GEOPHYSICAL SITE INVESTIGATION SURVEY

BORSSELE WIND FARM DEVELOPMENT ZONE
WIND FARM SITES 1 & 2
DUTCH ECONOMIC EXCLUSIVE ZONE

CALIBRATION REPORT
MULTI CHANNEL SEISMIC SURVEY
MV SEAZIP SURVEYOR

Netherlands Enterprise Agency

PROJECT:	Site studies wind farm zone Borssele
CLIENT:	Rijksdienst voor Ondernemend Nederland PO Box 93144 2509 AC Den Haag The Netherlands
DEEP BV PROJECT NUMBER:	P2849
DOCUMENT:	20150227_SDB_DEEP_Calibration report Seazip Surveyor_V03_F
VERSION:	V03
STATUS:	Final

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Deep BV project number:	P2849
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Document name:	20150227_SDB_DEEP_Calibration report Seazip Surveyor_V03_F

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CONTENT

FIGURES

TABLES

USED ABBREVIATIONS

CD	Chart Datum
C-O	Calculated minus Observed
COG	Centre of gravity
EEZ	Economic Exclusive Zone
ETRS	European Terrestrial Reference System
GPS	Global Positioning System
HSE	Health, Safety & Environment
LAT	Lowest Astronomical Tide
MRU	Motion Reference Unit
MW	Mega Watt
PEP	Project Execution Plan
PQP	Project Quality Plan
QMS	Quality Management System
RVO	Rijksdienst Voor Ondernemend Nederland
RTK	Real Time Kinematic
SB	Single Beam (Echosounder)
UTM	Universal Transverse Mercator

1 INTRODUCTION

1.1 General

The Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland –RVO-), awarded DeepBV the contract for the execution of a geophysical site investigation survey in the Borssele Wind Farm Zone, which is located near the southern border of the Dutch Exclusive Economic Zone (EEZ), approximately 0.5 km from the Belgian EEZ. The total area is approximately 344 square kilometres in size and is expected to be divided into four wind farm sites, each to be used for the development of a wind farm. Total capacity is expected to be 1400 MW.

The geophysical site investigation survey to be conducted by DeepBV, using two vessels, will cover the first two wind farm sites (future total capacity of approximately 700 MW).

This report presents the methodology and the results of the calibrations executed on board of the MV Seazip Surveyor, prior to the seismic multi-channel sparker survey. See figure 1-1 below for the vessel. Further reference is made to §1.3: vessel specifications document and vessel equipment document.

Figure 1-1: Vessel

All activities for the works were executed in compliance with Deep BV's Quality Management System (QMS) which is NEN-EN-ISO 9001:2008 and OHSAS 18001:2007 certified. Supplementary to the QMS, project specific plans are applicable, which title can be found in §1.3.

1.2 Project key plan

The Borssele Wind Farm Zone is located near the southern border of the Dutch Exclusive Economic Zone (EEZ).. A detailed chart of the wind farm location can be found in Figure 1-2: Borssele Wind Farm location plan.

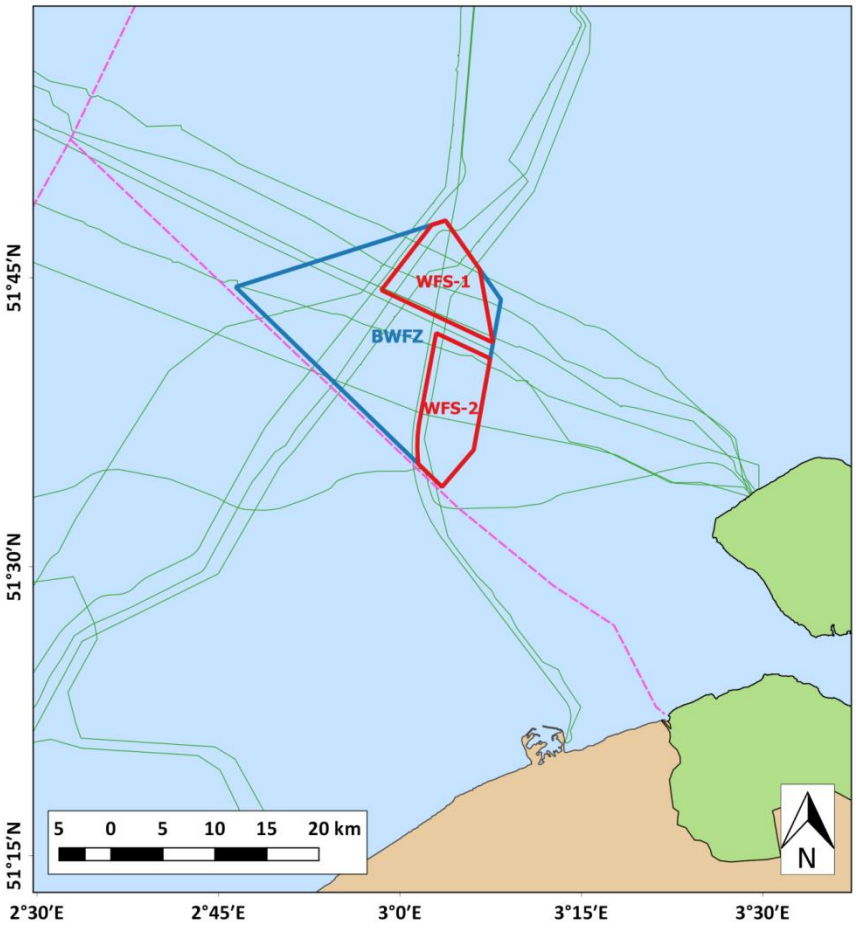

Figure 1-2: Borssele Wind Farm location plan

1.3 References

No.	*Document*	*Description*
1	Deep, Q2014_JBE_DOC_4217	Proposal minitender, Deep BV
2	Deep, QMS v_11 20140101	Quality Management System, Deep BV
3	Deep, P2008-HSE-01-R03	HSE Manual, Deep BV
4	Q4109_PEP_R03_150115	Project Execution Plan, Deep BV
5	Q4109_PQP_R03_v150115	Project Quality Plan, Deep BV
6	Q4109_Vessel Specifications_R01_v150114	Project Vessels, Deep BV
7	Q4109_Equipment Specifications_R03_v150115	Project Equipment, Deep BV

Table 1-1: Reference documents

2 CALIBRATIONS

The adequacy of a survey is the end product of the entire survey system and processes used during data collection. Besides the choice of equipment and how it is operated, it is important how the equipment is set up, calibrated, and how it interacts with the other components in the survey system as it is essential for the quality of the final product.
The objective of the calibrations is to establish and assess the accuracy and correctness of the survey systems in an independent and systematic manner.

2.1 Execution of calibrations

To ensure that all equipment, including cables, are fit for purpose and in good working order a so called 'full inspection' was performed prior to mobilisation to the project site. These inspections are executed by the Technical Department in the workshop of DeepBV according to documented internal procedures. After mobilisation of the survey equipment on board the vessel, checks were made to ensure that all systems were properly installed and correctly interfaced with other systems. Next, a series of calibrations and/or functional tests were carried out. All calibrations and checks were recorded on the applicable forms and included in the appendices.

The following calibrations were performed:

- Establishing the vessel geometry
- Position check
- Gyro calibration

2.2 Vessel geometry

The vessel geometry of the MV Seazip Surveyor was measured using a measuring tape. These measurements were made while the vessel was moored along the quay wall. The correctness of the measurements was confirmed by independently measuring each node twice and comparing the values for discrepancies. Positioning of the sparker source and streamer was done using a layback calculation based on the amount of cable out and with AIS beacons fitted to the streamer. The MV Seazip Surveyor vessel geometry includes the following nodes:

Node	X [m]	Y [m]	Z [m]
COG	*0.000*	*0.000*	*0.000*
RTK-GPS-antenna	*-0.310*	*-3.590*	*3.647*
Octans MRU	*-1.760*	*-0.500*	*0.815*
Quadrans MRU	*-1.525*	*-0.570*	*0.800*
Tow point sparker	*2.450*	*-16.450*	*-1.000*
Tow point streamer	*6.310*	*-7.500*	*-1.800*
Waterline SB	*3.560*	*-3.590*	*-3.485*

Table 2-1: Vessel offset nodes

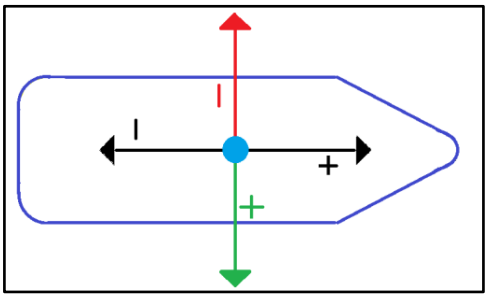

Figure 2-1: Node direction/sign convention

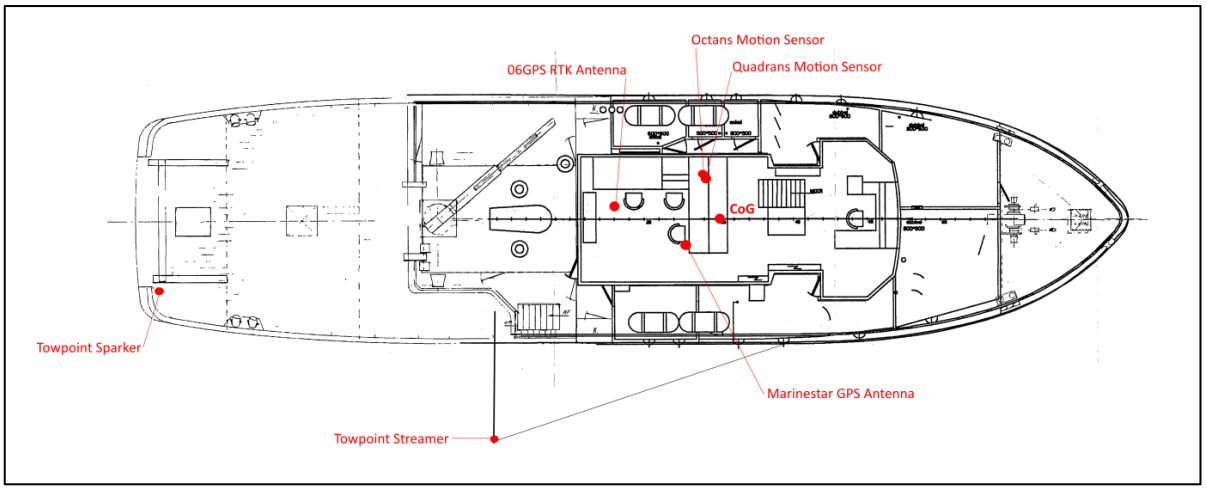

Figure 2-2: Vessel geometry

2.3 Position check

The aim of this procedure is to verify if correct geodetic settings are used and GPS-measurements comply with known benchmark information.

The following geodetic settings were used:

Horizontal datum:	ETRS89 (EUREF89)
Spheroid:	GRS 1980
Semi-major axis (a):	6378137.00m
Semi-minor axis (b):	6356752.314m
Inverse flattening (1/f):	298.257222101000
Flattening (f):	0.003352810681182
First eccentricity:	0.081819191042816
First eccentricity squared (e2):	0.006694380022901
Second eccentricity (e'):	0.082094438151917
Second eccentricity squared (e'2):	0.006739496775479
Projection:	UTM zone 31 North
Latitude of grid origin:	0;00;00.000
Longitude of grid origin:	3;00;00.000
Grid Easting at grid origin:	500000

Grid Northing at grid origin: 0.00
Scale factor at longitude of origin: 0.9996

Vertical datum: LAT GEONZ97 (Noordzee)

The GPS surface positioning system is checked by conducting a position check on a known benchmark. Said benchmark was provided to DeepBV by 'Rijkswaterstaat' in 2007 and consists of a nail on a concrete jetty called the 'Blokkensteiger' in IJmuiden.

Known coordinates	Measured coordinates	Difference
608028.61m E	*608028.61m E*	*0.00m*
5813307.86m N	*5813307.86m N*	*0.00m*
4.21m CD	*4.19m CD*	*-0.02m*

Table 2-2: Position check results

The results of the position check were accepted when after 5 minutes of averaging, the difference in X,Y and Z between the known coordinates and the measured coordinates did not exceed 5 cm.

The field calibration log sheets, signed by the RVO client representative on board the MV Seazip can be found in the appendices.

2.4 Gyro calibration

During the gyro calibration procedure the vessel was moored alongside a quay of which the grid heading was calculated by taking 4 bollard position measurements along the quayside with an RTK backpack. Then, several simultaneous measurements were taken from the quay to the bow and stern of the vessel for a fixed period of time. The distance between the two measurements provides a baseline for calculating the angle of the vessel's centre line relative to the quay, which was then applied to the quay heading to derive the computed grid heading of the vessel. The local convergence was applied to the computed grid heading to obtain the computed true heading which was compared with the observed gyro heading. The process was repeated after turning the vessel 180 degrees. Both heading reference sensors were calibrated at the same time (Octans/Quadrans).

The results of this check were approved when the difference between the computed true heading and the average observed heading was less than 1°.

Starboard side to quay wall			
Gyro compass	**Calculated vessel heading**	**Observed gyro heading**	**Difference (C-0)**
Octans	*121.75°*	*121.41°*	*0.34°*
Quadrans	*121.75°*	*121.78°*	*-0.03°*

Portside to quay wall			
Gyro compass	**Calculated vessel heading**	**Observed gyro heading**	**Difference (C-0)**
Octans	*301.75°*	*301.33°*	*0.42°*
Quadrans	*301.75°*	*301.81°*	*-0.06°*

Average C-O entered in software	
Gyro compass	**C-O**
Octans	*0.38°*
Quadrans	*-0.05°*

Table 2-3: Gyro calibration results

The field calibration log sheets, signed by the RVO client representative on board the MV Seazip Surveyor can be found in the appendices.

2.5 Equipment function tests

Prior to the survey works, several equipment function tests were carried out, which were all witnessed by the client representative.

- Source test [alongside]
- Tap test [alongside]
- Total system check [on site]
- Latency check [on site]
- Streamer balancing [on site]
- Noise analysis [on site]

Source test

The source test was carried out on 14th January 2015. It was performed by placing the Geo-Source in the seawater and firing the Geo-Spark for six hours on full power. During this period, PPS charge and discharge, signal strength consistency and stability and corrosion to sparker tip and frame were checked, to check for an indication for ground loops. No faults or irregularities were detected during this test.

Tap test

The responsivity of the hydrophone elements in the streamer were checked by gently tapping each element while checking whether acoustic responses were observed on the GeoRecorder laptop and Processing Workstation. It was found that each of the 48 elements showed a normal response.

2.6 Sea trails

After the static tests in the port of IJmuiden, a number of sea trials were carried out to test the system while sailing.

Total system check

With all sensors active and the sparker streamer wet, checks were done to ensure proper functioning of both equipment and (acquisition) software. All systems were found to be in order.

Latency check

By sailing twice (in opposite directions) over a well-defined feature on the seabed (e.g. sand dune), the position latency can be checked by analysing the overlaps between the two lines. If latency is detected, the feature does not line up. After the latency test the offsets were adjusted to compensate.

Streamer balancing

The streamer was initially weighted whilst alongside in IJmuiden. During the first deployment additional weight was added to ensure that it settled at the correct depth. Common offset plots were generated to determine signal stability (Figure 4 1). From this plot the wavelet shape of the seabed was extracted, the frequency spectrum response of the signal between the seabed reflection and its first multiple and identification of relevant frequency notches related to source-receiver ghosts.

After this test, additional weight was added to the streamer to improve its stability and improve constructive interference of ghosts. The figure below is a sketch of the weight distribution along the streamer array after sea trials.

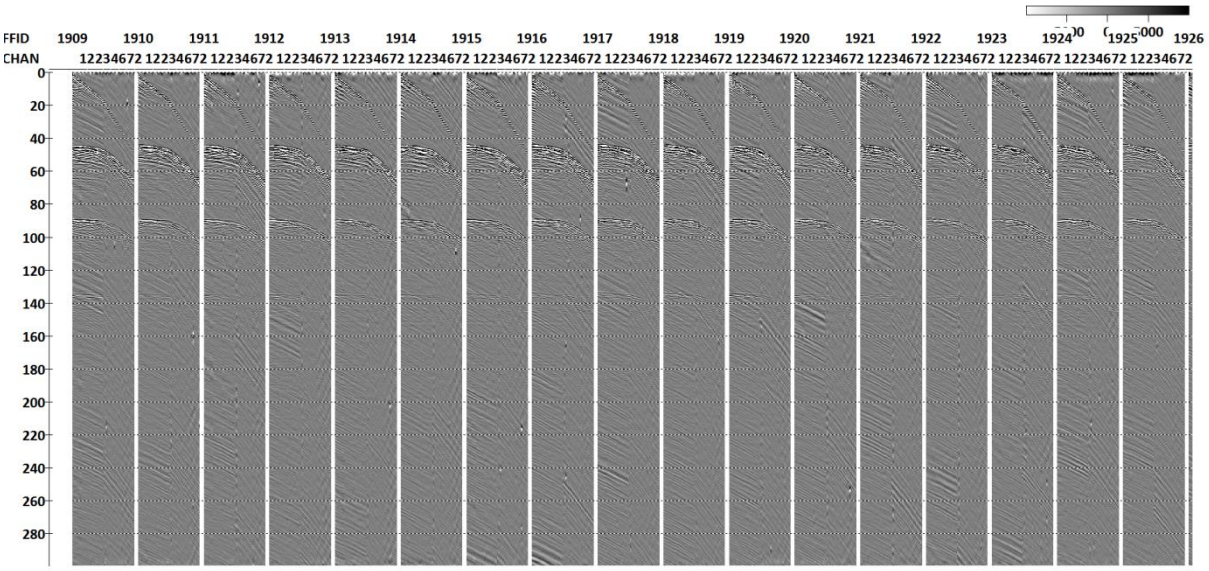

Figure 2-3: Common offset plot of the multi-channel seismic sparker system

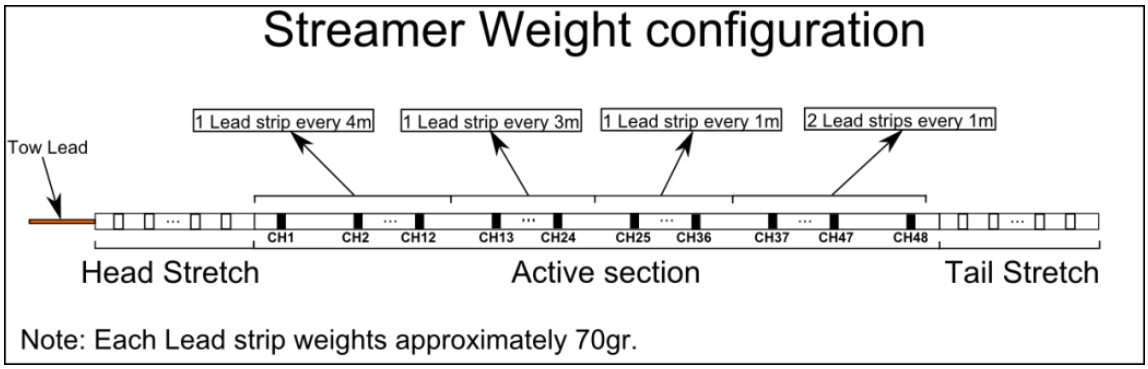

Figure 2-4: Streamer weight configuration after sea trails

Noise analysis

Analysis of acoustic noise caused by the ship propeller or weather has been carried out during the sea trials. The ship's engines were run at different RPM's, to assess which RPM caused the least frequency interference with the seismic signal. The survey was carried out at this specific RPM.

Additionally, some data spikes were observed in the data that are attributed to weather and wave conditions. These spikes have a sufficiently different frequency from the seismic data, so they can easily be filtered out during post-processing. The figure below is a screen-dump of a common offset plot, with the noise signatures from propeller wash and environmental effects annotated.

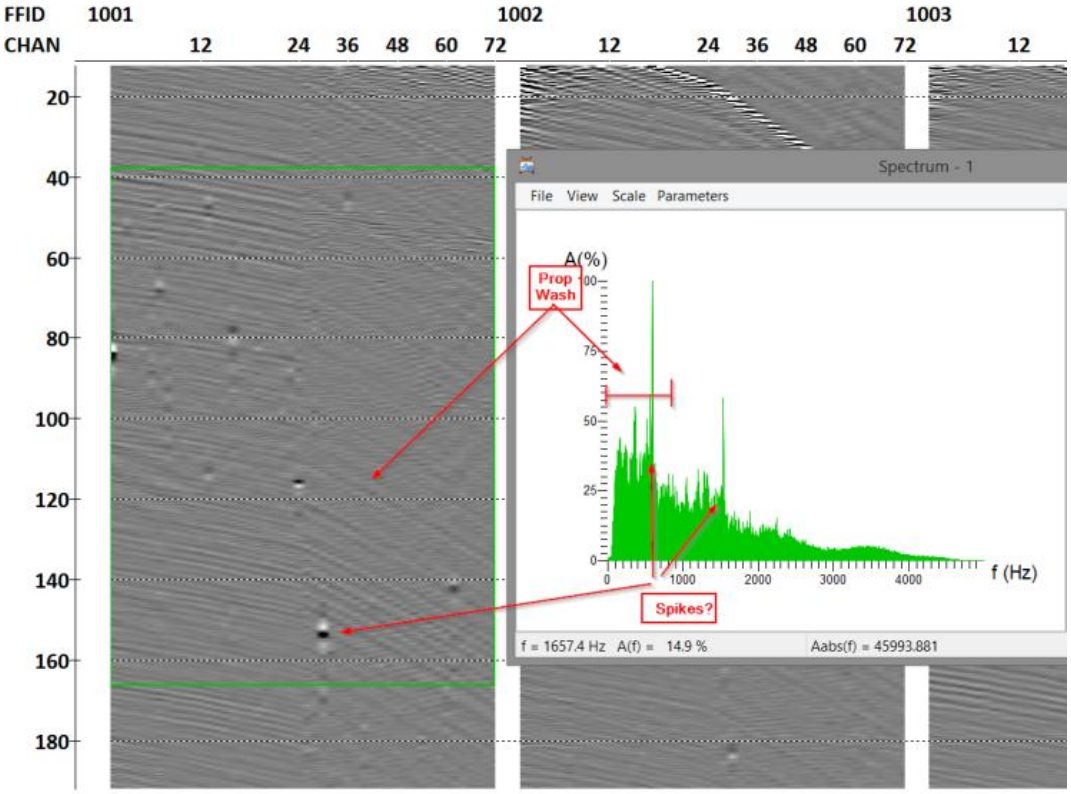

Figure 2-5: Seismic common offset plot.
Interference of the propeller and potential spikes caused by environmental circumstances are annotated

APPENDICES

A SCANNED CALIBRATION FORMS, SIGNED BY CLIENT

FIELD OPERATIONS

CALIBRATION - POSITION CHECK

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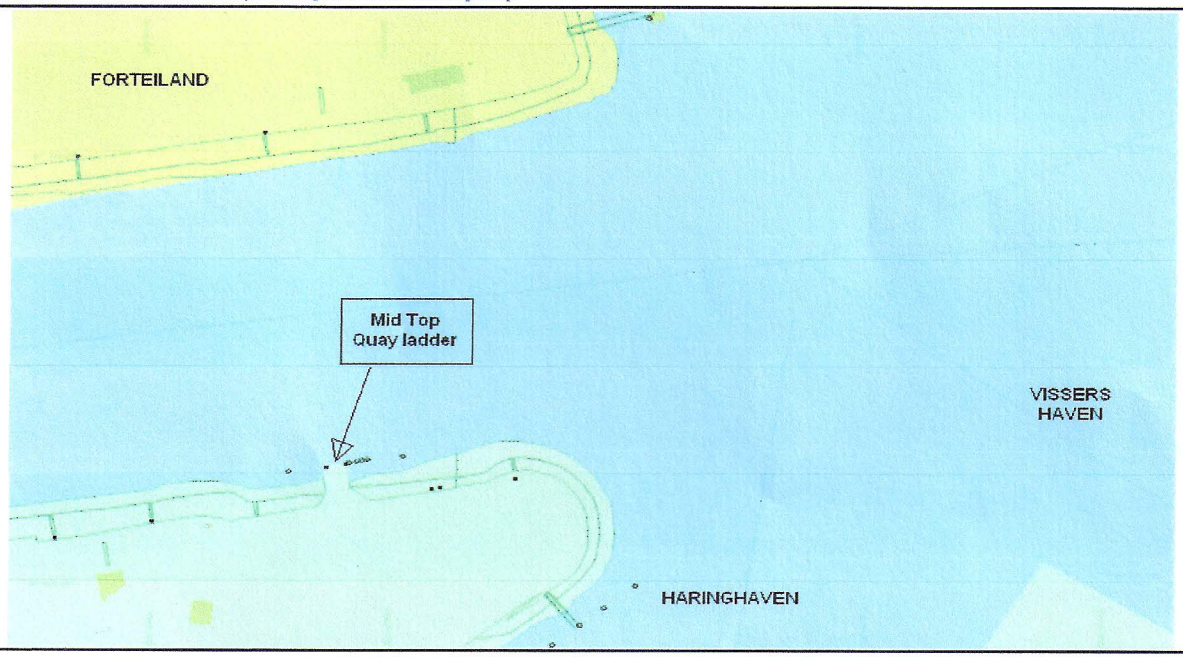
deep
Hydrography & Geophysics

PROJECT No:	P2746	**SURVEYOR:**	NPR
LOCATION:	Ijmuiden	**VESSEL:**	RTK BACKPACK
DATE:	1/14/2015	**REMARKS:**	RD NAP
PAGE:	1 of 1		

Positioning system						
Brand:	*NOVATEL 06GPS*	Type:	☑ RTK	☐ dGPS	☐ 06-GPS	☐ Netpos
Antenna height:	*0.065* m.					

Situation Sketch

Pointnumber: *Known point Ijmuiden RWS jetty*



No of observations:	*300 (5min)*
Logfile:	*P2849-150113-POSCHECKS.txt*

Coordinates known station		**Measured coordinates**		**Position difference**		
X:	*99948.54*	X:	*99948.54*	ΔX:	*0.00*	m.
Y:	*497541.53*	Y:	*497541.52*	ΔY:	*-0.01*	m.
Z:	*2.84*	Z:	*2.84*	ΔZ:	*0.00*	m.

Local datum	
Horizontal datum:	*RD*
Vertical reference:	*NAP*

Checked (Deep BV): 14/01/2015 **Approved (client):** 14/01/2015

FIELD OPERATIONS

CALIBRATION - POSITION CHECK

DEEP BV
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deep
Hydrography & Geophysics

PROJECT No:	P2746	**SURVEYOR:**	NPR
LOCATION:	Ijmuiden	**VESSEL:**	RTK BACKPACK
DATE:	1/14/2015	**REMARKS:**	Establishing Position check point
PAGE:	1 of 1		

Positioning system						
Brand:	*NOVATEL 06GPS*	Type:	☑ RTK	☐ dGPS	☐ 06-GPS	☐ Netpos
Antenna height:	*0.065* m.					

Situation Sketch	
Pointnumber:	*Creation of Gyro 2 point using calibrated RTK backpack*

No of observations:	*2x 300 (5min)*
Logfile:	*P2849-150113-POSCHECKS.txt*

Coordinates measured by RTK 06GPS		**Coordinates measured by RTK 06GPS**		**Converted to ETRS89 / GEONZ97 LAT**	
X:	*100815.19*	X:	*100815.18*	X:	*608028.61*
Y:	*497130.84*	Y:	*497130.84*	Y:	*5813307.86*
Z:	*3.24*	Z:	*3.23*	Z:	*4.21*
SURVEY DATUM :	RD	RD		ETRS89	
VERTICAL DATUM :	NAP	NAP		GEONZ97 LAT	

Local datum	
Horizontal datum:	*RD*
Vertical reference:	*NAP*

Checked (Deep BV): 14/01/2015 **Approved (client):** 14/01/2015

FIELD OPERATIONS

CALIBRATION - POSITION CHECK

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PROJECT No:	P2849	**SURVEYOR:**	NPR
LOCATION:	Ijmuiden	**VESSEL:**	Octans
DATE:	1/13/2015	**REMARKS:**	n.a.
PAGE:	1 of 1		

Positioning system								
Brand:	*Trimble*	Type:	☑ RTK	☐ dGPS	☑ 06-GPS	☐ Netpos	*Trimble 004 unit*	
Antenna height:	*1.78*	m.						

Situation Sketch

Pointnumber: *Gyro 2 Bolder*

POSITION FIX RESULTS

Position Fixes

Number of positions	2905		
Number of used positions	2905		
Number of disabled positions	0		
UTC time of first position	18:13:58.025	2015-01-13	
UTC time of last position	18:18:58.029	2015-01-13	

Statistics

Value	Mean Value	St. Deviation
Easting	608028.61 m	0.00 m
Northing	5813307.86 m	0.01 m
Latitude	52;27;33.297 N	0.01 m
Longitude	4;35;23.911 E	0.00 m
Height	4.19 m	0.01 m

No of observations:	*300*
Logfile:	*150113_PC_TRIMBLE_06GPS_GYRO2*

Coordinates known station		**Measured coordinates**		**Position difference**		
X:	*608028.61*	X:	*608028.61*	ΔX:	*0.00*	m.
Y:	*5813307.86*	Y:	*5813307.86*	ΔY:	*0.00*	m.
Z:	*4.21*	Z:	*4.19*	ΔZ:	*-0.02*	m.

Local datum	
Horizontal datum:	*ETRS89*
Vertical reference:	*GEONZ97 LAT Noordzee*

Checked (Deep BV): 14/01/2015 **Approved (client):** 14/01/2015

FIELD OPERATIONS

CALIBRATION - GYRO COMPASS

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deep Hydrography & Geophysics

PROJECT No: P2849
LOCATION: Vlissingen
DATE: 1/14/2015
PAGE: 1 of 1

SURVEYOR: NPR
VESSEL: Octans
REMARKS: RDcoörd used for quaywall heading

Equipment						
Gyro compass:	☐ Octans I	☐ Octans II	☐ Octans III	☐ Octans 3000TI III	☐ Octans 3000TI I	
	☐ ROVINS	☐ Hemisphere	☑ : Quadrans			

Location				
Description quaywall:	*Trawlerkade, Ijmuiden, 4 bolders measured. Gyro 1, Gyro 2, Gyro 3, Gyro 4*			
Known (or measured) benchmarks on quay or vessel:	BM no: *Gyro1*		BM no: *Gyro 4*	
	X: *100825.02*	m.	X: *100795.18*	m.
	Y: *497124.60*	m.	Y: *497143.52*	m.
	Heading calculated: *302.38* ° [GRID]		Distance calculated: *35.33*	m.
Known heading [GRID]:	*302.38* °			
Convergence at location:	*-0.63* ° +			
Known heading [TRUE]:	*301.75* °			

Vessel	
Distance bow to stern	*25* m.

Starboardside to quaywall

FIX no	**Observed** gyro heading (TRUE)	Distance bow to quaywall	Distance stern to quaywall	Angle vessel to quaywall	**Calculated** vessel heading (TRUE)	C-O
	121.78 °	m.	m.	*0.00* °	*121.75* °	*-0.03*
	°	m.	m.	°	°	
	°	m.	m.	°	°	
	°	m.	m.	°	°	
	°	m.	m.	°	°	
					Averaged correction:	***-0.03***

Portside to quaywall

FIX no	**Observed** gyro heading (TRUE)	Distance bow to quaywall	Distance stern to quaywall	Angle vessel to quaywall	**Calculated** vessel heading (TRUE)	C-O
	301.81 °	m.	m.	*0.00* °	*301.75* °	*-0.06*
	°	m.	m.	°	°	
	°	m.	m.	°	°	
	°	m.	m.	°	°	
	°	m.	m.	°	°	
					Averaged correction:	***-0.06***

C-O entered in software: ***-0.05*** °

Checked (Deep BV): 14/01/2015 **Approved (client):** 14/01/2015

FIELD OPERATIONS

CALIBRATION - GYRO COMPASS

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deep Hydrography & Geophysics

PROJECT No: P2849
LOCATION: Ijmuiden
DATE: 1/14/2015
PAGE: 1 of 1

SURVEYOR: NPR
VESSEL: Octans
REMARKS: RD coörd used for quaywall heading

Equipment						
Gyro compass:	☐ Octans I	☐ Octans II	☑ Octans	☐ Octans 3000TI II	☐ Octans 3000TI	
	☐ ROVINS	☐ Hemisphere	☐ :			

Location				
Description quaywall:	*Trawlerkade, Ijmuiden, 4 bolders measured. Gyro 1, Gyro 2, Gyro 3, Gyro 4*			
Known (or measured) benchmarks on quay or vessel:	BM no: *Gyro1*		BM no: *Gyro 4*	
	X: *100825.02* m.		X: *100795.18* m.	
	Y: *497124.60* m.		Y: *497143.52* m.	
	Heading calculated: *302.38* ° [GRID]		Distance calculated: *35.33* m.	
Known heading [GRID]:	*302.38* °			
Convergence at location:	*-0.63* ° +			
Known heading [TRUE]:	*301.75* °			

Vessel	
Distance bow to stern	*25* m.

Starboardside to quaywall

FIX no	**Observed** gyro heading (TRUE)	Distance bow to quaywall	Distance stern to quaywall	Angle vessel to quaywall	**Calculated** vessel heading (TRUE)	C-O
	121.41 °	m.	m.	*0.00* °	*121.75* °	*0.34*
	°	m.	m.	°	°	
	°	m.	m.	°	°	
	°	m.	m.	°	°	
	°	m.	m.	°	°	
					Averaged correction:	***0.34***

Portside to quaywall

FIX no	**Observed** gyro heading (TRUE)	Distance bow to quaywall	Distance stern to quaywall	Angle vessel to quaywall	**Calculated** vessel heading (TRUE)	C-O
	301.33 °	m.	m.	*0.00* °	*301.75* °	*0.42*
	°	m.	m.	°	°	
	°	m.	m.	°	°	
	°	m.	m.	°	°	
	°	m.	m.	°	°	
					Averaged correction:	***0.42***

C-O entered in software: ***0.38*** °

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GEOPHYSICAL SITE INVESTIGATION SURVEY

BORSSELE WIND FARM DEVELOPMENT ZONE
WIND FARM SITES 1 & 2

DUTCH ECONOMIC EXCLUSIVE ZONE

CALIBRATION REPORT
MULTIBEAM, SIDESCAN SONAR, MAGNETOMETER AND SUB BOTTOM PROFILER SURVEY
MV BREAKER

Netherlands Enterprise Agency

PROJECT:	Site studies wind farm zone Borssele
CLIENT:	Rijksdienst voor Ondernemend Nederland PO Box 93144 2509 AC Den Haag The Netherlands
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By:
Drs. J. Graven
Geologist

Checked by:
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Sr. Geologist &
Coordinator data processing
and reporting

Checked by:
A. de Lange
Sr. Hydrographic Surveyor

Approved by:
Client
Rijksdienst voor Ondernemend Nederland

CONTENT

FIGURES

TABLES

USED ABBREVIATIONS

C-O	Computed minus Observed
CD	Chart Datum
COG	Centre Of Gravity
EEZ	Economic Exclusive Zone
ETRS	European Terrestrial Reference System
GPS	Global Positioning System
HSE	Health, Safety & Environment
LAT	Lowest Astronomical Tide
MBE	MultiBeam Echosounder
MRU	Motion Reference Unit
MW	Mega Watt
PEP	Project Execution Plan
PPS	Pulse Per Second
PQP	Project Quality Plan
QMS	Quality Management System
RVO	Rijksdienst Voor Ondernemend Nederland
RTK	Real Time Kinematic
SBP	Sub Bottom Profiler
SSS	SideScan Sonar
THU	Total Horizontal Uncertainty
TVU	Total Vertical Uncertainty
SB	Single Beam (Echosounder)
UTM	Universal Transverse Mercator
WFS	Wind Farm Site
WFZ	Wind Farm Zone

1 INTRODUCTION

1.1 General

The Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland –RVO-), awarded DeepBV the contract for the execution of a geophysical site investigation survey in the Borssele Wind Farm Zone, which is located near the southern border of the Dutch Exclusive Economic Zone (EEZ), approximately 0.5 km from the Belgian EEZ. The total area is approximately 344 square kilometres in size and is expected to be divided into four wind farm sites, each to be used for the development of a wind farm. Total capacity is expected to be of 1400 MW.

The geophysical site investigation survey to be conducted by DeepBV, using two vessels will cover the first two wind farm sites (future total capacity of approximately 700 MW).

This report presents the methodology and the results of the calibrations executed on board of the MV Breaker prior to the multibeam, sidescan sonar, magnetometer and sub-bottom profiler survey. See figure 1-1 below for the vessel. Further reference is made to §1.3: vessel specifications document and vessel equipment document.

Figure 1-1: Vessel MV Breaker

All activities for the works were executed in compliance with DeepBV's Quality Management System (QMS) which is NEN-EN-ISO 9001:2008 and OHSAS 18001:2007 certified. Supplementary to the QMS, project specific plans are applicable, which title can be found in §1.3.

1.2 Project key plan

The Borssele Wind Farm Zone (WFZ) is located near the southern border of the Dutch Exclusive Economic Zone (EEZ). A detailed chart of the wind farm location can be found in figure 1-2.

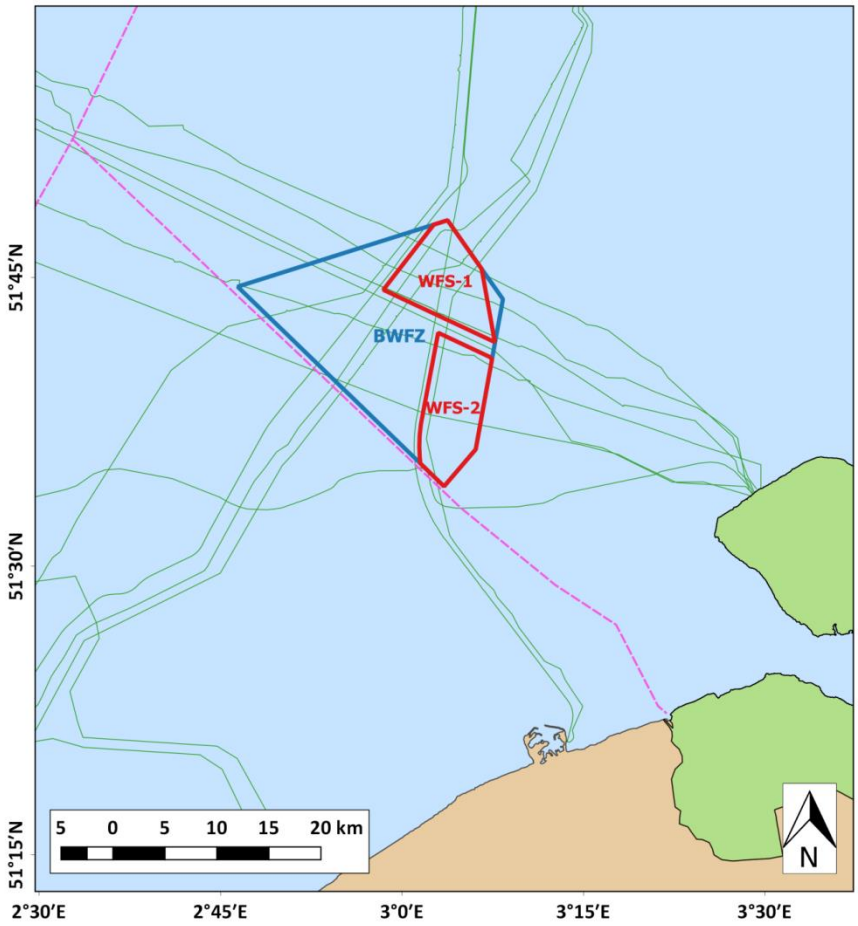

Figure 1-2: Borssele Wind Farm location plan

1.3 References

No.	*Document*	*Description*
1	Deep, Q2014_JBE_DOC_4217	*Proposal minitender, Deep BV*
2	Deep, QMS v_11 20140101	*Quality Management System, Deep BV*
3	Deep, P2008-HSE-01-R03	*HSE Manual, Deep BV*
4	Q4109_PEP_R03_150115	*Project Execution Plan, Deep BV*
5	Q4109_PQP_R03_v150115	*Project Quality Plan, Deep BV*
6	Q4109_Vessel Specifications_R01_v150114	*Project Vessels, Deep BV*
7	Q4109_Equipment Specifications_R03_v150115	*Project Equipment, Deep BV*

Table 1-1: Reference documents

2 CALIBRATIONS

The adequacy of a survey is the end product of the entire survey system and processes used during data collection. Besides the choice of equipment and how it is operated, it is important how the equipment is set up, calibrated, and how it interacts with the other components in the survey system as it is essential for the quality of the final product. The objective of the calibrations is to establish and assess the accuracy and correctness of the survey systems in an independent and systematic manner.

2.1 Execution of calibrations

To ensure that all equipment, including cables, are fit for purpose and in good working order a so called 'full inspection' was performed prior to mobilisation to the project site. These inspections are executed by the Technical Department in the workshop of DeepBV according to documented internal procedures. After mobilisation of the survey equipment on board the vessel, checks were made to ensure that all systems were properly installed and correctly interfaced with other systems. Next, a series of calibrations and/or functional tests were carried out. All calibrations and checks were recorded on the applicable forms and are included in the appendices.

The following calibrations or checks were performed:

- Execution of calibrations
- Vessel geometry
- Position check
- Gyro calibration
- USBL calibration
- Multibeam calibration
- Sidescan sonar rub test and position check
- Sub bottom profiler latency check
- Multibeam performance test

2.2 Vessel geometry

The vessel geometry of the Breaker was measured using land survey techniques by Ratio Survey. The measurements were taken while the vessel was moored alongside the quay wall. A brief overview of the measured sensor locations is given in figure 2-1 below.

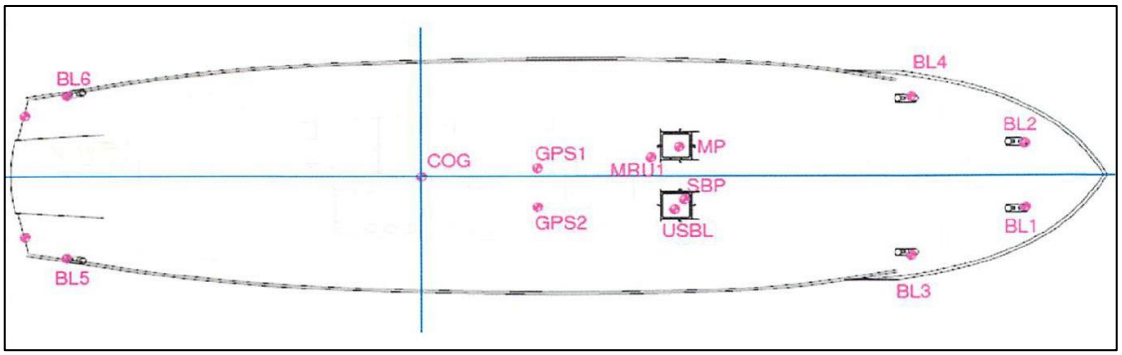

Figure 2-1: Breaker geometry

The Breaker's vessel geometry, signed by the RVO client representative on board the MV Breaker is included with Appendix A, as well as the geometry report by Ratio Survey in Appendix B.

2.3 Position check

The aim of this procedure is to verify if correct geodetic settings are used and GPS-measurements comply with known benchmark information.

The following geodetic settings were used:

Horizontal datum:	ETRS89 (EUREF89)
Spheroid:	GRS 1980
Semi-major axis (a):	6378137.00m
Semi-minor axis (b):	6356752.314m
Inverse flattening (1/f):	298.257222101000
Flattening (f):	0.003352810681182
First eccentricity:	0.081819191042816
First eccentricity squared (e2):	0.006694380022901
Second eccentricity (e'):	0.082094438151917
Second eccentricity squared (e'2):	0.006739496775479
Projection:	UTM zone 31 North
Latitude of grid origin:	0;00;00.000
Longitude of grid origin:	3;00;00.000
Grid Easting at grid origin:	500000
Grid Northing at grid origin:	0.00
Scale factor at longitude of origin:	0.9996
Vertical datum:	LAT GEONZ97 (Noordzee)

The GPS surface positioning system was checked by conducting a position check on a benchmark created by RTK backpack measurements (≤3 cm accuracy) on the spot, in absence of an official benchmark. After 5 minutes of averaging, the difference in X, Y and Z between the known coordinates and the measured coordinates were not exceeding 5 cm in case of 06-GPS RTK and 20 cm in case of Marinestar. The results of the position check were accepted.

Coordinates known station		Measured coordinates		Position difference		
X:	*619952.637*	X:	*619952.61*	ΔX:	***-0.03***	m.
Y:	*5868281.416*	Y:	*5868281.39*	ΔY:	***-0.03***	m.
Z:	*4.771*	Z:	*4.77*	ΔZ:	***0.00***	m.

Table 2-1: Position check 06-GPS

Coordinates known station		Measured coordinates		Position difference		
X:	*619952.637*	X:	*619952.57*	ΔX:	***-0.07***	m.
Y:	*5868281.416*	Y:	*5868281.34*	ΔY:	***-0.08***	m.
Z:	*4.771*	Z:	*4.82*	ΔZ:	***0.05***	m.

Table 2-2: Position check Marinestar

The two position check log sheets, signed by the RVO client representative on board the MV Breaker can be found in the appendices.

2.4 Gyro calibration

During the gyro calibration, 15 time-tagged position fixes of vessel's bow and stern were taken by simultaneous RTK backpack positioning (≤3 cm accuracy). For each position fix the vessel's TRUE heading was calculated and compared to the observed heading. The resulting C-O's were implemented in the survey software.

Calibration results			
Gyro compass	Observed gyro heading (TRUE)	Calculated vessel heading (TRUE)	Difference (C-0)
Breaker – Octans IV	*126.40°*	*126.70°*	*0.30°*
Moonpool – Octans 3000	*125.84°*	*126.69*	*0.85°*

Table 2-3: Gyro calibration results Breaker & moonpool

The gyro calibration log sheets, signed by the RVO client representative on board the MV Breaker can be found in the appendices.

2.5 USBL calibration

To calibrate for the misalignment between the USBL transceiver head, the vessel's heading and MRU reference, a transponder beacon was mounted on a steel frame and lowered onto the seabed. USBL range observations were logged while sailing a cardinal calibration pattern around the transponder.

From the difference between the logged transponder positions for the various cardinal directions, the misalignment angles for the roll, pitch and heading of the USBL head were determined in the USBL calibration utility. The resulting C-O's were implemented in the survey software.

After applying the misalignment corrections, the resulting static accuracy was less than 1 metre and therefore accepted.

Calibration results		
Parameter	Value	SD
Roll Angle	*-1.624*	*2.080°*
Pitch Angle	*-1.025*	*0.652°*
Heading Angle	*1.104*	*0.563°*

Table 2-4: USBL calibration results

The USBL calibration log sheet, signed by the RVO client representative on board the MV Breaker can be found in the appendices.

2.6 Multibeam calibration

To accurately measure the seabed, the measurements made by multibeam echosounder must be relative to true vertical as reported by the motion sensor and the heading reported by the gyro compass. When the sensors are installed and calibrated on a vessel, it is not possible to get them in perfect alignment. A calibration procedure, commonly referred to as a patch test, was performed to derive actual offset values, which can then be applied to the data to bring the system in proper alignment. The procedure involves collecting data over certain types of terrain and processing it by

means of a set of patch test tools, integrated in the survey software. The resulting C-O's were implemented in the survey software.

Calibration results	Portside head	Starboard head
Parameter	Value	Value
Latency ms	*0*	*0*
Roll Angle	*18.09*	*-20.32*
Pitch Angle	*2.25*	*0.55*
Heading Angle	*0.00*	*-0.60*

Table 2-5: MBE calibration results

The multibeam calibration log sheet, signed by the RVO client representative on board the MV Breaker can be found in the appendices.

2.7 Sidescan sonar rub test and position check

The sidescan sonar is functionally tested by means of a so-called rub test. A rub test is a common practice to test the system on deck. Because air is high impedance medium for sonar, the best method of testing system functionality is to tap or rub the transducer face. In a dual channel sidescan sonar system, one transducer is rubbed, then the opposite and then the first one again. This is to verify that the transducers are not 'wired' to the wrong display channels.

The absolute positioning of the sidescan sonar data was checked by sailing two lines in opposite direction over a seabed feature. While performing this check the multibeam bathymetry was also recorded in order to cross-reference the object detection. The resulting static accuracy was less than 3 metres and therefore accepted. To further improve positioning the calculated latency, resulting from USBL positioning, was incorporated into the survey software.

Position Check	Object 1	Object 2
Parameter	Value	Value
Horizontal difference	*2.35 m*	*0.35 m*
Latency used sec	*0.0033 sec*	*0.0033 sec*

Table 2-6: SSS position check results

The sidescan sonar position check log sheet, signed by the RVO client representative on board the MV Breaker can be found in the appendices. The rub test is logged in the DPR.

2.8 Sub bottom profiler latency check

The Innomar system does not employ PPS to achieve accurate timing of the data. To eliminate any latency in the system, two delay lines were sailed over a clearly defined object in opposite directions. The used frequency during the check was 110 Hz and the water depth was 29 metres. During processing, the latency check results will be used to correct the data.

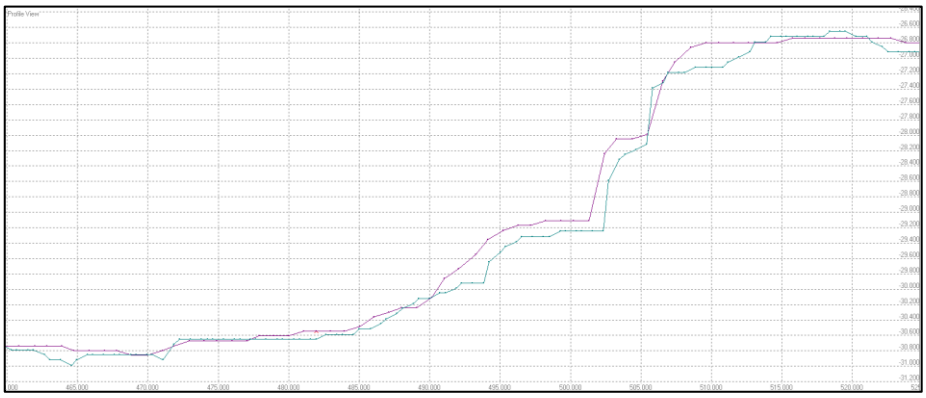

Figure 2-2: Latency check SBP

The sub bottom profiler latency check log sheet, signed by the RVO client representative on board the MV Breaker can be found in the appendices.

2.9 Magnetometer pressure and altimeter check

The magnetometer system is factory calibrated and does not need any additional adjustments. The depth of the magnetometer will be determined by means of the internal pressure sensor. The height above the seabed will be measured by a built-in altimeter.

The factory calibration values are labelled on the magnetometer itself. See figure 2-2 below.

Figure 2-3: Maggy factory calibrations

Both the pressure sensor and the altimeter were checked prior to usage to ensure correct functioning. This was done by lowering the magnetometer into the water whilst the vessel was stationary. The magnetometer was lowered to various depths and held at depth while the depth and altitude readings were compared to the readings on the (vessel mounted) echosounder.

Pressure sensor verification				
Known depth [m]		Measured raw values	Depth derived from factory calibration settings	Difference
Towfish	Seabed			
1.40	*8.20*	*183*	*1.36* m	*0.04*
2.90	*8.20*	*276*	*2.88* m	*0.02*
4.50	*8.20*	*374*	*4.48* m	*0.02*
6.10	*8.20*	*474*	*6.12* m	*0.02*
Altimeter verification				
Known depth [m]		Reported altitude (factory calibration)	Altitude + known depth towfish	Difference
Towfish	Seabed			
1.40	*8.20*	*6.69* m	*8.09* m	*0.11*
2.90	*8.20*	*5.21* m	*8.11* m	*0.09*
4.50	*8.20*	*3.77* m	*8.27* m	*0.07*
6.10	*8.20*	*2.22* m	*8.32* m	*0.12*

Table 2-7: Pressure and Altimeter verification

The magnetometer pressure and altimeter check log sheet, signed by the RVO client representative on board the MV Breaker can be found in the appendices.

2.10 Multibeam performance test

Absolute depth check

This involves a survey over a known calibration object or lock sill. The measured absolute depth should not exceed 20 cm in case of Marinestar and 5 cm in case of 06-GPS positioning. The location chosen was the well-known lock sill of the Noordersluis in Ijmuiden, of which the lock sill depth has been provided by 'Rijkswaterstaat' (-15.05m NAP).

The resulting difference was less than 5 cm and therefore accepted.

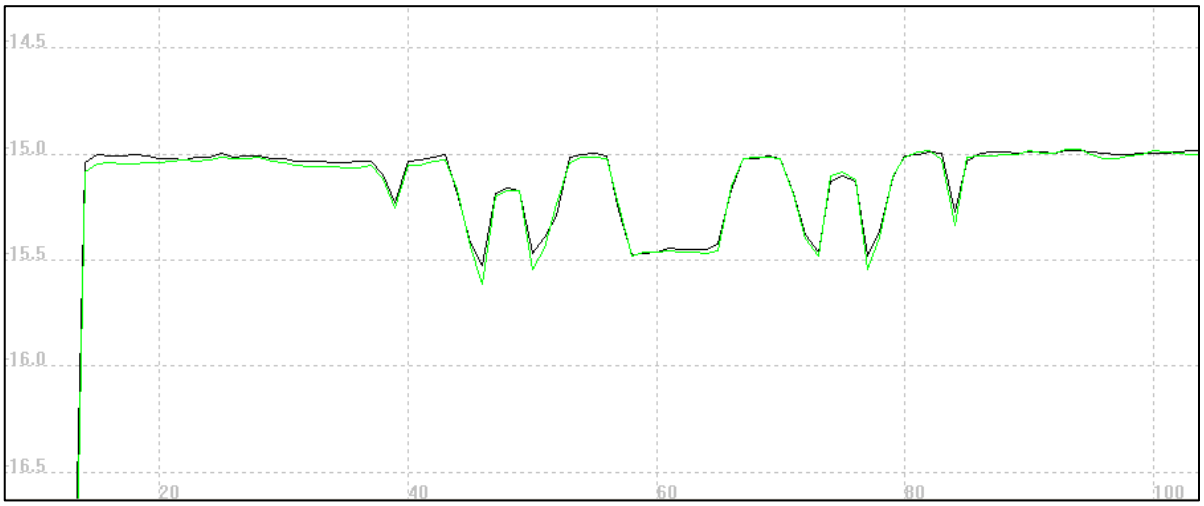

Figure 2-4: Absolute depth check.
Black: known level, green: data MV Breaker

Repeatability check

This check was performed by sailing 7 lines over the same area and comparing the results. Acceptance limit is the applicable THU at 95% confidence level, which is 56 cm at 25 metres water depth. The resulting THU was 20 cm at 25 metre water depth and therefore accepted.

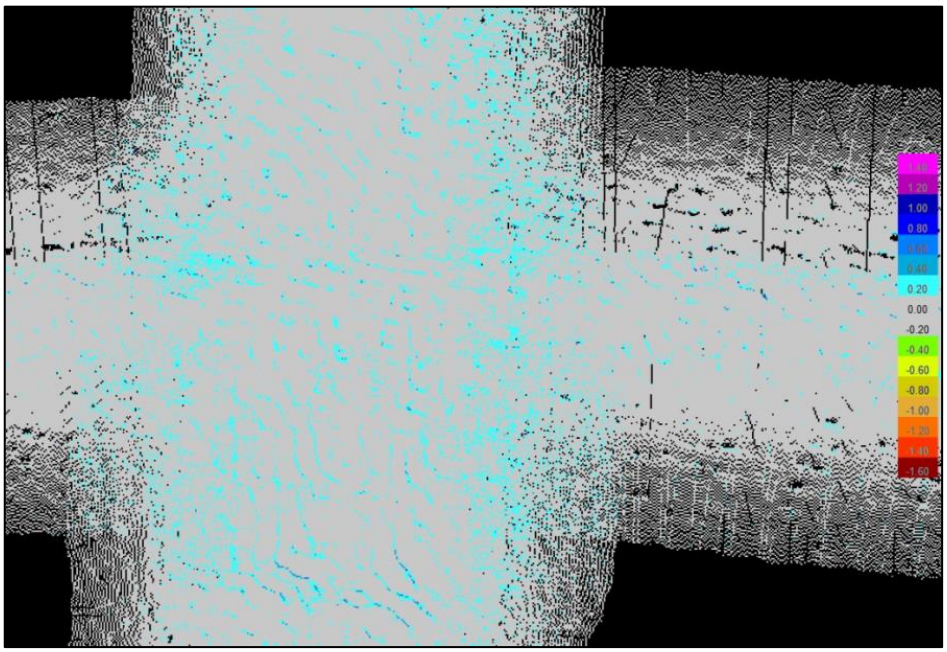

Figure 2-5: Repeatability check

APPENDICES

A CALIBRATION FORMS (SIGNED BY CLIENT)

B VESSEL GEOMETRY REPORT (RATIO SURVEY)

APPENDIX A

CALIBRATION FORMS (SIGNED BY CLIENT)

FIELD OPERATIONS

CALIBRATION - VESSEL GEOMETRY

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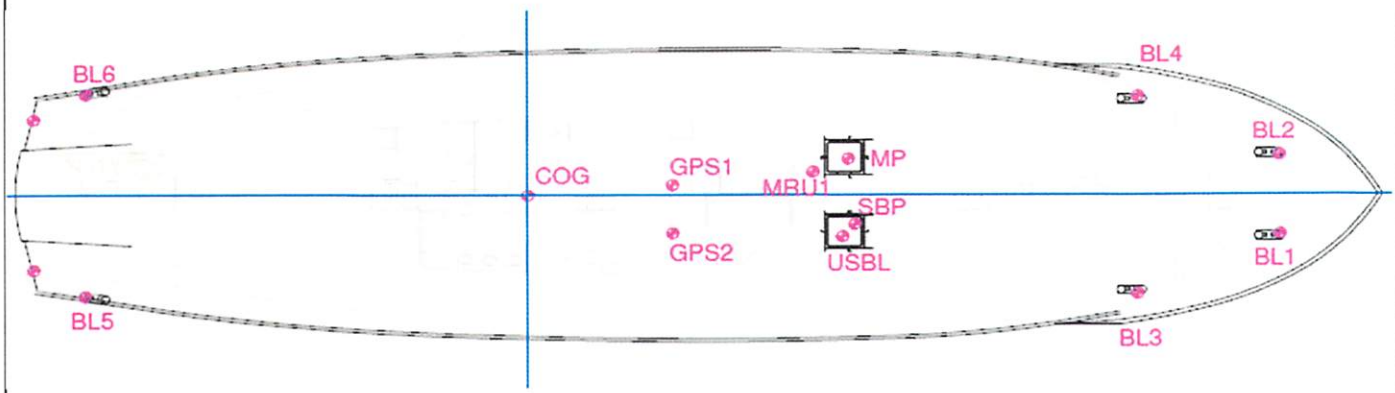
PROJECT No:	P2849	**SURVEYOR:**	Ratio survey
LOCATION:	Den Helder	**VESSEL:**	BREAKER
DATE:	22-01-2015	**REMARKS:**	
PAGE:	1 of 2		

Topview



Offsets BREAKER

Name	Description	X	Y	Z	Remarks
COG	*C.O.G. Breaker*	*0.000*	*0.000*	*0.000*	
MP	*C.O.G. portside moonpool*	*-0.917*	*7.349*	*-1.684*	*cradle down*
GPS1 (PS)	*Trimble GA810 bottom antenna mount*	*-0.271*	*3.135*	*12.790*	
GPS1 (PS)	*Trimble GA810 antenna phase centre*	*-0.271*	*3.135*	*12.862*	*06-GPS*
GPS2 (SB)	*Trimble GA810 bottom antenna mount*	*0.962*	*3.315*	*12.217*	
GPS2 (SB)	*Trimble GA810 antenna phase centre*	*0.962*	*3.315*	*12.289*	*Marinestar*
MRU1	*Centre of baseplate*	*-0.594*	*6.532*	*-0.975*	
MRU1	*Octans IV phase centre*	*-0.595*	*6.584*	*-0.903*	
USBL	*Hipap 350p centre of transducer*	*1.051*	*7.221*	*-2.830*	
SBP	*Innomar SES-2000 SBP transducer*	*0.742*	*7.503*	*-2.569*	
MB1	*Sonic 2024 acoustic centre*	*-0.859*	*7.277*	*-2.559*	*facing to portside*
MB2	*Sonic 2024 acoustic centre*	*-0.944*	*7.432*	*-2.553*	*facing to starboard*
Draft	*MiniSVS pressure sensor*	*-1.107*	*7.322*	*-2.391*	
WL PS	*Waterline node moonpool PS*	*-0.518*	*7.731*	*1.664*	*node = 1.664 - dist to water*
WL SB	*Waterline node moonpool SB*	*0.508*	*7.732*	*1.668*	*node = 1.6684 - dist to water*
WL	*Averaged waterline node*	*0.000*	*7.732*	*1.666*	

FIELD OPERATIONS

CALIBRATION - VESSEL GEOMETRY

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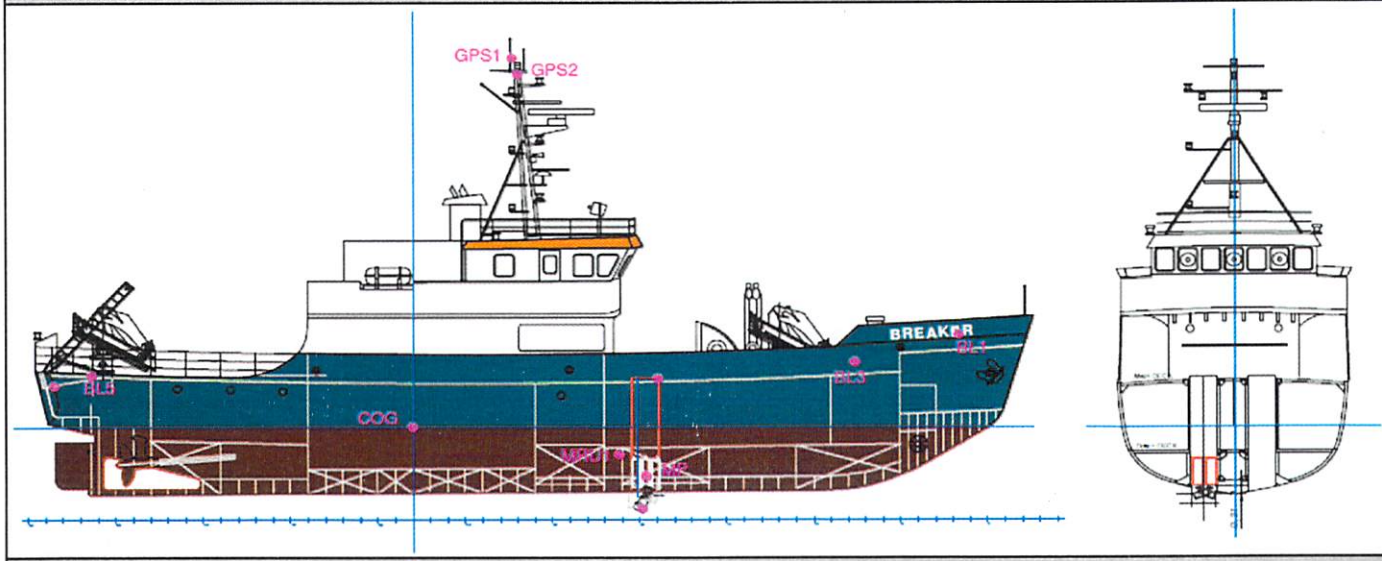
deep Hydrography & Geophysics

PROJECT No:	P2849	**SURVEYOR:**	Ratio survey
LOCATION:	Den Helder	**VESSEL:**	BREAKER
DATE:	22-01-2015	**REMARKS:**	
PAGE:	2 of 2		

Sideview



Offsets BREAKER

Name	Description	X	Y	Z	Remarks
A-frame PS	*rotation point*	*-1.917*	*-11.293*	*1.418*	
A-frame SB	*rotation point*	*1.886*	*-11.291*	*1.347*	
BL1	*Bollard SB forepeak*	*1.002*	*17.228*	*3.203*	
BL2	*Bollard PS forepeak*	*-1.013*	*17.213*	*3.186*	
BL3	*Bollard SB*	*2.489*	*13.967*	*2.247*	
BL4	*Bollard PS*	*-2.499*	*13.969*	*2.236*	
BL5	*Bollard SB aft*	*2.553*	*-10.113*	*1.775*	
BL6	*Bollard PS aft*	*-2.558*	*-10.094*	*1.808*	

Offsets MOONPOOL portside

Name	Description	X	Y	Z	Remarks
COG moonpool	*Centre of MRU baseplate*	*0.000*	*0.000*	*0.000*	
MRU2	*Octans 3000 phase centre*	*0.003*	*0.003*	*0.076*	
MB1	*Sonic 2024 acoustic centre*	*0.058*	*-0.072*	*-0.875*	*facing to portside*
MB2	*Sonic 2024 acoustic centre*	*-0.027*	*0.083*	*-0.869*	*facing to starboard*
Draft	*MiniSVS pressure sensor*	*-0.190*	*-0.027*	*-0.707*	

	23-01-2015	{Date}		{Date}
Checked (Deep BV):		**Witnessed (client):**	{SIGNATURE}	**Approved (client):** {SIGNATURE}

FIELD OPERATIONS

CALIBRATION - GYRO COMPASS

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deep Hydrography & Geophysics

PROJECT No:	P2849	**SURVEYOR:**	Ratio survey
LOCATION:	Den Helder	**VESSEL:**	Breaker
DATE:	22-01-15	**REMARKS:**	Octans Breaker
PAGE:	1 of 1		

Equipment									
Gyro compass:	☐	Octans I	☐	Octans III	☑	Octans IV	☐	Octans 3000TI III	☐ Octans 3000TI IV
	☐	ROVINS	☐	Hemisphere	☐	:			

Location	
Description quaywall:	*Nieuwe Diep, Den Helder.*
Known (or measured) benchmarks on quay or vessel:	*Timetagged position fixes of vessels bow and stern were taken by means of landsurvey techniques. For each position fix the vessel's TRUE heading was calculated and compared to the observed heading.*

Summarized results

Time	**Observed** gyro heading (TRUE)				**Calculated** vessel heading (TRUE)	C-O
14:23:04	126.32 °				126.63 °	*0.31*
14:23:32	126.32 °				126.60 °	*0.28*
14:24:23	126.91 °				127.24 °	*0.33*
14:25:06	126.48 °				126.74 °	*0.26*
14:25:44	126.32 °				126.61 °	*0.29*
14:26:14	126.35 °				126.65 °	*0.30*
14:26:42	126.31 °				126.60 °	*0.29*
14:27:15	126.22 °				126.51 °	*0.29*
14:27:52	126.29 °				126.56 °	*0.27*
14:28:21	126.47 °				126.77 °	*0.30*
14:29:08	126.36 °				126.67 °	*0.31*
14:29:50	126.36 °				126.66 °	*0.30*
14:30:20	126.36 °				126.66 °	*0.30*
14:31:13	126.48 °				126.78 °	*0.30*
14:32:21	126.42 °				126.74 °	*0.32*
					Averaged correction:	***0.30***

C-O entered in software: ***0.30*** °

	22-01-2015	{Date}		{Date}
Checked (Deep BV):		**Witnessed (client):**	{SIGNATURE}	**Approved (client):**

FIELD OPERATIONS

CALIBRATION - GYRO COMPASS

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deep Hydrography & Geophysics

PROJECT No:	P2849	**SURVEYOR:**	Ratio survey
LOCATION:	Den Helder	**VESSEL:**	Breaker
DATE:	22-01-15	**REMARKS:**	Octans Moonpool
PAGE:	1 of 1		

Equipment									
Gyro compass:	☐	Octans I	☐	Octans III	☐	Octans IV	☐	Octans 3000TI III	☑ Octans 3000TI IV
	☐	ROVINS	☐	Hemisphere	☐	:			

Location	
Description quaywall:	*Nieuwe Diep, Den Helder.*
Known (or measured) benchmarks on quay or vessel:	*Timetagged position fixes of vessels bow and stern were taken by means of landsurvey techniques. For each position fix the vessel's TRUE heading was calculated and compared to the observed heading.*

Summarized results

Time	**Observed** gyro heading (TRUE)				**Calculated** vessel heading (TRUE)	C-O
14:23:04	125.77 °				126.63 °	*0.86*
14:23:32	125.76 °				126.60 °	*0.84*
14:24:23	126.35 °				127.24 °	*0.89*
14:25:06	125.92 °				126.74 °	*0.82*
14:25:44	125.76 °				126.61 °	*0.85*
14:26:14	125.80 °				126.65 °	*0.85*
14:26:42	125.76 °				126.60 °	*0.84*
14:27:15	125.67 °				126.51 °	*0.84*
14:27:52	125.73 °				126.56 °	*0.83*
14:28:21	125.91 °				126.77 °	*0.86*
14:29:08	125.80 °				126.67 °	*0.87*
14:29:50	125.81 °				126.66 °	*0.85*
14:30:20	125.81 °				126.66 °	*0.85*
14:31:13	125.92 °				126.78 °	*0.86*
14:32:21	125.86 °				126.74 °	*0.88*
					Averaged correction:	***0.85***

C-O entered in software: ***0.85*** °

	22-01-2015		{Date}		{Date}
Checked (Deep BV):		**Witnessed (client):**	{SIGNATURE}	**Approved (client):**	{SIGNATURE}

FIELD OPERATIONS

CALIBRATION - MOTION SENSOR

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deep Hydrography & Geophysics

PROJECT No:	P2849	**SURVEYOR:**	Ratio survey
LOCATION:	Den Helder	**VESSEL:**	BREAKER
DATE:	22-01-15	**REMARKS:**	Octans Breaker
PAGE:	1 of 1		

Equipment	
Motion sensor:	*Octans IV*
QINSy driver:	*Ixsea_Octans_TAH_UTC*

Rotation conventions		**Delay (QINSy)**	
Pitch	*Positive bow down*	Latency:	*0 sec.*
Roll	*Positive heeling starboard*	Heave delay:	*0 sec.*
Heave	*Positive upwards*		

Alignment corrections

	Observed (average)	Standard Deviation	Calculated	Correction (C-O)	Remarks
Roll	*-1.12* °	*0.21* °	*-1.35* °	***-0.23*** °	
Pitch	*0.66* °	*0.01* °	*-0.27* °	***0.94*** °	
Heave	*0.00* m.	*0.01* m.	*0.00* m.	***0.00*** m.	

Duration of the measurements:	*10*	min.	*(20 observations)*

	22-01-2015		{Date}		{Date}
Checked (Deep BV):		**Witnessed (client):**	{SIGNATURE}	**Approved (client):**	{SIGNATURE}

FIELD OPERATIONS

CALIBRATION - MOTION SENSOR

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deep Hydrography & Geophysics

PROJECT No:	P2849	**SURVEYOR:**	Ratio survey
LOCATION:	Den Helder	**VESSEL:**	BREAKER
DATE:	22-01-15	**REMARKS:**	Octans Moonpool
PAGE:	1 of 1		

Equipment	
Motion sensor:	*Octans 3000TI IV*
QINSy driver:	*Ixsea_Octans_TAH_UTC*

Rotation conventions		**Delay (QINSy)**	
Pitch	*Positive bow down*	Latency:	*0 sec.*
Roll	*Positive heeling starboard*	Heave delay:	*0 sec.*
Heave	*Positive upwards*		

Alignment corrections

	Observed (average)	Standard Deviation	Calculated	Correction (C-O)	Remarks
Roll	*-1.71* °	*0.21* °	*-1.35* °	***0.36*** °	
Pitch	*0.60* °	*0.01* °	*-0.27* °	***0.87*** °	
Heave	*0.00* m.	*0.01* m.	*0.00* m.	***0.00*** m.	

Duration of the measurements:	*10*	min.	*(20 observations)*

	22-01-2015	{Date}		{Date}
Checked (Deep BV):		**Witnessed (client):**	{SIGNATURE}	**Approved (client):** {SIGNATURE}

FIELD OPERATIONS

CALIBRATION - POSITION CHECK

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deep Hydrography & Geophysics

PROJECT No:	P2849	**SURVEYOR:**	DBR
LOCATION:	Den Helder	**VESSEL:**	BREAKER
DATE:	22-1-2015	**REMARKS:**	Primary positioning system
PAGE:	1 of 1		

Positioning system									
Brand:	*Trimble*	Type:	☑	RTK	☐	dGPS	☑	06-GPS	☐ Marinestar
Antenna height:	*1.38* m.								

Situation Sketch

Pointnumber: *Bollard III (Den Helder, Nieuwe Diep)*

No of observations:	*2894*
Logfile:	*150122_Position check 06GPS-RTK - 0001.db*

Coordinates known station		**Measured coordinates**		**Position difference**	
X:	*619952.637*	X:	*619952.61*	ΔX:	***-0.03*** m.
Y:	*5868281.416*	Y:	*5868281.39*	ΔY:	***-0.03*** m.
Z:	*4.771*	Z:	*4.77*	ΔZ:	***0.00*** m.

Local datum	
Horizontal datum:	*UTM31N ETRS89*
Vertical reference:	*LAT*

	22-01-2015	{Date}	{Date}
Checked (Deep BV):		Witnessed (client):	Approved (client):

VERSION: 121205
#N/A

FIELD OPERATIONS

LOGSHEET - BENCHMARK

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PROJECT No:	P2849	**BENCHMARK NAME**	B3
LOCATION:	Den Helder	**SURVEYOR:**	KHE
DATE:	22/01/2015	**REMARKS:**	Bollard III
PAGE:	1 of 1		

Benchmark description

Marker on bollard III in Den Helder, alongside quay. Benchmark created by RTK backpack. Equipment used: Novatel GNSS RTCMV3 using 06-GPS corrections (≤3cm accuracy)

Situation Sketch

Coordinates projection		Coordinates geographical	
X:	*619952.637*	Latitude:	*52.950728911 N*
Y:	*5868281.416*	Longitude:	*004.785440587 E*
Z:	*4.771*	Height:	*45.726*
Projection:	*UTM31N*	Ellipsoid:	*WGS84*
Datum:	*ETRS89*		

Remarks

Position established after 30 minutes of logging

Checked (Deep BV): 22/01/2015 **Approved (client):**

FIELD OPERATIONS

CALIBRATION - POSITION CHECK

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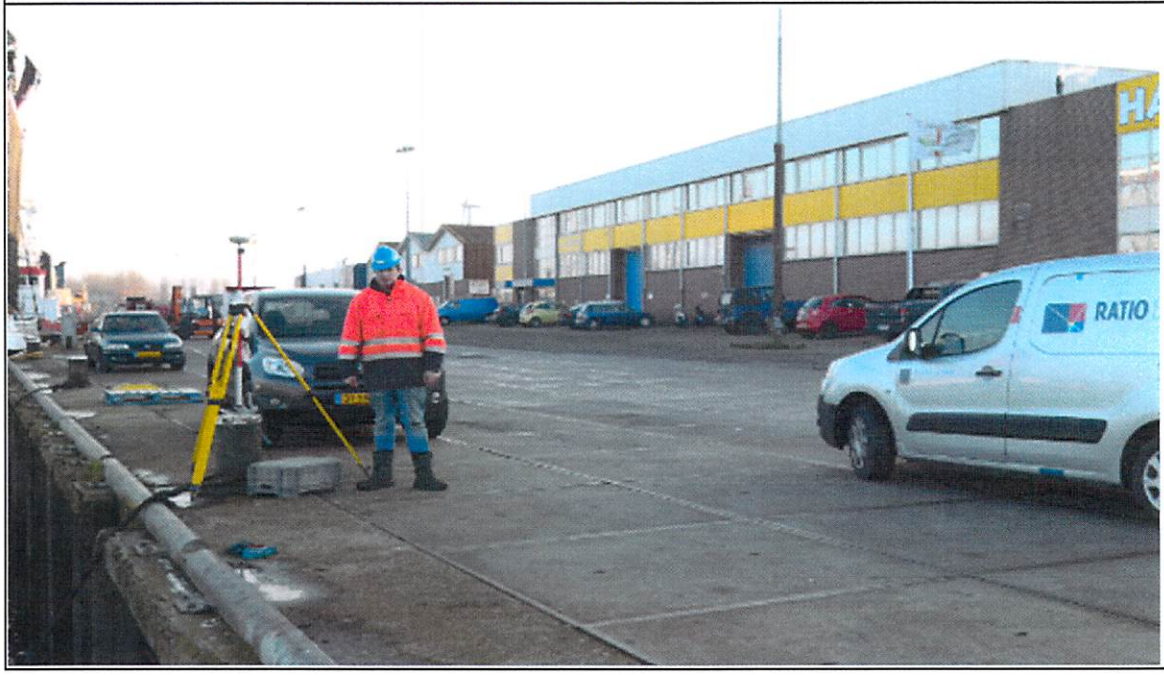
PROJECT No:	P2849	**SURVEYOR:**	DBR
LOCATION:	Den Helder	**VESSEL:**	BREAKER
DATE:	22-1-2015	**REMARKS:**	Secondary positioning system
PAGE:	1 of 1		

Positioning system									
Brand:	*Trimble*		Type:	☑	RTK	☐	dGPS	☐	06-GPS	☑	Marinestar
Antenna height:	*1.38*	m.									

Situation Sketch

Pointnumber: *Bollard III (Den Helder, Nieuwe Diep)*



No of observations:	*2892*
Logfile:	*150122_Position check Marinestar - 0001.db*

Coordinates known station		**Measured coordinates**		**Position difference**	
X:	*619952.637*	X:	*619952.57*	ΔX:	***-0.07*** m.
Y:	*5868281.416*	Y:	*5868281.34*	ΔY:	***-0.08*** m.
Z:	*4.771*	Z:	*4.82*	ΔZ:	***0.05*** m.

Local datum	
Horizontal datum:	*UTM31N ETRS89*
Vertical reference:	*LAT*

	22-01-2015		{Date}		{Date}
Checked (Deep BV):		**Witnessed (client):**	{SIGNATURE}	**Approved (client):**	{SIGNATURE}

FIELD OPERATIONS

CALIBRATION - PRESSURE/ALTIMETER MAGNETOMETER

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WWW.DEEPBV.NL

deep Hydrography & Geophysics

PROJECT No: P2849
LOCATION: Den Helder
DATE: 22-1-2015
PAGE: 1 of 1

SURVEYOR: KHE/MKO
VESSEL: Breaker
REMARKS:

Equipment				
Brand:	*Geometrics*	Factory calibration settings	Scale factor	Bias
Type:	*G-882*	Salt water (pressure)	*0.016340*	*-1.63*
S/N:	*882651*	Fresh water (pressure)	*0.016666*	*-1.67*
		Altimeter	*0.00315*	*-0.66*

Pressure sensor verification				
Known depth [m]		Measured raw values	Depth derived from factory calibration settings	Difference
Towfish	Seabed			
1.40	*8.20*	*183*	*1.36* m	*0.04*
2.90	*8.20*	*276*	*2.88* m	*0.02*
4.50	*8.20*	*374*	*4.48* m	*0.02*
6.10	*8.20*	*474*	*6.12* m	*0.02*

Altimeter verification				
Known depth [m]		Reported altitude using factory calibration	Altitude + known depth towfish	Difference
Towfish	Seabed			
1.40	*8.20*	*6.69* m	*8.09* m	*0.11*
2.90	*8.20*	*5.21* m	*8.11* m	*0.09*
4.50	*8.20*	*3.77* m	*8.27* m	*0.07*
6.10	*8.20*	*2.22* m	*8.32* m	*0.12*

Conclusion

Factory settings are accepted and implemented

23-01-2015

Checked (Deep BV): **Witnessed (client):** {SIGNATURE} **Approved (client):** {SIGNATURE}

FIELD OPERATIONS

CALIBRATION - LATENCY CHECK SBP

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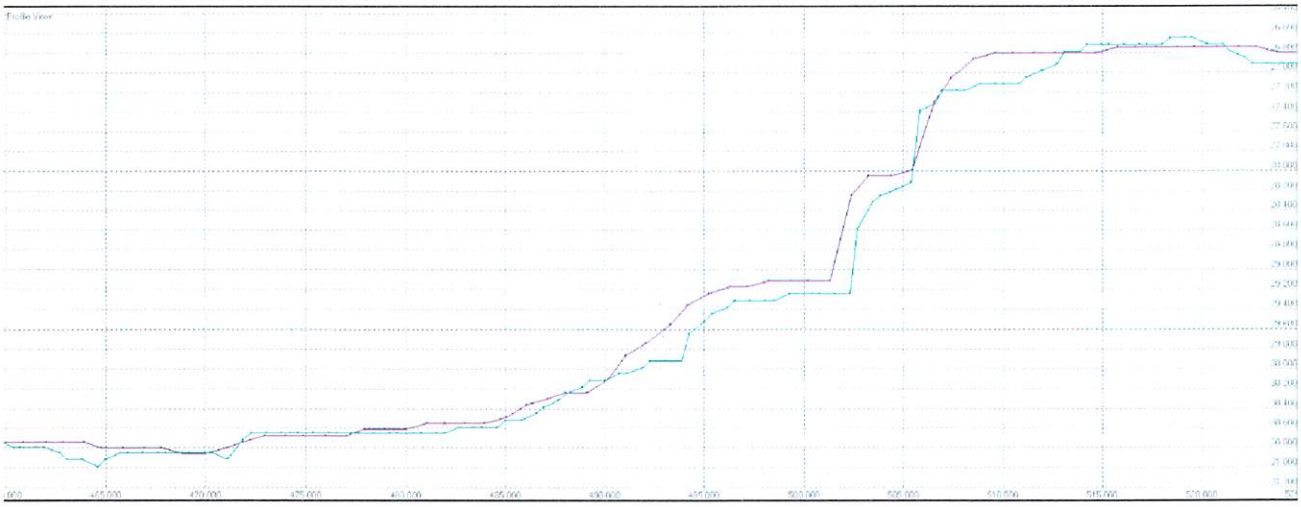
PROJECT No:	P2849	**SURVEYOR:**	KHE/MKO
LOCATION:	Den Helder	**VESSEL:**	Breaker
DATE:	25-1-2015	**REMARKS:**	
PAGE:	1 of 1		

Equipment	
Brand: *Innomar*	Settings
Type: *SES-STANDARD*	*High frequency 110 Hz* *Waterdepth: 29m.*



Conclusion
During the patch test 2 lines were sailed in opposite direction with a vessel speed of 6 knots *The results are shown in the profile above. The average latency is 1 meter, when divided by the two way travel distance.*

Checked (Deep BV):	25-01-~~2015~~	**Witnessed (client):**	AGS	**Approved (client):**	AGS

FIELD OPERATIONS

CALIBRATION - USBL

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deep Hydrography & Geophysics

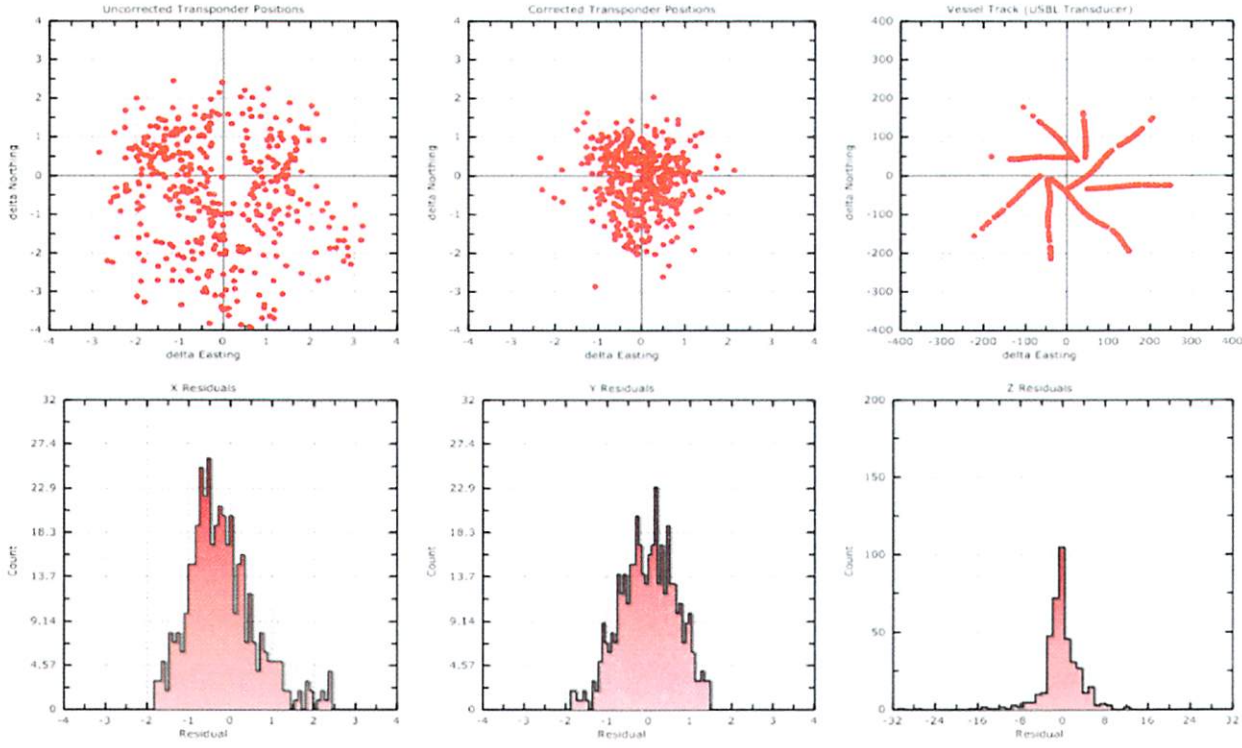
PROJECT No:	P2849	**SURVEYOR:**	SBR
LOCATION:	Petten	**VESSEL:**	Breaker
DATE:	23-1-2015	**REMARKS:**	none
PAGE:	1 of 1		

Equipment					
USBL System:	*Kongsberg HIPAP*	Type:	*350*		
Transducer offset:	*-2.83* m.	☑	Offsets to COG entered in USBL		
Calibration method:	☑ Absolute	☐	Relative	Soundvelocity:	*1463.0* m/s

Statistics		
Number of USBL observations	*634*	*100%*
Number of used observations	*449*	*78%*
Number of disabled observations	*135*	*21%*

Calibration results		
Parameter	Value	SD
Scale Factor	*1*	*N/A*
Roll Angle	*-1.624*	*2.080°*
Pitch Angle	*-1.025*	*0.652°*
Heading Angle	*1.104*	*0.563°*

Transponder position		
Coordinate	Value	SD
Easting	*602273.651*	*N/A*
Northing	*5851289.835*	*N/A*
Height	*-25.782*	*N/A*



	23-01-2015		{Date}		{Date}
Checked (Deep BV):		Witnessed (client):		Approved (client):	

FIELD OPERATIONS

CALIBRATION SIDE SCAN SONAR

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deep Hydrography & Geophysics

PROJECT No:	P2849	**SURVEYOR:**	KHE/MKO
LOCATION:	Petten	**VESSEL:**	Breaker
DATE:	23-1-2015	**REMARKS:**	
PAGE:	1 of 1		

Equipment	
Sidescan sonar	**USBL**
Brand: *EdgeTech*	Brand: *Kongsberg*
Type: *4200*	Type: *HIPAP 350 P*
☑ Rub test exectued	Latency: *0.0033* sec
Sound velocity: *1468.44 m/s*	

Absolute positioning check			
	Method	Logfiles	
☑ Latency	two lines in opposite direction over a seabed feature	*00005-0002* *00008-0001*	

Results		
Object	**Found difference in horizontal positioning**	
1	2.35 m.	
2	0.53 m.	

The result of this check is within quality requirements.
An additional check will be performed in the survey area.

23-01-2015

Checked (Deep BV): **Witnessed (client):** {SIGNATURE} **Approved (client):** {SIGNATURE}

FIELD OPERATIONS

CALIBRATION - MULTIBEAM DUALHEAD

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deep Hydrography & Geophysics

PROJECT No:	P2849	**SURVEYOR:**	SBR
LOCATION:	Texelstroom	**VESSEL:**	Breaker
DATE:	24-1-2015	**REMARKS:**	
PAGE:	1 of 1		

Equipment

Multibeam: ☐ Seabat 8101 ☐ Seabat 8125 ☐ R2Sonic 2022 ☑ R2Sonic 2024 ☐ :
☐ SeaSwath+ H ☐ Seaswath+ M

Frequency: *260/320* kHz

☑ PPS input ☑ Roll stabalized ☑ Sound Velocity at head

Calibration results portside

	Method	Logfiles	Correction
☑ Latency	Perpendicular to slope, different speed	*14* – *16*	*0.00* sec.
☑ Roll	Deep & flat bottom, opposite directions, same speed	*5* – *6*	*18.09* °
☑ Pitch	Perpendicular to slope, opposite sailing direction, same speed	*6* – *7*	*2.25* °
☑ Yaw	Perpendicular to slope or typical feature, same direction, same speed 50 % overlap in swath, slope or typical feature in the overlap	*6* – *8*	*0.00* °

Calibration results starboard

	Method	Logfiles	Correction
☑ Latency	Perpendicular to slope, different speed	*14* – *16*	*0.00* sec.
☑ Roll	Deep & flat bottom, opposite directions, same speed	*9* – *10*	*-20.32* °
☑ Pitch	Perpendicular to slope, opposite sailing direction, same speed	*10* – *11*	*0.55* °
☑ Yaw	Perpendicular to slope or typical feature, same direction, same speed 50 % overlap in swath, slope or typical feature in the overlap	*10* – *12*	*-0.60* °

	24-01-2015		{Date}		{Date}
Checked (Deep BV):		**Witnessed (client):**	{SIGNATURE}	**Approved (client):**	{SIGNATURE}

FIELD OPERATIONS

PERFORMANCE TEST

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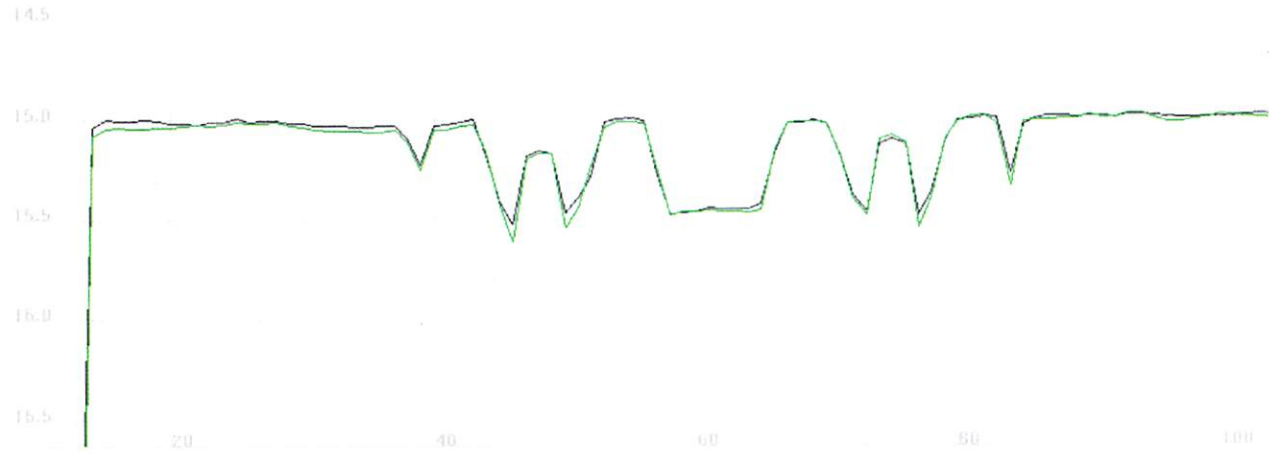
deep Hydrography & Geophysics

PROJECT No:	P2849	**SURVEYOR:**	SBR
LOCATION:	IJmuiden / Texelstroom	**VESSEL:**	Breaker
DATE:	25-1-2015	**REMARKS:**	
PAGE:	1 of 1		

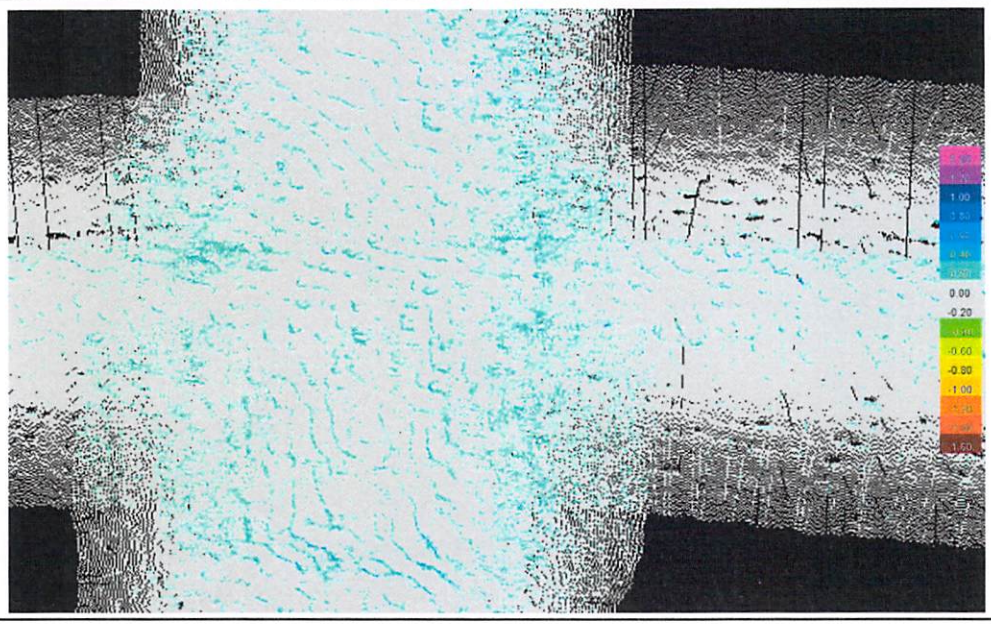
Absolute depth check

Known object: Noordersluis IJmuiden
Found difference: 5 cm

Black: Known level
Green: Data Breaker



Repeatability check



Depth:	-28 LAT
lines	7
TVU IHO 1a:	56 cm
TVU measured:	20 cm

Conclusion

The measured absolute depth is not exceeding 5 cm.
Repeatability is better than the IHO 1a standard.

25-01-2015	{Date}	{Date}
Checked (Deep BV):	Witnessed (client): {SIGNATURE}	Approved (clier {SIGNATURE}

APPENDIX B

VESSEL GEOMETRY REPORT (RATIO SURVEY)

MV. BREAKER

GEOMETRY
SURVEY REPORT

Offset survey and calibrations

Den Helder (The Netherlands)

Client: DEEP B.V.

Survey date: 2015/01/15

DOCUMENT- AND REVISION

Ratio Survey B.V.
Postbus 252
3860 AG NIJKERK
info@ratiosurvey.nl

Ratio Survey
Johan van Hasseltweg 39-N
1021 KN AMSTERDAM
www.ratiosurvey.nl

Projectnumber Ratio Survey:	14083
Revisie:	A0
Date:	2015-01-24

Version: A	Document: 14083 A0 150126 MR Geometry Survey Report			
		Date		Definition change
Compiled by:	K. Bontje	2015-01-26	KBo	Original document
Checked by:	P. Vermeer		PVe	Spread:
				Client

INDEX

1 INTRODUCTION

This report concerns the offset survey of all relevant survey points and the calibration of the motion sensors in Den Helder on board the MV Breaker.
The following objects were surveyed as discussed with Daniëlle Brandwijk prior to the survey.

Deliver offset Positions with X,Y,Z from the CRP (1) of the following:

Nr	Instrument	Manifacturer	Type
1	Multibeam	R2 Sonic	RS2024
2	Octans	IXBlue	
3	Sound Velocity Profiler	Valeport	Mini SVS
4	Sub-bottom profiler	Innomar	SES-2000
5	GPS	Trimble	SPS855
6	USBL	Kongsberg	HIPAP 351P
7	Reference points across the ship		
8	To deliver the Vessel Roll C-O, Vessel Roll time stamped Log files will be provided by the Vessel Surveyors		
9	To deliver the Vessel Pitch C-O, Vessel Pitch time stamped Log files will be provided by the Vessel Surveyors.		

NB 1. The position of the Coordinate Reference Point (CRP) is an arbitrary point positioned on the intersection of the 3 coordinate centerlines of the vessel.

2 SUMMARY

From the survey the following data became apparent:

- The position of the sensors in the SRF, when the moonpools are lowered down.
- The position of the GPS-antennas in the SRF
- The position of reference points in the SRF.

2.1 Accompanying documents

This report was supplied with the following documents:

- Instrument specification See Appendix I
- Lay out of mv Breaker
- Computation in the survey network can be supplied upon request

2.2 Coordinate system

The SRF was defined as follows:

- X-axis is positive over starboard and perpendicular to the Y/ Z-plane. [1)]
- Y-axis is positive over the bow and perpendicular to the X/ Z-plane. [2)]
- Z-axis is positive upwards and perpendicular to the X/Y plane. [3)]
- Origin is the CRP (0,0,0).

[1)] The X-axis was determined on the frame near the center of the vessel.
[2)] The Y-axis was determined from the easily identifiable point of the centerline and the ships contour.
[3)] The Z-axis was determined on the deck, over a length of 12 meters from the stern.

2.3 Survey location and date

All offsets were surveyed on January 21st and January 22nd, 2015. During the survey the vessel was afloat at quay near Het Nieuwe Diep in Den Helder, The Netherlands.

2.4 Survey method

The offset survey has been carried out by tachymetry under dynamic (while vessel afloat) conditions using a robotic total station Geomax Zoom80 2".

2.4.1 Methods

Tachymetry measures objects in 3D, with a point cloud as result. For this a series of stations is created on the object in a way that each point of interest is measured at least once, but twice or more for high reliability. Points that require the highest accuracy are marked with retro reflective targets. Within dedicated geodetic network adjustment software the observations from the total station are processed using a least squares routine, solving their relative positions in 3D.
The whole project is rotated and translated to get a convenient coordinate system.
The final product created is a point cloud which not only includes ID, description and X, Y and Z -coordinates, but also several quality indicators as explained below under QA/QC.

2.5.2 Equipment

Tachymetry (Pitch, Roll, and on board survey) is conducted using a Geomax Zoom80 2" (Appendix I).

2.5.3 Processing

All tachymetric data is processed in Move3 using a least squares network adjustment. Calibrations are processed in dedicated – in-house developed – software.

2.6 Weather conditions

During the surveys it was about 0°C, sunny, with winds up to 3Bft.

3 QA/QC

DEEP and Ratio Survey aim for the highest quality. The quality of the measurement is checked afterwards (QC), and care is taken to assure high quality survey prior to the survey (QA).

3.1 Quality Assurance

The quality assurance comprises of:

- All main points are measured with enough redundancy, in which is taken account of the amount of redundancy to obtain high reliability. This means that each point is preferably measured more than once, which preferably will be taken from different stations.
- For consistency no offsets during measurements are used.
- All offset data is adjusted using least squares routines by which any defects will be detected.
  In addition to that quality parameters are generated automatically and incorporated into the report:
  - X, Y and Z standard deviations (1σ, 68%)
  - The number of observations.
- Calibrations are preferably done dynamically and double. By calibrating dynamically not only the alignment offsets are found but also the correct sign for them.

3.2 Quality control

Least squares adjustment
The least squares adjustment closed successfully with the following parameters:

Input	
Idealisation precision X/Y	0.0010 m
Idealisation precision Z	0.0010 m
Output	
Maximum F-toets *	1,030
F-toets *	0,385
Maximum W-toets	3,290
W-toets (lowest)	-1,700
W-toets (largest)	+1,450

*) With tachymetry the Test value is the F-toets. In both cases this value should be smaller than 1 to indicate that the observations fit the expected/applied accuracies.

4 GEOMETRY LIST

When after a re-survey it is required to change the origin of the vessel the coordinates in both the old and new situation will be given.

4.1 Existing SRF

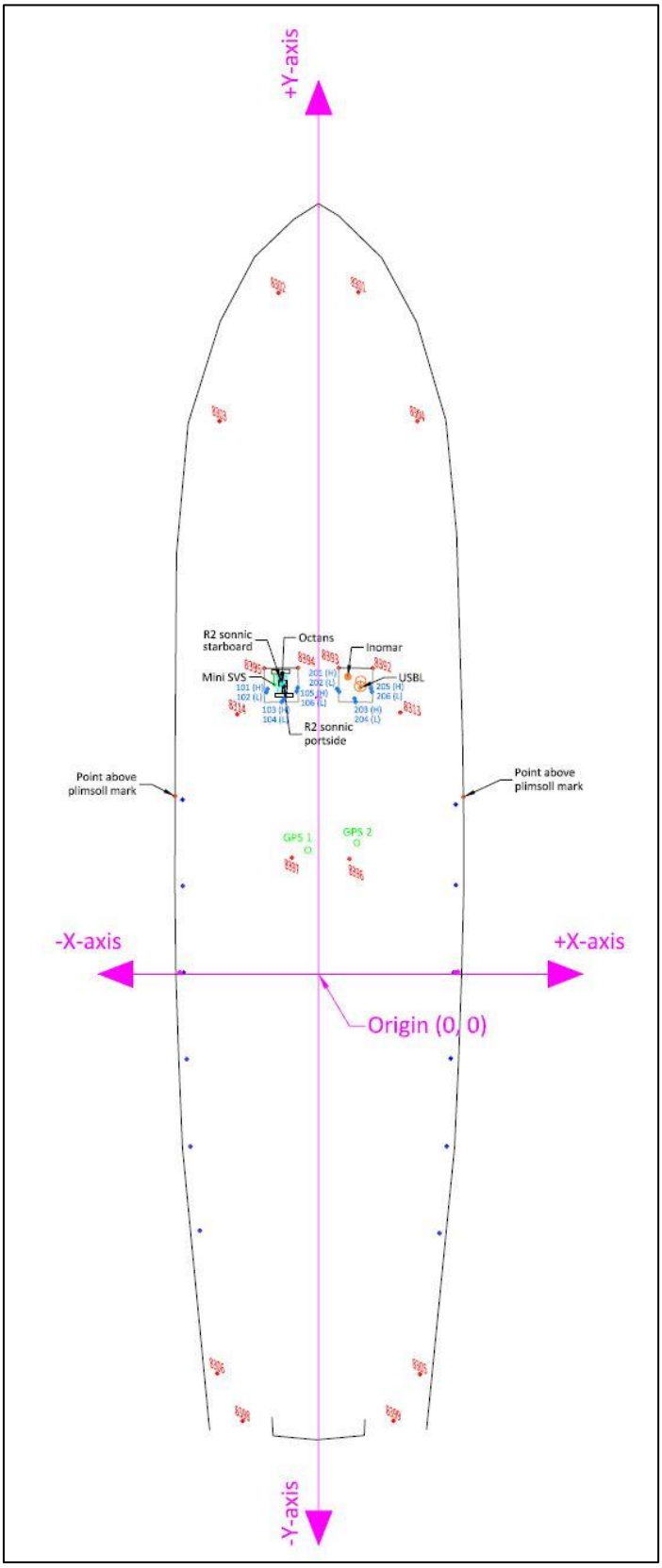
Based on the existing SRF the coordinates are as follows:

POINTNUMBER	X [M]	Y [M]	Z [M]	DESCRIPTION
USBL	1,043	7,229	-2,834	
Inomar	0,734	7,511	-2,572	
R2 sonnic	-0,868	7,269	-2,553	Port side aimed
R2 sonnic	-0,953	7,424	-2,546	Starboard aimed
Mini SVS	-1,114	7,313	-2,383	
Octans	-0,926	7,341	-1,679	Height is measured on the underside of the octans
GPS-1	-0,269	3,135	12,792	Height is measured on the underside of the antenna
GPS-2	0,962	3,317	12,219	Height is measured on the underside of the antenna

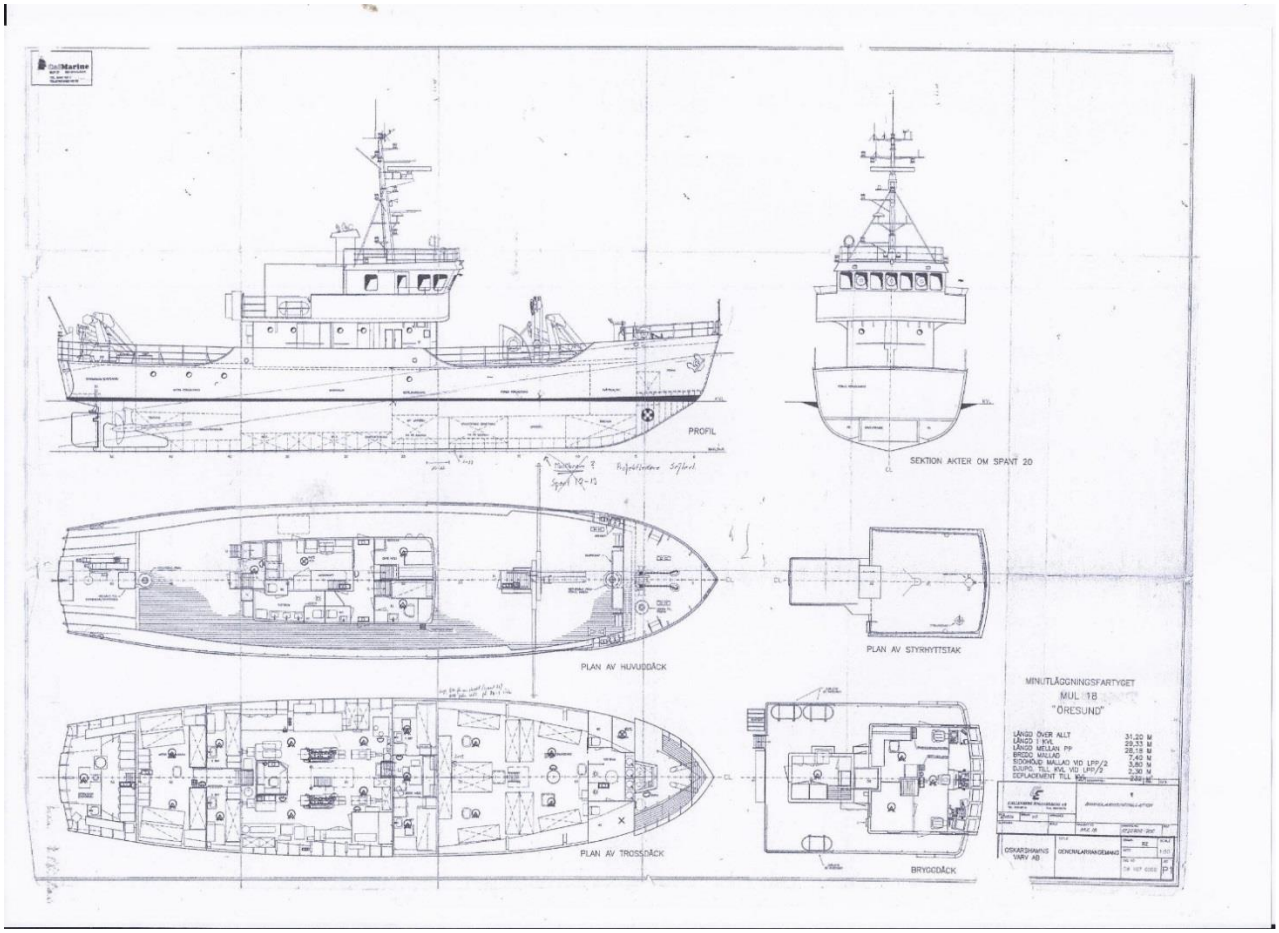
POINTNUMBER	X [M]	Y [M]	Z [M]	DESCRIPTION
8301	1,001	17,229	3,204	Center point in bolder
8302	-1,014	17,213	3,188	Center point in bolder
8303	-2,500	13,969	2,239	Center point in bolder
8304	2,488	13,968	2,248	Center point in bolder
8305	2,553	-10,110	1,778	Center point in bolder
8306	-2,558	-10,092	1,813	Center point in bolder
8313	2,056	6,606	6,871	Reflective tape on railing
8314	-2,051	6,560	6,896	Reflective tape on railing
8392	1,366	7,728	1,662	Center in metal strip around top moonpool
8393	0,507	7,734	1,670	Center in metal strip around top moonpool
8394	-0,520	7,733	1,666	Center in metal strip around top moonpool
8395	-1,376	7,726	1,657	Center in metal strip around top moonpool
8396	0,777	2,909	11,153	Hart point bolt in antenna pole
8397	-0,673	2,938	11,181	Hart point bolt in antenna pole
8398	-1,916	-11,294	1,421	Center rotation point A-frame port side
8399	1,886	-11,289	1,351	Center rotation point A-frame starboard
Plimsoll	-	4,474	1,324	Line above Plimsoll mark starboard
Plimsoll	-	4,493	1,305	Line above Plimsoll mark portside

4.2 Point overview

A more detailed overview is included with appendix 2.



Point overview (TOP)



General arrangement MV Breaker

5 CALIBRATIONS

On board of the cs. Breaker the motion sensor (pitch and roll) has been calibrated:

5.1 Calibration heavecompensator

Onboard of the vessel is heave compensator, which provides pitch, roll and heave to the survey system. The sign convention of the sensors was determined as it was defined in the hardware.

Roll: Starboard down = +
Pitch: Bow up = +

5.1.1 Roll

Calibration of the Roll is done by tachymetry from an onshore position.
Two points measured and calculated in the vessel geometry are marked at the sternside of the vessel.
Because these points are known in the vessel geometry, the difference in height and vertical angle between these points and the reference baseline can be calculated.
These points can now be measured from a level onshore position.
By repetative measurements on these points from onshore the vertical angle between these points can be given.
This can be compared to the onboard pitch indicator.

The Roll is a calculated average from 20 readings from RS:

Computed	RS/LM	-0.330 dec. degrees
Observed	Breaker	
C/O		

5.1.2 Pitch

Calibration of the Pitch is done by tachymetry from an onshore position.
Two points measured and calculated in the vessel geometry are marked at the starboardside of the vessel.
Because these points are known in the vessel geometry, the difference in height and vertical angle between these points and the reference baseline can be calculated.
These points can now be measured from a level onshore position.
By repetative measurements on these points from onshore the vertical angle between these points can be given.
This can be compared to the onboard pitch indicator.

The Pitch is a calculated average from 20 readings from RS/LM:

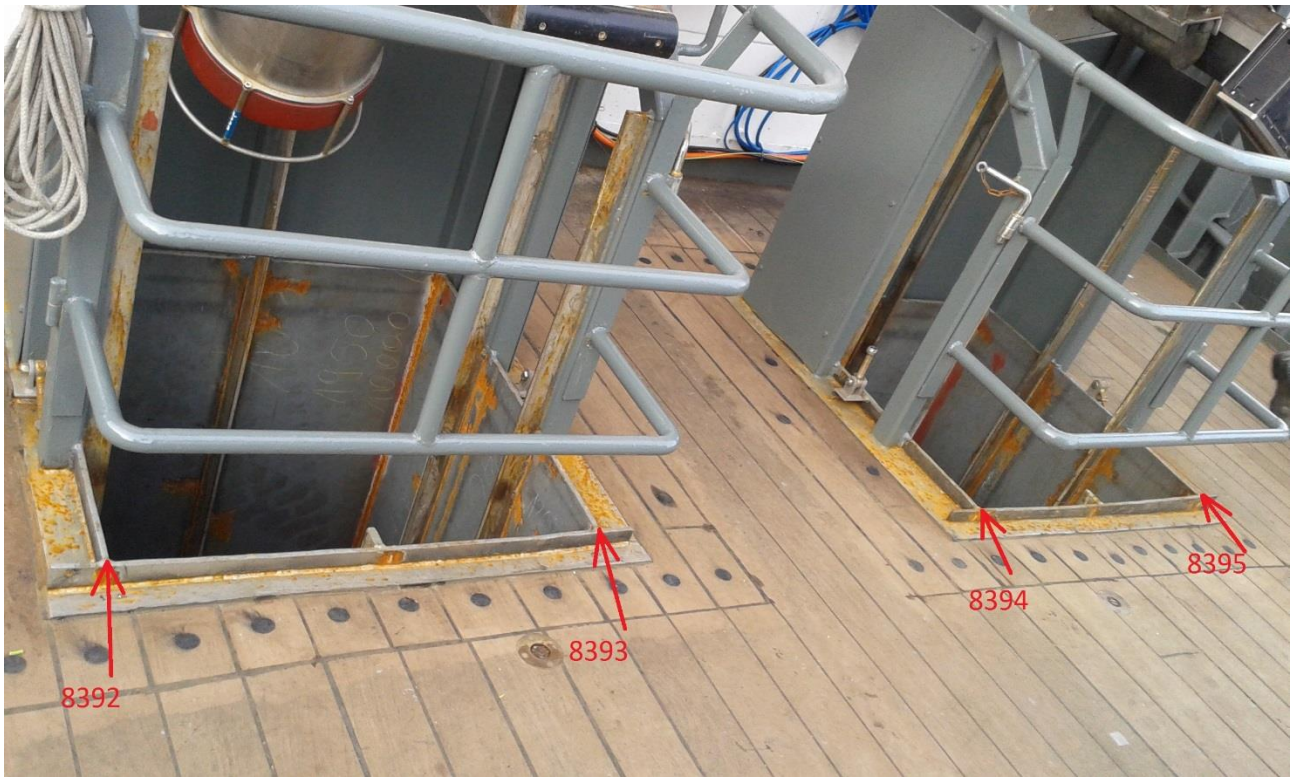
Computed	RS/LM	-4.644 dec. degrees
Observed	Breaker	
C/O		

6 TARGET OFFSETS

The requested points are always measured directly on the point.
When the point is not visible (for example hart of antenna) the item is measured at more points (4 points at the side), so the heart point can be calculated.

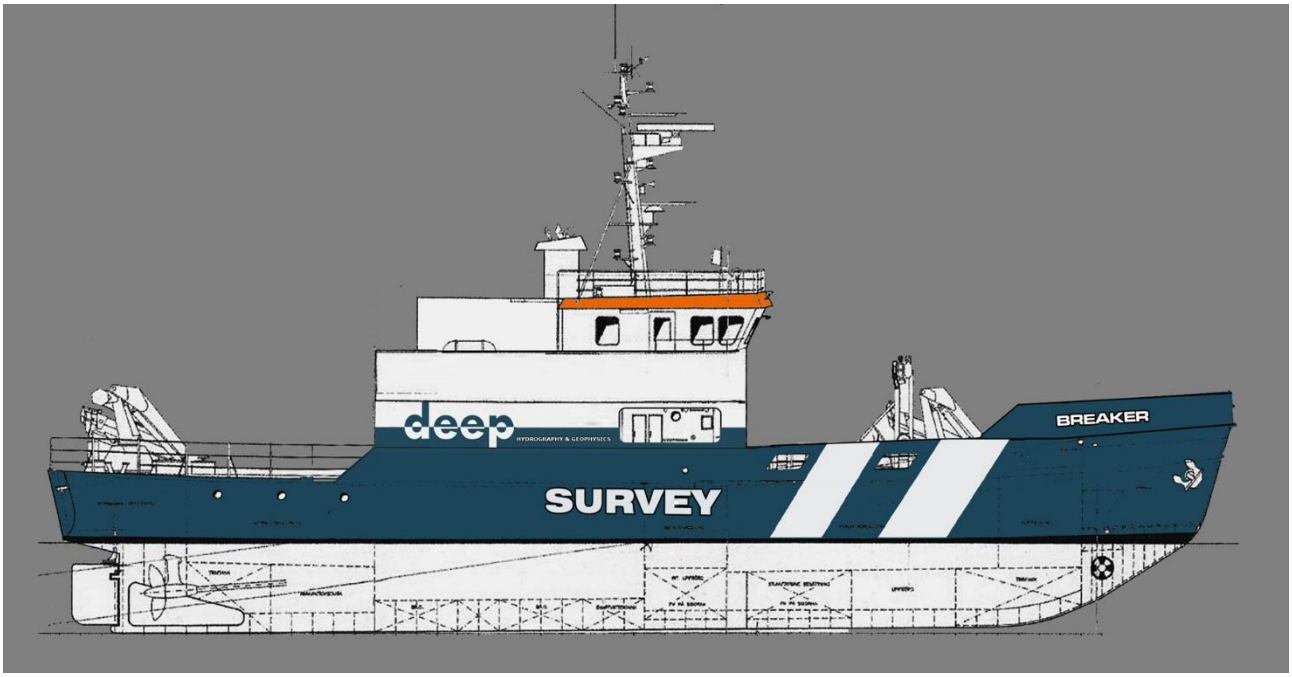
7 PICTURES

Picture 1:Indication of location of survey points in mast



Picture 2:Indication of location of survey points near moonpool

GENERAL PICTURES


deep
HYDROGRAPHY & GEOPHYSICS
SURVEY
BREAKER

MOONPOOL AND SENSORS (1)

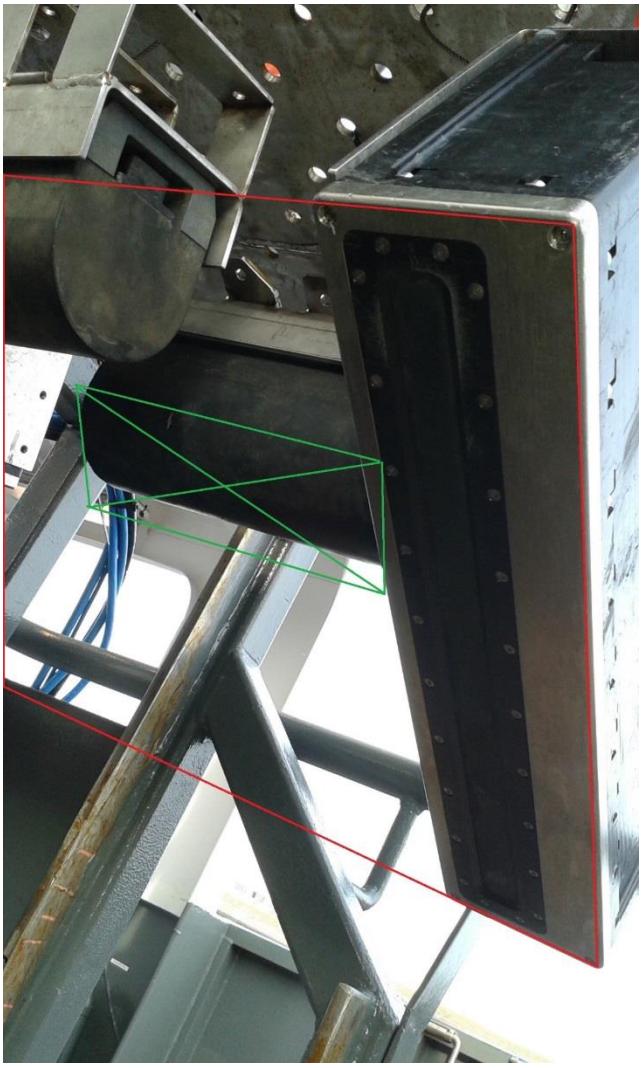
MOONPOOL AND SENSORS (2)

MOONPOOL AND SENSORS (3)

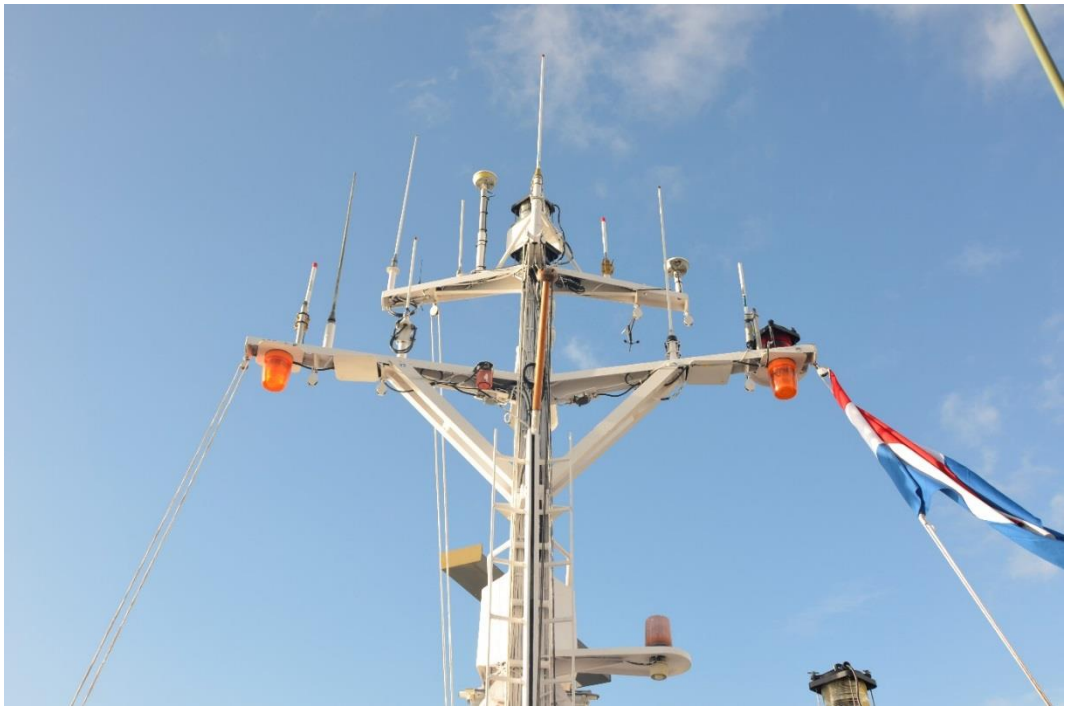
MOONPOOL AND SENSORS(4)

MOONPOOL AND SENSORS(5)

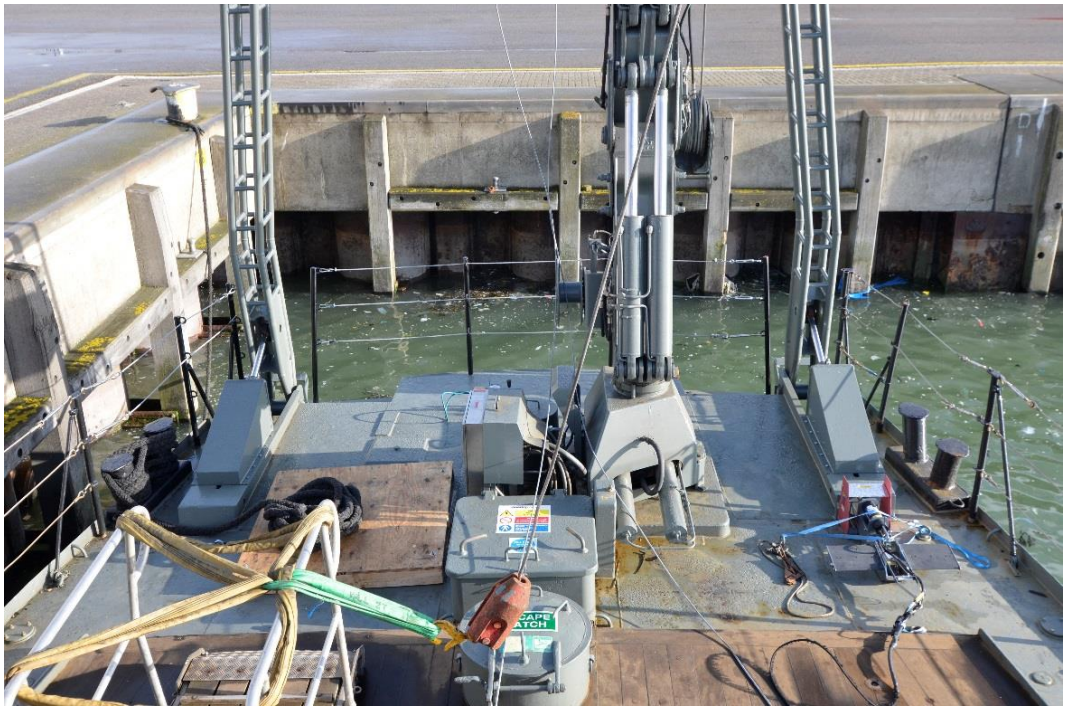
MOONPOOL AND SENSORS (6)



MAST AND ANTENNAE



AFT DECK



8 APPENDICES

I Specifications EDM
II Geometry plot MV Breaker

Robotic Total Station
Zoom80 Series

STReAM360
- **S**cout – Auto Find
- **TR**ack – Auto Tracking
- **AiM** – Auto Targeting

Long Range Bluetooth
- High-Speed Data Link
- Reliable Connectivity
- License Free

Powerful Handheld
- Inbuilt Camera (3 M Pixel)
- Compass & Altimeter
- Long-range Bluetooth®

ZOOM80

PART OF HEXAGON

GEOMAX

Zoom80 Series

Find your target, follow it and measure with constant accuracy – the three steps you repeat continously with every single measurement. Now fully automatically done by your total station incorporating the new STReAM technology, that "works when you do".

STReAM360

- **S**cout – finds your passive prism fully automatically
- **TR**ack – continously follows your prism
- **AiM** – highest precision aiming at your prism – any time, any condition with constantly high accuracy

Together with the additional incredible features such as 1,000 m reflectorless measurement capability, Navigation light and 1" accuracy, this robotic total station boosts you performance and accuracy all day long – day by day.

Zoom80S	One Man Servo TRack360, AiM360
Zoom80R	One Man Fully Robotic Scout360, TRack360, AiM360

Angle measurements

Accuracy	1" (0.3 mgon), 2" (0.6 mgon), 5" (1.5 mgon)
Display resolution	0.1" (0.1 mgon)
Method	Absolute, continuous, diametrical
Compensation	Quadruple axis

Distance measurements

Prism	3,500 m / 1 mm + 1.5 ppm
Long-range	10,000 m / 5 mm + 2 ppm
Reflectorless	1,000 m / 2 mm + 2 ppm *

Interfaces

Keyboard	Dual with 34 keys, illuminated
Display	¼ VGA colour LCD, touch screen
Data recording	Removable CF-card
Bluetooth	Device Class II, long-range
Interface	Serial & external power

Distance meter (Reflector Mode): Laser class 1 in accordance with IEC 60825-1 resp. EN 60825-1; **Laser plummet:** Laser class 2 in accordance with IEC 60825-1 resp. EN 60825-1, **Distance meter (Reflectorless Mode accXess™):** Laser class 3R in accordance with IEC 60825-1 resp. EN 60825-1

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Power supply

Internal battery	Removable Li-Ion 4.4 Ah / 7.4 V
Operating time	Typically 6 – 8 h
External power	11.5 V to 13.5 V DC

Physical specifications

Weight	5.5 kg when fully equipped
Operating temp.	–20°C to 50°C
Storage temp.	–40°C to 70°C
Protection class	IP54 dust- and waterproof
Humidity	95 %, non-condensing

Handheld

Operating system	Microsoft Windows Mobile®
Memory	Up to 16 GB
Ports	Serial, USB, expansion slot for long-range Bluetooth® cap, Bluetooth®, WLAN
Operating time	Up to 9 hours
Weight	2.7 kg (pole, prism, handheld)

* > 500 m: 4 mm + 2 ppm

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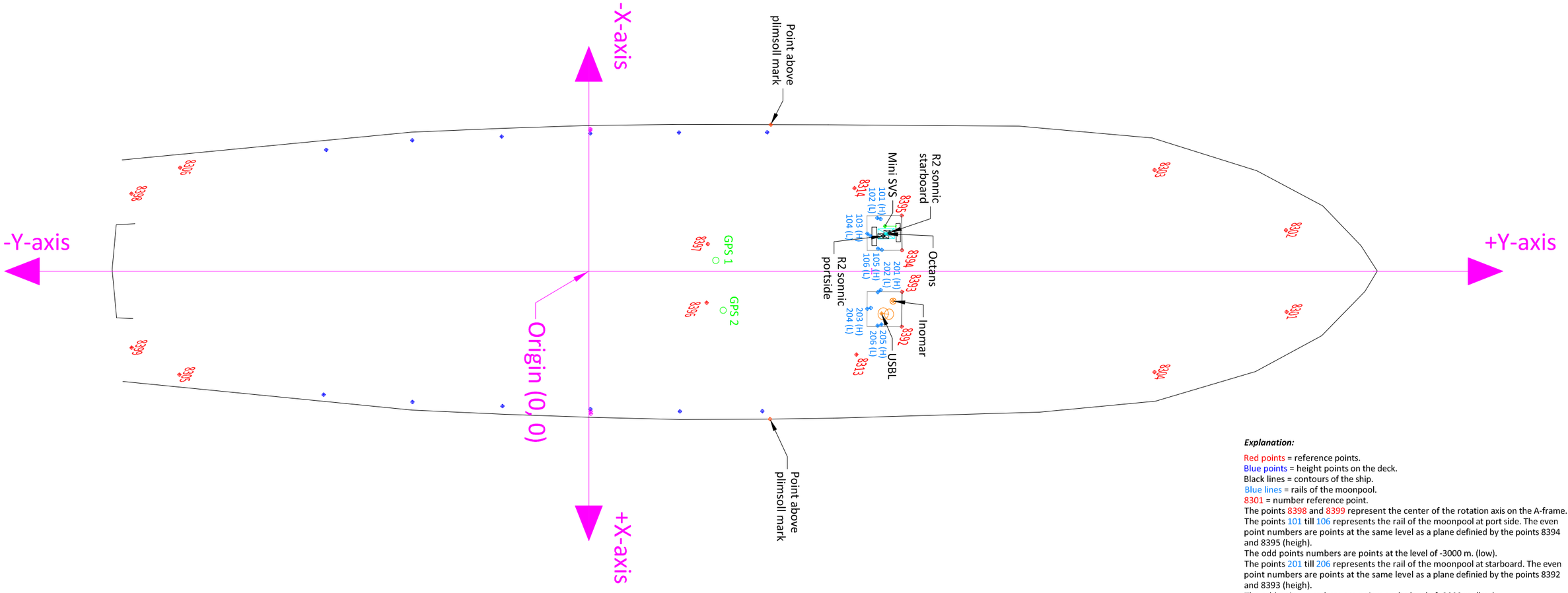
Works when you do

GEOMAX

GeoMax AG
www.geomax-positioning.com
info@geomax-positioning.com



Explanation:

Red points = reference points.
Blue points = height points on the deck.
Black lines = contours of the ship.
Blue lines = rails of the moonpool.
8301 = number reference point.
The points 8398 and 8399 represent the center of the rotation axis on the A-frame.
The points 101 till 106 represents the rail of the moonpool at port side. The even point numbers are points at the same level as a plane definied by the points 8394 and 8395 (heigh).
The odd points numbers are points at the level of -3000 m. (low).
The points 201 till 206 represents the rail of the moonpool at starboard. The even point numbers are points at the same level as a plane definied by the points 8392 and 8393 (heigh).
The odd points numbers are points at the level of -3000 m. (low).

Other lines and points are explained in the drawing.

The x- and the y-axis are defined by the middle of the ship and the frame of the ship.
The orthogonality of the planes in the x- and y-direction are checked.
The z-plane is definied by an ideal plane through the four outer height points of the deck. Also is the orthogonality checked of the z-plane towards the x- and y-plane.

See document '140830002 150122 RAIM1A0 Coordinates points Breaker' for the list of coordinates of the reference points and the other points (GPS and sensors).

Ver	Description (for each version)	Name editor	Date

CAD drawing — manual adjustment in this drawing are not allowed — Ver. no: B0

XY-coordinates are given in Local system
Z-coordinates are given in Local system
Dimensioning is given in mm.

RATIO SURVEY

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1021 KN Amsterdam
E:info@ratiosurvey.nl

Projectnumber:	14083	
Drawingnumber:	14083-0003	
Sheetnumber:	1 of 1	
Surveyed:	KBO	21, 22-01-2015
Drawn:	LTH	09-02-2015
Verified:	LTH	09-02-2015
Scale:	1 : 100	
Paper size:	A3	421 x 297 mm

Survey file: Diverse.
Source file: Not applicable

Client: DEEP B.V.
Project: Breaker
Location: Den Helder
Subject: Survey of reference points, GPS-antenna's and sensors at the Breaker.

140830003 150122 TBM1A0 Breaker Ampt