-fu	FRO	Fugro Engi	neering Servic	es					
	\sim	Client:	Scottish and Sc	outhern Energy PLC	Log Type:				
	\rightarrow	Borehole:	BH6	, a 2000	Acoustic Televiewer Log				
Project: CO	N103001 Sk	ov Power Station			Approved:				
Location: Sloy		Grid Re	ference:	Elevation:					
Drilled Depth:	35m		Date:	05/03/2010					
Logged Depth:	33.73m		Recorde	d By:					
Logging Datum:	Ground Leve	I			Remarks:				5
Logged Interval:					North reference is magnetic, Tadpo	le log and tabulated data is correct	ted for borehole deviation		
Fluid Level:									
Structure Key:	Folia	tion — Fracture —	Vein						
BOREHOL	E RECORD)			CASING RECORD				
Bit Diameter:	From:		То:		Туре	Size	From	То	
150mm	0m		4.5m		Steel	150mm	Om	4.5m	
120mm	4.5m		35.0m						
Depth	Caliper	Tilt	3D Log	Amplitude	Travel	Time	Structure	Tadpole	
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		0 deg 360							



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	\rightarrow	Client:	Scottish and	Southern Energy PLC	Log Type:				
	\rightarrow	Borehole:	BH7		Acoustic Televiewer Log				
Project: CO	N103001 Slo	y Power Station	1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.		Approved:				
Location: Sloy	Power Station	Grid Re	erence:	Elevation:					
Drilled Depth:	8.0m		Date:	04/03/2010					
Logged Depth:	7.3m		Reco	rded By:					
Logging Datum:	Ground Level				Remarks:				5.
Logged Interval:	:				North reference is magnetic, Tadpo	ble log and tabulated data is correct	ed for borehole deviation		
Fluid Level:									
Structure Key:	Foliati	on ——Fracture —	Vein						
BOREHOL	E RECORD				CASING RECORD				
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	\sim	Client:	Scottish and	Southern Energy PLC	Log Type:				
	\rightarrow	Borehole:	BH12		Acoustic Televiewer Log				
Project: CO	N103001 Sloy	Power Station	1-1-1807-1804-19		Approved:				
Location: SLoy		Grid Re	erence:	Elevation:					
Drilled Depth:	35m		Date:	05/03/2010					
Logged Depth:	34.51m		Recor	rded By:	29				
Logging Datum:	Ground Level				Remarks:				
Logged Interval:					North reference is magnetic, Tadpo	le log and tabulated data is correct	ted for borehole deviation		
Fluid Level:]				
Structure Key:		n — Fracture —	Vein						
BOREHOL	E RECORD				CASING RECORD				
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APPENDIX D Cross Hole Geophysics

Fugro Aperio Report Reference 3525



CLIENT: SCOTTISH & SOUTHERN ENERGY

ENGINEER: JACOBS ENGINEERING UK LIMITED

REPORT ISSUE STATUS

001	28/04/10	FINAL				
001	09/04/10	DRAFT				
Issue	Date	Description	Prepared	Checked	Approved (Printed)	Approved (Signature)
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EXECUTIVE SUMMARY

- This report documents a seismic cross-hole tomography survey carried out at Sloy Pumping Station, Inveruglas.
- The brief was to provide seismic P wave velocity data of ground materials between a five boreholes to provide an indication of rippability and isotropy of the rock.
- To achieve this objective a seismic tomographic cross-hole approach was carried out.
- The survey was carried out between 8th-10th March 2010 using a Geometric Geode recording system, a Geotomographie Sparker seismic source and a 24 channel Geospace hydrophone string.
- Sensitivity analyses were carried out to assess the affect of typical first arrival recognition. It
 was established that such errors could lead to a velocity error of ~ 2%. It was concluded that,
 data were satisfactory for both direct and tomographic analyses.
- It was established that a relatively low velocity (<4500 m/s) layer was present across the area of investigation generally above an elevation of 5m. Local increases in thickness (up to 9m) of this layer were identified. This layer was interpreted as being related to upper superficial deposits and/or a variable, weathered or fractured upper bedrock surface.
- Below an elevation of ~5 m velocities were predominantly in excess of 5000 m/s
- Notable areas of relatively lower velocity (~4850-5150 m/s; equivalent to up to ~10% reduction) were noted on section BH6-BH12, BH6-BH12, BH2-BH3 and BH2-BH12.
- The data indicated a general increase in seismic velocity was apparent towards the north eastern part of the investigation area.
- Below about 5 m elevation the analyses indicate velocities in excess of 4000 m/s Reference to standard rippability charts (Appendix D) would indicate that velocities of this magnitude, in metamorphic rock can be classified as non-rippable.



TABLE OF CONTENTS

1.	INTRODUCTION	.1
1.1	General	.1
1.2	The Brief	.1
1.3	Terms of Reference	.1
1.4	Service Constraints	.2
2.	BACKGROUND INFORMATION	.3
2.1	General	.3
3.	DATA ACQUISITION	.5
3.1	General	.5
3.2	Cross-hole tomography	.5
3.3	Survey Rationale & Methodology	.6
3.4	Borehole verticality	.6
4.	PROCESSING	.8
4.1	General	.8
4.2	Shot records	.8
4.3	Time zero determination	.9
4.4	First arrival recognition accuracy	10
4.5	Direct Velocities	11
4.6	Tomographic analysis	11
4.3	Time zero determination	.9
4.4	First arrival recognition accuracy	10
4.5	Direct Velocities	11
4.6	Tomographic analysis	11
5.	CONCLUSIONS	13

List of Drawings

Appendices



1. INTRODUCTION

1.1 General

1.1.1 This report documents a geophysical investigation that comprised of a shallow seismic cross-hole tomography survey. The work was carried out between five boreholes (BH2, BH3, BH4, BH6 & BH12) drilled to a maximum depth of ~35 m.

1.2 The Brief

1.2.1 The brief was to establish the in-situ seismic signal propagation/attenuation characteristics for two source types over a range of travel paths in order to assess the feasibility of the technique for deep investigation of potential collapsed zones.

1.3 Terms of Reference

- 1.3.1 This investigation was conducted by Fugro Aperio Limited on behalf of Fugro Engineering Services Limited for Scottish & Southern Energy and is based on seismic data collected on site between 8th and 10th March 2010.
- 1.3.2 The findings presented within this report are the result of the measurement and interpretation of acoustic signals. As such any results derived from the geophysical investigation should be taken in the context of and in reference to the complete ground investigation.
- 1.3.3 Additionally with specific reference to seismic data and respective derived parameters, the following constraints apply. Seismic velocities are derived from calculations resulting from the identification of appropriate seismic waveforms and their time of travel along a source-receiver path from source to receiver. The shape and phase characteristics of a received compressional waveforms and associated arrival time selection may be influenced by frequency-selective attenuation, dispersion, reflection, refraction, scattering, mode conversion processes and source and receiver coupling effects dependent on variations in ground conditions along the corresponding source-receiver travel path. In the derivation of velocities or associated properties apparent variations arising from both the relative and absolute influence of these processes along a particular source-receiver path may not be known or be calculable.



1.3.4 This draft report supersedes any previous reports, whether written or oral.

1.4 Service Constraints

1.4.1 Appendix A (Service Constraints) outlines the limitations of this report in terms of a range of considerations including, but not limited to, its purpose, its scope, the data on which it is based, its use by Third Parties, possible future changes in design procedures and possible changes in the conditions at the site with time. Appendix A represents a clear exposition of the constraints, which apply to all reports issued by Fugro Aperio Limited. It should be noted that the Service Constraints do not in any way supersede the terms and conditions of the contract between Fugro Aperio Limited or Fugro Engineering Services Limited and the Client.



2. BACKGROUND INFORMATION

2.1 General

- 2.1.1 The site is located adjacent to the existing Sloy Hydro-electric power station in Inveruglas. The area of investigation covered a roughly circular area approximately 30 m diameter. Four number boreholes were located around the perimeter (BH2, 3, 4 and 6) and the fifth borehole (BH12) was located roughly in the centre.
- 2.1.2 The location of all test boreholes is provided on drawing 3525-01.
- 2.1.3 The local geology was understood to comprise of 2-3 m of superficial deposits over highly metamorphosed Schist (to at least 35 m). Anecdotal evidence received on site indicated a potential increase in fracturing within the area adjacent to the existing power station, possibly linked to blasting operations during construction.
- 2.1.4 The survey was initially commenced in open hole boreholes, however, during acquisition of the first dataset the source tool became stuck at ~ 12m (BH12). It was thought that rock fragment(s) from the borehole wall had become wedged between the tool and the borehole wall. The tool was retrieved and a decision made to carry out testing in ungrouted plastic cased holes.
- 2.1.5 The testing was carried out successfully. The presence of ungrouted plastic casing did not detrimentally affect the quality of the raw seismic data.
- 2.1.6 Measurements were made at 1 m increments between all available boreholes as described in Table 1 below:

Source Borehole	Receiver Borehole	Start Depth	End Depth	Inter borehole distance (m)
BH2	BH3	3	35	17.94
BH2	BH6	3	35	19.52
BH4	BH3	3	34	14.59
BH4	BH6	3	34	22.25
BH12	BH2	3	35	10.66
BH12	BH3	3	35	12.15
BH12	BH4	3	35	9.67
BH12	BH6	3	35	19.60

Table 1 – Tomographic dataset details



2.1.7 Coordinates and elevations for each test borehole were provided relative to survey control point 2 provided by the Client.

BH	Easting	Northing	Ground Level
SCP2	232109.64	709873.71	15.501
BH2	232144.10	709839.35	11.97
BH3	232162.01	709840.49	12.04
BH4	232157.68	709854.43	13.15
BH6	232134.51	709856.35	12.33
BH12	232151.67	709846.86	12.38

Table 2 – Borehole coordinates



3. DATA ACQUISITION

3.1 General

3.1.1 The seismic cross-hole survey was carried out between 8th and 10th March 2010 Specifications for the equipment are provided in Appendix C.

3.2 Cross-hole tomography

- 3.2.1 For seismic techniques in general, stress applied at the surface of an elastic media creates the conditions for the associated strains to propagate as compressive elastic waves in the subsurface material as a pattern of particle deformation travelling with velocities that are dependent on the elastic properties and densities of the media through which they travel.
- 3.2.2 P-wave tomography involves initiating elastic waves at a known point, within a borehole, and determining at a number of other known positions the arrival times of the seismic energy that has refracted, reflected or directly travelled through subsurface material back to the surface from discontinuities or interfaces between subsurface layers.
- 3.2.3 The objective of the P-wave tomography survey was, primarily, to establish P wave seismic velocities of rock material to provide an indication of rippability and isotropy of the rock.
- 3.2.4 In practice this was performed by measuring, between two source and receiver locations, the in-situ primary (compression) P wave velocities.
- 3.2.5 Field testing was performed by measuring the P wave at a number of sourcereceiver configurations.
- 3.2.6 A typical cross-hole seismic spread used for tomography is presented on Drawing No. 3525-02.



3.3 Survey Rationale & Methodology

- 3.3.1 The purpose of the trial was to ascertain seismic P wave velocity characteristics of the rock mass material at the Sloy site.
- 3.3.2 The location of the boreholes was specified by the Client to provide coverage within the area proposed for excavation of a shaft associated with proposed pumping station infrastructure.
- 3.3.3 Seismic energy was created in each source borehole by deployment of a borehole sparker system.
- 3.3.4 The compression wave energy generated by the borehole source was transmitted through the ground material and detected by a series of hydrophones placed in the receiver borehole. The seismic data was recorded using a seismograph and saved in industry standard SEG-2 format for office based processing.
- 3.3.5 For each borehole pair, shots were carried out at 1 m increments along the full length of the borehole (excluding the top 2-3 m due to steel casing/groundwater levels) for hydrophone positions at depths of 1 m to 24 m. The shooting process was repeated with hydrophone positions at 11 m to 35 m to ensure full coverage for the full length of the boreholes (3 35 m).
- 3.3.6 Acquisition parameters were established on site based upon an initial assessment of approximate velocities and ambient site noise. The following were applied:

Record length	100 ms
Pre trigger	10 ms
Sample interval	20.833 µs
Acquisition filters	None
Stacks	Multiple (typically 3 to 10)

3.3.7 Where necessary individual shots were stacked to improve signal-noise ratio.

3.4 Borehole verticality

3.4.1 In order to analyse cross-hole seismic data and determine velocities it was necessary to obtain 3D coordinates for all source and receiver locations. Since these positions are located within the borehole at depth it was necessary to measure the verticality (or deviation away from the vertical) of each drilled hole. This



information was measured through use of a verticality tool used primarily for wireline logging. All source and receiver boreholes were logged by Fugro Engineering Services Limited during the course of the geophysical survey.

3.4.2 Coordinates for each source and receiver location were calculated by applying the measured deviation to the respective surface coordinates.



4. **PROCESSING**

4.1 General

4.1.1 All seismic data were recorded as digital SEG-2 format shot records to enable office based processing to be carried out. Basic trace operations were applied, including bandpass filtering, to improve signal-noise ration for each shot record prior to time break analysis and full inversion.

4.2 Shot records

- 4.2.1 Individual shot records from each borehole pair acquired with both source types were analysed and compared to provide an assessment of signal propagation characteristics.
- 4.2.2 It was found that for all borehole pairs of ~30 m, signal propagation from the sparker source was generally sufficient to enable first arrival recognition.
- 4.2.3 An example shot record is provided below on Figure 1 taken from the BH4-BH6 (largest inter borehole spacing). For the purposes of clarity and comparison a single source-receiver trace has been isolated.
- 4.2.4 Inspection of the trace would indicate an arrival time for first break P-wave energy of approximately 4.39 ms, equating to a seismic velocity of ~5050 m/s.
- 4.2.5 Analysis of the incident sparker energy would indicate a dominant frequency of ~1350 Hz.



Figure 1 – BH4-BH6 : Sparker Source, Test Depth 21 m, Inter borehole spacing ~22.25 m (Lo-cut (100 Hz) and high cut (4000 Hz) applied)



4.3 Time zero determination

- 4.3.1 Accurate determination of time zero is essential in order that reliable velocity measurements and variations may be determined from a seismic data set. The time zero for the sparker system was determined during acquisition by a trigger impulse generated by the control unit at the moment of firing.
- 4.3.2 To assess any potential time zero errors or 'trigger jitter' a series of three single repeat shots were carried out at a fixed depth. The resulting waveforms for the consecutive shot records are provided overleaf on Figure 2. Assuming no trigger jitter the waveforms should theoretically be identical with arrival of incident P wave energy identifiable at a consistent time.



Figure 2 – BH12-BH6 : Repeat sparker source shot records, Test Depth 33 m, Inter borehole spacing ~19.60m (Lo-cut (100 Hz) and high cut (3000 Hz) applied)



4.4 First arrival recognition accuracy

- 4.4.1 Recognition of first arrival energy ('pick point) and the a.ccuracy ('error window') at which such recognition can be made is critical to any seismic velocity investigation.
- 4.4.2 Using the example sparker shot records provided in section 4.2.5 an assessment of likely picking accuracy can be made. The relevant section of the shot record is provided below on Figure 3.



Figure 3 - First arrival P wave energy (BH4-BH6)

- 4.4.3 The data example provided from the BH4-BH6 dataset would indicate a 'pick point' of 4.39 ms with a corresponding error window of +/- 0.05 ms. The straight line raypath distance for this record was 22.25 m.
- 4.4.4 The tomographic data would therefore indicate a first arrival recognition error window (i.e. trigger jitter + picking error) of approximately +/- 0.075 ms over a source-receiver separation of ~ 23 m.

UGRO



4.5 Direct Velocities

- 4.5.1 A basic velocity analysis of the tomographic dataset was carried out to establish direct raypath velocity profiles as a function depth. Velocities were calculated for source-receiver raypaths at equal depths below ground level for each dataset. Direct raypath velocity profiles for each borehole set are presented on in Appendix B (Figures B1-B8 respectively). A composite profile showing all direct velocities is provided in Appendix B, Figure B9.
- 4.5.2 A basic analysis of the profiles indicated a range of P-wave velocities between ~4500 and 5800 m/s, generally increasing with depth. Below about 5 m elevation the majority of direct velocity values were between 5150 m/s and 5600 m/s. It is considered that the lower velocities above 5 m elevation are likely to be attributed to a weathered upper bedrock surface.
- 4.5.3 All datasets showed relatively consistent velocity distributions as a function of depth. The dataset for BH2-BH6 showed relatively lower P wave velocities (5000-5200 m/s) between -10 m and -21 m elevation. This equated to a reduction in velocity of ~ 7.5% in comparison to the other datasets.

4.6 Tomographic analysis

- 4.6.1 Further tomographic analysis of each dataset was carried out using Divine v4.70 Mk3.
- 4.6.2 Raypath modelling using a 3D wavefield propagation algorithm to determine least time raypaths for specific source-receiver geometries was performed.
- 4.6.3 Traveltime inversion using a SIRT (simultaneous iterative reconstruction technique) algorithm was then applied to attempt to reconstruct the starting velocity model.
- 4.6.4 The results of each tomographic analysis are provided in Drawing 3525-03.
 Tomographic data were combined into a 3-D volume to enable 3-D representation.
 The results are provided at 4 different projections (NW, NE, SE, SW) on Drawing 3525-04.
- 4.6.5 Tomography panels have been relocated and presented to provide a continuous cross-section for BH6-BH12- B3 and for BH2-BH12-BH4. Similarly tomographic



panels have been relocated and presented to provide a continuous cross-section around the perimeter boreholes (i.e. BH6- BH2- BH3- BH4- BH6). Note that the individual perimeter sections were acquired in different planes as a function of the borehole layout.

- 4.6.6 The tomographic analyses for datasets show a generally consistent velocity distribution to that described by the basic direct velocity analyses (section 4.5). In general velocities were in the range 2500 m/s to 5750 m/s and generally increased as a function of depth.
- 4.6.7 The majority of the low velocity (<4750 m/s) velocities were noted in a laterally continuous upper layer. The thickness of this upper layer was noted to vary between ~ 2m and ~9 m with notable increases in thickness apparent on tomographic panels BH6 to BH2, BH12 to B3 and BH2 to BH12. It is considered that this relatively low velocity layer may relate to upper superficial deposits and/or a variable, weathered or fractured upper bedrock surface.</p>
- 4.6.8 Typically, below an elevation of ~5 m, the tomographic sections show velocity in excess of 5000 m/s (predominantly 5000-5500 m/s). Notable areas of relatively lower velocity (~4850-5150 m/s; equivalent to up to ~10% reduction) were noted on section BH6-BH12. This observation was consistent with the relatively lower velocities identified from the basic direct velocity analysis for this dataset.
- 4.6.9 Additional, similar low velocity regions were identified on sections BH6-BH12, BH2-BH3 and BH2-BH12.
- 4.6.10 In general, relatively higher velocities (>5250 m/s) were noted on sections BH4-BH6, BH12-BH4 and BH3-BH4.



5. CONCLUSIONS

5.1 General

5.1.1 Cross-hole seismic data were acquired between five boreholes (BH2, BH3, BH4, BH6 and BH12) within an area adjacent to the existing Sloy power

5.2 Data Quality

5.2.1 Data quality was monitored on site and shot records were appropriately stacked to improve signal-noise ratios. Analysis of the shot records indicated good signal-noise interborehole spacing of up to ~23 m sufficient to allow visual recognition of first arrivals. Data quality was sufficient to enable basic direct and tomographic analyses to be undertaken.

5.3 First arrival recognition

- 5.3.1 Basic analysis of the shot records indicated a higher than expected velocity for bedrock material (~5000 m/s). The commensurate reduction in absolute transit time necessitated a critical analysis of the potential errors associated with recognition of first arrival events.
- 5.3.2 The trial data sets acquired with the sparker tool would indicate that first arrivals may be confidently identified within error bounds of approximately +/- 0.075 ms over a source-receiver separation of ~ 23 m. Based upon an average material velocity of 5000 m/s, first arrival recognition errors may have contributed to final velocity errors of approximately +/- 2%.

5.4 Velocity analysis of trial data

5.4.1 Basic direct raypath velocity analysis was carried out on all datasets (Appendix B). Consistent seismic velocities were identified in all datasets in the range between 5150 m/s and 5600 m/s below about 5 m elevation. Velocity values were generally noted to increase a function of depth. A relative decrease in seismic velocity of ~7.5% was noted below -10 m and -21 m elevation in dataset BH6-BH2.

- 5.4.2 Tomographic analysis of each dataset was carried out and section presented accordingly (Drawing 3525-03). The tomographic panels were generally consistent with the velocities derived from the basic direct raypath analysis.
- 5.4.3 Tomographic data were combined into a 3-D volume to enable 3-D representation. The results are provided at 4 different projections (NW, NE, SE, SW) on Drawing 3525-04.
- 5.4.4 The majority of the low velocity (<4750 m/s) velocities were noted in a laterally continuous upper layer. The thickness of this upper layer was noted to vary between ~ 2m and ~9 m with notable increases in thickness apparent on tomographic panels BH6 to BH2, BH12 to B3 and BH2 to BH12. It is considered that this relatively low velocity layer may relate to upper superficial deposits and/or a variable, weathered or fractured upper bedrock surface.
- 5.4.5 Typically, below an elevation of ~5 m, the tomographic sections show velocity in excess of 5000 m/s (predominantly 5000-5500 m/s). Notable areas of relatively lower velocity (~4850-5150 m/s; equivalent to up to ~10% reduction) were noted on section BH6-BH12. This observation was consistent with the relatively lower velocities identified from the basic direct velocity analysis for this dataset.
- 5.4.6 Additional, similar low velocity regions were identified on sections BH6-BH12, BH2-BH3 and BH2-BH12.
- 5.4.7 In general, relatively higher velocities (>5250 m/s) were noted on sections BH4-BH6, BH12-BH4 and BH3-BH4.
- 5.4.8 It can be concluded from these analyses that a general increase in seismic velocity was apparent towards the north eastern part of the investigation area (i.e. away from the existing infrastructure). This conclusion is consistent with the suspected increase in fracturing due to blast damage for the area adjacent to the existing power station (between BH2, BH3 and BH6).
- 5.4.9 Below about 5 m elevation the analyses indicate velocities in excess of 4000 m/s Reference to standard rippability charts (Appendix D) would indicate that velocities of this magnitude, in metamorphic rock can be classified as non-rippable. In summary, both the basic direct raypath and tomographic analyses indicated seismic velocities in the range 4400-5500 m/s. In generally the lower velocities were



identified within the near surface (<10-15 m) rock material and are thought to be related to near surface weathering.

5.4.10 It must be emphasised that geophysical methods can only identify areas yielding results that are different, i.e. anomalous to the site norm. The interpretation of the cause of such anomalies is inevitably based on assumptions utilising the best information available on the nature of the site. Positive identification of these anomalies can only be made by visual or physical sampling methods.



LIST OF DRAWINGS

Drawing No. 3525-01:	Location of test boreholes
Drawing No. 3525-02:	Schematic representation of cross-hole tomography method
Drawing No. 3525-03:	Cross-hole tomography panels
Drawing No. 3525-03:	Cross-hole tomography panels – 3D representations



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\bigcirc	Boreholes
	Trial Pits
•	Cross-hole tomography test boreholes
	Cross-hole tomography panel BH2-BH3
	Cross-hole tomography panel BH2-BH6
	Cross-hole tomography panel BH4-BH3
	Cross-hole tomography panel BH4-BH6
	Cross-hole tomography panel BH12-BH2
	Cross-hole tomography panel BH12-BH3
	Cross-hole tomography panel BH12-BH4
	Cross-hole tomography panel BH12-BH6

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SCOTTISH & SOUTHERN ENERGY SLOY PUMPING STATION - CROSS-HOLE TOMOGRAPHY SURVEY



SCHEMATIC ILLUSTRATION OF THE CROSS HOLE P WAVE TOMOGRAPHY TECHNIQUE



BH6 BH12 BH3 BH12 BH4 BH2 ÷ ¥ * 10 _ 10 ____ 10 — 0 - (m) - 01- 01-- 01-0 — 0 - 0 Elevation (m) Elevation (m) -10 __ -10 -20 -20 -20



10 - 0 Elevation (m) -10 -20

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LEGEND :

•	Boreholes
	Trial Pits
•	Cross-hole tomography test boreholes
	Cross-hole tomography panel BH2-BH3
	Cross-hole tomography panel BH2-BH6
	Cross-hole tomography panel BH4-BH3
	Cross-hole tomography panel BH4-BH6
	Cross-hole tomography panel BH12-BH2
	Cross-hole tomography panel BH12-BH3
	Cross-hole tomography panel BH12-BH4
	Cross-hole tomography panel BH12-BH6

CLIENT :

SCOTTISH AND SOUTHERN ENERGY

PROJECT :

SLOY PUMPING STATION

TITLE :

CROSS-HOLE TOMOGRAPHY PANELS

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	Trial Pits
•	Cross-hole tomography test boreholes
	Cross-hole tomography panel BH2-BH3
	Cross-hole tomography panel BH2-BH6
	Cross-hole tomography panel BH4-BH3
	Cross-hole tomography panel BH4-BH6
	Cross-hole tomography panel BH12-BH2
	Cross-hole tomography panel BH12-BH3
	Cross-hole tomography panel BH12-BH4
	Cross-hole tomography panel BH12-BH6

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APPENDIX A

SERVICE CONSTRAINTS



Service Constraints

- 1. This report and the assessment carried out in connection with the report (together the "Services") were compiled and carried out by Fugro Aperio Limited on behalf of Fugro Engineering Services for Scottish & Southern Energy (the "Client") in accordance with the terms of a contract between Fugro Aperio Limited and the Client. The Services were performed by Fugro Aperio Limited with the skill and care ordinarily exercised by a reasonable specialist at the time the Services were performed. Further, and in particular, the Services were performed by Fugro Aperio Limited taking into account the limits of the scope of works required by the Client, the time scale involved and the resources, including financial and manpower resources, agreed between Fugro Aperio Limited and the Client.
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- 4. It is Fugro Aperio Limited's understanding that this report is to be used for the purpose described in Section 2 "Introduction" of this report. That purpose was a significant factor in determining the scope and level of the Services. Should the purpose for which the report is used, and/or should the Client's proposed development or use of the site change (including in particular any change in any design and/or specification relating to the proposed use or development of the site), this report may no longer be valid or appropriate and any further use of or reliance upon the report in those circumstances by the Client without Fugro Aperio Limited's review and advice shall be at the Client's sole and own risk. Should Fugro Aperio Limited be requested, and Fugro Aperio Limited agree, to review the report after the date hereof, Fugro Aperio Limited shall be entitled to additional payment at the then existing rates or such other terms as may be agreed between Fugro Aperio Limited and the Client.
- 5. The passage of time may result in changes (whether man-made or otherwise) in site conditions and changes in regulatory or other legal provisions, technology, methods of analysis, or economic conditions which could render the report inaccurate or unreliable. The information, recommendations and conclusions contained in this report should not be relied upon if any such changes have taken place or after a period of 2 years from the date of this report or such other period as maybe expressly stated in the report, without the written agreement of Fugro Aperio Limited. In the absence of such written agreement of Fugro Aperio Limited, reliance on the report after any such changes have occurred or after the period of 2 years has expired shall be at the Client's own and sole risk. Should Fugro Aperio Limited agree to review the report after the period of 2 years has expired, Fugro Aperio Limited shall be entitled to additional payment at the then existing rates or such other terms as may be agreed between Fugro Aperio Limited and the Client.
- 6. The observations, recommendations and conclusions in this report are based solely upon the Services, which were provided pursuant to the contract between the Client and Fugro Aperio Limited. Fugro Aperio Limited has not performed any observations, investigations, studies or testing not specifically set out or required by the contract between the Client and Fugro Aperio Limited. Fugro Aperio Limited is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the Services.
- 7. Where the Services have involved Fugro Aperio Limited's interpretation and/or other use of any information (including documentation or materials, analysis, recommendations and conclusions) provided by third parties (including independent testing and/or information services or laboratories)



or the Client and upon which Fugro Aperio Limited was reasonably entitled to rely or involved Fugro Aperio Limited's observations of existing physical conditions of any site involved in the Services, then the Services clearly are limited by the accuracy of such information and the observations which were reasonably possible of the said site. Unless otherwise stated, Fugro Aperio Limited was not authorised and did not attempt to independently verify the accuracy or completeness of such information, received from the Client or third parties during the performance of the Services. Fugro Aperio Limited is not liable for any inaccuracies (including any incompleteness) in the said information, the discovery of which inaccuracies required the doing of any act including the gathering of any information which it was not reasonably possible for Fugro Aperio Limited to do including the doing of any independent investigation of the information provided to Fugro Aperio Limited save as otherwise provided in the terms of the contract between the Client and Fugro Aperio Limited.



APPENDIX B

DIRECT VELOCITY PROFILES



Direct P-wave Velocity - BH2-BH3





Direct P-wave Velocity - BH2-BH6



5000

4750

4500



6000



Direct P-wave Velocity - BH4-BH3

5250

5500

5750














Direct P-wave Velocity - BH12-BH3



Velocity (m/s)







Velocity (m/s)







Velocity (m/s)



Direct P-wave Velocity - All boreholes





APPENDIX C

EQUIPMENT SPECIFICATIONS



Geotomographie



P-wave sparker equipment

The basic seismic crosshole source equipment consists of the electric surge generator IPG and the remote control unit RCU. To the surge generator various seismic sparker sources can be connected. Triggering of the seismic aquisition system is performed by the remote unit.



5 #s Sparker discharge Trigger signa

The remote control unit RCU converts the reference signal of the surge generator to a trigger signal (right). Sparker pulses are released through manual or automatic triggering of the generator by the remote unit. The background noise can be recorded automatically and used to interrupt data aquisition if the noise level is to high. Trigger accuracy is below 10 µs (left).

To generate the sparker pulses within the borehole the p-wave sparker probe SBS 42 is used (left). The SBS 42 consists of a probe tube and a rubber tube system. The sparker predominantly produces high frequency pwaves even over large distances as shown below.

Technical data IPG 1005 Impulse voltage: 5 KV Impuls energy: 1000 J Repetition rate: from 4 to 7 s Power supply: 230 V 50 Hz 2,5 A Dimensions: 52 x 25 x 50 cm Weight: ~ 52 Kg Working Mode: Manual/Continuous Emergency OFF button Safety key switch



Technical data RCU TTL Low/High trigger output Trigger test option Trigger level adjustment Impulse Counting Single shot release Continuous shot release (with variable repetition rate from 4..7 sec.) Emergency OFF button Safety key switch



Borehole distance 45 m





Borehole distance 95 m



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Borehole Hydrophone String (24No. @ 1m separation Geospace MP25)



The Borehole Hydrophone Chain 2 is a compact seismic receiver system of up to 24 hydrophones having fixed spacings, e.g. 1 m.

In the standard version Geospace MP25 hydrophones are used, which have a maximum operation depth of about 200 m. Other types of hydrophones can be delivered on request.



For running the hydrophone string in an open hole, an additional pulling rope with sinker bar can be used. These accessories will be delivered together with the borehole hydrophone chain.

SCOTTISH & SOUTHERN ENERGY SLOY PUMPING STATION – CROSS-HOLE TOMOGRAPHY SURVEY



PRODUCTS	REQUEST INFO		SUPPORT	1 4	CONTACT INFORMATION	NEWS & EVE	NTS
Geophysical		11					
Sensors	100.00					The second s	-
Geophones	MP-25	5					-
Hydrophones						-	
MP18	>Fasy metho	d to check	nolarity				
MP24	>6 months w	ananty	permity			and the second sec	1000
MP25	>High output	the a cheart y					
MP24R	>Acceleration	n noise can	celine configura	tion			
MP25R			and a second second	Constraint -			
MIP26						-	
MP-5D & MP-6F							
Multi-Component	The MP-25 is	a high our	truit messure ser	sitive deter	tor for	0	and the second second
Geophysical Acquisition Systems	use in swamm	s must b	ans and transitio	n zones			
Telemetry Cable & Leader Wire	the monthly						
Connectors	The MP-25 is	transform	er-coupled and h	as 8 niezoe	lectric	-	
Adaptors	crystals com	ected in an	acceleration-can	celing array	rement		
Geophone Cases/Splices/Ts	with each cry	stal operat	ing in the high se	ensitivity be	nder		
Accessories	mode. The cr	vstals and	transformer are p	ermanently	molded		
	in a durable p	olvurethan	ne case. This seal	ed unit has	3		
Industrial/Geophones	thermoplastic	resin oute	a case with easy	access port	for	100	
Seismology	polarity testin	ng. The Sid	lewinder version	does not ha	ve the	ecs	
and a second	outer case.						
marme seismic sourions							
	The MP-25 S	idewinder	version is design	ed for easy	mounting		
	to bay cable a	and reducti	on of leader cabl	e stress. Its	tapered		
	design positio	ons the lead	der flush with the	cable there	eby		
	greatly reduc	ing the fric	tion in this area :	as the hydro	phone		
	travels through	gh the squir	rter.				
	Anchor slots	have been	provided for ties	wrapping th	e		
	hydrophone t	o the bay o	able thus facilita	ting the pro	cess of		
	taping the un	it to the cal	ble.				

seismic exploration

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PRODUCTE	ALQUELT INFO	UPPORT CONTACT I	APCRIMATION I	NEWS & EVENTS		
necul ota opticina prophistan	MP-25 Specifi	cations				
1918 1924 1925	Natural Frequency ± 15 *	MP-25-250 10 Hz	MP-25-350 10 Hz	MP-25-656 10 Hz		
IF24R IF25R IF26	Voltage Sensitivity = 1.5 dB Impedance	11.2 Volts/Bar 250 Ohms	8.0 Volts/Bar 250 Ohms	6.4 Volts/Bar 250 Ohms		
F-4D & MP-4F	DC Resistance = 10% Operating Temperature Range	160 Ohms 0-35*C	160 Ohms 0-35°C	160 Chans 0-35°C		
Hysical Acquisition Systems netry Cable & Leader Wire	Operational Depth Dimensions	1-250 ft (.30-76 m) Without Outer Case	1-350 ft (.30-107 n With Outer Cate	n) 1-556 ft (.30-200 m) Sidewinder		
ectore tore	Langth	4.75 in (12.07 cm)	5.50 in (13.97 cm) 6.50 in (16.75 cm)		
horn CasesifylicesTa marke	Weight:	2.00 in (5.08 cm) .52 lbs (236 g)	2.40 in (6.10 cm) .77 lbs (349 g)	2.00 m (5.08 cm) .58 lbs (263 g)		
alGosphones						

a c c a d



APPENDIX D

D9R CATERPILLAR RIPPABILITY CHART





Caterpillar 'D9R Rippability Chart'



APPENDIX E Geotechnical Laboratory Test Results

- Geotechnical Testing Schedules of UKAS Accreditation General Notes on Laboratory Test Results Summary of Classification Tests Particle Size Distribution Curves Rock Test Results Aggregate Test Results Seismic Velocity Test Results DETS Test Certificate 10-36994
- Figure LKS/01 Figure LT1/1 Figures LT2/1 to LT2/20 Figures LT8/1 to LT8/41

Schedule of Accreditation issued by

United Kingdom Accreditation Service

21 - 47 High Street, Feltham, Middlesex, TW13 4UN, UK



Testing performed at the above address only

DETAIL OF ACCREDITATION

Materials/Products tested	Type of test/Properties measured/Range of measurement	Standard specifications/ Equipment/Techniques used
ROCK	Point load strength and anisotropy indices	ISRM Commission on Testing Methods. Suggested Method for Determining Point Load Strength 1985
	Water content	ISRM Suggested Methods - Rock Characterisation Testing and Monitoring. Ed E T Brown 1981
	Porosity and density - by saturation and calliper techniques	ISRM Suggested Methods - Rock Characterisation Testing and Monitoring. Ed E T Brown 1981
	Porosity and density - by saturation and buoyancy techniques	ISRM Suggested Methods - Rock Characterisation Testing and Monitoring. Ed E T Brown 1981
	Slake-durability index	ISRM Suggested Methods - Rock Characterisation Testing and Monitoring. Ed E T Brown 1981
SOILS for civil engineering purposes	California Bearing Ratio (CBR)	BS 1377:Part 4:1990
	Unconfined compressive strength - load frame method	BS 1377:Part 7:1990
	Undrained shear strength - triaxial compression without measurement of pore pressure	BS 1377:Part 7:1990



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Fugro Engineering Services Limited

Accredited to ISO/IEC 17025:2005

Issue No: 016 Issue date: 15 November 2006

Testing performed at main address only

Materials/Products tested	Type of test/Properties measured/Range of measurement	Standard specifications/ Equipment/Techniques used
SOILS for civil engineering purposes (Cont'd)	Undrained shear strength - triaxial compression with multistage loading and without measurement of pore pressure	BS 1377:Part 7:1990
	Moisture content - oven drying method	BS 1377:Part 2:1990
	Saturation moisture content of chalk	BS 1377:Part 2:1990
	Liquid limit - cone penetrometer	BS 1377:Part 2:1990
	Liquid limit - cone penetrometer - one point	BS 1377:Part 2:1990
	Plastic limit	BS 1377:Part 2:1990
	Plasticity index and liquidity index	BS 1377:Part 2:1990
	Density - linear measurement	BS 1377:Part 2:1990
	Density - immersion in water	BS 1377:Part 2:1990
	Density - water displacement	BS 1377:Part 2:1990
	Particle density - gas jar	BS 1377:Part 2:1990
	Particle size distribution - wet sieving	BS 1377:Part 2:1990
	Particle size distribution - dry sieving	BS 1377:Part 2:1990
	Particle size distribution - sedimentation - pipette method	BS 1377:Part 2:1990
	Dry density/moisture content relationship (2.5 kg rammer)	BS 1377:Part 4:1990
	Dry density/moisture content relationship (4.5 kg rammer)	BS 1377:Part 4:1990
	Dry density/moisture content relationship (vibrating hammer)	BS 1377:Part 4:1990
	I	



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ISO/IEC 17025:2005

Issue No: 016 Issue date: 15 November 2006

Testing performed at main address only

Materials/Products tested	Type of test/Properties measured/Range of measurement	Standard specifications/ Equipment/Techniques used
SOILS for civil engineering purposes (Cont'd	Moisture condition value (MCV)	BS 1377:Part 4:1990
	Chalk crushing value	BS 1377:Part 4:1990
	One-dimensional consolidation properties	BS 1377:Part 5:1990
	END	

SCOTTISH & SOUTHERN ENERGY SLOY PUMPING STATION

GENERAL NOTES ON LABORATORY TEST RESULTS

1. TEST METHODS

The tests reported on the following sheets have been carried out in accordance with the methods given in BS 1377:1990 'Methods of test for soils for civil engineering purposes', subject to a small number of variances as described below under the respective headings. These notes also serve as keysheets to any notation used in reporting the laboratory tests.

2. KEY TO NOTATION OF SAMPLE TYPE

- D Small disturbed sample
- B Bulk disturbed sample
- U General purpose open drive tube sample
- P Piston sample
- TW Thin wall sample
- C Rotary core sample

3. CLASSIFICATION TESTS

% passing 425µm: this figure is only correctly reported when 'WS' is shown in the 'Method of preparation' column. For 'HP' and 'AR', the reported figure is an estimate only.

- WS sample prepared by Wet Sieving
- HP sample prepared by Hand Picking (removal) of gravel sized fragments
- AR sample tested "As Received"

NP: non-plastic

4. COMPACTION RELATED TESTS

Sample preparation: Individual indicates test carried out on individual sub-samples

Single indicates test carried out on a single sample

Assumed values of particle density are reported in brackets e.g. (2.67)

5. SAMPLE DESCRIPTIONS

The sample descriptions shown on the test report sheets are the technician's visual descriptions of the test samples, in accordance with Clause 9.1 of Part 1 of BS 1377:1990 and do not necessarily comply with the requirements of BS 5930:1999 or BS EN ISO 14688-1:2002. For a more comprehensive description of the soil samples to these standards, reference should be made to the exploratory hole records, or an engineering description can be provided on request.

6. INTERPRETATION OF TEST RESULTS

Laboratory test results in this report give the soil properties of individual specimens tested under specified conditions. Individual results or groups of results may not be appropriate for use as design parameters for some geotechnical analyses. The samples may be non-representative, disturbed internally, or prepared and tested under conditions suited for different geotechnical applications. Unless the selection of design parameters is discussed in this report, it is recommended that the advice of an appropriately qualified and experienced specialist is sought.

7. U100 DRIVEN OPEN TUBE SAMPLES

It should be noted that the sampling method generally gives Class 2 samples, ie for use for laboratory classification, moisture content and density testing. BS5930 states that the U100 sampling procedure may sometimes give Class 1 samples (strength, deformation and consolidation testing as well as Class 2 type testing) in non sensitive fine cohesive soils of stiff or lower consistency, but more often provides Class 2 samples. In brittle or closely fissured materials such as hard clays, the sampling method gives Class 3 samples, ie for use for laboratory classification and moisture content testing.

Scottish and Southern Energy SLOY PUMPING STATION

Hole	Sample No	Type	Depth	Bulk Density (Mg/m ³)	Moisture Content (%)	Dry Density (Mg/m ³)	Particle Density (Mg/m ³)	Liquid Limit (%)	Plastic Limit (%)	Pfasticity Index	% passing 425 µm	Method	Description
BH2	6	В	3.00		4								Brown slightly silty cobbly sandy GRAVEL
внз	4	В	1.20		18			27	21	6	47	HP	Brown slightly gravelly sandy clayey SILT
внз	4	в	1.20		17								Brown silty very gravelly SAND
BH4	6	В	3.00		3								Brown slightly silty sandy GRAVEL and COBBLES
BH10	5	В	2.00		2								Brown COBBLES
BH10	7	В	3.00		9								Brown slightly clayey slightly cobbly very sandy GRAVEL

SUMMARY OF SOIL CLASSIFICATION TESTS BS : 1377 Part 2 : 1990

Remarks						
Prepared By	Checked By	Date	29/04/2010	Project No	CON	1103001
FES/LR/04/01			Figure No.	LT1/ 1	Sheet	

Scottish and Southern Energy SLOY PUMPING STATION

PARTICLE SIZE DISTRIBUTION BS 1377 : Part 2 : 1990 : Test 9.2 & 9.4

Hole No	.:	BH1			Sam	ple No) . :	1				Sa	mple	Тур	e:	В		D	epth	(m) :	0.50
Specim Test Dat Loss on	en D e Prei)etails treatme	nt	:	26/04 Not a	4/201(applica) able														
Soil Des	cripi	tion :	Bro	wn s	ilty col	bbly v	ery s	san	idy G	RA∖	/EL										
Percentage Passing (%)	90 80 70 60 50 40 30 20 10			0.00		0.03	0.06										20		60		
		CLAY	FINE	ME	DIUM	COARS	SE	FIN	Siev E	e Siz		m) COAR	SE	FINE	E	MED	IUM	COAR	SEC	OBBLE	s
	r	I I							s	SA UMI		RY .	l			GRA	VEL				_]
		CL	AY (%)	5	SILT (%)			SAN	D (%	6)	(GRA	VEL	. (%)		СОВ	BLE	S (%)	
	12							27				41				20					

	Unifo	mity Coefficient :		Not Applical	ole					
	Remarks :	Insufficient material to	comply with	BS1377. Treat re	esults	with caution				
	Natas	16 m					-1.			
	Notes :	If no value given for pe	ercentage cla	iy, all fines includ	ed in	percentage	silt			
Prepared By		Checked By		Date		29/04/20	10	Project No	CON1	03001
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FES/LR/04/02					Figu	re No.	1	_T2/ 1	Sheet	

Scottish and Southern Energy SLOY PUMPING STATION

PARTICLE SIZE DISTRIBUTION BS 1377 : Part 2 : 1990 : Test 9.2 & 9.4

Hole No. :	BH1		San	nple No. :	4		Samp	ole Type :	в	De	epth (m) :	2.00
Specimen I Test Date Loss on Pre	Details treatme	nt	: 26/0 : Not)4/2010 applicable	e							
Soil Descrip	tion :	Brov	vn slightl	y silty very	y sand	y very	cobbly GRA	VEL				
100 90												
80												
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~											$H_{\parallel}$	_
buiss 60										$X \parallel$		
de 50									IIIK			
04 rcenta								+				
a 30												_
20								1				
10						$\mathbb{H}$						
0	 c		 0 0		2 2 2	0.2	0 0 0 0	N C	»	20	<u>ප</u>	200
	02	) )	06	ω ο	n S	lieve Siz	ze (mm)					0
	CLAY	FINE	MEDIUM	COARSE	FINE	MED SA	IUM COARSE	FINE	MEDIU	M COARS	COBBLE	s
						SUM	MARY					
										1		1

	CLAY (%)	SILT	. (%)	SAND (%)	GRAVEL (%	6) COBBL	ES (%)	
		2	2	25	44	2	9	
	Uniformity Co	pefficient :		48.8	,			
	Remarks : Insufficie	nt material to o	comply with BS	1377. Treat results	with caution.			
	Notes : If no valu	ie given for pe	rcentage clay, a	all fines included in	percentage silt			
Prepared By	CI	hecked By		Date	29/04/2010	Project No	CON1	03001

Figure No.

LT2/ 2

Sheet