

Project SIREN: Phase 2b

Further Investigation (Phase 2b) of the SIREN (Site for Innovative Research on Natural Attenuation) site

R&D Technical Report P2-208/TR/3

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© Environment Agency, March 2003.

ISBN: 1 84432 106 1

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This document summarises the findings of additional site characterisation at the SIREN site and supplements previous reports on the characterisation and conceptualisation of attenuation processes acting at the site. The report has been prepared as part of the SIREN consortium's efforts to provide a well-characterised site for independent research into attenuation processes acting on contaminants in the subsurface.

Keywords

Contamination, Groundwater, Monitored Natural Attenuation, Soil

Research contractor

This document was produced under R&D Project P2-208 (Umbrella Project P2-169) by:
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The Environment Agency's Project Manager for R&D Project P2-208 was:
Dr Alwyn Hart, National Groundwater and Contaminated Land Centre.

The SIREN team are grateful for support from Biffaward during this project.

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EXECUTIVE SUMMARY

SIReN (Site for Innovative Research in Natural Attenuation) is a joint initiative between Shell Global Solutions International, the Environment Agency for England and Wales, CL:AIRE (Contaminated Land: Applications in Real Environments) and AEA Technology, to promote field-based research in monitored natural attenuation (MNA).

The objectives are to:

1. Facilitate the development of confidence in MNA and its acceptance as a technically defensible risk management option for contaminated sites in the UK
2. Provide a well-characterised site for research groups to carry out projects on any aspect of MNA that will be funded by the Research Councils or other funding bodies.

The objectives of the work described in this report were:

- 1) To use direct push technology (cone penetrometer and Geoprobe) to gain further information on the lateral and vertical distribution of contaminants at the site to improve the delineation of groundwater plumes and aid our understanding of the vertical migration of contaminants at the site.
- 2) To install groundwater monitoring wells in the sandstone aquifer in the vicinity of borehole 309 to delineate an apparent benzene plume in this region of the site

The main conclusions of this phase of the site investigation are:

- 1) BTEX (primarily benzene) contamination at the top of the sandstone aquifer in the region of BH309 has been confirmed (up to 5.6 mg/l). No hole in the boulder clay has been found to explain how the benzene contamination in BH309D has reached the sandstone aquifer. However, the clay layer does reduce in thickness to approximately 4 m and contains a high proportion of sand and gravel in the vicinity of BH309.
- 2) There is no evidence from the vertical profiling that contamination has migrated through the boulder clay and into the sandstone at any other locations.
- 3) The extent of contamination in the shallow aquifer does not extend as far to the south-east as was originally postulated in the Conceptual Site Model.
- 4) The presence of a styrene plume co-mingled with BTEX, TMBs and naphthalenes has been confirmed in the shallow groundwater. No new chlorinated solvent contamination has been detected.

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1. INTRODUCTION

SIREN (Site for Innovative Research in Natural Attenuation) is a joint initiative between Shell Global Solutions International, the Environment Agency for England and Wales, CL:AIRE and AEA Technology (Towler *et al.*, 2000) to promote field-based research in monitored natural attenuation (MNA) The objectives are to:

- 1) Facilitate the development of confidence in MNA and its acceptance as a technically defensible risk management option for contaminated sites in the UK.
- 2) Provide a well-characterized site for research groups to carry out projects on any aspect of MNA that will be funded by the Research Councils or other funding bodies.

The site is a large (180 ha) operational petrochemicals manufacturing plant. Over its long history (50 years) it has manufactured a range of products (e.g. alcohols, glycols, amines, detergents, polystyrene, polypropylene) from refined petroleum hydrocarbon feedstocks. As a result of the activities undertaken on the site, both the ground and groundwater have been impacted with various contaminants, primarily benzene, toluene, ethylbenzene and xylenes (BTEX), trimethylbenzenes (TMB), styrene and naphthalenes along with smaller amounts of chlorinated aliphatic hydrocarbon solvents (CAH).

A preliminary site conceptual model has been developed along with a groundwater model for the site (Earle *et al.*, 2001; Jones *et al.*, 2001). In general terms, the vertical profile of the ground at the site is as follows:

- Made ground < 1 m
- Sand and gravels 2.85 m – 8.5 m
- Boulder clay 0.36 m – 30 m
- Sands and gravels 0 m – 7.6 m
- Sandstone > 77 m.

The first encountered groundwater in the upper sands and gravels occurs at 0.5 m – 2.0 mbgl. Groundwater in both the shallow aquifer and deep (sandstone) aquifer flows to the northwest, north or northeast (depending on the part of the site) towards a river and a canal. A number of site investigations (76 boreholes at 26 locations and numerous trial pits and shallow CPT LIF (cone penetrometer with light induced fluorescence probe) points have detected these contaminants at several locations around the site almost exclusively in the shallow groundwater and associated ground. At only one location has significant contamination (benzene only) penetrated into the sandstone aquifer.

The objective of the work described in this report was two fold:

- 1) To use direct push technology (cone penetrometer and Geoprobe) to gain further information on the lateral and vertical distribution of contaminants at the site to improve the delineation of groundwater plumes and aid our understanding of the vertical migration of contaminants at the site. Push technology was viewed as a more cost effective means of gaining information on deep contamination at the site compared to traditional drilling methods. It costs approximately £10,000 to install a monitoring well in the sandstone aquifer by traditional methods. A key question is:

how has benzene got into the sandstone aquifer, given the presence of a substantial layer of boulder clay above the sandstone? Thus, a key aim was to continue the vertical profiling through the boulder clay and into the sand/gravel layer above the sandstone while recognizing that push technologies will not penetrate the sandstone.

- 2) To install groundwater monitoring wells in the sandstone aquifer in the vicinity of borehole 309 to delineate an apparent benzene plume in this region of the site.

2. METHODS

2.1 Vertical Profiling

Between the 30th May and 8th June, 2001 Fugro carried out cone penetration tests (CPT) at each of six locations and installed 1-4 piezometers at each of 10 locations using a Geoprobe (Table 2.1 and Figure 2.1).

Table 2.1. Vertical profiling at each location

Location	Static cone	LIF	MIP	Soil core	Piezometer screen (m)	Piezometer type
VP1	√√	√	√		1.0 – 3.0	H
					7.5 – 8.0	S
					14.0 – 14.5	S
VP2	√√	√	√		1.0 – 3.0	H
					1.0 – 5.0	H
					8.5 – 9.0	S
					14.0 – 14.5	S
VP4	√√√	√	√		1.0 – 3.0	H
					7.5 – 8.0	S
					12.3 – 12.8	S
VP8					1.0 – 3.0	H
					8.0 – 8.5	S
					12.5 – 13.0	S
VP10					1.0 – 3.0	H
					7.5 – 8.0	S
					11.8 – 12.3	S
VP11				0 – 1.2	2.0 – 5.0	H
				1.2 – 2.2	6.5 – 7.0	S
				3.2 – 4.2		
VP12	√√	√	√	0 – 1.2	1.0 – 3.0	H
				1.2 – 2.2	10.5 – 11.0	S
				2.2 – 3.2	11.2 – 11.7	S
VP13	√√	√	√	0 – 1.2	2.0 – 3.0	H
				1.2 – 2.2	1.0 – 5.0	H
				2.2 – 3.2	11.5 – 12.0	S
VP15	√√	√	√		1.0 – 3.0	H
					10.5 – 11.0	S
VP16					11.8 – 12.3	S

Key: LIF = light induced fluorescence

MIP = membrane interface probe

H = 22 mm id HDPE

S = 6 mm id steel mesh well screen

2.1.1 Cone penetrometer testing

At each of the six CPT locations, two separate tests were carried out in which the cone penetrometer contained either an LIF (light induced fluorescence) probe or MIP (membrane interface probe).

Static cone penetration tests were carried out using a 20 t capacity hydraulic penetrometer equipment mounted in a heavy truck ballasted to provide a reaction weight of about 18 t. A 7.5 t capacity electric cone was used. During each test, measurements of local side friction were made in addition to cone end resistance. The ratio of the two (friction ratio) is indicative of soil type. All tests were terminated when the maximum available safe thrust capacity of the equipment was reached in very dense or hard materials.

The LIF probe detects chemicals containing one or more aromatic rings such as BTEX or polyaromatic hydrocarbons (Kenny *et al.*, 2000). The MIP probe samples volatiles which are transported to the surface in a stream of nitrogen and analyzed sequentially through photoionisation (PID), flame ionisation (FID) and dry electrolytic conductivity (DELCD) detectors to indicate the presence of volatile aromatic (PID), aliphatic (FID) and halogenated (DELCD) contaminants in the sub-surface.

Thus, continuous readings of soil type and contamination were obtained down the profile.

2.1.2 Installation of groundwater monitoring and well points

Groundwater monitoring and well points were installed using a van mounted Geoprobe (a combined hydraulic push/percussion drive system). Shallow (< 5 m) monitoring wells were composed of 25 mm id HDPE with a protective filter sock to prevent blockage of the screen. Due to difficult conditions at the site (very dense and running sands) a drive in well point system was used for deeper groundwater sampling installations. A small diameter casing pipe was fitted with a sacrificial tip which covered the open end of the casing to prevent the ingress of water or soil. The casing pipe was driven to the required depth with successive lengths of pipe using the Geoprobe percussion soil sampling equipment or the 20 t CPT truck. A steel mesh well point (6 mm id) with sample tubing (6 mm id) was introduced to the casing pipes and screwed into the sacrificial point. The casing string was pulled back leaving the sacrificial tip and installed monitoring point in the ground.

Given the nature of the ground at the site, it did not prove possible to get deeper than 15 m (shallower in some locations) with either the cone penetrometer or the Geoprobe.

The locations of the monitoring and well points with the screened intervals are given in Table 2.1 and Figure 2.1.

2.1.3 Groundwater sampling

Groundwater from the new monitoring wells and well points was sampled in August 2001. Some of the 50 mm id monitoring wells installed in previous rounds of site investigation were sampled at the same time (Figure 2.1).

The 50 mm id monitoring wells were sampled with a bladder pump, but this could not be used on the 22 mm or 6 mm diameter wells. Peristaltic and/or vacuum pumps were used to sample the latter (Table 3.1). In several cases both types of pump were used on the same well to compare the effect of sampling pump on the data obtained to address concerns that vacuum pumping might strip volatiles from the groundwater and aerate it, thereby changing the chemistry of the sample prior to analysis.

To ensure that the sample was representative of the aquifer, groundwater was pumped through a flow through cell (Well Wizard) for 20 –60 min, until relatively stable readings for temperature, pH, electrical conductivity, dissolved oxygen and redox potential were obtained, before samples were collected for laboratory analysis.

Dissolved oxygen and Fe(II) were also measured on-site using Hach field test kits for comparative purposes.

2.2 Installation and sampling of deep groundwater monitoring wells in the sandstone aquifer

Between 20th November 2001 and 26th March 2002, ten boreholes (BH401, BH402a, BH402b, BH402c, BH403, BH404, BH405, BH406, BH407 and BH408) were drilled in the vicinity of borehole 309 where benzene has been consistently detected (in the region of 5 mg/l) over the previous two years (Figure 2.2). The circles in Figure 2.2 represent 25m, 50m and 100m radii from BH309. A combination of soft ground cable percussion drilling, rotary open hole drilling and rotary coring was used to achieve the desired depths (up to 49 m). A schematic summary of the borehole logs is given in Figure 3.1. The original drillers logs are in Appendix 4.

Falling head permeability tests were carried out in all boreholes apart from 404 and 406 (Figure 3.2). Borehole 404 was abandoned at 2.0 m when a pocket of highly pungent chemical was encountered.

A Waterra multi-level sampler with seven ports was installed in borehole 406 under the supervision of Peter Dumble (Waterra) and Gary Wealthall (University of Sheffield/BGS).

Following development, the wells were sampled for chemical analysis in May 2002 and again in August 2002.

Water level data over time are given in Appendix 5.

3. RESULTS AND DISCUSSION

3.1 Vertical profiling

3.1.1 Static cone tests

Static cone penetrometer tests were performed at locations VP1, VP2, VP4, VP12, VP13, and VP15 (Figure 2.1). At least two tests were carried out at each location, one during the LIF screening and one during the MIP screening. The raw data of the static cone tests and their interpretation are given in Appendix one. Note that Fugro use the location identifiers CPT1 (=VP1 LIF) and CPTM1 (=VP1 MIP).

It did not prove possible to get deeper than 15 m at any location due to the hard and compacted nature of the ground.

Interpretation of the friction ratio measurements gave vertical ground profiles similar to those observed by traditional borehole drilling and logging techniques. Approximately 1 m of made ground was underlain by sands with some gravel to a depth of 4 – 7 mbgl. Beneath the sandy layer, firm to stiff clay was present at all locations ranging from 4 – 9 m in thickness. Beneath the firm/stiff clay layer, was a layer of sandy clay with gravels.

At none of the locations was there an obvious pathway for contamination to reach the sandstone aquifer, although it is interesting to note that the two vertical profiling locations closest to BH309 where benzene has been found in the sandstone aquifer had either the thinnest layer of boulder clay (~4 m at VP13) or gravel within the boulder clay (VP12), which may increase the permeability of the boulder clay.

Light induced fluorescence cone testing

The LIF data are given in Appendix 2. There was no indication of aromatic hydrocarbon contamination at locations VP1, VP2 and VP4 all the way down to 15 m. Strong signals were obtained at 1 – 3 m at VP12 and VP13, but there was no indication of any contamination below 3 m. A weak signal was obtained at VP15 at around 1 m.

Membrane interface probe testing

MIP data are given in Appendix 3. Volatile hydrocarbons were detected at all locations.

The signal at VP1 is indicative of aromatic hydrocarbon (signals from both the PID and FID) contamination such as BTEX, styrene and naphthalene, primarily located at 4 – 6 m in the sandy layer above the clay, although some volatiles do appear to have penetrated into the clay to a depth of 9 m. The measurements were stopped at 14 m, which is still in the clay.

The signal at VP2 is indicative of aromatic hydrocarbon contamination located at 3-8 m, which is primarily in the sandy layer above the clay, although a small amount of penetration into the clay has taken place. Small pockets of aliphatic hydrocarbons (FID

signal, but no PID signal) are indicated at lower depths, which could well be methane. The measurements were stopped at 14 m, which is still in the clay.

The signal at VP4 is indicative of the presence of very few volatiles down the profile other than two small pockets of primarily aliphatic hydrocarbons (most likely methane) at 8 m and 10 m in the clay layer. The measurements were stopped at 13.5 m which is below the stiff clay layer. No volatiles were detected below the clay.

The signal at VP12 is indicative of aromatic hydrocarbon contamination located at 1 – 6 m which is primarily in the sandy layer above the clay, although a small amount of penetration into the clay has taken place. Significant pockets of aliphatic hydrocarbons are indicated at lower depths within the clay. This could represent methane. The measurements were stopped at 11 m which is just into the sand layer beneath the clay. The signal indicated aliphatic volatile hydrocarbons at 11 m.

The signal at VP13 was very strong (note the scale is attenuated by a factor of 5 compared to the traces for VP1, VP2, VP4 and VP12), indicating aromatic hydrocarbons located at 1.5 – 5 m which is primarily in the sandy layer above the clay, although a small amount of penetration into the clay (approximately 1 m) has taken place. Below this level, two small pockets of aliphatic hydrocarbons (most likely methane) were detected at 7.5 m and 8.5 m in the clay.

The signal at VP15 was also very strong (same scale as for VP13). It indicated pockets of aromatic hydrocarbons between 3.5 m and 5.5 m which covers the bottom of the sand layer above the clay and the upper 1.5 m of the clay layer. The measurements were stopped at 11.5 m. There was no indication of volatiles below the firm clay layer that runs out around 10 m. VP15 was the only location where the DELCD signal indicated the presence of volatile halogenated contamination.

3.1.2 Groundwater analysis

Field measurements

The temperature, pH and electrical conductivity measurements made in the field with a flow through cell (Well Wizard) are given in Table 3.1, along with water levels and type of pump used to sample each well.

Groundwater temperature ranged from 12.6°C to 21.9°C. The values are considerably higher than those reported in March 2000 (8°C – 12.7 °C). The upper end of the range is high for groundwater, even in August. They may be due to an underground steam leak, but this seems unlikely given that a temperature of 21.3°C was recorded in groundwater from a depth of 8.5 m.

Groundwater pH was generally around neutrality (pH 5.92 – 7.42), with the exception of borehole 308 where the pH was 10 at 5 m and 9.4 at 19 m (compared to 11.9 and 9.9 respectively in March 2000). Electrical conductivity ranged from 316 µS to 3400 µS, which is similar to the range reported in March 2000.

Oxidation reduction potential correlated well with dissolved oxygen concentration. It ranged from -120 mV in the well (BH308S) with the lowest dissolved oxygen concentration (0.33 mg/l by flow through cell) to +131 mV in the well (with one of the highest dissolved oxygen concentrations (4.1 mg/l by flow through cell). The range is somewhat narrower than that reported in March 2000 (- 230 mV to + 118 mV)

Table 3.1 Groundwater sampling and field measurements

Location	Borehole diameter (mm)	Depth (mbgl)	Sampling pump	Water level (m)	Temp (°C)	pH	EC (µS)	Redox (mV)	Comments
VP1									Unable to gain access
VP2	22	3.0	Peristaltic	1.5	18.6	7.42	316	131	
VP4	22	3.0	Peristaltic	1.5	21.9	6.92	1589	111	
VP8S	22	3.0	Peristaltic Vacuum	1.26	20.0	6.60	815	-35	
VP8I	6	8.5	Peristaltic Vacuum	1.0	21.3	7.17	3200	-88	
VP8D	6	13.0	Vacuum						Insufficient sample recovered. Too deep for peristaltic
VP10	22/6	2.6	Peristaltic	0.49	18.0	5.92	322	-50	
VP11	22/6	5.0	Peristaltic	0.79	17.4	6.37	1078	-37	
VP12S	22	2.79	Vacuum	1.64	15.1	6.58	632	30	
VP12D	6	11.5	Vacuum						Insufficient sample recovered.
VP13S	22	3.05	Peristaltic Vacuum	1.71	16.1	6.32	413	18	
VP13I	6	6.09	Peristaltic Vacuum	1.7	15.5	5.93	725	0	
VP13D	6	11.5							Too deep for peristaltic or vacuum
VP16	6	7.6	Vacuum	5.5	14.6	7.32	554	39	Tube kinked?
DW2S	50	2.45	Bladder	1.53	17.6	7.10	407	9	
DW2I	50	4.83	Bladder	1.52	14.2	6.93	2210	-97	
DW2D	50	25.2	Bladder	2.50	13.2	6.84	694	-85	
DW4S	50	3.26	Bladder	1.56	16.3	6.55	1032	-35	
DW4I	50	5.52	Bladder	1.56	14.9	6.27	1042	-37	
DW4D	50	25.48	Bladder	2.32	13.6	6.37	1176	-47	
BH308S	50	5.08	Bladder	1.29	13.4	9.98	3400	-120	
BH308I	50	19.42	Bladder	4.65	13.6	9.44	1957	-65	
BH309S	50	3.97	Bladder	1.23	13.9	6.55	620	-61	
BH309I	50	25.84	Bladder	2.25	12.6	6.97	843	-96	
BH309D	50	29.53	Bladder	2.23	12.8	6.70	1005	-72	

Key: S = shallow
I = intermediate
D = deep

Electron acceptors and reduced products

The concentrations of electron acceptors and reduced products are listed in Table 3.2.

Nitrate concentrations in the shallow groundwater in wells VP10, VP11, VP12 and VP13 are very low (< 0.3 mg/l) which is in keeping with much of the site from previous rounds of investigation. These are however, the most heavily contaminated of the new wells. Even the relatively clean wells VP2 and VP4 contain only moderate concentrations of nitrate (3.0 and 5.7 mg/l) indicating that nitrate is not a major electron acceptor for anaerobic hydrocarbon degradation. This confirms previous observations at the site.

Fe(II) tended to be much higher (3.6 – 66.4 mg/l) in the more heavily contaminated wells (VP10, VP12 and VP13) and below the limit of detection (< 0.5 mg/l) in the clean wells VP2 and VP4, indicating that Fe(III) may be a significant electron acceptor for anaerobic hydrocarbon degradation at the site. In several samples Fe(II) was apparently greater than total dissolved phase Fe. Characterization of the iron chemistry of the groundwater at the site requires further work.

The concentrations of Mn(II) and total dissolved phase manganese are in the region of 1 mg/l or less, indicating that Mn(IV) is not acting as a significant electron acceptor at the site. There was little difference in the concentrations of Mn(II) and total dissolved phase manganese concentrations.

Sulphate was highest (358 mg/l) in one of the clean wells (VP4), compared to < 5 mg/l to 52 mg/l in the contaminated wells indicating that sulphate is a significant source of electron acceptor for anaerobic hydrocarbon degradation in parts of the site. This confirms previous findings.

Methane was only detected (2.6 – 6.4 mg/l) in the most heavily contaminated wells (VP12 and VP13). In all the other wells it was below the limit of detection (0.01 mg/l). This is strongly indicative of methanogenic driven anaerobic hydrocarbon degradation and confirms previous findings.

Table 3.2 Electron acceptors and reduced products in groundwater. Units are mg/l

Location	Depth (mbgl)	Sampling pump	NO3-N	Fe(II)	Total Fe in soln	Mn(II)	Total Mn in soln	SO4	CH4
VP2	3.0	Peristaltic	3.0	< 0.5	< 0.05	< 0.04	< 0.04	35	< 0.01
VP4	3.0	Peristaltic	5.7	< 0.5	0.4	0.49	0.58	358	< 0.01
VP8S	3.0	Peristaltic	3.7	< 0.5	1.29	0.14	0.18	137	< 0.01
VP8I	8.5	Peristaltic	0.6	< 0.5	3.37	< 0.04	0.38	< 5	< 0.01
VP10	2.6	Peristaltic	< 0.3	14.8	10.2	0.28	0.28	49	< 0.01
VP11	5.0	Peristaltic	< 0.3	< 0.5	5.72	0.40	0.74	< 5	< 0.01
VP12S	2.79	Peristaltic	< 0.3	22.4	15.1	0.79	0.77	< 5	6.39
		Vacuum		34.0					
VP13S	3.05	Peristaltic	< 0.3	3.6	2.3	1.12	1.10	49	2.63
		Vacuum	< 0.3	7.2	1.72	1.15	1.05	52	3.16
VP13I	6.09	Peristaltic		66.4					
		Vacuum		52.8					

Comparison of field and laboratory measurements of dissolved oxygen and ferrous iron

The data from a comparison of different methods for measuring dissolved oxygen (flow through cell, Hach colorimetric field test kit and laboratory analysis) and ferrous iron (Hach field test kit versus laboratory analysis) are given in Table 3.3.

The correlation in dissolved oxygen measurements made on-site between the flow through cell and the Hach field test kit was quite good, although some measurements could not be made with Hach method because of the cloudy nature of the sample. Laboratory measurements of dissolved oxygen were generally lower than those obtained in the field indicating possible consumption of oxygen during transit.

Dissolved oxygen was generally higher in the new vertical profile wells (1.1 mg/l – 7.2 mg/l) than the original traditional boreholes (0.62 mg/l – 2.1 mg/l). The different methods of sampling (bladder pump versus peristaltic pump) may have had something to do with this, although sampling with a peristaltic pump is a gentle means of sampling which has been successfully used to sample groundwater for analysis of volatiles, so it is unlikely to have led to aeration of the samples.

Correlation between dissolved phase Fe(II) concentrations in the groundwater analyzed on-site by the Hach colorimetric field test kit and on filtered and acidified samples analyzed in the laboratory was poor.

Table 3.3 Dissolved oxygen and iron in groundwater

Location	Depth (mbgl)	Sampling pump	DO FTC (mg/l)	DO HACH (mg/l)	DO LAB (mg/l)	Fe(II) HACH (mg/l)	Fe (II) LAB (mg/l)
VP2	3.0	Peristaltic	4.1	6.0	5.2	0.2	< 0.5
VP4	3.0	Peristaltic	7.2	8.0	2.6	0.2	< 0.5
VP8S	3.0	Peristaltic	1.1	1.0	0.8	1.8	< 0.5
VP8I	8.5	Peristaltic	5.3	4.0	3.3	0.4	< 0.5
VP10	2.6	Peristaltic	1.3	1.0	< 0.5	4.5	14.8
VP11	5.0	Peristaltic	3.7	1.0	< 0.5	3.2	< 0.5
VP12S	2.79	Peristaltic	3.8	Cloudy	< 0.5	Cloudy	22.4
		Vacuum			0.5		34.0
VP13S	3.05	Peristaltic	3.9	4.0	3.7	4.0	3.6
		Vacuum			1.8		7.2
VP13I	6.09	Peristaltic	1.3	1.0	< 0.5	1.0	66.4
		Vacuum			< 0.5		52.8
VP16	7.6	Vacuum	4.08	Cloudy		Cloudy	
DW2S	2.45	Bladder	2.12			0.0	
DW2I	4.83	Bladder	0.62			2.5	
DW2D	25.2	Bladder	1.22	1.0		6.0	
DW4S	3.26	Bladder	2.48	2.0		4.2	
DW4I	5.52	Bladder	1.33	1.0		5.0	
DW4D	25.48	Bladder	1.84	2.0		5.2	
BH308S	5.08	Bladder	0.33	Cloudy		Cloudy	
BH308I	19.42	Bladder	1.02	Cloudy		Cloudy	
BH309S	3.97	Bladder	1.04	1.0		4.5	
BH309I	25.84	Bladder	0.76	Cloudy		Cloudy	
BH309D	29.53	Bladder	0.82	0.0		5.5	

Key: FTC = flow through cell

Hach = field test kit

3.1.3 Organic contaminants

Data on the petroleum hydrocarbons detected in the groundwater samples are summarized in Table 3.4.

Two types of pumps were employed to sample the narrow wells (6mm and 22 mm id) installed with the Geoprobe, a peristaltic pump and a vacuum pump. Both pumps were at their limit for sampling from 11.0 – 13.0 mbgl. Some wells were sampled with both types of pump to assess the effect of vacuum pumping on the loss of volatiles from the groundwater. In general, samples recovered with the vacuum pump had lower concentrations of volatiles than those recovered with the peristaltic pump, however, the difference was only significant when the concentration of volatiles in the groundwater was low-moderate (< 1 mg/l). See for example, samples from VP8S. When the concentration of volatiles was high (> 1 mg/l) the difference was generally insignificant (see for example samples from VP12S, VP13S and VP13I). Duplicate sampling from the same well by the same method gave reasonably reproducible data (see VP12D and 309D).

Groundwater samples could only be obtained from two of the new well points that had penetrated beneath the firm/stiff clay layer, namely VP8D and VP12D. Neither of these contained significant concentrations of petroleum hydrocarbons.

Of the new wells in the shallow groundwater VP8, VP10, VP11, VP12, VP13 and VP 16 had concentrations of one or more of the following components TPH, BTEX, trimethylbenzenes, styrene and naphthalenes at > 1 mg/l. The TPH is in the C6-C16 range. The TPH values reported undoubtedly include the BTEX, TMBs, styrene and naphthalenes. The new wells thereby confirm the widespread contamination of the shallow groundwater in the centre of the site reported previously (Earle *et al*, 2001; Jones *et al*, 2001).

Wells VP2 and VP4 were essentially clean, suggesting that the shallow groundwater contamination does not extend as far south-eastwards as was proposed in the Conceptual Site Model report (Earle *et al*, 2001; Jones *et al*, 2001).

VP12 (1-2 mg/l styrene) confirms the presence of a styrene plume in the shallow groundwater first detected in DW4S. Repeat sampling of DW4S this time around yielded a styrene concentration of 38 mg/l. The styrene is co-mingled with petroleum hydrocarbons (TPH, BTEX, TMBs and naphthalenes). This provides the opportunity for an MNA study on styrene.

Repeat sampling of traditional borehole 309D screened in the top of the sandstone confirms the presence of benzene at 5 mg/l.

Only trace amounts of chlorinated organics were detected at DW2I (115 ppb dichloroethane and 254 ppb trichloroethane).

Table 3.4 Petroleum hydrocarbon contamination of groundwater. All units are mg/l

Location	Depth (m)	Pump	TPH	B	T	E	X	S	TMB	N	MN
VP1											
VP2	3	P			0.001	0.001	0.001			0.003	
VP4	3	P	0.056		0.002		0.005	0.001		0.003	
VP8S	3	V	0.049	0.001	0.012				0.001	0.001	
VP8S	3	P		0.210	1.92	0.009	0.033	0.003	0.012	0.006	
VP8I	8.5	V		0.010	0.059		0.032		0.009	0.003	
VP8I	8.5	P	0.002	0.027	0.076	0.002	0.009	0.001	0.002		
VP8D	13	V		0.003	0.030	0.007	0.034		0.001	0.008	
VP10	2.6	P	0.093	0.380	2.57						
VP11	5	P	0.742	1.13	6.88						
VP12S	2.8	V	71.4	0.909	3.12	4.76	5.33	1.89	1.15	13.1	2.68
VP12S	2.8	P	47.5	0.938	3.24	4.56	4.54	1.31	0.758	8.54	0.618
VP12D	11.5	V		0.047		0.146	0.016	0.004	0.002	0.043	
VP12D	11.5	V		0.036		0.011	0.013	0.003	0.001	0.041	
VP13S	3	V	230	15.0	248		1.17			0.197	0.077
VP13S	3	P	252	16.8	251		2.39			0.235	0.070
VP13I	6	V	205	76.5	155	1.73	6.36		2.19	0.578	0.051
VP13I	6	P	200	90.0	190		2.29			0.331	0.024
VP16	7.6	V		0.161	1.04						
DW2S	2.5	B									
DW2I	4.8	B									
DW2D	25.2	B									
DW4S	3.3	B			225	24.7		38.3		2.24	0.217
DW4I	5.5	B		1.41	22.7	10.2				0.959	0.076
DW4D	25.5	B		2.33	0.106	3.80				0.480	0.009
308S	5	B		18.9							
308I	19.4	B		10.2						0.001	
309S	4	B		7.68		0.138			0.148	0.069	0.031
309I	25.8	B		0.056						0.003	
309D	29.5	B		5.20						0.016	0.009
309D	29.5	B		5.03						0.013	0.008

Key

TPH = total petroleum hydrocarbons

B = benzene

T = toluene

E = ethylbenzene

X = xylenes

S = styrene

TMB = trimethylbenzenes

N = naphthalene

MN = methylnaphthalene

S = shallow

I = intermediate

D = deep

V = vacuum pump

P = peristaltic pump

A blank entry = below the detection limit

3.2. Groundwater chemistry from the deep boreholes in the sandstone aquifer

The contaminant analysis data from the August 2002 round of sampling is summarized in Table 3.5 and Figure 3.3.

Table 3.5 Petroleum hydrocarbon contamination ($\mu\text{g/l}$) of the sandstone aquifer (August 2002; NA = Not Analysed)

Well	Depth (m)	Benzene	Toluene	Ethylbenzene	Xylenes	BTEX	TPH
309D	30.5	3589	29	11	121	3750	NA
401	35.2	< 1	< 1	< 1	< 1	< 1	< 1
402A	44.1	167	79	< 1	7	253	202
402B	35.0	64	< 1	1	< 1	65	<1
402C	29.0	1583	84	16	19	1702	2547
403	35.0	45	12	8	3	68	137
405	35.0	5523	26	7	9	5565	10639
406	28.0	< 1	< 1	< 1	< 1	< 1	< 1
406	30.5	< 1	< 1	< 1	< 1	< 1	< 1
406	32.0	< 1	< 1	< 1	< 1	< 1	< 1
406	33.5	19	< 1	< 1	< 1	19	< 1
406	35.0	< 1	< 1	< 1	< 1	< 1	< 1
406	36.5	102	914	50	42	1108	< 1
406	38.0	42	683	3	16	744	< 1
407	35.0	< 1	< 1	< 1	< 1	< 1	< 1
408	25.0	46	2	1	< 1	48	< 1

The presence of a petroleum hydrocarbon contamination plume composed of BTEX (primarily benzene) plus some TPH (gasoline range) in the vicinity of BH309 was confirmed. The highest concentrations were recorded in boreholes 309, 406, 402 and 405. Given the variability in the depths at which contamination is detected in the different wells, interpretation of the data is not straightforward.

Data on electron acceptors/reduced products from the August 2002 round of sampling is summarised in Table 3.6.

Table 3.6 Electron acceptors/reduced products in groundwater from the sandstone aquifer (August 2002)

Well	Depth (m)	DO* (mg/l)	Nitrate (mg/l)	Ferrous iron (mg/l)	Sulphate (mg/l)	Methane (µg/l)	Alkalinity (mg/l)
309D	30.5	NA	NA	NA	NA	NA	NA
401	35.2	1.4	0.4	< 1	9	1107	696
402A	44.1	2.6	0.3	< 1	27	2110	308
402B	35.0	2.1	0.4	< 1	11	469	192
402C	29.0	1.6	0.4	< 1	24	714	506
403	35.0	4.8	0.4	< 1	11	1430	500
405	35.0	2.7	0.3	< 1	< 1	4654	92
406	28.0	0.3	0.4	< 1	12	337	224
406	30.5	0.3	0.5	< 1	4	253	292
406	32.0	0.3	0.5	1.1	45	52	388
406	33.5	0.3	0.4	< 1	36	1855	424
406	35.0	0.3	< 0.1	< 1	40	1555	332
406	36.5	0.3	0.8	< 1	89	784	416
406	38.0	0.3	< 0.1	< 1	< 1	226	NA
407	35.0	2.1	0.4	< 1	8	653	280
408	25.0	2.6	0.3	< 1	< 1	2336	256

NA = not analysed

* = data from March 2002 before installation of the multi-level sampler

Dissolved oxygen was generally < 2.5 mg/l, nitrate was insignificant (< 1 mg/l), ferrous iron was generally below the limit of detection (1 mg/l), sulphate ranged from > 1 to 89 mg/l, methane from 0.05 – 4.7 mg/l and alkalinity ranged from 92 – 696 mg/l.

4. CONCLUSIONS

- BTEX (primarily benzene) contamination at the top of the sandstone aquifer in the region of BH309 has been confirmed (up to 5.6 mg/l).
- No pathway through the boulder clay has been found to explain how the benzene contamination in BH309D has reached the sandstone aquifer. However the clay layer does reduce in thickness to approximately 4 m and contains a high proportion of sand and gravel in the vicinity of BH309.
- There is no evidence from the vertical profiling that contamination has migrated through the boulder clay and into the sandstone at any other locations.
- The extent of contamination in the shallow aquifer does not extend as far to the south-east as was originally postulated in the Conceptual Site Model (Earle *et al.*, 2001; Jones *et al.*, 2001).
- The presence of a styrene plume co-mingled with BTEX, TMBs and naphthalenes has been confirmed in the shallow groundwater.
- No new chlorinated solvent contamination has been detected.
- Fe(III), sulphate and bicarbonate appear to be the most significant electron acceptors for anaerobic hydrocarbon degradation in the shallow groundwater at the site.

List of Abbreviations

BGL	Below Ground Level
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes (components of petrol)
CAH	Chlorinated Aliphatic Hydrocarbons
CPT	Cone Penetrometer Test
DELCD	Dry Electrolytic Conductivity
FID	Flame Ionization Detection
LIF	Light Induced Fluorescence
mbgl	Metres Below Ground Level
MIP	Membrane Interface Probe
MNA	Monitored Natural Attenuation
MN	Methylnaphthalene
PID	PhotoIonization Detection
SIReN	Site of Innovative Research into Monitored Natural Attenuation
TMB	Trimethylbenzenes
TPH	Total Petroleum Hydrocarbons

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FIGURES



Figure 2.1 Locations of vertical profiling points

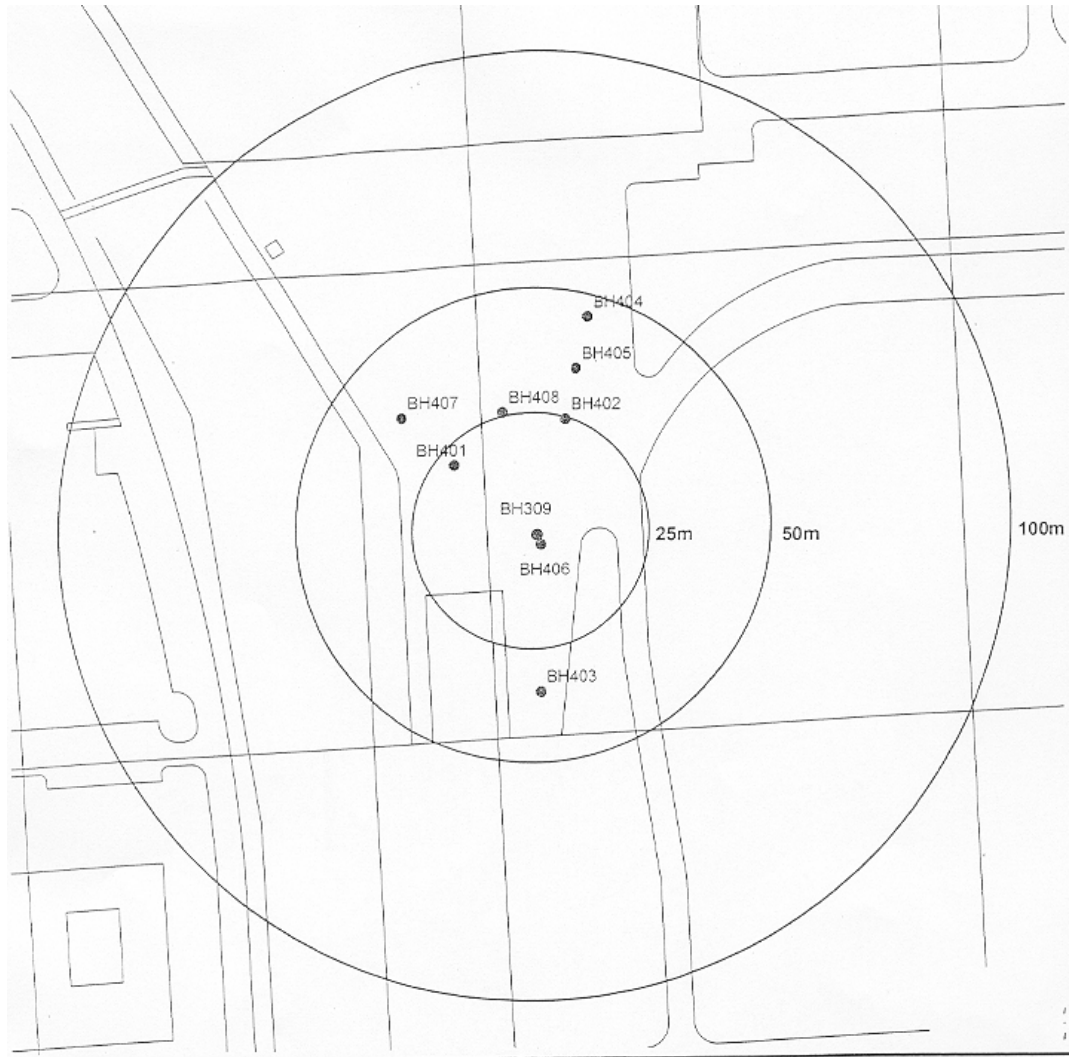
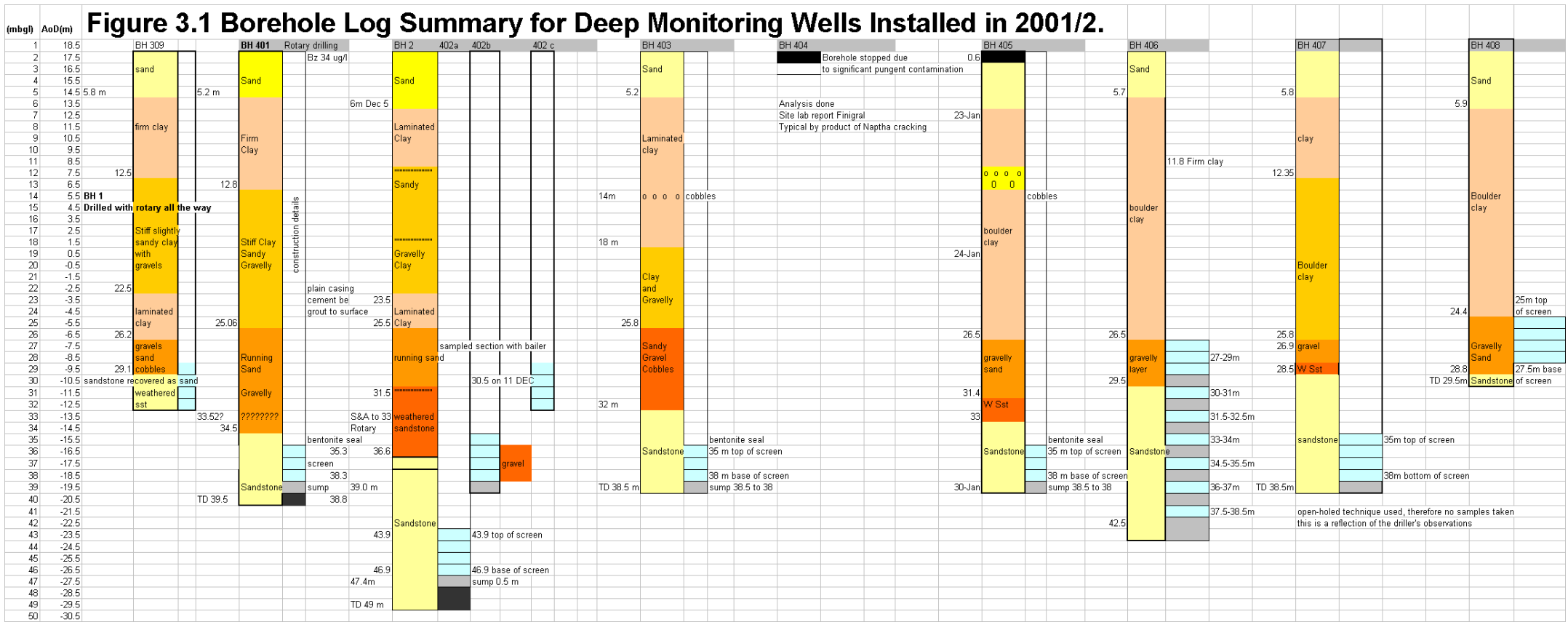
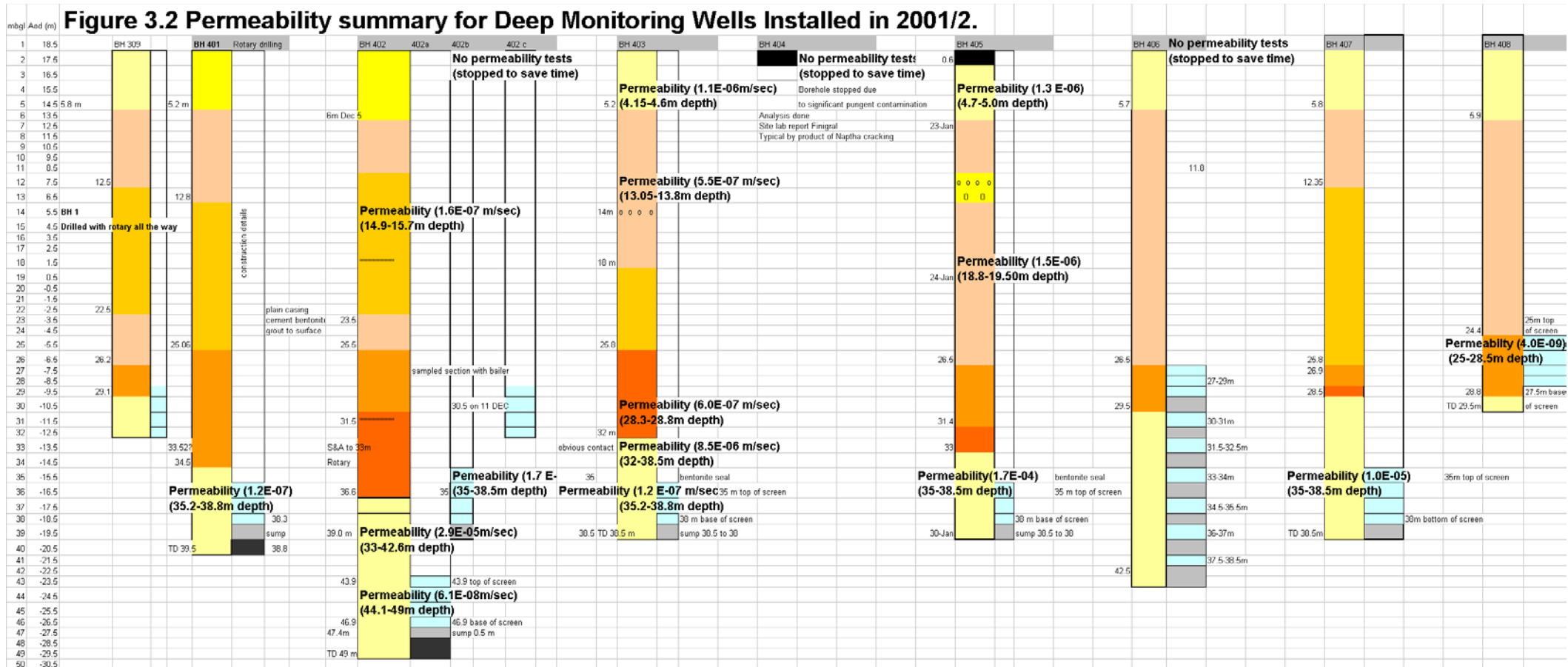


Figure 2.2 Location of deep groundwater quality monitoring wells installed in 2001/2





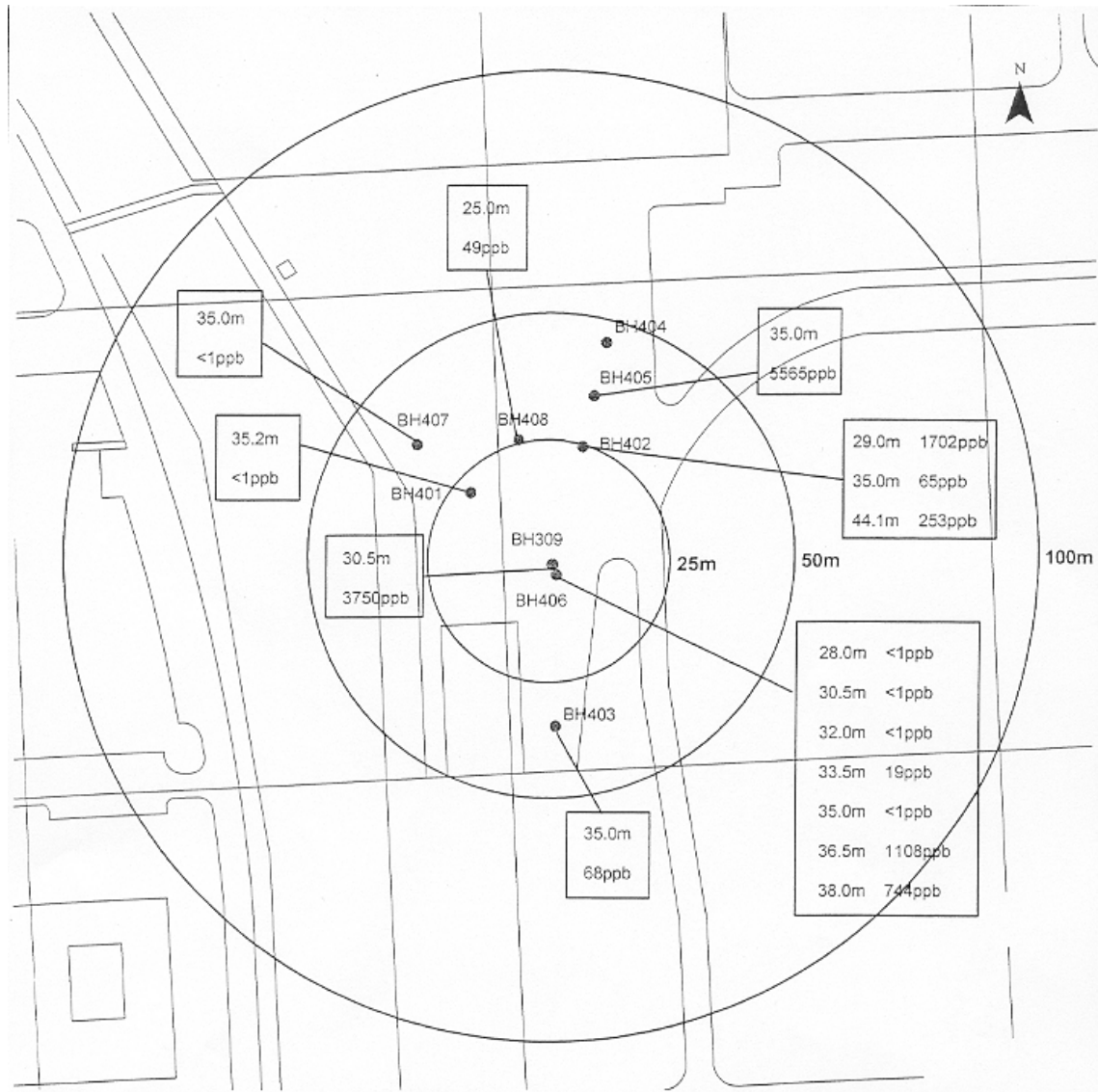
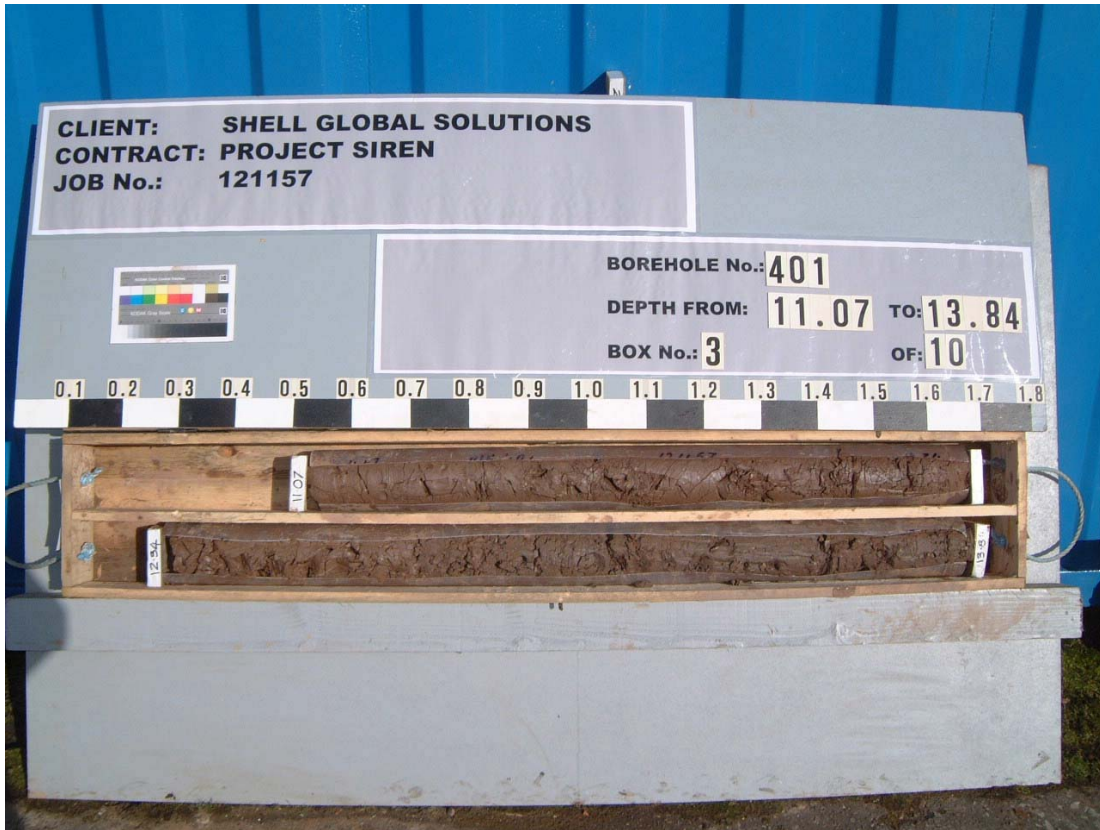


FIGURE 3.3 BTEX IN GROUNDWATER IN THE DEEP MONITORING WELLS (AUG 2002)

FIGURE 3.4 (A – J) CORES OF TRIASSIC SANDSTONE FROM BH 401





C AND D





E AND F





G AND H





I AND J



**FIGURE 3.5 (A - D) TRIASSIC SANDSTONE CORES FROM BH 402
A AND B**





C AND D



**FIGURE 3.6 (A - B) TRIASSIC SANDSTONE CORES FROM BH 403
A AND B**



**FIGURE 3.7 (A – C) TRIASSIC SANDSTONE CORES FROM BH 406
A AND B**



C

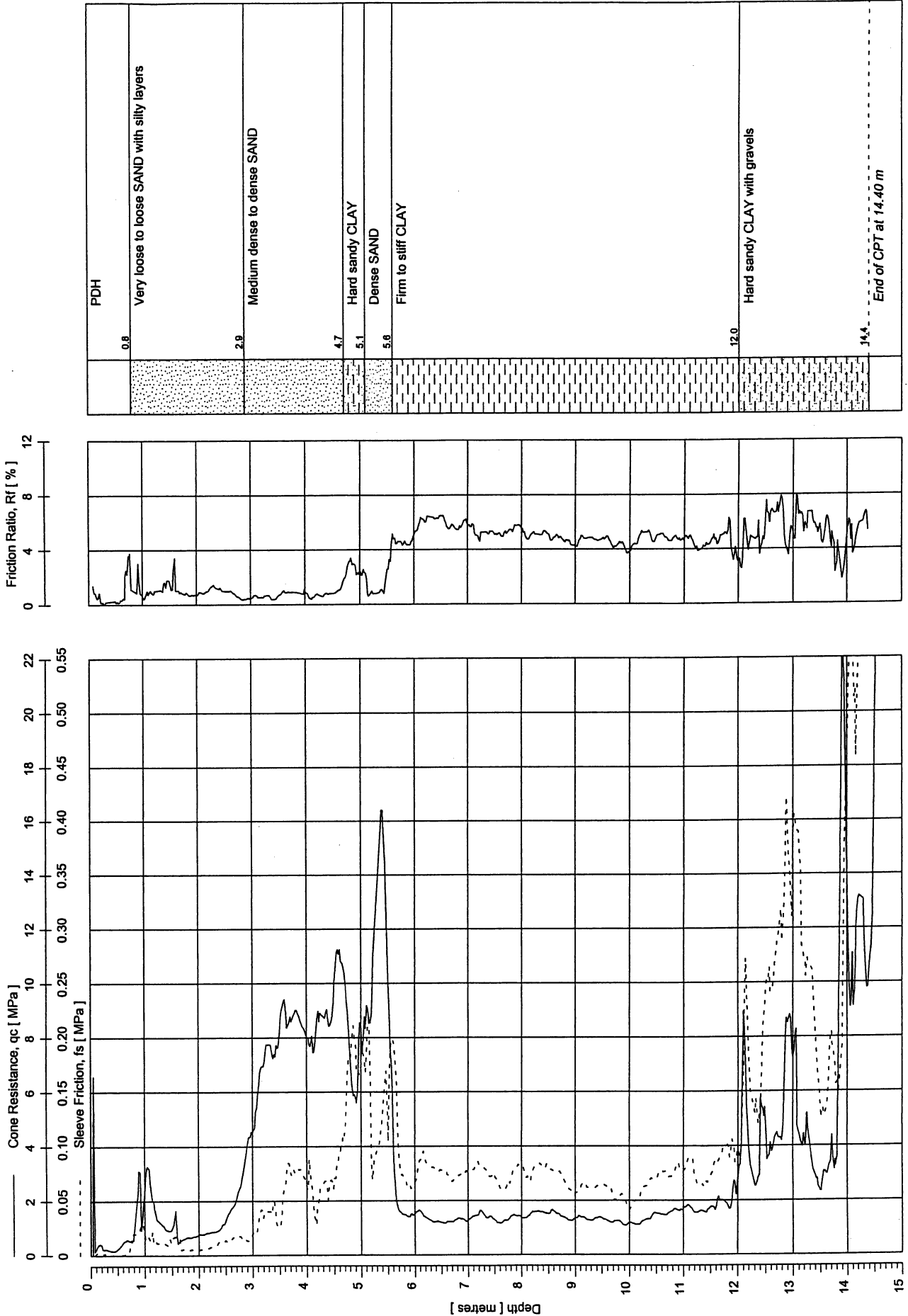


APPENDIX ONE – STATIC CONE TEST DATA



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Approved By: *PT* Date: 22/6/01
 Checked By: *TL* Date: 21-6-01



Interpretation Checked By: *PT*

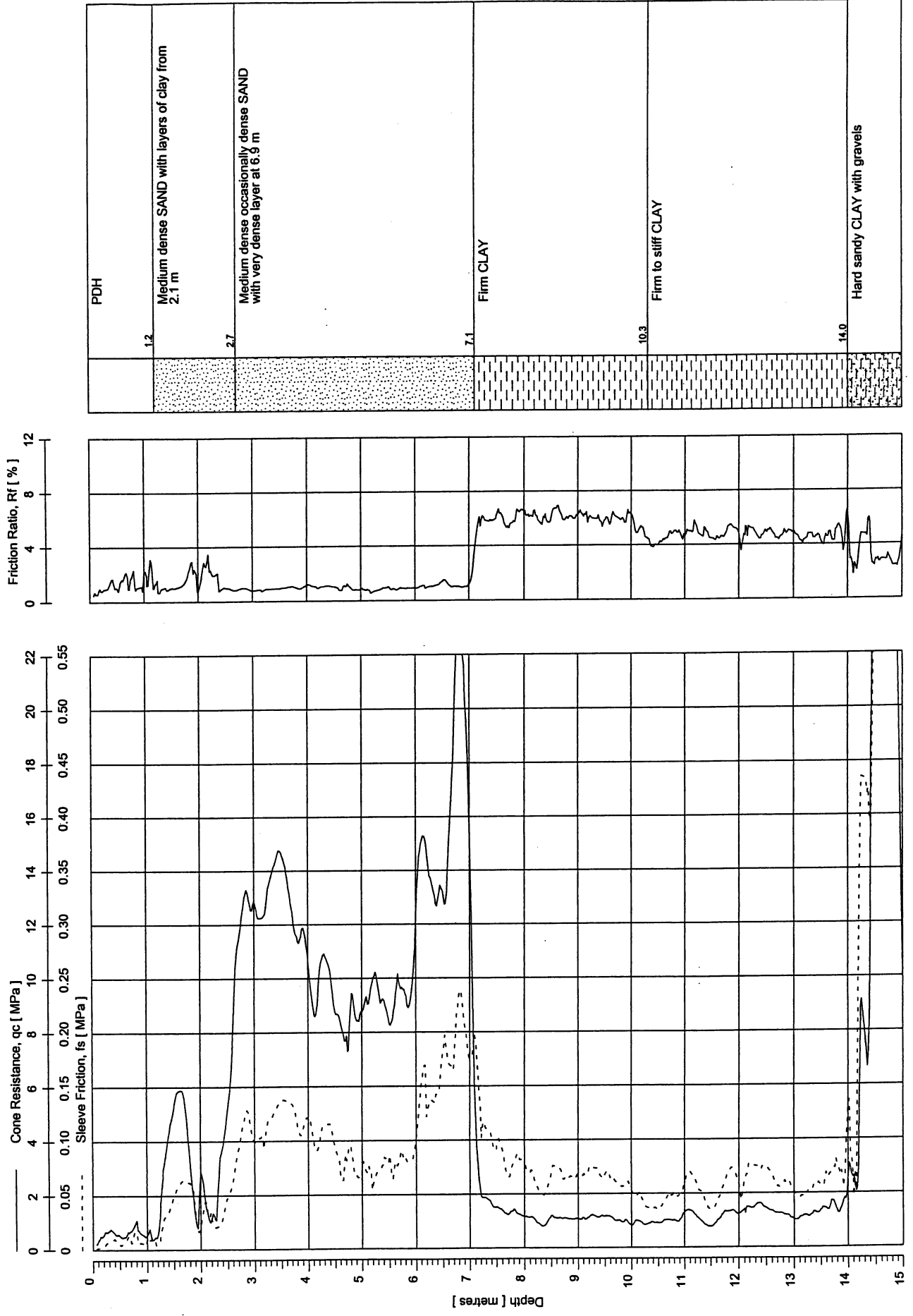
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 Ground Level (metres) :

STATIC CONE PENETRATION TEST

CPT1

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Approved By: *RA* Date: 22/6/01
 Checked By: *RC* Date: 21-6-01



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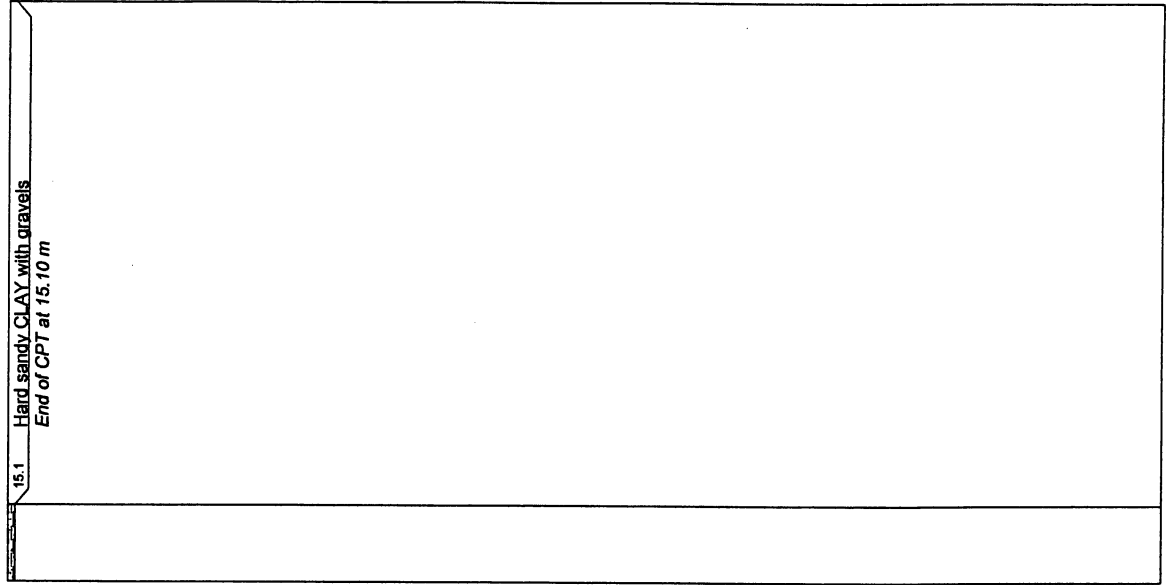
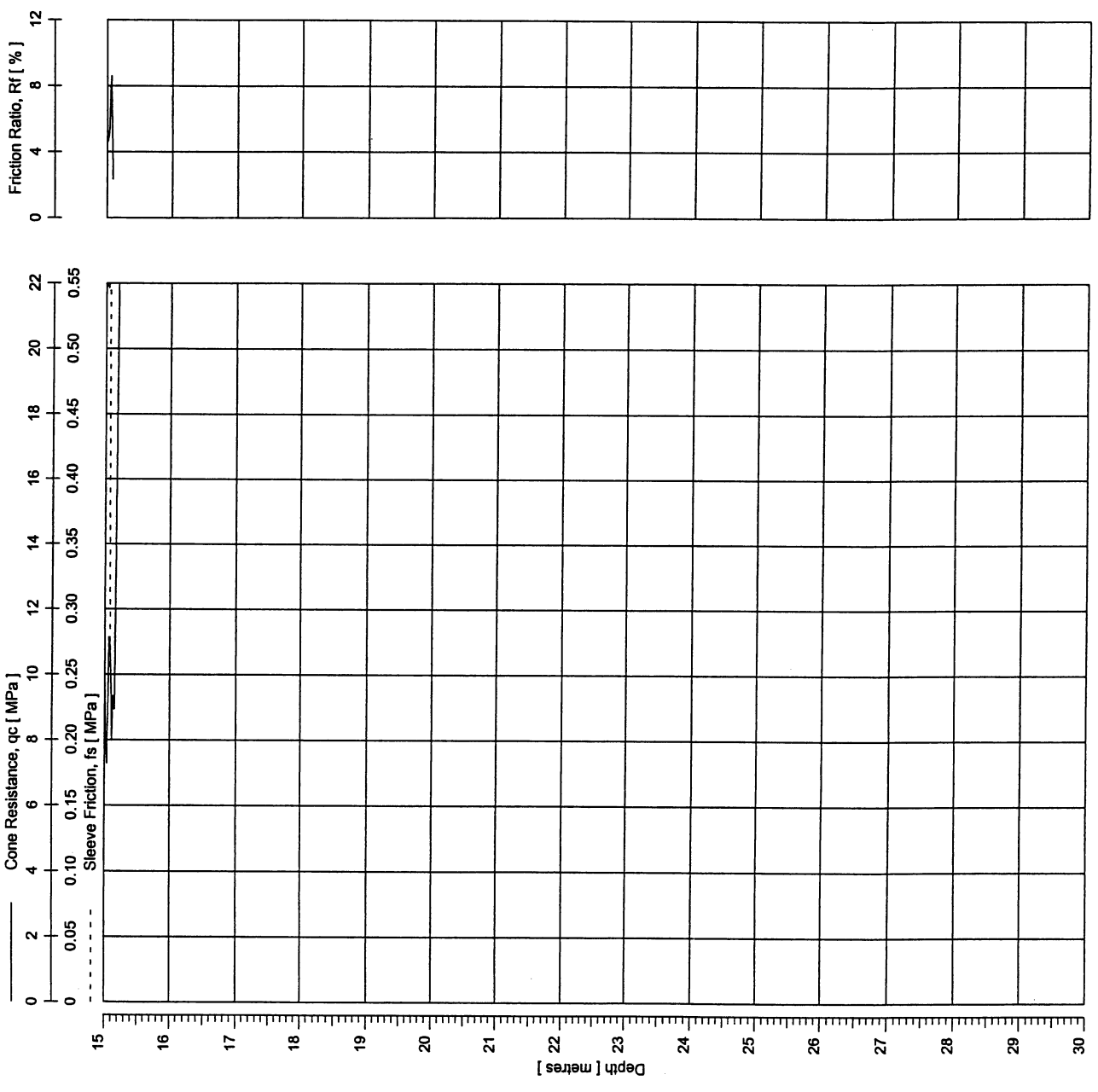
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STATIC CONE PENETRATION TEST CPT2



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Approved By: *HA* Date: 22/6/01
 Checked By: *DC* Date: 21-6-01



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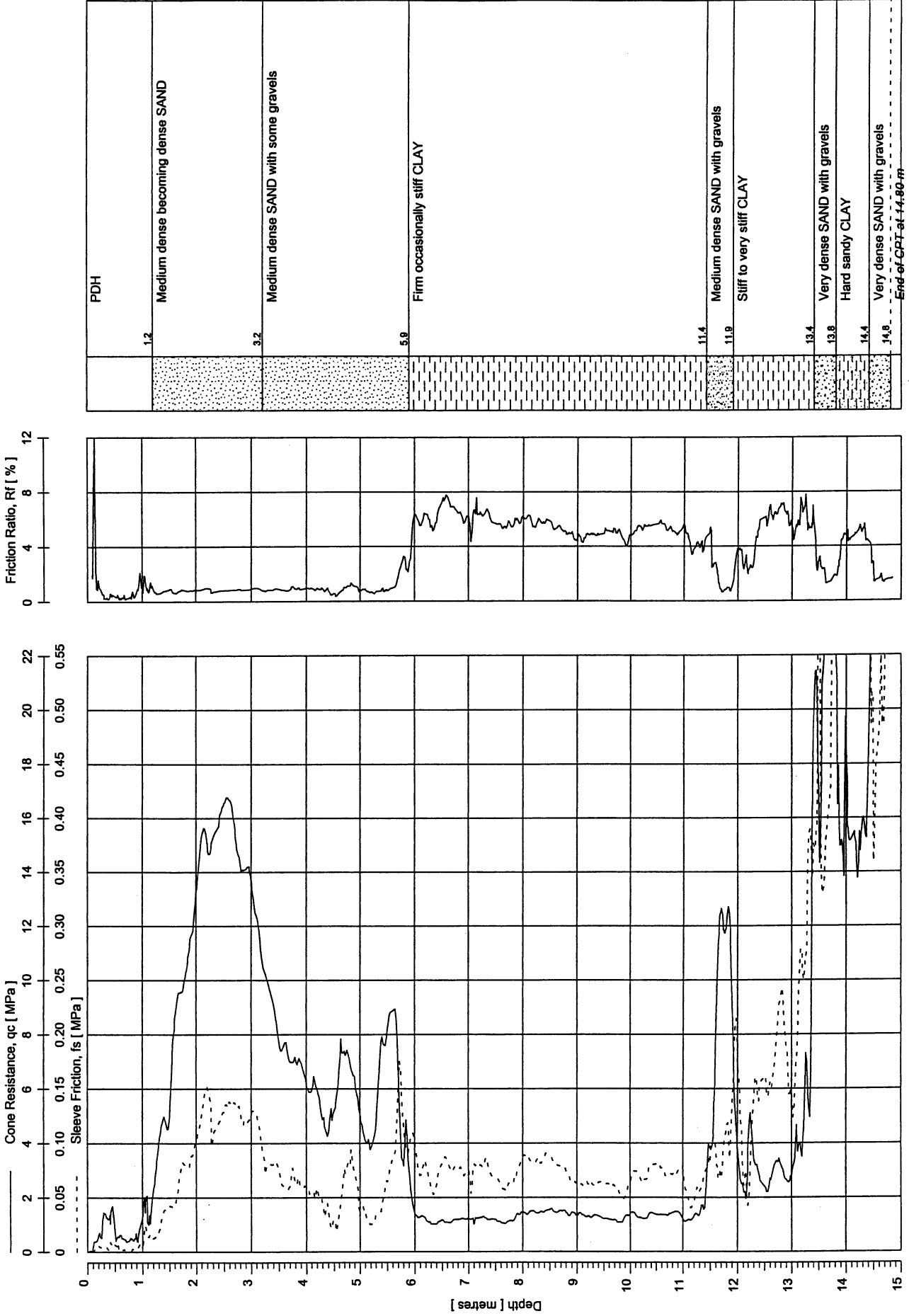
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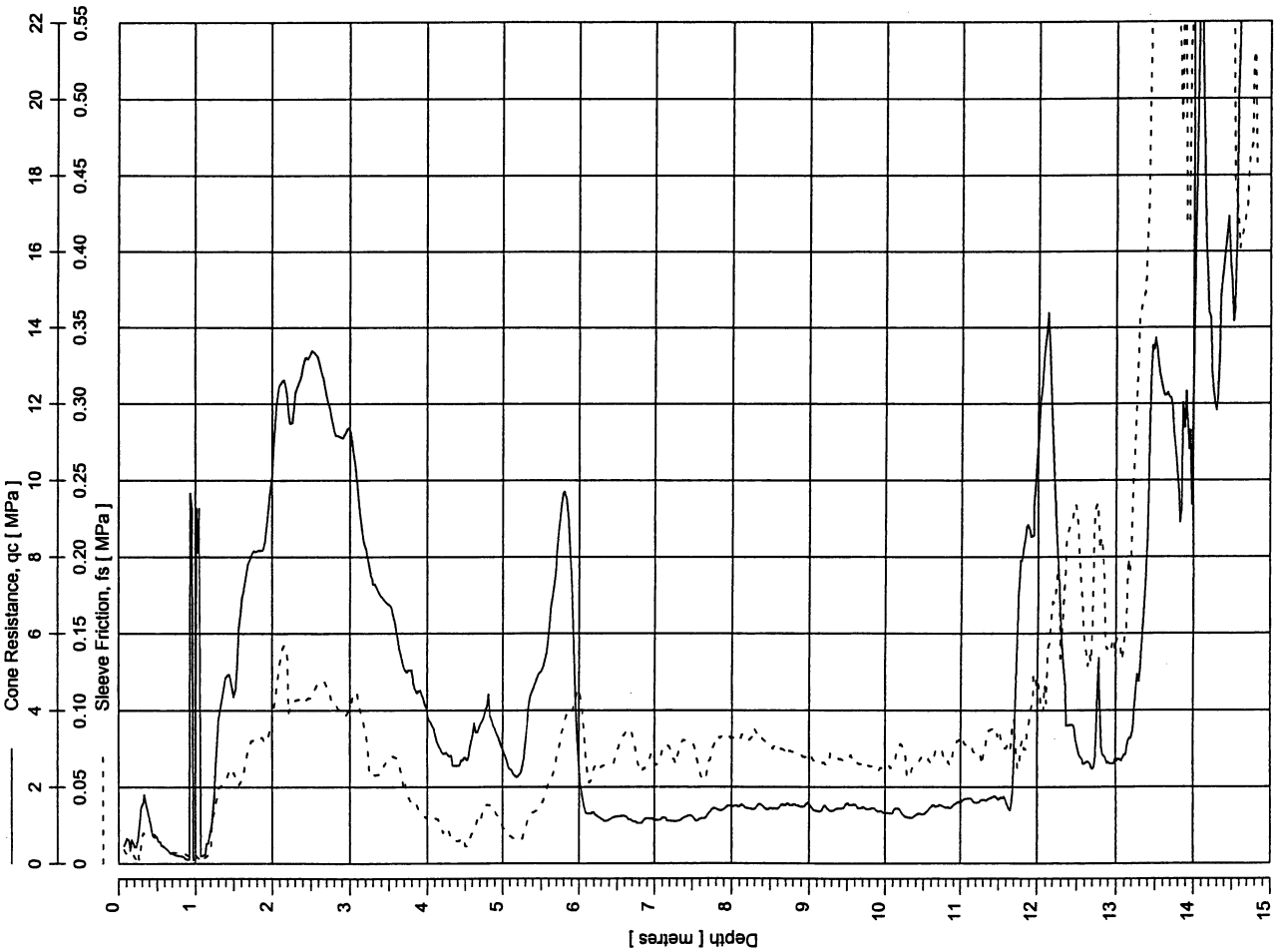
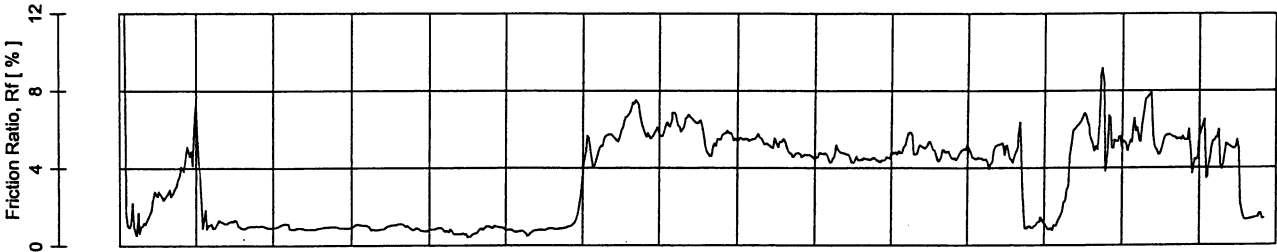
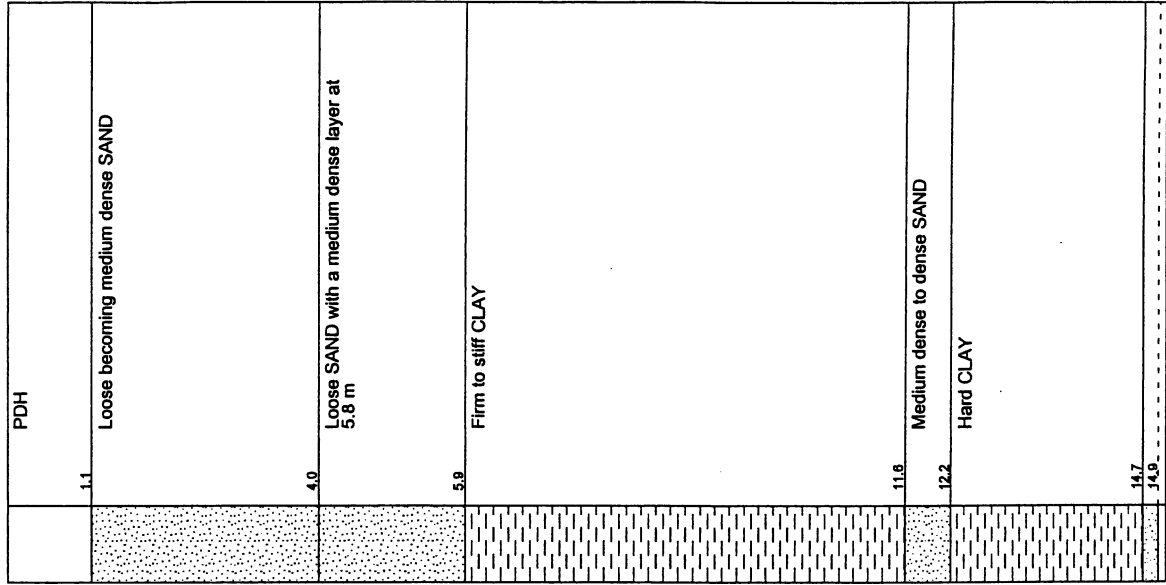
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 CPT4
 E7 ECV/EA/224

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 Date Drawn : / /



Approved By : MS
 Date : 22/6/01
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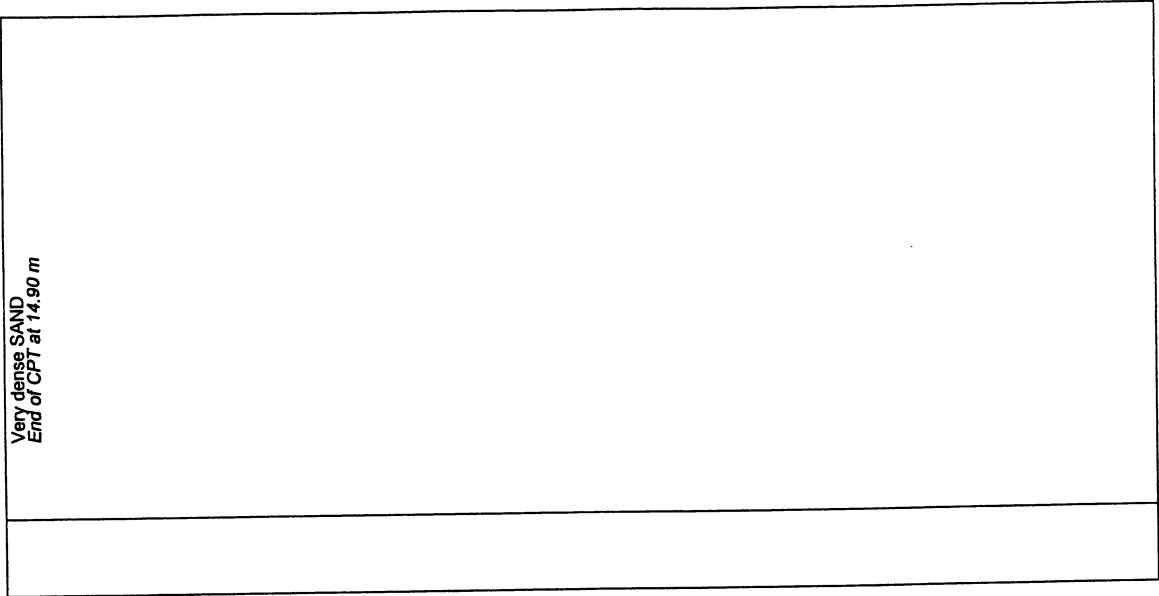
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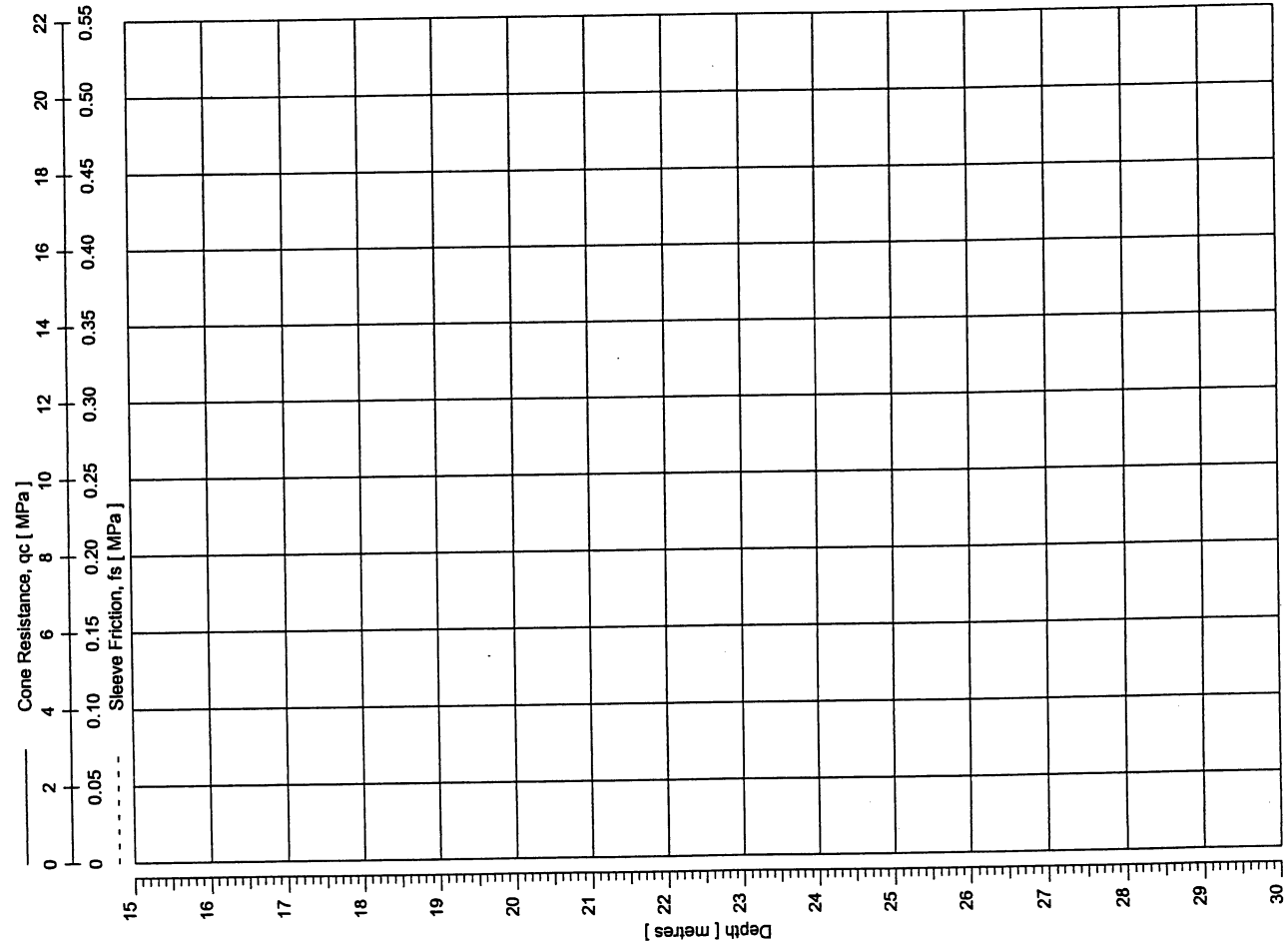
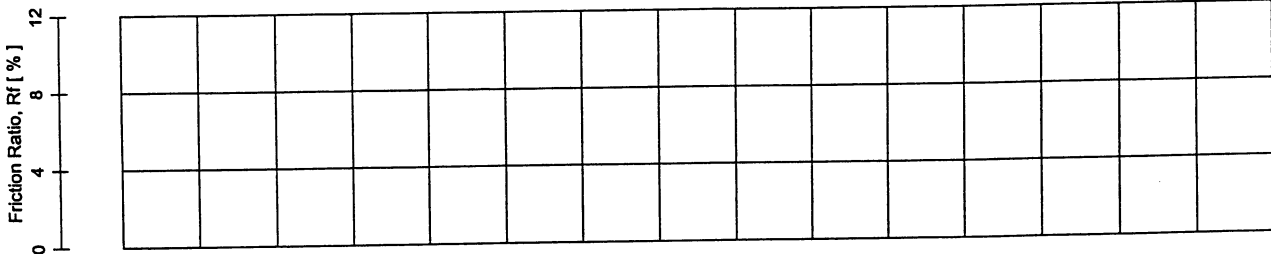
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Operator : MS Date Performed : 30/05/2001
Drawn By : PT Date Drawn : / /



Very dense SAND
End of CPT at 14.90 m



Approved By : *PT* Date : 22/6/01
Checked By : *DC* Date : 21-6-01

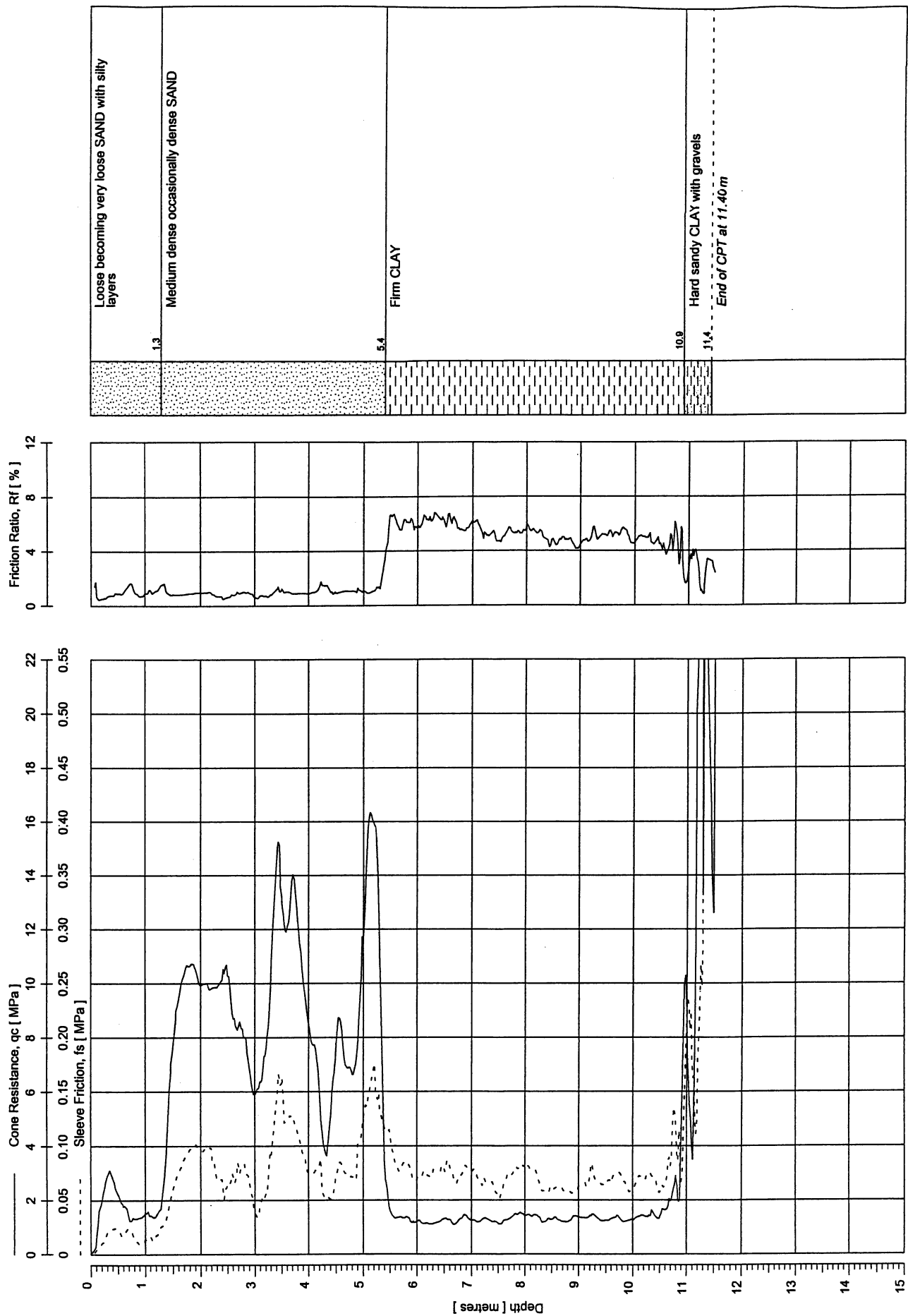
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Approved By : *PT* Date : 22/6/01
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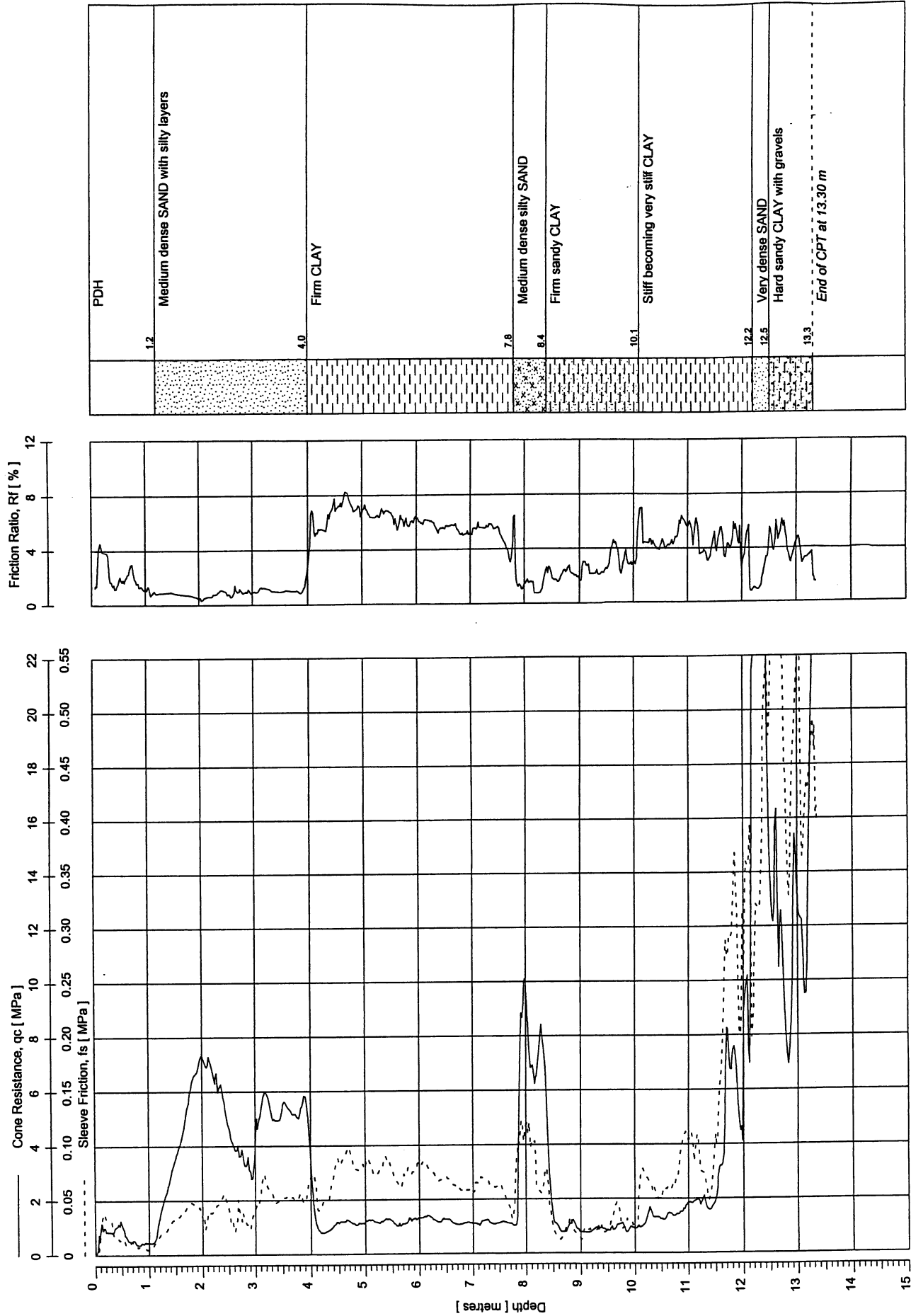
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 Checked By : *TX* Date : 21-6-01



Interpretation Checked By : *PAE*

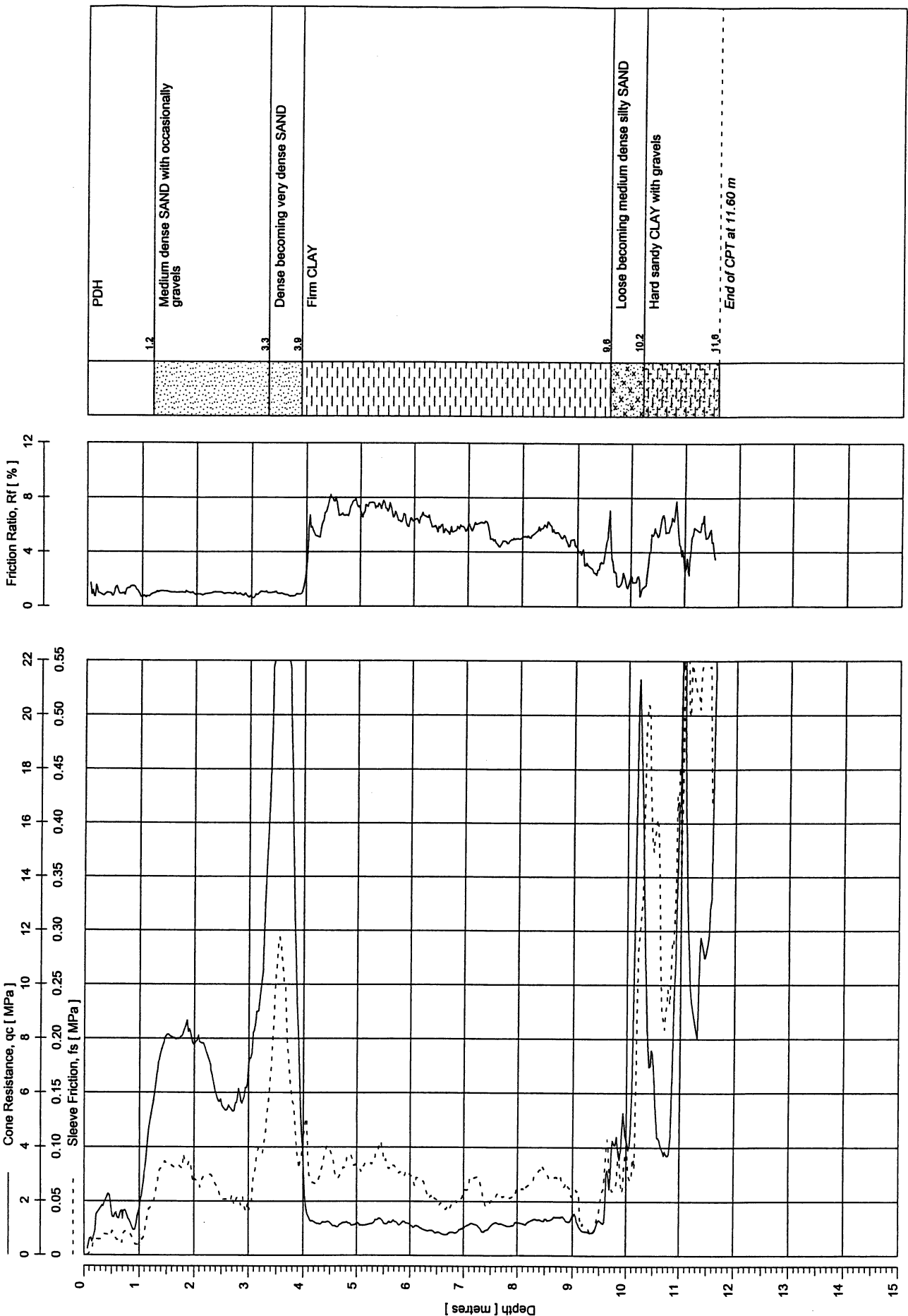
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Checked By : DC Date : 21-6-01



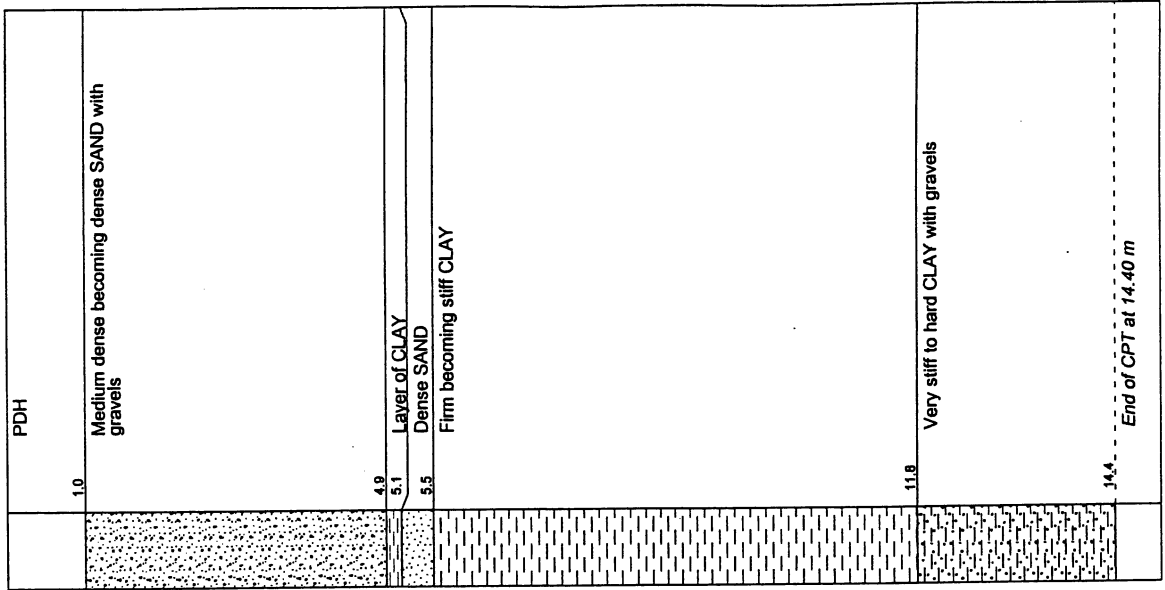
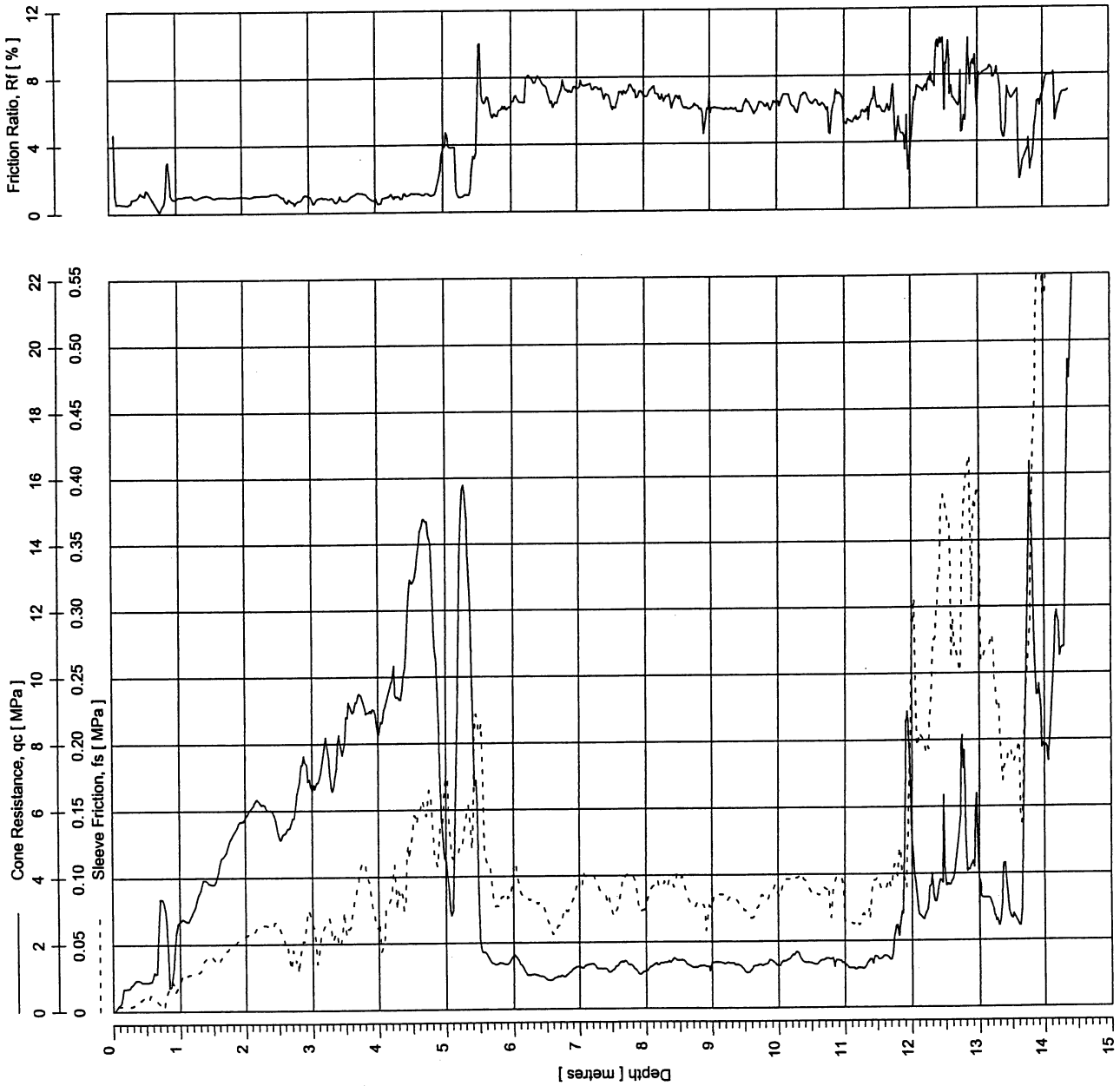
Interpretation Checked By : *MS*

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Approved By : *PT* Date : 22/6/01
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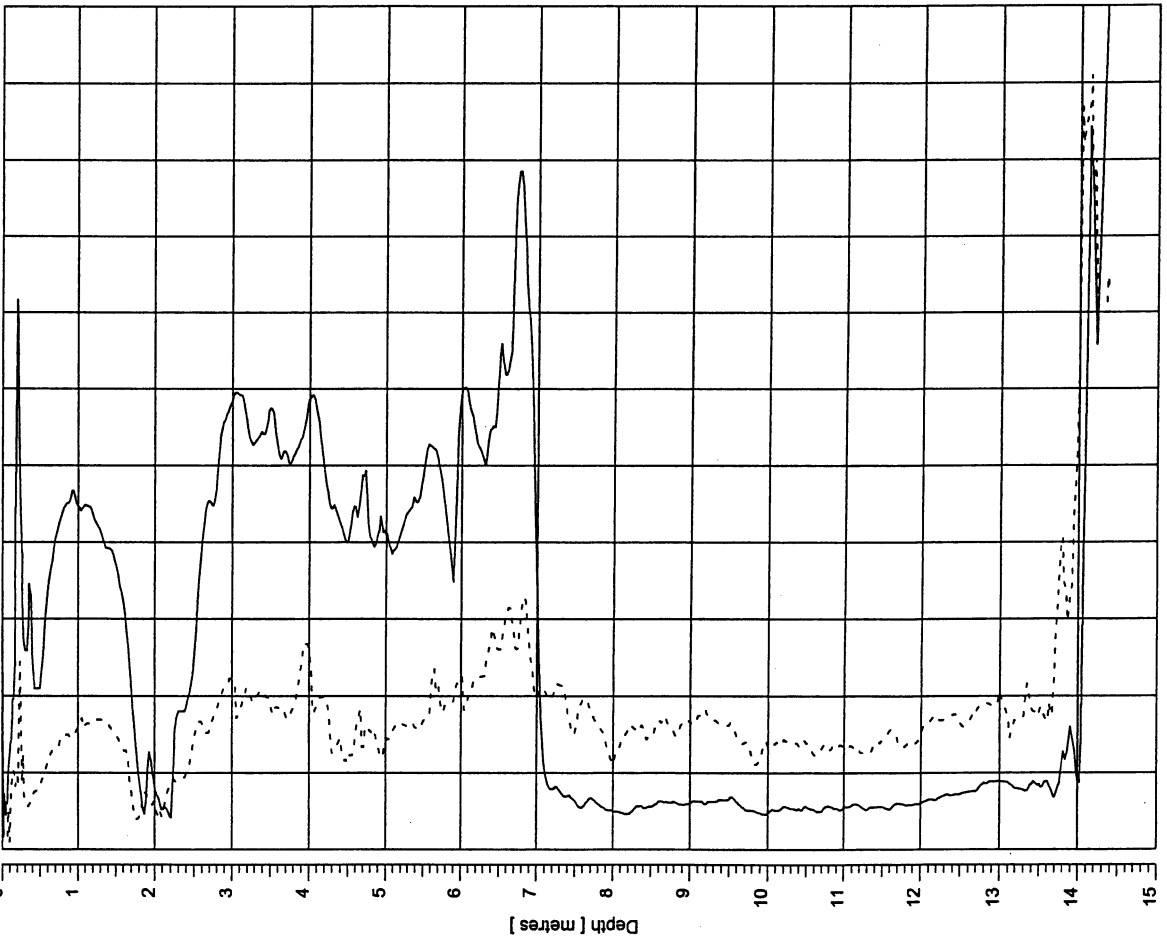
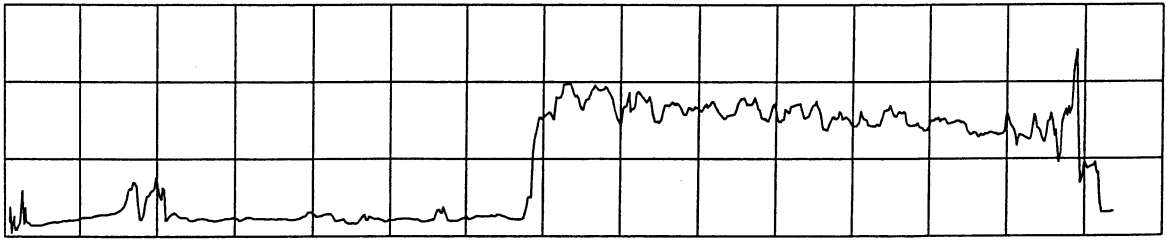
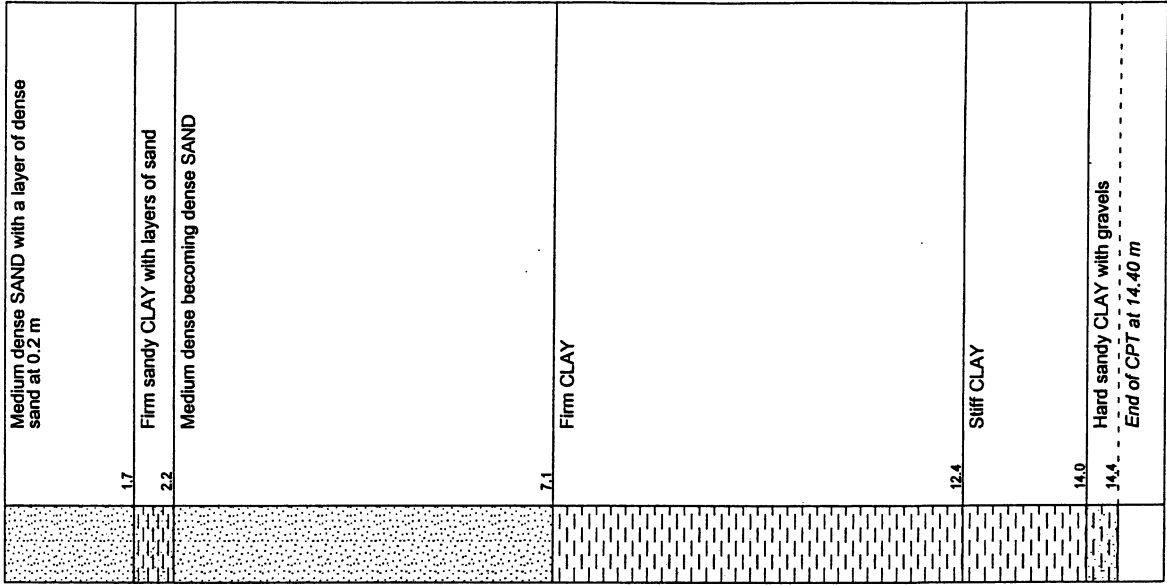
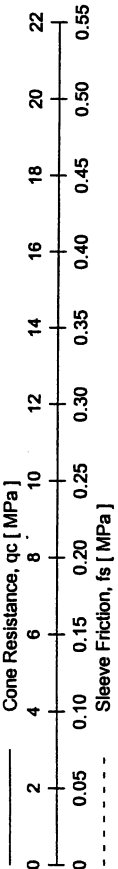
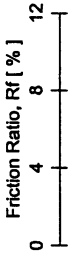
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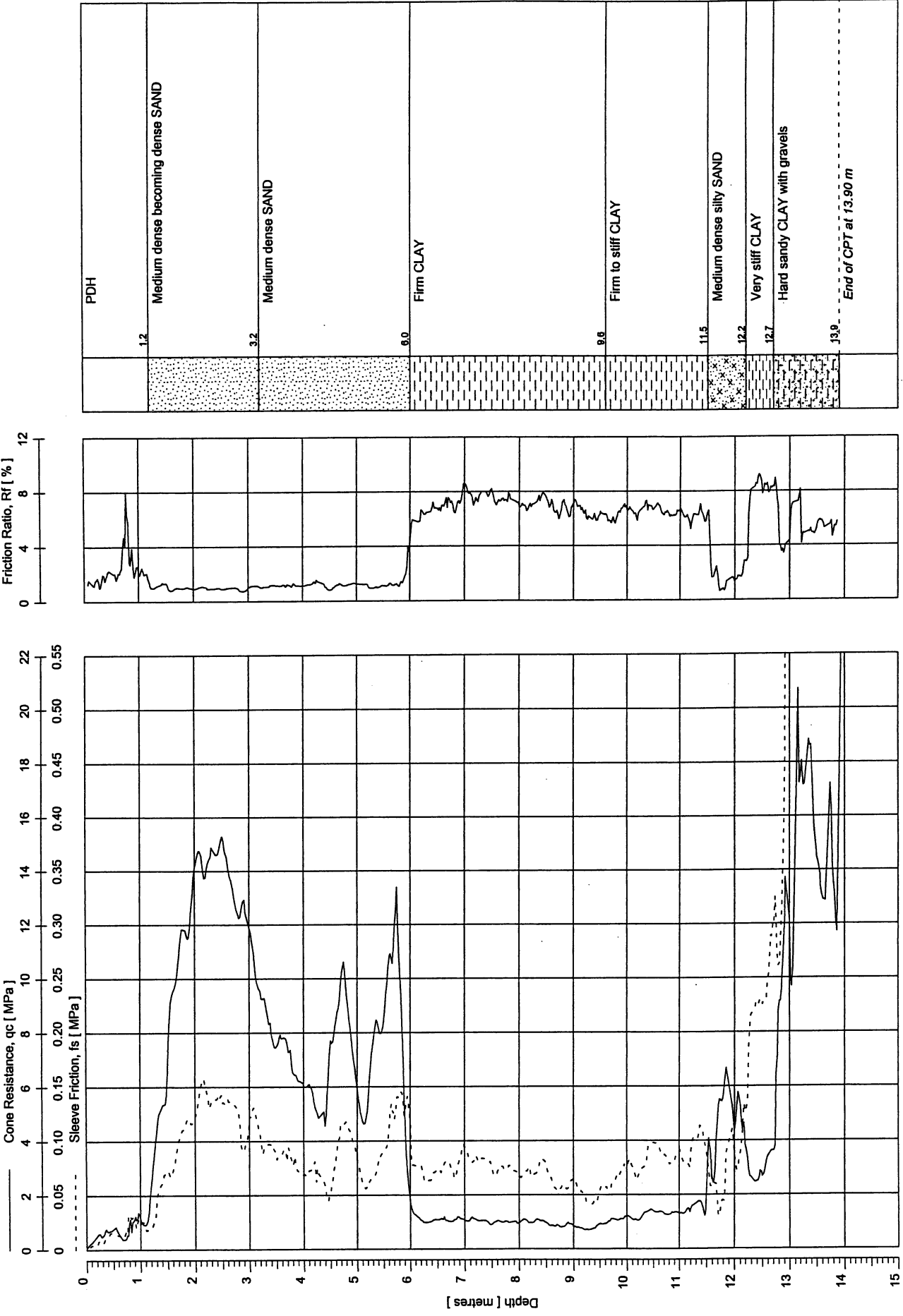
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Approved By : *PT* Date : 22/6/01
 Checked By : *DC* Date : 21-6-01



Interpretation Checked By : *PT*

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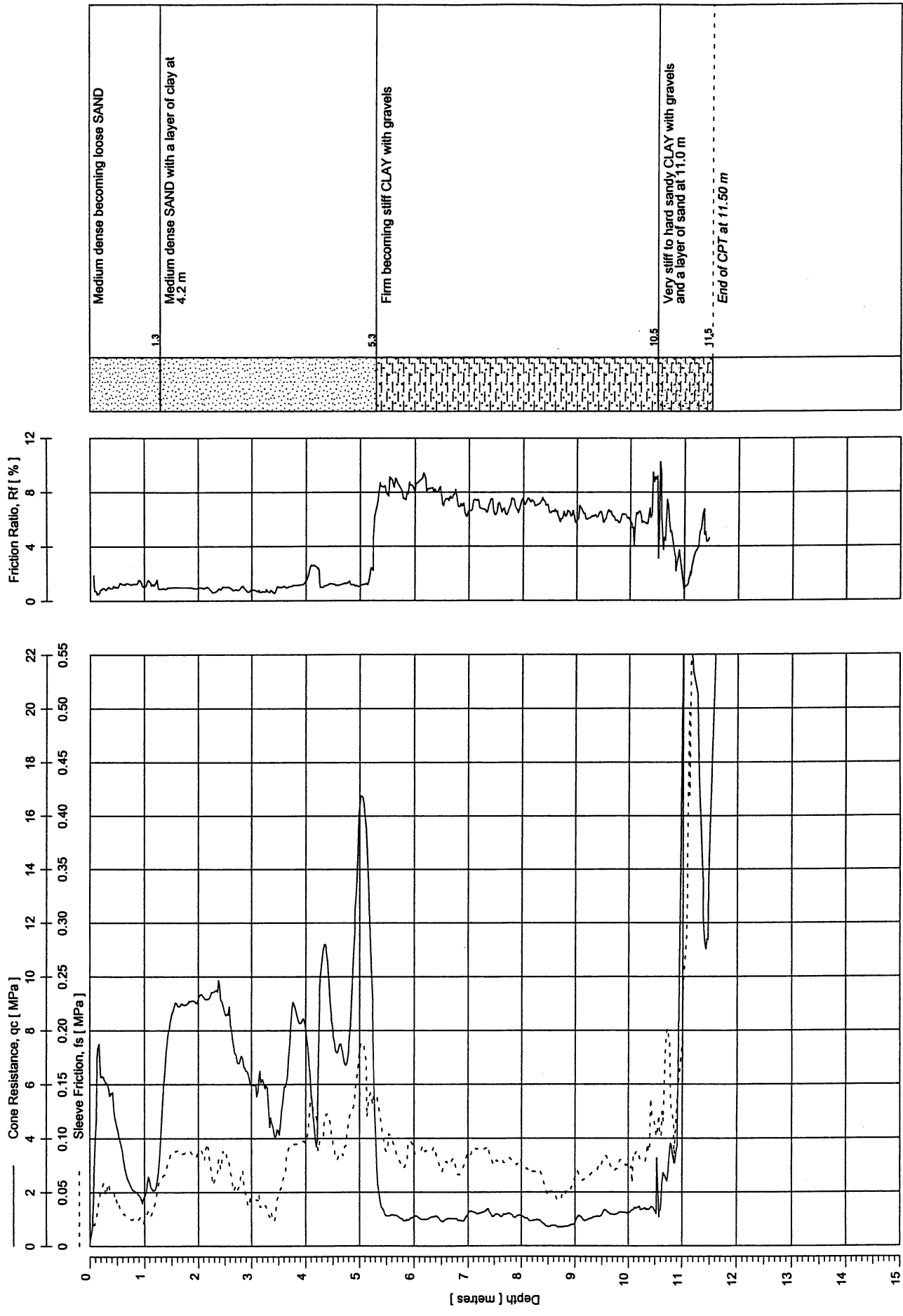
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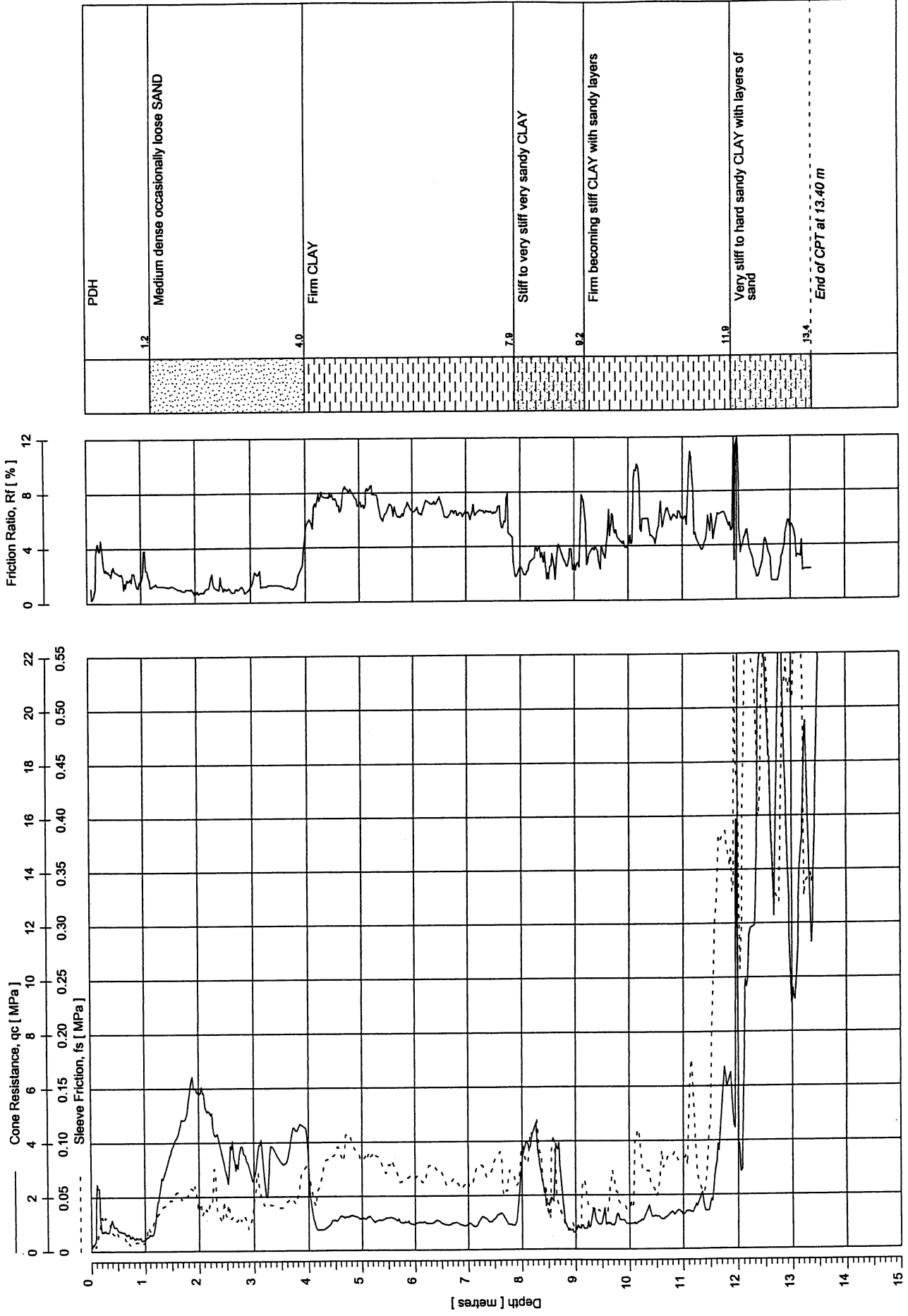
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 Drawn By : PT Date Drawn : / /

Approved By : *PT* Date : 22/6/01
 Checked By : *PC* Date : 21-6-01

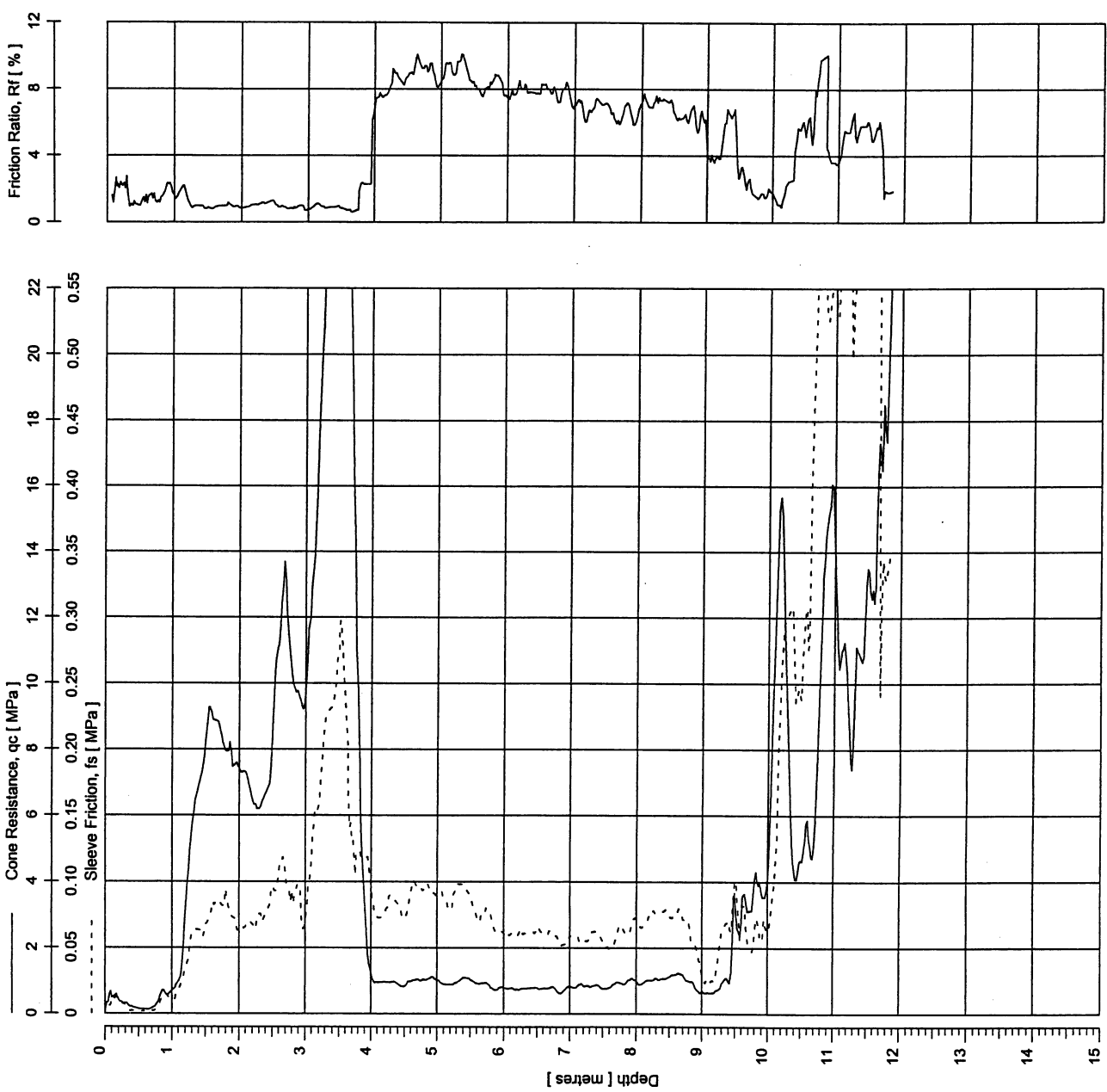


Location :
 Coordinates (metres) :
 Ground Level (metres) :
 Interpretation Checked By : *PT*

STATIC CONE PENETRATION TEST CPTM13



Operator: MS Date Performed: 05/06/2001
 Drawn By: PT Date Drawn: / /



Approved By: *MS* Date: 22/6/01
 Checked By: *PT* Date: 21-6-01

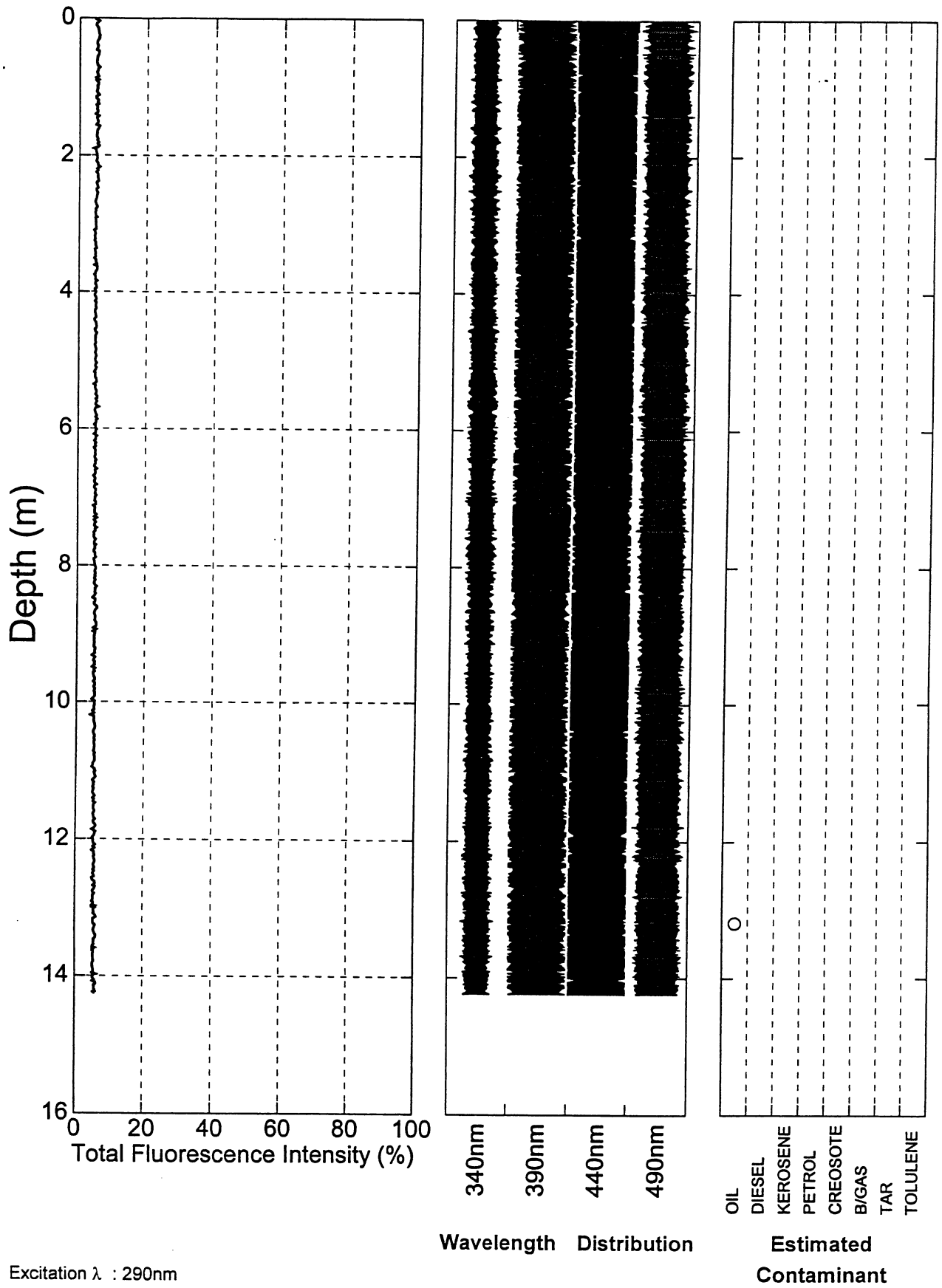
Interpretation Checked By: *PAJ*

Location:
 Coordinates (metres):
 Ground Level (metres):
 Cone Used: F7.5CKEV 1171

STATIC CONE PENETRATION TEST CPTM15

APPENDIX TWO – CONE PENETROMETER LIF DATA

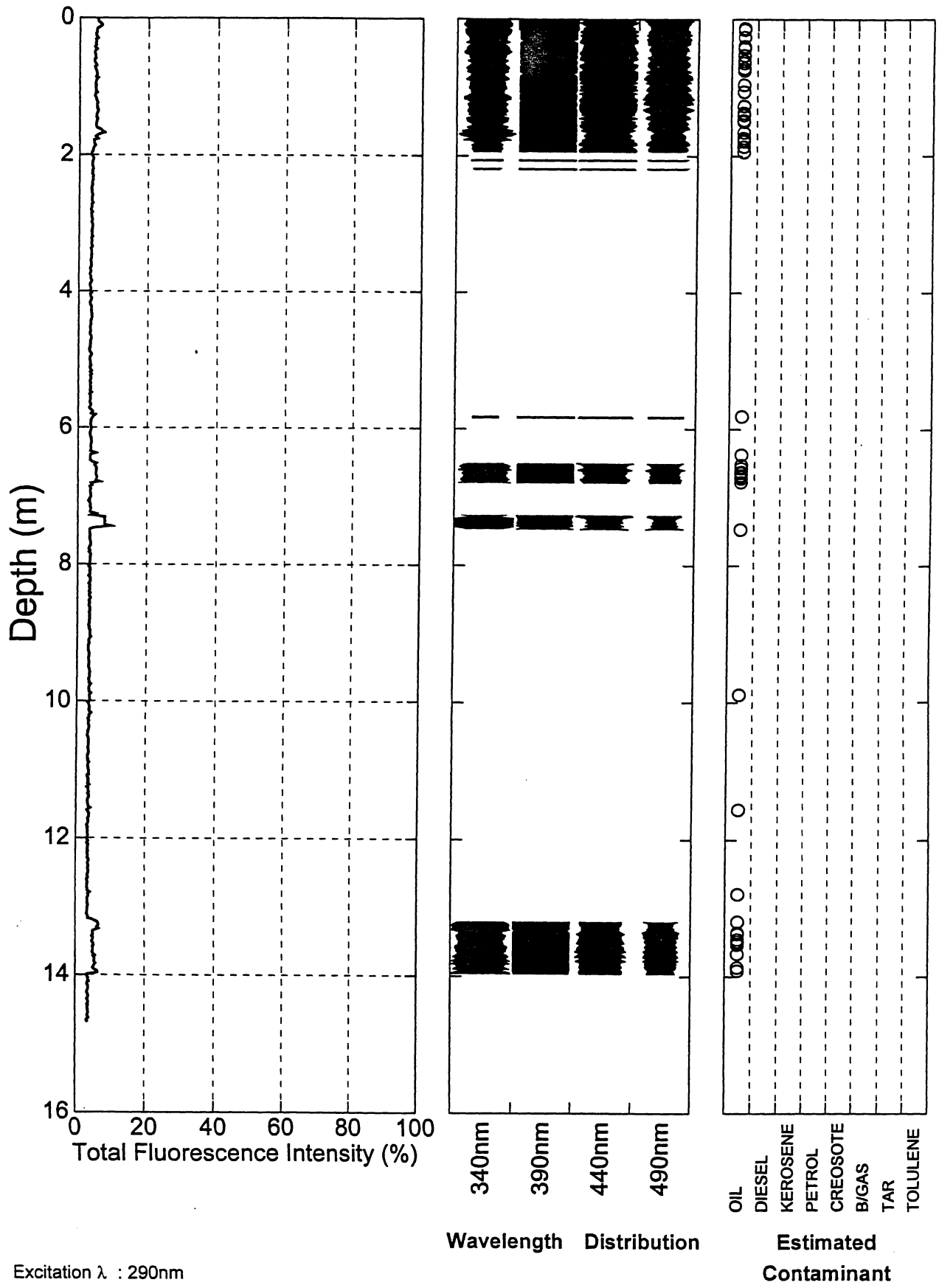
CPT1



LASER INDUCED FLUORESCENCE RESULT



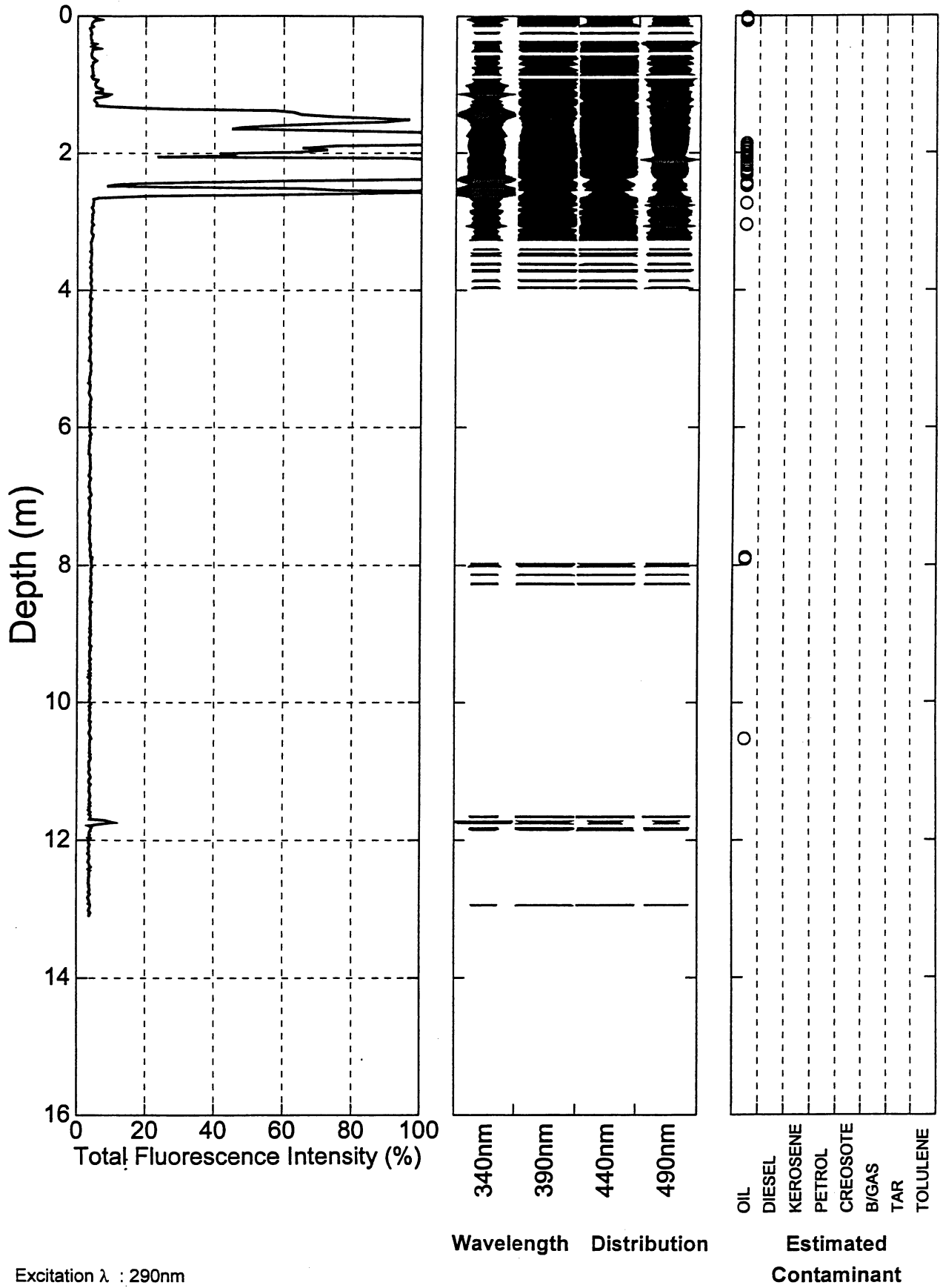
CPT4A



Excitation λ : 290nm

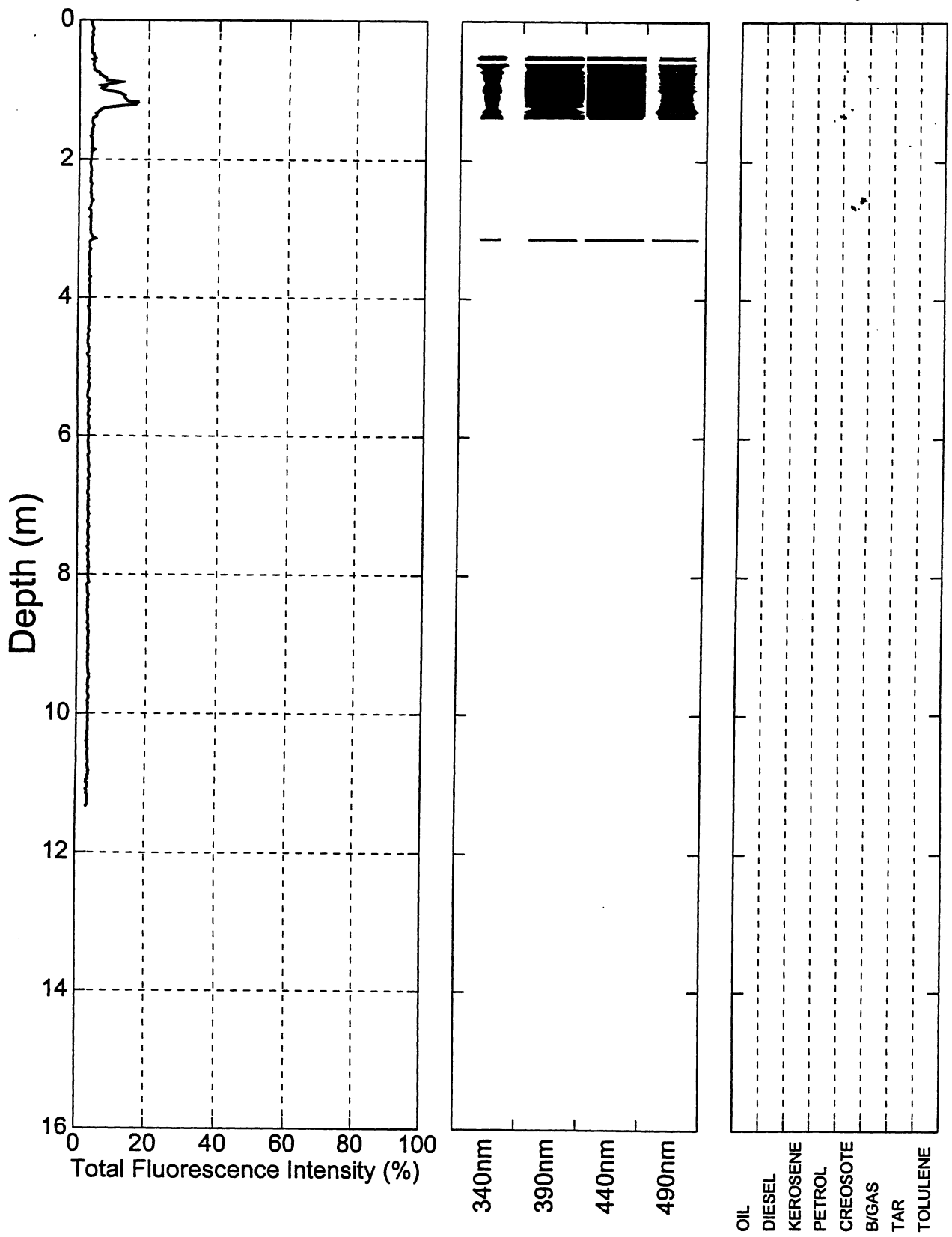
LASER INDUCED FLUORESCENCE RESULT

CPT13





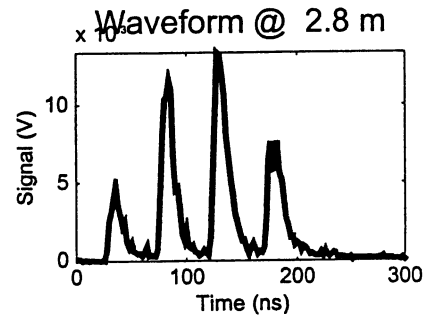
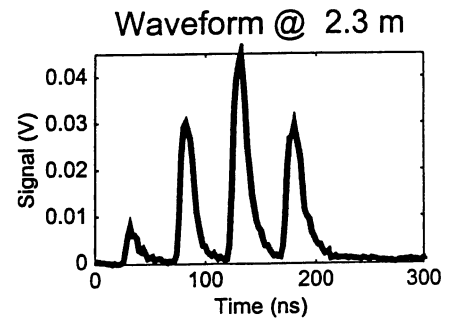
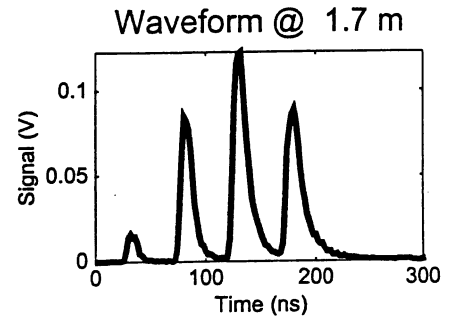
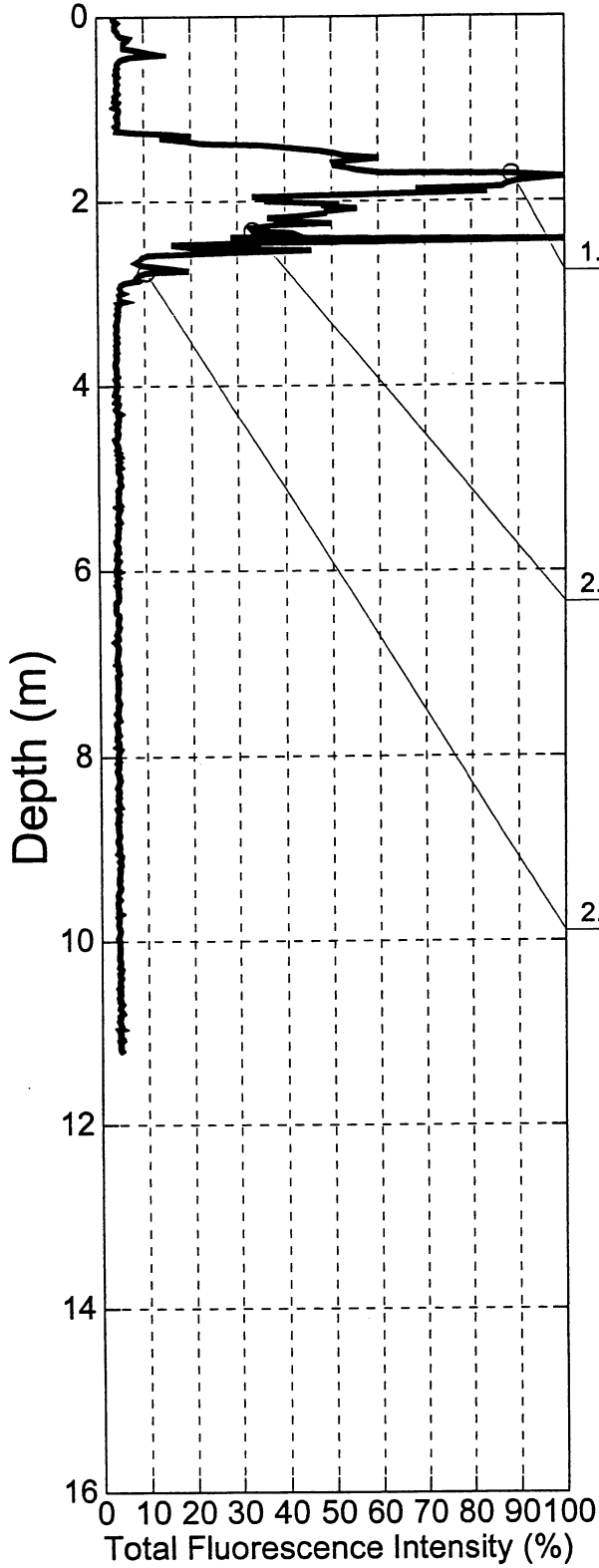
CPT15



Excitation λ : 290nm

LASER INDUCED FLUORESCENCE RESULT

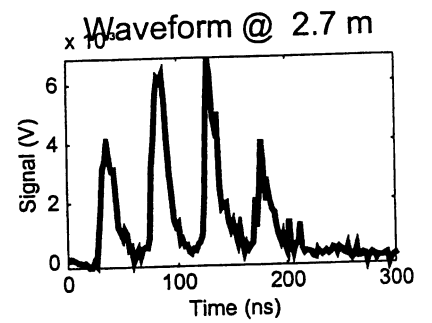
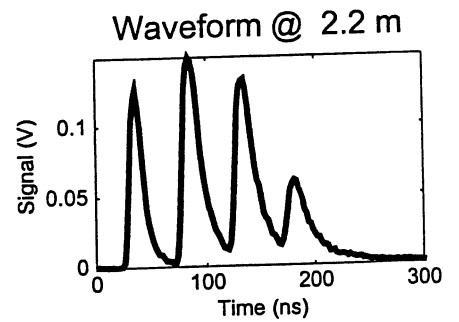
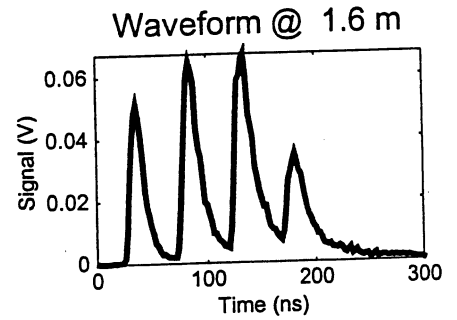
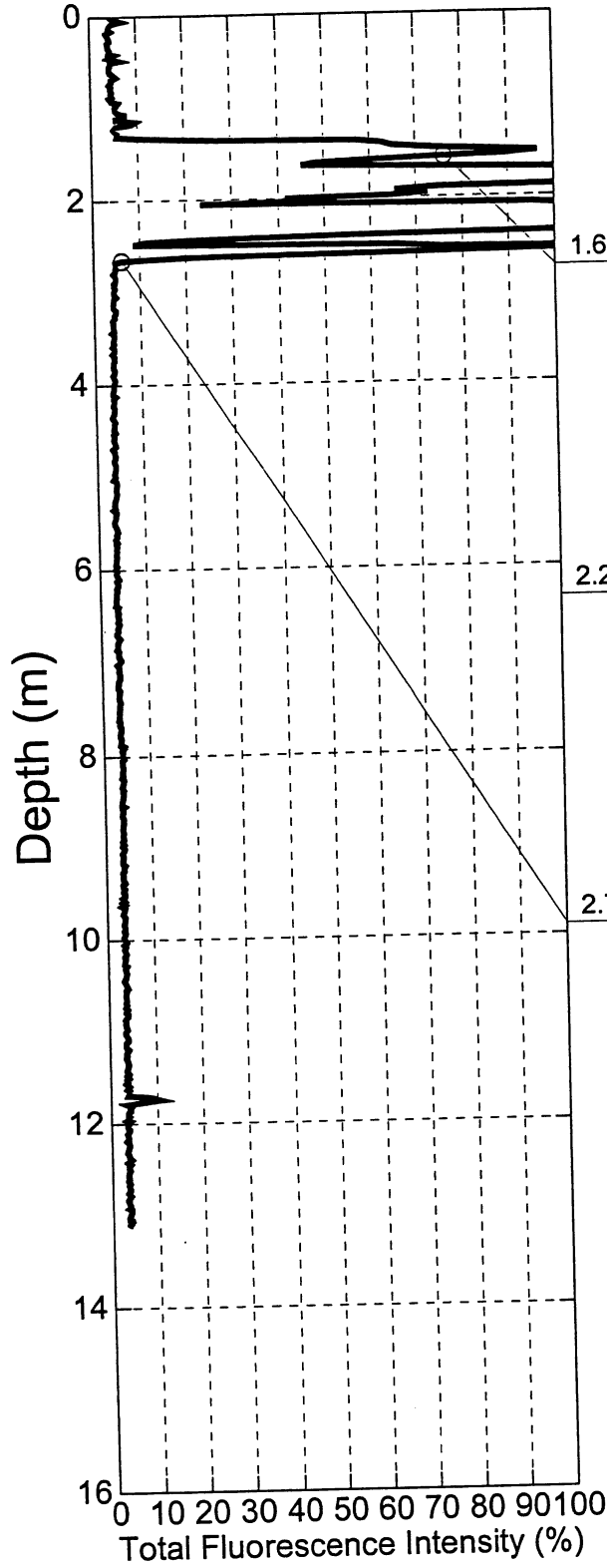
cpt12



WAVELENGTH DISTRIBUTION RESULT

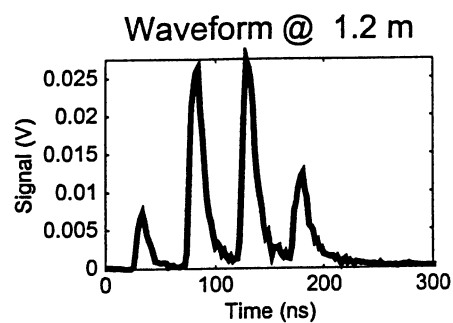
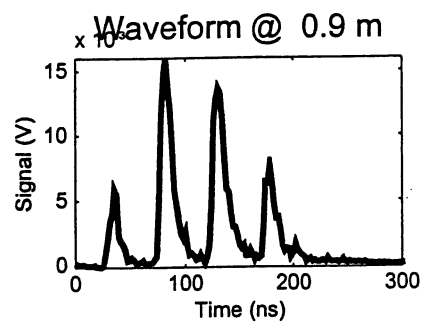
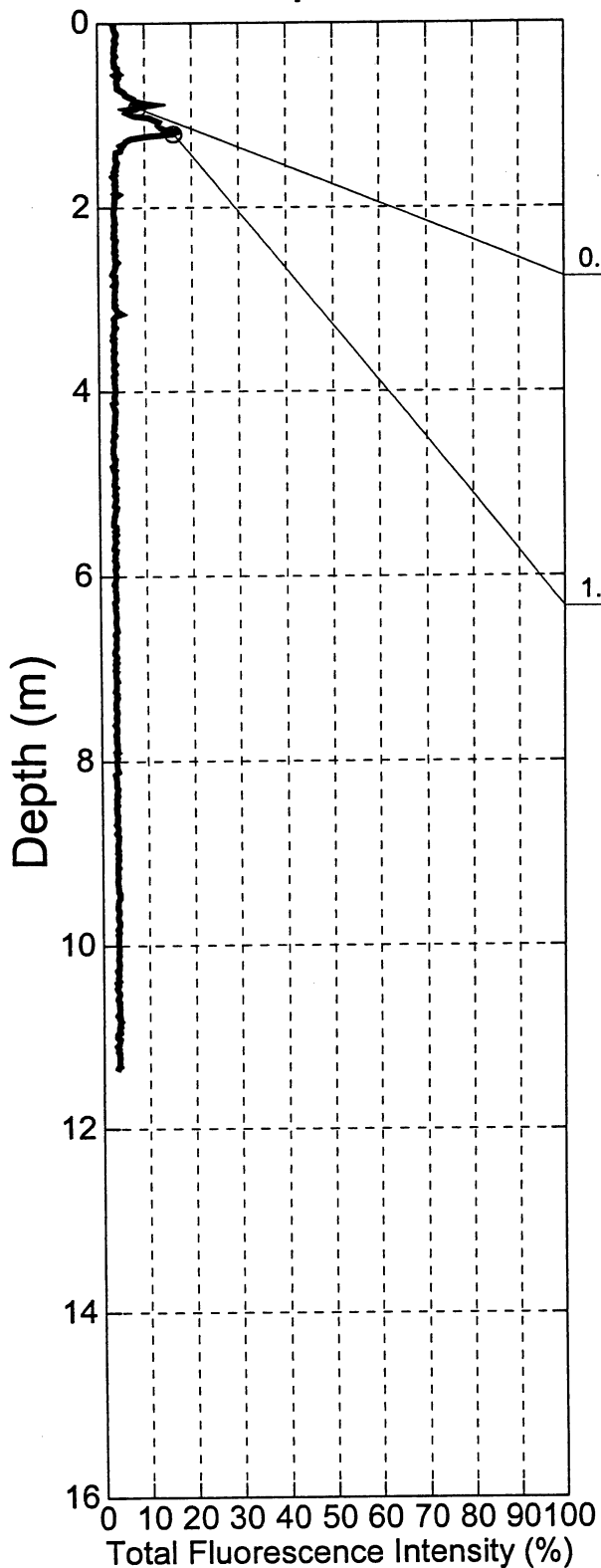


cpt13



WAVELENGTH DISTRIBUTION RESULT

cpt15



WAVELENGTH DISTRIBUTION RESULT

APPENDIX THREE – MEMBRANE INTERFACE PROBE DATA

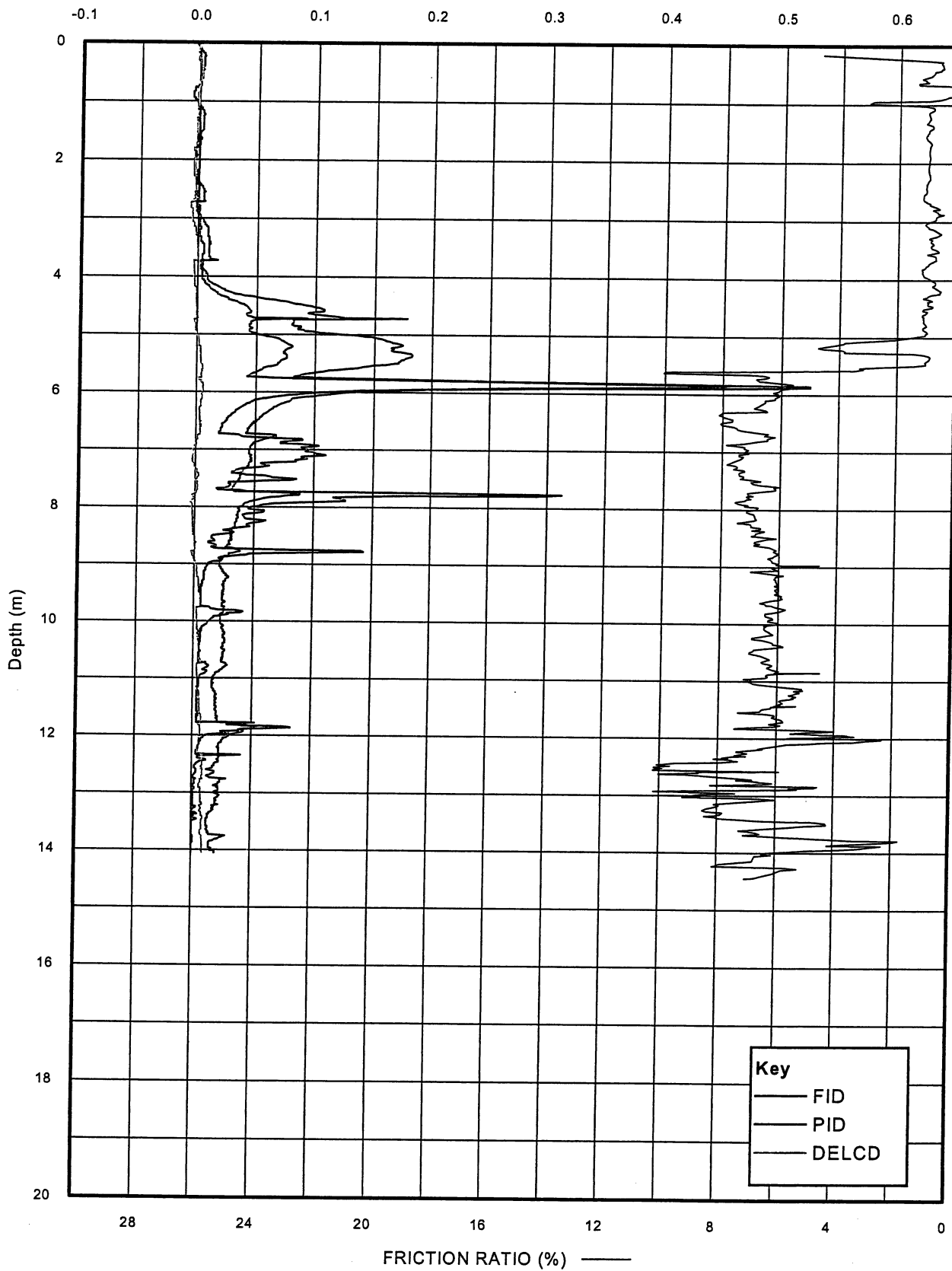
FID, PID & DELCD (Volts)

Date: 08/06/01

Drawn by: DLC

Date:

Checked by:

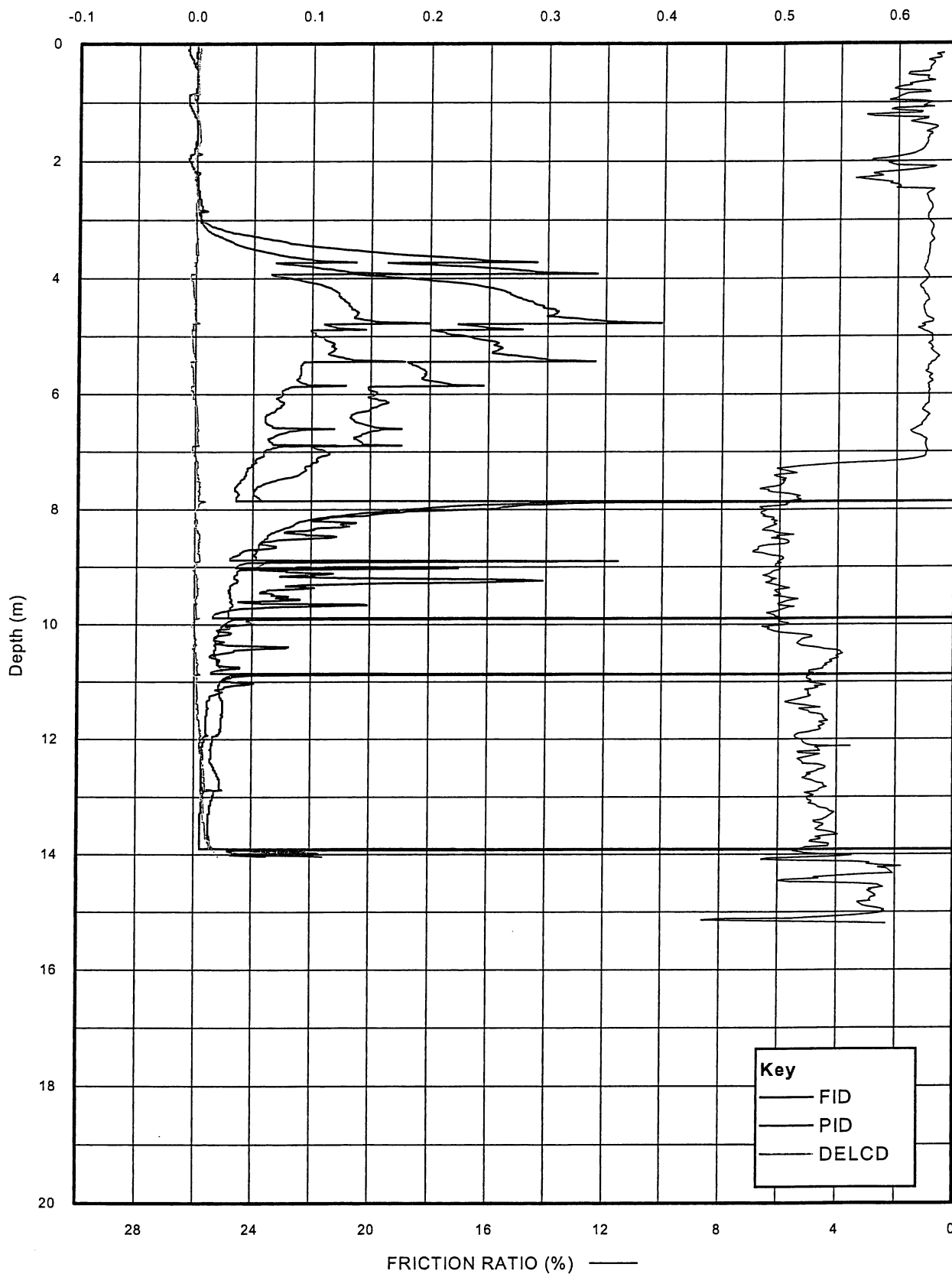


MEMBRANE INTERFACE PROBE TEST RESULTS
TEST NO.CPTM1

FID, PID & DELCD (Volts)

Date: 08/06/01

Drawn by: DLC

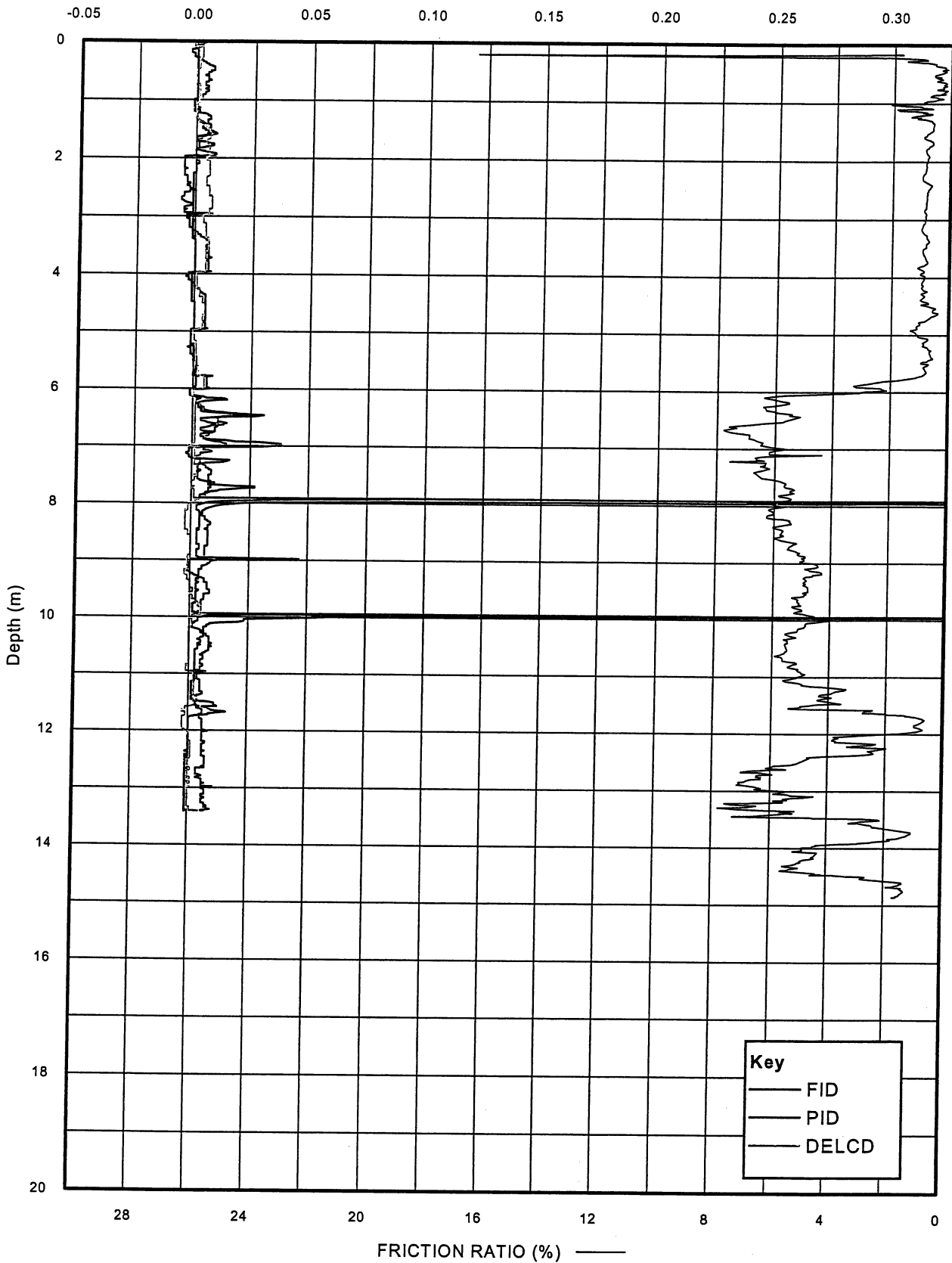


MEMBRANE INTERFACE PROBE TEST RESULTS
TEST NO.CPTM2

FID, PID & DELCD (Volts)

Date: 08/06/01

Drawn by: DLC

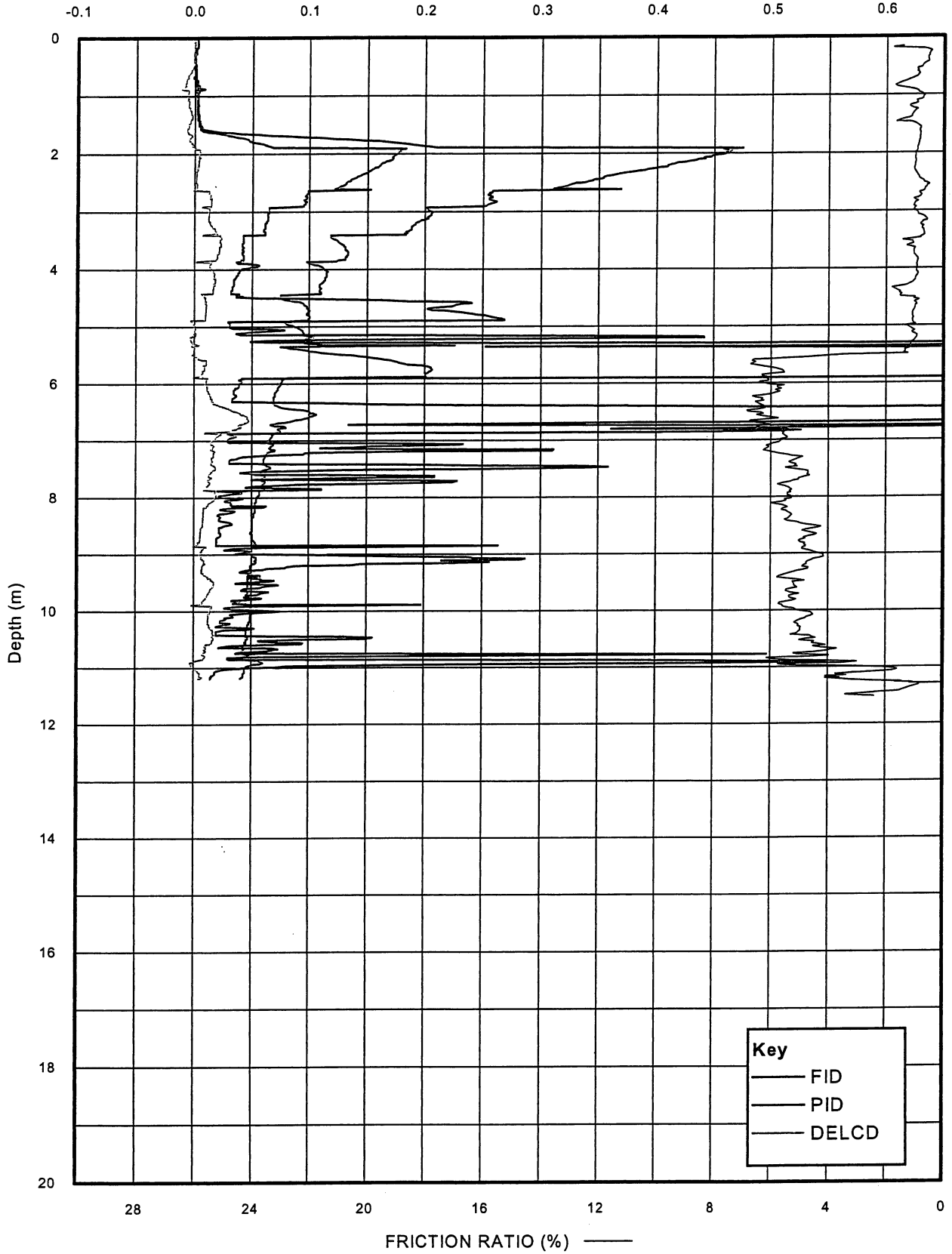


MEMBRANE INTERFACE PROBE TEST RESULTS
TEST NO.CPTM4

FID, PID & DELCD (Volts)

Date: 08/06/2001

Drawn by: DLC

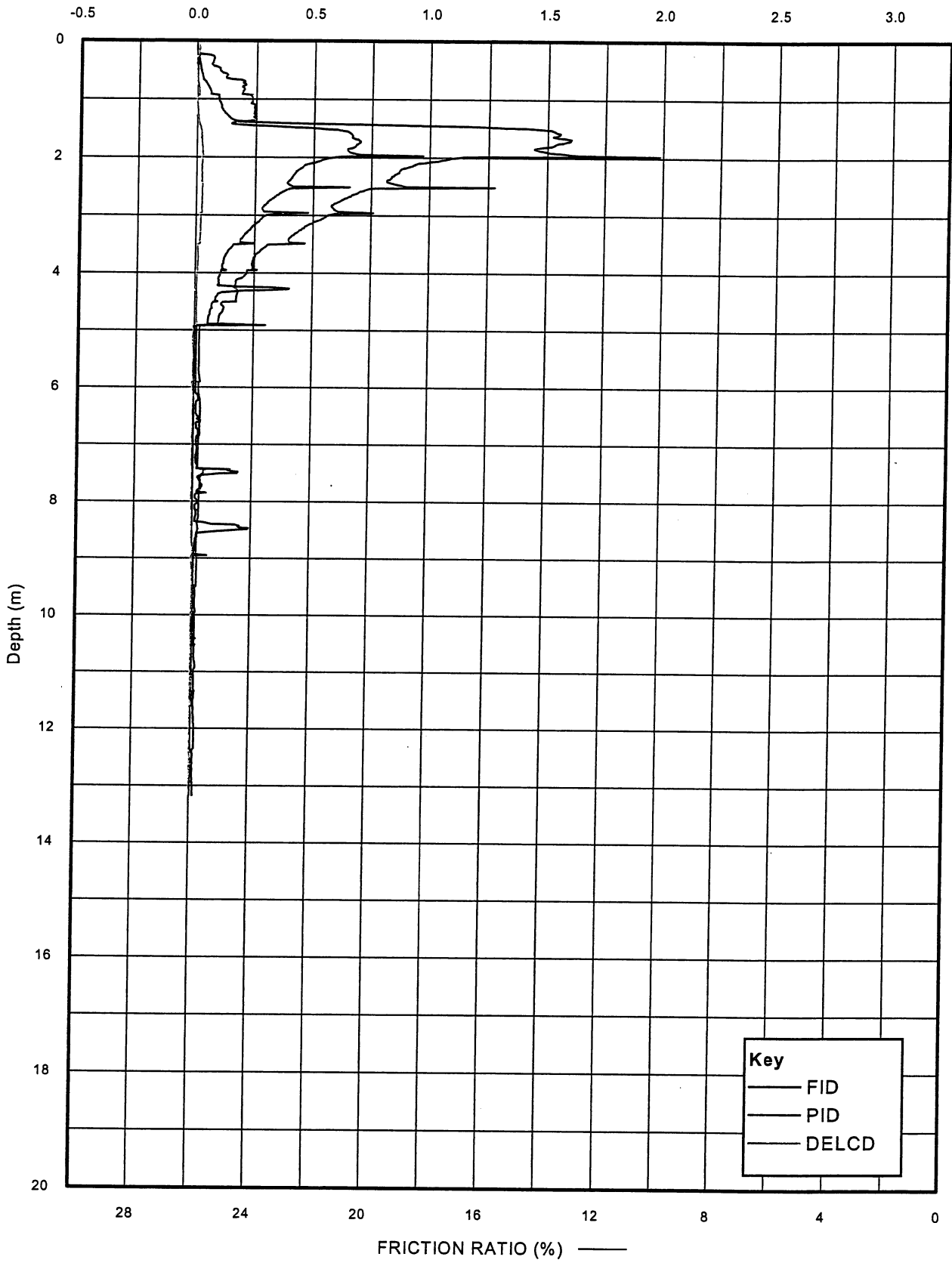


MEMBRANE INTERFACE PROBE TEST RESULTS
TEST NO.CPTM12



FID, PID & DELCD (Volts)

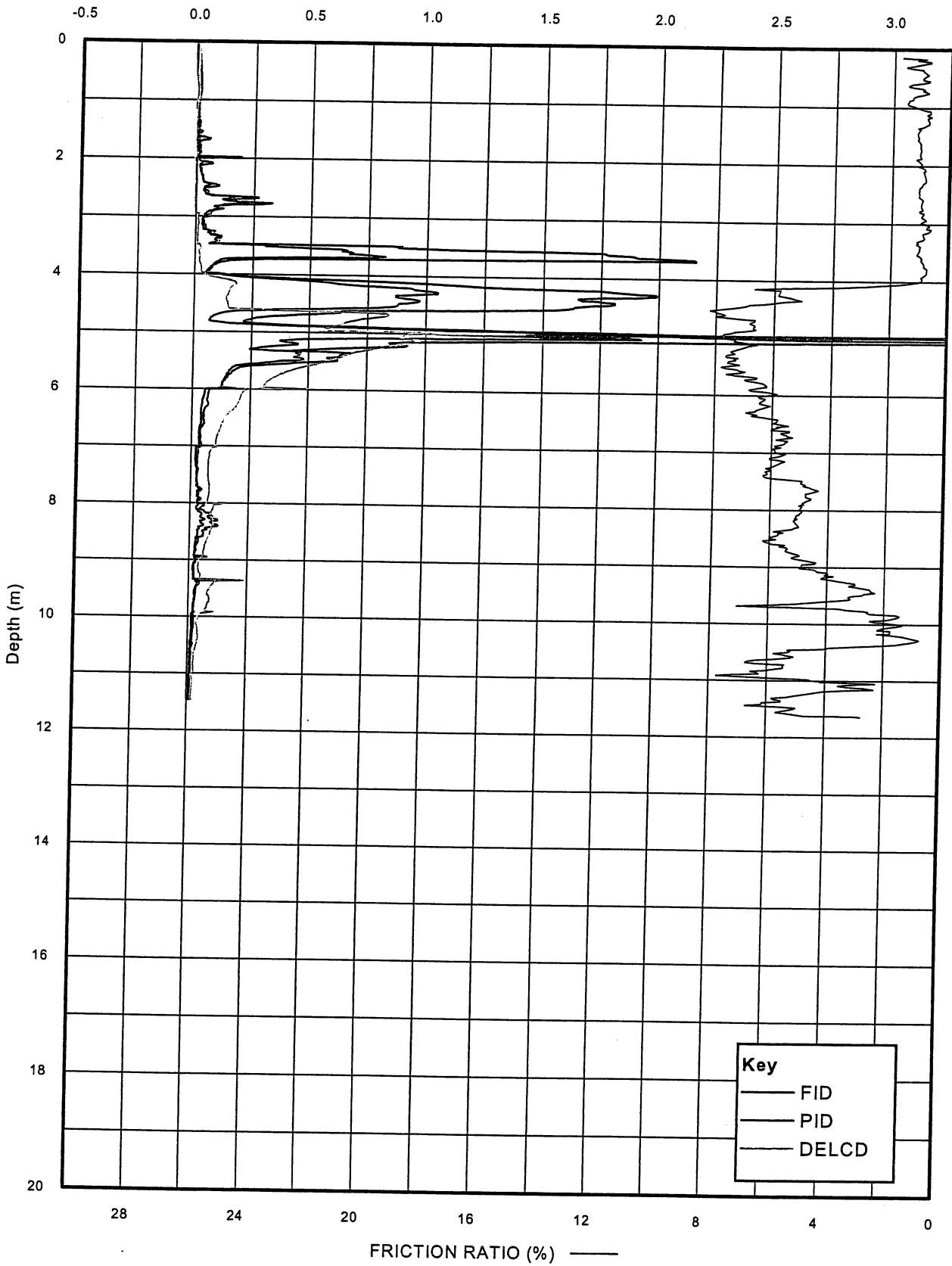
Drawn by: DLC Date: 11/06/01



MEMBRANE INTERFACE PROBE TEST RESULTS
TEST NO.CPTM13

FID, PID & DELCD (Volts)

Date: 11/06/01
Drawn by: DLC
Date:
Checked by:



MEMBRANE INTERFACE PROBE TEST RESULTS
TEST NO.CPTM15

APPENDIX FOUR – DEEP BOREHOLE LOGS

Key to Exploratory Hole Records

SAMPLES

Undisturbed

U	Driven tube sample	} nominally 100 mm diameter and full recovery unless otherwise stated
TW	Pushed thin wall tube sample	
P	Pushed piston sample	
L	Liner sample (from Windowless or similar sampler), full recovery unless otherwise stated	
CBR	CBR mould sample	
BLK	Block sample	
CS	Core sample (from rotary core) taken for laboratory testing	

Disturbed

D	Small sample
B	Bulk sample

Other

W	Water sample
G	Gas sample
	Environmental chemistry samples (in more than one container where appropriate)
ES	Soil sample
EW	Water sample

TEST RESULTS

S or C Standard Penetration Test, open shoe (S) or solid cone (C)

The Standard Penetration Test is defined in BS 1377 : Part 9 (1990). The incremental blow counts are given in the Field Records column; each increment is 75 mm unless stated otherwise and any penetration under self weight in mm (SW) is noted. Where the full 300 mm test drive is achieved the total number of blows for the test drive is presented as N = ** in the Test column. Where the test drive blows reach 50 (either in total or for a single increment) the total blow count beyond the seating drive is given (without the N = prefix).

IVp IVr	In situ vane test results given as peak and remoulded shear strengths (kN/m ²).
HVp HVr	Hand vane test results given as mean peak and mean remoulded shear strengths (kN/m ²).
PP	Pocket penetrometer test results given as mean undrained shear strength (kN/m ²).

DRILLING RECORDS

The mechanical indices (TCR/SCR/RQD & If) are defined in BS 5930 (1999)

TCR	Total Core Recovery, %
SCR	Solid Core Recovery, %
RQD	Rock Quality Designation, %
If	Fracture spacing, mm. Minimum, typical and maximum spacings are presented. The term non-intact (NI) is used where the core is fragmented.

Flush returns, estimated percentage with colour where relevant, are given in the Records column

CRF	Core recovered (length in m) in the following run
AZCL	Assessed zone of core loss

GROUNDWATER

▼	Groundwater strike
▽	Groundwater level after standing period

INSTALLATION

Standpipe/piezometer Details of standpipe/piezometer installations are given on the Record. Legend column shows installed instrument depths including slotted pipe section or tip depth, response zone filter material type and layers of backfill. Details of backfill are provided in Remarks at the base of record.

NOTES

- Water level observations during boring and drilling are given at the foot of the log and in the Legend column.
- The assessment of SCR, RQD and Fracture Spacing excludes artificial fractures
- The declination of bedding and joints is given with respect to the normal to the core axis. Thus in a vertical borehole this will be the dip.
- Legends are in accordance with BS 5930 (1999)

REFERENCES

BS 1377 : 1990 : British Standard Methods of test for soils for civil engineering purposes. British Standards Institution
 BS 5930 : 1999 : Code of Practice for site investigations. British Standards Institution

Notes:

Project

Project Siren

Key

Borehole Log



Exploration Associates

Drilled by Logged by Checked by	GD/LS FW DJLS	Equipment and Methods Inspection Pit from 0.00m to 1.20m. Cable Percussion 250 mm diameter from 1.20m to 6.00m, 200 mm diameter from 1.20m to 6.00m. Rotary Cored 150 mm diameter from 6.00m to 39.50m.	Ground Level National Grid Coordinates	+18.38 m OD E 373400.86 N 392450.40
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Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
0.50 - 1.00	B1		20/11/2001 0.00	dry	MADE GROUND: Loose orange brown fine and medium SAND.	(0.30) 0.30 +18.08	
1.00 - 2.00	B2	PID = 2.3 KPa	0.00				
2.00 - 3.00	B3		20/11/2001 2.50	1.70 dry			
2.50	W7		21/11/2001 2.50	1.70 0.00	Grey brown slightly gravelly silty SAND. Gravel is rounded fine and medium.	(4.90)	
3.00 - 4.00	B4	PID = 15.7 KPa					
4.00 - 5.00	B5	PID = 6.3 KPa					
5.20 - 6.00	B6	PID = 2.0 KPa	6.00	1.95		5.20 +13.18	
			22/11/2001 6.00	1.30	Soft to firm brown slightly sandy CLAY with some lenses of coarse sand.	(0.80)	
6.00 - 6.66m	100 0	100%	23/11/2001 6.00	1.30		6.00 +12.38	
6.66 - 8.07m	100	100%			Firm to stiff orange brown slightly gravelly CLAY. Gravel is subrounded and rounded fine to coarse.	(3.57)	
8.07 - 9.57m	100	100%					
9.57 - 11.07m	100	80%			Firm to stiff red orange brown locally thinly laminated slightly gravelly CLAY with occasional pockets of sand. Gravel is rounded fine and medium.	9.57 +8.81 (2.77)	
Depth	TCA SCR ROD	If	Records	Date Casing	Time Water		

Groundwater No. Struck Behaviour	1 2.50m	Remarks 1. Service inspection pit excavated by Basell sub-contractors. Hole backfill : 0.00m to 0.30m Concrete (c), 0.30m to 0.60m Imported Material (i), 0.60m to 33.70m Grout (g), 33.70m to 35.20m Bentonite (b), 38.80m to 39.50m Arisings (a). Surface protection : Stop Cock Cover Standpipe installed, 50mm diameter, response zone from 35.20m to 38.80m.
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column. Scale 1 : 50	Project PROJECT SIREN	Project no. 121157	Carried out for Shell Global Solutions	Borehole 401	Sheet 1 of 8
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08/2002 11:30:47 ES-01.09 V2.11

Borehole Log



Exploration Associates

Drilled by GD/LS	Equipment and Methods See sheet 1	Ground Level +18.38 m OD
Logged by FW		National Grid E 373400.86
Checked by DJLS		Coordinates N 392450.40

Samples and Tests				Strata				
Depth	TCR SCR RQD	If	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
9.57 - 11.07m	100		80%			As sheet 1	(2.77)	
11.07 - 12.43m	100		80%	23/11/2001 6.00	1.30			
				26/11/2001 6.00	1.30		12.34 +6.04	
12.34 - 13.34m	100		100%			Soft to firm orange brown gravelly very sandy CLAY. Gravel is subangular to rounded fine to coarse.	(3.06)	
13.34 - 15.15m	100		100%					
						15.25m to 15.40m: Lense of subangular to rounded coarse gravels and cobbles.	15.40 +2.98	
15.40 - 16.50m	100		100%					
16.50 - 18.05m	100		100%	26/11/2001 18.05	1.30	Stiff to very stiff dark red brown sandy gravelly CLAY. Gravel is subangular and subrounded fine to coarse. Occasional lenses of very gravelly clay.	(5.60)	
18.05 - 18.50m	100		100%	27/11/2001 18.05	1.30			
18.50 - 20.03m	100		80%					

Groundwater No. Struck Behaviour	Remarks
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Borehole Log



Exploration Associates

Drilled by GD/LS	Equipment and Methods See sheet 1	Ground Level +18.38 m OD
Logged by FW		National Grid E 373400.86
Checked by DJLS		Coordinates N 392450.40

Samples and Tests				Strata				
Depth	TCR SCR RQD	If	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
18.50 - 20.03m			80%			As sheet 2	(5.60)	
20.03 - 21.34m	100		80%				21.00 - 2.62	
21.34 - 22.84m	100		100%			Firm to stiff thinly to medium distinctly laminated slightly gravelly CLAY with thin laminations of fine sand. Gravel is subrounded fine and medium.	(4.06)	
22.84 - 23.56m	100		100%	27/11/2001 18.30	1.30		28/11/2001 18.30	
23.56 - 25.07m	100		100%			Red brown gravelly silty SAND with occasional rounded cobbles and rounded fine gravel.	(8.46)	
25.06 - 25.56m	21		100%				25.06 - 6.68	
25.56 - 26.56m				28/11/2001 25.00	1.30		29/11/2001 25.00	
26.56 - 29.06m	0		100%					
29.06 - 30.52m	0		100%					

Groundwater No. Struck Behaviour	Remarks TCR/SCR/RQD: 20.00m to 20.03m 100//
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08/2002 11:30:57 ESIG-LOG V2.11

Borehole Log



Exploration Associates

Drilled by		GD/LS		Equipment and Methods		Ground Level		+18.38 m OD	
Logged by		FW		See sheet 1		National Grid		E 373400.86	
Checked by		DJLS				Coordinates		N 392450.40	
Samples and Tests					Strata				
Depth	TCR SCR RQD	If	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend	
29.06 - 30.52m	0		100%	29/11/2001 30.52	1.30	As sheet 3	(8.46)	g	
				30/11/2001 30.52	2.45				
30.52 - 32.02m	0		100%						
32.02 - 33.52m	0		100%			Multicoloured sandy coarse GRAVEL with subrounded cobbles.	33.52 -15.14		
						Open irregular subvertical discontinuity.	33.72 -15.34		b
33.52 - 35.02m	73 60 13		100%			Non intact recovered as angular cobbles and gravels.			
				03/12/2001 33.52	2.45	Weak thickly laminated to thinly bedded red brown fine to medium grained SANDSTONE with subhorizontal closely spaced discontinuities.	(5.78pen)	a	
				30/11/2001 33.52	4.20				
35.02 - 36.52m	87 77 33	25 72.5 120	100%			Open irregular subvertical discontinuity.			
36.52 - 37.95m	100 98 42		100%						
38.30		40 110 180	kFH						
37.95 - 39.50m	74 72 39		100%						
				03/12/2001 33.52		EXPLORATORY HOLE ENDS AT 39.50 m.	39.50 -21.12		
Groundwater					Remarks				
No. Struck Behaviour									
Notes: For explanation of symbols and abbreviations see key sheet. All depths and reduced					Project		PROJECT SIREN		
Borehole					Project no.		121157		
							401		

02 11:31:04 ESGLog v2.11

Borehole Log



Exploration Associates

Drilled by GD/LS Logged by FVW Checked by DJLS	Equipment and Methods Inspection Pit from 0.00m to 1.20m. Cable Percussion 250 mm diameter from 1.20m to 7.00m, 200 mm diameter from 7.00m to 33.00m. Rotary Cored 150 mm diameter from 33.00m to 49.00m.	Ground Level +18.42 m OD National Grid E 373423.55 Coordinates N 392456.98
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Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
			05/12/2001	dry			
			0.00		Very loose red fine SAND. (Imported material)	(1.10)	
2.00 - 2.50	B1	PID = 2.0 KPa			Dark grey brown silty gravelly SAND. Gravel is subangular to rounded fine and medium.	1.10 +17.32 (1.45)	
2.75	D2				Dark brown silty very gravelly SAND. Gravel is subangular to rounded fine to coarse. Strong hydrocarbon odour.	2.55 +15.87	
3.00 - 3.50	B3	PID = 28.0 KPa				(2.25)	
3.75	D4						
4.00 - 4.50	B5	PID = 68.0 KPa					
4.50	W9				Brown silty slightly gravelly SAND. Gravel is subrounded and rounded fine and medium. Strong hydrocarbon odour.	4.80 +13.62	
4.75	D6					(1.20)	
5.00 - 5.50	B7	PID = 270.9 KPa					
6.00 - 6.50	B8	PID = 14.0 KPa			Firm to stiff brown locally thinly laminated CLAY. Occasional bands of subrounded fine gravel.	6.00 +12.42	
			05/12/2001	1.20			
7.00	D10		06/12/2001	1.2			
8.00 - 8.50	B11	PID = 0.3 KPa				(5.50)	
9.00	D12						

Groundwater No. Struck Behaviour 1 1.30m Rising to 1.20m after 20 mins.	Remarks 1. Service inspection pit excavated by Basell. Chiselling : 3.50m to 14.00m 90minutes Hole backfill : 0.00m to 0.30m Concrete (c), 0.30m to 42.00m Grout (g), 42.00m to 44.10m Bentonite (b). Surface protection : Stop Cock Cover Standpipe installed, 50mm diameter, response zone from 44.10m to 49.00m.
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column. Scale 1 : 50	Project PROJECT SIREN Project no. 121157 Carried out for Shell Global Solutions	Borehole 402 Sheet 1 of 5
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Borehole Log



Exploration Associates

Drilled by GD/LS	Equipment and Methods See sheet 1	Ground Level +18.42 m OD
Logged by FW		National Grid E 373423.55
Checked by DJLS		Coordinates N 392456.98

Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
10.00 - 10.50	B13	PID = 19.3 KPa			As sheet 1	(5.50)	9
11.00	D14					11.50 +6.92	
12.00 - 12.50	B15	PID = 7.5 KPa			Firm to stiff red brown very sandy slightly gravelly CLAY. Gravel is subangular to rounded fine to coarse.	(1.00)	2
13.00	D16		06/12/2001			12.50 +5.92	
14.00 - 14.50	B17	PID = 1.3 KPa	07/12/2001	1.4			2
15.00	D18						
15.70		kFH					2
16.00 - 16.50	B19				Stiff to very stiff red brown very sandy gravelly CLAY. Gravel is subangular to rounded fine to coarse. Occasional cobbles.	(11.00)	
					18.25m to 18.80m: Red brown sand.		

Groundwater No. Struck Behaviour 2 18.80m Rising to 13.40m after 20 mins.	Remarks Chiselling : 14.00m to 14.35m 75minutes, 17.20m to 17.80m 105minutes
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2002 11:31:14 ESGLog v2.11

Borehole Log



Exploration Associates

Samples and Tests		Strata			Ground Level	+18.42 m OD
Depth	Type & No.	Records	Date Casing	Time Water	National Grid	E 373423.55
					Coordinates	N 392456.98
			07/12/2001	10.0		
			10/12/2001	10.0		
			As she : 2		(11.00)	
			Firm brown thinly laminated CLAY.		(2.00)	
25.50 - 26.00	B20	PID = 4.4 KPa			25.50	-7.08
26.50 - 27.00	B21					
27.50 - 28.00	B22	PID = 16.8 KPa				
28.50 - 29.00	B24					
29.50 - 30.00	B25	PID = 19.3 KPa	10/12/2001	12.80		
			11/12/2001	11.90		
					Below 29.50m: Gravelly and cobbly.	
Groundwater No. Struck Behaviour					Remarks Chiselling: 20.10m to 20.60m 60minutes, 27.20m to 27.90m 105minutes, 28.40m to 28.75m 45minutes, 29.10m to 29.80m 120minutes, 29.90m to 31.00m 270minutes	
Notes For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.			Project PROJECT HIREN		Borehole 402	
			Project no. 121157		Sheet 3 of 5	
			Carried out for Shell Global Solutions			

20/2002 11 31 1R FSG Log v2 11

Borehole Log



Exploration Associates

Drilled by Logged by Checked by	GD/LS FW DJLS	Equipment and Methods See sheet 1	Ground Level National Grid Coordinates	+18.42 m OD E 373423.55 N 392456.98
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Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
30.00	W23						
30.50 - 31.00	B26	PID = 21.0 KPa			As sheet 3	(5.50)	
31.50 - 32.00	B27					31.00 - 12.58	
32.50 - 33.00	B28		11/12/2001	8.8	Red brown very silty slightly gravelly fine SAND Gravel is angular and subrounded fine and medium (Highly weathered sandstone)	(2.00)	
33.00 - 34.50m	0 0 0	100%	12/12/2001 33.00	3.27	No recovery	33.00 - 14.58	
34.50 - 36.60m	0 0 0	100%				(3.60)	
36.60 - 38.10m 36.60 - 38.10m	44 27 7	95% 95%			Very weak to weak thickly laminated to medium bedded red brown fine to medium grained SANDSTONE	36.60 - 18.18	
38.10 - 39.60m	47 23 7	95%			Non intact recovered as rec brown subrounded coarse gravel Open irregular subvertical discontinuity	(12.40)	
39.60 - 41.10m	61 49 20	95%					

Groundwater No. Struck Behaviour	Remarks Chiselling 32.50m to 33.00m 60minutes
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Notes: For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column. Scale 1:50	Project PROJECT SHREN	Borehole 402
	Project no. 121157 Carried out for Shell Global Solutions	Sheet 4 of 5

5/08/2002 11:31:23 ESGLog v2.1

Borehole Log



Exploration Associates

Drilled by GD/LS Logged by FW Checked by DJLS	Equipment and Methods See sheet 1	Ground Level +18.42 m OD National Grid E 373423.55 Coordinates N 392456.98
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Samples and Tests				Strata				
Depth	TCR SCR ROD	If	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
39.50 - 41.10m	61 49 20		95%			Completely weathered recovered as slightly gravelly red brown fine and medium sand.		g
41.10 - 42.60m	57 47 47		95%					
42.50	0		kFH	17/12/2001 38.50				
42.50 - 43.00m	0 0 0		100%	18/12/2001 38.50	0.7			
43.00 - 45.00m	87 84 40		100%			As sheet 4	(12.40pen)	
		60 255 450				Tight vertical regular discontinuity.		
47.00			kFH					
46.00 - 49.00m	37 0 0		100%			Grey rounded subangular to rounded fine to coarse GRAVEL.		
				18/12/2001 38.50				
EXPLORATORY HOLE ENDS AT 49.00 m.							49.00 -30.58	

Groundwater No. Struck Behaviour	Remarks
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Notes For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.	Project PROJECT SIREN Project no. 121157 Carried out for Shell Global Solutions	Borehole 402 Sheet 5 of 5
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08/2002 11:31:28 ESGI log v2 11

Borehole Log



Exploration Associates

Drilled by GD/LS Logged by FW Checked by DJLS	Equipment and Methods Inspection Pit from 0.00m to 1.20m. Cable Percussion 250 mm diameter from 0.00m to 6.00m. 200 mm diameter from 6.00m to 30.80m. Rotary Cored 150 mm diameter from 30.80m to 38.50m.	Ground Level +18.40 m OD National Grid E 373424.87 Coordinates N 392458.69
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Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
			31/01/2002	0	MADE GROUND: Concrete and steel mesh at 0.40m.	(0.40)	c
					Orange brown medium and coarse SAND.	0.40 +18.00 (0.40)	g
					Dark brown silty slightly organic SAND.	0.80 +17.60 1.00 +17.40	1
					Yellow grey coarse SAND.	(1.65)	
3.00 - 4.00	B1	PID = 3.7 KPa			Grey gravelly SAND. Gravel is subrounded to rounded fine to coarse.	2.65 +15.75 (2.00)	
					Brown SAND.	4.65 +13.75 (1.25)	
8.00 - 9.00	B2	PID = 5.5 KPa			Firm grey brown locally thinly laminated CLAY.	5.90 +12.50 (5.75)	

Groundwater No. Struck Behaviour 1 1.40m Rising to 1.10m after 20 mins.	Remarks 1. Service inspection pit excavated by Soil Mechanics. Hole backfill : 0.00m to 0.50m Concrete (c), 0.50m to 33.00m Grout (g), 33.00m to 35.00m Bentonite (b). Standpipe installed, 97mm diameter, response zone from 35.00m to 38.50m.
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02 11:31:33 ESGLog v2.11

Borehole Log



Exploration Associates

Drilled by GD/LS Logged by FW Checked by DJLS	Equipment and Methods See sheet 1	Ground Level +18.40 m OD National Grid E 373424.87 Coordinates N 392458.69
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Samples and Tests Strata

Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
					As sheet 1	(5.75)	
			31/01/2002	4.75	Stiff red brown sandy slightly gravelly CLAY. Gravel is subangular to rounded fine and medium.	11.65 +6.75 (1.25)	
			01/02/2002	1.45		12.90 +5.50	
					Stiff red brown sandy slightly gravelly cobbly CLAY with occasional boulders and sand lenses. Gravel is subangular to rounded fine and medium.	(5.65)	
18.00 - 19.00	B3	PID = 3.1 KPa				18.55 -0.15 (0.95)	
					Dense red silty SAND.		
					Stiff red brown sandy slightly gravelly cobbly CLAY with occasional boulders and sand lenses. Gravel is subangular to rounded fine and medium.	19.50 -1.10 (3.00)	

Groundwater No. Struck Behaviour	Remarks
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Borehole Log



Exploration Associates

Drilled by GD/LS	Equipment and Methods See sheet 1	Ground Level +18.40 m OD
Logged by FW		National Grid E 373424.87
Checked by DJLS		Coordinates N 392458.69

Samples and Tests				Strata		Depth, Level (Thickness)	Legend
Depth	Type & No.	Records	Date Casing	Time Water	Description		
20.00 - 21.00	B4	PID = 7.5 KPa			As sheet 2	(3.00)	
			01/02/2002	3.8			
			04/02/2002	1.35		22.50 -4.10	
24.00 - 25.00	B5	PID = 8.4 KPa			Firm brown locally thinly laminated CLAY.	(3.70)	
			04/02/2002	6.4			
			05/02/2002	3.65		26.20 -7.80	
28.00 - 29.00	B6	PID = 8.1 KPa			Brown sandy cobbly subrounded and rounded medium and coarse GRAVEL. Occasional boulders.	(4.60)	

Groundwater No. Struck Behaviour	Remarks
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2002 11:31:41 ESGLog v2.11

Borehole Log



Exploration Associates

Drilled by		Equipment and Methods		Ground Level			
GD/LS		See sheet 1		+18.40 m OD			
Logged by		Date		National Grid			
FW				E 373424.87			
Checked by		Time		Coordinates			
DJLS				N 392458.69			
Samples and Tests			Strata				
Depth	Type & No.	Records	Date	Time	Description	Depth, Level (Thickness)	Legend
					As sheet 3	(4.60)	
30.80 - 33.42m	0 0 0					30.80 -12.40	
33.42 - 36.42m	0 0 0				NO RECOVERY	(7.15)	
36.42 - 38.50m	26 3 0						
	30 60 80		05/02/2002		Weak red brown fine and medium grained SANDSTONE.	37.95 -19.55 (0.55pen)	
					Multicoloured subangular to rounded coarse GRAVEL.		
					EXPLORATORY HOLE ENDS AT 38.50 m.	38.50 -20.10	
Depth	TCR SCR ROD	If	Records	Date	Time	Remarks	
						Groundwater No. Struck Behaviour	
Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column. Scale 1 : 50			Project	PROJECT SIREN		Borehole	
			Project no.	121157		402B	
			Carried out for	Shell Global Solutions		Sheet 4 of 4	

08/2002 11:31:45 ESGLog v2.11

Borehole Log



Exploration Associates

Drilled by GD	Equipment and Methods Inspection Pit from 0.00m to 1.20m. Cable Percussion 250 mm diameter from 1.20m to 7.50m, 200 mm diameter from 7.50m to 32.50m.	Ground Level +18.44 m OD
Logged by FW		National Grid E 373422.61
Checked by DJLS		Coordinates N 392458.11

Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
			07/02/2002 0.00	dry	MADE GROUND: Tarmac	(0.30)	
					MADE GROUND: Yellow grey angular coarse GRAVEL.	0.30 +18.14 (0.30)	
					Yellow brown SAND.	0.60 +17.84 (0.60)	
2.00	D1	PID = 3.3 KPa			Brown grey slightly silty slightly gravelly coarse SAND. Gravel is subangular fine. Hydrocarbon odour.	1.20 +17.24 (1.65)	
3.00	D2				Grey very gravelly coarse SAND. Gravel is subrounded and rounded fine to coarse. Hydrocarbon odour.	2.85 +15.59 (1.05)	
4.00	D3	PID = 1.2 KPa			Brown silty slightly gravelly SAND. Gravel is subangular to rounded fine and medium. Slight hydrocarbon odour.	3.90 +14.54 (1.95)	
5.00	D4						
6.00	D5						
7.00	D6		07/02/2002 7.50	4.85			
8.00	D7		08/02/2002 7.50	1.4	Firm brown locally thinly laminated CLAY.	5.85 +12.59 (5.35)	
9.00	D8						

Groundwater No. Struck Behaviour 1 1.40m Rising to 1.10m after 20 mins.	Remarks 1. Service inspection pit excavated by Soil Mechanics 9.00m to 15.00m Water added Hole backfill : 0.00m to 0.50m Concrete (c), 0.50m to 27.50m Grout (g), 27.50m to 29.00m Bentonite (b). Surface protection : Stop Cock Cover Standpipe installed, 97mm diameter, response zone from 29.00m to 32.50m.
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets	Project PROJECT SIREN Project no. 121157	Borehole 402C Sheet 1 of 4
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002 11:31:50 ESGLog v2.11

Borehole Log



Exploration Associates

Drilled by Logged by Checked by		Equipment and Methods See sheet 1			Ground Level +18.44 m OD National Grid E 373422.61 Coordinates N 392458.11		
Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
10.00	D9				As sheet 1	(5.35)	
11.00	D10	PID = 20 KPa				11.20 +7.24	
12.00 - 12.50	B11				Stiff red brown very gravelly very sandy CLAY. Gravel is subangular to rounded fine and medium.	(2.00)	
13.00	D12	PID = 3 KPa				13.20 +5.24	
14.00	D13						
15.00	D14						
			08/02/2002 16.00	3.4			
16.00	D15		11/02/2002 16.00	1.45	Stiff to very stiff red brown sandy slightly gravelly CLAY with cobbles, boulders and occasional sand bands. Gravel is subangular to rounded fine and medium.	(9.05)	
17.00	D16	PID = 28.4 KPa					
18.00	D17				Red brown slightly gravelly clayey sand.		
19.00	D18						
Groundwater No. Struck Behaviour					Remarks		
Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.					Project PROJECT SIREN		Borehole 402C
					Project no. 121157		Sheet 2 of 4
					Carried out for Shell Global Solutions		

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Borehole Log



Exploration Associates

Drilled by Logged by Checked by	GD FW DJLS	Equipment and Methods See sheet 1	Ground Level National Grid Coordinates	+18.44 m OD E 373422.61 N 392458.11
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Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
20.00	D19	PID = 2 KPa			As sheet 2	(9.05)	
21.00	D20						
22.00	D21						
23.00	D22	PID = 7.8 KPa			Firm brown locally thinly laminated CLAY.	22.25 -3.81	
24.00	D23	PID = 87.8 KPa					
25.00	D24						
26.00	D25						
			11/02/2002 26.50	9.9		26.50 -8.06	
			12/02/2002 26.50	1.4			
27.00	D26	PID = 2.0 KPa			Grey brown slightly silty sandy subrounded and rounded medium and coarse GRAVELS and COBBLES. Occasional rounded boulders.	(4.10)	
28.00	D27	PID = 5.0 KPa					
29.00	D28	PID = 2.6 KPa					

Groundwater No. Struck Behaviour	Remarks
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.	Project PROJECT SIREN	Borehole 402C
	Project no. 121157	Sheet 3 of 4
	Carried out for Shell Global Solutions	

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Borehole Log



Exploration Associates

Drilled by GD Logged by FW Checked by DJLS		Equipment and Methods See sheet 1			Ground Level +18.44 m OD National Grid E 373422.61 Coordinates N 392458.11		
Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
30.00	D29	PID = 3.6 KPa			As sheet 3	(4.10)	
31.00	D30				Red brown silty slightly gravelly SAND. Gravel is rounded fine. (Completely weathered sandstone)	30.60 -12.16	
32.00	D31					(1.90pen)	
			12/02/2002	6.4		32.50 -14.06	
					EXPLORATORY HOLE ENDS AT 32.50 m.		
Groundwater					Remarks		
No. Struck Behaviour							
Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.			Project	PROJECT SIREN		Borehole	
			Project no.	121157		402C	
			Carried out for	Shell Global Solutions		Sheet 4 of 4	

8/2/002 11:32:02 ESGLog v2.11

Borehole Log



Exploration Associates

Drilled by Logged by Checked by	GD/LS FW DJLS	Equipment and Methods Inspection Pit from 0.00m to 1.20m. Cable Percussion 250 mm diameter from 1.20m to 6.00m, 200 mm diameter from 6.00m to 32.20m. Rotary Cored 150 mm diameter from 32.20m to 38.50m.	Ground Level National Grid Coordinates	+18.42 m OD E 373418.89 N 392402.32
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Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
			08/01/2002 0.00	0.00	MADE GROUND: Concrete/Tarmac	(0.30)	c
					MADE GROUND: Black ash and brick fill.	0.30 +18.12 (0.35)	g
					Light brown yellow SAND.	0.65 +17.77 (1.15)	1 1
2.00 - 2.50	B1	PID = 55.0 KPa				1.80 +16.62	
3.00 - 3.50	B2	PID = 7.0KPa			Brown very gravelly silty SAND. Gravel is subrounded and rounded fine to coarse. Strong hydrocarbon odour.	(2.00)	
3.60	W6						
4.00 - 4.50	B3	PID = 10.0KPa				3.80 +14.62	
4.60		kFH			Dark brown slightly gravelly coarse SAND with pockets of soft brown and orange CLAY. Slight hydrocarbon odour.	(1.40)	
5.00 - 5.50	B4	PID = 6.0KPa				5.20 +13.22	
			08/01/2002 6.00	3.60			
6.00 - 6.50	B5	PID = 2.0KPa	09/01/2002 6.00	2.20			
7.00 - 7.50	B7						
8.00 - 8.50	B8	PID = 1.3KPa			Firm to stiff brown locally thinly laminated CLAY.	(6.30)	
9.00 - 9.50	B9						

Groundwater No. Struck Behaviour 1 1.35m Rising to 1.05m after 20 mins.	Remarks 1. Service inspection pit excavated by Soil Mechanics. Hole backfill : 0.00m to 0.30m Concrete (c), 0.30m to 32.50m Grout (g), 32.50m to 35.00m Bentonite (b). Surface protection : Stop Cock Cover Standpipe installed, 97mm diameter. response zone from 35.00m to 38.50m.
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in-metres. Stratum thickness given in brackets	Project PROJECT SIREN Project no. 121157	Borehole 403 Sheet 1 of 4
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1002 11:32:07 ESGLog v2.11

Borehole Log



Exploration Associates

Drilled by GD/LS	Equipment and Methods See sheet 1	Ground Level +18.42 m OD
Logged by FW		National Grid E 373418.89
Checked by DJLS		Coordinates N 392402.32

Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
10.00 - 10.50	B10				As sheet 1	(6.30)	9
11.00 - 11.50	B11	PID = 1.5KPa					
12.00 - 12.50	B12	PID = 5.5KPa			Very stiff brown slightly sandy slightly gravelly CLAY. Gravel is angular to subrounded fine and medium occasionally coarse. Occasional angular to subrounded cobbles.	11.50 +6.92	
13.00 - 13.50	B13	PID = 2.0KPa					
13.80		kFH					
14.00 - 14.50	B14						
15.00 - 15.50	B15		09/01/2002				
			10/01/2002	0.00			
16.00 - 16.50	B16	PID = 2.1KPa					
17.00 - 17.50	B17						
18.00 - 18.50	B18	PID = 1.0KPa	10/01/2002	4.65			
			11/01/2002	3.90			
19.00 - 19.50	B19	PID = 1.3KPa					

Groundwater No. Struck Behaviour	Remarks Chiselling : 12.30m to 12.95m 90minutes, 13.65m to 14.40m 60minutes, 15.50m to 16.25m 225minutes, 17.75m to 18.25m 60minutes
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column. Scale 1 : 50	Project PROJECT SIREN	Borehole 403
	Project no. 121157	Sheet 2 of 4
	Carried out for Shell Global Solutions	

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Borehole Log



Exploration Associates

Drilled by GD/LS	Equipment and Methods See sheet 1	Ground Level +18.42 m OD
Logged by FW		National Grid E 373418.89
Checked by DJLS		Coordinates N 392402.32

Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
20.00 - 20.50	B20				As sheet 2	(11.50)	
21.00 - 21.50	B21						
22.00 - 22.50	B22						
			11/01/2002	4.45		23.00	-4.58
23.00 - 23.50	B23		14/01/2002	3.95	Firm to stiff brown locally thinly laminated slightly gravelly CLAY.	(2.80)	
24.00 - 24.50	B24						
25.00 - 25.50	B25						
26.00 - 26.50	B26	PID = 1.5KPa					
27.00 - 27.50	B27	PID = 2.0KPa					
28.00 - 28.50	B28	PID = 3.0KPa	14/01/2002	0.30	Dark brown slightly sandy angular to rounded fine to coarse GRAVEL and COBBLES.	(4.95)	
			15/01/2002	0.45			
28.80		kFH					
29.00 - 29.50	B29	PID = 1.0KPa					
						Below 30.00m: Very sandy	

Groundwater No. Struck Behaviour	Remarks 28.50m to 32.20m Water added. Chiselling : 21.30m to 21.60m 45minutes, 22.60m to 23.00m 45minutes, 25.40m to 26.85m 60minutes, 27.70m to 28.20m 60minutes, 29.90m to 30.30m 75minutes
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets	Project PROJECT SIREN	Borehole 403
	Project no. 121157 Shell Global Solutions	Sheet 3 of 4

1002 11:32:15 ESGLog v2.11

Borehole Log



Exploration Associates

Drilled by		GD/LS		Equipment and Methods		Ground Level		+18.42 m OD	
Logged by		FW		See sheet 1		National Grid		E 373418.89	
Checked by		DJLS				Coordinates		N 392402.32	
Samples and Tests					Strata				
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend		
30.00 - 30.50	B30				As sheet 3	(4.95)	g		
31.00 - 31.50	B31		15/01/2002	3.25	Highly weathered SANDSTONE recovered as red brown very sandy silty subangular fine to coarse gravel.	30.75 -12.33 (1.45)			
32.00 - 32.50	B32		15/01/2002	0.00	Non intact recovered as subangular fine to coarse gravel. Open regular subvertical discontinuity.	32.20 -13.78	b		
32.20 - 34.84m	39 40 15 75 4 110	100%							
34.84 - 37.67m	76 0 32 0 18 0	95%			Weak red brown very thinly bedded fine and medium grained SANDSTONE. Completely weathered recovered as red brown slightly gravelly sand. Gravel is subrounded fine. Highly weathered recovered as weak sandstone and subangular fine to coarse gravel. Completely weathered recovered as fine and medium sand.	(6.30pen)			
38.00 37.67 - 38.50m	100 50 90 95 36 140	kFH 95%	17/01/2002		Non intact recovered as subangular coarse gravel.				
38.50		kFH	17/01/2002	2.45	EXPLORATORY HOLE ENDS AT 38.50 m.	38.50 -20.08			
Depth	TCR SCR ROD	If	Records	Date Casing	Time Water				
Groundwater					Remarks				
No. Struck Behaviour					Chiselling : 31.50m to 32.20m 75minutes				

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Notes: For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale: 50

Project PROJECT SIREN
Project no. 121157
Carried out for Shell Global Solutions

Borehole 403
Sheet 4 of 4

Borehole Log



Exploration Associates

Drilled by GD	Equipment and Methods Inspection Pit from 0.00m to 1.20m. Cable Percussion from 0.20m to 2.00m.	Ground Level +18.36 m OD
Logged by		National Grid E 373429.27
Checked by		Coordinates N 392481.43

Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
			21/01/2002		MADE GROUND: Medium fine reddish brown sand (drillers description)	(1.10)	
			21/01/2002		MADE GROUND: Medium coarse greyish medium dense sand. Very strong chemical odour. (drillers description)	1.10 +17.26 (0.90open)	
					EXPLORATORY HOLE ENDS AT 2.00 m.	2.00 +16.36	

Groundwater No. Struck Behaviour 1 1.35m Rising to 1.20m after 20 mins.	Remarks 1. Borehole terminated due to very strong chemical odour. Borehole backfilled with arisings and covered with sand to prevent further contamination. Hole backfill : 0.00m to 2.00m Arisings (a).
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.	Project PROJECT SIREN	Borehole 404
	Project no. 121157	Sheet 1 of 1
	Carried out for Shell Global Solutions	

/2002 11:32:24 ESGLog v2.11

Borehole Log



Exploration Associates

Drilled by GD Logged by FW Checked by DJLS	Equipment and Methods See sheet 1	Ground Level +18.39 m OD National Grid E 373427.58 Coordinates N 392467.34
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Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
10.00 - 10.50	B9				As sheet 1	(5.20)	g
11.00 - 11.50	B10					11.10 +7.29	
12.00 - 12.50	B11		23/01/2002	5.35	Red brown slightly gravelly clayey SAND with pockets of soft slightly gravelly very sandy clay. Gravel is subrounded and rounded fine and medium.	(1.95)	
13.00 - 13.50	B12		24/01/2002	4.35		13.05 +5.34	
14.00 - 14.50	B13						
15.00 - 15.50	B14						
16.00 - 16.50	B15				Stiff to very stiff red brown sandy slightly gravelly CLAY. Gravel is angular to subrounded fine and medium. Occasional cobbles and boulders.	(9.95)	
17.00 - 17.50	B16						
18.00 - 18.50	B17						
19.00 - 19.50	B18						
19.50		kFH					

Groundwater No. Struck Behaviour	Remarks 13.00m to 23.00m Water added Chiselling : 19.00m to 19.85m 210minutes
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.	Project PROJECT SIREN Project no. 121157 Carried out for Shell Global Solutions	Borehole 405 Sheet 2 of 4
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1/2002 11:32:33 ESGLog v2.11

Borehole Log



Exploration Associates

Drilled by Logged by Checked by		Equipment and Methods See sheet 1			Ground Level National Grid Coordinates		
GD FW DJLS					+18.39 m OD E 373427.58 N 392467.34		
Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
20.00 - 20.50	B19						
21.00 - 21.50	B20				As sheet 2	(9.95)	
22.00 - 22.50	B21		24/01/2002	4.8			
23.00 - 23.50	B22		25/01/2002	4.8		23.00 -4.61	
24.00 - 24.50	B23				Firm brown thinly laminated CLAY.	(3.40)	
25.00 - 25.50	B24						
26.00 - 26.50	B25						
27.00 - 27.50	B26				27.00m to 27.50m: Very gravelly with slight hydrocarbon odour.	26.40 -8.01	
28.00 - 28.50	B27		25/01/2002	4.4	Brown silty gravelly SAND. Gravel is subangular to rounded fine to coarse.	(4.10)	
			28/01/2002	1.45			
29.00 - 29.50	B28						
Groundwater No. Struck Behaviour					Remarks 23.00m to 28.00m Water added Chiselling : 21.10m to 21.70m 150minutes, 26.80m to 27.30m 105minutes, 28.00m to 28.50m 120minutes, 28.50m to 29.20m 150minutes		
Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column. Scale 1 : 50			Project PROJECT SIREN		Borehole 405 Sheet 3 of 4		
			Project no. 121157				
			Carried out for Shell Global Solutions				

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Borehole Log



Exploration Associates

Drilled by GD Logged by FW Checked by DJLS	Equipment and Methods See sheet 1	Ground Level +18.39 m OD National Grid E 373427.58 Coordinates N 392467.34
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Samples and Tests				Strata		Depth, Level (Thickness)	Legend
Depth	Type & No.	Records	Date Casing	Time Water	Description		
30.00 - 30.50	B29				As sheet 3	(4.10)	g
31.00 - 31.50	B30				Red brown silty cobbly SAND. Occasional pockets of soft clay. Cobbles are subangular to rounded.	30.50 -12.11 (0.90)	
32.00 - 32.50	B31				Weathered SANDSTONE recovered as red silty fine and medium sand.	31.40 -13.01	b
33.00 - 33.50	B32						
34.00 - 34.50	B33						
35.00 - 35.50	B34						
36.00 - 36.50	B35						
			28/01/2002	8.65		(7.10pen)	
			29/01/2002	4.65			
37.00 - 37.50	B36						
38.00 - 38.50 38.00	B37	kFH	29/01/2002	5.6			
EXPLORATORY HOLE ENDS AT 38.50 m.						38.50 -20.11	

Groundwater No. Struck Behaviour	Remarks Chiselling : 35.20m to 35.50m 30minutes, 36.60m to 37.00m 60minutes, 37.00m to 38.50m 180minutes
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets	Project PROJECT SIREN Project no. 121157 Shell Global Solutions	Borehole 405 Sheet 4 of 4
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Borehole Log



Exploration Associates

Drilled by GD/LS	Equipment and Methods Inspection Pit from 0.00m to 1.20m. Cable Percussion 250 mm diameter from 0.00m to 6.00m. 200 mm diameter from 6.00m to 31.50m. Rotary Cored 150 mm diameter from 31.50m to 42.50m.	Ground Level +18.45 m OD
Logged by FW		National Grid E 373418.36
Checked by DJLS		Coordinates N 392428.92

Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
			14/02/2002	0.00	MADE GROUND: Tarmac		
					MADE GROUND: Grey slightly sandy angular and subangular medium and coarse GRAVEL.	0.25 +18.20 (0.35)	
					Yellow grey coarse SAND.	0.60 +17.85 (0.50)	
2.00	D1	PID = 17.5 KPa			Grey brown slightly silty gravelly coarse SAND. Gravel is subangular and subrounded fine and medium. Smell of gas.	1.10 +17.35 (1.45)	
3.00	D2	PID = 18 KPa			Grey brown very gravelly SAND. Gravel is subangular to rounded fine to coarse.	2.55 +15.90 (1.05)	
4.00	D3	PID = 11.2 KPa			Brown silty gravelly SAND. Gravel is subangular to rounded fine and medium.	3.60 +14.85 (2.10)	
5.00	D4	PID = 17.3 KPa					
			14/02/2002	6.00		5.70 +12.75	
6.00	D5	PID = 4.8 KPa	15/02/2002	6.00			
7.00 - 7.50	B6						
8.00	D7	PID = 3.3 KPa			Firm to stiff brown locally thinly laminated CLAY.	(6.10)	
9.00 - 9.50	B8						

Groundwater		
No. Struck Behaviour		
1	1.40m	Rising to 1.10m after 20 mins.

Remarks
 1. Service inspection pit excavated by Soil Mechanics.
 2. A 40mm diameter CMT Waterra pipe installed to 38m. Ports situated at :- 1) 28.0m 2) 30.5m 3) 32.0m 4) 33.5m 5) 35.0m 6) 36.5m 7) 38.0m. Imported material is 2 - 5mm clean gravel.
 Hole backfill : 0.00m to 0.50m Concrete (c), 0.50m to 21.00m Grout (g), 21.00m to 27.00m Bentonite (b), 27.00m to 29.00m Imported Material (i), 29.00m to 30.00m Bentonite (b), 30.00m to 31.00m Imported Material (i), 31.00m to 31.50m Bentonite (b), 31.50m to 32.50m Imported Material (i), 32.50m to 33.00m Bentonite (b), 33.00m to 34.00m Standpipe Piezometer installed, 40mm diameter, response zone from 0.00m to 38.50m.

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
 Scale 1 : 50

Project PROJECT SIREN
 Project no. 121157
 Carried out for Shell Global Solutions

Borehole 406
 Sheet 1 of 5

Borehole Log



Exploration Associates

Drilled by GD/LS	Equipment and Methods See sheet 1	Ground Level +18.45 m OD
Logged by FW		National Grid E 373418.36
Checked by DJLS		Coordinates N 392428.92

Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
10.00	D9	PID = 15.3 KPa					
11.00 - 11.50	B10		15/02/2002	4.2	As sheet 1	(6.10)	
12.00	D11	PID = 8.9 KPa	18/02/2002	1.4		11.80 +6.65	
13.00 - 13.50	B12						
14.00	D13	PID = 15.3 KPa					
15.00 - 15.50	B14						
16.00	D15				Stiff red brown sandy gravelly CLAY. Gravel is subangular to rounded fine and medium. Some cobbles and occasional boulders.	(10.60)	
17.00 - 17.50	B16						
18.00 - 18.50	B17	PID = 106.0 KPa					
19.00	D18	PID = 96 KPa					

Groundwater No. Struck Behaviour	Remarks Chiselling : 14.30m to 15.10m 105minutes, 17.70m to 18.60m 120minutes
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets	Project PROJECT SIREN	Borehole 406
	Project no. 121157	Sheet 2 of 5
	Shell Global Solutions	

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Borehole Log



Exploration Associates

Drilled by GD/LS		Equipment and Methods See sheet 1		Ground Level +18.45 m OD			
Logged by FW				National Grid E 373418.36			
Checked by DJLS				Coordinates N 392428.92			
Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
20.00 - 20.50	B19						
			18/02/2002	5.35			
21.00	D20	PID = 7.3 KPa	19/02/2002	1.35	As sheet 2	(10.60)	
22.00 - 22.50	B21						
						22.40 -3.95	
23.00	D22	PID = 13.6 KPa					
24.00 - 24.50	B23				Firm to stiff brown locally thinly laminated CLAY.	(4.05)	
25.00	D24	PID = 7.1 KPa					
27.00 - 27.50	B25		19/02/2002	4.1			
			20/02/2002	1.35	Grey sandy cobbly subrounded and rounded coarse GRAVEL. Occasional boulders.	(3.05)	
28.00	D26						
28.50 - 29.00	B27		20/02/2002	1.2	Below 28.5m: Slightly sandy with many cobbles and frequent boulders.		
			21/02/2002	1.2			
					Weathered SANDSTONE recovered as gravelly sand. Gravel is subangular coarse of sandstone.	29.50 -11.05 (2.00)	
Groundwater No. Struck Behaviour			Remarks Chiselling : 20.10m to 20.60m 60minutes, 21.60m to 22.40m 135minutes, 27.05m to 27.50m 150minutes, 27.50m to 29.00m 270minutes, 29.00m to 29.50m 150minutes				

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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project PROJECT SIREN
Project no. 121157
Carried out for Shell Global Solutions

Borehole 406
Sheet 3 of 5

Borehole Log



Exploration Associates

Drilled by		Equipment and Methods		Ground Level			
GD/LS		See sheet 1		+18.45 m OD			
Logged by		Date		National Grid			
FW		21/02/2002		E 373418.36			
Checked by		Time		Coordinates			
DJLS		3.8		N 392428.92			
Samples and Tests				Strata			
Depth	Type & No.	Records	Date	Time	Description	Depth, Level (Thickness)	Legend
			21/02/2002	3.8	As sheet 3	(2.00)	i
31.50	D28		22/02/2002	2.27		31.50 -13.05	i
31.50 - 33.58m	0 0 0	100%			No recovery	(2.08)	b
					Non intact recovered as subangular and subrounded medium and coarse gravel.	33.58 -15.13	i
					Closed subvertical discontinuity.		b
33.58 - 36.58m	69 59 23	100%			Non intact recovered as sandy subrounded medium gravel.		i
	10 140 270						b
					Weak red brown very thinly to medium bedded fine and medium grained SANDSTONE.	(8.92)	i
36.58 - 38.08m	77 53 7	100%					b
	30 185 340						i
38.08 - 39.58m	90 77 33	100%			Open vertical discontinuity.		b
39.58 - 41.08m	0 0 0	100%					i
Depth	TCR SCR ROD	If	Date	Time	Remarks		
					No. Struck Behaviour		
					Chiselling : 30.50m to 31.50m 120minutes		

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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets

Project PROJECT SIREN
Project no. 121157

Borehole 406
Sheet 4 of 5

Borehole Log



Exploration Associates

Drilled by GD/LS Logged by FW Checked by DJLS	Equipment and Methods See sheet 1	Ground Level +18.45 m OD National Grid E 373418.36 Coordinates N 392428.92
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Samples and Tests				Strata				
Depth	TCR SCR RQD	If	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
39.58 - 41.08m	0 0 0		100%			As sheet 4	(8.92pen)	
41.08 - 42.50m	77 63 14	20 60 100	100%	22/02/2002 31.50	2.56			
EXPLORATORY HOLE ENDS AT 42.50 m.							42.50 -24.05	

Groundwater No. Struck Behaviour	Remarks
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Notes . For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column. Scale 1 : 50	Project PROJECT SIREN Project no. 121157 Carried out for Shell Global Solutions	Borehole 406 Sheet 5 of 5
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Borehole Log



Exploration Associates

Drilled by GD Logged by FW Checked by DJLS	Equipment and Methods Inspection Pit from 0.00m to 1.20m. Cable Percussion 250 mm diameter from 1.20m to 6.50m. 200 mm diameter from 6.50m to 28.50m. Rotary Open Hole 200 mm diameter from 28.50m to 38.50m.	Ground Level +18.56 m OD National Grid E 373389.83 Coordinates N 392460.36
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Samples and Tests				Strata		Depth, Level (Thickness)	Legend
Depth	Type & No.	Records	Date Casing	Time Water	Description		
			27/02/2002		MADE GROUND: TARMAC	0.20 +18.36	c
			0.00		MADE GROUND: Light grey angular medium and coarse GRAVEL.	(0.35) 0.55 +18.01	
1.65	W3				Orange brown fine SAND.	(2.25)	1 1
2.00 - 2.50	B1						
4.00 - 4.50	B2				Grey brown slightly silty gravelly coarse SAND. Gravel is subrounded and rounded fine and medium.	2.80 +15.76 (3.00)	
7.00 - 7.50	B4		27/02/2002 6.50		Firm to stiff brown thinly laminated CLAY.	5.80 +12.76 (6.55)	
			28/02/2002 6.50				

Groundwater No. Struck Behaviour 1 1.40m Rising to 1.10m after 20 mins.	Remarks 1. Service inspection pit excavated by Soil Mechanics. Hole backfill : 0.00m to 0.50m Concrete (c), 0.50m to 33.50m Grout (g), 33.50m to 35.00m Bentonite (b). Surface protection : Stop Cock Cover Standpipe installed, 97mm diameter, response zone from 35.00m to 38.50m.
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Borehole Log



Exploration Associates

Drilled by GD Logged by FW Checked by DJLS	Equipment and Methods See sheet 1	Ground Level +18.56 m OD National Grid E 373389.83 Coordinates N 392460.36
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Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
					As sheet 1	(6.55)	
12.50 - 13.50	B5		28/02/2002 12.00			12.35 +6.21	
			01/03/2002 12.00				
			01/03/2002 13.50				
			04/03/2002 13.50		Brown grey clayey rounded coarse GRAVELS and COBBLES.	(2.65)	
						15.00 +3.56	
18.50 - 19.00	B6				Very stiff red brown slightly sandy gravelly CLAY. Some rounded cobbles and boulders. Gravel is subrounded fine.	(5.60)	

Groundwater No. Struck Behaviour	Remarks Chiselling : 12.50m to 13.50m 345minutes, 13.50m to 15.00m 165minutes, 18.50m to 20.00m 225minutes
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column. Scale 1 : 50	Project PROJECT SIREN Project no. 121157 Carried out for Shell Global Solutions	Borehole 407 Sheet 2 of 4
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Borehole Log



Exploration Associates

Drilled by GD Logged by FW Checked by DJLS	Equipment and Methods See sheet 1	Ground Level +18.56 m OD National Grid E 373389.83 Coordinates N 392460.36
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Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
21.00 - 21.50	B7		05/03/2002	19.50	As sheet 2	(5.60)	
26.00 - 26.50	B8		05/03/2002	24.00	Firm to stiff brown distinctly thinly laminated CLAY.	(5.20)	
			06/03/2002	24.00			
28.00 - 28.50	B9		06/03/2002	27.00	Weathered SANDSTONE recovered as red silty fine and medium sand.	(1.60)	
			07/03/2002	27.00			
			07/03/2002	28.50			
			08/03/2002	28.50	Red SANDSTONE (Drillers description)	(10.00)	
Depth	TCR SCR RGD	If	Records	Date Casing	Time Water		
Groundwater No. Struck Behaviour					Remarks Chiselling : 20.00m to 20.60m 90minutes, 27.50m to 28.00m 90minutes, 28.00m to 28.50m 105minutes		

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets

Project PROJECT SIREN
Project no. 121157
Shell Global Solutions

Borehole 407
Sheet 3 of 4

Borehole Log



Exploration Associates

Drilled by Logged by Checked by	GD FW DJLS	Equipment and Methods See sheet 1	Ground Level National Grid Coordinates	+18.56 m OD E 373389.83 N 392460.36
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Samples and Tests				Strata				
Depth	TCR SCR RQD	If	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
38.00			kFH	08/03/2002 28.50		As sheet 3	(10.00pen)	g b
						EXPLORATORY HOLE ENDS AT 38.50 m.	38.50 -19.94	

Groundwater No. Struck Behaviour	Remarks
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Notes: For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column. Scale 1:50	Project Project no. Carried out for	PROJECT SIREN 121157 Shell Global Solutions	Borehole 407 Sheet 4 of 4
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Borehole Log



Exploration Associates

Drilled by GD Logged by FW Checked by DJLS	Equipment and Methods Inspection Pit from 0.00m to 1.20m. Cable Percussion 250 mm diameter from 0.00m to 6.50m. 200 mm diameter from 6.50m to 29.50m.	Ground Level +18.40 m OD National Grid E 373411.24 Coordinates N 392451.39
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Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
			14/03/2002 0.00	dry	MADE GROUND: Tarmac	0.25 +18.15	
					MADE GROUND: Light grey angular and subangular coarse GRAVEL.	(0.35) 0.60 +17.80	
2.00 - 2.50	B1				Grey brown very silty gravelly SAND. Gravel is subangular to rounded fine to coarse.	(5.30)	
					Below 5.40m: Bands of soft brown clay.		
			14/03/2002 0.00	1.1		5.90 +12.50	
7.00 - 7.50	B2		15/03/2002		Firm to stiff brown locally distinctly thinly laminated CLAY.	(6.50)	

Groundwater No. Struck Behaviour 1 1.40m Rising to 1.10m after 20 mins.	Remarks Hole backfill : 0.00m to 0.50m Concrete (c), 0.50m to 23.00m Grout (g), 23.00m to 25.00m Bentonite (b), 28.50m to 29.50m Bentonite (b). Surface protection : Stop Cock Cover Standpipe installed, 50mm diameter, response zone from 25.00m to 28.50m.
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Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.	Project PROJECT SIREN Project no. 121157 Carried out for Shell Global Solutions	Borehole 408 Sheet 1 of 3
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Borehole Log



Exploration Associates

Drilled by GD Logged by FW Checked by DJLS		Equipment and Methods See sheet 1			Ground Level +18.40 m OD National Grid E 373411.24 Coordinates N 392461.39		
Samples and Tests				Strata			
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
					As sheet 1	(6.50)	
15.00 - 15.50	B3					12.40 +6.00	
			15/03/2002		Stiff red brown slightly sandy gravelly CLAY with some rounded cobbles and boulders. Gravel is subangular to rounded fine and medium.	(8.40)	
			18/03/2002		From 18.00m to 18.50m : Band of cobbly subrounded and rounded coarse gravel with occasional boulders.		
18.50 - 19.00	B4						
Groundwater No. Struck Behaviour				Remarks			
Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column. Scale 1 : 50			Project PROJECT SIREN Project no. 121157 Carried out for Shell Global Solutions		Borehole 408 Sheet 2 of 3		

Borehole Log



Exploration Associates

Samples and Tests		Strata					
Depth	Type & No.	Records	Date Casing	Time Water	Description	Depth, Level (Thickness)	Legend
		Equipment and Methods See sheet 1		Ground Level +18.40 m OD National Grid E 373411.24 Coordinates N 392461.39			
					As sheet 2	(8.40)	g
			18/03/2002			20.80 -2.40	
22.00 - 22.50	B5		19/03/2002		Stiff red brown locally distinctly thinly laminated CLAY.	(3.60)	b
26.00 - 26.50	B6				Grey sandy cobbly subrounded and rounded coarse GRAVEL.	(4.40)	
27.50		KFH				24.40 -6.00	
			19/03/2002		Weathered SANDSTONE recovered as red slightly gravelly silty fine and medium sand. Gravel is subangular fine to coarse of sandstone.	28.80 -10.40 (0.70pen)	
					EXPLORATORY HOLE ENDS AT 29.50 m.	29.50 -11.10	
Groundwater No. Struck Behaviour					Remarks 22.00m to 29.50m Water added.		
Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column. Scale 1 : 50			Project PROJECT SIREN Project no. 121157 Carried out for Shell Global Solutions		Borehole 408 Sheet 3 of 3		

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APPENDIX FIVE – WATER LEVEL DATA

