DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2004/54

Demonstration Survey Bahrain

Seismic survey in the Navigation Channel, Area D.

Jørn Bo Jensen, Steen Lomholt and
Peter Trøst Jørgensen

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF THE ENVIRONMENT

GEUS

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GEUS

Contents

1. Introduction

GEUS has been invited to Bahrain by the General Directorate for the Protection of Marine Resources by General Director Jassim Ahmed Al-Qaseer to demonstrate the possibilities in using Shallow Seismic Acquisition as a tool in mapping of Marine Sand Resources for reclamation purposes, and as a resource for the building industry.

The Geological Survey of Denmark and Greenland (GEUS) is a scientific research institute under the Danish Ministry of Environment. GEUS was established in 1995 by the amalgamation of the Geological Survey of Denmark (founded 1888) and the Geological Survey of Greenland (founded 1946). The main objectives of GEUS include research activities and consultant services for the Danish Government, local authorities, and private enterprises in Denmark and international development agencies. Most of the international projects are integrated projects, where we corporate with governmental offices and agencies in the countries. As a governmental offices, free of private commercial interest, we are looking at this project as an opportunity to work together with the General Directorate for the Protection of Marine Resources in Bahrain, solving resource problems and during this process transfer knowledge and experience if possibly.

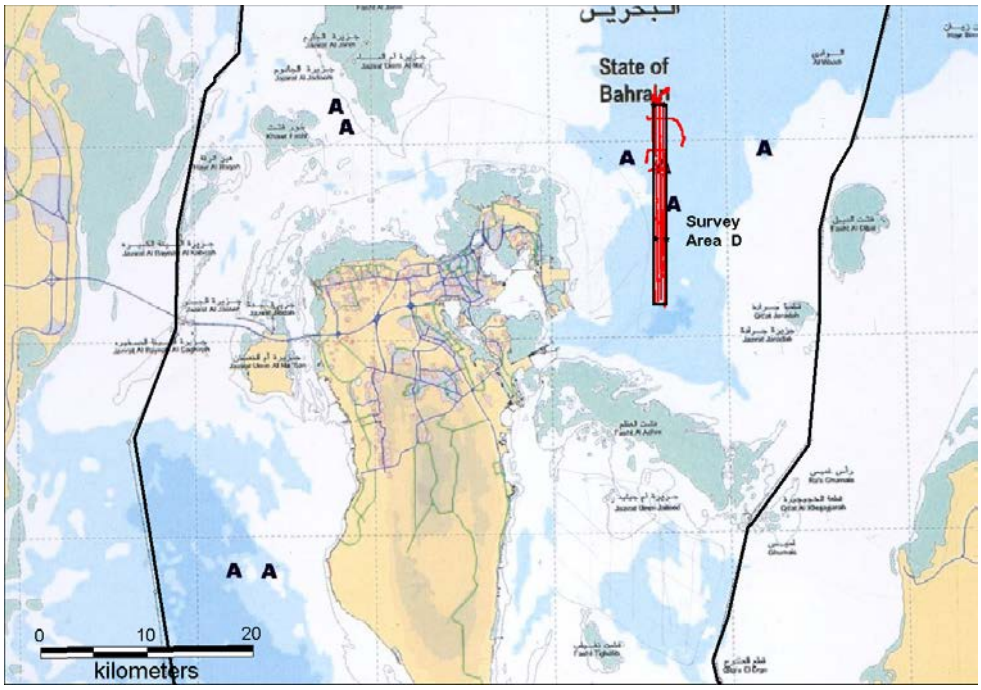


Figure 1. Overview map of area D.

This report contains a description of the acquisition and interpretation of the shallow seismic demonstration survey in the navigation channel north east of the Manama Harbour, called Area “D” located next to the main Borrow Area, carried out by GEUS in the period 28th and 29th of April 2004. (See Figure 1) .
The main purpose with the seismic program was to demonstrate the newest seismic equipment and up to date techniques in mapping procedures and seismic interpretation techniques that can be used in a raw material mapping project in Bahrain.

2. Summery

A seismic survey of app.120 km. has been acquired during two days; covering an area approximately 1.5 km wide and 18 km in length with 5 strike lines and 3 dip lines.

The seismic mapping shows significant volumes of approximately 80 mill. Cubic meters of potential sand resources in the northern part of the investigated area based on the seismic data and the available cores from the Area, as it can be seen on Figure 7. The resources need to be proved through a limited numbers of corings. 8 core positions are proposed inside the survey area and 1 optional outside.

It is obvious that the locations of the existing corings in general is outside the sand resource areas found by the seismic survey as it can be seen on figures 2, 4, 5 and 6.

An Areal distribution of possibly sand resources is proved to be more accurate using a combination of seismic and corings and furthermore the overall cost in sand mapping could be optimised and reduced, using a combination of the two methods.

3. Seismic interpretation and mapping

Approximately 120km seismic lines have been acquired in survey area D
Survey area D contains 11 existing core locations, (Figure 2).
Based on the seismic data a bathymetric map has been produced and the seismic data have been interpreted with the purpose to map the thickness of potential sand resources in the area.

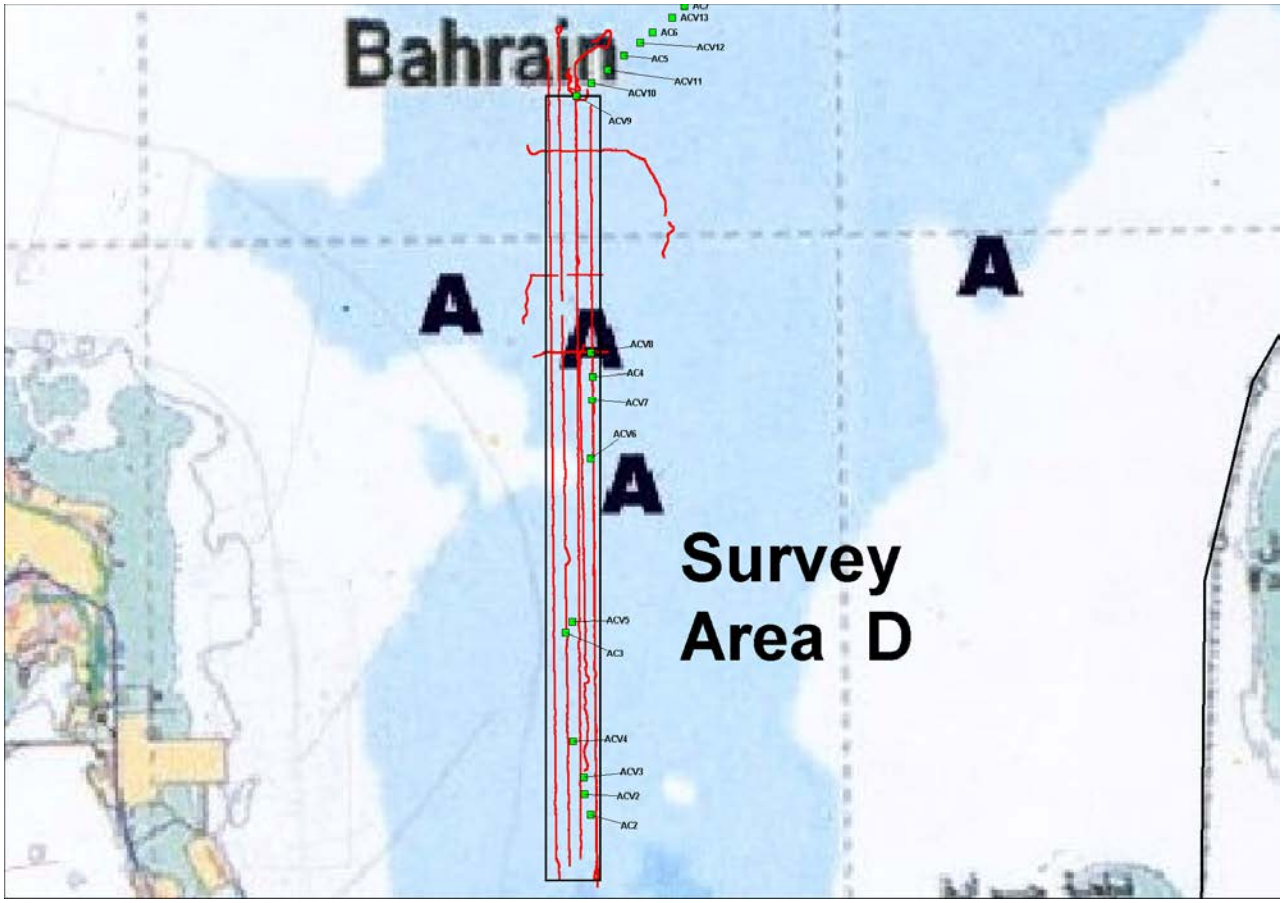


Figure 2. Survey grid and existing core locations.

3.1 Bathymetry

Based on digitisation of the seabed reflector a depth map has been produced as reference level for the calculation of sand thickness. This map is not corrected for tidal range and must not be used for navigational purposes. The depths map is show in figure 3.

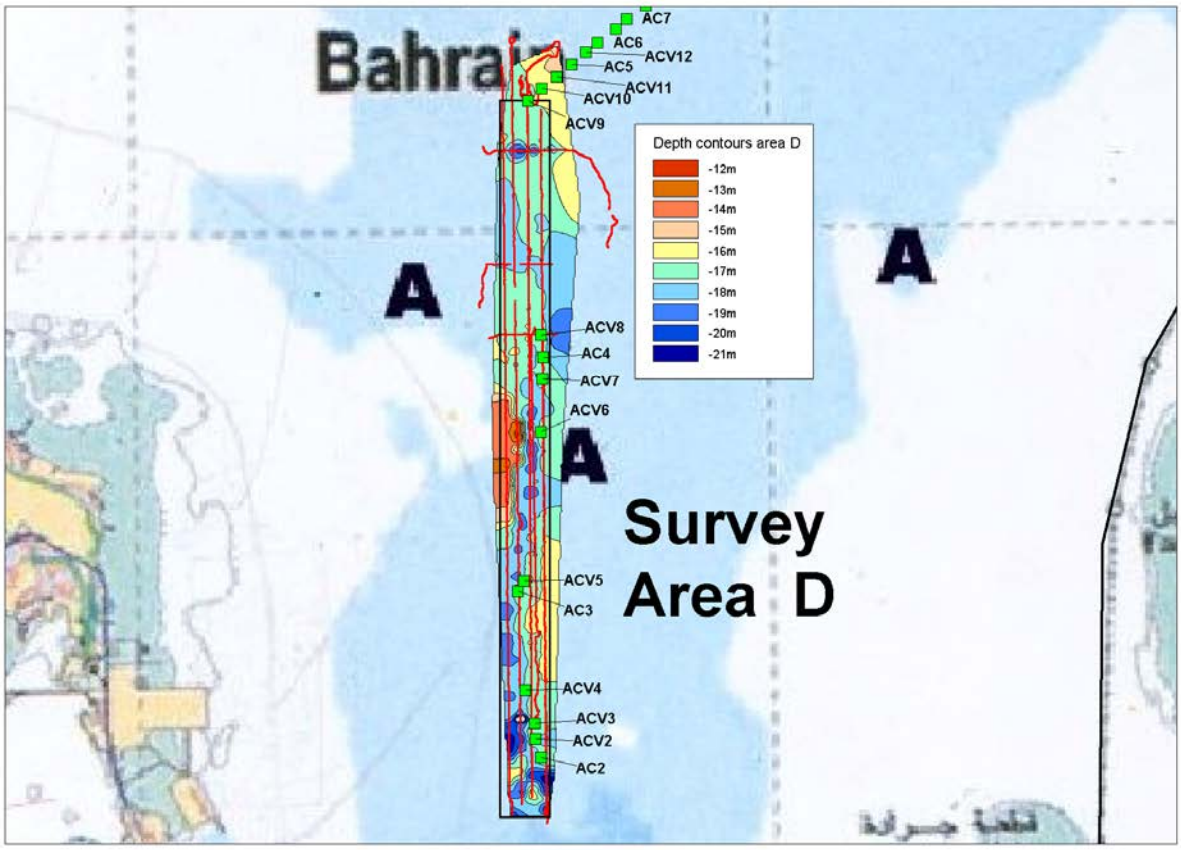


Figure 3. General bathymetric map and depth data form area D.

3.2 Seismic mapping

The digital seismic data have been loaded in the Sonar Web interpretation program and characteristic reflectors have been interpreted in order to map the distribution of the potential sand resources. Existing corings have been used as guidance for the seismic interpretation as it can be seen on the figures (Figures 4 - 6).

It is possible based on the seismic data to interpret an upper sand layer with a thickness up to 12m. Below the upper sand layer it is possible to map a deeper seismic reflector that might be a lower sand unit even though no core documentation exists in the area (Figures 4 -6).

We have mapped the thickness of the upper sand unit throughout the whole area and created a grid based on the interpreted horizons (Figure 7).

The sand thickness map shows that a major sand body is located in the northern part of the investigated area in an area practically without existing corings. The sand body is located in a depression in the seabed probably with an east-west orientation. It is likely that this sand body could extend towards west and might be connected to the existing borrow area.

In the central part of the survey area a possible sand ridge is located on the seismic data most likely connected to the Northwest – Southeast bathymetric ridge shown on the existing general depth map (Figure 3 and 7).

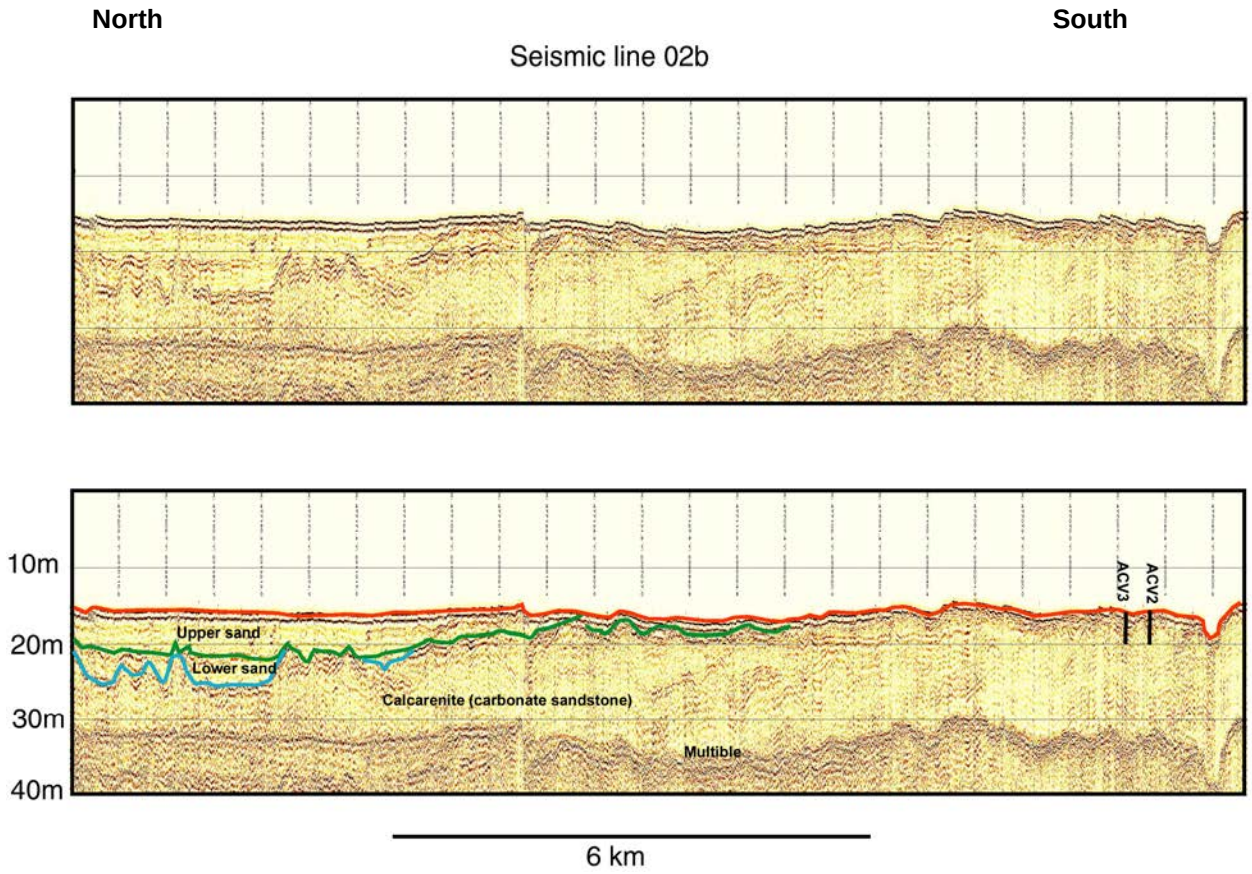


Figure 4. North – south seismic profile 02b area D

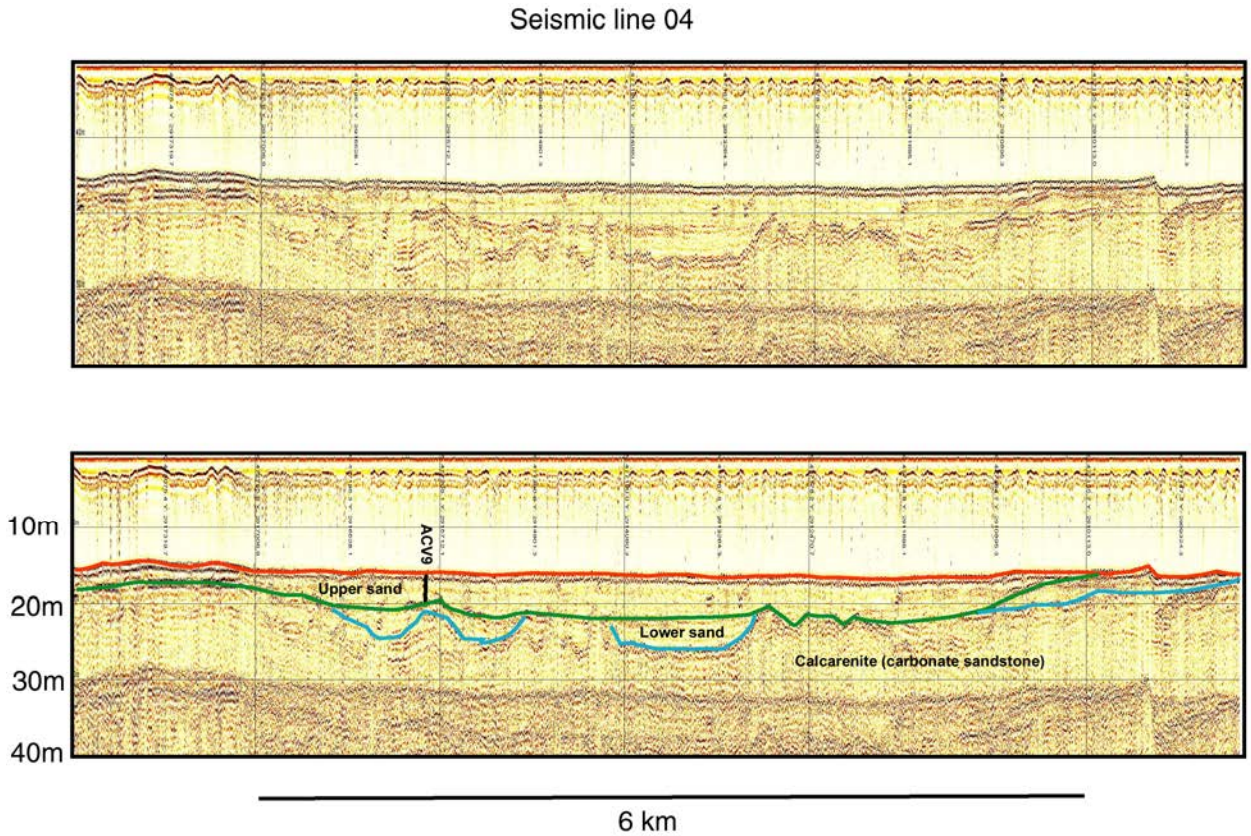


Figure 5. North – south seismic profile 04 area D

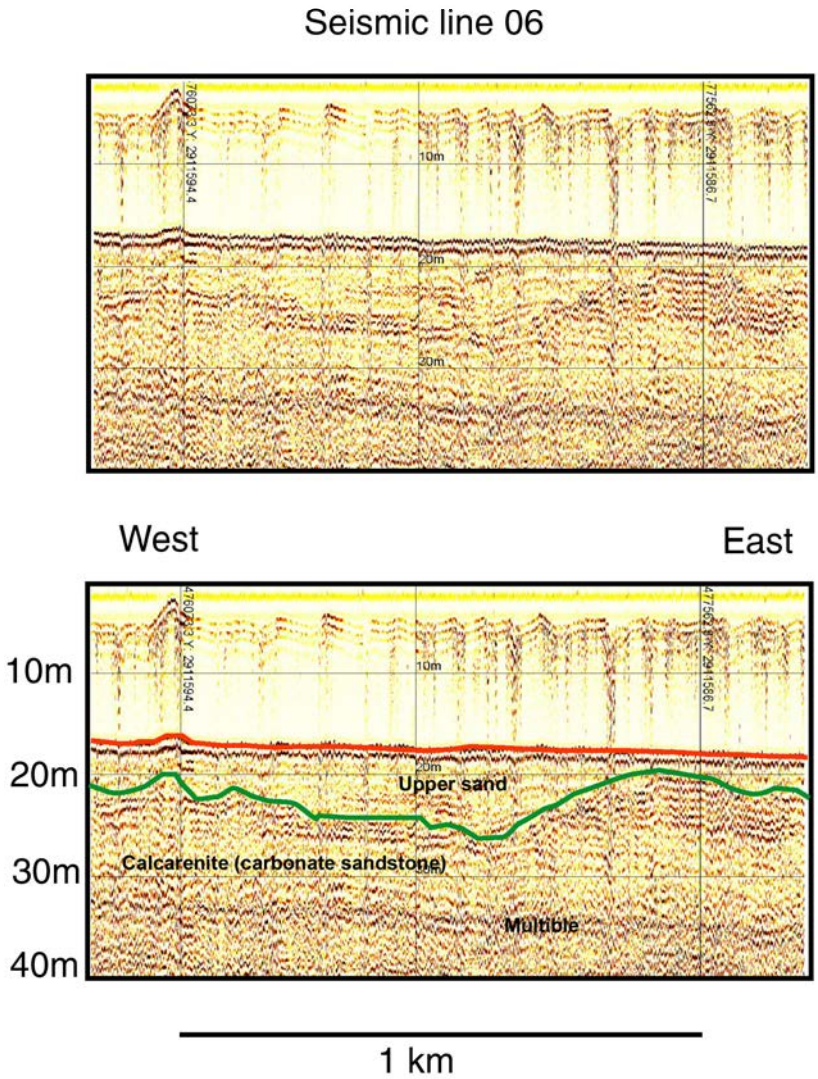


Figure 6. East - West seismic profile 06 area D.

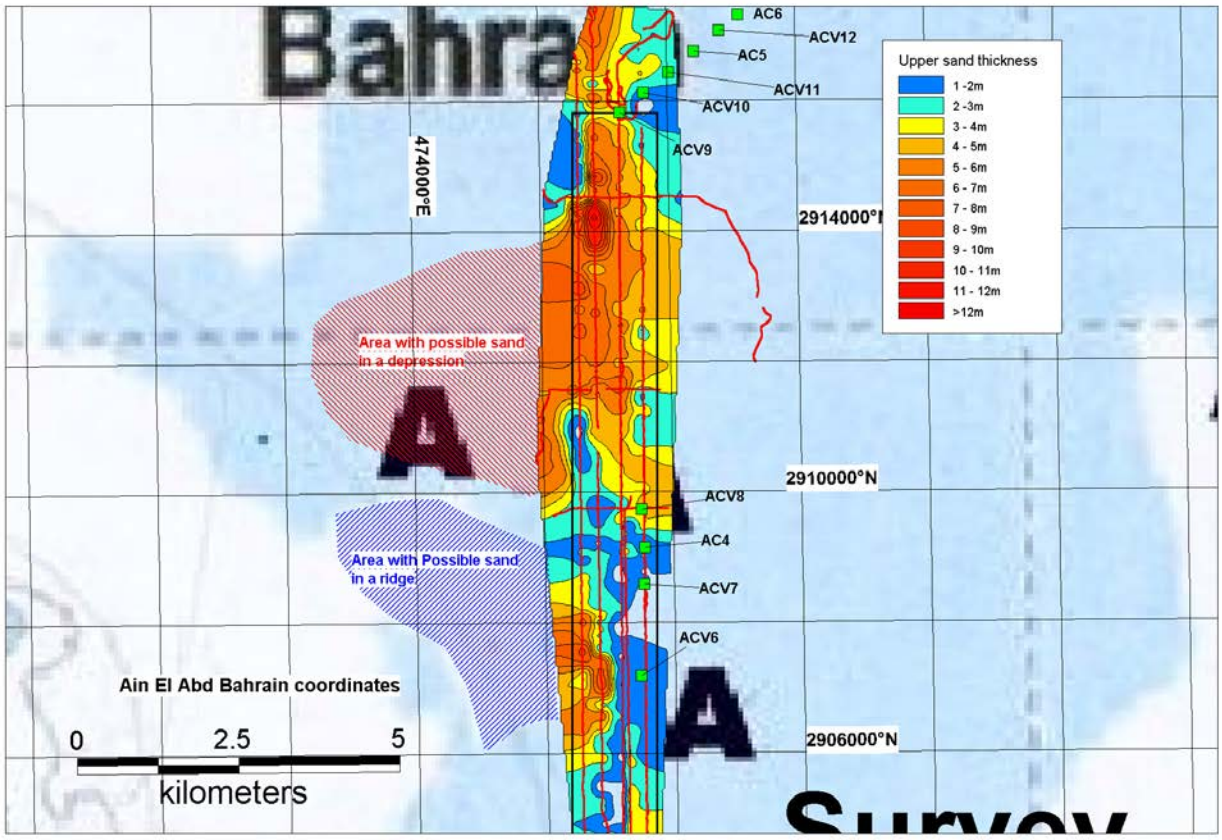


Figure 7. Possible sand thickness in Area D and expected extensions west of the mapped area.

3.3 Possible sand volumes in area D

The distribution of the sand thickness is shown on figure 7 that shows that the possible sand resources are located in the northern part of area D.

A volume calculation has been applied for the area based on the thickness map shown in Figures 3 and 7. The potential Sand volume's, based on an assumption that the upper interval as interpreted on the seismic survey is sand, have been estimated to be respectively 79,2 mill m3 in the Northern Area and 1,3 in the Southern area as shown in table 1 and 2

Southern Area Thickness Interval	Thickness In m.	Area km2	Volume Mill m3
3-4	3,5	0,03	0,1
2-3	2,5	0,1	0,4
1-2	1,5	0,6	0,9
Total			1,3

Table 1 Volume Calculation Southern Area

Northern Area Thickness Interval	Thickness In m.	km2	Volume Mill m3
+12	12,5	0,01	0,1
11-12	11,5	0,03	0,3
10-11	10,5	0,1	0,7
9-10	9,5	0,1	0,7
8-9	8,5	0,1	0,8
7-8	7,5	0,4	2,7
6-7	6,5	1,2	8,1
5-6	5,5	2,4	13,2
4-5	4,5	3,3	14,9
3-4	3,5	3,8	13,4
2-3	2,5	4,9	12,2
1-2	1,5	8,1	12,2
Total			79,2

Table 2 Volume Calculation Northern Area

3.4 Proposed coring program

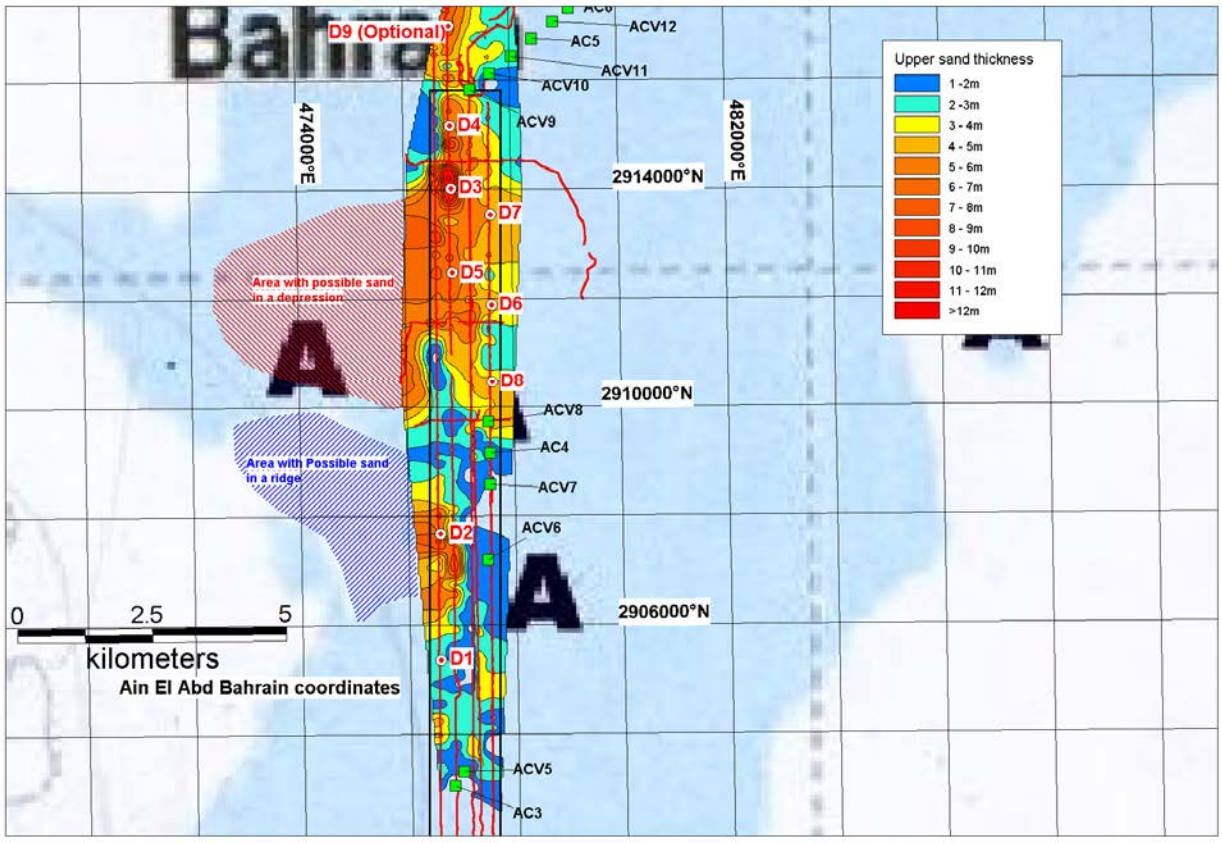


Figure 8. Proposed core positions D1 – D9.

To evaluated the possible sand resources it is proposed to carry out a number of corings. The locations of 8 proposed positions inside the survey area and 1 optional outside is based on the acquired seismic data and the mapping of these data (Figure 8 and table 3). In order to evaluate the northern extension of the sand resource an additional core position D9 has been proposed.

Ain El Abd Bahrain Co-ordinates			Seismic
Core position	Eastern	Northern	Line no.
D1	476530.64	2905379.51	8
D2	476547.74	2907690.20	8
D3	476837.24	2914037.77	9a
D4	476838.04	2915190.37	9a
D5	476838.84	2912493.28	9a
D6	477562.73	2911907.18	3
D7	477570.33	2913561.58	3
D8	477556.83	2910478.89	3
D9 (Optional)	476841.54	2917006.86	9a

Table 3 proposed core positions.

4. Conclusions and recommendations

Despite that the seismic data coverage is not sufficient for a detailed sand resource mapping, the investigations in area D has proven that seismic studies supplemented by few corings area suitable for sand investigations on the Bahrain shelf.

The study of area D based on seismic data has located significant possible sand resources even though that the existing corings are not placed optimal for verification of the sand estimated from the seismic data.

The seismic mapping shows significant volumes of approximately 80 mill. Cubic meters of potential sand resources in the northern part of the investigated area based on the seismic data and the available cores from the Area, as it can be seen on Figure 7. The resources need to be proved through limited numbers of corings positioned on basis of the seismic data.

An Areal distribution of possibly sand resources is proved to be more accurate using a combination of seismic and corings and furthermore the overall cost in sand mapping could be optimised and reduced, using a combination of the two methods.

The locations of 8 proposed positions inside the survey area and 1 optional outside is based on the acquired seismic data and the mapping of these data (Figure 8 and table 3).

It can be concluded that seismic studies are necessary for sand resource mapping of the offshore area of Bahrain.

Based on the experience from previous raw material mapping and the test survey in area D it can be recommended as a first step that seismic surveys be used as basis for identification of potential sand resource areas on the Bahrain continental shelf.

Detailed investigations of the identified potential sand resources should follow the first phase including a dense net of seismic data. Based on the seismic studies an optimal and cost-effective coring program must be performed in order to give detailed information on raw material quality and quantity.

5. Operations

5.1 Time schedule

A time schedule for mobilisation and data acquisition is presented in table 4.

Mobilisation and Transfer	
26 – April.	Mobilisation of Seismic.
27 – April.	Mobilisation Seismic and Coring
28 – April.	Transfer and Seismic Acquisition
29 – April.	Transfer and Seismic Acquisition

Table 4 Timetable

The transfer between the harbour and the survey area was approximately one hour one way.

5.2 Seismic lines

A total of 123.3 km has been acquired throughout the two survey days. The single lines are listed in table 5 and Figure 2.

Summery of Seismic :	Line no.	Km.
	Bah_Ch_01	14.7
	Bah_Ch_01a	01.3
	Bah_Ch_02	01.1
	Bah_Ch_02b	18.0
	Bah_Ch_03	20.0
	Bah_Ch_04	09.7
	Bah_Ch_04c	10.3
	Bah_Ch_05	01.8
	Bah_Ch_06	01.6
	Bah_Ch_6d	00.8
	Bah_Ch_07	04.5
	Bah_Ch_08	19.6
	Bah_Ch_09	13.2
	Bah_Ch_09a	06.7
Total Seismic		123.3

Table 5: Seismic lines in Kilometres.

5.3 Seismic Vessel and equipment

The survey vessel is a Crew Boat build by Halter Marine Services, New Orleans in 1975. Its overall length is approximately 20 m. Transit speed is 11 knot. A sketch of Hanna with position of seismic equipment is shown in Figure 9

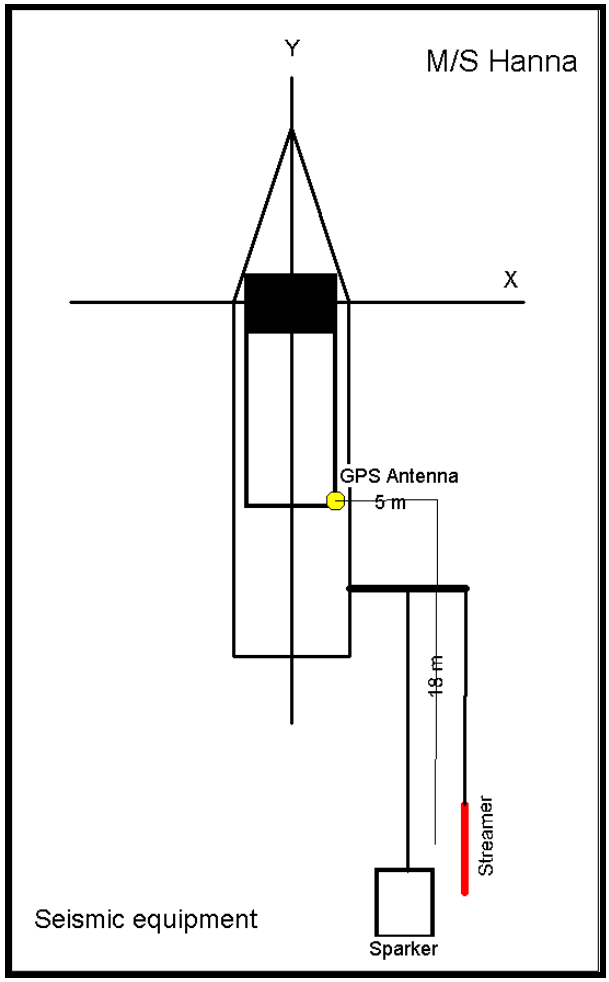


Figure 9 M/S Hanna and location of survey equipment.

5.4 Position system

A differential GPS system: Thales DG-16 GPS Beacon Receiver (WAAS/ENGOS) have been mounted along the starboard side of the ship as illustrated in Figure 10. The antenna

position is used as reference for the seismic survey. The accuracy of the position system in X, Y is ± 5 m.

Figure 10 DGPS antenna position

5.5 Navigation and Data Acquisition software

For this survey a NaviPac Online navigation and data acquisition System Environment have been used.

System Description

The NaviPac on-line navigation and data acquisition software enables escalation of one or more positions from a variety of sensors. For this survey position of the Sparker survey is annotated to the seismic with the position of equipment as shown in figure 1, with offsets of 5 m along the side of the ship and a lay down at 18 m, with reference to the antenna position.

Geodetic System

The NaviPac system offers an extensive number of projections. WGS 84 have been used for the present survey.

5.6 Seismic and acquisition system

Seismic

A Geo-Spark 200 system has been used for the seismic survey. The Geo-Spark is a new generation of very high-resolution multi-tip sparkers and HV pulsed power supplies developed and manufactured by Geo-Resources Instruments.

It is operated with the Geo-Spark 1000 Pulsed Power Supply using the Preserving Electrode Mode. In this patented mode the electrodes are negative with respect to the frame (ground referenced), reducing the electrode wear to practically zero.

The Geo-Spark 200 source system is capable to acquire very high-resolution 30-cm) seismic profiles of the "shallow" sub-bottom strata. Depending on the energy level, the geology and water depth, the effective penetration can exceed 300 - 400 ms below seabed.

The standard Geo-Spark 200 very high-resolution seismic spread typically consists of:
Geo-Spark 200 Sparker source c/w cable and patch panel
Geo-Sense dedicated high-resolution single channel streamer
Geo-Spark 1 kJ solid state pulsed power supply.

For the present survey an external generator have been used for the power supply for the Geo-Spark 200 system.

Specifications Geo-Spark 200 Multi-tip Sparker:
Dimensions: L x W x H = 105 x 75 x 55 cm
Overall Weight: 55 kg
Shipping: Standard Euro pallet / container 75 x 80 x 120 cm
Frame: Marine quality stainless steel (316)
Entirely passivated c/w aluminium protection anodes
Array Depth: Adjustable from 10 cm to 40 cm below surface
Array Geometry; planar configuration of 0.75 x 1.00 m for enhanced downward projection of acoustic energy
Number of active Electrode Modules (1 - 4) corresponding to 50, 100, 150, or 200 tips can be selected onboard
Electrode Modules are available with: Small diameter tip, surface = 0.45 mm2, for low power per tip
Large diameter tips, surface = 2.50 mm2, for high power per tip
Energy Level: Max energy per tip in PE mode, 3 Joule / tip for small diameter tips and
12.5 Joule / tip for large diameter tips

Configuration: A combination of 2 modules with 50 small diameter tips plus 2 modules with 50 large diameter tips
Primary Pulse Length: Around 0.5 ms
Dominate Frequencies: Between 500 - 2000 Hz, depending on the selected energy level
PE Mode.
The Geo-Spark 200 Multi-tip Sparker is used with the Geo-Spark 1000 High Voltage Pulsed Power Supply in Preserving Electrode Mode. In this mode, the electrodes have negative potential with respect to the frame (ground referenced). This mode reduces the electrode wear to practically zero.

Acquisition system

A Delph Seismic system has been used for the data acquisition. The efficiency of the Windows NT system gives maximum performance in marine geotechnical work and offshore mining investigation.
Delph Seismic is used for real-time processing and quality control with a display of raw or processed in real-time on a high-resolution screen.

The following features have been used during the survey.

Key Features	Specifications
Real-time quality control and on-site processing	Optimises the use of survey time
User-defined Shot Rate	Can be set based on time or distance
Band pass filter	Allows the attenuation of spectral components between the user-defined upper and lower band limits
Swell filter	Carries out static corrections on each trace to attenuate the effect of the swell. A Seabed detector determines travel time of the first Seabed return echo for each shot
Automatic gain control	AGC allows improved visualisation of seismic signals to compensate for variations in the signal envelope
Signature deconvolution	Used to improve the quality of seismic images by increasing the vertical resolution and stabilising the signature from one shot to another
Time varying filter (TVF)	Allows a band pass filter with characteristics varying over time to be applied to the digitised signal between the signal from the Seabed and the end of the recording time

System specifications

Key Features	Specifications
Host Processor	350 MHz Pentium II, 128 MB RAM; 10 serial ports, 1 parallel port
Graphics Processor	128-bit 16 MB SDRAM
Digital Signal Processor	TI TMS320C31 (60 MHz); 30 MIPS/60 MFLOPS; 32-bit hardware floating point DSP

Mass storage

Key Features	Specifications
Hard disk drive	80 GB
CD R/W	650 MB disc

The seismic equipment is towed behind the ship as shown in Figure 9, with a distance between Sparker unit and streamer of 3 m. The Sparker seismic can be seen in Figure 11.

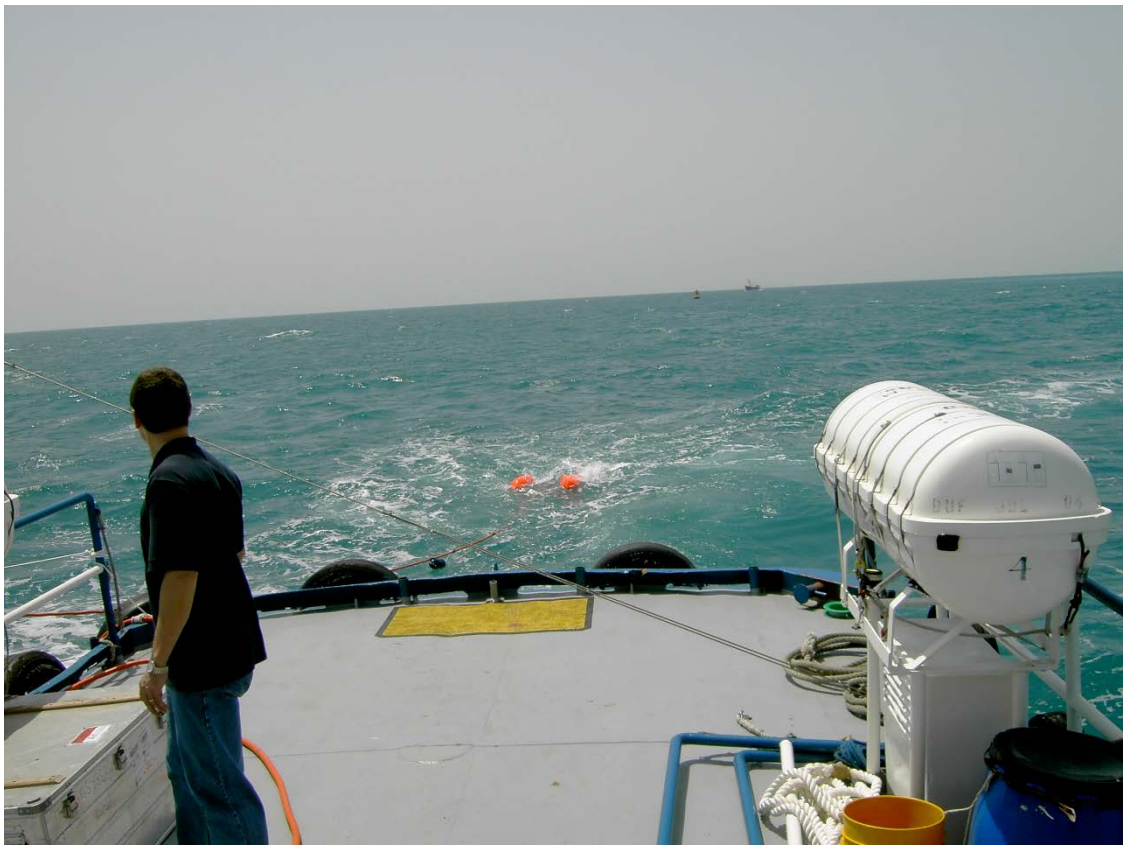
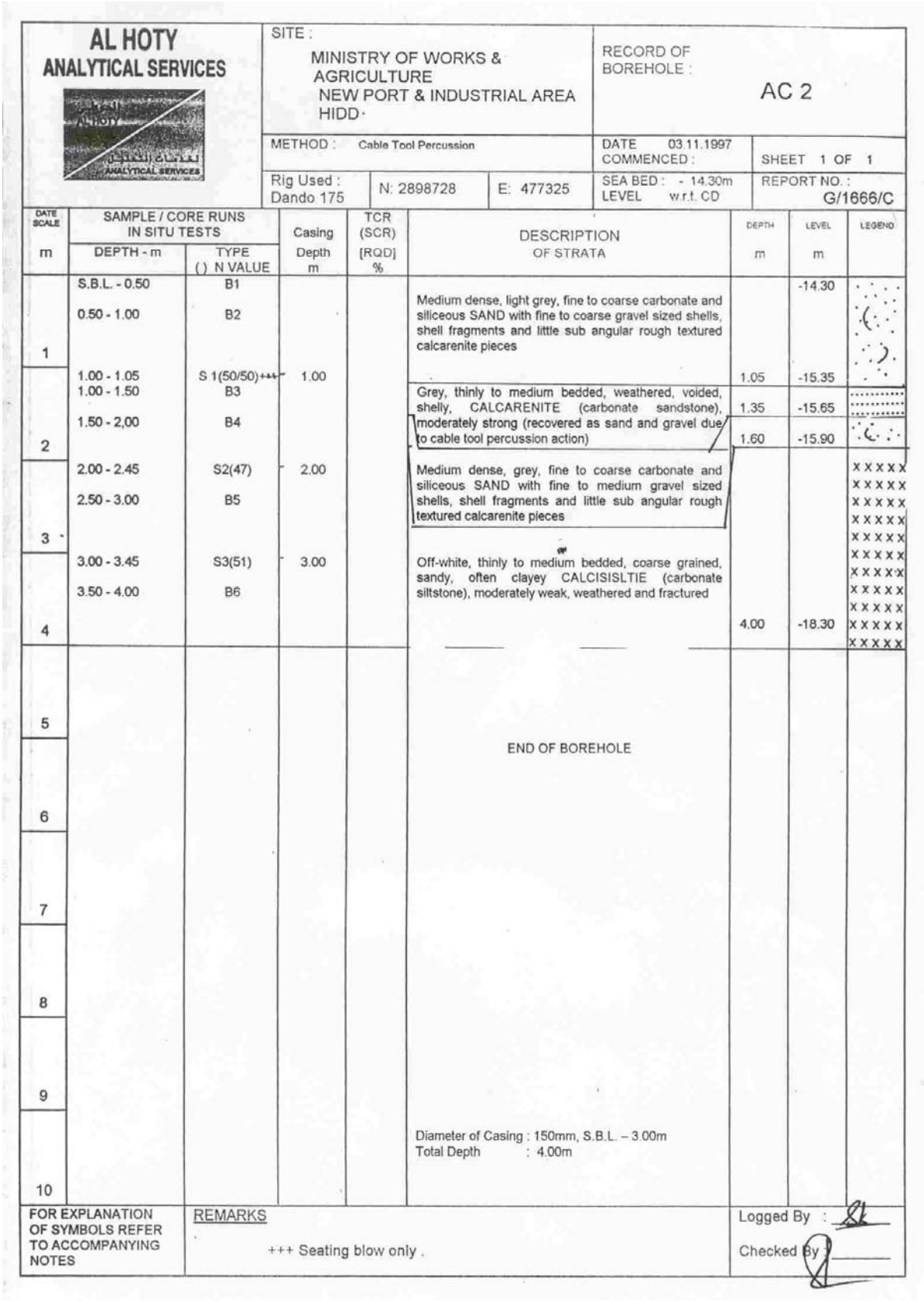


Figure 11 Sparker seismic in Navigation Channel, Bahrain 2004.

6. Appendix 1



AL HOTY ANALYTICAL SERVICES

SITE : MINISTRY OF WORKS & AGRICULTURE NEW PORT & INDUSTRIAL AREA HIDD

RECORD OF BOREHOLE : AC 2

METHOD : Cable Tool Percussion | DATE COMMENCED : 03.11.1997 | SHEET 1 OF 1

Rig Used : Dando 175 | N: 2898728 | E: 477325 | SEA BED LEVEL : - 14.30m w.r.t. CD | REPORT NO. : G/1666/C

DATE SCALE m	SAMPLE / CORE RUNS IN SITU TESTS DEPTH - m	TYPE ( ) N VALUE	Casing Depth m	TCR (SCR) [RQD] %	DESCRIPTION OF STRATA	DEPTH m	LEVEL m	LEGEND
1	S.B.L. - 0.50	B1					-14.30	
	0.50 - 1.00	B2			Medium dense, light grey, fine to coarse carbonate and siliceous SAND with fine to coarse gravel sized shells, shell fragments and little sub angular rough textured calcarenite pieces			
	1.00 - 1.05	S 1(50/50)+++	1.00			1.05	-15.35	
2	1.00 - 1.50	B3			Grey, thinly to medium bedded, weathered, voided, shelly, CALCARENITE (carbonate sandstone), moderately strong (recovered as sand and gravel due to cable tool percussion action)	1.35	-15.65	
	1.50 - 2.00	B4				1.60	-15.90	
3	2.00 - 2.45	S2(47)	2.00		Medium dense, grey, fine to coarse carbonate and siliceous SAND with fine to medium gravel sized shells, shell fragments and little sub angular rough textured calcarenite pieces			
	2.50 - 3.00	B5						
4	3.00 - 3.45	S3(51)	3.00		Off-white, thinly to medium bedded, coarse grained, sandy, often clayey CALCISISLTIE (carbonate siltstone), moderately weak, weathered and fractured			
	3.50 - 4.00	B6				4.00	-18.30	
5					END OF BOREHOLE			
6								
7								
8								
9								
10					Diameter of Casing : 150mm, S.B.L. – 3.00m Total Depth : 4.00m			

FOR EXPLANATION OF SYMBOLS REFER TO ACCOMPANYING NOTES

REMARKS

+++ Seating blow only .

Logged By :

Checked By :

AL HOTY
ANALYTICAL SERVICES

SITE :
MINISTRY OF WORKS & AGRICULTURE
NEW PORT & INDUSTRIAL AREA
HIDD

RECORD OF BOREHOLE : ACV3

METHOD : Cable Tool Percussion

DATE COMMENCED : 08.11.1997

SHEET 1 OF 1

Rig Used : Dando 175

N:2899613 E:477181

SEA BED LEVEL : - 14.60m w.r.t. CD

REPORT NO. : G/1666/C

DATE SCALE m	SAMPLE / CORE RUNS IN SITU TESTS DEPTH - m	TYPE ( ) N VALUE	Casing Depth m	TCR (SCR) [RQD] %	DESCRIPTION OF STRATA	DEPTH m	LEVEL m	LEGEND
1	S.B.L. -0.50	B1					-14.60	
	0.50 - 0.95	S1(5)	0.50		Loose, becoming medium dense, fine to coarse carbonate and siliceous SAND with considerable fine to medium occasionally coarse gravel sized shells, shell fragments and little sub angular rough textured calcarenite pieces			
	0.50 - 1.00	B2						
	1.00 - 1.50	B3				1.20	-15.80	
2	1.50 - 2.00	S2(1)	1.50		Very soft, grey, very clayey fine to medium sandy SILT with abundant fine to coarse gravel sized shells, shell fragments and little sub angular rough textured calcarenite pieces	2.00	-16.60	
	1.50 - 2.00	B4						
3	2.00 - 2.50	B5			Medium dense, grey, fine to coarse carbonate and siliceous SAND with considerable fine to medium gravel sized shells, shell fragments and little sub angular rough textured calcarenite pieces	2.80	-17.40	
	2.50 - 3.00	B6				3.00	-17.60	XXXXX XXXXX
4					Off-white, thinly to medium bedded, coarse grained, Sandy, clayey CALCISILTITE (carbonate siltstone), moderately weak, weathered and fractured			
5					END OF BOREHOLE			
6								
7								
8								
9								
10					Diameter of Casing :150mm, S.B.L. - 1.50m Total Depth : 3.00m			

FOR EXPLANATION OF SYMBOLS REFER TO ACCOMPANYING NOTES

REMARKS

Logged By :

Checked By :

AL HOTY
ANALYTICAL SERVICES

SITE :
MINISTRY OF WORKS & AGRICULTURE
NEW PORT & INDUSTRIAL AREA
HIDD

RECORD OF BOREHOLE : ACV2

METHOD : Cable Tool Percussion

DATE COMMENCED : 08.11.1997

SHEET 1 OF 1

Rig Used : Dando 175

N: 2899214

E: 477190

SEA BED LEVEL : - 14.90m w.r.t. CD

REPORT NO. : G/1666/C

DATE SCALE m	SAMPLE / CORE RUNS IN SITU TESTS DEPTH - m	TYPE ( ) N VALUE	Casing Depth m	TCR (SCR) [RQD] %	DESCRIPTION OF STRATA	DEPTH m	LEVEL m	LEGEND
	S.B.L. -0.50	B1					-14.90	
	0.50 - 0.95	S1(8)	0.50		Loose, becoming medium dense, light grey, fine to coarse carbonate and siliceous SAND with abundant fine to coarse gravel sized shells, shell fragments and little sub angular rough textured calcarenite pieces			
1	0.50 - 1.00	B2						
	1.00 - 1.50	B3				1.20	-16.10	
	1.50 - 1.57	S2(50/70)+++	1.50		Grey, thinly to medium bedded, coarse grained, shelly, vuggy*, weathered and fractured CALCARENITE (carbonate sandstone), moderately strong			
2	1.50 - 2.00	B4						
	2.00 - 2.50	B5			Below 1.70m becoming off-white and moderately Strong to strong			
	2.50 - 3.00	B6						
3						3.00	-17.90	
4								
5					END OF BOREHOLE			
6								
7								
8								
9								
10					Diameter of Casing :150mm, SBL - 1.50m Total Depth : 3.00m			

FOR EXPLANATION OF SYMBOLS REFER TO ACCOMPANYING NOTES

REMARKS

+++ Seating blow. * Vuggy – small voids or microcavities.

Logged By :

Checked By :

AL HOTY
ANALYTICAL SERVICES

SITE :
MINISTRY OF WORKS & AGRICULTURE
NEW PORT & INDUSTRIAL AREA
HIDD

RECORD OF BOREHOLE : ACV4

METHOD : Cable Tool Percussion
Rotary Coring with Water Flush

DATE COMMENCED : 08.11.1997

SHEET 1 OF 1

Rig Used : Dando 175 | N:2900481 | E:476940

SEA BED LEVEL : - 14.25m w.r.t. CD

REPORT NO : G/1666/C

DATE SCALE m	SAMPLE / CORE RUNS IN SITU TESTS DEPTH - m	TYPE () N VALUE	Casing Depth m	TCR (SCR) [RQD] %	DESCRIPTION OF STRATA	DEPTH m	LEVEL m	LEGEND
1	S.B.L. -0.50 0.50 - 0.95 0.50 - 1.00	B1 S1(8) B2	0.50		Medium dense, becoming loose, slightly silty, fine to coarse carbonate and siliceous SAND with fine to coarse gravel sized shells, shell fragments and little sub angular rough textured calcarenite pieces	1.00	-14.25 -15.25	
2	1.00 - 1.25 1.25 - 1.50 1.50 - 2.00 1.50 - 2.00	R1 B3 S 2(18) B4	1.50	100 (100) [100]	Grey, thinly to medium bedded, voided, coarse grained, silty, vuggy*, CALCARENITE (carbonate sandstone), moderately strong, weathered and fractured	1.30	-15.55	
3	2.00 - 2.50 2.50 - 3.00	B5 B6			Medium dense, grey, fine to coarse carbonate and siliceous SAND with abundant, fine to coarse gravel Sized shells, shell fragments and little sub angular rough textured calcarenite pieces Below 2.00m gravel sized fragments less	2.80	-17.05	
4					Off-white, thinly to medium bedded, coarse grained, sandy often clayey CALCISILTITE (carbonate Siltstone), weak to moderately weak	3.00	-17.25	
5					END OF BOREHOLE			
6								
7								
8								
9								
10					Diameter of Casing :150mm, SBL - 1.50m Diameter of Coring : 86mm, 1.00 - 1.25m Total Depth : 3.00m			

FOR EXPLANATION OF SYMBOLS REFER TO ACCOMPANYING NOTES

REMARKS

* Vuggy – small voids or microcavities.

Logged By : SK

Checked By :

AL HOTY ANALYTICAL SERVICES

SITE : MINISTRY OF WORKS & AGRICULTURE
NEW PORT & INDUSTRIAL AREA
HIDD

RECORD OF BOREHOLE : ACV7

METHOD : Cable Tool Percussion
Rotary Coring with Water Flush

DATE COMMENCED : 18.11.1997

SHEET 1 OF 1

Rig Used : Dando 175

N: 2908584 E: 477526

SEA BED LEVEL : - 14.70m w.r.t. CD

REPORT NO. : G/1666/

DATE SCALE m	SAMPLE / CORE RUNS IN SITU TESTS DEPTH - m	TYPE ( ) N VALUE	Casing Depth m	TCR (SCR) [RQD] %	DESCRIPTION OF STRATA	DEPTH m	LEVEL m	LEGEND
	S.B.L. - 0.50	B1					-14.70	
1	0.50 - 0.95 0.50 - 1.00	S 1(9) B2	0.50		Medium dense, grey, fine to medium occasionally coarse carbonate and siliceous SAND with considerable fine to medium gravel sized shells, shell fragments and little sub angular rough textured calcarenite pieces			
2	1.00 - 1.50	B3						
	1.50 - 1.80 1.50 - 2.00	S 2(29/150)+ B4	1.50			1.80	-16.50	
	2.00 - 2.50	R1		80 (50) [50]	Grey, thinly to medium bedded, coarse grained, shelly, vuggy*, voided CALCARENITE (carbonate sandstone), moderately strong, weathered and fractured	2.50	-17.20	
3								
4								
5					END OF BOREHOLE			
6								
7								
8								
9								
10					Diameter of Casing :150mm, SBL - 1.50m Diameter of Coring : 86mm, 2.00 - 2.50m Total Depth : 2.50m			

FOR EXPLANATION OF SYMBOLS REFER TO ACCOMPANYING NOTES

REMARKS

+ Full penetration not attained. * Vuggy – small voids or microcavities.

Logged By :

Checked By :

AL HOTY ANALYTICAL SERVICES

SITE : MINISTRY OF WORKS & AGRICULTURE
NEW PORT & INDUSTRIAL AREA
HIDD

RECORD OF BOREHOLE : AC 3

METHOD : Cable Tool Percussion
Rotary Coring with Water Flush

DATE COMMENCED : 03.11.1997

SHEET 1 OF 1

Rig Used : Dando 175 | N: 2903057 | E: 476790

SEA BED LEVEL : - 14.20m w.r.t. CD

REPORT NO. : G/1666/C

DATE / SCALE m	SAMPLE / CORE RUNS IN SITU TESTS DEPTH - m	TYPE (-) N VALUE	Casing Depth m	TCR (SCR) [RQD] %	DESCRIPTION OF STRATA	DEPTH m	LEVEL m	LEGEND
	0.00 - 0.50	B1			Loose grey slightly silty fine to medium occasionally coarse subangular and subrounded SAND with little fine to medium GravEL shell shell fragments and occasional calcarenite pieces	0.00	-14.20	
1	1.00 - 1.50	B2		0 (60) {60}	Grey, thinly to medium bedded, coarse grained, voided Shelly, vuggy*, CALCARENITE (carbonate sandstone), moderately strong	1.00	-15.20	x x x x
	1.50 -1.65	S 1(37/150)+++	1.50					x x x x
2	1.50 - 2,00	B3						x x x x
	2.00 - 3.00	R2		NIL				x x x x
	2.00 - 2.50	B4		(NIL)	Grey, thinly bedded, sandy, fine grained, CALCISILTITE (carbonate siltstone), moderately weak, weathered and fractured			x x x x
3	2.50 - 3.00	B5		[NIL]				x x x x
	3.00 - 3.20	S 2(35/50)+	3.00		Below 3.40m becoming yellow and more sandy (recovered as sand and gravel due to cable tool percussion action)			x x x x
	3.00 - 3.50	B6	3.50					x x x x
	3.50 - 3.80	S 3(61/150)+						x x x x
4	3.50 – 4.00	B7				4.00	-18.20	x x x x
5					END OF BOREHOLE			
6								
7								
8								
9								
10					Diameter of Casing : 150mm, S.B.L. – 3.50m Diameter of Coring : 86mm, 0.50 - 1.00m Total Depth : 4.00m			

FOR EXPLANATION OF SYMBOLS REFER TO ACCOMPANYING NOTES

REMARKS

* Vuggy – small voids or microcavities.
+++ Seating blow only. +Full penetration not attained.

Logged By :

Checked By :

AL HOTY
ANALYTICAL SERVICES

SITE :
MINISTRY OF WORKS & AGRICULTURE
NEW PORT & INDUSTRIAL AREA
HIDD

RECORD OF BOREHOLE : ACV5

METHOD : Cable Tool Percussion

DATE COMMENCED : 18.11.1997

SHEET 1 OF 1

Rig Used : Dando 175

N: 2903320

E: 476961

SEA BED LEVEL : - 14.10m w.r.t. CD

REPORT NO. : G/1666/C

DATE SCALE m	SAMPLE / CORE RUNS IN SITU TESTS DEPTH - m	TYPE () N VALUE	Casing Depth m	TCR (SCR) [RQD] %	DESCRIPTION OF STRATA	DEPTH m	LEVEL m	LEGEND
	S.B.L. - 0.50	B1					-14.10	
	0.50 - 0.95	S 1(7)	0.50					
1	0.50 - 1.00	B2						
	1.00 - 1.50	B3			Medium dense, grey, slightly silty, fine to coarse carbonate and siliceous SAND with considerable fine to coarse gravel sized shells, shell fragments and little sub angular rough textured calcarenite pieces			
	1.50 - 1.95	S 2(12)	1.50					
2	1.50 - 2.00	B4						
	2.00 - 2.50	B5						
	2.50 - 3.00	B6						
3	3.00 - 3.50	B7						
	3.50 - 4.00	B8			Below 3.70m with abundant gravel sized sub angular rough textured calcarenite fragments			
4						4.00	-18.10	
5					END OF BOREHOLE			
6								
7								
8								
9								
10					Diameter of Casing :150mm, SBL - 1.50m Total Depth : 4.00m			

FOR EXPLANATION OF SYMBOLS REFER TO ACCOMPANYING NOTES

REMARKS

Logged By : SK

Checked By :

AL HOTY ANALYTICAL SERVICES

SITE : MINISTRY OF WORKS & AGRICULTURE
NEW PORT & INDUSTRIAL AREA
HIDD

RECORD OF BOREHOLE : AC 4

METHOD : Cable Tool Percussion

DATE COMMENCED : 04.11.1997

SHEET 1 OF 1

Rig Used : Dando 175 | N:2909150 | E:477545

SEA BED LEVEL : - 14.30m w.r.t. CD

REPORT NO. : G/1666/C

DATE SCALE m	SAMPLE / CORE RUNS IN SITU TESTS DEPTH - m	TYPE ( ) N VALUE	Casing Depth m	TCR (SCR) [RQD] %	DESCRIPTION OF STRATA	DEPTH m	LEVEL m	LEGEND
	S.B.L. - 0.50	B1					-14.30	
	0.50 - 0.95	S1(11)	0.50		Medium dense light grey, fine to coarse carbonate and siliceous SAND with fine to coarse GRAVEL sized shells, shell fragments and little sub angular rough textured calcarenite pieces			
1	0.50 - 1.00	B2						
	1.00 - 1.50	B3						
	1.50 -1.95	S 2(15)	1.50					
2	1.50 - 2,00	B4						
	2.00 - 2.50	B5				2.10	-16.40	
	2.50 - 2.70	S3(38/50)+	2.50		Grey, to light yellow, thinly to medium bedded, coarse grained, shelly, vuggy*, voided CALCARENITE (carbonate sandstone), moderately strong to strong			
3	2.50 - 3.00	B6						
	3.00 - 3.50	B7			(recovered as sand and gravel due to cable tool percussion action)			
	3.50 - 3.65	S4(60/150)+++	3.50					
4	3.50 - 4.00	B8				4.00	-18.30	
5					END OF BOREHOLE			
6								
7								
8								
9								
10					Diameter of Casing : 150mm, S.B.L. – 3.50m Total Depth : 4.00m			

FOR EXPLANATION OF SYMBOLS REFER TO ACCOMPANYING NOTES

REMARKS

* Vuggy – small voids or microcavities.
+++ Seating blow . +Full penetration not attained..

Logged By : Sk

Checked By :

AL HOTY ANALYTICAL SERVICES

SITE : MINISTRY OF WORKS & AGRICULTURE
NEW PORT & INDUSTRIAL AREA
HIDD .

RECORD OF BOREHOLE : ACV6

METHOD : Cable Tool Percussion

DATE COMMENCED : 18.11.1997

SHEET 1 OF 1

Rig Used : Dando 175 | N: 2907188 | E: 477469

SEA BED LEVEL : - 14.90m w.r.t. CD

REPORT NO. : G/1666/C

DATE SCALE m	SAMPLE / CORE RUNS IN SITU TESTS DEPTH - m	TYPE ( ) N VALUE	Casing Depth m	TCR (SCR) [RQD] %	DESCRIPTION OF STRATA	DEPTH m	LEVEL m	LEGEND
	S.B.L. - 0.50	B1					-14.90	
	0.50 - 0.95	S 1(6)	0.50					
1	0.50 - 1.00	B2						
	1.00 - 1.50	B3			Medium dense, grey, slightly silty, fine to coarse carbonate and siliceous SAND with considerable fine to coarse gravel sized shells, shell fragments and little sub angular rough textured calcarenite pieces			
	1.50 - 1.95	S 2(14)	1.50					
2	1.50 - 2.00	B4						
	2.00 - 2.50	B5						
	2.50 - 3.00	B6				2.80	-17.70	
3					Grey, thinly to medium bedded, coarse grained, shelly, vuggy*, CALCARENITE (carbonate sandstone), moderately strong, weathered and fractured	3.00	-17.90	
4								
5					END OF BOREHOLE			
6								
7								
8								
9								
10					Diameter of Casing :150mm, SBL - 1.50m Total Depth : 3.00m			

FOR EXPLANATION OF SYMBOLS REFER TO ACCOMPANYING NOTES

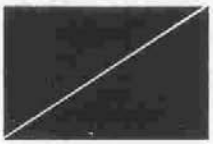
REMARKS

* Vuggy – small voids or microcavities

Logged By : SL

Checked By :

AL HOTY ANALYTICAL SERVICES



SITE : MINISTRY OF WORKS & AGRICULTURE NEW PORT & INDUSTRIAL AREA HIDD

RECORD OF BOREHOLE : ACV8

METHOD : Cable Tool Percussion

DATE COMMENCED : 18.11.1997

SHEET 1 OF 1

Rig Used : Dando 175 | N: 2909733 | E: 477505

SEA BED LEVEL : - 14.80m w.r.t. CD

REPORT NO. : G/1666/C

DATE SCALE m	SAMPLE / CORE RUNS IN SITU TESTS DEPTH - m	TYPE ( ) N VALUE	Casing Depth m	TCR (SCR) [RQD] %	DESCRIPTION OF STRATA	DEPTH m	LEVEL m	LEGEND
	S.B.L. - 0.50	B1					-14.80	
1	0.50 - 0.95	S 1(8)	0.50		Loose, becoming medium dense, slightly silty, fine to coarse carbonate and siliceous SAND with fine to coarse gravel sized shells, shell fragments and little calcarenite pieces			
	1.00 - 1.50	B2						
	1.50 - 1.80	S 2(41/150)+	1.50			1.40	-16.20	
2	1.50 - 2.00	B3						
	2.00 - 2.50	B4			Light grey, thinly to medium bedded, coarse grained, silty, vuggy*, weathered CALCARENITE (carbonate sandstone), moderately strong			
3	2.50 - 3.00	B5			Below 2.00m becoming off-white and coarse grained (recovered as sand and gravel due to cable tool percussion action)			
	3.00 - 3.50	B6				3.50	-18.30	
4								
5					END OF BOREHOLE			
6								
7								
8								
9								
10					Diameter of Casing :150mm, SBL - 1.50m Total Depth : 3.50m			

FOR EXPLANATION OF SYMBOLS REFER TO ACCOMPANYING NOTES

REMARKS

+ Full penetration not attained. * Vuggy – small voids or microcavities.

Logged By :

Checked By :

AL HOTY ANALYTICAL SERVICES

SITE : MINISTRY OF WORKS & AGRICULTURE
NEW PORT & INDUSTRIAL AREA
HIDD

RECORD OF BOREHOLE : ACV9

METHOD : Cable Tool Percussion

DATE COMMENCED : 18.11.1997

SHEET 1 OF 1

Rig Used : Dando 175 | N: 2915828 | E: 477259

SEA BED LEVEL : - 14.40m w.r.t. CD

REPORT NO. : G/1666/C

DATE SCALE m	SAMPLE / CORE RUNS IN SITU TESTS DEPTH - m	TYPE ( ) N VALUE	Casing Depth m	TCR (SCR) [RQD] %	DESCRIPTION OF STRATA	DEPTH m	LEVEL m	LEGEND
	S.B.L. - 0.50	B1					-14.40	
	0.50 - 0.95	S 1(5)	0.50					
1	0.50 - 1.00	B2						
	1.00 - 1.50	B3						
	1.50 - 1.95	S 2(11)	1.50					
2								
	2.00 - 2.50	B4			Loose, becoming medium dense, light grey, very silty, fine to coarse carbonate and siliceous SAND with considerable fine to coarse gravel sized shells, shell fragments and little sub angular rough textured calcarenite pieces			
	2.50 - 2.95	S 3(12)	2.50					
3								
	3.00 - 3.50	B5			Below 2.00m shells and shell fragments abundant			
	3.50 - 4.00	B6						
4								
	4.00 - 4.50	B7						
						4.50	-18.90	
5					END OF BOREHOLE			
6								
7								
8								
9								
10					Diameter of Casing :150mm, SBL - 2.50m Total Depth : 4.50m			

FOR EXPLANATION OF SYMBOLS REFER TO ACCOMPANYING NOTES

REMARKS

Logged By : SK

Checked By :