piezometric depth from other location(s)
 Termination Remark:
 Lateral support

Internal QA Diss.
 Dissipation Test
 Penetration
 Pause (<1cm/s)
 Both drained and undrained parameters are calculated for mixed SBTs = I_c 2.40-2.70. See report text for methods and discussion of parameter evaluation.

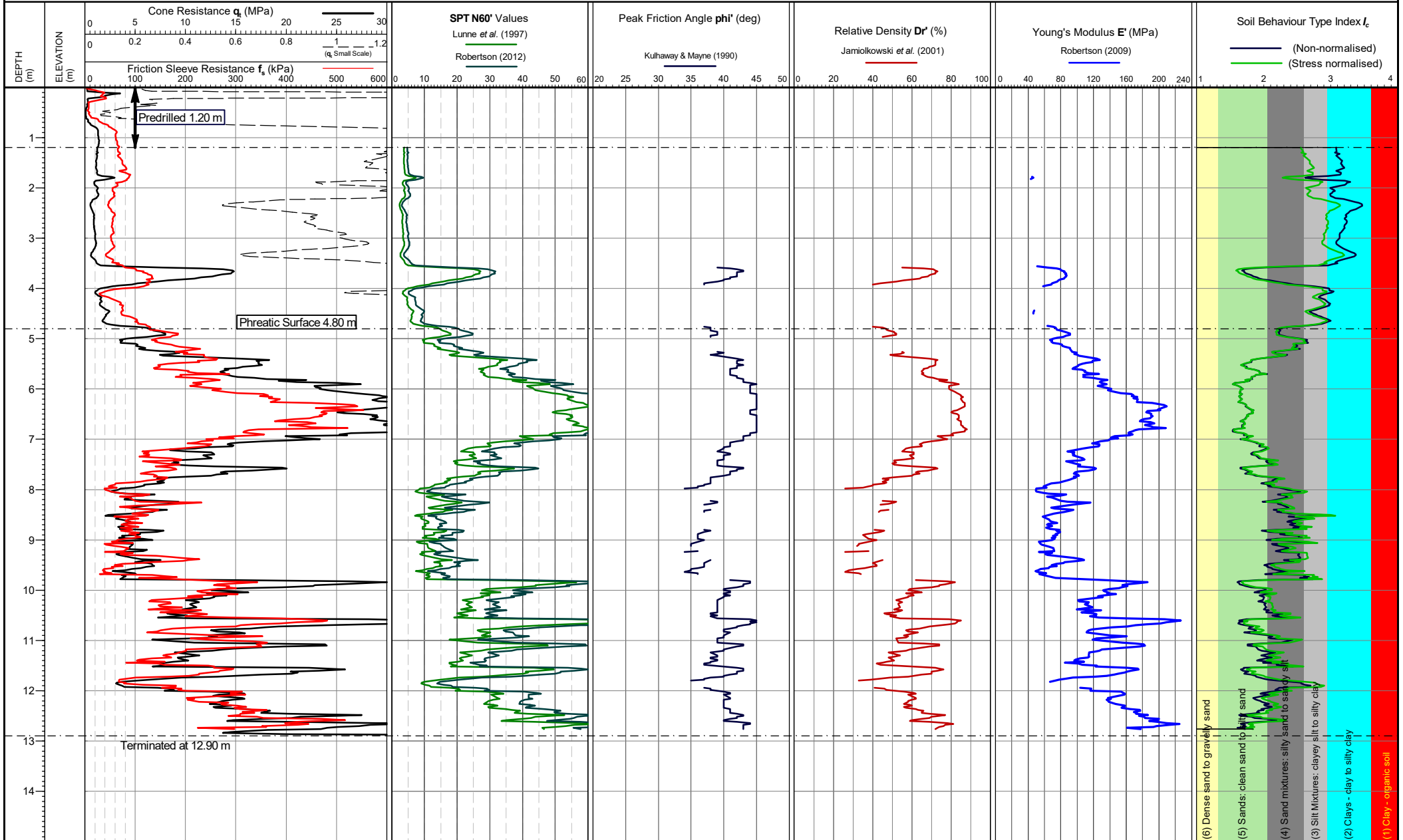
Date of plot: 26-01-21
 Checked by: Chris Player
 Lankelma Project Ref: P-107644-7

TEST ID: CPT06

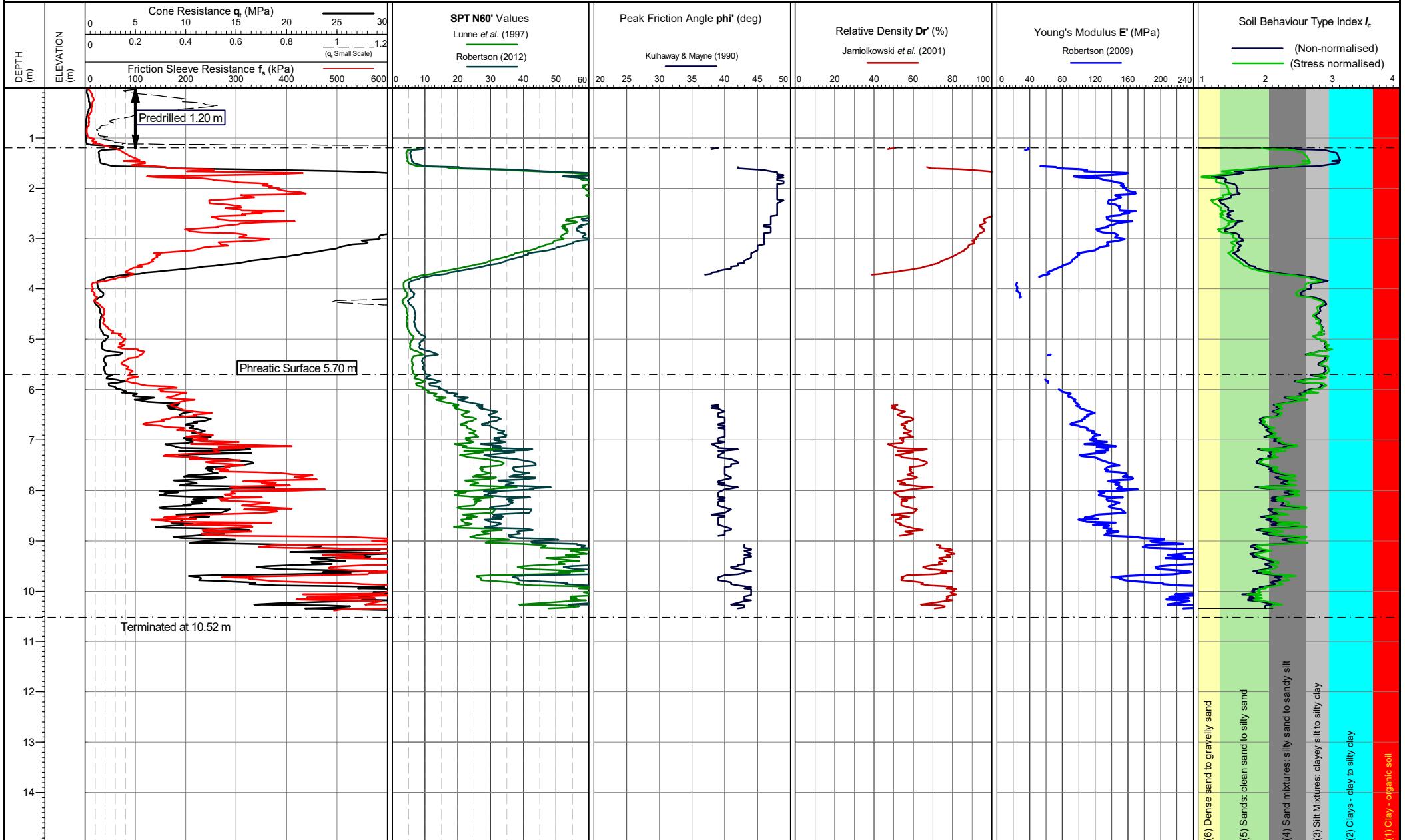
APPENDIX E INTERPRETATION RESULTS - SET 2

**EQUIVALENT SPT N60
PEAK FRICTION ANGLE
RELATIVE DENSITY
YOUNG'S MODULUS**

Plots are provided for all locations



- (6) Dense sand to gravelly sand
- (5) Sands: clean sand to silty sand
- (4) Sand mixtures: silty sand to sandy silt
- (3) Silt Mixtures: clayey silt to silty clay
- (2) Clays - clay to silty clay
- (1) Clay - organic soil



Cone area (mm²):1500
Cone ID: S15-CFIPM(100).1431
Operator: Gary Connor
Date of test: 19/01/2021 09:49:00

Location: West Sussex, UK
Coordinates: ,
Elevation:
Coordinate system:

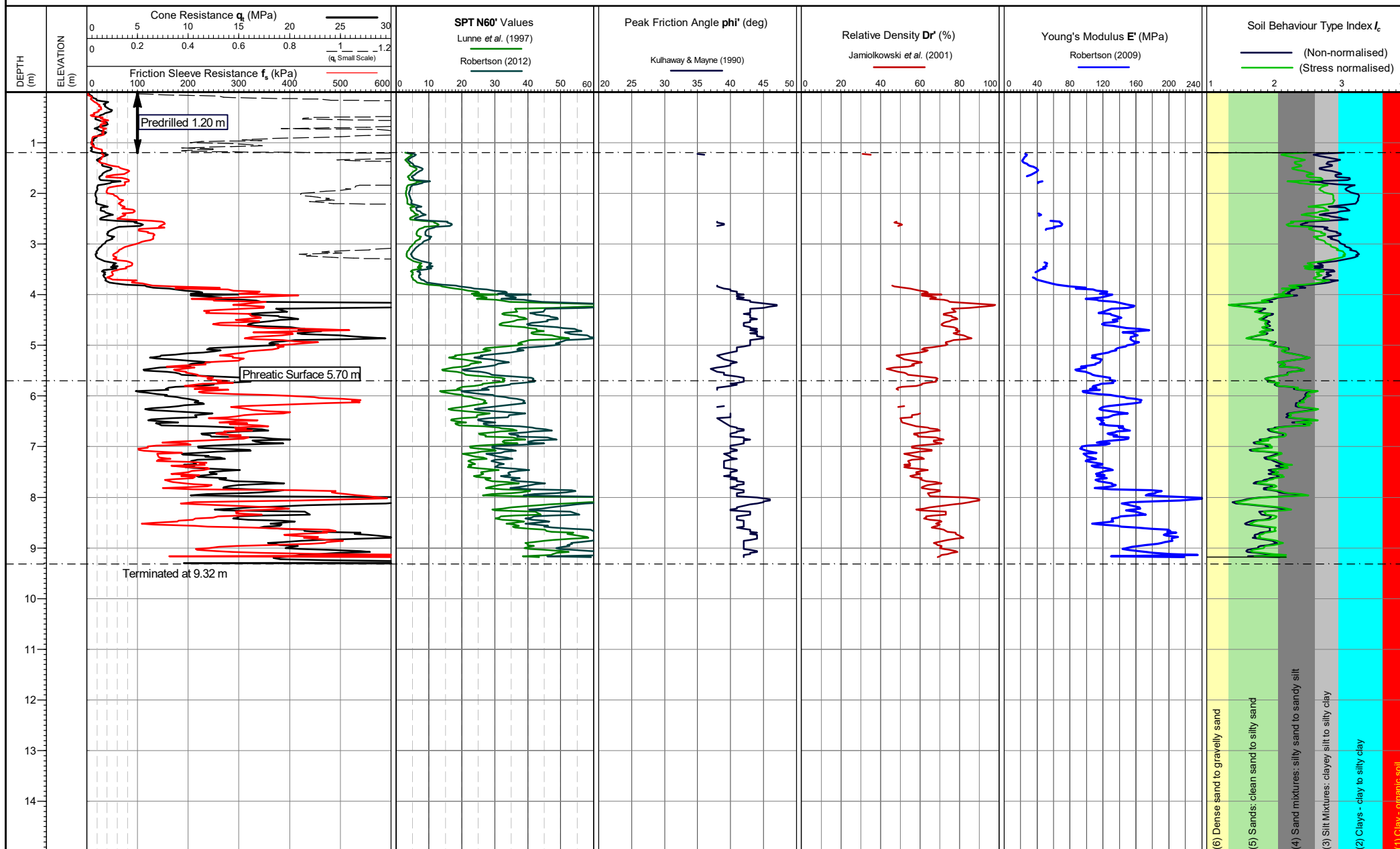
Both drained and undrained parameters are calculated for mixed SBTs = Ic 2.40-2.70. See report text for methods and discussion of parameter evaluation.

Date of plot:
26-01-21
Checked by:
Chris Player

Lankelma Project Ref:
P-107644-7

TEST ID: CPT02

Page 1 of 1



Cone area (mm²):1500
Cone ID: S15-CFIPM(100).1431
Operator: Gary Connor
Date of test: 19/01/2021 10:58:00

Location: West Sussex, UK
Coordinates: ,
Elevation:
Coordinate system:

Both drained and undrained parameters are calculated for mixed SBTs = I_c 2.40-2.70. See report text for methods and discussion of parameter evaluation.

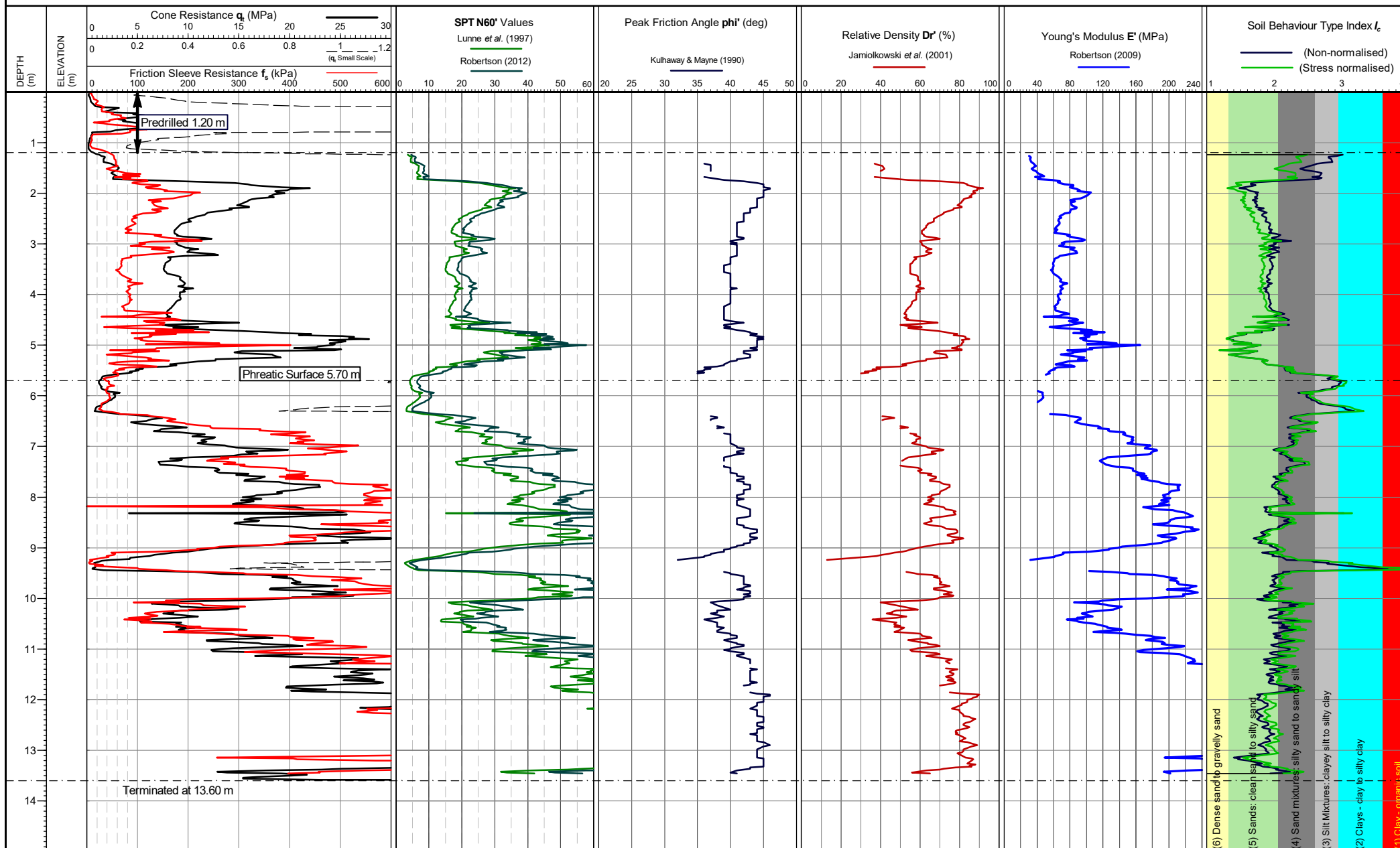
Date of plot:
26-01-21

Checked by:
Chris Player

Lankelma Project Ref:
P-107644-7

TEST ID: CPT03

Page 1 of 1



Cone area (mm²):1500
 Cone ID: S15-CFIPM(100).1431
 Operator: Gary Connor
 Date of test: 19/01/2021 13:44:00

Location: West Sussex, UK
 Coordinates: ,
 Elevation:
 Coordinate system:

Both drained and undrained parameters are calculated for mixed SBTs = I_c 2.40-2.70. See report text for methods and discussion of parameter evaluation.

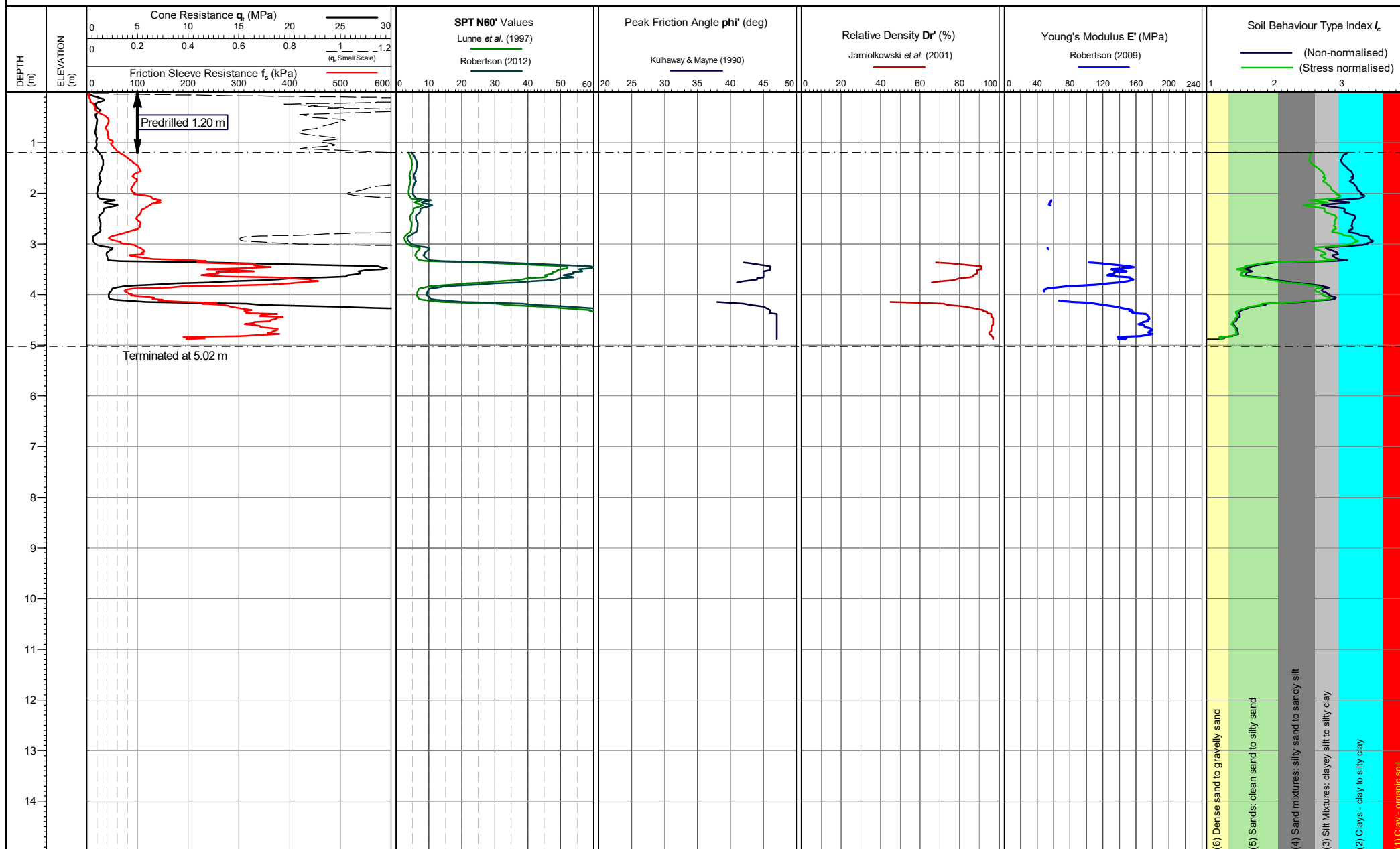
Date of plot:
 26-01-21

Checked by:
 Chris Player

Lankelma Project Ref:
 P-107644-7

TEST ID: CPT04

Page 1 of 1



Cone area (mm²):1500
Cone ID: S15-CFIPM(100).1431
Operator: Gary Connor
Date of test: 19/01/2021 12:16:00

Location: West Sussex, UK
Coordinates: ,
Elevation:
Coordinate system:

Both drained and undrained parameters are calculated for mixed SBTs = I_c 2.40-2.70. See report text for methods and discussion of parameter evaluation.

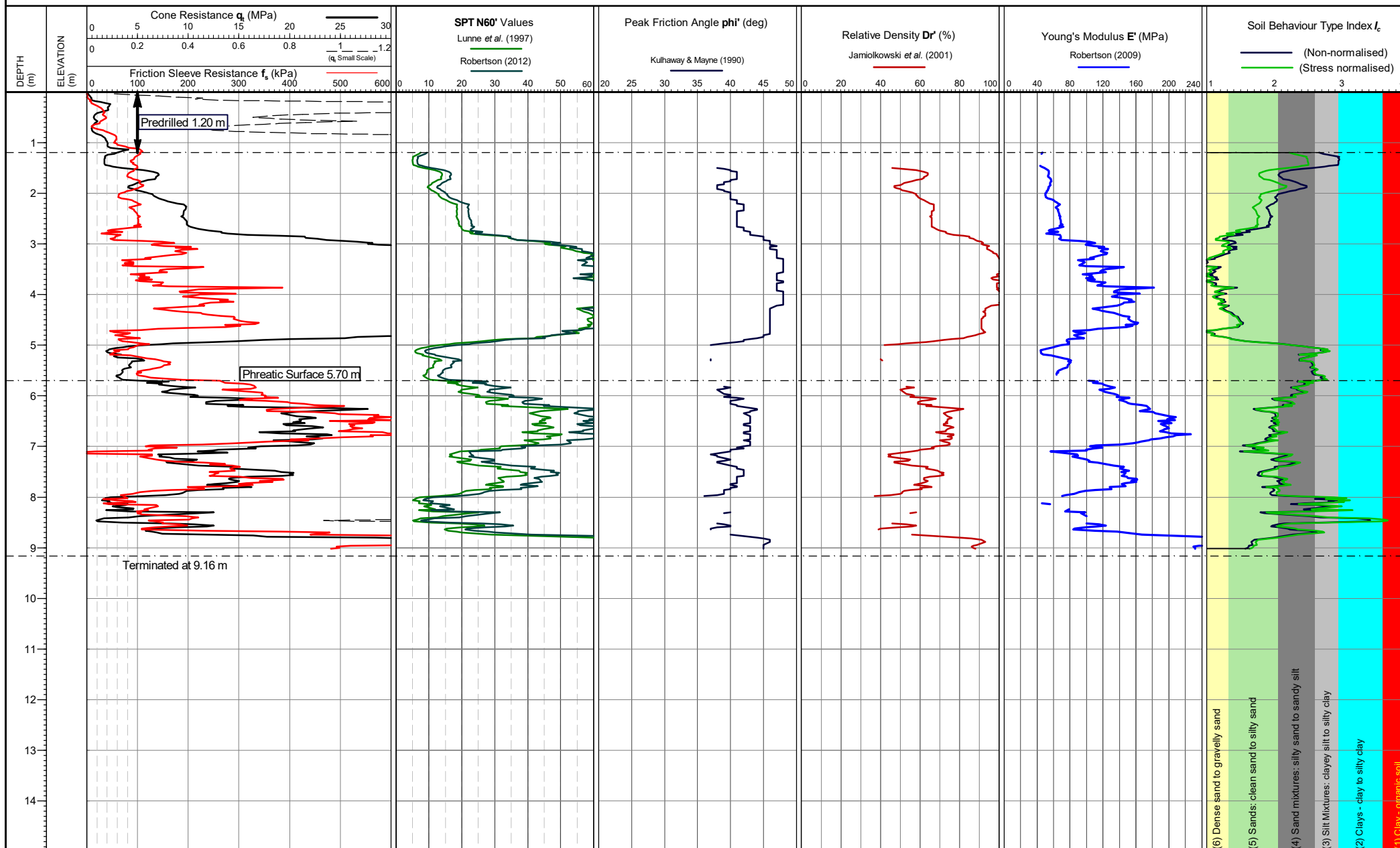
Date of plot:
26-01-21

Checked by:
Chris Player

Lankelma Project Ref:
P-107644-7

TEST ID: CPT05

Page 1 of 1



Cone area (mm²):1500
Cone ID: S15-CFIPM(250).841
Operator: Gary Connor
Date of test: 19/01/2021 15:25:00

Location: West Sussex, UK
Coordinates: ,
Elevation:
Coordinate system:

Both drained and undrained parameters are calculated for mixed SBTs = I_c 2.40-2.70. See report text for methods and discussion of parameter evaluation.

Date of plot:
26-01-21

Checked by:
Chris Player

Lankelma Project Ref:
P-107644-7

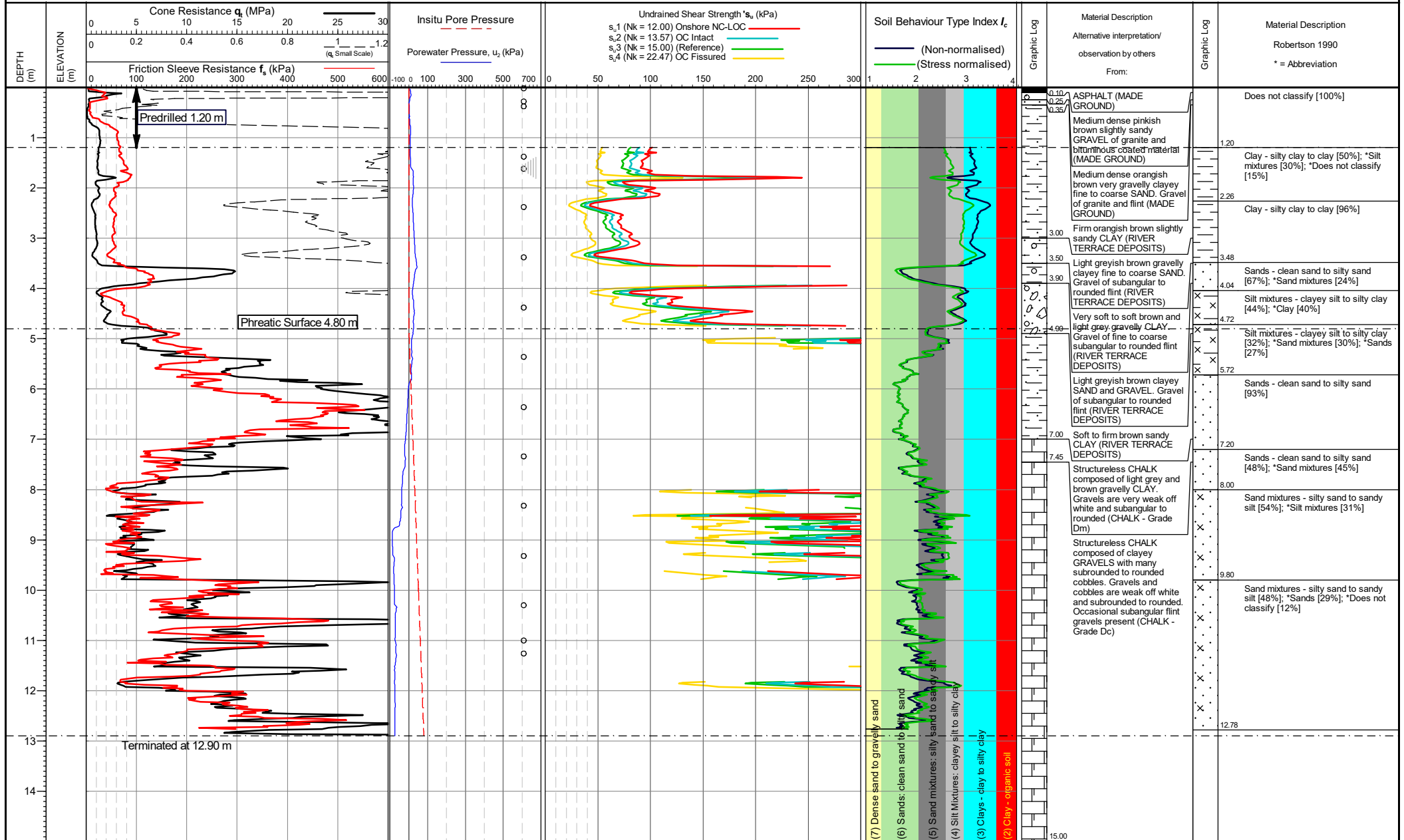
TEST ID: CPT06

Page 1 of 1

APPENDIX F ADDITIONAL INTERPRETATION RESULTS

UNDRAINED SHEAR STRENGTH MATERIAL DESCRIPTIONS FROM CLIENT BOREHOLE RECORDS SOIL BEHAVIOUR TYPE (SBT) DESCRIPTIONS

Plots are provided for selected locations only



Cone area (mm²):1500
 ConeID: S15-CFIPM(100).1431
 Operator: Gary Connor
 Rig Used: UK22
 Date of test: 19/01/2021 14:34:00

Location: West Sussex, UK
 Coordinates: ,
 Elevation:

Remarks: *Phreatic surface origin: Observation from nearby client borehole records: BH01

Termination Remark:
 Lateral support

Internal QA Diss.
 Dissipation Test
 Penetration
 Pause (<1cm/s)

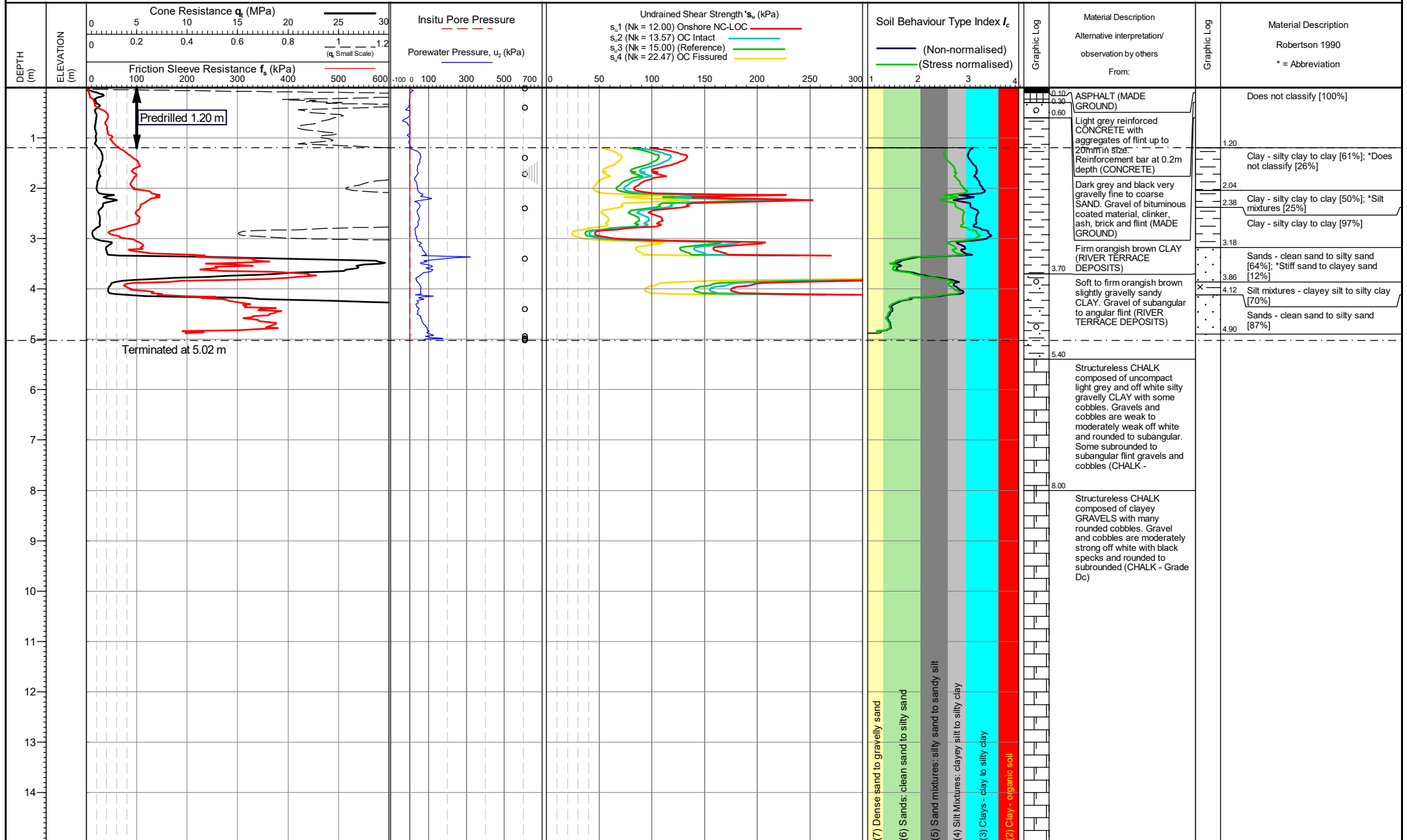
Both drained and undrained parameters are calculated for mixed SBTs = I_c 2.40-2.70. See report text for methods and discussion of parameter evaluation.

Date of plot: 26-01-21
 Lankelma Project Ref: P-107644-7

Checked by:
 Chris Player

TEST ID: CPT01

Page 1 of 1



Cone area (mm²):1500
ConeID: S15-CFIPM(100).1431
Operator: Gary Connor
Rig Used: UK22
Date of test: 19/01/2021 12:16:00

Location: West Sussex, UK
Coordinates: ,
Elevation:

Remarks: *Phreatic surface origin: Observation from nearby client borehole records: BH03

Termination Remark:
Lateral support

Internal
QA Diss.
Dissipation
Test
Penetration
Pause (<1cm/s)

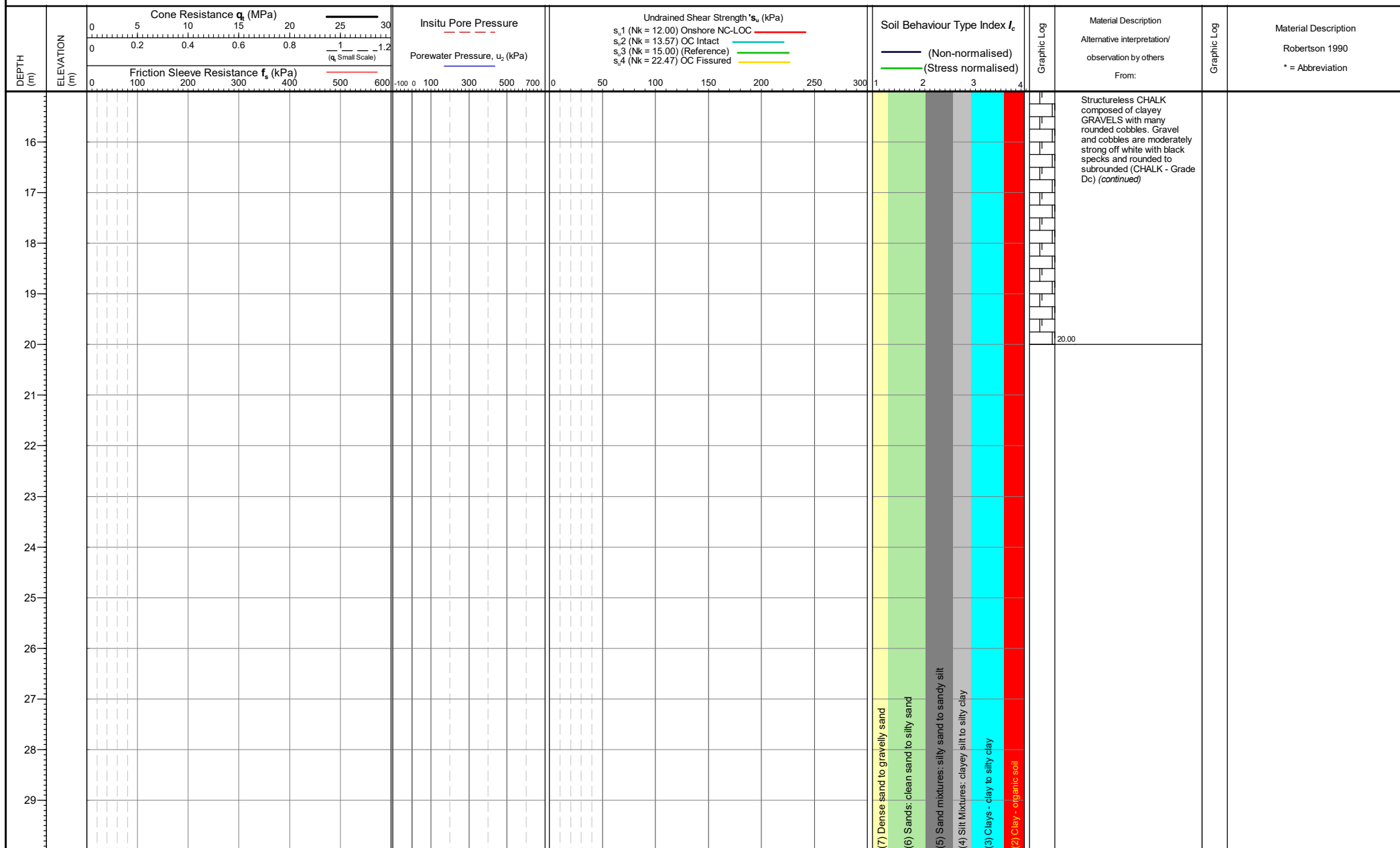
Both drained and undrained parameters are calculated for mixed SBTs = I_c 2.40-2.70. See report text for methods and discussion of parameter evaluation.

Date of plot:
26-01-21
Checked by:
Chris Player

Lankelma Project Ref:
P-107644-7

TEST ID: CPT05

Page 1 of 2



Cone area (mm²):1500
 ConeID: S15-CFIPM(100).1431
 Operator: Gary Connor
 Rig Used: UK22
 Date of test: 19/01/2021 12:16:00

Location: West Sussex, UK
 Coordinates: ,
 Elevation:

Remarks: *Phreatic surface origin: Observation from nearby client borehole records: BH03

Termination Remark:
 Lateral support

Internal QA Diss.
 Dissipation Test
 Penetration
 Pause (<1cm/s)

Both drained and undrained parameters are calculated for mixed SBTs = I_c 2.40-2.70. See report text for methods and discussion of parameter evaluation.

Date of plot: 26-01-21
 Checked by: Chris Player

Lankelma Project Ref: P-107644-7

TEST ID: CPT05

Detailed insitu gas monitoring results

Location	Pipe Ref.	Date / Time of Reading	Instrument	Atmospheric pressure (mB)	Atmospheric Temperature (°C)	Methane, CH ₄ (%v/v) Chg		Carbon dioxide, CO ₂ (%v/v) Chg		Oxygen, O ₂ (%v/v)		Carbon Monoxide	Hydrogen Sulphide	Balance	Lower explosive limit	Gas flow (q)	Peak hazardous gas flow rate Qhgs		Steady hazardous gas flow rate Qhgs		Indicative NHBC guideline		Indicative CIRA Characteristic Situation	Potentially explosive
						Peak	Steady	Peak	Steady	Minimum	Average	(ppm)	(ppm)	(%v/v)	(% LEL)	(l/Hr)	CH ₄	CO ₂	CH ₄	CO ₂	Peak	Steady		
BH04	1	26/02/2021 10:53:00	GA5000	1039	12*	0	0	0.2	0.2	20.6	20.6	0	0	79.2	0	0	0.00	0.00	0.00	0.00	GREEN	GREEN	ONE	NO