



British Geological Survey



DFID Department For
International
Development

TECHNICAL REPORT WC/99/3
Overseas Geology Series

The hydrogeology of the Oju/Obi area, Eastern Nigeria: Ugbodum area data report

J Davies and A M MacDonald



TECHNICAL REPORT WC/99/3R
Overseas Geology Series

The hydrogeology of the Oju/Obi area, eastern Nigeria: Ugbodum area data report

J Davies and A M MacDonald

This document is an output from a project funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of the DFID.

DFID classification:

Subsector: Water and Sanitation

Theme: W1 - Improve integrated water resources development and management, including systems for flood and drought control

Project title: Oju LGA Benue State Water Supply Project - Nigeria

Project reference: CNTR 960023A

Bibliographic reference:

Davies J and Macdonald A M 1999. The hydrogeology of the Oju/Obi area, eastern Nigeria: Ugbodum area data report. BGS Technical Report WC/99/3R

Keywords:

Groundwater, Nigeria, Mudstones, aquifer, Benue Trough.

Front cover illustration:

Three women collecting water from a source at Ugbodum.

©NERC 1999

Keyworth, Nottingham, British Geological Survey, 1999

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desk at the Survey headquarters, Keyworth, Nottingham. The more popular maps and books may be purchased from BGS-approved stockists and agents and over the counter at the Bookshop, Gallery 37, Natural History Museum, Cromwell Road, (Earth Galleries), London. Sales Desks are also located at the BGS London Information Office, and at Murchison House, Edinburgh. The London Information Office maintains a reference collection of BGS publications including maps for consultation. Some BGS books and reports may also be obtained from HMSO Publications Centre or from HMSO bookshops and agents.

The Survey publishes an annual catalogue of maps, which lists published material and contains index maps for several of the BGS series.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development.

The British Geological Survey is a component body of the Natural Environment Research Council.

Keyworth, Nottingham NG12 5GG

☎ 0115-936 3100

Telex 378173 BGSKEY G

Fax 0115-936 3200

Murchison House, West Mains Road, Edinburgh, EH9 3LA

☎ 0131-667 1000

Telex 727343 SEISED G

Fax 0131-668 2683

London Information Office at the Natural History Museum, Earth Galleries, Exhibition Road, South Kensington, London SW7 2DE

☎ 0171-589 4090

Fax 0171-584 8270

☎ 0171-938 9056/57

St Just, 30 Pennsylvania Road, Exeter EX4 6BX

☎ 01392-78312

Fax 01392-437505

Geological Survey of Northern Ireland, 20 College Gardens, Belfast BT9 6BS

☎ 01232-666595

Fax 01232-662835

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

☎ 01491-838800

Fax 01491-692345

Parent Body

Natural Environment Research Council

Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

☎ 01793-411500

Telex 444293 ENVRE G

Fax 01793-411501

CONTENTS

PREFACE	1
EXECUTIVE SUMMARY	2
1. BACKGROUND INFORMATION	3
2. GEOPHYSICS	3
3. DRILLING	8
4. PUMPING TESTS	11
5. SUMMARY AND CONCLUSIONS	13
REFERENCES	14

LIST OF TABLES

Table 1	Available map and satellite image information for Ugbodum traverse.
Table 2	Main geophysical surveys carried out along the Ugbodum traverse (data in Annex 1)
Table 3	Summary details of drilling. Full details given in Annex 2
Table 4	Summary of pumping tests carried out along the Ugbodum traverse. (Annex 4 Contains data and analyses).
Table 5	Chemistry samples taken from the Ugbodum boreholes.

LIST OF FIGURES

Figure 1	The location of the Ugbodum traverse and outcrop of Awgu Shale
Figure 2	Available map information for Ugbodum, and location of boreholes and geophysical traverses.
Figure 3	Satellite image for Ugbodum
Figure 4	Typical EM34-3 survey results across Ugbodum. See Annex 1 for data.
Figure 5	Simplified lithological logs for the Ugbodum traverse (not to scale horizontally). Details in Annex 3.

LIST OF ANNEXES

Annex 1	Geophysics Data
Annex 2	Drilling and Borehole Construction Data
Annex 3	Geological Logs
Annex 4	Test Pumping Data

Preface

Oju is a remote part of south-eastern Nigeria that suffers from severe water shortage during the annual dry season. From November to April, unprotected ponds, seepages and hollows are the primary source of domestic water. Unfortunately, these sources become less reliable towards the end of the dry season and many are contaminated. As a consequence, much of the population of Oju (300 000 approx.) is badly affected by a variety of water related illnesses, of which guinea worm and malaria are endemic; outbreaks of cholera, typhoid and dysentery are also common. In response, DFID have commissioned WaterAid to provide improved village level, year round water sources, primarily utilising the limited groundwater resources of the area.

Due to the complex hydrogeology, WaterAid have asked the British Geological Survey (BGS) to assist with the project. BGS are applying the results of TDR projects undertaken within other parts of the world to study these marginal groundwater resources.

The groundwater investigations by BGS started in September 1996. There are three main aims of the research: (1) to assess the potential of the Oju area for sustainable groundwater supplies; (2) to develop appropriate methods for siting wells or boreholes in the Oju environment; and (3) to recommend appropriate methods and designs for exploiting groundwater.

This report forms one of a series of data reports designed to complement the summary assessment of the hydrogeology of the Oju/Obi area and the Groundwater Development Map. The data presented were collected on six separate trips, August - September 1996, November - December 1996, February - March 1997, October - December 1997, January - April 1998 and January - February 1999.

Executive Summary

The groundwater development potentials of the Agbani Sandstone and dolerite intrusions within the Awgu Shale were investigated at Ugbodum. Testing was carried out between January and February 1999. EM34-3 and magnetic surveys were carried out over an 8 km traverse and six resistivity soundings carried out. Seven boreholes were drilled and chip and core samples taken for analysis and logging. Six boreholes (BGS40, BGS41, BGS42, BGS44, BGS45 and BGS46) were completed with screen and casing. Test pumping and water quality analysis was carried out on these boreholes. The following conclusions can be made from the test site.

- The Awgu Shale generally comprises soft mudstones with some siltstone and fine sandstone.
- The Agbani Sandstone is fine grained and interbedded with much black carbonaceous mudstone and some light grey ashy mudstone
- Dolerite exists as thin intrusions (unlike at Adum West and Ito), and comprises hard dark grey/green fine-grained basic rock with some white zeolite.
- Significant groundwater was only found within dolerite occurring in valleys.
- Adjacent to the dolerite, shales and sandstones baked within contact zones contained some groundwater.
- Pumping tests indicated low transmissivity values ($< 1 \text{ m}^2/\text{d}$) from the dolerite underlying ridges. Dolerites occurring along valleys had higher transmissivities ($> 20 \text{ m}^2/\text{d}$).
- Little groundwater was found within the Agbani Sandstone. Pumping tests from three boreholes indicated transmissivity of 0.1 to $0.2 \text{ m}^2/\text{d}$. The best method for using the limited resources within the sandstone is to construct shallow hand dug wells within the weathered zone – possible within valleys. However, the high amount of smectite clay within the sands may hamper development.
- The presence of dolerite at shallow depths was easily identified from geophysics: EM34-3 readings reduced and the magnetometer recorded many magnetic anomalies.
- The presence of sandstone was indicated by low conductivity values ($< 40 \text{ mmhos/m}$).
- Water quality within the dolerite appears to be good. Brackish water occurs within the Agbani Sandstone at depth. The quality of groundwater within the near surface weathered sandstone appears to be good.
- The sustainability of the groundwater resources from neither valley dolerite nor the shallow sandstone is known. Longer pumping tests and long term monitoring of water levels are required to produce the data necessary for a realistic sustainability assessment.

1. Background information

The groundwater potential of dolerite intrusions within the Awgu Shale and the Agbani Sandstones were investigated along the road from Ugbodum to Adum West Owo. A 7-km geophysical survey traverse was undertaken from north to south between Ugbodum and Adum West Owo (see Figure 1). The hydrogeology map (MacDonald and Davies, 1998) indicates that black carbonaceous mudstones of the Awgu Shale Formation underlie much of the traverse. Several distinct anomalies, shown on the aeromagnetic anomaly map, suggest the presence of dolerite intrusions in the area. Blocks of dolerite were noted in the beds of several valleys. The satellite image was interpreted to identify lineations indicating fracture zones of potential hydrogeological significance. Figures 2 and 3 show available map data for the area, satellite lineations and locations of the geophysical survey traverse line and the test boreholes. Table 1 shows the appropriate maps and aerial photographs for the Ugbodum traverse.

The traverse passes through several villages, where there are neither boreholes nor properly constructed wells. There are several traditional wells but these are shallow and dry-up by the end of January. During the dry season, drinking water is obtained from ephemeral pools along the River Obi, located several kilometres away. The traverse line crosses several ridges and valleys, through an area characterised by grassland with well-spaced trees and occasional patches of woodland.

Table 1. Available map information for the Ugbodum traverse

Data type	Source
Aerial Photographs	Sheet 270, run14, 194-197 Sheet 289, run 1, 102-105 Sheet 289, run 2, 43-45
Topographic maps	1:50,000 Sheet 270SE Oturkpo SE 1:50,000 Sheet 270SW Oturkpo SW 1:50,000 Sheet 289NE Ejekwe NE
Geology map	Makurdi Area, Map No. 64, Scale 1:250,000
Satellite image	LANDSAT TM 188-055 Acquired 17 January 1986 Bands 4-5-7 (Red, Green, Blue)

2. Geophysics

Several types of geophysical survey were carried out along the Ugbodum traverse. EM34-3 and magnetic profiling were undertaken along the 7-km traverse, from the road junction at Ugbodum in the north, to the Obi river in the south. According to available maps (see Figure 2) dolerite intrusions should be encountered within the Awgu Shale. The various geophysical traverses and soundings undertaken are listed and summarised in Table 2. The geophysical data collected are presented in Appendix 1.

The EM34-3 data show that electrical conductivity of the rocks surveyed vary greatly along the traverse. The traverse can be divided into areas with conductivity less than 20 mmhos/m and others where the conductivity is above 100 mmhos/m (see Figure 4). Generally, vertical coil readings are higher than horizontal coil readings. Significant magnetic profile anomalies are present along most of the traverse. Significant geophysical survey anomalies include:

1. Conductivity values are highly variable: vertical coil measurements range from 20 to 140 mmhos/m.
2. Vertical coil readings are generally higher than horizontal coil readings

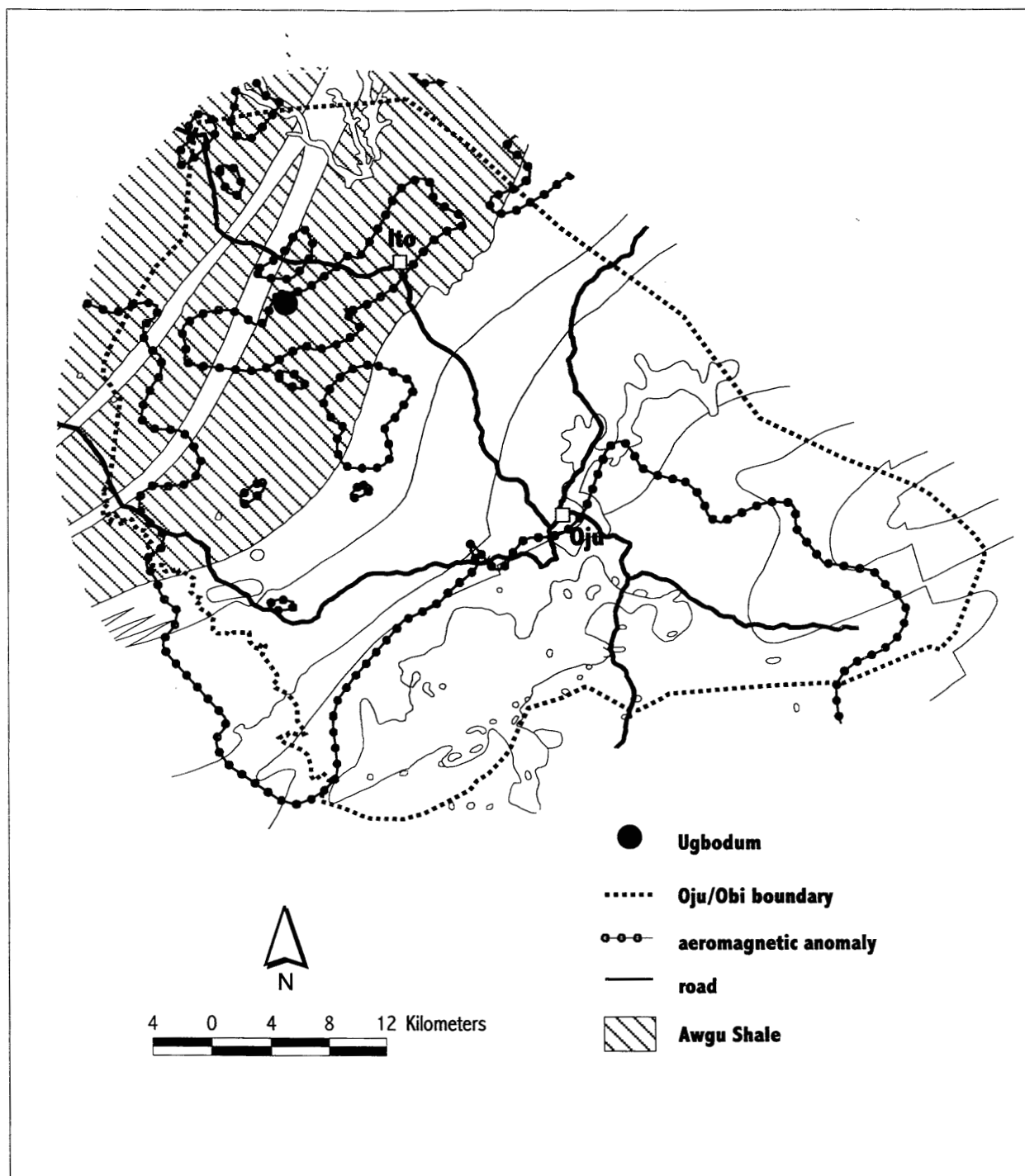


Figure 1. The location of Ugbodum and the outcrop of Awgu Shale.

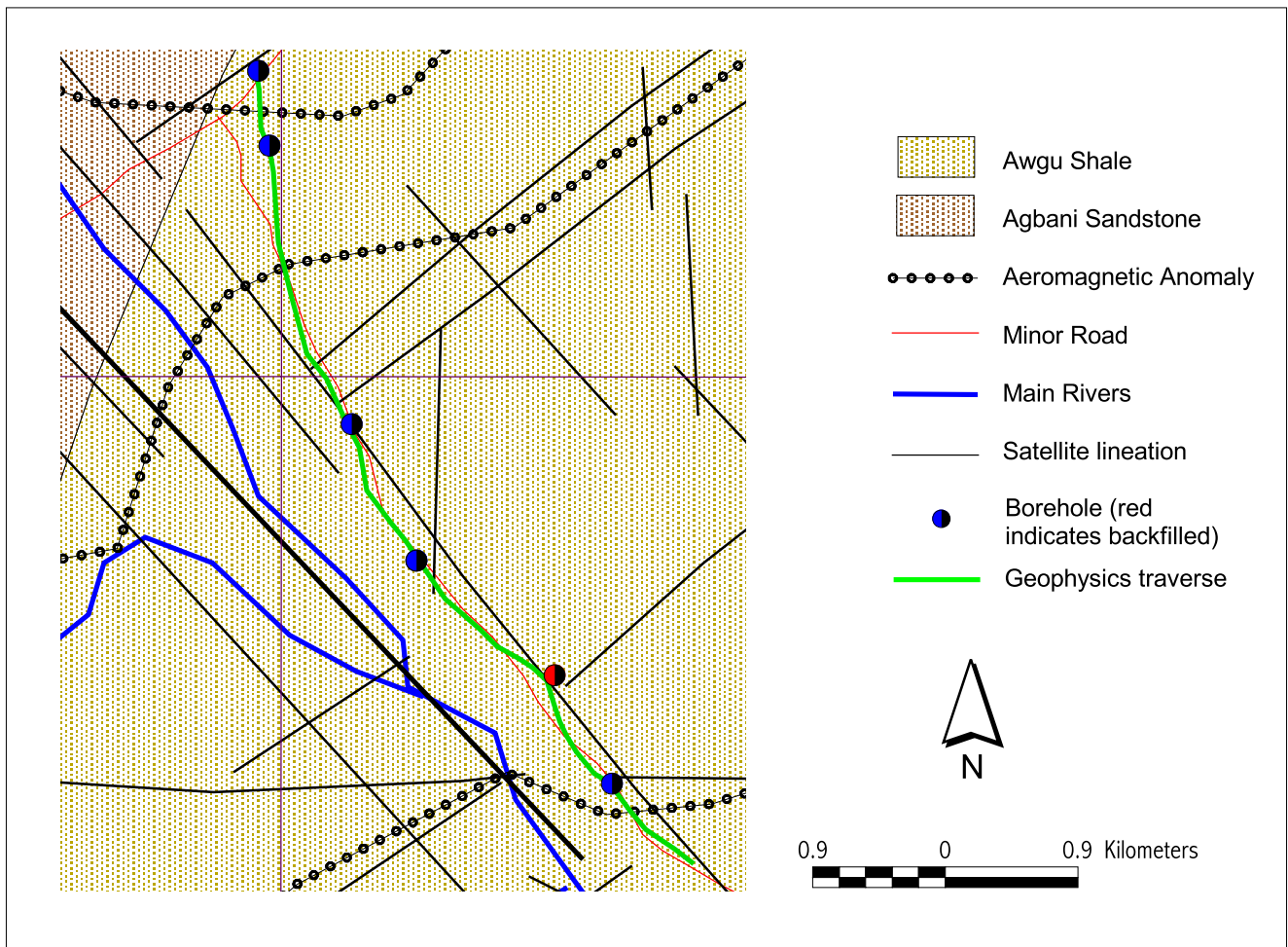


Figure 2. Available map information for Ugbodum, and location of boreholes and geophysical surveys.

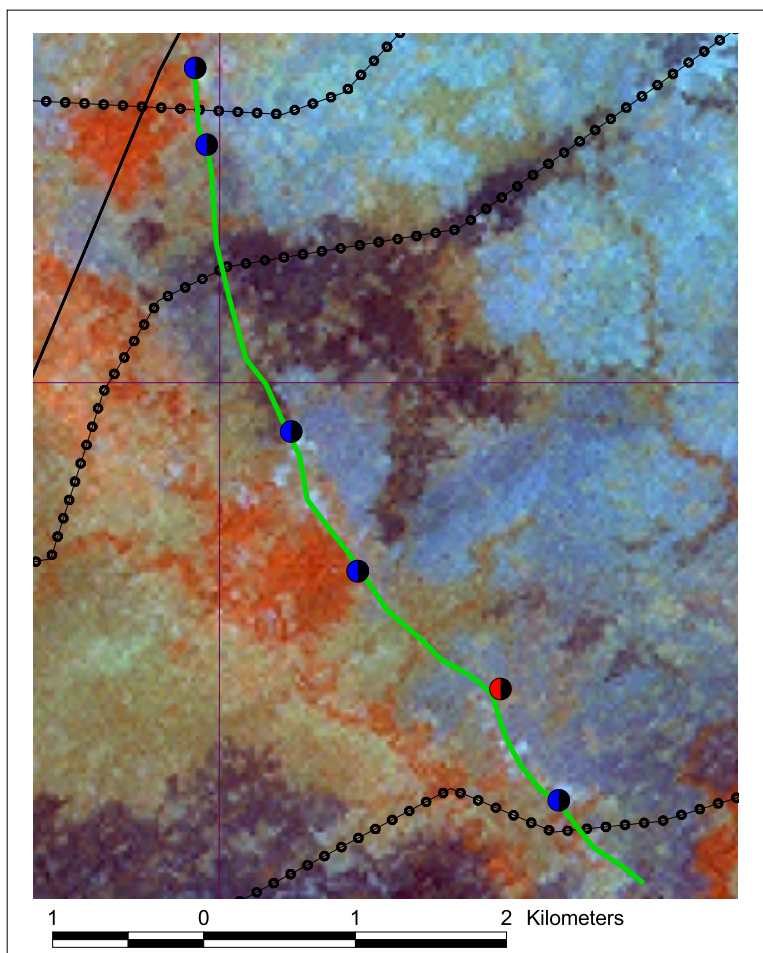


Figure 3. Satellite image for Ugbodum.

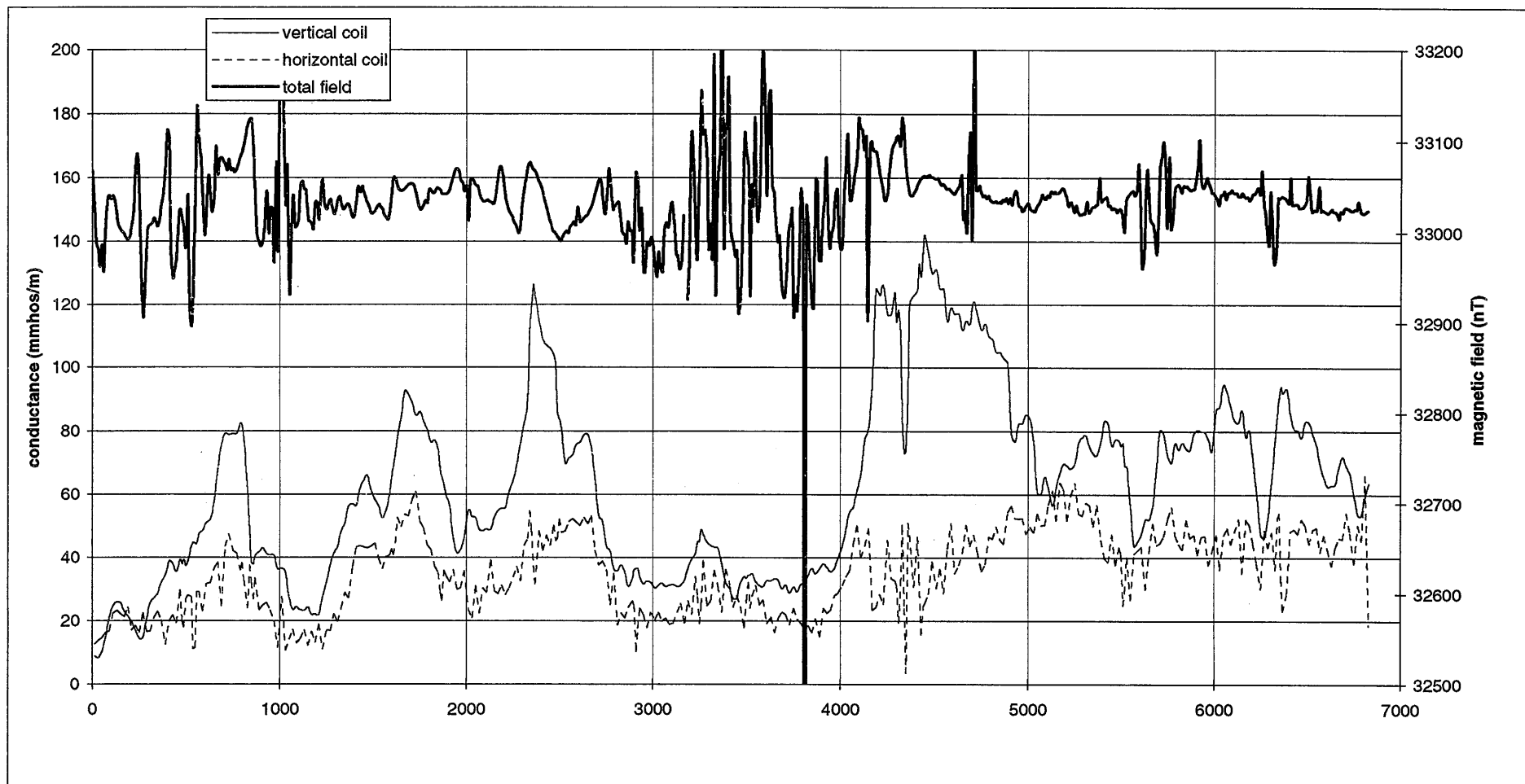


Figure 4. EM34-3 and magnetic field data for Ugbodum

3. Areas of low conductivity (<50 mmhos/m) occur at: 0 - 500 m, 1900 - 2200 m, 2800 - 4000 m, 5600 m and 6250 m.
4. High conductivity zones (>80 mmhos/m) occur at: 700-800 m, 1700-1900 m, and 5000 - 6500 m.
5. Pronounced high conductivity zones (>100 mmhos/m) occur at: 2400 m, and 4200 - 5000 m. Although magnetic profiling anomalies are observed along the entire traverse, those recorded in villages may be due to sheet metal roofs and domestic metal fittings.
6. The largest magnetic anomalies approximately correspond to the low conductivity zones.
7. EM34-3 readings taken with a 40 m coil (deeper penetration) generally gave higher conductivity - indicating that conductivity increases with depth.

Test boreholes were located on various parts of the traverse:

- BGS 40: -50 m along UG 1(in primary school). This is where the electrical conductivity is low and there are several magnetic anomalies (although there is interference from zinc roofs).
- BGS41: 2590 m along UG 1 (next to football field). Here conductivity values are high (60 mmhos/m), and there are some subdued long wavelength magnetic anomalies.
- BGS42: 3550 m along UG 1 (next to church). The EM34-3 traverse shows low conductivity; there are intense magnetic anomalies (again there is possible interference from village objects). BGS45 was drilled next to BGS42.
- BGS43: 4830 m along UG 1 (next to Catholic Church). Conductivity is very high (>100 mmhos/m) and there are no significant magnetic anomalies.
- BGS44: 5600 m along UG 1 (next to malina tree). There is a low conductivity anomaly within generally high conductivity and a pronounced magnetic anomaly.
- BGS46: 700 m along UG1 – low conductivity and many magnetic anomalies within a valley.

Table 2. Main Geophysical Surveys carried out at Ugbodum (data in Annex 1)

Survey number	Co-ordinates start	Length	Average Spacing	Survey type	Description
UG1	7° 01.149' 8° 14.937'	7 km	20 m	EM34-3 (20 m)	From malina tree by primary school in Ugbodum along laterite road to Adum West Owo.
UG 2	7° 01.149' 8° 14.937'	7 km	10 m	Magnetic	As UG1
UG 3	7° 01.149' 8° 14.937'	0.5 km	20 m	EM34-3 (40 m)	about 100 m taken at each borehole site on UG1
UG 4	6 58.248' 8 18.084	1.2 km	20 m	EM34-3 (20 m)	Through Okpe Adum West on the east side of the River Obi.
UG 5	7° 01.204' 8° 14.938		0.5 – 64 m	Offset Wenner	BGS40
UG 6	6° 59.809' 8° 15.229'		0.5 – 64 m	Offset Wenner	BGS 41
UG 7	6 59.345' 8° 15.499'		0.5 – 64 m	Offset Wenner	BGS42
UG 8	6° 59.345 8° 15.409'		0.5 – 64 m	Offset Wenner	BGS 43
UG 9	6° 58.539' 8° 16.227'		0.5 – 64 m	Offset Wenner	BGS44
UG 10	7° 0.842' 8° 14.993'		0.5 – 64 m	Offset Wenner	BGS 46

3. Drilling

Seven boreholes were drilled along the Ugbodum traverse. The boreholes were drilled with a drag bit through the soft weathered horizon and hammer through the unweathered bedrock. Rock chip and core samples were taken from each borehole. Summary information gathered during borehole drilling is given in Table 3. Construction details and penetration logs are given in Annex 2.

Table 3. Summary details of drilling. Full details given in Annex 2

Borehole ID	Location	Date completed	Total depth	Drilled diameter	Section cored	Water strike	Comments
BGS40	7° 01.204' 8° 14.938'	26/1/99	32.1	165 mm	29.5 – 32.1 m	17 – 26.5 m	Much sand ingress
BGS41	6° 59.809' 8° 15.229'	28/1/99	41.5 m	165 mm	29.5 – 32.6 m	29.5 m	
BGS42	6° 59.345' 8° 15.499'	29/1/99	32.05 m	165 mm	29.5 – 32.05	15, 18, 24.5	
BGS43	6° 59.345' 8° 15.409'	30/1/99	31.86 m	165 mm	29.5 – 31.86	dry	Backfilled
BGS44	6° 58.539' 8° 16.227'	2/2/99	32 m	165 mm	29.5 – 32 m	5.5, 20 m	
BGS45	6° 59.345' 8° 15.499'	3/2/99	19.7 m	165 mm	14.5 – 19.7 m		Filled with concrete to 10 m
BGS46	7° 0.842' 8° 14.993'	5/2/99	32.07 m	165 mm	30 – 32.07 m	8.5, 10, 11, 12	

Rock chip samples for every 0.5-m were logged and analysed along with the core samples. The following sections give a brief summary of the lithological logs. Full details are given in Annex3. Figure 5 shows a schematic of the borehole logs.

Summary lithological Log: BGS 40

0.0 – 4.0	Soil/ferricrete horizon
4.0 – 8.0	Clayey very weathered horizon
8.0 – 13.5	Weathered clayey sand
13.5 – 17.5	Weathered medium grained sandstone
17.5 – 24.5	Dolerite
24.5 – 26.5	Hard baked sandstone
26.5 – 32.0	Fine grained sandstones and carbonaceous shaley mudstones

Summary lithological Log: BGS 41

0.0 – 2.0	Soil/ferricrete horizon
2.0 – 6.0	Clayey very weathered horizon
6.0 – 8.5	Very weathered mudstones
8.5 – 13.0	Weathered mudstones
13.0 – 29.0	Black carbonaceous mudstones
29.0 – 29.6	Fine-grained limestone

Figure 5. Simplified lithological logs for the Ugbodum traverse (horizontal axis not to scale).

29.6 – 30.2	Black carbonaceous mudstones
30.2 – 30.7	Muddy fine-grained sandstone
30.7 – 31.7	Black carbonaceous mudstones
31.7 – 32.3	Muddy fine-grained sandstone
32.3 – 41.5	Black carbonaceous mudstones

Summary lithological Log: BGS 42

0.0 – 1.5	Soil/ferricrete horizon
1.5 – 3.0	Clayey very weathered horizon
3.0 – 4.0	Weathered silty clay
4.0 – 5.5	Weathered clayey fine-grained sand
5.5 – 9.5	Weathered fine-grained sand
9.5 – 13.0	Weathered ashy mudstone
13.0 – 17.5	Fine-grained ashy mudstone
17.5 – 18.5	Weathered ashy mudstone
18.5 – 20.0	Dolerite
20.0 – 24.0	Hard baked black carbonaceous mudstones
24.0 – 26.0	Black carbonaceous mudstones
26.0 – 27.0	Black carbonaceous mudstones with silty fine-grained sandstones
27.0 – 28.0	Black carbonaceous mudstones
28.0 – 28.5	Muddy fine-grained sandstones
28.5 – 30.2	Black carbonaceous mudstones
30.2 – 30.6	Black carbonaceous mudstones with fine-grained sandstones
30.6 – 31.6	Black carbonaceous mudstones
31.6 – 31.8	Black carbonaceous mudstones with fine-grained sandstones
31.8 – 32.1	Black carbonaceous mudstones

Summary lithological Log: BGS 43

0.0 – 2.0	Soil/ferricrete horizon
2.0 – 7.0	Clayey very weathered horizon
7.0 – 11.5	Weathered mudstones
11.5 – 29.7	Black carbonaceous mudstones
29.7 – 29.8	Black carbonaceous mudstones with some fine-grained sandstone
29.8 – 31.4	Black carbonaceous mudstones
31.4 – 31.7	Black carbonaceous mudstones with some fine-grained sandstone
31.7 – 31.9	Black carbonaceous mudstones

Summary lithological Log: BGS 44

0.0 – 2.5	Soil/ferricrete horizon
2.5 – 4.5	Clayey very weathered horizon
4.5 – 6.0	Weathered baked quartzite
6.0 – 9.0	Dolerite
9.0 – 10.5	Weathered baked mudstones with thin fine-grained sandstones
10.5 – 11.5	Weathered black carbonaceous mudstones
11.5 – 21.5	Black carbonaceous mudstones
21.5 – 23.0	Black carbonaceous mudstones with fine-grained sandstones
23.0 – 26.0	Black carbonaceous mudstones
26.0 – 28.5	Black carbonaceous mudstones with fine-grained sandstones
28.5 – 32.0	Black carbonaceous mudstones

Summary lithological Log: BGS 45

0.0 – 1.5	Soil/ferricrete horizon
1.5 – 3.0	Clayey very weathered horizon
3.0 – 7.5	Weathered clayey fine grained sand
7.5 – 8.0	Green chloritic very weathered ashy mudstone
8.0 – 11.5	Very weathered ashy mudstone
11.5 – 14.5	Weathered ashy mudstone
14.5 – 17.3	Pyritic ashy mudstone
17.3 – 17.4	Baked ashy mudstone
17.4 – 18.5	Dolerite
18.5 – 18.7	Baked mudstone
18.7 – 19.6	Sandy brittle black carbonaceous mudstone
19.6 – 19.65	Dolerite
19.65 – 19.7	Baked black carbonaceous mudstone

Summary lithological Log: BGS 46

0.0 – 0.5	Soil horizon
0.5 – 2.5	Clayey very weathered horizon
2.5 – 5.0	Very weathered doleritic sand
5.0 – 6.5	Weathered medium grained doleritic sand
6.5 – 8.0	Weathered coarse grained dolerite
8.0 – 10.0	Hard zeolitic dolerite
10.0 – 12.5	Hard baked silty mudstones
12.5 – 13.5	Muddy fine-grained hard baked sandstones
13.5 – 14.0	Baked black chloritic carbonaceous mudstones
14.0 – 15.0	Black sandy carbonaceous mudstones
15.0 – 30.0	Black carbonaceous mudstones
30.0 – 30.1	Muddy medium- to coarse-grained sandstone
30.1 – 30.2	Black carbonaceous mudstones
30.2 – 30.8	Black carbonaceous mudstones with fine grained sandstones
30.8 – 30.9	Black sandy carbonaceous mudstones
30.9 – 31.6	Black carbonaceous mudstones
31.6 – 31.7	Muddy medium grained chloritic sandstones
31.7 – 32.1	Black carbonaceous mudstones

4. Test Pumping

Several types of pumping test were carried out at six of the boreholes drilled at Ugbodum. Only BGS43 was not tested, being dry on completion this borehole was backfilled. The borehole yields measured during drilling varied significantly, therefore a variety of types of tests were used to determine the aquifer properties. Table 4 gives a summary of the test pumping; data and analyses are presented in Annex 4. The bailer tests were analysed using the Theis Recovery method (Kruseman and de Ridder 1990) and Barker's large diameter well method (Barker 1989). The longer pumping tests, undertaken using sets of Whale pumps, were analysed using standard drawdown and recovery methods (Kruseman and de Ridder 1990).

Borehole BGS46, drilled in a valley underlain by dolerite produced the best aquifer properties. This borehole has sufficient yield to be equipped with a handpump. The long-term sustainability of this borehole's groundwater supply has yet to be assessed. Longer-term test pumping should be carried out in the area and water-levels in the vicinity monitored. Most of the other boreholes tested had poor

yields, insufficient to support a handpump. Unfortunately, the aquifer properties determined also indicate that hand dug wells, as presently configured, are unlikely to be successful. Borehole BGS42 (drilled into dolerite but not in a valley) recorded moderate aquifer properties. Unfortunately, the pumping tests results obtained were affected by silt production during pumping, probably due to lack of borehole development upon completion. If this borehole was further developed and then retested it may prove to have sufficient yield to warrant equipping with a hand pump.

Table 4. Summary of pumping tests carried out at Ugbodum. (Annex 4 contains data and analysis).

Borehole and Test	Date	Casing height above ground	RWL (mbtc)	Length of test (mins)	P-rate (l/s)	Transmissivity (m ² /d)
BGS40						
Bailer test	29/1/99	0.3 m	13.198	12:30	0.13 l/s	Barker: 0.15 Theis Rec: 0.05
BGS41						
Bailer test	29/1/99	0.2 m	8.582	10:00	0.23 l/s	Barker: 0.25 Theis Rec: 0.15
BGS42						
Bailer test	29/1/99	0.35 m	6.375	9:44	0.29	Barker: 2.7 Theis Rec: 0.6
Whale	30/1/99	0.35 m	6.26	220	0.11	Jacob 0.7 Theis rec 0.8
BGS44						
Bailer test	3/2/99	0.35 m	4.098	10	0.28	Barker: 1.4 Theis Rec: 0.13
Whale	3/2/99	0.35 m	4.098	47	0.1	Jacob 0.26 Theis rec 0.1
BGS45						
Bailer test	5/2/99		6.262	6:44	0.1	Barker: 0.19 Theis Rec: 0.06
BGS46						
Centrifugal	8/2/99	0.45 m	3.798	300	0.65	Logan: 23 Theis Rec: 59
Whale	6/2/99	0.45 m	3.775	141.5	0.28	Jacob 31 Theis rec 45

A water sample was taken from each borehole during test pumping using a Whale pump or a bailer. Field determinations included measurement of SEC, TDS, pH, temperature and alkalinity (see Table 5). A high specific electrical conductance of 2500 $\mu\text{S}/\text{cm}^2$ was obtained from borehole BGS41. The water from this borehole comes from a thin sandstone layer at about 30-m depth. Samples from the other boreholes had low conductivity. Groundwater from the shallow sources had lower conductivity than deeper sources.

Table 5. Chemistry samples taken from Adum West.

Sample No	Source	date	Conductivity ($\mu\text{S/cm@25}^\circ\text{C}$)	TDS (mg/l)	pH	Temp ($^\circ\text{C}$)	CaCO ₃ (mg/l)	Comments
Oju/401	BGS42	30/1/99	563	285	7.01	30.2	196	Taken after 200 mins pumping – much black silt
none	Shallow well	30/1/99	371	187	6.4	26.6		From shallow well next to BGS42
Oju/402	BGS39	2/2/99	521	262	6.69	30.2	282	Taken after 260 mins pumping
Oju/403	BGS44	3/2/99	417	210	6.71	29.2	214	Taken after 30 mins pumping
Oju/404	BGS40	3/2/99	614	306	7.78	29.7	306	Taken after 2 nd bail
Oju/405	BGS41	3/2/99	2500	1250	6.47	29.4	194	Taken with whale pump (not pumped prior to sample)
Oju/407	BGS46	6/2/99	316	159	6.67	29.5	132	Taken after 2 hours pumping
Oju/408	Pond	6/2/99	370	200	6.74	29.5	200	Pond about 100 m from borehole

5. Summary and Conclusions

The groundwater development potentials of the Awgu Shales, Agbani Sandstone and dolerite intrusions were investigated at Ugbodum. Various geophysical surveys were undertaken and a series of boreholes drilled and tested. The following work was undertaken at Ugbodum:

- 7-km of EM34-3 surveys at 20 m intercoil spacing; 40 m intercoil spacing was undertaken around the borehole sites
- 7-km magnetic profiling
- 6 resistivity VES
- 7 boreholes were drilled and at least 2.5-m of core taken from each borehole
- chip and core samples from each borehole were photographed, logged and analysed
- six boreholes, BGS40, BGS41, BGS42, BGS44, BGS45 and BGS46 were screened and cased
- short pumping tests were carried out on each screened borehole
- groundwater samples were obtained from each test pumped borehole

The geophysical surveys were interpreted using geological data obtained during drilling:

1. Conductivity values were highly variable (vertical coil measurements vary from 10 to 140 mmhos/m), reflecting variations in the geology.
2. Low conductivity measurements (<40 mmhos/m for the vertical coil) indicated the presence of sand within the weathered zone. Often the sandy weathered zone was underlain by high conductivity carbonaceous mudstone (as indicated by the 40-m EM34-3 measurements and resistivity soundings).
3. Marked reductions in conductivity (approximately 40 mmhos/m) and the presence of magnetic anomalies indicated the presence of shallow dolerite intrusions
4. High conductivity values (<60 mmhos/m for vertical coil) corresponded to the presence of unbaked Awgu Shale at shallow depths.

5. Resistivity soundings correlated well with the EM34-3 survey results. Mudstones had low resistivity (<20 ohm-m), and the Agbani Sandstone and dolerite higher resistivity.

Several conclusions can be made from the rock and chip samples.

- The Awgu Shale generally comprises soft carbonaceous mudstones with some siltstone and thin fine-grained sandstones
- The dolerite exists as thin, fine-grained intrusions (unlike at Adum West (MacDonald and Davies 1998) where the dolerite is coarse grained). Although the dolerite does contain some zeolite it does not occur as thick highly fractured layers at the mudstone/dolerite contact zone.
- The dolerite did not contain many fractures – possibly because it was intruded mainly into fine sandstones rather than mudstone. The dolerite and associated baked horizon were most fractured within valleys.
- The sandstones did not contain much water. Where found during drilling, the Agbani Sandstone is fine grained often occurring as a light grey upward coarsening ashy mudstone to siltstone. Where unweathered at depth, rock permeability is very low. Where fractured a little poor quality groundwater was found at 30-m depth. Groundwater of good quality was only found within the weathered horizons. Within the weathered zone, the muddy sandstone is weathered to fine clayey sand. However, the permeability of these clayey sands is low however, and the weathered zone thin (<10 m). Therefore, any hand-dug wells constructed within the Agbani Sandstone will have limited resource potential, and may only serve 30 - 50 people. It is possible that wells located near to rivers may have higher chances of success. Close to rivers, more of the weathered zone will be saturated and receive greater recharge.
- The high amount of smectite clay within the sandstone may pose problems for development. Wells may be difficult to construct, and yields may decrease with time if the clays are mobile.

In summary, the groundwater potential of the area is disappointing. The Agbani Sandstone contains little groundwater. The dolerite intrusions were generally thin and fine-grained and have low permeability. The best targets for groundwater within the area are dolerite intrusions where they occur in valleys (yields may be highest where the dolerite has been intruded into mudstone rather than sandstone). The weathered zone of the Agbani Sandstone may also be considered for hand dug wells, although yields will be low.

References

- Barker J A, 1989. Programs to simulate and analyse pumping tests in large diameter wells. British geological Survey technical report WD/89/24.
- Kruseman G P and de Ridder N A, 1990. Analysis and evaluation of pumping test data. IRLI publication 47, The Netherlands.
- MacDonald A M and Davies J 1998. The hydrogeology of the Oju/Obi area, Eastern Nigeria: Adum West area data report. British Geological Survey Technical Report WC/98/66R.

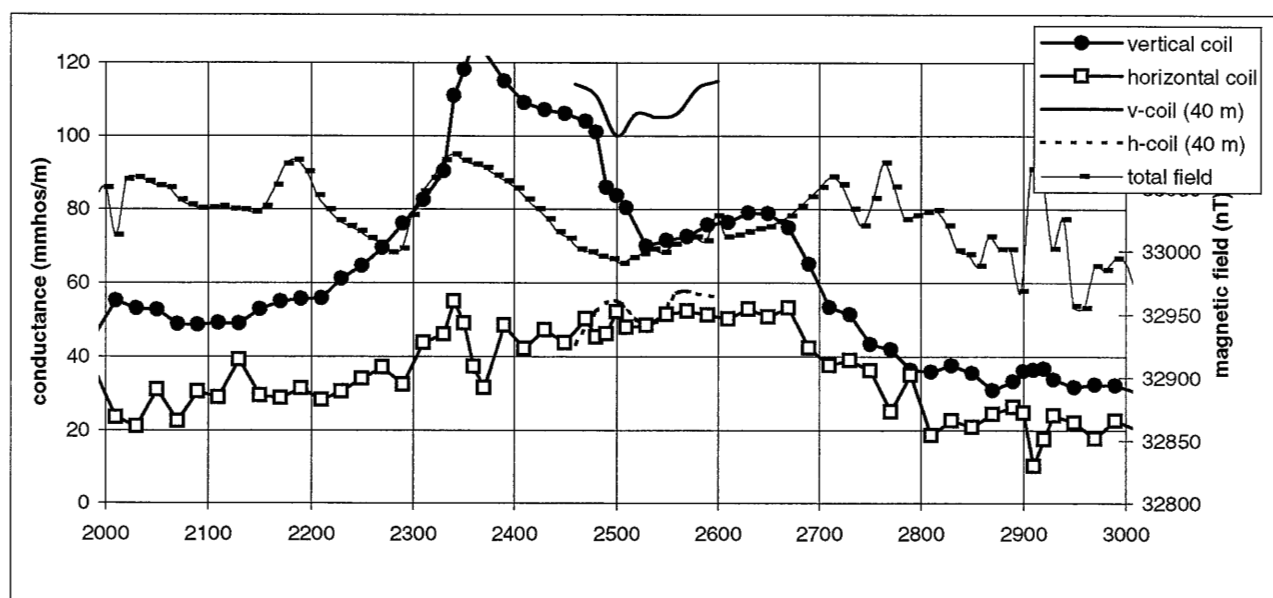
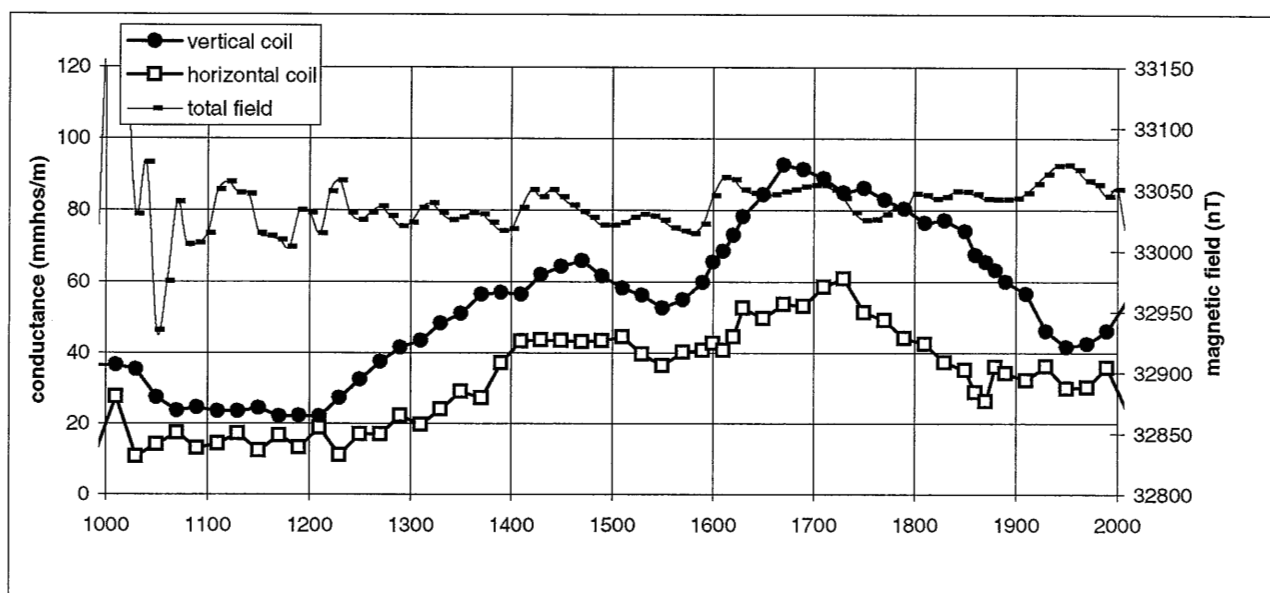
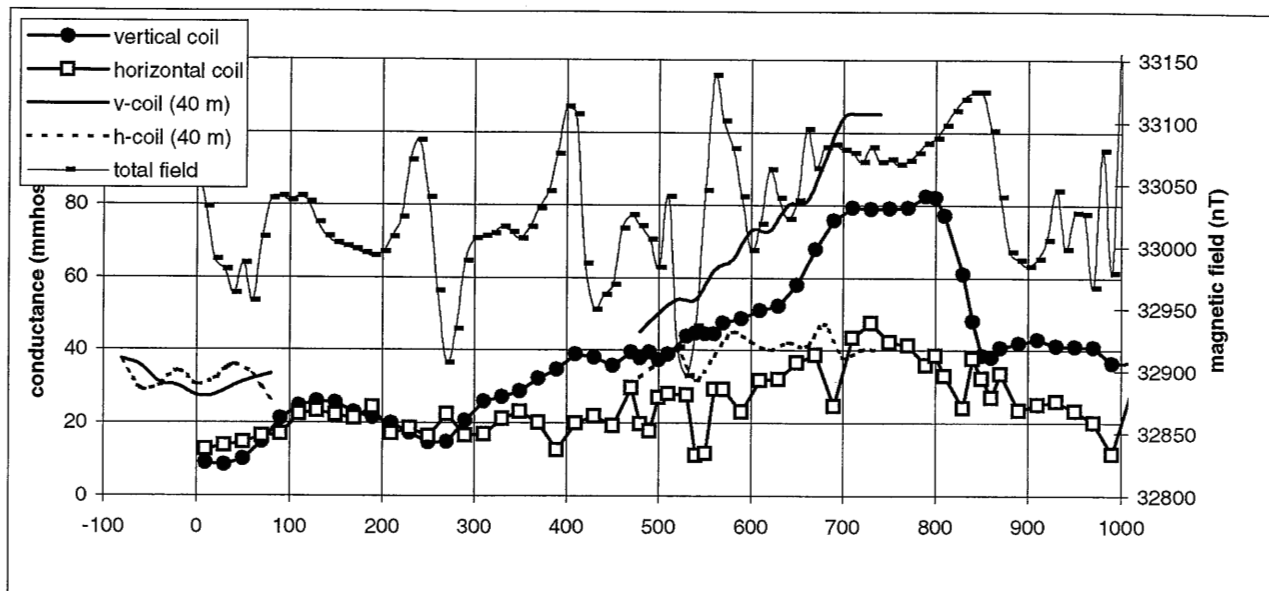
Annex 1: Geophysics data

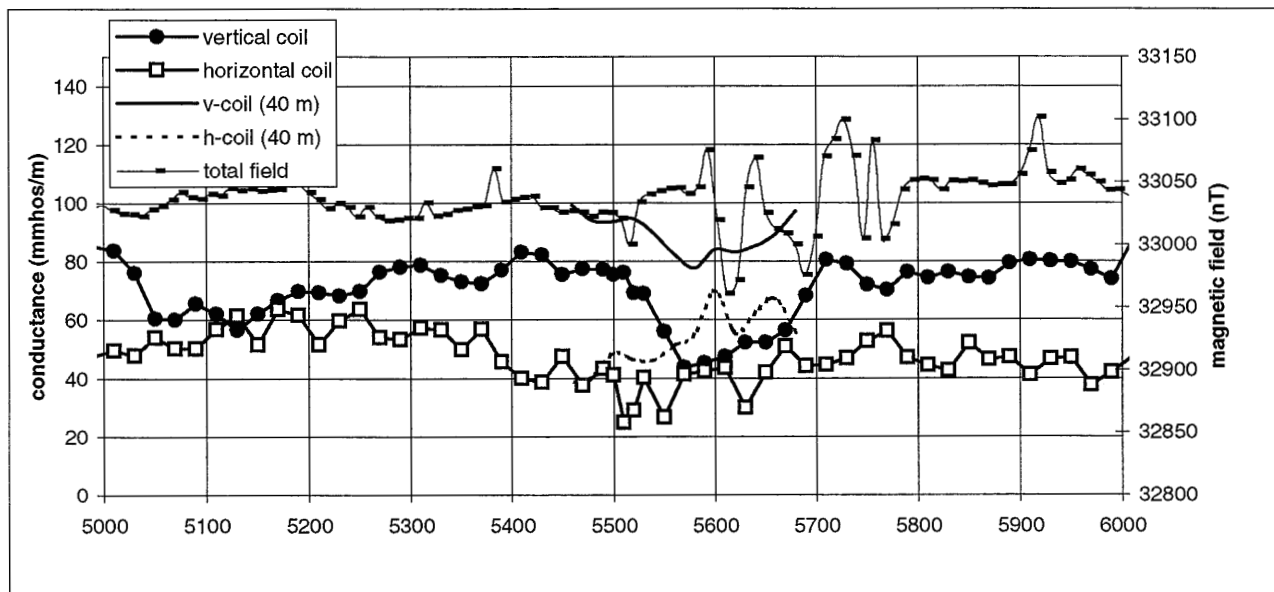
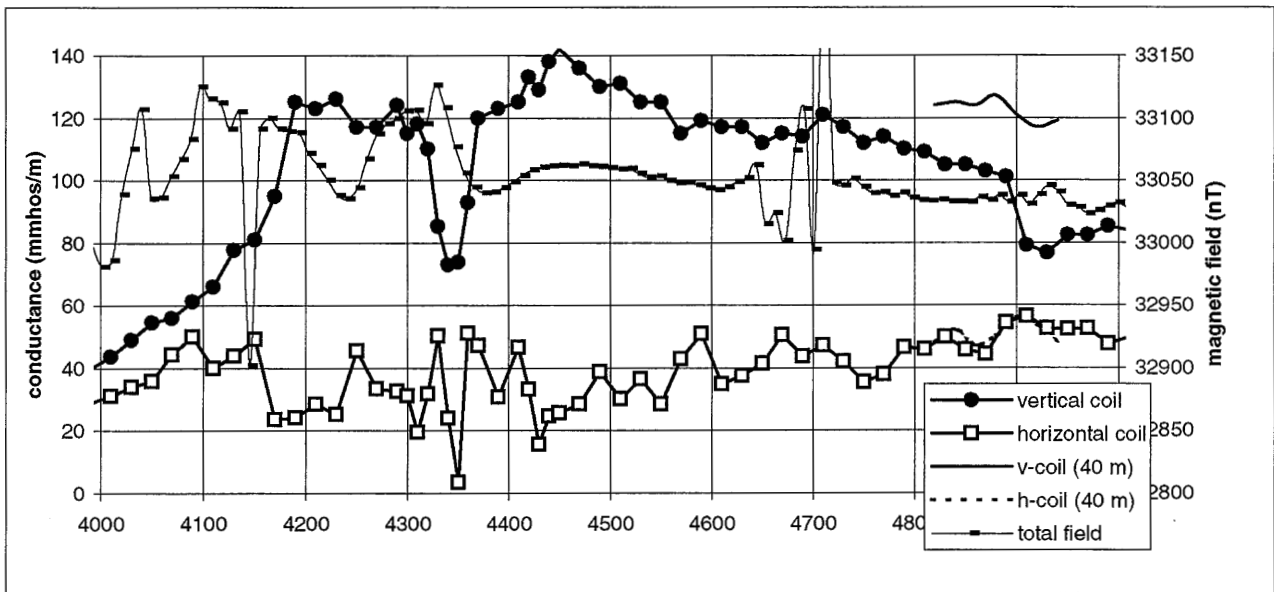
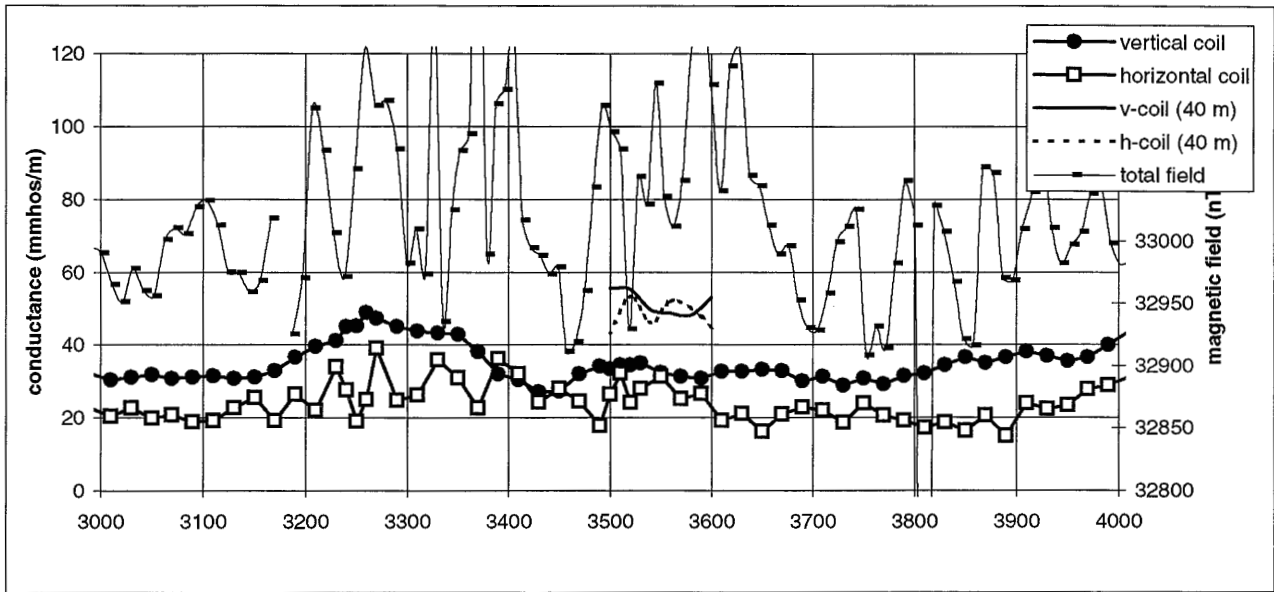
Ugbodum UG 1

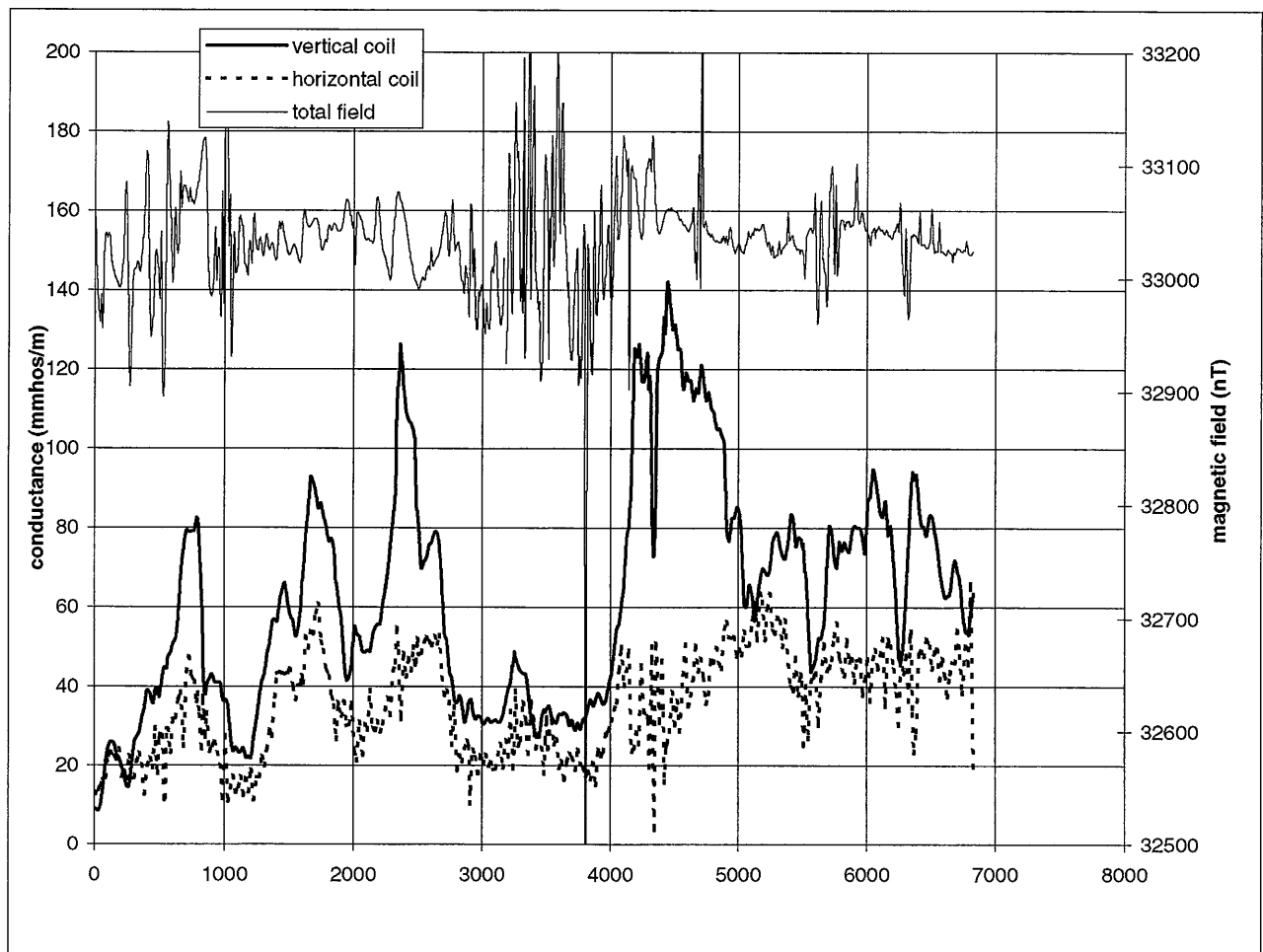
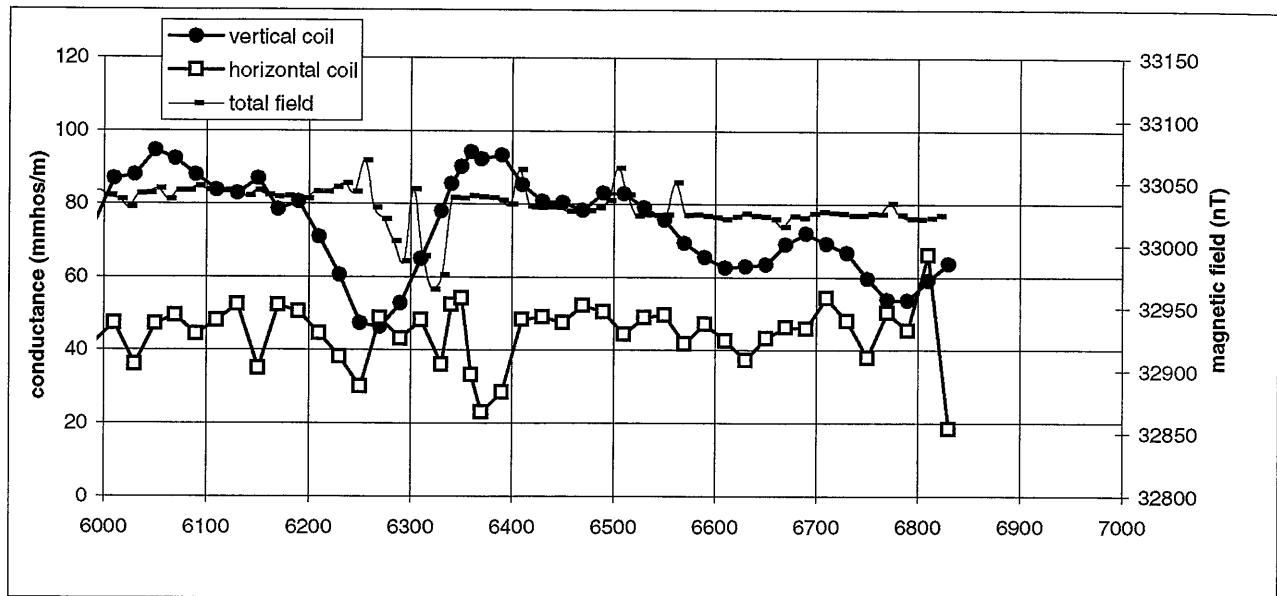
UG 1 end 6 degs 58.157; 8 degs 16.702 from Ugbodum to Adum owo. EM34-3 (20 m)
 UG 2 as UG2 but magnetic
 UG 3 EM34-3 (40 m) at borehole sites along UG 1

d (m)	comment	d (m)	comment	d (m)	comment
20	tin roof	2660	Y junction	4660	big malina by hut
90	temp classroom	2700	forest right	4700	two palms by L shd comp
240	small tree left	2780	malina trees	4800	paths x mango tree left
340	3 palms left	2920	tall tree right	4840	church left
420	path right	3040	footpath right	4920	pinapple hedge left
460	paths crossing	3200	round hut left	4960	start of terraced farm
600	cracks in ground	3240	cashew and flowers L	5040	mango tree by right
725	culvert	3300	zinc roof l	5100	start of football field
790	middle of depression	3380	tall tree left	5140	mango tree right
1010	box culvert	3480	flowers both sides	5240	methodist church left
1140	tree right	3580	church right	5280	malina tree right
1280	trees on both sides	3600	footpath right	5340	plastered tomab right
1360	culvert by rice farm	3620	path left	5380	c and C church
1420	agba tree right	3680	malina tree right	5460	round tree left
1460	rice farm on R	3720	paw-paw right	5580	tree fence right
1580	agba tree right	3800	middle benni-seed farm	5640	czinc roof left
1600	trees on both sides	3860	dry tree right	5680	palm tree left
1640	agba tree left	3920	small ant hill left	5780	first big tree in playground
1740	end cassava farm	3960	tree right	5840	broken pot shrine
1760	tree on left	4010	big tree left	5920	bend to left
1800	cassava farm L and R	4100	start clearing left	5940	palm tree right
1940	palm tree right	4160	end wood bridge	6060	palm tree both sides
2000	culvert	4180	bamboo left	6100	cluster of palm trees
2200	guinea farm both sides	4290	palm tree right	6260	end of fence right
2300	palm trees right	4360	tree right	6400	big tree stump left
2340	bamboo tree left	4400	small tree right	6520	two mango trees right
2440	primary school right	4470	locust bean	6680	cassava farm left
2540	end of football field R	4570	two trees left	6780	bend right to stream
2590	church and hdw left	4640	tree by path to 1st comp	6820	river forest

d (m)	strike	d (m)	strike	d (m)	strike
0	176	4540	140	6020	102
470	172	4940	134	6100	190
2200	146	5460	128	6140	152
3740	132	5560	144	6340	124
4320	138	5920	134		







Ugbodum 5

Resistivity 1: Offset Wenner

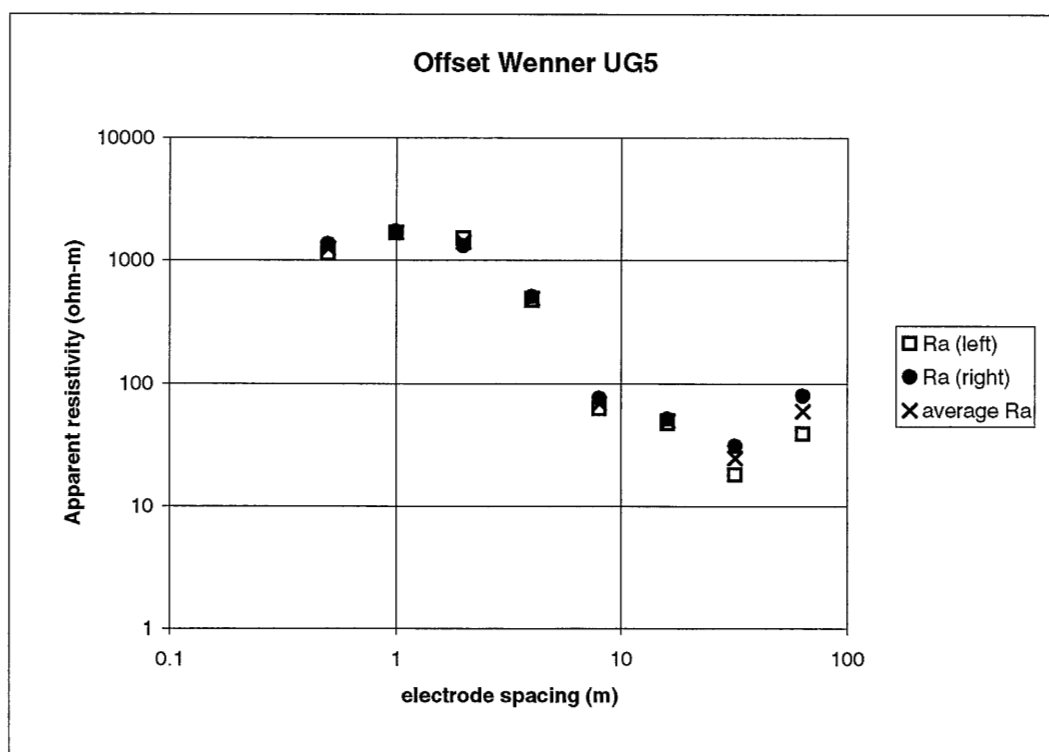
sited on BGS 40

strike 27 degs

29/01/99

ferecret - some contacts difficult

spacing	left	right	Ra (left)	Ra (right)	average Ra
0.5	362	433	1136.68	1359.62	1248.15
1	266	273	1670.48	1714.44	1692.46
2	120.2	104.1	1509.712	1307.496	1408.604
4	18.7	20.1	469.744	504.912	487.328
8	1.23	1.5	61.7952	75.36	68.5776
16	0.47	0.511	47.2256	51.34528	49.28544
32	0.09	0.154	18.0864	30.94784	24.51712
64	0.097	0.197	38.98624	79.17824	59.08224



DATA SET: UGBODUM5

```
CLIENT: WaterAid                                DATE: Jan 1999
LOCATION: Ugboodum BGS40                          SOUNDING: 1
COUNTY: Obi                                    AZIMUTH: 27 degs N
PROJECT: Oju Water Supply                       EQUIPMENT: BGS128
ELEVATION: 0.00
SOUNDING COORDINATES: X:      0.0000 Y:      0.0000
```

Offset Wenner Configuration

FITTING ERROR: 13.589 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m ²)
			0.0		
1	1630.3	2.14	-2.14	0.00132	3497.8
2	24.85	4.87	-7.02	0.196	121.2
3	62.55				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	1426.528	1630.334	1860.490
	2	7.674	24.851	46.094
	3	49.699	62.560	82.434
THICK	1	1.951	2.145	2.360
	2	0.862	4.880	15.726
DEPTH	1	1.951	2.145	2.360
	2	3.090	7.025	17.817

No.	SPACING (m)	RHO-A (ohm-m)		DIFFERENCE (percent)
		DATA	SYNTHETIC	
1	0.500	1248.0	1617.2	-29.58
2	1.00	1692.0	1541.4	8.89
3	2.00	1409.0	1189.3	15.58
4	4.00	487.0	471.5	3.17
5	8.00	68.60	73.68	-7.40
6	16.00	49.30	46.78	5.09

No.	SPACING (m)	RHO-A (ohm-m)		DIFFERENCE (percent)
		DATA	SYNTHETIC	
7	32.00	24.50	55.12	-125.0
8	64.00	59.10	59.90	-1.36

PARAMETER RESOLUTION MATRIX:

"F" INDICATES FIXED PARAMETER

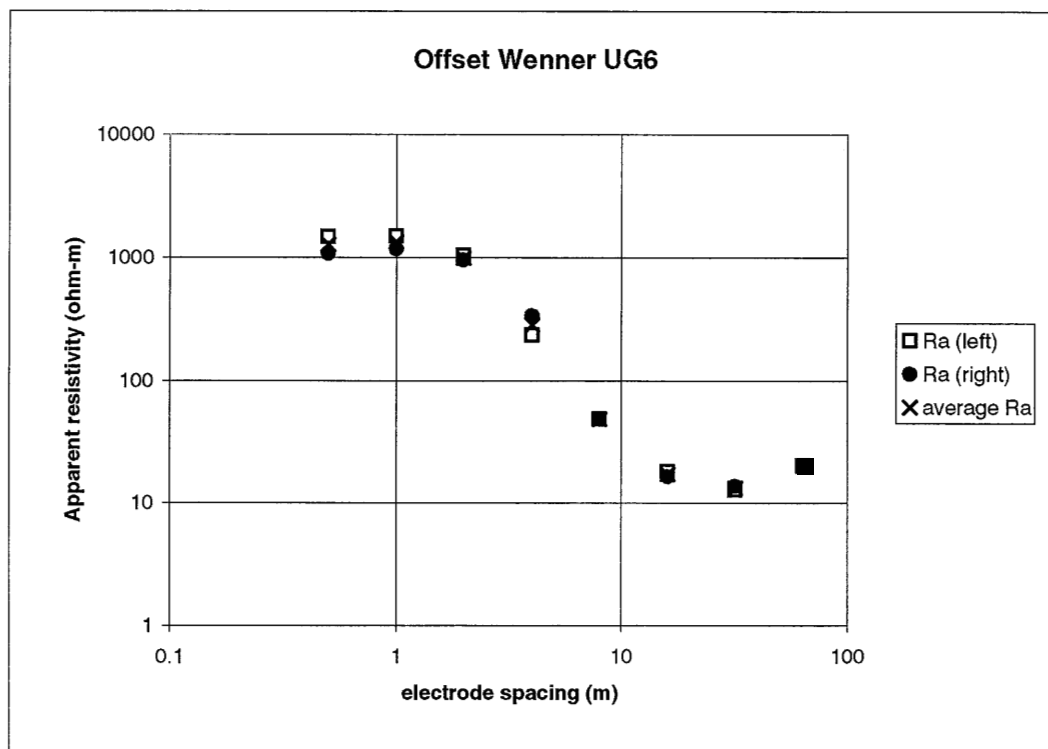
P 1	0.99				
P 2	-0.01	0.59			
P 3	0.00	0.03	0.95		
T 1	0.01	0.03	0.00	0.99	
T 2	0.00	-0.37	-0.06	0.02	0.29
	P 1	P 2	P 3	T 1	T 2

Ugbodum 6

Resistivity 2: Offset Wenner
sited on BGS 41, 2440 m along UG 1

29/01/99

spacing	left	right	Ra (left)	Ra (right)	average Ra
0.5	470	345	1475.8	1083.3	1279.55
1	237	187	1488.36	1174.36	1331.36
2	82.9	75.8	1041.224	952.048	996.636
4	9.25	13.4	232.36	336.608	284.484
8	0.964	0.961	48.43136	48.28064	48.356
16	0.178	0.163	17.88544	16.37824	17.13184
32	0.063	0.068	12.66048	13.66528	13.16288
64	0.05	0.0498	20.096	20.01562	20.05581



DATA SET: UGBODUM6

CLIENT: WaterAid DATE: Jan 1999
 LOCATION: BGS41 SOUNDING: 1
 COUNTY: Obi AZIMUTH: 27 degs N
 PROJECT: Oju Water Supply EQUIPMENT: BGS128
 ELEVATION: 0.00
 SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

Offset Wenner Configuration

FITTING ERROR: 4.959 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m ²)
			0.0		
1	1408.6	1.81	-1.81	0.00129	2556.6
2	43.69	6.79	-8.60	0.155	296.7
3	7.38	21.16	-29.76	2.86	156.2
4	53.28				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER	MINIMUM	BEST	MAXIMUM
RHO	1 1323.909	1408.645	1498.477
	2 31.220	43.693	62.428
	3 4.936	7.385	11.191
	4 32.032	53.286	124.217
THICK	1 1.710	1.815	1.929
	2 4.964	6.791	9.124
	3 11.511	21.160	44.915
DEPTH	1 1.710	1.815	1.929
	2 6.689	8.606	11.028
	3 21.391	29.766	52.719

No.	SPACING (m)	RHO-A (ohm-m)		DIFFERENCE (percent)
		DATA	SYNTHETIC	
1	0.500	1279.0	1390.9	-8.75
2	1.00	1331.0	1294.0	2.77

* BRITISH GEOLOGICAL SURVEY

*

No.	SPACING (m)	RHO-A (ohm-m)		DIFFERENCE (percent)
		DATA	SYNTHETIC	
3	2.00	996.5	906.6	9.02
4	4.00	284.5	297.1	-4.45
5	8.00	48.40	48.10	0.606
6	16.00	17.10	17.17	-0.421
7	32.00	13.20	13.19	0.0127
8	64.00	20.10	20.09	0.0248

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	1.00						
P 2	0.00	0.97					
P 3	0.00	-0.03	0.80				
P 4	0.00	-0.01	-0.18	0.59			
T 1	0.00	0.00	0.00	0.00	1.00		
T 2	0.00	0.03	0.09	0.06	0.00	0.95	
T 3	0.00	-0.04	-0.30	-0.36	0.00	0.12	0.51
	P 1	P 2	P 3	P 4	T 1	T 2	T 3

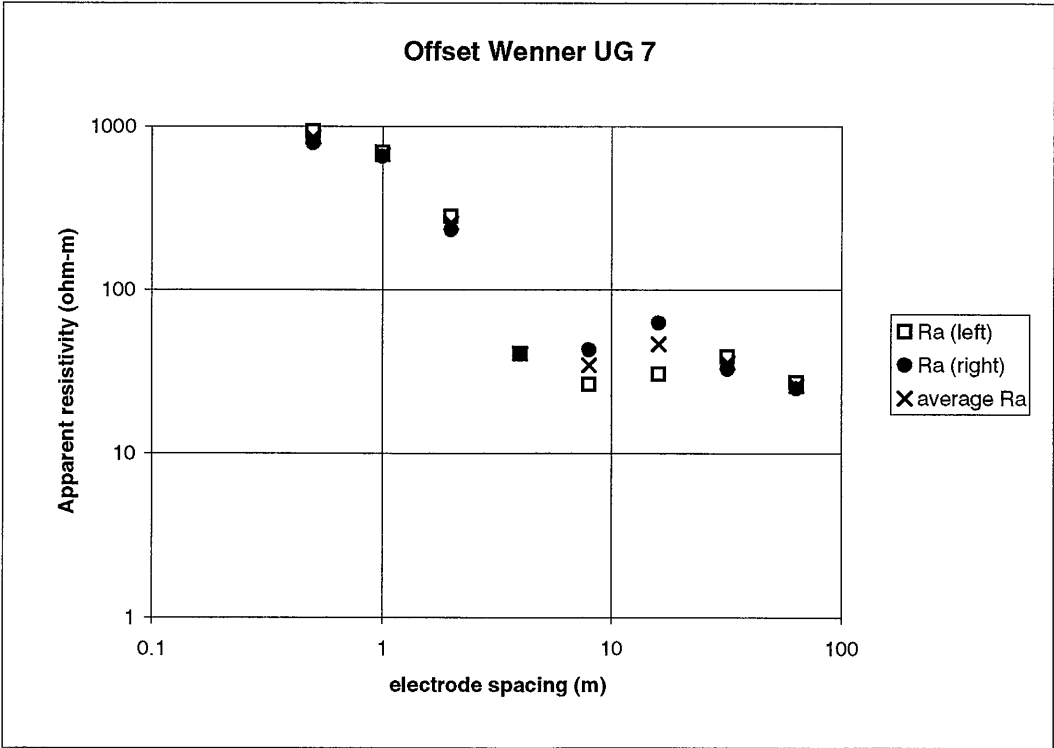
* BRITISH GEOLOGICAL SURVEY

*

Ugbodum 7

Resistivity 3: Offset Wenner
sited on BGS 42
strike 334 degs
29/01/99

spacing	left	right	Ra (left)	Ra (right)	average Ra
0.5	297	251	932.58	788.14	860.36
1	110.4	104.1	693.312	653.748	673.53
2	22.3	18.4	280.088	231.104	255.596
4	1.621	1.595	40.71952	40.0664	40.39296
8	0.523	0.85	26.27552	42.704	34.48976
16	0.301	0.62	30.24448	62.2976	46.27104
32	0.193	0.162	38.78528	32.55552	35.6704
64	0.067	0.062	26.92864	24.91904	25.92384



DATA SET: UGBODUM7

CLIENT: WaterAid
 LOCATION: BGS42
 COUNTY: Obi
 PROJECT: Oju Water Supply
 ELEVATION: 0.00
 SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: Jan 1999
 SOUNDING: 1
 AZIMUTH: 27 degs N
 EQUIPMENT: BGS128

Offset Wenner Configuration

FITTING ERROR: 2.815 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m ²)
			0.0		
1	926.2	1.05	-1.05	0.00114	977.4
2	7.84	1.67	-2.72	0.212	13.11
3	209.2	3.63	-6.35	0.0173	760.0
4	20.87				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER	MINIMUM	BEST	MAXIMUM
RHO	1 888.932	926.265	965.992
	2 3.373	7.848	14.543
	3 104.970	209.251	643.410
	4 18.854	20.877	22.964
THICK	1 1.025	1.055	1.083
	2 0.710	1.671	3.152
	3 1.168	3.632	7.497
DEPTH	1 1.025	1.055	1.083
	2 1.785	2.726	4.194
	3 3.902	6.359	10.219

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	0.500	860.0	873.0	-1.51
2	1.00	673.5	665.1	1.23

* BRITISH GEOLOGICAL SURVEY *

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
3	2.00	255.6	254.1	0.567
4	4.00	40.40	40.72	-0.792
5	8.00	34.50	35.41	-2.65
6	16.00	46.30	43.61	5.80
7	32.00	35.70	37.01	-3.68
8	64.00	25.90	25.61	1.08

PARAMETER RESOLUTION MATRIX:
 "F" INDICATES FIXED PARAMETER

P 1	1.00						
P 2	0.00	0.54					
P 3	0.00	0.00	0.51				
P 4	0.00	0.01	0.00	0.99			
T 1	0.00	0.01	0.00	0.00	1.00		
T 2	0.00	-0.47	-0.04	0.02	0.01	0.52	
T 3	0.00	-0.03	0.49	0.01	0.00	0.00	0.48
	P 1	P 2	P 3	P 4	T 1	T 2	T 3

* BRITISH GEOLOGICAL SURVEY *

Ugbodum 8

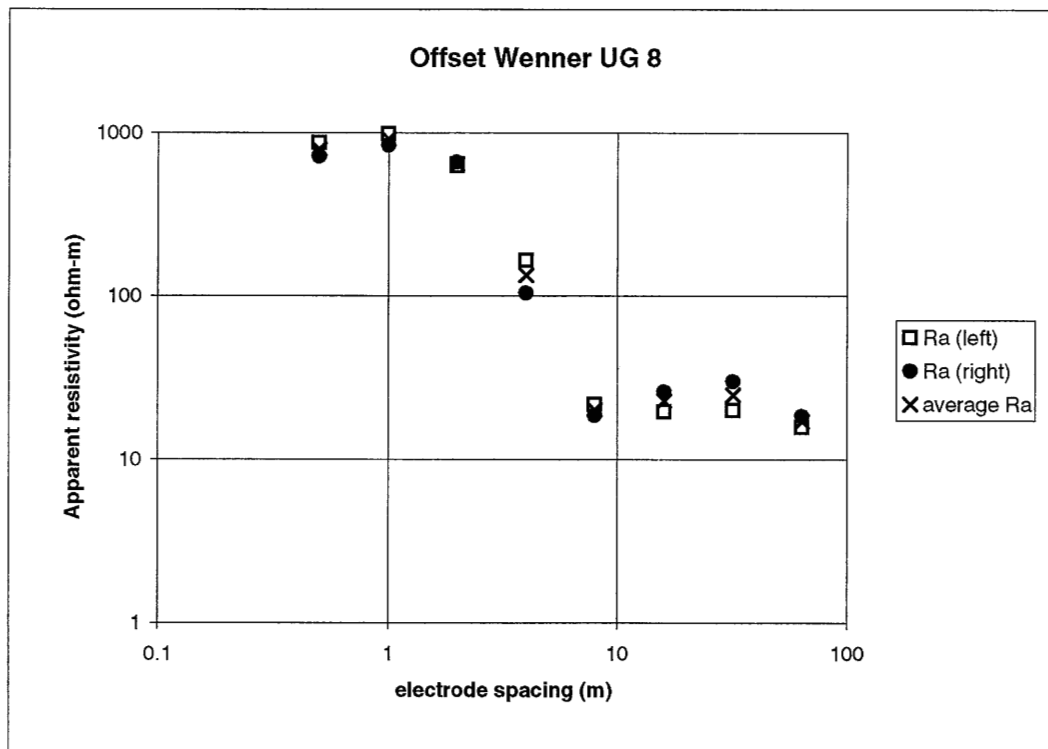
Resistivity 4: Offset Wenner

sited on BGS 43

GPS: 6 degs 58.853; 8 degs 15.960

30/01/99

spacing	left	right	Ra (left)	Ra (right)	average Ra
0.5	275	228	863.5	715.92	789.71
1	156.5	133.4	982.82	837.752	910.286
2	49.7	52.6	624.232	660.656	642.444
4	6.52	4.14	163.7824	103.9968	133.8896
8	0.428	0.369	21.50272	18.53856	20.02064
16	0.195	0.256	19.5936	25.72288	22.65824
32	0.0984	0.148	19.77446	29.74208	24.75827
64	0.039	0.0456	15.67488	18.32755	17.00122



DATA SET: UGBODUM8

CLIENT: WaterAid
 LOCATION: BGS43
 COUNTY: Obi
 PROJECT: Oju Water Supply
 ELEVATION: 0.00
 SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: Jan 1999
 SOUNDING: 1
 AZIMUTH: 27 degs N
 EQUIPMENT: BGS128

Offset Wenner Configuration

FITTING ERROR: 9.051 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m ²)
			0.0		
1	945.8	1.68	-1.68	0.00178	1595.6
2	4.05	2.20	-3.89	0.543	8.93
3	58.13	15.22	-19.11	0.261	884.8
4	7.39				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER	MINIMUM	BEST	MAXIMUM
RHO			
1	850.414	945.880	1056.928
2	0.254	4.054	13.083
3	30.215	58.138	131.492
4	3.274	7.392	14.114
THICK			
1	1.577	1.687	1.785
2	0.113	2.205	7.737
3	5.362	15.221	36.724
DEPTH			
1	1.577	1.687	1.785
2	1.836	3.892	9.409
3	9.606	19.113	40.355

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	0.500	789.7	930.6	-17.84
2	1.00	910.0	849.4	6.65

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
3	2.00	642.4	549.9	14.38
4	4.00	134.0	142.9	-6.65
5	8.00	20.00	19.95	0.209
6	16.00	22.70	22.55	0.657
7	32.00	24.80	24.75	0.192
8	64.00	17.00	16.92	0.430

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	1.00						
P 2	0.00	0.52					
P 3	0.00	0.00	0.71				
P 4	0.00	0.03	-0.10	0.72			
T 1	0.00	0.01	0.00	0.00	1.00		
T 2	0.00	-0.48	-0.09	0.03	0.00	0.48	
T 3	0.00	-0.03	0.36	0.24	0.00	0.07	0.50
	P 1	P 2	P 3	P 4	T 1	T 2	T 3

Ugbodum 9

Resistivity 5: Offset Wenner

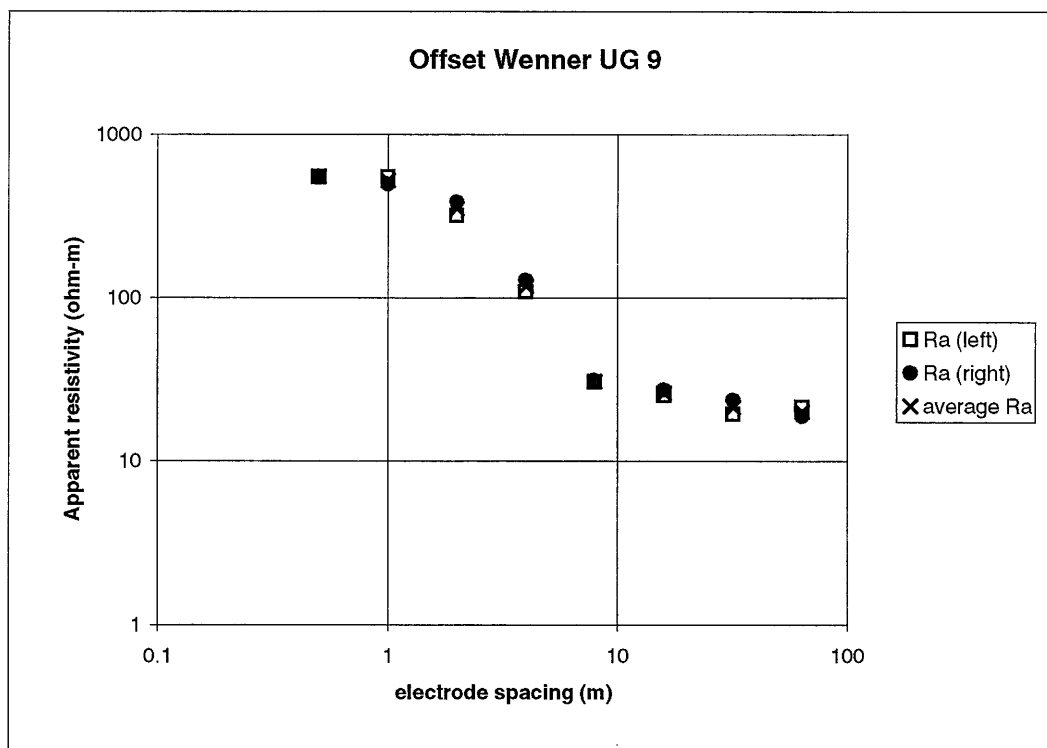
sited on BGS 44 strike 150 degs

left to Ugbodum

6 degs 58.539; 8 degs 16.227'

03/02/99

spacing	left	right	Ra (left)	Ra (right)	average Ra
0.5	174.4	176.1	547.616	552.954	550.285
1	86.9	78.8	545.732	494.864	520.298
2	25.3	30.7	317.768	385.592	351.68
4	4.3	5.09	108.016	127.8608	117.9384
8	0.606	0.619	30.44544	31.09856	30.772
16	0.25	0.27	25.12	27.1296	26.1248
32	0.096	0.117	19.29216	23.51232	21.40224
64	0.053	0.047	21.30176	18.89024	20.096



DATA SET: UGBODUM9

CLIENT: WaterAid
 LOCATION: BGS44
 COUNTY: Obi
 PROJECT: Oju Water Supply
 ELEVATION: 0.00
 SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: Jan 1999
 SOUNDING: 1
 AZIMUTH: 27 degs N
 EQUIPMENT: BGS128

Offset Wenner Configuration

FITTING ERROR: 1.316 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m ²)
			0.0		
1	560.9	1.79	-1.79	0.00321	1009.6
2	9.53	1.24	-3.04	0.131	11.91
3	34.57	6.99	-10.04	0.202	241.9
4	19.19				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER	MINIMUM	BEST	MAXIMUM
RHO	1 551.525	560.949	570.779
	2 7.323	9.536	12.361
	3 31.269	34.574	42.530
	4 18.660	19.193	19.699
THICK	1 1.774	1.800	1.829
	2 0.887	1.250	1.729
	3 4.873	6.998	9.270
DEPTH	1 1.774	1.800	1.829
	2 2.672	3.050	3.543
	3 7.968	10.047	12.285

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	0.500	550.0	553.6	-0.658
2	1.00	520.0	513.6	1.22

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
3	2.00	352.0	355.9	-1.13
4	4.00	117.9	116.9	0.778
5	8.00	30.70	30.97	-0.902
6	16.00	26.10	25.65	1.68
7	32.00	21.40	21.87	-2.21
8	64.00	20.10	19.86	1.15

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	0.99						
P 2	-0.01	0.26					
P 3	0.00	0.16	0.76				
P 4	0.00	-0.03	0.02	0.97			
T 1	0.01	0.03	0.00	0.00	0.99		
T 2	0.01	-0.25	-0.16	0.03	-0.02	0.24	
T 3	0.00	-0.09	0.27	0.06	0.00	0.08	0.20
	P 1	P 2	P 3	P 4	T 1	T 2	T 3

Ugbodum 10

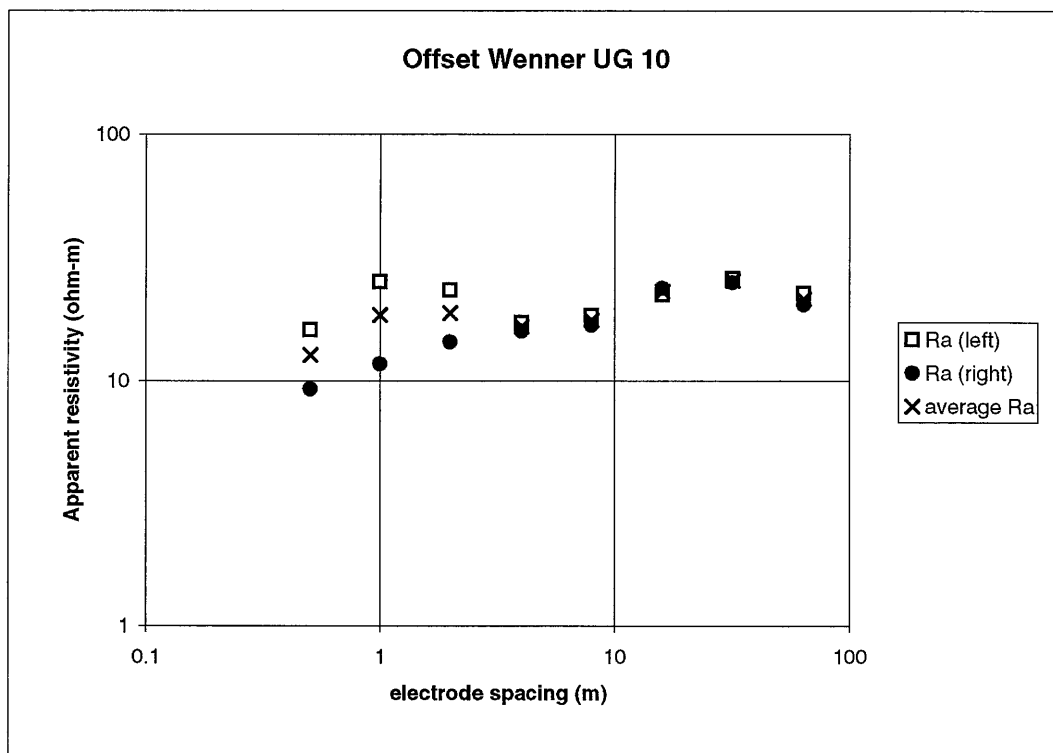
Resistivity 6: Offset Wenner

sited on BGS 46

7 degs 0.842' 8 degs 14.993

08/02/99

spacing	left	right	Ra (left)	Ra (right)	average Ra
0.5	5.11	2.94	16.0454	9.2316	12.6385
1	4	1.86	25.12	11.6808	18.4004
2	1.85	1.14	23.236	14.3184	18.7772
4	0.68	0.631	17.0816	15.85072	16.46616
8	0.363	0.333	18.23712	16.72992	17.48352
16	0.222	0.236	22.30656	23.71328	23.00992
32	0.129	0.1243	25.92384	24.97933	25.45158
64	0.056	0.0503	22.50752	20.21658	21.36205



DATA SET: UGBOD10

CLIENT: WaterAid DATE: Jan 1999
 LOCATION: BGS46 SOUNDING: 1
 COUNTY: Obi AZIMUTH: 27 degs N
 PROJECT: Oju Water Supply EQUIPMENT: BGS128
 ELEVATION: 0.00
 SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

Offset Wenner Configuration

FITTING ERROR: 1.064 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m ²)
			0.0		
1	4.14	0.170	-0.170	0.0411	0.707
2	74.28	0.334	-0.505	0.00451	24.87
3	12.09	5.10	-5.60	0.421	61.70
4	38.81	19.86	-25.47	0.511	771.0
5	14.60				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER	MINIMUM	BEST	MAXIMUM
RHO			
1	2.336	4.148	5.827
2	49.912	74.281	112.529
3	10.936	12.094	13.246
4	33.106	38.813	44.229
5	11.924	14.608	16.519
THICK			
1	0.095	0.171	0.242
2	0.214	0.335	0.523
3	4.105	5.102	6.211
4	14.295	19.866	30.519
DEPTH			
1	0.095	0.171	0.242
2	0.385	0.506	0.693
3	4.666	5.608	6.665
4	20.603	25.474	35.534

No.	SPACING	RHO-A (ohm-m)	DIFFERENCE
-----	---------	---------------	------------

	(m)	DATA	SYNTHETIC	(percent)
1	0.500	12.60	12.72	-0.960
2	1.00	18.40	18.00	2.15
3	2.00	18.80	19.08	-1.49
4	4.00	16.60	16.45	0.870
5	8.00	17.50	17.57	-0.429
6	16.00	23.00	22.91	0.373
7	32.00	25.50	25.52	-0.0789
8	64.00	21.40	21.40	-0.0140

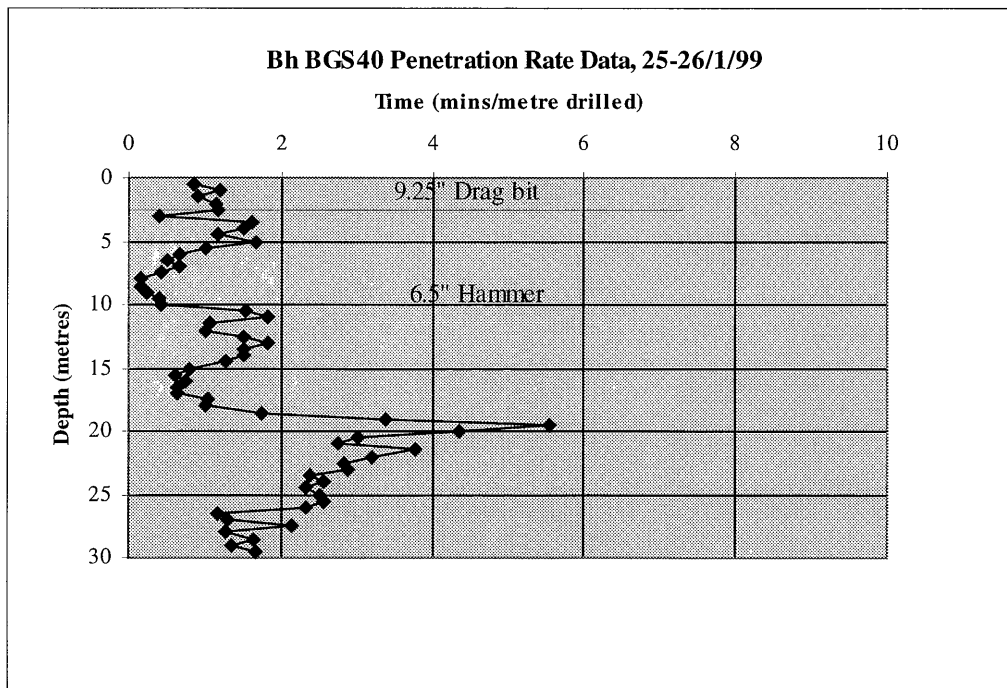
PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	0.51								
P 2	0.00	0.54							
P 3	0.01	0.00	0.98						
P 4	0.00	0.00	-0.02	0.92					
P 5	0.00	0.00	-0.01	-0.06	0.89				
T 1	-0.50	-0.04	0.02	0.00	0.00	0.49			
T 2	-0.04	0.49	0.02	0.01	0.00	0.00	0.46		
T 3	0.02	-0.01	-0.04	-0.08	-0.04	0.03	0.05	0.89	
T 4	0.00	-0.01	0.04	0.19	0.23	0.00	-0.02	0.16	0.44
	P 1	P 2	P 3	P 4	P 5	T 1	T 2	T 3	T 4

Annex 2: Drilling and borehole construction data

Borehole Drilling/Construction Details: Borehole BGS40

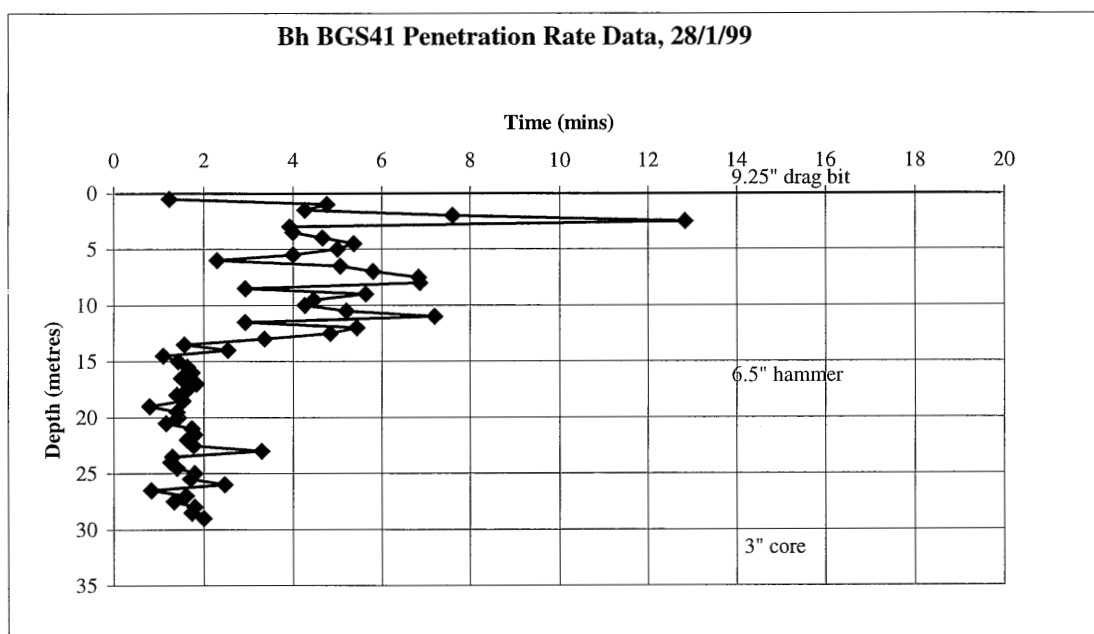
Date drilling started	25/1/99
Date drilling completed	26/1/99
25/1/99 - Drilled with 9.25" drag bit	0.0 - 2.5m
25/1/99 - Drilled with 6.5"hammer	2.5 - 8.5m
26/1/99 - Drilled with 6.5" hammer	8.5 - 29.5m
Xx/1/99 – Cored at 3"	29.5 - 32.1m
Depths water struck	17.0,17.5, 22.5, 26.5,
Depth of borehole on completion	32.1mbgs
Borehole diameter	6½"
Casing erected in hole	8x2.9mx125mm casing
	2x2.9mx125mm screen
	1x2.9mx125mm casing



Borehole Drilling/Construction Details: Borehole BGS41

Borehole Drilling/Construction Details

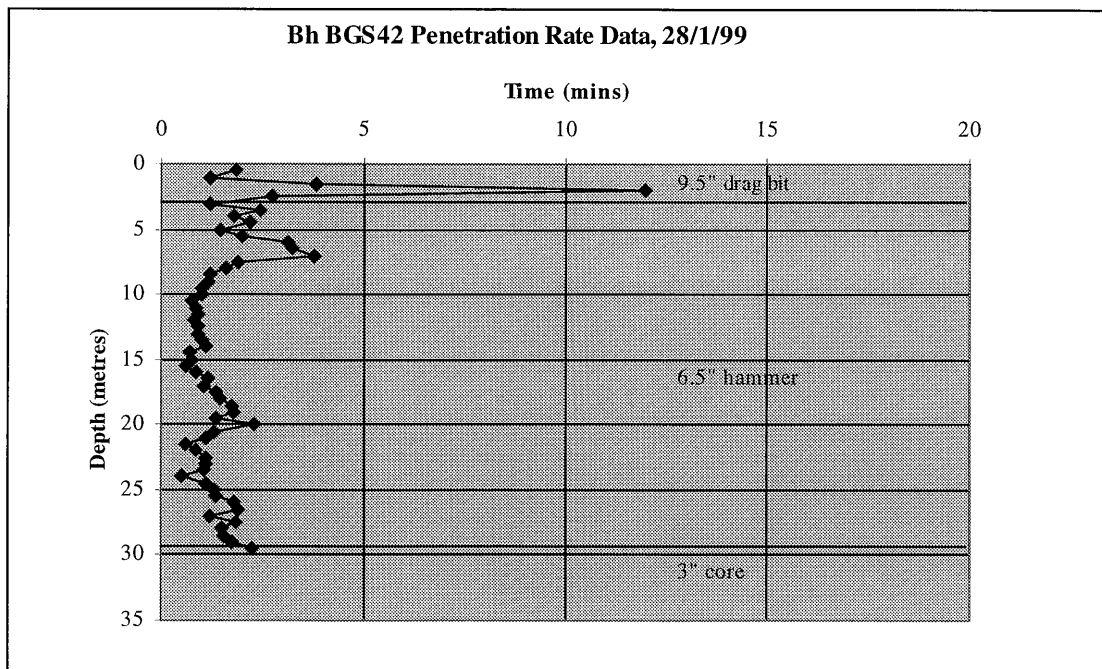
Date drilling started	27/1/99
Date drilling completed	28/1/99
27/1/99 – Drilled with 9.25" drag bit	0.0 - 2.5m
27/1/99 - Drilled with 6.5" hammer	2.5 - 29.5m
27/1/99 – Cored at 3"	29.5 - 32.6m
28/1/99 - Reamed with 6.5" hammer	29.5 - 32.6m
28/1/99 - Drilled with 6.5" hammer	32.6 - 41.5m
Depths water struck	29.5
Depth of borehole on completion	41.5mbgs
Borehole diameter	6 $\frac{1}{2}$ "
Casing erected in hole	11x2.9mx125mm casing
	1x2.9mx125mm screen
	3x2.9mx125mm casing



Borehole Drilling/Construction Details: Borehole BGS42

Borehole Drilling/Construction Details

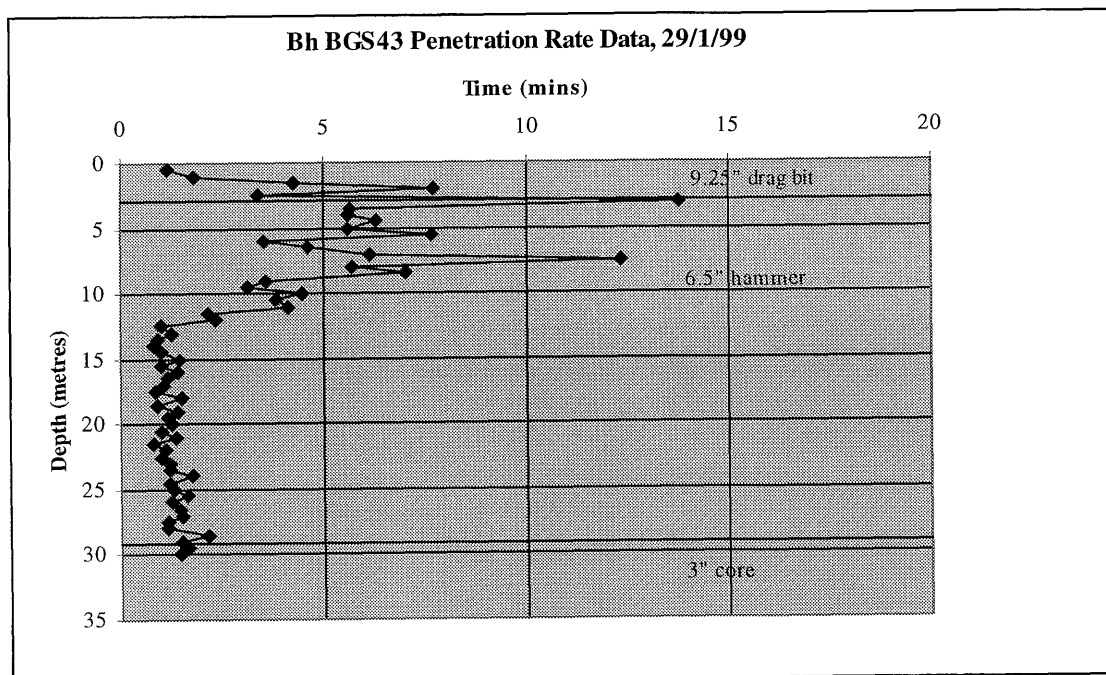
Date drilling started	28/1/99
Date drilling completed	29/1/99
28/1/99 – Drilled with 9.25" drag bit	0.0 - 2.5m
28/1/99 - Drilled with 6.5" hammer	2.5 - 20.5m
29/1/99 - Drilled with 6.5" hammer	20.5 - 29.5m
29/1/99 – Cored at 3"	29.5-32.05m
Depths water struck	15.0, 18.0, 24.5
Depth of borehole on completion	32.05mbgs
Borehole diameter	6 $\frac{1}{2}$ "
Casing erected in hole	7x2.9mx125mm casing
	2x2.9mx125mm screen
	2x2.9mx125mm casing



Borehole Drilling/Construction Details: Borehole BGS43

Borehole Drilling/Construction Details

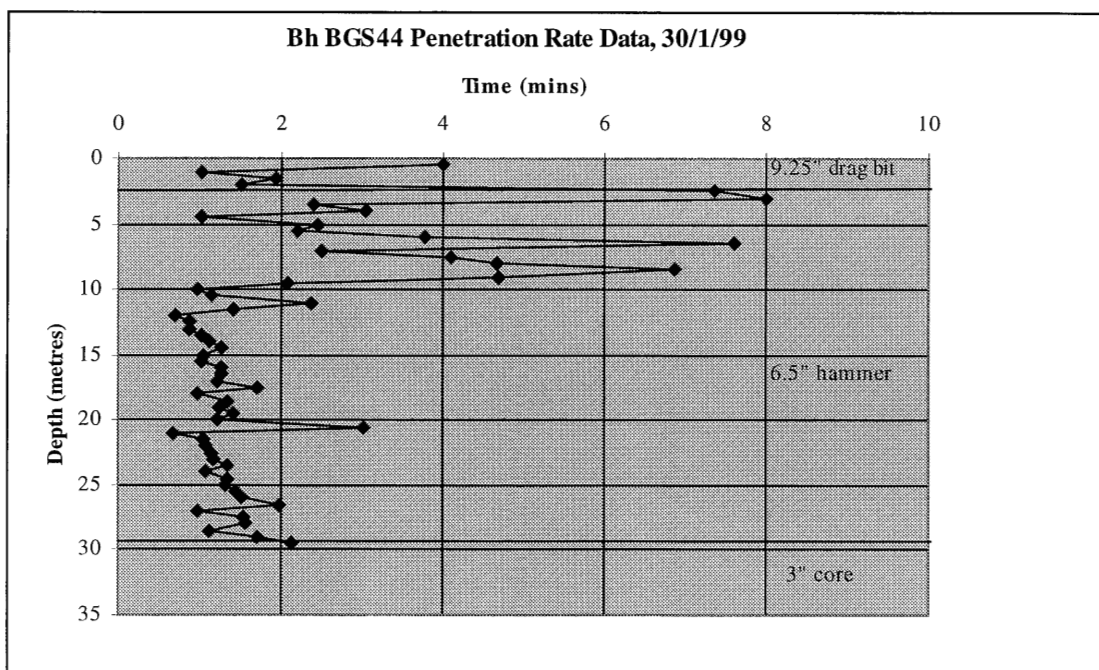
Date drilling started	29/1/99
Date drilling completed	30/1/99
29/1/99 – Drilled with 9.25" drag bit	0.0 - 2.5m
29/1/99 - Drilled with 6.5" hammer	2.5 - 8.5m
30/1/99 - Drilled with 6.5" hammer	8.5 - 29.5m
30/1/99 – Cored at 3"	29.5-31.86m
Depths water struck	dry
Depth of borehole on completion	31.86mbgs
Borehole diameter	6 $\frac{1}{2}$ "
Casing erected in hole	nil



Borehole Drilling/Construction Details: Borehole BGS44

Borehole Drilling/Construction Details

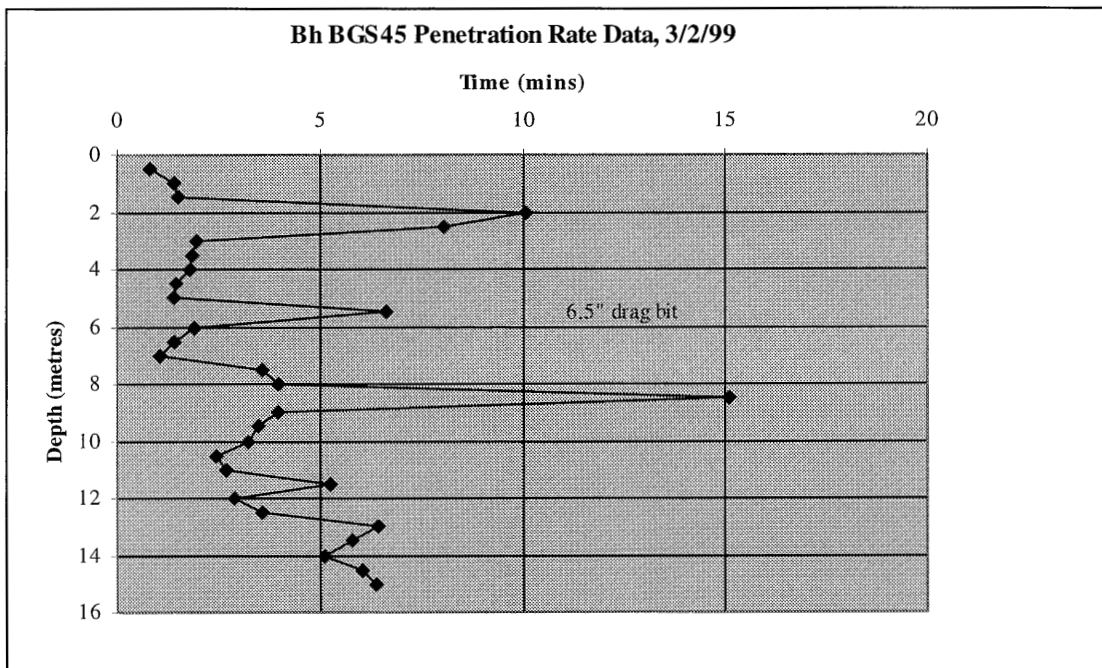
Date drilling started	30/1/99
Date drilling completed	2/2/99
30/1/99 – Drilled with 9.25” drag bit	0.0 - 2.5m
30/1/99 - Drilled with 6.5” hammer	2.5 - 29.5m
2/2/99 – Cored at 3”	29.5 - 32.0m
Depths water struck	5.5, 20.0
Depth of borehole on completion	32.0mbgs
Borehole diameter	6½”
Casing erected in hole	1x5.8mx125mm casing 2x2.9mx125mm screen 1x2.9mx125mm casing 1x5.8mx125mm casing 1x2.9mx125mm screen 1x5.8mx125mm casing 1x1.6mx125mm casing
Top of casing above ground level	0.25m
Rest water level below casing top	16.41m



Borehole Drilling/Construction Details: Borehole BGS45

Borehole Drilling/Construction Details

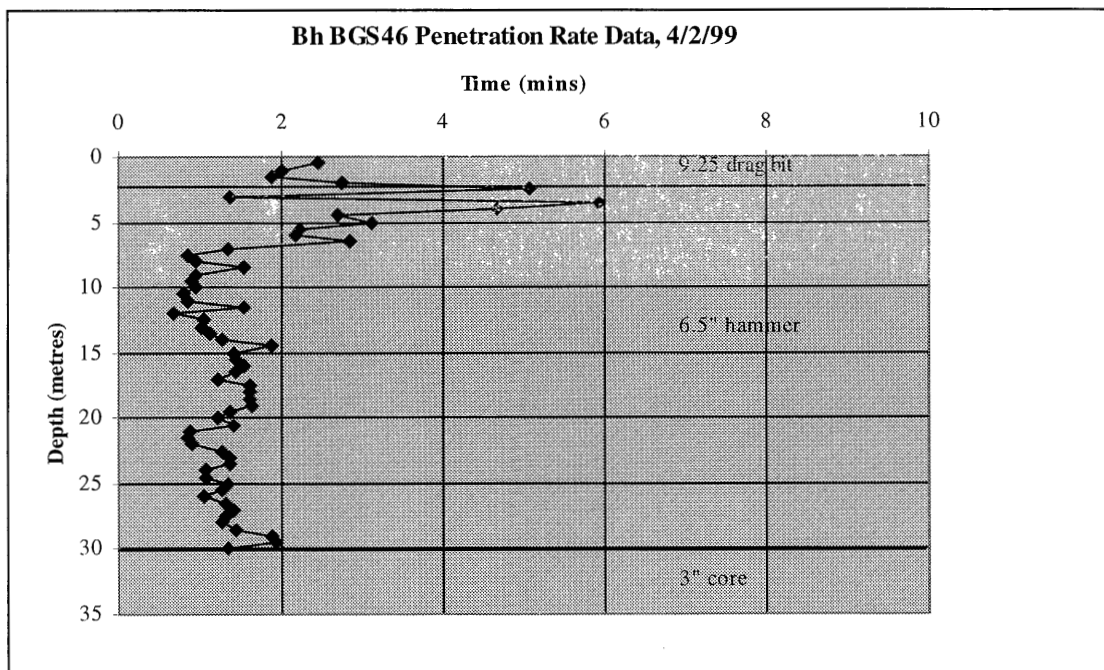
Date drilling started	3/2/99
Date drilling completed	3/2/99
3/2/99 - Drilled with 6.5" drag bit	0.0-14.5m
3/2/99 - Cored at 3"	14.5-19.7m
Depths water struck	
Depth of borehole on completion	19.7 mbgs
Borehole diameter	6 $\frac{1}{2}$ "
Casing erected in hole	2x2.9mx125mm casing
	1x5.8mx125mm casing
	2x2.9mx125mm screen



Borehole Drilling/Construction Details: Borehole BGS46

Borehole Drilling/Construction Details

Date drilling started	4/2/99
Date drilling completed	5/2/99
4/2/99 – Drilled with 9.25" drag bit	0.0-2.5m
5/2/99 - Drilled with 6.5" hammer	2.5-30.0m
5/2/99 – Cored at 3"	30.0-32.07m
Depths water struck	8.5, 10.0, 11.0, 12.0
Depth of borehole on completion	32.07mbgs
Borehole diameter	6 1/2"
Casing erected in hole	2x5.8mx125mm casing
	2x2.9mx125mm screen
	2x5.8mx125mm casing
	1x2.9mx125mm casing



Annex 3: Lithological logs

Lithological Log: BGS40

Soil/ferricrete horizon

0.0 - 0.5	Reddish brown 2.5YR4/4, reddish yellow 7.5YR6/8 ferricrete with some yellow limonite and black manganese, hard
0.5 - 1.0	Reddish brown 2.5YR4/4, reddish yellow 7.5YR6/8 ferricrete with some yellow limonite and black manganese, hard with red 7.5R6/8 partings
1.0 - 1.5	Earthy reddish brown 2.5YR4/4 soft ferricrete with black manganese partings
1.5 - 2.0	Earthy sub-nodular black manganese with 10YR5/8 yellow ochre and 2.5YR5/8 reddish brown partings
2.0 - 2.5	Earthy black manganese with 2.5YR5/8 reddish brown partings
2.5 - 3.0	Red 2.5YR4/6 hard sandy ferricrete with brownish yellow 10YR6/8 partings
3.0 - 3.5	Soft black manganese oxide
3.5 - 4.0	Soft black manganese oxide with red 2.5YR5/8 ferric oxide partings

Clayey very weathered horizon

4.0 - 4.5	Soft white kaolinite clay with soft yellowish red 5YR5/8 partings
4.5 - 5.0	Yellowish red 5YR4/6 sandy clay with white patches
5.0 - 5.5	Mottled yellowish red 5YR4/6 to 5/8 clay and white kaolin clay with odd fragments of black manganese oxide
5.5 - 6.0	Mottled yellowish red 7.5YR6/8 and white kaolin clay
6.0 - 6.5	Mottled strong brown 7.5YR5/8, red 2.5YR5/8 and about 10% white kaolin clays with earthy texture
6.5 - 7.0	Light grey 2.5Y7/2 kaolin clay mottled with brownish yellow 10YR6/6 earthy clay
7.0 - 7.5	Reddish yellow 7.5YR6/8 and very pale brown 10YR8/3 mottled earthy clay
7.5 - 8.0	Brown 7.5YR4/4 and black mottled with some light yellow kaolin clay

Weathered clayey sand

8.0 - 8.5	Mottled reddish yellow 7.5YR6/8 and very pale brown 10YR8/3 with layers of light grey very clayey sand
8.5 - 9.0	Yellowish brown 10YR5/6 clayey sand
9.0 - 9.5	Mottled yellowish brown 10YR5/8 and very pale brown and black clayey weathered sand
9.5 - 10.0	Dark yellowish brown 10YR4/4 clayey sand
10.0 - 10.5	Mottled brown 7.5YR4/4 and light olive brown 2.5Y5/4 clayey sand
10.5 - 11.0	Light olive brown 2.5Y5/6 clayey sand
11.0 - 11.5	Light olive brown 2.5Y5/6 clayey sand
11.5 - 12.0	Light olive brown 2.5Y5/6 clayey sand
12.0 - 12.5	Yellowish brown 10YR5/6 clayey sand
12.5 - 13.0	Light olive brown 2.5Y5/6 clayey medium-grained sand
13.0 - 13.5	Light olive brown 2.5Y5/6 clayey medium-grained sand, with dark brown grains and light red/pink thin partings

Weathered medium-grained sandstone

13.5 - 14.0	Dark yellowish brown 10YR4/4 medium-grained sand little clay
14.0 - 14.5	Dark yellowish brown 10YR4/4 fine- to medium-grained sand little clay
14.5 - 15.0	Yellowish brown 10YR5/6 soft weathered medium-grained sandstone
15.0 - 15.5	Yellowish brown 10YR5/6 soft weathered medium-grained sandstone
15.5 - 16.0	Yellowish brown 10YR5/8 very weathered soft medium- to fine-grained sandstone
16.0 - 16.5	Yellowish brown 10YR5/8 very weathered soft medium-grained sandstone, rounded grains
16.5 - 17.0	Yellowish brown 10YR5/8 very weathered soft medium-grained sandstone, rounded grains, with numerous black fragments
17.0 - 17.5	Dark yellowish brown 10YR weathered medium-grained sandstone with yellow to light brown and white mottled smectitic clay fragments - weathered dolerite

Dolerite

17.5 - 18.0	Hard black fine-grained dolerite
18.0 - 18.5	Hard black fine-grained dolerite
18.5 - 19.0	Dark grey/black very fine-grained soft dolerite, platy fragments
19.0 - 19.5	Dark grey/black very fine-grained dolerite, platy fragments

19.5 - 20.0	Dark grey/black very fine-grained dolerite, some white vein fragments
20.0 - 20.5	Dark grey/black very fine-grained dolerite, little white vein fragments
20.5 - 21.0	Dark grey/black very fine-grained dolerite, increased white vein fragments
21.0 - 21.5	Dark grey/black very fine-grained dolerite, some white vein fragments
21.5 - 22.0	Dark grey/black very fine-grained dolerite, much white vein fragments, some zeolite
22.0 - 22.5	Dark grey/black fine-grained dolerite, much white vein fragments
22.5 - 23.0	Dark grey/black fine-grained dolerite, much white vein fragments
23.0 - 23.5	Dark grey/black fine-grained dolerite, much white vein fragments
23.5 - 24.0	Dark grey/black fine-grained dolerite, much white vein fragments, with small cubic iron pyrite crystals in veins
24.0 - 24.5	Dark grey/black fine-grained dolerite, much white vein fragments

Hard baked sandstone

24.5 - 25.0	Weak red 7.5R5/3 baked fine-grained sandstone and dark grey/black fine-grained dolerite
25.0 - 25.5	Increased weak red 7.5R5/3 baked fine-grained sandstone and dark grey/black fine-grained dolerite
25.5 - 26.0	Baked interbedded hard fine-grained pink sandstone with black mudstones
26.0 - 26.5	Alternations of thin and fairly hard light grey fine-grained sandstone and dark grey hard carbonaceous shale

Fine-grained sandstones and carbonaceous shaley mudstones

26.5 - 27.0	Alternations of thin and fairly hard light grey fine-grained sandstone and increased dark grey hard carbonaceous shaley mudstones
27.0 - 27.5	Alternations of thin and fairly hard light grey fine-grained sandstone and increased dark grey hard carbonaceous shaley mudstones
27.5 - 28.0	Fairly hard light grey fine-grained sandstones with interbedded thin to blocky dark grey shales
28.0 - 28.5	Light grey fine-grained sandstones with some interbedded dark grey shales
28.5 - 29.0	Light grey fine-grained sandstone with purple shales
29.0 - 29.5	Light grey fine-grained sandstones with much dark grey shaley mudstone partings
29.50 - 30.80	No core
30.80 - 31.50	Mixed medium-grained light grey sandstones with grey muddy sandstones, slump bedded throughout with bioturbation with sand infilled tubules
31.50 - 31.85	Interbedded medium-grained light grey sands and fine-grained dark grey siltstones, sandstones are mainly slump bedded into rounded masses with dark grey silty mudstones folded around them, some bioturbation between 31.80 and 31.85
31.85 - 32.01	Thin light grey medium-grained sandstones, crudely cross bedded and slumped interbedded with thicker silty dark grey to black mudstones, series of fining upward cyclic deposits

Lithological Log: BGS41

Soil/ferricrete horizon

0.0 - 0.5	Yellowish brown 10YR5/4 loamy soil
0.5 - 1.0	Reddish brown 2.5YR4/3 nodular ferric laterite
1.0 - 1.5	Black manganese 15mm nodules with red 10R4/6 partings, some brownish yellow 10YR6/8 coatings
1.5 - 2.0	Yellowish red 5YR4/6 earthy nodules of ferricrete with strong brown 7.5YR5/8 earthy clay and grey clay

Clayey very weathered horizon

2.0 - 2.5	Light greenish grey clay 7/10Y (gley 1) with dark red 2.5YR3/6 and strong brown 7.5YR5/8 and brownish yellow 10YR6/8 partings
2.5 - 3.0	Light grey 10YR7/2 and reddish brown 2.5YR5/4 mottled clays
3.0 - 3.5	Reddish brown 5YR5/4 and light grey 10YR7/2 mottled clays
3.5 - 4.0	Grey 5YR6/1 clay with reddish yellow 7.5YR6/8 partings
4.0 - 4.5	Mottled light bluish grey 8/5PB and light reddish brown 2.5YR6/4 clay with reddish brown 7.5YR7/8 partings
4.5 - 5.0	Grey 6/n clay with orange partings
5.0 - 5.5	Dark grey 4/N earthy clay
5.5 - 6.0	Very weathered dark grey clay

Very weathered mudstones

6.0 - 6.5	Weathered dark grey soft mudstone
6.5 - 7.0	Dark grey weathered mudstone with orange partings
7.0 - 7.5	Soft dark grey weathered mudstone with yellow, orange and red partings
7.5 - 8.0	Soft dark grey 4/N weathered mudstones with some orange/strong yellow partings
8.0 - 8.5	Soft dark bluish grey 4/5PB weathered carbonaceous mudstones, some orange and white partings (gypsum??)

Weathered mudstones

8.5 - 9.0	Soft dark bluish grey 4/5PB weathered carbonaceous mudstone
9.0 - 9.5	Soft dark bluish grey 4/5PB weathered carbonaceous mudstone, with light brown partings
9.5 - 10.0	Soft bluish grey 5/10B weathered carbonaceous mudstone with light yellow brown partings
10.0 - 10.5	Mottled dark bluish grey 4/5PB weathered carbonaceous mudstone with much strong yellow, red and white partings
10.5 - 11.0	Mottled brown 10/YR4/3 and dark grey soft weathered mudstones
11.0 - 11.5	Dark blue grey 4/10B soft weathered mudstones, some red 10R4/6 and orange 7.5YR5/8 partings
11.5 - 12.0	Dark blue grey weathered mudstones 3/5B, some orange partings
12.0 - 12.5	Dark blue grey weathered mudstones 3/5B, some orange partings
12.5 - 13.0	Very dark blue grey weathered mudstone, soft with orange yellow partings

Black carbonaceous mudstones

13.0 - 13.5	Harder black carbonaceous mudstones
13.5 - 14.0	Black carbonaceous mudstones
14.0 - 14.5	Black carbonaceous mudstones
14.5 - 15.0	Black carbonaceous mudstones with hard thin limestone bands, some calcite crystals
15.0 - 15.5	Black carbonaceous mudstones
15.5 - 16.0	Black carbonaceous mudstones
16.0 - 16.5	Black carbonaceous mudstones
16.5 - 17.0	Black carbonaceous mudstones with hard thin limestone bands
17.0 - 17.5	Black carbonaceous mudstones
17.5 - 18.0	Black carbonaceous mudstones
18.0 - 18.5	Black carbonaceous mudstones
18.5 - 19.0	Black carbonaceous mudstones with hard thin limestone bands
19.0 - 19.5	Black carbonaceous mudstones
19.5 - 20.0	Black carbonaceous mudstones with hard thin limestone bands
20.0 - 20.5	Black carbonaceous mudstones
20.5 - 21.0	Black carbonaceous mudstones

21.0 - 21.5	Black carbonaceous mudstones
21.5 - 22.0	Black carbonaceous mudstones
22.0 - 22.5	Black carbonaceous mudstones
22.5 - 23.0	Black carbonaceous mudstones
23.0 - 23.5	Black carbonaceous mudstones
23.5 - 24.0	Black carbonaceous mudstones
24.0 - 24.5	Black carbonaceous mudstones
24.5 - 25.0	Black carbonaceous mudstones
25.0 - 25.5	Black carbonaceous mudstones
25.5 - 26.0	Black carbonaceous mudstones
26.0 - 26.5	Black carbonaceous mudstones
26.5 - 27.0	Black carbonaceous mudstones
27.0 - 27.5	Black carbonaceous mudstones
27.5 - 28.0	Black carbonaceous mudstones
28.0 - 28.5	Black carbonaceous mudstones
28.5 - 29.0	Black carbonaceous mudstones
Fine-grained limestone	
29.0 - 29.5	Black carbonaceous mudstones with hard thin limestone bands
29.50 - 29.62	Light grey very fossiliferous bio-micrite or very fine-grained sandstone or ash
Black carbonaceous mudstones	
29.62 - 29.73	Soft shaley black very carbonaceous mudstones
29.73 - 30.10	Blocky black carbonaceous mudstones
30.10 - 30.18	Sandy carbonaceous grey-black mudstones to siltstones
30.18 - 30.22	Blocky to shaley black very carbonaceous mudstones
Muddy fine-grained sandstone	
30.22 - 30.29	Dark grey bioturbated very muddy sandstones
30.29 - 30.34	Light grey fine-grained sandstones, slump bedded
30.34 - 30.39	Dark grey muddy fine-grained sandstone, some poor cross bedding
Black carbonaceous mudstones	
30.39 - 30.42	Silt black carbonaceous mudstones
Muddy fine-grained sandstone	
30.42 - 30.47	Grey bioturbated muddy fine-grained sandstone
30.47 - 30.70	Light grey fine-grained hard sandstone, some cross bedding and bioturbation
Black carbonaceous mudstones	
30.70 - 31.10	Blocky black carbonaceous mudstone
31.10 - 31.48	Black very carbonaceous well bedded mudstone with some mica, no fossils
31.48 - 31.73	Black very carbonaceous mudstones, no fossils, silty in parts, iron pyrite line crack from 31.68
Muddy fine-grained sandstone	
31.73 - 31.85	Grey to dark grey muddy fine-grained sandstone thinly cross-bedded. Near vertical fracture infilled with iron pyrite, water producing
31.85 - 32.31	Grey muddy fine-grained sandstone, bioturbated with numerous infilled tubules, some slump bedding, more competent and well bedded below 32.25
32.31 - 32.34	Bioturbated muddy dark grey fine-grained sandstone vugs infilled with iron pyrite and large >5mm baryte crystals
Black carbonaceous mudstones	
32.34 - 32.50	Black soft shaley very carbonaceous mudstones
32.5 - 34.0	Black soft carbonaceous mudstones
34.0 - 37.0	Black carbonaceous mudstones
37.0 - 37.5	Interbedded black carbonaceous mudstones and dark grey fine-grained sandstones
37.5 - 40.0	Black carbonaceous mudstones
40.0 - 41.5	Harder black carbonaceous mudstones

Lithological Log: BGS42

Soil/ferricrete horizon

0.0 - 0.5	Dark greyish brown 10YR4/2 soil above black manganiferous nodules up to 10mm diameter
0.5 - 1.0	Black manganese oxide nodules with red 10R4/6 ferric oxide rims
1.0 - 1.5	Black manganese oxide nodules with red 10R4/6 ferric oxide rims and reddish brown 2.5YR5/4 clay

Clayey very weathered horizon

1.5 - 2.0	Reddish brown 2.5YR5/4 clay
2.0 - 2.5	Reddish brown 2.5YR5/4 clay above strong brown 7.5YR5/8 clay with light greenish grey partings
2.5 - 3.0	Strong brown 7.5YR5/6 clay

Weathered silty clay

3.0 - 3.5	Yellowish brown 10YR5/6 silty clay
3.5 - 4.0	Light grey 10YR7/1 and strong brown 7.5YR5/8 mottled yellow brown 10YR5/6 silty clay

Weathered clayey fine-grained sand

4.0 - 4.5	Yellow brown 10YR5/6 sandy clay
4.5 - 5.0	Yellow brown 10YR5/6 clayey fine-grained sand
5.0 - 5.5	Yellow brown 10YR5/6 fine-grained sand some clay

Weathered fine-grained sand

5.5 - 6.0	Yellow brown 10YR5/6 fine-grained sand
6.0 - 6.5	Yellow brown 10YR5/6 fine-grained sand
6.5 - 7.0	Yellow brown 10YR5/6 fine-grained sand
7.0 - 7.5	Yellow brown 10YR5/6 fine-grained sand
7.5 - 8.0	Yellow brown 10YR5/6 fine-grained sand
8.0 - 8.5	Dark yellow brown 10YR4/4 fine-grained sand
8.5 - 9.0	Dark yellow brown 10YR4/4 fine-grained sand
9.0 - 9.5	Hard dark grey-brown, fine-grained sandstone with orange partings

Weathered ashy mudstone

9.5 - 10.0	Pale yellow 2.5Y7/4 soft fine-grained weathered ashy mudstone
10.0 - 10.5	Pale yellow 2.5Y7/4 soft fine-grained weathered ashy mudstone
10.5 - 11.0	Light yellowish brown 10YR6/4 well bedded silty fine grained ashy mudstone with red brown partings
11.0 - 11.5	Light olive brown 2.5Y5/4 weathered ashy mudstone
11.5 - 12.0	Soft olive 5Y5/3 weathered ashy mudstone
12.0 - 12.5	Olive grey 5Y5/2 hard silty fine-grained volcanic ashy mudstone
12.5 - 13.0	Light olive grey 5Y6/2 fairly weathered ashy mudstone

Fine-grained ashy mudstone

13.0 - 13.5	Hard light grey ashy mudstone
13.5 - 14.0	Grey 5Y6/1 hard ashy mudstone
14.0 - 14.5	Bluish grey 6/10B fissile ashy mudstone
14.5 - 15.0	Light blue grey 7/10B ashy mudstone
15.0 - 15.5	Light blue grey 7/10B ashy mudstone
15.5 - 16.0	Light blue grey 7/10B silty fine-grained ashy mudstone
16.0 - 16.5	Light blue grey 7/10B silty fine-grained ashy mudstone
16.5 - 17.0	Light blue grey 7/10B silty fine-grained ashy mudstone
17.0 - 17.5	Light blue grey 7/10B silty fine-grained ashy mudstone

Weathered ashy mudstone

17.5 - 18.0	Grey soft ashy mudstone
18.0 - 18.5	Grey soft ashy mudstone

Dolerite

18.5 - 19.0	Hard dark grey dolerite
19.0 - 19.5	Hard dark grey dolerite
19.5 - 20.0	Hard dark grey dolerite

Hard baked black carbonaceous mudstones

20.0 - 20.5	Black carbonaceous silty mudstone
20.5 - 21.0	Brittle shaley black mudstones some pyrite
21.0 - 21.5	Brittle shaley black mudstones some thin fine-grained sandstone layers
21.5 - 22.0	Brittle shaley black mudstones
22.0 - 22.5	Brittle shaley black carbonaceous mudstones
22.5 - 23.0	Harder more shaley black carbonaceous mudstones, some interbedded sandstones, damp
23.0 - 23.5	Harder and more shaley black very carbonaceous mudstone
23.5 - 24.0	Blocky black carbonaceous mudstone, damp
Black carbonaceous mudstones	
24.0 - 24.5	Soft black carbonaceous mudstone
24.5 - 25.0	Soft black carbonaceous mudstone
25.0 - 25.5	Soft black carbonaceous mudstone
25.5 - 26.0	Soft black carbonaceous mudstone
Black carbonaceous mudstones with silty fine-grained sandstones	
26.0 - 26.5	Soft black carbonaceous mudstone with thin light grey interbedded fine-grained sandstones and siltstones
26.5 - 27.0	Interbedded soft, black carbonaceous mudstone with subordinate light grey silty fine-grained thin sandstones
Black carbonaceous mudstones	
27.0 - 27.5	Black carbonaceous mudstone
27.5 - 28.0	Black carbonaceous mudstone
Muddy fine-grained sandstones	
28.0 - 28.5	Hard black muddy fine-grained sandstone
Black carbonaceous mudstones	
28.5 - 29.0	Black sandy carbonaceous mudstone
29.0 - 29.5	Black very carbonaceous mudstone
29.50 - 30.20	Black carbonaceous shaley mudstones, thinly bedded
Black carbonaceous mudstones with fine-grained sandstones	
30.20 - 30.30	Black carbonaceous shaley mudstones with white fine-grained sandstone discontinuous stringers
30.30 - 30.55	Black carbonaceous shaley mudstones some light grey fine-grained sandstone stringers, many infilled horizontal tubes with fine-grained sand
Muddy fine-grained sandstones	
30.55 - 30.60	Grey slumps with fine-grained muddy sandstone
Black carbonaceous mudstones	
30.60 - 30.86	Black very carbonaceous shaley mudstones
Muddy fine-grained sandstones	
30.86 - 30.91	Bioturbated grey-white muddy fine-grained sandstone
Black carbonaceous mudstones	
30.91 - 31.29	Black very carbonaceous shaley mudstones with prominent sub-vertical cracks
31.29 - 31.56	Interbedded very carbonaceous black mudstones and bioturbated grey and black shaley mudstones with fine-grained sand in tubules
Black carbonaceous mudstones with fine-grained sandstones	
31.56 - 31.83	Thin bedded alternations of black carbonaceous mudstones and fine-grained light grey sandstones
Black carbonaceous mudstones	
31.83 - 32.05	Black very carbonaceous shaley mudstones, with odd white fine-grained sand stringer
32.01 - 32.05	Prominent calcite and iron pyrite filled fracture

Lithological Log: BGS43

Soil/ferricrete horizon

0.0 - 0.5	Light greyish brown 10YR5/2 soil with dusky red 7.5R3/3 laterite nodules
0.5 - 1.0	Dusky red 7.5R3/3 laterite nodules
1.0 - 1.5	Dark red 10R3/6 earthy clay partings, some nodules and some greenish clay partings
1.5 - 2.0	Light greenish grey 7/5GY clay with brownish yellow 10YR6/8 and red 10R4/6 mottled clays

Clayey very weathered horizon

2.0 - 2.5	Light greenish grey 7/5GY clay with dark red 10R3/6 partings and ferricrete nodules
2.5 - 3.0	Light greenish grey 7/10Y clayey sand with red partings
3.0 - 3.5	Light yellow brown 10YR6/4 and light grey 10YR7/1 mottled clay
3.5 - 4.0	Mottled strong brown 7.5YR5/6, red 10R4/8 and light bluish grey 8/5B clays
4.0 - 4.5	Mottled strong brown 7.5YR5/6, red 10R4/8 and light bluish grey 8/5B clays
4.5 - 5.0	Light olive brown 2.5Y5/4 and grey 2.5Y5/1 mottled clays
5.0 - 5.5	Grey 2.5Y5/1 clay with some light olive brown 2.5Y5/6 partings
5.5 - 6.0	Grey 2.5Y5/1 to dark grey 2.5Y4/1 clay
6.0 - 6.5	Grey 2.5Y6/1 clay with brownish yellow 10YR6/8 mottles
6.5 - 7.0	Grey 10YR6/1 clay with dark red 10R3/6 and yellowish brown 10YR5/4 mottles

Weathered mudstones

7.0 - 7.5	Mottled grey 10YR5/1 and yellowish brown 10YR5/6 weathered clayey mudstone
7.5 - 8.0	Mottled grey 10YR5/1, greyish brown 10YR5/2 and yellowish brown 10YR5/6 clayey weathered mudstone
8.0 - 8.5	Light olive brown 2.5Y5/4, grey 2.5Y5/1 and greyish brown 2.5Y5/2 mottled clays - weathered mudstones
8.5 - 9.0	Mottled grey 10YR6/1 and yellowish brown 10YR5/4 weathered mudstone
9.0 - 9.5	Mottled grey 10YR5/1 and yellowish brown 10YR5/8 very weathered mudstone
9.5 - 10.0	Dark grey 4/N and yellowish brown 10YR4/6 mottled clayey weathered mudstone with gypsum bands
10.0 - 10.5	Dark grey 4/N clayey weathered mudstones with some gypsum
10.5 - 11.0	Very dark grey 3/N with dark yellow brown 10YR4/4 mottled clayey weathered mudstones with some gypsum
11.0 - 11.5	Very dark greyish brown 2.5YR3/2 and black soft earthy weathered mudstone with much cellenite

Black carbonaceous mudstones

11.5 - 12.0	Black carbonaceous mudstone some gypsum
12.0 - 12.5	Black very soft, very carbonaceous mudstone
12.5 - 13.0	Black very soft, very carbonaceous mudstone
13.0 - 13.5	Black very soft, very carbonaceous mudstone, some limestone
13.5 - 14.0	Black very soft, very carbonaceous mudstone
14.0 - 14.5	Black very soft, very carbonaceous mudstone
14.5 - 15.0	Black very soft, very carbonaceous mudstone
15.0 - 15.5	Black very soft, very carbonaceous mudstone
15.5 - 16.0	Black very soft, very carbonaceous mudstone, thin limestone or ash band
16.0 - 16.5	Black very soft, very carbonaceous mudstone, thicker harder bands of ash?
16.5 - 17.0	Black very soft, very carbonaceous mudstone, thick hard siliceous bands of ash?
17.0 - 17.5	Black very soft, very carbonaceous mudstone, fewer hard bands
17.5 - 18.0	Black very carbonaceous mudstone
18.0 - 18.5	Black very carbonaceous mudstone
18.5 - 19.0	Black very carbonaceous mudstone, some hard fragments
19.0 - 19.5	Black soft, very carbonaceous mudstone
19.5 - 20.0	Black very carbonaceous mudstone, hard siliceous bands
20.0 - 20.5	Black very carbonaceous mudstone
20.5 - 21.0	Black very carbonaceous mudstone, some hard bands
21.0 - 21.5	Black very carbonaceous mudstone
21.5 - 22.0	Black very carbonaceous mudstone, odd hard bands
22.0 - 22.5	Black very carbonaceous mudstone, calcareous hard bands
22.5 - 23.0	Black very soft, very carbonaceous mudstone

23.0 - 23.5	Black very soft, very carbonaceous mudstone
23.5 - 24.0	Black soft, very carbonaceous mudstone
24.0 - 24.5	Black soft, very carbonaceous mudstone
24.5 - 25.0	Black soft, very carbonaceous mudstone
25.0 - 25.5	Black soft, very carbonaceous mudstone
25.5 - 26.0	Black soft, very carbonaceous mudstone
26.0 - 26.5	Black soft, very carbonaceous mudstone
26.5 - 27.0	Black very soft, very carbonaceous mudstone
27.0 - 27.5	Black very carbonaceous mudstone, some hard ashy bands
27.5 - 28.0	Black very carbonaceous mudstone, thin hard bands with white veining
28.0 - 28.5	Black very carbonaceous mudstone, some hard fragments
28.5 - 29.0	Black soft, very carbonaceous mudstone
29.0 - 29.5	Black soft, very carbonaceous mudstone, some hard bands
29.50 - 29.65	Dark grey carbonaceous shaley mudstone with specks of white barytes, elongate pyrite nodule

Black carbonaceous mudstones with some fine-grained sandstone

29.65 - 29.77	Sandy dark grey mudstone with some white fine-grained sandstone stringers, white barytes specks on bedding planes
---------------	---

Black carbonaceous mudstones

29.77 - 29.90	Black very carbonaceous mudstones, some white barytes speckles on bedding planes
29.90 - 30.40	No core
30.40 - 30.55	Black carbonaceous shaley mudstones with white barytes speckles on bedding planes. Hard dark green siliceous nodule/ash band at 30.66m
30.55 - 30.90	Blocky to shaley black carbonaceous mudstone with white barytes speckles on bedding planes
30.90 - 31.00	Crushed black carbonaceous mudstone
31.00 - 31.24	Black very compact shiney mudstone, looks baked with much iron pyrite along bedding planes, similar to ash deposits, area of fault zone affected by hot gases from nearby igneous body??
31.24 - 31.42	Very dense, slightly baked carbonaceous mudstone with much iron pyrite along bedding planes

Black carbonaceous mudstones with some fine-grained sandstones

31.42 - 31.66	Black sandy, carbonaceous mudstone with light grey fine-grained sandstone stringers, some small scale cross-bedding above slump bedding. No pyrite, no evidence of baking. Pyrite rich siliceous nodule at 31.60m
---------------	---

Black carbonaceous mudstones

31.66 - 31.78	Black carbonaceous shaley to splintery mudstones, some fine-grained pyrite crystals on bedding planes
31.78 - 31.82	Thinly bedded sandy black carbonaceous mudstones
31.82 - 31.86	Earthy black carbonaceous mudstone

Lithological Log: BGS44

Soil/ferricrete horizon

0.0 - 0.5	Brown 7.5Y4/2 to strong brown 7.5YR5/6 sand fine-grained soil
0.5 - 1.0	Strong brown 7.5YR5/8 silty fine-grained sand with iron oxide nodules
1.0 - 1.5	Dusky red 10R3/2 iron oxide nodules
1.5 - 2.0	Dusky red 10R3/2 iron oxide nodules, black manganese nodules and mottled red 10R4/8, strong brown 7.5YR5/8 and light greenish grey clay
2.0 - 2.5	Dusky red 10R3/2 iron oxide nodules, black manganese nodules and mottled red 10R4/8, strong brown 7.5YR5/8 and light greenish grey clay, with increased manganese nodules

Clayey very weathered horizon

2.5 - 3.0	Red 2.5YR5/6 clay
3.0 - 3.5	Sticky red 2.5YR5/6 clay
3.5 - 4.0	Mottled light grey 7N and brownish yellow 10YR6/8 clays
4.0 - 4.5	Mottled light grey 7N and brownish yellow 10YR6/8 clays with fragments of light olive grey 5Y6/2 weathered rock

Weathered baked quartzite

4.5 - 5.0	Hard grey silcrete with angular fragments
5.0 - 5.5	Hard grey silcrete with yellowish brown 10YR5/6 weathered zone
5.5 - 6.0	Baked fine- to medium-grained very hard quartzite with dolerite and some vein material

Dolerite

6.0 - 6.5	Dark grey/black meta-quartzite/contact with dolerite, some vein material
6.5 - 7.0	Dark black green fine-grained dolerite with white vein material and orange brown weathering
7.0 - 7.5	Dark black green fine-grained dolerite, some orange brown fragments
7.5 - 8.0	Hard dark brown/black fine-grained dolerite with orange brown weathered layers
8.0 - 8.5	Hard dark brown black fine-grained dolerite
8.5 - 9.0	Contact zone between dark greenish grey fine-grained dolerite and very weathered and baked sandstone and mudstone, much orange brown iron staining

Weathered baked mudstones with thin fine-grained sandstones

9.0 - 9.5	Baked and weathered thin sandstones and mudstones with much iron staining
9.5 - 10.0	Baked and weathered thin sandstones and mudstones with much iron staining
10.0 - 10.5	Weathered grey to dark grey mudstone with fine-grained sandstone partings, weathered orange along thin sandstone bands

Weathered black carbonaceous mudstones

10.5 - 11.0	Dark grey to black weathered mudstones with orange partings
11.0 - 11.5	Very dark greyish brown 2.5Y3/2 slightly weathered soft and black carbonaceous shaley mudstone with orange brown partings

Black carbonaceous mudstones

11.5 - 12.0	Black very carbonaceous mudstone, slightly weathered
12.0 - 12.5	Black very carbonaceous mudstone
12.5 - 13.0	Black very carbonaceous mudstone
13.0 - 13.5	Black very carbonaceous mudstone
13.5 - 14.0	Dark grey to black carbonaceous mudstone
14.0 - 14.5	Dark grey muddy fine grained sandstone
14.5 - 15.0	Black very carbonaceous mudstone
15.0 - 15.5	Black very carbonaceous mudstone
15.5 - 16.0	Black very carbonaceous mudstone
16.0 - 16.5	Black very carbonaceous mudstone
16.5 - 17.0	Black very carbonaceous mudstone, with thin sandstones
17.0 - 17.5	Black very carbonaceous mudstone
17.5 - 18.0	Black very carbonaceous mudstone
18.0 - 18.5	Black very carbonaceous mudstone
18.5 - 19.0	Black very carbonaceous mudstone
19.0 - 19.5	Black very carbonaceous mudstone
19.5 - 20.0	Black very carbonaceous mudstone

20.0 - 20.5	Very soft black very carbonaceous mudstone then hard band at 20.3-20.5, more water
20.5 - 21.0	Black very carbonaceous mudstone
21.0 - 21.5	Black very carbonaceous mudstone
Black carbonaceous mudstones with fine-grained sandstones	
21.5 - 22.0	Black very carbonaceous mudstone, with thin white to light grey sandstone bands
22.0 - 22.5	Black very carbonaceous mudstone, with thin hard grey sandstone bands
22.5 - 23.0	Black very carbonaceous mudstone, with thin white sandstone stringers and hard grey sandstone bands
Black carbonaceous mudstones	
23.0 - 23.5	Black very carbonaceous mudstone
23.5 - 24.0	Black very carbonaceous mudstone
24.0 - 24.5	Black very carbonaceous mudstone
24.5 - 25.0	Black very carbonaceous mudstone
25.0 - 25.5	Black very carbonaceous mudstone
25.5 - 26.0	Black very carbonaceous mudstone
Black carbonaceous mudstones with fine-grained sandstones	
26.0 - 26.5	Black very carbonaceous mudstone, with thin sandstone bands
26.5 - 27.0	Black very carbonaceous mudstone
27.0 - 27.5	Black very carbonaceous mudstone, with thin sandstone bands
27.5 - 28.0	Black very carbonaceous mudstone
28.0 - 28.5	Black very carbonaceous mudstone, with thin sandstone bands
Black carbonaceous mudstones	
28.5 - 29.0	Black very carbonaceous mudstone
29.0 - 29.5	Black very carbonaceous mudstone
29.50 - 30.20	Black finely bedded shaley very carbonaceous mudstone, no fossils, clear crystal of baryte at 30.20
30.20 - 30.25	Fawn grey fine-grained silty siliceous nodule, irregular rounded shape, with iron pyrite
	core, set in mudstone
30.25 - 30.60	Black finely bedded shaley very carbonaceous mudstone, no fossils, sandy nodule at 30.50m
30.60 - 30.65	Black finely bedded carbonaceous mudstone, some thin light greenish grey fine-grained sandstone stringers
30.65 - 31.10	Black fine-grained finely bedded shaley very carbonaceous mudstone
31.10 - 31.35	Black fine-grained finely bedded shaley very carbonaceous mudstones with thin grey green sandstone stringers
31.35 - 31.60	Black fine-grained finely bedded shaley very carbonaceous mudstone, no fossils, some baryte at 31.60m
31.60 - 31.98	Black fine-grained finely bedded shaley very carbonaceous mudstone with fine-grained hard grey green siliceous nodule at 31.84m
Black carbonaceous mudstones with fine-grained sandstones	
31.98 - 32.00	Ashy black very fine-grained and very carbonaceous mudstone layer with a siliceous horizon with crystals of barytes within vertical cracks. Blebs of fine-grained greenish grey sandstone within mudstone above.

Lithological Log: BGS45

Soil/ferricrete horizon

0.0 - 0.5	Brown 7.5YR5/2 fine-grained soil some nodules of black manganese oxide and strong brown 7.5YR5/8 iron oxide
0.5 - 1.0	Black manganese oxide nodules with red 10R5/8 ferric oxide rims
1.0 - 1.5	Large nodules of black manganese oxide with red 10R4/8 haematite rims and passing downward into mottled light grey and red clays

Clayey very weathered horizon

1.5 - 2.0	Mottled red 10R4/8, light grey and strong brown 7.5YR5/8 clays
2.0 - 2.5	Mottled pale yellow 5Y8/2, 5Y7/1 light grey and reddish yellow 7.5YR6/8 clays
2.5 - 3.0	Mottled light grey 5Y7/1 and reddish yellow 7.5YR6/6 clays

Weathered clayey fine-grained sand

3.0 - 3.5	Mottled yellowish brown 10YR5/6 and light brownish grey 10YR6/2 with black manganese spots clayey fine-grained sand
3.5 - 4.0	Mottled light yellowish brown 2.5Y6/3 and pale yellow 2.5Y8/2 clayey sand with black manganese oxide spots
4.0 - 4.5	Grey 5Y6/1 clay and yellowish brown 10YR5/8 mottled clayey fine-grained sand
4.5 - 5.0	Damp mottled yellowish brown 10YR5/6-8 clayey fine-grained sand and pale yellow 5Y7/4 to light olive grey 5Y6/2 clay
5.0 - 5.5	Damp mottled yellowish brown 10YR5/6 clayey fine-grained sand and grey 10YR5/1 clay with black manganiferous spots
5.5 - 6.0	Yellowish brown 10YR5/6 clayey fine-grained sand
6.0 - 6.5	Olive grey 5Y5/2 and yellowish brown 10YR5/6 mottled clayey fine-grained sand with black manganiferous spots
6.5 - 7.0	Greyish green 5/5G chlorite rich clayey silt
7.0 - 7.5	Greenish grey 5/10YG and dark yellowish brown 10YR4/6 mottled clayey fine-grained sand and olive grey 5Y4/2 and dark brown partings

Green chloritic very weathered ashy mudstone

7.5 - 8.0	Pale yellow 5Y7/4 weathered ash with pale green 7/5G chlorite rich thin layers
-----------	--

Very weathered ashy mudstone

8.0 - 8.5	Light yellow brown 2.5Y6/4 weathered ash with 10YR6/8 brownish yellow partings
8.5 - 9.0	Light greenish grey 7/5GY weathered ash with orange and black brown partings
9.0 - 9.5	Pale olive 5Y6/3-4 weathered ash with orange partings, brownish yellow 10YR6/8 and light yellowish brown 2.5Y6/4 ash
9.5 - 10.0	Olive grey 5Y5/2 weathered ash with brownish yellow 10YR6/8 partings
10.0 - 10.5	Light yellowish brown 2.5Y5/3 weathered ash with brown, orange and black partings
10.5 - 11.0	Damp pale olive 5Y6/3 weathered ash with orange and brown/black partings
11.0 - 11.5	Grey 5Y5/1 ash with orange brown partings, little water

Weathered ashy mudstone

11.5 - 12.0	Light grey 5Y7/2 weathered ash with orange brown weathered partings
12.0 - 12.5	Light olive grey 5Y6/2 slightly weathered ash with orange brown partings
12.5 - 13.0	Light greenish grey 7/10Y thinly bedded ash
13.0 - 13.5	Light grey 7/N thinly laminated ash with dark grey square section spots
13.5 - 14.0	Blueish grey 6/10B thinly laminated ash with square section dark grey spots
14.0 - 14.5	Blueish grey 6/10B thinly laminated ash with square section dark grey spots

Pyritic ashy mudstone

14.50 - 15.10	Light grey compact ash, subvertical and near horizontal fractures with iron pyrite linings
15.10 - 15.58	Grey water lain fine-grained ash deposit, few fractures
15.58 - 16.37	Compact light grey to grey water lain fine-grained ash, some pyrite lined horizontal cracks at 15.60 and 16.12m, some variations in mafic content, little change in grain size. Vertical to subvertical crack at 16.25 to 16.37m
16.37 - 16.52	Water lain light grey to grey fine grained ash with greenish chlorite rich badly fractured horizon with much pyrite
16.52 - 16.69	Light grey to grey water lain fine-grained ash some prominent subvertical pyrite lined cracks

16.69 - 16.90	Dark grey compact, parallel layered ash, flaser structures at base, shallow water lain
17.00 - 17.30	Grey to dark grey ash deposits? with much pyrite on bedding planes

Baked ashy mudstone

17.30 - 17.44	Fine-grained light grey baked ash, much fractured with iron pyrite in fractures and along bedding planes
---------------	--

Dolerite

17.44 - 18.53	Fine- to medium-grained black to dark green hard compact dolerite
---------------	---

Baked mudstone

18.53 - 18.70	Light grey to grey baked mudstone with several horizontal white veined cracks, very light grey baked material 18.53-18.55
---------------	---

Sandy brittle black carbonaceous mudstones

18.55 - 18.83	Grey to dark grey sandy mudstone
18.83 - 19.03	Compact well bedded fine-grained mudstone
19.03 - 19.57	Black carbonaceous shaley brittle mudstone with much pyrite
19.57 - 19.595	Thin white veins of zeolite within baked mudstone horizon

Dolerite

19.595 - 19.635	Fine-grained dark black-green dolerite
-----------------	--

Baked black carbonaceous mudstone

19.635 - 19.65	Thin white veins of zeolite within baked mudstone horizon
19.65 - 19.70	Dark grey black carbonaceous mudstone with much pyrite

Lithological Log: BGS46

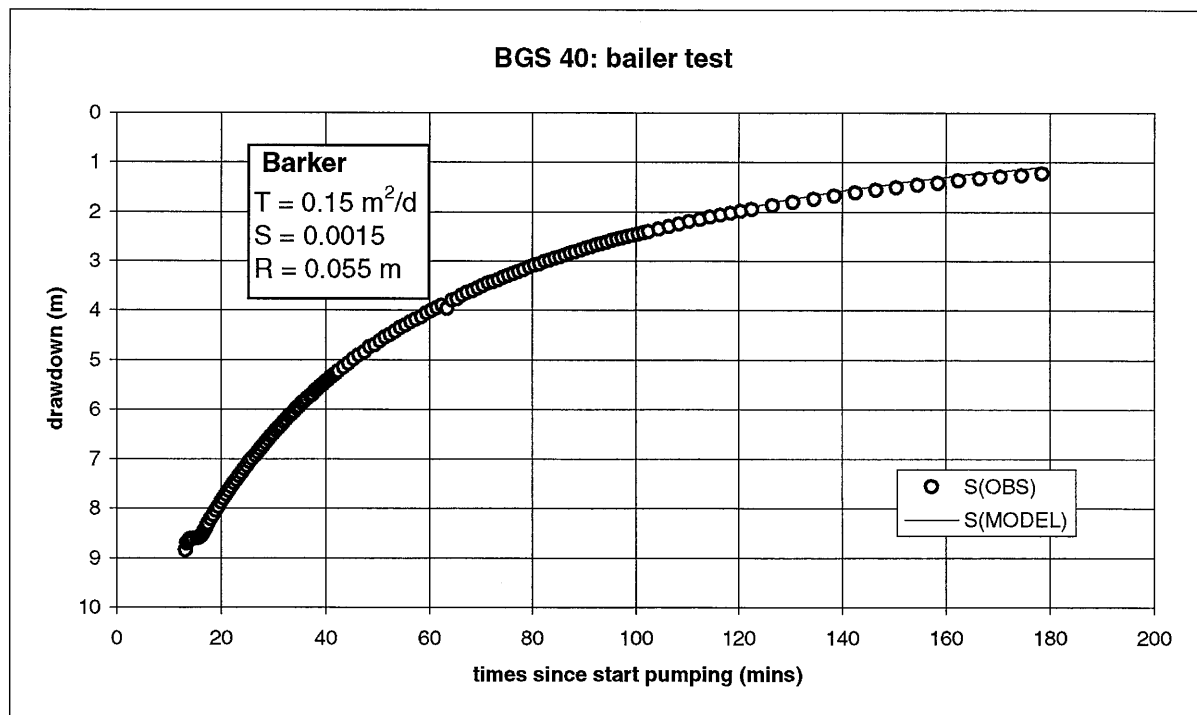
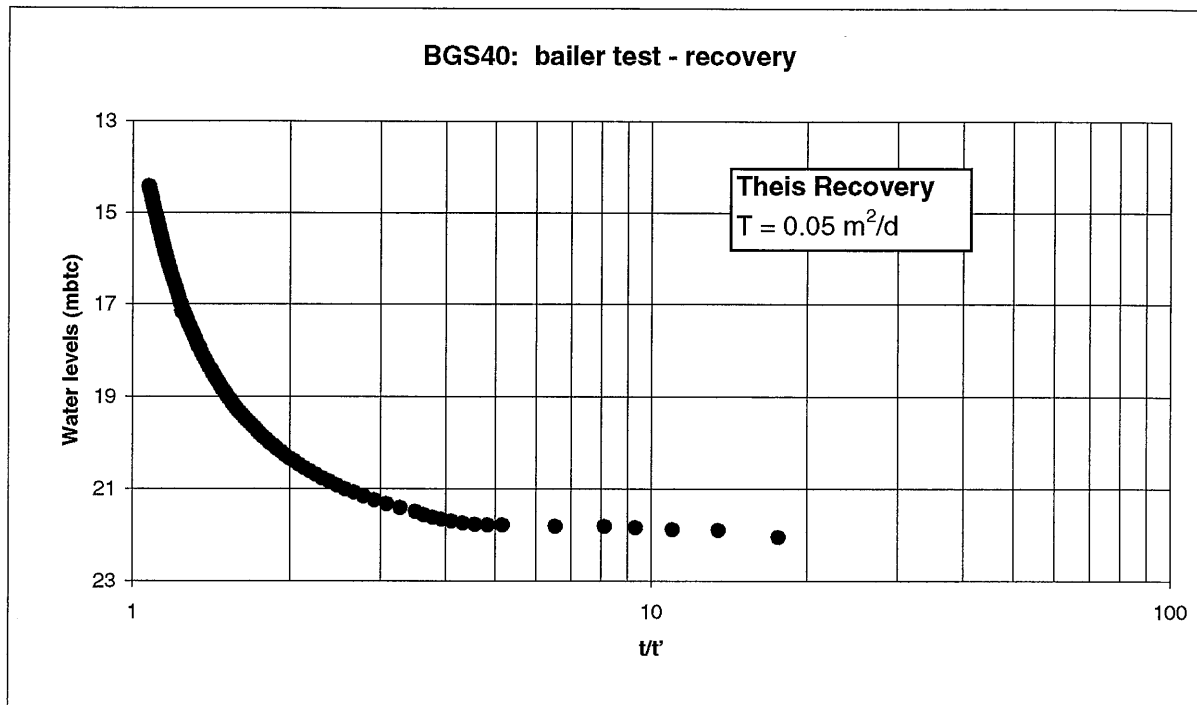
Soil horizon	
0.0 - 0.5	Dark grey 7.5YR4/1 soft fine-grained clayey soil
Clayey very weathered horizon	
0.5 - 1.0	Light brown fine-grained silty loose clay
1.0 - 1.5	Light brown fine-grained silty loose clay
1.5 - 2.0	Yellow brown silty soft clay
2.0 - 2.5	Yellow brown silty soft clay
Very weathered doleritic sand	
2.5 - 3.0	Dark yellowish brown 10YR4/4 silty fine-grained sand of weathered dolerite
3.0 - 3.5	Dark yellowish brown 10YR4/4 silty fine-grained sand of weathered dolerite
3.5 - 4.0	Dark yellowish brown 10YR4/4 silty fine-grained sand of weathered dolerite
4.0 - 4.5	Dark yellowish brown 10YR4/4 silty fine-grained sand of weathered dolerite
4.5 - 5.0	Dark yellowish brown 10YR4/4 silty fine-grained sand of weathered dolerite
Weathered medium-grained doleritic sand	
5.0 - 5.5	Dark yellowish brown 10YR4/4 silty fine- to medium-grained sand of weathered dolerite
5.5 - 6.0	Dark yellowish brown 10YR4/4 silty fine- to medium-grained sand of weathered dolerite
6.0 - 6.5	Dark yellowish brown 10YR4/4 silty fine- to medium-grained sand of weathered dolerite
Weathered coarse-grained dolerite	
6.5 - 7.0	Dark yellowish brown 10YR4/4 silty fine- to coarse-grained sand of weathered and dark green black fresh dolerite, some white zeolite fragments
7.0 - 7.5	Dark yellowish brown 10YR4/4 silty fine- to coarse-grained sand of weathered and dark green black fresh dolerite, some white zeolite fragments
7.5 - 8.0	Dark yellowish brown 10YR4/4 silty fine- to coarse-grained sand of weathered and dark green black fresh dolerite, some white zeolite fragments
Hard zeolitic dolerite	
8.0 - 8.5	Olive brown 2.5Y4/4 silty fine- to coarse-grained sand of weathered and dark green black fresh dolerite, some white zeolite fragments
8.5 - 9.0	Olive brown 2.5Y4/4 silty fine- to coarse-grained sand and gravel of weathered and dark green black fresh dolerite, some white zeolite fragments
9.0 - 9.5	Olive brown 2.5Y4/4 silty fine- to coarse-grained sand and gravel of weathered and dark green black fresh dolerite, some white zeolite fragments
9.5 - 10.0	Dark green black dolerite and grey to dark greyish brown 2.5Y4/2 hard baked siltstone - contact zone
Hard baked silty mudstones	
10.0 - 10.5	Dark green black dolerite and dark grey 2.5Y4/1 hard baked siltstone - contact zone
10.5 - 11.0	Hard chips of and dark grey 2.5Y4/1 hard baked mudstone
11.0 - 11.5	Hard dark grey 2.5Y4/1 hard baked mudstone and grey siltstone
11.5 - 12.0	Baked reddish dark grey to dark grey hard mudstone
12.0 - 12.5	Hard fine grained fragments of green/black dolerite and brownish dark grey baked mudstone
Muddy fine-grained hard baked sandstones	
12.5 - 13.0	Hard baked fine-grained dark grey muddy sandstone
13.0 - 13.5	Hard splintery dark grey baked mudstone and dark grey medium-grained quartzites
Baked black chloritic carbonaceous mudstones	
13.5 - 14.0	Fairly baked splintery black carbonaceous mudstone with some green chlorite
Black sandy carbonaceous mudstones	
14.0 - 14.5	Hard splintery black carbonaceous mudstone and sandy mudstone, brown partings with some green chlorite
14.5 - 15.0	Splintery black carbonaceous mudstone and sandy mudstone, brown partings
Black carbonaceous mudstones	
15.0 - 15.5	Hard compact black carbonaceous mudstone
15.5 - 16.0	Hard compact black carbonaceous mudstone

16.0 - 16.5	Hard compact black carbonaceous mudstone
16.5 - 17.0	Hard compact black carbonaceous mudstone, much iron pyrite and brown partings
17.0 - 17.5	Soft black carbonaceous mudstone, some iron pyrite
17.5 - 18.0	Splintery black carbonaceous mudstone some iron pyrite
18.0 - 18.5	Splintery black carbonaceous mudstone some iron pyrite
18.5 - 19.0	Splintery black carbonaceous mudstone some iron pyrite
19.0 - 19.5	Black carbonaceous mudstones much iron pyrite
19.5 - 20.0	Black carbonaceous mudstones
20.0 - 20.5	Black carbonaceous mudstones some iron pyrite
20.5 - 21.0	Splintery black carbonaceous mudstone
21.0 - 21.5	Splintery black carbonaceous mudstone
21.5 - 22.0	Splintery black carbonaceous mudstone
22.0 - 22.5	Splintery black carbonaceous mudstone
22.5 - 23.0	Black carbonaceous mudstones
23.0 - 23.5	Black carbonaceous mudstone with sandstone bands
23.5 - 24.0	Soft black very carbonaceous mudstones
24.0 - 24.5	Soft black very carbonaceous mudstones
24.5 - 25.0	Soft black very carbonaceous mudstones
25.0 - 25.5	Soft black very carbonaceous mudstones
25.5 - 26.0	Soft black very carbonaceous mudstones
26.0 - 26.5	Soft black very carbonaceous mudstones
26.5 - 27.0	Soft black very carbonaceous mudstones
27.0 - 27.5	Soft black very carbonaceous mudstones
27.5 - 28.0	Soft black very carbonaceous mudstones
28.0 - 28.5	Soft black very carbonaceous mudstones
28.5 - 29.0	Soft black very carbonaceous mudstones
29.0 - 29.5	Soft black very carbonaceous mudstones
29.5 - 30.0	Soft black very carbonaceous mudstones
30.00 - 30.02	Black carbonaceous mudstones with some shell fragments
Muddy medium- to coarse-grained sandstone	
30.02 - 30.05	Light grey to grey medium to coarse-grained very muddy sandstone, some gravel fragments and shell fragments including Lingulla
Black carbonaceous mudstones	
30.05 - 30.19	Black carbonaceous thinly bedded mudstones
Black carbonaceous mudstones with fine-grained sandstones	
30.19 - 30.24	Black carbonaceous shaley mudstones with light grey/white medium- to fine-grained sandstone stringers
30.24 - 30.88	Black carbonaceous shaley mudstones with intermittent very thin light grey sandstone stringers
Black sandy carbonaceous mudstones	
30.88 - 30.92	Bioturbated black sandy mudstones with horizontal tubules infilled with medium-grained light grey sandstone
Black carbonaceous mudstones	
30.92 - 30.99	Black carbonaceous shaley mudstones, with odd sandstone stringer
Black sandy carbonaceous mudstones	
30.99 - 31.00	Bioturbated black sandy carbonaceous mudstone with horizontal tubules
Black carbonaceous mudstones	
31.00 - 31.19	Black carbonaceous shaley mudstone with intermittent sandstone stringers
31.19 - 31.22	Dark grey brown very fine-grained hard siliceous band
31.22 - 31.57	Black carbonaceous shaley mudstones with thin stringers of light grey fine-grained sand
Muddy medium-grained chloritic sandstones	
31.57 - 31.72	Grey to light grey slump bedded convoluted hard medium-grained sandstone, some green chlorite and iron pyrite, sandstone is muddy in parts
Black carbonaceous mudstones	
31.72 - 32.07	Black carbonaceous shaley mudstones

Annex 4: Pump test data

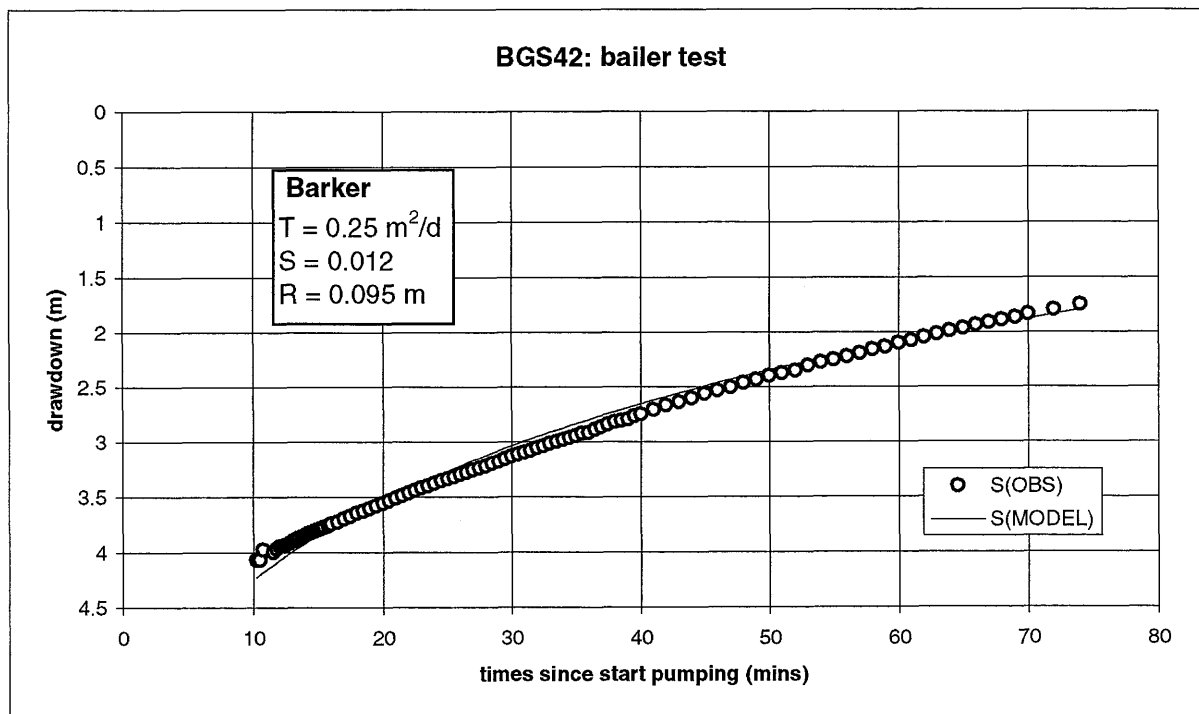
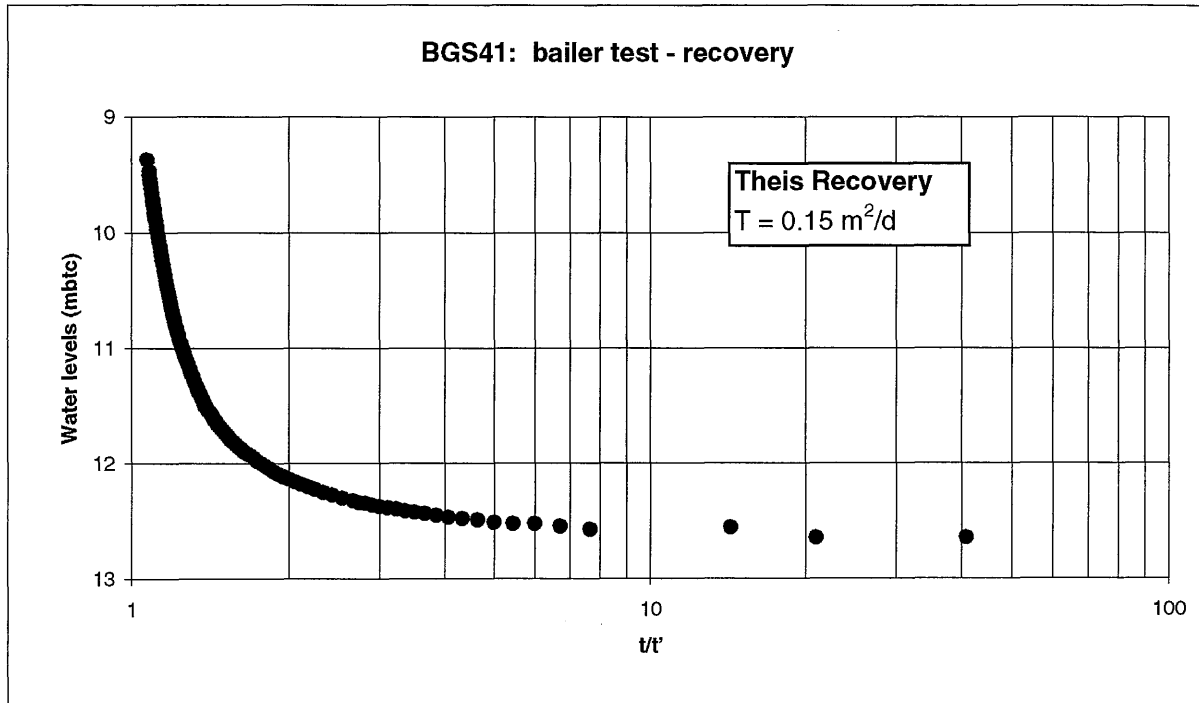
BGS 40: bailer test

GPS: 7 degs 01.204' 8 degs 14.938'
date 29/01/99
casing 0.3 m
rwf: 13.198m btc
20 bails in 12:30 mins
pumping rate = 0.13 l/s = 11.5 m³/d



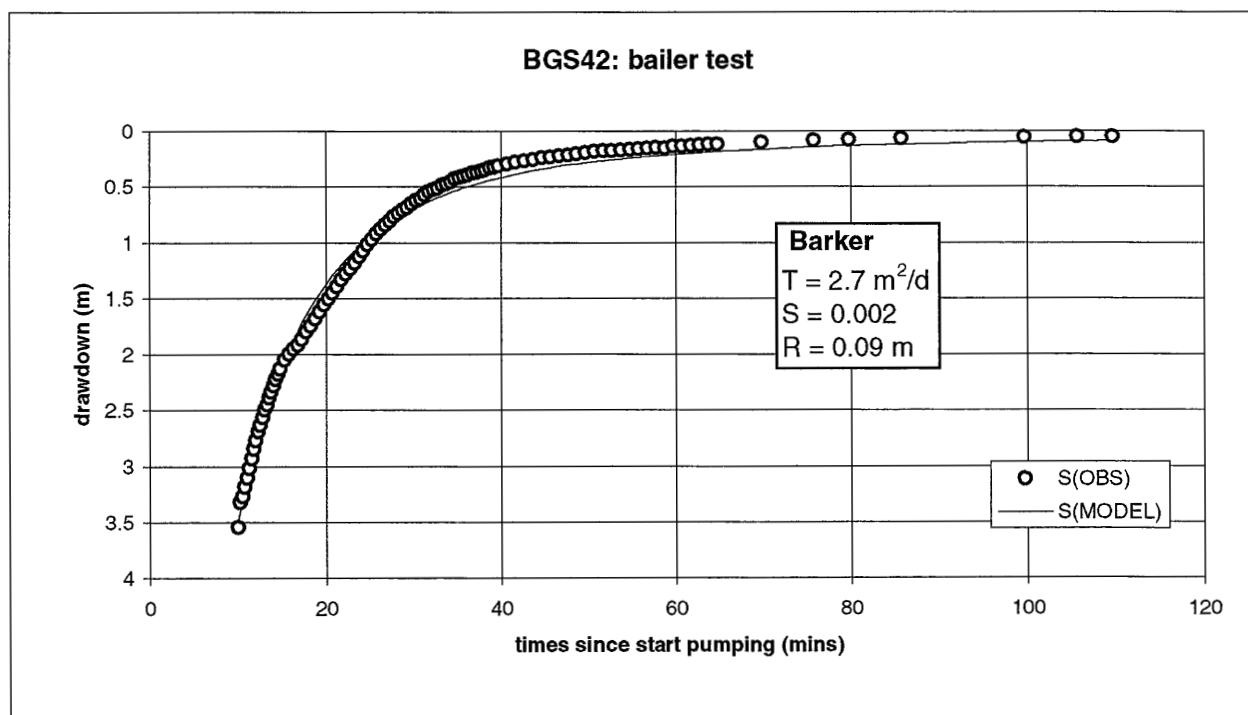
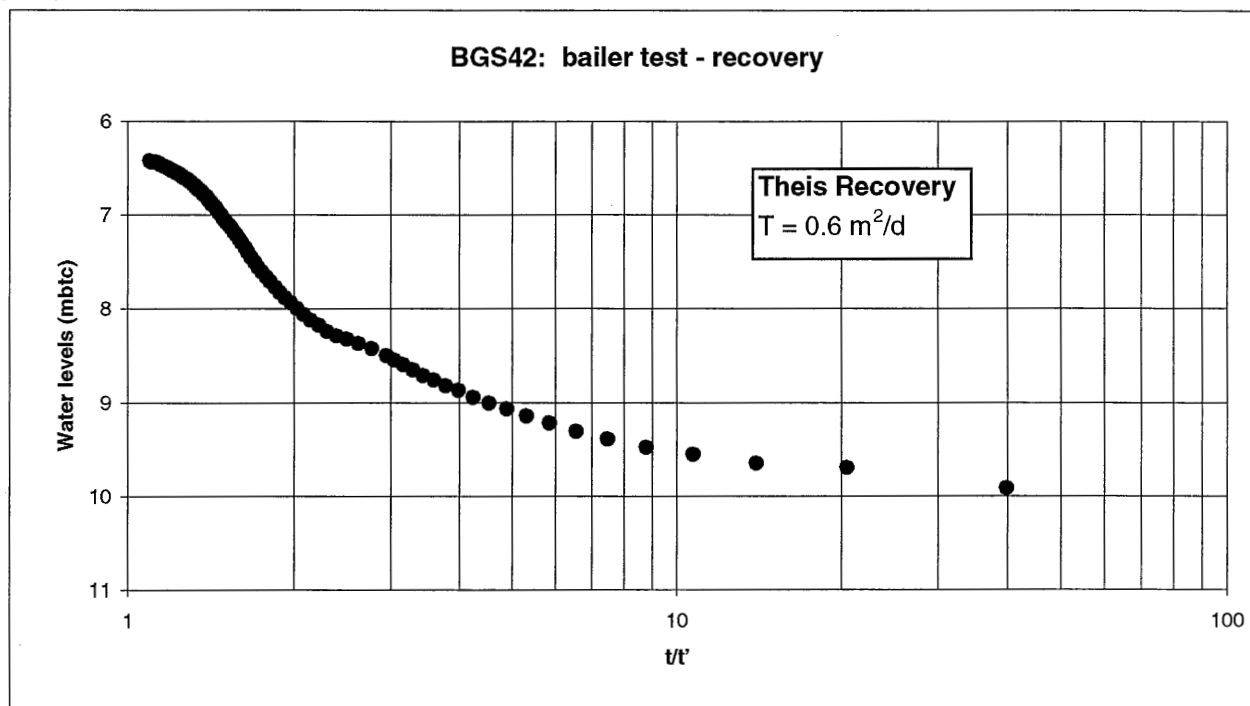
BGS 41: bailer test

GPS: 6 degs 59.809' 8 degs 15.229'
date 29/01/99
casing 0.2 m
rwf: 8.582 mbtc
28 bails in 10 minutes
pumping rate = 0.23 l/s = 20 .2 m3/d



BGS 42: bailer test

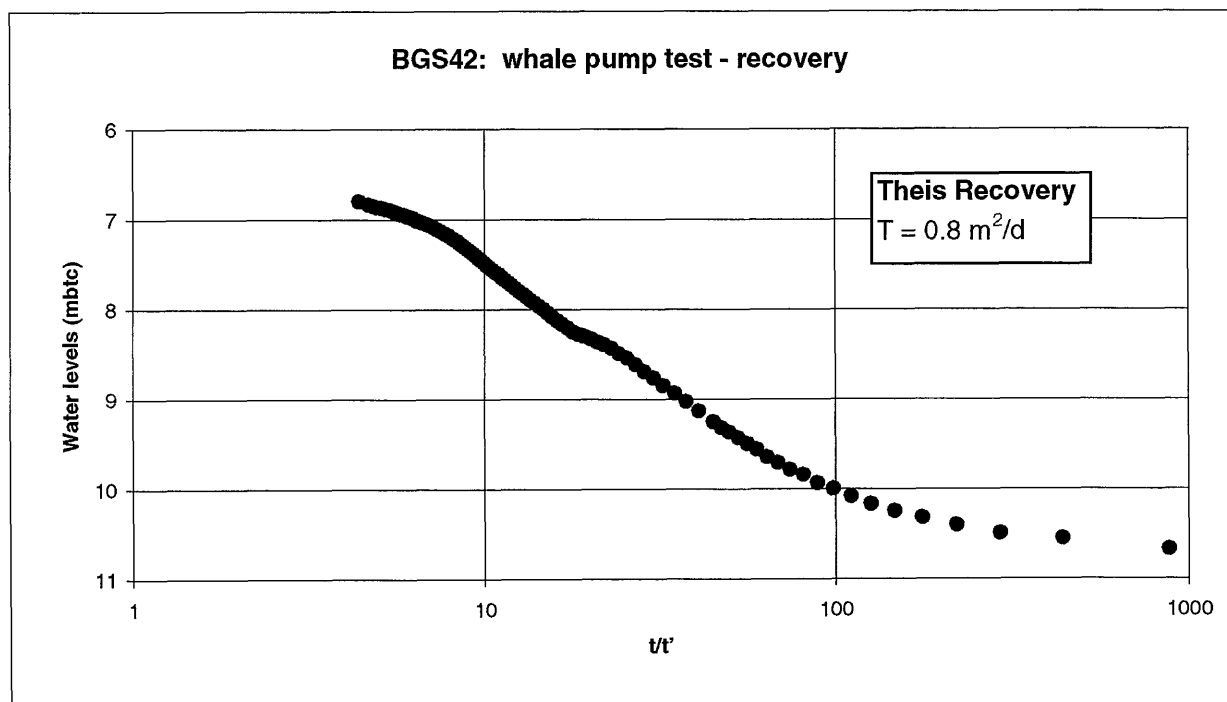
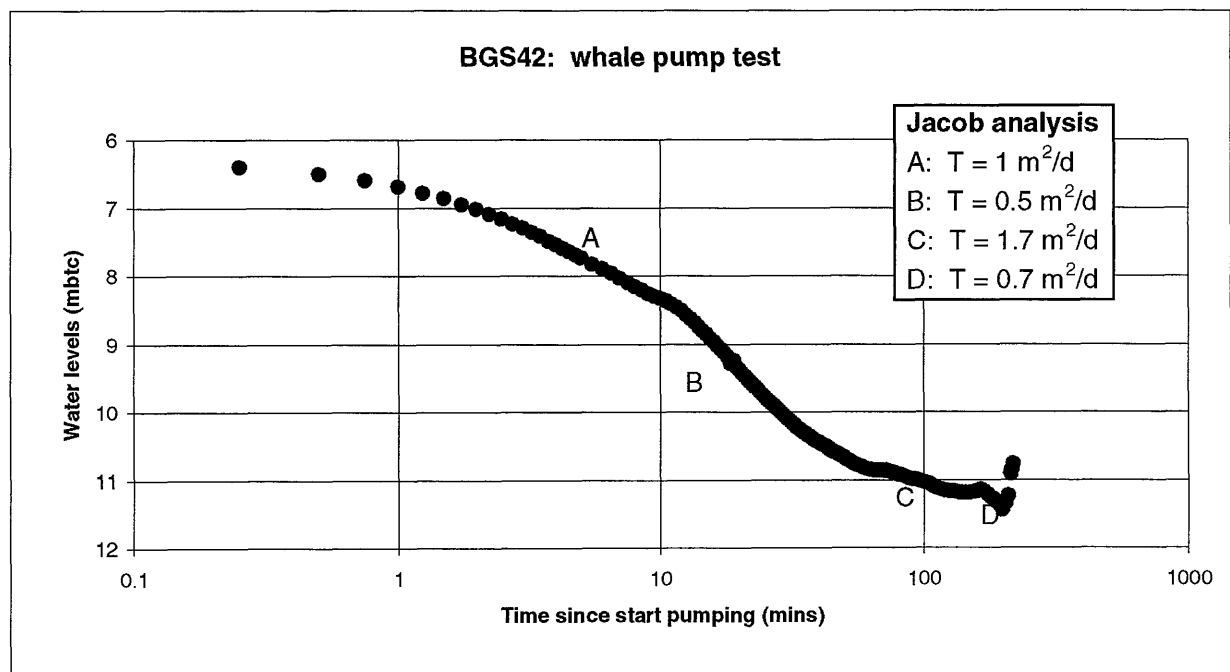
GPS: 6 degs 59.345 8 degs 15.499
date 29/01/99
casing 0.35 m agl
rwf: 6.375 mbtc
34 bails in 9 mins 44 secs
pumping rate = 0.29 l/s



BGS 42: whale pump test

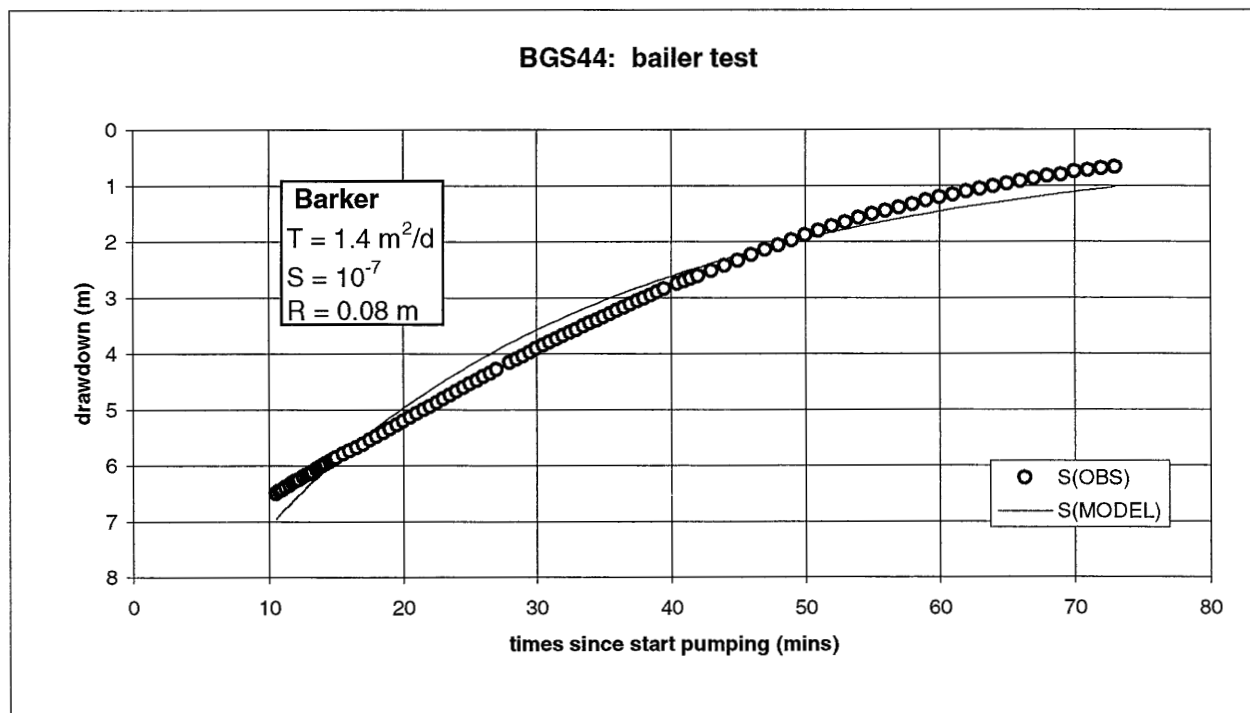
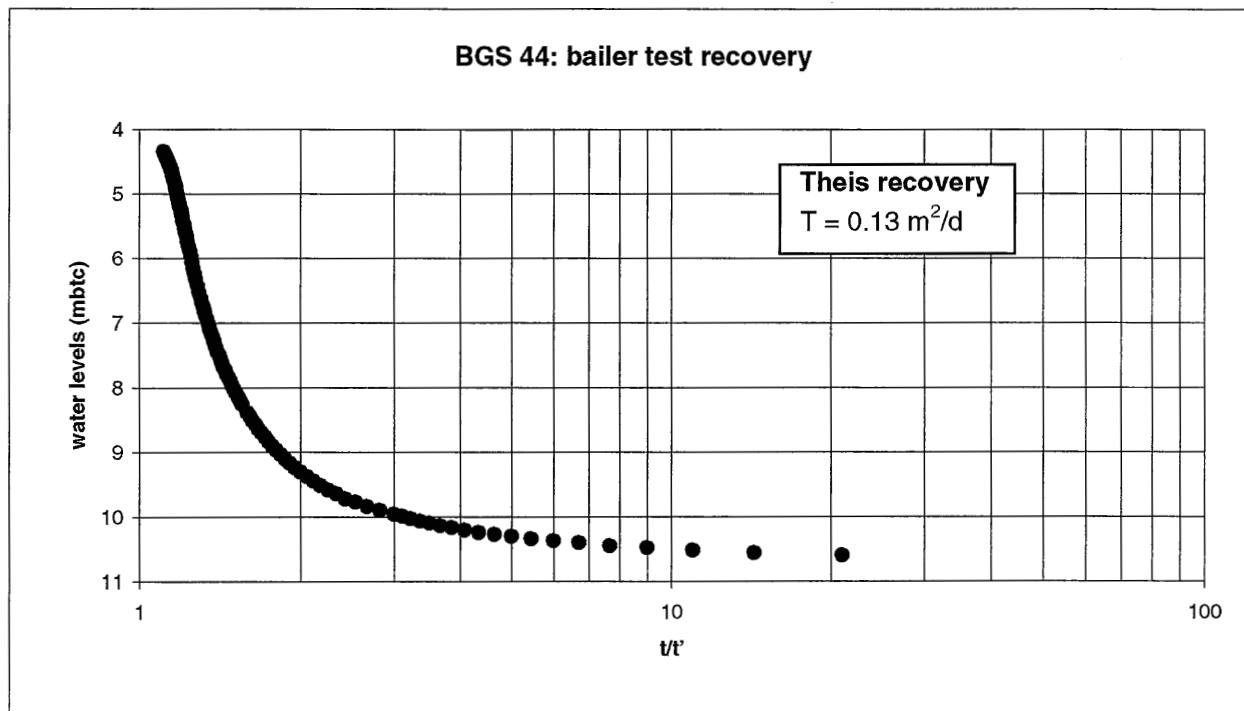
GPS: 6 degs 59.345 8 degs 15.499
30/01/99
casing 0.35 m agl
rwf: 6.26 mbtc
pump at 12.8 m
length of test; 220 minutes
pumping with one whale pump: 0.15 - 0.14 l/s
0.11 l/s from 216-220 minutes

After 10 minutes started drawing in much
black fine silt - cleared slightly after 200 mins



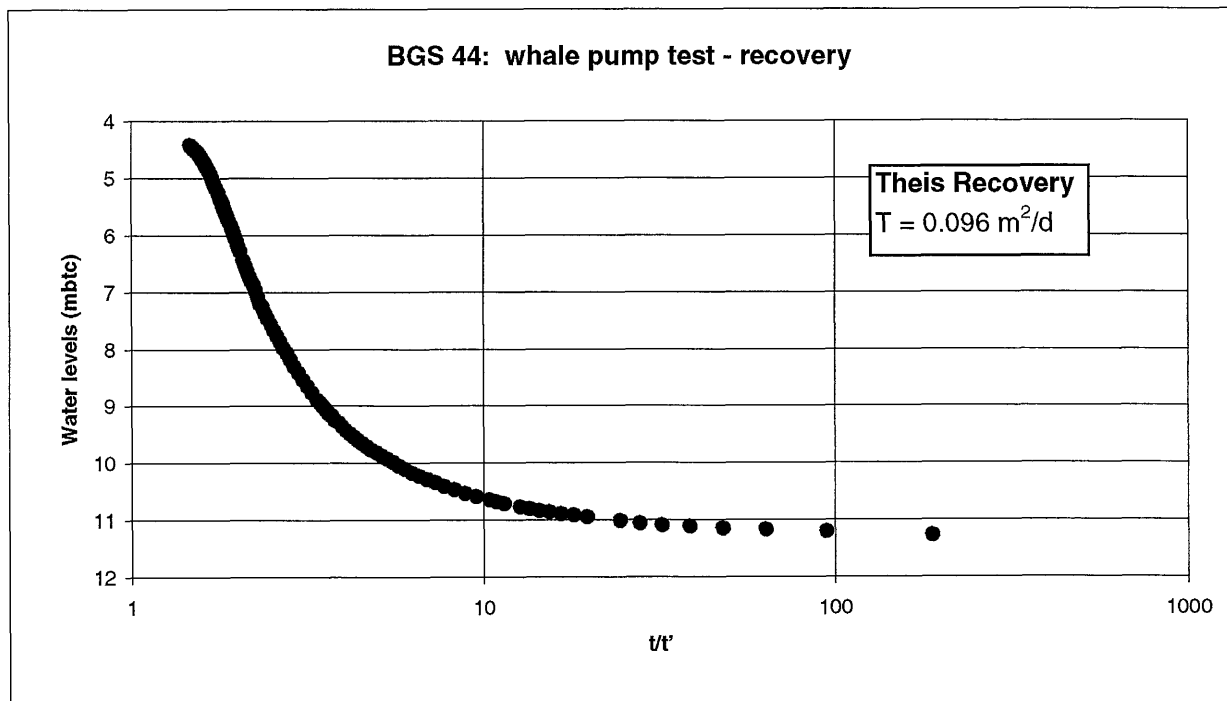
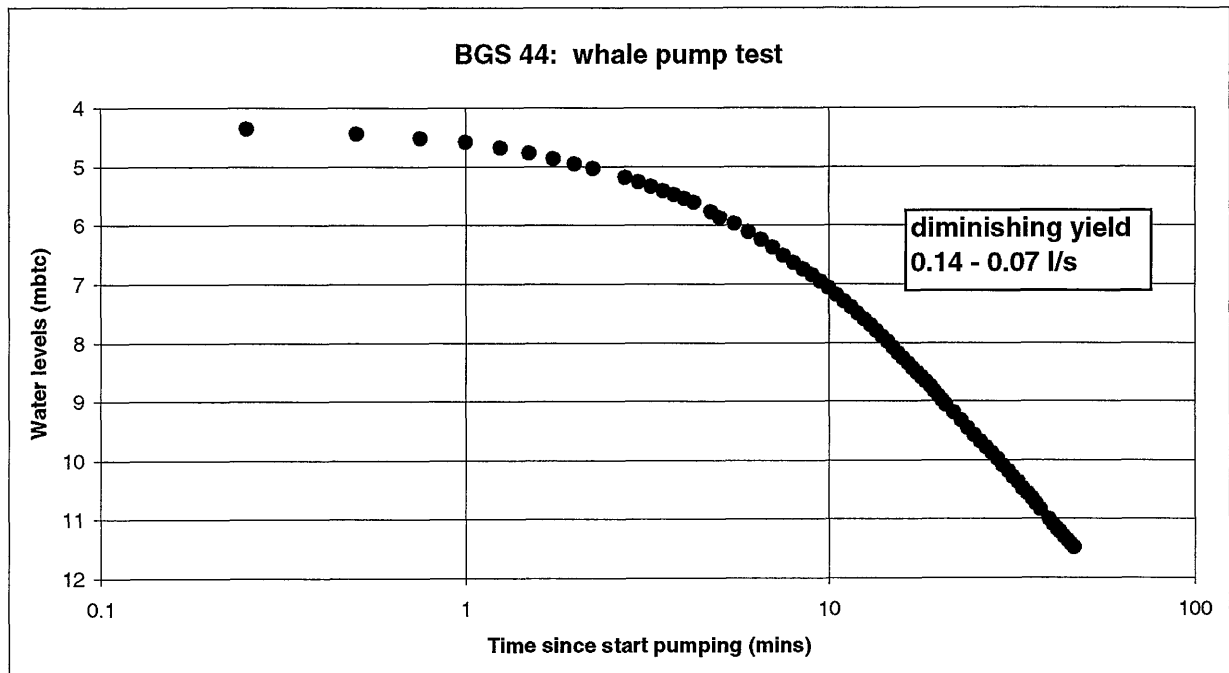
BGS 44: bailer test

GPS: 6 degs 58.539' 8 degs 16.227
date 03/02/99
casing 0'.35 m
rwf: 4.098 mbtc
34 bails in 10 mins
pumping rate = 0.28 l/s - 24.5 m3/d



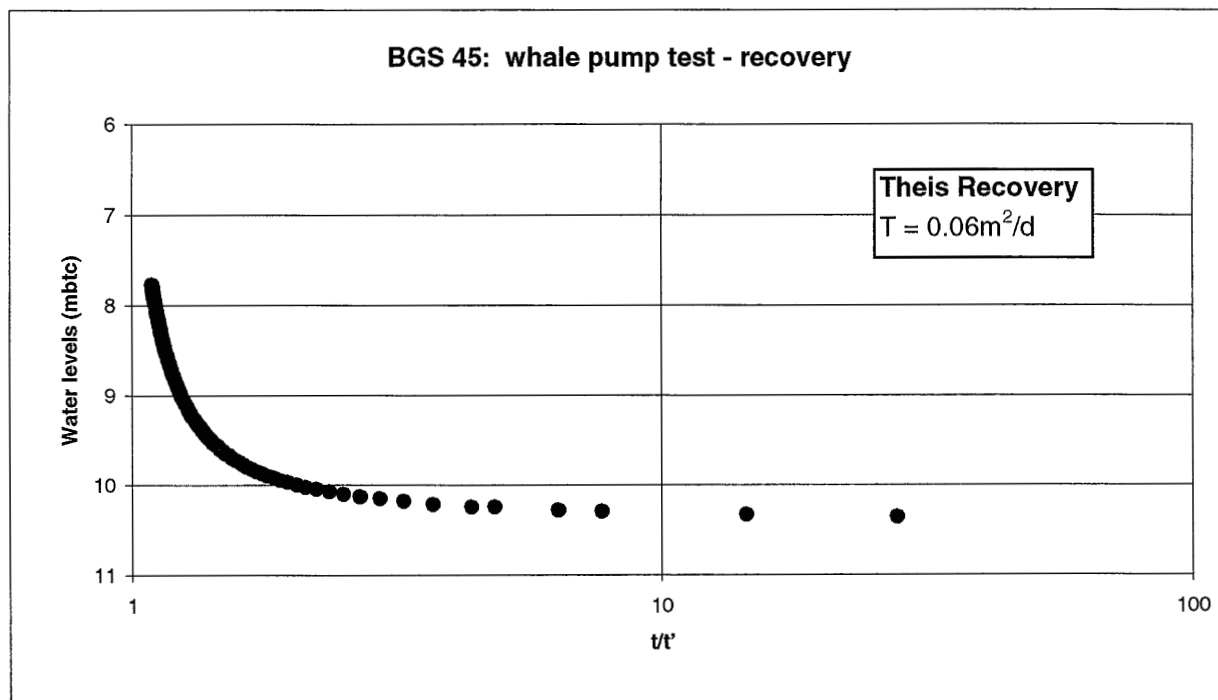
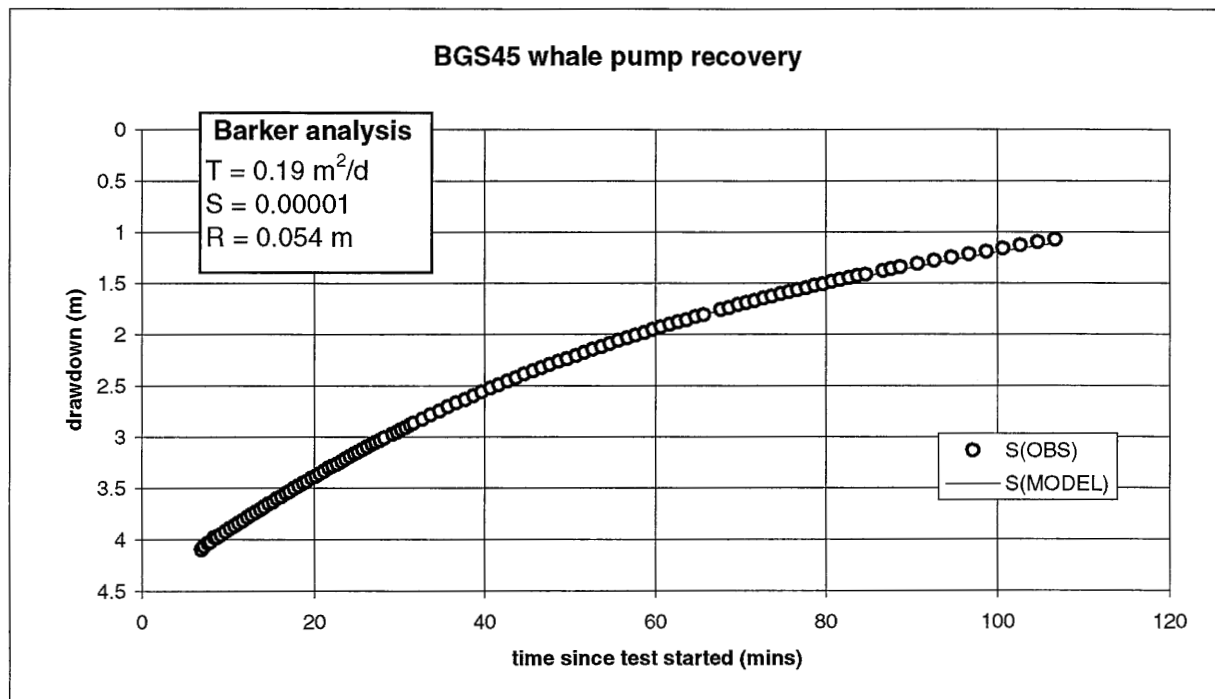
BGS 44: whale pump test

GPS: 6 degs 58.539' 8 degs 16.227
date 03/02/99
casing .35 m
rwf: 4.098 mbtc
pump at 12.5 m
length of test; 47 minutes
pumping with one whale pump: 0.14 - 0.07 l/s
average over test = 0.1 l/s



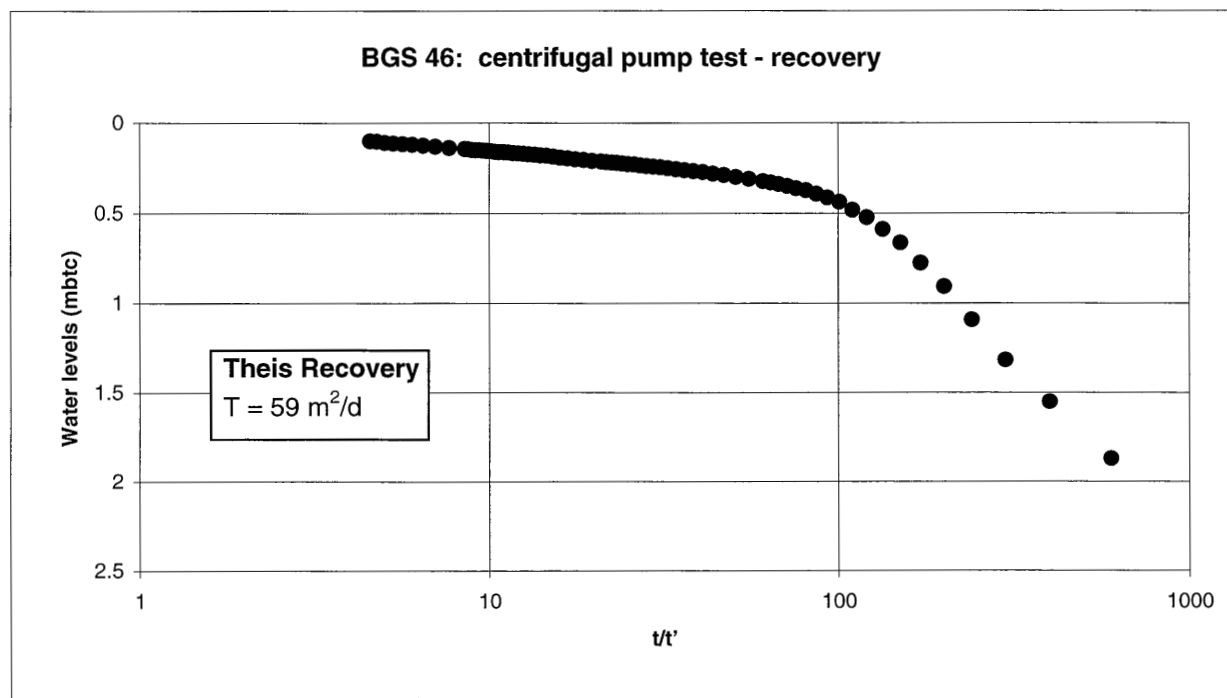
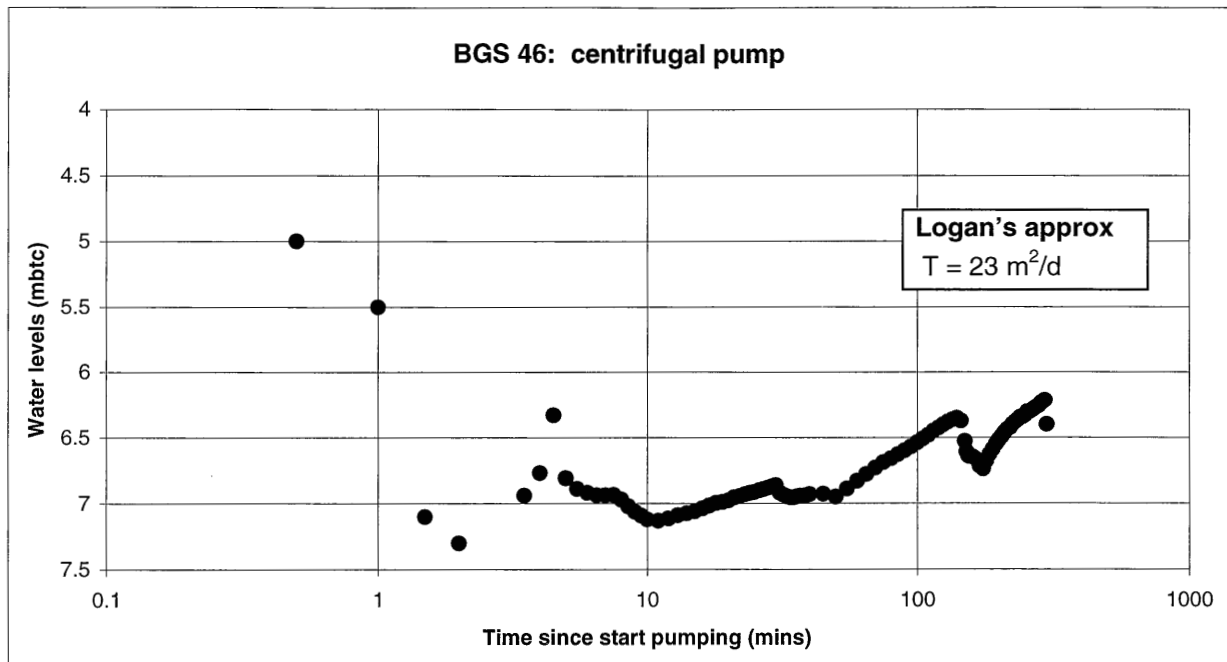
BGS 45: whale pump test

location 10 m from BGS 42
date 05/02/99
depth 10.85 m
rwf: 6.262 m
pump at 10.4 m
length of test; 6:44 minutes
pumping with one whale pump: 0.1 l/s



BGS 46: centrifugal pump test

GPS: 7 degs 842' 8 degs 14.993
date 08/02/99
casing 0.45 m
rwf: 3.798 m
centrifugal pump at 8 m
length of test; 300 minutes
pumping rate = 0.79 - 0.56 l/s
average over test = 0.65 l/s = 56 m³/d



BGS 46: whale pump test

GPS: 7 degs 842' 8 degs 14.993
date 06/02/99
casing 0.45 m
rwf: 3.775 m
pump at 12.5 m
length of test; 141.5 minutes
pumping with two whale pumps: 0.29 - 0.28 l/s
average over test = 0.28 l/s = 24 m³/d

