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Overseas Geology Series

The hydrogeology of the Oju/Obi area, Eastern Nigeria: Adega, Ojokwe (southern Oju), Ohuiye, Ijokwe (Obi) and Akiraba-Ainu areas data report

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Borehole drilling at Adega.

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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 is 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

The report brings together miscellaneous investigations conducted at Adega, Ojokwe (southern Oju), Ohuiye, Ijekwe (Obi) and Akiraba-Ainu during November 1996 to January 1998. Most of the exploratory work entailed short geophysical surveys. These areas were not chosen for detailed investigation due to poor access and/or socio-economic factors. In all, 13 km of EM34-3, 8 km of magnetic and 3 resistivity surveys were carried out. One exploration borehole was drilled at Adega.

Only general conclusions can be made from these studies, since little confirmatory drilling has been undertaken.

- Within the Awgu Shale, low conductivity measurements (<40 mmhos/m) – especially where both the vertical and horizontal coil readings are similar - may indicate the presence of sandstone.

- Areas having marked aeromagnetic anomalies will indicate the location of most dolerite intrusions.

- It is recommended that more drilling is carried out to delimit the extent and nature of the dolerite and Agbani Sandstone formations as these form the only significant groundwater development targets within Obi

1. Introduction

This report is a compilation of results from several small investigations carried out in Oju and Obi during 1996-1998. The data are from geophysical surveys undertaken in areas where no extensive drilling has yet been undertaken. Therefore, the report is a collection of miscellaneous data from which few definite conclusions can be made. Some of the data substantiate observations and conclusions drawn from other studies carried out in Oju and Obi. The report covers investigations carried out at Adega, Ojokwe (southern Oju), Ohuiye, Ijekwe (Obi) and Akiraba-Ainu. (Figure 1).

2. Adega

Adega is a village in Obi that has severe water problems. Some wells have been dug in the village, which supply water in the wet season. However, there is a tendency for these wells to collapse, becoming dangerous to use. These wells dry up soon after cessation of the wet season. The majority of community members then have to walk about 2-3 km to Udegi village to obtain water.

According to the geology map, the village is underlain by black compact shallow marine mudstones of the Awgu Shale formation that is interbedded with some fine to medium grained Agbani Sandstone. Dolerite intrusions may occur within the area. The satellite image was interpreted to identify lineations indicating fracture zones of potential hydrogeological significance. Available map and satellite image information is given in Table 1 and shown in Figures 2 and 3.

Table 1. Available map and satellite image information for Adega.

Data type	Source
Aerial Photographs	Sheet 270 run 13, 11-14
Topographic maps	1:50,000 Sheet 270SE Oturkpo SE
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)

Three kilometres of EM34-3 surveys and one resistivity sounding were carried out at Adega. The locations of the surveys are given in Table 2; detailed data are presented in Annex 1. Figure 4 summarises the EM34-3 survey data obtained along the main survey line AD 1. This EM34-3 survey can be split into three distinct parts:

1. From 0 to 400 m conductivity is moderate – vertical coil readings 60 mmhos/m and horizontal coil approximately 50 mmhos-m. The results of a resistivity sounding undertaken at 340 m indicates moderately resistive soil overlying low resistivity (9 ohm-m) bedrock.

2. From 400 to 2500 m conductivity is very high – vertical coil readings ranged from 80-120 mmhos/m, horizontal coil readings ranged from 40-50 mmhos/m. These results are very similar to those obtained along the North Obi traverse (Davies and MacDonald, 1998b) probably indicative of soft mudstone of the Awgu Shale formation.

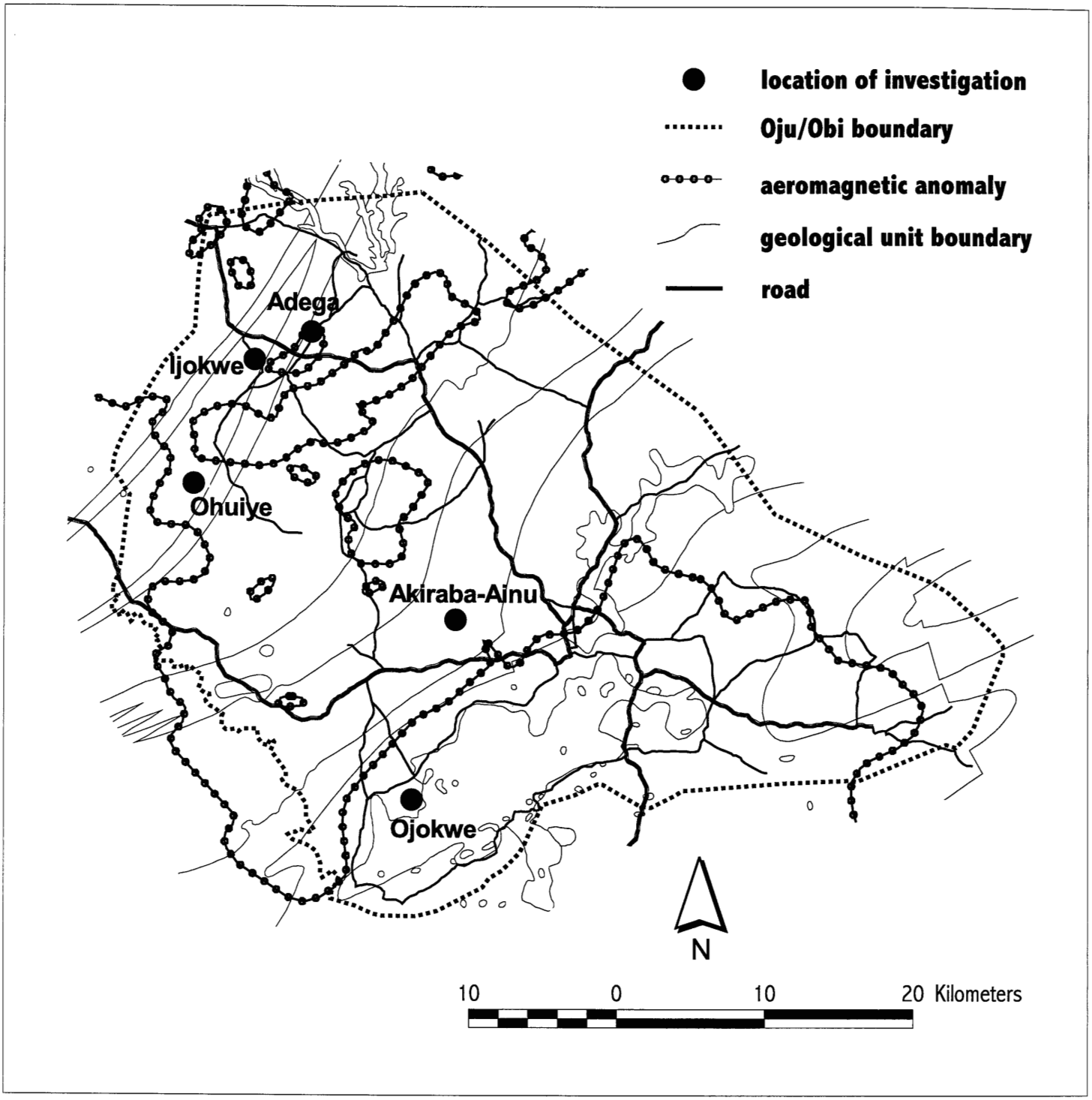


Figure 1. Location of investigations detailed in this report.

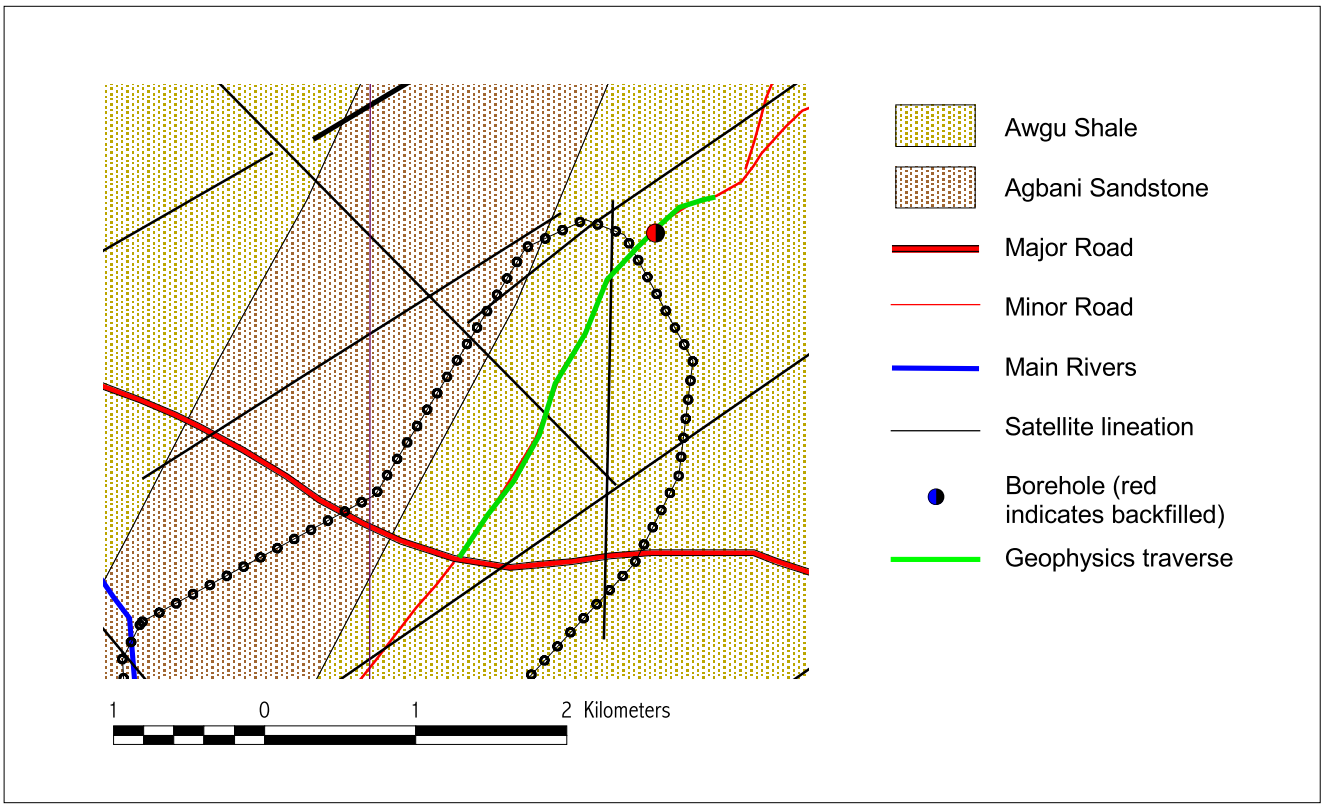


Figure 2. Available map information for Adega and location of borehole and geophysics traverses. NB geological boundary marked on the map is uncertain.

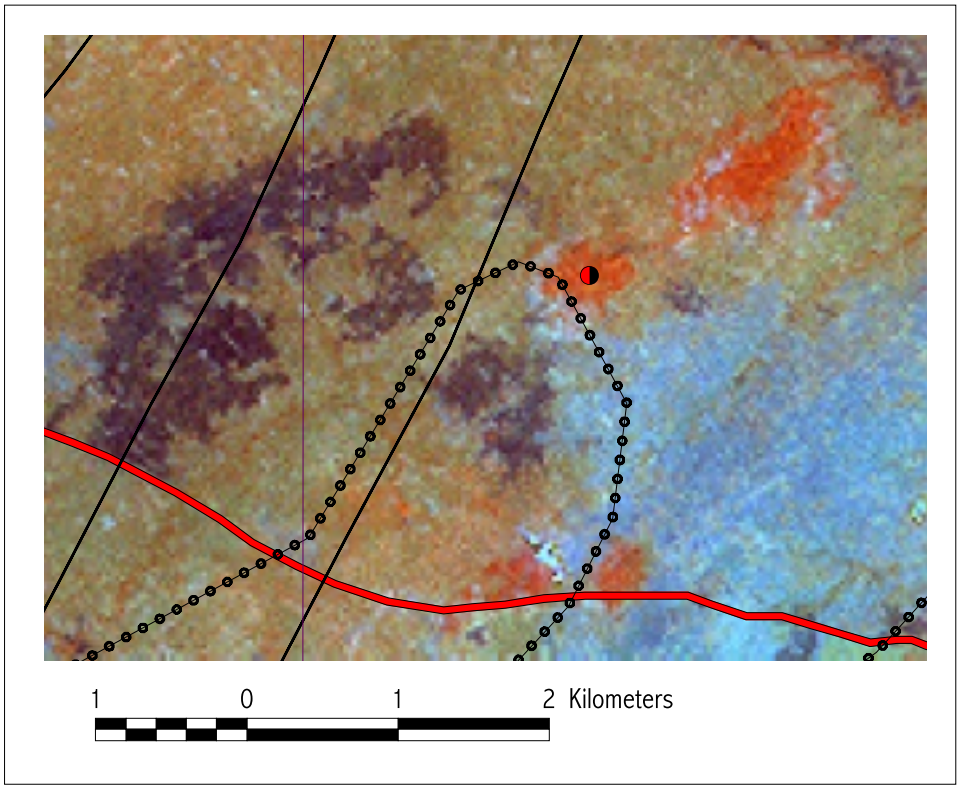


Figure 3. Satellite image for Adega.

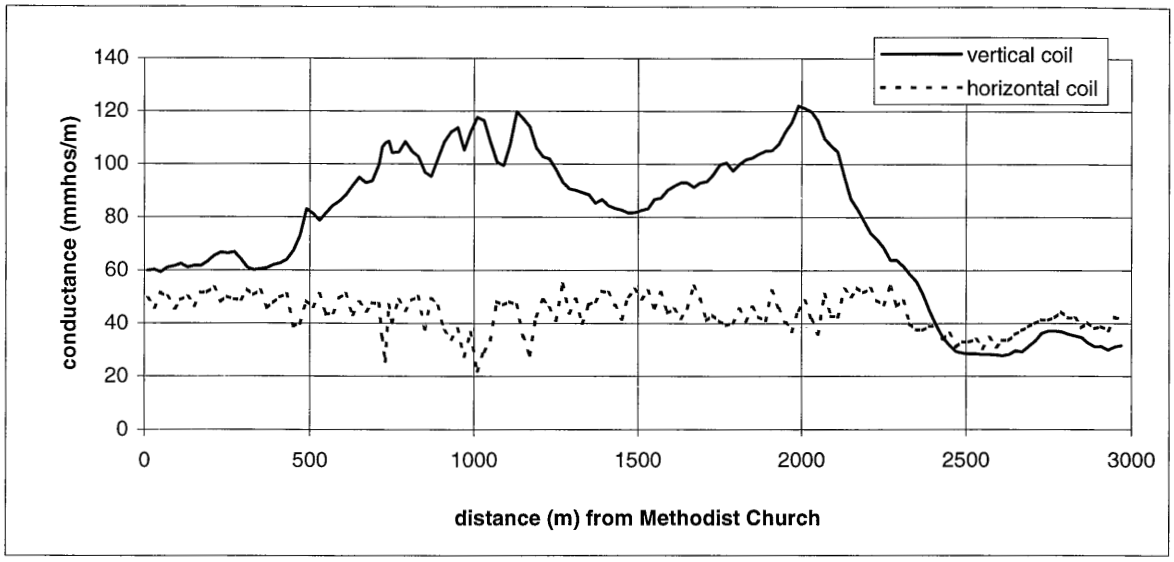


Figure 4. EM34-3 survey for Adega (AD 1). BGS 32 was drilled at about 340 m.

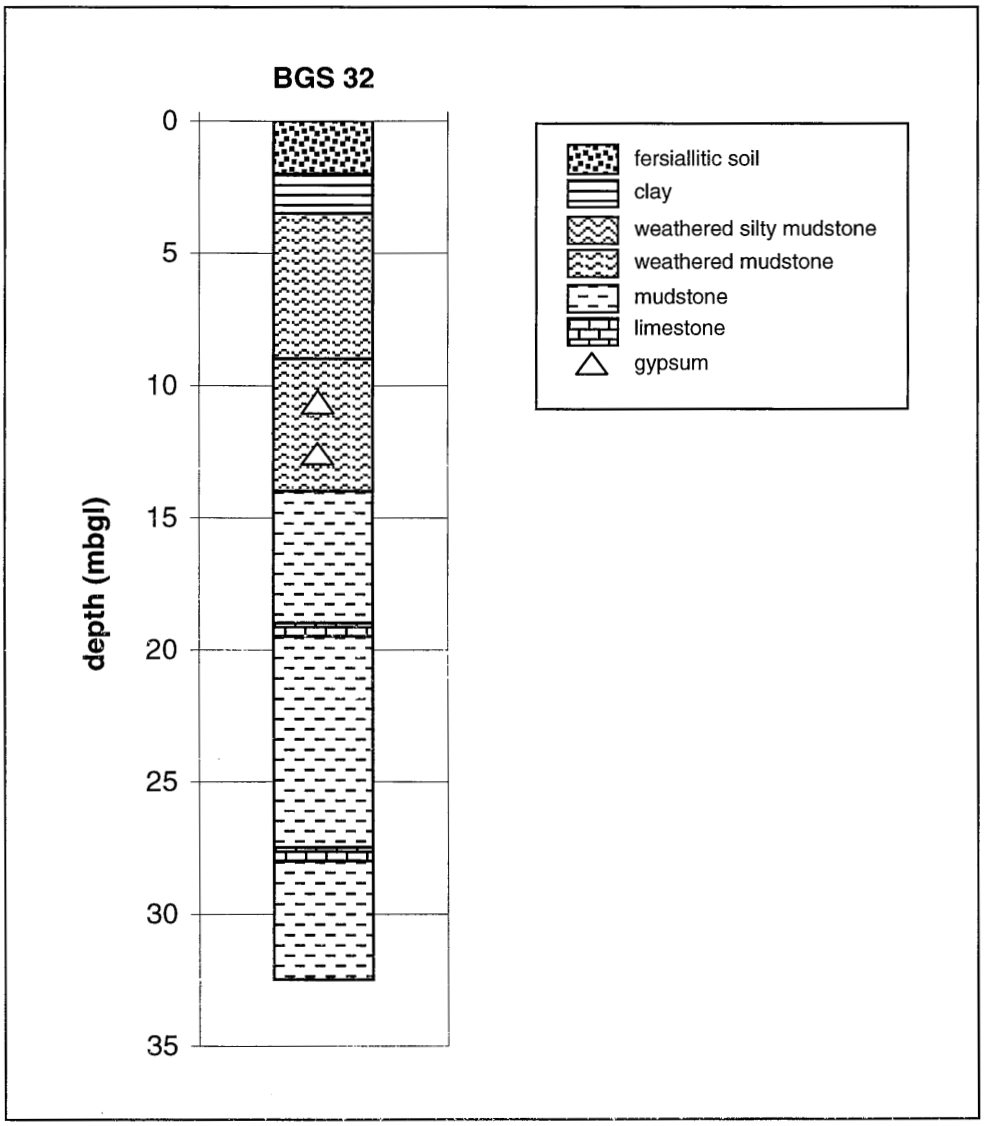


Figure 5. Simplified borehole log for BGS 32. Horizontal axis not to scale.

3. From 2500 to 3000 m conductivity was moderate-low and measurements did not vary much – vertical coil readings were consistently less than those taken using the horizontal coil – both ranged from 30 – 40 mmhos/m.

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

Survey number	Co-ordinates start	Length	Average Spacing	Survey type	Description
AD 1	7° 2.869' 8° 16.253'	3 km	20 m	EM34-3 (20 m)	From mango tree at Methodist church through village to tarred road at Udegi
AD 2	7° 2.869' 8° 16.253'		0.5 – 64 m	Offset Wenner	At shrine, 340 m along AD 1

A resistivity sounding undertaken at 340 m along AD 1 produced results similar to those produced along the north Obi traverse; a resistive soil overlying very low resistivity (8 ohm-m) bedrock.

Plans were made to drill two exploratory boreholes: one in each of the areas of lower conductivity. However, the area of most interest (from 2500-3000 m) was outside the boundary of the village. Despite much negotiation, the village could not gain access to this site to drill. Therefore, only borehole BGS32 was drilled at 340 m along AD 1. Construction details are given in Annex 1. This borehole was drilled to 32.5 m and cored from 20.5 to 23.5 m primarily through compact black shallow marine very carbonaceous mudstones of the Awgu Shales formation. Although some interbedded thin siltstones and limestones were encountered the borehole was dry on completion and was therefore back-filled. A summary of the lithological log is given below; the full log is given in Annex 1. A simplified log is shown in Figure 5. The rocks penetrated are very similar to Awgu Shale formation mudstones investigated along the north Obi traverse, especially those from boreholes BGS 27 to BGS 29.

Summary lithological log: BGS 32

0.0 - 2.0	Soil/ferricrete horizon
2.0 - 3.5	Clayey very weathered horizon
3.5 - 4.5	Very weathered clayey silts and fine grained sands
4.5 - 9.0	Weathered silty mudstone
9.0 - 11.0	Weathered mudstones
11.0 - 14.0	Weathered mudstones with gypsum
14.0 - 18.5	Carbonaceous shaley mudstones
18.5 - 20.0	Carbonaceous mudstone and hard limestones
20.0 - 23.5	Carbonaceous shaley mudstones
23.5 - 25.5	Carbonaceous mudstone
25.5 - 27.0	Carbonaceous shaley mudstone
27.0 - 28.5	Carbonaceous shaley mudstones and limestones
28.5 - 32.5	Carbonaceous mudstones

There are a number of shallow wells in this area, which appear to penetrate sandstone. The geophysical results were similar to those determined at Ameka village (at the beginning of the north Obi traverse). A

suitable site at Ameka village could not be drilled due to lack of safe access for the drilling rig. It is likely that these low readings correspond to the Agbani Sandstone.

3. Ojokwe

Ojokwe village is in the south-west of Oju, on the edge of the Wokum Hills (Figure 1). There are no wells or boreholes within this village. Water is obtained from a river approximately 1 km west of the village. However, this source and adjacent streams tend to dry up by January after which only small supplies can be obtained from shallow pits dug into the streambed. Most of the community walk to rivers much further away for their dry season supplies. There are two failed groundwater sources in the village: a shallow hand dug well that never yielded during the dry season; and a borehole that was not completed due to problems encountered during drilling. In the riverbeds, hard splintery black shales of the Asu River Group crop out. Medium grained yellow/orange micaceous rock found near the village could be a weathered intrusive or a sandy layer within the Asu River group.

According to the geology map, the village lies on the boundary between the metamorphosed Asu River Group and the Asu River Group. The satellite image was interpreted to identify lineations indicating fracture zones of potential hydrogeological significance. The available map and satellite image information is listed in Table 3. Maps of the village and the location of the geophysical traverses is shown in Figures 6 and 7.

Table 3. Available map and satellite image information for Ojokwe, southern Obi.

Data type	Source
Aerial Photographs	Sheet 289, run 7, 136-139
Topographic maps	1:50,000 Sheet 289NE Ejekwe NE
Geology map	Ogoja Area, Map No. 73, Scale 1:250,000
Satellite image	LANDSAT TM 188-055 Acquired 17 January 1986 Bands 4-5-7 (Red, Green, Blue)

Several kilometres of EM34-3 and magnetic surveys and a resistivity sounding were carried out at Ojokwe during November 1996. The locations of the surveys are given in Table 4; detailed survey data are presented in Annex 2. Several observations can be made from the survey results:

1. The electrical conductivity of the rocks varies from 0 to 45 mmhos/m

2. Vertical and horizontal coil measurements are similar, although where conductivity is high (> 20 mmhos/s) measurements taken with the horizontal coil are generally greater.

3. The measured bulk conductivity increases with inter-coil spacing implying greater electrical conductivity at depth.

4. Several distinct EM34-3 anomalies are present and are mostly associated with small valleys

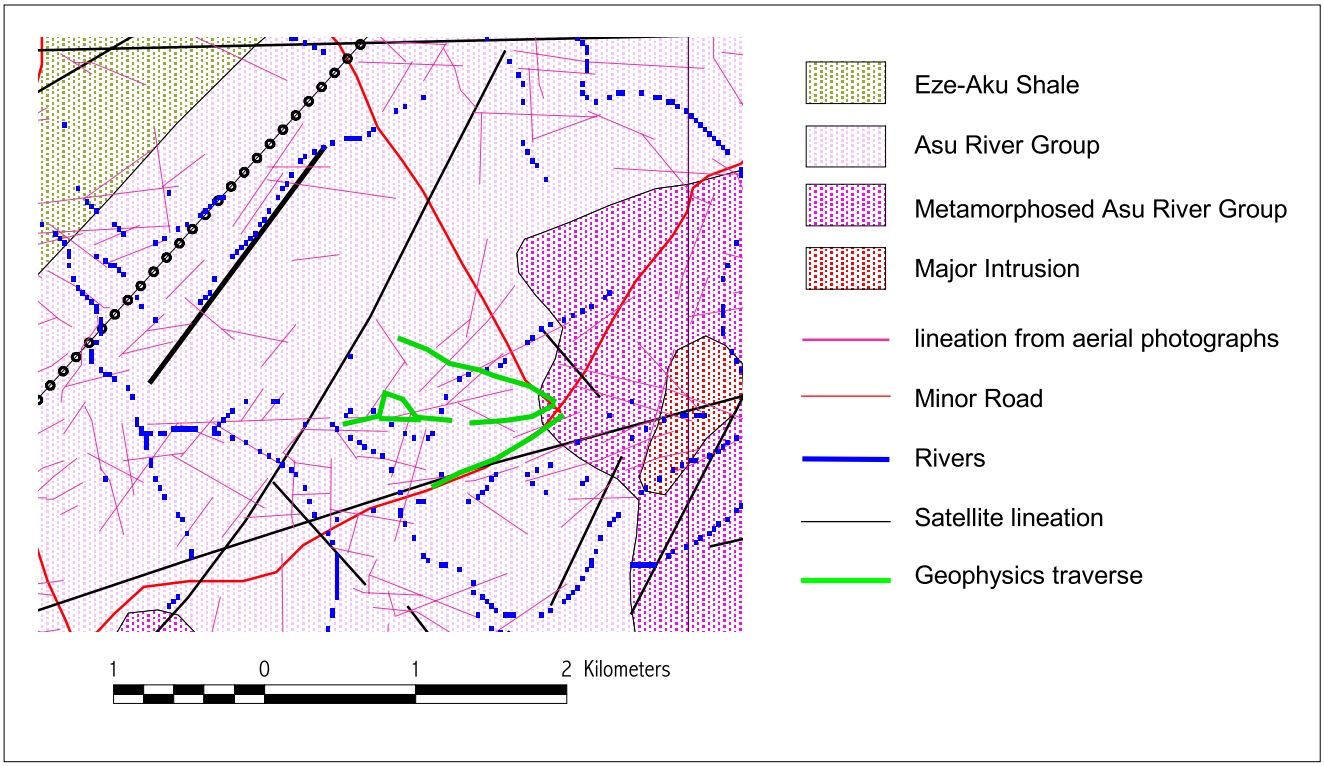


Figure 6. Available map information for Ojokwe and location of geophysics traverses.

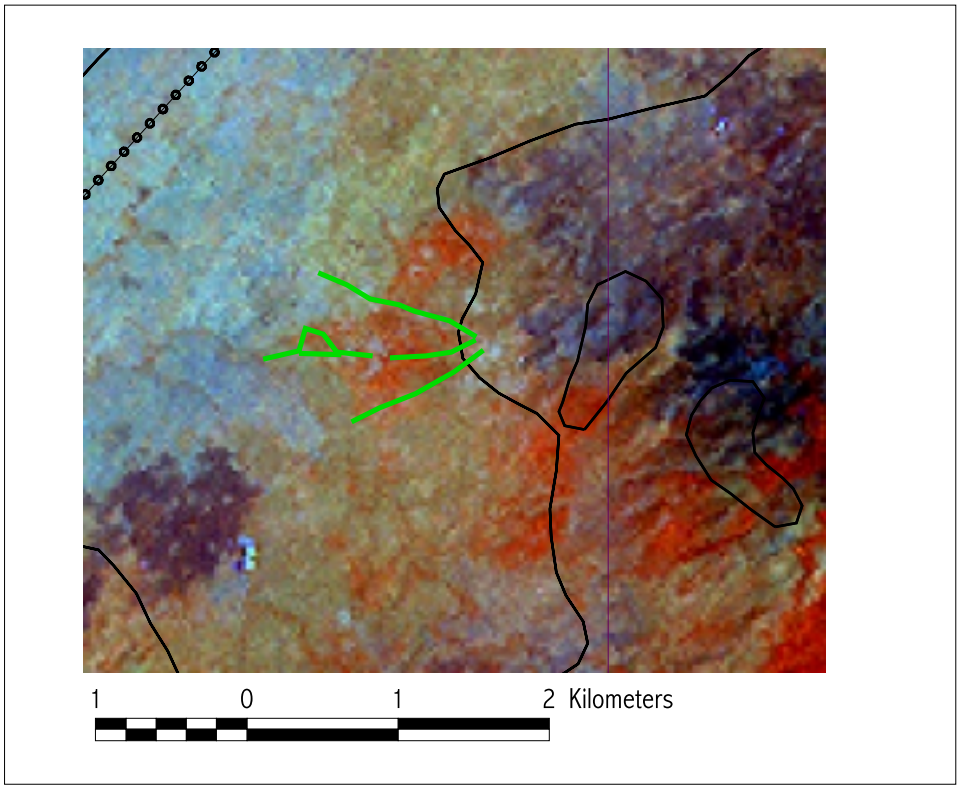


Figure 7. Satellite image for Ojokwe and location of geophysical surveys.

5. The magnetic surveys are noisy due to the presence of steel roofs in the village. Several natural anomalies are also evident and are probably due to igneous intrusions.

6. The resistivity sounding suffered from poor electrode contact in the dry soil, the results were therefore unreliable. Interpretation of the curve indicated a very resistive soil overlying a low moderate resistivity (100 ohm/m) bedrock.

The survey results are similar to those produced at Oyinyi Iyechi and Odubwo. Higher conductivity values (especially where conductivity increases with depth) may be due to increased fracturing and therefore may indicate greater groundwater potential. However, the bedrock may also be highly conductive due to the effects of metamorphism.

Table 4. Geophysical Surveys carried out at Ojokwe (data in Annex 2).

Survey number	Co-ordinates start	Length	Average Spacing	Survey type	Description
OJ 1	6° 46.305' 8° 19.494'	1.1 km	20 m	EM34-3 (20 m)	From tree in market square across stream to school.
OJ 2	6° 46.305' 8° 19.494'	1.1 km	10 m	magnetic	As OJ 1
OJ 3	6° 46.175' 8° 19.502'	1 km	20 m	EM34-3 (20 m)	From market square along main road to bridge
OJ 4	6° 46.175' 8° 19.502'	1 km	10 m	magnetic	As OJ 3
OJ 5	6° 46.210' 8° 19.095'	1 km	20 m	EM34-3 (20 m)	From chiefs house winding through village to river.
OJ 6	6° 46.210' 8° 19.095'	0.6 km	10 m	magnetic	As OJ 5
OJ 7		0.7 km	20 m	EM34-3 (20 m)	From river straight back to chief's house.
OJ 8		0.7 km	10 m	magnetic	As OJ 7
OJ 9	6° 46.18' 8° 19.50'	0.5 km	10 m	EM34-3 (10 m)	From market to chief's house
OJ 10	6° 46.18' 8° 19.50'	0.5 km	10 m	EM34-3 (20 m)	As OJ 9 20 m coil spacing
OJ 11	6° 46.18' 8° 19.50'	0.5 km	20 m	EM34-3 (40 m)	As OJ 9 40 m coil spacing
OJ 12	6° 46.18' 8° 19.50'		0.5 – 64 m	Offset Wenner	Located 200 m along OJ11

4. Ijekwe

Ijekwe village is located within the northwestern part of Obi. The community obtains water from traditional wells located in the village, and a river about 1 km to the south-west. The wells generally dry up with the onset of the dry season; they have not been deepened due to the collapsing nature of the weathered sediments that underlie the village. The map suggests that the village lies on the boundary between the Awgu Shale and the Agbani Sandstone. Although sandstone is exposed in the river the location of this boundary is uncertain. Available map information is shown in Figures 8 and 9.

EM34-3 and magnetic surveys were carried out at Ijekwe on 7 December 1996. Details of the survey are shown in Table 5; the detailed data being presented in Annex 3. The following observations can be made from the results of the geophysical surveys:

1. The EM34-3 survey indicates conductivity values from 35 to 105 mmhos/m

2. Close to the river, where sandstone is exposed, the conductivity is approximately 40 mmhos/m and the horizontal coil readings are greater than the vertical coil readings.

3. Between 500 and 1000 m the conductivity is high, and there is a great disparity between vertical and horizontal coil measurements – this is very similar to the geophysical response on the north Obi traverse.

4. Within the village, the bulk conductivity reduces to about 50 mmhos/m and the vertical and horizontal coil readings are similar.

A well was constructed within the village where the electrical conductivity readings were low. Since this well, dug into weathered Agbani Sandstone, has a high yield it is anticipated that this formation can be recognised by low conductivity measurements, the horizontal and vertical coil readings being similar.

Table 5. Main geophysical surveys carried out at Ijekwe (data in Annex 3).

Survey number	Co-ordinates start	Length	Average Spacing	Survey type	Description
IJ 1	7° 01.37' 8° 13.63'	1.5 km	20 m	EM34 (20)	Survey started at School playing fields and travelled at about 200° along the dirt road to the river
IJ 2	7° 01.37' 8° 13.63'	1.5 km	10 m	Magnetic	As IJ1.

5. Ohuiye

Ohuiye is located south-west of Echuri in the western part of Obi. The two traditional wells located in the village have caving problems and dry up soon after the rains stop. According to the geology map, Awgu Shale underlies the village of Ohuiye. Agbani Sandstone was noted to crop out to the northwest of the village (the location of the Agbani Sandstone is very uncertain). The village also lies close to an area of intense aeromagnetic anomalies (Figure 10 and 11).

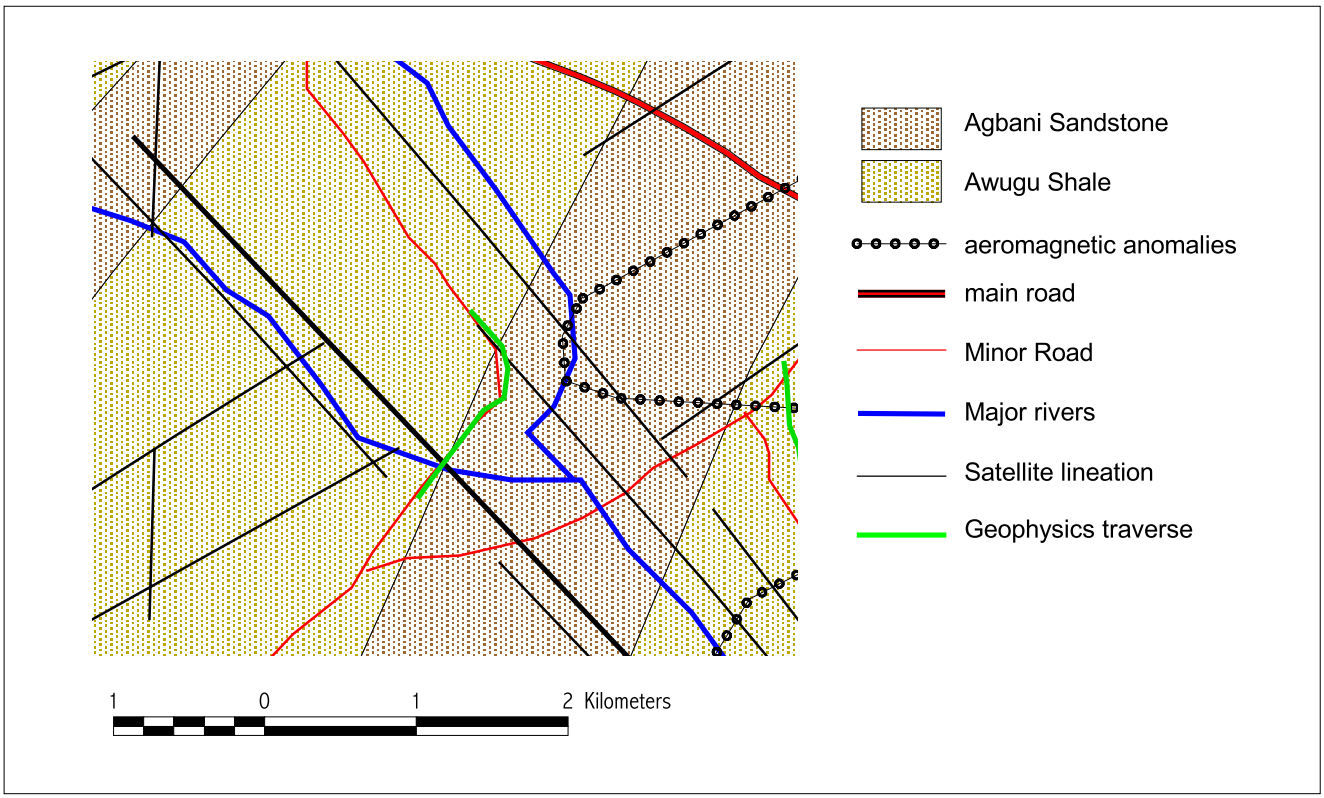


Figure 8. Available map information for Ijekwe and location of geophysical survey. Note that the boundary between the Agbani Sandstone and the Awgu Shale is uncertain.

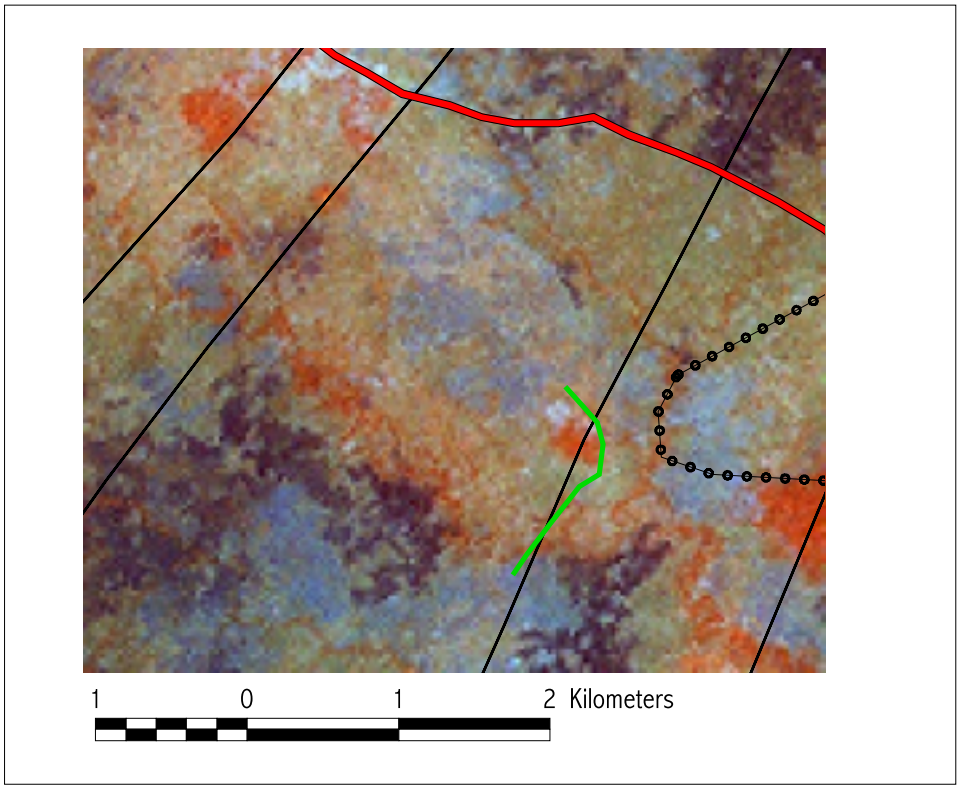


Figure 9. Satellite image for Ijekwe and location of geophysical survey.

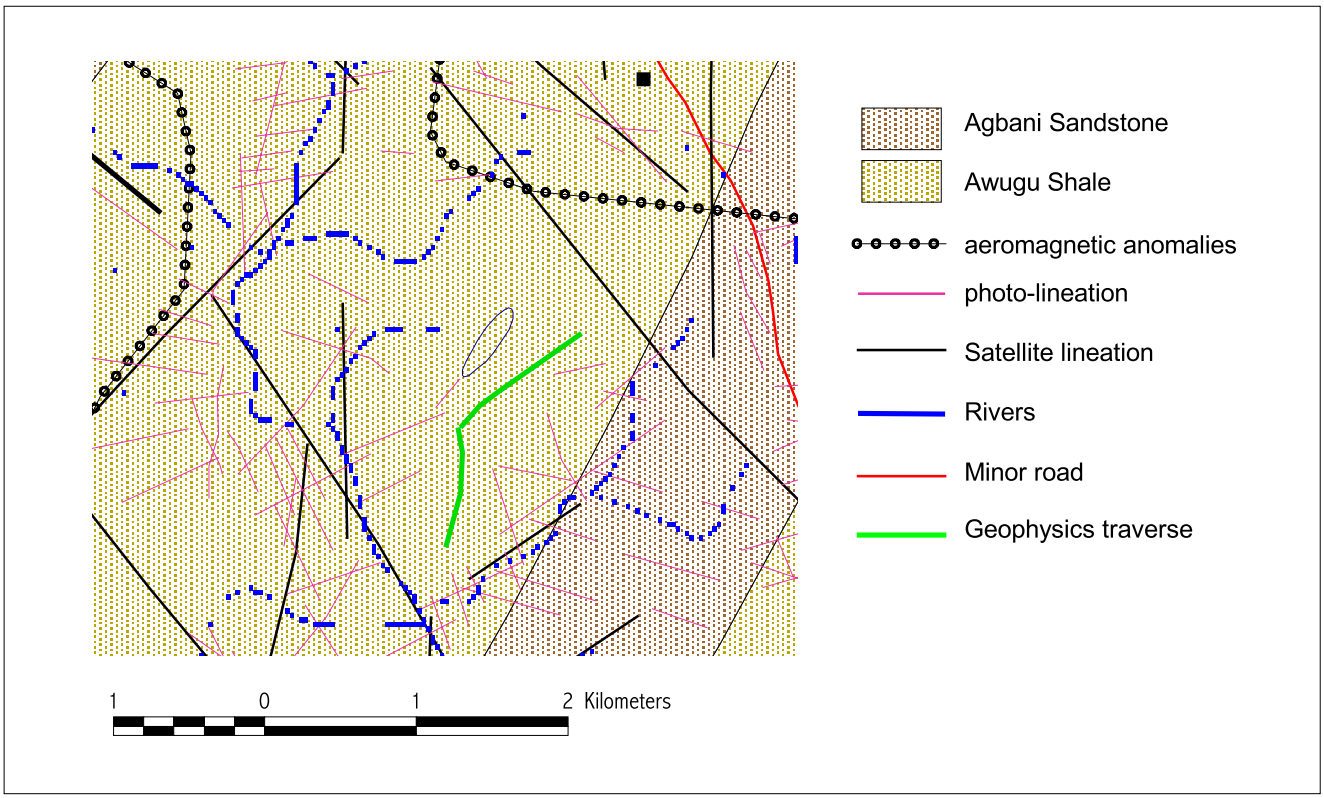


Figure 10. Available map information for Ohuiye and location of geophysical survey. Note that the boundary between the Agbani Sandstone and the Awgu Shale is uncertain.

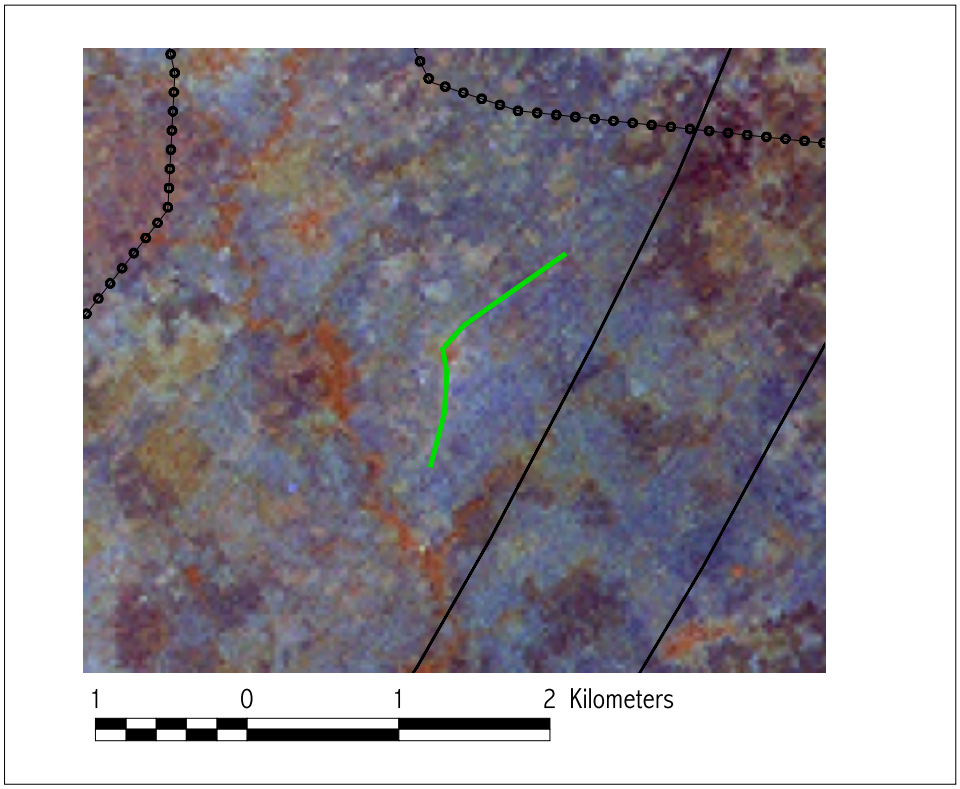


Figure 11. Satellite image for Ohuiye and location of geophysical survey.

Both EM34-3 and magnetic surveys were carried out at Ohuiye; Table 6 summarises the location, details of the surveys; detailed survey data and analyses are presented in Annex 4. The following observations can be made from the geophysical survey results:

1. The EM34-3 survey indicates conductivity values from 30 to 90 mmhos/m.

2. Where conductivity is low (< 40 mmhos/m), the vertical and horizontal coil measurements are equal; at greater electrical conductivity, vertical coil values are significantly higher than horizontal coil values.

3. There are significant magnetic anomalies throughout the village.

4. There are several significant EM34-3 anomalies.

The survey results do not correlate with those produced from investigation of the Awgu Shales along the north Obi traverse (Davies and MacDonald 1998b). There appear to be several dolerite intrusions and maybe sandier horizons, possibly corresponding to the Agbani Sandstone passing through the village. The village would be a good location for an exploratory borehole.

Table 6. Main geophysical surveys carried out at Ohuiye (data in Annex 4).

Survey number	Coordinates Start	Length	Average Spacing	Survey type	Description
OH1	6° 56.94' 8° 11.46'	0.7 km	20 m	EM34 (20)	From village towards river at about 180°
OH2	6° 56.94' 8° 11.46'	0.7 km	10 m	Magnetic	As OH1.
OH3	6° 56.94' 8° 11.46'	0.9 km	20 m	EM34 (20)	Same starting point as OH1 but heading at 60° towards Echori.
OH4	6° 56.94' 8° 11.46'	0.9 km	20 m	Magnetic	As OH3.

5. Akiraba-Ainu

Akiraba-Ainu is a remote village located in central Oju. Community members take their water from seepages in a shallow valley, close to the village. As the dry season progresses, the seepages dry out and community members walk further down stream to take water from ponds in the river. Several wells located within the village have been abandoned either because of collapse, or the shallow bedrock was too hard to dig through. According to the geology map, the village is underlain by Makurdi Sandstone (see Figure 12 and 13).

EM34-3 and magnetic surveys were carried out at Akiraba Ainu; Table 7 summarises the location details of the surveys and Annex 5 contains the detailed survey data. The following observations can be made from the geophysical survey results:

1. Electrical conductivity values vary from 10 to 50 mmhos/m; horizontal and vertical coil measurements are broadly similar.

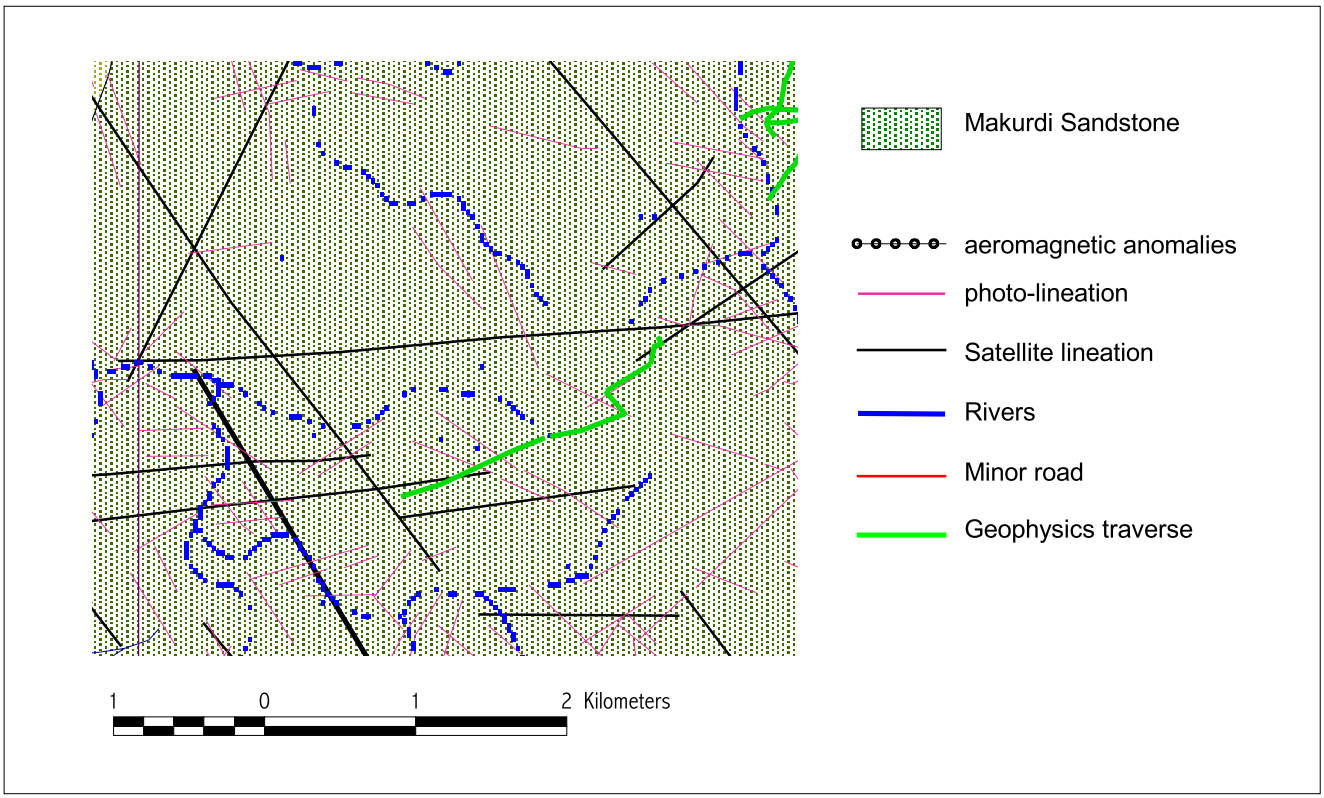


Figure 12. Available map information for Akiraba Ainu and location of geophysical surveys. Surveys carried out at Edumoga are shown in the northeast corner of the map.

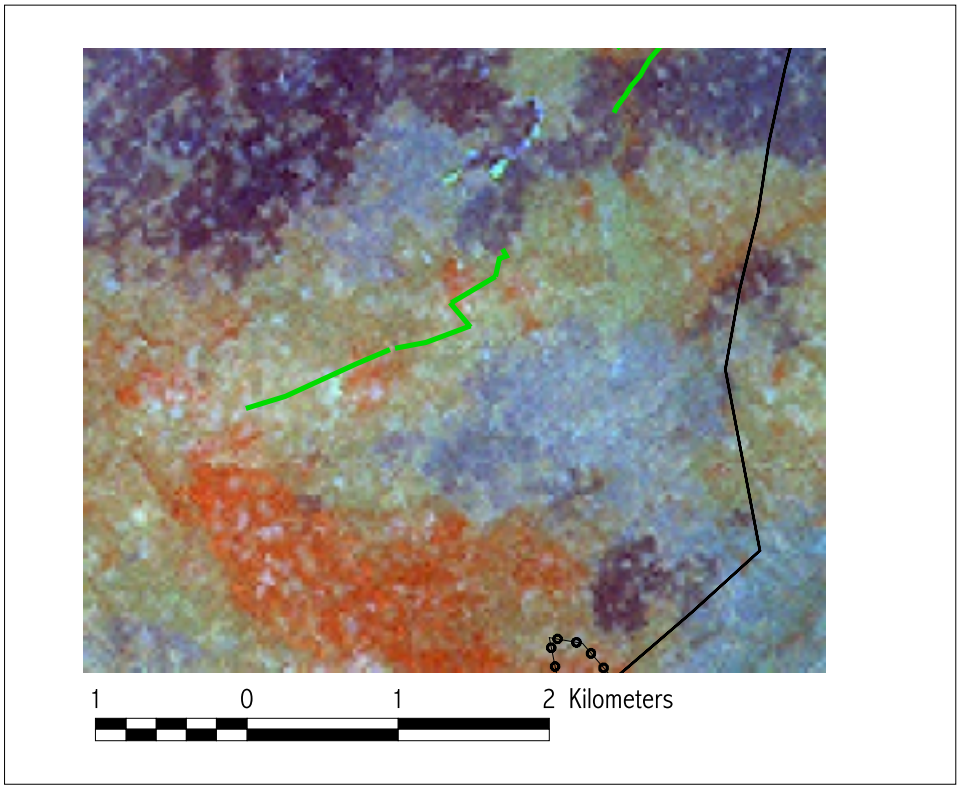


Figure 13. Satellite image for Akiraba Ainu and location of geophysical surveys

2. To the east, conductivity values are lower - conductivity increases to the west. At the end of the eastern traverse, conductivity values are similar to those found within the Makurdi Sandstone at Odaleko Adiko and Ochingingi (MacDonald and Davies 1998b).

3. There are several small negative EM34-3 anomalies, which may correspond to fracture zones as at Edumoga (Davies and MacDonald 1998a)

4. There are no magnetic anomalies.

5. A resistivity sounding located at the Methodist church showed a resistive soil overlying a low resistivity (25 ohm-m) weathered zone (10 m thick) with a moderate resistive (50 ohm-m) bedrock.

A well was dug towards the end of AA 1 where the electrical conductivity was low. The well was dug into sandstone and produced significant quantities of water. There are no obvious sites for a well within the center of the village, the conductivity varies from 20 to 50 mmhos/m indicating that no significant sandstone layers underlie that site. The best option may be to drill on any negative anomaly hoping for a fracture zone. This technique proved successful at Edumoga.

Table 7. Main geophysical surveys carried out at Akiraba Ainu (data in Annex 5).

Survey number	Coordinates Start	Length	Average Spacing	Survey type	Description
AA 1	6° 52.400' 8° 21.743'	1 km	20 m	EM34-3 (20)	From Lucas tree at Church to school at Oganari Anyago
AA 2	6° 52.400' 8° 21.743'	0.5 km	20 m	EM34-3 (20)	From Lucas tree at Church to failed wells
AA 3		0.2 km	20 m	EM34-3 (20)	From failed wells through community to path
AA 4		0.5 km	20 m	EM34-3 (20)	Along path across depression to well in community
AA 5	6° 52.400' 8° 21.743'	0.5 km	10 m	magnetic	Equivalent to AA 2
AA 6		0.3 km	10 m	magnetic	Equivalent to AA 3
AA 7		0.4 km	10 m	magnetic	Equivalent to AA 4
AA 8	6° 52.400' 8° 21.743'		0.5 – 64 m	Offset Wenner	Located at Methodist church

7. Summary and Conclusions

The report brings together miscellaneous investigations carried out at Adega, Ojokwe (southern Oju), Ohuiye, Ijekwe (Obi) and Akiraba-Ainu. Most of the investigations entailed short geophysical surveys; extensive drilling and testing was not carried out at the sites for a variety of reasons. The following work was carried out:

- 13 km of EM34-3 surveys.
- 8 km magnetic surveys.
- 3 resistivity VES.
- One borehole (BGS 32) was drilled at Adega and several metres of core taken.
- chip and core samples from BGS32 were logged and analysed and the borehole back-filled.

For each location some observations can be made from the geophysical surveys:

1. At Adega, conductivity was generally high (60-100 mmhos/m) indicating Awgu Shale; this was substantiated by drilling BGS 32. Part of the profile had low conductivity (30 mmhos/m) very similar to that observed at Ameka. Unfortunately, no drilling could take place here, however, it is likely that the low conductivity corresponds to a sandstone unit.

2. Ojokwe is located on the Asu River group next to the metamorphic aureole of the Workum Hills. The geophysics surveys here were very similar to those carried out at Oyinyi Iyechi and Odubwo. Conductivity varied from 0-45 mmhos/m. Higher conductivity values (especially where conductivity increases with depth) may be due to increased fracturing and therefore a greater groundwater potential. However, due to the metamorphism the bedrock may also be highly conductive and account for an increase in the conductivity.

3. Ijekwe is in the northwestern part of Obi and according to the maps may be underlain by the Awgu Shale and the Agbani Sandstone. Conductivity varied from 35-105 mmhos/m. Low conductivity values were recorded next to an outcrop of sandstone. A new well constructed in a part of the village with low conductivity met sandstone and was high yielding.

4. Ohuiye, located in western Obi, is underlain either by Awgu Shale or possible Agbani Sandstone. Conductivity varied from 30 to 90 mmhos/m. Low conductivity values were associated with pronounced magnetic anomalies.

5. Akiraba Ainu is located on the outcrop of the Makurdi Sandstone. Electrical conductivity values varied from 10-50 mmhos/m. A well constructed where conductivity is low encountered sandstone and was high yielding. High conductivity rocks underlie much of the village. Negative anomalies may be the best target for groundwater here.

Some general conclusions can be made from these studies, since very little drilling has been undertaken, these conclusions must be treated with caution.

- Within the Awgu Shale, low conductivity measurements (<40 mmhos/m) - where both the vertical and horizontal coil readings are similar - may indicate the presence of sandstone.

- Significant magnetic anomalies were found at Ohuiye using the proton precession magnetometer – these corresponded to low conductivity values. No regional magnetic anomalies were present on the

aeromagnetic map (although some were recorded 1.5 km away). Therefore, dolerite may exist outside the areas marked on groundwater potential map (MacDonald and Davies 1998a)

- It is recommended that more drilling be carried out to delimit the extent and nature of the dolerite and Agbani Sandstone within Obi. These are the only possibility for groundwater within the area and as yet, little is known about them.

References

Davies J and MacDonald A M. 1998a. The hydrogeology of the Oju/Obi area, Eastern Nigeria: Edumoga – data report. British Geological Survey Technical WC/98/50R

Davies J and MacDonald A M 1998b. The hydrogeology of the Oju/Obi area, Eastern Nigeria: North Obi traverse - data report. British Geological Survey Technical Report WC/98/52R.

MacDonald A M and Davies J. 1998a. Groundwater Development Maps for Oju and Obi Local Government Areas, Eastern Nigeria. . British Geological Survey Technical Report WC/98/53

MacDonald A M and Davies J. 1998b. The hydrogeology of the Oju/Obi are, Eastern Nigeria: Ochingini traverse – data report. British Geological Survey Technical WC/98/51R

Annex 1: Data for Adega

Adega

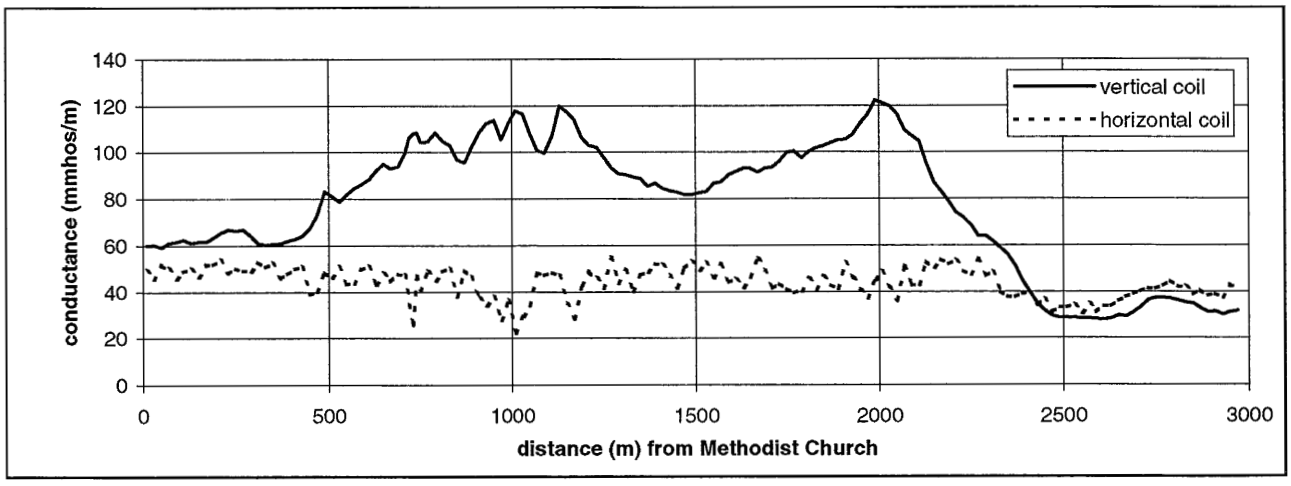
AD1

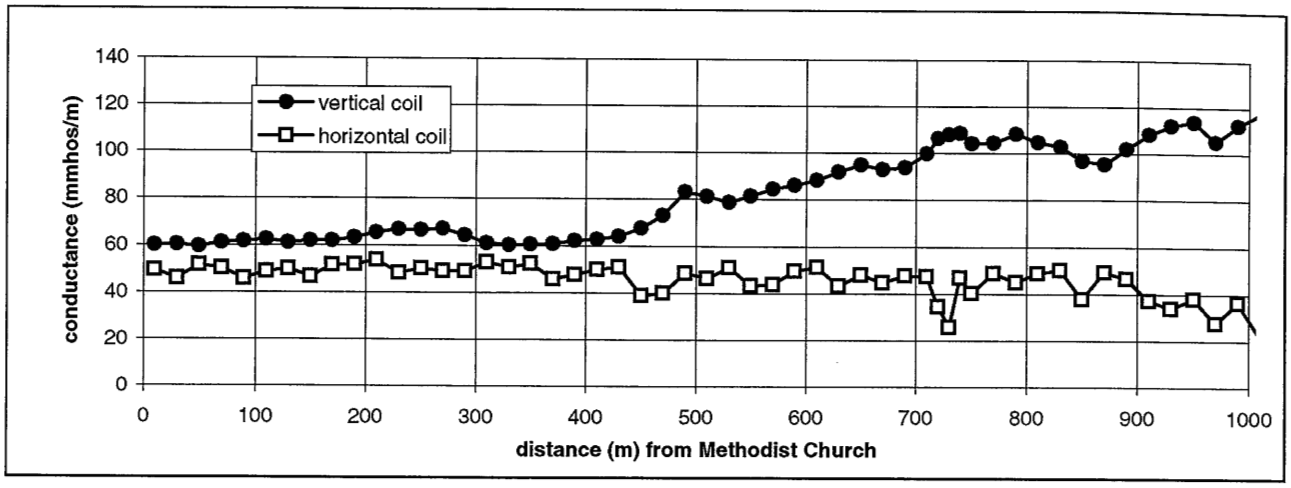
GPS start: 7 degs 2.869; 8 degs 16.253
GPS finish
Date and time: 27/02/98 9:00 - 15:00
Survey: AD1 From methodist church through village to tarmac Road. EM34 20 m.

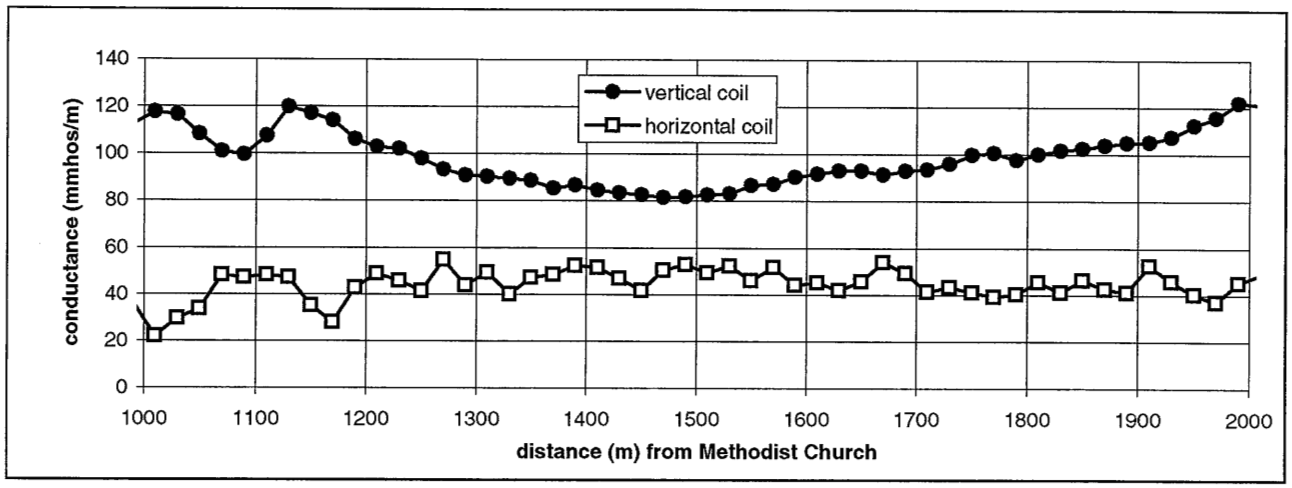
AA 1:

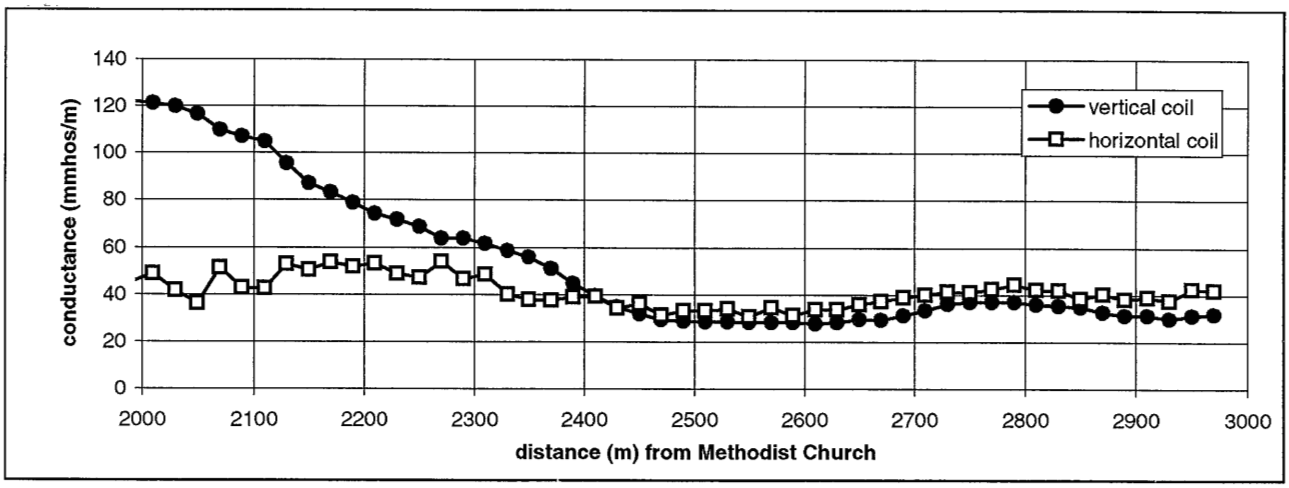
position (m)	strike (deg)
0	253
140	232
240	248
380	194
540	192
640	224
960	208
1340	219
1540	208
2660	230

position (m)	comments
0	Mango tree by church
160	thicker forest
195	tree stump right
300	small path right
340	path R by shrine
350	tree
460	small wood culvert
500	small x roads
590	x roads to compounds
640	corner with palm tree
740	small wood culvert
820	coconut palm
990	wood culvert
1100	tree in catholic compound
1130	middle depression
1240	large dry tree
1360	2 mango trees
1420	half burnt tree
1620	small path right
1690	mango tree right
1855	tree stump left
1985	culvert (village boundary)
2105	small anthill
2180	palm tree left
2320	x roads - shallow dry well
2465	big tree wells
2540	path left (+5 to path right)
2690	path right
2780	beginning compound 1st house
2835	path left
2965	edge tarmac road




conductance (mmhos/m)
vertical coil
horizontal coil
0
20
40
60
80
100
120
140
0
100
200
300
400
500
600
700
800
900
1000
distance (m) from Methodist Church


conductance (mmhos/m)
vertical coil
horizontal coil
0
20
40
60
80
100
120
140
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
distance (m) from Methodist Church

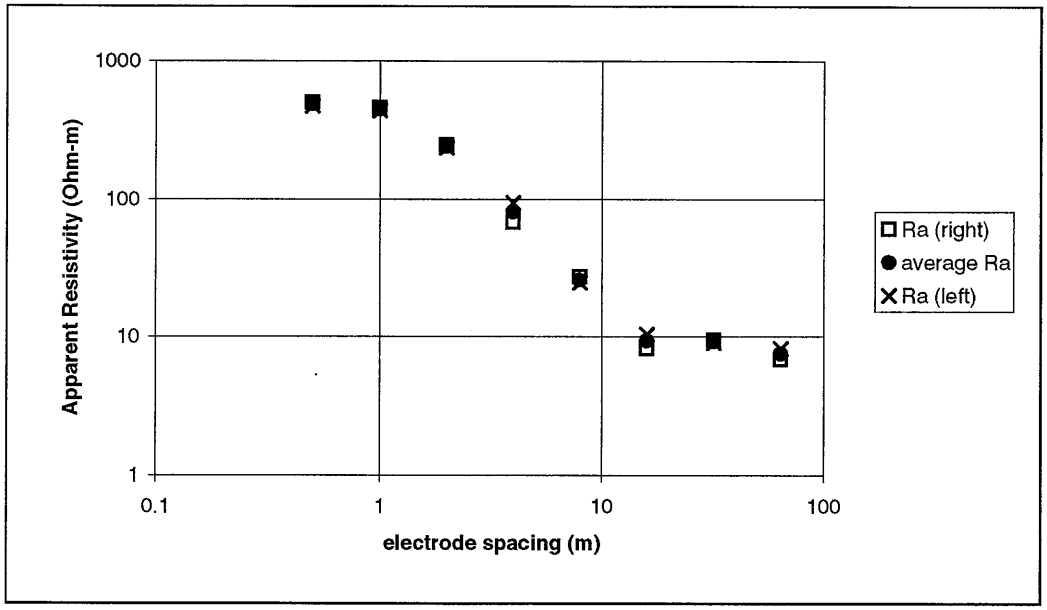

conductance (mmhos/m)
vertical coil
horizontal coil
0
20
40
60
80
100
120
140
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
distance (m) from Methodist Church

Adega

AD 2

Resistivity Survey 1
Located at playground 340 m along AD1
Offset Wenner right to church
Strike 288 degs
24/02/98

spacing (m)	left	right	Ra (left)	Ra (right)	average Ra
0.5	150.3	158.6	471.942	498.004	484.973
1	69.6	72.9	437.088	457.812	447.45
2	18.64	19.61	234.1184	246.3016	240.21
4	3.7	2.7	92.944	67.824	80.384
8	0.49	0.54	24.6176	27.1296	25.8736
16	0.103	0.0815	10.34944	8.18912	9.26928
32	0.045	0.047	9.0432	9.44512	9.24416
64	0.0204	0.017	8.199168	6.83264	7.515904



DATA SET: ADEGA1

CLIENT: WaterAid DATE: FEb 1998
LOCATION: Adega SOUNDING: 1
COUNTY: Oju LGA Nigeria AZIMUTH: 0
PROJECT: Water and Sanitation EQUIPMENT: BGS128
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

Offset Wenner Configuration

FITTING ERROR: 5.830 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	521.2	1.18	-1.18	0.00227	617.0
2	72.27	3.39	-4.58	0.0470	245.6
3	8.03				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

	LAYER	MINIMUM	BEST	MAXIMUM
RHO	1	475.641	521.300	571.342
	2	49.595	72.280	105.739
	3	7.493	8.039	8.590
THICK	1	1.003	1.184	1.363
	2	2.861	3.398	4.097
DEPTH	1	1.003	1.184	1.363
	2	3.919	4.582	5.433

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	0.500	485.0	503.7	-3.86
2	1.00	447.0	427.5	4.35
3	2.00	240.0	239.6	0.151
4	4.00	80.00	81.65	-2.06
5	8.00	26.00	25.31	2.64
6	16.00	9.26	9.74	-5.22

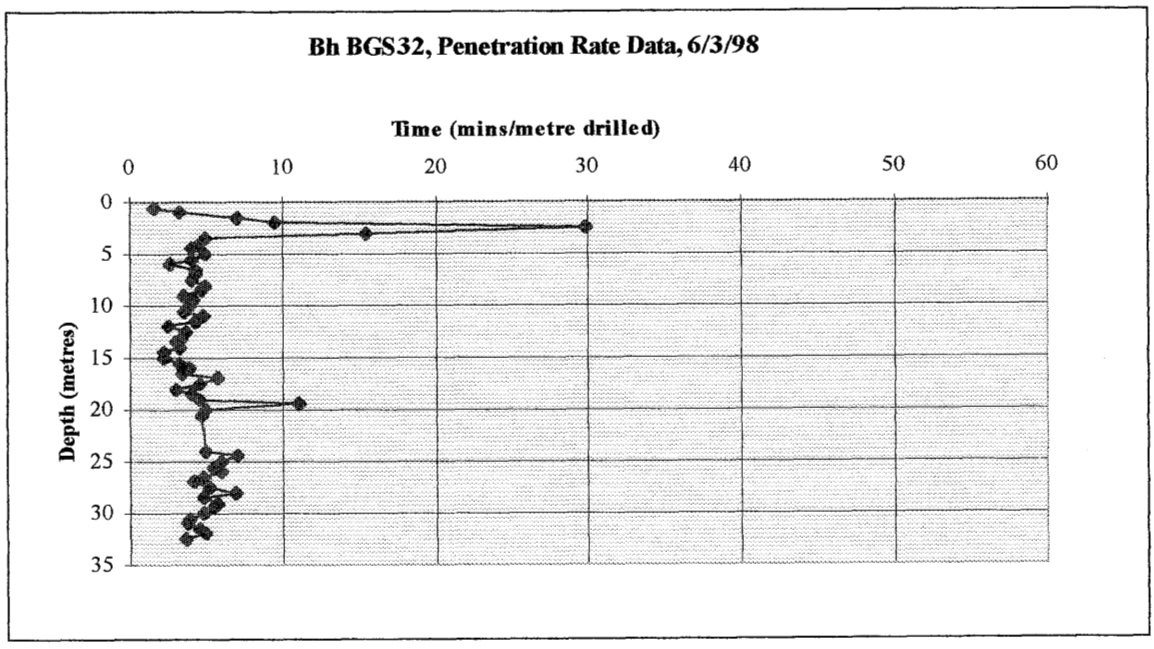
No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
7	32.00	9.24	8.24	10.72
8	64.00	7.50	8.08	-7.80

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	1.00				
P 2	0.00	0.98			
P 3	0.00	0.00	1.00		
T 1	0.00	0.01	0.00	1.00	
T 2	0.00	0.01	0.00	0.00	1.00
	P 1	P 2	P 3	T 1	T 2

Borehole BGS32

Borehole Drilling/Construction Details	
Date drilling started	6/3/98
Date drilling completed	6/3/98
6/3/98 - Drilled with 6.5" tricone	0.00 - 20.5m
6/3/98 - Cored at 3"	20.5 - 23.5m
6/3/98 - Drilled with 6.5" tricone	23.5 - 32.5m
Depth of borehole on completion	32.5mbgs
Borehole diameter	$6^1/_2$"
Casing erected in hole	none
Rest water level below casing top	dry

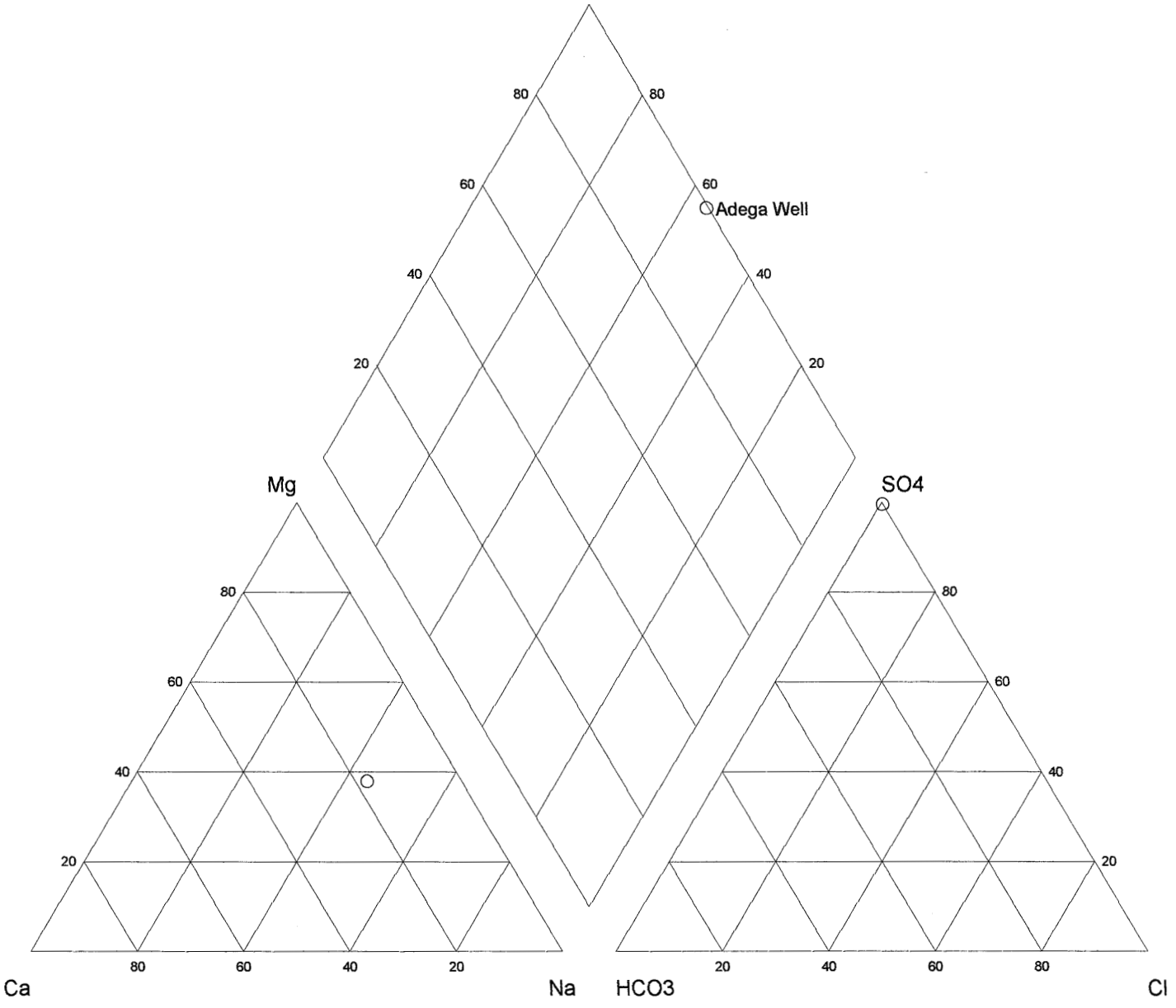


Lithological log: BGS 32

Soil/ferrecrete horizon	
0.0 - 0.5	Light brown 7.5YR6/4 fine grained soil
0.5 - 1.0	Red 10R4/6, light brown 7.5YR6/4 and reddish yellow 7.5YR6/6 mottled sandy clay
1.0 - 1.5	Reddish grey 2.5YR6/1 to pale red 2.5YR6/2 and red 10R4/8 mottled sandy clay
1.5 - 2.0	Dark red 10R3/3 nodules of ferrecrete in yellowish red 5YR4/6 matrix with some red 10R4/6 nodule rims
Clayey very weathered horizon	
2.0 - 2.5	Mottled brown yellow 10YR5/8, reddish yellow 7.5YR6/6 and light grey clays
2.5 - 3.0	Brownish yellow sand with clay below light grey clay
3.0 - 3.5	Grey 10YR6/1 grey silty clay with some brownish yellow 10YR6/8 fine grained sand
Very weathered clayey silts and fine grained sands	
3.5 - 4.0	Grey 10YR6/1 grey clayey silt to fine sand with some brownish yellow 10YR6/8 and orange partings
4.0 - 4.5	Brownish yellow 10YR6/6 fine grained sands with brown grey partings
Weathered silty mudstone	
4.5 - 5.0	Grey 10YR5/1 grey clayey silt
5.0 - 5.5	Grey 10YR5/1 grey silty mudstone with orange partings
5.5 - 6.0	Grey weathered silty and clayey mudstones with yellow and orange partings
6.0 - 6.5	Grey weathered silty and clayey mudstones with orange and yellow partings
6.5 - 7.0	Grey weathered silty shales with thin hard dark brown fine sandstone layers, much orange weathering
7.0 - 7.5	Grey to light grey clayey siltstone, some orange weathering
7.5 - 8.0	Varigated dark grey and bright orange silty clay with some dark red partings
8.0 - 8.5	Weathered soft grey sitly clayey mudstones with orange partings and some dark red layers
8.5 - 9.0	Weathered dark grey and ochre silty clayey mudstones
Weathered mudstones	
9.0 - 9.5	Dark grey to brownish dark grey weathered carbonaceous mudstones
9.5 - 10.0	Soft dark grey purple with ochre and orange partings weathered carbonaceous mudstones
10.0 - 10.5	Dark grey weathered mudstones with ochre and dark red partings, soft
10.5 - 11.0	Dark grey weathered mudstones with ochre to dark olive green partings
Weathered mudstones with gypsum	
11.0 - 11.5	Dark grey weathered mudstones, some dark red, ochre and orange partings, some **gypsum**, thin hard dark red brown fine grained layer noted
11.5 - 12.0	Dark grey mudstones with dark red to olive brown weathered partings with **gypsum** layers with dark red and orange partings
12.0 - 12.5	Dark purple grey soft weathered mudstones and soft thin red layer
12.5 - 13.0	Very dark purple grey weathered mudstones some **gypsum**
13.0 - 13.5	Very carbonaceous brownish black mudstones with some **gypsum**
13.5 - 14.0	Very carbonaceous black shaley mudstones, some dark red brown weathered layers, odd hard light grey fine bands
Carbonaceous shaley mudstones	
14.0 - 14.5	Black to dark grey very carbonaceous blocky mudstones
14.5 - 15.0	Black to dark grey very carbonaceous blocky mudstones
15.0 - 15.5	Black to dark grey very carbonaceous shaley mudstones
15.5 - 16.0	Blocky black very carbonaceous mudstones
16.0 - 16.5	Shaley and splintery black very carbonaceous mudstones
16.5 - 17.0	Shaley and splintery black very carbonaceous mudstones
17.0 - 17.5	Shaley and splintery black very carbonaceous mudstones
17.5 - 18.0	Black carbonaceous shaley mudstones with hard thin grey sandstone or limestone layers
18.0 - 18.5	Black carbonaceous shaley mudstones
Carbonaceous mudstone and hard limestones	
18.5 - 19.0	Dark grey carbonaceous shaley mudstones with thin hard dark grey limestone bands

19.0 - 19.5	Grey hard limestones interbedded with dark grey mudstones
19.5 - 20.0	Dark grey and black mudstones with thin limestone layers
Carbonaceous shaley mudstones	
20.0 - 20.5	Black carbonaceous shaley mudstones
20.50 - 20.70	Dark grey compact blocky to shaley mudstone, no fossils
20.70 - 20.75	Grey very shaley thinly bedded mudstones compact with fairly small clay nodules passing down into larger calcareous nodules, some microfossils
20.75 - 22.00	Grey shaley mudstones with earthy texture with many fossiliferous beds of microfossils and macrofossils including bivalve fragments, gastropods and odd ammonite as at 21.20m
22.00 - 22.50	Grey fine grained mudstones with subconcoidal fracture, blocky to shaley, few fossils
22.50 - 22.75	Grey earthy soft shaley mudstones fragments
22.75 - 23.00	Grey campact to shaley and blocky fine grained mudstones with subconcoidal fracture
23.00 - 23.50	Soft grey thinly laminated fragile and earthy mudstones, some bivalves eg lingular, echinoid hemicidaris? at 23.20m, and microfossils, some iron pyrite
Carbonaceous mudstone	
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 soft carbonaceous mudstones
Carbonaceous shaley mudstone	
25.5 - 26.0	Black shaley carbonaceous mudstones
26.0 - 26.5	Black very carbonaceous shaley mudstones
26.5 - 27.0	Black carbonaceous soft shaley mudstones
Carbonaceous shaley mudstones and limestones	
27.0 - 27.5	Black carbonaceous shaley mudstones with some limestone
27.5 - 28.0	Black very carbonaceous shaley mudstones with hard dark grey limestone bands
28.0 - 28.5	Black very carbonaceous shaley mudstones with hard dark grey limestone bands
Carbonaceous mudstones	
28.5 - 29.0	Black soft very carbonaceous shaley mudstones
29.0 - 29.5	Black carbonaceous blocky mudstone
29.5 - 30.0	Black very carbonaceous mudstones
30.0 - 30.5	Black very carbonaceous mudstones
30.5 - 31.0	Black very carbonaceous mudstones
31.0 - 31.5	Black very carbonaceous mudstones
31.5 - 32.0	Black very carbonaceous mudstones
32.0 - 32.5	Black very carbonaceous mudstones

Groundwater Hydrochemistry - Adega



SampleID : Oju217
Location : Obi
Site : Adega Well
Sampling Date : 17/03/98
Geology : Awgu Shale
Watertype : Na-Mg-SO4

Sum of Anions (meq/l) : 21.56
Sum of Cations (meq/l) : 21.20
Balance: : 0.9%

Total dissolved solids : 42.8 meq/l 1422.7 mg/l

Hardness	: meq/l	°f	°g	mg/l CaCO3
Total hardness	: 11.27	56.37	31.57	563.7
Permanent hardness	: 11.26	56.29	31.52	562.9
Temporary hardness	: 0.02	0.08	0.05	0.8
Alkalinity	: 0.02	0.08	0.05	0.8

(1 °f = 10 mg/l CaCO3/l 1 °g = 10 mg/l CaO)

Major ion composition

	mg/l	mmol/l	meq/l	meq%
Na+	206.0	8.96	8.96	20.953
K +	6.5	0.166	0.166	0.388
Ca++	72.1	1.799	3.598	8.414
Mg++	93.3	3.838	7.676	17.95
Cl-	2.5	0.071	0.071	0.166
SO4--	1030.0	10.723	21.446	50.152
HCO3-	1.0	0.016	0.016	0.037

Ratios			Comparison to Seawater	
	mg/l	mmol/l	mg/l	mmol/l
Ca/Mg	0.773	0.469	0.319	0.194
Ca/SO4	0.07	0.168	0.152	0.364
Na/Cl	82.4	127.069	0.556	0.858

Dissolved Minerals:		mg/l	mmol/l
Halite (NaCl)	:	0.116	0.002
Anhydrite (CaSO4)	:	1460.461	10.723
SiO2 as Quartz	:	43.721	0.728
or Feldspar (NaAlSi3O8):		190.915	0.729

SampleID : Oju217
Location : Obi
Site : Adega Well
Sampling Date : 17/03/98

Drinking Water Quality Regulations:

Element	Measured	Recommended	Maximum
pH	4.31	6.5- 8.5	< 9.5
T(Wa)	29.2	< 12	< 25
Cond	2010	< 400	< 1250
Na	206	< 20	< 200
Mg	93.3	< 30	
Mn	5.59	< .02	< .05
Fe	1.69	< .05	< .2
NH4	0.97	< .5	
Zn	0.67	< .1	
Ni	0.42		< .05
SO4	1030	< 25	< 250
Al	11.2	< .05	< .2

Irrigation water:
Conductivity = 2010 uS (group C3: High salinity water)
Sodium Adsorption Ratio (SAR) : 3.77
Exchangeable sodium ratio (ESR) : 0.79
Magnesium hazard (MH) : 68.09

Annex 2: Data for Ojokwe

Ojokwe

OJ1/OJ2

GPS start: 6 46.305 8 19.494

Date and time: 25/11/96 9:40-11:30

Survey: OJ1 EM34 with 20 m spacing; both horizontal and vertical dipoles

OJ 2 as OJ1 magnetic survey

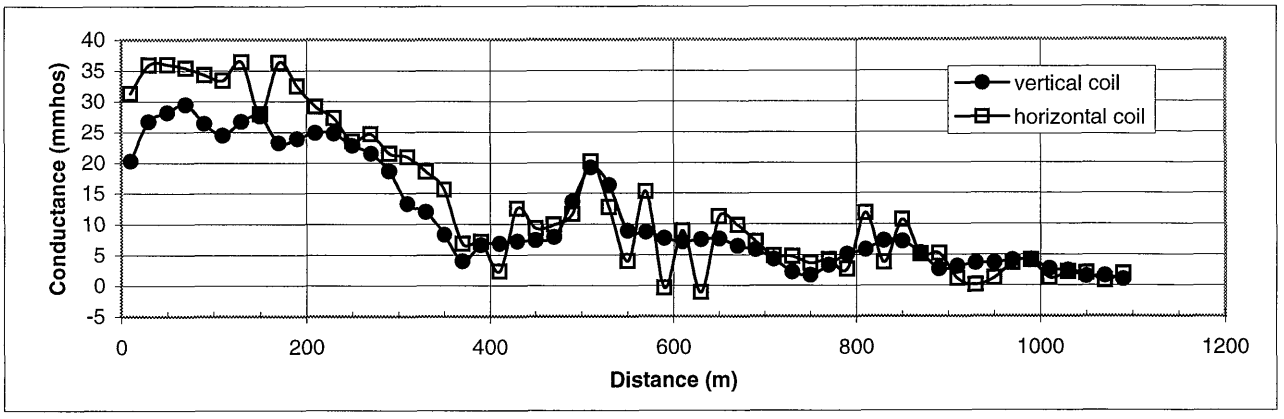
Strike:

position (m)	strike (deg)
0	290
210	296
350	288
430	282
510	292
610	295
710	291
790	293
1090	294

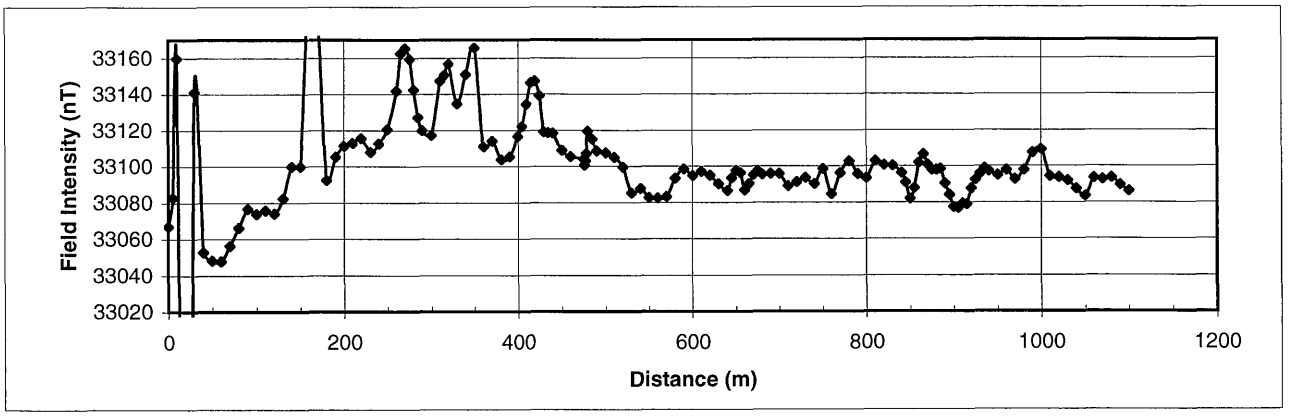
Comments:

position (m)	comments
10	roof 4 m
110	roof 15 m
150	roof 5 m
210	roof 30 m
265	roof 20 m
320	roof 15
340	roof 10 m
360	roof 10 m
420	roof 15m
590	bridge
690	roof 40 m
730	top of rise
850ish	dry valley

OJ1 (EM34):



OJ2 (magnetic):



Ojokwe

OJ3/OJ4

GPS start: 6 46.175 8 19.502
Date and time: 25/11/1996 11:40 - 13:30
Survey: (1) EM34 with 20 m spacing; both horizontal and vertical dipoles
(2) magnetic survey

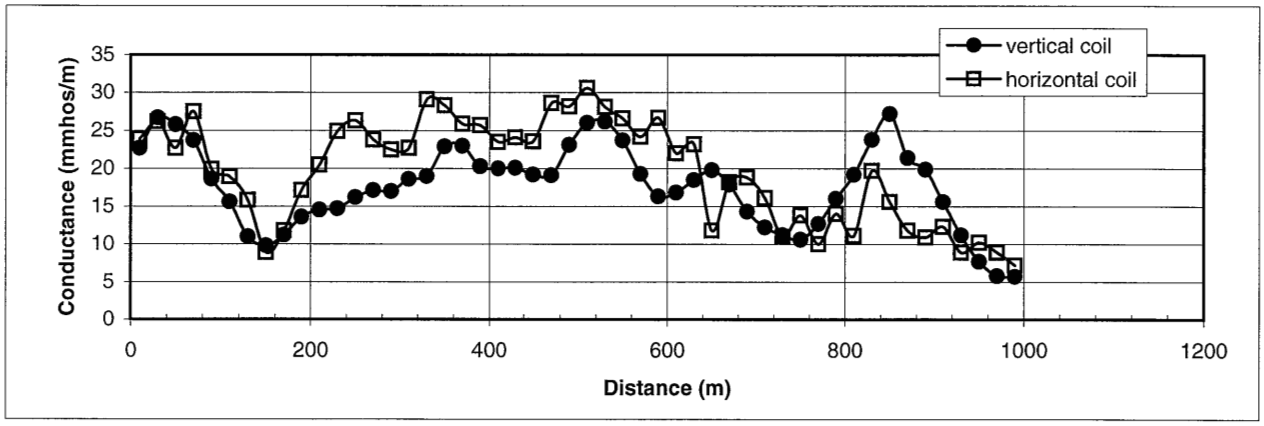
Strike:

position (m)	strike (deg)
0	215
110	225
270	246
350	253
490	246
570	249
710	233
850	246
970	250

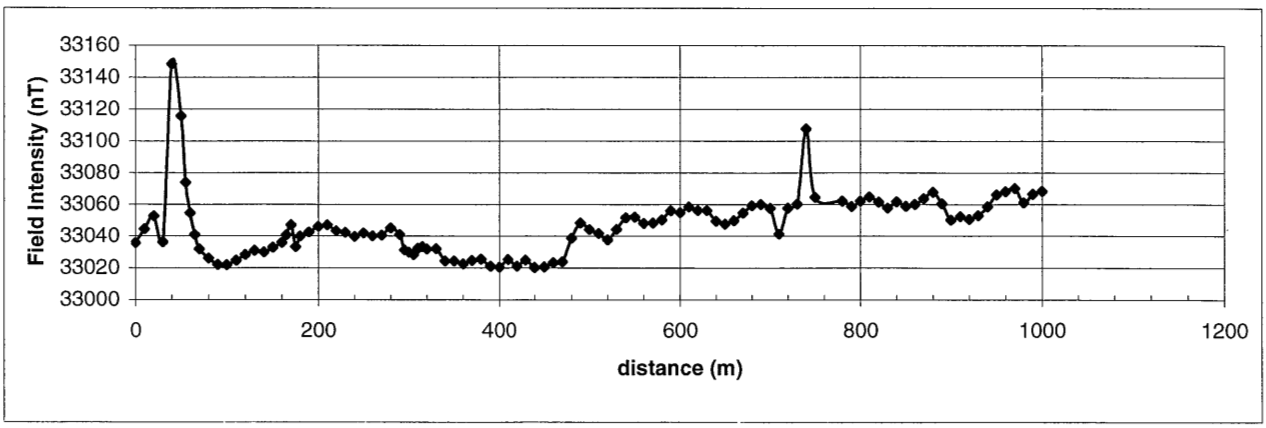
Comments:

position (m)	comments
0	bikes 10 m away
30	roof 20 m
60	roof 10 m
480	basins 2 m
490	roof 40 m
540	roof 20 m
610	bike 4 m
690	roof 20 m
740	basins
770	metal bike
840	bridge

OJ3 (EM34):



OJ4 (magnetic):



Ojokwe

OJ5/OJ6

GPS start: 6 46.210 8 19.095
Date and time: 26/11/1996 10:30-12:00
Survey: (1) EM34 with 20 m spacing; both horizontal and vertical dipoles
(2) magnetic survey

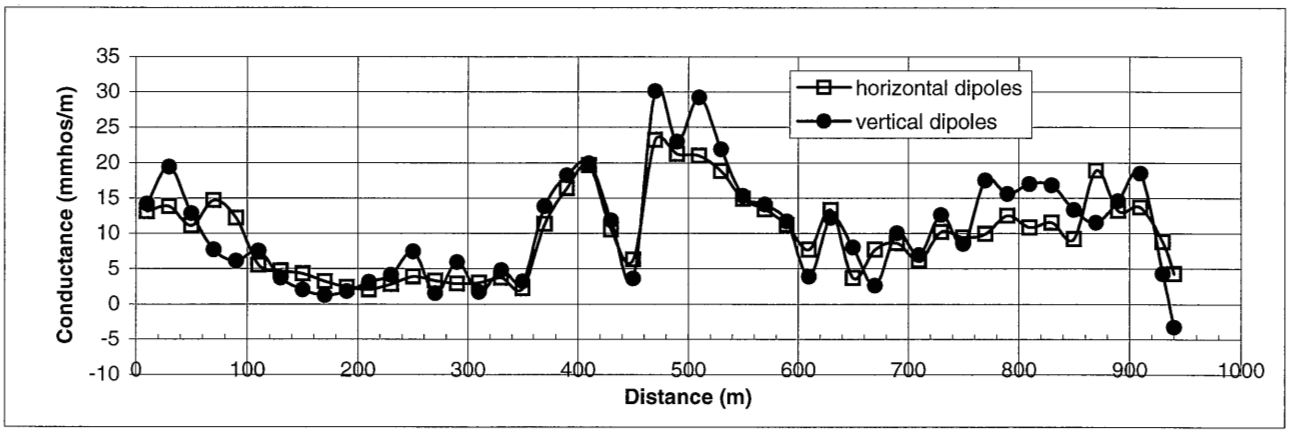
Strike:

position (m)	strike (deg)
10	252
50	260
230	304
430	228
470	218
550	241
610	279
650	292
690	270
730	300
890	238
930	271

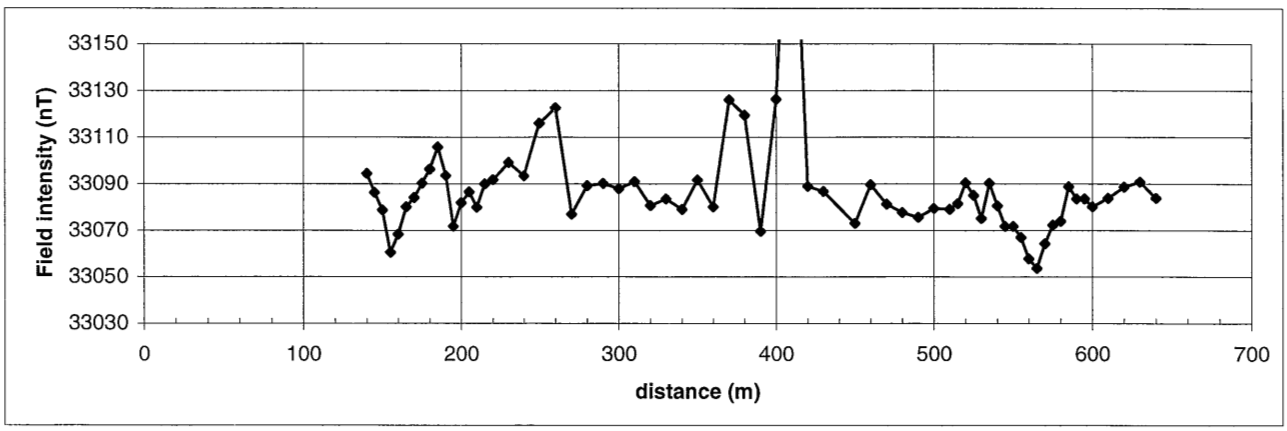
Comments:

position (m)	comments
0-150	in village - too noisy for mag
180	dry valley
220	mud huts
250	roof 10 m
280	mud huts
350	roof 4 m
360	mud hut 2 m
370	roof 10
400	roof 7
410	roof 4
420	hut 2
520	valley with water
940	river

OJ5 (EM34):



OJ6 (magnetic):



Ojokwe

OJ7/OJ8

GPS start: 6 46.268 8 18.747
Date and time: 26/11/1996 12:00 - 14:00
Survey: (1) EM34 with 20 m spacing; both horizontal and vertical dipoles
(2) magnetic survey

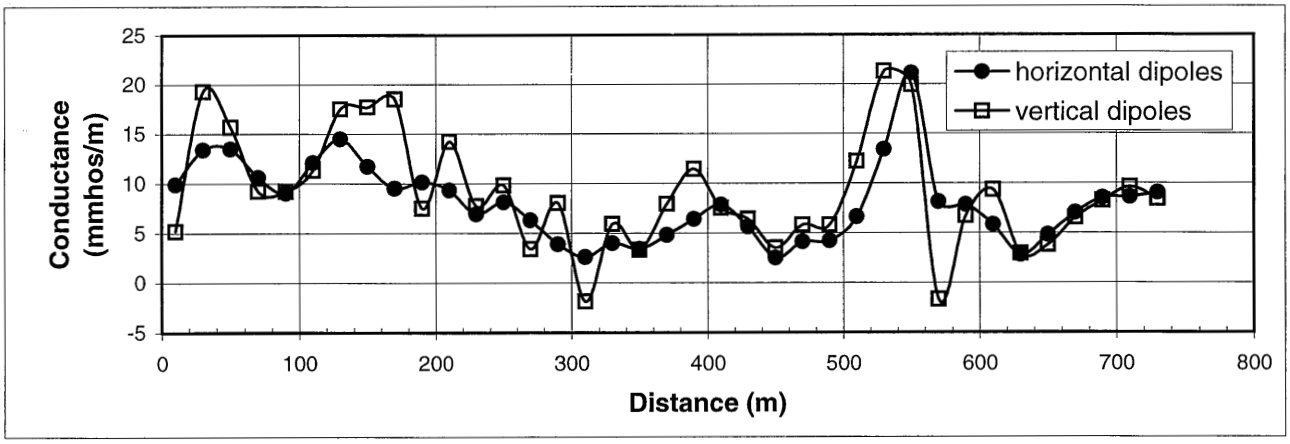
Strike:

position (m)	strike (deg)
0	91
50	51
210	120
310	130
450	110
490	84
600	69
710	36

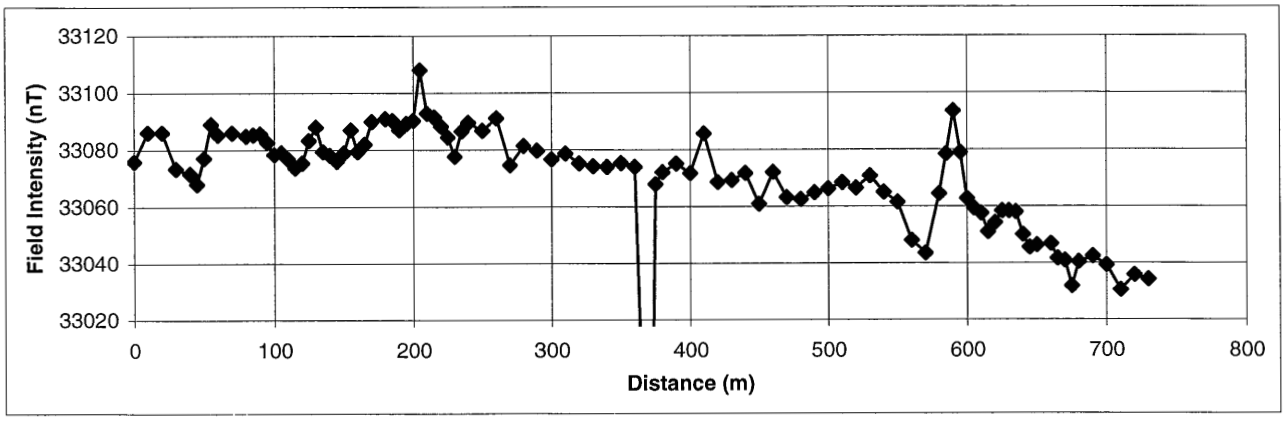
Comments:

position (m)	comments
0-300	coincident with 640 - 940 m of OJ5
0	river valley
600	depression (dry valley)
620-720	10 m south of dry valley

OJ7 (EM34):



OJ8 (magnetic):



Ojokwe

OJ9/10/11

GPS start: 6 46.336, 8 19.512
Date and time: 27/11/96
Survey: (OJ9) EM34 with 10 m spacing; both horizontal and vertical dipoles
(OJ10) EM34 with 20 m spacing; both horizontal and vertical dipoles
(OJ11) EM34 with 40 m spacing; both horizontal and vertical dipoles

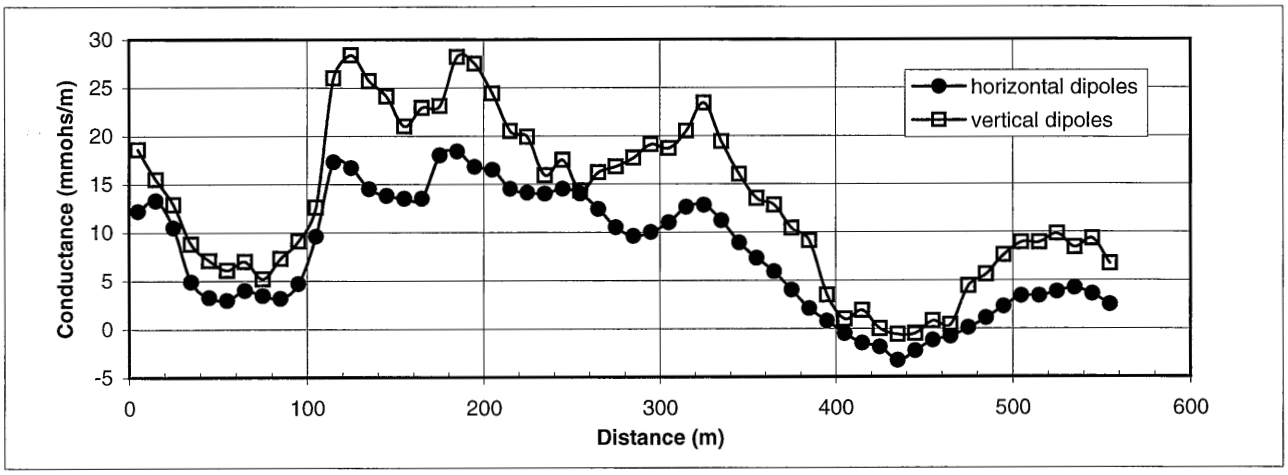
Strike:

position (m)	strike (deg)
0	241
175	250
300	260
355	276
455	270

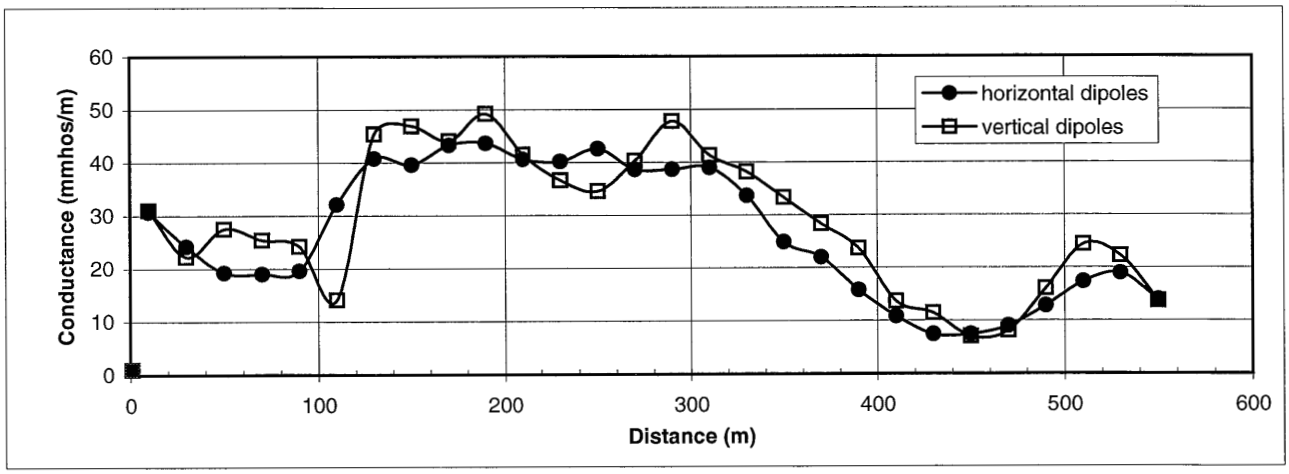
Comments:

position (m)	comments
0-550	from market place to chiefs house
	along hard packed dirt road
	High trees either side

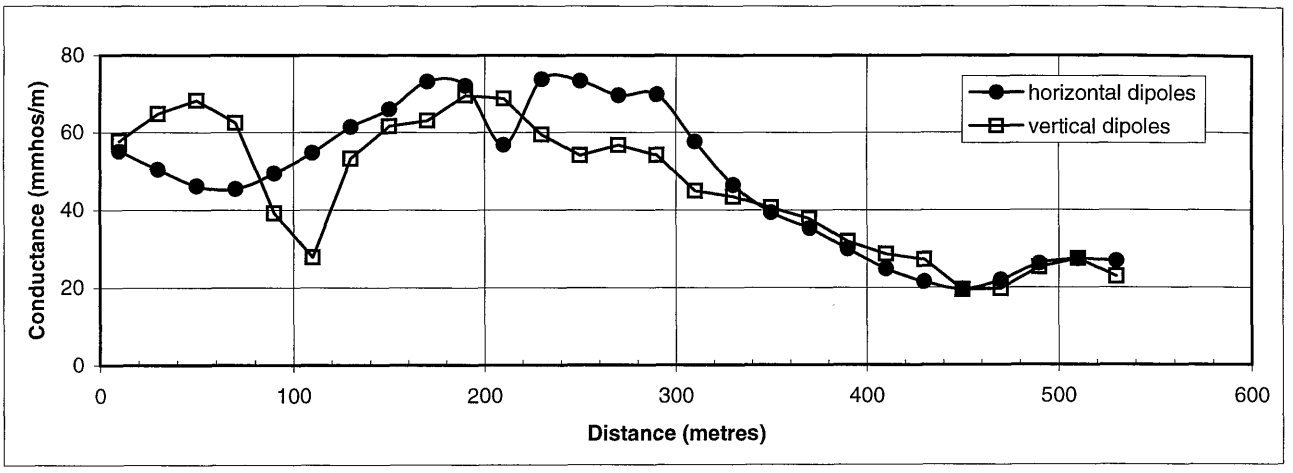
OJ9 (EM34 - 10 m spacing):



OJ10 (EM34 - 20 m spacing):



OJ11 (EM34 - 40 m spacing):

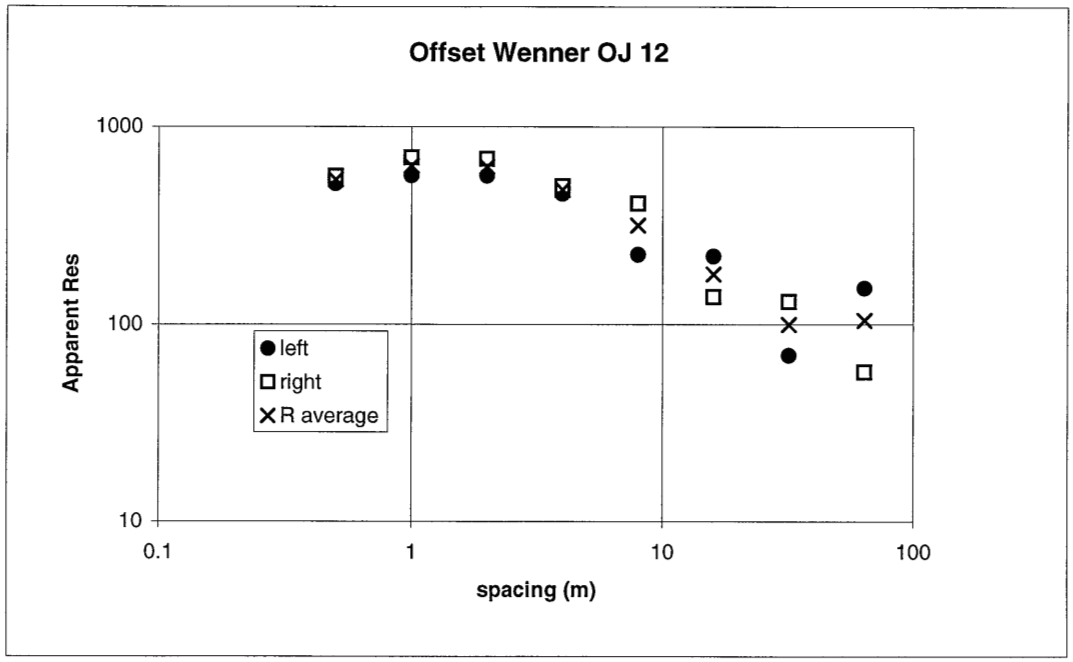


Ojokwe

OJ 12

27/11/96 (raked)
6 degs 46.336, 8 degs 19.512
pyroclastics all observed
200 m from market along OJ 9

spacing	left	right	R (left)	R (right)	R average
0.5	164.1	178.5	515.274	560.49	537.882
1	89.9	111.3	564.572	698.964	631.768
2	44.8	54.7	562.688	687.032	624.86
4	18.24	19.92	458.1888	500.3904	479.2896
8	4.49	8.16	225.5776	409.9584	317.768
16	2.2	1.368	221.056	137.4566	179.2563
32	0.346	0.647	69.53216	130.0211	99.77664
64	0.379	0.1424	152.3277	57.23341	104.7805



DATA SET: OJOKWE

CLIENT: WaterAid
LOCATION: Ojokwe
COUNTY: Oju
PROJECT: Water and Sanitation
ELEVATION: 0.00
DATE: November96
SOUNDING: 1
AZIMUTH: 11.5 Deg N-NE
EQUIPMENT: BGS128
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

Offset Wenner Configuration

FITTING ERROR: 8.069 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	201.7	0.0403	-0.0403	2.002E-04	8.14
2	594.6	5.46	-5.51	0.00920	3252.8
3	101.0				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

	LAYER	MINIMUM	BEST	MAXIMUM
RHO	1	143.273	201.745	826.031
	2	542.744	594.688	646.900
	3	90.312	101.002	113.030
THICK	1	0.022	0.040	0.175
	2	4.707	5.470	6.402
DEPTH	1	0.022	0.040	0.175
	2	4.779	5.510	6.424

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	0.500	538.0	556.3	-3.41
2	1.00	632.0	581.3	8.02
3	2.00	625.0	579.5	7.27
4	4.00	479.0	523.8	-9.35
5	8.00	318.0	347.9	-9.42
6	16.00	179.0	160.8	10.13

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
7	32.00	100.0	108.1	-8.16
8	64.00	105.0	102.3	2.51

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

	P 1	P 2	P 3	T 1	T 2
P 1	0.48				
P 2	0.00	1.00			
P 3	0.00	0.00	1.00		
T 1	-0.47	0.00	0.00	0.47	
T 2	0.00	0.00	0.00	0.00	1.00

Annex 3: Data for Ijekwe

Ijekwe

IJ1/2

GPS start: 7 01.371, 8 13.629
Date and time: 07/12/96 9:15-11:30
Survey: (IJ1) EM34 with 20 m spacing; both horizontal and vertical dipoles
(IJ2) Magnetic
Survey from School playing fields through village to the river

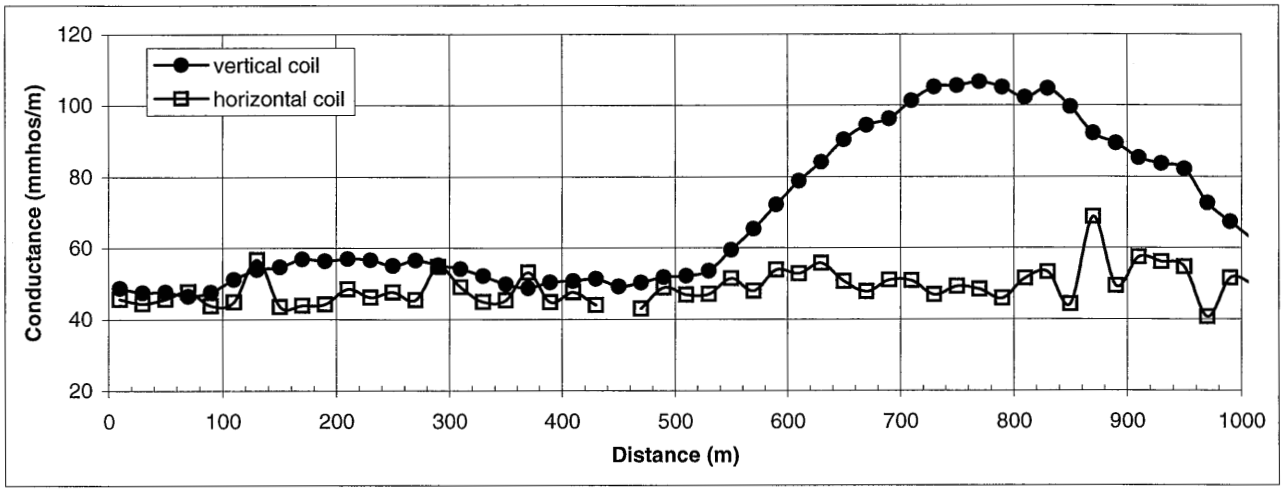
Strike:

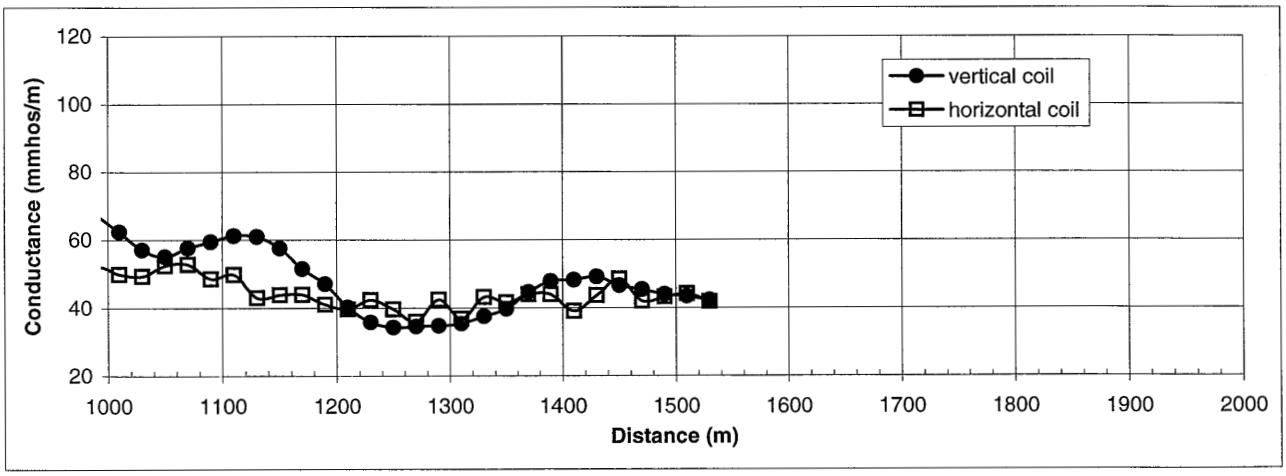
position (m)	strike (deg)
0	159
190	152
450	171
530	190
550	198
610	220
810	208
890	194
970	212
1210	195
1330	200

Comments:

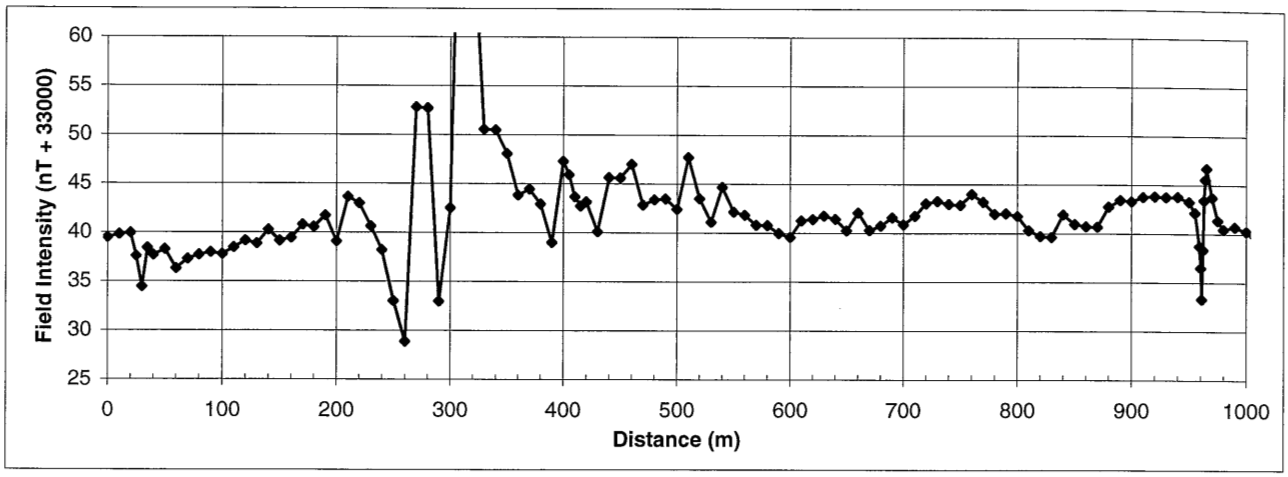
position (m)	comments
230	roof 30-40m
240	roof 30 m and 20 m
260	roof
300	roof 10 m
310	roof 10 m
320	roof 15 m
350	roof 20 m
370	mud huts
510	bikes
	down hill
740	silty clay with cracks
1290	slight depression
1390	bridge

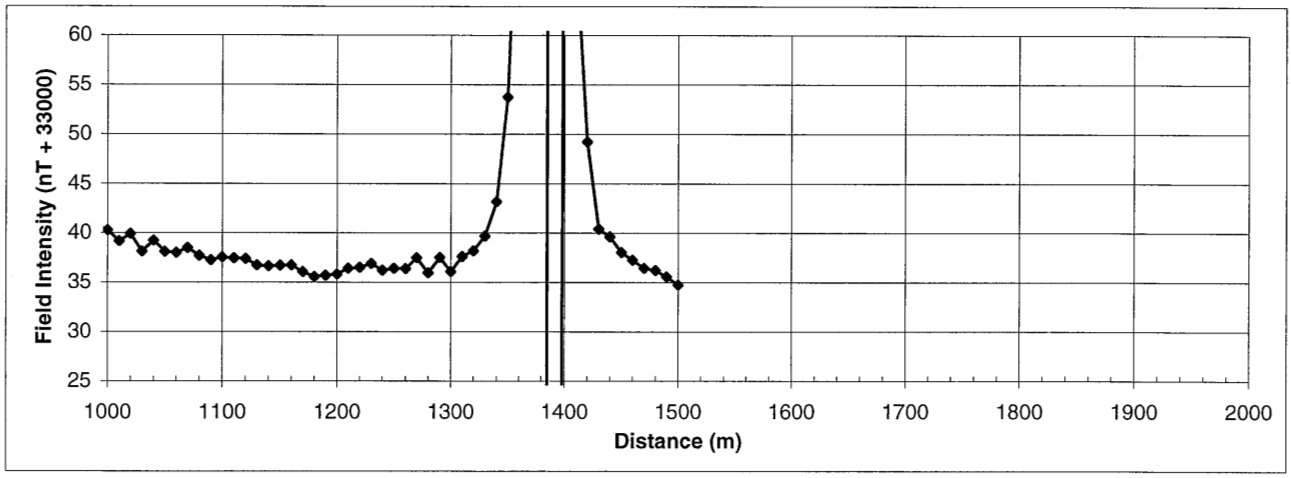
IJ1 (EM34):





IJ2 (magnetic):





Annex 4: Data for Ohuiye

Ohuiye

OH1/2

GPS start: 56.944, 8 11.46
Date and time: 06/12/1996 11:15-12:30
Survey: (OH1) EM34 with 20 m spacing; both horizontal and vertical dipoles
(OH2) Magnetic
Survey from village towards river along path

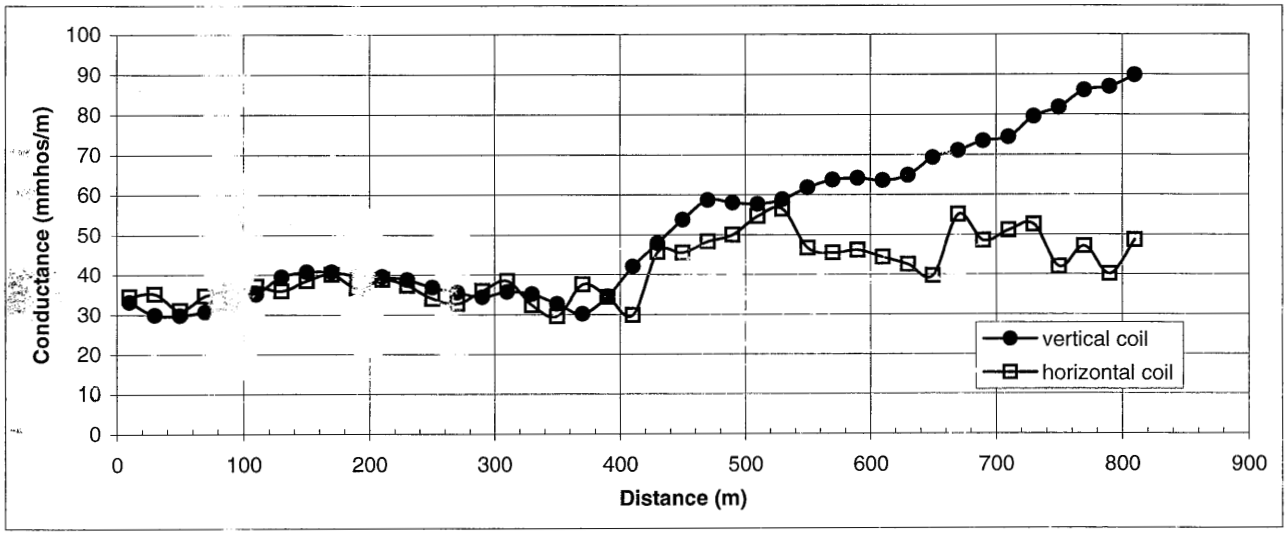
Strike:

position (m)	strike (deg)
0	160
4	166
170	176
310	184
710	186

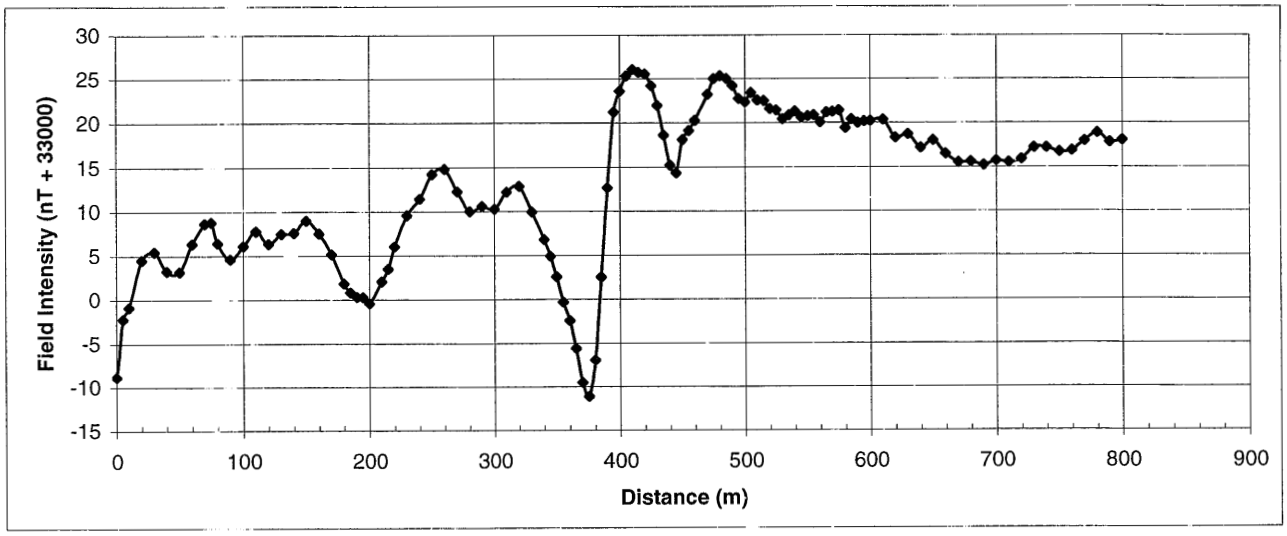
Comments:

position (m)	comments
0	in village no visible noise
20	mud hut 10 m left

OH1 (EM 34):



OH2 (magnetic):



Ohuiye

OH3/4

GPS start: 6 56.944, 8 11.46
Date and time: 06/12/1996 13:30 - 16:00
Survey: (OH3) EM34 with 20 m spacing; both horizontal and vertical dipoles
(OH4) Magnetic
Survey from village (same start as OH1/2) towards Echuri along road.

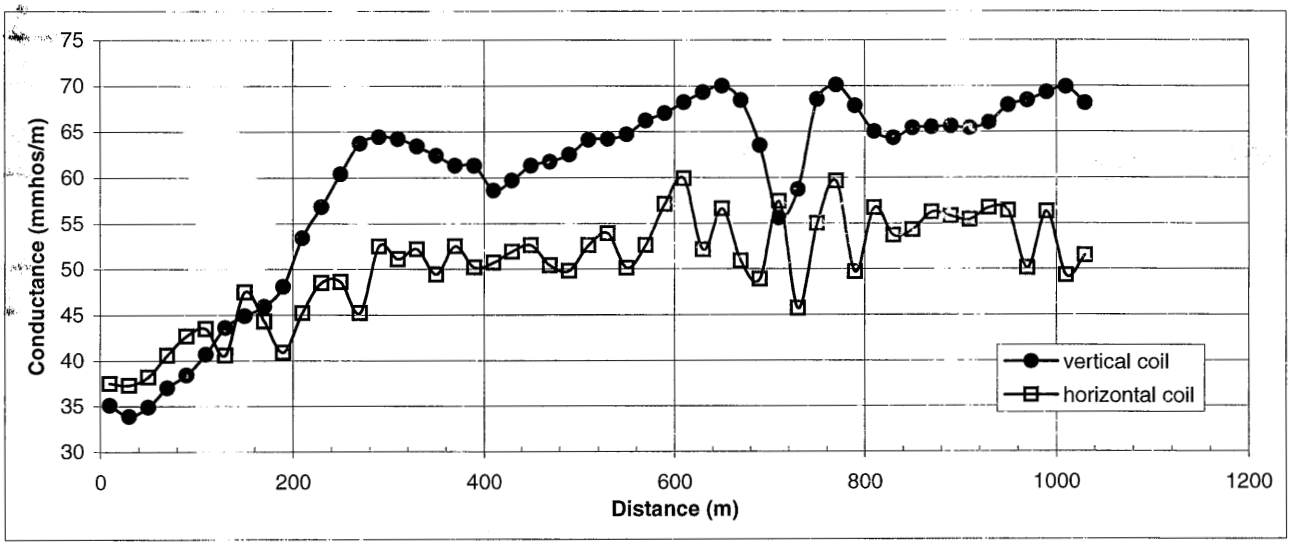
Strike:

position (m)	strike (deg)
0	60
70	45
130	39
270	58
430	49
630	50
770	56
910	51
1000	12

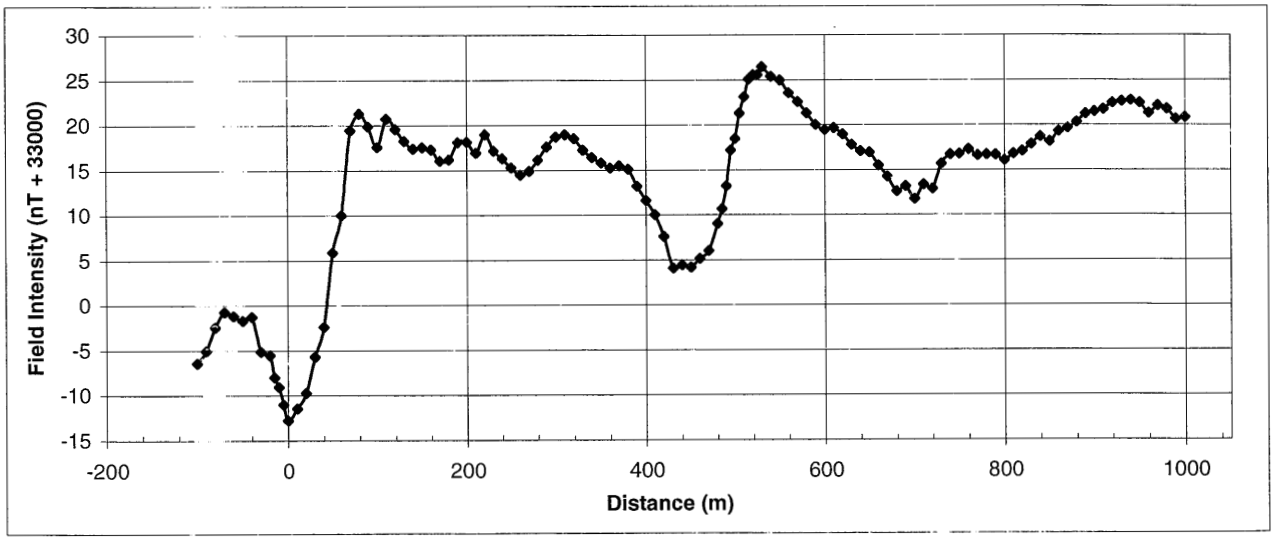
Comments:

position (m)	comments
200	start of rice fields
	hard path most of the way
720	fine/medim grained sand
1000	joins road

OH3 (EM 34):



OH4 (magnetic):



Annex 5: Data for Akiraba Ainu

Akiraba-ainu

AA 1-7

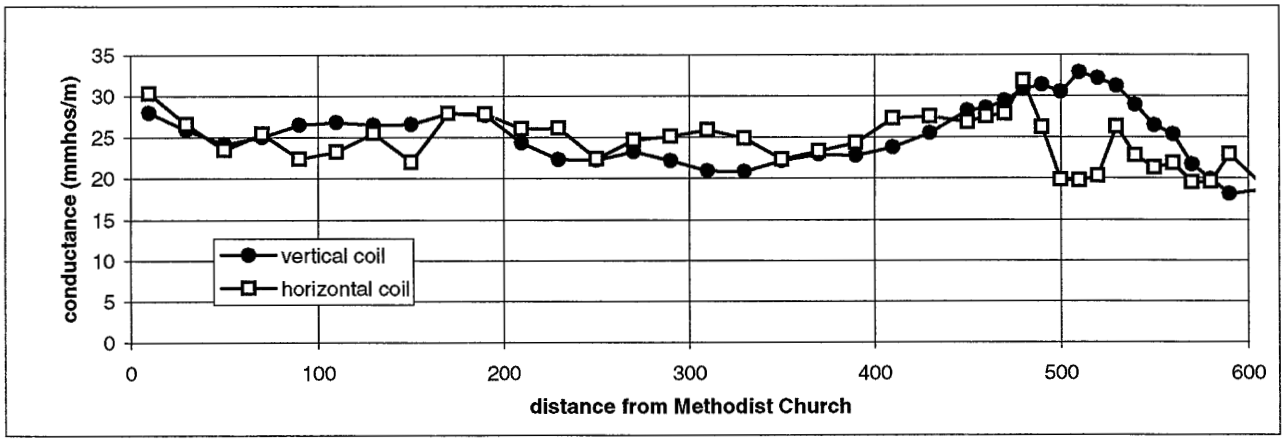
GPS start: 6 degs 52.400
GPS finish 8 degs 21.743
Date and time: 23/01/98 11:30 - 17:00
Survey:

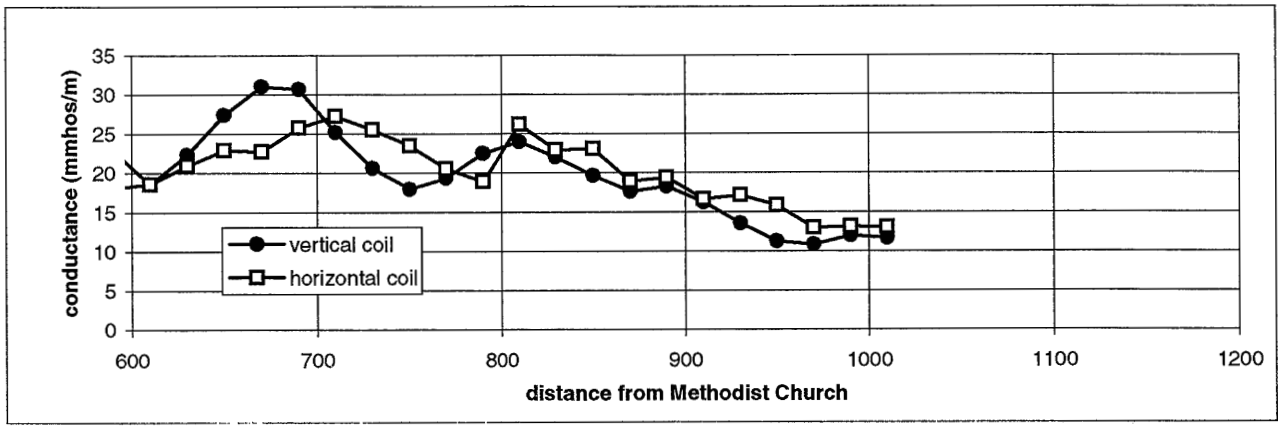
AA 1	from Lucas Tree beside methodist church to Oganari Anyago Em 34 (20 m)
AA 2	from Lucas Tree towards failed wells Em 34 (20 m)
AA 3	from failed wells throught third community to path EM 34 (20 m)
AA 4	from path towards third community EM 34 (20 m)
AA 5	mag equivalent of AA 2
AA 6	mag equivalent of AA 3
AA 7	mag equivalent of AA 4

AA 1:

position (m)	strike (deg)
0	262
60	248
260	234
530	240
760	263

position (m)	comments
0	Lucas Tree
40	small X roads
260	slight down
320	path tp assemblies church
470	path to dugouts
490	small drain base depression
740	1st path to village
830	path to village
860	x roads
970	P school sign board



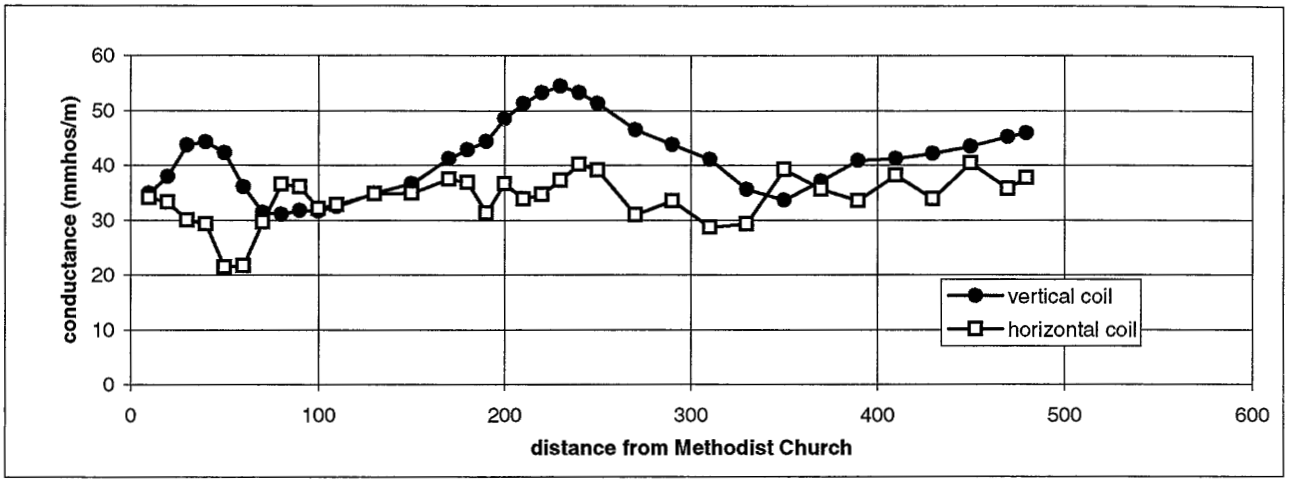


AA 2:

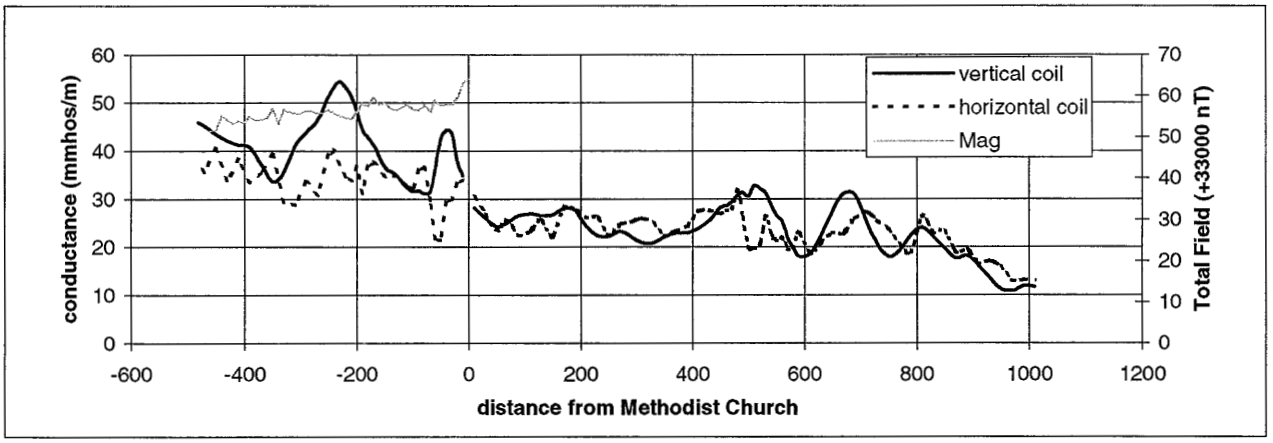
position (m)	strike (deg)
0	78
200	68

position (m)	comments
0	Lucas Tree
360	mango tree
460	path to collapsed wells

AA 2 (20 m)



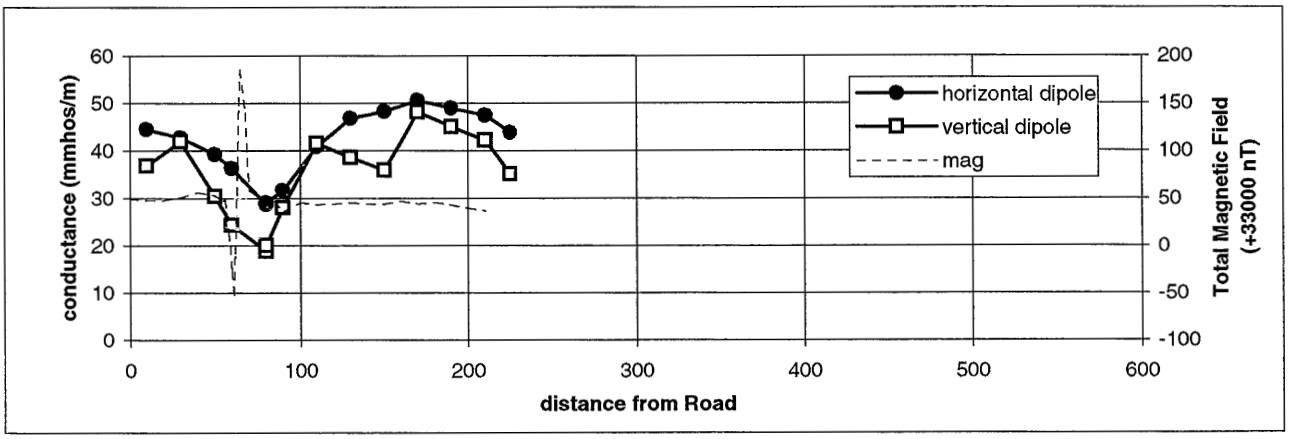
Combined AA 1 and 2



AA 3:

distance	strike
0	330
100	342

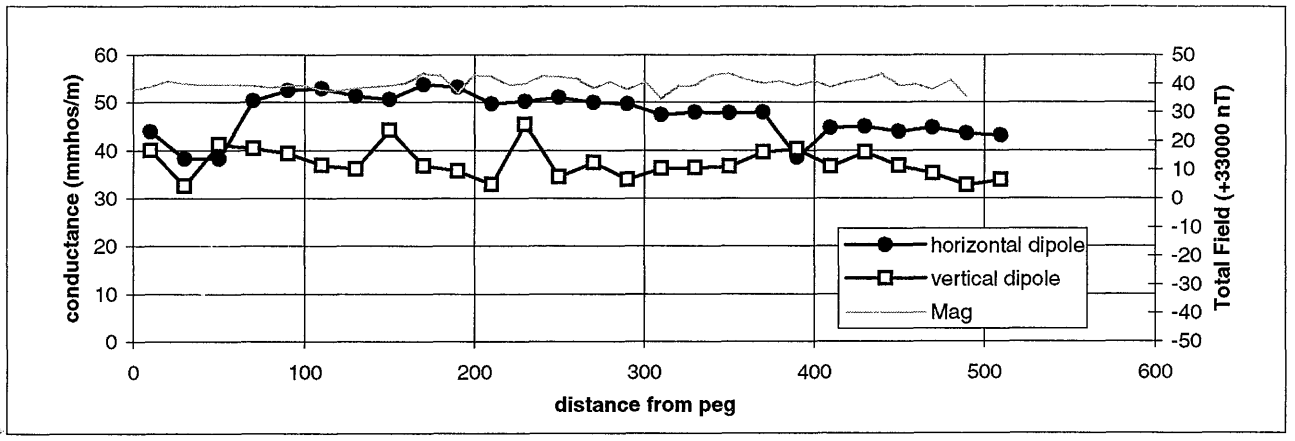
distance	comments
0	road
40	bathroom



AA 4:

position (m)	strike (deg)
0	54
120	65
160	48
340	4
420	6
460	38
500	353

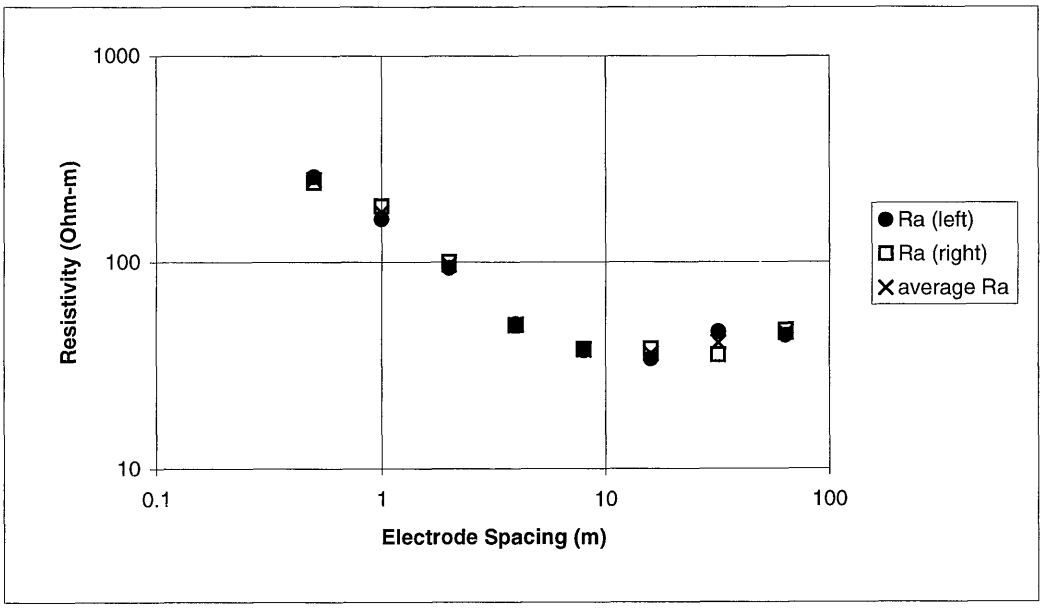
position (m)	comments
0	peg on small path
40	path right
270	wooden drain bottom depression
520	well



Akiraba Ainu AA8

Resistivity Survey 1 6 degs 52.400
Located at Lucas tree by methodist Church
Offset Wenner Left to collapse well
Strike 250 degs
04/02/98

spacing (m)	left	right	Ra (left)	Ra (right)	average Ra
0.5	82.3	77.1	258.422	242.094	250.258
1	25.6	29.6	160.768	185.888	173.328
2	7.46	7.96	93.6976	99.9776	96.8376
4	2	1.969	50.24	49.46128	49.85064
8	0.744	0.756	37.37856	37.98144	37.68
16	0.339	0.379	34.06272	38.08192	36.07232
32	0.229	0.177	46.01984	35.56992	40.79488
64	0.11	0.1168	44.2112	46.94426	45.57773



DATA SET: AKIRABA

CLIENT: WaterAid DATE: Feb, 98
LOCATION: Akiraba Ainu SOUNDING: 1
COUNTY: Oju AZIMUTH: 0
PROJECT: Water and Sanitation EQUIPMENT: BGS128
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

Offset Wenner Configuration

FITTING ERROR: 2.865 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	260.2	0.857	-0.857	0.00329	223.0
2	50.07	3.70	-4.55	0.0739	185.3
3	25.41	8.47	-13.03	0.333	215.4
4	49.77				

ALL PARAMETERS ARE FREE

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

	LAYER	MINIMUM	BEST	MAXIMUM
RHO	1	245.420	260.205	278.482
	2	43.020	50.071	59.114
	3	19.581	25.417	31.529
	4	46.319	49.775	53.227
THICK	1	0.764	0.857	0.946
	2	2.357	3.701	6.096
	3	4.739	8.475	14.320
DEPTH	1	0.764	0.857	0.946
	2	3.120	4.558	7.023
	3	10.086	13.033	18.325

No.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	0.500	250.3	242.0	3.32
2	1.00	173.4	183.3	-5.74

No.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
3	2.00	96.88	93.63	3.35
4	4.00	49.76	50.75	-1.98
5	8.00	37.69	37.20	1.31
6	16.00	34.07	34.52	-1.34
7	32.00	40.80	40.25	1.32
8	64.00	45.43	45.69	-0.573

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	1.00						
P 2	0.00	0.99					
P 3	0.00	-0.01	0.90				
P 4	0.00	0.00	-0.01	1.00			
T 1	0.00	0.00	0.01	0.00	1.00		
T 2	0.00	0.03	0.12	0.01	-0.01	0.83	
T 3	0.00	-0.03	-0.21	-0.03	0.01	0.24	0.54
	P 1	P 2	P 3	P 4	T 1	T 2	T 3