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Neptun Deep Project

Geotechnical Interpretative Report for Pipeline and Flowlines

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Neptun Deep Project

Geotechnical Interpretative Report for Pipeline and Flowlines

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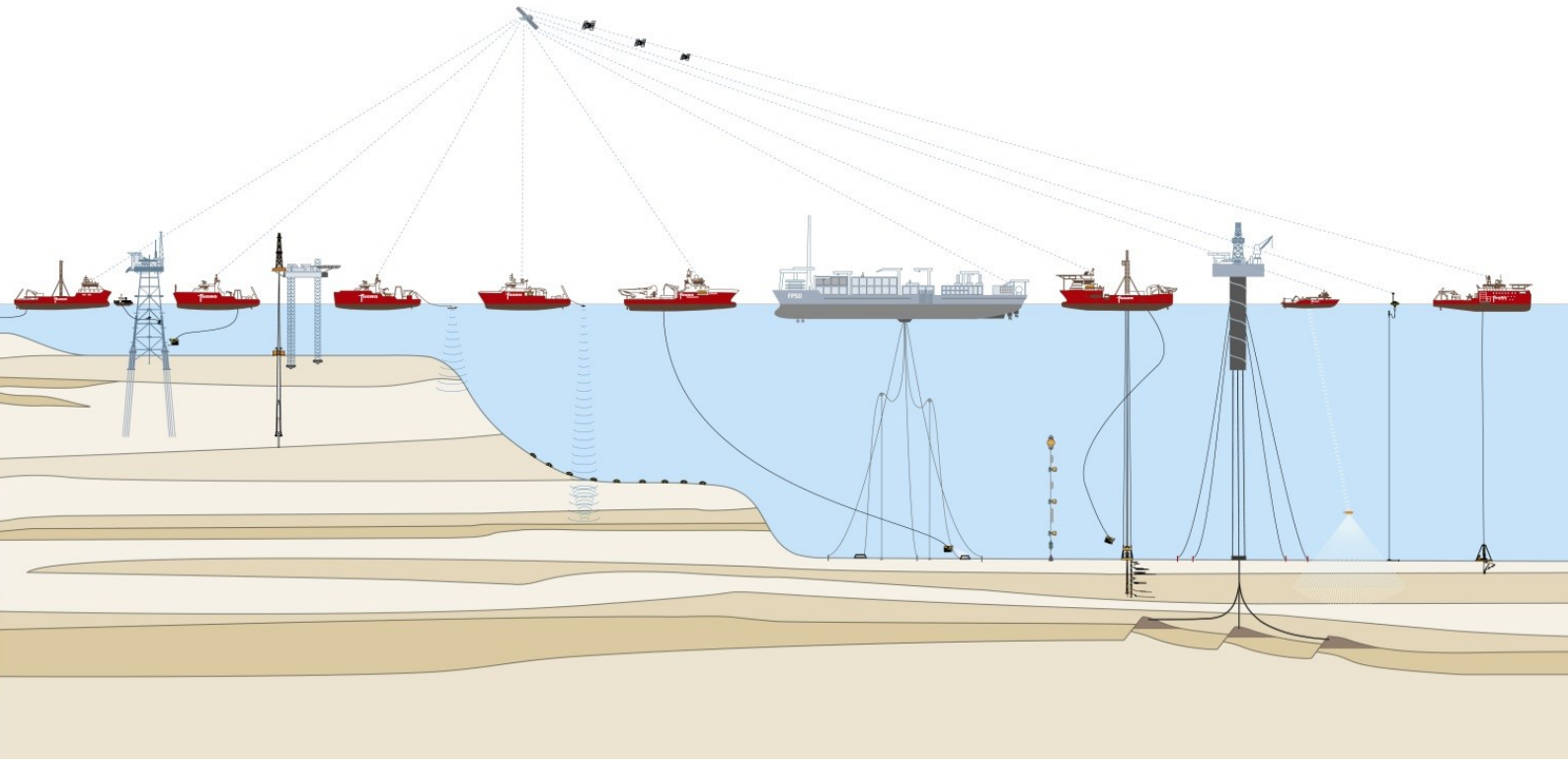
FUGRO

Pipeline and Flowline Geotechnical Interpretive Report
Neptun Deep Survey
Pelican South Field

Fugro Document No.: 173570-05d(03)
Issue Date: 19 June 2018

ExxonMobil Exploration and Production Romania Limited

Final Report



FUGRO

Pipeline and Flowline Geotechnical Interpretive Report
Neptun Deep Survey
Pelican South Field
Black Sea, Romania

Fugro Document No: 173570-05d (03)
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Dear Yvonne Moret and Patrick Lee,

Neptun Deep Survey
Pelican South Field, Black Sea, Romania

We have the pleasure of submitting the Pipeline and Flowline Geotechnical Interpretive Report for Neptun Deep Survey. This report presents the geotechnical models for the pipeline and flowline routes for the Neptun deep development. In addition, this report presents geotechnical conditions for three fault crossings on the shelf.

This report was prepared by Charles Bloore, Kathy Lehmann and Lorraine O'Leary.

We hope that you find this report to your satisfaction; should you have any queries, please do not hesitate to contact us.

Yours sincerely,
Fugro GB Marine Limited

CBloore

Charles Bloore
Engineering Geologist

Distribution: One electronic copy to Yvonne Moret and Patrick Lee

QUALITY ASSURANCE RECORD

Section	Prepared By	Checked By	Approved By
Main text	LO/KL	LO/CAS	GML
Plates following the main text	LO/KL	LO/CAS	GML
Appendix A – Guidelines On Use Of Report	FGBML	FGBML	FGBML
Appendix B – PIPELINE AND FLOWLINE UNIT PARAMETER PROFILES	KL/LO	CB	GML
Appendix C - FAULT CROSSING GEOTECHNICAL MODEL	LO	CB	GML

Notes:
The personnel stated above were responsible for preparing, checking and approving this report
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REPORT ISSUE LOG

Issue No.	Status	Reason for Issue/Reissue	Comments on Content	Date
01	Draft	First issue to client	Awaiting client comments	18 May 2018
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FRONTISPIECE

EXECUTIVE SUMMARY

The Neptun Deep development area is located within the Neptun Block, Black Sea, offshore Romania. The planned development comprises the proposed Platform G location, flowline route and three drill centers in the Neptun Block with a Production Pipeline crossing the shelf from the proposed Platform G to shore. This report presents derived geotechnical parameters and a geotechnical model for the proposed infield flowlines, pipeline route to shore and fault crossings on the shelf. This work was carried out under Marine Site Survey order A2552390. Call Off 2 Change Order 6.

Geotechnical unitisation was performed on sample and test data available from the shelf and infield area (Geoquip 2017, Fugro, 2015c; Fugro 2018a) for the purposes of pipeline and flowline parameter derivation. The geotechnical unitisation was performed individually for the Production Pipeline (on the shelf) and the flowlines between the proposed platform and the Domino drill centers (infield area).

Eleven Pipeline Geotechnical Units (PGU) were identified from sample and test data available from the shelf along the Production Pipeline. The PGUs are split into four main groups based on their distribution in the physiographic domains:

i. S-1 – identified throughout the shelf;
ii. S-2 – identified on the outer shelf in the area surrounding the planned Platform G and Pelican South Drill Center;
iii. S-3 – identified on the mid-shelf;
iv. S-4 – identified on the inner shelf as the pipeline route heads towards landfall.

Flowline Geotechnical Units were derived for the flowline route from the proposed Domino drill centers to the planned platform location (Table S.1). These units are based on the geotechnical units presented in Fugro (2016b).

Table S.1: Flowline Geotechnical Units

Flowline Geotechnical Unit	Depth Range [m BML]	Generalised Soil Description
1	0.00 – 1.25	Extremely low strength to low strength CLAY
2	0.00/1.25 – 0.00/5.45	Extremely low strength organic CLAY with many extremely closely spaced planar parallel thin laminae of highly organic clay
3	0.00/3.80 – 0.06/19.70	Extremely low strength to low strength CLAY
3a	1.25/5.01 – 1.48/6.40	Low strength CLAY (peak in undrained shear strength)
4	0.00 – 1.30/2.25	Low strength (lightly overconsolidated) CLAY with few pockets and laminae of dark grey clay and silt
4a	1.30/1.82 – 1.74/2.15	Low strength to medium strength CLAY (peak in undrained shear strength)
5	0.00/0.20 – 4.30/15.72	Low strength to medium strength (lightly overconsolidated) CLAY with pockets and laminae of dark grey clay and silt

The distribution of the PGUs both laterally and vertically forms the basis for the definition of Pipeline Geotechnical Zones. The depth of interest for the Pipeline Geotechnical Zonation is 3 m BML between KP 0 and KP 152.4 for surface-laid pipeline; and 5 m BML between KP 152.4 and KP 156.075 where the pipeline will be trenched. Twelve pipeline geotechnical zones were delineated along the to-shore pipeline route.

Geotechnical parameters were derived for each Flowline and Pipeline Geotechnical Unit to a depth of 3 m BML for surface laid sections of the pipeline and 5 m BML for trenched sections of the pipeline. The derived parameters include:

i. Water Content (w);
ii. Unit Weight (γ);
iii. Cone Resistance (q_c) measured from CPT;
iv. Undrained Shear Strength (s_u);
v. Remoulded Strength (s_{ur});
vi. Strength Sensitivity (s_t);
vii. Relative Density (D_r);
viii. Friction Angle (ϕ).

For each parameter, geotechnical parameter profiles are presented per pipeline geotechnical unit for input into pipeline design analyses. Geotechnical parameter profiles for each parameter are presented in the form of lowest expected (LE), best estimate (BE) and highest expected (HE).

Three fault crossings, Eastern Fault, Central Fault and Western Fault, were investigated on the shelf along the pipeline route to shore to understand the soil conditions for input into rock dumping analyses. A geotechnical borehole was performed either side of each of three faults. Geotechnical parameters are presented for each borehole at each fault crossing including:

i. Unit Weight (γ);
ii. Undrained Shear Strength (s_u);
iii. Strain at 50% deviator stress (ε_{50});
iv. Relative Density (D_r);
v. Friction Angle (ϕ).

The geotechnical data indicate that the locations sampled either side of the fault are variable with the downthrown section of the fault showing generally lower strength. For example, the downthrown section of the Eastern Fault was characterised by undrained shear strengths less than a tenth those observed on the upthrown side.

CONTENTS

TABLES IN THE MAIN TEXT

FIGURES IN THE MAIN TEXT

PLATES FOLLOWING THE MAIN TEXT

ABBREVIATIONS

2DHR	2-dimensional high resolution
3DHR	3-dimensional high resolution
BC	Boxcore
BE	Best Estimate
BML	Below Mudline
CPT	Cone Penetration Test
DDC	Domino Drill Center
EMEPRL	ExxonMobil Exploration Production Romania Ltd
FGU	Flowline Geotechnical Unit
FGZ	Flowline Geotechnical Zone
HE	Highest Expected
Ka BP	Thousand years before present
KP	Kilometre Post
LDPC	Large Diameter Piston Core
LE	Lowest Expected
LGM	Last Glacial Maximum
MBES	Multibeam Echosounder
PC	Piston Core
PG	Platform G
PGU	Pipeline Geotechnical Unit
PGZ	Pipeline Geotechnical Zone
PTU	Pipeline Terrain Unit
SBP	Sub-bottom Profiler
SSS	Sidescan Sonar
VC	Vibrocore

1. INTRODUCTION

1.1 Project Setting

The Neptun Deep development area is located within the Neptun Block, Black Sea, offshore Romania. The planned development comprises the Domino Drill Center 1 and Domino Drill Center 2. These are positioned in approximately 900 m water depth, 23 km south-east of the planned Platform G location and Pelican South Drill Center. The Domino Deep Drill Centers are tied back to the platform on the shelf by a flowline. A second flowline runs from the Pelican Drill Center to the Platform. A production pipeline runs from the planned platform location to shore. Figure 1.1 presents an overview of the planned development.

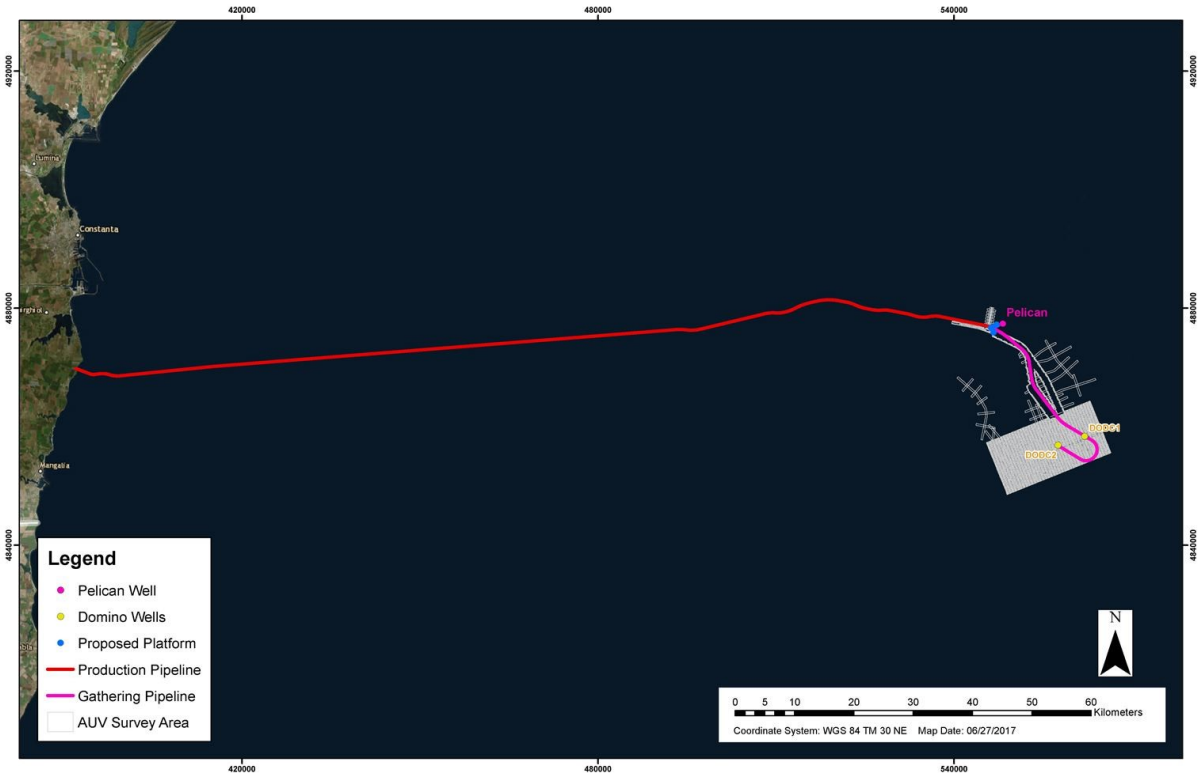


Figure 1.1: Main proposed infrastructure associated with the Neptun Deep development area

1.2 Project Summary

ExxonMobil Exploration Production Romania Ltd (EMEPRL) contracted Fugro to perform and report on a geotechnical site survey for the proposed Platform G location, flowline route and three drill centers in the Neptun Block, Black Sea, offshore Romania. This work was carried out under Marine Site Survey order A2552390. Call Off 2 Change Order 6.

The scope of work comprised:

- 4 seabed CPTs;
- 7 sampling boreholes,
- 7 CPT boreholes;
- 14 combined sampling boreholes.

The site investigation took place from the MV Fugro Synergy between 28 December 2017 and 08 February 2018.

The geotechnical data were acquired to assess the sub-seafloor conditions and to provide data for input to foundation design. This report forms part of a series of reports for the geotechnical site investigation; as detailed in Table 1.1.

Table 1.1: Reporting Structure

Type	Deliverable	
Engineering / Interpretive	**WORK PACKAGE 4 INTERPRETIVE REPORTS**	
	Integrated Report Update Report Number: 173570-08	**Slope Stability and Debris Flow Run-Out Modelling Update Report** Report Number: 173570-09
	Geological Interpretative Report Report Number: 173570-06	**Site Response Analysis** Report Number: 173570-07
	Geotechnical Interpretive Report Pelican Drill Center Report Number: 173570-05a	**Geotechnical Interpretive Report Platform** Report Number: 173570-05b
	Geotechnical Interpretive Report Domino Drill Center Report Number: 173570-05c	**Geotechnical Interpretive Report Pipeline and Flowlines** Report Number: 173570 -05d
Factual	**WORK PACKAGE 3 FACTUAL/LABORATORY REPORT**	
	Laboratory and Insitu Testing Data report Report Number: 173570-04	
	WORK PACKAGE 3 FIELD/RESULTS REPORTS	
	Operations Report Report No.: 173570-01	**MMO Report** Report No.: 173570-02
	Field Data Report Report No.: 173570-03	
Preliminary Data	**Preliminary Interpretation Technical Note** TN-173570-05	
Execution	**Project Execution Plan** Document No.: 173570-PEP	**Safety, Security, Health and Environmental Plan** Document No.: 173570-SSHE
	Emergency Response Plan Document No.: 173570 -ERP	**Shallow Gas Management Plan** Document No.: 173570-SGMP

1.3 Scope of Report

The scope of this report is to provide derived geotechnical parameters and a geotechnical model for the proposed infield flowlines, pipeline route to shore and fault crossings. This report includes a review of the available geotechnical data and a discussion on the geotechnical results.

The depth of interest for the pipeline route varies depending on the installation method.

- Surface laid pipeline depth of interest 3 m below mudline (BML);
- Trenched pipeline depth of interest 5 m BML;
- Trenched flowline depth of interest 3 m BML;
- Fault crossing to maximum depth of available data (between 10 m and 15 m BML).

Table 1.2 summarises the kilometre post (KP) ranges of trenched and surface laid sections of the pipeline and flowlines as provided by EMEPRL (email, 12 April 2018). Production Pipeline starts at the platform (KP0) and ends onshore (KP156.075). The Domino Flowline and Pelican Flowline start at the manifold (KP0) and ends at the production platform (KP36.449 and KP1.426 respectively).

Table 1.2: Summary of KP ranges of Trenched and Surface Laid sections of the Pipeline and Flowlines

Infrastructure	Trenched (KP Range)	Surface Laid (KP Range)
Production Pipeline	152.4 – 156.075 (Shore Crossing is 156.075- 156.965)	0 – 152.400
Domino Flowline	27.744 - 36.449	0 – 27.744
Pelican Flowline	0.0 to 1.426 (Whole Length)	None

Design parameter profiles are presented to the depth of interest as follows:

- Water Content (w);
- Unit Weight (γ);
- Cone Resistance (q_c) measured from CPT;
- Undrained Shear Strength (s_u);
- Remoulded Strength (s_{ur});
- Strength Sensitivity (S_t);
- Relative Density (D_r);
- Friction Angle (ϕ).

1.4 Data Sources

This report uses the results of multiple geophysical surveys and geotechnical site investigation to assess the soil conditions along the proposed flowline routes and pipeline route. Section 2 provides more detail on the available datasets.

1.5 Project Coordinate Reference System

Table 1.3 presents the geodetic parameters for this project.

Table 1.3: Project Coordinate Reference System Parameters

Geodetic Datum	
Datum	WGS84
Ellipsoid	WGS84
Semi-major axis	6 378 137.000 m
Semi-minor axis	6 356 752.314245179
Inverse flattening	$^1/_f$ = 298.257223563
Angular unit	Degrees
Map Projection	
Projection system	TM 30 NE
Central meridian	30º 00’ 00.00” east
Latitude of origin	0º north
False easting	500 000.0 m
False northing	0.0 m
Scale factor on central meridian	0.9996
Linear unit	Metres

1.6 Guidelines on Use of Report

Appendix A (GUIDELINES ON USE OF REPORT) outlines the limitations of this report, in terms of a range of considerations including, but not limited to, its purpose, its scope, the data on which it is based, its use by third parties, possible future changes in design procedures and possible changes in the conditions at the site with time. It represents a clear exposition of the constraints which apply to all reports issued by Fugro. It should be noted that the Guidelines do not in any way supersede the terms and conditions of the contract between Fugro and ExxonMobil.

2. DATA REVIEW

2.1 General

This section details geophysical, geotechnical and geological datasets that were used to develop the geotechnical model for the flowlines and proposed to shore pipeline.

Table 2.1 presents a summary of the reports and work completed to date.

Table 2.1: Summary of Integrated Geophysical, Geological and Geotechnical datasets

Report Type	Report Name	Year	Reference	Contractor Report Number	Description	Pipeline and Flowline Specific work
Geohazard desk studies	Neptun Block Task 1, 2 and 3 Desk Studies	2013	Fugro,2013a	J31070-2	■ Pre-data acquisition desk study completed with 3D seismic data with recommendations for data acquisition	■ Development of Physiographic Domains and Regional Terrain Units
Geophysical survey reports	Infield and Slope Geophysical Survey Report	2014	Fugro, 2014a	J31100-4	■ Survey for Infield area and slope ■ SSS, MBES, SBP (chirp), and magnetometer survey	■ Acquisition of geophysical data in the infield area along proposed flowline route
	Shelf Geophysical Survey Report	2014 - **updated in 2016**	Fugro, 2016a	J31107-4	■ Survey for Pipeline route on shelf ■ SSS, MBES, SBP (pinger and sparker), and magnetometer survey	■ Acquisition of geophysical data in the infield area along proposed pipeline route to shore ■ Development of pipeline terrain units and pipeline geotechnical units and pipeline soil categories – report updated in 2016 to include geological interpretation of the route and key findings from the geohazard core logging report (Fugro, 2015b)
	Platform Geophysical Survey Report	2014	Fugro, 2014b	J31110-2	■ Survey for notional platform location on shelf ■ SSS, MBES, SBP (pinger), and magnetometer survey	■ Geotechnical data for input into parameter derivation
	Nearshore Geophysical Survey Report	2015	Fugro, 2015a	J31112-1	■ Survey for notional Pipeline landfalls ■ SSS, MBES, SBP (pinger), and magnetometer survey	■ Acquisition of geophysical data at pipeline landfalls
	Platform Geophysical Survey	2017	Fugro, 2017	160424V3.3	■ Survey for Planned platform location ■ SSS, MBES, SBP (pinger), and magnetometer survey ■ 2DHR Seismic and 3DHR Seismic Survey	■ Acquisition of geophysical data around the platform location / pipeline terminals
Geohazard core logging test results	Geohazard Core Logging Report	2013	Fugro, 2014c	J31087-1	■ Geohazard core logging and testing for 7 LDPC locations in the Infield Area	■ Definition of geological units along the infield flowline routes
	Geohazard Core Logging Report	2015	Fugro, 2015b	J31109-3	■ Geohazard core logging and testing for locations in the Infield, Upslope and Shelf Areas	■ Development of regional ground model for the site ■ Geological logging of selected cores along the pipeline route to shore. From Fugro ,2015c
Geotechnical Laboratory testing and in situ results reports	Geotechnical Site Investigation Factual Report	2013	Fugro, 2013b	120582-3	■ Reconnaissance survey for Infield Area and Upslope ■ LDPC, CPT, PC, and VC data	■ Acquisition of geotechnical data along the proposed flowline route, and pipeline route to shore
	Geotechnical Site Investigation Factual Report	2015	Fugro 2015c	J31109-2	■ Reconnaissance survey for Infield Area, Upslope and Shelf ■ LDPC, CPT, PC, and VC data	■ Acquisition of geotechnical data along the proposed flowline route, and pipeline route to shore
	Geoquip	2017	Geoquip, 2017	GMOP17-G-008-DAT-D1	■ PC and BC data for pipeline and flowline route	■ Acquisition of geotechnical data along the proposed flowline route, pipeline route to shore and fault crossings
	Fugro	2018	Fugro, 2018b	173570-04(03	■ Boreholes for Platform Location, Pelican Drill Center, Domino Drill Centers, slope stability and pipeline fault crossings ■ Seabed CPTs for flowlines and pipelines	■ Acquisition of geotechnical data along the proposed flowline route, pipeline route to shore and fault crossings
	Fugro	2018	Fugro, 2018a	TN-173570-05	■ Preliminary unitisation of the Field Geotechnical data	■ Preliminary unitisation of geotechnical samples based on regional ground model developed in Fugro (2015b)
Geotechnical Parameters Report	Pelican South Drill Center Geotechnical Parameters report	2018	Fugro, 2018c	173570-05a	■ Interpretation and presentation of geotechnical parameters for Pelican South Drill Center	■ Derivation of geotechnical parameters for near surface sediments
	Pelican South Platform Geotechnical Parameters report	2018	Fugro, 2018d	173570-05b	■ Interpretation and presentation of geotechnical parameters for Proposed Platform G location ■ Pile sizing analyses	■ Derivation of geotechnical parameters for near surface sediments
	Domino Deep Drill Center Geotechnical Parameters report	2018	Fugro, 2018e	173570-05c	■ Interpretation and presentation of geotechnical parameters for Proposed Domino Deep Drill Centers location ■ Mudmat and Suction Anchor Analyses	■ Derivation of geotechnical parameters for near surface sediments

Report Type	Report Name	Year	Reference	Contractor Report Number	Description	Pipeline and Flowline Specific work
Integrated reporting	Consultancy Report Neptun Deep Integrated Report	2016	Fugro, 2016b	J31135-R-001(03)	■ Integration of geotechnical and geophysical data for the infield area ■ Development of geotechnical model for the infield area	■ Development of geotechnical model for the infield area ■ Soil province maps for infield area and flowline from Domino well locations to proposed platform location ■ Presentation of Pipeline Route summary sheets for infield flowline and pipeline route to shore

Notes
SSS = Sidescan sonar
MBES = Multibeam echosounder
SBP= Sub-bottom profiler
LDPC = Large diameter piston core
PC = Piston core
VC = Vibrocore
BC = Boxcore
CPT = Cone penetration test
2DHR Seismic = 2-dimentional high resolution seismic data
3DHR Seismic = 3-dimentional high resolution seismic data

2.2 Previous Unitisation

2.2.1 General

This section details the unitisation performed to date and forms the basis of the geotechnical model presented in this report.

Fugro (2016a) presents the previous geotechnical and geological unitisation for the proposed pipeline route to shore. Fugro (2016b) presents the geotechnical model for the upslope and infield area; and combines the established unitisations for each part of the site to develop a site-wide geotechnical model.

2.2.2 Shelf Geological Facies

Shelf geological facies were assigned to selected geotechnical cores from each PTU along the planned pipeline route and in the vicinity of the proposed platform to establish the environment of deposition for the sampled sediments (Fugro, 2015b). These facies provide information on the depositional environment for the shelf and provide a robust basis for the delineation of the pipeline route corridor into pipeline geotechnical zones. Infield Geotechnical Units.

Following completion of the laboratory and insitu testing (Fugro, 2015c), geotechnical units for the infield area were allocated (Fugro, 2016b), these are based on the geotechnical properties and agree with the interpreted depositional environment. The units within the infield area in the flowline depth of interest are:

- GU1 - clay with coccolith ooze;
- GU2 - organic clay (sapropel);
- GU3 - normally consolidated dark grey to reddish brown clay;
- GU3A - clay rich in amorphous iron sulphides (hydrotroilite);
- GU4 - lightly overconsolidated CLAY with few pockets and laminae of dark grey clay and silt;
- GU5 - overconsolidated clay with sand and silt layers.

2.2.3 Pipeline Geotechnical Categories

Pipeline geotechnical categories were assigned to the sediments on the pipeline route (Fugro, 2016a). Pipeline geotechnical categories split the sampled soil conditions into sediment types and undrained shear strengths that are known to have an impact on the pipe-sediment interaction. The pipeline geotechnical categories presented previously (Fugro, 2016a) were not taken forward into the geotechnical model in this report as they do not provide sufficient differentiation between the geotechnical units in different parts of the shelf. New units based on the shelf geological facies, calibrated by the geotechnical conditions and Infield Geotechnical Units, are presented in Section 4.2.

2.3 Existing Pipeline Spatial Delineation (Terrain Units and Soil Provinces)

2.3.1 Pipeline Terrain Units (Shelf Pipeline)

Pipeline terrain units (PTUs) were defined (Fugro, 2016a) using the geophysical data to delineate areas of similar seafloor morphology and seismic character observed from the available data and where similar geological conditions are interpreted to be present. Seabed morphology was identified from the Multibeam echosounder (MBES) bathymetry data with seismic character defined by its appearance in

the sub-bottom profiler (SBP) data. The 12 Pipeline Geotechnical Zones (Section 4.2) along the shelf from Platform G to landfall are based on the PTU mapping and the boundaries of the Pipeline Geotechnical Zones agree with the pipeline terrain units.

2.3.2 Soil Provinces (Infield Area and Upslope Area)

For the Infield Area, Soil Provinces were assigned based on the integration of geophysical and geotechnical data (Fugro 2016b). Four main zones were delineated across the infield area and upslope, these are:

- Geotechnical conditions associated with normal sediment accumulation (Soil Province 1);
- Overconsolidated sediments close to seafloor due to removal of overlying sediments (sediment removal) (Soil Province 2);
- Buried overconsolidated sediments due to deposition by mass transport processes (Soil Province 3);
- Overconsolidated sediments on the shelf and shelf break due to deposition in a shallower shelf environment (Soil Province 4).

3. GEOLOGICAL SETTING

3.1 General

This section presents a brief geological setting for Neptun Block, a more comprehensive regional geological setting can be found for the site in the integrated report for the site (Fugro Report Number 173570-08).

3.2 Geological Setting

The shallow geology across the Neptun Block is dominated by sediments deposited during and following the Last Glacial Maximum (LGM). The geological setting is based on publicly available literature, observations of the geology in geohazard and geotechnical cores and is a summary of the geological model presented in the Fugro (2016a) geohazard core logging report and Fugro (2016b) integrated report.

The north-western Black Sea is characterised by a wide shelf extending approximately 160 km from the Romanian coast. The Romanian continental slope dips gently to the south-east and is incised by a number of canyons. The largest of these canyons, the Viteaz canyon, is located west of the Neptun block. Canyons in the area have been active sediment transport pathways, or subject to down-canyon processes during various time periods as a result of changes in sea level, sediment source and the position of the Danube delta.

Geological processes in the Neptun block were controlled by global sea level change during the Quaternary. Figure 3.1 presents the sea level curve for the late Quaternary showing the changing water level in the Black Sea and environmental conditions over the last 40,000 years.

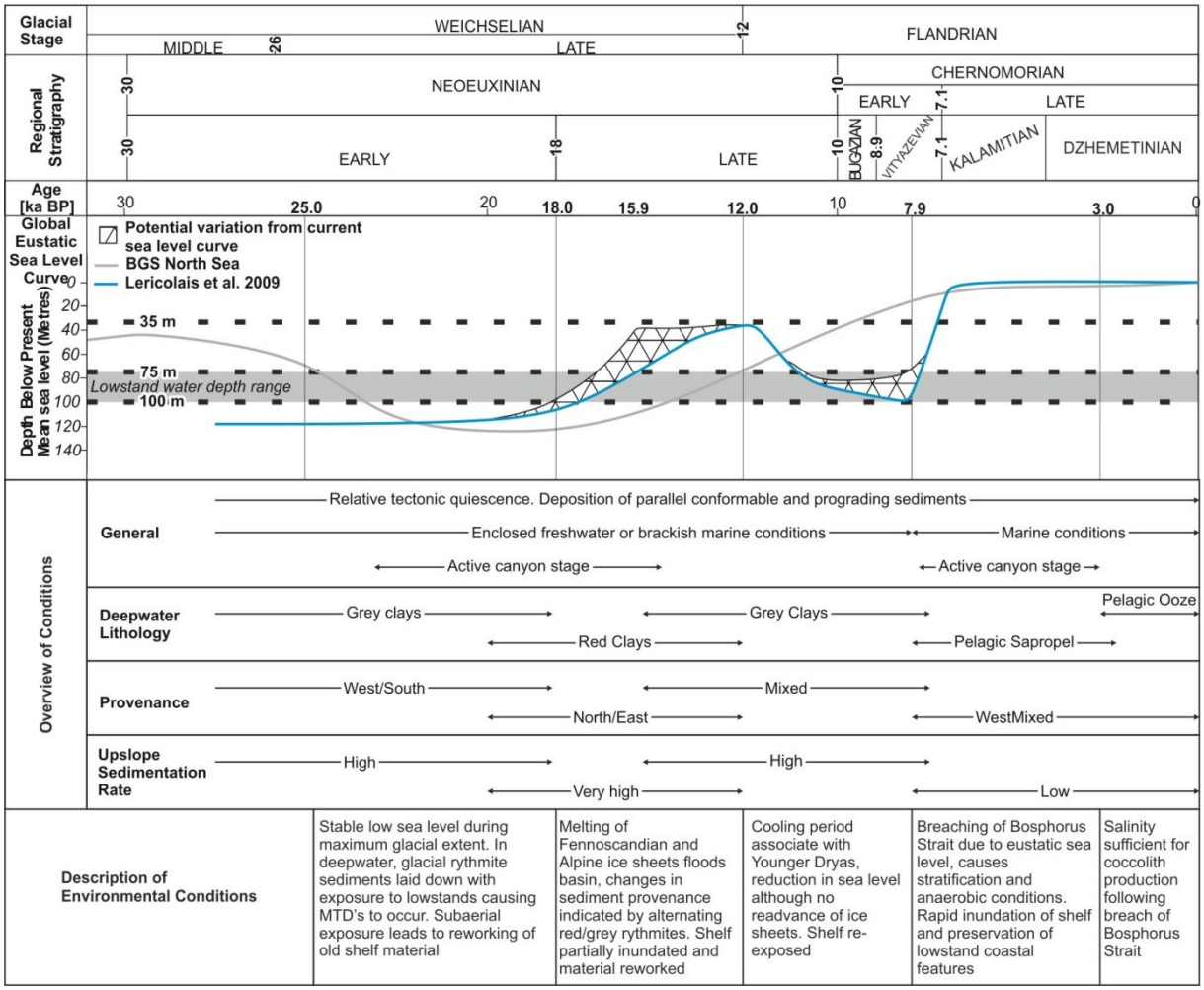


Figure 3.1: Sea level curve for the Neptun Block

Up to 8 ka (thousand years BP) the Black Sea was a fresh water lake fed by rivers from across Eastern Europe and Turkey, with its water level controlled by the advance and retreat of ice sheets. During this time sediment deposition in the deeper water areas was predominantly lacustrine clay. Global sea level rise at 8 ka and the re-connection of the Bosphorus Strait and the flooding of the Black Sea led to the deposition of organic rich clay (sapropel) and coccolith ooze. The organic rich sapropel is not preserved in water depths less than 200m, however the shell rich surface layer observed at the planned platform location represents the recent marine depositional environment following the flooding of the Black Sea.

Earlier lowstand events during the Younger Dryas (12.0 ka to 7.9 ka) and the last glacial maximum (25 ka to 30 ka) resulted in periods of higher sediment input which are interpreted to relate to greater canyon activity and slope instability. During these lowstands the Pelican Drill Center location is likely to have been in a nearshore or shallow marine environment.

4. PIPELINE GEOTECHNICAL MODEL

4.1 Pipeline Geotechnical Units

Eleven Pipeline Geotechnical Units (PGU) were identified from sample and test data available from the shelf. The PGUs are based on the geological facies presented in Fugro (2015b) and for ease of cross referencing the nomenclature is maintained throughout this report. The 11 Pipeline Geotechnical Units (PGUs) were delineated along the shelf to platform pipeline route for this report are based on the shelf geological facies presented in Fugro (2015b) (Section 2.2.2). PGUs define vertical stratigraphy and differ from PTUs which define spatial extents of seafloor terrain and the seismostratigraphic units (see Section 2.3.1).

The PGUs replace the Pipeline Geotechnical Categories (Section 2.2.3). The PGUs are split into four main groups based on their distribution in the physiographic domains:

i. S-1 – identified throughout the shelf, not unique to one physiographic domain;
ii. S-2 – identified on the outer shelf in the area surrounding the planned Platform G and Pelican South Drill Center;
iii. S-3 – identified on the mid-shelf;
iv. S-4 – identified on the inner shelf as the pipeline route heads towards landfall.

Table 4.1 summarises the depth range of occurrence and the generalised soil description for each PGU.

Table 4.1: Summary of Pipeline Geotechnical Units on the Shelf

Physiographic Domain	Pipeline Geotechnical Unit	Depth Range [m BML]*	Generalised Soil Description
All shelf	S-1	0.00 - 0.00/2.40	Very soft sandy CLAY with many very small to medium white shells and shell fragments
Outer Shelf	S-2a	0.00/4.60 – 0.60/25.20	Soft to firm silty sandy CLAY with laminae and pockets of clayey sand
	S-2b	0.10/11.60 – 0.45/17.90	Fine to medium SAND with traces of shells and shell fragments and lamina of clay and shell fragments
Mid-Shelf	S-3a	2.00 – 2.85	Very stiff silty CLAY
	S-3b	0.00/0.67 – 0.37/5.51	Fine to medium SAND with small white shells and shell fragments
	S-3c	0.00/1.13 – 1.50/9.95	Slightly silty fine SAND with traces of muscovite mica
	S-3d	0.00/4.21– 0.45/5.26	Very stiff clayey SILT with traces of shell fragments
Inner Shelf	S-4a	0.07/0.95 – 1.22/4.65	Very soft to soft CLAY interlaminated with silt and with traces of shell fragments
	S-4b	0.00/1.07 – 1.00/5.40	Slightly silty fine SAND
	S-4d	0.00/3.11 – 1.39/6.10	Stiff to firm SILT with lamina of soft clay with traces of mica and shell fragments
	S-4e	4.40/4.55 – 4.62/4.65	Fine to coarse clayey GRAVEL with shell fragments

Notes:
* Depth range based on available geotechnical data

The unitisation was performed for input into the determination of parameters appropriate to input for pipeline design studies. As a result, the unitisation may differ to that presented in the Platform or Pelican South Drill Center reports (Fugro 2018c, 2018d). For example, the unitisation for the Platform G locations presented in this report comprises S-1 and S-2a; these are equivalent to Units 1 and 2 presented in the Platform Parameters report (Fugro, 2018c).

The density of data available in the above units varies and this influences the derivation of parameters for each unit. Table 4.2 summarises the number of occurrences where a PGU was sampled and tested; where an occurrence is defined as a borehole, CPT, piston core, vibrocore, or grab sample. Paired or bump over locations are counted as separate locations for this purpose. The number of occurrences of the unit does not necessarily equate to the amount of testing performed on the unit; however, it gives an indication of the availability of data for the derivation of parameter ranges.

Table 4.2: Summary of Number of Occurrences of each Pipeline Geotechnical Unit

Pipeline Geotechnical Unit	Number of Occurrences
S-1	99
S-2a	51
S-2b	32
S-3a	1
S-3b	13
S-3c	25
S-3d	12
S-4a	7
S-4b	7
S-4d	18
S-4e	2

4.2 Pipeline Geotechnical Zonation

The distribution of the PGUs both laterally and vertically forms the basis for the definition of Pipeline Geotechnical Zones. Pipeline Geotechnical Zones therefore delineate the pipeline route into areas of similar geological and geotechnical conditions by performing an iterative process of geological unitisation, geotechnical unitisation and geotechnical parameter review, and integration with the available geophysical data. The Pipeline Geotechnical Zones present an update to the Pipeline Terrain Units presented in Fugro (2016a); based on the newly acquired geotechnical data and with no reinterpretation of the geophysical data performed. As a result, the distribution of the Pipeline Geotechnical Zones is unchanged to that of the Pipeline Terrain Units (Fugro, 2016a); however, the definition of the soil conditions within each zone is better constrained. Consideration of the seafloor mapping included in Fugro (2016a) must occur when utilising the Pipeline Geotechnical Zonation.

The Pipeline Geotechnical Zones are based on the available geotechnical data with varying amounts of geotechnical data for each zone; thus, consideration must be taken of the potential variability which may occur over short lateral or vertical distances within the zone, but particularly when approaching the boundary between zones. Summary vertical profiles (Figure 4.2) summarise the depth range of each unit based on the available geotechnical data within the zone. These profiles illustrate the potential variability which may be encountered in each zone. The quantity, type of sampling/testing and location

of a core/CPT available has influenced the observed variability of the soil conditions within the zone. This variability cannot be reduced based on the available geophysical and geotechnical data.

The depth of interest for the Pipeline Geotechnical Zonation is 3 m BML between KP 0 and KP 152.4 for surface-laid pipeline; and 5 m BML between KP 152.4 and KP 156.075 where the pipeline will be trenched.

Twelve pipeline geotechnical zones were delineated along the to-shore pipeline route (Plate 1). The Pipeline Geotechnical Zonation was performed along the centreline of the proposed pipeline; however, is presented in a corridor which extends 1 km either side of the proposed pipeline to ensure visual clarity and to capture any variability in the soil conditions as observed from the geophysical data. Where the pipeline corridor is outside of the available geophysical data, the boundary between zones is extrapolated along the same orientation as that observed from the geophysical data. A summary vertical profile defines the vertical distribution of the pipeline geotechnical units within each zone (Figure 4.2). Section 6 presents guidance on how to use the vertical profiles to extract the predicted stratigraphy in each zone. Table 4.3 and Table 4.4 present the KP distribution of each PGZ and the associated PGUs within that zone. The KP accuracy for the distribution of the PGZ's are limited by the resolution of the geophysical data (Fugro, 2016a) and are presented to the nearest 10 metres.

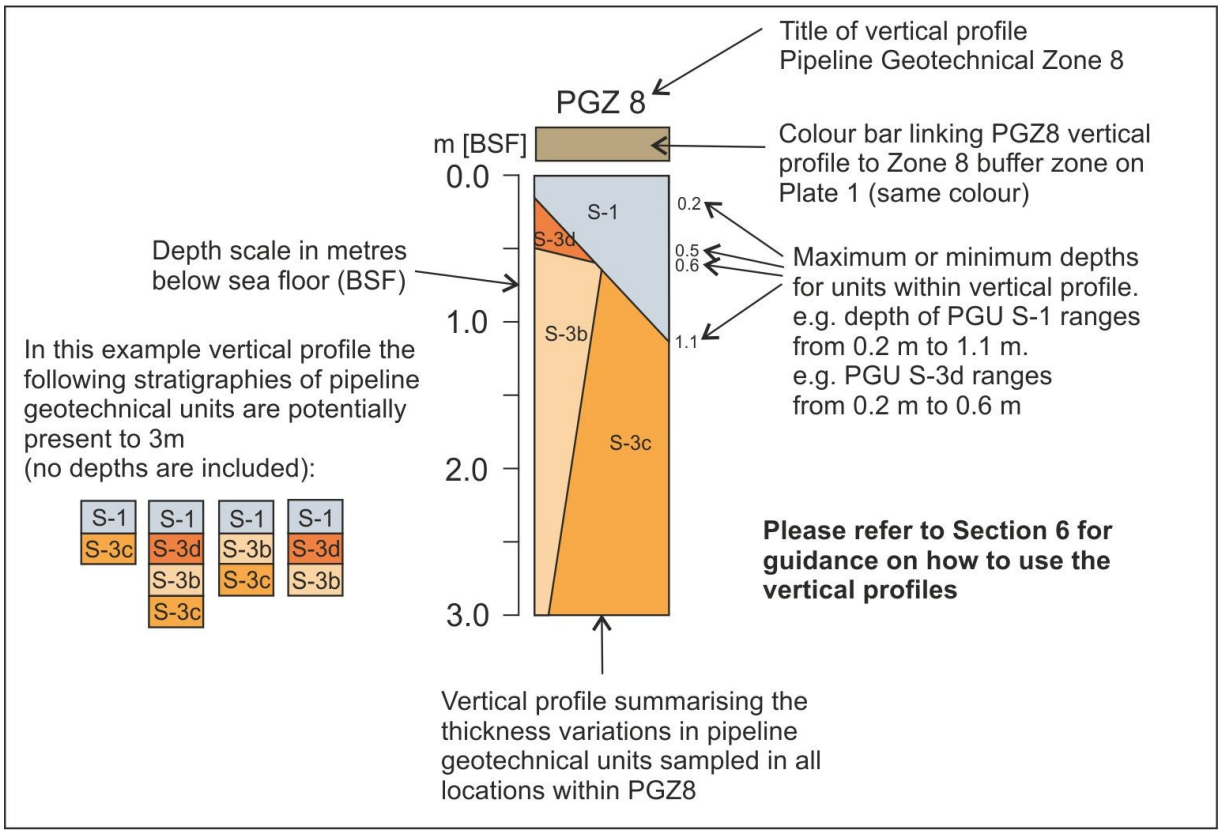


Figure 4.1: Annotated vertical profile

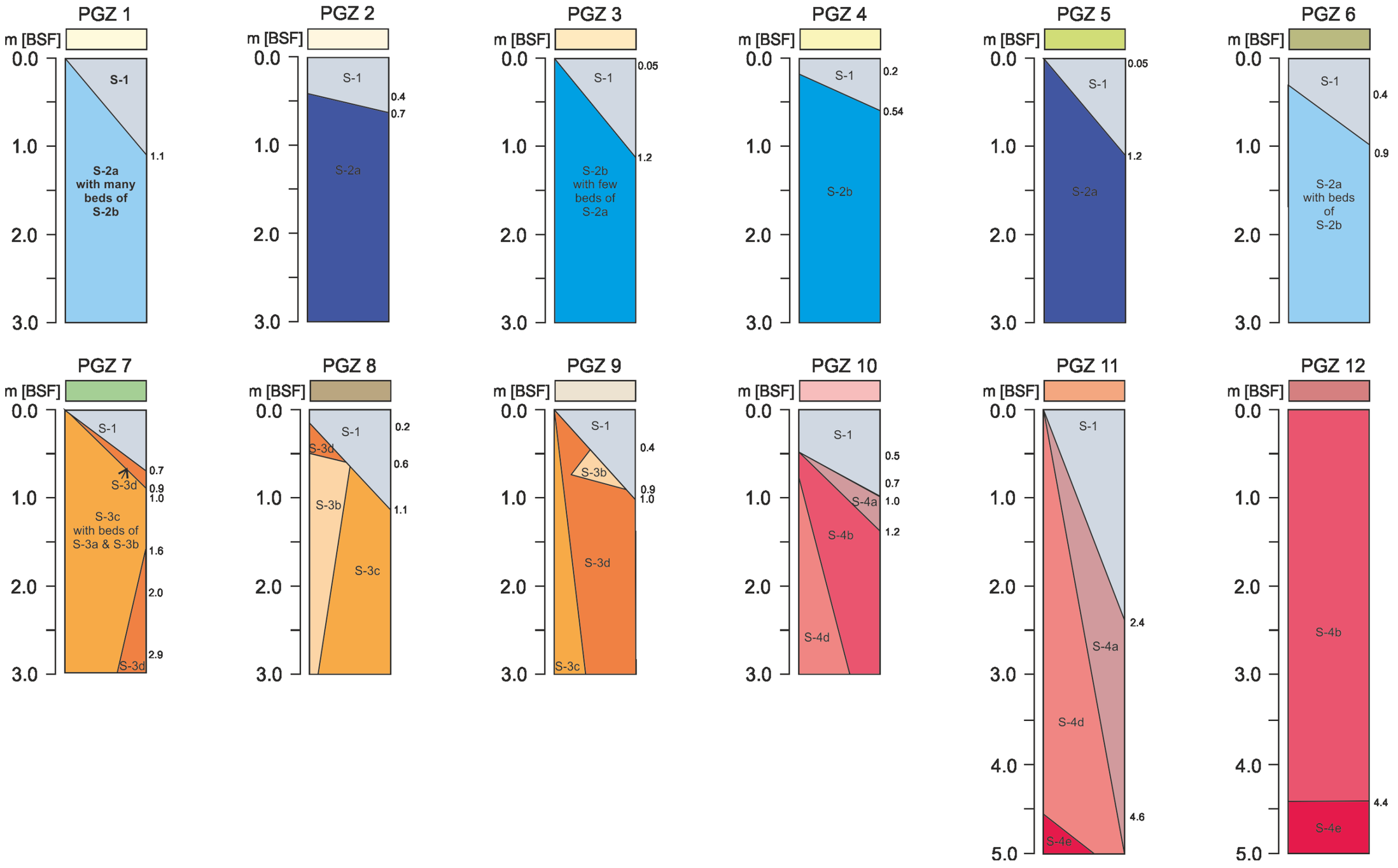


Figure 4.2: Summary vertical profiles illustrating distribution of Pipeline Geotechnical Units within each zone

Table 4.3: Distribution of Each Pipeline Geotechnical Unit per Zone (PGZ 1 to 5a)

PGU	Distribution of Pipeline Geotechnical Units Per Zone					
	PGZ1	PGZ2	PGZ3	PGZ4	PGZ5	PGZ5a
S-1	✓	✓	✓	✓	✓	✓
S-2a	✓	✓	(✓)		✓	✓
S-2b	(✓)		✓	✓		
KP Extent of Zone	0 – 11.46 12.47 – 12.76	11.46 – 12.46 12.76 – 15.21	15.21 – 21.95	21.95 – 29.31	29.31 – 32.04 33.04 – 34.90	32.04 – 33.04 34.90 – 41.97

Notes:
Ranges in brackets denote occurs as beds within the main soil unit
Reference Figure 4.2 for vertical summary profiles summarising PGU distribution

Table 4.4: Distribution of Each Pipeline Geotechnical Unit per Zone (PGZ 6 to 12)

PGU	Distribution of Pipeline Geotechnical Units Per Zone						
	PGZ6	PGZ7	PGZ8	PGZ9	PGZ10	PGZ11	PGZ12
S-1	✓	✓	✓	✓	✓	✓	
S-2a	✓						
S-2b	(✓)						
S-3a		✓					
S-3b		✓	✓	✓			
S-3c		✓	✓ *	✓			
S-3d		✓	✓	x *			
S-4a					✓	✓	
S-4b					✓		✓
S-4d					✓	✓	
S-4e						✓	✓
KP Extent of Zone	41.97 – 49.04	49.04 – 62.36 74.47 – 80.88	62.36 – 74.47 80.88 – 83.51	83.51 – 114.08	114.09 – 135.65	135.66 – 153.08	153.08 – 155.05

Notes:
Ranges in brackets denote occurs as beds within the main soil unit
* Predominant unit observed in the zone
Reference Figure 4.2 for vertical summary profiles summarising PGU distribution

4.3 Pipeline Geotechnical Parameters

The following geotechnical parameters were derived for each Pipeline Geotechnical Unit to a depth of 3 m BML or 5 m BML depending on depth of interest of the relevant zones:

i. Water Content (w);
ii. Unit Weight (γ);
iii. Cone Resistance (q_c) measured from CPT;
iv. Undrained Shear Strength (s_u);
v. Remoulded Strength (s_{ur});
vi. Strength Sensitivity (s_t);
vii. Relative Density (D_r);
viii. Friction Angle (ϕ).

For each parameter, geotechnical parameter profiles are presented per pipeline geotechnical unit for input into pipeline design analyses. Geotechnical parameter profiles for each parameter are presented in the form of lowest expected (LE), best estimate (BE) and highest expected (HE). The lowest and highest expected provide an indicative range of the majority of the data but do not necessarily capture all the outliers.

The geotechnical parameter profiles for the water content, unit weight and sensitivity were derived statistically where suitable data points are available, using the recommendations provided by DNV GL (2015). DNV GL (2015) specifies data outliers as those with a value greater than 2 standard deviations from the overall mean value of the dataset. Data points greater than 2 standard deviations of the mean have not been presented. For geotechnical design applications, where a linearly increasing or decreasing trend in basic physical properties is observed, data are assumed to be normally distributed. Where suitable data points are not available an indicative best estimate was derived using the limited data.

The geotechnical parameter profiles for the other parameters (cone resistance, undrained shear strength and relative density) listed above were derived based on engineering geological judgement of the data sets available. The parameter profiles are presented for the total depth range of the pipeline geotechnical unit or to maximum depth of interest (3 m BML or 5 m BML). Therefore, interpolation of the profiles may be required to the maximum depth range and geotechnical data presented on the parameter profiles may include data beyond the depth of interest.

All relevant available data were plotted against depth for cone resistance, undrained shear strength and relative density within each pipeline geotechnical unit. Using engineering geological judgement, the lowest expected, highest expected and best estimate parameter profiles were derived for each parameter and geotechnical unit Emphasis is given to advanced tests, for example laboratory vanes and effective stress tests for the undrained shear strength parameter. The lowest and highest expected profiles derived do not necessarily represent the absolute range of the data but recommend values which are a credible representation of the majority of the data available. In some cases, test data falls outside of the lowest and highest expected range. These data are deemed to be unrepresentative of the pipeline geotechnical unit for example due to the presence of sand or silt layers, or the presence of locally increased content of shell fragments.

It may be possible that, within areas where there are no or limited data available, the soil parameters fall outside of the ranges represented in this report.

Sensitivities are relatively high in Unit S-1, these are based on the available geotechnical data within the unit and are the result of low (approximately 0.5 kPa remoulded shear strengths values) measured from laboratory vane tests only. Measurements of very low strength soils using laboratory vanes test can be difficult and the yielded results may not be representative of the very low strength soils. The highest results are not considered credible and thus were removed from the range of sensitivity presented for Unit S-1 and Unit S-2a in Table 4.5; however, consideration should be made of the potential for very low remoulded shear strengths (less than 0.5kPa) in Unit S-1 and S-2a.

Table 4.5: Soil Parameters for Pipeline Geotechnical Units

Pipeline Geotechnical Unit	Depth [m BML]	Water Content (w) [%]			Unit Weight (γ) [kN/m^3]			Cone Resistance (q_c) [MPa]			Undrained Shear Strength (s_u) [kPa]			Remoulded Shear Strength (s_{ur}) [kPa]			Strength Sensitivity (s_t) [-]			Relative Density (D_r) [%]			Friction Angle (ϕ) [°]		
		LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE
S-1	0.0	46.2	92.0	137.9	12.5	14.9	17.3	0	0.01	0.05	0.1	1.2	7.5	0.0	0.4	3.6	2.1	3.4	4.7						
	0.25	46.2	92.0	137.9	12.5	14.9	17.3	0.01	0.05	0.25	0.8	2.5	10.0	0.2	0.7	4.8	2.1	3.4	4.7						
	0.25	34.8	57.6	80.3	15.2	16.6	18.1	0.01	0.05	0.25	0.8	2.5	10.0	-	0.6	-	-	4.3‡	-						
	2.4	34.8	57.6	80.3	15.2	16.6	18.1	0.10	0.25	0.70	3.5	9.0	17.0	-	2.1	-	-	4.3‡	-						
S-2a	0.0	26.5	33.0	39.5	17.2	18.5	19.7	0.10	0.30	0.50	1.0	7.0	12.0	0.3	1.3	1.6	3.2	5.6	7.6#	2	20	70	20	25	35
	1.0	26.5	33.0	39.5	17.2	18.5	19.7	0.12	0.50	2.00	3.0	18.0	100.0	0.9	3.2	13.1	3.2	5.6	7.6#	2	20	70	20	25	35
	3.0	26.5	33.0	39.5	17.2	18.5	19.7	0.15	0.80	3.00	10.0	37.0	130.0	3.1	6.6	17.1	3.2	5.6	7.6#	2	20	70	20	25	35
S-2b	0.0	20.5	26.9	33.2	17.3	18.6	20.0	0.10	0.80	2.00										5	30	100	20	25	40
	1.4	20.5	26.9	33.2	17.3	18.6	20.0	0.19	1.83	3.80										5	30	100	20	25	40
	2.0	20.5	26.9	33.2	17.3	18.6	20.0	0.37	2.27	10.00										5	30	100	20	25	40
	3.0	20.5	26.9	33.2	17.3	18.6	20.0	0.50	3.00	15.00										5	30	100	20	25	40
S-3a	2.0	–	42.0	-	-	18.1	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND						
	2.85	–	42.0	-	-	18.1	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND						
S-3b	0.0	18.7	30.5	42.2	16.1	18.2	20.3	0.10	3.50	5.50										25	65	85	25	35	40
	3.0	18.7	30.5	42.2	16.1	18.2	20.3	5.00	8.00	10.00										25	65	85	25	35	40
S-3c	0.0	18.1	23.3	28.5	18.3	19.5	20.7	0.20	0.70	2.00										30	60	100	25	30	35
	0.28	18.1	23.3	28.5	18.3	19.5	20.7	0.28	1.10	2.50										30	60	100	25	30	35
	2.25	18.1	23.3	28.5	18.3	19.5	20.7	0.43	4.47	25.00										30	60	100	25	30	35
	3.0	18.1	23.3	28.5	18.3	19.5	20.7	0.50	6.00	28.00										30	60	100	25	30	35
S-3d	0.0	23.5	29.0	34.6	18.5	19.4	20.3	0.05	0.07	0.15	1.0	3.0	17.0	0.2	0.6	5.0	3.4	4.7	6.1						
	3.0	23.5	29.0	34.6	18.5	19.4	20.3	0.20	0.80	3.00	3.0	40.0	80.0	0.5	8.5	23.5	3.4	4.7	6.1						
S-4a	0.0	54.4	60.6	66.9	14.9	16.4	18.0	0.05	0.07	0.10	0.5	3.0	11.5	0.1	0.6	4.4	2.6	4.7	6.8						
	5.0	54.4	60.6	66.9	14.9	16.4	18.0	0.25	0.35	0.50	18.0	22.0	30.0	2.6	4.7	11.5	2.6	4.7	6.8						
S-4b	0.0	–	30.5	-	-	18.5	-	0.10	2.00	3.00										15	47	80	20	30	35
	5.0	–	30.5	-	-	18.5	-	1.50	3.50	12.00										15	47	80	20	30	35
S-4d*	0.0	25.9	33.6	41.4	17.4	18.5	19.6	0.05	0.10	0.35	2.0	5.0	20.0	0.3	1.0	5.7	3.5	4.9	6.3	10	20	40	20	25	30
	1.5	25.9	33.6	41.4	17.4	18.5	19.6	0.21	0.37	0.75	2.5	12.5	50.0	0.8	2.6	14.3	3.5	4.9	6.3	10	20	40	20	25	30
	2.5	25.9	33.6	41.4	17.4	18.5	19.6	0.23	0.55	2.50	3.5	17.5	120.0	1.1	3.6	34.3	3.5	4.9	6.3	10	20	40	20	25	30
	5.0	25.9	33.6	41.4	17.4	18.5	19.6	0.40	1.00	3.00	6.0	30.0	150.0	1.9	6.1	42.9	3.5	4.9	6.3	10	20	40	20	25	30
S-4e†	4.4	ND	ND	ND	ND	ND	ND	20.00	32.00	40.00										ND	ND	ND	ND	ND	ND
	4.65	ND	ND	ND	ND	ND	ND	20.00	32.00	40.00										ND	ND	ND	ND	ND	ND

Notes:
'-' not enough data within PGU to derive LE and HE
ND = No Data
* silt is considered undrained in PGU S-4d
† - Limited sample data available in gravel
‡ - only a single credible sensitivity value available, very high sensitivities (greater than 10) were calculated for this unit; however, these are considered not credible and are excluded from the presented values. Consideration should be made for the potential for high sensitivity values in this unit
# - very high sensitivities (greater than 10) were calculated for this unit based on remoulded laboratory test results; however, these are considered not credible and are excluded from the presented value. Consideration should be made for the potential for high sensitivity values in this unit
BML = Below Mudline
LE = Lowest Expected
BE = Best Estimate
HE = Highest Expected

5. FLOWLINE GEOTECHNICAL MODEL

5.1 Flowline Geotechnical Units

Flowline Geotechnical Units (FGU) are correlated with, and use the same nomenclature as, the Infield Geotechnical Units (Fugro, 2015b) as summarised in Table 5.1. These units were derived for the flowline route from the proposed Domino drill centers to the planned platform location.

Table 5.1: Flowline Geotechnical Units

Flowline Geotechnical Unit	Depth Range [m BML]	Generalised Soil Description
1	0.00 – 1.25	Extremely low strength to low strength CLAY
2	0.00/1.25 – 0.00/5.45	Extremely low strength organic CLAY with many extremely closely spaced planar parallel thin laminae of highly organic clay
3	0.00/3.80 – 0.06/19.70	Extremely low strength to low strength CLAY
3a	1.25/5.01 – 1.48/6.40	Low strength CLAY (peak in undrained shear strength)
4	0.00 – 1.30/2.25	Low strength (lightly overconsolidated) CLAY with few pockets and laminae of dark grey clay and silt
4a	1.30/1.82 – 1.74/2.15	Low strength to medium strength CLAY (peak in undrained shear strength)
5	0.00/0.20 – 4.30/15.72	Low strength to medium strength (lightly overconsolidated) CLAY with pockets and laminae of dark grey clay and silt

5.2 Flowline Geotechnical Zonation

The distribution of the FGU's both laterally and vertically forms the basis for the definition of the Flowline Geotechnical Zones. Like the Pipeline Geotechnical Zones for the pipeline route on the shelf, the Flowline Geotechnical Zonation delineates the Domino and Pelican flowline routes in the Infield area into areas of similar geological and geotechnical conditions. The Flowline Geotechnical Zonation utilised the Soil Province boundaries (Fugro, 2016b) as the basis for the division into zones. The mapped geophysical horizon depth to base of surficial sediments was used to delineate the FGZ where FGU 1 and 2 were present in depth of interest (3 m BML). Six Flowline Geotechnical Zones were delineated along the Domino flowline route between Platform G and the Domino Drill Center 1 and 2. Only one Pipeline Geotechnical Zone (FGZ1) is present along the Pelican flowline route between the Pelican Drill Center and Platform G. The Flowline Geotechnical Zonation was performed along the centreline of the proposed flowline; however, is presented in a 1 km corridor either side of the proposed pipeline to ensure visual clarity and to capture any variability in the soil conditions as observed from the geophysical data. Where the pipeline corridor is outside of the available geophysical data, the boundary between zones was not extrapolated to avoid any interpretation of a relatively complex area.

The depth of interest for the Flowline Geotechnical Zonation is 3 m BML for the full extent of the flowline route from the Domino drill centers to the proposed platform location.

Flowline Geotechnical Zone 2 and 4 are characterised by similar geotechnical profiles (FGU1, FGU2 and FGU3); however, they are differentiated in the flowline geotechnical zonation because FGZ has the potential to be characterised by thicker occurrences of FGU1 and 2. In addition, the division between

FGZ2 and FGZ4 maintains the boundaries of the previously mapped soil provinces. A summary vertical profile defines the vertical distribution of the soil conditions within each zone (Figure 5.1). Section 6 presents guidance on how to use the vertical profiles to extract the predicted stratigraphy in each zone. Table 5.2 presents the KP distribution of each FGZ and the associated FGUs within that zone. The KP accuracy for the distribution of FGZ has been rounded to the nearest 10 metres, as this is limited by the resolution of geophysical data (Fugro, 2014a; 2016a).

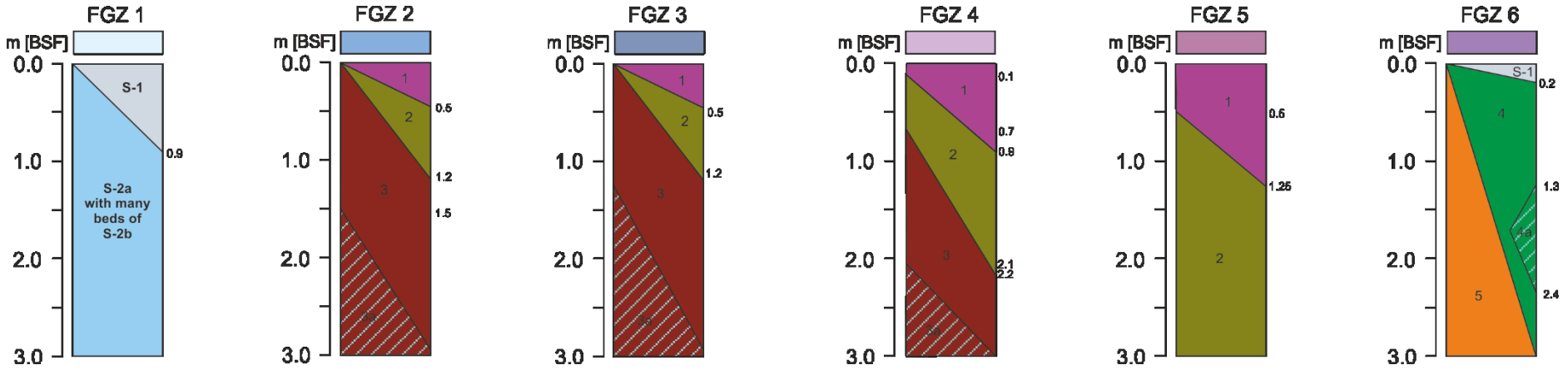


Figure 5.1: Summary vertical profiles illustrating distribution of Flowline Geotechnical Units within each Flowline Geotechnical Zone

Table 5.2: Distribution of Each Flowline Geotechnical Unit per Zone along the Domino Flowline Route

Flowline Geotechnical Unit (FGU)	Distribution of Flowline Geotechnical Units Per Zone along the Domino Flowline Route					
	FGZ1	FGZ2	FGZ3	FGZ4	FGZ5	FGZ6
1	✓	✓	✓	✓	✓	
2	✓	✓	✓	✓	✓	
3		✓	✓	✓		
3a		✓	✓	✓		
4						✓
5						✓
KP Extent of Zone (PG-DDC1)	0.00 – 5.38	8.40 – 14.80 18.24 – 18.60	17.34 – 18.04	17.80 – 17.34 18.04 – 18.24 18.60 – 26.01		5.38 – 8.40
KP Extent of Zone (PG-DDC2)	31.22 – 35.51*	18.17 – 18.29 21.43 – 28.08		1.00– 1.12 1.31 – 1.38 1.67 – 1.87 2.22 – 2.75 2.89 – 3.16 3.25 – 6.16 6.18 – 6.35 6.39 – 12.69 12.80 – 13.00 13.13 – 17.60 17.66 – 18.17 18.29 – 21.43	1.12 – 1.31 1.38 – 1.67 1.87 – 2.22 2.75 – 2.89 3.16 – 3.26 6.16 – 6.18 6.35 – 6.39 12.69 – 21.80 13.00 – 13.13 17.60 – 17.66	28.08 – 31.22
KP Extent of Zone (DDC1-DDC2)				0.00 – 6.00		

Notes:
* - KP 35.51 to 36.45 characterised by PGZ1
PG – Platform G
DDC – Domino Drill Center

5.3 Flowline Geotechnical Parameters

The following geotechnical parameters were derived for each Flowline Geotechnical Unit to a depth of 3 m BML:

i. Water Content (w);
ii. Unit Weight (γ);
iii. Cone Resistance (q_c) measured from CPT;
iv. Undrained Shear Strength (s_u);
v. Remoulded Strength (s_{ur});
vi. Strength Sensitivity (s_t).

For each parameter, geotechnical parameter profiles are presented per pipeline geotechnical unit for input into pipeline design analyses. Geotechnical parameter profiles for each parameter are presented in the form of lowest expected (LE), best estimate (BE) and highest expected (HE). The lowest and highest expected provide an indicative range of the majority of the data but do not necessarily capture all the outliers. The geotechnical parameter profiles for the water content, unit weight and sensitivity were derived statistically where suitable data points are available, using the recommendations provided by DNV GL (2012). DNV GL (2012) specifies data outliers as those with a value greater than 2 standard deviations from the overall mean value of the dataset. Data outliers have been removed from the unit weight and water contact parameter profile graphs presented in Appendix B. For geotechnical design applications, where a linearly increasing or decreasing trend in basic physical properties is observed, data are assumed to be normally distributed. Where suitable data points are not available the total range of the measured data are presented with an indication of the number of data points available.

The geotechnical parameter profiles for the other parameters (cone resistance, undrained shear strength and relative density) listed above were updated based on those previously presented in Fugro (2016c) for FGU's 1 to 3. This update to the geotechnical parameter profiles was required due to additional geotechnical data acquired in 2018. Geotechnical parameter profiles were derived for FGU´s 4 and 5 in this report because the number of relevant data points along the flowline route are reduced compared to FGU 4 and 5 data at all depths used to derive the geotechnical parameter profiles in Fugro (2016c). The parameter profiles are presented for the total depth range of the pipeline geotechnical unit or to depth of interest and therefore interpolation of the parameter profiles was required to the maximum depth range. Data presented with the parameter profiles may include data beyond the depth of interest. Data points greater than 2 standard deviations of the mean have not been presented.

All relevant available data were plotted against depth for cone resistance, undrained shear strength and relative density within each flowline geotechnical unit. Using engineering geological judgement, the lowest expected, highest expected and best estimate parameter profiles were derived for each parameter and geotechnical unit. Emphasis is given to advanced tests, for example laboratory vanes and effective stress tests for the undrained shear strength parameter. The lowest and highest expected profiles derived do not necessarily represent the absolute range of the data but recommend values which are a credible representation of the majority of the data available. In some cases, test data falls outside of the lowest and highest expected range. These data are deemed to be unrepresentative of the flowline geotechnical unit for example due to the presence of sand or silt layers, or the presence of

locally increased content of shell fragments. It may be possible that, within areas where there are no or limited data available, the soil parameters fall outside of the ranges represented in this report.

Sensitivities are relatively high in Units 2 and 3, these are based on the available geotechnical data within the unit and are the result of low (approximately 0.2 kPa remoulded shear strengths values) measured from laboratory vane tests only. Measurements of very low strength soils using laboratory vanes test can be difficult and the yielded results may not be representative of very low strength soils. The highest results are not considered credible and thus were removed from the calculation of the range of sensitivity presented for Unit 2 and Unit 3 in Table 5.3; however, consideration should be made of the potential for very low remoulded shear strengths (less than 0.2 kPa), and thus very high sensitivities, in Units 2 and 3.

Table 5.3: Soil Parameters for Flowline Geotechnical Units along the Domino Flowline Route

Flowline Geotechnical Unit	Depth [m BML]	Water Content (w) [%]			Unit Weight (γ) [kN/m3]			Cone Resistance (q_c) [MPa]			Undrained Shear Strength (s_u) [kPa]			Remoulded Shear Strength (s_{ur}) [kPa]			Strength Sensitivity (s_t) [-]		
		LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE
1	0	187	318	449	8.9	11.1	13.2	0.0025	0.0075	0.0125	0.1	0.5	1.0	0.0	0.1	0.5	2.1	4.8	7.5
	1.25	187	318	449	8.9	11.1	13.2	0.025	0.0375	0.05	0.8	1.6	3.2	0.1	0.3	1.5	2.1	4.8	7.5
2	0.0	142	311	480	9.3	11.5	13.8	0.00	0.01	0.03	0.1	0.5	2.0	0.0	0.1	0.3	2.2*	4.3*	6.3*
	3.0	142	311	480	9.3	11.5	13.8	0.04	0.05	0.08	0.7	1.6	5.0	0.3	0.4	0.8	2.2*	4.3*	6.3*
3	0.0	63	109	156	12.1	13.9	15.7	0.01	0.02	0.04	0.1	0.5	2.0	0.1	0.1	0.3	2.0*	5.0*	8.0*
	2.0	63	109	156	12.1	13.9	15.7	0.04	0.07	0.09	1.0	3.0	7.0	0.5	0.6	0.9	2.0*	5.0*	8.0*
	2.0	63	109	156	12.1	13.9	15.7	0.04	0.07	0.25	1.0	3.0	12.5	0.5	0.6	1.6	2.0*	5.0*	8.0*
	3.0	63	109	156	12.1	13.9	15.7	0.06	0.10	0.25	1.0	3.0	12.5	0.5	0.6	1.6	2.0*	5.0*	8.0*
4	0.0	44	56	68	15.6	16.6	17.6	0.035	0.06	0.10	1.0	3.0	5.0	0.2	-	2.5	2.0	-	5.9
	3.0	44	56	68	15.6	16.6	17.6	0.18	0.21	0.27	6.0	9.0	13.0	1.0	-	6.5	2.0	-	5.9
5	0.0	44	61	78	15.3	16.3	17.2	0.015	0.05	0.28	1.0	2.0	15.0	0.1	-	7.1	2.1	-	9.3
	3.0	44	61	78	15.3	16.3	17.2	0.18	0.21	0.75	6.0	9.0	40.0	0.6	-	19.0	2.1	-	9.3

Notes:

* - very high sensitivities (greater than 10) were calculated for this unit based on remoulded laboratory test results; however, these are considered not credible and are excluded from the presented value. Consideration should be made for the potential for high sensitivity values in this unit

'-' not enough data to derive BE. Values for LE and HE in this case represent the total range of data

BML = Below Mudline

LE = Lowest Expected

BE = Best Estimate

HE = Highest Expected

6. GUIDANCE ON HOW TO USE PIPELINE AND FLOWLINE VERTICAL PROFILES

Sections 4.2 to 5.2 present vertical profiles of the stratigraphy of the pipeline and flowline geotechnical units (PGU and FGU) within each zone to a depth of interest of between 3 m BML and 5 m BML. For each geotechnical unit credible lowest (LE) and highest (HE) and best estimate geotechnical parameters have been derived to capture the range for each PGU and FGU and summarised in tables against depth wherever the data permits. These predicted profiles and associated geotechnical parameter tables summarise the expected range of geotechnical conditions within each PGZ and FGZ to enable prediction of the range of soil conditions between sampled geotechnical locations and therefore along the entire length of the pipeline and flowline routes. For example, in PGZ 8 between the geotechnical locations, it would be possible, using the soil profile of PGZ 8, to predict the soil parameters to 3 m BML along the whole length of the PGZ.

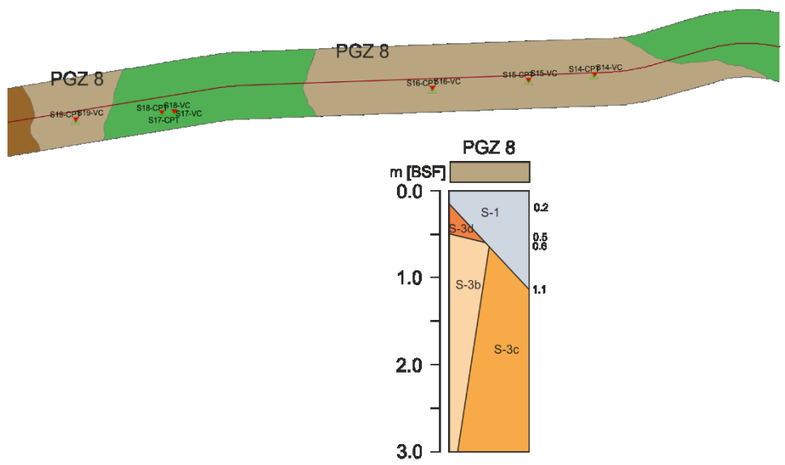
The accuracy of the predicted profiles and the zonation is dependent on the amount and quality of data used to produce it (Section 2). The predicted profiles reflect the potential variability of the soil which may be encountered in each zone. The predicted profiles are based on the geotechnical unit depths derived from the core and CPT data acquired constrained wherever possible by interpretation of the geophysical data, which in most cases does not specifically identify geotechnical units and boundaries, and therefore do not necessarily present the complete depth range which may be present in the zone. The inclination and directionality of the depth change is for illustrative purposes only and is not representative of lateral variability in a particular cardinal direction, e.g. from west to east.

To produce a zone-specific predicted profile and parameter values for design purposes along the pipeline or flowline routes, the following steps should be undertaken to effectively use the pipeline and flowline soil profiles:

i. Find which PGZ or FGZ you require the vertical profile for (Plate 1 or supplied GIS deliverable);
ii. Find corresponding vertical profile for the PGZ or FGZ (Figure 4.2, or Figure 5.1);
iii. Extract soil unit thicknesses from soil profile to depth required;
    a. The profile selection will depend on the specific design requirements for either a surface laid or trenched pipeline
iv. Make parameter profiles by selecting the lowest expected, highest expected and best estimate parameter in the tabulated data (Appendix B) using the zone-specific soil profile constructed in steps 2 and 3.

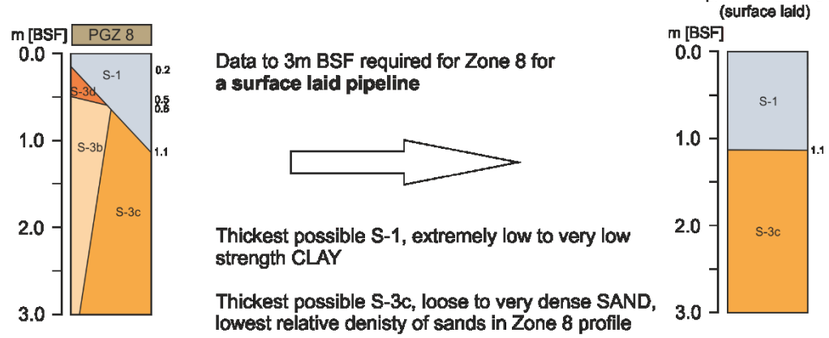
Figure 6.1 and Figure 6.2 present the above-mentioned steps describing how to use the pipeline and flowline predicted profiles with two example zones along the pipeline route, firstly for assessing pipeline embedment and secondly for rate of progress of trenching.

Step 1 and 2: Profile required for Zone 8. Soil profile for PGZ8 extracted from Fig 4.1

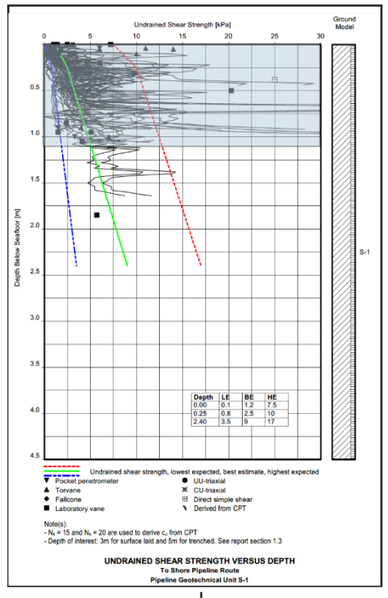


Step 3: Unit thicknesses extracted from predicted profile to depth required

Select the most appropriate predicted profile for the engineering design being considered.
For example, low strength clay from surface to assess quantity of pipeline embedment:



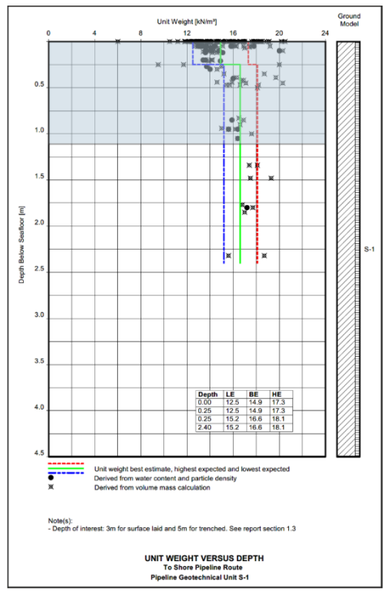
Step 4: Undrained shear strength data pieced together from parameter plot data

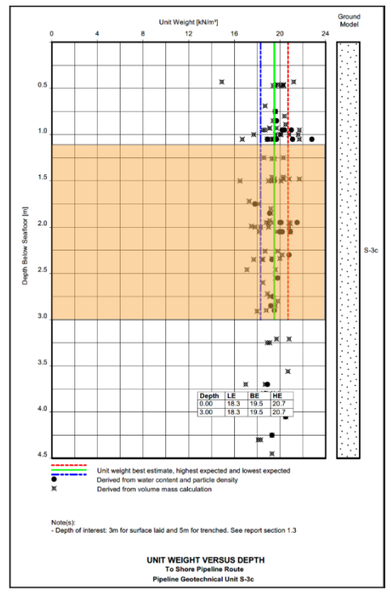


PGU	Depth	LE	BE	HE
S-1	0.00	0.1	1.2	7.5
	0.25	0.8	2.5	10
	1.10	1.9	5.1	12.8
S-3c	1.10	SAND - no data		
	3.00			

← LE,BE and HE calculated using gradient of straight line formula: y=mx+c

Step 4: Submerged unit weight data pieced together from parameter plot data



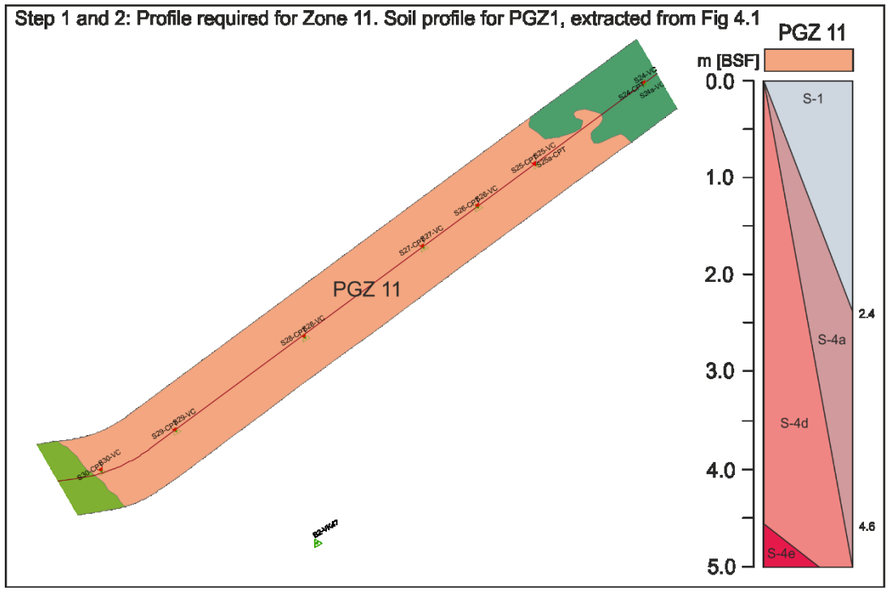


PGU	Depth	LE	BE	HE
S-1	0.00	12.5	14.9	17.3
	0.25	12.5	14.9	17.3
	0.25	15.2	16.6	18.1
	1.10	15.2	16.6	18.1
S-3c	1.10	18.3	19.5	20.7
	3.00	18.3	19.5	20.7

Based on the engineering design methods being used, the most appropriate parameter range can be selected. For example, quantity of pipeline embedment assessed using S-1 LE parameters

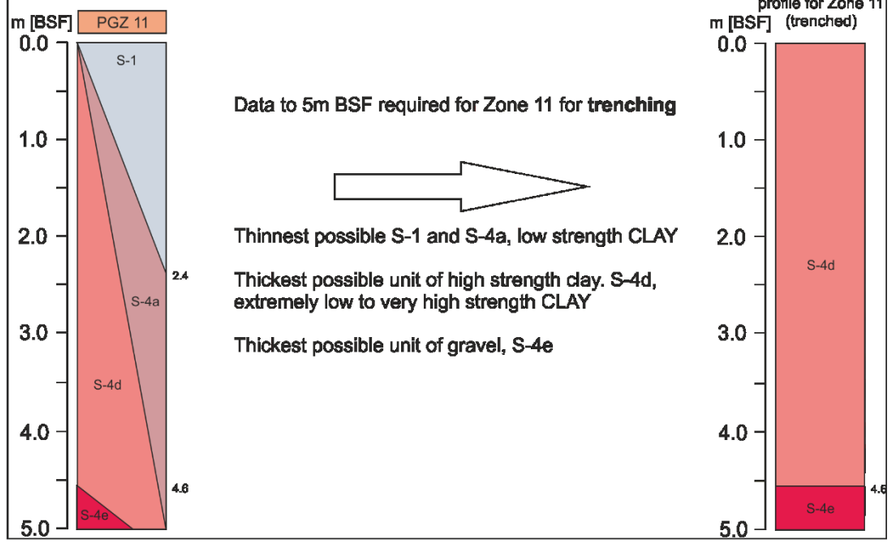
Figure 6.1: Guidance on how to use vertical profiles – PGZ 8 example

Step 1 and 2: Profile required for Zone 11. Soil profile for PGZ1, extracted from Fig 4.1

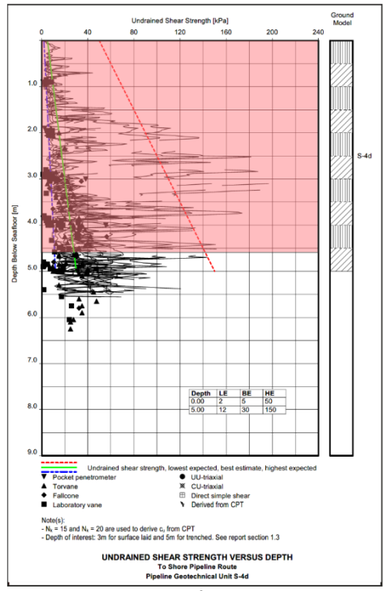


Step 3: Soil unit thicknesses extracted from soil profile to depth required

Select the most appropriate predicted profile for the engineering design being considered.
For example, high strength clay from surface to assess rate of progress for trenching:



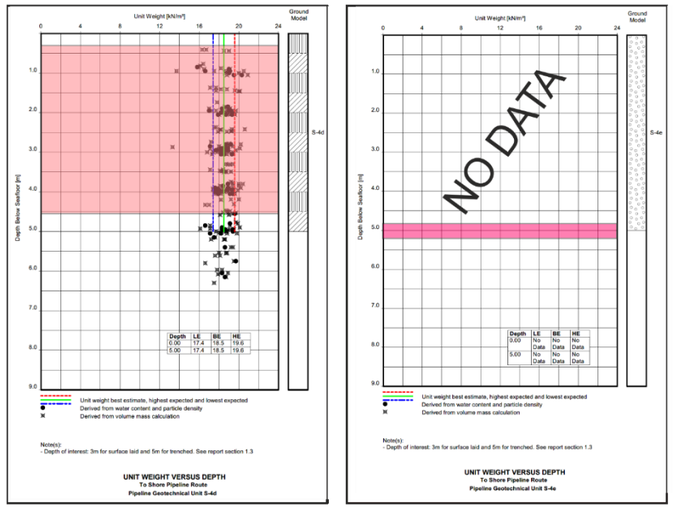
Step 4: Undrained shear strength data pieced together from parameter plot data



PGU	Depth	LE	BE	HE
S-4d	0.00	2	5	50
	4.60	11	28	142
S-4e	4.60	GRAVEL - no data		
	5.00			

LE,BE and HE calculated using gradient of straight line formula: y=mx+c

Step 4: Submerged unit weight data pieced together from parameter plot data



PGU	Depth	LE	BE	HE
S-4d	0.00	17.4	18.5	19.6
	4.60	17.4	18.5	19.6
S-4e	4.60	no data		
	5.00			

Based on the engineering design methods being used, the most appropriate parameter range can be selected. For example, rate of progress for trenchability assessed using S-4d HE parameters

Figure 6.2: Guidance on how to use vertical profiles – PGZ 11 example

7. FAULT CROSSING GEOTECHNICAL MODEL

7.1 General

Three fault crossings were investigated on the shelf along the pipeline route to shore to understand the soil conditions for input into rock dumping analyses. (Table 7.1 and Figure 7.1)

Table 7.1: Summary of Fault locations along the proposed to shore pipeline Route

Fault	Pipeline KP	Offset at seafloor [m]	Comment
Eastern Fault	1.15	15	■ Gas observed escaping from fault pockmarks and fluid escape feature observed ■ Localised slope failure on fault scarp ■ Clay Profile
Central Fault	9.40	6	■ Headspace gas present within the clay sediment
Western Fault	21.90	2	■ Small offset no gas measured in sediment during headspace gas analyses

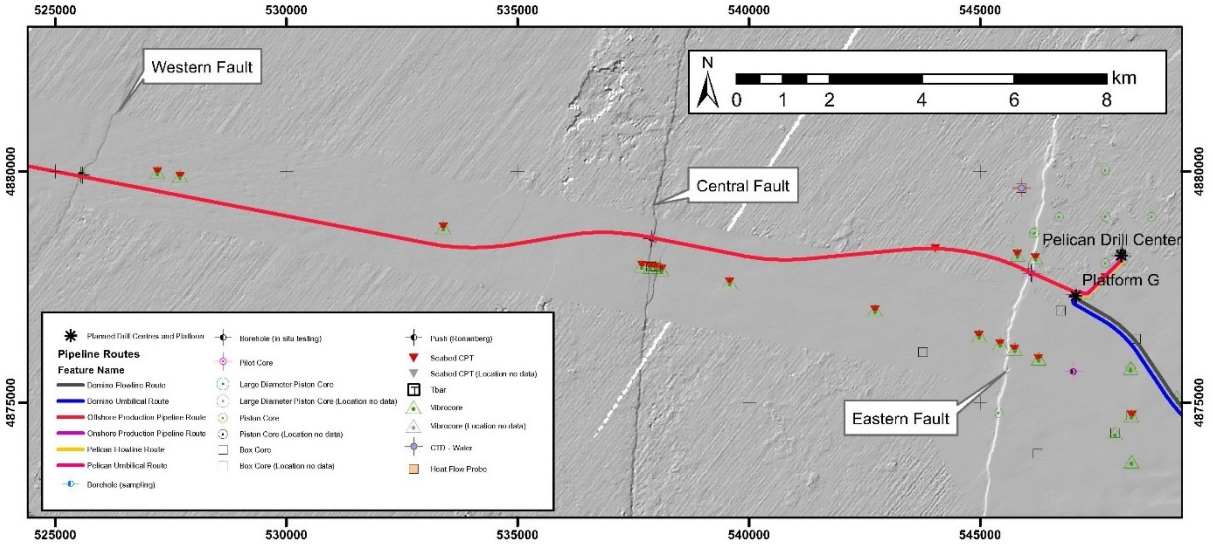


Figure 7.1: Map of Proposed Fault Crossing Locations

A geotechnical borehole was performed either side of each of three faults. Plates C.1.1 to C.1.3 summarise the geotechnical conditions for each fault crossing.

7.2 Eastern Fault

A fault scarp, oriented south-south-west to north-north-east, crosses the pipeline route corridor at KP 1.15.

The seafloor on the western side of the fault scarp is displaced downwards by a maximum 15 m (Figure 7.2). The gradient of the fault scarp is generally between 25° and 30°. The minimum seafloor gradient associated with the fault scarp surface is approximately 20°. This fault shows evidence of gas escape at the top of the fault scarp. The maximum seafloor gradient associated with the fault scarp surface is approximately 61°. The fault scarp comprises several discrete planes of failure and rotational slumps, creating a stepped appearance on the seafloor.

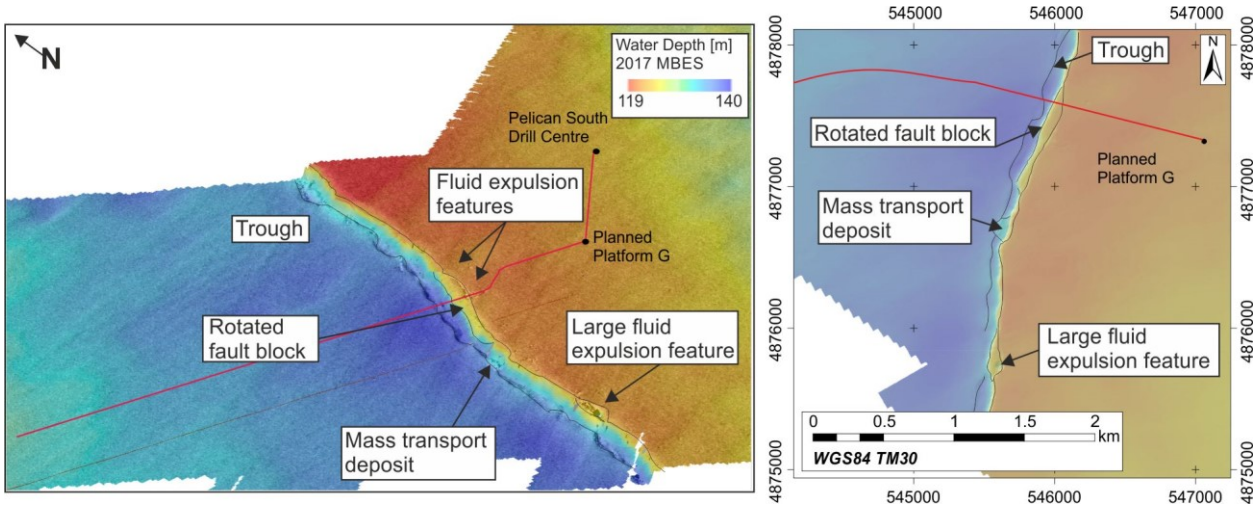


Figure 7.2: MBES Bathymetry image from eastern fault showing possible fluid expulsion features.

One borehole was sampled either side of the Eastern Fault: FE-BH-01 was sampled on the downthrown side of the fault and penetrated to a maximum depth of 9.90 m BML, and FE-BH-02 was sampled on the upthrown side of the fault to a maximum penetration of 19.90 m. The geotechnical data at the Eastern Fault (FE) crossing indicates variability across the fault with the downthrown section of the fault (characterised by FE-BH-01) showing generally lower strength (BE at FE-BH-01 is less than a tenth that of FE-BH-02 at seafloor). Generally, FE-BH-01 shows lower variability than FE-BH-02; however, this could be the effect of the shallower penetration of FE-BH-01.

Plate C.1.1 presents a summary of the geotechnical conditions at the two boreholes from the FE. The geotechnical data present on Plate C.1.1 are those sampled and tested at the FE locations; however, due to limited data, particularly in Unit S-1 at these locations the regionally derived design lines are presented as indicative ranges of the parameters which are predicted in these units. The LE, BE and HE for the units may vary to those presented for the Pipeline Geotechnical Zone within which these locations are sited. No unit weight data are available from Unit S-1 at FE and the range derived for Unit S-1 across the shelf (Table 4.5) is presented.

No unconsolidated, undrained (UU) tests were performed on the sediments sampled at FE-BH-01 and the parameter range presented in Table 7.2 is the absolute range of results from the UU tests from all the fault locations on the shelf. Three UU tests were performed at FE-BH-02, the range of which are presented in Table 7.3. No UU testing were performed on sediments from Unit S-1 throughout the shelf and therefore no ε_{50} values are available for this unit.

Undrained shear strength and unit weight ranges are both presented in Table 7.2 and Table 7.3; and graphically on Plate C.1.1. Epsilon 50 values are presented in Table 7.2 and Table 7.3 only.

Table 7.2: Summary of Geotechnical Conditions at Eastern Fault Crossing– FE-BH-01

Soil Unit	Depth [m BML]	Undrained Shear Strength; (s_u) [kPa]			Unit Weight (γ) [kN/m3]			Strain at 50% deviator stress * (ε_{50}) [%]		
		LE	BE	HE	LE	BE	HE	LE	BE	HE
S-1	0.0	1.0	2.0	5.0	12.5	14.9	17.3	-	-	-
	0.25	1.5	3.0	6.0	12.5	14.9	17.3	-	-	-
	0.25	1.5	3.0	6.0	15.2	16.6	18.1	-	-	-
	0.86	3.0	5.0	10.0	15.2	16.6	18.1	-	-	-
S-2a	0.86	3.0	5.0	10.0	18.0	18.5	19.0	0.5	-	3.0
	4.0	10.0	17.0	28.0	18.0	18.5	19.0	0.5	-	3.0
	4.0	18.0	38.0	55.0	18.0	18.5	19.0	0.5	-	3.0
	8.0	18.0	38.0	55.0	18.0	18.5	19.0	0.5	-	3.0
	8.0	18.0	38.0	55.0	16.5	17.0	17.5	0.5	-	3.0
	9.80	18.0	38.0	55.0	16.5	17.0	17.5	0.5	-	3.0

Notes:
* No UU testing performed on samples from FE-BH-01, therefore full range of ε_{50}values from Fault crossing locations presented
- denoted no data available
BML = Below Mudline
LE = Lowest Expected
BE = Best Estimate
HE = Highest Expected
ε_{50} as calculated from UU tests

Table 7.3: Summary of Geotechnical Conditions at Eastern Fault Crossing– FE-BH-02

Soil Unit	Depth [m BML]	Undrained Shear Strength; (s_u) [kPa]			Unit Weight (γ) [kN/m3]			Strain at 50% deviator stress * (ε_{50}) [%]			Relative Density [%]			Angle of Internal Friction angle (φ) [°]		
		LE	BE	HE	HE	BE	HE	LE	BE	HE	LE	LE	BE	LE	BE	HE
S-1	0.0	18.0	25.0	38.0	13.3	15.3	17.2	-	-	-	NA	NA	NA	NA	NA	NA
	0.3	19.0	26.0	40.0	13.3	15.3	17.2	-	-	-	NA	NA	NA	NA	NA	NA
S-2a	0.3	19.0	26.0	40.0	18.0	19.8	20.0	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	2.0	24.0	32.0	49.0	18.0	19.8	20.0	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	2.0	24.0	32.0	49.0	18.0	18.5	19.5	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	4.0	30.0	40.0	60.0	18.0	18.5	19.5	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	7.0	36.0	50.0	95.0	18.0	18.5	19.5	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	7.0	36.0	62.0	95.0	18.0	18.5	19.5	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	8.0	36.0	62.0	95.0	18.0	18.5	19.5	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	8.0	36.0	62.0	95.0	16.4	17.0	18.0	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	10.0	36.0	62.0	95.0	16.4	17.0	18.0	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	10.0	36.0	45.0	95.0	16.4	17.0	18.0	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	11.5	36.0	45.0	95.0	16.4	17.0	18.0	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	11.5	36.0	60.0	95.0	16.4	17.0	18.0	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	12.5	36.0	60.0	95.0	16.4	17.0	18.0	2.4	-	3.0	NA	NA	NA	NA	NA	NA
S-2b	12.5	NA	NA	NA	18.0	18.6†	19.5†	NA	NA	NA	60	75	85	25	30	35
	13.5	NA	NA	NA	18.0	18.6	19.5	NA	NA	NA	60	75	85	25	30	35
S-2a	13.5	36.0	60.0	95.0	16.4	17.0	18.0	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	17.0	36.0	60.0	95.0	16.4	17.0	18.0	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	17.0	90.0	130.0	170.0	16.4	17.0	18.0	2.4	-	3.0	NA	NA	NA	NA	NA	NA
	19.9	90.0	130.0	170.0	16.4	17.0	18.0	2.4	-	3.0	NA	NA	NA	NA	NA	NA

Notes:

* ε_{50} as calculated from UU tests Limited UU testing performed at FE-BH-02, full range of measured ε_{50} values presented

- denoted no data available BML = Below Mudline NA = Not applicable to soil unit

LE = Lowest Expected BE = Best Estimate HE = Highest Expected

† no unit weight data within Unit S-2b, unit weight values based on full range of Unit S-2b at the fault crossings

7.3 Central Fault

The Central Fault is located at KP 9.40 along the planned to shore pipeline route this was surveyed in Fugro, 2017a. This shows similar features with a trough on the down thrown side of the fault (Figure 7.3). This fault has a smaller offset at seafloor than the Eastern Fault with an offset of 9.5 m at seafloor).

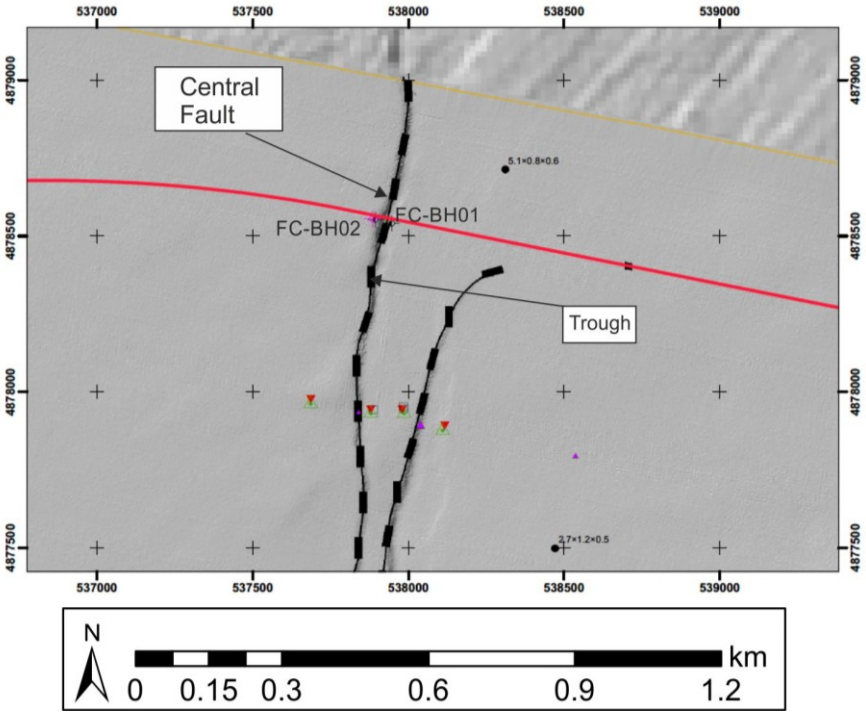


Figure 7.3: Shaded bathymetry image showing location of Central Fault

One borehole was sampled either side of the Central Fault: FC-BH-01 was sampled on the downthrown side of the fault and penetrated to a maximum depth of 9.95 m BML, and FC-BH-02 was sampled on the upthrown side of the fault to a maximum penetration of 19.89 m. As with the Eastern Fault crossing, the Central Fault (FC) crossing indicates that geotechnical conditions show a lower strength and decreased variability in the downthrown section (characterised by FC-BH-01) compared to that on the upthrown side. The two boreholes are both characterised by clay-grade sediments with localised layers and laminations of sand which led to increased undrained shear strengths measured through the advanced testing programme (Fugro, 2018a). Plate C.1.2 presents a summary of the geotechnical conditions at the two boreholes from the FC crossing. Only the geotechnical data from the FC crossing locations were utilised in the definition of the conditions at the crossing. As a result, the quantity of the data is limited for each borehole location and therefore ranges in conditions may be locally varied.

For the clay-grade sediments, undrained shear strength and unit weight ranges are both presented in Table 7.4 and Table 7.5; and graphically on Plate C.1.2. Epsilon 50 values are presented in Table 7.4 and Table 7.5 only. For the sand-grade sediments, relative density, angle of internal friction and unit weight are presented in Table 7.4 and Table 7.5.

The parameter profiles for each location were derived based on the data available in the vicinity of FC. Therefore, the LE, BE and HE for the units may vary to those presented for the Pipeline Geotechnical Zone within which these locations are sited. The parameter profiles were developed based on

engineering geological judgement of the data available at the fault crossing and are representative of the majority of the data. Localised outliers, particularly within the undrained shear strength profile are not included in the ranges for the parameter profiles as these are considered to not be representative of the majority of the soil and are interpreted to represent the effect of sand or silt laminations or increased coarse-grained material within the predominantly clay-grade unit.

Limited unit weight data are available in Unit S-1; however, the unit weight data present is much higher than would typically be associated with the soft clay interpreted from the CPT. To provide an appropriate range for this unit, the lowest expected and best estimate for the unit weight in FC-BH-01 are based on the shelf-wide derivation of unit weight parameter profiles (Table 4.5), and the highest expected based on the data available at FC-BH-01.

Limited UU tests were performed on the sediments sampled at FC-BH-01, therefore only LE and HE are presented. The LE (Table 7.4) is based on the single UU test result available from FC-BH-01 and the HE is the absolute range of results from the UU tests from all the fault locations on the shelf. Four UU tests were performed at FC-BH-02, the range of which are presented in Table 7.5. No UU testing were performed on sediments from Unit S-1 throughout the shelf and therefore no ε_{50} values are available for this unit. Fugro experience of these soil types indicates that typical ε_{50} values for these soil types range between 1% and 4% and engineering judgement should be used in the selection of the most credible value specific to the analysis to be performed.

Table 7.4: Summary of Geotechnical Conditions at Central Fault Crossing – FC-BH-01

Soil Unit	Depth [m BML]	Undrained Shear Strength (s_u) [kPa]			Unit Weight (γ) [kN/m3]			Strain at 50% deviator stress * (ε_{50}) [%]			Relative Density [%]			Angle of Internal Friction angle (φ) [°]		
		LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE
S-1	0.0	0.5	1.0	2.0	18.0	18.4	19.0	-	-	-	NA	NA	NA	NA	NA	NA
	0.3	1.0	2.0	5.0	18.0	18.4	19.0	-	-	-	NA	NA	NA	NA	NA	NA
	1.05	2.0	4.0	6.0	18.0	18.4	19.0	-	-	-	NA	NA	NA	NA	NA	NA
S-2a	1.05	2.0	4.0	6.0	18.0	19.6	20.5	1.7	-	3.0	NA	NA	NA	NA	NA	NA
	1.3	3.0	8.0	21.0	18.0	19.6	20.5	1.7	-	3.0	NA	NA	NA	NA	NA	NA
	1.7	3.5	5.0	26.0	18.0	19.6	20.5	1.7	-	3.0	NA	NA	NA	NA	NA	NA
	1.9	4.0	5.0	27.0	18.0	19.6	20.5	1.7	-	3.0	NA	NA	NA	NA	NA	NA
	2.2	5.0	17.0	30.0	18.0	19.6	20.5	1.7	-	3.0	NA	NA	NA	NA	NA	NA
	3.0	15.0	20.0	34.0	18.0	19.6	20.5	1.7	-	3.0	NA	NA	NA	NA	NA	NA
	8.0	32.0	42.0	60.0	18.0	19.6	20.5	1.7	-	3.0	NA	NA	NA	NA	NA	NA
	8.0	32.0	42.0	60.0	16.0	17.0	18.0	1.7	-	3.0	NA	NA	NA	NA	NA	NA
	8.5	34.0	44.0	62.0	16.0	17.0	18.0	1.7	-	3.0	NA	NA	NA	NA	NA	NA
S-2b	8.5	NA	NA	NA	16.0	17.0	18.0	NA	NA	NA	10**	35**	50**	20**	25**	30**
	9.8	NA	NA	NA	16.0	17.0	18.0	NA	NA	NA	10**	35**	50**	20**	25**	30**

Notes:

* Limited UU testing performed at FC-BH-01, full range of measured ε_{50} values presented

- denoted no data available

NA – denotes parameter not applicable to soil type

BML = Below Mudline

LE = Lowest Expected

BE = Best Estimate

HE = Highest Expected

ε_{50} as calculated from UU tests

** S-2b data for relative density and internal friction angle taken from FC-BH-02

Table 7.5: Summary of Geotechnical Conditions at Central Fault Crossing – FC-BH-02

Soil Unit	Depth [m BML]	Undrained Shear Strength; (s_u) [kPa]			Unit Weight (γ) [kN/m3]			Strain at 50% deviator stress * (ε_{50}) [%]			Relative Density [%]			Angle of Internal Friction angle (φ) [°]		
		LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE
S-2a	0.0	18.0	30.0	42.0	17.5	20.0	20.5	0.5	-	2.8	NA	NA	NA	NA	NA	NA
	2.0	24.0	38.0	50.0	17.5	20.0	20.5	0.5	-	2.8	NA	NA	NA	NA	NA	NA
	2.0	24.0	38.0	50.0	17.5	18.4	19.0	0.5	-	2.8	NA	NA	NA	NA	NA	NA
	6.5	42.0	55.0	55.0	17.5	18.4	19.0	0.5	-	2.8	NA	NA	NA	NA	NA	NA
	8.0	42.0	55.0	55.0	17.5	18.4	19.0	0.5	-	2.8	NA	NA	NA	NA	NA	NA
	8.0	42.0	55.0	55.0	16.5	17.0	18.0	0.5	-	2.8	NA	NA	NA	NA	NA	NA
	11.6	42.0	55.0	55.0	16.5	17.0	18.0	0.5	-	2.8	NA	NA	NA	NA	NA	NA
S-2b	11.6	NA	NA	NA	17.5	18.1	18.5	NA	NA	NA	10	35	50	20	25	30
	17.9	NA	NA	NA	17.5	18.1	18.5	NA	NA	NA	10	35	50	20	25	30
S-2a	17.9	80.0	155.0	155.0	17.5	18.1	18.5	0.5	-	2.8	NA	NA	NA	NA	NA	NA
	19.8	80.0	155.0	155.0	17.5	18.1	18.5	0.5	-	2.8	NA	NA	NA	NA	NA	NA

Notes:

* Limited UU testing performed at FC-BH-02, full range of measured ε_{50}values presented

- denoted no data available

NA – denotes parameter not applicable to soil type

BML = Below Mudline

LE = Lowest Expected

BE = Best Estimate

HE = Highest Expected

ε_{50} as calculated from UU tests

7.4 Western Fault

The Western Fault is a small fault with a shallow offset located at KP 21.9 along the pipeline route. The fault is in an area of seabed scars, with no trough at seafloor (Figure 7.1). This has an offset of 2.0 m at seafloor and has a shallower gradient that the other faults.

One borehole was sampled either side of the Western Fault: FW-BH-01 was sampled on the upthrown side of the fault and penetrated to a maximum depth of 7.84 m BML, and FW-BH-02 was sampled on the downthrown side of the fault to a maximum penetration of 7.57 m. The Western Fault (FW) crossing differs from the Eastern Fault and Central Fault locations in that it is characterised by sand-grade material; however, like the other fault crossing locations, the FW crossing is characterised by variability across the fault. FW-BH-01 is on the upthrown side of the fault and is characterised by uniform dense to very dense sand, with a thin veneer (0.2 m thick) of Unit S-1 clay at surface. FW-BH-02 is characterised by 0.6 m of Unit S-1 at surface underlain by a highly variable clayey sand unit. The clayey nature of the Unit S-2b at FW-BH-02 differentiates it from the clean sand of FW-BH-01.

Plate C.1.3 presents a summary of the geotechnical conditions at the two boreholes from the FW crossing. The parameter profiles for FW-BH-01 and FW-BH-02 were derived based on the data available from these two borehole locations; however, where data quantity was limited, particularly in Unit S-1, the shelf-wide parameters (Table 4.5) are presented.

Relative density and unit weight ranges are both presented in Table 7.6 and Table 7.7; and graphically on Plate C.1.3. Friction angle values are presented in Table 7.6 and Table 7.7 only.

Table 7.6: Summary of Geotechnical Conditions at Western Fault Crossing – FW-BH-01

Soil Unit	Depth [m BML]	Undrained Shear Strength (s_u) [kPa]			Relative Density [%]			Unit Weight (γ) [kN/m3]			Friction Angle * (Φ) [°]		
		LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE
S-1	0.0	0.1	1.0	7.5	NA	NA	NA	13.3	15.3	17.2	NA	NA	NA
	0.2	0.8	2.0	10.0	NA	NA	NA	13.3	15.3	17.2	NA	NA	NA
S-2b	0.2	NA	NA	NA	87	95	100	18.0	18.5	19.6	30	35	40
	6.0	NA	NA	NA	87	95	100	18.0	18.5	19.6	30	35	40
	6.0	NA	NA	NA	72	95	100	18.0	18.5	19.6	30	35	40
	6.3	NA	NA	NA	72	95	100	18.0	18.5	19.6	30	35	40
	6.3	NA	NA	NA	72	80	100	18.0	18.5	19.6	30	35	40
	6.5	NA	NA	NA	72	80	100	18.0	18.5	19.6	30	35	40
	6.5	NA	NA	NA	72	80	90	18.0	18.5	19.6	30	35	40
	7.8	NA	NA	NA	72	80	90	18.0	18.5	19.6	30	35	40

Notes:
* Angle of internal friction based on correlation with API (2011)
- denoted no data available
NA – denotes parameter not applicable to soil type
BML = Below Mudline
LE = Lowest Expected
BE = Best Estimate
HE = Highest Expected

Table 7.7: Summary of Geotechnical Conditions at Western Fault Crossing – FW-BH-02

Soil Unit	Depth [m BML]	Undrained Shear Strength (s_u) [kPa]			Relative Density [%]			Unit Weight (γ) [kN/m3]			Friction Angle * (Φ) [°]		
		LE	BE	HE	LE	BE	HE	LE	BE	HE	LE	BE	HE
S-1	0.0	0.1	1.0	7.5	NA	NA	NA	13.3	15.3	17.2	NA	NA	NA
	0.6	1.0	2.0	4.0	NA	NA	NA	13.3	15.3	17.2	NA	NA	NA
S-2b	0.6	NA	NA	NA	10	25	60	18.0	18.5	19.0	20	25	30
	6.2	NA	NA	NA	10	25	60	18.0	18.5	19.0	20	25	30
	6.2	NA	NA	NA	90	97	100	18.0	18.5	19.0	30	35	40
	7.6	NA	NA	NA	90	97	100	18.0	18.5	19.0	30	35	40

Notes:
* Angle of internal friction based on correlation with API (2010)
- denoted no data available
NA – denotes parameter not applicable to soil type
BML = Below Mudline
LE = Lowest Expected
BE = Best Estimate
HE = Highest Expected

7.5 Chemical Composition

The eastern and central fault crossing locations were selected for headspace gas analysis as they act as potential pathways for the migration of gas to seafloor. The greater depth below seafloor at these locations allows trends in the data to be more easily identified. Chemical composition and salinity content tests were performed in accordance with the procedures presented in BS 1377 (2015). Table 7.8, to Table 7.12 summarise the chemical content results per soil unit.

The results of the chemical composition are presented in this report and are fully discussed in the updated integrated report for the site (Fugro report number 173570-8) where the results will be used to update the geological model. The observed changes in chemistry are interpreted to have been caused by multiple transitions from freshwater to marine environments and agree with the geological model for the Neptun Block.

Table 7.8: Carbonate Content Test Results for Eastern Fault and Central Fault Locations

Soil Unit	Carbonate Content [%] Result Range	Number of Tests
S-1	5.7	1
S-2a	5.7 to 12.0	14
S-2b	5.9	1

Table 7.9: Organic Content Test Results for Eastern Fault and Central Fault Locations

Soil Unit	Organic Content [%]	Number of Tests
S-1	1.0	1
S-2a	0.8 to 1.4	14
S-2b	-	-

Table 7.10: Chloride Content for Eastern Fault and Central Fault Locations

Soil Unit	Chloride Content [mg/l]	Number of Tests
S-1	960	1
S-2a	310 to 1700	15

Table 7.11: pH Test Results for Eastern Fault and Central Fault Locations

Soil Unit	pH [-]	Number of Tests
S-1	8.2	1
S-2a	7.8 to 8.5	8

Table 7.12: Sulphate Content Test Results for Eastern Fault and Central Fault Locations

Soil Unit	Sulphate Content [% as SO4]	Number of Tests
S-1	260	1
S-2a	29 to 220	8

7.5.1 Carbonate Content

Plate C.2.1, Plate C.2.6 and Table 7.8 present the composite carbonate content versus depth for all geotechnical units. Carbonate content tests were performed with the results expressed as a percentage by mass of carbonate (CO_3). The results range from 5.7 % to 12.0 %. Values are all considered low, with only small variations seen with depth. These are consistent with the carbonate content observed at the Planned Platform G location (Fugro Report Number 173570-05a). The carbonate content of Unit S-1 is tested on the bulk clay sample and the shell fragments are removed from the sample before testing.

7.5.2 Organic Content

Plate C.2.2, Plate C.2.7 and Table 7.9 present the results of total organic content testing. Total organic content ranges from 0.8 % to 1.4 %. Based on the BS 5930 (2015) soil classification, the measured range indicates that the samples tested are inorganic. The inorganic nature of the sediments suggests that the sediments were deposited in an oxygenated shallow water environment without the stratification that is now present in the Black Sea.

7.5.3 Chloride Content

Plate C.2.3, Plate C.2.8 and Table 7.10 present the composite plot of aqueous chloride content versus depth for the Eastern Fault and Central Fault Locations. Within Unit S-2a general trend shows a decrease in chloride content with depth from 1700 mg/l at 1.4 m BML decreasing to 310 mg/l at 16.5 m BML. This decrease in chloride content is consistent with the sediments of Unit S-2a having been deposited in a freshwater lacustrine environment with the uppermost sediments showing an elevated chloride content due to the influx of higher salinity seawater following the breach of the Bosphorus and the migration of chloride-rich porewater through the sediment column over the past 8200 years (Riboulot et al., 2018).

7.5.4 Sulphate Content and Ph

Plate C.2.4, Plate C.2.9 and Table 7.12 summarise sulphate content and pH at the Eastern Fault and Central Fault Locations. Sulphate contents for geotechnical units S-1A is higher than the results from S-2a. which are 28 % at 1.4 m BSF dropping to 29% at 10.3 m BSF.

Sulphate values are elevated in Unit S-2a close to seafloor this is interpreted to be as a result of the influx of saline rich porewater from the higher salinity seawater following the breach of the Bosphorus.

Plate C.2.5, Plate C.2.10 and Table 7.12 summarise the pH ranges for S-1 and S-2a. The pH ranges are between 7.80 to 8.50 across all of the samples, consistent with samples deposited in in a freshwater to marine environment.

7.5.5 Headspace Gas and Carbon Isotope Analysis.

Headspace gas analysis was carried out on 25 samples at the Platform G location. Table 7.13 summarises the test results. Plate C.2.11 presents the headspace gas results versus depth.

Table 7.13: Headspace Gas Analysis and Carbon Isotope analysis test results Eastern Fault, Western Fault and Central Fault

Soil Unit	Headspace Gas Analysis [ppm] (Methane C1)		Carbon Isotope Ratio (Methane C1) [13C versus 12C, δ13C]	
	Result Range	Number of Tests	Result Range	Number of Tests
Eastern Fault				
S-2a	10999.56 to 29442	8	-47.2 to -69.3	5
Central Fault				
S-2a	7.29 to 24732	7	-65.4	1
Western Fault				
S-2a	8.49	1	-	-

The headspace gas values show that Methane (C1) is present in geotechnical unit S-1a at the fault locations. The quantity of gas decreases in shallower water along the pipeline route with the largest volumes of gas observed in the Eastern Fault with lower quantities observed at the Central Fault. The Western Fault appears to have very low volumes of gas. This correlates with the geological model for the site, where higher volumes of gas are present on the outer shelf in the vicinity of the platform (Fugro, 2017) with the gas migrating along the fault and accumulating in the shallow sediments.

The carbon isotope ratio is calculated from the ratio of methane ethane and propane and is used to provide an origin for the gas (Equation 7.1).

$$C1/(C2 + C3)$$

Equation 7.1

Where:
$C1$ = Methane
$C2$ = Ethane
$C3$ = Propane

The results of the headspace gas analysis, correlated with the geological model, suggest that the methane in the sediment is biogenic in origin. The limited range in the measured carbon isotope ratio suggests that the methane in the sample have undergone the same processes. Figure 7.4 shows the relationship between the carbon isotope and the origin of the gas.

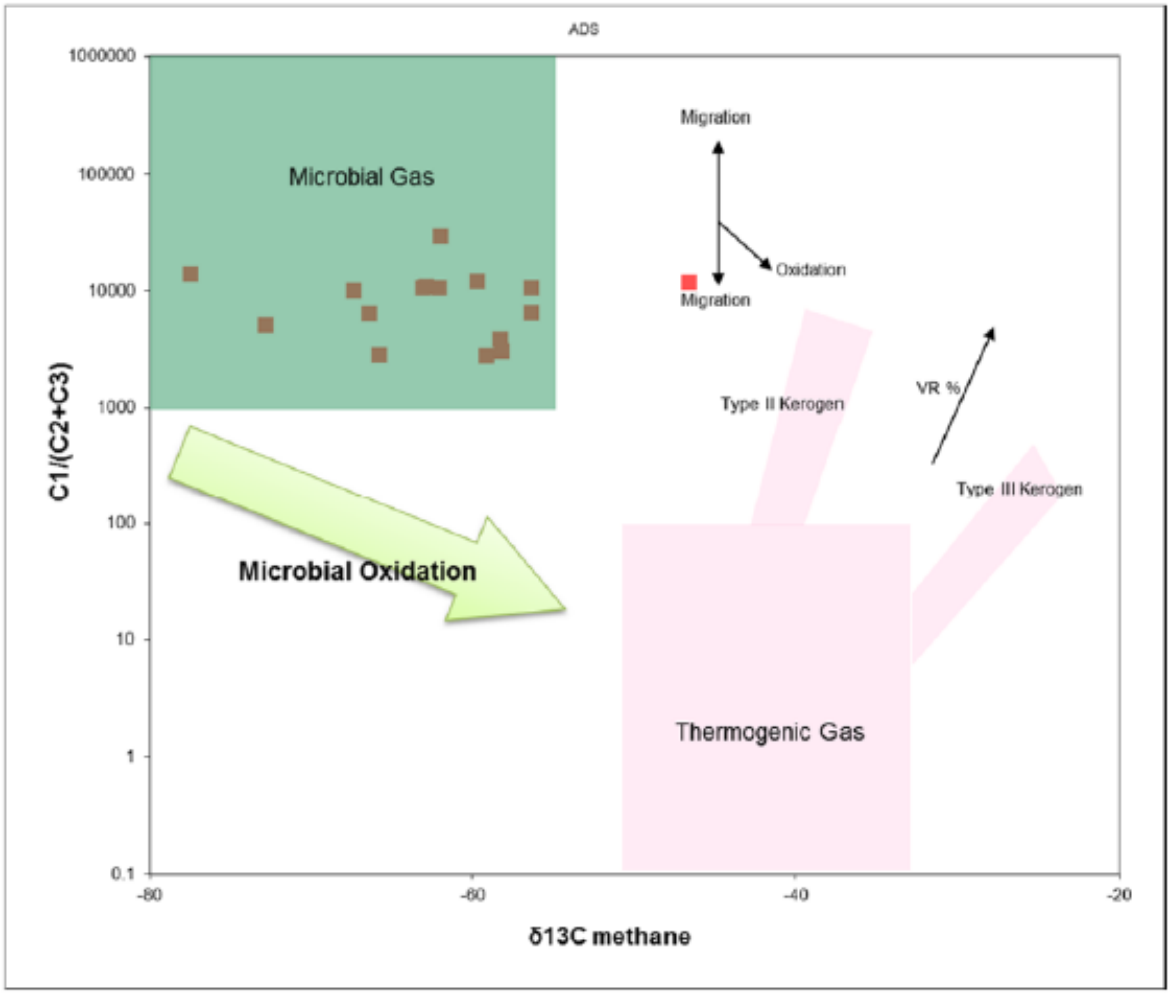


Figure 7.4: Carbon isotope characterisation, (Bernard Diagram) from Fugro 2015b, Test results for Neptun Block plot in the top left hand corner and suggest biogenic origin for the Methane

Previous testing carried out on samples from Neptun block (Fugro, 2015b) suggested a biogenic origin for the samples, and is further supported by recent data from scientific cruises adjacent to the Neptun Block (Ifremer, 2015).

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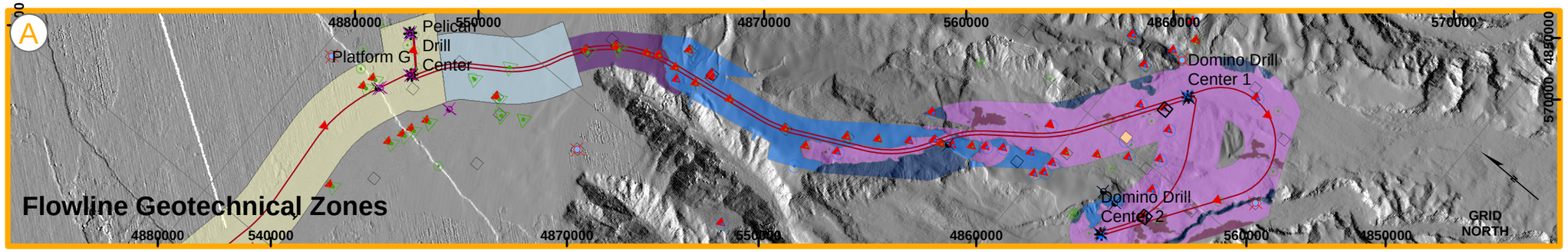
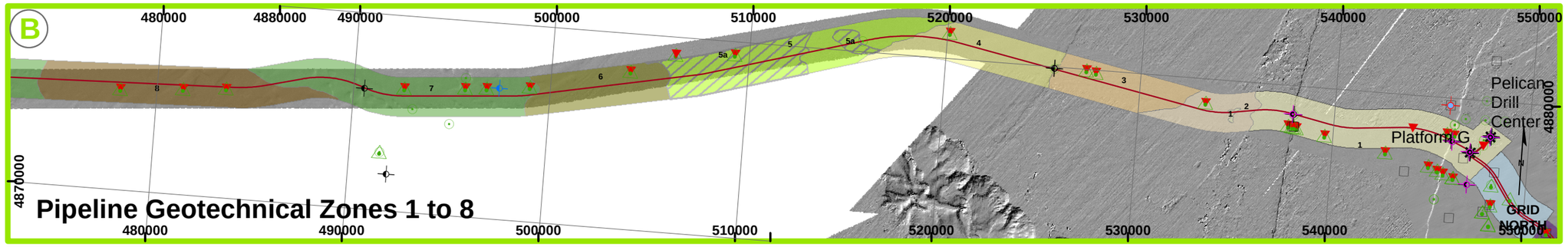
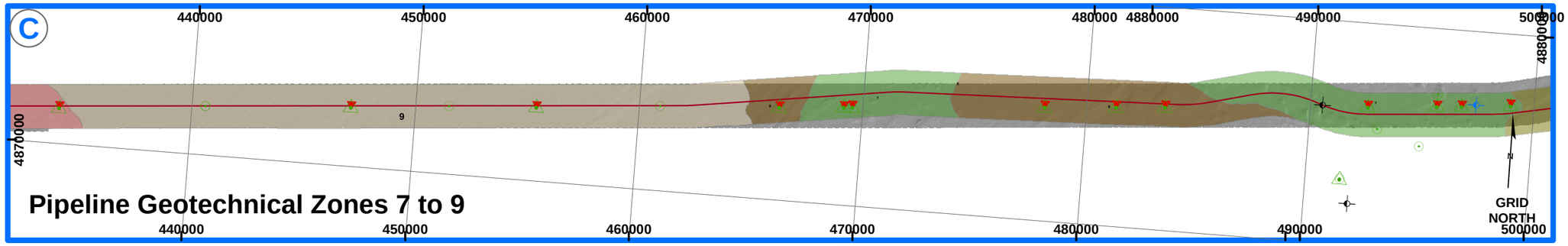
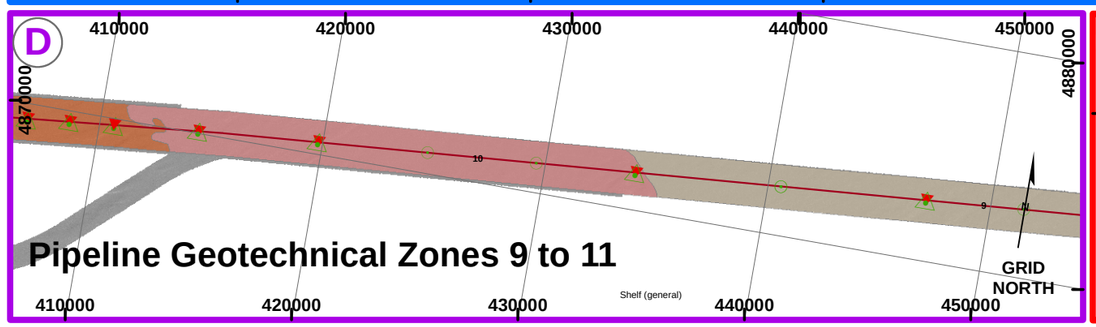
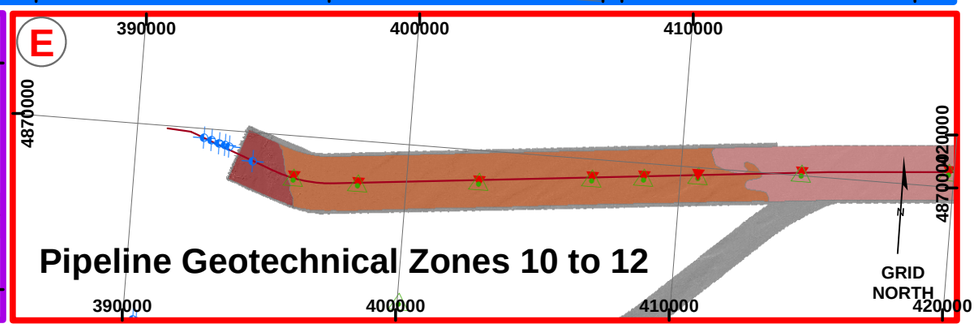
LIST OF PLATES

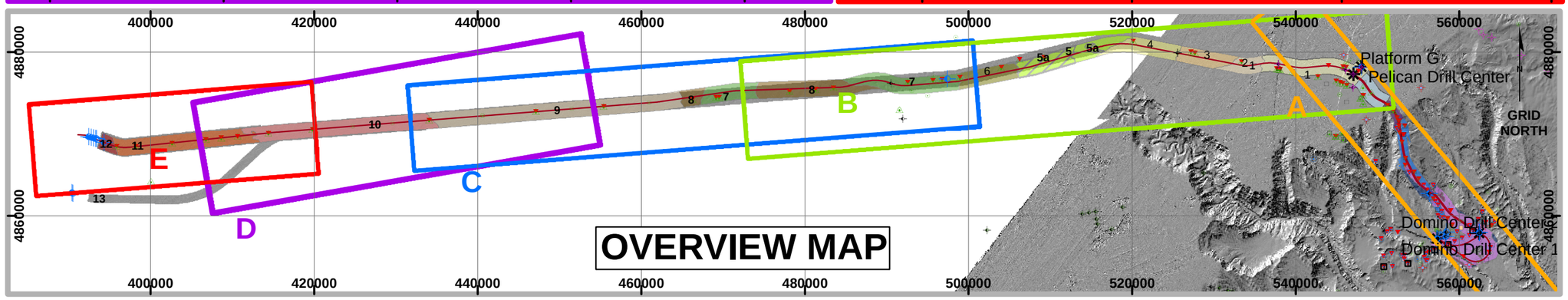












Legend

- Borehole (sampling)
- Borehole (in situ testing)
- Pilot Core
- Large Diameter Piston Core
- Piston Core
- Box Core
- Push (Ronanberg)
- Seabed CPT
- Tbar
- Vibrocore
- CTD - Water
- Heat Flow Probe
- Planned Drill Centres and Platform
- Proposed Pipeline Routes

Pipeline and Flowline Geotechnical Zonation

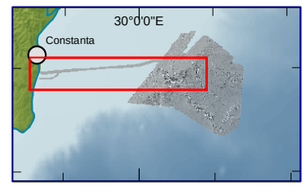
FGZ1	PGZ1	PGZ6
FGZ2	PGZ2	PGZ7
FGZ3	PGZ3	PGZ8
FGZ4	PGZ4	PGZ9
FGZ5	PGZ5	PGZ10
FGZ6	PGZ5a	PGZ11
		PGZ12

NOTES:
1. Water depths presented on the regional bathymetry data are to Lowest Astronomical Tide (LAT) and are from Tcarta bathymetry provided by Exxon

GEODETIC PARAMETERS:

Geodetic Datum WGS84 Transverse Mercator 30 NE

Datum: WGS1984
Spheroid: WGS_1984
Semimajor Axis: 6378137.0
Seminminor Axis: 6356752.314245179
Inverse Flattening: 298.257223563
False Easting: 500000.0
False Northing: 0.0
Central Meridian: 30.0



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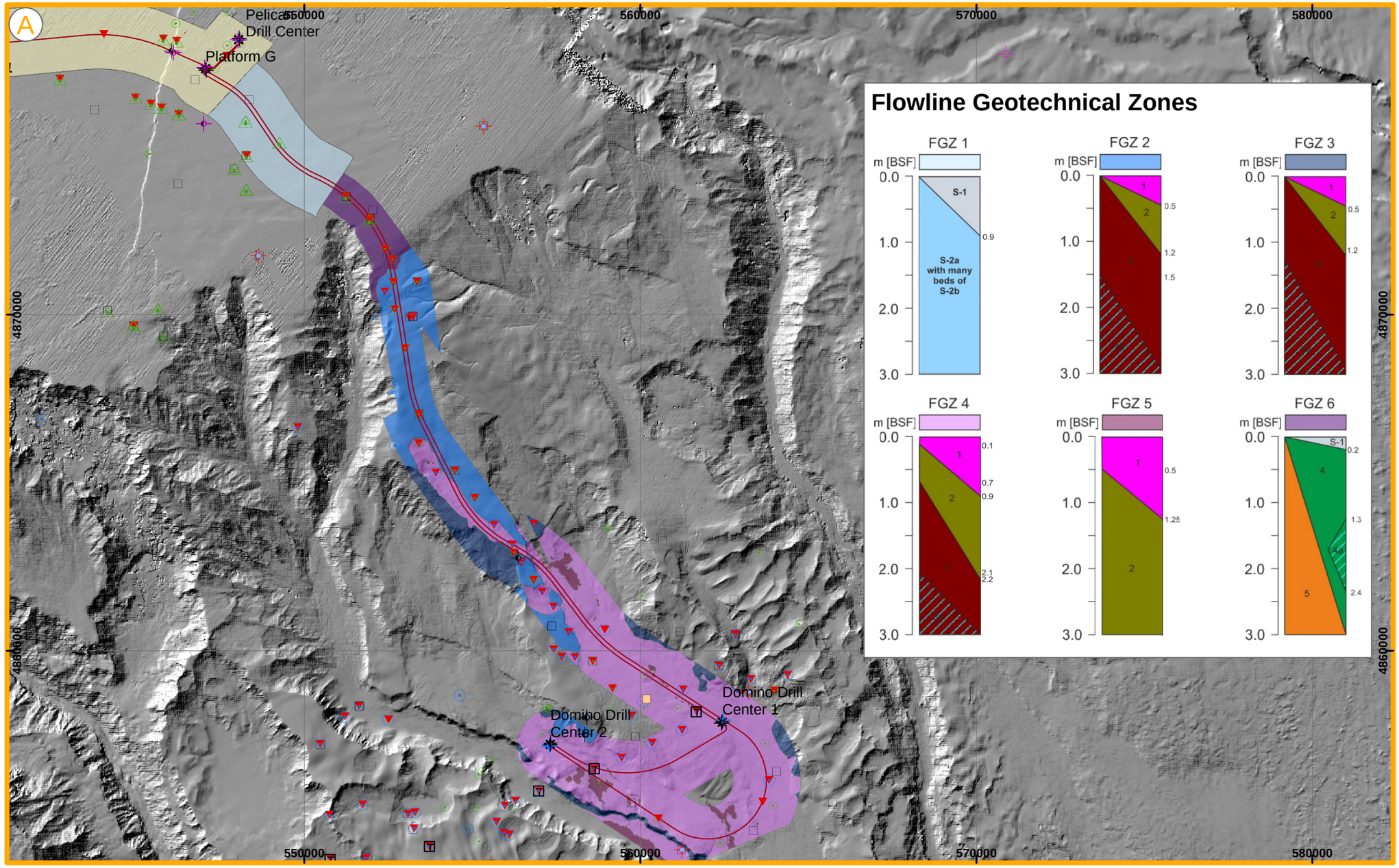
Pipeline and Flowline Geotechnical Interpretive Report
Pipeline/Flowline Geotechnical Zonation

Scale: 1:240,000 at A3
0 2.25 4.5 9 Km

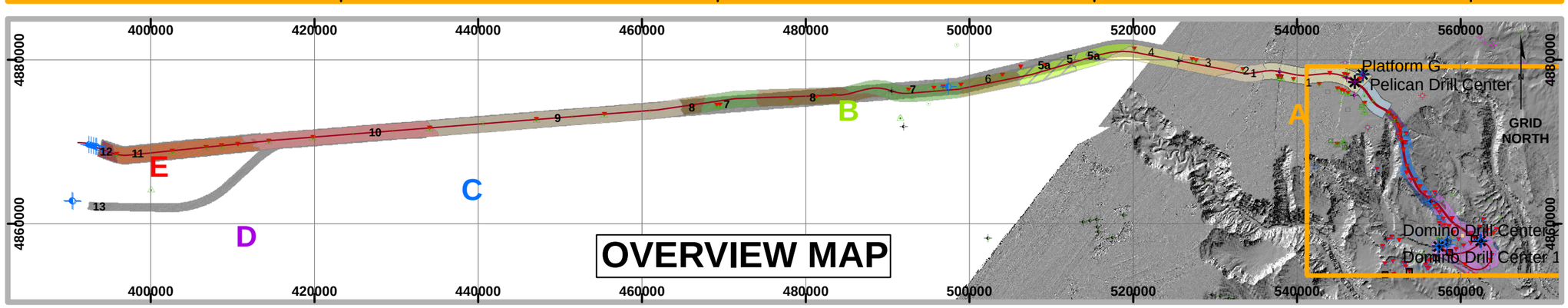
Overview Map Scale: 1:575,000 at A3
0 2.75 5.5 11 16.5 22 Km

Project No: 173570-5d
Plate No: 1

Issue No:	Date:	Description:	Interp:	Drawn:	Check:	App:
2	08/06/2018	Final Deliverable	LO	CB	LO	ST
1	18/05/2018	Complete Deliverable	LO	LO	CB	ST



Flowline Geotechnical Zones



Legend

- Borehole (sampling)
- Borehole (in situ testing)
- Pilot Core
- Large Diameter Piston Core
- Piston Core
- Box Core
- Push (Ronanberg)
- Seabed CPT
- Tbar
- Vibrocore
- CTD - Water
- Heat Flow Probe
- Planned Drill Centres and Platform
- Proposed Pipeline Routes

Pipeline and Flowline Geotechnical Zonation

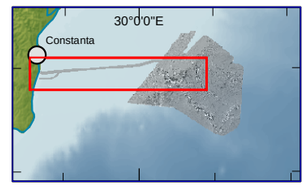
FGZ1	PGZ1	PGZ6
FGZ2	PGZ2	PGZ7
FGZ3	PGZ3	PGZ8
FGZ4	PGZ4	PGZ9
FGZ5	PGZ5	PGZ10
FGZ6	PGZ5a	PGZ11
		PGZ12

NOTES:
1. Water depths presented on the regional bathymetry data are to Lowest Astronomical Tide (LAT) and are from Tcarta bathymetry provided by Exxon

GEODETIC PARAMETERS:

Geodetic Datum WGS84 Transverse Mercator 30 NE

Datum: WGS1984
Spheroid: WGS_1984
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314245179
Inverse Flattening: 298.257223563
False Easting: 500000.0
False Northing: 0.0
Central Meridian: 30.0



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Pipeline and Flowline Geotechnical Interpretive Report
Flowline Geotechnical Zonation - Section A

Scale: 1:125,000 at A3
0 0.5 1 2 3 4 Km
Overview Map Scale: 1:575,000 at A3
0 2.75 5.5 11 16.5 22 Km

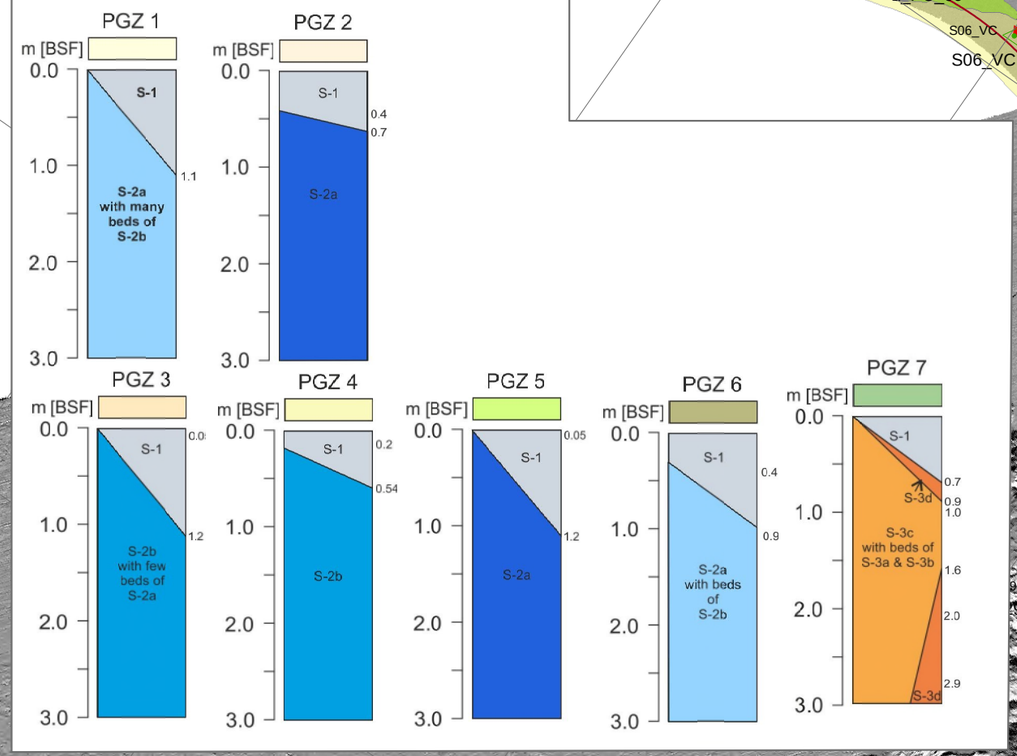
Project No: 173570-5d
Plate No: 2

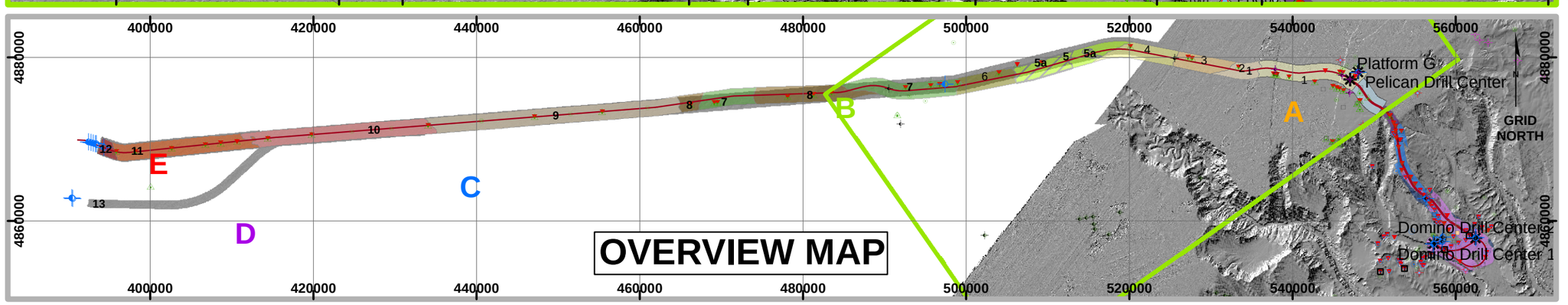
Issue No:	Date:	Description:	Interp:	Drawn:	Check:	App:
1	08/06/2015	Complete Deliverable	LO	CB	LO	ST

Pipeline Geotechnical Zones 1 to 8

B

Geotechnical Profile





Legend

- Borehole (sampling)
- Borehole (in situ testing)
- Pilot Core
- Large Diameter Piston Core
- Piston Core
- Box Core
- Push (Ronanberg)
- Seabed CPT
- Tbar
- Vibrocore
- CTD - Water
- Heat Flow Probe
- Planned Drill Centres and Platform
- Proposed Pipeline Routes

Pipeline and Flowline Geotechnical Zonation

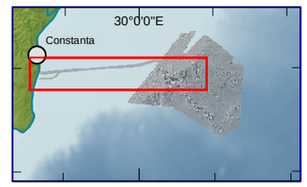
FGZ1	PGZ1	PGZ6
FGZ2	PGZ2	PGZ7
FGZ3	PGZ3	PGZ8
FGZ4	PGZ4	PGZ9
FGZ5	PGZ5	PGZ10
FGZ6	PGZ5a	PGZ11
		PGZ12

NOTES:
1. Water depths presented on the regional bathymetry data are to Lowest Astronomical Tide (LAT) and are from Tcarta bathymetry provided by Exxon

GEODETIC PARAMETERS:

Geodetic Datum WGS84 Transverse Mercator 30 NE

Datum: WGS1984
Spheroid: WGS_1984
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314245179
Inverse Flattening: 298.257223563
False Easting: 500000.0
False Northing: 0.0
Central Meridian: 30.0



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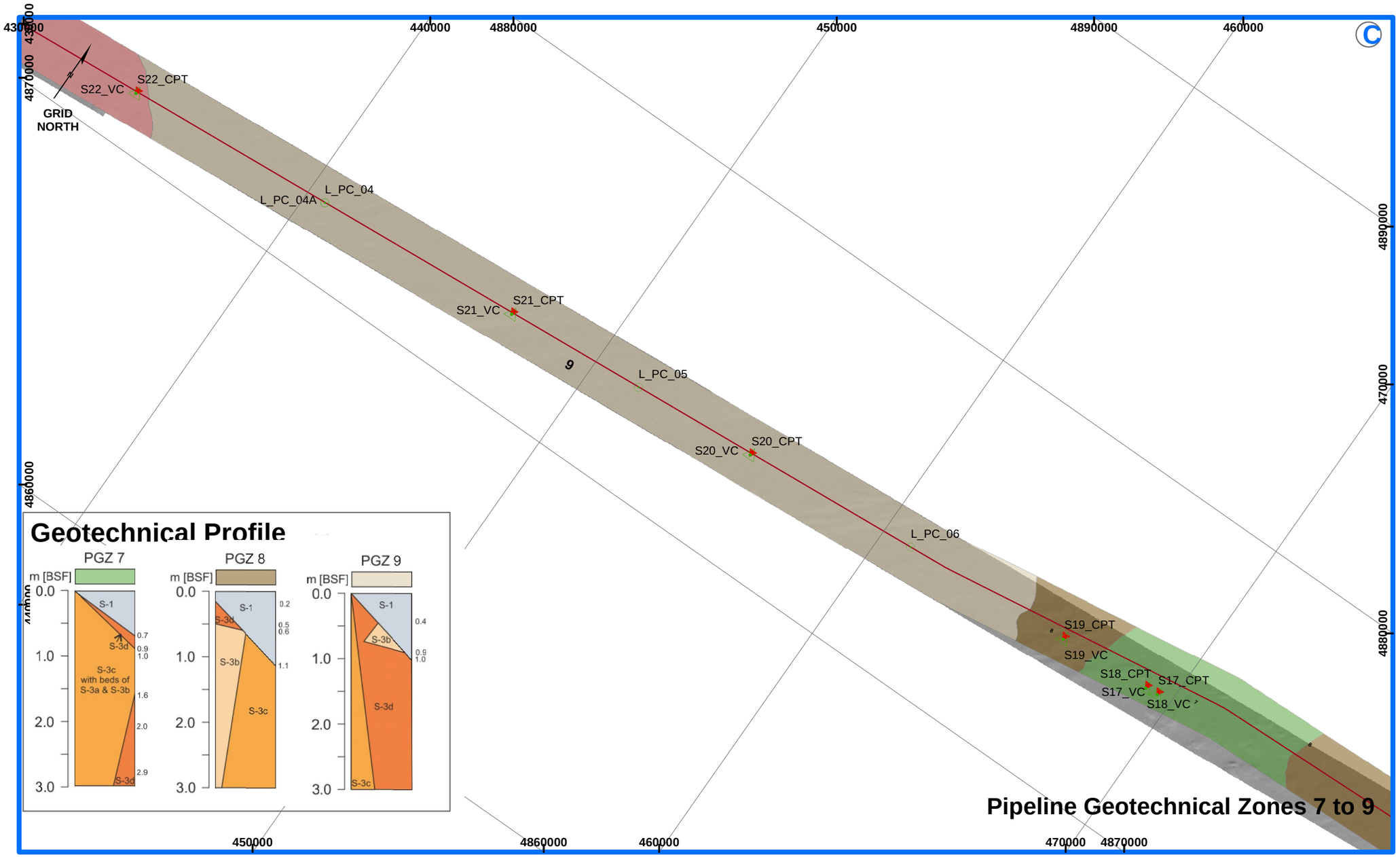
Pipeline and Flowline Geotechnical Interpretive Report
Pipeline Geotechnical Zonation-Section B

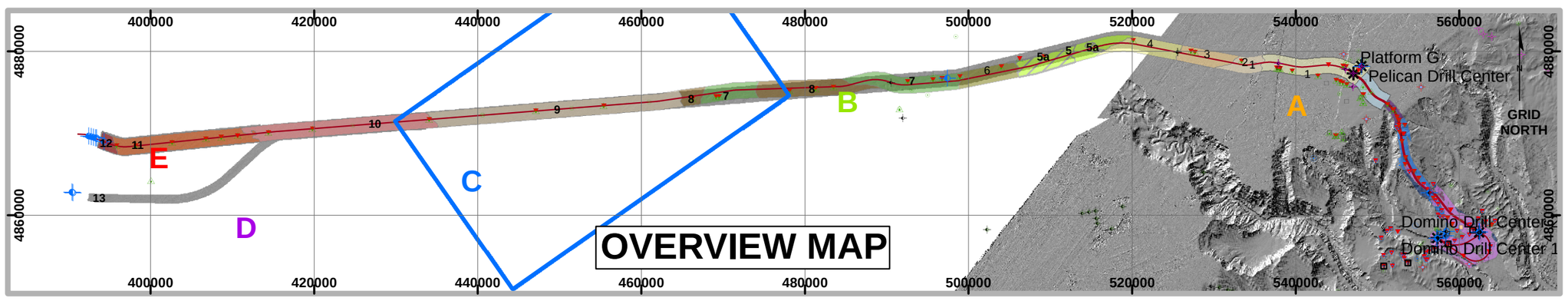
Scale: 1:200,000 at A3
0 1.75 3.5 7 Km
Overview Map Scale: 1:575,000 at A3
0 2.75 5.5 11 16.5 22 Km

Project No: 173570-5d
Plate No: 3

Issue No:	Date:	Description:	Interp:	Drawn:	Check:	App:
1	08/06/2015	Final Deliverable	LO	CB	LO	ST



Geotechnical Profile



Legend

- Borehole (sampling)
- Borehole (in situ testing)
- Pilot Core
- Large Diameter Piston Core
- Piston Core
- Box Core
- Push (Ronanberg)
- Seabed CPT
- Tbar
- Vibrocore
- CTD - Water
- Heat Flow Probe
- Planned Drill Centres and Platform
- Proposed Pipeline Routes

Pipeline and Flowline Geotechnical Zonation

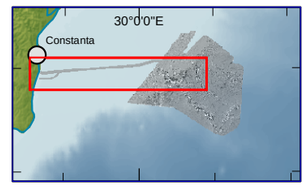
FGZ1	PGZ1	PGZ6
FGZ2	PGZ2	PGZ7
FGZ3	PGZ3	PGZ8
FGZ4	PGZ4	PGZ9
FGZ5	PGZ5	PGZ10
FGZ6	PGZ5a	PGZ11
		PGZ12

NOTES:
1. Water depths presented on the regional bathymetry data are to Lowest Astronomical Tide (LAT) and are from Tcarta bathymetry provided by Exxon

GEODETIC PARAMETERS:

Geodetic Datum WGS84 Transverse Mercator 30 NE

Datum: WGS1984
Spheroid: WGS_1984
Semimajor Axis: 6378137.0
Seminminor Axis: 6356752.314245179
Inverse Flattening: 298.257223563
False Easting: 500000.0
False Northing: 0.0
Central Meridian: 30.0



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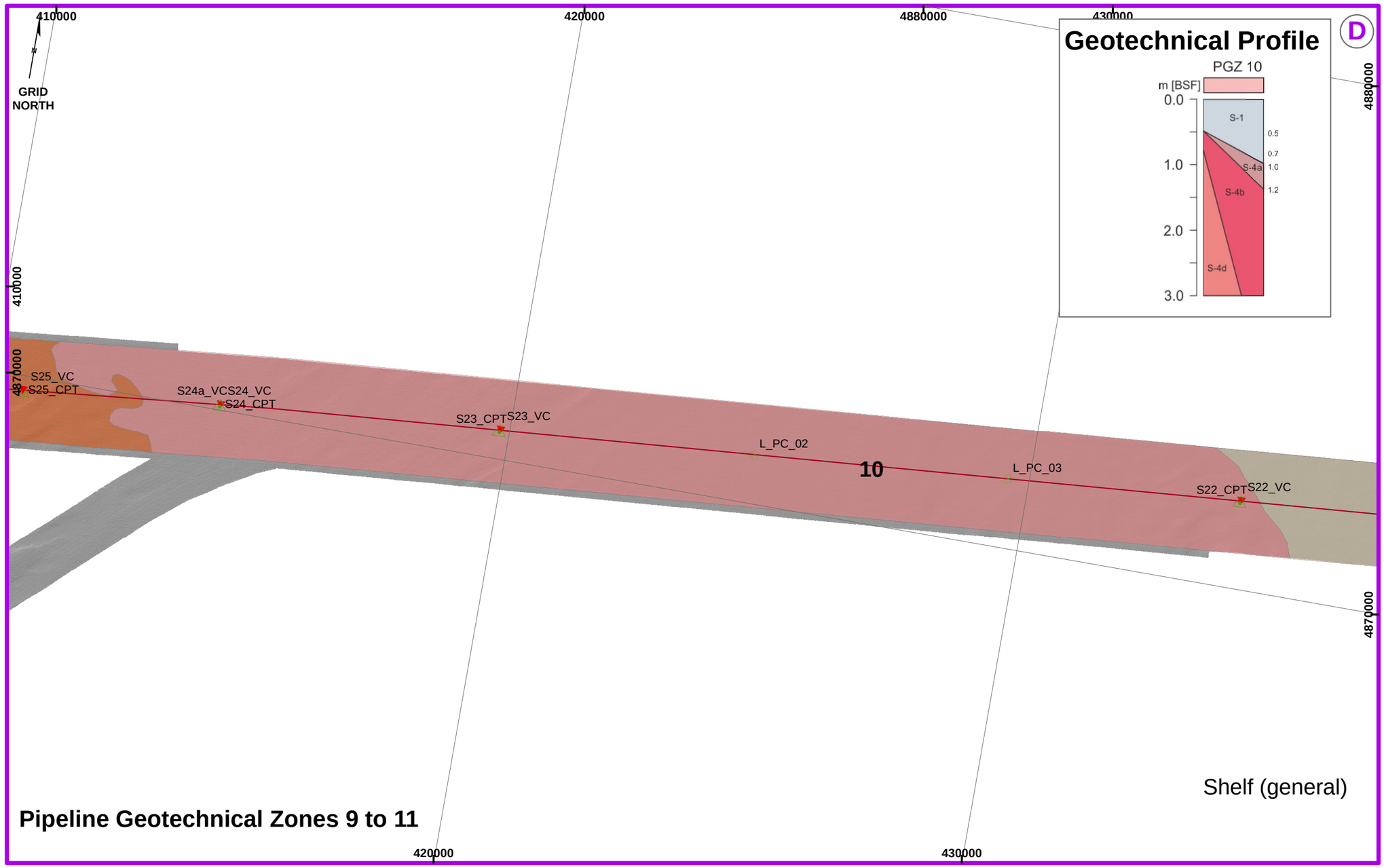
Pipeline and Flowline Geotechnical Interpretive Report
Pipeline Geotechnical Zonation - Section C

Scale: 1:125,000 at A3
0 0.3 0.6 1.2 1.8 2.4 Km
Overview Map Scale: 1:575,000 at A3
0 2.75 5.5 11 16.5 22 Km

Project No: 173570-5d
Plate No: 5

Issue No:	Date:	Description:	Interp:	Drawn:	Check:	App:
1	04/06/2018	Complete Deliverable	LO	CB	LO	ST



Legend

- Borehole (sampling)
- Borehole (in situ testing)
- Pilot Core
- Large Diameter Piston Core
- Piston Core
- Box Core
- Push (Ronanberg)
- Seabed CPT
- Tbar
- Vibrocore
- CTD - Water
- Heat Flow Probe
- Planned Drill Centres and Platform
- Proposed Pipeline Routes

Pipeline and Flowline Geotechnical Zonation

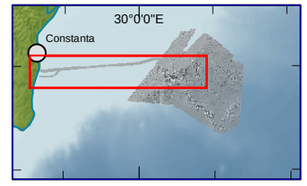
FGZ1	PGZ1	PGZ6
FGZ2	PGZ2	PGZ7
FGZ3	PGZ3	PGZ8
FGZ4	PGZ4	PGZ9
FGZ5	PGZ5	PGZ10
FGZ6	PGZ5a	PGZ11
		PGZ12

NOTES:
1. Water depths presented on the regional bathymetry data are to Lowest Astronomical Tide (LAT) and are from Tcarta bathymetry provided by Exxon

GEODETIC PARAMETERS:

Geodetic Datum WGS84 Transverse Mercator 30 NE

Datum: WGS1984
Spheroid: WGS_1984
Semimajor Axis: 6378137.0
Seminminor Axis: 6356752.314245179
Inverse Flattening: 298.257223563
False Easting: 500000.0
False Northing: 0.0
Central Meridian: 30.0



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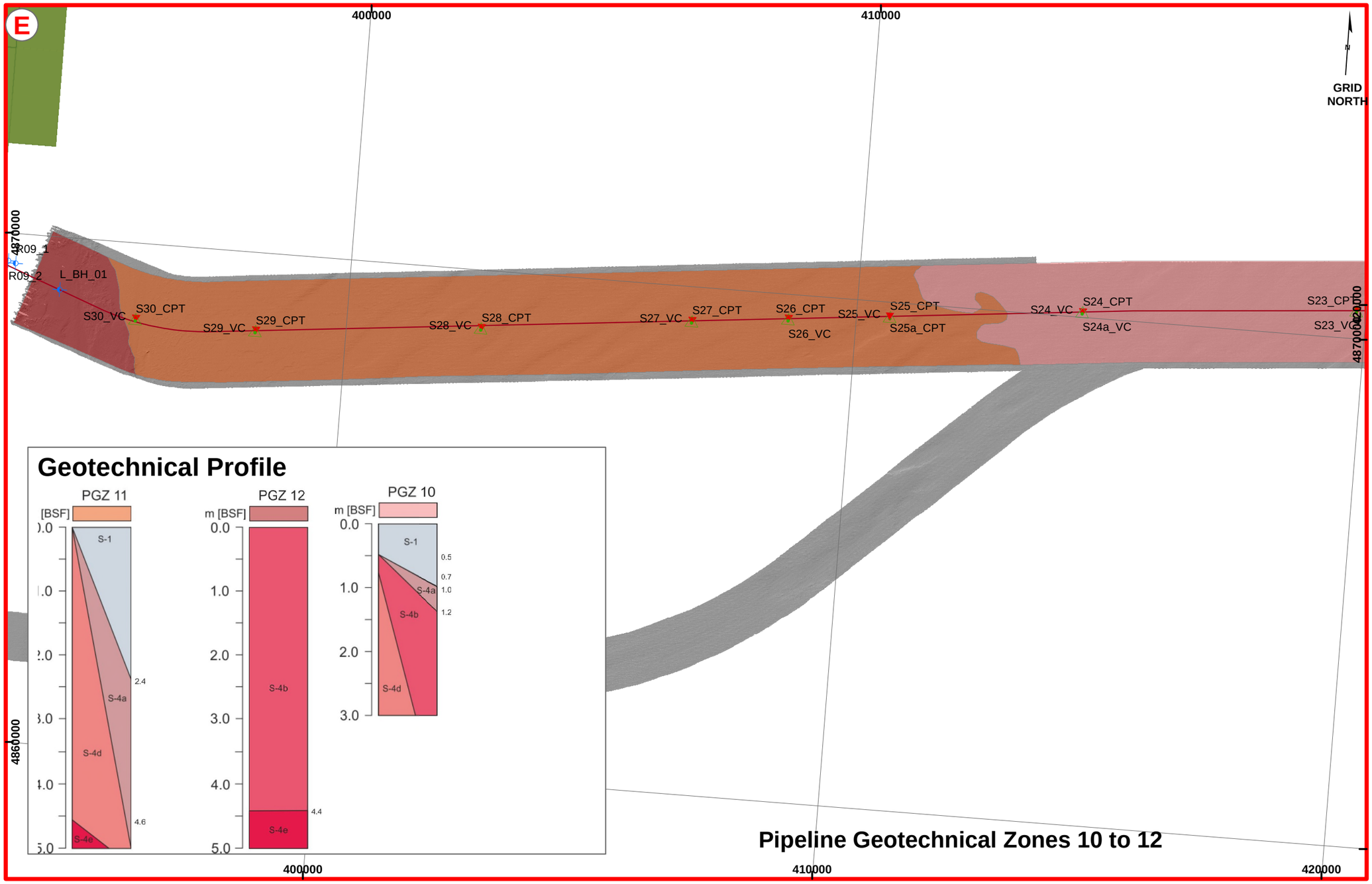
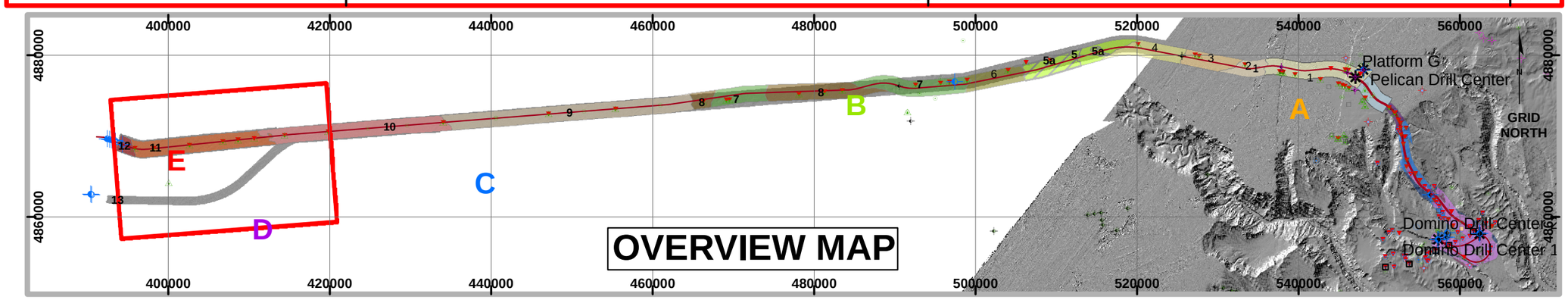
Pipeline and Flowline Geotechnical Interpretive Report
Pipeline Geotechnical Zonation Section D

Scale: 1:80,000 at A3
0 0.2 0.4 0.8 1.2 1.6 Km
Overview Map Scale: 1:575,000 at A3
0 2.75 5.5 11 16.5 22 Km

Project No: 173570-5d
Plate No: 5

Issue No:	Date:	Description:	Interp:	Drawn:	Check:	App:
1	08/06/2018	Complete Deliverable	LO	CB	LO	ST





Legend

- Borehole (sampling)
- Borehole (in situ testing)
- Pilot Core
- Large Diameter Piston Core
- Large Diameter Piston Core (Location no data)
- Piston Core
- Piston Core (Location no data)
- Box Core
- Box Core (Location no data)
- Push (Ronanberg)
- Seabed CPT
- Seabed CPT (Location no data)
- Tbar
- Vibrocore
- Vibrocore (Location no data)
- CTD - Water
- Heat Flow Probe
- Planned Drill Centres and Platform
- Proposed Pipeline Routes

Pipeline and Flowline Geotechnical Zonation

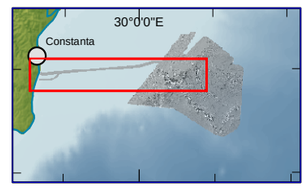
FGZ1	PGZ1	PGZ6
FGZ2	PGZ2	PGZ7
FGZ3	PGZ3	PGZ8
FGZ4	PGZ4	PGZ9
FGZ5	PGZ5	PGZ10
FGZ6	PGZ5a	PGZ11
		PGZ12

NOTES:
1. Water depths presented on the regional bathymetry data are to Lowest Astronomical Tide (LAT) and are from Tcarta bathymetry provided by Exxon

GEODETIC PARAMETERS:

Geodetic Datum WGS84 Transverse Mercator 30 NE

Datum: WGS1984
Spheroid: WGS_1984
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314245179
Inverse Flattening: 298.257223563
False Easting: 500000.0
False Northing: 0.0
Central Meridian: 30.0



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Pipeline and Flowline Geotechnical Interpretive Report
Pipeline/Flowline Geotechnical Zonation

Scale: 1:80,000 at A3
0 0.4 0.8 1.6 2.4 3.2 Km

Overview Map Scale: 1:575,000 at A3
0 2.75 5.5 11 16.5 22 Km

Project No: 173570-5d
Plate No: 6

Issue No:	Date:	Description:	Interp:	Drawn:	Check:	App:
1	08/06/2018	Complete Deliverable	LO	CB	LO	ST

APPENDICES

A. GUIDELINES ON USE OF REPORT

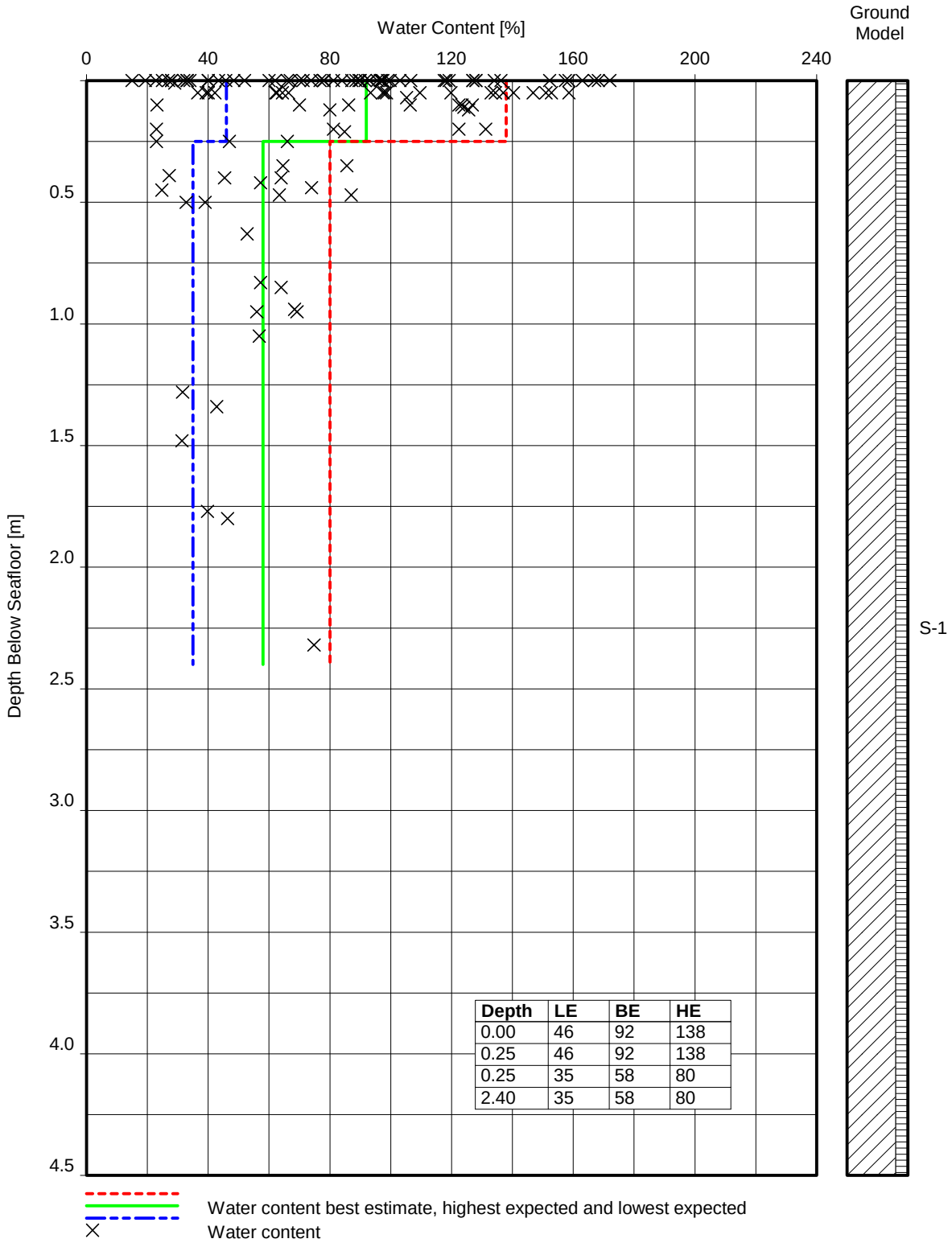
This report (the "Report") was prepared as part of the services (the "Services") provided by Fugro GB Marine Limited ("Fugro") for its client (the "Client") under terms of the relevant contract between the two parties (the "Contract"). The Services were performed by Fugro based on requirements of the Client set out in the Contract or otherwise made known by the Client to Fugro at the time.

Fugro's obligations and liabilities to the Client or any other party in respect of the Services and this Report are limited in time and value as defined in Contract (or in the absence of any express provision in the Contract as implied by the law of the Contract) and Fugro provides no other representation or warranty whether express or implied, in relation to the Services or for the use of this Report for any other purpose. Furthermore, Fugro has no obligation to update or revise this Report based on changes in conditions or information which emerge following issue of this Report unless expressly required by the Contract.

The Services were performed by Fugro exclusively for the Client and any other party identified in the Contract for the purpose set out therein. Any use and/or reliance on the Report or the Services for purposes not expressly stated in the Contract, by the Client or any other party is that party's risk and Fugro accepts no liability whatsoever for any such use and/or reliance.

B. PIPELINE AND FLOWLINE UNIT PARAMETER PROFILES

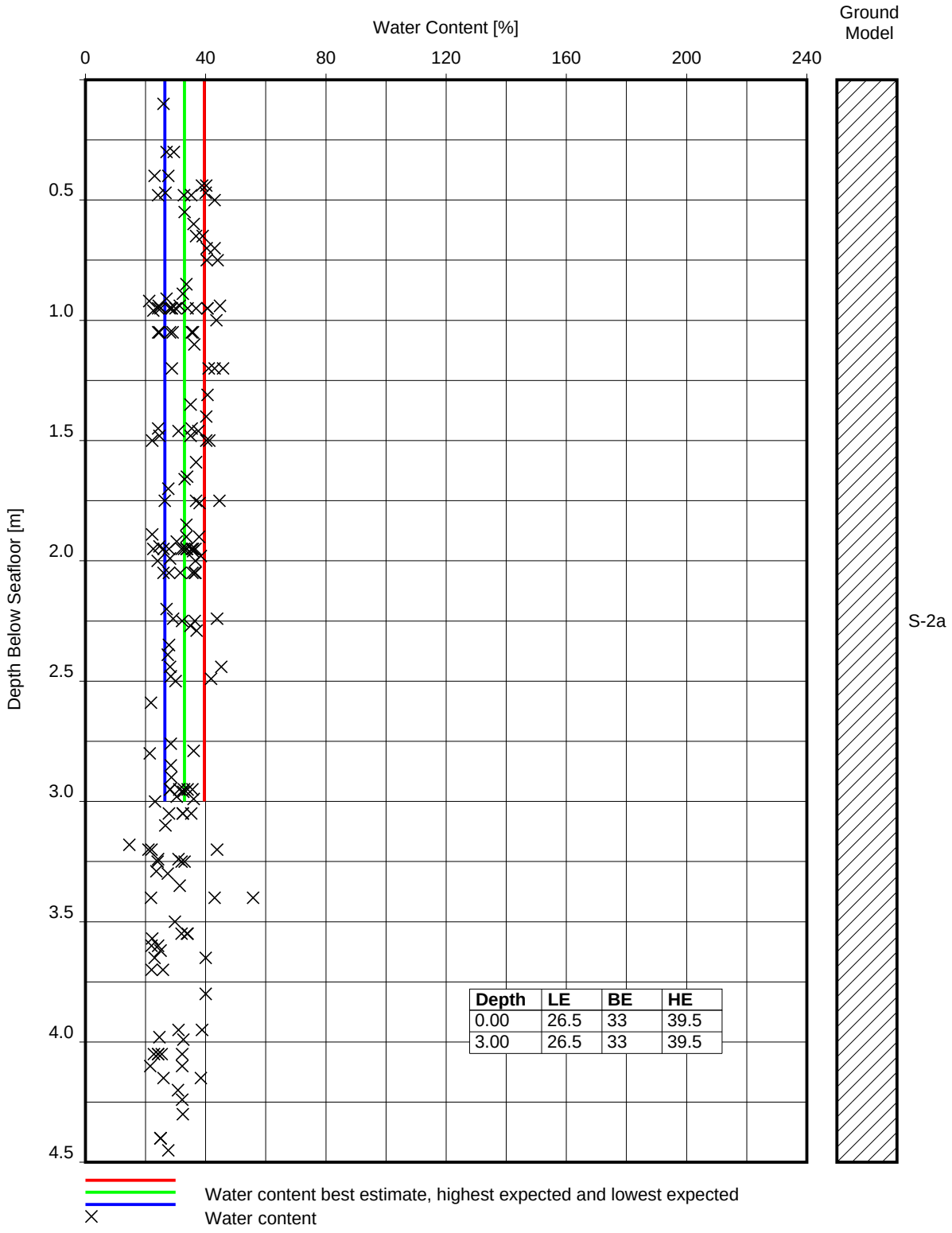
B.1 PIPELINE PARAMETER PROFILES



Depth	LE	BE	HE
0.00	46	92	138
0.25	46	92	138
0.25	35	58	80
2.40	35	58	80

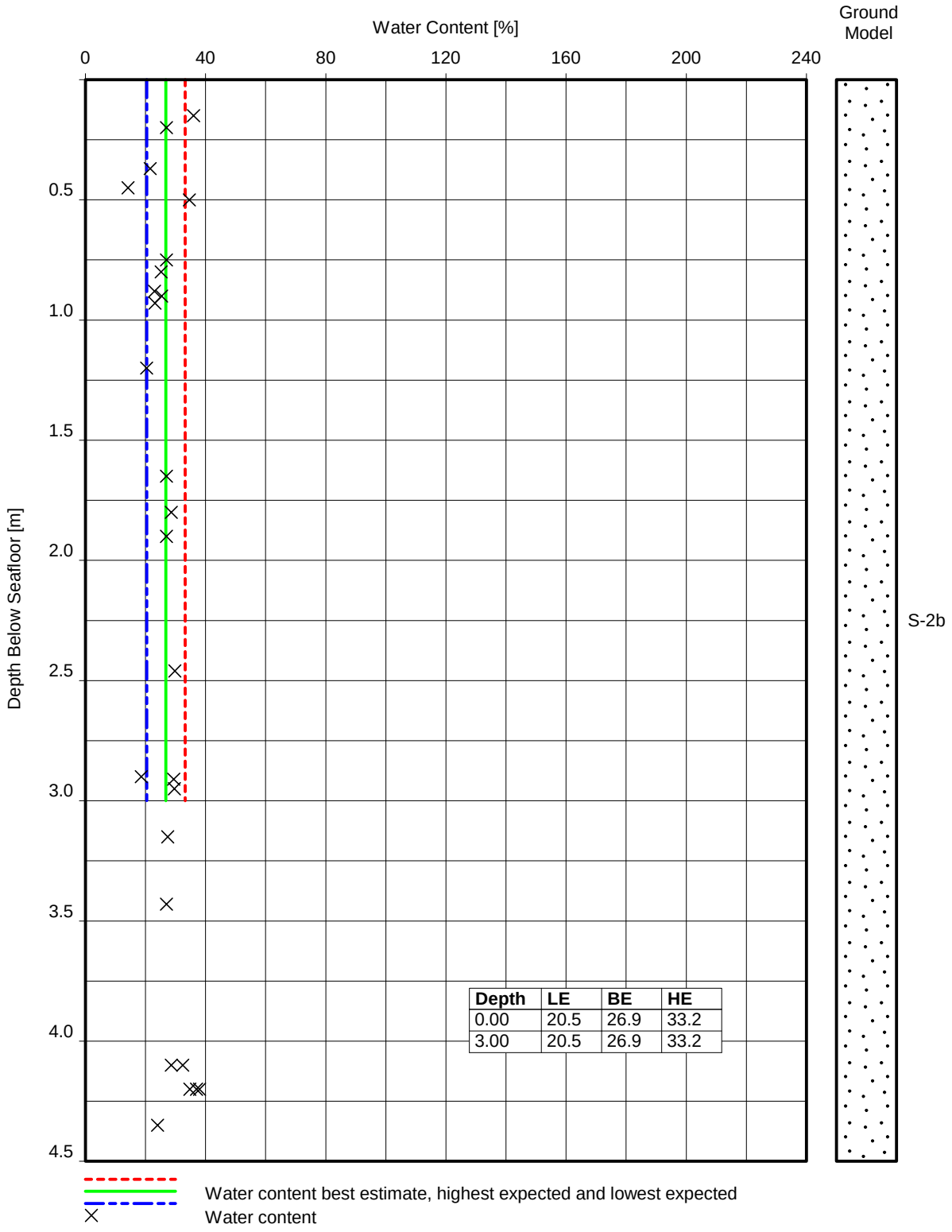
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

WATER CONTENT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-1



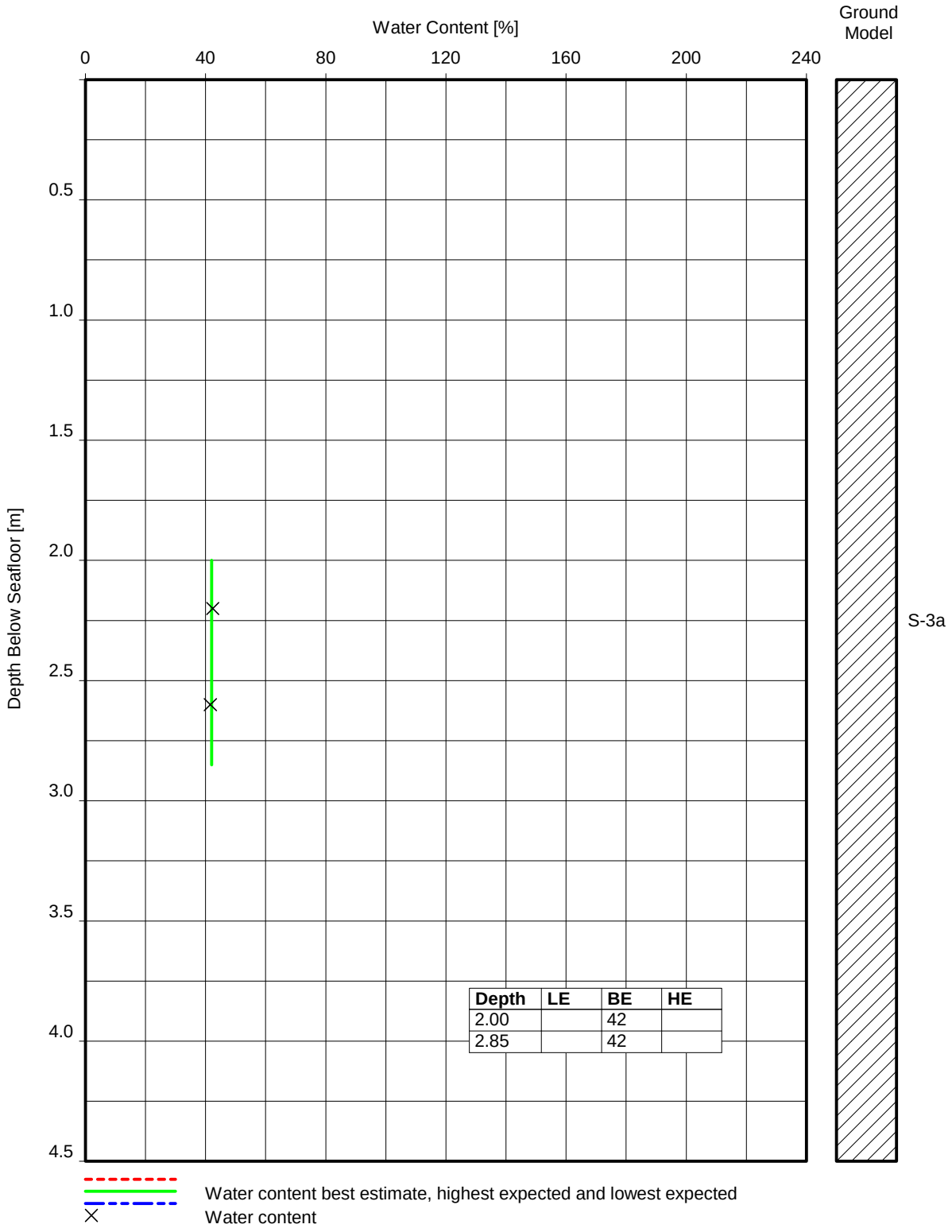
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

WATER CONTENT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-2a



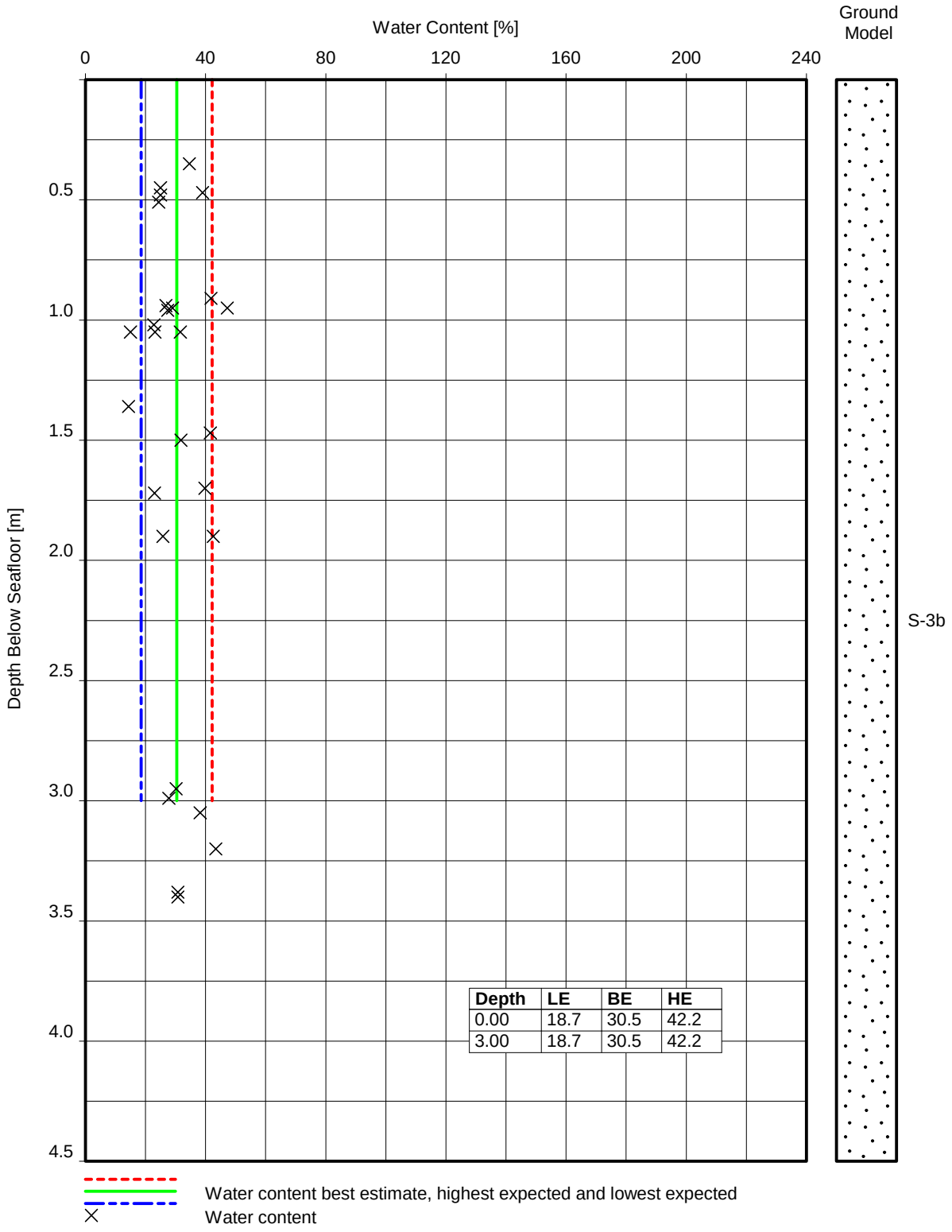
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

WATER CONTENT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-2b



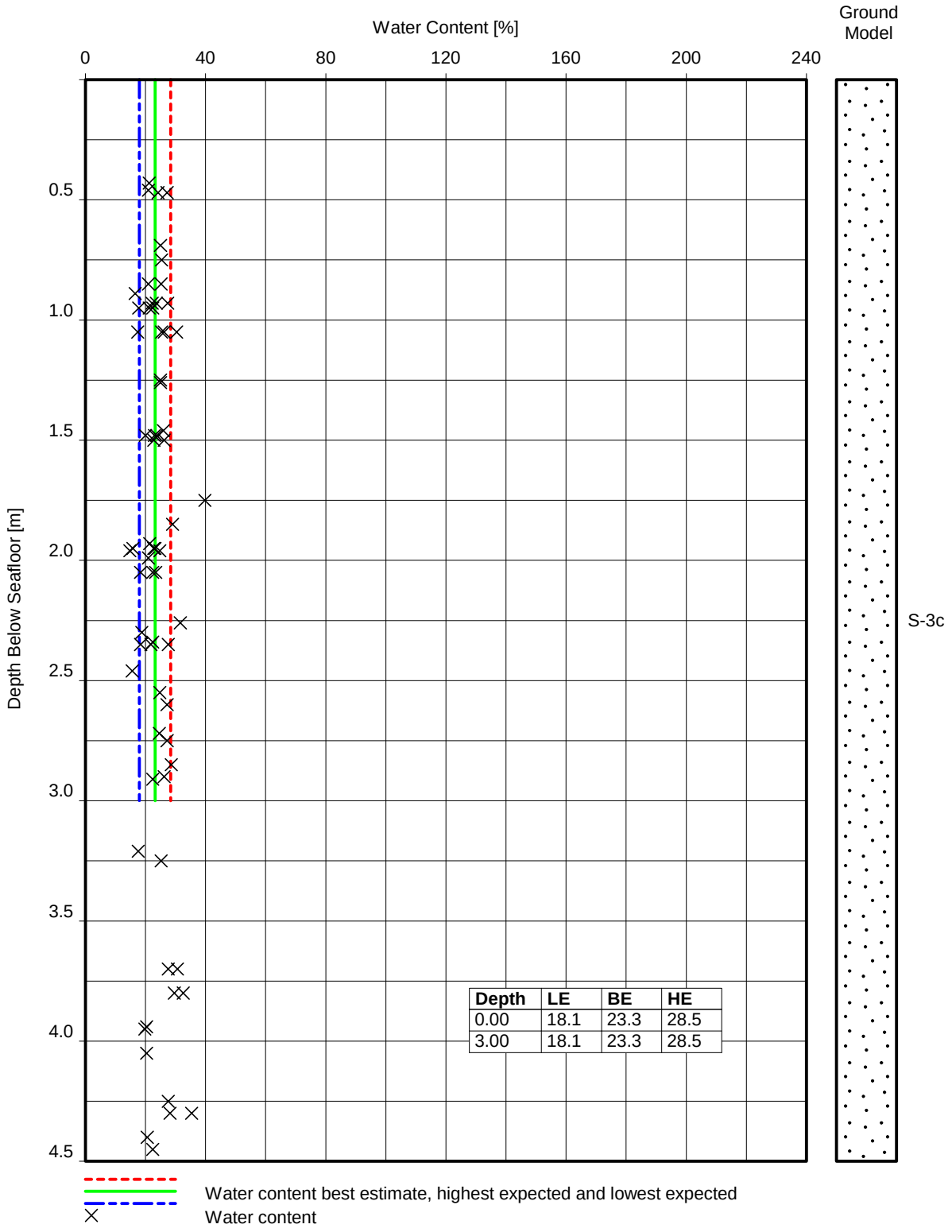
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

WATER CONTENT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-3a



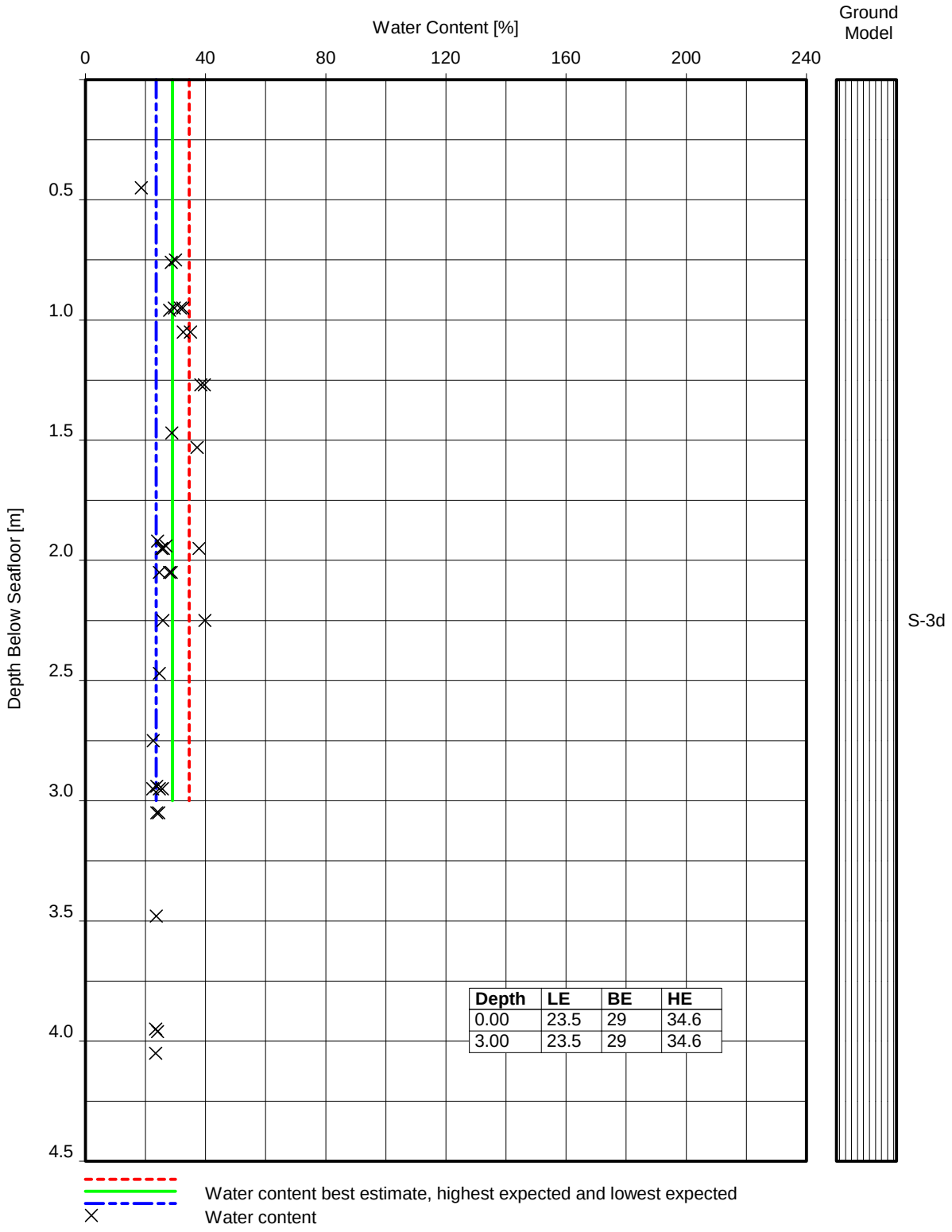
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

WATER CONTENT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-3b



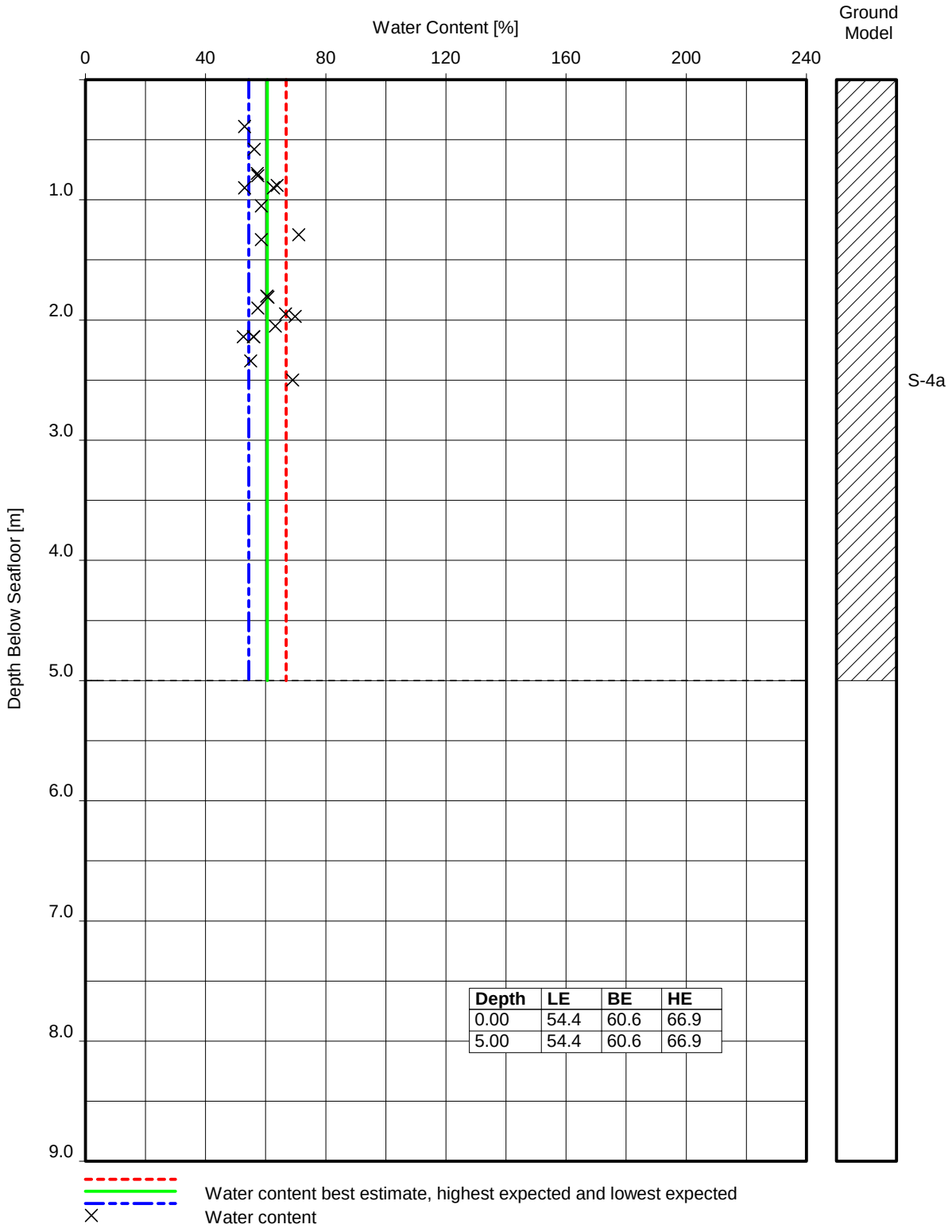
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

WATER CONTENT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-3c



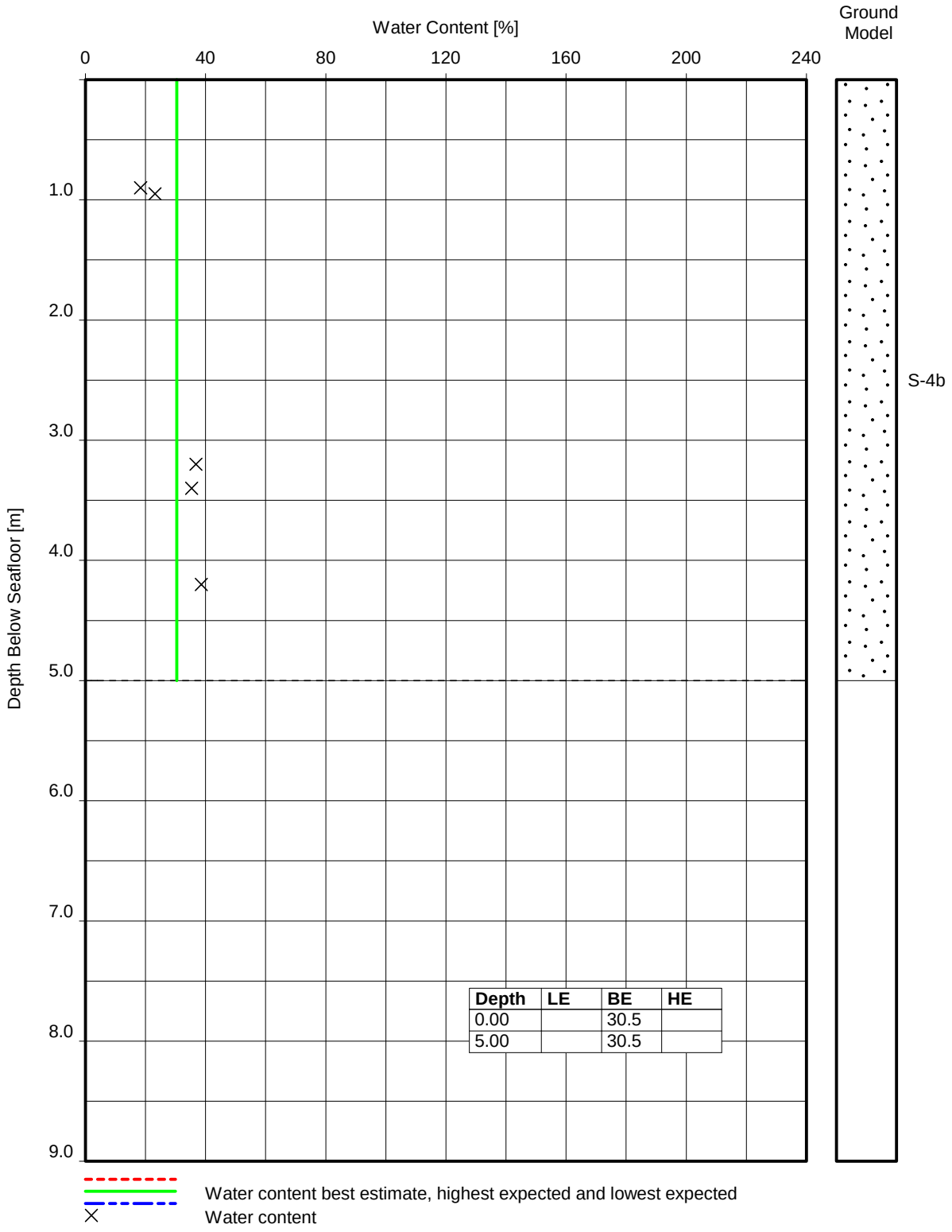
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

WATER CONTENT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-3d



Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

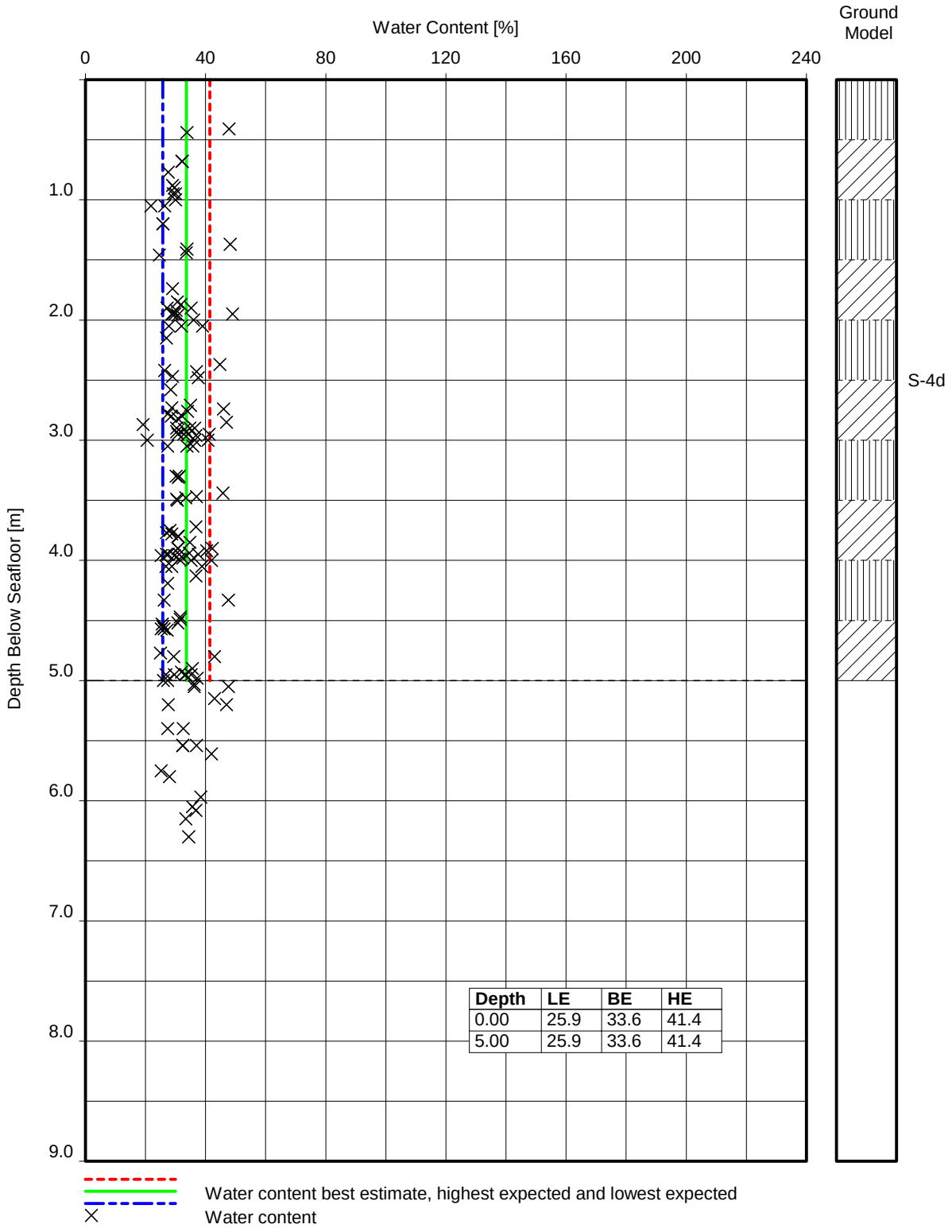
WATER CONTENT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-4a



Depth	LE	BE	HE
0.00		30.5	
5.00		30.5	

Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3
- Not enough data within PGU to derive LE and HE

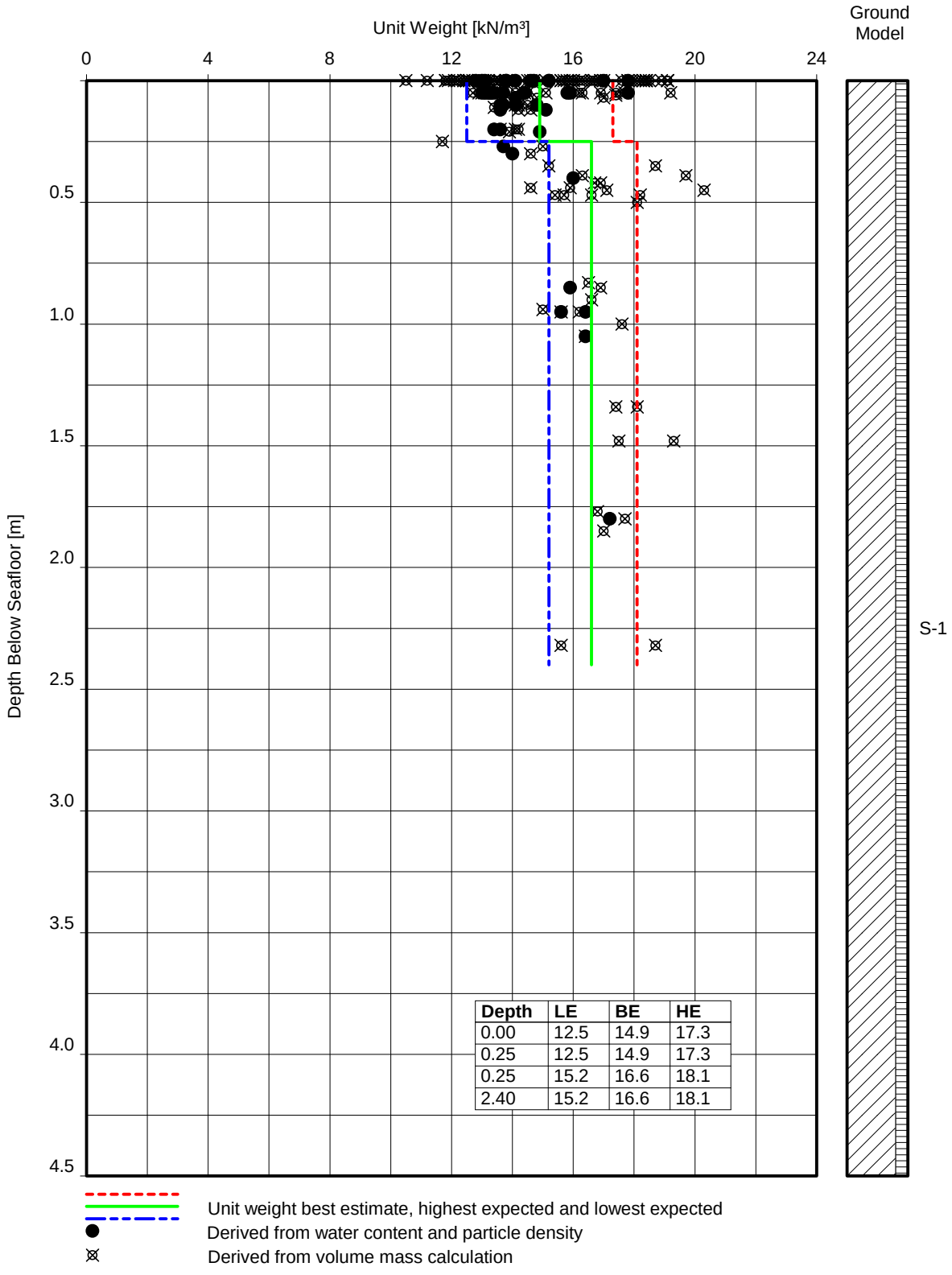
WATER CONTENT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-4b



Depth	LE	BE	HE
0.00	25.9	33.6	41.4
5.00	25.9	33.6	41.4

Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

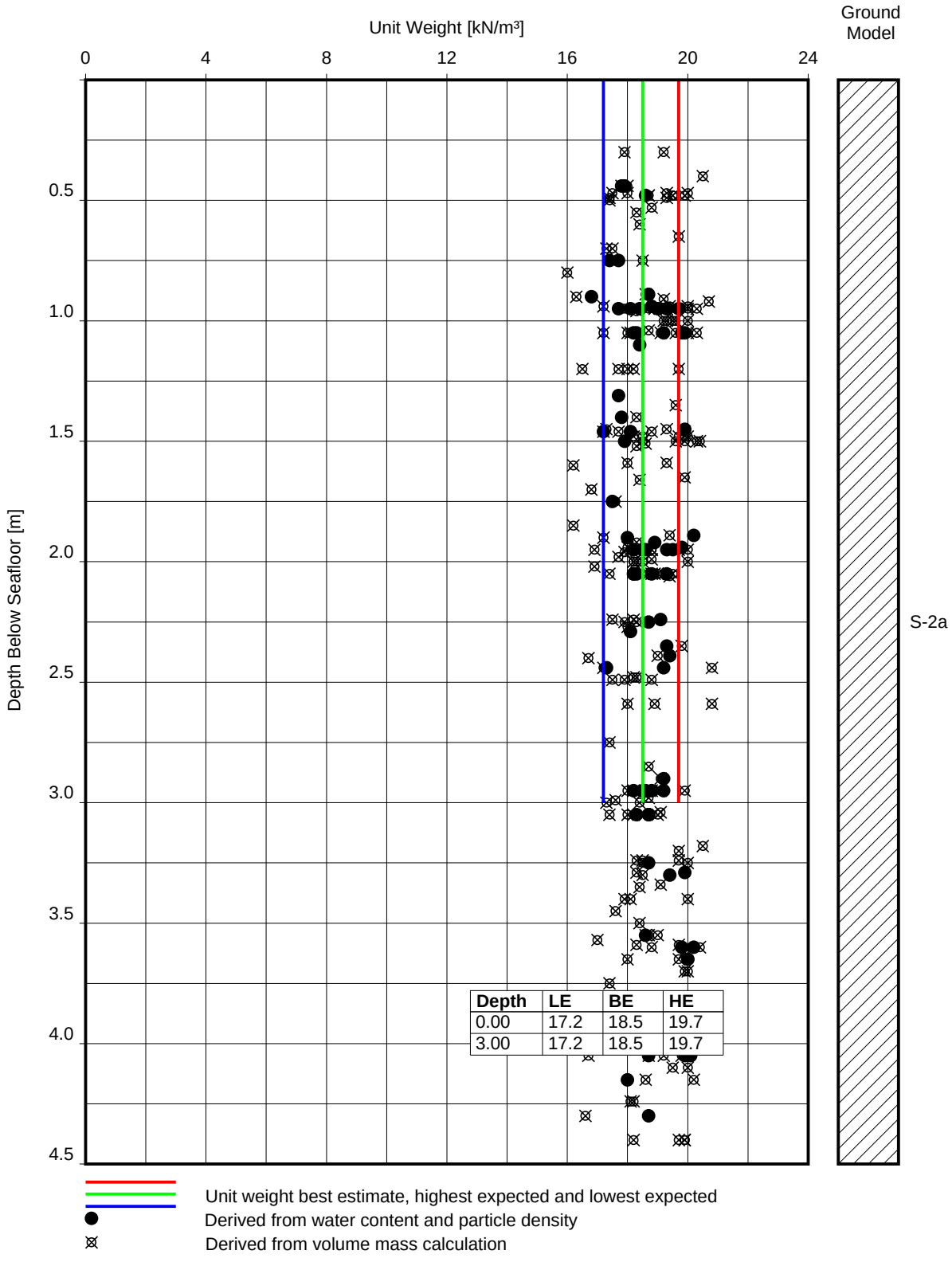
WATER CONTENT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-4d



Depth	LE	BE	HE
0.00	12.5	14.9	17.3
0.25	12.5	14.9	17.3
0.25	15.2	16.6	18.1
2.40	15.2	16.6	18.1

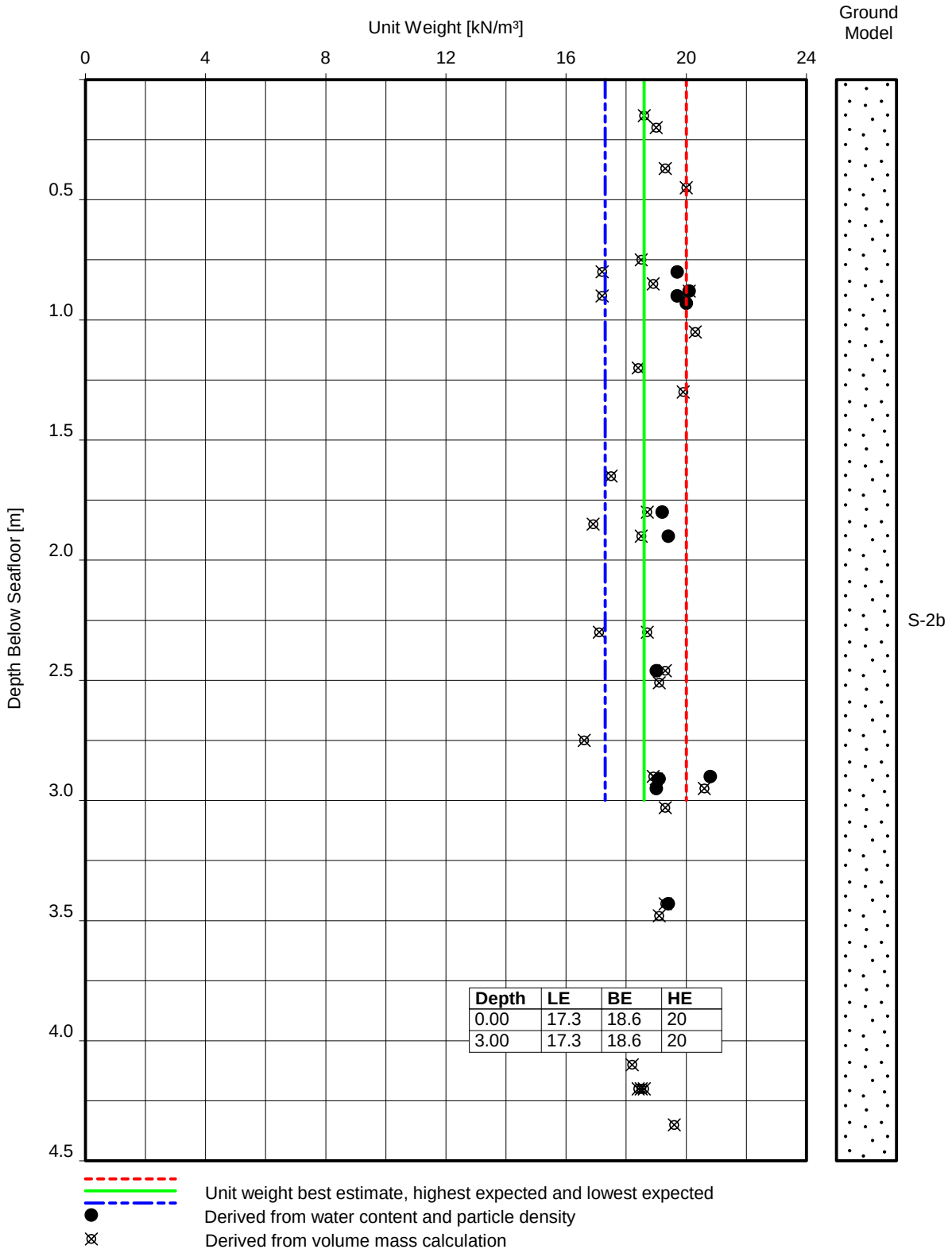
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-1



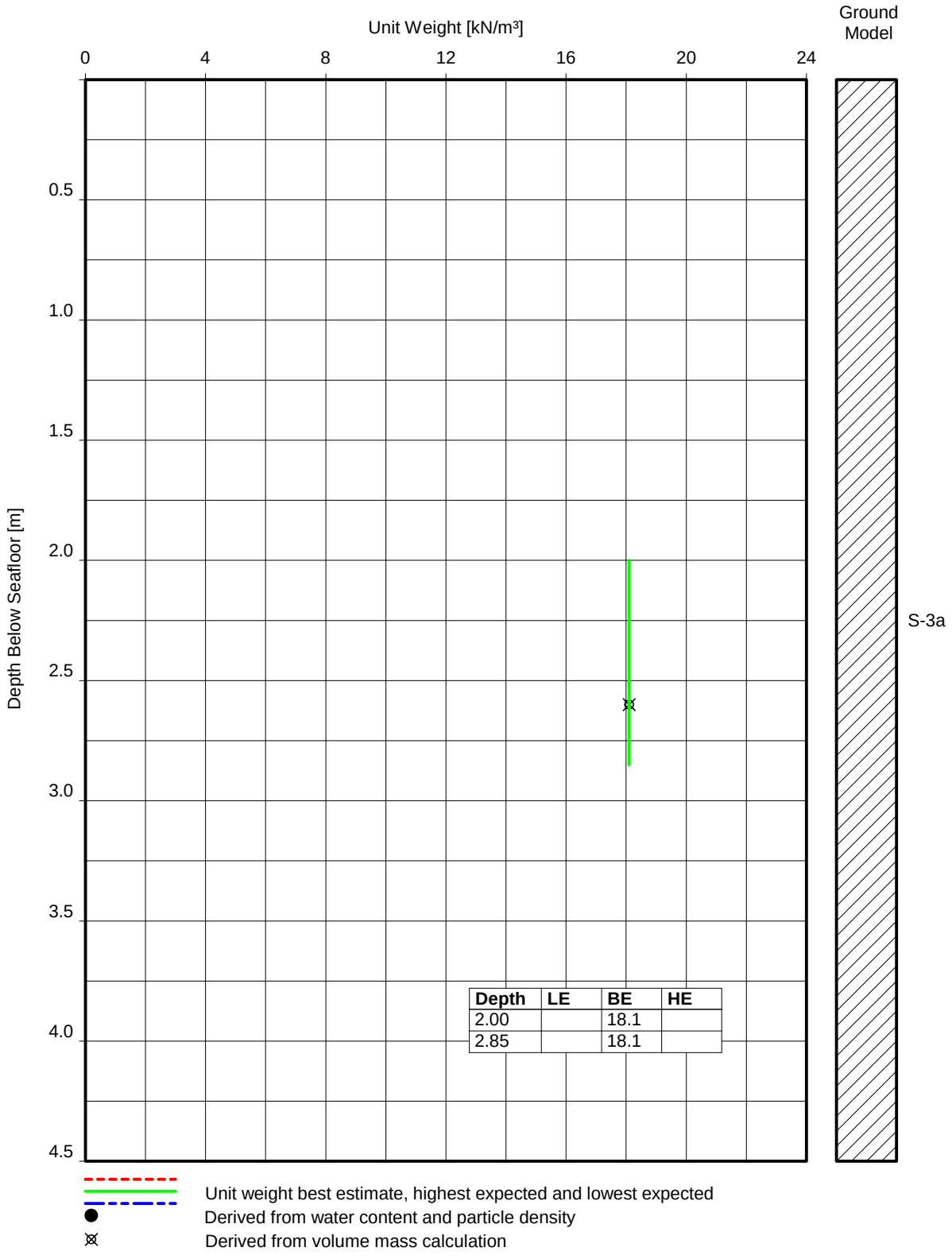
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-2a



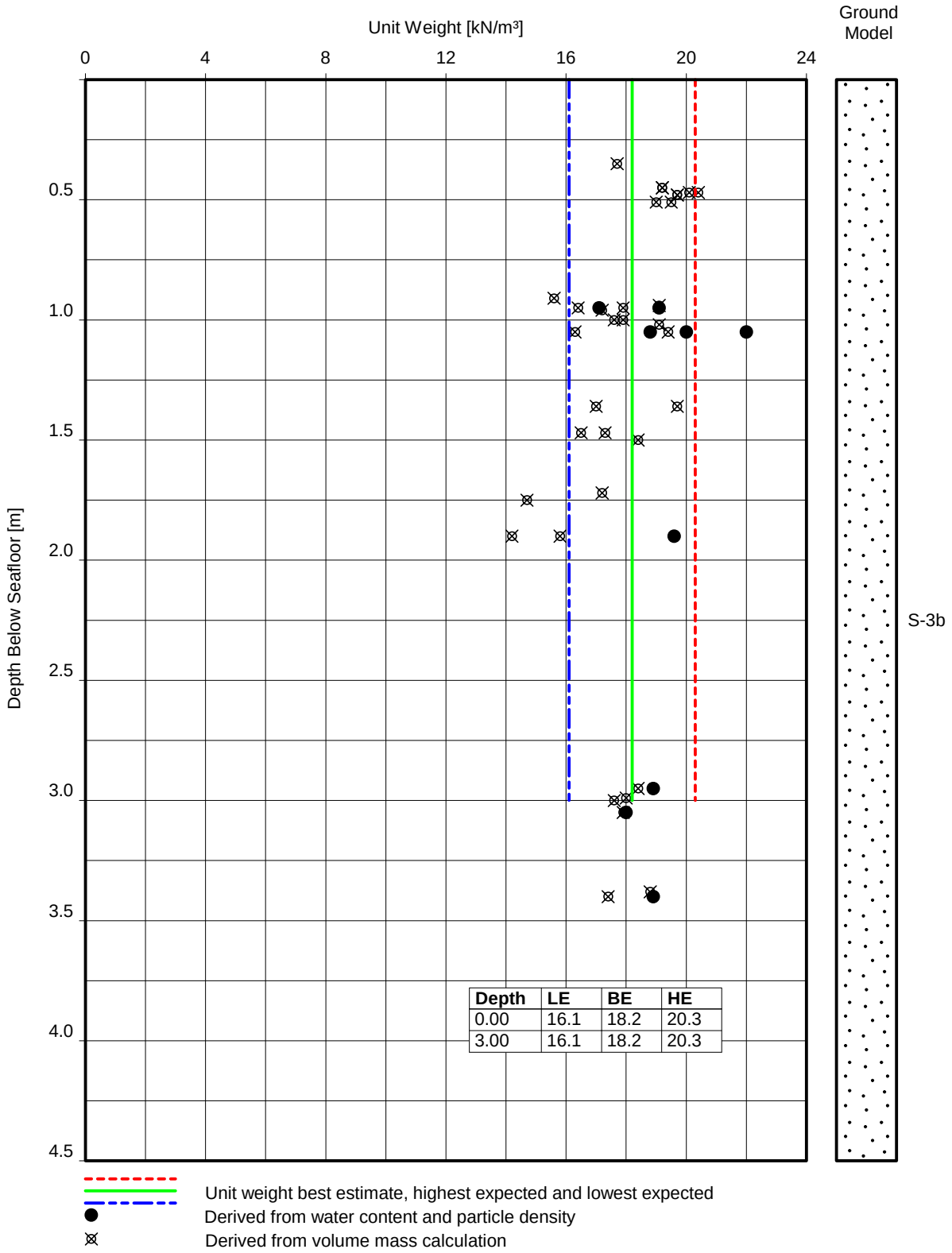
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-2b



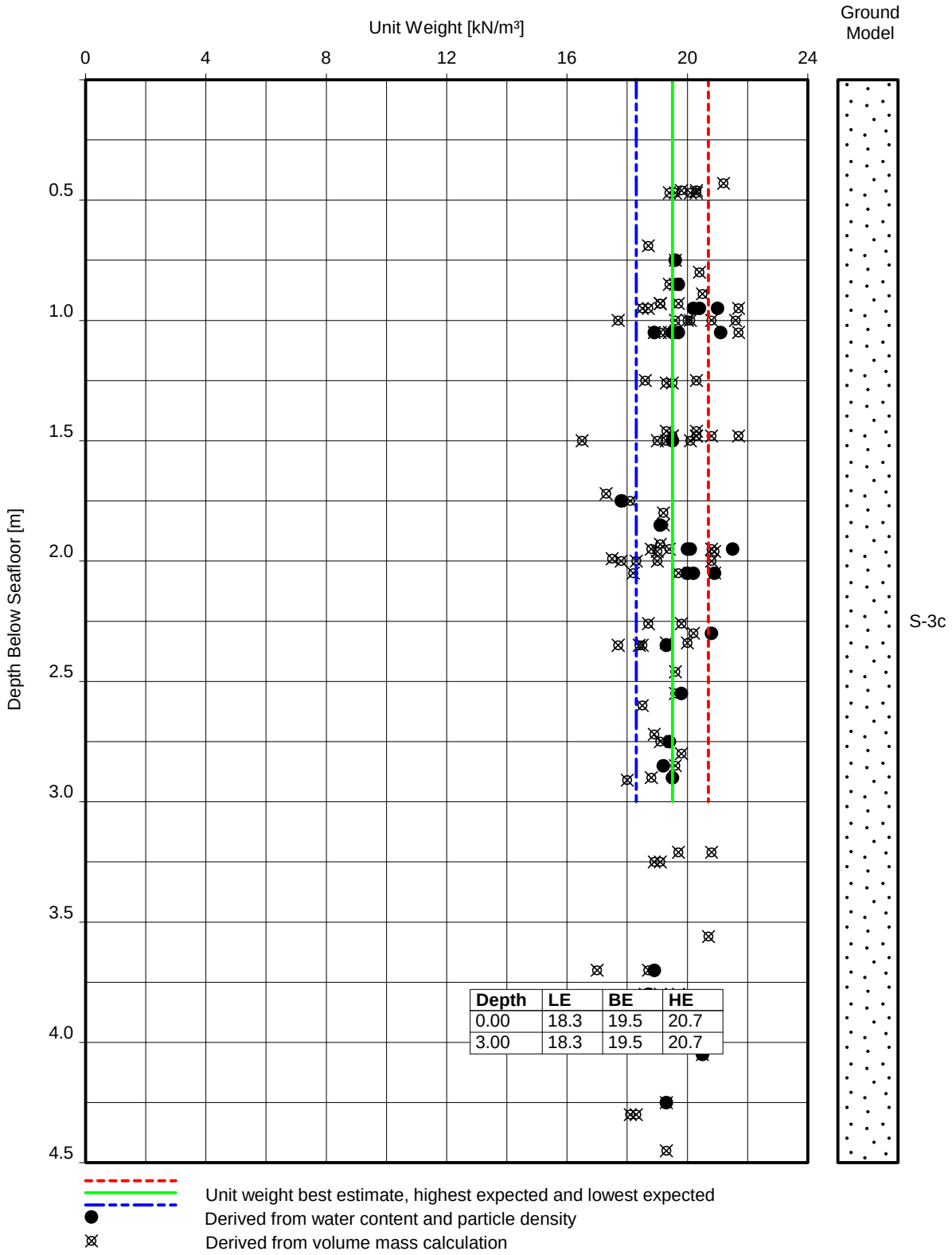
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-3a



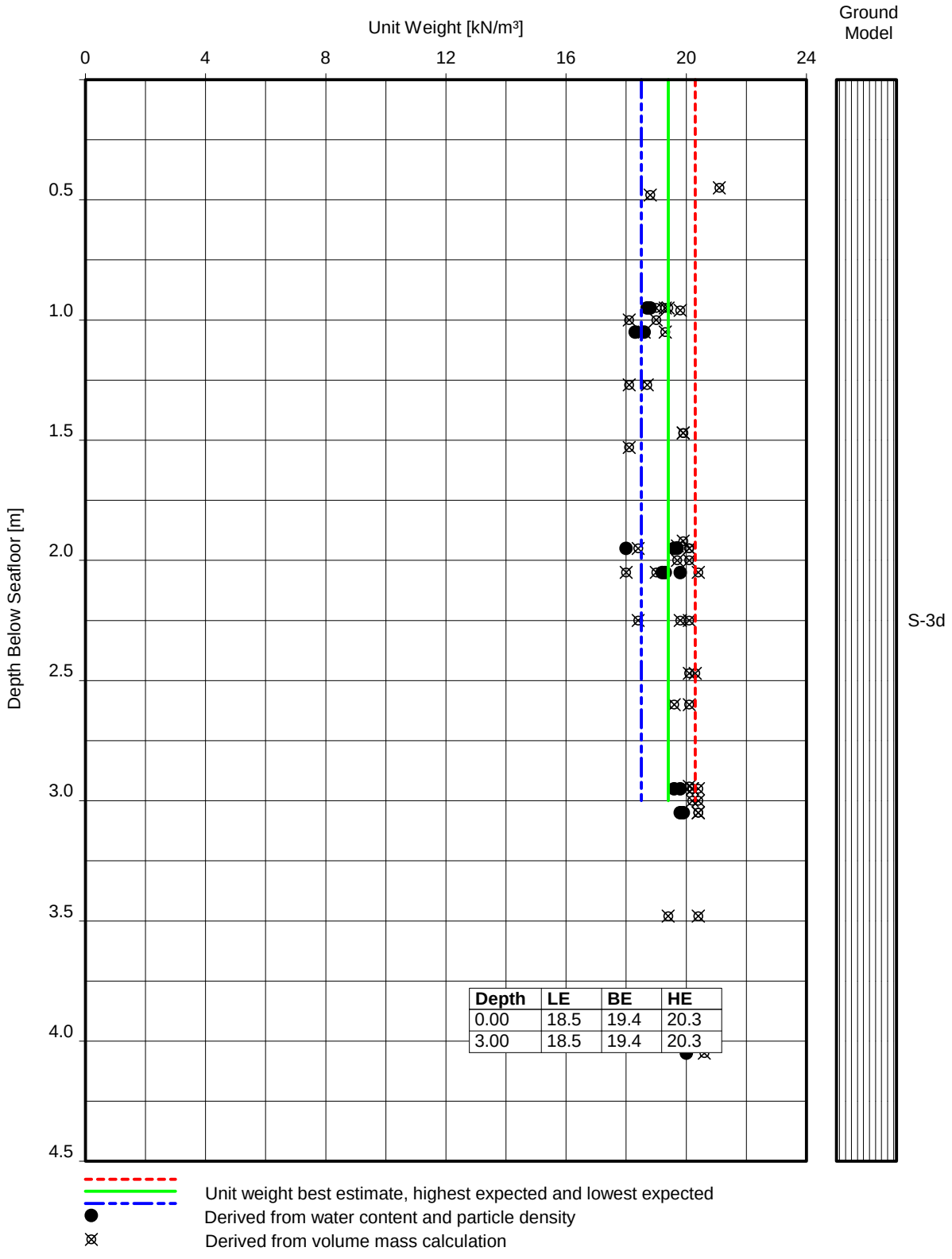
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-3b



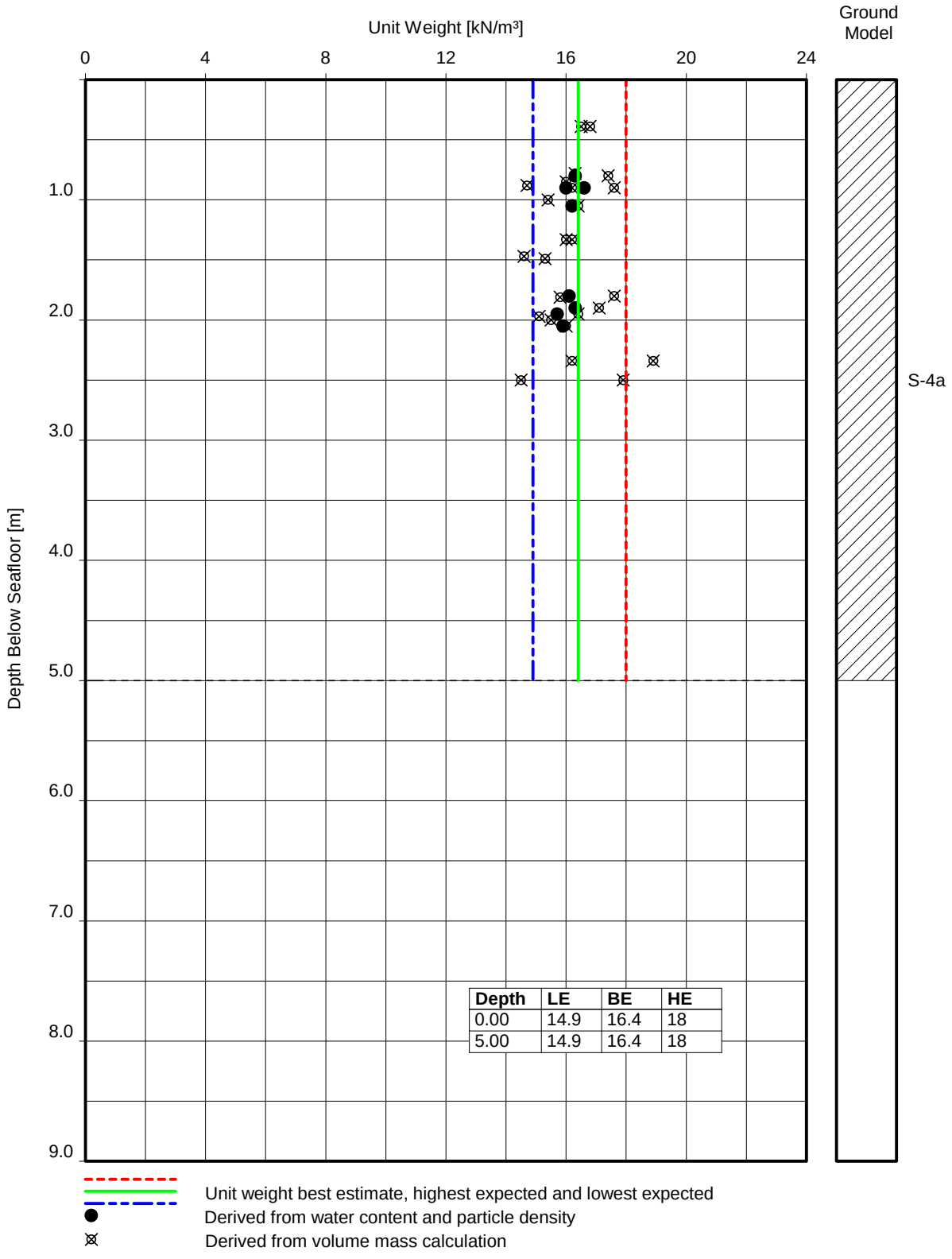
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-3c



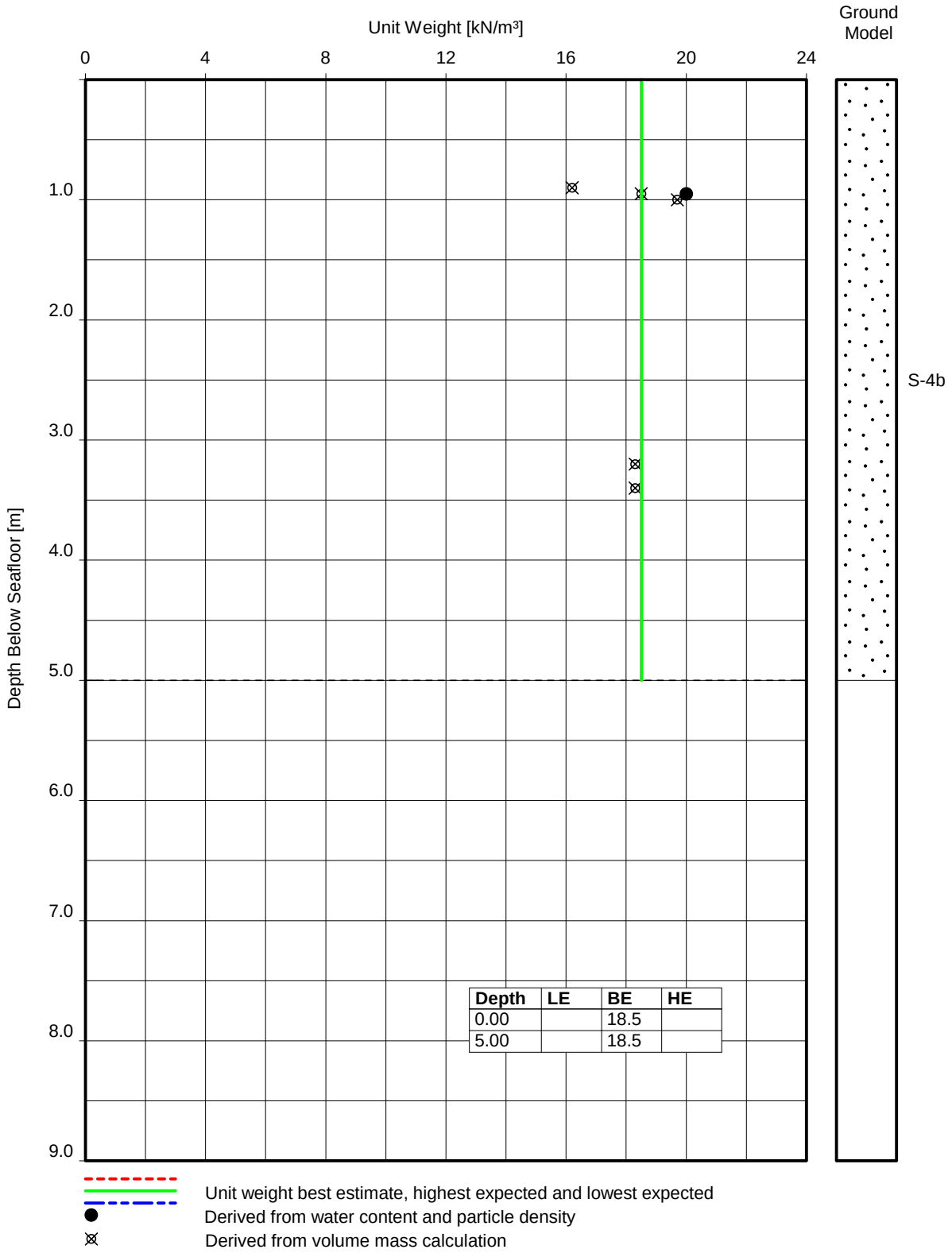
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-3d



Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

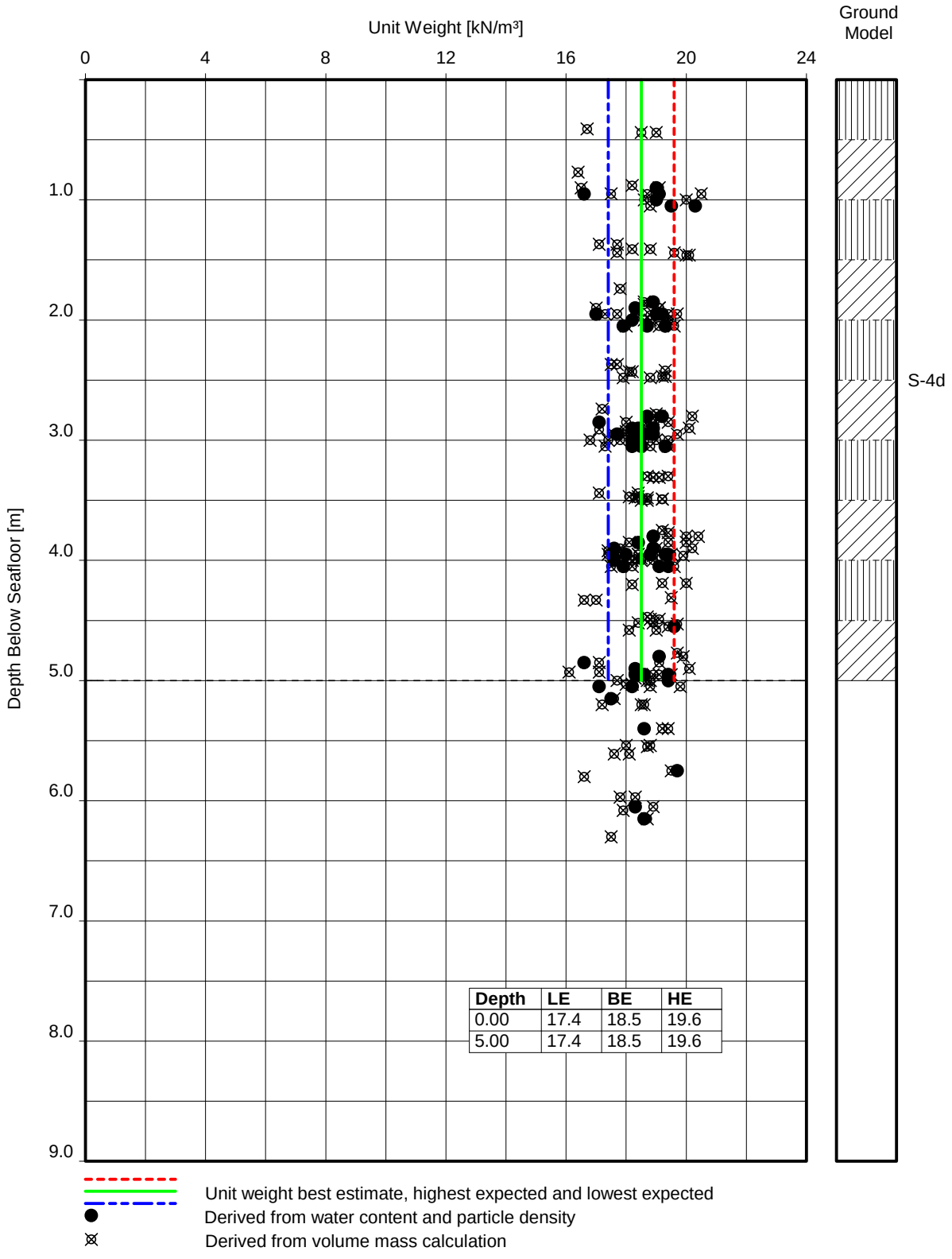
UNIT WEIGHT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-4a



Depth	LE	BE	HE
0.00		18.5	
5.00		18.5	

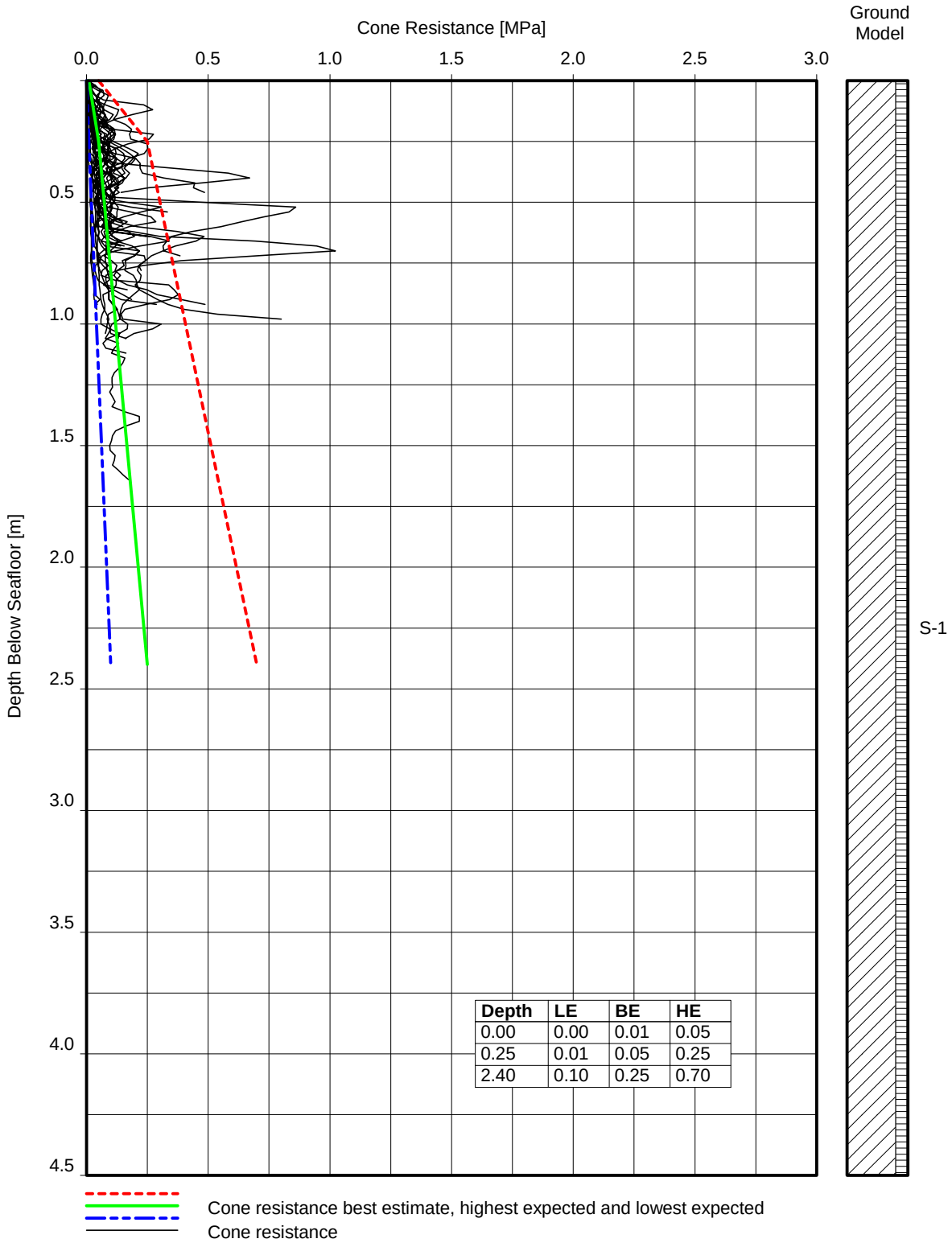
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3
- Not enough data within PGU to derive LE and HE

UNIT WEIGHT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-4b



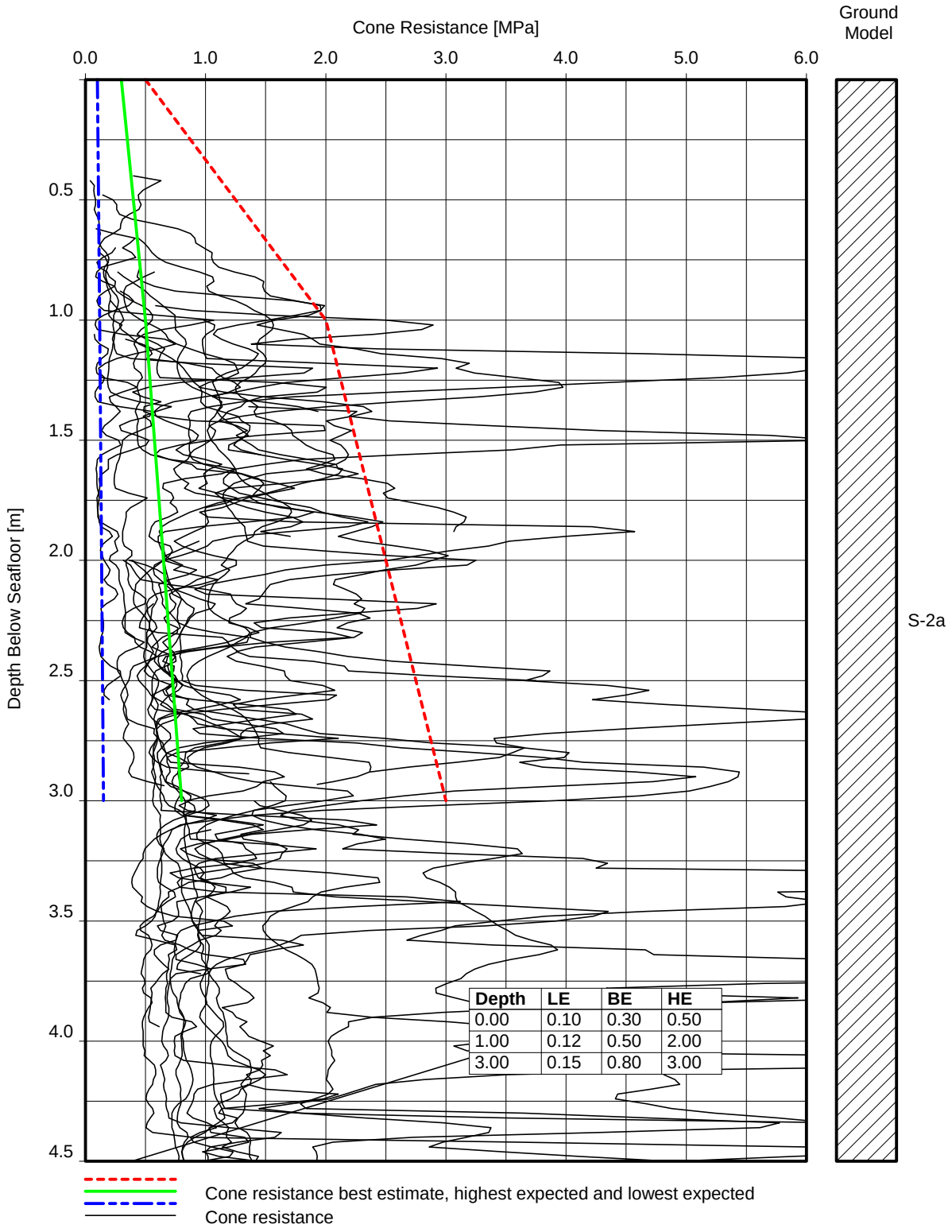
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-4d



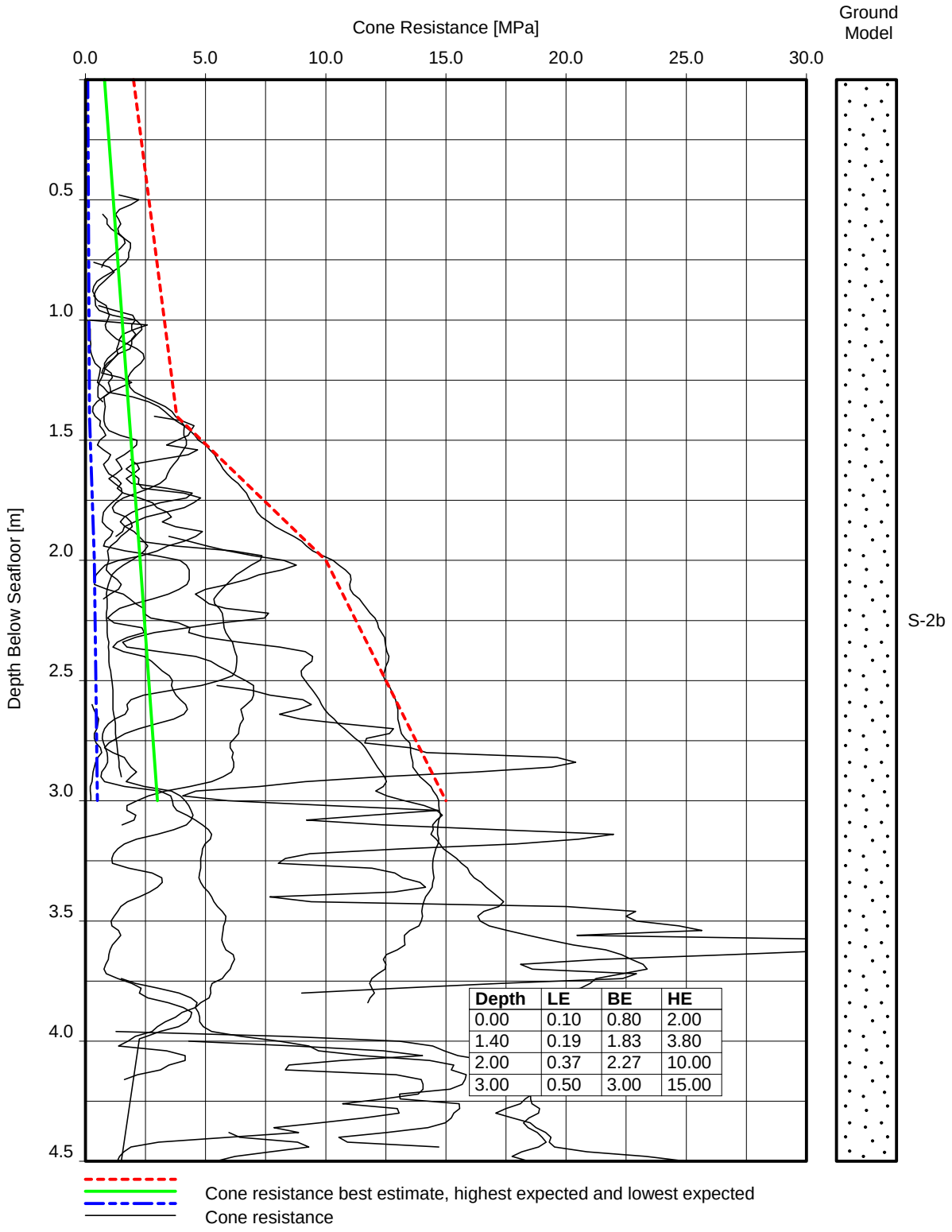
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-1



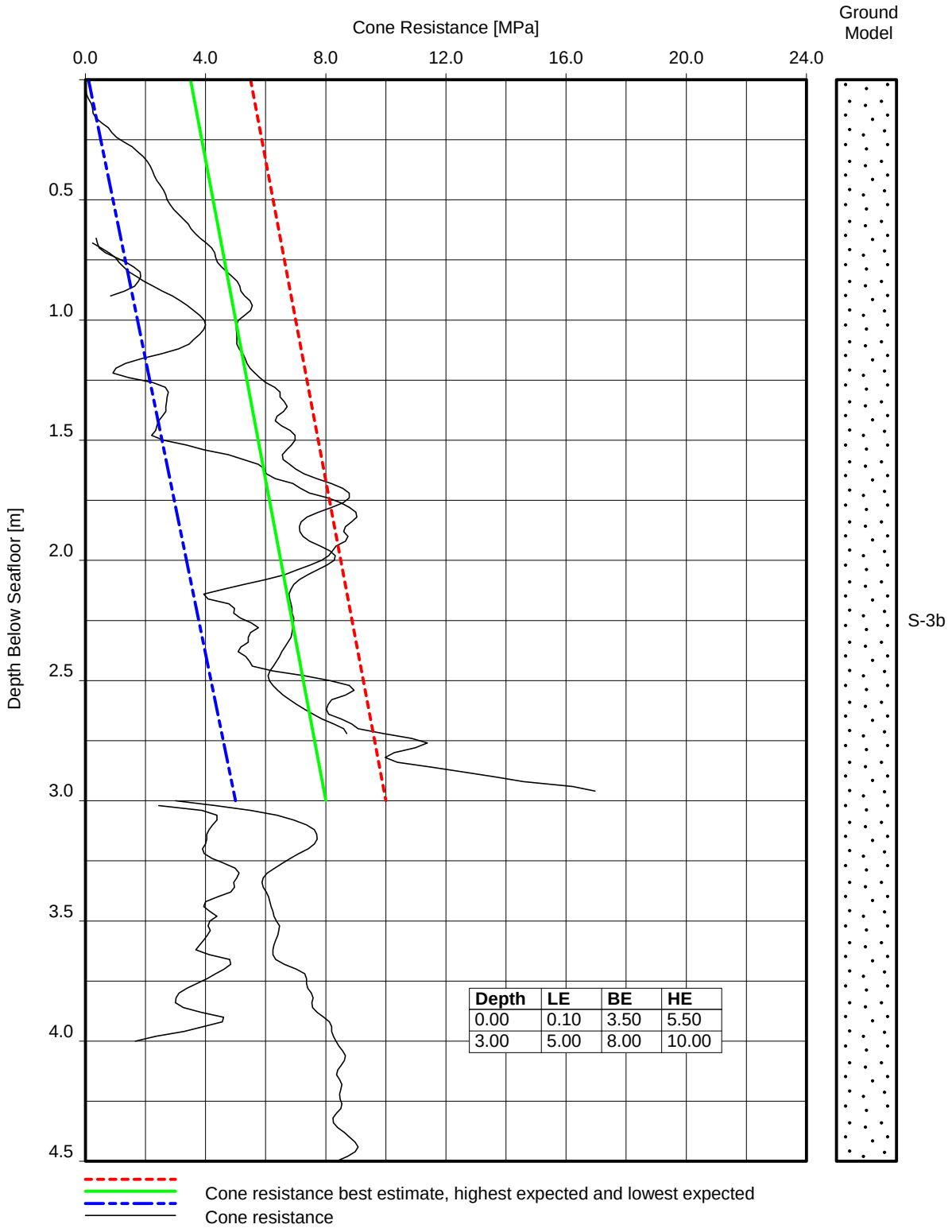
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-2a



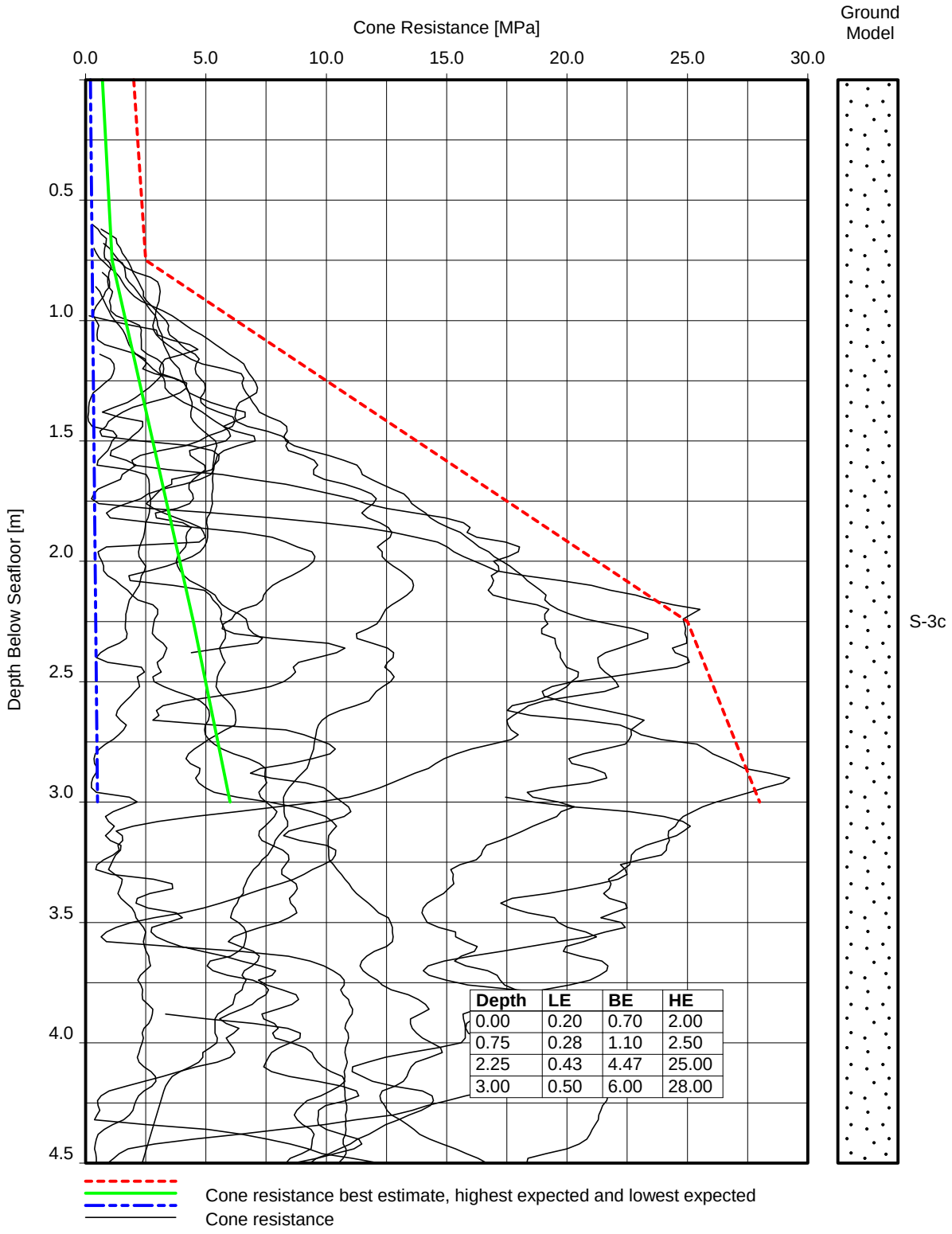
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-2b



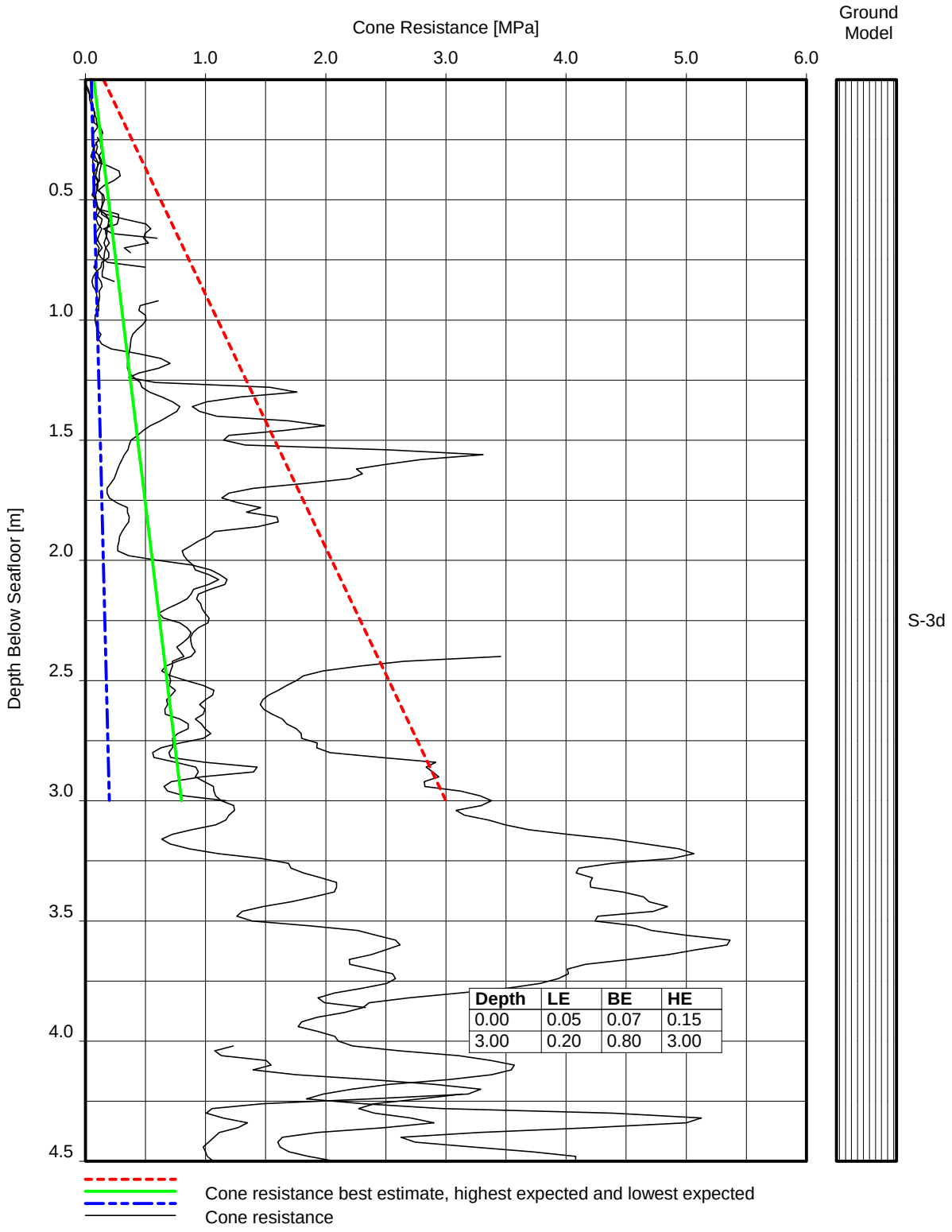
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-3b



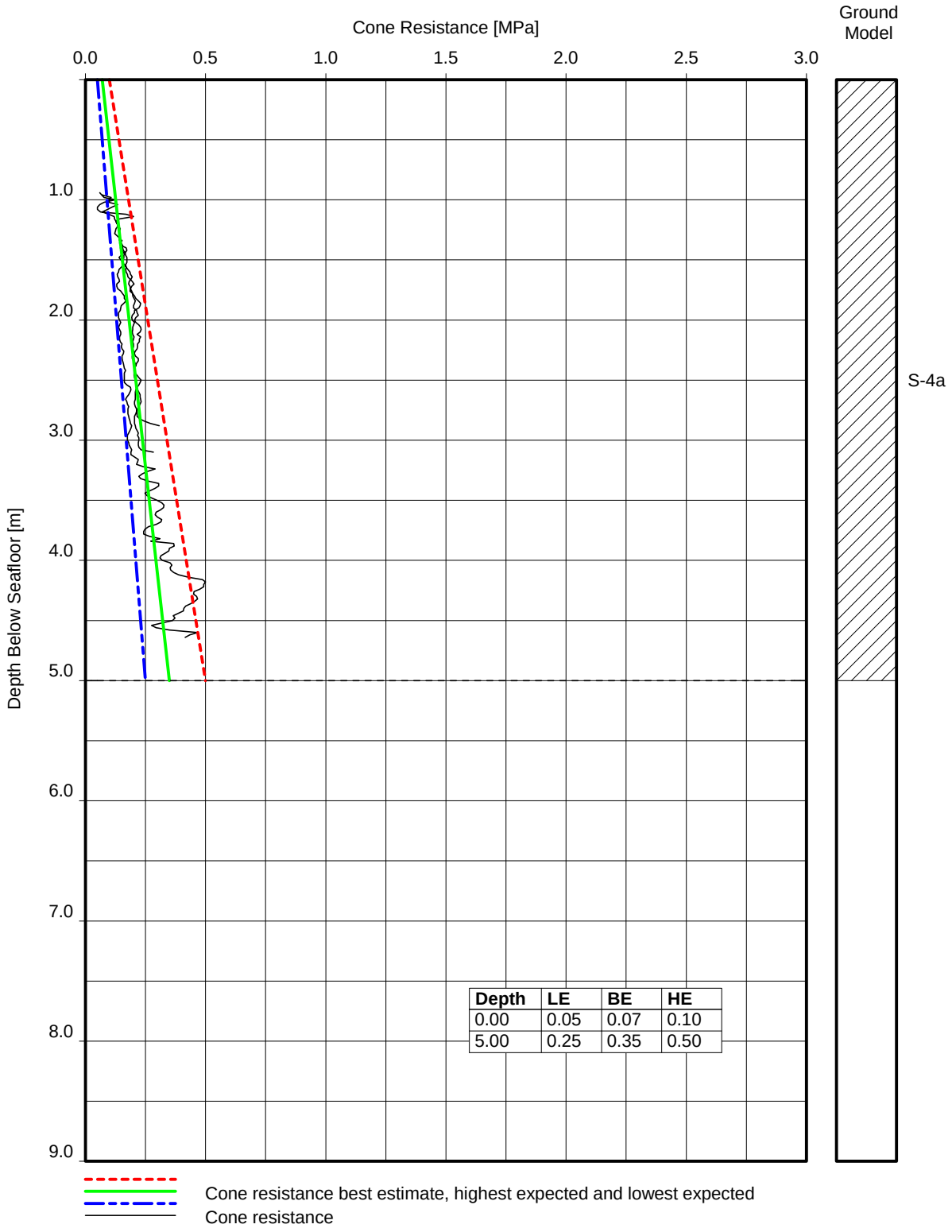
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-3c



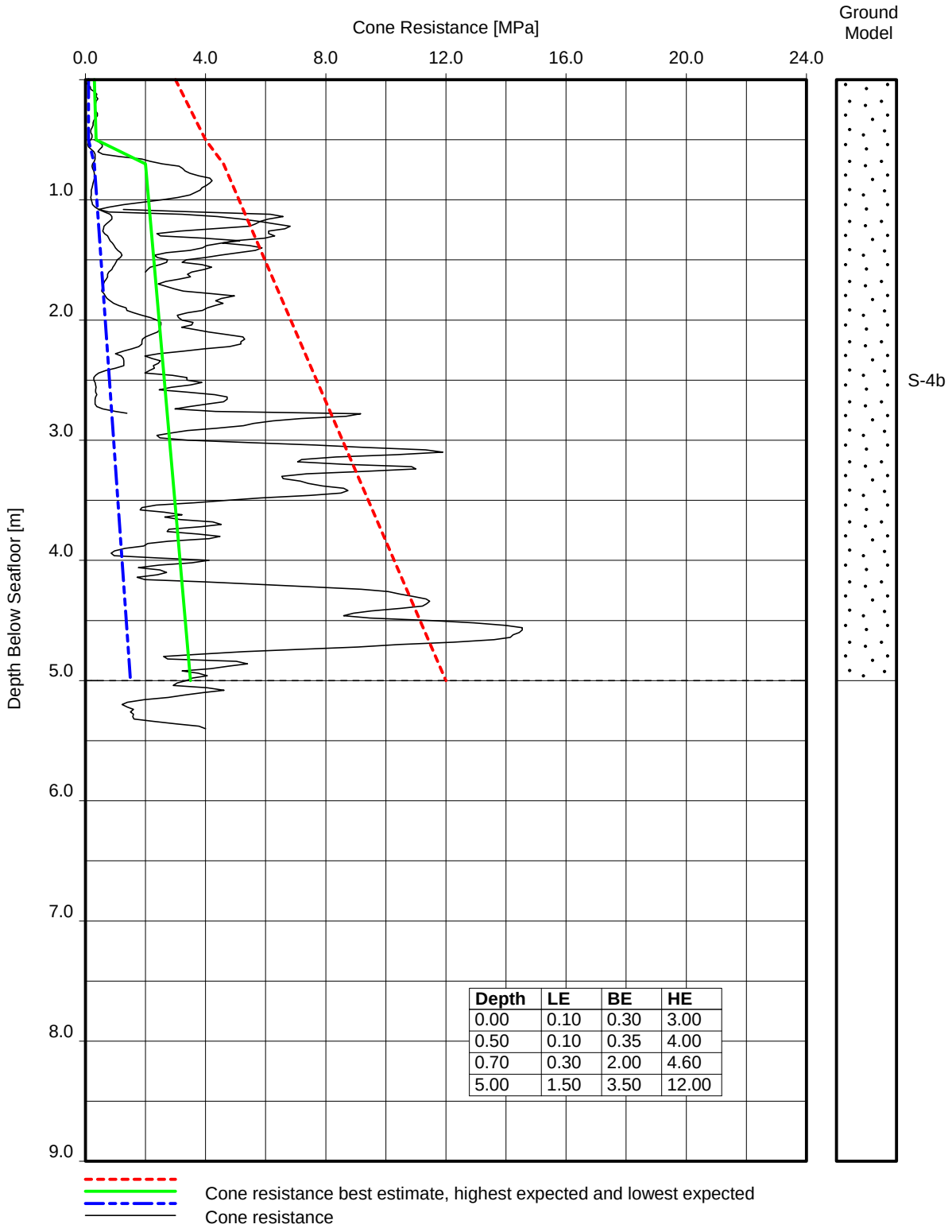
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-3d



Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

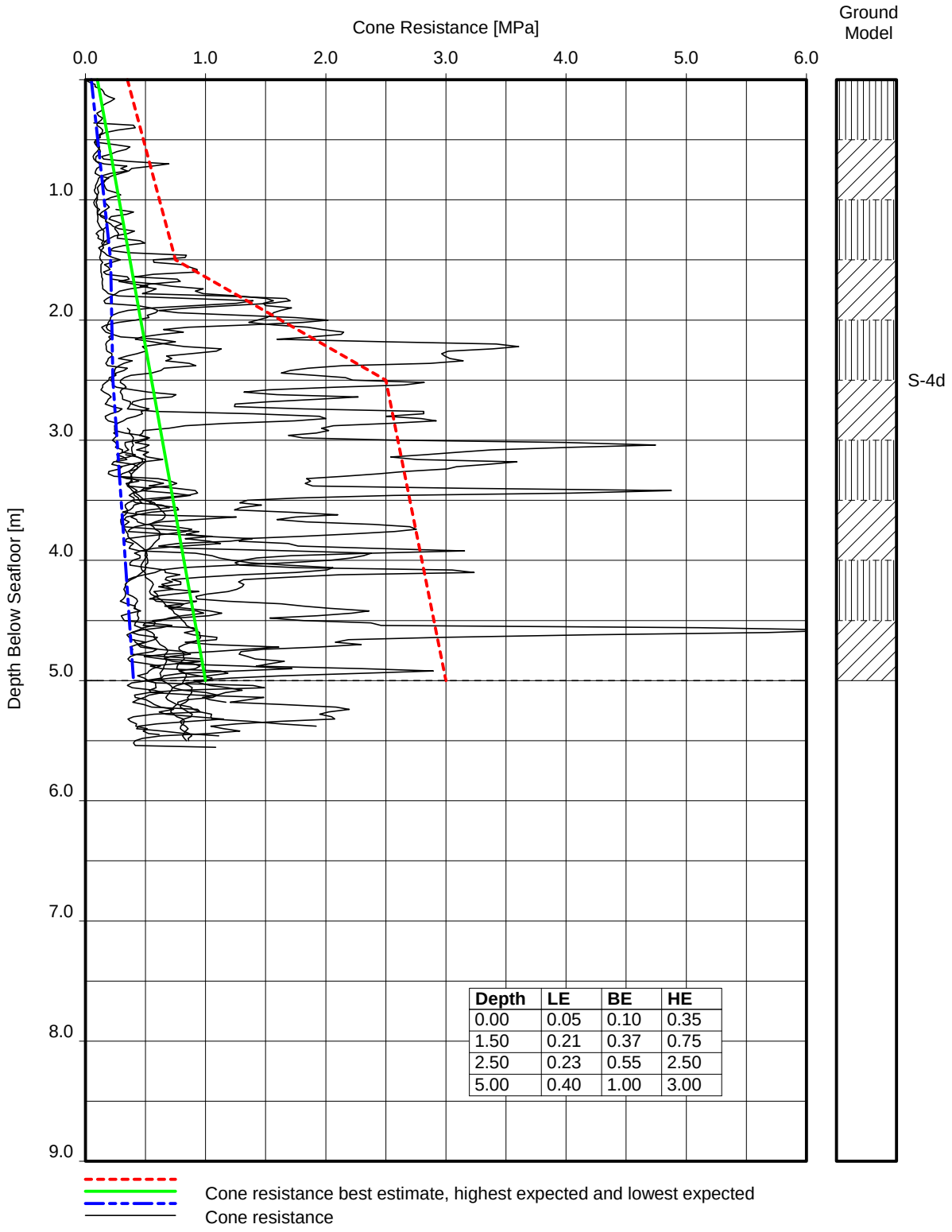
CONE RESISTANCE VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-4a



Depth	LE	BE	HE
0.00	0.10	0.30	3.00
0.50	0.10	0.35	4.00
0.70	0.30	2.00	4.60
5.00	1.50	3.50	12.00

Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

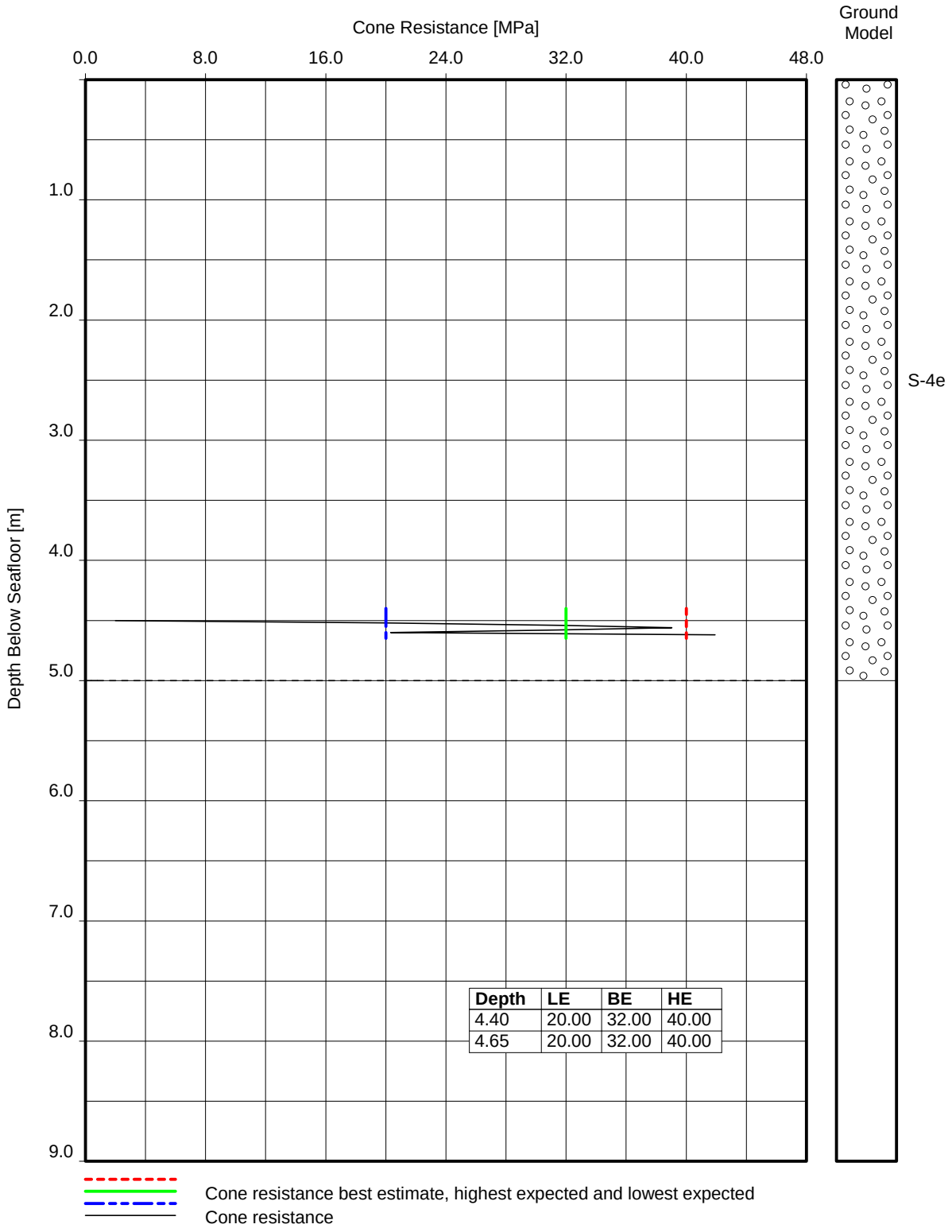
CONE RESISTANCE VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-4b



Depth	LE	BE	HE
0.00	0.05	0.10	0.35
1.50	0.21	0.37	0.75
2.50	0.23	0.55	2.50
5.00	0.40	1.00	3.00

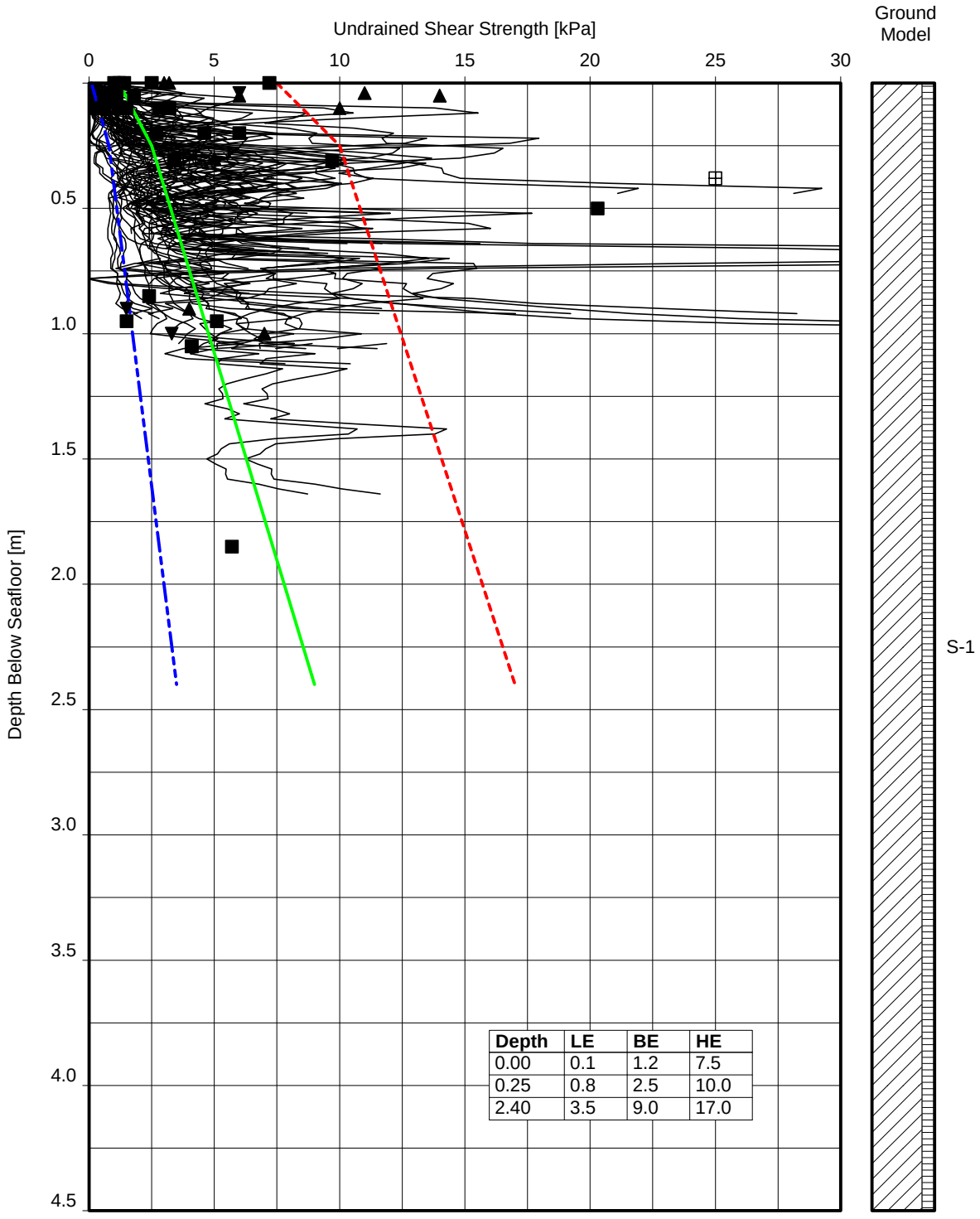
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-4d



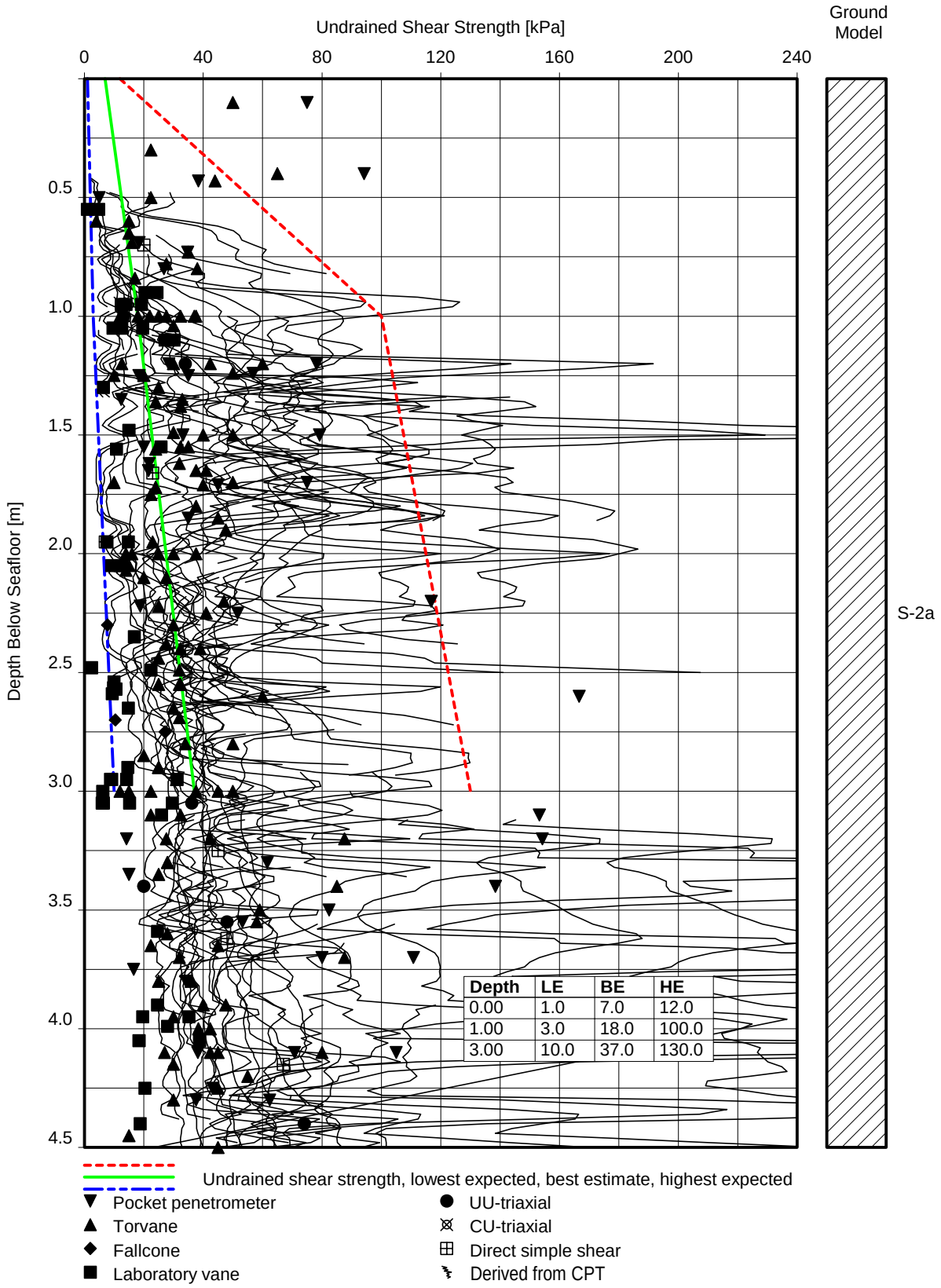
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-4e



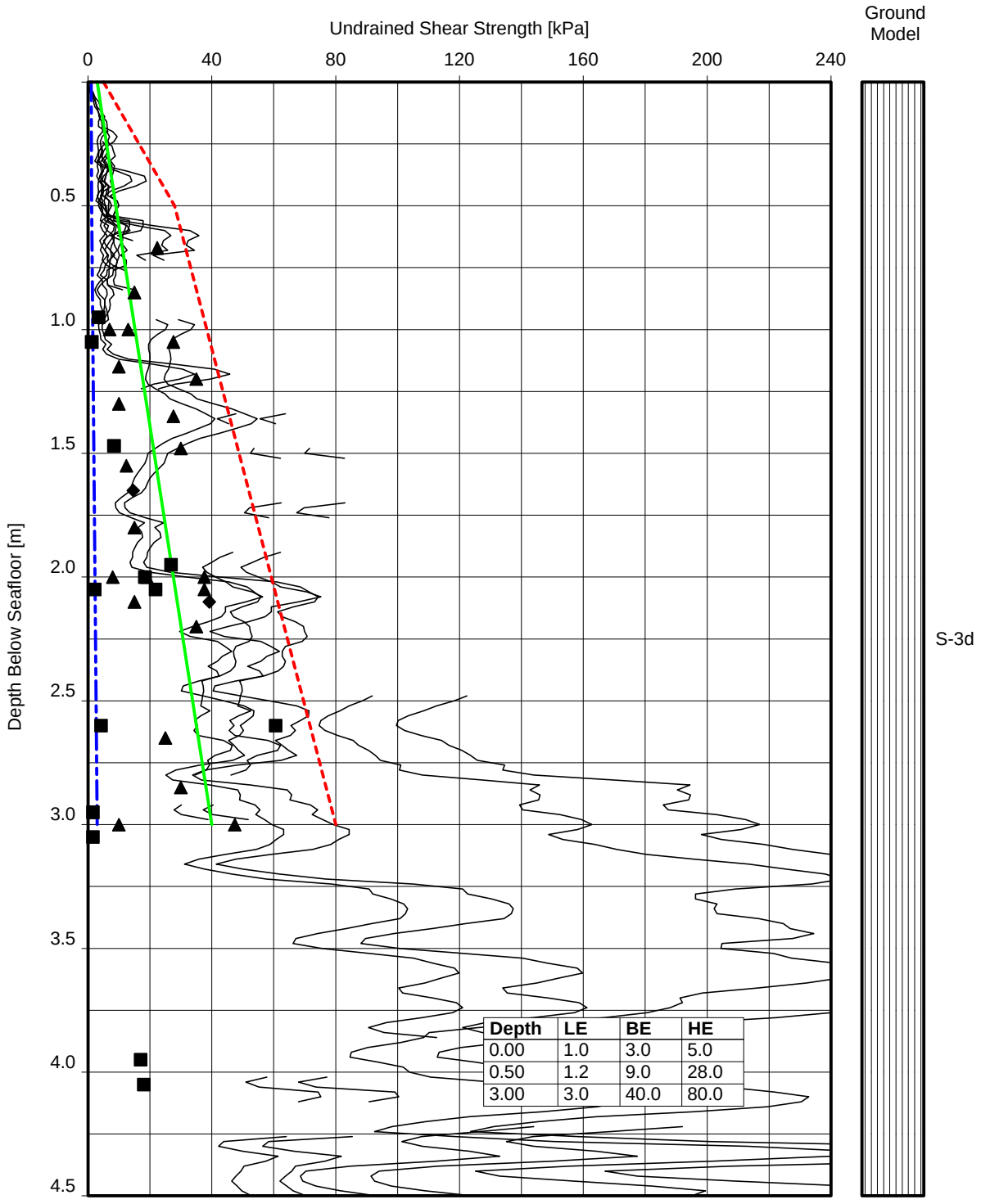
Note(s):
- N_k = 15 and N_k = 20 are used to derive c_u from CPT
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNDRAINED SHEAR STRENGTH VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-1



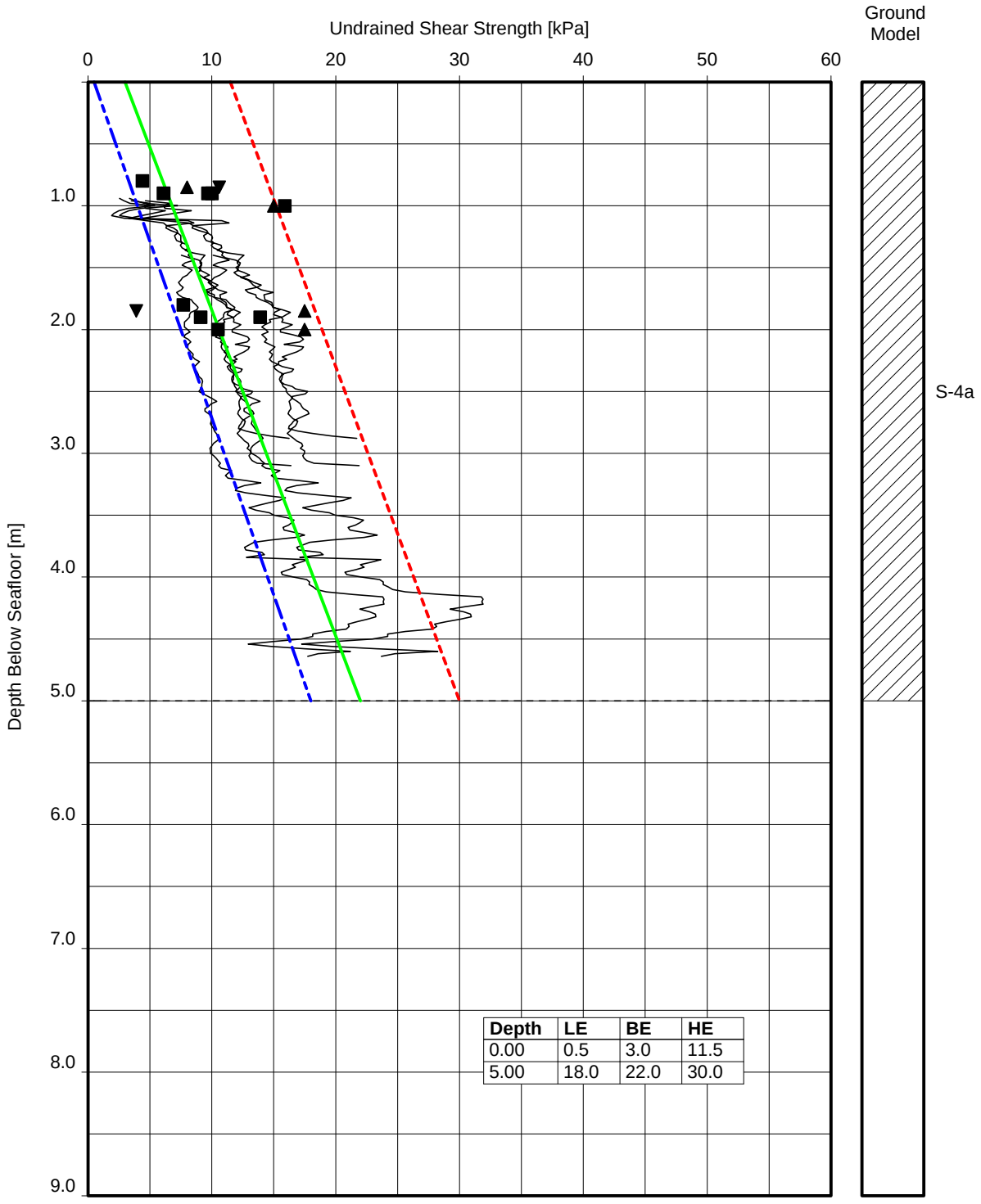
Note(s):
- N_k = 15 and N_k = 20 are used to derive c_u from CPT
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNDRAINED SHEAR STRENGTH VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-2a



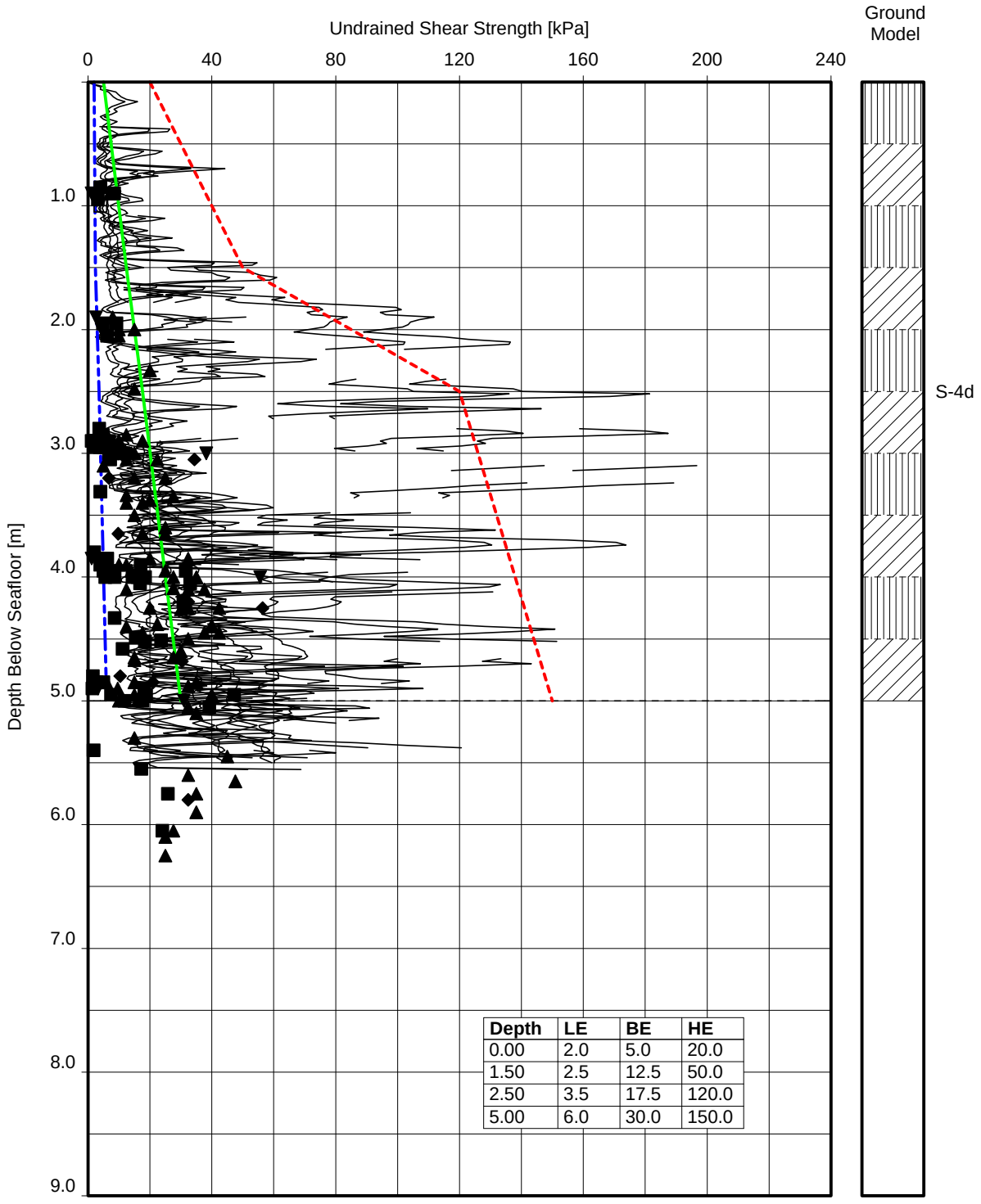
Note(s):
- N_k = 15 and N_k = 20 are used to derive c_u from CPT
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNDRAINED SHEAR STRENGTH VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-3d



Note(s):
- N_k = 15 and N_k = 20 are used to derive c_u from CPT
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

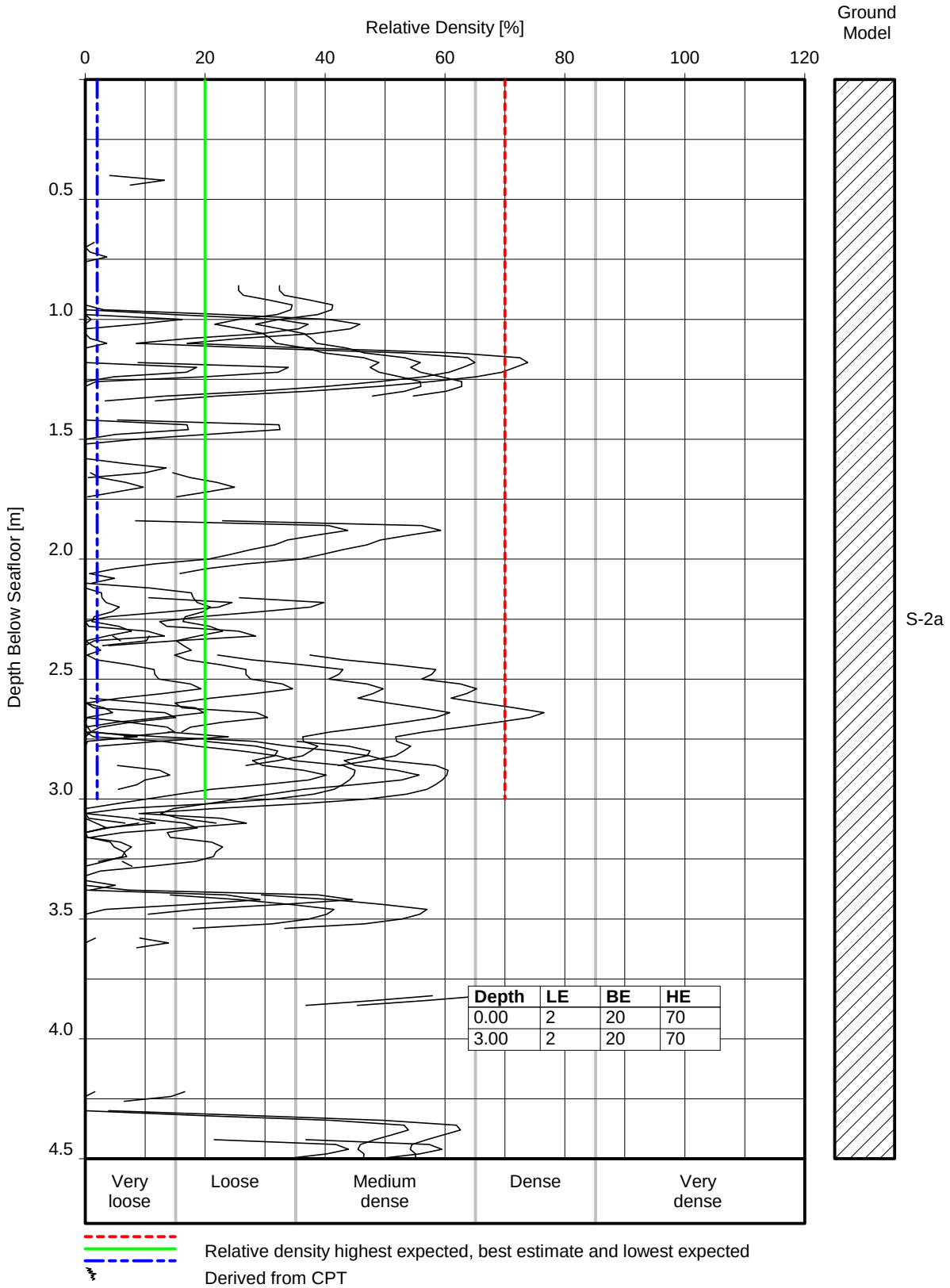
UNDRAINED SHEAR STRENGTH VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-4a



Depth	LE	BE	HE
0.00	2.0	5.0	20.0
1.50	2.5	12.5	50.0
2.50	3.5	17.5	120.0
5.00	6.0	30.0	150.0

Note(s):
- N_k = 15 and N_k = 20 are used to derive c_u from CPT
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNDRAINED SHEAR STRENGTH VERSUS DEPTH
To Shore Pipeline Route
Pipeline Geotechnical Unit S-4d

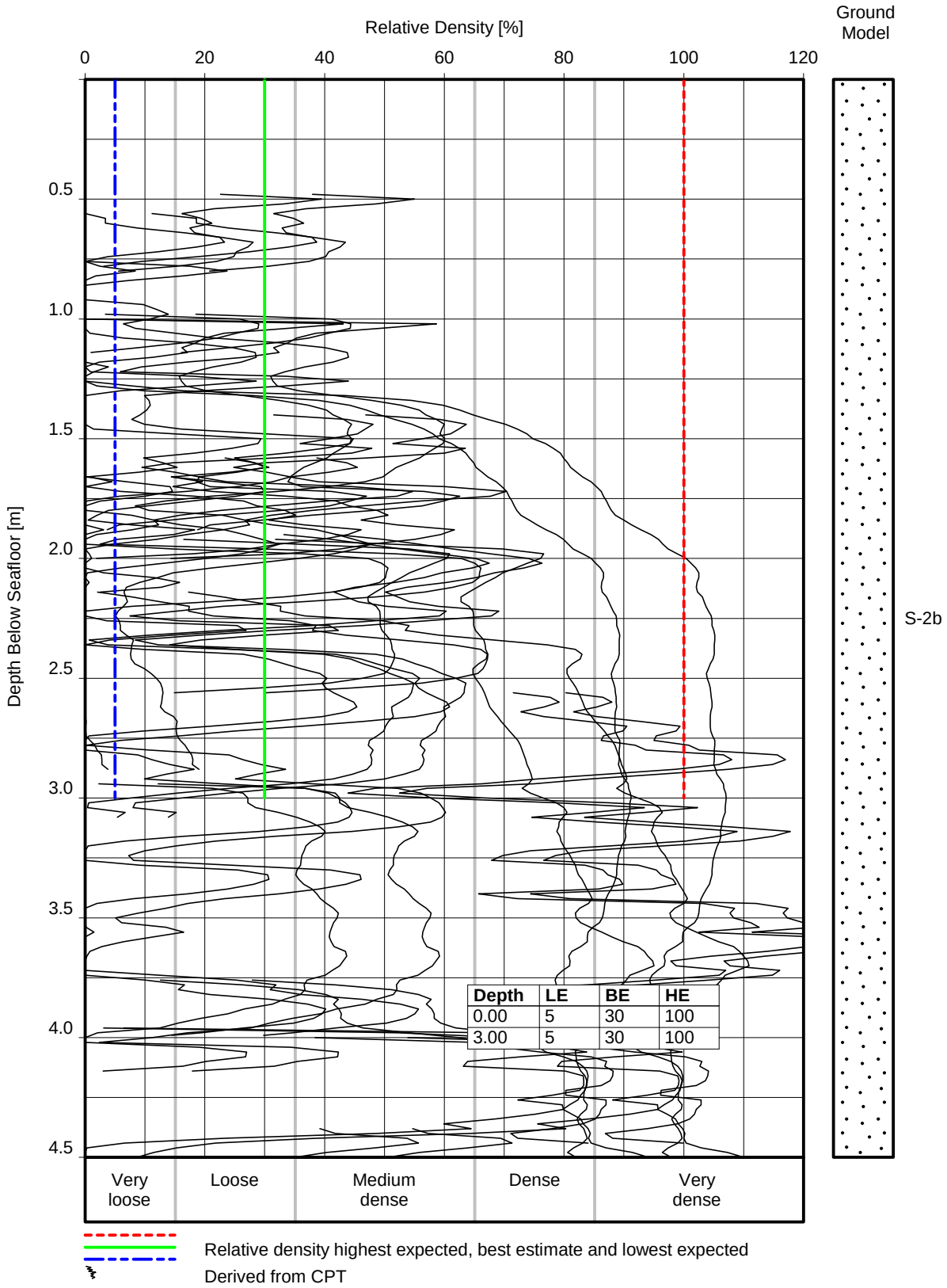


Depth	LE	BE	HE
0.00	2	20	70
3.00	2	20	70

Note(s):
- K_0 = 0.5 and K_0 = 2.0 are used to derive relative density from CPT
- Depth of interest: 3m for suface laid and 5m for trenched. See report section 1.3

RELATIVE DENSITY VERSUS DEPTH

To Shore Pipeline Route
Pipeline Geotechnical Unit S-2a

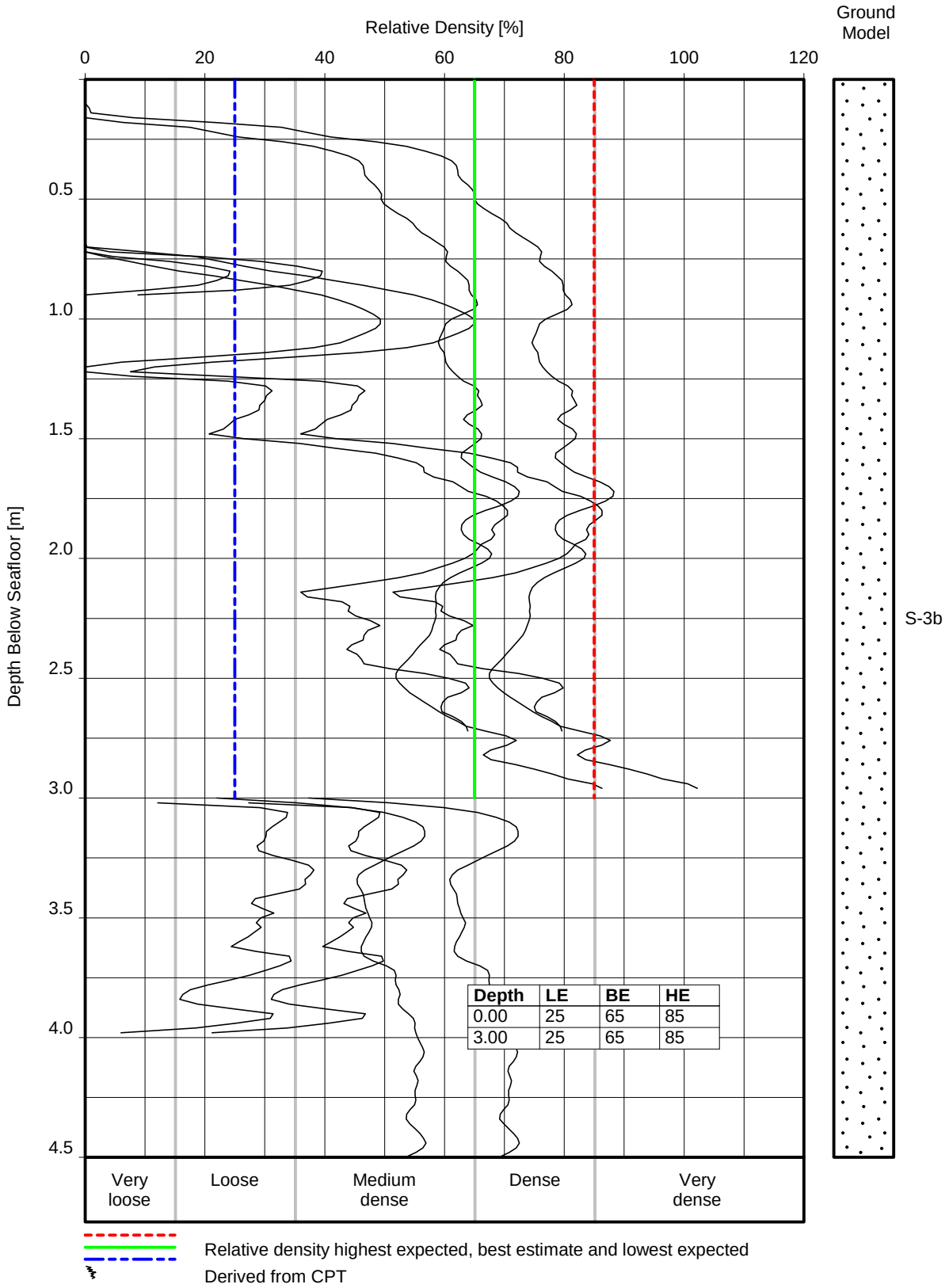


Depth	LE	BE	HE
0.00	5	30	100
3.00	5	30	100

Note(s):
- K_0 = 0.5 and K_0 = 2.0 are used to derive relative density from CPT
- Depth of interest: 3m for suface laid and 5m for trenched. See report section 1.3

RELATIVE DENSITY VERSUS DEPTH

To Shore Pipeline Route
Pipeline Geotechnical Unit S-2b

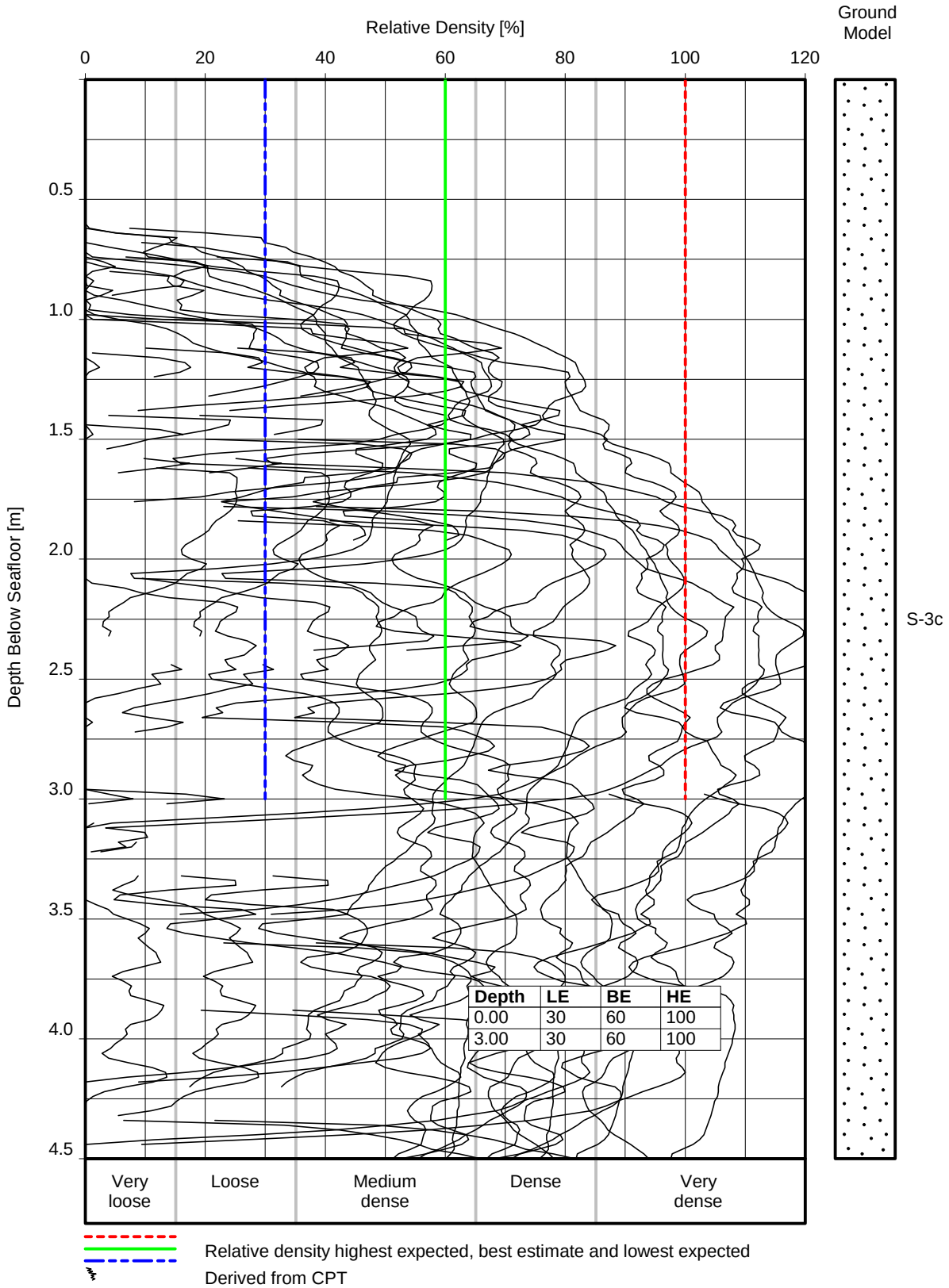


Depth	LE	BE	HE
0.00	25	65	85
3.00	25	65	85

Note(s):
- K_0 = 0.5 and K_0 = 2.0 are used to derive relative density from CPT
- Depth of interest: 3m for suface laid and 5m for trenched. See report section 1.3

RELATIVE DENSITY VERSUS DEPTH

To Shore Pipeline Route
Pipeline Geotechnical Unit S-3b

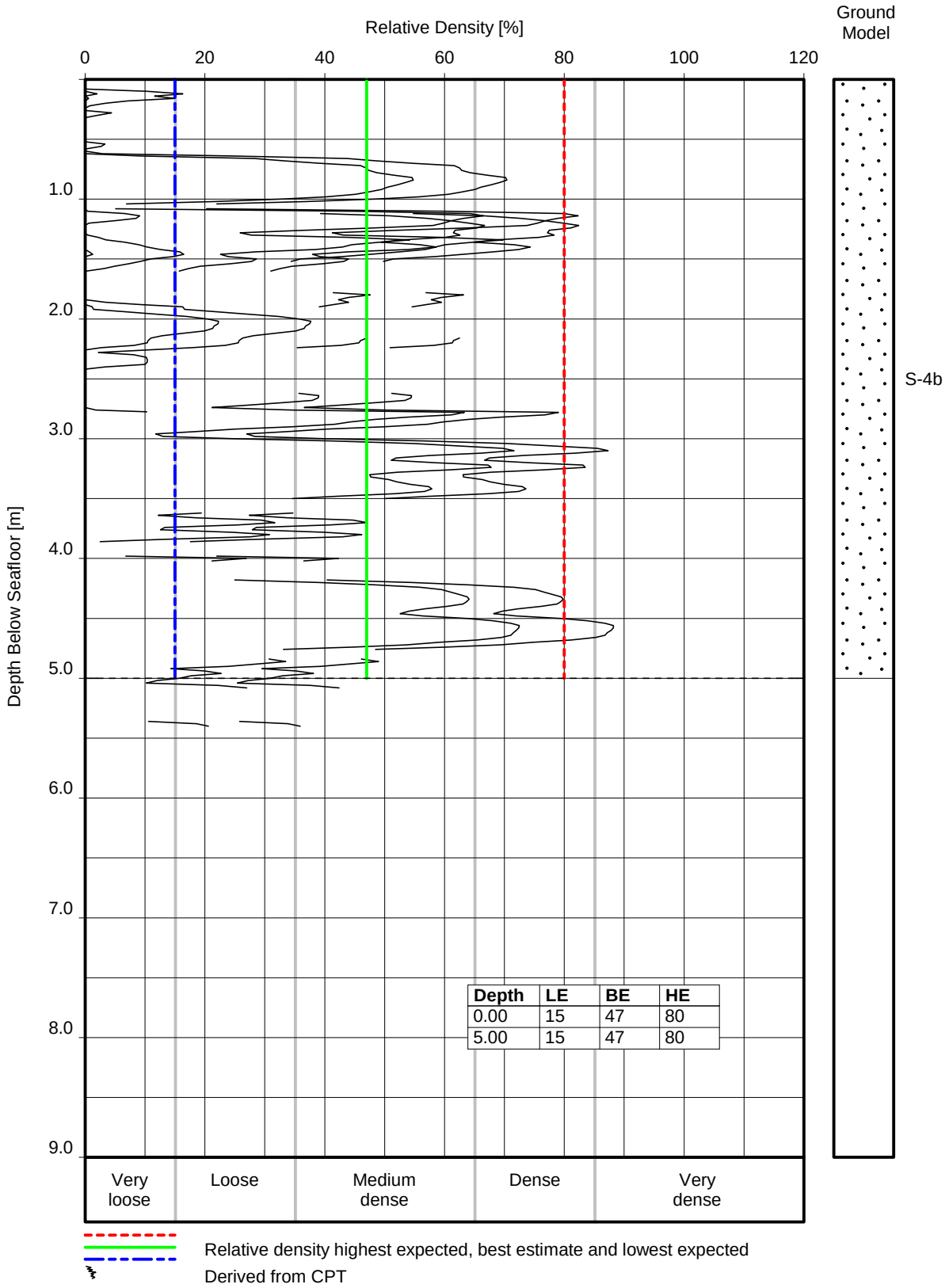


Depth	LE	BE	HE
0.00	30	60	100
3.00	30	60	100

Note(s):
- K_0 = 0.5 and K_0 = 2.0 are used to derive relative density from CPT
- Depth of interest: 3m for suface laid and 5m for trenched. See report section 1.3

RELATIVE DENSITY VERSUS DEPTH

To Shore Pipeline Route
Pipeline Geotechnical Unit S-3c

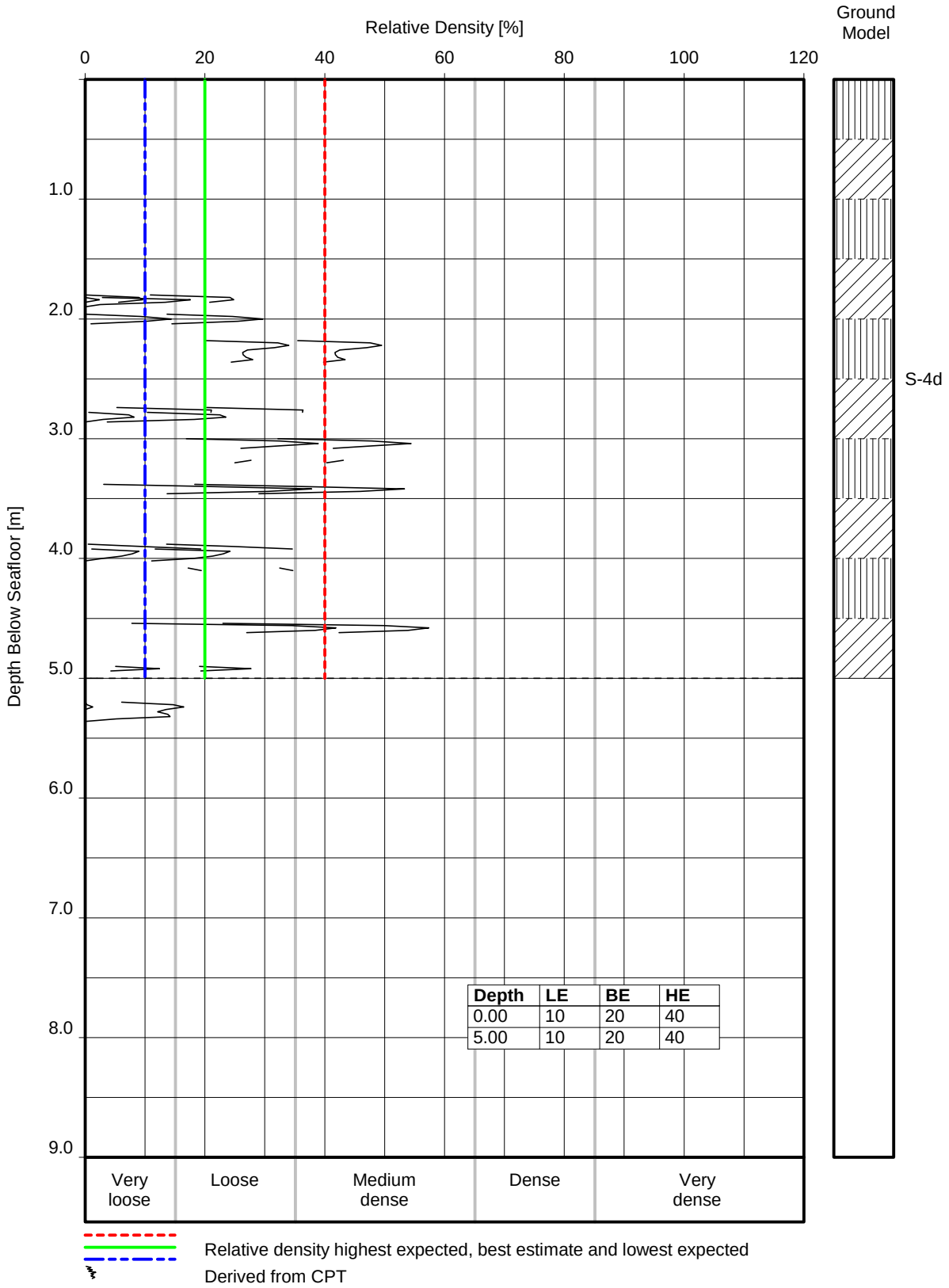


Depth	LE	BE	HE
0.00	15	47	80
5.00	15	47	80

Note(s):
- K_0 = 0.5 and K_0 = 2.0 are used to derive relative density from CPT
- Depth of interest: 3m for suface laid and 5m for trenched. See report section 1.3

RELATIVE DENSITY VERSUS DEPTH

To Shore Pipeline Route
Pipeline Geotechnical Unit S-4b



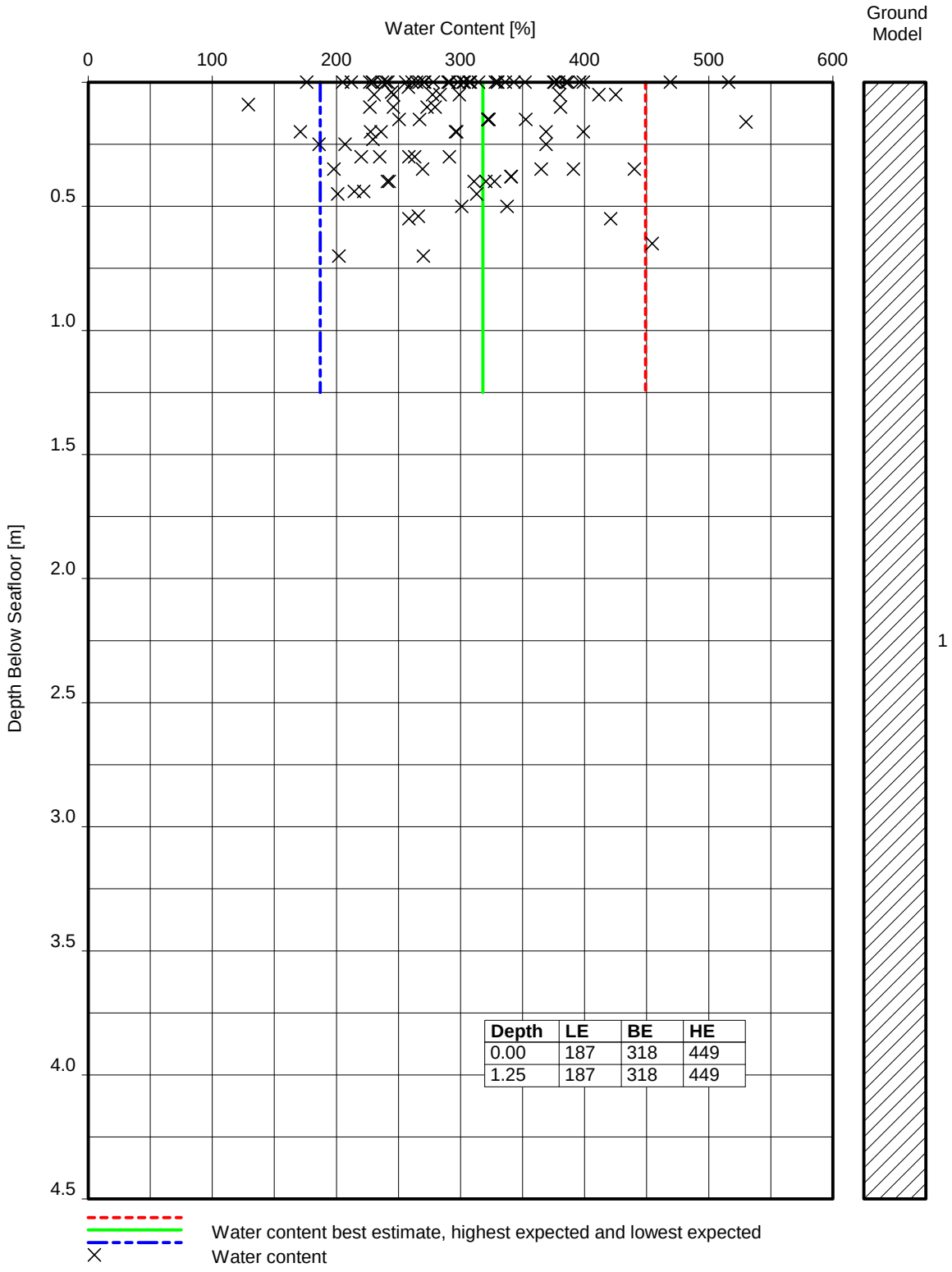
Depth	LE	BE	HE
0.00	10	20	40
5.00	10	20	40

Note(s):
- K_0 = 0.5 and K_0 = 2.0 are used to derive relative density from CPT
- Depth of interest: 3m for suface laid and 5m for trenched. See report section 1.3

RELATIVE DENSITY VERSUS DEPTH

To Shore Pipeline Route
Pipeline Geotechnical Unit S-4d

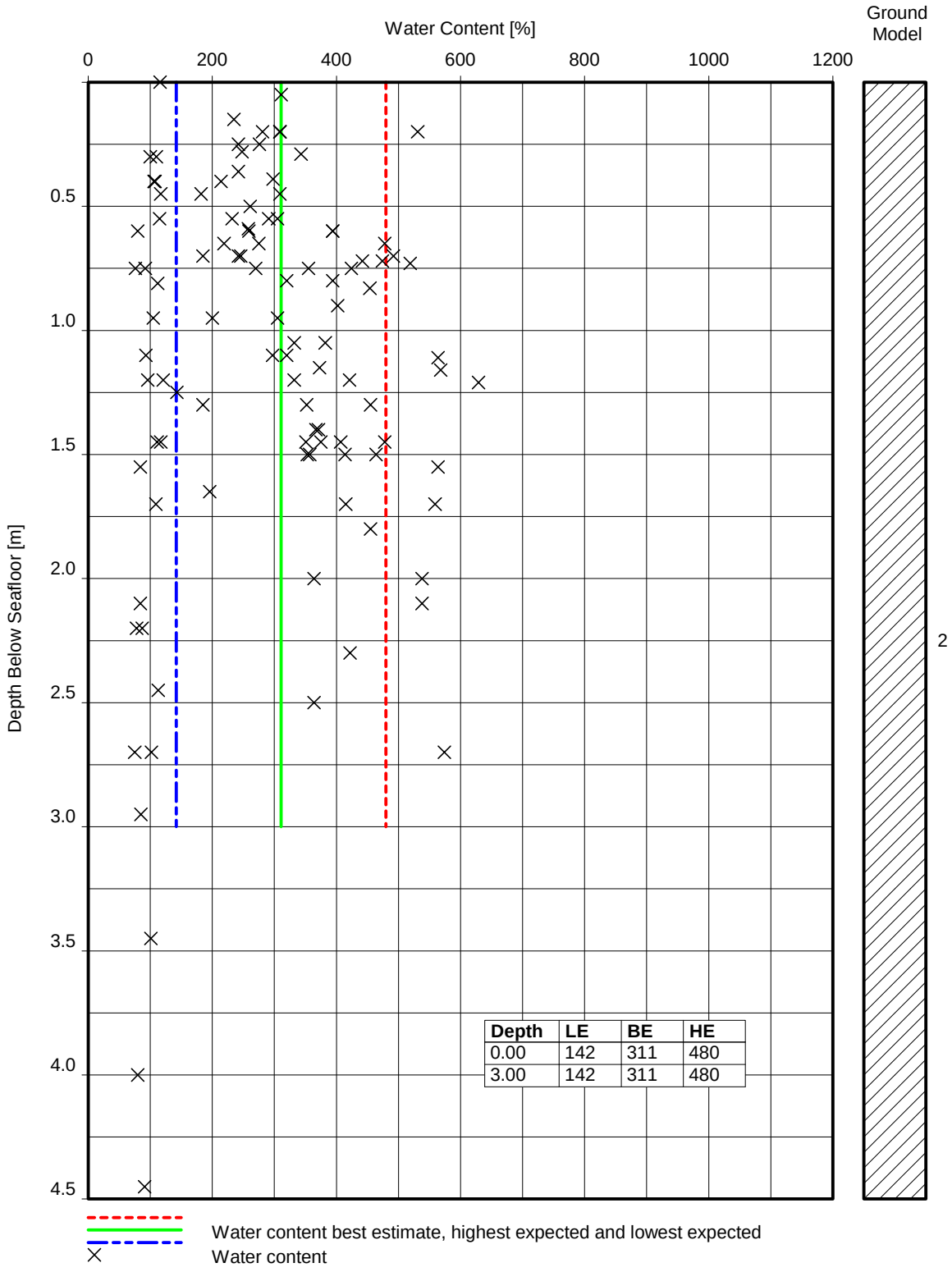
B.2 FLOWLINE PARAMETER PROFILES



Depth	LE	BE	HE
0.00	187	318	449
1.25	187	318	449

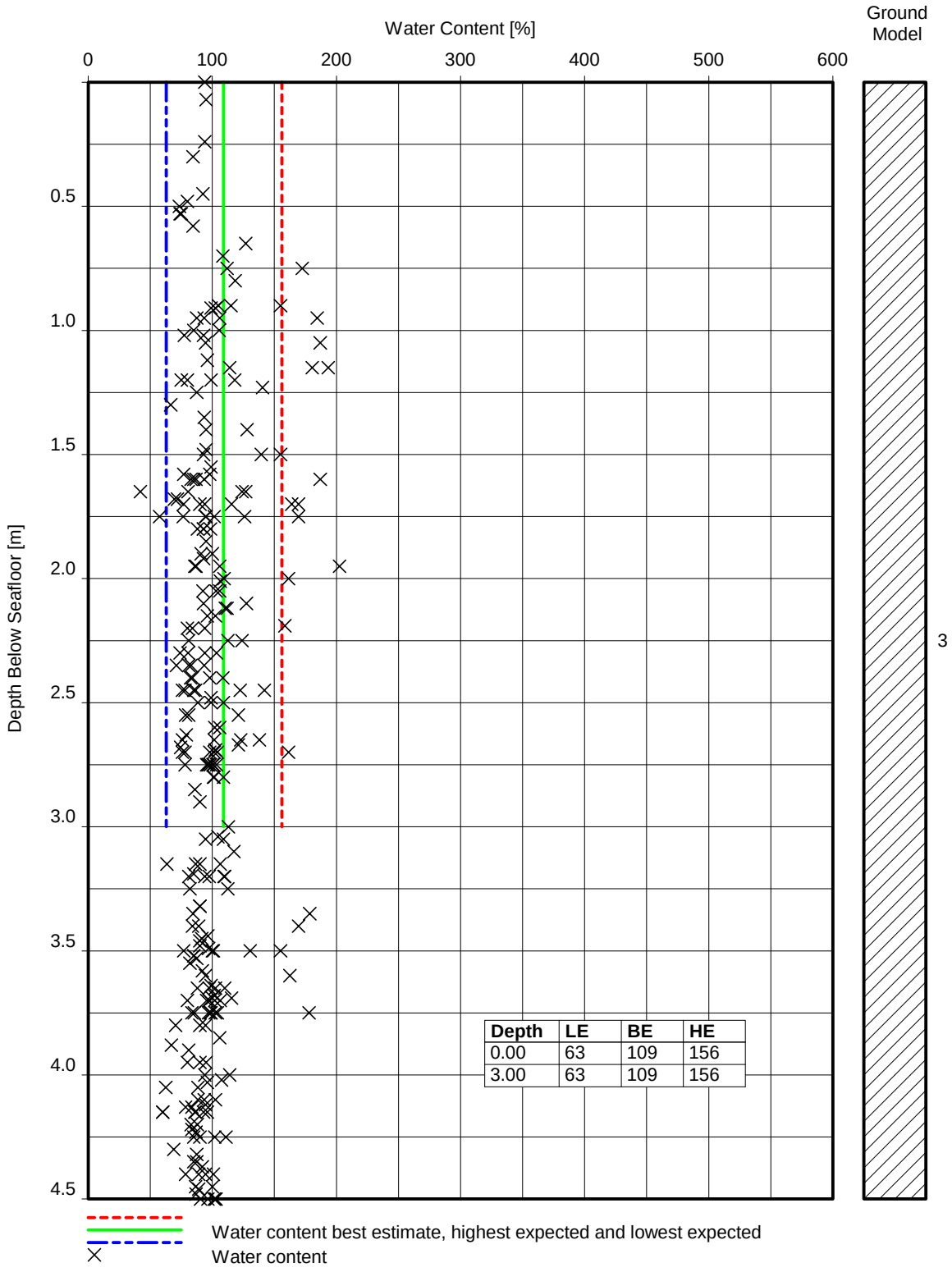
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

WATER CONTENT VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 1



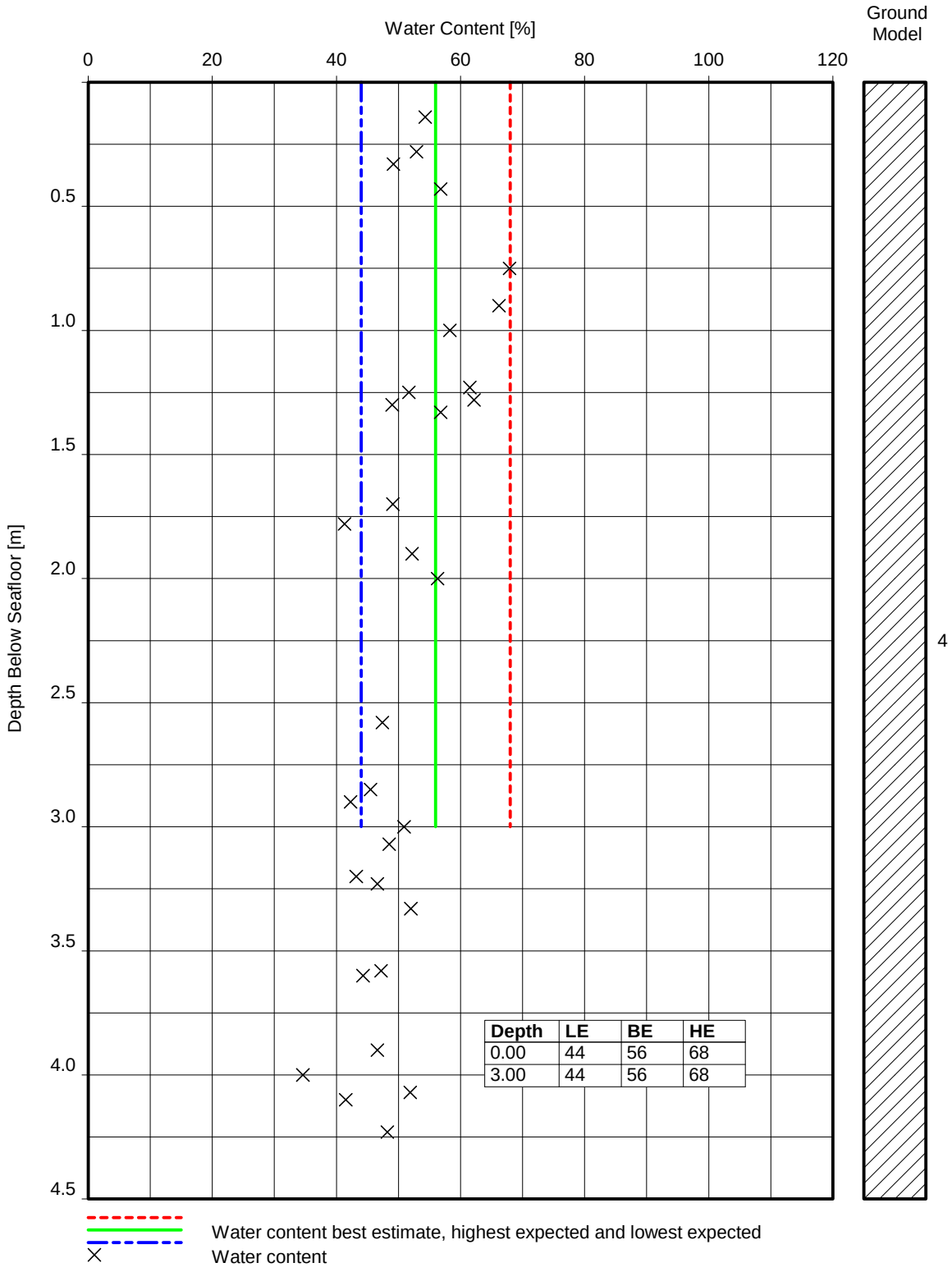
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

WATER CONTENT VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 2



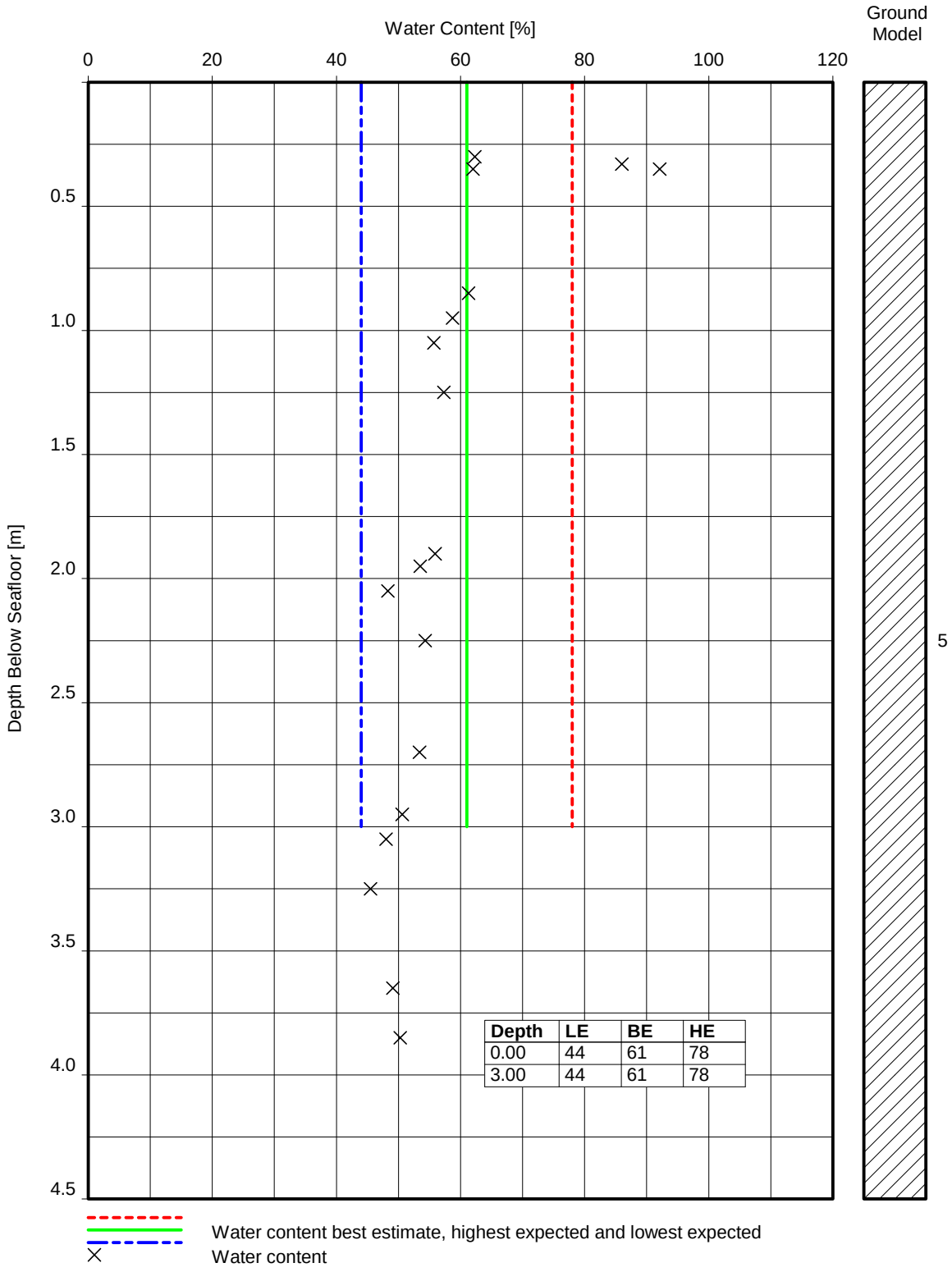
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

WATER CONTENT VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 3



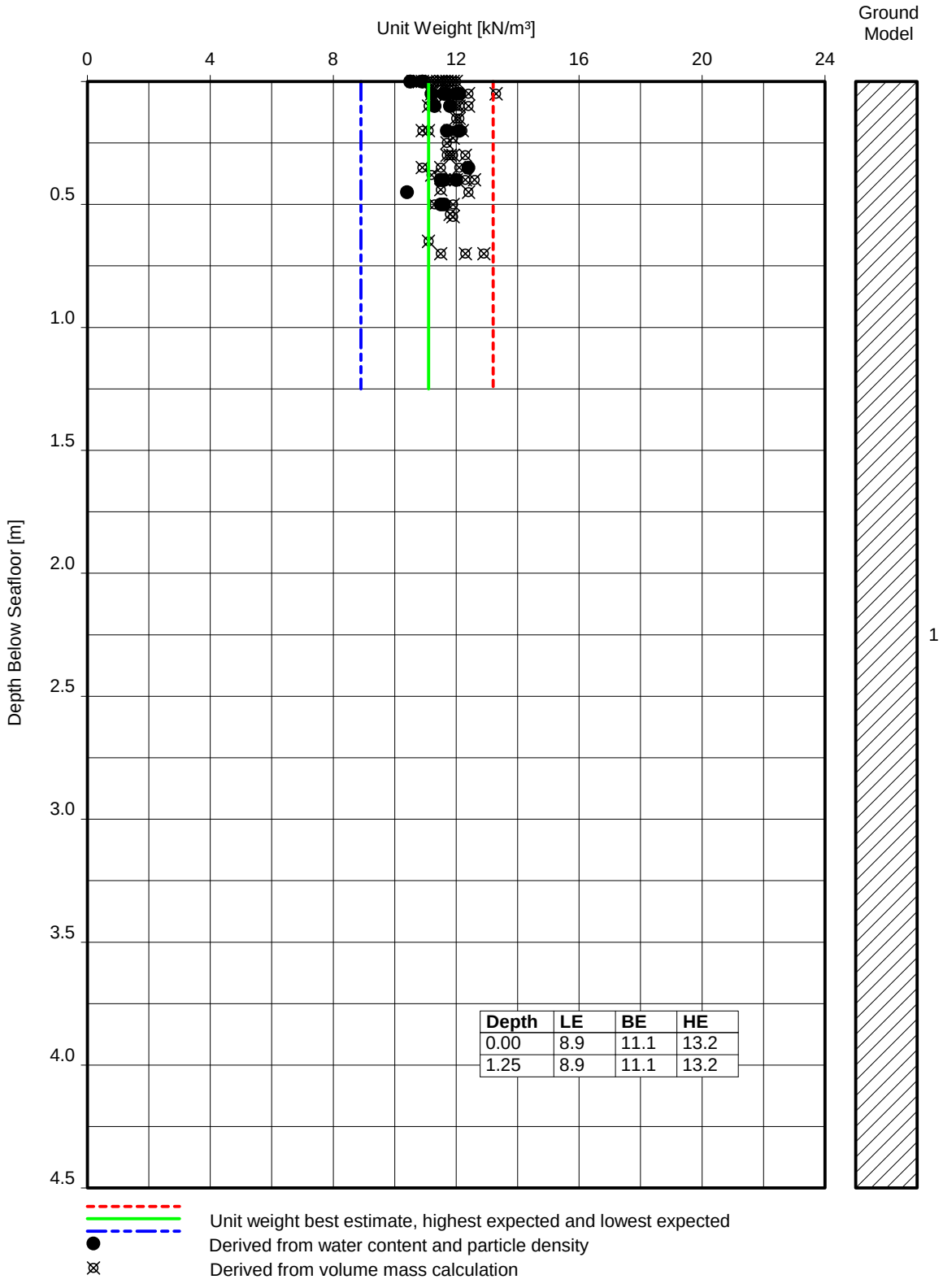
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

WATER CONTENT VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 4



Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

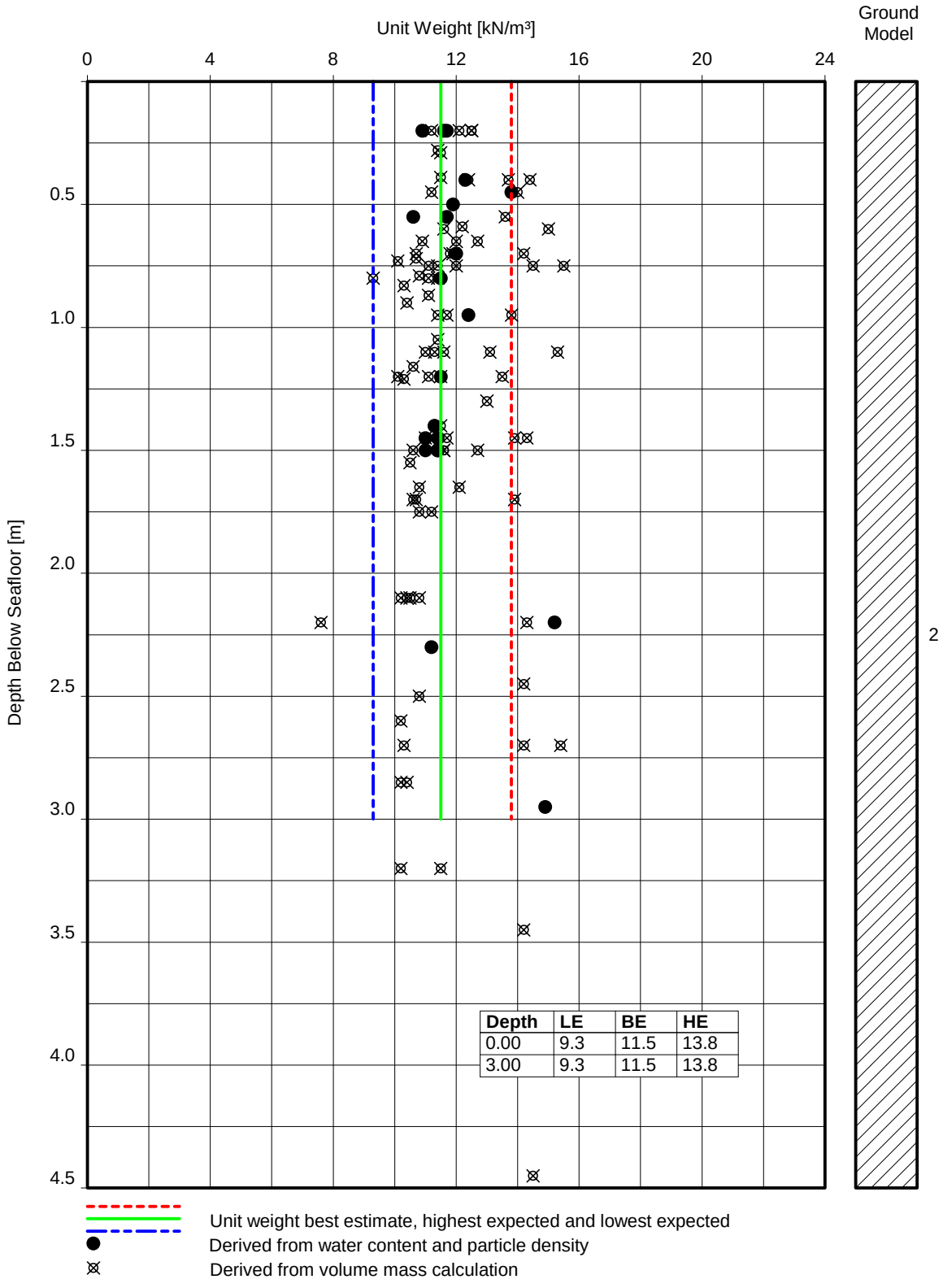
WATER CONTENT VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 5



Depth	LE	BE	HE
0.00	8.9	11.1	13.2
1.25	8.9	11.1	13.2

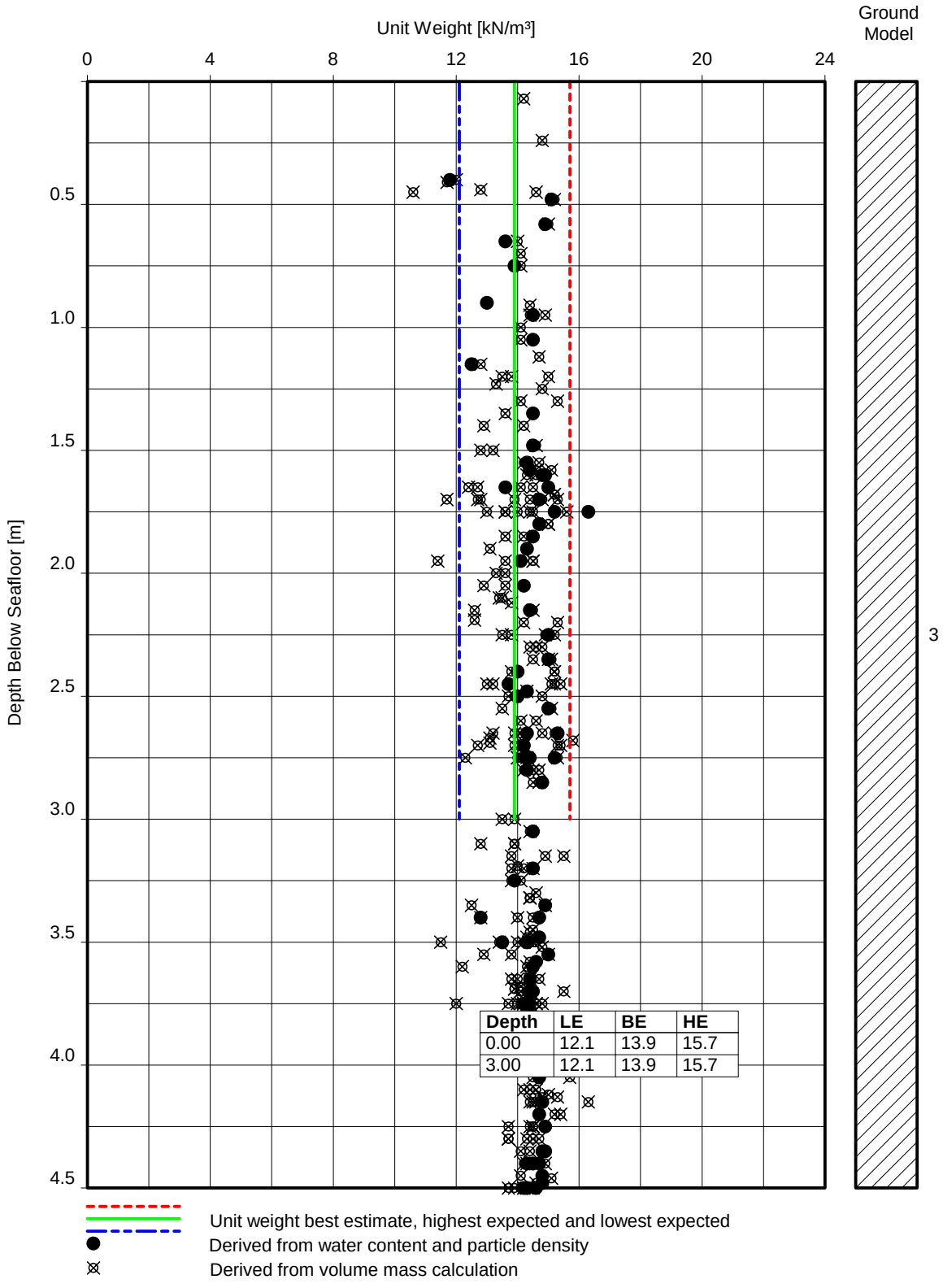
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 1



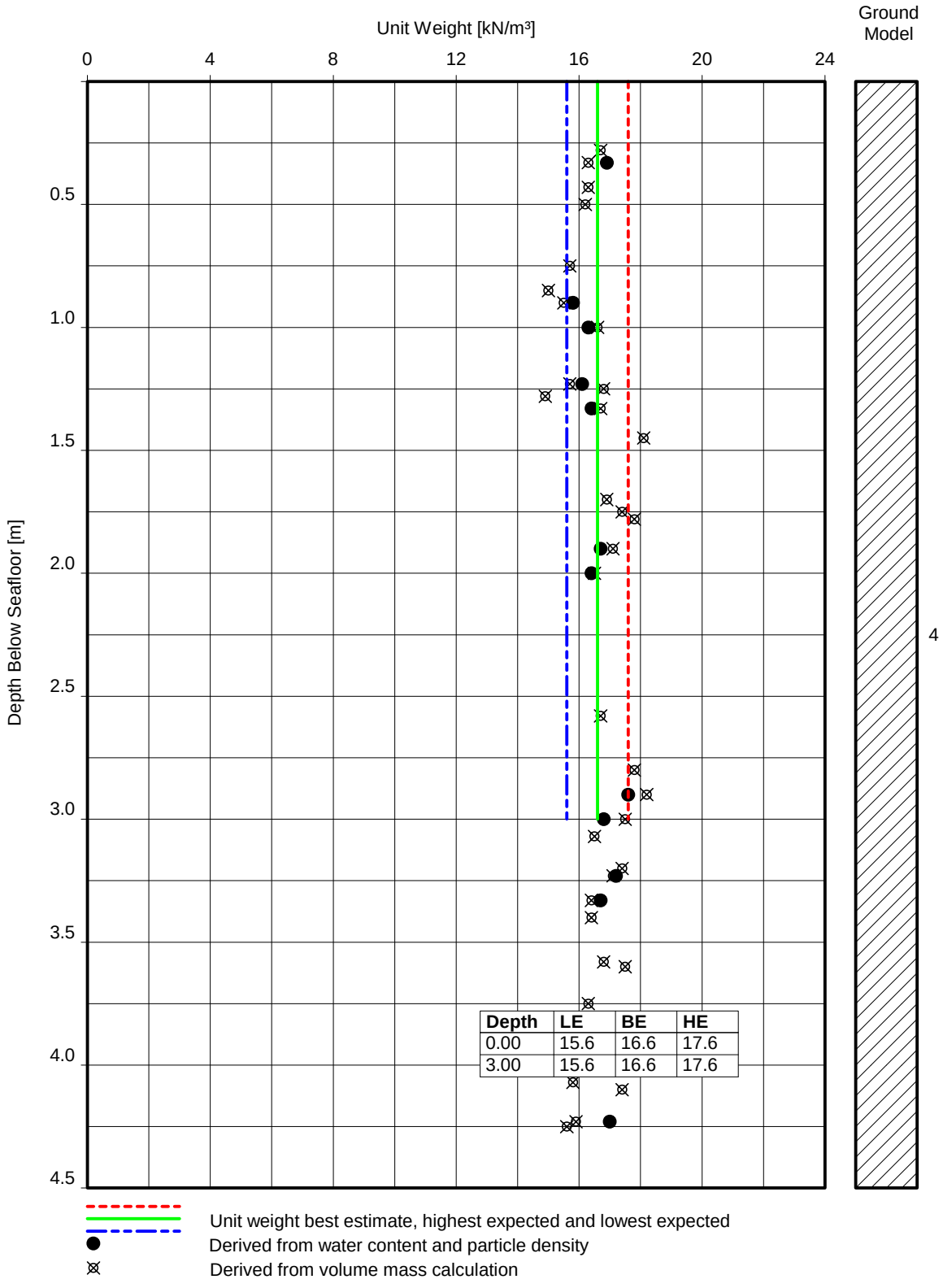
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 2



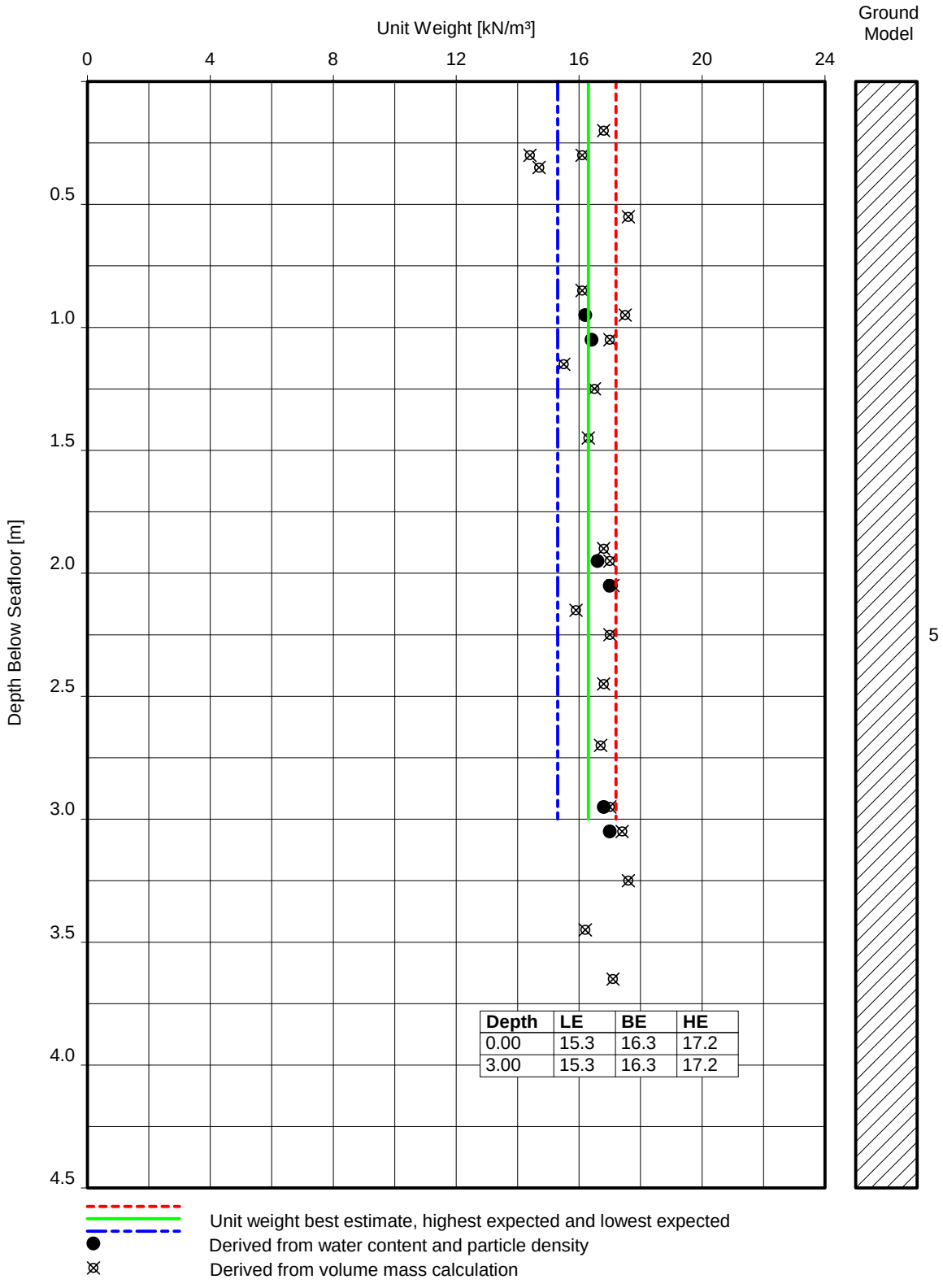
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 3



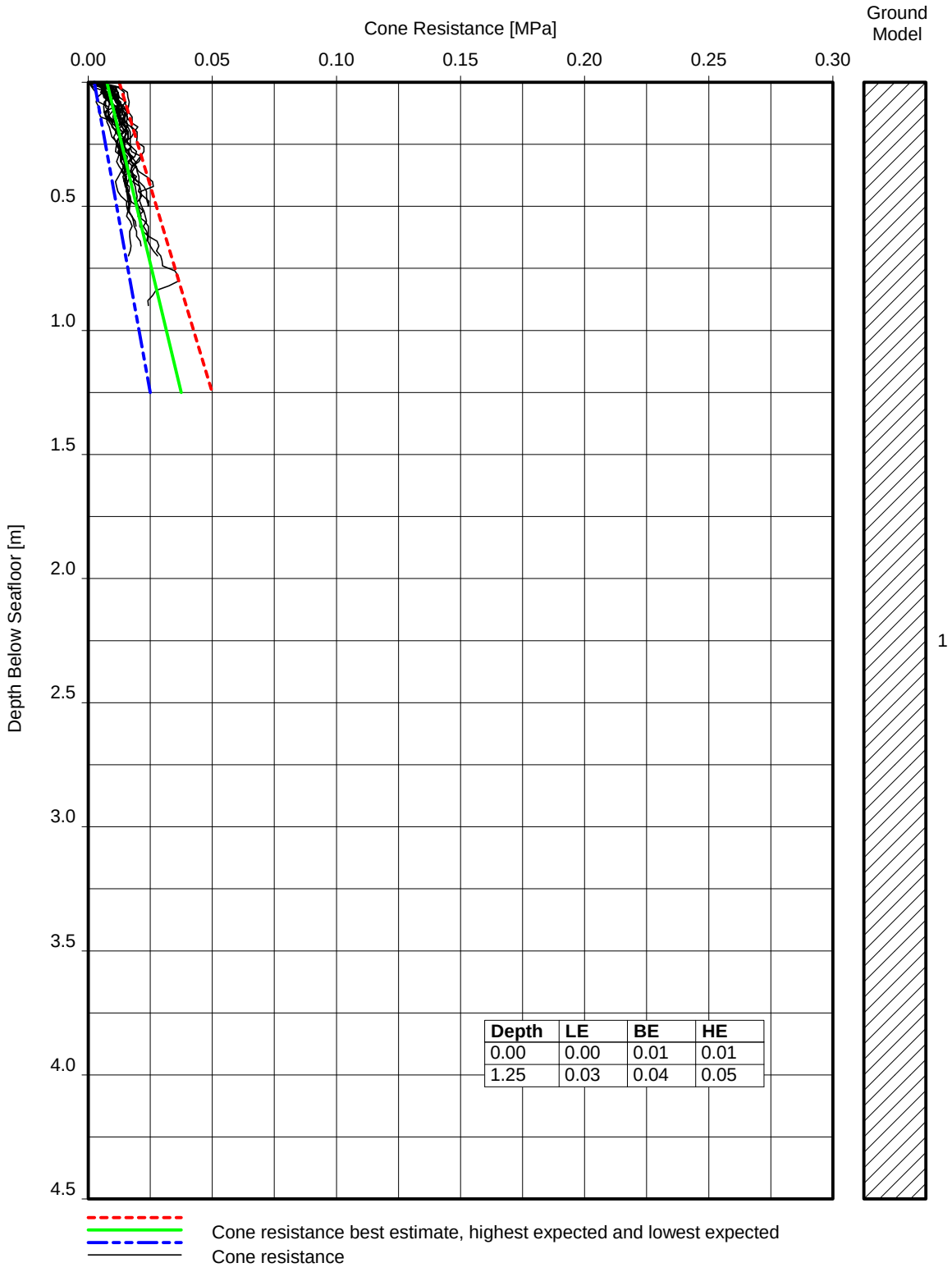
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 4



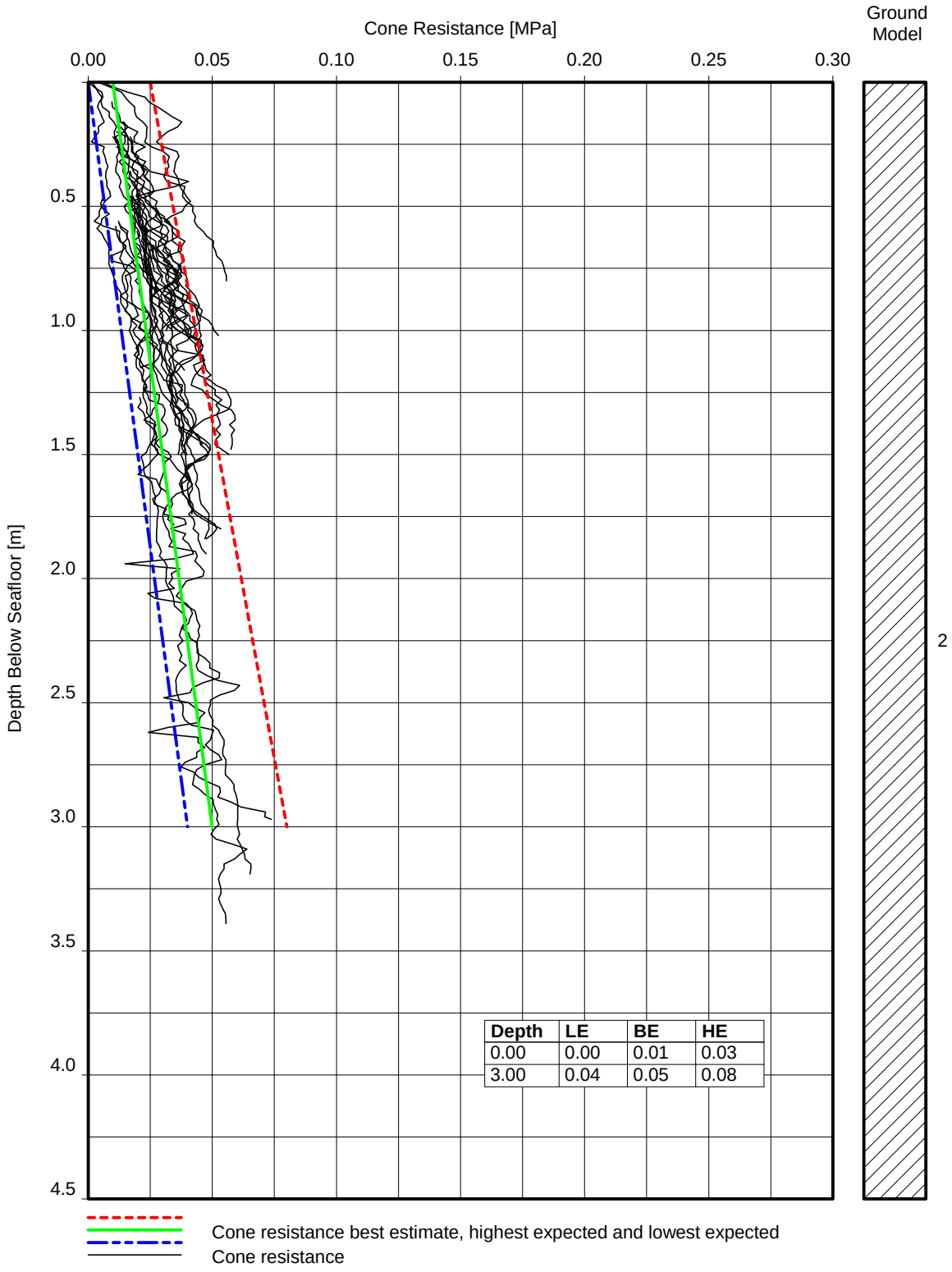
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNIT WEIGHT VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 5



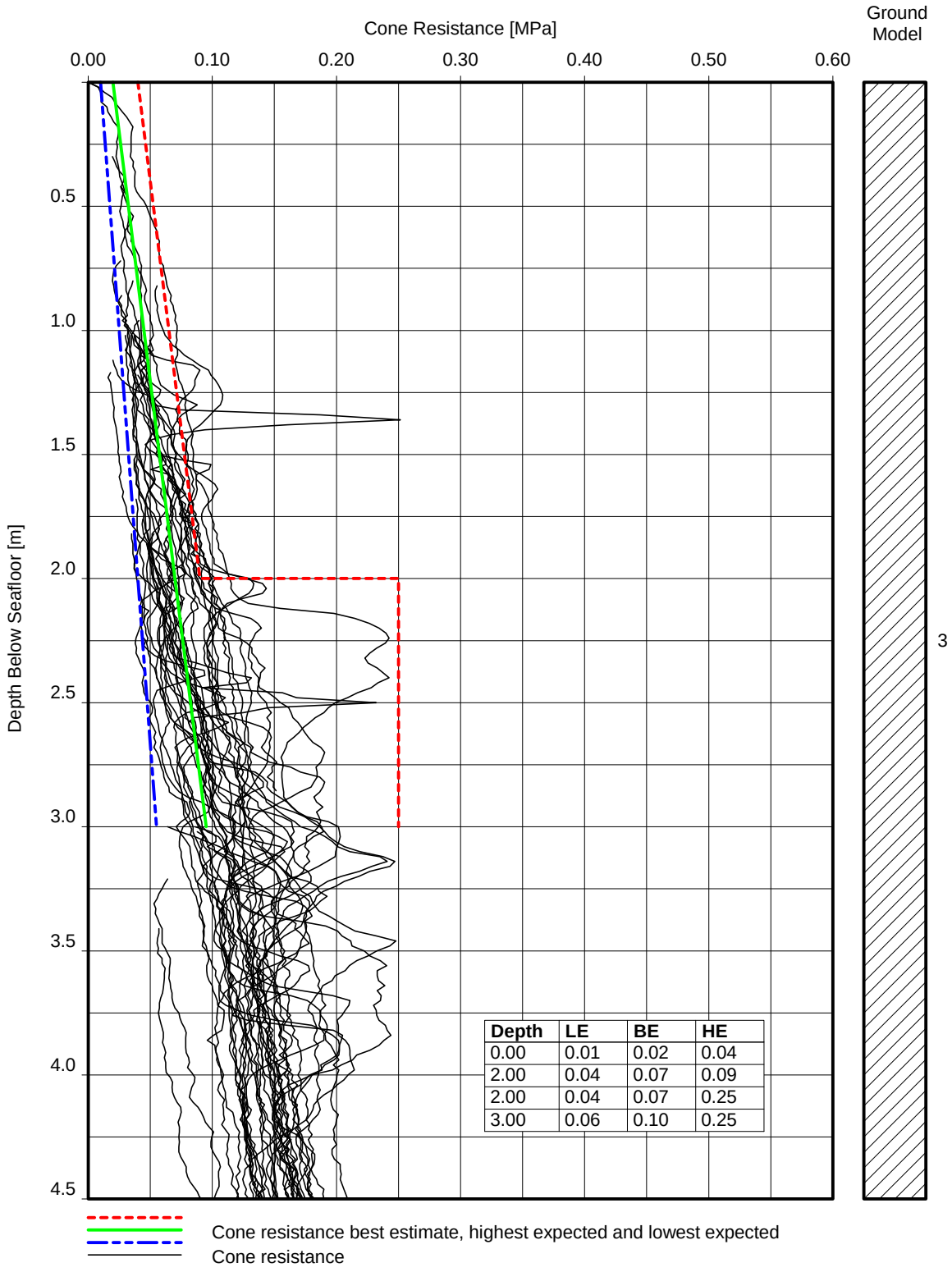
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 1



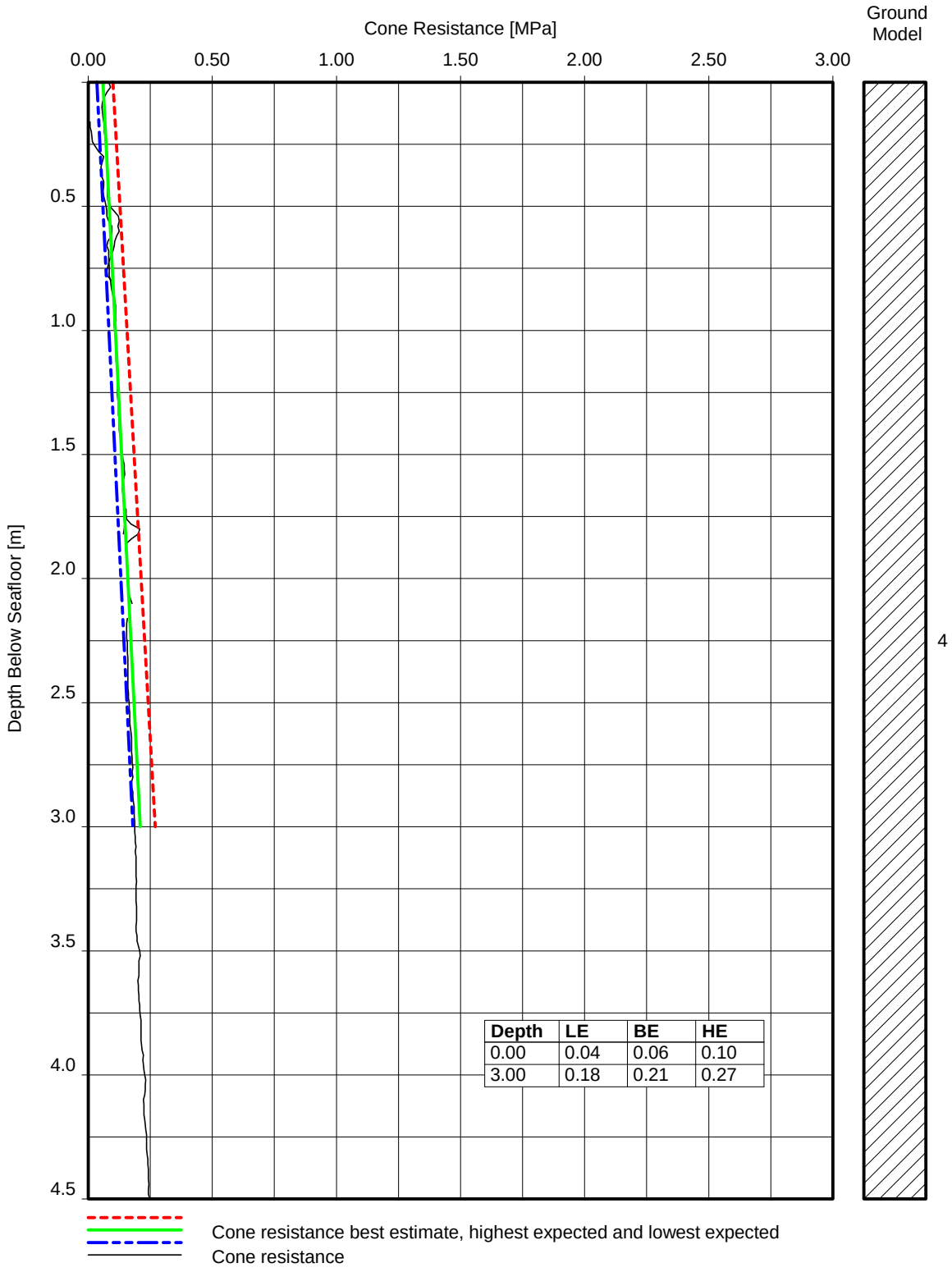
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 2



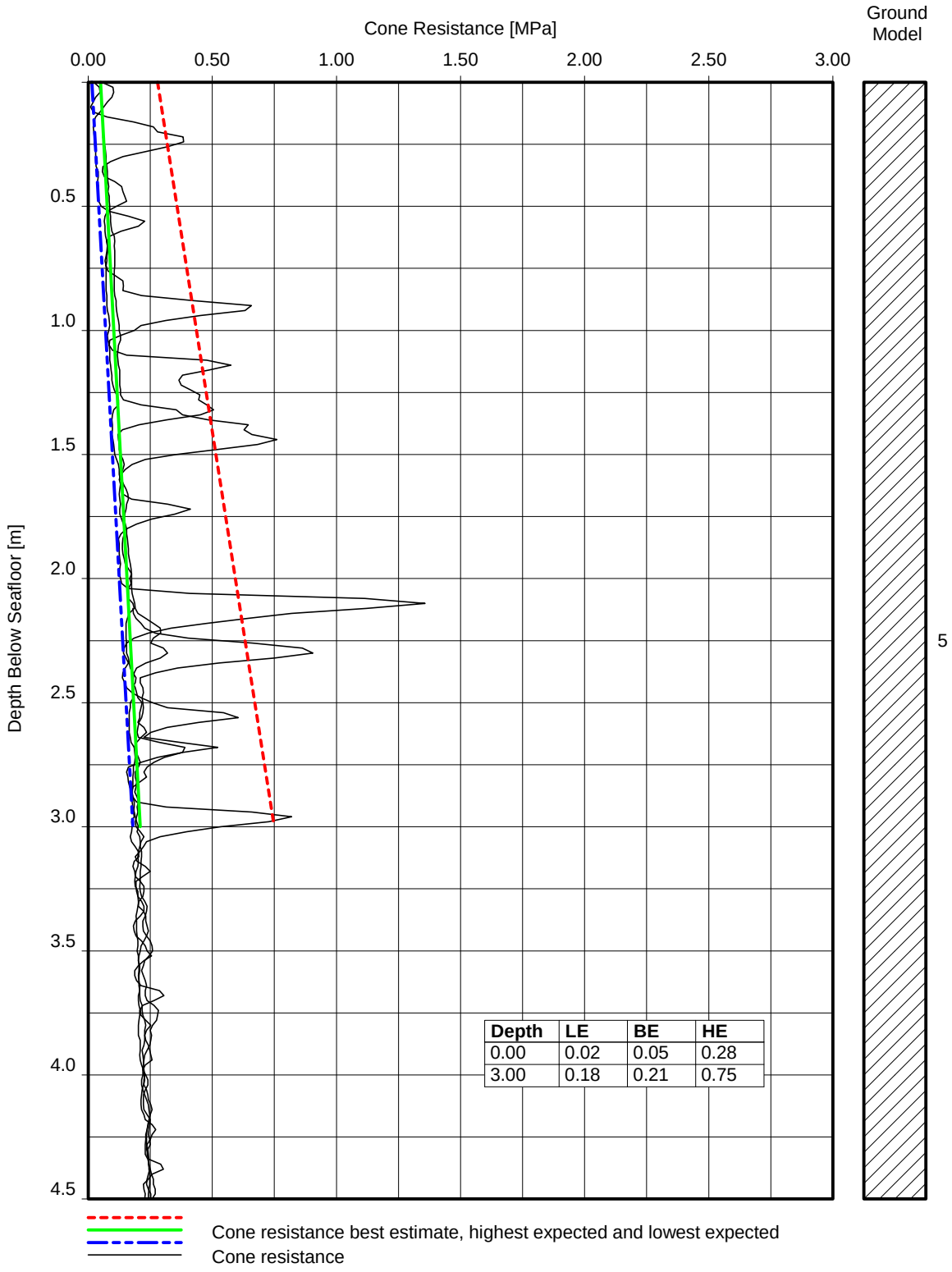
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 3



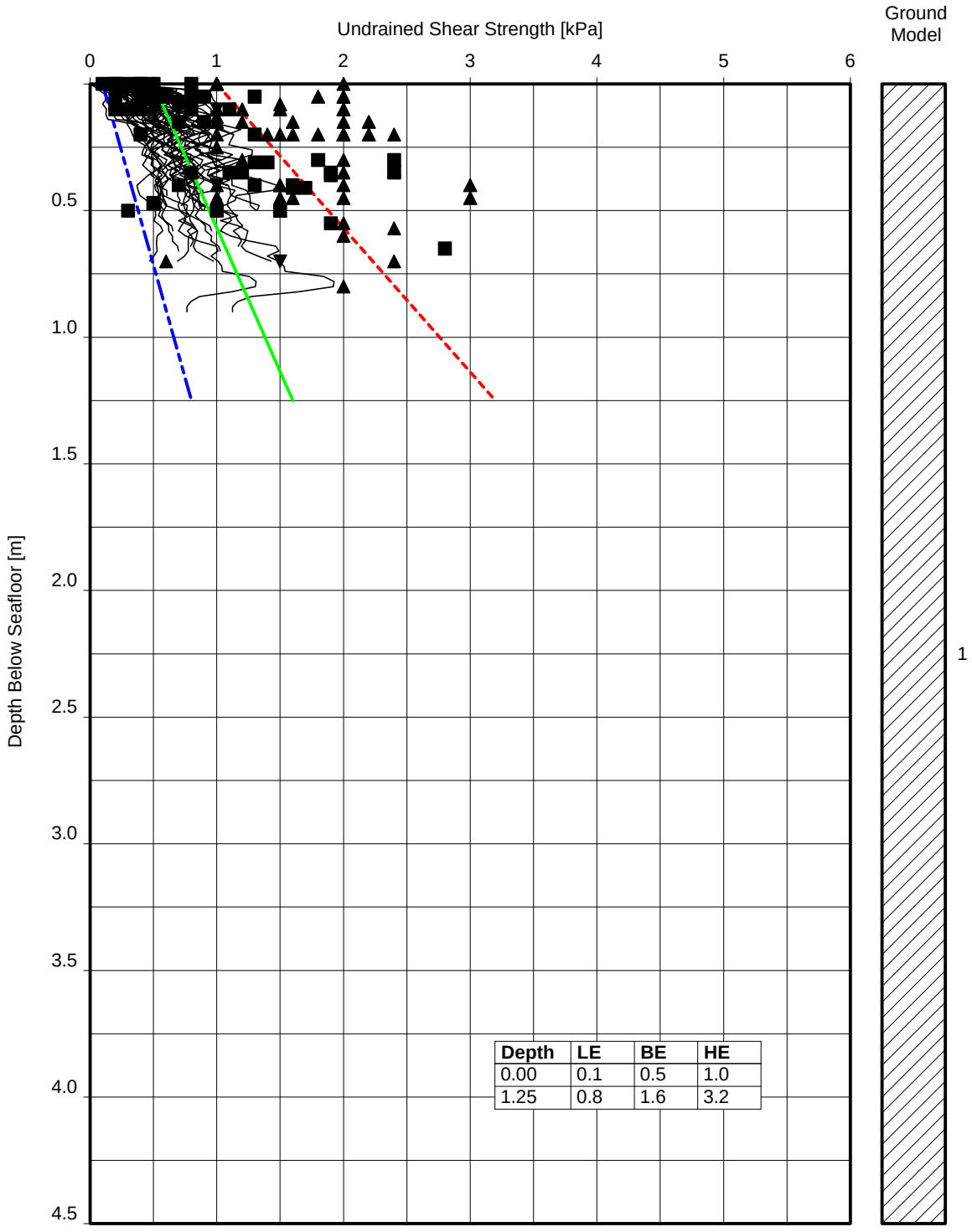
Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 4



Note(s):
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

CONE RESISTANCE VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 5



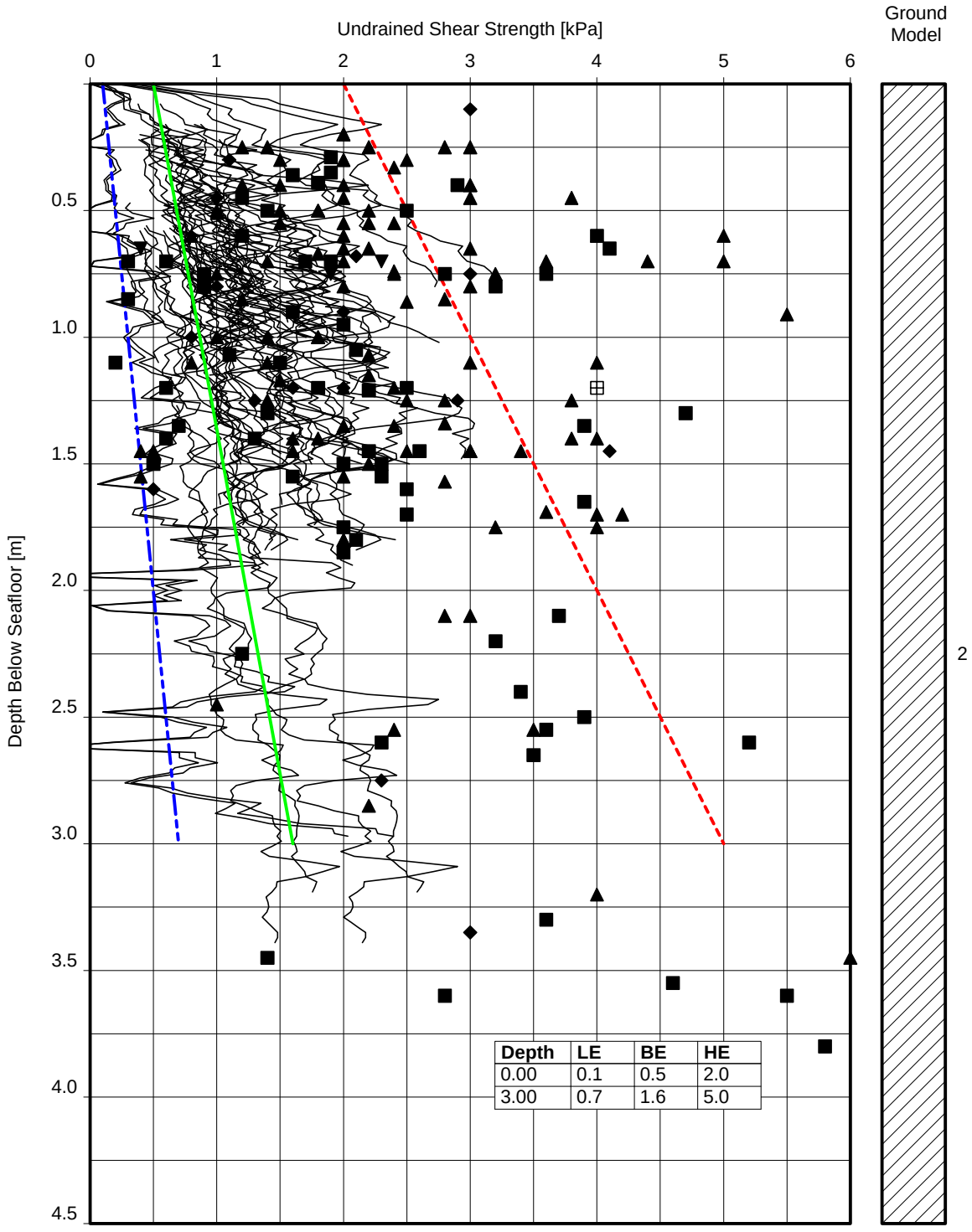
Depth	LE	BE	HE
0.00	0.1	0.5	1.0
1.25	0.8	1.6	3.2

Undrained shear strength, lowest expected, best estimate, highest expected

- Pocket penetrometer
- Torvane
- Fallcone
- Laboratory vane
- UU-triaxial
- CU-triaxial
- Direct simple shear
- Derived from CPT

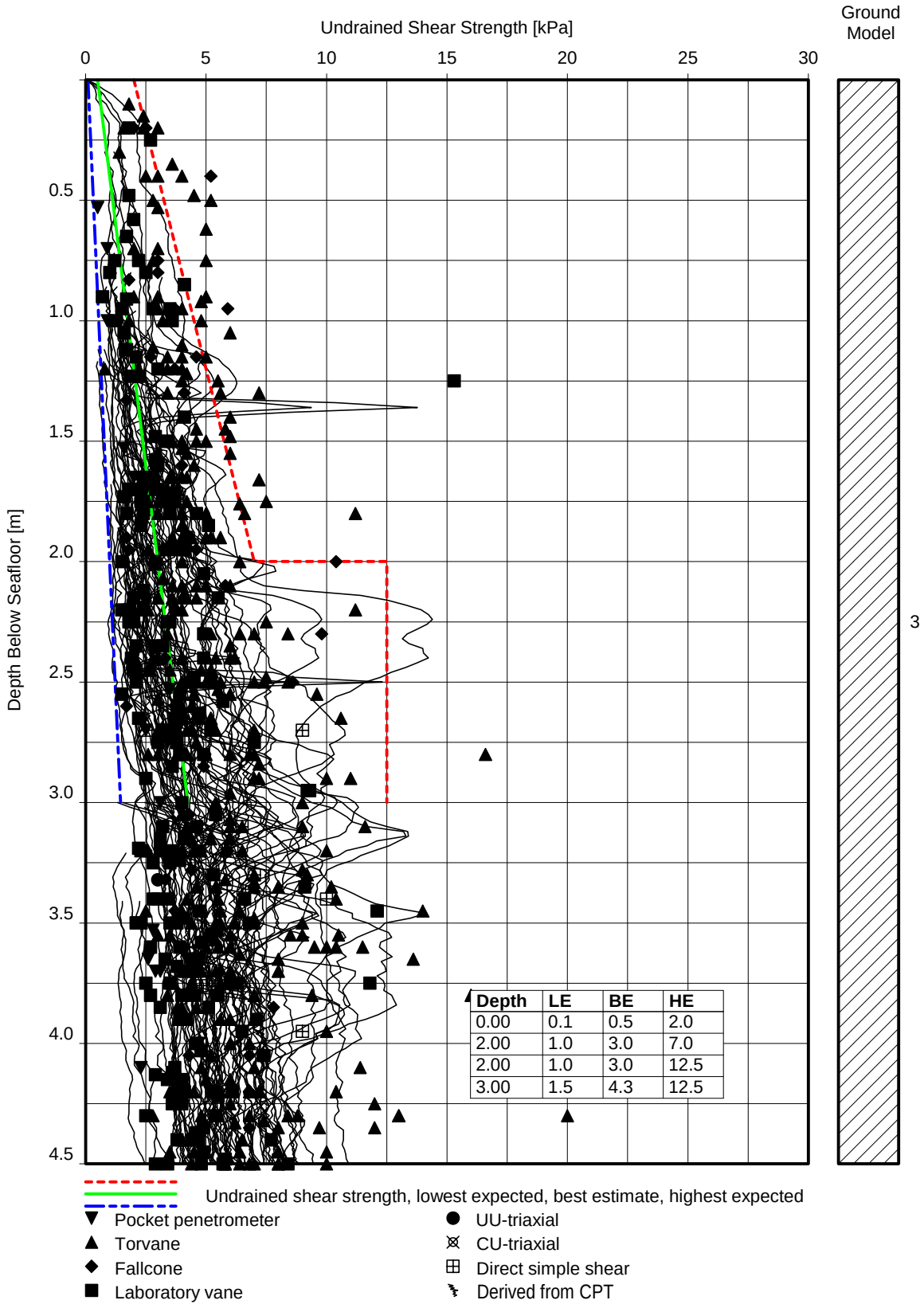
Note(s):
- N_k = 17 and N_k = 25 are used to derive c_u from CPT
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNDRAINED SHEAR STRENGTH VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 1



Note(s):
- N_k = 17 and N_k = 25 are used to derive c_u from CPT
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

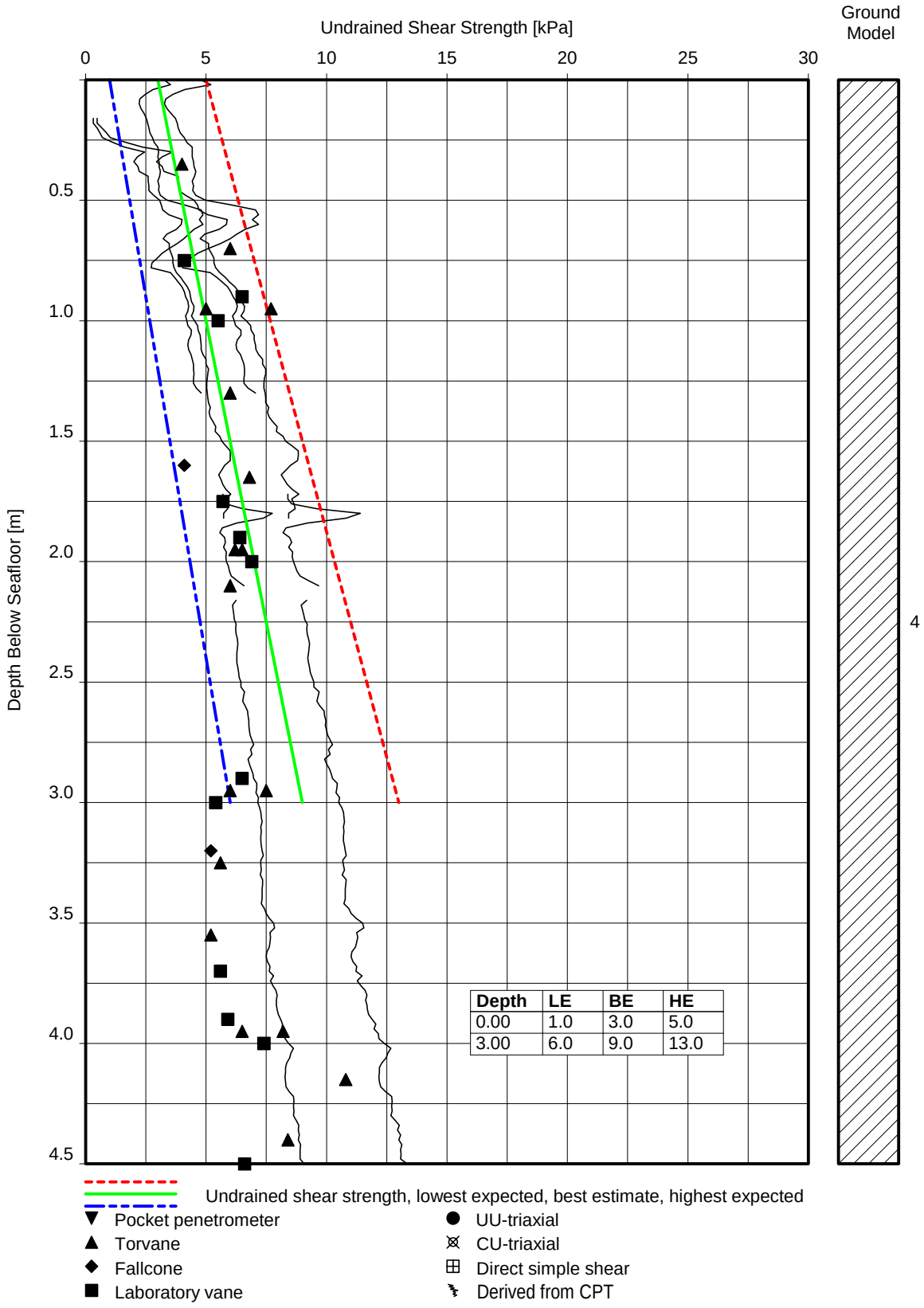
UNDRAINED SHEAR STRENGTH VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 2



Depth	LE	BE	HE
0.00	0.1	0.5	2.0
2.00	1.0	3.0	7.0
2.00	1.0	3.0	12.5
3.00	1.5	4.3	12.5

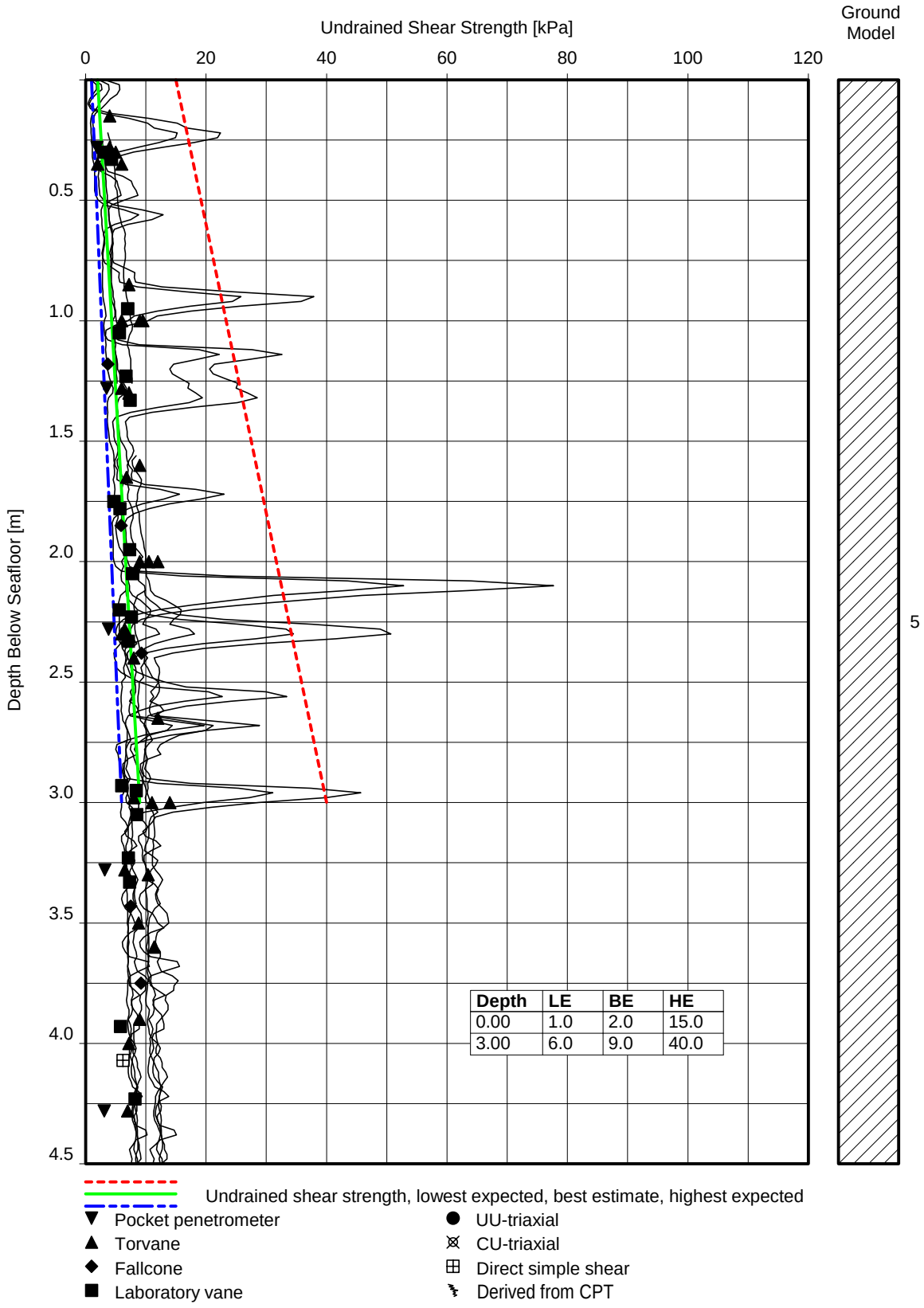
Note(s):
- N_k = 17 and N_k = 25 are used to derive c_u from CPT
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNDRAINED SHEAR STRENGTH VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 3



Note(s):
- N_k = 17 and N_k = 25 are used to derive c_u from CPT
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNDRAINED SHEAR STRENGTH VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 4



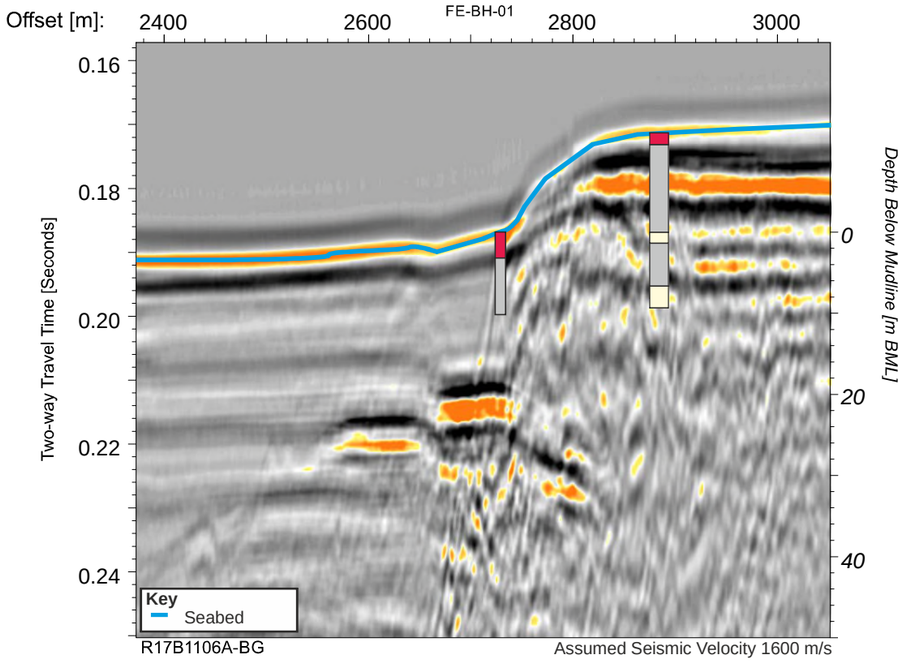
Note(s):
- N_k = 17 and N_k = 25 are used to derive c_u from CPT
- Depth of interest: 3m for surface laid and 5m for trenched. See report section 1.3

UNDRAINED SHEAR STRENGTH VERSUS DEPTH
Domino Flowline Route
Geotechnical Unit 5

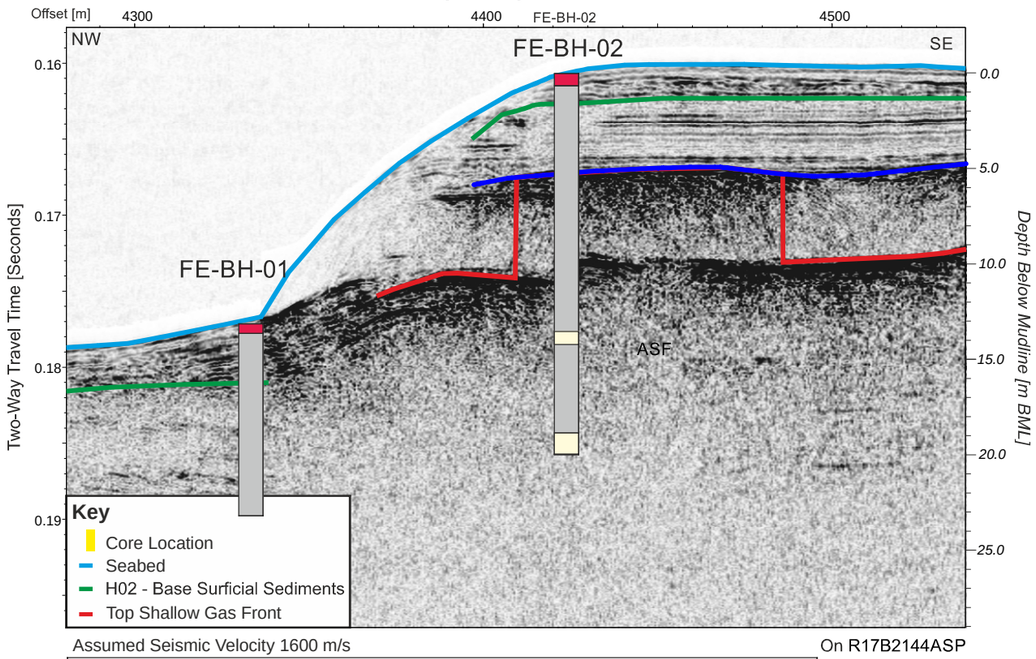
C. FAULT CROSSING GEOTECHNICAL MODEL

C.1 FAULT CROSSING SUMMARY PLATES

3D Seismic Data (2017)

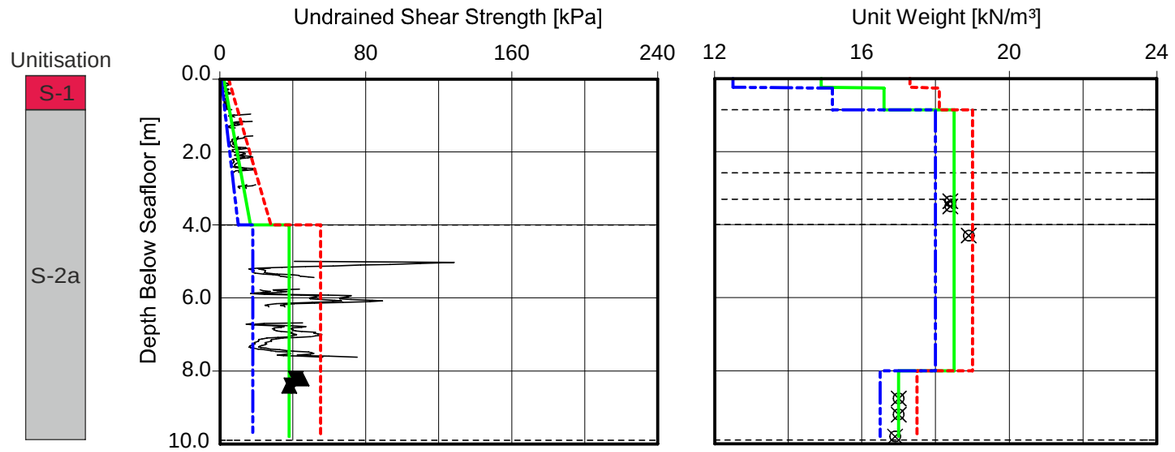


Sub-Bottom Profiler Data (2014)

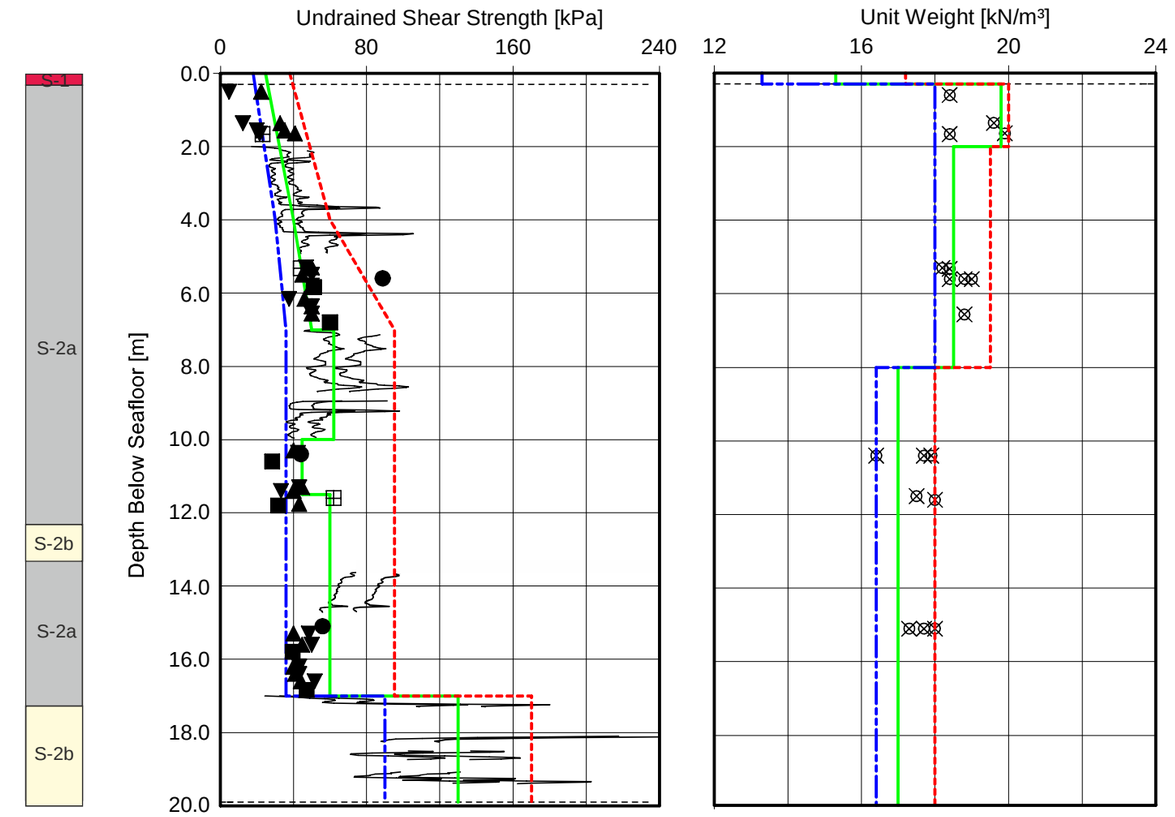


Project: Neptun Deep Survey, Pipeline and Flowline Interpretive Report	
Project No: 173570-05d(01)	Made By: LO
Preliminary Integration at Fault Crossings	Date: 12/05/2018
Geotechnical Location: FE-BH-01 & 02	Plate C.1.1

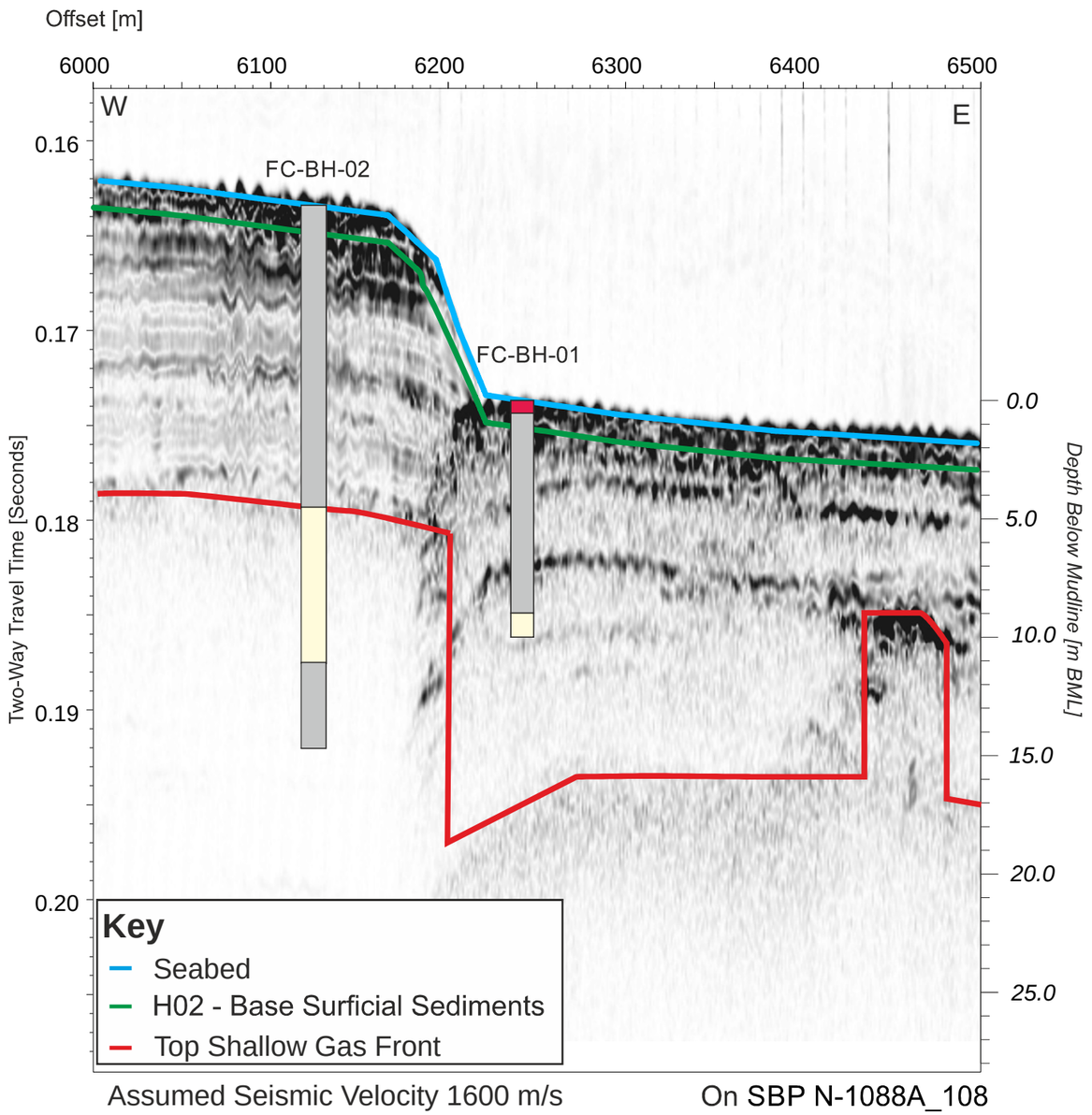
FE-BH-01 (Downthrown)



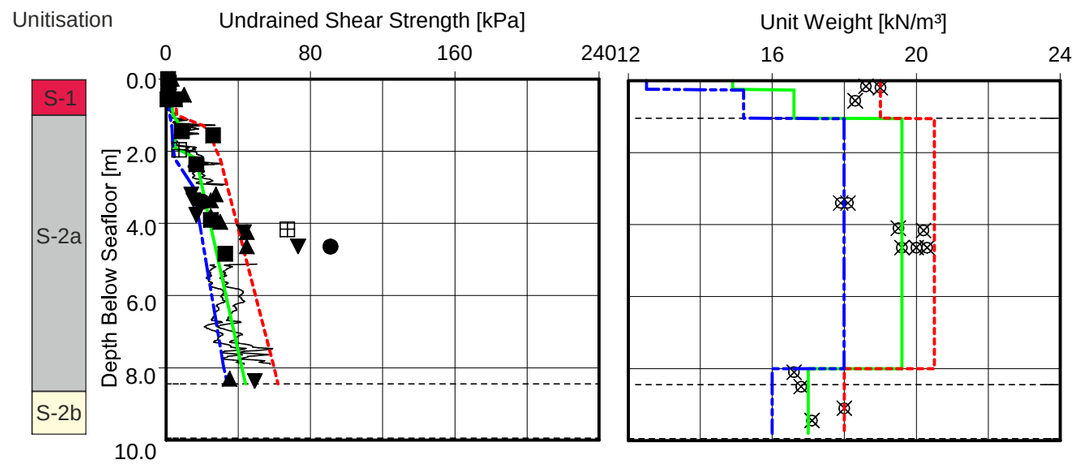
FE-BH-02 (Upthrown)



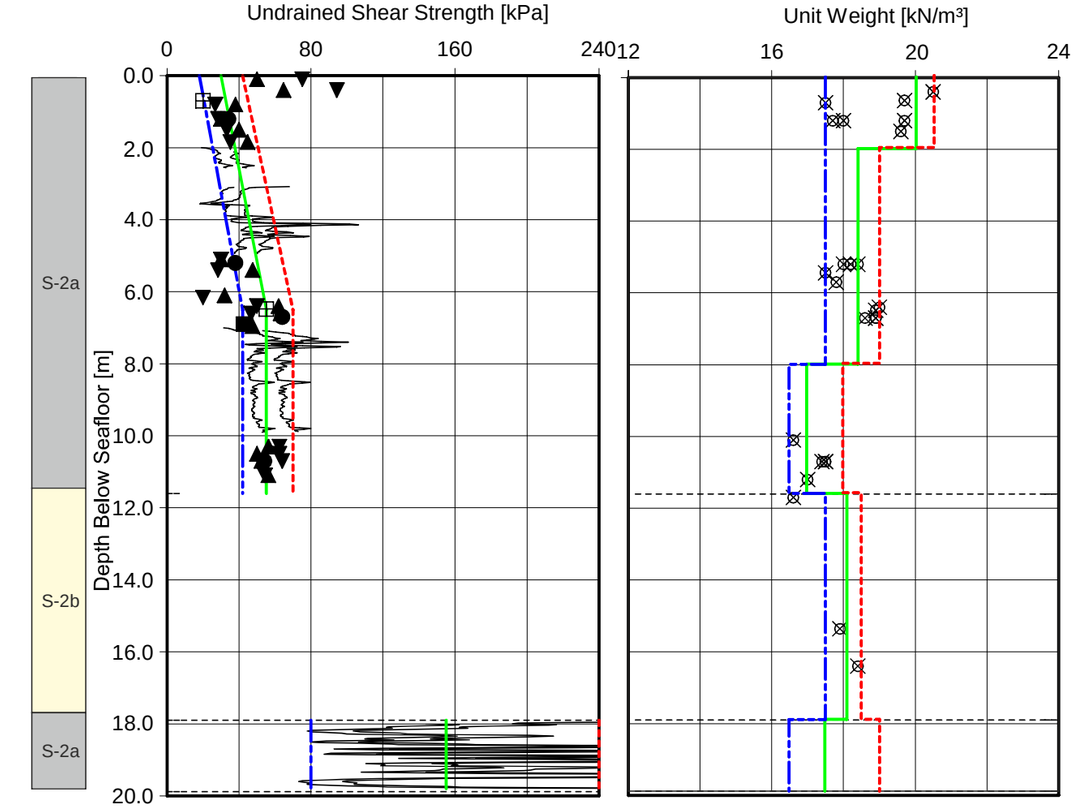
Sub-Bottom Profiler Data (2014)



FC-BH-01 (Downthrown)

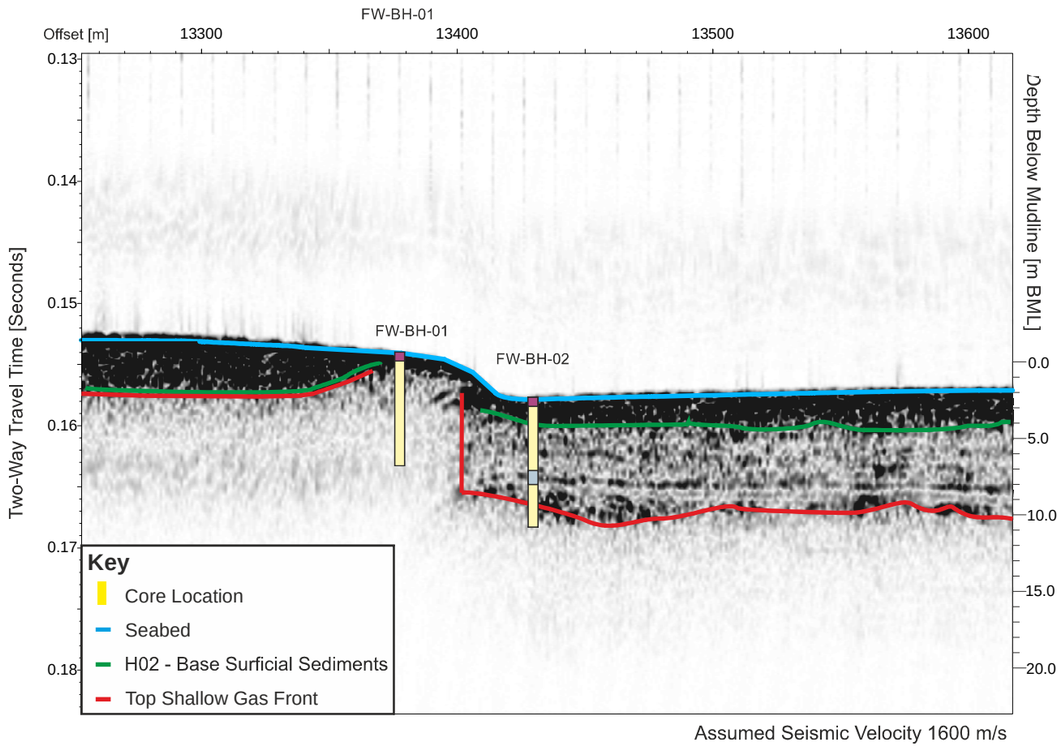


FC-BH-02 (Upthrown)



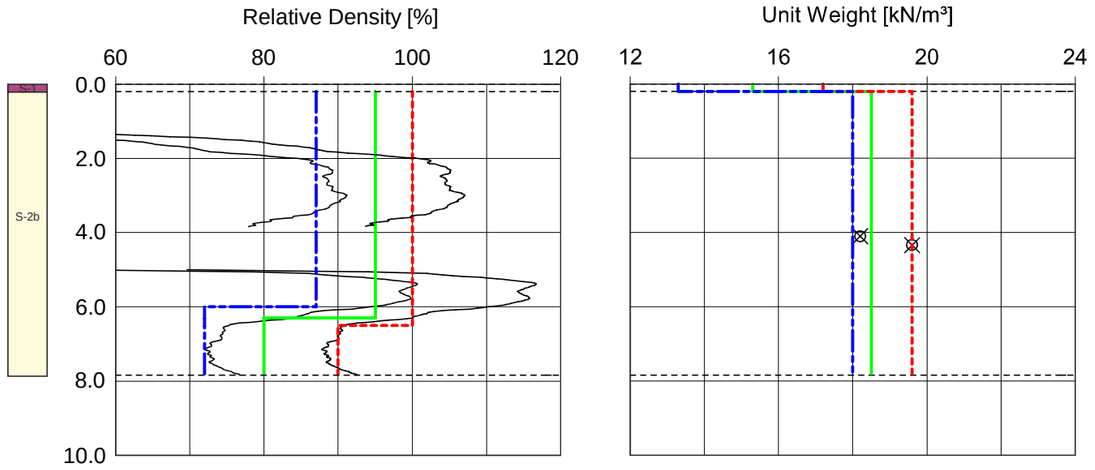
Project: Neptun Deep Survey, Pipeline and Flowline Interpretive Report	
Project No: 173570-05d(01)	Made By: LO
Preliminary Integration at Fault Crossings	Date: 12/05/2018
Geotechnical Location: FC-BH-01 & 02	Plate C.1.2

Sub-Bottom Profiler Data (2014)

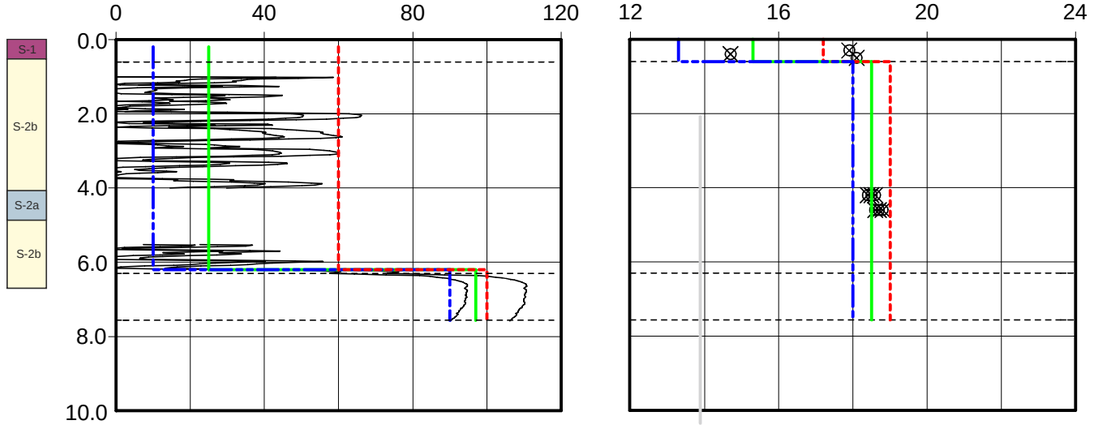


Assumed Seismic Velocity 1600 m/s

FW-BH-01 (Upthrown)

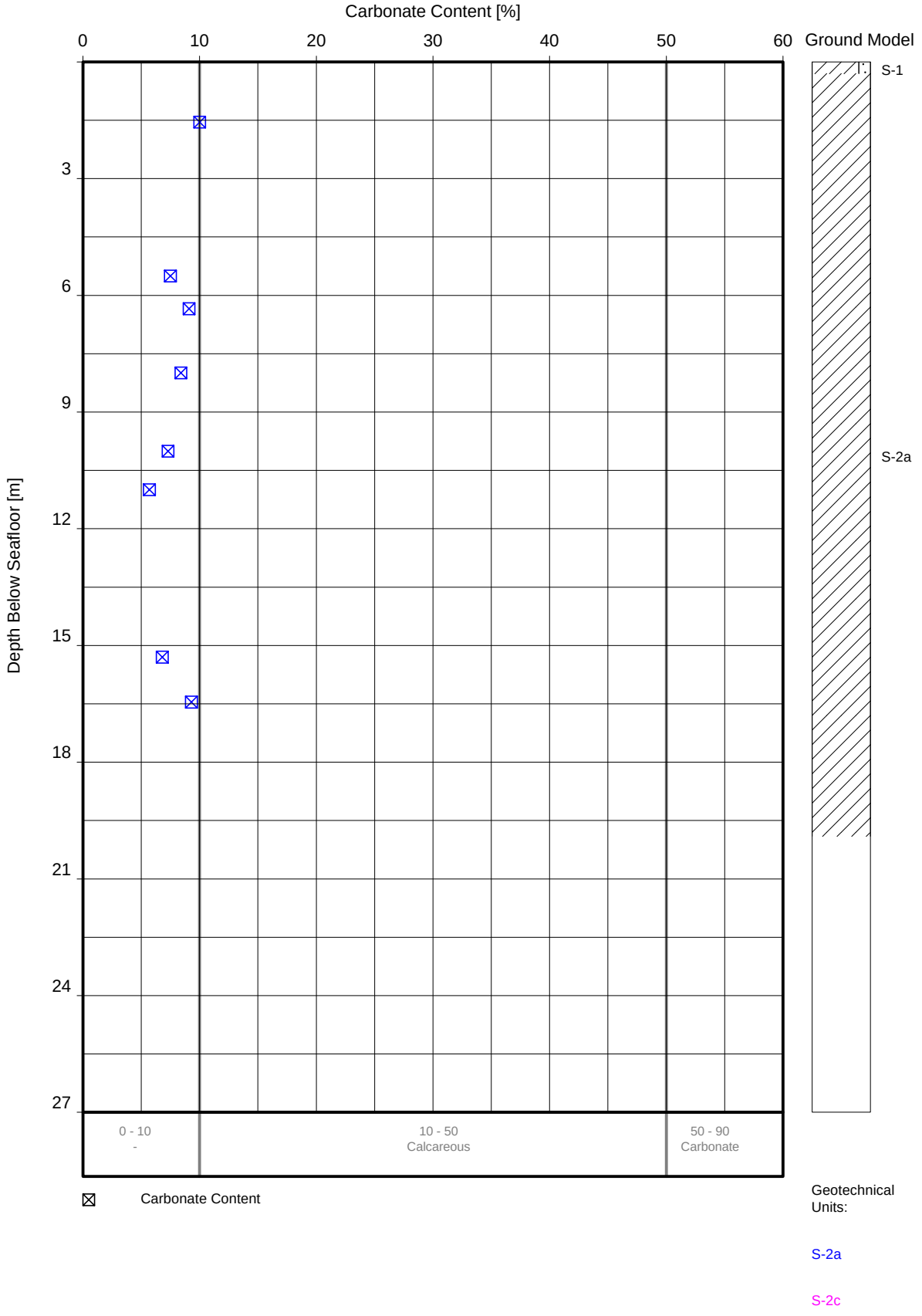


FW-BH-02 (Downthrown)

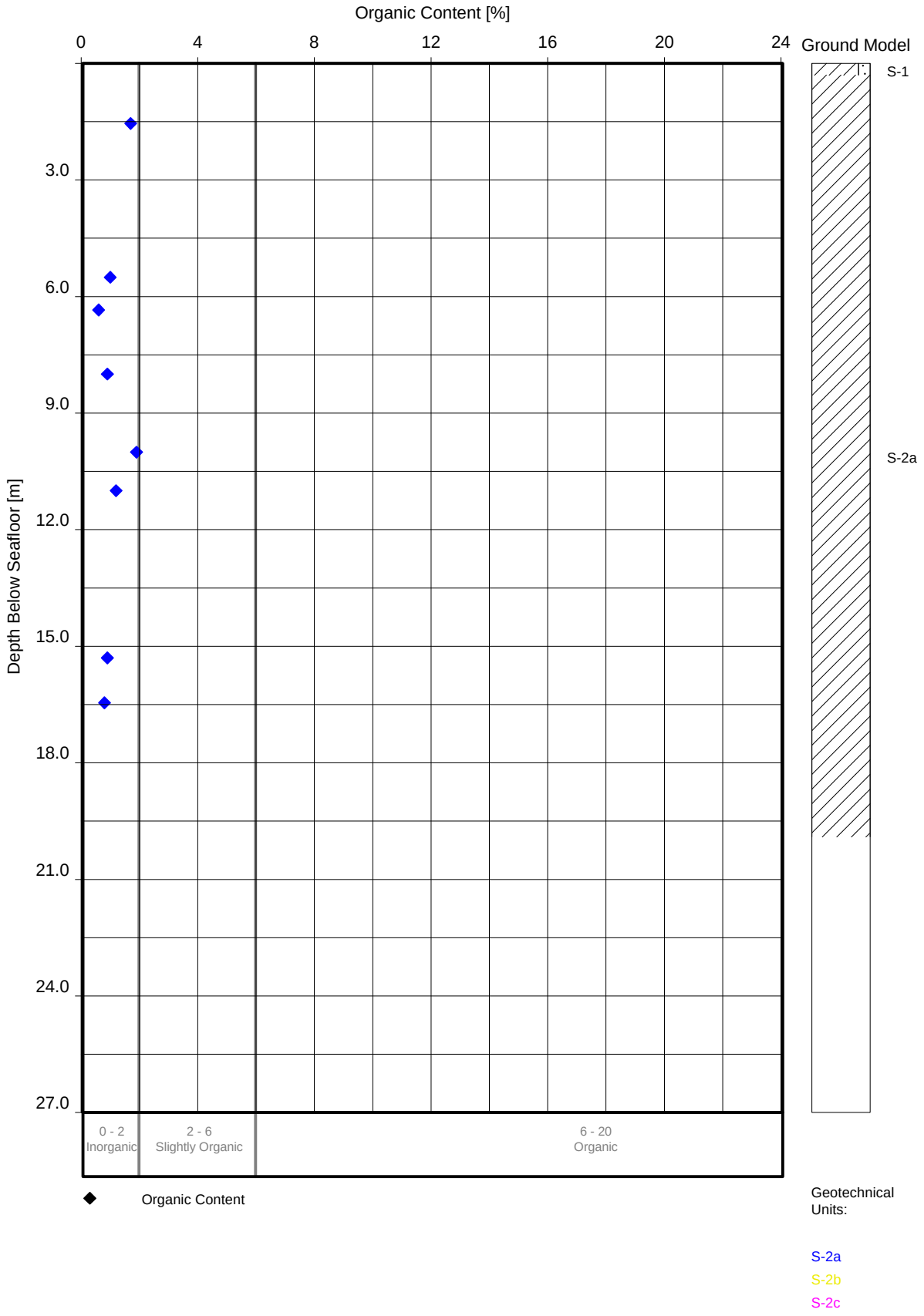


Project: Neptun Deep Survey, Pipeline and Flowline Interpretive Report	
Project No: 173570-05d(01)	Made By: LO
Preliminary Integration at Fault Crossings	Date: 12/05/2018
Geotechnical Location: FW-BH-01 & 02	Plate C.1.3

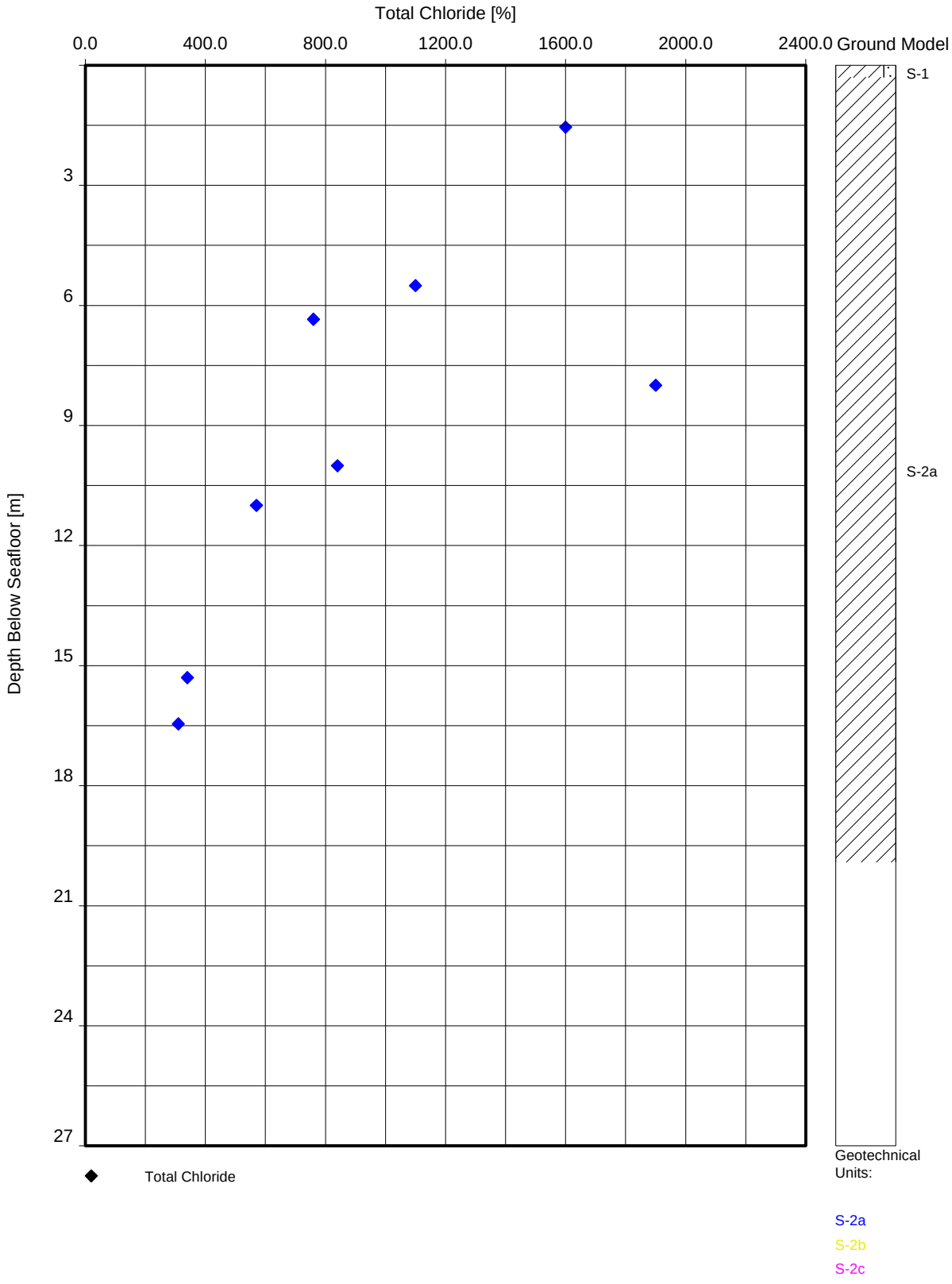
C.2 FAULT CROSSING CHEMICAL COMPOSITION



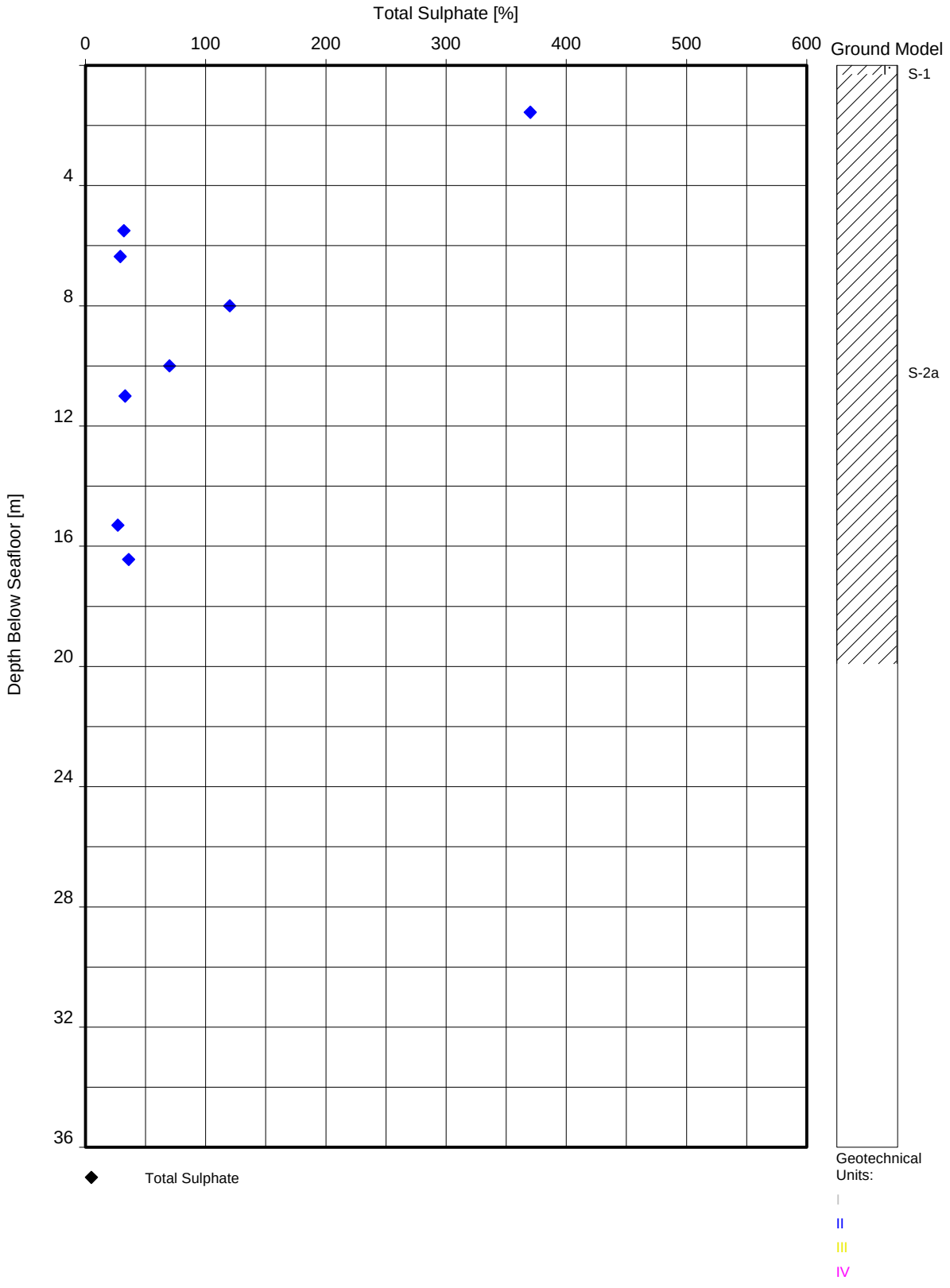
CARBONATE CONTENT VERSUS DEPTH
Eastern Fault Crossing
All Geotechnical Units



ORGANIC CONTENT VERSUS DEPTH
Eastern Fault Crossing
All Geotechnical Units

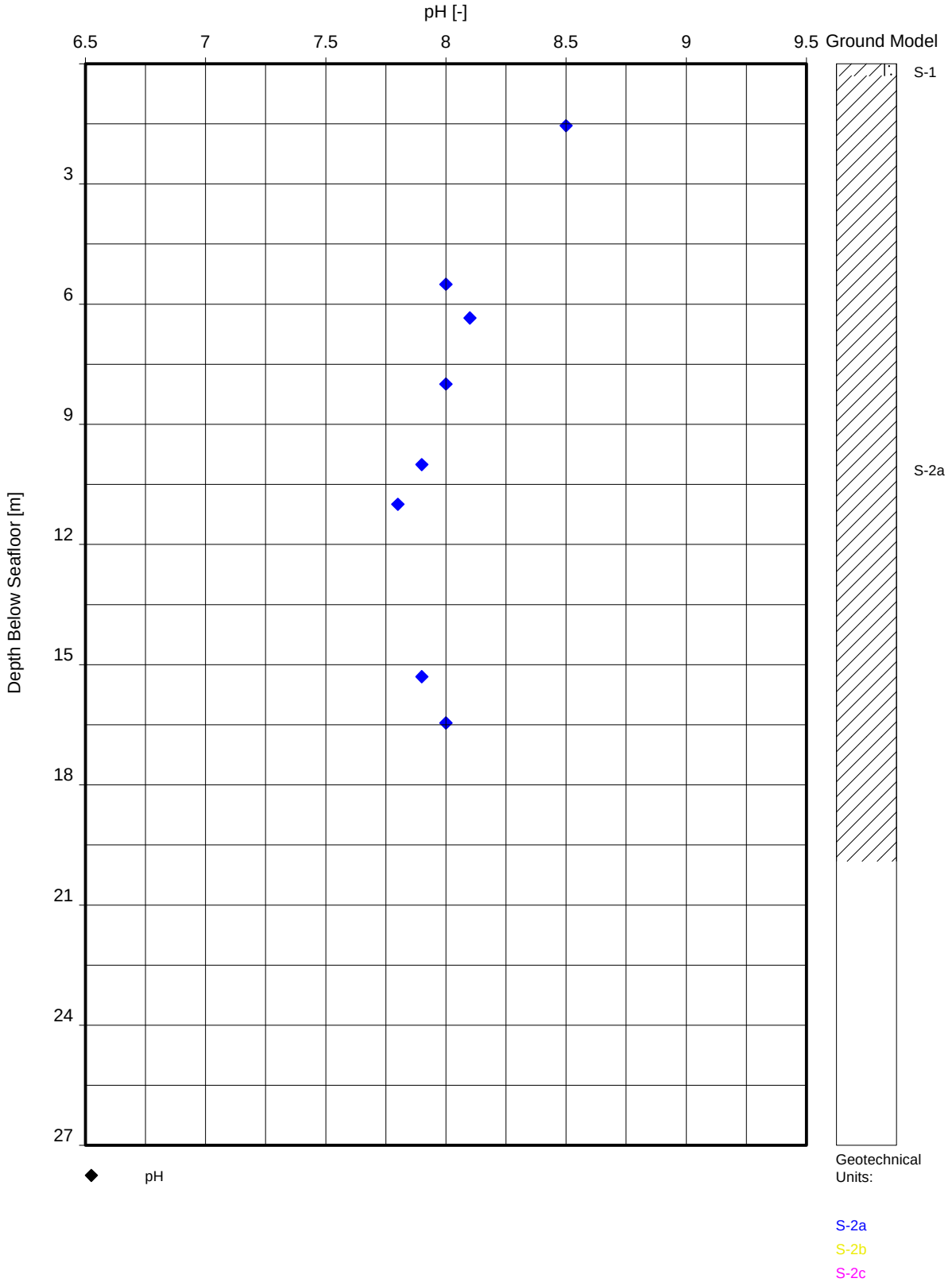


TOTAL CHLORIDE VERSUS DEPTH
Eastern Fault Crossing
All Geotechnical Units

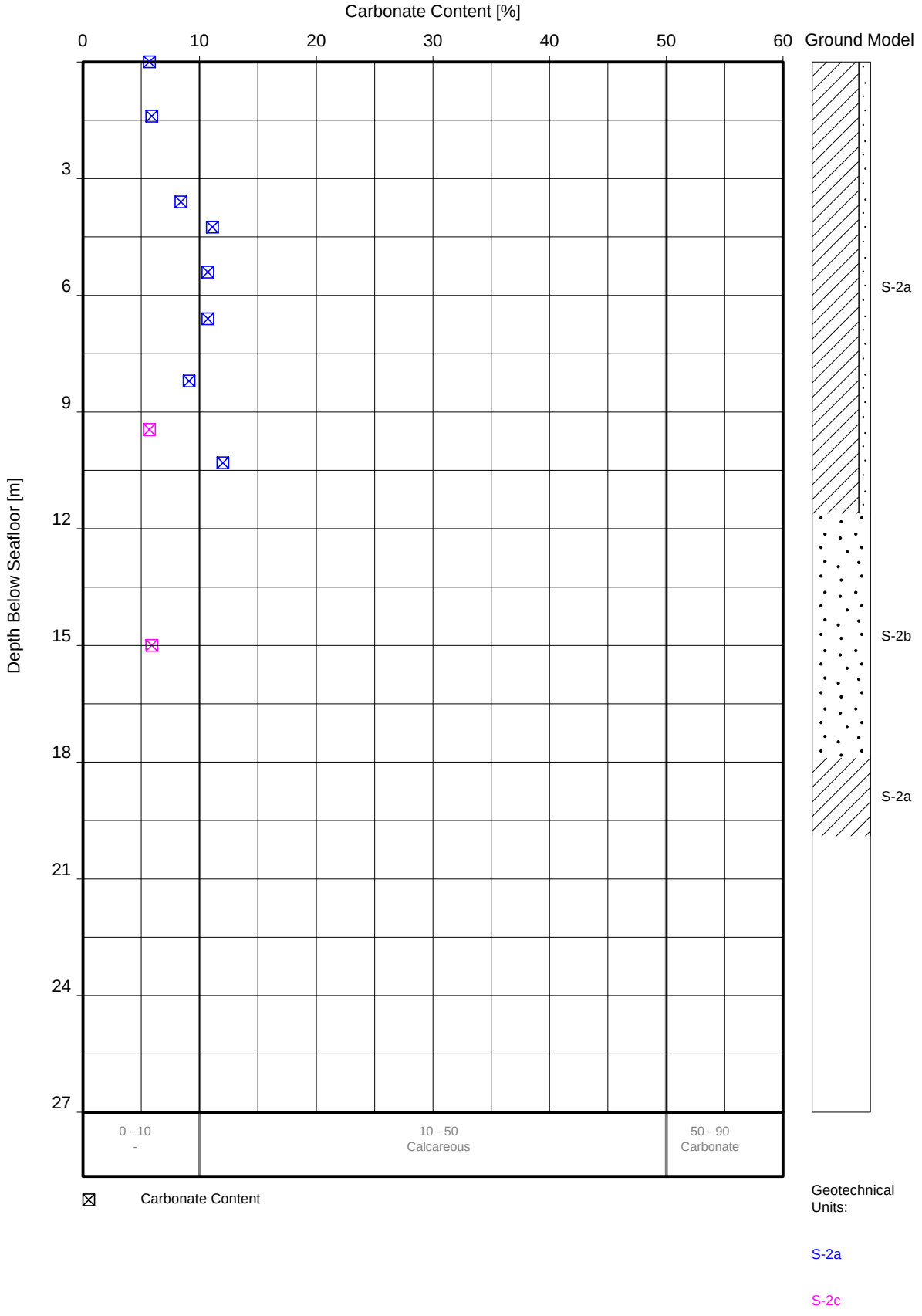


GeODin/Total Sulphate vs Depth - Units.GLO/2018-06-19 16:24:17

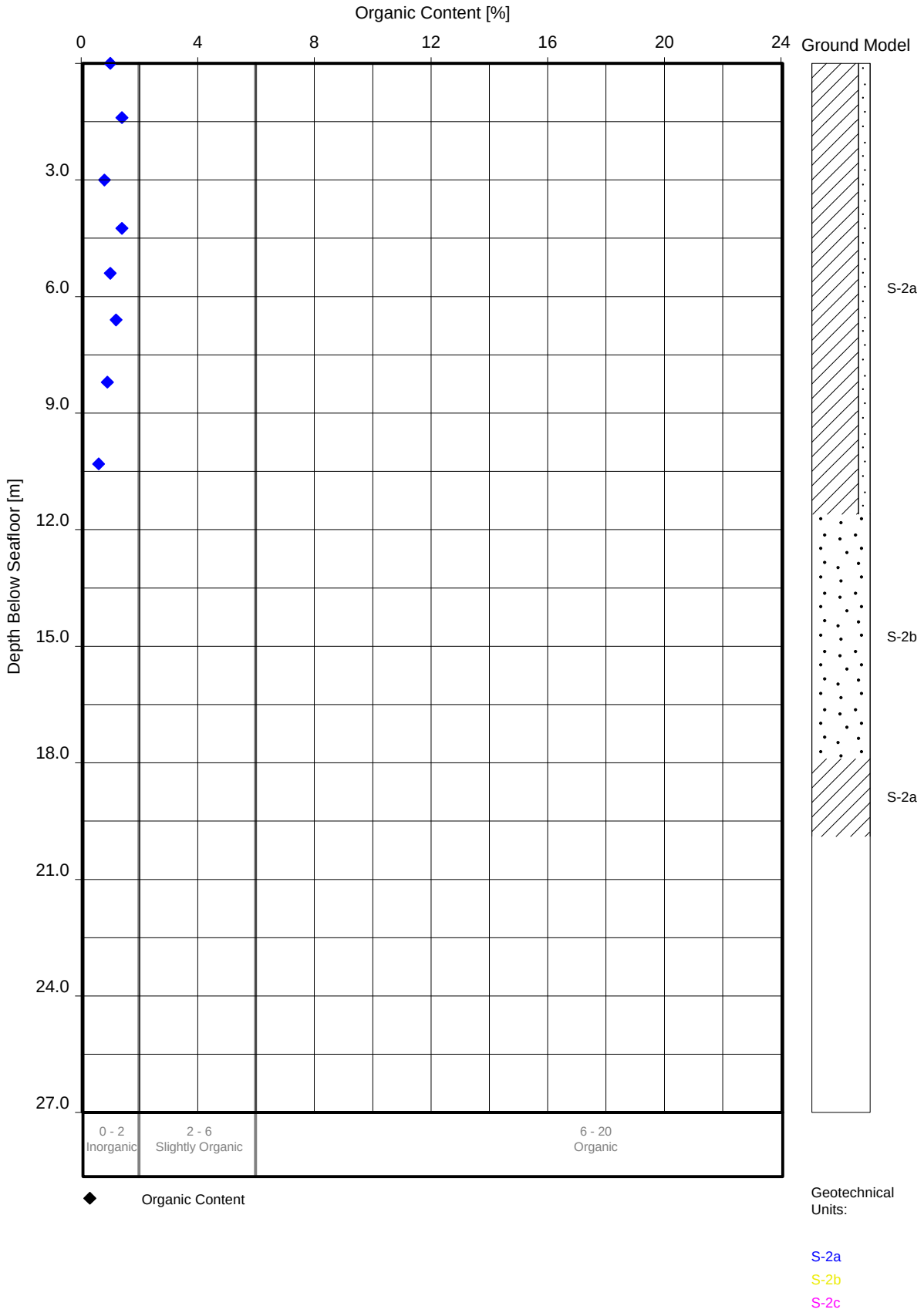
TOTAL SULPHATE VERSUS DEPTH
Eastern Fault Crossing
All Geotechnical Units



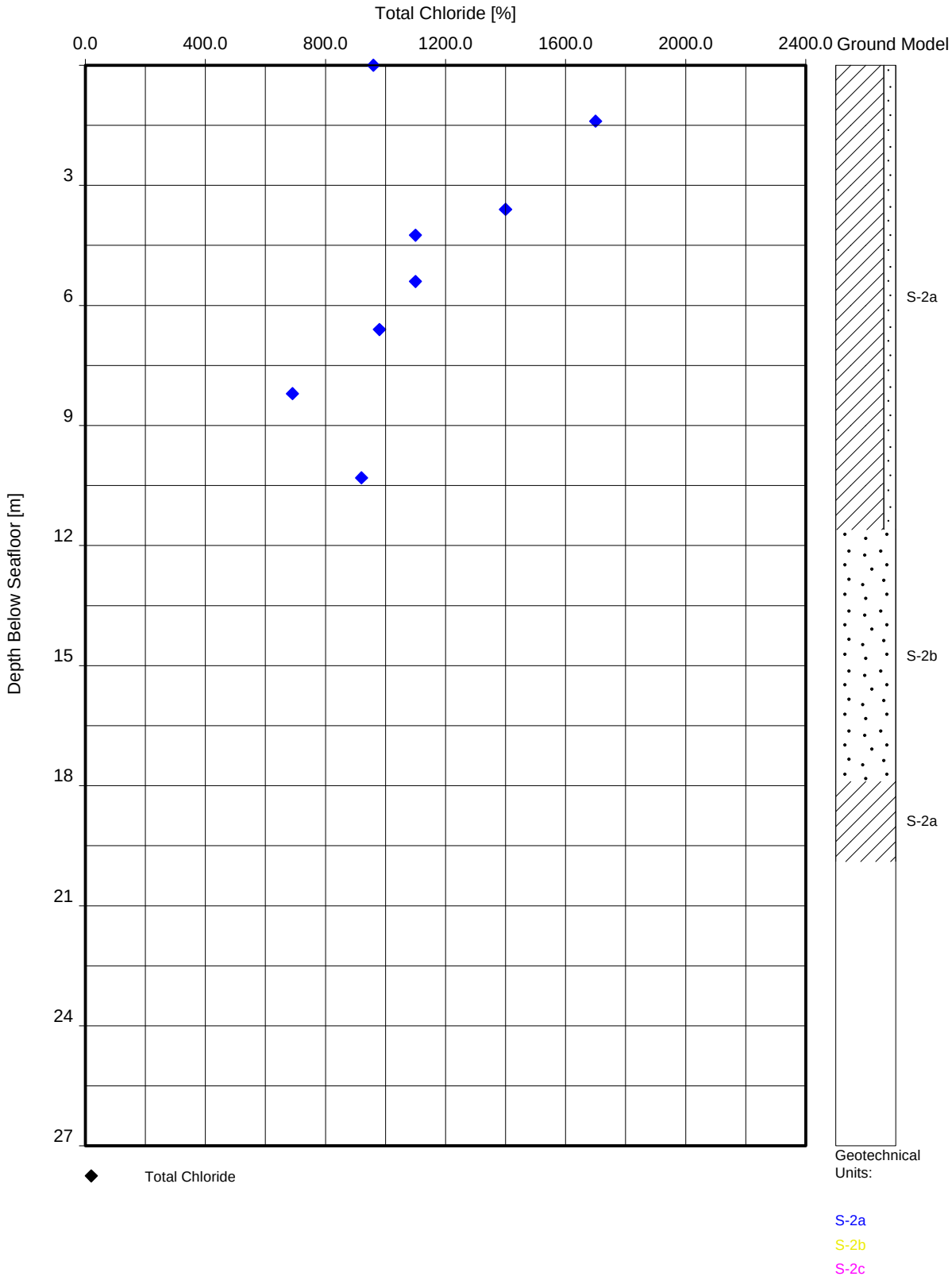
pH VERSUS DEPTH
Eastern Fault Crossing
All Geotechnical Units



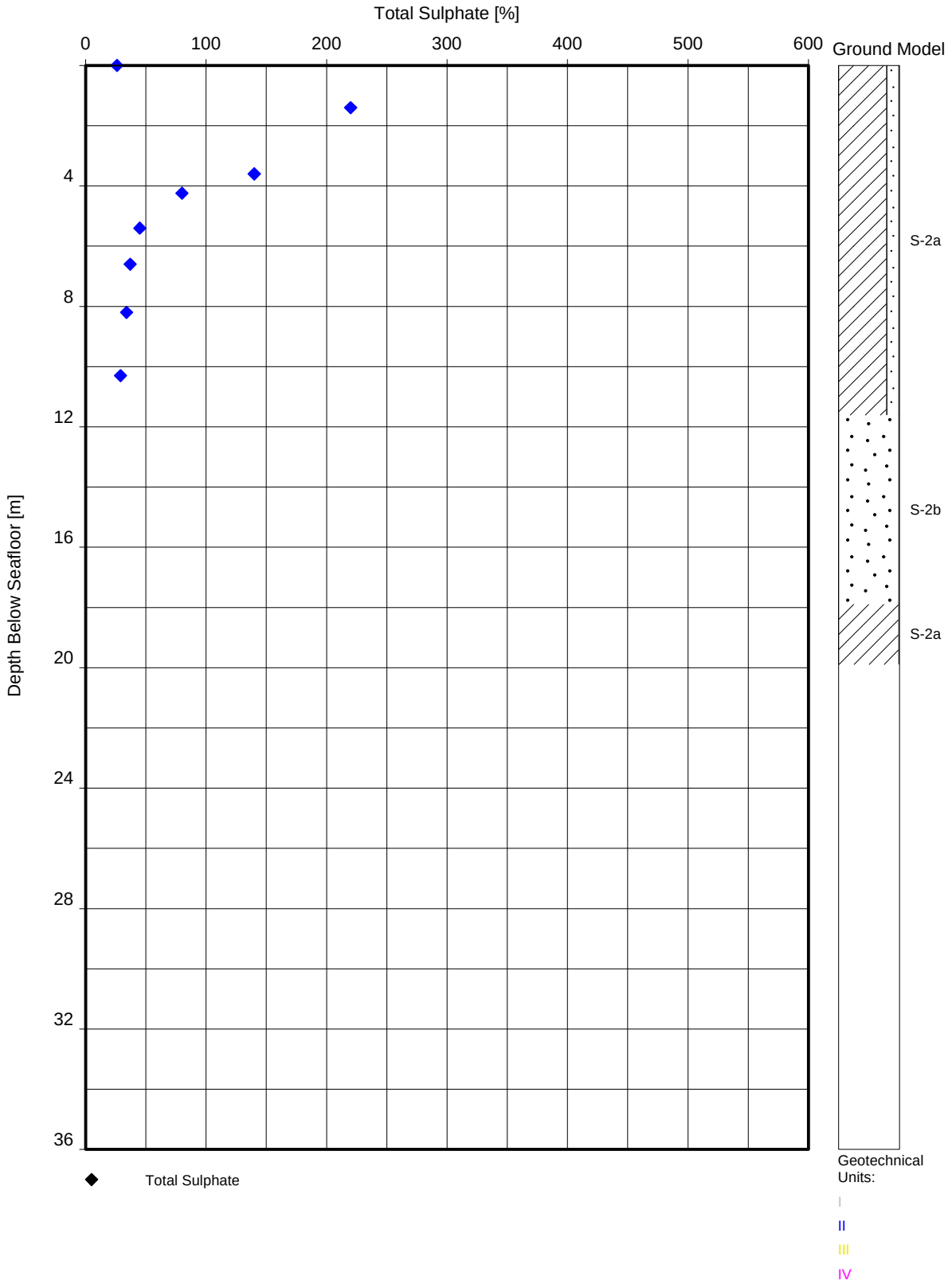
CARBONATE CONTENT VERSUS DEPTH
Central Fault Crossing
All Geotechnical Units



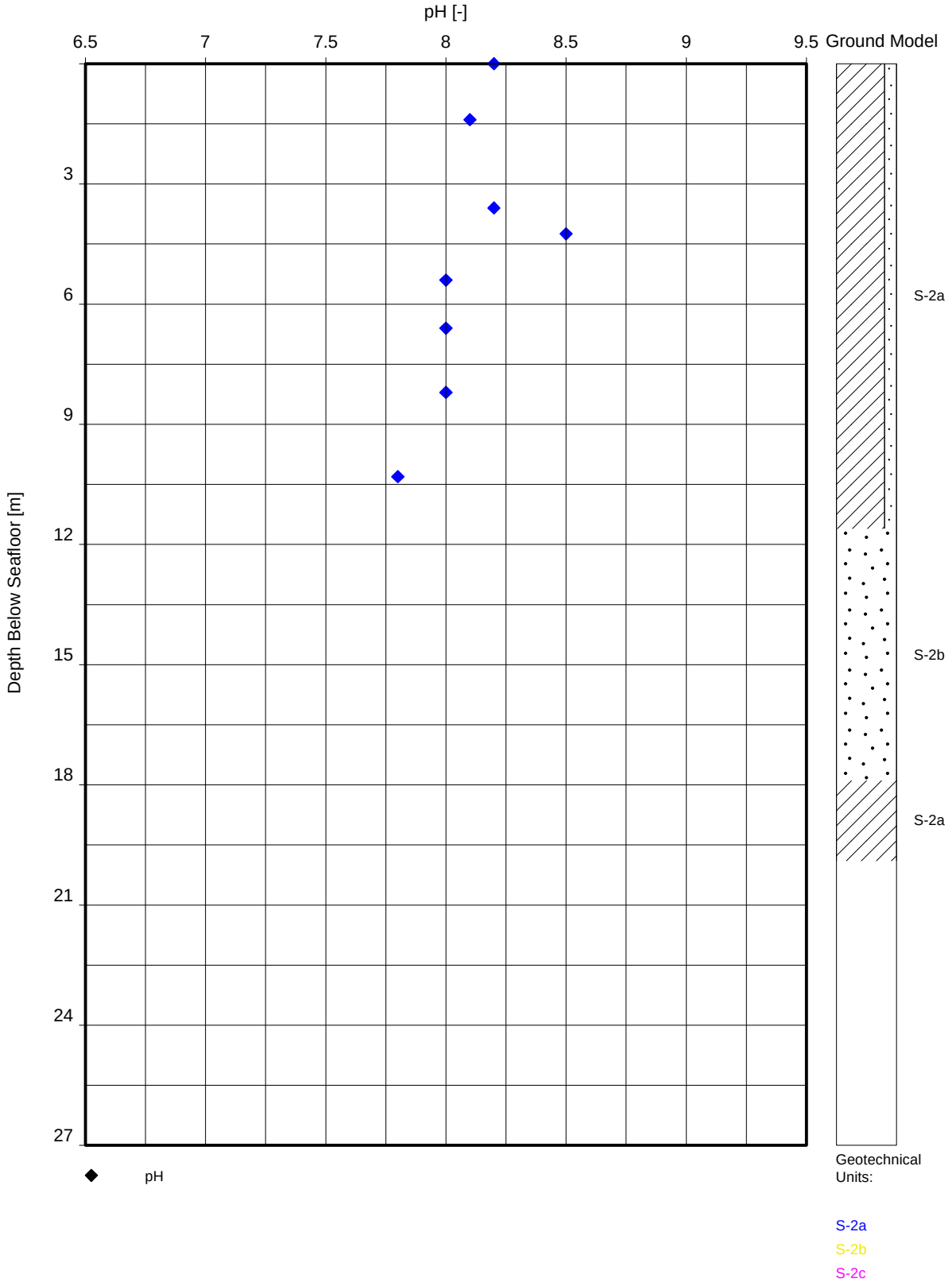
ORGANIC CONTENT VERSUS DEPTH
Central Fault Crossing
All Geotechnical Units



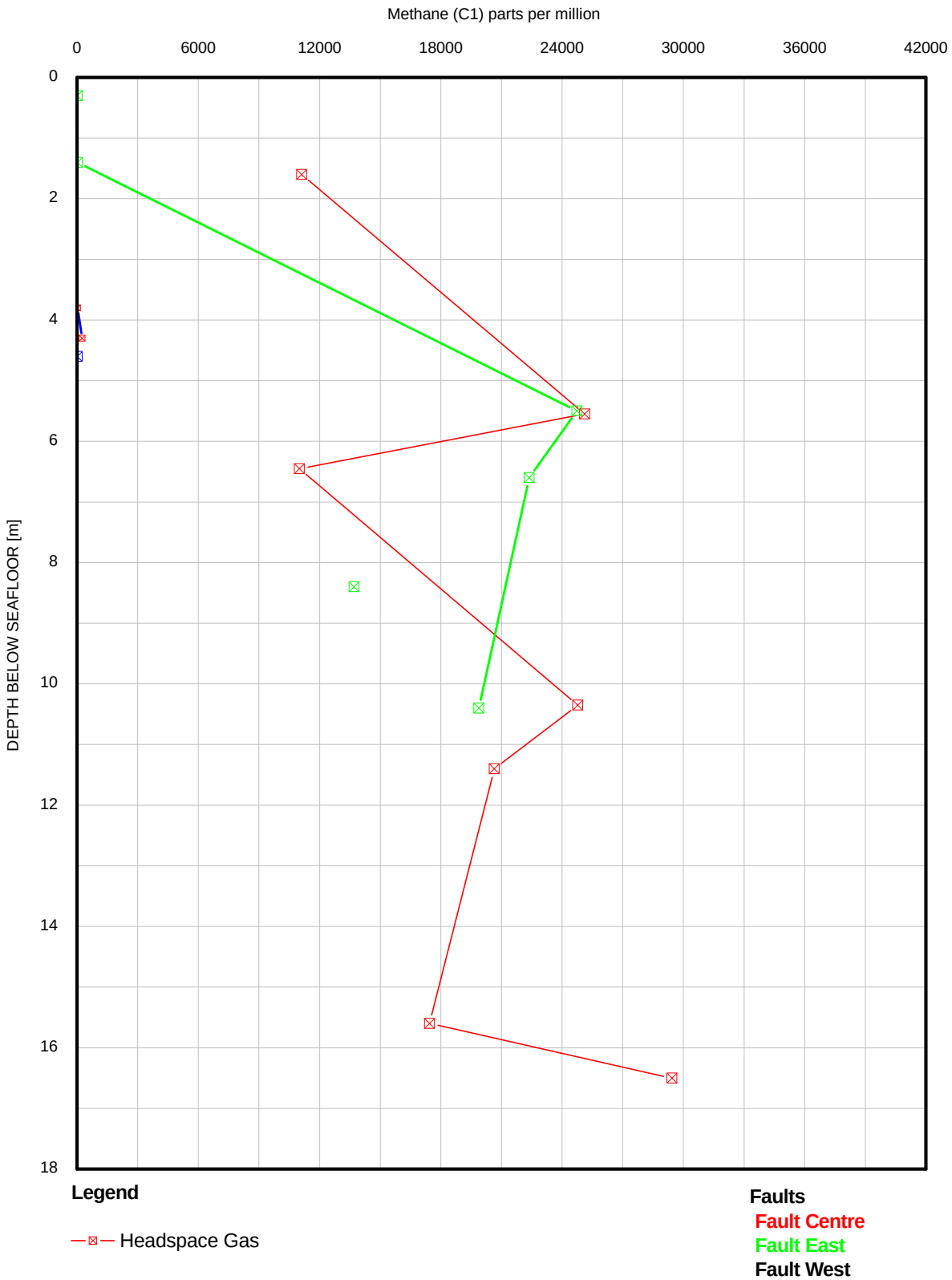
TOTAL CHLORIDE VERSUS DEPTH
Central Fault Crossing
All Geotechnical Units



TOTAL SULPHATE VERSUS DEPTH
Central Fault Crossing
All Geotechnical Units



pH VERSUS DEPTH
Central Fault Crossing
All Geotechnical Units



Headspace Gas Methane Versus Depth (C1)
Pipeline Fault Crossings