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

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Basins waiting to be filled during a pumping test at Edumoga.

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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 five separate trips, August-September 1996, November-December 1996, February-March 1997, October-December 1997 and January-April 1998.

EXECUTIVE SUMMARY

Edumoga was chosen as a test site for the Lower Eze-Aku Formation. Field surveys and drilling exercises were conducted during January to March 1998. EM34-3 and resistivity surveys were carried out throughout the area; five boreholes were drilled as a consequence. Chip and core samples were analysed and logged for each borehole, and three boreholes (BGS15, BGS16, BGS17) completed to production borehole standard with screen and casing. Test pumping and water quality analysis were carried out at these three boreholes. The following conclusions can be made from the test site.

- the Lower Eze-Aku Shale comprises mudstone with significant inter-beds of siltstone, fine sandstone and limestone;
- the mudstones are highly weathered in the top 10 m: 3 m of ferruginous soil overlies 2 m of plastic clay which gradually changes to mudstone with depth;
- there is negligible inter-granular porosity or permeability;
- significant groundwater is only found where the mudstone is highly fractured as indicated by the presence of (1) significant vein calcite, with gypsum/barytes; (2) slickensides; (3) iron oxide staining on many bedding and fracture surfaces; and (4) fault breccia (BGS17 only), within borehole chip and core samples.
- fracture zones were clearly identified from the EM34-3 survey as negative or 'noisy' anomalies;
- resistivity surveys identified the ferruginous soil and clay layers, but did not pick up the fracture zones;
- aquifer transmissivity calculated for BGS15, BGS16 and BGS17 were all > 1 m^2/d, which indicates they are appropriate for hand-pumps;
- test pumping identified no boundaries or leakage, but the long term sustainability of the sources was not tested.

1. BACKGROUND INFORMATION

Edumoga was chosen as an appropriate site to assess the hydrogeological characteristics of the Lower Eze-Aku formation. The location of Edumoga is shown in Figure 1. The surrounding countryside is fairly flat with hard ferricrete often exposed in the fields. Although the geology map suggested that Edumoga lay on Makurdi Sandstone, a quick observation of the rocks in the river bed showed the map to be incorrect and that Edumoga is underlain by Eze-Aku strata. The geology of the area is complex. Rocks tend to young in age to the north-west but they have been subjected to a moderate degree of folding locally. In addition the texture of the sediments changes from fine grained, deep-water mudstones to coarser shallow-water deltaic sediments to the north west. The former dominantly mudstones are present within the series of boreholes drilled within the village area while the latter crop out as cyclic deposits of sandstone, limestone and shaley mudstone along the stream section to the west and north of the village. Few satellite lineations were noted in the vicinity. Figure 2 and 3 show the available map data for the area and also the location of the geophysics traverse lines and the test boreholes. Table 1 shows the appropriate maps and aerial photographs for Edumoga.

There are several local hand-dug wells within the village. These are typically 5 m deep and stop in a hard layer. Below 3 m the wells tended to collapse within a clay layer. None of these wells produces water throughout the dry season, being primarily used by individual households during the rains. Water is also obtained from small dugouts excavated into the bed of the nearby river. As the dry season progresses, additional dugouts are excavated further and further downstream.

Table 1. Available map information for Edumoga.

Data type	Source
Aerial Photographs	Sheet 289, run 3, 21-24
Topographic maps	Sheet 289, run 4, 80-83
Geology map	1:50,000 Sheet 289NE Ejekwe NE Ogoja Area, Map No. 73, Scale 1:250,000

2. GEOPHYSICS

Various geophysical surveys were carried out at Edumoga. Table 2 gives a summary of the various traverses and soundings. These data are presented in Appendix 1. The EM34-3 method was found to be the most useful survey tool. The electrical conductivity of the rocks present generally lay between 30 and 50 mmhos/m. There were several pronounced negative anomalies where the conductivity fell to less than 15 mmhos/m. These were interpreted as fracture zones within moderately hard mudstone.

Five sites were identified for test drilling. Two of the sites, BGS 16 and 17 were located on negative geophysics anomalies (130 m along ED1 and 80 m along ED3 respectively); another two sites, BGS 14 and BGS 18, located where there were no anomalies (460 m along ED2 and 20 m along ED7 respectively); and BGS 15 located where there was no distinct anomaly but the EM34-3 readings were noisy.

Figure 4 shows EM34-3 readings for ED 1 and ED2. These are fairly typical for Edumoga and show three of the five borehole locations.

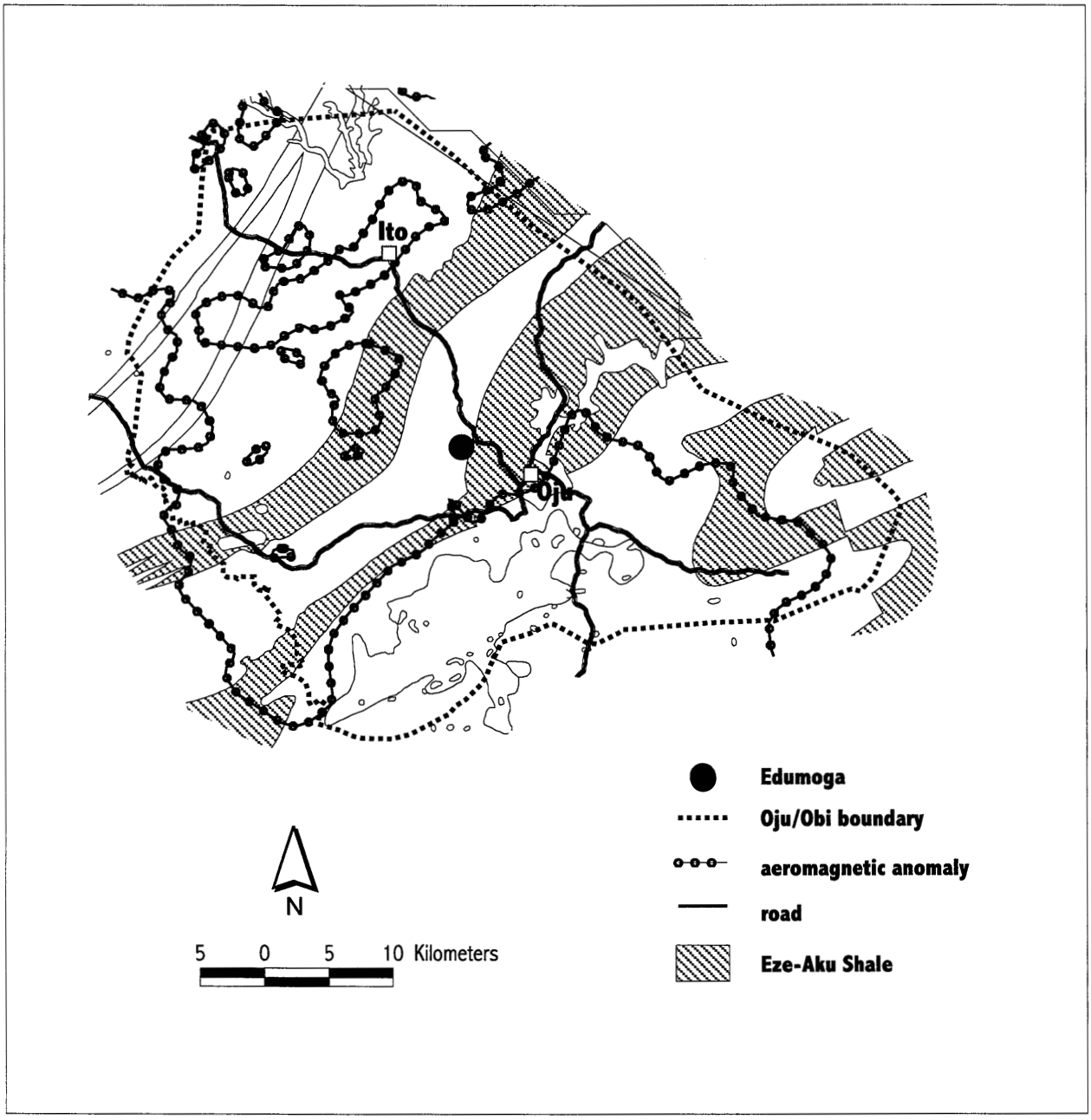

Figure 1. The location of Edumoga and outcrop of the Eze Aku Shale.

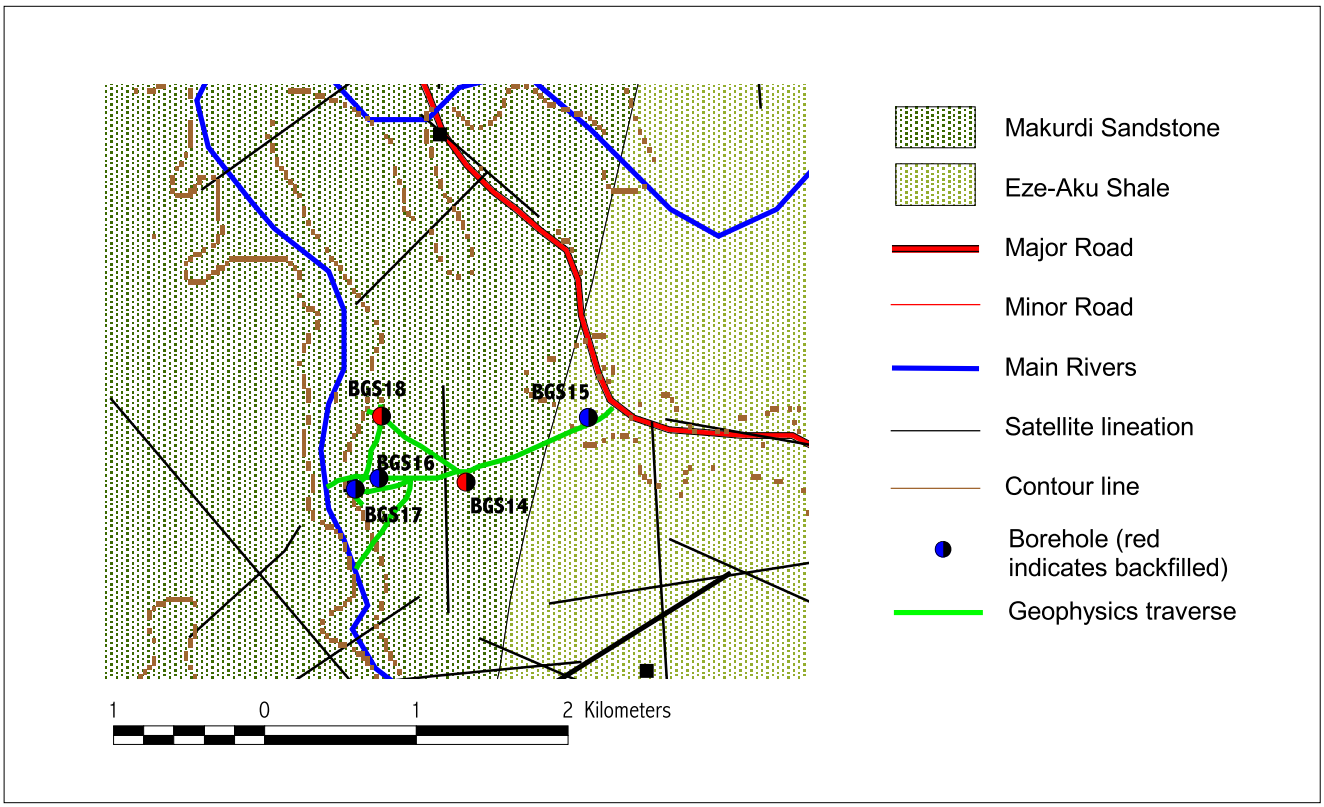

Figure 2. Available map information for Edumoga, and location of boreholes and geophysics traverses. NB geological boundary marked on the map is uncertain.

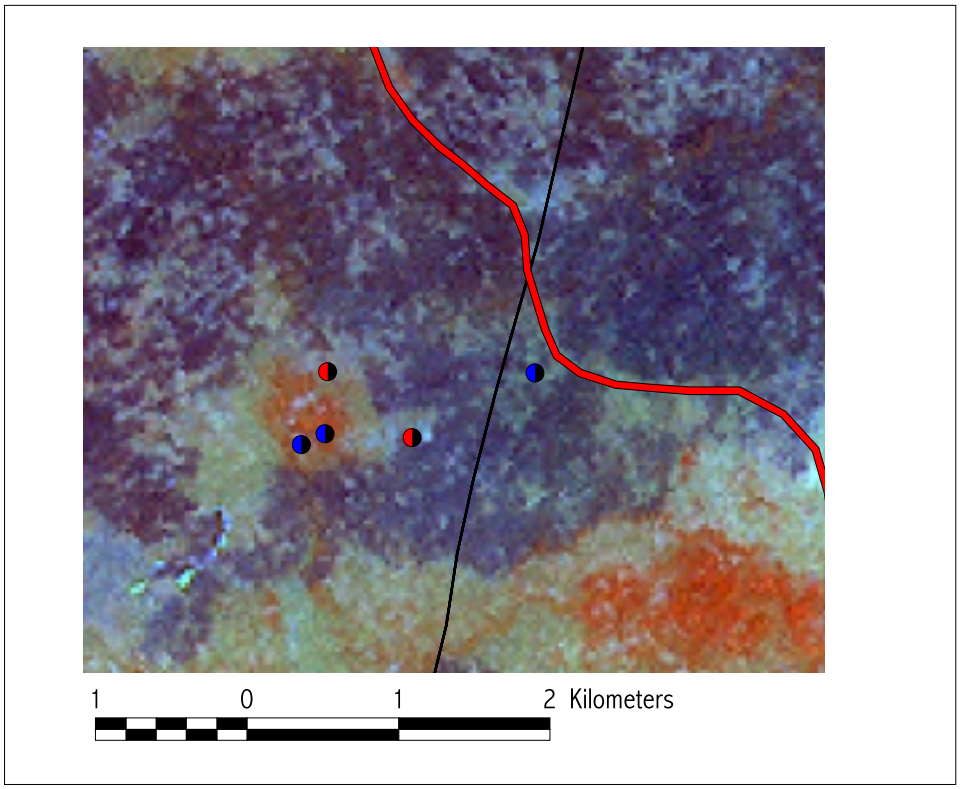

Figure 3. Satellite image for Edumoga.

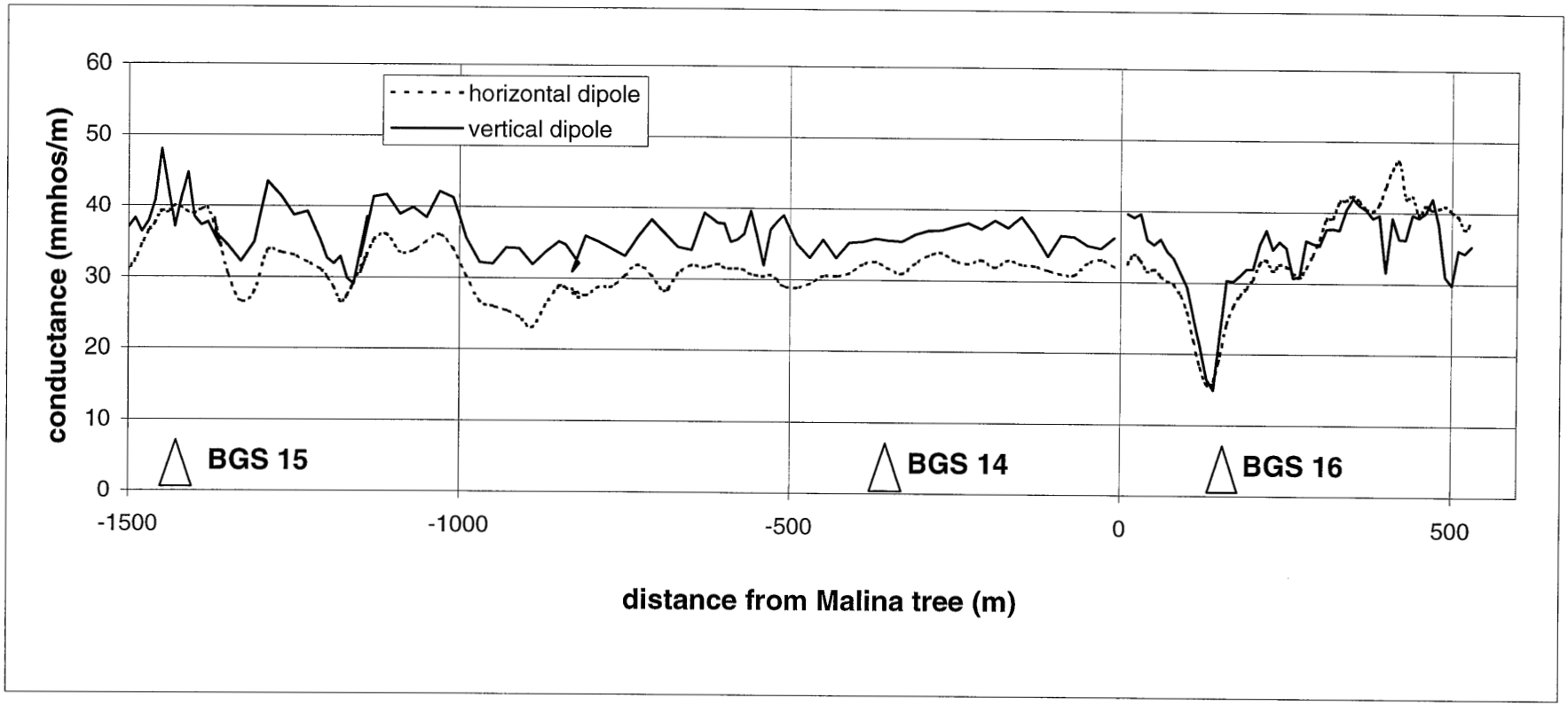

Figure 4. Typical EM34-3 survey results and borehole locations for Edumoga. ED1 and ED2 are shown.

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

Survey number	Co-ordinates start	Length	Average Spacing	Survey type	Description
ED1	6° 53.406' 8° 22.422'	0.6 km	10 m	EM34 (20 m)	From Malina tree at Methodist church, 300° to stream
ED2	6° 53.406' 8° 22.422'	1.6 km	20 m	EM34 (20 m)	From Malina tree at Methodist church, 70° to main road
ED3	6° 53.392' 8° 22.342'	0.6 km	10 m	EM34 (20 m)	From palm tree near BGS 17 through playground to BGS18
ED4	6° 53.406' 8° 22.422'	0.3 m	10 m	EM34 (40 m)	Repeat of first half of ED1 with 40 m cable.
ED5	6° 53.406' 8° 22.422'	0.3 m	10 m	EM34 (20 m)	From Malina tree at Methodist church by other path to ED3
ED6	6° 53.406' 8° 22.422'	0.5 km	20 m	EM34 (20 m)	From Malina tree at Methodist church away from village to stream
ED7		0.8 km	20 m	EM34 (20 m)	From end ED3 (BGS18) at 120° to school (BGS14)
ED8	6° 53.406' 8° 22.422'	0.3 km	10 m	magnetic	Repeat of first half of ED1 with magnetometer.
ED9	6° 53.418' 8° 22.655'		0.5 – 64 m	Offset Wenner	Located at BGS 14
ED10	6° 53.433' 8° 22.342'		0.5 – 64 m	Offset Wenner	Located at BGS 16
ED11	6° 53.651' 8° 23.095'		0.5 – 64 m	Offset Wenner	Located at BGS 15
ED12	6° 53.392' 8° 22.342'		0.5 – 64 m	Offset Wenner	Located at BGS 17

3. DRILLING

Five boreholes were drilled at Edumoga. Summary information on the boreholes are given in Table 3. More details of borehole construction are given in Annex 2. Three of the boreholes: BGS 15, 16 and 17 encountered significant water during the drilling and were therefore fitted with screen and casing. BGS 14 and BGS18 encountered very little water and were back-filled.

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	Casing above gl	comments
BGS14	6° 53.418' 8° 22.655'	28/1/98	27.4 m	165 mm	24.5 – 27.4	12.5, 16		Backfilled
BGS15	6° 53.651' 8° 23.095'	30/1/98	29.5 m	165 mm	26.5 – 29.4	15, 15.5, 26 (flowing)	0.7 m	Screened
BGS16	6° 53.433' 8° 22.342'	4/2/98	29.5 m	216 mm	26.5 – 29.5	14.5 (flowing), 20, 24.5	0.6 m	Screened
BGS17	6° 53.393' 8° 22.257'	5/2/98	29.5 m	165 mm	26.5 – 29.5	10.5, 15.5, 16.5, 24	0.35 m	Screened
BGS18	6° 53.655' 8° 22.352'	7/2/98	53 m	165 mm	50 – 53			Backfilled

The following sections give a brief summary of the geological logs. Full details are given in Annex 3. Figure 5 shows a schematic of the borehole logs.

Summary geological log: BGS14

0.0 - 3.0	Soil/ferricrete horizon
3.0 - 6.0	Clayey very weathered horizon
6.0 - 10.0	Weathered mudstones with clay
10.0 - 14.0	Soft mudstones with thin layers of hard fine grained sandstones, siltstones and medium grained saccaroidal calcareous sandstones, some weathering
14.0 - 16.0	Hard well cemented siltstone and fine grained sandstone bands with micaceous partings
16.0 - 18.0	Interbedded mudstones and hard siltstone and fine grained sandstone bands
18.0 - 20.5	Soft mudstone with thin siltstone bands
20.5 - 23.5	Soft mudstones
23.5 - 27.0	Soft mudstones with thin siltstone and fine grained sandstone bands

Summary geological log: BGS15

0.0 - 3.0	Soil/ferricrete horizon
3.0 - 7.0	Clayey very weathered horizon
7.0 - 8.5	Very weathered clayey mudstones
8.5 - 14.0	Soft weathered mudstones
14.0 - 18.0	Fairly weathered mudstone with hard siltstone layers and calcite veins
18.0 - 21.0	Compact mudstone with calcite and gypsum veins
21.0 - 26.5	Soft mudstone with sandy and silty layers with gypsum and calcite veins
26.5 - 27.5	Fractured mudstone with calcite and gypsum veins

Summary geological log: BGS16

0.0 - 3.5	Soil/ferricrete horizon
3.5 - 5.0	Clayey very weathered horizon
5.0 - 8.5	Weathered mudstone with clay
8.5 - 13.0	Fairly weathered mudstones
13.0 - 16.5	Mudstone with thin hard interbedded siltstone and fine grained sandstone layers, some weathering
16.5 - 18.5	Mudstone with thin hard siltstone and fine grained sandstone layers, some vein calcite
18.5 - 20.5	Mudstone with thin hard limestone layers, some vein calcite
20.5 - 26.5	Fissile mudstones
26.5 - 28.0	Fissile calcareous mudstone with interbedded sandstone, some vein calcite
28 - 29.5	Non-calcareous mudstone

Summary geological log: BGS17

0.0 - 2.5	Soil/ferricrete horizon
2.5 - 3.5	Clayey very weathered horizon
3.5 - 7.0	Very weathered mudstone with clay and weathered fine grained sandstones and siltstones
7.0 - 10.5	Fairly weathered mudstones
10.5 - 12.0	Mudstone and hard limestone with little fine grained sandstone
12.0 - 13.0	Mudstone and thin interbedded fine grained sandstones, some weathering and vein calcite
13.0 - 13.5	Mudstone with siltstone and fine grained sandstone, some vein calcite
13.5 - 14.0	Mudstone and limestone with siltstone and fine grained sandstone, some vein calcite

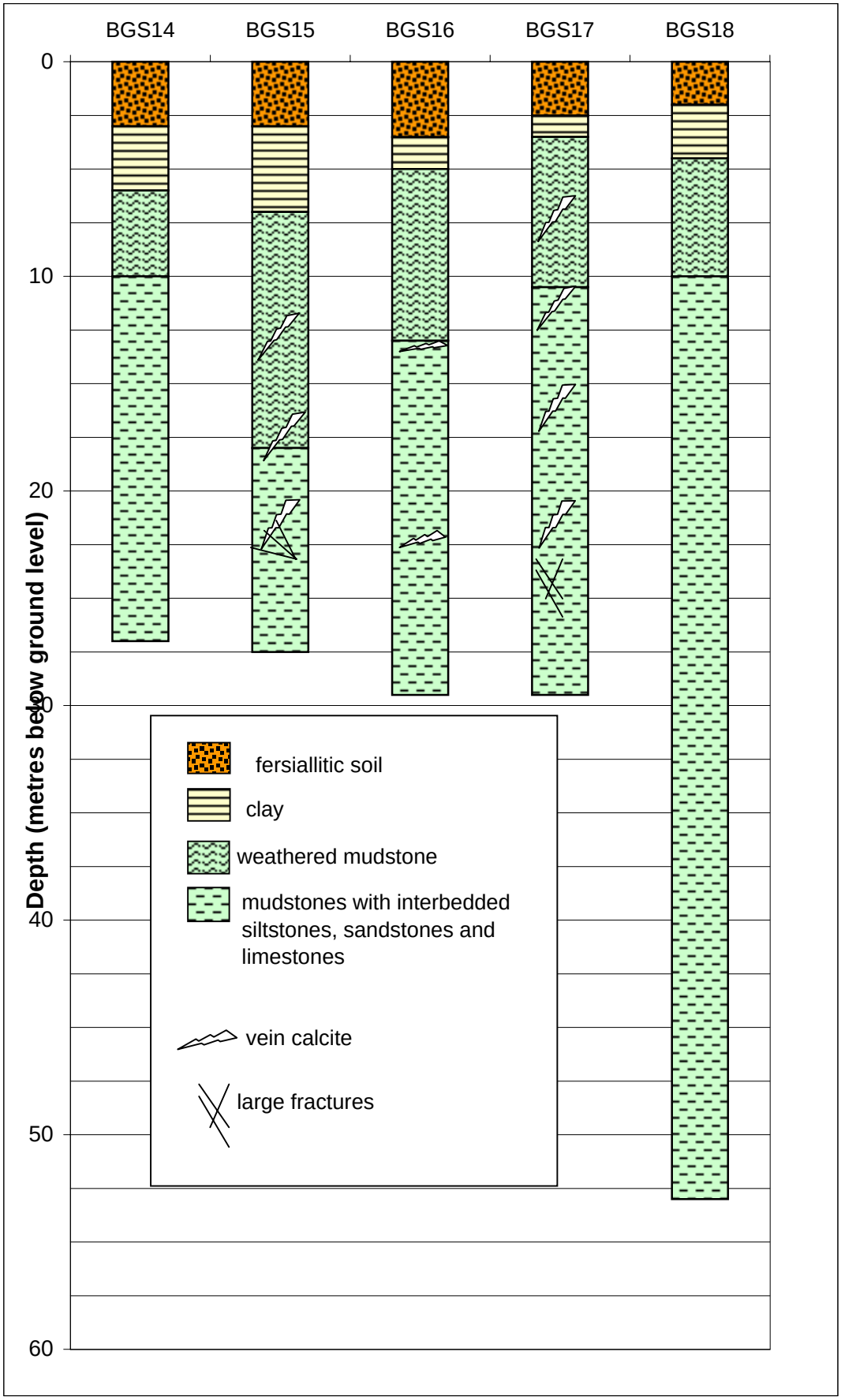

Figure 5. Simplified lithological logs for the Edumoga boreholes (not to scale horizontally).

14.0 - 15.0	Mudstone with siltstone and calcareous fine grained sandstone, some vein calcite
15.0 - 17.5	Mudstone with siltstone and fine grained micaceous sandstone, some vein calcite
17.5 - 18.5	Mudstones and interbedded thin micaceous fine grained sandstones
18.5 - 24.0	Mudstone with thin layers of siltstone and fine grained sandstones, some vein calcite and gypsum/barytes
24.0 - 26.5	Mudstone and interbedded siltstones, faulted with vein calcite and gypsum
26.5 - 29.5	Faulted dark grey mudstone

Summary geological log: BGS18

0.0 - 2.0	Soil/ferricrete horizon
2.0 - 4.5	Clayey very weathered horizon
4.5 - 6.	Weathered mudstones with clay
6.0 – 7.5	Weathered mudstones, fine grained sandstones and siltstones
7.5 - 10.0	Mudstones slightly weathered
10.0 – 53.0	Interbedded mudstone, siltstone, limestone and hard fine grained sandstone

4. PUMPING TESTS

Various pumping tests were carried out on the boreholes at Edumoga. Only BGS15, BGS16 and BGS17 could be tested, the other two boreholes containing insufficient water for testing. Table 4 gives a summary of the pumping tests carried out at Edumoga.

A simple slug test was carried out in each borehole using bailers. The data produced were analysed using both the Theis recovery method (Kruseman and de Ridder, 1990) and Barker's large diameter well method (Barker, 1989). Five hour constant rate tests were also carried out in each hole using a whale pump. The results of these were analysed using Jacob's method and Theis recovery. Each borehole showed a classical response – no boundary or leakage effects were noted during the time of pumping. BGS 16 showed the best aquifer properties, although each of the boreholes tested should supply sufficient water for a hand-pump. However, data from longer term tests are required for assessment of the sustainability of the aquifer.

A water sample for hydrochemical analysis was taken from each of the boreholes during the Whale pump tests. Some field chemical analyses were undertaken (see Table 5). Major, minor and trace element determinations undertaken at BGS Wallingford are detailed in Annex 5. The samples are typical of borehole water from the Oju area. The field samples conform to WHO drinking water guidelines, however, laboratory samples are still to be tested.

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

Borehole and Test	date	Casing height above ground	RWL (mbtc)	Length of test (min)	P-rate (l/s)	Transmissivity (m^2/d)
BGS15						
Bailer test	7/3/98	0.54 m	7.325	9:40	0.27	Barker: 2.0 Theis Rec: 1.3
Whale test	24/3/98	0.54 m	6.597	300	0.15	Jacob: 1.2 Theis Rec: 1.6
BGS 16						
Bailer test	7/3/98	0.14 m	9.56	9:53	0.19	Barker: 4.2 Theis Rec: 1.5
Whale test	25/3/98	0.14 m	9.295	300	0.14	Jacob: 3.2 Theis Rec: 2.1
BGS17						
Bailer test	9/3/98	0.31 m	6.29	10	0.29	Barker: 0.95 Theis Rec: 1.9
Whale test	26/3/98	0.31 m	6.767	40	0.31	Jacob: 1.6 Theis Rec: 1.7
Whale test	25/3/98	0.31 m	6.389	300	0.15	Jacob: 1.2 Theis Rec: 1.4

Table 5. Chemistry samples taken from the Edumoga boreholes (Annex 5 contains data and analysis).

ID No	Sample No	date	Conductivity (uS/cm@25°C)	TDS (mg/l)	pH	Temp (°C)	HCO_3 titr (50ml 1.6M)	Comments
BGS15	223	24/03/98	583	294	7	32	133	sample taken after 3 hours pumping
BGS16	225	26/03/98	558	280	7.15	28.4	124	sample taken after 3 hours pumping
BGS17	224	25/03/98	1149	575	7.47	28.9	188	sample taken after 3 hours pumping

5. SUMMARY AND CONCLUSIONS

Edumoga was chosen as a test site for the Lower Eze-Aku formation. There are numerous shallow hand-dug wells within the village area, many of which dry up during the post rains dry season. The following work was carried out at Edumoga:

- 4.5 km of EM34-3 surveys
- 4 resistivity VES
- 5 boreholes were drilled and 3 m core samples taken from each borehole
- chip and core samples from each borehole were logged and analysed

- 3 boreholes, BGS15, BGS16 and BGS17 were screened and cased
- bailer tests and 5 hour constant rate tests were carried out in each screened borehole
- water-samples for hydrochemical analysis were taken from BGS15, BGS16 and BGS17

The three successful boreholes were located on EM34-3 anomalies. BGS16 and BGS17 were located on pronounced negative anomalies; BGS15 was located where the vertical dipole (horizontal coil) was noisy. Both types of anomaly are consistent with fracture zones. The two unsuccessful boreholes (BGS14, BGS18) were positioned where EM34-3 responses were flat, indicating little likelihood of fractures. The resistivity VES produced similar results, each detecting the resistive ferruginous soils and the underlying conductive clays, common to all five boreholes.

Several conclusions can be made from logging the rock and chip and core samples:

- The Lower Eze-Aku is primarily mudstones, with appreciable siltstones, fine-sandstones and limestones layers.
- Some of the rocks show bioturbation although little palaeontological evidence was found.
- The rocks are highly weathered over the first 10 m or so: the first 3 m commonly a ferruginous soil with iron nodules or ferricrete, the next 2 - 3 m a plastic clay, and then from 6 - 12 m discoloured clayey, weathered mudstone.
- The intrinsic porosity and permeability of the sediments is negligible.
- The three boreholes containing water showed evidence of fracturing and faulting: (1) significant vein calcite, with gypsum/barytes; (2) slickensides; (3) iron oxide staining on many bedding and fracture surfaces; and (4) fault breccia (BGS17 only).

Test pumping of the boreholes showed that aquifer transmissivity was in excess of 1 m^2/d; sufficient to warrant installation of a hand-pump, although the long term sustainability of the groundwater system is as yet unknown. Test pumping data gathered from each borehole showed a classical response with no evidence of boundaries or leakage. The most productive borehole was BGS16. Field testing of the water quality indicates typical Oju borehole water with TDS of up to 500 mg/l.

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Barker J A 1989. Programs to simulate and analyse pumping tests in large diameter wells. British Geological Survey technical report WD/89/24.

Annex 1: Geophysics Data

Edumoga

ED 1/2/3

GPS start: 6 degs 53.406; 8 degs 22.422
GPS finish
Date and time: 14/01/98 11:30 - 14:00
Survey:

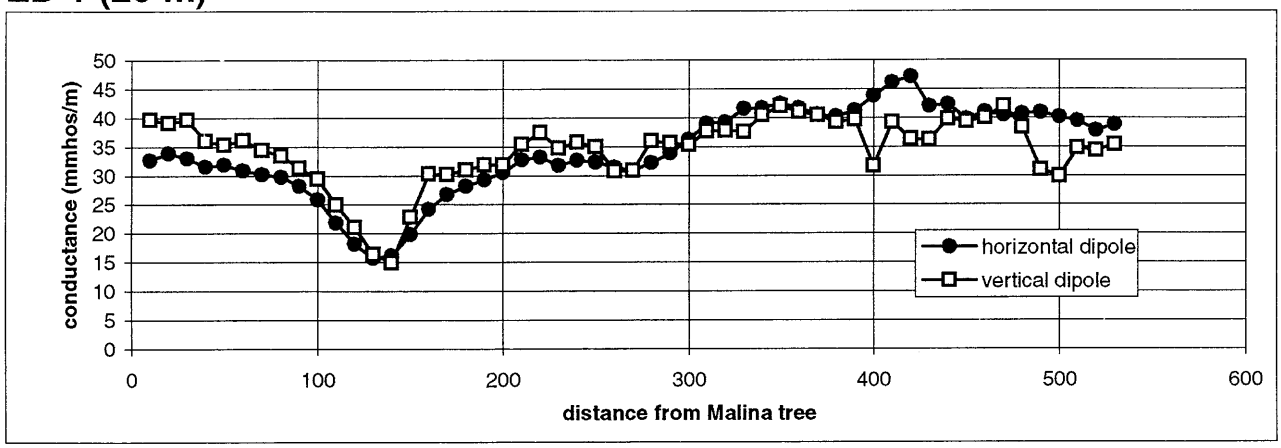
ED 1	From Malina Tree at the Methodist Church by playground to Stream
ED 2	From Malina tree past the School to the main road
ED 3	From well site 2 to 3, through play ground
ED 4	From Malina tree to playground. EM34 (40 m spacings)
ED 8	From Malina Tree to playground Magnetics

ED 1:

position (m)	strike (deg)
0	301
90	304
120	315
140	321
200	305
220	285
240	300
310	280
320	275
360	293
380	300
390	277
400	262
440	310
470	325
520	290

position (m)	comments
0	Malina Tree; R trailing
30	end Church
270	Playground cross roads
370	crossing path
410	Steel roof
540	top of channel
570	river

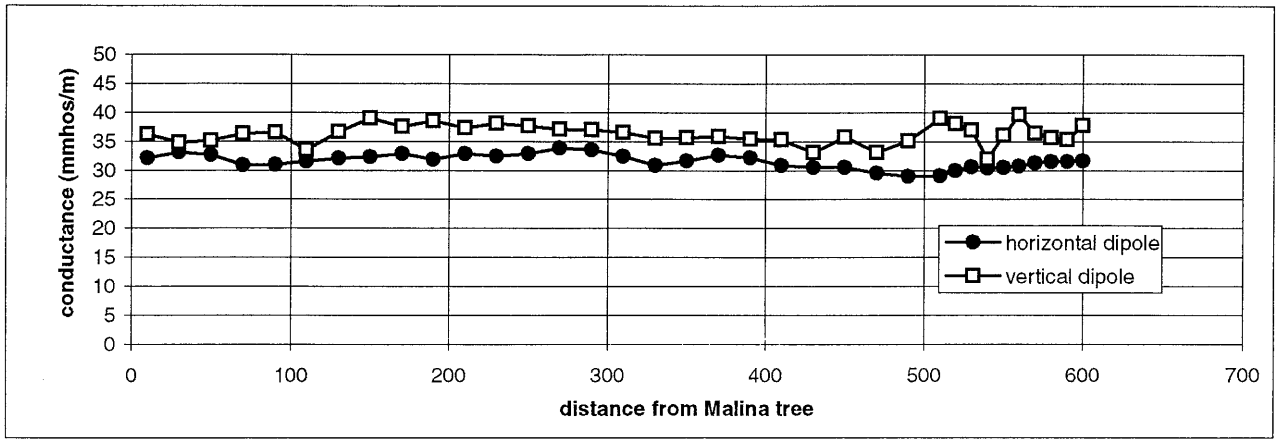
ED 1 (20 m)

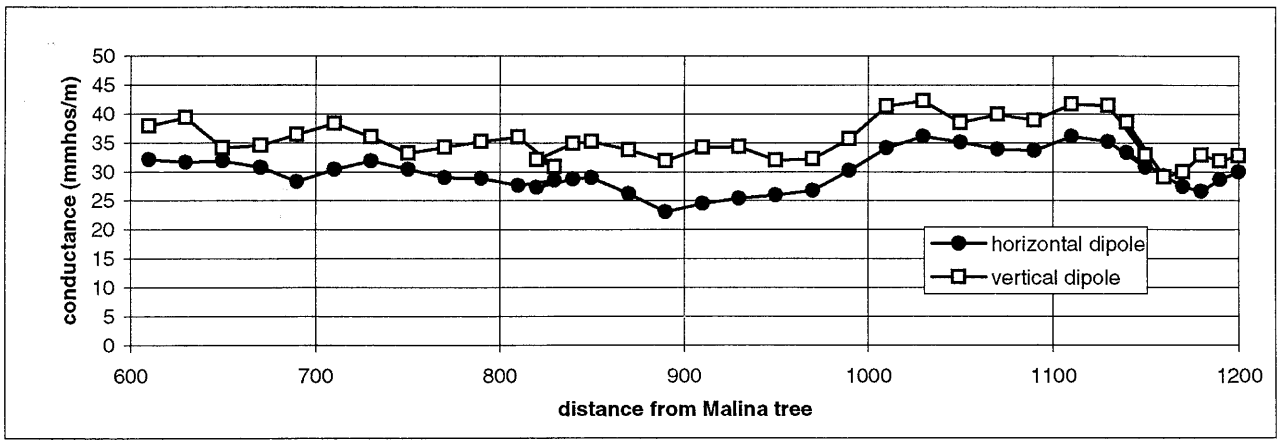


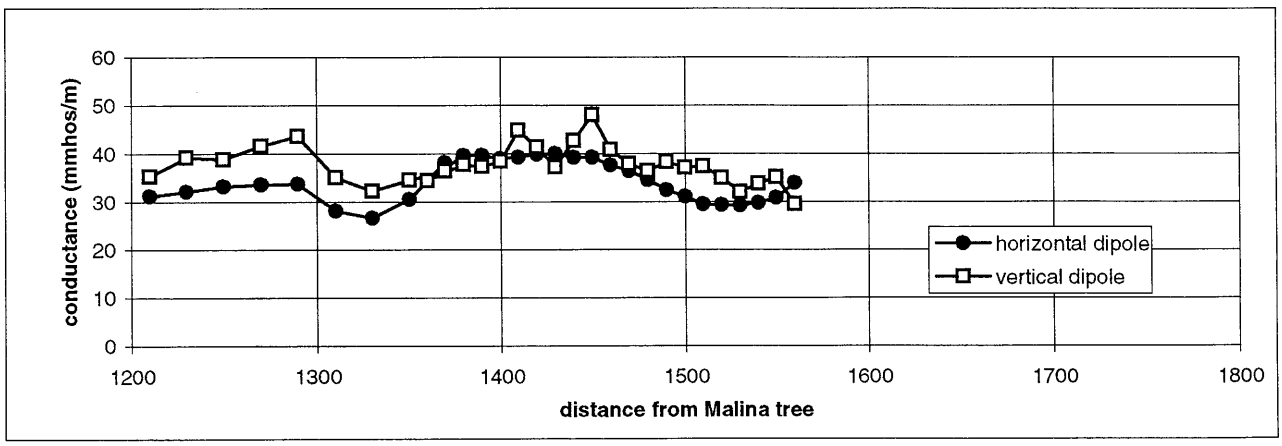
ED 2:

position (m)	strike (deg)
0	112
60	96
80	86
140	72
480	76
660	66
800	65
960	56
1080	66
1340	60
1400	52
1470	56
1490	60

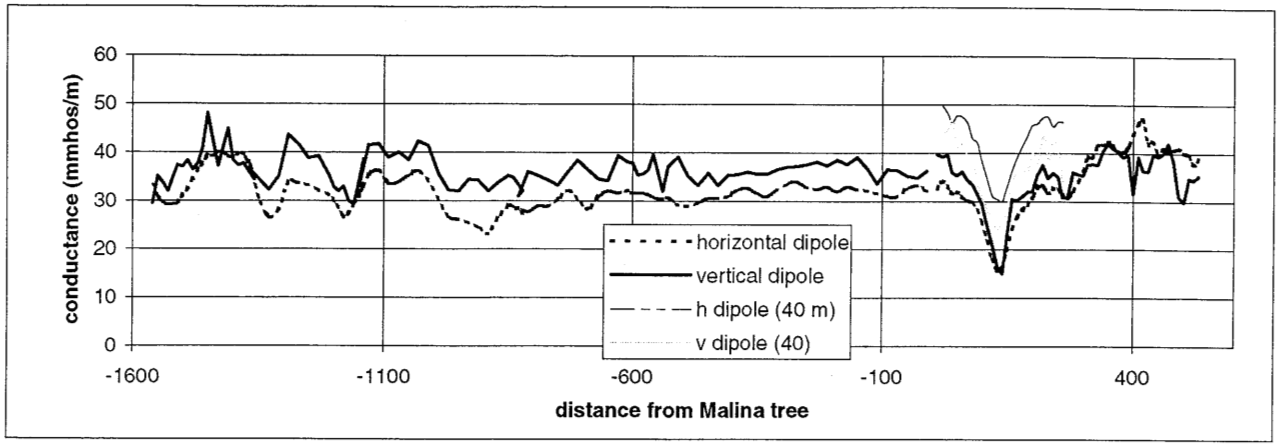
position (m)	comments
0	Malina Tree; R trailing
30	Ist St Rf left
280	btm fenced field
290	ferrecrete exposed
480	playing field road (well site)
570	middle road to school
780	by tree in gass roof compound
920	road to 2 SR compound
1150	end field burnt benne seed
1340	deadish tree
1440	enterance (R) to first comp
1460	pylons - no wires
1470	enterance (L) to comp
1540	top of rise
1580	main road







Combined ED 1/2:



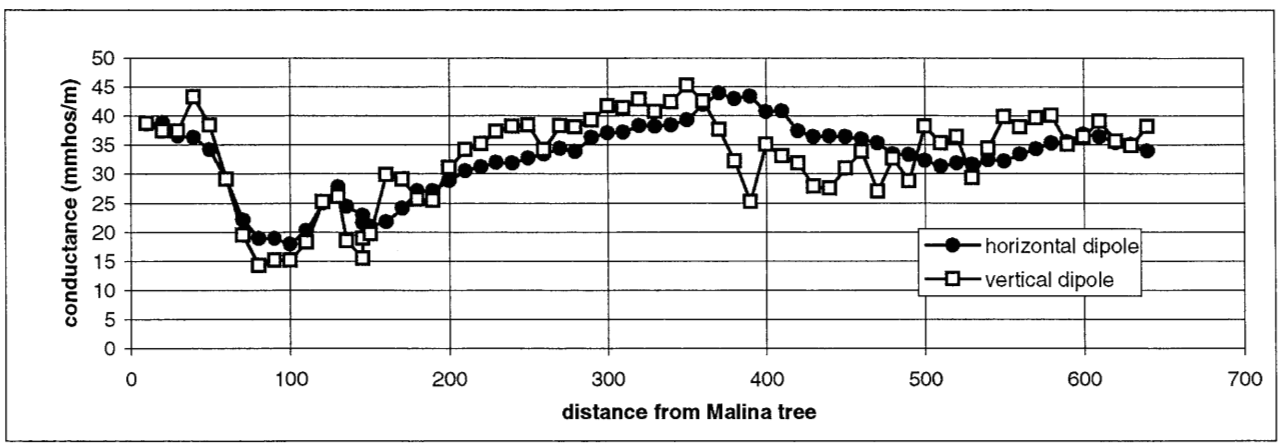
ED 3:

Strike:

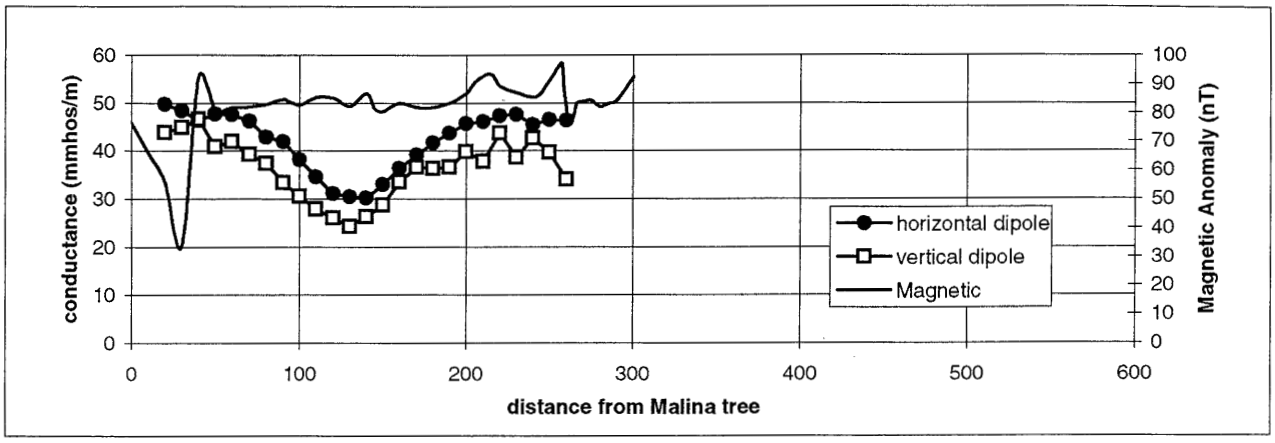
position (m)	strike (deg)
0	345
20	354
30	346
40	338
70	2
80	8
120	18
170	0
180	6
190	22
270	0
380	350
310	18
360	18
370	6
380	14
390	27
450	17
480	350
520	29.3
570	21
600	40

Comments:

position (m)	comments
0	Palm tree; potential well
50	Steel roof
90	X roads at tree
140	small path left
220	X roads playground
320	small path xing
340	ferrecrete exposed
460	cut trees
520	path branching right
590	small path X-ing
610	propsed well



ED 4 (40 m cable) and ED 8 (magnetics):



Edumoga

ED 5/6/7

GPS start: 6 degs 53.406; 8 degs 22.422
GPS finish
Date and time: 22/01/98 8:00 - 15:00
Survey:

ED 5	From 20m (301 degs) from Malina tree at the Methodist Church by other main path to ED 3 (20 m coil separation)
ED 6	From malina Tree towards stream along small path
ED 7	From well site 2 (at end of ED3) up to proimary school

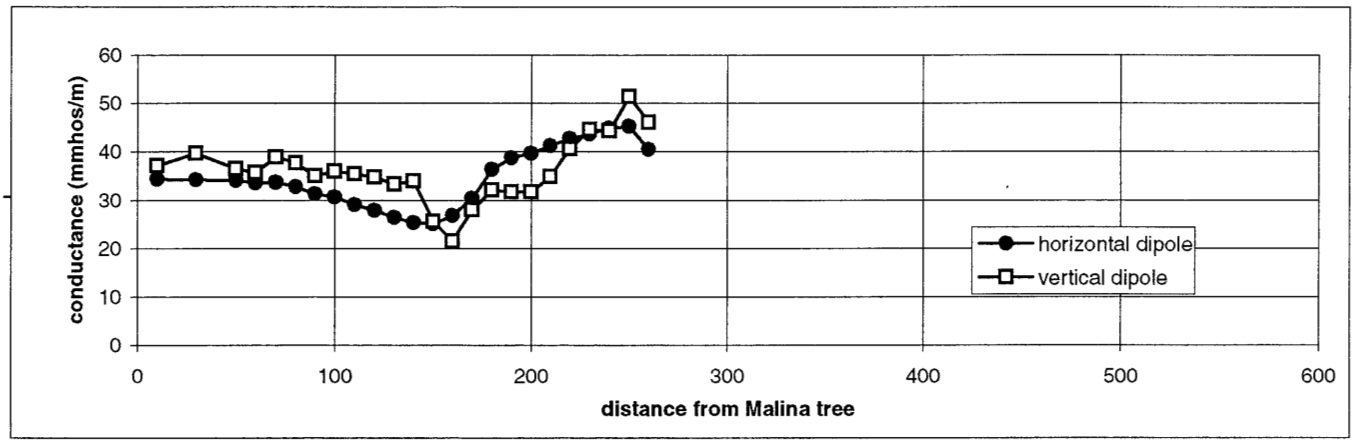
ED 5:

Strike:

position (m)	strike (deg)
0	297
80	283
160	269
230	250

Comments:

position (m)	comments
0	Parallel to Malina (20 m away)
40	church
130	termite mound
170	small path left
230	tree - crossing ED 3
270	compound



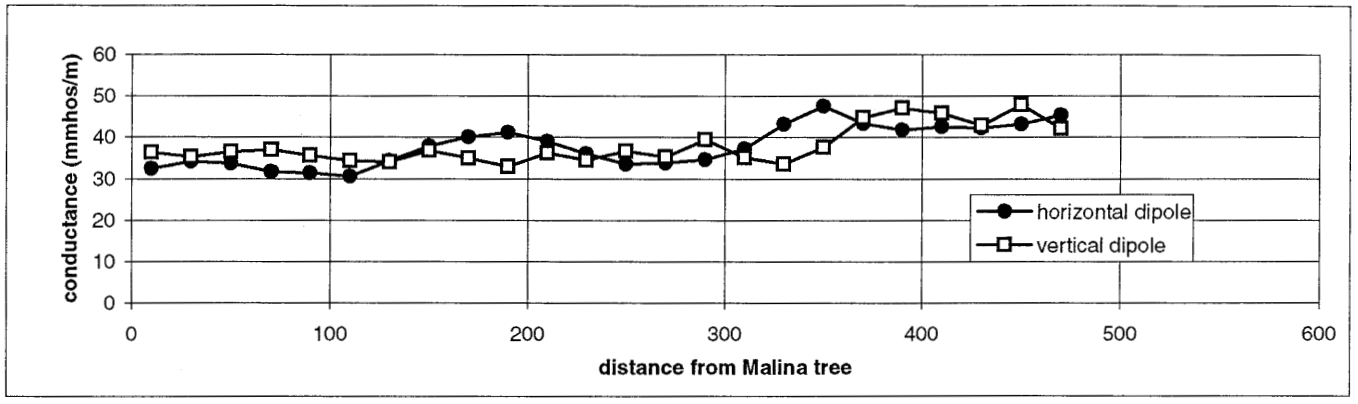
ED 6:

Strike:

position (m)	strike (deg)
0	210
160	196
220	174
260	190
300	201
320	214
360	255
380	238

Comments:

position (m)	comments
0	12 m from Malina, down ED 1
340	junction at ferrecrete exposure
490	river



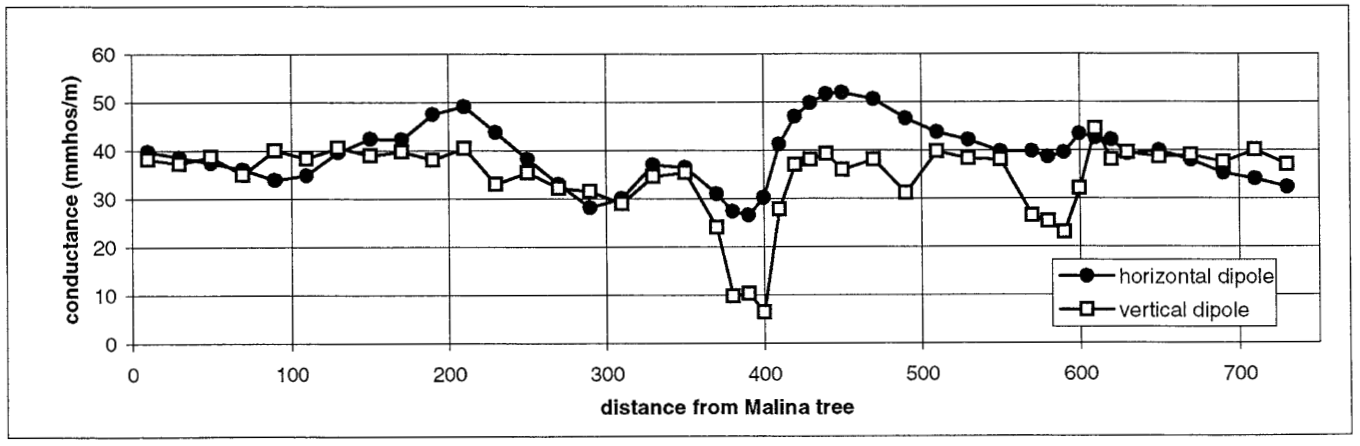
ED 7:

Strike:

position (m)	strike (deg)
0	111
60	122
240	138
410	146
500	132
540	124
620	130

Comments:

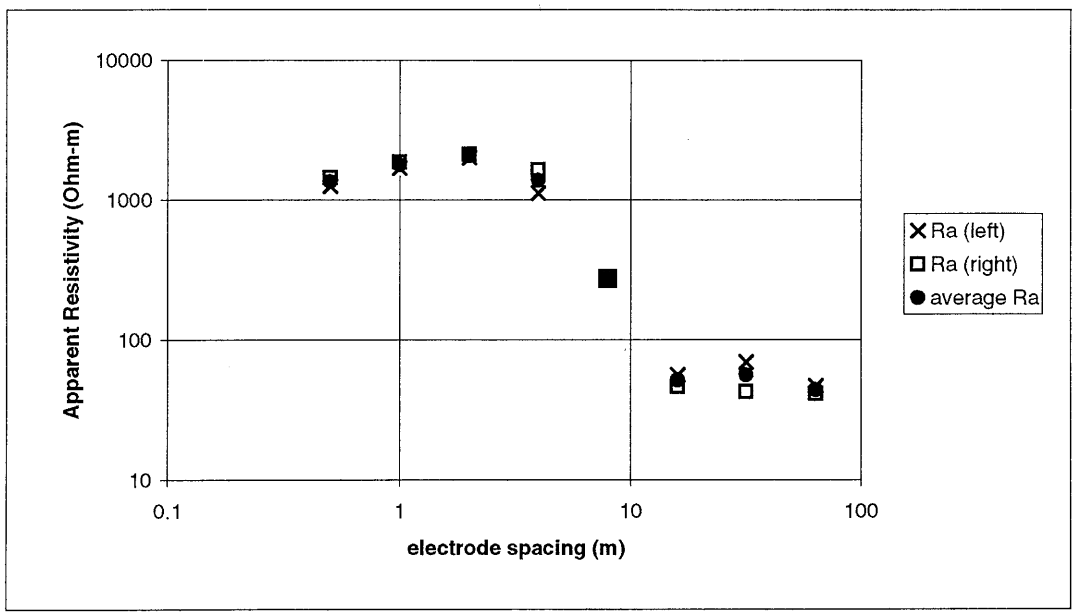
position (m)	comments
20	X roads with path (ED 3). well site
70	small path
375	small path
440	path joining left - large dead tree
640	path right
740	Road (about 460 m ED 2)



Edumoga

Resistivity Survey 1 6 degs 53.418; 8 degs 22.655
Located at primary school, BGS 14
Offset Wenner Left to road
Strike 355 degs
23/01/98

spacing (m)	left	right	Ra (left)	Ra (right)	average Ra
0.5	399	456	1252.86	1431.84	1342.35
1	268	296	1683.04	1858.88	1770.96
2	159.1	167.8	1998.296	2107.568	2052.932
4	44.1	65	1107.792	1632.8	1370.296
8	5.5	5.41	276.32	271.7984	274.0592
16	0.558	0.46	56.06784	46.2208	51.14432
32	0.345	0.211	69.3312	42.40256	55.86688
64	0.116	0.102	46.62272	40.99584	43.80928



DATA SET: ED9

CLIENT: WaterAid
DATE: Jan 1998
LOCATION: Primary School (BGS14)
SOUNDING: 1
COUNTY: Oju, Nigeria
AZIMUTH: 355 degs
PROJECT: Water and Sanitation
EQUIPMENT: BGS128
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

Offset Wenner Configuration

FITTING ERROR: 6.947 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	1085.9	0.526	-0.526	4.848E-04	571.8
2	4919.4	1.21	-1.74	2.479E-04	5998.6
3	16.08	1.15	-2.89	0.0716	18.52
4	48.87				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

	LAYER	MINIMUM	BEST	MAXIMUM
RHO	1	660.232	1085.988	1385.460
	2	3205.327	4919.446	8709.482
	3	6.687	16.080	180.081
	4	44.471	48.874	54.041
THICK	1	0.273	0.527	0.773
	2	0.683	1.219	1.916
	3	0.155	1.152	3.049
DEPTH	1	0.273	0.527	0.773
	2	1.317	1.746	2.353
	3	1.782	2.898	4.856

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	0.500	1343.0	1335.5	0.554
2	1.00	1771.8	1817.1	-2.55

* BRITISH GEOLOGICAL SURVEY *

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
3	2.00	2053.9	2076.5	-1.09
4	4.00	1370.9	1297.9	5.32
5	8.00	274.1	278.7	-1.66
6	16.00	51.14	52.92	-3.48
7	32.00	55.86	48.62	12.94
8	64.00	43.80	48.78	-11.38

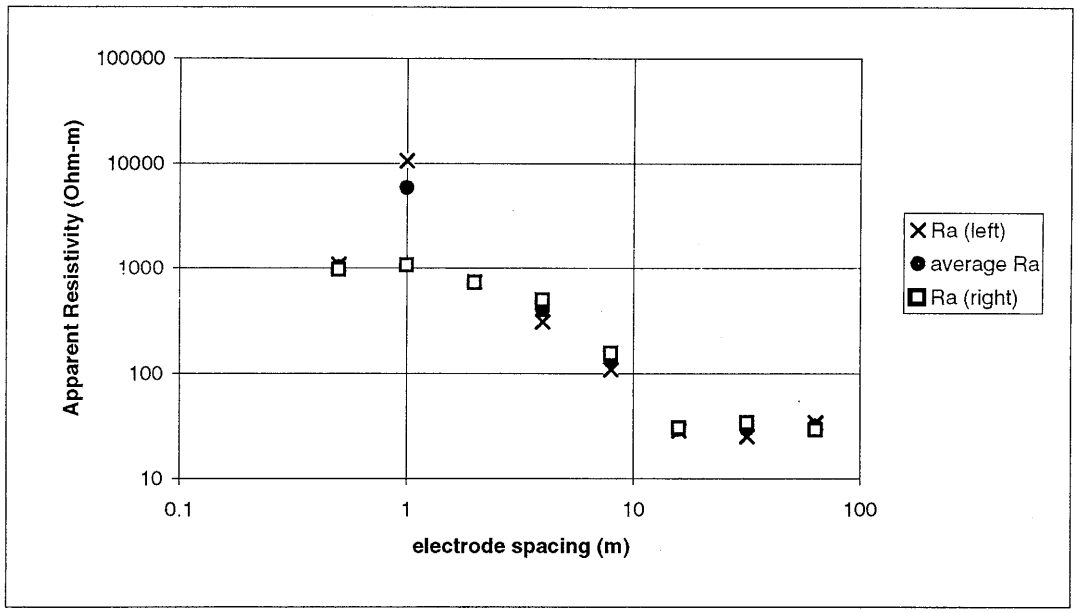
PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	0.87						
P 2	0.00	0.57					
P 3	0.02	-0.02	0.11				
P 4	0.00	0.00	0.03	0.98			
T 1	-0.17	-0.14	0.03	0.00	0.69		
T 2	0.03	0.44	0.04	0.00	0.19	0.54	
T 3	-0.02	0.03	-0.11	-0.04	-0.03	-0.03	0.10
	P 1	P 2	P 3	P 4	T 1	T 2	T 3

Edumoga

Resistivity Survey 2 6 degs 53.433; 8 degs 22.342
Located in woods BGS 16
Offset Wenner right to tarmac
Strike 126 degs
07/03/98

spacing (r	left	right	Ra (left)	Ra (right)	average Ra
0.5	343	306	1077.02	960.84	1018.93
1	1672	167.9	10500.16	1054.412	5777.286
2	58.4	57.8	733.504	725.968	729.736
4	12.2	19.63	306.464	493.1056	399.7848
8	2.14	3.06	107.5136	153.7344	130.624
16	0.283	0.3	28.43584	30.144	29.28992
32	0.1239	0.1681	24.89894	33.78138	29.34016
64	0.084	0.0719	33.76128	28.89805	31.32966



DATA SET: ED10

CLIENT: WaterAid
LOCATION: Forest (BGS16)
COUNTY: Oju, Nigeria
PROJECT: Water and Sanitation
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: Jan 1998
SOUNDING: 2
AZIMUTH: 355 degs
EQUIPMENT: BGS128

Offset Wenner Configuration

FITTING ERROR: 3.400 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	1089.3	1.23	-1.23	0.00114	1350.0
2	466.3	3.18	-4.42	0.00682	1483.9
3	11.03	4.60	-9.02	0.417	50.83
4	33.03				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

	LAYER	MINIMUM	BEST	MAXIMUM
RHO	1	1029.942	1089.373	1149.109
	2	365.682	466.336	558.659
	3	6.260	11.039	16.691
	4	31.023	33.038	36.389
THICK	1	1.016	1.239	1.564
	2	2.921	3.182	3.567
	3	2.451	4.605	11.129
DEPTH	1	1.016	1.239	1.564
	2	4.087	4.421	4.942
	3	6.741	9.026	15.742

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	0.500	1019.0	1070.9	-5.09
2	1.00	1054.0	986.3	6.42

* BRITISH GEOLOGICAL SURVEY *

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
3	2.00	730.0	740.8	-1.47
4	4.00	400.0	408.8	-2.21
5	8.00	131.0	128.2	2.09
6	16.00	29.30	29.71	-1.42
7	32.00	29.30	28.52	2.65
8	64.00	31.30	31.32	-0.0952

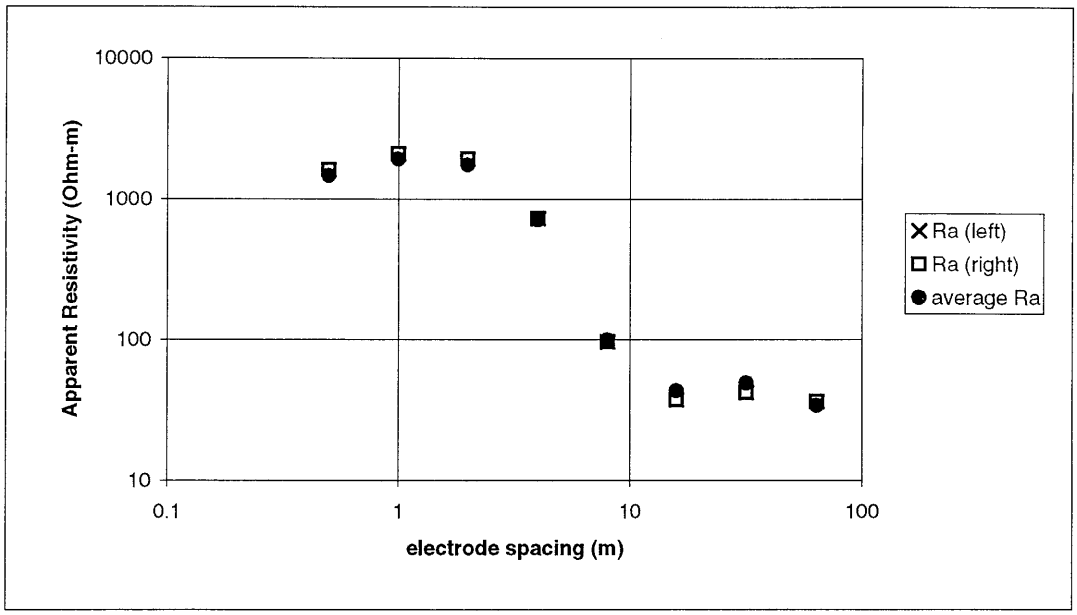
PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	0.98						
P 2	-0.02	0.69					
P 3	0.00	-0.10	0.42				
P 4	0.00	0.02	0.05	0.97			
T 1	0.04	0.30	0.06	-0.01	0.63		
T 2	-0.01	0.08	0.08	-0.01	-0.03	0.95	
T 3	0.00	0.07	-0.34	-0.05	-0.04	-0.03	0.28
	P 1	P 2	P 3	P 4	T 1	T 2	T 3

Edumoga

Resistivity Survey 3 6 degs 53.433; 8 degs 22.342
Located by road at BGS 15
Offset Wenner left to tarmac
Strike 45 degs
07/03/98

spacing (r	left	right	Ra (left)	Ra (right)	average Ra
0.5	417	508	1309.38	1595.12	1452.25
1	277	332	1739.56	2084.96	1912.26
2	123.3	153.1	1548.648	1922.936	1735.792
4	27.4	29	688.288	728.48	708.384
8	2.03	1.912	101.9872	96.05888	99.02304
16	0.487	0.373	48.93376	37.47904	43.2064
32	0.281	0.208	56.46976	41.79968	49.13472
64	0.0783	0.09	31.47034	36.1728	33.82157



DATA SET: ED11

CLIENT: WaterAid DATE: Jan 1998
LOCATION: Tarmac Road (BGS15) SOUNDING: 1
COUNTY: Oju, Nigeria AZIMUTH: 45 degs
PROJECT: Water and Sanitation EQUIPMENT: BGS128
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

Offset Wenner Configuration

FITTING ERROR: 1.684 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	576.0	0.150	-0.150	2.611E-04	86.63
2	2839.2	1.56	-1.71	5.502E-04	4435.6
3	19.19	5.42	-7.13	0.282	104.1
4	90.37	22.57	-29.71	0.249	2040.5
5	9.83				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

	LAYER	MINIMUM	BEST	MAXIMUM
RHO	1	315.163	576.017	824.147
	2	2645.206	2839.230	3135.450
	3	10.179	19.196	24.925
	4	69.688	90.375	118.957
	5	7.579	9.832	15.400
THICK	1	0.079	0.150	0.223
	2	1.414	1.562	1.677
	3	2.593	5.426	7.380
	4	15.190	22.579	31.325
DEPTH	1	0.079	0.150	0.223
	2	1.609	1.713	1.802
	3	4.359	7.139	9.071
	4	22.871	29.718	37.902

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

	(m)	DATA	SYNTHETIC	(percent)
1	0.500	1452.0	1468.0	-1.10
2	1.00	1912.0	1883.8	1.47
3	2.00	1736.0	1711.4	1.41
4	4.00	708.0	731.7	-3.35
5	8.00	99.00	97.35	1.66
6	16.00	43.00	43.63	-1.47
7	32.00	49.10	48.94	0.322
8	64.00	33.80	34.12	-0.975

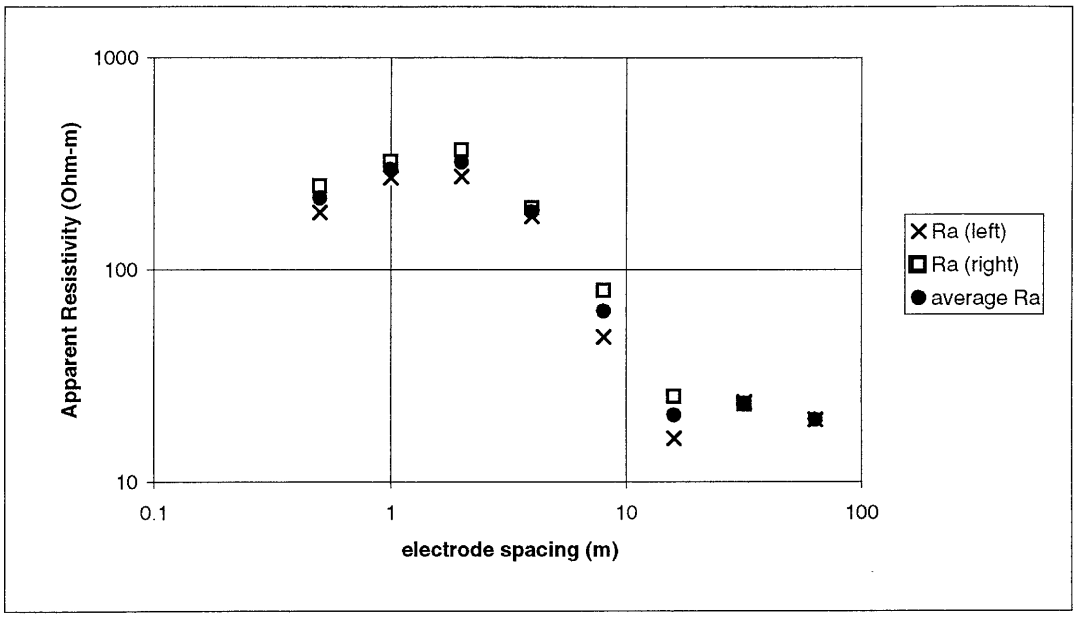
PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	0.54								
P 2	-0.02	0.98							
P 3	0.02	-0.02	0.55						
P 4	-0.01	0.01	0.03	0.76					
P 5	0.01	0.00	0.04	-0.10	0.36				
T 1	-0.49	-0.04	0.00	0.00	0.00	0.46			
T 2	0.03	0.02	0.03	-0.01	0.00	0.05	0.98		
T 3	0.01	-0.02	-0.45	-0.10	0.03	0.00	0.02	0.47	
T 4	0.01	-0.01	-0.04	0.31	0.32	0.00	0.01	0.11	0.54
	P 1	P 2	P 3	P 4	P 5	T 1	T 2	T 3	T 4

Edumoga

Resistivity Survey 4 6 degs 53.392; 8 degs 22.342
At Junction BGS 17
Offset Wenner left to playground
Strike 2 degs
09/03/98

spacing (r	left	right	Ra (left)	Ra (right)	average Ra
0.5	59.3	78.8	186.202	247.432	216.817
1	43.3	51.5	271.924	323.42	297.672
2	21.9	29.1	275.064	365.496	320.28
4	7.09	7.78	178.1008	195.4336	186.7672
8	0.956	1.578	48.02944	79.27872	63.65408
16	0.159	0.25	15.97632	25.12	20.54816
32	0.117	0.115	23.51232	23.1104	23.31136
64	0.0486		19.53331		19.53331



DATA SET: ED12

CLIENT: WaterAid DATE: Jan 1998
LOCATION: In village (BGS17) SOUNDING: 4
COUNTY: Oju, Nigeria AZIMUTH: 2 degs
PROJECT: Water and Sanitation EQUIPMENT: BGS128
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

Offset Wenner Configuration

FITTING ERROR: 4.592 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	91.76	0.148	-0.148	0.00162	13.61
2	386.0	2.62	-2.77	0.00681	1014.5
3	12.41	9.90	-12.67	0.797	122.9
4	57.91	12.64	-25.32	0.218	732.4
5	11.50				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

	LAYER	MINIMUM	BEST	MAXIMUM
RHO	1	15.948	91.766	174.809
	2	342.630	386.074	449.137
	3	7.324	12.416	17.113
	4	30.875	57.913	133.223
	5	7.347	11.509	17.470
THICK	1	0.030	0.148	0.333
	2	2.263	2.628	2.964
	3	5.233	9.904	16.382
	4	4.266	12.647	31.564
DEPTH	1	0.030	0.148	0.333
	2	2.435	2.776	3.095
	3	8.118	12.680	19.075
	4	16.757	25.327	44.405

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

	(m)	DATA	SYNTHETIC	(percent)
1	0.500	217.0	222.3	-2.46
2	1.00	298.0	288.3	3.25
3	2.00	320.0	303.6	5.10
4	4.00	187.0	205.5	-9.90
5	8.00	63.70	61.02	4.19
6	16.00	20.50	20.95	-2.22
7	32.00	23.30	22.85	1.90
8	64.00	19.50	19.67	-0.894

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

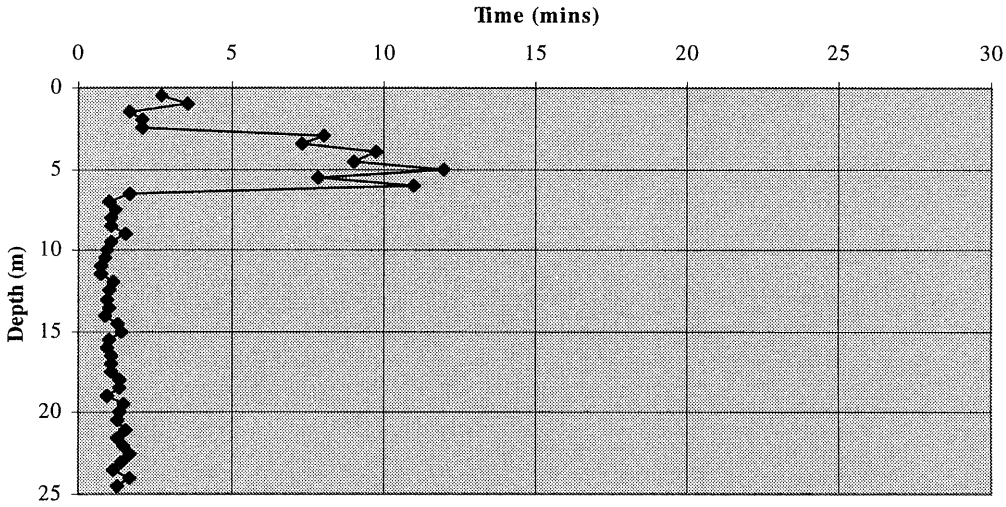
P 1	0.50								
P 2	0.02	0.95							
P 3	0.02	-0.03	0.64						
P 4	-0.01	0.01	0.08	0.41					
P 5	0.01	-0.01	-0.03	0.26	0.43				
T 1	-0.46	-0.05	-0.01	0.01	0.00	0.42			
T 2	-0.02	0.05	0.06	-0.02	0.01	0.06	0.94		
T 3	0.01	-0.01	-0.41	-0.10	0.13	-0.01	0.04	0.36	
T 4	0.00	0.01	0.00	0.34	0.27	0.00	-0.01	-0.01	0.29
	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 BGS14

Borehole Drilling/Construction Details	
Date drilling started	28/1/98
Date drilling completed	28/1/98
28/1/98 - Drilled with 6.5" hammer	0.00 - 24.5m
28/1/98 - Cored at 3"	24.5 - 27.4m
Depths water struck	12.5, 16.0m
Depth of borehole on completion	27.4mbgs
Borehole diameter	$6^1/_2$"
Casing erected in hole	none
Rest water level below ground surface	8.10m

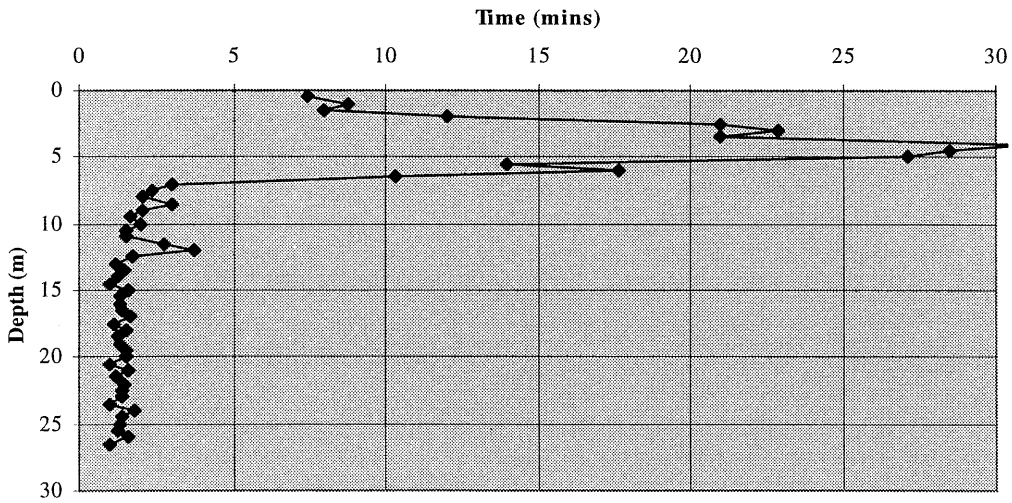
Bh BGS14, Penetration Rates, 28/1/98



Borehole BGS15

Borehole Drilling/Construction Details	
Date drilling started	29/1/98
Date drilling completed	30/1/98
29/1/98 - Drilled with 8.5" tricone	0.00 - 4.5m
29/1/98 - Drilled with 6.5" hammer	4.5 - 26.5m
29/1/98 - Cored at 3"	26.5 - 29.4m
Depths water struck	15.0, 15.5, 26.0m (flowing)
Depth of borehole on completion	29.5mbgs
Borehole diameter	$6^1/_2$"
Casing erected in hole	2x2.9mx125mm casing 1x5.8mx125mm casing 3x5.8mx125mm screen
Original top of casing above ground level	2.13m
Total length of casing/screen	28.64m
Amount of casing removed	1.53m
Top of casing above ground level	0.60m
Rest water level below casing top	10.50m

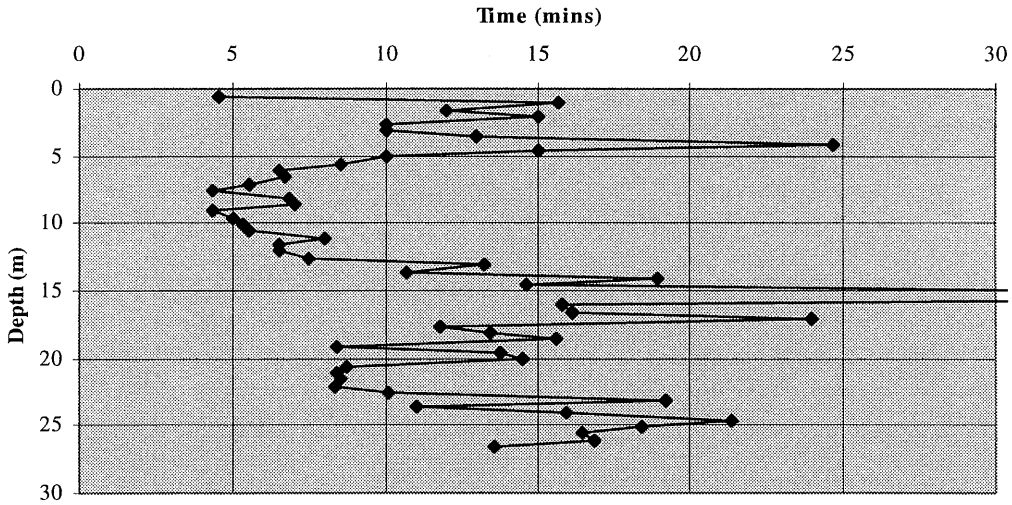
Bh BGS15 Penetration Rates, 29/1/98



Borehole BGS16

Borehole Drilling/Construction Details	
Date drilling started	30/1/98
Date drilling completed	4/2/98
30/1/98 - Drilled with 8.5" tricone	0.00 - 11.5m
31/1/98 - Drilled with 8.5" tricone	11.5 - 26.5m
31/1/98 - Cored at 3"	26.5 - 29.5m
Depth of borehole on completion	29.5mbgs
Borehole diameter	$6^1/_2$"
Casing erected in hole	2x2.9mx125mm casing
	1x5.8mx125mm casing
	3x5.8mx125mm screen
Original top of casing above ground level	1.90m
Total length of casing/screen	31.48m
Depth of borehole after gravel packing	mbtoc
Amount of casing removed	1.20m
Top of casing above ground level	0.70m

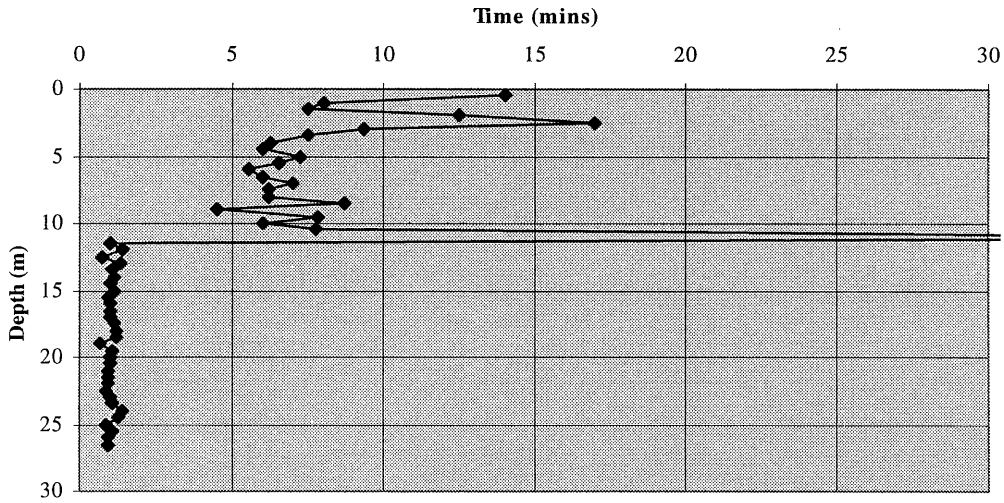
Bh BGS16 Penetration Rates, 30/1/98



Borehole BGS17

Borehole Drilling/Construction Details	
Date drilling started	4/2/98
Date drilling completed	5/2/98
4/2/98 - Drilled with 8.5" tricone	0.00 - 10.8m
4/2/98 - Drilled with 6.5" hammer	10.8 - 26.5m
4/2/98 - Cored at 3"	26.5 - 29.5m
Depths water struck	10.5,15.5, 16.0, 16.5, 24.0m
Depth of borehole on completion	29.5mbgs
Borehole diameter	$6^1/_2$"
Casing erected in hole	1x2.9mx125mm casing 1x5.8mx125mm casing 3x5.8mx125mm screen 1x1.5mx125mm casing
Original top of casing above ground level	0.35m
Total length of casing/screen	27.30m
Amount of casing removed	0.00m

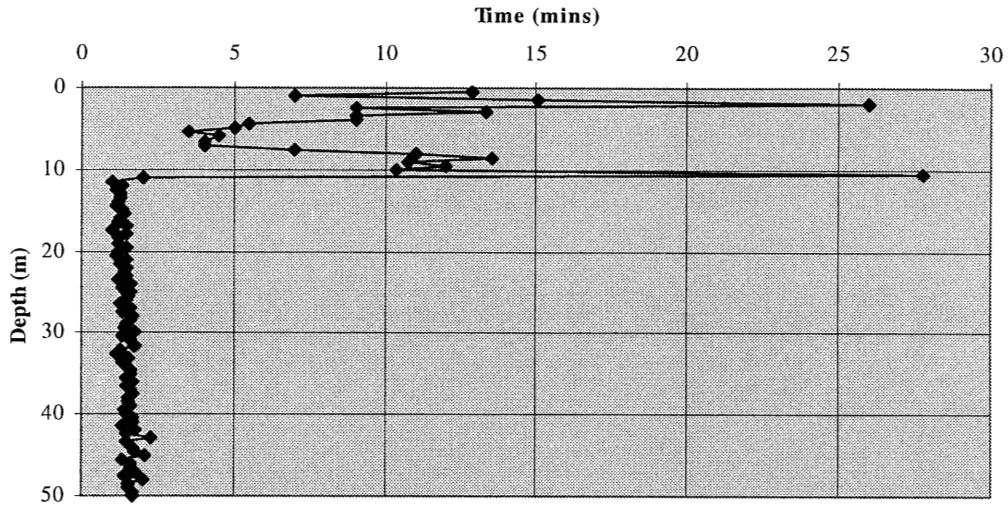
Bh BGS17 Penetration Rates, 4/2/98



Borehole BGS18

Borehole Drilling/Construction Details	
Date drilling started	6/2/98
Date drilling completed	7/2/98
6/2/98 - Drilled with 8.5" tricone	0.00 - 10.5m
6/2/98 - Drilled with 6.5" hammer	10.5 - 50.0m
7/2/98 - Cored at 3"	50.0 - 53.0m
Depth of borehole on completion	53.0mbgs
Borehole diameter	$6^1/_2$"
Casing erected in hole	none
Rest water level below casing top	33.70m

BGS18 Penetration Rate, 6/2/98



Annex 3: Geological Logs

Geological Log: Borehole No. BGS14

Soil/ferrecrete horizon	
0.0- 0.5	Yellowish red 5YR4/8 sandy soil with many dark reddish brown hard nodules up to 20 mm with smaller dark purple nodules.
0.5 - 1.0	Red 2.5YR4/6 gritty clay with many dark reddish brown hard nodules up to 20 mm with smaller dark purple nodules, some yellow staining.
1.0 - 1.5	Red 2.5YR4/6 gritty clay some dark reddish brown hard nodules up to 20 mm with smaller dark purple nodules
1.5 - 2.0	Red 2.5YR4/6 gritty clay some dark reddish brown hard nodules up to 20 mm with smaller dark purple nodules some soft light grey clay.
2.0 - 2.5	Gritty red clay with increased dark reddish brown nodules (some yellow staining).
2.5 - 3.0	Gritty red clay with nodules; much light grey clay with orange partings
Clayey very weathered horizon	
3.0 - 3.5	Light grey and yellowish brown clay; some red clay partings few nodules
3.5 - 4.0	Light grey and yellowish brown clay; some red clay partings
4.0 - 4.5	Light grey, reddish yellowish/strong brown and brownish yellow clay; some red clay partings.
4.5 - 5.0	Light grey and reddish yellow/strong brown clay, some red partings
5.0 - 5.5	Light grey and reddish yellow/strong brown clay with red partings.
5.5 - 6.0	Olive yellow 2.5Y6/6 clay with light grey and reddish yellow/strong brown clay partings.
Weathered mudstones with clay	
6.0 - 6.5	Pale olive 5Y6/3 mudstone with with light grey and reddish yellow/strong brown clay partings.
6.5 - 7.0	Pale olive 5Y6/3 mudstone with some yellowish brown 10YR5/4 fragments
7.0 - 7.5	Pale olive - olive 5Y6/3-5/3 soft mudstone, some dark reddish brown partings
7.5 - 8.0	Pale olive - olive soft mudstone - some dark reddish brown partings
8.0 - 8.5	Pale olive - olive 5Y6/3-5/3 soft mudstone, with some olive grey 5Y5/2-fragments, some dark reddish brown and black partings
8.5 - 9.0	Pale olive - olive 5Y6/3-5/3 soft mudstone, with some olive grey 5Y5/2-fragments, some dark reddish brown and black partings
9.0 - 9.5	Pale olive - olive 5Y6/3-5/3 soft mudstone, with some olive grey 5Y5/2-fragments, some dark reddish brown and black partings. Some dark greenish grey hard fine grained micaceous sandstone and siltstone
9.5 - 10.0	Olive grey - grey mudstone 5Y5/2 with some well cemented, hard dark greenish grey hard fine grained sandstone and siltstone, some orange and dark reddish brown partings
Soft mudstones with thin layers of hard fine grained sandstones, siltstones and medium grained saccaroidal calcareous sandstones, some weathering	
10.0 - 10.5	Soft grey mudstone with cemented dark greenish and brownish grey fine grained sandstone and siltstone and some light grey medium grained sacchorodial calcareous sandstone.
10.5 - 11.0	Grey soft mudstone with well cemented dark greenish and brownish fine grained sandstone and siltstone, some black layers with mica and orange and reddish brown staining.
11.0 - 11.5	Grey soft mudstone with well cemented dark greenish and brownish fine grained sandstone and siltstone, some black layers with mica and orange and reddish brown staining.

11.5 - 12.0	Grey soft mudstone with some dark greenish and brownish well cemented fine grained sandstone and siltstone and some thin light grey sacchorodial calcareous sandstone, with orange and reddish brown staining.
12.0 - 12.5	Grey soft mudstone with some dark greenish and brownish well cemented fine grained sandstone and siltstone and some thin light grey sacchorodial calcareous sandstone, with orange and reddish brown staining.
12.5 - 13.0	Grey soft mudstone with some dark greenish and brownish well cemented fine grained sandstone and siltstone and some thin light grey sacchorodial calcareous sandstone, with orange and reddish brown staining.
13.0 - 13.5	Grey soft mudstone with some dark greenish and brownish well cemented fine grained sandstone and siltstone and thin light grey sacchorodial calcareous sandstone.
13.5 - 14.0	Grey soft mudstone with some dark greenish and brownish well cemented fine grained sandstone and siltstone with mica.
Hard well cemented siltstone and fine grained sandstone bands with micaceous partings	
14.0 - 14.5	Hard well cemented dark brownish and greenish grey siltstone and fine grained sandstone with black layers with mica.
14.5 - 15.0	Hard well cemented dark brownish and greenish grey siltstone and fine grained sandstone with black layers with mica, odd mudstone (possible thin calcite vein?)
15.0 - 15.5	Hard well cemented dark brownish and greenish grey siltstone and fine grained sandstone with black layers with mica, with some mudstone and calcareous sacchorodial medium grained sandstones.
15.5 - 16.0	Hard well cemented dark brownish and greenish grey siltstone and fine grained sandstone with black layers with mica, with some mudstone and calcareous sacchorodial medium grained sandstones.
Interbedded mudstones and hard siltstone and fine grained sandstone bands	
16.0 - 16.5	Interbedded grey mudstone and hard dark greenish and brownish grey siltstone and fine grained sandstone. Some black micaceous layers and odd calcareous sacchorodial medium grained sandstones.
16.5 - 17.0	Interbedded grey mudstone and hard dark greenish and brownish grey siltstone and fine grained sandstone. Some black micaceous layers
17.0 - 17.5	Interbedded grey mudstone and hard dark greenish and brownish grey siltstone and fine grained sandstone. Some black micaceous layers and odd calcareous sandstone.
17.5 - 18.0	Soft grey mudstone with some interbedded layers of well cemented hard dark greenish grey siltstone/fine sandstone, some balck layers with mica.
Soft mudstone with thin siltstone bands	
18.0 - 18.5	Soft dark grey mudstone with siltstone and some mica.
18.5 - 19.0	Soft dark grey mudstone with siltstone and some mica
19.0 - 19.5	Soft dark grey mudstone with little siltstone
19.5 - 20.0	Soft dark grey mudstone with siltstone
20.0 - 20.5	Soft dark grey mudstone with siltstone
Soft mudstones	
20.5 - 21.0	Soft dark grey mudstone with occasional black micaceous layer
21.0 - 21.5	Soft dark grey mudstone.
21.5 - 22.0	Soft dark grey mudstone with some siltstone and black micaceous layers.
22.0 - 22.5	Soft dark grey mudstone.
22.5 - 23.0	Soft dark grey mudstone
23.0 - 23.5	Soft dark grey mudstone.

Soft mudstones with thin siltstone and fine grained sandstone bands

23.5 - 24.0	Soft dark grey mudstone with some siltstone to fine grained sandstone.
24.0 - 24.5	Soft dark grey mudstone with sacchorodial calcareous medium to fine grained sandstone.
24.5 - 27.0	Fissile soft dark grey mudstone, with conchoidal fracture. Cracks when dry. Few darker layers of silt and fine grained sandstone.

Geological Log Borehole No. BGS15

Soil/ferrecrete horizon	
0- 0.5	Reddish brown, red and dusky red hard nodules (5 - 10 mm) with some dark purple patches and ocasional yellow.
0.5 - 1.0	Reddish brown, red and dusky red hard nodules (5 - 10 mm) with some dark purple patches and ocasional yellow, with red 2.5YR5/6 clay.
1.0 - 1.5	Reddish brown, red and dusky red hard nodules (5 - 10 mm) with some dark purple and yellow patches, with red clay and occasional light grey clay.
1.5 - 2.0	Mottled red 10R5/6 and light grey clay; many small dusky red - dark reddish grey rounded nodules and reddish brown dusky red nodules.
2.0 - 2.5	Red 10R5/6 clay with light grey clay partings; many reddish brown and dusky red nodules (occasional yellow) - any smaller rounded dark reddish grey nodules.
2.5 - 3.0	Mottled weak red 10R5/4 and light grey clay; some small (< 5mm) dusky red and purple nodules.
Clayey very weathered horizon	
3.0 - 3.5	Mottled light reddish brown 5YR6/4 and light grey clay - occasional reddish yellow 7.5YR7/8 clay - few nodules.
3.5 - 4.0	Light reddish brown 5YR6/4 and light grey clay
4.0 - 4.5	Light reddish brown 5YR6/4 and light grey clay, with dark red clay.
4.5 - 5.0	Weak red, reddish brown, reddish brown yellow and light grey mottled clay
5.0 - 5.5	Red, reddish yellow mottled clay with some light grey clay partings. Brownish yellow 10YR6/6 and olive yellow 2.5Y6/6 soft clay.
5.5 - 6.0	Brownish yellow 10YR6/6 and olive yellow 2.5Y6/6 clay with red, reddish yellow and light grey mottled clay.
6.0 - 6.5	Brownish yellow 10YR6/6 and olive yellow 2.5Y6/6 clay with red, reddish yellow and light grey mottled clay
6.5 - 7.0	Brownish yellow 10YR6/6 and olive yellow 2.5Y6/6 clay with red, reddish yellow and light grey mottled clay, with occasional pale yellow soft mudstone.
Very weathered clayey mudstones	
7.0 - 7.5	Pale olive 5Y6/3 weathered mudstone; some reddish yellow, weak red and light grey partings and mottles
7.5 - 8.0	Pale olive 5Y6/3 weathered mudstone; some reddish yellow, weak red and light grey partings and mottles with some brownish yellow clay.
8.0 - 8.5	Olive 5Y5/3 and light yellowish brown 2.5Y6/3 soft mudstone with some softer reddish brown clay.
Soft weathered mudstones	
8.5 - 9.0	Soft dry olive mudstone, occasional reddish yellow partings.
9.0 - 9.5	Soft dry olive mudstone with reddish yellow partings.
9.5 - 10.0	Olive soft mudstone; some reddish yellow and red mottles
10.0 - 11.0	Olive - pale olive soft mudstone with some reddish brown partings and reddish brown and black staining along fractures.
11.0 - 11.5	Soft olive mudstone in large broken pieces. Reddish brown and black staining along fractures.
11.5 - 12.0	Soft olive mudstone in large broken pieces; much reddish brown, black and orange staining on broken pieces.
12.0 - 12.5	Soft olive mudstone in large broken pieces; much reddish brown, black and orange staining on broken pieces
12.5 - 13.0	Soft olive mudstone in large broken pieces; much reddish brown, black and orange staining on broken pieces

13.0 - 13.5	Soft olive and some grey mudstone in large broken pieces; much reddish brown, black and orange staining on broken pieces
13.5 - 14.0	Soft olive and grey mudstone in large broken pieces; much reddish brown, black and orange staining on broken pieces
Fairly weathered mudstone with hard siltstone layers and calcite veins	
14.0 - 14.5	Soft grey and olive mudstone in large broken pieces; some **calcite** fragments and much reddish brown, black and orange staining on broken pieces
14.5 - 15.0	Olive and grey mudstone, much staining (mainly on olive mudstone) and occasional **calcite.**
15.0 - 15.5	Olive and grey mudstone, much staining (mainly on olive mudstone) with **calcite** veins. Occasional black silty and sandy micaceous layer.
15.5 - 16.0	Olive and grey mudstone. Olive pieces tend to be large with much staining (yellow, reddish brown and black); occasional **calcite**.
16.0 - 16.5	Grey and olive mudstone, some yellow, reddish brown staining as well as dark grey/black very hard silty layers and some **calcite**.
16.5 - 17.0	Grey and olive mudstone, some yellow, reddish brown staining as well as dark grey/black very hard silty layers
17.0 - 17.5	Grey and some olive mudstone, some yellow, reddish brown staining as well as dark grey/black very hard silty layers
17.5 - 18.0	Grey mudstone with occasional **calcite** vein; some olive mudstone with dark reddish brown, black and orange stains.
Compact mudstone with calcite and gypsum veins	
18.0 - 18.5	Grey mudstone with occasional **calcite** veins; some olive yellow mudstone with staining. Thin granular white deposit on grey mudstone (no reaction with nitric acid) possibly **gypsum**.
18.5 - 19.0	Grey and increased olive yellow and olive mudstone with **calcite** veins; some hard dark grey black siltstone.
19.0 - 19.5	Grey and increased olive yellow and olive mudstone with **calcite** veins; some hard dark grey black siltstone
19.5 - 20.0	Olive yellow/olive and grey soft mudstone, olive mudstones are oxide stained,, some **gypsum**.
20.0 - 20.5	Olive yellow/olive and grey soft mudstone, olive mudstones are oxide stained, some **calcite**.
20.5 - 21.0	Grey and some olive mudstone.
Soft mudstone with sandy and silty layers with gypsum and calcite veins	
21.0 - 21.5	Soft grey mudstone with some olive mudstone, some hard dark grey chips and sandy and silty black micaceous layers.
21.5 - 22.0	Soft grey mudstone with some olive mudstone, some hard dark grey chips and sandy and silty black micaceous layers with a little **gypsum**.
22.0 - 22.5	Soft grey mudstone, some hard dark grey chips and sandy and silty black micaceous layers. Some olive mudstone with **gypsum** and **calcite**.
22.5 - 23.0	Soft grey mudstone, some hard dark grey chips and sandy and silty black micaceous layers. Some olive mudstone with **gypsum** and **calcite**.
23.0 - 23.5	Soft grey mudstone, some hard dark grey chips and sandy and silty black micaceous layers. Some olive mudstone with **calcite**.
23.5 - 24.0	Soft grey mudstone, some hard dark grey chips and sandy and silty black micaceous layers. Some olive mudstone.
24.0 - 24.5	Soft grey mudstone, some hard dark grey chips and sandy and silty black micaceous layers. Some olive mudstone with **calcite**.

24.5 - 25.0	Soft grey mudstone with black micaceous silty and sandy layers; some olive yellow/olive mudstone with staining, with **calcite** and **gypsum**.
25.0 - 25.5	Soft grey mudstone with black micaceous silty and sandy layers; some olive yellow/olive mudstone with staining, with **calcite** and thick (3 mm) **gypsum**
25.5 - 26.0	Soft grey mudstone with black micaceous silty and sandy layers; some olive yellow/olive mudstone with staining, with **calcite**
26.0 - 26.5	Soft grey mudstone with some olive colouring, some **calcite** and **gypsum**.
Fractured mudstone with calcite and gypsum veins	
26.5 - 27.0	Grey mudstone with occasional silty micaceous bands, with secondary **gypsum** deposits along fractures, some **calcite**.
27.0 - 27.5	Grey mudstone with occasional silty micaceous bands, with secondary **gypsum** deposits along fractures, with thick **calcite** veining (up to 10 mm), some slickenslides.
27.5 - 28.0	Grey mudstone with **gypsum** and **calcite** along fractures.
27.0 - 27.5	Grey mudstone with **gypsum** and thick **calcite** veining (up to 10 mm), some slickenslides.

Geological Log: Borehole No. BGS16

Soil/ferrecrete horizon	
0.0 - 0.5	Fine to medium grained sand soil; strong brown 7.5YR5/8
0.5 - 1.0	Reddish yellow 5YR6/8 sandy clay with sand as above
1.0 - 1.5	Reddish yellow 5YR6/8 sandy clay with yellow and light grey clay. Many irregularly shaped dark purple/black and red hard nodules
1.5 - 2.0	Light grey clay with red partings 10R5/1 Many irregularly shaped dark purple/black and red hard nodules
2.0 - 2.5	Light grey clay with red partings and some yellow mottles; less nodules.
2.5 - 3.0	Hard, red and yellow irregularly shaped nodules and broken pieces; ocassionl small rounded dark brown/black nodules. Some light grey clay.
3.0 - 3.5	Hard, red and yellow irregularly shaped nodules and broken pieces; ocassionl small rounded dark brown/black nodules. Some light grey clay
Clayey very weathered horizon	
3.5 - 4.0	Dry light grey clay with red and reddish yellow 7.5YR7/8 partings with dark red nodules and occasional yellow nodule.
4.0 - 4.5	Large pieces of clay. Light grey and reddish yellow partings with some red. Very Occasional dark red purple hard nodule (up to 10 mm)
4.5 - 5.0	Large pieces of clay. Light grey and reddish yellow partings with some red. Very Occasional dark red purple hard nodule (up to 10 mm), with some brownish yellow clay 10Y6/8
Weathered mudstone with clay	
5.0 - 5.5	Olive yellow 2.5Y6/8 mudstone with light grey, reddish yellow and red mottled clay, and some soft brownish yellow clay.
5.5 - 6.0	Olive yellow dry friable clay with occasional harder lump of light grey clay and soft brownish yellow clay.
6.0 - 6.5	Light yellowish brown 2.5Y6/4 mudstone with occasional light grey and brownish yellow partings
6.5 - 7.0	Light yellowish brown (sometimes yellow 2.5Y7/4) mudstone with occasional light grey and brownish yellow clay.
7.0 - 7.5	Pale olive 5Y6/3 and olive yellow 2.5Y6/8 mudstone with occassional light grey and brownish yellow partings.
7.5 - 8.0	Pale olive and olive grey 5Y6/2 mudstone. Increase in light grey and brownish yellow clay (about 10%).
8.0 - 8.5	Pale olive, olive grey and olive yellow mudstone with light grey and brownish yellow clay.
Fairly weathered mudstones	
8.5 - 9.0	Olive mudstone with yellow/reddish yellow, red/reddish brown, purple/black partings
9.0 - 9.5	Olive mudstone with yellow/reddish yellow, red/reddish brown, purple/black partings
9.5 - 10.0	Olive mudstone with yellow/reddish yellow, red/reddish brown, purple/black partings
10.0 - 10.5	Olive mudstone with yellow, yellow/reddish, red/reddish brown, purple/black partings
10.5 - 11.0	Olive mudstone with yellow/reddish yellow, red/reddish brown, purple/black partings
11.0 - 11.5	Olive mudstone with yellow/reddish yellow, red/reddish brown, purple/black partings

11.5 - 12.0	Olive mudstone with reddish brown staining and occasional black or yellow staining.
12.0 - 12.5	Olive and some grey mudstone with reddish brown staining and occasional black or yellow staining
12.5 - 13.0	Olive and grey mudstone with reddish brown staining and occasional black or yellow staining
Mudstone with thin hard interbedded siltstone and fine grained sandstone layerers, some weathering	
13.0 - 13.5	Grey mudstone with some olive pieces; some reddish brown and yellow staining; occasional black with some mica, some dark reddish brown harder silty fine grained sandstone
13.5 - 14.0	Grey mudstone with olive brown siltstone and fine grained sandstone, decreased staining - some black with mica..
14.0 - 14.5	Grey mudstone with some olive brown fine sandstone - staining only on the top and bottom of sandstone. Occassional light grey medium - fine quartzite. Both the quartzite and sandstone react weakly with acid. Some black with mica.
14.5 - 15.0	Grey shaly mudstone , sometimes olive. Occasional olive brown siltstone/fine sandstone with reddish brown staining. Some very hard light grey chips which react weakly with acid. Some black with mica.
15.0 - 15.5	Grey shaly mudstone , sometimes olive. Occasional olive brown siltstone/fine sandstone with reddish brown staining. Some very hard light grey chips which react weakly with acid. Some black with mica, with small piece of **calcite**.
15.5 - 16.0	Grey shaly mudstone , sometimes olive. Occasional olive brown siltstone/fine sandstone with reddish brown staining. Some very hard light grey chips which react weakly with acid. Some black with mica
16.0 - 16.5	Grey shaly mudstone , sometimes olive. Occasional olive brown siltstone/fine sandstone with reddish brown staining. Some very hard light grey chips which react weakly with acid. Some black with mica
Mudstone with thin hard siltstone and fine grained sandstone layers, some vein calcite	
16.5 - 17.0	Grey mudstone with **calcite** veining. Some hard dark brown siltstone/fine sandstone layers.
17.0 - 17.5	Grey mudstone with **calcite** veining. Some hard dark brown siltstone/fine sandstone layers, with black micaceous layers.
17.5 - 18.0	Grey mudstone with **calcite** veining. Some hard dark brown siltstone/fine sandstone layers.
18.0 - 18.5	Grey mudstone with **calcite** veining. Some hard dark brown siltstone/fine sandstone layers.
Mudstone with thin hard limestone layers, some vein calcite	
18.5 - 19.0	Grey mudstone/siltstone. Occasional brown fine sandstone/siltstone which sometime reacts with acid. Some thin light grey limestone layers.
19.0 - 19.5	Grey fissile mudstone with siltstone fine sandstone - occasional limestone and **calcite** veining
19.5 - 20.0	Grey mudstone with concoidal fracture; occasional hard light grey limestone layers; some **calcite.**
20.0 - 20.5	Grey mudstone with concoidal fracture - occasional light grey limestone and some black layers with mica.
Fissile mudstones	
20.5 - 21.0	Grey mudstone with concoidal fracture, some darker siltstone fine sandstone
21.0 - 21.5	Grey fissile mudstone with concoidal fracture.
21.5 - 22.0	Grey fissile mudstone with concoidal fracture

22.0 - 22.5	Grey fissile mudstone with concoidal fracture with thin darker siltstone layers.
22.5 - 23.0	Grey fissile mudstone with concoidal fracture
23.0 - 23.5	Grey fissile mudstone with concoidal fracture
23.5 - 24.0	Grey fissile mudstone with concoidal fracture
24.0 - 24.5	Grey fissile mudstone with concoidal fracture
24.5 - 25.0	Grey fissile mudstone with concoidal fracture
25.0 - 25.5	Grey fissile mudstone with concoidal fracture
25.5 - 26.0	Grey fissile mudstone with concoidal fracture
26.0 - 26.5	Grey fissile mudstone with concoidal fracture
Fissile calcareous mudstone with interbedded sandstone, some vein calcite	
26.5 - 28.0	Grey calcareous friable mudstone with concoidal fracture. Cracks when dry. Some thin black intercalations - possible organic, dipping at about 20 degs. Some thicker lumps of dark grey/brown calcareous sandstone. Thin black layer with mica (?) at about 27.2 m. **Calcite** veining along fractures at 27.35 m. Occasional thin white calcareous layers falling bedding.
Non-calcareous mudstone	
28 - 29.5	Non calcareous mudstone; friable with concoidal fracture, grey. Occasional white calcareous layers and occasional **calcite** on small fractures. Black intercalations (one thin vertical dark vein). Occasionally thicker dark sandy deposit (about 15 mm across) seemingly associated with the black intercalations.

Geological Log: Borehole No. BGS17

Soil/ferrecrete horizon	
0 - 0.5	Missing
0.5 - 1	Yellowish red 5YR5/8 ferrecrete with dark reddish brown and black nodules
1 - 1.5	Yellowish red 5YR5/8 ferrecrete with many dark purple/black and dark red fragments and nodules, some yellow mottles
1.5 - 2	Yellowish red 5YR5/8 ferrecrete with many dark purple/black and dark red fragments and nodules, some yellow mottles, with white and red friable clay
2 - 2.5	Light grey and yellowish brown 10YR6/8 clay: many rounded dark purple and reddish black nodules: some red fragments
Clayey very weathered horizon	
2.5 - 3	Pale yellow 2.5Y7/6 highly weathered mudstone with 10YR7/8 yellow partings and harder grey partings
3 - 3.5	Pale yellow 5Y7/3 mudstone with softer yellow 10YR7/8 clayey partings and light grey clay
Very weathered mudstone with clay and weathered fine grained sandstones and siltstones	
3.5 - 4	Pale yellow to pale olive 5Y7-6/3 weathered mudstone (more competent than above); some light grey and brownish yellow clay; reddish brown and reddish black staining; some dark brown siltstones and fine grained sandstones
4 - 4.5	Pale olive and olive mudstone with some brownish yellow clay; much black and reddish brown staining; some dark brown siltstones and fine grained sandstones
4.5 - 5	Olive mudstone with much brownish yellow and light grey clay
5 - 5.5	Olive mudstone and dark olive grey fine grained sandstones; much light grey and brownish yellow clay; brownish yellow, dark reddish brown and black staining
5.5 - 6	Olive grey 5Y5/2 mudstone with some light grey, olive brown and brownish yellow clayey partings; much staining, some thin siltstones and fine grained sandstones
6 - 6.5	Olive grey mudstone with some clay, much staining; some siltstones and fine grained sandstones
6.5 - 7	Thinly laminated olive grey and olive mudstone; some micaceous silty partings; much staining
Fairly weathered mudstones	
7 - 7.5	Olive 5Y4/3 thinly laminated mudstone with staining, some light grey clay
7.5 - 8	Olive 5Y4/3 thinly laminated mudstone with staining
8 - 8.5	Olive mudstone, large fragments, fairly hard with staining
8.5 - 9	Thinly laminated olive mudstone, some grey fragments with light grey soft partings
9 - 9.5	Thinly laminated olive mudstone, some grey fragments with light grey soft partings
9.5 - 10	Dark greenish grey mudstone; yellowish brown and some black and reddish brown partings
10 - 10.5	Dark greenish grey thinly laminated mudstone with much staining, some soft grey fragments
Mudstones and hard limestones with little fine grained sandstone	
10.5 - 11	Olive green to olive grey mudstone with staining; much hard grey and brown limestone
11 - 11.5	Large fragments of olive green mudstone with much hard dark grey siltstones and fine grained sandstones; some thin limestone and white translucent non-calcareous vein material

11.5 - 12	Soft olive and grey mudstone with dark greenish grey and dark grey fine grained sandstones, some limestone
Mudstone and thin interbedded fine grained sandstones, some weathering and vein calcite	
12 - 12.5	Olive green and grey mudstone with some dark grey/dark greenish grey fine grained sandstones; brown and reddish brown staining; some **calcite**
12.5 - 13	Olive green and grey mudstone with some dark grey/dark greenish grey fine grained sandstones; brown and reddish brown staining; some **calcite**
Mudstone with siltstone and fine grained sandstone, some vein calcite	
13 - 13.5	Grey and olive mudstone, some staining; very dark grey siltstones and fine grained sandstones; some **calcite**
Mudstone and limestone with siltstone and fine grained sandstone, some vein calcite	
13.5 - 14	Grey and olive mudstone some staining; some vein **calcite**; very dark grey siltstones and fine grained sandstones and grey limestone
Mudstone with siltstone and calcareous fine grained sandstone, some vein calcite	
14 - 14.5	Dark grey and olive mudstone with staining; some thin dark grey/black siltstones and fine grained sandstones occasionally calcareous
14.5 - 15	Dark grey and olive mudstone with staining;; some thin dark grey/black siltstones and fine grained sandstones occasionally calcareous, some **calcite**
Mudstone with siltstone and fine grained micaceous sandstone, some vein calcite	
15 - 15.5	Dark grey olive green splintery mudstone, some dark grey/black siltstones and fine grained sandstones with mica and vein **calcite**
15.5 - 16	Dark grey olive green splintery mudstone, some dark grey/black siltstones and fine grained sandstones with mica
16 - 16.5	Dark grey olive green splintery mudstone, some dark grey/black and dark greenish grey siltstones and fine grained sandstones with mica
16.5 - 17	Dark grey and olive mudstone, much hard dark grey/black and dark greenish grey siltstones and fine grained sandstones, some **calcite** veining
17 - 17.5	Dark grey and olive mudstone, much dark greenish grey and grey siltstones and fine grained sandstones, some **calcite**
Mudstones and interbedded thin micaceous fine grained sandstones	
17.5 - 18	Dark grey mudstone and dark grey fine grained sandstones with thin black micaceous layers
18 - 18.5	Dark grey mudstone with grey and dark grey fine grained sandstones, with thin black partings
Mudstone with thin layers of siltstone and fine grained sandstones, some vein calcite and gypsum/barytes	
18.5 - 19	Dark grey mudstone with grey to very dark grey siltstones and fine grained sandstones, some vein **calcite and barytes/gypsum**?
19 - 19.5	Large fragments of dark olive grey mudstone, splintery with brown staining; with grey to very dark grey siltstones and fine grained sandstones, much vein **calcite**
19.5 - 20	Dark grey and olive brown mudstone, some calcite; some hard black siltstone and very dark grey siltstones and fine grained sandstones
20 - 20.5	Dark grey and olive brown mudstone, with black siltstone and grey-very dark grey fine grained sandstone; some vein **calcite and baryte/gypsum**?
20.5 - 21	Dark grey mudstone with grey-very dark grey fine grained sandstone with thin black partings, some vein **calcite and baryte/gypsum**?
21 - 21.5	Dark grey and slightly brown mudstone, some fine grained sandstone with thin black partings

21.5 -22	Dark grey and olive brown mudstone, some dark brown staining; some fine grained sandstone with thin black partings, some vein **calcite and baryte/gypsum**?
22 - 22.5	Dark grey mudstone somethimes splintery; some very dark grey thin layers of hard fine grained sandstones, some vein **calcite and baryte/gypsum**?
22.5 - 23	Dark grey mudstone, some yellow/brown staining, thin layers of hard siltstones and fine grained sandstones, some vein **calcite and baryte/gypsum**?
23 - 23.5	Dark grey mudstone, some yellow/brown staining, thin layers of hard siltstones and fine grained sandstones, some vein **calcite and baryte/gypsum**?
23.5 - 24	Dark grey and olive brown mudstone, with thin grey to very dark grey and brown siltstones and fine grained sandstones, some vein **calcite and gypsum**?
Mudstone and interbedded siltstones, faulted with vein calcite and gypsum	
24 - 24.5	Dark grey mudstone with thin very dark grey hard siltstone with black partings, some vein **calcite and gypsum**?; slickensides with brown staining on surface present
24.5 - 25	Dark grey mudstone, some thin black layers; also some convoluted bedding, much brown staining, some **gypsum**?
25 - 25.5	Dark grey mudstone with some thinly bedded grey to dark grey siltstones and fine grained sandstones, some brown staining and **gypsum?**
25.5 - 26	Dark grey splintery mudstone; some hard black siltstone with slickensides and brown staining
26 - 26.5	Dark grey splintery mudstone, some siltstone with brown staining and **gypsum**?
Faulted dark grey mudstone	
26.5 - 29.5	Core is crushed, little competent core recovery. Dark grey mudstone; very friable and broken; some dark grey siltstone. White **barytes or gypsum** coating many of the pieces; some veins appear consistent through some of the crushed core - possible fault breccia

Geological Log Borehole No. BGS18

Soil/ferrecrete horizon	
0.0 - 0.5	Reddish yellow 7.5YR6/6 clayey soil with sand
0.5 - 1.0	Stiff yellowish red 5YR6/6 and light grey clay; many red, dark reddish-brown, purple and yellow nodules
1.0 - 1.5	Stiff yellowish red 5YR6/6 and light grey clay; many red, dark reddish-brown, purple and yellow nodules
1.5 - 2.0	Light grey and white dry friable clay with many red/dusky red and yellow nodules
Clayey very weathered horizon	
2.0 - 2.5	Strong brown 7.5YR5/6 gritty clay; some light grey partings; some yellow 7.5YR5/6 and red partings; some hard well cemented brown fine grained sandstone and siltstone
2.5 - 3.0	Soft reddish yellow 7.5YR6/6 clay with light grey and yellow partings
3.0 - 3.5	Mottled brownish yellow 10YR6/6, yellow 10YR7/8, red and light grey clay
3.5 - 4.0	Brownish yellow 10YR6/8 and light grey clay with red and yellow partings
4.0 - 4.5	Olive yellow 2.5Y6/6 clay with strong brown 7.5YR5/6 and light grey partings; some thin hard well cemented fine grained sandstone.
Weathered mudstones with clay	
4.5 - 5.0	Olive yellow/brownish yellow highly weathered mudstone with light grey and yellow to reddish yellow partings
5.0 - 5.5	Pale olive 5Y6/4 weathered mudstone with some light grey and yellow to reddish yellow clayey partings; reddish brown 5YR4/4, yellow 10YR5/6 and black staining
5.5 - 6.0	Olive 5YR5/3 laminated mudstone with reddish brown 5YR4/4, yellow 10YR5/6 and black staining, little clay
Fairly weathered mudstones, fine grained sandstones and siltstones	
6.0 - 6.5	Thinly laminated olive mudstone with reddish brown, yellowish brown and black partings; some thin black well cemented fine grained sandstone and siltstone
6.5 - 7.0	Olive and olive grey 10YR5/3-1 thinly laminated mudstone with reddish brown, yellowish brown and black partings; some thin black well cemented fine grained sandstone and siltstone
7.0 - 7.5	Olive and dark grey thinly laminated mudstone, some micaceous green brown siltstone and fine grained sandstone
Mudstones slightly weathered	
7.5 - 8.0	Dark grey thinly laminated mudstone and olive mudstone
8.0 - 8.5	Dark grey thinly laminated mudstone and olive mudstone
8.5 - 9.0	Dark grey and olive green thinly laminated mudstone
9.0 - 9.5	Dark grey and olive green thinly laminated mudstone
9.5 - 10	Dark grey and olive green thinly laminated mudstone, with some hard black siltstone and gypsum/barytes?
Interbedded mudstone, siltstone and hard fine grained sandstone	
10 - 10.5	Dark grey and olive green thinly laminated mudstone, and some hard black siltstone with concoidal fracture
10.5 - 11	Dark grey thinly laminated soft mudstone with much dark grey well cemented micaceous fine grained sandstone and siltstone, some dark reddish brown staining

Interbedded hard calcareous fine grained sandstone, siltestones and mudstones	
11 - 11.5	Dark grey well cemented micaceous fine grained sandstone and siltstone, calcareous in parts, with dark grey thinly laminated soft mudstone, some dark reddish brown staining
11.5 - 12	Dark grey well cemented micaceous fine grained sandstone and siltstone, calcareous in parts, with dark grey thinly laminated soft mudstone, some dark reddish brown staining
Interbedded mudstone, calcareous fine grained sandstone and micaceous siltstone	
12 - 12.5	Thinly laminated grey mudstone with dark grey micaceous fine grained sandstone and siltstone, calcareous in parts, some black silty micaceous partings
12.5 - 13	Thinly laminated grey mudstone with dark grey micaceous fine grained sandstone and siltstone, calcareous in parts, some black silty micaceous partings
13 - 13.5	Thinly laminated grey mudstone with dark grey micaceous fine grained sandstone and siltstone, calcareous in parts, some black silty micaceous partings
Interbedded siltstone, fine grained sandstone, mudstone and limestone	
13.5 - 14	Calcareous fine grained sandstone and limestone with thin dark grey and brown siltstone
14 - 14.5	Dark grey and brown siltstone and fine grained sandstone with reddish yellow/brown staining; some thinly laminated dark grey mudstone and black limestone
14.5 - 15	Dark grey and brown siltstone and fine grained sandstone with reddish yellow/brown staining; some thinly laminated dark grey mudstone and black limestone
15 - 15.5	Dark grey mudstone with some dark grey siltstone and fine grained sandstone with black micaceous partings and some limestone
Interbedded mudstone, siltstone, fine grained sandstone and limestone	
15.5 - 16	Dark grey mudstone; some dark grey siltstone and fine grained sandstone with red-brown staining
16 - 16.5	Dark grey mudstone with dark grey siltstone and fine grained sandstone, some limestone
16.5 - 17	Dark grey fairly hard mudstone with siltstone and fine grained calcareous sandstone
Interbedded hard fine grained sandstone, limestone and mudstone	
17 - 17.5	Dark grey siltstone and fine grained sandstone and dark grey fairly hard mudstone
17.5 - 18	Dark grey hard siltstone and fine grained sandstone, well cemented with black micaceous partings, some light grey limestone and dark grey mudstone
18 - 18.5	Dark grey hard siltstone and fine grained sandstone, well cemented with black micaceous partings, some light grey limestone and dark grey mudstone
18.5 - 19	Dark greenish grey 10G4/1 fine grained sandstone with grey fine grained sandstone and limestone; little mudstone
19 - 19.5	Dark grey and dark greenish grey hard fine grained sandstone with black micaceous partings, some limestone and dark grey mudstone
19.5 - 20	Dark grey and dark greenish grey hard fine grained sandstone with black micaceous partings, some limestone and dark grey mudstone
20 - 20.5	Dark grey and dark greenish grey hard fine grained sandstone with black micaceous partings, some limestone and dark grey mudstone
20.5 - 21	Dark grey and dark greenish grey hard fine grained sandstone with black micaceous partings, some limestone and dark grey mudstone
Interbedded mudstone, siltstone and fine grained sandstone	

21 - 21.5	Dark grey thinly laminated mudstone with limestone and some fine grained sandstone
21.5 -22	Dark grey thinly laminated mudstone with limestone and fine grained sandstone
22 - 22.5	Dark grey thinly laminated mudstone with dark grey/black fine sandstone
22.5 - 23	Dark grey laminated mudstone with some dark grey siltstone and fine grained sandstone
23 - 23.5	Dark grey laminated mudstone with some dark grey siltstone and fine grained sandstone
Micaceous mudstone some limestone	
23.5 - 24	Dark grey soft fissile mudstone, some black micaceous layers
24 - 24.5	Dark grey soft fissile mudstone, some black micaceous layers
24.5 - 25	Dark grey soft fissile mudstone, some black micaceous layers
25 - 25.5	Dark grey soft fissile mudstone, some black micaceous layers
25.5 - 26	Dark grey fissile mudstone, some black micaceous layers and some thin light grey limestone
26 - 26.5	Dark grey fissile mudstone
26.5 - 27	Dark grey fissile mudstone, some dark grey black micaceous layers
Micaceous mudstone and limestone	
27 - 27.5	Dark grey fissile mudstone, some dark grey black micaceous layers and some limestone layers
27.5 - 28	Dark grey fissile mudstone, some dark grey black micaceous layers with some limestone and fine grained sandstone and siltstone
Interbedded mudstone, siltstone and calcareous fine grained sandstone	
28 - 28.5	Dark grey mudstone, some dark grey/black siltstone and calcareous fine grained sandstone
28.5 - 29	Dark grey mudstone, some dark grey/black siltstone and calcareous fine grained sandstone
29 - 29.5	Dark grey mudstone, some dark grey/black siltstone and calcareous fine grained sandstone
29.5 - 30	Dark grey mudstone, dark grey/black siltstone and calcareous fine grained sandstone
Interbedded hard fine grained sandstone, siltstone , mudstone and limestone	
30 - 30.5	Dark grey and dark greenish grey fine grained sandstone and siltstone and dark grey mudstone, some limestone
30.5 - 31	Dark greenish grey and dark grey fine grained sandstone and siltstone with black micaceous layers with some mudstone
31 - 31.5	Dark grey and dark greenish grey hard fine grained sandstone and siltstone with black micaceous layers, some mudstone
31.5 - 32	Dark grey and dark greenish grey hard fine grained sandstone and siltstone with black micaceous layers, some mudstone and light grey limestone
32 - 32.5	Dark grey and dark greenish grey hard fine grained sandstone and siltstone with black micaceous layers, some mudstone and light grey limestone
32.5 - 33	Dark grey and dark greenish grey hard fine grained sandstone and siltstone with black micaceous layers, with mudstone
33 - 33.5	Grey siltstone and fine grained sandstone with black micaceous layers, some dark greenish grey siltstone, fine grained sandstone and dark grey mudstone
Interbedded calcareous mudstone, siltstone and fine grained sandstone	
33.5 - 34	Dark grey mudstone with hard dark grey siltstone and black/greenish grey fine grained calcareous sandstone

34 - 34.5	Dark grey calcareous mudstone
34.5 - 35	Dark grey calcareous mudstone with some dark grey fine grained sandstone and siltstone
Interbedded siltstone, fine grained sandstone, limestone and mudstone	
35 - 35.5	Dark grey and dark greenish grey/black micaceous siltstone and fine grained sandstone, some brownish grey limestone and dark grey mudstone
35.5 - 36	Dark grey and dark greenish grey/black micaceous siltstone and fine grained sandstone, some brownish grey limestone and dark grey mudstone
Interbedded mudstone, fine grained sandstone, siltstone and limestone	
36 - 36.5	Dark grey mudstone with some dark grey fine grained sandstone and siltstone and brownish grey limestone
36.5 - 37	Dark grey mudstone with some dark grey fine grained sandstone and siltstone with black micaceous partings
37 - 37.5	Dark grey mudstone with some dark grey siltstone and fine grained sandstone and some brownish grey limestone
37.5 - 38	Dark grey mudstone with siltstone and fine grained sandstone, some black and dark brown siltstone with some limestone
Interbedded mudstone, siltstone and fine grained sandstone	
38 - 38.5	Dark grey mudstone, some dark grey siltstone and fine grained sandstone and black siltstone
38.5 - 39	Dark grey fissile mudstone, some dark grey and black siltstone and fine grained sandstone
Interbedded siltstone, fine grained sandstone, limestone and mudstone	
39 - 39.5	Dark grey and dark greenish grey siltstone and fine grained sandstone, some brown limestone and dark grey mudstone
39.5 - 40	Dark grey and dark greenish grey siltstone and fine grained sandstone, some brown limestone and dark grey mudstone
Interbedded mudstone, siltstone and fine grained sandstone	
40 - 40.5	Dark grey fissile mudstone with hard black siltstone and dark grey fine grained sandstone and siltstone
40.5 - 41	Dark grey fissile mudstone with hard black siltstone and dark grey fine grained sandstone and siltstone
41 - 41.5	Dark grey fissile mudstone with some dark grey/ black siltstone
41.5 - 42	Dark grey fissile mudstone with some dark grey/ black siltstone
42 - 42.5	Dark grey fissile mudstone with dark grey and dark greenish grey siltstone and fine grained sandstone
Interbedded hard fine grained fine sandstone, micaceous siltstone and mudstone	
42.5 - 43	Dark grey and dark greenish grey well cemented fine grained sandstone with some dark grey fissile mudstone
43 - 43.5	Dark grey and dark greenish grey well cemented fine grained sandstone with dark grey fissile mudstone and some black micaceous siltstone
Interbedded siltstone, fine grained sandstone and mudstone	
43.5 - 44	Dark grey and dark greenish grey siltstone and fine grained sandstone with dark grey fissile mudstone
44 - 44.5	Dark grey and dark greenish grey siltstone and fine grained sandstone with dark grey fissile mudstone
44.5 - 45	Dark grey and dark greenish grey siltstone and fine grained sandstone with dark grey fissile mudstone
Interbedded fine grained sandstone and mudstone	
45 - 45.5	Dark grey and dark greenish grey fine grained sandstone with mudstone

45.5 - 46	Dark grey and dark greenish grey fine grained sandstone with mudstone
46 - 46.5	Dark grey and dark greenish grey fine grained sandstone with mudstone
46.5 - 47	Dark grey and dark greenish grey fine grained sandstone with mudstone
47.5 - 48	Dark grey mudstone with black siltstone and some very dark grey and dark greenish grey fine grained sandstone
Interbedded mudstone, siltstone and fine grained sandstone	
48 - 48.5	Dark grey mudstone with black siltstone and some very dark grey and dark greenish grey fine grained sandstone
48.5 - 49	Dark grey mudstone and very dark grey and dark greenish grey fine grained sandstone with black siltstone
49 - 49.5	Dark grey mudstone and very dark grey and dark greenish grey fine grained sandstone with black siltstone
49.5 - 50	Dark grey mudstone and very dark grey and dark greenish grey fine grained sandstone with black siltstone
50.00 - 50.16	Light grey blocky fine grained soft mudstones
Hard micaceous fine grained sandstones	
50.16 - 50.18	Hard grey muddy fine grained micaceous sandstone
50.18 - 50.30	Thin bands of green fine grained sandstones interbedded with fine grained light grey shaley mudstone, some sand filled worm tubules
Interbedded silty mudstones and micaceous fine grained sandstones	
50.30 - 50.40	Light grey fine grained silty mudstone with earthy fracture, some black mica associated with coarser silty bands
50.40 - 50.65	Alternations of thinly bedded light grey shaley fine grained mudstones and thin fine grained greenish grey very micaceous sandstones
50.65 - 51.40	Light grey blocky to fairly shaley fine grained mudstones, some mudcracks
51.40 - 51.52	Light grey earthy mudstones with thin micaceous silty layers
51.52 - 51.56	Light grey silty mudstones with interbedded thin layers of cross bedded green very micaceous fine grained sandstone, some sand filled worm tubules
51.56 - 51.75	Light grey fine grained shaley mudstones with subconcoidal to blocky fracture, thin micaceous silty bands with much black biotite mica
51.75 - 52.00	Light grey earthy silty mudstones with thin greenish grey very micaceous fine grained sandstone layers
52.00 - 52.06	Soft light grey fine grained blocky and shaley mudstones with very thin silty micaceous layers
Hard medium grained quarzitic sandstones	
52.06 - 52.11	Light brownish grey very hard medium grained quartzitic sandstone with calcite cement
52.11 - 52.18	Dark green to greenish grey very hard medium grained quartzite
Interbedded shaley mudstones and micaceous fine to medium grained sandstones	
52.18 - 52.24	Thinly bedded alternations of shaley grey mudstone, grey micaceous siltstones and green grey micaceous sandstone, slickenslides at 52.22
52.24 - 52.33	Interbedded thin grey sandy mudstones, greyish white fine to medium cross-bedded sandstones and thin green fine grained sandstones, all micaceous with much biotite mica
Interbedded fissile micaceous fine grained sandstones, siltstones and silty mudstones	
52.24 - 52.50	Grey fissile interbedded thin green micaceous fine grained sandstones, grey siltstones and silty mudstones with much black biotite mica

Interbedded silty mudstones and micaceous fine grained sandstones	
52.50 - 52.60	Grey fine grained silty mudstones, some thin green very micaceous fine grained sandstone layers
Interbedded fine grained sandstones and silty mudstones	
52.60 - 52.73	Horizontally bedded alternations of thin green fine grained crossbedded sandstones and very thin grey silty mudstones
52.73 -	Junction between horizontally bedded little disturbed sediments above and highly dipping (>30°) slumped and chaotically bedded sediments below
Faulted muddy sandstones, bioturbated	
52.73 - 53.00	Thinly bedded green fine grained muddy sandstones with interbedded occassional thicker blocky to shaley light brown grey fine grained mudstones, **calcite** lined slickenslide at 52.79, some bioturbated and slump bedded fine grained green sandstones at 52.95 with much black biotite mica

Note

Typical flood water/ slack water overbund sequence with thin sands deposited, micas falling out of suspension with silts, clays falling out last to form mudstones, occassional mud coated surface, difference in dip of fine sediments indicative of contemporaneous tectonism. Some indication of life from worm burrows and organics on bedding planes but little or no direct fossil evidence. Hard bands appear as silcretised sandstones indicative of a hot climate?, clays are light grey with reddish cementation? although sandstones are reduced with much green ferrous iron oxide occurring derived from dissolution of biotite?

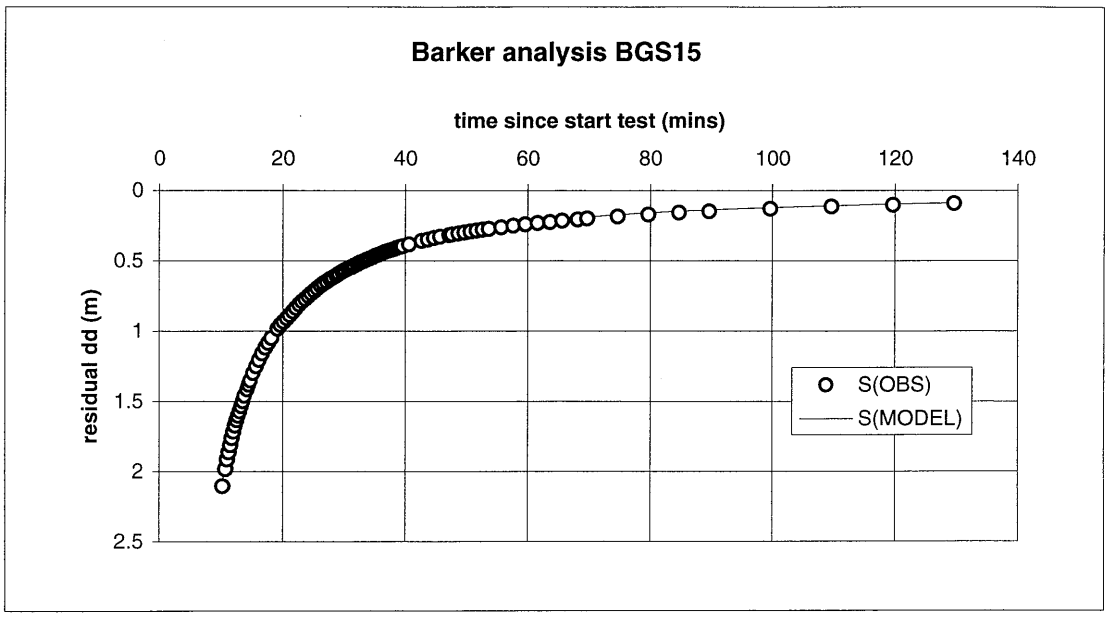
Annex 4: Test Pumping Data

BGS15

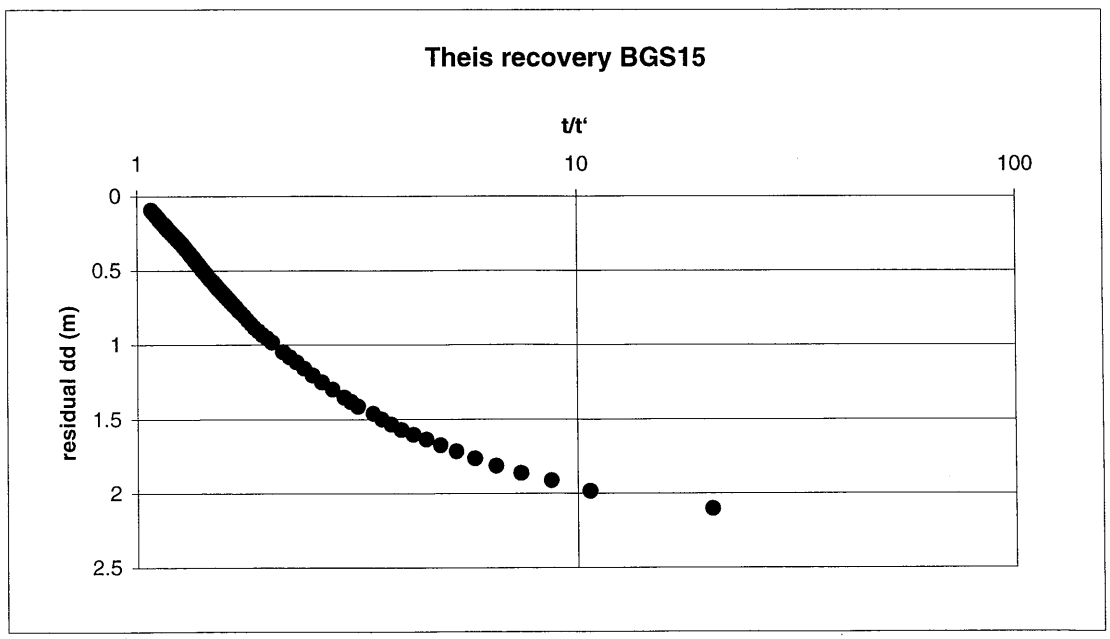
Bailer Test

date: 07/03/98
rwl: 7.325
length of pumping 09:40 mins
No of bails 35 = average p-rate 0.27 l/s

Barker analysis
T = 2.0 m2/d
S = 0.07
R = 0.1 m



Theis recovery
T = 1.3 m^2/d



BGS15

Whale test 24/03/98

rwl 6.597 m

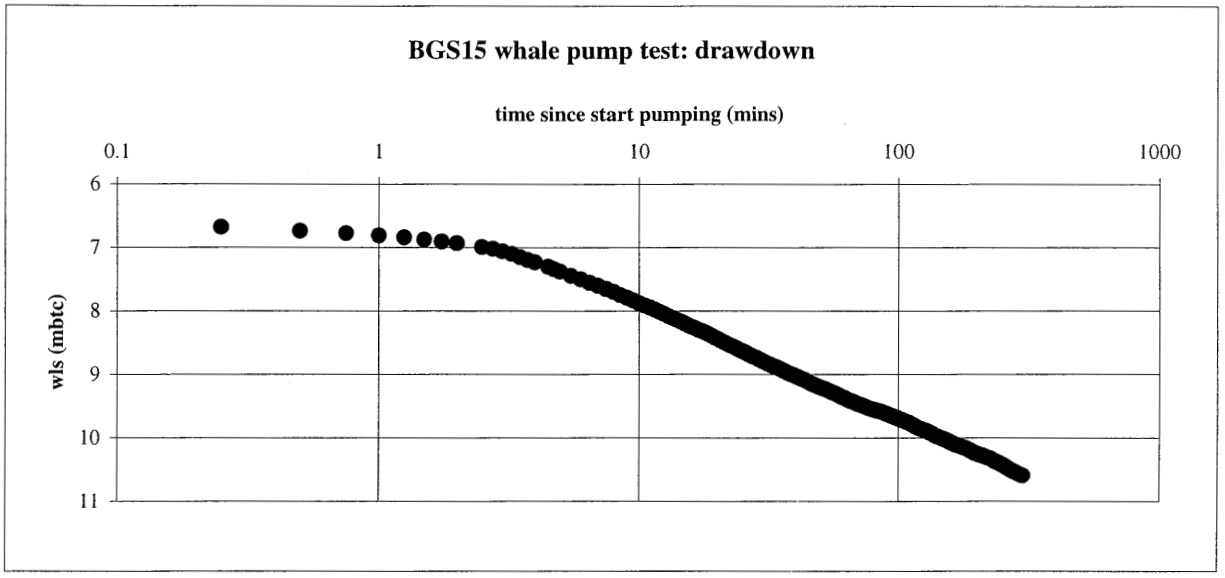
height casing = 0.54 m agl

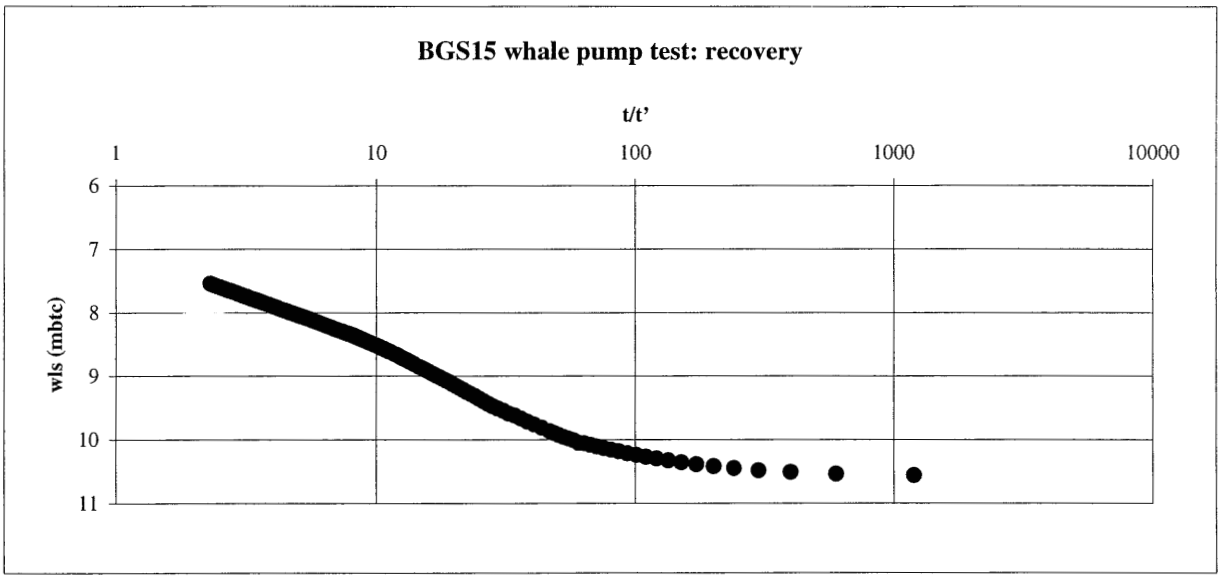
time pumping = 300 mins

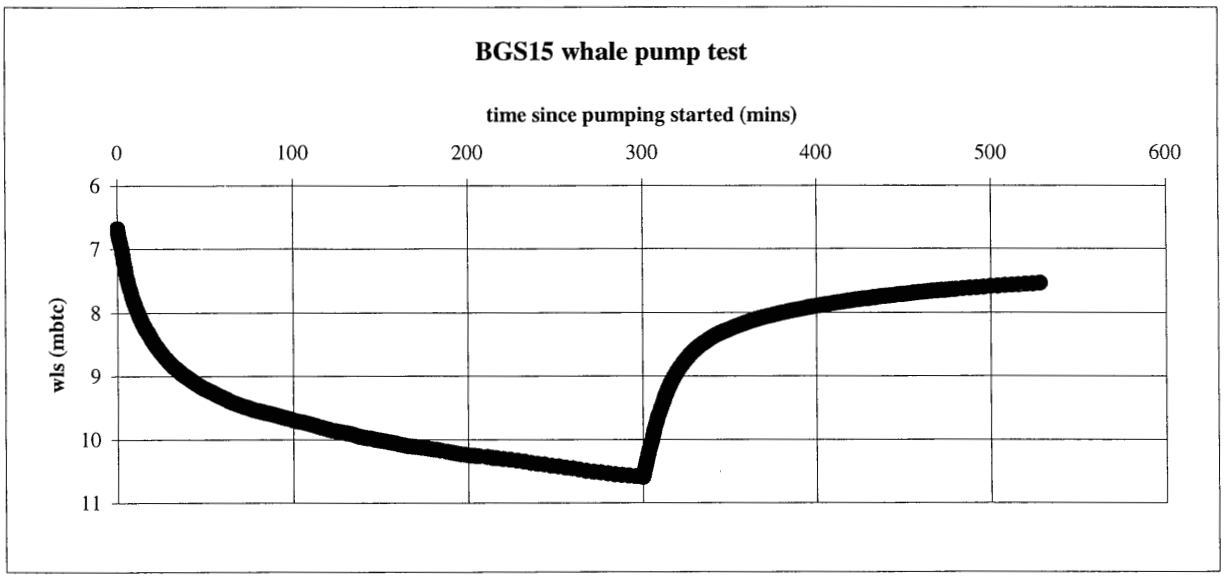
prate = 0.15 l/s

drawdown: T = 1.2 m^2/d

recovery: T = 1.6 m^2/d





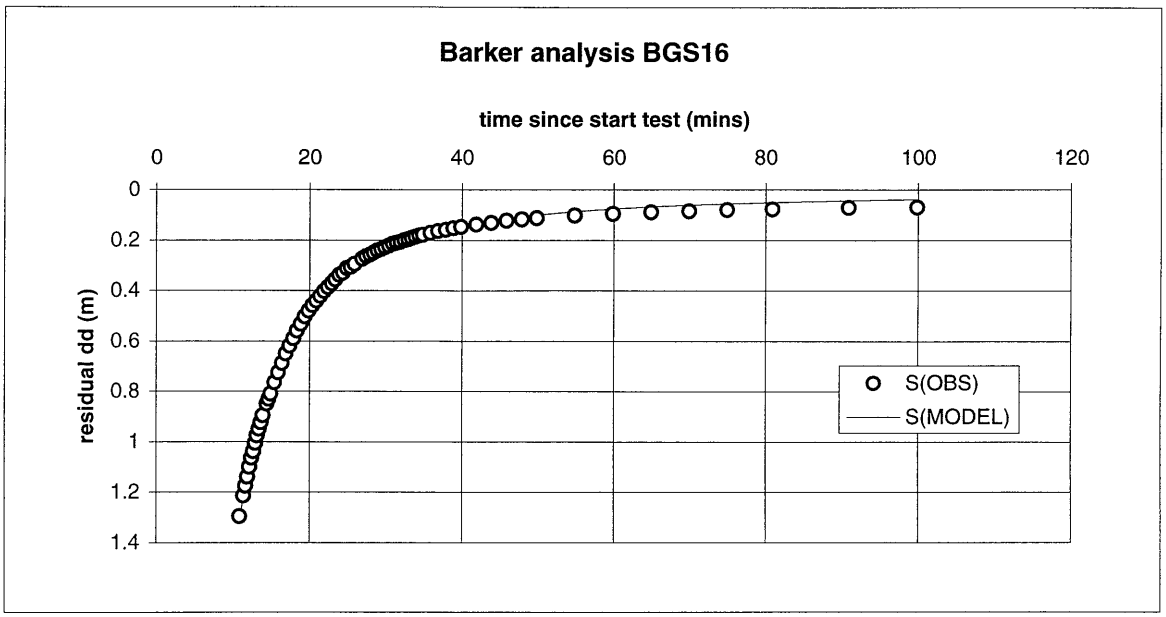


BGS16

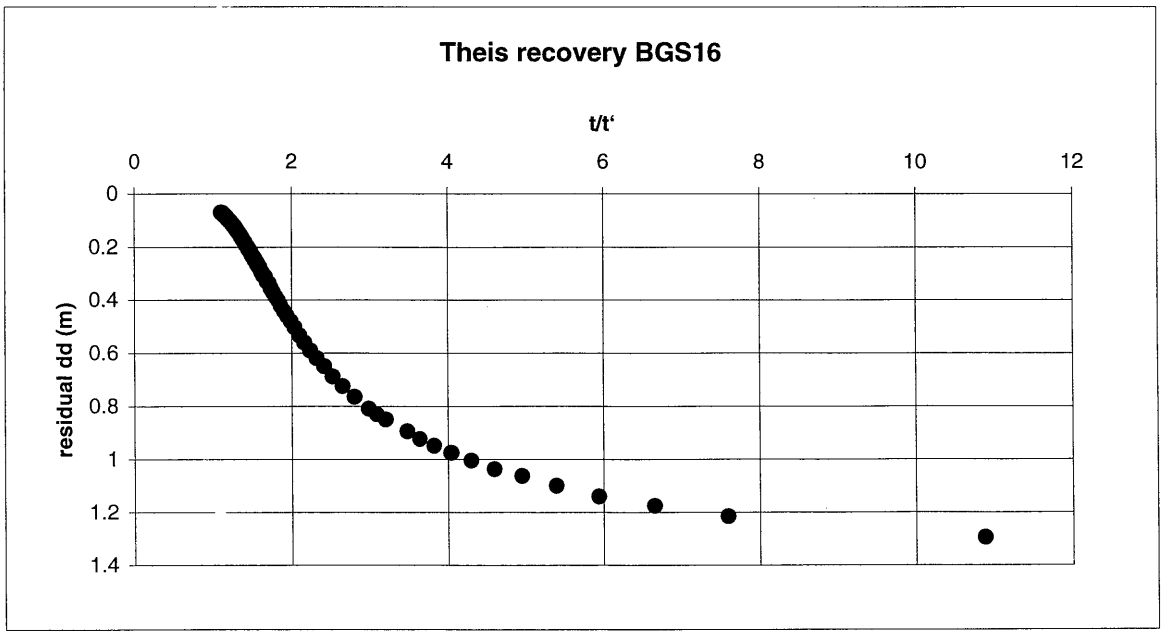
Bailer Test

date: 07/03/98
rwl: 9.56 m btc
length of pumping 09:53
No of bails 25 = average p-rate 0.19 l/s

Barker analysis
T = 4.2 m2/d
S = 0.007
RC = 0.1 m



Theis recovery
T = 1.5 m^2/d



BGS16

Whale test 25/03/98

rwl 9.295 m

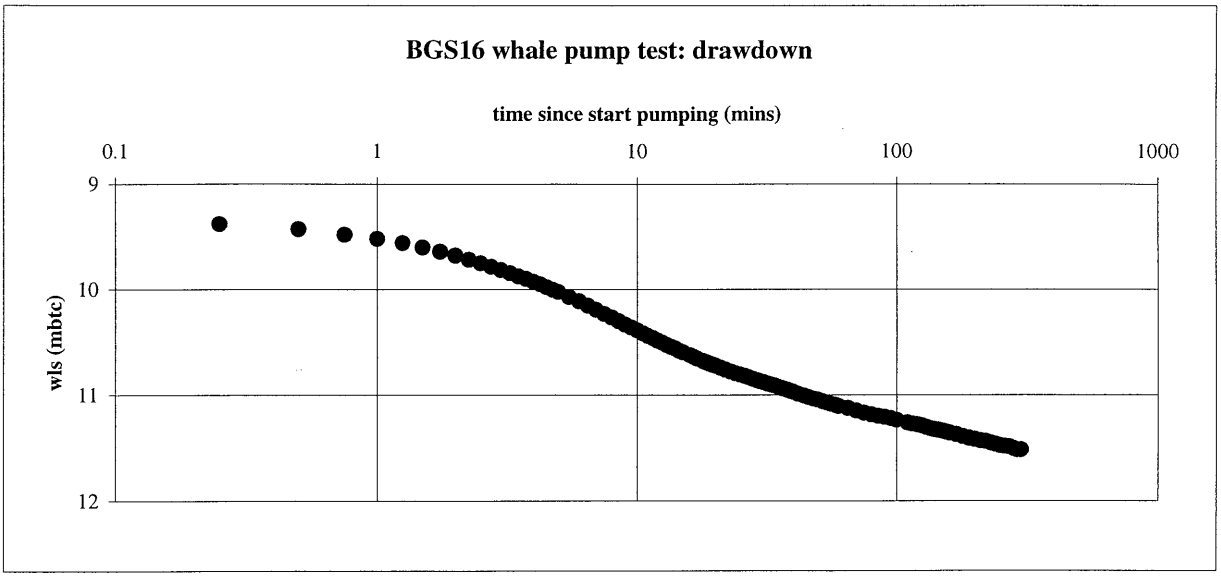
height casing = 0.14 m agl

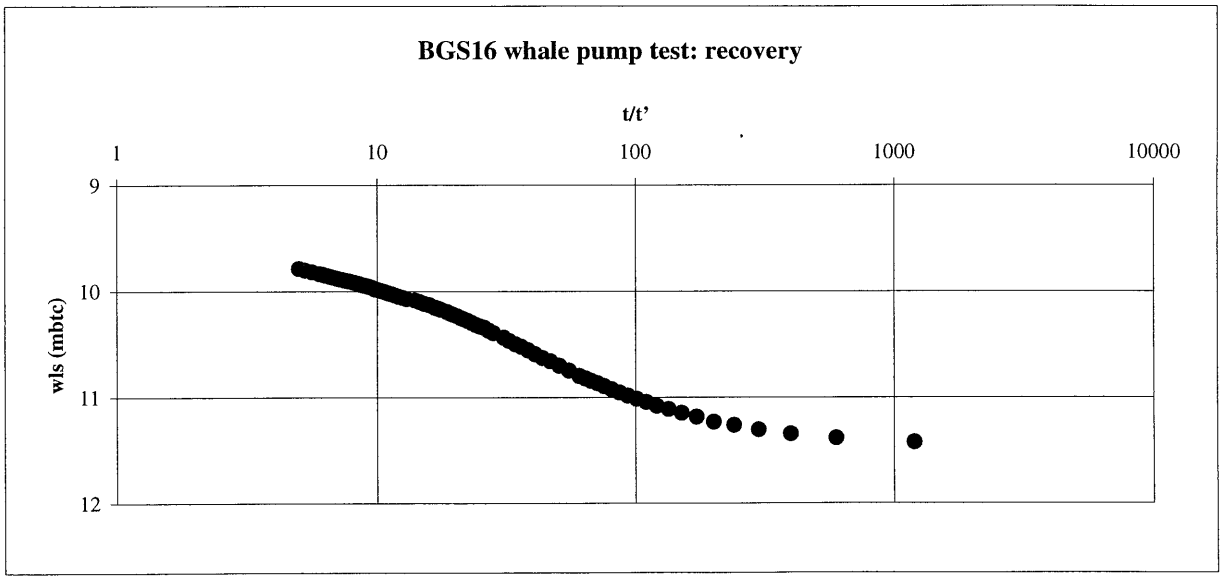
time pumping = 300 mins

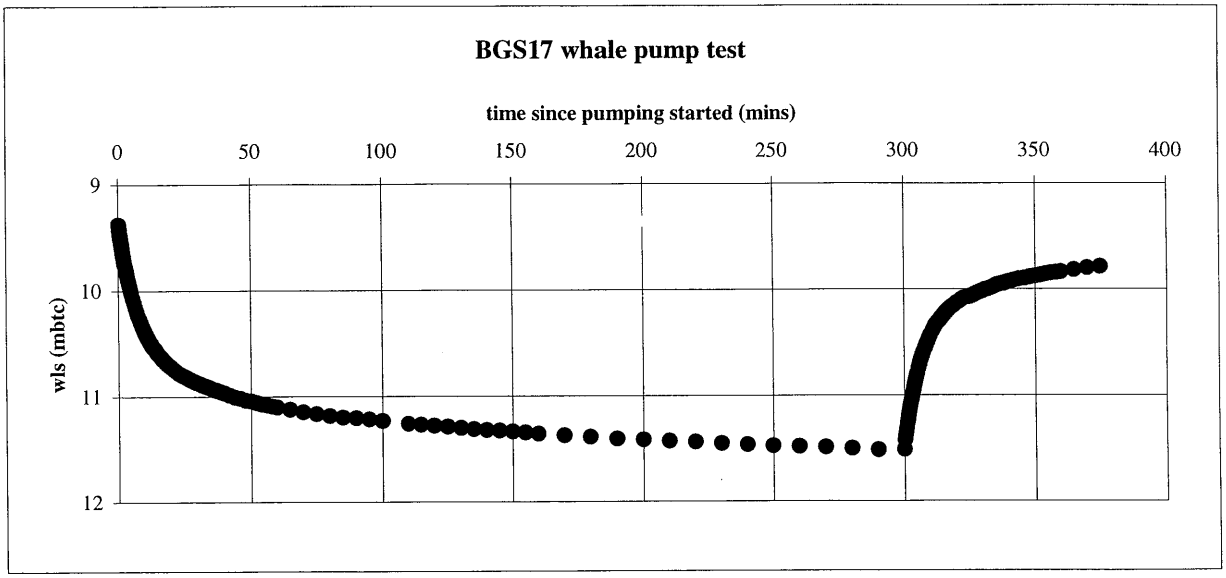
prate = 0.14 l/s

drawdown: T = 3.2 m^2/d

recovery: T = 2.1 m^2/d





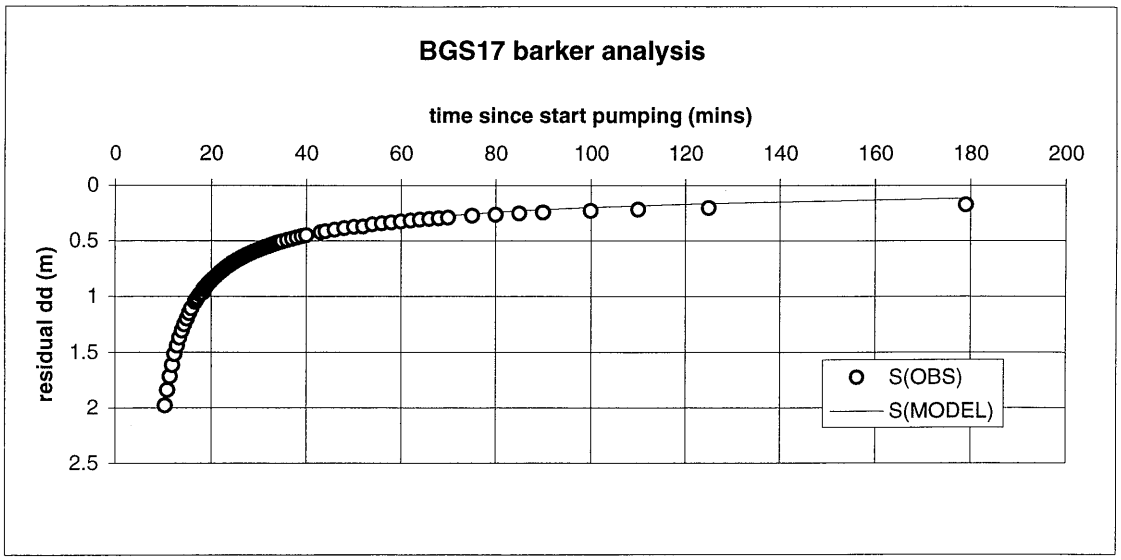


BGS17: test pump analysis

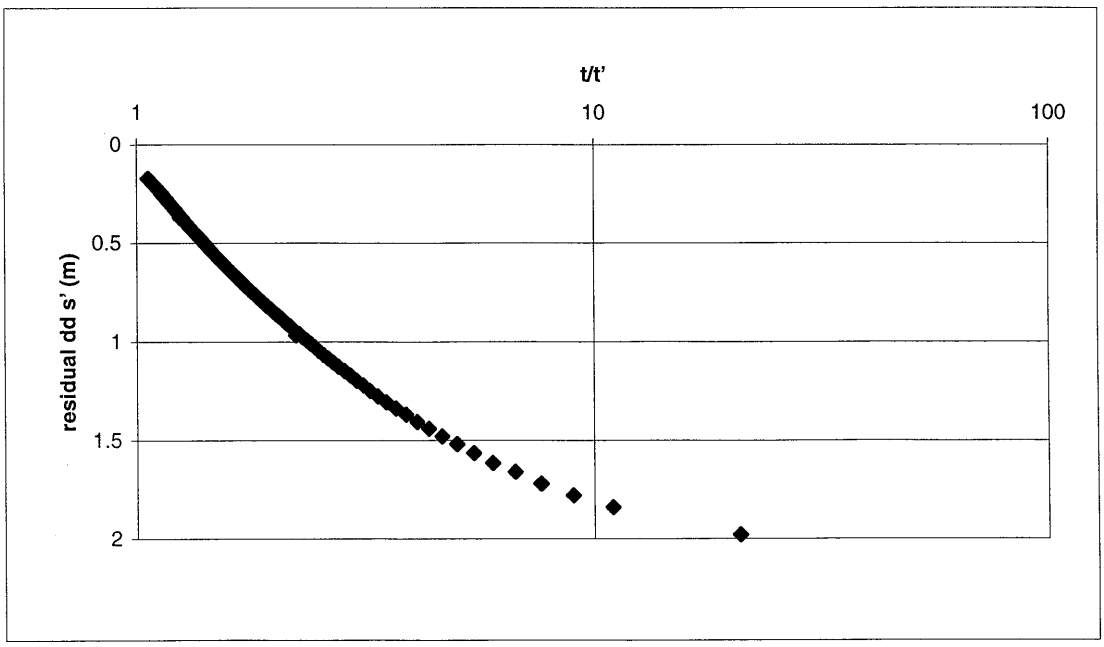
Bailer Test

date:	9/3/98	
rwl:	6.29 m	
casing	0..31 m agl	
length of pumping	10:00 mins	
No of bails	39	= average p-rate 0.29 l/s

Barker analysis
T = 0.95 m2/d
S = 0.05 FIXED
rc = 0.064
rw = 0.58



Theis recovery
T = 1.9



BGS17

Whale test 25/03/98

rwl 6.389 mbtc

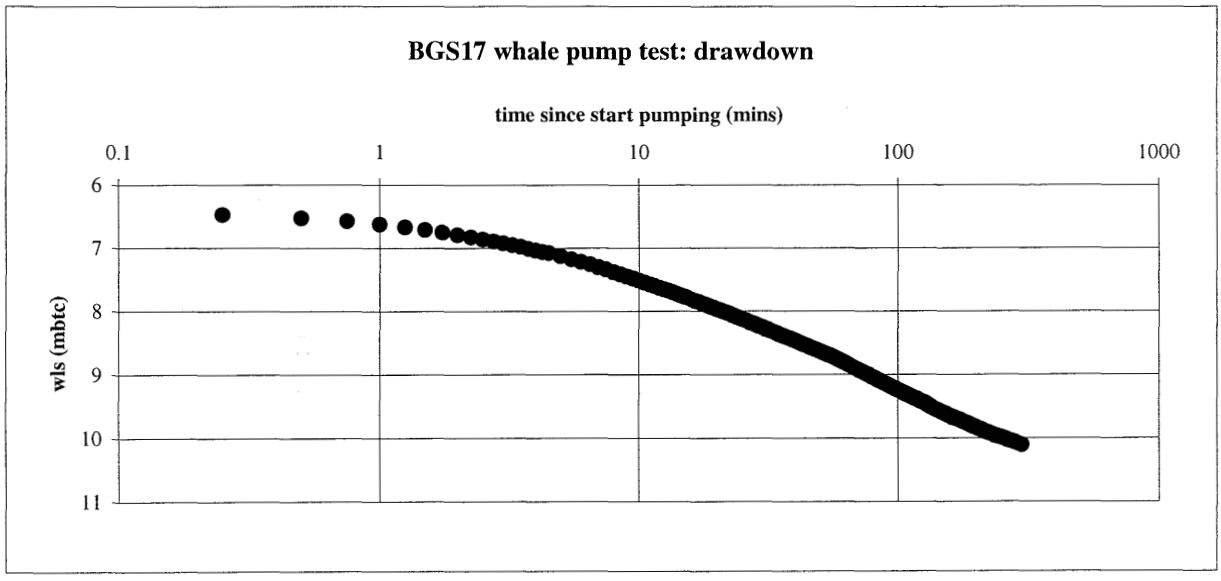
height casing = 0.3 m agl

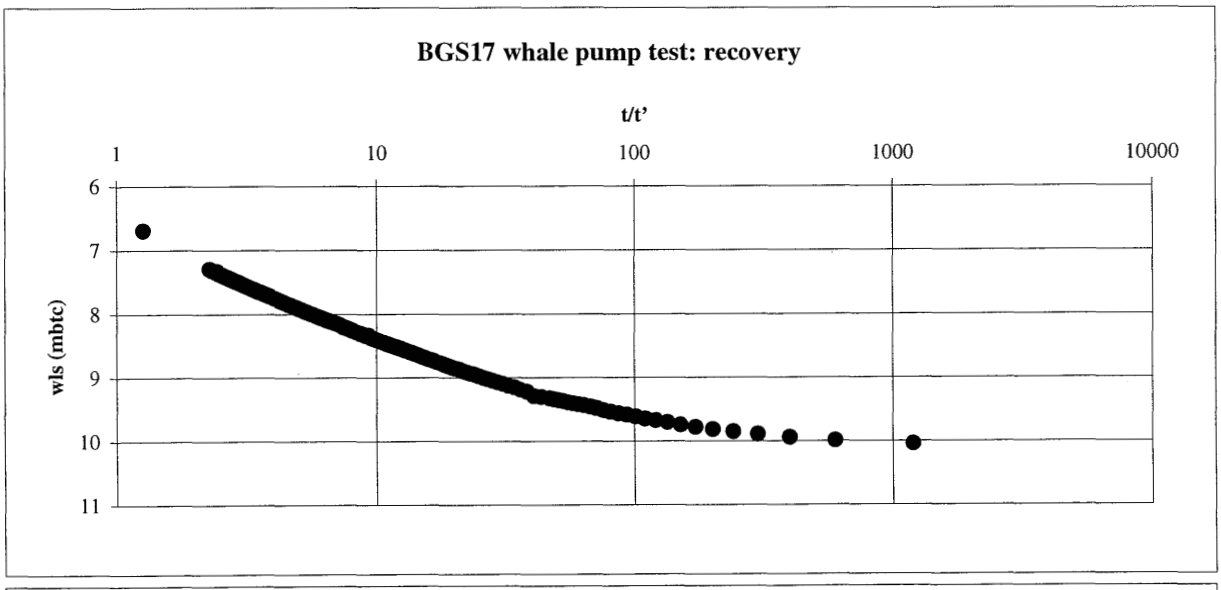
time pumping = 300 mins

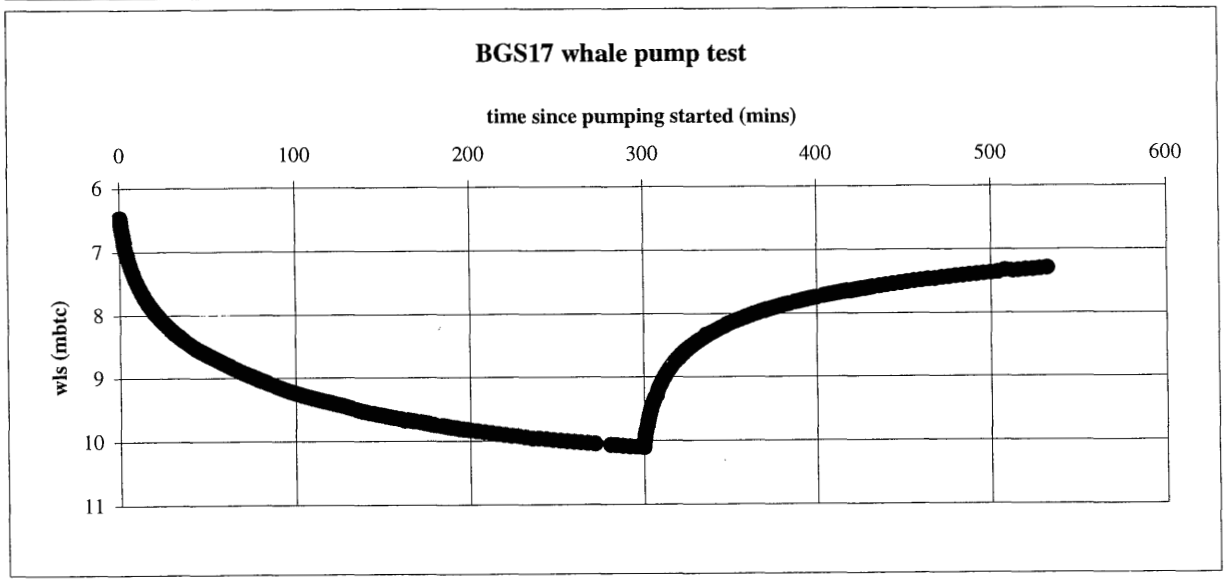
prate = 0.15 l/s

drawdown: T = 1.2 m^2/d

recovery: T = 1.4 m^2/d







BGS17

Whale test 26/03/98

rwl 6.767 m

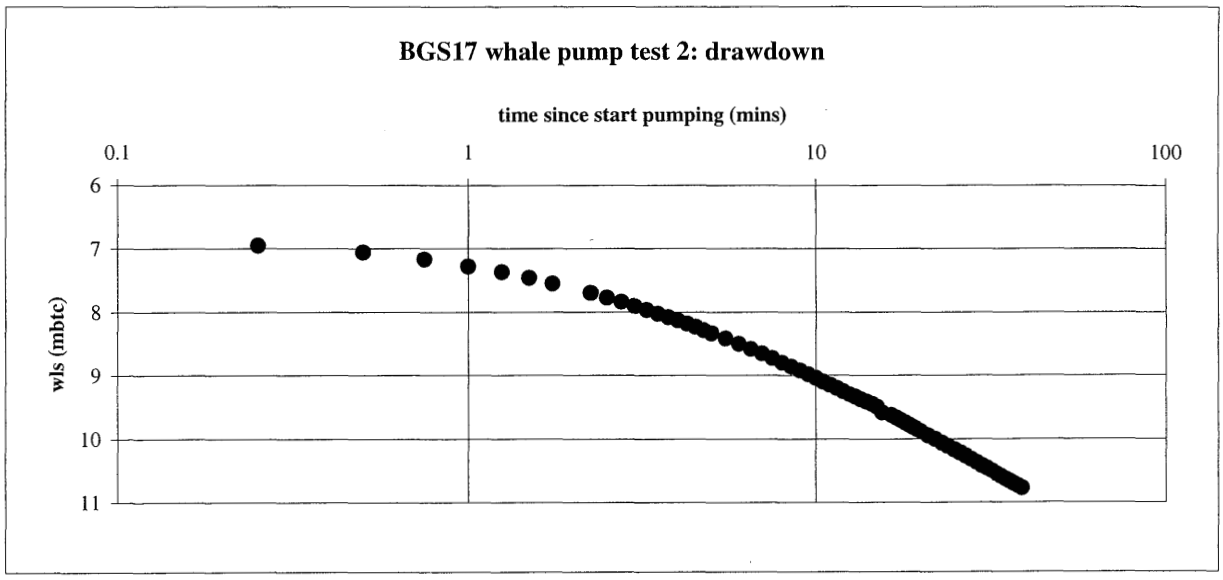
height casing = 0.3 m agl

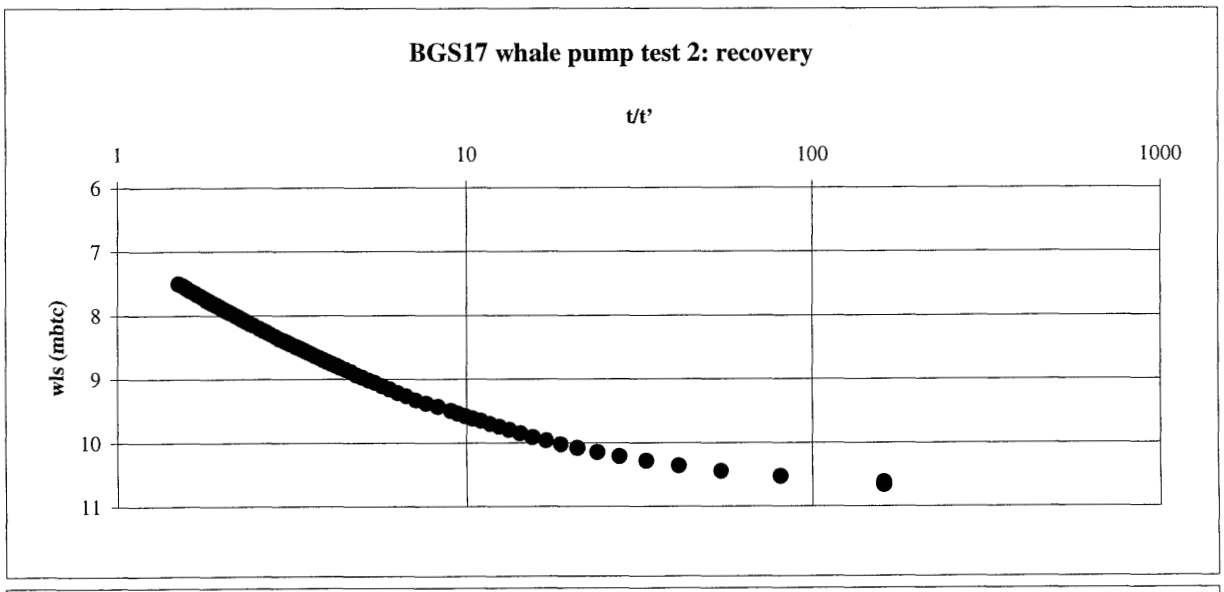
time pumping = 40 mins

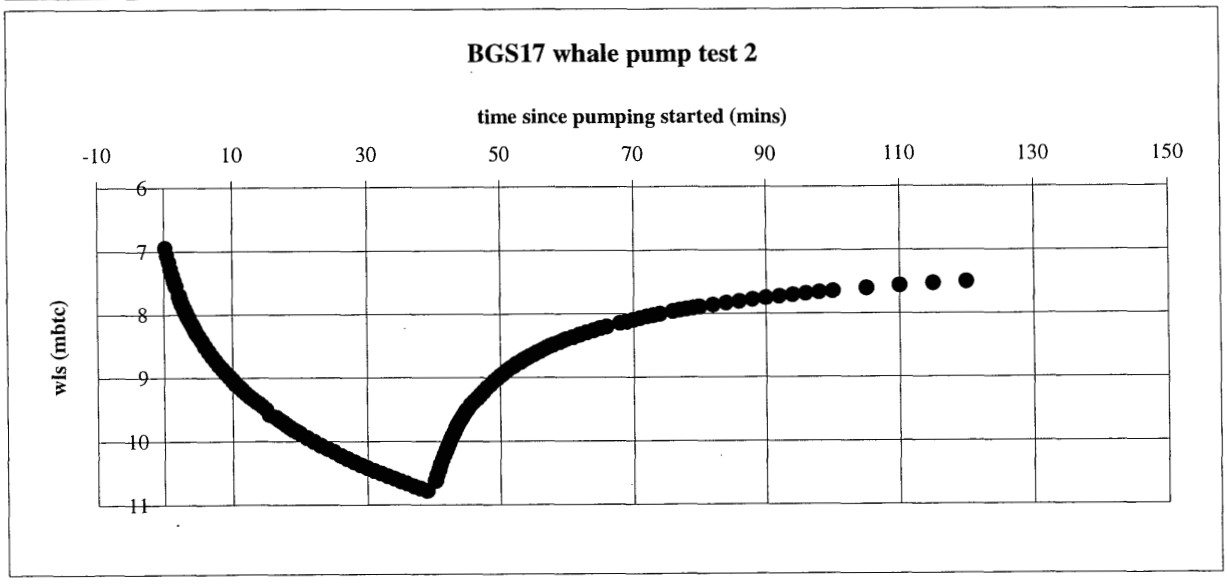
prate = 0.31 l/s

drawdown: T = 1.6 m^2/d

recovery: T = 1.7 m^2/d

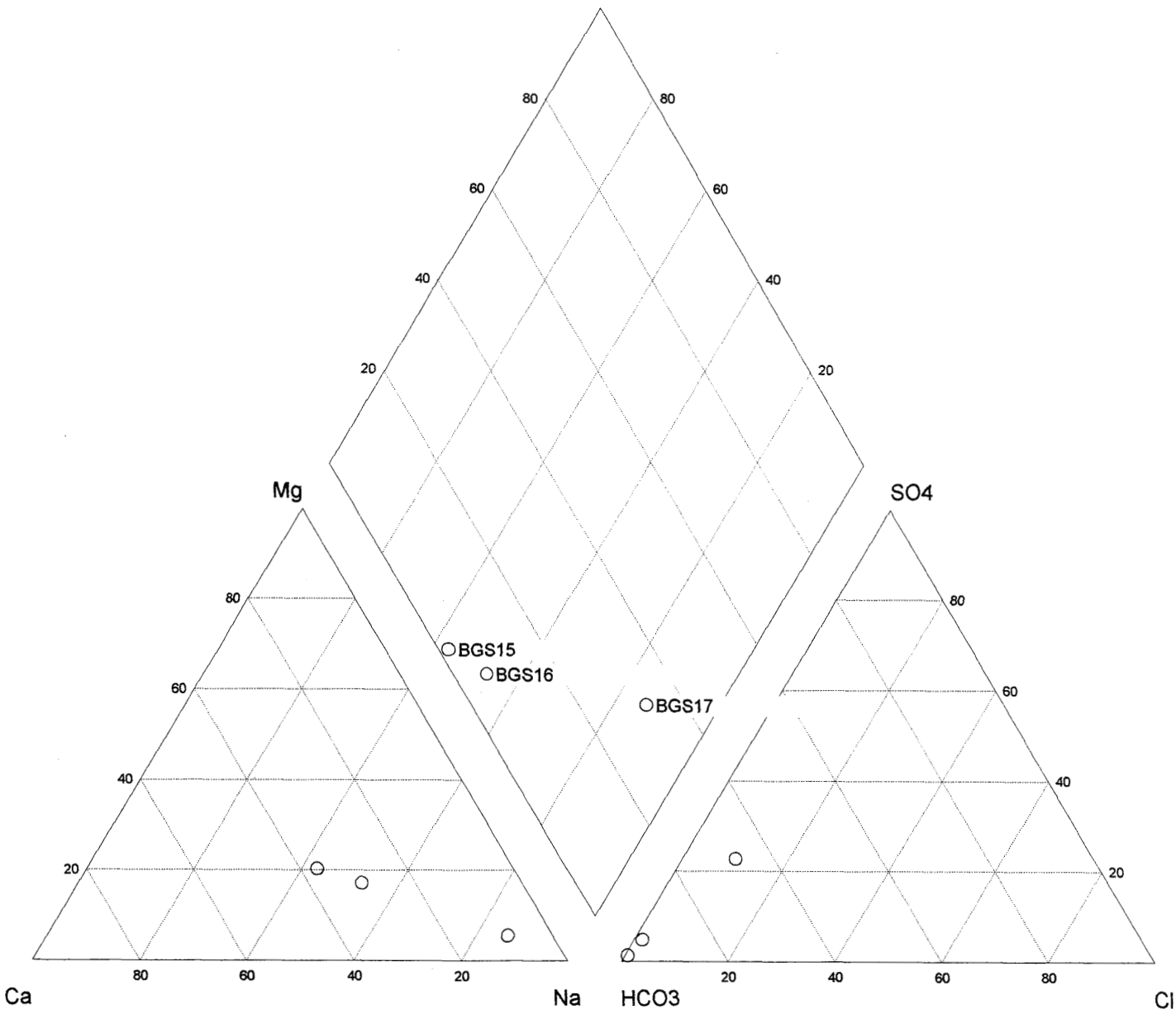






Annex 5: Hydrochemical Data

Groundwater Hydrochemistry - Edumoga



Edumoga

Jan-Apr 1998

Easting	Northing	sample ID No	Bh No	pH	Temp DegC	Cond microS/cm	HCO3 mg/l	Na mg/l	K mg/l	Ca mg/l	Mg mg/l	SO4 mg/l	Cl mg/l
8.384917	6.894183	223	BGS15	7	32	583	324	63.6	1	47.4	15.9	3.4	
8.37095	6.889883	224	BGS17	7.47	28.9	1149	458	239	1	20.3	8.1	122	
8.372367	6.89055	225	BGS16	7.15	28.4	558	302	74.6	0.8	36.8	12.8	12.2	

sample ID No	NO3-N mg/l	Si mg/l	Sr mg/l	Ba mg/l	Li mg/l	B mg/l	Fe Total mg/l	Mn mg/l	I mg/l	F mg/l	Br mg/l
223		15.3	0.637	0.154	0.032	0.07	0.12	0.232	0.0044		
224		8	0.418	0.064	0.067	0.22	0.12	0.068	0.14		
225		14	0.595	0.316	0.029	0.1	0.18	0.399	0.0086		