GEOTECHNICAL REPORT

INVESTIGATION DATA

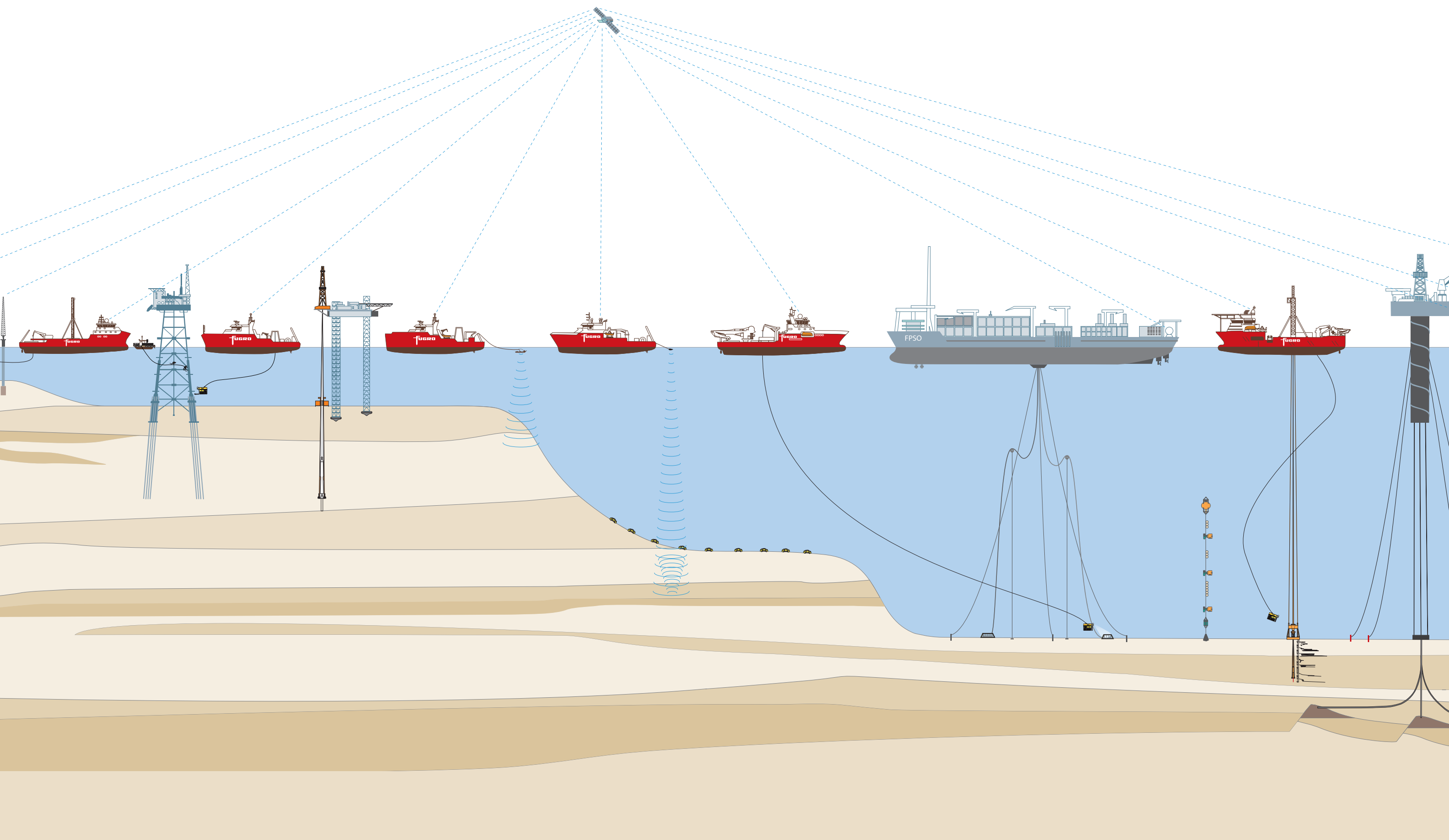
PORT OF RIO DE JANEIRO

GUANABARA BAY

Fugro Report No. VOO-002-REP-001

ISSUE 1

Van Oord Serviços de Operações Marítimas Ltda.



GEOTECHNICAL REPORT
INVESTIGATION DATA
PORT OF RIO DE JANEIRO
GUANABARA BAY

Client	Van Oord Serviços de Operações Marítimas Ltda.
Client Address	Rua da Assembléia, 11, 6th floor Centro, Rio de Janeiro 20.011-001 Rio de Janeiro
Fugro Report No.	**VOO-002-REP-001**
Confidentiality	Report distribution is restricted to project participants approved by the Client

Abstract:

This report presents results from the marine geotechnical soil investigation and provides geotechnical soil classification at the planned area for the widening, by means of dredging, of the existing access channel to the Rio de Janeiro Port, in Guanabara Bay, Rio de Janeiro. The water depth at the borehole locations ranges approximately between 1.6 m and 13.0 m with respect to DHN.

Geotechnical information presented in this report includes:

- Geotechnical logs from 17 borehole locations to different depths
- Visual description of all collected soil and rock samples
- Laboratory test results of index strength tests
- Mean positioning reports.

The geotechnical investigation indicated that the soils at the investigated locations consisted of very soft clay to sandy clay on top overlying stiff to hard sandy clay on most boreholes. On some locations, layers of sand and gravel were found within the stiff clays. Very weak, completely weathered to residual soil, Gneiss was also collected.

Report Issue No.	Date	Report Status	Approved
1	19-Jun-2015	Field Report – Marine Site Investigation	PTM

Van Oord Serviços de Operações Marítimas LTDA.
Rua da Assembléia, 11, 6th floor
Centro, Rio de Janeiro
20.011-001 Rio de Janeiro

Attention: Mr Joop Rijkers

Our ref: VOO-002-REP-001 (1) Rio de Janeiro, 19 June, 2015.

GEOTECHNICAL REPORT - INVESTIGATION DATA
PORT OF RIO DE JANEIRO - GUANABARA BAY

This report presents data from a marine geotechnical investigation at Guanabara Bay area, in the municipality of Rio de Janeiro, RJ. The report was prepared in accordance with Contract No. C1721 from 24 April, 2015.

The principal team member for report preparation was Ms M. Vieira (Project Geologist). Mrs P. Tulha Moutinho (Senior Geotechnical Engineer) was the project reviewer. We acknowledge the valuable assistance of Mr. M. Van Oord who acted as field 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 GEOTECNIA MARINHA

M. Vieira
Project Geologist

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REPORT ISSUE CONTROL

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Notes:

1) The *report* issue number is the same as the highest issue number of any individual page.

2) Pages of this report are at Issue 1.

3) 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

Report Section	Prepared By	Reviewed By
Main Text	MV	PTM
Plates following Main Text	MV	PTM
A Geotechnical Logs	MV	PTM
B In-situ Test Results	MV	PTM
D Positioning and Water Depth Data	MV	PTM

Person(s):
MV: Marianna Vieira
PTM: Paula Tulha Moutinho

1. INTRODUCTION

1.1 Purpose of Report

Van Oord Serviços de Operações Marítimas Ltda, henceforth referred to as Client, is planning the widening of the access channel to the port of Rio de Janeiro in Guanabara Bay, Rio de Janeiro. The proposed site is located inside Guanabara Bay. The Client therefore requires geotechnical information about the ground conditions at the proposed site (Plate 1-1).

The purpose of this report is then to present data from a geotechnical soil investigation, performed by means of downhole sampling and testing, to help with the planned dredging operations of the channel.

This report, presents data from the marine site investigation. In a near future the report will be updated with the onshore laboratory test results.

1.2 Scope of Report

The main scope of the marine site investigation campaign includes the following:

- 14 Boreholes including Standard Penetration Tests (SPTs) and undisturbed soil samples collected at depths indicated by the client on site.
- 1 Borehole including SPTs, undisturbed soil samples and rock core samples
- 1 Borehole including SPTs and rock core samples
- 1 Borehole including only rock core samples.

This field report includes all the marine information collected during the site work. Therefore, the scope of this report includes:

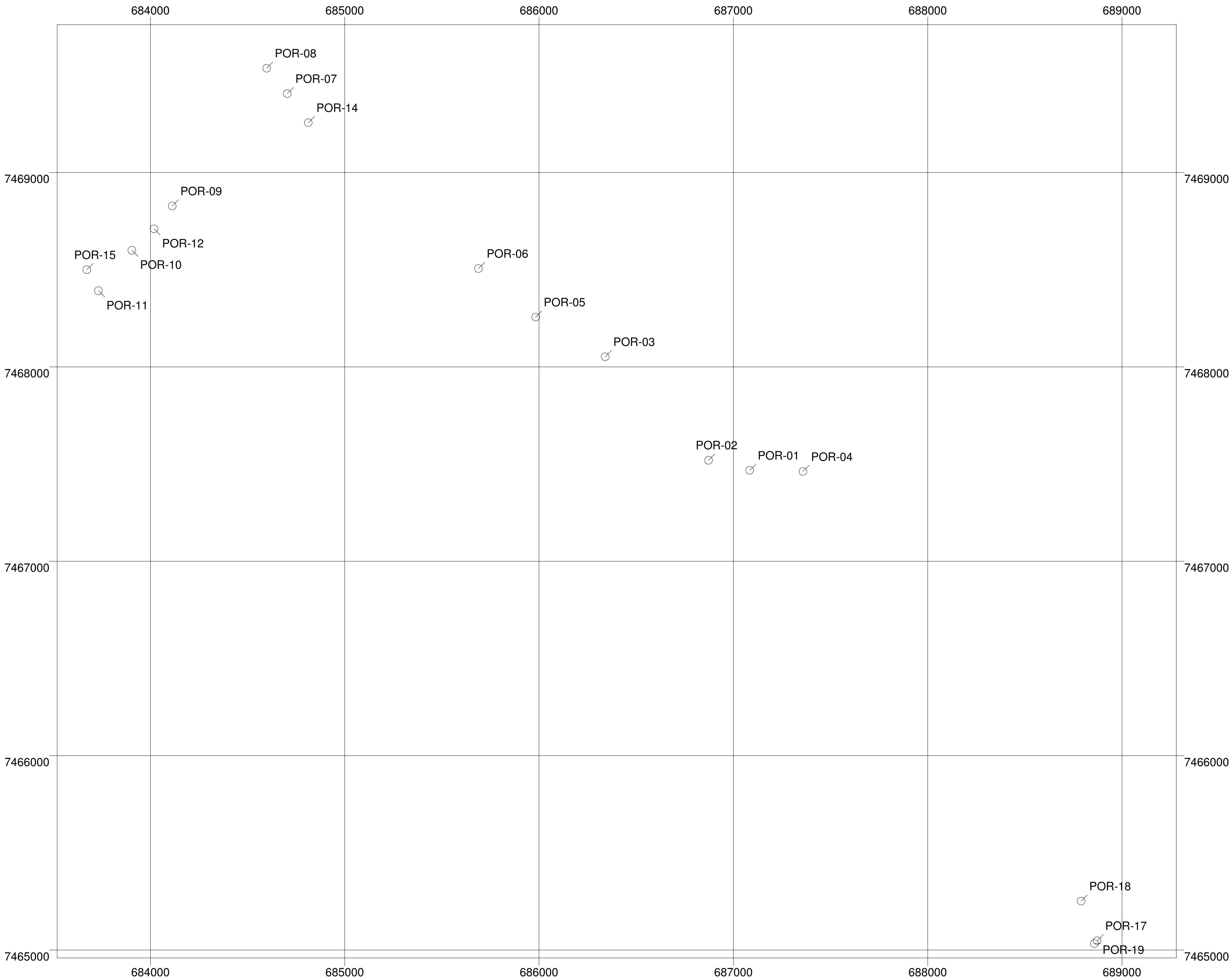
- Geotechnical logs from 17 marine borehole locations to different depths
- SPT results
- Index strength test results

1.3 Use of Report

This report must be read in conjunction with “Guide for use of Report”, Section E.

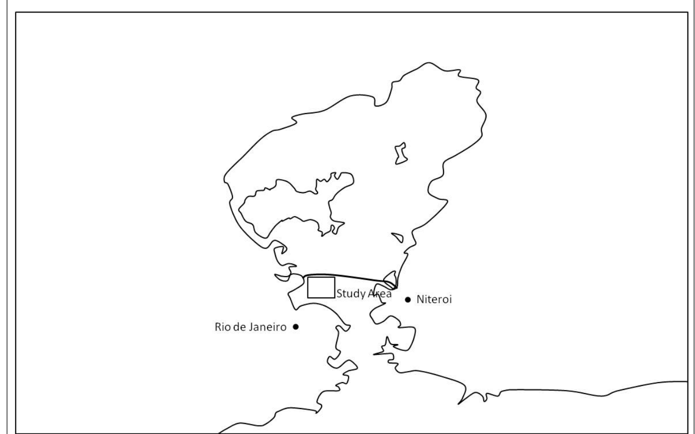
Fugro understands that this report will be used for the purpose described in this “Introduction” section. That purpose was a significant factor in determining the scope and level of the services. Results must not be used if the purpose for which the report was prepared or the Client’s proposed development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

VICINITY MAP
PORT OF RIO DE JANEIRO - GUANABARA BAY



BH	Actual Coordinates E	N
POR-01	687084	7467467
POR-02	686872	7467520
POR-03	686340	7468053
POR-04	687357	7467462
POR-05	685983	7468255
POR-06	685689	7468507
POR-07	684705	7469406
POR-08	684599	7469536
POR-09	684113	7468827
POR-10	683904	7468601
POR-11	683732	7468392
POR-12	684019	7468709
POR-14	684812	7469257
POR-15	683672	7468500
POR-17	688871	7465047
POR-18	688791	7465252
POR-19	688858	745034

Location Map



Van Oord
Marine ingenuity

FUGRO IN SITU GEOTECNIA LTDA.

Borehole Location Map

Scale - 1:20000

PORT OF RIO DE JANEIRO - GUANABARA BAY

Fugro Job n. VOO-002

Geodetic Datum: WGS 84
Projection: UTM 23 (South)
Grid Units: Meters

2. STUDY OVERVIEW

2.1 Sources of Information

Client supplied information included the following:

– location details (reproduced on Plate 1-1)

This report uses and summarises selected information.

2.2 Investigation Programme

2.2.1 Positioning Survey and Water Depth Measurement

The geodetic system used for horizontal projection is WGS84, UTM projection, Zone 23 S. The co-ordinates and water depths of the test locations are shown on the Plate 2-1, on the Borehole Logs of Section A and presented in the location reports of Section D.

Surface positioning was performed using differential GPS. Starfix HP was used as the primary positioning system. The SkyFix-XP system was on board as a backup positioning system.

On location POR-15 a position report was not printed, therefore this document will not be presented on Section D. An excel spreadsheet with the co-ordinates was delivered and approved by the client. The corrected co-ordinates are presented on Plate 2-1 and on the Borehole Logs of Section A.

Water depth was measured using a scale with a weight at the end. The water depth measurement was obtained by the difference of two measurements: the depth from the platform deck to seafloor (DML) and the distance from the platform deck to the water surface (DWL). The measurements were taken inside the drill string in order to minimize the effect of the local currents and wind. The measured water depths were then corrected to DHN and those values are shown on Plate 2-1 and on the Borehole Logs of Section A as Ground Elevation. Ground elevation is vertical reference level for water depth measurement and geotechnical testing.

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

2.2.2 Marine Site Investigation

A specific geotechnical site investigation project was conducted from the jack-up platform Skate 3C, between June 5th and June 12th, 2015.

The Client planned the on-site/field investigation programme. During the investigation, the Client's programme was adjusted to suit as-found conditions and operational constraints. The scope of the report includes the results of the final decisions.

The sampling programme consisted, in the majority of the locations and depending on the target depth of the borehole, of SPT testing, with collection of disturbed samples, undisturbed samples collected with 4’’ and 3’’ sample tubes and rock coring in the more competent formations such as weak rocks to residual soil, and gravelly soils.

The in-situ testing programme consisted of SPTs.

Refer to Sections A and B, respectively titled “Geotechnical Logs” and “In-Situ Test Results” for further information about sampling, testing and test results. Refer to the document titled “Geotechnical Borehole” presented in Appendix 1 for details about the procedures.

2.2.3 Sample Handling

Important stages in sample handling included:

- Measurement of sample recovery in tube
- Visual description of the soil or rock collected
- Packing samples for transport to onshore geotechnical laboratory. SPT samples were bagged and labeled and undisturbed samples were waxed at both ends, labeled and stored vertically. Rock core samples were kept inside the plastic liners and placed in proper plastic boxes.

The Report Section titled “Geotechnical Laboratory Test Results” will provide further details about sample handling.

2.2.4 Laboratory Tests

Only basic index strength tests, such as pocket penetrometer (PP) and torvane (TV) were performed offshore. All the laboratory tests will be performed at Fugro’s laboratory in Curitiba and the results will be presented in the next issue of this report.

2.3 Geotechnical Data Processing

Geotechnical data processing included:

- Preparation of borehole logs including SPT blows and undrained shear strength from index strength tests
- Strata description by integrating visual description of samples and in-situ test results

BH	Proposed Coordinates		Actual Coordinates		Water Depth (m)	Water Depth Corrected (m)	Ground Elevation (m)
	E	N	E	N			
POR-01	687083	7467467	687084	7467467	12.10	11.11	-11.11
POR-02	686873	7467522	686872	7467520	11.00	9.81	-9.81
POR-03	686339	7468053	686340	7468053	9.10	7.88	-7.88
POR-04	687354	7467461	687357	7467462	11.40	10.31	-10.31
POR-05	685987	7468255	685983	7468255	9.30	8.41	-8.41
POR-06	685689	7468505	685689	7468507	8.00	6.91	-6.91
POR-07	684705	7469406	684705	7469406	5.00	4.56	-4.56
POR-08	684599	7469536	684599	7469536	3.65	2.94	-2.94
POR-09	684116	7468828	684113	7468827	6.90	6.51	-6.51
POR-10	683903	7468599	683904	7468601	4.60	3.51	-3.51
POR-11	683732	7468388	683732	7468392	2.30	1.61	-1.61
POR-12	684017	7468713	684019	7468709	4.70	3.71	-3.71
POR-14	684816	7469259	684812	7469257	9.70	9.41	-9.41
POR-15	683674	7468503	683672	7468500	13.80	13.01	-13.01
POR-17	688870	7465044	688871	7465047	6.80	5.61	-5.61
POR-18	688791	7465249	688791	7465252	6.70	5.91	-5.91
POR-19	688859	7465034	688858	745034	5.10	3.86	-3.86

* Datum: WGS 84

COORDINATES AND WATER DEPTH

PORT OF RIO DE JANEIRO - GUANABARA BAY

SECTION A: GEOTECHNICAL LOGS

TEXT – SECTION A: Page

LIST OF PLATES IN SECTION A: Plate

A. GEOTECHNICAL LOGS

A.1 DETAILS

Whenever in two consecutive samples, the soil sampled is the same we do correlate between them and it is assumed the same soil. When they show different soils it was assumed that the layer changed at half of the distance between them. The soil collected from the bailer during borehole advance was also used to help characterizing the strata.

Every time a sample looked suitable, index strength tests (PP and/or TV) were performed. Even in the SPT samples despite those being consider to be disturbed.

The first 50 cm of RC1, from 1.5 m to 3.0 m and RC2 from 3.0 m to 4.5 m on borehole POR-01 are consider to be disturbed from the SPTs performed at 1.5 m and 3.0 m, respectively.

The location POR-19 was not part of the initial scope. This location was added to help characterizing the area around POR-17 since rock fragments and cobbles were found on that location. A rock outcrop was observed approximately 50 m from this location.

On locations POR-01 and POR-05 residual soil grading to very weathered Gneiss was observed around 5.6 m. On location POR-05 residual soil was also described around 2.6 m.

On some of the collected samples PP and TV were not performed due to 3 main reasons: too soft soils, too hard soil conditions and too sandy or shelly clays.

All the descriptions will be updated in the next issue of this report after receiving the results from the onshore tests.

A.2 COMMENTS ON RESULTS

The soil description on the collected push samples are based on the top and bottom of each sample.
The Push sample at mudline on locations POR-06, POR-08, POR-10, POR-12, POR-15 and POR-17 had no recovery. Soil was collected from the bailer during borehole advancement and those samples were considered to be Bulk samples, therefore disturbed. The samples can be used to characterize the soil.

The Push sample at 7.0 m on location POR-03 was replaced by a SPT because during the advancement of the hole coarse sand to fine gravel were observed.

The Push sample at 1.0 m from location POR-11 fell from the sample tube when the sample was on deck. The soil was bagged.

An extra SPT was performed at 13.5 m on location POR-11 due to the short recovery (30 cm) from the Push sample at 7.0 m.

The first attempt to take a Push sample at 5.5 m on location POR-12 was made with a 3” Shelby tube and came with no recovery. A second attempt using a 4” Shelby tube collected a sample of 70 cm. The sample collected is considered to be disturbed.

The Push sample at 2.5 m from location POR-14 had only a 5 cm recovery. The sample was bagged and considered to be disturbed. Due to the short recovery another sample was collected from the bailer.

The Push sample at 1.0 m on location POR-15 recovered 30 cm of soil in the middle of the sample tube. The bottom 25 cm had fallout. While cleaning the hole two cobbles of quartz were collected; one with 8 cm and the other with 5 cm, approximately.

A.3 PRACTICE FOR GEOTECHNICAL LOG

Geotechnical Log

Purpose:	Provide geotechnical characteristics of the sampled and tested formations for the widening of the access channel of Rio de Janeiro Port
Data Processing and Interpretation:	– 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 test data, sample size, quality, coverage, availability of supplementary information, and project requirements
Matching Sample and In-Situ Test Data:	Geotechnical logs include SPT results
Ground Description:	According to document titled “Soil Description” (Fugro ref. FEBV/CDE/APP/005) presented in Appendix 1
Unit Weight derived from In-Situ Test:	– Not applicable
Relative Density derived from In-Situ Test:	– refer to document titled “Standard Penetration Tests” (Fugro ref. FEBV/CDE/APP/036), presented in Appendix 1 – applies to interpreted coarse-grained, cohesionless soil behaviour
Undrained Shear Strength derived from In-Situ Test:	– SPT results give a rough indication – applies to interpreted fine-grained, cohesive soil behaviour
Co-ordinates and Water Depth:	Applicable to borehole location
Water Depth Reference:	As obtained from measurements at start of testing/sampling
Depth Reference Correction:	None applied. Downhole sampling and testing depth refer to seafloor

References

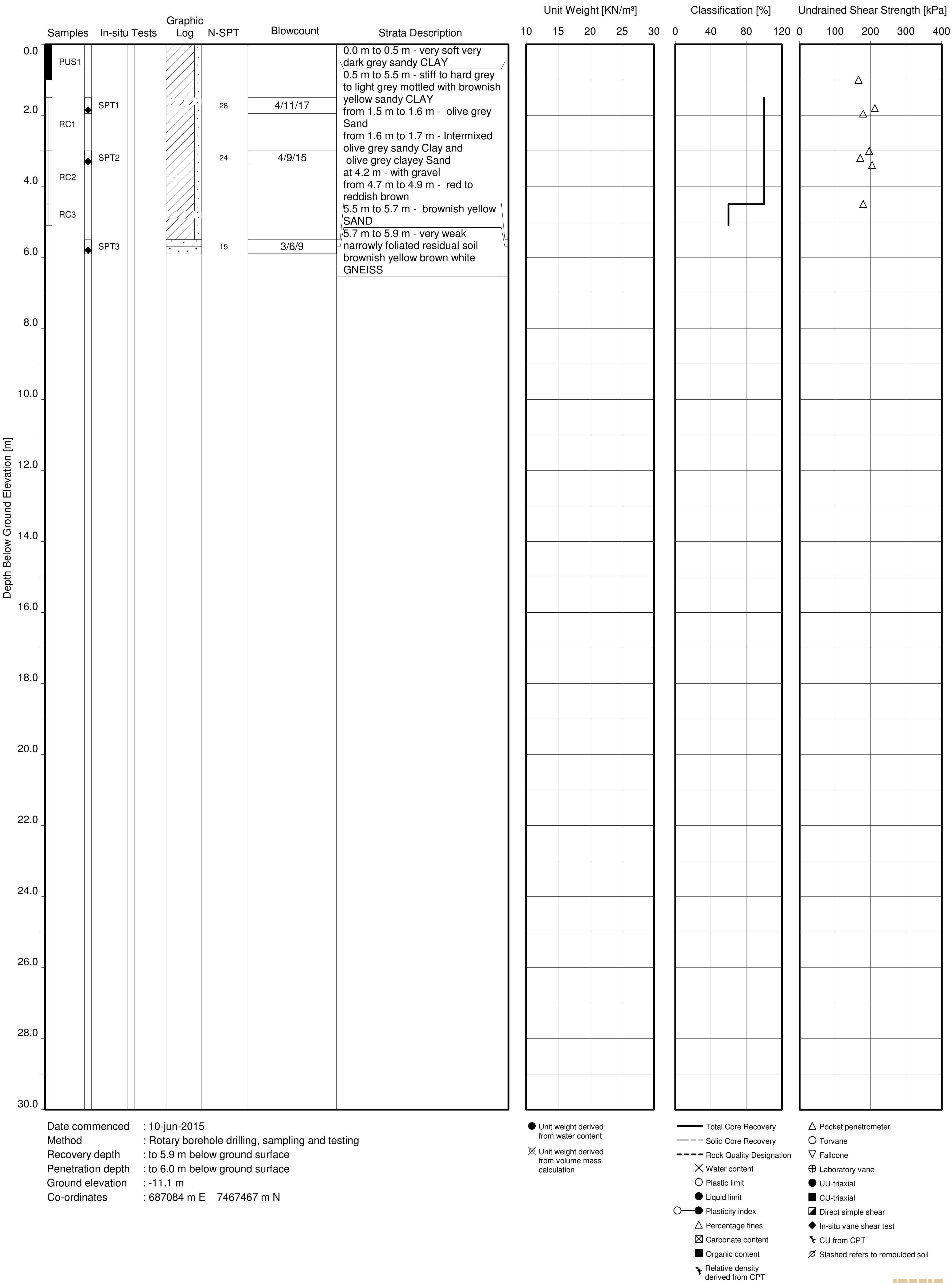
– Computer Program GeODin®, Recording, Presentation and Analysis of Geo-data.
– NBR 6502:1995 – Rochas e Solos- Terminologia
– NBR 6484:2001 – Solo – Sondagem de Simples Reconhecimento com SPT – Método de Ensaio

A.4 PRACTICE FOR GEOTECHNICAL BOREHOLE

Borehole Stage Control	
General Procedure:	Refer to document titled "Geotechnical Borehole" (Fugro ref. FEBV/CDE/APP/002), presented in Appendix 1
Set-up Stage:	Location as directed by the Client
Depth Reference Level:	Depth accuracy assessment of "Downhole – Favorable"; refer to document titled Positioning Survey and Depth Measurement (Fugro ref. FEBV/CDE/APP/029) presented in Appendix 1
Drilling Stage:	Open hole percussive and rotary drilling
Sampling and Testing:	Refer to Main Text and Section A for details
Borehole Water Level Monitoring:	Not applicable
Borehole Termination Stage:	Whichever occurs first: – as instructed by Client – reaching target borehole depth – circumstances at the discretion of the equipment operator, such as risk of equipment damage or risk to personnel safety
Test Site Restoration:	– No borehole backfill – Local seabed disturbance – Possibility of local seafloor depression(s) and drill cuttings on seafloor
In-situ Test – SPT	Refer to report section titled "In-Situ Test Results"
Push Sampling	
Sampler Insertion Equipment:	Jacking unit with maximum thrust capacity of 60 kN to 80 kN and penetration rate of about 20 mm/s
Reaction Equipment:	Self-weight of drill pipes and drill rig
Open-Tube Sampler:	Thick-walled 3" cylindrical sample tube, 80 mm OD, 72 mm ID Thin-walled 4" cylindrical sample tube, 102 mm OD, 100 mm ID
Core Catcher:	Applicable in case of sample recovery problems
Push Sampling Termination:	Whichever occurs first: – reaching maximum permissible sample tube penetration – reaching maximum capacity of sample insertion equipment and/or sample tube – reaching maximum capacity of reaction equipment – circumstances at the discretion of the equipment operator, such as risk of equipment damage or risk to personnel safety
Rotary Core Sampling	
Sampling System:	Wireline rotary corer
Type and Make of Rotary Corer	Geobor-S
Sampler Insertion Equipment:	Jacking unit with maximum thrust capacity of 60 kN to 80 kN and penetration rate of about 20 mm/s
Sampler:	Triple tube, 100 mm diameter and maximum 1.5 m sample length
Core Sampling Termination:	Whichever occurs first: – reaching maximum permissible penetration – penetration rate of <1 m/hour – circumstances at the discretion of the equipment operator, such as risk of equipment damage or risk to personnel safety

Sample Handling

Refer to sub-section “Practice for Sample Handling and Laboratory Testing” presented in report section titled “Geotechnical Laboratory Test Results”

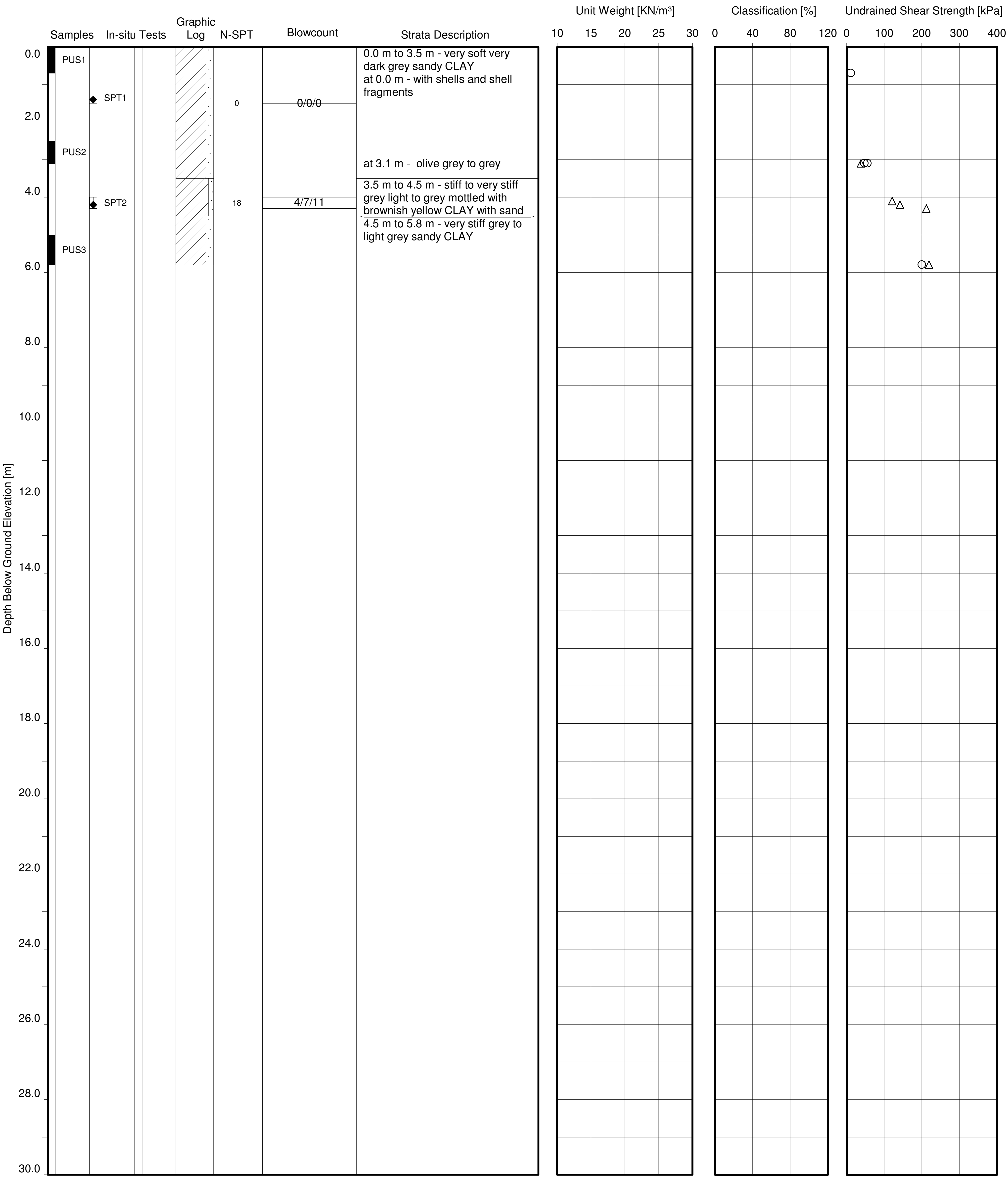


Date commenced : 10-jun-2015
Method : Rotary borehole drilling, sampling and testing
Recovery depth : to 5.9 m below ground surface
Penetration depth : to 6.0 m below ground surface
Ground elevation : -11.1 m
Co-ordinates : 687084 m E 7467467 m N

GEOTECHNICAL LOG

LOCATION POR-01

PORT OF RIO DE JANEIRO - GUANABARA BAY



Date commenced : 11-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 5.8 m below ground surface
Penetration depth : to 6.0 m below ground surface
Ground elevation : -9.8 m
Co-ordinates : 686872 m E 7467520 m N

● Unit weight derived from water content
Unit weight derived from volume mass calculation

Total Core Recovery
Solid Core Recovery
Rock Quality Designation
× Water content
○ Plastic limit
● Liquid limit
○—● Plasticity index
△ Percentage fines
Carbonate content
■ Organic content
Relative density derived from CPT

△ Pocket penetrometer
○ Torvane
▽ Fallcone
⊕ Laboratory vane
● UU-triaxial
■ CU-triaxial
Direct simple shear
◆ In-situ vane shear test
CU from CPT
Ø Slashed refers to remoulded soil

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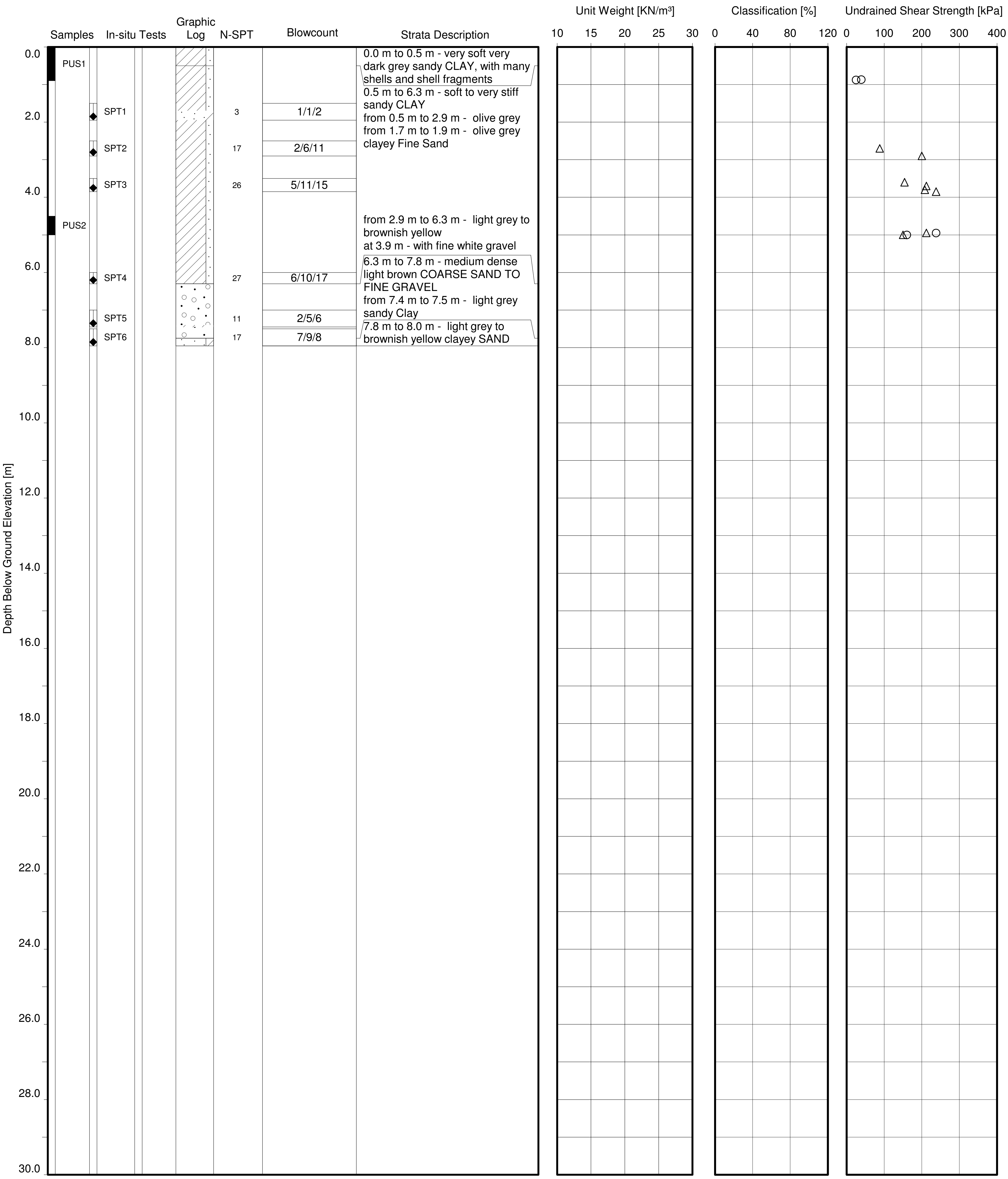
GEOTECHNICAL LOG

LOCATION POR-02

PORT OF RIO DE JANEIRO - GUANABARA BAY

Plate A2



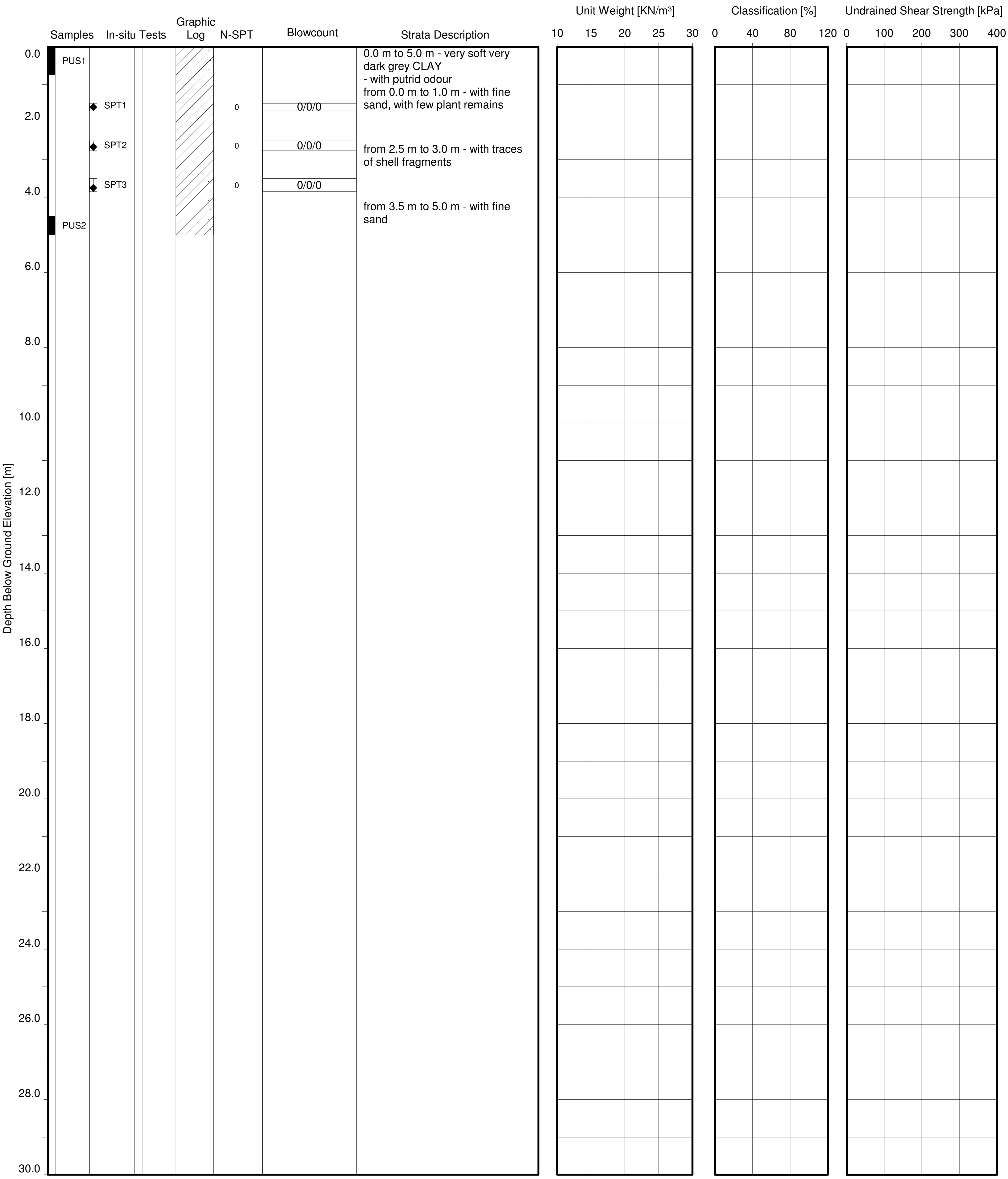
Date commenced : 10-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 8.0 m below ground surface
Penetration depth : to 8.0 m below ground surface
Ground elevation : -7.9 m
Co-ordinates : 686340 m E 7468053 m N

● Unit weight derived from water content
☒ Unit weight derived from volume mass calculation

Total Core Recovery
Solid Core Recovery
Rock Quality Designation
× Water content
○ Plastic limit
● Liquid limit
○—● Plasticity index
△ Percentage fines
☒ Carbonate content
■ Organic content
Relative density derived from CPT

△ Pocket penetrometer
○ Torvane
▽ Fallcone
⊕ Laboratory vane
● UU-triaxial
■ CU-triaxial
◪ Direct simple shear
◆ In-situ vane shear test
CU from CPT
Ø Slashed refers to remoulded soil

GEOTECHNICAL LOG
LOCATION POR-03
PORT OF RIO DE JANEIRO - GUANABARA BAY



Date commenced : 11-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 5.5 m below ground surface
Penetration depth : to 5.5 m below ground surface
Ground elevation : -10.3 m
Co-ordinates : 687357 m E 7467462 m N

- ● Unit weight derived from water content
- ☒ Unit weight derived from volume mass calculation

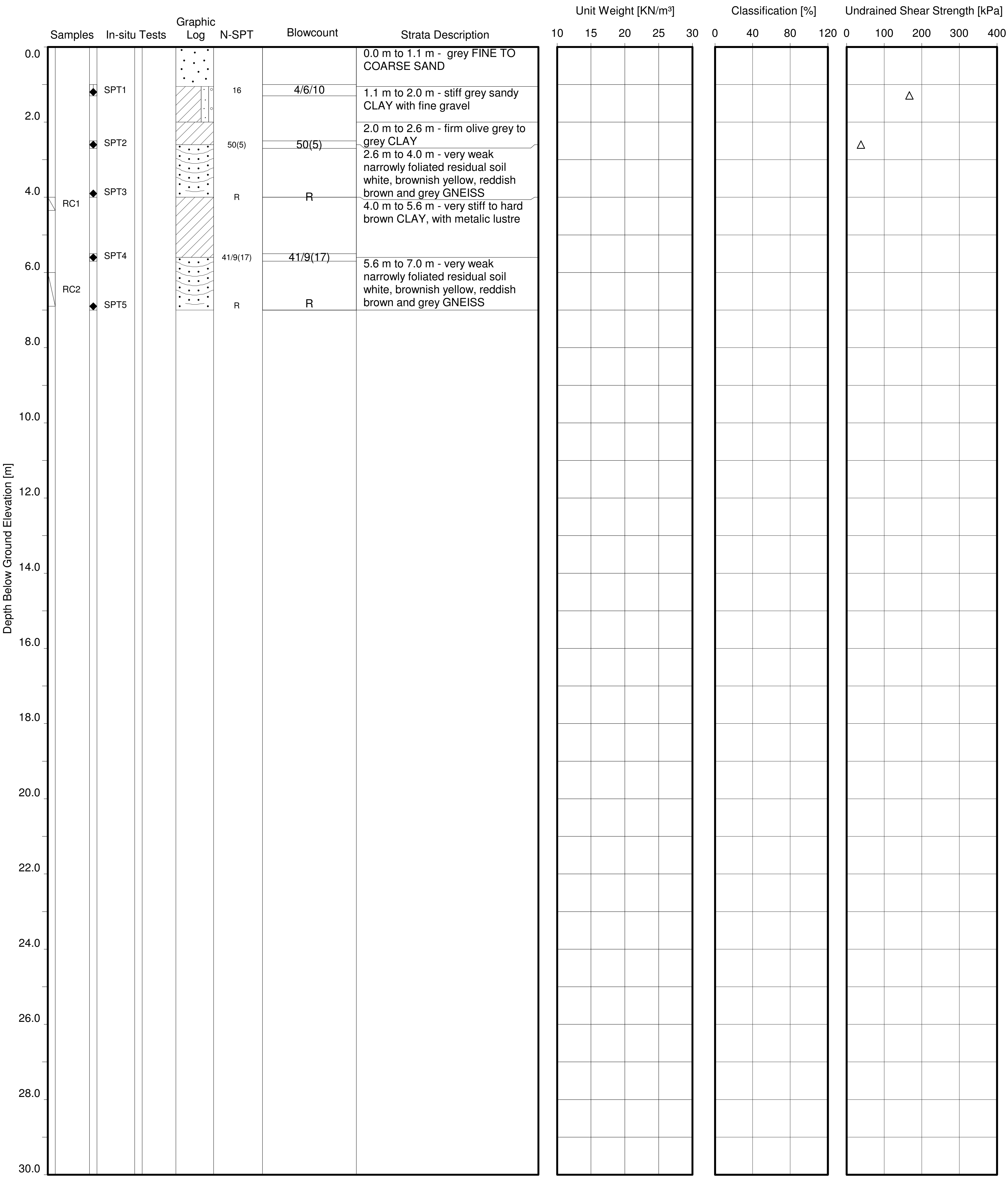
- Total Core Recovery
- Solid Core Recovery
- Rock Quality Designation
- × Water content
- ○ Plastic limit
- ● Liquid limit
- ○—● Plasticity index
- △ Percentage fines
- ☒ Carbonate content
- ■ Organic content
- Relative density derived from CPT

- △ Pocket penetrometer
- ○ Torvane
- ▽ Fallcone
- ⊕ Laboratory vane
- ● UU-triaxial
- ■ CU-triaxial
- ◪ Direct simple shear
- ◆ In-situ vane shear test
- CU from CPT
- Ø Slashed refers to remoulded soil

GEOTECHNICAL LOG

LOCATION POR-04

PORT OF RIO DE JANEIRO - GUANABARA BAY



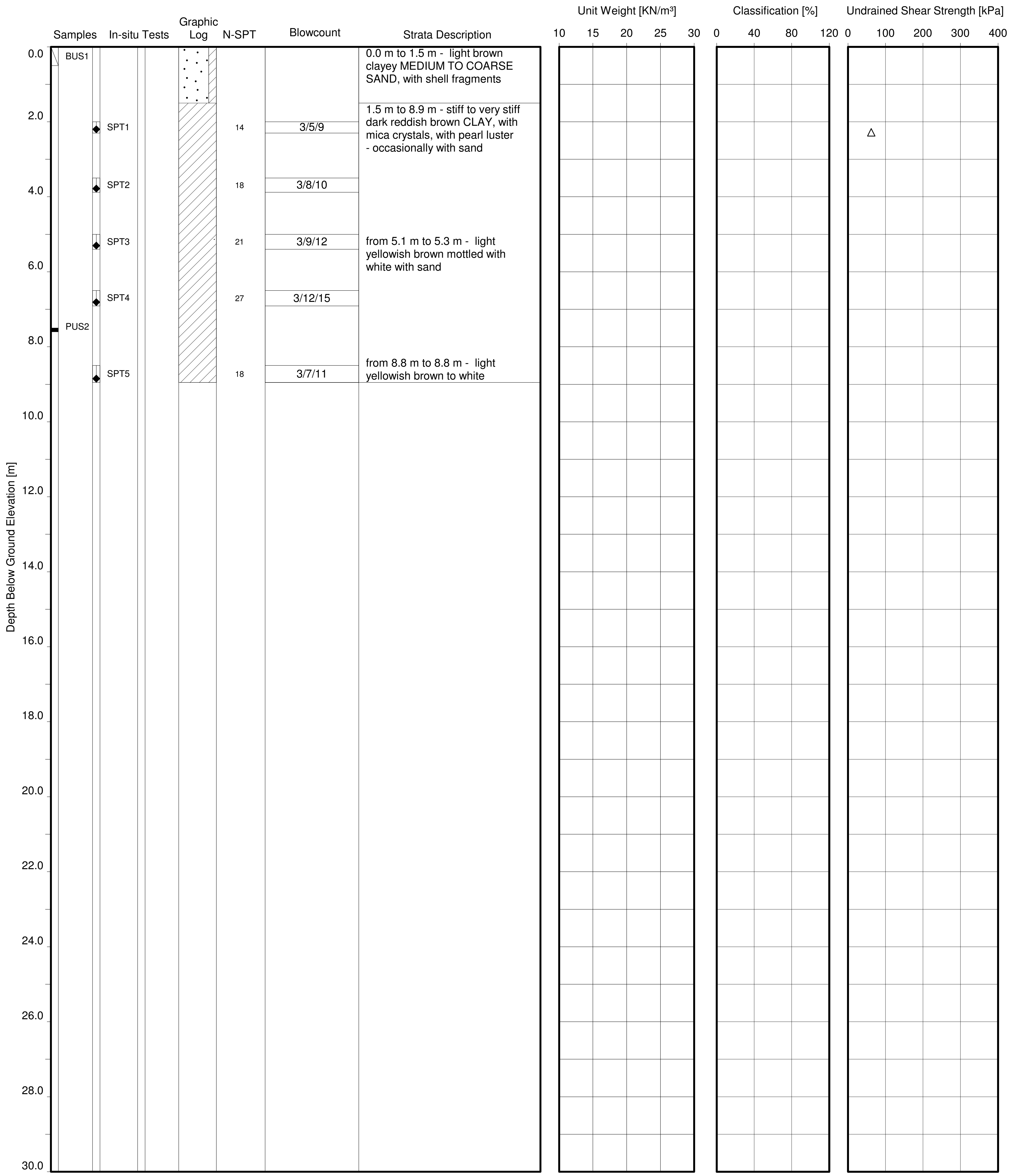
Date commenced : 09-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 7.0 m below ground surface
Penetration depth : to 7.2 m below ground surface
Ground elevation : -8.4 m
Co-ordinates : 685983 m E 7468255 m N

● Unit weight derived from water content
☒ Unit weight derived from volume mass calculation

Total Core Recovery
Solid Core Recovery
Rock Quality Designation
× Water content
○ Plastic limit
● Liquid limit
○—● Plasticity index
△ Percentage fines
☒ Carbonate content
■ Organic content
Relative density derived from CPT

△ Pocket penetrometer
○ Torvane
▽ Fallcone
⊕ Laboratory vane
● UU-triaxial
■ CU-triaxial
Direct simple shear
◆ In-situ vane shear test
CU from CPT
Ø Slashed refers to remoulded soil

GEOTECHNICAL LOG
LOCATION POR-05
PORT OF RIO DE JANEIRO - GUANABARA BAY



Date commenced : 09-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 8.9 m below ground surface
Penetration depth : to 8.9 m below ground surface
Ground elevation : -6.9 m
Co-ordinates : 685689 m E 7468507 m N

● Unit weight derived from water content
☒ Unit weight derived from volume mass calculation

Total Core Recovery
Solid Core Recovery
Rock Quality Designation
× Water content
○ Plastic limit
● Liquid limit
○—● Plasticity index
△ Percentage fines
☒ Carbonate content
■ Organic content
Relative density derived from CPT

△ Pocket penetrometer
○ Torvane
▽ Fallcone
⊕ Laboratory vane
● UU-triaxial
■ CU-triaxial
◪ Direct simple shear
◆ In-situ vane shear test
CU from CPT
∅ Slashed refers to remoulded soil

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Plate A6

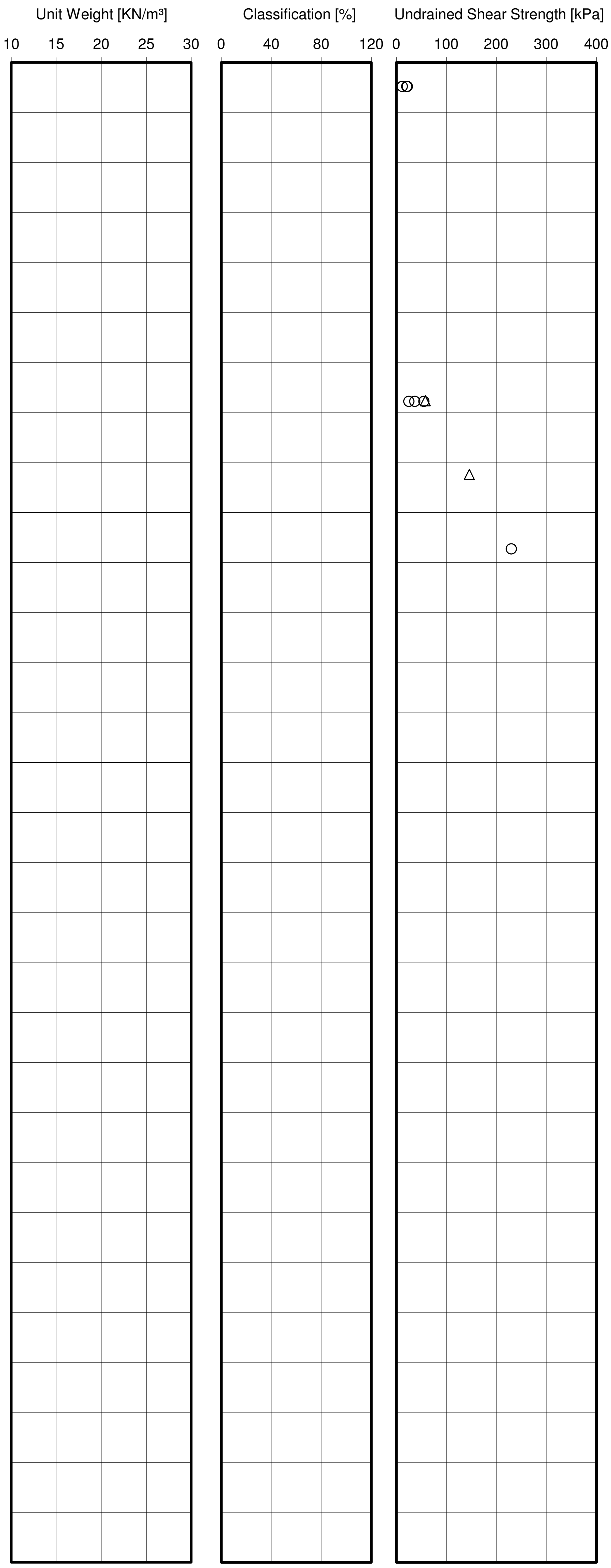
GEOTECHNICAL LOG

LOCATION POR-06

PORT OF RIO DE JANEIRO - GUANABARA BAY

Depth Below Ground Elevation [m]	Samples	In-situ Tests	Graphic Log	N-SPT	Blowcount	Strata Description
0.0	PUS1					0.0 m to 4.0 m - very soft to soft grey sandy CLAY at 0.5 m - light grey mottled with dark grey and brown
2.0		SPT1		0	0/0/0	
		SPT2		0	0/0/0	
4.0						4.0 m to 6.4 m - very soft to firm dark grey CLAY, occasionally with shells and shell fragments from 4.5 m to 5.0 m - with H2S odour at 6.0 m - with sand
		SPT3		0	0/0/0	
6.0	PUS2					6.4 m to 10.8 m - firm to very stiff grey sandy CLAY
8.0		SPT4		15	3/6/9	from 8.2 m to 9.8 m - mottled with brownish yellow at 9.5 m - with organic matter
10.0		SPT5		35	8/12/23	from 10.5 m to 10.8 m - brownish yellow mottled with grey
		SPT6		53	6/18/35	

Depth scale: 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0, 28.0, 30.0

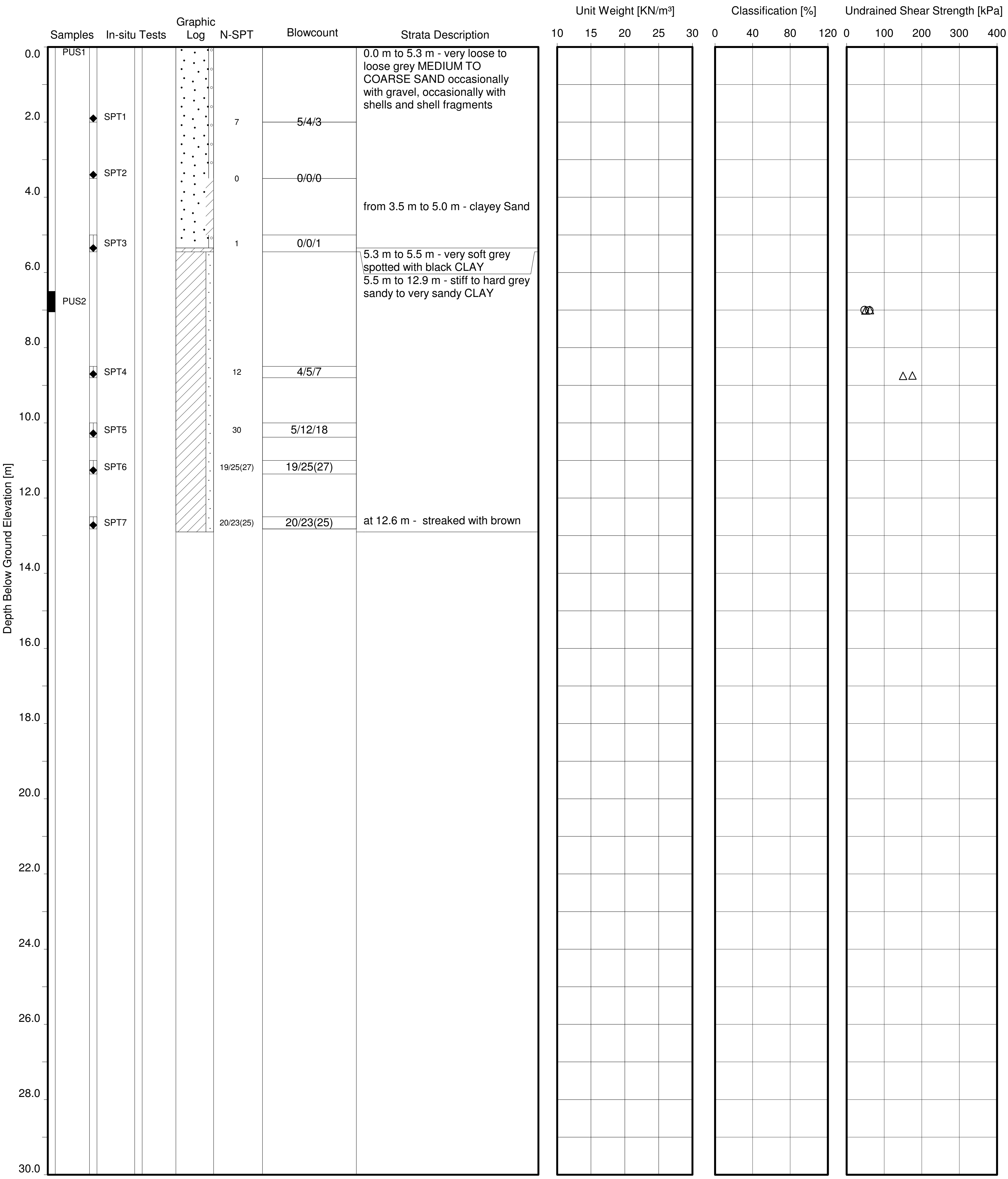


Date commenced : 06-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 10.8 m below ground surface
Penetration depth : to 10.9 m below ground surface
Ground elevation : -4.7 m
Co-ordinates : 684705 m E 7469406 m N

Legend:
- ● Unit weight derived from water content
- ☒ Unit weight derived from volume mass calculation
- Total Core Recovery
- Solid Core Recovery
- Rock Quality Designation
- × Water content
- ○ Plastic limit
- ● Liquid limit
- ○—● Plasticity index
- △ Percentage fines
- ☒ Carbonate content
- ■ Organic content
- Relative density derived from CPT
- △ Pocket penetrometer
- ○ Torvane
- ▽ Fallcone
- ⊕ Laboratory vane
- ● UU-triaxial
- ■ CU-triaxial
- Direct simple shear
- ◆ In-situ vane shear test
- CU from CPT
- Slashed refers to remoulded soil

Fugro Report No. VOO-002-REP-001(1)

GEOTECHNICAL LOG
LOCATION POR-07
PORT OF RIO DE JANEIRO - GUANABARA BAY



Date commenced	: 05-jun-2015
Method	: Percussion borehole drilling, sampling and testing
Recovery depth	: to 12.9 m below ground surface
Penetration depth	: to 12.9 m below ground surface
Ground elevation	: -3.7 m
Co-ordinates	: 684599 m E 7469536 m N

- ● Unit weight derived from water content
- ⊠ Unit weight derived from volume mass calculation

- Total Core Recovery
- Solid Core Recovery
- Rock Quality Designation
- × Water content
- ○ Plastic limit
- ● Liquid limit
- ○—● Plasticity index
- △ Percentage fines
- ⊠ Carbonate content
- ■ Organic content
- Relative density derived from CPT

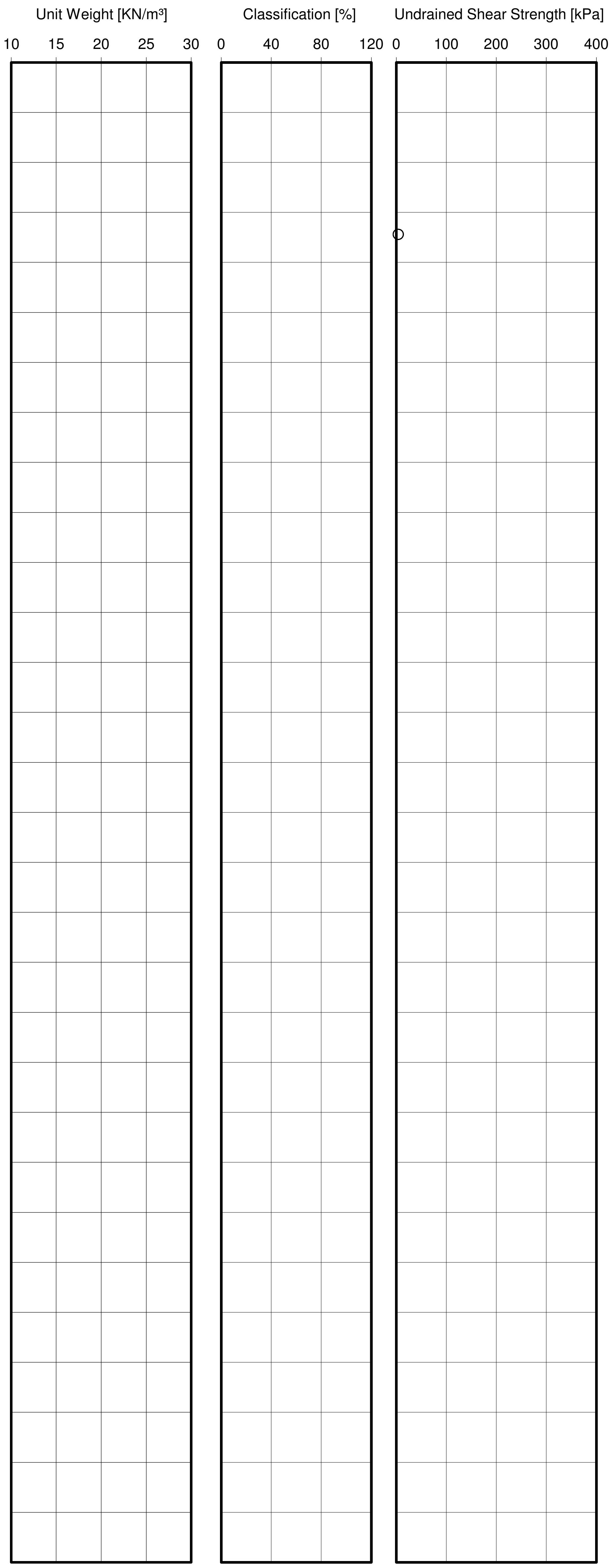
- △ Pocket penetrometer
- ○ Torvane
- ▽ Fallcone
- ⊕ Laboratory vane
- ● UU-triaxial
- ■ CU-triaxial
- Direct simple shear
- ◆ In-situ vane shear test
- CU from CPT
- Ø Slashed refers to remoulded soil

GEOTECHNICAL LOG

LOCATION POR-08

PORT OF RIO DE JANEIRO - GUANABARA BAY

Depth Below Ground Elevation [m]	Samples	In-situ Tests	N-SPT	Blowcount	Strata Description
0.0					0.0 m to 5.7 m - very soft very dark grey CLAY
1.0		SPT1	0	0/0/0	
2.5–3.5	PUS1				
4.0		SPT2	0	0/0/0	from 4.0 m to 5.7 m - with few shells and shell fragments, with few organic matter
5.7		SPT3	40	8/18/22	5.7 m to 9.8 m - very stiff light grey CLAY from 5.7 m to 5.9 m - slightly cemented grey spotted with brownish yellow Clay
7.2		SPT4	25	4/9/16	
8.7		SPT5	28	7/11/17	from 7.0 m to 9.8 m - with sand
9.7		SPT6	41	9/18/23	from 8.5 m to 9.8 m - with few fine gravel



Date commenced : 07-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 9.8 m below ground surface
Penetration depth : to 9.9 m below ground surface
Ground elevation : -6.5 m
Co-ordinates : 684113 m E 7468827 m N

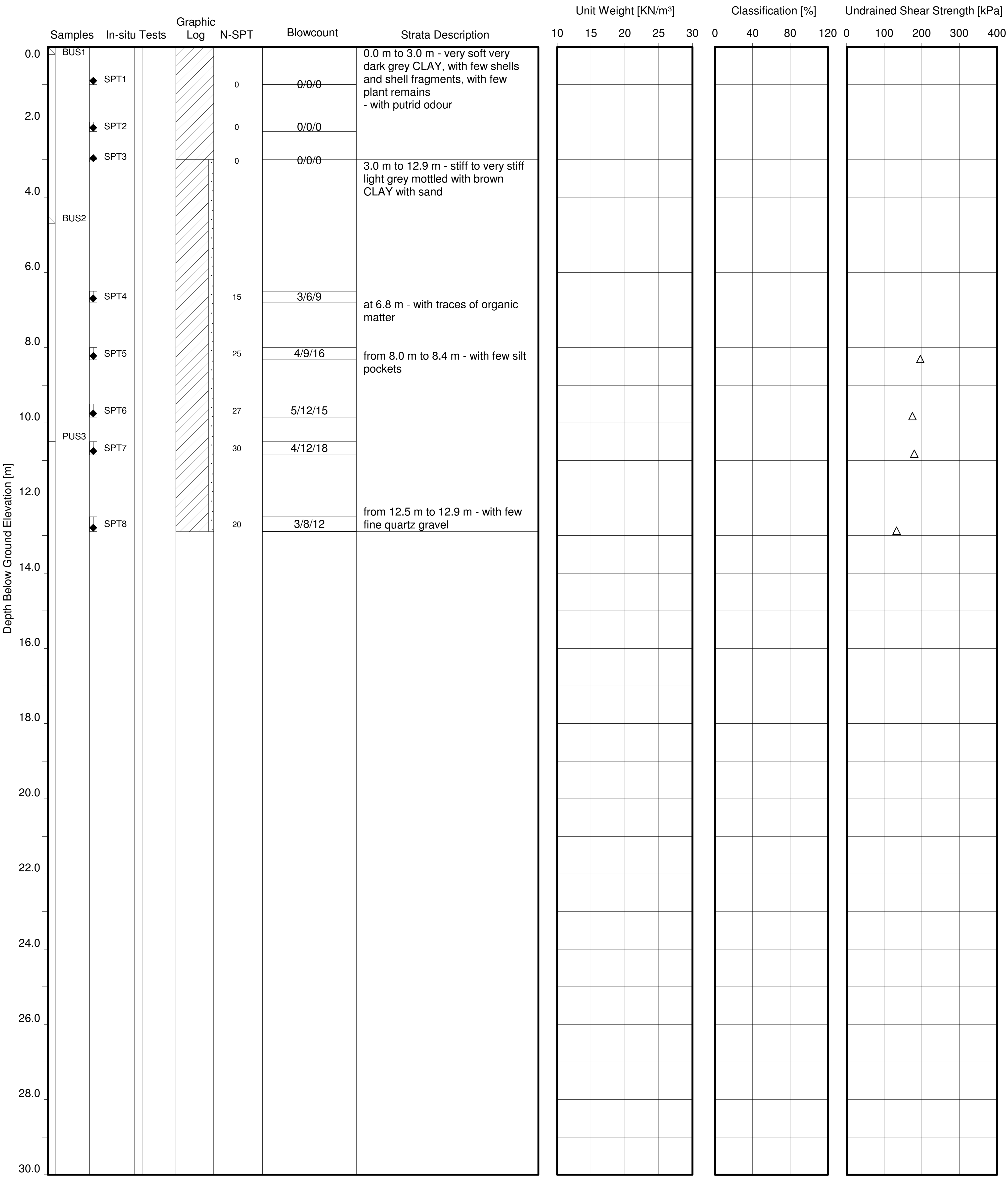
● Unit weight derived from water content
⊠ Unit weight derived from volume mass calculation

Total Core Recovery
Solid Core Recovery
Rock Quality Designation
× Water content
○ Plastic limit
● Liquid limit
○—● Plasticity index
△ Percentage fines
⊠ Carbonate content
■ Organic content
Relative density derived from CPT

△ Pocket penetrometer
○ Torvane
▽ Fallcone
⊕ Laboratory vane
● UU-triaxial
■ CU-triaxial
Direct simple shear
◆ In-situ vane shear test
CU from CPT
Ø Slashed refers to remoulded soil

Fugro Report No. VOO-002-REP-001(1)

GEOTECHNICAL LOG
LOCATION POR-09
PORT OF RIO DE JANEIRO - GUANABARA BAY



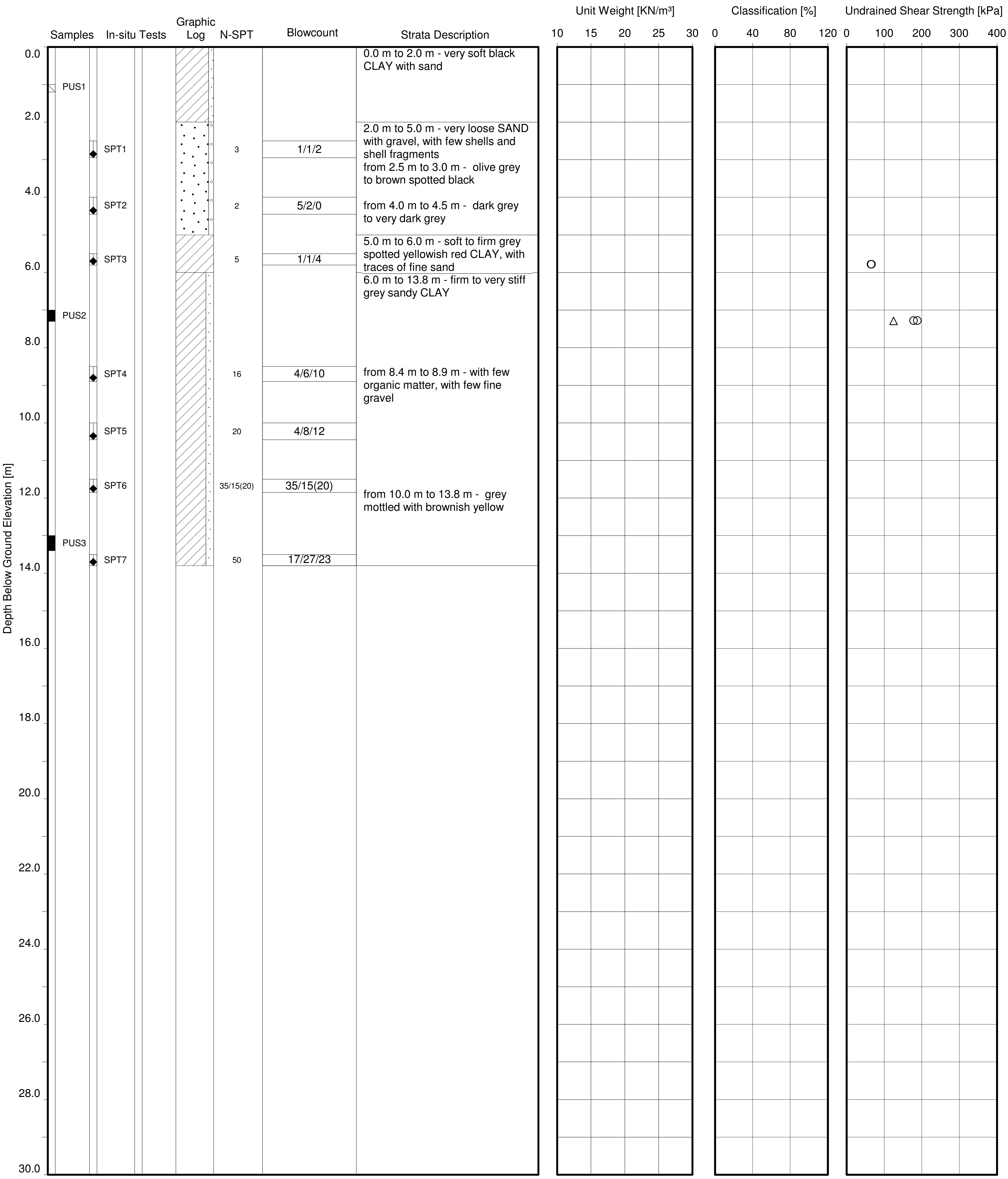
Date commenced : 08-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 12.9 m below ground surface
Penetration depth : to 13.0 m below ground surface
Ground elevation : -3.5 m
Co-ordinates : 683904 m E 7468601 m N

Unit weight derived from water content
Unit weight derived from volume mass calculation

Total Core Recovery
Solid Core Recovery
Rock Quality Designation
Water content
Plastic limit
Liquid limit
Plasticity index
Percentage fines
Carbonate content
Organic content
Relative density derived from CPT

Pocket penetrometer
Torvane
Fallcone
Laboratory vane
UU-triaxial
CU-triaxial
Direct simple shear
In-situ vane shear test
CU from CPT
Slashed refers to remoulded soil

GEOTECHNICAL LOG
LOCATION POR-10
PORT OF RIO DE JANEIRO - GUANABARA BAY



Date commenced : 08-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 13.8 m below ground surface
Penetration depth : to 14.0 m below ground surface
Ground elevation : -1.6 m
Co-ordinates : 683732 m E 7468392 m N

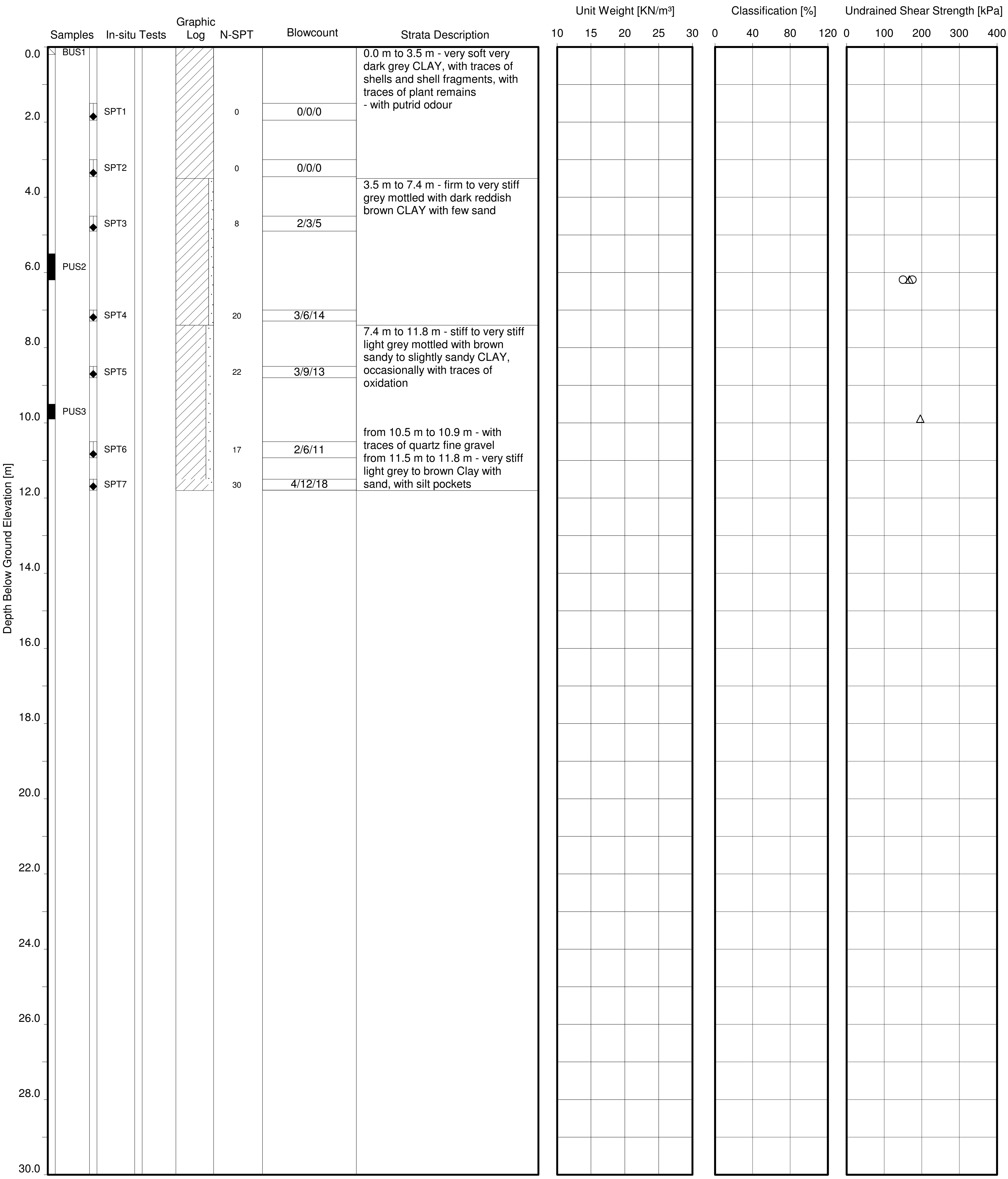
● Unit weight derived from water content
⊠ Unit weight derived from volume mass calculation

Total Core Recovery
Solid Core Recovery
Rock Quality Designation
Water content
Plastic limit
Liquid limit
Plasticity index
Percentage fines
Carbonate content
Organic content
Relative density derived from CPT

Pocket penetrometer
Torvane
Fallcone
Laboratory vane
UU-triaxial
CU-triaxial
Direct simple shear
In-situ vane shear test
CU from CPT
Slashed refers to remoulded soil

Fugro Report No. VOO-002-REP-001(1)

GEOTECHNICAL LOG
LOCATION POR-11
PORT OF RIO DE JANEIRO - GUANABARA BAY



Fugro Report No. VOO-002-REP-001(1)

Date commenced : 07-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 11.8 m below ground surface
Penetration depth : to 12.0 m below ground surface
Ground elevation : -3.7 m
Co-ordinates : 684019 m E 7468709 m N

● Unit weight derived from water content
⊠ Unit weight derived from volume mass calculation

Total Core Recovery
Solid Core Recovery
Rock Quality Designation
× Water content
○ Plastic limit
● Liquid limit
○—● Plasticity index
△ Percentage fines
⊠ Carbonate content
■ Organic content
Relative density derived from CPT

△ Pocket penetrometer
○ Torvane
▽ Fallcone
⊕ Laboratory vane
● UU-triaxial
■ CU-triaxial
◪ Direct simple shear
◆ In-situ vane shear test
CU from CPT
Ø Slashed refers to remoulded soil

GEOTECHNICAL LOG
LOCATION POR-12
PORT OF RIO DE JANEIRO - GUANABARA BAY

Depth Below Ground Elevation [m]	Samples	In-situ Tests	N-SPT	Blowcount	Strata Description
0.0					0.0 m to 5.2 m - very soft very dark grey CLAY, with traces of shells and shell fragments
~1.0		SPT1	0	0/0/0	
~2.5	PUS1				from 2.5 m to 3.5 m - with H2S odour
~4.0		SPT2	0	0/0/0	
~5.0		SPT3	0	0/0/0	
5.2					5.2 m to 5.3 m - light grey clayey MEDIUM TO COARSE SAND
5.3					5.3 m to 7.0 m - very stiff grey sandy CLAY
~6.6		SPT4	34	1/12/22	
7.0					7.0 m to 9.9 m - dense light grey to grey clayey quartz MEDIUM TO COARSE SAND
~7.6		SPT5	28	15/14/14	
8.7					from 8.7 m to 9.0 m - hard grey mottled with brown Clay with sand, with silt pockets
~8.6		SPT6	35	5/12/23	
~9.6		SPT7	25	9/11/14	

Depth scale: 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0, 28.0, 30.0

Unit Weight [KN/m³]: 10, 15, 20, 25, 30

Classification [%]: 0, 40, 80, 120

Undrained Shear Strength [kPa]: 0, 100, 200, 300, 400

Date commenced : 06-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 9.9 m below ground surface
Penetration depth : to 9.9 m below ground surface
Ground elevation : -9.4 m
Co-ordinates : 684812 m E 7469257 m N

● Unit weight derived from water content
⊠ Unit weight derived from volume mass calculation

Total Core Recovery
Solid Core Recovery
Rock Quality Designation
× Water content
○ Plastic limit
● Liquid limit
○—● Plasticity index
△ Percentage fines
⊠ Carbonate content
■ Organic content
Relative density derived from CPT

△ Pocket penetrometer
○ Torvane
▽ Fallcone
⊕ Laboratory vane
● UU-triaxial
■ CU-triaxial
Direct simple shear
◆ In-situ vane shear test
CU from CPT
Ø Slashed refers to remoulded soil

GEOTECHNICAL LOG
LOCATION POR-14
PORT OF RIO DE JANEIRO - GUANABARA BAY

Depth Below Ground Elevation [m]	Samples	In-situ Tests	Graphic Log	N-SPT	Blowcount	Strata Description
0.0	BUS1					0.0 m to 1.0 m - very soft black CLAY with sand
1.0	PUS2					1.0 m to 2.3 m - very stiff light grey sandy CLAY from 2.0 m to 2.3 m - with few gravel, with few organic matter
2.0		SPT1		20	5/7/13	

Unit Weight [KN/m³]: 10, 15, 20, 25, 30

Classification [%]: 0, 40, 80, 120

Undrained Shear Strength [kPa]: 0, 100, 200, 300, 400

Depth axis: 0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0, 28.0, 30.0

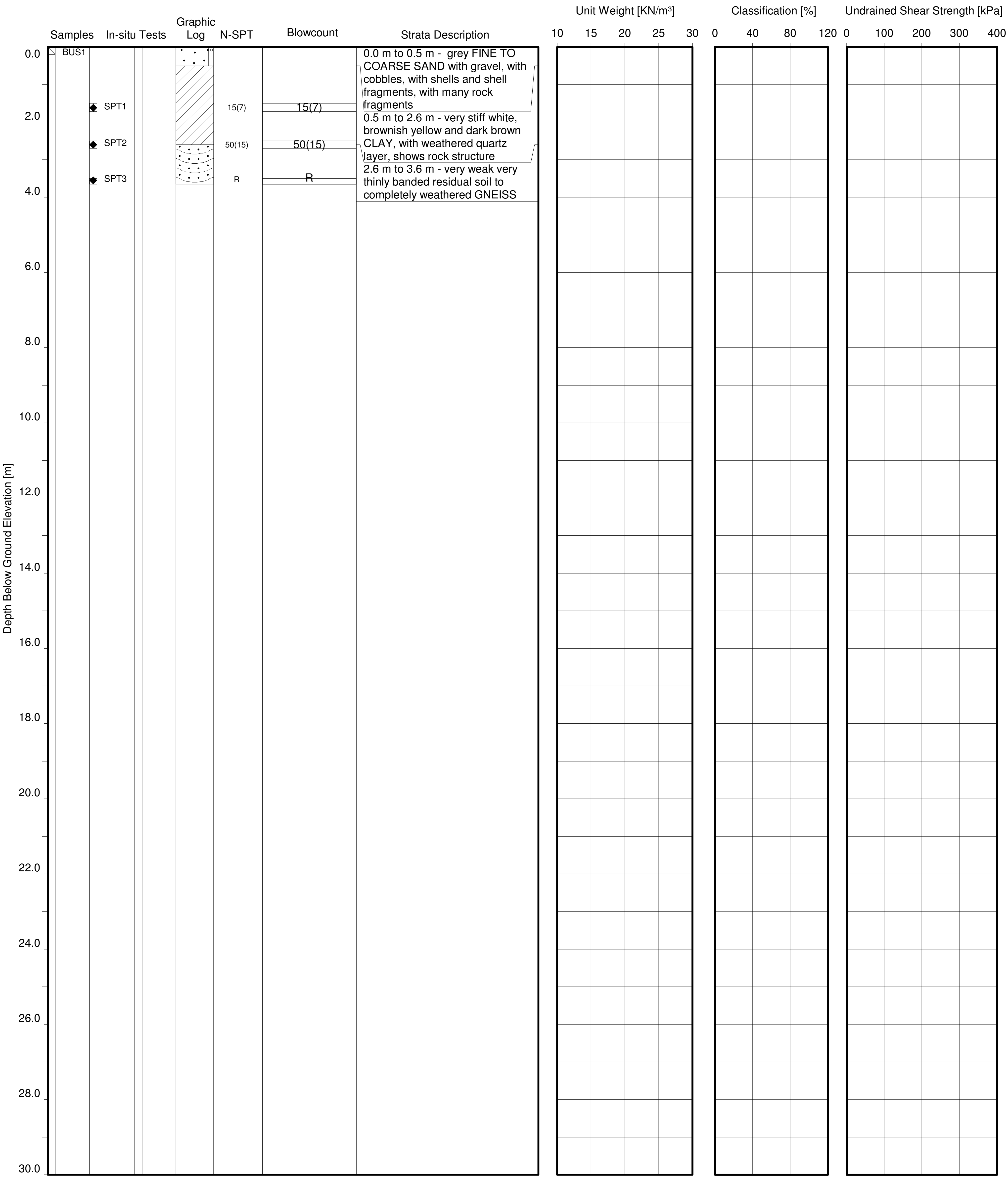
Date commenced : 08-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 2.3 m below ground surface
Penetration depth : to 2.5 m below ground surface
Ground elevation : -13.0 m
Co-ordinates : 683672 m E 7468500 m N

Legend:

- Unit weight derived from water content
- Unit weight derived from volume mass calculation
- Total Core Recovery
- Solid Core Recovery
- Rock Quality Designation
- Water content
- Plastic limit
- Liquid limit
- Plasticity index
- Percentage fines
- Carbonate content
- Organic content
- Relative density derived from CPT
- Pocket penetrometer
- Torvane
- Fallcone
- Laboratory vane
- UU-triaxial
- CU-triaxial
- Direct simple shear
- In-situ vane shear test
- CU from CPT
- Slashed refers to remoulded soil

Fugro Report No. VOO-002-REP-001(1)

GEOTECHNICAL LOG
LOCATION POR-15
PORT OF RIO DE JANEIRO - GUANABARA BAY



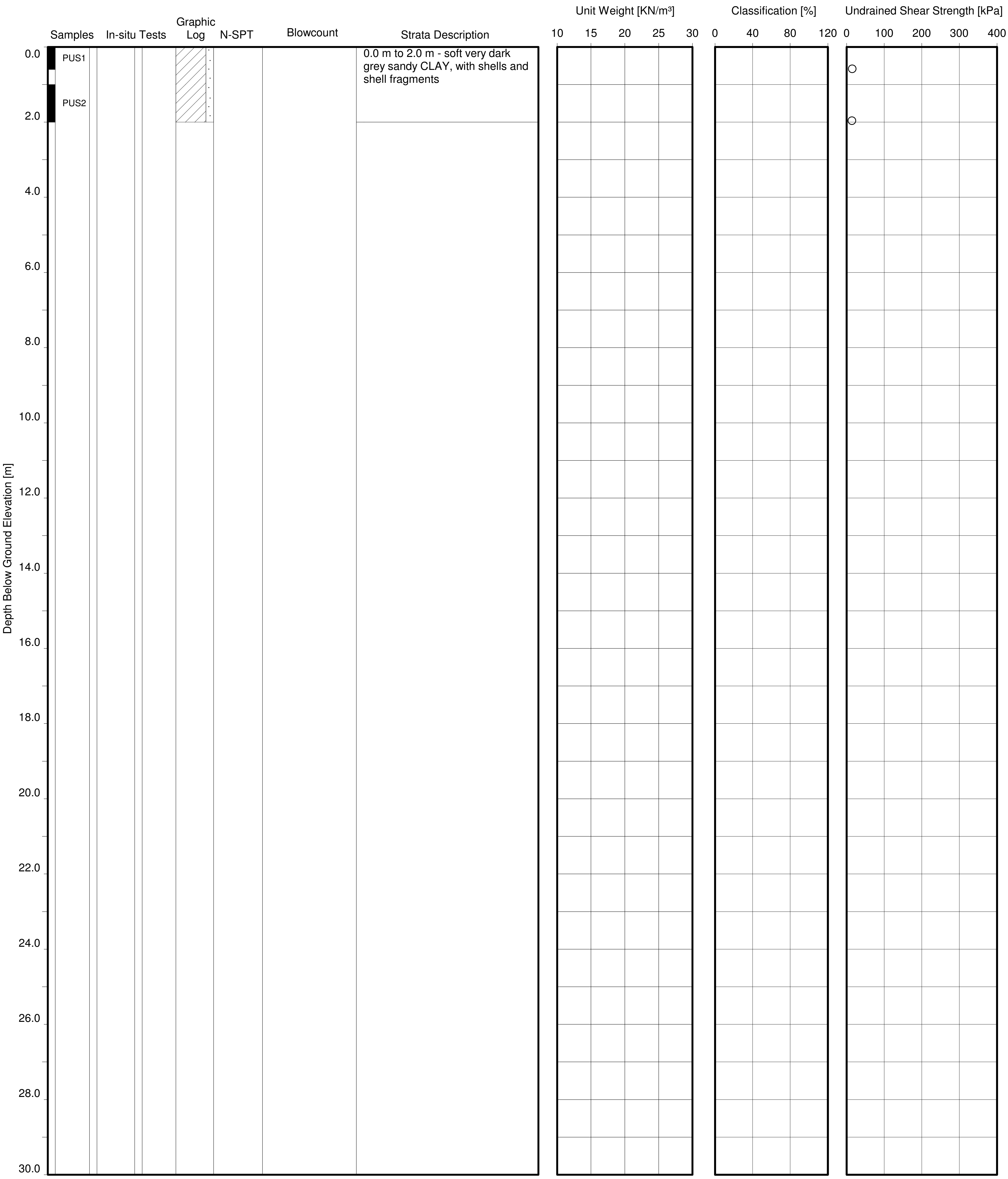
Date commenced : 10-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 3.7 m below ground surface
Penetration depth : to 3.7 m below ground surface
Ground elevation : -5.6 m
Co-ordinates : 688871 m E 7465047 m N

● Unit weight derived from water content
⊠ Unit weight derived from volume mass calculation

Total Core Recovery
Solid Core Recovery
Rock Quality Designation
× Water content
○ Plastic limit
● Liquid limit
○—● Plasticity index
△ Percentage fines
⊠ Carbonate content
■ Organic content
Relative density derived from CPT

△ Pocket penetrometer
○ Torvane
▽ Fallcone
⊕ Laboratory vane
● UU-triaxial
■ CU-triaxial
◪ Direct simple shear
◆ In-situ vane shear test
CU from CPT
Ø Slashed refers to remoulded soil

GEOTECHNICAL LOG
LOCATION POR-17
PORT OF RIO DE JANEIRO - GUANABARA BAY



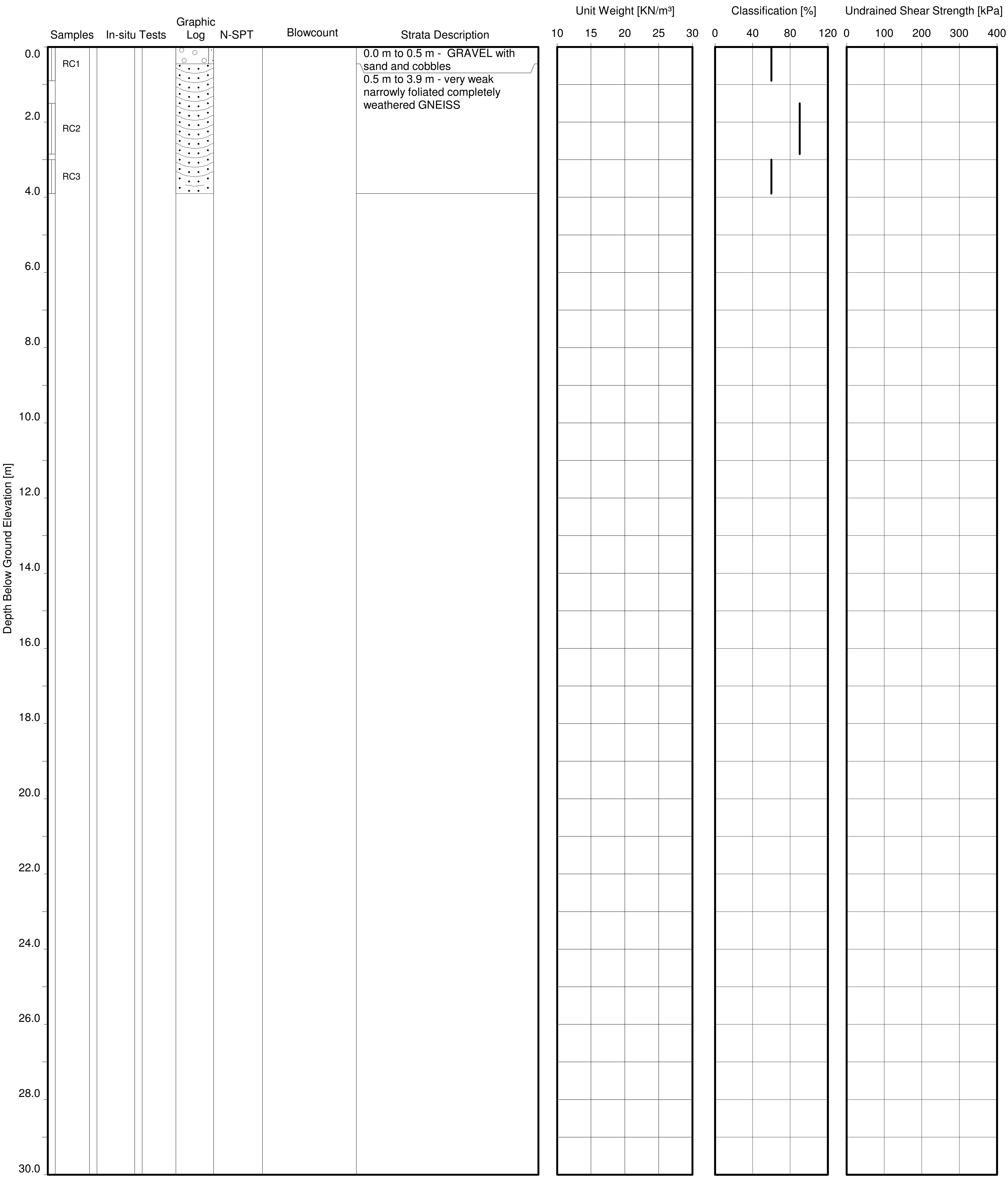
Date commenced : 10-jun-2015
Method : Percussion borehole drilling, sampling and testing
Recovery depth : to 2.0 m below ground surface
Penetration depth : to 2.0 m below ground surface
Ground elevation : -5.9 m
Co-ordinates : 688791 m E 7465252 m N

● Unit weight derived from water content
☒ Unit weight derived from volume mass calculation

Total Core Recovery
Solid Core Recovery
Rock Quality Designation
× Water content
○ Plastic limit
● Liquid limit
○—● Plasticity index
△ Percentage fines
☒ Carbonate content
■ Organic content
Relative density derived from CPT

△ Pocket penetrometer
○ Torvane
▽ Fallcone
⊕ Laboratory vane
● UU-triaxial
■ CU-triaxial
Direct simple shear
◆ In-situ vane shear test
CU from CPT
Ø Slashed refers to remoulded soil

GEOTECHNICAL LOG
LOCATION POR-18
PORT OF RIO DE JANEIRO - GUANABARA BAY



Date commenced : 12-jun-2015
Method : Rotary borehole drilling, sampling and testing
Recovery depth : to 3.9 m below ground surface
Penetration depth : to 4.5 m below ground surface
Ground elevation : -3.9 m
Co-ordinates : 688858 m E 7465034 m N

Unit weight derived from water content
Unit weight derived from volume mass calculation

Total Core Recovery
Solid Core Recovery
Rock Quality Designation
Water content
Plastic limit
Liquid limit
Plasticity index
Percentage fines
Carbonate content
Organic content
Relative density derived from CPT

Pocket penetrometer
Torvane
Fallcone
Laboratory vane
UU-triaxial
CU-triaxial
Direct simple shear
In-situ vane shear test
CU from CPT
Slashed refers to remoulded soil

GEOTECHNICAL LOG

LOCATION POR-19

PORT OF RIO DE JANEIRO - GUANABARA BAY

SECTION B: STANDARD PENETRATION TESTS

TEXT – SECTION B: Page

B STANDARD PENETRATION TESTS

B.1 DETAILS

The SPTs were conducted according to Brazilian Standard NBR 6484:1997.

Energy measurement was conducted to suite the Standard. The results are shown on Appendix 2, only in Portuguese. The average energy measured was between 61.7% and 63%. With the presented values, the correction of the SPT values is at the discretion of the client.

B.2 COMMENTS ON RESULTS

For the majority of the very soft clays tested, the SPT sampler had self-weight penetration, meaning that no blows were recorded for each 45 cm of penetration.

The SPT sample at 2.0m on location POR-08 had no recovery. A sample from the bailer was collected.

The SPT results are in accordance with the sampled soils.

B1.3 PRACTICE FOR STANDARD PENETRATION TEST - SPT

In-situ Test – SPT

General Procedure:	Refer to document titled "Standard Penetration Test" (Fugro ref. FEBV/CDE/APP/036), presented in Appendix 1
Hammer Drop System:	Automatic trip hammer
Operating Speed of Rotation of Cathead:	0 to 240 rpm
Sampling Rods:	1"
Split Liner:	Applicable
Core Catcher:	Not Applicable
Solid Cone:	Not Applicable
SPT Termination:	Penetration of 45 cm or refusal

Sample Handling

Refer to Main Text and sub-section "Practice for Sample Handling and Laboratory Testing" presented in report section titled "Geotechnical Laboratory Test Results"

References

Computer Program GeODin®, Recording, Presentation and Analysis of Geo-data.
NBR 6484:2001: Solo – Sondagem de Simples Reconhecimento com SPT – Método de Ensaio (2001)

SECTION C: GEOTECHNICAL LABORATORY TEST RESULTS

SECTION C1: LABORATORY TESTING OVERVIEW

SECTION C2: LABORATORY CLASSIFICATION TEST RESULTS

SECTION C1: LABORATORY TESTING OVERVIEW

TEXT – SECTION C1: Page

C1. LABORATORY TESTING OVERVIEW

C1.1 SUMMARY OF LABORATORY TESTS

Only index strength tests (PP and TV) were conducted offshore. The values for undrained shear strength (s_u) measured by the torvane tests and pocket penetrometer are indicative only.
This report will be updated with the onshore laboratory results in the next issue.

C1.2 PRACTICE FOR SAMPLE HANDLING AND LABORATORY TESTING

Initial Sample Handling

Undisturbed Sample:	Identification/labelling Measurement of recovery Logging of top and bottom of sample Waxing at both ends and fixing plastic end caps at both ends with tape
Disturbed Sample:	Measurement of recovery Placing the sample in a zip bag and close it, air tight Identification/labelling Logging of the sample
Core Barrel:	On-deck removal of liner core from barrel Initial identification/labelling Measurement of recovery and logging of core

Sample Protection

Packaging of Sample in Tube:	Bubble wrap placed around the tubes to avoid vibration Transportation container lined with rubber and polystyrene All samples placed in vertical position in labelled shipping container

Sample Transport

Fugro Sample Transport:	Off-loading from jack-up platform Road-freight to Fugro In Situ’s laboratory in Curitiba

C1.3 INDEX LABORATORY TESTS

C1.3.1 DETAILS

The torvane and pocket penetrometer have a limited accuracy in silt, sandy clay and/or clays with shells and shell fragments. The results of index tests performed in such soils should be analysed with caution.

SECTION C2: LABORATORY CLASSIFICATION TEST RESULTS

LIST OF PLATES IN SECTION C2: Plate

GeODin/Laboratory Classification Test Results (with Ground Descriptions).GLO/2015-06-19 11:23:33

FUGRO IN SITU GEOTECNIA

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-01

PORT OF RIO DE JANEIRO - GUANABARA BAY

Sample				Unit Weight [kN/m³]							Atterberg Limits				c_u [kPa]			
No.	Ground Description	Test Depth [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
1	CLAY	0.00																
		0.50																
		1.00													166			
	SAND	1.50																
	CLAY	1.60																
		1.80													213			
		1.95													179			
	CLAY	1.50																
		3.00													196			
2	CLAY	3.00																
		3.20													171			
		3.40													204			
	CLAY	3.00																
		4.50													179			
3	CLAY	4.50																
	SAND	5.50																

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

FUGRO

FUGRO IN SITU GEOTECNIA

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-02

PORT OF RIO DE JANEIRO - GUANABARA BAY

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	0.00 m to 0.70 m - very soft very dark grey sandy CLAY, with shells and shell fragments	0.00																
		0.69														11		
	no recovery	1.50																
2	2.50 m to 2.80 m - soft very dark grey sandy CLAY	2.50																
	2.80 m to 3.10 m - firm olive grey to grey sandy CLAY	2.80																
		3.09														47		
		3.09														55		
		3.10													38			
	4.00 m to 4.30 m - stiff grey to light grey mottled with brownish yellow CLAY with sand	4.00																
		4.10													121			
		4.20													142			
		4.30													213			
3	5.00 m to 5.80 m - very stiff grey to light grey sandy CLAY	5.00																
		5.79													219	200		

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

LABORATORY CLASSIFICATION TEST RESULTS
LOCATION POR-03
PORT OF RIO DE JANEIRO - GUANABARA BAY

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	0.00 m to 0.50 m - very soft very dark grey sandy CLAY, with many shells and shell fragments	0.00																
	0.50 m to 0.90 m - soft to firm olive grey sandy CLAY	0.50																
		0.87														39		
		0.88														25		
	1.50 m to 1.70 m - soft to firm olive grey sandy CLAY	1.50																
	1.70 m to 1.95 m - olive grey clayey FINE SAND	1.70																
2	2.50 m to 2.90 m - grey to olive grey sandy CLAY	2.50																
		2.70													88			
		2.90													200			
3	3.50 m to 3.85 m - very stiff grey to light grey mottled with olive grey and brownish yellow sandy CLAY - at bottom with gravel	3.50																
		3.60													154			
		3.70													213			
		3.80													208			
		3.85													238			
2	4.50 m to 5.00 m - very stiff light grey to brownish yellow sandy CLAY	4.50																
		4.95													213	238		
		5.00													150	160		
4	6.00 m to 6.30 m - very stiff light grey to brownish yellow sandy CLAY with fine white gravel	6.00																
5	7.00 m to 7.40 m - medium dense light brown COARSE SAND TO FINE GRAVEL	7.00																
	7.40 m to 7.45 m - stiff light grey sandy CLAY	7.40																

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-03

PORT OF RIO DE JANEIRO - GUANABARA BAY

FUGRO IN SITU GEOTECNIA

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
6	7.50 m to 7.75 m - medium dense light brown COARSE SAND TO FINE GRAVEL	7.50																
	7.75 m to 7.95 m - medium dense light grey to brownish yellow clayey SAND	7.75																

Key:

- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

FUGRO IN SITU GEOTECNIA

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-04

PORT OF RIO DE JANEIRO - GUANABARA BAY

Sample				Unit Weight [kN/m³]							Atterberg Limits				c_u [kPa]			
No.	Ground Description	Test Depth [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
1	0.00 m to 0.74 m - very soft very dark grey CLAY with sand - with putrid odour - with plant remains	0.00																
	1.50 m to 1.70 m - very soft very dark grey CLAY - with putrid odour	1.50																
2	2.50 m to 2.76 m - very soft very dark grey CLAY, with traces of shell fragments - with putrid odour	2.50																
3	3.50 m to 3.85 m - very soft very dark grey CLAY with fine sand - with putrid odour	3.50																
2	4.50 m to 5.00 m - very soft very dark grey CLAY with fine sand - with putrid odour	4.50																

Key:

- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-05

PORT OF RIO DE JANEIRO - GUANABARA BAY

FUGRO IN SITU GEOTECNIA

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	1.00 m to 1.05 m - grey FINE TO COARSE SAND	1.00																
	1.05 m to 1.30 m - stiff grey sandy CLAY with fine gravel	1.05																
		1.29													167			
2	2.50 m to 2.60 m - firm olive grey to grey CLAY	2.50																
	2.60 m to 2.70 m - striped white brownish yellow reddish brown and light grey SAND, with rock structure	2.60													38			
3	no recovery	4.00																
1	4.00 m to 4.35 m - hard brown CLAY, with metallic luster	4.00																
4	5.50 m to 5.70 m - hard brown CLAY, with metallic luster	5.50																
2	6.00 m to 6.90 m - very weak very thinly banded residual soil white brownish yellow reddish brown and grey GNEISS	6.00																
5	no recovery	7.00																

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-06

PORT OF RIO DE JANEIRO - GUANABARA BAY

FUGRO IN SITU GEOTECNIA

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	0.00 m to 0.50 m - light brown very clayey MEDIUM TO COARSE SAND, with shell fragments	0.00																
	2.00 m to 2.30 m - stiff light grey mottled with dark reddish brown CLAY, with pearl luster	2.00																
		2.28													63			
2	3.50 m to 3.88 m - stiff white mottled with dark reddish brown CLAY with sand, with mica crystals, with traces of quartz gravel	3.50																
3	5.00 m to 5.10 m - very stiff dark reddish brown CLAY, with mica crystals, with traces of sand, with pearl luster	5.00																
	5.10 m to 5.28 m - light yellowish brown white slightly sandy CLAY	5.10																
	5.28 m to 5.40 m - very stiff dark reddish brown CLAY, with mica crystals, with traces of sand, with pearl luster	5.28																
4	6.50 m to 6.91 m - very stiff dark reddish brown CLAY, with mica crystals, with pearl luster	6.50																
2	7.50 m to 7.60 m - very stiff dark reddish brown CLAY, with mica crystals, with pearl luster	7.50																
5	8.50 m to 8.77 m - stiff dark reddish brown CLAY, with mica crystals, with pearl luster	8.50																
	8.77 m to 8.82 m - white to pale yellow CLAY	8.77																
	8.82 m to 8.95 m - stiff dark reddish brown CLAY, with mica crystals, with pearl luster	8.82																

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

FUGRO IN SITU GEOTECNIA

GeODin/Laboratory Classification Test Results (with Ground Descriptions).GLO/2015-06-19 11:25:48

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-07

PORT OF RIO DE JANEIRO - GUANABARA BAY

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	0.00 m to 0.50 m - very soft light grey mottled with dark grey and dark brown sandy CLAY	0.00																
		0.48														21		
		0.48														22		
		0.48														12		
	1.50 m to 1.95 m - very soft grey sandy CLAY	1.50																
2	3.00 m to 3.45 m - very soft grey sandy CLAY	3.00																
3	4.50 m to 4.95 m - very soft dark grey CLAY, with few shells and shell fragments - with H2S odour	4.50																
2	6.00 m to 6.40 m - firm dark grey CLAY with sand	6.00																
	6.40 m to 6.80 m - firm grey sandy CLAY	6.40																
		6.77													58			
		6.78														37		
		6.78														55		
		6.78														25		
4	8.00 m to 8.25 m - stiff grey spotted with brownish yellow sandy CLAY	8.00																
		8.24													146			
5	9.50 m to 9.75 m - very stiff grey mottledwith brownish yellow very sandy CLAY, with traces of organic matter	9.50																
		9.73														230		
6	10.50 m to 10.75 m - very stiff to hard brownish yellow mottled with grey sandy CLAY	10.50																

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_U : undrained shear strength
- 10r : r refers to test on remoulded soil

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-08

PORT OF RIO DE JANEIRO - GUANABARA BAY

FUGRO IN SITU GEOTECNIA

GeODin/Laboratory Classification Test Results (with Ground Descriptions).GLO/2015-06-19 11:26:04

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	no recovery	0.00																
		2.00																
2		3.50																
3	5.00 m to 5.35 m - very loose grey MEDIUM TO COARSE SAND with gravel, with few shells and shell fragments	5.00																
	5.35 m to 5.45 m - very soft grey spotted black CLAY	5.35																
2	6.50 m to 7.05 m - firm grey sandy CLAY	6.50																
		7.00													63	48		
		7.01													50	60		
4	8.50 m to 8.80 m - very stiff grey sandy CLAY	8.50																
		8.74													175			
		8.75													150			
5	10.00 m to 10.38 m - very stiff grey very sandy CLAY	10.00																
6	11.00 m to 11.36 m - hard grey sandy CLAY	11.00																
7	12.50 m to 12.82 m - hard grey very sandy CLAY - at top brown inclusions	12.50																

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

GeODin/Laboratory Classification Test Results (with Ground Descriptions).GLO/2015-06-19 11:26:22

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-09

PORT OF RIO DE JANEIRO - GUANABARA BAY

FUGRO IN SITU GEOTECNIA

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	1.00 m to 1.45 m - very soft dark grey CLAY	1.00																
	2.50 m to 3.45 m - very soft very dark grey CLAY	2.50																
		3.44														4		
		3.44														4		
2	4.00 m to 4.45 m - very soft very dark grey CLAY, with few shells and shell fragments, with few organic matter	4.00																
3	5.50 m to 5.65 m - firm very dark grey CLAY, with few shells and shell fragments, with few organic matter	5.50																
	5.65 m to 5.90 m - very stiff slightly cemented light grey spotted with brownish yellow CLAY	5.65																
4	7.00 m to 7.30 m - very stiff light grey CLAY with sand	7.00																
5	8.50 m to 8.90 m - very stiff light grey CLAY with sand with fine gravel	8.50																
6	9.50 m to 9.80 m - very stiff light grey CLAY with sand with fine gravel	9.50																

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_s : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

GeODin/Laboratory Classification Test Results (with Ground Descriptions).GLO/2015-06-19 11:26:39

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-10

PORT OF RIO DE JANEIRO - GUANABARA BAY

FUGRO IN SITU GEOTECNIA

Sample		Test	w	Unit Weight [kN/m³]				ρ_s	Carb.	Org.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	Test Depth [m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
1	0.00 m to 0.20 m - very soft very dark grey to black CLAY, with shell fragments, with plant remains - with putrid odour	0.00																
	no recovery	1.00																
2	2.00 m to 2.25 m - very soft very dark grey CLAY, with shell fragments, with plant remains - with putrid odour	2.00																
3	3.00 m to 3.06 m - very soft grey CLAY	3.00																
2	4.50 m to 4.70 m - stiff light grey CLAY with sand	4.50																
4	6.50 m to 6.79 m - stiff light grey mottled with brown CLAY with sand, with traces of organic matter	6.50																
5	8.00 m to 8.32 m - very stiff light grey mottled with brown CLAY with sand, with few silt pockets	8.00																
		8.30													196			
6	9.50 m to 9.85 m - very stiff light grey mottled with brown CLAY with sand	9.50																
		9.82													175			
3	no recovery	10.50																
7	10.50 m to 10.85 m - very stiff light grey spotted with brown CLAY with sand	10.50																
		10.82													180			
8	12.50 m to 12.85 m - very stiff light grey mottled with brown CLAY with sand, with few fine quartz gravel	12.50																
		12.87													133			

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

GeODin/Laboratory Classification Test Results (with Ground Descriptions).GLO/2015-06-19 11:27:05

FUGRO IN SITU GEOTECNIA

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-11

PORT OF RIO DE JANEIRO - GUANABARA BAY

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	1.00 m to 1.20 m - very soft black CLAY with sand	1.00																
	2.50 m to 2.95 m - very loose olive grey to brown spotted with black SAND with gravel, with few shells and shell fragments	2.50																
2	4.00 m to 4.45 m - loose to very loose very dark grey to dark grey SAND with gravel, with few shells and shell fragments	4.00																
3	5.50 m to 5.80 m - soft grey spotted with yellowish red CLAY, with traces of fine sand	5.50																
		5.78														66		
		5.78														65		
2	7.00 m to 7.30 m - stiff grey sandy CLAY	7.00																
		7.28														188		
		7.28														178		
		7.29													125			
4	8.50 m to 8.90 m - stiff grey sandy CLAY, with few organic matter, with few fine gravel	8.50																
5	10.00 m to 10.45 m - very stiff grey to light grey dappled with brownish yellow very sandy CLAY	10.00																
6	11.50 m to 11.85 m - very stiff to hard brownish yellow very sandy CLAY	11.50																
3	13.00 m to 13.40 m - very stiff grey to brownish yellow sandy CLAY	13.00																
7	13.50 m to 13.80 m - very stiff to hard brownish yellow mottled with grey sandy CLAY	13.50																

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_U : undrained shear strength
- 10r : r refers to test on remoulded soil

LABORATORY CLASSIFICATION TEST RESULTS
LOCATION POR-12
PORT OF RIO DE JANEIRO - GUANABARA BAY

FUGRO IN SITU GEOTECNIA

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	0.00 m to 0.20 m - very soft very dark grey CLAY, with traces of shells and shell fragments, with plant remains - with putrid odour	0.00																
	1.50 m to 1.95 m - very soft very dark grey CLAY, with traces of shells, with traces of plant remains - with putrid odour	1.50																
2	3.00 m to 3.45 m - very soft very dark grey CLAY, with traces of shells and shell fragments - with putrid odour	3.00																
3	4.50 m to 4.90 m - firm grey mottled with brown and red CLAY, with traces of mica crystals - at top sandy	4.50																
2	5.50 m to 6.20 m - very stiff grey mottled with reddish brown CLAY with sand	5.50																
		6.19														175		
		6.19													167	150		
4	7.00 m to 7.27 m - very stiff grey mottled with reddish brown CLAY - occasionally with sand	7.00																
	7.27 m to 7.29 m - grey sandy CLAY	7.27																
5	8.50 m to 8.80 m - very stiff grey dappled with brown slightly sandy CLAY, with few oxidation spots	8.50																
3	9.50 m to 9.90 m - very stiff light grey spotted with brown slightly sandy CLAY	9.50																
		9.89													196			
6	10.50 m to 10.93 m - stiff light grey sandy CLAY, with traces of fine quartz gravel	10.50																
7	11.50 m to 11.79 m - very stiff light grey mottled with brown CLAY with sand	11.50																

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-14

PORT OF RIO DE JANEIRO - GUANABARA BAY

FUGRO IN SITU GEOTECNIA

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	1.00 m to 1.25 m - very soft very dark grey CLAY, with shell fragments - at top with sand	1.00																
	2.50 m to 2.55 m - very soft very dark grey CLAY - with H2S odour	2.50																
2	4.00 m to 4.20 m - very soft very dark grey CLAY, with shells and shell fragments	4.00																
3	5.00 m to 5.13 m - very soft very dark grey CLAY, with traces of shell fragments	5.00																
	5.13 m to 5.21 m - very loose light grey clayey MEDIUM TO COARSE SAND	5.13																
4	6.50 m to 6.79 m - very stiff grey sandy CLAY - at top brown inclusions	6.50																
5	7.50 m to 7.95 m - dense light grey slightly clayey MEDIUM TO COARSE SAND	7.50																
6	8.50 m to 8.70 m - medium dense grey slightly clayey MEDIUM TO COARSE SAND	8.50																
	8.70 m to 8.93 m - very stiff grey mottled with brown CLAY with sand	8.70																
7	9.50 m to 9.95 m - dense light grey to grey clayey MEDIUM TO COARSE SAND	9.50																

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

FUGRO IN SITU GEOTECNIA

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-15

PORT OF RIO DE JANEIRO - GUANABARA BAY

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	0.00 m to 0.20 m - very soft black CLAY with sand	0.00																
2	1.00 m to 1.30 m - very stiff light grey sandy CLAY	1.00																
1	2.00 m to 2.30 m - very stiff light grey sandy CLAY, with few organic matter, with few fine gravel	2.00																
		2.29													156			

Key:

w : water content
γ_1 : unit weight derived from water content
γ_2 : unit weight derived from volume mass calculation
γ_{dmin} : minimum index unit weight
γ_{dmax} : maximum index unit weight
ρ_s : density of solid particles

Carb.Cont. : carbonate content
Org.Cont. : organic matter content
w_P : plastic limit
w_L : liquid limit
I_P : plasticity index
Fines : mass percentage of material passing 63 µm or 75 µm sieve

PP : pocket penetrometer
TV : torvane
FC : fall cone
LV : laboratory vane
c_u : undrained shear strength
10r : r refers to test on remoulded soil

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-17

PORT OF RIO DE JANEIRO - GUANABARA BAY

FUGRO IN SITU GEOTECNIA

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	0.00 m to 0.20 m - grey to dark grey FINE TO COARSE SAND, with shells and shell fragments, with cobbles, with rock fragments	0.00																
	1.50 m to 1.72 m - hard striped white yellow and dark brown CLAY, with a layer of weathered quartz	1.50																
2	2.50 m to 2.70 m - hard striped white brownish yellow and black CLAY, with rock structure	2.50																
3	3.50 m to 3.65 m - hard striped white brownish yellow and black CLAY, with rock structure	3.50																

Key:

- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_S : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-18

PORT OF RIO DE JANEIRO - GUANABARA BAY

FUGRO IN SITU GEOTECNIA

Sample				Unit Weight [kN/m³]							Atterberg Limits				c_u [kPa]			
No.	Ground Description	Test Depth [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
1	0.00 m to 0.60 m - very soft very dark grey sandy CLAY, with shells and shell fragments	0.00																
		0.58														15		
2	1.00 m to 2.00 m - very soft very dark grey very sandy CLAY, with few shells and shell fragments	1.00																
		1.96														14		

Key:

- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_s : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

FUGRO IN SITU GEOTECNIA

LABORATORY CLASSIFICATION TEST RESULTS

LOCATION POR-19

PORT OF RIO DE JANEIRO - GUANABARA BAY

Sample		Test Depth	w	Unit Weight [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Atterberg Limits			Fines	c_u [kPa]			
No.	Ground Description	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
1	0.00 m to 0.45 m - FINE SAND TO GRAVEL, with cobbles	0.00																
	0.45 m to 0.90 m - very weak to weak narrowly foliated completely weathered GNEISS	0.45																
2	1.50 m to 2.85 m - very weak to weak narrowly foliated completely weathered GNEISS	1.50																
3	3.00 m to 3.90 m - very weak to weak narrowly foliated completely weathered GNEISS	3.00																

Key:
- w : water content
- γ_1 : unit weight derived from water content
- γ_2 : unit weight derived from volume mass calculation
- γ_{dmin} : minimum index unit weight
- γ_{dmax} : maximum index unit weight
- ρ_s : density of solid particles
- Carb.Cont. : carbonate content
- Org.Cont. : organic matter content
- w_P : plastic limit
- w_L : liquid limit
- I_P : plasticity index
- Fines : mass percentage of material passing 63 µm or 75 µm sieve
- PP : pocket penetrometer
- TV : torvane
- FC : fall cone
- LV : laboratory vane
- c_u : undrained shear strength
- 10r : r refers to test on remoulded soil

SECTION D: POSITIONING REPORTS

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	**Skate IIIC REV1**
Project Name	**Skate IIIC Brazil**
Project Number	**150303 Skate IIIC Brazil**
Offset Name	**Rotary Table**
Sampling Started	**11-Jun-2015 14:33:26 (local)**
Sampling Ended	**11-Jun-2015 14:38:27 (local)**
Comment	**at 14:30**

DML = 13.6 m
DWL = 1.5 m

Results

	Mean	**Standard Deviation**
Local Latitude	**22°53'25.0158"S**	
Local Longitude	**43°10'34.1255"W**	
Ellipsoidal Height	**-4.45 m**	
Local Easting	**687084.26 m**	**0.01 m**
Local Northing	**7467467.40 m**	**0.02 m**
Orthometric Height	**-4.45 m**	**0.04 m**
WGS84 Latitude	**22°53'25.0158"S**	
WGS84 Longitude	**43°10'34.1255"W**	
Ellipsoidal Height	**-4.45 m**	
Quality	**1.23**	**0.13 m**
Depth	**0.00 m**	**0.00 m**
Heading	**106.23°T**	**0.44°**

Line Navigation Data

Line Name	**N/A**
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	**POR-1**
Range TO	1.32 m
Bearing TO	251.46°T

Observations

Total 296
Used 296

Geodetic Parameters

Geodetic Datum	**WGS84**		
Ellipsoid	**WGS84**		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	**Universal Transverse Mercator Zone: 23**		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'34.6581"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	11-Jun-2015 13:12:50 (local)
Sampling Ended	11-Jun-2015 13:17:50 (local)
Comment	at 12:00

DML = 12.1 m
DWL = 1.1

Results

	Mean	Standard Deviation
Local Latitude	22°53'23.3873"S	
Local Longitude	43°10'41.6086"W	
Ellipsoidal Height	-4.75 m	
Local Easting	686871.61 m	0.01 m
Local Northing	7467520.14 m	0.01 m
Orthometric Height	-4.75 m	0.07 m
WGS84 Latitude	22°53'23.3873"S	
WGS84 Longitude	43°10'41.6086"W	
Ellipsoidal Height	-4.75 m	
Quality	0.95	0.05 m
Depth	0.00 m	0.00 m
Heading	94.96°T	0.64°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-2
Range TO	2.32 m
Bearing TO	36.09°T

Observations

Total 299
Used 299

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'31.6972"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	10-Jun-2015 09:34:56 (local)
Sampling Ended	10-Jun-2015 09:39:56 (local)
Comment	@ 9:10 am

DML = 10.0 m
DWL = 0.9 m

Results

	Mean	Standard Deviation
Local Latitude	22°53'06.2896"S	
Local Longitude	43°11'00.4806"W	
Ellipsoidal Height	-4.87 m	
Local Easting	686340.24 m	0.01 m
Local Northing	7468052.71 m	0.01 m
Orthometric Height	-4.87 m	0.04 m
WGS84 Latitude	22°53'06.2896"S	
WGS84 Longitude	43°11'00.4806"W	
Ellipsoidal Height	-4.87 m	
Quality	0.90	0.00 m
Depth	0.00 m	0.00 m
Heading	150.62°T	0.58°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-3
Range TO	1.27 m
Bearing TO	282.32°T

Observations

Total	299
Used	299

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'23.8508"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	11-Jun-2015 22:54:24 (local)
Sampling Ended	11-Jun-2015 22:59:24 (local)
Comment	DTW - 0.8m

DTM - 12.2m
D/CD - 2.39m
D/MSL - 1.7
0m

Results

	Mean	Standard Deviation
Local Latitude	22°53'25.0665"S	
Local Longitude	43°10'24.5479"W	
Ellipsoidal Height	-4.82 m	
Local Easting	687357.20 m	0.02 m
Local Northing	7467462.46 m	0.02 m
Orthometric Height	-4.82 m	0.02 m
WGS84 Latitude	22°53'25.0665"S	
WGS84 Longitude	43°10'24.5479"W	
Ellipsoidal Height	-4.82 m	
Quality	1.10	0.00 m
Depth	0.00 m	0.00 m
Heading	213.95°T	0.30°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-4
Chainage	N/A	Range TO	3.52 m
Cross Track	N/A	Bearing TO	244.73°T

Observations
Total 300
Used 300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'38.3882"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	09-Jun-2015 12:03:08 (local)
Sampling Ended	09-Jun-2015 12:08:08 (local)
Comment	at 11:40

DML = 10.2
DWL = 0.9

Results

	Mean	Standard Deviation
Local Latitude	22°52'59.8436"S	
Local Longitude	43°11'13.1042"W	
Ellipsoidal Height	-5.02 m	
Local Easting	685982.89 m	0.01 m
Local Northing	7468255.43 m	0.01 m
Orthometric Height	-5.02 m	0.03 m
WGS84 Latitude	22°52'59.8436"S	
WGS84 Longitude	43°11'13.1042"W	
Ellipsoidal Height	-5.02 m	
Quality	1.01	0.02 m
Depth	0.00 m	0.00 m
Heading	309.25°T	1.56°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-5
Range TO	4.13 m
Bearing TO	95.24°T

Observations

Total 301
Used 301

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'18.7495"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	09-Jun-2015 20:33:09 (local)
Sampling Ended	09-Jun-2015 20:38:15 (local)
Comment	DTM - 8.8m, DTW - 0.8m

Deck above CD - 2.27, Deck above MSL - 1.60

Results

	Mean	Standard Deviation
Local Latitude	22°52'51.7951"S	
Local Longitude	43°11'23.5248"W	
Ellipsoidal Height	-4.90 m	
Local Easting	685688.93 m	0.01 m
Local Northing	7468506.66 m	0.01 m
Orthometric Height	-4.90 m	0.03 m
WGS84 Latitude	22°52'51.7951"S	
WGS84 Longitude	43°11'23.5248"W	
Ellipsoidal Height	-4.90 m	
Quality	1.11	0.02 m
Depth	0.00 m	0.00 m
Heading	303.83°T	0.42°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-6
Chainage	N/A	Range TO	1.66 m
Cross Track	N/A	Bearing TO	176.96°T

Observations

Total	300
Used	300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'14.4596"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	06-Jun-2015 10:13:46 (local)
Sampling Ended	06-Jun-2015 10:18:46 (local)
Comment	D/ML = 6.60m

D/WI = 1.60m
D Above MSL =1.80m

Results

	Mean	Standard Deviation
Local Latitude	22°52'22.9560"S	
Local Longitude	43°11'58.4266"W	
Ellipsoidal Height	-4.73 m	
Local Easting	684705.00 m	0.01 m
Local Northing	7469405.94 m	0.01 m
Orthometric Height	-4.73 m	0.04 m
WGS84 Latitude	22°52'22.9560"S	
WGS84 Longitude	43°11'58.4266"W	
Ellipsoidal Height	-4.73 m	
Quality	0.90	0.00 m
Depth	0.00 m	0.00 m
Heading	290.54°T	0.62°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-7
Range TO	0.06 m
Bearing TO	354.65°T

Observations

Total 294
Used 294

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'00.0423"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	05-Jun-2015 15:18:55 (local)
Sampling Ended	05-Jun-2015 15:23:57 (local)
Comment	D/ML =6.00m

D/WL =2.35m
D Above MSL =3.65

Results

	Mean	Standard Deviation
Local Latitude	22°52'18.7655"S	
Local Longitude	43°12'02.2100"W	
Ellipsoidal Height	-2.88 m	
Local Easting	684598.74 m	0.02 m
Local Northing	7469536.16 m	0.02 m
Orthometric Height	-2.88 m	0.04 m
WGS84 Latitude	22°52'18.7655"S	
WGS84 Longitude	43°12'02.2100"W	
Ellipsoidal Height	-2.88 m	
Quality	1.35	0.42 m
Depth	0.00 m	0.00 m
Heading	270.66°T	0.99°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-8
Chainage	N/A	Range TO	0.31 m
Cross Track	N/A	Bearing TO	120.19°T

Observations

Total	300
Used	300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°41'58.4492"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	07-Jun-2015 14:10:33 (local)
Sampling Ended	07-Jun-2015 14:15:33 (local)
Comment	DWL = 0.6

DML = 6.6
at 9:55 am

Results

	Mean	Standard Deviation
Local Latitude	22°52'42.0045"S	
Local Longitude	43°12'18.9566"W	
Ellipsoidal Height	-5.51 m	
Local Easting	684112.69 m	0.01 m
Local Northing	7468827.15 m	0.01 m
Orthometric Height	-5.51 m	0.04 m
WGS84 Latitude	22°52'42.0045"S	
WGS84 Longitude	43°12'18.9566"W	
Ellipsoidal Height	-5.51 m	
Quality	0.89	0.02 m
Depth	0.00 m	0.00 m
Heading	273.07°T	0.43°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-9
Range TO	3.42 m
Bearing TO	74.85°T

Observations

Total 300
Used 300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°41'52.6056"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	08-Jun-2015 20:05:57 (local)
Sampling Ended	08-Jun-2015 20:10:58 (local)
Comment	DTM - 5.4m, DTW - 0.8m, Deck above MSL - 1.57, Deck above CD - 2.28

Results

	Mean	Standard Deviation
Local Latitude	22°52'49.4467"S	
Local Longitude	43°12'26.1739"W	
Ellipsoidal Height	-4.89 m	
Local Easting	683904.20 m	0.01 m
Local Northing	7468600.73 m	0.02 m
Orthometric Height	-4.89 m	0.05 m
WGS84 Latitude	22°52'49.4467"S	
WGS84 Longitude	43°12'26.1739"W	
Ellipsoidal Height	-4.89 m	
Quality	1.59	0.26 m
Depth	0.00 m	0.00 m
Heading	208.85°T	0.32°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-10
Chainage	N/A	Range TO	2.10 m
Cross Track	N/A	Bearing TO	213.99°T

Observations

Total	300
Used	300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°41'50.0119"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	08-Jun-2015 13:20:12 (local)
Sampling Ended	08-Jun-2015 13:25:13 (local)
Comment	D/ML=3.50m

D/WL=1.10
Water Depth 2.10m
DL above
MSL=1.92
Time = 11:45

Results

	Mean	Standard Deviation
Local Latitude	22°52'56.2940"S	
Local Longitude	43°12'32.1260"W	
Ellipsoidal Height	-4.69 m	
Local Easting	683731.99 m	0.01 m
Local Northing	7468392.17 m	0.01 m
Orthometric Height	-4.69 m	0.05 m
WGS84 Latitude	22°52'56.2940"S	
WGS84 Longitude	43°12'32.1260"W	
Ellipsoidal Height	-4.69 m	
Quality	0.91	0.03 m
Depth	0.00 m	0.00 m
Heading	121.82°T	0.65°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-11
Chainage	N/A	Range TO	4.17 m
Cross Track	N/A	Bearing TO	179.15°T

Observations
Total 294
Used 294

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°41'47.8929"		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	07-Jun-2015 20:50:42 (local)
Sampling Ended	07-Jun-2015 20:55:49 (local)
Comment	DTM - 5.5m, DTW - 0.8m, Deck above CD - 2.25, Deck above MSL - 1.62

Results

	Mean	Standard Deviation
Local Latitude	22°52'45.8713"S	
Local Longitude	43°12'22.2034"W	
Ellipsoidal Height	-4.90 m	
Local Easting	684018.70 m	0.01 m
Local Northing	7468709.33 m	0.01 m
Orthometric Height	-4.90 m	0.03 m
WGS84 Latitude	22°52'45.8713"S	
WGS84 Longitude	43°12'22.2034"W	
Ellipsoidal Height	-4.90 m	
Quality	1.10	0.00 m
Depth	0.00 m	0.00 m
Heading	189.80°T	0.28°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-12
Range TO	4.05 m
Bearing TO	334.45°T

Observations

Total 300
Used 300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°41'51.4538"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	06-Jun-2015 20:35:52 (local)
Sampling Ended	06-Jun-2015 20:41:00 (local)
Comment	DML - 11.7m

DTW - 2.0m
DCD - 3.30
DMSL - 2.63

Results

	Mean	Standard Deviation
Local Latitude	22°52'27.7697"S	
Local Longitude	43°11'54.6052"W	
Ellipsoidal Height	-3.91 m	
Local Easting	684812.12 m	0.01 m
Local Northing	7469256.54 m	0.01 m
Orthometric Height	-3.91 m	0.02 m
WGS84 Latitude	22°52'27.7697"S	
WGS84 Longitude	43°11'54.6052"W	
Ellipsoidal Height	-3.91 m	
Quality	1.10	0.00 m
Depth	0.00 m	0.00 m
Heading	60.71°T	0.68°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-14
Range TO	4.60 m
Bearing TO	56.91°T

Observations

Total 300
Used 300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'01.6684"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	11-Jun-2015 00:54:50 (local)
Sampling Ended	11-Jun-2015 00:59:53 (local)
Comment	DTM - 7.9m, DTW - 1.1m

D/MSL - 1.79, D/CD - 2.42

Results

	Mean	Standard Deviation
Local Latitude	22°54'42.9607"S	
Local Longitude	43°09'30.3664"W	
Ellipsoidal Height	-4.75 m	
Local Easting	688871.41 m	0.01 m
Local Northing	7465047.15 m	0.02 m
Orthometric Height	-4.75 m	0.05 m
WGS84 Latitude	22°54'42.9607"S	
WGS84 Longitude	43°09'30.3664"W	
Ellipsoidal Height	-4.75 m	
Quality	1.10	0.00 m
Depth	0.00 m	0.00 m
Heading	230.79°T	0.49°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-17
Range TO	3.45 m
Bearing TO	203.40°T

Observations

Total	300
Used	300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°43'01.7885"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	10-Jun-2015 17:51:35 (local)
Sampling Ended	10-Jun-2015 17:56:35 (local)
Comment	at 17:50

D/ML=7.5
D/Wl = 0.800

Results

	Mean	Standard Deviation
Local Latitude	22°54'36.3487"S	
Local Longitude	43°09'33.2865"W	
Ellipsoidal Height	-5.65 m	
Local Easting	688790.75 m	0.11 m
Local Northing	7465251.58 m	0.09 m
Orthometric Height	-5.65 m	0.04 m
WGS84 Latitude	22°54'36.3487"S	
WGS84 Longitude	43°09'33.2865"W	
Ellipsoidal Height	-5.65 m	
Quality	0.86	0.05 m
Depth	0.00 m	0.00 m
Heading	272.45°T	0.51°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-18
Range TO	2.59 m
Bearing TO	173.68°T

Observations

Total 301
Used 301

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°43'00.4549"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	12-Jun-2015 10:49:51 (local)
Sampling Ended	12-Jun-2015 10:54:52 (local)
Comment	at 9:50

DWL = 1.5m
DML = 6.6 m

Results

	Mean	Standard Deviation
Local Latitude	22°54'43.4073"S	
Local Longitude	43°09'30.8480"W	
Ellipsoidal Height	-4.17 m	
Local Easting	688857.52 m	0.01 m
Local Northing	7465033.58 m	0.01 m
Orthometric Height	-4.17 m	0.04 m
WGS84 Latitude	22°54'43.4073"S	
WGS84 Longitude	43°09'30.8480"W	
Ellipsoidal Height	-4.17 m	
Quality	1.06	0.05 m
Depth	0.00 m	0.00 m
Heading	217.86°T	0.43°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR 19
Chainage	N/A	Range TO	1.54 m
Cross Track	N/A	Bearing TO	73.60°T

Observations
Total 297
Used 297

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°43'01.6140"		
Calculation Mode	Spheroidal		

SECTION E: GUIDELINES FOR USE OF REPORT

CONTENTS Reference

INTRODUCTION

Fugro Engineers B.V. (FEBV) prepared this report. FEBV is a Fugro N.V. Group operating company. FEBV specialises in providing geotechnical information and engineering advice for on-land, nearshore and offshore construction projects. FEBV will hereafter be referred to as Fugro.

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 INVESTIGATIONS

Fugro follows ISO 9001 quality principles for project management. Project activities usually comprise part of specific phases of a construction project. The quality plan for the entire construction project must incorporate geotechnical input in every phase - from the feasibility planning stages to project completion. The parties involved must do the following.

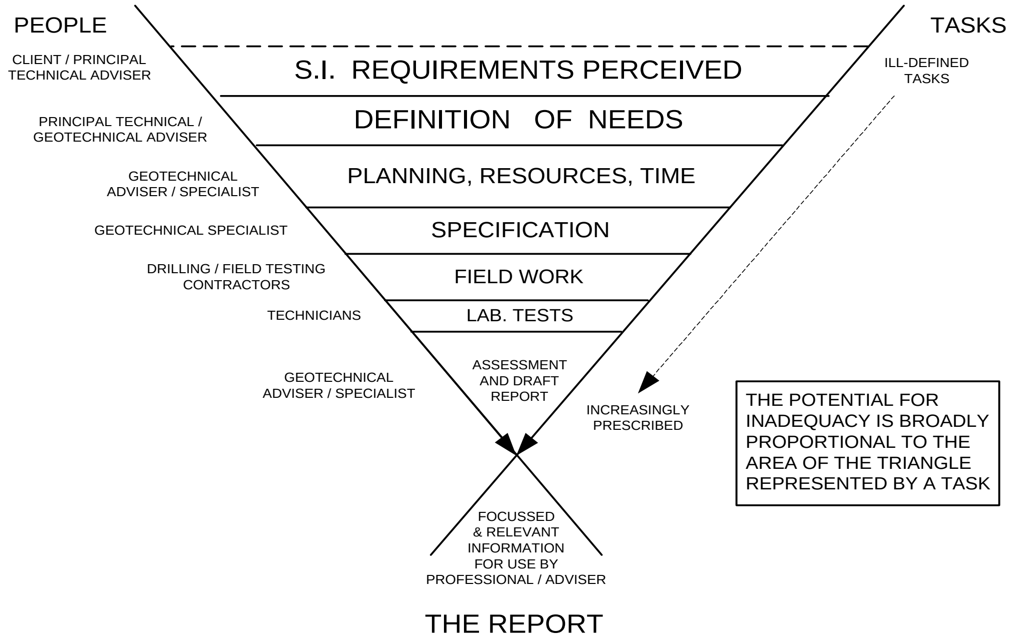
– Provide complete and accurate information necessary to plan an appropriate geotechnical site investigation.
– Describe the purpose(s), type(s) and construction methods of planned structures in detail.
– Provide the time, financial, personnel and other resources necessary for the planning, execution 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 RESOUCES NECESSARY FOR QUALITY GEOTECHNICAL INVESTIGATIONS

To ensure compliance with these requirements, there must be adequate designation of authority and accountability for geotechnical aspects of construction projects. 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 in ensuring that adequate geotechnical information is gathered 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 must 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 borehole 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 between 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

1 Site Investigation Steering Group SISG (1993), "Site Investigation in Construction 2: Planning, Procurement and Quality Management", Thomas Telford, London.

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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.

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 (Halligan et al.[1]). 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 must 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.

1 Halligan D.W., Hester W.T., Thomas H.R., (1987), "Managing Unforeseen Site Conditions", ASCE Journal of Construction Engineering and Management, Vol. 113, No. 2, pp. 273-287.

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

This document describes borehole activities for a geotechnical project. The activities comprise borehole drilling and, optionally (1) in-situ testing in borehole and/or (2) sampling and sample handling.

The common drilling techniques for onshore and nearshore projects are:
- Open-hole drilling: a drilling method whereby all material within the diameter of the borehole is cut, such as open-hole rotary drilling, cable percussion drilling and auger drilling.
- Open-hole rotary drilling: an open-hole drilling method whereby ground at the bottom of the borehole is cut by a drill bit rotated on the bottom of a borehole, and drill fluid is pumped down to the drill bit through the hollow drill pipe.
- Cable percussion drilling: an open-hole drilling method whereby ground at the bottom of the borehole is broken up by percussive action of a bailer, clay cutter or chisel, and brought to the surface by the bailer or clay cutter.
- Auger drilling: an open-hole drilling method whereby ground at the bottom of the borehole is cut and brought to the surface by auger flights.
- Core drilling: a rotary drilling method that cuts out cylindrical ground samples.

The common drilling techniques for an offshore project are open-hole rotary drilling and core drilling. Offshore core drilling is by either piggyback or by downhole system. Piggyback core drilling uses drilling techniques whereby the drill pipe for open-hole rotary drilling acts as drill casing and as support for the drill rig. Downhole core drilling uses a core barrel that latches in a bottomhole assembly for open-hole rotary drilling.

A wide range of in-situ tests is available for boreholes. Examples are the Standard Penetration Test (SPT), the pressuremeter test for onshore and nearshore boreholes and the Cone Penetration Test (CPT) for offshore boreholes. This document describes such tests as an integral part of borehole activities, but gives no test details. Separate descriptions apply, if appropriate.

The common sampling techniques are drive sampling and/or push sampling of an open-tube sampler, and push sampling in case of a PISTON SAMPLER. Sampling of cuttings from drilling may be feasible for some types of drilling techniques.

Borehole activities are based on ISO, CEN, BSI and ASTM standards.

DRILLING APPARATUS

GENERAL

Descriptions of common borehole drilling apparatus are as follows:
- Drilling Equipment: any equipment that provides a suitably clean open hole before insertion of downhole sampling and/or testing apparatus and ensures that sampling and/or testing is performed in undisturbed ground.
- Drill Rig: machine capable of providing:
  . rotation, feed and retraction to drill pipe, casing and/or auger,
  . drill fluid pumping capacity, as required,
  . sampler or test apparatus insertion.
- Drill Casing: cylindrical pipe with one or more of the following purposes:
  . to support the sides of a borehole,
  . to support drill pipe above ground surface in case of over-water drilling,
  . to promote return of drilling fluid.
- Drill Pipe: cylindrical pipe connecting drill rig and drill bit.
- Drill Collar: thick-walled drill pipe providing self-weight thrust for the drill bit.
- Drill Bit: device attached to drill pipe and used as a cutting tool to drill into the ground.
- Bottom Hole Assembly: lower section of offshore drill pipe and drill bit, shaped to permit latching of downhole in-situ testing and sampling apparatus.

An optional facility for rotary drilling is analogue or digital recording of MWD (Measure-While-Drilling) parameters, such as penetration rate, torque and drill fluid pressure.

CORING

Core drilling is a ground investigation technique comprising simultaneous drilling and sampling. Descriptions of apparatus are as follows:
- Single Tube Core Barrel: hollow steel tube with a head at the upper end threaded for drill pipe, and a threaded connection for the core bit at the lower end.
- Double Tube Core Barrel: assembly of two concentric steel tubes joined at the upper end by means of a swivel arranged to permit rotation of the outer tube without causing rotation of the inner tube; the upper end of the outer tube is threaded for drill pipe and the lower end is threaded for the core bit.
- Double Tube Core Barrel with Retrievable Inner Tube: double tube core barrel that permits retrieval of the core-laden inner tube assembly to the surface through matching drill pipe without the need for withdrawal of the drill pipe.
- Core Bit: device attached to the core barrel and used as a cutting tool to drill into the ground.
- Core Catcher: device that assists retention of core in the core barrel.
- Core Box: box with longitudinal separators for the protection and storage of core.

OFFSHORE OPERATIONS

Offshore drilling can require additional apparatus, in particular when drilling from a vessel:
- Seabed Reaction Frame: seafloor-based apparatus capable of providing one or more of the following:
  . improved horizontal and vertical control of the drill pipe
  . re-entry of a borehole by drill pipe after earlier retraction
  . vertical reaction for the drill pipe during downhole testing and sampling
  . vertical reaction for hard-tie rigging.
- Heave Compensator: apparatus to compensate the drill pipe for vertical motion of a drill rig mounted on a vessel.
- Hard-tie Rigging: special rigging system incorporating a seabed reaction frame and a heave compensator, for heave-compensated drilling with low drill bit load and/or increased depth control of the drill bit.

SAMPLING APPARATUS

DRIVE SAMPLING

- Drive-Weight Assembly: Device consisting of hammer, hammer fall guide, anvil and hammer drop system.
- Hammer: impact mass, which is successively lifted and dropped to provide the energy that accomplishes sampler penetration.
- Hammer Fall Guide: guide arrangement for the fall of the hammer.
- Anvil: drive-head which the hammer strikes and through which the hammer energy passes into the sampling rods.
- Hammer Drop System: pick-up and release mechanism by which lifting and dropping of the hammer is accomplished.
- Cathead: rotating drum in a rope-cathead hammer drop system around which a rope is wrapped to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.
- Self-Tripping Release: hammer drop system that ensures a free fall of the hammer after lifting by a cable or rope.
- Free-Fall Winch: hammer drop system that permits a free release of the rotating drum of the winch around which a cable is wrapped to lift and drop the hammer.
- Hydraulic Percussion: hammer drop system that provides rapid impact hammer blows by fluid flow.
- Sampling Rods: rods that connect the drive-weight assembly to the sampler head.

PUSH SAMPLING APPARATUS

- Sampler Insertion Equipment: apparatus providing relatively rapid continuous penetration force.
- Reaction Equipment: reaction for the sampler insertion equipment.
- Sampling Rods: rods that connect the sampler insertion equipment to the sampler head.

SAMPLER

- Open-Tube Sampler: sampler with tube that is open at one end and fitted to the sampler head at the other end.
- PISTON SAMPLER: sampler with close-fitting sliding piston that is held stationary during penetration of a flush sample tube into ground.
- Sampler Head: coupling between sampling rods and sample tube, and containing a non-return valve to allow free exit of water and air above sample.
- Sample Tube: cylindrical tube with cutting edge or cylindrical tube fitted with separate cutting shoe.
- Thin-Walled Sample Tube: sample tube with area ratio of less than 15% and inside clearance ratio of less than 1%.
- Thick-Walled Sample Tube: sample tube not meeting the requirements of a thin-walled sample tube.
- Core Catcher: device that assists retention of the sample in the sample tube.

Table 1 shows dimensions of common tube samplers.

TABLE 1 - DIMENSIONS OF SAMPLERS

Sampler type	Inside diameter D_1 [mm]	Outside diameter D_2 [mm]	Inside diameter D_3 [mm]	Wall thickness [mm]	Area ratio A_r [%]	Inside clearance ratio C_r [%]	Tube length [mm]	Sample length [mm]
Piston	72	76	72	2.0	11	0	1028	845
Thin-walled 3 inch tube	72	76	72	2.0	11	0	1028	950
Thin-walled 5° - 10° tube	72	76	72	2.0	11	0	1028	950
Thick-walled 3 inch tube	72	80	72	4	24	0	1028	950
Thin-walled 2 inch tube	54	57	54	1.5	11	0	1028 and 645	950 and 570
Thick-walled 2 inch tube	53	60.3	53.1	3.6	29	0	645	570
Rapid PISTON SAMPLER	56	77	58	10.5	89	3.9	3222	3050
Hammer Sampler 2 inch splitspoon	40	51	41	5	63	2.5	600	600
Hammer Sampler 3 inch splitspoon	61	76.1	63.5	6.3	56	4.1	600	600
Fugro CORER® 67 mm tube	66	76.1	67	3	42	3	2031	1884
Fugro CORER® 54 mm tube	53.7	63	54	3.6	38	0.7	1000	950

Notes
1. D_1 = inside diameter of the cutting shoe.
2. D_2 = greatest outside diameter of the sample tube and/or cutting shoe.
3. D_3 = inside diameter of the flush portion of the sample tube or liner.
4. "Length" dimension considers manufactured length. Re-use of a sampler may lead to shortening, for example to reshape cutting edge.
5. Thin walled 5° - 10° tube is equivalent to conventional thin-walled 3 inch tube except for specially machined cutting edge with 5° and 10° taper to reduce sampling disturbance.
6. Penetration of Rapid PISTON SAMPLER is by pressurising drill string (with minimum length of 55 m) and controlled fracturing of shear pins in the sampler, giving estimated impact velocity in the order of 10 m/s.
7. Machined cutting edge of Rapid PISTON SAMPLER has taper of 10°.
8. Penetration of Fugro CORER® is by self-weight supplemented by mud-driven hammering.
9. Machined cutting edge of Fugro CORER® (54 mm) has taper of 7°.
10. Fugro CORER® (54 mm) also allows use of conventional 2 inch sample tubes.

The definitions of area ratio and inside clearance ratio are as follows:

Area Ratio: Indication of volume of ground displaced by the sample tube, calculated as follows:

$$A_r = [(D_2^2 - D_1^2)/D_1^2] \times 100$$

where:
A_r = area ratio expressed as percentage
D_2 = greatest outside diameter of the sample tube and/or cutting shoe
D_1 = inside diameter of the cutting shoe.

Inside Clearance Ratio: Indication of clearance of sample inside the sample tube, calculated as follows:

$$C_r = [(D_3 - D_1)/D_1] \times 100$$

where:
C_r = inside clearance ratio expressed as percentage
D_3 = inside diameter of the flush portion of the sample tube or liner
D_1 = inside diameter of the cutting shoe.
The worst case of manufacturing tolerances applies for calculation of C_r.

PROCEDURE

Figure 1 summarises the procedure for boreholes. The procedure includes several stages, as follows:

BOREHOLE SET-UP STAGE

- assignment of borehole details such as location, target borehole depth, types of apparatus, sequence of sampling
- positioning of drill rig at assigned location
- selection of drilling, sampling or in-situ testing stage.

The subsequent stage is one of the following:

OPEN-HOLE DRILLING STAGE

- open-hole drilling
- borehole logging, such as drill bits and drill fluids used, borehole size and depth, drilling observations
- borehole water level, where practicable
- selection of subsequent drilling, sampling or in-situ testing stage.

IN-SITU TESTING STAGE

- in-situ test
- logging, such as test depth and test parameters
- selection of subsequent drilling stage.

SAMPLING STAGE

- sampling
- logging, such as sample depth and visual description of samples where available for inspection at the time of sampling
- sample handling
- selection of subsequent drilling stage.

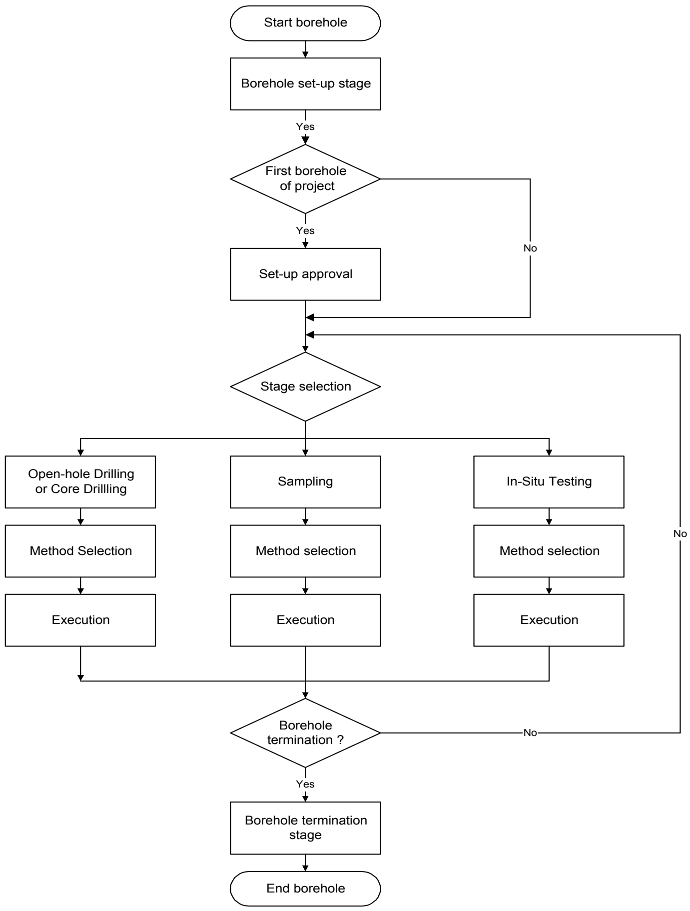

Figure 1 - Flow chart

CORE DRILLING STAGE

- core drilling
- operational logging, such as drill bits and drill fluids used, borehole size and depth, drilling observations
- borehole water level, where practicable
- core logging, such as recovery and visual description
- core handling
- selection of subsequent drilling, sampling or in-situ testing stage.

BOREHOLE TERMINATION STAGE

- termination of borehole
- backfilling of borehole, if appropriate
- data processing.

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 equipment operator, considering risks such as damage to apparatus or safety of personnel. Most onshore drilling systems have levelling facilities allowing a vertical start of drilling. Seabed reaction frames used for offshore drilling activities have no levelling facilities. Drill pipe passage through a seabed reaction frame must be (near-)vertical.

The sampling stage or the core drilling stage may result in no-recovery or partial recovery of a sample due to unfavourable conditions for the deployment of a particular sampler. A subsequent sampling event at the same depth or immediately below the initial sampling depth is a separate sampling activity, unless specifically agreed otherwise or unless no specific evidence shows departure from the agreed procedure for the earlier activity.

Criteria for borehole termination are as follows, unless specifically agreed otherwise:

- as instructed by Client
- reaching target penetration
- drilling progress rate of less than 1m/hour based on half-hourly observation
- circumstances at discretion of system operator, such as risk of damage to apparatus or safety of personnel

whichever occurs first and as applicable.

RESULTS

GEOTECHNICAL LOG

The geotechnical log or borehole log contains the geotechnical descriptions of the encountered strata, and the borehole water level measurements, if applicable. In addition, it may include the principal details of the borehole operational activities.

The penetration depth of a (vertical) borehole is defined as the deepest point reached by drilling, sampling or in-situ testing. The recovery depth of a borehole is the deepest point for which sample or test data are presented.

Unless indicated otherwise, recovery of a tube sample or a core sample is assumed to be continuous from the starting depth of sampling. In other words, the geotechnical log ignores possible plugging, flow-in and/or wash-out.

MWD PARAMETERS

Optional presentation of MWD parameters for rotary drilling is usually in graphical format. Interpretation of MWD parameters can help characterisation of ground conditions such as cemented strata, weak rock and formations with cavities.

GEOTECHNICAL DESCRIPTION

The geotechnical description, including the strata boundaries, is an interpretation of the processed data available at the time of the preparation of the geotechnical log. Subsequent processing and integration of supplementary ground investigation data may require adjustment of the log. Supplementary information can include:

- geological information
- geophysical data
- results of nearby boreholes and in-situ tests
- laboratory test results
- analysis of drilling parameters such as torque, feed, drill fluid pressure and drilling time.

Level of detail and accuracy in geotechnical description depend on factors such as sample size, quality, coverage of samples and test data, availability of supplementary information, and project requirements. For example, geotechnical descriptions prepared for the purpose of a pile foundation may differ from those prepared for a pipeline.

Any graphical presentation of test results considers values within the scale limits only. No automatic scaling applies, unless indicated otherwise.

WATER LEVEL

Water level measurements taken in boreholes can be valuable. Interpretation of water levels requires due caution. They may or may not be representative of the ground water levels. In any case, water levels apply to the time and date of the measurements only. They will vary due to seasonal and other environmental influences, including construction activities.

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SAMPLE QUALITY

Additional documentation of borehole operational activities can include further details on drilling, sampling and in-situ testing. In particular, details of sampling techniques and samplers can be important for the evaluation of the results of laboratory tests.

An example is the open-tube sampler fitted with a thin-walled sample tube of 50 mm to 100 mm diameter. The sample quality (BSI, 1999) is typically undisturbed, Class 2, for very soft fine-grained soil and Class 1 for firm to very stiff fine-grained soil. The sample quality for coarse-grained soils is typically disturbed, Class 3. For a thick-walled sample tube, the sample quality for fine-grained soil is typically one class worse than for a thin-walled tube. A PISTON SAMPLER with a thin-walled sample tube allows Class 1 sample quality for very soft fine-grained soil.

The classification system for sample quality recognises 5 classes on the basis of feasibility of specific geotechnical identification and laboratory tests. A summary of these classes is as follows:
Class 1: undisturbed: strength, stiffness and consolidation
Class 2: undisturbed: layering, permeability, unit weight
Class 3: disturbed: water content
Class 4: disturbed: particle size analysis, Atterberg limits, soil type
Class 5: disturbed: stratigraphy
The higher class includes the laboratory tests of the lower classes.

Comments on Class 1 and Class 2 fine-grained soil samples are as follows:

- Some sample disturbance is inevitable because of the required sampling process and subsequent on-site and laboratory sample handling.
- Silt soil is more sensitive to disturbance than clay soil.
- Sample disturbance typically increases with increasing total stress conditions applicable to the in-situ soil. Negative pore pressures develop after sampling, upon reduction of total stresses. The resulting effective stresses within the sample cause sample disturbance. Sample disturbance may thus increase with sampling depth or with increasing water depth for offshore boreholes.
- Reduction in water pressure occurring after sampling causes a change in equilibrium between dissolved gasses, gas bubbles and gas hydrates, where present. The amount of gas release increases with water pressure. This may result in increased sample disturbance, in particular for deep-water sites.

ASTM International (2002) provides descriptions for rock core quality as follows:
TCR Total Core Recovery: the total core length divided by the core run length
SCR Solid Core Recovery: the total length of the pieces of solid core that have a complete circumference divided by the core run length
RQD Rock Quality Designation: the total length of the pieces of sound core over 100 mm long along the centreline divided by the core run lengths per stratum or core run; sound core includes core with obvious drilling breaks
I_F Fracture Index: spacing of natural discontinuities.

Table 2 shows a classification of rock quality according to ASTM International (2002).

TABLE 2 CLASSIFICATION OF ROCK QUALITY

RQD	Classification of Rock Quality
0 to 25%	Very poor
25 to 50%	Poor
50 to 75%	Fair
75 to 90%	Good
90 to 100%	Excellent

Sample quality may change with time and storage conditions. The type of soil or rock will influence the degree of change. For example, exposure to air may initiate chemical processes, such as rapid oxidisation of organic soil.

SYMBOLS

The geotechnical log contains a graphic log of the ground conditions. Figures 2 through 4 present details for soils, cementation degrees and rocks. In addition, the geotechnical log may show specific symbols for sampling and in-situ testing. Figure 5 presents details.

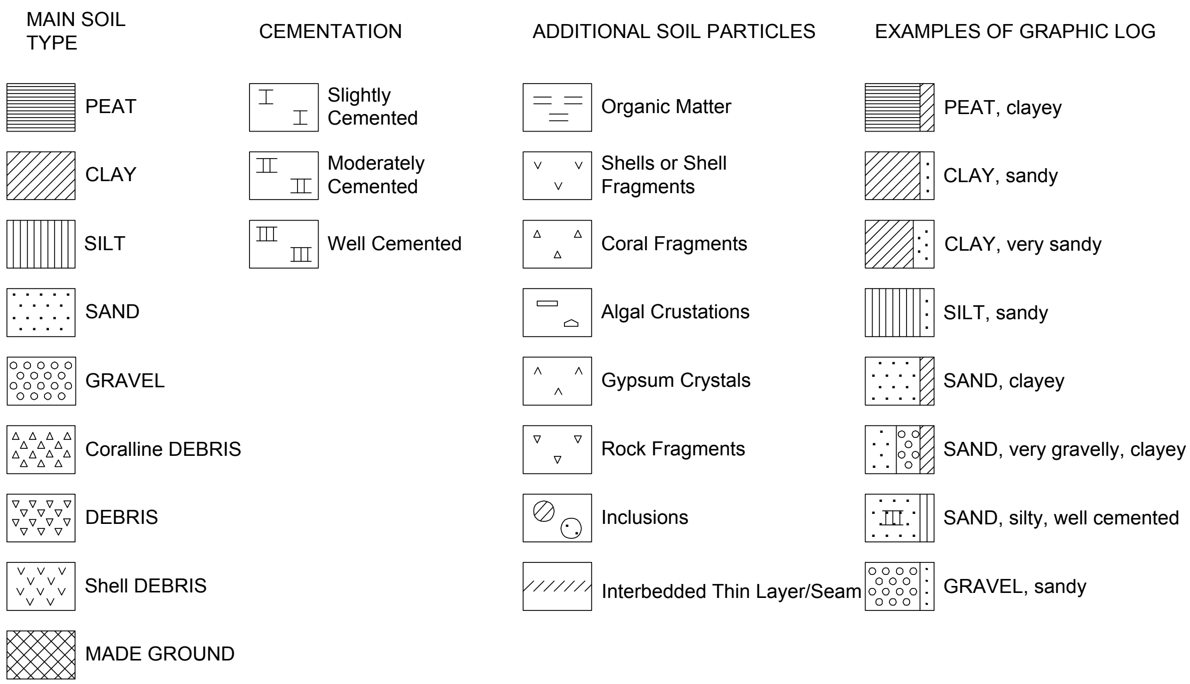

Figure 2 - Symbols for soils

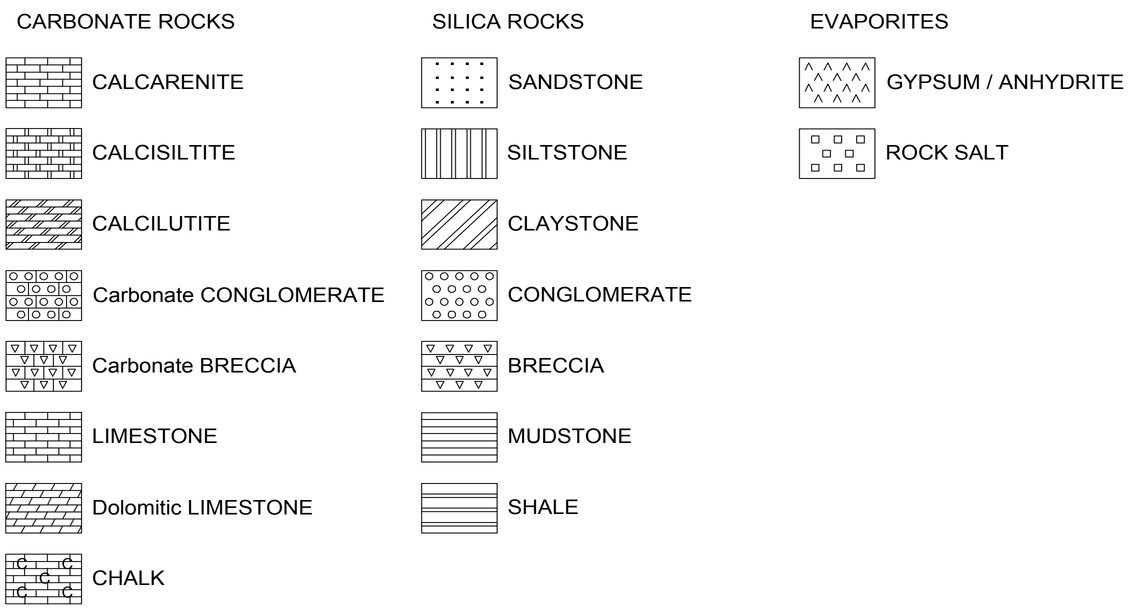

Figure 3 - Symbols for sedimentary rocks

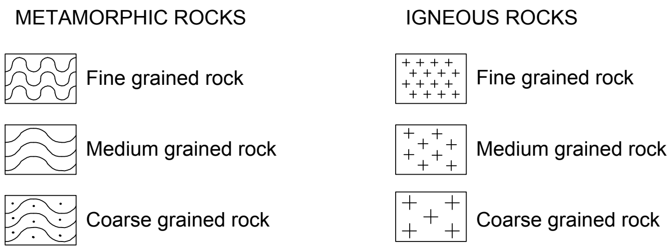

Figure 4 - Symbols for metamorphic and igneous rocks

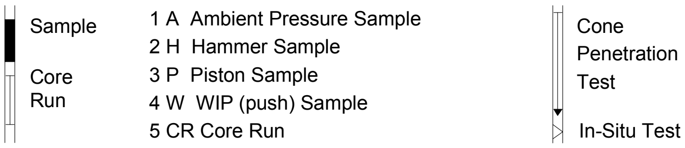

Figure 5 - Symbols for identification of samples and in-situ tests

REFERENCES

ASTM International (1995), “Standard Practices for Preserving and Transporting Soil Samples", ASTM D 4220-95 (Re-approved 2000).

ASTM International (2011), "Standard Test Method for Standard Penetration Test (SPT) and Split Barrel Sampling of Soils", ASTM D 1586-11.

ASTM International (1999), “Standard Practice for Rock Core Drilling and Sampling for Site Investigation", ASTM D 2113-99.

ASTM International (2000), “Standard Practice for Thin-walled Tube Sampling of Soils for Geotechnical Purposes", ASTM D 1587-00.

ASTM International (2002), “Standard Practices for Preserving and Transporting Rock Core Samples", ASTM D 5079-02.

ASTM International (2002), “Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core”, ASTM D 6032-02.

ASTM International (2003), “Standard Practices for Handling, Storing and Preparing Soft Undisturbed Marine Soil", ASTM D 3213-03.

ASTM International (2009), “Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock", ASTM D 5434-09.

BSI British Standards Institution (1999), "Code of Practice for Site Investigations", British Standard BS 5930:1999.

CEN European Committee for Standardization (2007), “Eurocode 7 - Geotechnical Design – Part 2: Ground Investigation and Testing”, European Standard EN 1997-2:2007.

ISO International Organization for Standardization (2005), “Geotechnical Investigation and Testing – Sampling Methods and Groundwater Measurements – Part 1: Technical Principles for Execution”, ISO/FDIS 22475-1:2005.

INTRODUCTION

Fugro employs a range of industry-standard classification systems 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).

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 classification 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 (Kolk, 2000).

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, carbonate and organic soil compositions. The determination of particle type is used for both the BS and the ASTM standard.

TABLE 1 - PARTICLE TYPE

Clay soil	Other Soils	Carbonate Content [%]	Organic Content
--	Silica	< 10	< 1% by weight
Calcareous	Calcareous silica	10 to 50	
Carbonate	Siliceous carbonate	50 to 90	
Carbonate	Carbonate	> 90	
Organic	Organic	--	1% to 30% by weight (BS 5930) $w_{L(oven)}/w_{L(nat)}$ < 0.75 (ASTM D 2488)

Key:
$w_{L(oven)}$: liquid limit of a soil sample after oven drying at 105 °C
$w_{L(nat)}$: liquid limit of a soil sample without oven drying

The description method does not distinguish between types of carbonate material, and assumes that non-carbonate particles are siliceous. Organic soils are further described in the soil description procedures for BS and ASTM (Table 4).

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 the equivalent rock strength classification in Table 2:

TABLE 2 - CEMENTATION

Cementation	Equivalent Rock Strength	
	Description	Uniaxial Compressive Strength σ_c [MPa]
Slightly cemented	very weak	0.3 to 1.25
Moderately cemented	Weak	1.25 to 5.0
Well cemented	Moderately weak	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						σ_c [MPa]
	Clay	Silt	Sand	Gravel	Cobbles	Boulders	
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.

Very coarse 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 coarse or fine 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.”

Organic soils 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	2 to 5	Grey
Slightly organic sand	1 to 3	Same as mineral
Organic clay or silt	5 to 10	Dark grey
Organic sand	3 to 5	Dark grey
Very organic clay or silt	> 10	Black
Very organic sand	> 5	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 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 with ≤12% fines 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 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:

$$I_P \geq 6 \text{ and } I_P \geq 0.73(w_L\text{-}20)$$

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	SAND and/or GRAVEL		< 5%
Clayey or silty	SAND and/or GRAVEL		5% to 20%
Very clayey or silty	SAND and/or GRAVEL		> 20% (1)
Slightly sandy or gravelly	SAND and/or GRAVEL	< 5%	
Sandy or gravelly	SAND and/or GRAVEL	5% to 20%	
Very sandy or gravelly	SAND and/or GRAVEL	> 20%	
Slightly sandy and/or gravelly	SILT or CLAY	< 35%	
Sandy and/or gravelly	SILT or CLAY	35% to 65%	
Very sandy and/or gravelly	SILT or CLAY	> 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 $I_P \geq 0.73(w_L-20)$

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 silt when it plots below the A-line or 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 elastic silt, and are given the group symbol "MH".

Soils are classified as silty clay 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 organic 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 form (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.

Angularity 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 Standard Penetration Test (SPT) is a combined sampling and in-situ test technique for within a borehole. It includes driving a split-barrel sampler to obtain a ground sample and a measure of the resistance of the ground to penetration of the sampler.

The test method provides a ground sample for identification purposes and for laboratory tests that allow the use of disturbed samples. In addition, there are many geotechnical correlations, which relate SPT blow count, or N-value, and geotechnical behaviour.

SPT APPARATUS

Descriptions of common SPT apparatus are as follows:

- Drive-Weight Assembly: device consisting of hammer, hammer fall guide, anvil and hammer drop system.
- Hammer: impact mass of 63.5 kg which is successively lifted and dropped over 0.76 m to provide the energy that accomplishes the sampling and penetration.
- Hammer Fall Guide: guide arrangement for the fall of the hammer.
- Anvil: drive-head which the hammer strikes and through which the hammer energy passes into the sampling rods.
- Hammer Drop System: pick-up and release mechanism by which lifting and dropping of the hammer is accomplished.
- Cathead: rotating drum in a rope-cathead hammer drop system around which a rope is wrapped to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.
- Self-Tripping Release: mechanism that ensures a free fall of the hammer.
- Sampling Rods: rods that connect the drive-weight assembly to the split barrel sampler or solid cone.
- Split Barrel Sampler: flush sampler with 35 mm I.D. (lined) or 38 mm I.D. (unlined) and 51 mm O.D., of minimum 0.5 m length and with a longitudinal split.
- Split Liner: internal lining of the split barrel sampler.
- Core Catcher: device that assists retention of the sample in the split barrel sampler.
- Solid Cone: conical part having a 60^{o} apex angle that replaces the drive shoe of the split barrel sampler under special conditions.

PROCEDURE

The procedure for a Standard Penetration Test includes the following:

- advancement of the borehole to the selected test depth, while maintaining the drill fluid at or above the in-situ ground water level
- lowering of the split barrel sampler and sampling rods into the borehole and positioning of the drive weight assembly
- marking of the sampling rods in three successive 0.15 m increments
- driving the split barrel sampler with the hammer and counting the number of blows applied in each increment until one of the following stop criteria in the procedure of choice occurs:

	ASTM D 1586-11	**BS EN ISO 22476-3:2005**	**BS 1377:Part 9:1990 pre-Amd 2***
Seating drive (150 mm)	Number of blows for penetration of 150 mm or 50 blows, whichever is reached first. Driving is terminated if after 10 successive blows no advance is observed.	Number of blows for penetration of 150 mm	Number of blows for penetration of 150 mm or 25 blows, whichever is reached first
Test drive (2 increments of 150 mm)	Number of blows for penetration of each 150 mm increment. If 150 mm has not been achieved after 50 blows, terminate the increment. Driving is also terminated if a total of 100 blows is reached, including the seating drive.	Number of blows for penetration of 300 mm. If 300 mm has not been achieved after 50 successive blows (or 100 in soft rock), terminate the test drive, record blow count and actual penetration achieved.	Number of blows for penetration of 300 mm. If 300 mm has not been achieved after 50 successive blows (or 100 in soft rock), terminate the test drive, record blow count and actual penetration achieved.

	ASTM D 1586-11	BS EN ISO 22476-3:2005	BS 1377:Part 9:1990 pre-Amd 2*
	Driving is terminated for an increment if after 10 successive blows no advance is observed.		
Remarks	Record seating and test drive blows for 150 mm increments	Record seating and test drive blows for 150 mm increments	Record seating and test drive blows for 75 mm increments

* BS 1377:Part 9:1990 was partially replaced by ISO 22476-3:2005. If however the driving of the seating drive is not reasonably possible following ISO 22476-3:2005, guidelines of BS 1377:Part 9:1990 may be adopted (Hepton and Gosling, 2008).

RESULTS

SAMPLE

The following comments apply to the sample:

- Sample description is applicable.
- Sample quality (CEN, 2007) is typically disturbed, Class 3 for cohesive soil and Class 4 for cohesionless soil.

The classification system for sample quality recognises 5 classes on the basis of feasibility of specific geotechnical identification and laboratory tests. A summary of these classes is as follows:
Class 1: undisturbed: strength, stiffness and consolidation
Class 2: undisturbed: layering, permeability, unit weight
Class 3: disturbed: water content
Class 4: disturbed: particle size analysis, Atterberg limits, soil type
Class 5: disturbed: stratigraphy
The higher class includes the laboratory tests of the lower classes.

PENETRATION RESISTANCE

The initial 0.15 m penetration is the seating drive. The N-value or the standard penetration resistance is the sum of the number of blows required for the second and third 0.15 m increments.

If the sampler penetration is less than 0.45 m then the results include:

- the number of blows per each complete increment
- the number of blows per partial increment
- the depth of penetration for the partial increment.

For this situation, it is common practice (Decourt, 1989) to apply linear extrapolation to a blow count for 300 mm penetration to obtain the "N-value". This extrapolation usually takes account of the blow count for the seating drive.

The results can include the initial self-weight penetration of the split barrel sampler below the bottom of the borehole, if significant.

INTERPRETATION

Geotechnical practice may require correction factors for comparative studies and/or to account for regional variations in practice. The more important correction factors are effective in-situ vertical stress, overconsolidation ratio, particle size distribution, kinetic energy, enthru energy and critical (rod) length. For example, the so-called N60-value denotes an N-value corrected to 60% enthru energy.

BSI (1999) presents a commonly used correlation between N-value and relative density of sands and gravels, as follows:

Descriptive Term	N-value
Very loose	0 to 4
Loose	4 to 10
Medium dense	10 to 30
Dense	30 to 50
Very dense	>50

This correlation excludes corrections for rod energy and vertical effective stress, unless specifically stated otherwise. Skempton (1986) presents recommendations for more fundamental correlation between N-value and relative density.

Cole and Stroud (1976) suggest an approximate correlation between N-value and clay and rock strength.

Experience (e.g. Peuchen and NeSmith, 2004) indicates that SPT results can no longer be interpreted with confidence when rod length exceeds about 25 m. This observation is based on comparative studies between SPT, Cone Penetration Tests (P/CPT) and Cone Pressuremeter Tests (CPMT) to beyond 100 m depth. A possible mitigation measure is to apply N-value adjustment on the basis of downhole energy measurement. Alternatively, PCPT technology and separate sampling may be applied. Equivalent SPT values can then be obtained, if required, by application of correlations such as published by Robertson et al. (1983) and Kulhawy and Mayne (1990).

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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.

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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 co-ordinates
- sub-surface 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 sub-surface 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.

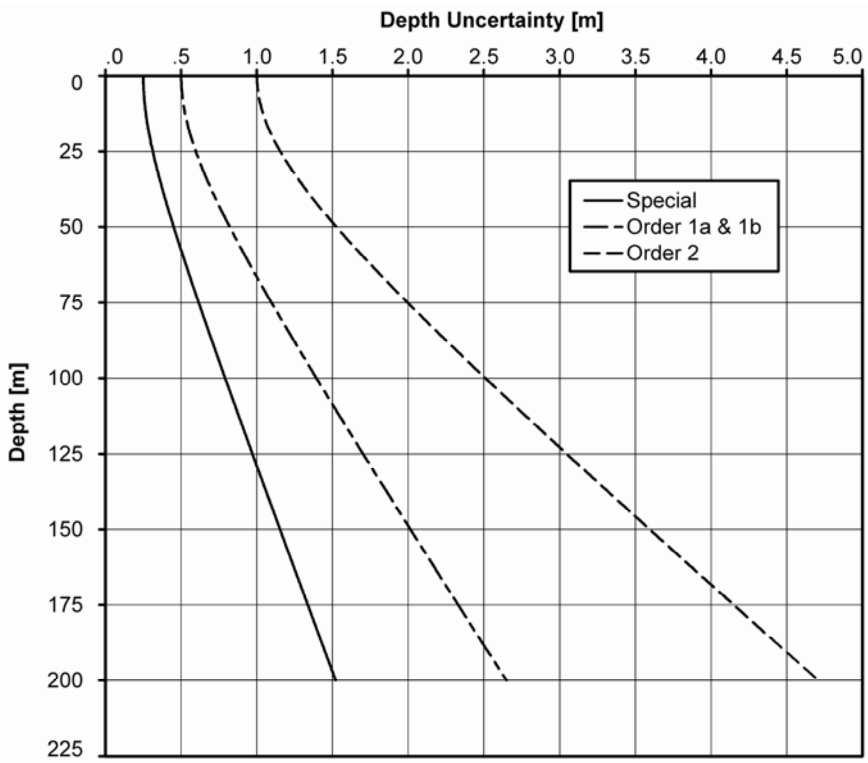

Figure 1 IHO depth uncertainty

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 echosounder; a motion compensator, and a Conductivity Temperature Depth (CTD) probe. Sub-surface 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) sub-surface 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) sub-surface positioning (IMCA, 2011); CTD probe; single beam echosounder 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. For example, surface position may be determined by two independent DGPS systems or direct sounding by drill pipe and echosounding.

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.

Sub-surface 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.
- Echosounder: 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 echosounder 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 echosounder water depth measurements.

An irregular or sloping seafloor may affect echosounder measurements. An echosounder 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^o 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	-	3.1416
e	-	2.71831
ln	-	Natural logarithm
log	-	Logarithm base 10
II - STRESS AND STRAIN		
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
$\sigma_1,\sigma_2,\sigma_3$	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/σ_{vo}]
p'	kPa	Mean effective stress [= $(\sigma'_1 + 2\sigma'_3)/3$] or [= $(\sigma'_1 + \sigma'_2 + \sigma'_3)/3$]
q	kPa	Principal deviator stress [= $\sigma'_1 - \sigma'_3$] or [= $\sigma_1 - \sigma_3$]
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
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 [= $\gamma_{dmax}(\gamma_d-\gamma_{dmin})/\gamma_d(\gamma_{dmax}-\gamma_{dmin})$]
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 [= $(\gamma_d-\gamma_{dmin})/(\gamma_{dmax}-\gamma_{dmin})$]
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)

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 c_u
N_k	-	Cone factor between q_n and c_u

(b) Standard Penetration Test (SPT)

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

c_u	kPa	Undrained shear strength (or s_u)
c_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
$c_{u;r}$	kPa	Undrained shear strength of remoulded soil
c_R	kPa	Undrained residual shear strength
S_t	-	Sensitivity [= $c_u/c_{u;r}$ or c_u/c_R]
T_x	-	Thixotropy ratio [$T_x(t) = c_{u;r}(t)/c_{u;r}(t=0)$]
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'_{vy}	kPa	Effective vertical yield stress in-situ (or effective preconsolidation pressure)
C_c	-	Compression index
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}
C_α	-	Coefficient of secondary consolidation (primary compression)
$C_{\alpha s}$	-	Coefficient of secondary consolidation (swell/re-compression)
c_v	m^2/s	Coefficient of consolidation
H	m	Drainage path length
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}]
YSR	-	Yield stress ratio [= $\sigma'_{vy}/\sigma'_{vo}$]

V - GEOTECHNICAL DESIGN

(a) Partial factors

γ_m	-	Material factor (partial safety factor)
γ_f	-	Load factor (partial action 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

Symbol	Unit	Quantity
(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/c_u)
β	-	Adhesion factor between ground and foundation (= f/σ'_v or f/σ'_{vo})
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 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: ENERGY MEASUREMENTS

ANEXO I
PROGRAMA DE INSTRUMENTAÇÃO – RESUMO DOS RESULTADOS

Obra:	ALARGAMENTO DO CANAL DRAGADO
Área/Setor:	BAIA DE GUANABARA
Furo:	POR-06
Tipo de Sondagem:	SPT
Perfuratriz:	COMMACHIO 1200
Martelo:	AUTOMATIC TRIP HAMMER

Date	Time	LP meters	BN	ENERGIA MÁX kN-meters	EFICIÊNCIA (%)	Local
09/06/2015	22:07:05	10,8	1	0,3041	63,6	
09/06/2015	22:07:16	10,8	2	0,2931	61,3	
09/06/2015	22:07:28	10,8	3	0,2887	60,4	
09/06/2015	22:07:41	10,8	4	0,2944	61,6	
09/06/2015	22:07:51	10,8	5	0,2849	59,6	
09/06/2015	22:08:01	10,8	6	0,2923	61,1	
09/06/2015	22:08:12	10,8	7	0,2891	60,5	
09/06/2015	22:08:21	10,8	8	0,2918	61,0	
09/06/2015	22:08:32	10,8	9	0,2806	58,7	
09/06/2015	22:08:43	10,8	10	0,2826	59,1	
09/06/2015	22:08:54	10,8	11	0,2971	62,1	
09/06/2015	22:09:05	10,8	12	0,2867	59,9	
09/06/2015	22:09:18	10,8	13	0,2935	61,4	
09/06/2015	22:09:30	10,8	14	0,2852	59,6	
09/06/2015	22:09:39	10,8	15	0,2908	60,8	
09/06/2015	23:34:11	12,3	16	0,2967	62,0	
09/06/2015	23:34:24	12,3	17	0,3036	63,5	
09/06/2015	23:34:36	12,3	18	0,2936	61,4	
09/06/2015	23:34:46	12,3	19	0,2847	59,5	
09/06/2015	23:35:08	12,3	20	0,2802	58,6	
09/06/2015	23:35:18	12,3	21	0,2919	61,0	
09/06/2015	23:35:32	12,3	22	0,2808	58,7	
09/06/2015	23:35:44	12,3	23	0,2790	58,3	
09/06/2015	23:35:56	12,3	24	0,2851	59,6	
09/06/2015	23:36:06	12,3	25	0,2959	61,9	
09/06/2015	23:36:14	12,3	26	0,2916	61,0	
09/06/2015	23:36:35	12,3	27	0,2899	60,6	
09/06/2015	23:36:45	12,3	28	0,2896	60,6	
09/06/2015	23:36:56	12,3	29	0,2938	61,4	POR-06
09/06/2015	23:37:05	12,3	30	0,3001	62,8	
09/06/2015	23:37:15	12,3	31	0,2987	62,5	
09/06/2015	23:37:24	12,3	32	0,2890	60,4	
09/06/2015	23:37:34	12,3	33	0,2896	60,6	
09/06/2015	23:37:47	12,3	34	0,2940	61,5	
10/06/2015	00:38:40	13,8	35	0,3010	62,9	
10/06/2015	00:38:47	13,8	36	0,2871	60,0	
10/06/2015	00:38:53	13,8	37	0,2875	60,1	
10/06/2015	00:39:05	13,8	38	0,2863	59,9	
10/06/2015	00:39:10	13,8	39	0,3001	62,8	
10/06/2015	00:39:17	13,8	40	0,2825	59,1	
10/06/2015	00:39:26	13,8	41	0,2900	60,6	
10/06/2015	00:39:35	13,8	42	0,2988	62,5	
10/06/2015	00:39:42	13,8	43	0,3054	63,9	
10/06/2015	00:39:49	13,8	44	0,2960	61,9	
10/06/2015	00:39:54	13,8	45	0,2958	61,9	
10/06/2015	00:40:00	13,8	46	0,3019	63,1	
10/06/2015	00:40:05	13,8	47	0,2992	62,6	
10/06/2015	00:40:11	13,8	48	0,2924	61,1	
10/06/2015	00:40:17	13,8	49	0,2866	59,9	
10/06/2015	00:40:28	13,8	50	0,2931	61,3	
10/06/2015	00:40:40	13,8	51	0,2871	60,0	
10/06/2015	00:40:46	13,8	52	0,2929	61,2	
10/06/2015	00:40:53	13,8	53	0,2816	58,9	
10/06/2015	00:40:59	13,8	54	0,2982	62,4	
10/06/2015	00:41:05	13,8	55	0,2923	61,1	
10/06/2015	00:41:10	13,8	56	0,2974	62,2	
10/06/2015	00:41:18	13,8	57	0,2965	62,0	

ANEXO I
PROGRAMA DE INSTRUMENTAÇÃO – RESUMO DOS RESULTADOS

Obra:	ALARGAMENTO DO CANAL DRAGADO
Área/Setor:	BAIA DE GUANABARA
Furo:	POR-06
Tipo de Sondagem:	SPT
Perfuratriz:	COMMACHIO 1200
Martelo:	AUTOMATIC TRIP HAMMER

Date	Time	LP meters	BN	ENERGIA MÁX kN-meters	EFICIÊNCIA (%)	Local
10/06/2015	01:57:17	15,3	58	0,2879	60,2	POR-06
10/06/2015	01:57:23	15,3	59	0,2979	62,3	
10/06/2015	01:57:29	15,3	60	0,3121	65,3	
10/06/2015	01:57:35	15,3	61	0,3110	65,0	
10/06/2015	01:57:41	15,3	62	0,3055	63,9	
10/06/2015	01:57:46	15,3	63	0,3048	63,7	
10/06/2015	01:57:52	15,3	64	0,3035	63,5	
10/06/2015	01:57:58	15,3	65	0,2971	62,1	
10/06/2015	01:58:04	15,3	66	0,3042	63,6	
10/06/2015	01:58:09	15,3	67	0,2937	61,4	
10/06/2015	01:58:17	15,3	68	0,3045	63,7	
10/06/2015	01:58:26	15,3	69	0,2923	61,1	
10/06/2015	01:58:32	15,3	70	0,3109	65,0	
10/06/2015	01:58:38	15,3	71	0,3050	63,8	
10/06/2015	01:58:43	15,3	72	0,3024	63,2	
10/06/2015	01:58:48	15,3	73	0,2866	59,9	
10/06/2015	01:59:07	15,3	74	0,2895	60,5	
10/06/2015	01:59:12	15,3	75	0,2936	61,4	
10/06/2015	01:59:24	15,3	76	0,2975	62,2	
10/06/2015	01:59:29	15,3	77	0,2910	60,8	
10/06/2015	01:59:34	15,3	78	0,3042	63,6	
10/06/2015	01:59:40	15,3	79	0,2897	60,6	
10/06/2015	01:59:45	15,3	80	0,2998	62,7	
10/06/2015	01:59:51	15,3	81	0,2989	62,5	
10/06/2015	01:59:56	15,3	82	0,2969	62,1	
10/06/2015	02:00:01	15,3	83	0,3146	65,8	
10/06/2015	02:00:06	15,3	84	0,2860	59,8	
10/06/2015	02:00:12	15,3	85	0,2958	61,9	
10/06/2015	02:00:17	15,3	86	0,2958	61,9	
10/06/2015	04:09:05	17,3	87	0,3018	63,1	
10/06/2015	04:09:14	17,3	88	0,2892	60,5	
10/06/2015	04:09:22	17,3	89	0,2931	61,3	
10/06/2015	04:09:28	17,3	90	0,3032	63,4	
10/06/2015	04:09:34	17,3	91	0,2838	59,3	
10/06/2015	04:09:41	17,3	92	0,2800	58,5	
10/06/2015	04:09:47	17,3	93	0,2976	62,2	
10/06/2015	04:09:53	17,3	94	0,2878	60,2	
10/06/2015	04:10:00	17,3	95	0,2971	62,1	
10/06/2015	04:10:07	17,3	96	0,3032	63,4	
10/06/2015	04:10:13	17,3	97	0,3023	63,2	
10/06/2015	04:10:20	17,3	98	0,2991	62,5	
10/06/2015	04:10:26	17,3	99	0,3042	63,6	
10/06/2015	04:10:31	17,3	100	0,3076	64,3	
10/06/2015	04:10:37	17,3	101	0,3179	66,5	
10/06/2015	04:10:44	17,3	102	0,2956	61,8	
10/06/2015	04:10:53	17,3	103	0,3020	63,1	
10/06/2015	04:11:02	17,3	104	0,3014	63,0	
10/06/2015	04:11:08	17,3	105	0,3145	65,8	
			Média	0,2951	61,7	
			Desvio padrão	0,0083	1,7	

ANEXO I
PROGRAMA DE INSTRUMENTAÇÃO – RESUMO DOS RESULTADOS

Obra:	ALARGAMENTO DO CANAL DRAGADO
Área/Setor:	BAIA DE GUANABARA
Furo:	POR-10
Tipo de Sondagem:	SPT
Perfuratriz:	COMMACHIO 1200
Martelo:	AUTOMATIC TRIP HAMMER

Date	Time	LP meters	BN	ENERGIA MÁX kN-meters	EFICIÊNCIA (%)	Local
09/06/2015	00:09:47	11,9	1	0,2904	60,7	POR-10
09/06/2015	00:09:58	11,9	2	0,3120	65,2	
09/06/2015	00:10:09	11,9	3	0,3053	63,8	
09/06/2015	00:10:18	11,9	4	0,3084	64,5	
09/06/2015	00:10:27	11,9	5	0,3069	64,2	
09/06/2015	00:10:38	11,9	6	0,3135	65,6	
09/06/2015	00:10:48	11,9	7	0,3114	65,1	
09/06/2015	00:10:59	11,9	8	0,3101	64,8	
09/06/2015	00:11:10	11,9	9	0,2974	62,2	
09/06/2015	00:11:20	11,9	10	0,3038	63,5	
09/06/2015	00:11:34	11,9	11	0,3102	64,9	
09/06/2015	00:11:43	11,9	12	0,3051	63,8	
09/06/2015	00:11:53	11,9	13	0,3048	63,7	
09/06/2015	00:12:03	11,9	14	0,3000	62,7	
09/06/2015	00:12:14	11,9	15	0,2933	61,3	
09/06/2015	00:12:23	11,9	16	0,3023	63,2	
09/06/2015	00:12:33	11,9	17	0,3062	64,0	
09/06/2015	00:12:44	11,9	18	0,2953	61,7	
09/06/2015	01:35:55	13,4	19	0,2783	58,2	
09/06/2015	01:36:05	13,4	20	0,2954	61,8	
09/06/2015	01:36:12	13,4	21	0,3014	63,0	
09/06/2015	01:36:20	13,4	22	0,2947	61,6	
09/06/2015	01:36:33	13,4	23	0,2869	60,0	
09/06/2015	01:36:46	13,4	24	0,2837	59,3	
09/06/2015	01:36:55	13,4	25	0,2926	61,2	
09/06/2015	01:37:03	13,4	26	0,2998	62,7	
09/06/2015	01:37:12	13,4	27	0,2931	61,3	
09/06/2015	01:37:18	13,4	28	0,2813	58,8	
09/06/2015	01:37:29	13,4	29	0,3010	62,9	
09/06/2015	01:37:36	13,4	30	0,2800	58,5	
09/06/2015	01:37:44	13,4	31	0,2933	61,3	
09/06/2015	01:38:05	13,4	32	0,2906	60,8	
09/06/2015	01:38:12	13,4	33	0,2948	61,6	
09/06/2015	01:38:19	13,4	34	0,2841	59,4	
09/06/2015	01:38:34	13,4	35	0,2856	59,7	
09/06/2015	01:38:41	13,4	36	0,2899	60,6	
09/06/2015	01:38:48	13,4	37	0,2848	59,6	
09/06/2015	01:38:56	13,4	38	0,2961	61,9	
09/06/2015	01:39:04	13,4	39	0,2988	62,5	
09/06/2015	01:39:14	13,4	40	0,2937	61,4	
09/06/2015	01:39:20	13,4	41	0,2934	61,4	
09/06/2015	01:39:27	13,4	42	0,3001	62,8	
09/06/2015	01:39:35	13,4	43	0,2906	60,8	
09/06/2015	01:39:44	13,4	44	0,2918	61,0	
09/06/2015	01:39:53	13,4	45	0,3069	64,2	
09/06/2015	01:40:00	13,4	46	0,2810	58,8	
09/06/2015	03:11:37	14,9	47	0,2824	59,1	
09/06/2015	03:11:48	14,9	48	0,2834	59,3	
09/06/2015	03:12:02	14,9	49	0,3082	64,4	
09/06/2015	03:12:21	14,9	50	0,3074	64,3	
09/06/2015	03:12:34	14,9	51	0,3082	64,4	
09/06/2015	03:13:01	14,9	52	0,3037	63,5	
09/06/2015	03:13:20	14,9	53	0,2857	59,7	
09/06/2015	03:13:34	14,9	54	0,2980	62,3	
09/06/2015	03:13:42	14,9	55	0,2901	60,7	
09/06/2015	03:36:14	14,9	56	0,3048	63,7	
09/06/2015	03:36:23	14,9	57	0,3008	62,9	
09/06/2015	03:36:33	14,9	58	0,3024	63,2	
09/06/2015	03:36:42	14,9	59	0,3034	63,4	
09/06/2015	03:36:52	14,9	60	0,2997	62,7	
09/06/2015	03:37:04	14,9	61	0,3012	63,0	
09/06/2015	03:37:13	14,9	62	0,2984	62,4	
09/06/2015	03:37:25	14,9	63	0,2975	62,2	
09/06/2015	03:37:36	14,9	64	0,3030	63,4	
09/06/2015	03:37:45	14,9	65	0,3007	62,9	
09/06/2015	03:37:56	14,9	66	0,3063	64,0	
09/06/2015	03:38:05	14,9	67	0,3064	64,1	
09/06/2015	03:38:21	14,9	68	0,2911	60,9	
09/06/2015	03:38:31	14,9	69	0,3102	64,9	
09/06/2015	03:38:39	14,9	70	0,3083	64,5	
09/06/2015	03:38:45	14,9	71	0,3005	62,8	
09/06/2015	03:38:56	14,9	72	0,3082	64,4	
09/06/2015	03:39:04	14,9	73	0,3076	64,3	
09/06/2015	03:39:16	14,9	74	0,3020	63,1	

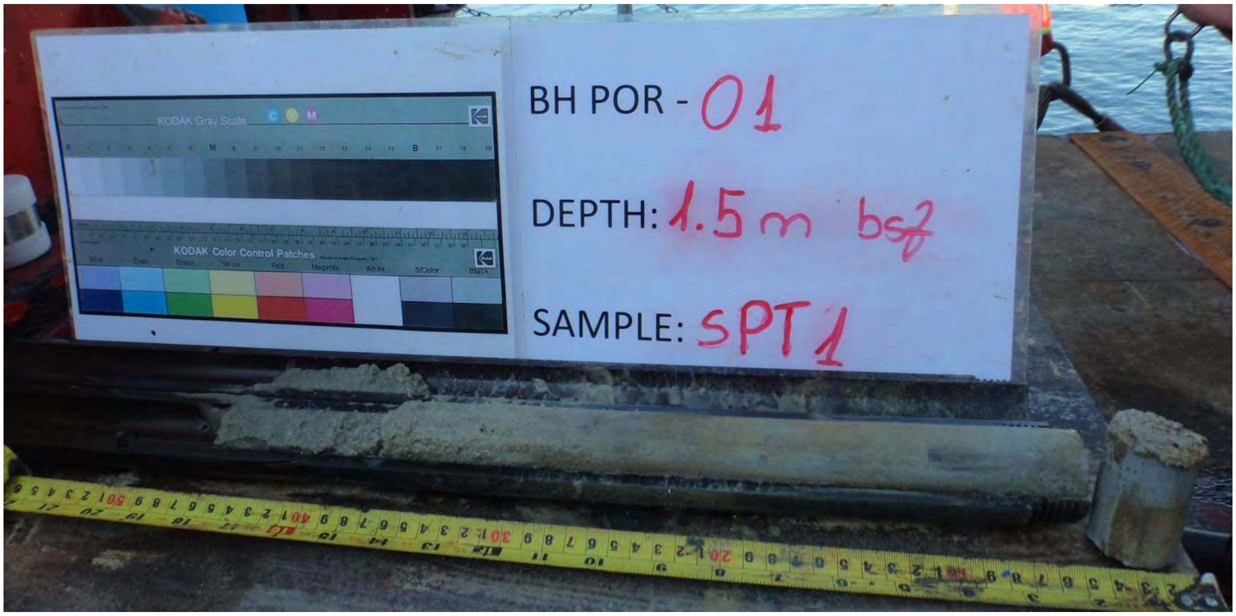
ANEXO I
PROGRAMA DE INSTRUMENTAÇÃO – RESUMO DOS RESULTADOS

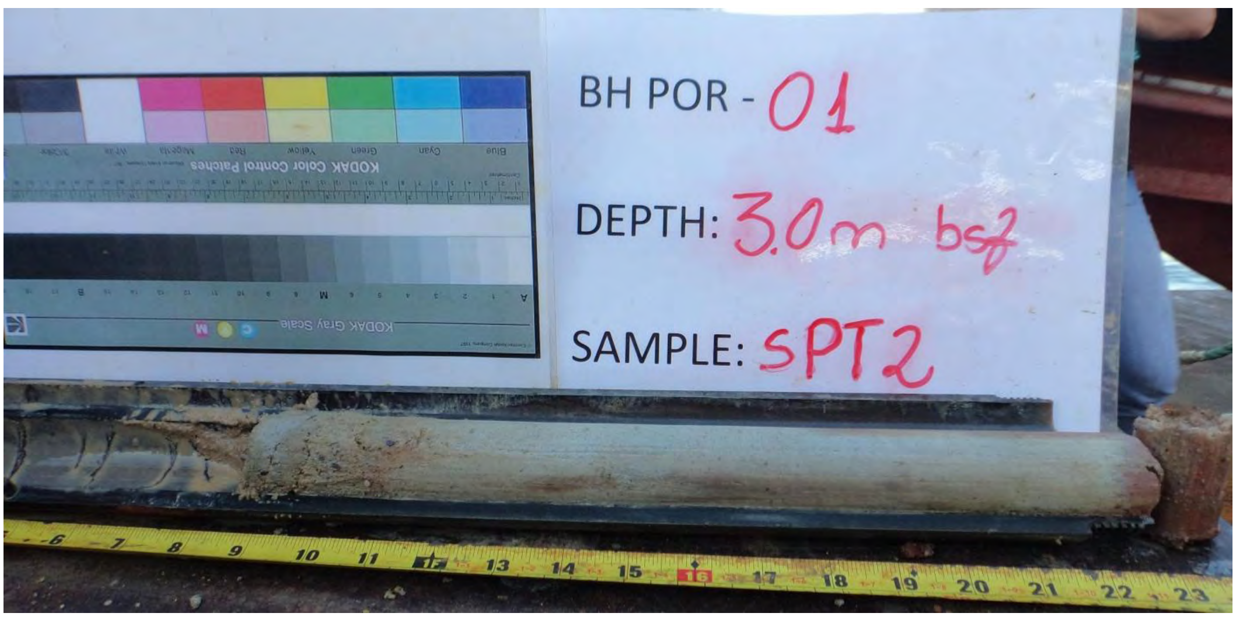
Obra:	ALARGAMENTO DO CANAL DRAGADO
Área/Setor:	BAIA DE GUANABARA
Furo:	POR-10
Tipo de Sondagem:	SPT
Perfuratriz:	COMMACHIO 1200
Martelo:	AUTOMATIC TRIP HAMMER

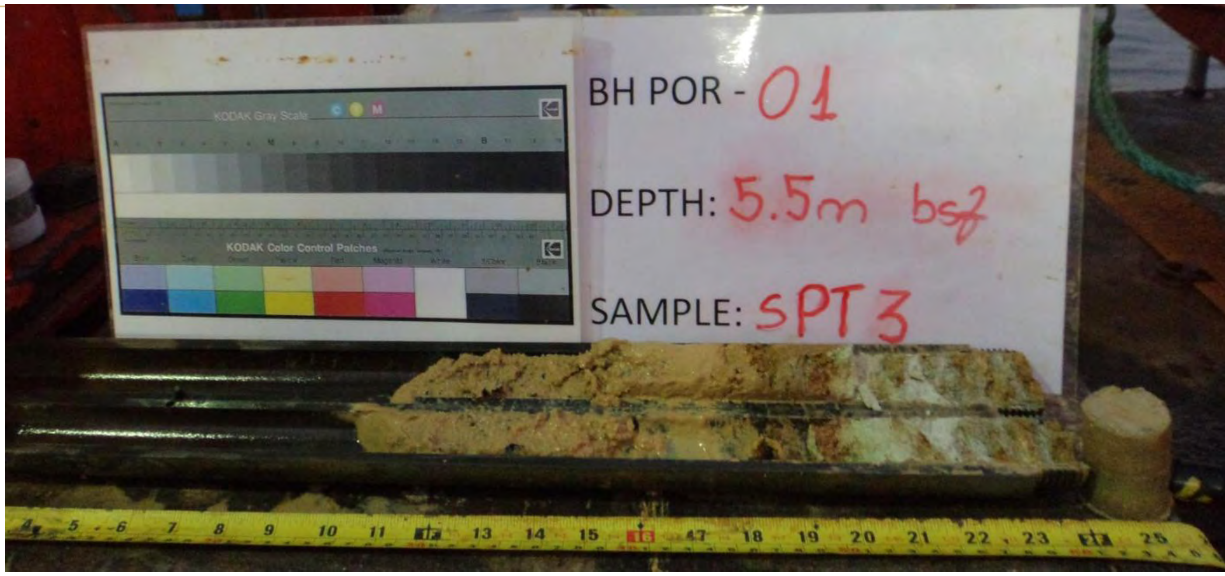
Date	Time	LP meters	BN	ENERGIA MÁX kN-meters	EFICIÊNCIA (%)	Local
09/06/2015	04:57:19	15,9	75	0,2915	61,0	POR-10
09/06/2015	04:57:28	15,9	76	0,3021	63,2	
09/06/2015	04:57:37	15,9	77	0,3112	65,1	
09/06/2015	04:57:47	15,9	78	0,3130	65,4	
09/06/2015	04:58:03	15,9	79	0,3078	64,4	
09/06/2015	04:58:14	15,9	80	0,3087	64,5	
09/06/2015	04:58:24	15,9	81	0,3083	64,5	
09/06/2015	04:58:34	15,9	82	0,3106	64,9	
09/06/2015	04:58:46	15,9	83	0,2980	62,3	
09/06/2015	04:59:01	15,9	84	0,3168	66,2	
09/06/2015	04:59:10	15,9	85	0,3051	63,8	
09/06/2015	04:59:49	15,9	86	0,2998	62,7	
09/06/2015	05:00:02	15,9	87	0,3103	64,9	
09/06/2015	05:00:29	15,9	88	0,3099	64,8	
09/06/2015	05:00:46	15,9	89	0,3149	65,8	
09/06/2015	05:01:00	15,9	90	0,3131	65,5	
09/06/2015	05:01:11	15,9	91	0,2933	61,3	
09/06/2015	05:01:24	15,9	92	0,3139	65,6	
09/06/2015	05:01:35	15,9	93	0,3180	66,5	
09/06/2015	05:01:45	15,9	94	0,3149	65,8	
09/06/2015	05:01:56	15,9	95	0,3120	65,2	
09/06/2015	05:02:22	15,9	96	0,3131	65,5	
09/06/2015	05:02:41	15,9	97	0,3089	64,6	
09/06/2015	05:02:51	15,9	98	0,3116	65,2	
09/06/2015	05:53:12	17,9	99	0,3066	64,1	
09/06/2015	05:53:37	17,9	100	0,2945	61,6	
09/06/2015	05:53:45	17,9	101	0,2949	61,7	
09/06/2015	05:53:57	17,9	102	0,3010	62,9	
09/06/2015	05:54:08	17,9	103	0,3002	62,8	
09/06/2015	05:54:20	17,9	104	0,3166	66,2	
09/06/2015	05:54:31	17,9	105	0,3030	63,4	
09/06/2015	05:54:44	17,9	106	0,3045	63,7	
09/06/2015	05:54:55	17,9	107	0,3045	63,7	
09/06/2015	05:55:07	17,9	108	0,3044	63,7	
09/06/2015	05:55:19	17,9	109	0,3115	65,1	
09/06/2015	05:55:30	17,9	110	0,3135	65,6	
09/06/2015	05:55:40	17,9	111	0,3158	66,0	
09/06/2015	05:55:52	17,9	112	0,2979	62,3	
09/06/2015	05:56:03	17,9	113	0,3001	62,8	
09/06/2015	05:56:15	17,9	114	0,3041	63,6	
09/06/2015	05:56:27	17,9	115	0,3064	64,1	
09/06/2015	05:56:38	17,9	116	0,3047	63,7	
09/06/2015	05:56:49	17,9	117	0,3046	63,7	
09/06/2015	05:57:01	17,9	118	0,3080	64,4	
09/06/2015	05:57:20	17,9	119	0,3071	64,2	
09/06/2015	05:57:33	17,9	120	0,3025	63,3	
			Média	0,3014	63,0	
			Desvio padrão	0,0092	1,9	

APPENDIX 3: SAMPLE PHOTOGRAPHS

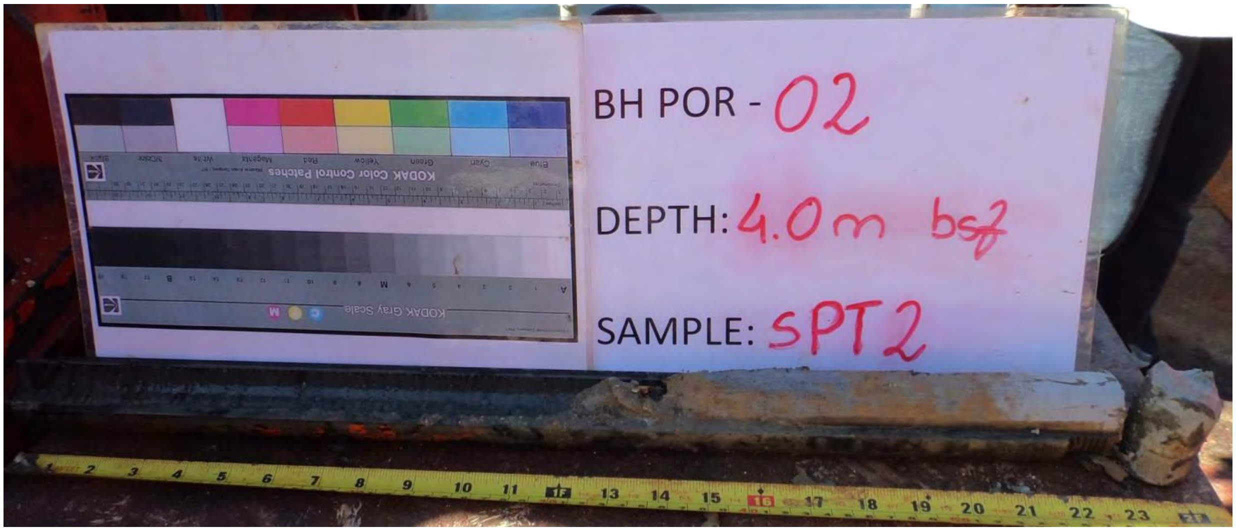
POR-01


KODAK Gray Scale
KODAK Color Control Patches
BH POR - 01
DEPTH: 1.5 m bsf
SAMPLE: SPT 1

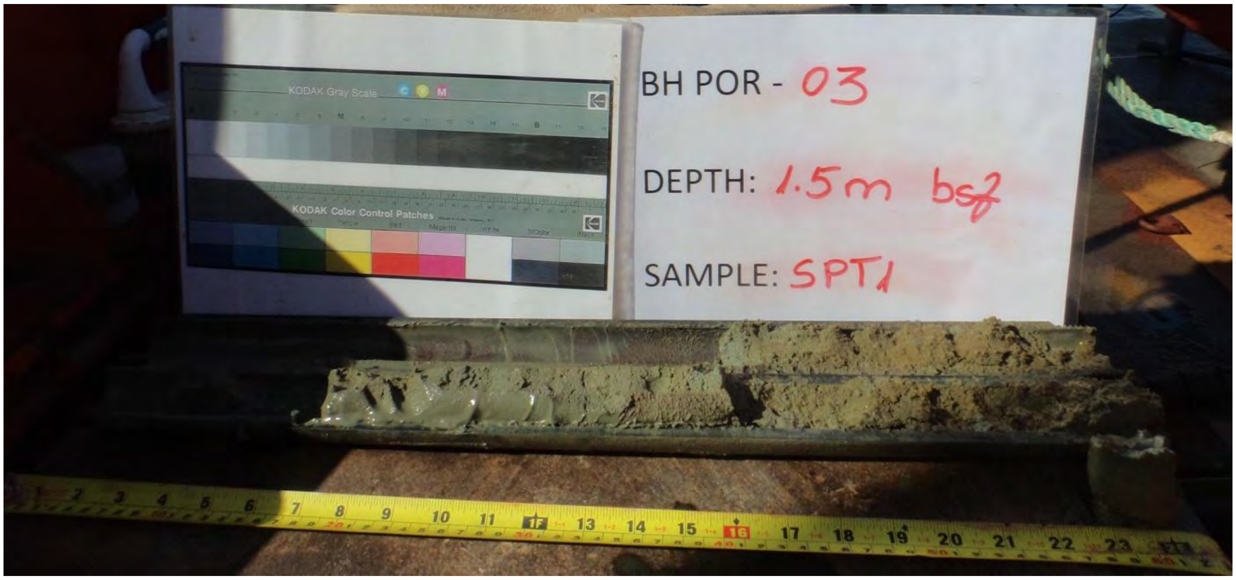

KODAK Color Control Patches
KODAK Gray Scale
BH POR - 01
DEPTH: 3.0m bsf
SAMPLE: SPT2


KODAK Gray Scale
KODAK Color Control Patches
BH POR - 01
DEPTH: 5.5m bsf
SAMPLE: SPT 3

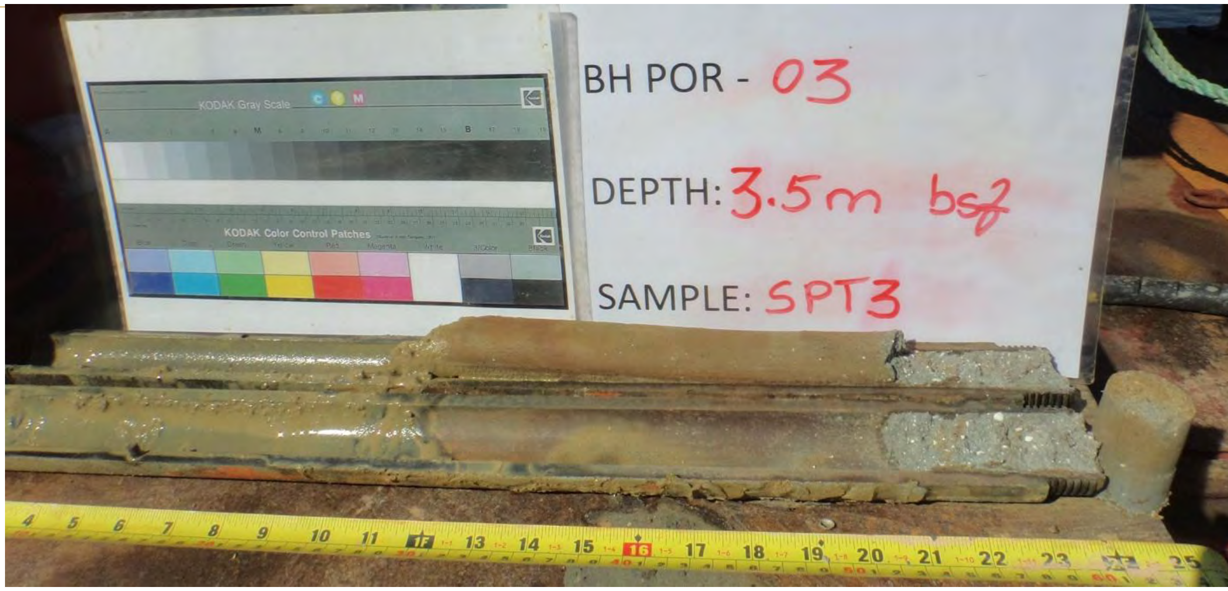
POR-02


BH POR - 02
DEPTH: 4.0m bsf
SAMPLE: SPT2
KODAK Color Control Patches
KODAK Gray Scale

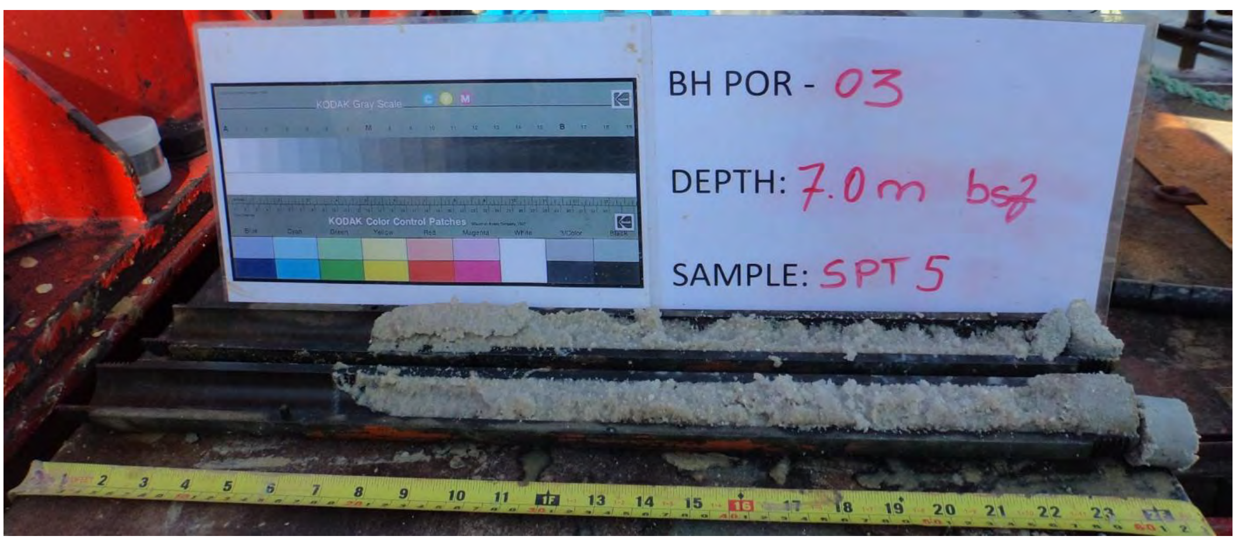
POR-03

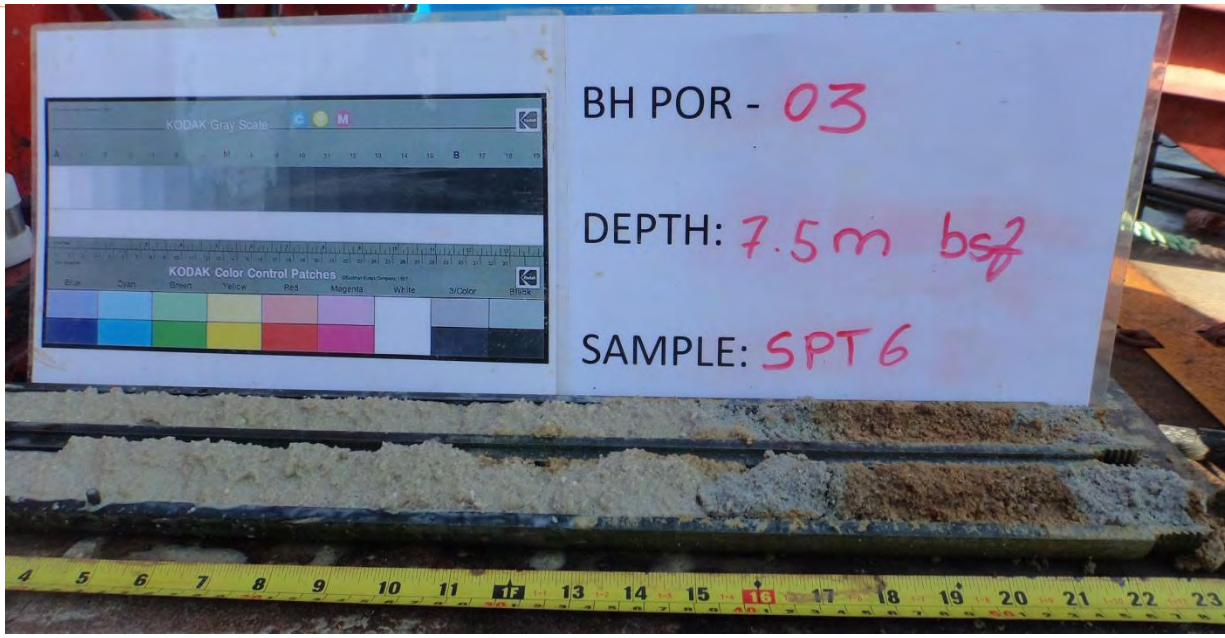

KODAK Gray Scale
KODAK Color Control Patches
BH POR - 03
DEPTH: 1.5m bsf
SAMPLE: SPT1


KODAK Gray Scale
KODAK Color Control Patches
BH POR - 03
DEPTH: 2.5m bsf
SAMPLE: SPT2

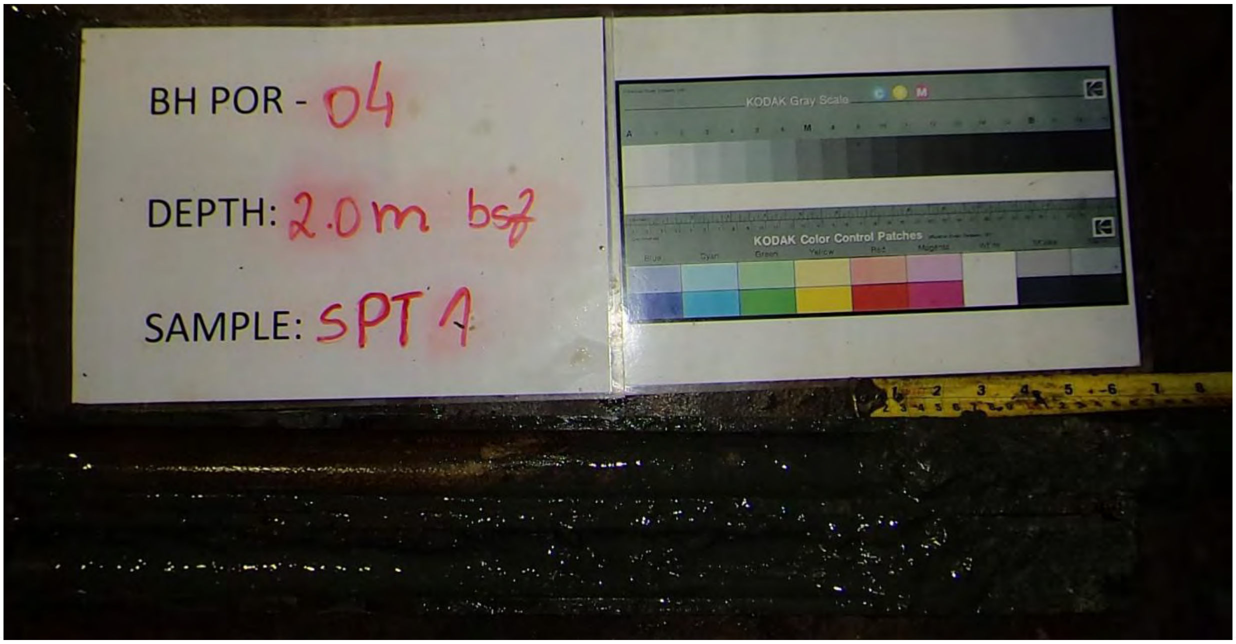

BH POR - 03
DEPTH: 3.5m bsf
SAMPLE: SPT3
KODAK Gray Scale
KODAK Color Control Patches

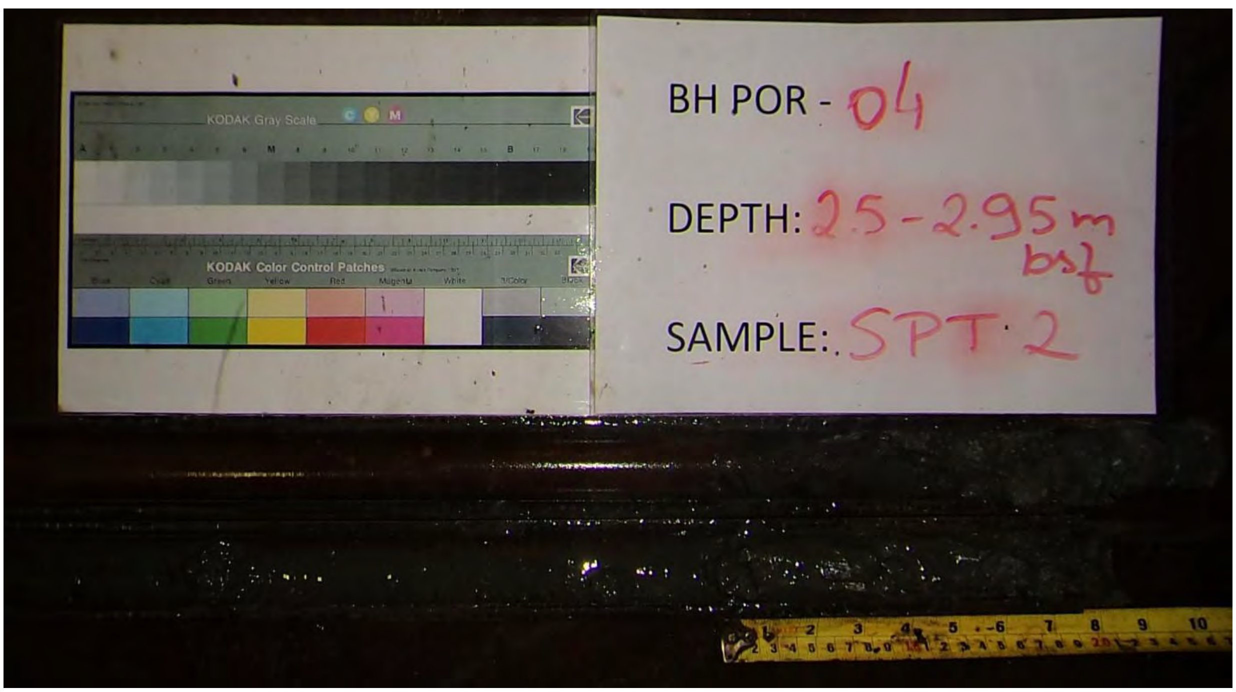

BH POR - 03
DEPTH: 6.0m bsf
SAMPLE: SPT4
KODAK Gray Scale
KODAK Color Control Patches

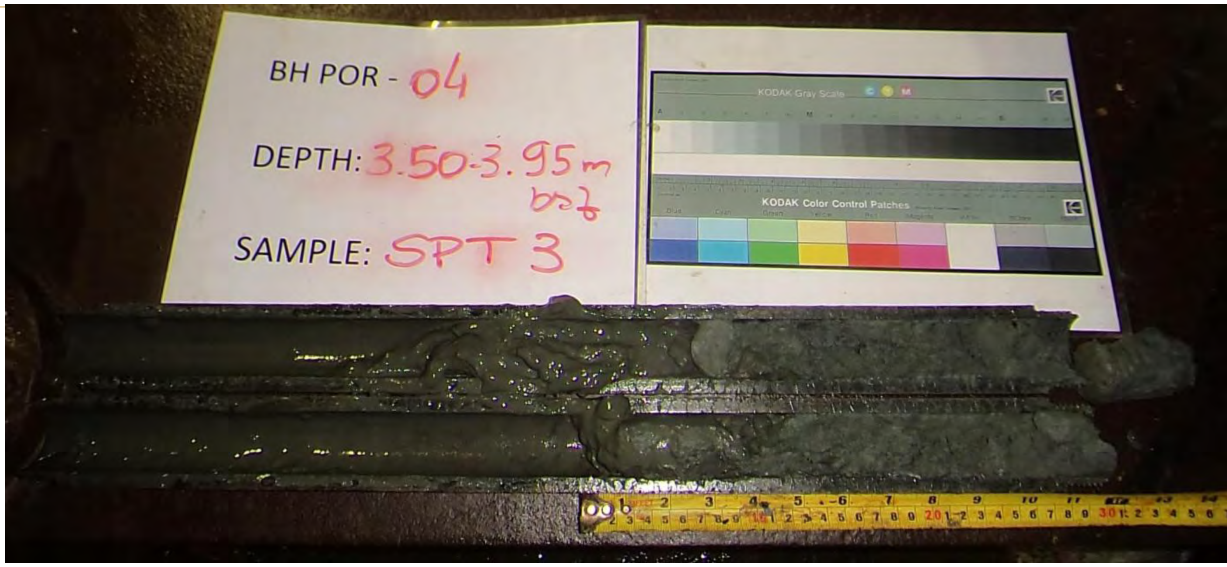

BH POR - 03
DEPTH: 7.0m bsf
SAMPLE: SPT 5
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 03
DEPTH: 7.5m bsf
SAMPLE: SPT6
KODAK Gray Scale
KODAK Color Control Patches

POR-04

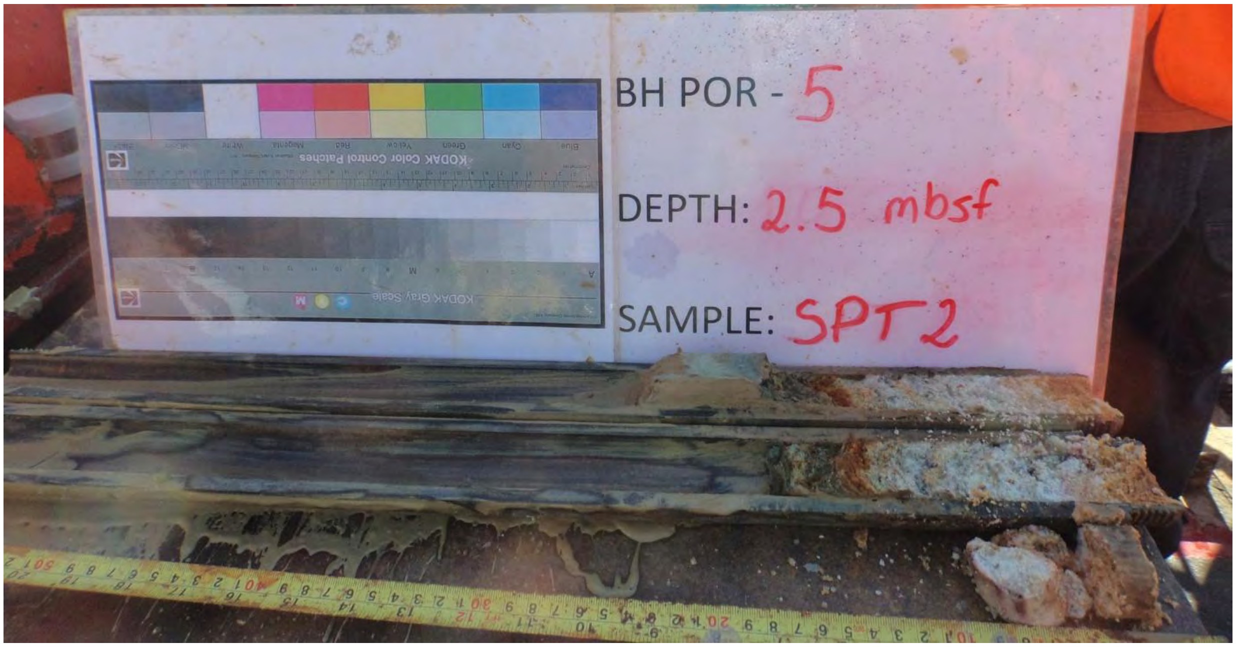

BH POR - 04
DEPTH: 2.0m bsf
SAMPLE: SPT 1
KODAK Gray Scale
KODAK Color Control Patches

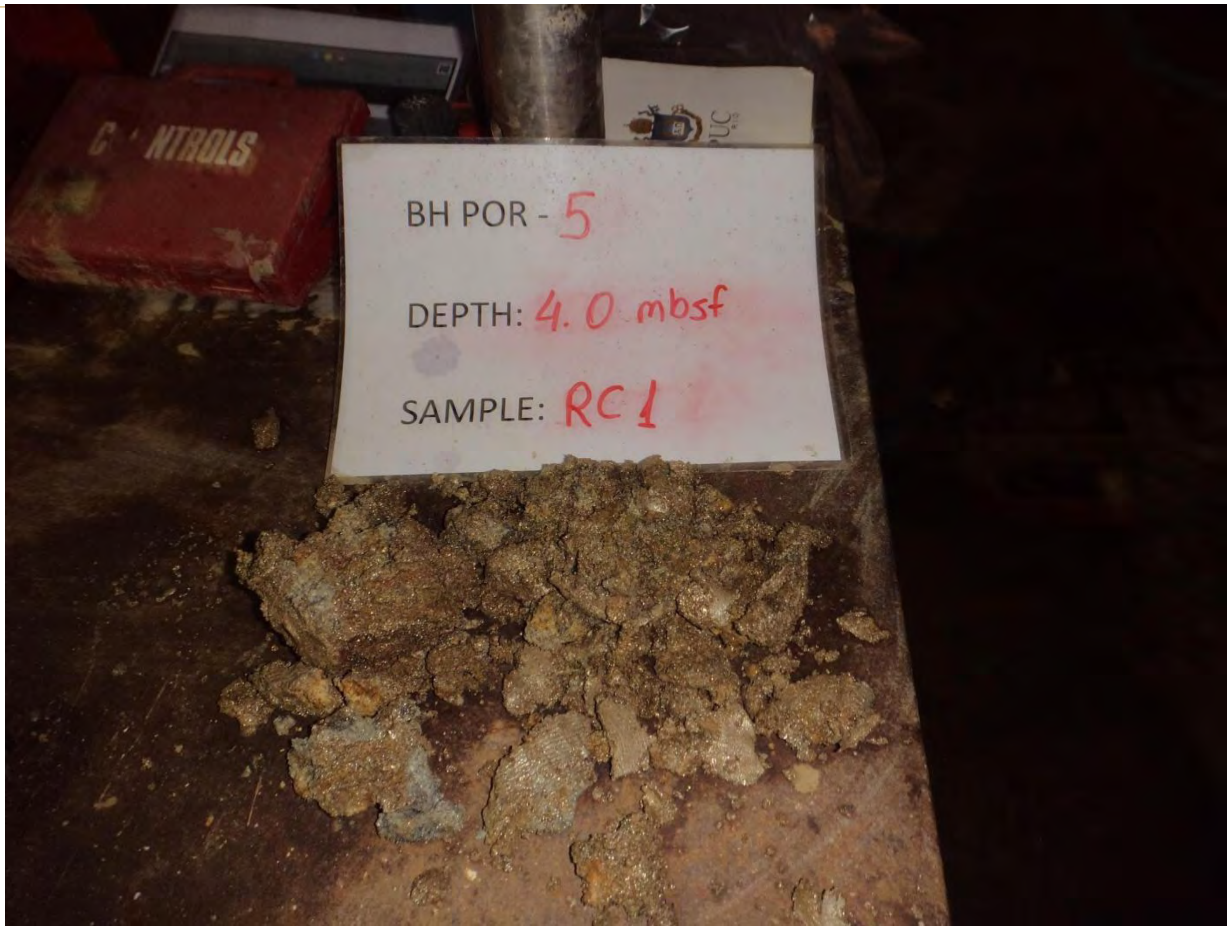

KODAK Gray Scale
KODAK Color Control Patches
BH POR - 04
DEPTH: 2.5-2.95m bsf
SAMPLE: SPT 2

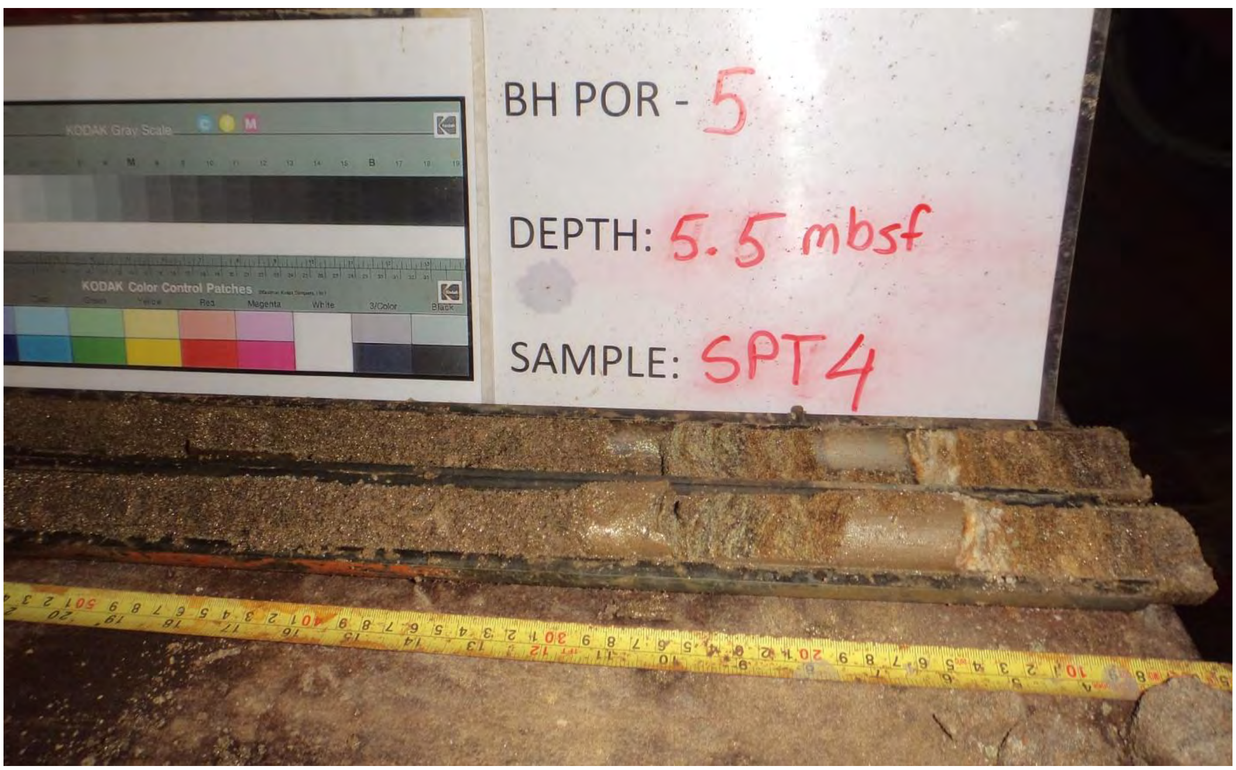

BH POR - 04
DEPTH: 3.50-3.95 m bsf
SAMPLE: SPT 3
KODAK Gray Scale
KODAK Color Control Patches

POR-05


BH POR - 5
DEPTH: 1.0 mbsf
SAMPLE: SPT1
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 5
DEPTH: 2.5 mbsf
SAMPLE: SPT2


BH POR - 5
DEPTH: 4.0 mbsf
SAMPLE: RC1

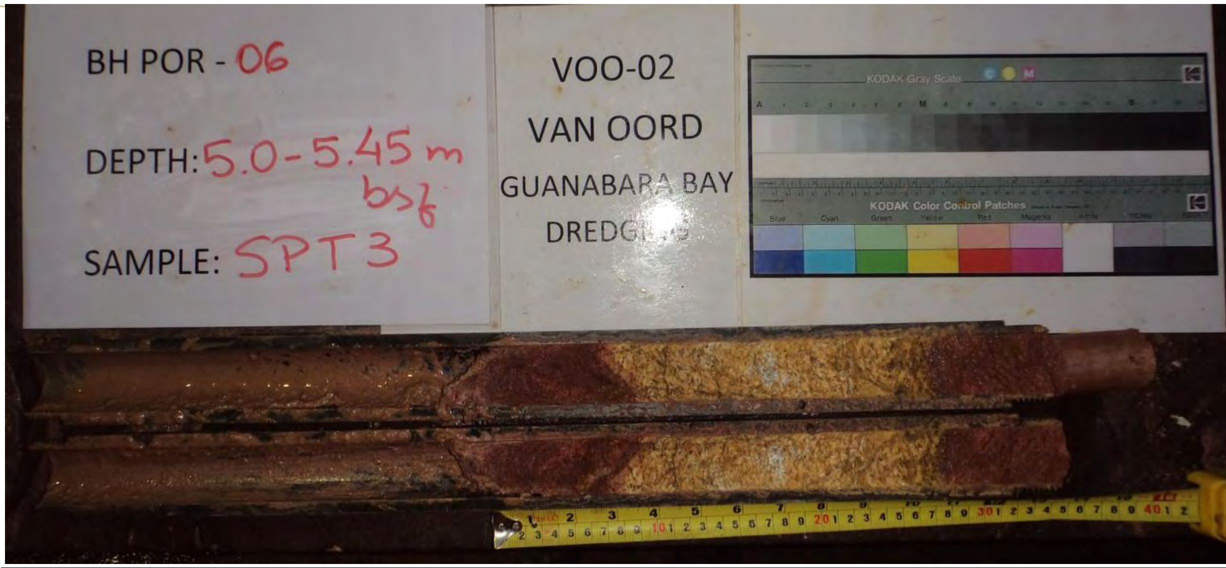

BH POR - 5
DEPTH: 5.5 mbsf
SAMPLE: SPT4
KODAK Gray Scale
KODAK Color Control Patches


FUGRO GEOTECNIA MARINHA
Project: V00-02
Borehole: POR.05
Sample: RC2(shoe)
Depth:
Blowcount:

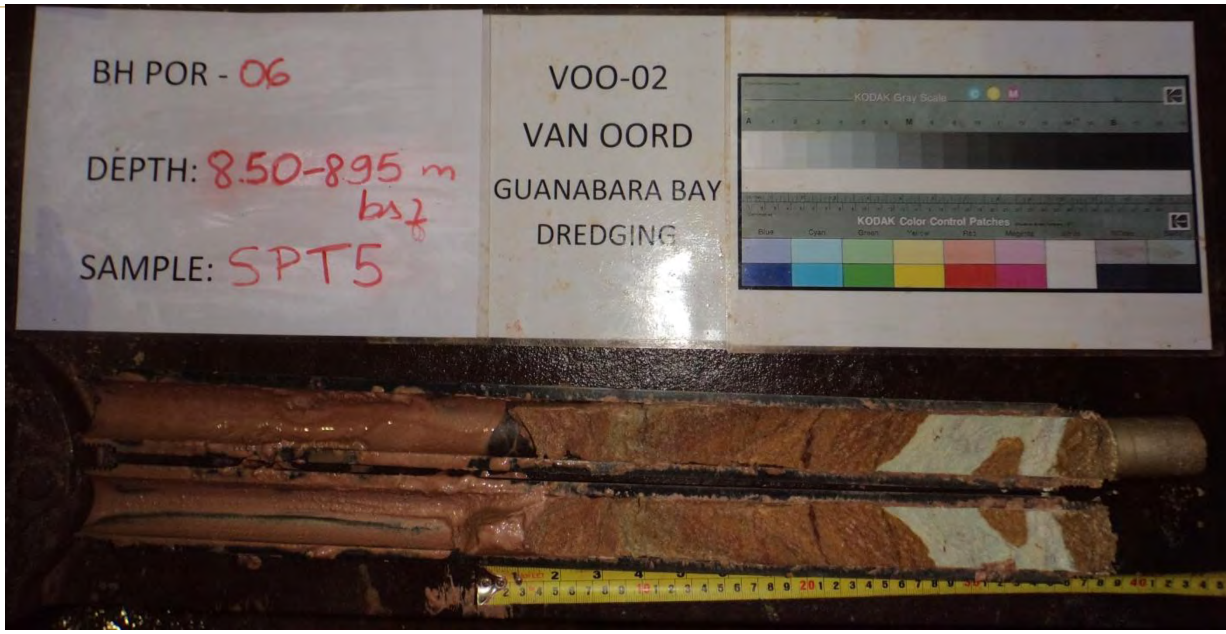
POR-06


BH POR - 6
DEPT 2.0-2.45m bsf
SAMPLE: SPT 1
VOO-02
VAN OORD
GUANABARA BA
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 06
DEPTH: 3.50-3.95m bsf
SAMPLE: SPT 2
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 06
DEPTH: 5.0-5.45 m bsf
SAMPLE: SPT 3
VOO-02
VAN OORD
GUANABARA BAY
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 06
DEPTH: 6.50-6.95 m bsf
SAMPLE: SPT 4
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 06
DEPTH: 8.50-895 m bsf
SAMPLE: SPT5
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

POR-07


BH POR - 07
DEPTH: 1.5 m bsf
SAMPLE:
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 07
DEPTH: 3.0 m bsf
SAMPLE:
KODAK Gray Scale
KODAK Color Control Patches

,

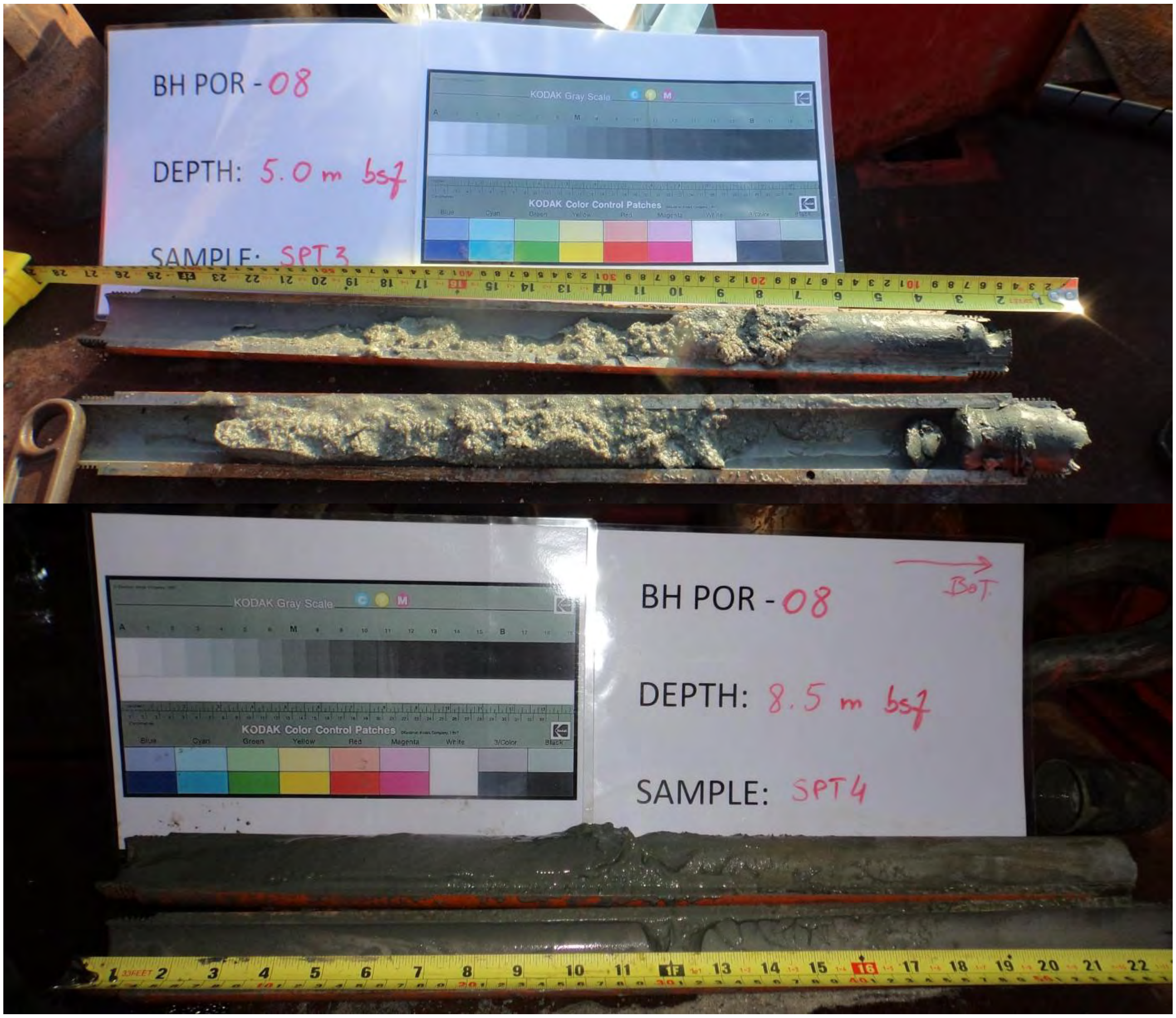

BH POR - 07
DEPTH: 4.5 m bsf
SAMPLE: SPT3 3BAGA
KODAK Gray Scale
KODAK Color Control Patches

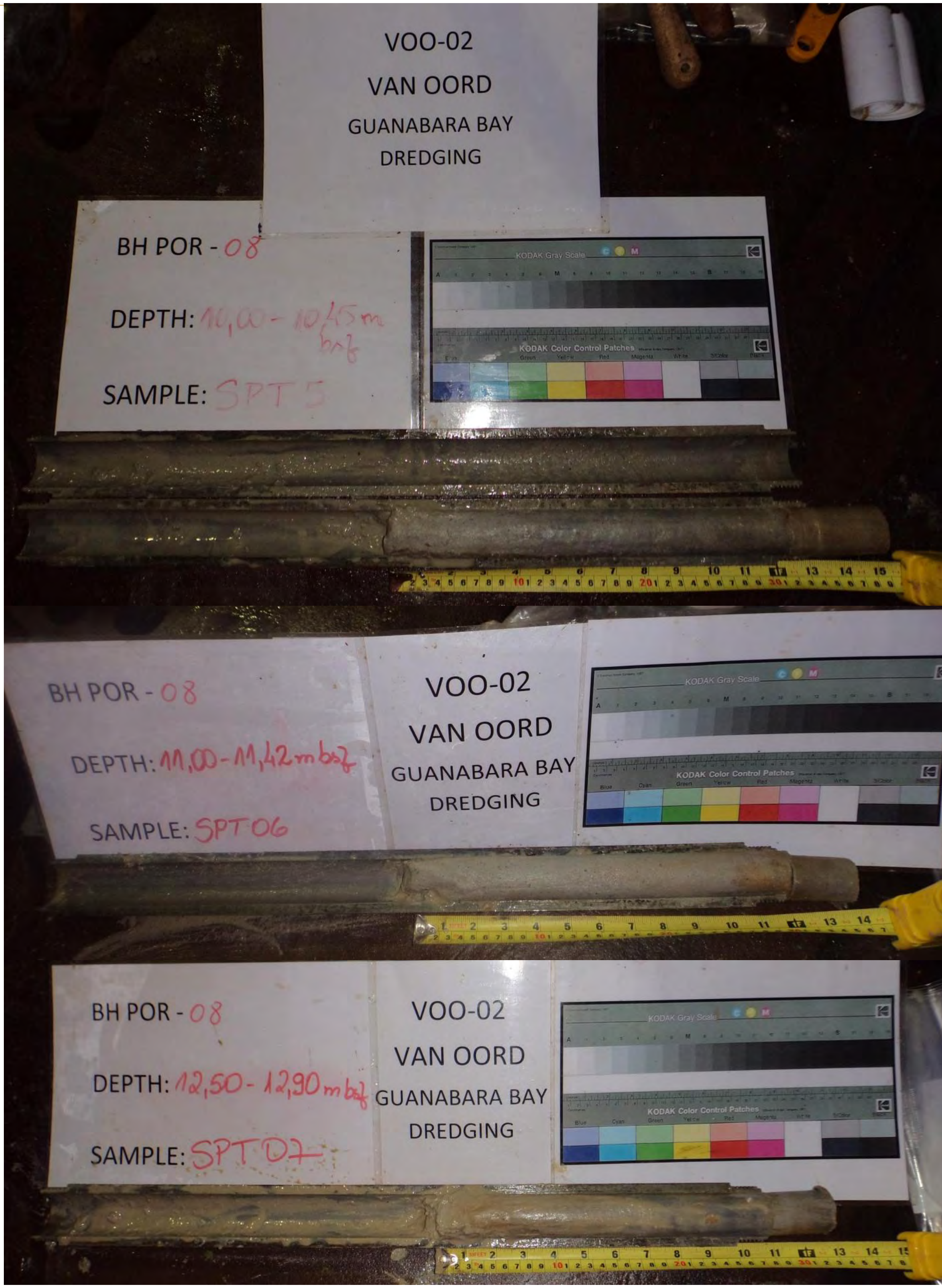

BH POR - 07
DEPTH: 8.0m bsf
SAMPLE: SPT4 4BAGA
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 07
DEPTH: 9.5 m bsf
SAMPLE: SPT5 5BAGA
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 07
DEPTH: 10.5 m bsf
SAMPLE: SPT6 6BAGA
KODAK Gray Scale
KODAK Color Control Patches

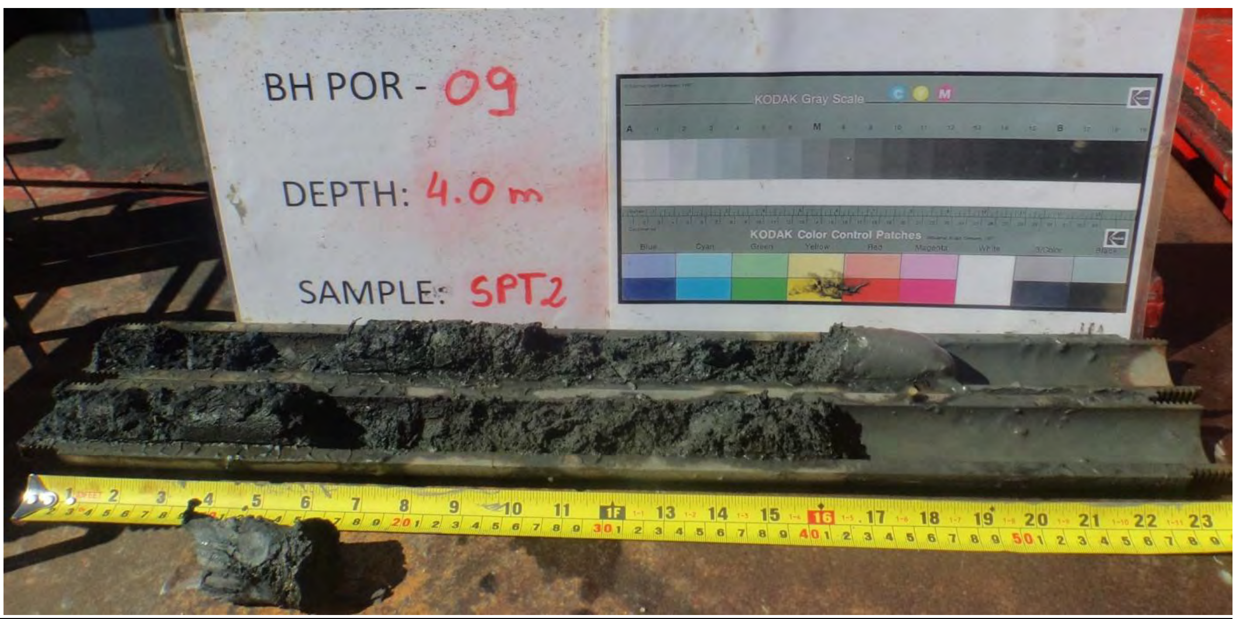
POR-08


BH POR - 08
DEPTH: 5.0 m bsf
SAMPLE: SPT 3
KODAK Gray Scale
KODAK Color Control Patches
KODAK Gray Scale
KODAK Color Control Patches
BoT
BH POR - 08
DEPTH: 8.5 m bsf
SAMPLE: SPT4


VOO-02
VAN OORD
GUANABARA BAY
DREDGING
BH POR - 08
DEPTH: 10,00 - 10,45 m bnf
SAMPLE: SPT 5
BH POR - 08
DEPTH: 11,00-11,42 m bnf
SAMPLE: SPT 06
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
BH POR - 08
DEPTH: 12,50 - 12,90 m bnf
SAMPLE: SPT 07
VOO-02
VAN OORD
GUANABARA BAY
DREDGING

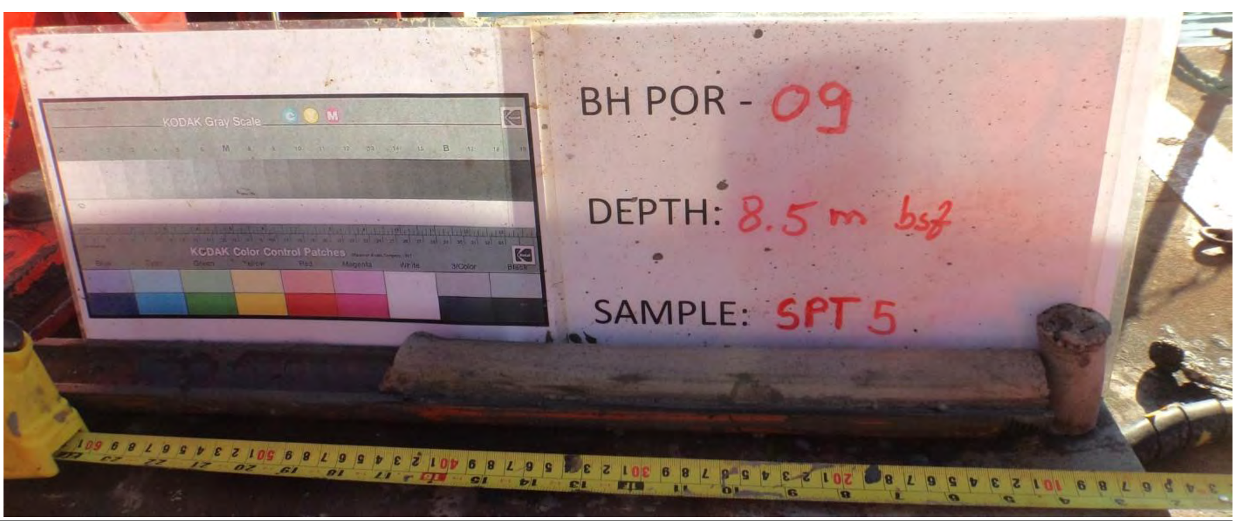
POR-09


BH POR - 09
DEPTH: 1.0 m
SAMPLE: SPT1
KODAK Gray Scale
KODAK Color Control Patches

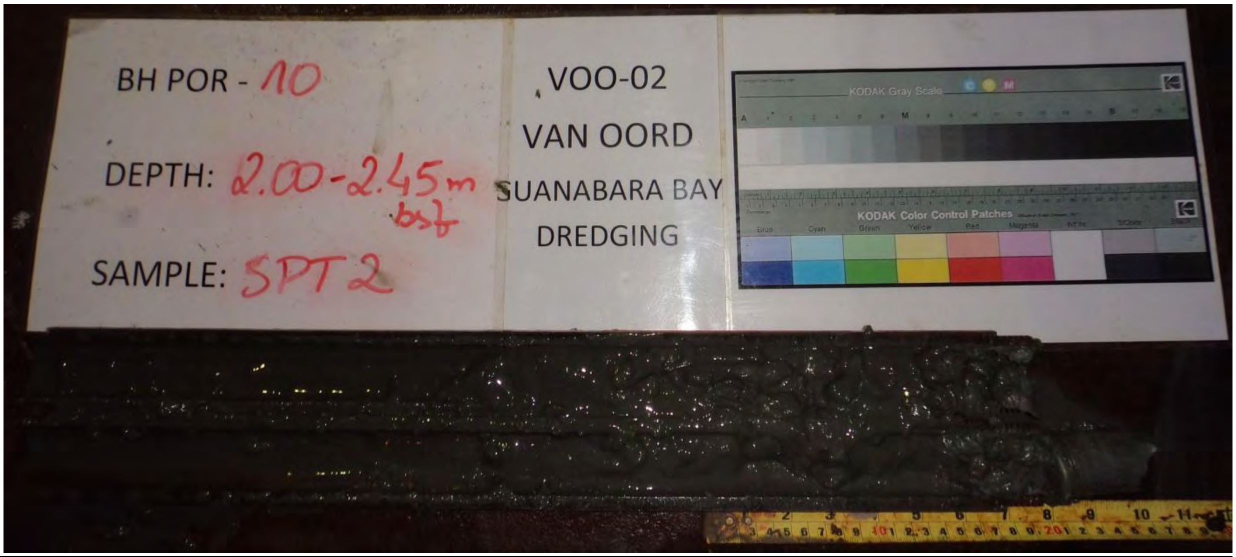

BH POR - 09
DEPTH: 4.0 m
SAMPLE: SPT2
KODAK Gray Scale
KODAK Color Control Patches

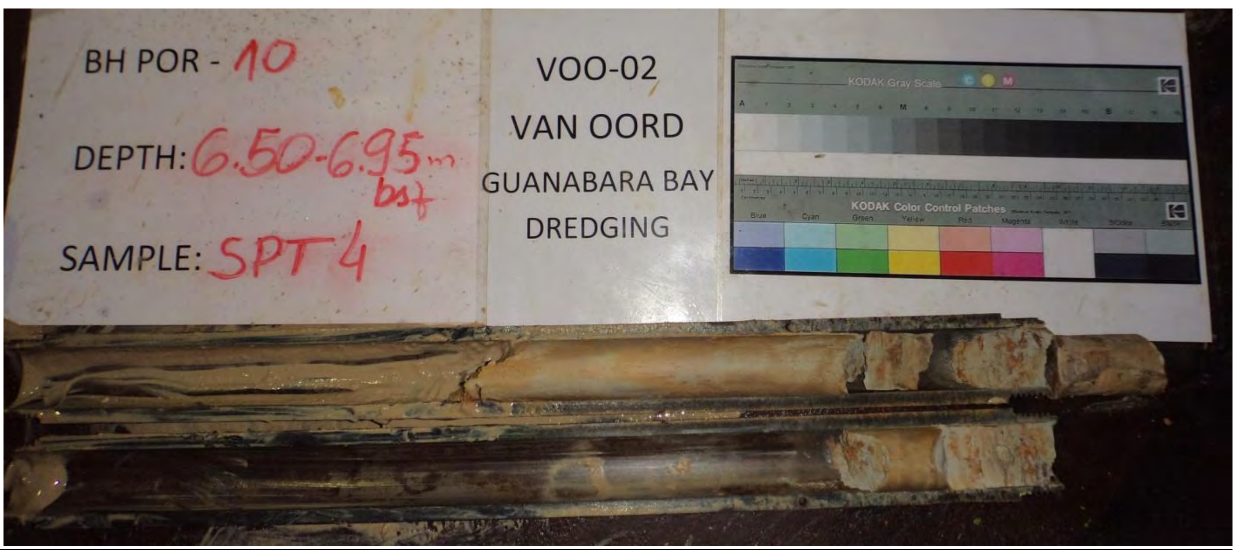

BH POR - 09
DEPTH: 5.5 m bsf
SAMPLE: SPT 3
KODAK Gray Scale
KODAK Color Control Patches

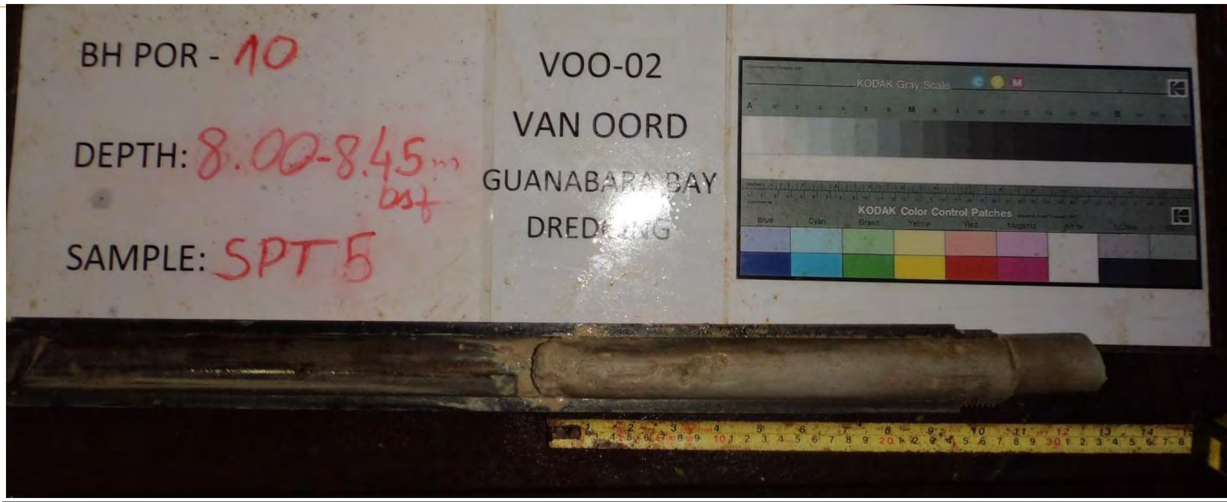

BH POR - 09
DEPTH: 7.0 m bsf
SAMPLE: SPT 4
KODAK Gray Scale
KCDAK Color Control Patches

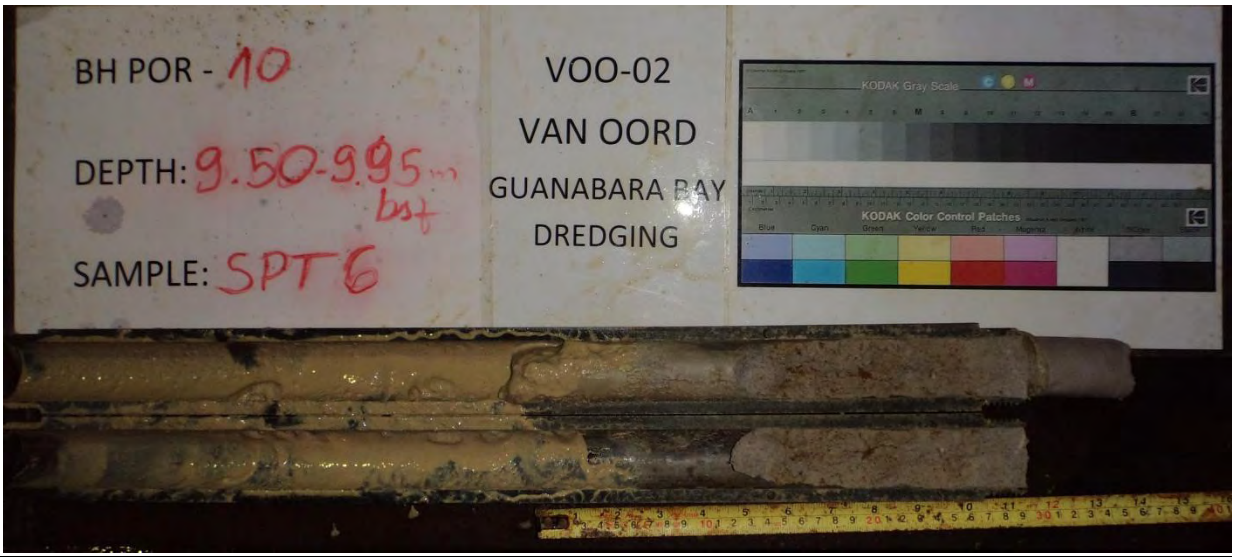

BH POR - 09
DEPTH: 8.5 m bsf
SAMPLE: SPT 5
KODAK Gray Scale
KCDAK Color Control Patches

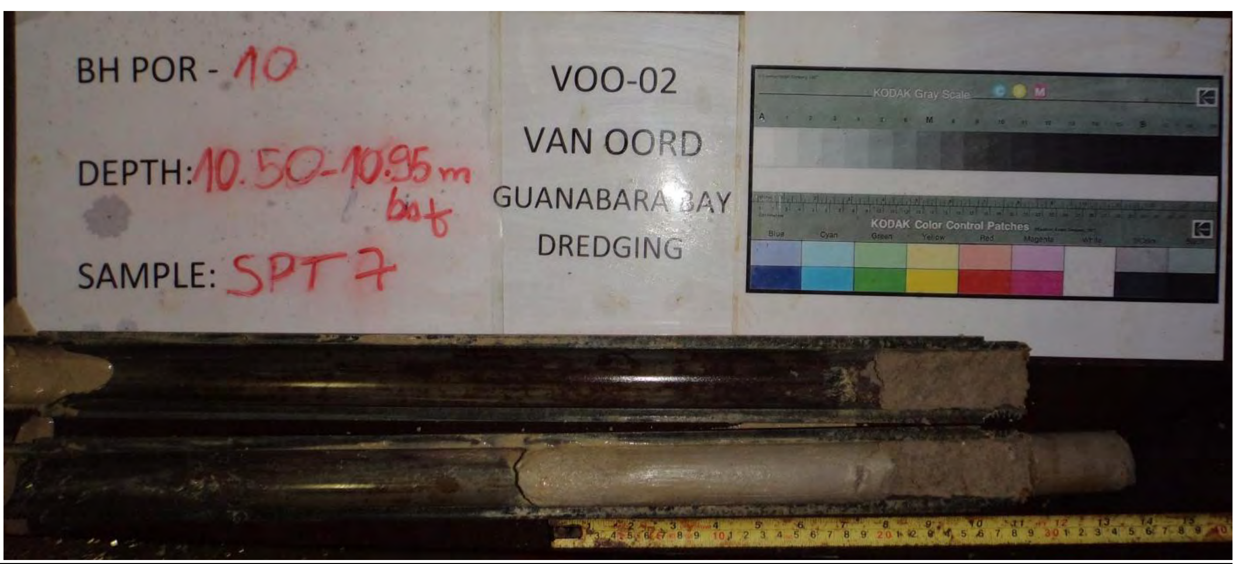
POR-10

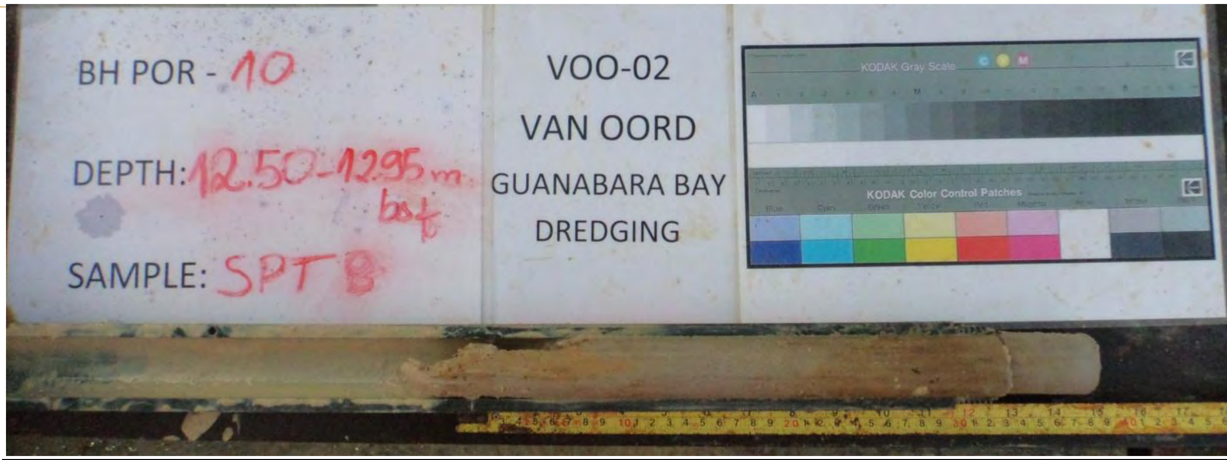

BH POR - 10
DEPTH: 2.00-2.45m bsf
SAMPLE: SPT 2
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 10
DEPTH: 6.50-6.95m bsf
SAMPLE: SPT 4
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 10
DEPTH: 8.00-8.45 m bsf
SAMPLE: SPT 5
VOO-02
VAN OORD
GUANABARA BAY
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 10
DEPTH: 9.50-9.95 m bsf
SAMPLE: SPT 6
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 10
DEPTH: 10.50-10.95 m bsf
SAMPLE: SPT 7
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

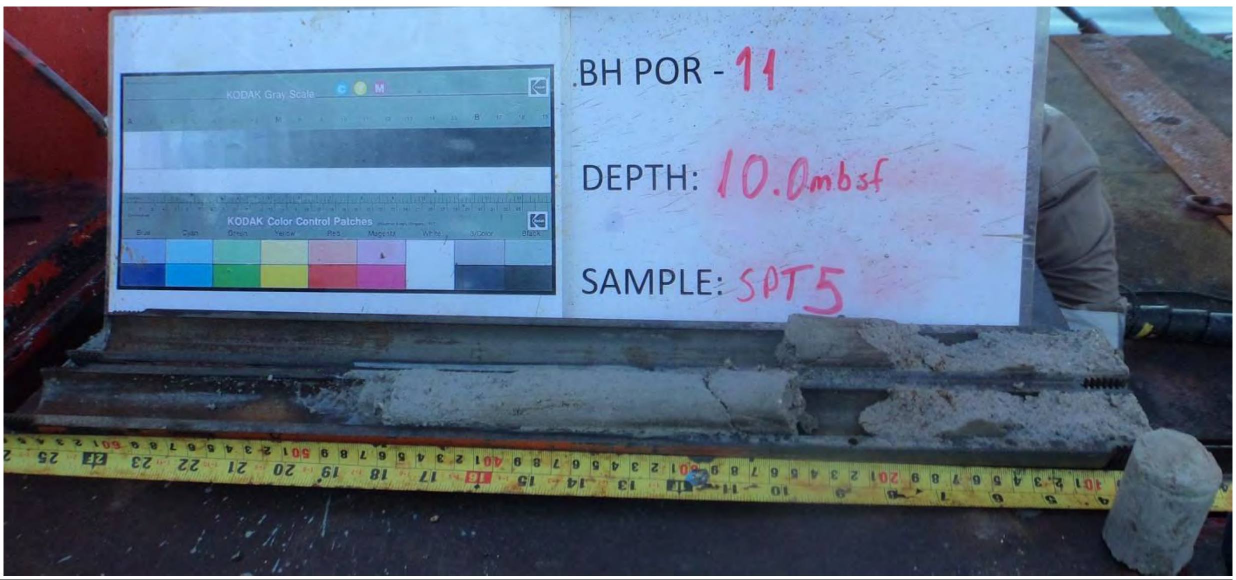

BH POR - 10
DEPTH: 12.50-12.95 m bsf
SAMPLE: SPT 8
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

POR-11

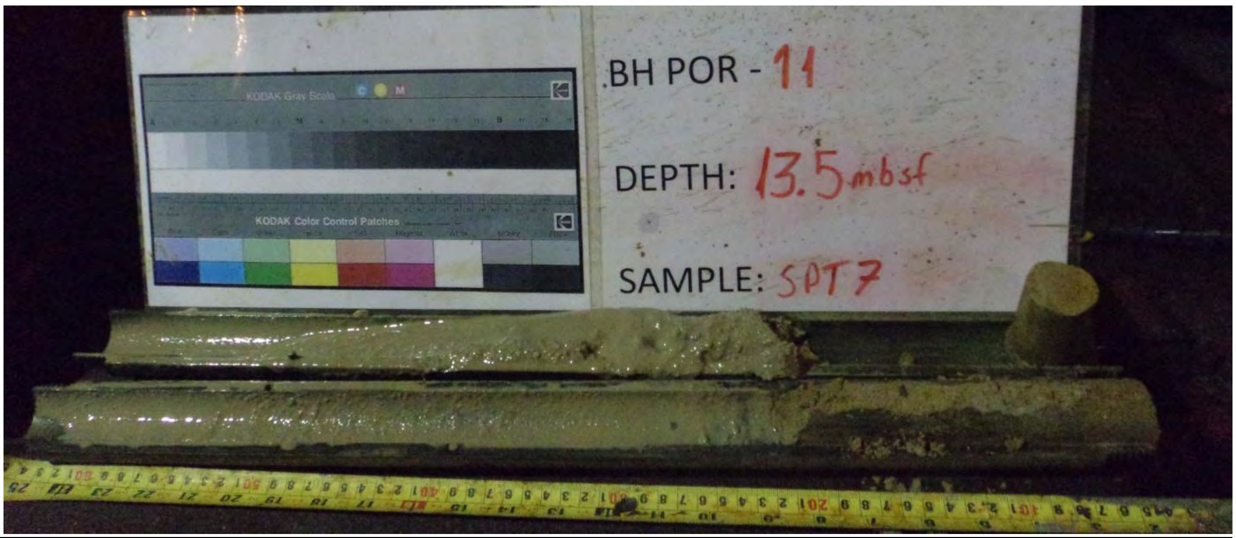

KODAK Gray Scale
KODAK Color Control Patches
BH POR - 11
DEPTH: 4. 0 mbsf
SAMPLE: SPT 2


KODAK Gray Scale
KODAK Color Control Patches
BH POR - 11
DEPTH: 5. 5 mbsf
SAMPLE: SPT 3


BH POR - 11
DEPTH: 8.5 mbsf
SAMPLE: SPT4
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 11
DEPTH: 10.0mbsf
SAMPLE: SPT5
KODAK Gray Scale
KODAK Color Control Patches

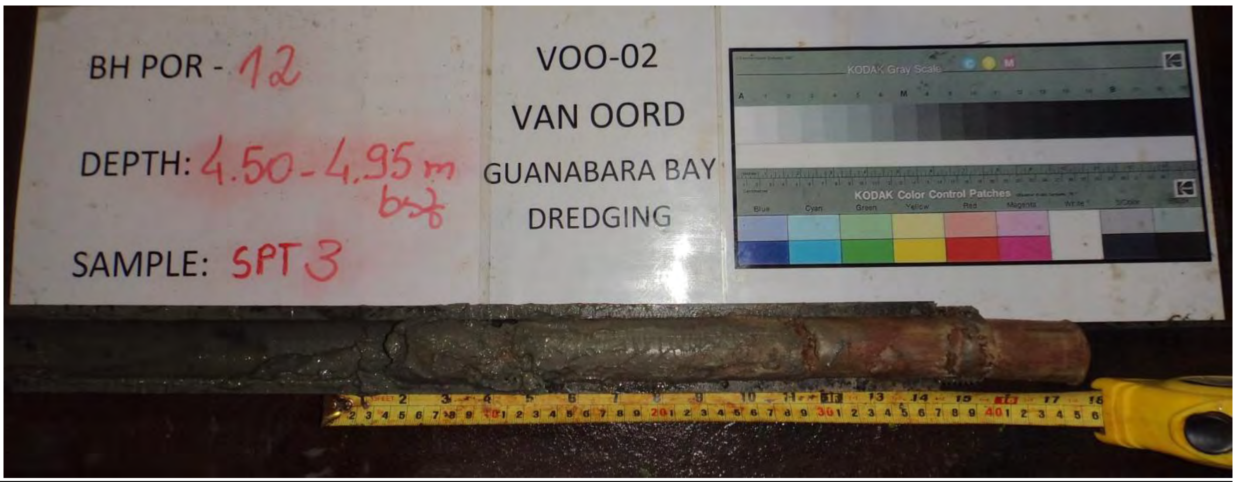

KODAK Gray Scale
KODAK Color Control Patches
BH POR - 11
DEPTH: 11.5 mbsf
SAMPLE: SPT6

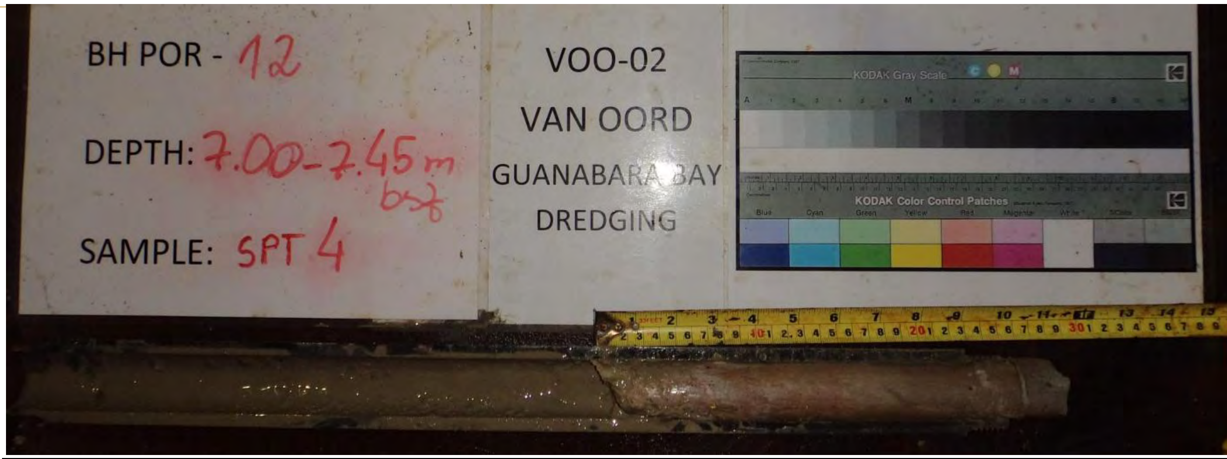

KODAK Gray Scale
KODAK Color Control Patches
BH POR - 11
DEPTH: 13.5 mbsf
SAMPLE: SPT7

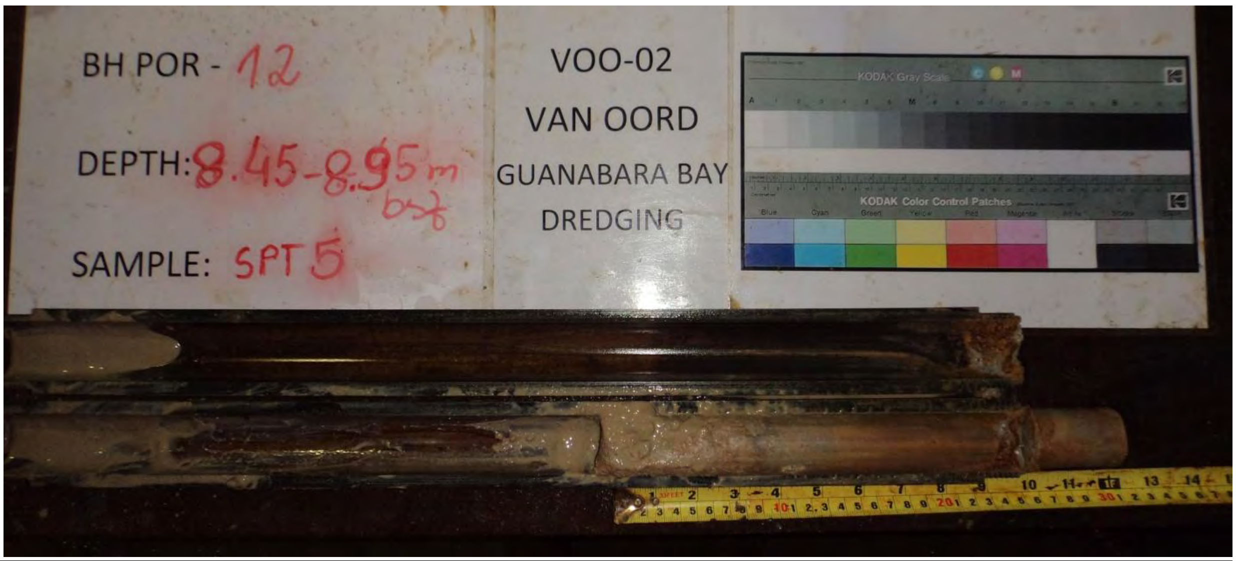
POR-12

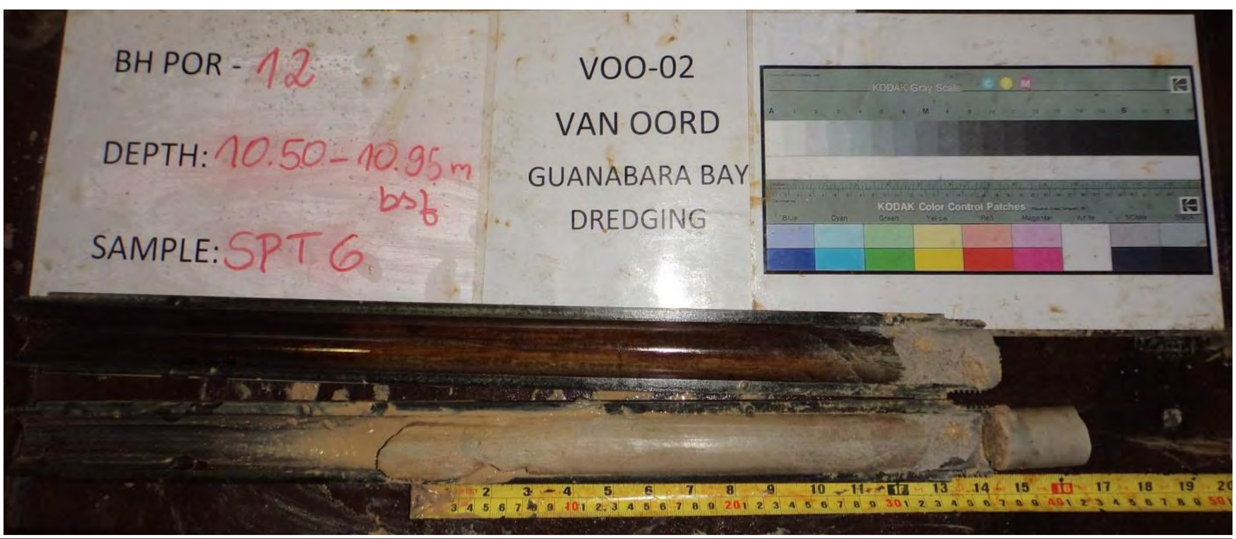

BH POR - 12
DEPTH: 1.50-1.95 mbsf
SAMPLE: SPT 1
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

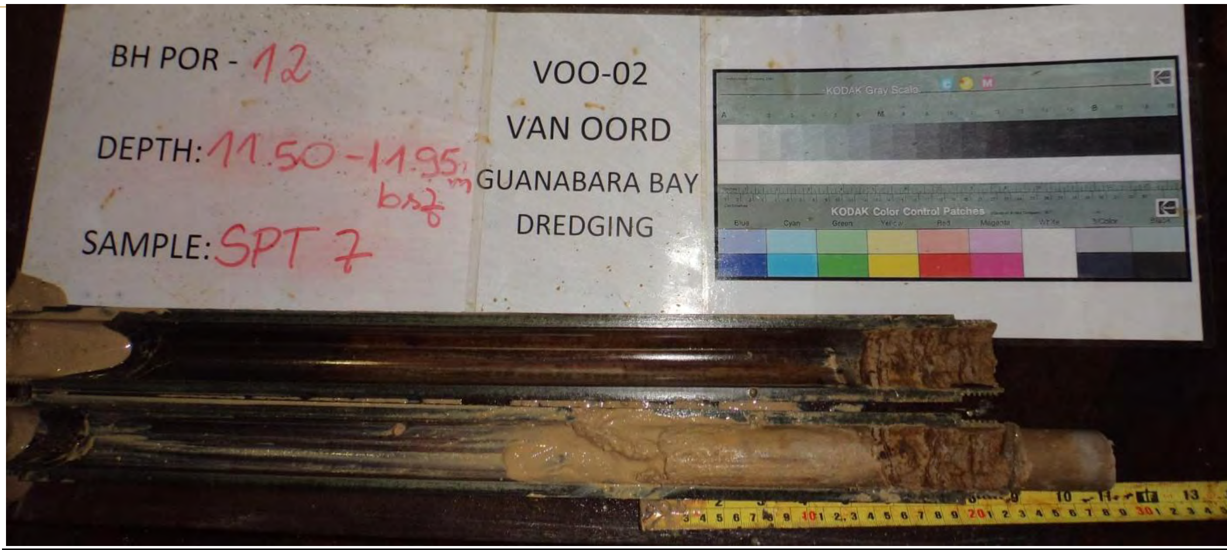

BH POR - 12
DEPTH: 3.00-3.45mbsf
SAMPLE: SPT 2
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 12
DEPTH: 4.50-4.95 m bsf
SAMPLE: SPT 3
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

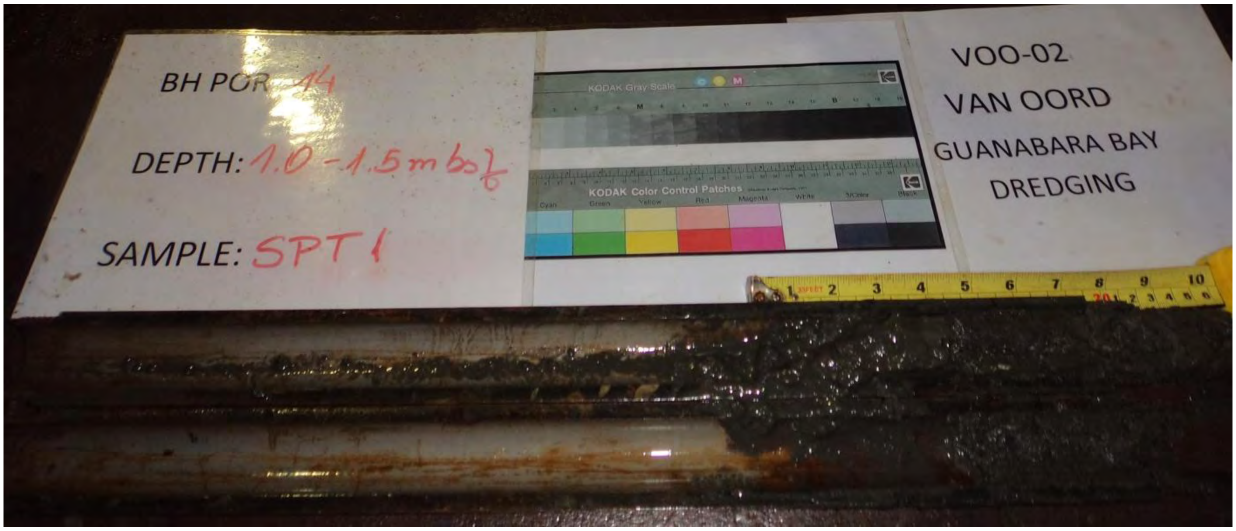

BH POR - 12
DEPTH: 7.00-7.45 m bsf
SAMPLE: SPT 4
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

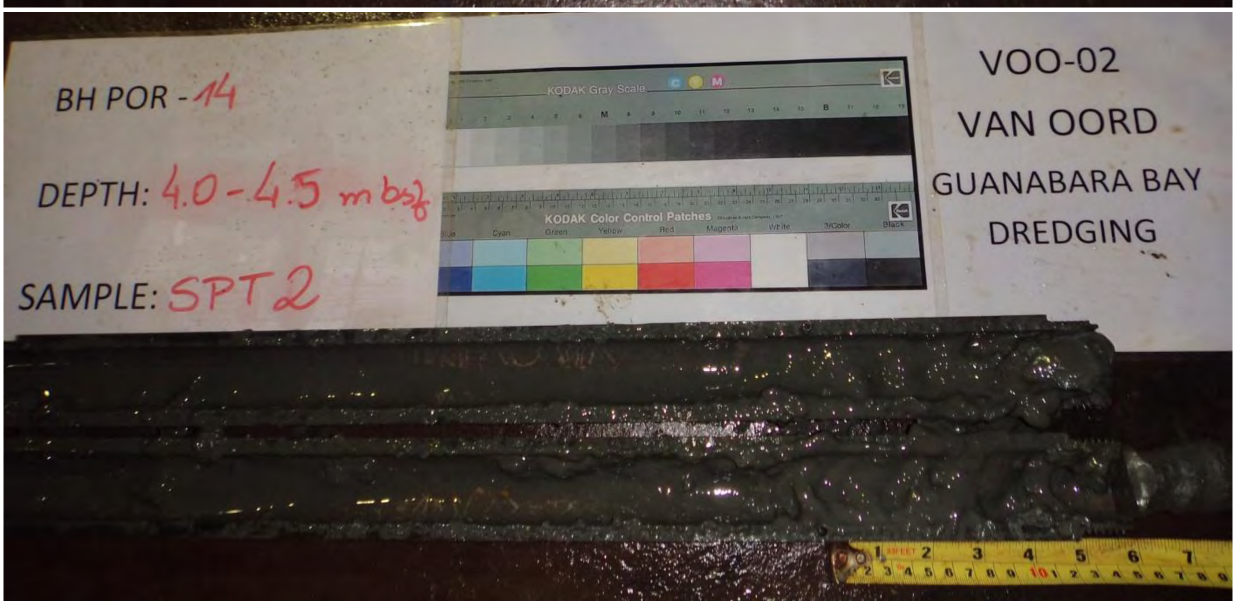

BH POR - 12
DEPTH: 8.45-8.95 m bsf
SAMPLE: SPT 5
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

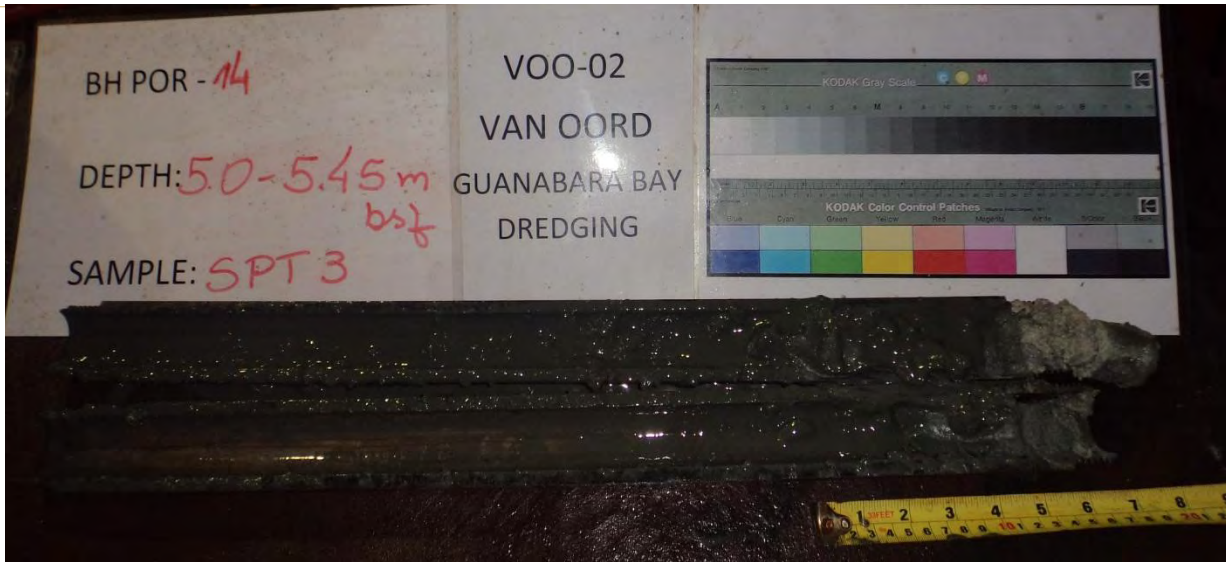

BH POR - 12
DEPTH: 10.50-10.95 m bsf
SAMPLE: SPT 6
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 12
DEPTH: 11.50 - 11.95 m bsf
SAMPLE: SPT 7
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

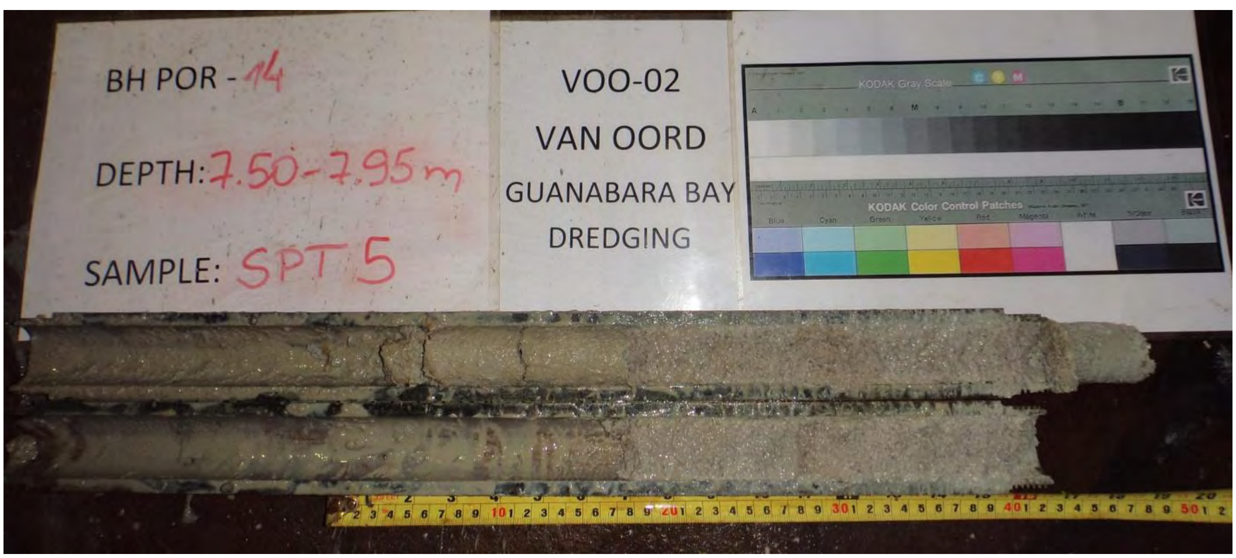
POR-14


BH POR - 14
DEPTH: 1.0 - 1.5 m bsf
SAMPLE: SPT 1
KODAK Gray Scale
KODAK Color Control Patches
VOO-02
VAN OORD
GUANABARA BAY
DREDGING

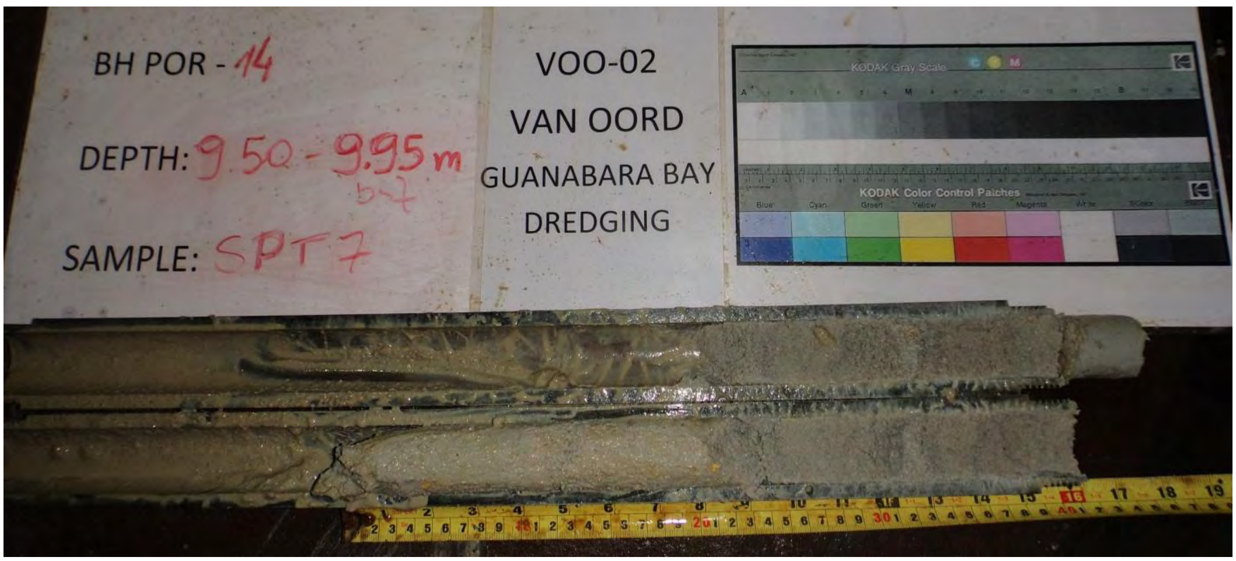

BH POR - 14
DEPTH: 4.0 - 4.5 m bsf
SAMPLE: SPT 2
KODAK Gray Scale
KODAK Color Control Patches
VOO-02
VAN OORD
GUANABARA BAY
DREDGING


BH POR - 14
DEPTH: 5.0 - 5.45 m bsf
SAMPLE: SPT 3
VOO-02
VAN OORD
GUANABARA BAY
DREDGING


BH POR - 14
DEPTH: 6.50 - 6.95 m bsf
SAMPLE: SPT 4
VOO-02
VAN OORD
GUANABARA BAY
DREDGING


BH POR - 14
DEPTH: 7.50 - 7.95 m
SAMPLE: SPT 5
VOO-02
VAN OORD
GUANABARA BAY
DREDGING

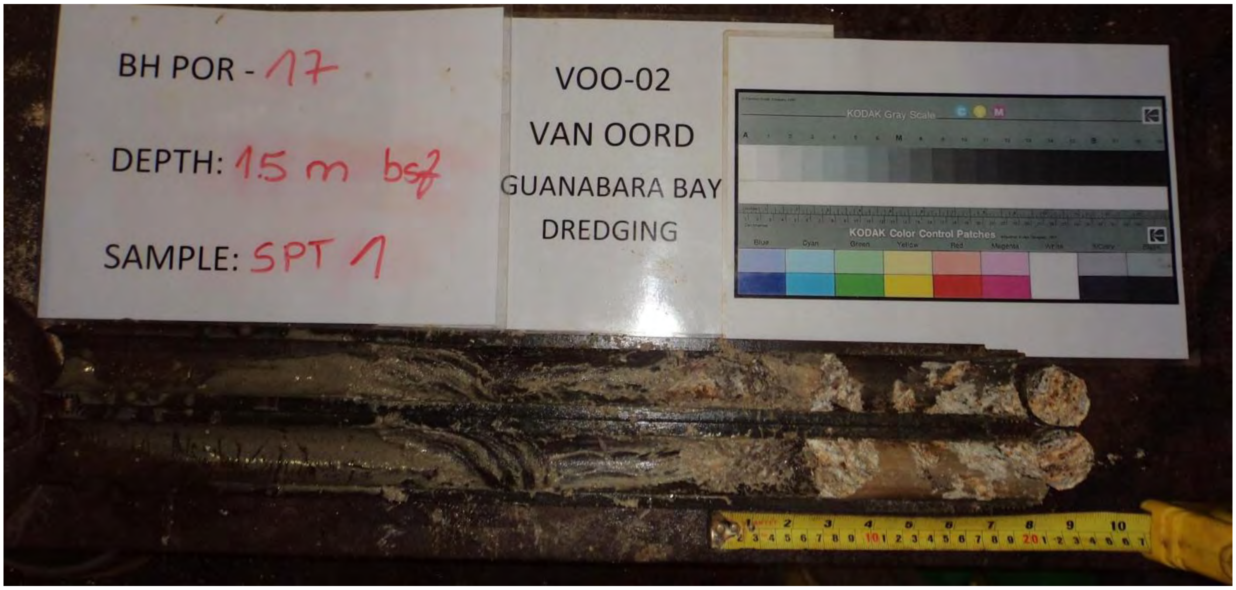

BH POR - 14
DEPTH: 8.50 - 8.95 m
SAMPLE: SPT 6
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 14
DEPTH: 9.50 - 9.95 m
SAMPLE: SPT 7
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

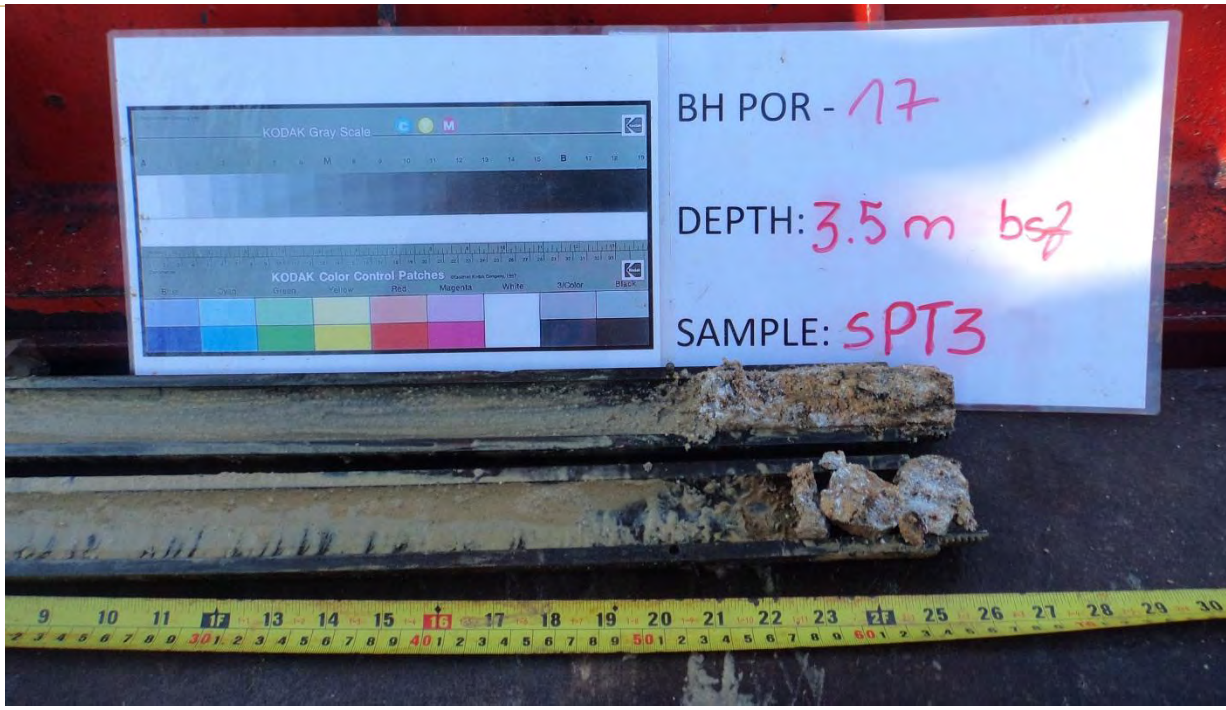
POR-15


BH POR - 15
DEPTH: 2.0 mbsf
SAMPLE: SPT 1
KODAK Gray Scale
KODAK Color Control Patches

POR-17


BH POR - 17
DEPTH: 1.5 m bsf
SAMPLE: SPT 1
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


KODAK Gray Scale
KODAK Color Control Patches
BH POR - 17
DEPTH: 2.5 m bsf
SAMPLE: SPT2


KODAK Gray Scale
KODAK Color Control Patches
BH POR - 17
DEPTH: 3.5 m bsf
SAMPLE: SPT3