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Vattenfall Wind Power Ltd

Thanet Extension Offshore Wind Farm

Annex 2-2: Geophysical Investigation Report 1 of 3 - Operations & Calibration

June, 2017, Revision A

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Vattenfall Wind Power Ltd

Thanet Extension Offshore Wind Farm

Annex 2-2: Geophysical Investigation Report 1 of 3 - Operations and Calibrations

June, 2018

Drafted By:	Fugro Group
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Date of Approval	June 2018
Revision	A

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REPORT AMENDMENT SHEET

Issue No.	Report section	Page No.	Table No.	Figure No.	Description
0	1	1	-	-	Text amended.

DOCUMENT ARRANGEMENT

REPORT 1: GEOPHYSICAL INVESTIGATION REPORT
VOLUME 1: OPERATIONS & CALIBRATIONS
VOLUME 2: GEOPHYSICAL SITE SURVEY
VOLUME 3: GEOPHYSICAL ROUTE SURVEY
REPORT 2: GEOTECHNICAL INVESTIGATION REPORT
REPORT 3: ENVIRONMENTAL INVESTIGATION REPORT

CONTENTS

APPENDICES

1. INTRODUCTION

Vattenfall Wind Power Ltd contracted Fugro Survey B.V. (FSBV) to perform a geophysical investigation to improve the bathymetrical, morphological and geological understanding of the Thanet Extension Offshore Wind Farm, located north east of Kent off the United Kingdom coast. Furthermore the geophysical results were used for UXO/obstructions clearance for the following geotechnical campaign. The results of the geotechnical campaign are integrated with the geophysical data to create a ground model. The ground model will serve as the base for the design and installation requirements.

Details of the survey operations, including vessels, equipment and calibrations are presented in the Operations and Calibrations Report. The geophysical survey was carried out using three survey vessels: M.V. Fugro Pioneer for the site survey and R.V. Discovery and Valkyrie for the route survey.

A detailed report of the operations and calibrations for these three vessels can be found in the appendices to this report.

Unless otherwise specified, all geographical and projection coordinates in the report and in the charts are based on local datum ETRS89. Projection coordinates are expressed in Universal Transverse Mercator (UTM) grid, Zone 31, Northern Hemisphere. The vertical datum is Lowest Astronomical Tide (LAT). The time standard is UTC +1.

The investigation provided geophysical bathymetric and shallow seismic data using the following equipment: sidescan sonar (SSS), magnetometer, multibeam and single echo sounder (MBES/SBES), sub-bottom profiler (SBP) and ultra-high resolution multichannel sparker (UHR).

1.1 Purpose of Work

The general objectives for the site and cable route surveys were:

- Gather accurate bathymetric data and assess topography for areas with steep gradients and provide assessment of seabed movements;
- Collect sidescan sonar data and provide interpretation of seabed sediments and identification of any object on seabed larger than 1 m;
- Collect sub-bottom profiler seismic data to assess variations in thickness of seabed sediments and shallow geology;
- Collect UHR seismic data and build seismic stratigraphic model of deeper geology (not for export cable);
- Locate any structural complexities or geohazards within the shallow geological succession, such as faulting, accumulations of shallow gas, buried channels;
- Collect magnetometer data and include data in assessment of regional geology and provide identification of any magnetic anomalies;
- Gather seismic information about geotechnical borehole locations;
- Provide acoustic sediment type data to inform benthic surveys;
- Production of charts and maps suitable for use in GIS systems, including track plots, bathymetry, and seabed features with contacts, relative to LAT.

APPENDICES

A. OPERATIONS & CALIBRATIONS – M.V. FUGRO PIONEER

FUGRO

Thanet Extension Offshore Wind Farm

UK Continental Shelf, North Sea

Report 1 of 3:
Geophysical Investigation Report

Volume 1 of 3:
Operations & Calibrations – M.V. Fugro Pioneer

July to September 2016

Fugro (FSBV) Report No.: GE051-R1

Fugro (FEMU) Report No.: 160508

Vattenfall Wind Power Ltd.

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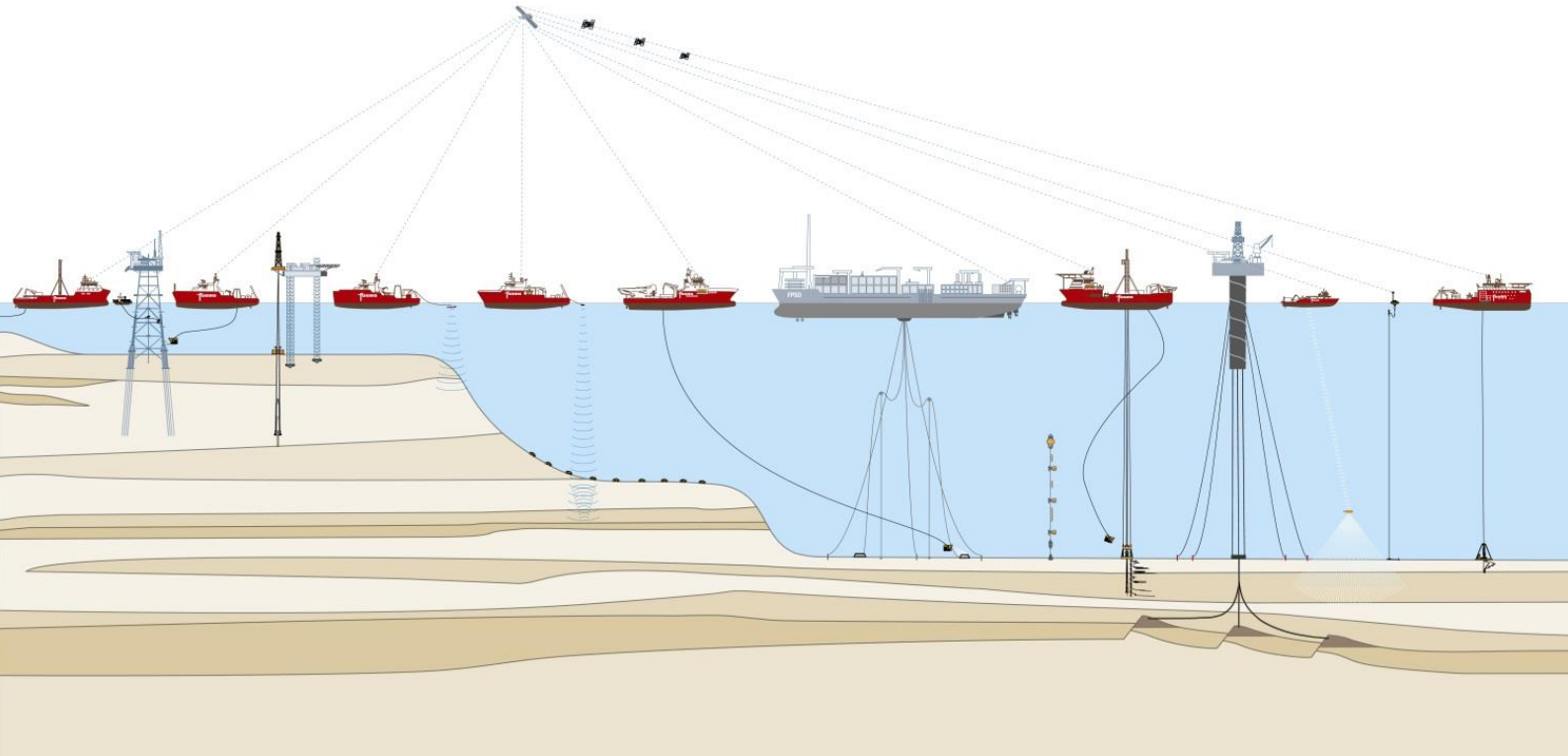

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0	1	1	-	-	Text amended
0	2.2	3	2.2/2.3	-	Header amended
0	3.1	5	-	-	“European Terrestrial System 1980” replaced with “…1989”

CONTENTS

Page

APPENDICES

NO TABLE OF CONTENTS ENTRIES FOUND.

TABLES

FIGURES

1. INTRODUCTION

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Details of the survey operations, including vessels, equipment and calibrations are presented in the Operations and Calibrations Report

The geophysical survey was carried out using the survey vessels MV Fugro Pioneer for the site and the MV Discovery and Valkyrie for the cable route.

The geophysical survey was carried out between 29 July and 6 September 2016.

Unless otherwise specified, all geographical and projection coordinates in the report and in the charts are based on local datum ETRS89. Projection coordinates are expressed in Universal Transverse Mercator (UTM) grid, Zone 31, Northern Hemisphere. The vertical datum is Lowest Astronomical Tide (LAT). The time standard is UTC +1.

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2. EQUIPMENT AND PERSONNEL

2.1 Summary of Resources

FSBV provided the necessary personnel, equipment and vessels to carry out the survey. This section provides information regarding the equipment used and personnel employed to obtain the results presented in the accompanying volumes of this report. The vessels M.V. Fugro Pioneer, RV Discovery and Valkyrie were used during this survey.

Table 2.1: Equipment on board M.V. Fugro Pioneer

Equipment on board M.V. Fugro Pioneer	
Positioning and Navigation	5 x StarPack unit (c/w cables and antenna)
	1 x Access to Starfix L1, L2, Dif, HP, G2 corrections
	4 x Online survey computer (Starfix.Seis)
	4 x StarPort
	1 x iXBlue Hydrins Fibre Optic Gyro
	1 x Meridian Gyrocompass
	1 x iXBlue Octans 3000
	1 x Teledyne TSS DMS-25 Motion sensor
	3 x Additional monitors as helmsman display
	1 x Adams draught reader
	1 x Leica TS15 total station with tripod and prisms
Geophysical Equipment	1 x Kongsberg EA400 SBES (dual frequency transducer, 33 kHz and 210 kHz, hull-mounted)
	2 x SD204 probe with wireless controller
	2 x EdgeTech 4200-FS Digital SSS
	2 x EdgeTech 701-DL Topside unit
	2 x SSS Tow winch (c/w cable and cable counter)
	2 x STR Digital Transceiver
	1 x Massa TR-1075 Pinger 4 x 4 array (hull mounted)
	1 x Kongsberg EM 2040 Dual Head MBES
	2 x Valeport MiniSVP velocity probe
	1 x Kongsberg HiPAP 501 cymbal USBL system
	7 x Beacons
	4 x Kongsberg Mini 34 Transponder
	2 x Kongsberg Maxi Transponder
	1 x Kongsberg APOS system
	2 x Kemo Benchmaster
	1 x Applied Acoustics Duraspark 1000j 200 tip Sparker
	1 x 48 channel solid Geometrics streamer CNT2
UHRS Equipment	2 x Applied Acoustics Duraspark 360 tip 1KJ sparker
	1 x Applied Acoustics CSP-N1200 power supply unit
	1 x GSO Geo-spark 1000 power supply unit
	2 x MACA power supply
	2 x Geometrics Geo-Eel Seismic Cable 48 channel streamer (3.125 m group spacing, 150m active) Streamer with Tail Buoy
Digital Data Acquisition	Starfix.GLog/GPlot data acquisition and processing system
	GLogIV system

Equipment on board M.V. Fugro Pioneer	
	Geometrics Geode
Data Processing	Starfix.VBA Proc software
	Starfix.Workbench software
	Starfix.Interp software
	Chesapeake SonarWiz 5 software
	IHS Kingdom 8.8 software
	DECO Geophysical RadExPro and Uniseis software
	MagPick software
	Bentley MicroStation software
	AutoDesk AutoCAD software

2.2 Project Personnel

Table 2.2: Key Personnel in FSBV Office

Personnel M.V. Fugro Pioneer		
Location	**Function**	**Name**
Project Management	Project Director	R. Davies
	General Project Manager	P-P. Lebbink
	Project Manager WP A	C. Wood
	Project Manager WP B	S. Litchfield
Reporting	Processing & Reporting Manager	P. Apostle
	Report Coordinator	J. Chisholm, V. Minorenti
	Geophysicists	V. Minorenti R. Nieboer M. van der Linde
	Data Processor	T. Rhodes S. Mourad R. Bhattacharyya B-J. Tijmes

Table 2.3: Personnel M.V. Fugro Pioneer

Personnel M.V. Fugro Pioneer		
Location	**Function**	**Name**
Offshore	Party Chief	C. Maree
		T. Harrison
		P. Miller
	Surveyor	P. Bhattacharjee
		M. Volterrani
		K. Bos
		C. Caielli
		D. West
		F. Lucenti
	Online Engineer	G. Reynolds
		M. Needham
		B. Luckhoo

		S. Kiyang
	Maintenance Engineer	J. Claudius
		J. De Wolf
	Engineer	K. Vepanjeri
		S. Kiyang
	Digital Engineer	P. Wright
		C. Cicolini
	Gun mechanic	E. Di Curzio
		A. Demma
	Geophysicist	R. Roepnarain
		F. May
		D. Seccia
		G. Blackie
		A. Izotov
		A. Darbo
		R. Nieboer
	Seismic Processor	V.Vitale
		A. Senocak
		D. Seccia
		E. Bursin
	Seismic Engineers	M. Provvisionato
		R. Belfiore
		M. Buffone
		J. Draves
		C. Cicolini
	Data Processor	C. Luna
		B. De Tommaso
		R. Codd
		N. Tatalovic
		Y.C. Tan
		R. Garnett
	Client Representative (Vattenfall)	J. Brand
		A.Sharp

3. SURVEY CONTROL

3.1 Geodetic Parameters

Unless otherwise specified, all geographical and projection coordinates in the report and in the charts are based on local datum European Terrestrial System 1989 (ETRS89). Projection coordinates are expressed in Universal Transverse Mercator (UTM) grid, Zone 31, Northern Hemisphere. The vertical datum is Lowest Astronomical Tide (LAT). The time standard is UTC +1.

Satellite navigation and positioning was operated in differential mode. DGPS geographical coordinates were based on datum World Geodetic System 1984. The UKOOA datum shift parameters were used for the transformation from WGS84 to the local coordinates in the ETRS89 datum. The geodetic parameters are detailed in Table 3.1.

Table 3.1: Project Geodetic and Projection Parameters

Global Positioning System Geodetic Parameters					
Datum:	World Geodetic System 1984 (WGS 84)				
Spheroid:	World Geodetic System 1984				
Semi major axis:	a = 6 378 137 m				
Inverse Flattening:	$^1/_f$ = 298.257 223 563				
EPSG Code:	6326				
EUREF89 Geodetic Parameters [1)]					
Datum:	European Terrestrial Reference System 1989 (ETRS89)				
Spheroid:	GRS80				
Semi major axis:	a = 6 378 137 m				
Inverse Flattening:	$^1/_f$ = 298.257 222 101				
EPSG Code:	6258				
Datum Transformation Parameters [2)] from WGS 84 to ETRS89 for epoch 2016. 647540984 (25 August 2016)[3)]					
Shift dX:	+0.05376 m	Rotation rX:	-0.002239 arcsec	Scale Factor:	0.0026718 ppm
Shift dY:	+0.05096 m	Rotation rY:	-0.013547 arcsec	EPSG Code:	N/A
Shift dZ:	-0.08847 m	Rotation rZ:	0.021897 arcsec		
Project Projection Parameters					
Grid Projection:	Universal Transverse Mercator				
Projection Name	UTM zone 31N				
Central Meridian:	003° 00’ 00” East				
Latitude of Origin:	00° 00’ 00” North				
False Easting:	500 000 m				
False Northing:	0 m				
Scale factor on Central Meridian:	0.9996				
Units:	Metre				
EPSG Code:	25831				

Notes:

1. Source: Starfix.NG. Starfix.NG determines the transformation parameters according to the Memo of C. Boucher and Z. Altamimi, dated 18 May 2011.
2. This is the right-handed coordinate frame rotation convention used by the Fugro Starfix navigation software

3. The coordinate transformation parameters are the combined result of the 14 parameter transformation from ITRF2008 to ETRS89 and do take into account the yearly changes on the mentioned epoch.
The WGS 84 realisation is nearly equal to the ITRF2008 on the above mentioned epoch. WGS 84 is maintained by the US Department of Defence to be nearly identical to ITRF2008.

3.2 Horizontal Control

The vessel Centre of Gravity (COG) was defined as the origin of the vessel's survey coordinate system or Common Reference Point (CRP). Refer to Figure 3.1 for a photograph, to Figure 3.2 for an offset diagram and to Table 3.2 for an offsets table of M.V. Fugro Pioneer.

Figure 3.1: Photograph of M.V. Fugro Pioneer

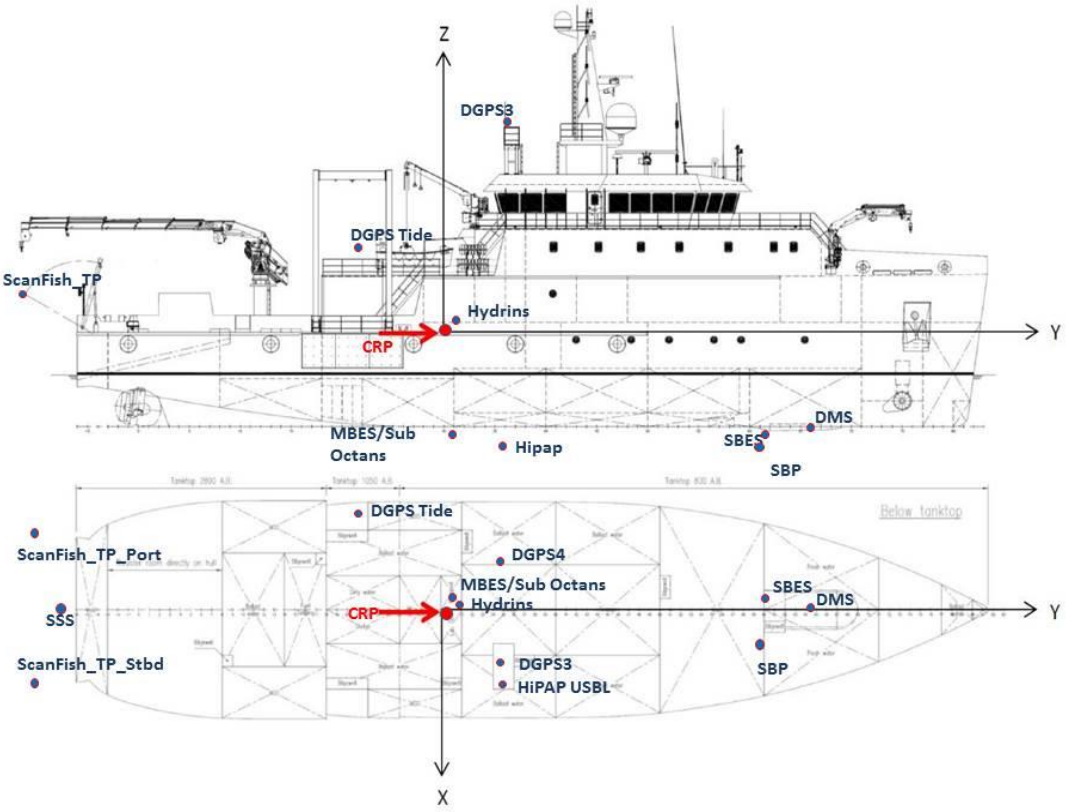


Figure 3.2: Offset diagram M.V. Fugro Pioneer

Table 3.2: Offsets M.V. Fugro Pioneer

Offsets (from CRP)	X [m]	Y [m]	Z [m]
CRP	0.00	0.00	0.00
USBL (deployed position)	3.91	3.56	-6.96
DS1 Draught transducer (for SBES)	-2.22	18.24	-5.54
DS2 Draught transducer (for MBES)	-0.83	1.37	-5.53
SBES transducer	-0.66	20.19	-5.79
SBP 4x4 (centre of array)	0.01	22.24	-5.73
MBES	-0.70	0.49	-6.05
HydrINS (Primary MRU/Heading)	0.39	0.77	0.46
DMS 25 (MRU)	-0.35	21.90	-4.59
Subsea Octans (MRU/Heading)	-0.74	0.96	-5.33
DGPS1	-3.55	16.88	9.42
DGPS2	3.52	16.91	9.40
DGPS3_1 (Starboard)	3.18	4.26	12.13
DGPS3_2 (Port)	-3.17	4.26	12.13
DGPS4	-3.16	5.09	12.13
SSS_TP (Sonar tow-point)	-3.65	-23.74	5.30
CTD Crane	5.75	0.00	0.00
DGPS_Tide	-5.82	-7.18	5.34
Mag_TP (Magnetometer tow-point)	-3.65	-23.74	5.30
Streamer_TP (Streamer tow-point)	1.18	-21.15	0.00
Air Gun_TP (Air gun tow-point)	6.28	-21.15	0.00
CMP	3.73	-66.15	-2.94

3.3 Vertical Control

Tidal levels were recorded GNSS height observations from a Starpack G2+ and Best solution onboard the MV Fugro Pioneer and data was post processed in Starfix.VBAProc software.

GNSS heights are referenced to LAT (Lowest Astronomical Tide) by using the DVR90 model supplied by the Danish Geodata Agency.

3.4 Time Reference

The time zone for the survey was UTC +1 hr and UTC (daylight saving time).

All logged data and associated record annotation are referenced to UTC. For the offshore operations (MV Fugro Pioneer) the Daily Operations Reports and the survey log book are recorded in local time (UTC +1 hr).

4. CALIBRATION AND VERIFICATION RESULTS

4.1 Positioning and Navigation Systems

The positioning system on M.V. Fugro Pioneer uses a Starfix.G2 solution. The Starfix.G2 solution is Fugro's positioning solution based on GLONASS and GPS with clock and orbit corrections received by the Starpack DGNSS receiver from Fugro's independent network of reference stations. The iXSea Hydrins INS sensor was interfaced to the navigation system to compensate for antenna movement induced by the heave, pitch and roll of the vessel and to provide vessel heading data.

The positioning systems were operated under the following conditions:

- minimum elevation mask of 5 degrees;
- PDOP less than 5;
- Minimum number of satellites 5.

The primary positioning system (GPS Antenna StarPack 3) was verified onboard M.V. Fugro Pioneer during vessel mobilisation in Scheveningen, The Netherlands, on 30 July 2016 using land survey techniques with a total station and known points on the quayside. The results of this verification are shown in Table 4.1. Details of the verification are presented in Appendix A.1.

Table 4.1: Positioning system verification M.V. Fugro Pioneer

Date	Description	ΔEasting	S.D.	ΔNorthing	S.D.
		[m]	[m]	[m]	[m]
30 July 2016	GNSS Antenna StarPack 3	-0.08	0.01	-0.09	0.01

The comparison between the primary and secondary positioning systems, GPS Antenna StarPack 3 and GPS Antenna StarPack 4, took place on 30 July 2016 in Scheveningen, The Netherlands. The results of this comparison are shown in Table 4.2. Details of the comparison are presented in Appendix A.2.

Table 4.2: Positioning system comparison M.V. Fugro Pioneer

Date	Description	ΔEasting	S.D.	ΔNorthing	S.D.
		[m]	[m]	[m]	[m]
30 July 2016	GNSS Antenna StarPack 3 and 4 comparison	0.01	0.02	0.00	0.02

4.2 Heading System and Motion Sensor

The survey gyrocompass alignments were calibrated in Scheveningen, The Netherlands, on 29 July 2016 using a total station measurement method. The results of the alignment checks are shown in Table 4.3. Detailed reports of the alignment checks are presented in Appendix A.3.

Table 4.3: Gyrocompass alignment check M.V. Fugro Pioneer

Date	Gyro	Method	C-O [°]
29 July 2016	Hydrins	Sunshot	-0.07
29 July 2016	Subsea Octans	Sunshot	-0.66
29 July 2016	Meridian	Sunshot	-0.00
29 July 2016	GNSS Heading	Sunshot	-0.22

4.3 Single Beam Echo Sounder

A Kongsberg EA400 SBES with 33 kHz / 210 kHz hull-mounted transducer was used for bathymetry. In addition a DMS25 MRU was interfaced to the SBES in order to reduce the influence of the vessel's vertical movement on depth readings. Refer to Table 4.4 for the installation details.

Table 4.4: SBES operational installation MV Fugro Pioneer

SBES	Kongsberg EA400
Frequency	33 kHz
Range	Dependent on water depth
Heave compensation	DMS25
Transducer Draught	3.0 to 3.5 m

4.4 Multibeam Echo Sounder

A Kongsberg EM2040 MBES, in a single transmitting transducer (Tx) / dual receiving transducer (Rx) configuration, was used to accurately map seabed bathymetry across the survey site. An iXBlue Hydrins INS (inertial gyrocompass and motion sensor) mounted close to the CRP was interfaced with the MBES in order to reduce the influence of the ship's movement on depth readings. The vessel draught was measured during mobilisation in Scheveningen, The Netherlands, and periodically during the project. Refer to Table 4.5 for the installation details.

Table 4.5: MBES operational installation M.V. Fugro Pioneer

MBES	Kongsberg EM 2040
Frequency	400 kHz
Swath coverage	Variable; modal value 150m
Number of beams	800
Motion & Heave compensation	iXBlue Hydrins INS
Transducer draught	3.4 m to 3.6 m

A MBES calibration was carried out onboard the M.V. Fugro Pioneer on 23 April 2016 on a side tap (Dutch Sector, North Sea), at Latitude: 53° 02' 53'' N Longitude: 04° 18' 12'' E (ETRS89) in a water depth of 32 metres.

The results of the calibration are summarised in Table 4.6. To verify the MBES calibration, an MBES verification was conducted on 31 July 2016 over a rock dump in Block Q, Dutch Sector, North Sea. Details of the verification are presented in Appendix A.4 of this report.

Table 4.6: MBES calibration M.V. Fugro Pioneer

Date	Derived Corrections	Latency	Pitch	Roll	Yaw
		[sec]	[°]	[°]	[°]
23 April 2016	Rx Port	0.0	-0.68	-0.08	0.005
	Rx Stbd	0.0	-0.68	0.14	0.005

4.5 Sidescan Sonar System

The EdgeTech 4200-FS is a dual simultaneous frequency SSS system, which utilises Full Spectrum CHIRP technology. The frequencies utilised on the project are 100 kHz and 600 kHz. The theoretical maximum range for this model is 500 m per side at 100 kHz and 100 m per side at 600 kHz. The data was digitally recorded on Starfix.GLog/GPlot software for digital processing.

A Kongsberg HiPAP USBL positioning system was used for towfish positioning. The EdgeTech 4200-FS system incorporates an internal fluxgate compass which can be used for post-processing of towfish heading values. Refer to Table 4.7 for the operational installation details of the SSS on the MV Fugro Pioneer.

Table 4.7: SSS operational installation MV Fugro Pioneer

SSS	EdgeTech 4200-FS
Range	125 m
Low Frequency	Linear sweep: 116.5-131.8 kHz
High Frequency	Linear sweep: 528.5-581.5 kHz
Cable out	Variable (depending on water depth and vessel speed)

4.6 Magnetometer

The G-882 Marine magnetometer used for this project has a very high resolution Caesium Vapour performance. These magnetometers are capable of achieving high sensitivity and sampling rates in both shallow and deep water. They have a minimum sensitivity of less than 0.004 nT/Hz rms and a maximum sampling rate of 40 samples per second.

In order to check if the magnetometer was working effectively a verification was carried out on 31 July 2016. The verification consisted of running two (2) survey lines, with magnetometer, in opposite direction over the TAT 14 Seg J cable in Block Q, Dutch sector, North Sea. The result of this verification can be found in Appendix A.6.

4.7 Sub-bottom Profiler System

The hull-mounted Pinger (HMP) Massa TR-1075 Pinger array installed on-board M.V. Fugro Pioneer was used as the primary tool for detecting shallow sub-surface layers. The system comprises an array of sixteen (16) transducers, with two (2) additional transducers added to the front row. The array was operated using the following configurations:

- 4 x 4, where all transducers were set in combined mode (Tx/Rx).

For this configuration the transducers were operated at 5.0 kHz.

A TSS DMS-25 motion reference unit was installed close to the transducer array, to compensate for the influence of the vertical movement on the recordings. Refer to Table 4.8 for the SBP (pinger) operational installation details.

Table 4.8: SBP (pinger) Operational Installation MV Fugro Pioneer

HMP (4 x 4 configuration)	Massa TR-1075
Record length	120 ms
Source frequency	4.5 kHz
Sampling interval	0.05 ms
Bandpass filter	3.0 – 6.0 kHz (3 kHz bandwidth) and 3.5 – 6.5 kHz (2 kHz bandwidth)
Power (3 x 3 setting)	0.466 kW (2% of max. 23.33 kW)
Firing rate	140 ms

In order to determine the functionality of the sub-bottom profiler system (SBP) a verification was carried out on 01 August 2016. The verification consisted of running two sub-bottom profiler lines in opposite directions over the existing 20” Helm A to Ijmuiden pipeline in Block Q, Dutch sector, North Sea. The results of this verification can be found in Appendix A.7.

4.8 Ultra Short Baseline (USBL) System

A USBL system allows the measurement of range and bearing from a vessel-based transceiver to a single subsea transponder. It generally operates through the phase discrimination of an acoustic signal recorded by three orthogonal transducers. A Kongsberg HiPAP USBL positioning system was used on board the M.V. Fugro Pioneer for tow fish positioning.

The M.V. Fugro Pioneer carried out a USBL calibration on 04 March 2016 in Skagerrak, Denmark, at Latitude: 58° 13.5` N Longitude: 009° 58.4` E. The calibration was carried out to determine the accuracy and possible corrections for the Kongsberg HiPAP USBL positioning system. The beacon was moored on the sea bottom and the vessel stationed on 4 cardinal points to determine orientation, pitch and roll corrections. These values were then entered into the APOS software that controls the HiPAP system.

In addition to the calibration, a USBL verification was conducted. The USBL verification was conducted on 31 July 2016 before starting survey operations for the Thanet Extension Wind Farm site study over a rock dump in the vicinity of the Q8-a platform in the Dutch sector of the North Sea. The verification was conducted in order to determine the accuracy of the HiPAP USBL system in conjunction with the SSS system. A detailed report of the USBL calibration and verification are presented in Appendix A.5.

4.9 Sparker and Mini Sleeve Gun – UHR System

Two sources were used depending on the area surveyed. The first source consisted of an Applied Acoustic DuraSpark 360 tip source and Applied Acoustics CSP-N1200 power supply unit. The second source consisted of a mini sleeve gun controlled by a MACA power supply unit. A 48 channel solid Geometrics streamer CNT2 was used as a receiver for both sources. Data was recorded by Geometrics CNT2 software in digital SEG- 8058D format.

The sparker system was operated using the following parameters:

Power:	600J or 800 J
Range:	250 ms
Source Tow Depth:	0.5 ± 0.1 m
Shot Interval:	1.5625 m

The mini sleeve gun was operated using the following parameters:

Power:	5 $inch^3$
Range:	250 ms
Source Tow Depth:	0.8 m
Shot Interval:	3.125 m

The 150 m solid Geometrics streamer CNT2 comprised 48 channels, each comprising a group of 12 hydrophone sensors. The streamer was maintained at the required tow depth of 0.5 m (+/- 0.3m) during acquisition, with streamer balance and level monitored and corrected by the Digicourse active

leveller system communicating with Digicourse depth sensors. The streamer was decoupled from the vessel heave using a tow leader and 20 m stretch section with a Norwegian buoy acting as a tail buoy.

The digital streamer specifications were as follows:

Active Length:	150 m
No of Groups:	48
Group Interval:	3.125 m
Hydrophones:	12 per group
Streamer Sensitivity:	20μV/μb
Streamer Tow Depth:	0.5 ± 0.3 m

Mobilisation tests were, where practical, carried out as per the proposal in the operational plan.

Mobilisation Quayside Tests			
Test / Cal	**Description**	**Test / Calibration Deliverable**	**Test Result**
Sparker source and mini sleeve gun test	Deploy and fire the source alongside up to maximum energy	Source fires without malfunction.	Test performed alongside. Fired at maximum energy without malfunction.
Recording unit test (Analogue system)	Start-up recorder – record a test file without streamer connected.	Record trace data. Should produce a white noise baseline spectrum.	Not applicable on digital streamer
Integrated seismic spread test	The following tests will occur with the full system assembled and source firing for 0.5h period as a minimum	Power supply fires without overheating or interruptions. Simulated distance triggering fires the PS without miss-fires	Completed successfully during Test Line at start of the survey
Navigation recording test	Log position data including shot number, FFID, centre of source, centre of each receiver group and feather angle.	Log files record valid values for every shot.	Completed during Test Line at start of the survey

Mobilisation tests performed at sea			
Test / Cal	**Description**	**Test / Calibration Deliverable**	**Test Result**
Streamer working noise limit	Record noise file of entire towed spread without source firing	Background noise to ascertain signal to noise ratio.	Background noise of acceptable level. Average noise values during the test were 8- 20 µBar. Noise files are recorded at start and end of every survey line
Signature test (Sparker and mini sleeve gun)	Deploy and calibrate reference hydrophone 5 m below source and record 100> shots and various energy levels	Test signatures conform with manufacturers signature library	Pulse test carried out with calibrated reference hydrophone offshore. The pulse test shows a good short initial pulse with minimal residual
Seismic source tow depth (Sparker and mini sleeve gun)	Deploy seismic source at various depths to monitor ghost noise levels	Determine optimal tow depth for seismic source	Optimal source tow depth for sparker was determined at 0.5 m and for the mini sleeve gun at 0.8 m.
Streamer tow depth and balancing	Balance streamer to survey specifications	Ensure ghost/wave noise minimised and sound recorded equally across all channels	Streamer balanced and checked on first deployment. Tow depth configured to 0.8 m.
Feathering	Monitor feather angle at in line and cross line directions	Feather angle within specification under normal survey conditions	Feather angle is monitored via compass birds.

During mobilisation, pulse tests were performed to optimise source depth and power settings for the GSO 360-tip sparker. A test line was performed at sea on 31 July 2016 before the start of the Thanet Extension survey. This trial confirmed the suitability of the settings determined by the pulse tests.

On 19 August 2016 a second pulse test was performed for the sparker. This was done to check the functionality of the sparker after replacement of the CSP unit. A test line (line 1_TS_53A) was re-run and the data from this re-run were compared to the data from the original line.

The result of this test proved comparable to the previous test both in terms of amplitude and resolution, despite slight differences due to local marine conditions at the time, resulting in a slight increase in the separation between the sparker and the hydrophone.

A report of the signature tests are presented in Appendix A.8, A.9 and A.10.

4.10 Sound Velocity Profiler

A Valeport sound velocity probe is used to acquire SVP readings at the MBE head. On top of this, profile data is acquired by a SAIV204 CTD profiler and utilised for the MBES and APOS software of the MV Fugro Pioneer. Both CTD profilers were calibrated on 08 March 2016. Also, on 09 September 2016, two (2) simultaneous sound velocity profiles were acquired with these profilers. This verified that both profilers give similar results. Refer to Appendix A.12 for calibration certificates and Appendix A.13 for the CTD comparison.

The profilers are programmed to measure and calculate salinity, conductivity (density), temperature, depth (density) and sound velocity at pre-set intervals. A list of the average sound velocities acquired is presented in Table 4.9. The individual sound velocity profiles can be found in Appendix A.14.

Table 4.9: Sound Velocity Measurements

Date	Average Velocity of Sound [m/s]
30/07/2016	1513.18
30/01/2016	1513.21
01/08/2016	1517.51
02/08/2016	1517.28
02/08/2016	1517.43
03/08/2016	1515.24
04/08/2016	1514.64
05/08/2016	1515.98
06/08/2016	1517.47
06/08/2016	1515.87
07/08/2016	1516.03
08/08/2016	1516.69
09/08/2016	1517.53
09/08/2016	1517.44
10/08/2016	1516.60
10/08/2016	1516.76
11/08/2016	1516.64

Date	Average Velocity of Sound [m/s]
15/08/2016	1517.81
15/08/2016	1517.54
16/08/2016	1518.06
16/08/2016	1517.82
17/08/2016	1518.69
17/08/2016	1519.05
19/08/2016	1518.66
26/08/2016	1518.27
26/08/2016	1518.27
27/08/2016	1517.75
27/08/2016	1518.81
29/08/2016	1519.43
30/08/2016	1519.06
30/08/2016	1519.42
31/08/2016	1519.31
31/08/2016	1519.87
01/09/2016	1519.39

Date	Average Velocity of Sound [m/s]
11/08/2016	1517.39
12/08/2016	1516.66
13/08/2016	1517.55
14/08/2016	1517.44
14/08/2016	1517.61

Date	Average Velocity of Sound [m/s]
01/09/2016	1519.75
02/09/2016	1519.67
01/09/2016	1519.59
03/09/2016	1519.36

5. HEALTH, SAFETY & ENVIRONMENT

A vessel safety tour and meeting were performed for all new members, both marine and survey crew, prior to the start of the survey and following each crew change.

A daily Vessel Coordination Meeting was held on-board attended by the vessel Master, survey Party Chief and the two Offshore Client Representatives. The meeting was used to discuss the previous 24 hours' operations, planned operations, the current and expected weather and sea state conditions and other safety related matters, including toolbox talks and Permits to Work.

Toolbox talks were performed prior to all back deck operations.

No HSE incidents were reported during the mobilisation of the survey.

APPENDICES

NO TABLE OF CONTENTS ENTRIES FOUND.

A. CALIBRATIONS AND VERIFICATIONS

No table of contents entries found.

A.1 POSITIONING SYSTEM VERIFICATION

(1 page, not numbered)

FO-102 DGPS VERIFICATION

Project: **Thanet Extension Offshore Windfarm**

Vessel : **Fugro Pioneer** **Project No. :** **GE051**
Location : **Scheveningen** **Date :** **30/ Jul/2016**
Positioning System : **DGPS3 G2+**

		Easting (m)	Northing (m)
Survey Control Station ID :	S00	586,823.957	5,772,948.097
Reference Object RO1 :	S11	586,867.567	5,772,999.513
Reference Object RO2 :	S12	586,803.268	5,772,923.553

Point Scale Factor : 0.99966 (Grid distance = spheroidal distance * scale factor)
Convergence : 1.00100 (Grid bearing = azimuth - convergence) **care with sign convention

Observations to : DGPS3 G2+ Antenna

Results Summary :

	C-O	
	dE m	**dN m**
S.D.	0.01	0.01
Mean	-0.08	-0.09

Notes:

Datum	ETRS89	Datum Shifts	dX (m)	0.05376	rX (")	-0.002239
Projection	UTM31	(WGS84 to local)	dY (m)	0.05096	rY (")	-0.013547
CM	3°E		dZ (m)	-0.08847	rZ (")	0.021897
Hemisphere	North				Scale (ppm)	0.0026718

Comments:

For Fugro **For Client**

C. Maree [redacted] R. Chippendale [redacted]

A.2 POSITIONING SYSTEM COMPARISON

(1 page, not numbered)

POSITIONING SYSTEM COMPARISON

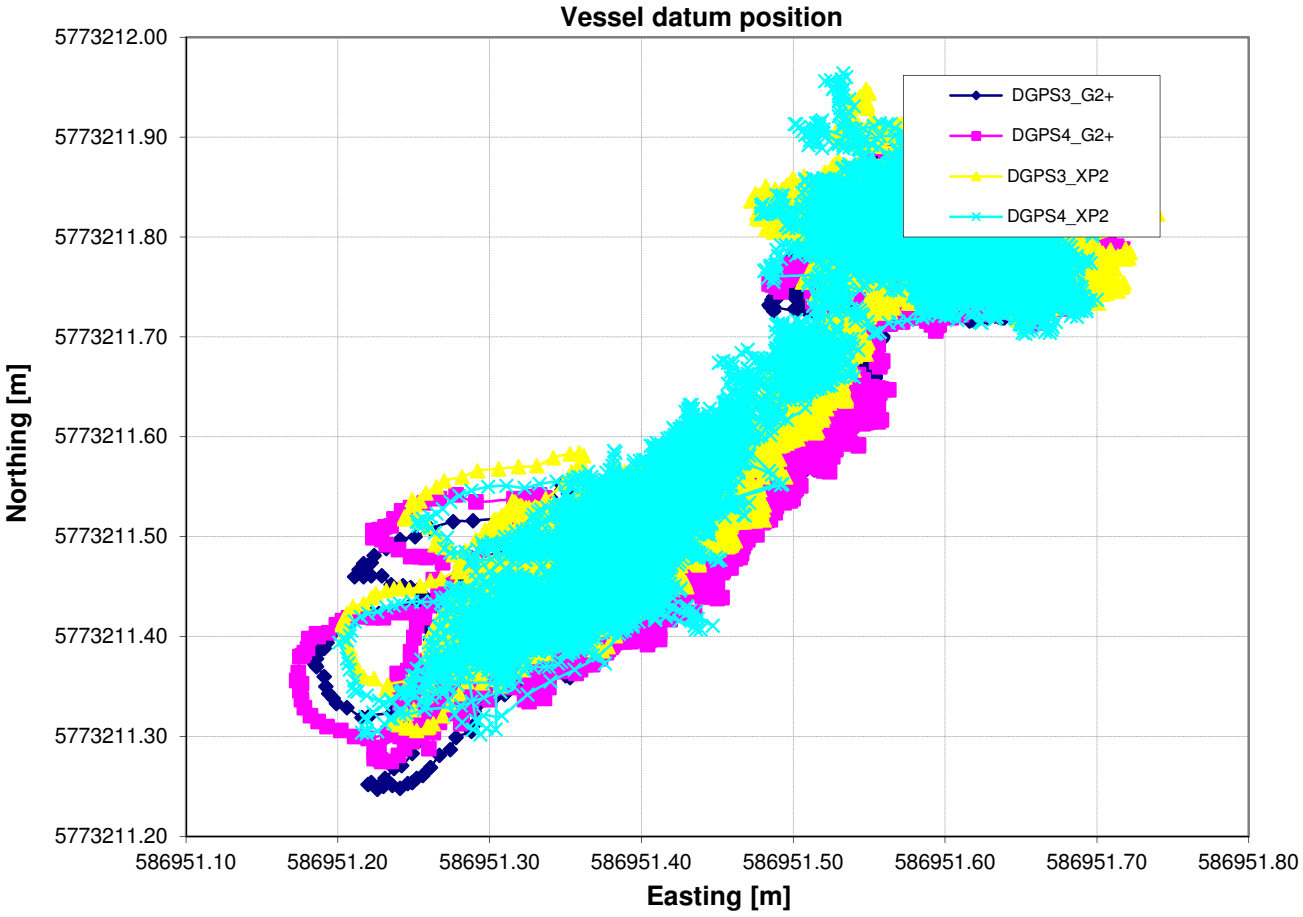
Vattenfall
Thanet Extension Offshore Windfarm

Project no: GE051
Date: 30 Jul 2016
Vessel: Fugro Pioneer
Start time: 23:59:53
Location: Scheveningen
Stop time: 07:02:54

Antenna offset			
No.	**System name**	**X**	**Y**
1	DGPS3_G2+	3.18	4.26
2	DGPS4_G2+	-3.16	5.09
3	DGPS3_XP2	3.18	4.26
4	DGPS4_XP2	-3.16	5.09

Geodesy

Datum		ETRS89
Projection		UTM31
CM		3°E
Hemisphere		North



	Comparison DGPS3_G2+ / DGPS4_G2+		Comparison DGPS3_G2+ / DGPS3_XP2		Comparison DGPS3_G2+ / DGPS4_XP2	
	dE [m]	dN [m]	dE [m]	dN [m]	dE [m]	dN [m]
Mean	0.01	0.00	0.00	0.03	-0.01	0.02
S.D.	0.02	0.02	0.02	0.02	0.02	0.03
	Comparison DGPS4_G2+ / DGPS3_XP2		**Comparison DGPS4_G2+ / DGPS4_XP2**		**Comparison DGPS3_XP2 / DGPS4_XP2**	
	dE [m]	dN [m]	dE [m]	dN [m]	dE [m]	dN [m]
Mean	-0.01	0.03	-0.02	0.02	-0.01	-0.01
S.D.	0.03	0.03	0.02	0.02	0.02	0.02

For Fugro Survey B.V.

C. Maree

For Client

R. Chippendale

A.3 GYROCOMPASS ALIGNMENT CHECK

(4 pages, not numbered)

GYRO CALIBRATION FROM SUN OBSERVATIONS

Thanet Extension Offshore Windfarm

Project no: GE051
Vessel: Fugro Pioneer

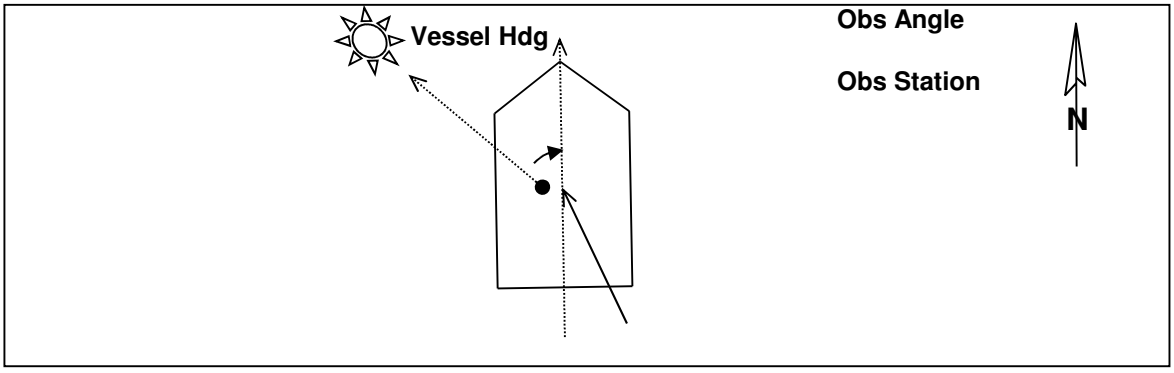
Gyro name: Octans
Date : 29-Jul-16

Position : 52 6 02.71 N
4 16 05.48 E

Location : Scheveningen
Datum : ETRS89
Projection : UTM 31
CM : 3
Hemisphere : N

Obs. vessel north		
Deg	Min	Sec
0	0	0

Fix	UTC	Observed Sun			Calc Sun Azimuth			Obs. Gyro	Calc. Vessel	C-O
No.	hh:mm:ss	Deg	Min	Sec	Deg	Min	Sec	deg true	deg true	deg
1	15:43:03	215	29	53	256	19	37	41.46	40.83	-0.63
2	15:43:24	215	30	40	256	24	16	41.54	40.89	-0.65
3	15:43:38	215	32	50	256	27	21	41.58	40.91	-0.67
4	15:44:16	215	39	30	256	35	45	41.60	40.94	-0.66
5	15:44:36	215	45	40	256	40	10	41.56	40.91	-0.65
6	15:45:18	215	55	32	256	49	26	41.56	40.90	-0.66
7	15:45:35	215	57	59	256	53	10	41.55	40.92	-0.63
8	15:47:18	216	23	6	257	15	48	41.50	40.88	-0.62
9	15:47:37	216	32	15	257	19	58	41.39	40.80	-0.59
10	15:48:16	216	40	18	257	28	30	41.44	40.80	-0.64
11	16:02:24	219	37	22	260	31	11	41.53	40.90	-0.63
12	16:03:04	219	52	25	260	39	40	41.44	40.79	-0.65
13	16:03:20	219	53	49	260	43	4	41.48	40.82	-0.66
14	16:03:39	219	54	33	260	47	5	41.54	40.88	-0.66
15	16:03:53	220	0	50	260	50	3	41.44	40.82	-0.62
16	16:04:16	220	1	25	260	54	55	41.60	40.89	-0.71
17	16:04:34	220	10	15	260	58	43	41.48	40.81	-0.67
18	16:04:55	220	16	2	261	3	10	41.45	40.79	-0.66
19	16:06:42	220	44	55	261	25	43	41.38	40.68	-0.70
20	16:07:37	220	56	29	261	37	17	41.41	40.68	-0.73
									Average:	-0.66
									St. dev.	0.03



For Fugro Survey B.V.

C. Maree

[redacted]

For Client

R. Chippendale

[redacted]

GYRO CALIBRATION FROM SUN OBSERVATIONS

Thanet Extension Offshore Windfarm

Project no: GE051
Vessel: Fugro Pioneer

Gyro name: Meridians
Date : 29-Jul-16

Position : 52 6 02.71 N
4 16 05.48 E

Location : Scheveningen
Datum : ETRS89
Projection : UTM 31
CM : 3
Hemisphere : N

Obs. vessel north		
Deg	Min	Sec
0	0	0

Fix	UTC	Observed Sun			Calc Sun Azimuth			Obs. Gyro	Calc. Vessel	C-O
No.	hh:mm:ss	Deg	Min	Sec	Deg	Min	Sec	deg true	deg true	deg
1	15:43:03	215	29	53	256	19	37	40.80	40.83	0.03
2	15:43:24	215	30	40	256	24	16	40.88	40.89	0.01
3	15:43:38	215	32	50	256	27	21	40.92	40.91	-0.01
4	15:44:16	215	39	30	256	35	45	40.95	40.94	-0.01
5	15:44:36	215	45	40	256	40	10	40.91	40.91	0.00
6	15:45:18	215	55	32	256	49	26	40.91	40.90	-0.01
7	15:45:35	215	57	59	256	53	10	40.90	40.92	0.02
8	15:47:18	216	23	6	257	15	48	40.86	40.88	0.02
9	15:47:37	216	32	15	257	19	58	40.77	40.80	0.03
10	15:48:16	216	40	18	257	28	30	40.82	40.80	-0.02
11	16:02:24	219	37	22	260	31	11	40.89	40.90	0.01
12	16:03:04	219	52	25	260	39	40	40.80	40.79	-0.01
13	16:03:20	219	53	49	260	43	4	40.83	40.82	-0.01
14	16:03:39	219	54	33	260	47	5	40.89	40.88	-0.01
15	16:03:53	220	0	50	260	50	3	40.79	40.82	0.03
16	16:04:16	220	1	25	260	54	55	40.95	40.89	-0.06
17	16:04:34	220	10	15	260	58	43	40.82	40.81	-0.01
18	16:04:55	220	16	2	261	3	10	40.79	40.79	0.00
19	16:06:42	220	44	55	261	25	43	40.69	40.68	-0.01
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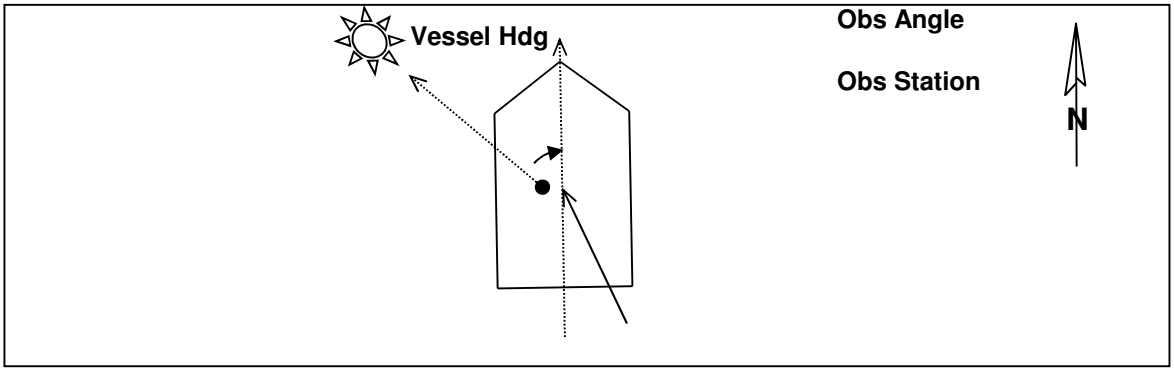
									Average:	0.00
									St. dev.	0.02



For Fugro Survey B.V.

C. Maree [redacted]

For Client

R. Chippendale [redacted]

 GE051 Heading Alignment Check Meridians 20160729.xls

GYRO CALIBRATION FROM SUN OBSERVATIONS

Thanet Extension Offshore Windfarm

Project no: GE051
Vessel: Fugro Pioneer

Gyro name: HydrIns
Date : 29-Jul-16

Position : 52 6 02.71 N
4 16 05.48 E

Location : Scheveningen
Datum : ETRS89
Projection : UTM 31
CM : 3
Hemisphere : N

Obs. vessel north		
Deg	Min	Sec
0	0	0

Fix	UTC	Observed Sun			Calc Sun Azimuth			Obs. Gyro	Calc. Vessel	C-O
No.	hh:mm:ss	Deg	Min	Sec	Deg	Min	Sec	deg true	deg true	deg
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2	15:43:24	215	30	40	256	24	16	40.95	40.89	-0.06
3	15:43:38	215	32	50	256	27	21	40.99	40.91	-0.08
4	15:44:16	215	39	30	256	35	45	41.02	40.94	-0.08
5	15:44:36	215	45	40	256	40	10	40.98	40.91	-0.07
6	15:45:18	215	55	32	256	49	26	40.98	40.90	-0.08
7	15:45:35	215	57	59	256	53	10	40.97	40.92	-0.05
8	15:47:18	216	23	6	257	15	48	40.93	40.88	-0.05
9	15:47:37	216	32	15	257	19	58	40.83	40.80	-0.03
10	15:48:16	216	40	18	257	28	30	40.89	40.80	-0.09
11	16:02:24	219	37	22	260	31	11	40.95	40.90	-0.05
12	16:03:04	219	52	25	260	39	40	40.86	40.79	-0.07
13	16:03:20	219	53	49	260	43	4	40.89	40.82	-0.07
14	16:03:39	219	54	33	260	47	5	40.94	40.88	-0.06
15	16:03:53	220	0	50	260	50	3	40.85	40.82	-0.03
16	16:04:16	220	1	25	260	54	55	41.00	40.89	-0.11
17	16:04:34	220	10	15	260	58	43	40.88	40.81	-0.07
18	16:04:55	220	16	2	261	3	10	40.85	40.79	-0.06
19	16:06:42	220	44	55	261	25	43	40.76	40.68	-0.08
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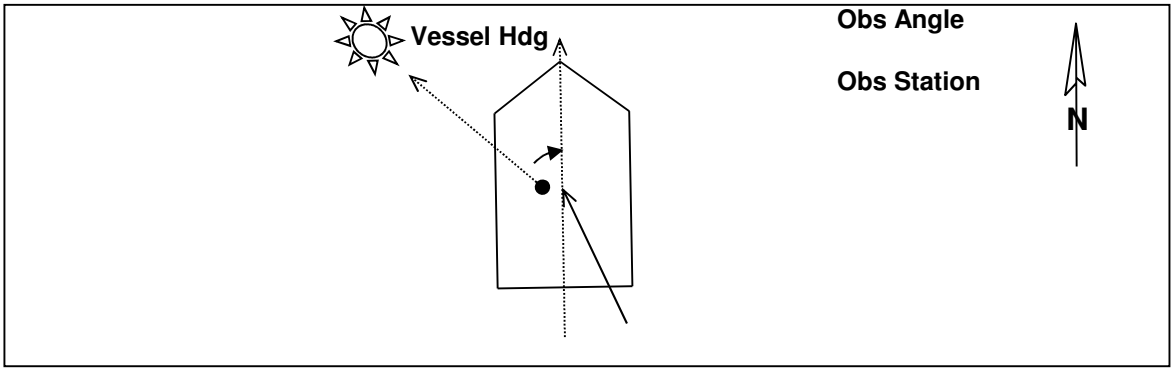
									Average:	-0.07
									St. dev.	0.02



For Fugro Survey B.V.

C. Maree

For Client

R. Chippendale

GYRO CALIBRATION FROM SUN OBSERVATIONS

Thanet Extension Offshore Windfarm

Project no: GE051
Vessel: Fugro Pioneer

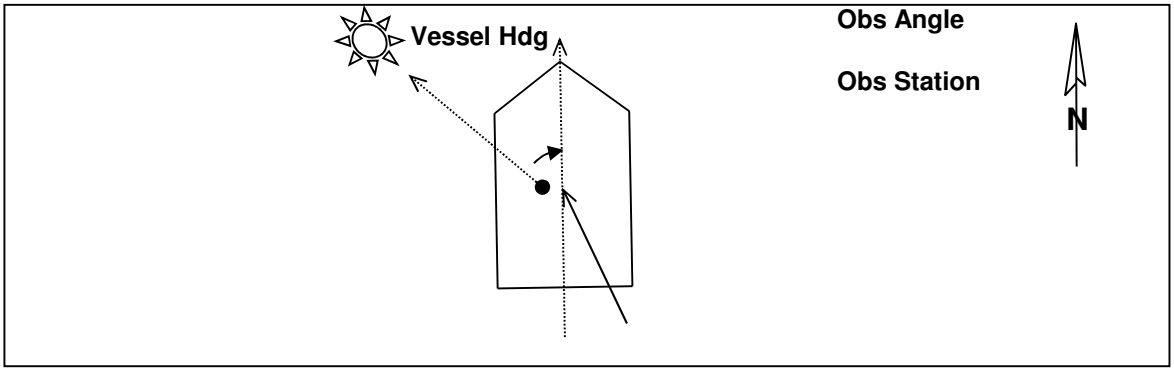
Gyro name: DGPS3
Date : 29-Jul-16

Position : 52 6 02.71 N
4 16 05.48 E

Location : Scheveningen
Datum : ETRS89
Projection : UTM 31
CM : 3
Hemisphere : N

Obs. vessel north		
Deg	Min	Sec
0	0	0

Fix	UTC	Observed Sun			Calc Sun Azimuth			Obs. Gyro	Calc. Vessel	C-O
No.	hh:mm:ss	Deg	Min	Sec	Deg	Min	Sec	deg true	deg true	deg
1	15:43:03	215	29	53	256	19	37	41.03	40.83	-0.20
2	15:43:24	215	30	40	256	24	16	41.06	40.89	-0.17
3	15:43:38	215	32	50	256	27	21	41.11	40.91	-0.20
4	15:44:16	215	39	30	256	35	45	41.16	40.94	-0.22
5	15:44:36	215	45	40	256	40	10	41.10	40.91	-0.19
6	15:45:18	215	55	32	256	49	26	41.17	40.90	-0.27
7	15:45:35	215	57	59	256	53	10	41.15	40.92	-0.23
8	15:47:18	216	23	6	257	15	48	41.08	40.88	-0.20
9	15:47:37	216	32	15	257	19	58	40.97	40.80	-0.17
10	15:48:16	216	40	18	257	28	30	41.00	40.80	-0.20
11	16:02:24	219	37	22	260	31	11	41.12	40.90	-0.22
12	16:03:04	219	52	25	260	39	40	41.00	40.79	-0.21
13	16:03:20	219	53	49	260	43	4	41.05	40.82	-0.23
14	16:03:39	219	54	33	260	47	5	41.16	40.88	-0.28
15	16:03:53	220	0	50	260	50	3	41.03	40.82	-0.21
16	16:04:16	220	1	25	260	54	55	41.17	40.89	-0.28
17	16:04:34	220	10	15	260	58	43	41.01	40.81	-0.20
18	16:04:55	220	16	2	261	3	10	40.98	40.79	-0.19
19	16:06:42	220	44	55	261	25	43	40.88	40.68	-0.20
20	16:07:37	220	56	29	261	37	17	40.92	40.68	-0.24
									Average:	-0.22
									St. dev.	0.03



For Fugro Survey B.V.

C. Maree [redacted]

For Client

R. Chippendale [redacted]

A.4 MULTIBEAM ECHO SOUNDER CALIBRATION AND VERIFICATION

(10 pages, not numbered)

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Veurse Achterweg 12 Tel : +31-70-3 111 800
2264 SG Leidschendam Telefax : +31-70-3 111 838
P.O. Box 128 E-mail : info@fugro-survey.nl
2260 AC Leidschendam, The Netherlands
Trade Register Number: 34070322 / VAT Number: NL005621409B11

Preliminary Field Report

Subject	Multibeam Verification, Fugro Pioneer		
Date	31-07-2016	**Page**	1 of 4
To	Roger Chippendale	**File**	GE050-GE051 MBE Verification
Attn		**E-mail Address**	
Copy		**E-mail Address**	
Copy		**E-mail Address**	
Copy		**E-mail Address**	
From	Chris Maree	**E-mail Address**	Partychief@pioneer.fugro.com

1. INTRODUCTION

The purpose of the multi beam echo sounder verification was:

- To verify that the previous Multibeam Calibration conducted on the 23th of April 2016 is still applicable during the current survey job.

2. SCOPE OF WORK

The verification consisted of running few lines in opposite directions over a subsea structure. Two lines were sailed on top of the feature and two more with an offset of 50 m each side from the structure.

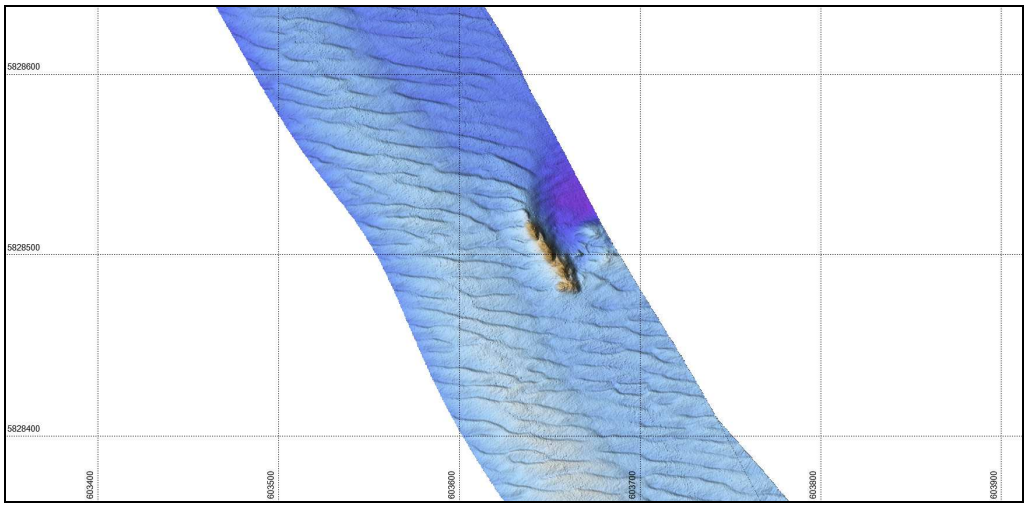

Figure 1: Colour mapped seabed as background

3. OPERATIONS

The verification was carried out on board the vessel Fugro Pioneer on 31st of July 2016 before the operation for Vattenfall to verify correction for the multi beam echo sounder acquisition system.

FUGRO SURVEY B.V.
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2260 AC Leidschendam, The Netherlands
Trade Register Number: 34070322 / VAT Number: NL005621409B11

The verification was conducted on Q07-07 (British sector, North Sea), at Latitude: 52° 35' 40'' N Longitude: 04° 31' 44'' W (WGS84) in a water depth of 15 metres.

Positioning and Navigation	Kongsberg EM2040
	Water Depth Approximately 15 metres
	Multibeam Draft 3.48 m
	Speed of sound in water at surface 1514.78 m/s from CTD probe
	Speed of sound in water at seabed 1515.12 m/s from CTD probe
	Sound Velocity Probe at head,1514.14 m/s Valeport Mini SVP
	Hydrins Gyrocompass and Hydrins Motion Sensor

4. RESULTS

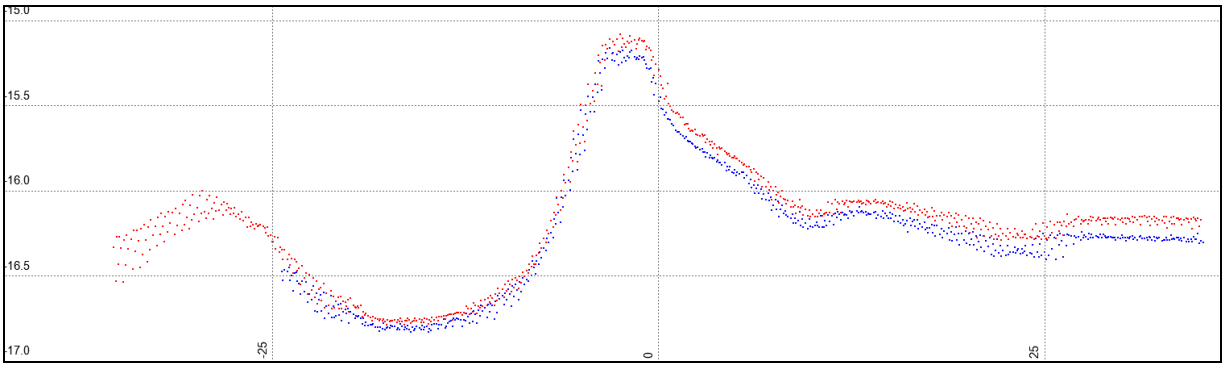

Figure 2: Profile from Pitch Lines Uncorrected, Port Head and Stbd Head.

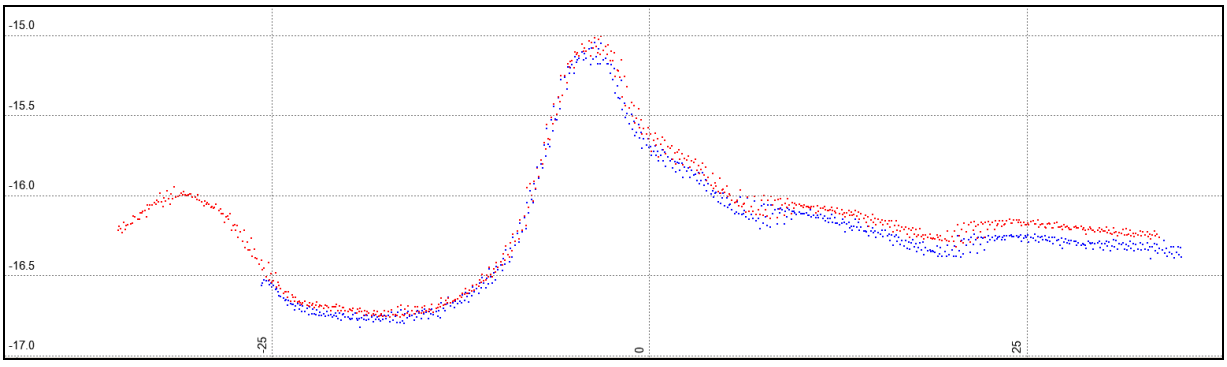

Figure 3: Profile from Pitch Lines Corrected, Port Head and Stbd Head.

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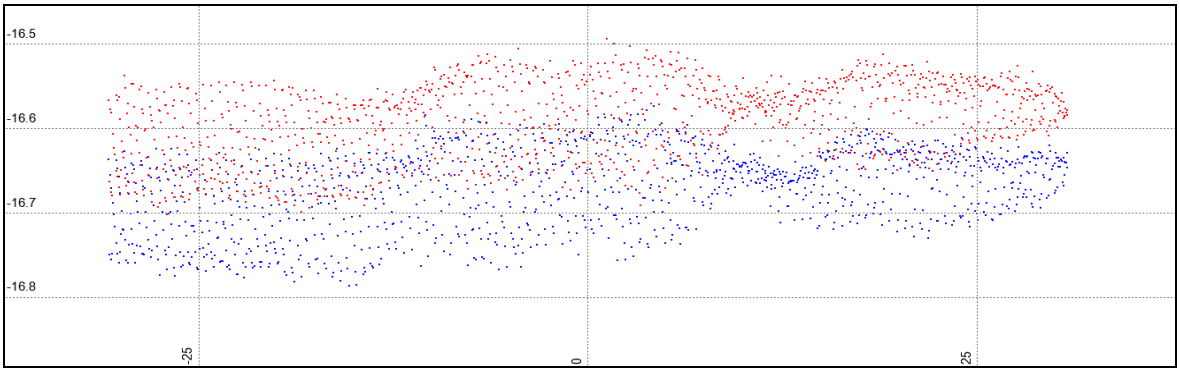

Figure 4: Profile from Roll Lines Uncorrected, Port Head and Stbd Head.

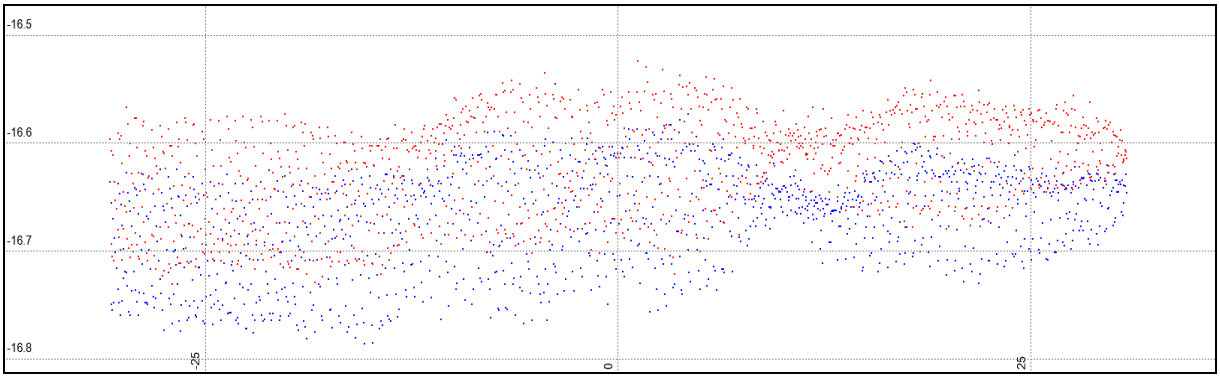

Figure 5: Profile from Roll Lines Corrected, Port Head and Stbd Head.

5. CONCLUSIONS

The multi beam verification has been proven that the Patch Test conducted in April 2016 is still applicable to this job.
In the picture below the corrected value for Latency, Pitch, Roll and Yaw applied.

Derived System Corrections		
	Rx PORT	**RX STBD**
Latency	+0.000 sec	+0.000 sec
Pitch	-0.68°	-0.68°
Roll	-0.08°	+0.14°
Yaw	0.005°	0.005°

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[redacted]

[redacted]

[redacted] Maree
[redacted]
Party Chief
(Fugro Survey B.V.)

R. Chippendale
[redacted]
Client Representative
(Vatenfall)

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Preliminary Field Report

Subject	Multibeam Calibration, Fugro Pioneer		
Date	23.04.2016	**Page**	1 of 6
To	R. Chippendale	**File**	GE050-51 Multibeam Calibration
Attn		**E-mail Address**	
Copy		**E-mail Address**	
From	C. Maree	**E-mail Address**	Partychief@pioneer.fugro.com

1. INTRODUCTION

The purpose of the multibeam echo sounder calibration was:

- To determine the accuracy and possible corrections required for the Kongsberg EM 2040, dual head system.

2. SCOPE OF WORK

The calibration comprised of lines run in a traditional 'patch test' manner, 2 lines with an offset of 50m and 3 lines on top of each other and opposite directions. See Table 1 for the survey line configuration for multibeam corrections.

Table 1: Survey Line Configuration for Multibeam Corrections

Correction	Survey line configuration
System Latency	Two lines run in the same direction at different survey speeds over the feature (4 knots and 6 knots).
Pitch	Two lines run at the same speed in opposite directions over the feature.
Roll	Three lines run at the same speed in opposite directions over a flat seabed
Yaw	Three lines run at the same speed in same direction over the feature

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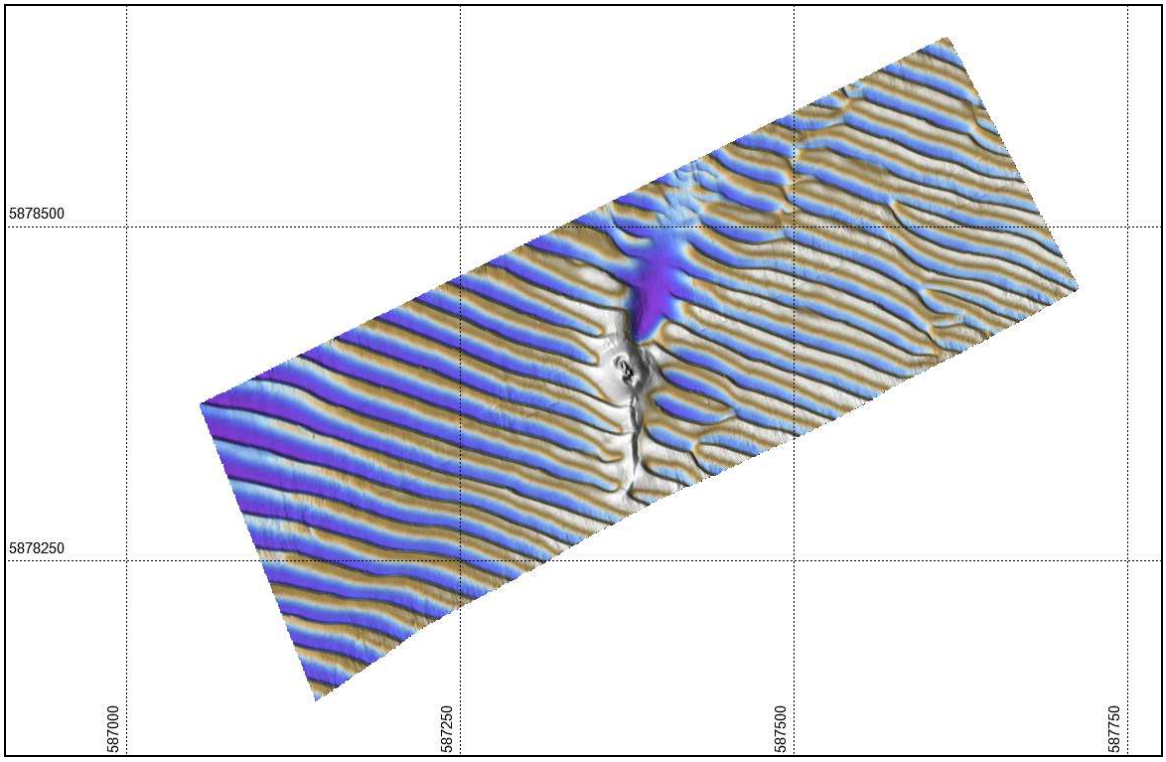

Figure 1: Colour mapped seabed as background

3. OPERATIONS

The calibration was carried out on board the vessel Fugro Pioneer on 23rd April 2016 to determine corrections for the multibeam echo sounder acquisition system.

The calibration was conducted on side tap (Dutch Sector, North Sea), at Latitude: 53° 02' 53'' N Longitude: 04° 18' 12'' E (ETRS89) in a water depth of 32 metres.

Positioning and Navigation Kongsberg EM2040
Water Depth Approximately 32 metres
Multibeam Draft 3.46 m
Speed of sound in water at surface 1485.56 m/s from CTD probe
Speed of sound in water at seabed 1488.31 m/s from CTD probe
Sound Velocity Probe at head,1485.500 m/s Valeport Mini SVP
Hydrins Gyrocompass and Hydrins Motion Sensor

4. RESULTS

Derived System Corrections		
	Rx PORT	**RX STBD**
Latency	+0.000 sec	+0.000 sec
Pitch	-0.68°	-0.68°
Roll	-0.08°	+0.14 °
Yaw	0.005°	0.005°

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The Starfix.Surface screen prints below show profiles of the grid data from the alignment calibration lines. The data was corrected for pitch, roll, latency and yaw. The X axis is in metres along the profile and the Y axis is in metres of water depth.

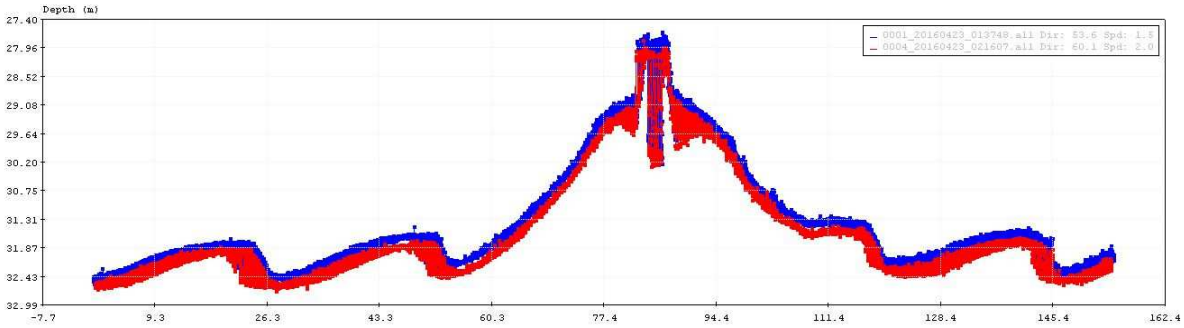

Figure 2: Profile of Latency Lines Uncorrected, Both Heads (Latency = 0 second)

A comparison of the latency profile shows no offset between the two lines run at different speed. The position system used is a Starpack unit and no positioning latency was observed.

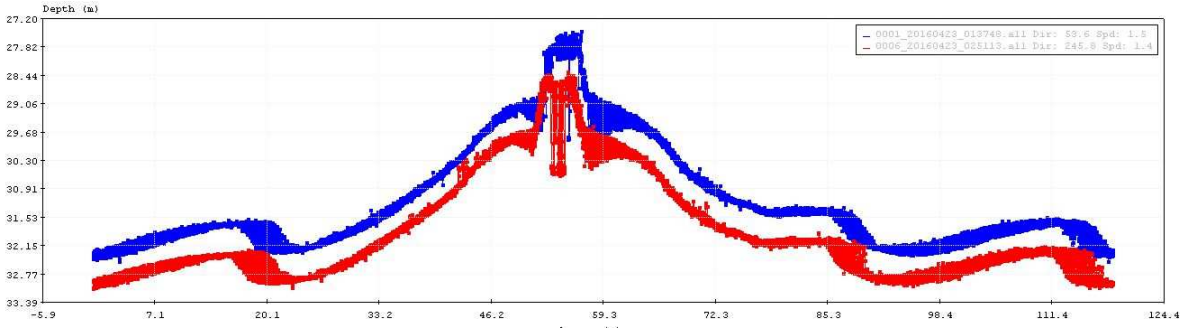

Figure 3: Profile from Pitch Lines Uncorrected, Port Head (Pitch = 0.000°)

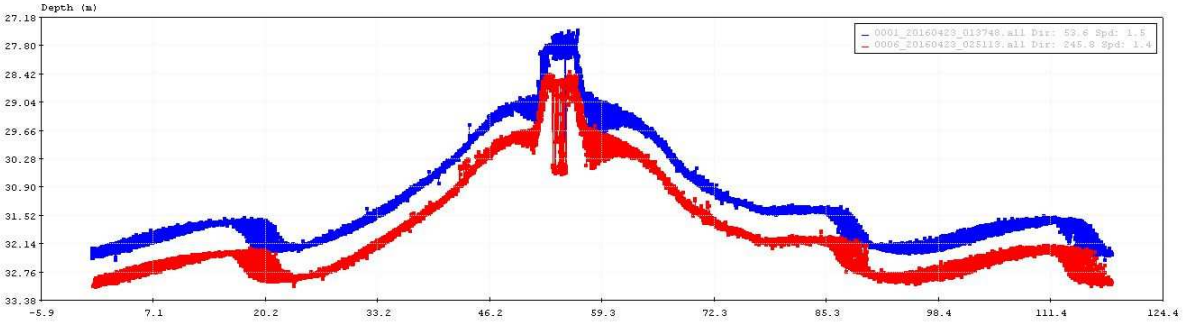

Figure 4 Profile from Pitch Lines Corrected, Port Head (Pitch =- 0.68°)

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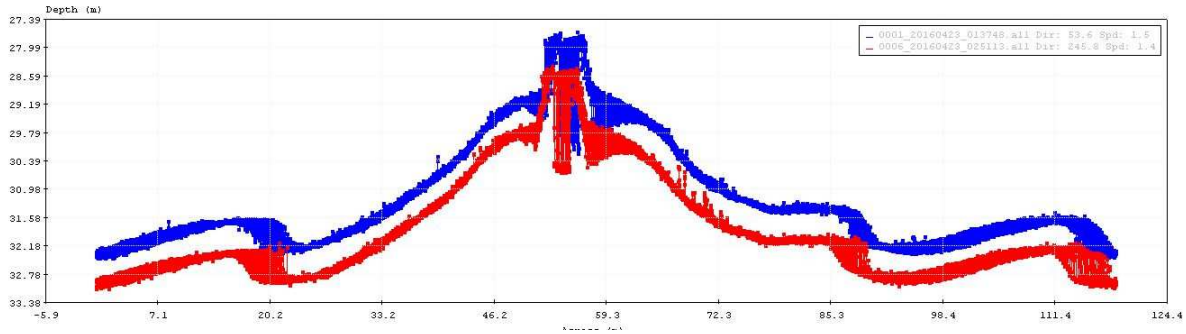

Figure 3: Profile from Pitch Lines Uncorrected, Starboard Head (Pitch = 0.000°)

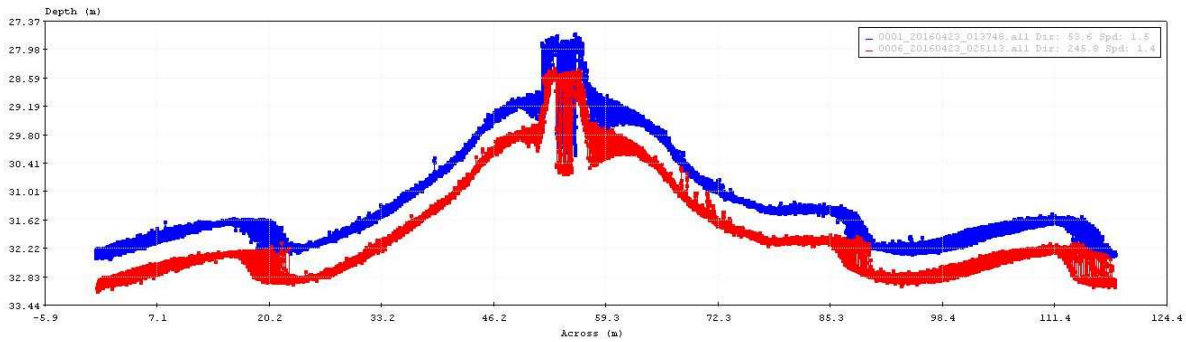

Figure 4: Profile from Pitch Lines Corrected, Starboard Head (Pitch = -0.68°)

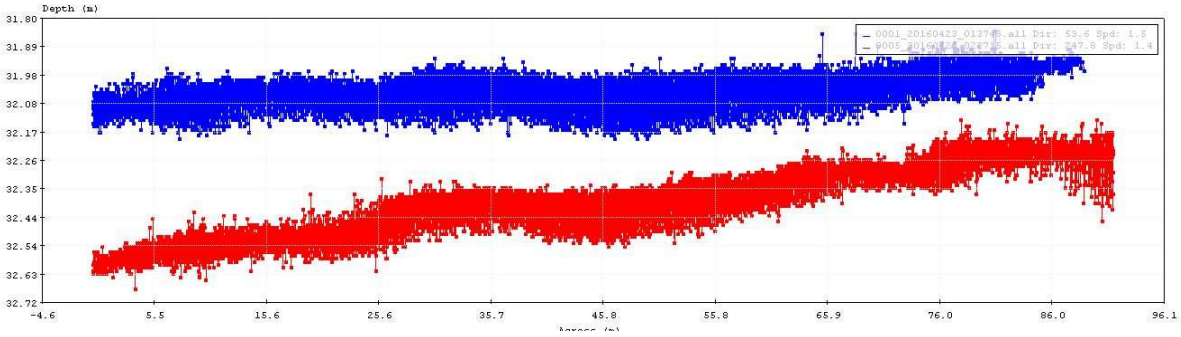

Figure 5: Profile from Roll Lines Uncorrected, Port Head (Roll = 0.000°)

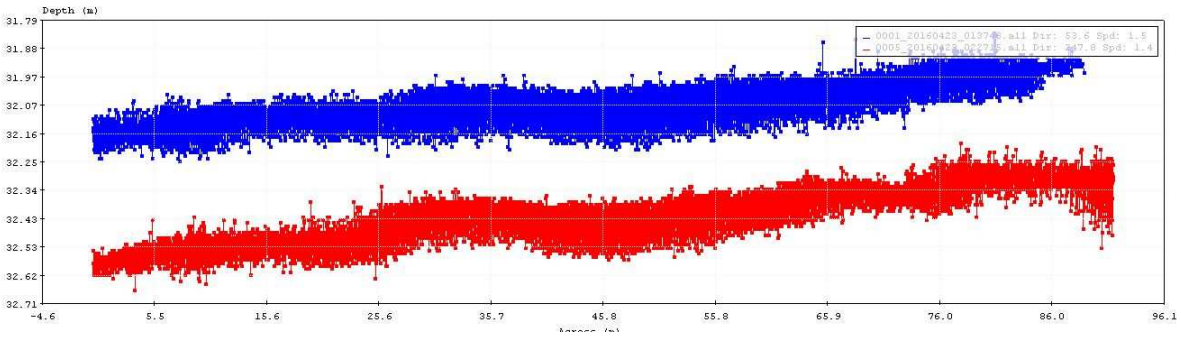

Figure 6: Profile from Roll Lines Corrected, Port Head (Roll -0.08°)

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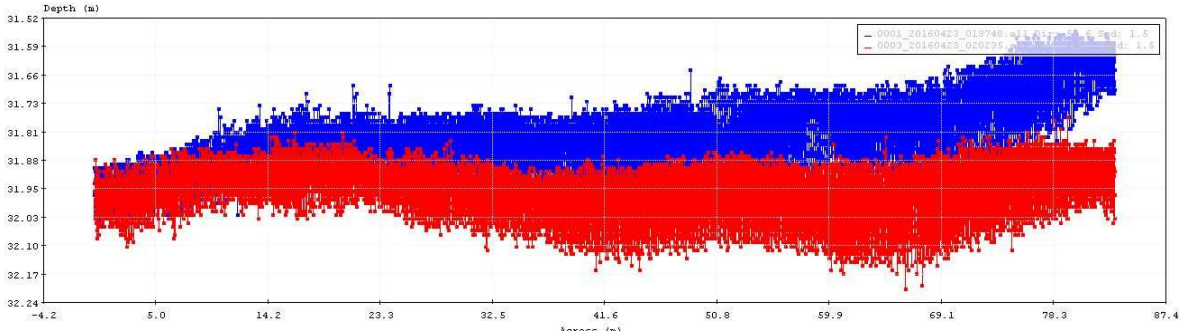

Figure 5: Profile from Roll Lines Uncorrected, Starboard Head (Roll = 0.000°)

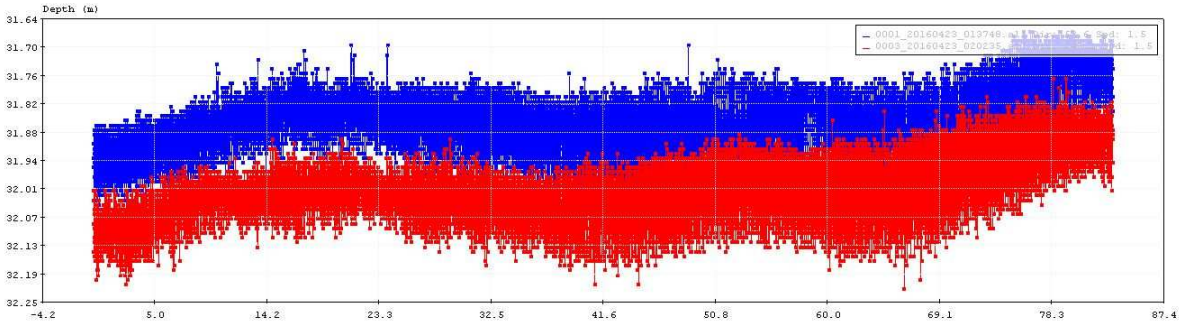

Figure 6: Profile from Roll Lines Corrected, Starboard Head (Roll 0.14°)

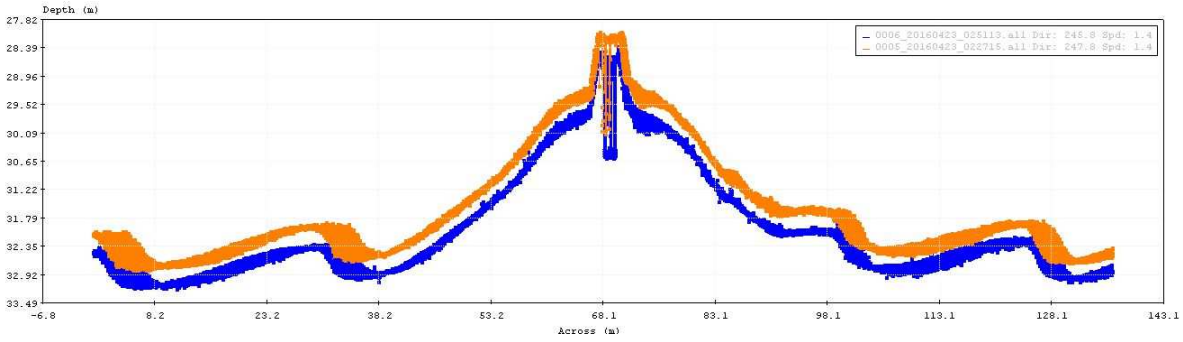

Figure 7: Profile from Yaw Lines Uncorrected, Port Head (Yaw = 0.000°)

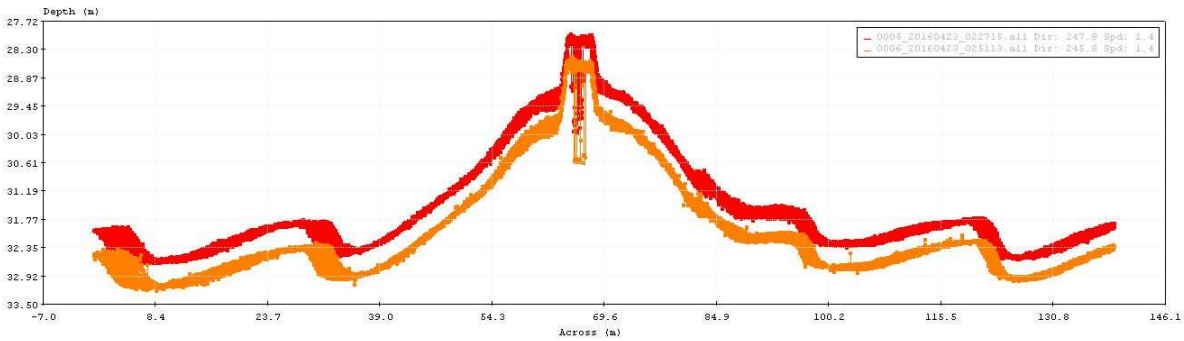

Figure 8: Profile of Yaw Lines Corrected, Port Head (Yaw = 0.0050°)

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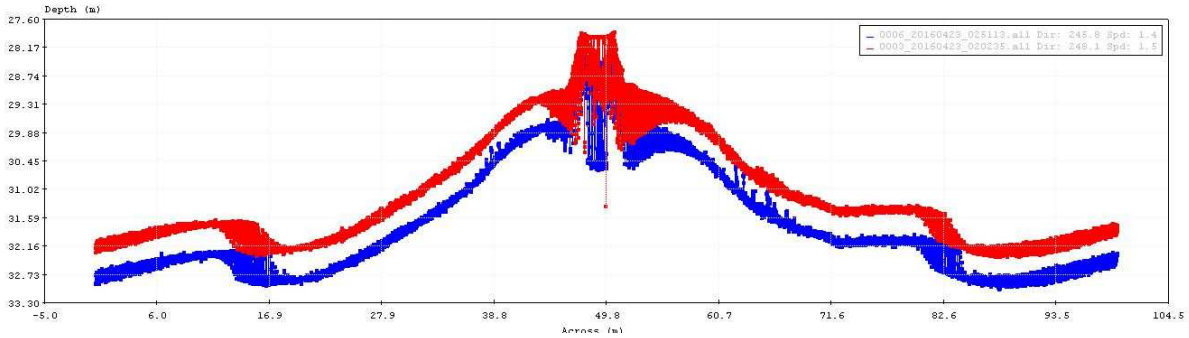

Figure 7: Profile from Yaw Lines Uncorrected (Yaw = 0.000°) Starboard

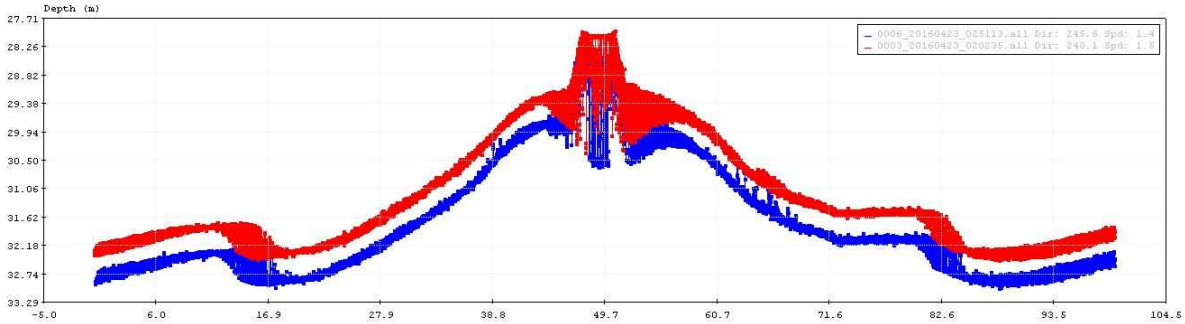

Figure 8: Profile of Yaw Lines Corrected, Starboard Head (Yaw = 0.0050°)

5. CONCLUSIONS

The multibeam system was verified to within the system tolerances as based on the project specification, a cross check of the MBES patch test settings was performed as a patch test verification.

6. HEALTH, SAFETY, & ENVIRONMENT

No safety or HSE incidents were reported during the Patch Test operations.

Signed:

C. Maree

[redacted]

Party Chief
(Fugro Survey B.V.)

R. Chippendale

[redacted]

Client Representative
(Vattenfall Wind Power Ltd)

A.5 USBL CALIBRATION AND VERIFICATION

(13 pages, not numbered)

USBL / SSS system verification report

Subject	USBL System Verification		
Date	31-07-2016		
To	C. Wood	**File**	GE051_USBL_Verification
Attn		**E-mail Address**	
Copy		**E-mail Address**	
Copy		**E-mail Address**	
From	C. Maree	**E-mail Address**	partychief@pioneer.fugro.com

1. INTRODUCTION

The purpose of the USBL verification was:

- To determine the accuracy of the HiPAP USBL system in conjunction with the SSS system

A USBL calibration was performed on 04 March 2016 in the Dutch Sector of the North Sea. The calibration report is included for reference.

2. SCOPE OF WORK

The verification consisted of running two side scan sonar lines in opposite directions at 40 m offset from a rock dump surrounding the side valve assembly at Q8-a platform (removed). Table 1 shows the details of the derived centre position of the rock dump.

Table 1: Rock dump centre coordinates

Datum ED50 UTM31N*				
Location	**Easting [m]**	**Northing [m]**	**Latitude North**	**Longitude East**
Rock dump at side valve assembly Q8-a platform (removed)	603646	5828503	52° 35’ 44.01”	04° 31’ 48.45”

*Note: Verification was run in ED50 instead of ETRS89

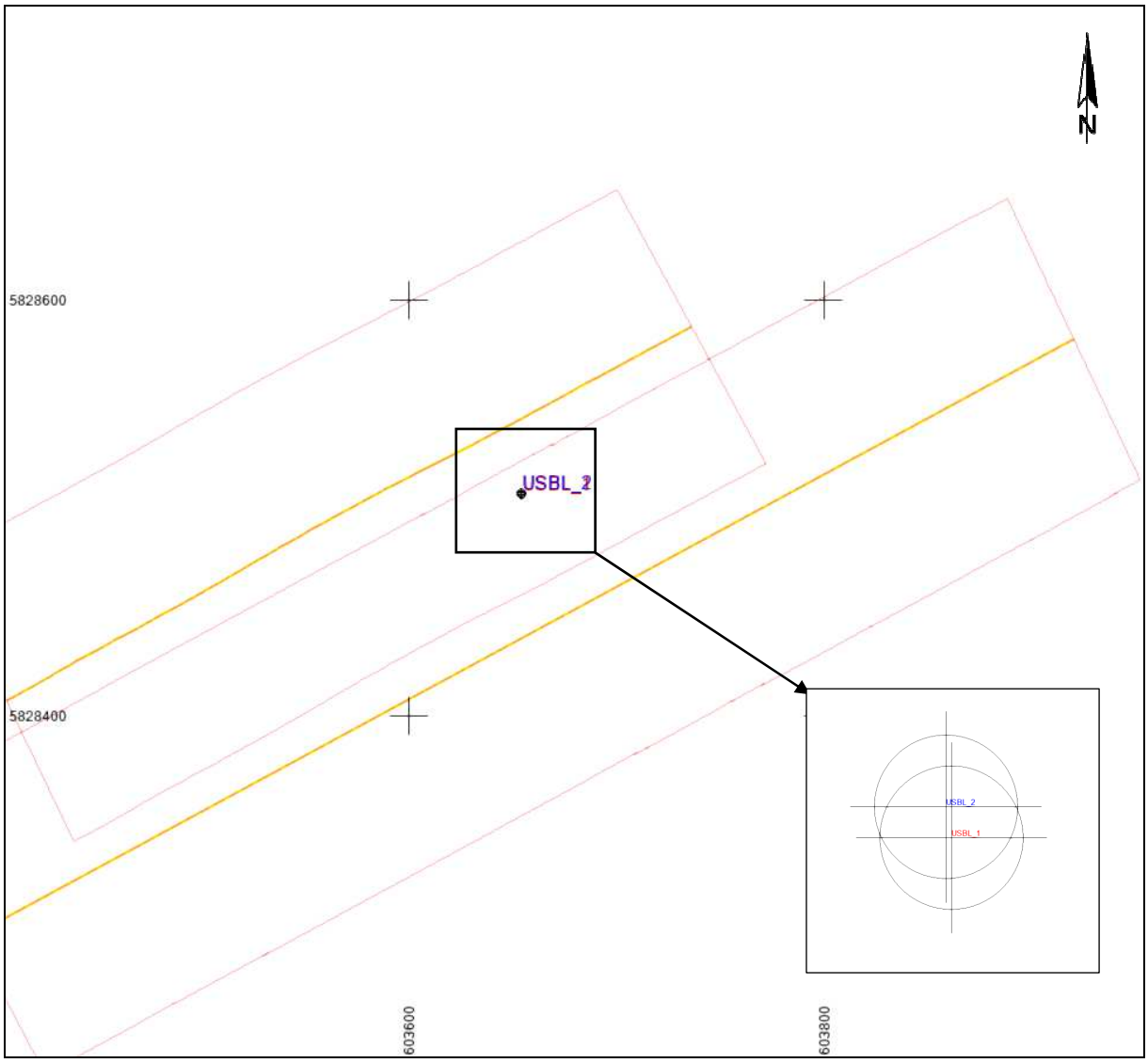

Figure 1: North-up side scan sonar tracks at USBL verification location

3. OPERATIONS

The verification was carried out onboard the vessel MV Fugro Pioneer on 31 July 2016.

4. RESULTS

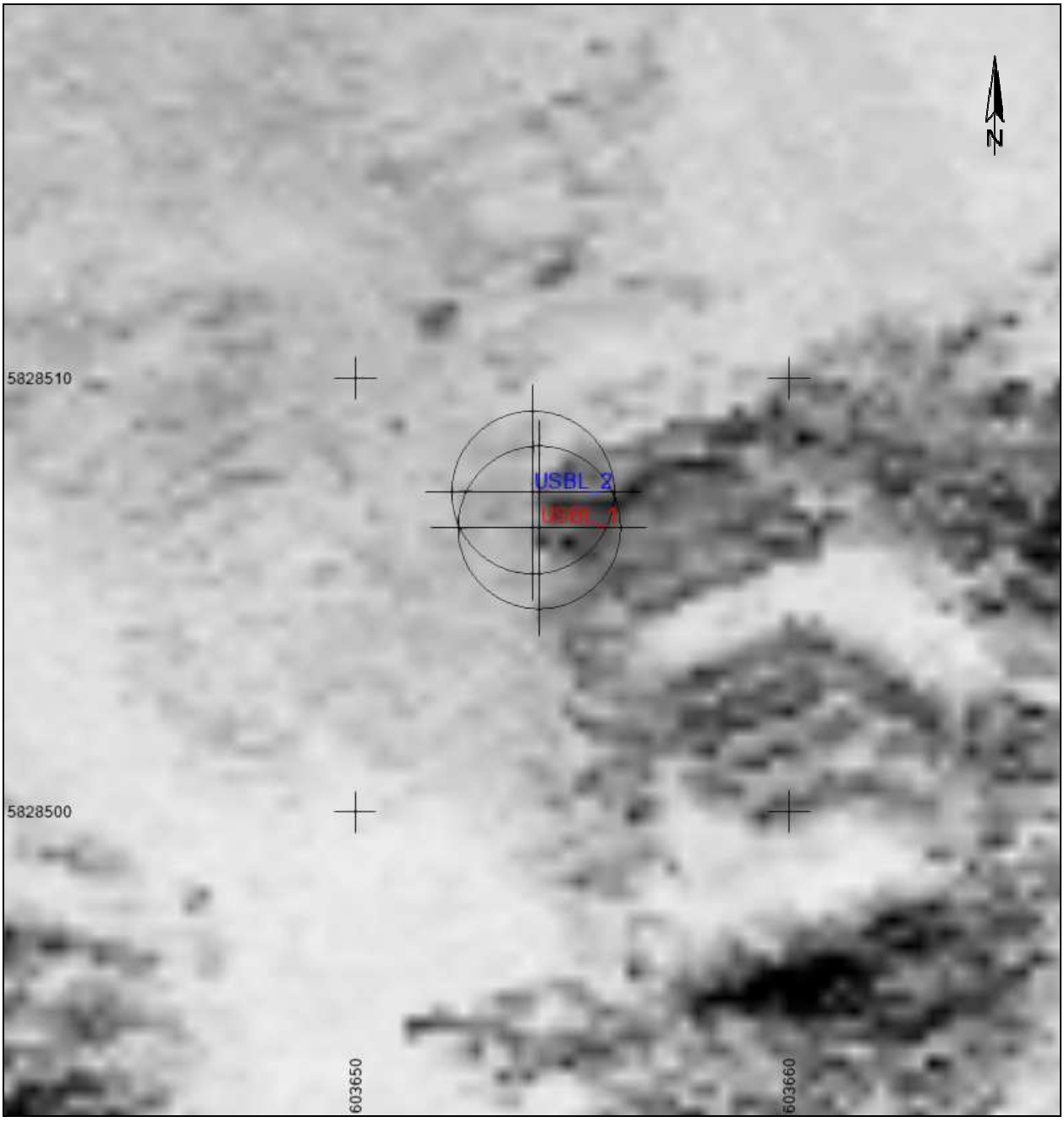

Figure 2: North-up side scan sonar mosaic showing both USBL verification data sets overlapping.

As a reference point, an edge of the rock dump surrounding the side valve was chosen (Figure 2). Two positions for the reference point were derived from the side scan sonar data. The side scan sonar tracks are shown in Figure 1 and the derived positions are listed in Table 2.

Table 2: SSS positions of the edge of the rock dump

Datum ED50 UTM31N				
Location	**Easting [m]**	**Northing [m]**	**Latitude North**	**Longitude East**
USBL_1	603654.2	5828506.5	52° 35' 44.12"	04° 31' 48.89"
USBL_2	603654.1	5828507.4	52° 35' 44.15"	04° 31' 48.88"

An along track difference of 0.2 metres and an across track error of 0.8 metres were found between observed locations USBL_1 and USBL_2, which results in a range difference of 0.8 m. Differences between the observed locations are listed in Table 3.

Table 3: Differences between USBL_1 and USBL_2 on the corner of the mattress

Differences in USBL_1 and USBL_2 location				
Location	**dX [m]**	**dY [m]**	**Range [m]**	**Bearing [°]**
USBL_1 and USBL_2	0.2	0.8	0.8	349

5. CONCLUSION

Based on the obtained results, the USBL system was verified to be within the requested tolerance of 3 m and therefore deemed fit for survey.

6. HSE

No safety or HSE incidents were reported.

Signed:	C. Maree		R. Chippendale
	[redacted]		[redacted]
	Party Chief		Client Representative
	(Fugro)		(Vattenfall Wind Power Ltd)

Fugro Pioneer USBL Calibration Report

SUMMARY

Introduction	
Survey Date:	4th March 2016. All times Local (UTC+1)
Location:	Skagerrak, Denmark. Approximate WGS-84 position: 58° 13.5` N, 009° 58.4` E
Weather Conditions:	Wind NE1/2, Sea State 1
Coordinate System:	Datum: ED50. Projection: UTM Zone 32N, CM 9°E
Personnel:	A. Jones, M. Volterrani

Equipment

Kongsberg HiPAP 501 USBL
Kongsberg APOS
Kongsberg cNode Maxi (S/N 13455 M51)
Fugro StarPack (DGPS 3 G2+)
iXBlue HydrINS

Sequence of Events

Fugro Pioneer arrived at the USBL site at 0600. After a tool box talk an SVP was carried out and the HiPAP pole was deployed. The laser measure in the HiPAP system was calibrated and verified using beacons deployed at fixed length over the side. At 1100 the cNode Maxi beacon was tested over the side to ensure connection and that the acoustic release worked. The beacon was redeployed with seabed weights to the seabed at 1205. The 4-cardinal point survey procedure started at 1240 and finished at 1531. After computing the results an offset spin verification was carried out between 1608 and 1657. The beacon was released from the seabed and recovered to Fugro Pioneer at 1725.

Conclusion

The HiPAP USBL system on board Fugro Pioneer was successfully calibrated for Roll, Pitch and Orientation. Calibration results were proven by a USBL verification.

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1. PREPARATION

1.1 Attitude and Heading

An iXBlue HydrINS provided corrected attitude and heading to the HiPAP system. The HydrINS is corrected for roll, pitch and heading so it is aligned with the vessel reference frame. The HydrINS lever arms are set for the HiPAP position.

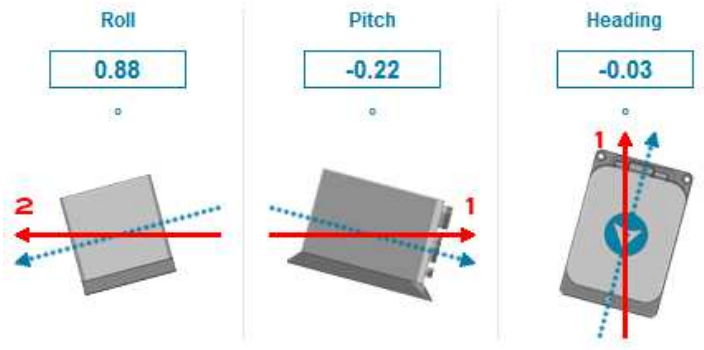

Figure 1.1: HydrINS alignments

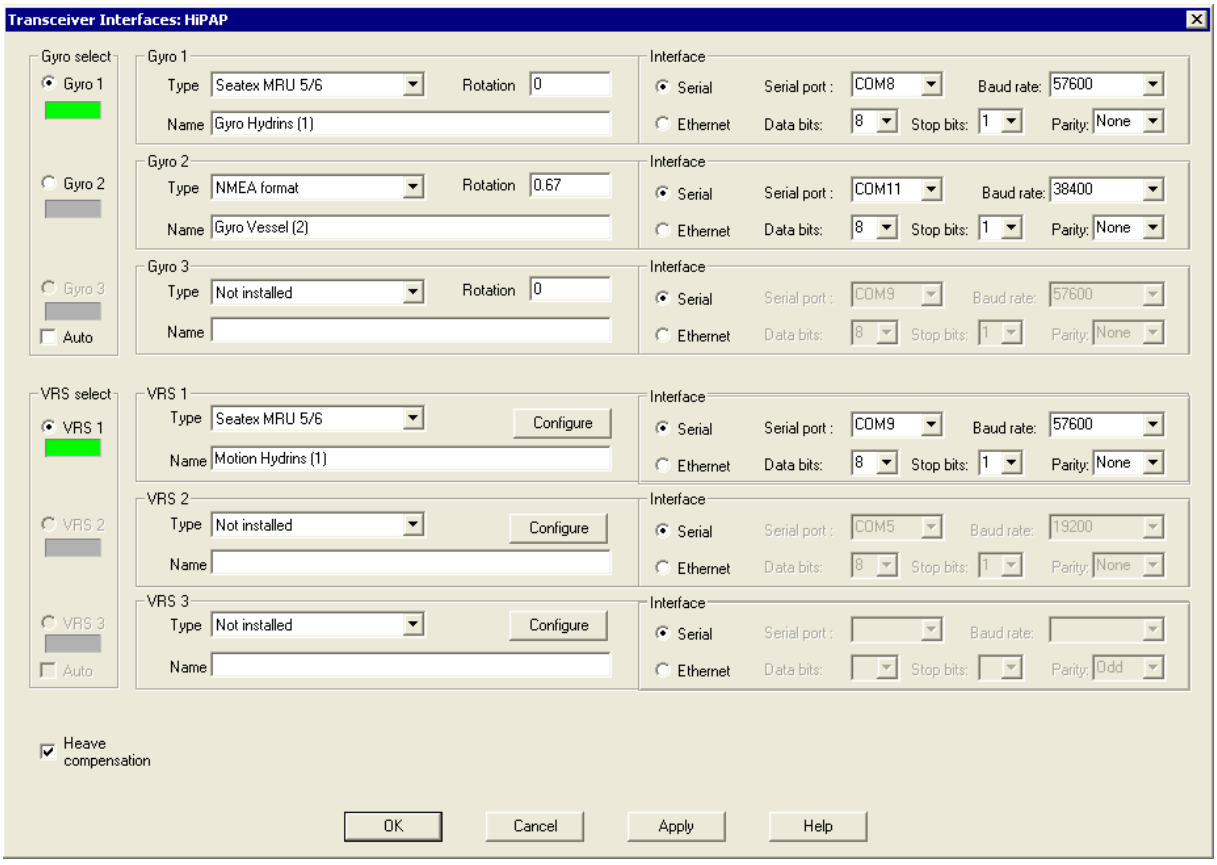

Figure 1.2: HiPAP Attitude sensors in

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1.2 Offsets

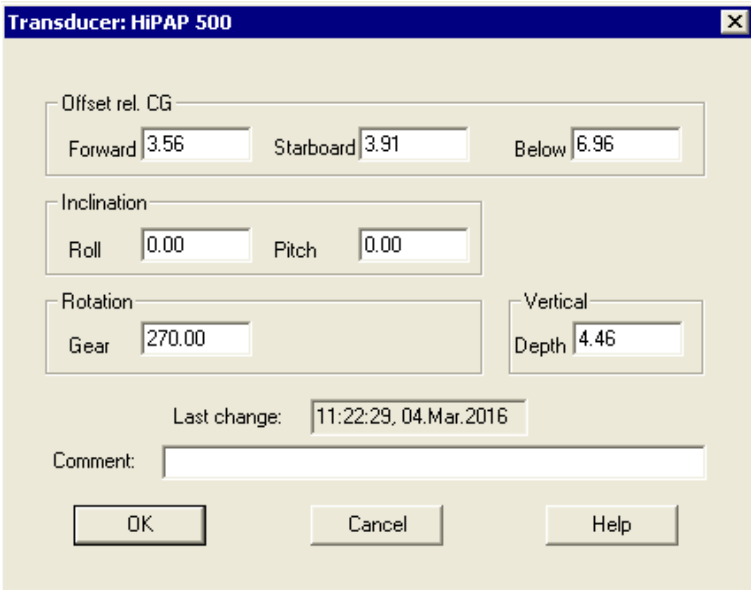
Vessel offsets were measured by total station in dry dock during construction in 2014, in the raised and deployed (lowered) position. The deployed offsets are entered into the APOS transceiver configuration.

The DGPS data received by the HiPAP system is already CRP corrected so there is no need to enter offsets in APOS.

Table 1.1: Calibration Offsets

Name	X	Y	Z	Remarks
HiPAP raised	3.91	3.56	-4.31	To CRP
HiPAP deployed	3.91	3.56	-6.96	To CRP
DGPS 3	3.176	4.262	12.134	To CRP

Figure 1.3: HiPAP transceiver offsets in APOS



Before calibration the laser measure was calibrated to ensure that the HiPAP pole is lowered to its full position.

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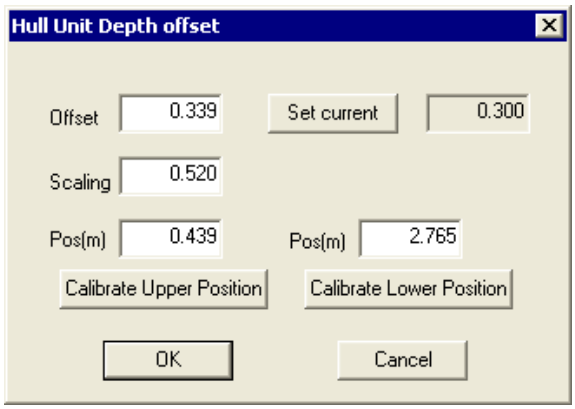
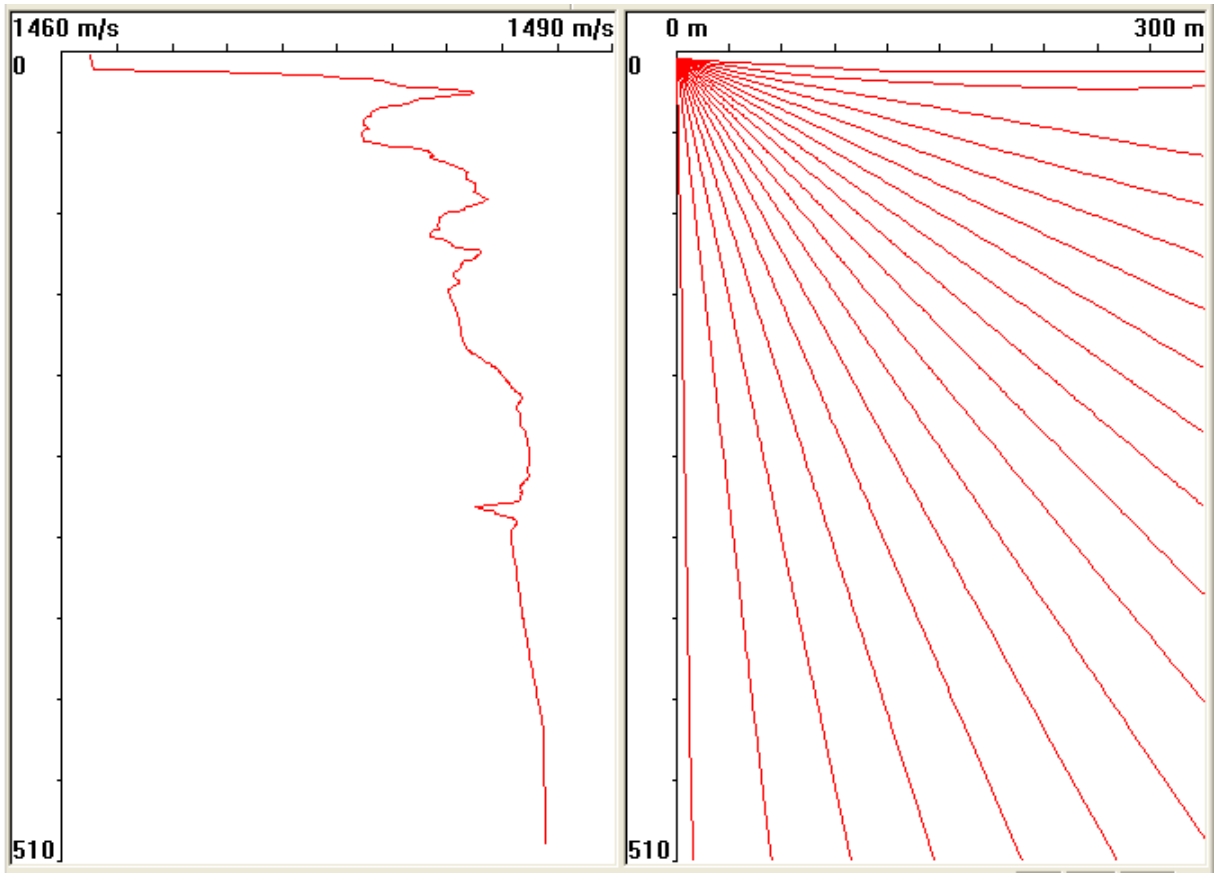
Figure 1.4: HiPAP laser depth offset



1.3 Sound Velocity Profile

An SVP was carried out on arrival at the calibration site and entered into the EA400 echosounder and APOS.

Figure 1.5: Active SVP in APOS



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2. ACQUISITION

2.1 Beacon Position

The cNode Maxi beacon was deployed to the seabed. Once settled, the mean position of the beacon was recorded using Starfix.NG. The pre-calibration roll, pitch and orientation values were used in the USBL system to help measure an accurate position. This position was used to centre the cardinal points set-up.

Easting versus northing from Transponder M51 (In-use of Sandbag Beacon) - Easting Minimum: 557336.76 Maximum: 557338.32 Mean: 557337.43 SD: 0.34 Count: 148
Easting versus northing from Transponder M51 (In-use of Sandbag Beacon) - Northing Minimum: 6454002.99 Maximum: 6454004.32 Mean: 6454003.69 SD: 0.27 Count: 148

2.2 Water Depth and Beacon Height

The EA400 echosounder displayed a flat seabed of 438m

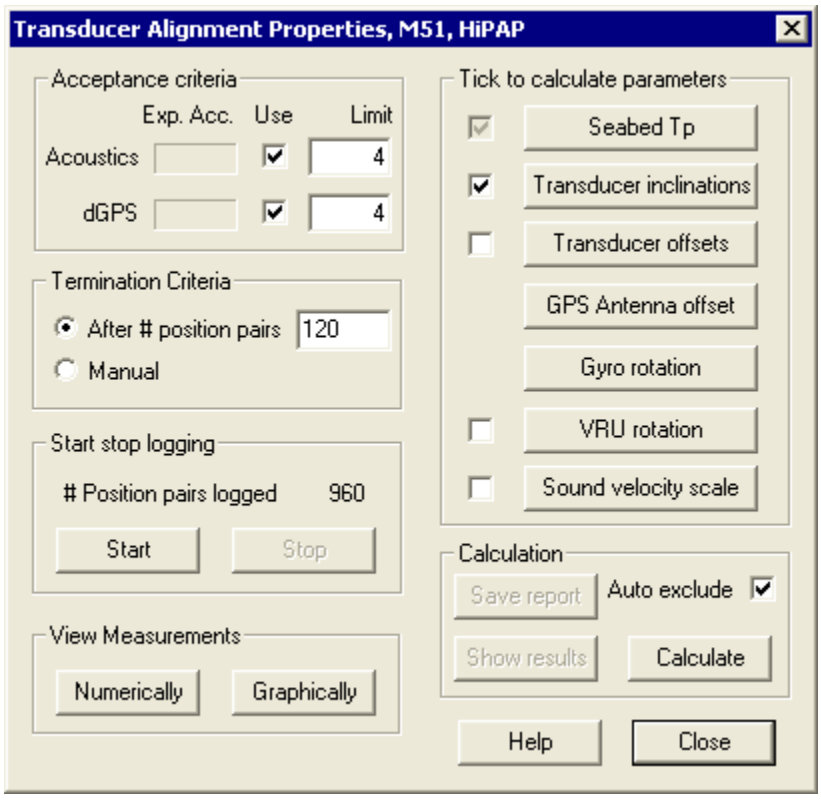
The height from seabed clump weight to beacon was 5m.

2.3 Transducer Alignment Properties

An acceptance criterion was set for acquisition of 4m for DGPS and HiPAP. APOS would collect 120 records at each point. No offsets were set for GPS Antenna or Gyro rotation.

Only *Transducer inclinations* were set, i.e. for the calibration of roll, pitch and orientation.

Figure 2.1: Active SVP in APOS



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Veurse Achterweg 12 Tel : +31-70-3 111 800
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2260 AC Leidschendam, The Netherlands
Trade Register Number: 34070322 / VAT Number: NL005621409B11

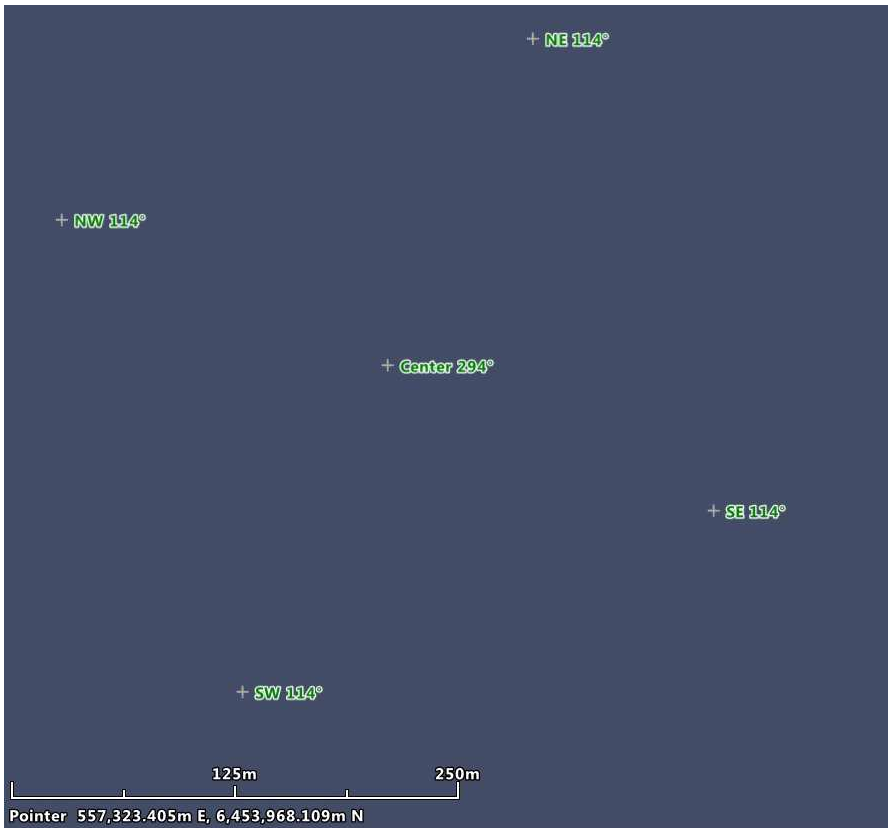
2.4 Acquisition Method

Starfix.NG was used for setting the waypoints and vessel navigation. Waypoints were set 200m away from the beacon.

The transponder position was measured at 4 cardinal points using dynamic positioning to keep the vessel stationary on a heading 114°. 4 additional static positions on top of the transponder were logged, each with a different vessel heading of 24°, 114°, 204°, and 294°.

120 records at 1 second intervals were taken at each point.

Figure 2.2: NG Calibration cardinal waypoints



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3. CALCULATIONS

3.1 Measurements

At the end of acquisition, 960 values had been recorded. The Figures below show the raw, uncorrected measurements. Measurements auto-excluded by APOS are circled in red.

Figure 3.1: Measured transponder position

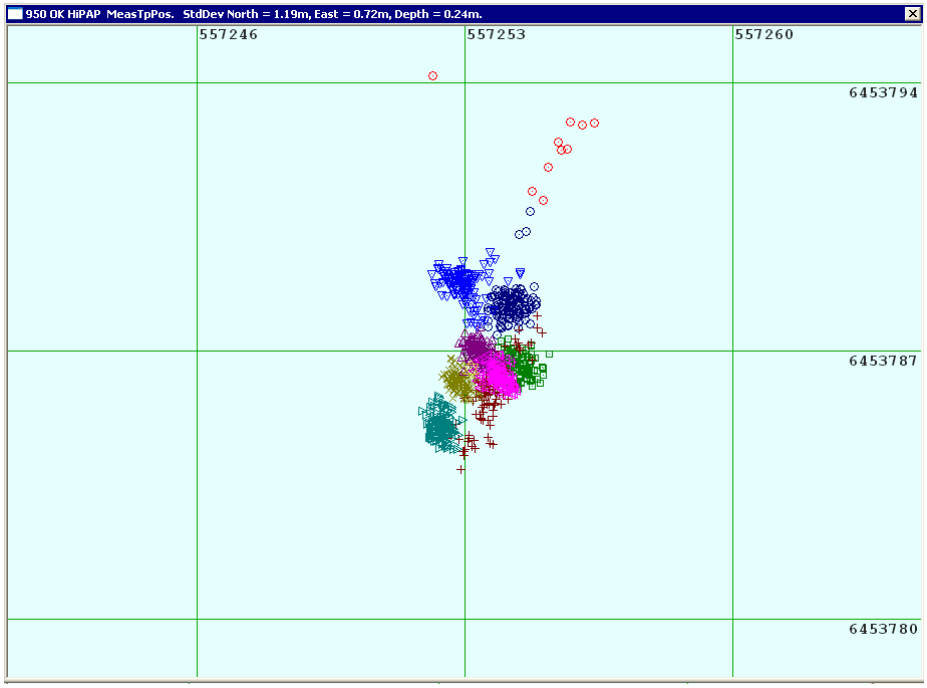
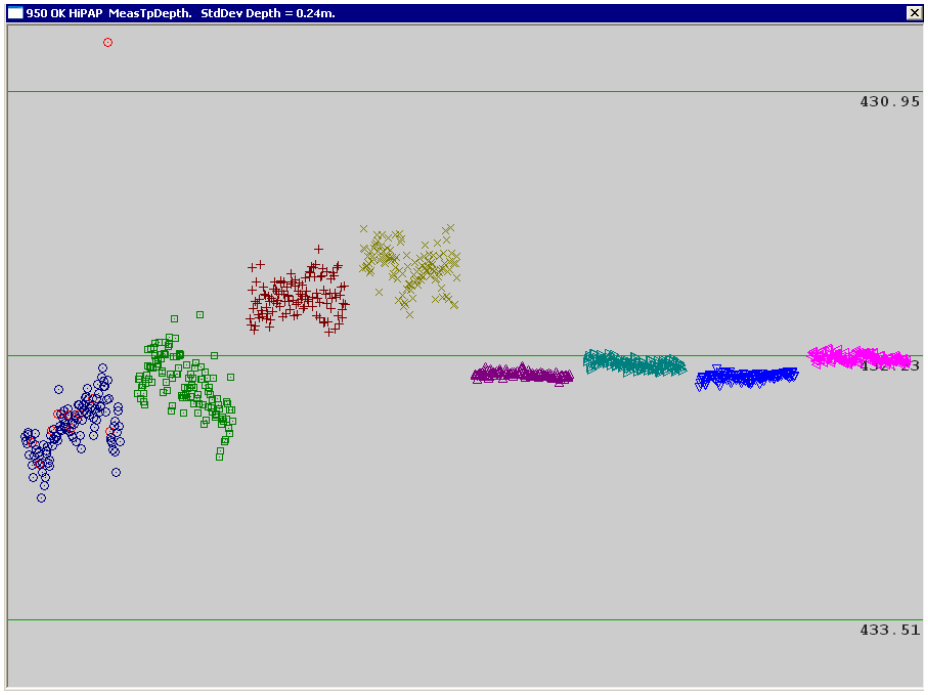


Figure 3.2: Measured transponder depth



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2260 AC Leidschendam, The Netherlands
Trade Register Number: 34070322 / VAT Number: NL005621409B11

3.2 Measurements

Figure 3.3: Compensated transponder position

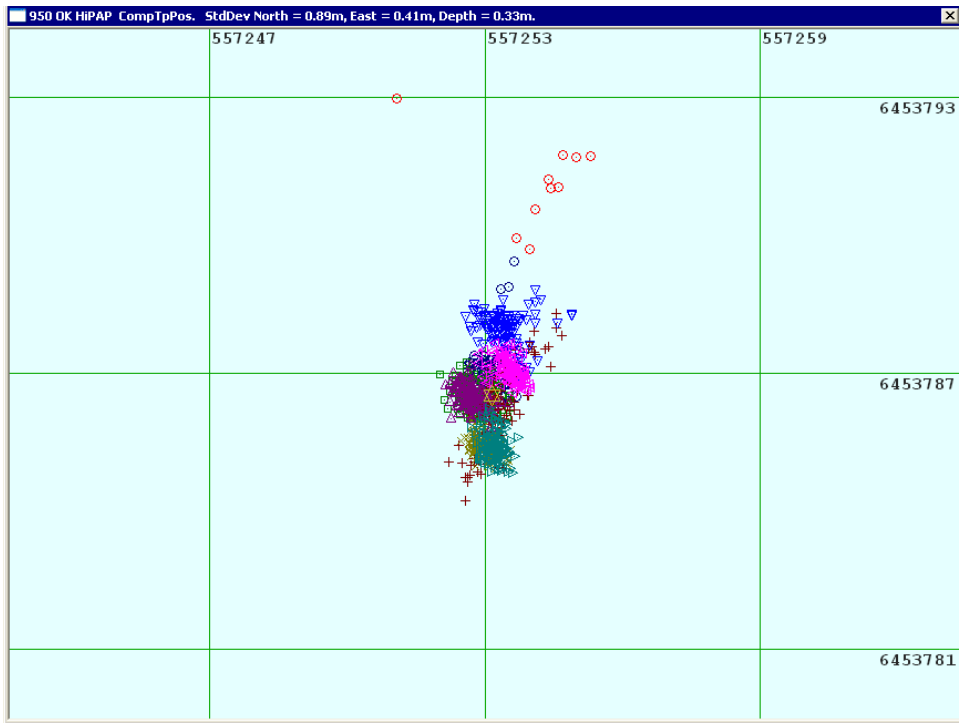
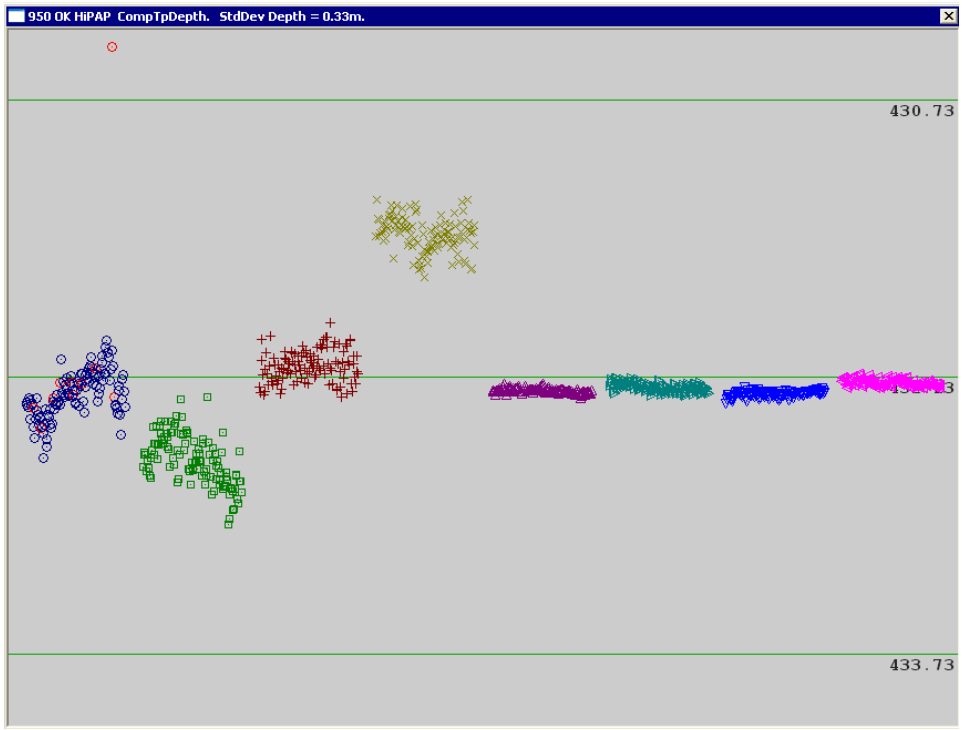


Figure 3.4: Compensated transponder depth



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4. COMPUTED RESULTS

Table 4.1: Transducer alignment results

Name	Calculated	SD	Installation
Roll	0.07°	0.01°	0°
Pitch	-0.09°	0.01°	0°
Orientation	269.75°	0.02°	270°

Figure 4.1: Calculated parameters

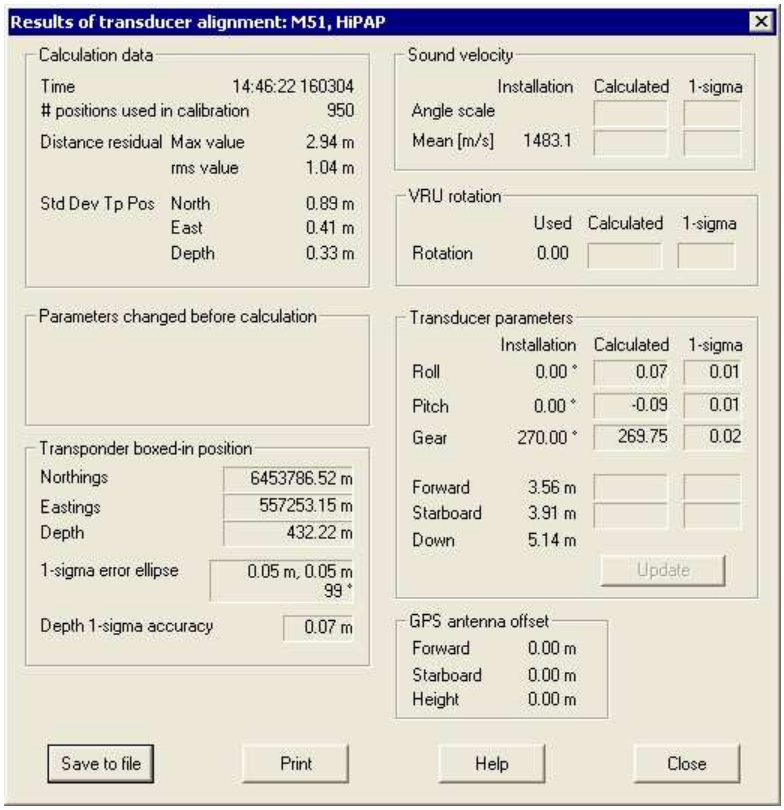
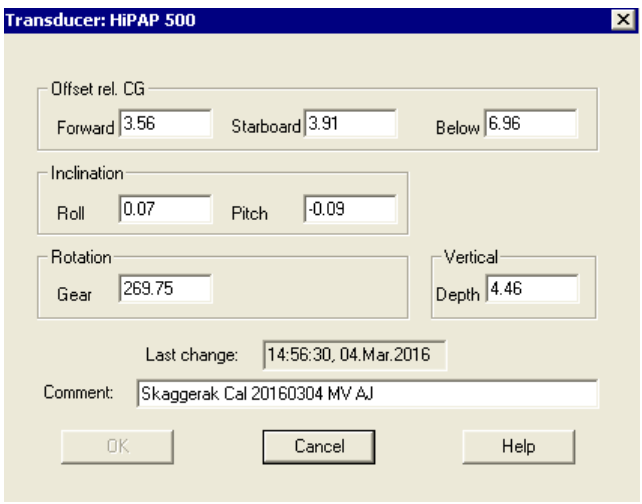


Figure 4.2: Applied results in APOS



A.6 MAGNETOMETER SYSTEM VERIFICATION

(3 pages, not numbered)

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2260 AC Leidschendam, The Netherlands
Trade Register Number: 34070322 / VAT Number: NL005621409B11

MAG verification report

Subject	SBP Verification		
Date	31-07-2016	**Page**	1 of 4
To	R. Chippendale	**File**	GE051_MAG_Verification
Attn		**E-mail Address**	
Copy		**E-mail Address**	
Copy		**E-mail Address**	
From	C. Maree	**E-mail Address**	partychief@pioneer.fugro.com

1. INTRODUCTION

The purpose of the MAG verification was:

- To determine the functionality of the magnetometer

2. SCOPE OF WORK

The verification consisted of running two lines, with the magnetometer deployed, in opposite directions over the TAT 14 Seg J cable in the Dutch sector (Block Q) of the North Sea.

3. OPERATIONS

The verification was carried out on-board the vessel MV Fugro Pioneer on 31 July 2016.

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Veurse Achterweg 12 Tel : +31-70-3 111 800
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2260 AC Leidschendam, The Netherlands
Trade Register Number: 34070322 / VAT Number: NL005621409B11

4. RESULTS

The MAG lines surveyed over the cable with their corresponding magnetometer readings are shown in Figure 1.

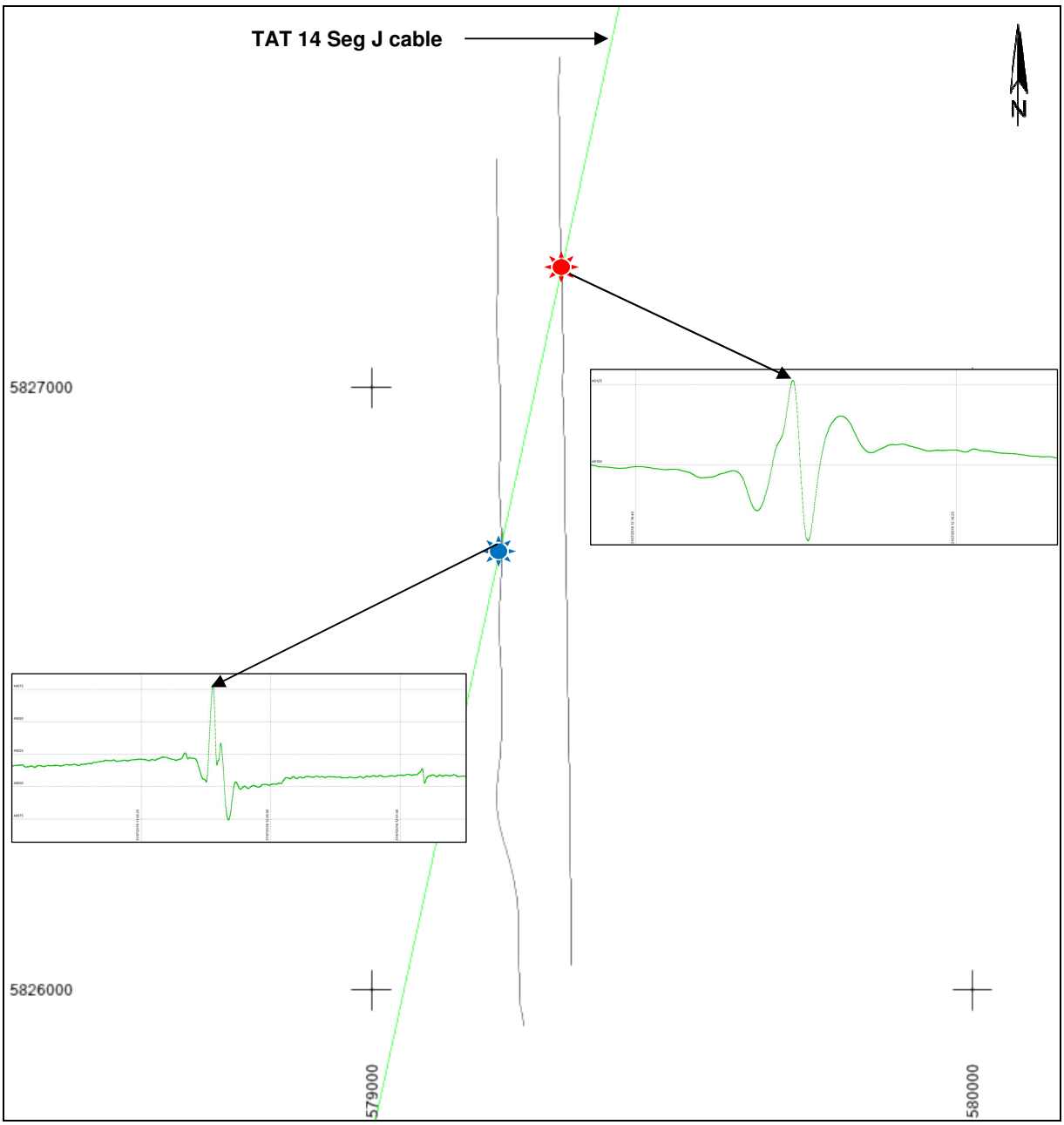

Figure 1: MAG lines (black) crossing over the TAT 14 Seg J cable (green). At the crossings, the corresponding magnetometer readings are displayed.

The cable was identified on both survey lines. In Starfix Suite's VBA Proc it was determined and confirmed that the location of the anomalies in the magnetic readings corresponds to the location where the survey lines cross over the cable.

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5. CONCLUSION

This test has proved that the magnetometer works effectively.

6. HSE

No safety or HSE incidents were reported.

Signed:	C. Maree		R. Chippendale
	[redacted]		[redacted]
	Party Chief		Client Representative
	(Fugro)		(Vattenfall Wind Power Ltd)

A.7 SBP SYSTEM VERIFICATION

(5 pages, not numbered)

FUGRO SURVEY B.V.
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2264 SG Leidschendam Telefax : +31-70-3 111 838
P.O. Box 128 E-mail : info@fugro-survey.nl
2260 AC Leidschendam, The Netherlands
Trade Register Number: 34070322 / VAT Number: NL005621409B11

SBP verification report

Subject	SBP Verification		
Date	01-08-2016	**Page**	1 of 4
To	R. Chippendale	**File**	GE051 SBP _Verification
Attn		**E-mail Address**	
Copy		**E-mail Address**	
Copy		**E-mail Address**	
From	C. Maree	**E-mail Address**	partychief@pioneer.fugro.com

1. INTRODUCTION

The purpose of the SBP verification was:

- To determine the functionality of the sub-bottom profiler (SBP).

2. SCOPE OF WORK

The verification consisted of running two sub-bottom profiler lines in opposite directions over existing 20 inch Helma to Ijmuiden pipeline in Dutch sector. See Table 1 for details.

Table 1: Helma to Ijmuiden pipeline 20 inch pipeline

Pipeline Name	Diameter [inch]	Length [km]	Product
20 inch Helma to Ijmuiden pipeline	20	-	Gas

3. OPERATIONS

The verification was carried out on-board the vessel MV Fugro Pioneer on 1 August 2016.

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2260 AC Leidschendam, The Netherlands
Trade Register Number: 34070322 / VAT Number: NL005621409B11

4. RESULTS

The SBP lines surveyed over the detected pipeline are shown in Figure 1 and Figure 2.

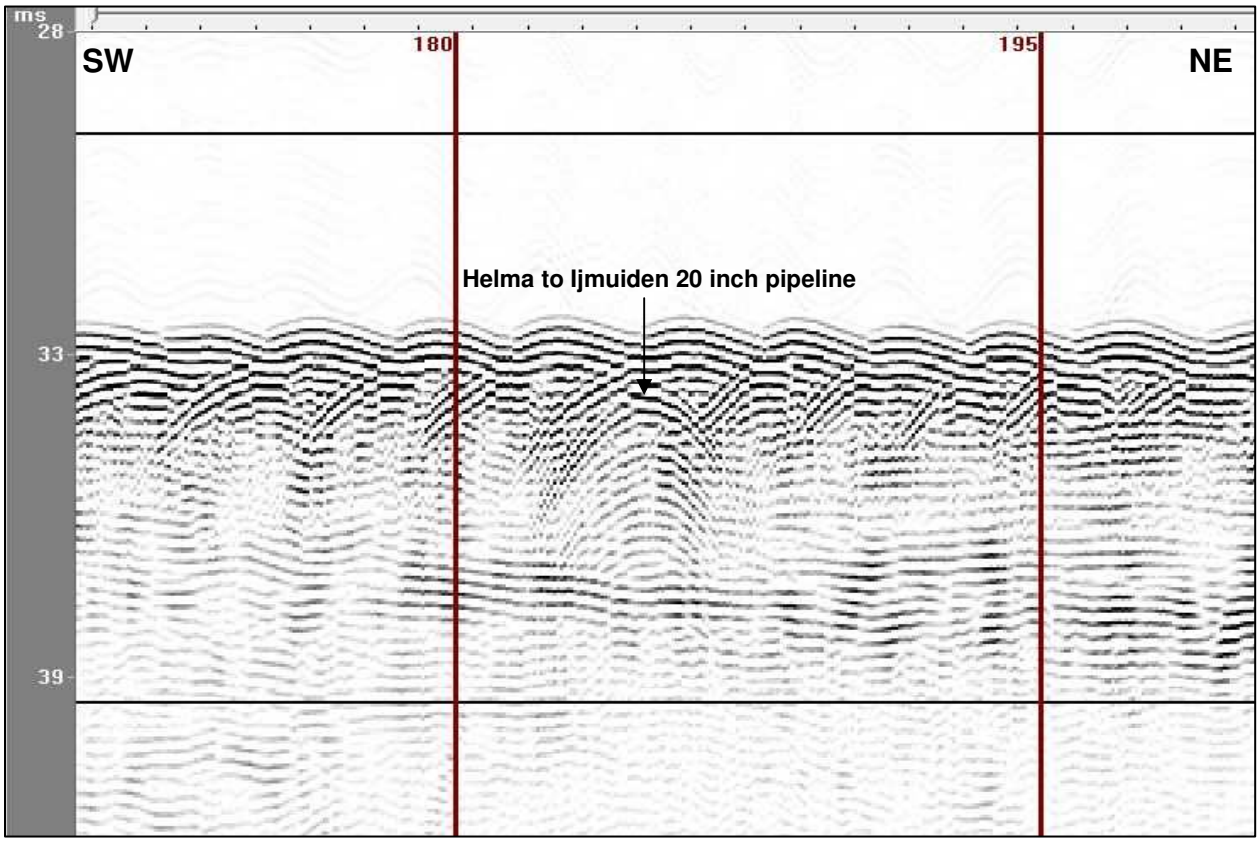

Figure 1: The 20 inch pipeline observed on SBP Line Pinger1_HMP_105 sailed from SW to NE

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2260 AC Leidschendam, The Netherlands
Trade Register Number: 34070322 / VAT Number: NL005621409B11

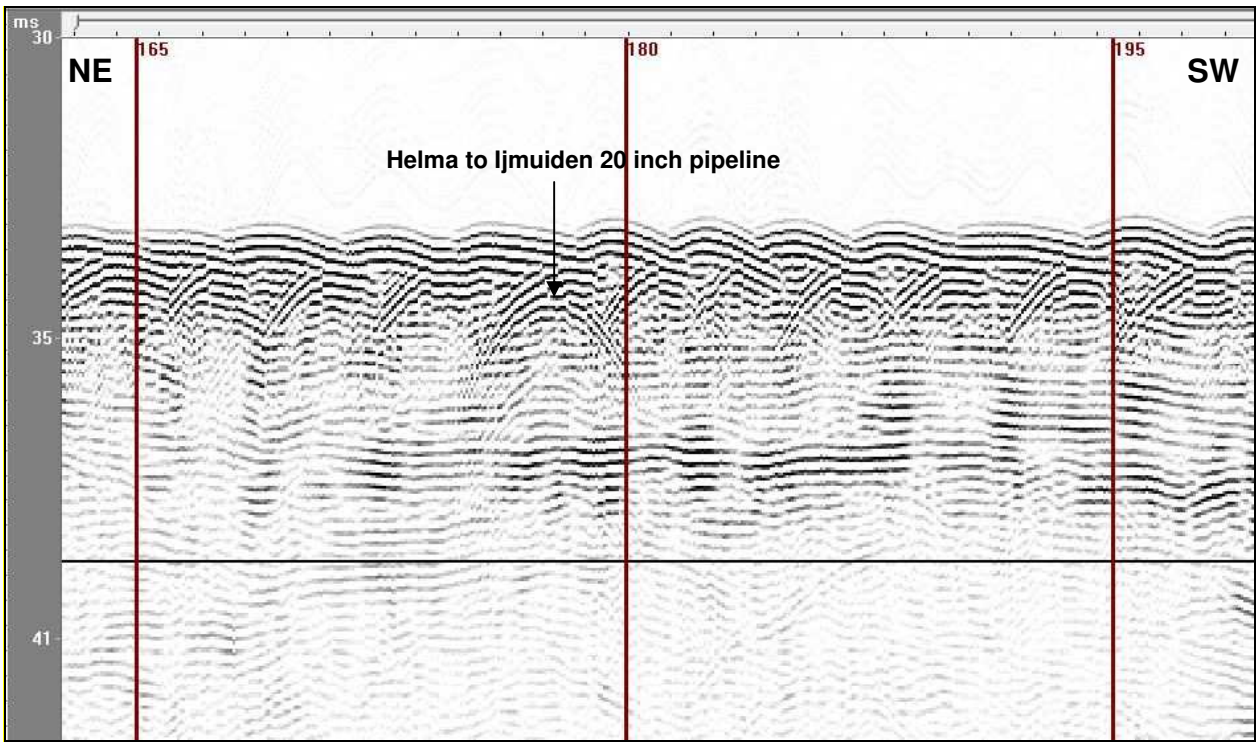

Figure 2: The 20 inch pipeline observed on SBP Line Pinger1_HMP_107 sailed from NE to SW

The sub-bottom profiler exhibits good quality data.

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2260 AC Leidschendam, The Netherlands
Trade Register Number: 34070322 / VAT Number: NL005621409B11

The pipeline was observed and identified on both survey lines. Its location was digitised in the seismic software Starfix Suite's INTERP to validate the accuracy of the SBP sensor (Figure 3).

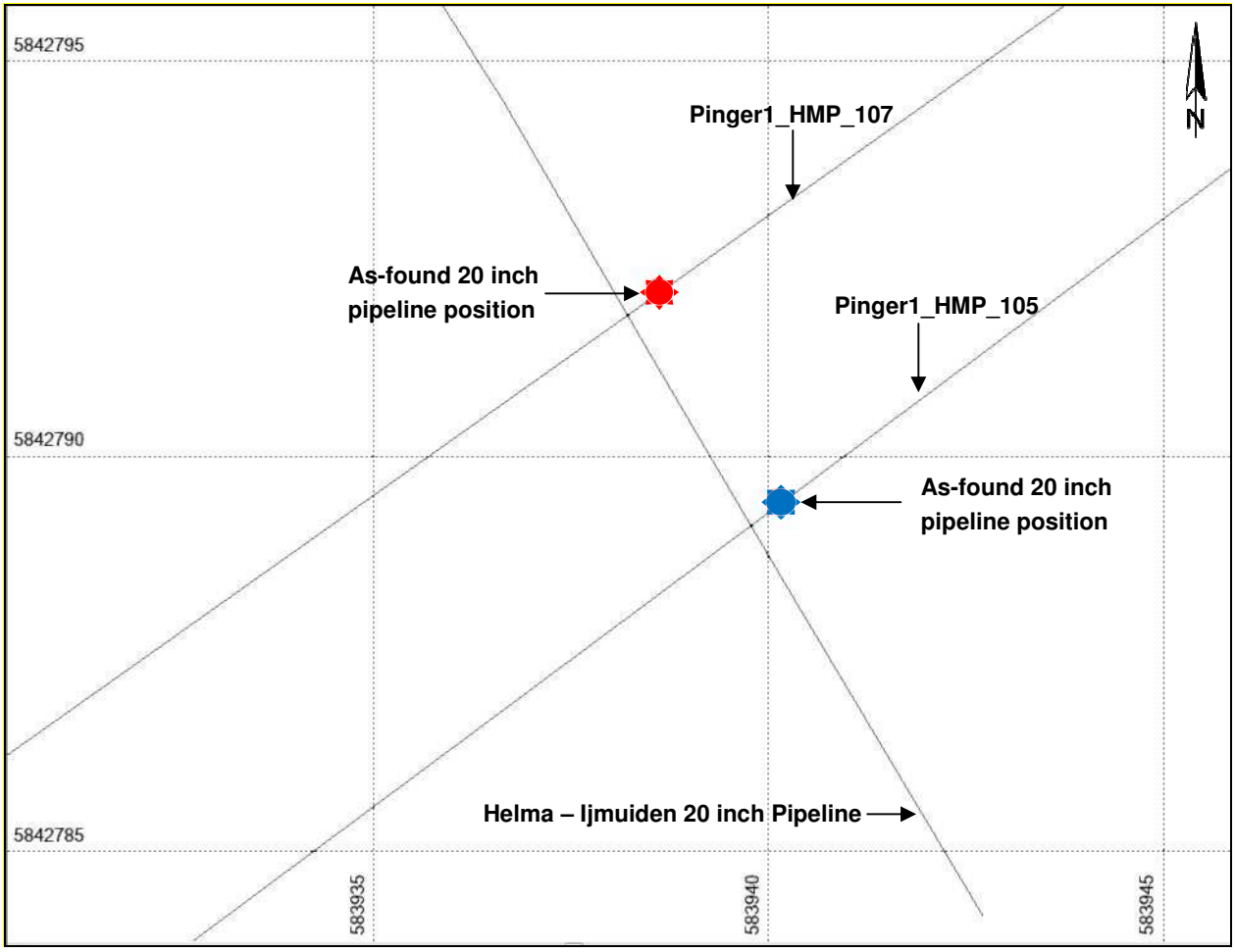

Figure 3: Overview of the two surveyed lines. Blue and red dots on the lines represent the as-found 20 inch pipeline position

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2260 AC Leidschendam, The Netherlands
Trade Register Number: 34070322 / VAT Number: NL005621409B11

5. CONCLUSION

Based on the obtained results, the system accuracy is within the requested tolerances and the system is deemed fit for survey.

6. HSE

No safety or HSE incidents were reported.

Signed:			
	C. Maree		R. Chippendale
	[redacted]		[redacted]
	Party Chief		Client Representative
	(Fugro)		(Vattenfall)

A.8 UHRS MINI SLEEVE GUN SIGNATURE TEST

Fugro Oceansismica spa, Rome

Client: VATTENFALL
Area: THANET

Pulse Test sleeve gun 5 cu. in.

www.fugro.com

INTRODUCTION

Before the start of the production phase, a pulse test has been performed in order to check the operativity of the gun.

A calibrated hydrophone Bruel & Kjaer mod. 8104 has been used during the test.

The source is a sleeve gun with a camera volume of 5 cu.in.

www.fugro.com

Parameters

According to the client specs the calibrated hydrophone was towed 5 m below the gun frame and more than 100 shots has been fired and recorded into the auxiliary channel of the recording system.

The data collected has been analysed by using UNISEIS software.

www.fugro.com

Hydrophone specs

Calibration Chart for
Hydrophone Type 8104

Brüel & Kjær

Serial No.: 2881339

Reference Sensitivity at 250 Hz* ± 2 % at 23.0 °C
Including integral cable 10.0 m
Voltage Sensitivity (Open Circuit Sensitivity):
-205.8 dB re 1 V/µPa** or 51.1 µV/Pa
Charge Sensitivity: 0.410 pC/Pa
Capacitance (including integral cable): 8029 pF
Cable Capacitance: 120 pF/m
Leakage Resistance: 40 GΩ at 23.0 °C

Measuring Uncertainty
Sensitivity at 250 Hz: ± 0.25 dB
Frequency Response at 4 kHz to 200 kHz: ± 1 dB

Frequency Response (at ref. pos.):
Individual Free Field Frequency Response Curve attached
Measured in watertank at 21.5 °C

Summarized Specifications (re 250 Hz)
Frequency Response (Tolerance field excluding measurement uncertainty):
0.1 Hz to 10 kHz: ± 1.5 dB
0.1 Hz to 80 kHz: ± 4 dB
0.1 Hz to 120 kHz: + 4 dB, -12 dB

Horizontal Directivity 100 kHz:
(XY – plane) ± 2 dB
Vertical Directivity 50 kHz:
(XZ – plane) ± 2 dB

For further information, please see http://www.bk.dk and Product Data Sheet BP 0317

Date 18 Dec. 2013 13:25 Operator SP

Physical (mm)

Ref. Point
Acoustic Centre
40
35
57
122

Cable: Shielded low noise with two conductors, waterblocked to MIL – C – 915
Weight (including 10m cable): 1.6 kg

Environmental
Operating Temperature range:
Short term – 40 °C to + 120 °C
Continuous – 40 °C to + 80 °C
Change of Sensitivity with Temperature:
Charge 0 to 0.03 dB/°C
Voltage 0 to – 0.04 dB/°C
Change of Sensitivity with Static Pressure:
0 to – 3 x 10⁷ dB/Pa
(0 to – 0.03 dB/atm)
Temperature Transient Sensitivity: ≤ 70 Pa/°C
(ANSI S.2.11–1969), measured with Brüel & Kjær Charge Preamplifier Type 2626, LLF 3 Hz
Allowable Total Radiation Dose: 5 x 10⁷ Rad
Maximum Operating Static Pressure:
4 x 10⁵ Pa (40 atm)

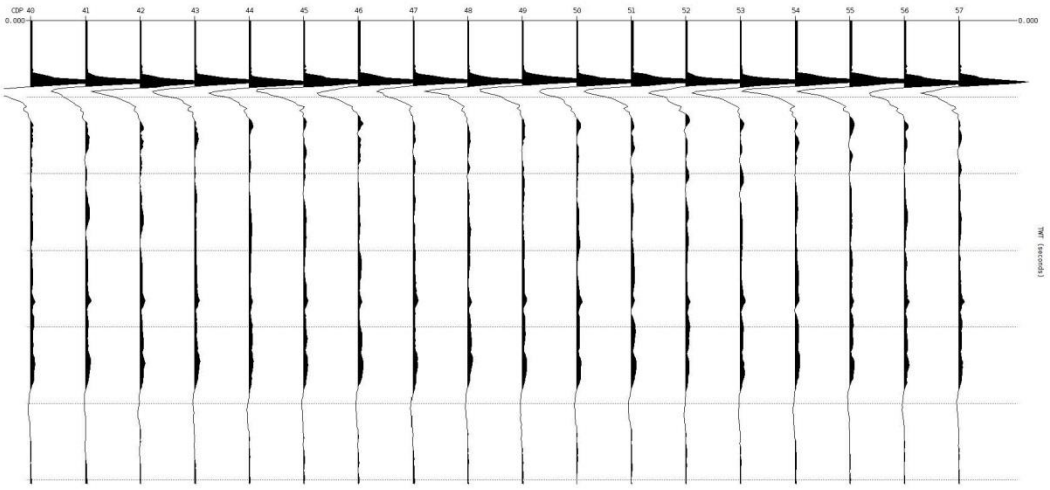
Note: All Values are typical at 25 °C (77 °F), unless measurement uncertainty or tolerance limit is specified. All uncertainty values are specified at 2 σ (i.e. expanded uncertainty using a coverage factor of 2).

For further information see User manual

* Sensitivity Traceable to:
DFLA: Danish Primary Laboratory of Acoustics
NIST: National Institute of Standards and Technology, USA
** 1 Pascal = 1N/m² = 10 µbar

www.fugro.com

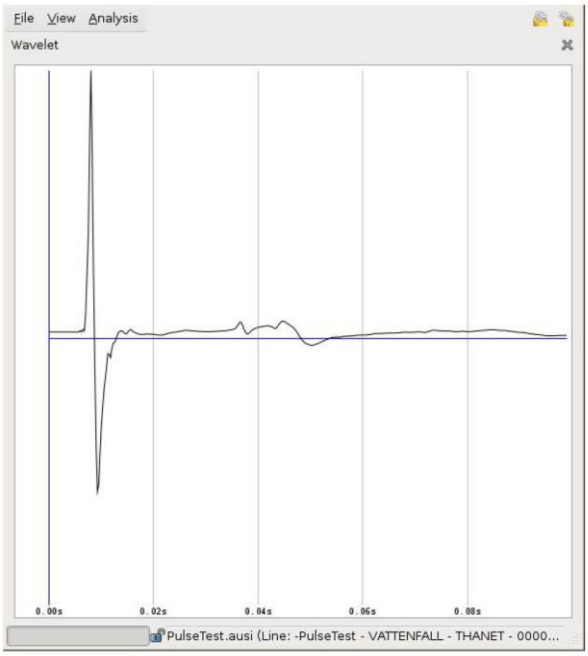
Wavelet analysis – neartrace (shot 40 to 57)



www.fugro.com

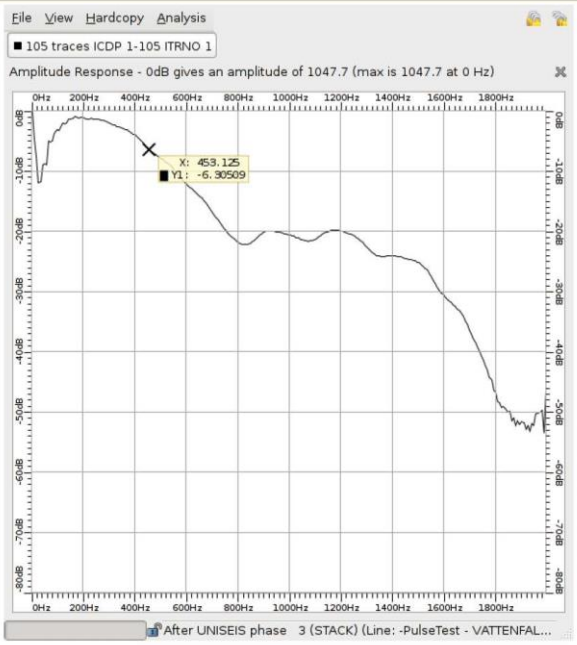
Wavelet analysis: stacked traces - peak to peak

1.997 Bar * meter



www.fugro.com

Frequency spectrum



www.fugro.com

Results

The resulting Peak to Peak is 1.997 bar * meter. This value is within the error uncertainty of the Gundalf modeling: 2.1±0.105 bar * meter.

The frequency spectrum fit the modeled one, and the source behaves coherently during all the test.

www.fugro.com

A.9 FIRST UHRS SPARKER SIGNATURE TEST

Fugro Oceansismica spa, Rome

Client: VATTENFALL
Area: THANET

Pulse Test Sparker

www.fugro.com

INTRODUCTION

Before the start of the production phase, a pulse test has been performed in order to check the operativity of the sparker.

A calibrated hydrophone Bruel & Kjaer mod. 8104 has been used during the test.

The sparker used was a GSO - 360 tips powered by the charging unit CSP-CSPN-8000/E by Applied Acoustic

www.fugro.com

Parameters

According to the client specs the calibrated hydrophone was towed 5 m below the sparker and more than 100 shots has been fired and recorded into the auxiliary channel of the recording system.

The data collected has been analysed by using UNISEIS software.

www.fugro.com

Hydrophone specs

Calibration Chart for
Hydrophone Type 8104

Brüel & Kjær

Serial No.: 2881339

Reference Sensitivity at 250 Hz* ± 2 % at 23.0 °C
Including integral cable 10.0 m
Voltage Sensitivity (Open Circuit Sensitivity):
-205.8 dB re 1 V/µPa** or 51.1 µV/Pa
Charge Sensitivity: 0.410 pC/Pa
Capacitance (including integral cable): 8029 pF
Cable Capacitance: 120 pF/m
Leakage Resistance: 40 GΩ at 23.0 °C

Measuring Uncertainty
Sensitivity at 250 Hz: ± 0.25 dB
Frequency Response at 4 kHz to 200 kHz: ± 1 dB

Frequency Response (at ref. pos.):
Individual Free Field Frequency Response Curve attached
Measured in watertank at 21.5 °C

Summarized Specifications (re 250 Hz)
Frequency Response (Tolerance field excluding measurement uncertainty):
0.1 Hz to 10 kHz: ± 1.5 dB
0.1 Hz to 80 kHz: ± 4 dB
0.1 Hz to 120 kHz: + 4 dB, -12 dB

Horizontal Directivity 100 kHz:
(XY – plane) ± 2 dB
Vertical Directivity 50 kHz:
(XZ – plane) ± 2 dB

For further information, please see http://www.bk.dk and Product Data Sheet BP 0317

Date 18 Dec. 2013 13:25 Operator SP

Physical (mm)

Cable: Shielded low noise with two conductors, waterblocked to MIL – C – 915
Weight (including 10m cable): 1.6 kg

Environmental
Operating Temperature range:
Short term – 40 °C to + 120 °C
Continuous – 40 °C to + 80 °C
Change of Sensitivity with Temperature:
Charge 0 to 0.03 dB/°C
Voltage 0 to – 0.04 dB/°C
Change of Sensitivity with Static Pressure:
0 to – 3 x 10⁷ dB/Pa
(0 to – 0.03 dB/atm)
Temperature Transient Sensitivity: ≤ 70 Pa/°C
(ANSI S.2.11–1969), measured with Brüel & Kjær Charge Preamplifier Type 2626, LLF 3 Hz
Allowable Total Radiation Dose: 5 x 10⁷ Rad
Maximum Operating Static Pressure:
4 x 10⁵ Pa (40 atm)

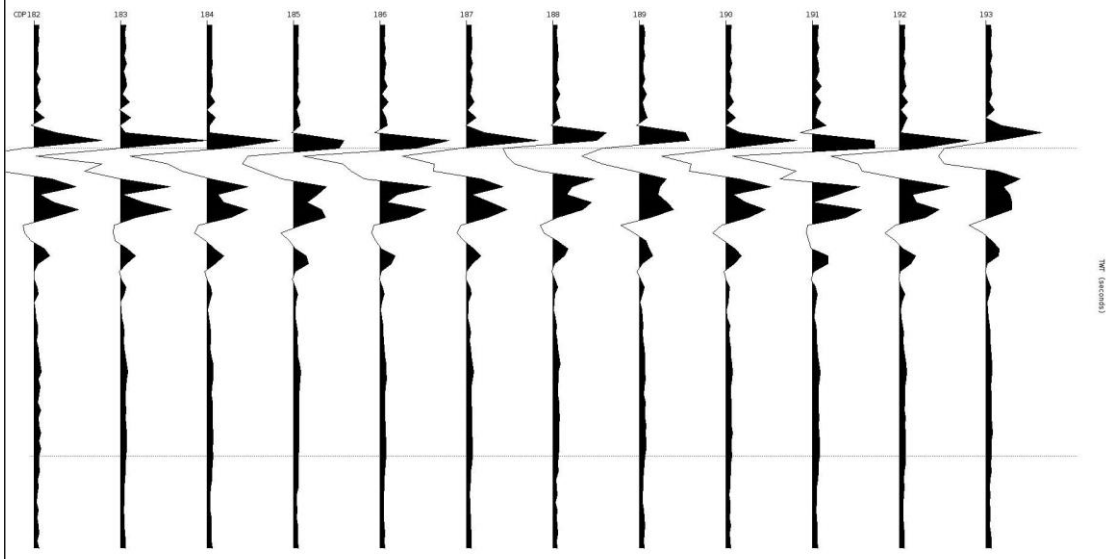
Note: All Values are typical at 25 °C (77 °F), unless measurement uncertainty or tolerance limit is specified. All uncertainty values are specified at 2 σ (i.e. expanded uncertainty using a coverage factor of 2).

For further information see User manual

* Sensitivity Traceable to:
DFLA: Danish Primary Laboratory of Acoustics
NIST: National Institute of Standards and Technology, USA
** 1 Pascal = 1N/m² = 10 µbar

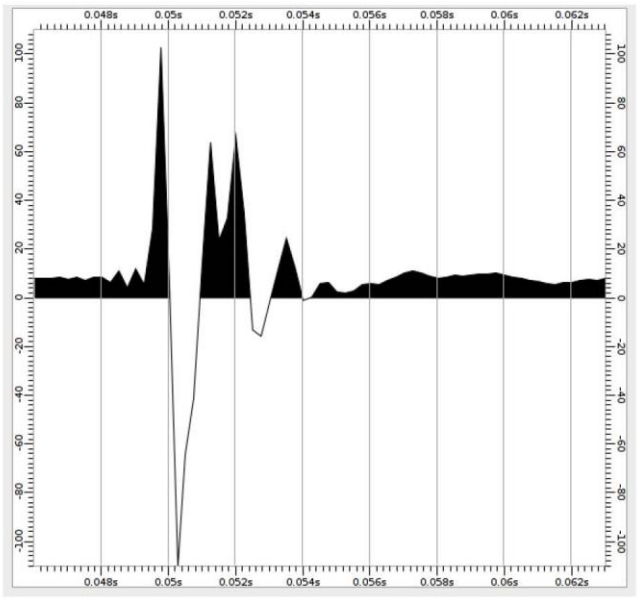
www.fugro.com

neartrace source (shot 182-193) power 600 J



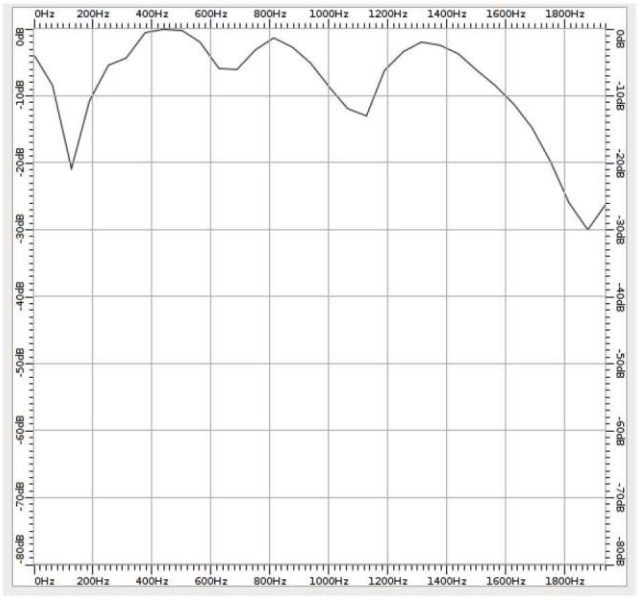
www.fugro.com

Wavelet analysis: stacked traces - 600J



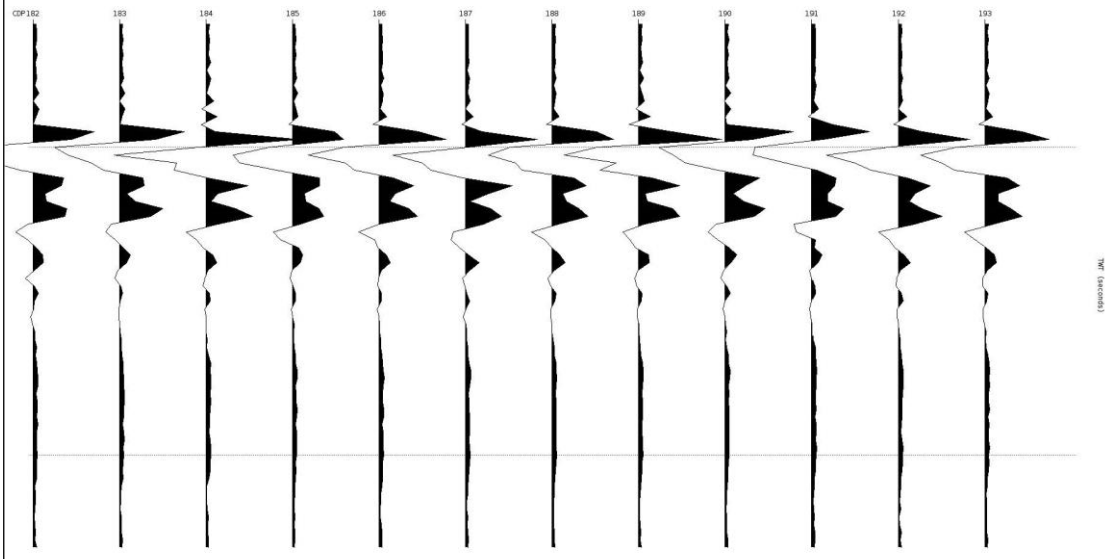
www.fugro.com

Frequency spectrum - 600J



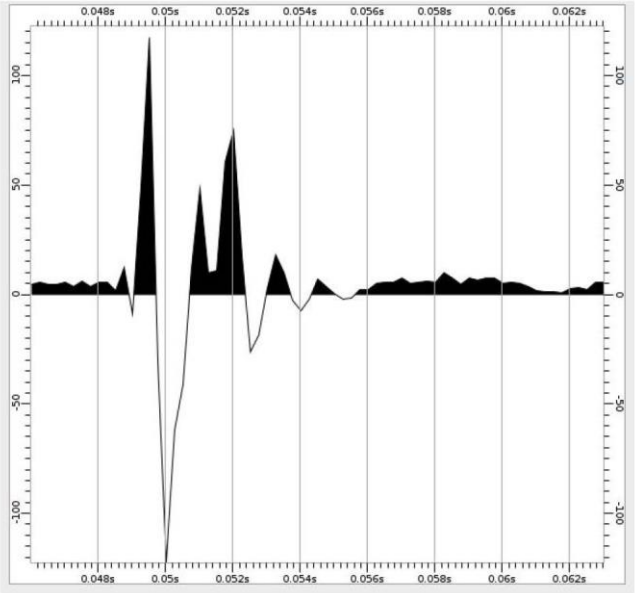
www.fugro.com

neartrace source (shot 182-193) power 800 J



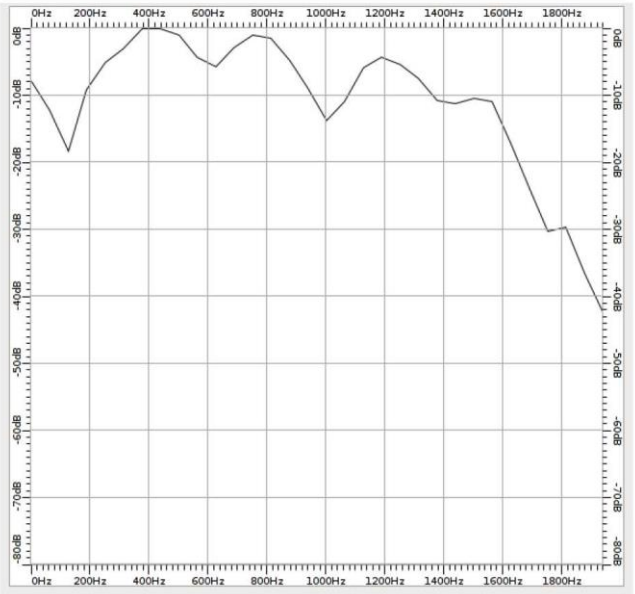
www.fugro.com

Wavelet analysis: stacked traces - 800J



www.fugro.com

Frequency spectrum - 800J



www.fugro.com

Results

The resulting signatures show similar shapes.

From 600J to 800J the distance primary-bubble slightly increases, as expected.
The primary pulse for 800 J shows a wider shape than 600 J.
The bubble pulse for 600J is less pronounced than 800 J.

The source behaves coherently during all the test, both for 600J and for 800J.

www.fugro.com

A.10 SECOND UHRS SPARKER SIGNATURE TEST

Fugro Oceansismica spa, Rome

Client: VATTENFALL
Area: THANET

Pulse Test Sparker

www.fugro.com

INTRODUCTION

After the bangbox replacement, a second pulse test has been performed in order to check the operativity of the sparker.

A calibrated hydrophone Bruel & Kjaer mod. 8104 has been used during the test.

The sparker used was a GSO - 360 tips powered by the charging unit CSP-CSPN-8000/E by Applied Acoustic

www.fugro.com

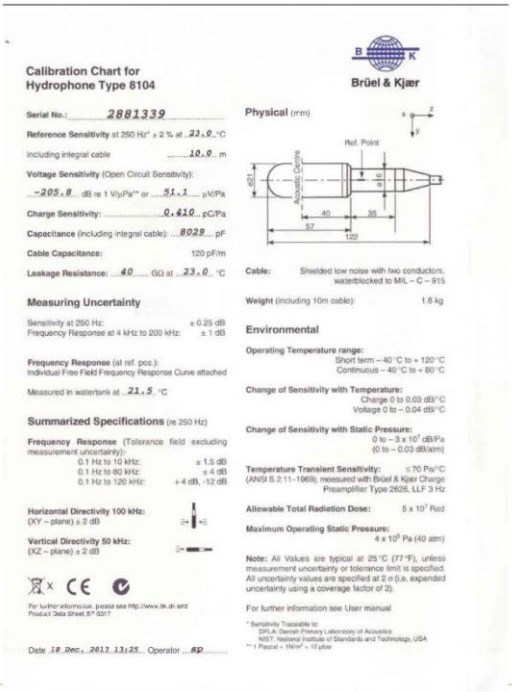
Parameters

According to the client specs the calibrated hydrophone was towed 5 m below the sparker and more than 100 shots has been fired and recorded into the auxiliary channel of the recording system.

The data collected has been analysed by using UNISEIS software.

www.fugro.com

Hydrophone specs



Calibration Chart for Hydrophone Type 8104

Brüel & Kjær

Serial No.: 2881339

Reference Sensitivity at 250 Hz* ± 2 % at 23.0 °C
Including integral cable 10.0 m
Voltage Sensitivity (Open Circuit Sensitivity):
-205.8 dB re 1 V/µPa** or 51.1 µV/Pa
Charge Sensitivity: 0.610 pC/Pa
Capacitance (including integral cable): 8029 pF
Cable Capacitance: 120 pF/m
Leakage Resistance: 40 GΩ at 23.0 °C

Measuring Uncertainty

Sensitivity at 250 Hz: ± 0.25 dB
Frequency Response at 4 kHz to 200 kHz: ± 1 dB

Frequency Response (at ref. pos.):
Individual Free Field Frequency Response Curve attached
Measured in watertank at 21.5 °C

Summarized Specifications (re 250 Hz)

Frequency Response (Tolerance field excluding measurement uncertainty):
0.1 Hz to 10 kHz: ± 1.5 dB
0.1 Hz to 80 kHz: ± 4 dB
0.1 Hz to 120 kHz: + 4 dB, -12 dB

Horizontal Directivity 100 kHz: (XY – plane) ± 2 dB
Vertical Directivity 50 kHz: (XZ – plane) ± 2 dB

For further information, please see http://www.bk.dk and Product Data Sheet BP 0317

Date 18 Dec. 2013 13:25 Operator SP

Physical (mm)

Cable: Shielded low noise with two conductors, waterblocked to MIL – C – 915
Weight (including 10m cable): 1.6 kg

Environmental

Operating Temperature range:
Short term – 40 °C to + 120 °C
Continuous – 40 °C to + 80 °C

Change of Sensitivity with Temperature:
Charge 0 to 0.03 dB/°C
Voltage 0 to – 0.04 dB/°C

Change of Sensitivity with Static Pressure:
0 to – 3 x 10^{-7} dB/Pa
(0 to – 0.03 dB/atm)

Temperature Transient Sensitivity: ≤ 70 Pa/°C
(ANSI S.2.11–1969), measured with Brüel & Kjær Charge Preamplifier Type 2626, LLF 3 Hz

Allowable Total Radiation Dose: 5 x 10^7 Rad

Maximum Operating Static Pressure: 4 x 10^5 Pa (40 atm)

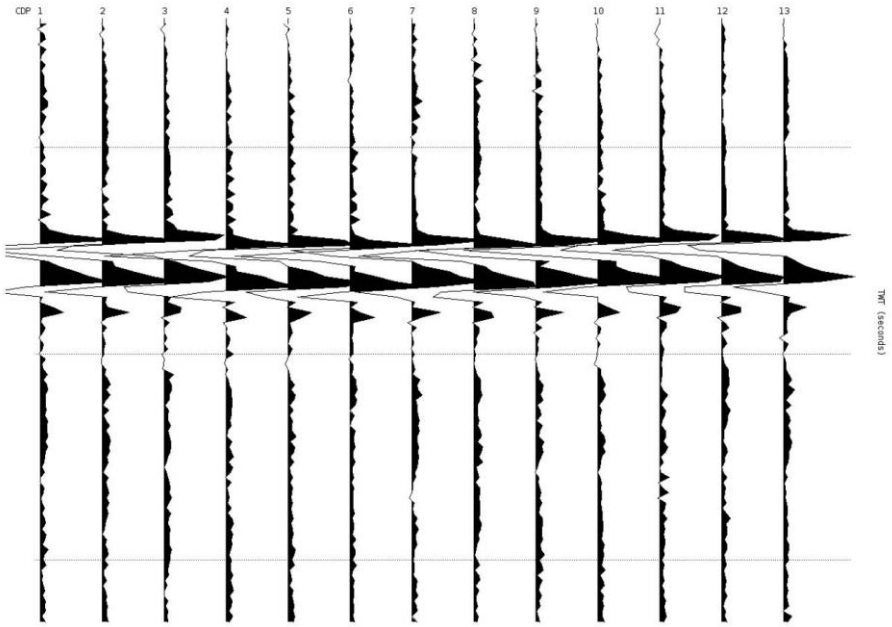
Note: All Values are typical at 25 °C (77 °F), unless measurement uncertainty or tolerance limit is specified. All uncertainty values are specified at 2 σ (i.e. expanded uncertainty using a coverage factor of 2).

For further information see User manual

* Sensitivity Traceable to:
DFLA: Danish Primary Laboratory of Acoustics
NIST: National Institute of Standards and Technology, USA
** 1 Pascal = 1N/m² = 10 µbar

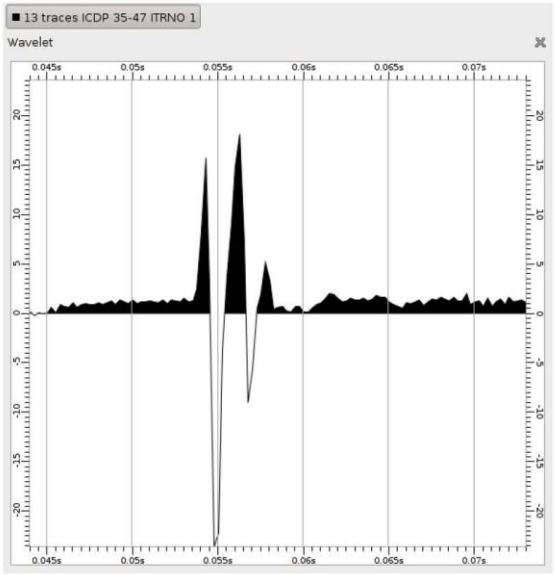
www.fugro.com

neartrace source (shot 182-193) power 600 J



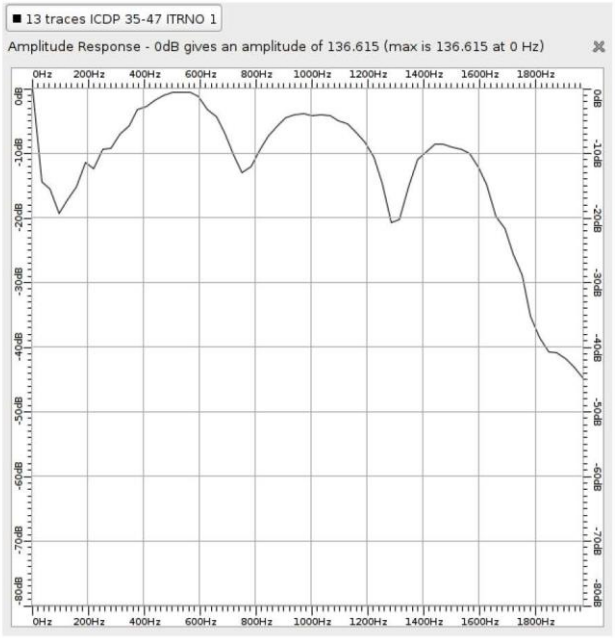
www.fugro.com

Wavelet analysis: stacked traces - 600J



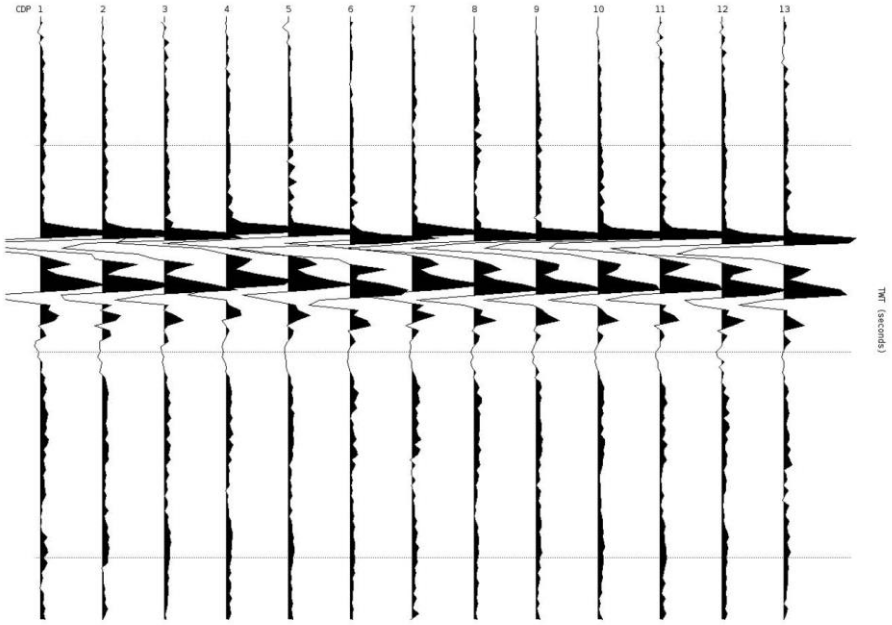
www.fugro.com

Frequency spectrum - 600J



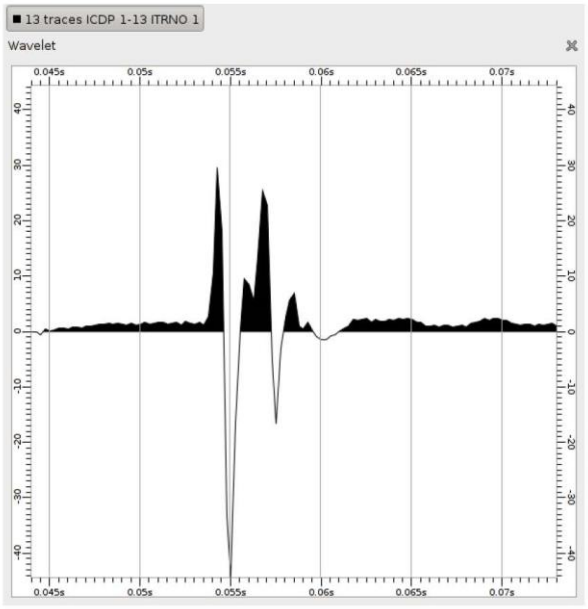
www.fugro.com

neartrace source (shot 182-193) power 800 J



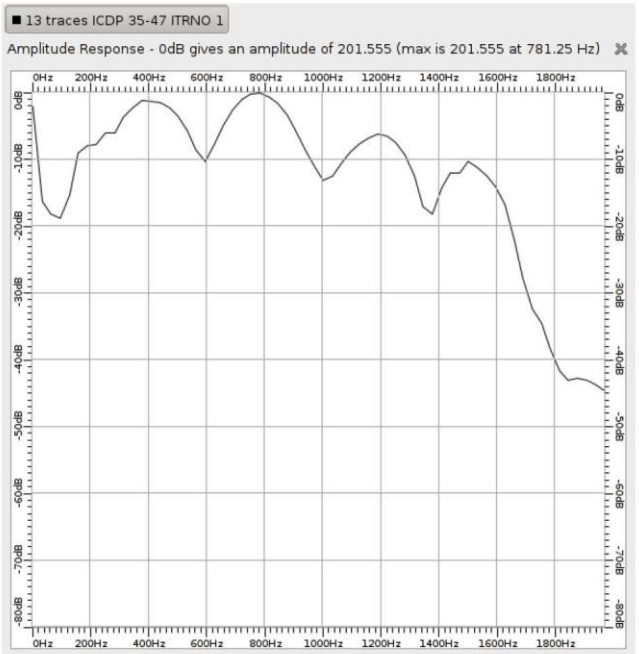
www.fugro.com

Wavelet analysis: stacked traces - 800J



www.fugro.com

Frequency spectrum - 800J



www.fugro.com

Results

From 600J to 800J the distance primary-bubble slightly increases, as expected.
The primary pulse for 800 J shows a wider shape than 600 J.

The source behaves coherently during all the test, both for 600J and for 800J.

Despite the differences from the first pulse test due to the local marine conditions and separation between the sparker and the hydrophone , the test is acceptable.

A test line on top of a previous one has been acquired to check the source: the data are comparable both in terms of amplitude and frequency.

www.fugro.com

A.11 MOBILISATION ACCEPTANCE CERTIFICATE

(1 page, not numbered)

MOBILISATION ACCEPTANCE CERTIFICATE

Project: Thanet Extension Offshore Windfarm Geophysical Site Investigation 2016

Project Number: GE051

Contractor: Fugro Survey B.V.

Company: Vattenfall Wind Power Ltd

Date: 05 August 2016

CONTRACTOR hereby notifies COMPANY that it considers the mobilisation of the survey vessel Fugro Pioneer to be complete and its obligations thereunder to be fulfilled.

The CONTRACTOR therefor requests the COMPANY to issue a Mobilisation Acceptance Certificate.

For and on behalf of CONTRACTOR:

Signature: [redacted]

Name: C. Maree (Party Chief)

Date: 05 August 2016

COMPANY hereby agrees and accepts that the activities described in Revision 1 of the Mobilisation Report have been performed and completed by CONTRACTOR and that the vessel is ready to commence field work for the project.

This Mobilisation Acceptance Certificate does not relieve CONTRACTOR of any of its obligations to COMPANY under the contract nor any rights held by COMPANY.

For and on behalf of COMPANY:

Signature: [redacted]

Name: R. Chippendale (Client Representative)

Date: 05 August 2016

A.12 SOUND VELOCITY PROFILER CALIBRATIONS

(4 pages, not numbered)

This certifies that the instrument detailed below has been verified against SAIV A/S calibrated equipment standards, who used equipment with calibrations traceable to UKAS or National Standards.

SAIV A/S SD204

Verification Certificate

Sensor Model:	SD204	Sensor Serial #:	1166
Reference Model:	SD208	Reference Serial #:	1221

Speed of Sound

Reference [m/s]	Instrument [m/s]	Error [m/s]	Acceptable Error [m/s]	Result
0.000	0.000	0.000	±0.030	Pass

Temperature

Reference [°C] IPTS 90	Instrument [°C] IPTS 90	Error [°C] IPTS 90	Acceptable Error [°C] IPTS 90	Result
20.823	20.826	-0.003	±0.01	Pass
15.210	15.208	0.002	±0.01	Pass
10.114	10.116	-0.002	±0.01	Pass

Conductivity

Reference [mS/cm]	Instrument [mS/cm]	Error [mS/cm]	Acceptable Error [mS/cm]	Result
16.068	16.060	-0.008	±0.015	Pass

Pressure

Reference [dBar]	Instrument [dBar]	Error %FS	Acceptable Error %FS	Result
10.15	10.05	0.005	±0.05	Pass

Tested by: MPA van Leeuwen Test Date: 8 March 2016

Signature: [redacted]

Tested at location: Fugro Survey B.V.
Veurse Achterweg 12
2264 SG Leidschendam
The Netherlands

SAIV A/S SD204

Pressure Sensor Test Certificate

Sensor Make:	SAIV A/S	Sensor Model:	SD204
Sensor Range (Bar):	200	Sensor Serial #:	1166
DWT Model:	GE Sensing P3124-1	DWT Serial #:	66987
Atm. Pressure (Bar):	1.015	Temperature (ºC):	18.2

Applied Pressure (Bar)	Pressure % of Full Scale	Readback Pressure (Bar)	Error % of Full Scale	Test Limit % of Full Scale	Result
1.015	1	1.005	0.005	0.05	PASS
41.040	21	41.044	-0.002	0.05	PASS
81.064	41	81.092	-0.014	0.05	PASS
121.089	61	121.136	-0.023	0.05	PASS
161.114	81	161.202	-0.044	0.05	PASS
201.138	101	201.227	-0.044	0.05	PASS
161.114	81	161.194	-0.040	0.05	PASS
121.089	61	121.123	-0.017	0.05	PASS
81.064	41	81.086	-0.011	0.05	PASS
41.040	21	41.038	0.001	0.05	PASS
1.015	1	0.992	0.012	0.05	PASS

Tested by: MPA van Leeuwen Test Date: 8 March 2016

Signature: [redacted]

Tested at location:

Fugro Survey B.V.
Veurse Achterweg 12
2264 SG Leidschendam
The Netherlands

Verification Certificate SAIV SD204

This certifies that the instrument detailed below has been verified against SAIV A/S calibrated equipment standards, who used equipment with calibrations traceable to UKAS or National Standards.

SAIV A/S SD204

Verification Certificate

Sensor Model:	SD204	Sensor Serial #:	1165
Reference Model:	SD208	Reference Serial #:	1221

Speed of Sound

Reference [m/s]	Instrument [m/s]	Error [m/s]	Acceptable Error [m/s]	Result
0.000	0.000	0.000	±0.030	Pass

Temperature

Reference [°C] IPTS 90	Instrument [°C] IPTS 90	Error [°C] IPTS 90	Acceptable Error [°C] IPTS 90	Result
20.467	20.462	0.005	±0.01	Pass
15.168	15.164	0.004	±0.01	Pass
9.358	9.355	0.003	±0.01	Pass

Conductivity

Reference [mS/cm]	Instrument [mS/cm]	Error [mS/cm]	Acceptable Error [mS/cm]	Result
20.016	20.010	-0.006	±0.015	Pass

Pressure

Reference [dBar]	Instrument [dBar]	Error %FS	Acceptable Error %FS	Result
10.02	10.13	-0.006	±0.05	Pass

Tested by: MPA van Leeuwen Test Date: 12 May 2016

Signature: [redacted]

Tested at location:

Fugro Survey B.V.
Veurse Achterweg 12
2264 SG Leidschendam
The Netherlands

SAIV A/S SD204

Pressure Sensor Test Certificate

Sensor Make:	SAIV A/S	Sensor Model:	SD204
Sensor Range (Bar):	200	Sensor Serial #:	1165
DWT Model:	GE Sensing P3124-1	DWT Serial #:	66987
Atm. Pressure (Bar):	1.002	Temperature (ºC):	20.5

Applied Pressure (Bar)	Pressure % of Full Scale	Readback Pressure (Bar)	Error % of Full Scale	Test Limit % of Full Scale	Result
1.002	1	1.013	-0.005	0.05	PASS
41.027	21	41.065	-0.019	0.05	PASS
81.051	41	81.123	-0.036	0.05	PASS
121.076	61	121.158	-0.041	0.05	PASS
161.100	81	161.188	-0.044	0.05	PASS
201.125	101	201.218	-0.046	0.05	PASS
161.100	81	161.185	-0.042	0.05	PASS
121.076	61	121.156	-0.040	0.05	PASS
81.051	41	81.120	-0.034	0.05	PASS
41.027	21	41.061	-0.017	0.05	PASS
1.002	1	1.008	-0.003	0.05	PASS

Tested by: MPA van Leeuwen Test Date: 12 May 2016

Signature: [redacted]

Tested at location:

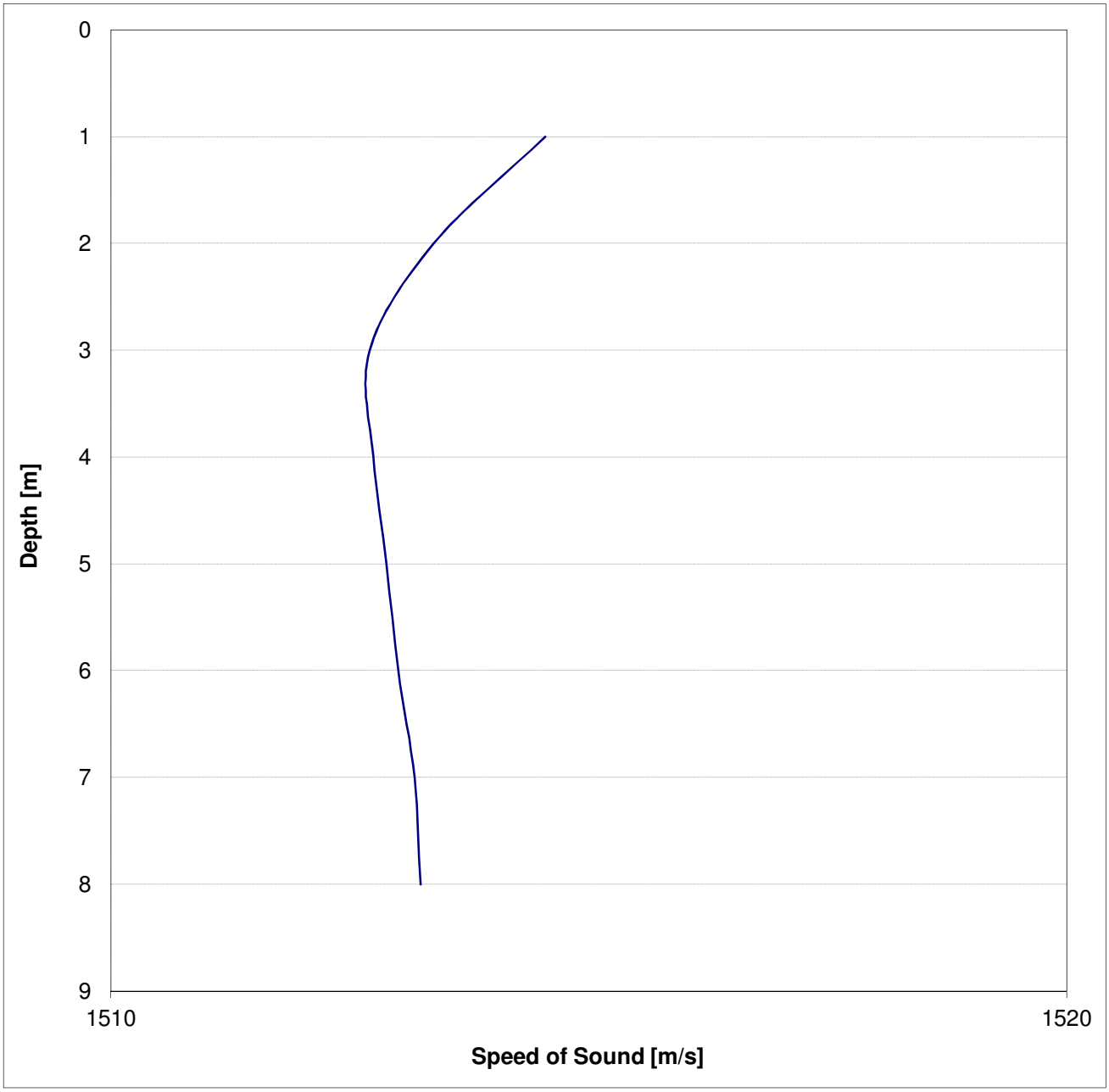
Fugro Survey B.V.
Veurse Achterweg 12
2264 SG Leidschendam
The Netherlands

A.13 SOUND VELOCITY PROFILER COMPARISON

(2 pages, not numbered)

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	14:21 30/Jul/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	8.03 m
Easting:	586858 m	Transducer speed of sound:	1512.68 m/s
Northing:	5773000 m	Bottom speed of sound:	1513.24 m/s
Datum and projection:	ETRS89	Average speed of sound:	1513.21 m/s
Sensor type and S/N:	SD1165	Average density:	1018.93 kg/m^3



For Fugro Survey B.V.

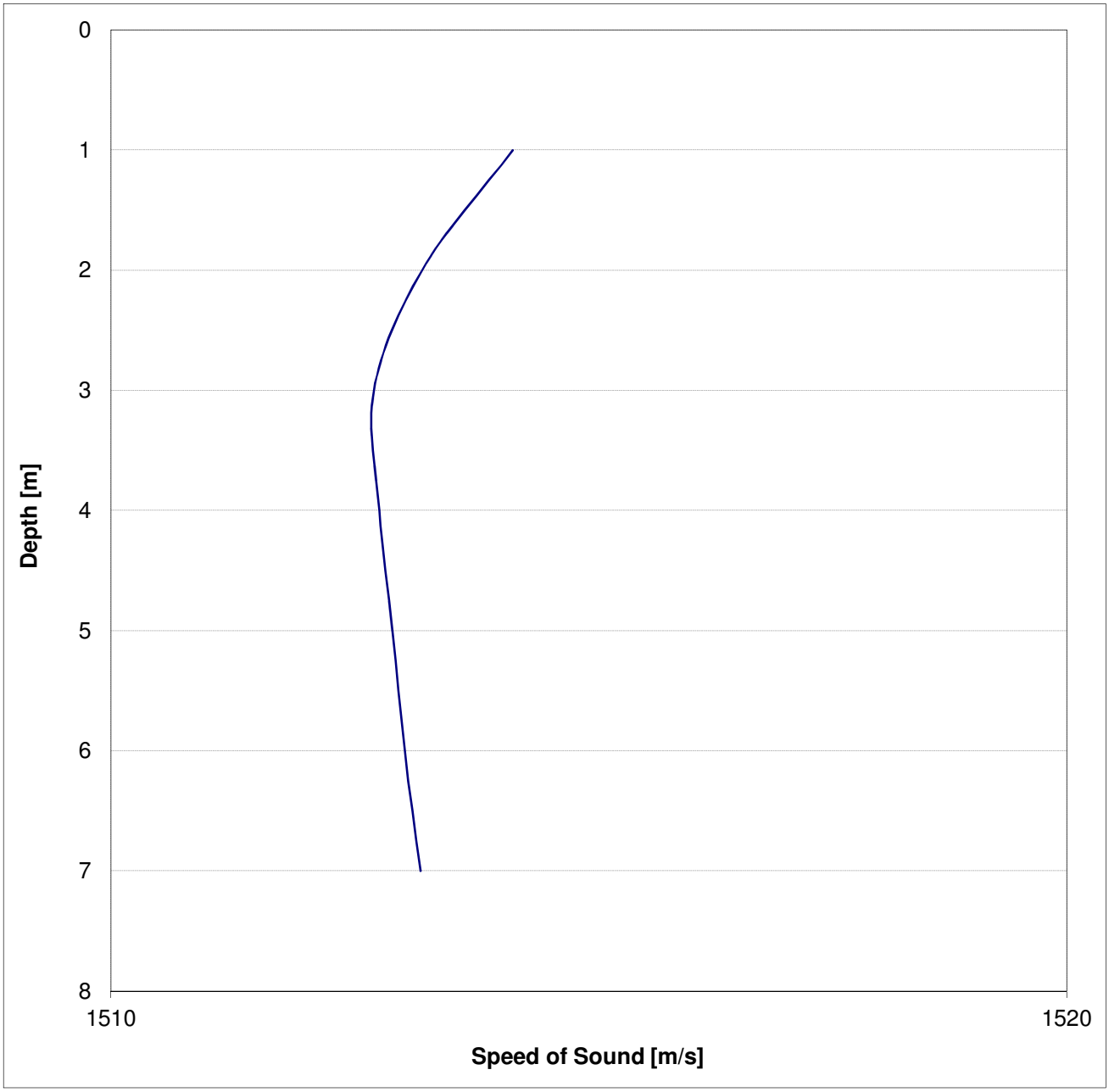
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	14:21 30/Jul/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	7.97 m
Easting:	586858 m	Transducer speed of sound:	1512.74 m/s
Northing:	5773000 m	Bottom speed of sound:	1513.28 m/s
Datum and projection:	ETRS89	Average speed of sound:	1513.18 m/s
Sensor type and S/N:	SD1165	Average density:	1018.86 kg/m^3



For Fugro Survey B.V.

C. Maree [redacted]

For Client

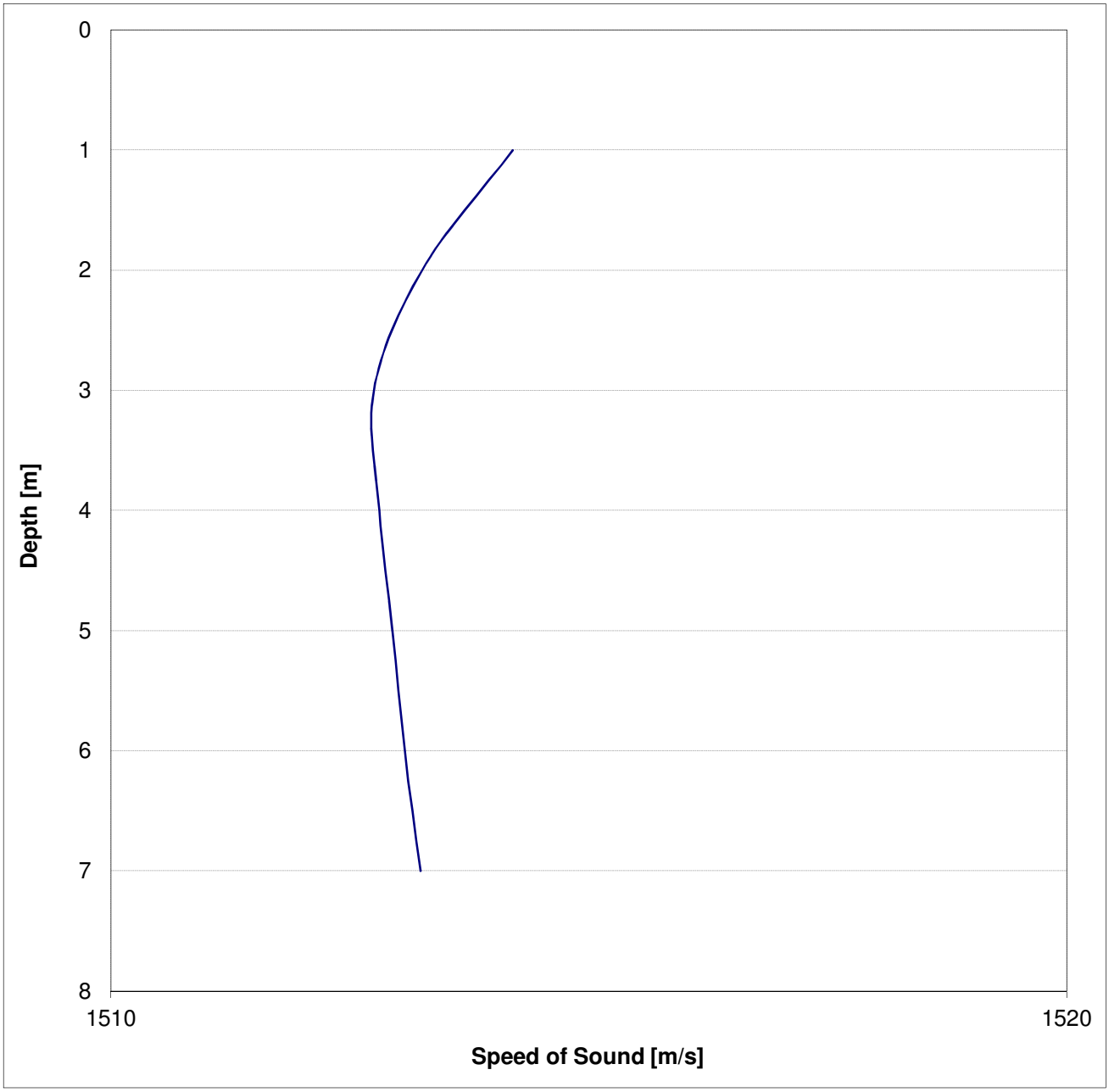
R. Chippendale [redacted]

A.14 SOUND VELOCITY PROFILER MEASUREMENTS

(43 pages, not numbered)

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	14:21 30/Jul/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	7.97 m
Easting:	586858 m	Transducer speed of sound:	1512.74 m/s
Northing:	5773000 m	Bottom speed of sound:	1513.28 m/s
Datum and projection:	ETRS89	Average speed of sound:	1513.18 m/s
Sensor type and S/N:	SD1165	Average density:	1018.86 kg/m^3



For Fugro Survey B.V.

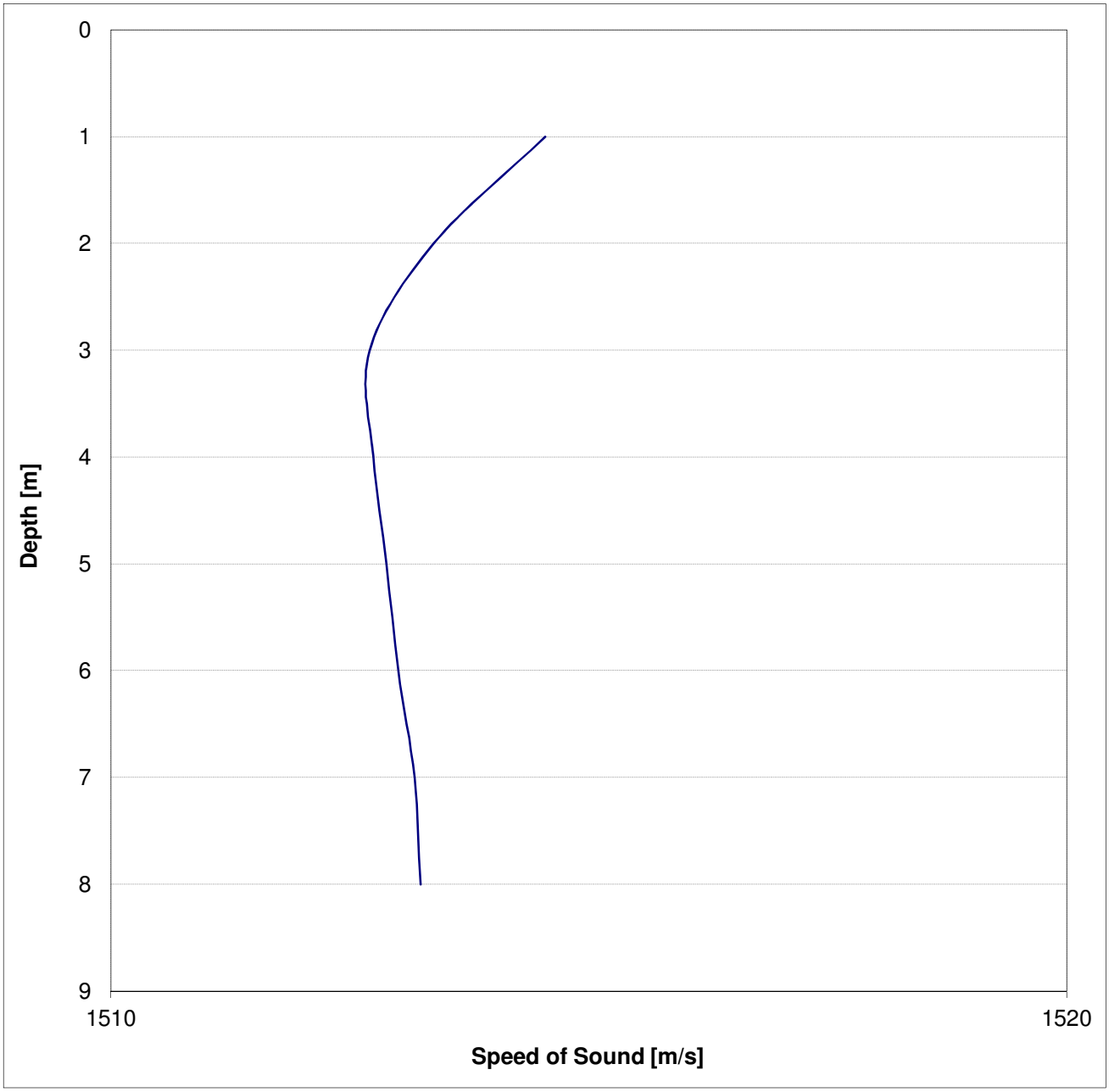
C. Maree [redacted]

For Client

R. Chippendale [redacted]

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	14:21 30/Jul/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	8.03 m
Easting:	586858 m	Transducer speed of sound:	1512.68 m/s
Northing:	5773000 m	Bottom speed of sound:	1513.24 m/s
Datum and projection:	ETRS89	Average speed of sound:	1513.21 m/s
Sensor type and S/N:	SD1165	Average density:	1018.93 kg/m^3



For Fugro Survey B.V.

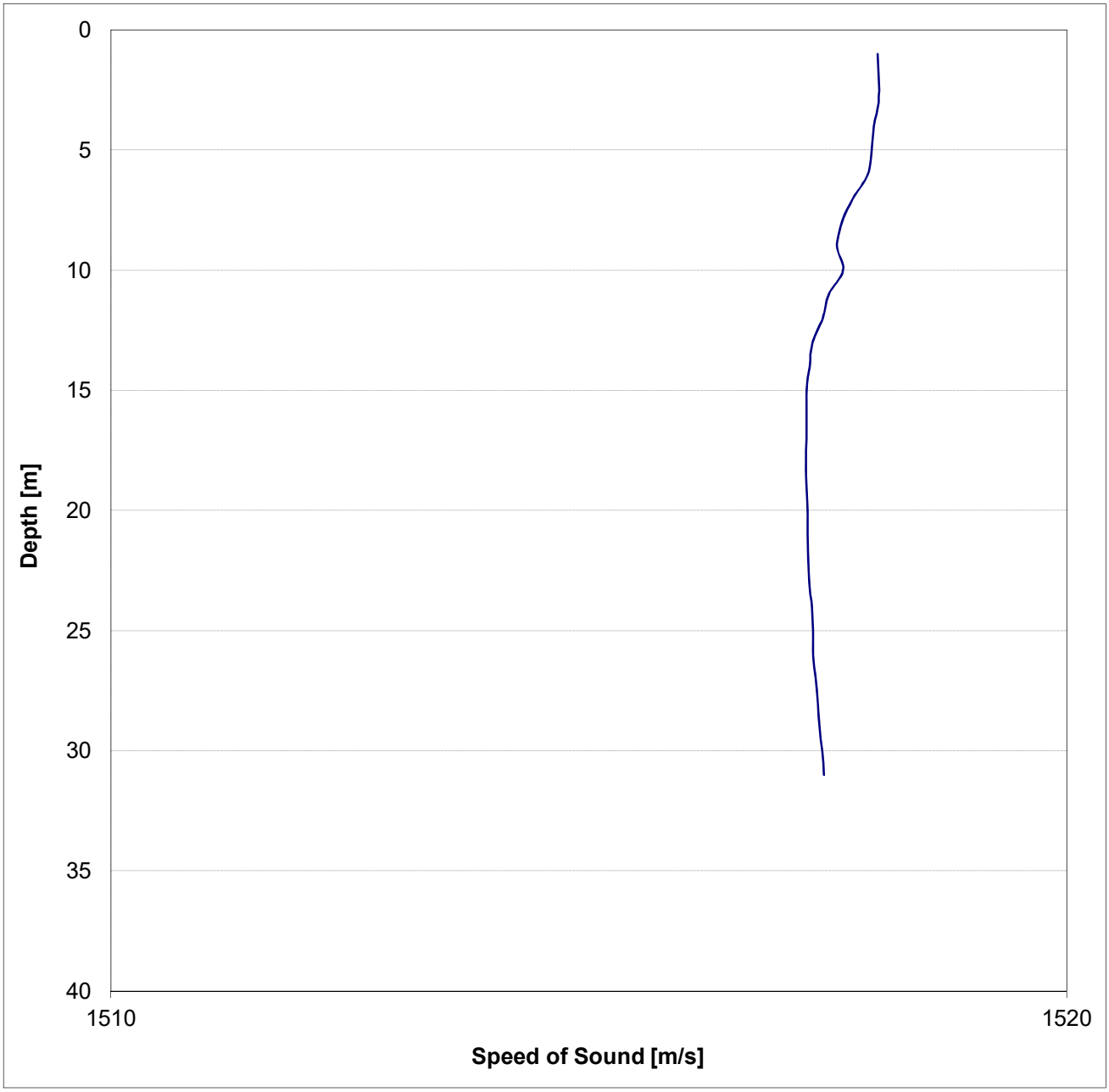
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	16:06 01/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	31.96 m
Easting:	411700 m	Transducer speed of sound:	1518.01 m/s
Northing:	5702290 m	Bottom speed of sound:	1517.49 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.51 m/s
Sensor type and S/N:	SD1165	Average density:	1025.11 kg/m^3



For Fugro Survey B.V.

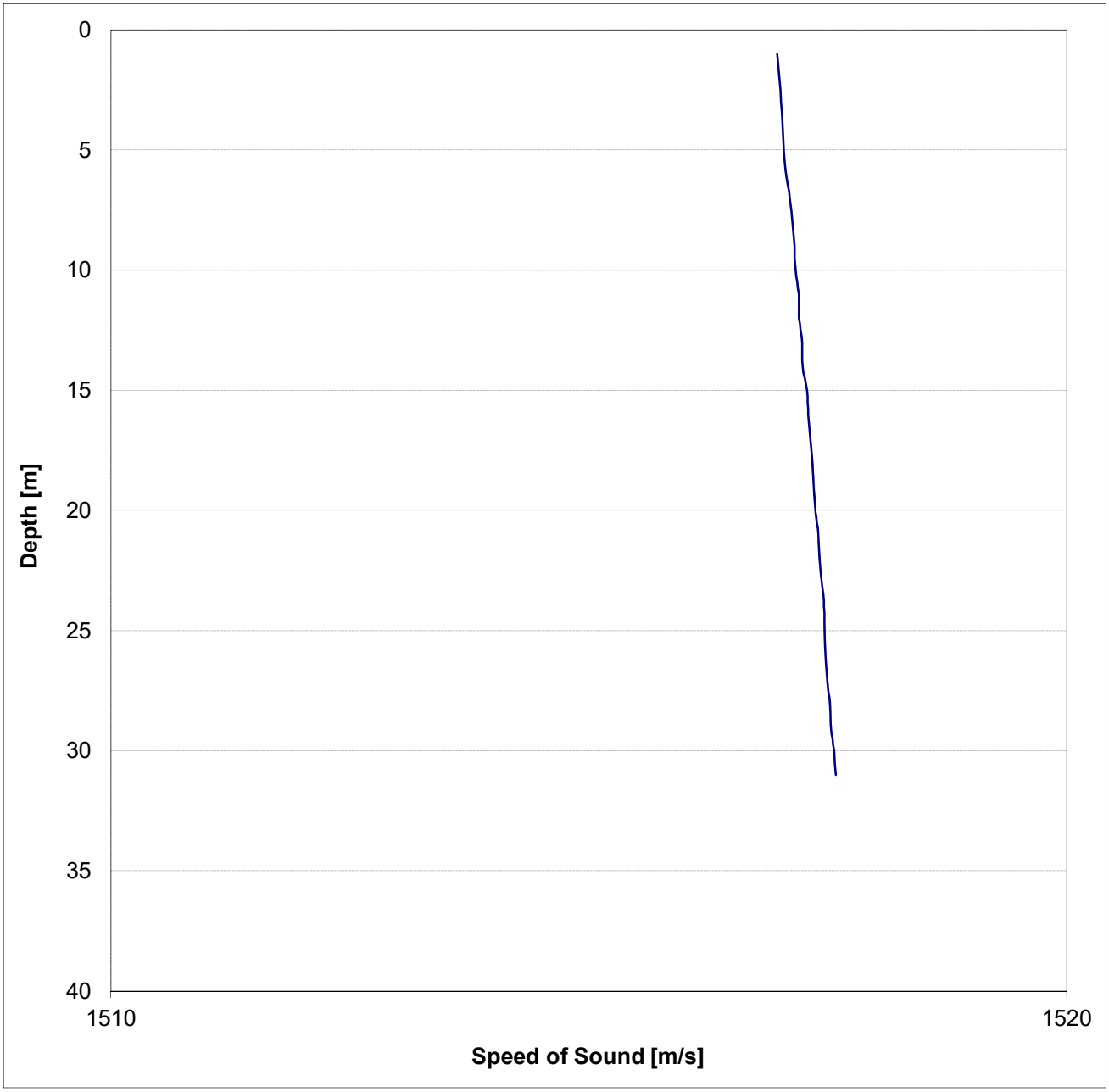
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	09:03 02/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	31.02 m
Easting:	410656 m	Transducer speed of sound:	1517.02 m/s
Northing:	5698759 m	Bottom speed of sound:	1517.58 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.28 m/s
Sensor type and S/N:	SD1165	Average density:	1025.17 kg/m^3



For Fugro Survey B.V.

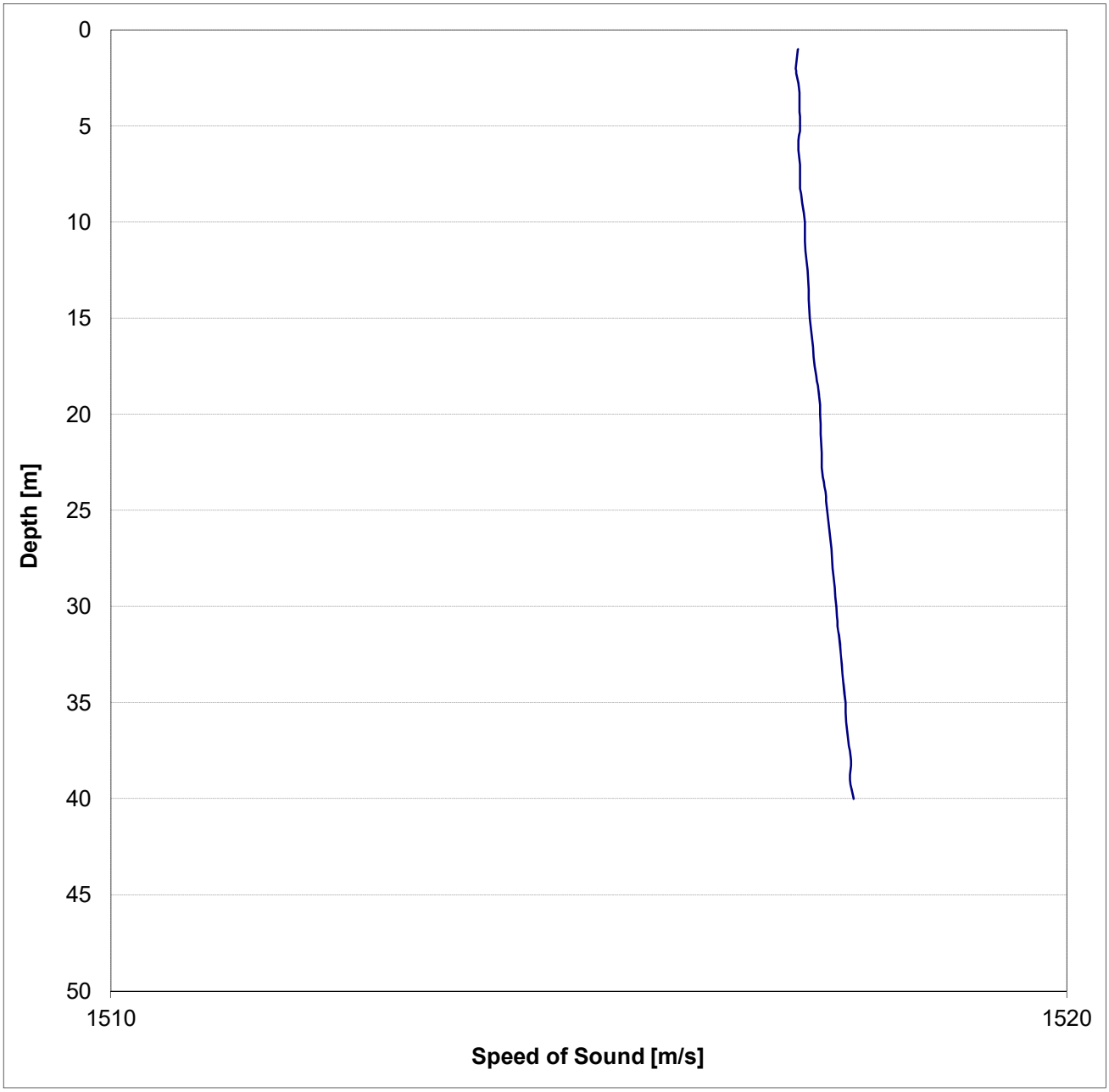
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	21:27 02/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	40.47 m
Easting:	410990 m	Transducer speed of sound:	1517.23 m/s
Northing:	5698333 m	Bottom speed of sound:	1517.78 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.43 m/s
Sensor type and S/N:	SD1165	Average density:	1025.15 kg/m^3



For Fugro Survey B.V.

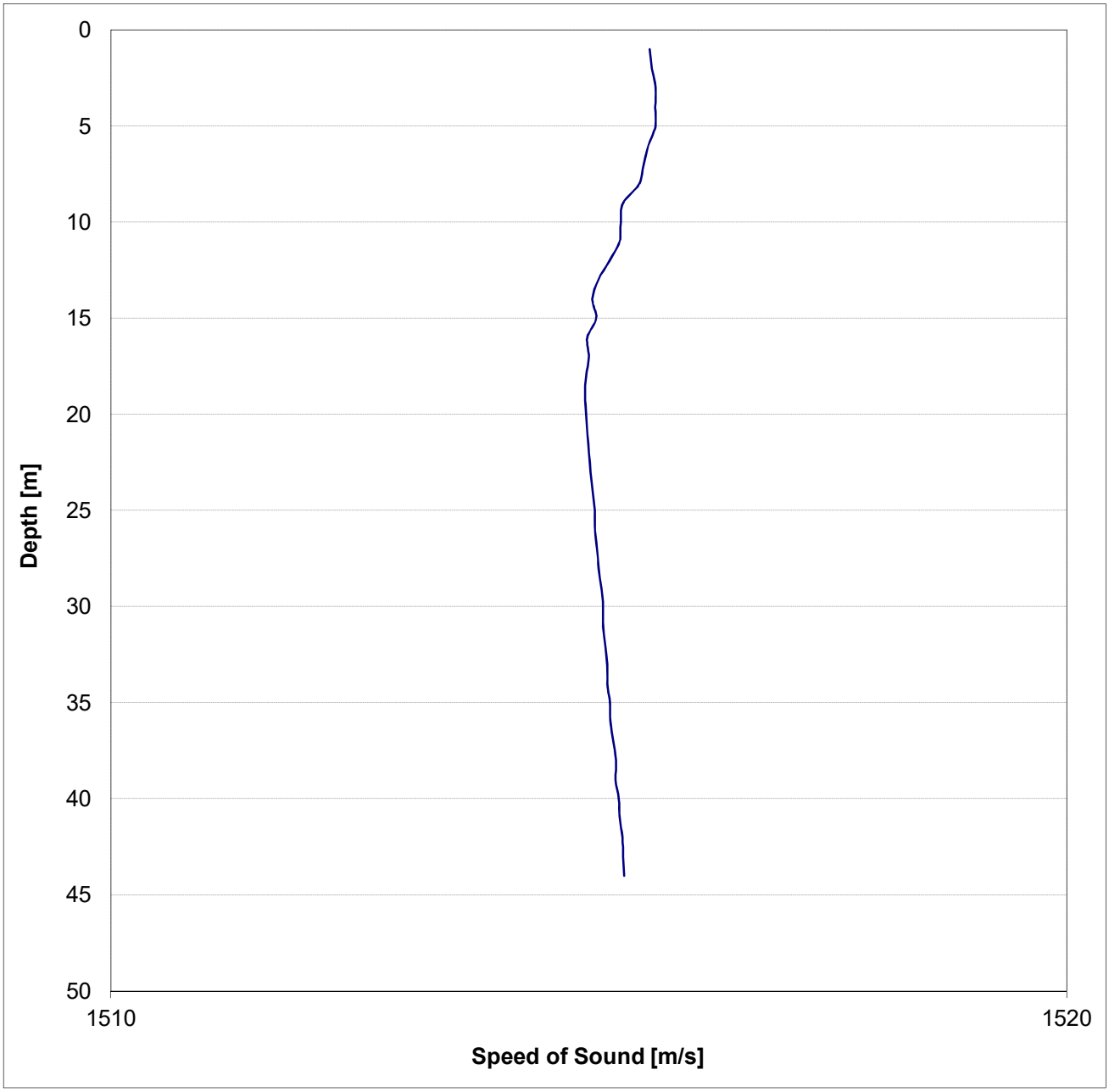
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	05:49 03/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	44.04 m
Easting:	412680 m	Transducer speed of sound:	1515.70 m/s
Northing:	5698100 m	Bottom speed of sound:	1515.38 m/s
Datum and projection:	ETRS89	Average speed of sound:	1515.24 m/s
Sensor type and S/N:	SD1165	Average density:	1025.58 kg/m^3



For Fugro Survey B.V.

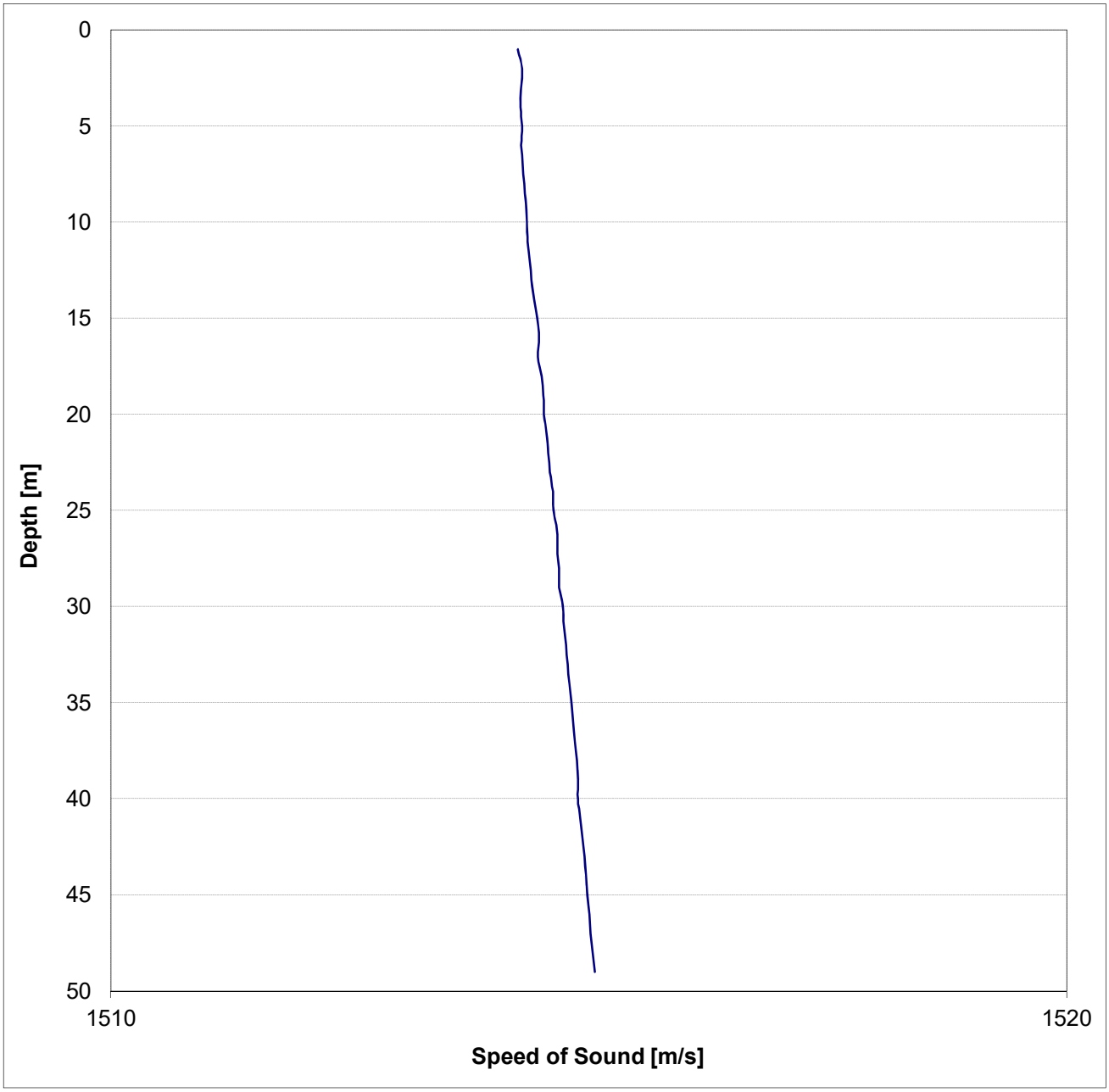
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	18:18 04/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	49.48 m
Easting:	410191 m	Transducer speed of sound:	1514.28 m/s
Northing:	5691576 m	Bottom speed of sound:	1515.07 m/s
Datum and projection:	ETRS89	Average speed of sound:	1514.64 m/s
Sensor type and S/N:	SD1165	Average density:	1025.70 kg/m^3



For Fugro Survey B.V.

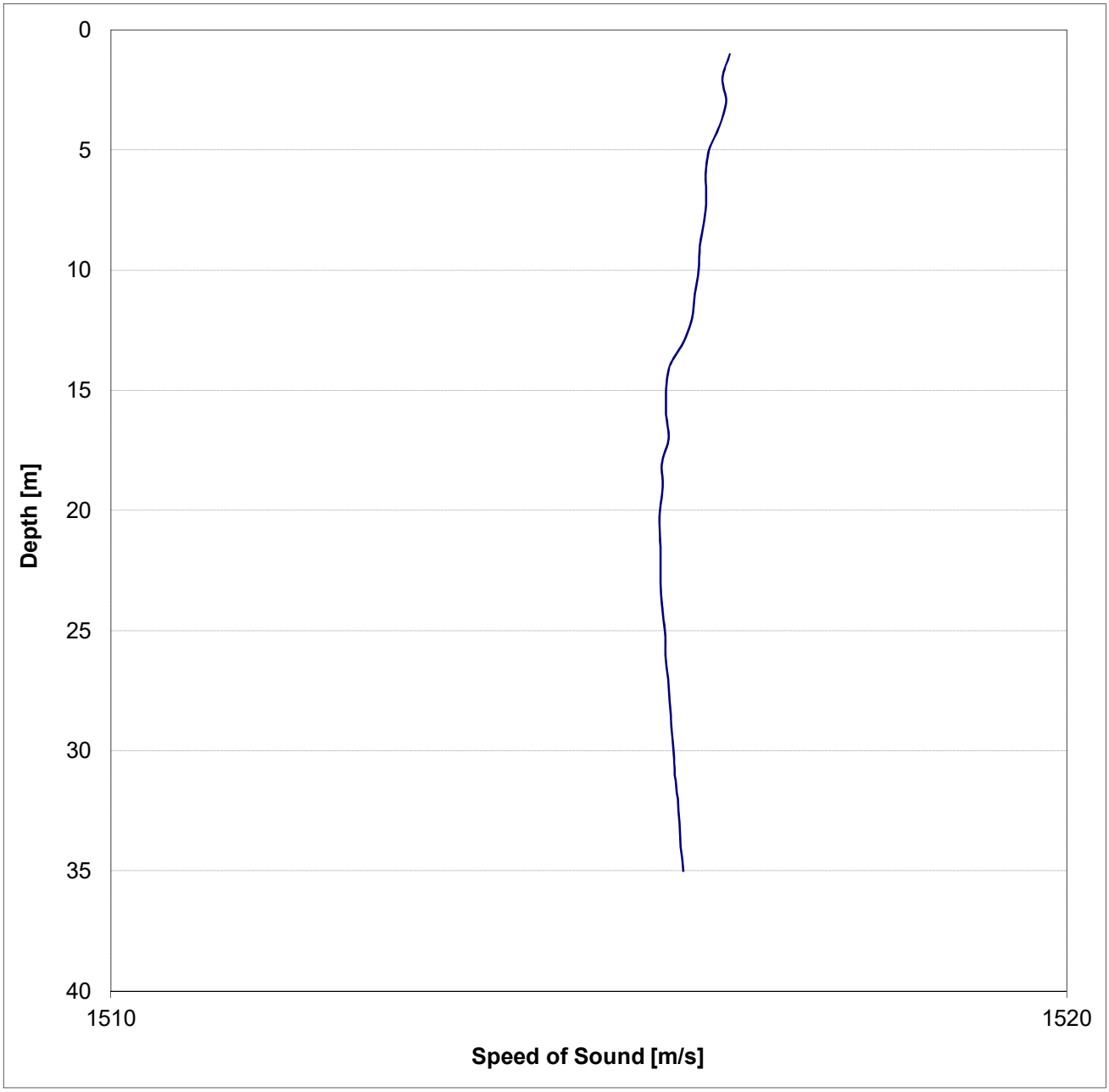
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	08:37 05/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	35.08 m
Easting:	408267 m	Transducer speed of sound:	1516.50 m/s
Northing:	5691264 m	Bottom speed of sound:	1516.00 m/s
Datum and projection:	ETRS89	Average speed of sound:	1515.98 m/s
Sensor type and S/N:	SD1165	Average density:	1025.46 kg/m^3



For Fugro Survey B.V.

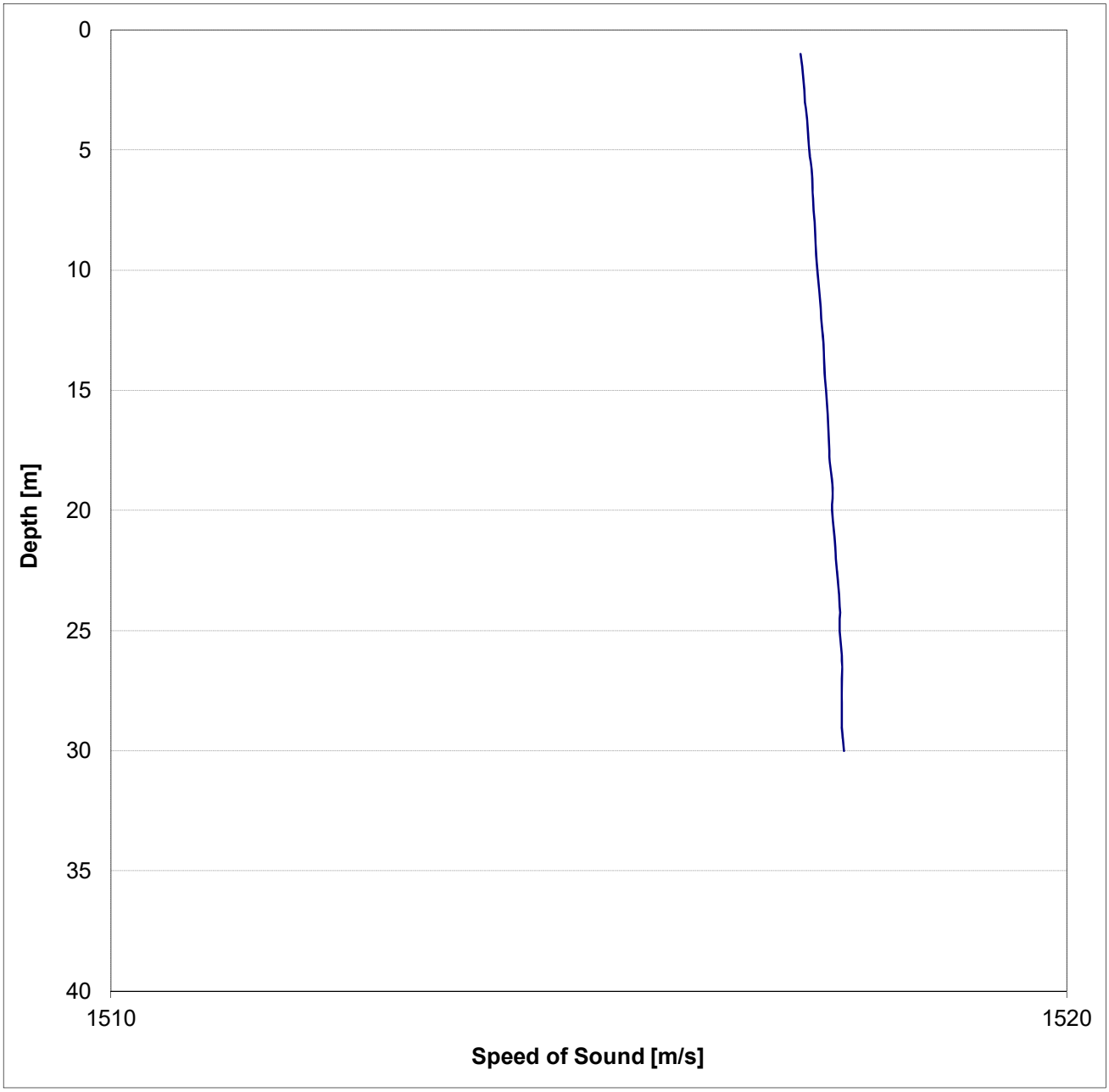
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	04:21 06/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	30.95 m
Easting:	412378 m	Transducer speed of sound:	1517.27 m/s
Northing:	5699331 m	Bottom speed of sound:	1517.67 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.47 m/s
Sensor type and S/N:	SD1165	Average density:	1025.15 kg/m^3



For Fugro Survey B.V.

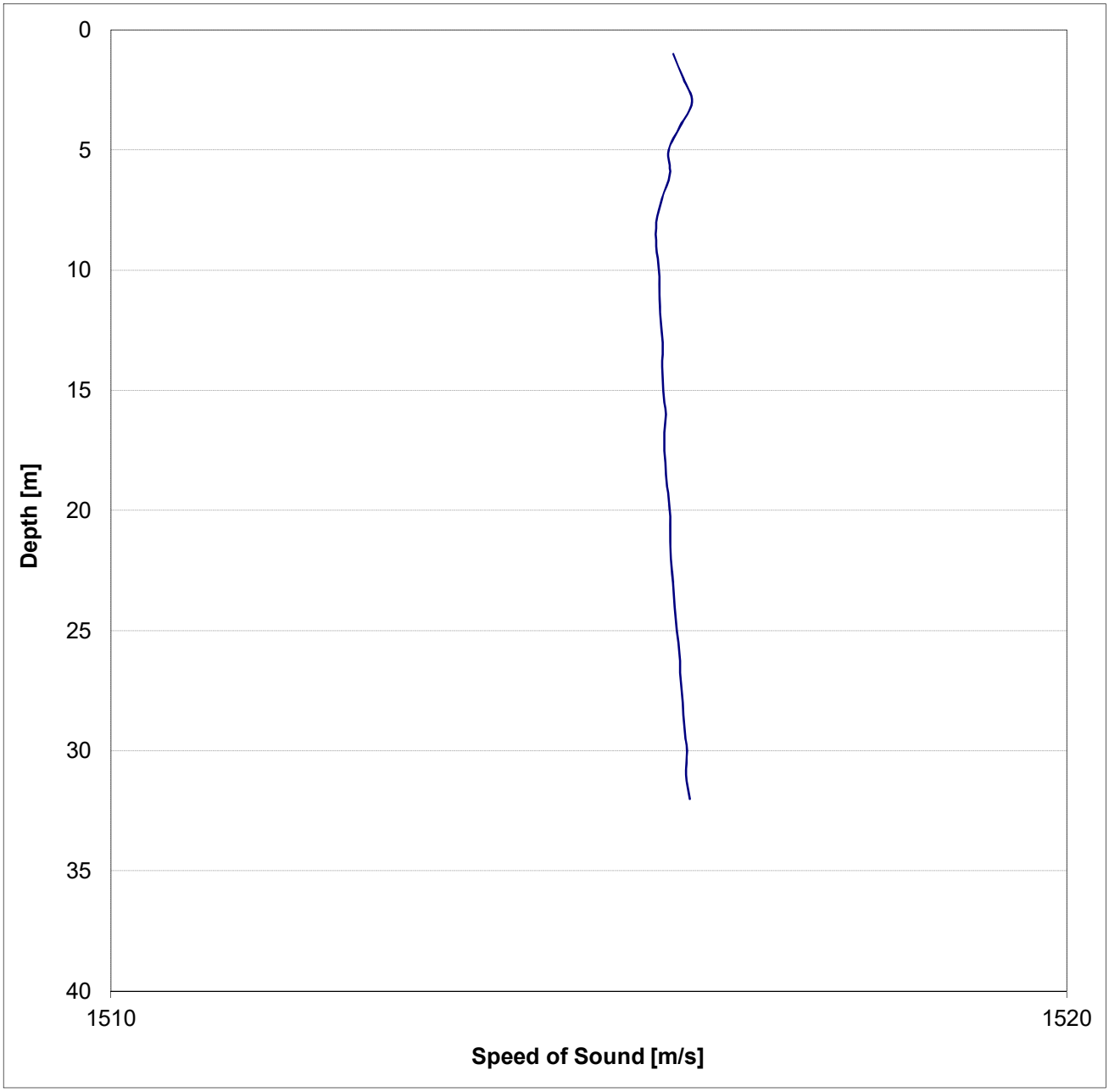
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	13:33 06/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	32.33 m
Easting:	408164 m	Transducer speed of sound:	1516.16 m/s
Northing:	5704391 m	Bottom speed of sound:	1516.08 m/s
Datum and projection:	ETRS89	Average speed of sound:	1515.87 m/s
Sensor type and S/N:	SD1165	Average density:	1025.47 kg/m^3



For Fugro Survey B.V.

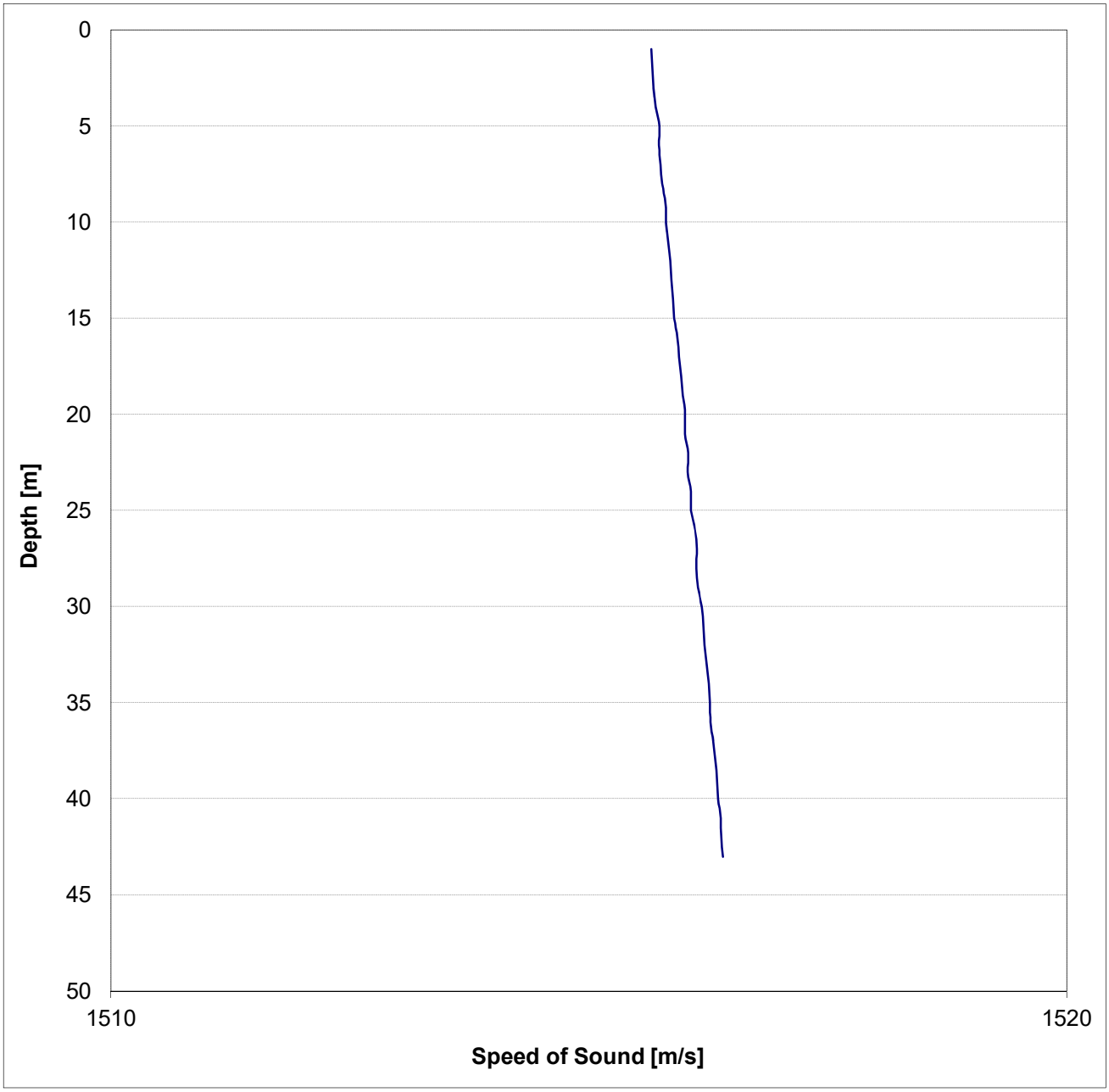
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	08:35 07/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	43.22 m
Easting:	410545 m	Transducer speed of sound:	1515.68 m/s
Northing:	5700101 m	Bottom speed of sound:	1516.42 m/s
Datum and projection:	ETRS89	Average speed of sound:	1516.03 m/s
Sensor type and S/N:	SD1165	Average density:	1025.46 kg/m^3



For Fugro Survey B.V.

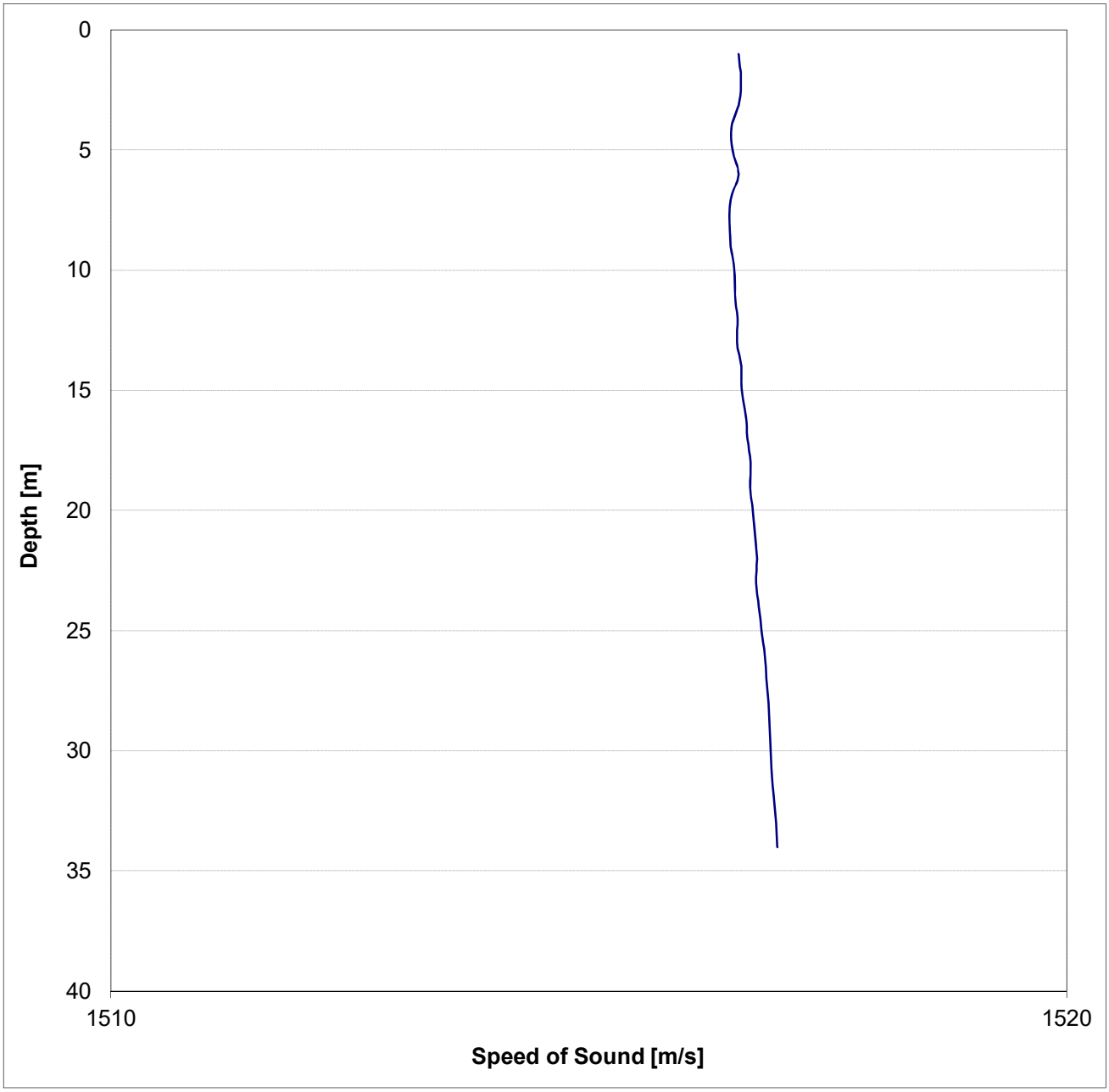
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	14:38 08/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	34.38 m
Easting:	410148 m	Transducer speed of sound:	1516.62 m/s
Northing:	5700109 m	Bottom speed of sound:	1516.97 m/s
Datum and projection:	ETRS89	Average speed of sound:	1516.69 m/s
Sensor type and S/N:	SD1165	Average density:	1025.34 kg/m^3



For Fugro Survey B.V.

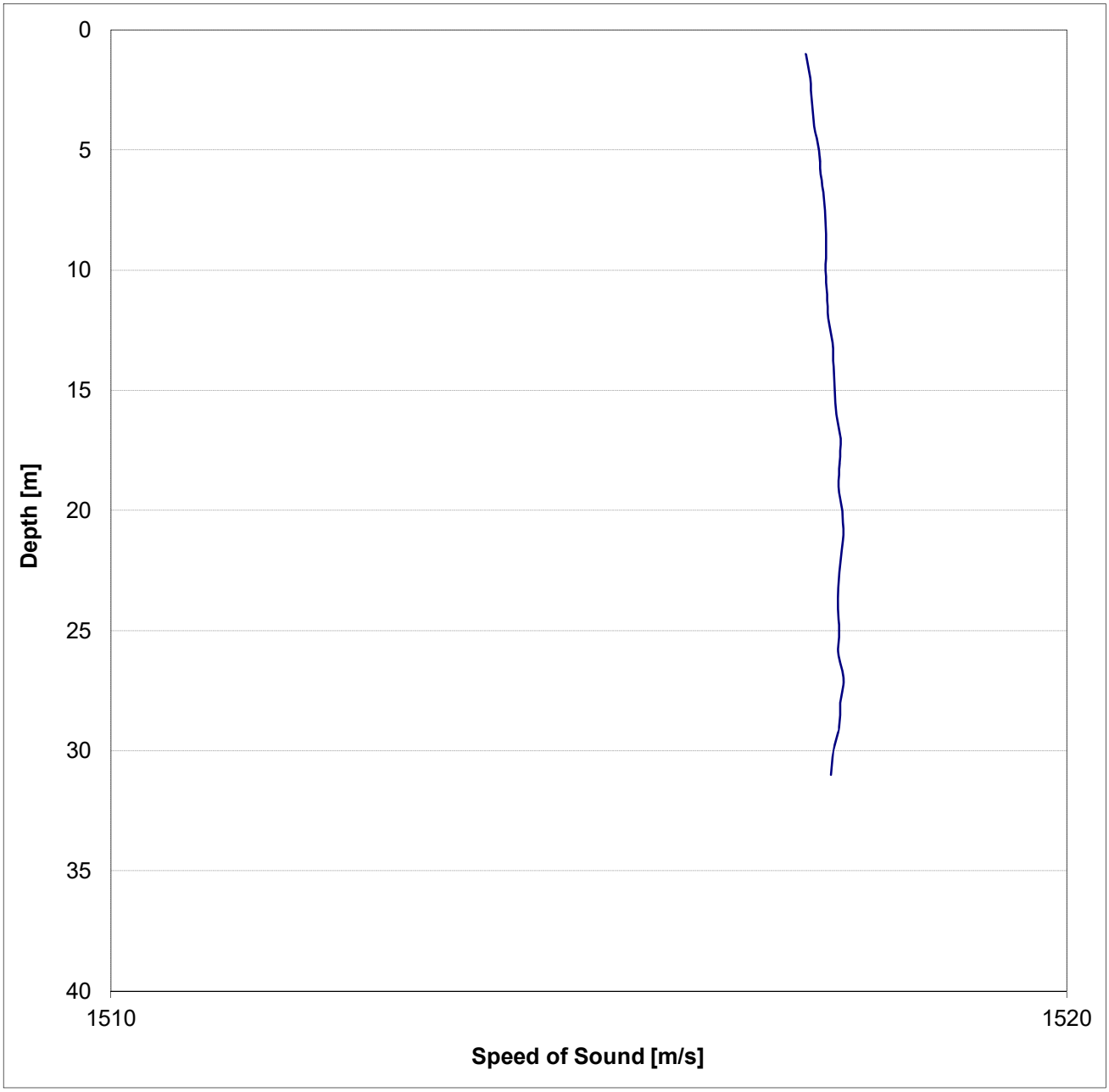
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	04:54 09/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	31.37 m
Easting:	407790 m	Transducer speed of sound:	1517.35 m/s
Northing:	5690943 m	Bottom speed of sound:	1517.53 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.53 m/s
Sensor type and S/N:	SD1165	Average density:	1025.21 kg/m^3



For Fugro Survey B.V.

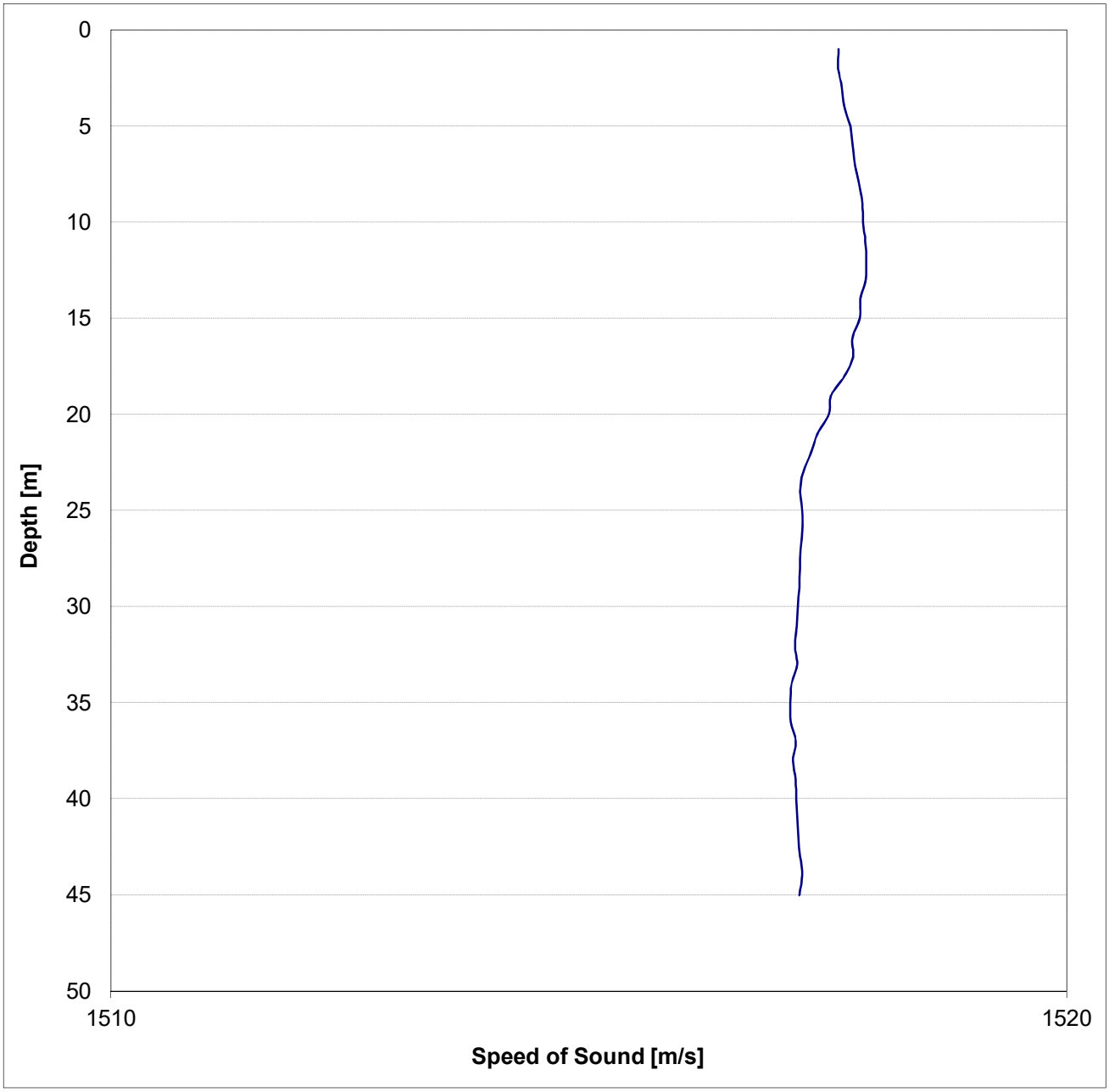
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	20:00 09/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	45.25 m
Easting:	408954 m	Transducer speed of sound:	1517.67 m/s
Northing:	5693069 m	Bottom speed of sound:	1517.14 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.44 m/s
Sensor type and S/N:	SD1165	Average density:	1025.27 kg/m^3



For Fugro Survey B.V.

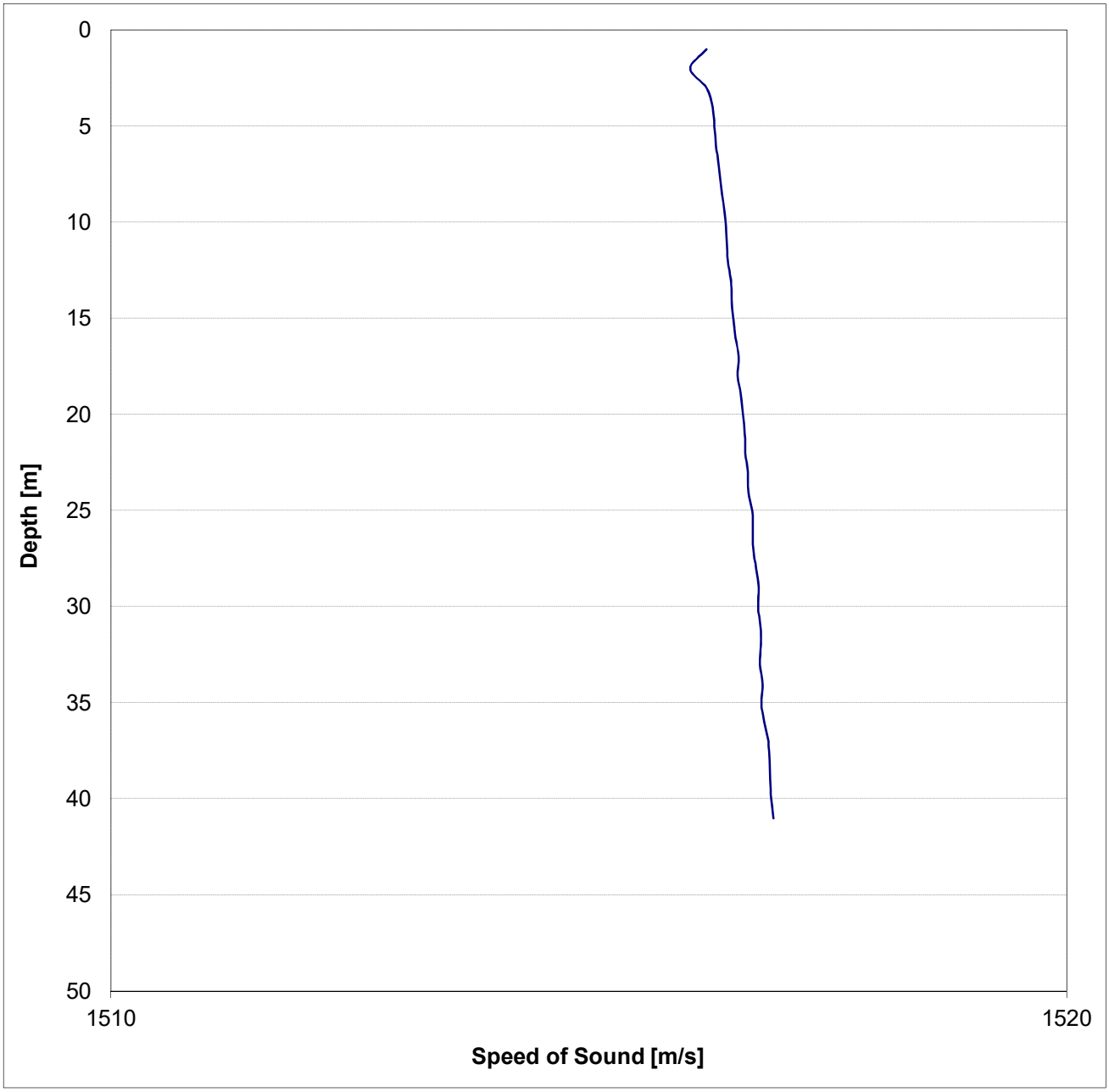
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	04:52 10/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	42.00 m
Easting:	412097 m	Transducer speed of sound:	1516.29 m/s
Northing:	5697058 m	Bottom speed of sound:	1516.94 m/s
Datum and projection:	ETRS89	Average speed of sound:	1516.60 m/s
Sensor type and S/N:	SD1165	Average density:	1025.42 kg/m^3



For Fugro Survey B.V.

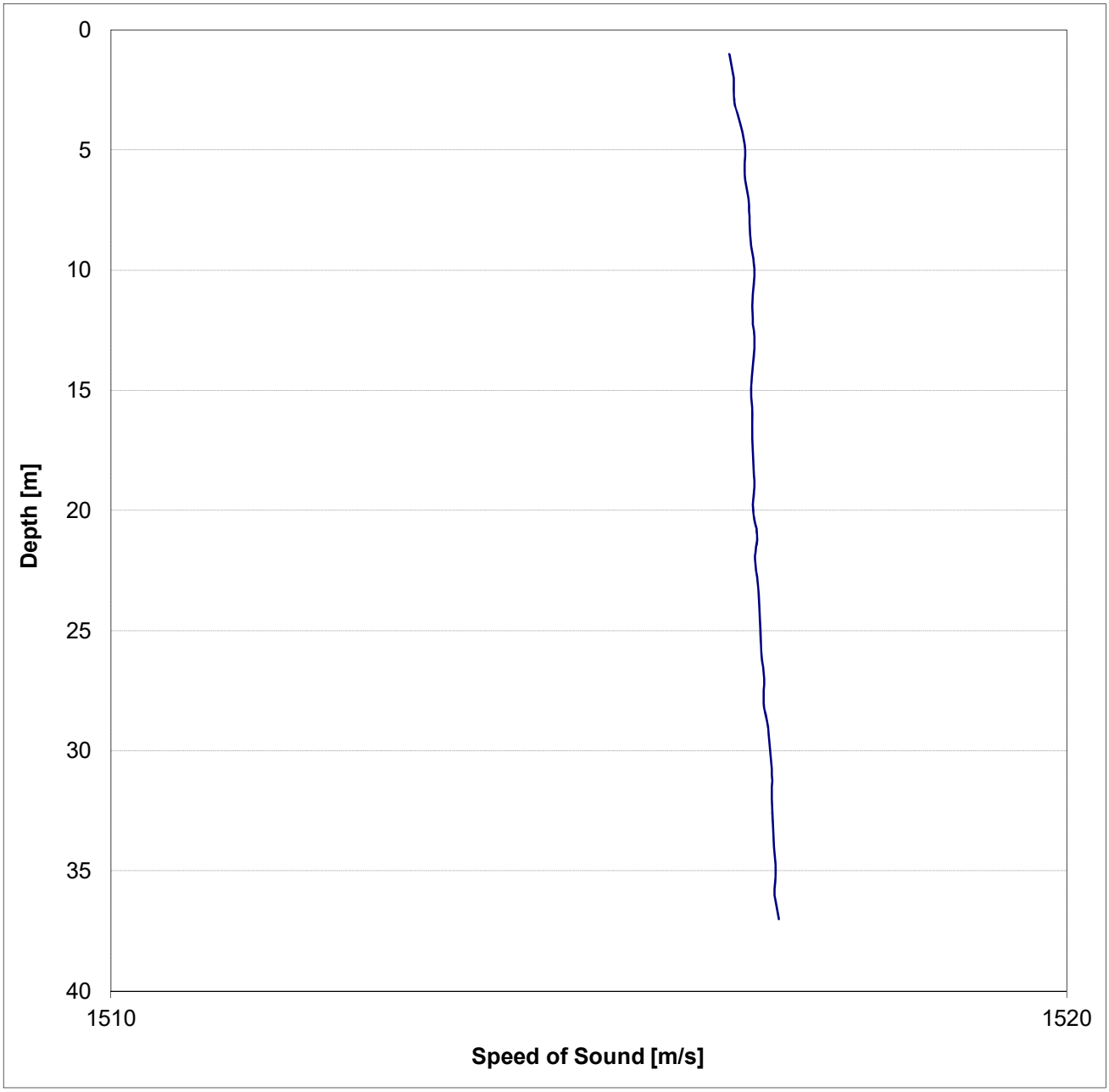
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	21:01 10/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	37.83 m
Easting:	411167 m	Transducer speed of sound:	1516.59 m/s
Northing:	5695590 m	Bottom speed of sound:	1516.99 m/s
Datum and projection:	ETRS89	Average speed of sound:	1516.76 m/s
Sensor type and S/N:	SD1165	Average density:	1025.37 kg/m^3



For Fugro Survey B.V.

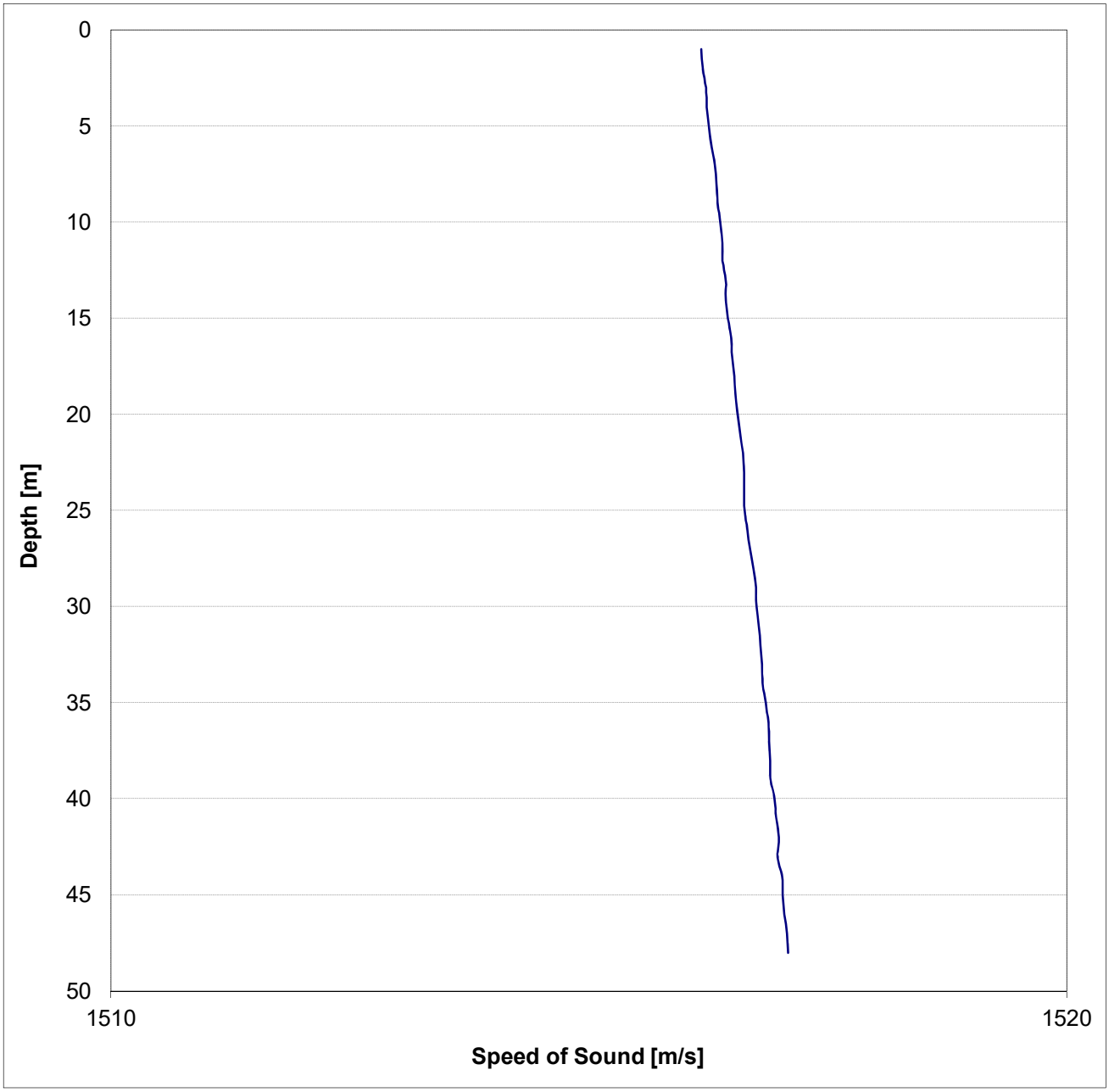
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	04:13 11/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	48.02 m
Easting:	410365 m	Transducer speed of sound:	1516.24 m/s
Northing:	5697256 m	Bottom speed of sound:	1517.09 m/s
Datum and projection:	ETRS89	Average speed of sound:	1516.64 m/s
Sensor type and S/N:	SD1165	Average density:	1025.44 kg/m^3



For Fugro Survey B.V.

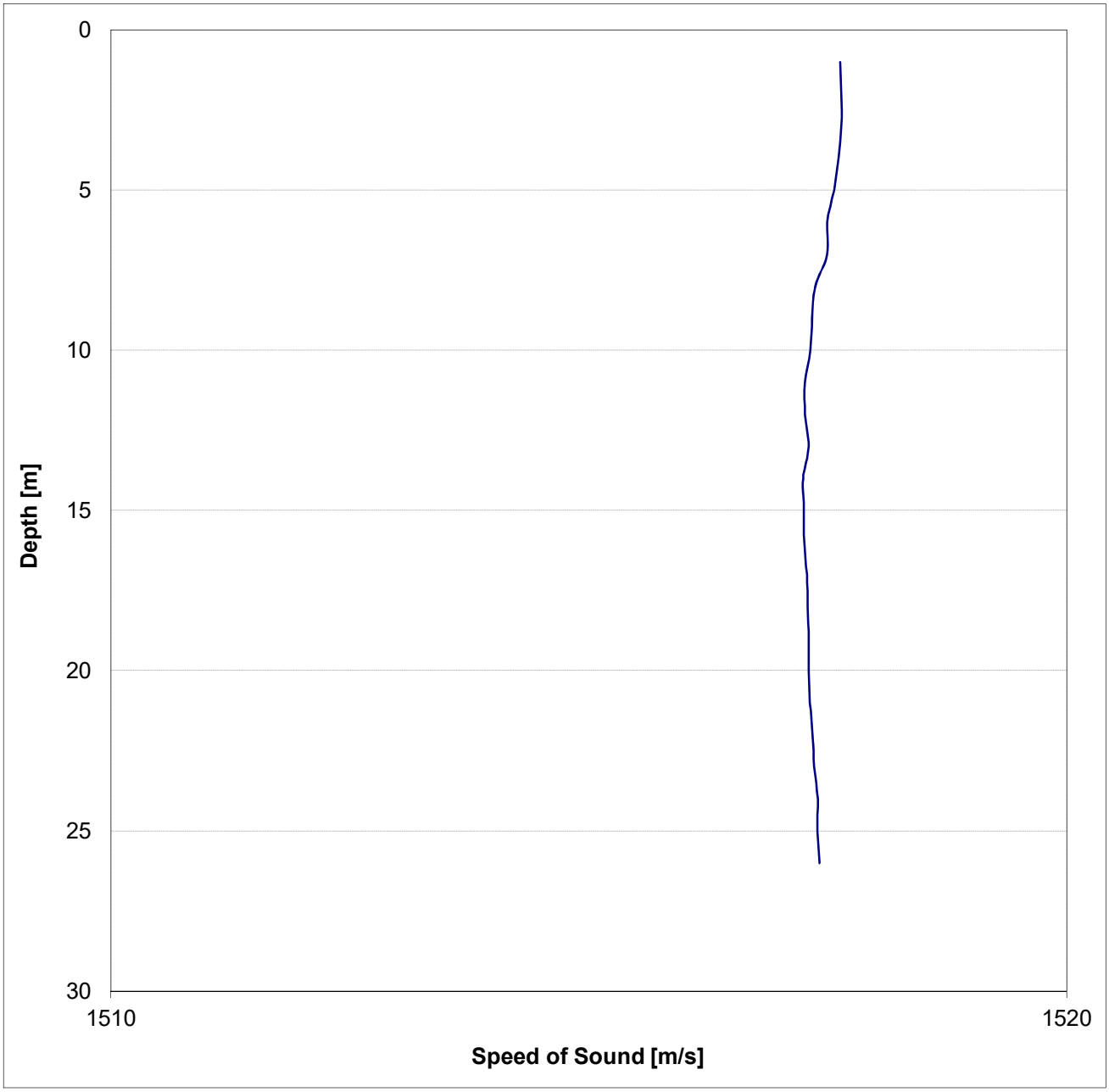
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	15:54 11/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	26.69 m
Easting:	406508 m	Transducer speed of sound:	1517.62 m/s
Northing:	5704627 m	Bottom speed of sound:	1517.44 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.39 m/s
Sensor type and S/N:	SD1165	Average density:	1025.19 kg/m^3



For Fugro Survey B.V.

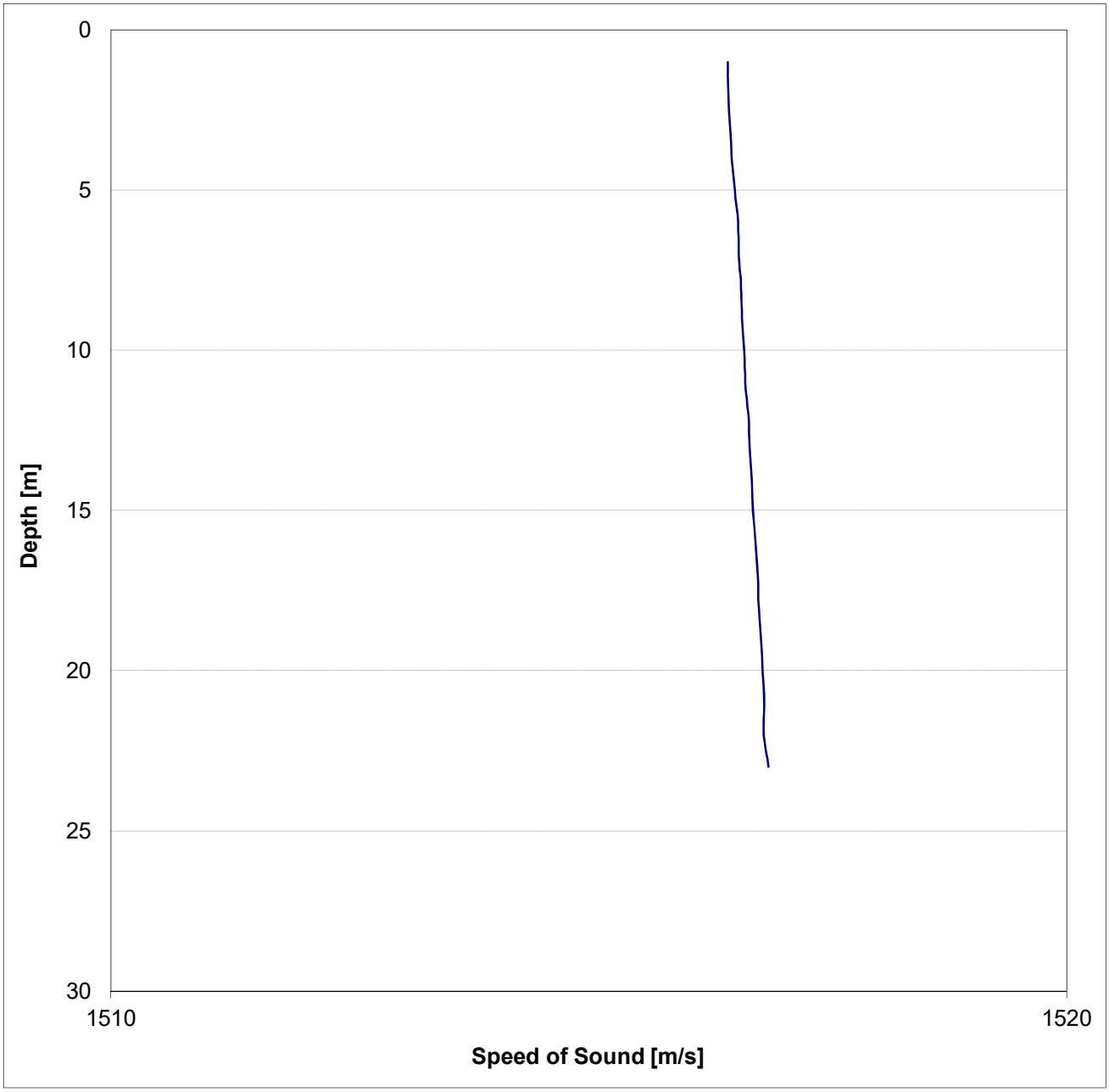
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	04:16 12/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	23.14 m
Easting:	398328 m	Transducer speed of sound:	1516.49 m/s
Northing:	5701334 m	Bottom speed of sound:	1516.88 m/s
Datum and projection:	ETRS89	Average speed of sound:	1516.66 m/s
Sensor type and S/N:	SD1165	Average density:	1025.32 kg/m^3



For Fugro Survey B.V.

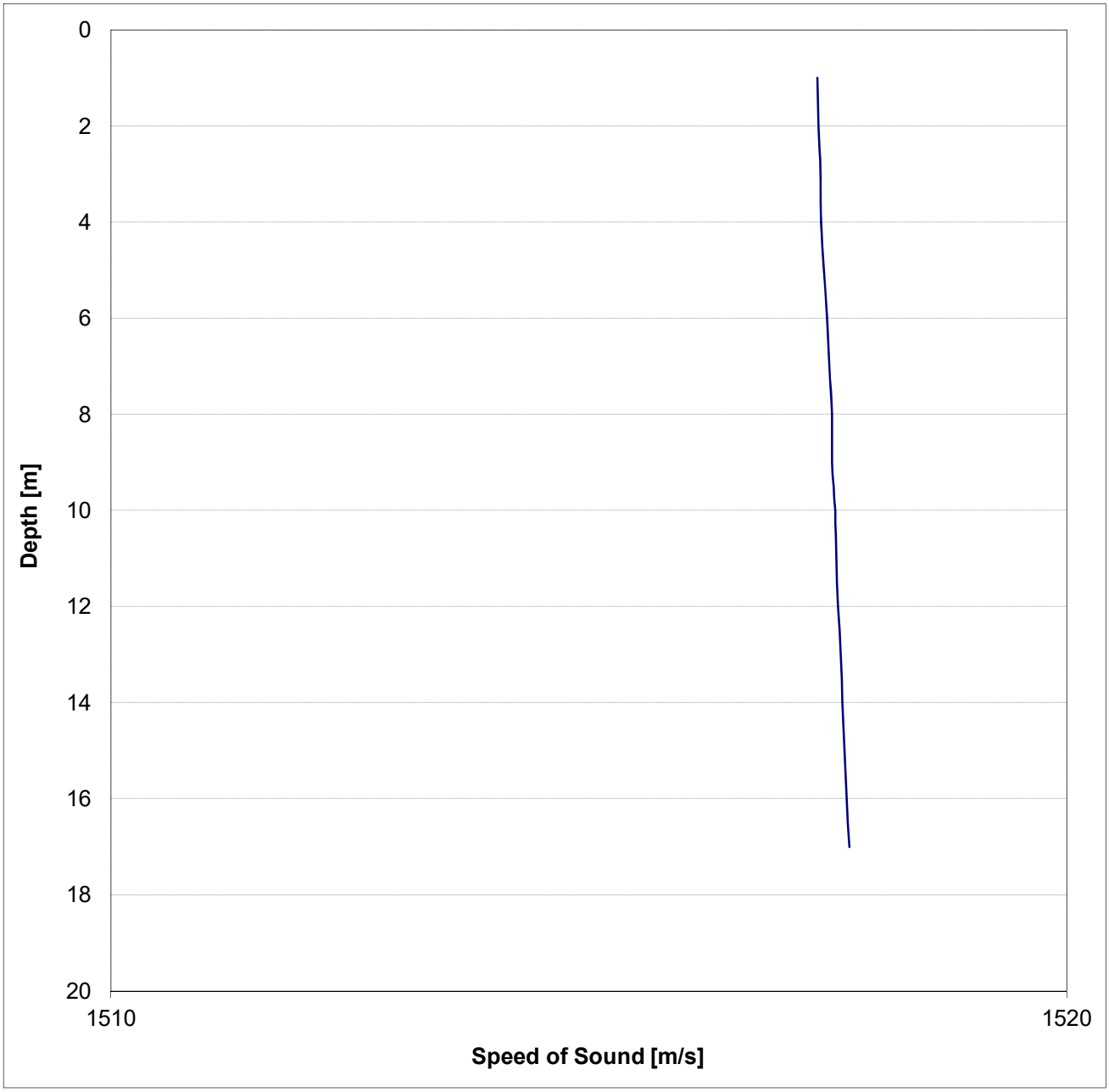
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	17:08 13/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	17.45 m
Easting:	404958 m	Transducer speed of sound:	1517.42 m/s
Northing:	5692225 m	Bottom speed of sound:	1517.74 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.55 m/s
Sensor type and S/N:	SD1165	Average density:	1025.23 kg/m^3



For Fugro Survey B.V.

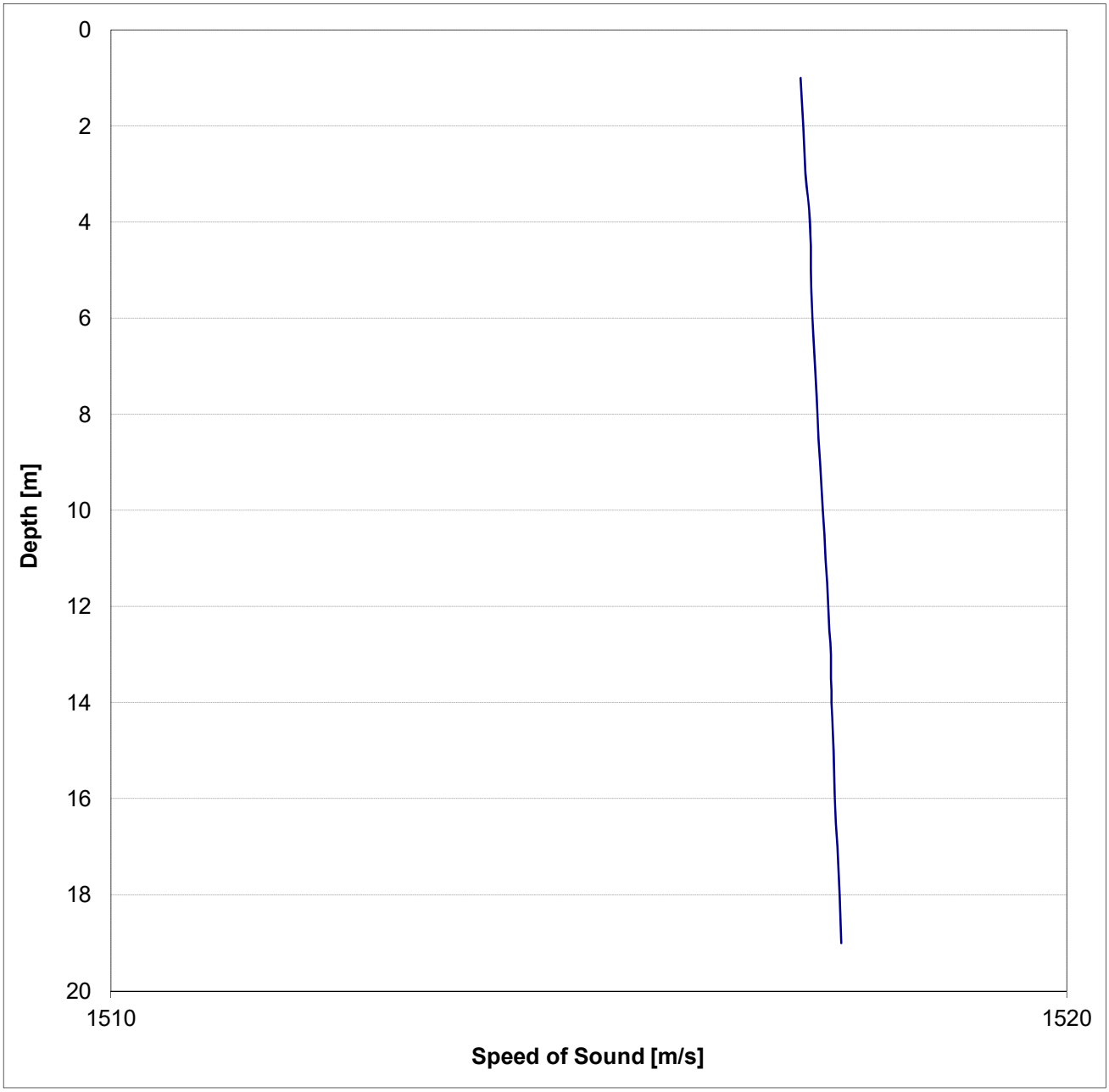
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	04:17 14/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	19.59 m
Easting:	398509 m	Transducer speed of sound:	1517.28 m/s
Northing:	5700888 m	Bottom speed of sound:	1517.65 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.44 m/s
Sensor type and S/N:	SD1165	Average density:	1025.22 kg/m^3



For Fugro Survey B.V.

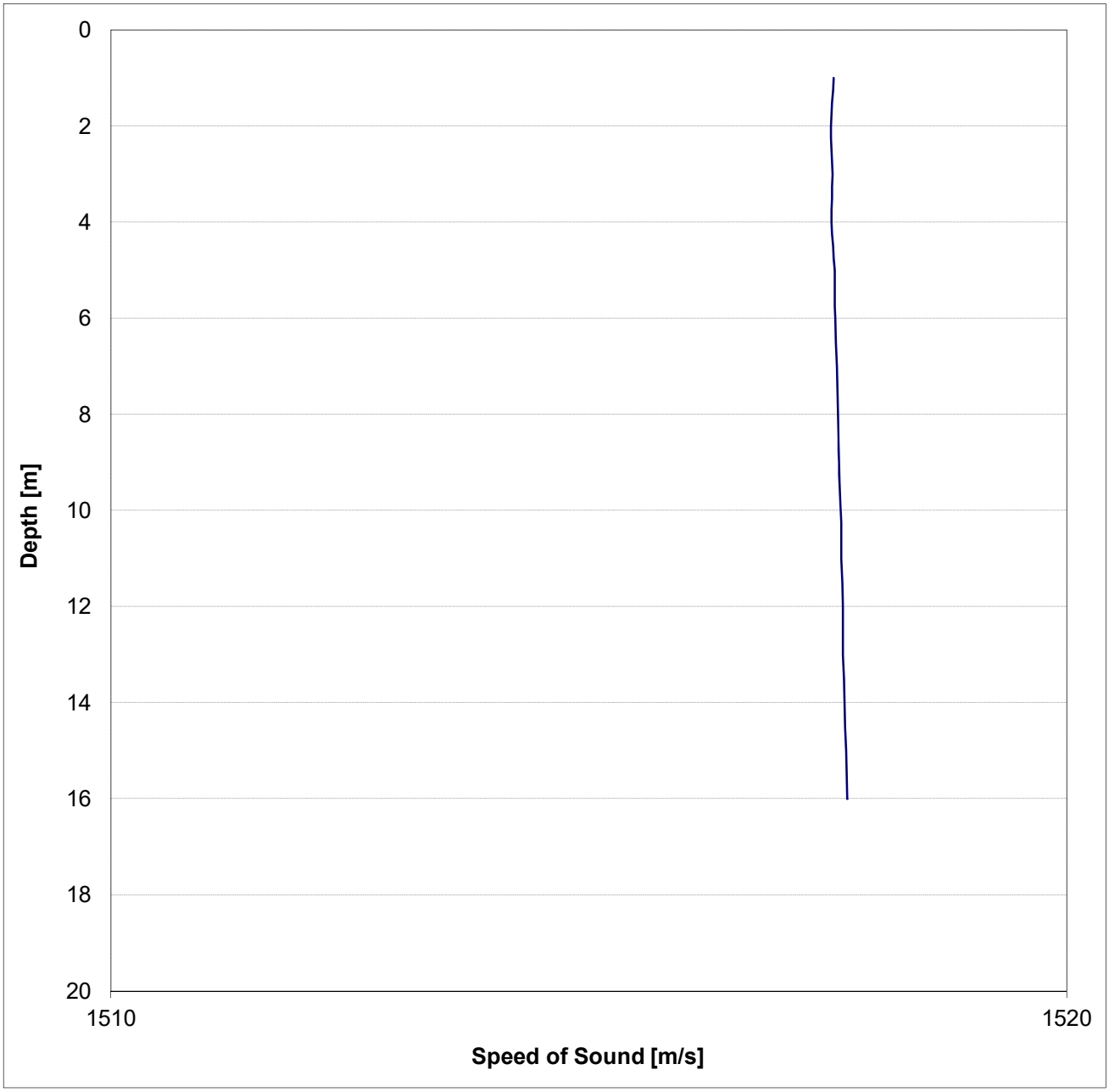
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	16:21 14/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	16.31 m
Easting:	401993 m	Transducer speed of sound:	1517.55 m/s
Northing:	5692869 m	Bottom speed of sound:	1517.72 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.61 m/s
Sensor type and S/N:	SD1165	Average density:	1025.19 kg/m^3



For Fugro Survey B.V.

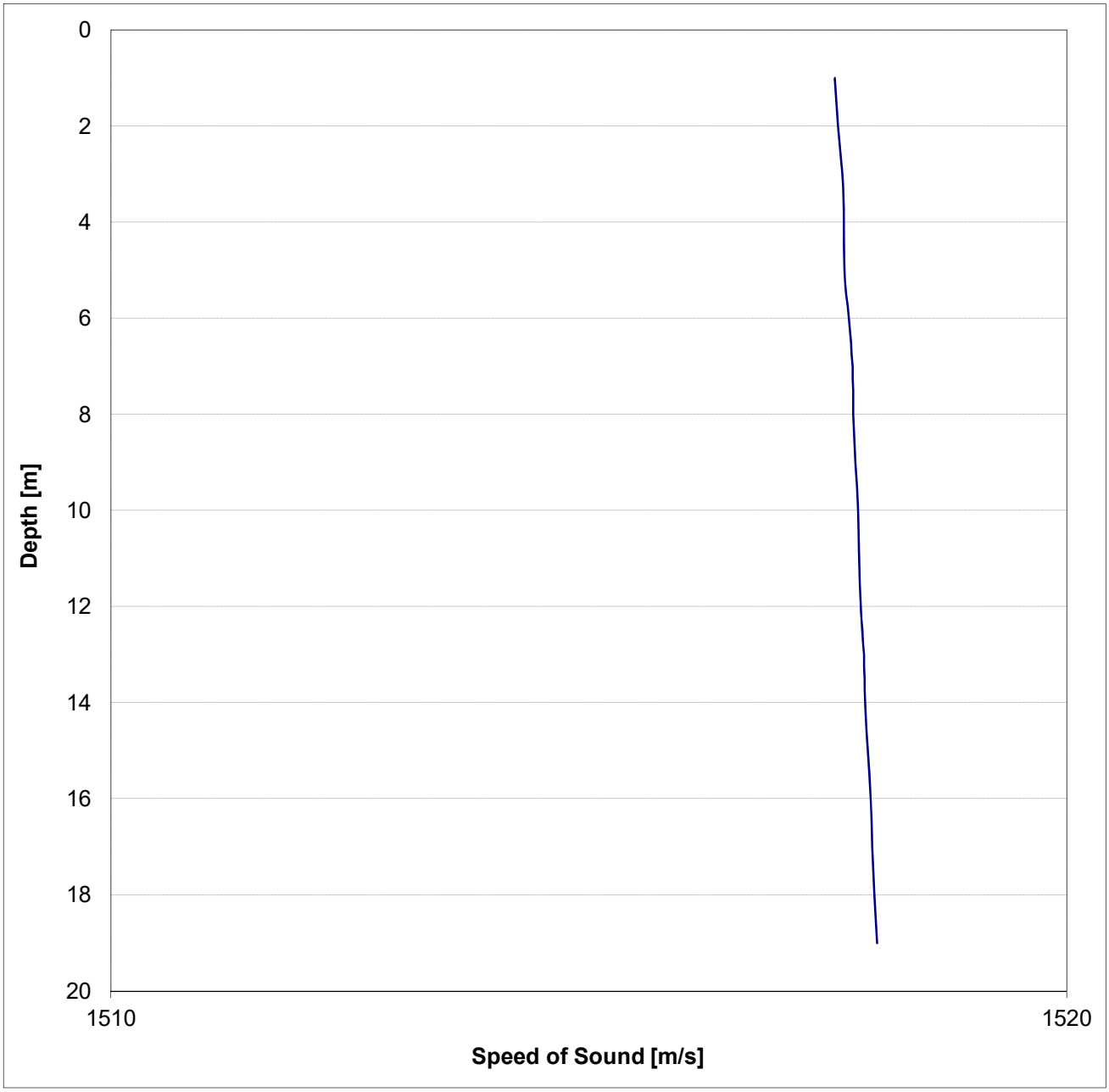
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	04:46 15/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	19.60 m
Easting:	399125 m	Transducer speed of sound:	1517.64 m/s
Northing:	5698219 m	Bottom speed of sound:	1518.02 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.81 m/s
Sensor type and S/N:	SD1165	Average density:	1025.13 kg/m^3



For Fugro Survey B.V.

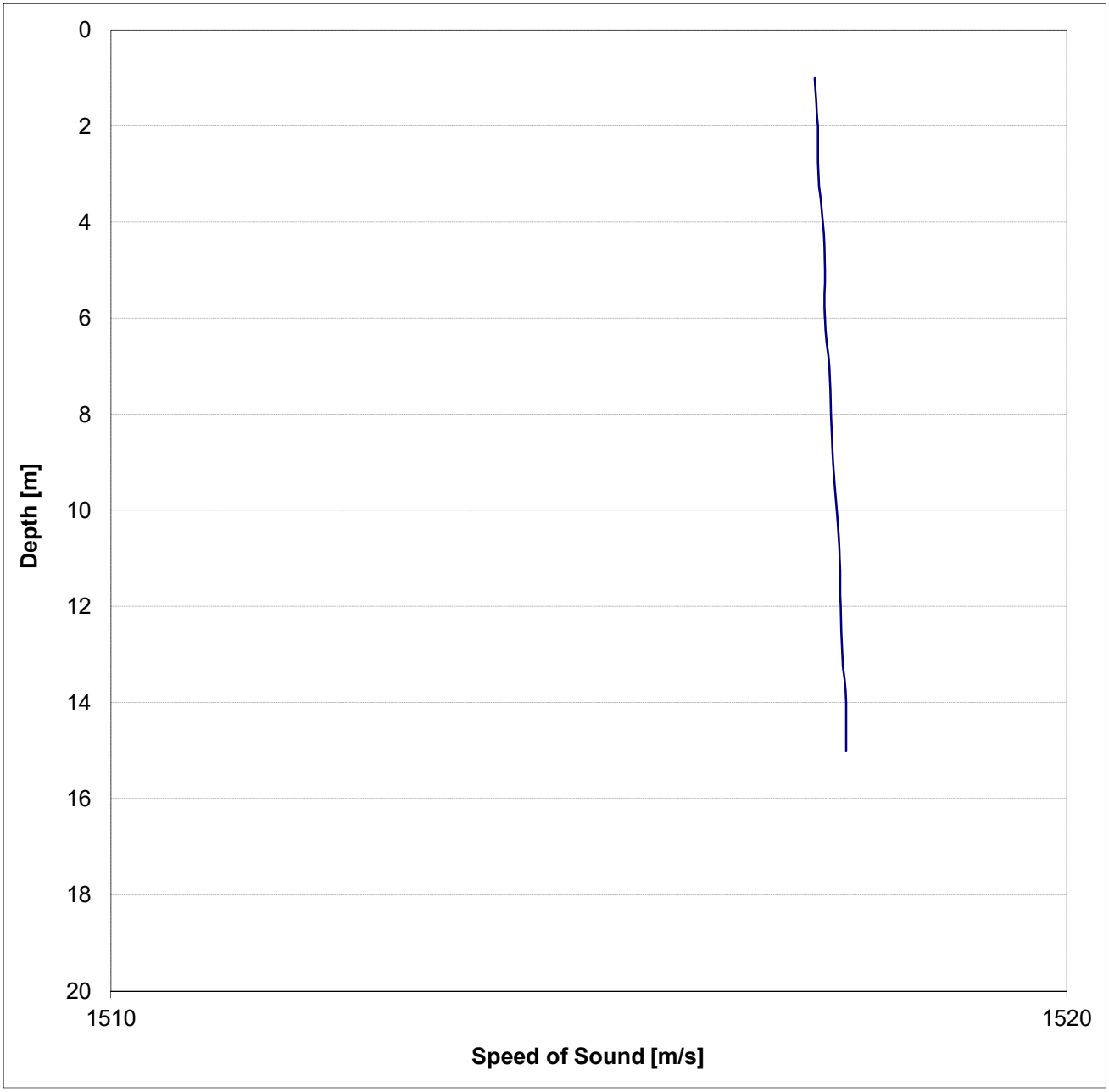
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	21:59 15/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	15.84 m
Easting:	405053 m	Transducer speed of sound:	1517.45 m/s
Northing:	5693263 m	Bottom speed of sound:	1517.69 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.54 m/s
Sensor type and S/N:	SD1165	Average density:	1025.16 kg/m^3



For Fugro Survey B.V.

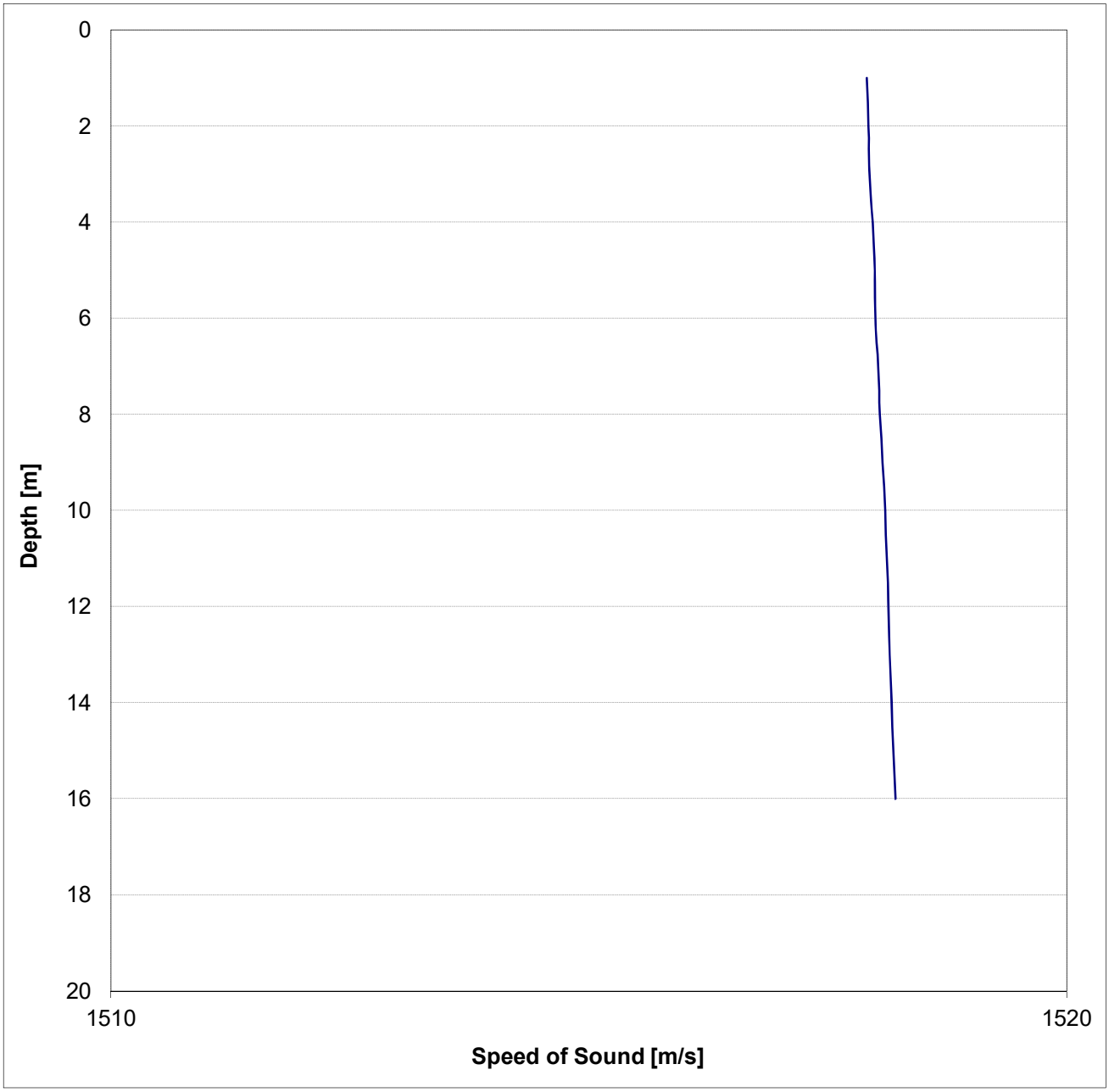
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	04:49 16/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	16.95 m
Easting:	403739 m	Transducer speed of sound:	1517.95 m/s
Northing:	5694047 m	Bottom speed of sound:	1518.23 m/s
Datum and projection:	ETRS89	Average speed of sound:	1518.06 m/s
Sensor type and S/N:	SD1165	Average density:	1025.10 kg/m^3



For Fugro Survey B.V.

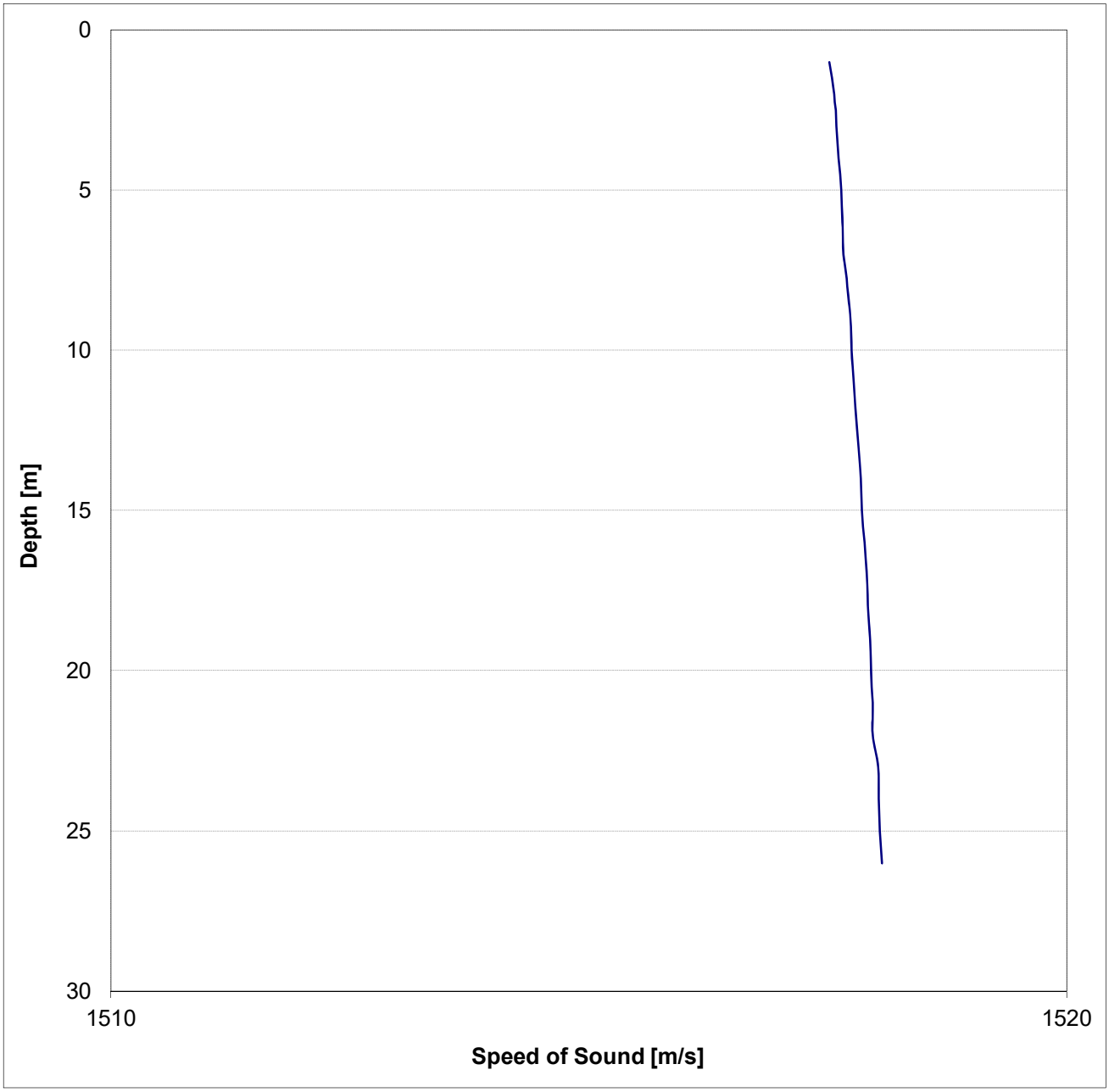
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	21:06 16/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	26.49 m
Easting:	407442 m	Transducer speed of sound:	1517.62 m/s
Northing:	5692575 m	Bottom speed of sound:	1518.08 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.82 m/s
Sensor type and S/N:	SD1165	Average density:	1025.14 kg/m^3



For Fugro Survey B.V.

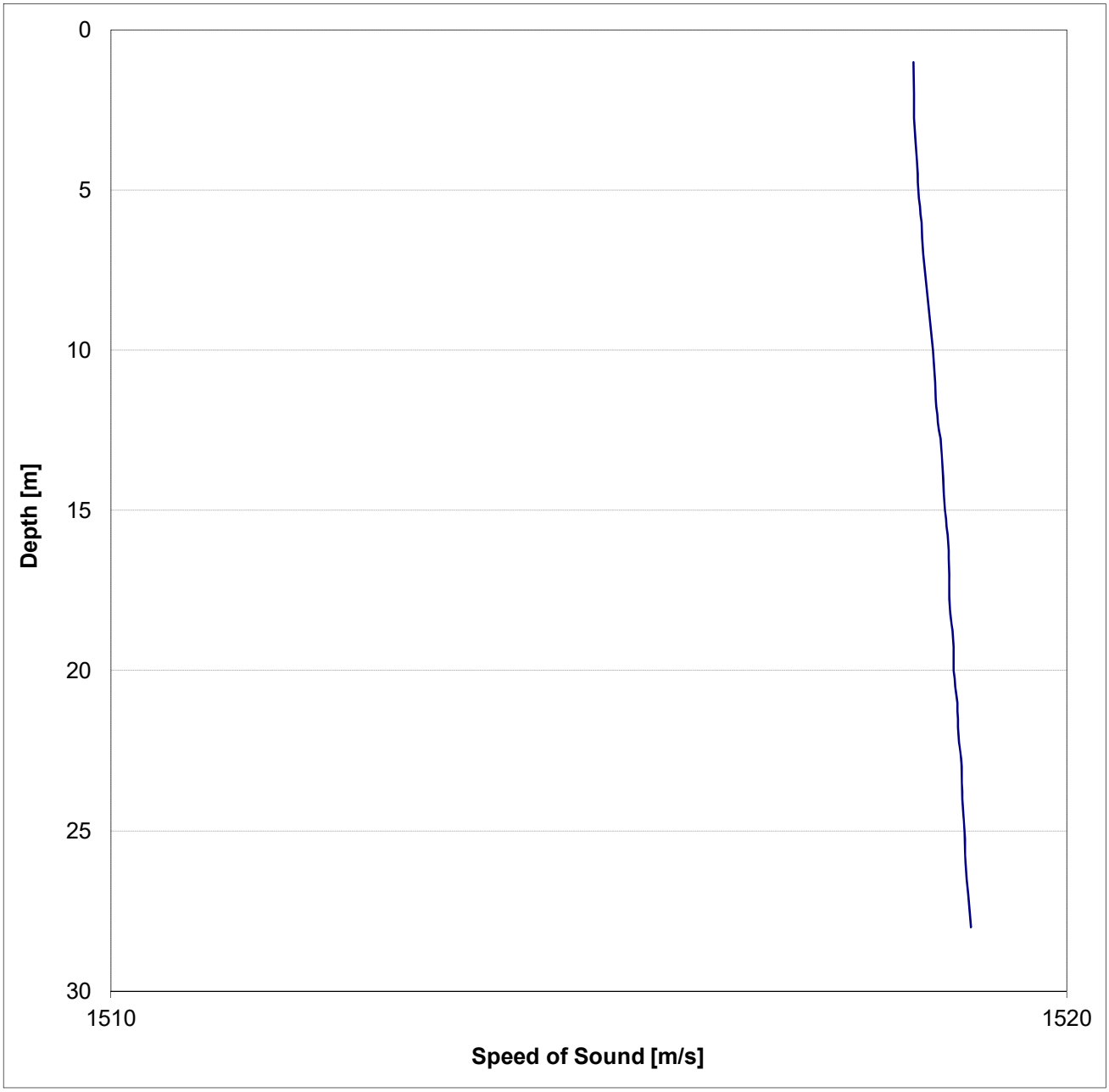
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	05:33 17/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	28.58 m
Easting:	404118 m	Transducer speed of sound:	1518.42 m/s
Northing:	5695007 m	Bottom speed of sound:	1519.01 m/s
Datum and projection:	ETRS89	Average speed of sound:	1518.69 m/s
Sensor type and S/N:	SD1165	Average density:	1025.07 kg/m^3



For Fugro Survey B.V.

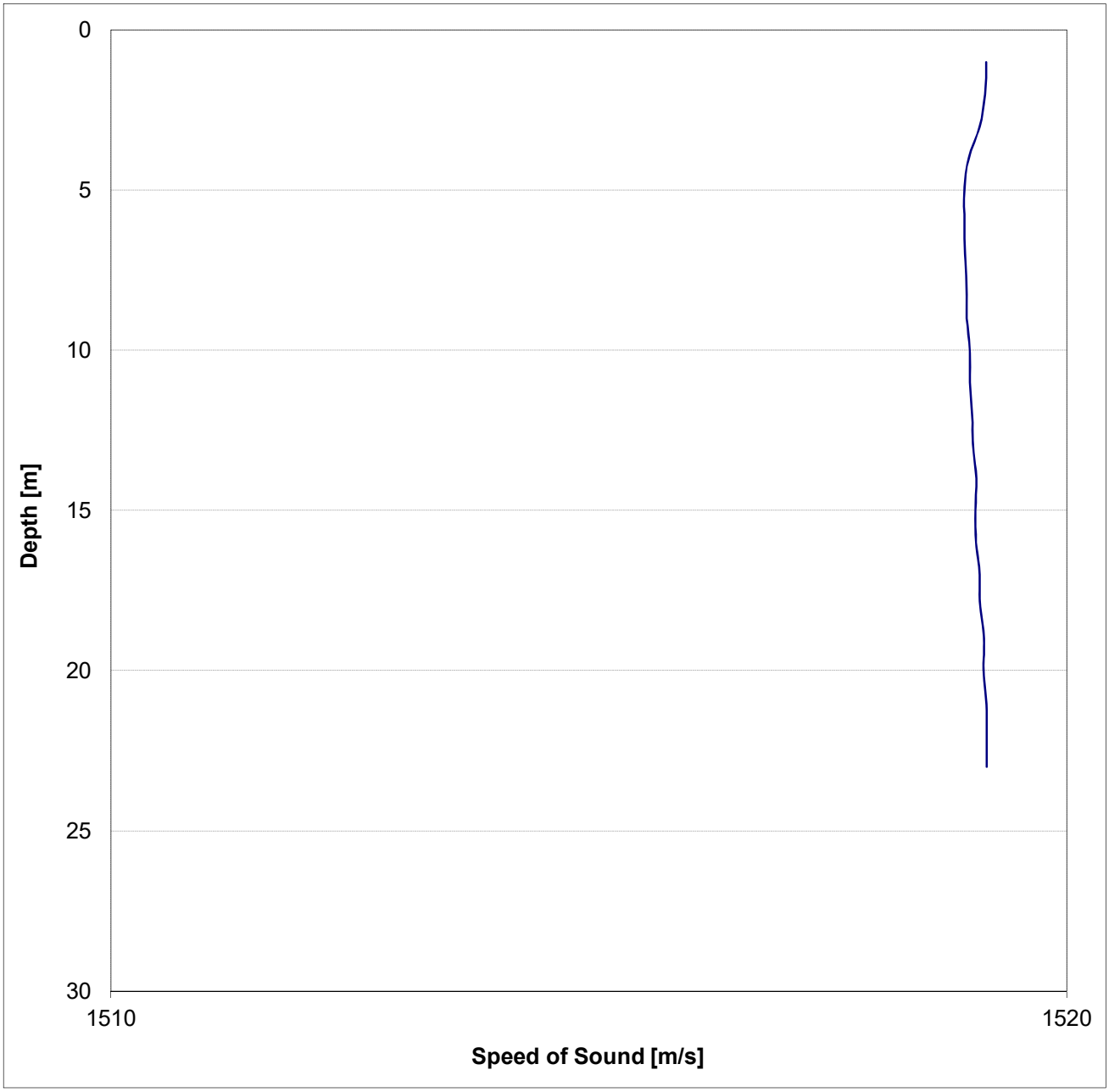
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	16:46 17/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	23.43 m
Easting:	407458 m	Transducer speed of sound:	1518.99 m/s
Northing:	5693947 m	Bottom speed of sound:	1519.09 m/s
Datum and projection:	ETRS89	Average speed of sound:	1519.05 m/s
Sensor type and S/N:	SD1165	Average density:	1024.97 kg/m^3



For Fugro Survey B.V.

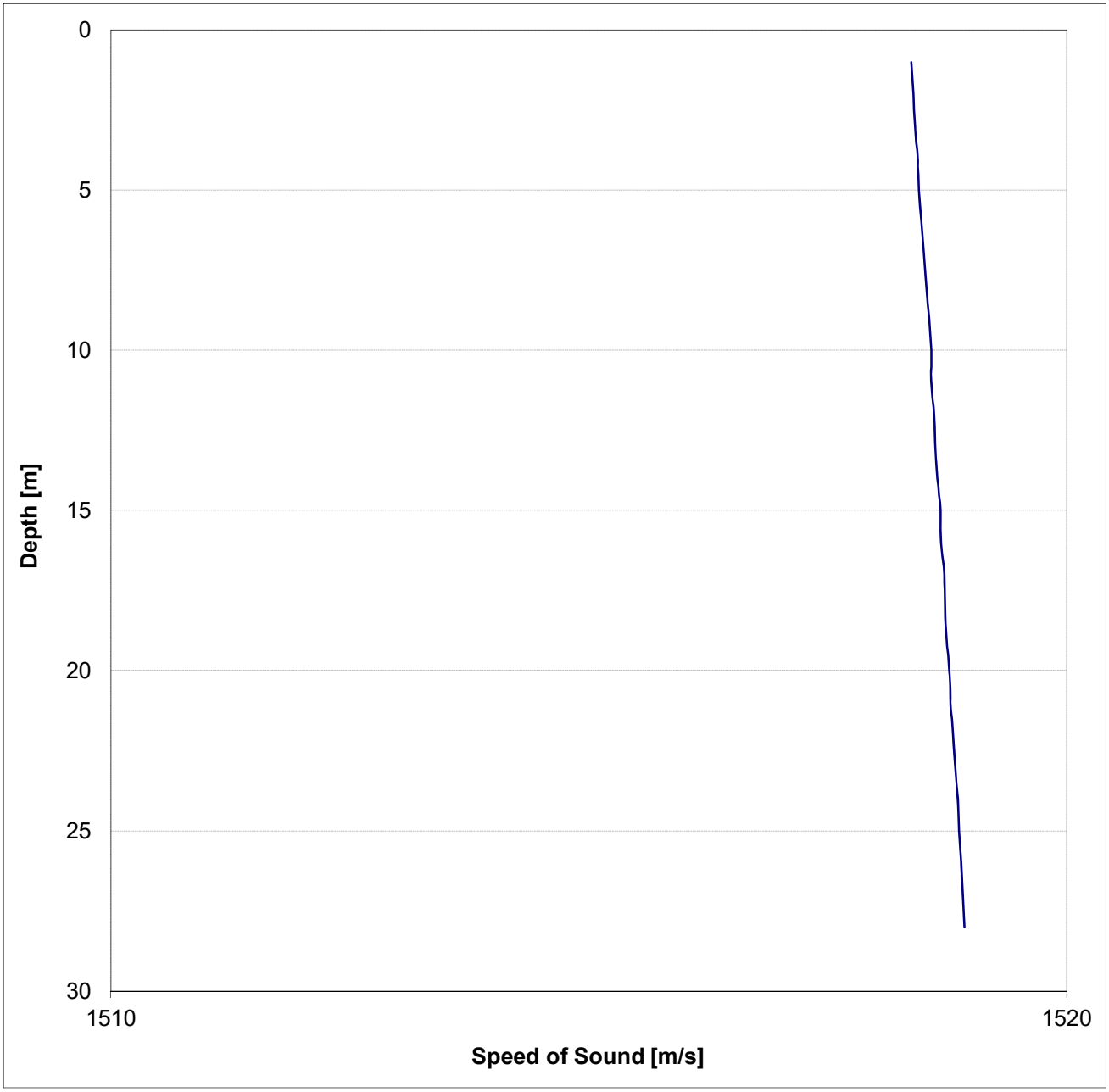
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	02:14 19/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	28.58 m
Easting:	409420 m	Transducer speed of sound:	1518.45 m/s
Northing:	5701805 m	Bottom speed of sound:	1518.94 m/s
Datum and projection:	ETRS89	Average speed of sound:	1518.66 m/s
Sensor type and S/N:	SD1165	Average density:	1025.08 kg/m^3



For Fugro Survey B.V.

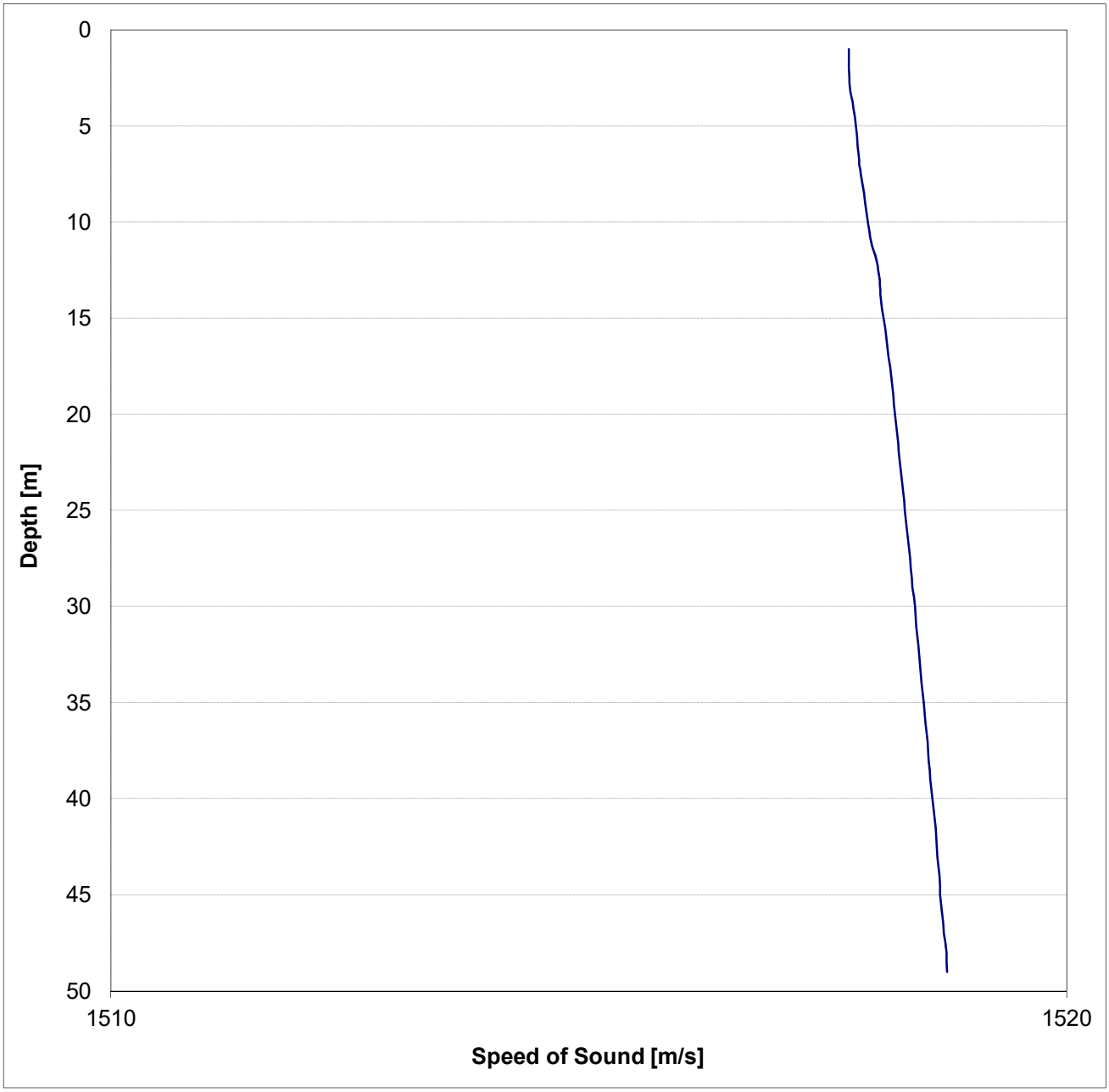
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	06:25 26/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	49.67 m
Easting:	411317 m	Transducer speed of sound:	1517.75 m/s
Northing:	5695371 m	Bottom speed of sound:	1518.76 m/s
Datum and projection:	ETRS89	Average speed of sound:	1518.27 m/s
Sensor type and S/N:	SD1165	Average density:	1025.29 kg/m^3



For Fugro Survey B.V.

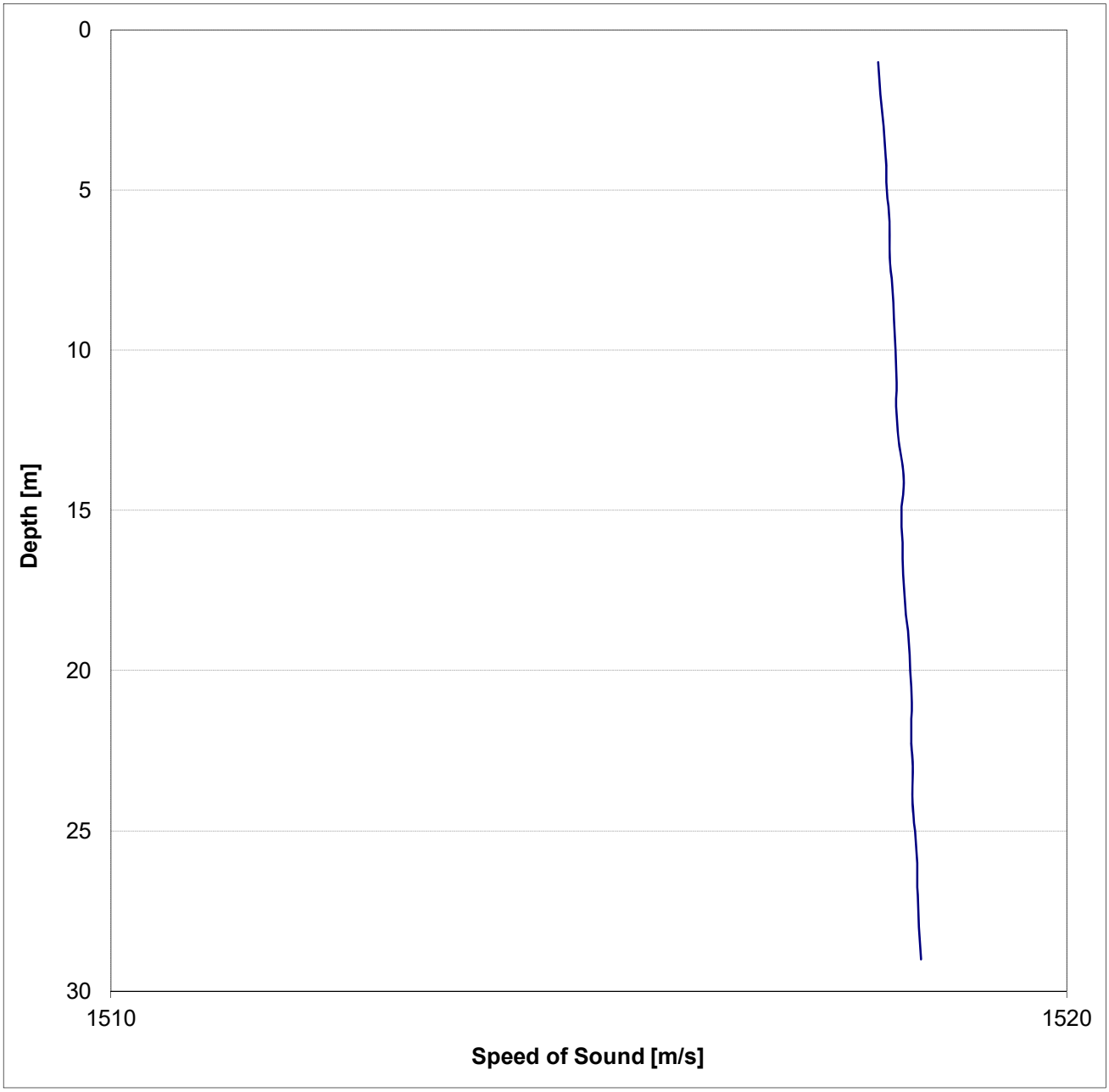
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	20:01 26/aug/2016
Client:	Vattenfall	Transducer depth:	3.44 m
Survey area:	North Sea	Water depth:	29.06 m
Easting:	411620 m	Transducer speed of sound:	1518.09 m/s
Northing:	5698282 m	Bottom speed of sound:	1518.48 m/s
Datum and projection:	ETRS89	Average speed of sound:	1518.27 m/s
Sensor type and S/N:	SD1165	Average density:	1025.19 kg/m^3



For Fugro Survey B.V.

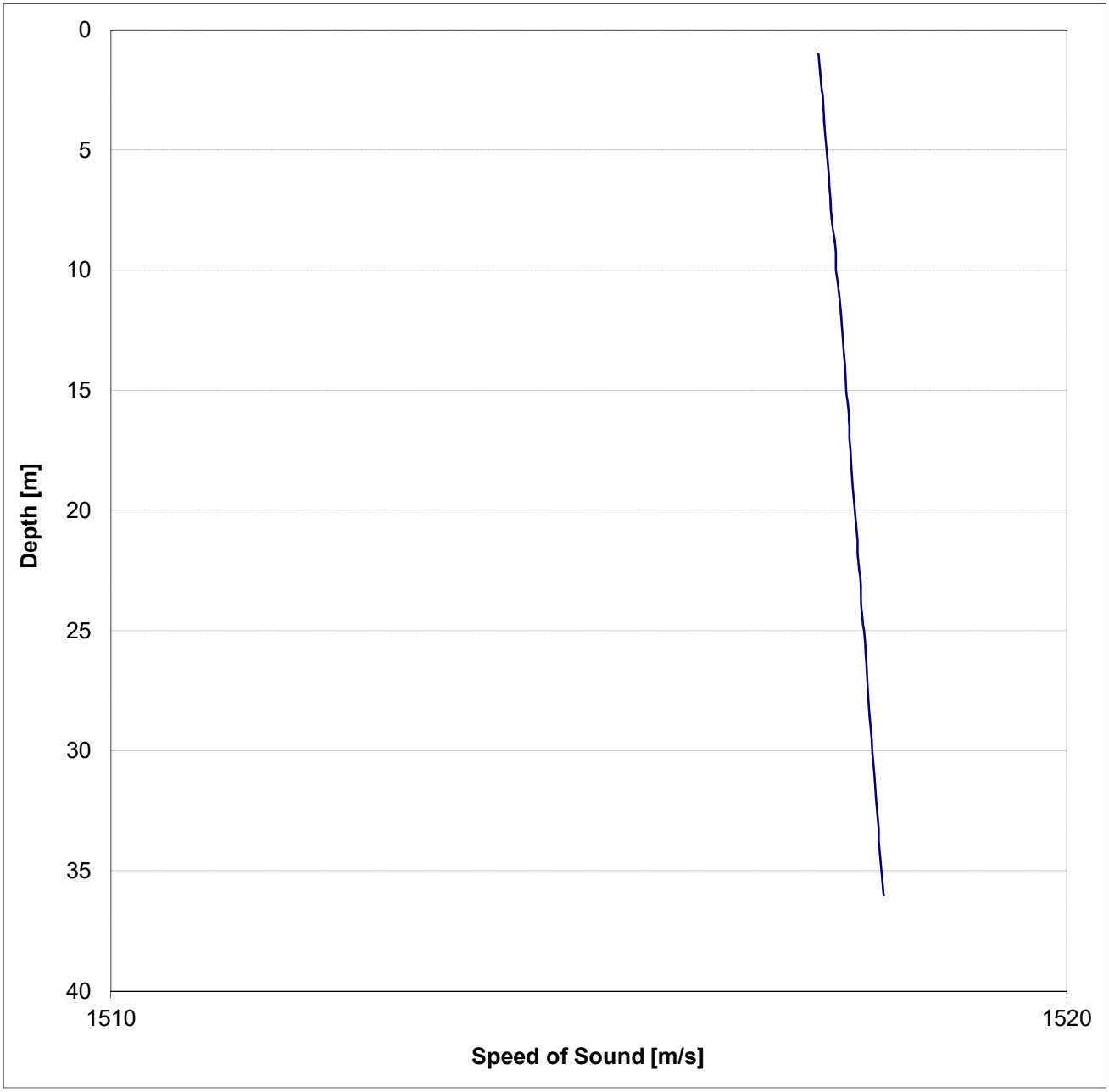
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	05:51 27/aug/2016
Client:	Vattenfall	Transducer depth:	3.53 m
Survey area:	North Sea	Water depth:	36.51 m
Easting:	413331 m	Transducer speed of sound:	1517.47 m/s
Northing:	5700884 m	Bottom speed of sound:	1518.08 m/s
Datum and projection:	ETRS89	Average speed of sound:	1517.75 m/s
Sensor type and S/N:	SD1165	Average density:	1025.32 kg/m^3



For Fugro Survey B.V.

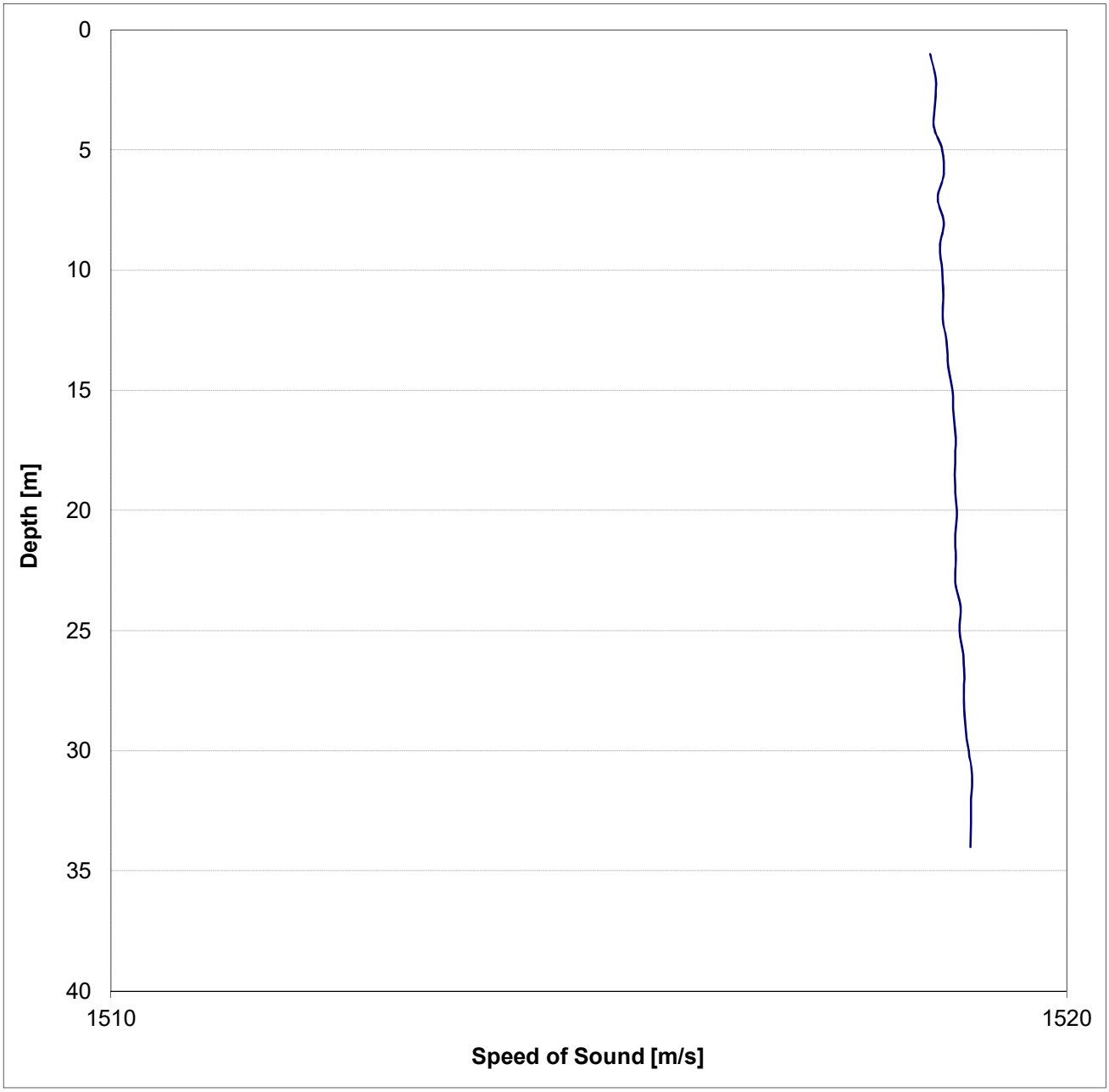
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	22:19 27/aug/2016
Client:	Vattenfall	Transducer depth:	3.44 m
Survey area:	North Sea	Water depth:	34.07 m
Easting:	412516 m	Transducer speed of sound:	1518.53 m/s
Northing:	5698040 m	Bottom speed of sound:	1518.98 m/s
Datum and projection:	ETRS89	Average speed of sound:	1518.81 m/s
Sensor type and S/N:	SD1165	Average density:	1025.15 kg/m^3



For Fugro Survey B.V.

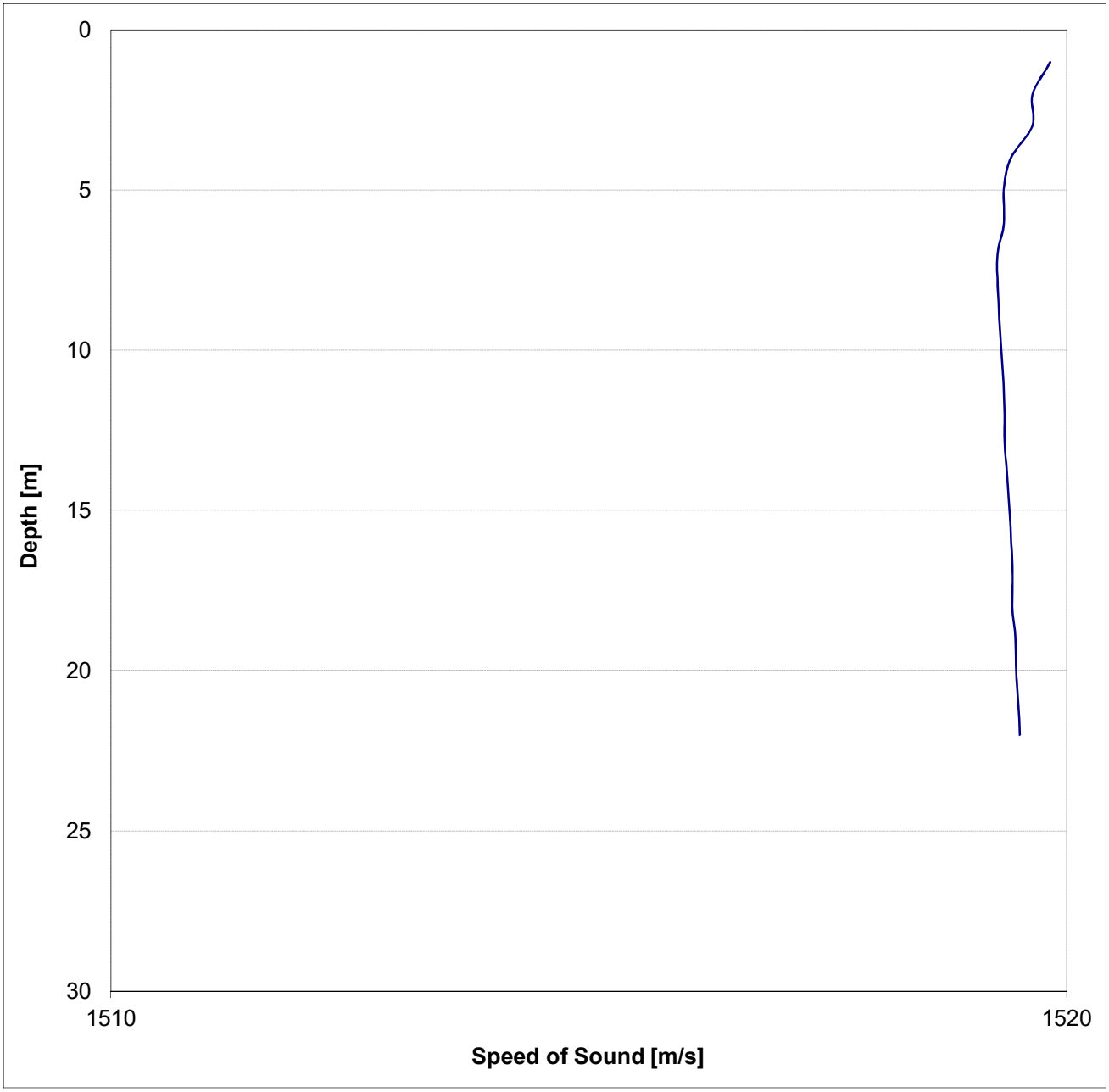
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	13:49 29/aug/2016
Client:	Vattenfall	Transducer depth:	3.47 m
Survey area:	North Sea	Water depth:	23.00 m
Easting:	404935 m	Transducer speed of sound:	1519.57 m/s
Northing:	5702765 m	Bottom speed of sound:	1519.54 m/s
Datum and projection:	ETRS89	Average speed of sound:	1519.43 m/s
Sensor type and S/N:	SD1165	Average density:	1025.04 kg/m^3



For Fugro Survey B.V.

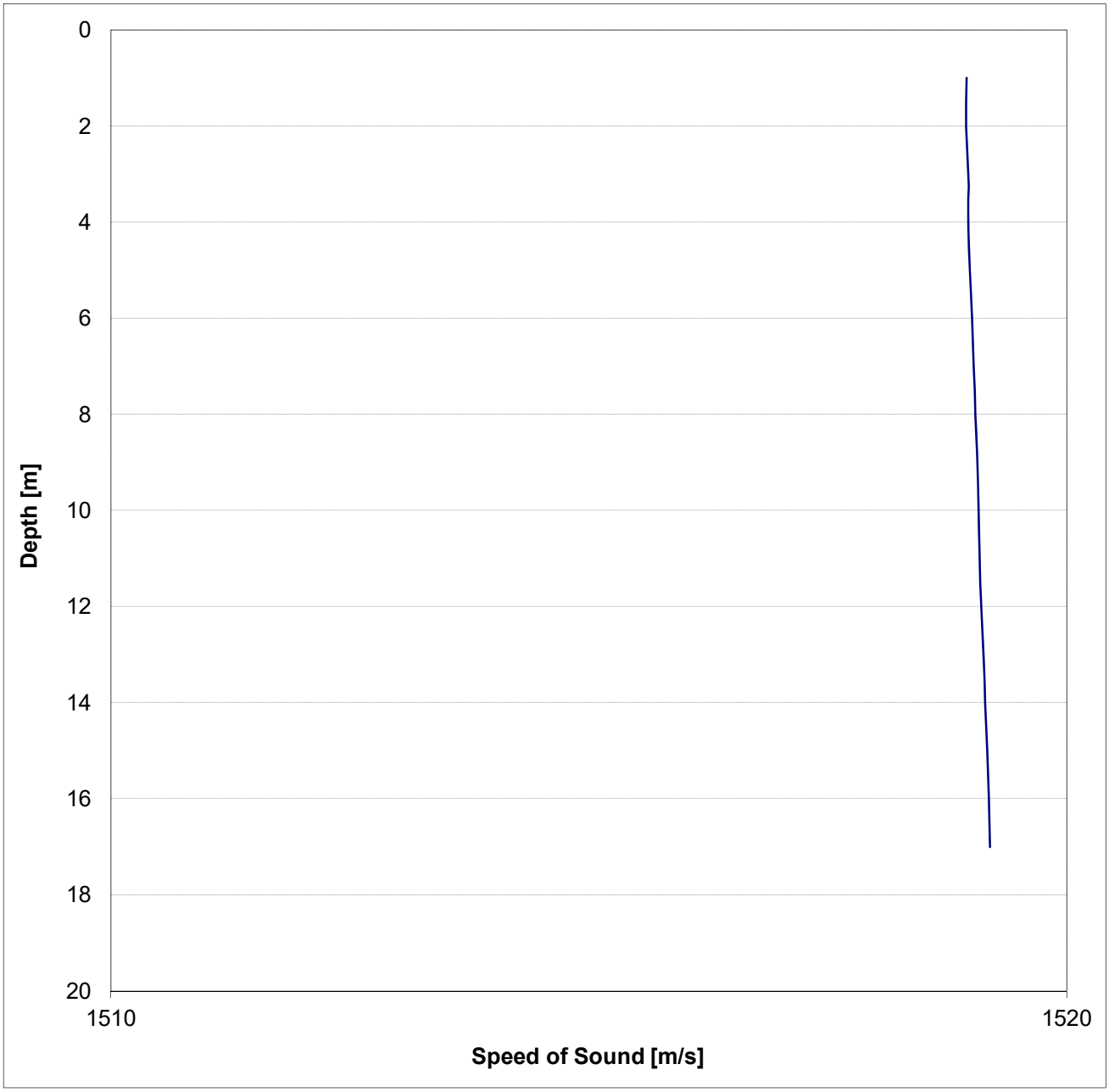
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	07:51 30/aug/2016
Client:	Vattenfall	Transducer depth:	3.47 m
Survey area:	North Sea	Water depth:	17.96 m
Easting:	403865 m	Transducer speed of sound:	1518.96 m/s
Northing:	5704221 m	Bottom speed of sound:	1519.23 m/s
Datum and projection:	ETRS89	Average speed of sound:	1519.06 m/s
Sensor type and S/N:	SD1165	Average density:	1025.04 kg/m^3



For Fugro Survey B.V.

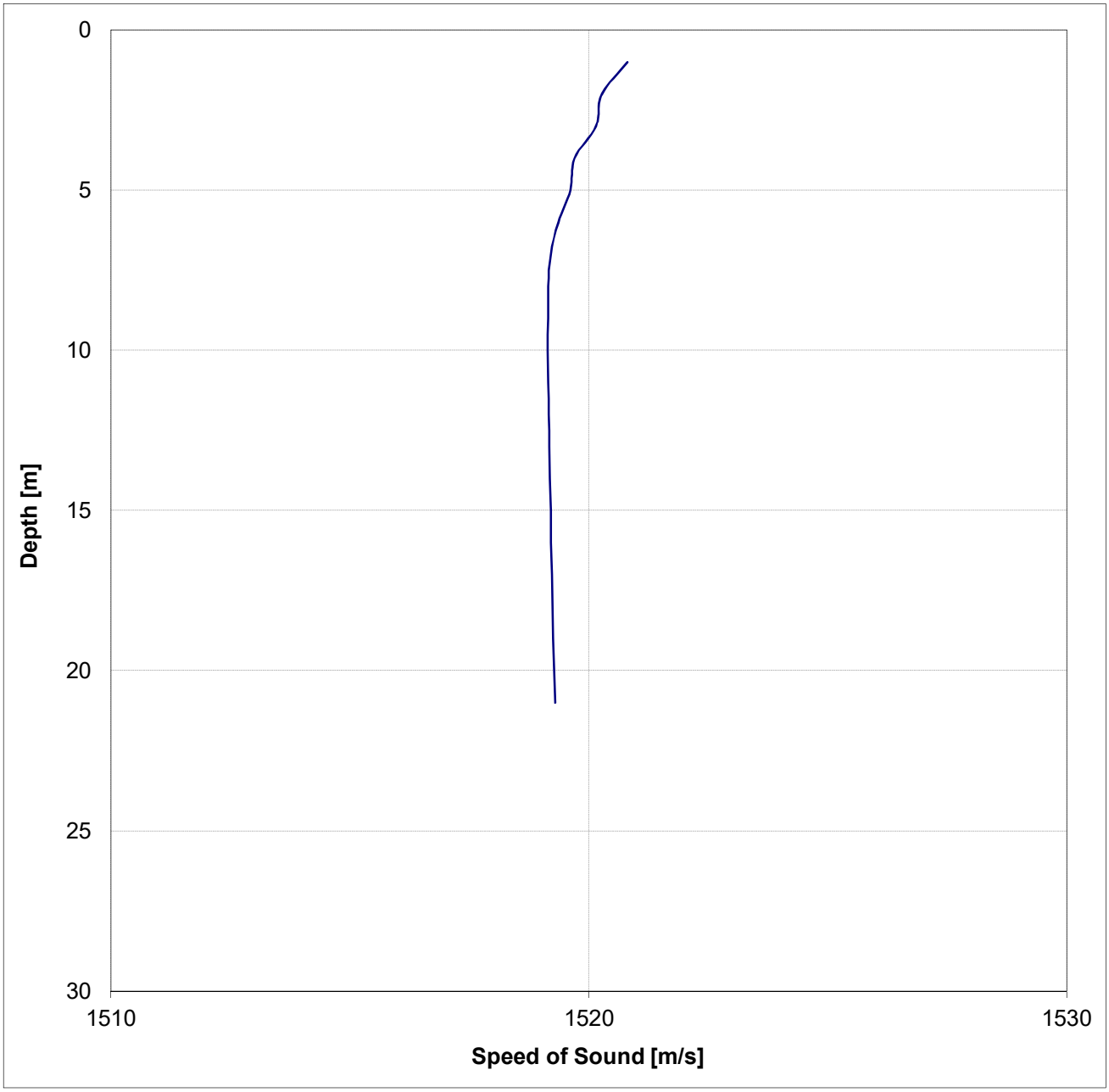
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	14:32 30/aug/2016
Client:	Vattenfall	Transducer depth:	3.47 m
Survey area:	North Sea	Water depth:	21.24 m
Easting:	402619 m	Transducer speed of sound:	1519.66 m/s
Northing:	5702083 m	Bottom speed of sound:	1519.31 m/s
Datum and projection:	ETRS89	Average speed of sound:	1519.42 m/s
Sensor type and S/N:	SD1165	Average density:	1025.04 kg/m^3



For Fugro Survey B.V.

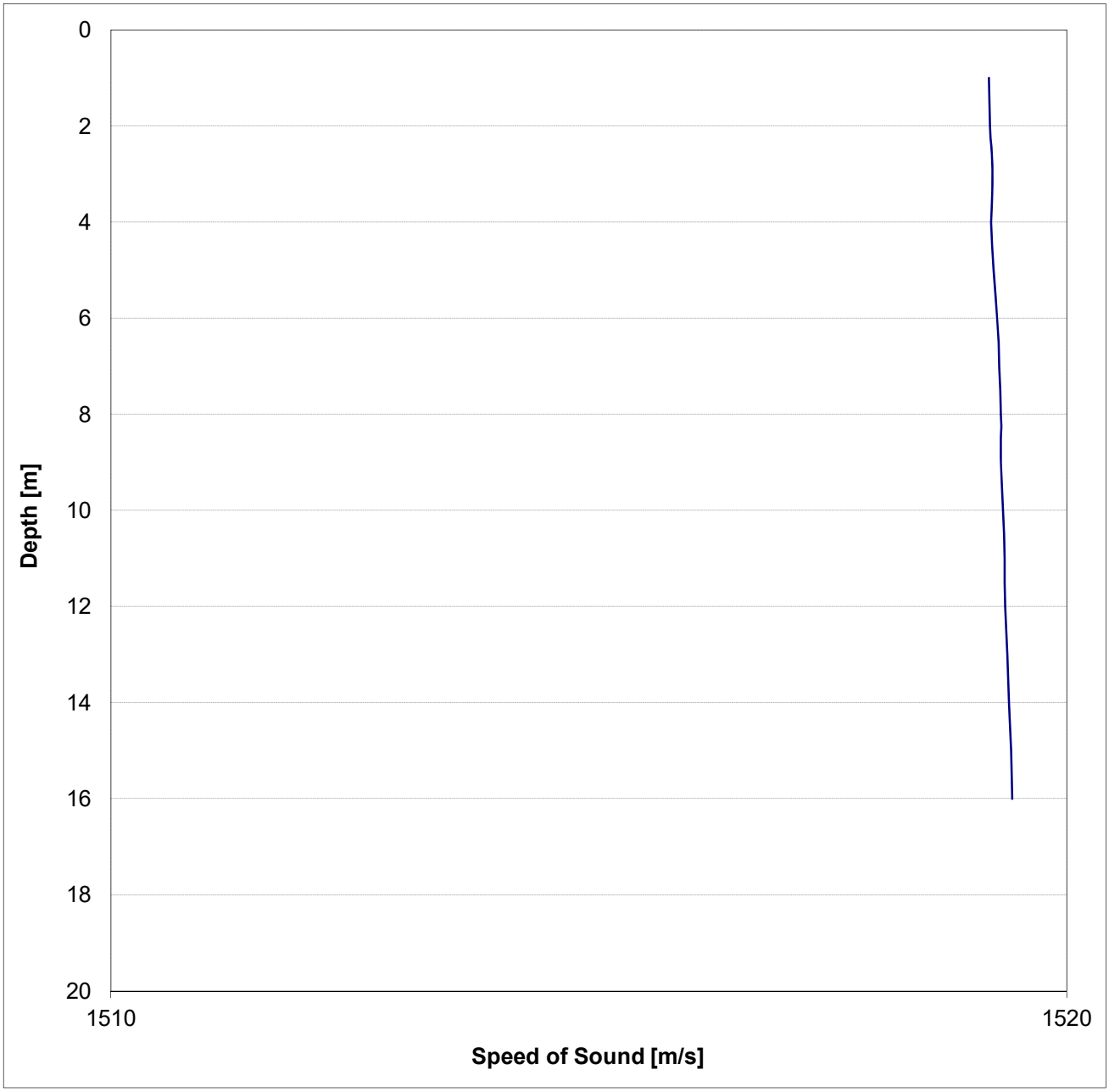
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	08:42 31/aug/2016
Client:	Vattenfall	Transducer depth:	3.47 m
Survey area:	North Sea	Water depth:	16.37 m
Easting:	402415 m	Transducer speed of sound:	1519.24 m/s
Northing:	5701655 m	Bottom speed of sound:	1519.44 m/s
Datum and projection:	ETRS89	Average speed of sound:	1519.31 m/s
Sensor type and S/N:	SD1165	Average density:	1025.03 kg/m^3



For Fugro Survey B.V.

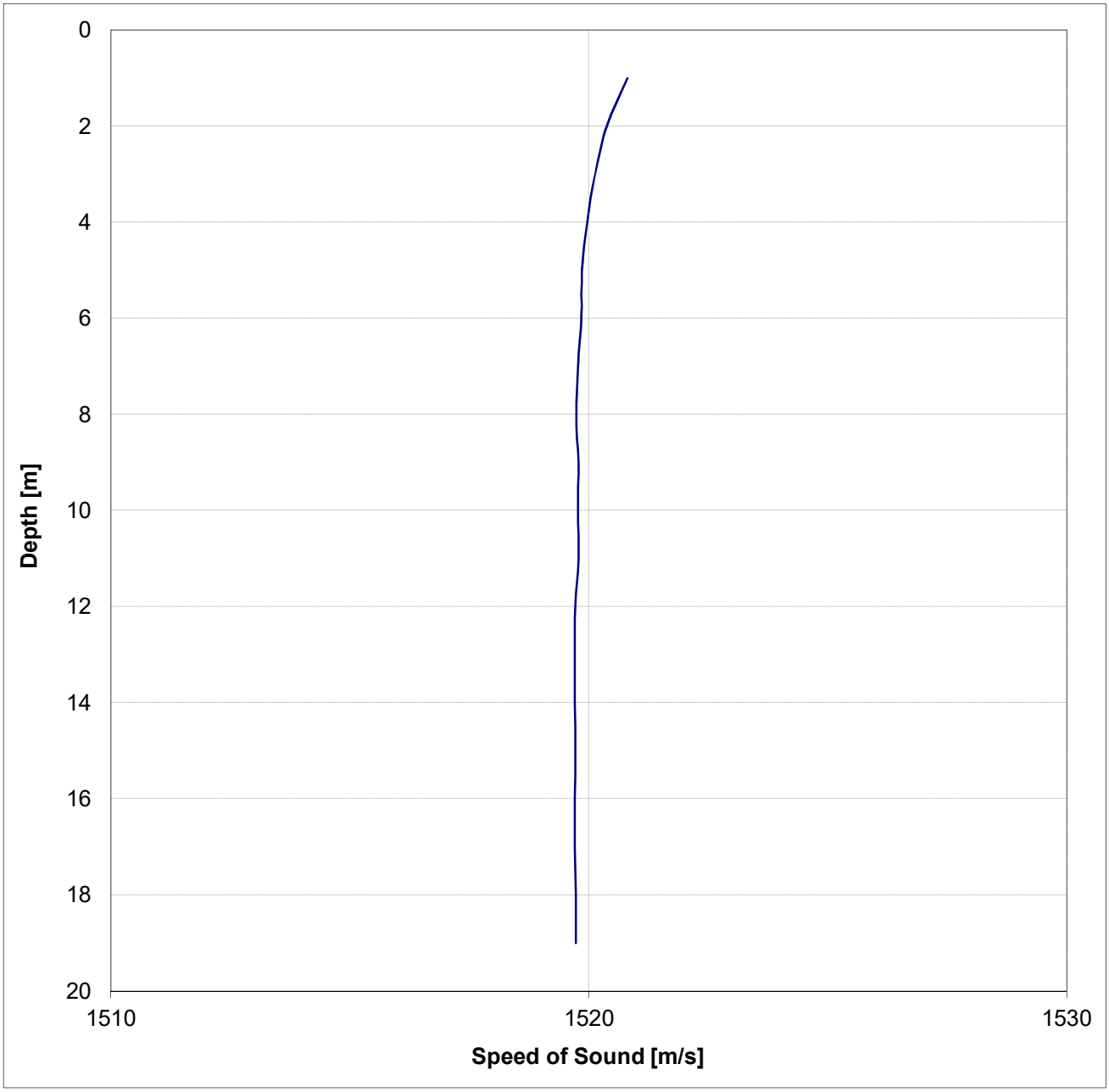
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	14:59 31/aug/2016
Client:	Vattenfall	Transducer depth:	3.47 m
Survey area:	North Sea	Water depth:	19.04 m
Easting:	401621 m	Transducer speed of sound:	1520.04 m/s
Northing:	5701350 m	Bottom speed of sound:	1519.75 m/s
Datum and projection:	ETRS89	Average speed of sound:	1519.87 m/s
Sensor type and S/N:	SD1165	Average density:	1024.96 kg/m^3



For Fugro Survey B.V.

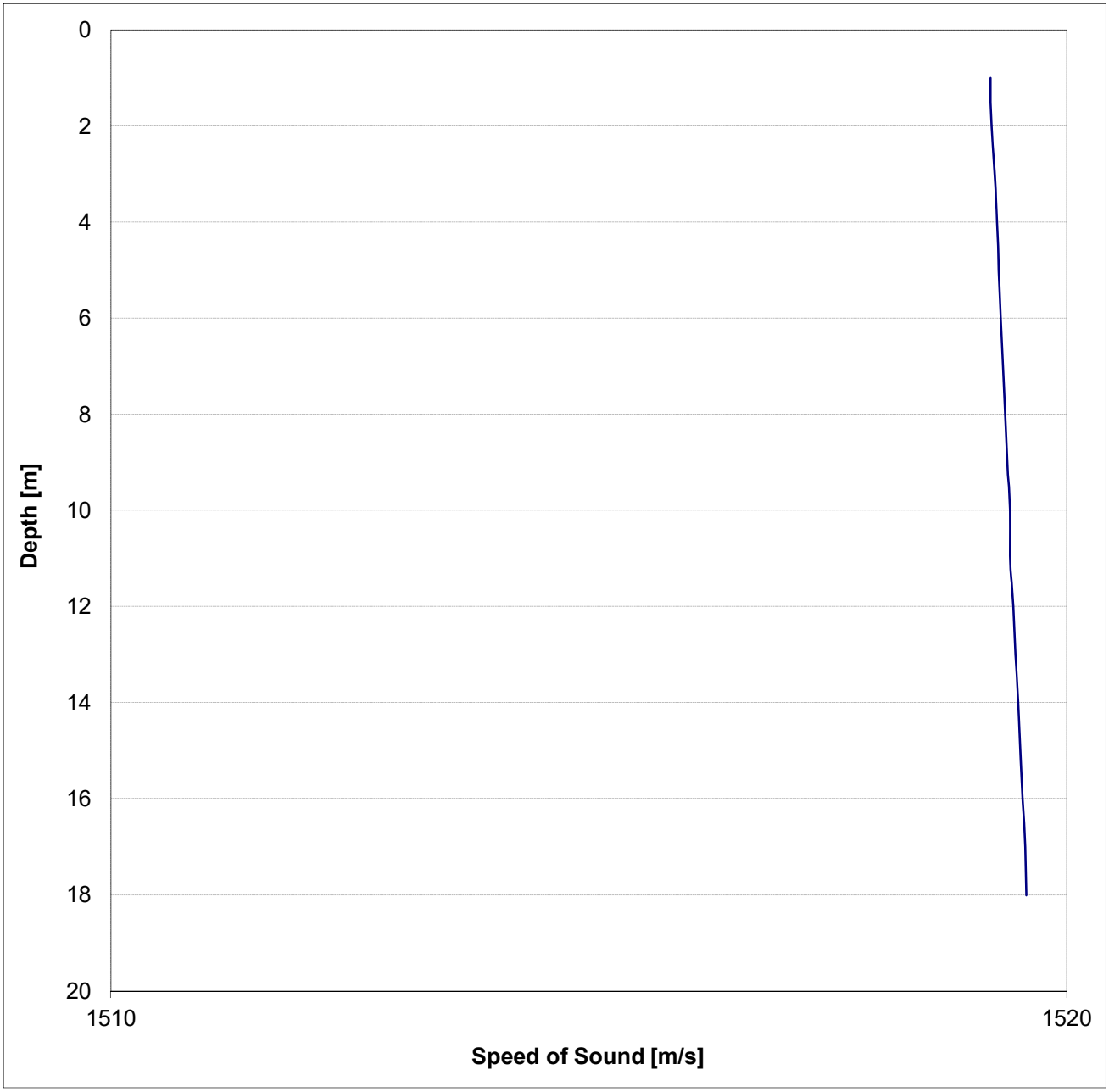
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	00:28 01/sep/2016
Client:	Vattenfall	Transducer depth:	3.47 m
Survey area:	North Sea	Water depth:	18.37 m
Easting:	394953 m	Transducer speed of sound:	1519.28 m/s
Northing:	5698964 m	Bottom speed of sound:	1519.56 m/s
Datum and projection:	ETRS89	Average speed of sound:	1519.39 m/s
Sensor type and S/N:	SD1165	Average density:	1025.01 kg/m^3



For Fugro Survey B.V.

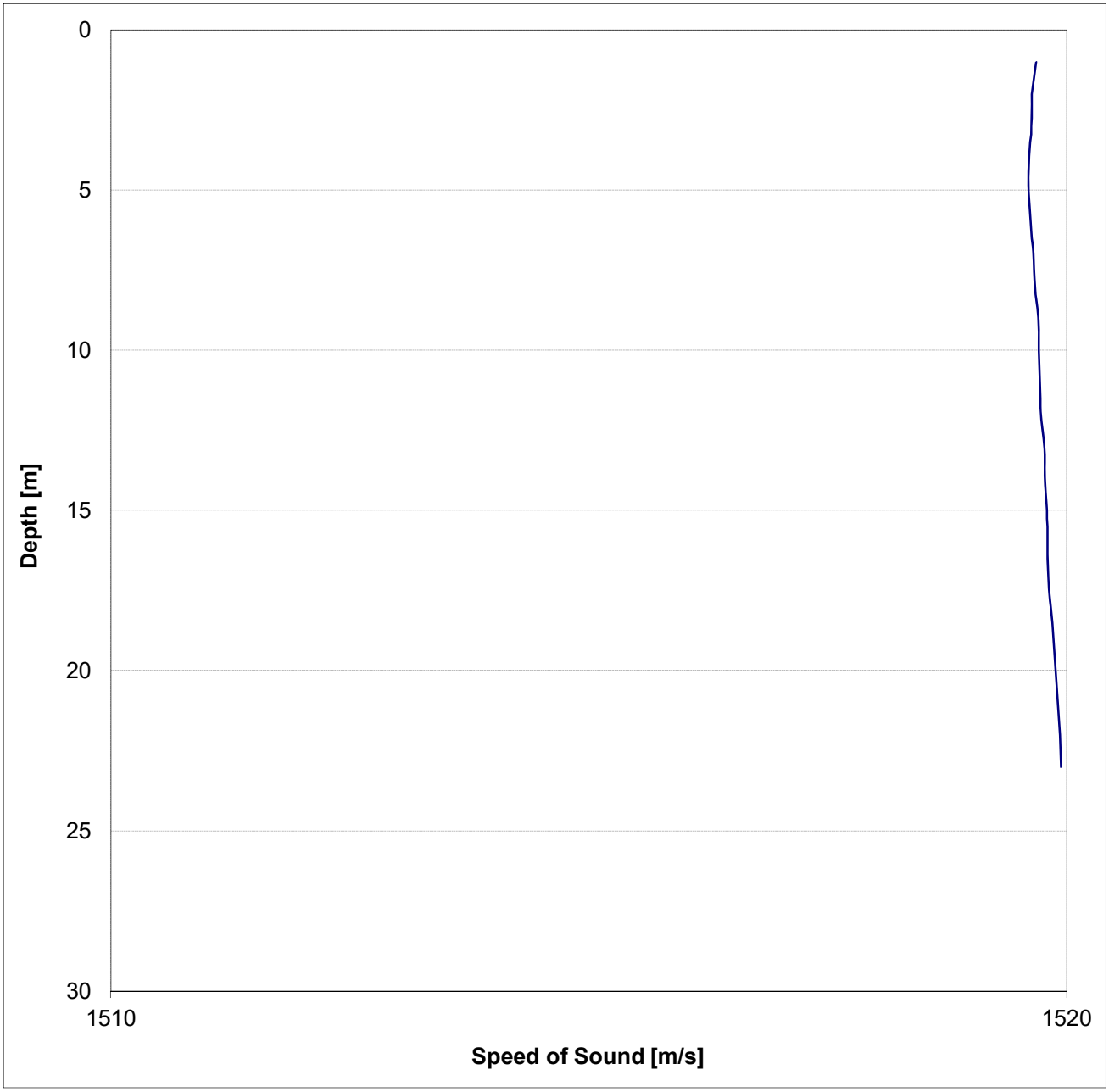
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	14:17 01/sep/2016
Client:	Vattenfall	Transducer depth:	3.47 m
Survey area:	North Sea	Water depth:	23.42 m
Easting:	401929 m	Transducer speed of sound:	1519.67 m/s
Northing:	5702217 m	Bottom speed of sound:	1519.95 m/s
Datum and projection:	ETRS89	Average speed of sound:	1519.75 m/s
Sensor type and S/N:	SD1165	Average density:	1025.02 kg/m^3



For Fugro Survey B.V.

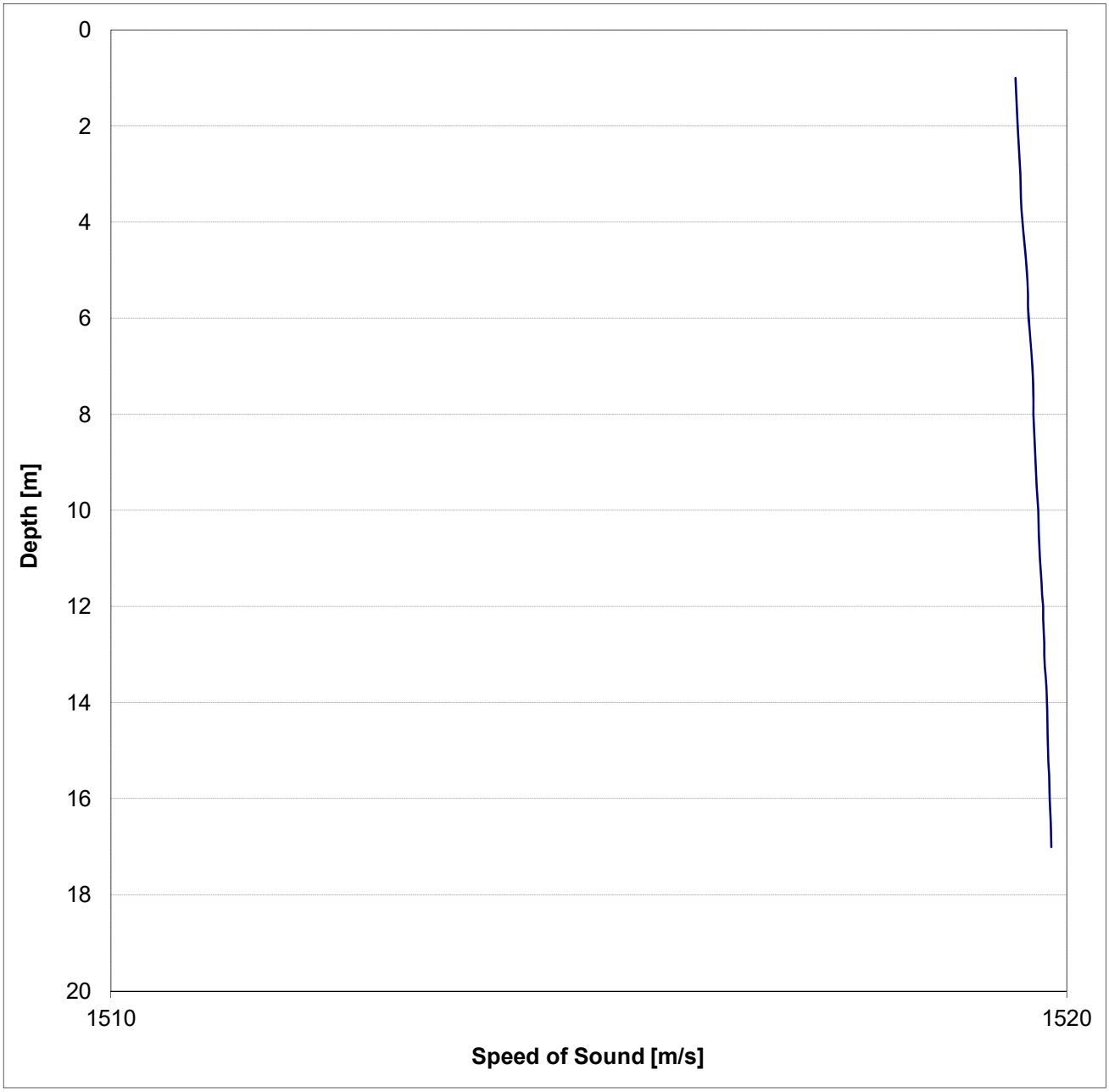
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	06:04 02/sep/2016
Client:	Vattenfall	Transducer depth:	3.47 m
Survey area:	North Sea	Water depth:	17.33 m
Easting:	399946 m	Transducer speed of sound:	1519.54 m/s
Northing:	5699283 m	Bottom speed of sound:	1519.83 m/s
Datum and projection:	ETRS89	Average speed of sound:	1519.67 m/s
Sensor type and S/N:	SD1165	Average density:	1024.93 kg/m^3



For Fugro Survey B.V.

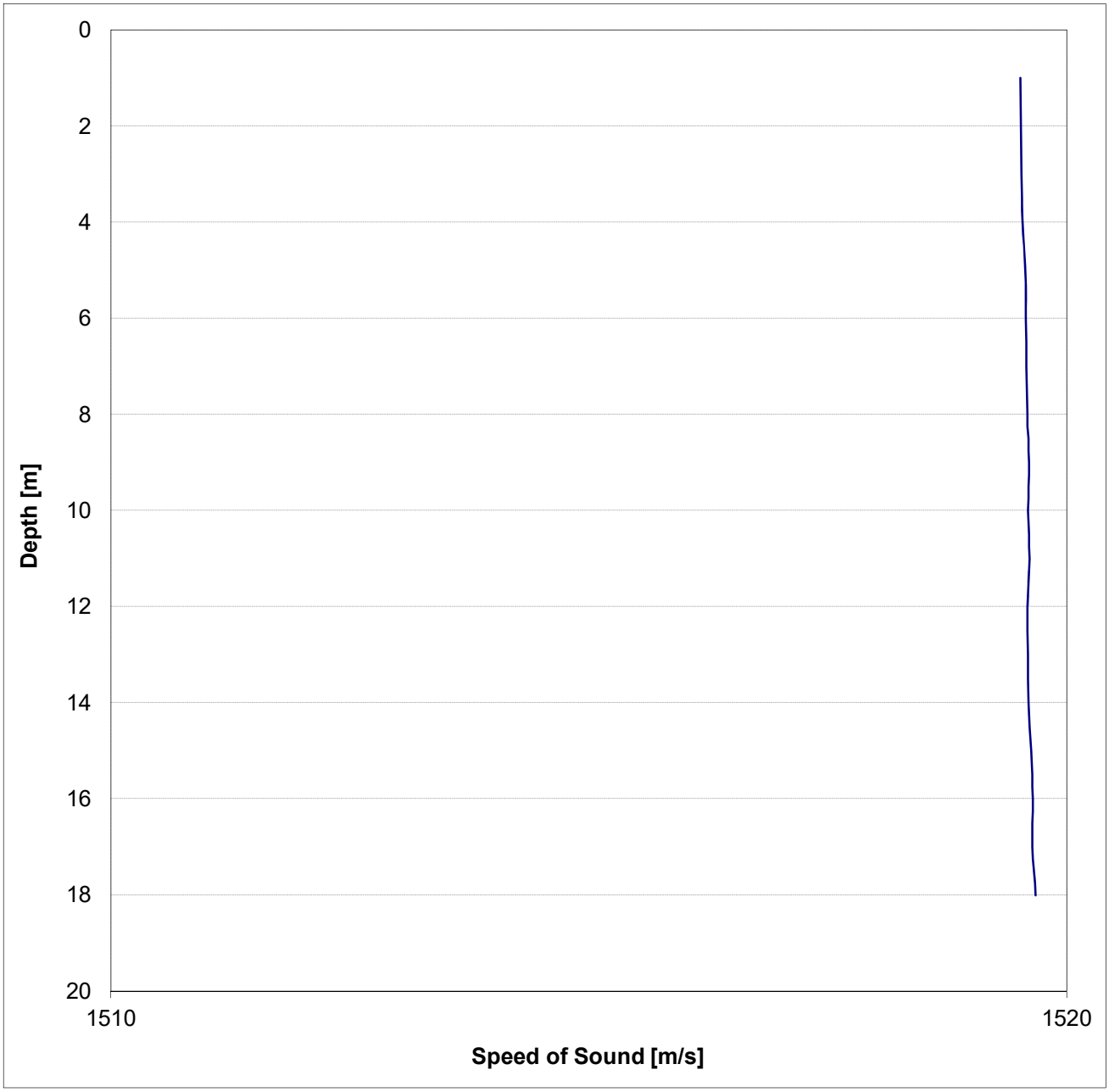
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	16:10 02/sep/2016
Client:	Vattenfall	Transducer depth:	3.47 m
Survey area:	North Sea	Water depth:	18.89 m
Easting:	400326 m	Transducer speed of sound:	1519.55 m/s
Northing:	5701692 m	Bottom speed of sound:	1519.67 m/s
Datum and projection:	ETRS89	Average speed of sound:	1519.59 m/s
Sensor type and S/N:	SD1165	Average density:	1024.97 kg/m^3



For Fugro Survey B.V.

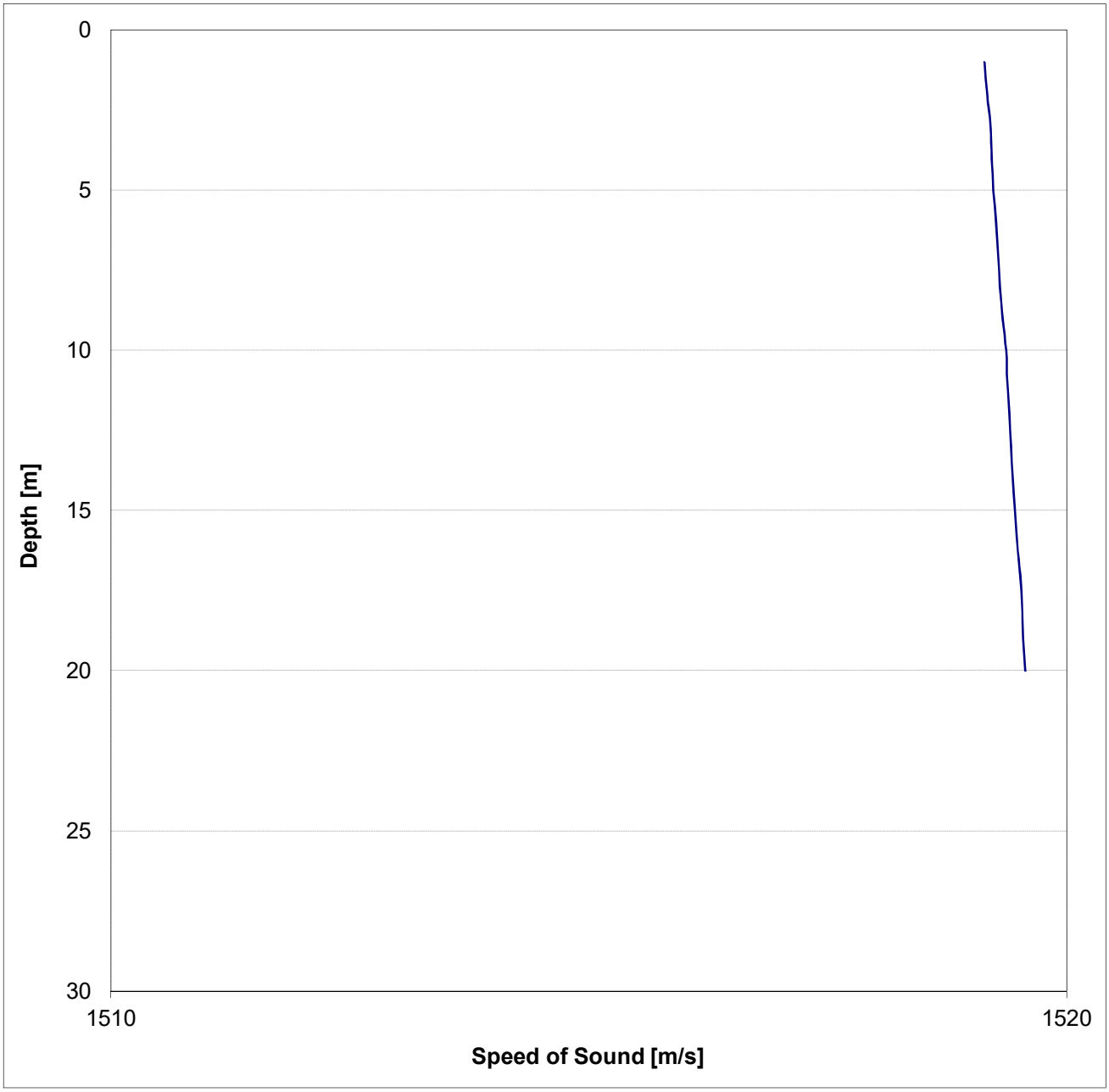
C. Maree

For Client

R. Chippendale

SOUND SPEED PROFILE REPORT

Profile details			
Project number:	GE051	Date and time:	05:57 03/sep/2016
Client:	Vattenfall	Transducer depth:	3.47 m
Survey area:	North Sea	Water depth:	20.30 m
Easting:	400298 m	Transducer speed of sound:	1519.22 m/s
Northing:	5704563 m	Bottom speed of sound:	1519.58 m/s
Datum and projection:	ETRS89	Average speed of sound:	1519.36 m/s
Sensor type and S/N:	SD1165	Average density:	1025.03 kg/m^3



For Fugro Survey B.V.

C. Maree

For Client

R. Chippendale