Netherlands Enterprise Agency

Geotechnical Report / Investigation Data

Seafloor In Situ Test Locations
Borssele Wind Farm Site III

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Netherlands Enterprise Agency (RVO.nl)
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P.O. Box 8242 | 3503 RE| Utrecht
Netherlands

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Date:	**Our reference**:	**Your reference**:
2016-02-23	DNV Doc. No: 1KI2TUA-14Rev.2 Sign: MICWAG Corresp. No.:	

Zone Borssele Site Data – Preliminary Geotechnical Investigations

The following geotechnical reports produced by Fugro Engineers B.V. have been reviewed by DNV GL:

1. Geotechnical Report / Investigation Data / Geotechnical Borehole Locations / Wind Farm Site III / Borssele Wind Farm Zone / Dutch Sector, North Sea / Report No. N6083/01 Issue 4 / 10-02-2016
2. Geotechnical Report / Investigation Data / Seafloor In Situ Test Locations / Wind Farm Site III / Borssele Wind Farm Zone / Dutch Sector, North Sea / Report No. N6083/02 Issue 3 / 18-12-2015
3. Geotechnical Report / Investigation Data / Geotechnical Borehole Locations / Wind Farm Site IV / Borssele Wind Farm Zone / Dutch Sector, North Sea / Report No. N6083/03 Issue 4 / 10-02-2016
4. Geotechnical Report / Investigation Data / Seafloor In Situ Test Locations / Wind Farm Site IV / Borssele Wind Farm Zone / Dutch Sector, North Sea / Report No. N6083/04 Issue 3 / 18-12-2015

Comments to the documents listed above have been given in the referenced Verification Comments Sheets (Reference /A/ and /B/).
Please note that meanwhile document 1 and 3 were updated to issue 4. However, the verification documented with /A/ and /B/ is still valid.

DNV GL has found that the above referenced reports provide sufficient information to improve the understanding of the geotechnical and geological conditions in the given wind farm areas WFS III and WFS IV. The data in these reports can be used for establishing a Design Basis for Offshore Wind Turbine Structures in accordance with DNV-OS-J101. The chosen sites for the conducted investigations are sufficient to develop an illustration of lateral and vertical soil and seabed variations.

References:

/A/: Verification Comment Sheet "644235-VCS-10"
Revision 01, dated 25.01.2016
Doc-ID: 644235-VCS-10-rev02-Geotechnical_Investigations WFSIII

/B/: Verification Comment Sheet "644235-VCS-11"
Revision 01, dated 25.01.2016
Doc-ID: 644235-VCS-11-rev02-Geotechnical_Investigations WFSIV

Please note that detailed geotechnical investigations will need to be performed in correspondence to the final choice of foundations for the wind turbines in future design phases.

Sincerely
for Det Norske Veritas, Danmark A/S

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Geotechnical Report
Investigation Data
Seafloor In Situ Test Locations
Wind Farm Site III
Borssele Wind Farm Zone
Dutch Sector, North Sea

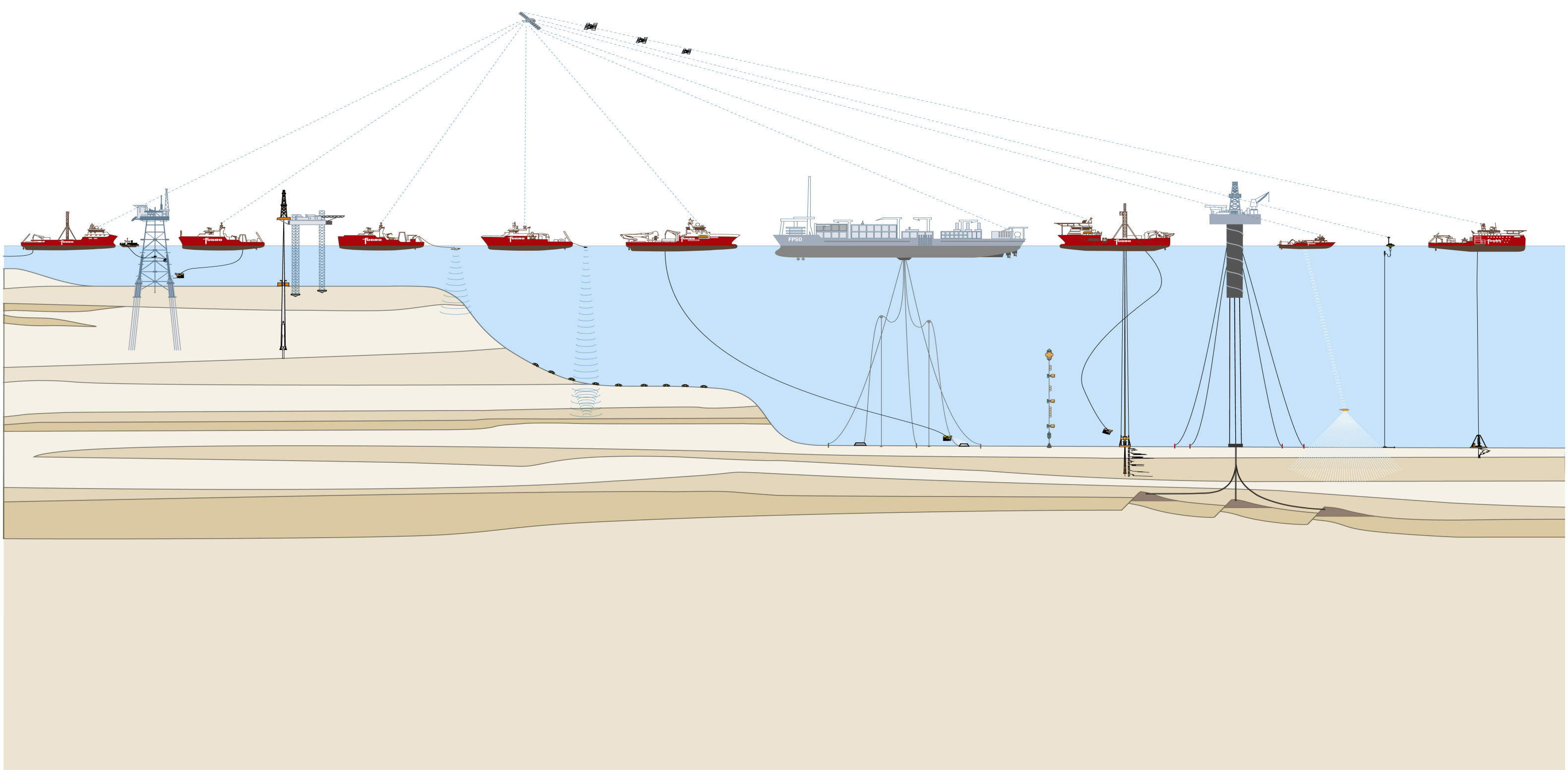
Client Reference No. WOZ1500010

Fugro Report No. N6083/02

Issue 3

Rijksdienst voor Ondernemend Nederland

Rijksdienst voor Ondernemend Nederland (RVO)



Geotechnical Report
Investigation Data
Seafloor In Situ Test Locations
Wind Farm Site III
Borssele Wind Farm Zone
Dutch Sector, North Sea

Client	Rijksdienst voor Ondernemend Nederland (RVO)
Client Address	Croeselaan 15 3521 BJ Utrecht The Netherlands
Client Reference No.	WOZ1500010
Fugro Report No.	**N6083/02 (3)**

Report Issue No.	Date	Report Status	Approved
3	18-Dec-2015	Revised Final	[signature]
2	11-Dec-2015	Final	MKL
1	9-Nov-2015	Fugro approved draft	MKL
0	Various	Provisional data – Individual Logs and CPT data	-

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Rijksdienst voor Ondernemend Nederland (RVO)
Croeselaan 15
3521 BJ Utrecht
The Netherlands

Attention: Mr R. de Bruijne

Our ref: N6083/02 (3)/JLI/EMG

Nootdorp, 18 December 2015

Geotechnical Report – Investigation Data – Seafloor In Situ Test Locations
Wind Farm Site III – Borssele Wind Farm Zone – Dutch Sector, North Sea

This report presents geotechnical information. The report was prepared in accordance with Contract WOZ1500010 between Rijksdienst voor Ondernemend Nederland (RVO) and Fugro Engineers B.V., dated 8 September 2015.

The principal team members for report preparation were Mr J. Marçal Liça, Mr W. Sotthewes, Ms L. Both and Mr J. Bol (Geotechnical Engineers). We acknowledge the valuable assistance of Mr R. de Bruijne, who acted as Client contact for this project.

Thank you for the opportunity to be of service. Please do not hesitate to contact us if you require any additional information.

Yours faithfully
FUGRO ENGINEERS B.V.

E. Schoute
Senior Project Engineer

CONTENTS

REPORT ISSUE CONTROL

Section	Page No.	Plate No.	Issue No.	Revision
Main Text	1	-	3	Editorial corrections to chapter 1.2 (Scope of Report)
Quality Management Record	ii	-	2	Table updated
Summary/ Samenvatting	All	-	2	Editorial corrections and additions
Main Text	All	-	2	Editorial corrections and additions
Plates following Main Text	-	2-1	2	Geodetic parameters corrected
Plates following Main Text	-	2-2 to 2-4	2	Coordinates and water depths updated. Bathymetric data updated for the majority of locations.
Section A	All	-	2	Editorial corrections and additions
Section A	-	All	2	Updates and corrections to strata descriptions and layer boundaries; CPT-derived data updated
Section B1	All	-	2	Unit weight selection comment added; editorial corrections and additions; data format (ASCII) added including literature reference
Section B1	-	Various	2	Plates "Cone Penetration Test; q_t, q_n, R_f and B_q" and "Parameter Values for Net Cone Resistance Calculation" updated with different unit weight value selections; coordinates and water depths updated
Section B2	B2-1	-	2	Editorial corrections and additions
Appendix 2	All	All	2	Positioning Report added
Appendix 3	All	All	2	Recovery Lists added
Appendix 4	All	All	2	Cone Calibration Certificates added

Notes:

1) The definitive copy of this report is held in Fugro's information system
2) Report distribution is restricted to project participants approved by the Client
3) The *report* issue number is the same as the highest issue number of any individual page
4) Pages of this report are at Issue 1, except those pages listed above
5) The number at the bottom left-hand corner of each page shows the Fugro report number and page issue number. The number in brackets indicates the issue number of the page

QUALITY MANAGEMENT RECORD

Project Lead: W. Sotthewes/E. Schoute – Senior Project Engineer

Report Review and Approval: M. Klein – Principal Geotechnical Engineer

Report Section	Prepared By	Checked By
Main Text	JLI	WSO
Plates following Main Text	LBH/JGB	JLI/WSO
A Interpreted CPT Logs	LBH/JGB	JLI/WSO
B In Situ Test Results		
- Cone Penetration Tests	LBH/JGB	JLI/WSO
- Pore Pressure Dissipation Tests	LBH/JGB	JLI/WSO

Person(s):

JGB: J. Bol

JLI: J. Marçal Liça

LBH: L. Both

WSO: W. Sotthewes

SUMMARY

The Dutch Government has developed a systematic framework under which offshore wind farm zones are designated. Within the designated wind farm zones the government decides the specific sites where wind farms can be constructed. Site development will be tendered. Winners of these site development tenders will be granted a permit to build a wind farm, a SDE+ grant, and will be offered a grid connection to the main land. The Ministry of Economic Affairs provides site data, which can be used for the preparation of bids for these tenders. This system is expected to contribute to cost savings.

As part of the tender preparations, the Netherlands Enterprise Agency (RVO), henceforth referred to as 'Client', has requested Fugro to perform a geotechnical investigation of Wind Farm Site WFS III & IV of the Borssele Wind Farm Zone (WFZ). The Borssele Wind Farm Zone is located in the Dutch Sector of the North Sea, approximately 36 km from the coastline (refer to "Vicinity Map" on Page v and "Detailed Location Plan" on Page vi).

The objective of the geotechnical investigation and associated laboratory testing programme for WFS III and WFS IV is to:

- improve the geological and geotechnical understanding;
- update an earlier geological and geophysical model;
- provide a detailed geological ground model;
- determine the vertical and lateral variation in seabed conditions;
- provide relevant geotechnical data to progress the design of windfarm foundation elements, including, but not limited to foundations and cables.

The offshore phase of the geotechnical investigation included geotechnical borehole drilling with downhole sampling and in situ testing, seafloor in situ testing and geotechnical laboratory testing. An office programme of geotechnical laboratory testing and reporting of results followed the offshore phase.

This report is one of a set of Fugro reports. This particular report provides geotechnical results for WFS III and comprises the following:

- Twenty-seven geotechnical logs for 25 locations, which include interpreted results from seafloor cone penetration testing;
- Results of 27 seafloor cone penetration tests at 25 locations, including two additional tests at Client's request;
- Results of three pore pressure dissipation tests at two locations.

The offshore phase of the geotechnical investigation which included the seafloor in situ testing was conducted from the geotechnical vessel Fugro Scout, between 20 October 2015 and 2 November 2015. The water depths at the investigated locations ranged from approximately 17 m to 37 m reduced to Lowest Astronomical Tide.

This report is one in a series of reports prepared as part of this project (refer to "List of Project Reports" on Page vii). Two companion reports for WFS III contain results of geotechnical borehole locations, and describe a geological ground model for WFS III including geological setting, stratigraphy, lateral variability, geohazards and basic geotechnical parameter values respectively.

SAMENVATTING

De Nederlandse overheid heeft een systematisch kader ontwikkeld waarin zones voor windparken op zee zijn aangewezen. De overheid bepaalt in welke specifieke gebieden binnen deze aangewezen zones windparken kunnen worden aangelegd. Ontwikkeling van de gebieden zal volgens subsidie- en vergunningstenders worden gegund. Winnaars van deze tenders zullen een vergunning ontvangen voor de bouw en exploitatie van een windpark, een SDE+ subsidie, en kunnen gebruik maken van een verbinding naar het elektriciteitsnet op het vaste land. Het Ministerie van Economische Zaken stelt locatiegegevens beschikbaar welke gebruikt kunnen worden bij het opstellen van biedingen voor de subsidie- en vergunningstenders. Dit systeem zal naar verwachting bijdragen aan kostenreductie.

T.b.v. de voorbereiding van de inschrijvingen heeft de Rijksdienst Voor Ondernemend Nederland (RVO) Fugro gecontracteerd voor een geotechnisch onderzoek in de kavels WFS III & IV van windgebied Borssele (WFZ). Het windgebied Borssele ligt in het Nederlandse deel van de Noordzee, ongeveer 36 km voor de kust (zie “Vicinity Map” op Page v en “Detailed Location Plan” op Page vi).

Het doel van het geotechnisch onderzoek en bijbehorend programma van laboratoriumproeven is om:

- inzicht te verkrijgen in de geologische en geotechnische omstandigheden;
- het bestaande geofysische en geologische model te verfijnen;
- een gedetailleerd geologisch grondmodel te genereren;
- de verticale en laterale variabiliteit van de grond te bepalen;
- relevante geotechnische data voor de ontwikkeling van het ontwerp van windpark funderingsconstructies beschikbaar te stellen, inclusief maar niet gelimiteerd tot funderingen en kabels.

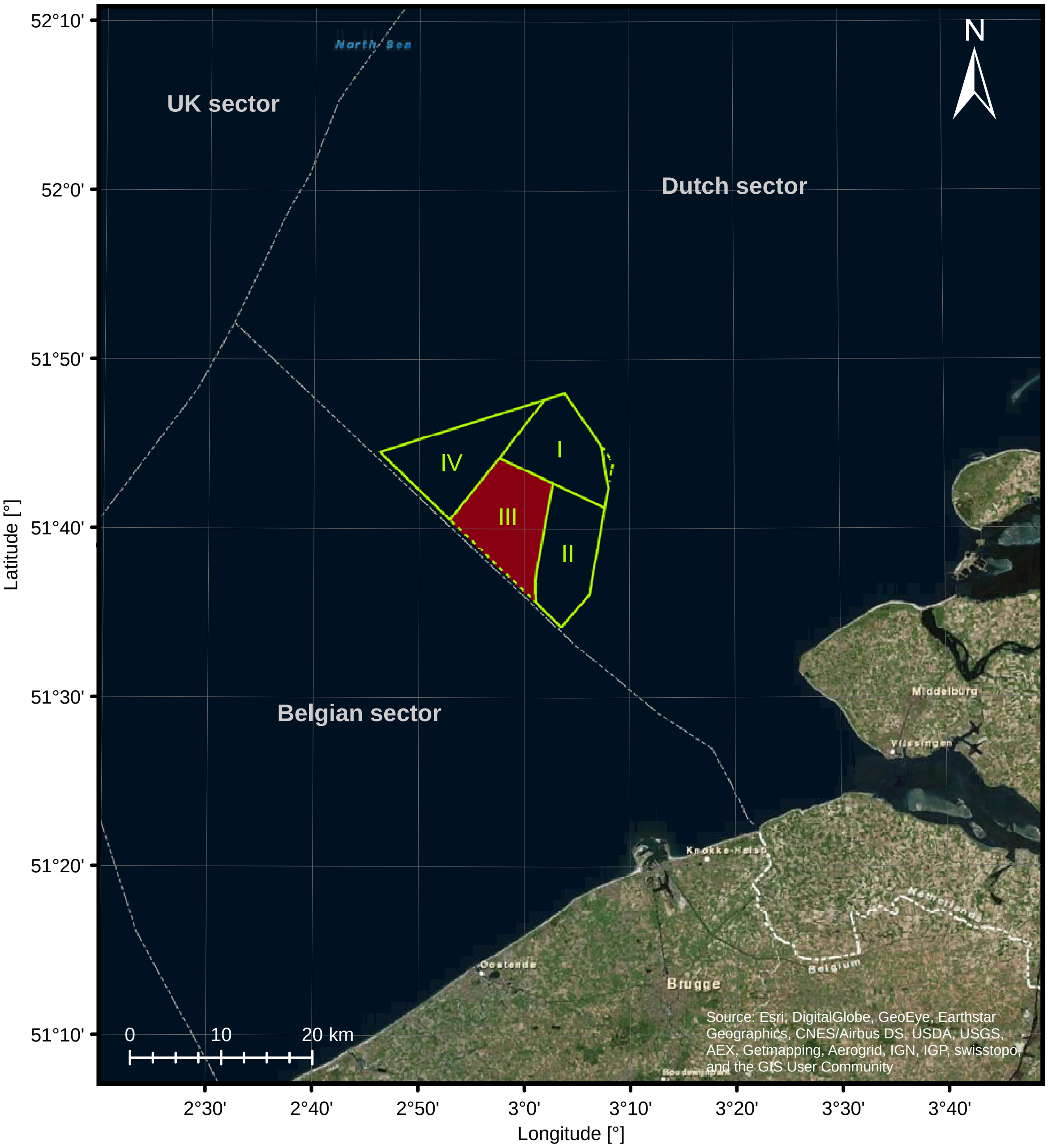
Het geotechnisch onderzoek op locatie bestond uit geotechnische boorgaten met monsternames en in situ testen, sonderingen vanaf de zeebodem en geotechnische laboratoriumproeven. Vervolgens zijn op kantoor een geotechnisch laboratorium testprogramma en rapportage van de resultaten uitgevoerd.

Dit rapport maakt deel uit van een serie van Fugro rapporten. Dit rapport bevat resultaten van geotechnisch onderzoek voor WFS III en omvat het volgende:

- Zevenentwintig geotechnische boorstaten van sonderingen op 25 locaties met geïnterpreteerde resultaten van sonderingen;
- Resultaten van 27 sonderingen, op 25 locaties inclusief twee additionele sonderingen op verzoek van RVO;
- Resultaten van drie dissipatietesten, uitgevoerd op twee locaties.

Het geotechnisch onderzoek op de sondeer locaties is vanaf het geotechnisch boorschip Fugro Scout uitgevoerd tussen 20 oktober en 2 november 2015. De waterdiepte op de testlocaties varieerde van ongeveer 17 m tot 37 m beneden het laagste astronomische getij (LAT).

Dit rapport maakt deel uit van een serie van rapporten t.b.v. dit project (zie “List of Project Reports” op Page vii). Twee andere rapporten die WFS III behandelen bevatten respectievelijk: de resultaten van de boorgaten, en een geologisch grondmodel voor WFS III voorzien van informatie over het geologisch kader, stratigrafie, laterale variabiliteit, geo-risico’s en algemene geotechnische parameters.



Investigation Area III (subject of this report)

Outline of Borssele Wind Farm Zone

Outline Borssele Investigation Area (Roman numeral indicates area number)

Maritime Boundary

Ellipsoid: GRS 1980
Datum: ETRS 1989

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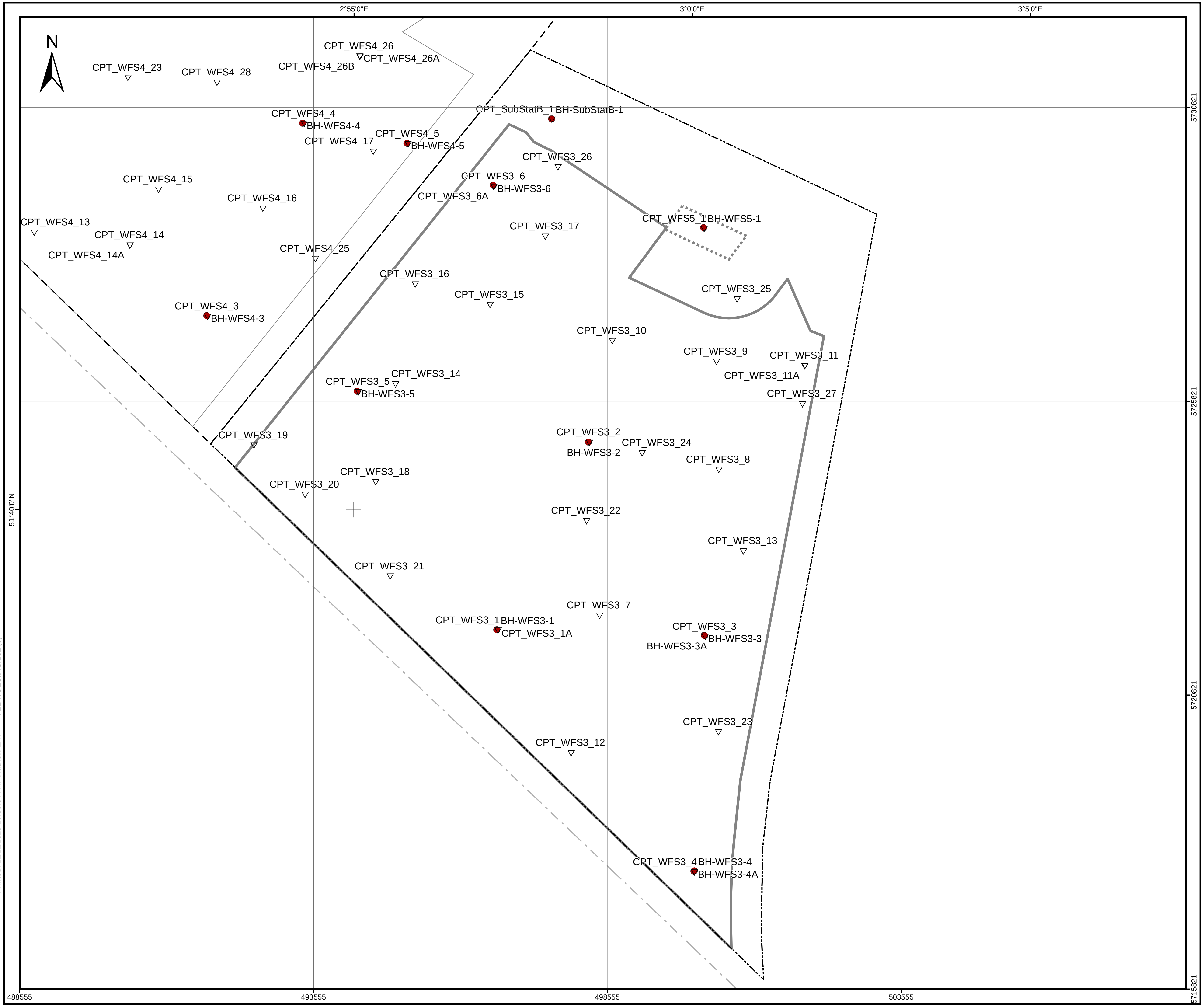
VICINITY MAP

BORSSELE WIND FARM ZONE, WFS III – DUTCH SECTOR, NORTH SEA



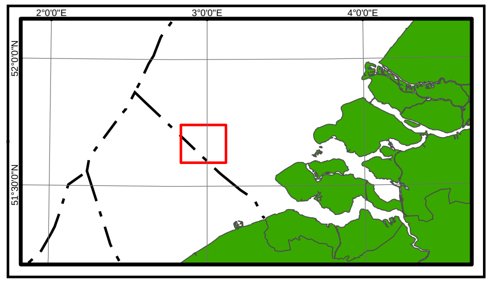
LEGEND:

- CPT location
- BH location
- Outline of WFS V
- Investigation Area III
- Investigation Area IV
- Outline of WFS III
- Outline of WFS IV
- Maritime Boundary

NOTES:

GEODETIC PARAMETERS:

DATUM	ETRS89
Ellipsoid	GRS80
Semi major axis	a = 6 378 137.000
Inverse flattening	1/f = 298.257222101
PROJECTION	UTM, Zone 31 North
Central Meridian (CM)	3° 00' 00" E
Latitude of Origin	0° 00' 00" N
False Easting	500 000 m
False Northing	000 000 m
Scale factor	0.9996
Units	metres/degrees



Rijksdienst voor Ondernemend Nederland (RVO)
Croeselaan 15, 3521 BJ, Utrecht - THE NETHERLANDS

Fugro
Prismastraat 4, 2631 RT, Nootdorp - THE NETHERLANDS

DETAILED LOCATION PLAN

BORSSELE WIND FARM ZONE, WFS III
DUTCH SECTOR, NORTH SEA

Scale 1:60,000
at original A3 page size

0 500 1,000 1,500 2,000 metres

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Printed: 11/11/2015 10:36:34 AM Author: LHT FEBV/GEO/FIG/152 (0)

Report Number	Title	Contents
N6083/01	Geotechnical Report - Investigation Data - Geotechnical Borehole Locations Wind Farm Site III Borssele Wind Farm Zone - Dutch Sector, North Sea	Geotechnical data including geotechnical logs, results from downhole (seismic) cone penetration tests, pore pressure dissipation tests and results from geotechnical laboratory tests.
N6083/02	Geotechnical Report - Investigation Data - Seafloor In Situ Test Locations Wind Farm Site III Borssele Wind Farm Zone - Dutch Sector, North Sea	Geotechnical data including interpreted geotechnical logs, results from seafloor cone penetration tests and pore pressure dissipation tests.
N6083/03	Geotechnical Report - Investigation Data - Geotechnical Borehole Locations Wind Farm Site IV Borssele Wind Farm Zone - Dutch Sector, North Sea	Geotechnical data including geotechnical logs, results from downhole (seismic) cone penetration tests, pore pressure dissipation tests and results from geotechnical laboratory tests.
N6083/04	Geotechnical Report - Investigation Data - Seafloor In Situ Test Locations Wind Farm Site IV Borssele Wind Farm Zone - Dutch Sector, North Sea	Geotechnical data including interpreted geotechnical logs, results from seafloor cone penetration tests and pore pressure dissipation tests.
N6083/05	Geological Ground Model Wind Farm Site III Borssele Wind Farm Zone - Dutch Sector, North Sea	Geological ground model including, stratigraphy, lateral soil variability, geohazards, basic geotechnical parameter values and assessment of geotechnical suitability of selected types of structures.
N6083/06	Geological Ground Model Wind Farm Site IV Borssele Wind Farm Zone - Dutch Sector, North Sea	Geological ground model including, stratigraphy, lateral soil variability, geohazards, basic geotechnical parameter values and assessment of geotechnical suitability of selected types of structures.
N6083/07	Geotechnical Report - Laboratory Test Data Wind Farm Sites III & IV Borssele Wind Farm Zone - Dutch Sector, North Sea	Results of advanced static and cyclic laboratory tests and microscopic analysis.

1. INTRODUCTION

1.1 Purpose of Report

The Dutch Government has developed a systematic framework under which offshore wind farm zones are designated. Within the designated wind farm zones the government decides the specific sites where wind farms can be constructed. Site development will be tendered. Winners of these site development tenders will be granted a permit to build a wind farm, a SDE+ grant, and will be offered a grid connection to the main land. The Ministry of Economic Affairs provides site data, which can be used for the preparation of bids for these tenders. This system is expected to contribute to cost savings.

As part of the tender preparations, the Netherlands Enterprise Agency (RVO), henceforth referred to as 'Client', has requested Fugro to perform a geotechnical investigation of Wind Farm Site WFS III & IV of the Borssele Wind Farm Zone (WFZ). The Borssele Wind Farm Zone is located in the Dutch Sector of the North Sea, approximately 36 km from the coastline (refer to "Vicinity Map" on Plate 1-1 and "Detailed Location Plan" on Plate 1-2).

The objective of the geotechnical investigation and associated laboratory testing programme for WFS III and WFS IV is to:

- improve the geological and geotechnical understanding;
- update an earlier geological and geophysical model;
- provide a detailed geological ground model;
- determine the vertical and lateral variation in seabed conditions;
- provide relevant geotechnical data to progress the design of windfarm foundation elements, including, but not limited to foundations and cables.

The offshore phase of the geotechnical investigation included geotechnical borehole drilling with downhole sampling and in situ testing, seafloor in situ testing and geotechnical laboratory testing. An office programme of geotechnical laboratory testing and reporting of results followed the offshore phase.

1.2 Scope of Report

This report is one of a set of Fugro reports. This particular report provides geotechnical results for WFS III and comprises the following:

- Geotechnical logs for 25 locations, which include interpreted results from seafloor cone penetration testing;
- Results of 27 seafloor Cone Penetration Tests (CPT) at 25 locations, including two additional tests at Client's request;
- Results of three Pore Pressure Dissipation Tests (PPDT) at two locations.

Results presented in this report are for an area demarcated as Investigation Area III (Plates 1-1 and 1-2). WFS III is within this area. The boundaries of WFS III may be subject to change within Investigation Area III.

The term ‘location’ used in this report refers to a specified target location. A location may consist of a single or multiple in situ testing operation(s). Results of the individual testing operations are designated with the term ‘test point’. Test points designated with a suffix A refer to additional test operations at a specific location. For instance, CPT_WFS3_11A is an additional test operation at location WFS3_11, performed after the initial CPT at location WFS3_11 was terminated for reasons other than the agreed stop criteria or at Client request (refer to Section B1 for details). Numbering of the test points presented in this report is not continuous. In situ testing at locations CPT_WFS3_1 and CPT_WFS3_4 were performed as geotechnical borehole with downhole in situ testing and results are presented in a companion report (Refer to Plate 1-3).

This report includes an interpreted CPT log per test point. As a result, multiple logs may be presented for a certain location. Refer to Section B1 titled “Cone Penetration Tests” for further details on additional testing operations.

1.3 Project Responsibilities and Use of Report

This report presents information according to a project specification determined and monitored by the Client. This report must be read in conjunction with “Guide for Use of Report”, Section C.

Fugro understands that this report will be used for the purpose described in this “Introduction” section. That purpose was a significant factor in determining the scope and level of the services. Results must not be used if the purpose for which the report was prepared or the Client’s proposed development or activity changes. Results may possibly suit alternative use. Suitability must be verified.

1.4 Report Format

This report is one in a series of reports. Refer to Plate 1-3 for a list of Fugro Reports prepared as part of this project. Two companion reports for WFS III contain results of geotechnical borehole locations, and describe a geological ground model for WFS III including geological setting, stratigraphy, lateral variability, geohazards and basic geotechnical parameter values respectively.

This report uses and summarises information from sources listed in Section 2. The reader should consult the source information for details. Understanding of site conditions improves upon further data acquisition and interpretation. This means that some of the source interpretations may be superseded by information presented in this report. Similarly, interpretations given in this report may require updating in the future.

The principal sections of this report are the Summary, Main Text, Plates following Main Text, and Sections A and B. Comments are as follows.

- The Summary section allows a quick-scan management overview. It includes a selection of plates. The selected plates are duplicates from a larger set of Plates following Main Text;
- Section 2 of the Main Text focuses on methodology;
- Sections A and B provide the principal information as described in Section 1.2 “Scope of Report”. These sections should be read in conjunction with the Plates following Main Text, where applicable;

- Sections A and B start with primary information, which may consist of links to Plates following Main Text. Plate numbering starts with a Section number, e.g. Plate B1-1 belongs to Section B1;
- Section C and Appendix 1 provide general practice statements and terminology. This background information supports the Main Text. It will be familiar to expert users of the type of information presented in this report.

2. STUDY OVERVIEW

2.1 Sources of Information

This report uses and summarises selected information.

Inspection of Client-supplied information yielded the following:

- Boundaries and coordinates for Wind Farm Zone Borssele (RVO, 2015a);
- Geotechnical scope of work (RVO, 2015b);
- Geological desk study (CRUX, 2014);
- Results of a geophysical survey including: bathymetry, side scan sonar and magnetometer (Fugro, 2015);
- Results of 2D UHR multi-channel seismic (sparker) and sub-bottom profiling (pinger) surveys (Fugro, 2015).

Survey of documents held in the Fugro database provided additional information, including information about the regional geology and general geotechnical data.

2.2 Investigation Programme

2.2.1 Project-specific Data Acquisition

This report includes results from a project-specific geotechnical investigation. The Client planned the investigation programme. During the investigation, the Client's programme was adjusted to suit as-found conditions and operational constraints (for instance minor deviations in target location due to seabed slope). The scope of the report includes the results of the final programme.

The offshore part of the investigation was performed using the geotechnical vessel Fugro Scout between 20 October 2015 and 2 November 2015. The investigation consisted of seafloor in situ testing.

The following sub-sections provide details.

2.2.2 Positioning Survey and Water Depth Measurement

The test points are displayed on Plate 1-2. Borehole locations are included for reference purposes. Coordinates and water depths at the testing points are presented on Plates 2-2 to 2-4. The coordinate reference system uses ETRS89 as datum with spheroid GRS80. The horizontal projection is Universal Transverse Mercator (UTM) with a Central Meridian of 3° East (Zone 31N), refer to Plate 2-1 for details.

Sub-surface positioning was performed using an Ultra Short Base Line (USBL) system with a transmitter mounted on the seafloor test unit. Sound velocity profiles were regularly obtained by a CTD-probe (measuring pressure, conductivity and temperature).

Lowest Astronomical Tide (LAT) and seafloor are used as vertical reference levels for water depth measurement and geotechnical testing. Water depth measurements were performed using an echo sounder mounted on the hull of the vessel and a CTD probe mounted on the seafloor test unit. Charted bathymetric data were used as verification of the water depth measurements (Fugro, 2015). Bathymetric data is included on Plates 2-2 to 2-4.

The user of the geodetic information presented must consider the accuracy of measurements, particularly where use may differ from original intentions. For example, the presented water depth measurements serve to establish the penetration depth below seafloor.

2.2.3 In Situ Testing

The in situ test programme consisted of seafloor Cone Penetration Tests (CPT) at 25 locations and Pore Pressure Dissipation Tests (PPDT) at two locations. CPTs were performed to depths ranging between 4.9 m and 50.3 m below seafloor (bsf). PPDT were performed within a CPT stroke at selected depths.

A SEACALF® 20 tons double block-drive unit was used for the seafloor CPTs in combination with piezo-cone penetrometers with a 1500 mm^2 (CP15) cone tip area.

2.3 Geotechnical Data Processing

Geotechnical data processing included:

- Preparation of geotechnical logs by interpreting CPT data;
- Evaluation, basic verification where practicable and incorporation of selected information supplied by Client;
- Further details on geotechnical data processing are described in Section A “Interpreted CPT Logs”, and Section B “In Situ Test Results”, where appropriate.

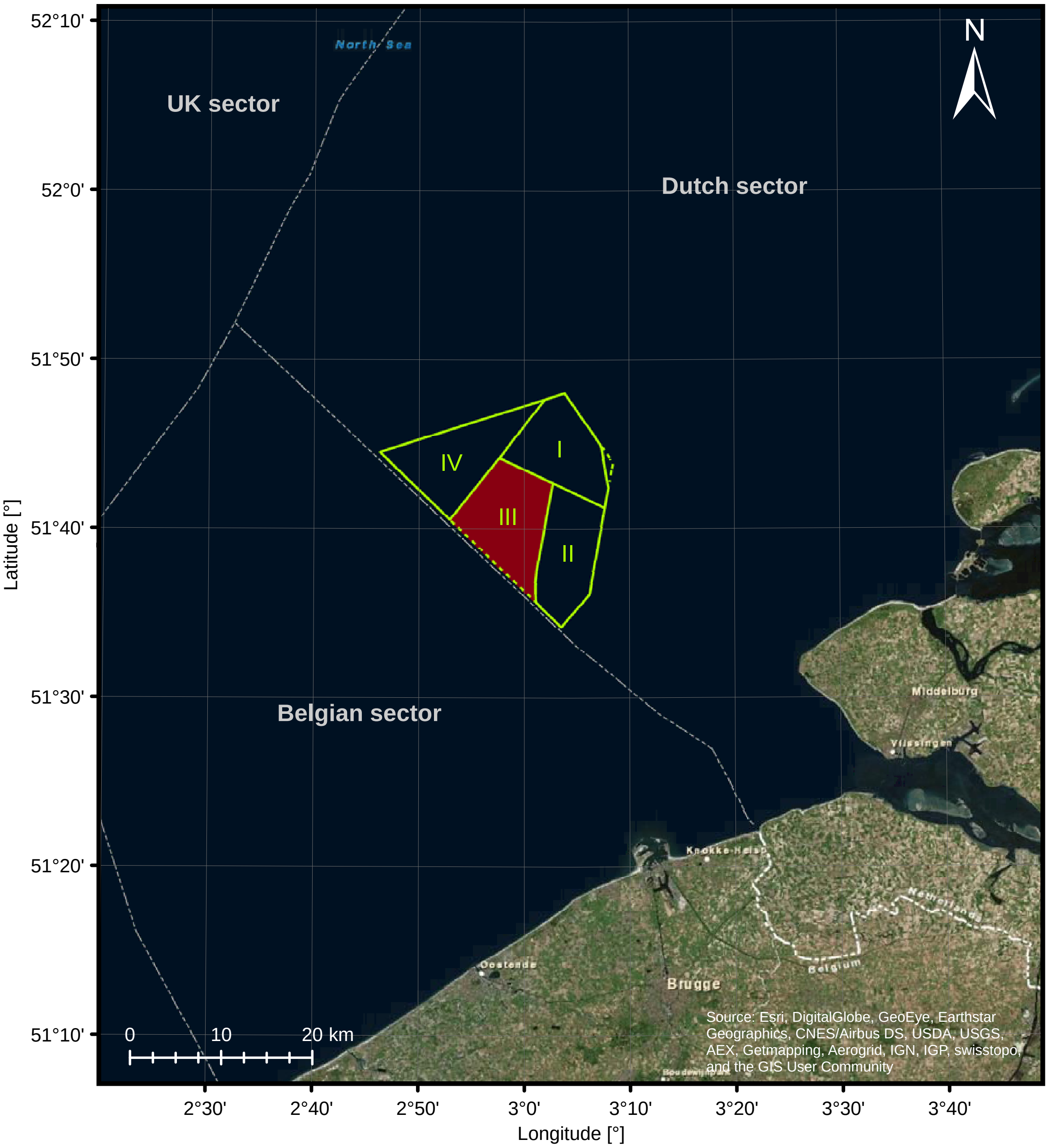
3. REFERENCES

CRUX Engineering BV (2014), “Borssele Wind Farm Zone - Geological Desk Study“, Report No. RE14254a4, Rev 4, 11 December 2014 (Report created by CRUX Engineering BV, ediGEO and GisSense).

Fugro (2015), “Geophysical Site Investigation Survey – Borssele Wind Farm Development Zone – Wind Farm Site III”, Final Issue (Rev A), 14 August 2015.

Rijksdienst voor Ondernemend Nederland (2015a), “Site Studies Wind Farm Zone Borssele – Boundaries & Coordinates Wind Farm Zone”, 23 July 2015.

Rijksdienst voor Ondernemend Nederland (2015b), “Soil Investigations Wind Farm Zones – Section IV-d. Scope of Work Geotechnical Survey - Borssele Wind Farm Zone - Wind Farm Site III & IV”, 8 September 2015.



Investigation Area III (subject of this report)

Outline of Borssele Wind Farm Zone

Outline Borssele Investigation Area (Roman numeral indicates area number)

Maritime Boundary

Ellipsoid: GRS 1980
Datum: ETRS 1989

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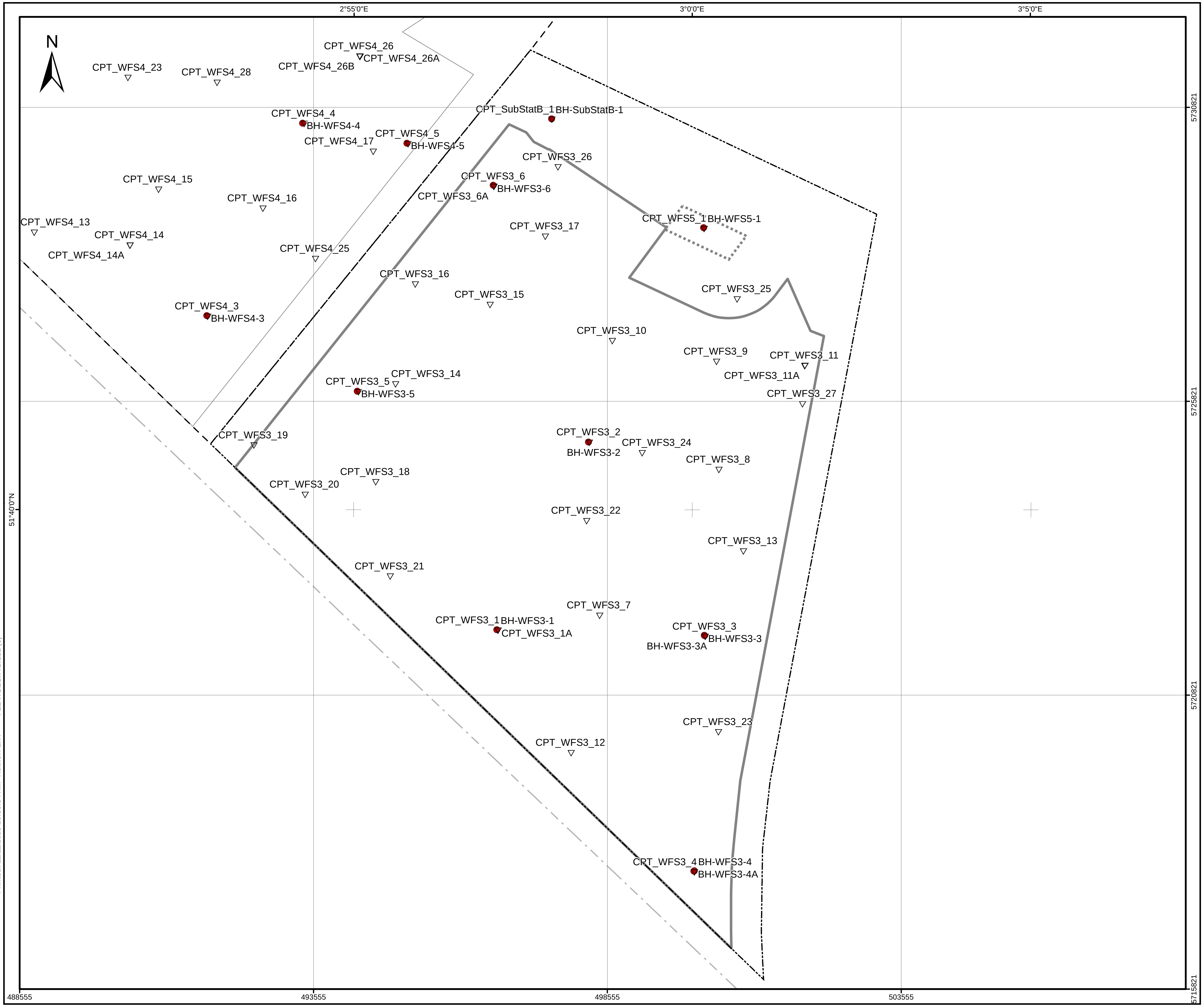
VICINITY MAP

BORSSELE WIND FARM ZONE, WFS III – DUTCH SECTOR, NORTH SEA



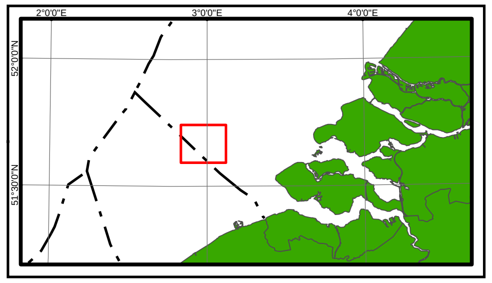
LEGEND:

- ▽ CPT location
- ● BH location
- Outline of WFS V
- Investigation Area III
- Investigation Area IV
- Outline of WFS III
- Outline of WFS IV
- Maritime Boundary

NOTES:

GEODETIC PARAMETERS:

DATUM	ETRS89
Ellipsoid	GRS80
Semi major axis	a = 6 378 137.000
Inverse flattening	1/f = 298.257222101
PROJECTION	UTM, Zone 31 North
Central Meridian (CM)	3° 00' 00" E
Latitude of Origin	0° 00' 00" N
False Easting	500 000 m
False Northing	000 000 m
Scale factor	0.9996
Units	metres/degrees



Rijksdienst voor Ondernemend Nederland (RVO)
Croeselaan 15, 3521 BJ, Utrecht - THE NETHERLANDS

Fugro
Prismastraat 4, 2631 RT, Nootdorp - THE NETHERLANDS

DETAILED LOCATION PLAN

BORSSELE WIND FARM ZONE, WFS III
DUTCH SECTOR, NORTH SEA

Scale 1:60,000
at original A3 page size

0 500 1,000 1,500 2,000 metres

FUGRO

Fugro Report No. N6083/02	Issue 2	Plate 1-2

Report Number	Title	Contents
N6083/01	Geotechnical Report - Investigation Data - Geotechnical Borehole Locations Wind Farm Site III Borssele Wind Farm Zone - Dutch Sector, North Sea	Geotechnical data including geotechnical logs, results from downhole (seismic) cone penetration tests, pore pressure dissipation tests and results from geotechnical laboratory tests.
N6083/02	Geotechnical Report - Investigation Data - Seafloor In Situ Test Locations Wind Farm Site III Borssele Wind Farm Zone - Dutch Sector, North Sea	Geotechnical data including interpreted geotechnical logs, results from seafloor cone penetration tests and pore pressure dissipation tests.
N6083/03	Geotechnical Report - Investigation Data - Geotechnical Borehole Locations Wind Farm Site IV Borssele Wind Farm Zone - Dutch Sector, North Sea	Geotechnical data including geotechnical logs, results from downhole (seismic) cone penetration tests, pore pressure dissipation tests and results from geotechnical laboratory tests.
N6083/04	Geotechnical Report - Investigation Data - Seafloor In Situ Test Locations Wind Farm Site IV Borssele Wind Farm Zone - Dutch Sector, North Sea	Geotechnical data including interpreted geotechnical logs, results from seafloor cone penetration tests and pore pressure dissipation tests.
N6083/05	Geological Ground Model Wind Farm Site III Borssele Wind Farm Zone - Dutch Sector, North Sea	Geological ground model including, stratigraphy, lateral soil variability, geohazards, basic geotechnical parameter values and assessment of geotechnical suitability of selected types of structures.
N6083/06	Geological Ground Model Wind Farm Site IV Borssele Wind Farm Zone - Dutch Sector, North Sea	Geological ground model including, stratigraphy, lateral soil variability, geohazards, basic geotechnical parameter values and assessment of geotechnical suitability of selected types of structures.
N6083/07	Geotechnical Report - Laboratory Test Data Wind Farm Sites III & IV Borssele Wind Farm Zone - Dutch Sector, North Sea	Results of advanced static and cyclic laboratory tests and microscopic analysis.

LIST OF FUGRO REPORTS
BORSSELE WIND FARM ZONE, WFS III – DUTCH SECTOR, NORTH SEA

DGPS Geodetic Parameters		
Datum		WGS84 (World Geodetic System 1984)
Spheroid		WGS84 (World Geodetic System 1984)
Semi-Major Axis, a		6378137.000 m
Inverse Flattening, 1/f		298.257223563
Transformation Parameters (from WGS84 to Local Grid for Epoch 2015.816438356 (26 October 2015))		
Source Shift		
dX		+0.05368 m
dY		+0.05088 m
dZ		- 0.08697 m
Rotation and Scale		
rX		- 0.002172“
rY		- 0.013104”
rZ		+0.021239”
dS (Scale Factor)		0.002605 ppm
Local Grid Geodetic Parameters		
Datum		ETRS89 (European Terrestrial Reference System 1989)
Ellipsoid		GRS80 (Geodetic Reference System 1980)
Semi-Major Axis, a		6378137.000 m
Inverse Flattening, 1/f		298.257222101
Local Projection Parameters		
Projection		Universal Transverse Mercator
UTM Zone		31 North
Central Meridian (CM)		03° 00’ 00” E
Latitude of Origin		00° 00’ 00” N
False Easting		500 000 m
False Northing		000 000
Scale Factor on CM		0.9996
Units		metres
Example Coordinates		
Local grid coordinates	Easting	503819.64 m
	Northing	5738442.18 m
Local geographical coordinates	Latitude	51° 47’ 48.5644” N
	Longitude	03° 03’ 19.3986” E
WGS84 geographical coordinates	Latitude	51° 47’ 48.5803” N
	Longitude	03° 03’ 19.4204” E

GEODETIC PARAMETERS

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

COORDINATES

Testing Point	Penetration Depth [m]	Easting [m]	Northing [m]	Latitude [deg]	Longitude [deg]
CPT_WFS3_2	43.1	498234	5725141	51°40'38.1" N	2°58'28.0" E
CPT_WFS3_3	47.2	500208	5721837	51°38'51.1" N	3°0'10.8" E
CPT_WFS3_5	39.4	494308	5726002	51°41'5.8" N	2°55'3.6" E
CPT_WFS3_6	20.9	496611	5729494	51°42'58.9" N	2°57'3.4" E
CPT_WFS3_6A	21.0	496608	5729497	51°42'59.0" N	2°57'3.2" E
CPT_WFS3_7	43.7	498408	5722197	51°39'2.8" N	2°58'37.2" E
CPT_WFS3_8	19.0	500438	5724679	51°40'23.1" N	3°0'22.8" E
CPT_WFS3_9	24.4	500399	5726517	51°41'22.6" N	3°0'20.8" E
CPT_WFS3_10	17.7	498625	5726871	51°41'34.1" N	2°58'48.4" E
CPT_WFS3_11	4.9	501904	5726449	51°41'20.4" N	3°1'39.2" E

Datum : ETRS89 Projection : Universal Transverse Mercator
Ellipsoid : GRS80 Central Meridian : 3° E
Penetration Depth: deepest point reached by in situ testing, relative to seafloor

WATER DEPTH

Testing Point	Date	Echo Sounder Reduced [m]	CTD Probe Reduced [m]	Bathymetry Chart Reduced [m]
CPT_WFS3_2	25-Oct-2015	36.9	36.8	37.2
CPT_WFS3_3	27-Oct-2015	28.4	28.4	28.6
CPT_WFS3_5	29-Oct-2015	29.3	29.2	29.5
CPT_WFS3_6	31-Oct-2015	33.4	33.0	33.9
CPT_WFS3_6A	31-Oct-2015	33.6	33.3	33.7
CPT_WFS3_7	27-Oct-2015	28.8	28.5	29.0
CPT_WFS3_8	26-Oct-2015	20.3	20.6	20.8
CPT_WFS3_9	30-Oct-2015	25.0	24.8	25.3
CPT_WFS3_10	30-Oct-2015	34.7	34.8	35.2
CPT_WFS3_11	31-Oct-2015	25.1	24.9	25.4

Reduced water depths are relative to Lowest Astronomical Tide (LAT)

GeODin/Coordinates and Water Depth Seafloor - ES+CTD+Bath.GLO/2015-11-23 17:08:10

COORDINATES AND WATER DEPTH

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

COORDINATES

Testing Point	Penetration Depth [m]	Easting [m]	Northing [m]	Latitude [deg]	Longitude [deg]
CPT_WFS3_11A	26.1	501900	5726444	51°41'20.2" N	3°1'39.0" E
CPT_WFS3_12	30.2	497925	5719860	51°37'47.1" N	2°58'12.1" E
CPT_WFS3_13	49.9	500855	5723291	51°39'38.2" N	3°0'44.5" E
CPT_WFS3_14	39.3	494938	5726134	51°41'10.1" N	2°55'36.4" E
CPT_WFS3_15	49.1	496545	5727484	51°41'53.9" N	2°57'0.0" E
CPT_WFS3_16	44.8	495274	5727833	51°42'5.1" N	2°55'53.8" E
CPT_WFS3_17	11.2	497485	5728646	51°42'31.5" N	2°57'48.9" E
CPT_WFS3_18	12.9	494599	5724469	51°40'16.2" N	2°55'18.8" E
CPT_WFS3_19	40.2	492527	5725094	51°40'36.4" N	2°53'30.9" E
CPT_WFS3_20	24.2	493397	5724254	51°40'9.2" N	2°54'16.3" E

Datum : ETRS89 Projection : Universal Transverse Mercator
Ellipsoid : GRS80 Central Meridian : 3° E
Penetration Depth: deepest point reached by in situ testing, relative to seafloor

WATER DEPTH

Testing Point	Date	Echo Sounder Reduced [m]	CTD Probe Reduced [m]	Bathymetry Chart Reduced [m]
CPT_WFS3_11A	31-Oct-2015	25.1	24.9	25.3
CPT_WFS3_12	27-Oct-2015	32.6	32.4	32.5
CPT_WFS3_13	26-Oct-2015	30.3	30.6	30.8
CPT_WFS3_14	29-Oct-2015	30.9	30.8	31.1
CPT_WFS3_15	29-Oct-2015	33.6	33.4	33.8
CPT_WFS3_16	29-Oct-2015	30.9	30.6	31.1
CPT_WFS3_17	31-Oct-2015	33.1	33.2	33.5
CPT_WFS3_18	28-Oct-2015	29.1	28.7	28.9
CPT_WFS3_19	29-Oct-2015	30.2	30.2	30.5
CPT_WFS3_20	28-Oct-2015	31.1	30.5	31.0

Reduced water depths are relative to Lowest Astronomical Tide (LAT)

GeODin/Coordinates and Water Depth Seafloor - ES+CTD+Bath.GLO/2015-11-23 17:08:10

COORDINATES AND WATER DEPTH

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

COORDINATES

Testing Point	Penetration Depth [m]	Easting [m]	Northing [m]	Latitude [deg]	Longitude [deg]
CPT_WFS3_21	39.9	494845	5722865	51°39'24.3" N	2°55'31.7" E
CPT_WFS3_22	50.3	498189	5723807	51°39'54.9" N	2°58'25.7" E
CPT_WFS3_23	44.7	500432	5720215	51°37'58.6" N	3°0'22.5" E
CPT_WFS3_24	28.2	499134	5724964	51°40'32.3" N	2°59'14.9" E
CPT_WFS3_25	24.8	500748	5727579	51°41'57.0" N	3°0'39.0" E
CPT_WFS3_26	21.3	497701	5729827	51°43'9.7" N	2°58'0.2" E
CPT_WFS3_27	28.8	501862	5725796	51°40'59.2" N	3°1'37.0" E

Datum : ETRS89 Projection : Universal Transverse Mercator
Ellipsoid : GRS80 Central Meridian : 3° E
Penetration Depth: deepest point reached by in situ testing, relative to seafloor

WATER DEPTH

Testing Point	Date	Echo Sounder Reduced [m]	CTD Probe Reduced [m]	Bathymetry Chart Reduced [m]
CPT_WFS3_21	28-Oct-2015	29.9	29.8	29.7
CPT_WFS3_22	26-Oct-2015	22.0	21.8	22.2
CPT_WFS3_23	27-Oct-2015	29.9	29.8	29.7
CPT_WFS3_24	26-Oct-2015	17.5	17.4	17.6
CPT_WFS3_25	31-Oct-2015	29.2	28.9	29.4
CPT_WFS3_26	31-Oct-2015	28.9	28.9	29.4
CPT_WFS3_27	31-Oct-2015	24.8	24.6	25.1

Reduced water depths are relative to Lowest Astronomical Tide (LAT)

GeODin/Coordinates and Water Depth Seafloor - ES+CTD+Bath.GLO/2015-11-23 17:08:10

COORDINATES AND WATER DEPTH

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

SECTION A: INTERPRETED CPT LOGS

TEXT – SECTION A: Page

LIST OF PLATES IN SECTION A: Plate

A. INTERPRETED CPT LOGS

A.1 COMMENTS ON RESULTS

This section presents interpreted Cone Penetration Test (CPT) logs. A log is presented per test point. Hence, for several locations multiple interpreted CPT logs are included; refer to Section B1 titled “Cone Penetration Tests” for details. Interpreted CPT logs include interpretation of the soil profile and associated strata description.

The interpreted CPT logs present undrained shear strength for fine-grained cohesive layers and relative density for coarse-grained cohesionless layers. Distinction was made between undrained shear strength (s_u) and relative density (D_r) for soil layers or sub layers with a thickness of 0.6 m or more, i.e. for thick beds and thicker. In other cases the CPT interpretation for the dominant soil type was maintained.

At various locations only limited penetration was achieved in the deepest interpreted layer, for example within unit E4 at location CPT_WFS3_6. D_r or s_u have been omitted from the strata description in case cone penetration was less than 0.3 m as D_r or s_u may not necessarily be typical for such layer.

In coarse-grained cohesionless layers, significant reduction in cone resistance (q_c) is occasionally observed and is associated with an increase of the fines fraction, i.e. the silt and clay fractions. Where applicable, these have been interpreted as beds of (very) clayey sand.

The geotechnical logs include a geotechnical unit identification. Division into geotechnical units and sub-units is based on:

- Geological formations and formation members’ boundaries interpreted from seismic reflection data;
- Geotechnical characteristics identified from the available in situ test data;
- Thicknesses of soil layers (i.e. main soil types) and their lateral continuity across the site.

The following naming convention was used:

- Capital letters have been assigned to each geological formation (i.e. A, B, C etc.);
- Numbers have been assigned to each geological formation member;
- Where difference in distinct geotechnical characteristics is evident within a formation member, lower case letters were assigned to a soil layer of considerable thickness (i.e. very thick beds, thus thicker than 2 m) that are laterally continuous across the site.

Companion Fugro Report N6083/05 (refer to Plate titled “List of Fugro Reports” following the Main Text) provides a detailed description of the geological formations (members) and geotechnical units. General stratigraphy for WFS III & IV is reproduced in Table A.1.

Table A.1 Stratigraphical Division of WFS III & IV

Unit	Sub-unit	Formation (Member)	Unit Description	Lower Unit Boundary Differentiators
A	-	Southern Bight (-)	Very loose to very dense (fine to) medium SAND, locally (slightly) gravelly and with beds of (slightly) gravelly clayey sand or clay	– Locally at base a bed of (slightly) gravelly clayey sand or clay – Locally, clear colour change observed – Frequently difficult to discriminate from the unit below. Where geotechnical boundary was not clear, the lower boundary is based on seismic data
B	-	Kreftenheye/ Eem (-)	– Medium dense to very dense fine to medium SAND, locally (slightly) gravelly – Unit has chaotic character on seismic data	– Typically sharp, erosional and clearly defined from the seismic data – Generally clear change in pore pressure response – Regularly relatively higher cone tip resistance than unit below
C1	-	Westkapelle Ground / Brielle Ground (-)	Alternation of dense fine SAND and stiff to very stiff CLAY	Typically sharp with relatively lower cone tip resistance than unit below (Unit C2)
C2	-	Westkapelle Ground / Brielle Ground (-)	Dense to very dense fine to coarse silty SAND, locally slightly gravelly	– Typically sharp, erosional on seismic data – Occasionally short and gradual transition from very dense sand to clay of unit below. This transition interval is included in Unit C2
D	-	Rupel (Rupel Clay)	Stiff to very stiff CLAY	Typically gradual from clay to very clayey sand. This transition interval is included in Unit E1
E1	-	Tongeren (Ruisbroek Sand)	Medium dense to very dense fine SAND, locally silty, locally (very) clayey, locally with beds of glauconitic sand	– Unit spatially variable and locally similar to Unit E2 – Where observed, the boundary was taken at a shift in friction ratio to above 2% and decrease in cone resistance
E2	-	Tongeren (Watervliet Clay)	– Very stiff to hard (sandy) CLAY, locally with beds of sand – Medium dense clayey or silty fine SAND	– Unit spatially variable and locally similar to Unit E3 – Where observed, the boundary was taken at shift in cone tip resistance towards higher values and decrease in friction ratio
E3	-	Tongeren (Bassevelde 3 Sand)	Medium dense to very dense silty fine to medium SAND, locally with beds of glauconitic sand, locally with beds of clay or clayey sand	Typically sharp, at top of very dense sand of Unit E4
E4	-	Tongeren (Bassevelde 2 Sand)	– Very dense fine to medium SAND – High cone tip resistance (frequent refusals)	Typically sharp, taken at base of very dense sand
E5	E5a	Tongeren (Bassevelde 1 Sand)	– Dense to very dense (slightly) silty fine SAND – Locally very silty	Typically taken at start of intervals (beds) with high friction ratios (>2%), associated with increased presence of glauconitic sands
	E5b		– Medium dense to dense (slightly) silty fine SAND, locally with beds of glauconitic sand – Locally very silty	Typically gradual; the transition interval is given to unit below

Unit	Sub-unit	Formation (Member)	Unit Description	Lower Unit Boundary Differentiators
F1	F1a	Dongen (Onderdijke)	Very stiff to hard (slightly/very) sandy CLAY, with beds of (very) sandy clay, with beds of ((very) clayey) sand, locally with pockets of sand	Typically sharp
	F1b		– Hard (slightly/very) sandy CLAY – Locally silt	– Typically sharp – Clear boundary in seismic reflection data (a seismo-stratigraphic boundary)
	F1c		Stiff to very stiff (sandy) CLAY, fissured	Sharp or gradual; the transition interval is given to unit below
F2	-	Dongen (Buisputten)	Dense to very dense becoming medium dense to dense clayey or silty SAND, locally with a bed of very clayey sand	Typically gradual, the transition interval is included in Unit F2.
F3	-	Dongen (Zomergem)	Very stiff to hard CLAY, fissured, locally with pockets of sand	Not penetrated - end of borehole

Notes:
- The table describes the stratigraphy for both WFSIII and IV. Not all units may have been investigated or are present across both WFS III and WFS IV.
- The Lower Unit Boundary Differentiators were used for interpretation of stratigraphy at the borehole and seafloor CPT locations, not all differentiators are applicable for every individual location

Relative density presented on the interpreted CPT logs is estimated using an empirical expression recommended by Jamiolkowski et al. (2003) for silica sands. Jamiolkowski et al. (2003) proposes a relationship between cone resistance (q_c) and D_r for silica sands (for details refer to document titled “Cone Penetration Test Interpretation” in Appendix 1). This relationship has limited applicability in layers with a significant percentage of fines (i.e. >10% silt and/or clay fractions) and in layers from seafloor to about 2 m to 3 m below seafloor. Relative density interpretation for these layers should be used with caution.

For correlation of s_u with CPT data (net cone resistance) typical cone factors (N_k) of 15 to 20 have been used. Site, layer or test type specific N_k assessment was beyond the scope of this report. Such assessment may be appropriate for specific use of CPT derived strength values.

Strata descriptions are based on CPT data, use the Robertson (1990) and Robertson (2009) methodology, and have been updated to BSI (1999). Strata descriptions are supported by knowledge of local geology and the results from sampling and in situ testing at nearby borehole locations.

High sleeve frictions and friction ratios were noted in various CPTs within sand layers. These high values were attributed to the presence of glauconite, refer to Section B.1 for details. The precise quantity and distribution of glauconite is likely to vary spatially within the various soil units. Also, a precise relation between the quantity of glauconite and associated CPT response was not established during this project, nor was such relationship found within literature available within the public domain. A descriptive terminology was selected for the geotechnical logs, i.e. “with beds of glauconitic sand”, but does not indicate the quantity of glauconite within these beds. Microscopic verification of selected samples is presented in companion report N6083/07 (see Plate 1-3).

A.2 PRACTICE FOR INTERPRETED GEOTECHNICAL LOG FROM CPT

Approach

Purpose:	Support of planning and design of subsea structures, e.g. foundations and cables
General Procedure:	According to ISO (2014)

Results

Data Processing and Interpretation:	– UNIPLOT software – Graphical scales selected to suit general presentation of data – No display of data outside of chart limits, i.e. some values may not be shown – Geotechnical description is an interpretation of processed data available at the time of preparation; for example, interfaces between strata may be more gradual than a log indicates – Level of detail and accuracy in geotechnical description and interpretation depend on factors such as investigation system(s), logging/ test data, sample size, quality, coverage, availability of supplementary information, and project requirements
Data Format(s):	– PDF for viewing and printing (this primary document)
Matching Test, Sample and Logging Data:	Refer to Section Text for details on matching data
Ground Description:	According to Robertson (1990) and Robertson (2009), updated to BSI (1999)
Unit Weight derived from In Situ Test:	Not applicable
Relative Density derived from In Situ Test:	If applicable: – refer to document titled "Cone Penetration Test Interpretation" presented in Appendix 1 – according to Jamiolkowski et al. (2003) for saturated coarse-grained, cohesionless soil behaviour, Ticino Sand correlation – based on earth pressure coefficient K_0 of 0.5 and 1.0
Undrained Shear Strength derived from In Situ Test:	If applicable: – refer to document titled "Cone Penetration Test Interpretation" presented in Appendix 1 – applies to interpreted fine-grained, cohesive soil behaviour – based on default cone factors of N_k = 15 and 20
Coordinates and Water Depth:	Applicable to test point
Water Depth Reference:	As obtained from echo sounder readings at start of testing, reduced to LAT
Depth Reference Correction:	None applied, in situ testing assumed continuous from seafloor to recovery depth, with no continuity gaps

References

– Computer Program UNIPLOT, Processing, Presentation and Analysis of In Situ Test Data.
– Computer Program GeODin®, Recording, Presentation and Analysis of Geo-data.
– ISO International Organization for Standardization (2014), "Petroleum and Natural Gas Industries - Specific Requirements for Offshore Structures – Part 8: Marine Soil Investigations", International Standard ISO 19901-8:2014.

- BSI British Standards Institution (1999), "Code of Practice for Site Investigations", British Standard BS 5930:1999.
- Jamiolkowski, M., Lo Presti, D.C.F. and Manassero, M. (2003), "Evaluation of Relative Density and Shear Strength of Sands from CPT and DMT", in Germaine, J.T., Sheahan, T.C. and Whitman, R.V. (Eds.), Soil Behavior and Soft Ground Construction: Proceedings of the Symposium, October 5-6, 2001, Cambridge, Massachusetts, Geotechnical Special Publication, No. 119, American Society of Civil Engineers, Reston, pp. 201-238.
- Robertson, P.K. (1990), "Soil Classification using the Cone Penetration Test", Can. Geotech. Jnl., Vol. 27, No. 1, pp. 151-158.
- Robertson, P.K. (2009), "Performance Based Earthquake Design Using the CPT", in Kokusho, T., Tsukamoto, Y. and Yoshimine, M. (Eds.), Performance-Based Design in Earthquake Geotechnical Engineering – from Case History to Practice: Proceedings of the International Conference on Performance-Based Design in Earthquake Geotechnical Engineering (IS-Tokyo 2009), 15-18 June 2009, CRC Press, Boca Raton, pp. 3-20.

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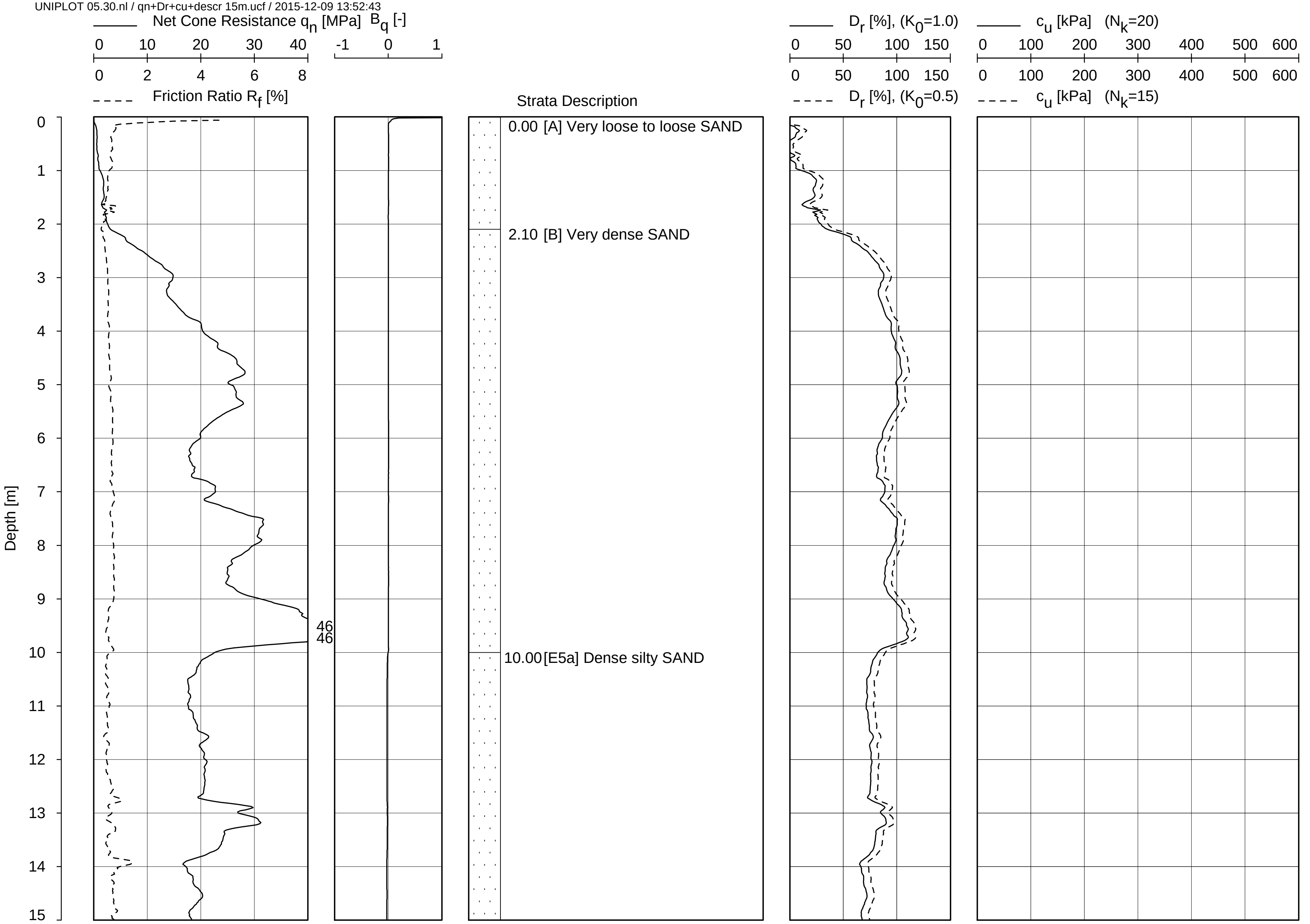

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Coordinates [m] : E498234 N5725141

CPT DATA INTERPRETATION

CPT_WFS3_2

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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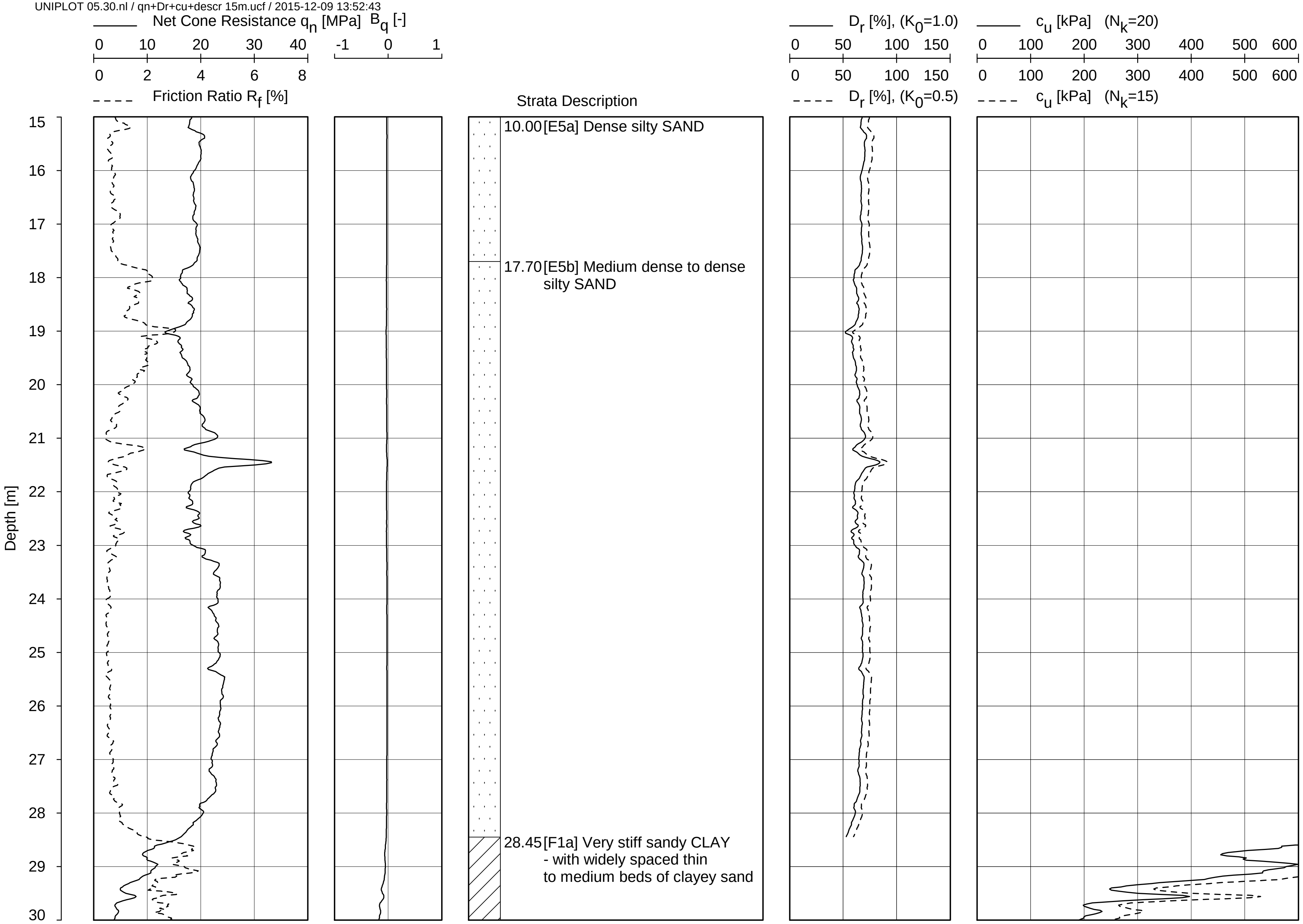
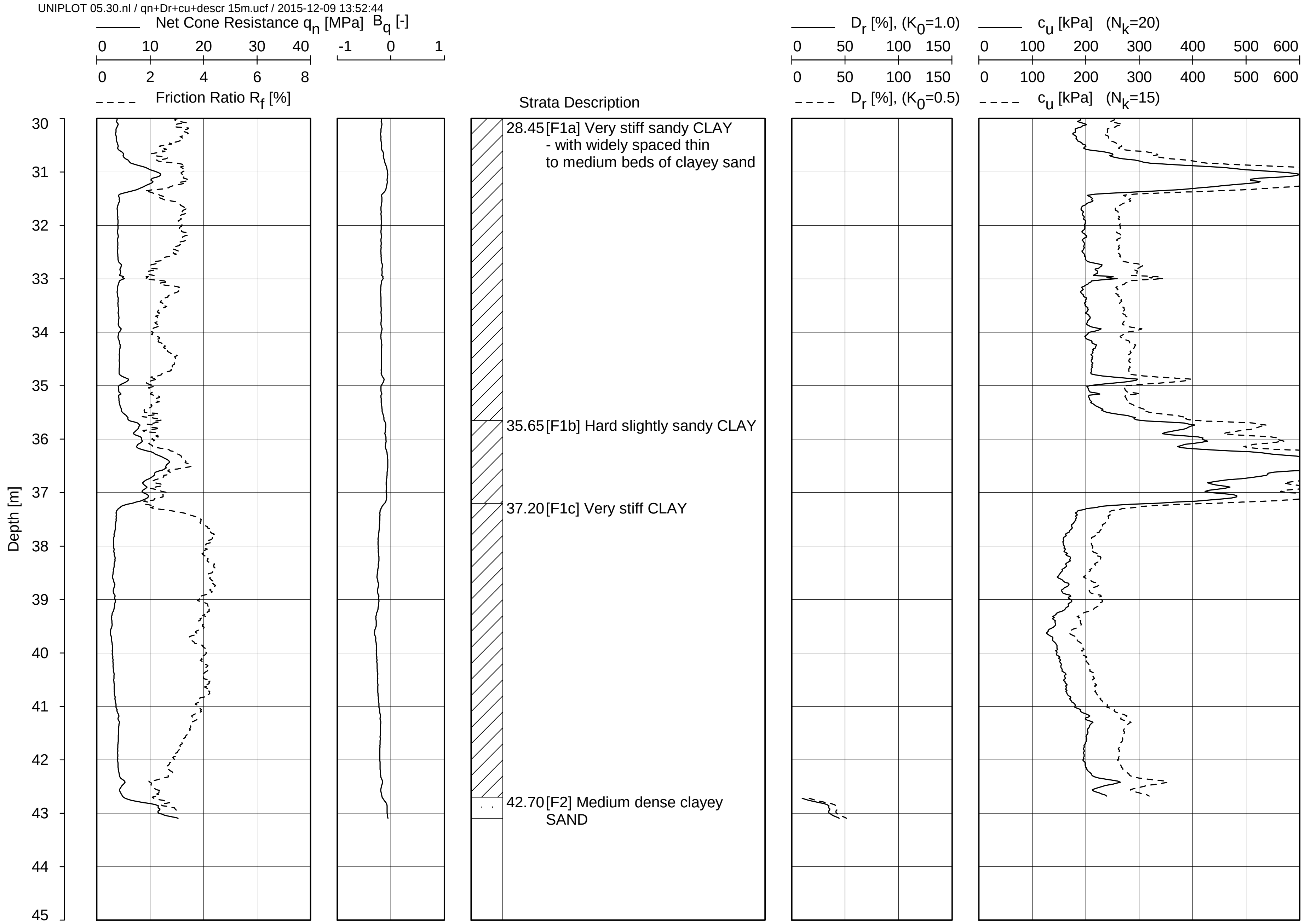


Date Of Testing : 30-Oct-2015
Water Depth [m] : 36.9
Coordinates [m] : E498234 N5725141

CPT DATA INTERPRETATION

CPT_WFS3_2

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

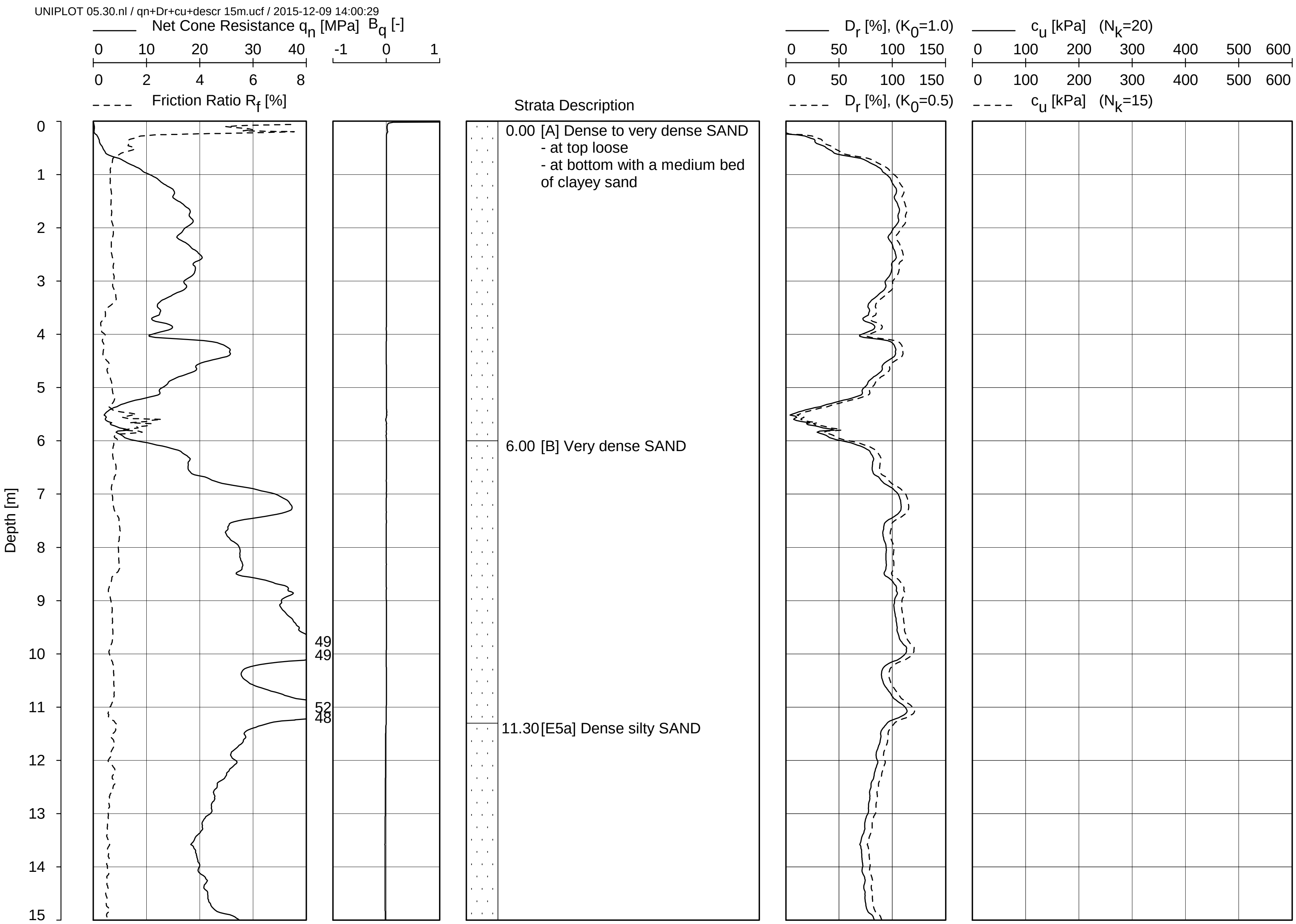


Date Of Testing : 30-Oct-2015
Water Depth [m] : 36.9
Coordinates [m] : E498234 N5725141

CPT DATA INTERPRETATION

CPT_WFS3_2

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



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Coordinates [m] : E500208 N5721837

CPT DATA INTERPRETATION

CPT_WFS3_3

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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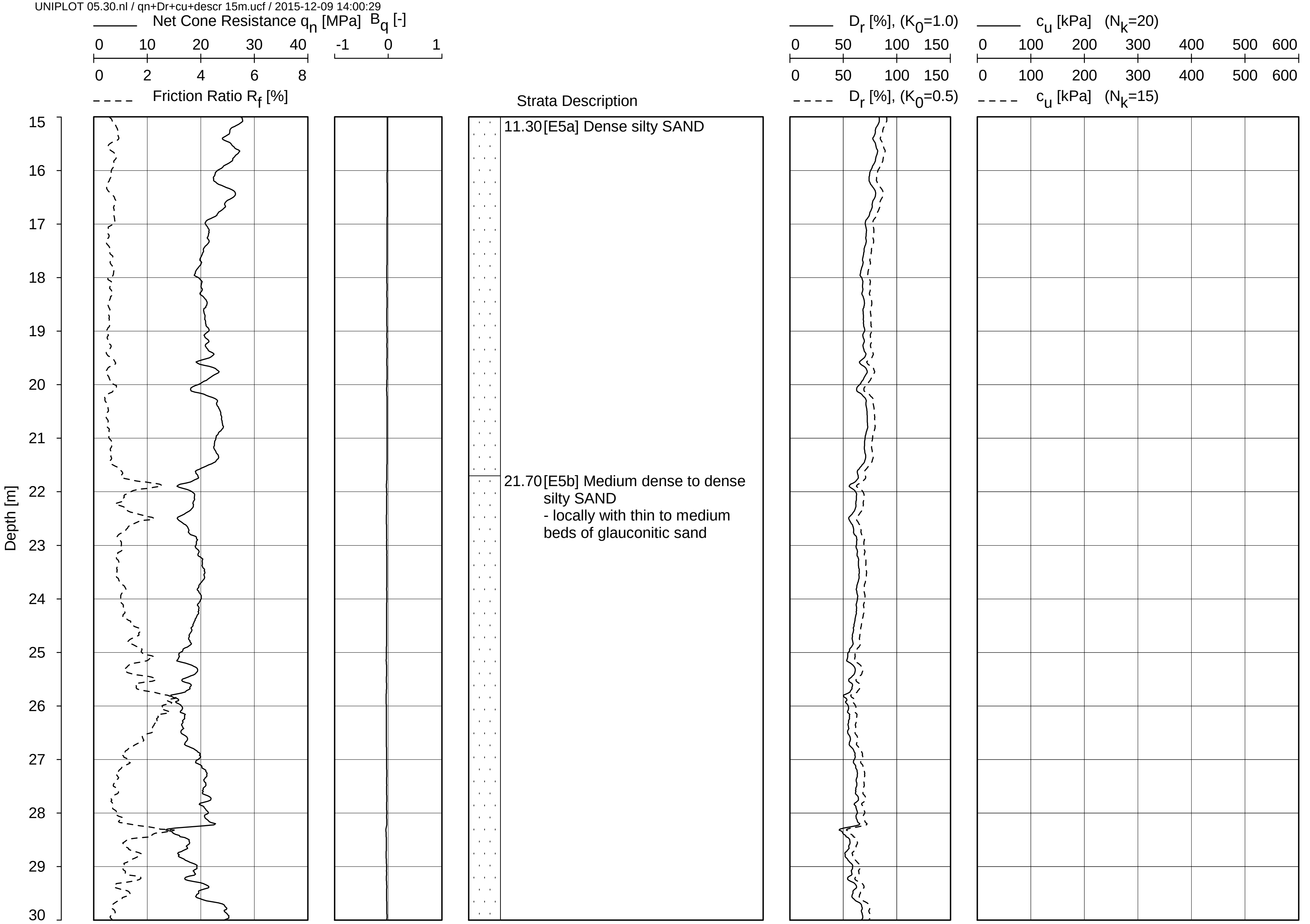


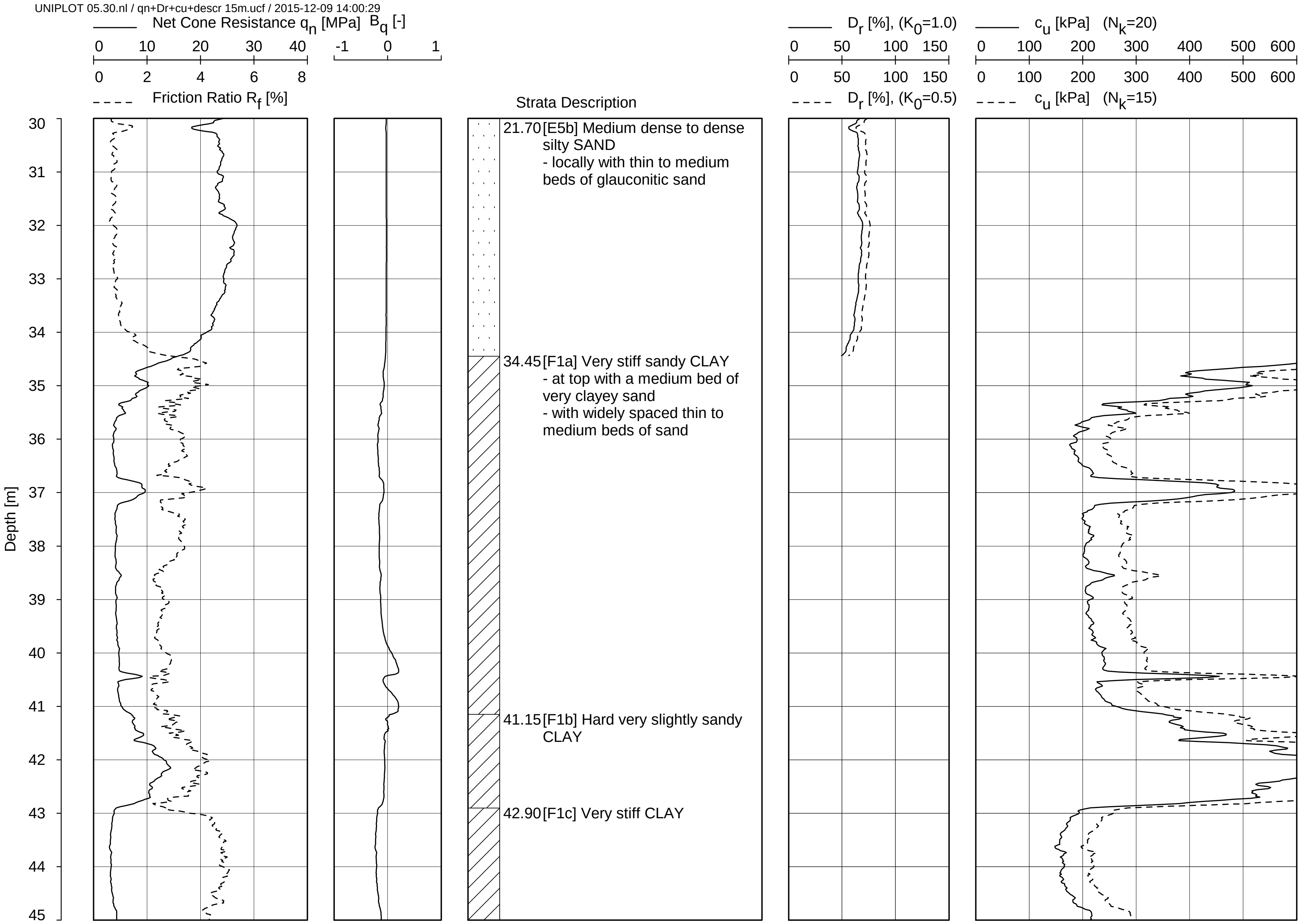
Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.4
Coordinates [m] : E500208 N5721837

CPT DATA INTERPRETATION

CPT_WFS3_3

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.4
Coordinates [m] : E500208 N5721837

CPT DATA INTERPRETATION

CPT_WFS3_3

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

Fugro Report No. N6083/02 (2)

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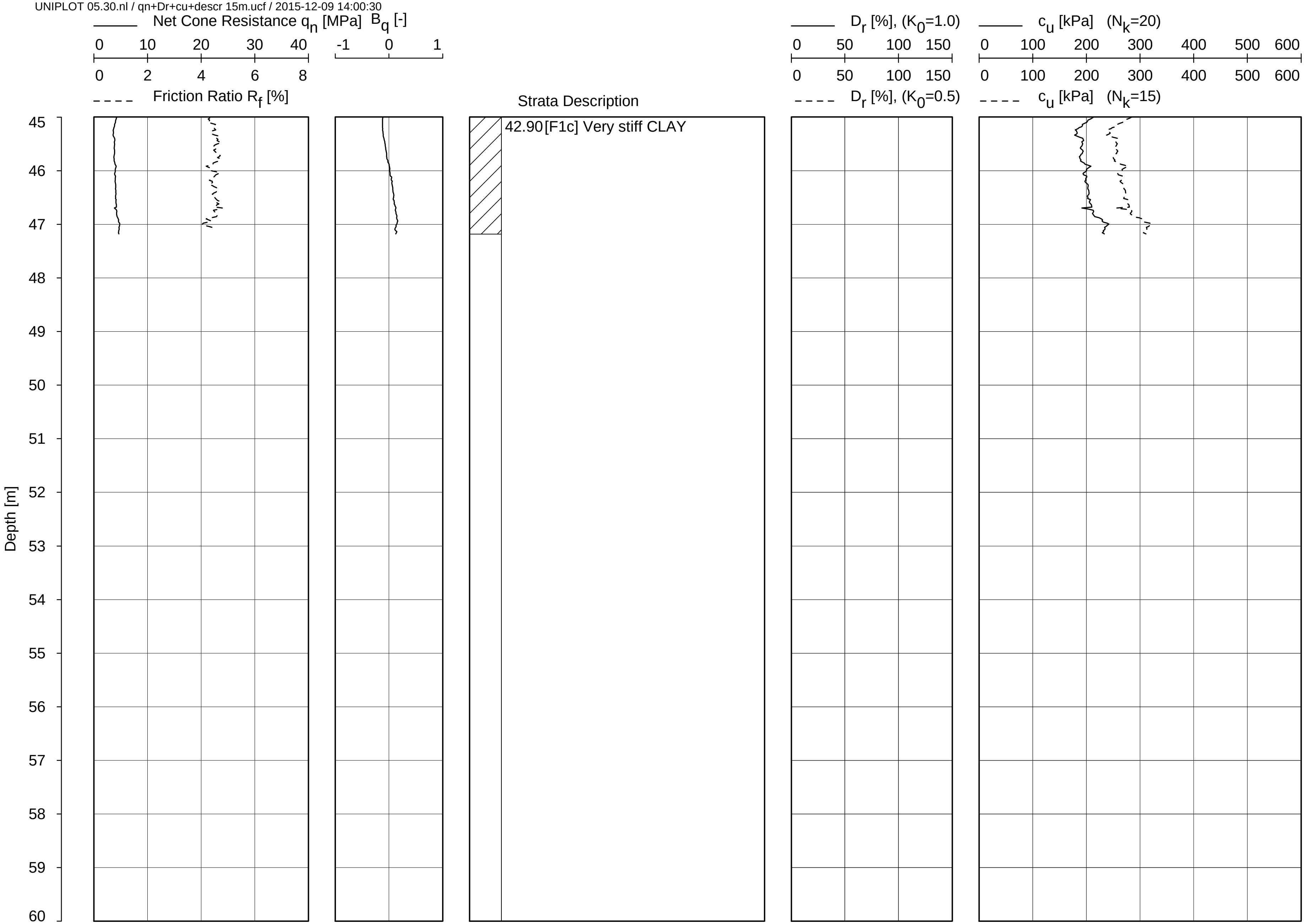
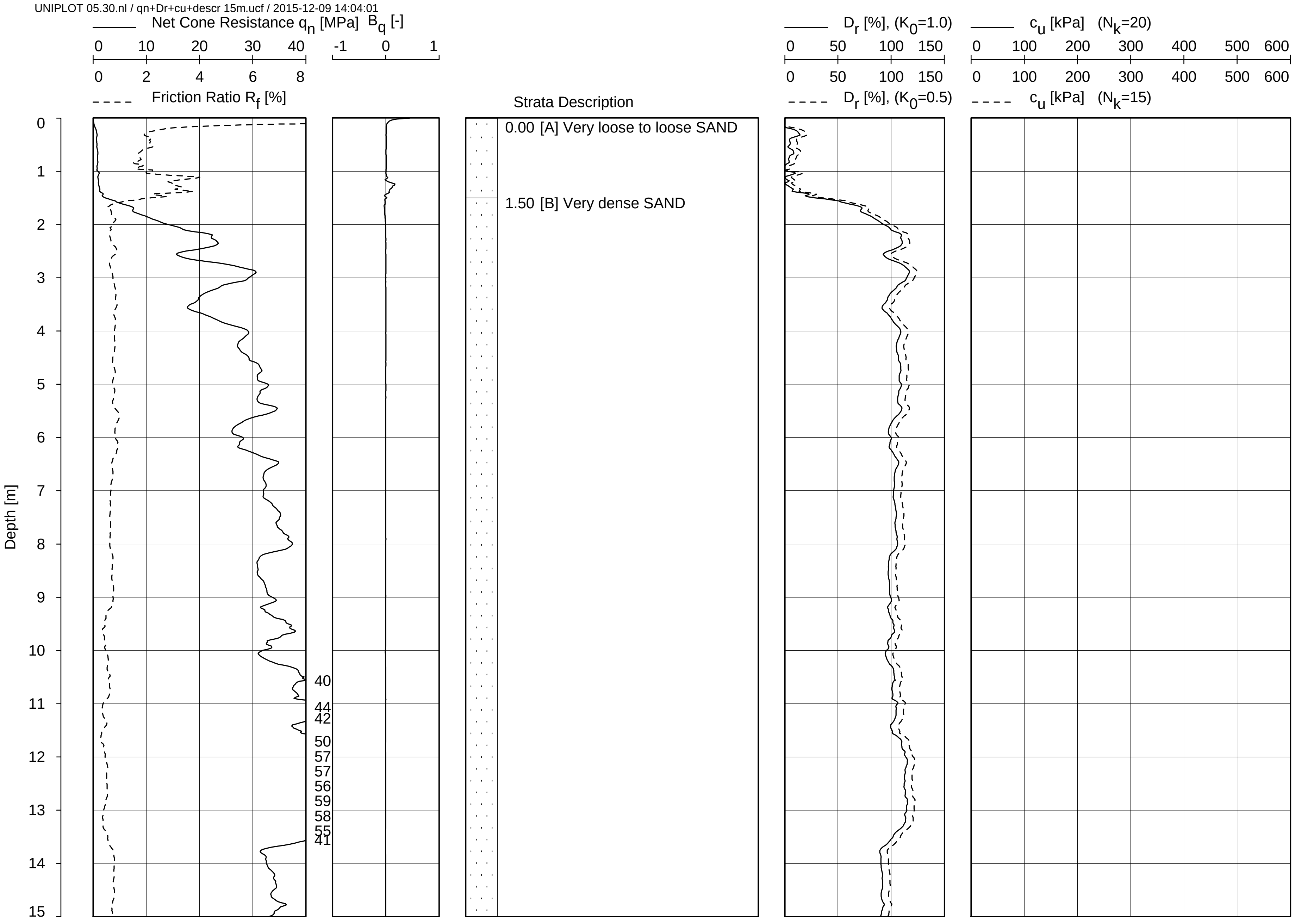


Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.4
Coordinates [m] : E500208 N5721837

CPT DATA INTERPRETATION

CPT_WFS3_3

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

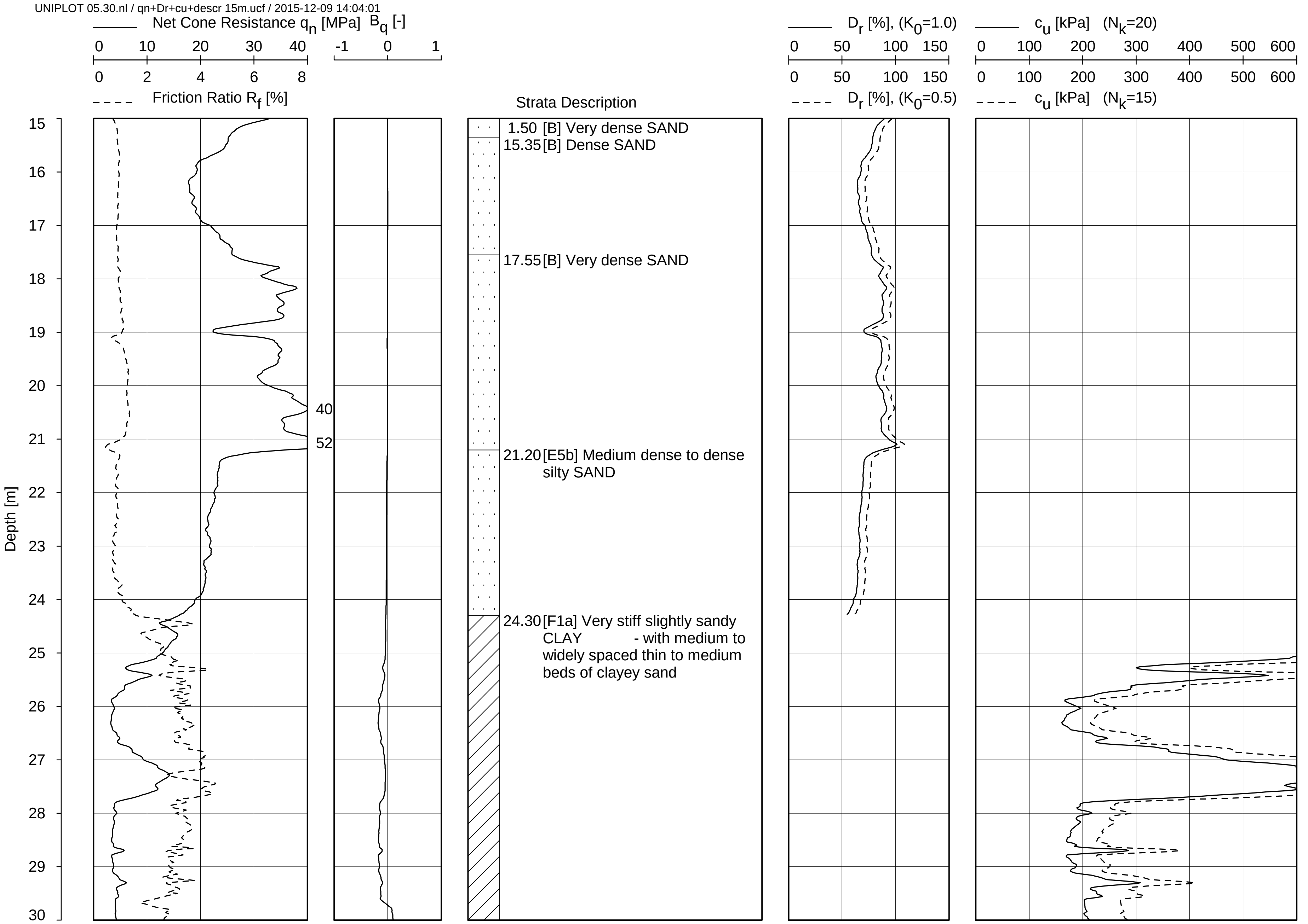


Date Of Testing : 29-Oct-2015
Water Depth [m] : 29.3
Coordinates [m] : E494308 N5726002

CPT DATA INTERPRETATION

CPT_WFS3_5

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

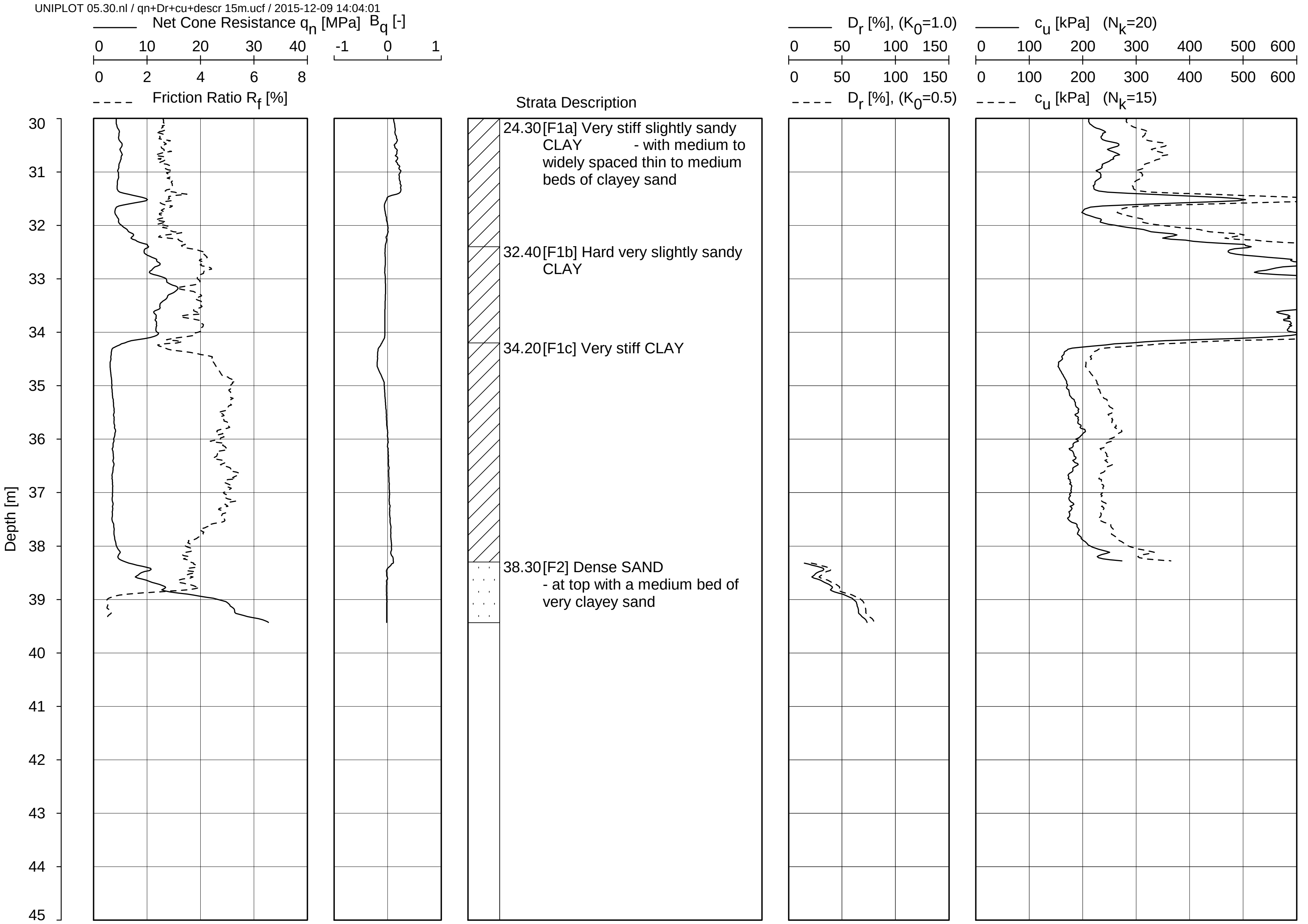


Date Of Testing : 29-Oct-2015
Water Depth [m] : 29.3
Coordinates [m] : E494308 N5726002

CPT DATA INTERPRETATION

CPT_WFS3_5

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

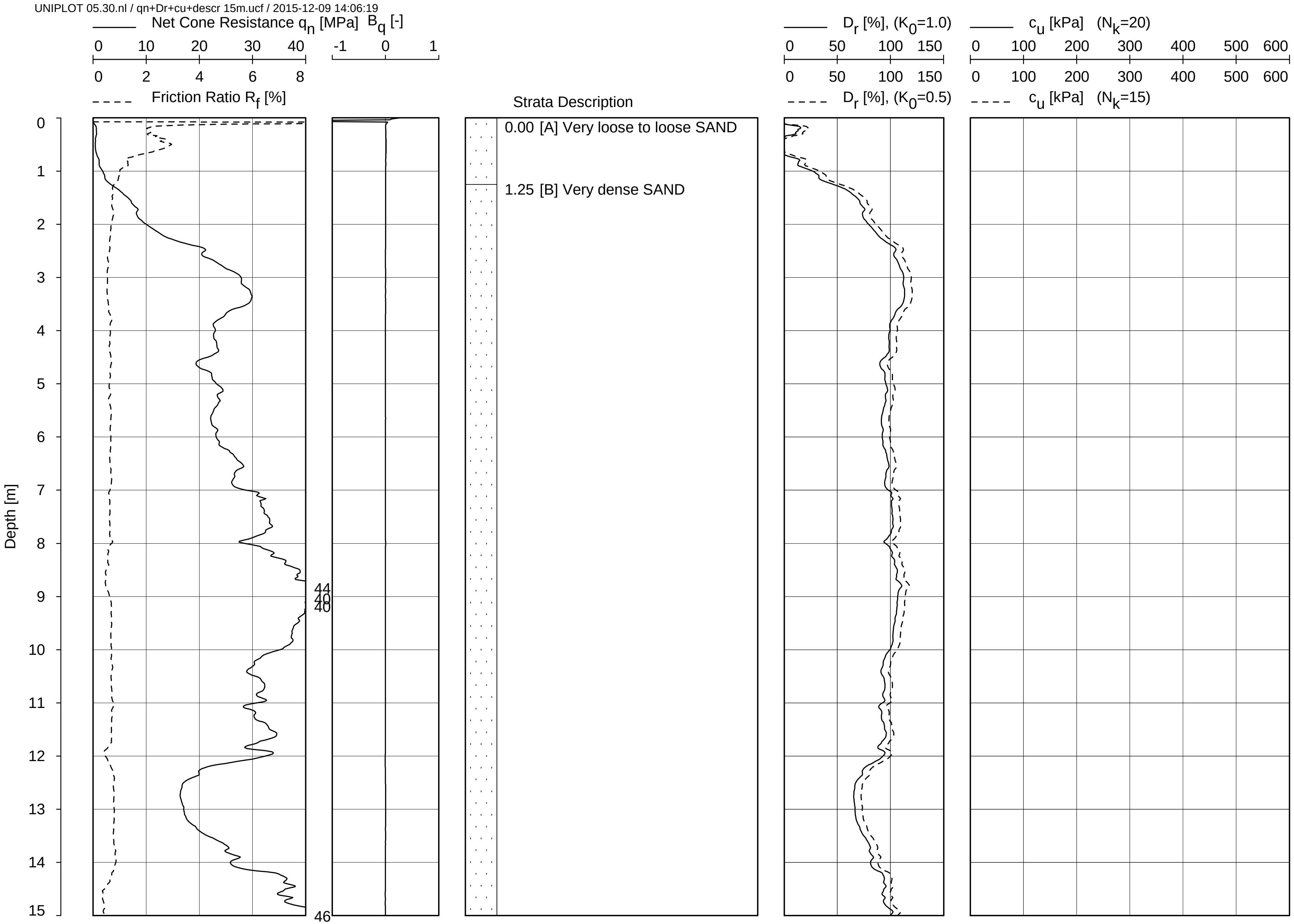


Date Of Testing : 29-Oct-2015
Water Depth [m] : 29.3
Coordinates [m] : E494308 N5726002

CPT DATA INTERPRETATION

CPT_WFS3_5

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.4
Coordinates [m] : E496611 N5729494

CPT DATA INTERPRETATION

CPT_WFS3_6

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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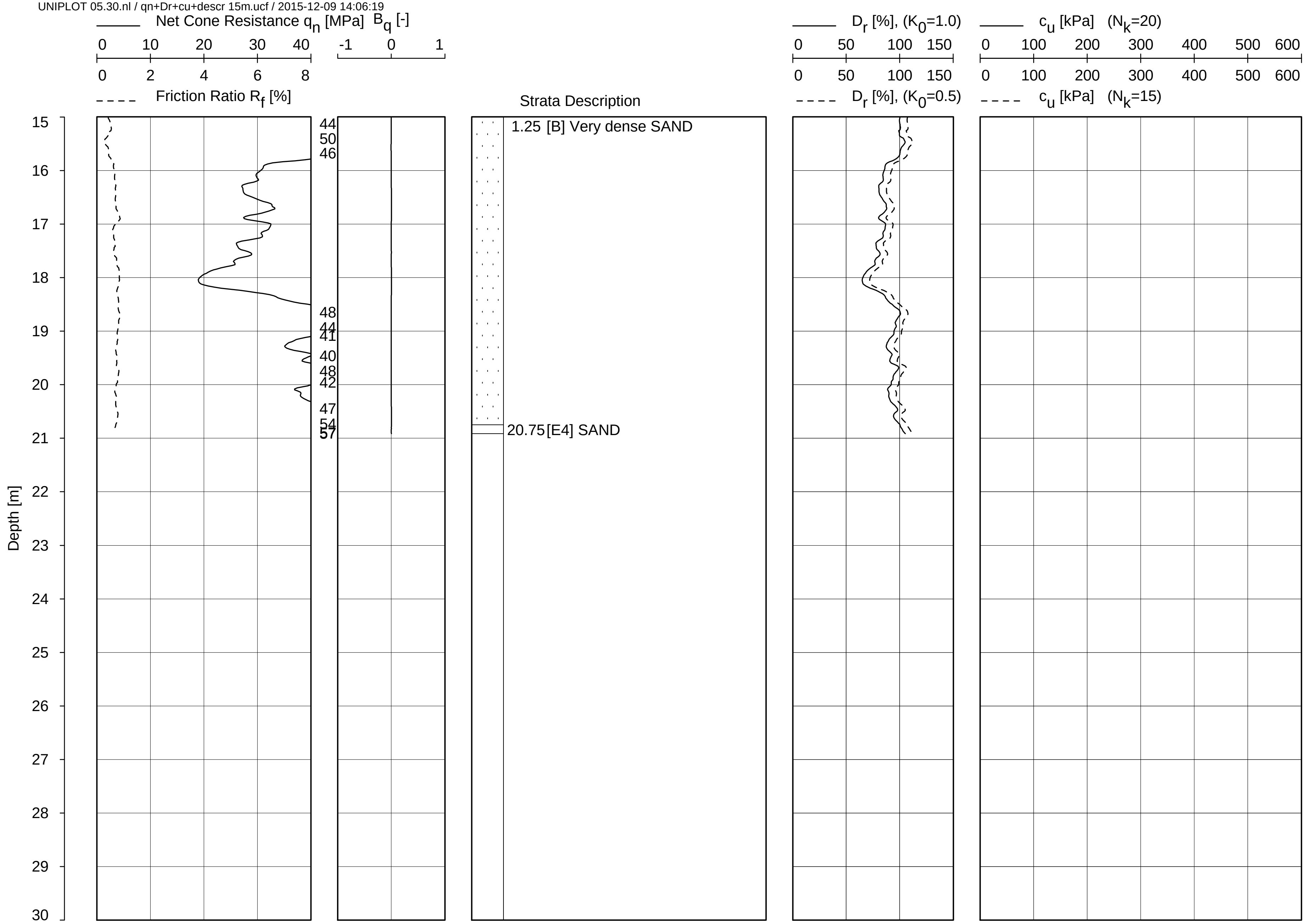

Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.4
Coordinates [m] : E496611 N5729494

CPT DATA INTERPRETATION

CPT_WFS3_6

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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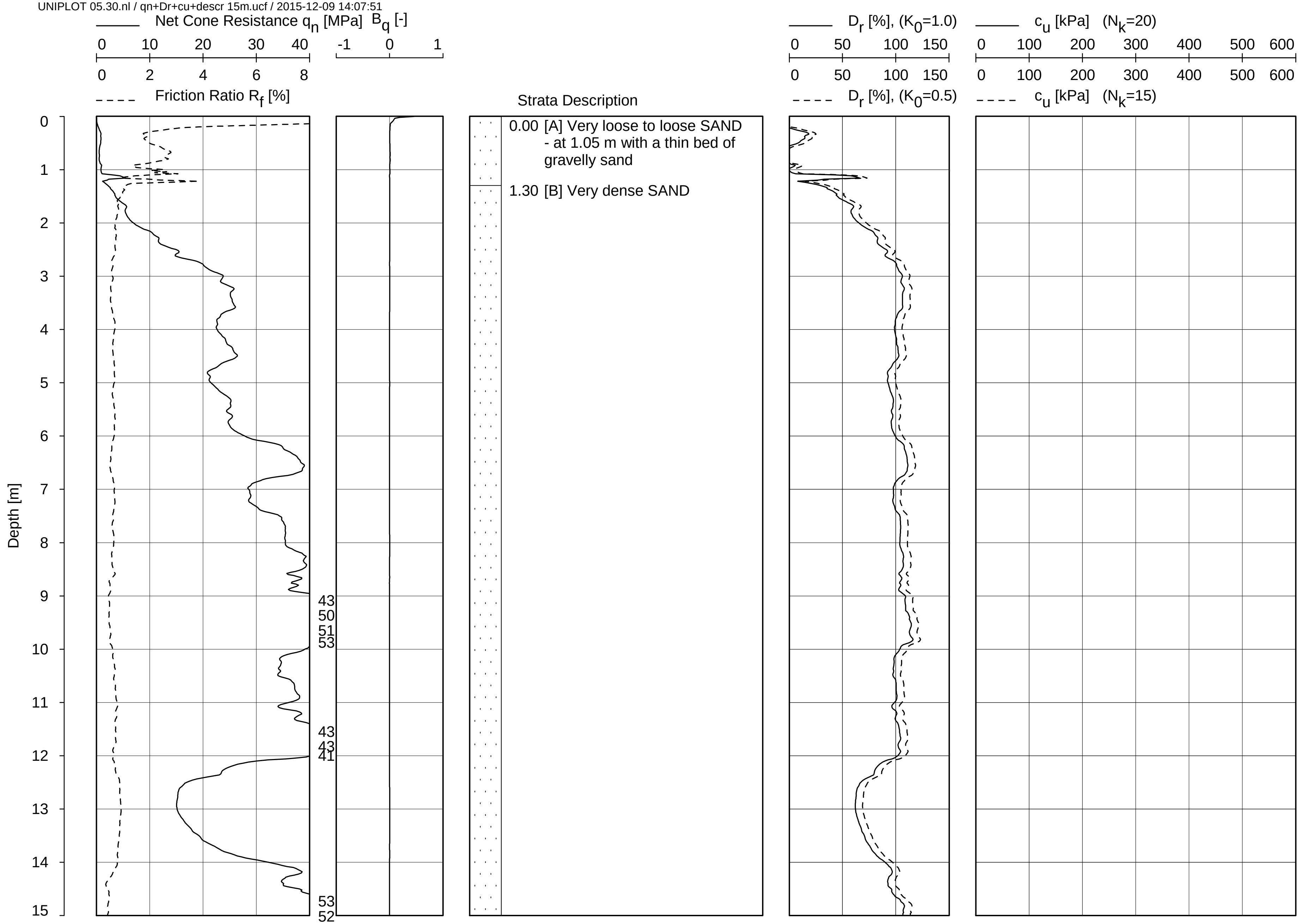


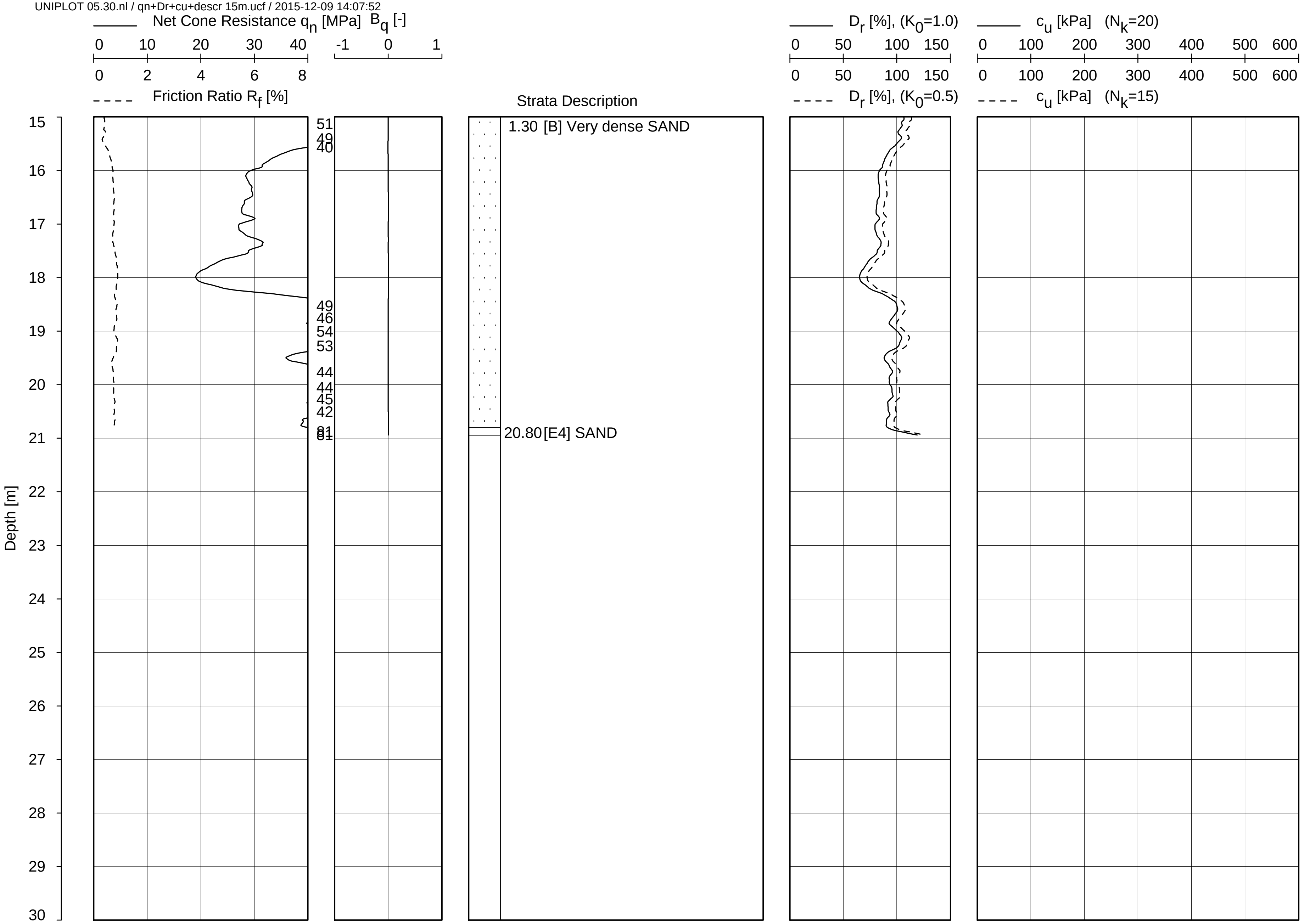
Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496608 N5729497

CPT DATA INTERPRETATION

CPT_WFS3_6A

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:07:52



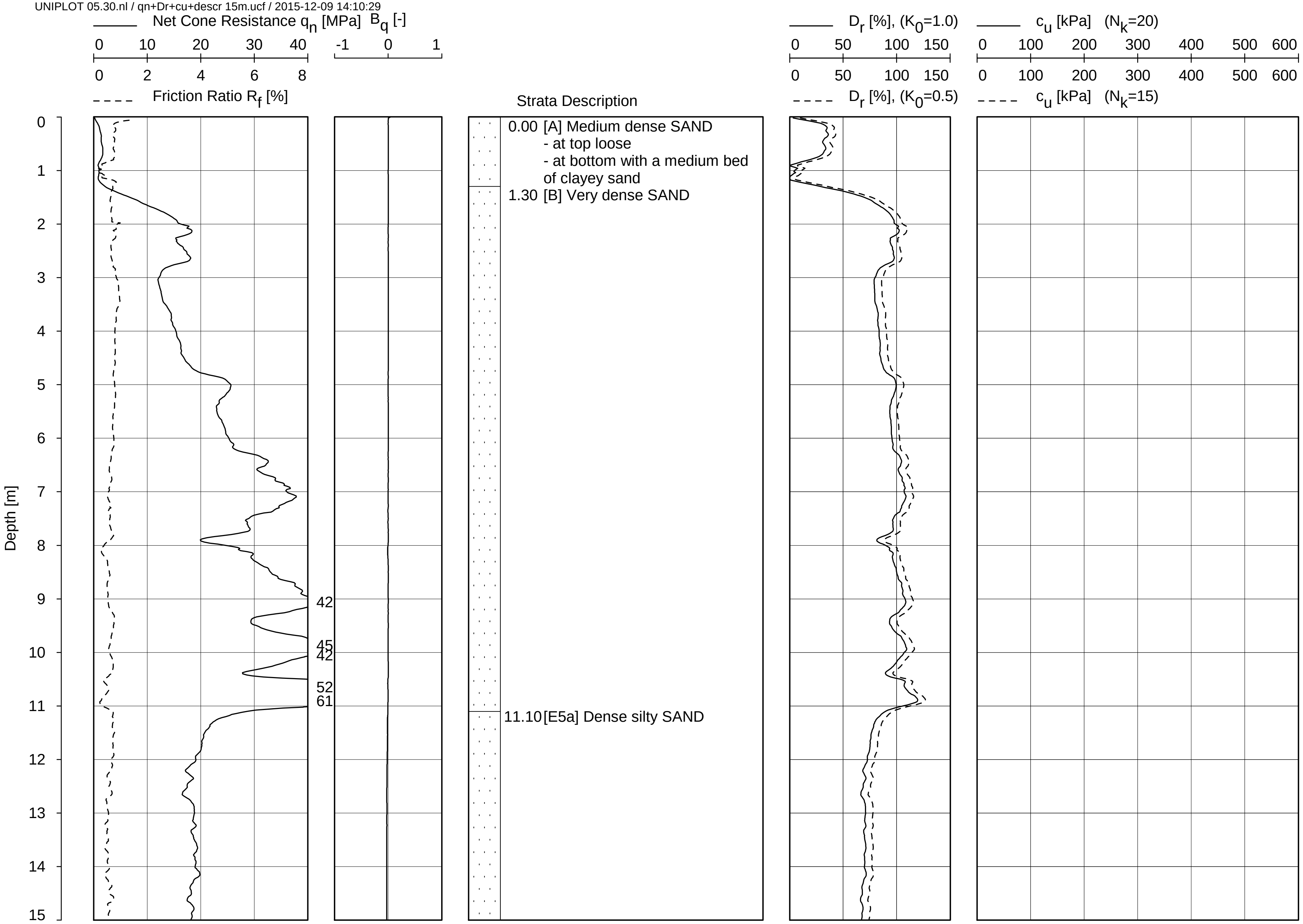
Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496608 N5729497

CPT DATA INTERPRETATION

CPT_WFS3_6A

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:10:29

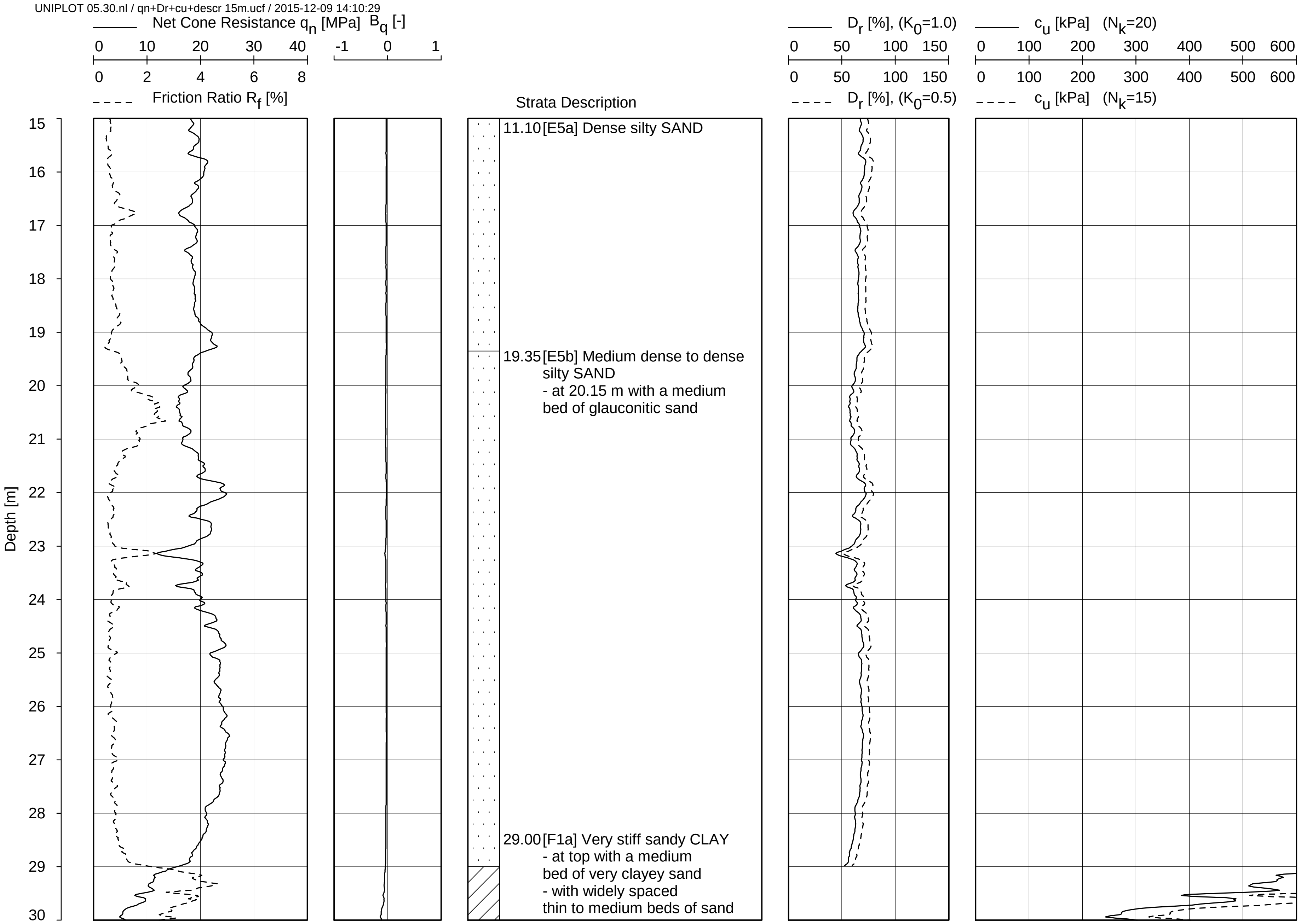


Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.8
Coordinates [m] : E498408 N5722197

CPT DATA INTERPRETATION

CPT_WFS3_7

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

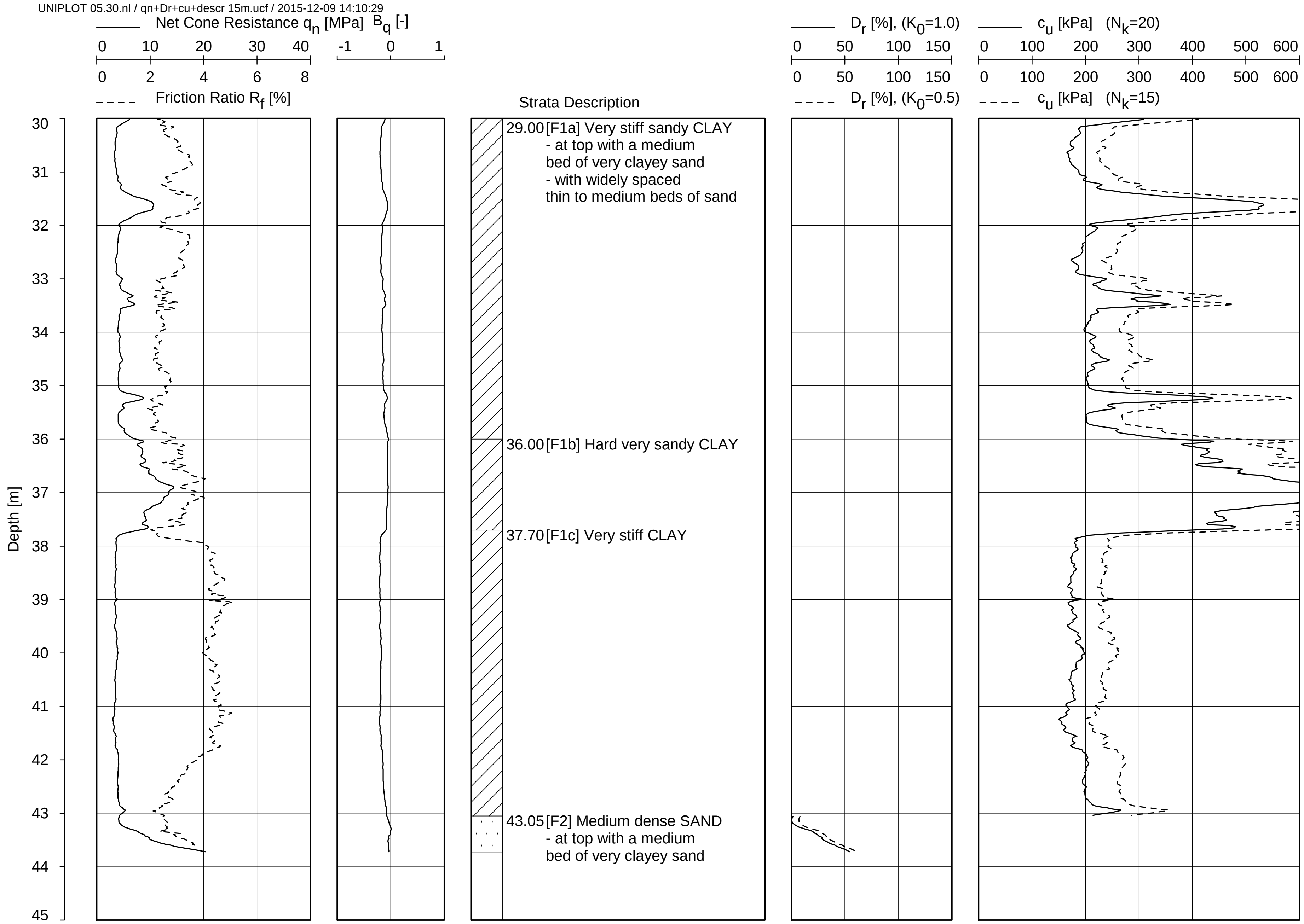


Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.8
Coordinates [m] : E498408 N5722197

CPT DATA INTERPRETATION

CPT_WFS3_7

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



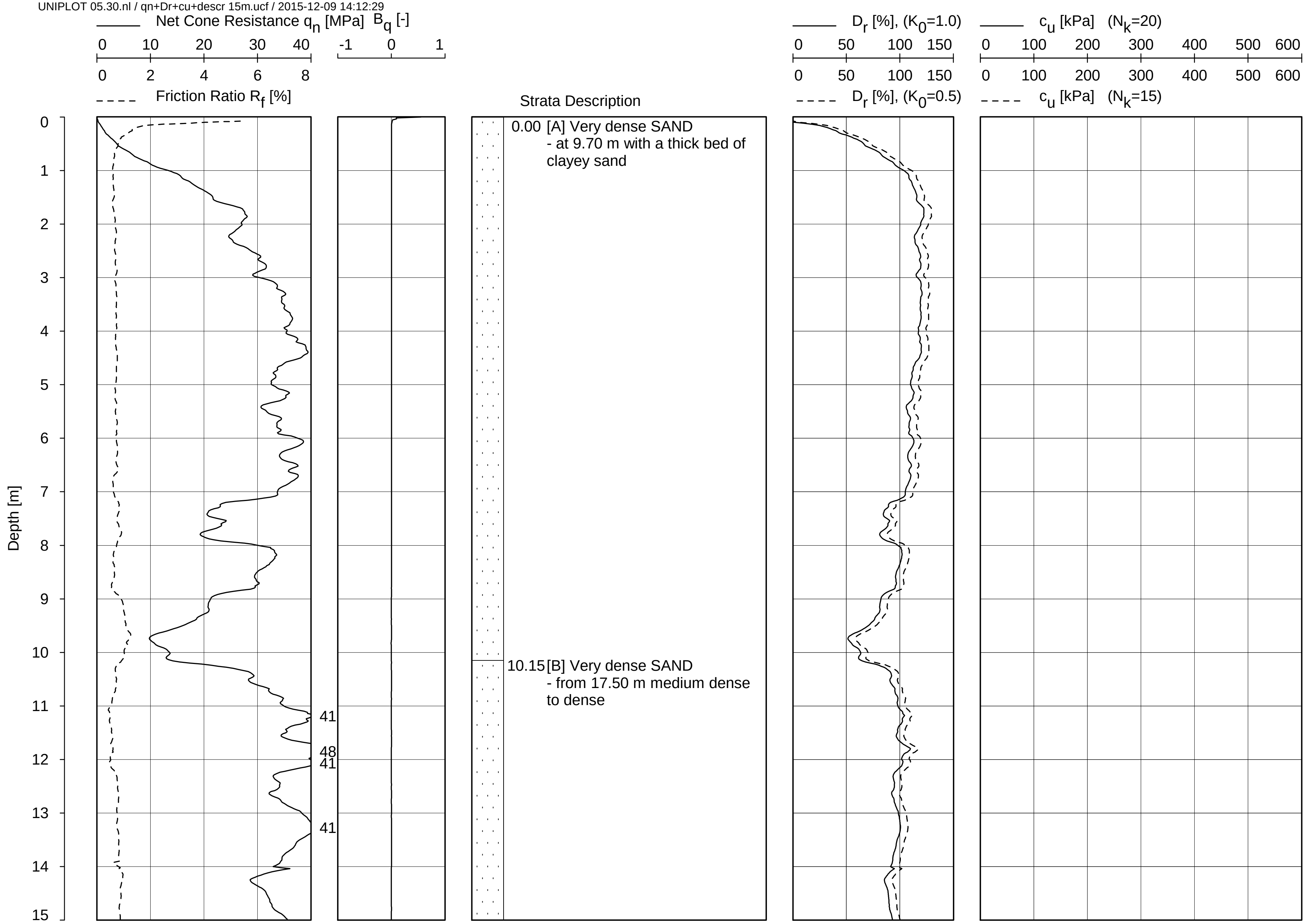
Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.8
Coordinates [m] : E498408 N5722197

CPT DATA INTERPRETATION

CPT_WFS3_7

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:12:29

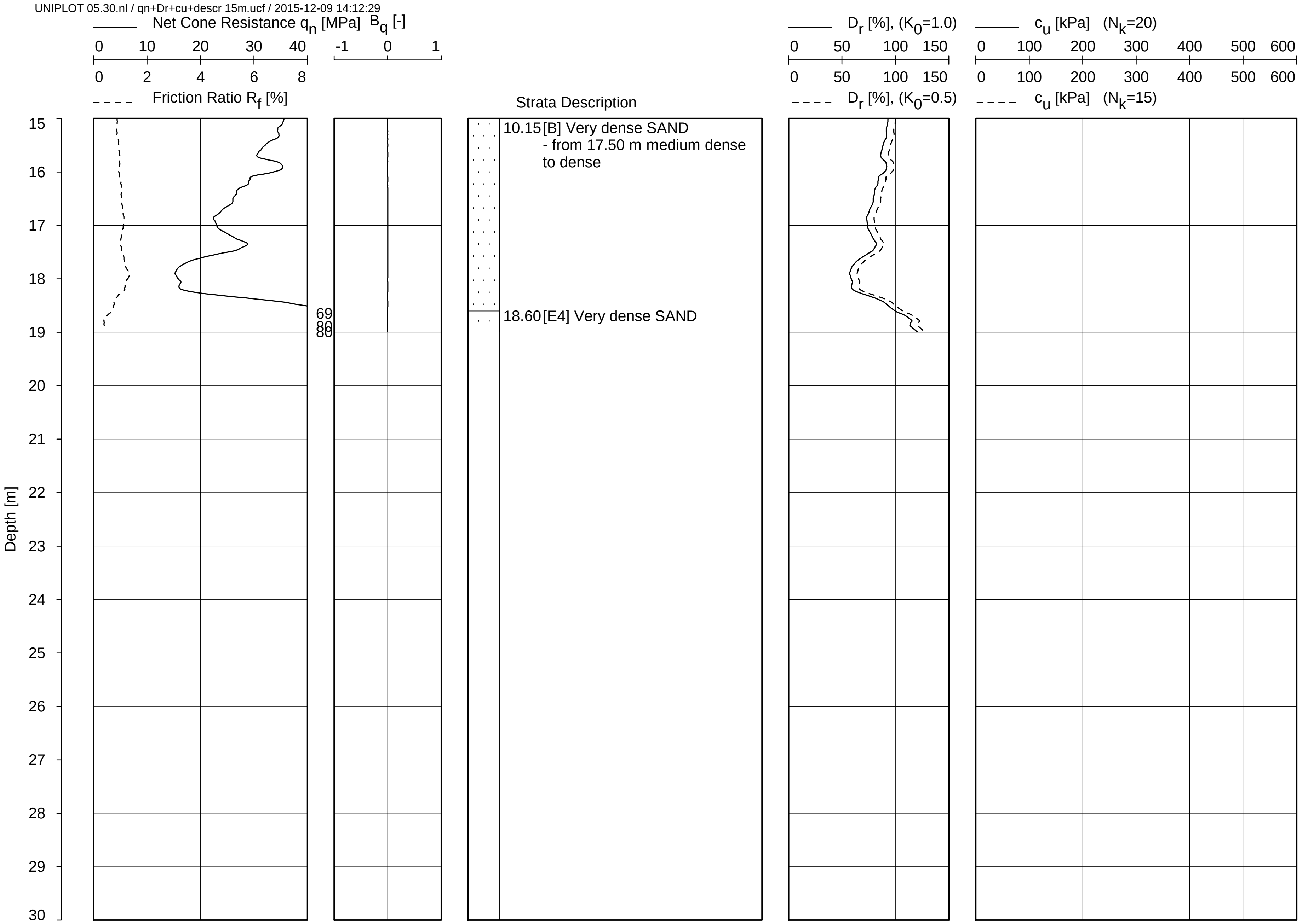


Date Of Testing : 26-Oct-2015
Water Depth [m] : 20.3
Coordinates [m] : E500438 N5724679

CPT DATA INTERPRETATION

CPT_WFS3_8

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



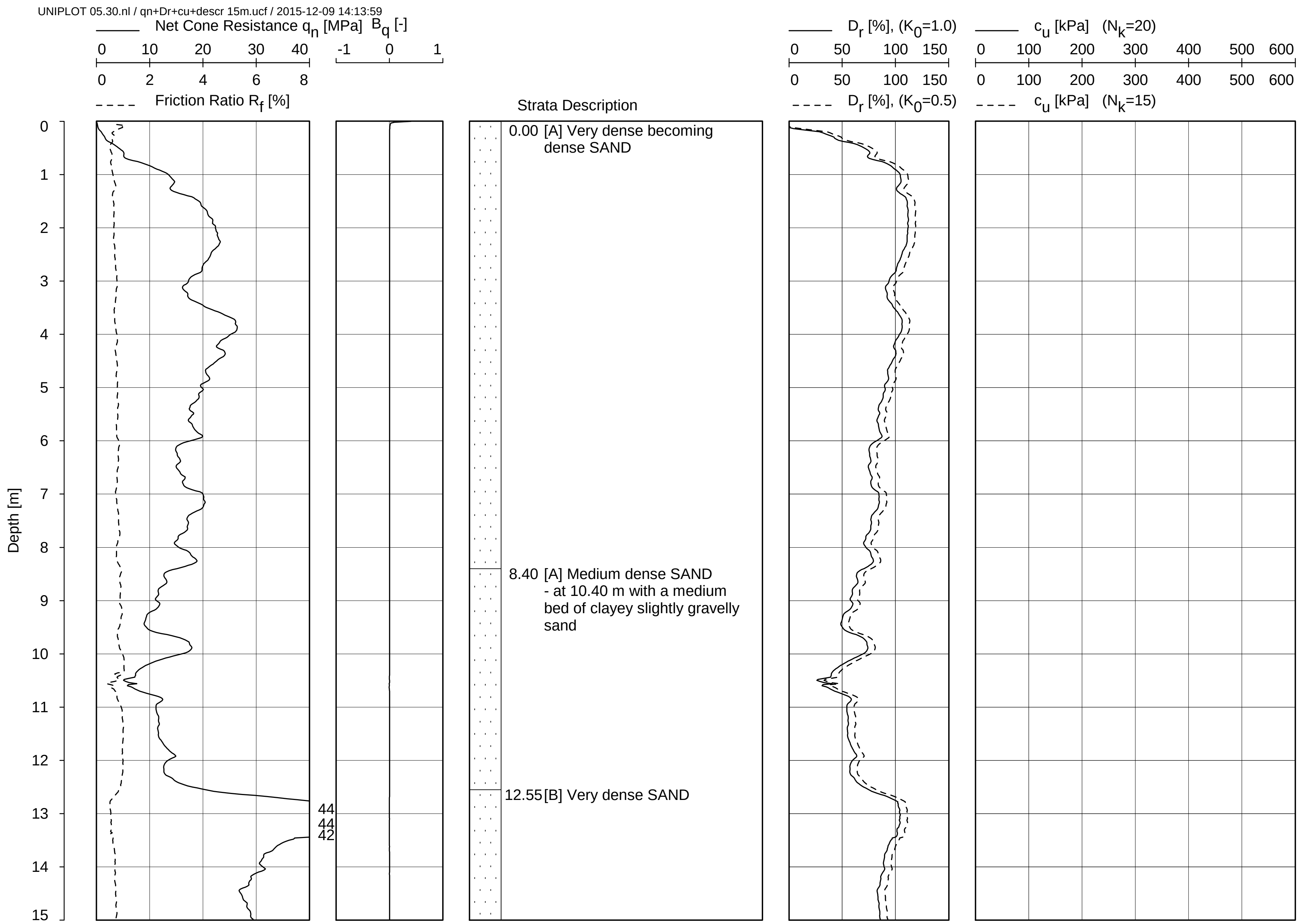
Date Of Testing : 26-Oct-2015
Water Depth [m] : 20.3
Coordinates [m] : E500438 N5724679

CPT DATA INTERPRETATION

CPT_WFS3_8

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO

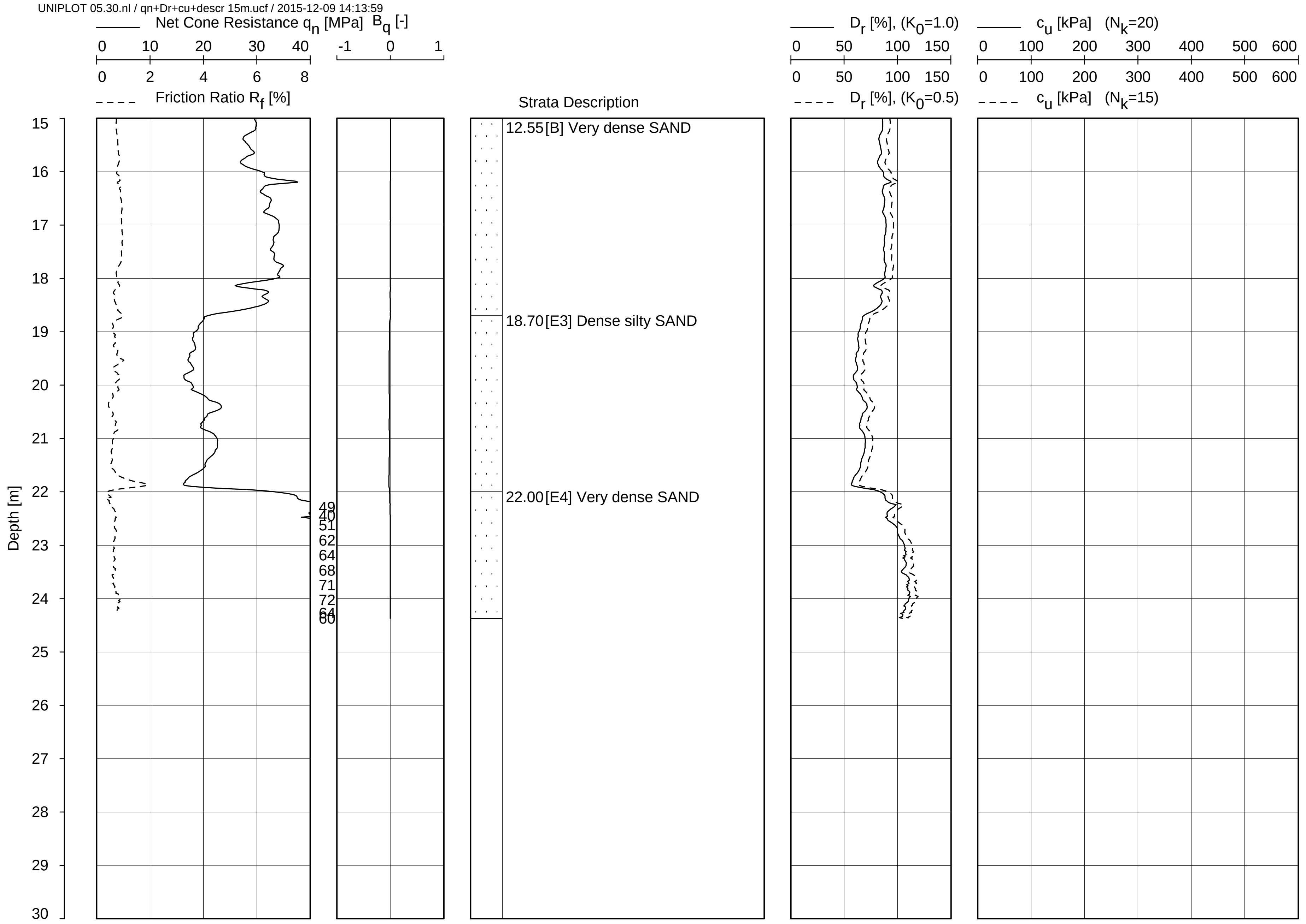


Date Of Testing : 30-Oct-2015
Water Depth [m] : 25.0
Coordinates [m] : E500399 N5726517

CPT DATA INTERPRETATION

CPT_WFS3_9

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

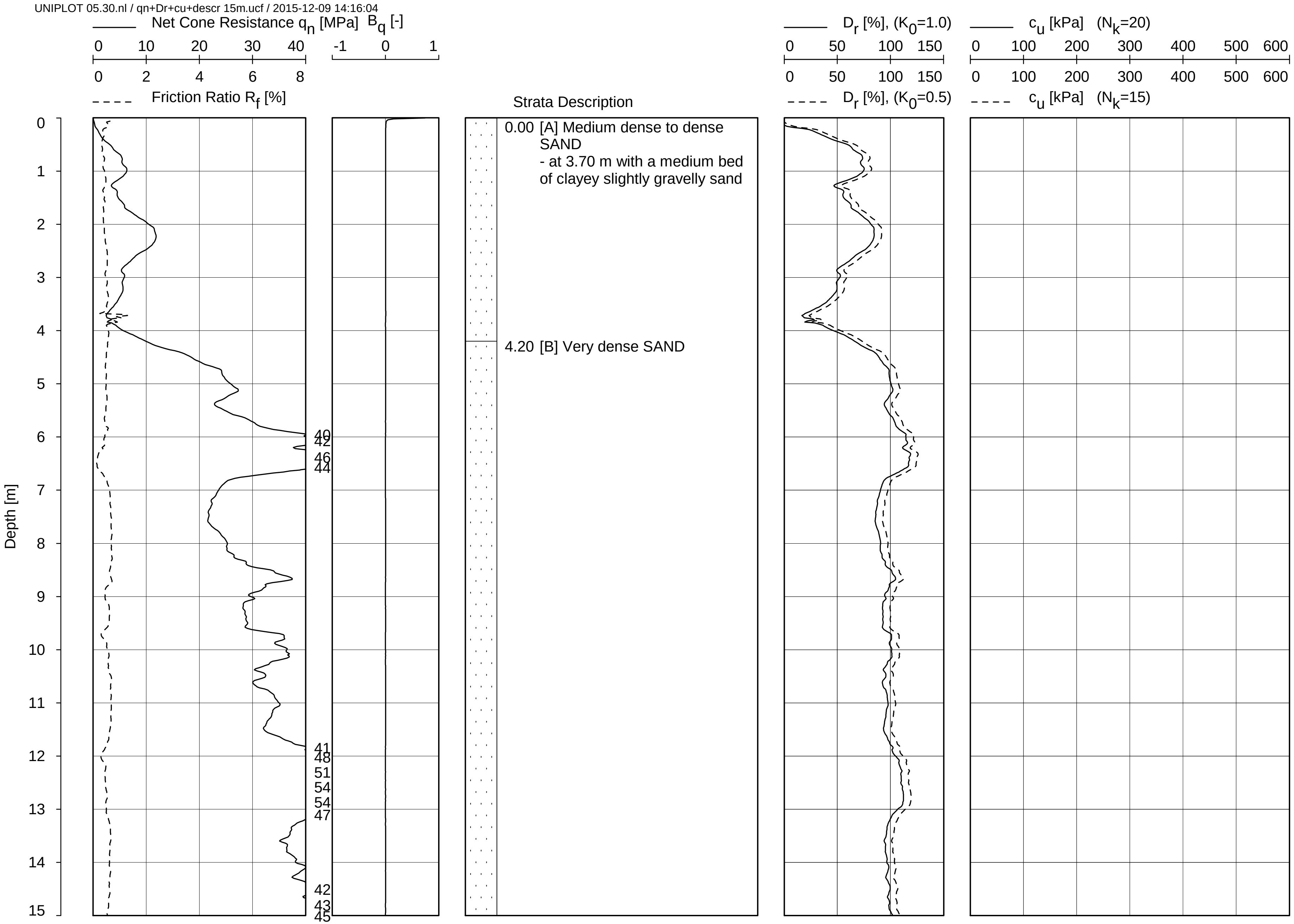


Date Of Testing : 30-Oct-2015
Water Depth [m] : 25.0
Coordinates [m] : E500399 N5726517

CPT DATA INTERPRETATION

CPT_WFS3_9

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 30-Oct-2015
Water Depth [m] : 34.7
Coordinates [m] : E498625 N5726871

CPT DATA INTERPRETATION

CPT_WFS3_10

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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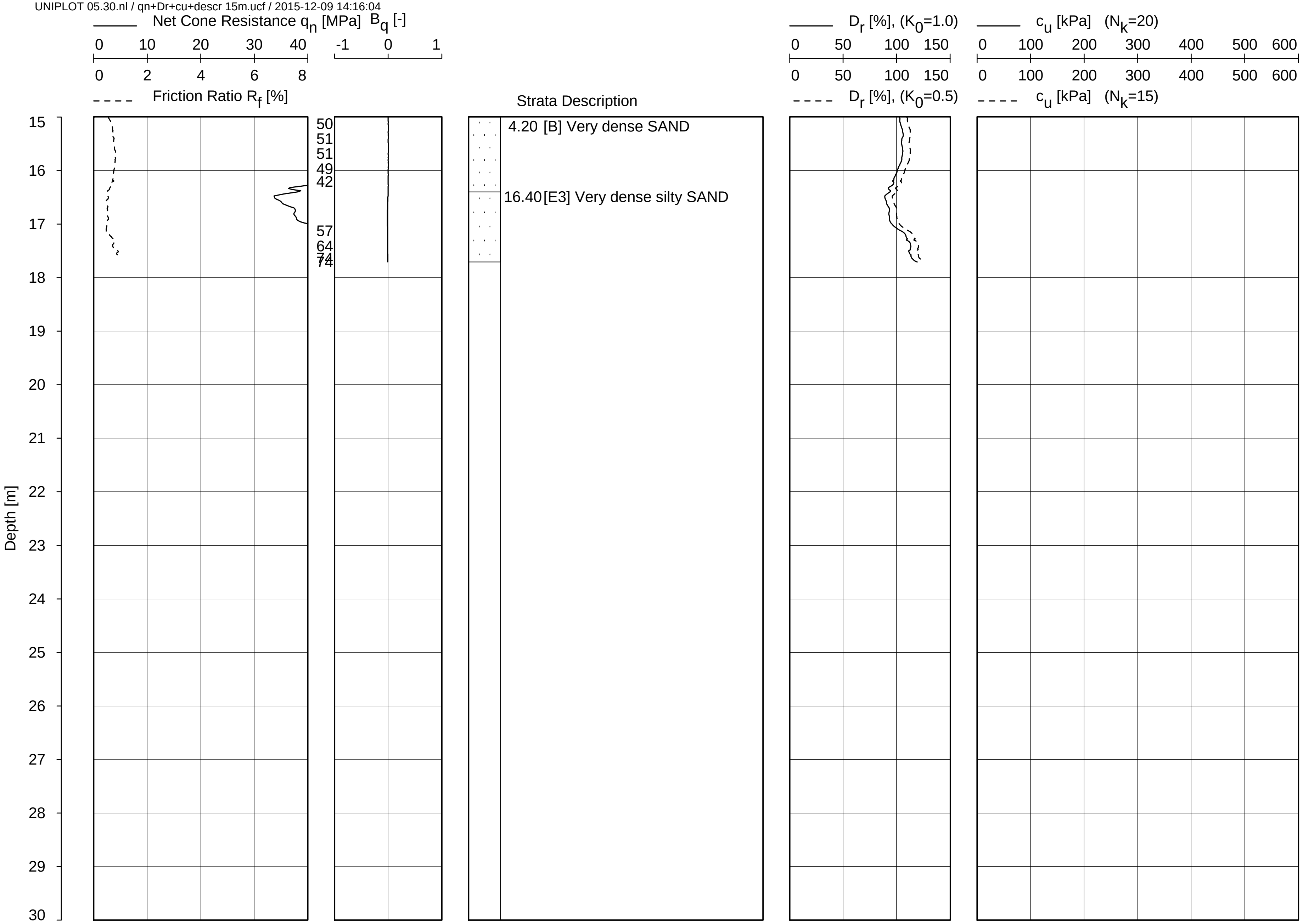
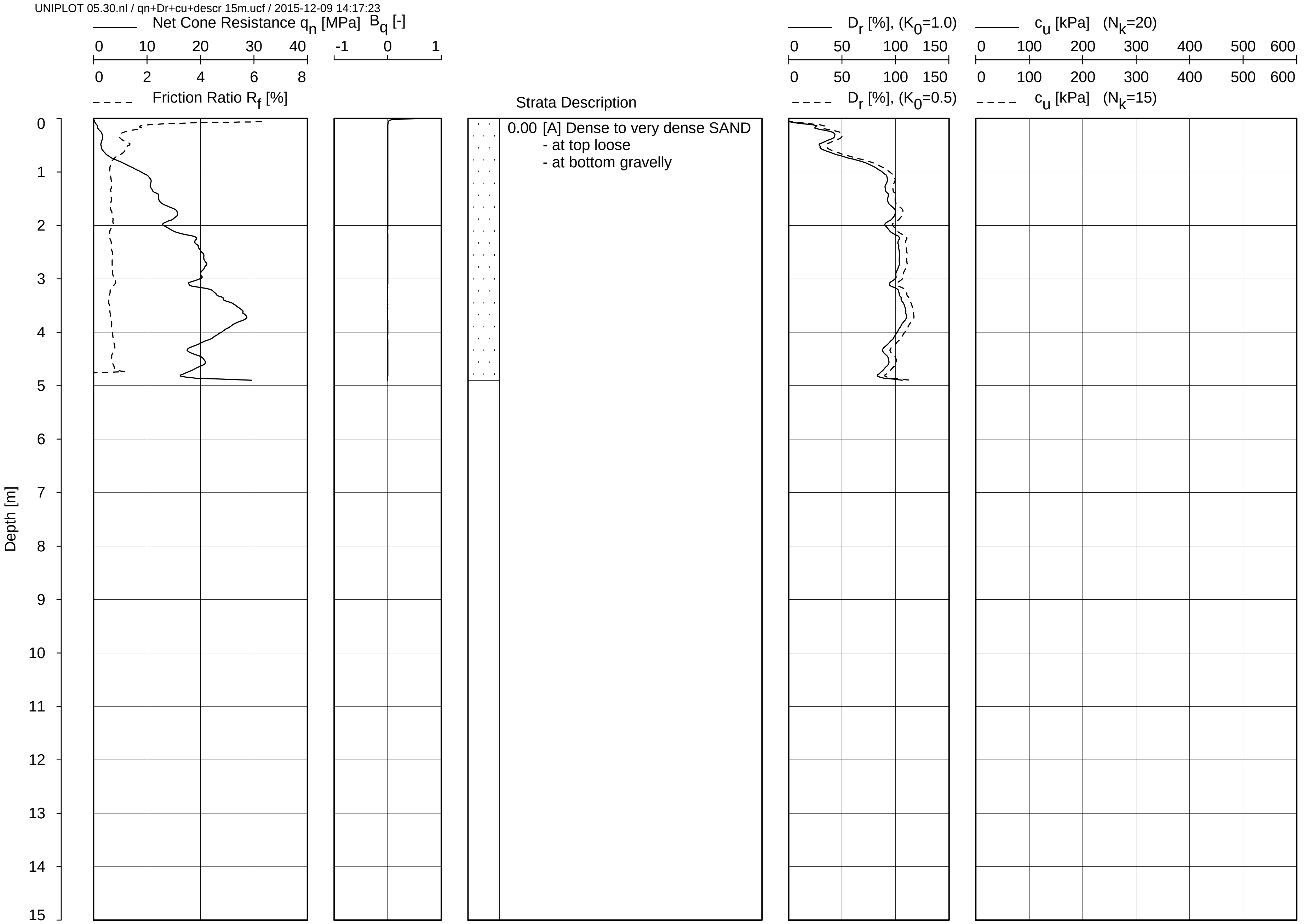


Date Of Testing : 30-Oct-2015
Water Depth [m] : 34.7
Coordinates [m] : E498625 N5726871

CPT DATA INTERPRETATION

CPT_WFS3_10

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



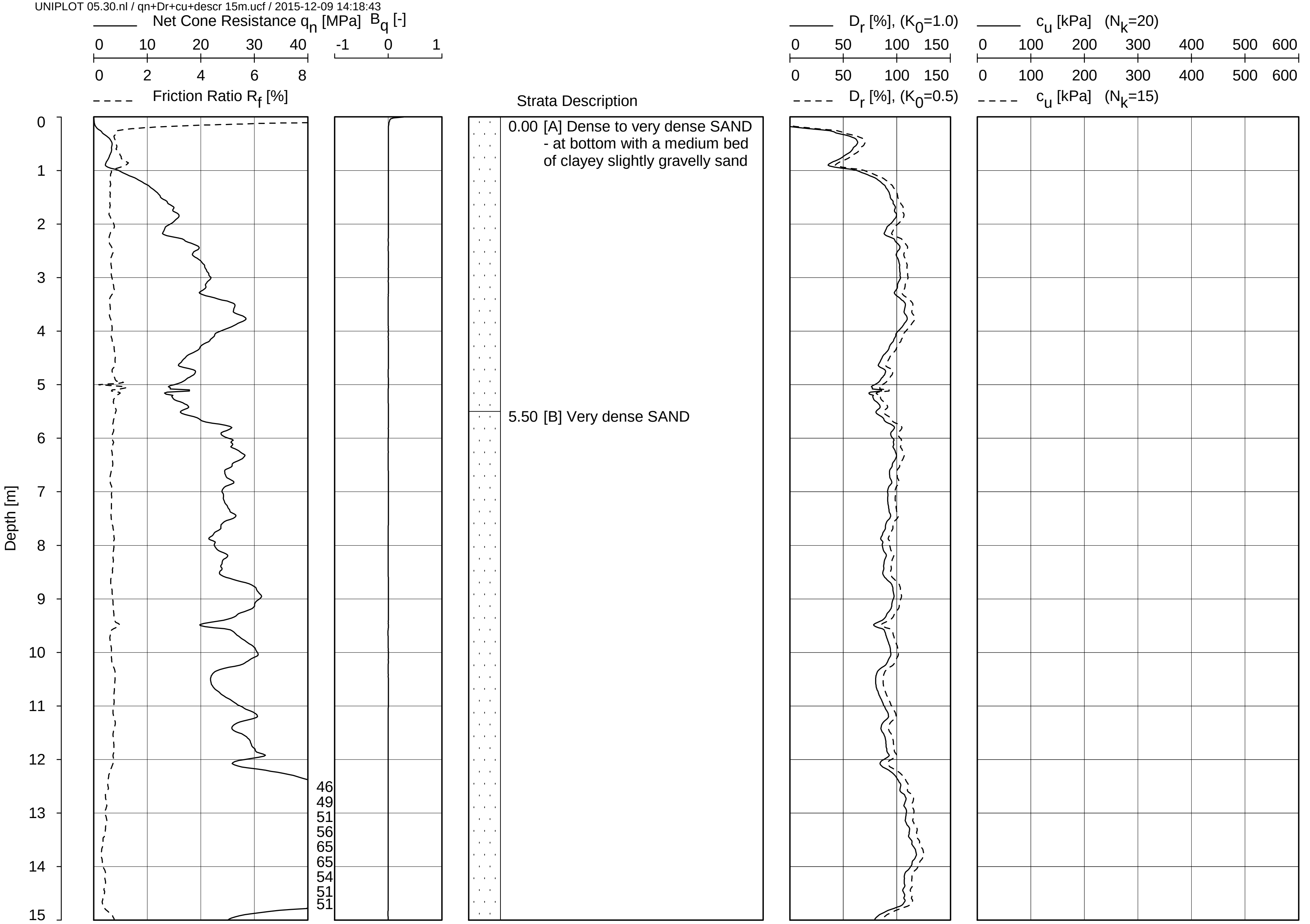
Date Of Testing : 31-Oct-2015
Water Depth [m] : 25.1
Coordinates [m] : E501904 N5726449

CPT DATA INTERPRETATION

CPT_WFS3_11

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:18:43



Date Of Testing : 31-Oct-2015

Water Depth [m] : 25.1

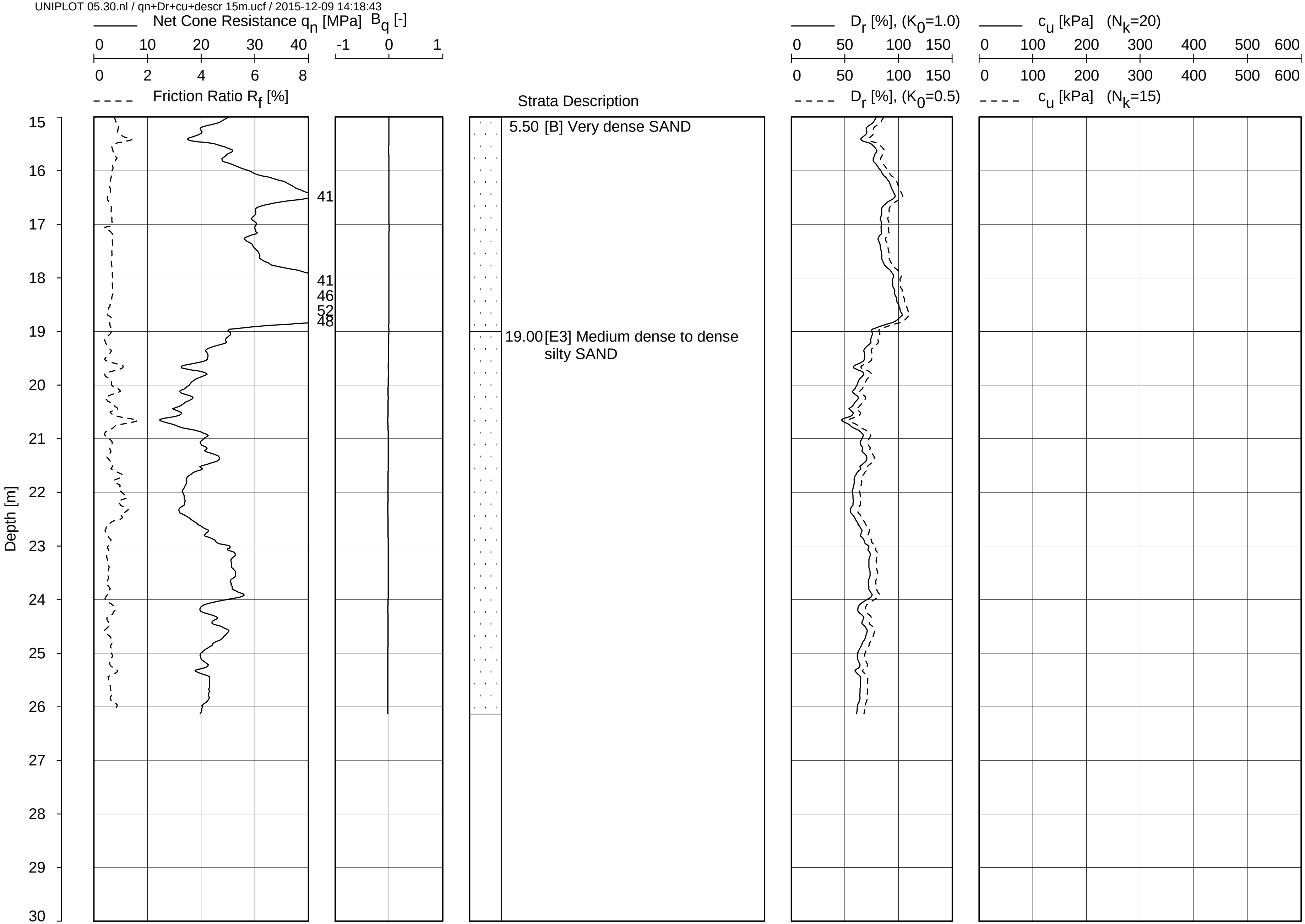
Coordinates [m] : E501900 N5726444

CPT DATA INTERPRETATION

CPT_WFS3_11A

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:18:43



Date Of Testing : 31-Oct-2015

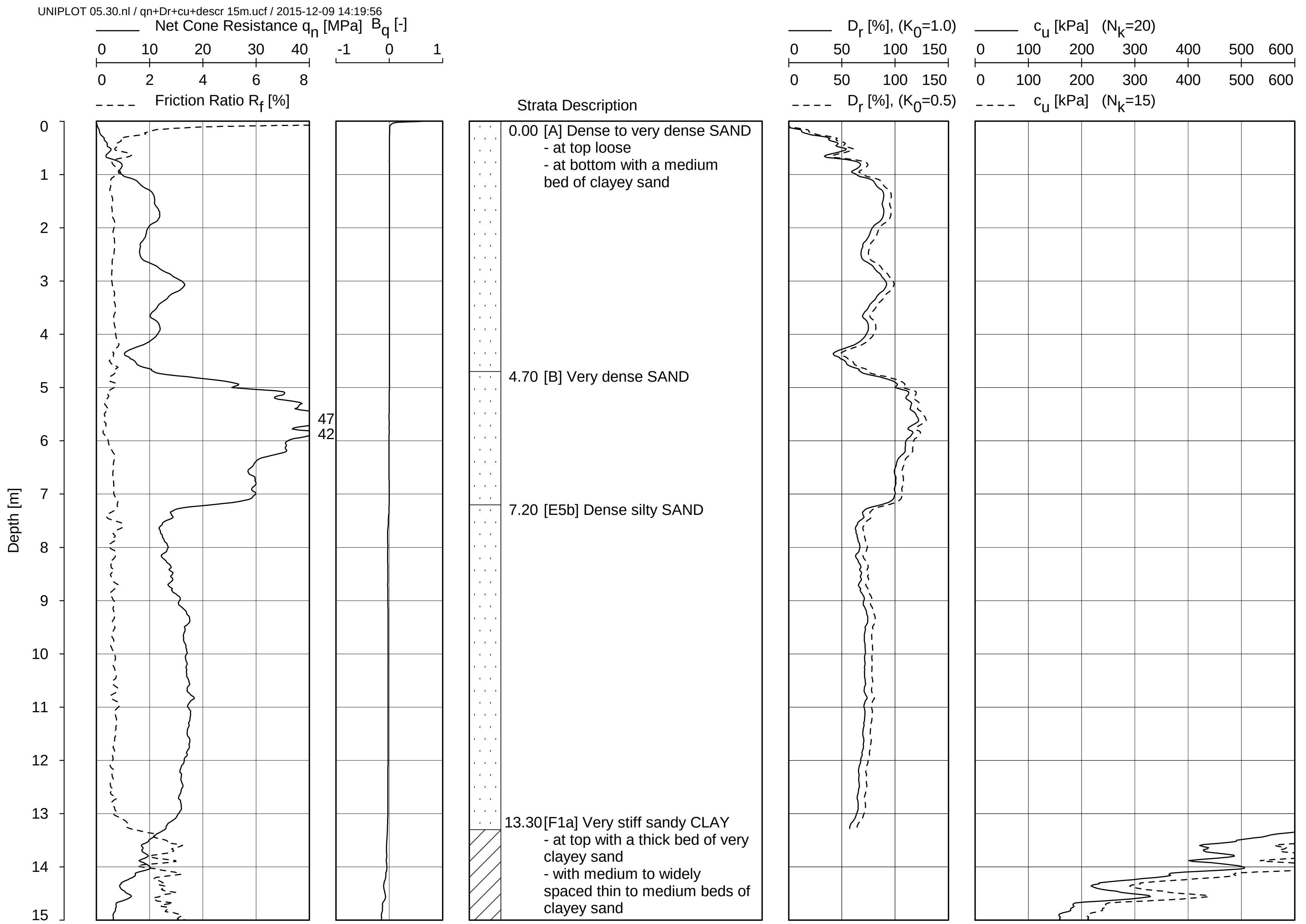
Water Depth [m] : 25.1

Coordinates [m] : E501900 N5726444

CPT DATA INTERPRETATION

CPT_WFS3_11A

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

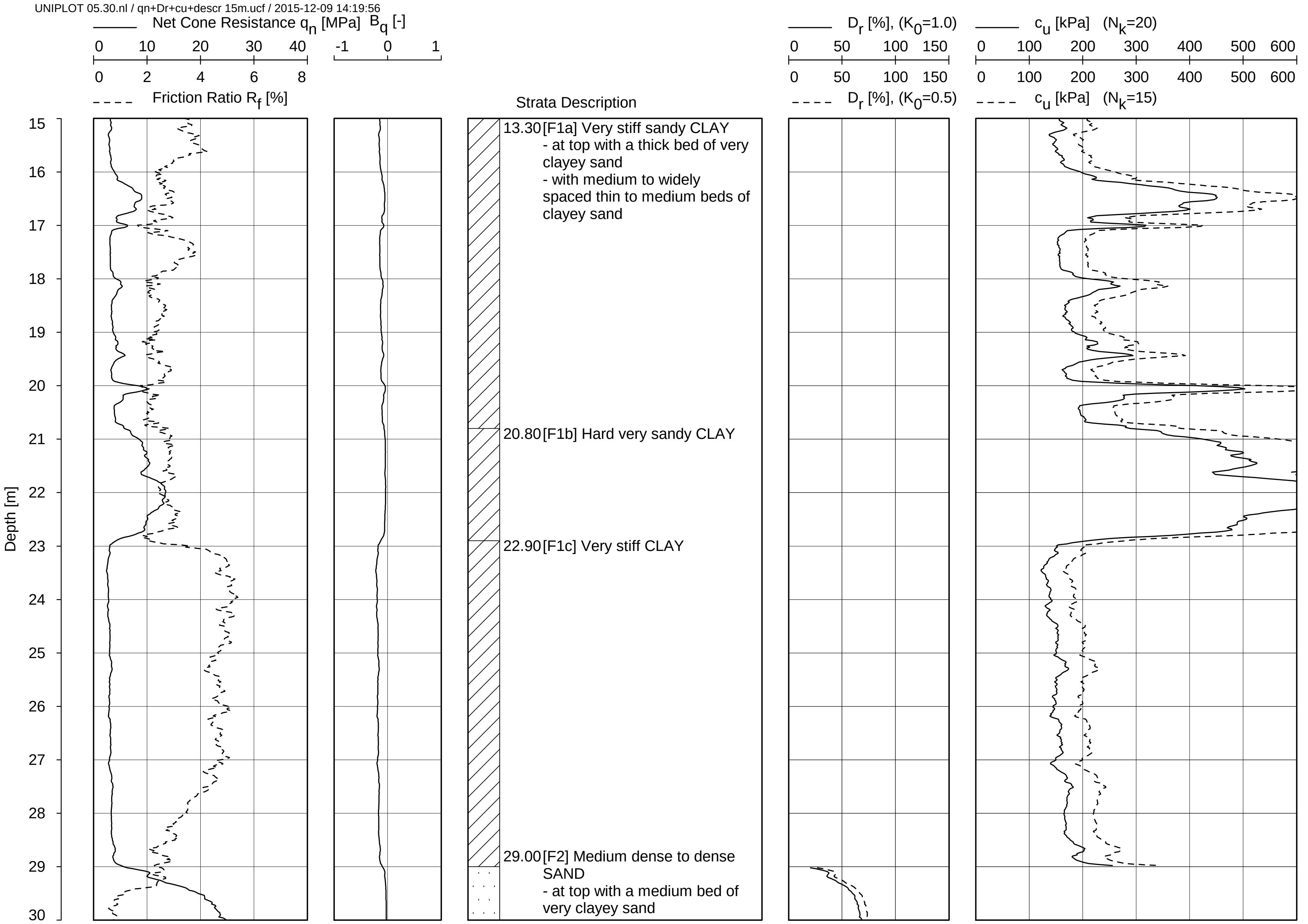


Date Of Testing : 27-Oct-2015
Water Depth [m] : 32.6
Coordinates [m] : E497925 N5719860

CPT DATA INTERPRETATION

CPT_WFS3_12

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 27-Oct-2015

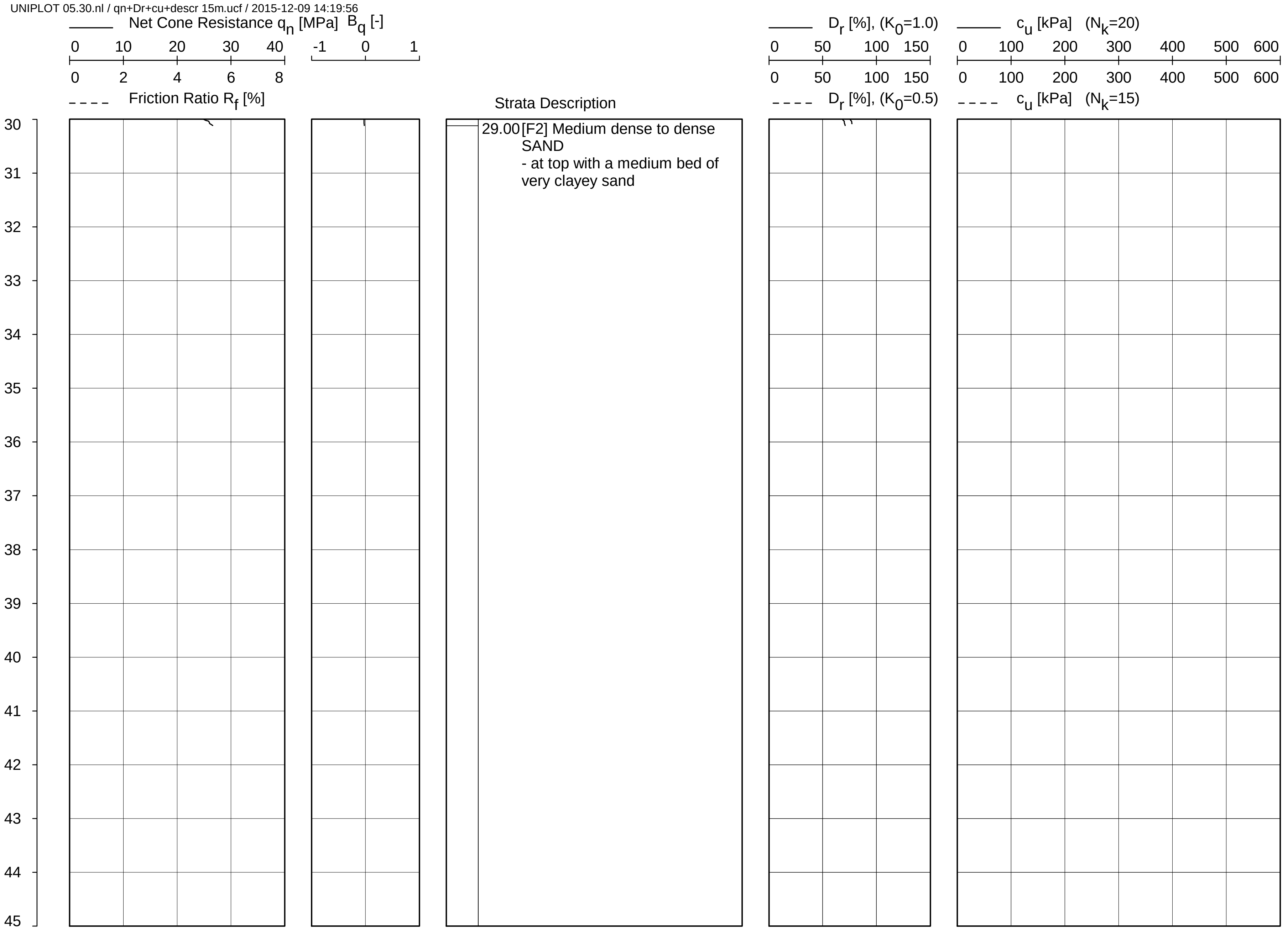
Water Depth [m] : 32.6

Coordinates [m] : E497925 N5719860

CPT DATA INTERPRETATION

CPT_WFS3_12

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

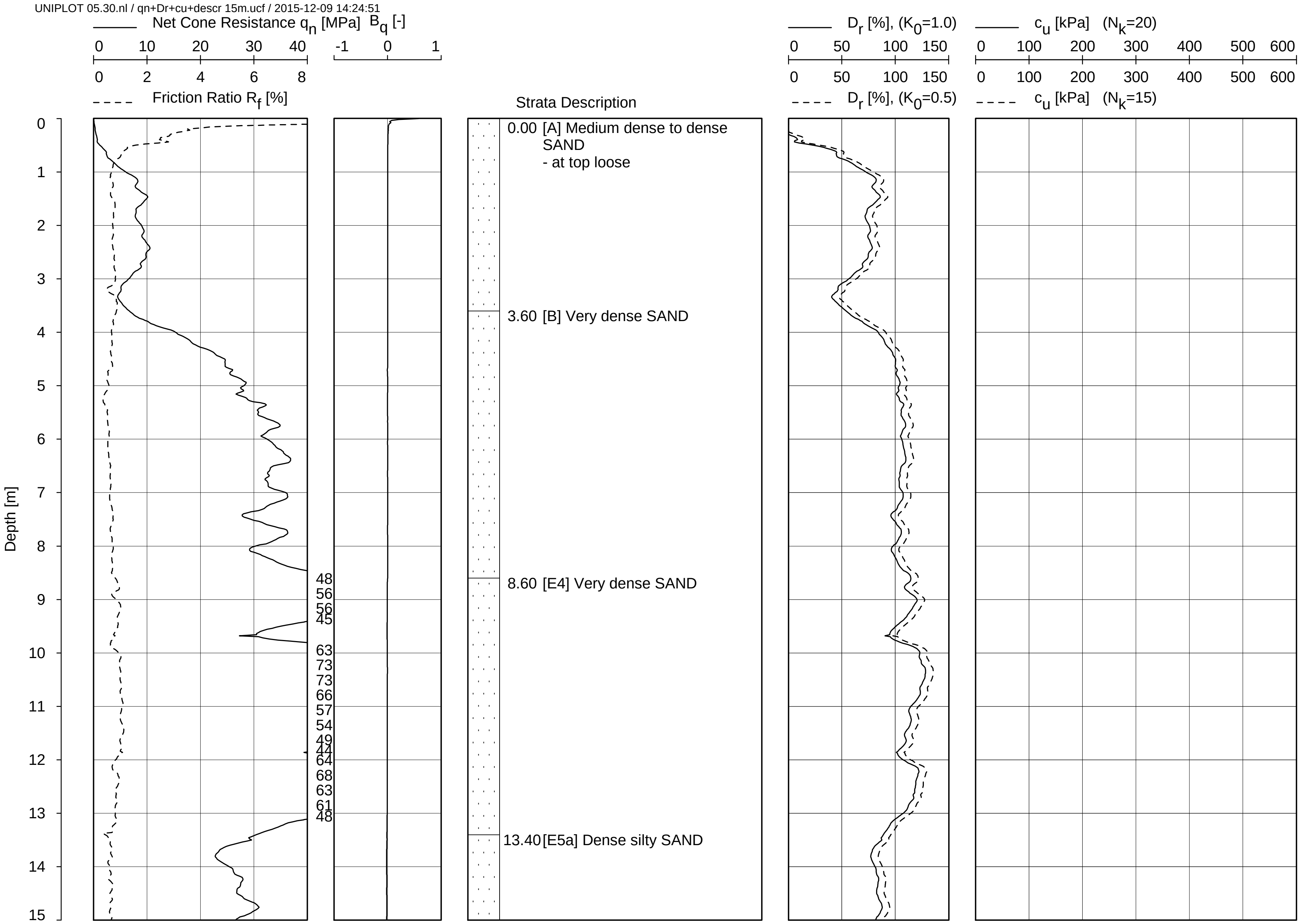


Date Of Testing : 27-Oct-2015
Water Depth [m] : 32.6
Coordinates [m] : E497925 N5719860

CPT DATA INTERPRETATION

CPT_WFS3_12

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



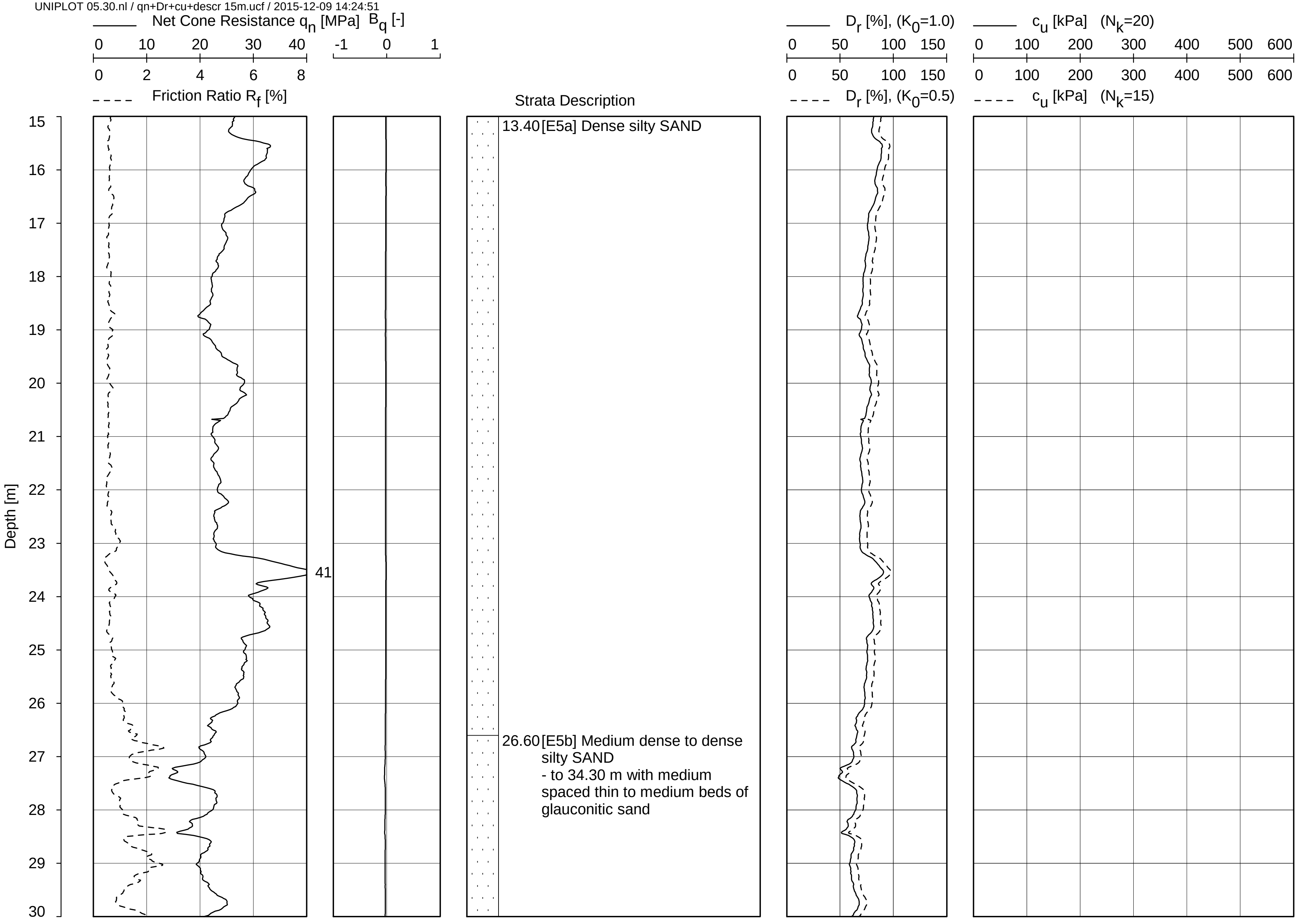
Date Of Testing : 26-Oct-2015
Water Depth [m] : 30.3
Coordinates [m] : E500855 N5723291

CPT DATA INTERPRETATION

CPT_WFS3_13

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:24:51



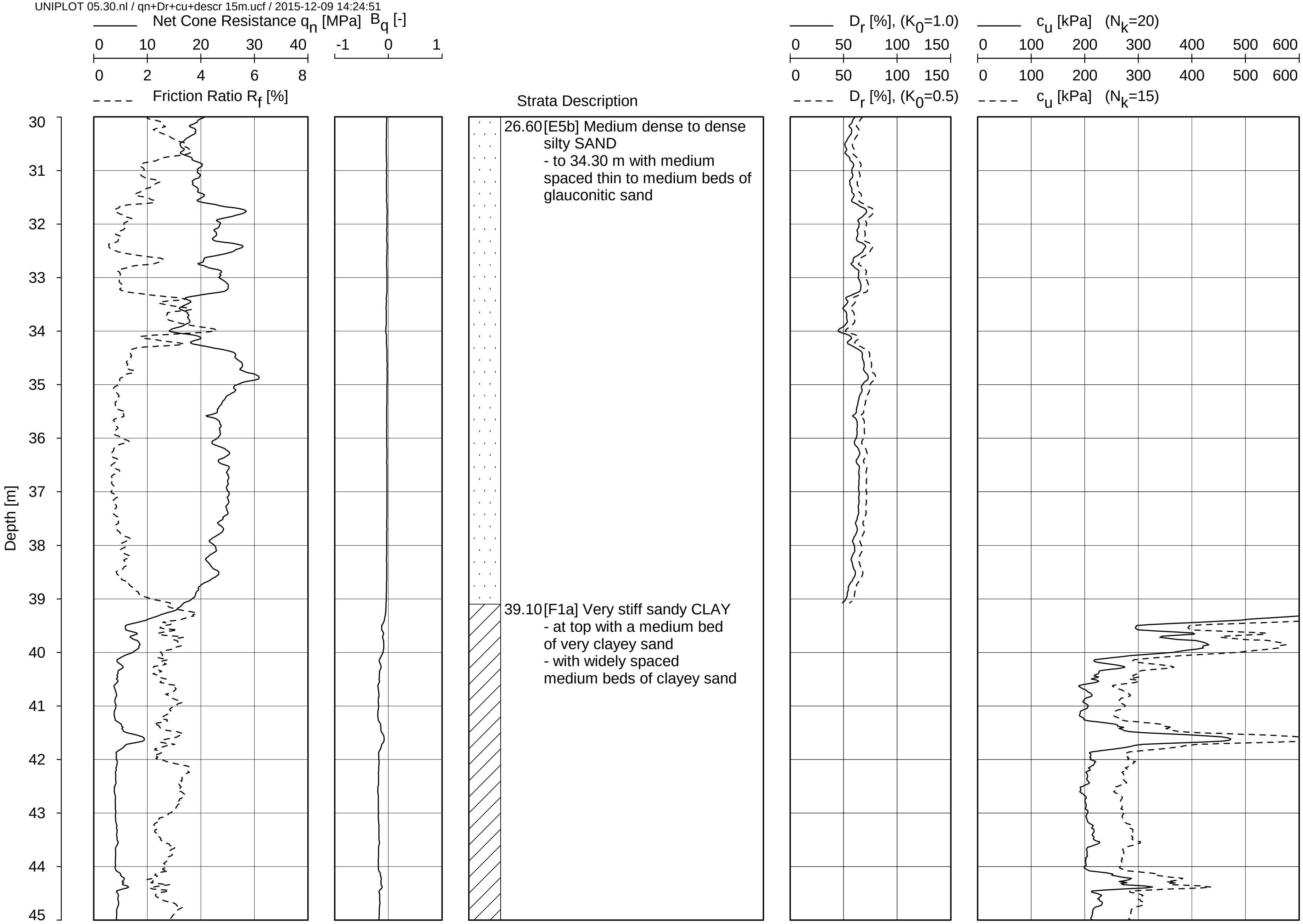
Date Of Testing : 26-Oct-2015
Water Depth [m] : 30.3
Coordinates [m] : E500855 N5723291

CPT DATA INTERPRETATION

CPT_WFS3_13

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:24:51



Date Of Testing : 26-Oct-2015

Water Depth [m] : 30.3

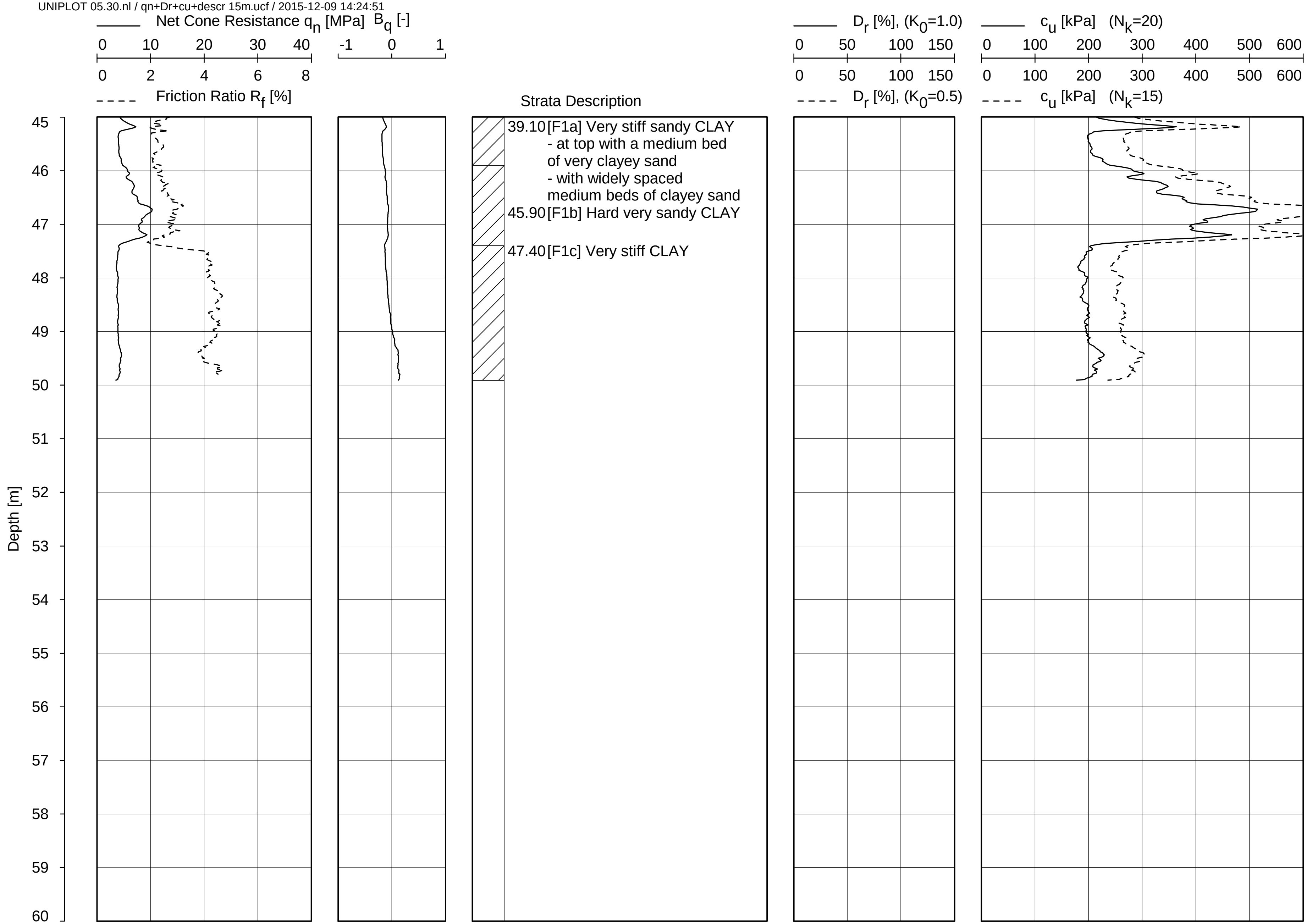
Coordinates [m] : E500855 N5723291

CPT DATA INTERPRETATION

CPT_WFS3_13

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:24:51



Date Of Testing : 26-Oct-2015
Water Depth [m] : 30.3
Coordinates [m] : E500855 N5723291

CPT DATA INTERPRETATION

CPT_WFS3_13

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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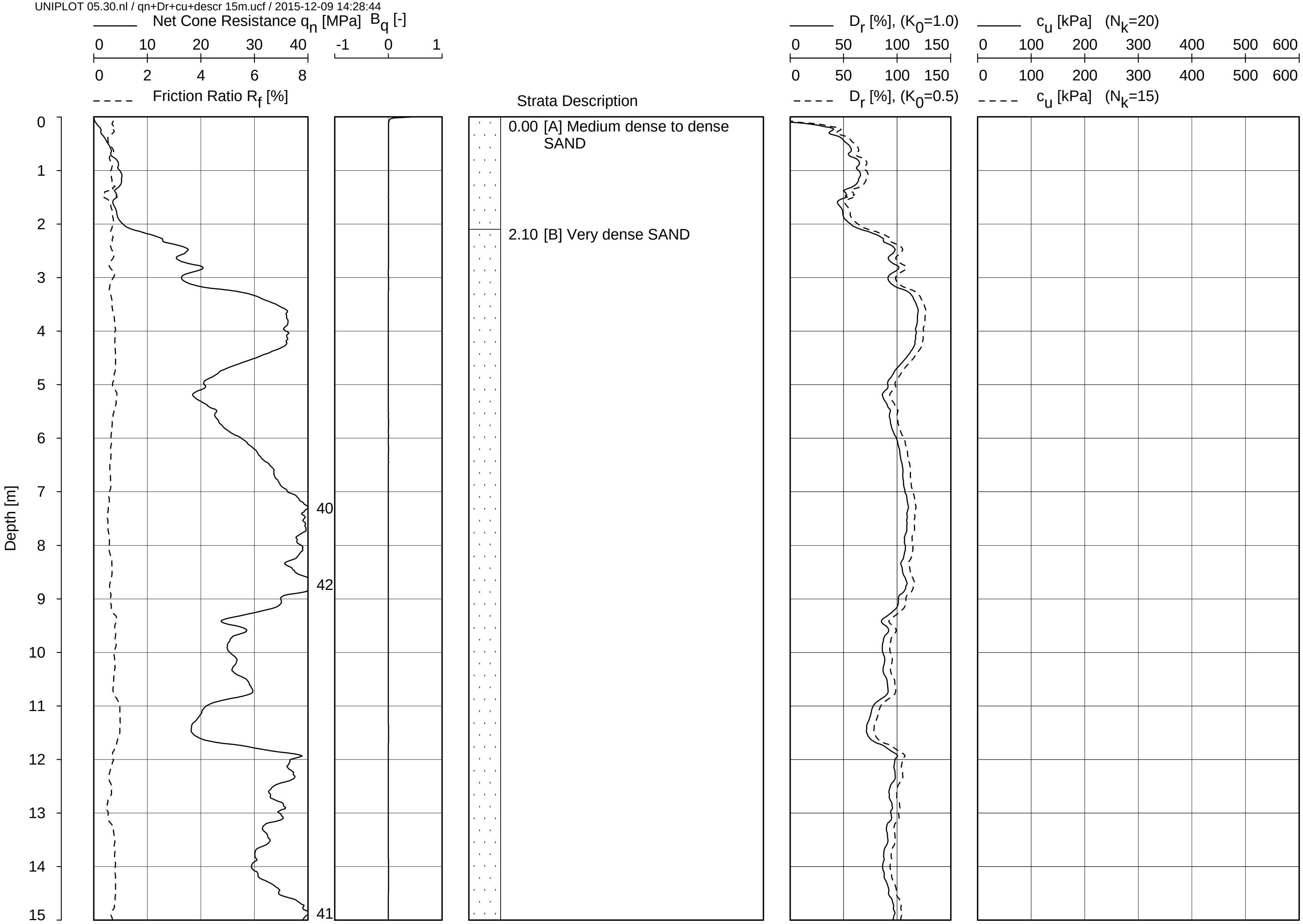


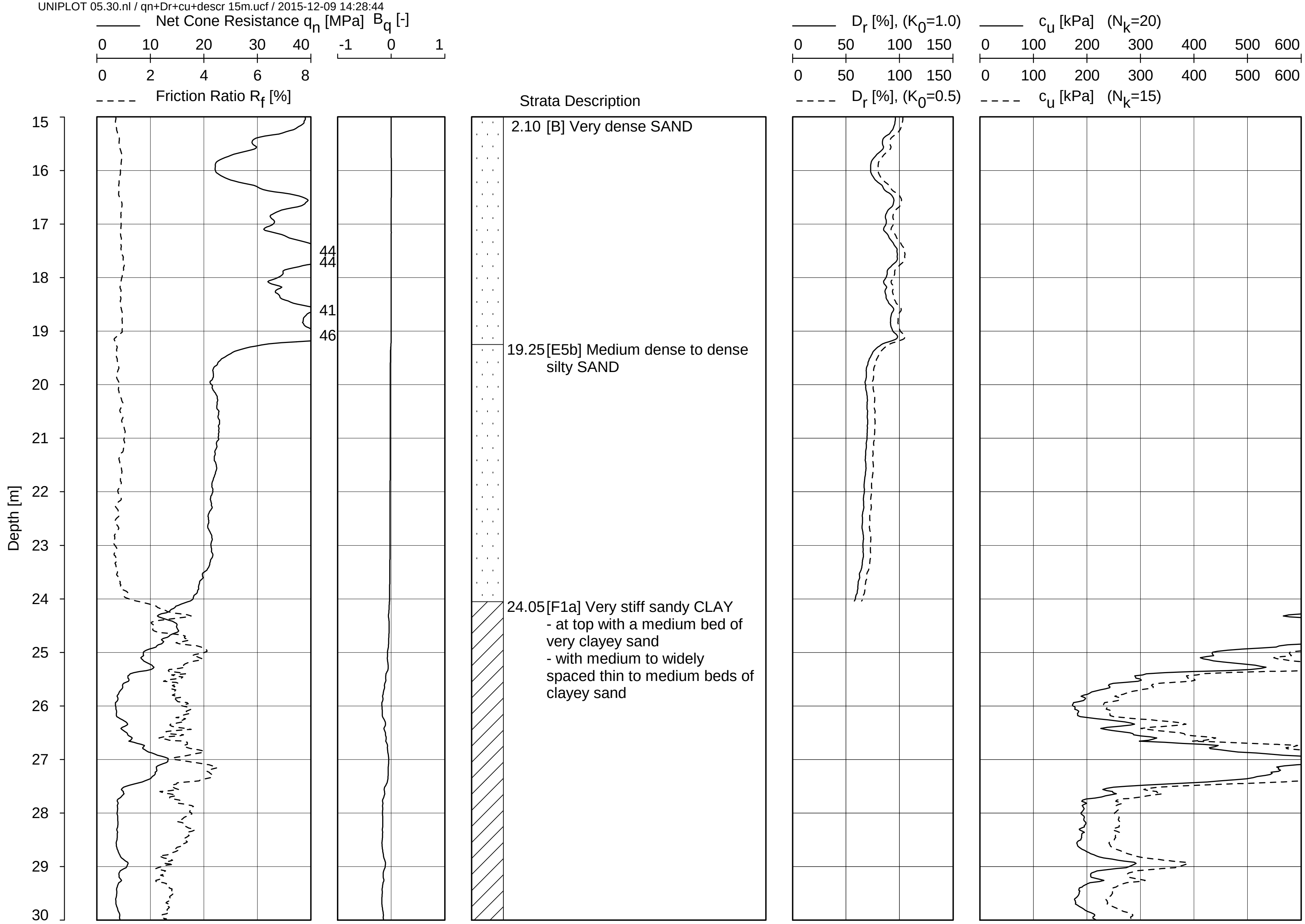
Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E494938 N5726134

CPT DATA INTERPRETATION

CPT_WFS3_14

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:28:44

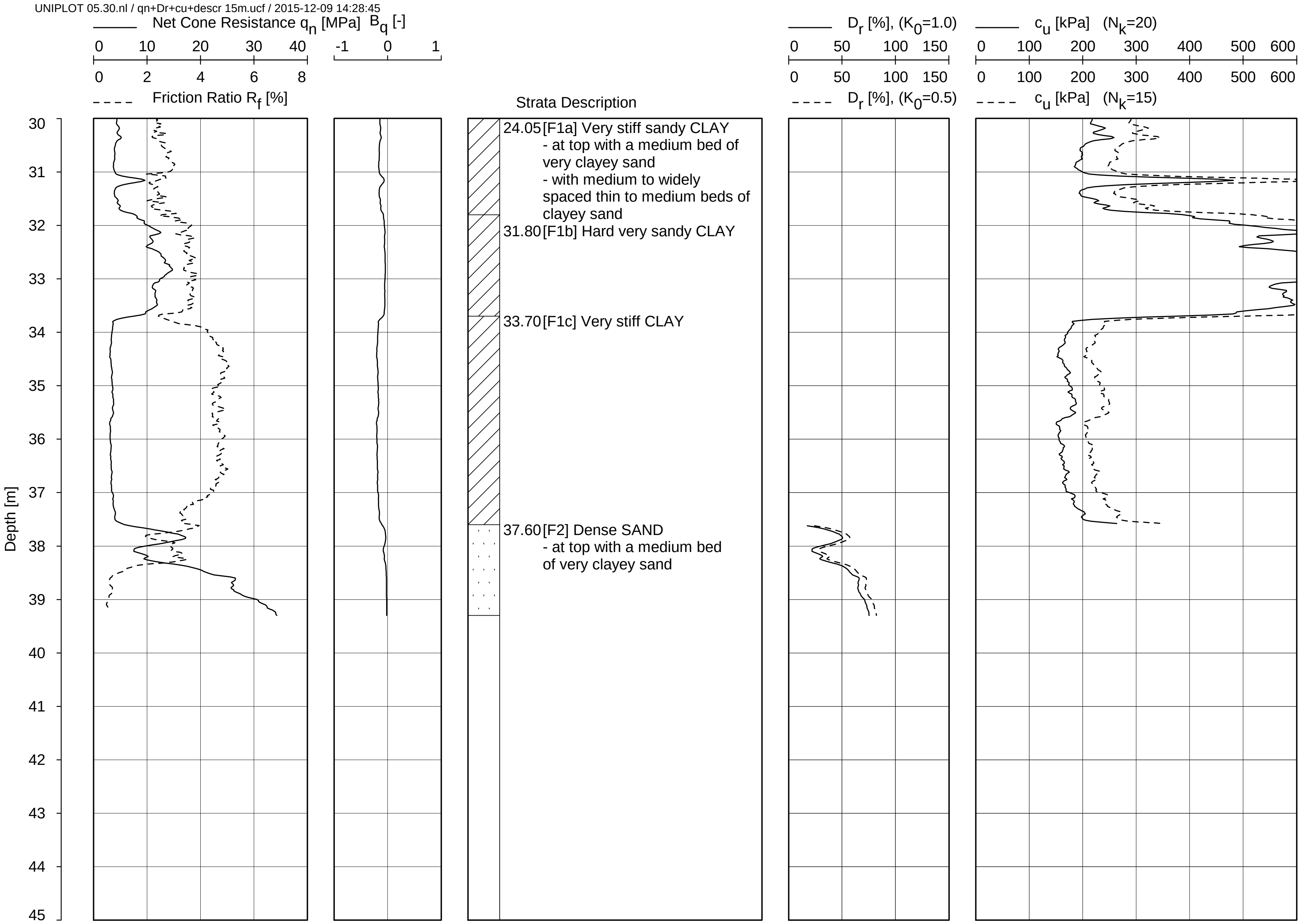


Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E494938 N5726134

CPT DATA INTERPRETATION

CPT_WFS3_14

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

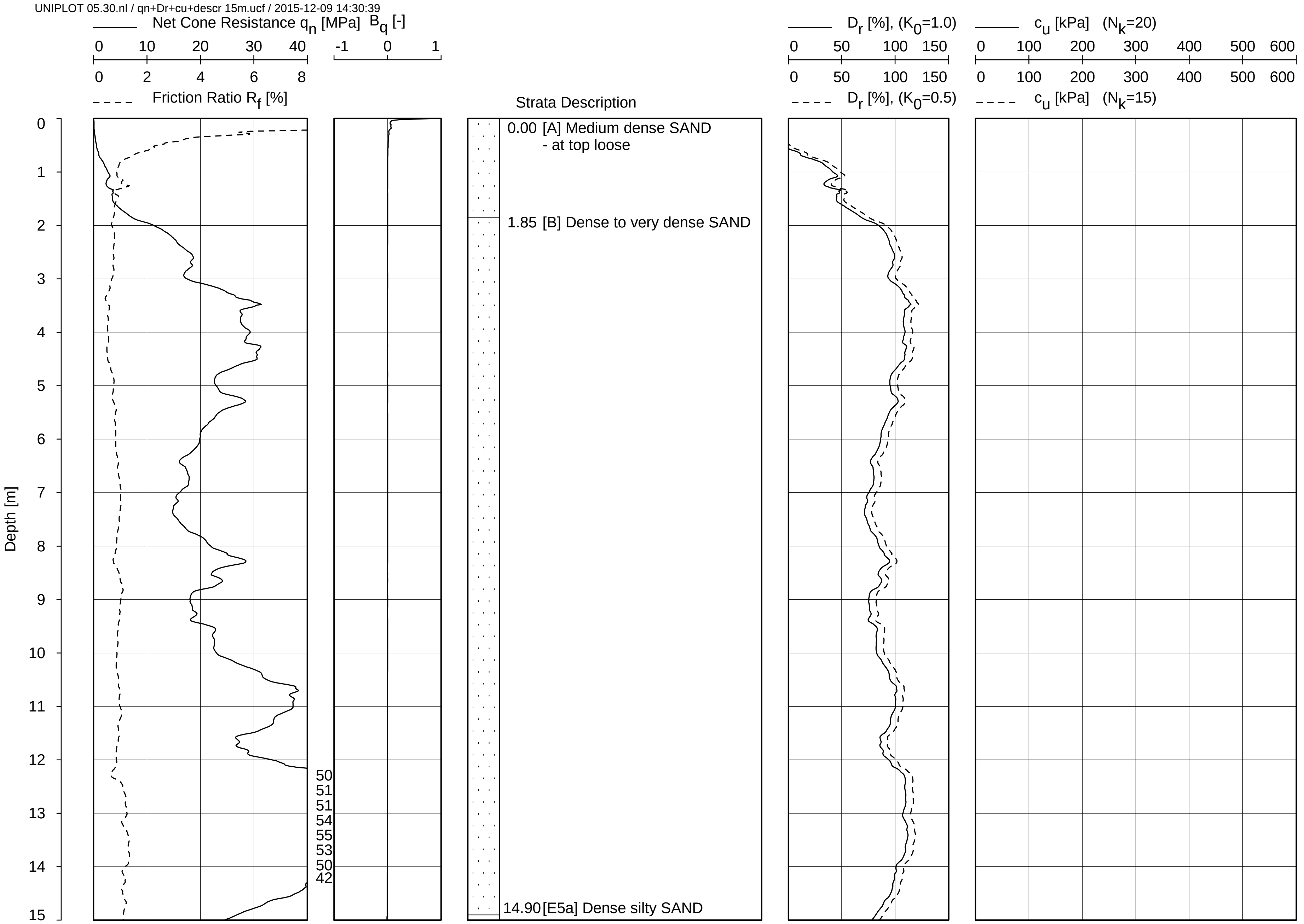


Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E494938 N5726134

CPT DATA INTERPRETATION

CPT_WFS3_14

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



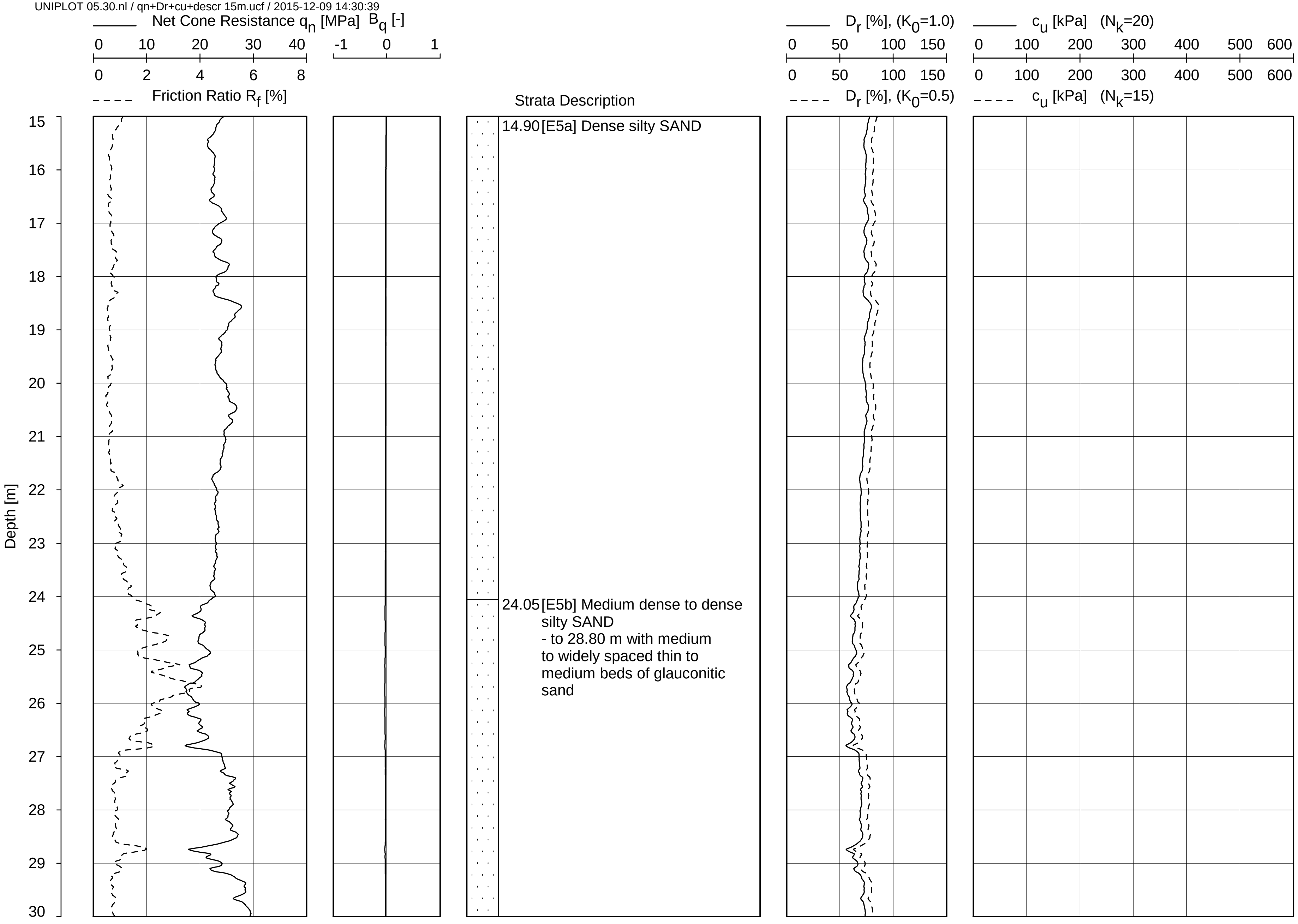
Date Of Testing : 29-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496545 N5727484

CPT DATA INTERPRETATION

CPT_WFS3_15

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:30:39



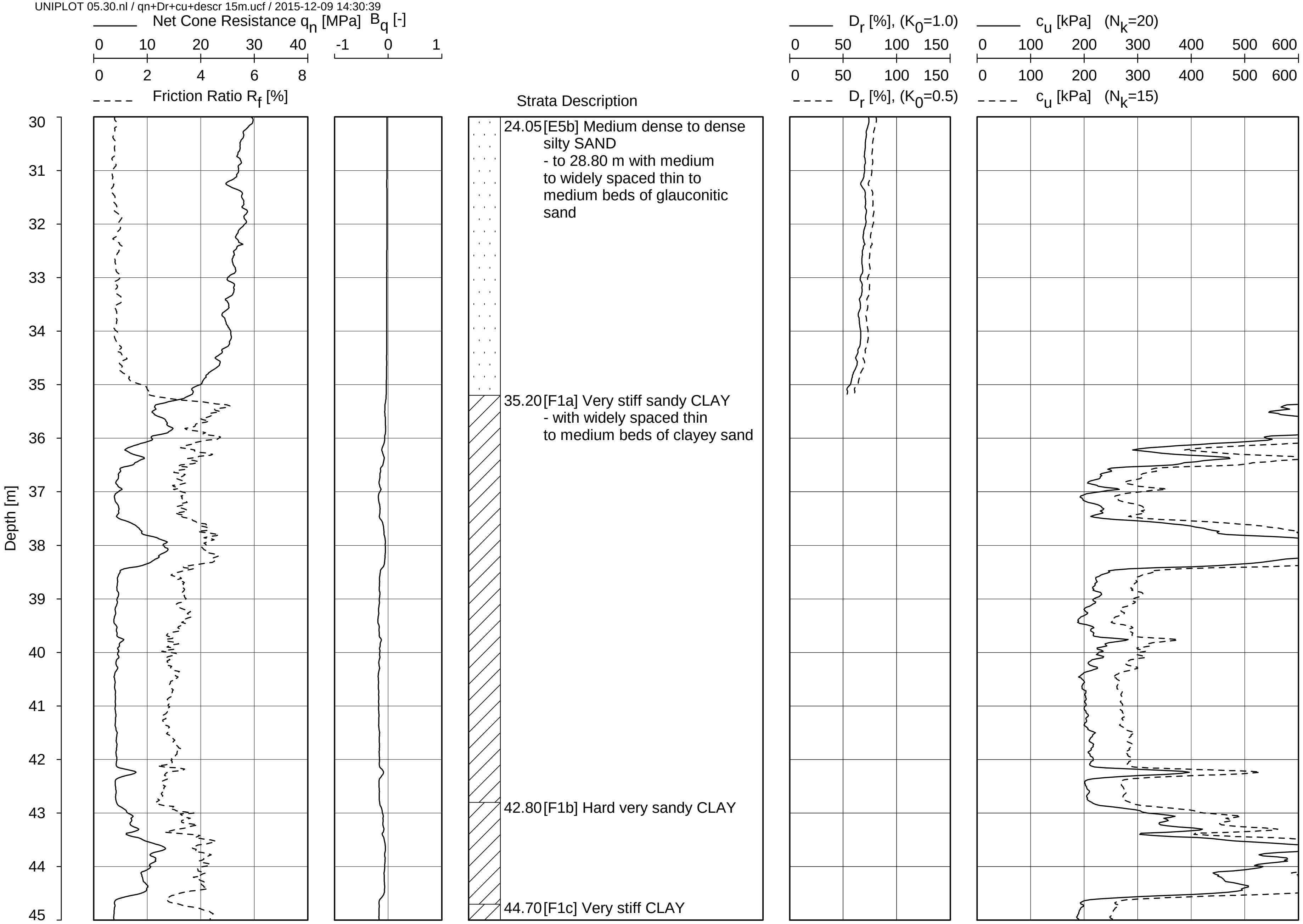
Date Of Testing : 29-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496545 N5727484

CPT DATA INTERPRETATION

CPT_WFS3_15

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:30:39



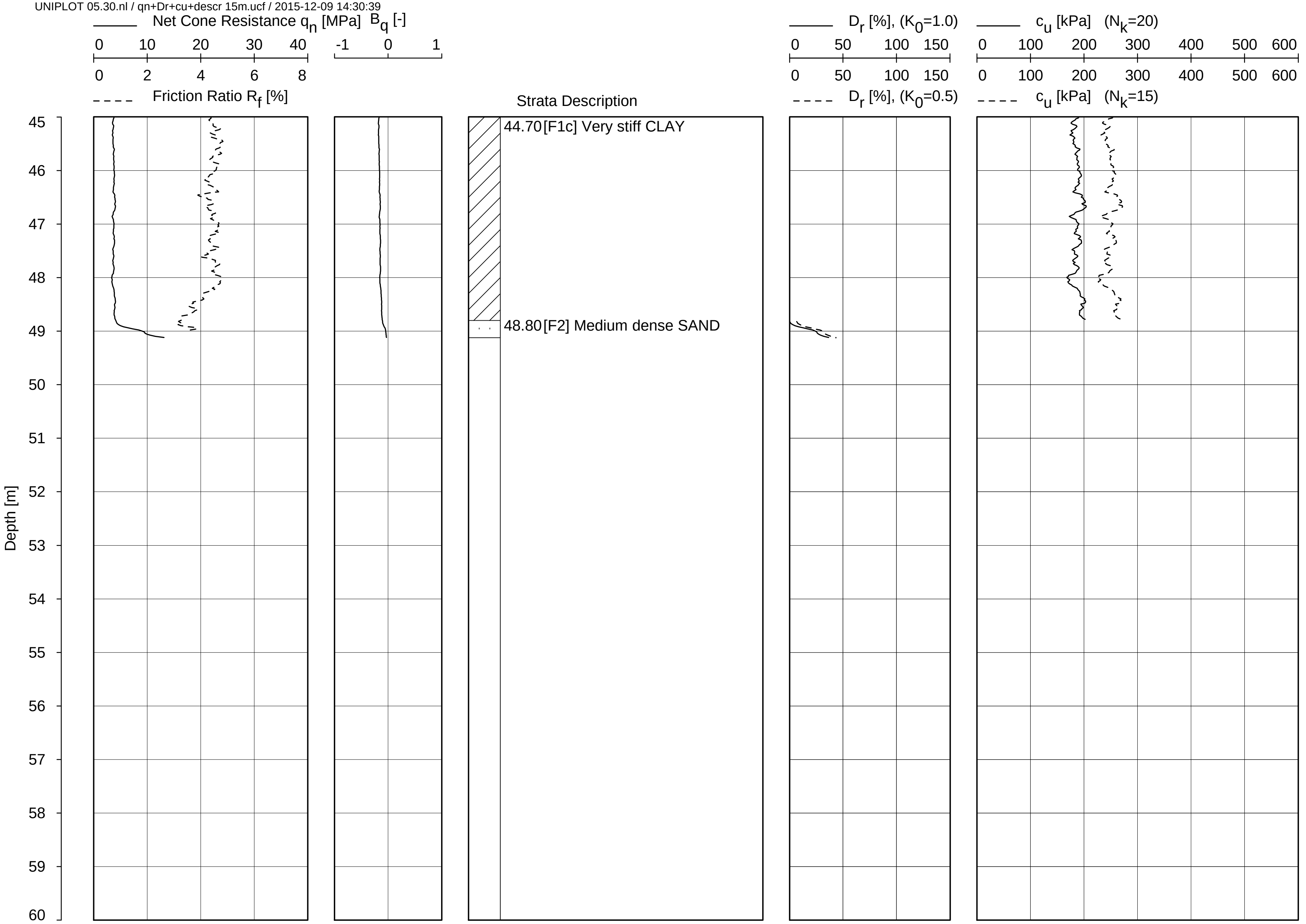
Date Of Testing : 29-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496545 N5727484

CPT DATA INTERPRETATION

CPT_WFS3_15

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:30:39

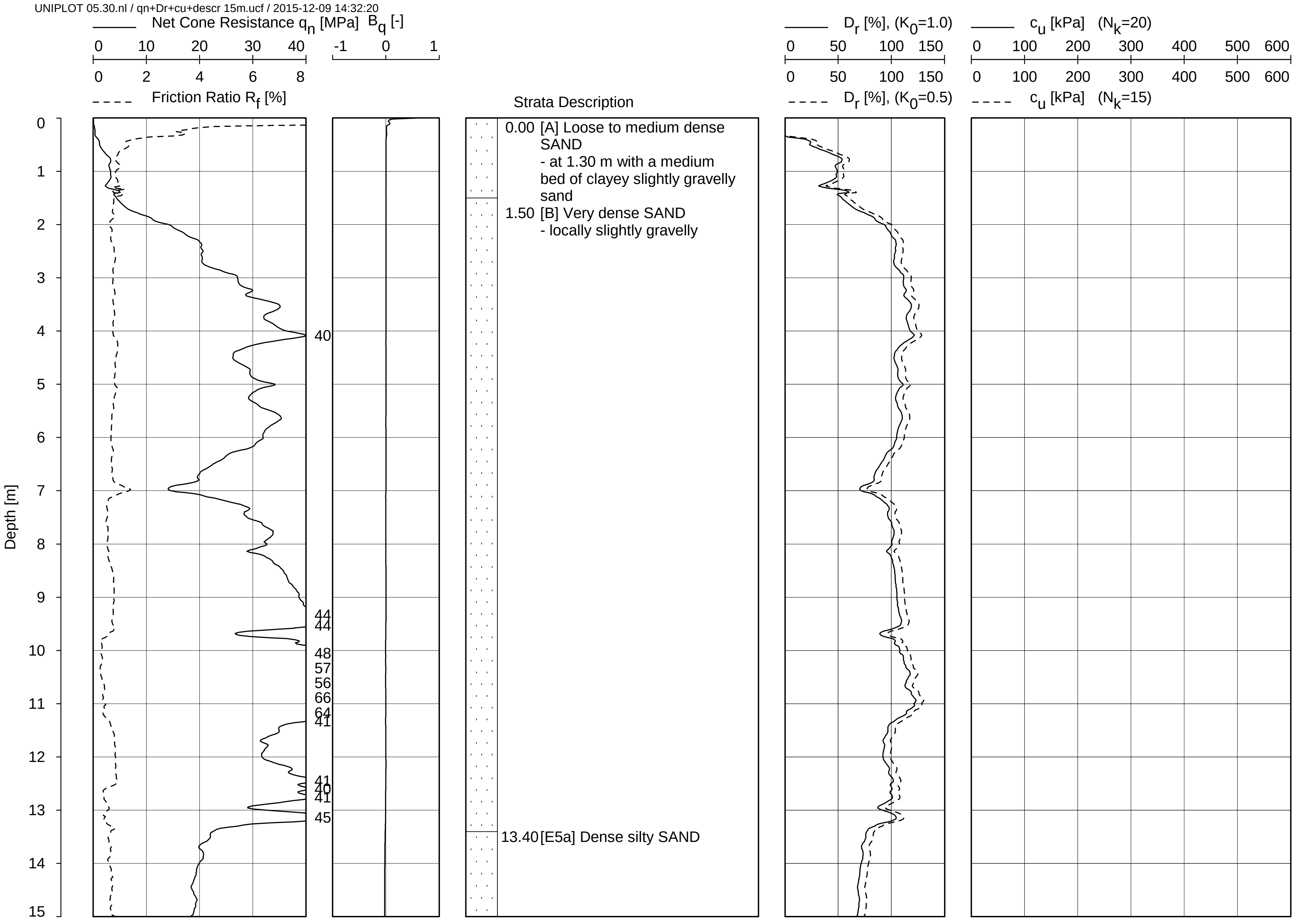


Date Of Testing : 29-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496545 N5727484

CPT DATA INTERPRETATION

CPT_WFS3_15

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E495274 N5727833

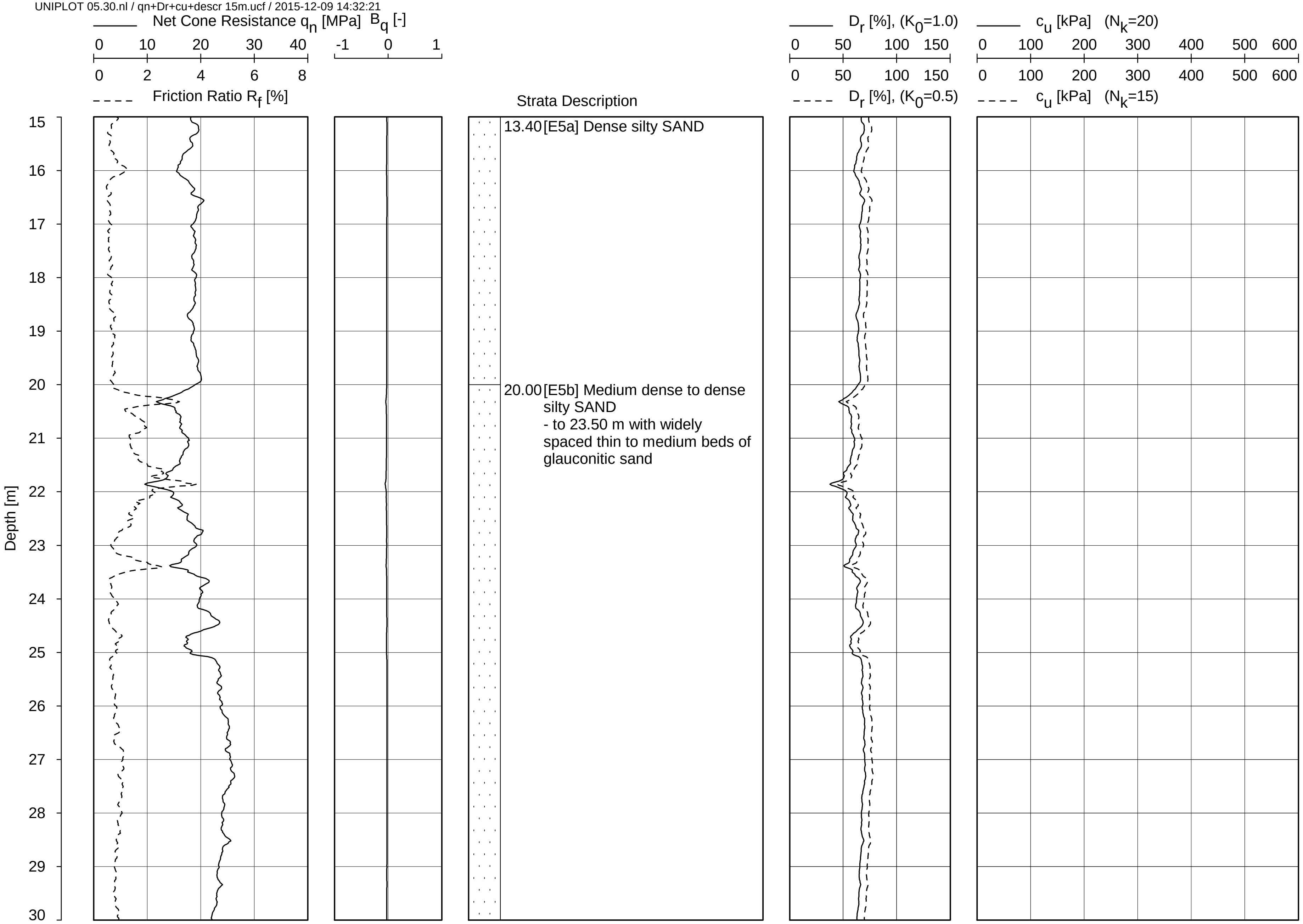
CPT DATA INTERPRETATION

CPT_WFS3_16

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

Fugro Report No. N6083/02 (2)

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:32:21



Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E495274 N5727833

CPT DATA INTERPRETATION

CPT_WFS3_16

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

Plate A42

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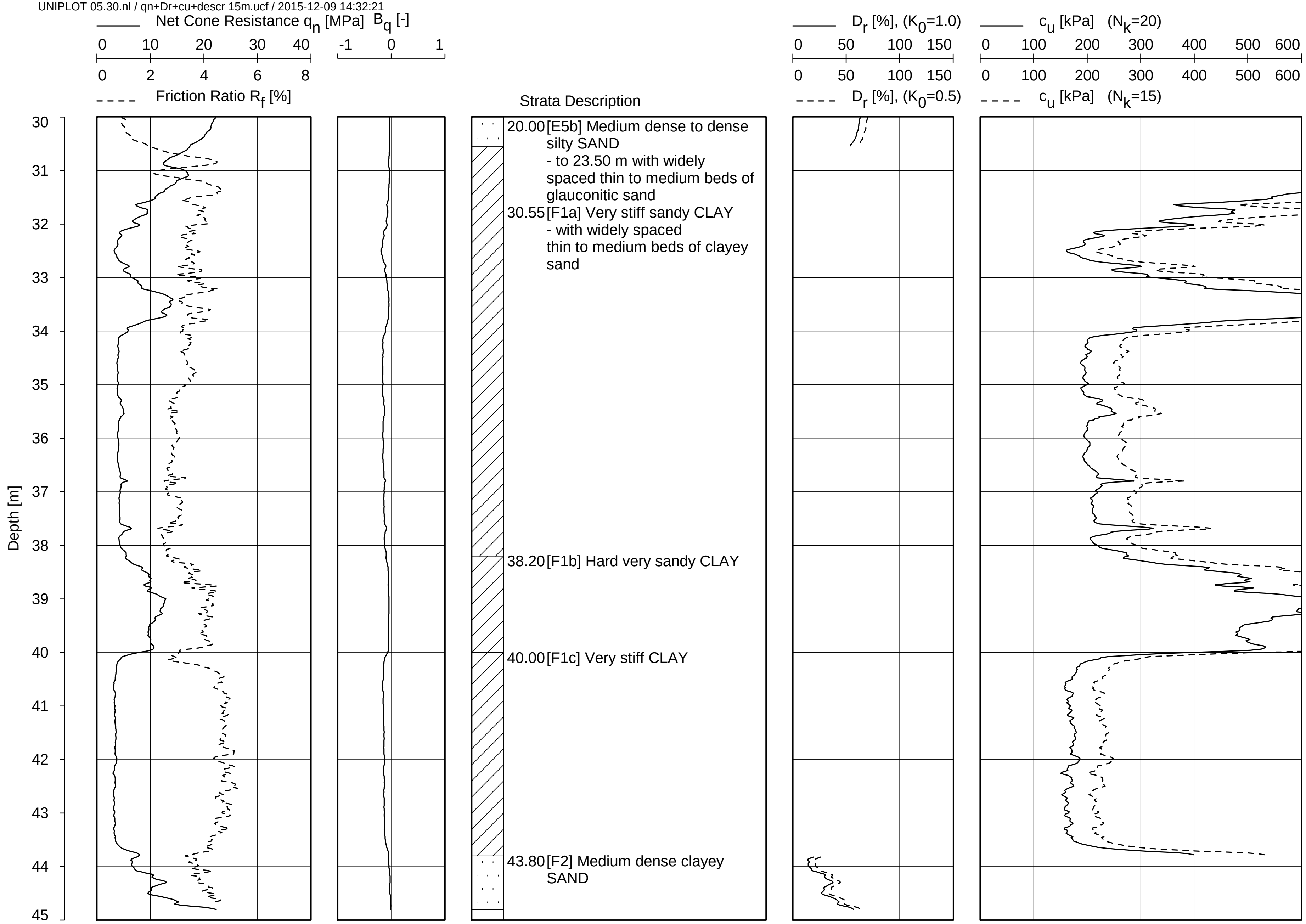


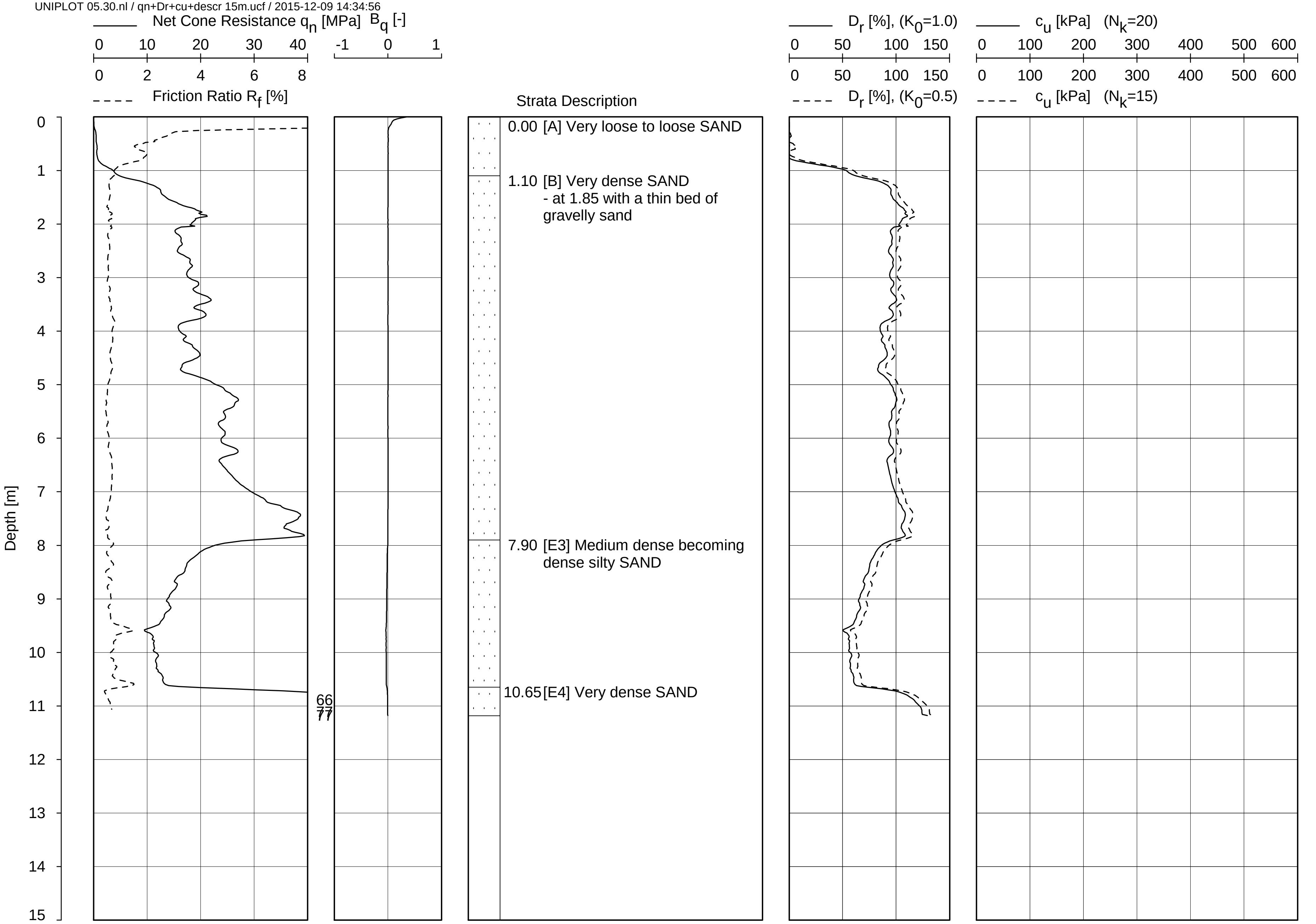
Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E495274 N5727833

CPT DATA INTERPRETATION

CPT_WFS3_16

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.30.nl / qn+Dr+cu+descr 15m.ucf / 2015-12-09 14:34:56

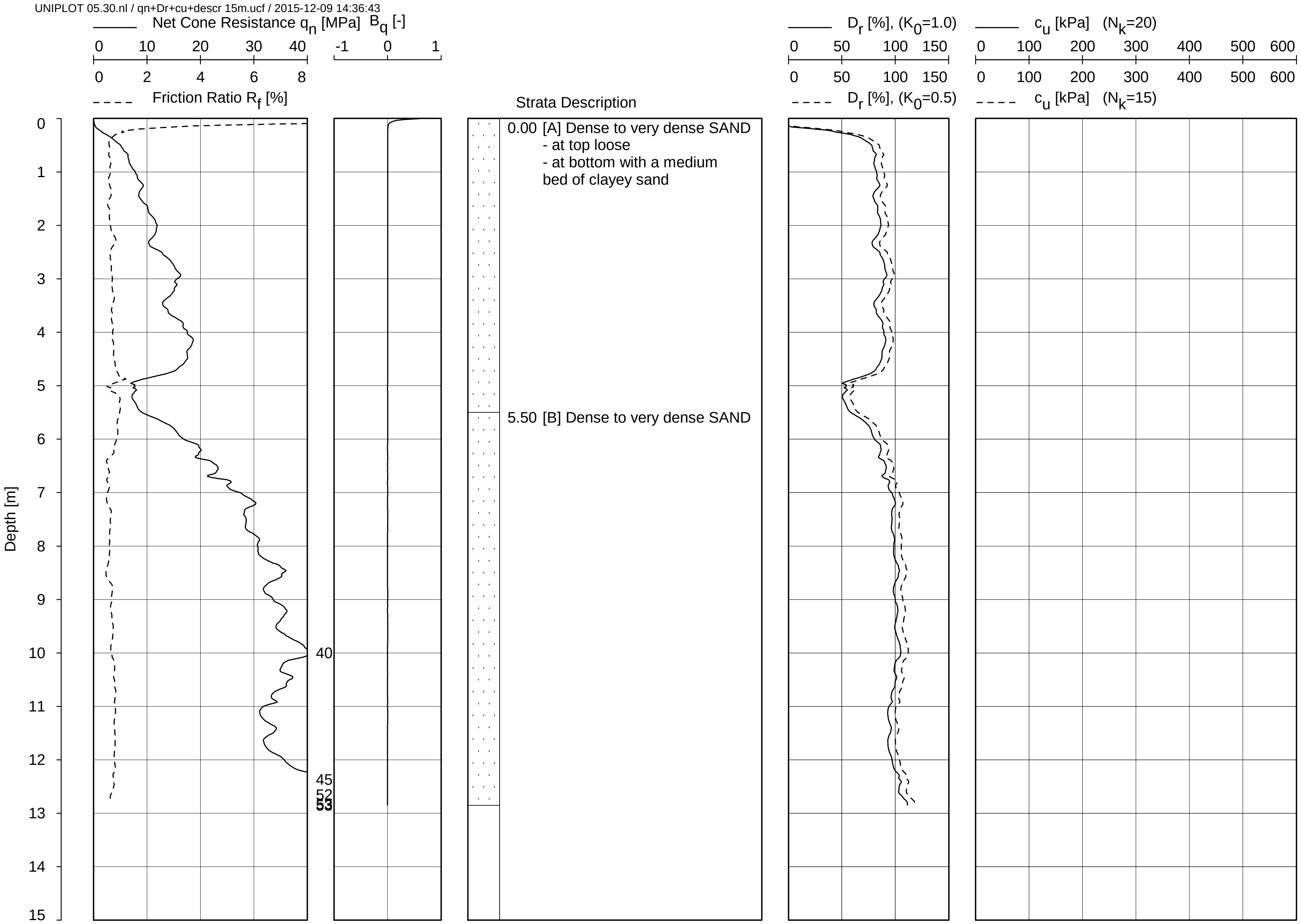


Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.1
Coordinates [m] : E497485 N5728646

CPT DATA INTERPRETATION

CPT_WFS3_17

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 28-Oct-2015
Water Depth [m] : 29.1
Coordinates [m] : E494599 N5724469

CPT DATA INTERPRETATION

CPT_WFS3_18

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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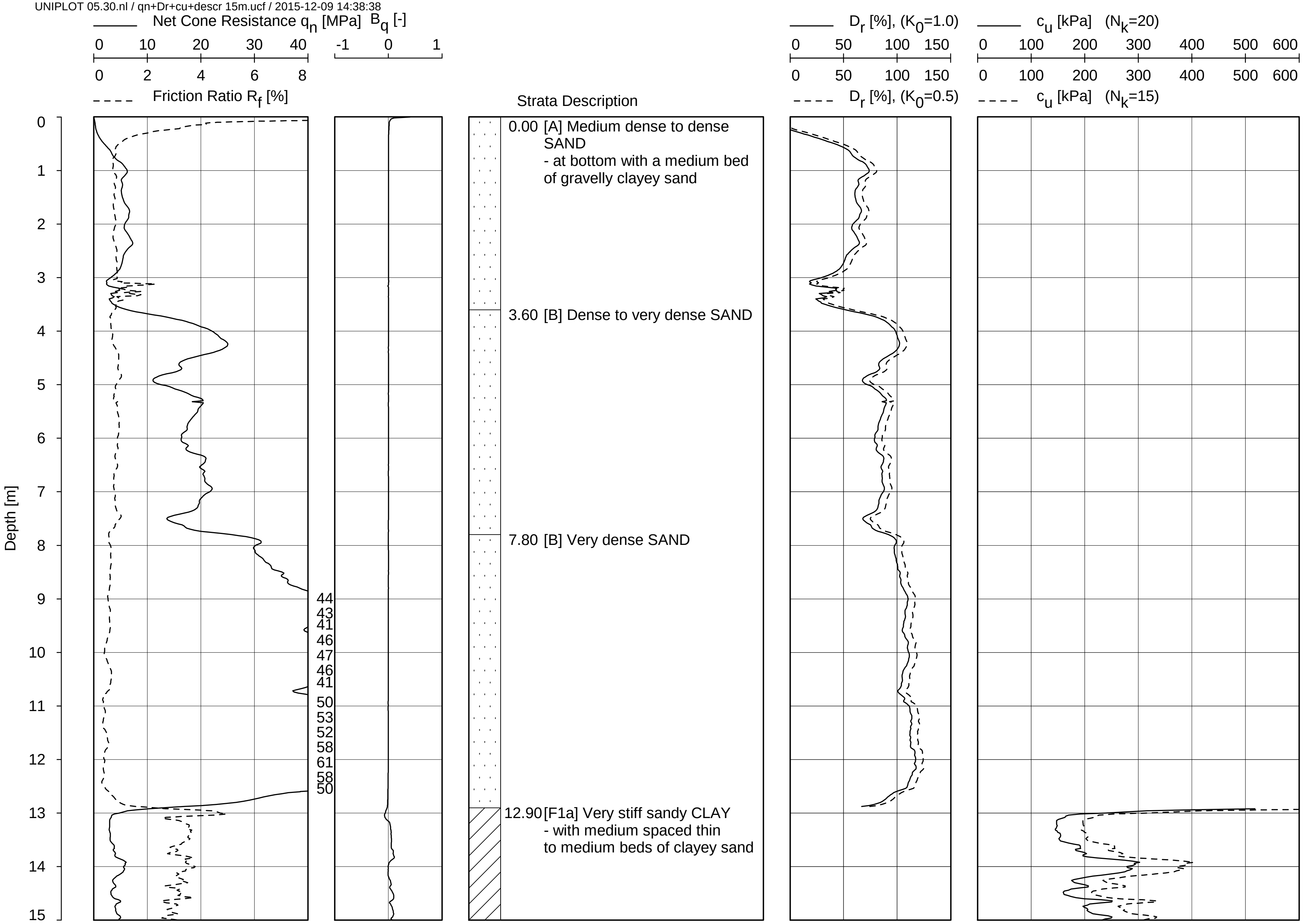

Date Of Testing : 28-Oct-2015
Water Depth [m] : 30.2
Coordinates [m] : E492527 N5725094

CPT DATA INTERPRETATION

CPT_WFS3_19

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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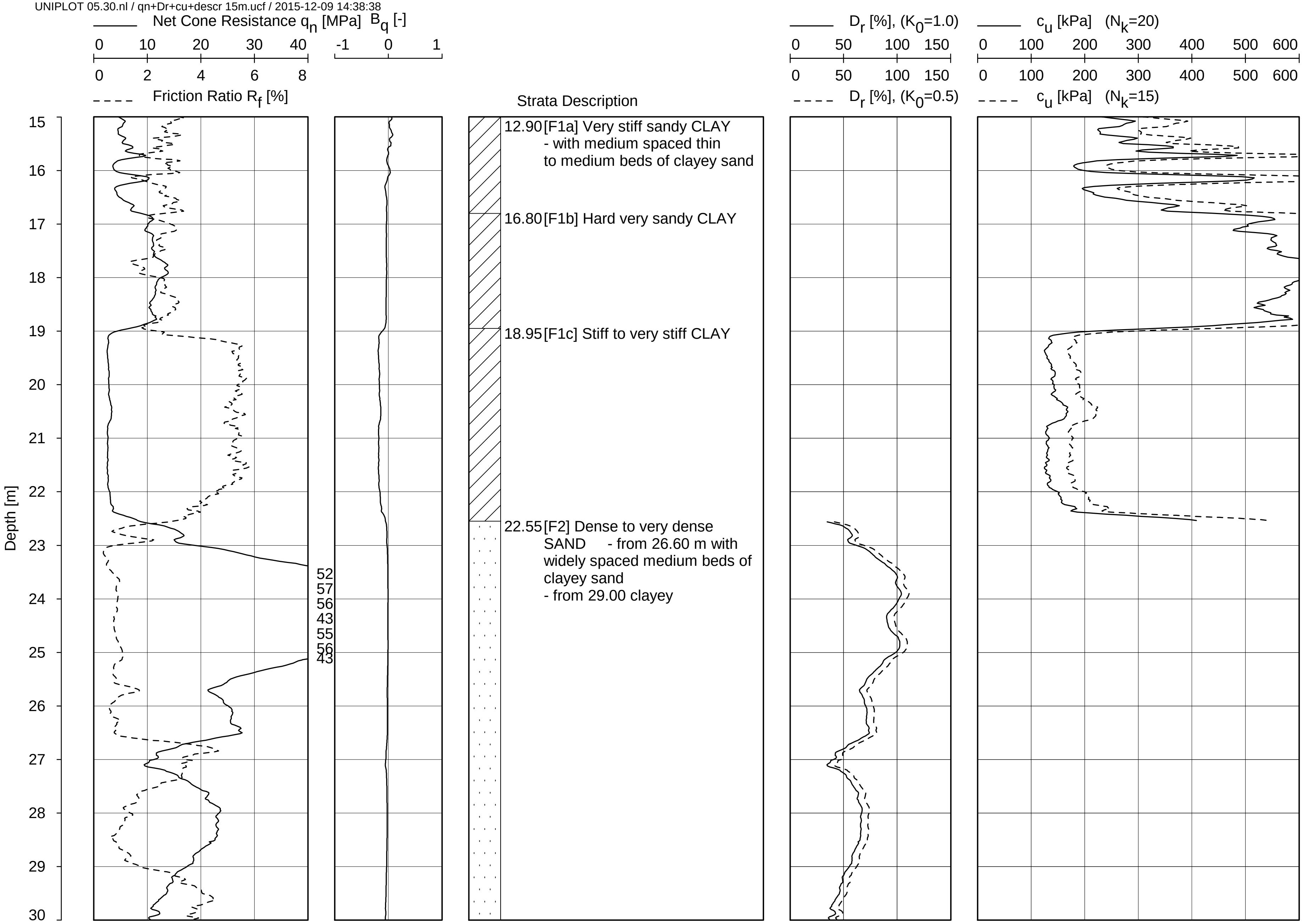

Date Of Testing : 28-Oct-2015
Water Depth [m] : 30.2
Coordinates [m] : E492527 N5725094

CPT DATA INTERPRETATION

CPT_WFS3_19

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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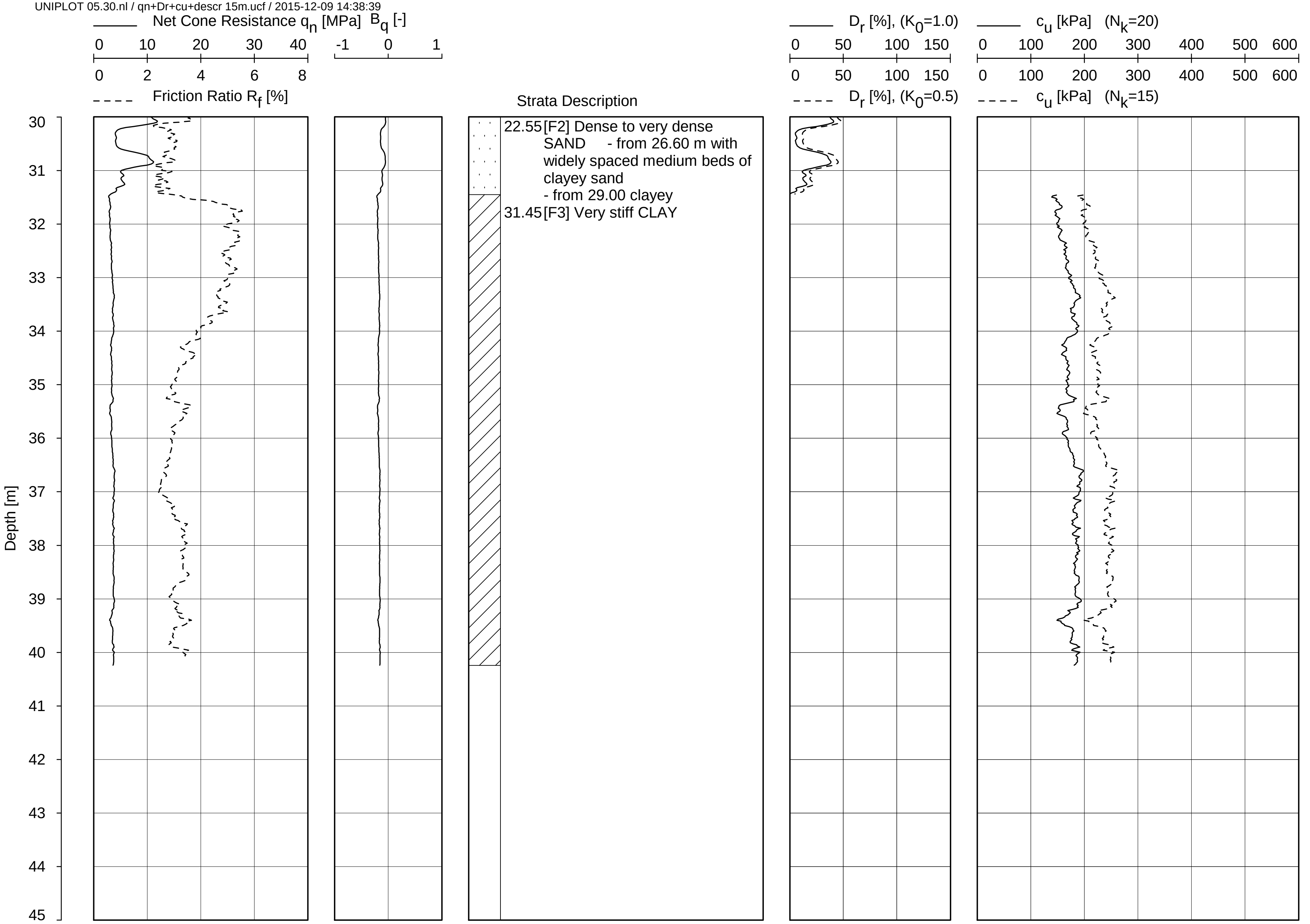

Date Of Testing : 28-Oct-2015

Water Depth [m] : 30.2

Coordinates [m] : E492527 N5725094

CPT DATA INTERPRETATION

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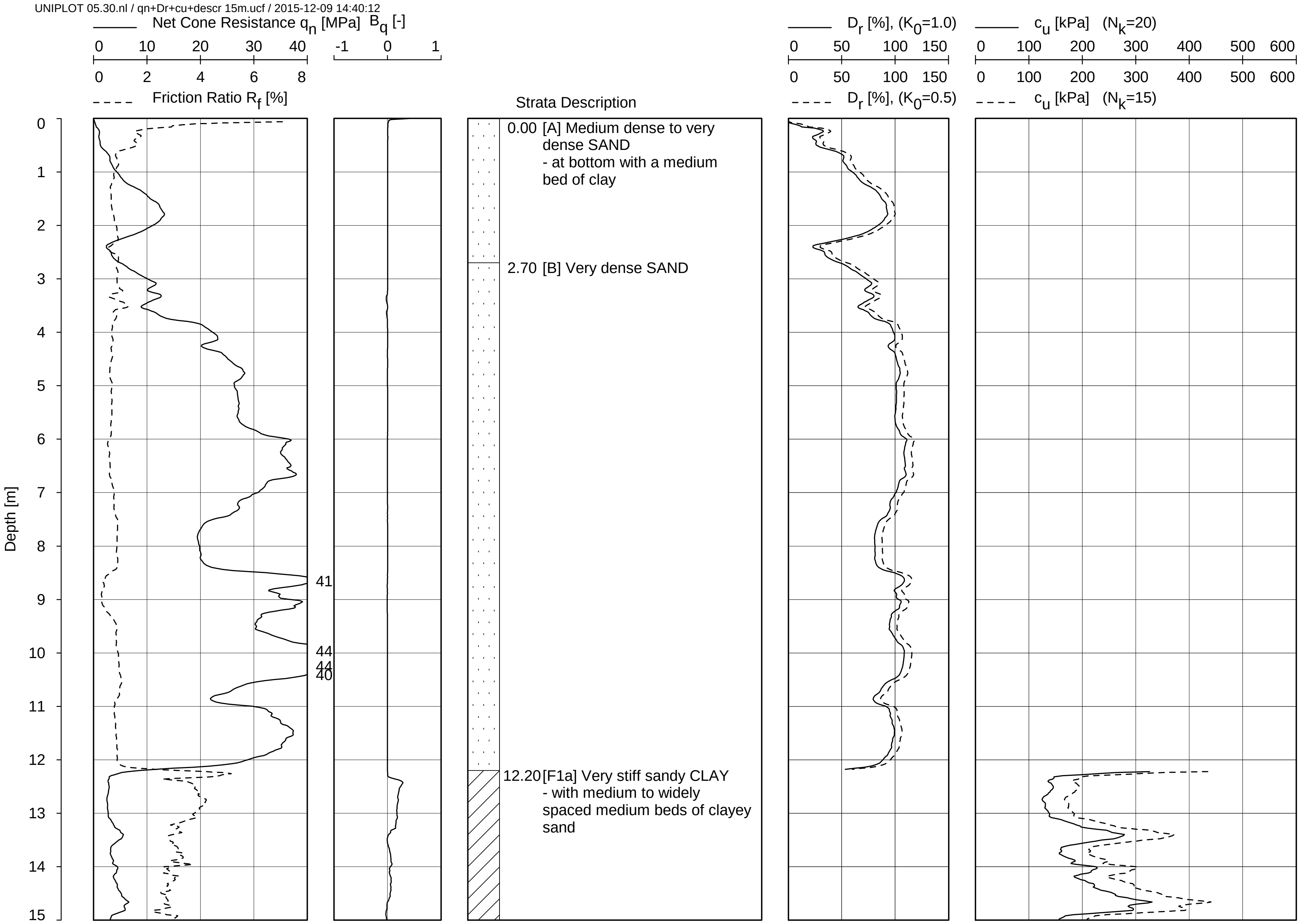

Date Of Testing : 28-Oct-2015
Water Depth [m] : 31.1
Coordinates [m] : E493397 N5724254

CPT DATA INTERPRETATION

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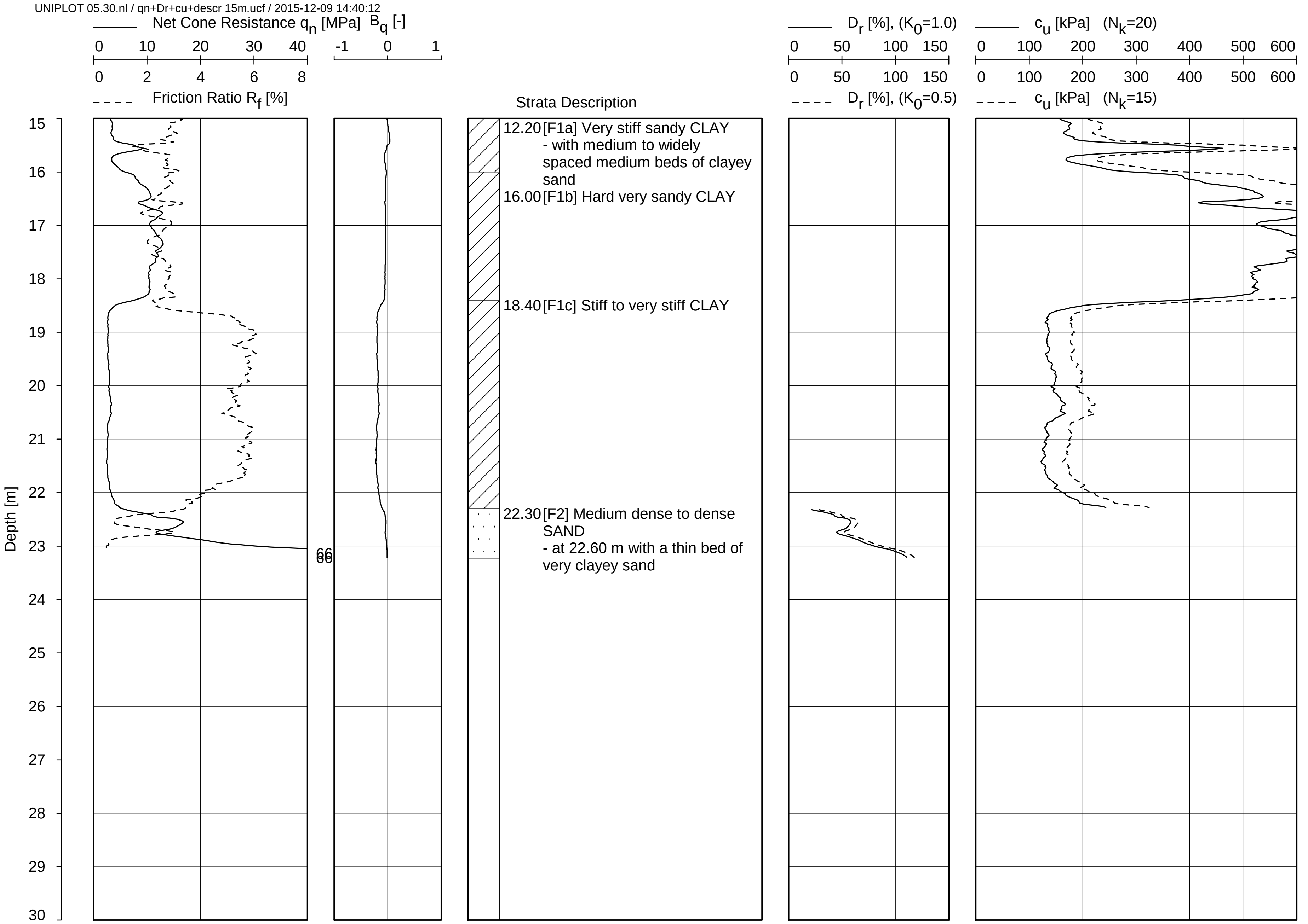

Date Of Testing : 28-Oct-2015
Water Depth [m] : 31.1
Coordinates [m] : E493397 N5724254

CPT DATA INTERPRETATION

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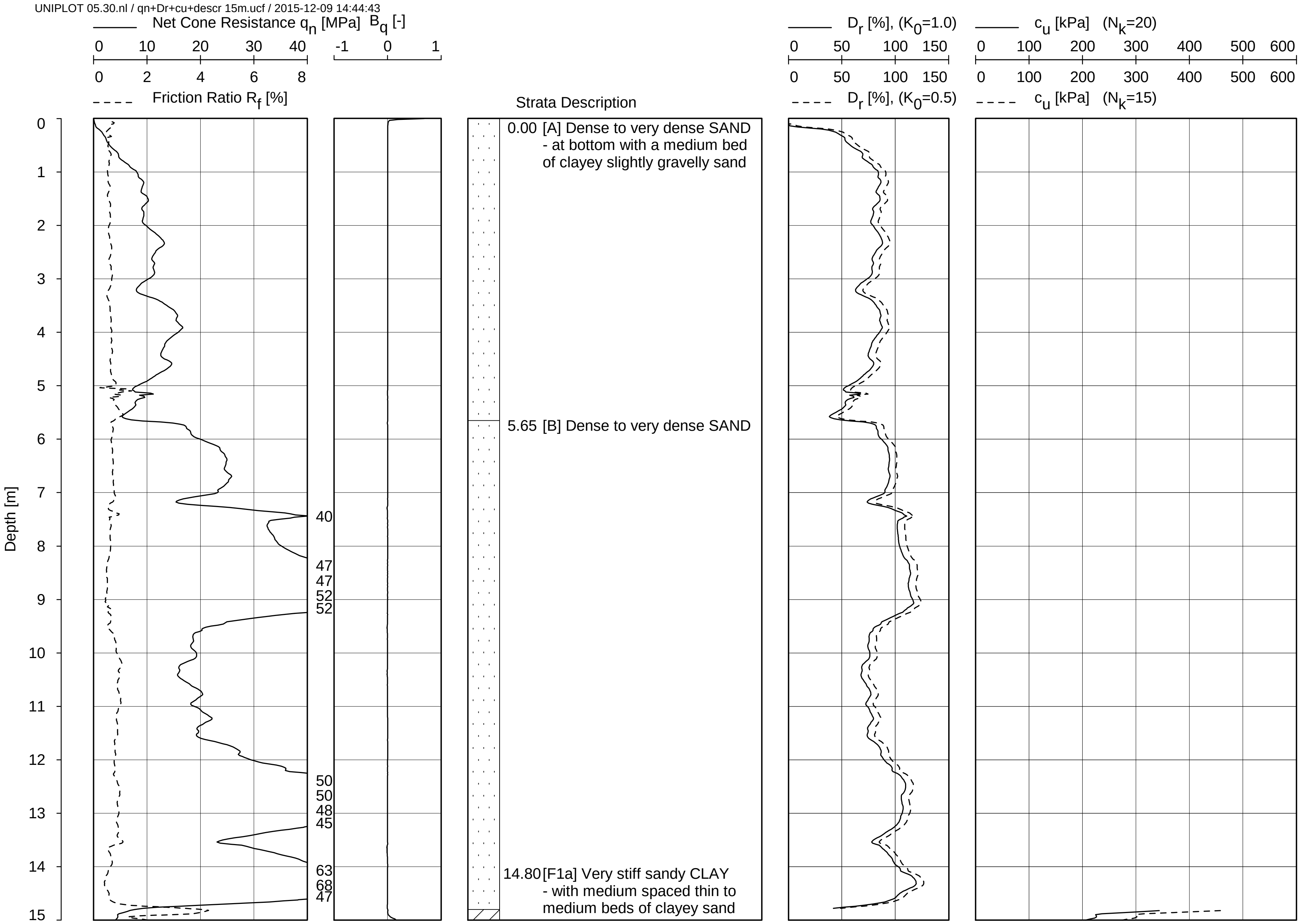

Date Of Testing : 28-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E494845 N5722865

CPT DATA INTERPRETATION

CPT_WFS3_21

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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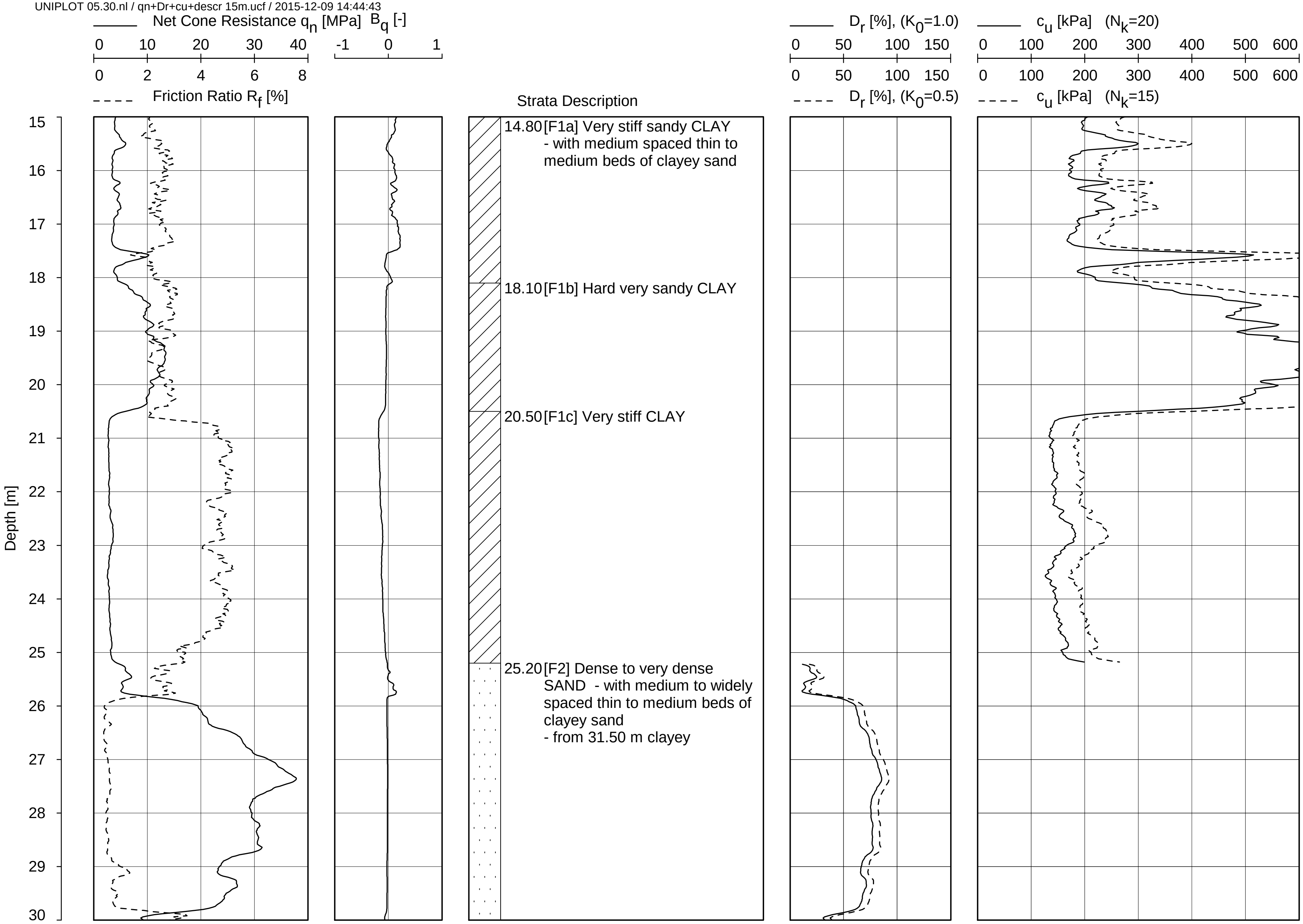

Date Of Testing : 28-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E494845 N5722865

CPT DATA INTERPRETATION

CPT_WFS3_21

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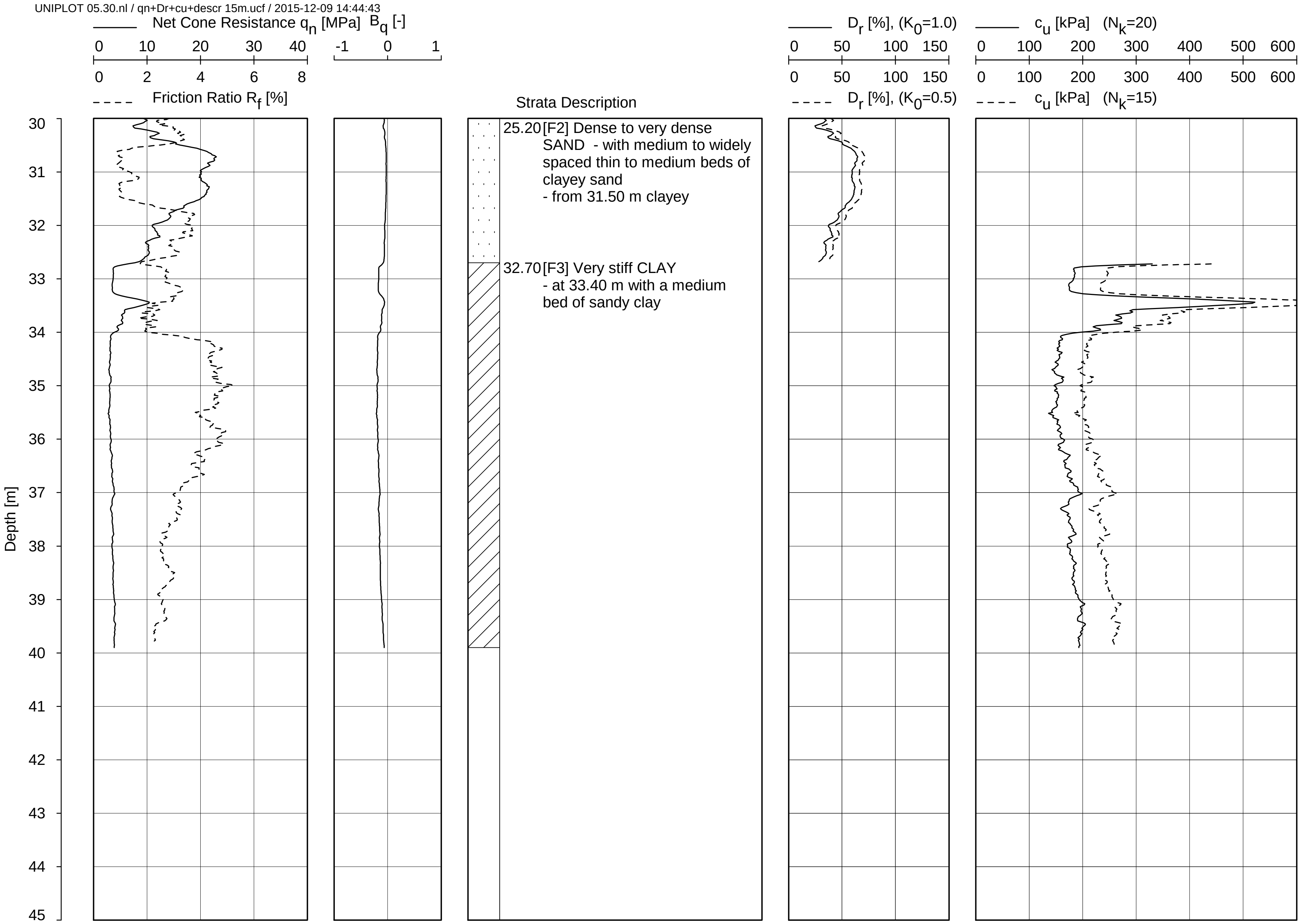

Date Of Testing : 28-Oct-2015
Water Depth [m] : 29.9
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CPT DATA INTERPRETATION

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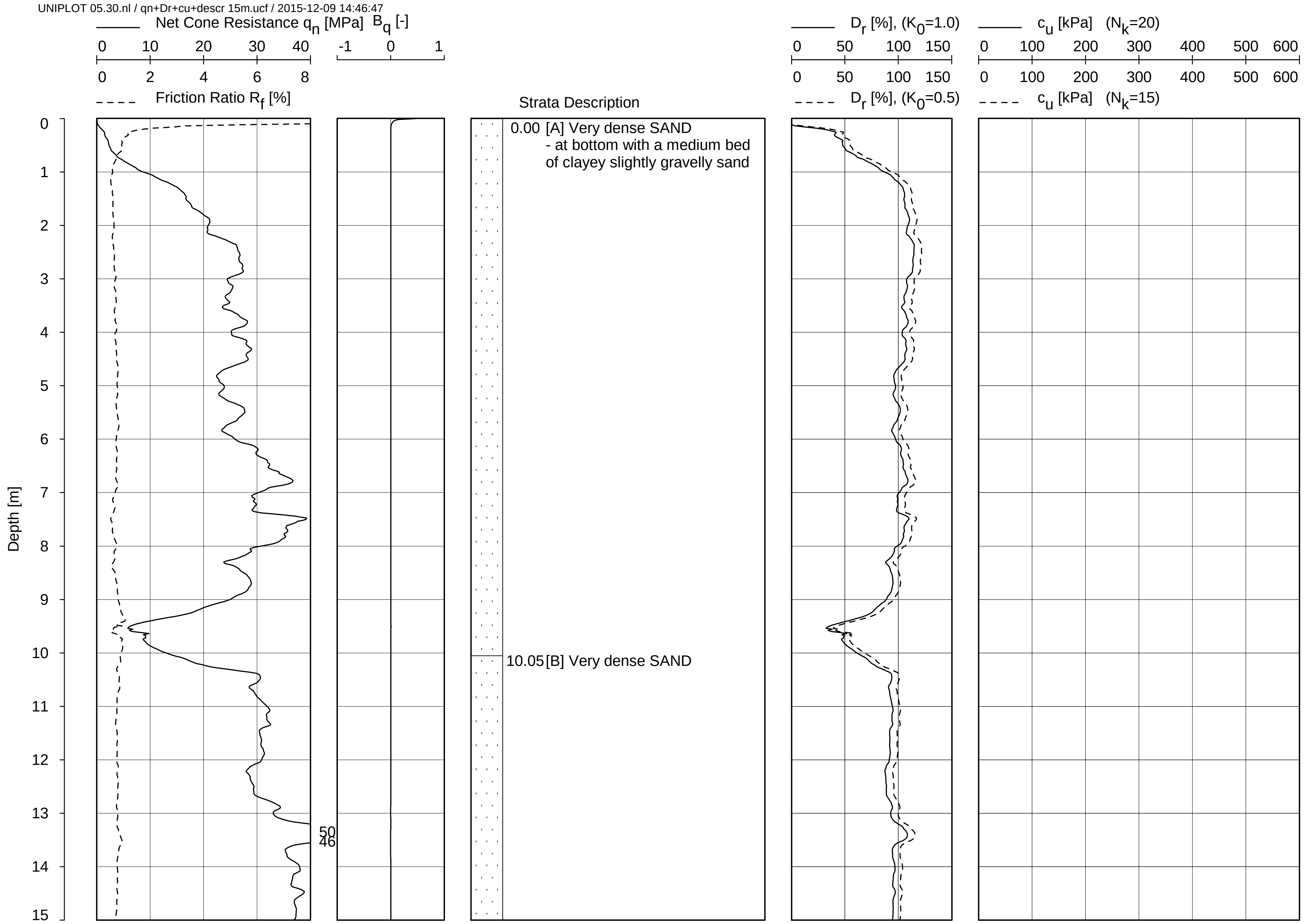

Date Of Testing : 26-Oct-2015
Water Depth [m] : 22.0
Coordinates [m] : E498189 N5723807

CPT DATA INTERPRETATION

CPT_WFS3_22

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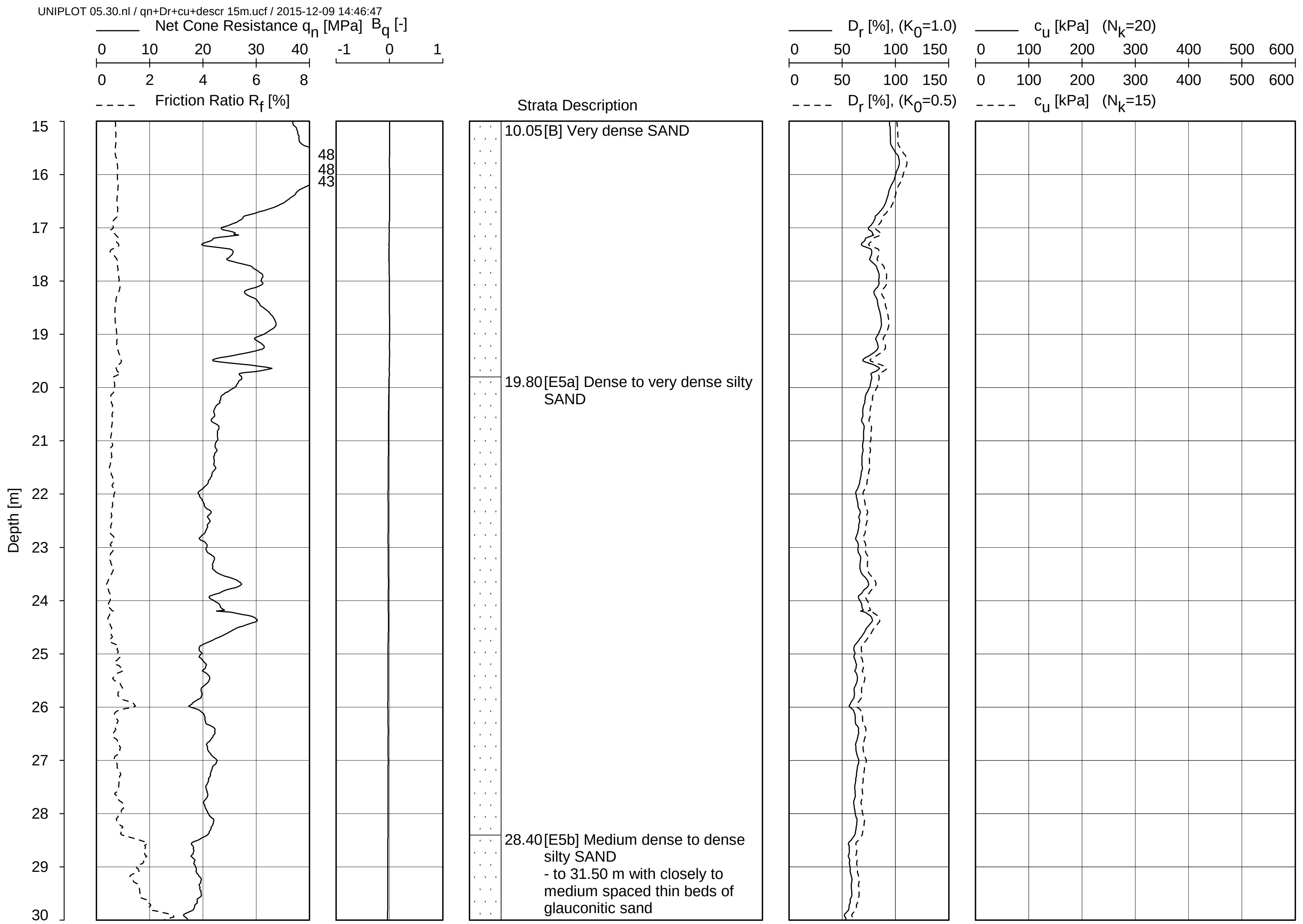

Date Of Testing : 26-Oct-2015
Water Depth [m] : 22.0
Coordinates [m] : E498189 N5723807

CPT DATA INTERPRETATION

CPT_WFS3_22

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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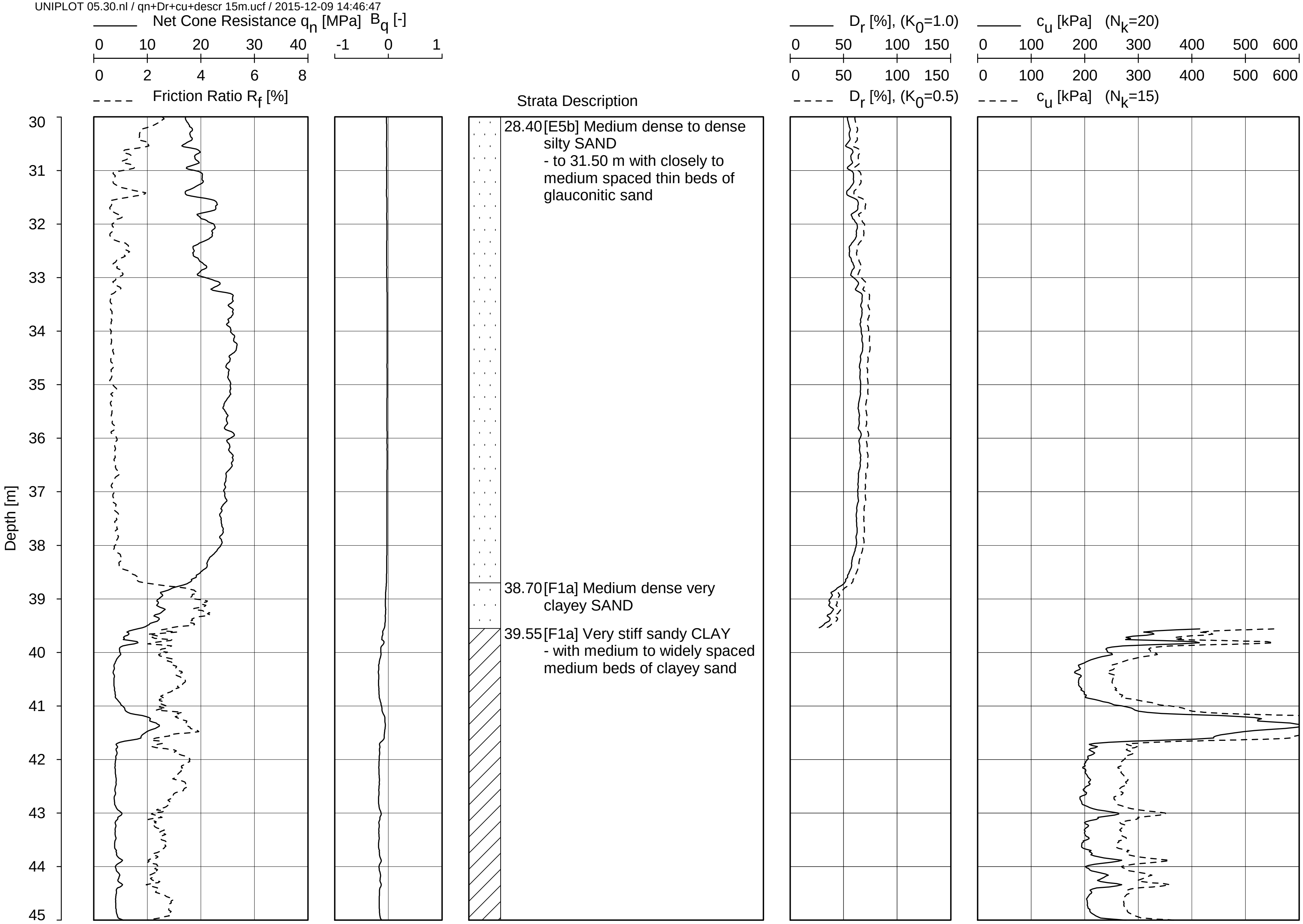
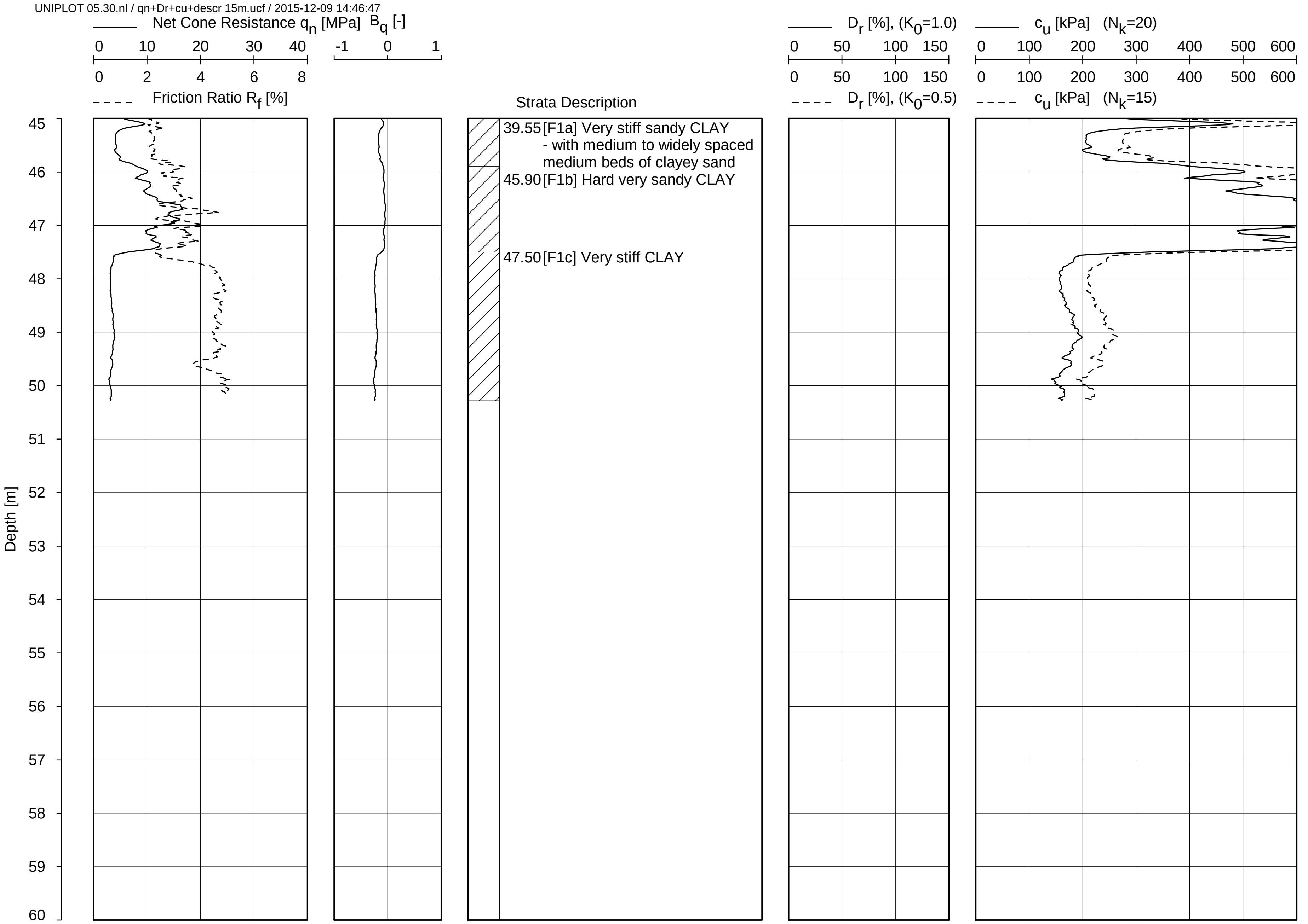


Date Of Testing : 26-Oct-2015
Water Depth [m] : 22.0
Coordinates [m] : E498189 N5723807

CPT DATA INTERPRETATION

CPT_WFS3_22

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

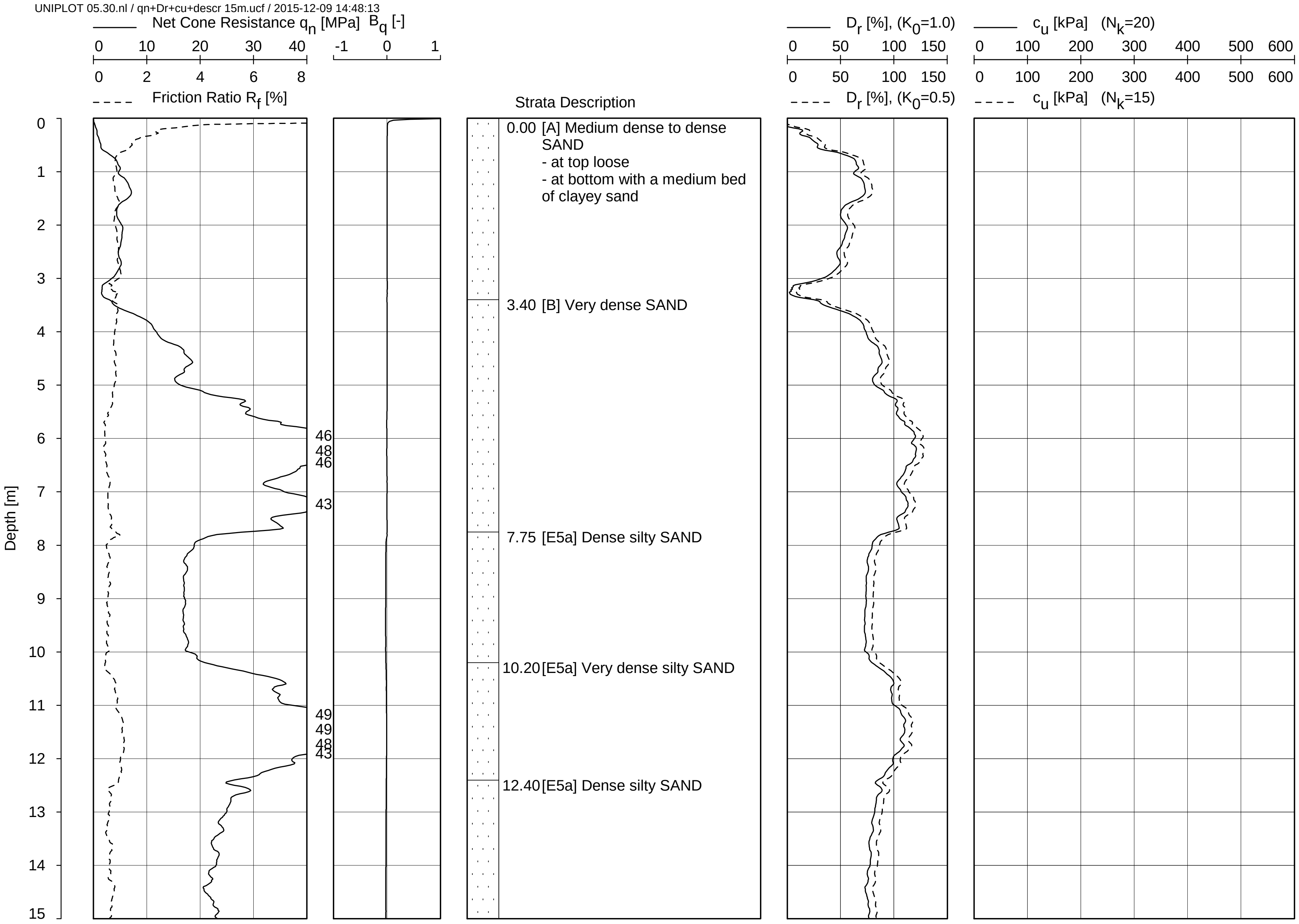


Date Of Testing : 26-Oct-2015
Water Depth [m] : 22.0
Coordinates [m] : E498189 N5723807

CPT DATA INTERPRETATION

CPT_WFS3_22

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 27-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E500432 N5720215

CPT DATA INTERPRETATION

CPT_WFS3_23

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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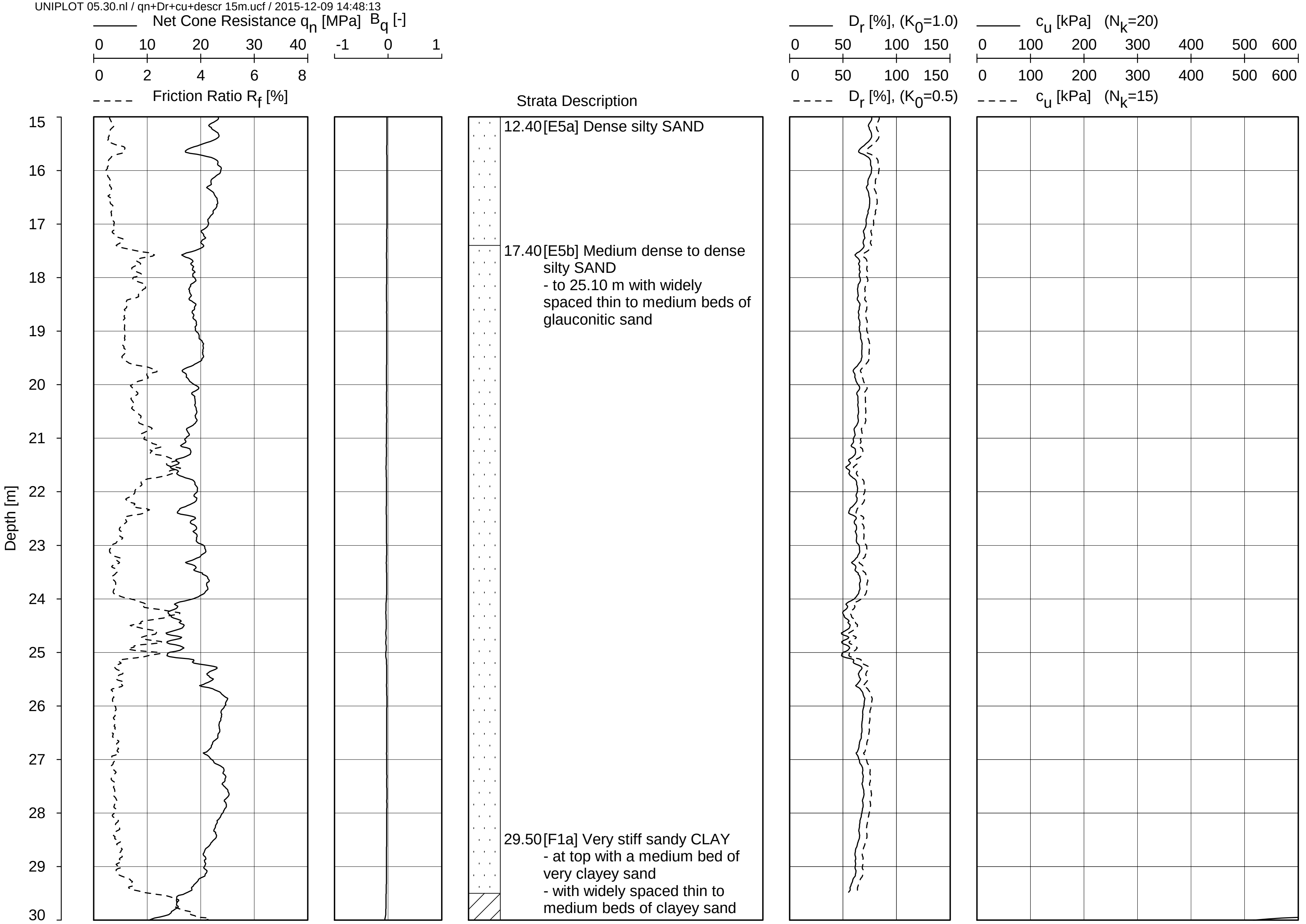
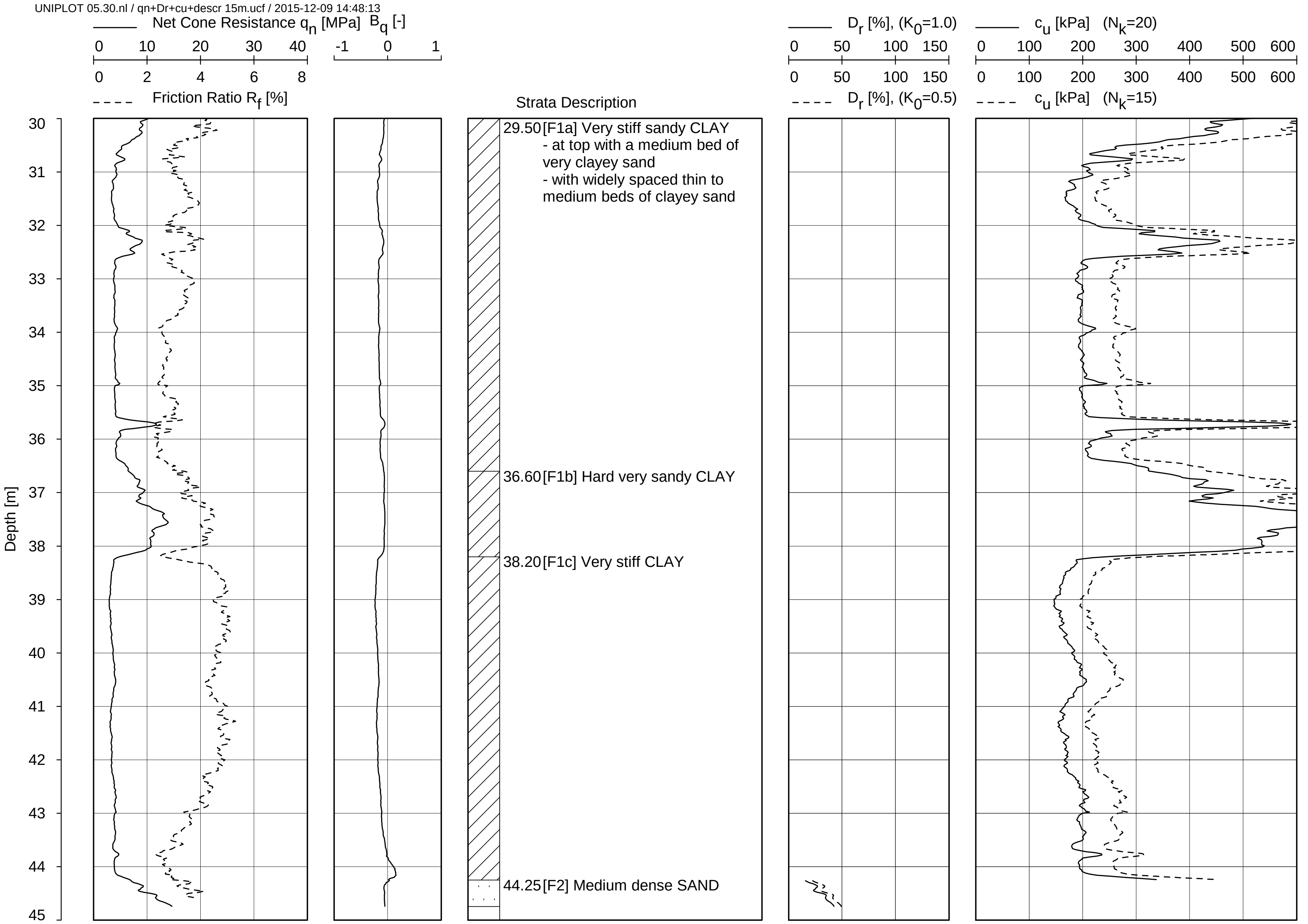


Date Of Testing : 27-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E500432 N5720215

CPT DATA INTERPRETATION

CPT_WFS3_23

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

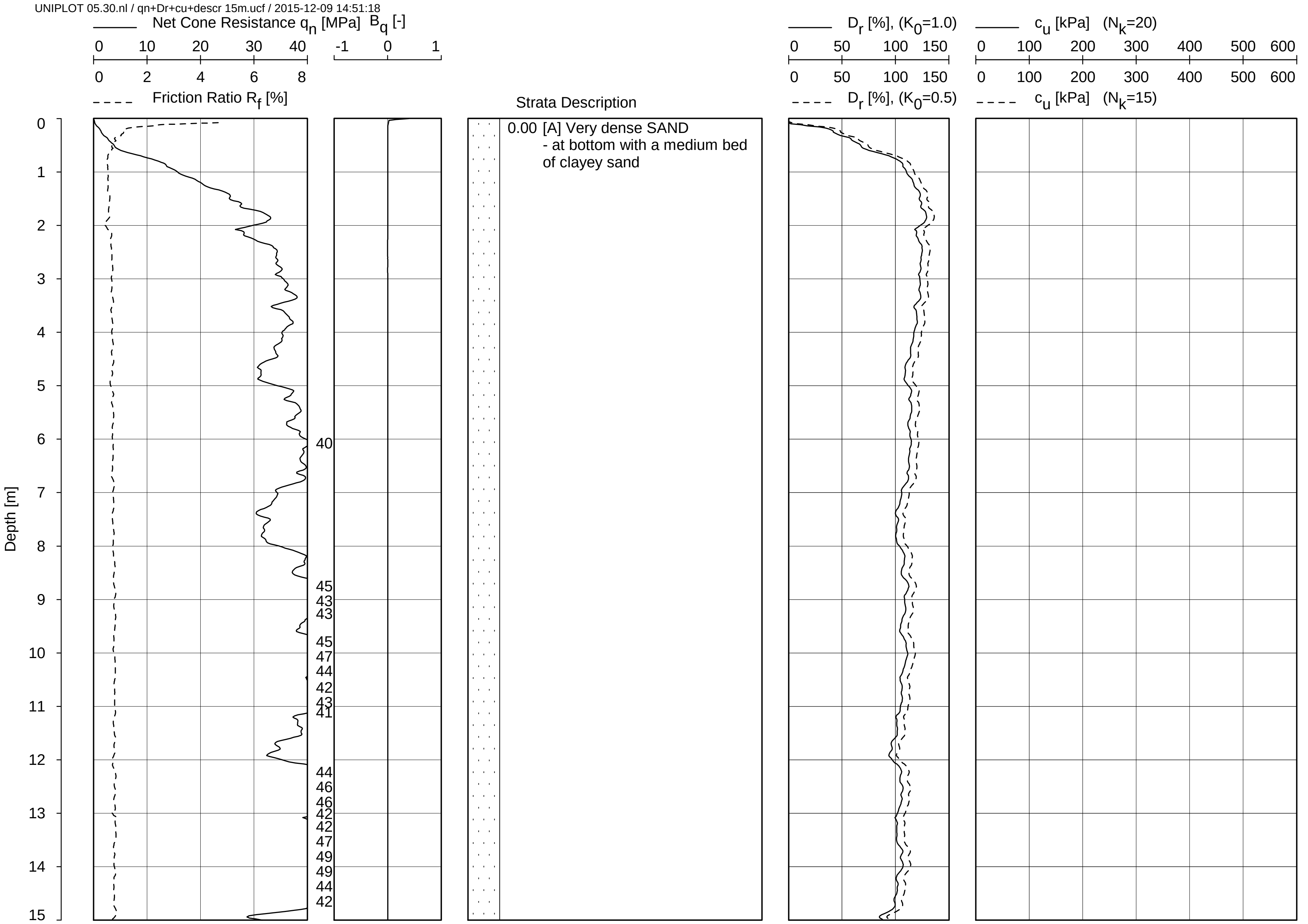


Date Of Testing : 27-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E500432 N5720215

CPT DATA INTERPRETATION

CPT_WFS3_23

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

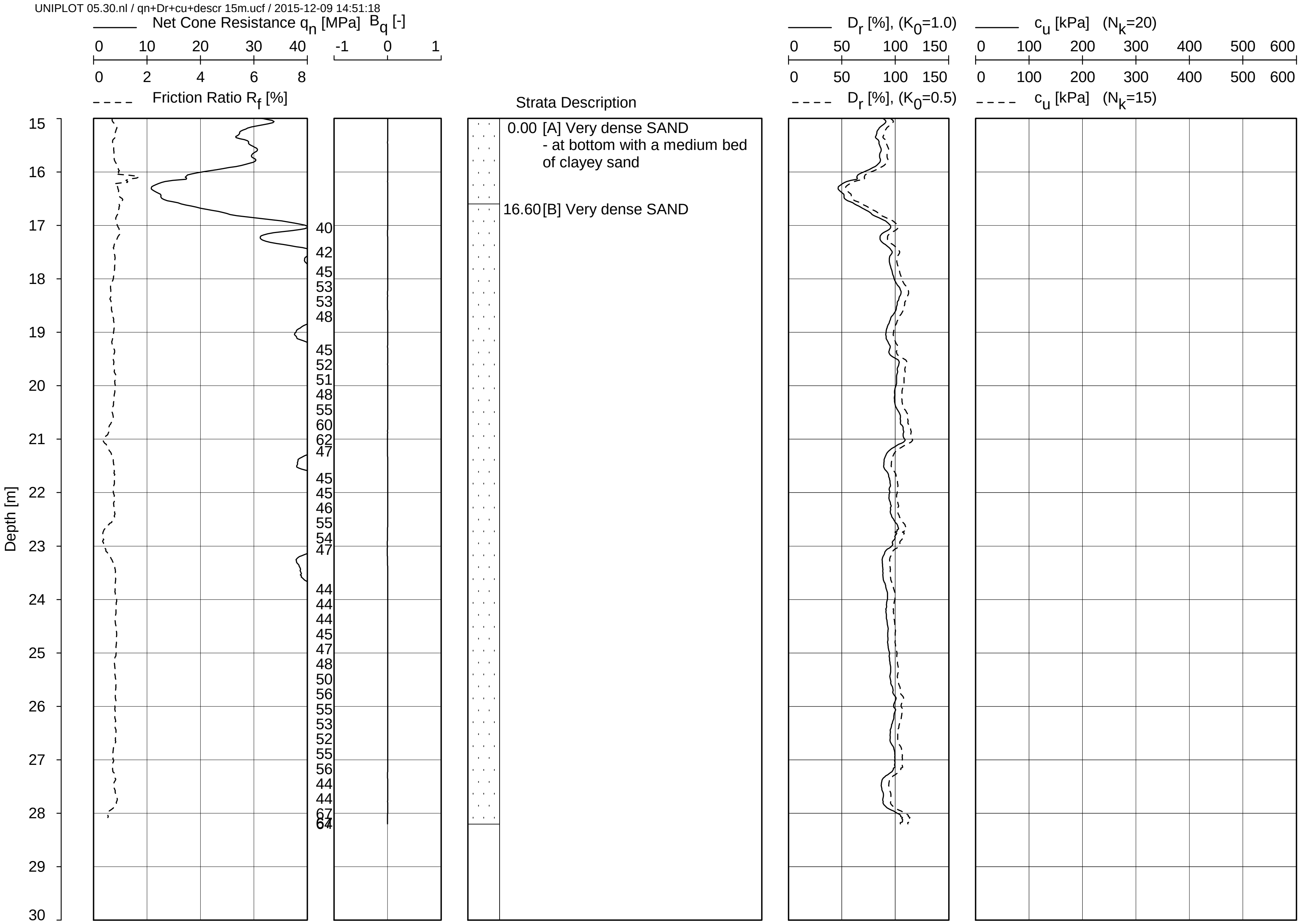


Date Of Testing : 26-Oct-2015
Water Depth [m] : 17.5
Coordinates [m] : E499134 N5724964

CPT DATA INTERPRETATION

CPT_WFS3_24

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

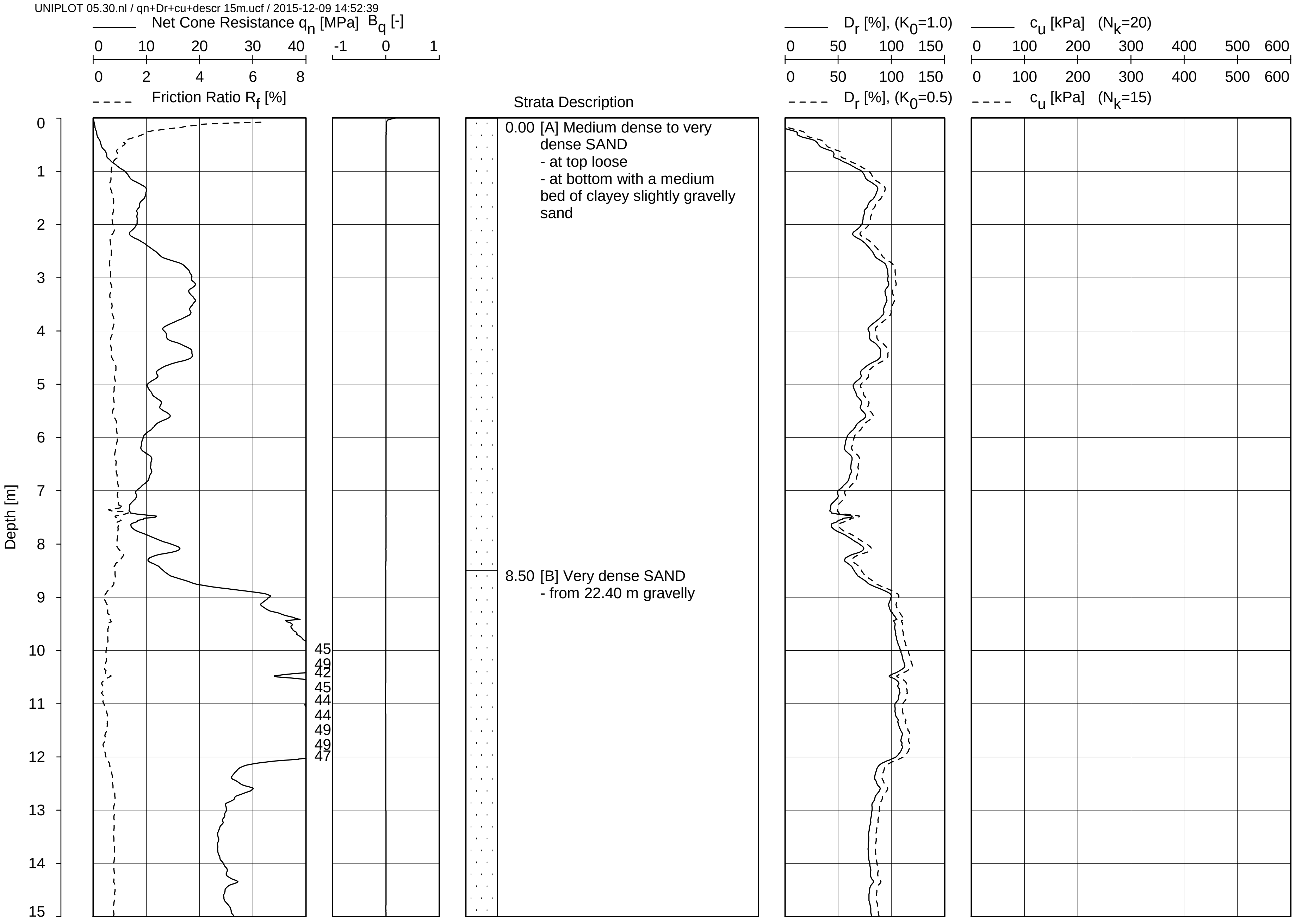


Date Of Testing : 26-Oct-2015
Water Depth [m] : 17.5
Coordinates [m] : E499134 N5724964

CPT DATA INTERPRETATION

CPT_WFS3_24

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

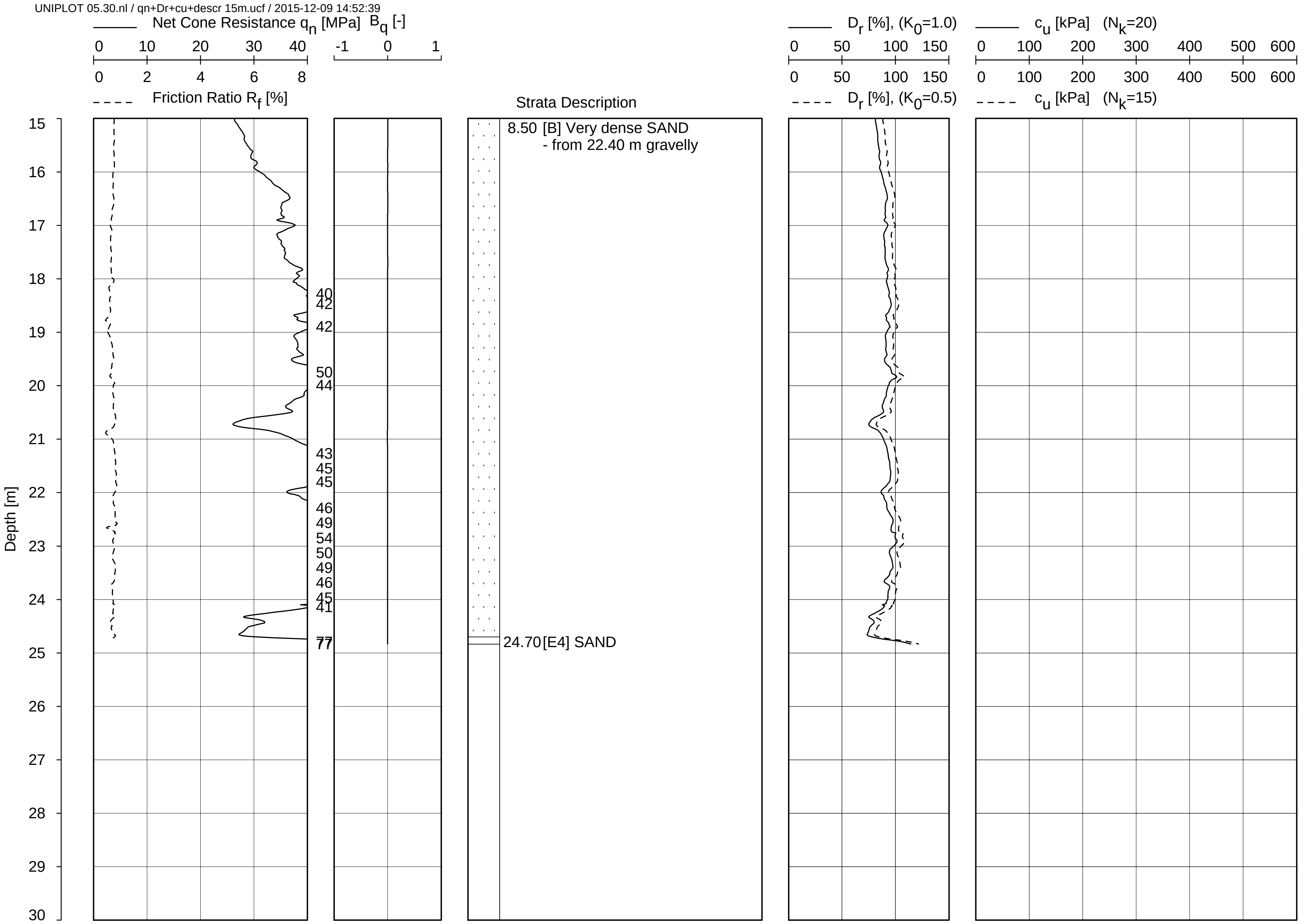


Date Of Testing : 31-Oct-2015
Water Depth [m] : 29.2
Coordinates [m] : E500748 N5727579

CPT DATA INTERPRETATION

CPT_WFS3_25

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

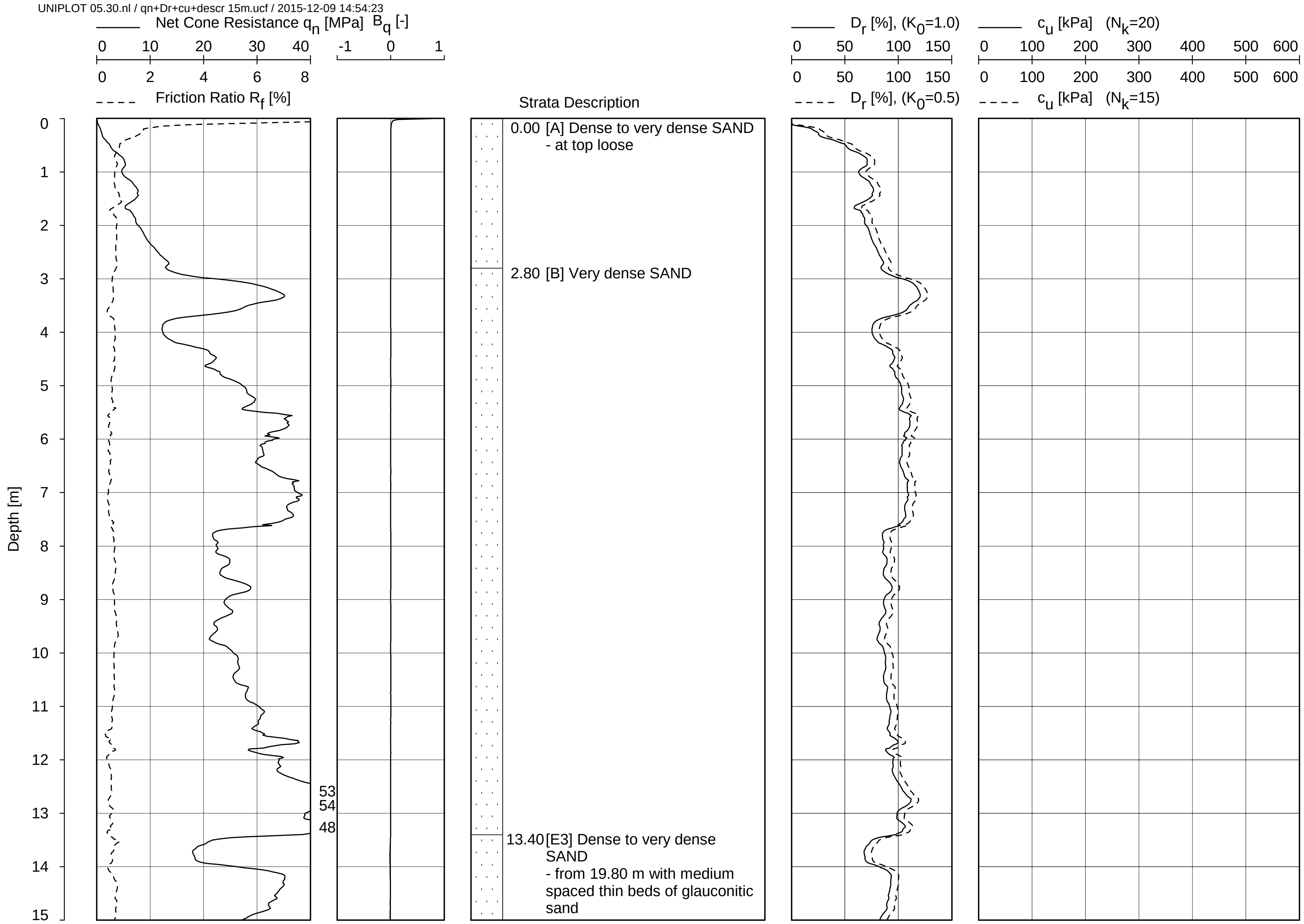


Date Of Testing : 31-Oct-2015
Water Depth [m] : 29.2
Coordinates [m] : E500748 N5727579

CPT DATA INTERPRETATION

CPT_WFS3_25

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

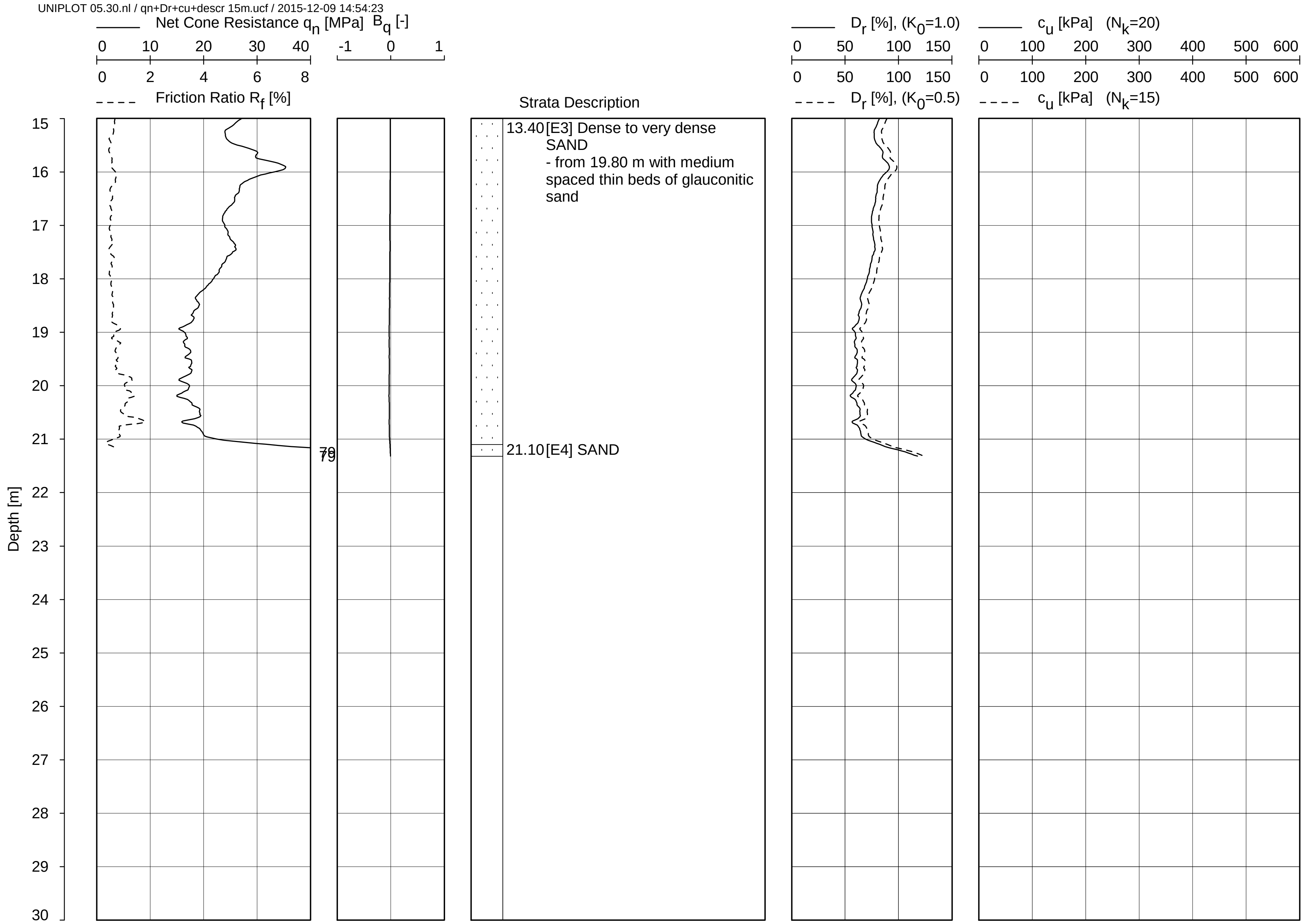


Date Of Testing : 31-Oct-2015
Water Depth [m] : 28.9
Coordinates [m] : E497701 N5729827

CPT DATA INTERPRETATION

CPT_WFS3_26

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

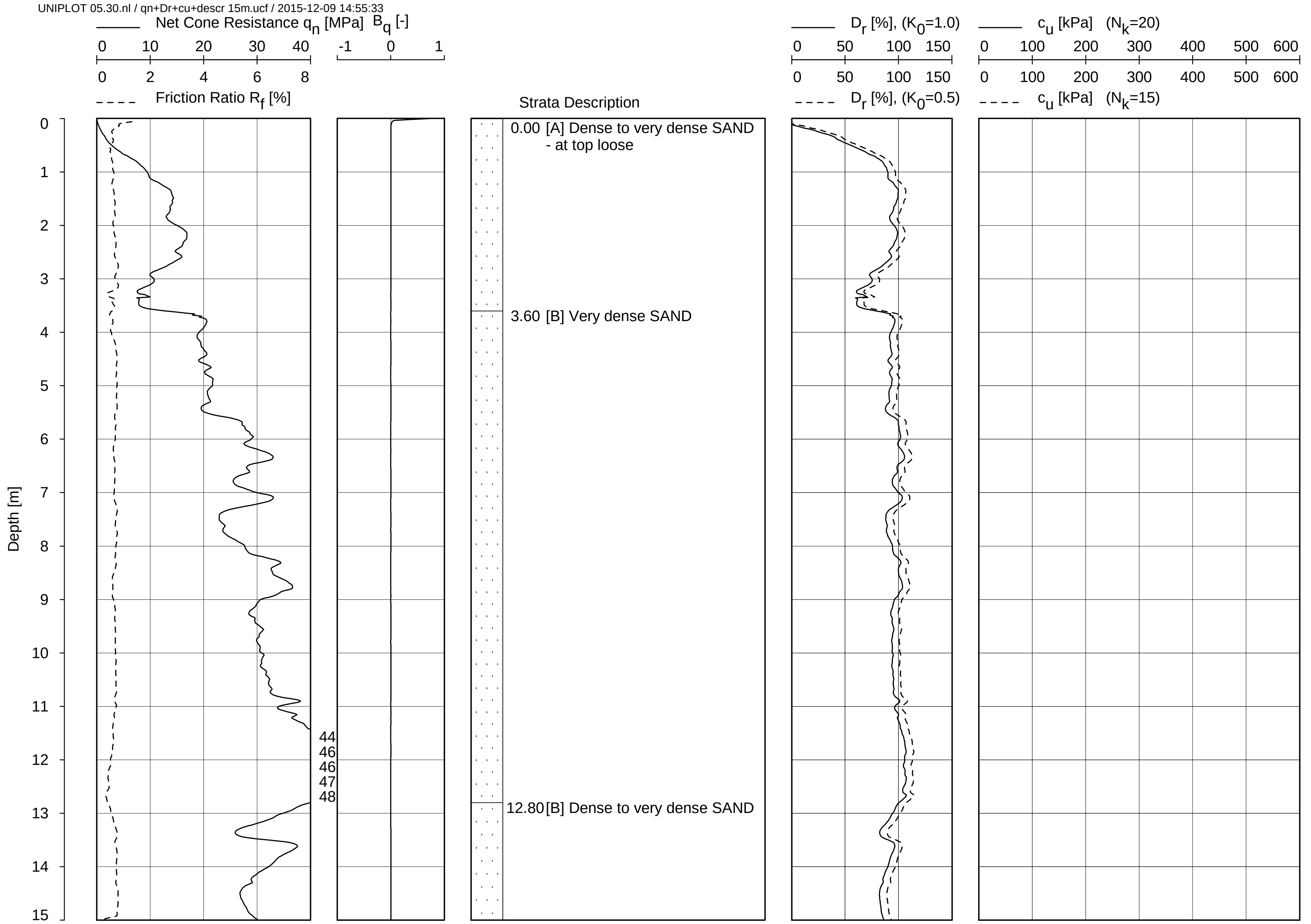


Date Of Testing : 31-Oct-2015
Water Depth [m] : 28.9
Coordinates [m] : E497701 N5729827

CPT DATA INTERPRETATION

CPT_WFS3_26

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

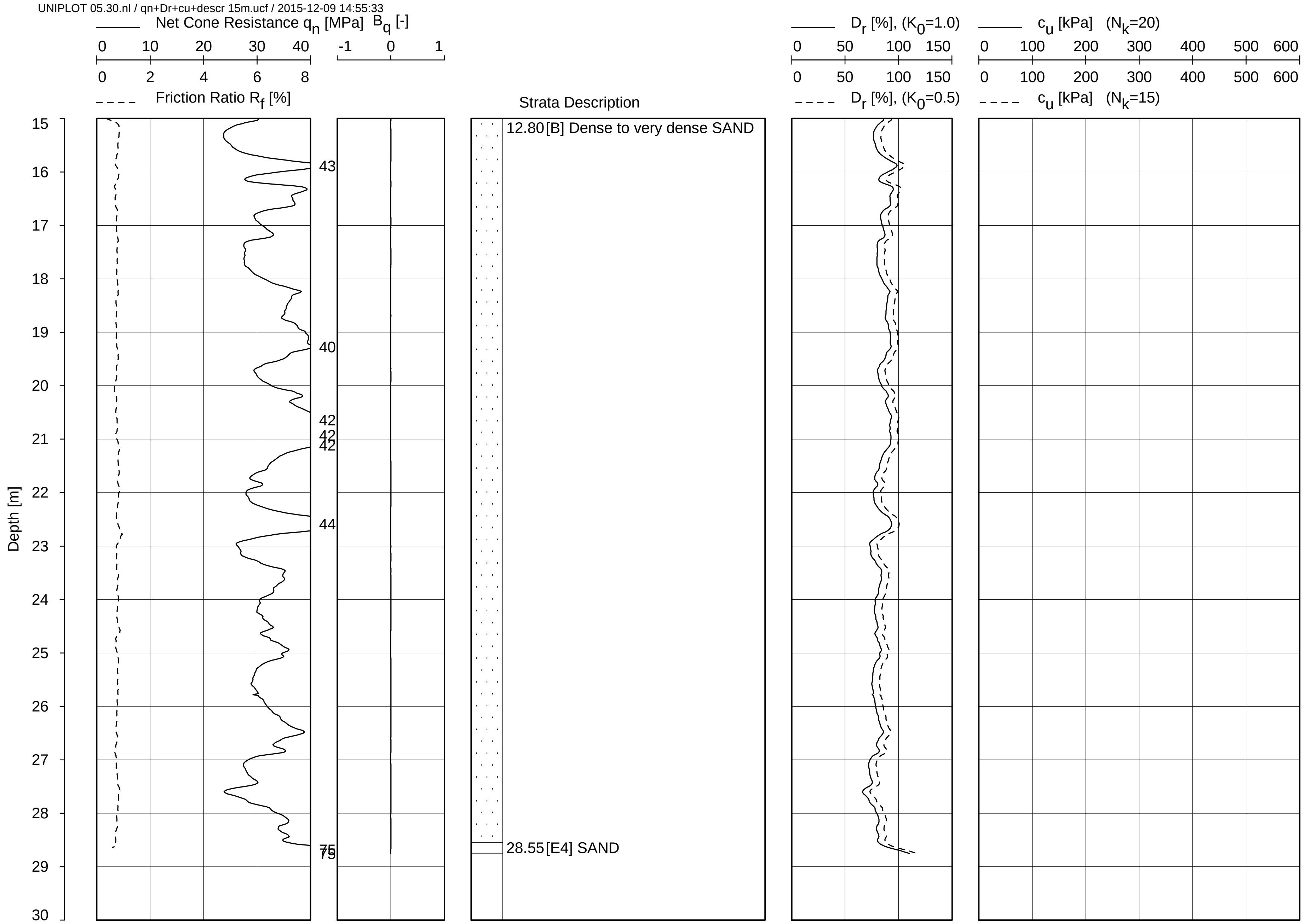


Date Of Testing : 31-Oct-2015
Water Depth [m] : 24.8
Coordinates [m] : E501862 N5725796

CPT DATA INTERPRETATION

CPT_WFS3_27

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 31-Oct-2015
Water Depth [m] : 24.8
Coordinates [m] : E501862 N5725796

CPT DATA INTERPRETATION

CPT_WFS3_27

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

SECTION B: IN SITU TEST RESULTS

SECTION B1: CONE PENETRATION TESTS

TEXT – SECTION B1: Page

LIST OF PLATES IN SECTION B1: Plate

B1. CONE PENETRATION TESTS

B1.1 COMMENTS ON RESULTS

Cone Penetration Tests (CPTs) were performed using CP15 cone penetrometers with a 1500 mm^2 cone tip area. The used cone type measures cone resistance (q_c), sleeve friction (f_s), pore pressure (u_2) and inclination.

Soil unit weight is assessed per unit, based on test data from borehole locations within WFZ Borssele and information about the regional geology, and is presented on plates titled "Parameter Values for Net Cone Resistance Calculation". The unit weight is used as an input for calculations of the effective vertical stress used to calculate the net cone resistance.

A value of 10.0 kN/m^3 was used as an average water density for the water column to calculate the theoretical hydrostatic pressure at seafloor. This water density profile schematisation is based on CTD probe measurements. The hydrostatic pressure is used for comparison with the cone measurements prior to testing and when calculating total cone resistance.

CPT target penetration was 50 m below seafloor (bsf). It was agreed with Client that the test could be terminated based on a number of stop criteria other than the target depth. These additional stop criteria were:

- As instructed by Client;
- Reaching the maximum thrust capacity of the thrust machine, reaction equipment, push rods and/or measuring sensors (of a cone):
  - Cone resistance >75 to 80 MPa
  - Sleeve friction >1.7 MPa
  - Total thrust >18 ton
- Sudden cone inclination >3° or total cone inclination >12° from the vertical;
- Circumstances at discretion of equipment operator, such as risk of damage to apparatus or safety of personnel[1];

whichever occurs first and as applicable.

Table B1.1 presents the stop criteria applicable for each test point.

Table B1.1: Test Penetration and Applicable Stop Criteria

Test Point	CPT Penetration(1) [m]	Stop Criteria
CPT_WFS3_2	43.1	Total thrust >18 ton
CPT_WFS3_3	47.2	Total thrust >18 ton
CPT_WFS3_5	38.4	Operator discretion; thrust of 15.5 ton and lack of support on rods at top
CPT_WFS3_6	20.9	Total inclination >12°
CPT_WFS3_6A	20.9	Cone resistance >75 MPa
CPT_WFS3_7	43.7	Total thrust >18 ton
CPT_WFS3_8	19.0	Cone resistance >75 MPa
CPT_WFS3_9	24.4	Total thrust >18 ton
CPT_WFS3_10	17.7	Cone resistance >75 MPa
CPT_WFS3_11	4.9	Sudden inclination >3°

1 The last criterion could for instance be a combination of total thrust and cone resistance nearing the limit values, whereby the CPT operator would terminate the test to prevent damage occurring to the system.

Test Point	CPT Penetration[1] [m]	Stop Criteria
CPT_WFS3_11A	26.1	Total inclination >12°
CPT_WFS3_12	30.1	Total thrust >18 ton
CPT_WFS3_13	49.9	End depth achieved
CPT_WFS3_14	39.3	Total thrust >18 ton
CPT_WFS3_15	49.1	Total thrust >18 ton
CPT_WFS3_16	44.8	Total thrust >18 ton
CPT_WFS3_17	11.2	Cone resistance >75 MPa
CPT_WFS3_18	12.9	Sudden inclination >3°
CPT_WFS3_19	40.2	Total thrust >18 ton
CPT_WFS3_20	23.2	Total thrust >18 ton
CPT_WFS3_21	39.9	Total thrust >18 ton
CPT_WFS3_22	50.3	End depth achieved
CPT_WFS3_23	44.7	Total thrust >18 ton
CPT_WFS3_24	28.2	Operator discretion; high cone resistance, increasing inclination and lack of supports on rods at top
CPT_WFS3_25	24.8	Cone resistance >75 MPa
CPT_WFS3_26	21.3	Cone resistance >75 MPa
CPT_WFS3_27	28.8	Cone resistance >75 MPa
(1) Values are rounded to the nearest 0.1 m		

The test apparatus was not always brought back to deck in-between tests. Verification of test results and cone performance was done based on the comparison of the cone measurements at seafloor before and after penetration of the soil. Reference readings are compared with water depth observed from CTD probe measurements. In the event the cone signal was lost, validation of test results in these cases was based on either:

- Comparison of the zero loads after the cone returned back to deck with zero loads (on deck) of the previous or following test. No zero load reading or drift value is presented for these tests.
- Comparison of results with adjacent tests in case the cone was lost in the soil and no zero loads could be derived after test (CPT_WFS3_2 and CPT_WFS3_23).

At CPT_WFS3_12 and CPT_WFS3_15 the rods were damaged while retrieving these from the soil and communication with the cone was lost. Consequently, zero load readings could not be taken at seafloor after penetration and no zero drift values could be determined. However, the cone was retrieved back to deck undamaged and was used in the following test. Validation of test results was based on comparison of the zero loads before the test with zero load of the following test. No zero load reading or drift values are presented for these tests.

Typically CPTs show negative pore pressures upon penetration of dense to very dense and/or (silty) fine sands. This is not uncommon. This is primarily related to the piezo-cone filter located at the cylindrical extension above the base of the cone (u_2 location). During cone penetration, negative pore pressures exist around the u_2 locations (Lunne et al., 1997)[1] such that cavitation occurs. Particularly, this may occur at the time of penetration of dense sand, silty fine sands or overconsolidated clay layers. Loss of saturation usually causes a negative or sluggish pore pressure response during penetration of ground below the zone causing desaturation of the pore pressure filter around the pressure sensor. Negative pore pressure measurements affect derived values such as

[1] Lunne, T., Robertson, P.K. and Powell, J.J.M. (1997), “Cone Penetration Testing in Geotechnical Practice”, Blackie Academic & Professional, London.

net cone resistance and pore pressure ratio. The influence of the negative pore pressure is to be considered when using the derived values.

Some CPTs show high sleeve friction values, for example at location CPT_WFS3_13, around 34 m bsf. This behaviour is believed to be the result of crushing of the glauconite particles during cone penetration. Typical CPT behaviour may be described by a relatively constant cone resistance and high (increased) sleeve friction values. It may be noted that the geological formations in which the high sleeve friction values were observed have been reported to contain significant quantities of glauconite (Alboom et al., 2012)[1].

1 Alboom, G. van, Dupont, H., Maertens, J. and Haelterma, K. (2012), "Glauconiethoudende zanden", Geotechniek, Vol. 16, No. 2, pp. 32-37.

B1.2 PRACTICE FOR CONE PENETRATION TEST

Test Control – Penetration

General Procedure:	– According to ISO (2014) – Refer to document titled "Cone Penetration Test" presented in Appendix 1
Metrological Confirmation:	Refer to document titled "Metrological Confirmation System for In Situ Test" presented in Appendix 1
Target Application Class:	Class 3 of ISO (2014), refer to document titled "Cone Penetration Test" presented in Appendix 1
Set-up Stage:	Location as directed by Client
Additional Measurements:	Pore pressure dissipation in accordance with sub-section "Practice for Pore Pressure Dissipation Test" presented in Section B2
Test Stage:	No project-specific practice
Test Termination:	Refer to Section Text B1
Drill-Out:	Not applicable
Test Site Restoration:	– No backfill of test hole – Local seabed disturbance – Possibility of local seafloor depression(s)

CPT Apparatus

Thrust Machine:	SEACALF® double wheeldrive hydraulic jacking unit of nominal 200 kN thrust capacity and with 50 m continuous push/retraction capacity
Mounting of Thrust Machine:	SEACALF® unit ballasted to maximum 240 kN underwater weight, upward heave compensation 0 to 20 kN, 3 m by 3 m in plan with 8.7 m^2 for seafloor support
Reaction Equipment:	Weight of thrust machine, equivalent to a maximum of 240 kN underwater weight
Push Rods:	36 mm OD
Push Rod Casing:	Applicable
Friction Reducer:	Not applicable
Penetrometer Type:	Type CP15-CF75PB7SN2/20SN2/30SN2 cone penetrometer, 75 kN load sensors (150 kN for overloading), 7 MPa, 20 MPa or 30 MPa pressure sensor, HDPE filter in cylindrical extension above base of cone, with non-directional inclinometer, 1,500 mm^2 cone base area, 20,000 mm^2 sleeve area, net area ratios for cone tip and friction sleeve as per plate(s) titled "Cone Penetration Test – Zero Drift"

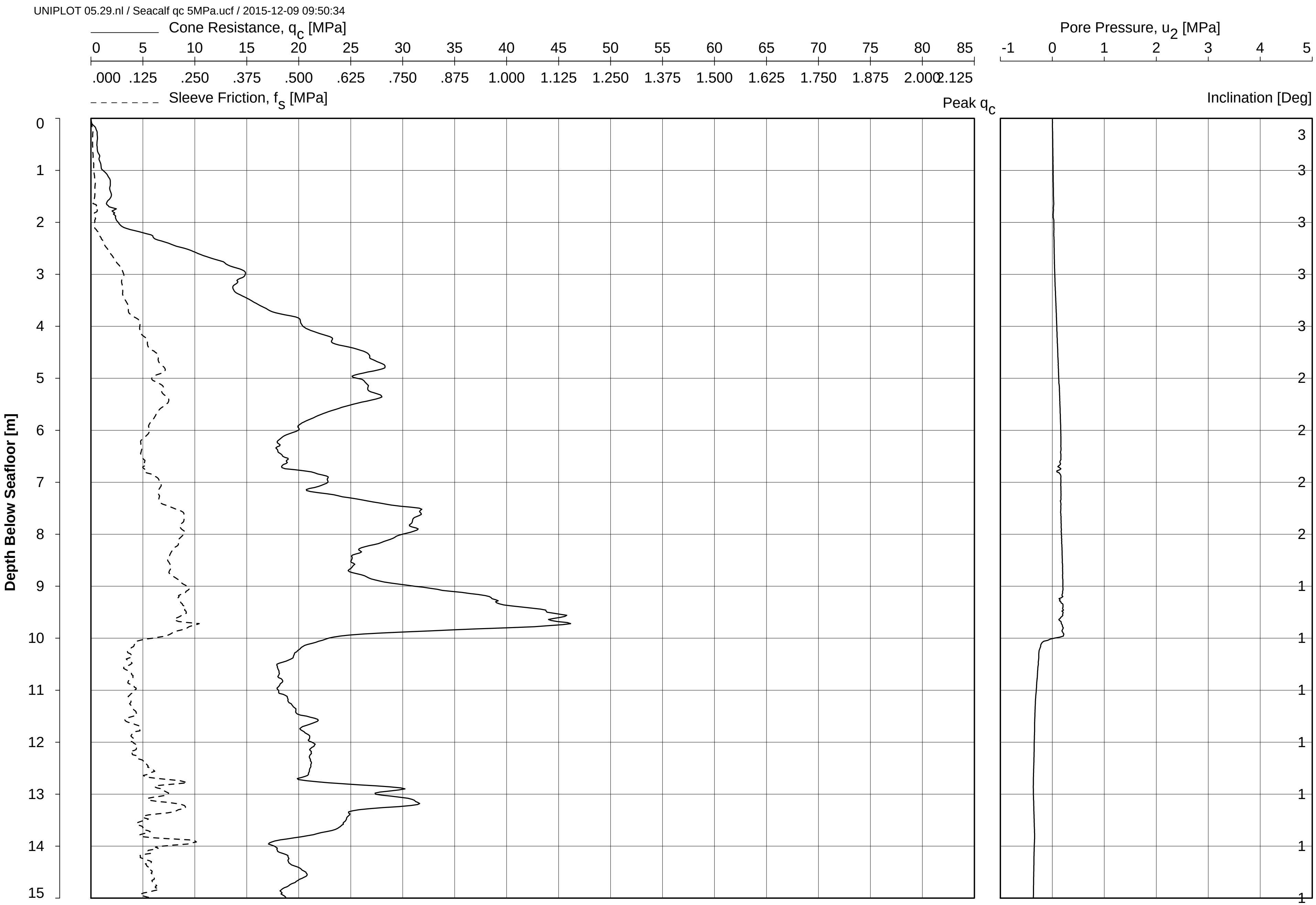
Test Results

Data Processing and Management:	– Refer to document titled "Cone Penetration Test" presented in Appendix 1 – UNIPLOT software – Graphical scales selected to suit general presentation of data and requirements of standards, where practicable – No display of data outside of chart limits, i.e. some values may not be shown
Data Format(s):	– PDF for viewing and printing (this primary document) – ASCII (ANSI, 2007) digital tabular data (separate deliverables, secondary to this document)
Water Depth Reference:	As obtained from echo sounder readings at start of testing, reduced to LAT

Depth Reference Level:	Seafloor, particularly: – No depth reference correction applied for depth below seafloor – No evidence for extremely soft ground at seafloor but no specific measurements performed – Base of seabed frame assumed level with seafloor at start of testing – Depth accuracy assessment of “Seabed – Favourable”; refer to document titled Positioning Survey and Depth Measurement presented in Appendix 1
Depth Correction for Penetrometer Inclination:	Applicable
Soil Unit Weight:	Refer to Section Text for details on soil unit weight
Parameter Values for Data Processing:	Refer to plate(s) titled “Parameter Values for Net Cone Resistance Calculation”

References

- ANSI American National Standards Institute, Inc. (2007), “Coded Character Sets – 7-Bit American National Standard Code for Information Interchange (7-Bit ASCII), 14 June 2007.
- Computer Program UNIPLOT, Processing of CPT data
- ISO International Organization for Standardization (2014), “Petroleum and Natural Gas Industries - Specific Requirements for Offshore Structures – Part 8: Marine Soil Investigations”, International Standard ISO 19901-8:2014.

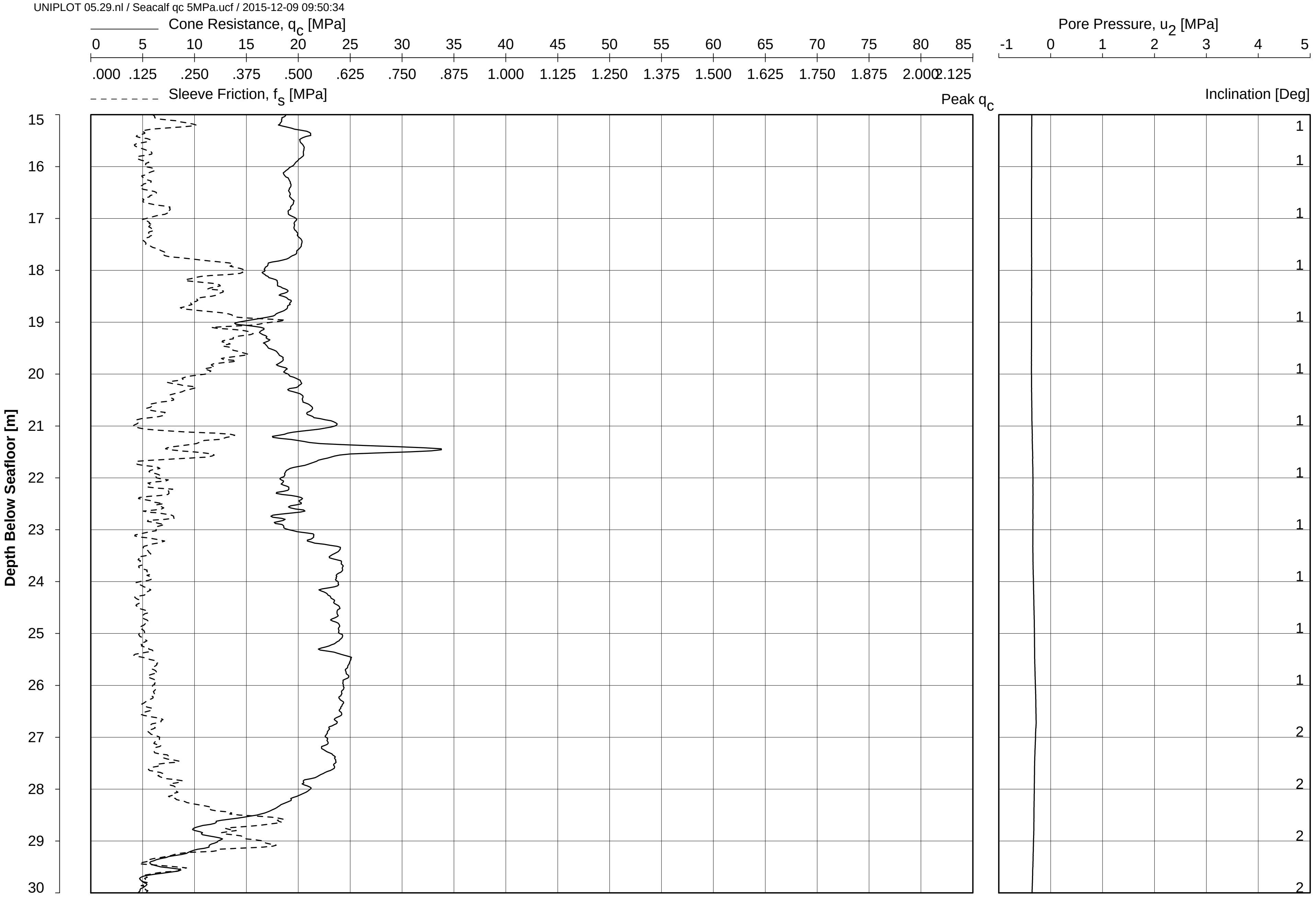


Date Of Testing	: 30-Oct-2015	Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 36.9	Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E498234 N5725141		

CONE PENETRATION TEST

CPT_WFS3_2

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 30-Oct-2015
Water Depth [m] : 36.9
Coordinates [m] : E498234 N5725141

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_2

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO

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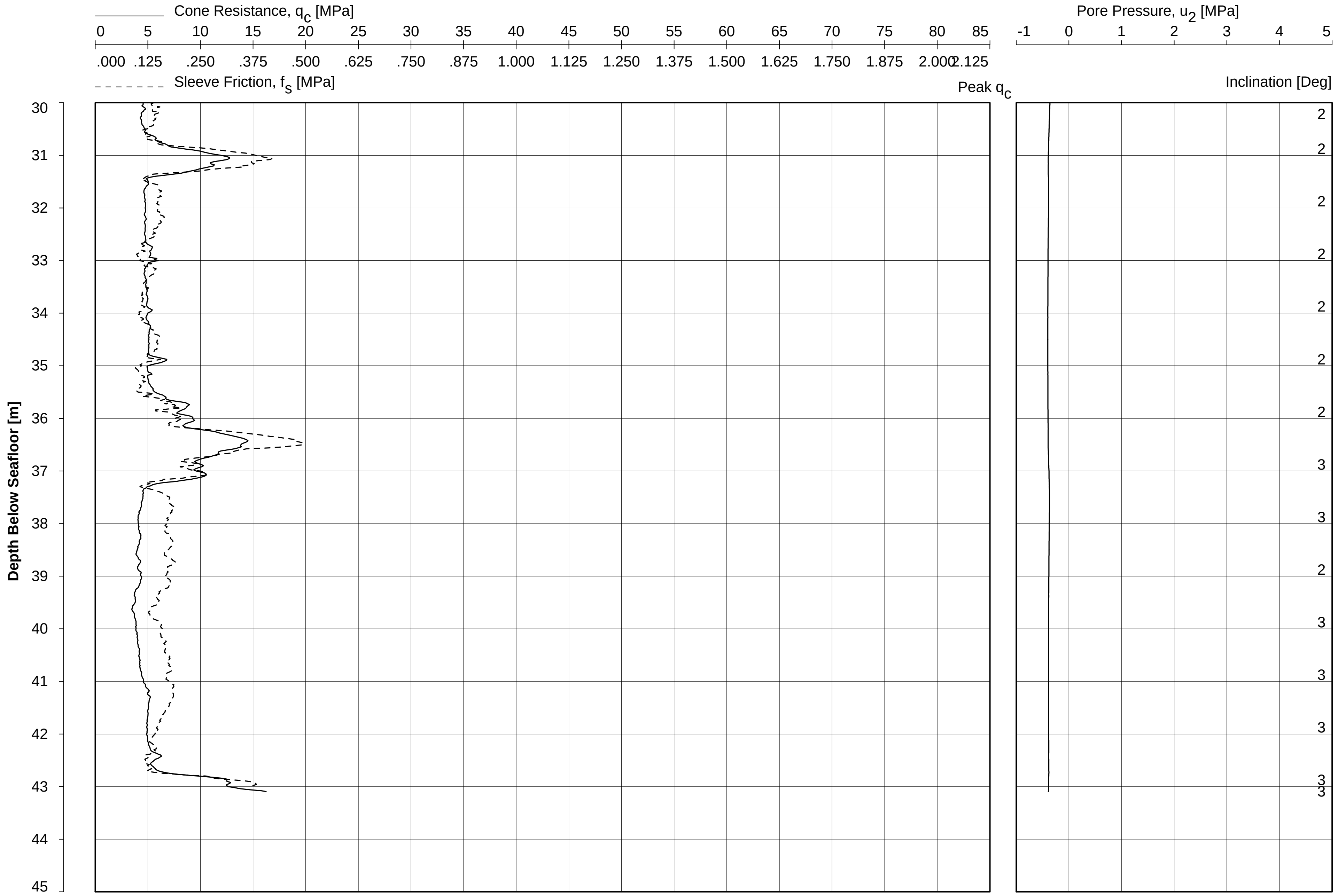


Date Of Testing : 30-Oct-2015
Water Depth [m] : 36.9
Coordinates [m] : E498234 N5725141

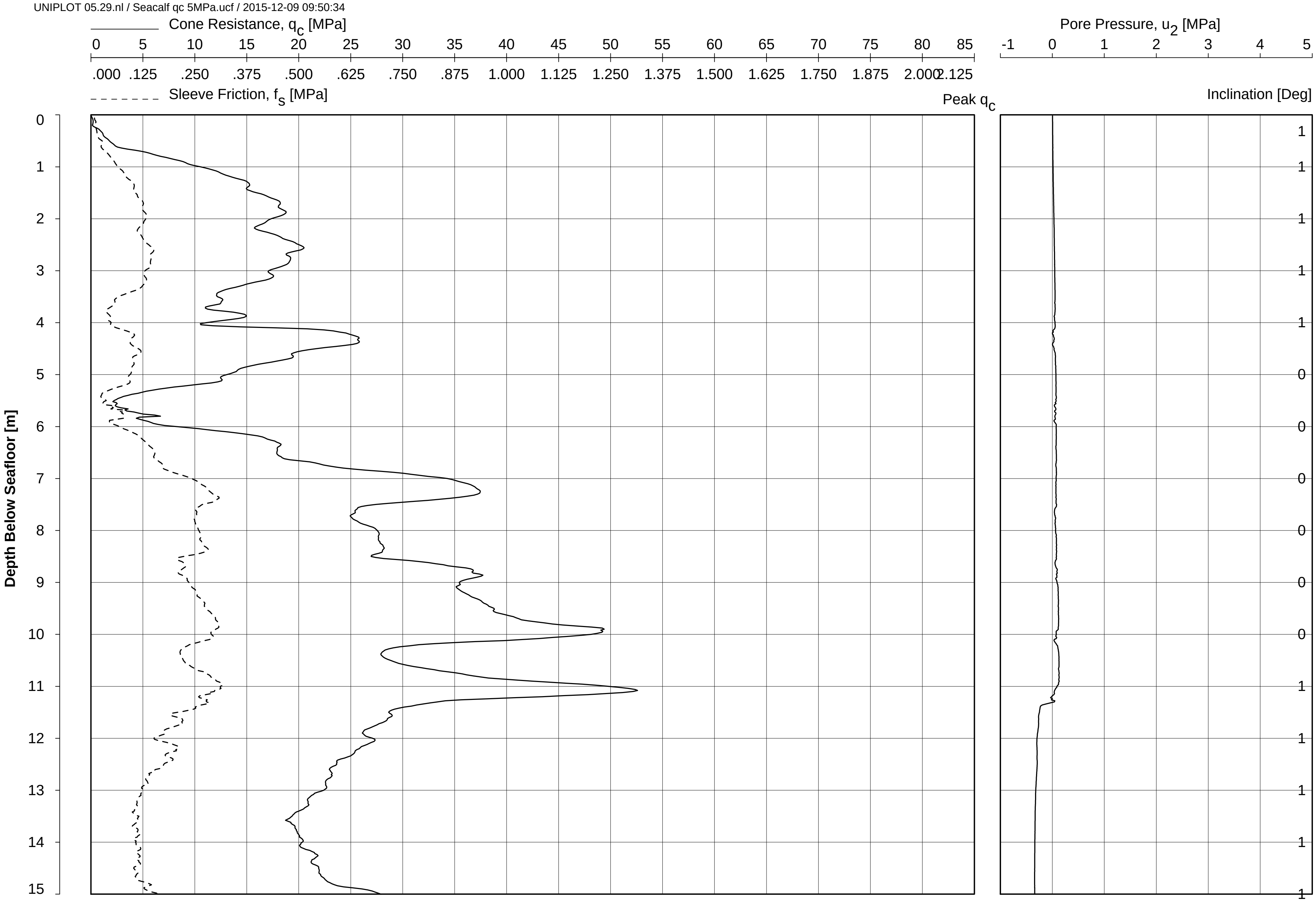
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_2

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO



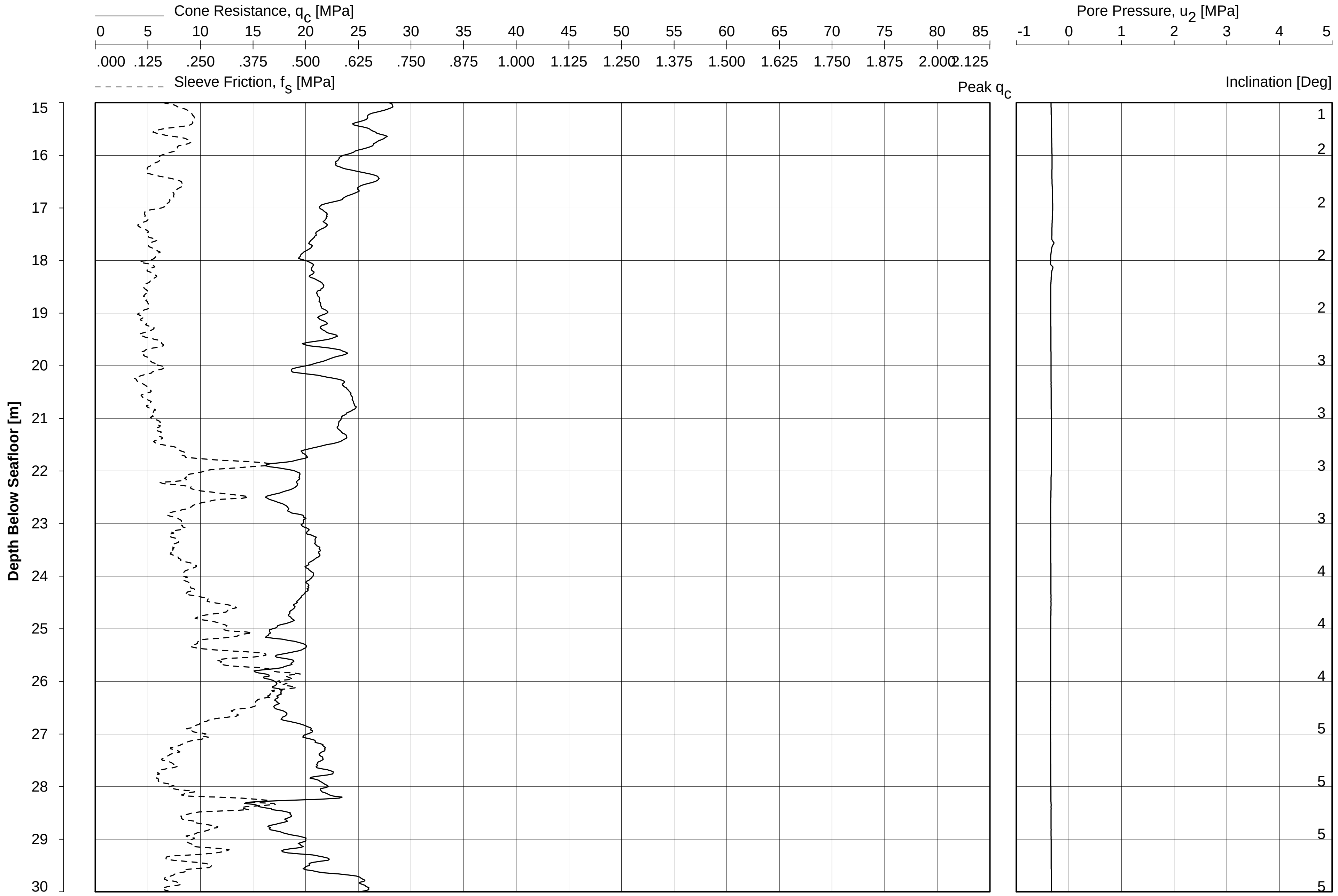
Date Of Testing	: 27-Oct-2015	Probe Type	: CP15-CF75PB30SN2	
Water Depth [m]	: 28.4	Cone Base Area [mm^2]	: 1510	
Coordinates [m]	: E500208 N5721837			

CONE PENETRATION TEST

CPT_WFS3_3

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:34



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.4
Coordinates [m] : E500208 N5721837

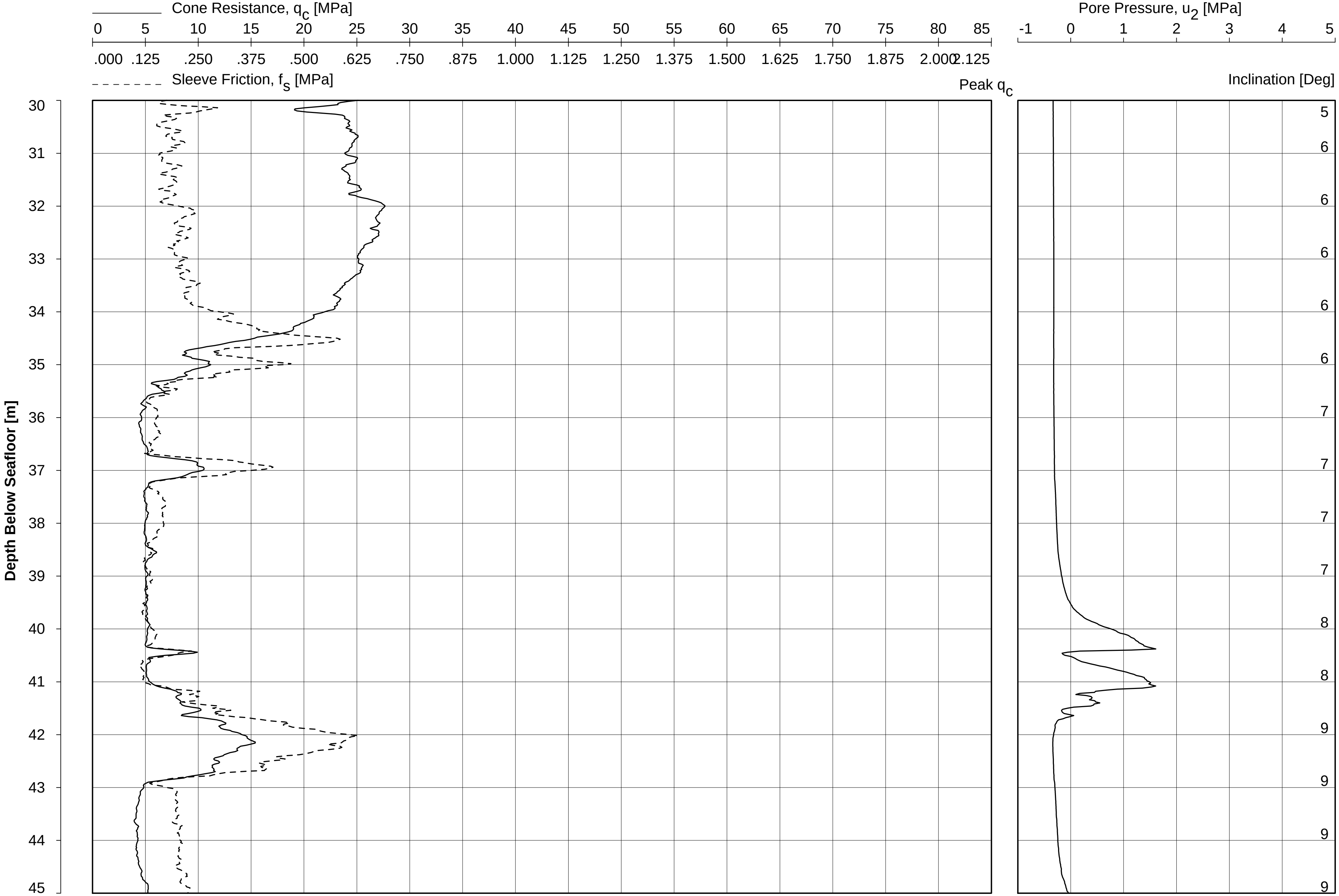
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_3

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:34



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.4
Coordinates [m] : E500208 N5721837

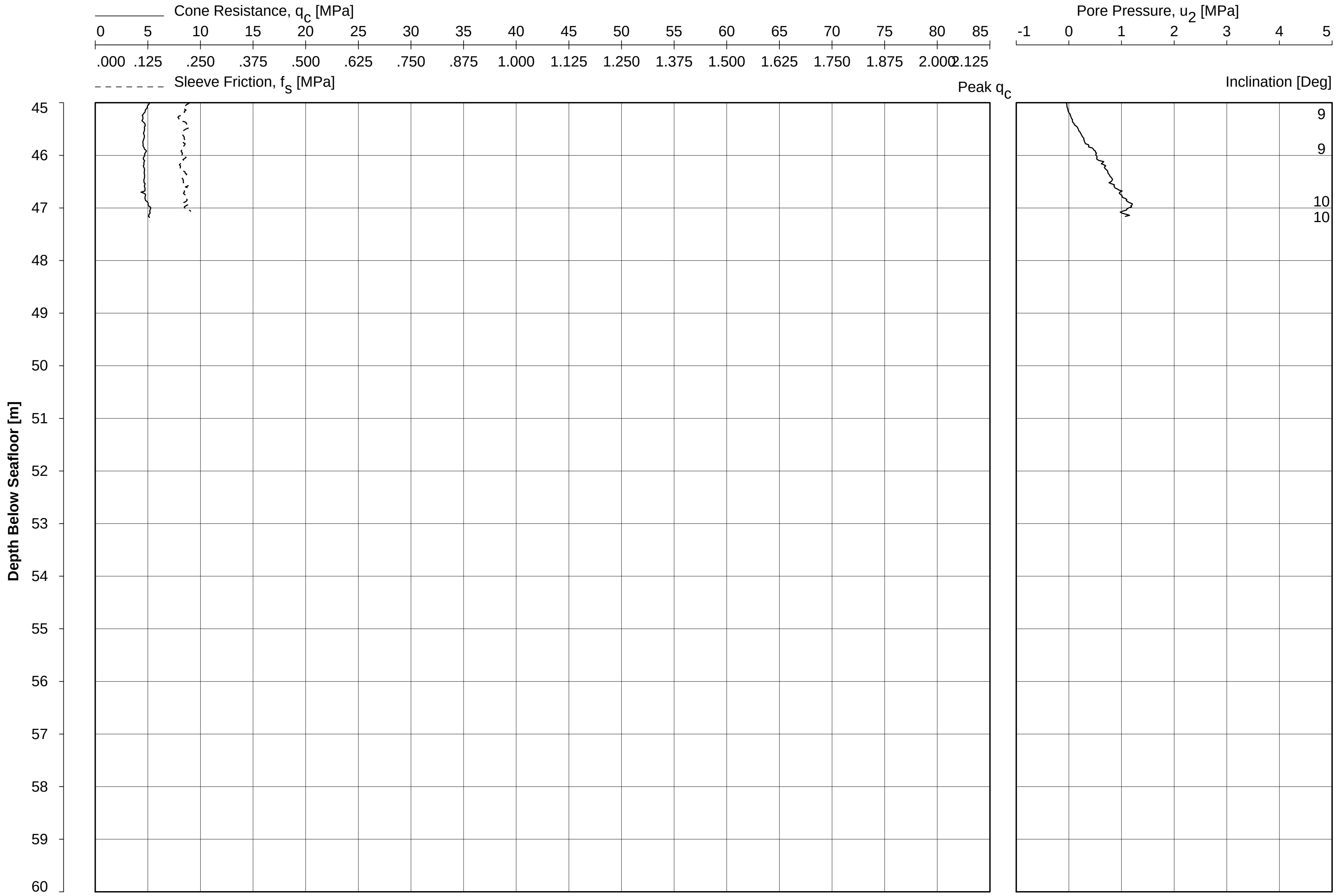
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_3

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:34



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.4
Coordinates [m] : E500208 N5721837

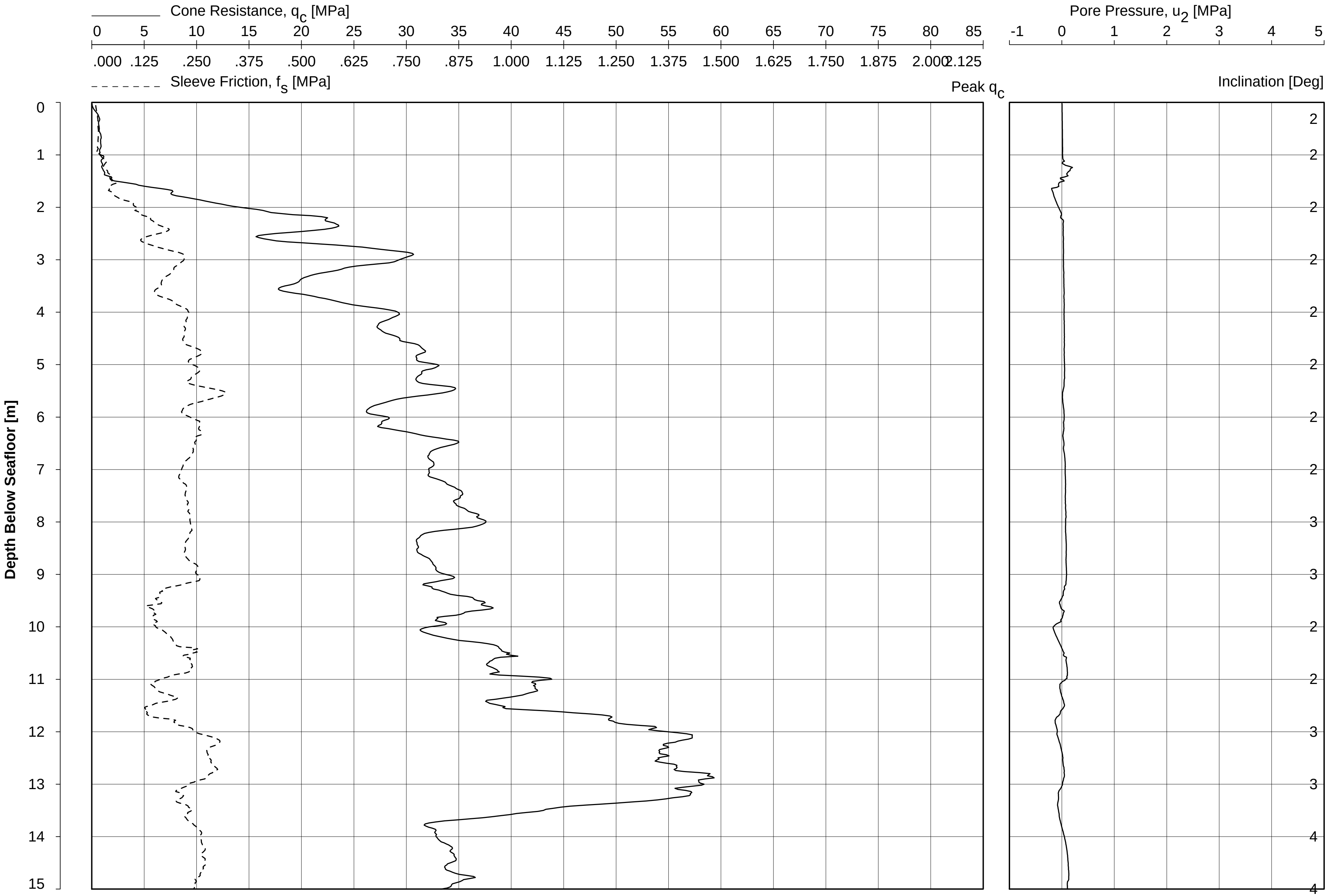
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_3

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:34



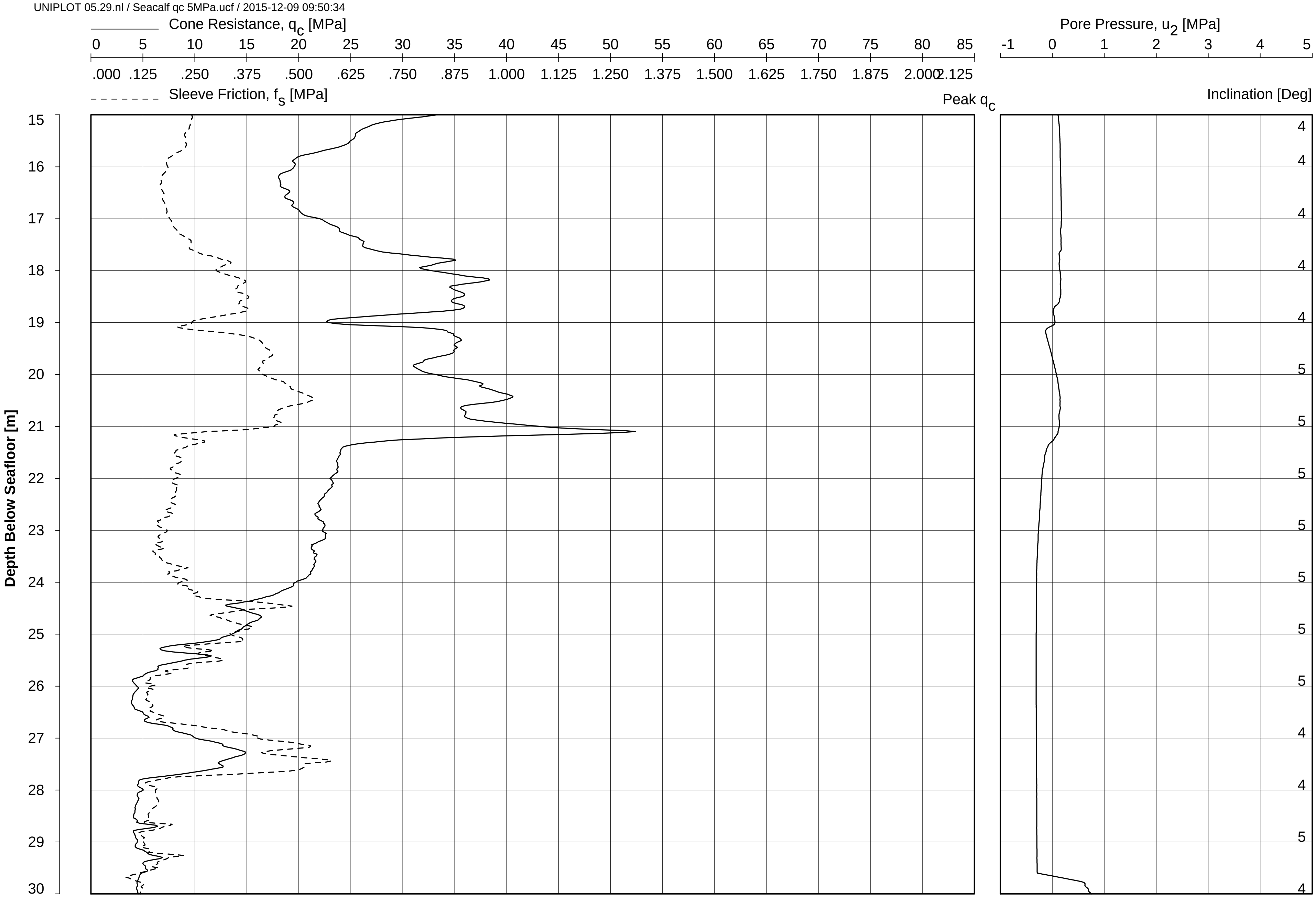
Date Of Testing : 29-Oct-2015		Probe Type	: CP15-CF75PB20SN2
Water Depth [m] : 29.3		Cone Base Area [mm^2]	: 1510
Coordinates [m] : E494308	N5726002		

CONE PENETRATION TEST

CPT_WFS3_5

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO



Date Of Testing : 29-Oct-2015
Water Depth [m] : 29.3
Coordinates [m] : E494308 N5726002

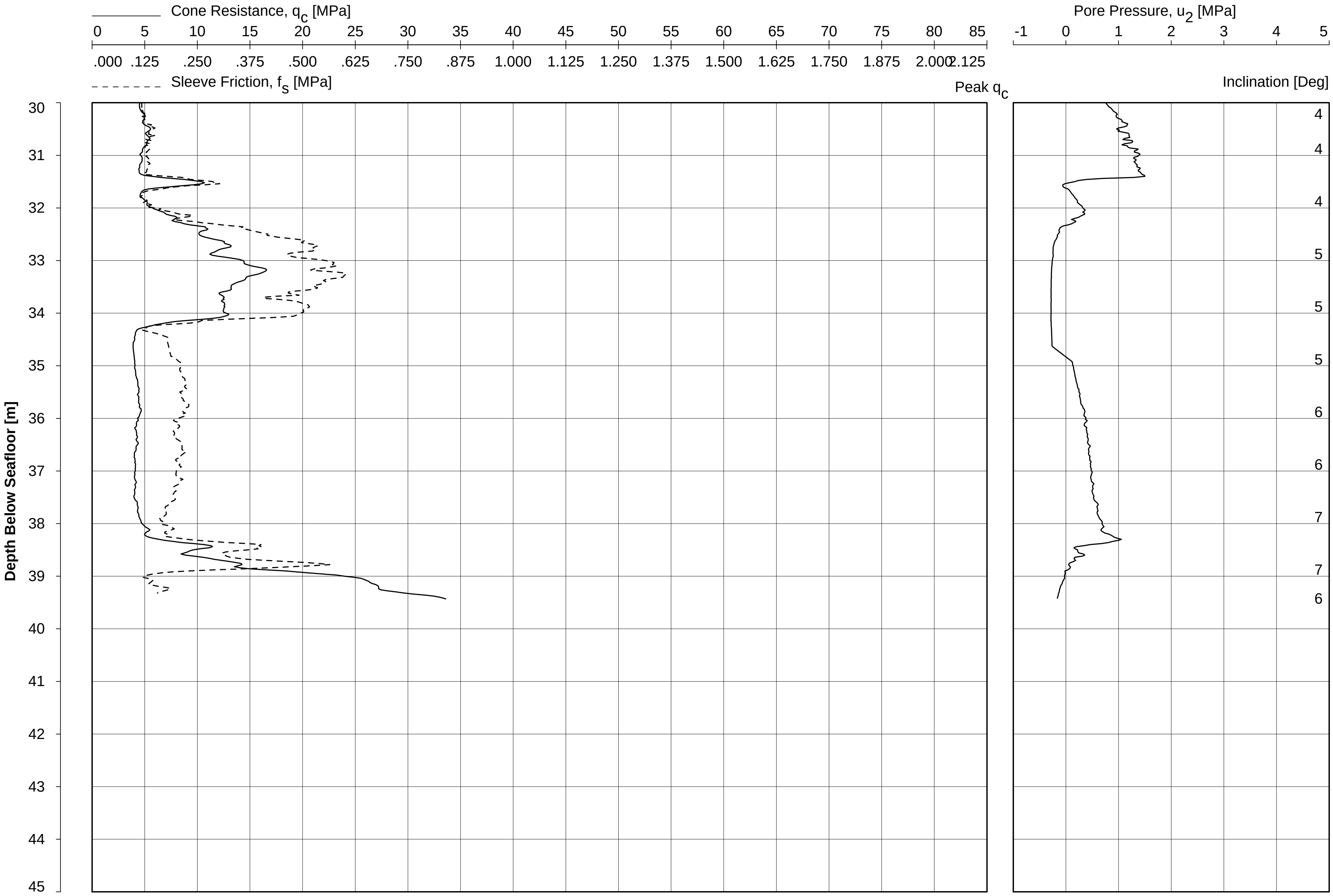
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_5

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:34



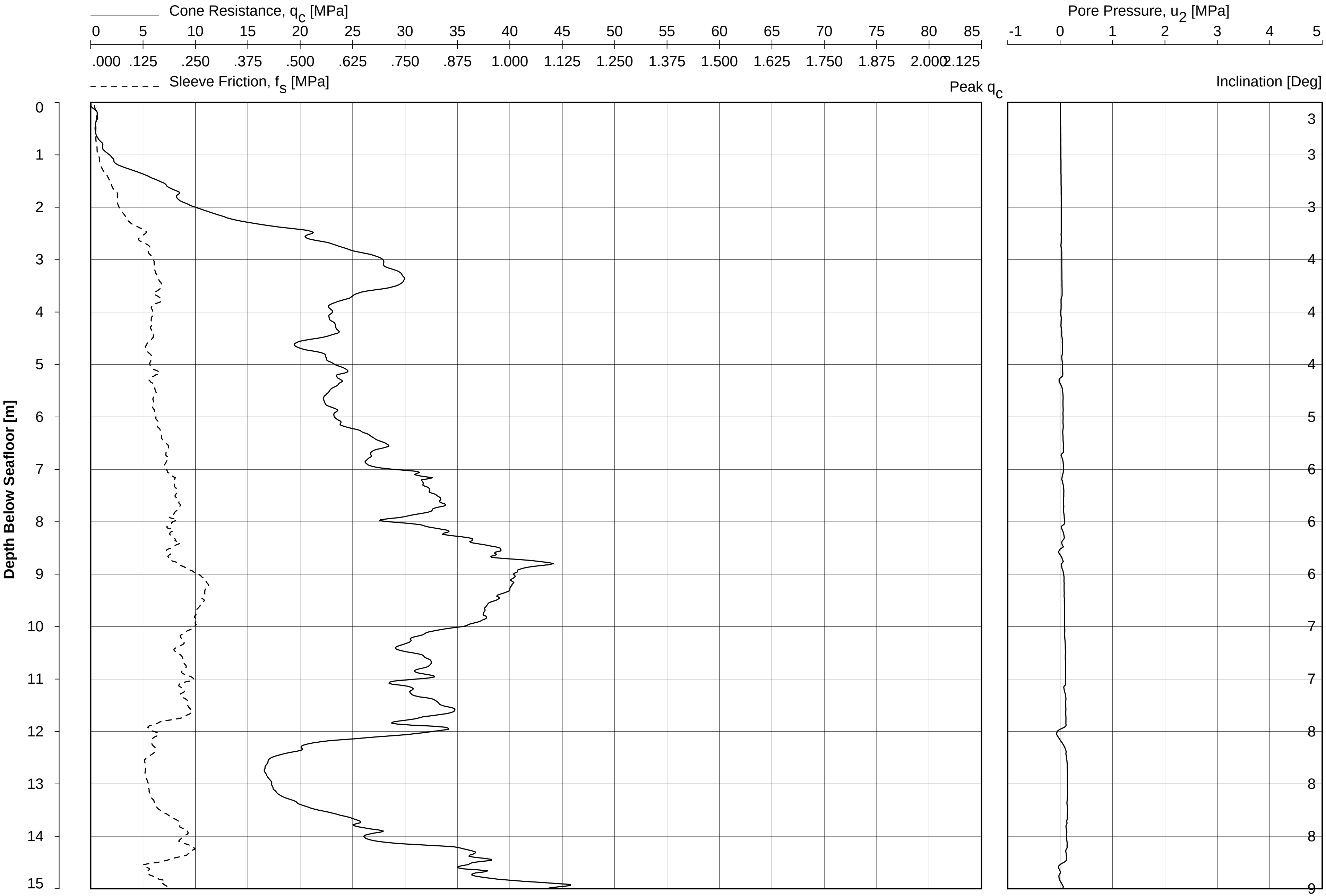
Date Of Testing	: 29-Oct-2015		Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 29.3		Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E494308	N5726002		

CONE PENETRATION TEST

CPT_WFS3_5

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



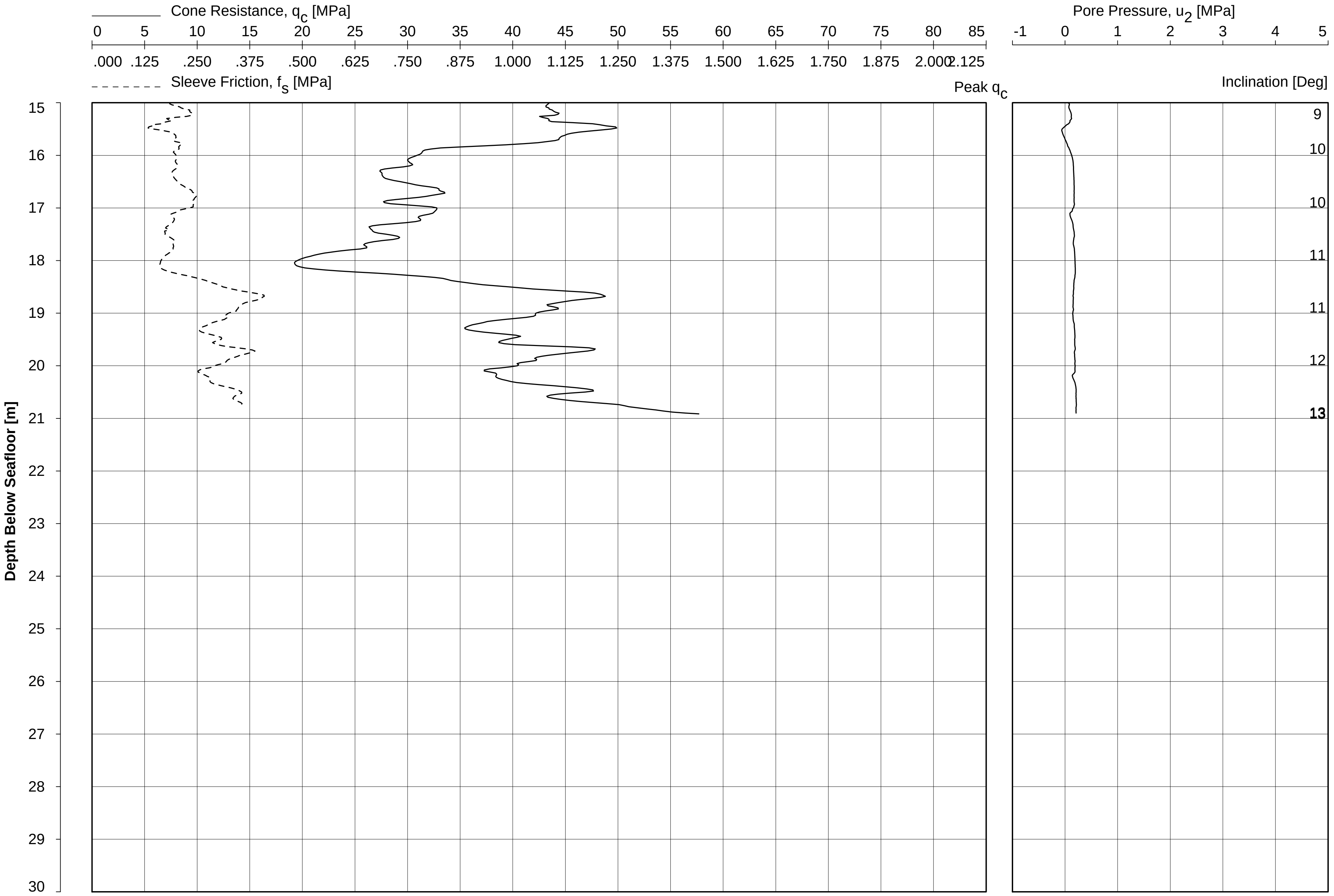
Date Of Testing	: 31-Oct-2015	Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 33.4	Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E496611 N5729494		

CONE PENETRATION TEST

CPT_WFS3_6

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.4
Coordinates [m] : E496611 N5729494

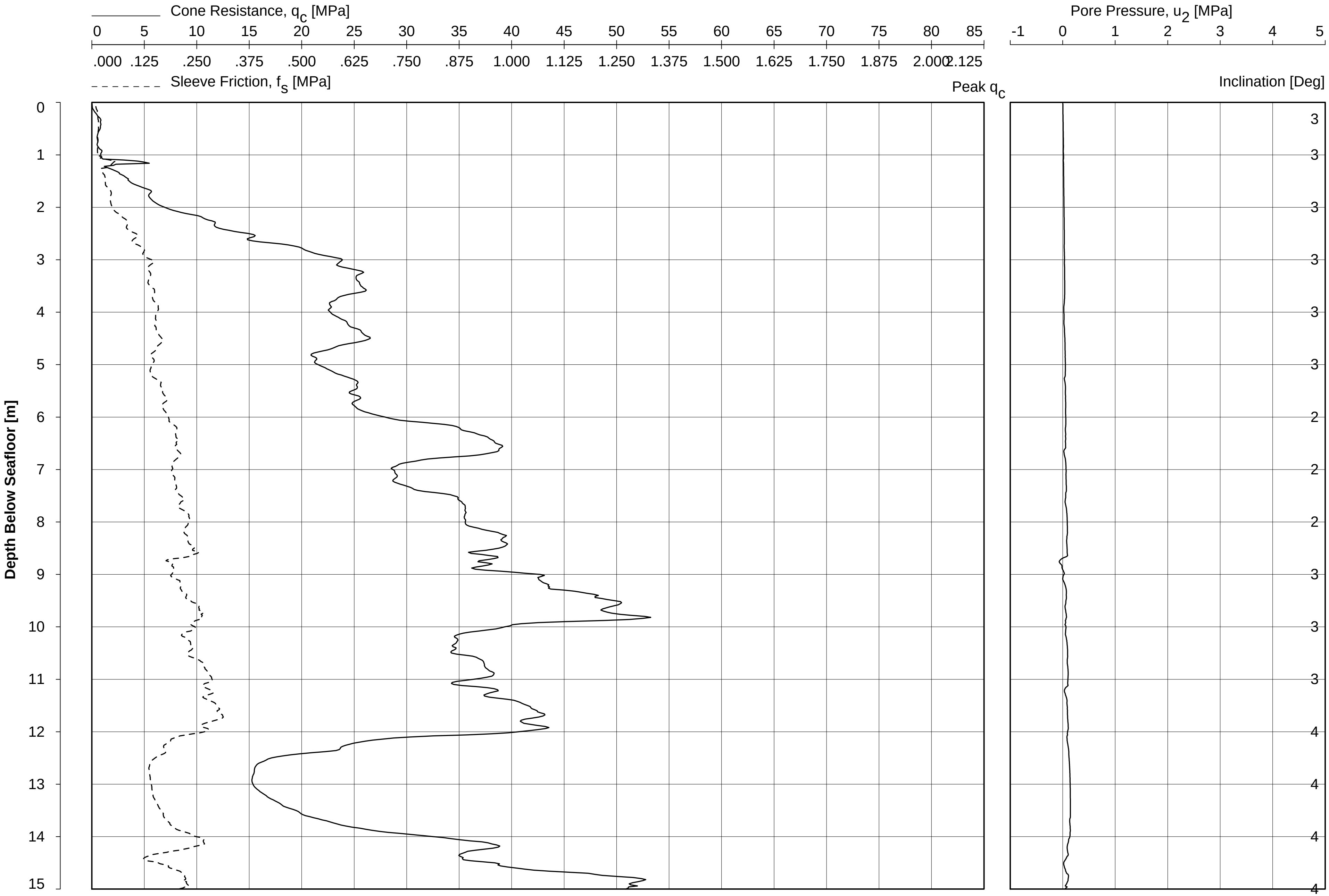
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_6

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



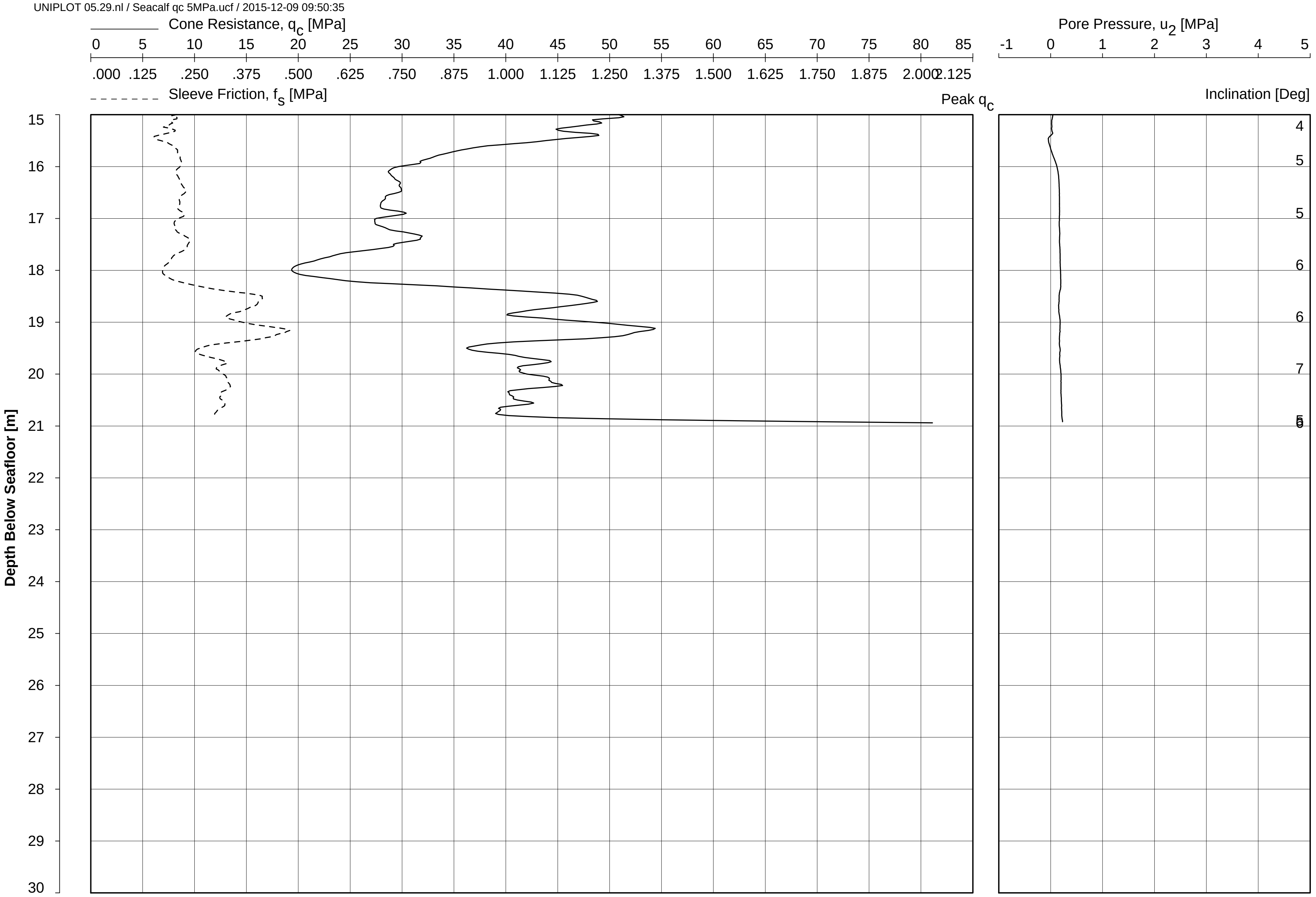
Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496608 N5729497

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_6A

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



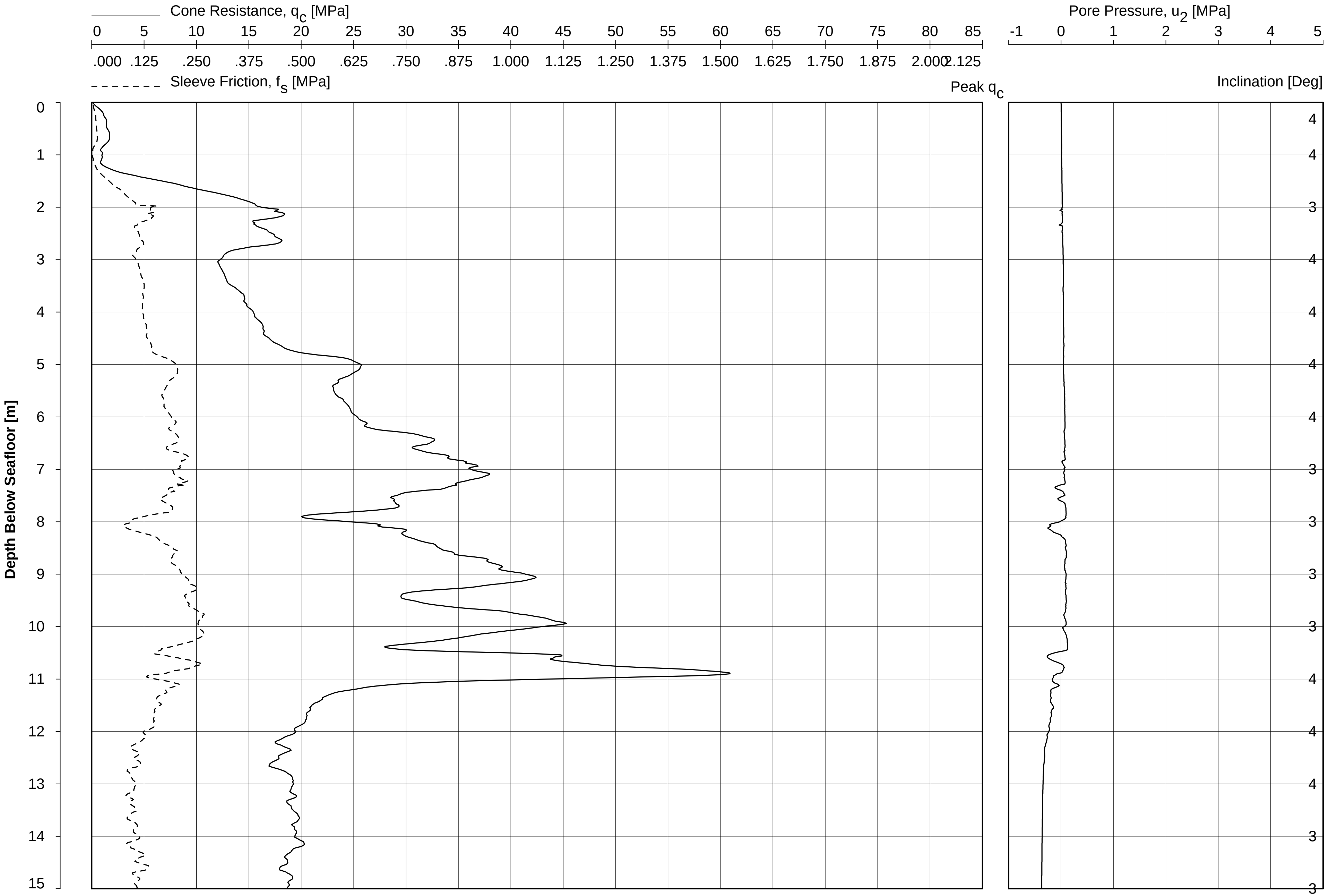
Date Of Testing	: 31-Oct-2015		Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 33.6		Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E496608	N5729497		

CONE PENETRATION TEST

CPT_WFS3_6A

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.8
Coordinates [m] : E498408 N5722197

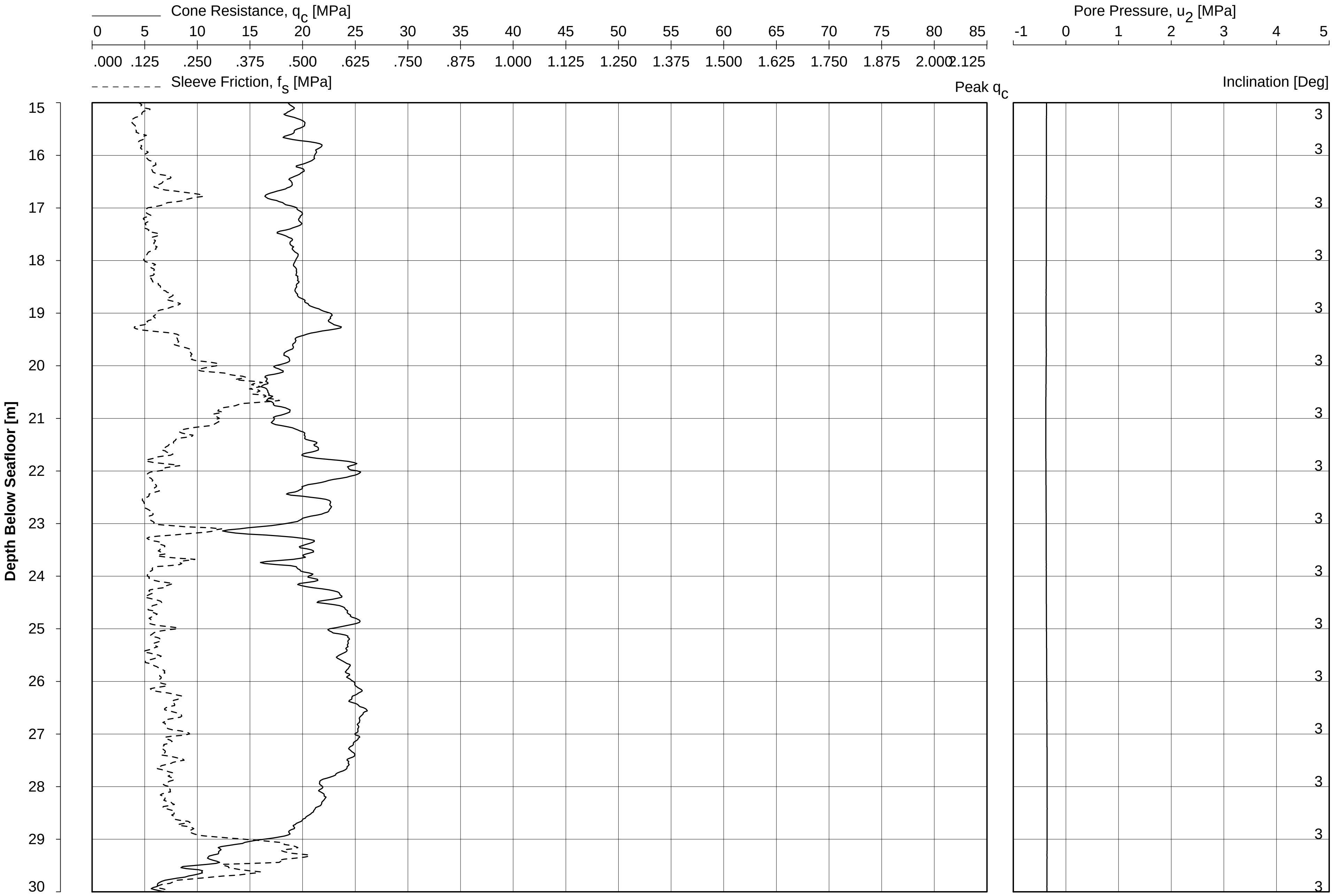
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_7

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.8
Coordinates [m] : E498408 N5722197

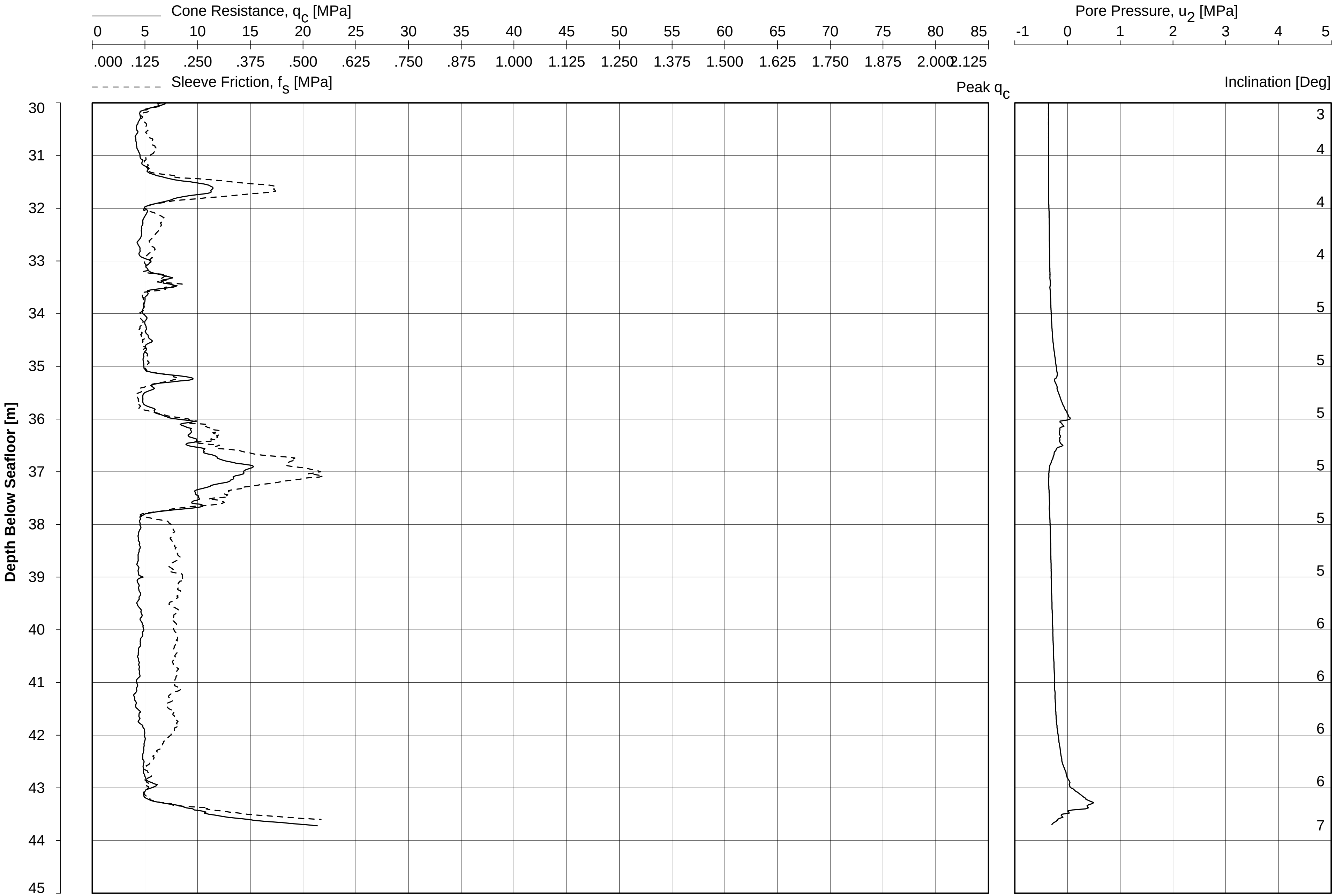
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_7

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.8
Coordinates [m] : E498408 N5722197

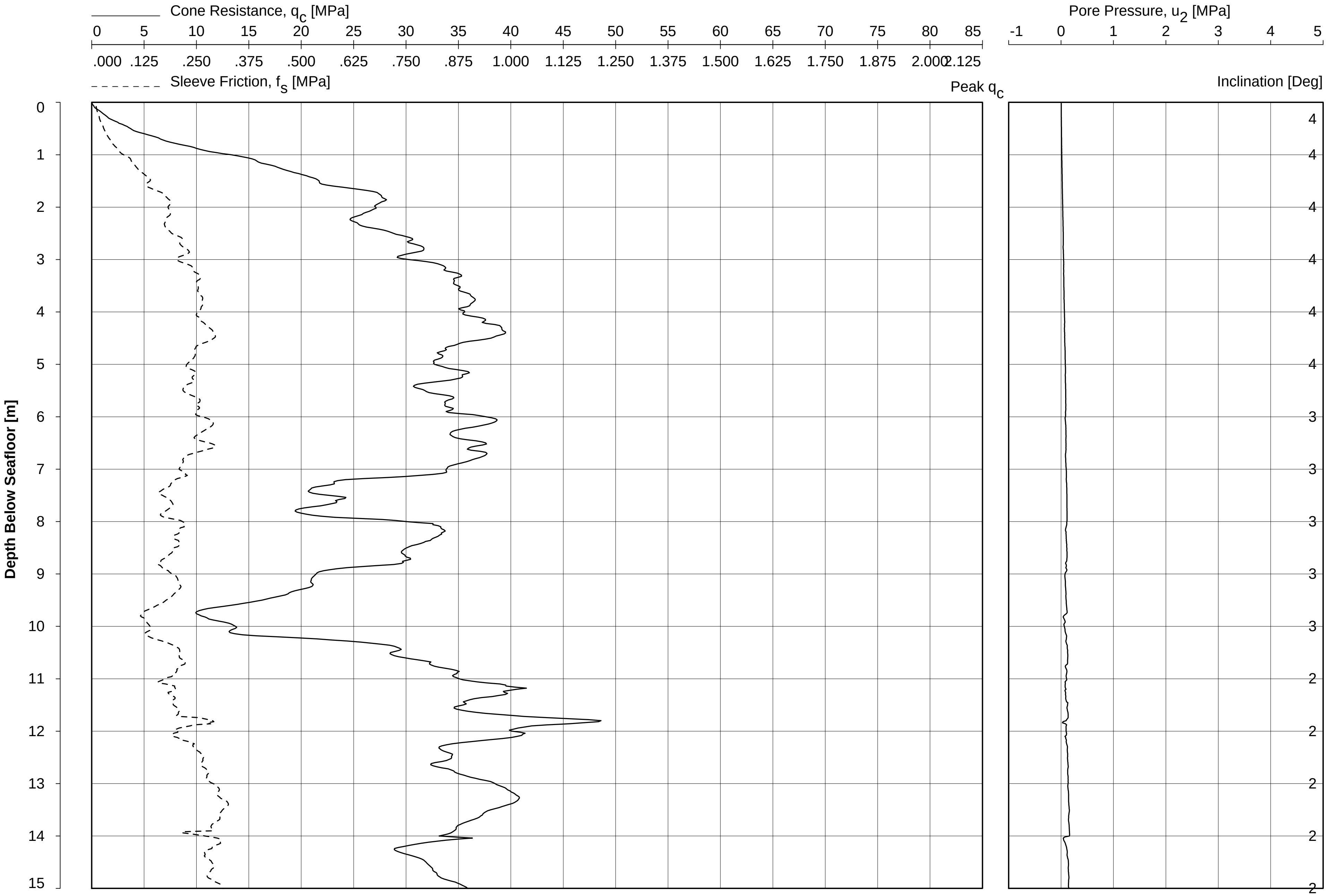
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_7

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



Date Of Testing : 26-Oct-2015
Water Depth [m] : 20.3
Coordinates [m] : E500438 N5724679

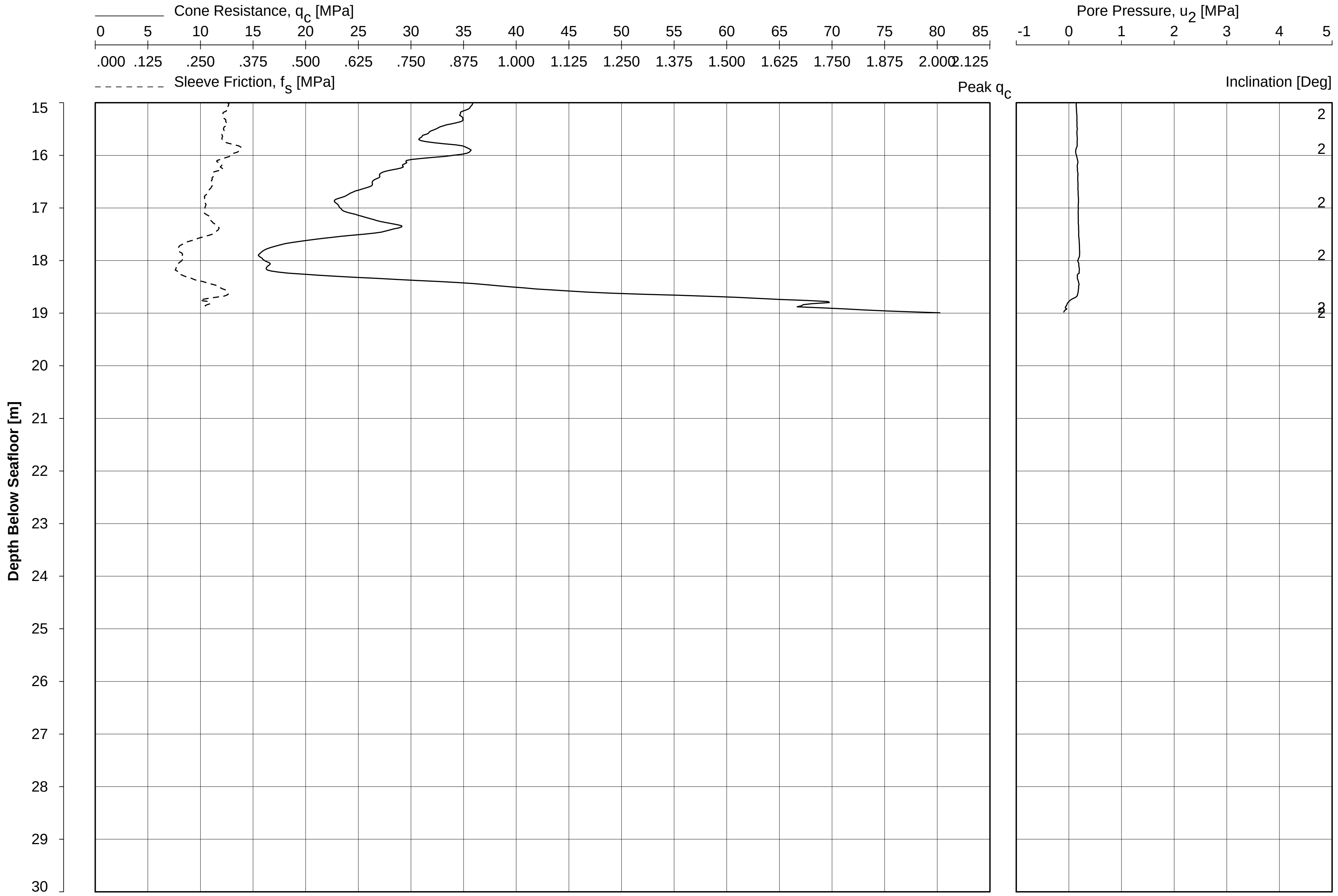
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_8

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



Date Of Testing : 26-Oct-2015
Water Depth [m] : 20.3
Coordinates [m] : E500438 N5724679

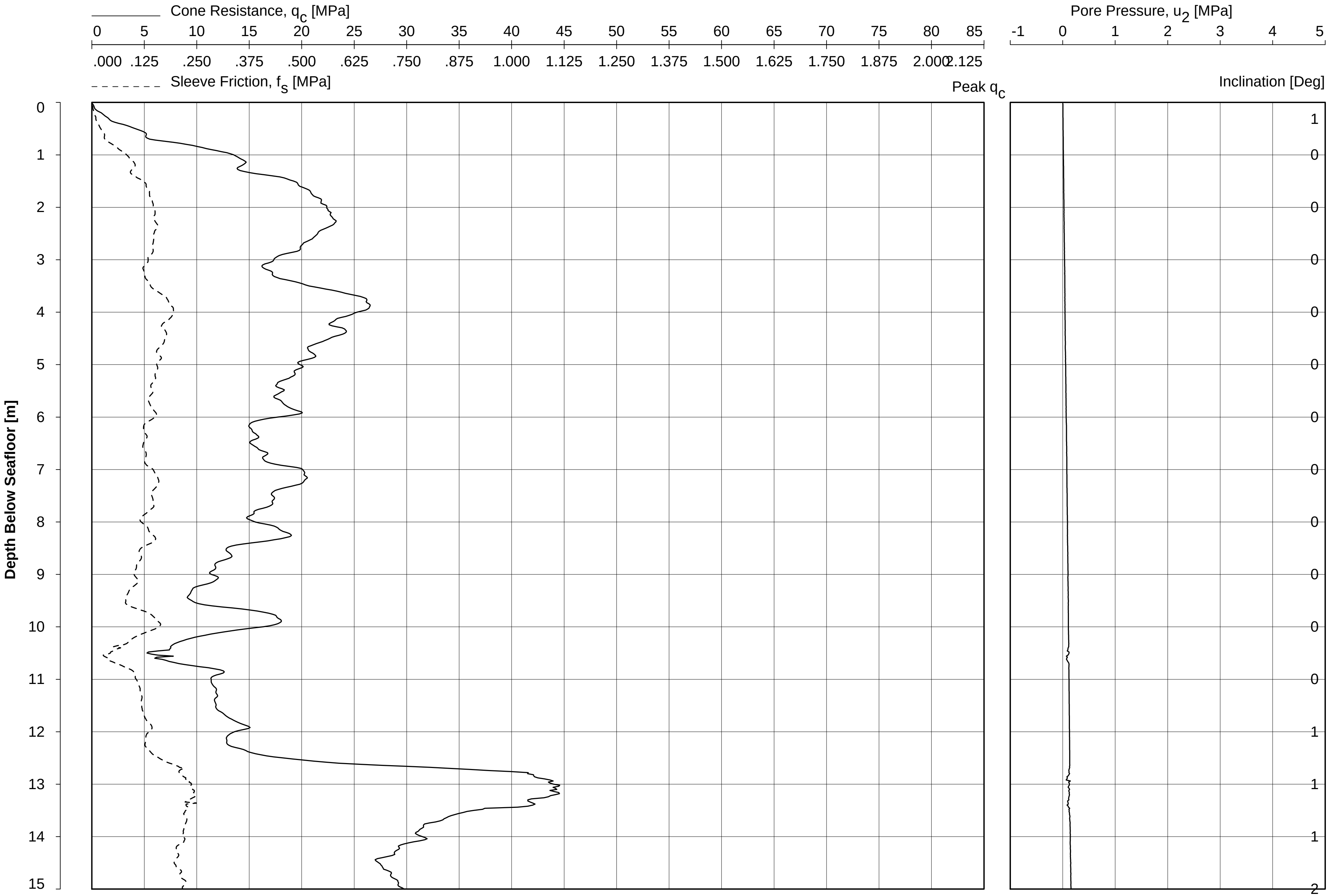
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_8

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



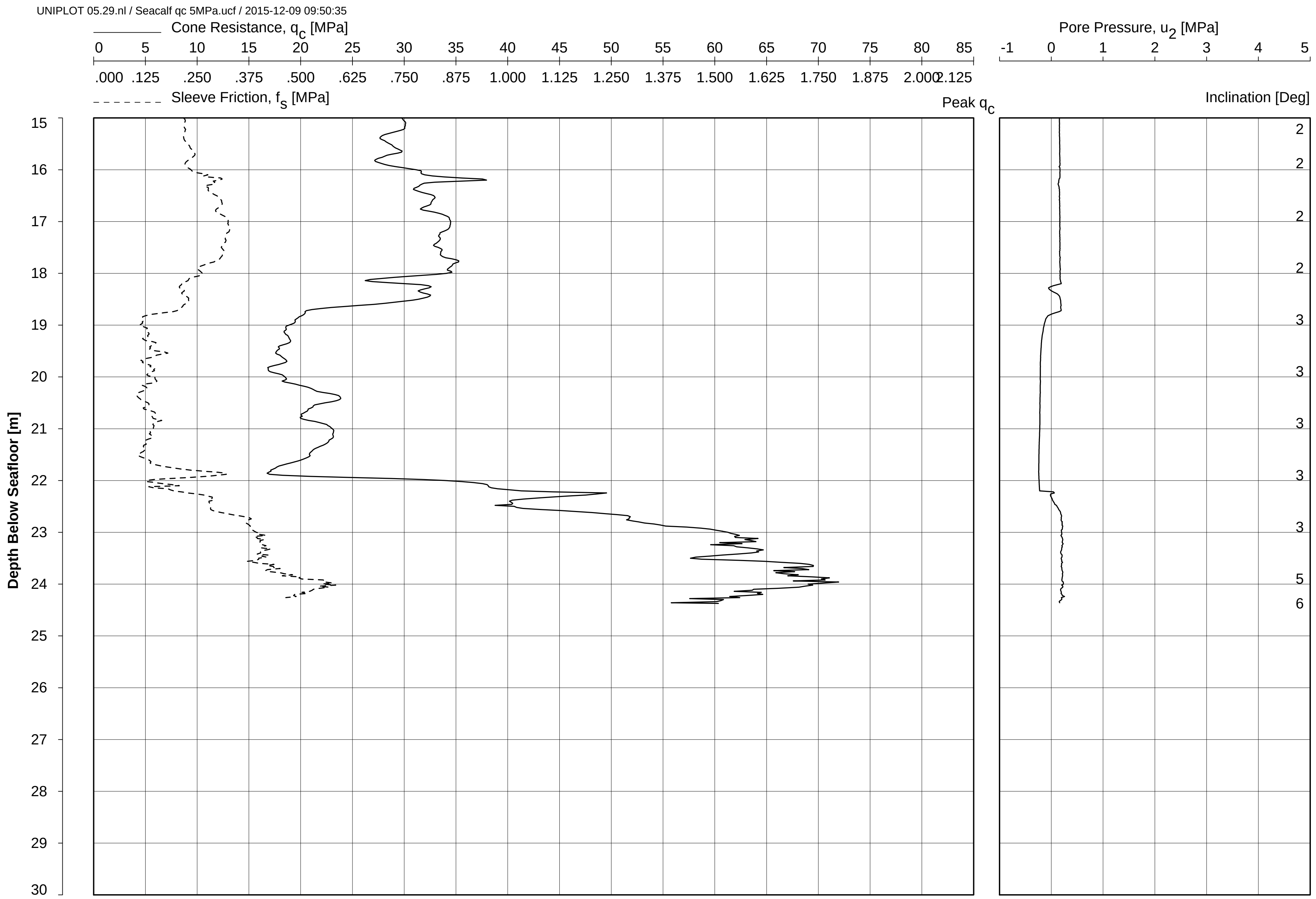
Date Of Testing : 30-Oct-2015
Water Depth [m] : 25.0
Coordinates [m] : E500399 N5726517

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_9

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



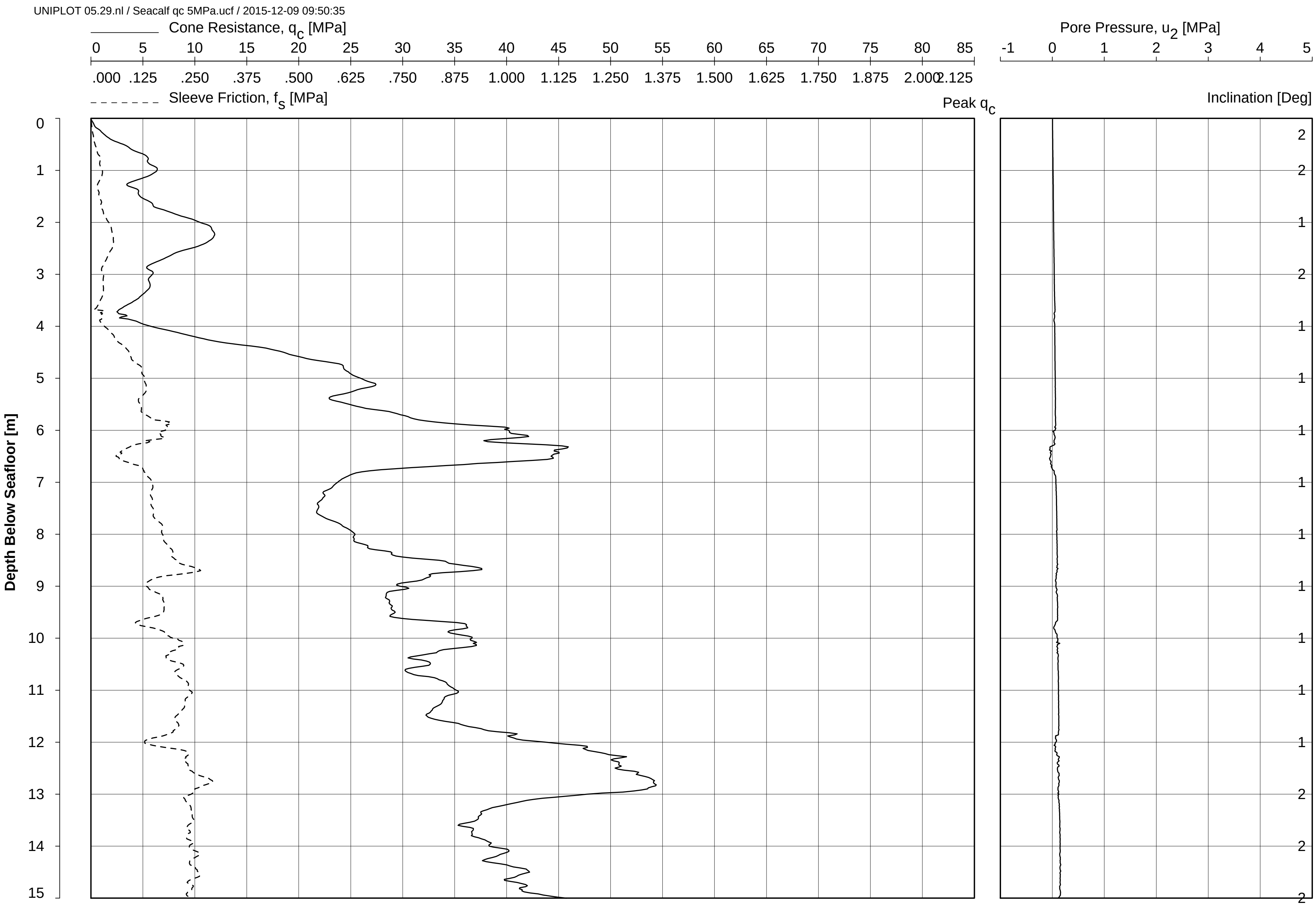
Date Of Testing : 30-Oct-2015
Water Depth [m] : 25.0
Coordinates [m] : E500399 N5726517

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_9

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



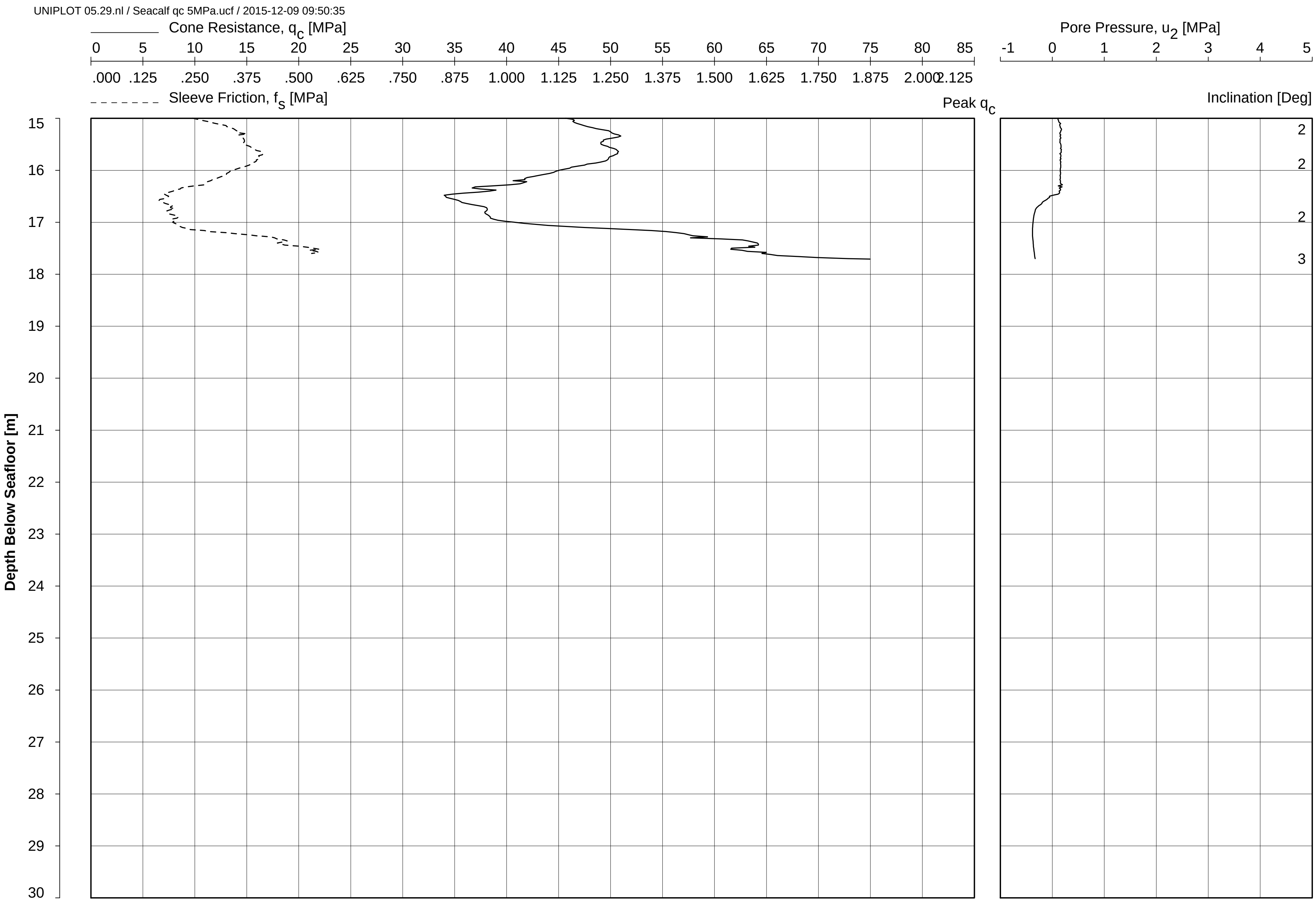
Date Of Testing : 30-Oct-2015
Water Depth [m] : 34.7
Coordinates [m] : E498625 N5726871

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_10

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 30-Oct-2015
Water Depth [m] : 34.7
Coordinates [m] : E498625 N5726871

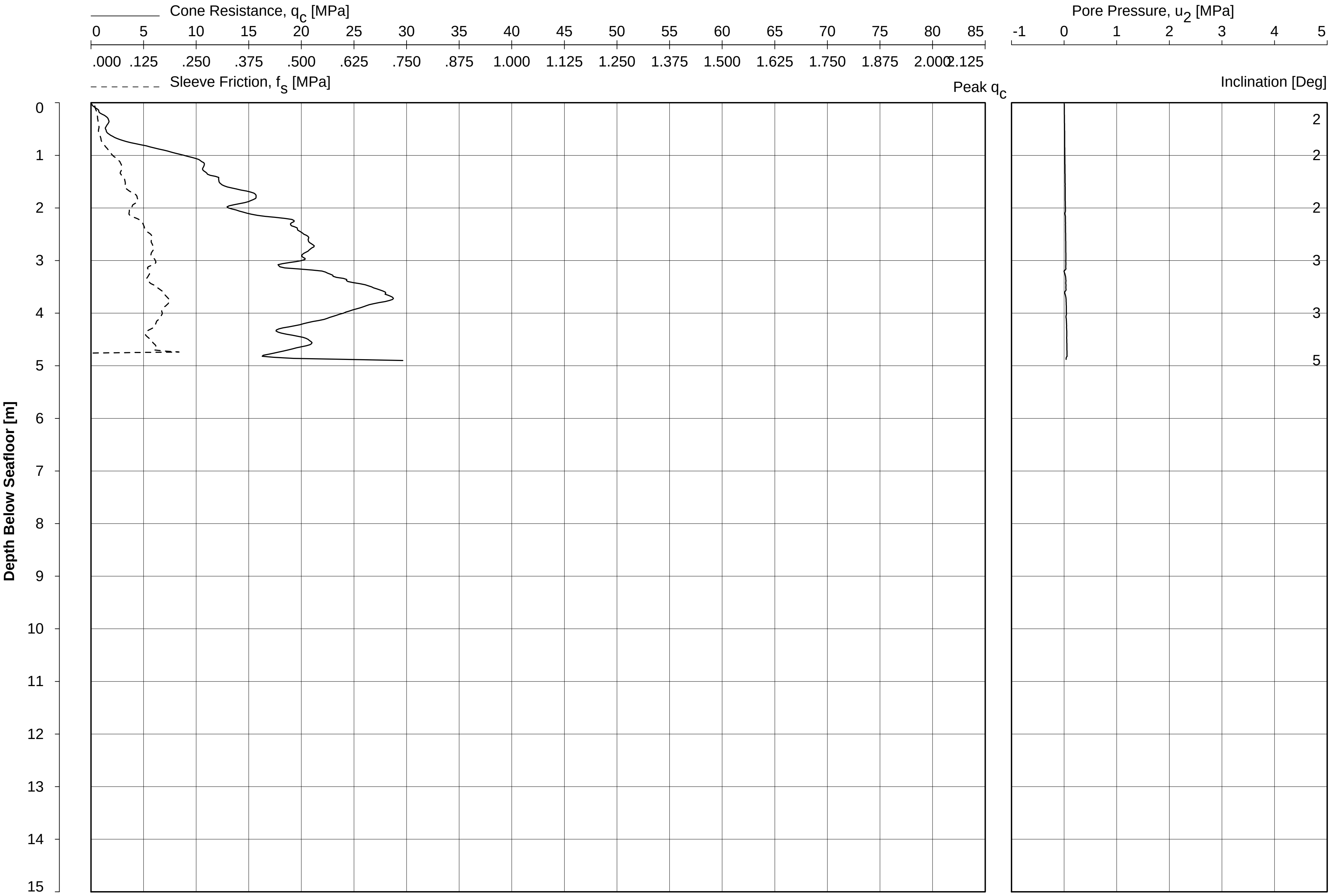
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_10

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



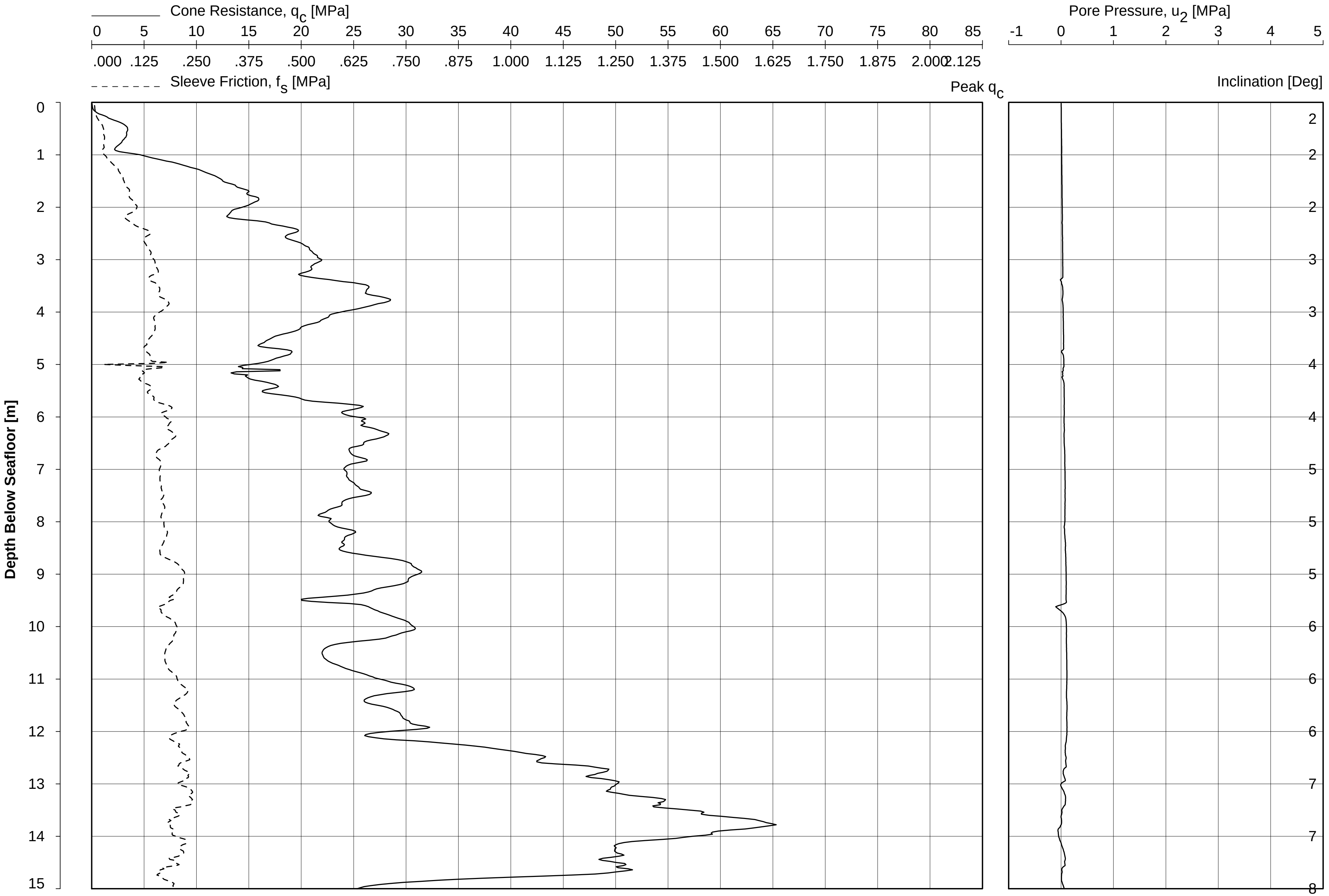
Date Of Testing	: 31-Oct-2015		Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 25.1		Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E501904	N5726449		

CONE PENETRATION TEST

CPT_WFS3_11

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



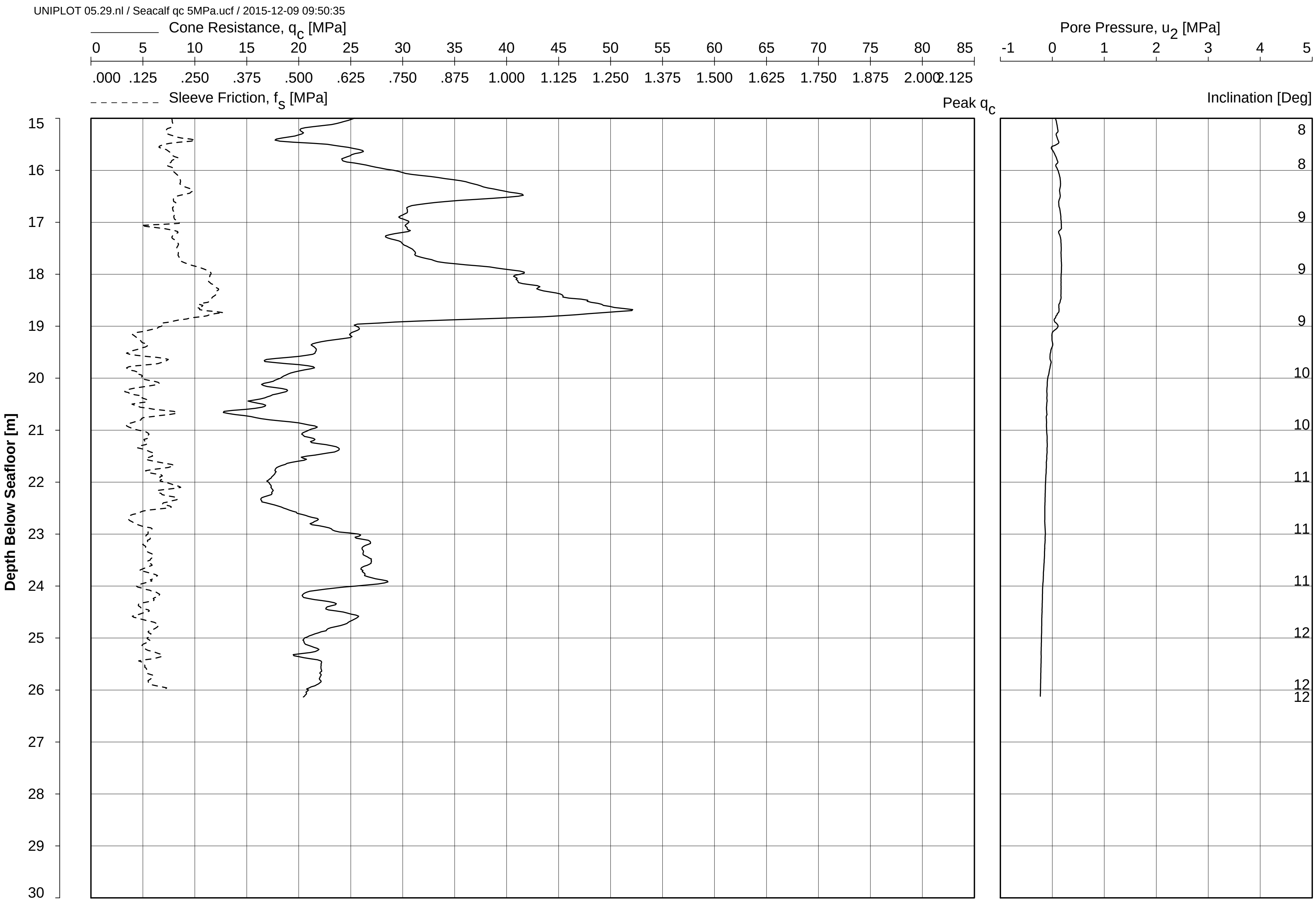
Date Of Testing : 31-Oct-2015
Water Depth [m] : 25.1
Coordinates [m] : E501900 N5726444

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_11A

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 31-Oct-2015
Water Depth [m] : 25.1
Coordinates [m] : E501900 N5726444

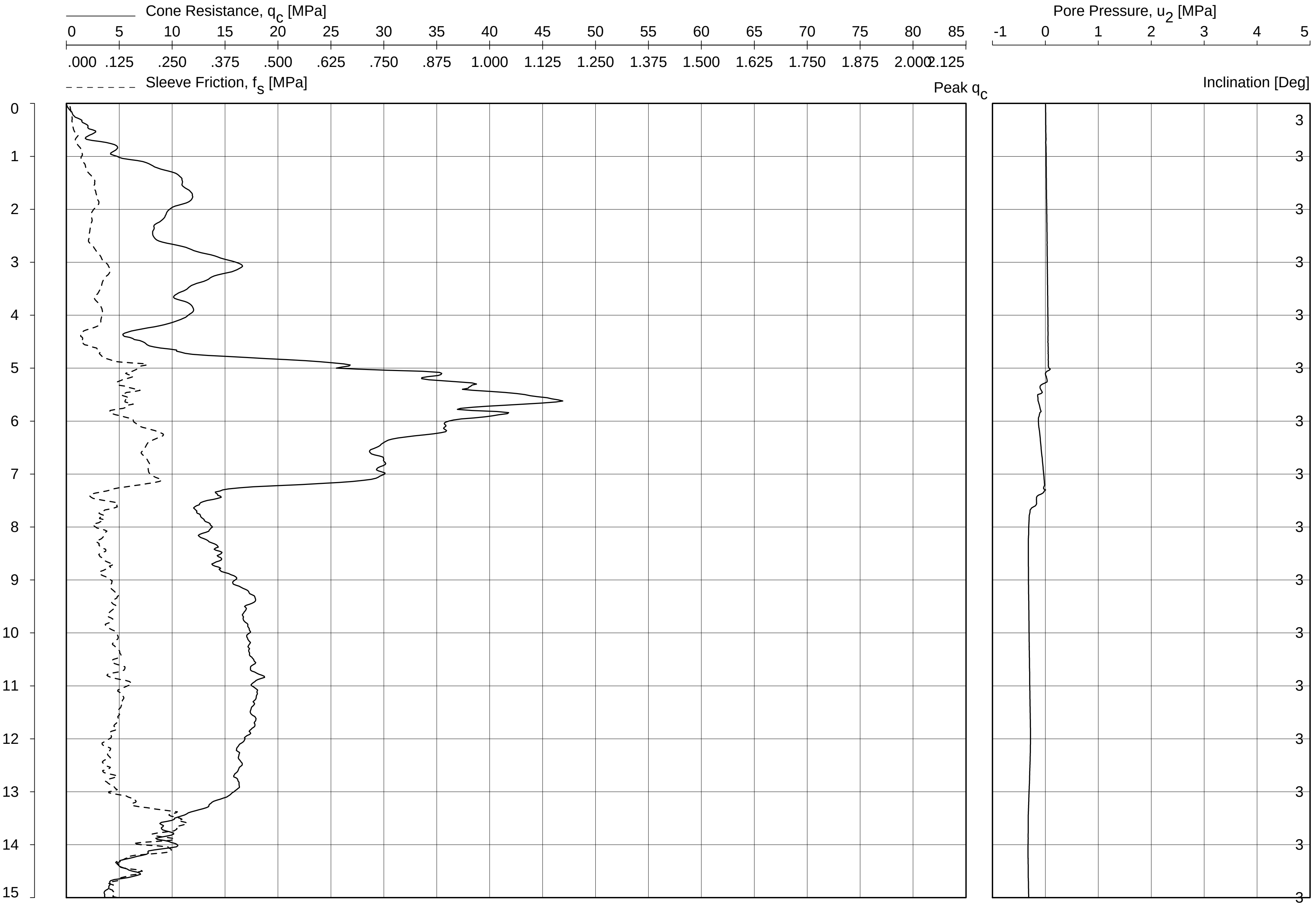
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_11A

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



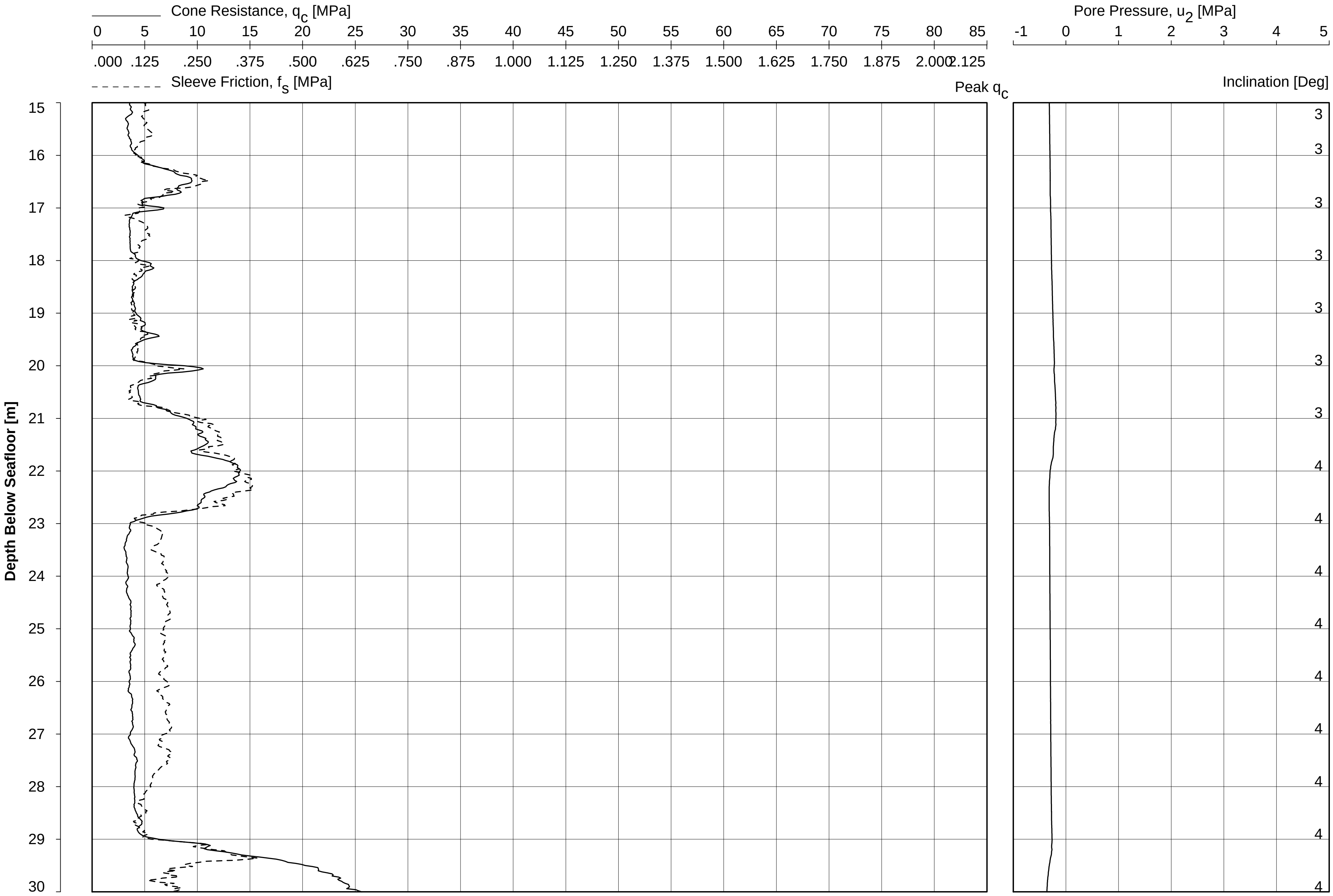
Date Of Testing	: 27-Oct-2015		Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 32.6		Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E497925	N5719860		

CONE PENETRATION TEST

CPT_WFS3_12

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:35



Date Of Testing : 27-Oct-2015
Water Depth [m] : 32.6
Coordinates [m] : E497925 N5719860

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

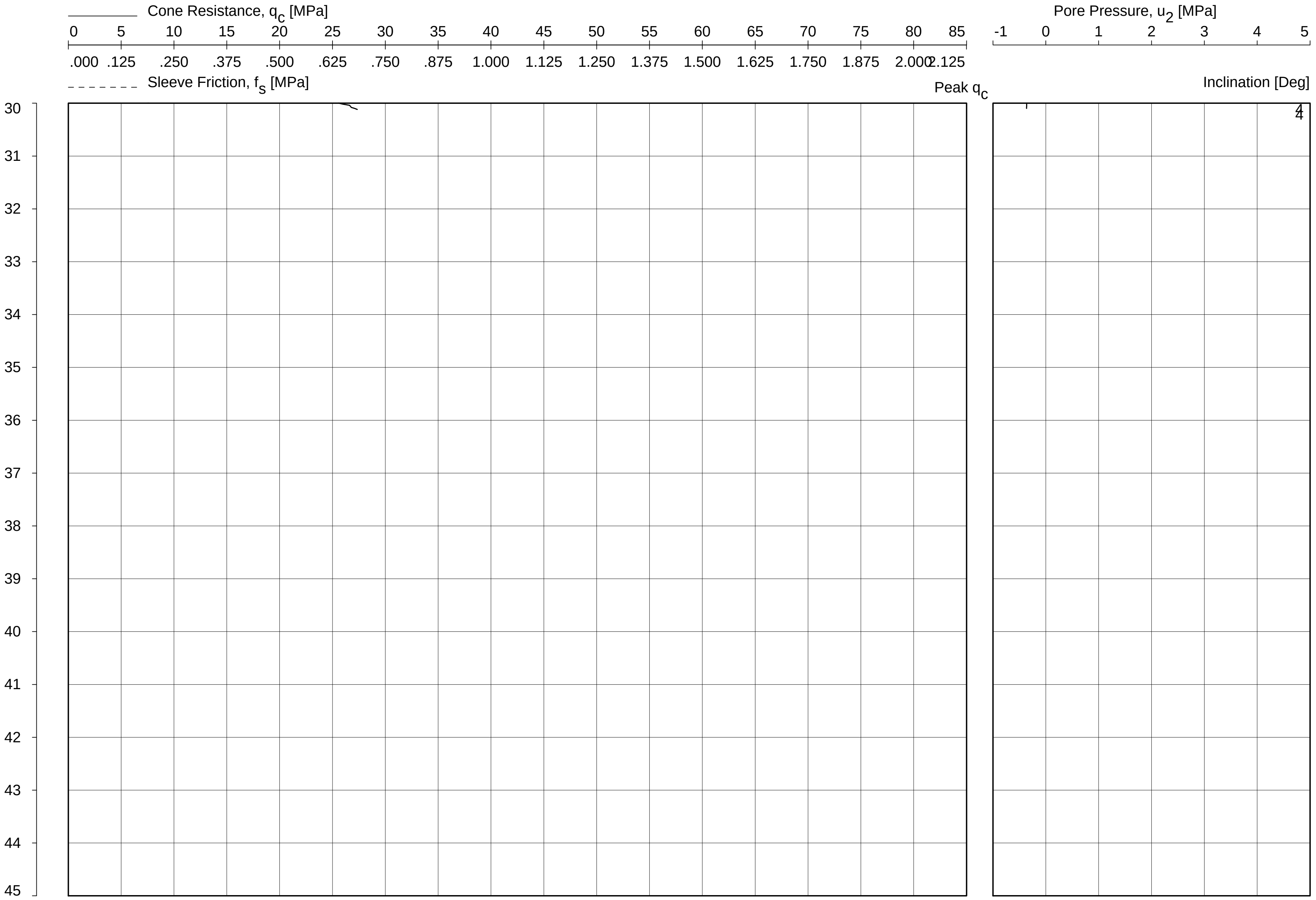
CONE PENETRATION TEST

CPT_WFS3_12

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

Fugro Report No. N6083/02 (2)

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



Date Of Testing	: 27-Oct-2015	Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 32.6	Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E497925 N5719860		

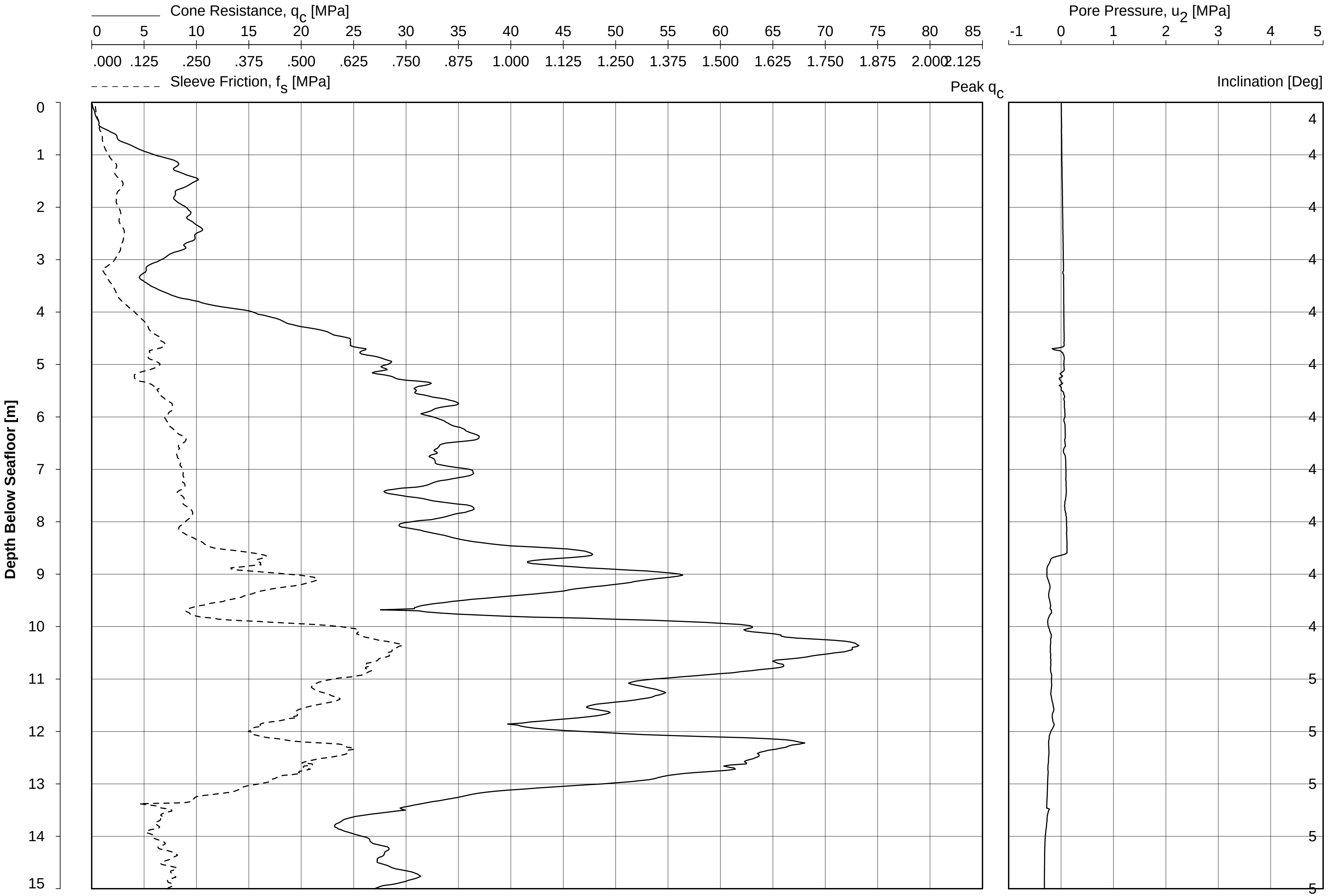
CONE PENETRATION TEST

CPT_WFS3_12

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



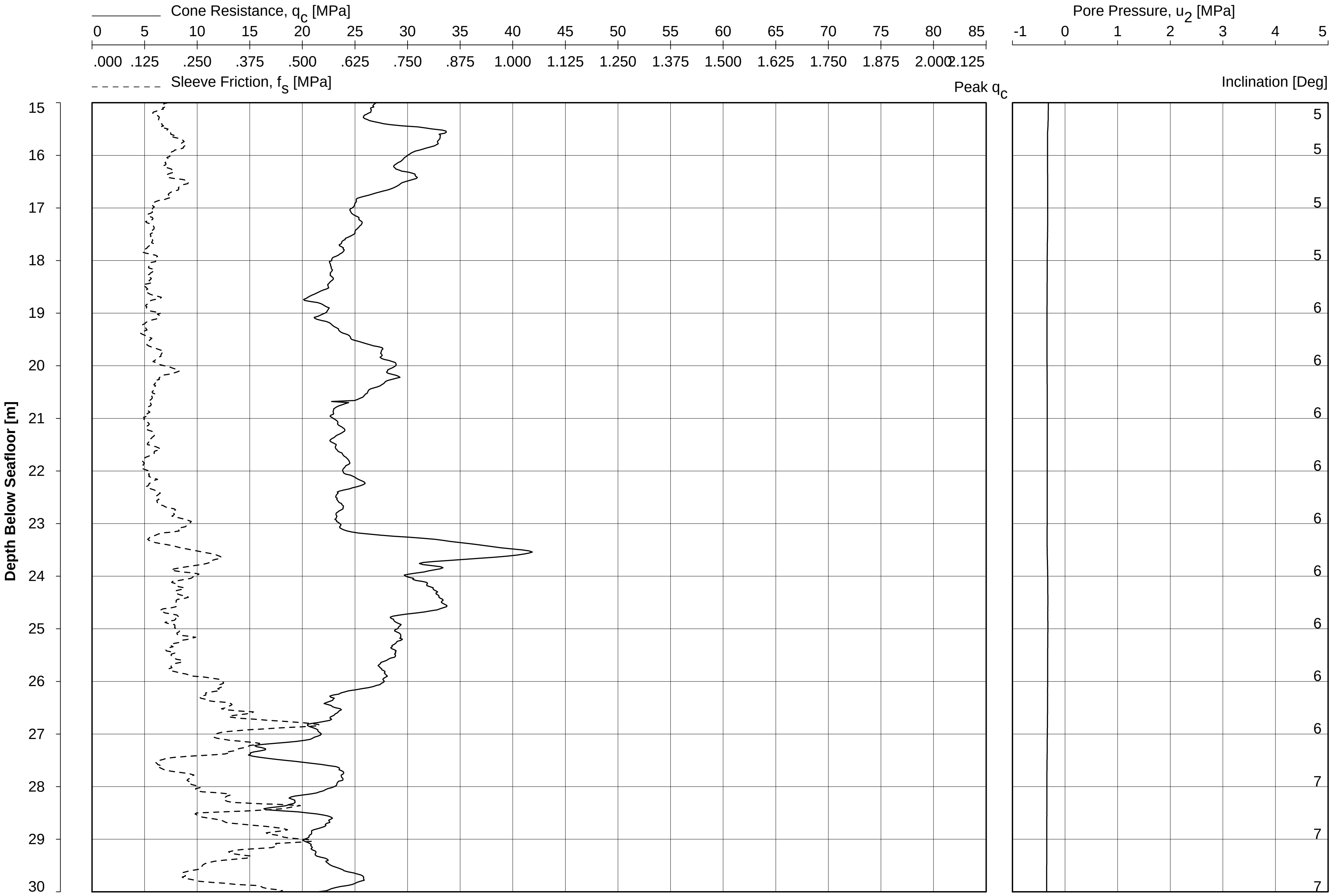
Date Of Testing	: 26-Oct-2015	Probe Type	: CP15-CF75PB30SN2
Water Depth [m]	: 30.3	Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E500855 N5723291		

CONE PENETRATION TEST

CPT_WFS3_13

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



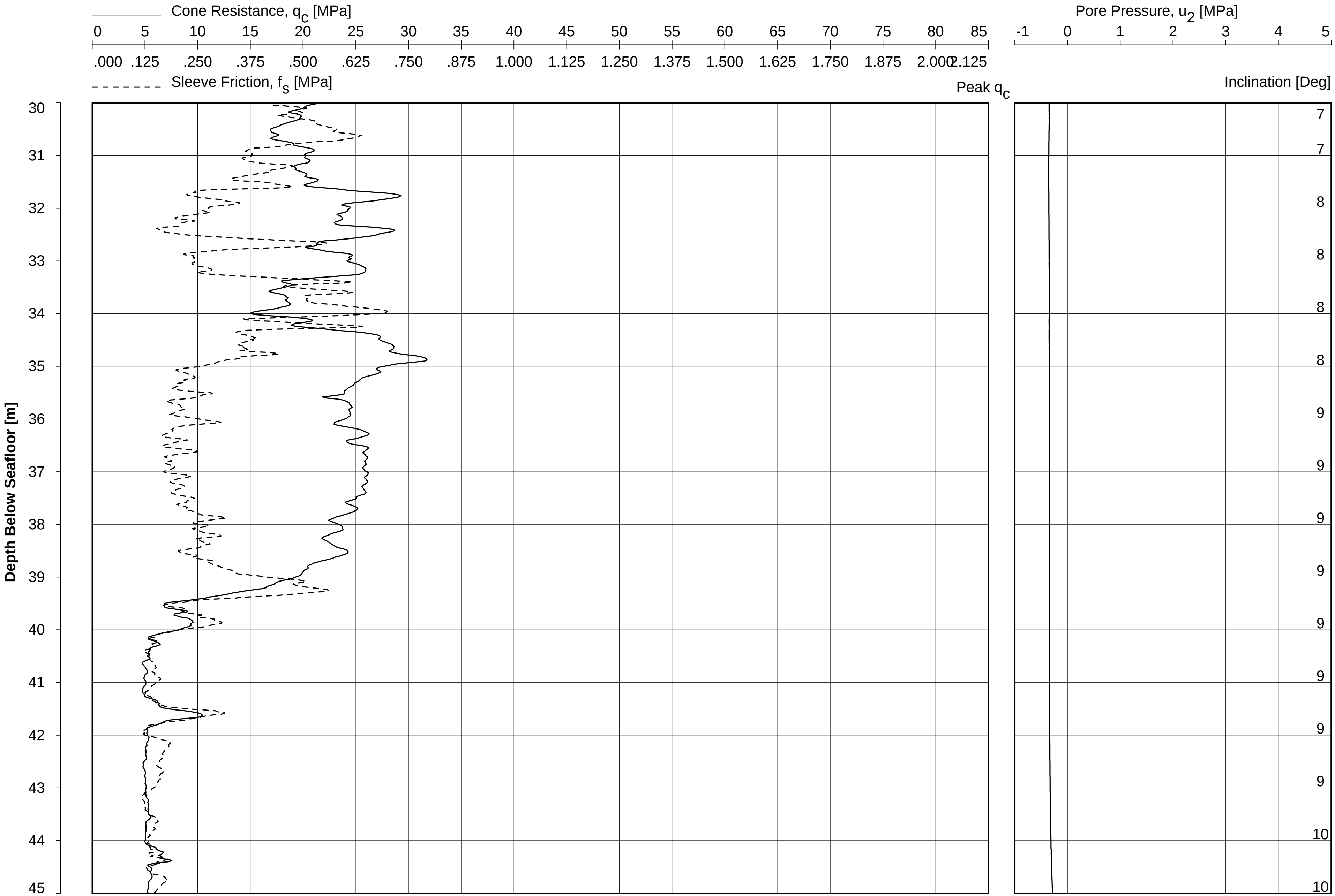
Date Of Testing	: 26-Oct-2015	Probe Type	: CP15-CF75PB30SN2
Water Depth [m]	: 30.3	Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E500855 N5723291		

CONE PENETRATION TEST

CPT_WFS3_13

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



Date Of Testing : 26-Oct-2015
Water Depth [m] : 30.3
Coordinates [m] : E500855 N5723291

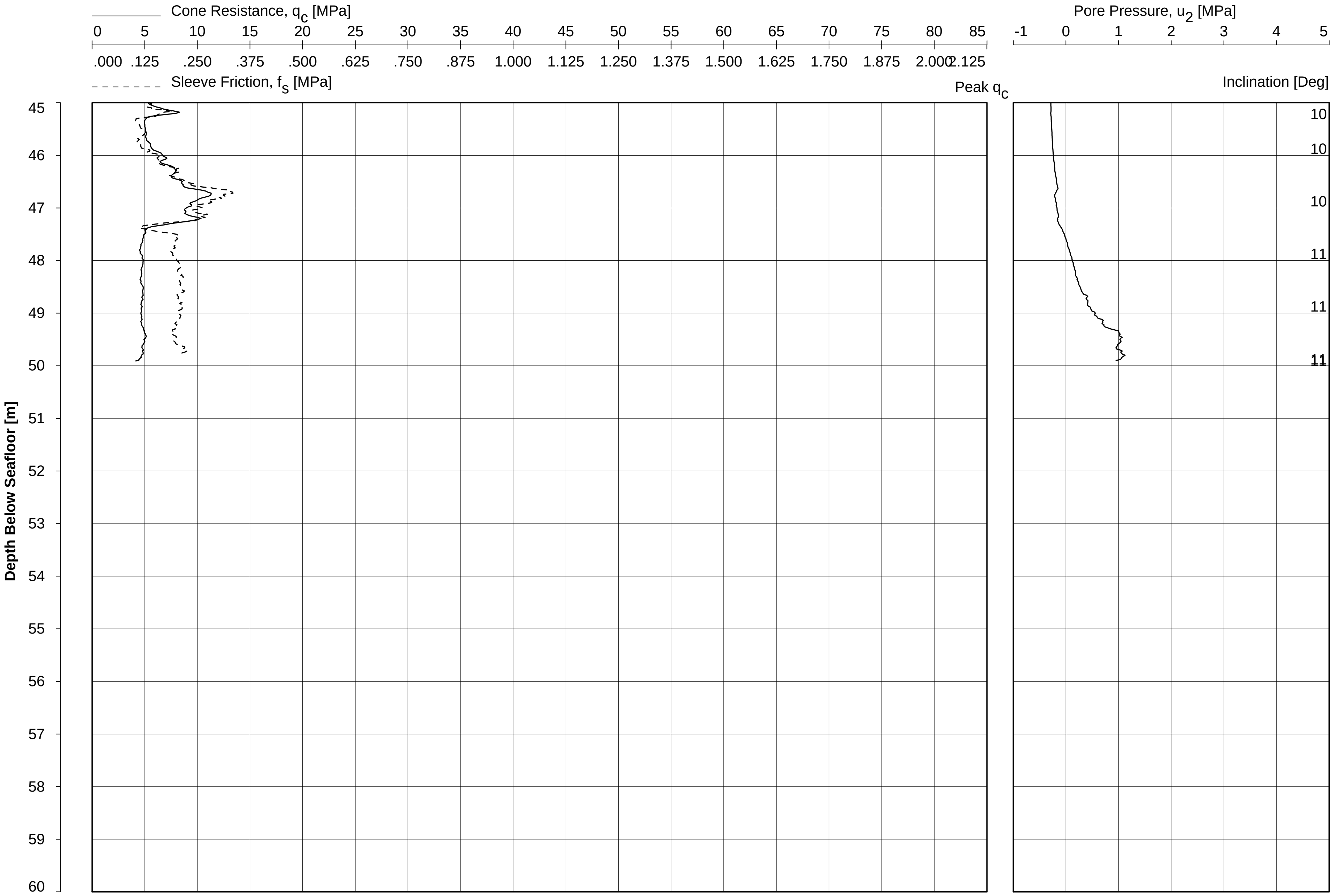
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_13

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



Date Of Testing : 26-Oct-2015
Water Depth [m] : 30.3
Coordinates [m] : E500855 N5723291

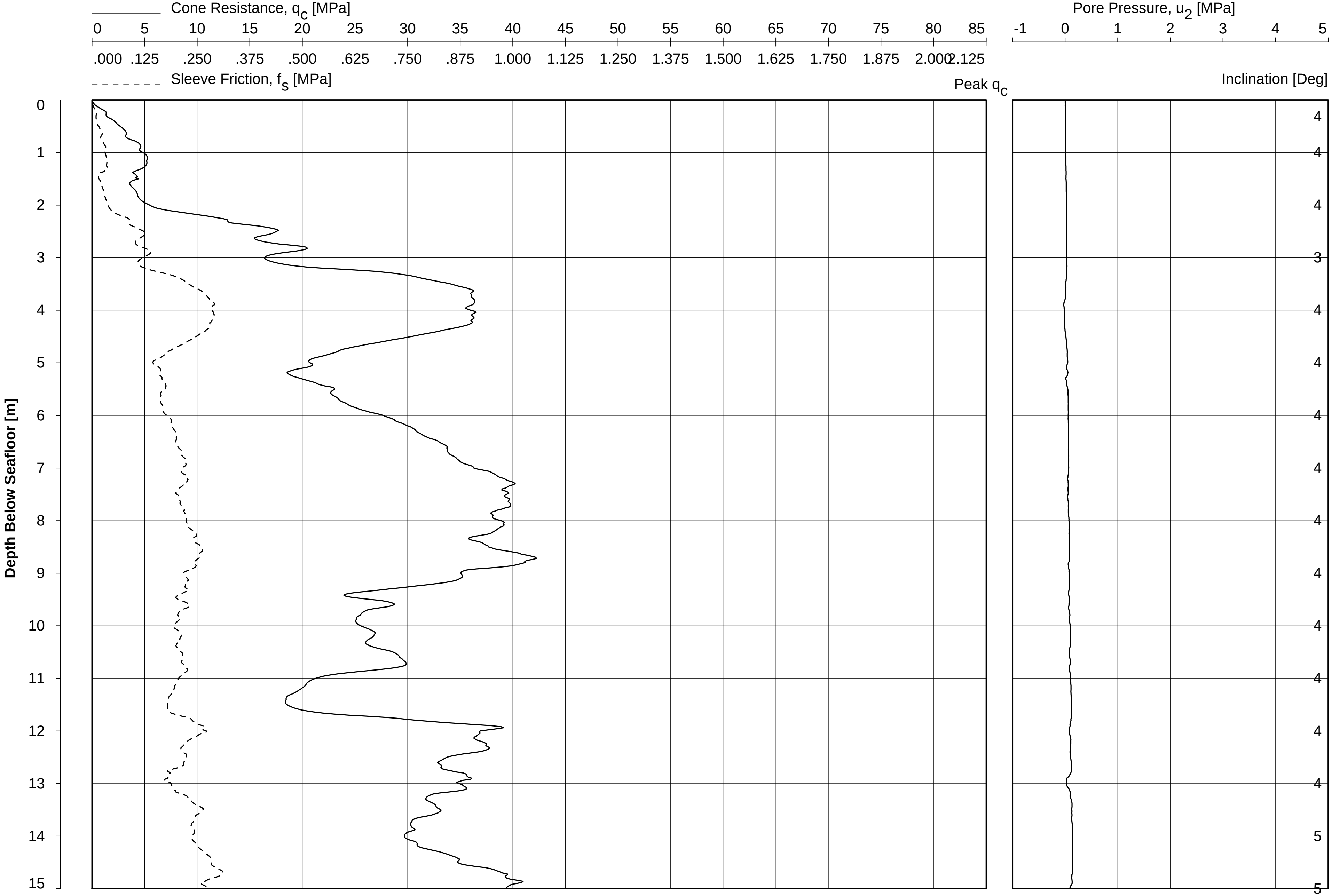
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_13

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E494938 N5726134

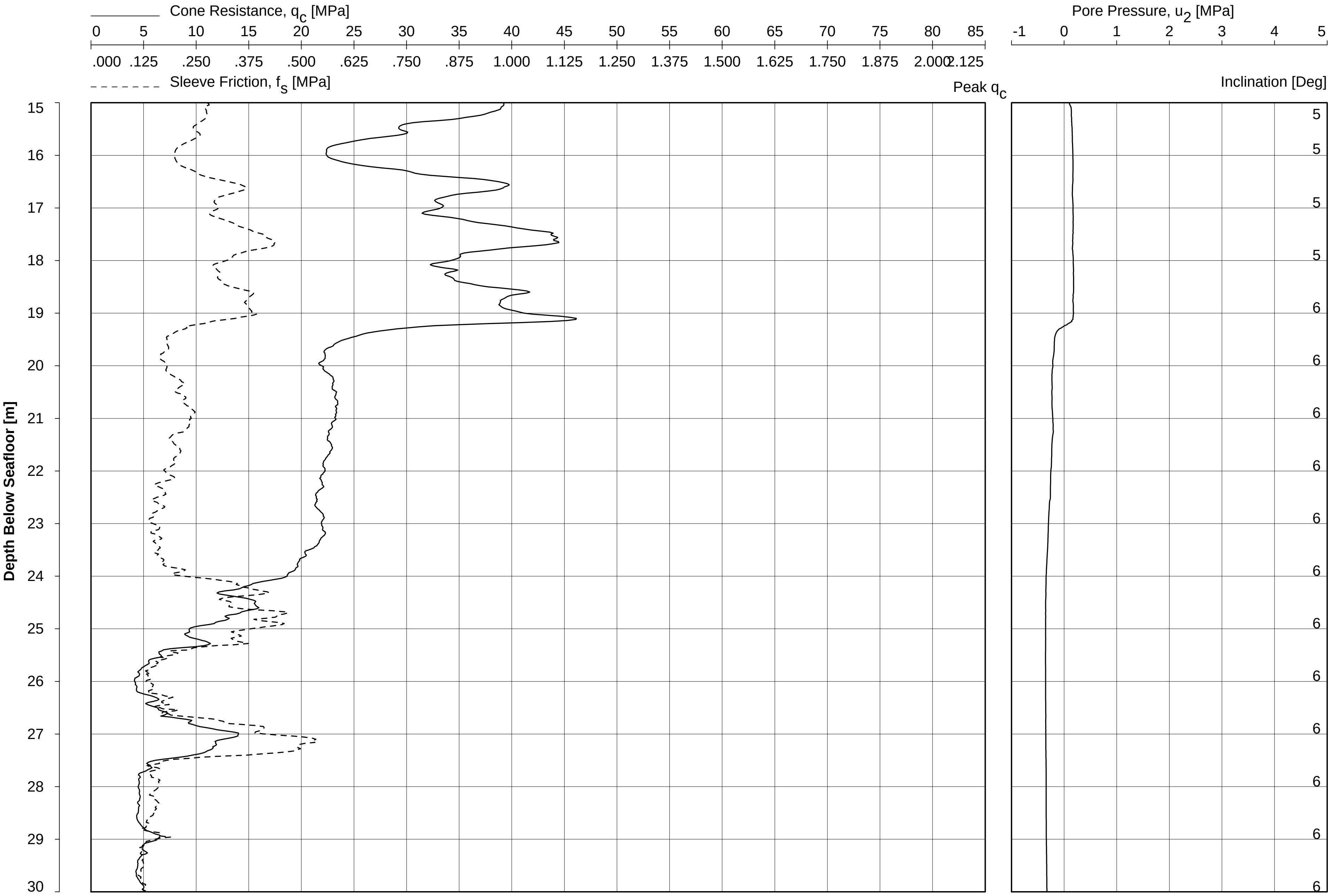
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_14

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



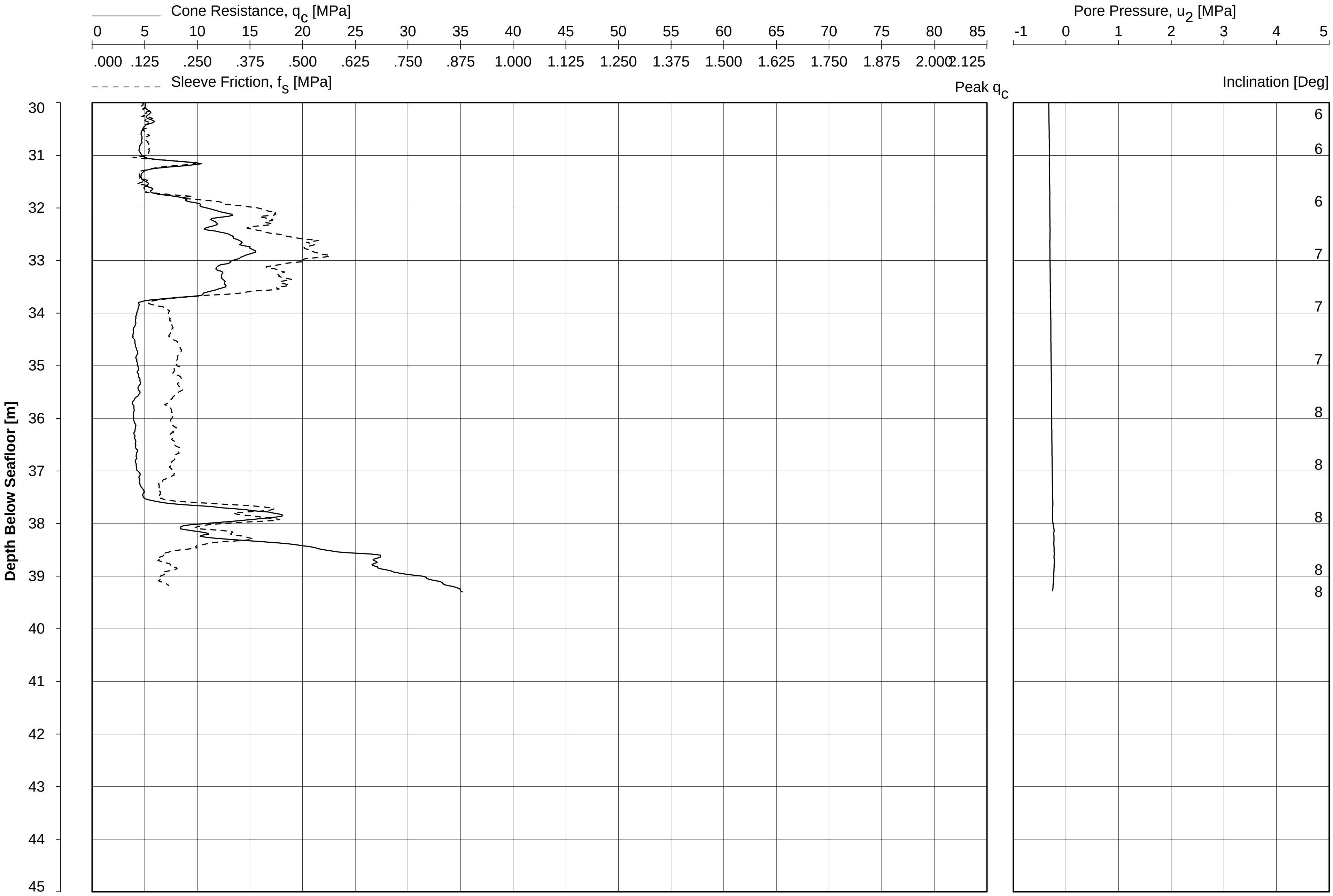
Date Of Testing	: 29-Oct-2015	Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 30.9	Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E494938 N5726134		

CONE PENETRATION TEST

CPT_WFS3_14

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E494938 N5726134

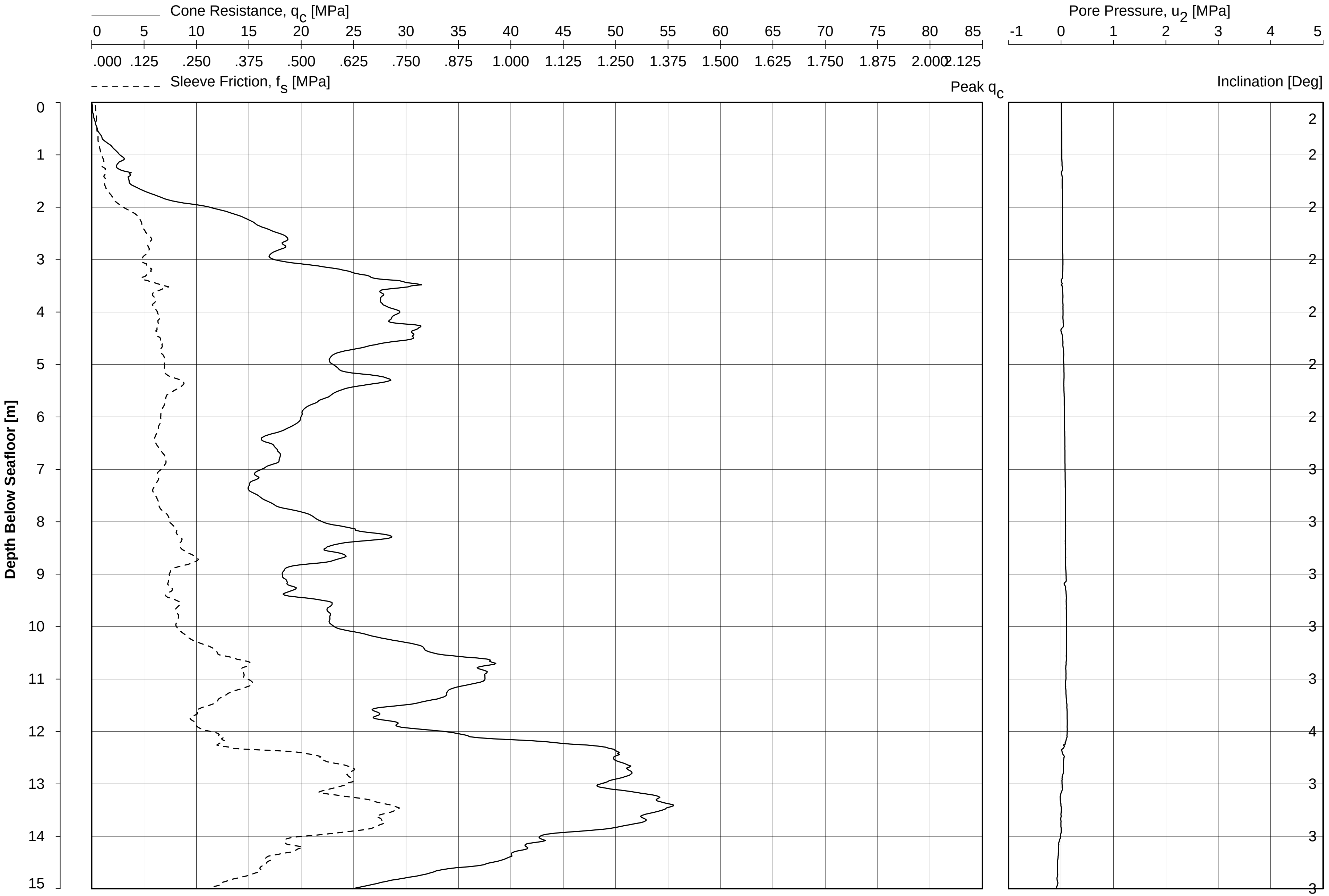
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_14

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



Date Of Testing : 29-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496545 N5727484

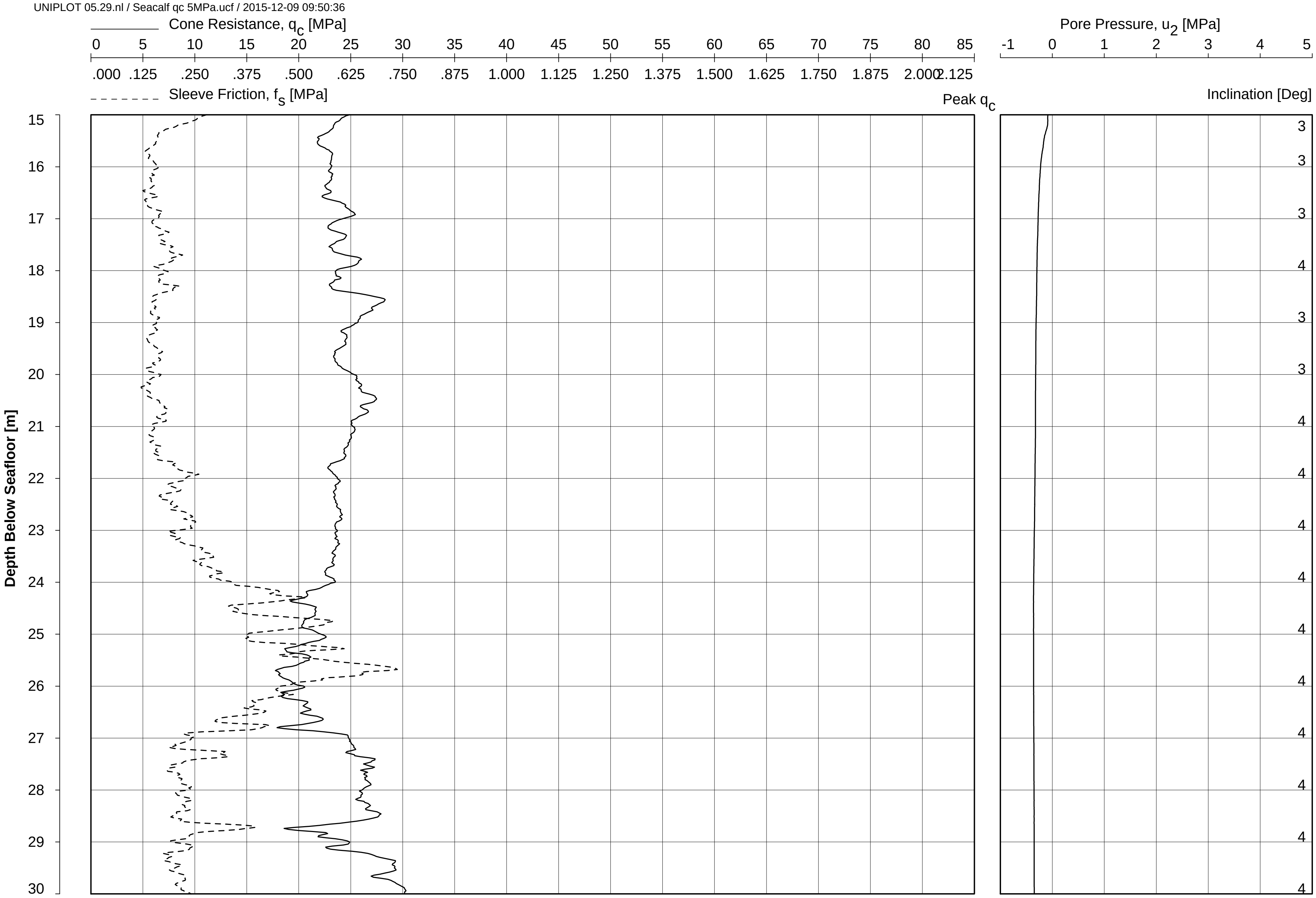
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_15

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO



Date Of Testing : 29-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496545 N5727484

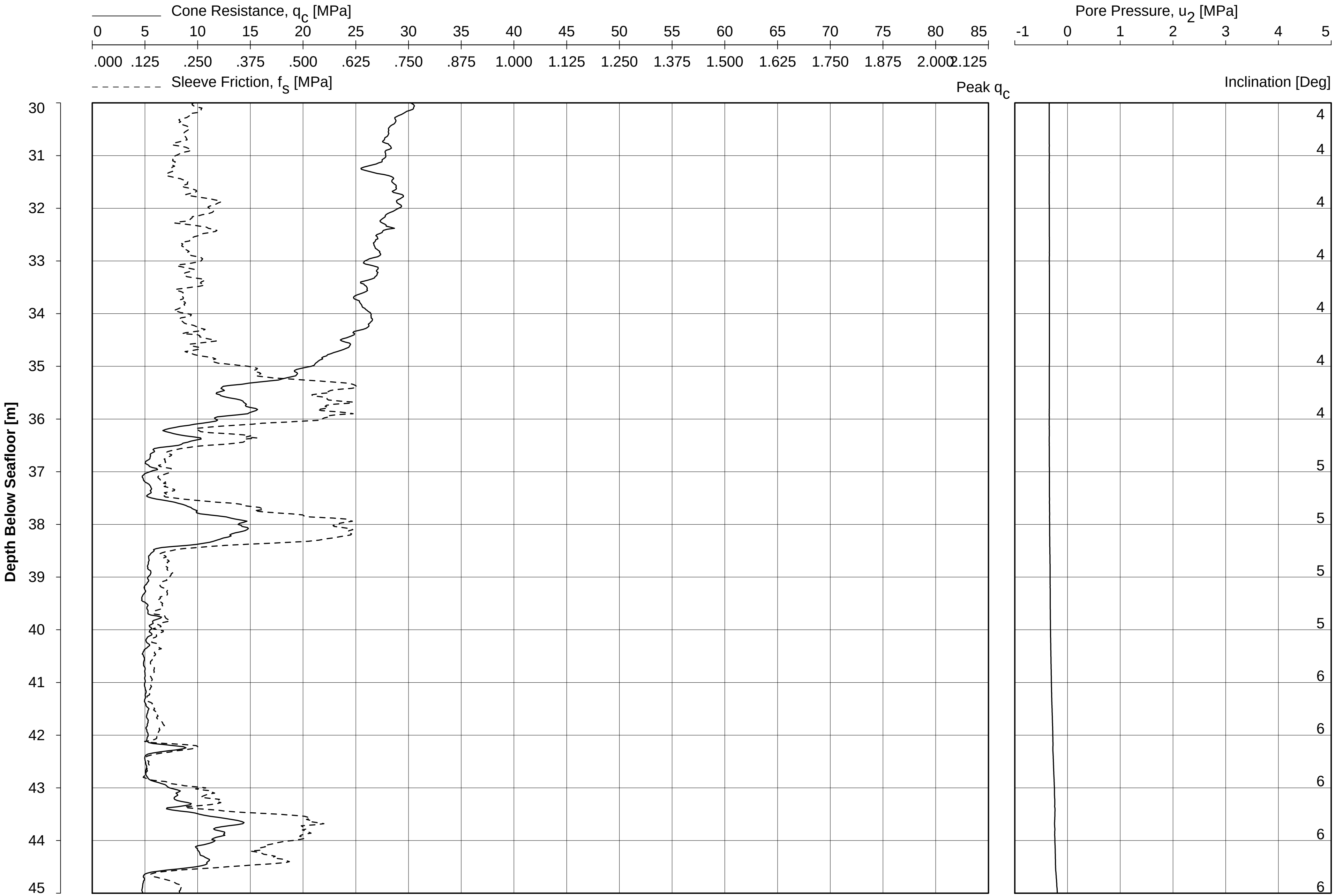
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm²] : 1510

CONE PENETRATION TEST

CPT_WFS3_15

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



Date Of Testing : 29-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496545 N5727484

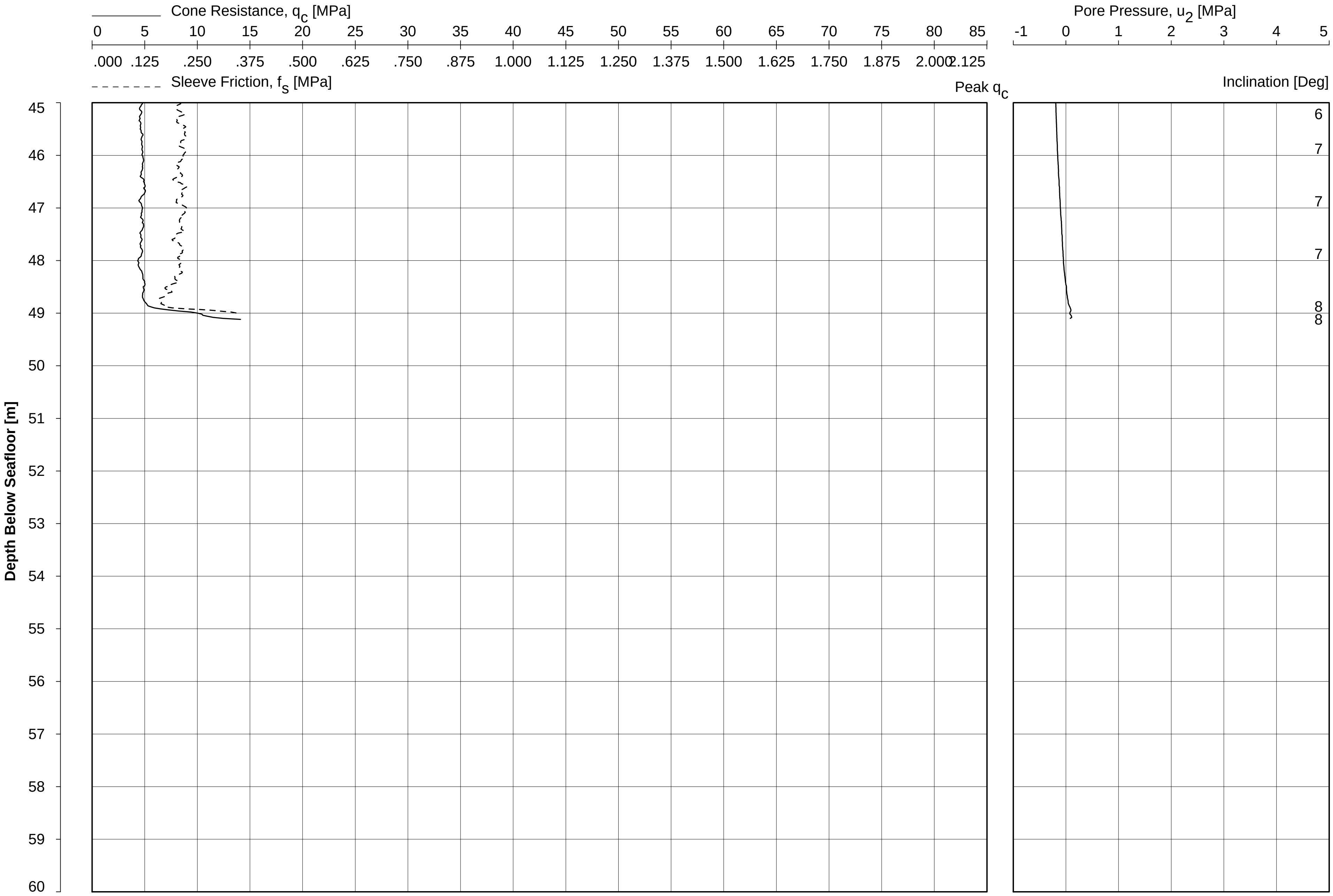
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_15

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



Date Of Testing : 29-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496545 N5727484

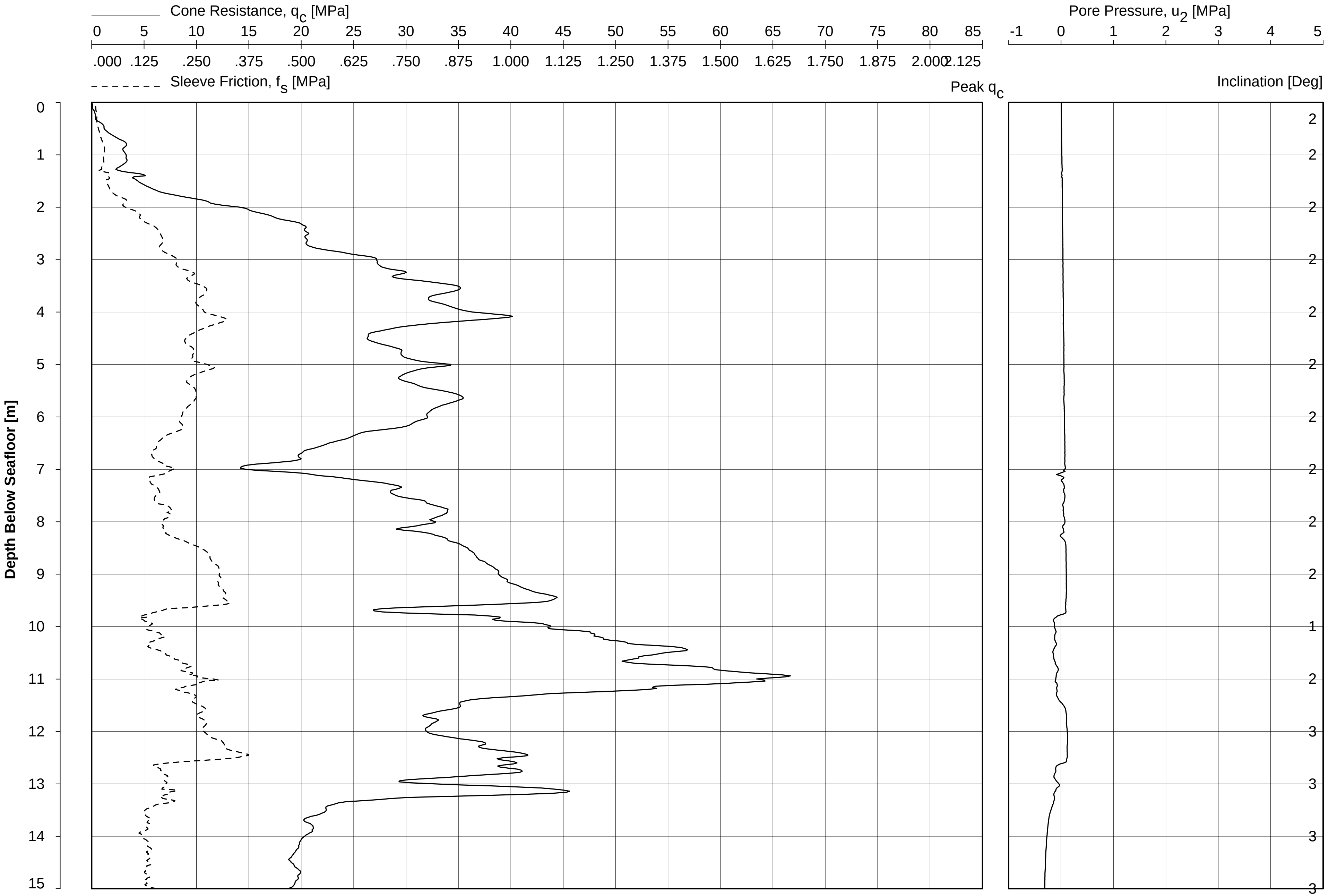
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_15

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E495274 N5727833

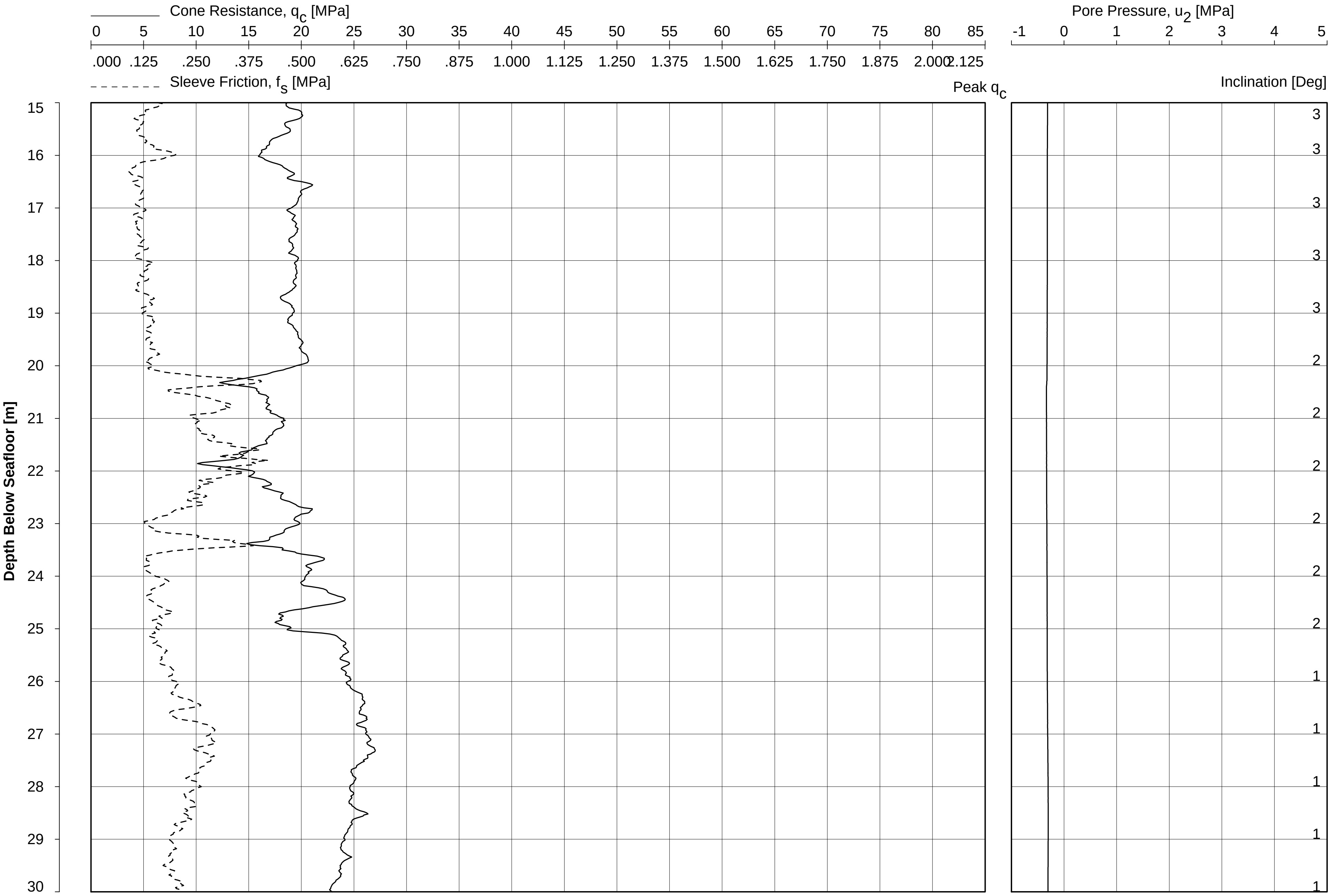
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_16

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



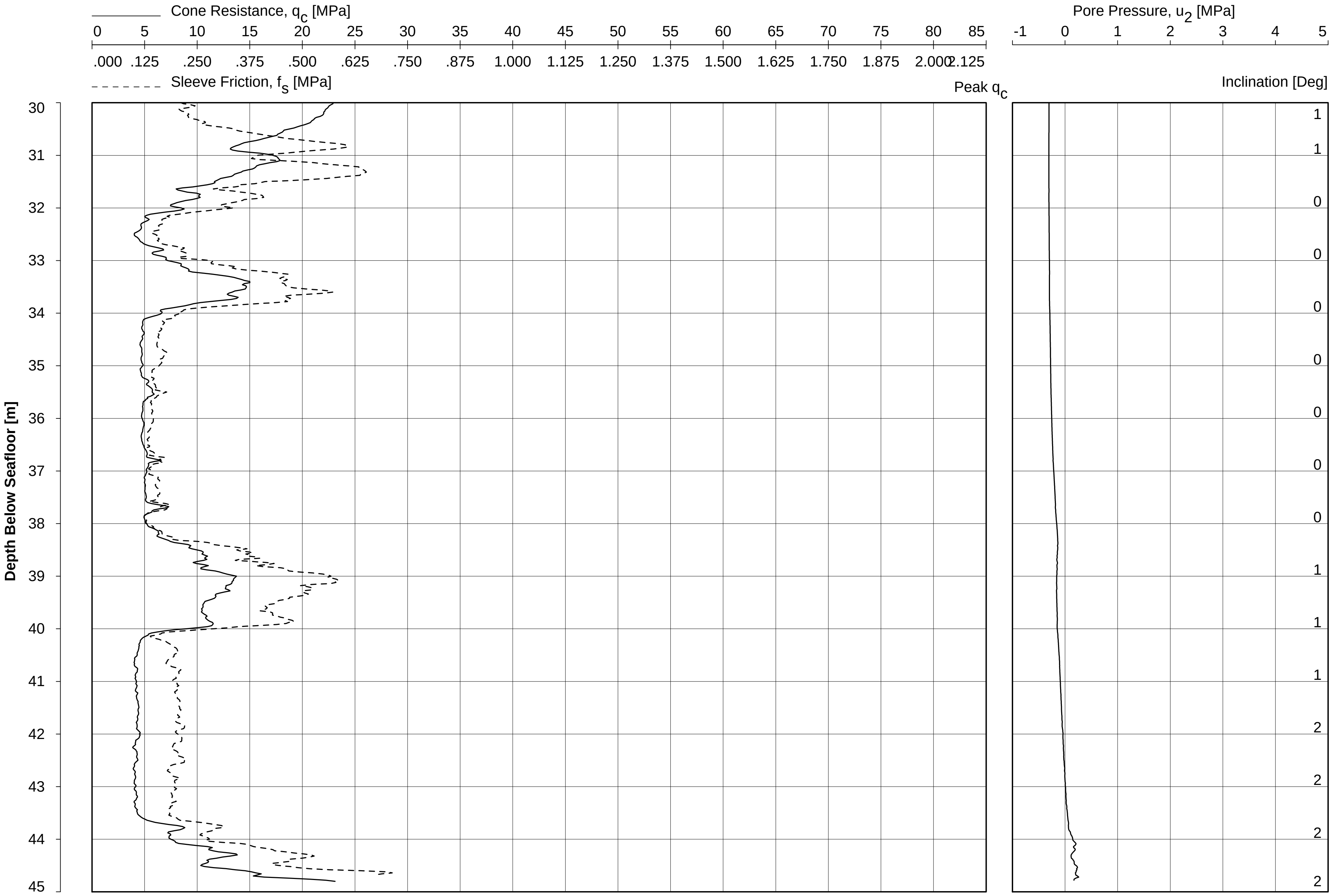
Date Of Testing	: 29-Oct-2015		Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 30.9		Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E495274	N5727833		

CONE PENETRATION TEST

CPT_WFS3_16

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:36



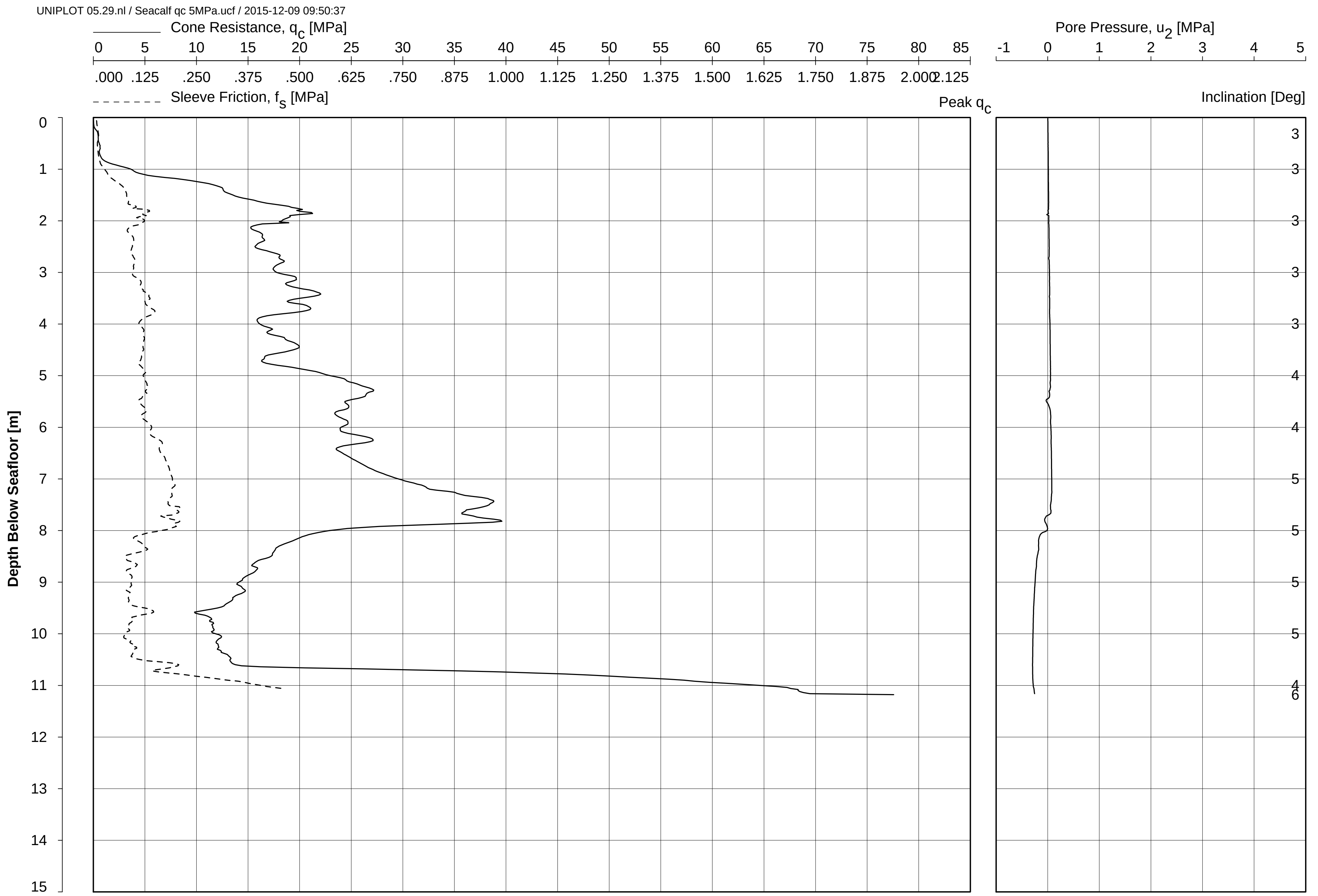
Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E495274 N5727833

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_16

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.1
Coordinates [m] : E497485 N5728646

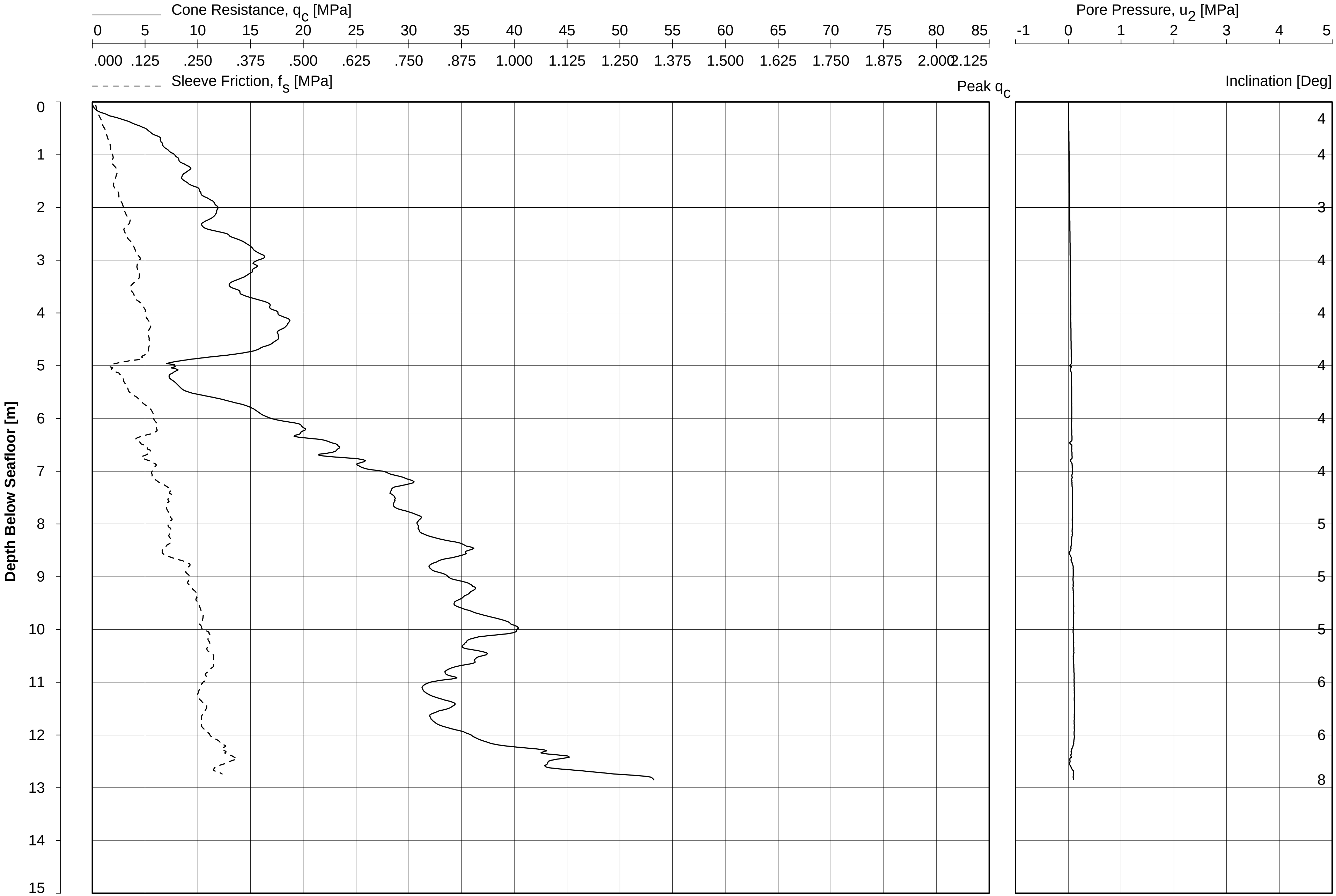
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_17

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:37



Date Of Testing : 28-Oct-2015
Water Depth [m] : 29.1
Coordinates [m] : E494599 N5724469

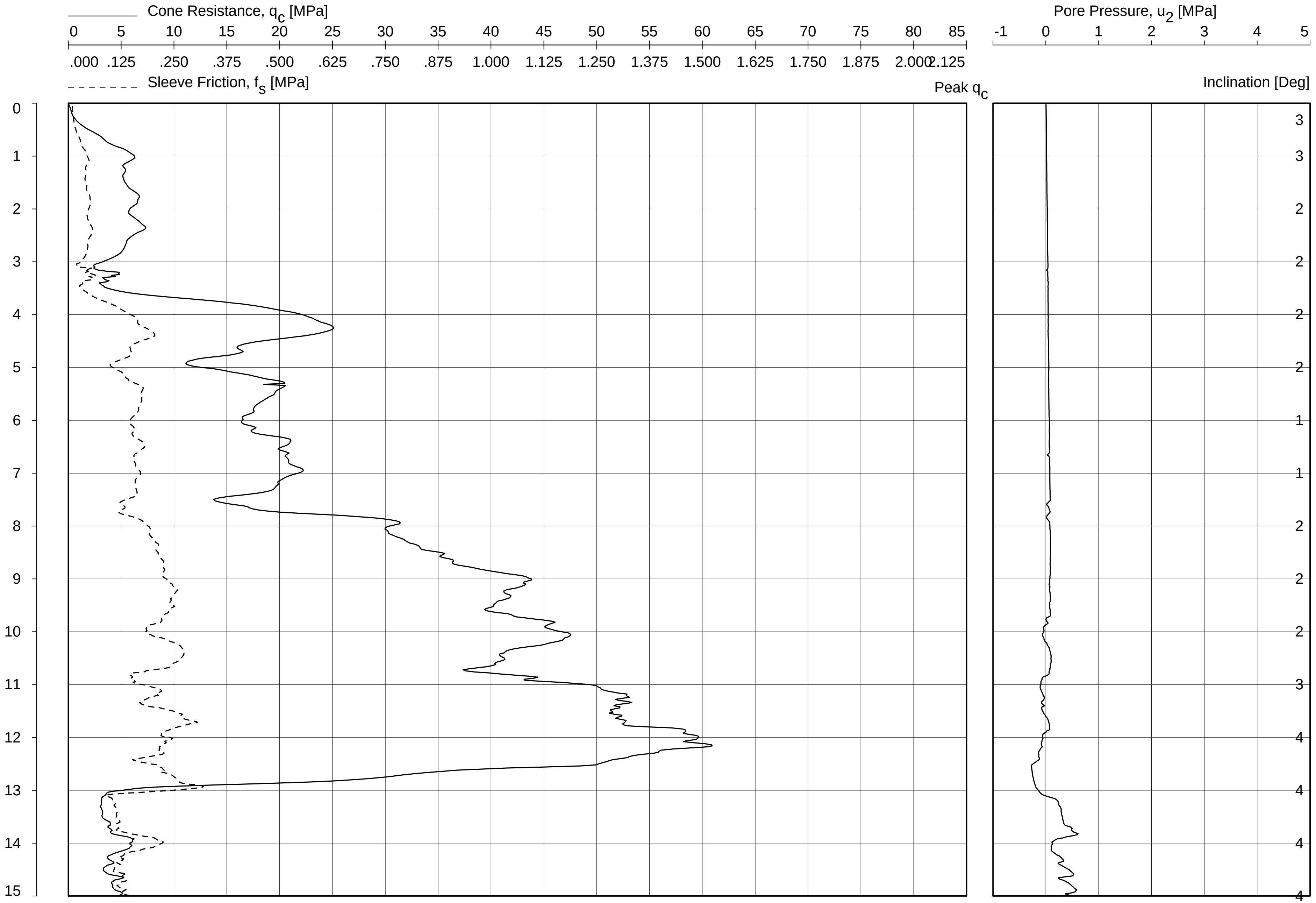
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_18

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:37



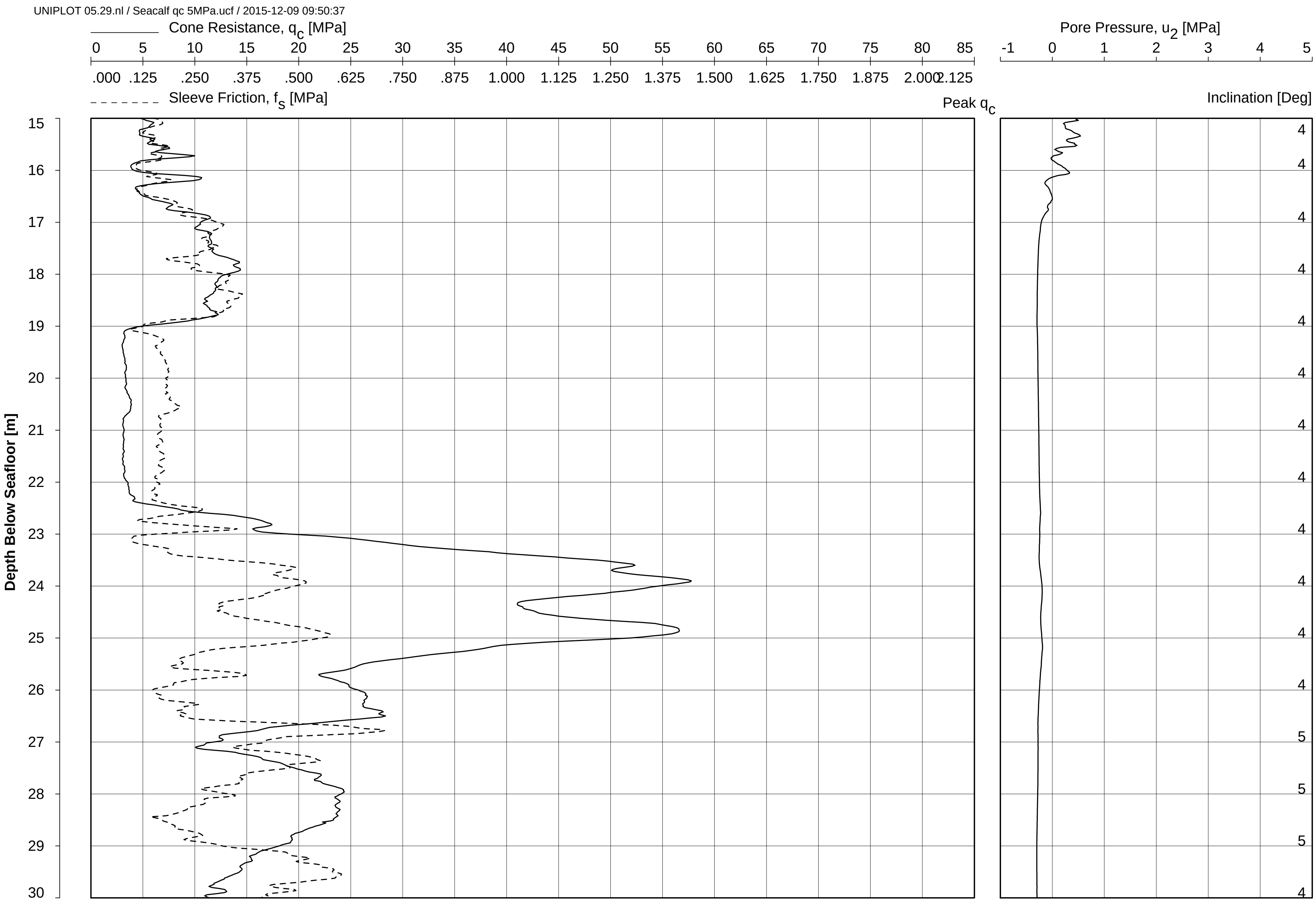
Date Of Testing : 28-Oct-2015
Water Depth [m] : 30.2
Coordinates [m] : E492527 N5725094

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_19

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 28-Oct-2015
Water Depth [m] : 30.2
Coordinates [m] : E492527 N5725094

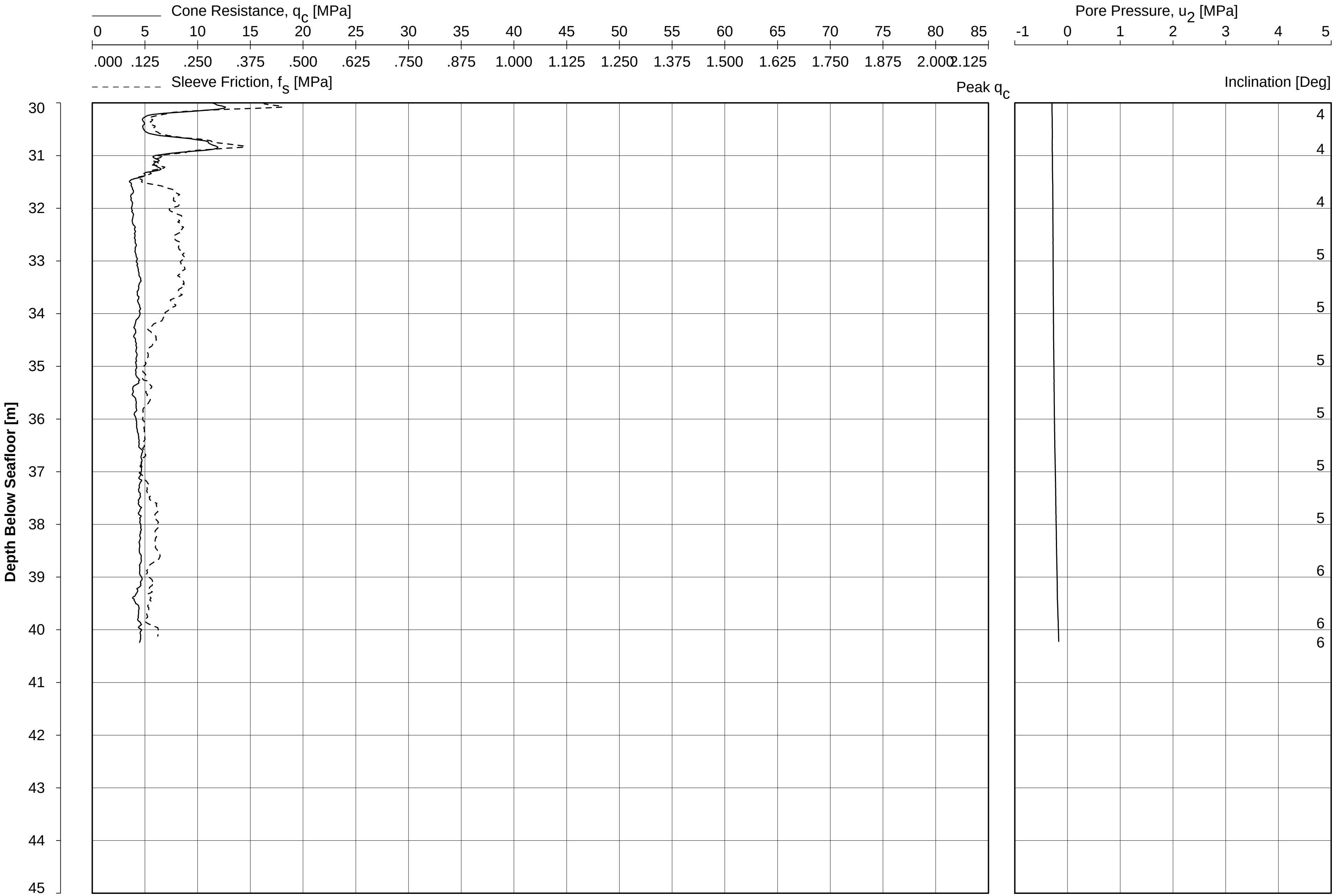
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_19

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:37



Date Of Testing : 28-Oct-2015
Water Depth [m] : 30.2
Coordinates [m] : E492527 N5725094

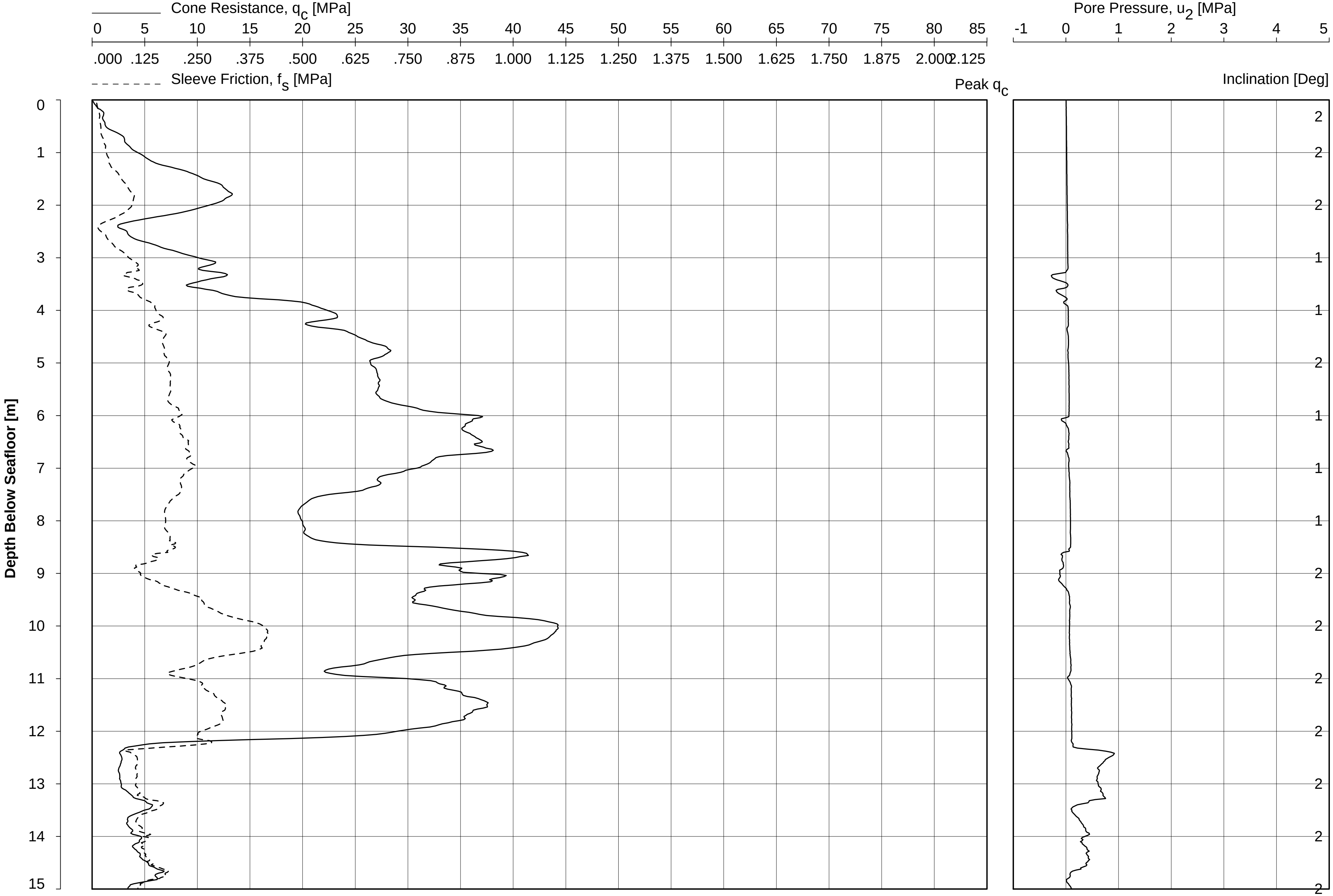
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_19

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:37



Date Of Testing : 28-Oct-2015
Water Depth [m] : 31.1
Coordinates [m] : E493397 N5724254

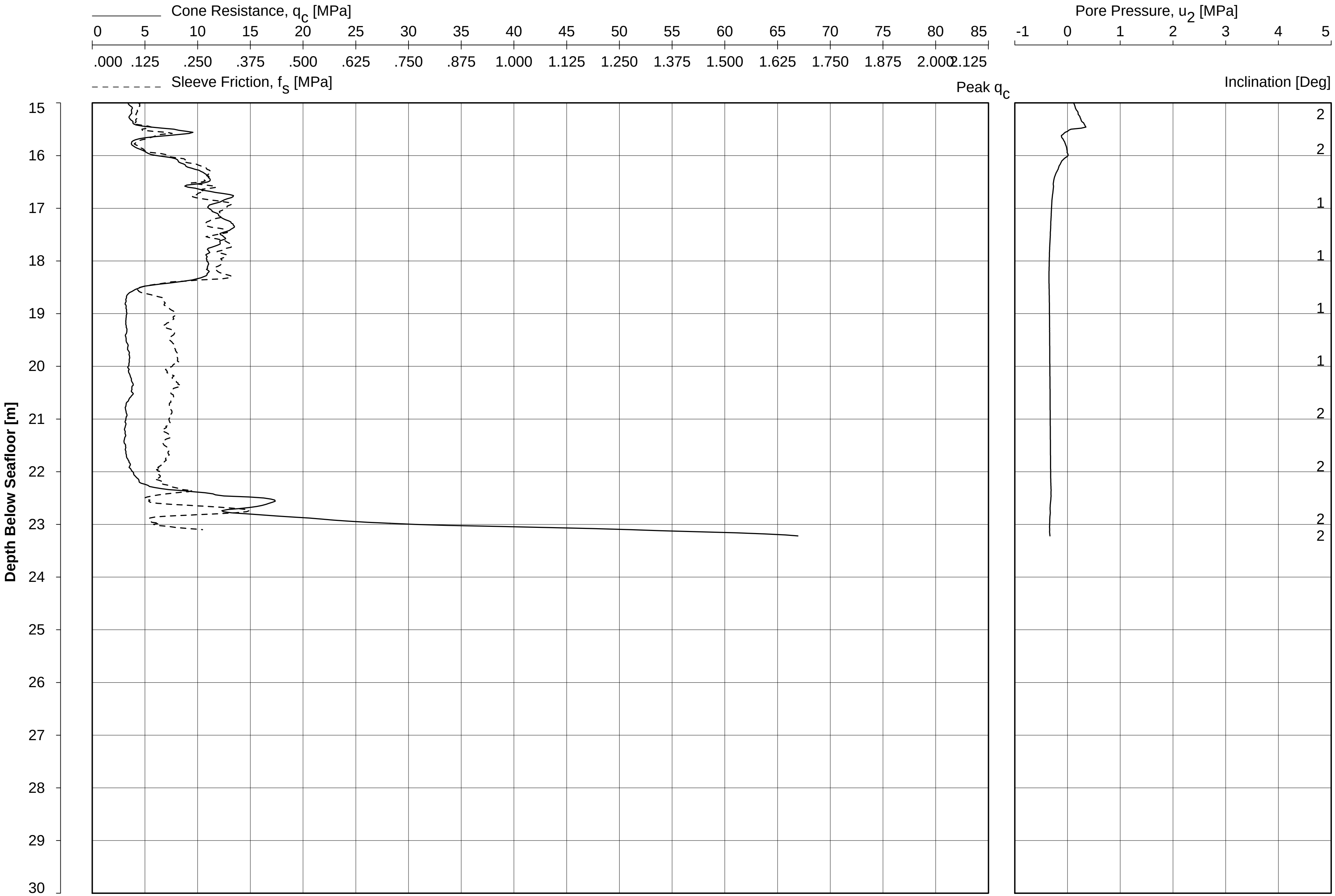
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_20

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:37



Date Of Testing : 28-Oct-2015
Water Depth [m] : 31.1
Coordinates [m] : E493397 N5724254

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_20

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

Fugro Report No. N6083/02 (2)

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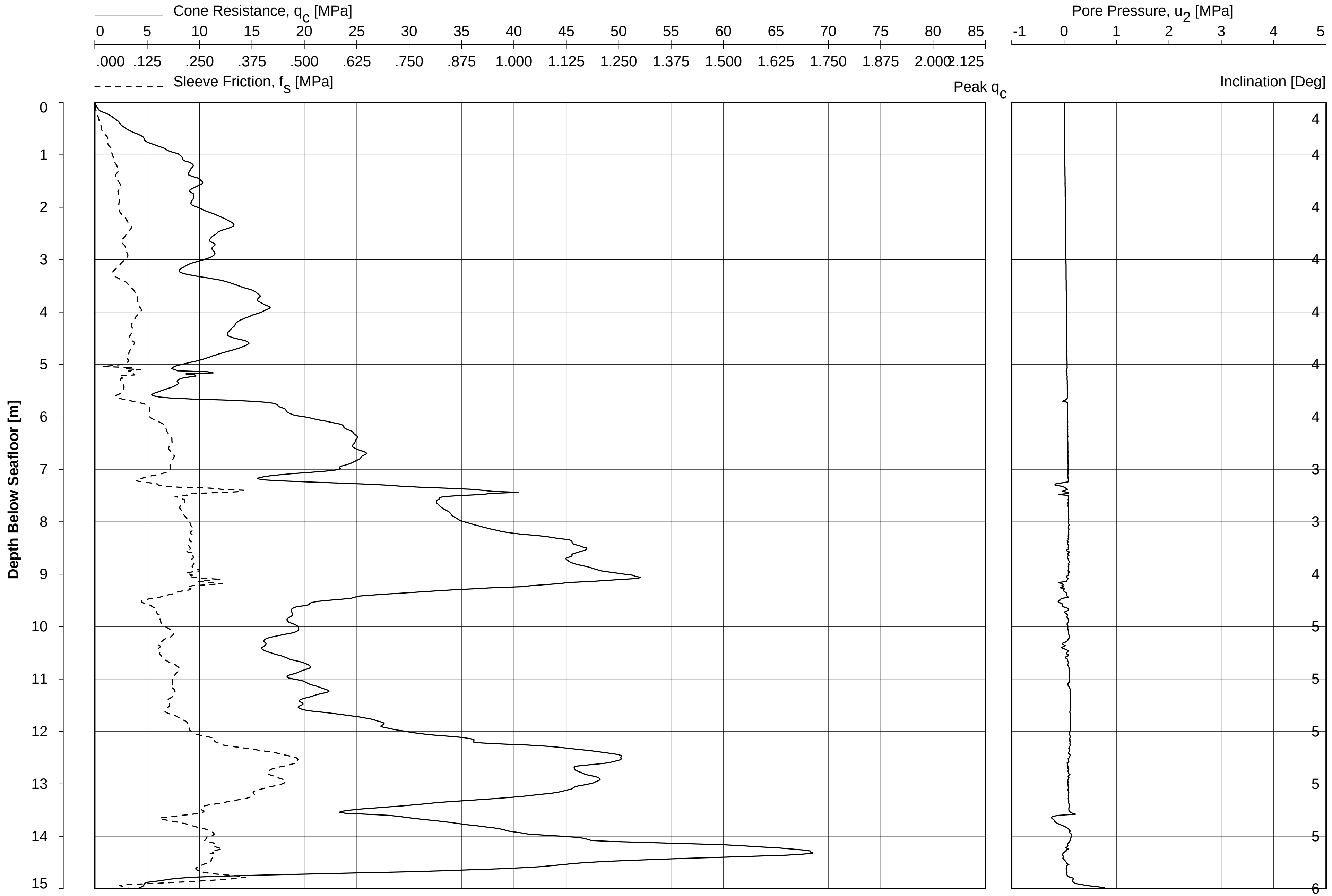


Date Of Testing	: 28-Oct-2015	Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 29.9	Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E494845 N5722865		

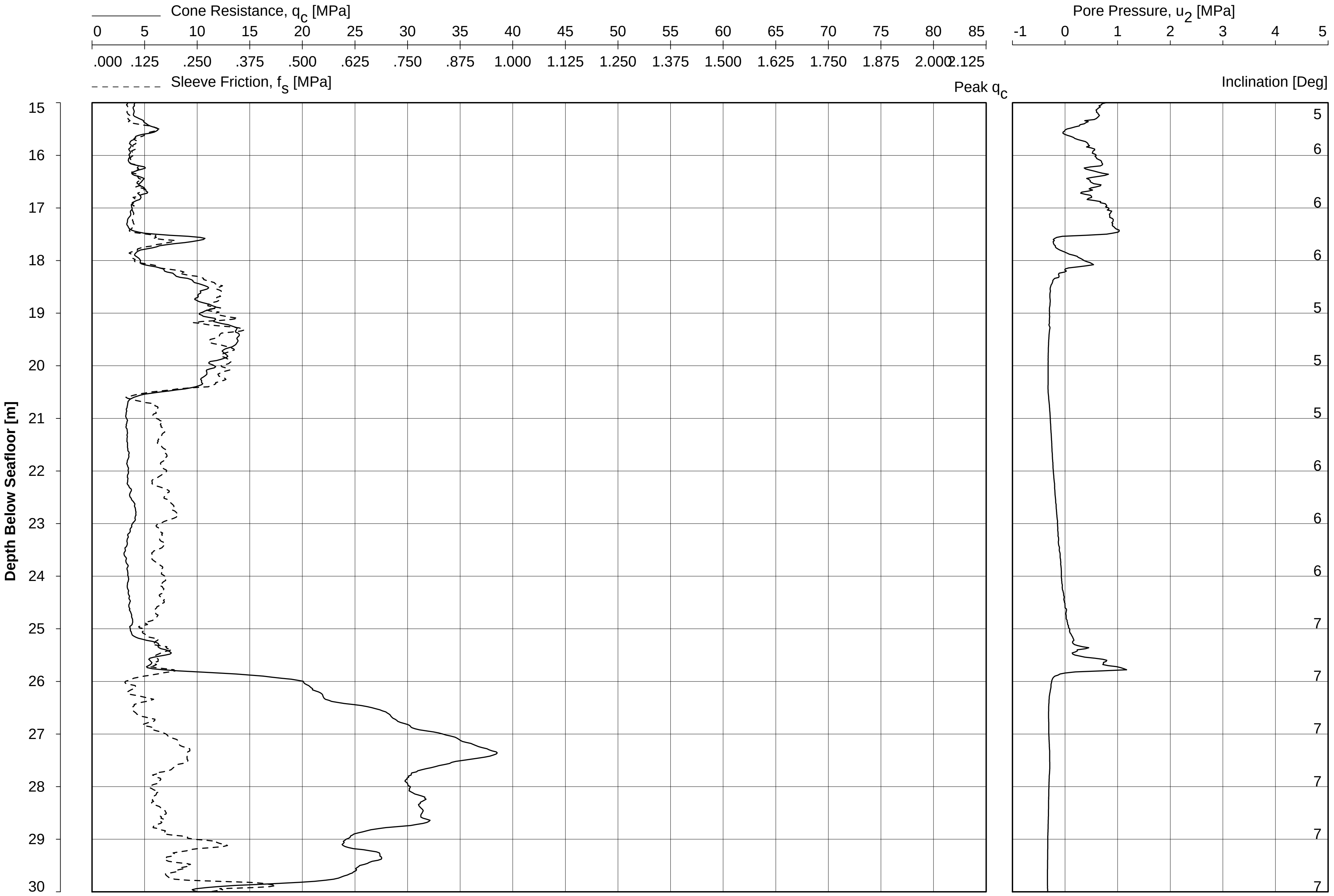
CONE PENETRATION TEST

CPT_WFS3_21

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:37



Date Of Testing : 28-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E494845 N5722865

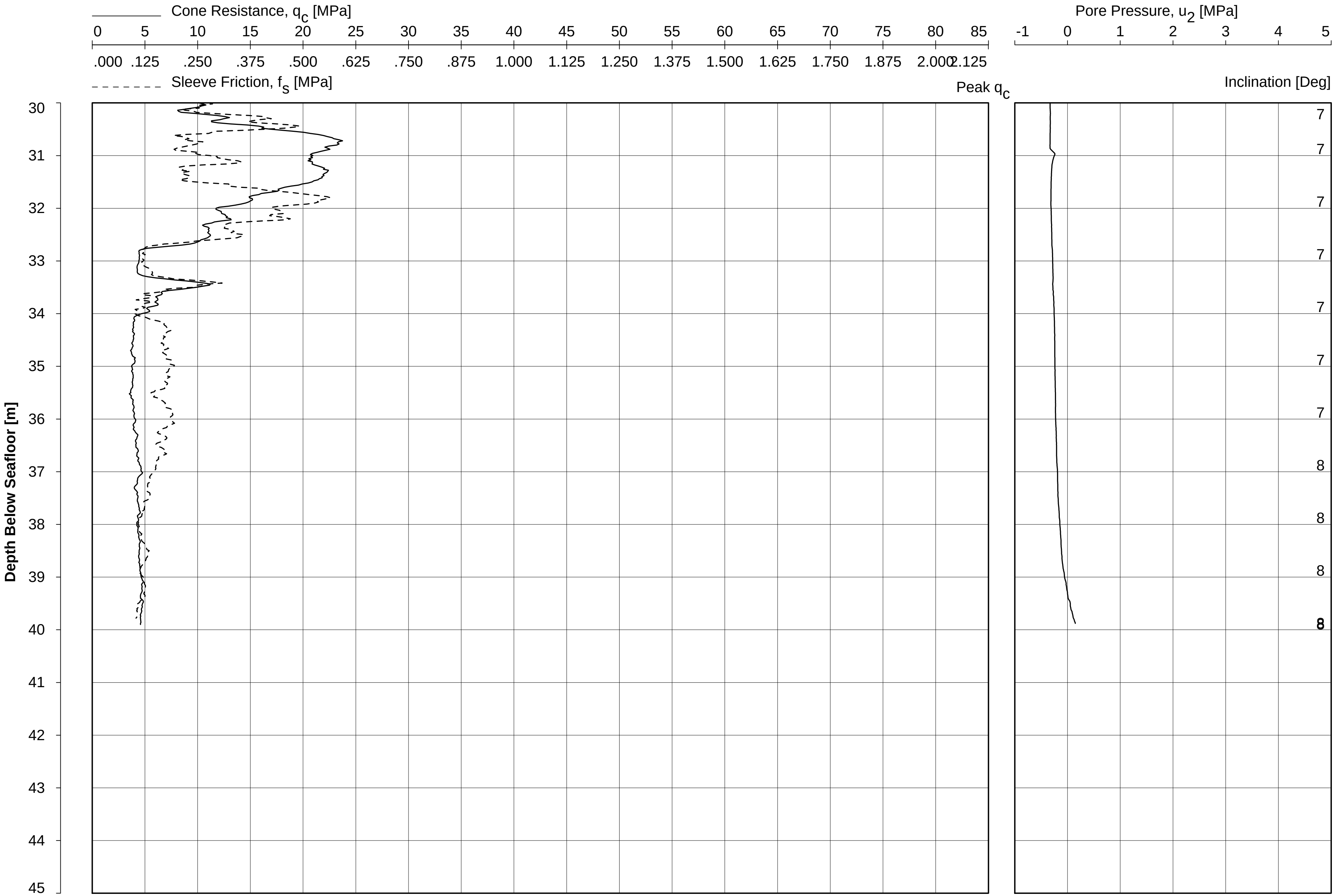
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_21

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:37



Date Of Testing : 28-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E494845 N5722865

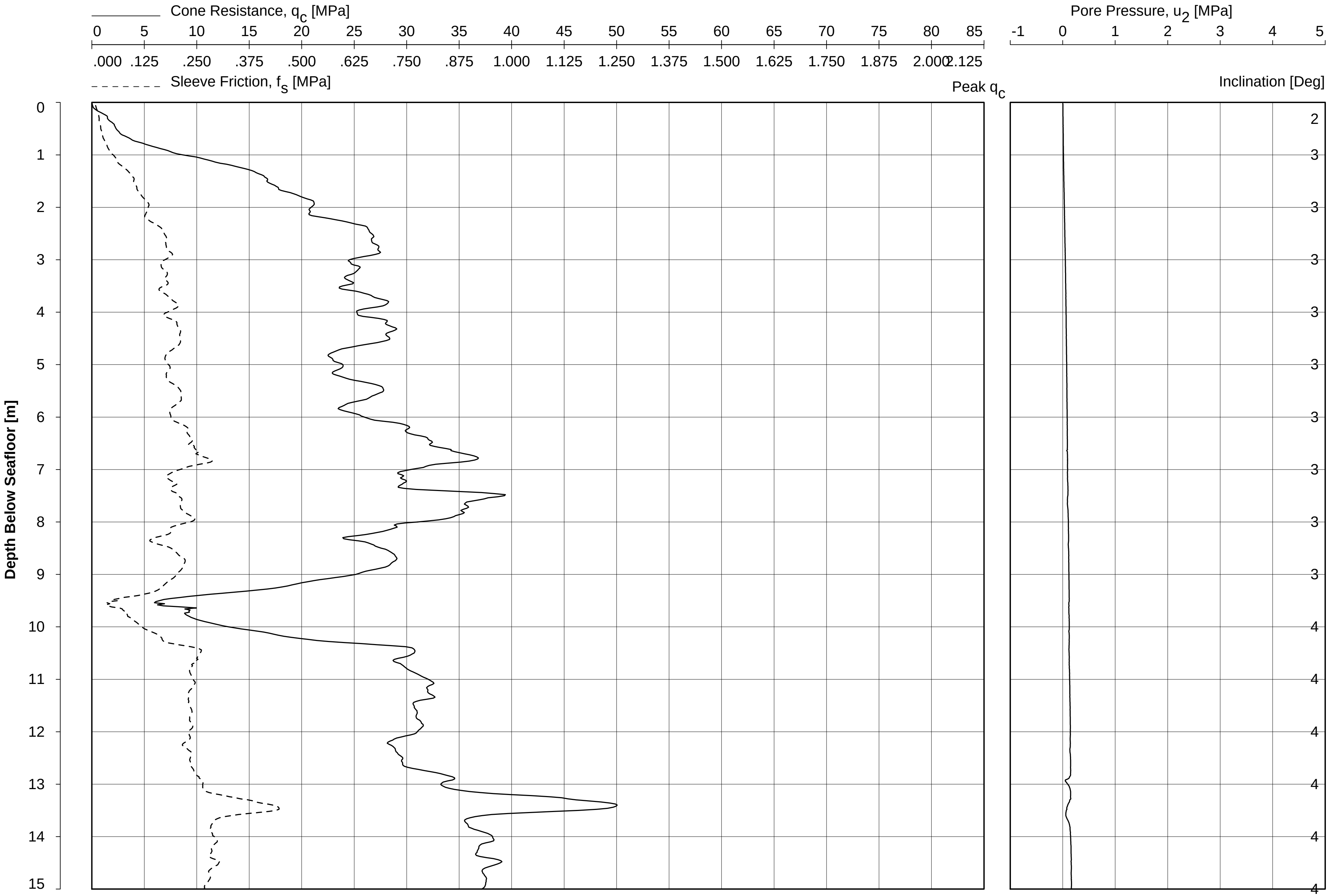
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_21

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:37



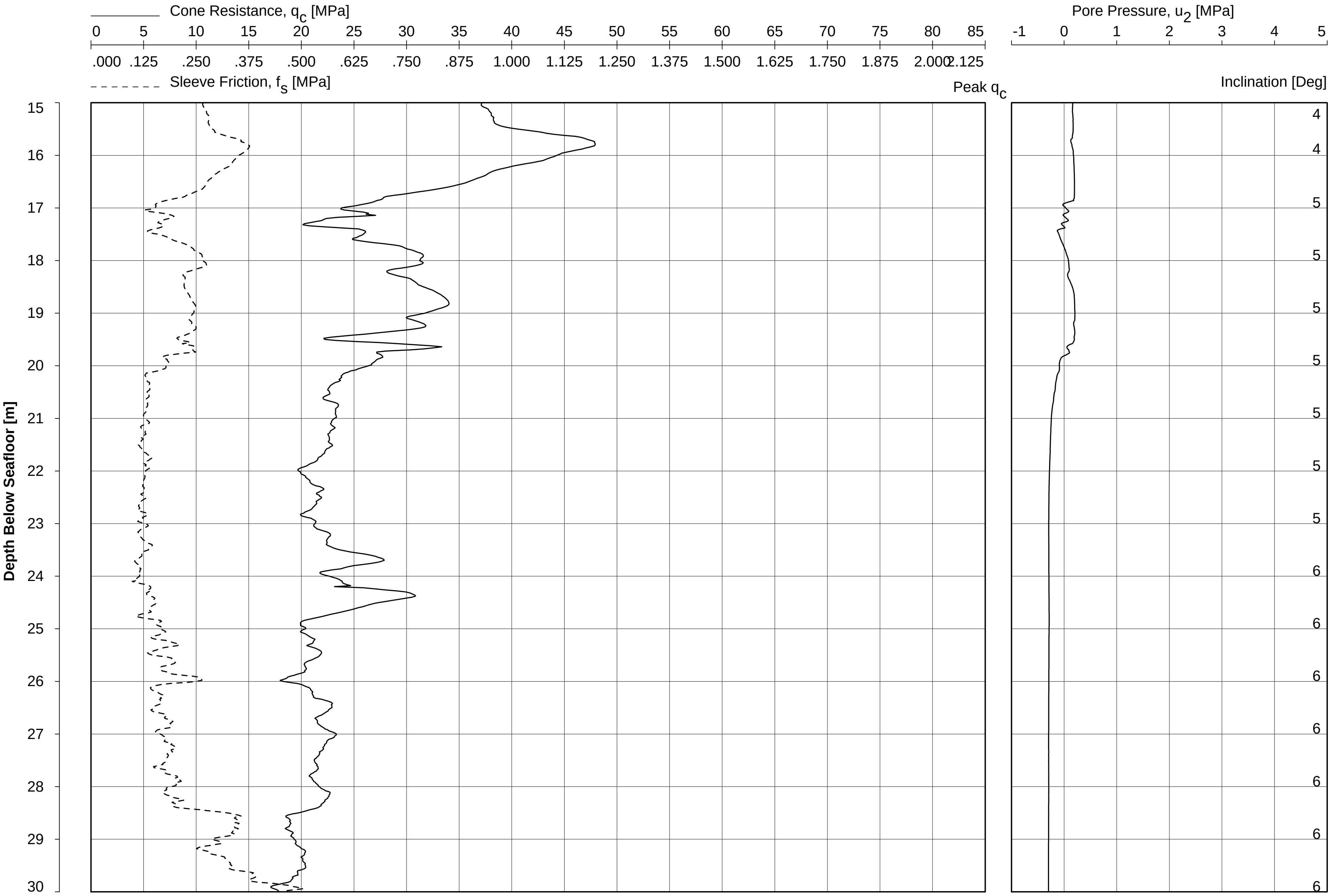
Date Of Testing	: 26-Oct-2015		Probe Type	: CP15-CF75PB30SN2
Water Depth [m]	: 22.0		Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E498189	N5723807		

CONE PENETRATION TEST

CPT_WFS3_22

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:37



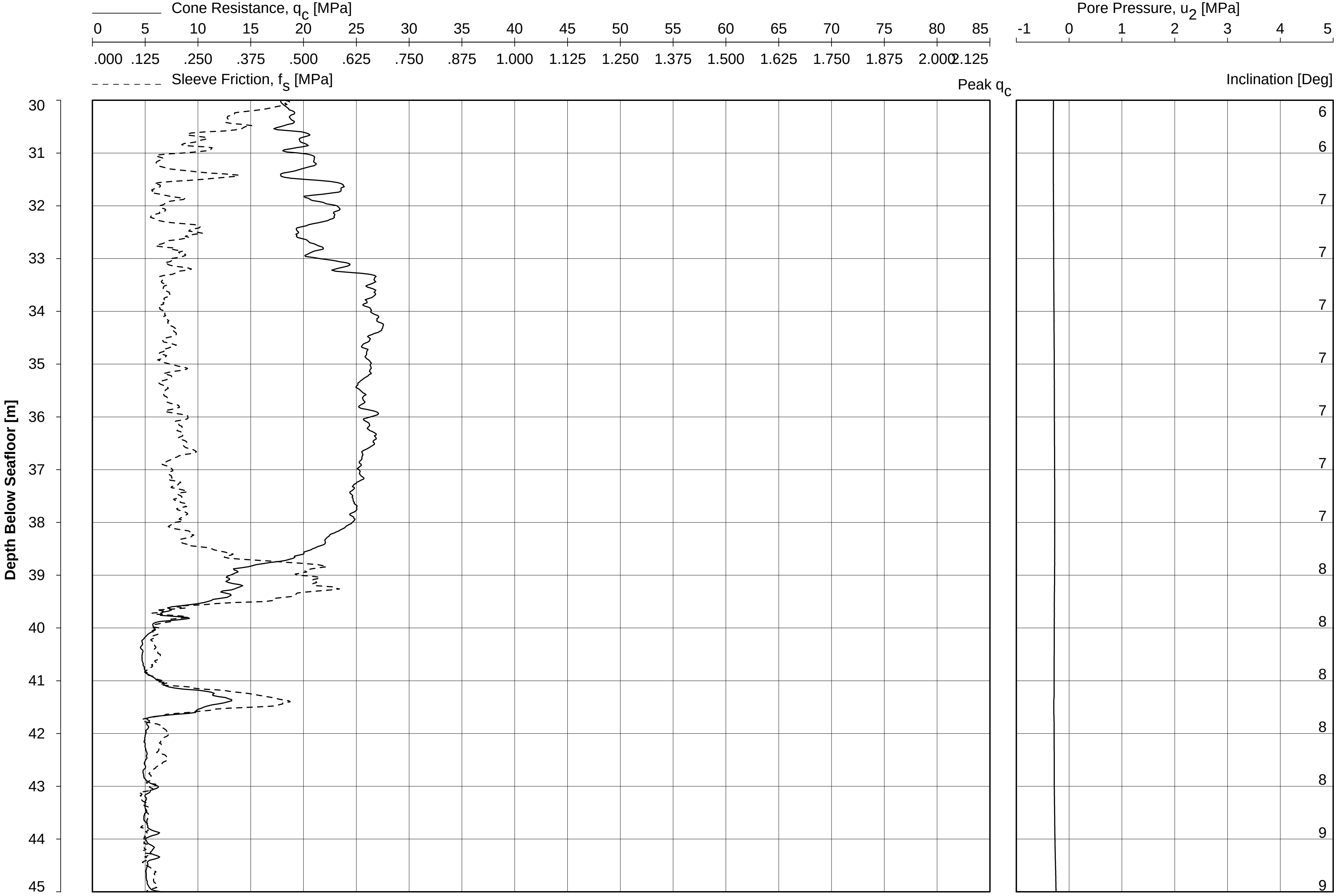
Date Of Testing	: 26-Oct-2015
Water Depth [m]	: 22.0
Coordinates [m]	: E498189 N5723807
Probe Type	: CP15-CF75PB30SN2
Cone Base Area [mm^2]	: 1510

CONE PENETRATION TEST

CPT_WFS3_22

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:37



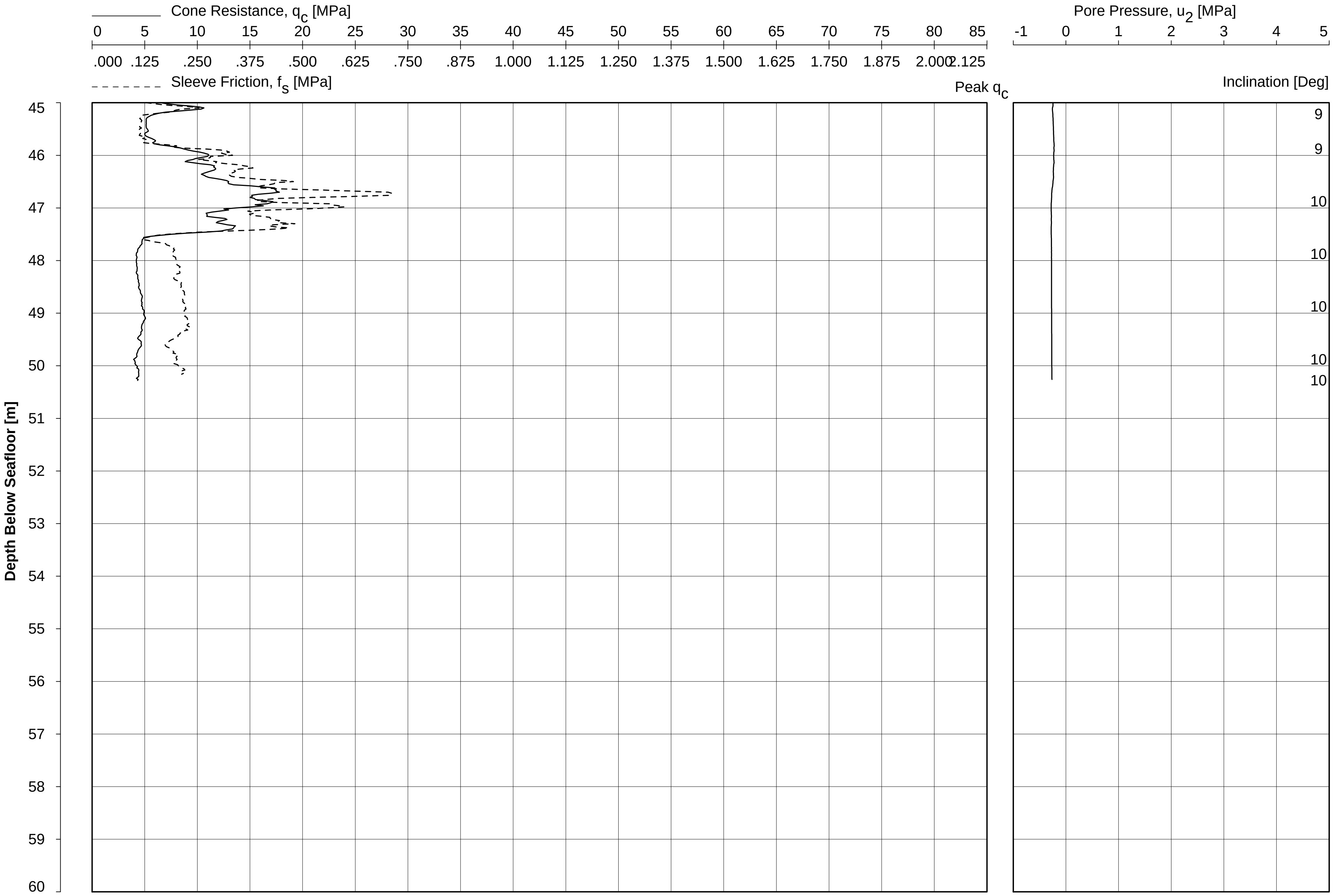
Date Of Testing	: 26-Oct-2015	Probe Type	: CP15-CF75PB30SN2	
Water Depth [m]	: 22.0	Cone Base Area [mm^2]	: 1510	
Coordinates [m]	: E498189	N5723807		

CONE PENETRATION TEST

CPT_WFS3_22

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:37



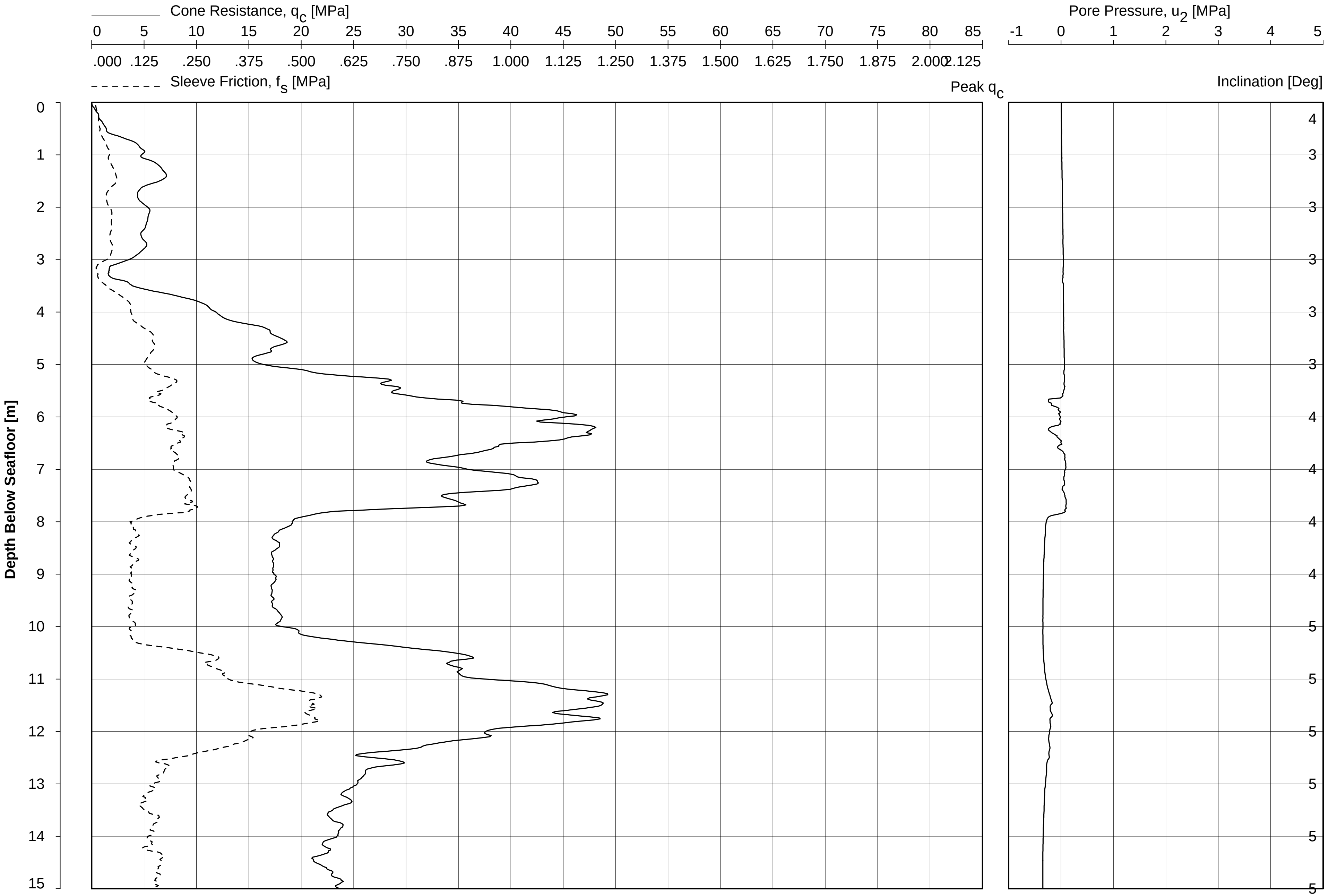
Date Of Testing	: 26-Oct-2015	Probe Type	: CP15-CF75PB30SN2
Water Depth [m]	: 22.0	Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E498189 N5723807		

CONE PENETRATION TEST

CPT_WFS3_22

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:38



Date Of Testing : 27-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E500432 N5720215

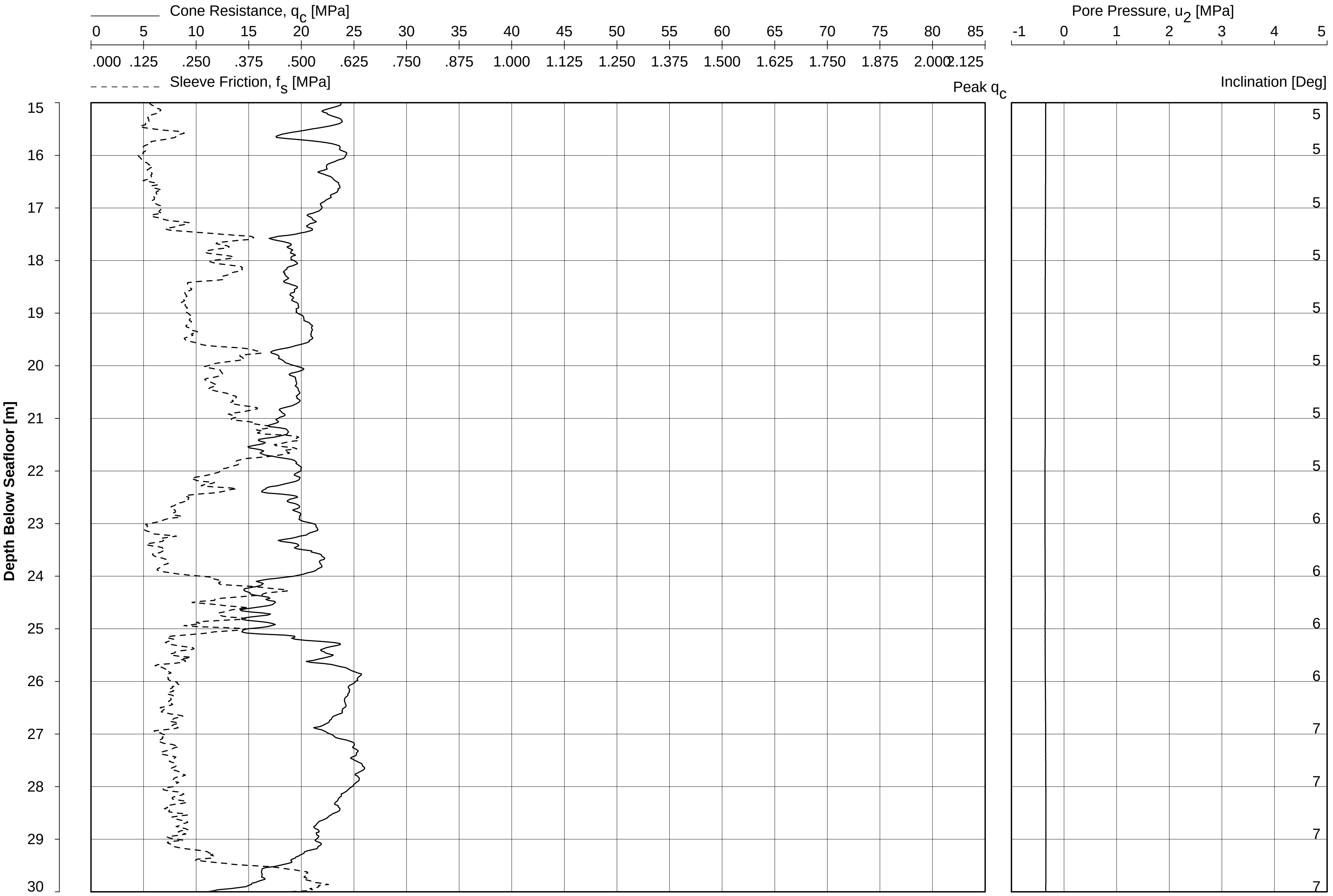
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_23

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:38



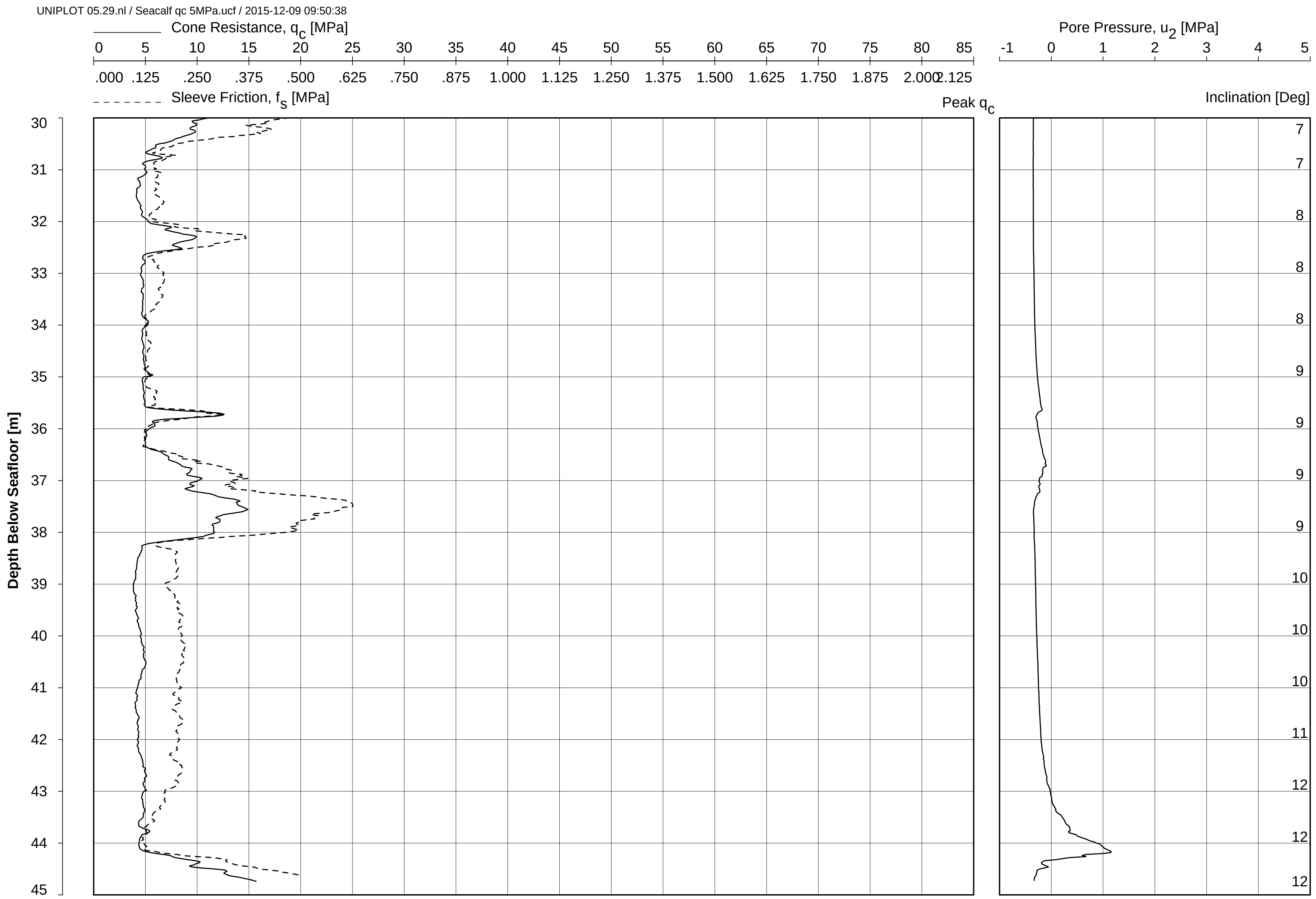
Date Of Testing : 27-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E500432 N5720215

Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_23

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 27-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E500432 N5720215

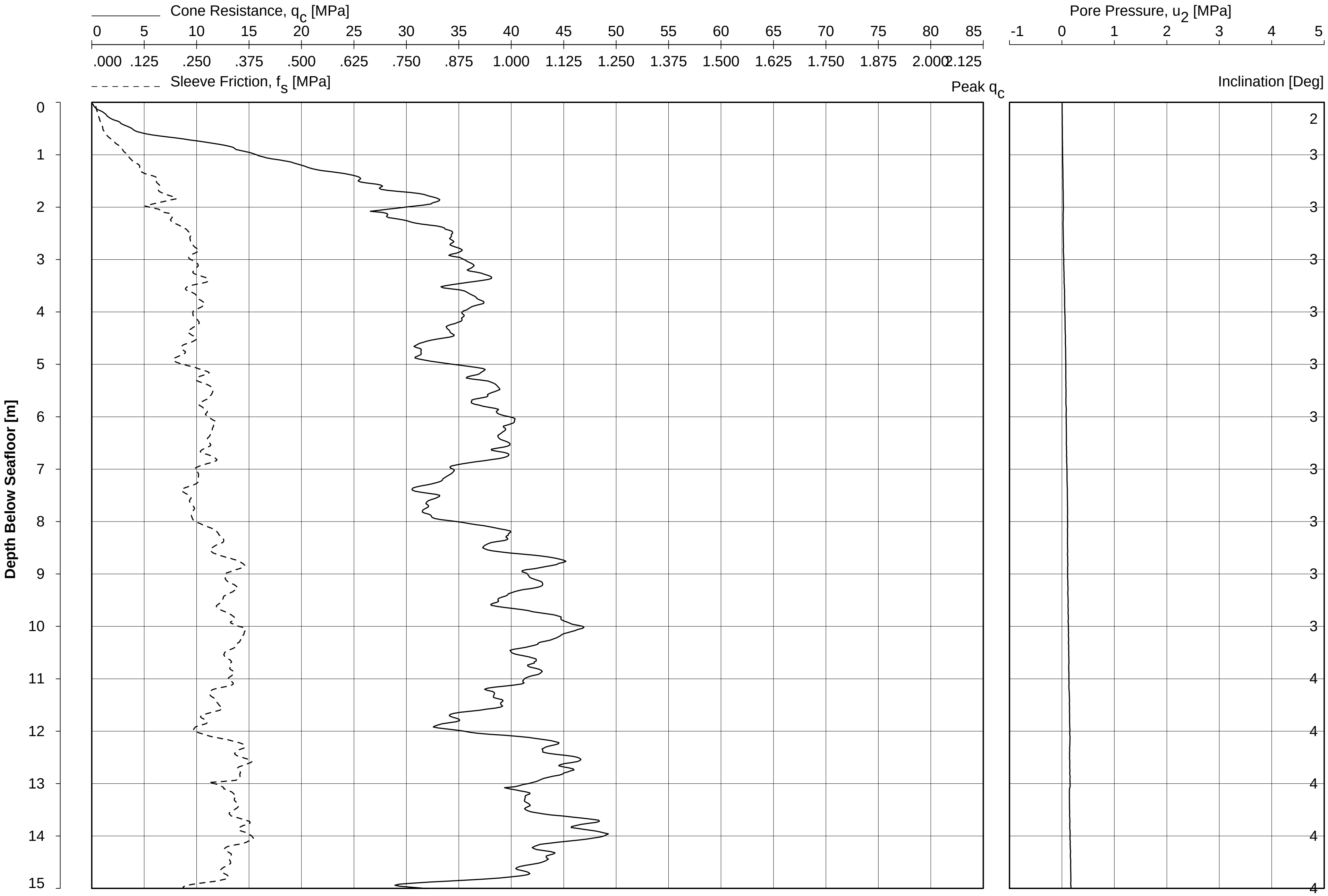
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_23

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:38



Date Of Testing : 26-Oct-2015
Water Depth [m] : 17.5
Coordinates [m] : E499134 N5724964

Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

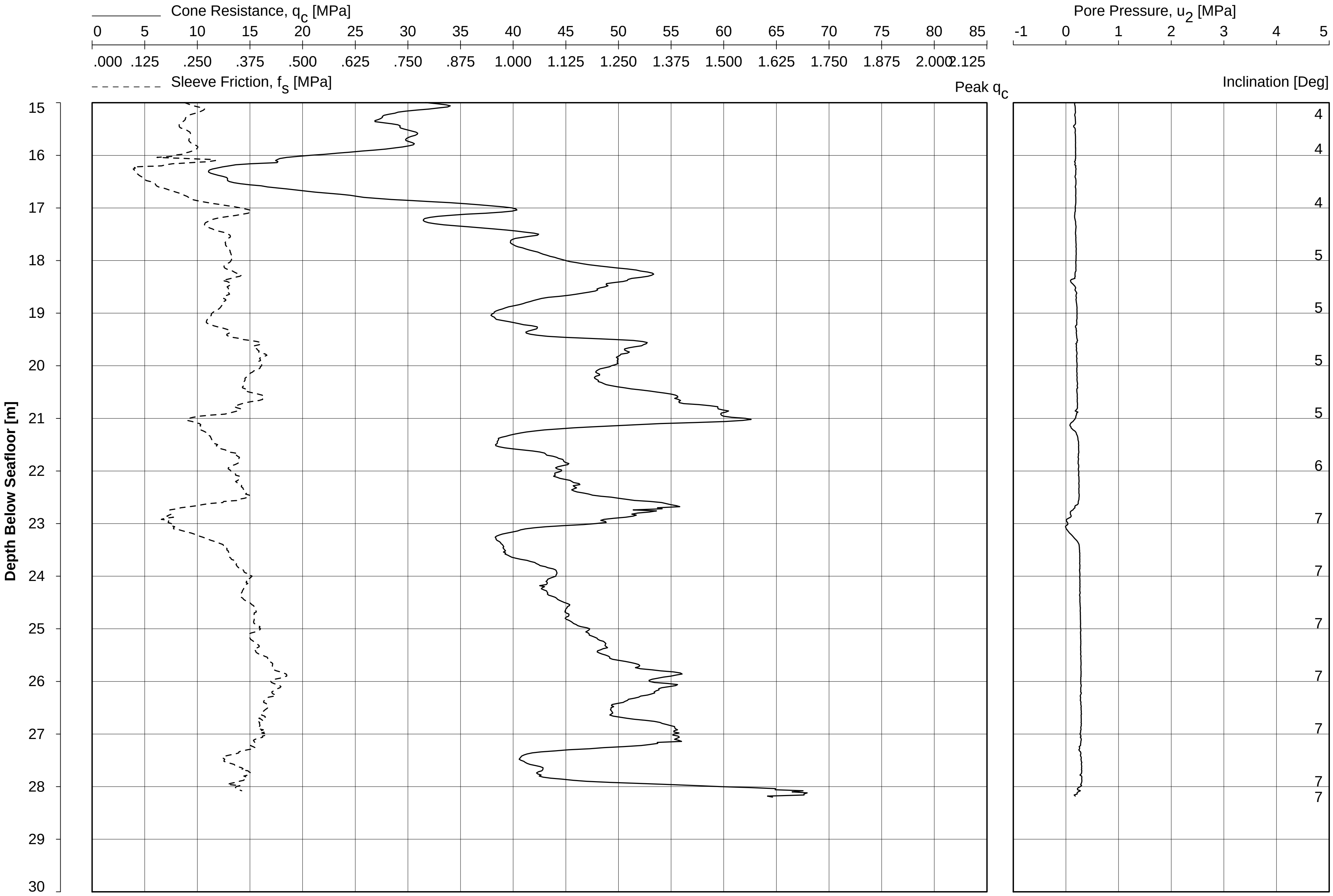
CONE PENETRATION TEST

CPT_WFS3_24

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:38



Date Of Testing : 26-Oct-2015
Water Depth [m] : 17.5
Coordinates [m] : E499134 N5724964

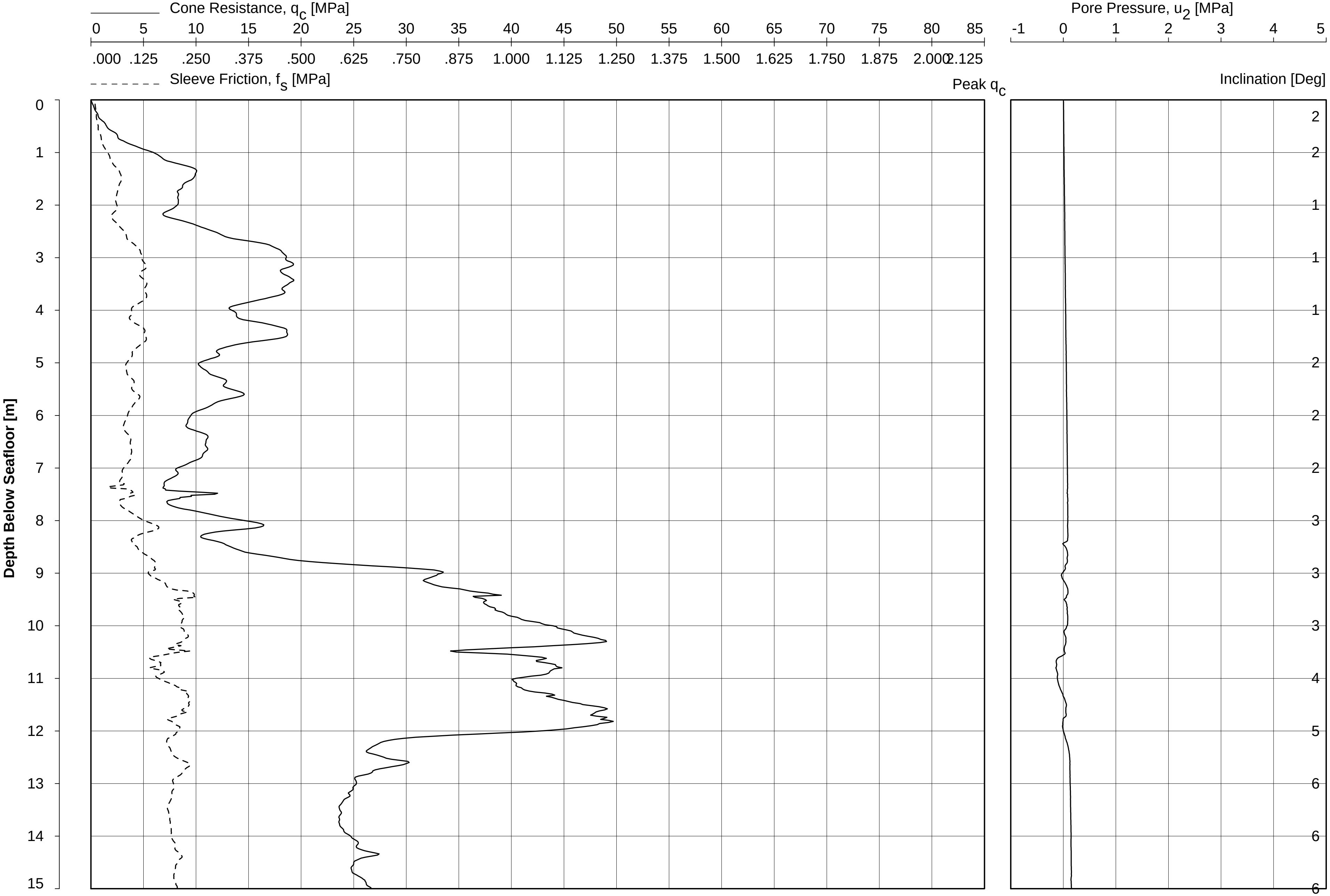
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_24

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:38



Date Of Testing : 31-Oct-2015
Water Depth [m] : 29.2
Coordinates [m] : E500748 N5727579

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

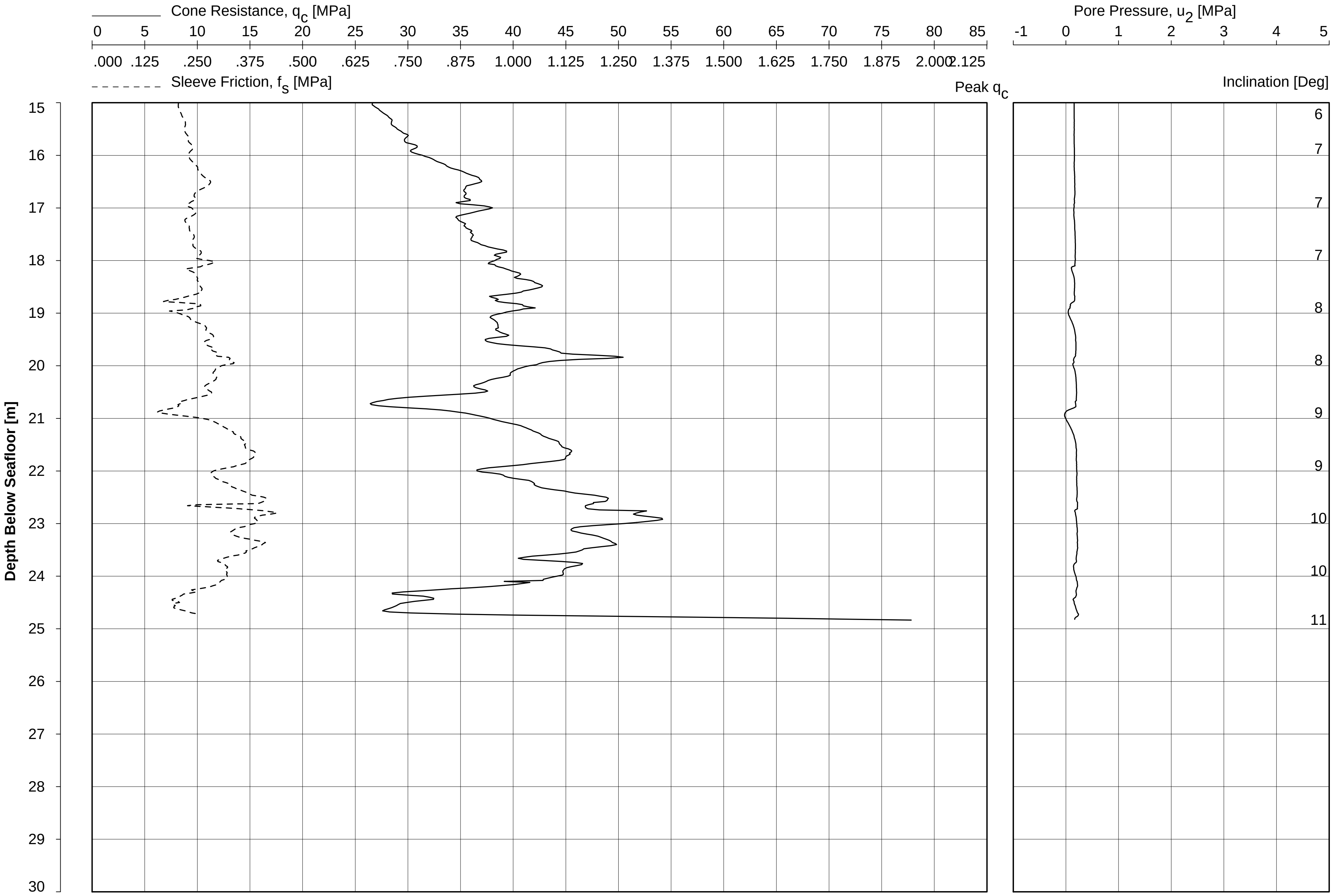
CONE PENETRATION TEST

CPT_WFS3_25

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:38



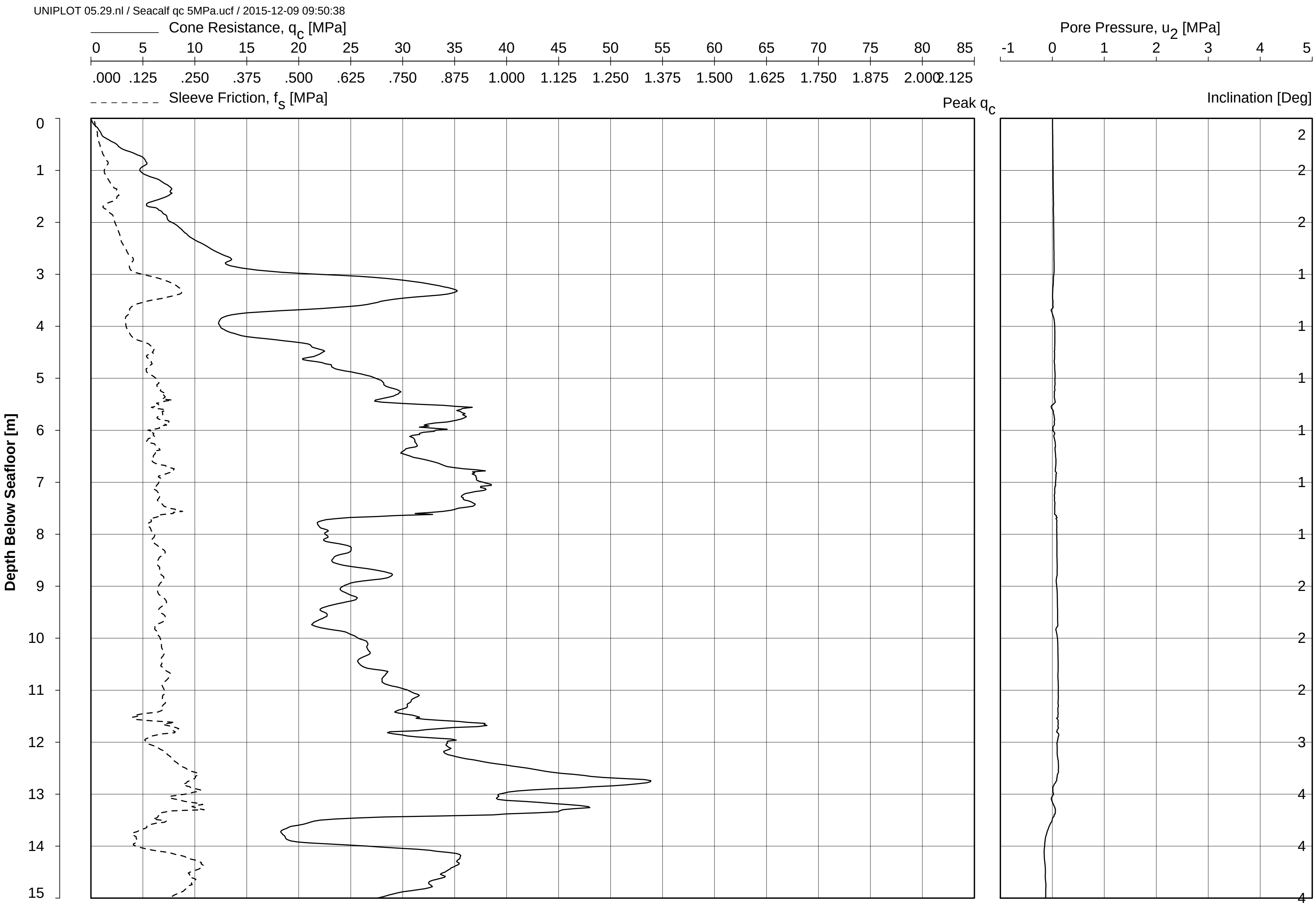
Date Of Testing : 31-Oct-2015
Water Depth [m] : 29.2
Coordinates [m] : E500748 N5727579

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_25

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 31-Oct-2015
Water Depth [m] : 28.9
Coordinates [m] : E497701 N5729827

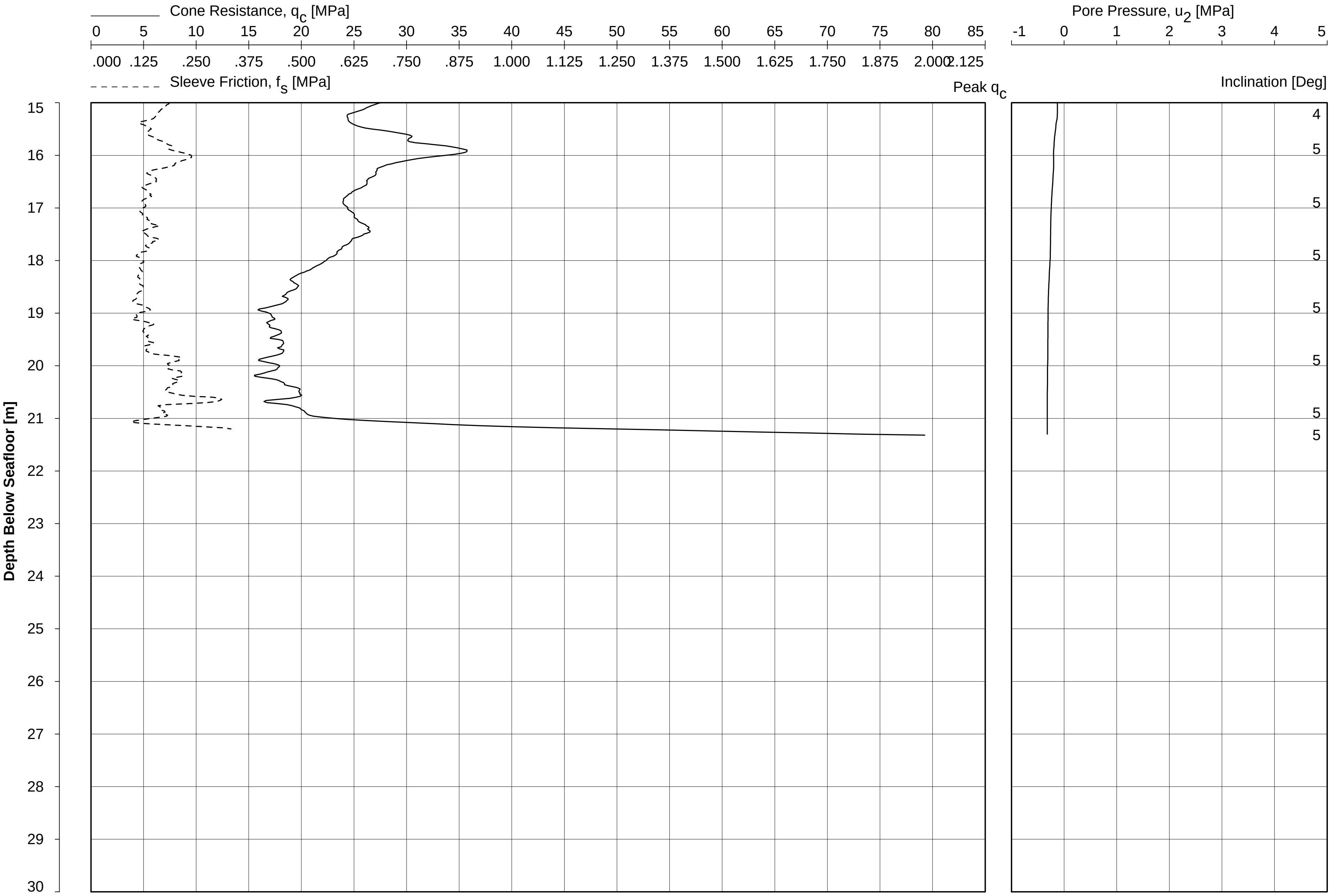
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_26

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:38



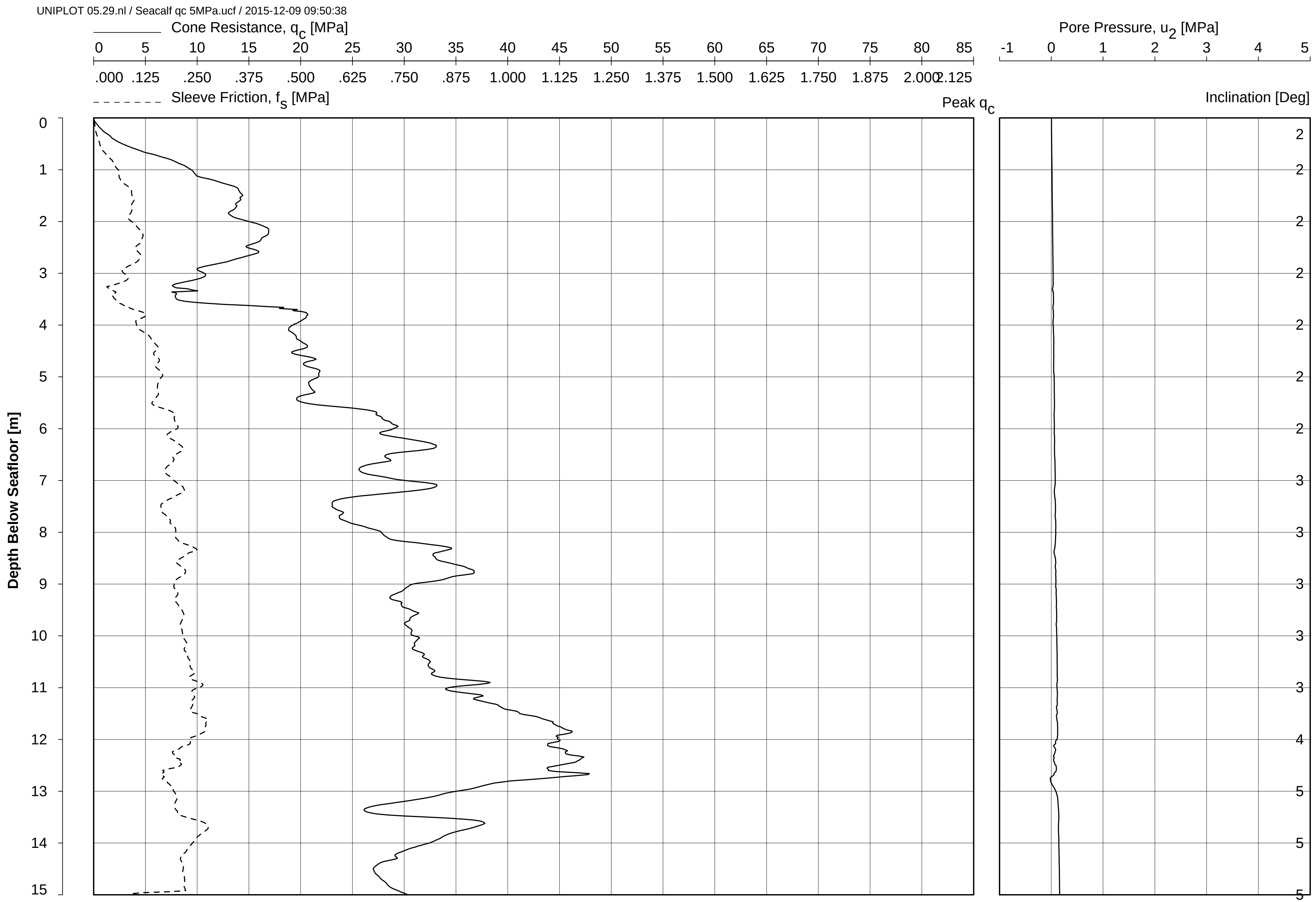
Date Of Testing : 31-Oct-2015
Water Depth [m] : 28.9
Coordinates [m] : E497701 N5729827

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_26

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 31-Oct-2015
Water Depth [m] : 24.8
Coordinates [m] : E501862 N5725796

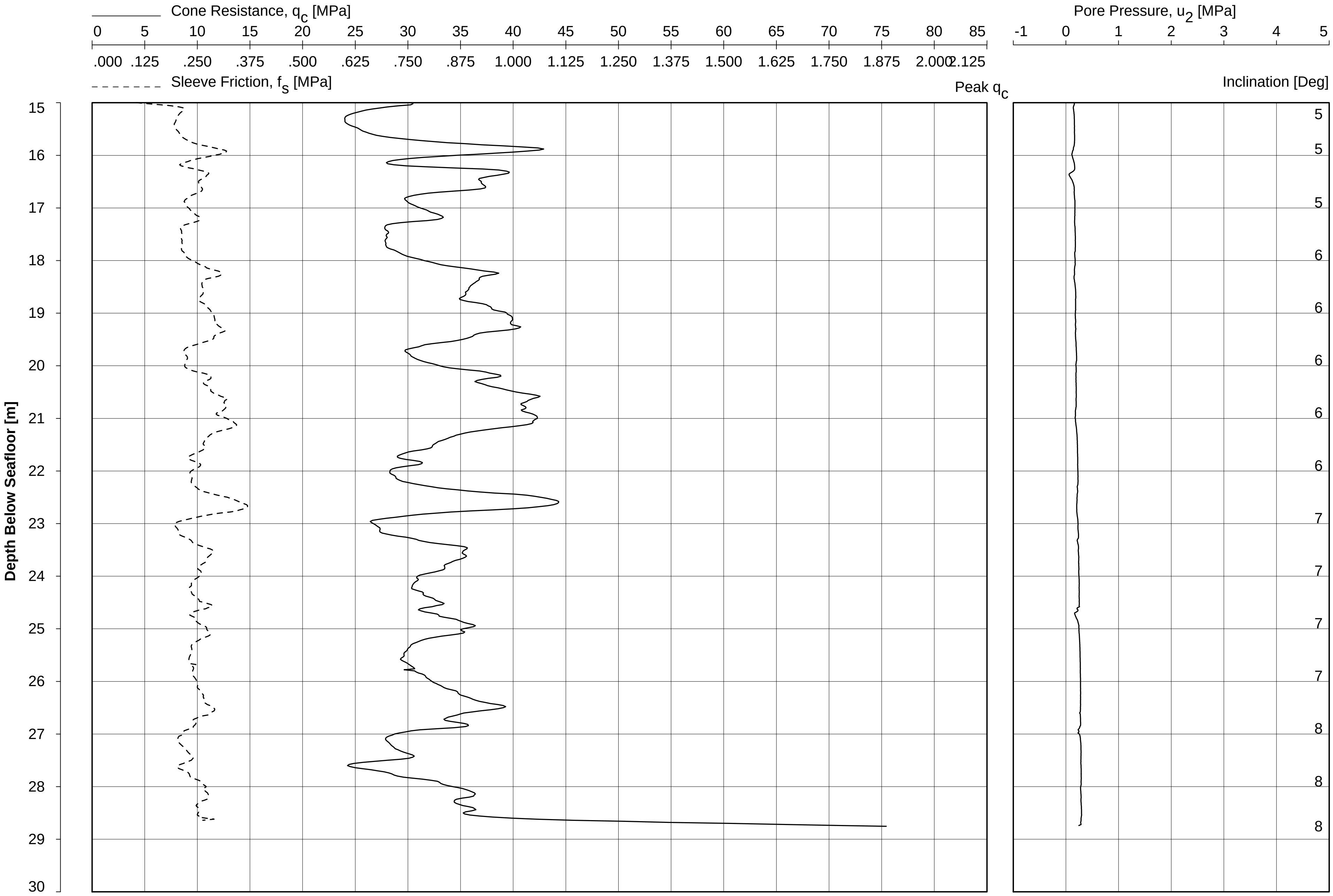
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_27

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qc 5MPa.ucf / 2015-12-09 09:50:38



Date Of Testing : 31-Oct-2015
Water Depth [m] : 24.8
Coordinates [m] : E501862 N5725796

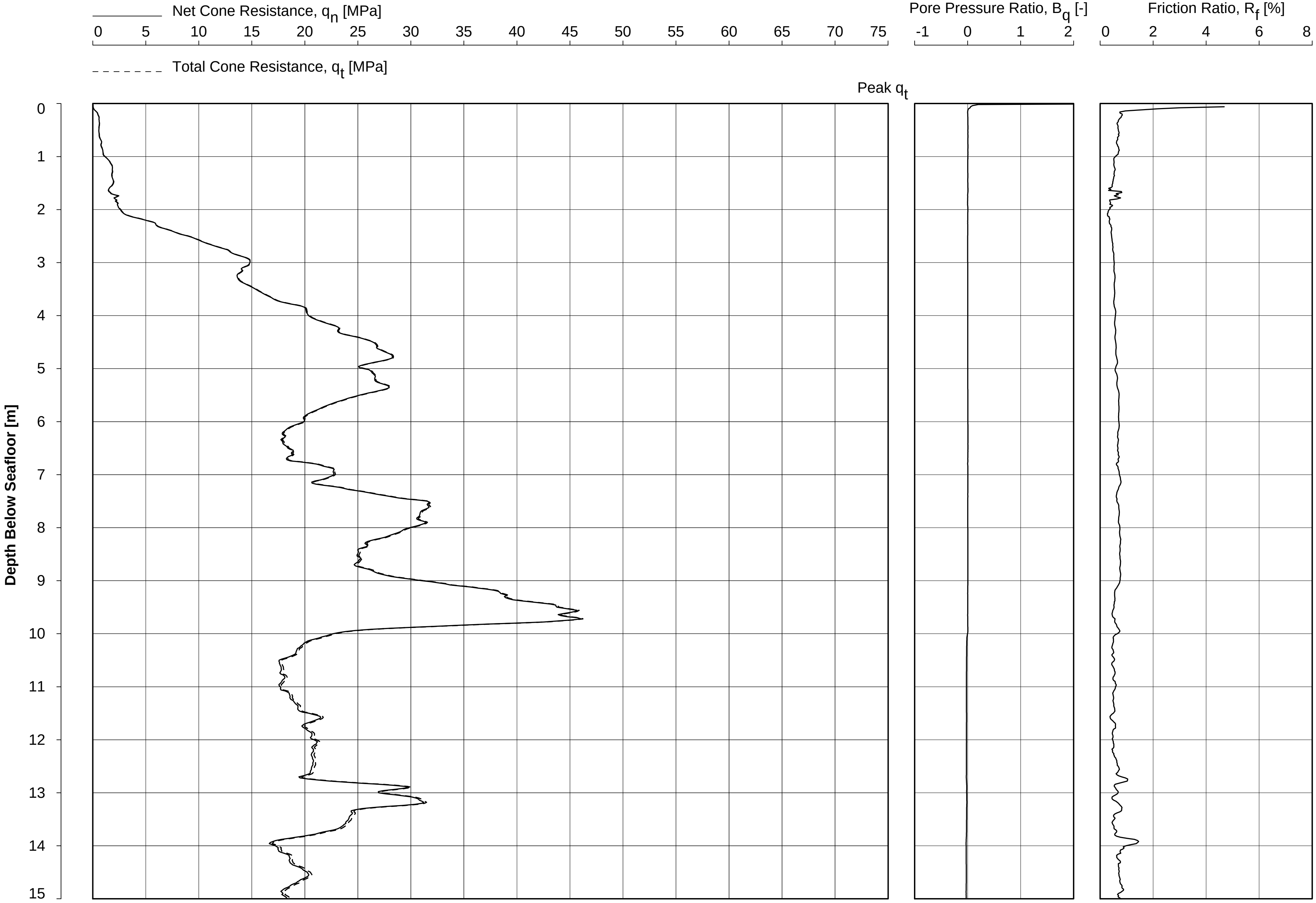
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_27

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:19



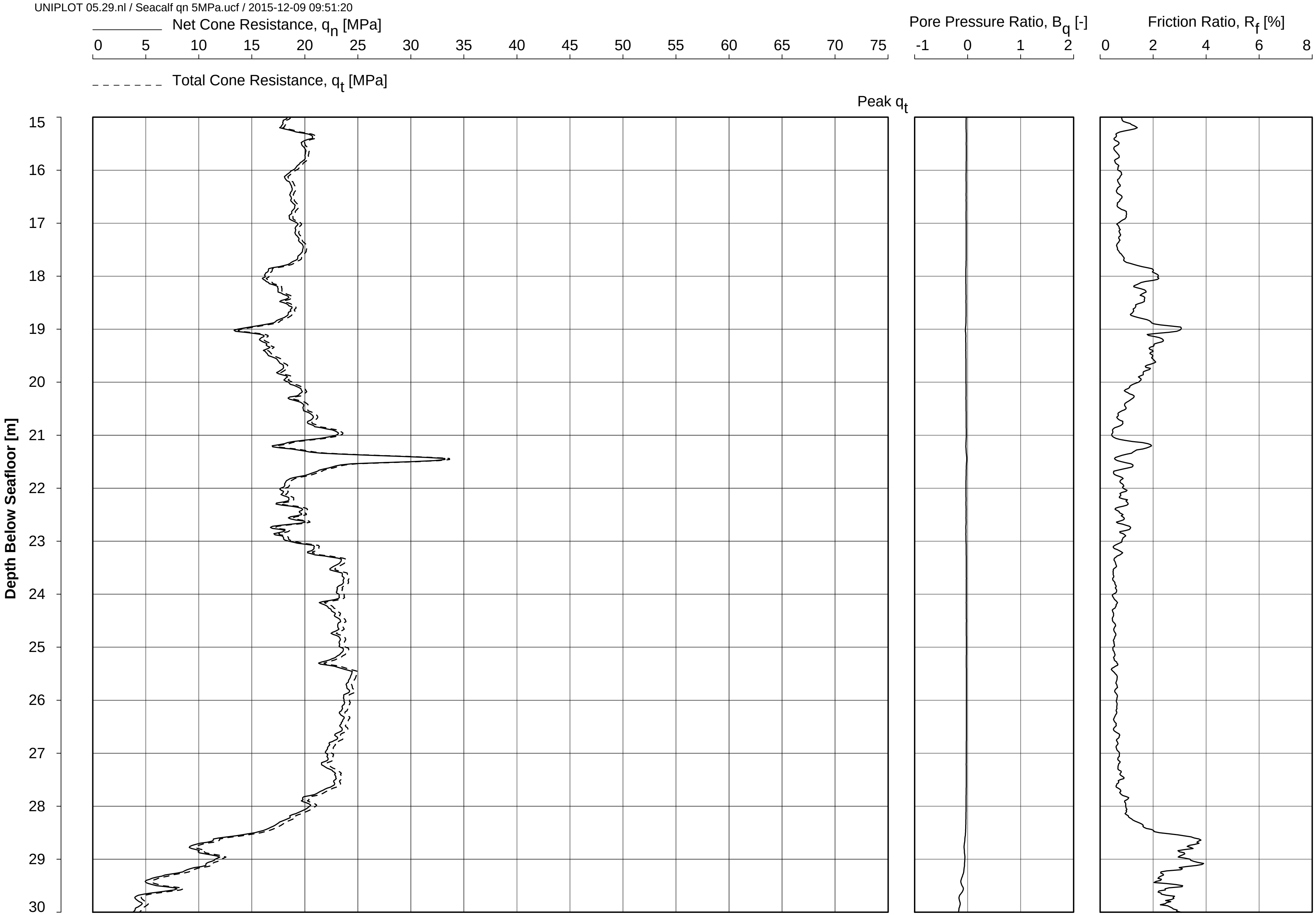
Date Of Testing : 30-Oct-2015
Water Depth [m] : 36.9
Coordinates [m] : E498234 N5725141

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_2

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



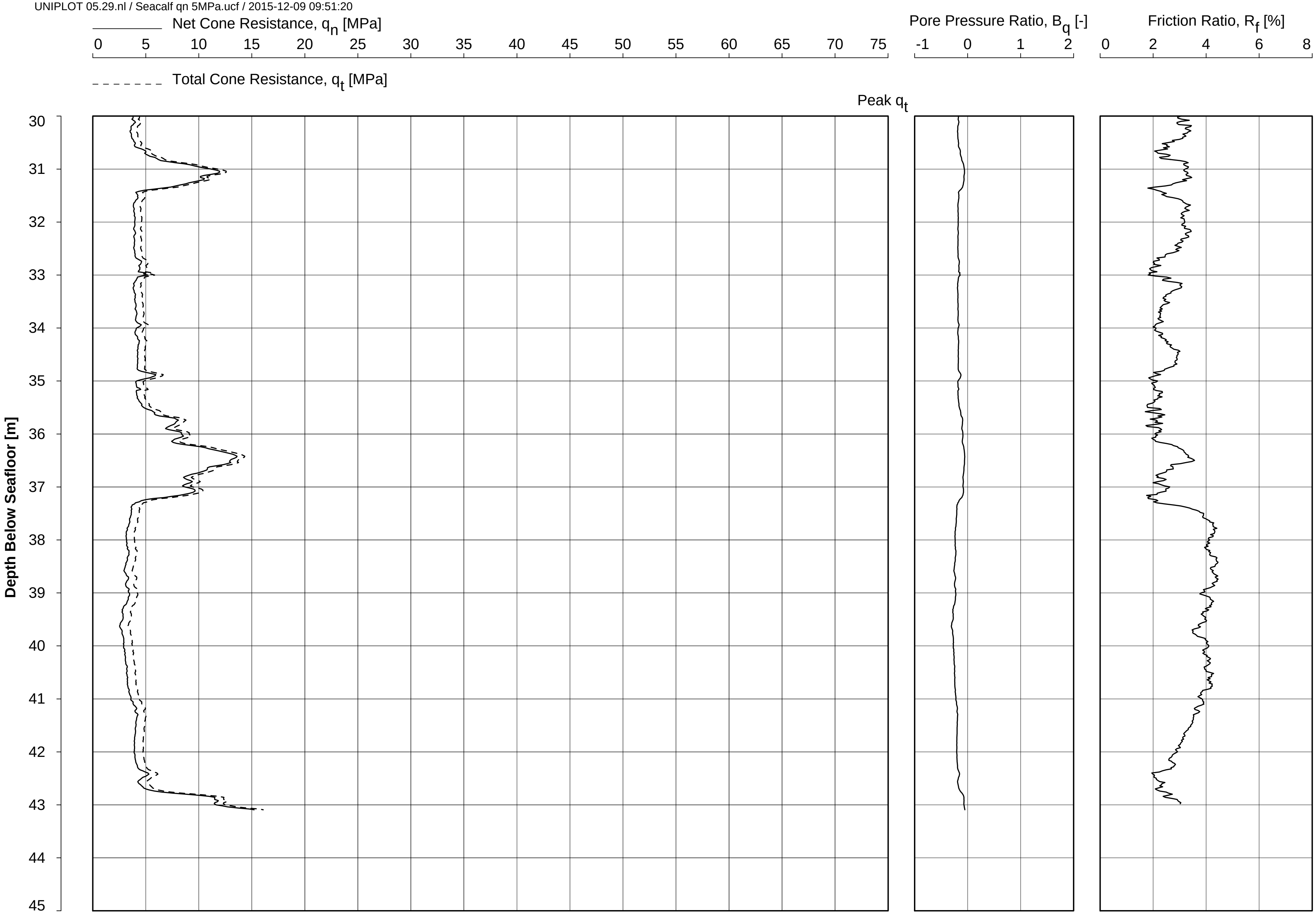
Date Of Testing	: 30-Oct-2015		Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 36.9		Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E498234	N5725141		

CONE PENETRATION TEST

CPT_WFS3_2

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:20



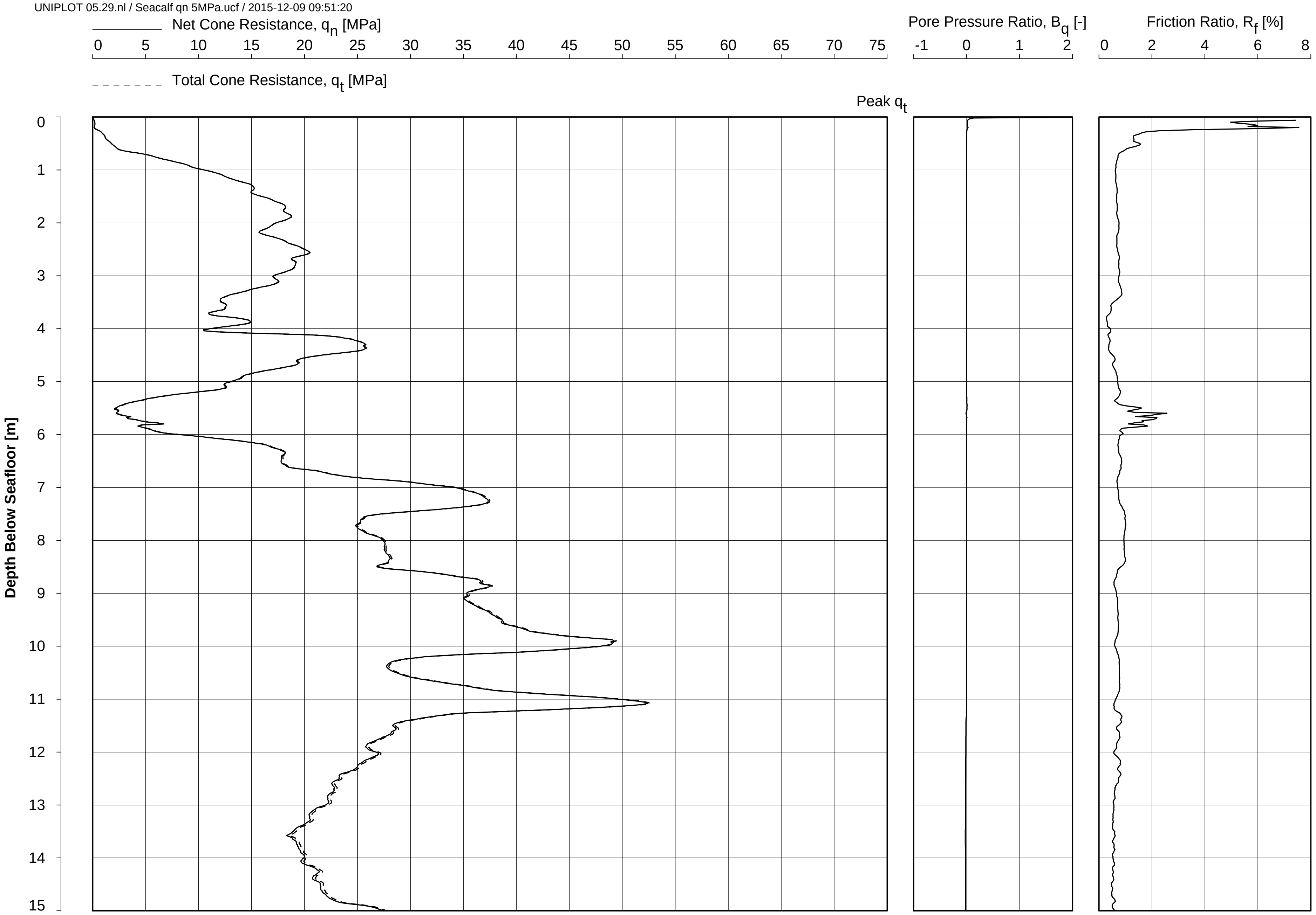
Date Of Testing : 30-Oct-2015
Water Depth [m] : 36.9
Coordinates [m] : E498234 N5725141

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_2

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.4
Coordinates [m] : E500208 N5721837

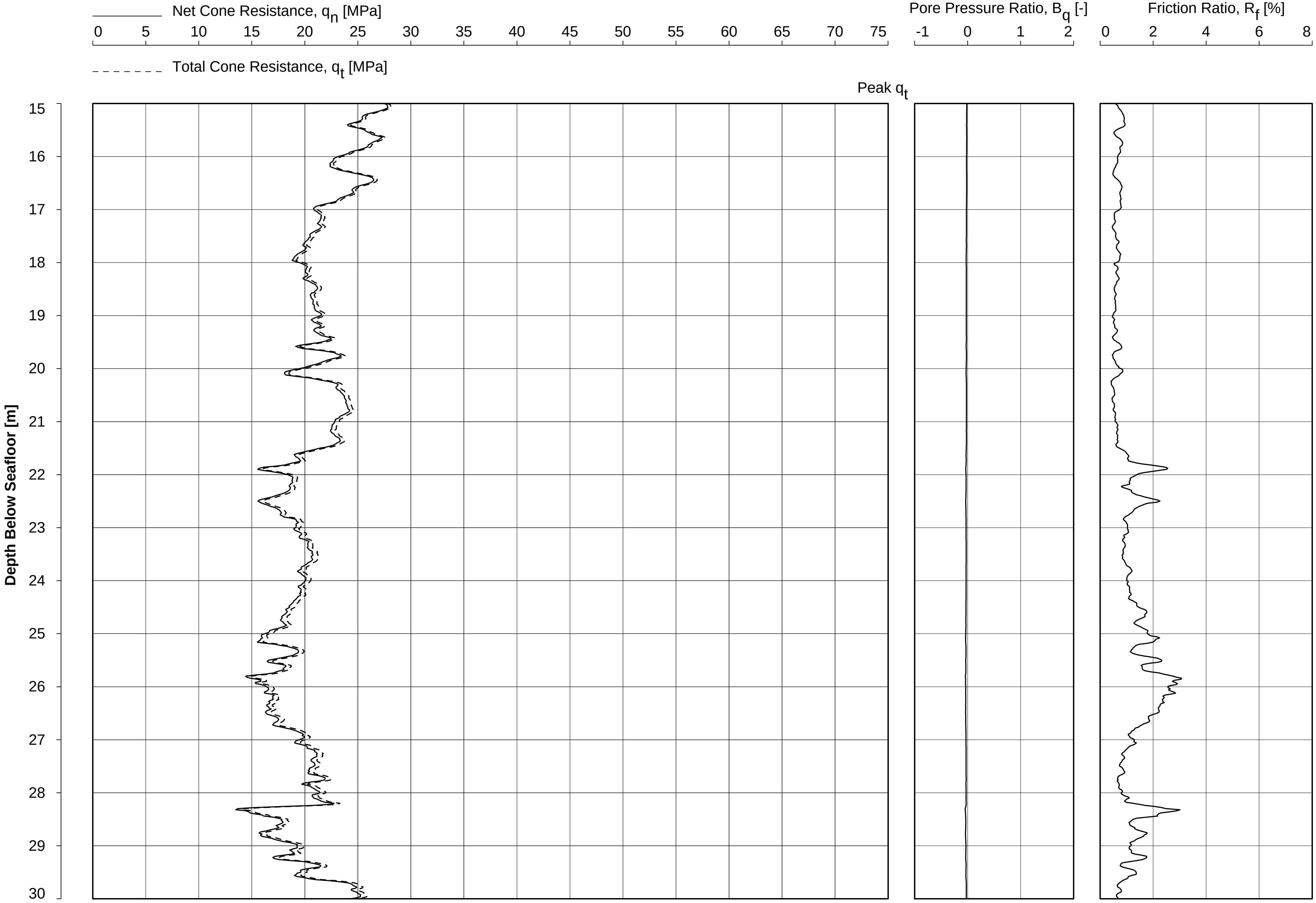
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_3

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:20



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.4
Coordinates [m] : E500208 N5721837

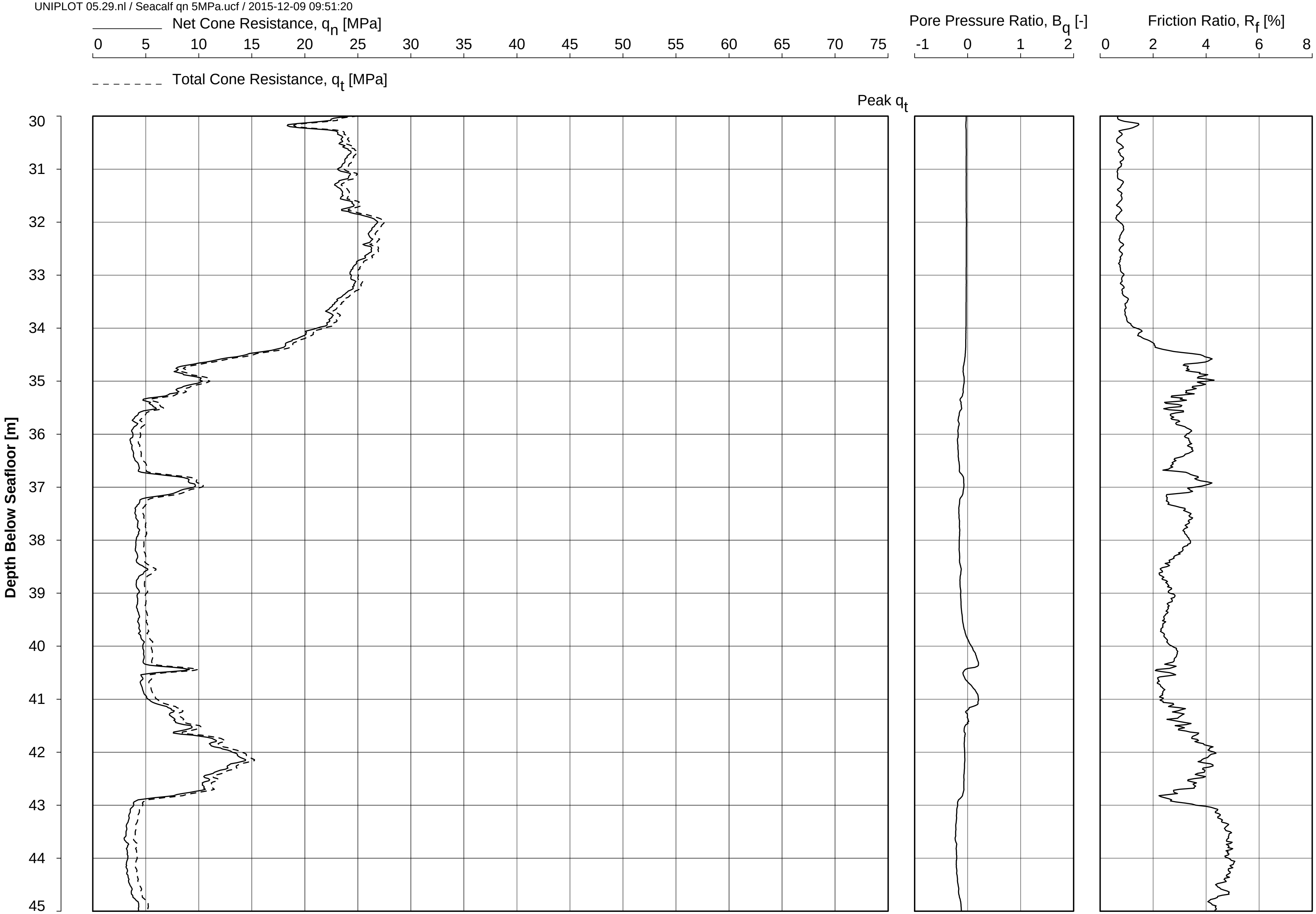
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_3

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:20



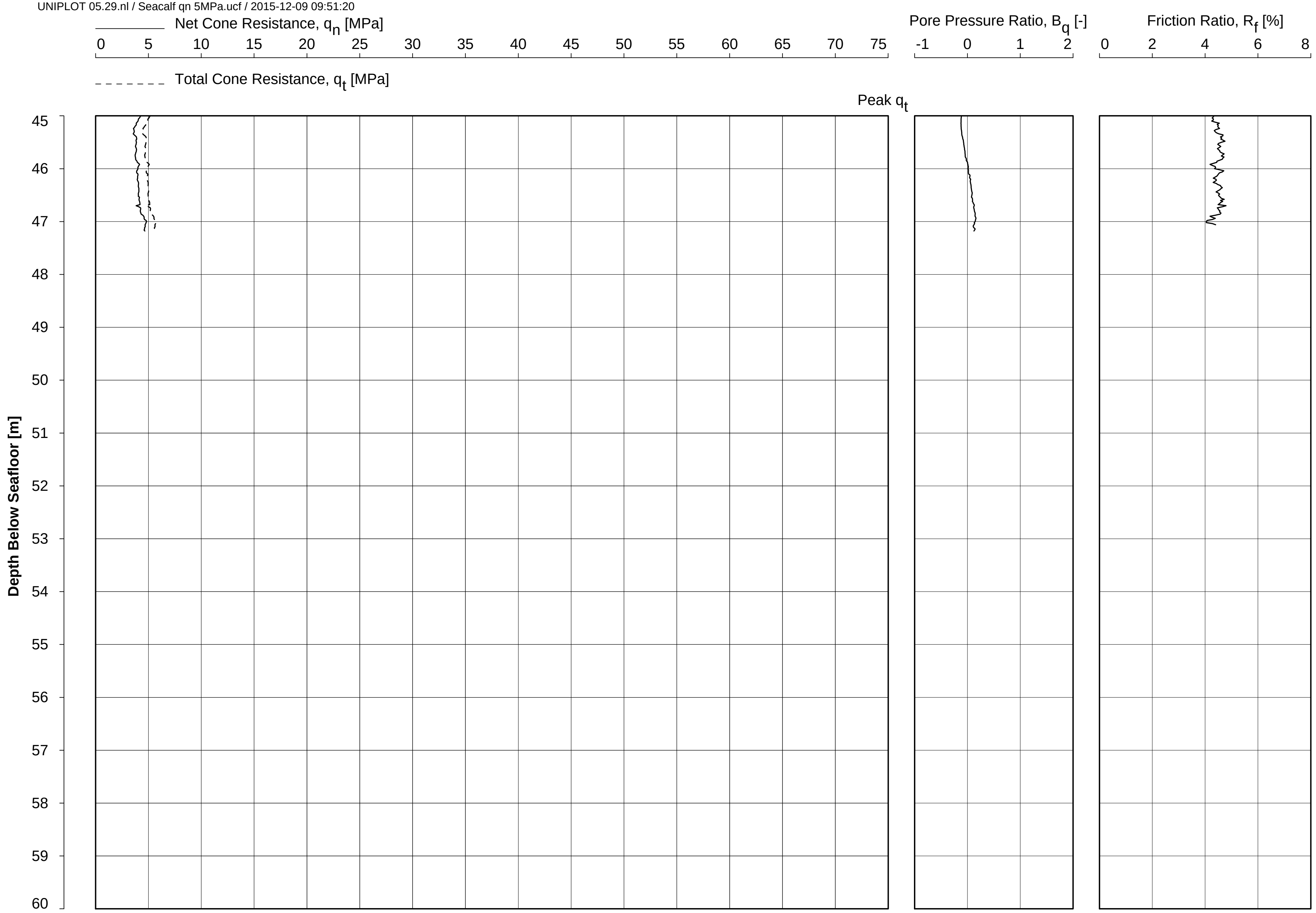
Date Of Testing	: 27-Oct-2015	Probe Type	: CP15-CF75PB30SN2
Water Depth [m]	: 28.4	Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E500208 N5721837		

CONE PENETRATION TEST

CPT_WFS3_3

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:20



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.4
Coordinates [m] : E500208 N5721837

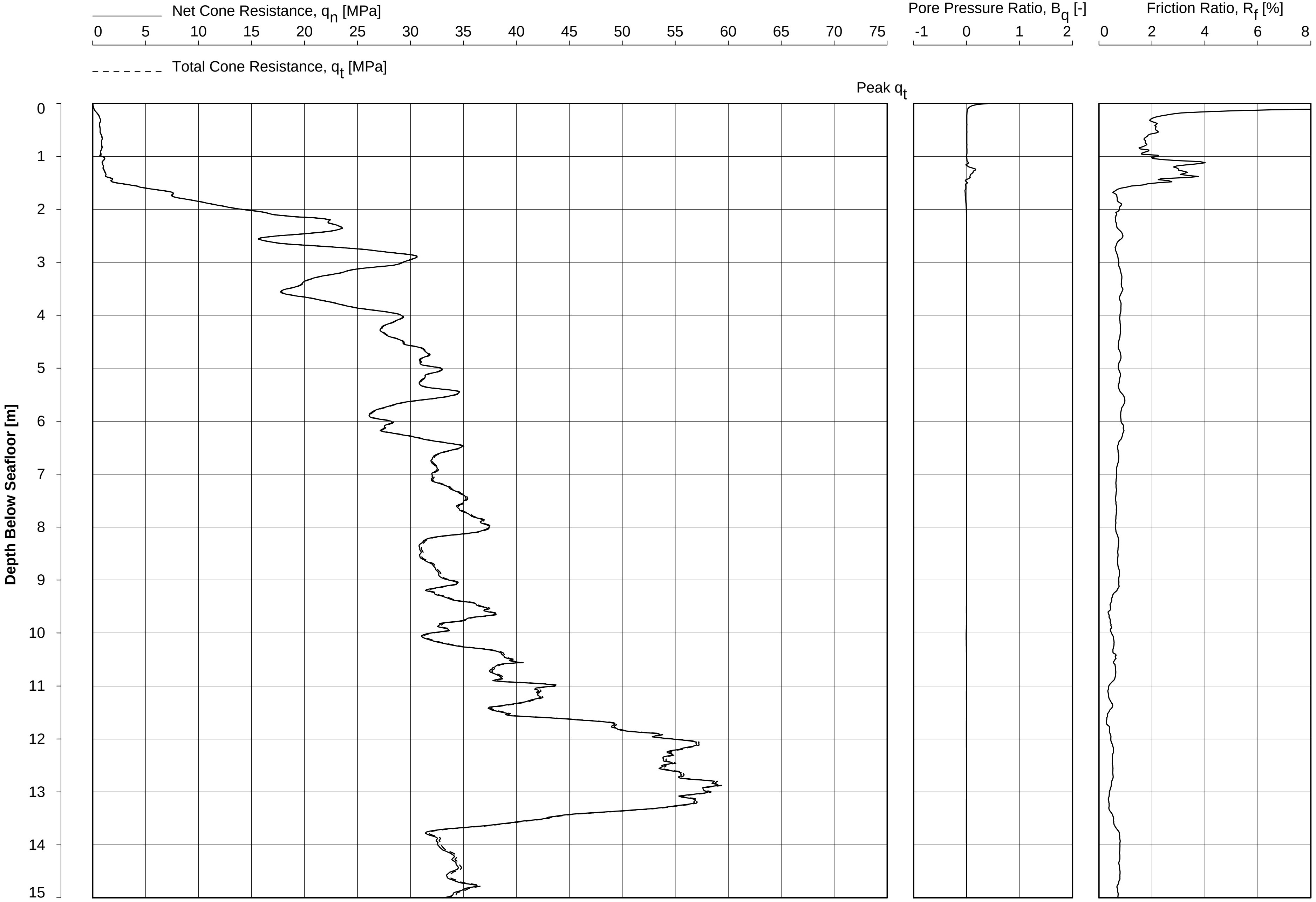
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_3

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:20



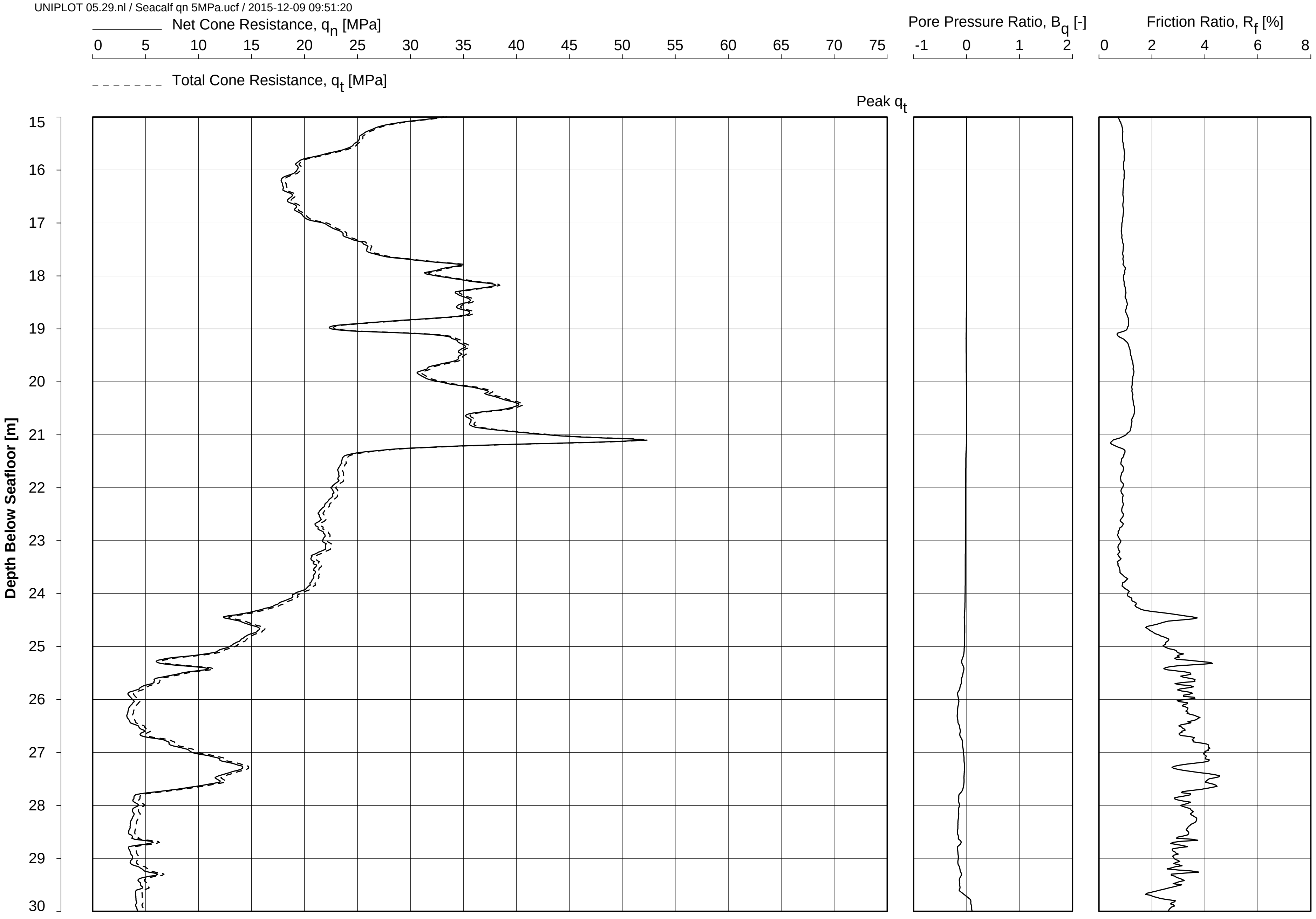
Date Of Testing : 29-Oct-2015
Water Depth [m] : 29.3
Coordinates [m] : E494308 N5726002

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_5

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 29-Oct-2015
Water Depth [m] : 29.3
Coordinates [m] : E494308 N5726002

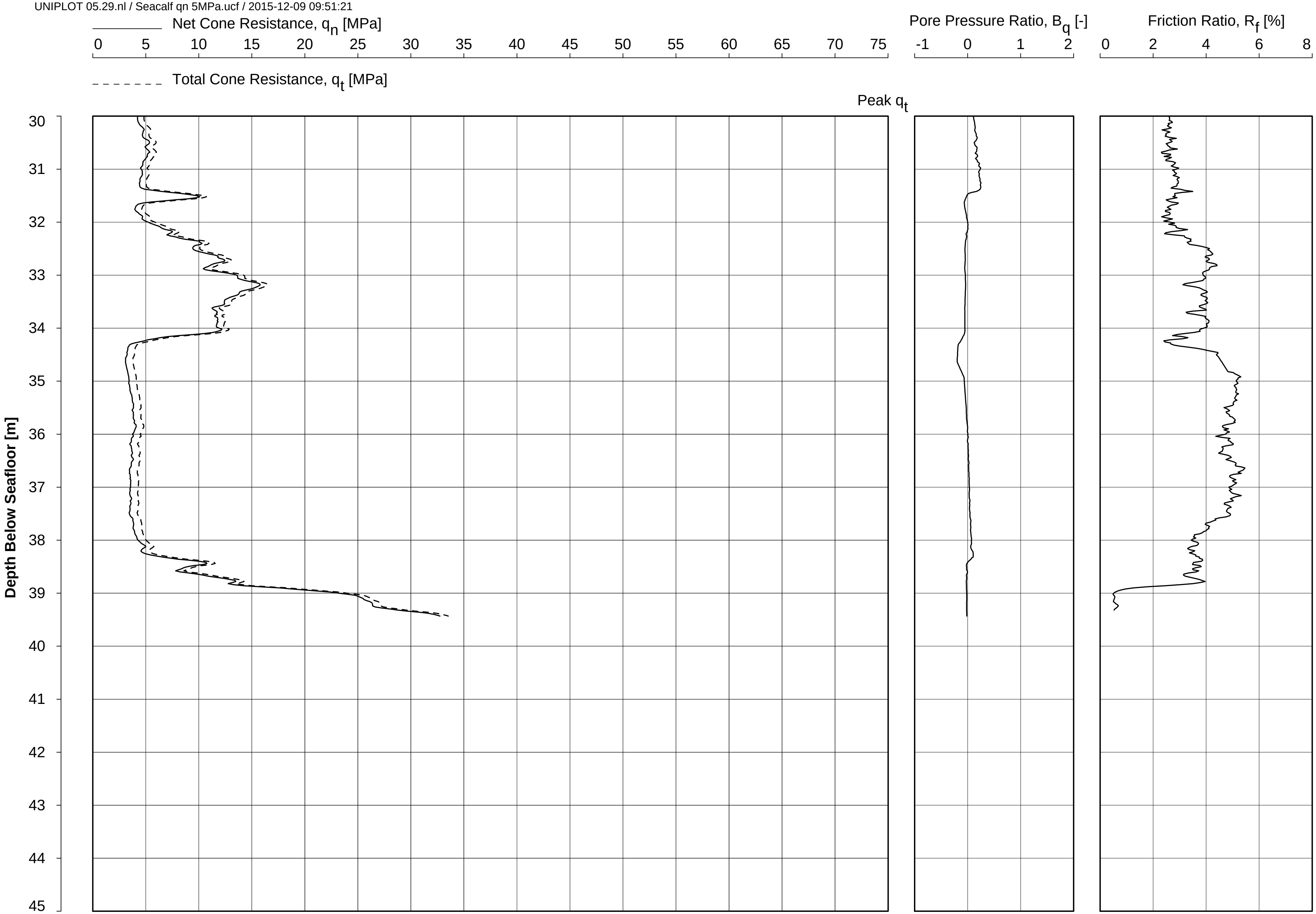
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_5

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:21



Date Of Testing : 29-Oct-2015
Water Depth [m] : 29.3
Coordinates [m] : E494308 N5726002

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

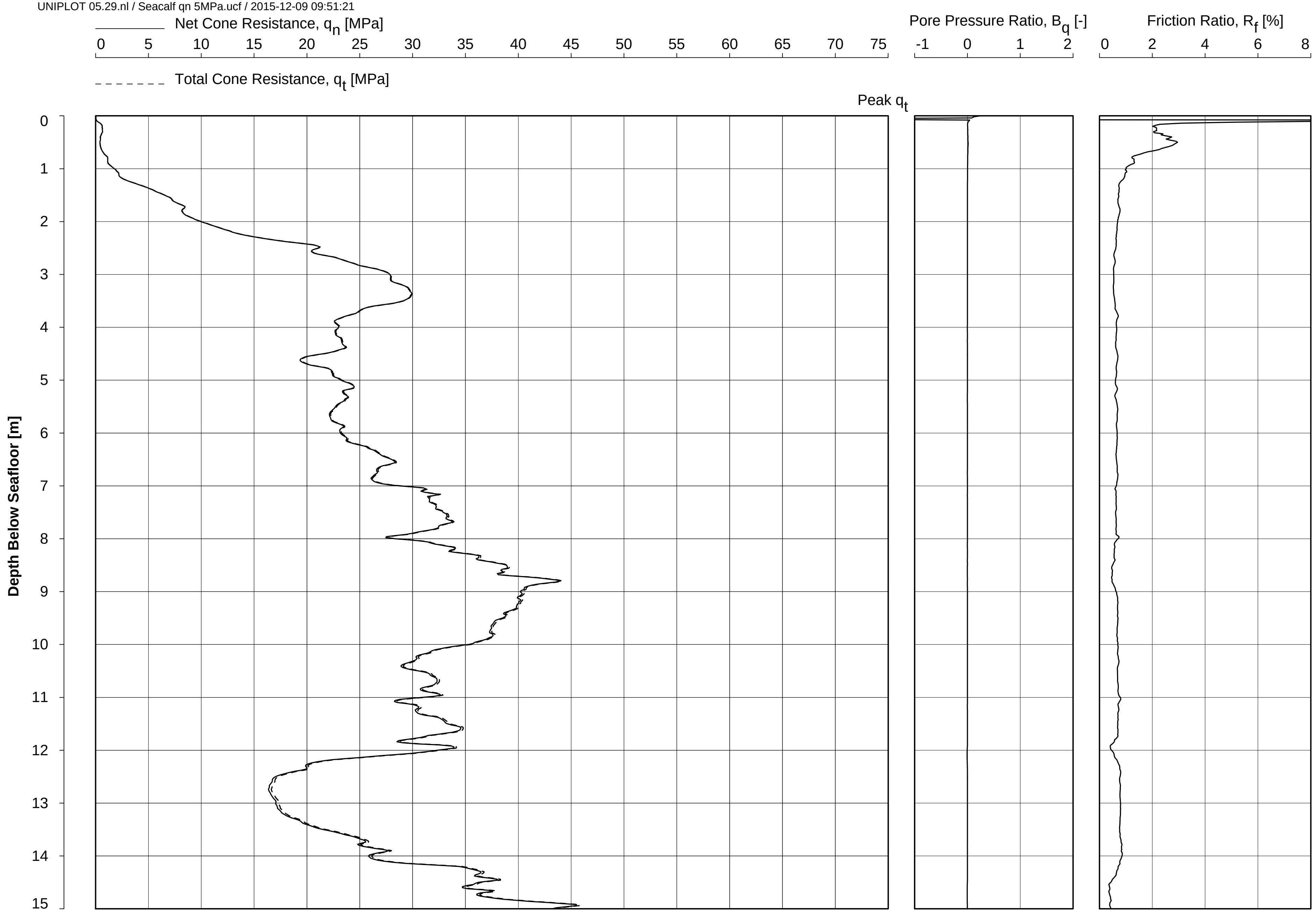
CONE PENETRATION TEST

CPT_WFS3_5

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

Fugro Report No. N6083/02 (2)

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:21



Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.4
Coordinates [m] : E496611 N5729494

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_6

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO

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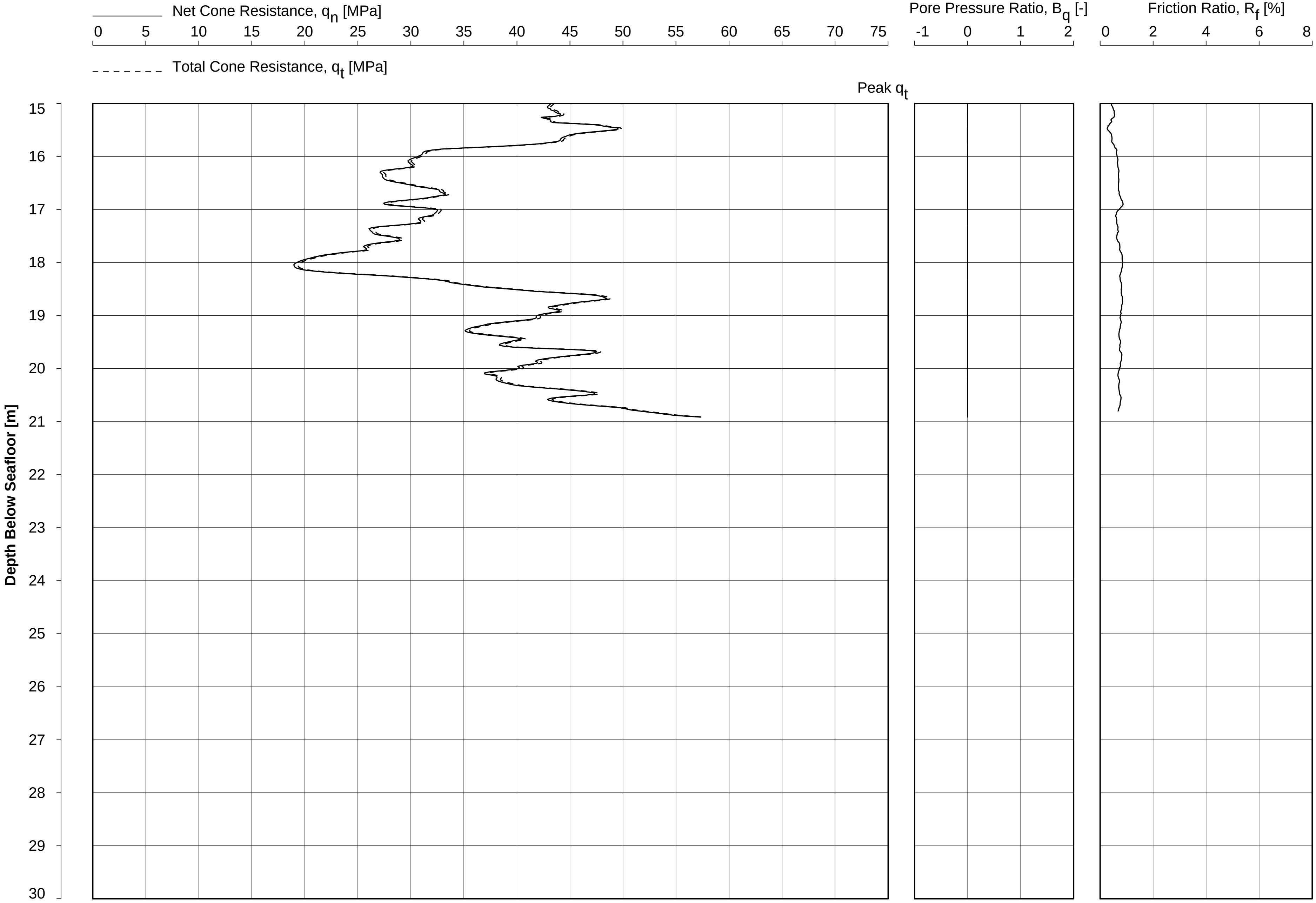


Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.4
Coordinates [m] : E496611 N5729494

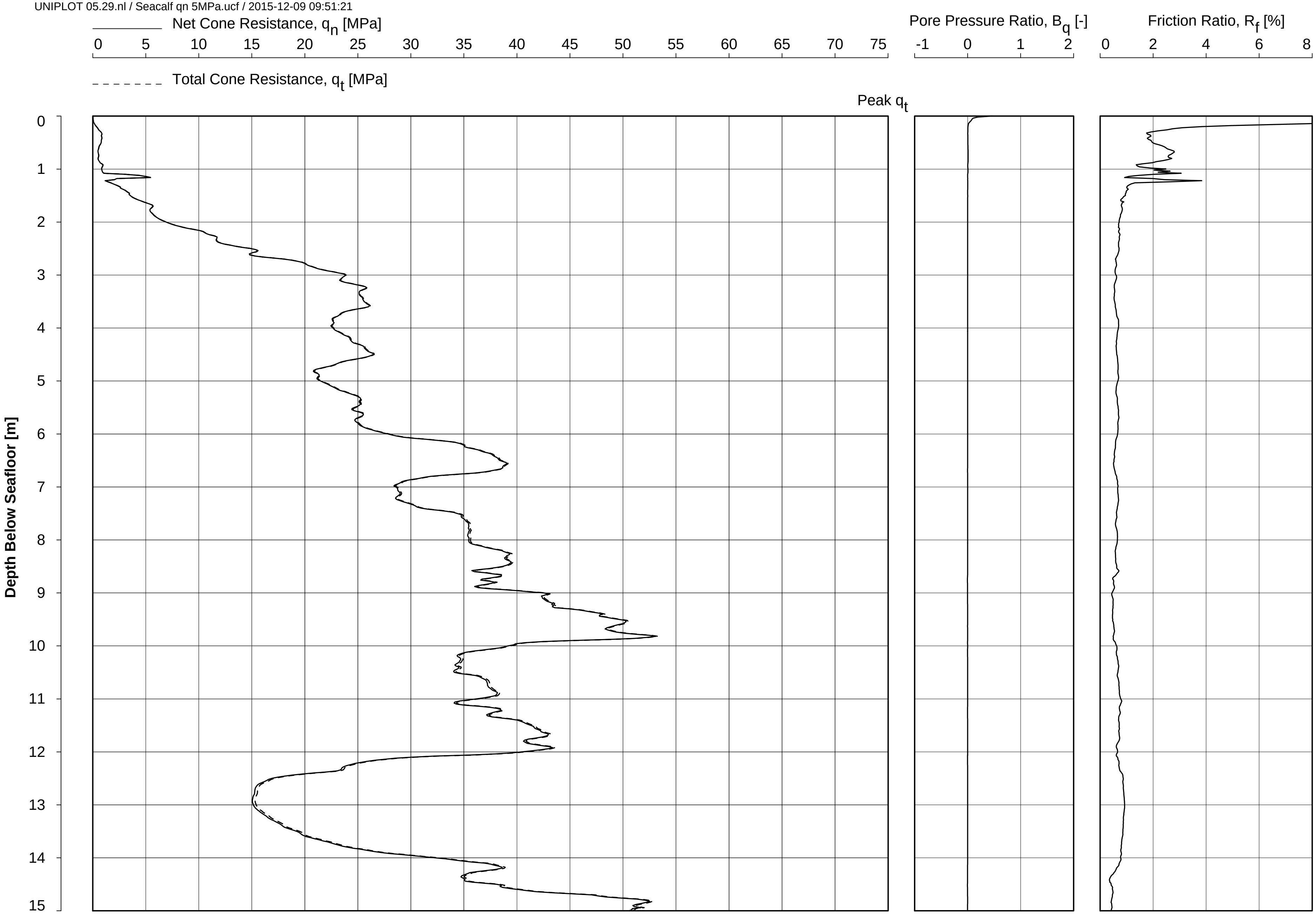
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_6

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:21



Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496608 N5729497

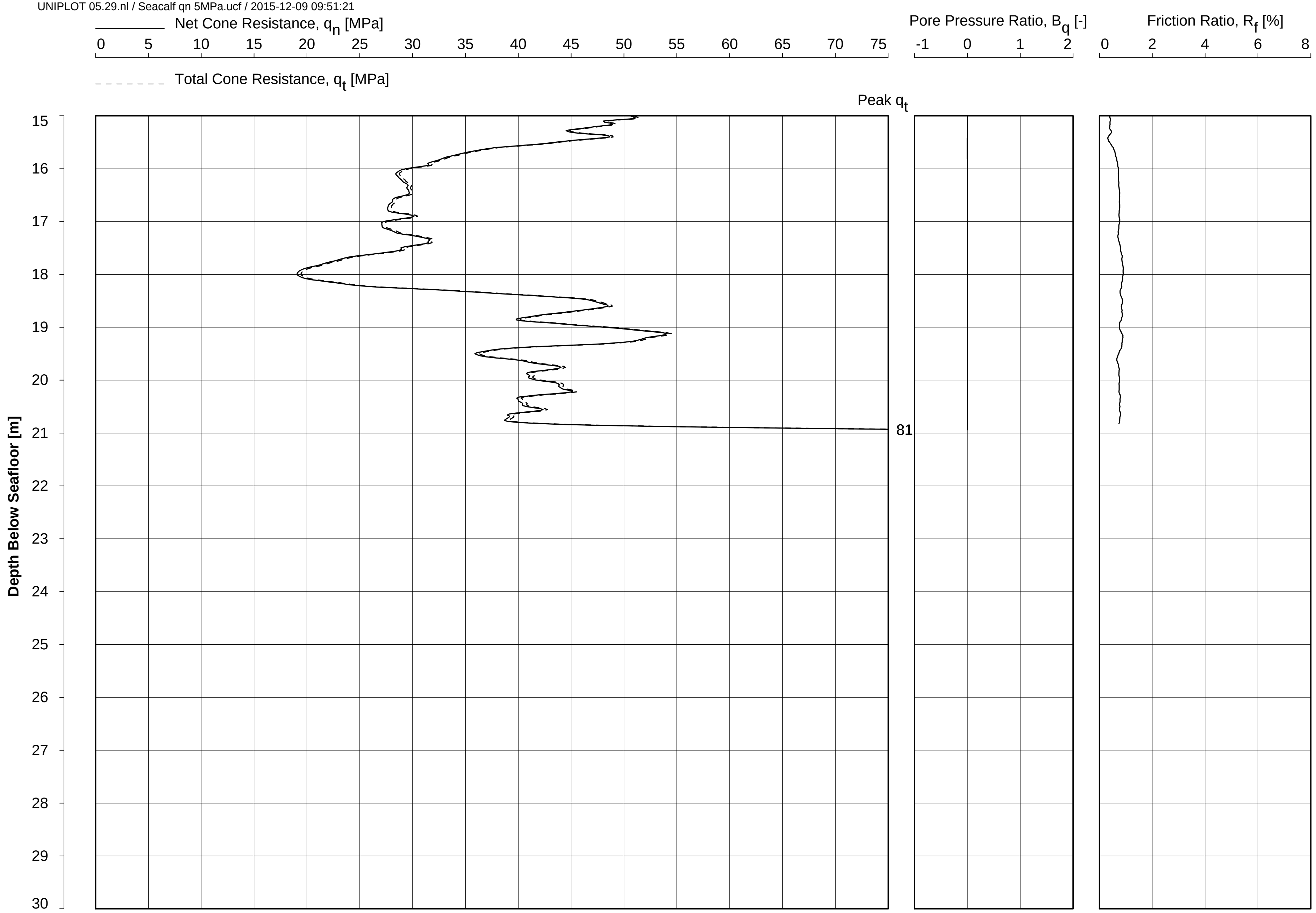
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_6A

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:21



Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496608 N5729497

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

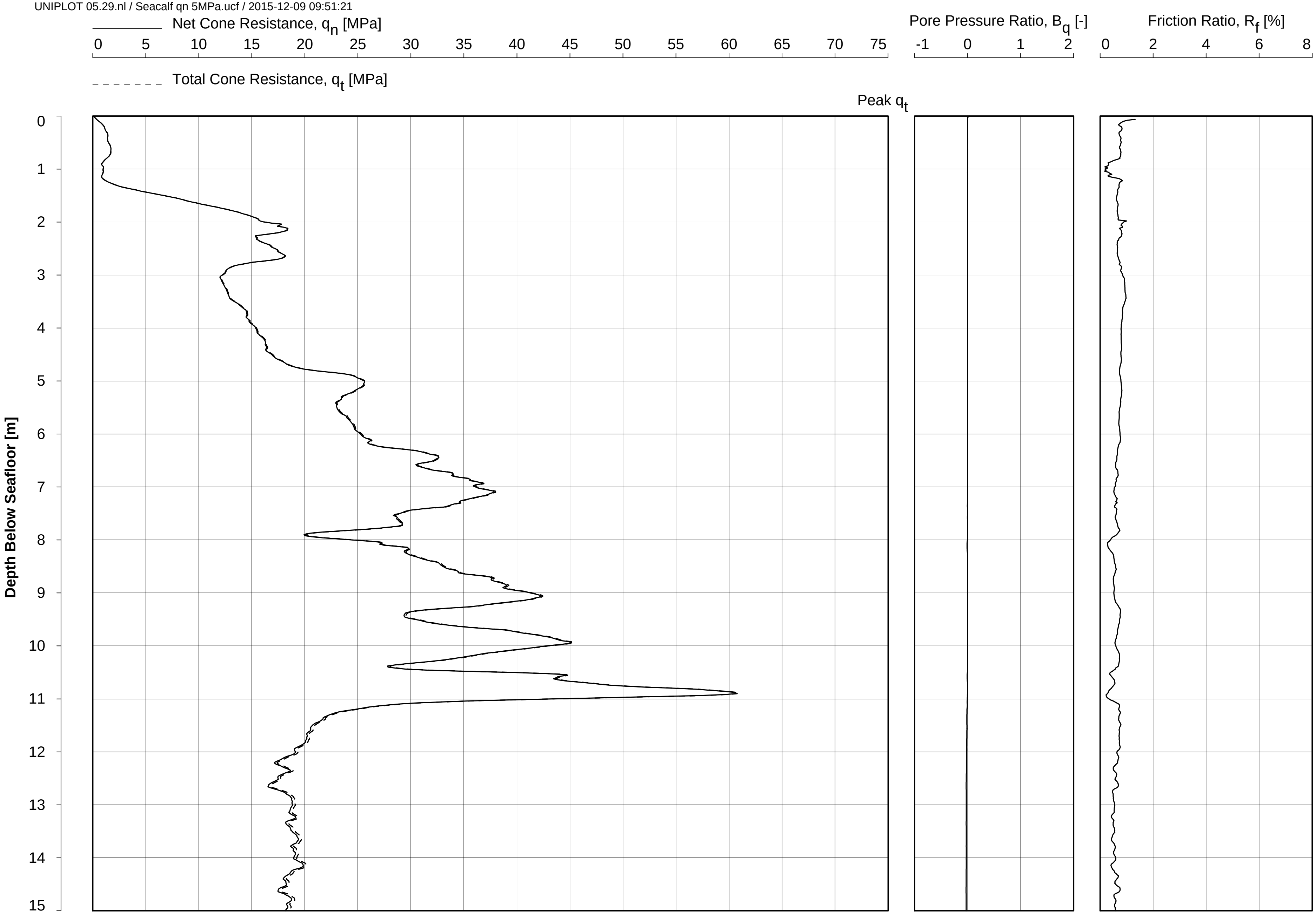
CONE PENETRATION TEST

CPT_WFS3_6A

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:21



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.8
Coordinates [m] : E498408 N5722197

Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

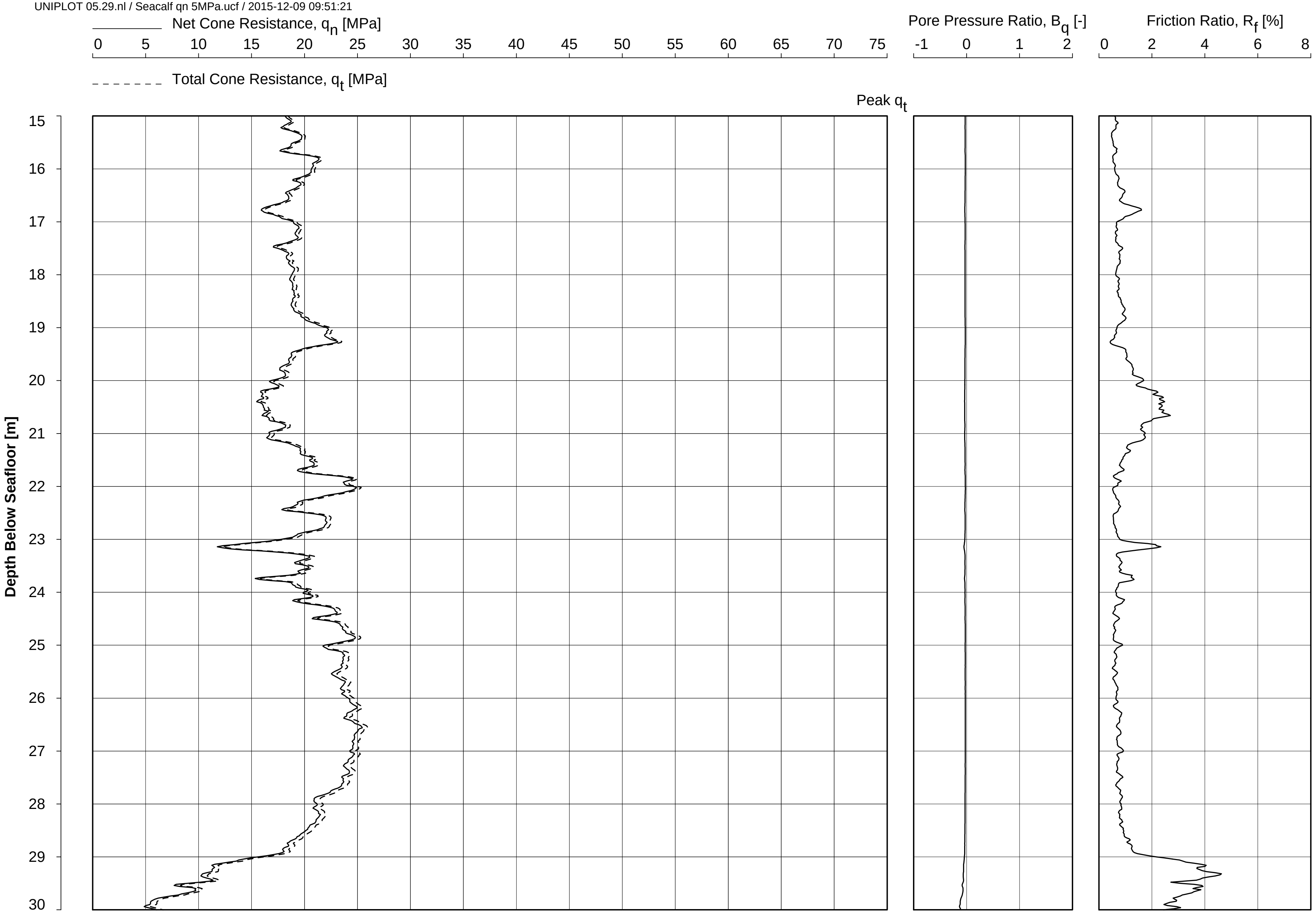
CONE PENETRATION TEST

CPT_WFS3_7

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:21



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.8
Coordinates [m] : E498408 N5722197

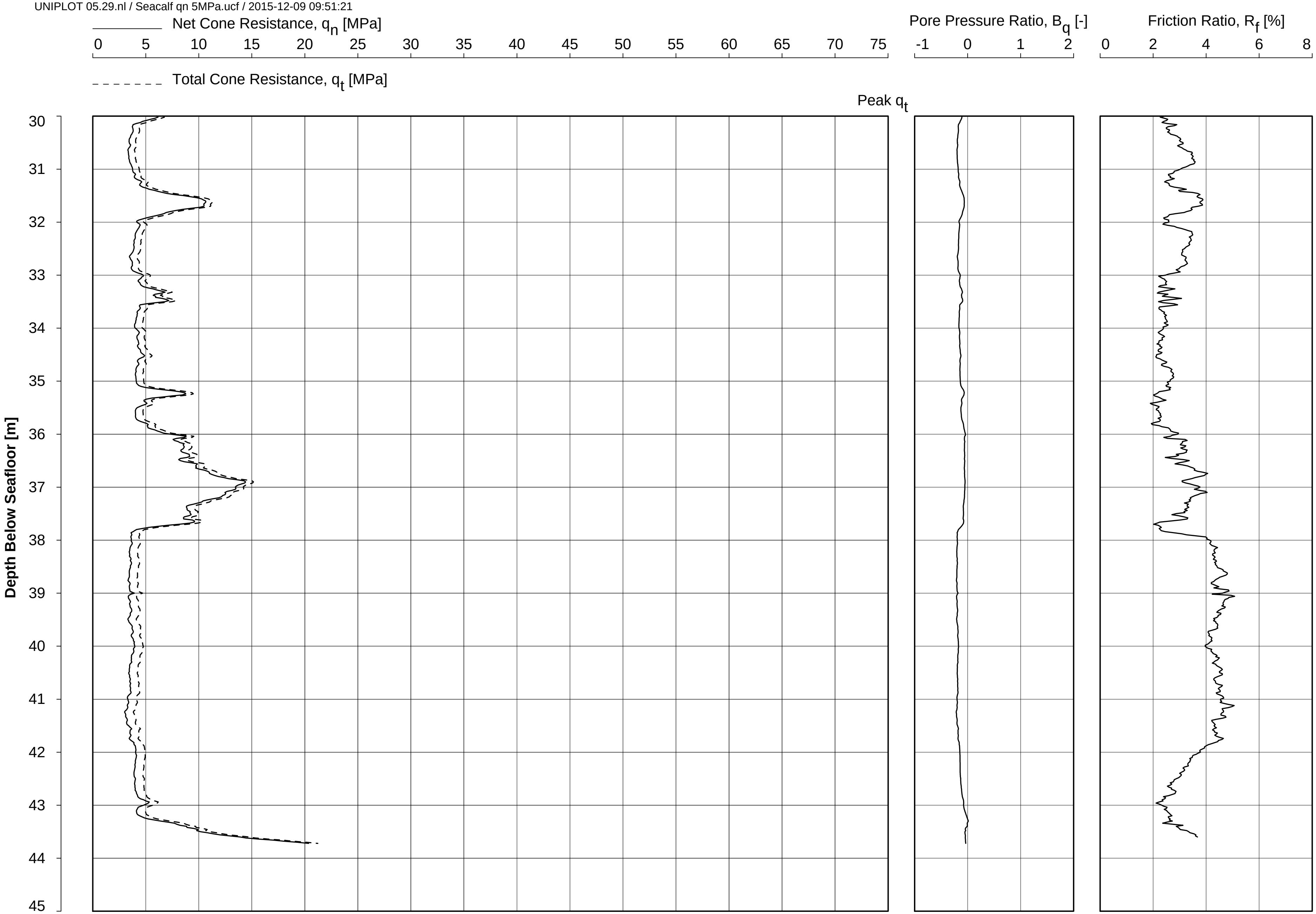
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_7

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:21



Date Of Testing : 27-Oct-2015
Water Depth [m] : 28.8
Coordinates [m] : E498408 N5722197

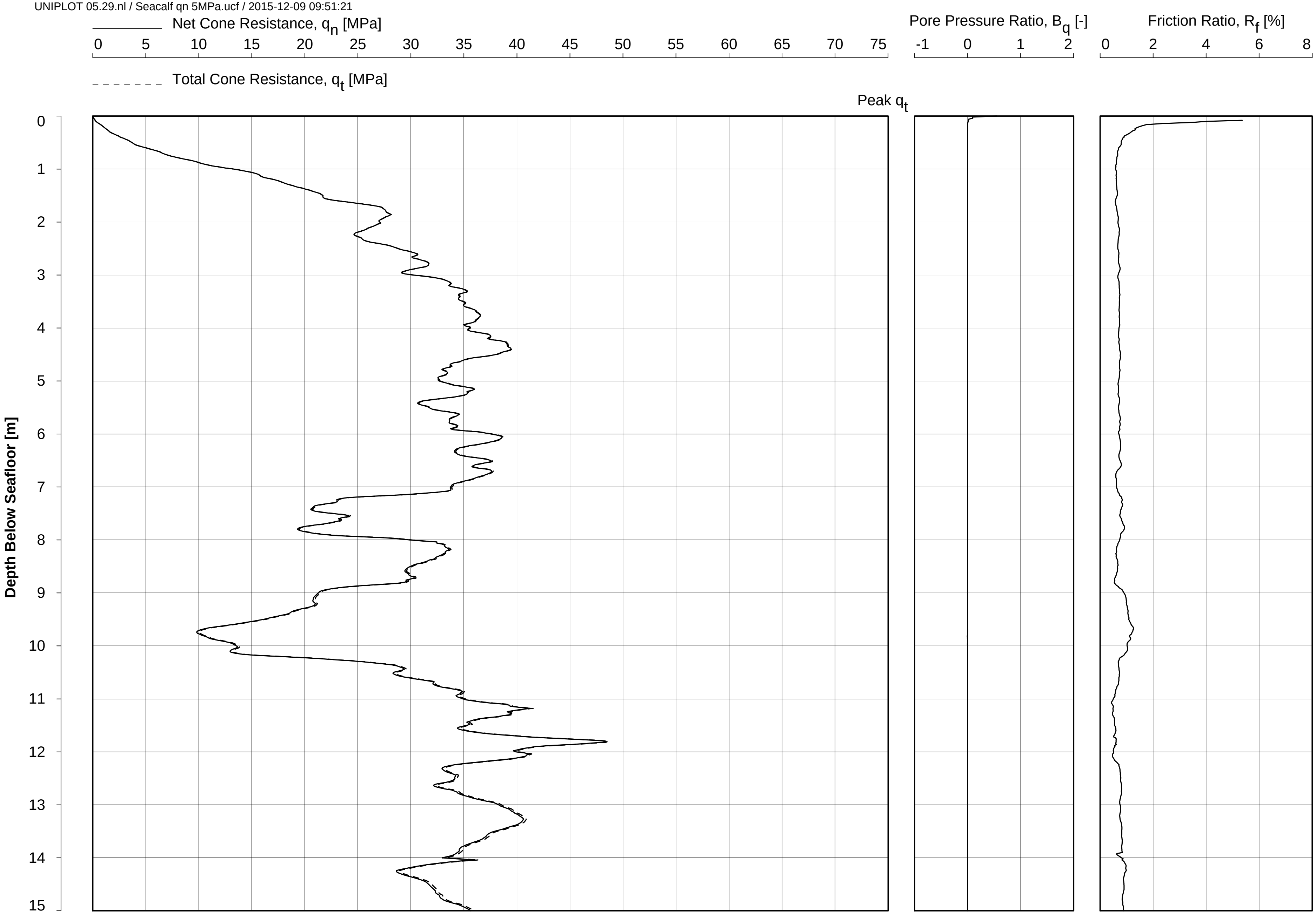
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_7

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:21



Date Of Testing : 26-Oct-2015
Water Depth [m] : 20.3
Coordinates [m] : E500438 N5724679

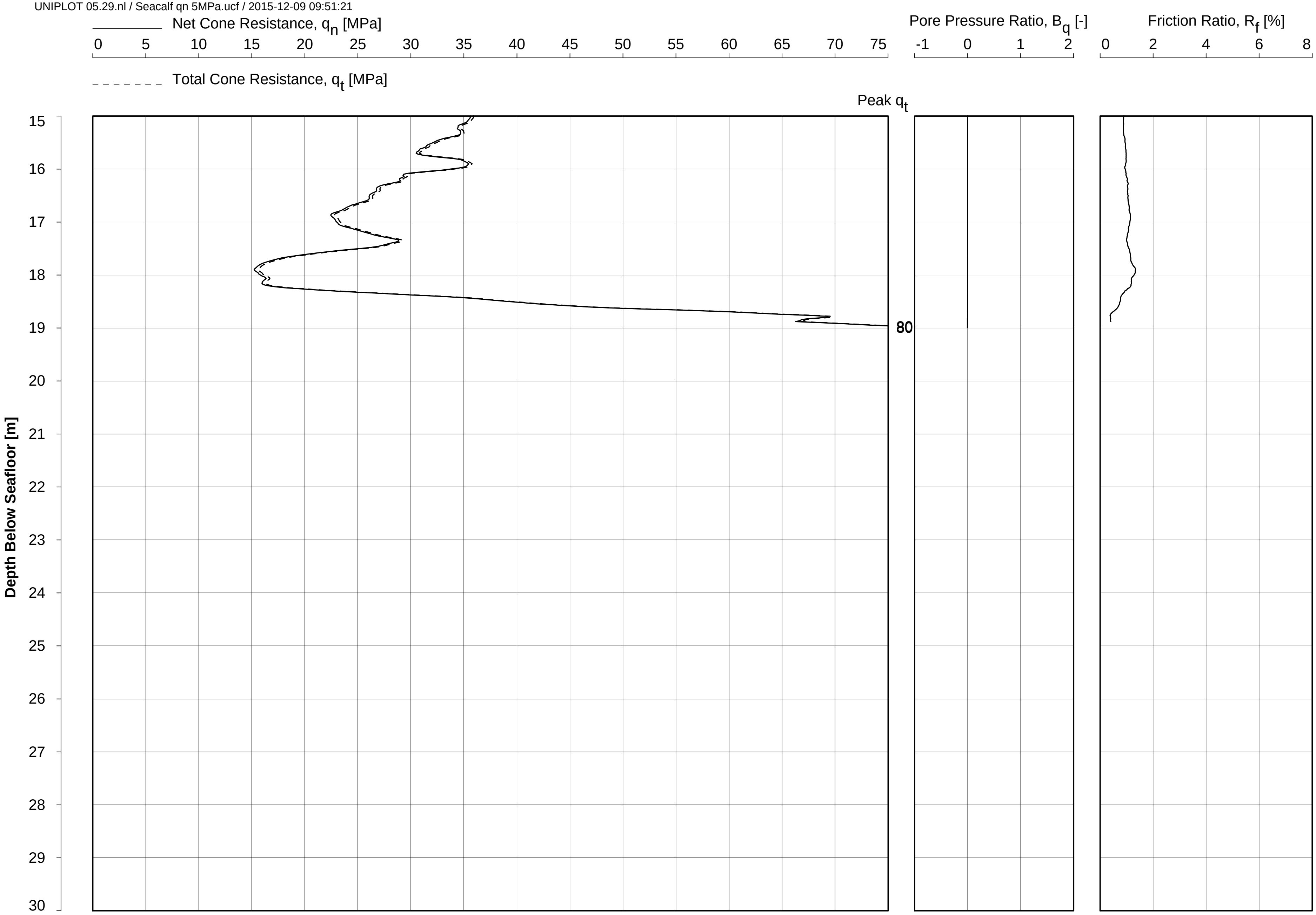
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_8

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:21



Date Of Testing : 26-Oct-2015
Water Depth [m] : 20.3
Coordinates [m] : E500438 N5724679

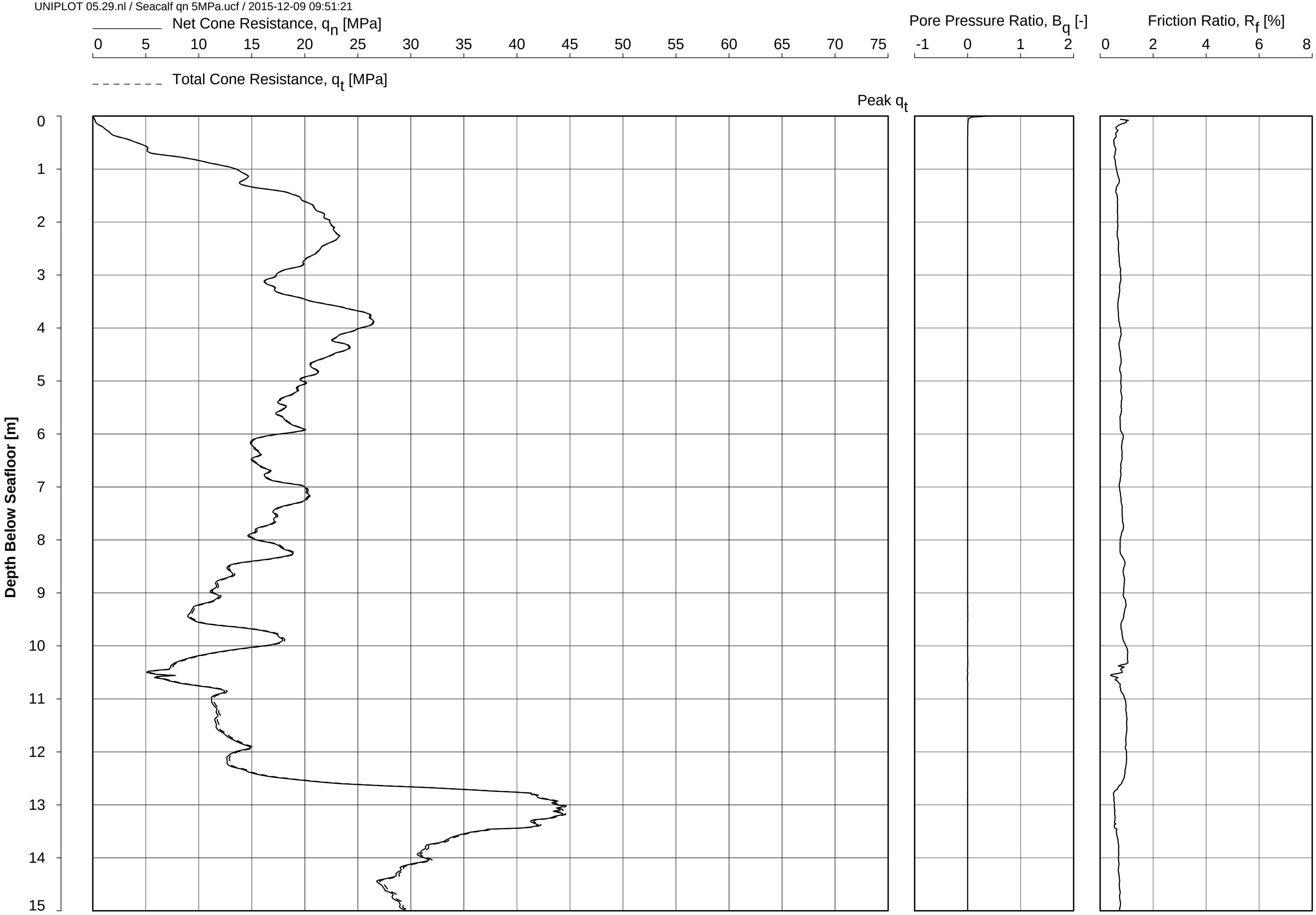
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_8

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:21



Date Of Testing : 30-Oct-2015
Water Depth [m] : 25.0
Coordinates [m] : E500399 N5726517

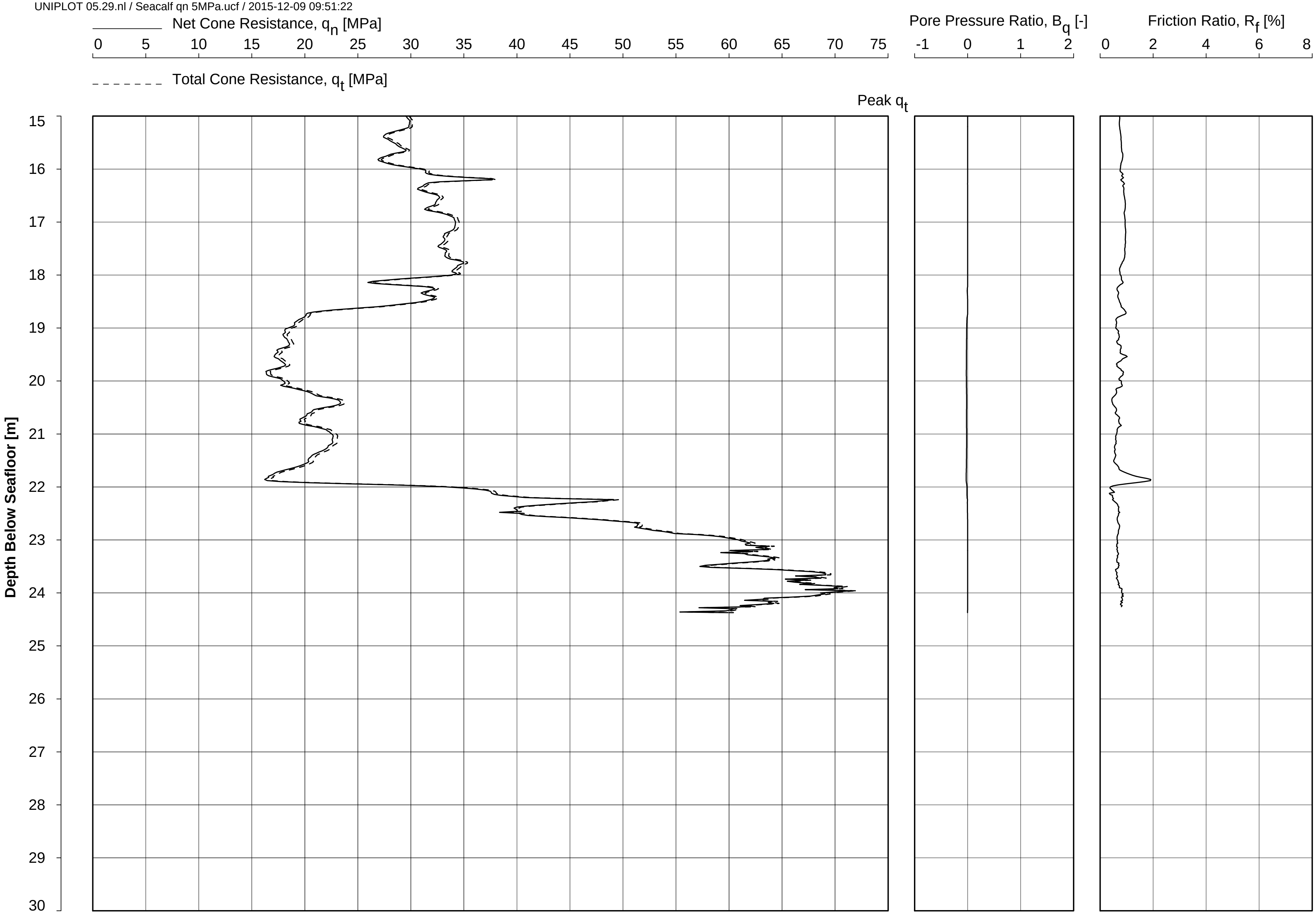
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_9

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:22



Date Of Testing : 30-Oct-2015
Water Depth [m] : 25.0
Coordinates [m] : E500399 N5726517

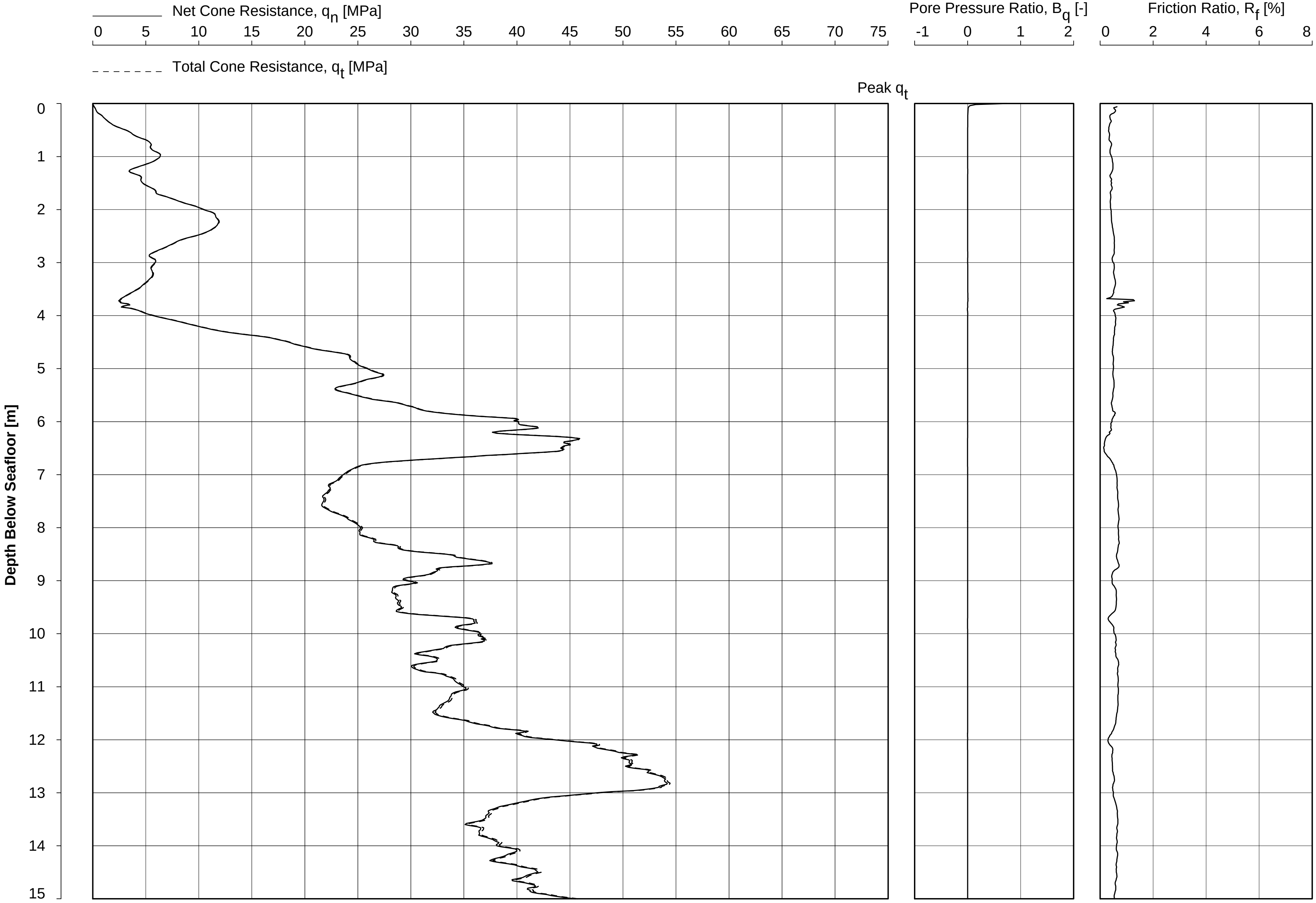
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_9

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:22



Date Of Testing : 30-Oct-2015
Water Depth [m] : 34.7
Coordinates [m] : E498625 N5726871

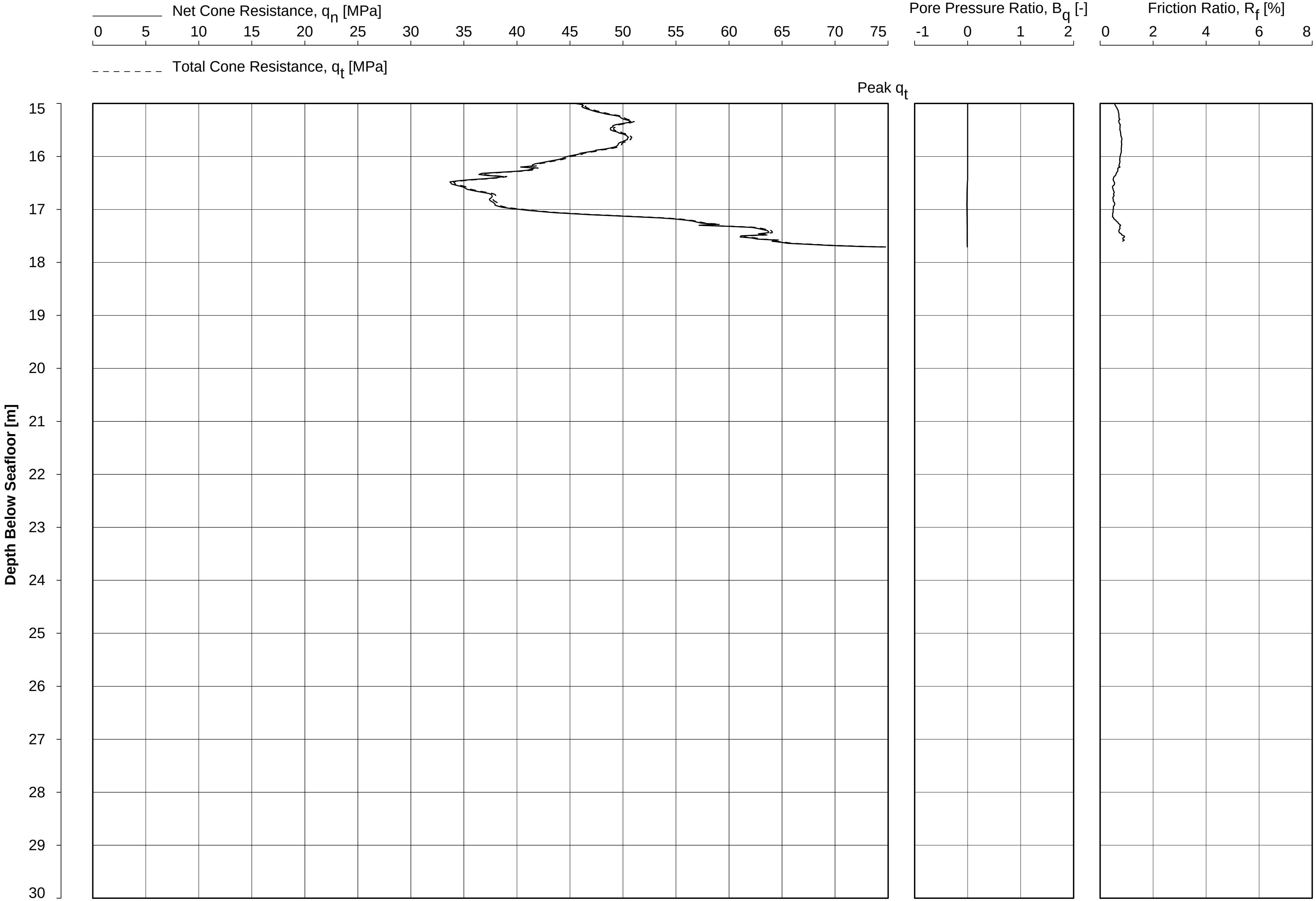
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_10

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:22



Date Of Testing : 30-Oct-2015
Water Depth [m] : 34.7
Coordinates [m] : E498625 N5726871

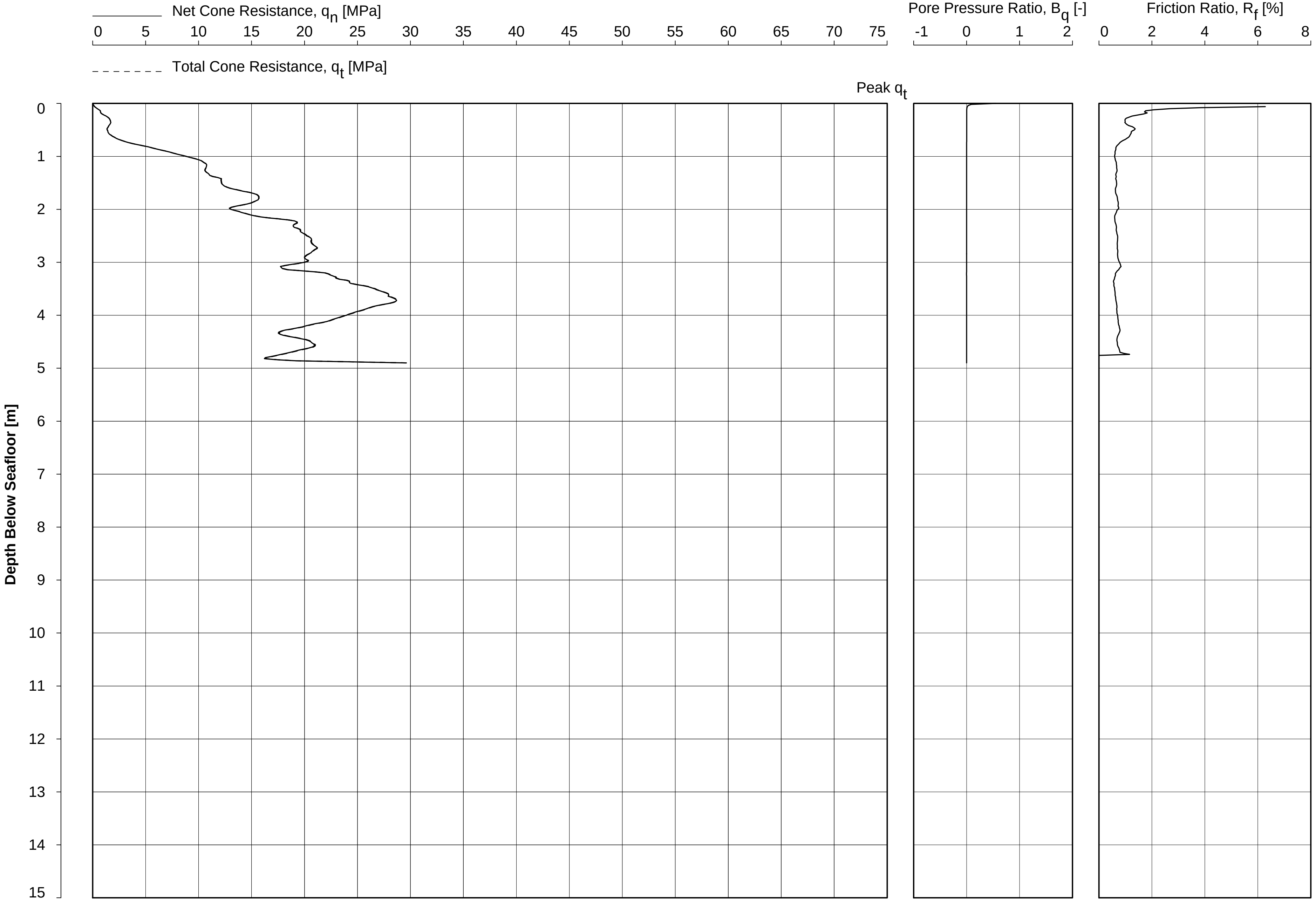
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_10

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:22



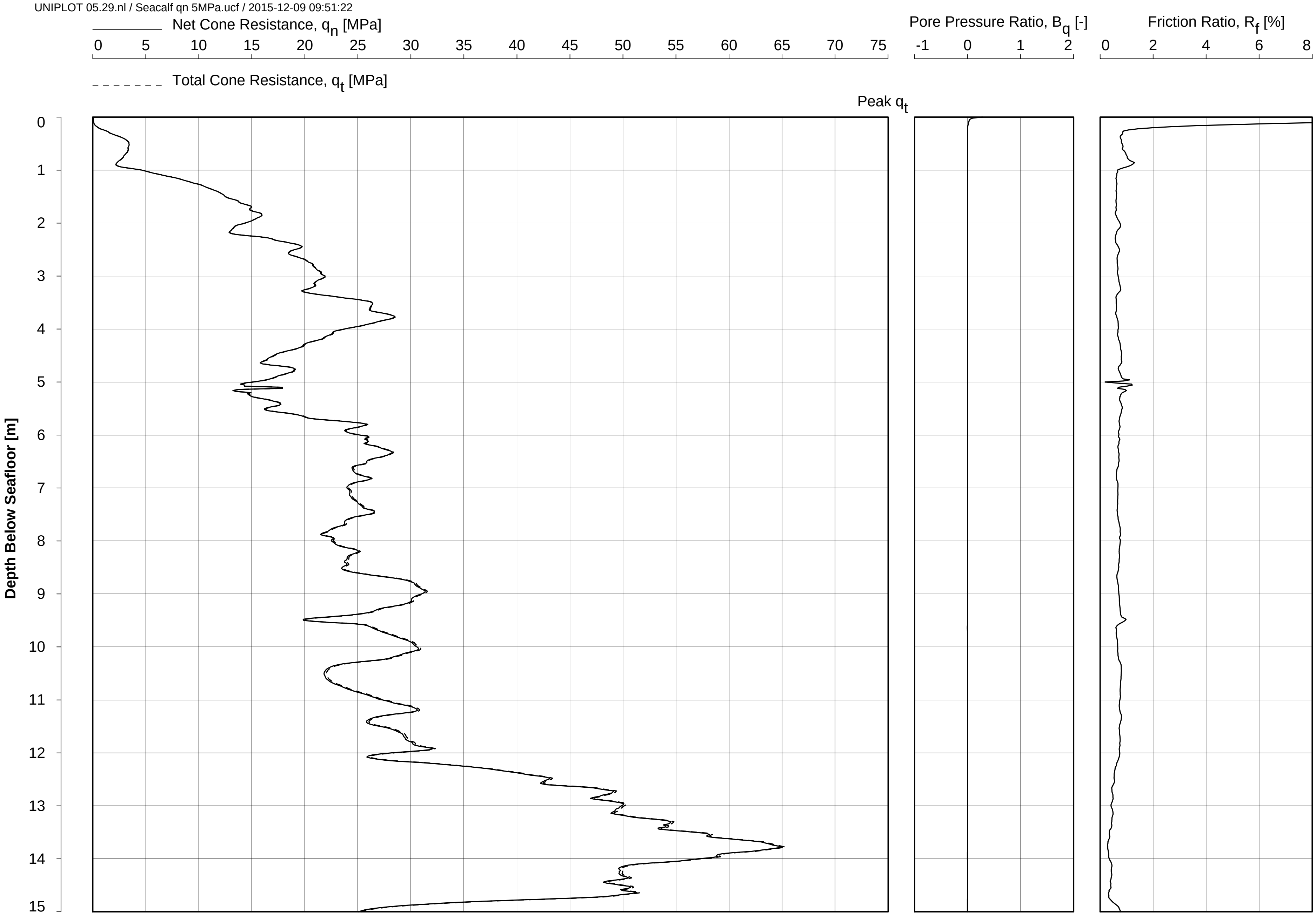
Date Of Testing : 31-Oct-2015
Water Depth [m] : 25.1
Coordinates [m] : E501904 N5726449

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_11

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



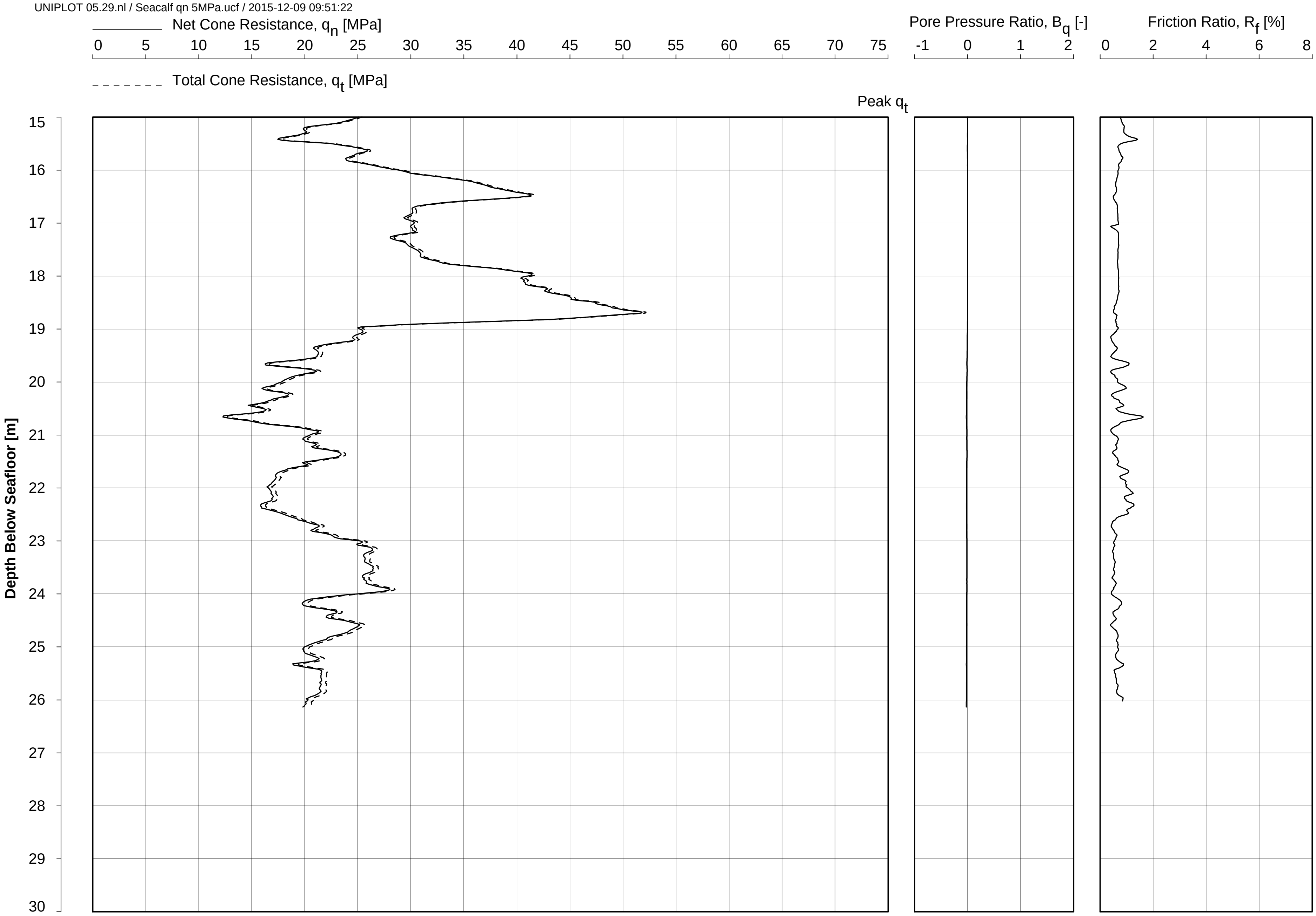
Date Of Testing : 31-Oct-2015
Water Depth [m] : 25.1
Coordinates [m] : E501900 N5726444

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_11A

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 31-Oct-2015
Water Depth [m] : 25.1
Coordinates [m] : E501900 N5726444

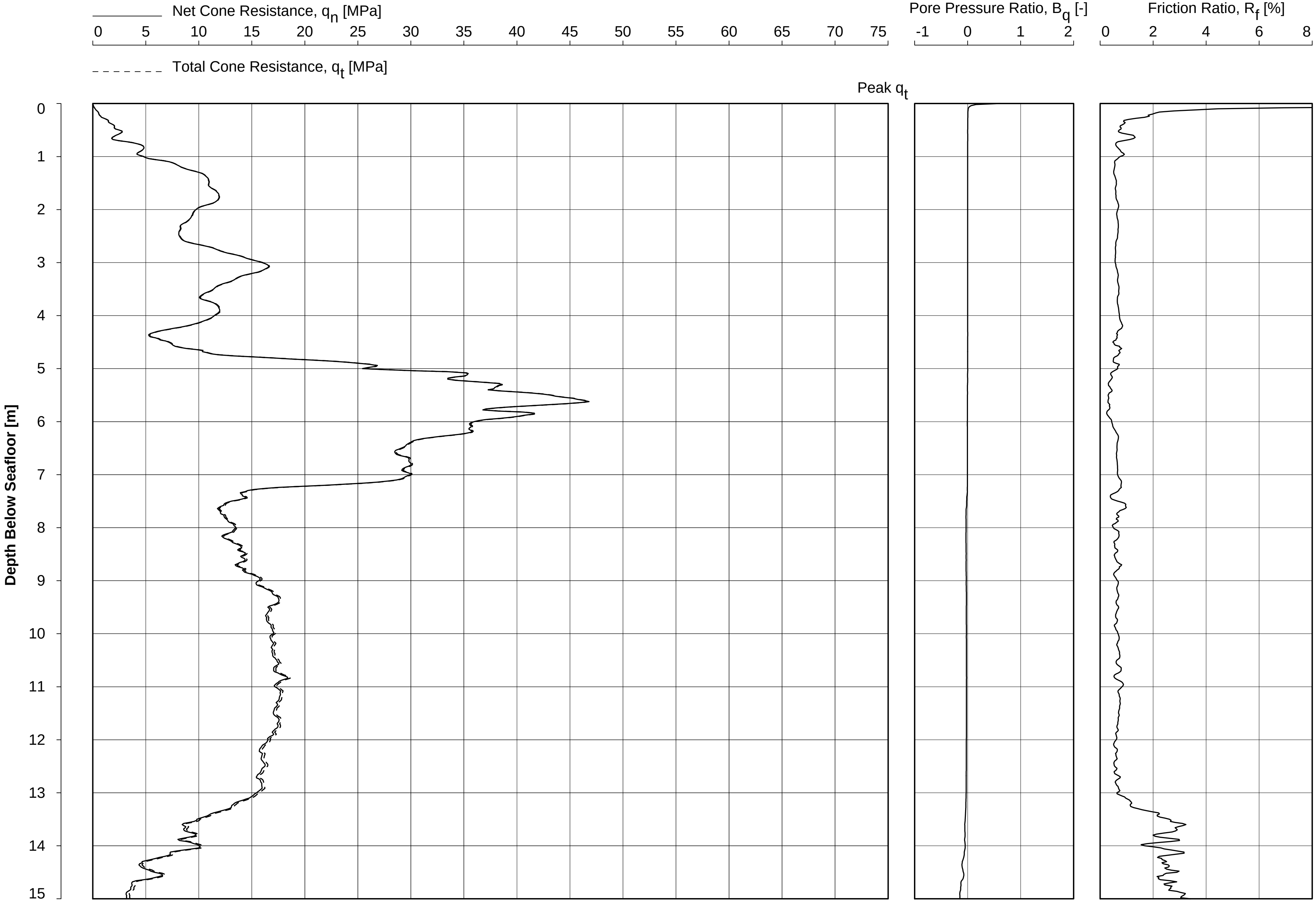
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_11A

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:22



Date Of Testing : 27-Oct-2015
Water Depth [m] : 32.6
Coordinates [m] : E497925 N5719860

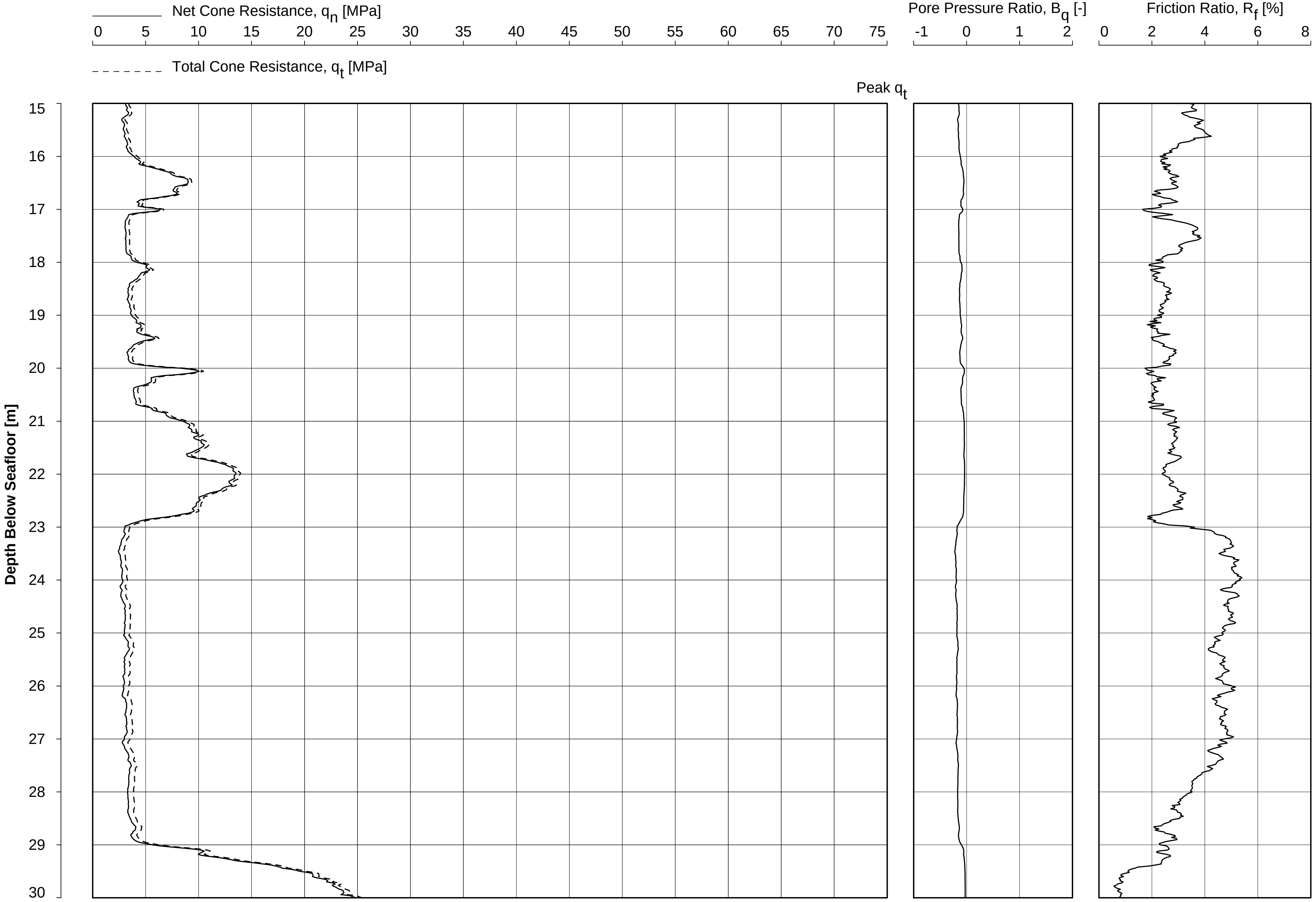
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_12

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:22



Date Of Testing : 27-Oct-2015
Water Depth [m] : 32.6
Coordinates [m] : E497925 N5719860

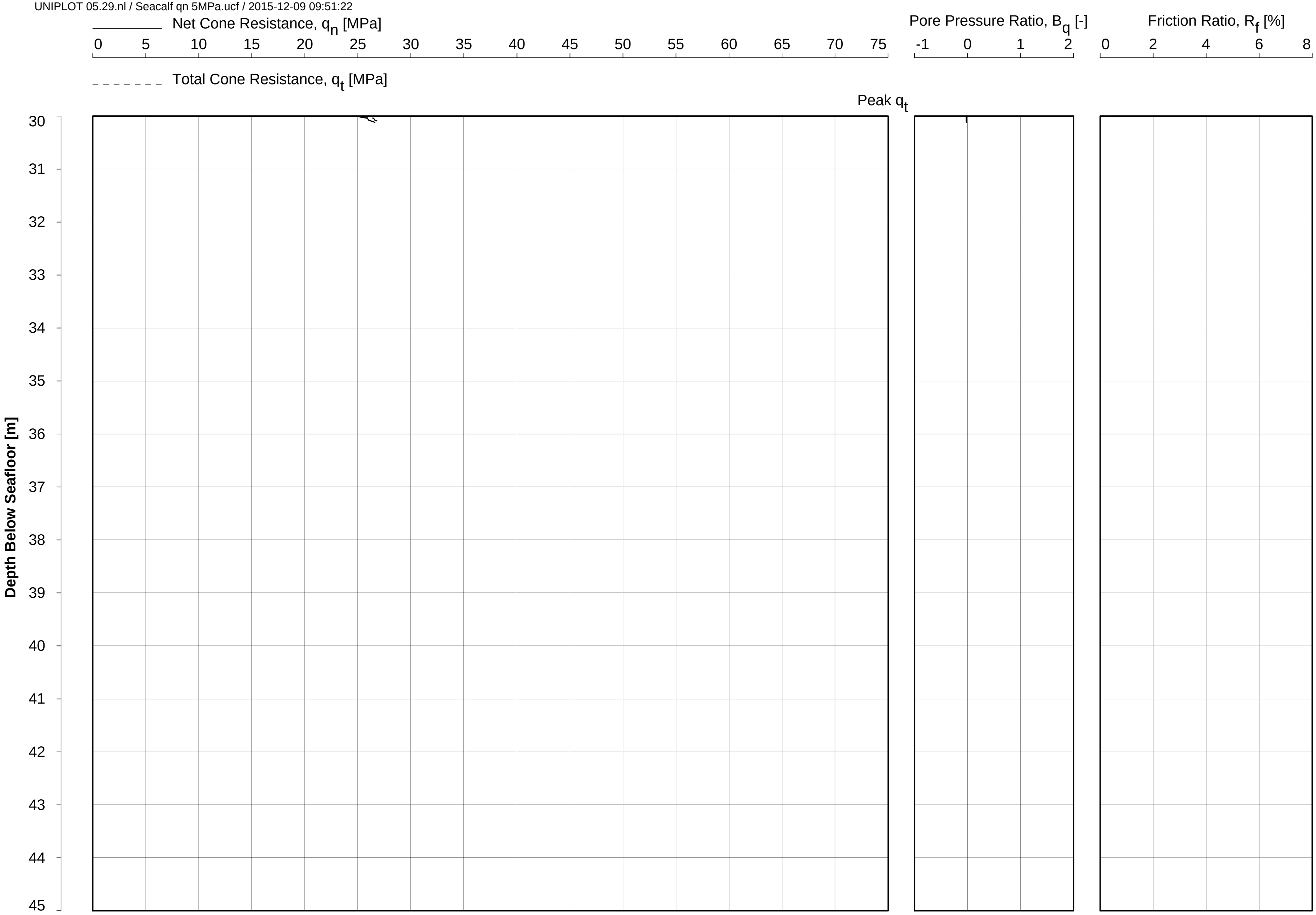
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_12

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:22



Date Of Testing : 27-Oct-2015
Water Depth [m] : 32.6
Coordinates [m] : E497925 N5719860

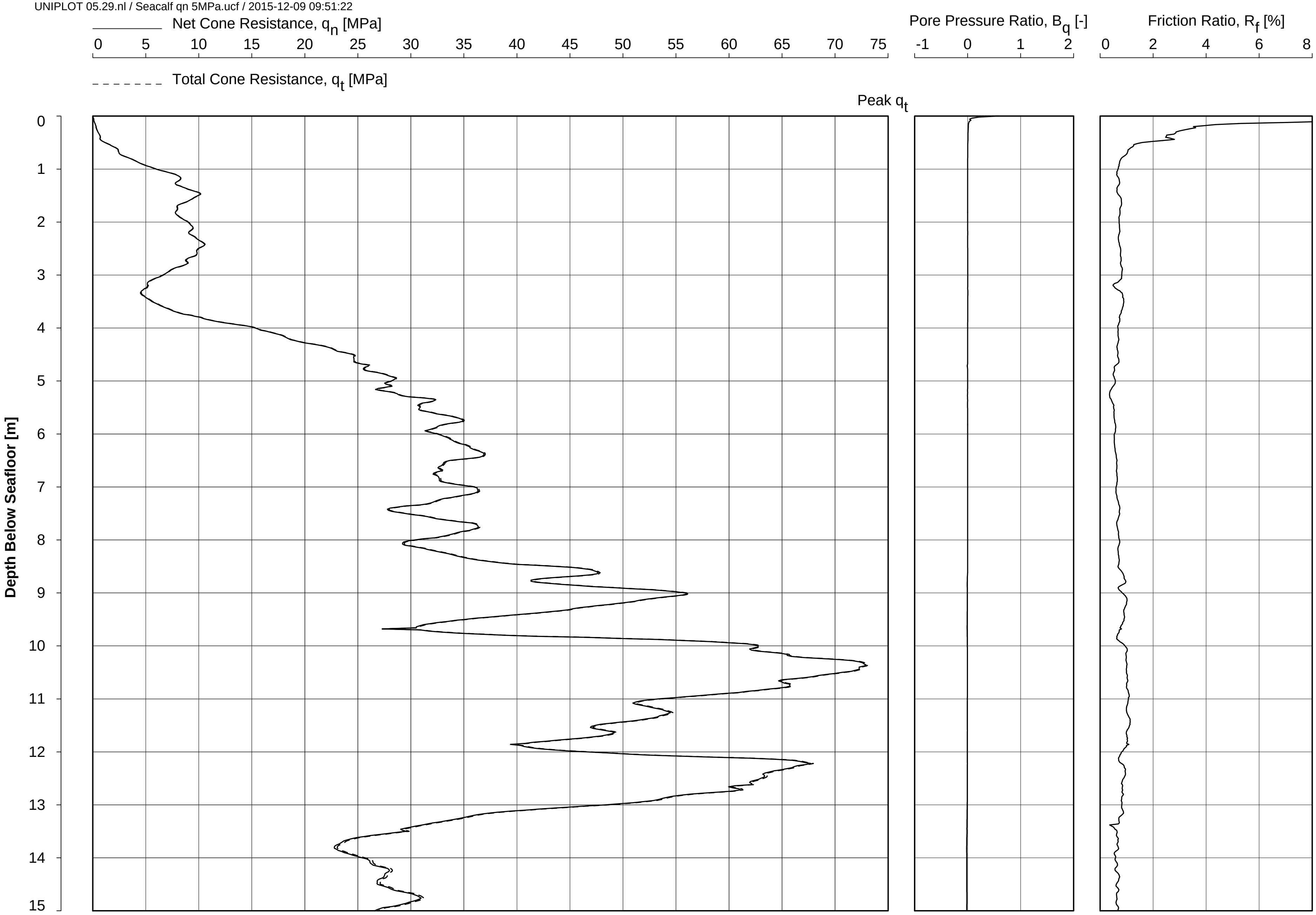
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_12

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:22



Date Of Testing : 26-Oct-2015
Water Depth [m] : 30.3
Coordinates [m] : E500855 N5723291

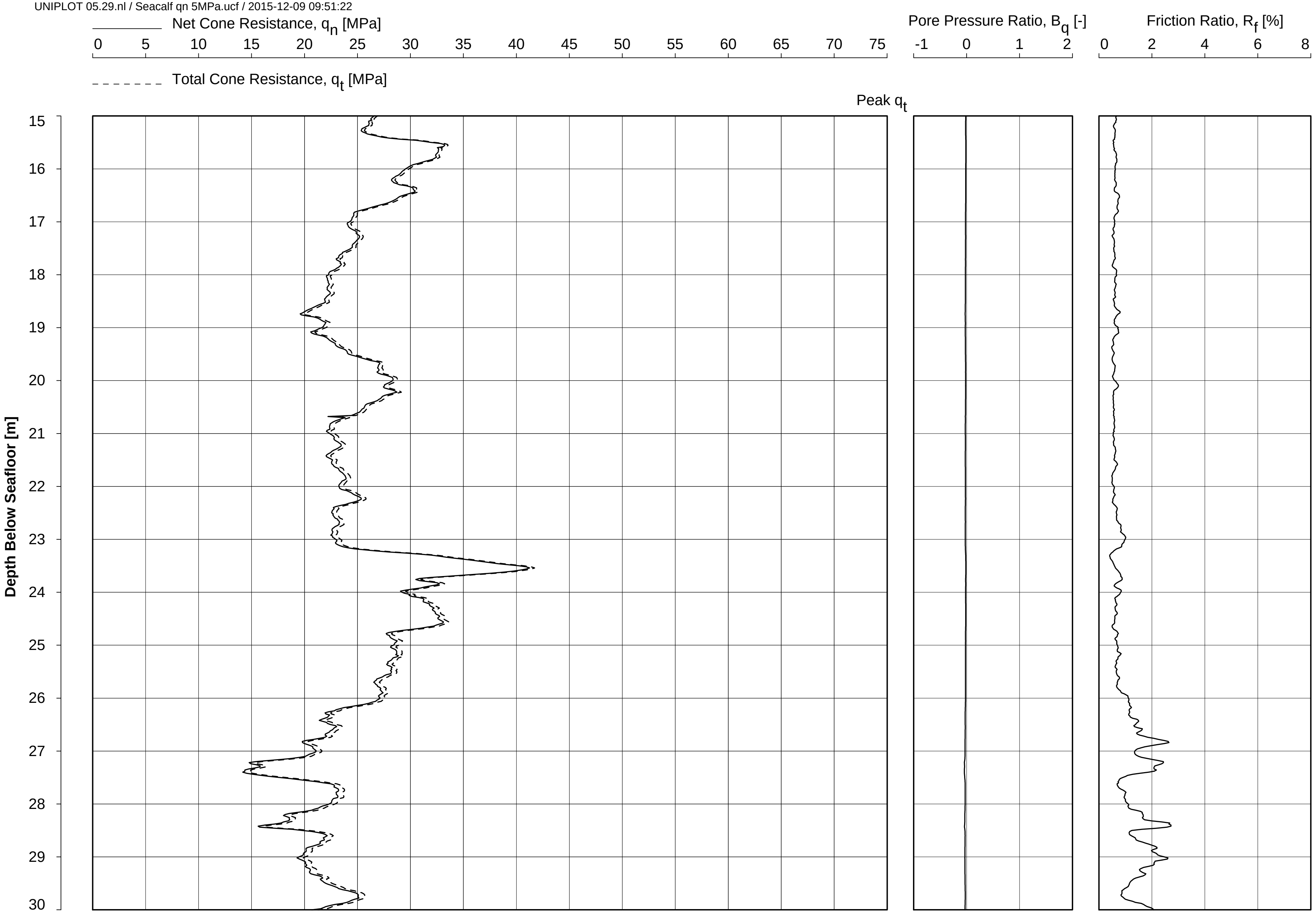
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_13

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:22



Date Of Testing : 26-Oct-2015
Water Depth [m] : 30.3
Coordinates [m] : E500855 N5723291

Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

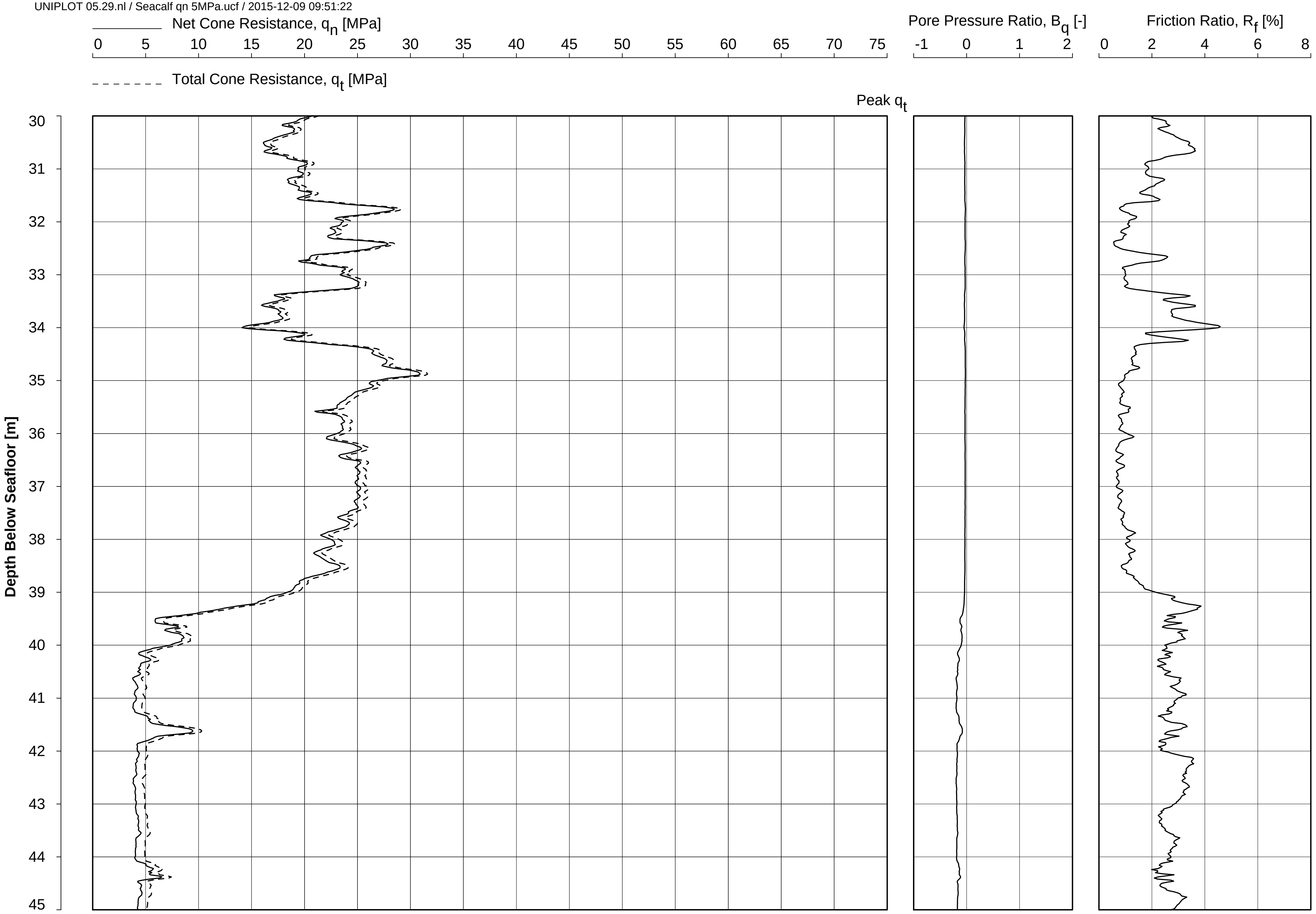
CONE PENETRATION TEST

CPT_WFS3_13

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:22



Date Of Testing : 26-Oct-2015
Water Depth [m] : 30.3
Coordinates [m] : E500855 N5723291

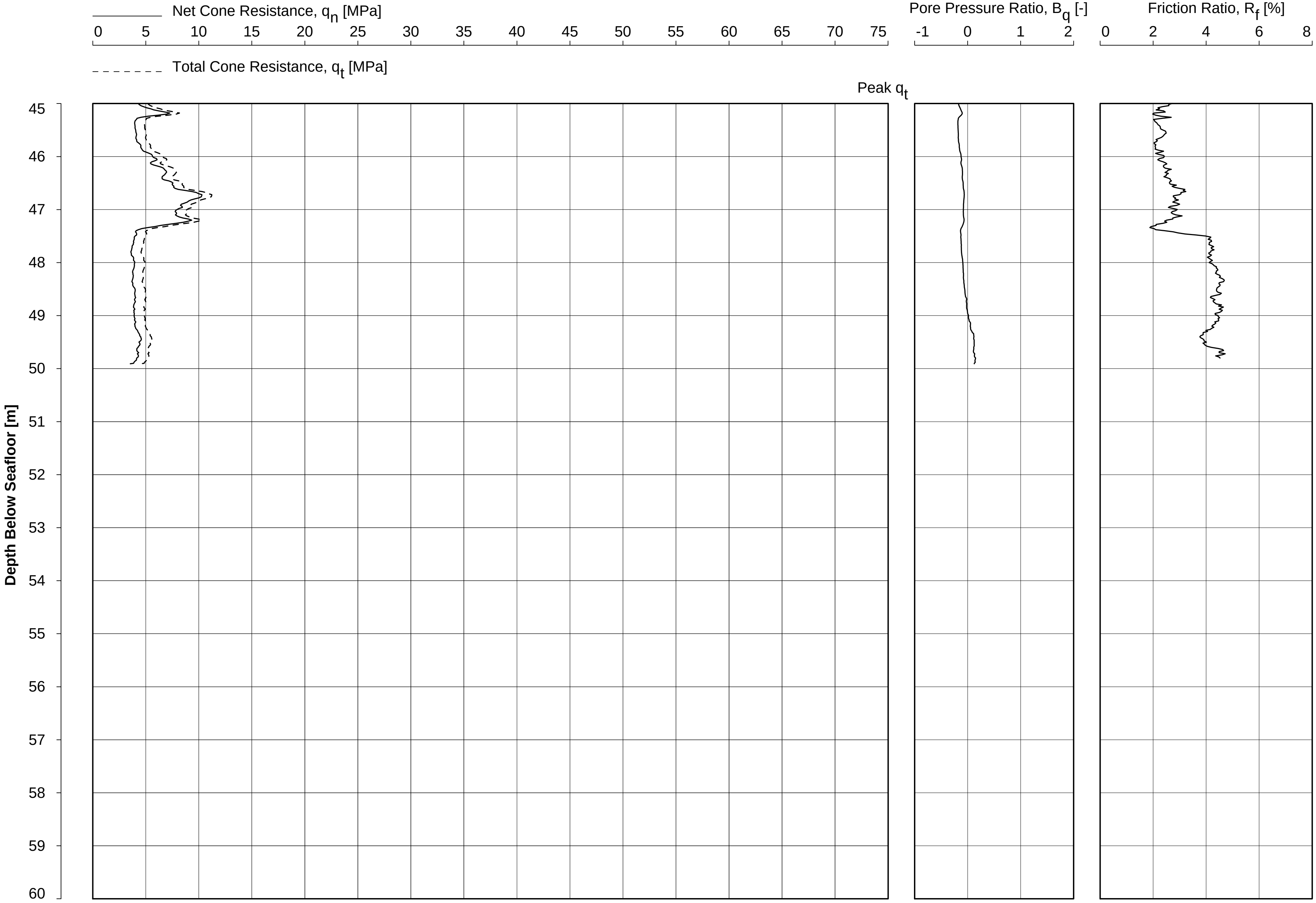
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_13

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:23



Date Of Testing : 26-Oct-2015
Water Depth [m] : 30.3
Coordinates [m] : E500855 N5723291

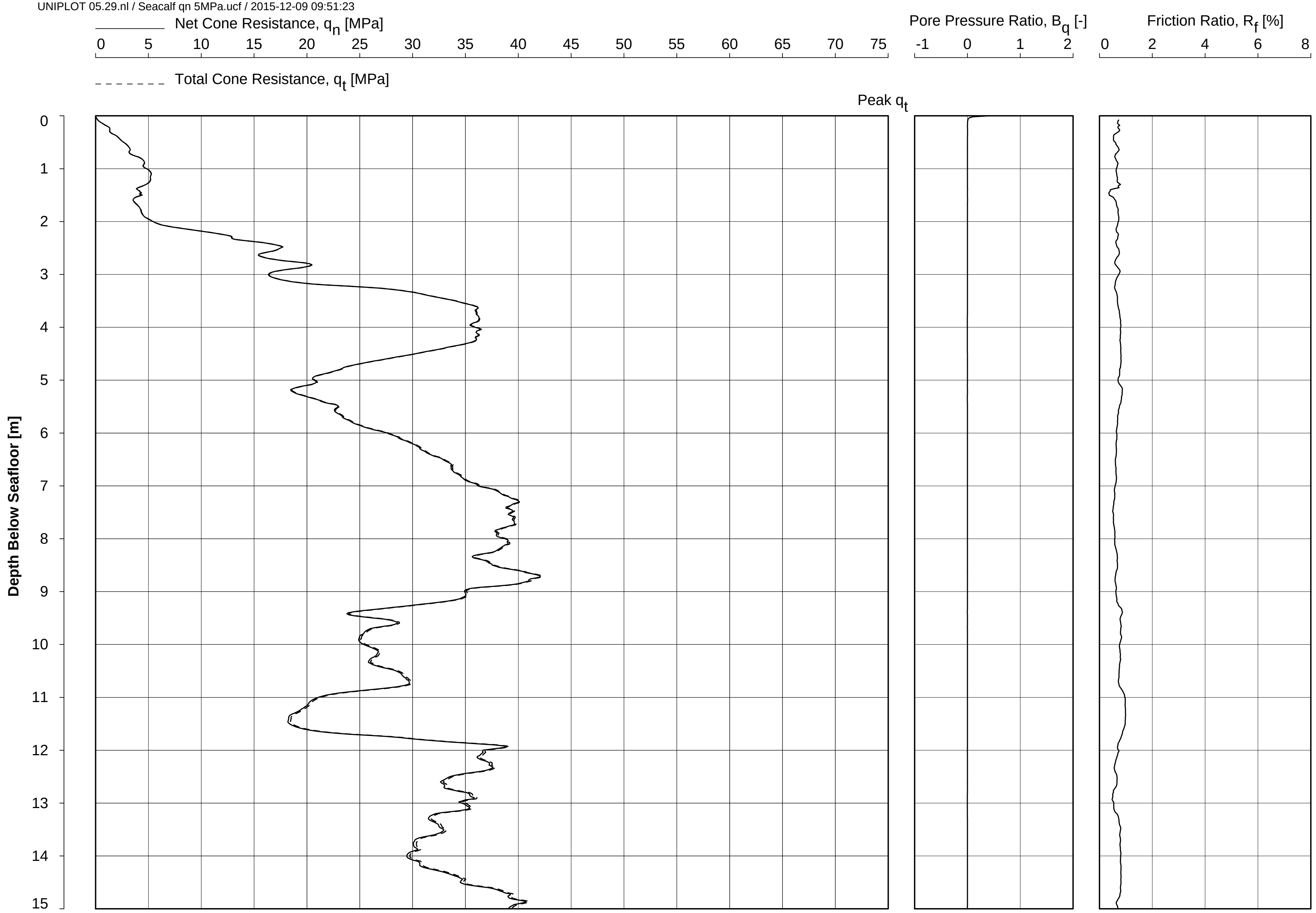
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_13

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:23



Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E494938 N5726134

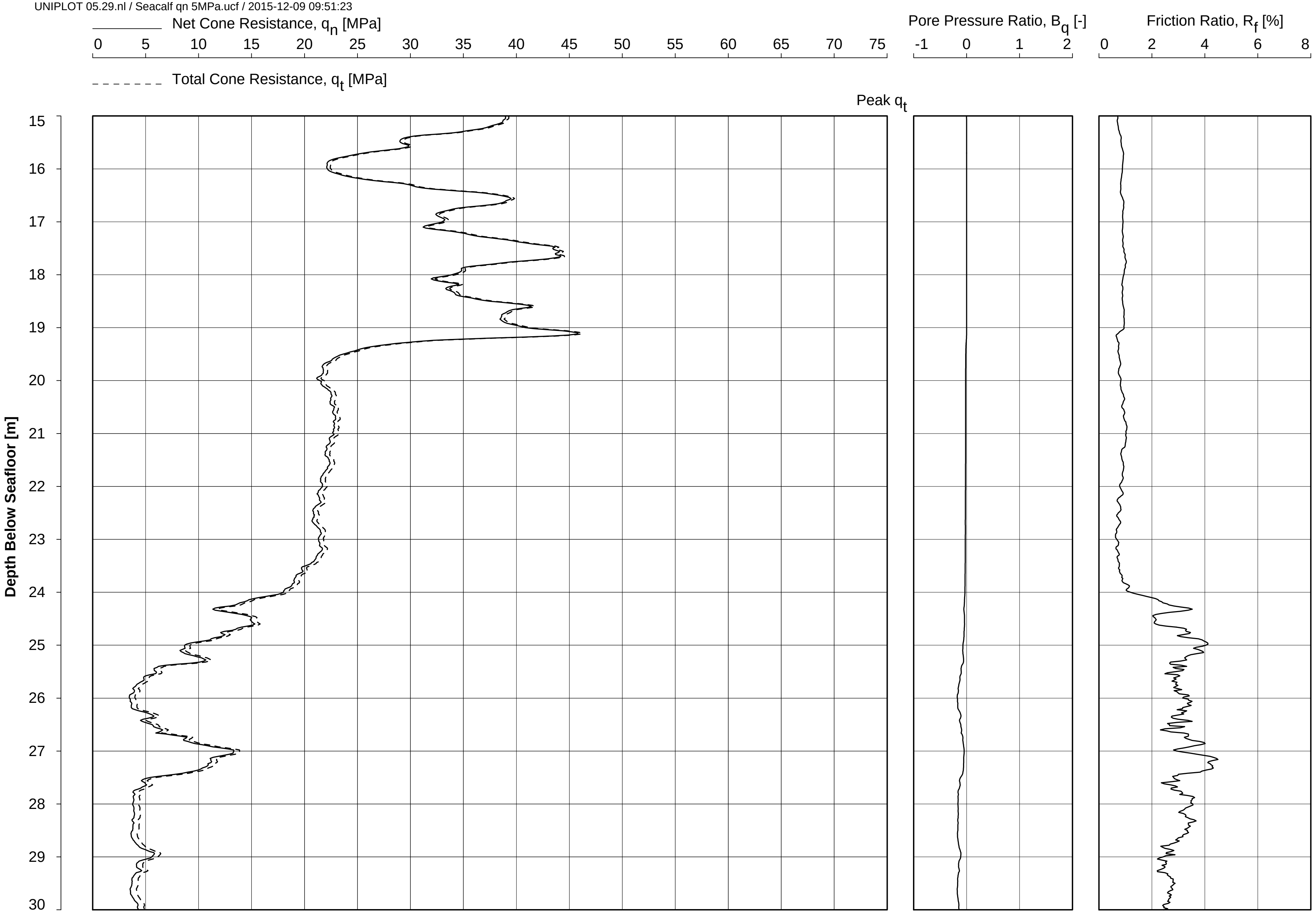
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_14

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:23



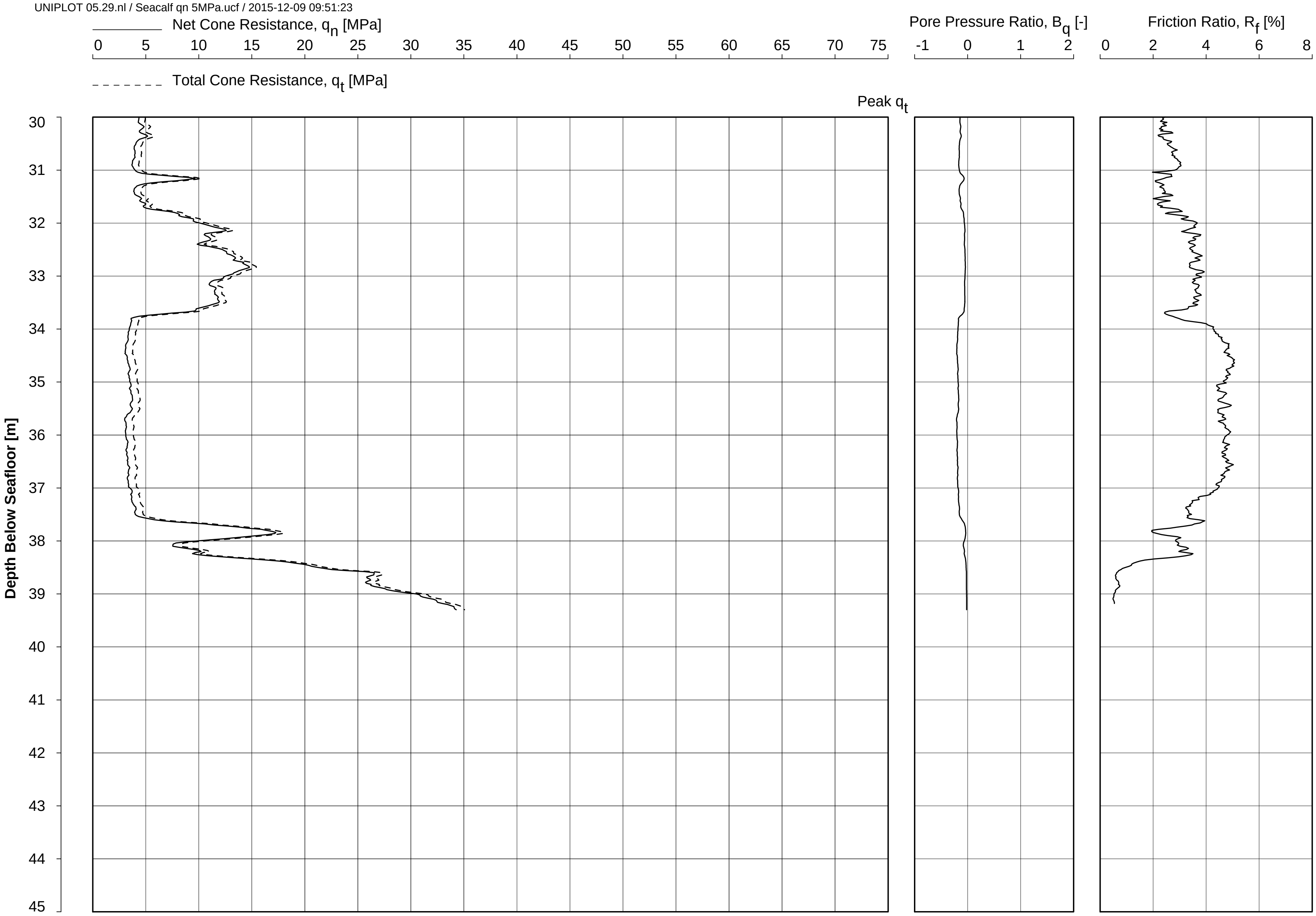
Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E494938 N5726134

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_14

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 29-Oct-2015

Water Depth [m] : 30.9

Coordinates [m] : E494938 N5726134

Probe Type : CP15-CF75PB20SN2

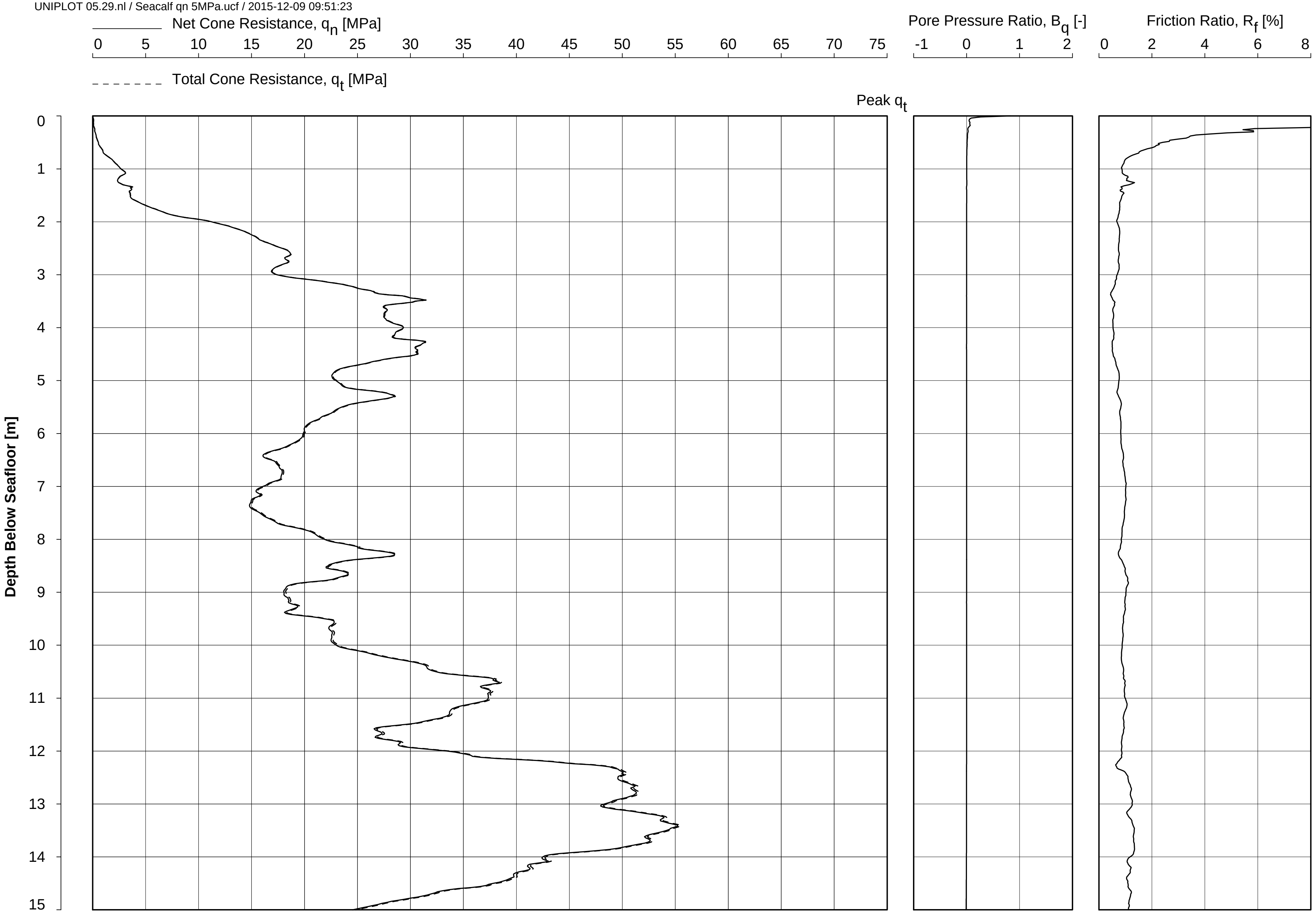
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_14

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:23



Date Of Testing : 29-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496545 N5727484

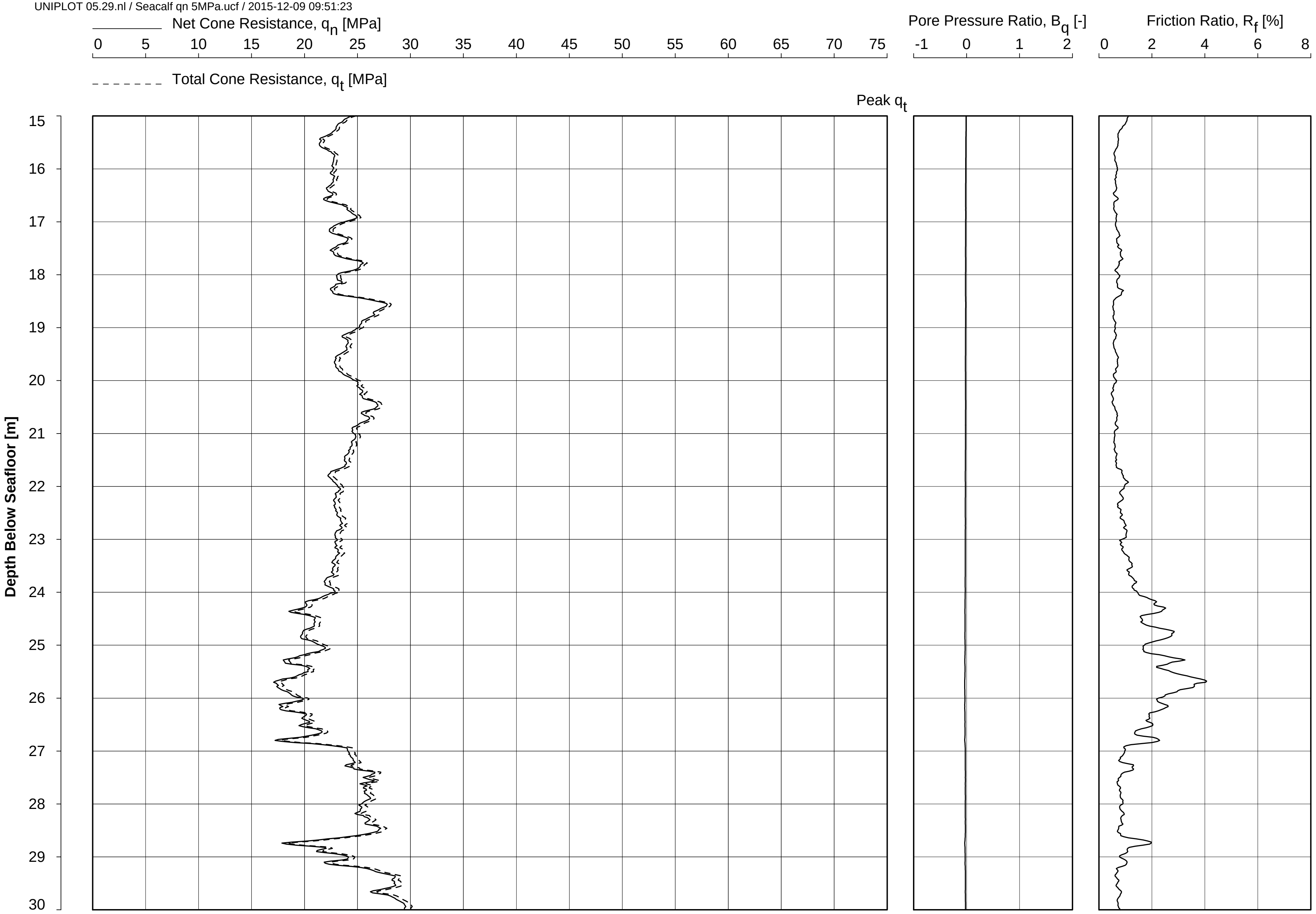
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_15

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:23



Date Of Testing : 29-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496545 N5727484

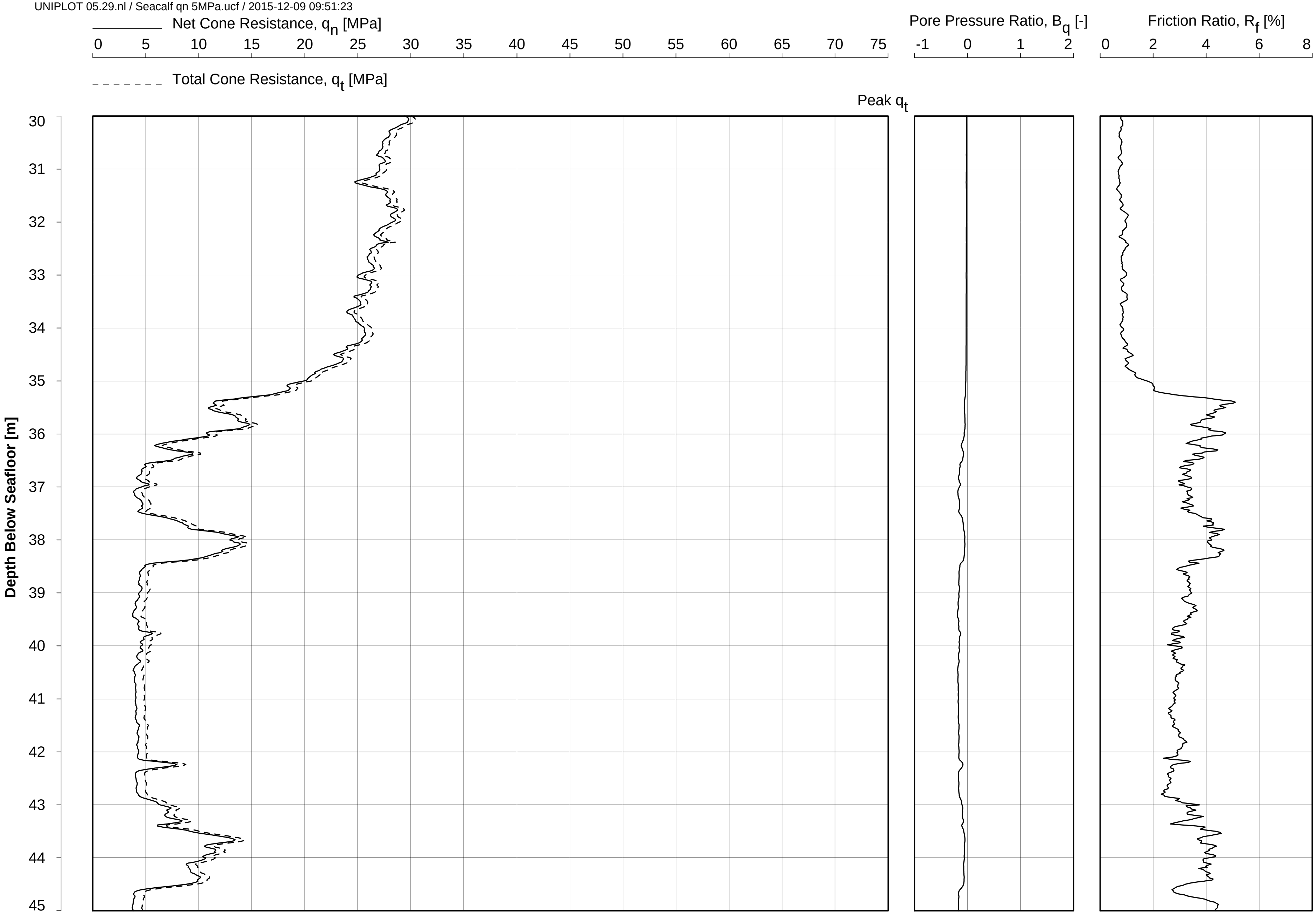
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_15

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:23



Date Of Testing : 29-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496545 N5727484

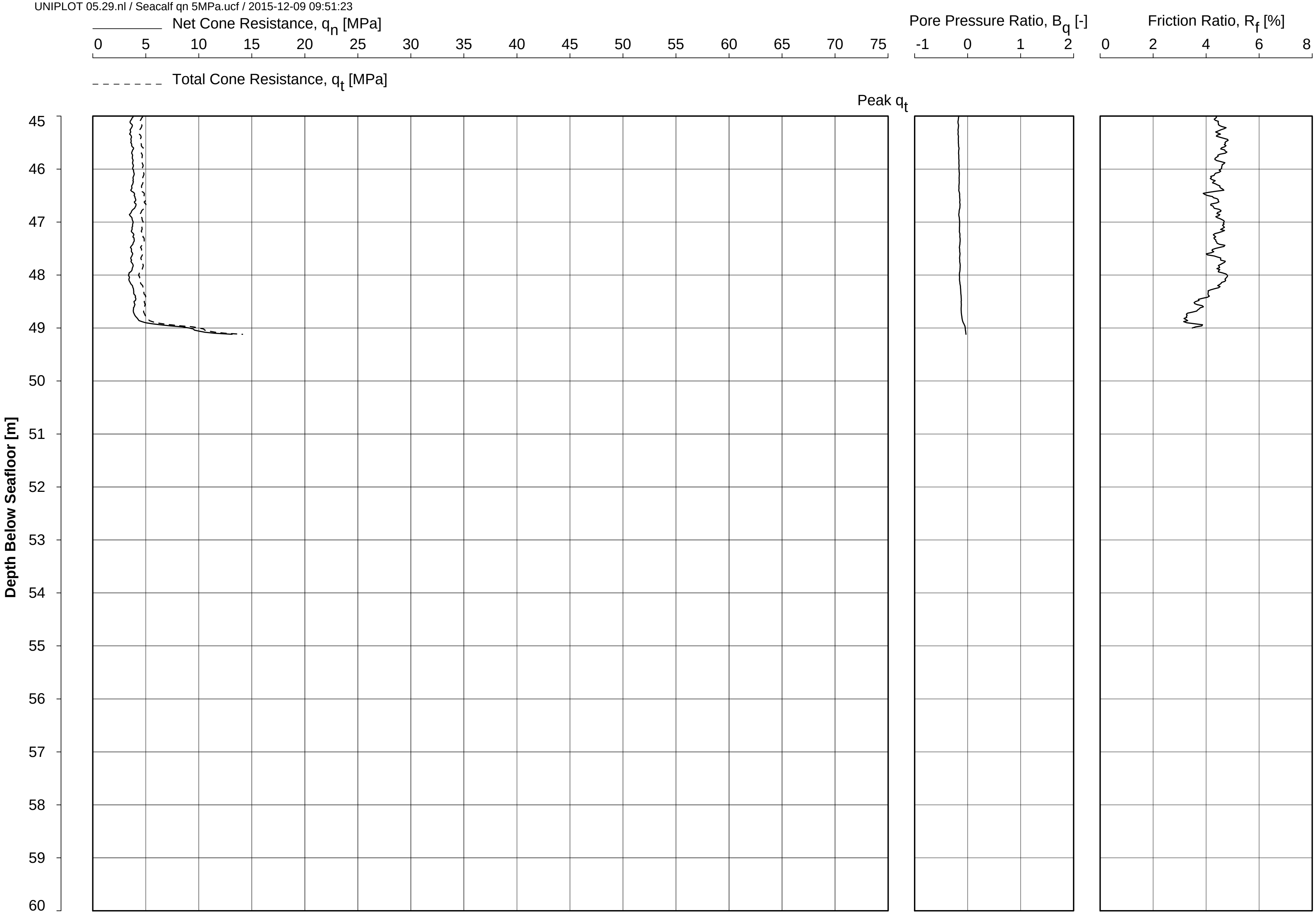
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_15

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:23



Date Of Testing : 29-Oct-2015
Water Depth [m] : 33.6
Coordinates [m] : E496545 N5727484

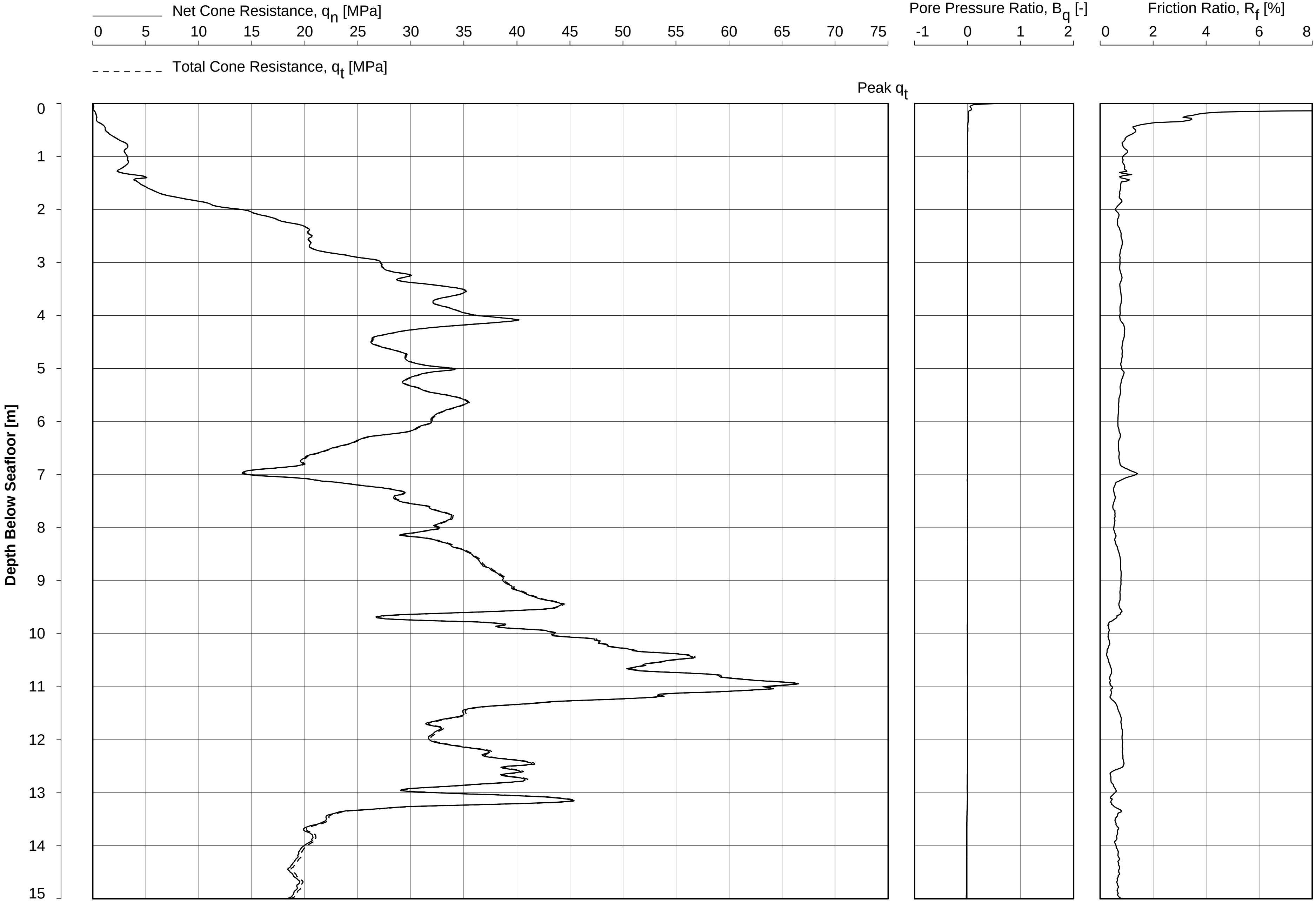
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_15

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:23



Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E495274 N5727833

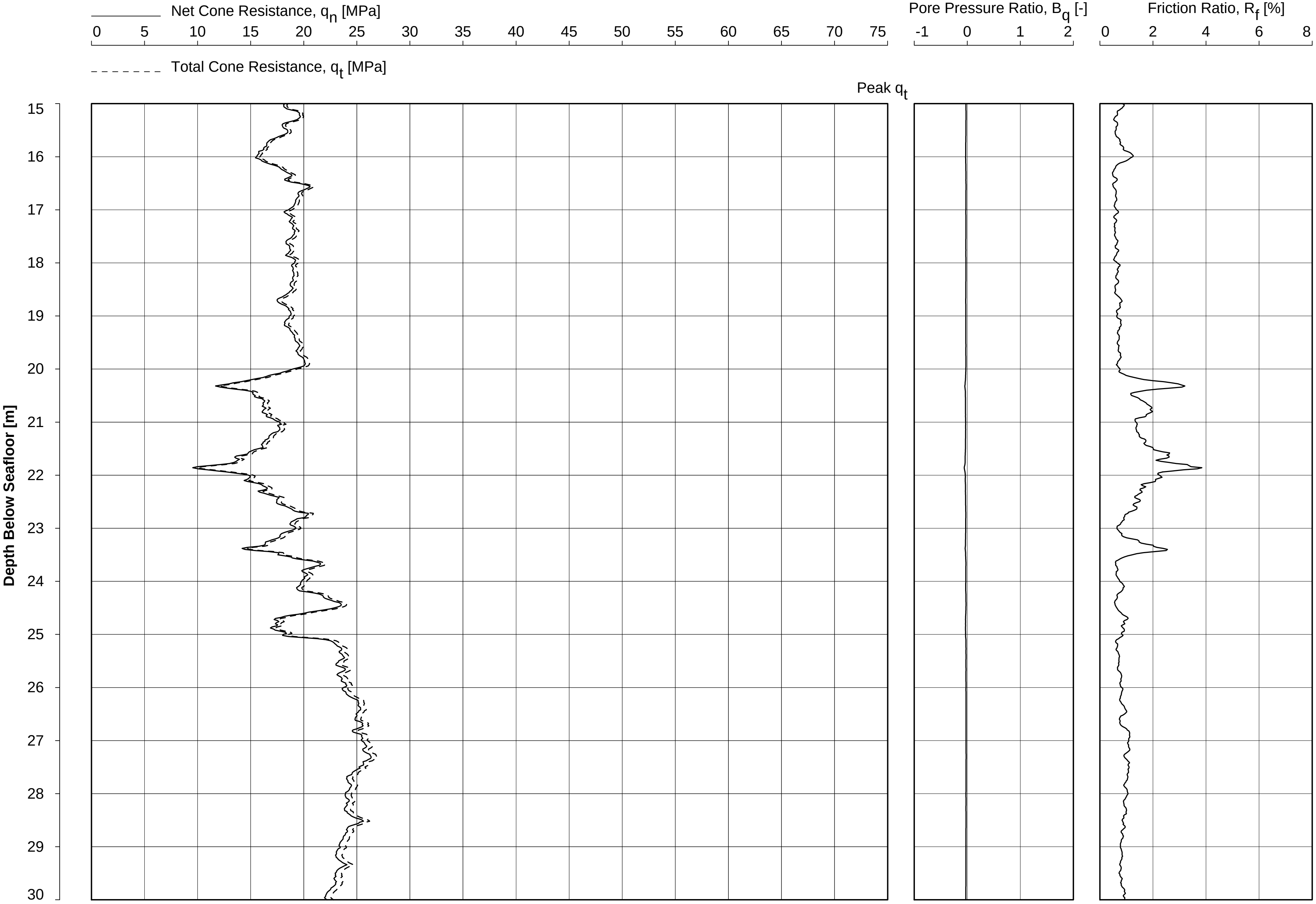
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_16

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:23



Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E495274 N5727833

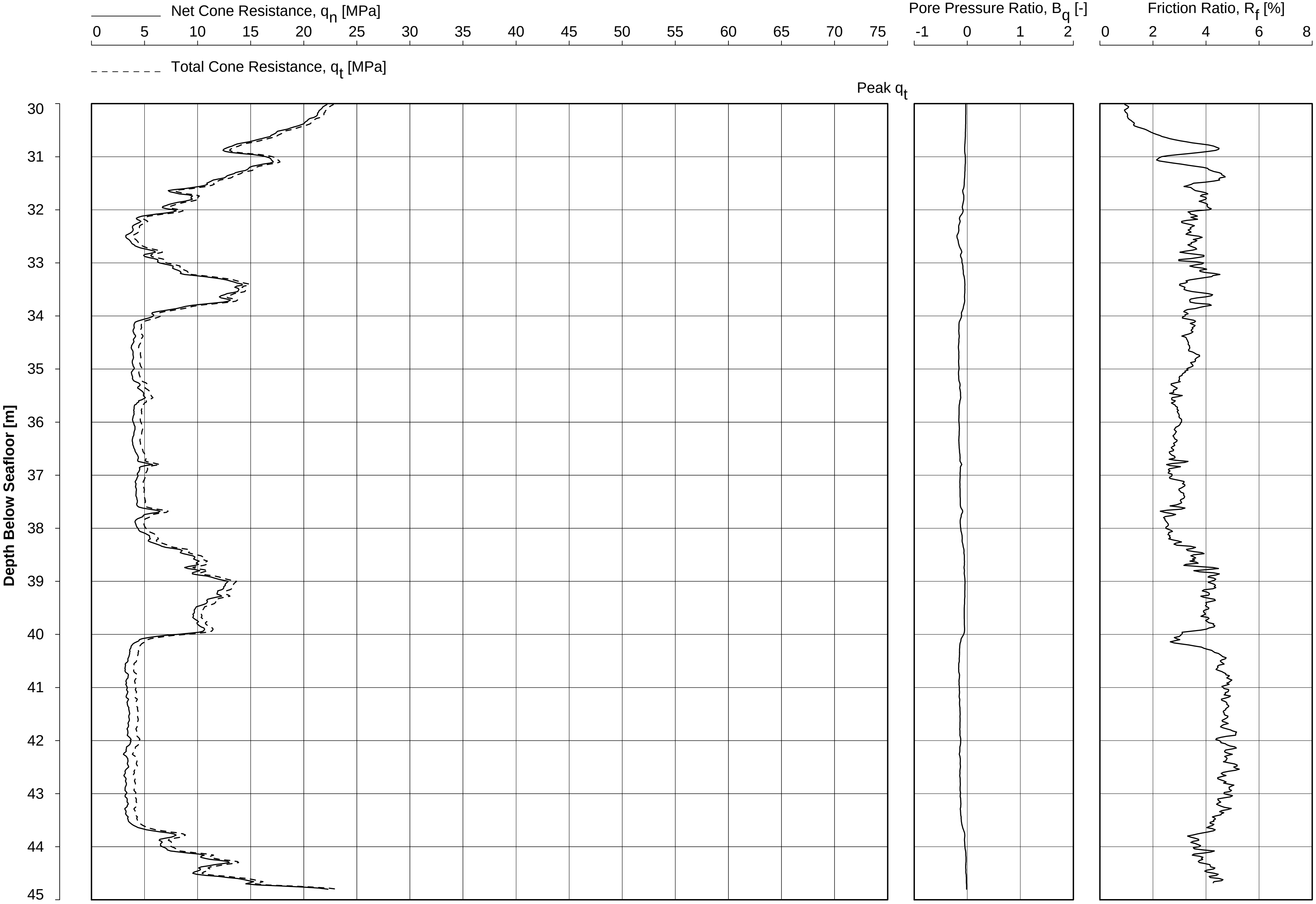
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_16

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:23



Date Of Testing : 29-Oct-2015
Water Depth [m] : 30.9
Coordinates [m] : E495274 N5727833

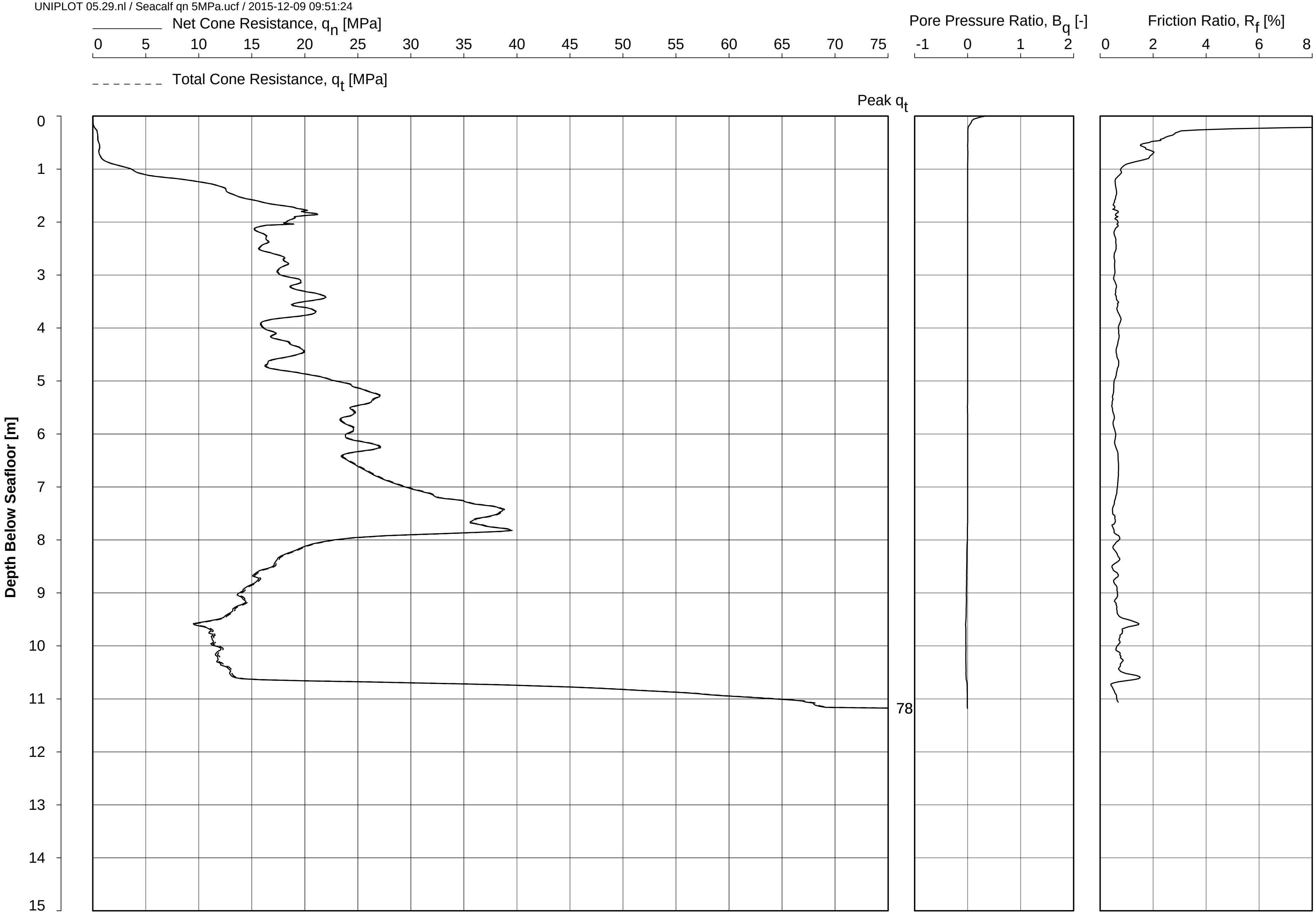
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_16

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:24



Date Of Testing : 31-Oct-2015
Water Depth [m] : 33.1
Coordinates [m] : E497485 N5728646

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

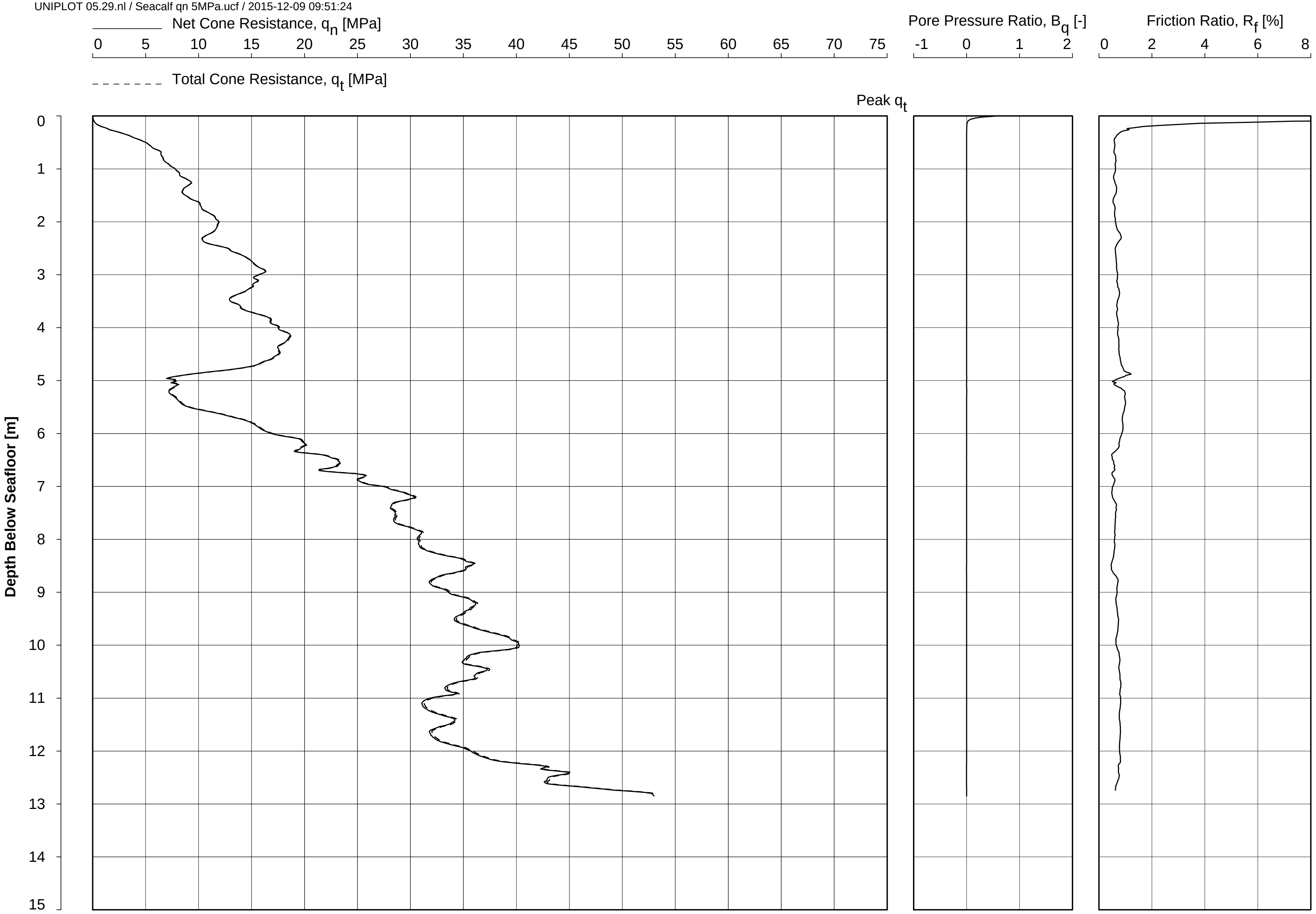
CONE PENETRATION TEST

CPT_WFS3_17

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

Fugro Report No. N6083/02 (2)

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:24



Date Of Testing : 28-Oct-2015
Water Depth [m] : 29.1
Coordinates [m] : E494599 N5724469

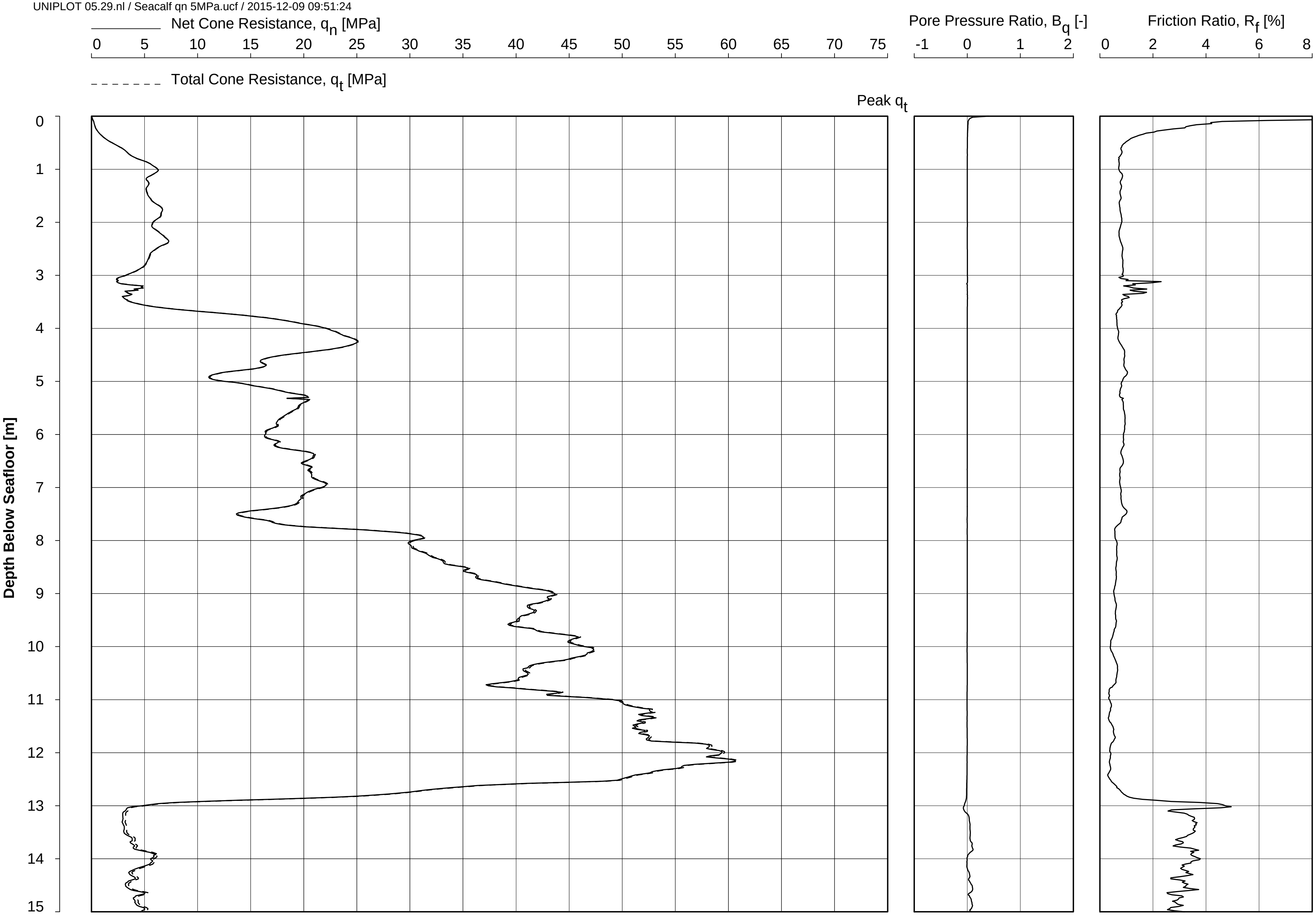
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_18

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:24



Date Of Testing : 28-Oct-2015
Water Depth [m] : 30.2
Coordinates [m] : E492527 N5725094

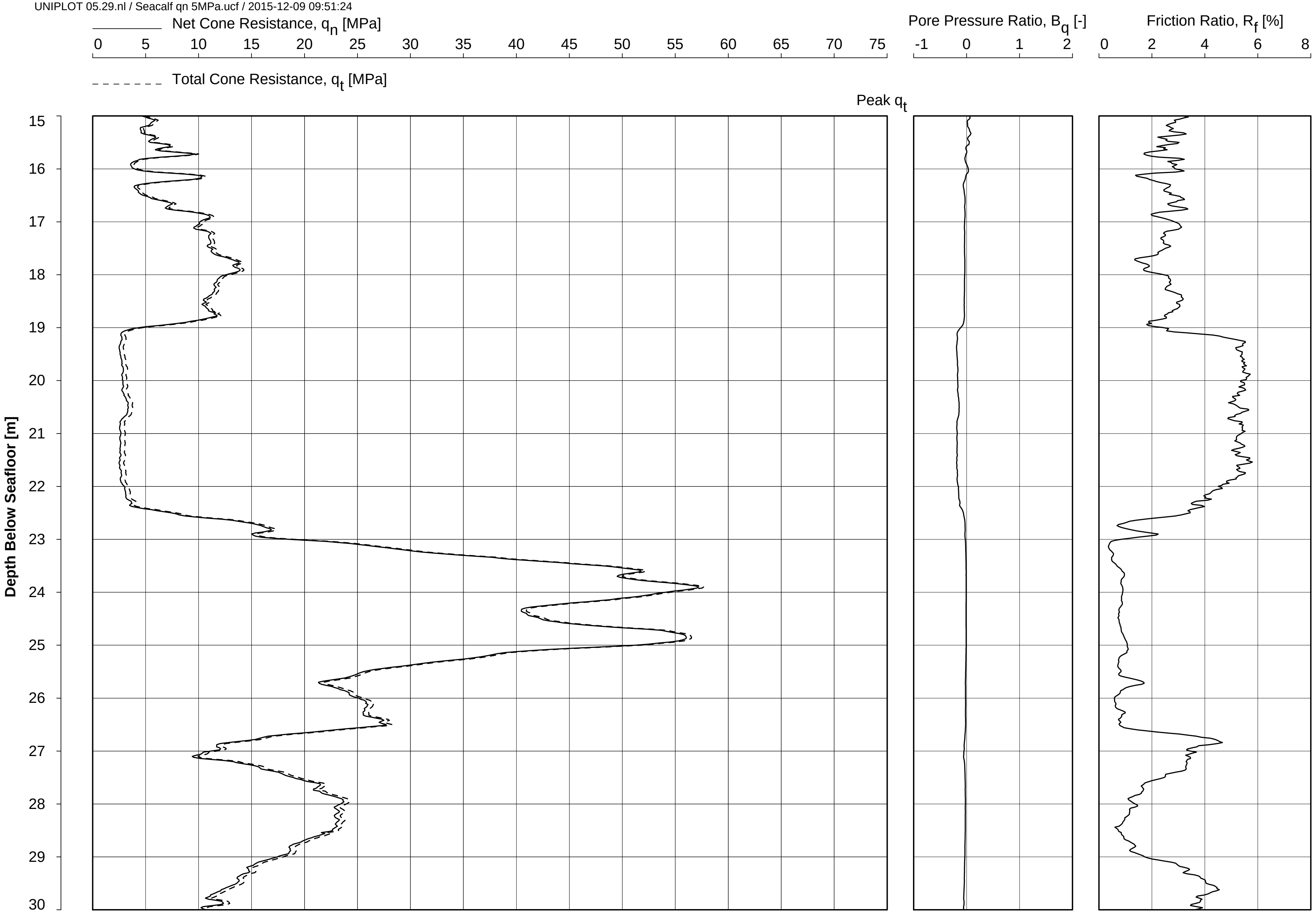
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_19

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:24



Date Of Testing : 28-Oct-2015
Water Depth [m] : 30.2
Coordinates [m] : E492527 N5725094

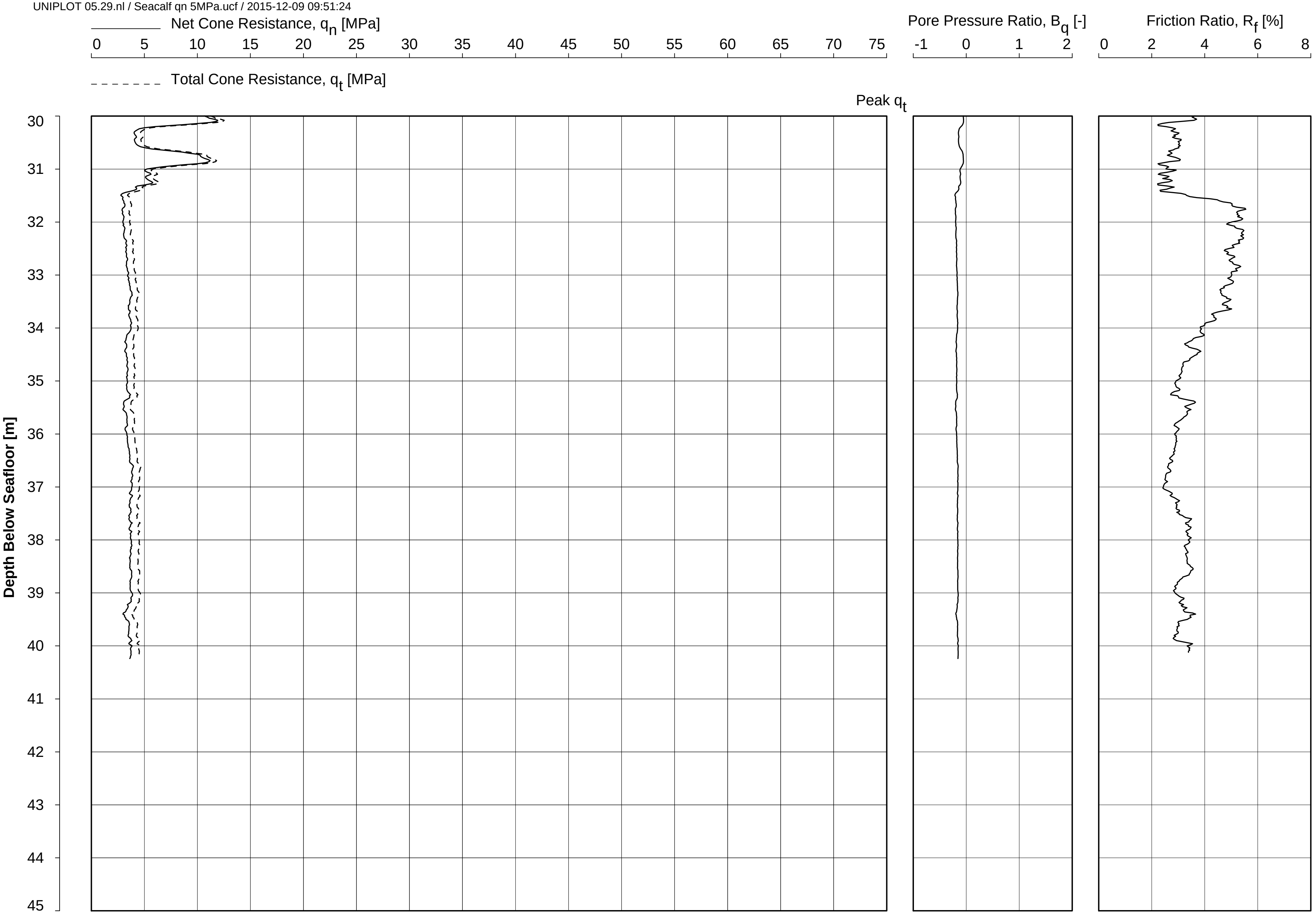
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm²] : 1510

CONE PENETRATION TEST

CPT_WFS3_19

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:24



Date Of Testing : 28-Oct-2015

Water Depth [m] : 30.2

Coordinates [m] : E492527 N5725094

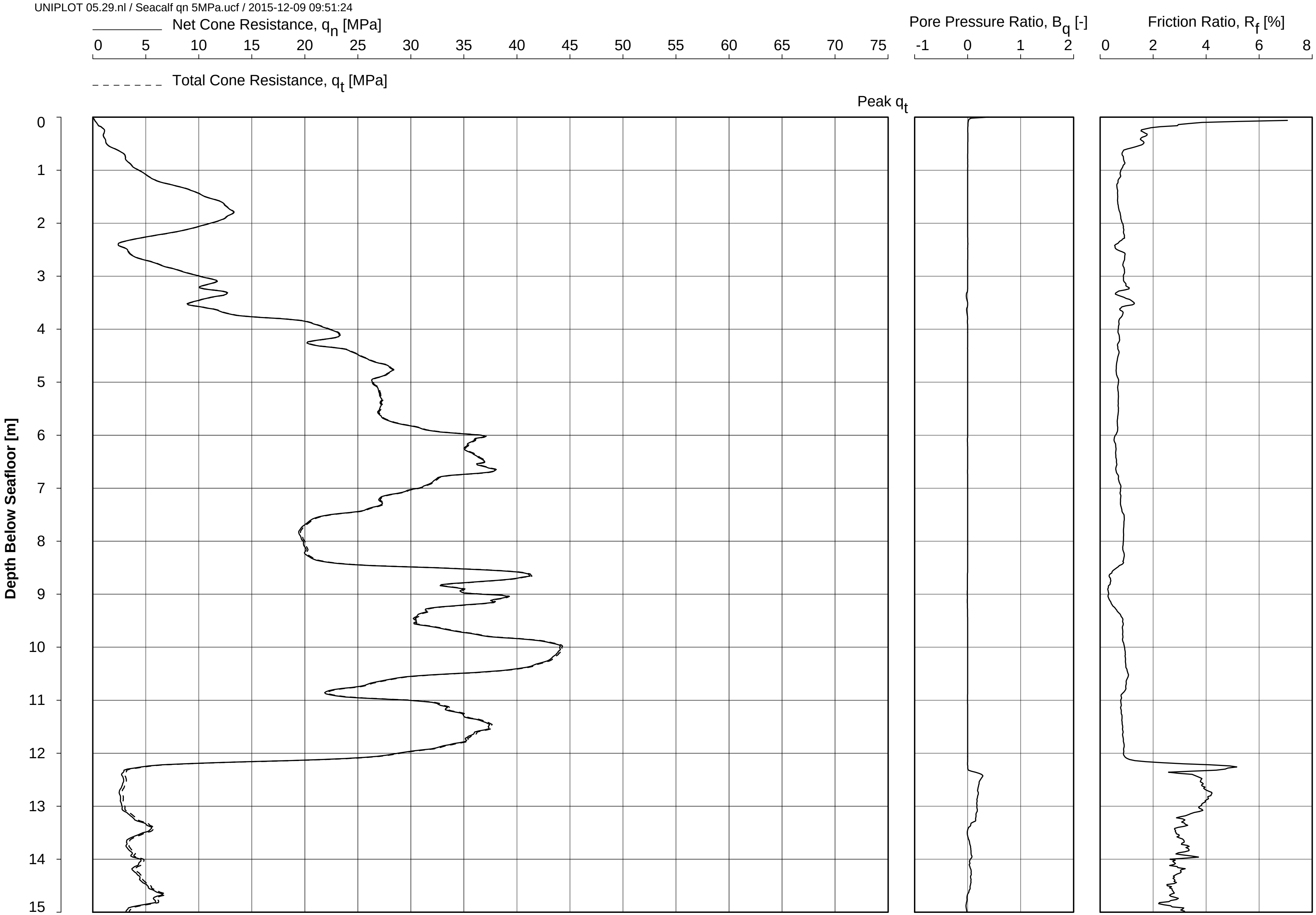
Probe Type : CP15-CF75PB20SN2

Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_19

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



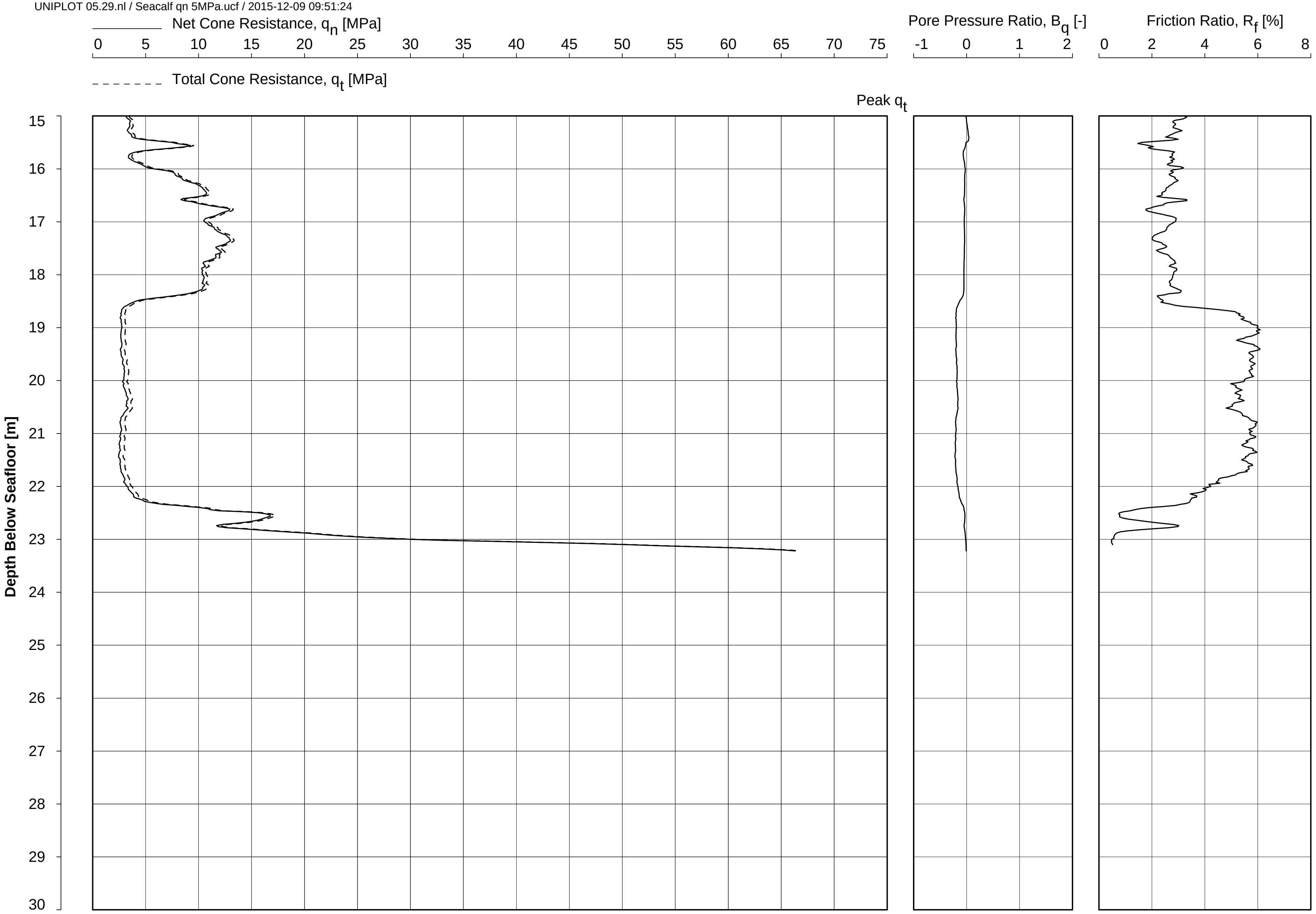
Date Of Testing	: 28-Oct-2015	Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 31.1	Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E493397 N5724254		

CONE PENETRATION TEST

CPT_WFS3_20

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:24



Date Of Testing : 28-Oct-2015
Water Depth [m] : 31.1
Coordinates [m] : E493397 N5724254

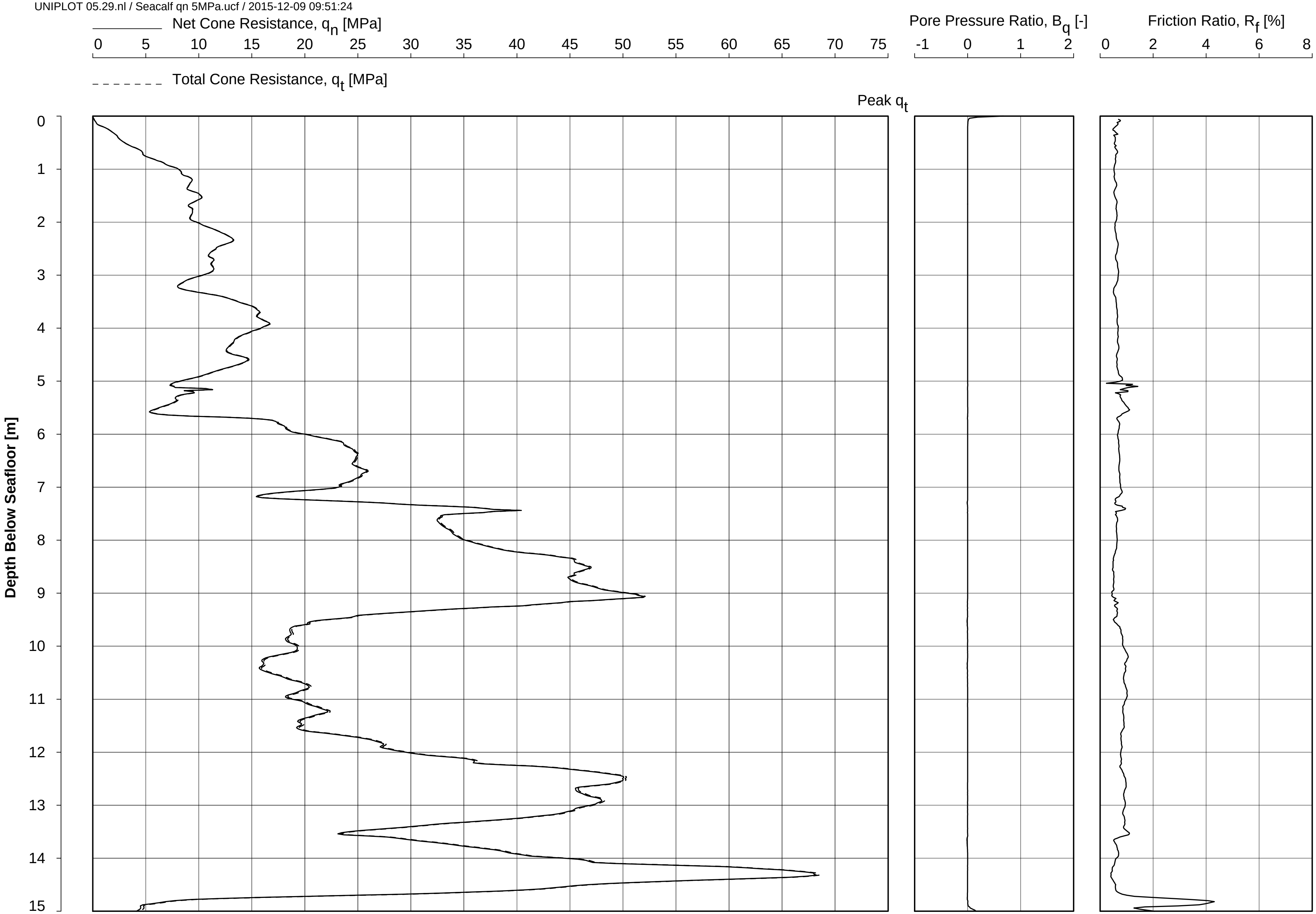
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_20

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:24



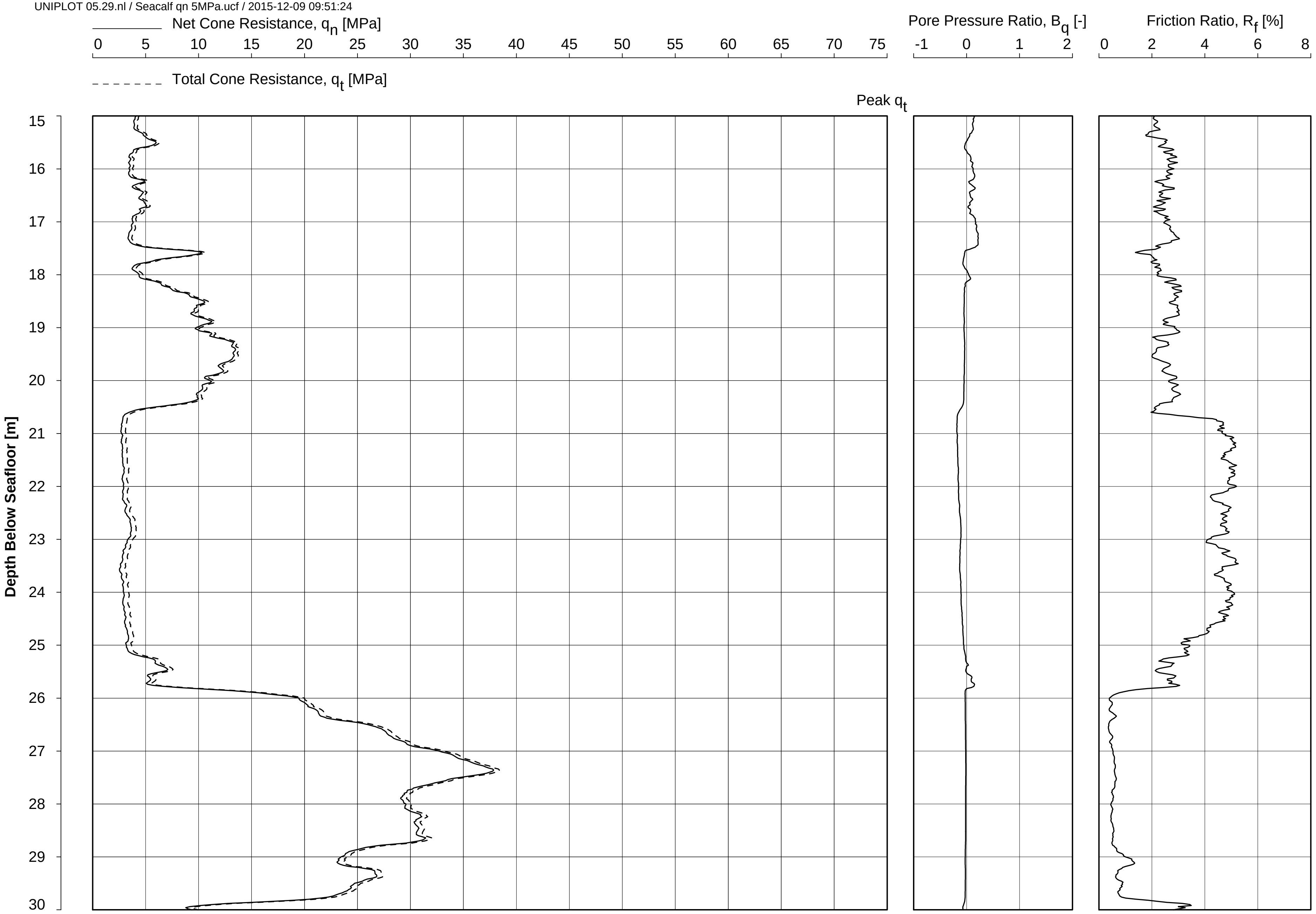
Date Of Testing	: 28-Oct-2015	Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 29.9	Cone Base Area [mm²]	: 1510
Coordinates [m]	: E494845 N5722865		

CONE PENETRATION TEST

CPT_WFS3_21

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:24



Date Of Testing : 28-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E494845 N5722865

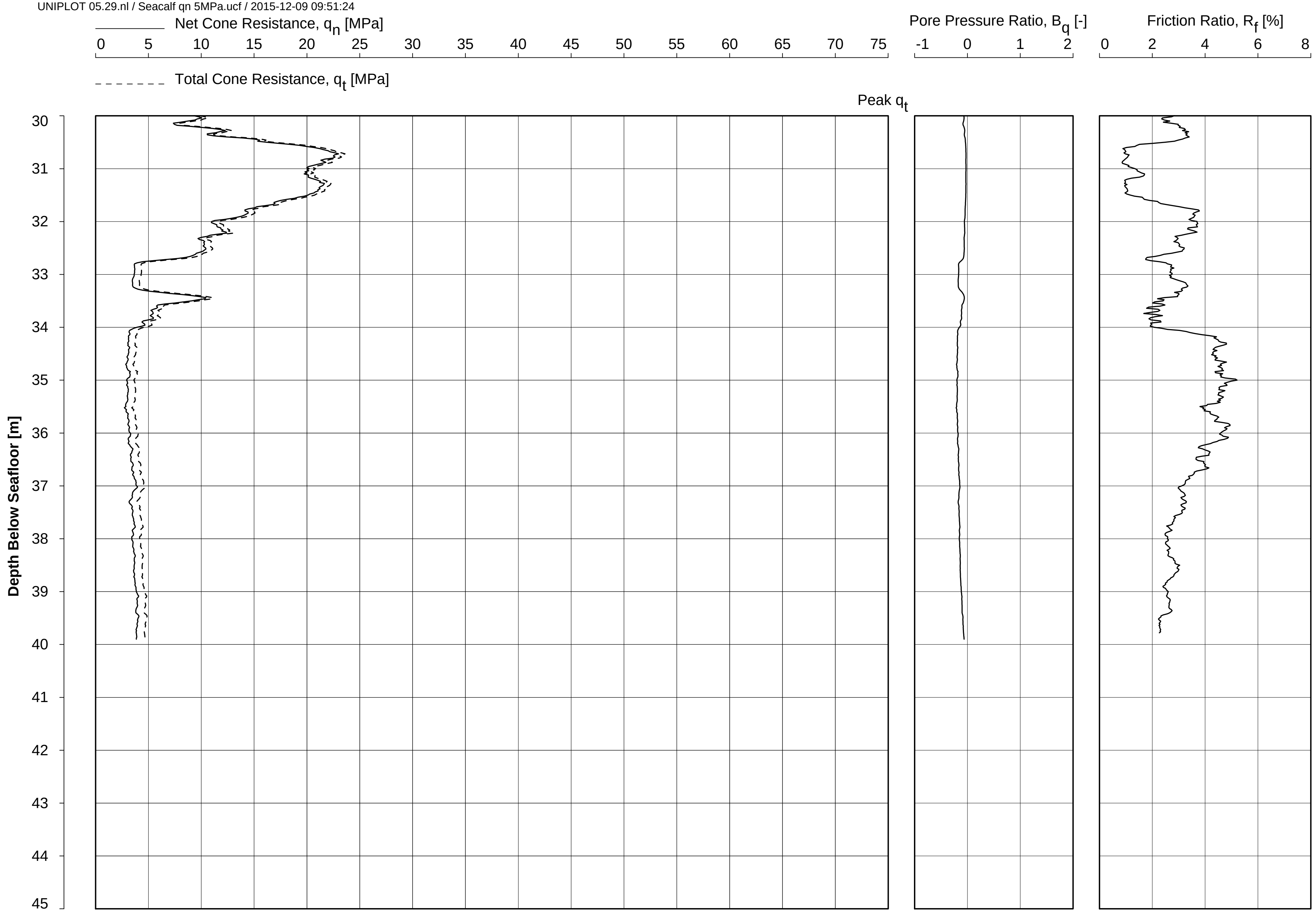
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_21

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:24



Date Of Testing : 28-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E494845 N5722865

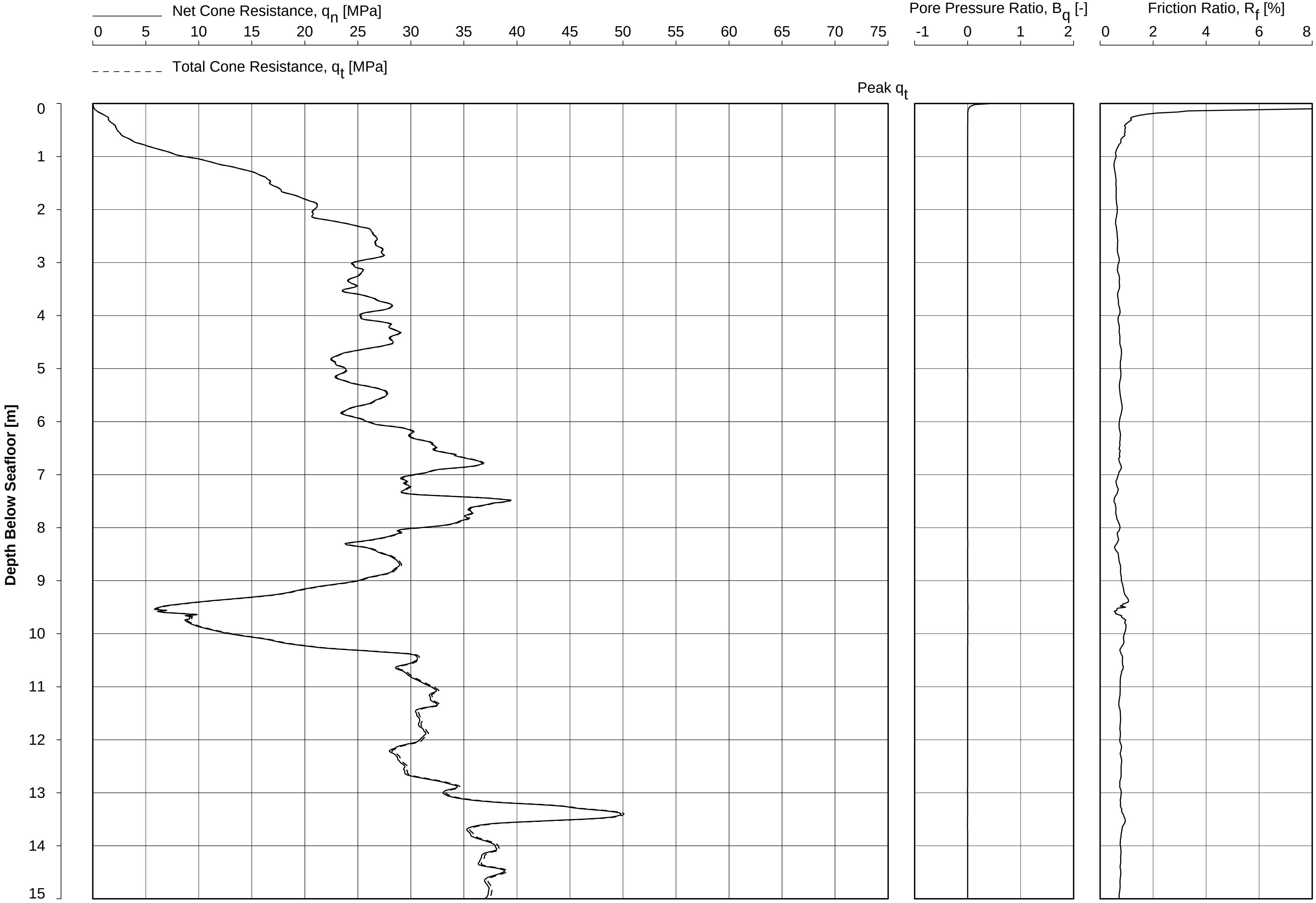
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_21

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:25



Date Of Testing : 26-Oct-2015
Water Depth [m] : 22.0
Coordinates [m] : E498189 N5723807

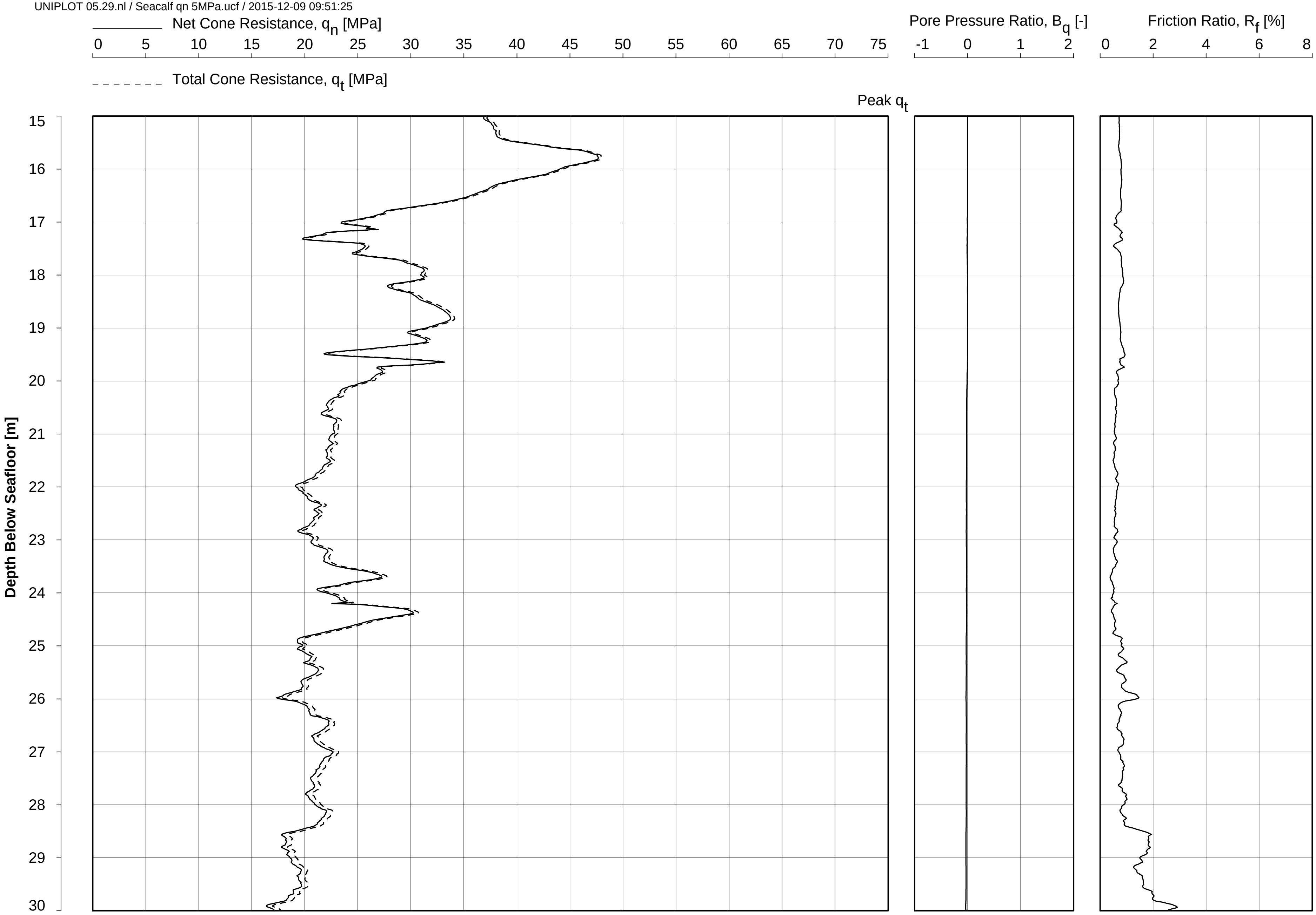
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_22

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:25



Date Of Testing : 26-Oct-2015
Water Depth [m] : 22.0
Coordinates [m] : E498189 N5723807

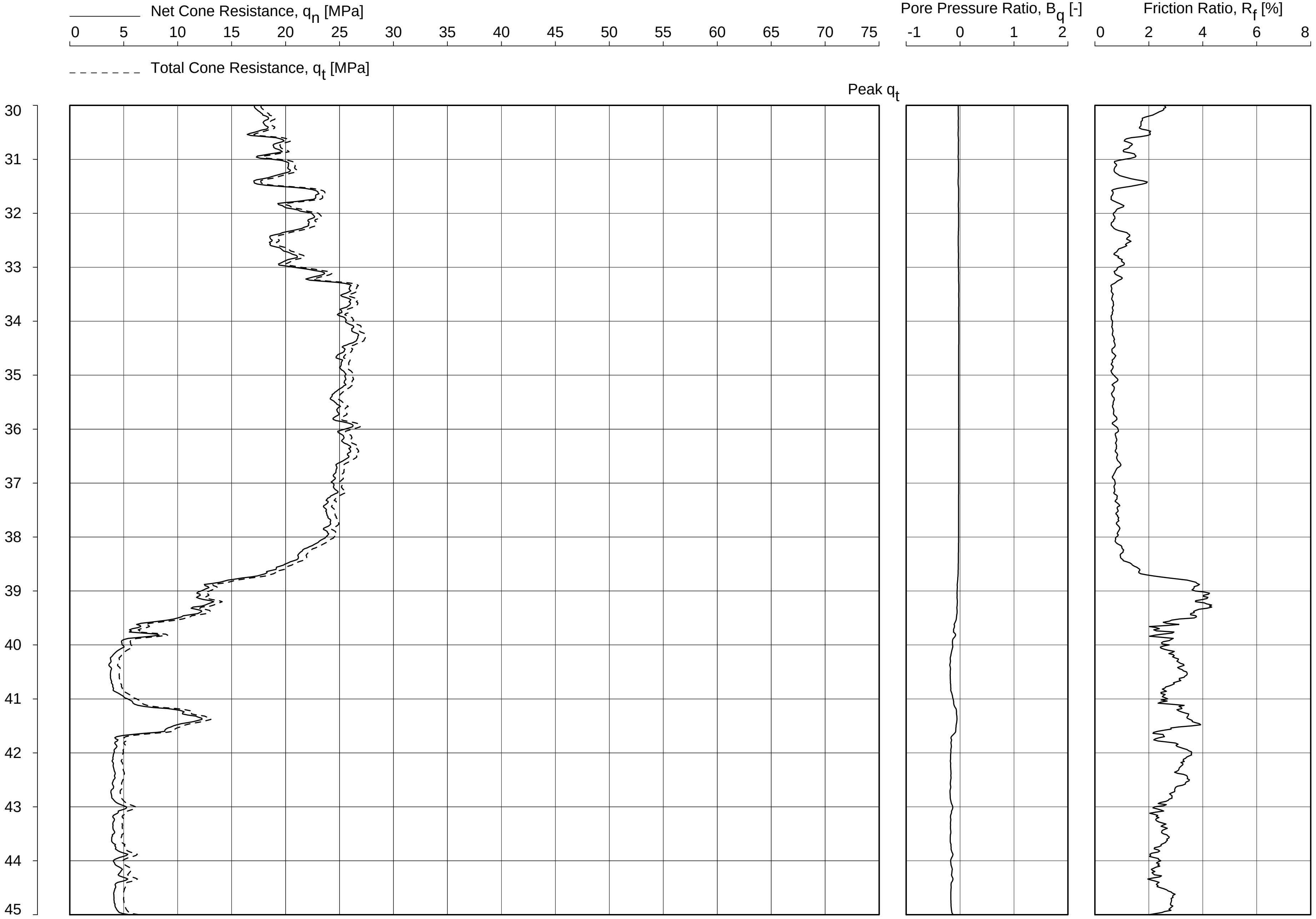
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_22

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:25



Date Of Testing : 26-Oct-2015
Water Depth [m] : 22.0
Coordinates [m] : E498189 N5723807

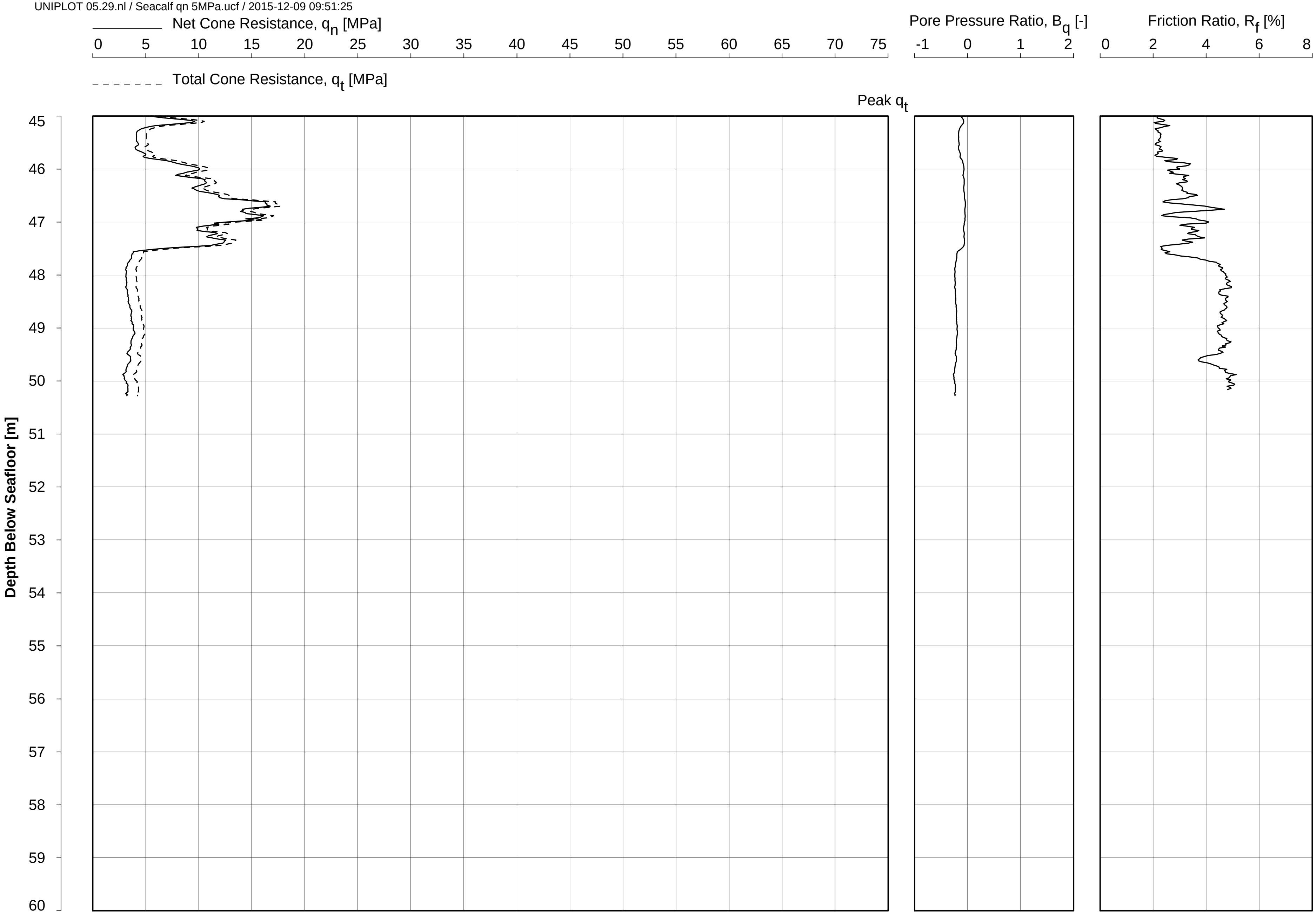
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_22

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:25



Date Of Testing : 26-Oct-2015
Water Depth [m] : 22.0
Coordinates [m] : E498189 N5723807

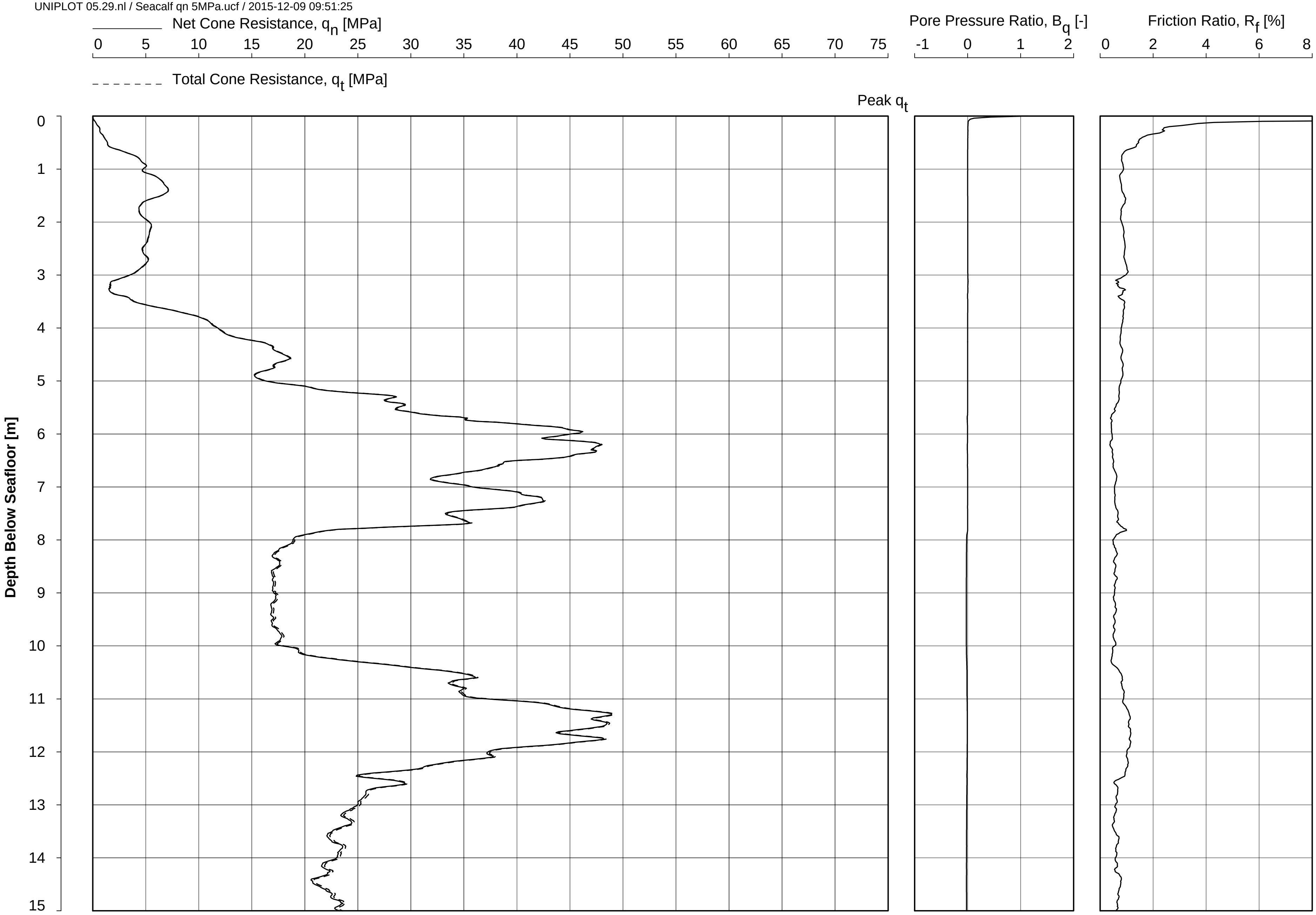
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_22

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:25



Date Of Testing : 27-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E500432 N5720215

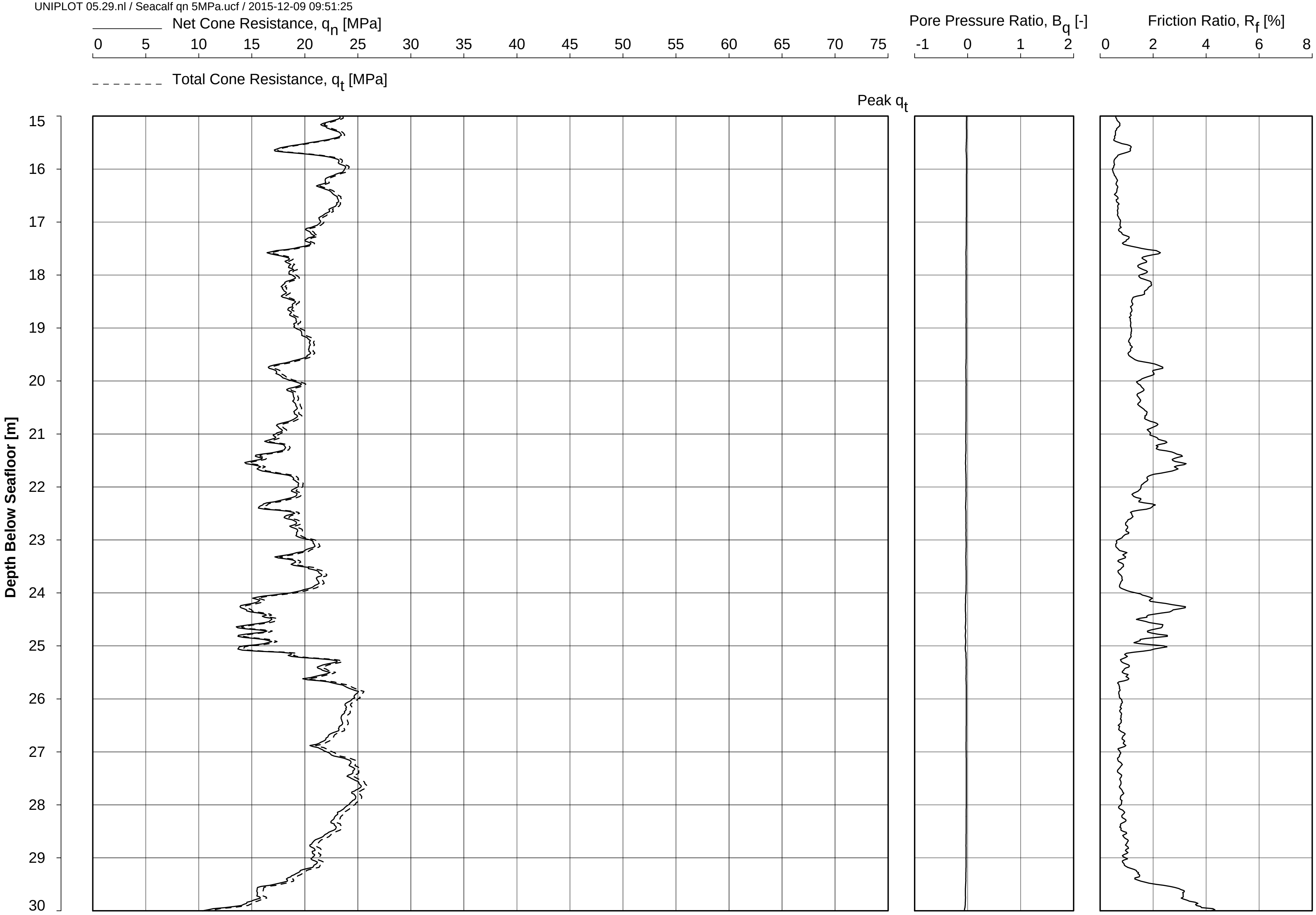
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_23

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:25



Date Of Testing : 27-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E500432 N5720215

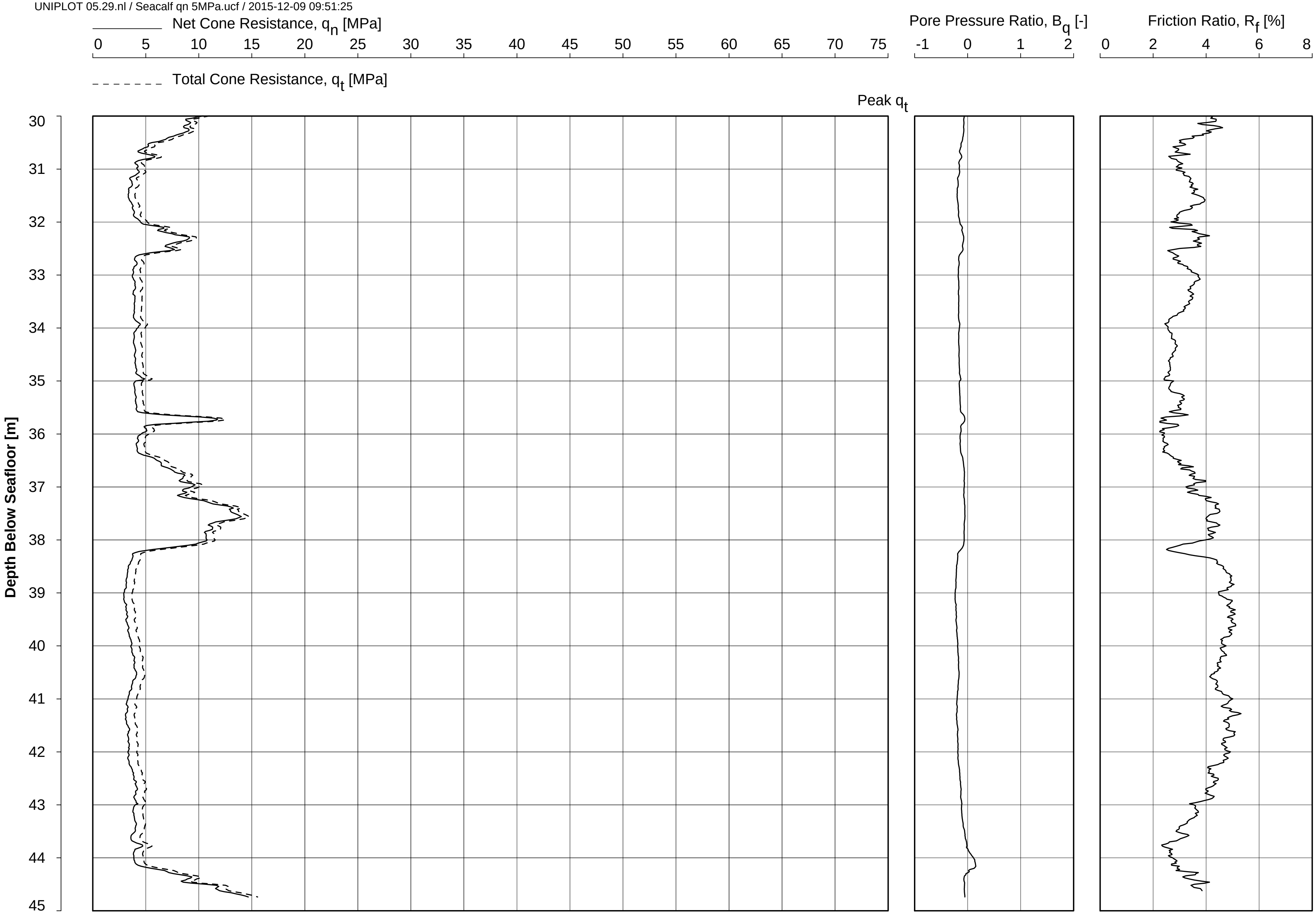
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_23

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:25



Date Of Testing : 27-Oct-2015
Water Depth [m] : 29.9
Coordinates [m] : E500432 N5720215

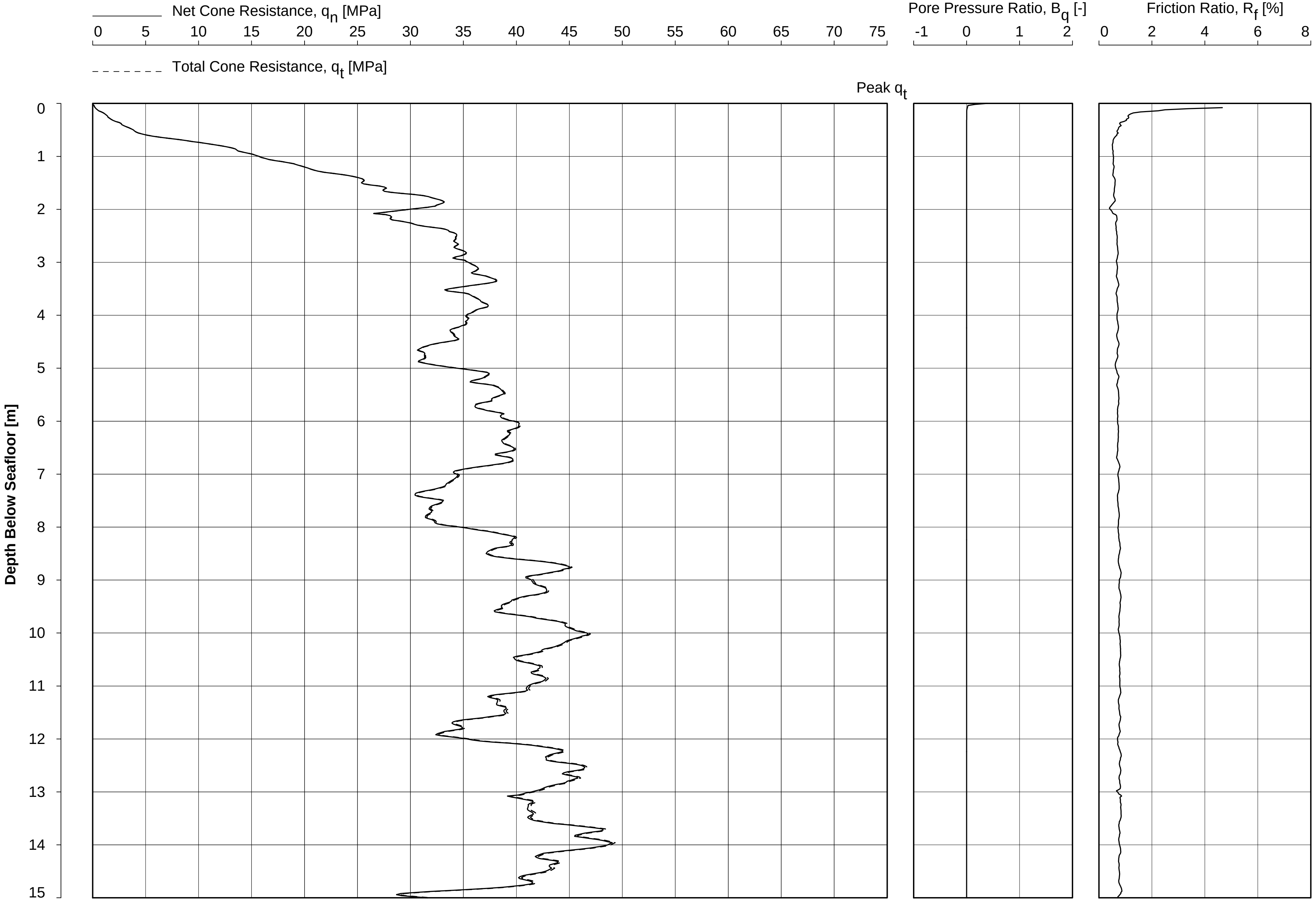
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_23

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:26



Date Of Testing : 26-Oct-2015
Water Depth [m] : 17.5
Coordinates [m] : E499134 N5724964

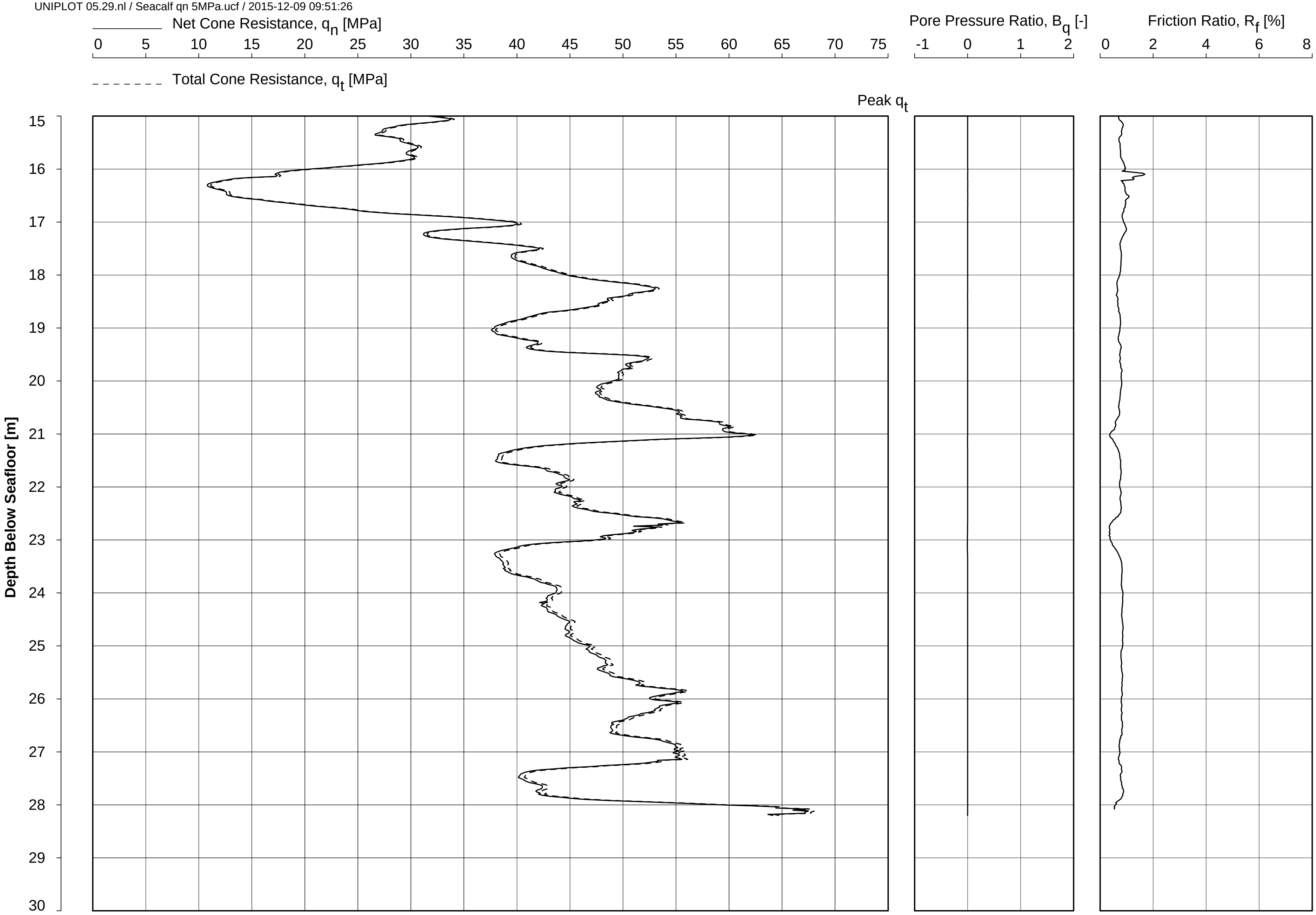
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_24

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:26



Date Of Testing : 26-Oct-2015
Water Depth [m] : 17.5
Coordinates [m] : E499134 N5724964

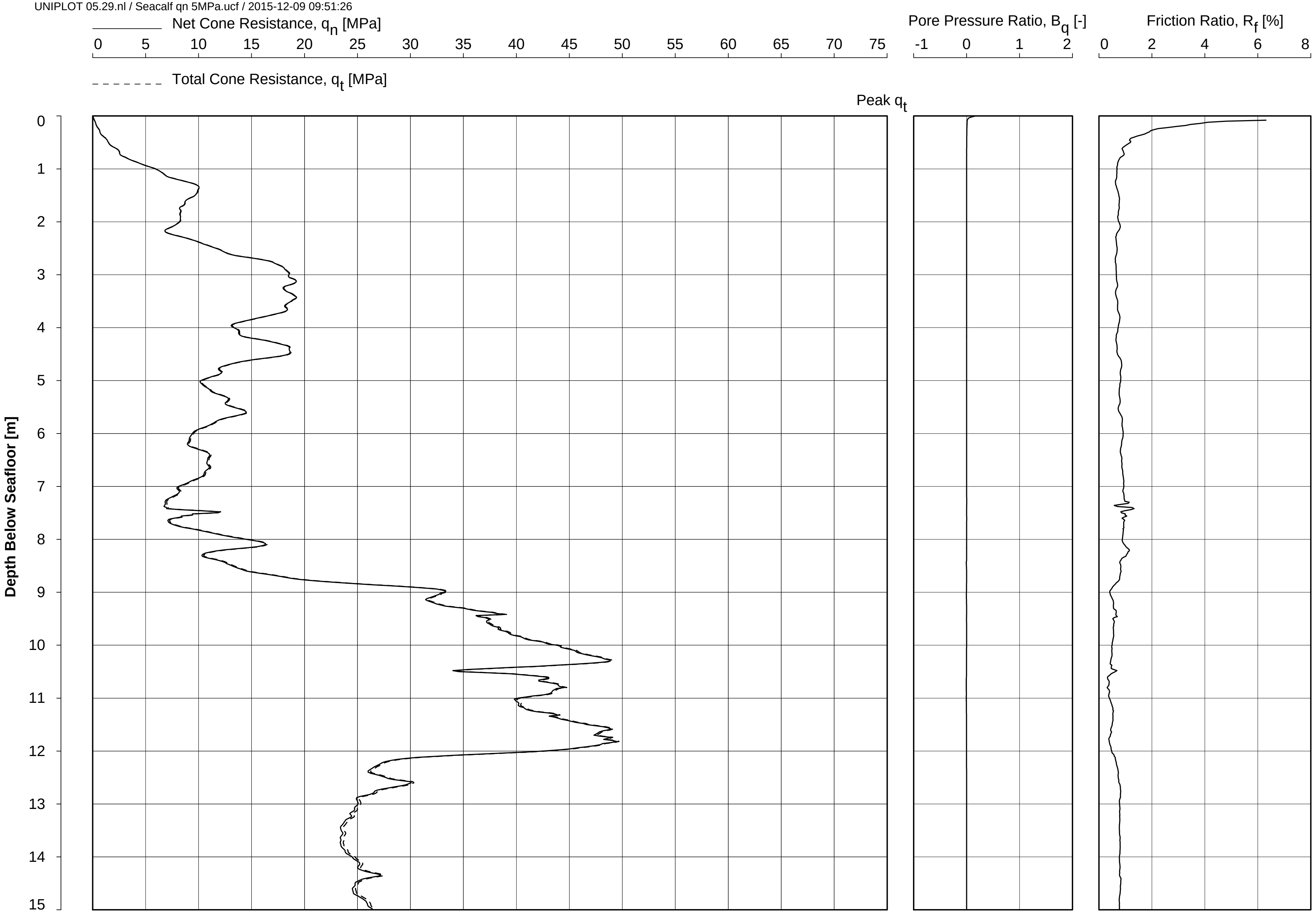
Probe Type : CP15-CF75PB30SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_24

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:26



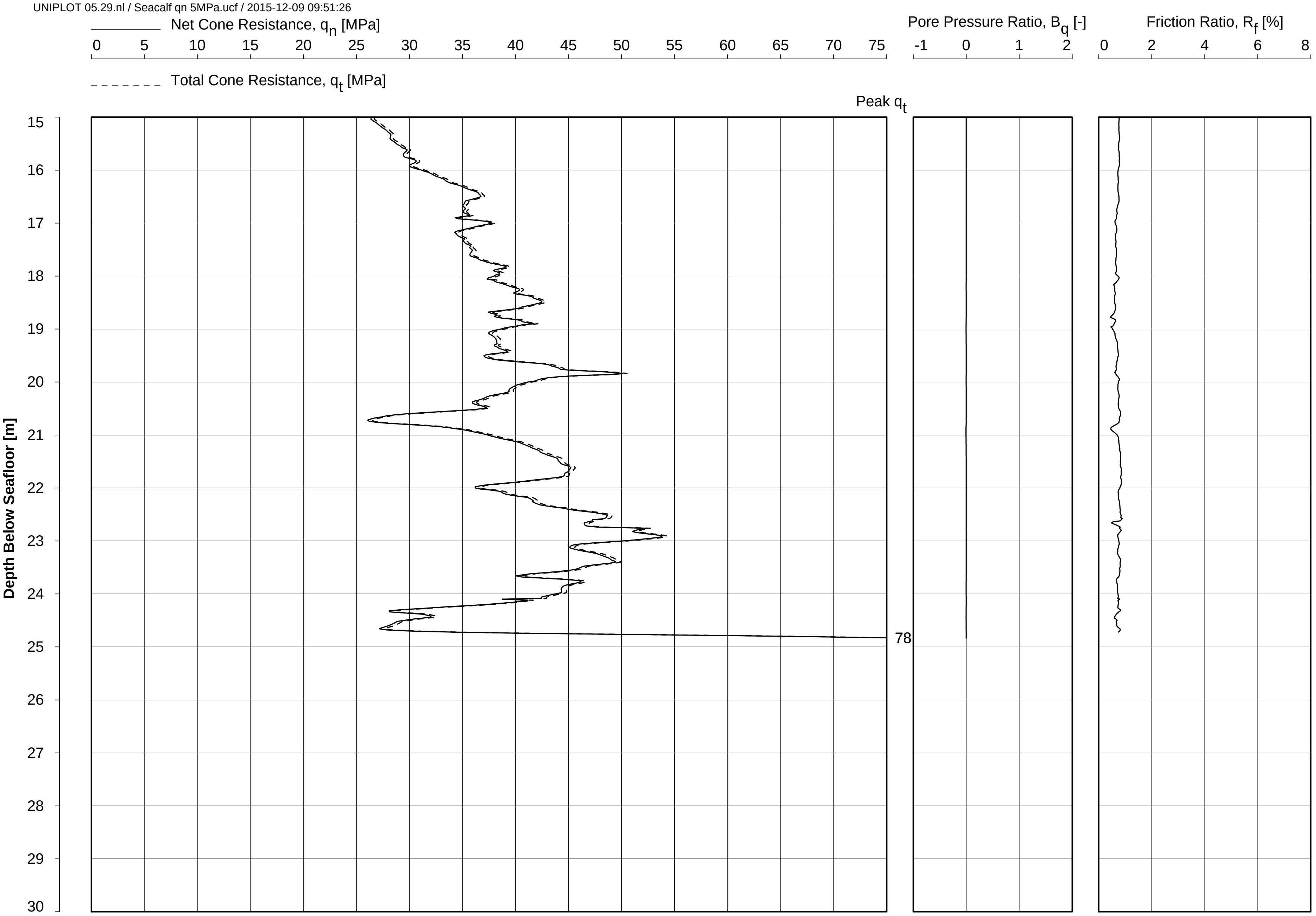
Date Of Testing : 31-Oct-2015
Water Depth [m] : 29.2
Coordinates [m] : E500748 N5727579

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_25

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA



Date Of Testing : 31-Oct-2015
Water Depth [m] : 29.2
Coordinates [m] : E500748 N5727579

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_25

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

FUGRO

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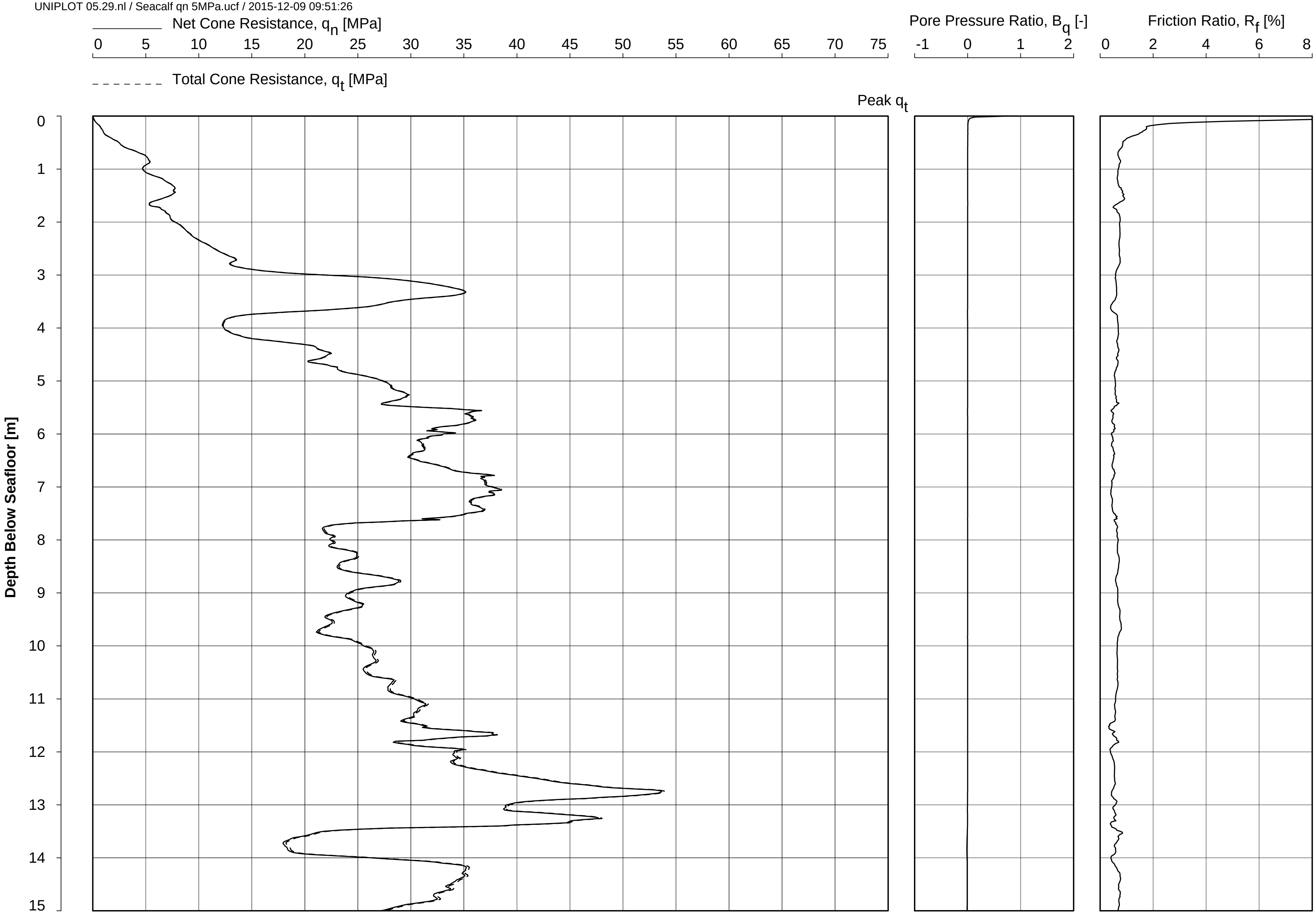


Date Of Testing : 31-Oct-2015
Water Depth [m] : 28.9
Coordinates [m] : E497701 N5729827

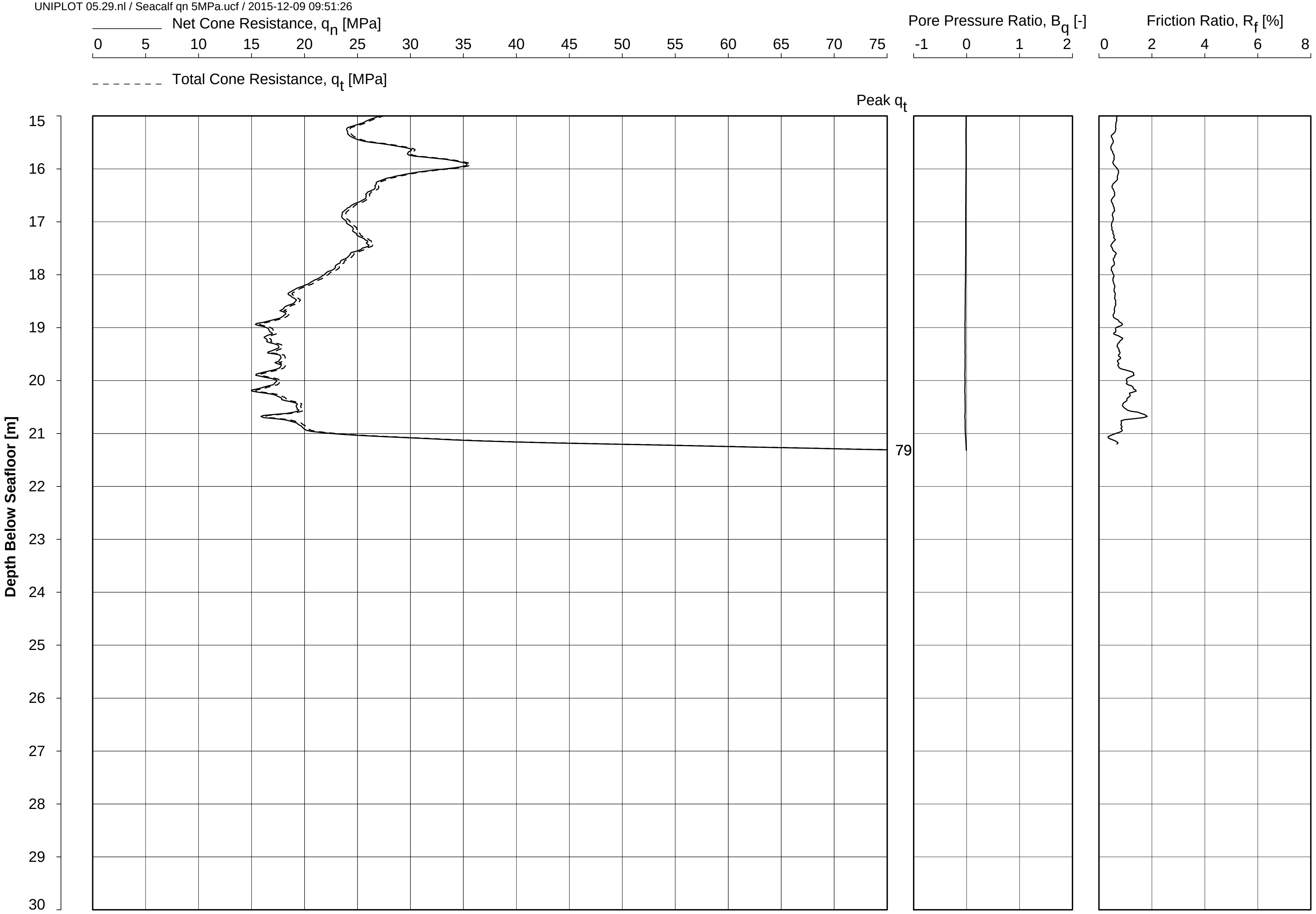
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_26

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:26



Date Of Testing	: 31-Oct-2015	Probe Type	: CP15-CF75PB20SN2
Water Depth [m]	: 28.9	Cone Base Area [mm^2]	: 1510
Coordinates [m]	: E497701 N5729827		

CONE PENETRATION TEST

CPT_WFS3_26

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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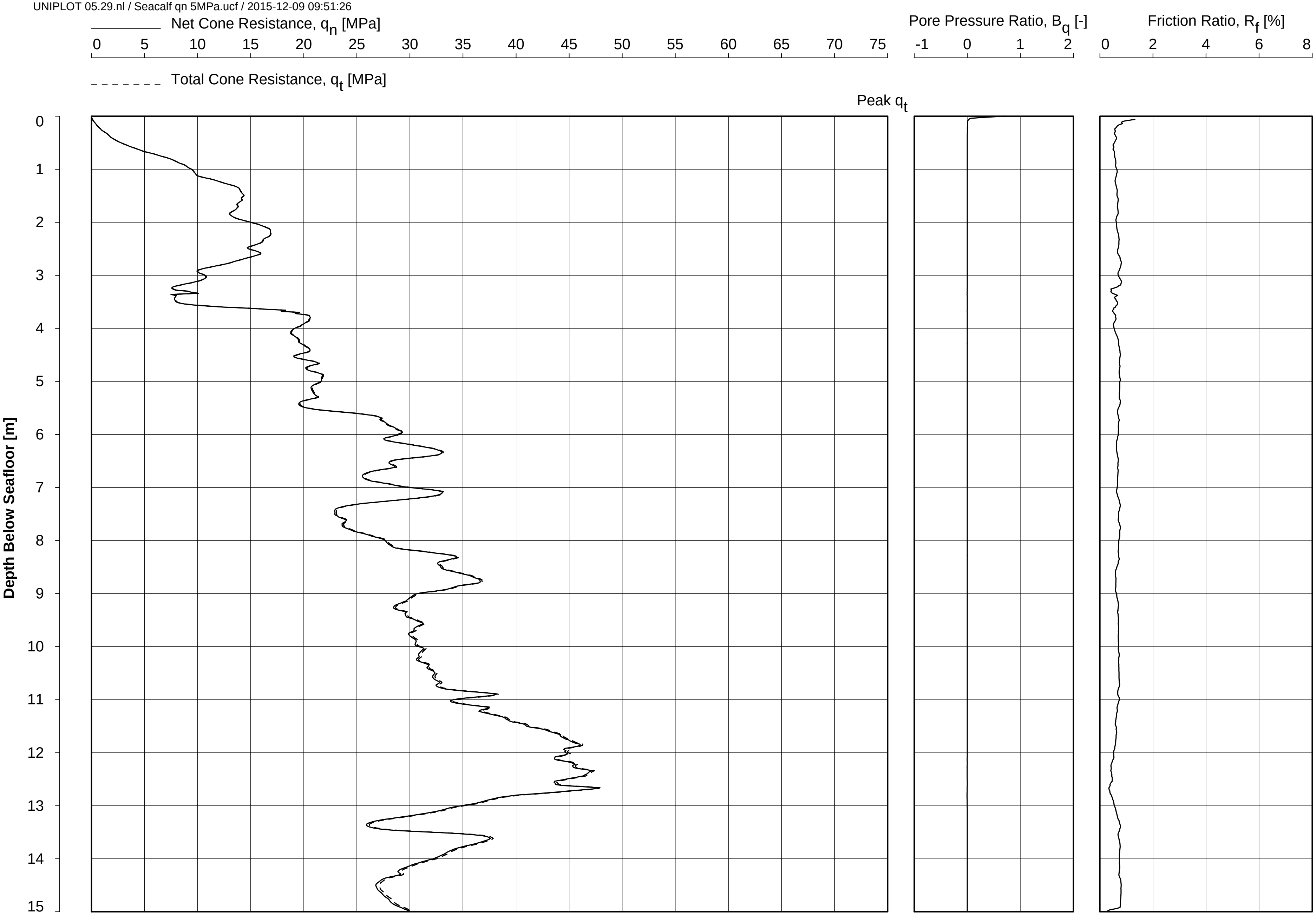


Date Of Testing : 31-Oct-2015
Water Depth [m] : 24.8
Coordinates [m] : E501862 N5725796

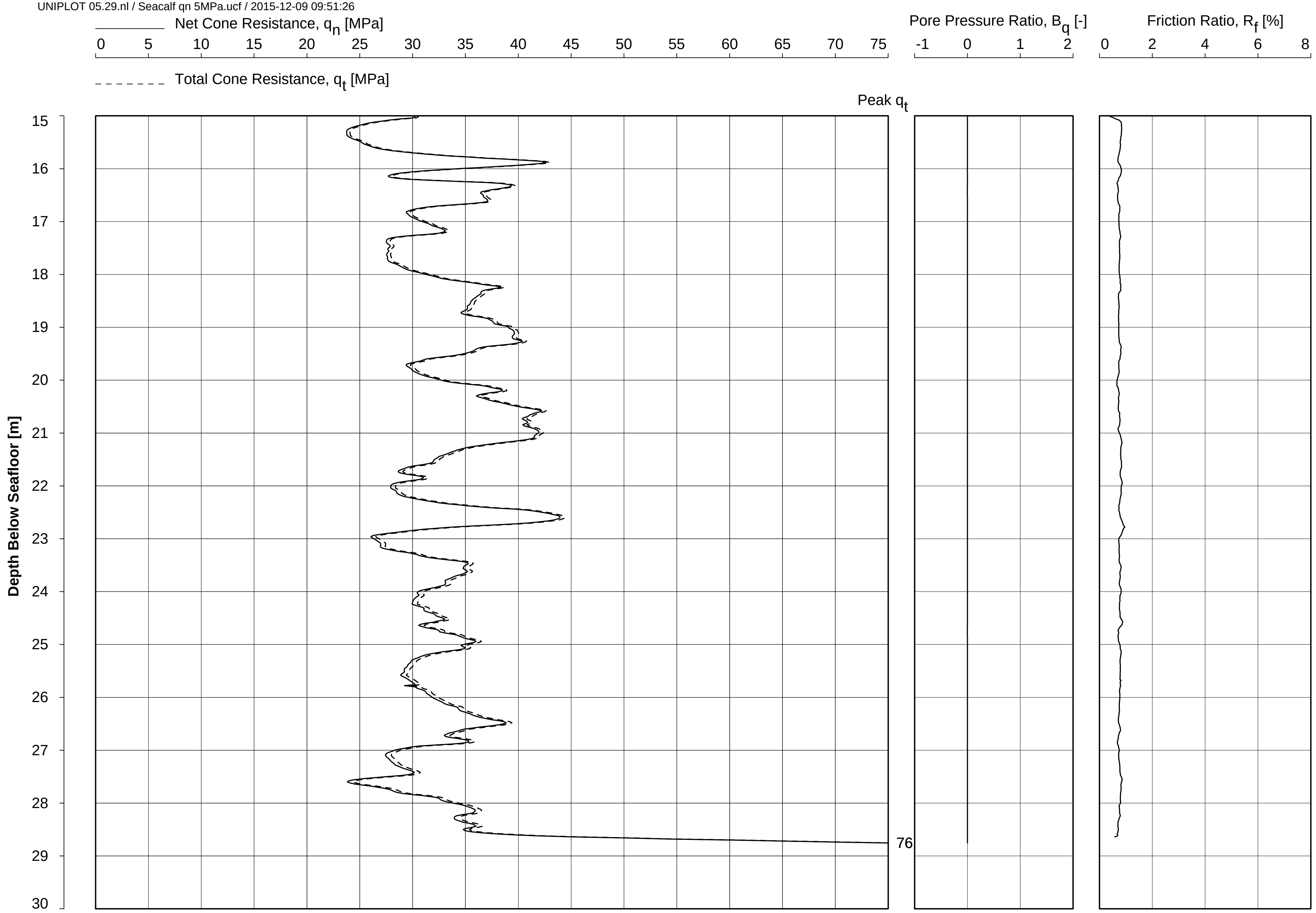
Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_27

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

UNIPLOT 05.29.nl / Seacalf qn 5MPa.ucf / 2015-12-09 09:51:26



Date Of Testing : 31-Oct-2015
Water Depth [m] : 24.8
Coordinates [m] : E501862 N5725796

Probe Type : CP15-CF75PB20SN2
Cone Base Area [mm^2] : 1510

CONE PENETRATION TEST

CPT_WFS3_27

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

Borehole/ Location	Depth Range [m]	Unit Weight γ Ground [kN/m^3]	Unit Weight γ Ground Water [kN/m^3]	Pore Pressure Adjustment Factor K [-]
CPT_WFS3_2	0.00 to 2.10	20.00	10.0	---
	2.10 to 10.00	20.50		
	10.00 to 17.70	20.00		
	17.70 to 28.45	20.00		
	28.45 to 35.65	19.50		
	35.65 to 37.20	19.50		
	37.20 to 42.70	18.50		
	42.70 to bottom	20.00		
CPT_WFS3_3	0.00 to 6.00	20.00	10.0	---
	6.00 to 11.30	20.50		
	11.30 to 21.70	20.00		
	21.70 to 34.45	20.00		
	34.45 to 41.15	19.50		
	41.15 to 42.90	19.50		
	42.90 to bottom	18.50		
CPT_WFS3_5	0.00 to 1.50	20.00	10.0	---
	1.50 to 15.35	20.50		
	15.35 to 17.55	20.50		
	17.55 to 21.20	20.50		
	21.20 to 24.30	20.00		
	24.30 to 32.40	19.50		
	32.40 to 34.20	19.50		
	34.20 to 38.30	18.50		
	38.30 to bottom	20.00		
CPT_WFS3_6	0.00 to 1.25	20.00	10.0	---
	1.25 to 20.75	20.50		
	20.75 to bottom	20.50		
CPT_WFS3_6A	0.00 to 1.30	20.00	10.0	---
	1.30 to 20.80	20.50		
	20.80 to bottom	20.50		
CPT_WFS3_7	0.00 to 1.30	20.00	10.0	---
	1.30 to 11.10	20.50		
	11.10 to 19.35	20.00		
	19.35 to 29.00	20.00		
	29.00 to 36.00	19.50		
	36.00 to 37.70	19.50		
	37.70 to 43.05	18.50		
	43.05 to bottom	20.00		
CPT_WFS3_8	0.00 to 10.15	20.00	10.0	---
	10.15 to 18.60	20.50		
	18.60 to bottom	20.50		

Note:
1. The adjustment factor K applies only to probes with a pore pressure filter in the face of the cone.

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PARAMETER VALUES FOR NET CONE RESISTANCE CALCULATION
BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

Borehole/ Location	Depth Range [m]	Unit Weight γ Ground [kN/m3]	Unit Weight γ Ground Water [kN/m3]	Pore Pressure Adjustment Factor K [-]
CPT_WFS3_9	0.00 to 8.40 8.40 to 12.55 12.55 to 18.70 18.70 to 22.00 22.00 to bottom	20.00 20.00 20.50 20.50 20.50	10.0	---
CPT_WFS3_10	0.00 to 4.20 4.20 to 16.40 16.40 to bottom	20.00 20.50 20.50	10.0	---
CPT_WFS3_11	0.00 to bottom	20.00	10.0	---
CPT_WFS3_11A	0.00 to 5.50 5.50 to 19.00 19.00 to bottom	20.00 20.50 20.50	10.0	---
CPT_WFS3_12	0.00 to 4.70 4.70 to 7.20 7.20 to 13.30 13.30 to 20.80 20.80 to 22.90 22.90 to 29.00 29.00 to bottom	20.00 20.50 20.00 19.50 19.50 18.50 20.00	10.0	---
CPT_WFS3_13	0.00 to 3.60 3.60 to 8.60 8.60 to 13.40 13.40 to 26.60 26.60 to 39.10 39.10 to 45.90 45.90 to 47.40 47.40 to bottom	20.00 20.50 20.50 20.00 20.00 19.50 19.50 18.50	10.0	---
CPT_WFS3_14	0.00 to 2.10 2.10 to 19.25 19.25 to 24.05 24.05 to 31.80 31.80 to 33.70 33.70 to 37.60 37.60 to bottom	20.00 20.50 20.00 19.50 19.50 18.50 20.00	10.0	---
CPT_WFS3_15	0.00 to 1.85 1.85 to 14.90 14.90 to 24.05 24.05 to 35.20 35.20 to 42.80 42.80 to 44.70 44.70 to 48.80 48.80 to bottom	20.00 20.50 20.00 20.00 19.50 19.50 18.50 20.00	10.0	---

Note:
1. The adjustment factor K applies only to probes with a pore pressure filter in the face of the cone.

UNIPLOT 05.29.nl/Seacalf QaQc parameter values.cmd/2015-12-09 09:52:17

PARAMETER VALUES FOR NET CONE RESISTANCE CALCULATION

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

Borehole/ Location	Depth Range [m]	Unit Weight γ Ground [kN/m³]	Unit Weight γ Ground Water [kN/m³]	Pore Pressure Adjustment Factor K [-]
CPT_WFS3_16	0.00 to 1.50	20.00	10.0	---
	1.50 to 13.40	20.50		
	13.40 to 20.00	20.00		
	20.00 to 30.55	20.00		
	30.55 to 38.20	19.50		
	38.20 to 40.00	19.50		
	40.00 to 43.80	18.50		
	43.80 to bottom	20.00		
CPT_WFS3_17	0.00 to 1.10	20.00	10.0	---
	1.10 to 7.90	20.50		
	7.90 to 10.65	20.50		
	10.65 to bottom	20.50		
CPT_WFS3_18	0.00 to 5.50	20.00	10.0	---
	5.50 to bottom	20.50		
CPT_WFS3_19	0.00 to 3.60	20.00	10.0	---
	3.60 to 7.80	20.50		
	7.80 to 12.90	20.50		
	12.90 to 16.80	19.50		
	16.80 to 18.95	19.50		
	18.95 to 22.55	18.50		
	22.55 to 31.45	20.00		
	31.45 to bottom	18.00		
CPT_WFS3_20	0.00 to 2.70	20.00	10.0	---
	2.70 to 12.20	20.50		
	12.20 to 16.00	19.50		
	16.00 to 18.40	19.50		
	18.40 to 22.30	18.50		
	22.30 to bottom	20.00		
CPT_WFS3_21	0.00 to 5.65	20.00	10.0	---
	5.65 to 14.80	20.50		
	14.80 to 18.10	19.50		
	18.10 to 20.50	19.50		
	20.50 to 25.20	18.50		
	25.20 to 32.70	20.00		
	32.70 to bottom	18.00		
CPT_WFS3_22	0.00 to 10.05	20.00	10.0	---
	10.05 to 19.80	20.50		
	19.80 to 28.40	20.00		
	28.40 to 38.70	20.00		
	38.70 to 39.55	19.50		
	39.55 to 45.90	19.50		
	45.90 to 47.50	19.50		
	47.50 to bottom	18.50		

Note:
1. The adjustment factor K applies only to probes with a pore pressure filter in the face of the cone.

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PARAMETER VALUES FOR NET CONE RESISTANCE CALCULATION
BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

Borehole/ Location	Depth Range [m]	Unit Weight γ		Pore Pressure Adjustment Factor K [-]
		Ground [kN/m3]	Ground Water [kN/m3]	
CPT_WFS3_23	0.00 to 3.40	20.00	10.0	---
	3.40 to 7.75	20.50		
	7.75 to 10.20	20.00		
	10.20 to 12.40	20.00		
	12.40 to 17.40	20.00		
	17.40 to 29.50	20.00		
	29.50 to 36.60	19.50		
	36.60 to 38.20	19.50		
	38.20 to 44.25	18.50		
	44.25 to bottom	20.00		
CPT_WFS3_24	0.00 to 16.60	20.00	10.0	---
	16.60 to bottom	20.50		
CPT_WFS3_25	0.00 to 8.50	20.00	10.0	---
	8.50 to 24.70	20.50		
	24.70 to bottom	20.50		
CPT_WFS3_26	0.00 to 2.80	20.00	10.0	---
	2.80 to 13.40	20.50		
	13.40 to 21.10	20.50		
	21.10 to bottom	20.50		
CPT_WFS3_27	0.00 to 3.60	20.00	10.0	---
	3.60 to 12.80	20.50		
	12.80 to 28.55	20.50		
	28.55 to bottom	20.50		

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Note:
1. The adjustment factor K applies only to probes with a pore pressure filter in the face of the cone.

PARAMETER VALUES FOR NET CONE RESISTANCE CALCULATION
BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

CONE PENETRATION TEST - ZERO DRIFT

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

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Borehole/ Location	Reference Reading at Start of Test			Zero Drift			Probe		Net Area Ratio
	q_c [MPa]	f_s [MPa]	u [MPa]	q_c [MPa]	f_s [MPa]	u [MPa]			a [-]
CPT_WFS3_2	0.331	-0.012	0.336	---	---	---	CP15-CF75PB20SN2	1701-1534	0.580
CPT_WFS3_3	0.391	-0.004	0.284	-0.029	0.000	-0.003	CP15-CF75PB30SN2	1701-2046	0.580
CPT_WFS3_5	0.359	0.019	0.280	-0.006	0.000	0.003	CP15-CF75PB20SN2	1701-2085	0.580
CPT_WFS3_6	0.183	0.002	0.348	0.018	-0.005	0.004	CP15-CF75PB20SN2	1701-2346	0.580
CPT_WFS3_6A	0.192	-0.002	0.351	-0.028	0.001	0.004	CP15-CF75PB20SN2	1701-2346	0.580
CPT_WFS3_7	0.423	0.000	0.316	-0.111	0.003	0.000	CP15-CF75PB30SN2	1701-2046	0.580
CPT_WFS3_8	0.332	-0.011	0.205	-0.065	0.001	0.005	CP15-CF75PB30SN2	1701-2046	0.580
CPT_WFS3_9	0.128	0.002	0.264	-0.009	0.001	-0.006	CP15-CF75PB20SN2	1701-2346	0.580
CPT_WFS3_10	0.223	0.006	0.384	-0.015	-0.004	-0.001	CP15-CF75PB20SN2	1701-2346	0.580
CPT_WFS3_11	0.130	-0.002	0.284	-0.028	-0.001	0.002	CP15-CF75PB20SN2	1701-2346	0.580
CPT_WFS3_11A	0.095	-0.001	0.285	-0.017	-0.005	-0.002	CP15-CF75PB20SN2	1701-2346	0.580
CPT_WFS3_12	0.178	-0.007	0.311	---	---	---	CP15-CF75PB20SN2	1701-2085	0.580
CPT_WFS3_13	0.379	-0.006	0.300	-0.020	0.004	0.008	CP15-CF75PB30SN2	1701-2046	0.580
CPT_WFS3_14	0.383	0.025	0.321	-0.023	-0.005	-0.006	CP15-CF75PB20SN2	1701-2085	0.580
CPT_WFS3_15	0.415	0.021	0.322	---	---	---	CP15-CF75PB20SN2	1701-2085	0.580
CPT_WFS3_16	0.403	0.018	0.317	-0.033	0.002	-0.001	CP15-CF75PB20SN2	1701-2085	0.580
CPT_WFS3_17	0.143	0.002	0.339	0.034	-0.003	0.001	CP15-CF75PB20SN2	1701-2346	0.580
CPT_WFS3_18	0.243	0.003	0.287	0.020	0.002	0.004	CP15-CF75PB20SN2	1701-2085	0.580
CPT_WFS3_19	0.342	0.018	0.303	0.002	-0.001	0.009	CP15-CF75PB20SN2	1701-2085	0.580
CPT_WFS3_20	0.318	0.014	0.315	-0.018	0.001	-0.004	CP15-CF75PB20SN2	1701-2085	0.580
CPT_WFS3_21	0.207	0.002	0.285	-0.011	-0.005	0.003	CP15-CF75PB20SN2	1701-2085	0.580
CPT_WFS3_22	0.320	-0.008	0.234	-0.048	-0.052	0.006	CP15-CF75PB30SN2	1701-2046	0.580
CPT_WFS3_23	0.413	-0.004	0.298	---	---	---	CP15-CF75PB30SN2	1701-2046	0.580
CPT_WFS3_24	0.279	-0.007	0.194	-0.043	-0.004	-0.009	CP15-CF75PB30SN2	1701-2046	0.580
CPT_WFS3_25	0.130	-0.002	0.313	-0.008	0.008	-0.004	CP15-CF75PB20SN2	1701-2346	0.580

Key:

q_c : cone resistance f_s : sleeve friction   u : pore water pressure

Note:

1. Zero Drift is the difference between the output at the start of the test and the output at the end of the test. Offshore tests may show Reference Readings. The Zero Reading or Reference Reading at Start of Test is a value presented in units of measurement result. The value itself is a conversion from system output, usually in mV. It has no explicit physical meaning.
2. --- : Zero Drift was not monitored. The drift can be assessed from the start values of successive tests.

CONE PENETRATION TEST - ZERO DRIFT

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

Borehole/ Location	Reference Reading at Start of Test			Zero Drift			Probe		Net Area Ratio
	q_c [MPa]	f_s [MPa]	u [MPa]	q_c [MPa]	f_s [MPa]	u [MPa]			a [-]
CPT_WFS3_26	0.143	0.001	0.324	-0.044	0.000	0.000	CP15-CF75PB20SN2	1701-2346	0.580
CPT_WFS3_27	0.138	0.005	0.263	-0.016	-0.001	0.009	CP15-CF75PB20SN2	1701-2346	0.580

Key:

q_c : cone resistance f_s : sleeve friction u : pore water pressure

Note:

1. Zero Drift is the difference between the output at the start of the test and the output at the end of the test.
   Offshore tests may show Reference Readings. The Zero Reading or Reference Reading at Start of Test is a value presented in units of measurement result. The value itself is a conversion from system output, usually in mV. It has no explicit physical meaning.
2. --- : Zero Drift was not monitored. The drift can be assessed from the start values of successive tests.

SECTION B2: PORE PRESSURE DISSIPATION TESTS

B2. PORE PRESSURE DISSIPATION TESTS

B2.1 COMMENTS ON RESULTS

A total of three Pore Pressure Dissipation Tests (PPDTs) were performed using piezo-cone penetrometers. Test durations were approximately 5 minutes in coarse-grained cohesionless soils and 120 minutes in fine-grained cohesive soils. Results are presented as graphs showing pore pressure relative to atmospheric pressure and cone resistance relative to seafloor during the dissipation test on a logarithmic time scale on Plates B2-1 to B2-3. Two different scales are used for tests in coarse-grained cohesionless soils and fine-grained cohesive soils respectively.

The acquired pore pressure test data is considered to be of good quality and measurements are assessed as reliable. Test results from PPDTs in fine-grained cohesive soils show that dissipation is still continuing at the end of the PPDT with pore pressures above the theoretical hydrostatic pore pressures at the test depth.

During cone penetration testing negative pore pressure can exist, refer to Section B1.1 for details. For all three PPDTs this was the case prior to start of the dissipation test. As a result, the pore pressure shows an increase rather than a decrease (dissipation). The tests at test points CPT_WFS3_3 and CPT_WFS3_5 are performed in coarse-grained cohesionless soil, pore pressure rise to equilibrium is in line with the theoretical hydrostatic pore pressure. The PPDT at test point CPT_WFS3_5 was performed in fine-grained cohesive soils and for this test, pressure continues to rise at the end of the test. Pressure around the cone will be higher as a result of cone penetration. Such excess pressure is evident from the downhole cone penetration tests performed in nearby borehole at similar depths. It can be expected that during the PPDT, pressure will initially rise to a certain excess pressure level before dissipation occurs. This behaviour is seen during the tests.

Measured water depth (not reduced to LAT) presented on the plates is at start of each PPDT obtained from echo sounder. These water depths represent the water column present at start of test, and differ from water depths presented elsewhere in this report.

For more detailed information about PPDTs and measured or calculated parameters refer to the document titled “Pore Pressure Dissipation Test”, presented in Appendix 1.

B2.2 PRACTICE FOR PORE PRESSURE DISSIPATION TESTS

Test Control – Penetration

Refer to sub-section titled "Practice for Cone Penetration Test", presented in Section B1

Test Control – Dissipation

General Procedure:	Refer to document titled "In Situ Pore Pressure Dissipation Test" presented in Appendix 1
Test Method:	Monitoring of pore pressure for estimation of equilibrium in situ pore water pressure
Test Stage:	– Dissipation test at depths as directed by Client – Real-time monitoring of cone resistance and pore pressure
Termination Stage:	Whichever occurs first: – reaching ~100% dissipation of excess pore pressure – as instructed by Client – unfavourable test conditions – circumstances at discretion of equipment operator, such as risk of damage to apparatus or safety of personnel

Piezo-Cone Apparatus

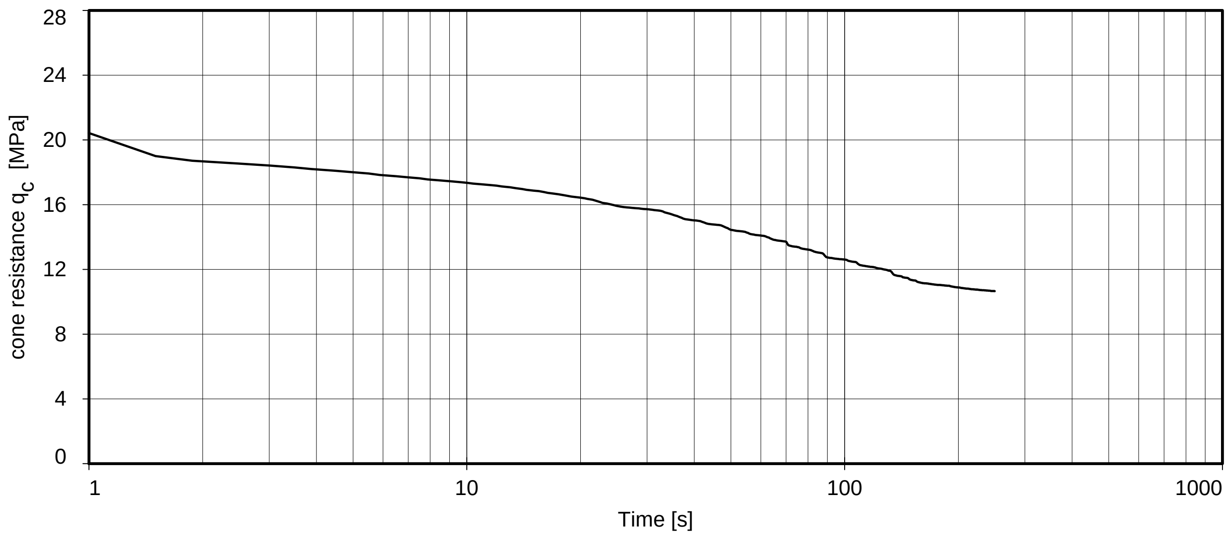
Refer to plate titled "Practice for Cone Penetration Test", presented in Section B1

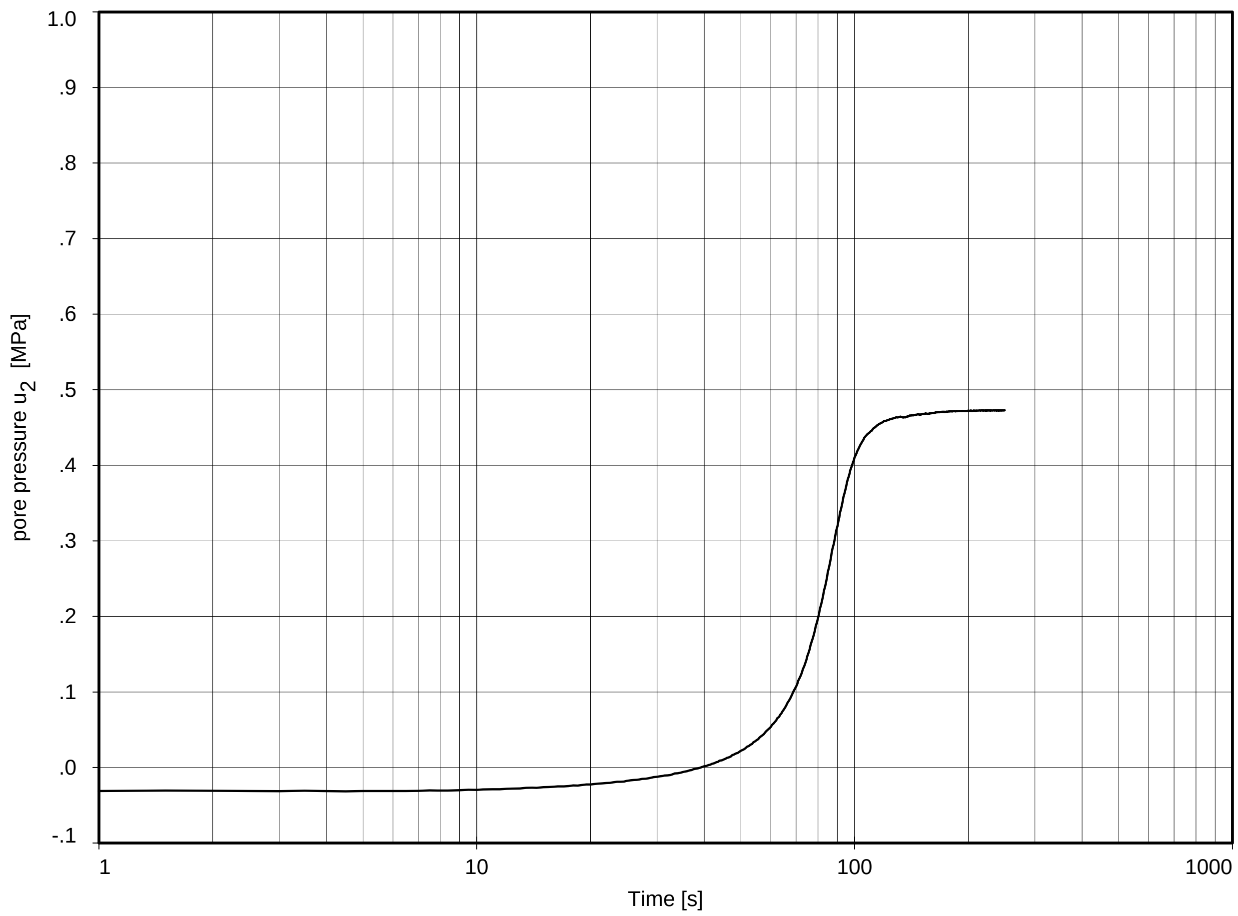
Test Results

Data Processing and Management:	– Refer to document titled "In Situ Pore Pressure Dissipation Test" presented in Appendix 1 – UNIPLOT software – Graphical scales selected to suit general presentation of data and requirements of standards, where practicable – Start of logarithmic time scale is at 1 s; the value of pore pressure at 0 s is numerically presented under "pore pressure at start" – No display of data outside of chart limits, i.e. some values may not be shown
Data recording:	During lowering 0.5 Hz, during penetration 2 Hz, during dissipation 0 to 900 s 2 Hz, during dissipation >900 s 1 Hz, during dissipation >6000 s 0.5 Hz during hoisting 0.5 Hz
Water Depth Reference:	As obtained from echo sounder readings at start of testing (not reduced to LAT)
Depth Reference Correction:	None applied
Depth Correction for Probe Inclination:	Applicable
Pressure Reference Level:	Refer to Section Text
Parameter Values for Data Processing:	Refer to Section Text

References

Computer Program UNIPLOT, Processing of Pore Pressure Dissipation Data





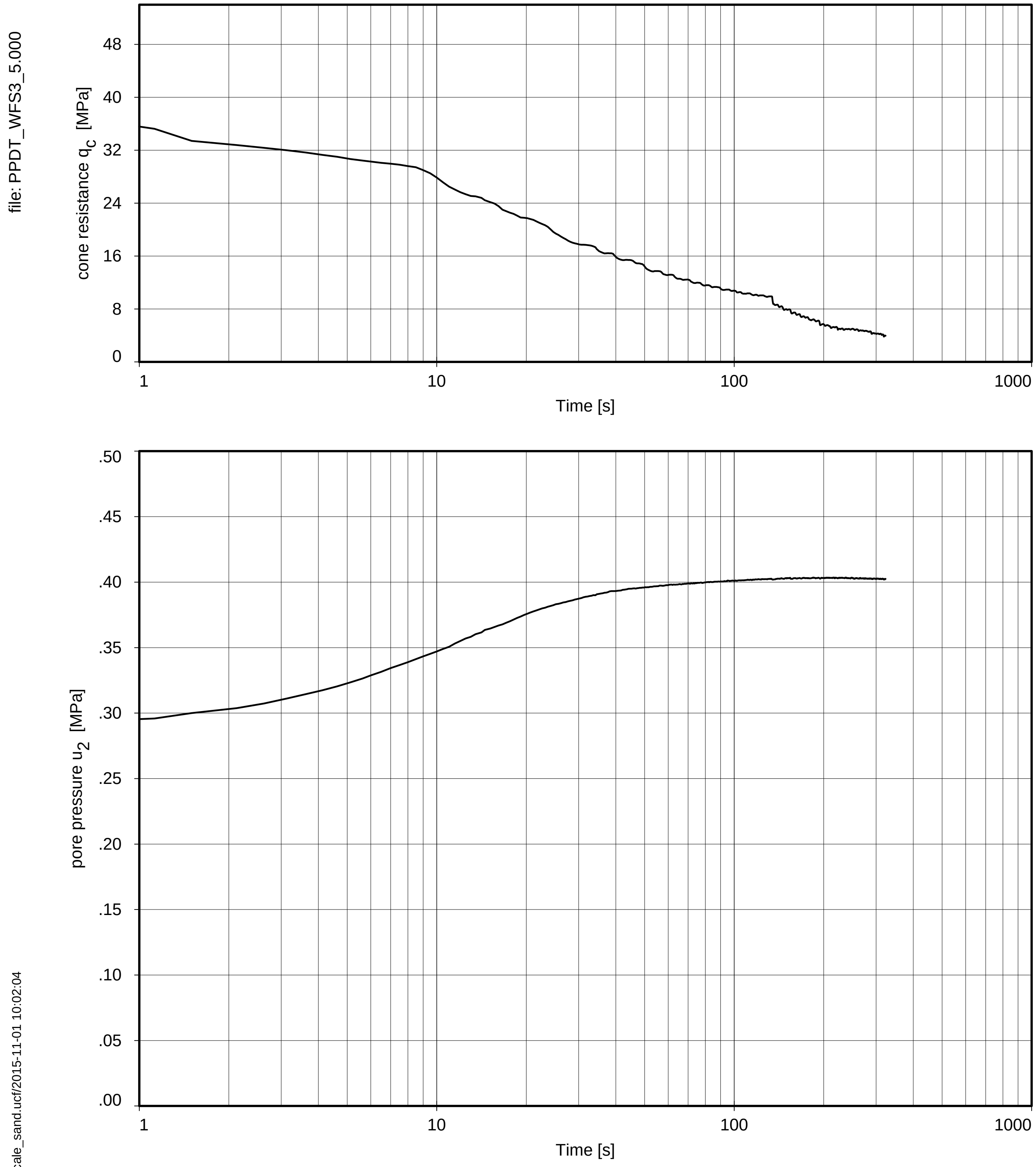
file: PPDT_WFS3_3.000

UNIPLOT 05.30.nl/Diss logTime u2 - fixed scale_sand - PPD/2015-11-01 09:59:35

location	:	CPT_WFS3_3		pore pressure at start	:	-0.030	MPa
date of testing	:	27-Oct-2015		pore pressure at end	:	0.473	MPa
dissipation test depth	:	17.62	m below seafloor				
measured water depth	:	29.0	m				
water depth reduced to LAT	:	28.4	m				
note	:	pressures relative to atmospheric					

PORE PRESSURE DISSIPATION TEST

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

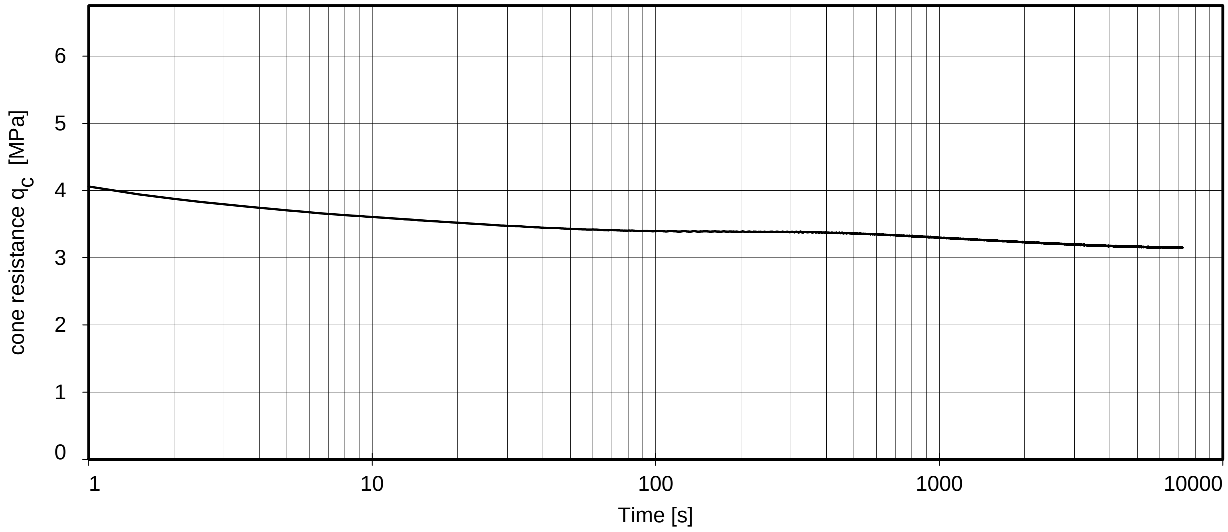


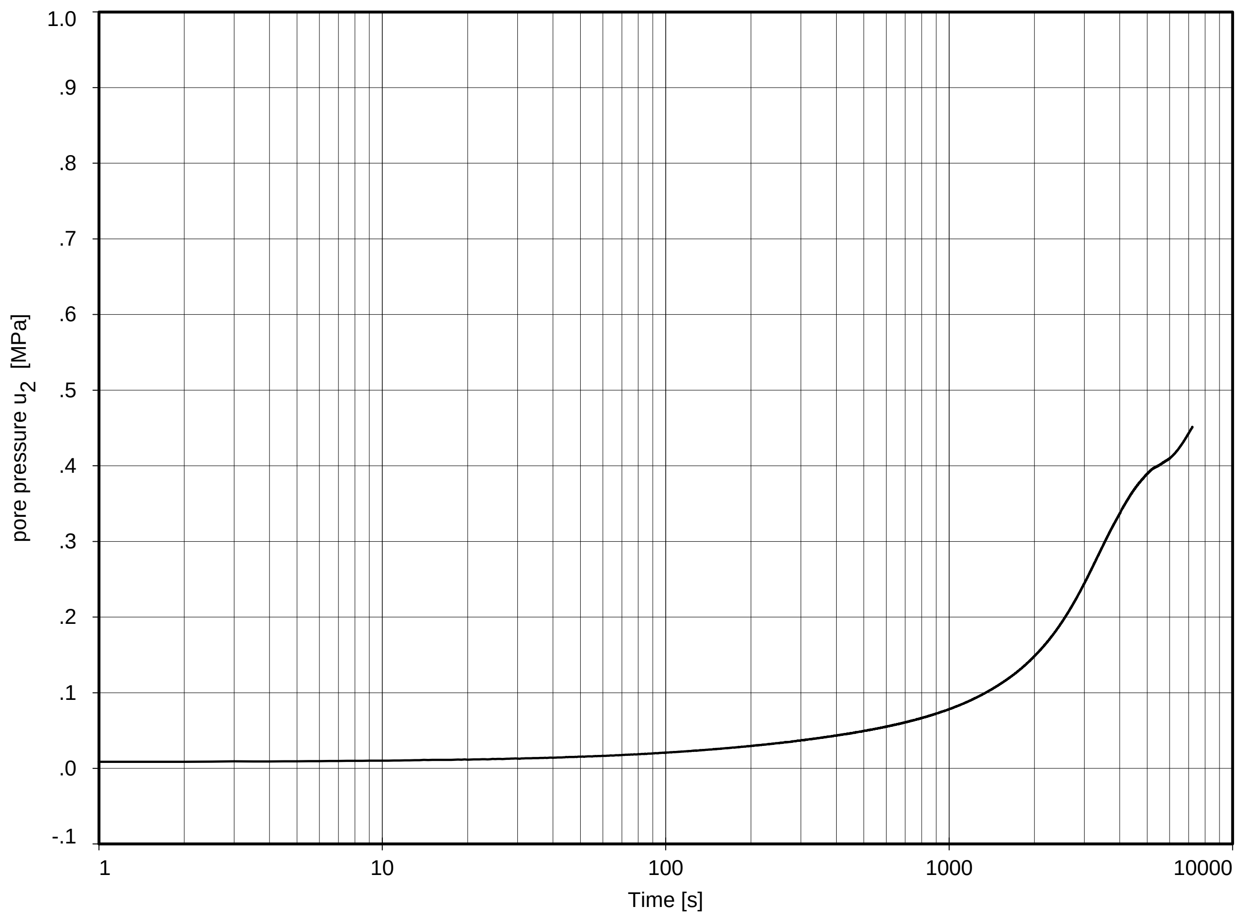
location	:	CPT_WFS3_5	pore pressure at start	:	0.290 MPa
date of testing	:	29-Oct-2015	pore pressure at end	:	0.402 MPa
dissipation test depth	:	9.69 m below seafloor			
measured water depth	:	29.8 m			
water depth reduced to LAT	:	29.3 m			
note	:	pressures relative to atmospheric			

UNIPLOT 05.30.nl/Diss logTime u2 - fixed scale_sand.ucf/2015-11-01 10:02:04

PORE PRESSURE DISSIPATION TEST

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA





location	:	CPT_WFS3_5	pore pressure at start	:	0.008	MPa
date of testing	:	29-Oct-2015	pore pressure at end	:	0.451	MPa
dissipation test depth	:	29.62 m below seafloor				
measured water depth	:	29.8 m				
water depth reduced to LAT	:	29.3 m				
note	:	pressures relative to atmospheric				

UNIPLOT 05.30.nl/Diss logTime u2 - fixed scale_clay - PPD/2015-11-01 10:01:36

PORE PRESSURE DISSIPATION TEST

BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA

SECTION C: GUIDELINES FOR USE OF REPORT

CONTENTS Reference

INTRODUCTION

This document provides guidelines, recommendations and limitations regarding the use of information in this report.

The cost of geotechnical data acquisition, interpretation and monitoring is a small portion of the total cost of a construction project. By contrast, the costs of correcting a wrongly designed programme or mobilising alternative construction methods are often far greater than the cost of the original investigation. Attention and adherence to the guidelines and recommendations presented in this guide and in the geotechnical report can reduce delays and cost overruns related to geotechnical factors.

This guide applies equally to the use of geotechnical and multi-disciplinary project information and advice.

REQUIREMENTS FOR QUALITY GEOTECHNICAL INFORMATION

Fugro follows ISO 9001 quality principles for project management and ISO 2394 for general principles on reliability for structures. Project activities usually comprise part of specific phases of a construction project. The quality plan for the entire construction project should incorporate geotechnical input in every phase - from the feasibility planning stages to project completion. The parties involved should do the following:

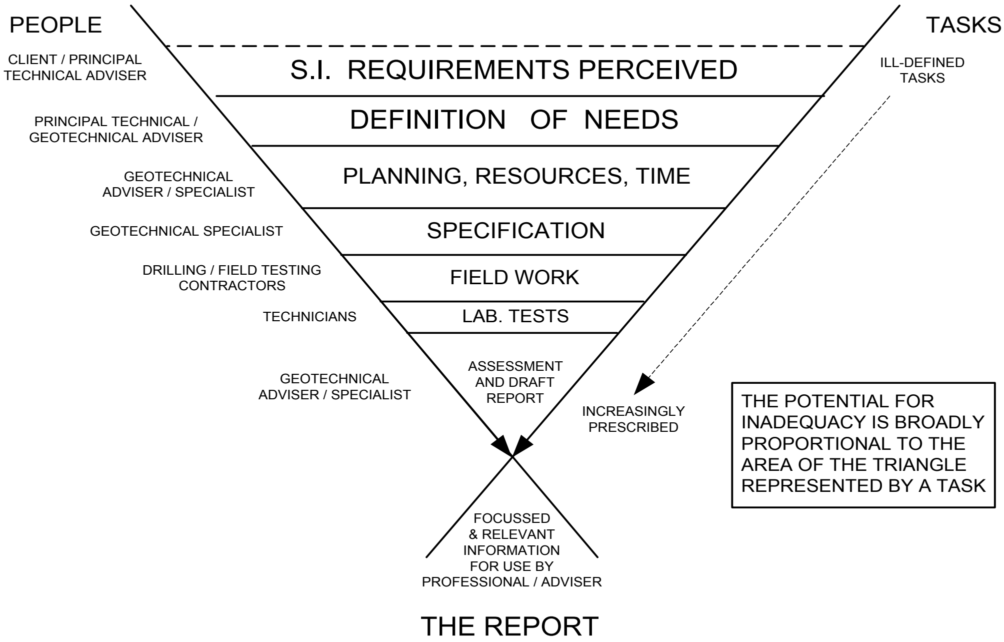
- Provide complete and accurate information necessary to plan an appropriate geotechnical site investigation.
- Describe the purpose(s), type(s) and construction methods of planned structures in detail.
- Provide the time, financial, personnel and other resources necessary for the planning, execution and follow-up of a site investigation programme.
- Understand the limitations and degree of accuracy inherent in the geotechnical data and engineering advice based upon these data.
- During all design and construction activities, be aware of the limitations of geotechnical data and geotechnical engineering analyses/advice, and use appropriate preventative measures.
- Incorporate all geotechnical input in the design, planning, construction and other activities involving the site and structures. Provide the entire geotechnical report to parties involved in design and construction.
- Use the geotechnical data and engineering advice for only the structures, site and activities which were described to Fugro prior to and for the purpose of planning the geotechnical site investigation or geotechnical engineering analysis programme.

AUTHORITY, TIME AND RESOURCES NECESSARY FOR GEOTECHNICAL INVESTIGATIONS

Adequate designation of authority and accountability for geotechnical aspects of construction projects is necessary. This way, an appropriate investigation can be performed, and the use of the results by project design and construction professionals can be optimised.

Figure 1 illustrates the importance of the initial project phases for gathering adequate geotechnical information for a project. The initial phases, when site investigation requirements are defined and resources are allocated, are represented by more than 50% of the Quality Triangle (Figure 1). Decisions and actions made during these phases have a large impact of the outcome and thus the potential of the investigation to meet project requirements.

Figure 1: Quality of Geotechnical Site Investigation (adapted from SISG[1]).



DATA ACQUISITION AND MONITORING PROGRAMMES

Geotechnical investigations are operations of discovery. Investigation should proceed in logical stages. Planning should allow operational adjustments deemed necessary by newly available information. This observational approach permits the development of a sound engineering strategy and reduces the risk of discovering unexpected hazards during or after construction.

GEOTECHNICAL INFORMATION – DATA TYPES AND LIMITATIONS

1. RELIABILITY OF SUPPLIED INFORMATION

Geotechnical engineering can involve the use of information and physical material that is publicly available or supplied by the Client. Examples are geodetic data, geological maps, geophysical records, earthquake data, earlier geotechnical logs and soil samples. Fugro endeavours to identify potential anomalies, but does not independently verify the accuracy or completeness of public or Client-supplied information unless indicated otherwise. This information, therefore, can limit the accuracy of the report.

2. COMPLEXITY OF GROUND CONDITIONS

There are hazards associated with the ground. An adequate understanding of these hazards can help to minimize risks to a project and the site. The ground is a vital element of all structures which rest on or in the ground. Information about ground behaviour is necessary to achieve a safe and economical structure. Often less is known about the ground than for any other element of a structure.

3. GEOTECHNICAL INVESTIGATION - SPATIAL COVERAGE LIMITATIONS

Geotechnical investigations collect data at specific test locations. Interpretation of ground conditions away from test locations is a matter of extrapolation and judgement based on geotechnical knowledge and experience, but actual conditions in untested areas may differ from predictions. For example, the interface between ground materials may be far more gradual or abrupt than a report indicates. It is not realistic to expect a geotechnical investigation to reveal or anticipate every detail of ground conditions. Nevertheless, an investigation can reduce the residual risk associated with unforeseen conditions to a tolerable level. If ground problems do arise, it is important to have geotechnical expertise available to help reduce and mitigate safety and financial risks.

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1 Site Investigation Steering Group SISG 1993. *Site Investigation in Construction 2: Planning, Procurement and Quality Management*. London: Thomas Telford.

4. ROLE OF JUDGEMENT AND OPINION IN GEOTECHNICAL ENGINEERING

Geotechnical engineering is less exact than most other design disciplines, and requires extensive judgement and opinion. Therefore, a geotechnical report may contain definitive statements that identify where the responsibility of Fugro begins and ends. These are not exculpatory clauses designed to transfer liabilities to another party, but they are statements that can help all parties involved to recognise their individual responsibilities and take appropriate actions.

COMPLETE GEOTECHNICAL REPORT SHOULD BE AVAILABILE TO ALL PARTIES INVOLVED

To prevent costly construction problems, construction contractors should have access to the best available information. They should have access to the complete original report to prevent or minimize any misinterpretation of site conditions and engineering advice. To prevent errors or omissions that could lead to misinterpretation, geotechnical logs and illustrations should not be redrawn, and users of geotechnical engineering information and advice should confer with the authors when applying the report information and/or recommendations.

GEOTECHNICAL INFORMATION IS PROJECT-SPECIFIC

Fugro’s investigative programmes and engineering assessments are designed and conducted specifically for the Client described project and conditions. Thus this report presents data and/or recommendations for a unique construction project. Project-specific factors for a structure include but are not limited to:

- location
- size and configuration of structure
- type and purpose or use of structure
- other facilities or structures in the area.

Any factor that changes subsequent to the preparation of this report may affect its applicability. A specialised review of the impact of changes would be necessary. Fugro is not responsible for conditions which develop after any factor in site investigation programming or report development changes.

For purposes or parties other than the original project or Client, the report may not be adequate and should not be used.

CHANGES IN SUBSURFACE CONDITIONS AFFECT THE ACCURACY / SUITABILITY OF THE DATA

Ground is complex and can be changed by natural phenomena such as earthquakes, floods, seabed scour and groundwater fluctuations. Construction operations at or near the site can also change ground conditions. This report considers conditions at the time of investigation. Construction decisions should consider any changes in site conditions, regulatory provisions, technology or economic conditions subsequent to the investigation. In general, two years after the report date, the information may be considered inaccurate or unreliable. A specialist should be consulted regarding the adequacy of this geotechnical report for use after any passage of time.

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APPENDIX 1: DESCRIPTIONS OF METHODS AND PRACTICES

CONTENTS Reference

This appendix presents method statements and terminology that are generally familiar to expert users of the information

INTRODUCTION

Fugro employs a range of industry-standard systems for soil description, with additional refinements. The more important systems are:

- British Standard 5930 (BS, specifically Section 6 Paragraphs 41 to 43 on Description of soils) published in 1999.
- American Society for Testing and Materials (ASTM) Standards D 2487-11 (Classification of soils for Engineering Purposes) and D 2488-09a (Description and Identification of Soils – Visual-Manual Procedure).
- International Standard ISO 14688-1:2002 (Geotechnical Investigation and Testing - Identification and Classification of Soil: Identification and Description) and International Standard ISO 14688-2:2004 (Principles for a Classification).
- International Standard ISO 19901-8:2014 (Marine Soil Investigations).

The standards are similar, as they are (1) based on the Unified Classification System (Casagrande, 1948), (2) rely on a range of relatively simple visual and manual observations and (3) classify soils according to particle-size distribution and plasticity. Laboratory particle-size distribution and Atterberg limits tests are used to confirm the observations. In addition, the standards include organic soils characterization under soil particle type description.

Significant differences between the standards include the particle-size boundaries and the degree to which plasticity is used as a basis for description. Other differences include the format and order of the soil description.

This document describes a convention that is consistent with either the BS or ASTM standard, and that produces soil descriptions, which can be converted to the other standard. In addition, to describe calcareous soils, Fugro has integrated the carbonate classification system outlined by Clark and Walker (1977) with both British Standard and ASTM systems (Landva et al., 2007). No further information is given about the ISO standards.

British Standard and ASTM systems apply primarily to common terrestrial soils in temperate climates. However, construction activities in coastal areas and offshore can also encounter major carbonate soil deposits. The engineering characteristics of carbonate soil deposits can differ substantially from those of silica-based soil deposits, primarily because of cementation and differences in void ratios.

Appropriate description is necessary. A commonly accepted procedure for calcareous soil deposits is the Clark and walker system, originally developed for the Middle East. This considers particle size, carbonate content and material strength. The particle size classification fits both BS and ASTM system. The carbonate content is an additional feature and the material strength classification relates to common post-depositional alteration of calcareous soil.

This document does not include rock description or specific engineering geological classification systems, such as those for the detailed identification of peat, chalk or micaceous sand.

The main steps of the soil description system are:

1. Measure or estimate particle type as silica-based, organic, or calcareous.
2. For soils that are predominantly silica-based and organic, select BS 5930:1999 or ASTM D 2487 based on local geotechnical practice or project requirements, and follow the appropriate descriptive procedure. For calcareous soils, use the process described by Peuchen et al. (1999).
3. Measure or estimate the particle-size distribution and Atterberg limits (plasticity) for use in defining the principal and secondary soil fractions.
4. Measure or estimate soil strength according to one of the following: (1) relative density of coarse-grained soil, (2) consistency of fine-grained soil, (3) cementation of cemented soil, or (4) lithification of soil undergoing diagenesis.
5. Complete the description using the additional terms for the soil mass characteristics and other features such as bedding, colour, and particle shape.

CALCAREOUS SOIL DESCRIPTION

The procedure considers particle size, carbonate content and material strength. The particle-size classification follows the Unified Soil Classification System. The carbonate content is an additional feature and the material strength classification relates to common post-depositional alteration of calcareous soil.

PARTICLE TYPE

The first determinant for soil description is particle type using Table 1. It mainly differentiates between silica and carbonate soil compositions with organic content of less than 1% of the dry weight. Organic soils are further described in the soil description procedures for BS and ASTM (Table 4).

TABLE 1 - PARTICLE TYPE

Clay soil	Other Soils	Carbonate Content (by dry weight)	Reaction with HCl (10%)
--	Silica	< 10 %	In clays: no bubbles, or slowly forming bubbles. In sands: reaction often limited to some individual particles, or particle surface Residue - Nearly all soil remaining
Calcareous	Calcareous silica	10 to 50	In clays: clearly visible, prolonged reaction and foaming. In sand: violent reaction Residue - Large part of soil remaining
Carbonate	Siliceous carbonate	50 to 90	Violent reaction Residue - Only small part of soil remaining
Carbonate	Carbonate	> 90	Violent reaction Residue - Hardly any soil remaining

The description method does not distinguish between types of carbonate material, and assumes that non-carbonate particles are siliceous.

CEMENTATION AND LITHIFICATION

Cementation is the process by which a binding material precipitates in the voids between the grains or minerals. Lithification is the process by which a soil is hardened due to pressure solution and transformation or new grain or mineral growth. Both processes contribute to the formation of rock.

The descriptions for cementation follow rock strength classification (Table 2) expressed as uniaxial compressive strength σ_c:

TABLE 2 – CEMENTATION

Cementation	σ_c [MPa]
Slightly cemented	0.3 to 1.25
Moderately cemented	1.25 to 5.0
Well cemented	5.0 to 12.5

The term "well cemented" in Table 2 applies to soil, which also shows sublayers with little or no cementation. In case of further lithification, the soil description becomes a rock description using Table 3. The rock strength is only indicative.

TABLE 3 - LITHIFICATION

Carbonate content [%]	Dominant fraction: Clay	Silt	Sand	Gravel	Cobbles	Boulders	σ_c [MPa]
incomplete lithification							
< 10	CLAYSTONE	SILTSTONE	SANDSTONE	CONGLOMERATE	CONGLOMERATE or BRECCIA		0.3 to 12.5
10 to 50	Calcareous CLAYSTONE	Calcareous SILTSTONE	Calcareous SANDSTONE	Calcareous CONGLOMERATE			
50 to 90	Clayey CALCILUTITE	Siliceous CALCISILTITE	Siliceous CALCARENITE	Conglomeratic CALCIRUDITE			
> 90	CALCILUTITE	CALCISILTITE	CALCARENITE	CALCIRUDITE			
complete lithification							
< 50	CLAYSTONE	SILTSTONE	SANDSTONE	GRAVEL CONGLOMERATE	CONGLOMERATE or BRECCIA		>12.5
> 50	Fine-grained Argillaceous LIMESTONE	Fine-grained Siliceous LIMESTONE	Medium grained LIMESTONE	Conglomeratic LIMESTONE			

The Clark and Walker system does not include reef limestone (biolithite). **Reef limestone** represents an in situ accumulation of biological origin (e.g. coral reef) and consists largely of carbonate skeletal material of colonising organisms. The carbonate content normally exceeds 90%. Classification of strength follows rock description procedures.

SOIL DESCRIPTION USING BS 5930:1999

In the following sections, each of the main characteristics is described in the order most commonly used for soil identification, with some portions of the text quoted (shown within quotation marks) or paraphrased from the BS 5930.

SOIL GROUP (BS)

The soil group subdivides the soils into very coarse, coarse, fine, and organic soils.

<u>Very coarse</u> soils consist of cobbles and boulders, with particles larger than 60 mm in diameter. These soil particles are rarely sampled using standard soil sampling techniques. They are described separately, and not included when determining the proportions of the other soil components.

The initial classification of silica soils as <u>coarse</u> or <u>fine</u> is based on the percentage of fine particles after the very coarse particles are removed. In BS 5930, the boundary between coarse (i.e. sands and gravels) and fines (i.e. silts and clays) is 0.060 mm (60 µm). When the soil contains approximately 35% or more fines, it is described as a fine soil; further classification of the fine soil as a clay or silt depends on the plasticity of the soil. When the soil contains less than about 35% fine material, it is usually described as a coarse soil. “The boundary between fine and coarse soils is approximate, as it depends on the plasticity of the fine fraction and the grading of the coarse fraction.”

<u>Organic soils</u> contain usually small quantities of dispersed organic matter that can have a significant effect on soil plasticity. Organic soil descriptions in BS 5930 are based on an organic content by weight determined by loss on ignition. Where organic matter is present as a secondary constituent, the following terms are used:

TABLE 4 - ORGANIC SOIL DESCRIPTIONS

Term	Organic content [% by weight]	Typical colour
Slightly organic clay or silt Slightly organic sand	2 to 5 1 to 3	Grey Same as mineral
Organic clay or silt Organic sand	5 to 10 3 to 5	Dark grey Dark grey
Very organic clay or silt Very organic sand	> 10 > 5	Black Black

Soils with organic contents up to approximately 30% by weight and water contents up to about 250% behave as mineral soils and are described using the terms given in the lower portion of Table 4.

Peat consists predominantly of plant remains, is usually dark brown or black, and has a distinctive smell. It is generally classified according to the degree of decomposition (fibrous, pseudo-fibrous, or amorphous) and strength (firm, spongy, or plastic). When encountered, reference can also be made to the classification given in ASTM Standard Procedure D 4427.

PRINCIPAL SOIL TYPE AND PARTICLE SIZE (BS)

Coarse-Grained Soils

The principal soil type in coarse-grained soils is sand if the dry weight of the sand fraction (0.06 mm to 2 mm particle sizes) exceeds that of the gravel fraction (2 mm to 60 mm particle sizes), and vice versa for gravel.

As an addition to the BS 5930 classification, coarse-grained soils are described as well-graded or poorly-graded based on the grain-size distribution curve, using the coefficient of uniformity (C_U) and, to a lesser extent, the coefficient of curvature (C_C), as follows:
– Sands with ≤12% fines are <u>well-graded</u> when $C_U \geq 6$ and C_C is between 1 and 3.
– Sands are <u>poorly-graded</u> for other values of C_U and C_C.
– Gravels with ≤12% fines are <u>well-graded</u> when $C_U \geq 4$ and C_C is between 1 and 3.
– Gravels are <u>poorly-graded</u> for other values of C_U and C_C.

For coarse-grained soils with fines contents > 12%, these terms are not used.

Sands and gravels are sub-divided into coarse, medium, and fine, as defined in Table 5.

TABLE 5 - SIZE FRACTION DESCRIPTIONS FOR COARSE-GRAINED SOILS

Soil	Particle diameter range [mm]		
	Coarse	Medium	Fine
Gravel	60 to 20	20 to 6	6 to 2
Sand	2 to 0.6	0.6 to 0.2	0.2 to 0.06

Fine-Grained Soils

Fine-grained soils are classified as clay or silt according to the results of Atterberg limits tests. A fine-grained soil is classified as clay if:

$$I_P \geq 6 \text{ and } I_P \geq 0.73\,(w_L-20)$$

where:
I_P = plasticity index [%]
w_L = liquid limit [%]

Otherwise the dominant soil fraction is silt. The equation $I_P = 0.73\,(w_L-20)$ represents the "A-line" in a plasticity chart. The plasticity chart may also show a "U-line" defined as $I_P = 0.9\,(w_L-8)$ and $w_L \geq 16$, according to Casagrande (1948). The U-line represents an approximate upper limit of correlation between plasticity index and liquid limit for natural soils.

The following additional descriptors (as used in the ASTM soil description procedure) are added:
– Clays with liquid limits of 50% or higher are described as "fat."
– Clays with liquid limits below 50% are described as "lean."
– Silts with liquid limits of 50% or higher are termed "elastic silt."
– Silts with liquid limits below 50% are simply "silts."

The term "silty clay" is not used, since BS 5930 explicitly states that silt and clay "are to be mutually exclusive."

Particle Shape

The description of particle shape includes terms for form, angularity, and surface texture. These terms are the same for BS 5930 as for ASTM D 2488. Reference should be made to the corresponding ASTM section of this document.

COMPOSITE (SECONDARY) SOIL TYPES (BS)

BS 5930 defines procedures for assigning secondary soil fractions to coarse-grained soils that are identical for sand and gravel, except that the secondary soil type is sandy when the principal soil type is gravel and vice versa. For fine-grained soils (silt and clay) there is a single procedure for assigning secondary soil fractions. The ranges for the percentages of the secondary constituents are similar to, though different from, those defined by ASTM.

If the principal soil type is sand, secondary soil fractions may be gravelly and silty or clayey (e.g. silty sand). Similarly, if the principal soil type is clay, secondary soil fractions may be sandy or gravelly. Table 6 (from BS 5930) gives the terms to be used for ranges of secondary constituents.

TABLE 6 - DESCRIPTIVE TERMS AND RANGES FOR SECONDARY CONSTITUENTS

Term	Principal soil type	Approximate proportion of secondary constituent	
		Coarse soil	Fine soil
Slightly clayey or silty Clayey or silty Very clayey or silty Slightly sandy or gravelly Sandy or gravelly Very sandy or gravelly	SAND and/or GRAVEL	< 5% 5% to 20% > 20%	< 5% 5% to 20% > 20% (1)
Slightly sandy and/or gravelly Sandy and/or gravelly Very sandy and/or gravelly	SILT or CLAY	< 35% 35% to 65% > 65% (2)	

Notes: (1) or can be described as fine soil depending on engineering behaviour
(2) or can be described as coarse soil depending on engineering behaviour.

COLOUR (BS)

Soil colours are described using the Munsell Soil Colour Charts (Gretag-Macbeth, 2000).

The Munsell colour is arranged according to three variables known as Hue, Value and Chroma. The Hue notation of a colour indicates its relation to red, yellow, green, blue and purple. The Value notation indicates the relative lightness. The Chroma notation indicates the intensity of the colour.

BEDDING/STRATIGRAPHY (BS)

Layers of different soil types within a stratum are called bedding units, and are described in terms of the unit thickness. In an otherwise homogeneous soil, these can be identified as bedding planes or as colour changes, and not necessarily as discontinuities.

Table 7 (from BS 5930) gives terms for bedding/stratigraphy.

TABLE 7 - DESCRIPTIVE TERMS FOR BEDDING/STRATIGRAPHY

Stratified	Bedding	Interbedded	Thickness [mm]
Very thick beds	Very thick bedded	Very thickly interbedded	>2000
Thick beds	Thickly bedded	Thickly interbedded	600 to 2000
Medium beds	Medium bedded	Medium interbedded	200 to 600
Thin beds	Thinly bedded	Thinly interbedded	60 to 200
Very thin beds	Very thinly bedded	Very thinly interbedded	20 to 60
Thick laminae	Thickly laminated	Thickly interlaminated	6 to 20
Thin laminae	Thinly laminated	Thinly interlaminated	<6

Strata with alternating or different beds or laminations can be described as interbedded or interlaminated. Where the soil types are approximately equal, both terms can be used (e.g. thinly interlaminated SAND and CLAY).

Partings are bedding surfaces that separate easily, and typically are laminae of no appreciable thickness. The spacing between partings is described in the same terms as for spacing of discontinuities (Table 8).

DISCONTINUITIES/STRUCTURE (BS)

Discontinuities include fissures and shear planes, and the descriptor refers to the mean spacing between such discontinuities in a soil mass. A soil is “fissured” when it breaks into blocks along unpolished discontinuities, and “sheared” when it breaks into blocks along polished discontinuities (which is equivalent to a slickensided soil). The spacing description ranges from extremely closely spaced (less than 20 mm) to very widely spaced (over 2000 mm). No other descriptive terms are used. An example would be: Firm grey very closely fissured fine sandy calcareous CLAY with many silt partings.

The spacing terms are also used for distances between partings, isolated beds or laminae, desiccation cracks, rootlets, etc.

TABLE 8 - SPACING OF DISCONTINUITIES

Term	**Mean spacing range [mm]**
Very widely	Over 2000
Widely	600 to 2000
Medium	200 to 600
Closely	60 to 200
Very closely	20 to 60
Extremely closely	Under 20

DENSITY/COMPACTNESS OF GRANULAR SOILS (BS)

Usually, soil description offers little evidence about the density condition of coarse-grained cohesionless (granular) soil samples. The reason for this is the substantial sampling disturbance incurred during conventional sampling operations such as push sampling, percussion sampling, and vibrocoring. Complementary investigation techniques, such as Cone Penetration Tests (CPT), are usually necessary. The strength of a cohesionless soil is normally measured as a function of its relative density (also termed compactness or density index). Relative density is the ratio of the difference between the void ratios of a cohesionless soil in its loosest state and existing natural state to the difference between its void ratio in the loosest and densest states.

Relative density (compactness) is referred to in BS 5930:1999 only in terms of N-values obtained by the Standard Penetration Test (which is not conducted in offshore site investigations). Rather than using SPT-based values, it is common practice to interpret relative density on the basis of CPT results. Ranges of relative density are given in Table 9. These ranges are in common use in the industry. They were originally given in Lambe and Whitman (1979) and in the API RP 2A guidelines generally used for offshore pile design. These terms also apply to cohesionless fine-grained soils.

TABLE 9- RANGE OF RELATIVE DENSITY OF GRANULAR SOILS

Term	**Range of relative density [%]**
Very loose	Less than 15
Loose	15 to 35
Medium dense	35 to 65
Dense	65 to 85
Very dense	Greater than 85

STRENGTH OF COHESIVE SOILS (BS)

The strength of cohesive soils is given in terms of undrained shear strength, using the terms and ranges given in Table 10, with an additional level to cover “very hard” soils.

TABLE 10 - UNDRAINED SHEAR STRENGTH SCALE FOR COHESIVE SOILS (BS 5930:1999)

Term	**Undrained shear strength**	
	[kPa]	**[ksf]** (1)
Very soft	Less than 20	Less than 0.4
Soft	20 to 40	0.4 to 0.8
Firm	40 to 75	0.8 to 1.5
Stiff	75 to 150	1.5 to 3.0
Very stiff	150 to 300	3.0 to 6.0
Hard	300 to 600	6.0 to 12.0
Very hard (2)	Greater than 600	Greater than 12.0

Notes: (1) Unit conversion added to table
(2) Added for global practice.

MINOR CONSTITUENTS (BS)

Percentages of minor constituents within the soil, such as shell or wood fragments, or small soil inclusions (such as partings or pockets), can be quantified using the terms “with trace”, “with few”, “with” and “with many” (in increasing order). These terms are usually added at the end of the main soil description (e.g. with many shell fragments, with silt pockets, etc.); exceptions are terms such as “shelly”, which are more appropriate before the soil group name. For beds of material within a soil matrix, the terminology for spacing and thickness of beds is used. For individual particles of soil or material within a soil matrix, the terms “partings” and “pockets” are used.

SOIL ODOUR (BS)

Describing the odour from soil samples as they are retrieved or extruded on board ship can be useful. Terms used to describe the odour are H_2S, “musty”, “putrid” and “chemical”. It must be emphasised that soil odour descriptions are unlikely to be fully consistent, because of factors such as variations in sample handling, ambient conditions at time of sample description, and strong dependence on a person’s ability to detect and identify odour.

SOIL DESCRIPTION USING ASTM D 2487 AND D 2488

The identification and description of silica soils in the ASTM system consists primarily of a group name and symbol, which are based on the particle-size distribution and the Atterberg limits test results, and the results of other laboratory classification tests.

The main standard for soil description, D 2487 Classification of Soils for Engineering Purposes, is applicable to naturally-occurring soils passing a 3-in. (75-mm) sieve, and identifies three major soil types: coarse-grained, fine-grained, and highly organic soils. The major soil types are further subdivided into 15 specific basic soil groups.

An accompanying Standard, D 2488, outlines the Description and Identification of Soils using a Visual-Manual Procedure. This standard is used primarily in the field, where full particle-size distribution curves and Atterberg limits values are not available. It gives guidance for detailed descriptions of soil particles and soil conditions (e.g. colour, structure, strength, cementation, etc.), which are not included in D 2487.

Soil types with particles larger than 75 mm (i.e. cobbles and boulders) are not included in the Standards, but are identified.

SOIL TYPES (ASTM)

The initial classification of silica soils as coarse-grained or fine-grained is based on the percentage fines, expressed as the percentage of dry weight of the total sample after the very coarse particles are removed, as with BS 5930. However, ASTM has defined the coarse-fine boundary as 0.075 mm (75 µm).

The soil is coarse-grained (sand or gravel) if the percentage fines is 50% or less. Otherwise, the soil is fine-grained (silt or clay) – the classification is not based on plasticity.

Coarse-grained soils are classified further as either sand or gravel using the results of particle-size distribution tests.

Fine-grained soils are classified further as silt or clay on the basis of the liquid limit and plasticity index (from Atterberg limits tests).

The soil is an organic soil if it contains sufficient quantities of dispersed organic matter that it has an influence on the liquid limits of the fines component after oven-drying, as outlined in the BS Section. The definition of peat is similar to that in BS 5930 and it is generally classified according to the degree of decomposition and strength. When encountered, reference should be made to the classification given in ASTM D 4427.

SOIL GROUP NAME AND SYMBOL (ASTM)

Coarse-Grained Soils

For coarse-grained soils, the dominant soil fraction is sand if the dry weight of the sand fraction, i.e. particle sizes from 0.075 mm to 4.75 mm, exceeds that of the gravel fraction, i.e. particles ranging from 4.75 mm to 75 mm, and vice versa for gravel.

Coarse-grained soils with ≤12% fines are also described as well-graded or poorly-graded based on the particle-size distribution curve, using the coefficient of uniformity (C_U) and, to a lesser extent, the coefficient of curvature (C_C) as follows:
– Sands are well-graded when $C_U \geq 6$ and C_C is between 1 and 3.
– Sands are poorly-graded for other values of C_U and C_C.
– Gravels are well-graded when $C_U \geq 4$ and C_C is between 1 and 3.
– Gravels are poorly-graded for other values of C_U and C_C.

For coarse-grained soils with fines contents >12%, these terms are not used.

Sands and gravels are also sub-divided into coarse, medium, and fine, as defined in Table 11.

TABLE 11 - SIZE FRACTION DESCRIPTIONS FOR COARSE-GRAINED SOILS

Soil	Particle diameter range [mm]		
	Coarse	Medium	Fine
Gravel	75 to 19	-	19 to 4.75
Sand	4.75 to 2.0	2.0 to 0.425	0.425 to 0.075

The predominant size fractions present are identified, and the absence of size range descriptors means that fine, medium, and coarse fractions are all present in roughly equal proportions.

Fine-Grained Soils

Fine-grained soils are classified as clay or silt according to the results of Atterberg limits tests. A soil is inorganic clay if: $I_P \geq 6$ and $I_P \geq 0.73(w_L\text{-}20)$

where:
I_P = plasticity index [%]
w_L = liquid limit [%]

The A-line and U-line in a plasticity chart are as described in the BS section.

Clays with liquid limit $w_L < 50$ and plasticity index $I_P > 7$ are further classified as lean clay, and given the group symbol “CL”. Clays with liquid limits $w_L \geq 50$ are further classified as fat clay, and are given the group symbol “CH”.

A soil is classified as a <u>silt</u> when it plots below the A-line <u>or</u> the plasticity index $I_P < 4$. Silts with liquid limit $w_L < 50$ are given the group symbol “ML”. Silts with liquid limits $w_L \geq 50$ are further classified as <u>elastic silt</u>, and are given the group symbol “MH”.

Soils are classified as <u>silty clay</u> where the liquid limit versus plasticity index plots on or above the A-line but where the plasticity index falls within the range $4 \leq I_P \leq 7$, i.e. the hatched zone in the lower left-hand corner of the plasticity chart. Silty clays are given the Group Symbol “CL-ML”.

Organic Soils

For both clay and silt, or the fines component of a coarse-grained soil, the additional term <u>organic</u> applies if the ratio of the liquid limit of a sample (or the fines portion of the sample) after oven drying at 105° C to the liquid limit without oven drying is less than 0.75.

Organic soils are classified in a manner similar to that for inorganic soils for plots of the liquid limit (not oven dried) versus plasticity index with respect to the A-line. Organic clays and silts with liquid limit $w_L < 50$ are given the same group symbol “OL”. Organic clays and silts with liquid limits $w_L \geq 50$ are given the group symbol “OH”.

Coarse-grained soils containing fine organic material are described using the term “with organic fines”.

SECONDARY SOIL TYPE (ASTM)

Secondary soil type descriptions follow the ranges given in Table 12. No other terms are used, though combinations of these terms are.

TABLE 12 - DESCRIPTIVE TERMS AND RANGES FOR SECONDARY CONSTITUENTS

Term	Principal soil type	Term	Approximate proportion of secondary constituent	
			Coarse soil	Fine soil
	SAND and/or GRAVEL[1]			< 5%
	SAND and/or GRAVEL[1]	with clay or silt		5% to 12%
Clayey or Silty	SAND and/or GRAVEL[1]			> 12%
	SAND and/or GRAVEL[1]		<15% gravel or sand	
	SAND and/or GRAVEL[1]	with gravel or sand	≥15% gravel or sand	
	SILT or CLAY		< 15%	
	SILT or CLAY	with sand or gravel[1]	15% to 29%	
Sandy and/or gravelly[1]	SILT or CLAY		≥30%	

Note: (1) choice depends on which has higher percentage.

PARTICLE SHAPE (ASTM)

The description of particle shape includes references to form, angularity, and surface texture. These terms are normally used only for gravels, cobbles, and boulders, though in some cases for coarse sands.

The <u>form</u> (or shape) of coarse particles is described as flat, elongated, or both.

Flat: Width/Thickness > 3
Elongated: Length/Width > 3
Flat and elongated meets both criteria. These terms are not used if the criteria are not strictly met.

<u>Angularity</u> terms are usually only applied to particles gravel-size and larger (Table 13, from ASTM D 2488).

TABLE 13 - ANGULARITY OF COARSE-GRAINED PARTICLES

Term	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

The surface texture of coarse particles are described as rough or smooth.

COLOUR (ASTM)

As noted for BS 5930 (BS section), soil colours are described using the Munsell Soil Colour Charts (Gretag-Macbeth, 2000).

SOIL ODOUR (ASTM)

The same descriptive terms suggested for BS 5930 (BS Section) are used with the ASTM Standards. It must be emphasised that soil odour descriptions are unlikely to be fully consistent, because of factors such as variations in sample handling, ambient conditions at time of sample description, and strong dependence on a person's ability to detect and identify odour.

STRENGTH OF COHESIVE SOILS (ASTM)

Descriptions of cohesive soil strength are not part of the ASTM classification system; however soil strength is incorporated whenever available from laboratory or in situ test results and interpretation. The boundaries for undrained shear strength ranges in current use in North American practice are given in Table 14. These boundaries are lower than those used with BS 5930.

TABLE 14 - UNDRAINED SHEAR STRENGTH SCALE FOR COHESIVE SOILS (1)

Term	Undrained shear strength	
	[kPa]	[ksf] (2)
Very soft	Less than 12.5	Less than 0.25
Soft	12.5 to 25	0.25 to 0.50
Firm	25 to 50	0.50 to 1.0
Stiff	50 to 100	1.0 to 2.0
Very stiff	100 to 200	2.0 to 4.0
Hard	200 to 400	4.0 to 8.0
Very hard (3)	Greater than 400	Greater than 8.0

Notes: 1) from Terzaghi and Peck (1967)
2) ksf used primarily for US projects
3) the upper boundary for "Hard", and the "Very hard" range have been added

DENSITY/COMPACTNESS OF GRANULAR SOILS (ASTM)

Tables of recommended values and descriptors for relative density are not provided in the ASTM Standards, but in practice relative density is often interpreted on the basis of cone penetration test results. The same ranges of relative density (compactness) as those recommended for use with BS 5930 (see BS Section) are used.

DISCONTINUITIES/STRUCTURE (ASTM)

Criteria for describing soil structure are provided in ASTM D 2488, and in Table 15 along with additional terms in use in the geotechnical industry.

TABLE 15 - DESCRIPTIVE TERMS FOR SOIL STRUCTURE

Term	Description
Slickensided	Fracture or shear planes (or planes of weakness) that appears slick and glossy.
Fissured	Cohesive soil that breaks into blocks along unpolished planes (discontinuities), often filled with a different material. The fill material is noted.
Blocky	Cohesive soil that breaks into small angular lumps along polished planes (discontinuities) which resist further breakdown.
Gassy	Soil has a porous nature and there is evidence of gas, such as blisters.
Expansive	Visibly expands after sampling. Degree of expansion is estimated and noted.
Platy	A stratified appearance when the soil can be broken into thin horizontal plates.
Cemented	Material grains bound together forming an intact mass.

The distance between the fissures, shear planes and expansion cracks is noted using the terms in Table 8.

BEDDING/STRATIGRAPHY (ASTM)

The terminology for bedding thickness and stratigraphic description used in North American offshore practice is more detailed than outlined in ASTM D 2488, and is different from BS 5930. In Table 16, the descriptive terms have been further defined and integrated with BS 5930 terminology.

TABLE 16 - DESCRIPTIVE TERMS FOR BEDDING THICKNESS AND INCLUSIONS

Term	Bedding thickness	
	[mm]	[inch]
Pocket	Inclusion of material of different texture that is smaller than the diameter of the sample	
Parting	< 3	1/8
Lamina	3 to < 6	1/8 to < 0.25
Laminated(1)	Alternating partings or laminae of different soil types in equal proportion	
Lens	6 to < 20	0.25 to < 0.75
Seam	20 to < 76	0.75 to < 3
Layer	Greater than 76	Greater than 3
Stratified(2)	Alternating lenses, seams or layers of different soil types in equal proportion	
Intermixed	Soil sample composed of pockets of different soil types, and laminated or stratified structure is not evident	

Notes: (1) Equivalent to “Interlaminated” term used in BS 5930:1999
(2) Equivalent to “Interbedded” term used in BS 5930:1999.

MINOR CONSTITUENTS (ASTM)

Minor constituents within a soil, such as shell or wood fragments, or small quantities of soil particles (not secondary soil types), are typically more relevant to the site geology or to laboratory testing procedures than to soil behaviour. Since the terms and percentages are not defined in either BS 5930 or ASTM D 2487/8, the terms “with trace”, “with few”, “with”, “with many” are used as a guide.

WRITTEN SOIL DESCRIPTIONS

Although soils are classified in the order of the characteristics described in the preceding sections, written descriptions are given in a different order in both Standards. To bring as much consistency as possible to the soil descriptions, Fugro selected a single preferred order of terms, which most closely resembled the majority of the descriptions used in Fugro offices around the world.

In this description, the principal soil type is given last as the soil name, with most other terms written as adjectives. The principal soil type is given in upper-case.

The preferred order of terms for a soil description are:
1. Density/compactness/strength.
2. Discontinuities.
3. Bedding.
4. Colour.
5. Secondary (composite) soil types.
6. Particle shape.
7. Particle size.
8. PRINCIPAL SOIL TYPE.

with:
9. Minor constituents (can be inserted in front of the principal soil type, such as “shelly”).
10. Soil odour.

For example: Firm closely-fissured dark olive grey sandy calcareous CLAY with few silt pockets. Where used, the Group Symbol is part of the soil description, e.g. loose poorly-graded fine to medium SAND with silt (SP-SM).

PARTICULATE DEPOSITS

The geological origin of a single particle type allows the following descriptions (optional):

Clastic: sediment transported and deposited as grains of inorganic origin. Typical clastic particles are:
- quartz grains: clear or milky white and ranging from very angular to very rounded; commonly a frosted surface for wind-blown grains
- feldspar grains: varying in colour from milky white to light yellowish brown
- mica flakes: varying in colour from gold-coloured to dark brown
- dark mineral grains: usually of igneous or metamorphic origin with undetermined mineralogy
- silicate grains: undetermined mineralogy
- rock fragments: including fragments of carbonate rock
- debris: deposit of rock fragments of a variety of particle sizes which may include sand and finer fractions; typical examples are rock debris and coral debris.

Organic: remains of plants and animals that consists mainly of carbon compounds

Bioclastic: sediment transported and deposited as grains of organic origin. Examples of bioclastic particles are:
- Calcareous algae: crustal or nodular growths or erect and branching forms produced by lime-secreting algae; microstructures include layered, rectangular structures and internal fine tube-like structures.
- Foraminifera: hard sediment test (external skeleton) consisting of calcite or aragonite and produced by unicellular organisms; commonly less than 1 mm in diameter, multi-chambered and intact.
- Sponge spicules: spicules of siliceous sponges in a variety of rayed shapes; dimensions ranging from less than 1 mm to over 1 cm in length but usually less than 1 mm in width.
- Corals: commonly consisting of small fibres set perpendicular to the walls and septal surfaces; mainly aragonite composition for relatively recent forms; conversion of aragonite to calcite for earlier corals, usually with consequent loss of original structural details.
- Echinoids: hard part of echinoids consisting of a plate or skeletal element forming a single crystal of calcite; five-rayed internal symmetry for spines of echinoids; typical widths ranging from several mm to a few cm.
- Bryozoans: chambered cell-like structures that are considerably coarser than those of calcareous algae; either aragonite or calcite composition; possible cell in-fill consisting of clear calcite and/or micrite.
- Bivalves and Gastropods: Mollusk shells, chiefly of aragonite composition; inner layer of aragonite protected by an outer layer of calcite for some bivalve shells and gastropods.

Oolitic: sediment consisting of solid, round or oval, highly polished and smooth coated grains, which may or may not have a nucleus. The coating consists of chemically precipitated aragonite, possibly converted to calcite. Ooliths have concentric structures and may also have radial structures. The grains are generally less than 2 mm diameter.

Pelletal: sediment consisting of well-rounded grains of ellipsoidal shape and no specific internal structure. The composition is clay to silt-sized carbonate material, which is probably the excretion product of sediment eating organisms. Pellets may have an oolitic crust. The grains are generally less than 2 mm diameter.

STRUCTURE OF NON PARTICULATE DEPOSITS

Reef: soil or rock formed by in situ accumulation or build-up of carbonate material by colonial organisms such as polyps (coral), algae (algal mats or balls) and sponges.

Orthochemical: orthochemical components precipitated during or after deposition. These components can include: (1) pyrite spherulites and grains, (2) crystal euhedra of anhydride or gypsum, (3) replacement patches and nodular masses of anhydrite and gypsum. Single grains are rare.

GEOLOGICAL INFORMATION

Specific geological terms can assist the geotechnical soil description by providing information on stratigraphy, origin (genesis) or regional significance (optional). Examples are:

- time stratigraphy, such as Eemian and Pleistocene
- lithostratigraphy, such as Yarmouth Roads Formation
- depositional environment, such as Marine, Glacio-lacustrine and Residual Soil
- regional significance, such as Chalk and Mud.

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INTRODUCTION

The Cone Penetration Test (CPT) involves the measurement of the resistance of ground to steady and continuous penetration of a cone penetrometer equipped with internal sensors. The measurements comprise penetration depth, cone resistance, sleeve friction and, optionally, pore pressure and inclination from vertical. These measurements permit interpretation of ground conditions.

CPT apparatus and procedures adopted by Fugro are in general accordance ISSMGE (1999), ASTM (2012), ISO (2012) and ISO (2014). BS 5930 (BSI, 1999) and NORSOK Standard G-CR-001 (NORSOK, 2004) refer to ISSMGE (1999). General agreement also applies to Eurocode 7 (CEN, 2007).

Fugro offers CPT systems operated from (1) ground surface and seafloor (non-drilling deployment mode) and (2) downhole in a borehole (drilling deployment mode).

CPT APPARATUS

GENERAL

CPT apparatus includes various parts as described below:
- Thrust machine: apparatus providing thrust to the push rods so that the required constant rate of penetration is controlled.
- Reaction equipment: reaction for the thrust machine.
- Push rod: thick-walled cylindrical tube used for advancing the penetrometer to the required test depth. Push rods may also consist of drill pipe.
- Friction-cone penetrometer (CPT): cylindrical terminal body mounted on the lower end of the push rods, including a cone, a friction sleeve and internal sensing devices for the measurement of cone resistance, sleeve friction and, optionally, inclination.
- Piezo-cone penetrometer (CPTU or PCPT): cylindrical terminal body mounted on the lower end of the push rods, including a cone, a friction sleeve, a filter and internal sensing devices for the measurement of cone resistance, sleeve friction, pressure and, optionally, inclination.
- Measuring system: apparatus and software, including sensors, data transmission apparatus, recording apparatus and data processing apparatus.

DEPLOYMENT FROM GROUND SURFACE OR SEAFLOOR

Specific additional apparatus for CPT deployment from ground surface and seafloor can include:
- Push rod casing: guide for the part of the push rods protruding above the soil, and for the push rod length exposed in water or soil, in order to prevent buckling when the required penetration pressure increases beyond the safe limit for the exposed upstanding length of push rods.
- Friction reducer: ring or special projections fixed on the outside of the push rods, with an outside diameter larger than the base of the cone, to reduce soil friction acting on the push rods.

DOWNHOLE BOREHOLE DEPLOYMENT

Downhole CPT systems latch into a bottom hole assembly at the lower end of a drill pipe. System options are:
1. Operation of a downhole thrust machine by applying mud pressure in the borehole.
2. Remote control of a downhole thrust machine by hydraulic pressure transmitted through an umbilical cable connected to a surface-based pump unit, together with.
3. Application of thrust to drill rods where CPT apparatus and a short push rod are latched in the bottom hole assembly; the thrust machine is at ground surface or seafloor.

Data recording can be surface-based and/or downhole.

Downhole CPTs require drilling apparatus for advancing the borehole. The maximum CPT stroke is generally 1.5 m or 3 m.

CONE PENETROMETER

Typical features of Fugro penetrometers (Figure 1) include:

- Cone base areas of 500 mm^2, 1000 mm^2 or 1500 mm^2; other sizes are also in use, e.g. 3300 mm^2
- Cone and friction sleeve sensors placed in series, i.e. subtraction-type penetrometers.
- Pore pressure measurements either at the face of the cone (u_1) or at the cylindrical extension of the cone (u_2). Multiple-sensor penetrometers (u_1, u_2 and u_3) are also available. The u_3 location is immediately above the friction sleeve.
- Inclinometer.
- Storage of signals from the penetrometer in digital form for subsequent computer-based processing and presentation.

PROCEDURE

Figure 2 summarises the test procedure. The procedure includes several stages. The stage of Additional Measurements is optional.

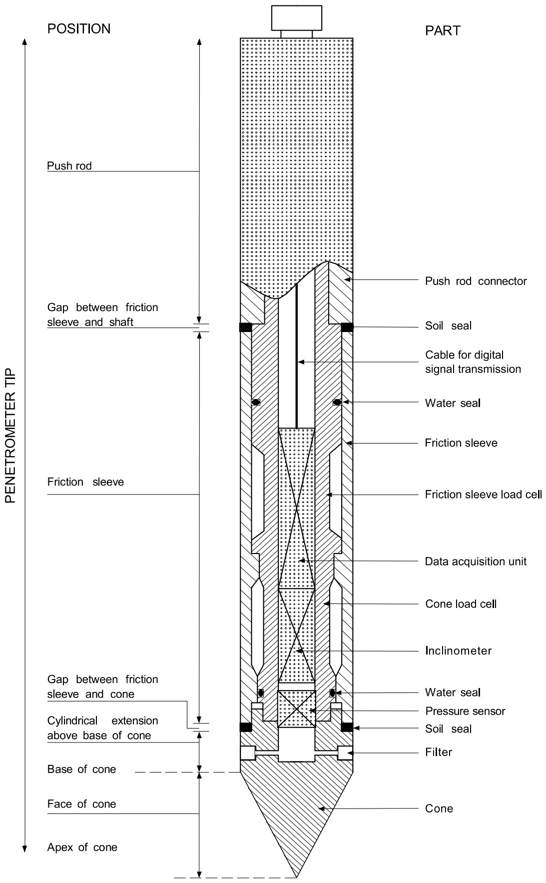

Figure 1 – Piezo-cone Penetrometer

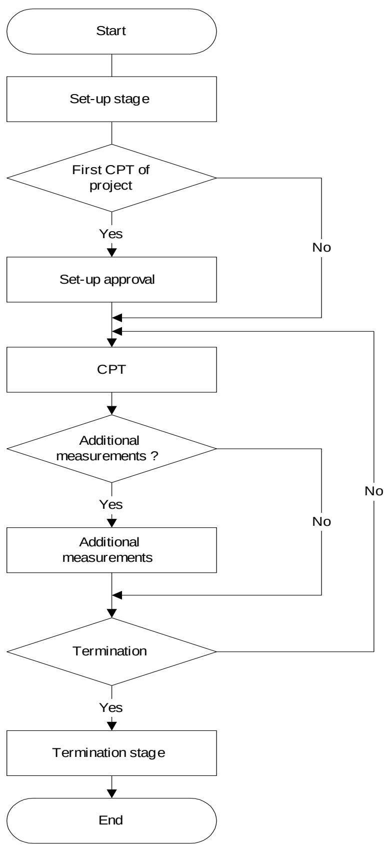

Figure 2 - Flow chart

Set-up requires a reasonably flat, accessible, ground surface with a slope of 5^o or less. In other cases, set-up is at discretion of the equipment operator, considering risks such as damage to apparatus or safety of personnel. Most onshore thrust machines have levelling facilities allowing a vertical start of penetration. Seabed frames used for offshore CPT activities have no levelling facilities, i.e. start of penetration may not be vertical.

The set-up stage includes selection of equipment and procedures according to project-specific agreements, such as a required accuracy class or application class, penetration, type of cone penetrometer and data processing/ submission. Table 1 presents ISSMGE accuracy classes and Tables 2 and 3 summarise ISO application classes. The allowable minimum accuracy of a measured parameter is the larger value of the two quoted. A percentage value applies to the measured value and not to the measuring range. The concept of application classes considers intended soil conditions for selection of an application class. For example, Application Class 1 of ISO (2014) can be selected for "very soft to soft soil deposits", which is approximately equivalent to q_c < 0.5 to q_c < 1 MPa. In other words, Application Class 1 should not apply to "mixed bedded soil profiles with weak to strong layers".

The accuracy values apply to ground surface or seafloor as reference. They are uncoupled from uncertainty of spatial position below ground surface or seafloor.

TABLE 1 ACCURACY CLASSES (ISSMGE, 1999)

Accuracy Class	Measured Parameter	Allowable Minimum Accuracy	Maximum Length between Measurements
1	Cone resistance, q_c Sleeve friction, f_s Pore pressure, u Inclination, i Penetration depth, z	50 kPa or 3% 10 kPa or 10% 5 kPa or 2% 2° 0.1 m or 1%	20 mm
2	Cone resistance, q_c Sleeve friction, f_s Pore pressure, u Inclination, i Penetration depth, z	200 kPa or 3% 25 kPa or 15% 25 kPa or 3% 2° 0.2 m or 2%	20 mm
3	Cone resistance, q_c Sleeve friction, f_s Pore pressure, u Inclination, i Penetration depth, z	400 kPa or 5% 50 kPa or 15% 50 kPa or 5% 5° 0.2 m or 2%	50 mm
4	Cone resistance, q_c Sleeve friction, f_s Penetration length, l	500 kPa or 5% 50 kPa or 20% 0.1 m or 1%	50 mm

TABLE 2 APPLICATION CLASSES (ISO, 2012)

Appl. Class	Measured Parameter	Allowable Minimum Accuracy	Maximum Length between Measurements
1	Cone resistance, q_c Sleeve friction, f_s Pore pressure, u Inclination, i Penetration length, l	35 kPa or 5% 5 kPa or 10% 10 kPa or 2% 2° 0.1 m or 1%	20 mm
2	Cone resistance, q_c Sleeve friction, f_s Pore pressure, u Inclination, i Penetration length, l	100 kPa or 5% 15 kPa or 15% 10 kPa or 3% 2° 0.1 m or 1%	20 mm
3	Cone resistance, q_c Sleeve friction, f_s Pore pressure, u Inclination, i Penetration length, l	200 kPa or 5% 25 kPa or 15% 50 kPa or 5% 5° 0.2 m or 2%	50 mm
4	Cone resistance, q_c Sleeve friction, f_s Penetration length, l	500 kPa or 5% 50 kPa or 20% 0.2 m or 2%	50 mm

TABLE 3 APPLICATION CLASSES (ISO, 2014)

Application Class	Measured Parameter	Allowable Minimum Accuracy
1	Cone Resistance Sleeve friction Pore pressure	35 kPa or 5% 5 kPa or 10% 25 kPa or 5%
2	Cone resistance Sleeve friction Pore pressure	100 kPa or 5% 15 kPa or 15% 50 kPa or 5%
3	Cone Resistance Sleeve friction Pore pressure	200 kPa or 5% 25 kPa or 15% 100 kPa or 5 %

The set-up stage or the termination stage includes the location survey, i.e. the determination of the co-ordinates and the ground surface elevation (or the water depth).

The set-up stage and the termination stage for a downhole CPT include lowering of the CPT apparatus into the borehole and lifting respectively. Most projects require multiple downhole tests in a single borehole.

For piezo-cone testing, the set-up stage also includes the following steps:
- Office-based or site-based: de-airing of the filter in glycerine by application of 24-hour vacuum and storage in a glycerine-filled container.
- On-site: glycerine filling of hollow space in the cone penetrometer and subsequent mounting of the filter.
- On-site: application of a flexible membrane around the filter to prevent loss of saturating fluid prior to the start of a test.

Land-based tests may include specific measures to help retention of filter saturation during penetration of partially saturated zones. Relaxation of requirements typically applies to offshore tests where water pressures will force entrapped air into solution.

Criteria for test termination are as follows, unless specifically agreed otherwise:
- as instructed by Client
- reaching target penetration
- reaching maximum capacity of the thrust machine, reaction equipment, push rods and/or measuring sensors
- penetrometer inclination of greater than 15^o
- sudden increase in penetrometer inclination
- circumstances at discretion of equipment operator, such as risk of damage to apparatus or safety of personnel,

whichever occurs first and as applicable.

A CPTU pore pressure measuring system is intended for use in water-saturated uncemented fine-grained soil. Results obtained for ground conditions such as partially saturated soils, very dense sands and cemented soils may not be reliable and/or repeatable. For example, stiffness differences between the steel components of the cone penetrometer and the piezo-cone filter can affect results for very dense sands. Also, loss of saturation of the pore pressure measuring system may occur during a test (Lunne et al. 1997; Peuchen and Terwindt 2014). Reasons can include:
- penetration of partially saturated ground, for example ground containing significant amounts of gas
- measurement of negative pore pressures such that cavitation occurs. For example, this is not uncommon for a piezo-cone filter located at the cylindrical extension above the base of the cone (u_2 location). Particularly, this may occur at the time of penetration of dense sand or overconsolidated clay layers. Loss of saturation usually causes a sluggish pore pressure response during penetration of ground below the zone causing desaturation of the pore pressure measuring system.

Special apparatus and procedures may apply to:

– specific additional measurements (for example shear wave velocity)
– specific applications (for example deepwater tests or measurements for application (accuracy) classes 1 and 2).

RESULTS

CPT PARAMETERS

Presentation of results from cone penetration tests typically includes:

– CPT parameters q_c, f_s and R_f versus depth below ground surface or versus elevation
– additional CPTU parameters u_1 or u_2 and, optionally, q_t, q_n, B_q, Q_t, Q_{tn}, F_r and I_c for tests with pore pressure measurements
– optionally, inclination i for tests with inclination measurements
– standard graphical format and optional ASCII and AGS formats.

Most standards specify scales for graphical presentation as follows:

– axis for penetration depth z: 1 scale unit = 1 m
– axis for cone resistance q_c, corrected cone resistance q_t and net cone resistance q_n: 1 scale unit = 2 MPa or 0.5 MPa
– axis for sleeve friction f_s: 1 scale unit = 50 kPa
– axis for friction ratio R_f: 1 scale unit = 2%
– axis for pore pressure u: 1 scale unit = 0.2 MPa or 0.02 MPa
– axis for pore pressure ratio B_q: 1 scale unit = 0.5.

Graphical presentation aims for these scale units and scale ratios, where suitable and practicable.

This reference level of a test is (1) the ground surface for onshore tests, (2) the seafloor for nearshore and offshore tests. Historically, the bottom of the borehole was used as the reference level of downhole tests. Data processing presumes a hydrostatic pore pressure profile relative to seafloor, unless specifically indicated otherwise. The definition of CPT parameters is as follows:

z = penetration depth relative to ground surface or seafloor, corrected for inclination from vertical (i) where a test includes inclination measurements, as follows:

$$z = \int_0^l \cos i \, . \, dl$$

where:
z = penetration depth for the conical base of the cone penetrometer
l = recorded penetration length
i = recorded inclination from vertical

q_c = cone resistance relative to the reference level of the test.

f_s = sleeve friction relative to the reference level of the test. A calculated depth correction applies so that the presented sleeve friction corresponds with the cone depth.

f_t = corrected sleeve friction relative to the reference level of the test. Sleeve friction is corrected for pore pressures acting on the end areas of the friction sleeve

$$f_t = f_s - \frac{(u_2 * A_{sb} - u_3 * A_{st})}{A_s}$$

or simplified to:

$$f_t = f_s - u_2 \frac{(A_{sb} - A_{st})}{A_s} \quad \text{or}$$

$$f_t = f_s - (u_2 * a_{fs})$$

where:
A_{sb} = cross sectional area in the gap between the friction sleeve and the cone
A_{st} = cross sectional area in the gap above the friction sleeve
A_s = surface area of the friction sleeve
a_{fs} = net area ratio of the friction sleeve $(A_{sb} - A_{st})/A_s$

R_f = ratio of sleeve friction to cone resistance (f_s/q_c). This calculated ratio is for the cone depth.

R_{ft} = corrected friction ratio (f_s/q_t). The ratio f_t/q_t applies if f_t is known.

I_{SBT} = non-normalized soil behaviour type index (Robertson, 2010)

$$I_{SBT} = [(3.47 - \log(q_c/P_a))^2 + (\log R_f + 1.22)^2]^{0.5}$$

where:
P_a = atmospheric pressure

u_1 = pore pressure at the face of the cone, relative to the reference level of the test.

u_2 = pore pressure at the cylindrical extension above the base of the cone or in the gap between the friction sleeve and the cone, relative to the reference level of the test.

u_3 = pore pressure immediately above the friction sleeve or in the gap above the friction sleeve, relative to the reference level of the test.

q_t = corrected cone resistance (also called total cone resistance). This includes corrections for hydrostatic and transient pore pressures, and cone construction. The corrected cone resistance is relative to ground surface or seafloor:

Ground surface / seafloor:
$q_t = q_c+(1-a)u_2$ or
$q_t = q_c+(1-a)\{K(u_1-u_o)+u_o\}$

Downhole (historic):
$q_t = q_c+(1-a)u_2+u_{oi}$ or
$q_t = q_c+(1-a)\{K(u_1+u_{oi}-u_o)+u_o\}+au_{oi}$

where:

a = net area ratio of the cross-sectional steel area at the gap between cone and friction sleeve to the cone base area. This ratio is penetrometer-type dependent. The a-factor indicates the effect of pore pressure on unequal cross-sectional areas of the cone.

u_o = hydrostatic pore pressure at the cone, relative to the phreatic surface or the seafloor. This is a calculated value.

u_{oi} = hydrostatic pore pressure at the bottom of the borehole, relative to seafloor. This is a calculated value.

K = adjustment factor for the ratio of pore pressure at the cylindrical extension above the base of the cone to pore pressure on the cone face.

Ground surface / seafloor:
$K = (u_2-u_o)/(u_1-u_o)$

Downhole (historic):
$K = (u_2+u_{oi}-u_o)/(u_1+u_{oi}-u_o)$

The term u_2-u_o or $u_2+u_{oi}-u_o$ refers to excess pore pressure (with respect to hydrostatic pore pressure). Common symbols for excess pore pressure are du_2 or Δu_2. Similarly, du_1 or Δu_1 may represent the term u_1-u_o or $u_1+u_{oi}-u_o$.

The K-factor is only of interest for processing of CPTU results with pore pressure measurement at the cone face (u_1). The factor depends on soil characteristics as fabric, overconsolidation ratio, compressibility and crushability. The K-factor is estimated from:

$$K = 0.91 e^{-0.09 Q_t^{0.47}} \left(\frac{1}{1 + F_r (0.17 + 0.061 (Q_t - 21.6)^{1/3})} - e^{-2F_r} \right) \quad \text{(Peuchen et al., 2010)}$$

q_n = q_t-σ_{vo} = net cone resistance. This includes corrections for hydrostatic and transient pore pressures, in situ stress, and cone construction. The symbol for q_n may also be q_{net}.

where:
σ_{vo} = total in situ vertical stress at the cone base, relative to ground surface or seafloor. This is a calculated value.

Q_t = q_n/σ'_{vo} = normalized cone resistance

where:
σ'_{vo} = effective in situ vertical stress at the cone base, relative to ground surface or seafloor. This is a calculated value.

Q_{tn} = normalized cone resistance with variable stress exponent n, where:

$$Q_{tn} = [(q_t - \sigma_{vo})/P_a]\ (P_a/\sigma'_{vo})^n$$

$$n = 0.381\ (I_c) + 0.05\ (\sigma'_{vo} / P_a) - 0.15 \text{ and } n \leq 1$$ (Zhang et al., 2002)

I_c = soil behaviour type index (Robertson and Wride,1998)

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

F_r = f_t/q_n = normalized friction ratio.

B_q = pore pressure ratio.

Ground surface / seafloor:
B_q = $K(u_1-u_o)/q_n$ or
B_q = $(u_2-u_o)/q_n$

Downhole (historic):
B_q = $K(u_1+u_{oi}-u_o)/q_n$ or
B_q = $(u_2+u_{oi}-u_o)/q_n$

Note that pore pressure measurements (u) are commonly assumed to represent pore water pressures. This assumption is reasonable for soils saturated under in situ stress conditions and remaining saturated during penetration of the cone penetrometer. Furthermore, pressure u_2 at the cylindrical extension is commonly assumed equal to u_{2g} in the gap. This assumption is reasonable for saturated low-permeability soils (clays) that are normally consolidated or lightly overconsolidated and where the gap can become saturated by adequate supply of water and/or water pressure. A similar comment applies to u_3.

Presented values for u_2, q_t, q_n and B_q may be denoted by u_2*, q_t*, q_n*, B_q*, Q_t* and F_r* if u_2 is derived rather than measured, for example if derived by applying a K-factor.

Some deployment systems allow monitoring of CPT parameters in reverse mode, i.e. upon retraction of the cone penetrometer. This optional feature presents additional information that can improve interpretation of ground behaviour, for example strength sensitivity of fine-grained soil.

ACCURACY OF MEASUREMENTS

Accuracy Classes and Application Classes

Cone penetration test standards can follow a “prescriptive” approach, whereby specific detailed measures provided a “deemed to comply” practice. ASTM (2012) is an example of this approach. ISSMGE (1999) and ISO (2012, 2014) specify “performance” criteria for cone penetration test measurements. The ISO standard on metrological confirmation (ISO, 2003) provides the general framework for assessment of performance compliance. Peuchen and Terwindt (2014, 2015) provide guidance on uncertainty estimation for cone penetration test results.

The following comments apply:

– Accuracy is the “closeness of a measurement to the true value of the quantity being measured”. It is the accuracy as a whole that is ultimately important not the individual parts. Precision is the “closeness of each set of measurements to each other”. The resolution of a measuring system is the “minimum size of the change in the value of a quantity that it can detect". It will influence the accuracy and precision of a measurement.

- Accuracy Class 3 and Application Class 3 typically represents industry practice. They are approximately equivalent to the more implicit requirements of ASTM International. Class 3 applies, unless specifically agreed otherwise.

So-called "zero drift" of a measured parameter is an approximate performance indicator for the measuring system. Zero drift is the absolute difference of the zero readings, reference readings or zero reference reading of a measuring system between the start and completion of the cone penetration test. The reference readings can be taken at (1) atmospheric pressure at ground surface or above water level or (2) under hydrostatic water pressure close to seafloor. The zero drift of the measured parameters should be within the allowable minimum accuracy according to the selected accuracy class. Correction of measured parameters for zero drift can be adopted if appropriate. Peuchen and Terwindt (2014) provide comments on interpretation of zero drift values.

Accuracy considerations for strongly layered soils should allow for heat flux phenomena. Heat flux gives an apparent shift in cone resistance (Post and Nebbeling, 1995). For example, friction in dense sand causes a cone to heat by about 1^{o}C/MPa cone resistance. Resulting heat flux decreases cone resistance by an apparent shift in the order of 100 kPa to 200 kPa for a penetrating probe going from dense sand into clay. This is a temporary decrease lasting about 5 minutes. Ambient temperature compensation systems cannot avoid heat flux effects. Penetration interruption can serve as mitigation measure.

Shallow Penetration

Use of reaction equipment will affect stress conditions for shallow penetration. Particularly, offshore conditions may include extremely soft ground at seafloor. Soil disturbance, pore pressure build-up and consolidation of near-surface soft soil may take place. This will affect the measurements.

Downhole borehole deployment implies a typical limiting CPT stroke of 1.5 m or 3 m. It is common to perform multiple semi-continuous tests. Graphics for such tests typically show a build-up of CPT values for the initial 0.1 m to 0.5 m penetration. This penetration zone is immediately below the required borehole and represents complex ground stress conditions and/or borehole-induced ground disturbance that cannot be avoided.

Penetration Interruption

A penetration interruption may be unavoidable, for example to add a push rod or to perform a pore pressure dissipation test. This will affect test results.

Consolidation of low-permeability soil around a cone tip is of particular interest. A stationary cone penetrometer can apply local stresses that approach failure conditions, i.e. about 9 times the undrained shear strength or about 2 times the in situ mean effective stress. Pore pressure re-distribution and dissipation occur, resulting in a local increase in undrained shear strength and hence cone (bearing) resistance. A doubling of cone resistance may not be unreasonable for 100% consolidation. Supplementary considerations include:

- Small downward movement of a penetrometer (order of millimetres) during a test can contribute to maintaining local stresses approaching failure conditions.
- Soil consolidation around a cone penetrometer may lead to soil/penetrometer adhesion that is sufficient to give an increase in "cone" diameter. Resumption of penetration will lead to loss of adhered soil, usually within an equivalent distance of a few times the cone diameter.
- A low B_q value may imply partially drained penetration conditions. It is likely that any steady-state penetration conditions will not apply instantaneously upon resumption of penetration.
- Measuring sensors in a probe generate heat, but this is probably not significant for any stationary measurement. Fugro's strain-gauge load sensors are compensated for ambient temperature fluctuations.

Depth Measurement for Offshore Conditions

Offshore definition of the seafloor (ground surface) is difficult for extremely soft ground at seafloor. Penetration of the reaction equipment into a near-fluid zone of the seabed may take place unnoticed. Such settlement affects the start of penetration depth z. Also, settlement may continue at the time of testing.

Downhole CPT systems rely on depth control applicable to borehole drilling. Depth control according to Z2 of Table 4 is feasible for drilling systems deployed from a fixed platform, for example a jack-up. This value excludes uncertainty associated with determination of seafloor level. Drilling control from floating equipment, for example a geotechnical survey vessel, may be subject to the additional influence of waves and tides. Z2 is typically feasible for favourable conditions. Z3 or Z4 may apply for adverse conditions.

TABLE 4 DEPTH ACCURACY CLASSES ACCORDING TO ISO (2014)

Depth Accuracy Class	Maximum Data Point Depth Uncertainty [m]
Z1	0.1
Z2	0.5
Z3	1.0
Z4	2.0
Z5	> 2.0

Zero-Correction for Offshore Conditions

Water pressures generate significant values of cone resistance and pore pressure. The standardised practice is to correct these reference readings to zero at seafloor. CPT systems for non-drilling mode and for seafloor drilling mode allow zero-correction to hydrostatic conditions prior to the start of a test, typically with a zero-correction uncertainty approaching the resolution of the CPT system. Downhole borehole CPT systems latch into the lower end of a drill pipe. The pressure conditions in the drill pipe may not be in full equilibrium with the surrounding ground water pressure and zero-correction will be subject to increased uncertainty, i.e. uncertainty for pore pressure in the order of 100 kPa for deepwater tests (Peuchen, 2000). This uncertainty depends on factors such as the free-flow and viscosity of drill fluid between the drill bit and the seafloor. The uncertainty typically decreases with decreasing depth of the drill bit below sea level and below seafloor. Uncertainty for the zero-correction of cone resistance is approximately equivalent, but by a factor representing the net area ratio effect.

Deepwater Tests

A deepwater environment presents some favourable conditions for cone penetration tests, notably temperature. Ambient temperature conditions are practically constant and the measuring system has ample time to adjust to these temperatures. In addition, transient heat flow phenomenain a cone penetrometer are usually not applicable due to the generally very soft soil consistency and the absence of crust layers formed by desiccation of clay or silt in geological history.

Deepwater (piezo-cone) pore pressure measurements are essentially similar to shallow-water measurements, with the exception of an increased measuring range for pore pressure leading to some reduction in sensor accuracy. Saturation of a pore pressure measuring system is excellent for a deepwater environment, as the high pressures will force any gas bubbles into solution.

Currently available evidence indicates that a high-quality subtraction-type cone penetrometer is adequate for very soft soil characterisation to a water depth of 3000 metres and probably beyond.

ADDITIONAL MEASUREMENTS

Friction-cone and piezo-cone penetrometers allow specific additional measurements, such as friction set-up tests, pore pressure dissipation tests and measurements of ground water pressure. These additional measurements require a penetration interruption or may be feasible at the end of a test. It is also common to add other in situ test devices to a cone penetrometer. Table 5 presents the more common types.

TABLE 5 PROBES FOR ADDITIONAL IN SITU TESTS

Type of Probe	Properties	Units
Electrical Conductivity Penetrometer (ECPT)	Electrical conductivity, K	S/m
Temperature Cone Penetrometer (TCPT)	Temperature, T	°C
Seismic Cone Penetrometer (SCPT)	Shear wave velocity, v_s	m/s
Cone Pressuremeter (CPMT)	Shear stress-strain-time response, σ, ε, t	MPa, -, s
Natural Gamma Penetrometer (GCPT)	Natural gamma ray, γ	CPS
Cone Magnetometer (CMMT)	Magnetic flux density B, magnetic field horizontal angle θ and vertical angle ϕ	μT, °, °
Hydraulic Profiling Tool (HPT)	Permeability, k	m/s
S = Siemens m = metre s = second	Pa = Pascal CPS = counts per second T = Tesla	

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INTRODUCTION

This document presents a summary of interpretation methods for Cone Penetration Test (CPT) results. The project-specific selection of methods depends on the agreed project requirements. Some of the methods suit computer-based interpretation of CPT data records.

Interpretation of Cone Penetration Test results helps provide parameters for geotechnical models. Conventional models are typically based on plasticity theory for ultimate limit states, and on elasticity theory and consolidation theory for serviceability limit states. Features of these geotechnical models are:

- analysis of either drained (sand model) behaviour or undrained (clay model) behaviour for plasticity models
- analysis for the ultimate limit state differs from that for the serviceability limit state.

CPT interpretation methods are mostly based on empirical correlations with limited theoretical backing. Data integration with other, complementary investigation techniques (such as drilling, sampling and laboratory testing) improves confidence levels.

The interpretation techniques discussed below are subject to limitations such as:

- The majority of interpretation methods apply to "conventional" sands and clays. Conventional methods may not be appropriate for silts, sand/clay/gravel mixtures, varved or layered soils, gassy soils, underconsolidated soils, peats, carbonate soils, cemented soils and residual soils. These non-conventional soils warrant a more specific approach.
- Empirical correlations use reference parameters such as the undrained shear strength determined from a laboratory single-stage Isotropically Consolidated Undrained triaxial test (CIU) on an undisturbed specimen obtained by means of push sampling techniques (Van der Wal et al., 2010). The reference parameter may not be appropriate for the selected geotechnical model, and adjustment may be necessary. Also, adjustment for test conditions may be necessary, for example in situ temperature versus laboratory temperature.
- The cone penetration test offers limited direct information on serviceability limit states (deformation), as the penetration process imposes large strains in the surrounding soil. In comparison to ultimate limit states, better complementary data will usually be required.
- CPT interpretation techniques are often indirect. Usually, interpretation requires estimates of various other parameters. This is consistent with an integrated geotechnical investigation approach. Inevitably, this approach also includes some redundancy of data.
- Drained or undrained behaviour for the geotechnical analysis at hand may or may not coincide with respectively drained or undrained behaviour during fixed-rate penetration testing. This interpretation difficulty remains largely unresolved at this time.
- The interpretations apply to conditions as encountered at the time of the geotechnical investigation. Geological, environmental and construction/operational factors may alter as-found conditions.

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PENETRATION BEHAVIOUR

Soil behaviour during cone penetration testing shows large displacements in the immediate vicinity of the penetrometer, and small elastic displacements further away from the penetrometer. Density/structure, stiffness and in situ stress conditions significantly affect the measured parameters.

The measured cone resistance (q_c) includes hydrostatic water pressures as well as stress-induced pore pressures. The pore pressures are usually negligible for clean sand because the ratio of effective stress to pore pressure is high. This ratio is, however, low for penetration into clay. Knowledge of pore pressures around the penetrometer can thus be important. CPT parameters that take account of pore pressure effects include total cone resistance (q_t), net cone resistance (q_n) and pore pressure ratio (B_q). These parameters can be calculated if Piezo-cone Penetration Test (PCPT or CPTU) data are available. The influence of pore pressures on sleeve friction f_s is relatively small. It is common to ignore this influence. Calculation of friction ratio R_f (defined as f_s/q_c) includes no allowance for pore pressure effects.

The penetration rate with respect to soil permeability determines whether soil behaviour is primarily undrained, drained or partially drained. In general, soil behaviour during cone penetration testing is drained in clean sand (no measurable pore pressures as a consequence of soil displacements) and undrained in clay (significant pore pressure changes). Partially drained behaviour occurs in soils with intermediate permeability, such as sandy silt. The following sections mostly consider interpretation of drained soil behaviour (sand) and undrained soil behaviour (clay).

SOIL BEHAVIOUR IDENTIFICATION

Identification of soil stratigraphy in terms of general soil behaviour (and to a lesser degree soil type) is a more important feature of CPT than other investigation technique.

Figures 1 to 3 show soil behaviour identification according to procedures given by Robertson (2009) and Ramsey (2002). Robertson (2009) represents an update of Robertson (1990), by exchange of Q_t with Q_{tn}. The procedures consider a normalised soil behaviour classification that provides general guidance on likely soil type (silty sand for example) and a preliminary indication of parameters such as angle of internal friction φ', overconsolidation ratio (OCR) and clay sensitivity (S_t). The procedures require piezo-cone test data:

$$Q_{tn} = [(q_t - \sigma_{vo})/P_a]\,(P_a/\sigma'_{vo})^n \qquad Q_t = \frac{q_t - \sigma_{vo}}{\sigma'_{vo}} \qquad F_r \text{ or } nR_f = \frac{f_s}{q_t - \sigma_{vo}} 100\% \qquad B_q = \frac{u - u_0}{q_t - \sigma_{vo}}$$

where:

Q_{tn} = normalised cone resistance with variable stress exponent
Q_t = normalised cone resistance
q_t = corrected cone resistance
σ_{vo} = total in situ vertical stress
σ'_{vo} = effective in situ vertical stress
P_a = atmospheric pressure
n = stress exponent
f_s = measured sleeve friction
u = measured pore pressure
u_0 = theoretical hydrostatic pore pressure.

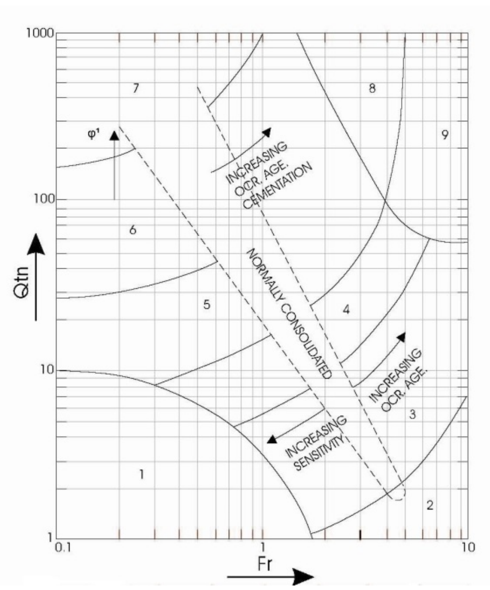
Zhang et al. (2002) defined stress exponent n as follows:

$$n = 0.381\,(I_c) + 0.05\,(\sigma'_{vo} / P_a) - 0.15 \text{ where } n \leq 1$$

Robertson and Wride (1998) defined soil behaviour type index I_c (Figure 3) as follows:

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

Soils with $I_c < 2.5$ are generally cohesionless, coarse grained, where cone penetration is generally drained and soils with $I_c > 2.7$ are generally cohesive, fine grained, where cone penetration is generally undrained (Robertson, 1990). Cone penetration in soils with $2.5 < I_c < 2.7$ is often partially drained.



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays- clay to silty clay
4. Silt mixtures – clayey silt to silty clay
5. Sand mixtures – silty sand to sandy silt
6. Sands – clean sand to silty sand
7. Gravelly sand to sand
8. Very stiff sand to clayey sand*
9. Very stiff, fine grained*

(*) Heavily overconsolidated or cemented

Figure 1, Classification chart Robertson (2009)

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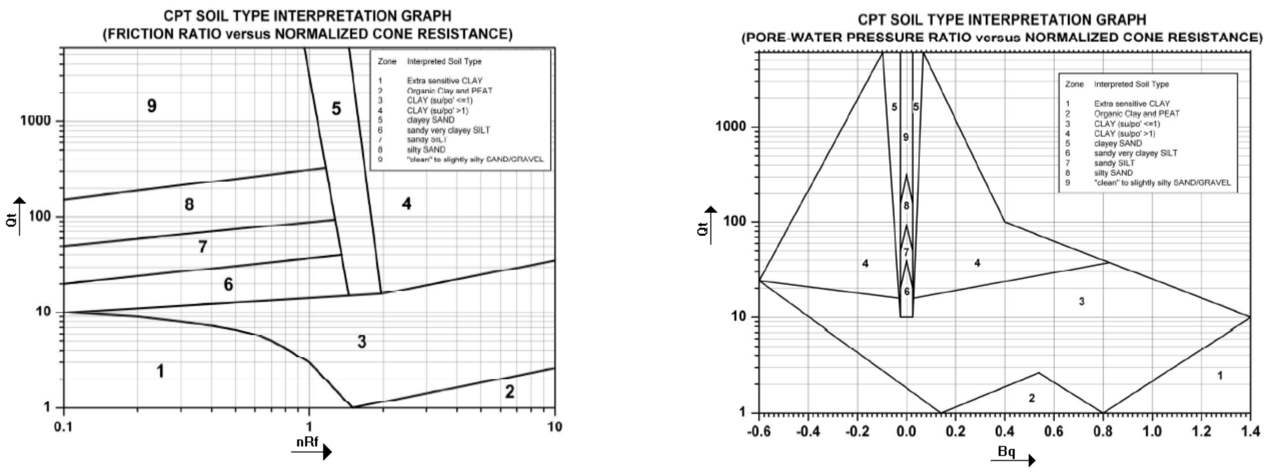

1.	Extra sensitive clay	6.	Sandy very clayey silt
2.	Organic clay and peat	7.	Sandy silt
3.	Clay (s_u/σ'_{vo} <= 1)	8.	Silty sand
4.	Clay (s_u/σ'_{vo} > 1)	9.	"Clean" sand/gravel
5.	Clayey sand		

Figure 2, Classification charts Ramsey (2002)

Classification is only possible for certain combinations of Q_{tn}, Q_t, F_r, nR_f and B_q, as shown below.

Classification Limits	
Robertson	**Ramsey**
$1 \le Q_{tn} \le 1000$ $0.1 \le F_r \le 10$ $-0.2 \le B_q \le 1.4$	$1 \le Q_t \le 6000$ $0.1 \le nR_f \le 10$ $-0.6 \le B_q \le 1.4$

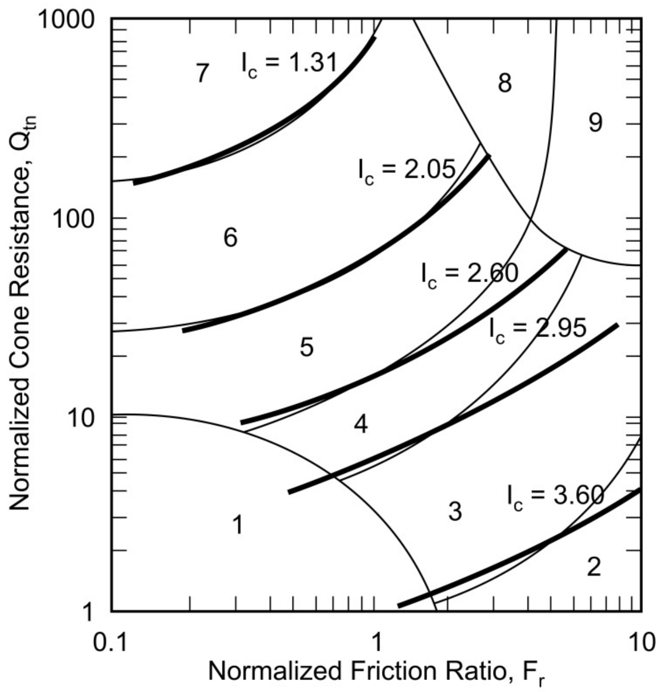

Figure 3, Soil behaviour type index I_c superimposed on Robertson (2009) classification chart

Figure 4 presents a classification chart for friction cone data according to Robertson (2010). This procedure requires no pore pressure input. A non-normalised soil behaviour type index, I_{SBT} applies:

$$I_{SBT} = [(3.47 - \log(q_c/P_a))^2 + (\log R_f + 1.22)^2]^{0.5}$$

I_{SBT} is similar to I_c. Values for I_{SBT} and I_c are typically comparable for effective in situ vertical stress between 50 kPa and 150 kPa.

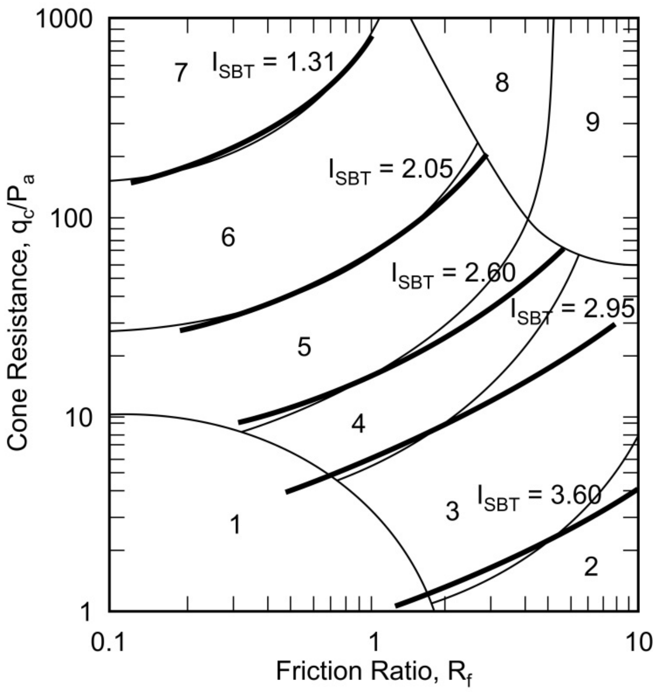

Figure 4, Robertson (2010) classification chart including I_{SBT}

SAND MODEL

Unit Weight – Sand

Unit weight of uncemented (silica) sand, silt and clay soils may be derived according to Mayne et al. (2010):

$$\gamma = 1.95\,\gamma_w \left(\frac{\sigma'_{vo}}{P_a}\right)^{0.06} \left(\frac{f_t}{P_a}\right)^{0.06}$$

where total unit weight γ and unit weight of water γ_w are in kN/m^3 and effective in situ vertical stress σ'_{vo} is in kPa. The symbol f_t refers to sleeve friction corrected for pore pressures acting on the end areas of the friction sleeve, with units in kPa. Atmospheric pressure P_a is in kPa.

In Situ Stress Conditions - Sand

A knowledge of in situ stress conditions is required for estimation of parameters such as relative density D_r and angle of internal friction of a sand deposit φ'. The effective in situ vertical stress σ'_{vo} may be calculated with a reasonable degree of accuracy but the effective in situ horizontal stress $\sigma'_{ho} = K_o\sigma'_{vo}$ is generally unknown. Usually, it is necessary to consider a range of conditions for K_o (coefficient of earth pressure at rest). The range considers overconsolidation as inferred from a geological assessment, pre-consolidation pressures of intermediate clay layers and/or theoretical limits of K_o.

Geological factors concerning overconsolidation include ice loading, soil loading and groundwater fluctuations. Possible subdivisions for these factors are mechanical, cyclic and ageing consolidation.

K_o may be directly correlated to Overconsolidation Ratio (OCR), as follows:

$$K_o = 0.4\sqrt{(OCR)}$$

Mayne and Kulhawy (1982) investigated mechanical overconsolidation of reconstituted laboratory specimens for over 170 different soils. A K_0 OCR correlation requiring effective angle of internal friction as input was found to provide a reasonable match. It can be shown that the $K_o = 0.4\sqrt{(OCR)}$ equation provides similar statistics to the Mayne and Kulhawy correlation.

No laboratory study can fully capture in situ behaviour. Particularly, K_o may be underestimated if effects such as ageing and cyclic loading are relevant.

In general, in situ K_o values are limited to the range $K_o = 0.5$ to $K_o = 1.5$. For many situations, K_o values are believed to be relatively low at greater depths (say $K_o < 1$ for depths exceeding 50 m). Jamiolkowski et al. (2003) recommend using a limiting value $K_o = 1$ in practice.

Relative Density - Sand

Procedures for estimation of in situ density condition (loose, dense, etc.) consist of:
(a) Estimation of in situ stress conditions σ'_{vo} and σ'_{ho}
(b) Empirical correlation of relative density D_r (or density condition) with q_c, σ'_{vo} and σ'_{ho}.

Estimation of stress conditions has been discussed above.

Common relationships between q_c and D_r are based on Cone Penetration Tests carried out in sand samples reconstituted in laboratory calibration chamber tests. Such tests are carried out as part of general geotechnical research projects and are subject to a number of limitations, such as:

- soil type dependence
- inaccuracies in determination of laboratory D_r
- limited range of stress levels and K_o values
- sample preparation and soil stress history simplifications.

Jamiolkowski et al. (2003) proposes the following relationship between q_c and D_r for normally and overconsolidated silica (dry) sands:

$$D_{r(dry)} = \frac{1}{2.96}\ln\left[\frac{\frac{q_c}{P_a}}{24.94\left(\frac{\sigma'_{vo}\left(\frac{1+2K_o}{3}\right)}{P_a}\right)^{0.46}}\right]$$

and for saturated sands:

$$D_{r(sat)} = \left(\frac{-1.87 + 2.32\ln\frac{q_c}{(P_a * \sigma'_{v0})^{0.5}}}{100} + 1\right)\frac{D_r(dry)}{100}$$

where relative density D_r is a fraction. The correlation for saturated sands results in relative densities that can be up to about 10% higher compared to the correlation for dry sands.

Determination of laboratory minimum and maximum index dry unit weights (γ_{dmin} and γ_{dmax}) forms the basis for the relative density concept (loose, dense sand, etc.). As yet, there is no internationally agreed procedure. Hence, laboratory test procedure dependence applies. Also, it is unlikely that any of the procedures consistently provide the "lowest" γ_{dmin} or the "highest" γ_{dmax}. In situ soil unit weights may therefore fall outside laboratory ranges. The relative density concept is necessary to provide a link between field investigations and laboratory testing on reconstituted specimens, as undisturbed sampling of sands is expensive.

Calibration chamber test results apply to a limited range of stress conditions only; typically:

$$50\ \text{kPa} < \sigma'_{vo} < 400\ \text{kPa}$$
$$0.4 < K_o < 1.5$$

Sample preparation for laboratory chamber tests is usually by means of dry pluviation. Soil stress history application is by mechanical overconsolidation.

Angle of Internal Friction - Sand

The effective shear strength parameter φ' is not a true constant. It depends on factors such as density, stress level, shearing mode and mineralogy. There is evidence that overconsolidation ratio, method of deposition and in situ stress anisotropy is less important.

Correlation of angle of internal friction φ' to cone resistance q_c may be done at various levels of sophistication. Simple procedures rely on a conservative assessment of soil behaviour classification. A more sophisticated empirical correlation consists of:
(a) Estimation of in situ stress conditions σ'_{vo} and σ'_{ho}
(b) Estimation of relative density D_r
(c) Empirical correlation of angle of internal friction φ' with D_r, σ'_{vo} and σ'_{ho}.

Estimation of stress conditions and relative density has been discussed above.

The empirical procedure proposed by Bolton (1986 and 1987) is used for estimation of φ'. This correlation applies to clean sands and considers peak secant angle of internal friction in Isotropically Consolidated Drained triaxial compression (CID) of reconstituted sand. This procedure requires estimation of the dilatancy index and the critical state angle of internal friction.

Kulhawy and Mayne (1990) determined an equation based upon 20 data sets obtained from calibration chamber tests. This equation is almost identical to the empirical formula determined earlier by Trofimenkov (1974) which was based on mechanical cone data. Mayne (2007) validated the use of total cone resistance q_t instead of cone resistance q_c used in the equation from Kulhawy and Mayne (1990).

$$\varphi' = 17.6 + 11.0 \log\left(\left(\frac{q_t}{P_a}\right) / \left(\frac{\sigma'_{vo}}{P_a}\right)^{0.5}\right) \qquad \text{(Mayne, 2007)}$$

Undrained Shear Strength - Sand

Undrained shear strength of cohesionless soil can be important for assessment of cyclic mobility and liquefaction potential. Geotechnical procedures other than the conventional limit state models are employed.

Compressibility - Sand

Correlations between CPT data and compressibility parameters are indicative only. Further developments in interpretation techniques may offer improvement in the future.

Elasticity theory is commonly employed for analysis of drained soil deformation behaviour. Secant moduli are adopted. A common guideline is an empirical correlation given by Baldi et al. (1989). The correlation is for silica-based sand and considers cone resistance q_c, in situ stress conditions and secant Young's modulus for drained stress change E'. The ratio of E'/q_c typically ranges from about 3 to 5 for recently deposited normally consolidated sands up to about E'/q_c = 6 to 25 for overconsolidated sands. The correlation has been inferred from laboratory conditions; including CPT tests in a calibration chamber and conventional triaxial compression tests on reconstituted sand samples. It takes account of the degree of deformation and overconsolidation. In this regard, it is noted that secant deformation moduli are strongly dependent on strain level: the elastic modulus increases with decreasing strain to an upper limit at about 10^{-4}% strain.

For estimation of initial (small strain) or dynamic shear moduli, ratios of G_{max}/q_c of between about 4 and 20 are considered, in accordance with Baldi et al. (1989).The basis for this correlation is similar to that of secant Young's modulus, except that laboratory resonant column tests serve as reference instead of triaxial compression tests. Results of limited in situ seismic cross-hole and downhole tests provide an approximate check of this correlation.

Constrained Modulus M - Sand

Kulhawy and Mayne (1990) derived two formulas for the determination of the constrained modulus for both normally consolidated and overconsolidated sands by indicating that the modulus is a function of relative density. The determination of relative density can be done with, for example, the methods indicated previously.

$$M = q_c * 10^{1.09-0.0075D_r} \quad \text{(Normally consolidated sands, Kulhawy and Mayne, 1990)}$$

$$M = q_c * 10^{1.78-0.0122D_r} \quad \text{(Overconsolidated sands, Kulhawy and Mayne, 1990)}$$

where D_r is in %, and q_c and M in kPa respectively.

Shear Wave Velocity v_s – Sand

If no in situ measurements of shear wave velocities (v_s) are available, then empirical correlation with CPT parameters may be considered. Hegazy and Mayne (2006) published a statistical correlation derived from 73 sites worldwide representing a range of soil types including sands, clays, soil mixtures and mine tailings (Figure 5). The correlation considers a normalized cone resistance (q_{c1N_hm}) and a soil behaviour type index (I_{c_hm}) as follows:

$$v_s = 0.0831 q_{c1N\_hm} (\sigma'_{vo} / P_a)^{0.25} \; e^{(1.786\, I_{c\_hm})} \quad \text{(Hegazy and Mayne, 2006)}$$

where shear wave velocity v_s is in m/s and q_{c1N_hm} and I_{c_hm} are dimensionless. Calculations for q_{c1N_hm} and I_{c_hm} require iteration, and consider measured cone resistance q_c or corrected cone resistance q_t, measured sleeve friction f_s, total in situ vertical stress σ_{vo}, effective in situ vertical stress σ'_{vo} and atmospheric pressure P_a.

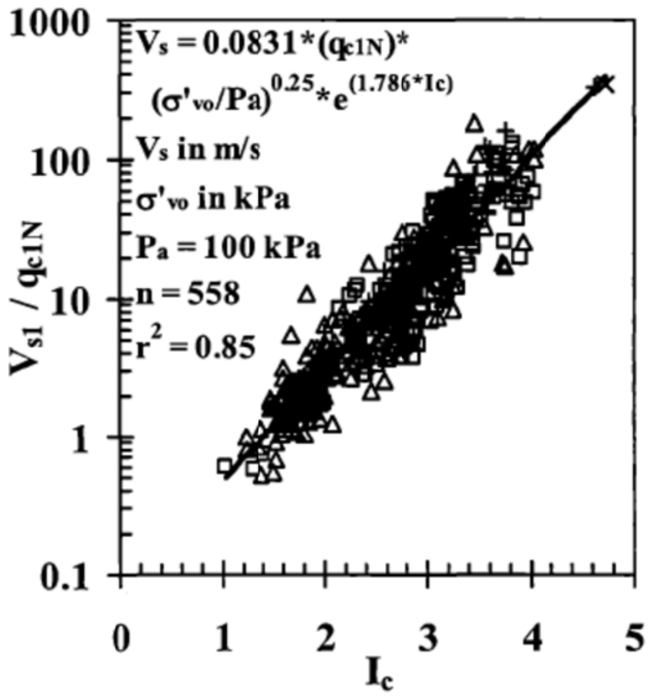

Figure 5, v_s – q_c correlation according to Hegazy and Mayne (2006)

Robertson and Cabal (2010) present a v_s correlation incorporating net cone resistance q_n (= $q_t - \sigma_{vo}$) and soil behaviour type index (I_c) as defined by Robertson and Wride (1998):

$$v_s = [\alpha_{vs}(q_t - \sigma_{v0})/P_a]^{0.5} \text{ where } \alpha_{vs} = 10^{(0.55\, I_c + 1.68)} \quad \text{(Robertson and Cabal, 2010)}$$

where shear wave velocity v_s is in m/s and total cone resistance q_t, total in situ vertical stress σ_{vo} and atmospheric pressure P_a are in kPa. The method can be applied to a wide range of soil behaviour types, notably uncemented Holocene to Pleistocene age soils. Older deposits could have a higher shear wave velocity. Exceptions are Zones 1, 8 and 9 of Robertson (1990 and 2009).

Baldi et al. (1989) derived a correlation between shear wave velocity v_s and cone resistance q_c for uncemented silica sands. This correlation is based on data from CPT, cross-hole and Seismic Cone Penetration Tests (SCPT) performed in quaternary deposits of the predominantly silica Po river sand and Gioia Tauro sand with gravel.

$$v_s = 277 q_c^{0.13} \sigma'_{vo}{}^{0.27} \qquad \text{(Baldi et al., 1989)}$$

where shear wave velocity v_s is in m/s and cone resistance q_c and effective in situ vertical stress σ'_{vo} are in MPa.

Shear wave velocity may be normalised according to Robertson and Cabal (2010):

$$v_{s1} = v_s \cdot (P_a / \sigma'_{vo})^{0.25} \qquad \text{(Robertson and Cabal, 2010)}$$

Shear Modulus G_{max} - Sand

Interpretation of low-strain shear modulus can be considered by using the modified correlation proposed by Rix and Stokoe (1991) in which data from calibration test measurements is compared to the correlation obtained between G_{max} and q_c by Baldi et al. (1989).

$$G_{max} = 1634 (q_c)^{0.25} (\sigma'_{vo})^{0.375} \qquad \text{(Rix and Stokoe, 1991)}$$

where G_{max}, q_c and σ'_{vo} are in kPa.

CLAY MODEL

Unit Weight – Clay

Empirical correlation between unit weight of clay and CPT parameters is as described in “Unit Weight – Sand” above.

In Situ Stress Conditions - Clay

Similar to sand, a knowledge of in situ stress conditions is generally necessary for estimation of other parameters such as consistency (soft, stiff, etc.) of a clay deposit and compressibility.

Calculation of the effective in situ vertical stress σ'_{vo} is reasonably accurate. A more approximate estimate applies to the effective in situ horizontal stress σ'_{ho}, or, more particular, K_o as $\sigma'_{ho} = K_o \sigma'_{vo}$.

Direct correlations for interpretation of the coefficient of earth pressure at rest K_o are uncommon.

For normally consolidated clays and silts, K_{onc} may be correlated with angle of internal friction, in accordance with Jaky (1944), or more simply in accordance with Mayne and Kulhawy (1982). The reference angle of internal friction is that obtained from a straight-line approximation of the Mohr-Coulomb failure envelope determined from Consolidated Undrained (CU) triaxial compression tests on undisturbed specimens.

For overconsolidated clays, K_{ooc} may be correlated with angle of internal friction and overconsolidation ratio, in accordance with Mayne and Kulhawy (1982). The plasticity index together with OCR may also be used for preliminary estimates of K_{ooc} as indicated by Brooker and Ireland (1965).

$$K_o = (1 - \sin\varphi') OCR^{\sin\varphi'} \qquad \text{(Mayne and Kulhawy, 1982)}$$

Overconsolidation Ratio - Clay

Overconsolidation ratio is defined as: OCR = σ'_p/σ'_{vo} where σ'_p is the pre-consolidation pressure considered to correspond with the maximum vertical effective stress to which the soil has been subjected, and σ'_{vo} is the current effective in situ vertical stress. The pre-consolidation pressure approximates a stress level where relatively small strains are separated from relatively large strains occurring on the virgin compression stress range. The reference OCR is usually based on laboratory oedometer tests carried out on undisturbed samples, and may thus be influenced by factors such as sample disturbance, strain rate effects and interpretation procedure.

Various analytical and semi-empirical models for interpretation of pre-consolidation pressure from piezo-cone test data are available. Sandven (1990) presents a summary. The procedures are mostly "experimental" and as yet uncommon in practice. Chen and Mayne (1996) presented a direct correlation between net cone resistance and overconsolidation ratio for 205 clay sites around the world, as follows:

$$OCR = 0.317\ Q_t \qquad \text{(Chen and Mayne, 1996)}$$

The overconsolidation ratio may also be inferred from a geological assessment and from undrained strength ratios.

Geological factors concerning overconsolidation have been discussed under "in situ stress conditions - sand". An empirical procedure for estimation of OCR based on undrained strength ratio s_u/σ'_{vo} is given by Wroth (1984). The procedure uses the strength rebound parameter Λ. Guidance for selection of Λ and normally consolidated undrained strength ratio is given by Mayne (1988). Historically, much use has also been made of the Skempton (1957) relationship between normally consolidated undrained strength ratio and plasticity index I_p. This equation is useful for preliminary estimates, considering that I_p probably relates to φ' in some complex manner.

Undrained Shear Strength - Clay

No single undrained shear strength exists. The in situ undrained shear strength s_u depends on factors such as mode of failure, stress history, anisotropy, strain rate and temperature.

Various theoretical and empirical procedures are available to correlate q_c with s_u. Theoretical approaches use bearing capacity, cavity expansion or steady penetration solutions, all of which require a number of simplifying assumptions. Empirical approaches are more common in engineering practice because of difficulties in realistic soil modelling. An empirical correlation for soft to stiff, intact and relatively homogeneous clays is given by Battaglio et al. (1986) as follows:

$$s_u = (q_c - \sigma_{vo})/N_c$$

where s_u, σ_{vo} and q_c are in kPa. N_c is an empirical factor that ranges between 10 and 25, with the higher N_c factors applying to clays with a relatively low plasticity index, and vice versa. The reference undrained shear strength is that determined from in situ vane test results. The term σ_{vo} (total in situ vertical stress) becomes insignificant for stiff clays at shallow depth so that the equation reduces to $s_u = q_c/N_c$.

For specific design situations, a different s_u reference strength should be used. For example, offshore axial pile capacity predictions in accordance with API (2011) recommend s_u to be based on undrained triaxial compression tests, which are likely to yield lower s_u values than in situ vane tests. A site-specific or regional approach should generally be preferred. For example, N_c factors of 15 to 20 have been commonly used for firm to hard North Sea clays. They give reasonable strength estimates for s_u values determined from pocket penetrometer, torvane and Unconsolidated Undrained triaxial tests (UU) on Shelby tube samples obtained by hammer sampling and push sampling techniques. Lower N_c factors are generally appropriate for soft clays and higher factors for heavily overconsolidated clays.

If piezo-cone test data are available, then improved correlations are feasible because of the pore pressure information. Empirical correlations of piezo-cone test results with laboratory undrained shear strengths are typically obtained from:

$$s_u = q_n/N_k$$

N_k ranges typically between 8 and 30 with the higher N_k factors applying to heavily overconsolidated clays.

Mayne et al. (2015) recommend $N_k = 12$ with a standard deviation of 2.8 for correlation with laboratory triaxial compressive strength. A mean value of 13.5 (Low et al., 2010) can be considered for correlation with average undrained shear strength defined as the average of laboratory triaxial compression, simple shear and triaxial extension. These recommendations apply to normally consolidated to slightly overconsolidated clays with q_n values between 0.1 MPa and 8 MPa.

Clay Sensitivity

The sensitivity of a clay (S_t) is the ratio of undisturbed undrained shear strength to remoulded undrained shear strength. Sensitivity may be assessed from the CPT friction ratio R_f, in accordance with Schmertmann (1978):

$$S_t = N_s/R_f$$

where N_s is a correlation factor typically ranging between 5 and 10. The correlation is expected to be inaccurate for sensitive clays where uncertainty in very low values for sleeve friction may dominate results.

The reference S_t value is often taken to be that determined from undisturbed and remoulded laboratory unconsolidated undrained triaxial tests. This reference S_t value may differ from that determined from other tests, for example laboratory miniature vane tests. This is partly related to the definition of sensitivity. For vane tests, several measurements of undrained shear strength are possible:

- Intact (I) = undisturbed undrained shear strength as measured on an intact/undisturbed specimen.
- Intact-Residual (I-R) = measured post peak during initial shearing of the intact specimen.
- Intact-Vane Remoulded (I-VR) = measured after multiple-quick rotations of the vane after completion of the intact test.
- Hand Remoulded (HR) = steady state (post-peak if exists) resistance of hand remoulded test specimen.
- Hand Remoulded – Vane Remoulded (HR-VR) = steady state resistance of hand remoulded specimen measured after applying multiple-quick vane rotations.

Skempton and Northey (1952) present a correlation of sensitivity and laboratory liquidity index I_L. This correlation may allow a check on CPT-based interpretation of sensitivity.

Effective Shear Strength Parameters - Clay

Measurement of pore water pressures during penetration testing has led to development of interpretation procedures for estimation of effective stress parameters of cohesive soils. Background information may be found in Sandven (1990). Currently available procedures are evaluated to be "experimental" and are as yet not commonly adopted.

In general, CPT interpretation of effective shear strength parameters for clay and silt relies on soil behaviour-type classification.

It is noted that significant silt and sand fractions in a clay deposit will increase φ', while a significant clay fraction in silt will decrease φ'.

Masood and Mitchell (1993) provide an equation for the determination of φ' by combining sleeve friction with the Rankine earth-pressure theory. The equation is based on the following assumptions:

- Unit adhesion between soil and sleeve is negligible.
- Friction angle between soil and sleeve = $\varphi'/3$.
- Lateral earth pressure coefficient during penetration is equal to the Rankine coefficient of lateral earth pressure under passive conditions.

$$\frac{f_s}{\sigma'_{vo}} = \tan^2(45° + \frac{\varphi'}{2})\tan(\frac{\varphi'}{3}) \quad \text{(Masood and Mitchell, 1993)}$$

Mayne (2001) proposed an approximation of the Masood and Mitchell equation, as follows:

$$\varphi' = 30.8\left[\log(\frac{f_s}{\sigma'_{vo}}) + 1.26\right] \quad \text{(Mayne, 2001)}$$

Mayne (2001) also proposed the following approximation of friction angle φ' based on pore pressure ratio B_q and the cone resistance number N_m (Senneset, Sandven and Janbu, 1989):

$$\varphi' = 29.5 B_q^{0.121}(0.256 + 0.336 B_q + \log N_m) \quad \text{(Mayne, 2001)}$$

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where

$$N_m = \frac{q_t - \sigma_{vo}}{\sigma'_{vo} + a}$$

where the cone resistance number N_m is dimensionless, total cone resistance q_t, total in situ vertical stress σ_{v0} and effective in situ vertical stress σ'_{v0} are in kPa.

Senneset et al. (1989) use the attraction value [a] as a function of soil type. In general the attraction value ranges from 5 to > 50 for both sands and clays and may be estimated directly from CPT results. The correlation is valid if the angle of plastification β is zero. In general a plastification angle of zero applies to medium sands and silts, sensitive clays and highly compressible clays.

Compressibility – Clay

Correlations between CPT data and compressibility parameters are viewed as indicative only, as discussed for sand compressibility.

The use of elasticity theory is common for analysis of undrained soil deformation behaviour. The adopted procedure is as follows:

(a) Estimation of undrained shear strength s_u from CPT data, as outlined above.

(b) Estimation of secant Young's moduli for undrained stress change E_u in general accordance with correlations based on s_u, as presented by Ladd et al. (1977).

Laboratory undrained triaxial tests carried out on undisturbed clay specimen form the basis for the E_u versus s_u correlations. Typical E_u/s_u ratios at a shear stress ratio of 0.3 range between about 300 and 900 for normally consolidated clays and E_u/s_u = 100 to 300 for heavily overconsolidated clay. Higher E_u/s_u ratios would apply to lower shear stress ratios, and vice versa.

Mitchell and Gardner (1976) present an approximate correlation of cone resistance with constrained modulus M (or coefficient of volume compressibility m_v, where $M = 1/m_v$). Typical ratios of M/q_c range between 1 and 8 for silts and clays. Refinements include q_c ranges and soil type (silt, clay, low plasticity, high plasticity, etc.). The correlation relies on the results of conventional laboratory oedometer tests carried out on undisturbed clay and silt samples. The constrained modulus can also be related (approximately) to secant Young's modulus E' and shear modulus G'.

It is noted that laboratory soil stiffness may differ from in situ stiffness because of inevitable sampling disturbance (in particular soil structure disturbance). In general, this implies that laboratory stiffness will usually be less than in situ stiffness.

Constrained Modulus M

Kulhawy and Mayne (1990) correlated constrained modulus M in clays with net cone resistance data. This relationship is based on data from 12 different test sites, with constrained moduli up to 60 MPa. The published standard deviation is 6.7 MPa.

$$M = 8.25\, q_n$$ (Kulhawy and Mayne, 1990)

Shear Wave Velocity v_s – Clay

Hegazy and Mayne (2006) and Roberson and Cabal (2010) present empirical correlations between shear wave velocity and CPT parameters for a wide range of soils including clays, as described in “Shear Wave Velocity v_s – Sand” above. The Hegazy and Mayne correlation is sensitive to use of q_c or q_t. It should be used with caution for soils showing undrained or partially drained CPT response.

Mayne and Rix (1995) derived a correlation between shear wave velocity v_s and cone resistance q_c for intact and fissured clays. A database from Mayne and Rix (1993) was used including 31 different clay sites.

$$v_s = 1.75 q_c^{0.627}$$ (Mayne and Rix, 1995)

where shear wave velocity v_s is in m/s and cone resistance q_c is in kPa.

Shear Modulus G_{max}

Mayne and Rix (1993) determined a relationship between G_{max} and q_c by studying 481 data sets from 31 sites all over the world. G_{max} ranged between about 0.7 MPa and 800 MPa.

$$G_{max} = 2.78\, q_c^{\,1.335}$$ (Mayne and Rix, 1993)

where G_{max} and q_c are in kPa.

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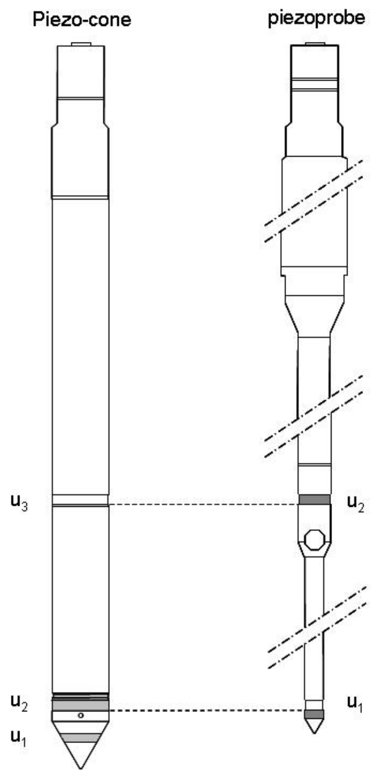
INTRODUCTION

A push-in probe equipped with a pore pressure sensor allows the in situ measurement of pore water pressure dissipation during a penetration interruption (ASTM, 2012; ISO, 2012; ISO, 2014). The variation of pore water pressure with time can give an indication of the consolidation and permeability characteristics of the soil. Measurement of equilibrium in situ pore water pressure is also possible if a sufficiently long dissipation period is maintained. The required period depends on factors such as geometry/size of the probe and soil coefficient of consolidation.

Common push-in probes for dissipation testing are as follows (Figure 1):
1. Piezo-cone penetrometer.
2. Piezoprobe.

The feasibility of test interpretation for consolidation or permeability depends primarily on the drainage characteristics of the soil and the location of the pore pressure filter in the probe. In low-permeability soil, the probe generates:
- excess (positive) pore pressures as a result of normal stresses due to plastic soil failure
- positive or negative pore pressures as a result of shear-induced stresses.



These transient pore pressures are generally high at the face (designated as u_1 for a piezo-cone penetration test PCPT or CPTU) of the probe where the normal and shear components are positive. Lower or negative pore pressures apply to locations above the base of the cone (designated as u_2 and u_3 for the CPTU), where the shear-induced pore pressures may be negative (Figure 1). In particular, negative pore pressures above the base of the probe may apply to overconsolidated low-permeability soil.

APPARATUS

Pore pressure dissipation testing requires a push-in probe equipped with a water pressure sensor, separated by a filter from the surrounding soil. Generally, CPT thrust equipment is used for penetration of the probe into the soil.

Figure 1, designations for pore pressure filter positions

PROCEDURE

The test procedure includes the following steps or a repeated sequence of these steps:
- interrupting the push-in penetration of the probe at the test level for pore pressure dissipation
- measurement of pore pressure versus time until the required termination criterion
- resuming penetration, where applicable.

Test termination criteria for analysis of equilibrium in situ pore pressure are as follows, unless agreed otherwise:
- reaching >90% dissipation of excess pore pressure (relative to equilibrium in situ pore pressure)
- dissipation period of 6 hours
- unfavourable test conditions
- circumstances at discretion of test operator, such as risk of damage to apparatus or safety of personnel
- whichever is earlier.

Test termination criteria for consolidation analysis are comparable, with >90% dissipation changed to >50% dissipation and a dissipation period of 6 hours changed to a dissipation period of 1000 seconds. Extension of a dissipation period to beyond 1000 s may be necessary for some geotechnical applications. This is optional.

Reasons for unfavourable test conditions can include the presence of gas in the soil, significant soil layering or absence of significant excess pore pressure at the location of the filter.

TEST RESULTS

Data processing results in a diagram showing pore pressure, u, and the logarithm of time. The presented pore pressure is relative to the reference level of a test. For analysis of equilibrium in situ pore pressure, this reference level is taken as atmospheric pressure. For consolidation analysis, the reference level is (1) the ground surface for onshore tests, (2) the seafloor for nearshore and offshore tests in seabed mode, or (3) the bottom of the borehole for downhole tests. Data processing for consolidation analysis presumes a hydrostatic in situ pore pressure profile, unless specifically indicated otherwise.

Data processing for cone penetration tests also includes a diagram showing cone resistance, q_c, and the logarithm of time.

The initial pore pressure variations in low-permeability soils warrant further attention:
- Interruption of penetration of the probe results in an inevitable and abrupt reduction of the push-in resistance and, hence, stress change. Thus, the excess pore pressure shows an abrupt decrease, which can be significant for measurements taken at the face of the probe, and, to a lesser extent, for measurements above the base of a cylindrical probe.
- Penetration of the probe into the soil results in the development of radial and axial pore pressure gradients. The magnitudes of the gradients depend primarily on the soil characteristics, such as soil type and stress history. Also, a non-uniform longitudinal shape of the probe will affect pore pressure distribution. Spatial pore pressure redistribution takes place shortly after penetration interruption. For example, at the CPT u_2 filter location this can include an initial negative pore pressure, followed by a rise to positive excess pore pressure and, finally dissipation to equilibrium in situ conditions.
- Dissipation of pore pressure also takes place during penetration of the probe into the soil. This effect is generally negligible near the base of the probe, where undrained conditions are likely to dominate for low-permeability soil. However, partially drained conditions may apply to a filter positions in the shaft of a cylindrical probe, for example the CPT u_3 location above the friction sleeve.
- Soil inhomogeneities can lead to a non-uniform development of pore pressures around the probe. This may affect both the initial and the subsequent pore pressure variations.

INTERPRETATION

Indication of permeability
If required, the test results can include qualitative interpretation of soil permeability, for example by comparing the initial excess pore pressure with the excess pore pressure after 5 or 10 minutes of dissipation.

Coefficient of consolidation
Interpretation can include an estimate of the coefficient of radial consolidation, c_r, which represents radial flow of pore water under vertical compression. This coefficient is the product of the compression modulus and the permeability of the soil. These parameters vary during consolidation. Common interpretation models for c_r are according to Baligh and Levadoux (1986) and Teh and Houlsby (1991).

The Baligh and Levadoux procedure includes a comparison of a curve of normalised excess pore pressure ratio (du/du_o) against time with a theoretical curve derived from cavity expansion theory. General consolidation theory applies in case of reasonable similarity of the curves up to 50% pore pressure dissipation. Limitations include:
- cavity expansion theory does not take account of actual stress-strain behaviour of the soil and rate effects
- the shape of the theoretical expanding cavity differs from the actual shape
- displacement and remoulding of the soil applies in the immediate vicinity of the probe.

The basis for the Teh and Houlsby method is also cavity expansion theory and consolidation theory. The method requires an estimate of the rigidity index, I_r, defined as G/c_u, where G is the shear modulus of the soil and c_u is the undrained shear strength.

Kurup et al. (1995) provide recommendations on the selection of the initial excess pore pressure. This procedure considers the initial dissipation values and not the excess pore pressure immediately before the penetration interruption. The root-time method offers the opportunity for extrapolation of dissipation records that are not sufficiently long to reach 50% dissipation of excess pore pressure (Teh and Houlsby, 1991; Sully and Campanella, 1994).

Improvement on the interpreted consolidation coefficients is possible by site-specific integration of in situ and laboratory consolidation parameters, including those made using non-standard (large diameter) Rowe hydraulic oedometer.

Equilibrium in situ pore water pressure
Equilibrium in situ pore water pressure can be estimated if dissipation of excess pore pressure is between 90% and 100% (Peuchen and Klein, 2011). The selected method uses inverse time (1/t), which is in general accordance with ASTM (2012). This method implies geometric data fitting as shown in Figures 2 and 3.

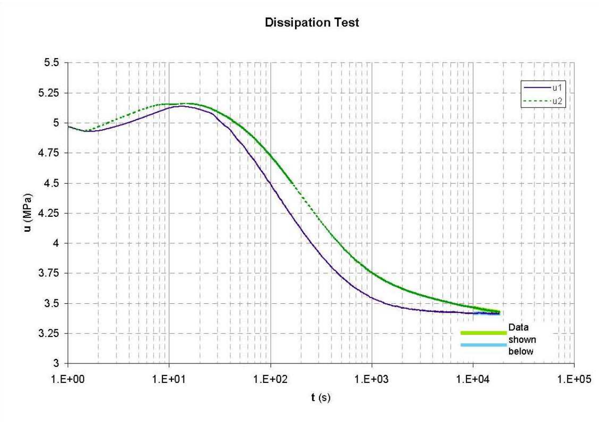


Figure 2, piezoprobe dissipation test results

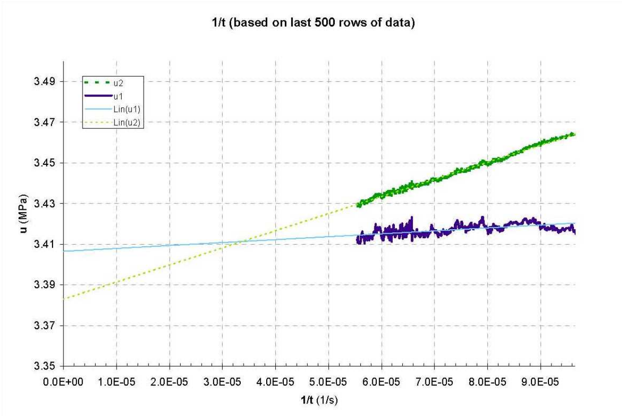


Figure 3, geometric data fitting of piezoprobe test data

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INTRODUCTION

This document is a summary of metrological confirmation systems adopted by Fugro for electric in situ test measuring equipment for geotechnical projects. Metrological confirmation compromises calibration and verification of measuring equipment. A confirmation system demonstrates compliance with reference standards by documenting the metrological characteristics of the measuring equipment, calibration and verification. The metrological confirmation described in ISO 10012:2003 is the basis for Fugro confirmation systems.

Fugro performs a wide range of geotechnical in situ tests with electrical measuring equipment, including the Pressuremeter Test (PMT), in situ Vane Test (VST), T-Bar Test (TBT), hydraulic fracturing test, electrical conductivity test and in situ temperature test. The Cone Penetration Test (CPT) is the most common in situ test.

In situ tests are not performed under controlled conditions, thus metrological confirmation processes are used to ensure confidence in the results. The mode of Fugro field control depends on the type of the in situ test system and the mode of deployment.

This document primarily illustrates the confirmation system for CPT measuring equipment, including the piezo-cone penetrometer (CPTU or PCPT). The principles also apply to in situ test measuring equipment with other types of probes.

MEASURAND

A measurand is the quantity to be measured. In most cases, this is not equivalent to the inferred value. For example, the principal measurand for a vane test is the torque required for rotation of the vane blade. The inferred value is undrained shear strength. Determination of the undrained shear strength from torque measurement requires a model for failure zone geometry and assumptions about soil behaviour during the test.

The principles for the Cone Penetration Test are similar, but more complex. For example, one of the measurands is cone resistance. This is a quantity calculated from (1) axial force measurement, (2) allowance for internal friction of penetrometer components and (3) geometry.

MEASURING EQUIPMENT

Measuring equipment includes the measuring instruments and the data acquisition system that are necessary to acquire a measurement.

Examples of in situ test measuring instruments are the vane blade and torque sensor for the VST and the pressuremeter module for the PMT. The measuring instruments for the CPT are the cone penetrometer and the penetration sensor.

The data acquisition system links the electrical output signals from the measuring instrument to the digitally recorded data. This system includes the transmission cable, the connectors, the analogue/digital converter and the data recording software.

METROLOGICAL CHARACTERISTICS OF MEASURING EQUIPMENT

Metrological characteristics of measuring equipment are the factors that contribute to measurement uncertainty. Examples include: range, bias, repeatability, stability, hysteresis, drift, effects of influencing quantities, resolution, threshold, error, and dead band.

CALIBRATION AND CONFIRMATION

The calibration of the measuring instruments takes place in a Fugro calibration laboratory. The calibration facilities use references that are traceable to (inter)national measurement standards. For example, force calibration for a cone penetrometer is traceable to Dutch NMi (Nederlands Meet-instituut) that is certified by the Dutch RvA (Raad voor Accreditatie), which is a member of the International Laboratory Accreditation Cooperation (ILAC). The confirmation interval for a calibration laboratory is 12 months.

For example, calibration and confirmation of a piezo-cone penetrometer considers four components: (1) the load sensors used for determination of cone resistance (q_c) and sleeve friction (f_s), (2) the pressure sensor for determination of water pressure (u), (3) the inclinometer for determination of the inclination of the cone penetrometer from vertical, and (4) the geometry. Practice details are as follows:

1) Load sensors are calibrated by a special test loading facility. The test loading facility provides the calibration factors for the specified measuring range and the zero-load offsets.
2) The pressure sensor is calibrated in a special pressure vessel for cone penetrometers.
3) A special test frame provides calibration data for the inclinometer.
4) Compliance of the geometry of the cone penetrometer to (inter)national standards is verified with vernier calliper length measurements.

INTERVALS BETWEEN METROLOGICAL CONFIRMATION

Metrological confirmation of measuring equipment is generally performed as follows:

(1) Laboratory calibration of the in situ test probe at given calendar and in-use time intervals.
(2) In-service testing of the penetration (depth) sensor to ensure it conforms to a set standard.
(3) In-service testing of the data acquisition system.

Confirmation intervals are reviewed and adjusted when necessary to ensure continuous compliance with the specified metrological requirements. Each time nonconforming measuring equipment is repaired, adjusted or modified, the interval for its metrological confirmation is reviewed. Table 1 presents a summary of typical confirmation intervals.

TABLE 1 CALIBRATION/CONFIRMATION INTERVALS

Measuring Equipment Component	Calibration/Confirmation Interval (at earliest occurrence)	Records
Measuring Instrument	- 6 months - single project or campaign of projects - in-service testing - suspected non-conformance	- calibration data certificate available on-site and in Fugro calibration laboratory - in-service testing data in project file - monitoring and control data in project file
Data Acquisition System	- in-service testing - suspected non-conformance	- calibration data certificate available on-site and in Fugro calibration laboratory - in-service testing data in project file - monitoring and control data in project file

RECORDS OF METROLOGICAL CONFIRMATION PROCESS

Dated records of the metrological confirmation process are approved by an authorized person to attest to the correctness of the results, as appropriate. These records and corresponding procedures are available to staff and to Clients upon request.

Records of the metrological confirmation process are examined to confirm that each item of measuring equipment satisfies the metrological requirements specified.

The records include the following, as applicable:

1) The description and unique identification of the in situ test equipment manufacturer, type, serial number.
2) The date on which the metrological confirmation was completed.
3) The assigned interval for metrological confirmation.
4) General review of the in situ test results for given ground conditions.
5) Visual inspection of the geometry of the measuring instrument and push rods upon retraction.
6) Visual inspection of the transmission cables and connectors.
7) Checks on and monitoring the zero-load offsets before and after each test. These provide an indication of the uncertainty of the test results.
8) Checks on and monitoring the responses of the load and pressure sensors to water depth. Responses provide an indication of the sensor performance.
9) Monitoring the pressure in the hydraulic thrust machine. This permits the calculation of the total force required for penetration.

10) Time checks. The real time on the clock of the recording apparatus provides the basis for recording of some measurands (for example q_c, f_s, u and z). Together, time and penetration measurements permit checks on the standardised penetration rate.

REFERENCES

ISO International Organization for Standardization (2003), "Measurement Management Systems - Requirements for Measurement Processes and Measuring Equipment", International Standard ISO 10012:2003.

INTRODUCTION

This document describes survey of horizontal and elevation/depth reference points for geotechnical and/or environmental data acquisition.

National and international standards for geotechnical and/or environmental data acquisition (as ASTM, BSI, CEN and ISO) require such surveys, but do not describe procedural details. This document summarises common practice.

PROCEDURE

The procedure for positioning survey and depth measurement is typically as follows:
– definition of the type of survey and the target location
– set-up and initial checks of the survey system
– surface positioning survey of the reference point, i.e. the determination of grid coordinates
– subsurface positioning survey, i.e. adjustment of the surface positioning results for underwater offset
– measurement of the water depth
– calculation of elevation relative to a vertical datum, e.g. water level correction.

The activities depend on the project programme. For example, water level correction and subsurface positioning may not be part of the activities agreed upon.

SURVEY CLASSIFICATIONS

Positioning surveys require specific systems and procedures, such as those presented below for offshore applications. The International Hydrographic Organization (IHO, 2008) defines four orders of hydrographic survey to accommodate different uncertainty requirements (Table 1).

TABLE 1 – SUMMARY OF IHO CLASSIFICATION

IHO Order	Special	1a	1b	2
Description of Areas	Areas where under-keel clearance is critical	Areas shallower than 100 m where under-keel clearance is less critical but features of concern to surface shipping may exist	Areas shallower than 100 m where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area	Areas generally deeper than 100 m where a general description of the seafloor is considered adequate
Maximum Allowable Total Horizontal Uncertainty 95% Confidence Level	2 m	5 m + 5% of depth	5 m + 5% of depth	20 m + 10% of depth
Maximum Allowable Total Vertical Uncertainty 95% Confidence Level	a = 0.25 m b = 0.0075	a = 0.5 m b = 0.013	a = 0.5 m b = 0.013	a = 1.0 m b = 0.023
Full Seafloor Search	Required	Required	Not required	Not required
Feature Detection	Cubic features > 1 m	Cubic features > 2 m in depths up to 40 m; 10% of depth beyond 40 m	Not applicable	Not applicable
Recommended Maximum Line Spacing	Not defined as full seafloor search is required	Not defined as full seafloor search is required	3 x average depth or 25 m, whichever is greater	4 x average depth

Note: The use of coefficients a and b is as follows:

$$\pm\sqrt{[a^2 + (b * d)^2]}$$

where:
a represents that portion of the uncertainty that does not vary with depth
b is a coefficient which represents that portion of the uncertainty that varies with depth
d is the depth
b*d represents that portion of the uncertainty that varies with depth.

Figure 1 illustrates the effect of coefficients a and b.

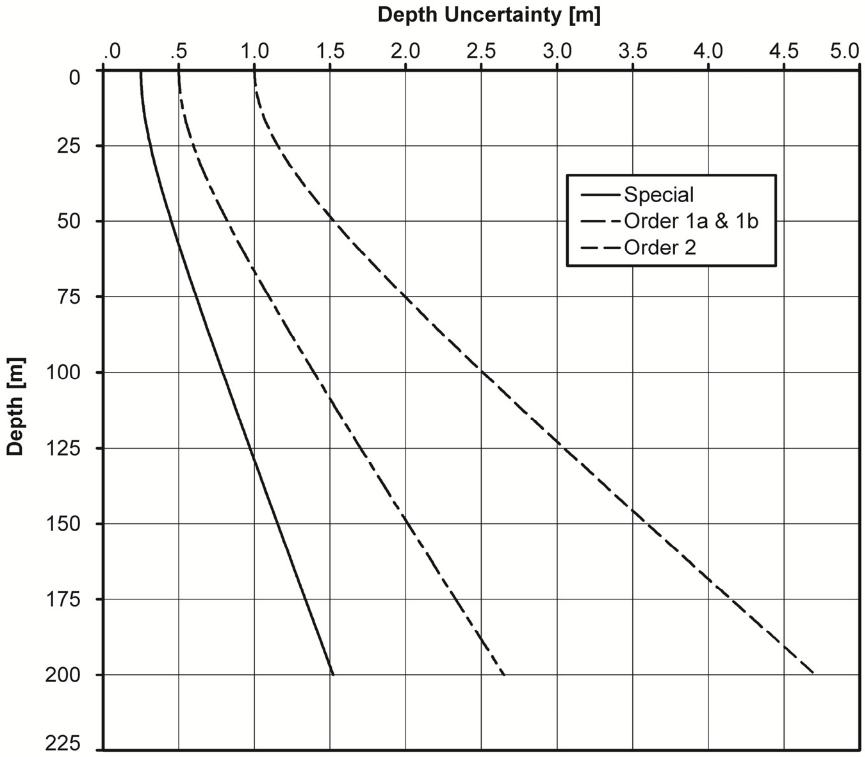

Figure 1 IHO depth uncertainty

IHO Survey Classification - Offshore Practice Examples

The IHO Special Order Survey is exceptional in geotechnical and/or environmental data acquisition. A Special Order system set-up may be comprised of: RTK DGPS; a multibeam echo sounder; a motion compensator, and a Conductivity Temperature Depth (CTD) probe. Subsurface positioning is uncommon in limited water depths.

An IHO Order 1a and 1b survey system set-up may include: high-accuracy DGPS; Long Base Line (LBL) subsurface positioning; a CTD probe with Digiquartz pressure sensor; a barometer; and a tide gauge.

IHO Order 2 surveys are common in geotechnical and/or environmental data acquisition. Such system set-ups could include: DGPS; Ultra Short Base Line (USBL) subsurface positioning (IMCA, 2011); CTD probe; single beam echo sounder or direct sounding by drill pipe; a motion compensator; and predicted tide correction.

These are examples of the simplest set-ups. Independent measurements are often made using a redundant system (OGP, 2011). For example, surface position may be determined by two independent DGPS systems or direct sounding by drill pipe and echo sounding.

Comments on Uncertainty Budget

IHO Order and offshore system set-ups involve relatively complex uncertainty budgets (uncertainty estimates). IHO considers total propagated uncertainties for the reference point on the seafloor. For example, horizontal positioning must not only consider the uncertainty of a DGPS antenna position, but also uncertainty in offset between antenna and actual position of a tool on the seafloor.

Horizontal positioning

- DGPS - antenna position uncertainty typically in the order of 1 to 2 metres.
- High accuracy DGPS - antenna position uncertainty typically in the order of 0.2 m.
- RTK DGPS – antenna position uncertainty typically in the order of centimetres.
- Gyro compass – uncertainty typically in the order of 0.5^{o} to 1^{o}.

DGPS uncertainty contributions include the geodetic network, vessel dynamics and antenna offset. Continuous logging on location allows some quantification of position uncertainty.

Subsurface positioning

- LBL system: receiver position uncertainty typically in the order of 1 metre.
- USBL system: uncertainty of typically 0.5 m plus 1% of distance between transducer and transceiver.

Uncertainty contributions include timing, ray bending, sound absorption, noise and offset.

Water depth measurement

- Direct sounding by drill pipe: uncertainty of typically about 1 m plus 0.5% of measured mean water depth.
- Echo sounder: uncertainty of typically about 0.3 m plus 1% of measured mean water depth.
- Digiquartz probe: probe position uncertainty of typically about 0.2 m plus 0.1% of measured mean water depth.
- Motion compensator: heave measurements have a typical uncertainty of 0.05 m, and roll and pitch an uncertainty of about 0.1°, relative to the mounting of the unit itself.

The pressure sensor estimates are corrected for atmospheric pressure. The echo sounder estimate typically incorporates CTD sound velocity checks, motion compensation, and transducer draught, including vessel squat correction. Vessel squat is a vertical displacement of the hull as a vessel moves, and is determined by water depth and the vessel shape and size. The direct sounding estimate includes uncertainties related to tape measurement, heave, drill pipe length variation due to self-weight and temperature change, drill pipe bending and offset from vertical axis.

Tide correction

- Predicted tides: correction uncertainty typically in the order of 0.2 m to 1 m, depending on tidal range and meteorological circumstances.
- High accuracy DGPS: antenna position uncertainty typically in the order of 0.3 m.
- Tide gauge: correction uncertainty typically in the order of 0.1 m.
- RTK DGPS: antenna position uncertainty typically in the order of 0.1 m.

Uncertainty budgets can be project-specific. Soft soils, for example, can introduce uncertainty in underwater vertical position of measurement. A water pressure measurement tool mounted on an underwater frame may sink into the soil, thus affecting the measurement. Insufficient acoustic contrast between water and soft soil may affect echo sounder water depth measurements.

An irregular or sloping seafloor may affect echo sounder measurements. An echo sounder determines the earliest arrival of acoustic waves within the beam area. The highest points within the beam are assumed to correlate with the seafloor position, and thus yield the "water depth".

Sample and Test Depths

The comments on IHO uncertainty budget apply to a reference point at seafloor. There may be additional uncertainty in the location of a test or sample. The reasons for this include:

- additional measurements. For example, measurement of the length of the drill pipe in case of a downhole sample
- offset of the test or sample location from the reference point, for example due to a towed device or inclined drill pipe.

Peuchen et al. (2005) present the following expression for offshore depth uncertainty assessment:

$$\Delta z = \pm\sqrt{[a^2 + (b * d)^2 + (c * z)^2]}$$

where:

a constant depth uncertainty, i.e. the sum of all uncertainties that do not vary with depth in metres
b uncertainty dependent on water depth, i.e. the sum of all water-depth dependent uncertainties
c uncertainty dependent on test depth, i.e. the sum of all test depth dependent uncertainties
d water depth in metres
z test depth in metres relative to seafloor
Δz test depth uncertainty in metres (95% confidence level)

Tables 2 through 4 present coefficients and accompanying premises.

TABLE 2 - COEFFICIENTS FOR DEPTH UNCERTAINTY ASSESSMENT

Geotechnical System	Test Depth Uncertainty Δz		
	a	b	c
Downhole – favourable	0.4 m	0.003	0.003
Downhole – adverse	1.0 m	0.005	0.004
Seabed – favourable	0.2 m	0	0.01
Seabed – adverse	0.8 m	0	0.02
Note: resolution estimated at 50% of uncertainty			

TABLE 3 - PREMISE TO ESTIMATED TEST DEPTH UNCERTAINTY – DOWNHOLE SYSTEM

Characteristics	Offshore setting – downhole system	
	Favourable	Adverse
Vessel - horizontal position	Variation within 5 m of target	Variation within 5 m of target
Vessel heave	1 m at “hook” point	3 m at “hook” point
Tidal variation	1.5 m, with correction for tidal variation by pressure sensor mounted on seabed frame	3 m, with correction for tidal variation by pressure sensor mounted on seabed frame
Seafloor	Firm and level	Very soft seabed soils or very rugged seafloor
Drill pipe checkpoint	Touchdown on seabed frame at borehole start	Touchdown on seabed frame at borehole start
Drill pipe bending	None	Minor
Borehole orientation	Vertical	Inclined at average 2° from vertical from sea level to test depth z

TABLE 4 - PREMISE TO ESTIMATED TEST DEPTH UNCERTAINTY – SEABED SYSTEM

Characteristics	Offshore setting – seabed system	
	Favourable	Adverse
Vessel - horizontal position	Variation within 5 m of target	Variation within 5 m of target
Vessel heave	1 m at “hook” point	3 m at “hook” point
Tidal variation	1.5 m	3 m
Seafloor	Firm and level	Very soft seabed soils or very rugged seafloor

Orientation of Penetration	Vertical at start, with correction for measured inclination	Inclined at average 5^{o} from vertical from seafloor to test depth z

Offshore definition of the seafloor (ground surface) is difficult for extremely soft ground. Reaction equipment may penetrate unnoticed into a near-fluid zone of the seabed. Settlement may also continue during testing (Bouwmeester et al., 2009). Seabed frame settlement is likely to be governed by the following factors:

(1) Descent velocity and penetration into seabed, including possible erosion (scouring) caused by seabed frame descent and resulting water overpressures.
(2) Non-centric loading during touchdown and testing.
(3) Variable on-bottom weight of reaction equipment, because of drilling, sampling and testing activities and because of tensioning and hysteresis forces in a heave compensation system.
(4) Consolidation of seabed sediments.

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Symbol	Unit	Quantity
I - GENERAL		
L	m	Length
B	m	Width
D	m	Diameter
d	m	Depth
h	m	Height or thickness
z	m	Penetration or depth below reference level (usually ground surface)
A	m^2	Area
V	m^3	Volume
W	kN	Weight
t	s	Time
v	m/s	Velocity
a	m/s^2	Acceleration
g	m/s^2	Acceleration due to gravity ($g = 9.81\ m/s^2$)
m	kg	Mass
ρ	kg/m^3	Density
π	-	Mathematical constant (= 3.14159)
e	-	Base of natural logarithm (= 2.71828)
ln	-	Natural logarithm
log	-	Logarithm base 10
II - STRESS AND STRAIN		
P_a	kPa	Atmospheric pressure
u	MPa	Pore water pressure
u_o	MPa	Hydrostatic pore pressure relative to seafloor or phreatic surface
σ	kPa	Total stress
σ'	kPa	Effective stress
τ	kPa	Shear stress
t	kPa	Shear stress in s'-t space [$= (\sigma'_1 - \sigma'_3)/2$] or [$= (\sigma_1 - \sigma_3)/2$]
$\sigma_1, \sigma_2, \sigma_3$	kPa	Principal stresses
σ'_{ho}	kPa	Effective in situ horizontal stress
σ_{vo}	kPa	Total in situ vertical stress relative to ground surface or phreatic surface
σ'_{vo}	kPa	Effective in situ vertical stress (or p'_o)
σ'_h	kPa	Effective horizontal stress
σ'_v	kPa	Effective vertical stress
r_u	-	Pore pressure ratio [$= u/\sigma_{vo}$]
p'	kPa	Mean effective stress [$= (\sigma'_1 + \sigma'_2 + \sigma'_3)/3$]
q	kPa	Principal deviator stress [$= \sigma'_1 - \sigma'_3$] or [$= \sigma_1 - \sigma_3$]
s'	kPa	Mean effective stress in s'-t space [$= (\sigma'_1 + \sigma'_3)/2$]
ε	-	Linear strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	-	Principal strains
ε_v	-	Volumetric strain
γ	-	Shear strain
ν	-	Poisson's ratio
ν_u	-	Poisson's ratio for undrained stress change
ν_d	-	Poisson's ratio for drained stress change
E	MPa	Modulus of linear deformation (Young's modulus)
E_u	MPa	Modulus of linear deformation (Young's modulus for undrained stress change)
E_d	MPa	Modulus of linear deformation (Young's modulus for drained stress change)
G	MPa	Modulus of shear deformation (shear modulus)
G_{max}	MPa	Shear modulus at small strain
I_r	-	Rigidity index [$= G/\tau_{max}$ or G/s_u]
K	MPa	Modulus of compressibility (bulk modulus)
M	MPa	Constrained modulus [$= 1/m_v$]
μ	-	Coefficient of friction
η	kPa.s	Coefficient of viscosity

Symbol	**Unit**	**Quantity**

III - PHYSICAL CHARACTERISTICS OF GROUND

(a) Density and Unit weights

γ	kN/m^3	Unit weight of ground (or bulk unit weight or total unit weight)
γ_d	kN/m^3	Unit weight of dry ground
γ_s	kN/m^3	Unit weight of solid particles
γ_w	kN/m^3	Unit weight of water
γ_{pf}	kN/m^3	Unit weight of pore fluid
γ_{dmin}	kN/m^3	Minimum index (dry) unit weight
γ_{dmax}	kN/m^3	Maximum index (dry) unit weight
γ' or γ_{sub}	kN/m^3	Unit weight of submerged ground
ρ	Mg/m^3 [= t/m^3]	Density of ground
ρ_d	Mg/m^3 [= t/m^3]	Density of dry ground
ρ_s	Mg/m^3 [= t/m^3]	Density of solid particles
ρ_w	Mg/m^3 [= t/m^3]	Density of water
D_r	-, %	Relative density [= $I_D = \gamma_{dmax} (\gamma_d-\gamma_{dmin})/\gamma_d(\gamma_{dmax}-\gamma_{dmin}) = (e_{max}-e)/(e_{max}-e_{min})$]
v	-	Specific volume [= 1+e]
e	-	Void ratio
e_o	-	Initial void ratio
e_{max}	-	Maximum index void ratio
e_{min}	-	Minimum index void ratio
I_D	-, %	Density index [= D_r]
R_D	-, %	Dry density ratio [= γ_d/γ_{dmax}]
n	-, %	Porosity
w	%	Water content
S_r	%	Degree of saturation
r	-, g/kg	Salinity of pore fluid [= ratio of mass of salt to mass of pore fluid]
R	g/l	Salinity of fluid [= ratio of mass of salt to volume of distilled water]
s	g/l	Salinity of fluid [= ratio of mass of salt to volume of fluid]
S	g/kg	Salinity of seawater [= ratio of mass of salt to mass of seawater]

(b) Consistency

w_L	%	Liquid limit
w_P	%	Plastic limit
I_P	%	Plasticity index [= $w_L - w_P$]
I_L	%	Liquidity index [= $(w - w_P)/(w_L - w_P)$]
I_C	%	Consistency index [= $(w_L - w)/(w_L - w_P)$]
A	-, %	Activity [= ratio of plasticity index to percentage by weight of clay-size particles]

(c) Particle size

D	mm	Particle diameter
D_n	mm	n percent diameter [n% < D]
C_u	-	Uniformity coefficient [= D_{60}/D_{10}]
C_c	-	Curvature coefficient [= $(D_{30})^2/D_{10}D_{60}$]

(d) Dynamic Properties

v_p	m/s	P-wave velocity (compression wave velocity)
v_s	m/s	S-wave velocity (shear wave velocity)
v_{s1}	m/s	S-wave velocity normalised to 100 kPa in situ vertical stress
D	-, %	Damping ratio of ground

Symbol	Unit	Quantity
(e) Hydraulic properties		
k	m/s	Coefficient of permeability
k_v	m/s	Coefficient of vertical permeability
k_h	m/s	Coefficient of horizontal permeability
i	-	Hydraulic gradient
(f) Thermal and Electrical properties		
T	°C	Temperature
k	W/(m·K)	Thermal conductivity
a_L	1/°C	Thermal expansion coefficient (linear)
α	m^2/s	Thermal diffusion coefficient
ρ	Ω.m	Electrical resistivity
K	S/m	Electrical conductivity
(g) Magnetic properties		
B	T	Magnetic flux density (or magnetic induction)
(h) Radioactive properties		
γ	CPS	Natural gamma ray

IV - MECHANICAL CHARACTERISTICS OF GROUND

(a) Cone Penetration Test (CPT)

Symbol	Unit	Quantity
q_c	MPa	Cone resistance
q_{c1}	MPa	Cone resistance normalised to 100 kPa effective in situ vertical stress
f_s	MPa	Sleeve friction
f_t	MPa	Sleeve friction corrected for pore pressures acting on the end areas of the friction sleeve
R_f	%	Ratio of sleeve friction to cone resistance
R_{ft}	%	Ratio of sleeve friction to corrected cone resistance (f_s/q_t or f_t/q_t)
u_1	MPa	Pore pressure at the face of the cone
u_2	MPa	Pore pressure at the cylindrical extension above the base of the cone or in the gap between the friction sleeve and the cone
u_2^*	MPa	Pore pressure u_2, but derived rather than measured
u_3	MPa	Pore pressure immediately above the friction sleeve or in the gap above the friction sleeve
K	-	Adjustment factor for ratio of pore pressure at u_1 to u_2 location
q_n	MPa	Net cone resistance
q_t	MPa	Corrected cone resistance (or total cone resistance)
B_q	-	Pore pressure ratio
Q_t	-	Normalized cone resistance [= q_n/σ'_{vo}]
F_r	%	Normalized friction ratio [= f_t/q_n]
N_c	-	Cone factor between q_c and s_u
N_k	-	Cone factor between q_n and s_u
I_c	-	Soil behaviour type index

(b) Standard Penetration Test (SPT)

Symbol	Unit	Quantity
N	Blows/0.3 m	SPT blowcount
N_{60}	Blows/0.3 m	SPT blowcount normalised to 60% energy
$N_{1,60}$	Blows/0.3 m	SPT blowcount normalised to 60% energy and to 100 kPa effective in situ vertical stress

Symbol	Unit	Quantity
(c) Strength of soil		
s_u	kPa	Undrained shear strength (or c_u)
s_u/σ'_{vo}	-	Undrained strength ratio
κ	kPa/m	Rate of increase of undrained shear strength with depth (linear)
c'	kPa	Effective cohesion intercept
φ'	°(deg)	Effective angle of internal friction
φ'_{cv}	°(deg)	Effective angle of internal friction at large strain
ε_{50}	%	Strain at 50% of peak deviator stress (or ε_c)
E_{50}	MPa	Young's modulus at 50% of peak deviator stress
$s_{u;r}$	kPa	Undrained shear strength of remoulded soil
$s_{u;ar}$	kPa	Undrained shear strength of aged remoulded soil
s_R	kPa	Undrained residual shear strength
S_t	-	Sensitivity [= $s_u/s_{u;r}$ or s_u/s_R]
T_x	-	Thixotropy strength ratio [$T_x(t) = s_{u;ar}(t)/s_{u;r}$]
σ'_c	kPa	Effective consolidation pressure
M	-	Gradient of critical state line when projected onto a constant volume plane
A	-	Pore pressure coefficient for anisotropic pressure increment
B	-	Pore pressure coefficient for isotropic pressure increment
(d) Strength of rock		
$I_{s(50)}$	MPa	Point load strength index
σ_c	MPa	Uni-axial compressive strength
(e) Consolidation (one dimensional)		
σ'_p	kPa	Effective preconsolidation pressure (or effective vertical yield stress in situ)
σ^*_{ve}	kPa	Effective vertical stress on ICL at e_0
σ'_{vy}	kPa	Effective vertical yield stress in situ (or effective preconsolidation pressure)
C_c	-	Compression index
C^*_c	-	Intrinsic compression index [= $e^*_{100} - e^*_{1000}$]
C_s	-	Swelling index (or re-compression)
CR	-	Primary compression ratio [= $C_c/(1+e_0)$]
RR	-	Recompression ratio [= $C_s/(1+e_0)$]
e_0	-	Void ratio at σ'_{vo}
e_L	-	Void ratio at liquid limit w_L
e^*_{100}	-	Void ratio at σ'_v = 100 kPa during one-dimensional intrinsic compression
e^*_{1000}	-	Void ratio at σ'_v = 1000 kPa during one-dimensional intrinsic compression
C_α	-	Coefficient of secondary compression (primary compression)
$C_{\alpha s}$	-	Coefficient of secondary compression (swelling/re-compression)
c_v	m^2/s	Coefficient of consolidation
H	m	Drainage path length
ICL	-	Intrinsic compression line (Burland 1990)
I_v	-	Void index [= $(e_0 - e^*_{100})/C^*_c$]
m_v	m^2/MN	Coefficient of volume compressibility
M	MPa	Constrained modulus [= $1/m_v$]
p	kPa	Vertical pressure
OCR	-	Overconsolidation ratio [= σ'_p/σ'_{vo}]
SCC	-	Sedimentation compression curve
SCL	-	Sedimentation compression line (Burland 1990)
S_σ	-	Stress sensitivity [= $\sigma'_{vy}/\sigma^*_{ve}$]
YSR	-	Yield stress ratio [= $\sigma'_{vy}/\sigma'_{vo}$]

V - GEOTECHNICAL DESIGN

(a) Partial factors

γ_d	-	Factor related to model uncertainty or other circumstances
γ_f	-	Partial action factor (load factor)
γ_m	-	Partial material factor (partial safety factor)
γ_R	-	Partial resistance factor (partial safety factor)

(b) Seismicity

a_g	m/s^2	Effective peak ground acceleration (design ground acceleration)
d_g	m	Peak ground displacement
α	-	Acceleration ratio [= a_g/g]
τ_c	kPa	Seismic shear stress

(c) Compaction

ρ_{dmax}	Mg/m^3 [= t/m^3]	Maximum dry density
ρ_{max}	Mg/m^3 [= t/m^3]	Maximum density
w_{opt}	%	Optimum moisture content

(d) Earth pressure

δ	°(deg)	Angle of interface friction (between ground and foundation)
K	-	Coefficient of lateral earth pressure
K_a	-	Coefficient of active earth pressure
K_{ac}	-	Coefficient of active earth pressure for total stress analysis
K_p	-	Coefficient of passive earth pressure
K_{pc}	-	Coefficient of passive earth pressure for total stress analysis
K_o	-	Coefficient of earth pressure at rest
K_{onc}	-	K_o for normally consolidated soil
K_{ooc}	-	K_o for overconsolidated soil

(e) Foundations

A	m^2	Total foundation area
A'	m^2	Effective foundation area
B'	m	Effective width of foundation
E_s	MN/m^3	Modulus of subgrade reaction
k	MPa/m	Rate of change of modulus of subgrade reaction E_s with depth z
L'	m	Effective length of foundation
H	MN	Horizontal external force or action
V	MN	Vertical external force or action
M	MN.m	External moment
T	MN.m	External torsion moment
Q	MN	Total vertical resistance of a foundation/pile
Q_p	MN	End-bearing of pile
Q_s	MN	Shaft resistance of pile
q_p	MPa	Unit end-bearing
q_{lim}	MPa	Limit unit end-bearing
f	kPa	Unit skin friction (or q_s)
f_{lim}	kPa	Limit unit skin friction
p	MN/m	Lateral resistance per unit length of pile
p_{lim}	MN/m	Limit lateral resistance per unit length of pile
s	m	Settlement
t	MN/m	Skin friction per unit length of pile
y	mm	Lateral pile deflection
z	mm	Axial pile displacement
α	-	Adhesion factor between ground and foundation (= f/s_u)
β	-	Adhesion factor between ground and foundation (= f/σ'_v or f/σ'_{vo})

Symbol	Unit	Quantity
δ	°(deg)	Angle of interface friction (between ground and foundation)
δ_{cv}	°(deg)	Constant volume or critical-state angle of interface friction (between ground and foundation)
N_c, N_q, N_γ	-	Bearing capacity factors
K_c, K_q, K_γ	-	Bearing capacity correction factors for inclined forces or actions, foundation shape and depth of embedment
i_c, i_q, i_γ	-	Bearing capacity correction factors for external force inclined from vertical shape
s_c, s_q, s_γ	-	Bearing capacity correction factors for foundation shape
d_c, d_q, d_γ	-	Bearing capacity correction factors for foundation embedment

Signs:
- A "prime" applies to effective stress.
- A "bar" above a symbol relates to average properties.
- A "dot" above a symbol denotes derivative with respect to time.
- The prefix "Δ" denotes an increment or a change.
- A “star” after a symbol denotes value corrected for pore fluid salinity.

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APPENDIX 2: POSITIONING REPORT

CONTENTS Reference

POSITIONING DATA FOR
MV FUGRO SCOUT
GEOTECHNICAL INVESTIGATION
BORSSELE III & IV WIND FARM SITES
DUTCH SECTOR, NORTH SEA

Survey Period: October - November 2015
Report Number: PH399-GEOT-01

Prepared for: Fugro Engineers B.V.
Prismastraat 4
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The Netherlands

Client Reference: N6083

Rev	Description	Prepared	Checked	Approved	Date
B	Revised Final Report	A. Maddison	M. Blawat	A. King	8 December 2015
A	Revised Final Report	A. Maddison	M. Blawat	A. King	4 December 2015
0	Final Report	A. Maddison	E. Tsompanopoulos	A. King	26 November 2015
2	Issue for Approval	A. Maddison	E. Tsompanopoulos	A. King	6 November 2015
1	Field Report	G. Lazenby	A. Maddison	A. King	3 November 2015

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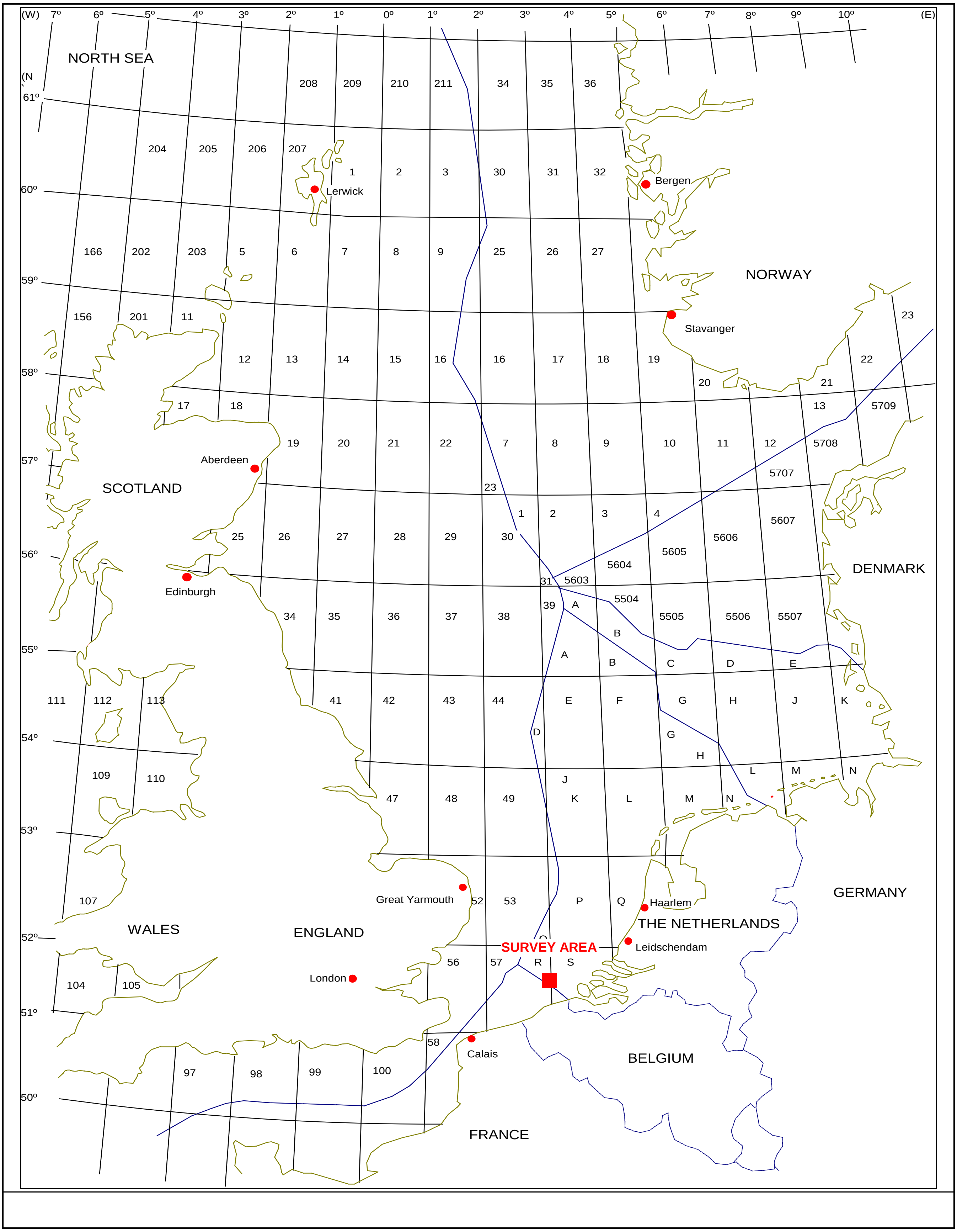
Trade Register Nr: 34070322 / VAT Nr: 005621409B11

REPORT AMENDMENT SHEET

Rev No.	Report Section	Page No.	Table No.	Figure No.	Description
2	Entire	-	-	-	Office QC
0	Entire	-	-	-	Add explanation and memorandum about USBL Offset Error
0	2	2	-	-	Add explanation about seabed frame landing attempts naming
A	Front Page				Changes in the descriptions of the revisions in the cover page table
B	2				Information summary on position and depth acquisition method of the seabed frame landing attempts added
B			2.1, 2.2, 2.3		Reference to bumpover CPT_WFS4_26A added
B			4.1		Project geodetic and projection parameters corrected
B			2.1, 2.2, 2.3, 3.1, 3.2		EPSG codes corrected in the tables header



LOCATION OF BORSSELE III & IV WIND FARM SITES, DUTCH SECTOR, NORTH SEA

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APPENDICES

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FIGURES

1. INTRODUCTION

Fugro Survey B.V. (FSBV) was contracted by Fugro Engineers B.V. to supply navigation and positioning services for the geotechnical drill vessel MV Fugro Scout at forty-nine in situ testing locations at Borssele III & IV wind farm sites.

The positions and depths reported here were checked and quality controlled by the FSBV office staff onshore and supersede the values in the preliminary field report.

The sampling and/or in situ testing was carried out between 19 October 2015 and 1 November 2015. The positioning results are given in Table 2.1, Table 2.2 and Table 2.3.

System positioning performance parameters are outlined in Section 5.3.

2. RESULTS

An incorrect USBL-transducer reference offset was set in the navigation software during recording of the positions of the seabed frame at locations CPT_WFS4_12 and CPT_WFS4_26. The locations were checked and reprocessed with the correct USBL-transducer reference offset in the office, and the corrected positions of those locations are listed in this report. Additional information can be found in Appendix A.

Additional test points at a location are indicated with a capital suffix at the end of the location name (e.g. CPT_WFS4_26A). At Client's request, seabed frame landing attempts are also presented in this report. These are indicated with a lower case suffix at the end of the location name (e.g. CPT_WFS4_26b).

It was observed on a number of occasions that the seabed frame's inclination after it had landed on the seafloor was not within the required limits. In those cases a single manual (surface) fix of the vessel´s CRP position was taken rather than a USBL fix of the seabed frame. It is assumed that the CRP and the seabed frame location coincided due to the shallow water and the small possibility of the seabed frame movements. Once the seabed frame got lifted from the seafloor a new attempt to horizontally position the frame on the seabed was made in the vicinity. Refer to section 5.2 for more details.

Water depth at the seabed frame landing attempts is taken from the water depth at the associated successful test location. Depth calculated from the pressure sensor logging is not available for the seabed frame landing attempts.

2.1 Field Locations

Table 2.1: Actual Coordinates and Water Depths ETRS89 UTM 31N

Datum: ETRS89, UTM Zone 31N, EPSG codes: 25831 and 6258					Water Depth (LAT) 3)		
Location	Easting [m]	Northing [m]	Latitude [North]	Longitude [East]	Pressure Sensor [m]	Echo Sounder [m]	Drill String [m]
CPT_WFS4_12 2)	493438.08	5732559.65	51° 44' 38.0630"	002° 54' 17.8452"	35.7	35.9	N/A
CPT_WFS4_26a	494322.45	5731716.71	51° 44' 10.8128"	002° 55' 04.0079"	N/A	32.9	N/A
CPT_WFS4_26 1)	494325.57	5731711.95	51° 44' 10.6588"	002° 55' 04.1708"	N/A	32.9	N/A
CPT_WFS4_26b	494318.89	5731720.60	51° 44' 10.9386"	002° 55' 03.8221"	N/A	32.9	N/A
CPT_WFS4_26A 1)	494328.38	5731708.94	51° 44' 10.5615"	002° 55' 04.3175"	N/A	32.9	N/A
CPT_WFS4_26B 2)	494331.76	5731704.56	51° 44' 10.4199"	002° 55' 04.4940"	32.6	32.9	N/A
CPT_WFS4_5	495150.60	5730220.17	51° 43' 22.3994"	002° 55' 47.2575"	35.3	35.9	N/A
CPT_WFS4_17	494555.16	5730091.57	51° 43' 18.2171"	002° 55' 16.2315"	30.8	30.6	N/A
CPT_WFS4_4	493381.86	5730564.75	51° 43' 33.4880"	002° 54' 15.0503"	34.4	34.4	N/A
CPT_WFS4_16	492679.99	5729123.24	51° 42' 46.7964"	002° 53' 38.5767"	35.1	35.4	N/A
CPT_WFS4_25	493573.61	5728267.28	51° 42' 19.1293"	002° 54' 25.1972"	32.9	32.7	N/A
CPT_WFS4_3a	491743.11	5727283.21	51° 41' 47.1896"	002° 52' 49.9157"	N/A	28.3	N/A

Datum: ETRS89, UTM Zone 31N, EPSG codes: 25831 and 6258					Water Depth (LAT) 3)		
Location	Easting [m]	Northing [m]	Latitude [North]	Longitude [East]	Pressure Sensor [m]	Echo Sounder [m]	Drill String [m]
CPT_WFS4_3b	491746.59	5727287.72	51° 41' 47.3358"	002° 52' 50.0966"	N/A	28.3	N/A
CPT_WFS4_3	491738.72	5727284.73	51° 41' 47.2386"	002° 52' 49.6870"	28.5	28.3	N/A
CPT_WFS4_15a	490906.03	5729450.25	51° 42' 57.2879"	002° 52' 06.1106"	N/A	35.0	N/A
CPT_WFS4_15	490903.64	5729446.44	51° 42' 57.1645"	002° 52' 05.9864"	35.0	35.0	N/A
CPT_WFS4_14a	490421.34	5728500.56	51° 42' 26.5184"	002° 51' 40.9473"	N/A	35.4	N/A
CPT_WFS4_14	490418.56	5728495.82	51° 42' 26.3648"	002° 51' 40.8029"	35.6	35.4	N/A
CPT_WFS4_14A	490415.79	5728491.99	51° 42' 26.2407"	002° 51' 40.6590"	35.3	35.4	N/A
CPT_WFS4_13a	488783.70	5728709.90	51° 42' 33.1853"	002° 50' 15.6016"	N/A	30.6	N/A
CPT_WFS4_13	488787.19	5728714.10	51° 42' 33.3215"	002° 50' 15.7829"	30.7	30.6	N/A
CPT_WFS4_22	488265.99	5730621.67	51° 43' 35.0290"	002° 49' 48.3958"	30.6	30.9	N/A
CPT_WFS4_8	487097.40	5731711.28	51° 44' 10.2059"	002° 48' 47.3411"	30.4	30.4	N/A
CPT_WFS4_9	487505.20	5732839.90	51° 44' 46.7711"	002° 49' 08.4551"	30.5	30.6	N/A
CPT_WFS4_10	489244.75	5732453.41	51° 44' 34.3909"	002° 50' 39.2071"	33.9	34.2	N/A
CPT_WFS4_10a	489248.13	5732457.20	51° 44' 34.5138"	002° 50' 39.3829"	N/A	34.2	N/A
CPT_WFS4_10b	489250.57	5732461.00	51° 44' 34.6370"	002° 50' 39.5097"	N/A	34.2	N/A
CPT_WFS4_10c	489253.89	5732464.95	51° 44' 34.7650"	002° 50' 39.6823"	N/A	34.2	N/A
CPT_WFS4_10d	489244.05	5732455.72	51° 44' 34.4656"	002° 50' 39.1703"	N/A	34.2	N/A
CPT_WFS4_10A	489239.22	5732453.12	51° 44' 34.3811"	002° 50' 38.9188"	33.9	34.2	N/A
CPT_WFS4_23	490383.09	5731346.41	51° 43' 58.6331"	002° 51' 38.6716"	35.3	35.1	N/A
CPT_WFS4_28	491899.16	5731264.54	51° 43' 56.0693"	002° 52' 57.7108"	35.0	34.7	N/A
CPT_WFS4_2	490533.01	5732772.86	51° 44' 44.8148"	002° 51' 46.3471"	35.9	35.8	N/A
CPT_WFS3_24	499134.08	5724963.53	51° 40' 32.3197"	002° 59' 14.9167"	17.4	17.5	N/A
CPT_WFS3_8	500437.55	5724678.60	51° 40' 23.0985"	003° 00' 22.7793"	20.6	20.3	N/A
CPT_WFS3_22	498189.22	5723807.34	51° 39' 54.8866"	002° 58' 25.7450"	21.8	22.0	N/A
CPT_WFS3_13	500855.49	5723291.43	51° 39' 38.1951"	003° 00' 44.5255"	30.6	30.3	N/A
CPT_WFS3_7	498408.34	5722197.47	51° 39' 02.7786"	002° 58' 37.1771"	28.5	28.8	N/A
CPT_WFS3_7a	498410.79	5722195.37	51° 39' 02.7106"	002° 58' 37.3046"	N/A	28.4	N/A
CPT_WFS3_3	500207.85	5721837.23	51° 38' 51.1258"	003° 00' 10.8148"	28.4	28.4	N/A
CPT_WFS3_23	500431.79	5720214.93	51° 37' 58.6124"	003° 00' 22.4596"	29.8	29.9	N/A
CPT_WFS3_12a	497916.39	5719868.06	51° 37' 47.3711"	002° 58' 11.6281"	N/A	32.6	N/A
CPT_WFS3_12b	497912.73	5719871.17	51° 37' 47.4717"	002° 58' 11.4377"	N/A	32.6	N/A
CPT_WFS3_12c	497908.79	5719874.51	51° 37' 47.5798"	002° 58' 11.2327"	N/A	32.6	N/A
CPT_WFS3_12d	497922.44	5719862.55	51° 37' 47.1928"	002° 58' 11.9429"	N/A	32.6	N/A
CPT_WFS3_12	497924.59	5719860.34	51° 37' 47.1213"	002° 58' 12.0548"	32.4	32.6	N/A
CPT_WFS3_21	494844.79	5722864.50	51° 39' 24.2929"	002° 55' 31.7105"	29.8	29.9	N/A
CPT_WFS3_18	494598.56	5724469.42	51° 40' 16.2347"	002° 55' 18.8068"	28.7	29.1	N/A
CPT_WFS3_20	493397.18	5724254.17	51° 40' 09.2210"	002° 54' 16.2790"	30.5	31.1	N/A
CPT_WFS3_19	492526.89	5725094.42	51° 40' 36.3799"	002° 53' 30.9099"	30.2	30.2	N/A
CPT_WFS3_14	494938.06	5726134.09	51° 41' 10.1301"	002° 55' 36.3939"	30.8	30.9	N/A
CPT_WFS3_5	494307.90	5726001.68	51° 41' 05.8224"	002° 55' 03.5854"	29.2	29.3	N/A

Datum: ETRS89, UTM Zone 31N, EPSG codes: 25831 and 6258					Water Depth (LAT) 3)		
Location	Easting [m]	Northing [m]	Latitude [North]	Longitude [East]	Pressure Sensor [m]	Echo Sounder [m]	Drill String [m]
CPT_WFS3_16	495273.54	5727833.14	51° 42' 05.1374"	002° 55' 53.7815"	30.6	30.9	N/A
CPT_WFS3_15	496545.19	5727484.14	51° 41' 53.8739"	002° 57' 00.0388"	33.4	33.6	N/A
CPT_WFS3_2	498233.76	5725141.29	51° 40' 38.0661"	002° 58' 28.0392"	36.8	36.9	N/A
CPT_WFS3_10a	498610.01	5726864.74	51° 41' 33.8566"	002° 58' 47.6042"	N/A	34.7	N/A
CPT_WFS3_10b	498612.18	5726864.17	51° 41' 33.8381"	002° 58' 47.7173"	N/A	34.7	N/A
CPT_WFS3_10c	498602.25	5726856.64	51° 41' 33.5943"	002° 58' 47.2002"	N/A	34.7	N/A
CPT_WFS3_10d	498606.01	5726861.05	51° 41' 33.7371"	002° 58' 47.3960"	N/A	34.7	N/A
CPT_WFS3_10e	498606.78	5726851.98	51° 41' 33.4435"	002° 58' 47.4362"	N/A	34.7	N/A
CPT_WFS3_10f	498598.55	5726860.62	51° 41' 33.7231"	002° 58' 47.0074"	N/A	34.7	N/A
CPT_WFS3_10	498624.57	5726870.89	51° 41' 34.0558"	002° 58' 48.3625"	34.8	34.7	N/A
CPT_WFS3_9	500399.04	5726517.46	51° 41' 22.6211"	003° 00' 20.7820"	24.8	25.0	N/A
CPT_WFS3_27	501861.84	5725795.68	51° 40' 59.2471"	003° 01' 36.9509"	24.6	24.8	N/A
CPT_WFS3_11	501903.85	5726449.17	51° 41' 20.3995"	003° 01' 39.1513"	24.9	25.1	N/A
CPT_WFS3_11A	501900.25	5726444.30	51° 41' 20.2419"	003° 01' 38.9637"	24.9	25.1	N/A
CPT_WFS3_25a	500746.47	5727576.30	51° 41' 56.8936"	003° 00' 38.8844"	N/A	29.2	N/A
CPT_WFS3_25	500748.46	5727579.12	51° 41' 56.9848"	003° 00' 38.9881"	28.9	29.2	N/A
CPT_WFS3_17	497484.69	5728645.81	51° 42' 31.4941"	002° 57' 48.9472"	33.2	33.1	N/A
CPT_WFS3_6	496610.51	5729493.81	51° 42' 58.9265"	002° 57' 03.3709"	33.0	33.4	N/A
CPT_WFS3_6A	496607.77	5729496.70	51° 42' 59.0200"	002° 57' 03.2281"	33.3	33.6	N/A
CPT_WFS3_26a	497696.97	5729829.47	51° 43' 09.8113"	002° 57' 59.9793"	N/A	28.9	N/A
CPT_WFS3_26b	497694.40	5729827.30	51° 43' 09.7410"	002° 57' 59.8454"	N/A	28.9	N/A
CPT_WFS3_26c	497690.64	5729822.54	51° 43' 09.5869"	002° 57' 59.6495"	N/A	28.9	N/A
CPT_WFS3_26d	497688.23	5729818.93	51° 43' 09.4700"	002° 57' 59.5240"	N/A	28.9	N/A
CPT_WFS3_26e	497700.19	5729834.12	51° 43' 09.9619"	002° 58' 00.1470"	N/A	28.9	N/A
CPT_WFS3_26f	497693.13	5729834.56	51° 43' 09.9760"	002° 57' 59.7790"	N/A	28.9	N/A
CPT_WFS3_26	497700.68	5729827.30	51° 43' 09.7411"	002° 58' 00.1726"	28.9	28.9	N/A
CPT_WFS4_24a	497054.58	5734446.15	51° 45' 39.2373"	002° 57' 26.3609"	N/A	35.4	N/A
CPT_WFS4_24b	497051.84	5734441.64	51° 45' 39.0912"	002° 57' 26.2181"	N/A	35.4	N/A
CPT_WFS4_24	497045.99	5734434.56	51° 45' 38.8619"	002° 57' 25.9131"	34.9	35.4	N/A
CPT_WFS4_20a	496286.83	5735375.75	51° 46' 09.3108"	002° 56' 46.2777"	N/A	36.3	N/A
CPT_WFS4_20	496284.16	5735373.39	51° 46' 09.2344"	002° 56' 46.1385"	36.4	36.3	N/A
CPT_WFS4_19	494787.93	5735439.46	51° 46' 11.3300"	002° 55' 28.0742"	32.5	32.4	N/A
CPT_WFS4_6a	493585.75	5734612.83	51° 45' 44.5281"	002° 54' 25.4087"	N/A	29.6	N/A
CPT_WFS4_6	493590.05	5734618.97	51° 45' 44.7270"	002° 54' 25.6326"	29.9	29.6	N/A
CPT_WFS4_27	492007.61	5733941.20	51° 45' 22.7152"	002° 53' 03.1427"	32.8	33.0	N/A
CPT_WFS4_11	489582.28	5733508.53	51° 45' 08.5667"	002° 50' 56.6925"	34.6	34.3	N/A

Notes:
1. MV Fugro Scout CRP position fix was used for the additional test point. No subsurface seabed frame position fix available.
2. Additional test point logged position was reprocessed. Refer to Appendix A for details.
3. Refer to Section 5, Methodology for details on the different water depth measurements

Table 2.2: Actual Coordinates in WGS 84

Datum: WGS 84, EPSG code: 6326		
Location	**Latitude [North]**	**Longitude [East]**
CPT_WFS4_12 [2)]	51° 44' 38.0792"	002° 54' 17.8675"
CPT_WFS4_26a	51° 44' 10.8290"	002° 55' 04.0302"
CPT_WFS4_26 [1)]	51° 44' 10.6750"	002° 55' 04.1931"
CPT_WFS4_26b	51° 44' 10.9548"	002° 55' 03.8444"
CPT_WFS4_26A [1)]	51° 44' 10.5777"	002° 55' 04.3398"
CPT_WFS4_26B [2)]	51° 44' 10.4360"	002° 55' 04.5163"
CPT_WFS4_5	51° 43' 22.4156"	002° 55' 47.2798"
CPT_WFS4_17	51° 43' 18.2333"	002° 55' 16.2538"
CPT_WFS4_4	51° 43' 33.5042"	002° 54' 15.0726"
CPT_WFS4_16	51° 42' 46.8126"	002° 53' 38.5990"
CPT_WFS4_25	51° 42' 19.1454"	002° 54' 25.2195"
CPT_WFS4_3a	51° 41' 47.2058"	002° 52' 49.9380"
CPT_WFS4_3b	51° 41' 47.3520"	002° 52' 50.1189"
CPT_WFS4_3	51° 41' 47.2548"	002° 52' 49.7092"
CPT_WFS4_15a	51° 42' 57.3041"	002° 52' 06.1329"
CPT_WFS4_15	51° 42' 57.1806"	002° 52' 06.0087"
CPT_WFS4_14a	51° 42' 26.5346"	002° 51' 40.9696"
CPT_WFS4_14	51° 42' 26.3810"	002° 51' 40.8252"
CPT_WFS4_14A	51° 42' 26.2568"	002° 51' 40.6813"
CPT_WFS4_13a	51° 42' 33.2014"	002° 50' 15.6238"
CPT_WFS4_13	51° 42' 33.3376"	002° 50' 15.8052"
CPT_WFS4_22	51° 43' 35.0451"	002° 49' 48.4181"
CPT_WFS4_8	51° 44' 10.2220"	002° 48' 47.3633"
CPT_WFS4_9	51° 44' 46.7873"	002° 49' 08.4774"
CPT_WFS4_10	51° 44' 34.4070"	002° 50' 39.2293"
CPT_WFS4_10a	51° 44' 34.5300"	002° 50' 39.4052"
CPT_WFS4_10b	51° 44' 34.6531"	002° 50' 39.5320"
CPT_WFS4_10c	51° 44' 34.7812"	002° 50' 39.7046"
CPT_WFS4_10d	51° 44' 34.4818"	002° 50' 39.1926"
CPT_WFS4_10A	51° 44' 34.3973"	002° 50' 38.9410"
CPT_WFS4_23	51° 43' 58.6493"	002° 51' 38.6939"
CPT_WFS4_28	51° 43' 56.0855"	002° 52' 57.7331"
CPT_WFS4_2	51° 44' 44.8309"	002° 51' 46.3694"
CPT_WFS3_24	51° 40' 32.3359"	002° 59' 14.9390"
CPT_WFS3_8	51° 40' 23.1147"	003° 00' 22.8017"
CPT_WFS3_22	51° 39' 54.9028"	002° 58' 25.7674"
CPT_WFS3_13	51° 39' 38.2113"	003° 00' 44.5479"
CPT_WFS3_7	51° 39' 02.7947"	002° 58' 37.1994"
CPT_WFS3_7a	51° 39' 02.7268"	002° 58' 37.3269"
CPT_WFS3_3	51° 38' 51.1419"	003° 00' 10.8372"

Datum: WGS 84, EPSG code: 6326		
Location	Latitude [North]	Longitude [East]
CPT_WFS3_23	51° 37' 58.6285"	003° 00' 22.4820"
CPT_WFS3_12a	51° 37' 47.3872"	002° 58' 11.6505"
CPT_WFS3_12b	51° 37' 47.4879"	002° 58' 11.4600"
CPT_WFS3_12c	51° 37' 47.5959"	002° 58' 11.2550"
CPT_WFS3_12d	51° 37' 47.2090"	002° 58' 11.9652"
CPT_WFS3_12	51° 37' 47.1374"	002° 58' 12.0771"
CPT_WFS3_21	51° 39' 24.3090"	002° 55' 31.7328"
CPT_WFS3_18	51° 40' 16.2508"	002° 55' 18.8291"
CPT_WFS3_20	51° 40' 09.2371"	002° 54' 16.3013"
CPT_WFS3_19	51° 40' 36.3961"	002° 53' 30.9322"
CPT_WFS3_14	51° 41' 10.1463"	002° 55' 36.4162"
CPT_WFS3_5	51° 41' 05.8385"	002° 55' 03.6077"
CPT_WFS3_16	51° 42' 05.1535"	002° 55' 53.8038"
CPT_WFS3_15	51° 41' 53.8901"	002° 57' 00.0611"
CPT_WFS3_2	51° 40' 38.0822"	002° 58' 28.0615"
CPT_WFS3_10a	51° 41' 33.8727"	002° 58' 47.6266"
CPT_WFS3_10b	51° 41' 33.8543"	002° 58' 47.7396"
CPT_WFS3_10c	51° 41' 33.6105"	002° 58' 47.2225"
CPT_WFS3_10d	51° 41' 33.7533"	002° 58' 47.4183"
CPT_WFS3_10e	51° 41' 33.4597"	002° 58' 47.4585"
CPT_WFS3_10f	51° 41' 33.7393"	002° 58' 47.0297"
CPT_WFS3_10	51° 41' 34.0719"	002° 58' 48.3848"
CPT_WFS3_9	51° 41' 22.6373"	003° 00' 20.8044"
CPT_WFS3_27	51° 40' 59.2632"	003° 01' 36.9733"
CPT_WFS3_11	51° 41' 20.4157"	003° 01' 39.1737"
CPT_WFS3_11A	51° 41' 20.2581"	003° 01' 38.9861"
CPT_WFS3_25a	51° 41' 56.9097"	003° 00' 38.9067"
CPT_WFS3_25	51° 41' 57.0010"	003° 00' 39.0104"
CPT_WFS3_17	51° 42' 31.5103"	002° 57' 48.9695"
CPT_WFS3_6	51° 42' 58.9427"	002° 57' 03.3933"
CPT_WFS3_6A	51° 42' 59.0361"	002° 57' 03.2504"
CPT_WFS3_26a	51° 43' 09.8275"	002° 58' 00.0016"
CPT_WFS3_26b	51° 43' 09.7572"	002° 57' 59.8677"
CPT_WFS3_26c	51° 43' 09.6031"	002° 57' 59.6719"
CPT_WFS3_26d	51° 43' 09.4862"	002° 57' 59.5463"
CPT_WFS3_26e	51° 43' 09.9780"	002° 58' 00.1693"
CPT_WFS3_26f	51° 43' 09.9922"	002° 57' 59.8013"
CPT_WFS3_26	51° 43' 09.7573"	002° 58' 00.1950"
CPT_WFS4_24a	51° 45' 39.2534"	002° 57' 26.3832"
CPT_WFS4_24b	51° 45' 39.1074"	002° 57' 26.2404"
CPT_WFS4_24	51° 45' 38.8781"	002° 57' 25.9355"

Datum: WGS 84, EPSG code: 6326		
Location	Latitude [North]	Longitude [East]
CPT_WFS4_20a	51° 46' 09.3270"	002° 56' 46.3000"
CPT_WFS4_20	51° 46' 09.2505"	002° 56' 46.1608"
CPT_WFS4_19	51° 46' 11.3462"	002° 55' 28.0965"
CPT_WFS4_6a	51° 45' 44.5443"	002° 54' 25.4310"
CPT_WFS4_6	51° 45' 44.7432"	002° 54' 25.6549"
CPT_WFS4_27	51° 45' 22.7314"	002° 53' 03.1650"
CPT_WFS4_11	51° 45' 08.5829"	002° 50' 56.7147"

1. MV Fugro Scout CRP position fix was used for the additional test point. No subsurface seabed frame position fix available.
2. Additional test point logged position was reprocessed. Refer to Appendix A for details.

Table 2.3: Actual Locations Details

Datum: ETRS89, UTM Zone 31N, EPSG code: 25831				Standard Deviation		Proposed to Actual	
Location	Easting [m]	Northing [m]	No. of Fixes	X [m]	Y [m]	Distance [m]	Bearing [°G]
CPT_WFS4_12 2)	493438.08	5732559.65	100	0.08	0.10	0.62	153.02
CPT_WFS4_26a	494322.45	5731716.71	1	N/A	N/A	0.57	26.11
CPT_WFS4_26 1)	494325.57	5731711.95	1	N/A	N/A	5.42	141.59
CPT_WFS4_26b	494318.89	5731720.60	1	N/A	N/A	5.51	323.05
CPT_WFS4_26A 1)	494328.38	5731708.94	1	N/A	N/A	9.53	139.59
CPT_WFS4_26B 2)	494331.76	5731704.56	100	0.07	0.15	15.06	140.60
CPT_WFS4_5	495150.60	5730220.17	100	0.26	0.18	1.02	17.19
CPT_WFS4_17	494555.16	5730091.57	100	0.18	0.18	1.56	87.43
CPT_WFS4_4	493381.86	5730564.75	100	0.36	0.23	0.74	151.02
CPT_WFS4_16	492679.99	5729123.24	100	0.38	0.10	0.67	341.83
CPT_WFS4_25	493573.61	5728267.28	100	0.13	0.09	0.42	47.91
CPT_WFS4_3a	491743.11	5727283.21	1	N/A	N/A	1.00	264.65
CPT_WFS4_3b	491746.59	5727287.72	1	N/A	N/A	5.07	29.43
CPT_WFS4_3	491738.72	5727284.73	100	0.21	0.13	5.57	284.89
CPT_WFS4_15a	490906.03	5729450.25	1	N/A	N/A	0.77	346.89
CPT_WFS4_15	490903.64	5729446.44	100	0.15	0.14	3.99	219.92
CPT_WFS4_14a	490421.34	5728500.56	1	N/A	N/A	1.01	310.97
CPT_WFS4_14	490418.56	5728495.82	99	0.08	0.12	5.40	220.95
CPT_WFS4_14A	490415.79	5728491.99	61	0.14	0.25	10.12	218.58
CPT_WFS4_13a	488783.70	5728709.90	1	N/A	N/A	0.57	315.00
CPT_WFS4_13	488787.19	5728714.10	100	0.07	0.12	5.54	33.87
CPT_WFS4_22	488265.99	5730621.67	100	0.07	0.11	0.51	22.70
CPT_WFS4_8	487097.40	5731711.28	100	0.13	0.10	0.89	353.32
CPT_WFS4_9	487505.20	5732839.90	100	0.18	0.84	1.84	45.02

Datum: ETRS89, UTM Zone 31N, EPSG code: 25831				Standard Deviation		Proposed to Actual	
Location	Easting [m]	Northing [m]	No. of Fixes	X [m]	Y [m]	Distance [m]	Bearing [°G]
CPT_WFS4_10	489244.75	5732453.41	100	0.14	0.13	0.72	64.65
CPT_WFS4_10a	489248.13	5732457.20	1	N/A	N/A	5.75	44.51
CPT_WFS4_10b	489250.57	5732461.00	1	N/A	N/A	10.21	39.32
CPT_WFS4_10c	489253.89	5732464.95	1	N/A	N/A	15.37	39.56
CPT_WFS4_10d	489244.05	5732455.72	1	N/A	N/A	2.62	358.91
CPT_WFS4_10A	489239.22	5732453.12	100	0.20	0.12	4.88	270.20
CPT_WFS4_23	490383.09	5731346.41	100	0.07	0.10	1.97	23.61
CPT_WFS4_28	491899.16	5731264.54	100	0.23	0.17	0.84	265.99
CPT_WFS4_2	490533.01	5732772.86	100	0.10	0.09	0.40	278.75
CPT_WFS3_24	499134.08	5724963.53	100	0.07	0.08	2.12	343.02
CPT_WFS3_8	500437.55	5724678.60	100	0.08	0.19	1.52	242.59
CPT_WFS3_22	498189.22	5723807.34	100	0.09	0.14	1.12	140.06
CPT_WFS3_13	500855.49	5723291.43	100	0.09	0.07	5.11	218.96
CPT_WFS3_7	498408.34	5722197.47	99	0.35	0.38	13.53	314.43
CPT_WFS3_7a	498410.79	5722195.37	1	N/A	N/A	10.31	315.63
CPT_WFS3_3	500207.85	5721837.23	100	0.10	0.06	0.20	310.91
CPT_WFS3_23	500431.79	5720214.93	100	0.10	0.12	0.65	290.66
CPT_WFS3_12a	497916.39	5719868.06	1	N/A	N/A	0.26	204.62
CPT_WFS3_12b	497912.73	5719871.17	1	N/A	N/A	4.74	307.29
CPT_WFS3_12c	497908.79	5719874.51	1	N/A	N/A	9.90	308.84
CPT_WFS3_12d	497922.44	5719862.55	1	N/A	N/A	8.27	134.05
CPT_WFS3_12	497924.59	5719860.34	100	0.07	0.11	11.35	134.54
CPT_WFS3_21	494844.79	5722864.50	100	0.09	0.07	0.70	135.91
CPT_WFS3_18	494598.56	5724469.42	100	0.09	0.19	0.49	31.60
CPT_WFS3_20	493397.18	5724254.17	100	0.08	0.08	0.03	211.27
CPT_WFS3_19	492526.89	5725094.42	100	0.13	0.48	0.35	239.72
CPT_WFS3_14	494938.06	5726134.09	100	0.10	0.13	1.06	90.58
CPT_WFS3_5	494307.90	5726001.68	100	0.06	0.08	0.92	78.80
CPT_WFS3_16	495273.54	5727833.14	100	0.11	0.16	0.80	162.47
CPT_WFS3_15	496545.19	5727484.14	100	0.12	0.09	0.93	106.15
CPT_WFS3_2	498233.76	5725141.29	100	0.08	0.10	0.70	107.67
CPT_WFS3_10a	498610.01	5726864.74	1	N/A	N/A	1.39	109.35
CPT_WFS3_10b	498612.18	5726864.17	1	N/A	N/A	3.63	106.50
CPT_WFS3_10c	498602.25	5726856.64	1	N/A	N/A	10.72	217.00
CPT_WFS3_10d	498606.01	5726861.05	1	N/A	N/A	4.95	212.95
CPT_WFS3_10e	498606.78	5726851.98	1	N/A	N/A	13.36	188.26
CPT_WFS3_10f	498598.55	5726860.62	1	N/A	N/A	11.14	245.71
CPT_WFS3_10	498624.57	5726870.89	100	0.07	0.09	16.86	70.28
CPT_WFS3_9	500399.04	5726517.46	100	0.08	0.08	0.72	309.40

Datum: ETRS89, UTM Zone 31N, EPSG code: 25831				Standard Deviation		Proposed to Actual	
Location	Easting [m]	Northing [m]	No. of Fixes	X [m]	Y [m]	Distance [m]	Bearing [°G]
CPT_WFS3_27	501861.84	5725795.68	100	0.07	0.08	0.54	141.01
CPT_WFS3_11	501903.85	5726449.17	100	0.07	0.13	0.70	67.44
CPT_WFS3_11A	501900.25	5726444.30	100	0.09	0.13	5.46	212.67
CPT_WFS3_25a	500746.47	5727576.30	1	N/A	N/A	1.00	181.72
CPT_WFS3_25	500748.46	5727579.12	100	0.09	0.09	2.67	47.12
CPT_WFS3_17	497484.69	5728645.81	100	0.09	0.12	0.50	51.52
CPT_WFS3_6	496610.51	5729493.81	100	0.09	0.09	1.21	280.01
CPT_WFS3_6A	496607.77	5729496.70	100	0.10	0.15	5.01	308.27
CPT_WFS3_26a	497696.97	5729829.47	1	N/A	N/A	1.14	176.54
CPT_WFS3_26b	497694.40	5729827.30	1	N/A	N/A	4.14	217.19
CPT_WFS3_26c	497690.64	5729822.54	1	N/A	N/A	10.21	217.83
CPT_WFS3_26d	497688.23	5729818.93	1	N/A	N/A	14.53	216.60
CPT_WFS3_26e	497700.19	5729834.12	1	N/A	N/A	4.82	43.09
CPT_WFS3_26f	497693.13	5729834.56	1	N/A	N/A	5.47	316.40
CPT_WFS3_26	497700.68	5729827.30	100	0.06	0.06	5.02	131.12
CPT_WFS4_24a	497054.58	5734446.15	1	N/A	N/A	1.41	324.28
CPT_WFS4_24b	497051.84	5734441.64	1	N/A	N/A	4.90	226.65
CPT_WFS4_24	497045.99	5734434.56	100	0.08	0.10	14.05	222.03
CPT_WFS4_20a	496286.83	5735375.75	1	N/A	N/A	0.70	141.98
CPT_WFS4_20	496284.16	5735373.39	100	0.07	0.08	3.67	271.59
CPT_WFS4_19	494787.93	5735439.46	100	0.07	0.07	0.89	328.27
CPT_WFS4_6a	493585.75	5734612.83	1	N/A	N/A	0.46	340.77
CPT_WFS4_6	493590.05	5734618.97	100	0.08	0.07	7.78	32.29
CPT_WFS4_27	492007.61	5733941.20	100	0.11	0.08	1.00	355.03
CPT_WFS4_11	489582.28	5733508.53	100	0.06	0.07	10.22	269.06

1. MV Fugro Scout CRP position fix was used for the additional test point. No subsurface seabed frame position fix available.
2. Additional test point logged position was reprocessed. Refer to Appendix A for details.

3. OPERATIONS

3.1 Scope of Work

FSBV was contracted to provide positioning support for navigation between the sampling and/or in situ testing locations and determination of the drill string position at each location. Sampling and/or in situ testing was carried out at 49 locations.

Table 3.1: Proposed Locations Provided by the Client

Datum: ETRS89, UTM, Zone 31N, EPSG codes: 25831 and 6258				
Location	**Easting [m]**	**Northing [m]**	**Latitude [North]**	**Longitude [East]**
CPT_WFS4_12	493437.8	5732560.2	51° 44' 38.0808"	002° 54' 17.8305"
CPT_WFS4_26	494322.2	5731716.2	51° 44' 10.7963"	002° 55' 03.9949"
CPT_WFS4_5	495150.3	5730219.2	51° 43' 22.3680"	002° 55' 47.2419"
CPT_WFS4_17	494553.6	5730091.5	51° 43' 18.2148"	002° 55' 16.1502"
CPT_WFS4_4	493381.5	5730565.4	51° 43' 33.5090"	002° 54' 15.0055"
CPT_WFS4_16	492680.2	5729122.6	51° 42' 46.7757"	002° 53' 38.5876"
CPT_WFS4_25	493573.3	5728267.0	51° 42' 19.1201"	002° 54' 25.1811"
CPT_WFS4_3	491744.1	5727283.3	51° 41' 47.1925"	002° 52' 49.9673"
CPT_WFS4_15	490906.2	5729449.5	51° 42' 57.2637"	002° 52' 06.1195"
CPT_WFS4_14	490422.1	5728499.9	51° 42' 26.4971"	002° 51' 40.9869"
CPT_WFS4_13	488784.1	5728709.5	51° 42' 33.1723"	002° 50' 15.6224"
CPT_WFS4_22	488265.8	5730621.2	51° 43' 35.0138"	002° 49' 48.3860"
CPT_WFS4_8	487097.5	5731710.4	51° 44' 10.1774"	002° 48' 47.3464"
CPT_WFS4_9	487503.9	5732838.6	51° 44' 46.7289"	002° 49' 08.3875"
CPT_WFS4_10	489244.1	5732453.1	51° 44' 34.3808"	002° 50' 39.1732"
CPT_WFS4_23	490382.3	5731344.6	51° 43' 58.5744"	002° 51' 38.6305"
CPT_WFS4_28	491900.0	5731264.6	51° 43' 56.0713"	002° 52' 57.7545"
CPT_WFS4_2	490533.4	5732772.8	51° 44' 44.8128"	002° 51' 46.3674"
CPT_WFS3_24	499134.7	5724961.5	51° 40' 32.2540"	002° 59' 14.9489"
CPT_WFS3_8	500438.9	5724679.3	51° 40' 23.1212"	003° 00' 22.8496"
CPT_WFS3_22	498188.5	5723808.2	51° 39' 54.9144"	002° 58' 25.7075"
CPT_WFS3_13	500858.7	5723295.4	51° 39' 38.3236"	003° 00' 44.6926"
CPT_WFS3_7	498418.0	5722188.0	51° 39' 02.4721"	002° 58 '37.6799"
CPT_WFS3_3	498418.0	5721837.1	51° 38' 51.1215"	003° 00 '10.8226"
CPT_WFS3_23	500432.4	5720214.7	51° 37' 58.6049"	003° 00 '22.4913"
CPT_WFS3_12	497916.5	5719868.3	51° 37' 47.3788"	002° 58 '11.6338"
CPT_WFS3_21	494844.3	5722865.0	51° 39' 24.3090"	002° 55 '31.6849"
CPT_WFS3_18	494598.3	5724469.0	51° 40' 16.2210"	002° 55' 18.7932"
CPT_WFS3_20	493397.2	5724254.2	51° 40' 09.2219"	002° 54' 16.2800"
CPT_WFS3_19	492527.2	5725094.6	51° 40' 36.3858"	002° 53' 30.9260"
CPT_WFS3_14	494937.0	5726134.1	51° 41' 10.1303"	002° 55' 36.3386"
CPT_WFS3_5	494307.0	5726001.5	51° 41' 05.8165"	002° 55' 03.5385"

Datum: ETRS89, UTM, Zone 31N, EPSG codes: 25831 and 6258				
Location	Easting [m]	Northing [m]	Latitude [North]	Longitude [East]
CPT_WFS3_16	495273.3	5727833.9	51° 42' 05.1619"	002° 55' 53.7689"
CPT_WFS3_15	496544.3	5727484.4	51° 41' 53.8823"	002° 56' 59.9924"
CPT_WFS3_2	498233.1	5725141.5	51° 40' 38.0728"	002° 58' 28.0047"
CPT_WFS3_10	498608.7	5726865.2	51° 41' 33.8714"	002° 58' 47.5359"
CPT_WFS3_9	500399.6	5726517.0	51° 41' 22.6062"	003° 00' 20.8112"
CPT_WFS3_27	501861.5	5725796.1	51° 40' 59.2606"	003° 01' 36.9332"
CPT_WFS3_11	501903.2	5726448.9	51° 41' 20.4069"	003° 01' 39.1174"
CPT_WFS3_25	500746.5	5727577.3	51° 41' 56.9259"	003° 00' 38.8859"
CPT_WFS3_17	497484.3	5728645.5	51° 42' 31.4840"	002° 57' 48.9268"
CPT_WFS3_6	496611.7	5729493.6	51° 42' 58.9197"	002° 57' 03.4329"
CPT_WFS3_26	496611.7	5729493.6	51° 42' 58.9197"	002° 57' 03.4329"
CPT_WFS4_24	497055.4	5734445.0	51° 45' 39.2001"	002° 57' 26.4037"
CPT_WFS4_20	496286.4	5735376.3	51° 46' 09.3285"	002° 56' 46.2552"
CPT_WFS4_19	494788.4	5735438.7	51° 46' 11.3054"	002° 55' 28.0987"
CPT_WFS4_6	493585.9	5734612.4	51° 45' 44.5141"	002° 54' 25.4165"
CPT_WFS4_27	492007.7	5733940.2	51° 45' 22.6828"	002° 53' 03.1475"
CPT_WFS4_11	489592.5	5733508.7	51° 45' 08.5729"	002° 50' 57.2254"

Table 3.2: Proposed Locations in WGS 84

Datum: WGS 84, EPSG code: 6326		
Location	Latitude [North]	Longitude [East]
CPT_WFS4_12	51° 44' 38.0970"	002° 54' 17.8528"
CPT_WFS4_26	51° 44' 10.8124"	002° 55' 04.0172"
CPT_WFS4_5	51° 43' 22.3842"	002° 55' 47.2642"
CPT_WFS4_17	51° 43' 18.2309"	002° 55' 16.1725"
CPT_WFS4_4	51° 43' 33.5252"	002° 54' 15.0538"
CPT_WFS4_16	51° 42' 46.7919"	002° 53' 38.6100"
CPT_WFS4_25	51° 42' 19.1363"	002° 54' 25.2034"
CPT_WFS4_3	51° 41' 47.2088"	002° 52' 49.9896"
CPT_WFS4_15	51° 42' 57.2798"	002° 52' 06.1418"
CPT_WFS4_14	51° 42' 26.5133"	002° 51' 41.0092"
CPT_WFS4_13	51° 42' 33.1885"	002° 50' 15.6447"
CPT_WFS4_22	51° 43' 35.0299"	002° 49' 48.4082"
CPT_WFS4_8	51° 44' 10.1936"	002° 48' 47.3687"
CPT_WFS4_9	51° 44' 46.7451"	002° 49' 08.4097"
CPT_WFS4_10	51° 44' 34.3970"	002° 50' 39.1955"
CPT_WFS4_23	51° 43' 58.5906"	002° 51' 38.6528"
CPT_WFS4_28	51° 43' 56.0875"	002° 52' 57.7769"
CPT_WFS4_2	51° 44' 44.8290"	002° 51' 46.3897"

Datum: WGS 84, EPSG code: 6326		
Location	Latitude [North]	Longitude [East]
CPT_WFS3_24	51° 40' 32.2702"	002° 59' 14.9713"
CPT_WFS3_8	51° 40' 23.1374"	003° 00' 22.8720"
CPT_WFS3_22	51° 39' 54.9306"	002° 58' 25.7299"
CPT_WFS3_13	51° 39' 38.3397"	003° 00' 44.7150"
CPT_WFS3_7	51° 39' 02.4883"	002° 58' 37.7022"
CPT_WFS3_3	51° 38' 51.1377"	003° 00' 10.8450"
CPT_WFS3_23	51° 37' 58.6211"	003° 00' 22.5137"
CPT_WFS3_12	51° 37' 58.6211"	003° 00' 22.5137"
CPT_WFS3_21	51° 39' 24.3252"	002° 55' 31.7073"
CPT_WFS3_18	51° 40' 16.2372"	002° 55' 18.8156"
CPT_WFS3_20	51° 40' 09.2381"	002° 54' 16.3023"
CPT_WFS3_19	51° 40' 36.4019"	002° 53' 30.9483"
CPT_WFS3_14	51° 41' 10.1465"	002° 55' 36.3610"
CPT_WFS3_5	51° 41' 05.8327"	002° 55' 03.5609"
CPT_WFS3_16	51° 42' 05.1781"	002° 55' 53.7913"
CPT_WFS3_15	51° 41' 53.8985"	002° 57' 00.0147"
CPT_WFS3_2	51° 40' 38.0890"	002° 58' 28.0271"
CPT_WFS3_10	51° 41' 33.8876"	002° 58' 47.5583"
CPT_WFS3_9	51° 41' 22.6224"	003° 00' 20.8335"
CPT_WFS3_27	51° 40' 59.2768"	003° 01' 36.9556"
CPT_WFS3_11	51° 41' 20.4069"	003° 01' 39.1398"
CPT_WFS3_25	51° 41' 56.9421"	003° 00' 38.9083"
CPT_WFS3_17	51° 42' 31.5002"	002° 57' 48.9492"
CPT_WFS3_6	51° 42' 58.9359"	002° 57' 03.4553"
CPT_WFS3_26	51° 43' 09.8641"	002° 57' 59.9979"
CPT_WFS4_24	51° 45' 39.2162"	002° 57' 26.4260"
CPT_WFS4_20	51° 46' 09.3448"	002° 56' 46.2775"
CPT_WFS4_19	51° 46' 11.3216"	002° 55' 28.1210"
CPT_WFS4_6	51° 45' 44.5304"	002° 54' 25.4388"
CPT_WFS4_27	51° 45' 22.6990"	002° 53' 03.1698"
CPT_WFS4_11	51° 45' 08.5891"	002° 50' 57.2477"

3.2 Resources

Only equipment used is listed below; refer to Section 5 (Methodology) for procedural explanations.

Personnel	**Name**	**From**	**To**
Team Leader / Surveyor	A. Maddison	16 October 2015	3 November 2015
Engineer	G. Lazenby	16 October 2015	3 November 2015

Positioning Equipment		
Navigation software		Starfix.NG online navigation suite
Primary positioning		GNSS with Starfix-G2+ corrections (delivered via AOR-E)
Secondary positioning		GNSS with Starfix-G2 corrections (delivered via ESAT)
Tertiary positioning		GNSS with Starfix-G2+ corrections (delivered via ESAT)
Quaternary positioning		GNSS with Starfix-G2 corrections (delivered via AOR-E)
Quinary positioning		GNSS with Starfix-HP corrections (delivered via AOR-E)
Senary positioning		GNSS with Starfix-XP corrections (delivered via ESAT)
Septenary positioning		GNSS with Starfix-HP corrections (delivered via ESAT)
Octonary positioning		GNSS with Starfix-XP corrections (delivered via AOR-E)
Nonary positioning	(DP1)	GNSS with Starfix.G2 (corrections via ESAT)
Denary positioning	(DP2)	GNSS with Starfix.G2 (corrections via AOR-E)
Acoustic positioning		Sonardyne Ranger2 USBL system
Primary heading system		TSS Meridian Surveyor heading system (Gyro 1)
Secondary heading system		TSS Meridian Surveyor heading system (Gyro 2)
Tertiary heading system		TSS Meridian Surveyor heading system (Gyro 3)
Reference stations		Leidschendam, Rogaland, Aberdeen, Galway, Jacou,

Bathymetry	
Primary System	Skipper Hydrographic Echo Sounder GDS102
Secondary System	Sensordata SD204 Pressure Sensor
Tertiary System	SBF CTD Probe
Vertical Motion Compensator	TSS DMS-05 VRU
Data Recording	Starfix.NG online navigation suite

3.3 Offsets

3.3.1 MV Fugro Scout Vessel Offsets

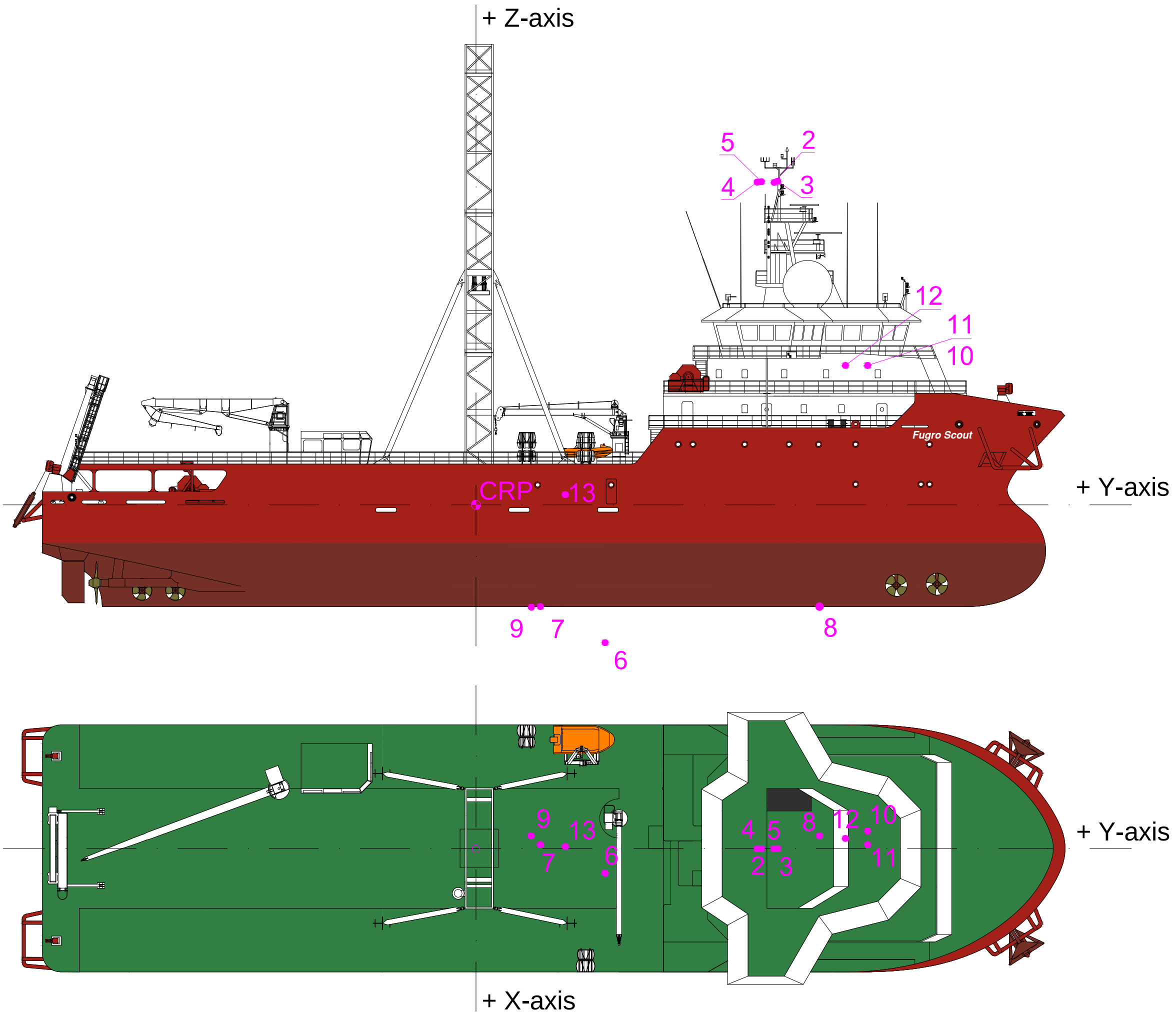


Figure 3.1: MV Fugro Scout Offsets Diagram

Table 3.3: MV Fugro Scout Vessel Offsets

ID	Offsets	Athwart (X) [m]	Along (Y) [m]	Height (Z) [m]
1	CRP (Drill String)	0.00	0.00	0.00
2	SPK-31-Ant (Aft)	0.00	23.17	25.90
3	SPK-32-Ant (Fwd)	-0.01	24.49	25.93
4	DP-DGPS1 (Aft)	-0.01	22.83	25.86
5	DP-DGPS2 (Fwd)	-0.01	24.18	25.92
6	Sonardyne Ranger2	1.95	10.48	-11.04
7	Sonardyne RP	-0.35	5.23	-8.15
8	Fwd ES	-1.04	27.88	-8.15
9	Aft ES	-1.04	4.48	-8.15
10	VRU-1	-0.84	29.98	11.18
11	VRU-2	-1.42	31.78	11.18
12	VRU-3	-0.35	31.78	11.18
13	COG (Reference point for DP)	-0.19	7.25	0.82

3.3.2 Seabed Frame Offsets

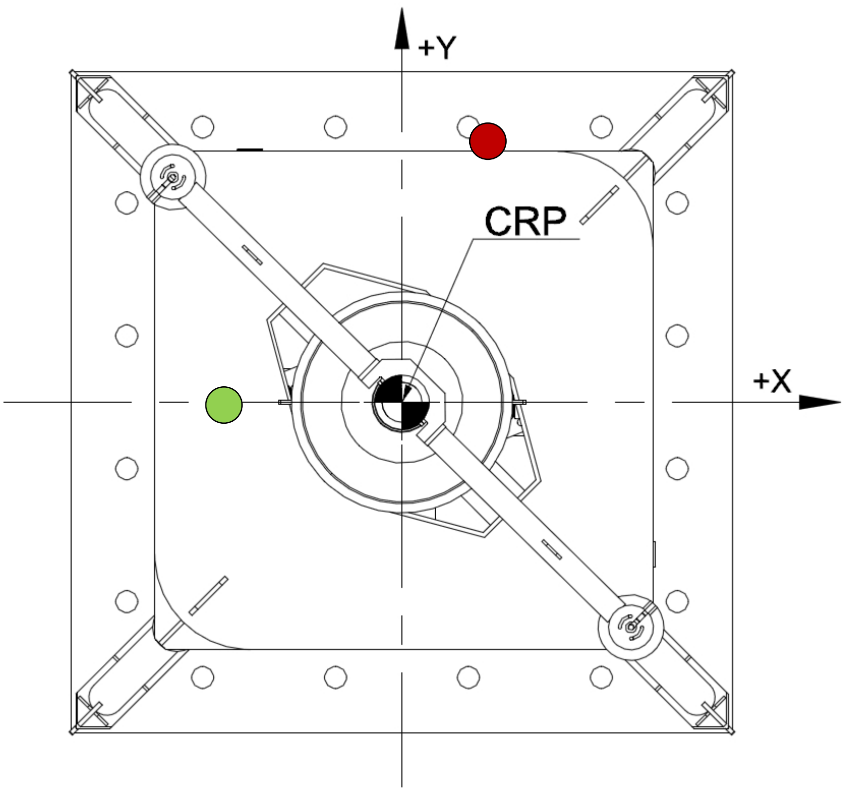


Figure 3.2: Seabed Frame Plan View

Table 3.4: Seabed Frame Offsets

Offsets	Athwart (X) [m]	Along (Y) [m]	Height (Z) [m]
CRP (Drill string centre)	0.00	0.00	0.00
HiPAP Beacon (B14)	-0.80	0.00	4.34
CTD Probe	0.52	1.13	3.46

3.4 Calibration Results

This section details the results of the system calibrations that were carried out prior to positioning operations. Refer to Section 5 (Methodology), for a detailed description of the calibration procedures. Detailed results of the calibrations are available on request.

3.4.1 Positioning Systems

A positioning system verification was carried out on 18 October 2015 in Vlissingen, Netherlands, by means of total station measurements from known points on the quay. The results of the verifications are presented in Table 3.5.

Table 3.5: Positioning System Verification

Date	Location	Method	ΔE [m]	S.D. [m]	ΔN [m]	S.D. [m]
18 October 2015	Vlissingen	Total Station	0.08	0.05	0.02	0.02

To check the integrity of the positioning systems a positioning system comparison was performed on 18 October 2015, in Vlissingen, Netherlands. The differences between the positioning systems were within the expected system accuracy. The results of the comparisons are presented in Table 3.6.

Table 3.6: Positioning System Comparison

Date	Location	Positioning system	ΔE [m]	S.D. [m]	ΔN [m]	S.D. [m]
18 October 2015	Vlissingen	SPK-31-G2 – SPK-32-HP	0.15	0.04	-0.03	0.04
18 October 2015	Vlissingen	SPK-31-G2 – SPK-32-G2	0.02	0.03	0.05	0.03
18 October 2015	Vlissingen	SPK-31-G2 – SPK-31-HP	0.13	0.09	0.03	0.09
18 October 2015	Vlissingen	SPK-32-HP – SPK-32-G2	-0.13	0.02	0.09	0.03
18 October 2015	Vlissingen	SPK-32-HP – SPK-31-HP	-0.02	0.09	0.07	0.10
18 October 2015	Vlissingen	SPK-32-G2 – SPK-31-HP	0.11	0.09	-0.02	0.09

3.4.2 Heading Systems Alignment

The heading systems were checked using Taped offset measurements in Vlissingen, Netherlands, on 18 October 2015. After completion of the checks the corrections were entered into the online navigation software. The results of the alignment checks are presented in Table 3.7.

Table 3.7: Heading Systems Alignment Check

Date	Location	Heading system	Method	Computed [°T]	Observed [°T]	C-O [°]
18 October 2015	Vlissingen	TSS Meridian Gyro 1	Taped offset	59.04°	58.09°	0.95°
18 October 2015	Vlissingen	TSS Meridian Gyro 2	Taped offset	59.04°	57.80°	1.24°
18 October 2015	Vlissingen	TSS Meridian Gyro 3	Taped offset	59.04°	58.30°	0.74°

3.4.3 Speed of Sound and Water Density Measurements

Before the start of project data acquisition and at regular intervals during the project; conductivity, temperature and pressure measurements were taken to establish the local speed of sound profile and average water density. The vessel's Skipper GDS102 echo sounder was corrected for measured sound velocity in NG. The speed of sound profile was entered into the Sonardyne Ranger2 Ultra Short Baseline (USBL) system. The average water density was used for depth determination in conjunction with the pressure sensor. The results of these measurements are presented in Table 3.8.

Table 3.8: Speed of Sound and Water Density Measurements

Date	Location	Mean [m/s]	Transducer [m/s]	Seabed [m/s]	Density [kg/m³]
19 October 2015	CPT_WFS4_12	1506.79	1506.58	1507.10	1026.01
26 October 2015	CPT_WFS3_13	1503.09	1502.89	1503.34	1025.51
31 October 2015	CPT_WFS4_24	1503.78	1503.52	1504.12	1025.97

3.4.4 Simrad HiPAP USBL

The Sonardyne Ranger2 USBL system, installed on board the MV Fugro Scout, was interfaced to the Starfix.NG as the sub-sea positioning system. A USBL Calibration was performed on 29 April 2015. The calibration was undertaken in the Southern Chinese Sea in a water depth of 428 metres. The results of the calibration and the settings in both the systems are presented in Table 3.9:

Table 3.9: USBL Settings

Measurement	Date	X Offset [m]	Y Offset [m]	Z Offset [m]	Orientation [°]	Scale	Pitch [°]	Roll [°]
Ranger 2	30 Jan 2015	2.30	5.30	2.89	1.19	1.00	0.34	-0.54
Starfix.NG	29 April 2015	0.00	0.00	0.00	0.54	1.00	0.19	-0.04

4. DATUM AND TOLERANCES

4.1 Geodetic and Projection Parameters

Table 4.1: Project Geodetic and Projection Parameters

Global Positioning System Geodetic Parameters [1)]					
Datum:	World Geodetic System 1984 (WGS 84)				
Spheroid:	World Geodetic System 1984				
Semi major axis:	a = 6 378 137 m				
Inverse Flattening:	1/f = 298.257 223 563				
EPSG Code:	6326				
Local Datum Geodetic Parameters [2)]					
Datum:	European Terrestrial Reference System 1989				
Spheroid:	GRS1980				
Semi major axis:	a = 6 378 137 m				
Inverse Flattening:	1/f = 298.257222101				
EPSG Code:	6258				
Datum Transformation Parameters [3)] from WGS 84 to ETRS89 for Epoch 2015.816438356 (26 October 2015)					
Shift dX:	+0.05368 m	Rotation rX:	-0.002172 arcsec	Scale Factor:	0.002605 ppm
Shift dY:	+0.05088 m	Rotation rY:	-0.013104 arcsec	EPSG Code:	Not available
Shift dZ:	-0.08697 m	Rotation rZ:	+0.021239 arcsec		
Project Projection Parameters					
Grid Projection:	Universal Transverse Mercator				
Projection Name	UTM Zone 31 North (UTM 31N)				
Central Meridian:	003° 00’ 00” East				
Latitude of Origin:	00° 00’ 00” North				
False Easting:	500 000 m				
False Northing:	0 m				
Scale factor on Central Meridian:	0.9996				
Units:	Metre				
EPSG Code:	25831				

Notes:

1. Source: Starfix.NG. Starfix.NG determines the transformation parameters according to the Memo of C. Boucher and Z. Altamimi, dated 18 May 2011.
2. This is the right-handed coordinate frame rotation convention used by the Fugro Starfix navigation software.
3. The coordinate transformation parameters are the combined result of the 14 parameter transformation from ITRF2008 to ETRS89 and do take into account the yearly changes on the mentioned epoch. The use of the year average values result in a maximum difference of <10 mm from the individual daily values.
4. The WGS 84 realisation is nearly equal to the ITRF2008 on the above mentioned epoch. WGS84 is maintained by the US Department of Defence to be nearly identical to ITRF2008.

4.2 Vertical Control

Chart Datum	LAT
Tidal Data	Predicted utilising the standard port of Zeebrugge
Time shift	0 h 34 min
Range factor	1.07
Barometric pressure variation	Factored in pressure to depth calculation
Effect of wind	Not considered
Shallow water corrections	Considered
Seasonal changes in mean level	Considered
Seasonal changes in harmonic constants	Considered

4.3 System Performance Parameters

Surface positioning	± 0.5 m
USBL positioning	1% slant range
Bathymetry (absolute)	± 0.5 m absolute using predicted tides
Bathymetry (relative)	Quartz pressure sensor CTD ± 0.01% of range
	Echo sounder ± 1.0% of depth
	Drill string - variable
GNSS 3D mode	5 satellites minimum, PDOP<6, Elevation > 10°
GNSS 2D mode	4 satellites minimum, HDOP<4, Elevation > 10°
Heading system	1°

5. METHODOLOGY

5.1 Introduction

Sections 5.2 to 5.4 inclusive describe the procedures for determining the coordinates and water depths of geotechnical sample and/or in situ testing locations. Section 5.6 describes the calibration procedures carried out for the heading system, surface and sub-surface positioning systems, and the echo sounder. The use of sub-surface positioning systems, primarily USBL and sector scan sonar, depends on the type of geotechnical sampling and/or in situ testing methods used, hence some descriptions in the sections below may not be applicable to this report.

5.2 Position Determination

The actual location may be determined by surface positioning alone or with additional use of USBL. The USBL determines the position of the centre of the seabed frame on the seafloor. Particularly in deeper water, use of USBL provides a more accurate position of the sample and/or in situ testing location since the seabed frame may be offset from the surface position of the drill string due to currents.

The position is determined once the seabed frame makes contact with the seafloor. A minimum of 100 position fixes are logged at five-second intervals for locations where testing occurs. It is not always possible to achieve a suitably level seabed frame for testing and thus in some circumstances several attempts must be made. In order to provide the client with every location the SBF touches down at in a time efficient manor, when the inclination of the seabed frame exceeds acceptable tolerances a single manual fix of the location is taken. At all testing locations once the SBF position has been logged, data outliers are discarded in accordance with standard statistical procedures. To determine the final seabed position of a sample and/or in situ testing location the following general sequence applies:

- From the global navigation satellite system (GNSS) receiver, the antenna's latitude and longitude in WGS84 are transmitted to the navigation computer and converted to Easting and Northing on the local projection by the navigation software;
- The grid heading and X and Y offsets from the antenna to the common reference point (CRP) are applied to the antenna Easting and Northing in order to compute the position of the CRP on the local projection. If the USBL system is not used then this corresponds to the sample and/or in situ testing location since the CRP has been defined as the centre of the drill string;
- The grid heading and X and Y offsets from the CRP to the USBL transducer, mounted on the vessel's hull, are applied to the CRP Easting and Northing to determine the transducer position on the local projection;
- The USBL system measures the slant range and relative bearing (measured clockwise from the vessel centreline) from the USBL transducer to the beacon, mounted on the seabed frame, and also the depth of the beacon relative to the transducer. These values are converted to ΔX, ΔY in the horizontal plane and ΔZ in the vertical plane by the USBL processor;
- The ΔX, ΔY, and ΔZ values are transmitted to the navigation computer where the Z offset of the USBL transducer is applied;

- The position of the beacon is computed in the local projection Easting and Northing and the beacon depth is computed relative to the water surface. The centre of the seabed frame, which corresponds to the seabed sample and/or in situ testing position, is derived from the USBL beacon position by applying the USBL beacons horizontal offsets. The heading of the frame is assumed to be the same as the vessel heading. When heading changes are implemented to the vessel after the location of the frame on the seafloor, the frame will be locked in its original heading by the use of a manual heading, derived from the position fix, in which heading information was logged.

5.3 System Configuration

5.3.1 DP Position System

The MV Fugro Scout is configured according to the classification “Well Intervention Vessel II”. The vessel’s DP system is fed with two independent GNSS positions. Although the same equipment is used, the position solutions are generated using different correction sources and calculation methods.

Position and correction data from the DP system are sent to the survey system by means of galvanic isolators. This enables survey personnel to monitor and compare the positional data from the DP system. All equipment is installed in 19″ rack mount housings.

Additional correction redundancy is provided by cross-linking the two DP StarPack receivers to provide both IOR and ESAT corrections to each receiver. This prevents correction loss due to antenna masking.

Within the area of operations, accuracy and repeatability of the Starfix.Best Position solution are designed to be within 0.2 m in the horizontal plane and 0.5 m in the vertical plane (95% confidence level). The position solution operates with a minimum of five GPS satellites.

For safety reasons, changes to the DP positioning solution were restricted to changing the selection of the corrections satellite (i.e. Indian Ocean Region (IOR), Éireann Satellite (ESAT)) and shore reference stations when entering a new work area. The system was under the full control and responsibility of the DP Operator. Position details from the DP system were not sent to the survey software. Quality control (QC) checks cannot be performed for this system and its performance was fully outside FSBV’s responsibility.

5.3.1.1 DP1 Position

The DP1 position is a Starfix.G2 calculated positions by using clock and orbit corrections from the Fugro G2 network for both GPS and the Russian Global Navigation Satellite System (GLONASS) space vehicles. These corrections were received by the StarPack via ESAT transmissions.

5.3.1.2 DP2 Position

The DP2 position is also a Starfix.G2 calculated positions by using clock and orbit corrections from the Fugro G2 network for both GPS and the Russian Global Navigation Satellite System (GLONASS) space vehicles. These corrections were received by the StarPack via IOR transmissions.

5.3.2 Survey Position and Navigation Systems

The survey team used two StarPack GNSS Precise Point Positioning (PPP) receivers for the surface positioning during the project. The three single modus calculation position solutions (Starfix.G2, Starfix.HP, and Starfix.Best) from the two StarPack receivers were interfaced to the survey computer by means of a galvanic isolated network connection and were made available for comparison and QC. Differential correction signal redundancy was achieved by cross-linking the two StarPack receivers to provide corrections from different satellite transmissions, if required. Both Starfix.G2 solutions were fed into Starfix.NG by means of a serial connection. All six position solutions, three per receiver, were fed into StarPack QC suite for QC purposes.

All positions and peripheral (heading system, USBL, etc.) data were sent to the navigation computer where all data transformations, offset and survey calculations, and data integration and logging were performed. All data can be graphically and numerically presented on the navigation computer or any other computer connected to the survey network. An off-line computer is available for the survey crew to post-process and report survey data.

The geodetic and the datum transformation parameters used are presented in Section 4.1.

5.3.2.1 Primary Positioning System

The primary survey positioning service used by the survey team was Starfix.G2+ solution generated from StarPack Receiver 1. Positions were calculated by using clock and orbit corrections from the Fugro G2 network for both GPS and the Russian Global Navigation Satellite System (GLONASS) space vehicles. These corrections were received by the StarPack via AORE transmissions and positions were output to the Starfix.NG software package.

5.3.2.2 Secondary Positioning System

The secondary positioning service used by the survey team was Starfix.G2 solution generated from StarPack Receiver 2. Positions were calculated using carrier phase corrections from the Fugro Starfix network. The corrections are received by the StarPack via ESAT satellite transmissions and positions are output to the Starfix.NG software package.

5.3.2.3 Tertiary Positioning System

The tertiary positioning service used by the survey team was Starfix.G2+ solution generated from StarPack Receiver 2. Positions were calculated using clock and orbit corrections from the Fugro G2 network for both GPS and GLONASS space vehicles. The corrections are received by the StarPack via ESAT satellite transmissions and positions are output to the Starfix.NG software package.

5.3.2.4 Quaternary Positioning System

The quaternary positioning service used by the survey team was Starfix.G2 solution generated from StarPack Receiver 1. Positions were calculated by using carrier phase corrections from the Fugro Starfix network. The corrections were received by the StarPack via AORE satellite transmissions and positions were output to the Starfix.NG software package.

5.3.2.5 Quinary Positioning System

The quaternary positioning service used by the survey team was Starfix.HP solution generated from StarPack Receiver 1. Positions were calculated by using carrier phase corrections from the Fugro Starfix network. The corrections were received by the StarPack via AORE satellite transmissions and positions were output to the Starfix.NG software package.

5.3.2.6 Senary Positioning System

The tertiary positioning service used by the survey team was Starfix.XP solution generated from StarPack Receiver 2. Positions were calculated using clock and orbit corrections from the Fugro G2 network for both GPS and GLONASS space vehicles. The corrections are received by the StarPack via ESAT satellite transmissions and positions are output to the Starfix.NG software package.

5.3.2.7 Septenary Positioning System

The quaternary positioning service used by the survey team was Starfix.HP solution generated from StarPack Receiver 2. Positions were calculated by using carrier phase corrections from the Fugro Starfix network. The corrections were received by the StarPack via ESAT satellite transmissions and positions were output to the Starfix.NG software package.

5.3.2.8 Octonary Positioning System

The quaternary positioning service used by the survey team was Starfix.XP solution generated from StarPack Receiver 1. Positions were calculated by using carrier phase corrections from the Fugro Starfix network. The corrections were received by the StarPack via AORE satellite transmissions and positions were output to the Starfix.NG software package.

5.3.2.9 Nonary and Denary Positioning Systems

The nonary and donary positioning service used by survey were the DP1 and DP2 Starfix.G2 Position solutions. These position solutions are sent to the Starfix.NG software for QC.

5.3.3 Quality Control

The DGNSS and GNSS PPP data was quality controlled using StarPackQC quality control monitoring application. Real-time QC information was displayed as Time Series graphs, tabulated data and graphical displays such as Sky Plots, Error Ellipses and Lock Time graphs depicting satellite lock status. The quality of DGNSS and GNSS PPP derived position fixing data was monitored whilst logging position data for individual locations and also throughout the entire project period.

An assessment of quality was made based on Position Time Series View with the following time series graphs available to display:

- Standard Deviations (Latitude, Longitude and Height);
- HDOP and VDOP;
- Number of SV's;
- Number of Station's;
- Deltas (Easting, Northing and Height);
- Correction Age;
- F-Test.

An assessment of quality was also made by:

- Data Table Views;
- Satellite Lock Time View,
- Error Ellipses View;
- Satellite Constellation Views.

Within the area of operations the accuracy and repeatability of the Starfix.G2 system was designed to be 0.1 m in the horizontal plane and 0.1 m in the vertical plane with 95% confidence level.

5.4 Depth Determination

The depth at each location was measured using a combination of the following techniques:

- Echo sounder;
- Conductivity, Temperature, and Depth (CTD) probe;
- Drill string reading;
- USBL reading.

5.4.1 Echo Sounder

An echo sounder determines water depth by measuring the two-way travel time of a sound wave travelling from the transducer to the seabed and back again. This value is divided by two and the resultant multiplied by the speed of sound through the water column.

The speed of sound values, entered into the echo sounder were determined by the use of CTD probe using the Chen and Millero (1977) formula, which is a function of temperature, pressure and salinity.

Depth values obtained by the echo sounder are corrected for the transducer’s draft. The transducer’s draft is directly entered into the echo sounder. Depth values derived from the echo sounder are obtained while the vessel’s echo sounder transducer is positioned over the sample and/or in situ testing location. A minimum of 100 measurements are used in the analysis, with any outliers being discarded, in accordance with standard statistical procedures.

5.4.2 Depth Measurement

A CTD probe or pressure sensor is secured to the seabed frame to measure water pressure using a Digiquartz sensor. The output from this unit is absolute pressure, i.e. atmospheric pressure plus water pressure. The atmospheric pressure is recorded on deployment and not updated until the probe returns to the surface. Adjustments are therefore necessary to take into account the actual atmospheric pressure changes that occur during the measurement cycle. Barometric pressure is recorded manually at four hourly intervals using the vessel’s barometer. An UNESCO-recognised formula is then used to convert the raw pressure values to depth values.

5.4.3 Drill String Reading

This is a physical measurement made by the drilling personnel and is the total length of pipe used to reach the seabed. The measurement is corrected for the distance between the drill floor and the water surface (air gap), and corrected for local tidal variations. When operating in deep water, errors due to the effects of current may be induced in the drill string depth measurement.

5.4.4 USBL Reading

This is a measurement made by taking the Sonardyne Ranger 2 system USBL beacon Z-values (depth) and applying the vertical offset of the frame-mounted beacon above the seabed frame base.

5.5 Sector Scan Sonar

This instrument is used to map ultra-sonic reflections in a 360° horizontal sector scan. The subsea unit is clamped to a frame, usually the seabed frame used for geotechnical drilling, and operated through an umbilical from the surveyor's station on the bridge. From the surface control unit, images are interpreted using the target shape, size, colour or shade variations and shadows. Various range scale options and measurement tools allow the operator to determine the range and bearing of subsea contacts from the seabed frame in relation to the intended drilling location. Sector scan sonar images can be saved digitally.

5.6 System Calibration Procedures

Calibrations of all position and depth measuring equipment are carried out prior to sampling and/or in situ testing. This checks that all equipment is operating within acceptable limits and that the accuracy of the logged data is not compromised. Most equipment is permanently installed on the geotechnical drilling vessel and therefore not all calibrations are performed before the start of every sampling and/or in situ testing programme. The most recent calibrations of the equipment are assessed and new calibrations are carried out if deemed necessary.

5.6.1 Offset Measurements

At the start of the mobilisation, offsets from the vessel's datum (normally the centre of the drill string) to the various DGNSS antennas and other relevant offset points are measured. These measurements are compared with measurements taken from a scaled vessel plan or a previous vessel offset diagram. Seabed frame offsets from the frame's CRP to its transponder and the Z offset for the CTD probe are also measured. Offsets are entered into the navigation software. The USBL transducer offset is already corrected to the vessel's CRP by the vessel's Sonardyne Ranger 2 system programme.

5.6.2 Heading System Alignment Check

Three methods are possible when performing a heading system alignment check alongside. The resulting differences between computed and observed headings are entered into the navigation software as the heading system's computed minus observed C-O correction.

5.6.2.1 Total Station

These methods of performing a heading system alignment check uses land survey techniques. Reflectors are placed at or near the bow and stern of the vessel on the centreline and their positions fixed at regular intervals. Simultaneous heading system readings and heading observations are taken. The true bearing between the reflectors is calculated and compared to the observed heading system reading.

5.6.2.2 Sun Azimuth

Sun azimuth observations are performed with a total station and a sun filter, when the sun is at a maximum elevation of approximately 30º. The vessel's heading is determined by measuring the angle between the vessel's centreline and the sun azimuth and applying this angle to the computed sun azimuth. The logged heading subtracted from the heading derived from the azimuth of the sun will give the heading system's C-O correction.

5.6.2.3 Taped Offsets

This method requires the known heading of the quay and two measurements are taken simultaneously from the quay to the vessel's centreline. The distance between the two measurements provides a baseline for calculating the angle of the vessel's centreline relative to the quay, which is then applied to the quay heading to derive the computed grid vessel heading. The convergence is applied to the computed grid heading to obtain the true heading which is compared with the observed heading system's reading in order to obtain the C-O correction.

5.6.3 Positioning System

In order to determine the integrity and reliability of the surface positioning systems, two main procedures are followed:

5.6.3.1 Positioning Verification

The position of the primary DGNSS antenna, in local projection coordinates, and computed from the navigation system, is compared to the position derived by land survey techniques. The total station measures directly to the DGNSS antenna from a known point on the quay. The DGPS antenna position and the position derived from land survey methods are logged simultaneously and should agree to better than 1 m. This process also verifies the geodetic parameters entered into the online survey software.

5.6.3.2 System Comparison

Once the position verification results are acceptable, a position comparison against all position computations is conducted. The antenna positions for all systems are logged and using the heading system and the measured antenna offsets are reduced to the vessel's CRP. The difference in the positions should agree to within 1 m and they are represented as Delta Easting (ΔE) and Delta Northing (ΔN).

5.6.4 Ultra Short Baseline System

A USBL allows the measurement of range and bearing from a vessel-based transceiver to one or more subsea transponders. It generally operates through the phase discrimination of an acoustic signal recorded by three orthogonal transducers combined in one head. A USBL calibration is executed whenever work is carried out on the transducer and at least once a year. Calibrations are carried out in water depths slightly deeper than those in which the operations will occur.

5.6.4.1 Preparation

During the USBL calibration sequence, the vessel must be free to manoeuvre around a stationary transponder. Before starting the actual USBL calibration, it is assumed that:

- The vessel's positioning system has been verified;
- The vessel's heading system alignment has been checked;
- All relevant offsets, including the height of the transponder's transducer above the seabed, have been measured.

The actual water depth, measured by the echo sounder, and not corrected for tide, should also be known at the calibration site.

A speed of sound profile, determined at the calibration site, is entered into the USBL system before calibration data is collected.

For the USBL calibration a transponder, equipped with a remote controlled release mechanism or a surface buoy, is deployed, clear of all structures and pipelines, in an area with an approximate water depth slightly deeper than the proposed survey area. The surface positioning system is used to navigate the vessel during the calibration.

5.6.4.2 Offset (Spin) Test

The first part of the calibration is carried out to verify the offsets between the USBL system and the navigation system. This is normally done by manoeuvring the vessel directly over a beacon deployed on the seabed and then rotating the vessel through 360° while logging the surface and USBL position. Any offset errors are displayed as a 'snail trail' showing the beacon position describing a circle around the intended beacon position. Alternatively, the vessel is positioned directly over the beacon, and an equal number of fixes are logged while the vessel is heading in each of the four cardinal directions.

The Z-offset is checked by comparing the Z component of the USBL observation and the value from the echo sounder, allowing for beacon height above the seafloor. As the vessel is directly over the seafloor beacon, this minimise any errors due to Range Scale and USBL transducer misalignment.

5.6.4.3 Range Scale, Orientation, Pitch and Roll

This phase of the calibration is carried out with the vessel positioned on the circumference of a circle of radius 1.5 to 2 times the water depth, centred on the beacon. The following describes a calibration with the vessel lying to the north, east, south, and west of the beacon with the vessel maintaining the same north heading. In the case of bad weather, this pattern may be rotated so that the vessel is heading into the current. The surface position of the vessel and the USBL position of the beacon are logged at each cardinal point. Generally a minimum of 100 fixes, at 5 second intervals, are logged at each cardinal point.

When the vessel is due north or south of the beacon and heading due north, roll errors are minimised and pitch errors are observed. Transducer alignment errors will plot the beacon offset to the east or west of its actual position. Range scaling errors will plot the beacon to the north or south of the actual position.

When the vessel moves to a position due east or west of the beacon, while still maintaining a heading of due north, roll errors are observed and pitch errors are minimised. Transducer alignment error will plot the beacon offset from its actual position. Range scaling errors will plot the beacon to the east or west of the actual position.

Any resultant errors will show the beacon plotted in four quadrants. If there are no errors, the beacon position will be shown as a circular scatter plot around the actual position.

The range error consists of a fixed error and the scalar multiplier. Overall it accounts for errors in ray path and speed of sound. The USBL module in Starfix.NG derives a range error value that contains and accounts for the range fixed error.

Starfix.NG computes the errors and displays the results as four parameters:

- Pitch error;
- Roll error;
- Transceiver misalignment;
- Range error.

5.6.4.4 Verification of Results

The calibration results are checked using one of two methods:

1) Two lines are run at right angles and in opposite directions over the top of the beacon.
2) By conducting a spin test, where the vessel rotates through 360° at a distance of approximately two times the water depth.

In both cases the beacon’s position is continuously logged and should not deviate, within operational parameters, from its calibrated position. A reasonably tight, circular scatter plot a few metres across, depending on the navigation system performance, the USBL system performance, and the depth of water, is an indication of a good calibration result.

5.7 Glossary of Terms

Accuracy	The accuracy of a measurement is its degree of closeness to its actual (true) value. Accuracy is the combination of the precision and reliability of an observation.
Augmentation Data	Additional information e.g. from a reference or tracking station, applied at a user receiver to improve the positioning solution. See also differential GNSS.
Azimuth	A horizontal angle measured from the spheroidal meridian clockwise from north through 360°. See also bearing and heading.
Bearing	Refers to a direction from one point to another on a chart right rotated from grid north (bearing = azimuth + convergence + arc to chord correction). See also azimuth and heading.
C-O Correction	Calculated minus observed correction. The difference found in a calibration procedure between a fixed value and an observation. The C-O correction must always be added to the observation.
Chart Datum	Vertical Datum used in charting. Chart data e.g. Mean Sea Level (MSL), Lowest Astronomical Tide (LAT), Lowest Low Water Springs (LLWS), Normaal Amsterdams Peil (Amsterdam Ordnance Datum) (NAP), Normal Null (NN). See also Vertical Datum.
CM	Central meridian, the meridian that defines the central line of longitude of the chart projection. It is a zone constant used in chart projections.
Convergence	Clockwise angle in a point between true north and grid north.
CRP	Common Reference Point is the origin of all vessel coordinates. It is also referred to as the vessel datum. It often corresponds to the drill string on drilling vessels.
Datum (Geodetic)	A mathematical model designed to best-fit part or all of the geoid. It is defined by an ellipsoid and the relationship between the ellipsoid and a point on the topographic surface established as the origin of datum. This relationship can be defined by six quantities, generally (but not necessarily) the geodetic latitude, longitude and the height of the origin, the two components of the deflection of the vertical at the origin, and the geodetic azimuth of a line, from the origin to some other point.

Datum Rotation (Geodetic)	Defined as the anti-clockwise rotation around the X-axis, Y-axis and Z-axis (Rx, Ry, and Rz) in the origin of two spheroids in terms of the Cartesian or geocentric coordinates. See also datum shift and scale.
Datum Shift (Geodetic)	Defined as the difference (ΔX, ΔY, ΔZ) in the origin of two spheroids in terms of the Cartesian or geocentric coordinates. See also datum rotation and scale.
Datum (Vessel)	The vessel datum is the origin of all vessel coordinates. It is referred to as the common reference point or CRP.
DGNSS	Augmentation technique requiring a GNSS receiver(s) to be placed at one or multiple known points from which GNSS observable (pseudo-range) corrections can be deduced. These corrections can then be applied to the offshore mobile receiver.
DP	Dynamic positioning, mainly referring to a system keeping the vessel in one position compensating for current, wind and other natural influences, using a variety of positioning systems as reference.
Differential Positioning	Determination of relative coordinates between two or more satellite receivers that are simultaneously tracking the same satellite signal.
Ellipsoid / Spheroid	In geodesy, unless otherwise specified, a mathematical figure formed by revolving an ellipse about its minor axis. It is often used interchangeably with spheroid. Two quantities define an ellipsoid: these are usually given as the length of the semi-major axis, a, and the inverse flattening, 1/f = a / (a-b), where b is the length of the semi-minor axis. Prolate and triaxial ellipsoids are invariably described as such.
False Easting / False Northing	Defined projection coordinate offsets to the origin point of the projection.
Geoid	The particular equipotential surface with coincides with mean sea level, and which may be imagined to extend through the continents. This surface is perpendicular to the force of gravity everywhere.
GLONASS	Russian global navigation satellite system.
GPS	Global positioning system.
GNSS	Global navigation satellite system. A combination solution of GPS and GLONASS with provision for the future European Galileo space system.
HDOP	Horizontal dilution of precision. A measure of the magnitude of DOP errors in latitude and longitude.

Heading	Course of a vessel measured with a heading system, i.e. a gyrocompass, or a GPS vector heading system. If the heading is magnetic this will be stated. See also azimuth and bearing.
HiPAP	High precision acoustic positioning. A USBL system developed by Simrad - Kongsberg. See USBL definition.
HPR	Hydro acoustic positioning reference. See USBL definition.
Line Scale Factor	The ratio of a distance from point A to point B on the grid to the corresponding distance on the spheroid. K = plane distance/spheroidal distance 1/k=1/6(1/kA + 4/kM +1/kB). (kA, kB, kM being point scale factors at A, B, M. See also point scale factor)
Multifix	Multi reference differential global positioning system based on simultaneous calculated single DGPS positions for each reference station which solutions are then applied to a least squares calculation by which a new solution is created by weighting the single solutions on distance of the used reference station used in the single computations.
Offset	A station offset from the main survey station. Must be defined by an azimuth and distance or ΔX, ΔY, ΔZ, or starboard/port, forward/aft, above/below.
PDOP	Position dilution of precision. A unit-less figure of merit expressing the relationship between the error in user position and the error in satellite position.
PPP	Precise Point Positioning. A global GNSS augmentation technique that corrects for GNSS satellite clock and orbit errors, and employs additional modelling techniques to further correct and improve the point positioning accuracy.
Precision	A measure of the random errors in observations and estimated parameters.
Reference Station	A GNSS receiver located at a precisely known location and used to determine the differential corrections employed for DGNSS augmentation techniques.
Satellite Configuration	State of the satellite configuration at a specific time, relative to a specific user or set of users.

Satellite Constellation	The arrangement in space of the complete set of satellites of a system such as GPS.
Scale	Reduction/expansion used in datum-datum transformations. Unit: ppm (parts per million). See also datum shift and datum rotation.
Scale Factor (Point)	Ratio of an infinitesimal distance at a point on the grid to the corresponding distance on the spheroid. K = Δ (plane distance) / Δ (spheroidal distance).
S/CTD (probe)	Salinity or conductivity, temperature and depth probe. Used to determine speed of sound through the water column. Pressure to depth conversions may be applied to provide true depth values.
SD	Standard deviation. Measure of the dispersion of random errors about the mean value. If a large number of measurements or observations of the same quantity are made, the standard deviation is the square root of the sum of the squares of deviations from the mean value divided by the number of observations less one.
Sonardyne Ranger 2	Ranger 2 is a high performance acoustic position reference system designed for tracking underwater targets and positioning dynamically positioned (DP) vessels.
Starfix.G2	A decimetre accuracy integrated GNSS service which utilises Fugro's own global network of reference stations to measure carrier phase observations. This data is then processed, producing a corrections solution for each navigation satellite. These corrections are applied to the satellite time reference clock and ephemeris ("orbit") information, hence "clock and orbit corrections". This service utilises both GPS and GLONASS L1 and L2 frequencies, thereby providing an accurate measurement of variations in Ionospheric thickness. This enables signal delay to be calculated more precisely, resulting in a more accurate satellite to antenna range, and hence a more accurate position solution. Starfix.G2 provides a high availability, high integrity, global solution to an accuracy of 10 cm (95% confidence level) both horizontally and vertically.

Starfix.HP	This service utilises the Fugro international network of approximately 100 land-based reference stations. Unlike standard L1, which uses code based measurements, Starfix.HP is based upon carrier phase measurements which provide a much higher resolution. This service utilises the GPS L1 and L2 frequencies, thereby providing an accurate measurement of Ionospheric thickness. This results in a more accurate satellite to antenna range, and hence a more accurate position solution. At a distance of 1000 km from the nearest reference station Starfix.HP accuracies are typically 10 cm and 15 cm (95% confidence level) in the horizontal and vertical planes respectively.
Starfix.XP	This service utilises a third party global network of reference stations to measure carrier phase observations. This data is then processed, producing a corrections solution for each navigation satellite. These corrections are applied to the satellite time reference clock and ephemeris (“orbit”) information, hence “clock and orbit corrections”. This service utilises the GPS L1 and L2 frequencies, thereby providing an accurate measurement of variations in Ionospheric thickness. This enables signal delay to be calculated more precisely, resulting in a more accurate satellite to antenna range, and hence a more accurate position solution. Starfix.XP provides a high performance global solution to an accuracy of 10 cm and 20 cm (95% confidence level) in the horizontal and vertical planes respectively.
Starfix.L1	This service is a GPS positioning correction system using single frequency code correction data from the Fugro network of reference stations, delivered via both Inmarsat and SpotBeam satellites. These corrections, combined with a single frequency GPS receiver, can provide a positional accuracy of better than 1.5 m (95%) horizontally at a distance of 500 km from the closest reference station.
Starfix.NG	Fugro’s in-house advanced vessel and ROV positioning software system.
StarPack	A StarPack unit consists of a survey grade GNSS receiver and powerful processor, running Linux multi-tasking operating system. The receiver is capable of tracking all current (GPS, GLONASS) and future (Galileo) systems. A StarPack can be extended with a second receiver (in the same unit), to provide accurate, GNSS derived heading.
Transceiver	A device that can transmit and receive signals.
Transducer	A device that converts electrical energy to acoustic energy and vice-versa.

Transponder	A device that can detect a signal on a particular frequency and in response transmits signal on another frequency.
UTM	Universal Transverse Mercator. A special case of the transverse Mercator projection whereby the projection parameters are specified by worldwide agreement, abbreviated as the UTM grid. It consists of 60 north south zones, each 6 degrees of longitude wide with a unique central meridian.
USBL	Ultra Short Base Line acoustic positioning method involving the measurement of range and bearing from a vessel-based transceiver to subsea transponders. It generally operates through phase discrimination of an acoustic signal as it passes over three transducers placed at right angles to each other within the Transducer head. Using this method, a three dimensional position of the beacon(s) can be determined.
Vertical Datum	An arbitrarily assumed value for a particular benchmark or a measured value at sea level at a tide station, or a fixed adjustment of many such measurements in a common adjustment. See also chart datum.
WGS 84	World Geodetic System 1984. A rotational ellipsoid having the following dimensions: semi-major axis 6378137.000 m, semi-minor axis (derived) 6356752.314 m, flattening (derived) 1/298.257224. This ellipsoid reference model / datum is the surface from which GPS coordinates are computed.

APPENDICES

A. FIELD MEMORANDUM

A. FIELD MEMORANDUM

(1 page, not numbered)

MEMORANDUM

To	:	P. Watson / J. van Houten, Client Representatives ; B. Berndsen, Party Chief
From	:	A. Maddison, Survey Team Leader
Ref.	:	PH399 Borssele III & IV Wind Farm Sites
Date	:	27/10/2015
Subject	:	**USBL Offset Error At Locations CPT_WFS4_12 & CPT_WFS4_26**

Positioning of the F-Scout's sea bed frame (SBF) onto the seabed is typically done by locating the vessel's moon-pool over the proposed sampling location, with the assumption made that the SBF stays right below the moon-pool. Once firmly located at the seabed the SBF's position coordinates are captured by logging USBL data.

It was observed that at sampling locations CPT_WFS4_12 and CPT_WFS4_26 an incorrect USBL transducer reference offset was used in the navigation software. Consequently the seabed frame's position based on USBL observations was calculated incorrectly and this was shown on the navigation displays. The logged data was post-processed in the FSBV office where the correct USBL offset values were used; resulting in the following updated SBF coordinates:

Datum: ETRS89, epoch 2015.816438356, UTM Zone 31N, EPSG code: n/a				Standard Deviation		Proposed to Actual	
Location	**Easting [m]**	**Northing [m]**	**No. of Fixes**	**X [m]**	**Y [m]**	**Distance [m]**	**Bearing [°G]**
CPT_WFS4_12	493438.08	5732559.65	100	0.08	0.10	0.62	153.02
CPT_WFS4_26B	494331.76	5731704.56	100	0.07	0.15	15.06	140.60

It shall be emphasized that because the vessel's moon-pool position was used to locate the SBF over the target location, the actual SBF frame's position on the seabed was not affected by the offset-error.

Survey Team Leader	Site Manager	Client representative
A. Maddison	B. Berndsen	P. Watson / J. van Houten

APPENDIX 3: RECOVERY LISTS

RECOVERY LIST

Project Title: BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA
Project No. N6083/02 (1)
Client: Rijksdienst voor Ondernemend Nederland (RVO) Date: 26/10/2015

Location	Type	Number	Depth [m]	Penetration [cm]	Recovery [cm]	Remarks
CPT_WFS3_24	CPT	1	0.00	2832	2820	CP15 1701-2046; End of test on operator discretion - risk of buckling and breaking CPT rod - qc of 68 MPa close to stop test criteria
CPT_WFS3_8	CPT	1	0.00	1903	1899	CP15 1701-2046; End of test due to the maximum QC
CPT_WFS3_22	CPT	1	0.00	5063	5028	CP15 1701-2046; End of test:50m depth achieved
CPT_WFS3_13	CPT	1	0.00	5032	4990	CP15 1701-2046; End of test:50m depth achieved

Total Number of CPT: 4 Total CPT Recovery: 14737 [cm]
Total Number of Pore Pressure Dissipation Tests :

Remarks:

Client Representative:
Name: P. Watson / J. van Houten

Fugro Representative:
Name: B. Berndsen

GeODin/N6083 - Daily Recovery List.GLO FEBV/GEN/FOR/011 ISSUE GeODin01

RECOVERY LIST

Project Title: BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA
Project No. N6083/02 (1)
Client: Rijksdienst voor Ondernemend Nederland (RVO) Date: 27/10/2015

Location	Type	Number	Depth [m]	Penetration [cm]	Recovery [cm]	Remarks
CPT_WFS3_7	CPT	1	0.00	4385	4372	CP15 1701-2046; End of test due to maximum thrust
CPT_WFS3_3	PPDT	1	18.00	0	0	CP15 1701-2046, Dissipation time:5min
CPT_WFS3_3	CPT	1	0.00	4739	4718	CP15 1701-2046; End of test due to the maximum thrust
CPT_WFS3_23	CPT	1	0.00	4512	4474	CP15 1701-2046; End of test due to maximum thrust and cone inclination>12°. Cone+ rods lost
CPT_WFS3_12	CPT	1	0.00	3019	3012	CP15 1701-2085; End test due to maximum thrust.

Total Number of CPT: 4 Total CPT Recovery: 16576 [cm]
Total Number of Pore Pressure Dissipation Tests : 1

Remarks:

Client Representative:
Name: P. Watson / J. van Houten

Fugro Representative:
Name: B. Berndsen

RECOVERY LIST

Project Title: BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA
Project No. N6083/02 (1)
Client: Rijksdienst voor Ondernemend Nederland (RVO) Date: 28/10/2015

Location	Type	Number	Depth [m]	Penetration [cm]	Recovery [cm]	Remarks
CPT_WFS3_21	CPT	1	0.00	4015	3990	CP15 1701-2085; End of test due to maximum thrust
CPT_WFS3_18	CPT	1	0.00	1290	1285	CP15 1701-2085; End of test due to sudden inclination >3°
CPT_WFS3_20	CPT	1	0.00	2324	2322	CP15 1701-2085; End test due to maximum thrust.
CPT_WFS3_19	CPT	1	0.00	4037	4024	CP15 1701-2085; End of test due to the maximum thrust

Total Number of CPT: 4 Total CPT Recovery: 11621 [cm]
Total Number of Pore Pressure Dissipation Tests :

Remarks:

Client Representative:
Name: P. Watson / J. van Houten

Fugro Representative:
Name: B. Berndsen

RECOVERY LIST

Project Title: BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA
Project No. N6083/02 (1)
Client: Rijksdienst voor Ondernemend Nederland (RVO) Date: 29/10/2015

Location	Type	Number	Depth [m]	Penetration [cm]	Recovery [cm]	Remarks
CPT_WFS3_14	CPT	1	0.00	3952	3930	CP15 1701-2085; End of test due to maximum thrust
CPT_WFS3_5	PPDT	1	10.00	0	0	CP15 1701-2085; Dissipation time:5 min
CPT_WFS3_5	PPDT	2	30.00	0	0	CP15 1701-2085; Dissipation time:120 min
CPT_WFS3_5	CPT	1	0.00	3956	3943	CP15 1701-2085; End of test on operator discretion - risk of breaking rods
CPT_WFS3_16	CPT	1	0.00	4484	4480	CP15 1701-2085; End test due to maximum thrust
CPT_WFS3_15	CPT	1	0.00	4929	4912	CP15 1701-2085; End test due to maximum thrust

Total Number of CPT: 4 Total CPT Recovery: 17265 [cm]
Total Number of Pore Pressure Dissipation Tests : 2

Remarks:

Client Representative:
Name: P. Watson / J. van Houten

Fugro Representative:
Name: B. Berndsen

GeODin/N6083 - Daily Recovery List.GLO FEBV/GEN/FOR/011 ISSUE GeODin01

RECOVERY LIST

Project Title:	BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA
Project No.	N6083/02 (1)
Client:	Rijksdienst voor Ondernemend Nederland (RVO)

Date: 30/10/2015

Location	Type	Number	Depth [m]	Penetration [cm]	Recovery [cm]	Remarks
CPT_WFS3_2	CPT	1	0.00	4313	4309	CP15 1701-1534; End of test due to the maximum thrust of 18 tons and broken rods at the peak of thrust.Cone+rods lost
CPT_WFS3_10	CPT	1	0.00	1772	1770	CP15 1701-2346; End oft test due to 75 MPa on the on the cone
CPT_WFS3_9	CPT	1	0.00	2440	2437	CP15 1701-2346; End test due to maximum thrust

Total Number of CPT: 3 Total CPT Recovery: 8516 [cm]

Total Number of Pore Pressure Dissipation Tests :

Remarks:

Client Representative:

Name: P. Watson / J. van Houten

Fugro Representative:

Name: B. Berndsen

GeODin/N6083 - Daily Recovery List GLO FEBV/GEN/FOR/011 ISSUE GeODin01

RECOVERY LIST

Project Title: BORSSELE WIND FARM ZONE, WFS III - DUTCH SECTOR, NORTH SEA
Project No. N6083/02 (1)
Client: Rijksdienst voor Ondernemend Nederland (RVO)
Date: 31/10/2015

Location	Type	Number	Depth [m]	Penetration [cm]	Recovery [cm]	Remarks
CPT_WFS3_27	CPT	1	0.00	2889	2876	CP15 1701-2085; End of test due to the maximum QC and rapid rise of cone inclination
CPT_WFS3_11	CPT	1	0.00	491	491	CP15 1701-2085; End of test due to the rapid rise of cone inclination
CPT_WFS3_11A	CPT	1	0.00	2640	2614	CP15 1701-2085; End of test due to the maximum cone inclination
CPT_WFS3_25	CPT	1	0.00	2499	2484	CP15 1701-2085; End of test due to the maximum QC
CPT_WFS3_17	CPT	1	0.00	1122	1118	CP15 1701-2085; End of test due to the maximum QC
CPT_WFS3_6	CPT	1	0.00	2112	2091	CP15 1701-2346; End of test due the maximum cone inclination
CPT_WFS3_6A	CPT	1	0.00	2101	2095	CP15 1701-2346; End of test due to max qc and sudden inclination of the cone
CPT_WFS3_26	CPT	1	0.00	2137	2132	CP15 1701-2346; End of test due to max qc
CPT_WFS4_24	PPDT	1	10.00	0	0	CP15 1701-2346; Dissipation time:60 minutes
CPT_WFS4_24	CPT	1	0.00	2719	2714	CP15 1701-2346; End test due to max qc

Total Number of CPT: 9 Total CPT Recovery: 18615 [cm]
Total Number of Pore Pressure Dissipation Tests : 1

Remarks:

Client Representative:

Name: P. Watson / J. van Houten

Fugro Representative:

Name: B. Berndsen

APPENDIX 4: CONE CALIBRATION CERTIFICATES

LIST OF PLATES IN APPENDIX 4: Plate

TECHNICAL SPECIFICATIONS
Fugro Engineers BV

CALIBRATION CERTIFICATE

Applicant	**FUGRO ENGINEERS B.V. (NOOTDORP)**	Certificate nr.	FCN15002931
Manufacturer	Fugro Engineers B.V.	Identification	1701-1534
Instrument	**A Cone Penetrometer**		

Calibration method:
The device was calibrated according to Fugro Engineers procedures using a comparison technique against a Fugro reference standard. Fugro reference standards are periodically recertified and traceable to the National Standards and Technology (NIST) (RVA). It is derived from accepted values of natural physical constants according to the International System of units (SI). Fugro's calibration system meets or exceeds the requirements of ISO 9001:2000 and ISO/IEC 17025:2005.

Cone and Friction Sleeve Calibration Reference

Equipment Serial Number	6034-0003
Equipment Manufacturer	ZWICK GMBH & CO
Equipment Calibration Valid till	22/09/2015
Equipment Certificate	14202947.1000.1EN/R1
Procedure used : in-house	FEBV.CAL.PRO.003

Cone and Friction Sleeve Sensor

Manufacturer	Fugro Engineers BV
Force Application Mode	Compression
Calibrated Range	0 – 75 kN
Max Load	0 – 150 kN

Pressure Calibration Reference

Equipment Serial Number	3257-0002
Equipment Manufacturer	KELLER MEETTECH
Equipment Calibration Valid till	26/03/2015
Equipment Certificate	FCLREF140072/73
Procedure used : in-house	FEBV.CAL.PRO.004

Pressure Sensor

Manufacturer	Kulite
Pressure Application Mode	Compression and tension
Calibrated Range	Nominal Range
Nominal Range	0 -20.0 MPa

Inclinometer Calibration Reference

Equipment Serial Number	2109-0003
Equipment Manufacturer	FEBV
Equipment Calibration Valid till	14/05/2015
Procedure used : in-house	FEBV.CAL.PRO.005

Inclinometer

Manufacturer	FEBV	ADXL
Calibrated Range	0° – 15°	-10° - 10°
Max Output	0° – 30°	-15° - 15°

Environmental Conditions

Temperature during calibration	21 ± 3 °C
Pressure during calibration	1000 ± 100 mbar

Remarks.
The values given in this calibration certificate only relate to the submitted device, and to the values measured at the time of the test. Any uncertainty defined here does not include allowances for environmental changes, variation and shock during transportation, or the capability of other laboratories to repeat the measurement.

This certificate shall not be reproduced, except in full, without written approval from Fugro Engineers B.V.

Calibration technician	Tempelaar, Rolf	Approved by :	Sinjorgo, Gerry
Calibration date:	27/01/2015	Approval date:	27/01/2015
Calibrate before:	27/01/2016		

FUGRO ENGINEERS B.V. Member of the Fugro group of companies with offices throughout the world. The Netherlands. VAT No. NL005621405B01. Trade Register No. 271141

CONE CALIBRATION RESULT [FORCE]

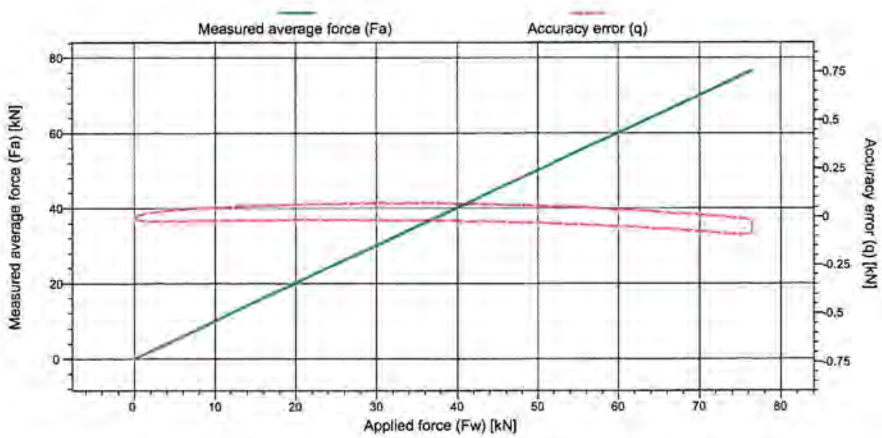
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E4M3-V3
Serial Number	1701-1534
Electronics	3613
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Zwick/Roell
Serial Number	6034-0003
Uncertainty	0.0026•Fw+0.011 [kN]

Calibration Details	
Calibration Date	26 jan 2015 09:26:34
Procedure	FEBV.CAL.PRO.003
Software Version	1.12.0.13400

Certificate Number
FCN15002931

Characteristics	Unit	Value
Accuracy error (q)	[kN]	0.094
Repeatability error (b)	[kN]	0.135
Reversibility error (v)	[kN]	0.089
Zero load error (Fc0)	[kN]	0.040
Zero load offset (F0)	[kN]	-0.026
Resolution	[kN]	2.98E-05
Noise RMS	[kN]	0.001



Applied force (Fw) [kN]	Measured force 1 (Fa,1) [kN]	Measured force 2 (Fa,2) [kN]	Measured force 3 (Fa,3) [kN]	Measured average force (Fa) [kN]	Accuracy error (q) [kN]	Repeatability error (b) [kN]	Reversibility error (v) [kN]
0.000	-0.006	-0.021	-0.009	-0.012	-0.012	0.014	0.006
15.000	15.016	14.904	15.021	14.980	-0.020	0.117	0.077
30.000	30.020	29.898	30.026	29.981	-0.019	0.128	0.088
45.000	45.012	44.887	45.021	44.973	-0.027	0.133	0.089
60.000	59.986	59.860	59.992	59.946	-0.054	0.132	0.088
75.000	74.947	74.818	74.953	74.906	-0.094	0.135	
60.000	59.992	60.119	59.990	60.034	0.034	0.129	
45.000	45.023	45.144	45.019	45.062	0.062	0.125	
30.000	30.033	30.146	30.030	30.070	0.070	0.116	
15.000	15.026	15.124	15.022	15.057	0.057	0.102	
0.000	-0.007	-0.002	-0.007	-0.005	-0.005	0.005	

CONE NET AREA RATIO RESULT

Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E4M3-V3
Serial Number	1701-1534
Electronics	3613
Node Type	7001
Hardware Version	3.00
Software Version	4.01

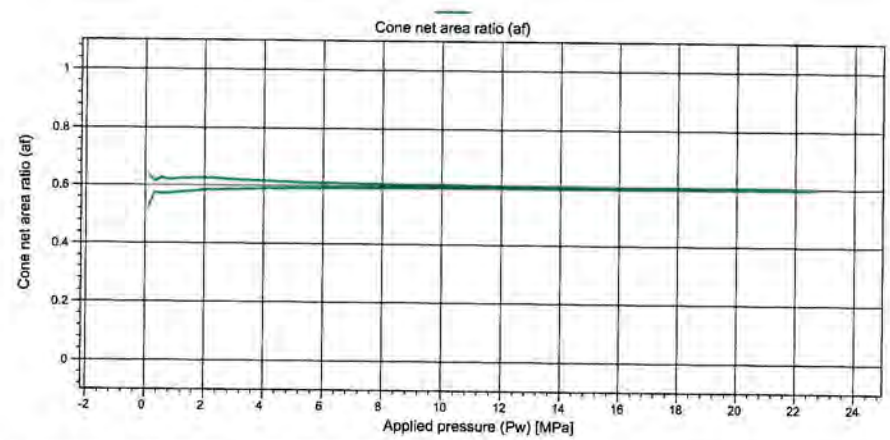
Reference	
Manufacturer	Keller PA33X
Serial Number	3257-0002
Uncertainty	0.00142•Pw+0.001787 [MPa]

Calibration Details	
Calibration Date	27 jan 2015 08:27:43
Procedure	FEBV.CAL.PRO.003
Software Version	1.12.0.13400

Certificate Number
FCN15002931

Characteristics	Unit	Value
Cone net area ratio (af)	[-]	0.60

The cone net area ratio presented above is determined at the maximum applied pressure during the measurement.



Applied pressure (Pw) [MPa]	Measured cone net area ratio 1 (af,1)	Measured cone net area ratio 2 (af,2)	Measured cone net area ratio 3 (af,3)	Measured average cone net area ratio (af)
4.000	0.591	0.590	0.589	0.590
8.000	0.594	0.594	0.594	0.594
12.000	0.595	0.596	0.595	0.595
16.000	0.595	0.596	0.596	0.596
20.000	0.596	0.596	0.596	0.596
16.000	0.603	0.604	0.603	0.603
12.000	0.604	0.605	0.605	0.605
8.000	0.608	0.606	0.609	0.608
4.000	0.615	0.618	0.617	0.617

CONE+FRIC. CALIBRATION RESULT [FORCE]

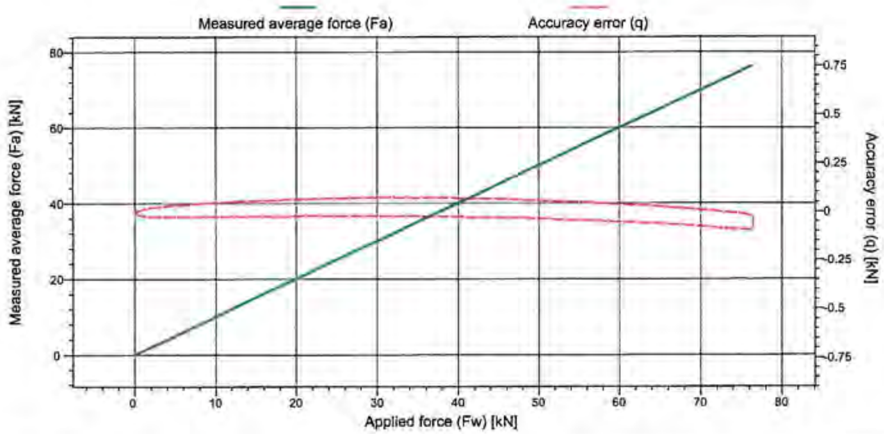
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E4M3-V3
Serial Number	1701-1534
Electronics	3613
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Zwick/Roell
Serial Number	6034-0003
Uncertainty	0.0026•Fw+0.011 [kN]

Calibration Details	
Calibration Date	26 jan 2015 09:26:35
Procedure	FEBV.CAL.PRO.003
Software Version	1.12.0.13400

Certificate Number
FCN15002931

Characteristics	Unit	Value
Accuracy error (q)	[kN]	0.092
Repeatability error (b)	[kN]	0.133
Reversibility error (v)	[kN]	0.097
Zero load error (Fc0)	[kN]	0.004
Zero load offset (F0)	[kN]	-0.010
Resolution	[kN]	2.93E-05
Noise RMS	[kN]	0.001
Tip-Sleeve Interaction	[kPa]	0.4
Tip-Sleeve Interaction %	[%]	0.09



Applied force (Fw) [kN]	Measured force 1 (Fa,1) [kN]	Measured force 2 (Fa,2) [kN]	Measured force 3 (Fa,3) [kN]	Measured average force (Fa) [kN]	Accuracy error (q) [kN]	Repeatability error (b) [kN]	Reversibility error (v) [kN]
0.000	-0.005	-0.017	-0.008	-0.010	-0.010	0.012	0.005
15.000	15.011	14.903	15.014	14.976	-0.024	0.112	0.081
30.000	30.018	29.897	30.020	29.978	-0.022	0.123	0.094
45.000	45.009	44.886	45.013	44.970	-0.030	0.127	0.097
60.000	59.985	59.864	59.987	59.945	-0.055	0.123	0.090
75.000	74.950	74.823	74.952	74.908	-0.092	0.129	
60.000	59.994	60.123	59.990	60.036	0.036	0.133	
45.000	45.026	45.151	45.022	45.066	0.066	0.130	
30.000	30.034	30.152	30.031	30.072	0.072	0.121	
15.000	15.023	15.128	15.020	15.057	0.057	0.108	
0.000	-0.007	0.001	-0.009	-0.005	-0.005	0.010	

FRICTION SLEEVE NET AREA RATIO RESULT

Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E4M3-V3
Serial Number	1701-1534
Electronics	3613
Node Type	7001
Hardware Version	3.00
Software Version	4.01

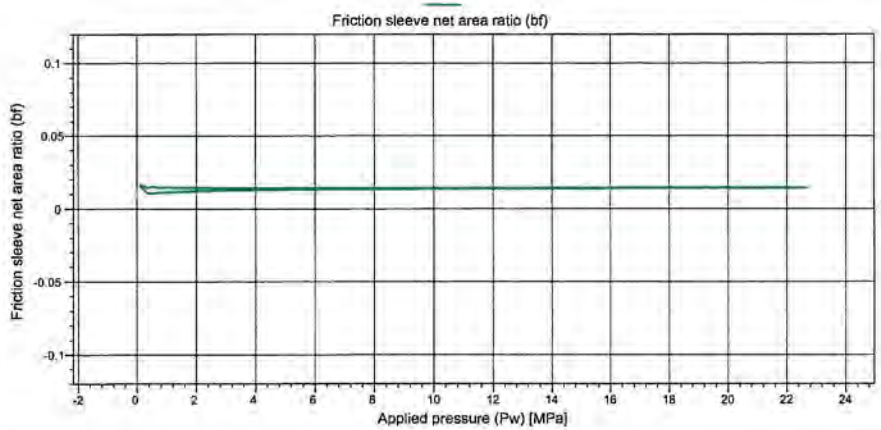
Reference	
Manufacturer	Keller PA33X
Serial Number	3257-0002
Uncertainty	0.00142•Pw+0.001787 [MPa]

Calibration Details	
Calibration Date	27 jan 2015 08:27:43
Procedure	FEBV.CAL.PRO.003
Software Version	1.12.0.13400

Certificate Number
FCN15002931

Characteristics	Unit	Value
Friction sleeve net area ratio (bf)	[-]	0.01411

The friction sleeve net area ratio presented above is determined at the maximum applied pressure during the measurement.



Applied pressure (Pw) [MPa]	Measured friction sleeve net area ratio 1 (bf,1)	Measured friction sleeve net area ratio 2 (bf,2)	Measured friction sleeve net area ratio 3 (bf,3)	Measured average friction sleeve net area ratio (bf)
4.000	0.013	0.013	0.013	0.013
8.000	0.014	0.014	0.014	0.014
12.000	0.014	0.014	0.014	0.014
16.000	0.014	0.014	0.014	0.014
20.000	0.014	0.014	0.014	0.014
16.000	0.014	0.014	0.014	0.014
12.000	0.014	0.014	0.014	0.014
8.000	0.014	0.014	0.014	0.014
4.000	0.014	0.014	0.014	0.014

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Fugro Calibration Laboratory, P.O. Box 250, 2260 AG Leidschendam, The Netherlands, Phone +31-70-3111444, www.fugro.com

PORE 2 CALIBRATION RESULT [PRESSURE]

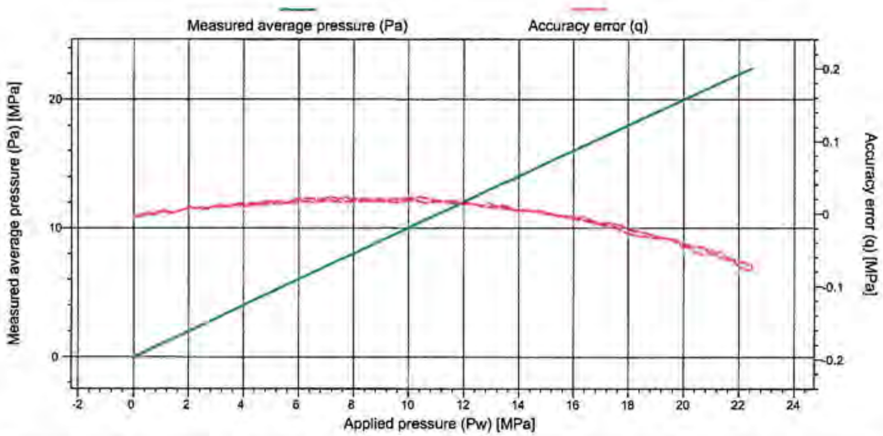
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E4M3-V3
Serial Number	1701-1534
Electronics	3613
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Keller PA33X
Serial Number	3257-0002
Uncertainty	0.00142·Pw+0.001787 [MPa]

Calibration Details	
Calibration Date	27 jan 2015 08:27:43
Procedure	FEBV.CAL.PRO.004
Software Version	1.12.0.13400

Certificate Number
FCN15002931

Characteristics	Unit	Value
Accuracy error (q)	[MPa]	0.041
Repeatability error (b)	[MPa]	0.010
Reversibility error (v)	[MPa]	0.002
Zero load error (Pc0)	[MPa]	0.007
Zero load offset (P0)	[MPa]	-0.004
Resolution	[MPa]	1.28E-05
Noise RMS	[MPa]	0.000



Applied pressure (Pw) [MPa]	Measured pressure 1 (Pa,1) [MPa]	Measured pressure 2 (Pa,2) [MPa]	Measured pressure 3 (Pa,3) [MPa]	Measured average pressure (Pa) [MPa]	Accuracy error (q) [MPa]	Repeatability error (b) [MPa]	Reversibility error (v) [MPa]
0.000	-0.006	-0.005	-0.004	-0.005	-0.005	0.001	0.001
4.000	4.012	4.009	4.011	4.011	0.011	0.003	0.002
8.000	8.020	8.016	8.017	8.017	0.017	0.004	0.002
12.000	12.013	12.019	12.014	12.016	0.016	0.006	0.002
16.000	15.996	15.993	15.992	15.994	-0.006	0.004	0.001
20.000	19.961	19.957	19.957	19.959	-0.041	0.004	
16.000	15.993	15.993	15.993	15.993	-0.007	0.001	
12.000	12.013	12.015	12.012	12.013	0.013	0.003	
8.000	8.020	8.017	8.022	8.020	0.020	0.005	
4.000	4.008	4.019	4.012	4.013	0.013	0.010	
0.000	-0.005	-0.004	-0.004	-0.004	-0.004	0.000	

SLOPE CALIBRATION RESULT [INCLINATION]

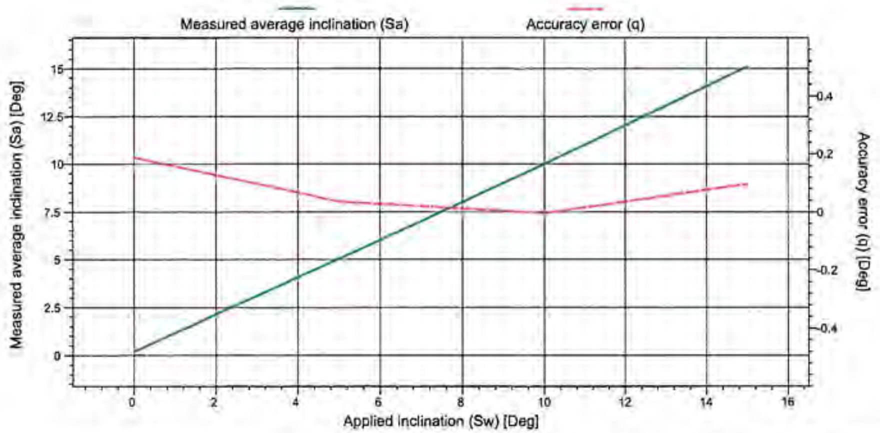
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E4M3-V3
Serial Number	1701-1534
Electronics	3613
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Hoek-O-Mat
Serial Number	2109-0002
Uncertainty	0.3 [Deg]

Calibration Details	
Calibration Date	27 jan 2015 08:27:31
Procedure	FEBV.CAL.PRO.005
Software Version	1.12.0.13400

Certificate Number
FCN15002931

Characteristics	Unit	Value
Accuracy error (q)	[Deg]	0.187
Repeatability error (b)	[Deg]	0.085
Zero load error (Sc0)	[Deg]	0.043
Zero load offset (S0)	[Deg]	0.241
Resolution	[Deg]	1.4E-05
Noise RMS	[Deg]	0.022



Applied inclination (Sw) [Deg]	Measured inclination 1 (Sa,1) [Deg]	Measured inclination 2 (Sa,2) [Deg]	Measured inclination 3 (Sa,3) [Deg]	Measured average inclination (Sa) [Deg]	Accuracy error (q) [Deg]	Repeatability error (b) [Deg]
0.000	0.215	0.130	0.215	0.187	0.187	0.085
5.000	5.053	5.028	5.028	5.036	0.036	0.025
10.000	10.010	10.020	9.955	9.995	-0.005	0.065
15.000	15.132	15.082	15.070	15.095	0.095	0.062

TECHNICAL SPECIFICATIONS
Fugro Engineers BV

CALIBRATION CERTIFICATE

Applicant	**FUGRO ENGINEERS B.V. (NOOTDORP)**	Certificate nr.	FCN15002926
Manufacturer	Fugro Engineers B.V.	Identification	1701-2046
Instrument	**A Cone Penetrometer**		

Calibration method:
The device was calibrated according to Fugro Engineers procedures using a comparison technique against a Fugro reference standard. Fugro reference standards are periodically recertified and traceable to the National Standards and Technology (NIST) (RVA). It is derived from accepted values of natural physical constants according to the International System of units (SI). Fugro's calibration system meets or exceeds the requirements of ISO 9001:2000 and ISO/IEC 17025:2005.

Cone and Friction Sleeve Calibration Reference

Equipment Serial Number	6034-0003
Equipment Manufacturer	ZWICK GMBH & CO
Equipment Calibration Valid till	22/09/2015
Equipment Certificate	14202947.1000.1EN/R1
Procedure used : in-house	FEBV.CAL.PRO.003

Cone and Friction Sleeve Sensor

Manufacturer	Fugro Engineers BV
Force Application Mode	Compression
Calibrated Range	0 – 75 kN
Max Load	0 – 150 kN

Pressure Calibration Reference

Equipment Serial Number	3257-0002
Equipment Manufacturer	KELLER MEETTECH
Equipment Calibration Valid till	26/03/2015
Equipment Certificate	FCLREF140072/73
Procedure used : in-house	FEBV.CAL.PRO.004

Pressure Sensor

Manufacturer	Kulite
Pressure Application Mode	Compression and tension
Calibrated Range	Nominal Range
Nominal Range	0 –30.0 MPa

Inclinometer Calibration Reference

Equipment Serial Number	2109-0003
Equipment Manufacturer	FEBV
Equipment Calibration Valid till	14/05/2015
Procedure used : in-house	FEBV.CAL.PRO.005

Inclinometer

Manufacturer	FEBV	ADXL
Calibrated Range	0° – 15°	-10° - 10°
Max Output	0° – 30°	-15° - 15°

Environmental Conditions

Temperature during calibration	21 ± 3 °C
Pressure during calibration	1000 ± 100 mbar

Remarks.
The values given in this calibration certificate only relate to the submitted device, and to the values measured at the time of the test. Any uncertainty defined here does not include allowances for environmental changes, variation and shock during transportation, or the capability of other laboratories to repeat the measurement.

This certificate shall not be reproduced, except in full, without written approval from Fugro Engineers B.V.

Calibration technician	Tempelaar, Rolf	Approved by :	Sinjorgo, Gerry
Calibration date:	27/01/2015	Approval date:	27/01/2015
Calibrate before:	27/01/2016		

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CONE CALIBRATION RESULT [FORCE]

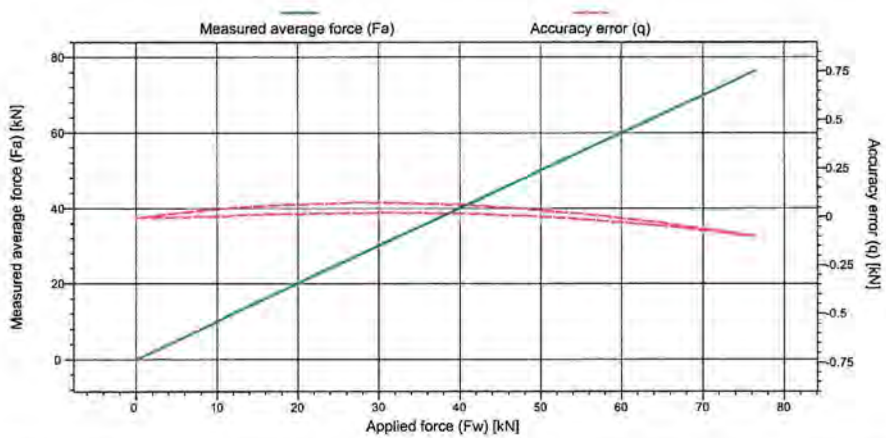
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB30SN2-P1E2M3-V1
Serial Number	1701-2046
Electronics	924
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Zwick/Roell
Serial Number	6034-0003
Uncertainty	0.0026•Fw+0.011 [kN]

Calibration Details	
Calibration Date	26 Jan 2015 08:26:26
Procedure	FEBV.CAL.PRO.003
Software Version	1.12.0.13400

Certificate Number FCN15002926

Characteristics	Unit	Value
Accuracy error (q)	[kN]	0.097
Repeatability error (b)	[kN]	0.014
Reversibility error (v)	[kN]	0.051
Zero load error (Fc0)	[kN]	0.053
Zero load offset (F0)	[kN]	-0.030
Resolution	[kN]	2.92E-05
Noise RMS	[kN]	0.001



Applied force (Fw) [kN]	Measured force 1 (Fa,1) [kN]	Measured force 2 (Fa,2) [kN]	Measured force 3 (Fa,3) [kN]	Measured average force (Fa) [kN]	Accuracy error (q) [kN]	Repeatability error (b) [kN]	Reversibility error (v) [kN]
0.000	-0.010	-0.008	-0.008	-0.009	-0.009	0.002	0.000
15.000	15.007	15.010	15.013	15.010	0.010	0.006	0.043
30.000	30.015	30.021	30.025	30.021	0.021	0.010	0.051
45.000	45.005	45.011	45.014	45.010	0.010	0.009	0.039
60.000	59.965	59.972	59.975	59.971	-0.029	0.010	0.021
75.000	74.896	74.903	74.910	74.903	-0.097	0.014	
60.000	59.989	59.990	59.995	59.991	-0.009	0.007	
45.000	45.047	45.046	45.055	45.049	0.049	0.008	
30.000	30.069	30.072	30.075	30.072	0.072	0.007	
15.000	15.052	15.052	15.056	15.053	0.053	0.004	
0.000	-0.010	-0.010	-0.007	-0.009	-0.009	0.003	

CONE NET AREA RATIO RESULT

Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB30SN2-P1E2M3-V1
Serial Number	1701-2046
Electronics	924
Node Type	7001
Hardware Version	3.00
Software Version	4.01

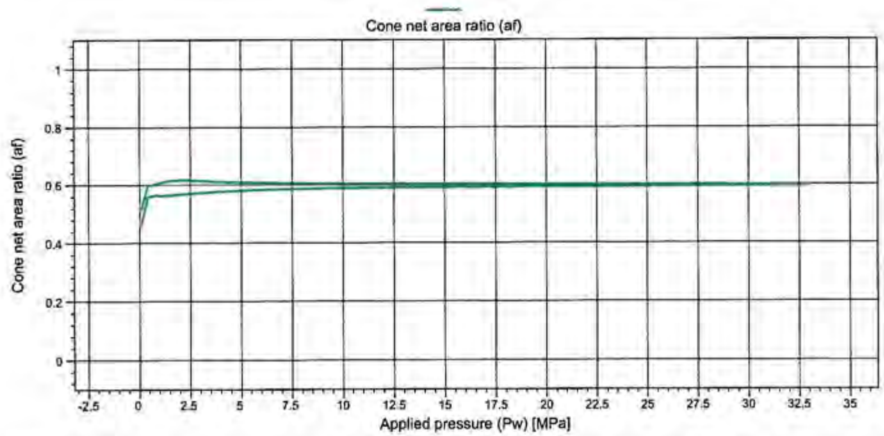
Reference	
Manufacturer	Keller PA33X
Serial Number	3257-0002
Uncertainty	0.00142•Pw+0.001787 [MPa]

Calibration Details	
Calibration Date	27 Jan 2015 10:27:32
Procedure	FEBV.CAL.PRO.003
Software Version	1.12.0.13400

Certificate Number FCN15002926

Characteristics	Unit	Value
Cone net area ratio (af)	[-]	0.60

The cone net area ratio presented above is determined at the maximum applied pressure during the measurement.



Applied pressure (Pw) [MPa]	Measured cone net area ratio 1 (af,1)	Measured cone net area ratio 2 (af,2)	Measured cone net area ratio 3 (af,3)	Measured average cone net area ratio (af)
6.000	0.584	0.584	0.584	0.584
12.000	0.590	0.590	0.590	0.590
18.000	0.593	0.593	0.593	0.593
24.000	0.594	0.594	0.594	0.594
30.000	0.595	0.595	0.595	0.595
24.000	0.601	0.602	0.602	0.602
18.000	0.602	0.603	0.603	0.603
12.000	0.604	0.604	0.604	0.604
6.000	0.608	0.609	0.609	0.609

CONE+FRIC. CALIBRATION RESULT [FORCE]

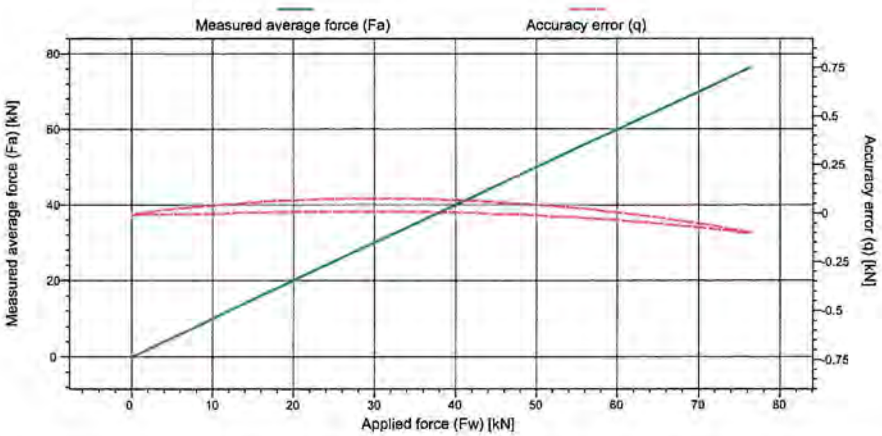
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB30SN2-P1E2M3-V1
Serial Number	1701-2046
Electronics	924
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Zwick/Roell
Serial Number	6034-0003
Uncertainty	0.0026·Fw+0.011 [kN]

Calibration Details	
Calibration Date	26 Jan 2015 08:26:26
Procedure	FEBV.CAL.PRO.003
Software Version	1.12.0.13400

Certificate Number
FCN15002926

Characteristics	Unit	Value
Accuracy error (q)	[kN]	0.097
Repeatability error (b)	[kN]	0.007
Reversibility error (v)	[kN]	0.066
Zero load error (Fc0)	[kN]	0.061
Zero load offset (F0)	[kN]	-0.035
Resolution	[kN]	2.9E-05
Noise RMS	[kN]	0.001
Tip-Sleeve Interaction	[kPa]	0.9
Tip-Sleeve Interaction %	[%]	0.18



Applied force (Fw) [kN]	Measured force 1 (Fa,1) [kN]	Measured force 2 (Fa,2) [kN]	Measured force 3 (Fa,3) [kN]	Measured average force (Fa) [kN]	Accuracy error (q) [kN]	Repeatability error (b) [kN]	Reversibility error (v) [kN]
0.000	-0.009	-0.011	-0.012	-0.010	-0.010	0.003	0.003
15.000	15.004	15.002	15.002	15.002	0.002	0.002	0.054
30.000	30.009	30.011	30.010	30.010	0.010	0.002	0.066
45.000	44.996	44.999	44.997	44.998	-0.002	0.003	0.060
60.000	59.961	59.964	59.966	59.964	-0.036	0.006	0.040
75.000	74.901	74.901	74.908	74.903	-0.097	0.007	
60.000	60.005	60.002	60.004	60.004	0.004	0.003	
45.000	45.056	45.056	45.059	45.058	0.058	0.003	
30.000	30.079	30.072	30.077	30.076	0.076	0.007	
15.000	15.059	15.055	15.056	15.057	0.057	0.004	
0.000	-0.006	-0.007	-0.007	-0.007	-0.007	0.001	

FRICTION SLEEVE NET AREA RATIO RESULT

Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB30SN2-P1E2M3-V1
Serial Number	1701-2046
Electronics	924
Node Type	7001
Hardware Version	3.00
Software Version	4.01

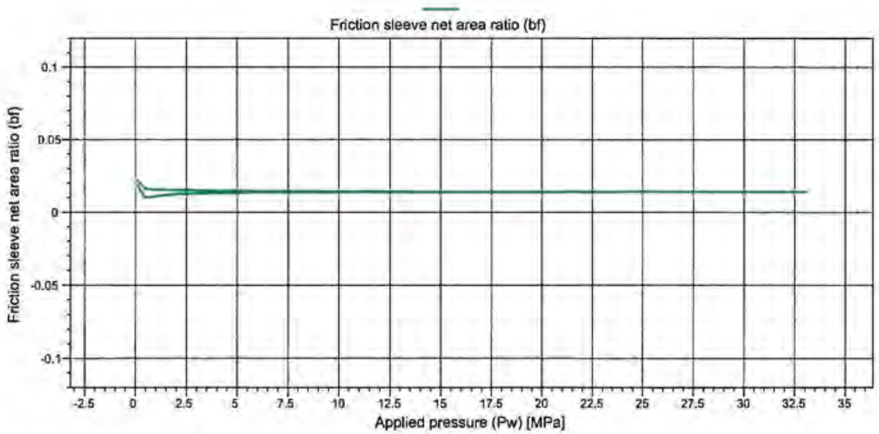
Reference	
Manufacturer	Keller PA33X
Serial Number	3257-0002
Uncertainty	0.00142·Pw+0.001787 [MPa]

Calibration Details	
Calibration Date	27 Jan 2015 10:27:32
Procedure	FEBV.CAL.PRO.003
Software Version	1.12.0.13400

Certificate Number
FCN15002926

Characteristics	Unit	Value
Friction sleeve net area ratio (bf)	[-]	0.01401

The friction sleeve net area ratio presented above is determined at the maximum applied pressure during the measurement.



Applied pressure (Pw) [MPa]	Measured friction sleeve net area ratio 1 (bf,1)	Measured friction sleeve net area ratio 2 (bf,2)	Measured friction sleeve net area ratio 3 (bf,3)	Measured average friction sleeve net area ratio (bf)
6.000	0.014	0.014	0.014	0.014
12.000	0.014	0.014	0.014	0.014
18.000	0.014	0.014	0.014	0.014
24.000	0.014	0.014	0.014	0.014
30.000	0.014	0.014	0.014	0.014
24.000	0.014	0.014	0.014	0.014
18.000	0.014	0.014	0.014	0.014
12.000	0.014	0.014	0.014	0.014
6.000	0.015	0.015	0.015	0.015

PORE 2 CALIBRATION RESULT [PRESSURE]

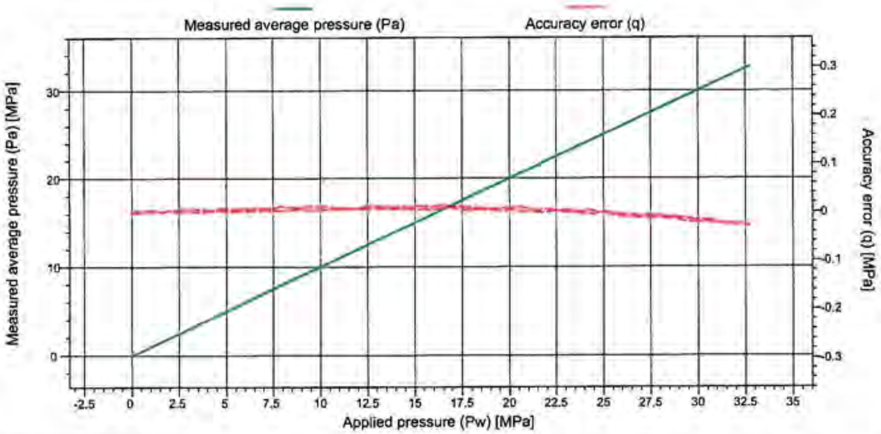
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB30SN2-P1E2M3-V1
Serial Number	1701-2046
Electronics	924
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Keller PA33X
Serial Number	3257-0002
Uncertainty	0.00142·Pw+0.001787 [MPa]

Calibration Details	
Calibration Date	27 Jan 2015 10:27:32
Procedure	FEBV.CAL.PRO.004
Software Version	1.12.0.13400

Certificate Number
FCN15002926

Characteristics	Unit	Value
Accuracy error (q)	[MPa]	0.023
Repeatability error (b)	[MPa]	0.012
Reversibility error (v)	[MPa]	0.006
Zero load error (Pc0)	[MPa]	0.000
Zero load offset (P0)	[MPa]	0.000
Resolution	[MPa]	1.16E-05
Noise RMS	[MPa]	0.000



Applied pressure (Pw) [MPa]	Measured pressure 1 (Pa,1) [MPa]	Measured pressure 2 (Pa,2) [MPa]	Measured pressure 3 (Pa,3) [MPa]	Measured average pressure (Pa) [MPa]	Accuracy error (q) [MPa]	Repeatability error (b) [MPa]	Reversibility error (v) [MPa]
0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
6.000	6.004	6.003	6.000	6.002	0.002	0.004	0.005
12.000	12.006	12.008	12.003	12.006	0.006	0.005	0.002
18.000	18.003	18.004	18.002	18.003	0.003	0.002	0.005
24.000	23.997	23.995	23.996	23.996	-0.004	0.002	0.006
30.000	29.978	29.977	29.976	29.977	-0.023	0.002	
24.000	24.000	24.004	24.000	24.002	0.002	0.004	
18.000	18.001	18.009	18.013	18.008	0.008	0.012	
12.000	12.010	12.006	12.009	12.008	0.008	0.004	
6.000	6.007	6.009	6.007	6.008	0.008	0.002	
0.000	-0.001	-0.001	0.000	-0.001	-0.001	0.001	

SLOPE CALIBRATION RESULT [INCLINATION]

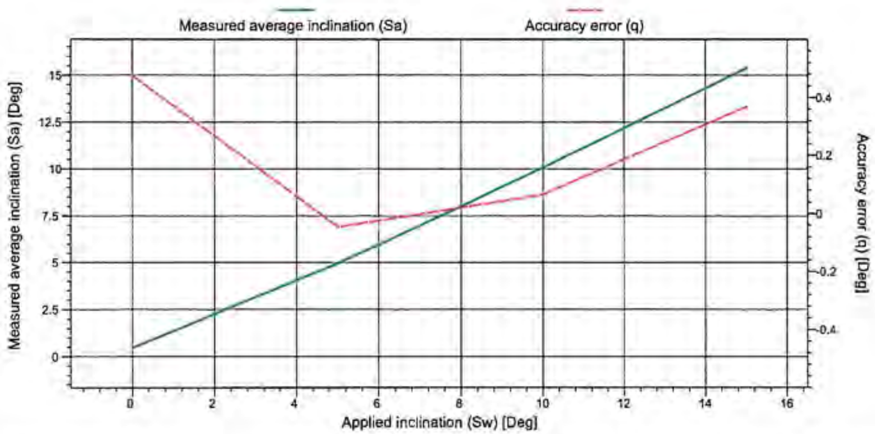
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB30SN2-P1E2M3-V1
Serial Number	1701-2046
Electronics	924
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Hoek-O-Mat
Serial Number	2109-0002
Uncertainty	0.3 [Deg]

Calibration Details	
Calibration Date	27 Jan 2015 11:27:39
Procedure	FEBV.CAL.PRO.005
Software Version	1.12.0.13400

Certificate Number
FCN15002926

Characteristics	Unit	Value
Accuracy error (q)	[Deg]	0.475
Repeatability error (b)	[Deg]	0.523
Zero load error (Sc0)	[Deg]	0.545
Zero load offset (S0)	[Deg]	0.451
Resolution	[Deg]	1.41E-05
Noise RMS	[Deg]	0.020



Applied inclination (Sw) [Deg]	Measured inclination 1 (Sa,1) [Deg]	Measured inclination 2 (Sa,2) [Deg]	Measured inclination 3 (Sa,3) [Deg]	Measured average inclination (Sa) [Deg]	Accuracy error (q) [Deg]	Repeatability error (b) [Deg]
0.000	0.197	0.507	0.720	0.475	0.475	0.523
5.000	5.098	4.935	4.827	4.953	-0.047	0.271
10.000	10.073	10.068	10.053	10.065	0.065	0.020
15.000	15.222	15.390	15.497	15.370	0.370	0.275

TECHNICAL SPECIFICATIONS
Fugro Engineers BV

CALIBRATION CERTIFICATE

Applicant	**FUGRO ENGINEERS B.V. (NOOTDORP)**	Certificate nr.	FCL14002499
Manufacturer	Fugro Engineers B.V.	Identification	1701-2085
Instrument	**A Cone Penetrometer**		

Calibration method:
The device was calibrated according to Fugro Engineers procedures using a comparison technique against a Fugro reference standard. Fugro reference standards are periodically recertified and traceable to the National Standards and Technology (NIST) (RVA). It is derived from accepted values of natural physical constants according to the International System of units (SI). Fugro's calibration system meets or exceeds the requirements of ISO 9001:2000 and ISO/IEC 17025:2005.

Cone and Friction Sleeve Calibration Reference

Equipment Serial Number	6034-0002
Equipment Manufacturer	ZWICK GMBH & CO
Equipment Calibration Valid till	16/02/2016
Equipment Certificate	15200495.1000.1EN
Procedure used : in-house	FEBV.CAL.PRO.003

Cone and Friction Sleeve Sensor

Manufacturer	Fugro Engineers BV
Force Application Mode	Compression
Calibrated Range	0 – 75 kN
Max Load	0 – 150 kN

Pressure Calibration Reference

Equipment Serial Number	3257-0002
Equipment Manufacturer	KELLER MEETTECH
Equipment Calibration Valid till	26/03/2015
Equipment Certificate	FCLREF140072/73
Procedure used : in-house	FEBV.CAL.PRO.004

Pressure Sensor

Manufacturer	Kulite
Pressure Application Mode	Compression and tension
Calibrated Range	Nominal Range
Nominal Range	0 –20.0 MPa

Inclinometer Calibration Reference

Equipment Serial Number	2109-0003
Equipment Manufacturer	FEBV
Equipment Calibration Valid till	14/05/2015
Procedure used : in-house	FEBV.CAL.PRO.005

Inclinometer

Manufacturer	FEBV	ADXL
Calibrated Range	0° – 15°	-10° - 10°
Max Output	0° – 30°	-15° - 15°

Environmental Conditions

Temperature during calibration	21 ± 3 °C
Pressure during calibration	1000 ± 100 mbar

Remarks.
The values given in this calibration certificate only relate to the submitted device, and to the values measured at the time of the test. Any uncertainty defined here does not include allowances for environmental changes, variation and shock during transportation, or the capability of other laboratories to repeat the measurement.

Calibration technician	Tempelaar, Rolf	Approved by :	Sinjorgo, Gerry
Calibration date:	11/12/2014	Approval date:	11/12/2014
Calibrate before:	11/12/2015		

CONE CALIBRATION RESULT [FORCE]

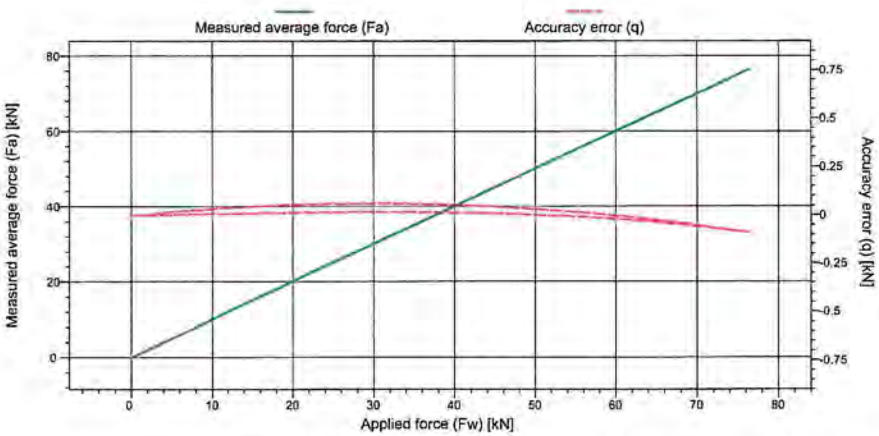
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E2M3-V2
Serial Number	1701-2085
Electronics	1320
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Zwick/Roell
Serial Number	6034-0003
Uncertainty	0.0026•Fw+0.011 [kN]

Calibration Details	
Calibration Date	24 Nov 2014 11:24:11
Procedure	FEBV.CAL.PRO.003
Software Version	1.12.0.13400

Certificate Number
FCL14002499

Characteristics	Unit	Value
Accuracy error (q)	[kN]	0.084
Repeatability error (b)	[kN]	0.004
Reversibility error (v)	[kN]	0.043
Zero load error (Fc0)	[kN]	0.033
Zero load offset (F0)	[kN]	-0.016
Resolution	[kN]	2.89E-05
Noise RMS	[kN]	0.002



Applied force (Fw) [kN]	Measured force 1 (Fa,1) [kN]	Measured force 2 (Fa,2) [kN]	Measured force 3 (Fa,3) [kN]	Measured average force (Fa) [kN]	Accuracy error (q) [kN]	Repeatability error (b) [kN]	Reversibility error (v) [kN]
0.000	-0.006	-0.004	-0.006	-0.005	-0.005	0.002	0.002
15.000	15.009	15.007	15.006	15.007	0.007	0.003	0.036
30.000	30.017	30.017	30.016	30.017	0.017	0.001	0.043
45.000	45.008	45.008	45.007	45.008	0.008	0.001	0.035
60.000	59.977	59.976	59.977	59.977	-0.023	0.001	0.017
75.000	74.916	74.918	74.915	74.916	-0.084	0.004	
60.000	59.992	59.995	59.995	59.994	-0.006	0.003	
45.000	45.043	45.044	45.041	45.042	0.042	0.003	
30.000	30.061	30.060	30.059	30.060	0.060	0.002	
15.000	15.045	15.042	15.042	15.043	0.043	0.003	
0.000	-0.002	-0.004	-0.004	-0.003	-0.003	0.002	

CONE NET AREA RATIO RESULT

Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E2M3-V2
Serial Number	1701-2085
Electronics	1320
Node Type	7001
Hardware Version	3.00
Software Version	4.01

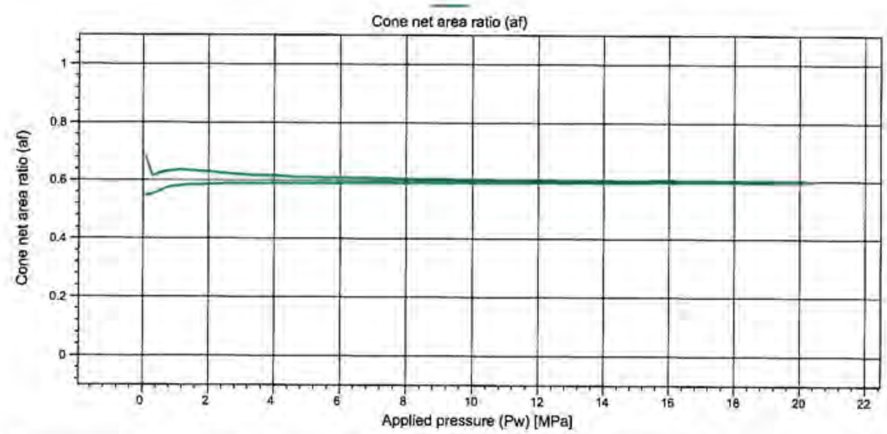
Reference	
Manufacturer	Keller PA33X
Serial Number	3257-0002
Uncertainty	0.00142•Pw+0.001787 [MPa]

Calibration Details	
Calibration Date	11 Dec 2014 14:11:43
Procedure	FEBV.CAL.PRO.003
Software Version	1.12.0.13400

Certificate Number
FCL14002499

Characteristics	Unit	Value
Cone net area ratio (af)	[-]	0.60

The cone net area ratio presented above is determined at the maximum applied pressure during the measurement.



Applied pressure (Pw) [MPa]	Measured cone net area ratio 1 (af,1)	Measured cone net area ratio 2 (af,2)	Measured cone net area ratio 3 (af,3)	Measured average cone net area ratio (af)
4.000	0.592	0.591	0.591	0.591
8.000	0.593	0.593	0.593	0.593
12.000	0.595	0.595	0.594	0.594
16.000	0.595	0.595	0.595	0.595
20.000	0.597	0.597	0.597	0.597
16.000	0.602	0.603	0.603	0.603
12.000	0.604	0.604	0.604	0.604
8.000	0.607	0.608	0.608	0.608
4.000	0.617	0.616	0.616	0.616

CONE+FRIC. CALIBRATION RESULT [FORCE]

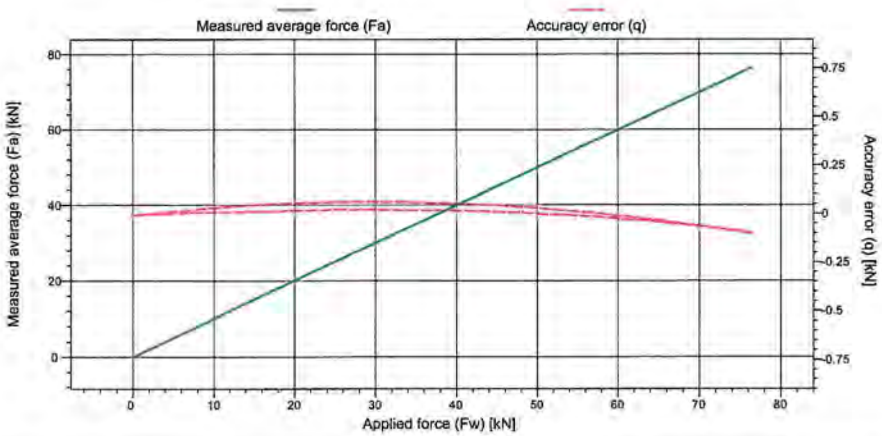
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E2M3-V2
Serial Number	1701-2085
Electronics	1320
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Zwick/Roell
Serial Number	6034-0003
Uncertainty	0.0026·Fw+0.011 [kN]

Calibration Details	
Calibration Date	24 Nov 2014 11:24:12
Procedure	FEBV.CAL.PRO.003
Software Version	1.12.0.13400

Certificate Number
FCL14002499

Characteristics	Unit	Value
Accuracy error (q)	[kN]	0.089
Repeatability error (b)	[kN]	0.008
Reversibility error (v)	[kN]	0.040
Zero load error (Fc0)	[kN]	0.023
Zero load offset (F0)	[kN]	-0.017
Resolution	[kN]	2.85E-05
Noise RMS	[kN]	0.001
Tip-Sleeve Interaction	[kPa]	0.6
Tip-Sleeve Interaction %	[%]	0.12



Applied force (Fw) [kN]	Measured force 1 (Fa,1) [kN]	Measured force 2 (Fa,2) [kN]	Measured force 3 (Fa,3) [kN]	Measured average force (Fa) [kN]	Accuracy error (q) [kN]	Repeatability error (b) [kN]	Reversibility error (v) [kN]
0.000	-0.007	-0.007	-0.010	-0.008	-0.008	0.003	0.002
15.000	15.017	15.010	15.009	15.012	0.012	0.008	0.033
30.000	30.025	30.022	30.022	30.023	0.023	0.004	0.040
45.000	45.015	45.010	45.009	45.011	0.011	0.006	0.033
60.000	59.978	59.974	59.974	59.976	-0.024	0.004	0.014
75.000	74.913	74.910	74.909	74.911	-0.089	0.004	
60.000	59.994	59.988	59.988	59.990	-0.010	0.006	
45.000	45.047	45.044	45.042	45.044	0.044	0.005	
30.000	30.066	30.062	30.060	30.063	0.063	0.006	
15.000	15.047	15.044	15.043	15.045	0.045	0.004	
0.000	-0.008	-0.010	-0.012	-0.010	-0.010	0.004	

FRICTION SLEEVE NET AREA RATIO RESULT

Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E2M3-V2
Serial Number	1701-2085
Electronics	1320
Node Type	7001
Hardware Version	3.00
Software Version	4.01

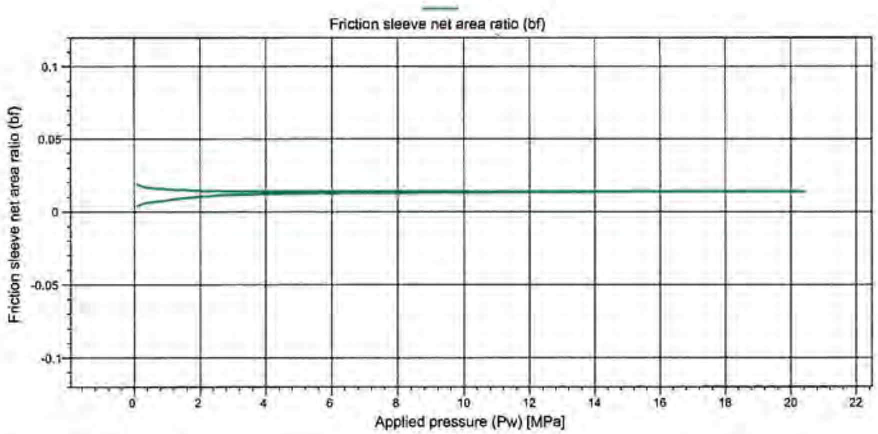
Reference	
Manufacturer	Keller PA33X
Serial Number	3257-0002
Uncertainty	0.00142·Pw+0.001787 [MPa]

Calibration Details	
Calibration Date	11 Dec 2014 14:11:43
Procedure	FEBV.CAL.PRO.003
Software Version	1.12.0.13400

Certificate Number
FCL14002499

Characteristics	Unit	Value
Friction sleeve net area ratio (bf)	[-]	0.01391

The friction sleeve net area ratio presented above is determined at the maximum applied pressure during the measurement.



Applied pressure (Pw) [MPa]	Measured friction sleeve net area ratio 1 (bf,1)	Measured friction sleeve net area ratio 2 (bf,2)	Measured friction sleeve net area ratio 3 (bf,3)	Measured average friction sleeve net area ratio (bf)
4.000	0.012	0.012	0.012	0.012
8.000	0.013	0.013	0.013	0.013
12.000	0.014	0.014	0.014	0.014
16.000	0.014	0.014	0.014	0.014
20.000	0.014	0.014	0.014	0.014
16.000	0.014	0.014	0.014	0.014
12.000	0.014	0.014	0.014	0.014
8.000	0.014	0.014	0.014	0.014
4.000	0.014	0.014	0.014	0.014

PORE 2 CALIBRATION RESULT [PRESSURE]

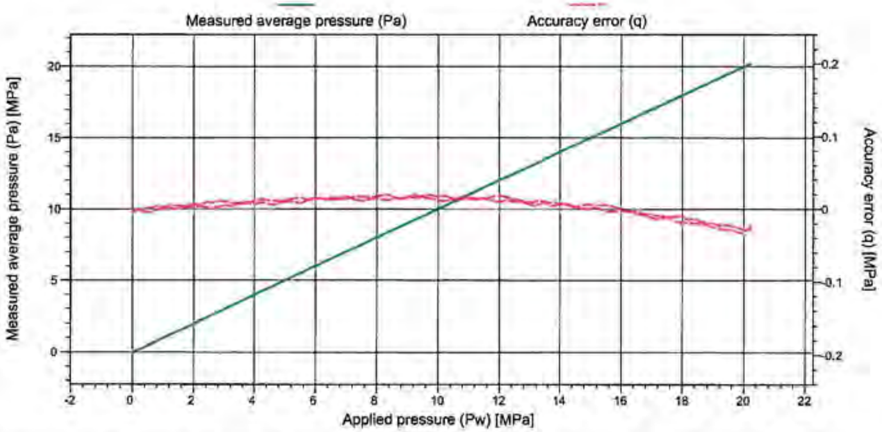
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E2M3-V2
Serial Number	1701-2085
Electronics	1320
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Keller PA33X
Serial Number	3257-0002
Uncertainty	0.00142·Pw+0.001787 [MPa]

Calibration Details	
Calibration Date	11 Dec 2014 14:11:42
Procedure	FEBV.CAL.PRO.004
Software Version	1.12.0.13400

Certificate Number
FCL14002499

Characteristics	Unit	Value
Accuracy error (q)	[MPa]	0.028
Repeatability error (b)	[MPa]	0.011
Reversibility error (v)	[MPa]	0.008
Zero load error (Pc0)	[MPa]	0.003
Zero load offset (P0)	[MPa]	-0.001
Resolution	[MPa]	7.55E-06
Noise RMS	[MPa]	0.000



Applied pressure (Pw) [MPa]	Measured pressure 1 (Pa,1) [MPa]	Measured pressure 2 (Pa,2) [MPa]	Measured pressure 3 (Pa,3) [MPa]	Measured average pressure (Pa) [MPa]	Accuracy error (q) [MPa]	Repeatability error (b) [MPa]	Reversibility error (v) [MPa]
0.000	-0.004	-0.004	-0.004	-0.004	-0.004	0.000	0.000
4.000	4.015	4.009	4.010	4.011	0.011	0.006	0.004
8.000	8.020	8.015	8.016	8.017	0.017	0.005	0.002
12.000	12.022	12.022	12.011	12.018	0.018	0.011	0.008
16.000	15.997	16.007	15.996	16.000	0.000	0.011	0.003
20.000	19.970	19.973	19.973	19.972	-0.028	0.003	
16.000	15.993	15.997	16.001	15.997	-0.003	0.007	
12.000	12.008	12.011	12.011	12.010	0.010	0.003	
8.000	8.013	8.017	8.016	8.015	0.015	0.004	
4.000	4.009	4.007	4.006	4.007	0.007	0.003	
0.000	-0.004	-0.003	-0.004	-0.004	-0.004	0.001	

SLOPE CALIBRATION RESULT [INCLINATION]

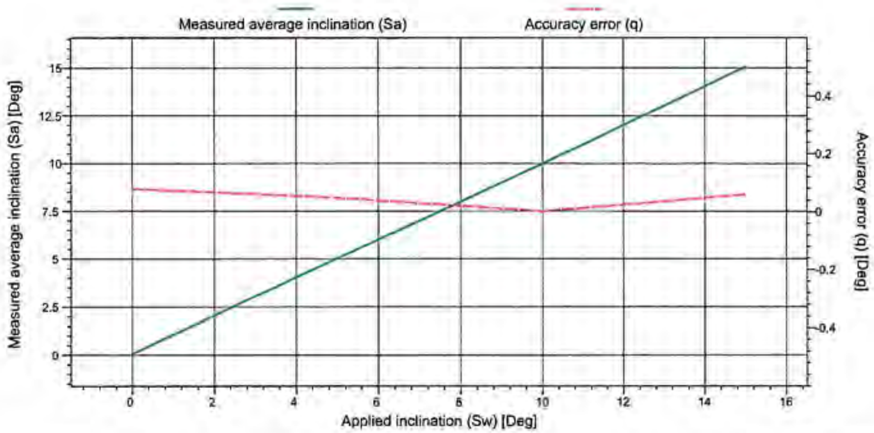
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E2M3-V2
Serial Number	1701-2085
Electronics	1320
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Hoek-O-Mat
Serial Number	2109-0001
Uncertainty	0.3 [Deg]

Calibration Details	
Calibration Date	24 Nov 2014 11:24:06
Procedure	FEBV.CAL.PRO.005
Software Version	1.12.0.13400

Certificate Number
FCL14002499

Characteristics	Unit	Value
Accuracy error (q)	[Deg]	0.078
Repeatability error (b)	[Deg]	0.129
Zero load error (Sc0)	[Deg]	-0.005
Zero load offset (S0)	[Deg]	0.071
Resolution	[Deg]	1.36E-05
Noise RMS	[Deg]	0.018



Applied inclination (Sw) [Deg]	Measured inclination 1 (Sa,1) [Deg]	Measured inclination 2 (Sa,2) [Deg]	Measured inclination 3 (Sa,3) [Deg]	Measured average inclination (Sa) [Deg]	Accuracy error (q) [Deg]	Repeatability error (b) [Deg]
0.000	0.054	0.099	0.082	0.078	0.078	0.045
5.000	5.072	5.052	5.021	5.048	0.048	0.051
10.000	10.056	9.979	9.971	10.002	0.002	0.084
15.000	15.121	14.992	15.064	15.059	0.059	0.129

TECHNICAL SPECIFICATIONS
Fugro Engineers BV

CALIBRATION CERTIFICATE

Applicant	**FUGRO ENGINEERS B.V. (NOOTDORP)**	Certificate nr.	FCN15004193
Manufacturer	Fugro Engineers B.V.	Identification	1701-2346
Instrument	**A Cone Penetrometer**		

Calibration method:
The device was calibrated according to Fugro Engineers procedures using a comparison technique against a Fugro reference standard. Fugro reference standards are periodically recertified and traceable to the National Standards and Technology (NIST) (RVA). It is derived from accepted values of natural physical constants according to the International System of units (SI). Fugro's calibration system meets or exceeds the requirements of ISO 9001:2000 and ISO/IEC 17025:2005.

Cone and Friction Sleeve Calibration Reference

Equipment Serial Number	6034-0002
Equipment Manufacturer	ZWICK GMBH & CO
Equipment Calibration Valid till	16/02/2016
Equipment Certificate	15200495.1000.1EN
Procedure used : in-house	FEBV.CAL.PRO.003

Cone and Friction Sleeve Sensor

Manufacturer	Fugro Engineers BV
Force Application Mode	Compression
Calibrated Range	0 – 75 kN
Max Load	0 – 150 kN

Pressure Calibration Reference

Equipment Serial Number	3257-0002
Equipment Manufacturer	KELLER MEETTECH
Equipment Calibration Valid till	28/09/2015
Equipment Certificate	FCNREF150116
Procedure used : in-house	FEBV.CAL.PRO.004

Pressure Sensor

Manufacturer	Kulite
Pressure Application Mode	Compression and tension
Calibrated Range	Nominal Range
Nominal Range	0 –20.0 MPa

Inclinometer Calibration Reference

Equipment Serial Number	2109-0005
Equipment Manufacturer	FEBV
Equipment Calibration Valid till	22/07/2016
Procedure used : in-house	FEBV.CAL.PRO.005

Inclinometer

Manufacturer	FEBV	ADXL
Calibrated Range	0° – 15°	-10° - 10°
Max Output	0° – 30°	-15° - 15°

Environmental Conditions

Temperature during calibration	21 ± 3 °C
Pressure during calibration	1000 ± 100 mbar

Remarks.
The values given in this calibration certificate only relate to the submitted device, and to the values measured at the time of the test. Any uncertainty defined here does not include allowances for environmental changes, variation and shock during transportation, or the capability of other laboratories to repeat the measurement.

Calibration technician	Mouaouya, Mo	Approved by :	Sinjorgo, Gerry
Calibration date:	17/06/2015	Approval date:	17/06/2015
Calibrate before:	16/06/2016		

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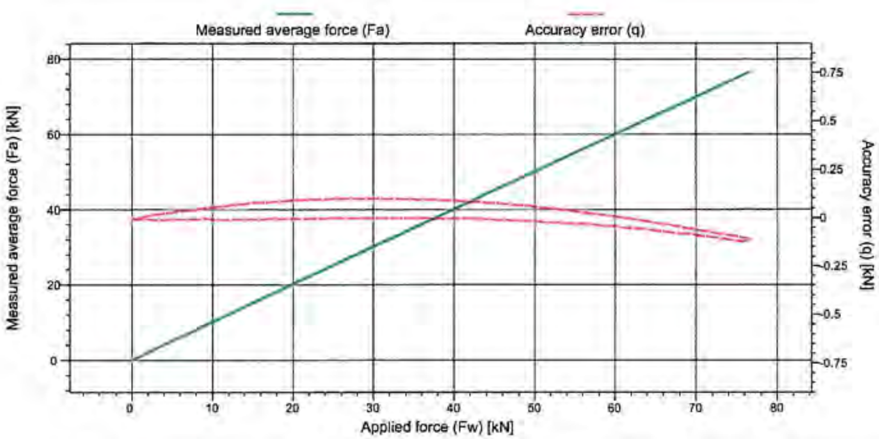
CONE CALIBRATION RESULT [FORCE]

Instrument		Reference	
Manufacturer	Fugro	Manufacturer	Zwick/Roell
Type	CP15-CF75PB20SN2-P1E2M3-V2	Serial Number	6034-0002
Serial Number	1701-2346	Uncertainty	0.00272·Fw+0.01672 [kN]
Electronics	2038	**Calibration Details**	
Node Type	7001	Calibration Date	17 Jun 2015 14:00:26
Hardware Version	3.00	Procedure	FEBV.CAL.PRO.003
Software Version	4.01	Software Version	1.15.0.14651

Certificate Number
FCN15004193

Characteristics	Unit	Value
Accuracy error (q)	[kN]	0.120
Repeatability error (b)	[kN]	0.015
Reversibility error (v)	[kN]	0.100
Zero load error (Fc0)	[kN]	0.056
Zero load offset (F0)	[kN]	-0.041
Resolution	[kN]	2.91E-05
Noise RMS	[kN]	0.001



Applied force (Fw) [kN]	Measured force 1 (Fa,1) [kN]	Measured force 2 (Fa,2) [kN]	Measured force 3 (Fa,3) [kN]	Measured average force (Fa) [kN]	Accuracy error (q) [kN]	Repeatability error (b) [kN]	Reversibility error (v) [kN]
0.000	-0.006	-0.002	-0.010	-0.006	-0.006	0.009	0.002
15.000	14.988	14.998	14.991	14.993	-0.007	0.010	0.081
30.000	29.996	30.004	29.994	29.998	-0.002	0.010	0.100
45.000	44.990	44.996	44.988	44.991	-0.009	0.007	0.085
60.000	59.952	59.961	59.950	59.954	-0.046	0.010	0.052
75.000	74.877	74.884	74.878	74.880	-0.120	0.006	
60.000	60.001	60.016	60.003	60.007	0.007	0.015	
45.000	45.072	45.084	45.071	45.076	0.076	0.013	
30.000	30.093	30.105	30.096	30.098	0.098	0.011	
15.000	15.070	15.078	15.073	15.074	0.074	0.008	
0.000	-0.011	-0.007	-0.005	-0.008	-0.008	0.006	

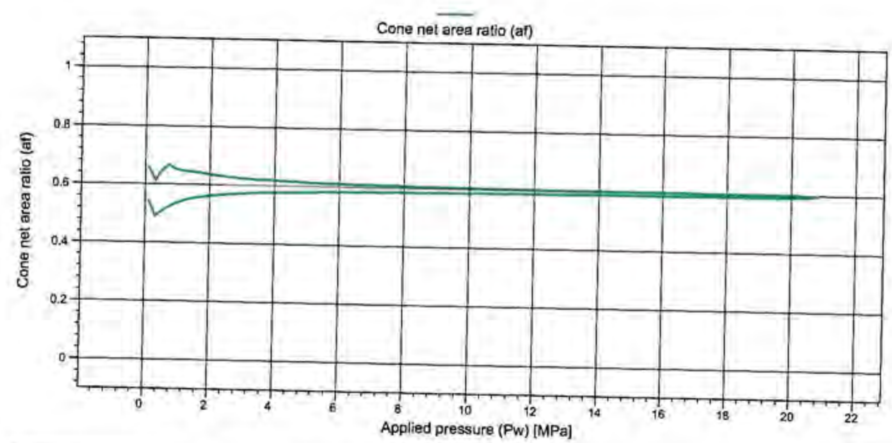
CONE NET AREA RATIO RESULT

Instrument		Reference	
Manufacturer	Fugro	Manufacturer	Keller PA33X
Type	CP15-CF75PB20SN2-P1E2M3-V2	Serial Number	3257-0002
Serial Number	1701-2346	Uncertainty	0.00143·Pw+0.0019 [MPa]
Electronics	2038	**Calibration Details**	
Node Type	7001	Calibration Date	17 Jun 2015 15:00:06
Hardware Version	3.00	Procedure	FEBV.CAL.PRO.003
Software Version	4.01	Software Version	1.15.0.14651

Certificate Number
FCN15004193

Characteristics	Unit	Value
Cone net area ratio (af)	[-]	0.60

The cone net area ratio presented above is determined at the maximum applied pressure during the measurement.



Applied pressure (Pw) [MPa]	Measured cone net area ratio 1 (af,1)	Measured cone net area ratio 2 (af,2)	Measured cone net area ratio 3 (af,3)	Measured average cone net area ratio (af)
4.000	0.577	0.577	0.577	0.577
8.000	0.586	0.586	0.586	0.586
12.000	0.589	0.589	0.589	0.589
16.000	0.590	0.590	0.590	0.590
20.000	0.593	0.593	0.593	0.593
16.000	0.602	0.602	0.602	0.602
12.000	0.604	0.604	0.604	0.604
8.000	0.608	0.608	0.608	0.608
4.000	0.619	0.619	0.619	0.619

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Fugro Calibration Laboratory, P.O. Box 130, 2630 AC Nootdorp, The Netherlands, Phone +31-70-3111444, www.fugro.com

CONE+FRIC. CALIBRATION RESULT [FORCE]

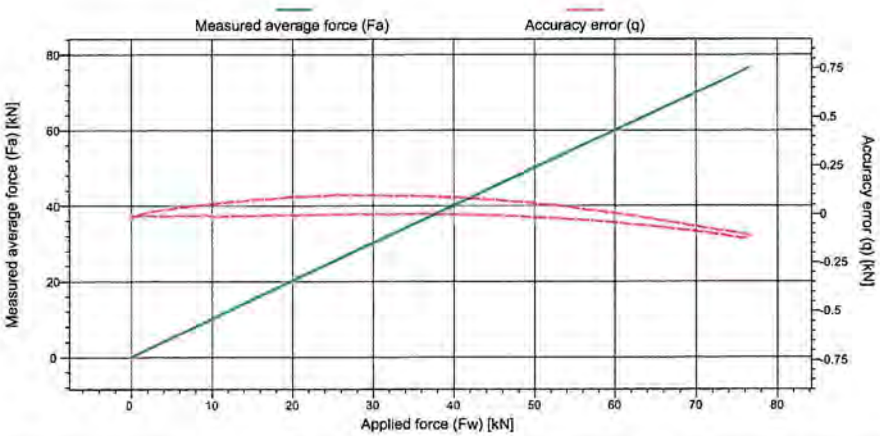
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E2M3-V2
Serial Number	1701-2346
Electronics	2038
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Zwick/Roell
Serial Number	6034-0002
Uncertainty	0.00272•Fw+0.01672 [kN]

Calibration Details	
Calibration Date	17 Jun 2015 14:00:27
Procedure	FEBV.CAL.PRO.003
Software Version	1.15.0.14651

Certificate Number
FCN15004193

Characteristics	Unit	Value
Accuracy error (q)	[kN]	0.120
Repeatability error (b)	[kN]	0.016
Reversibility error (v)	[kN]	0.097
Zero load error (Fc0)	[kN]	0.043
Zero load offset (F0)	[kN]	-0.037
Resolution	[kN]	2.89E-05
Noise RMS	[kN]	0.001
Tip-Sleeve Interaction	[kPa]	0.3
Tip-Sleeve Interaction %	[%]	0.06



Applied force (Fw) [kN]	Measured force 1 (Fa,1) [kN]	Measured force 2 (Fa,2) [kN]	Measured force 3 (Fa,3) [kN]	Measured average force (Fa) [kN]	Accuracy error (q) [kN]	Repeatability error (b) [kN]	Reversibility error (v) [kN]
0.000	-0.004	-0.002	-0.014	-0.007	-0.007	0.011	0.005
15.000	14.990	14.999	14.989	14.992	-0.008	0.010	0.081
30.000	29.999	30.008	29.995	30.001	0.001	0.012	0.097
45.000	44.993	44.999	44.988	44.993	-0.007	0.012	0.080
60.000	59.954	59.964	59.953	59.957	-0.043	0.011	0.048
75.000	74.882	74.882	74.878	74.880	-0.120	0.004	
60.000	60.002	60.014	60.000	60.005	0.005	0.014	
45.000	45.071	45.083	45.067	45.074	0.074	0.016	
30.000	30.095	30.105	30.093	30.098	0.098	0.012	
15.000	15.069	15.077	15.074	15.073	0.073	0.008	
0.000	-0.013	-0.011	-0.009	-0.011	-0.011	0.005	

FRICTION SLEEVE NET AREA RATIO RESULT

Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E2M3-V2
Serial Number	1701-2346
Electronics	2038
Node Type	7001
Hardware Version	3.00
Software Version	4.01

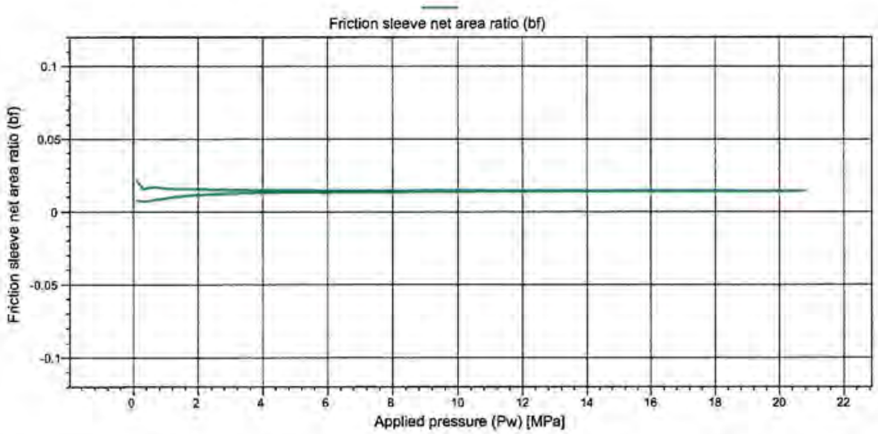
Reference	
Manufacturer	Keller PA33X
Serial Number	3257-0002
Uncertainty	0.00143•Pw+0.0019 [MPa]

Calibration Details	
Calibration Date	17 Jun 2015 15:00:06
Procedure	FEBV.CAL.PRO.003
Software Version	1.15.0.14651

Certificate Number
FCN15004193

Characteristics	Unit	Value
Friction sleeve net area ratio (bf)	[-]	0.01400

The friction sleeve net area ratio presented above is determined at the maximum applied pressure during the measurement.



Applied pressure (Pw) [MPa]	Measured friction sleeve net area ratio 1 (bf,1)	Measured friction sleeve net area ratio 2 (bf,2)	Measured friction sleeve net area ratio 3 (bf,3)	Measured average friction sleeve net area ratio (bf)
4.000	0.013	0.013	0.013	0.013
8.000	0.014	0.014	0.014	0.014
12.000	0.014	0.014	0.014	0.014
16.000	0.014	0.014	0.014	0.014
20.000	0.014	0.014	0.014	0.014
16.000	0.014	0.014	0.014	0.014
12.000	0.014	0.014	0.014	0.014
8.000	0.015	0.015	0.015	0.015
4.000	0.015	0.015	0.015	0.015

PORE 2 CALIBRATION RESULT [PRESSURE]

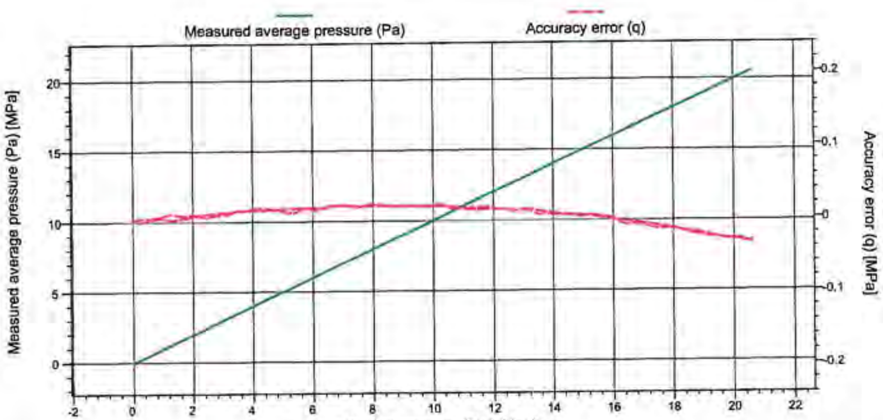
Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E2M3-V2
Serial Number	1701-2346
Electronics	2038
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Keller PA33X
Serial Number	3257-0002
Uncertainty	0.00143·Pw+0.0019 [MPa]

Calibration Details	
Calibration Date	17 Jun 2015 15:00:06
Procedure	FEBV.CAL.PRO.004
Software Version	1.15.0.14651

Certificate Number
FCN15004193

Characteristics	Unit	Value
Accuracy error (q)	[MPa]	0.030
Repeatability error (b)	[MPa]	0.005
Reversibility error (v)	[MPa]	0.002
Zero load error (Pc0)	[MPa]	0.000
Zero load offset (P0)	[MPa]	-0.003
Resolution	[MPa]	7.57E-06
Noise RMS	[MPa]	0.000



Applied pressure (Pw) [MPa]	Measured pressure 1 (Pa,1) [MPa]	Measured pressure 2 (Pa,2) [MPa]	Measured pressure 3 (Pa,3) [MPa]	Measured average pressure (Pa) [MPa]	Accuracy error (q) [MPa]	Repeatability error (b) [MPa]	Reversibility error (v) [MPa]
0.000	-0.002	-0.002	-0.001	-0.002	-0.002	0.001	0.001
4.000	4.011	4.011	4.011	4.011	0.011	0.001	0.002
8.000	8.018	8.017	8.016	8.017	0.017	0.001	0.002
12.000	12.012	12.015	12.013	12.013	0.013	0.002	0.002
16.000	15.997	15.996	15.998	15.997	-0.003	0.001	0.002
20.000	19.969	19.972	19.969	19.970	-0.030	0.003	
16.000	15.998	15.999	16.000	15.999	-0.001	0.002	
12.000	12.014	12.012	12.009	12.011	0.011	0.005	
8.000	8.019	8.017	8.019	8.018	0.018	0.002	
4.000	4.013	4.013	4.013	4.013	0.013	0.001	
0.000	-0.003	-0.003	-0.002	-0.003	-0.003	0.001	

SLOPE CALIBRATION RESULT [INCLINATION]

Instrument	
Manufacturer	Fugro
Type	CP15-CF75PB20SN2-P1E2M3-V2
Serial Number	1701-2346
Electronics	2038
Node Type	7001
Hardware Version	3.00
Software Version	4.01

Reference	
Manufacturer	Hoek-O-Mat
Serial Number	2109-0005
Uncertainty	0.3 [Deg]

Calibration Details	
Calibration Date	17 Jun 2015 14:04:05
Procedure	FEBV.CAL.PRO.005
Software Version	1.15.0.14651

Certificate Number
FCN15004193

Characteristics	Unit	Value
Accuracy error (q)	[Deg]	0.544
Repeatability error (b)	[Deg]	0.164
Zero load error (Sc0)	[Deg]	-0.050
Zero load offset (S0)	[Deg]	0.531
Resolution	[Deg]	1.34E-05
Noise RMS	[Deg]	0.022

Inclination is defined as the angular deviation of the cone penetrometer from the vertical.

Applied inclination (Sw) [Deg]	Measured inclination 1 (Sa,1) [Deg]	Measured inclination 2 (Sa,2) [Deg]	Measured inclination 3 (Sa,3) [Deg]	Measured average inclination (Sa) [Deg]	Accuracy error (q) [Deg]	Repeatability error (b) [Deg]
0.000	0.533	0.622	0.478	0.544	0.544	0.143
5.000	5.068	5.158	5.075	5.100	0.100	0.089
10.000	9.991	9.987	9.911	9.963	-0.037	0.080
15.000	15.052	14.942	14.888	14.960	-0.040	0.164

This investigation was carried out by Fugro Engineers B.V., commissioned by RVO.nl, an agency of the Ministry of Economic Affairs. Whilst a great deal of care has been taken in compiling the contents of this investigation, RVO.nl can not be held liable for any damages resulting from any inaccuracies and/or outdated information.

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Netherlands Enterprise Agency (RVO.nl) | January 2016