８．　その他の資料・情報

(1)　エチオピア国側負担金額の内容

エチオピア国側負担金額の内容

名称	規格	細別	数量	単位	単価 (Birr)	金額 (Birr)	合　計 (Birr)
通電工事	電線工事	380V, 3phase, 50HZ	400	m	50	20,000	60,000
	変圧器	25KVA	1	基	28,000	28,000	
	計器		1	基	1,000	1,000	
	諸雑費		1	式	11,000	11,000	
フェンス工事	フェンスA	プラットフォーム、公共水栓等	221	箇所	2,000	442,000	772,000
	フェンスB	配水池、機械室等	33	箇所	10,000	330,000	
アクセスロード整備、改修費	土工作業等	住民の協力による	1	式	0	0	0
機材免税措置に係る費用			1	式		1,344,000	1,344,000
銀行手数料		支払い授権書通知及び支払い手数料	1	式	70,000	70,000	70,000
ｿﾌﾄｺﾝﾎﾟｰﾈﾝﾄ予算		人件費、日当、経費等	1	式	425,000	425,000	425,000
合　計							2,671,000

(2)　電気探査結果

2 Geophysical Survey

2.1 General

The electrical resistivity method is most commonly employed in groundwater investigation primarily due to the fact that the electrical resistivity of rocks is heavily affected by porosity, water saturation and water quality rather than by the resistivity of the rock matrix. In most rocks, electric current is conducted electrolytically by the interstial fluid.

In a resistivity survey, a DC or very low frequency current is introduced into the ground via a pair of electrodes, usually labelled as current electrodes. The potential difference is measured between a second pair of electrodes. The current and potential measurements are used to obtain the resistivity of the geological formations. It is from the resistivity values obtained that the prevailing hydrogeological conditions in an area can be inferred. In this regard, geophysical surveys provide indirect information about the subsurface condition to supplement hydrogeological investigations.

The geophysical methods employed in the present study are the Vertical Electrical Sounding (VES) and Horizontal Resistivity Profiling (HRP) methods. These methods are able to furnish the information sought because different geologic materials show significantly different physical properties, the measured property, in this case, being the electrical resistivity of the subsurface.

2.2 Survey Layout

The exact survey points for the geophysical survey at each site has been instructed by the project hydrogeologist. The surveys have been grouped in to two as Level 1 and Level 2 surveys, depending mainly on the depth of investigation, the level of information required, and the planned scheme ,i.e. whether a hand pump or motorized. The Level 1 and Level 2 VES survey consisted of 100m and 200m depth of interest, respectively. Likewise, the Level 1 and Level 2 HRP survey were aimed at 30 m and 40 m depth of investigation.

In the present survey, both the Vertical Electrical Sounding (VES) and Horizontal Resistivity Profiling (HRP) methods were used in combination in fourteen selected target areas for Level 2 investigation, consisting of 5 VES and 8 HRP at each site, with the exception of the Natri site where the volume of work was reduced down to 2 VES and 4 HRP. The number of survey points for each site and the total summary are given in Table 1.

Where the Horizontal Resistivity Profiling method was used, each survey line having 380m length was laid out in a direction nearly perpendicular to the anticipated geological structure. Stations were pegged at 10 m interval along the line, and data recorded for the central 200 m section of the line. At each site, at least three or more parallel lines were surveyed, and the line separation varied between 50m and 100m.The UTM coordinates of each profile were read at three points, i.e. at the beginning ,centre and end points of the line, in **Adindan datum** using hand-held Garmin GPS receivers. The coordinates for each VES point were also recorded at the centre of the spread.

2.3 Instrumentation and Field Procedure

2.3.1 Instrumentation

As two field teams were deployed in the field, two sets of resistivity equipment were in use in the field. At the beginning of the survey, the instruments used were the ABEM Terrameter SAS 4000 and the PASI 16 GL Earth Resistivity meter. Shortly after a number of days, the SAS 4000 was replaced with the OYO McOhm 2332 resistivity meter. A common feature of these resistivity survey equipment is that they are integrated, portable and microprocessor-based outputting the resistance in a digital read out on the screen either in milliohm, ohm or kiloohm.

The PASI 16GL Earth Resistivity Meter is powered by the PASI model P300 Energizer that can deliver current up to 500mA, at a maximum output voltage of 350Volt, whereas the OYO McOhm is powered by a 12v car battery and has maximum current output of 200mA.

Additional pieces of equipment used include:

- Cable sets (for current and potential circuit)
- Stainless steel electrodes
- Connectors and clips, and
- Hammers

2.3.2 Field Procedure

2.3.2.1 VES

The Schlumberger electrode configuration was applied in the present survey, where the maximum half-current electrode spacing (AB/2) used varied between 330 and 500m.

In this type of VES survey electric current is injected into the ground by means of two outer current electrodes, and the resulting potential difference or potential drop is measured by a second pair of potential electrodes placed near the centre of the current electrodes. A series of measurements are taken by progressively increasing the current electrode separation; the potential electrodes are left fixed until the voltage drop or potential difference becomes too small, which occurs as the current electrodes get farther apart. Then the potential electrodes are expanded to a new position and the current electrode separation is increased again. In this field technique, resistivity data is generated by expanding the distance of the electrode spacing between readings. Expanding the electrodes causes an increase in the fraction of the injected current that penetrates below a given depth, and this results a deeper vertical penetration or probing.

The field sounding curve which is a log-log plot of apparent resistivity versus half the current electrode spacing (AB/2) is readily plotted in the field to detect if any erroneous data were measured, and thereby make corrections accordingly.

2.3.2.2 HRP

In the Horizontal Resistivity Profiling (HRP) survey, the Wenner electrode configuration was used, with inter-electrode spacing (a) of 60 m. With this configuration the total number of observations for each line amounted to 21. For each line, the readings started in one end of the line, and all four electrodes were progressively moved sequentially by the station spacing, i.e. 10 m, until the leading electrode reached the other end of the line. In all cases, the instrument and operator were kept stationed at the centre of the line, and only the four electrodes need to move; and the electrodes were connected to the equipment by cable of sufficient length.

2.4 Data Processing and Presentation

2.4.1 VES

The Schlumberger sounding curves collected in the field were smoothed into a single continuous curve before interpretation; and then interpreted using two layer master curves and auxiliary point charts to obtain starting (initial) layer parameters. The starting layer parameters (layer resistivities and thicknesses) were input into the RESIST inverse modelling program (Velpen, 1988) to generate best fit estimates of the layer resistivities and thicknesses. The best fit layer parameters are then examined in light of the local geological information, and updated, if necessary, so as match with the local geology by using the principle of equivalence. The final interpreted layer parameters together with the inferred lithologies are presented both in tabular and graphic form. The figures show the different subsurface layers which could be related to different lithologies, geological structures, variation in intensity of weathering and to other geological processes.

2.4.2 HRP

Data processing begins each day by entering the resistances directly read out from the resistivity equipment into a Microsoft EXCEL worksheet to calculate the apparent resistivity for the electrode configuration used. Besides, the UTM coordinates for each station are interpolated from the three GPS readings obtained in the field at the start, centre and end of each line.

The apparent resistivity values are then gridded and contoured using the Surfer software (Version 8.01) of Golden Software, Inc. A user defined contour interval was used as appropriate for each area. In this way, the Horizontal Resistivity Profiling data are presented in the form of apparent resistivity maps.

3 Results and Interpretation

3.1 West Shewa Zone

3.1.1 Ayeru

At Ayeru, two alternative sites have been investigated (Fig. 2a). The first site, Site I is located in the area of Fecha stream south of the village and the second site, Site II, is about 900 m to the north of Site I.

The Apparent resistivity maps at both the sites (Fig. 2b and 2c) show that the area is generally underlain by low resistivities of less than 30 Ohm-m. At Site I, the map (Fig.2b) indicates that the northern part of the area is characterized by relatively higher resistivities of greater than 20 Ohm-m, whereas the western and eastern parts are characterized by lower resistivities of less than 16 Ohm-m. As such, no definite structural trend is visible on this map.

The second site was selected at an intersection of two lineaments inferred from satellite imagery and Digital Elevation Model (DEM). The HRP lines were laid out in NE-SW direction to detect and exactly locate the position of the fractures on the ground. The apparent resistivity map (Fig. 2c) shows that there is a linear very low resistivity trend in the NW-SE direction occupying mainly the northern and central part of the site, which is clearly delineated by the 12 Ohm-m contour indicating the inferred structure.

At Site I, three VES (VES S08-1 to S08-3) were measured , and at Site II two VES (S08-4 and S08-5) were measured. These soundings (Fig.2d) show that the subsurface is underlain by 5 to 7 resistivity layers. The first 2 to 4 layers have very low resistivities in the range of 4-20 Ohm-m, a total thickness of 18-43m. These low resistivity layers are interpreted as highly weathered and/or fractured rock that are probably water bearing. Below these, a very high resistivity layer of 350-406 Ohm-m is observed having thickness in the order of 40 m, and interpreted as being the response of slightly to moderately weathered/fractured rock. Underlying it, there is another low resistivity layer of 12-20 Ohm-m, with thickness varying between 34 and 54 m, but on average about 42m. This layer is interpreted as a highly weathered and/or fractured rock which could be water bearing. At depth, the bottom layer is characterized by very high resistivities more than 400 Ohm-m, corresponding to moderately to slightly weathered bedrock.

Figure 2a. Location map of VES points and HRP lines, Ayeru.

Figure 2b. Apparent Resistivity Map, Site I, Ayeru.

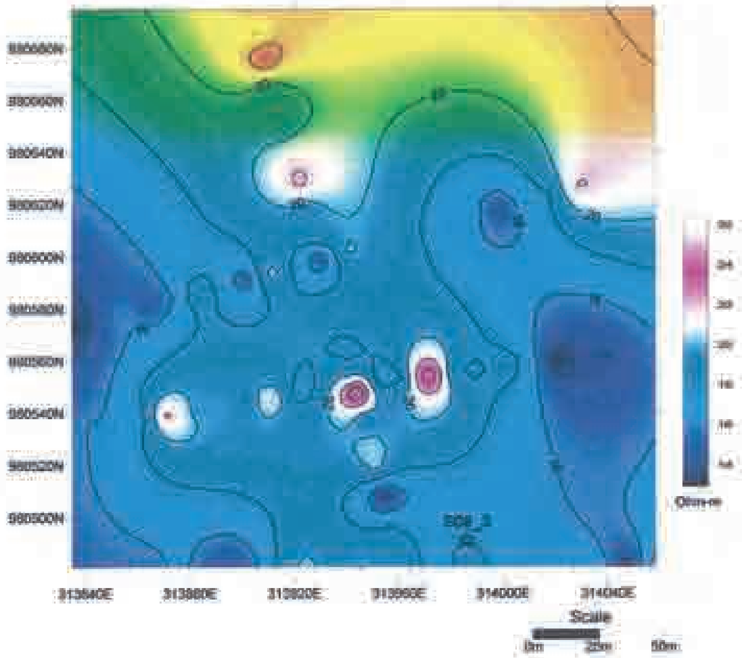


Figure 2c. Apparent Resistivity Map, Site II, Ayeru.

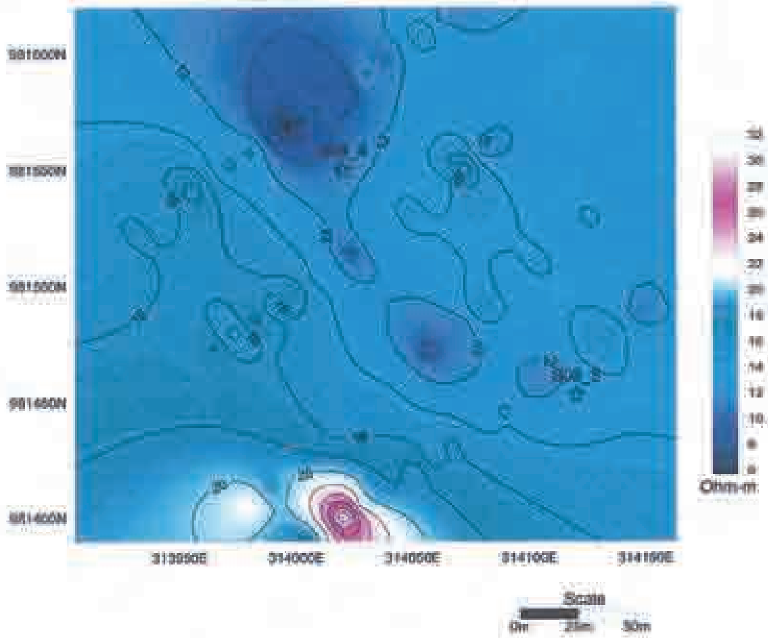
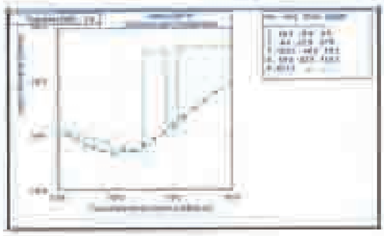


Figure 2d. Interpreted Layer Parameters, Ayeru.

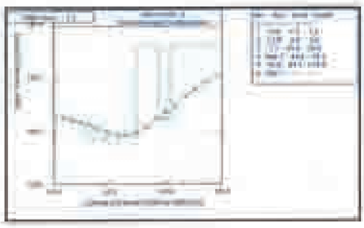
(a) VES- S08-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	14.2	0.9	0.9	Top soil
2	4.8	27	27.9	Highly weathered rock and/or pyroclastics, probably saturated
3	363.7	44.4	72.3	Moderately to slightly fractured rock
4	15.8	42.5	114.8	Highly weathered rock and/or pyroclastics, probably saturated
5	411.7			Moderately to slightly fractured rock



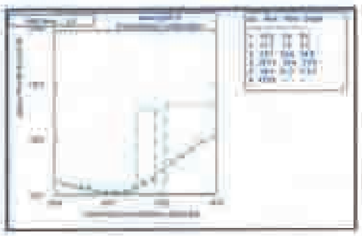
(b) VES-S08-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	19.6	1	1	Top soil
2	12.6	2.8	3.8	Silty clay
3	7.1	25.9	29.7	Highly weathered rock and/or pyroclastics, probably saturated
4	406.2	44.6	74.3	Moderately to slightly fractured rock
5	16.5	42.7	117	Highly weathered rock and/or pyroclastics, probably saturated
6	404.7			Moderately to slightly fractured rock



(c) VES-S08-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	19.5	0.6	0.6	Top soil
2	12.7	2.9	3.5	Silty clay
3	10.7	30.5	34	Highly weathered rock and/or pyroclastics, probably saturated
4	353.2	39.4	73.4	Moderately fractured rock
5	16.6	41.3	114.7	Highly weathered rock and/or pyroclastics, probably saturated
6	410.8			Moderately to slightly fractured rock

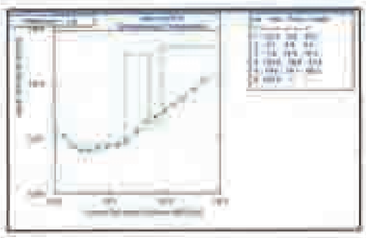


(d) VES-S08-4

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	8.7	1	1	Top soil
2	5.9	6.4	7.4	Clayey layer
3	6.4	8.9	16.3	Highly weathered rock and/or pyroclastics, probably saturated
4	4.4	26.9	43.2	Ditto
5	316.1	32.2	75.4	Moderately fractured rock
6	11.8	54	129.4	Highly weathered rock and/or pyroclastics, probably saturated
7	566.1			Moderately to slightly fractured rock

(e) VES-S08-5

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	22.3	0.6	0.6	Top soil
2	5.1	2.8	3.4	Clayey layer
3	7.8	14.8	18.2	Highly weathered rock and/or pyroclastics, probably saturated
4	339.5	34	52.2	Moderately fractured rock
5	19.6	34.1	86.3	Highly weathered rock and/or pyroclastics, probably saturated
6	452.9			Moderately to slightly fractured rock



3.1.2 Guyu Arere

The geophysical survey at Guyu Arere was conducted on the Bakicha plain to the north of the village. Here also, two alternative sites have been investigated (Fig.3a). The Bakicha plain follows an east-west structure anticipated to form the southern boundary of the plain. Two north-south valleys separated by about 500 m join the plain area. Therefore, the two alternative sites were selected at the junction of the valleys with the plain.

The apparent resistivity map of Site I (Fig. 3b) shows resistivity values below 10 Ohm-m to about 55 Ohm-m. The relatively higher resistivities (25-55 Ohm-m) are found in the central part of the area. The western part of the site is characterized by very low resistivities less than 10 Ohm-m correlated to alluvium and/or highly weathered rocks. Moderate resistivities characterize the eastern part.

In contrast, site II is represented by relatively higher resistivities in the range of 50-600 Ohm-m (Fig. 3c), although the very high resistivities (>350 Ohm-m) are concentrated at a small locality forming a circular feature, probably correlated to dry coarser material. The rest of the area is characterized by low to moderate resistivities .

Of the five VES conducted in the area, three were made at Site I and two at site II. All the soundings show almost similar subsurface resistivity structure (Fig 3d). A total of 6 to 7 resistivity layers have been identified. The first three layers of all soundings, but also including the fourth of VES S17-3, can be considered as either loose material or highly weathered /fractured rock. This low resistivity material, is anticipated to be water bearing, and ranges in thickness between 44 and 53 m at site 1, but diminishes to 15-34 m at Site II; and the maximum thickness of 53 m is found under VES S17-1. Below this material, a high resistivity layer (200-294 Ohm-m) is found having a nearly uniform thickness of 23-29m, and interpreted as moderately to slightly fractured rock. A very low resistivity layer (6-9 Ohm-m) underlying the slightly fractured rock has thickness of 60-80m, and is probably related to highly weathered /fractured rock saturated with water.

Very high resistivities in the range of 400-500 Ohm-m characterize the substratum, which is correlated to slightly weathered rock forming the bottom aquiclude.

Figure 3a. Location map of VES points and HRP lines, Guyu Arere.

Figure 3b. Apparent Resistivity Map, Site I, Guyu Arere.

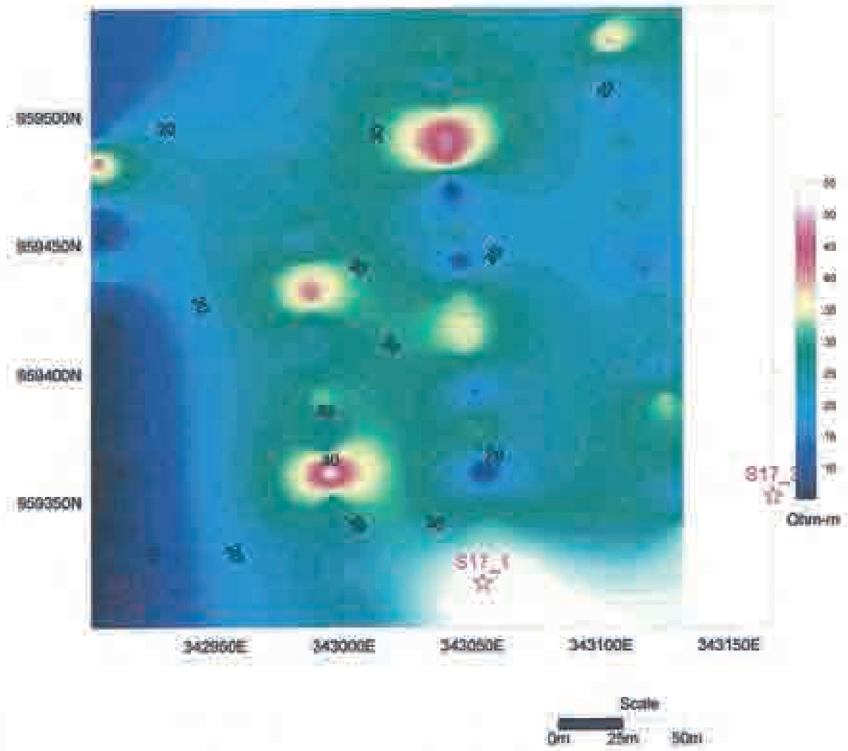


Figure 3c. Apparent Resistivity Map, Site II, Guyu Arere.

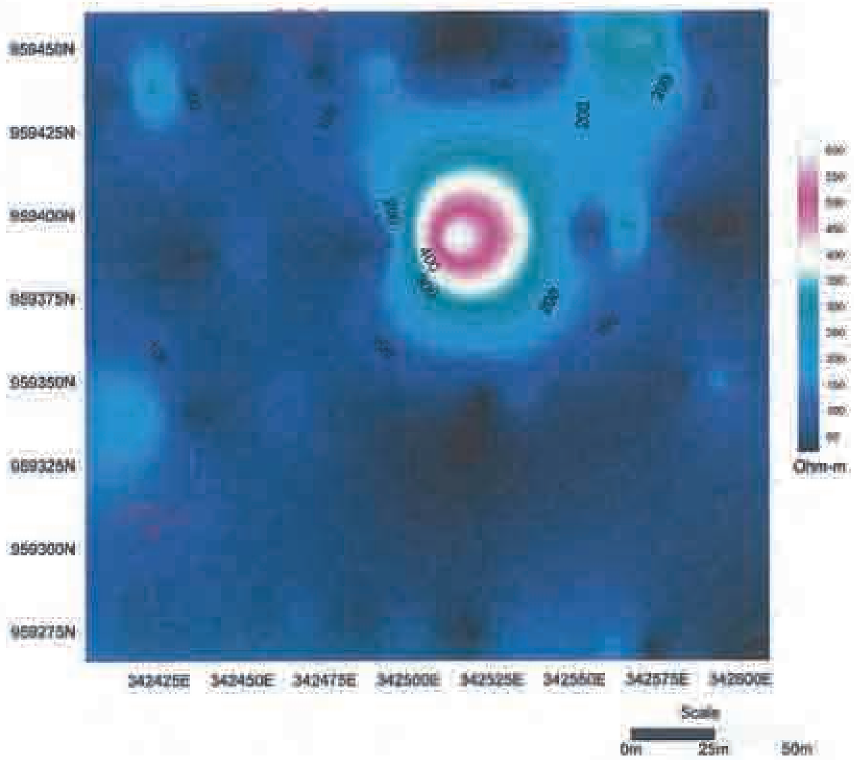


Figure 3d. Interpreted Layer Parameters, Guyu Arere.

(a) VES- S17-1

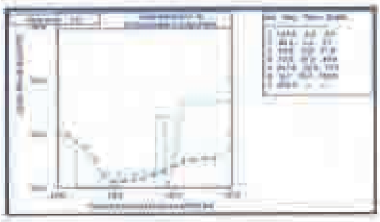
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	1038	0.9	0.9	Top soil
2	88.9	1.4	2.3	Gravelly Clay
3	20.4	50.7	53	Highly weathered rock and/or pyroclastics, probably saturated
4	201.8	23.1	76.1	Moderately fractured rock
5	6.9	80.9	157	Highly weathered rock and/or pyroclastics, probably saturated
6	402			Moderately to slightly fractured rock

(b) VES-S17-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	279.4	0.7	0.7	Top soil
2	79.2	1.1	1.8	Gravelly Clay
3	30.7	42.8	44.6	Highly weathered rock and/or pyroclastics, probably saturated
4	294	26.9	71.5	Moderately fractured rock
5	8	66.2	137.7	Highly weathered rock and/or pyroclastics, probably saturated
6	466			Moderately to slightly fractured rock

(c) VES-S17-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	137	0.8	0.8	Top soil
2	48.2	1.3	2.1	Gravelly Clay
3	10.5	8.9	11	Silty Clay
4	17.9	37.6	48.6	Highly weathered rock and/or pyroclastics, probably saturated
5	217.6	22.9	71.5	Moderately fractured rock
6	6.1	79.1	150.6	Highly weathered rock and/or pyroclastics, probably saturated
7	395.3			Moderately to slightly fractured rock

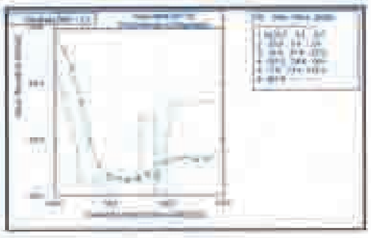


(d) VES-S17-4

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	588.5	0.9	0.9	Top soil
2	69.3	1.2	2.1	Gravelly Clay
3	15.9	12.8	14.9	Highly weathered rock and/or pyroclastics, probably saturated
4	285	29	43.9	Moderately fractured rock
5	9.6	58.6	102.5	Highly weathered rock and/or pyroclastics, probably saturated
6	477.6			Moderately to slightly fractured rock

(e) VES-S17-5

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	9535.7	0.7	0.7	Top soil
2	73.9	1.8	2.5	Gravelly Clay
3	18.5	31	33.5	Highly weathered rock and/or pyroclastics, probably saturated
4	251.5	26.6	60.1	Moderately fractured rock
5	7.6	74.4	134.5	Highly weathered rock and/or pyroclastics, probably saturated
6	461.8			Moderately to slightly fractured rock



3.1.3 Galesa

The Galesa site is situated on a flat swampy ground about 800m southwest of the village, which is close to the watershed between the Abay and Awash rivers. Both the VES and HRP survey were conducted on this plain (Fig. 4a).

The apparent resistivity map (Fig. 4b) shows two contrasting resistivity zones. The 40 Ohm-m contour clearly demarcates this two zones. The low resistivity zone of less than 40 Ohm-m occupying a wider area particulary to the west show areas of thick weathering with possible decomposition into clay at places, whereas the high resistivity zone (40-300 Ohm-m) shows areas of relatively moderate to slight weathering. Such high resistivity zones occur in the northeast of the site, and at an isolated location towards the centre in the south.

The VES points are distributed even outside of the area covered by the HRP. One VES (S13-3) was conducted near a borehole drilled recently by a Korean NGO. But, as no information was found, except that it is 55m deep and flowing (artesian), no correlation could be made. The VES data (Fig. 4c) indicate that the highly to moderately weathered basalt in the shallowest part of the subsurface is represented by resistivity of 6-100 Ohm-m, and is generally up to 70 m thick.

Underlying the highly to moderately weathered basalt, very high resistivities in the range of 196-270 Ohm-m are observed, having thickness of 22-28m, and interpreted as moderately to slightly weathered rock. At VES S13-2, the lowering of the apparent resistivity at large electrode separation, AB/2, of 150m point out the presence of low resistivity material at depth below the slightly weathered rock. This low resistivity layer is in the range of 6-30 Ohm-m, with its thckness varying between 46-60m, and was interpreted as a highly weatherd and/or fractured basalt which is potentially water bearing.

The bottom substratum is represented by very high resistivity of 200-266 Ohm-m indicating its slightly weathered nature.

Figure 4a. Location map of VES points and HRP lines, Galesa.

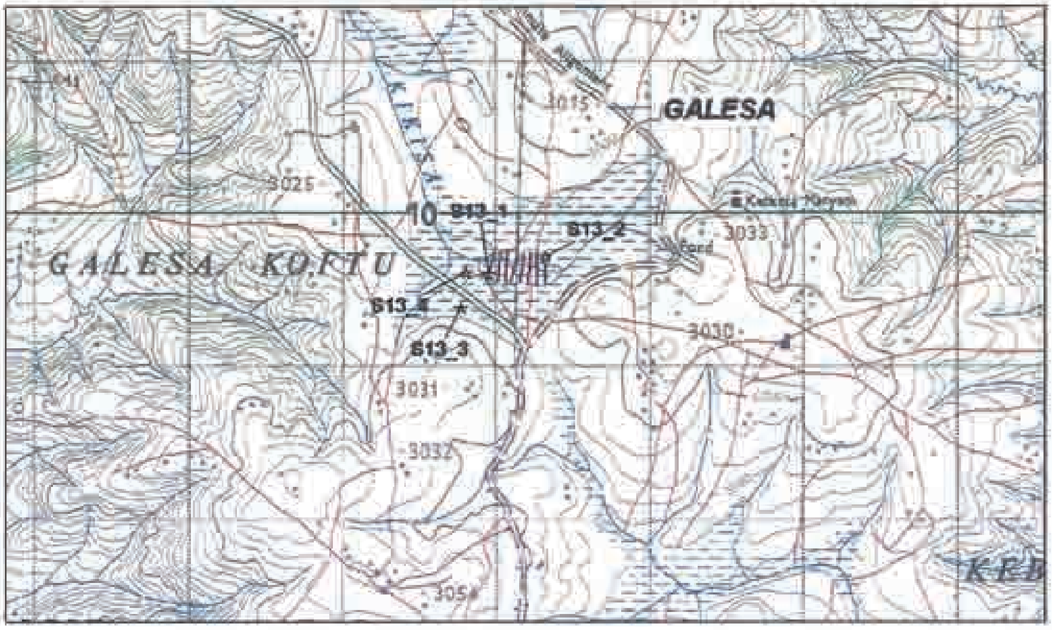


Figure 4b. Apparent Resistivity Map, Galesa.

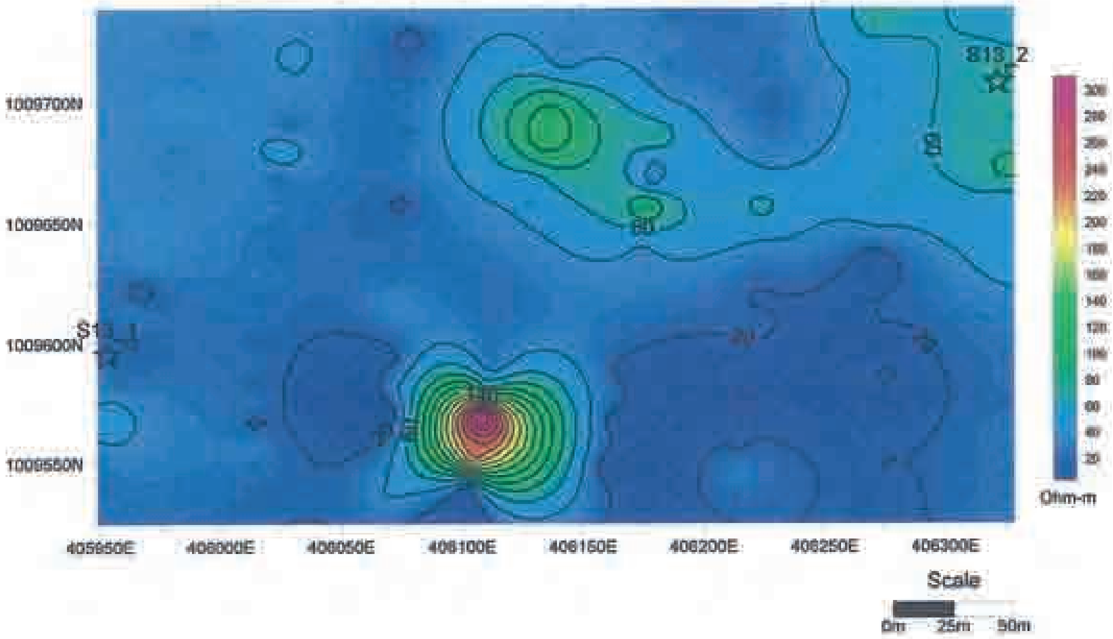
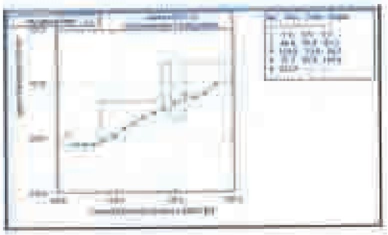


Figure 4c. Interpreted Layer Parameters, Galesa.

VES S13-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	7.4	5.5	5.5	Clay
2	44.8	55.8	61.3	Highly weathered Basalt
3	220.5	23.5	84.8	Moderately to Slightly weathered Basalt
4	21.7	60.8	145.6	Highly weathered and/or fractured Basalt-probably water bearing
5	233.7			Moderately to Slightly weathered Basalt



VES S13-2

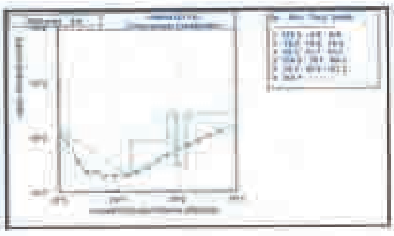
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	149.5	0.6	0.6	Topsoil
2	11.3	8.1	8.7	Clay
3	101.9	53.3	62	Highly to Moderately weathered Basalt
4	239.7	25.6	87.6	Moderately to Slightly weathered Basalt
5	9.9	49.5	137.1	Highly weathered and/or fractured Basalt-probably water bearing
6	199.6			Moderately to Slightly weathered Basalt

VES S13-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	98.3	1.3	1.3	Topsoil
2	6.7	21.7	23	Clay
3	75.7	47.1	70.1	Highly to Moderately weathered Basalt
4	196.1	21.4	91.5	Moderately to Slightly weathered Basalt
5	6.9	50.3	141.8	Highly weathered and/or fractured Basalt-probably water bearing
6	200.5			Moderately to Slightly weathered Basalt

VES S13-4

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	221.5	0.6	0.6	Topsoil
2	18.9	15.9	16.5	Highly weathered, fractured Basalt
3	86.8	51.7	68.2	Highly to Moderately weathered Basalt
4	270.6	28.1	96.3	Moderately to Slightly weathered Basalt
5	30.7	46	142.3	Highly weathered and/or fractured Basalt-probably water bearing
6	265.7			Moderately to Slightly weathered Basalt



3.1.4 Goremti

The Goremti site is located south of Ambo, in an area of high drainage density with parallel pattern towards the NNW, probably reflecting structural control of the drainage. At Goremti, two alternative sites have been selected for geophysical investigation separated by about 900m (Fig. 5a). The first site is located at the point where the NNW flowing Bolo river makes a sharp turn to the NNE.

The apparent resistivity map at Site I (Fig.5b) reveals a linear high resistivity zone of > 80 Ohm-m trending almost NNW in the western part of the site. In general, the western part of the map is underlain by high resistivities probably indicating the presence of relatively fresh rocks at relatively shallow depth. In contrast, the central and eastern part are underlain by low resistivities less than 40 Ohm-m showing loose sediments and/or pyroclastics or highly weathered rocks. In particular, the low resistivity zone bounded by the 30 Ohm-m contour and trending in the NNW direction may be interesting.

The apparent resistivity map at the second site, Site II (Fig.5c) also depicts two contrasting zones of resistivity, i.e. a high resistivity zone (60-120 Ohm-m) trending in the NW-SE direction and occupying the central and southeast part, and a low resistivity zone (10-40 Ohm-m) in the NE and SW corner of the site. These two zones are interpreted as slightly weathered and highly weathered/fractured rocks, respectively.

The VES results (Fig. 5d) also indicate variable response in the shallowest part of the subsurface. In general the top 34-46 m of the subsurface is underlain by relatively low resistivity layers of 5 to 38 Ohm-m correlated to loose sediments and/or pyroclastics. However, within the low resistivity layers, interbeds of high resistivity (126-295 Ohm-m) occur at VES S16-1, S16-2 and S16-4, their thickness varying between 8 to 12m, and interpreted as either slightly weathered rock or dry pyroclastics.

High resistivity in the range of 142-274 Ohm-m are found below the low resistivity layers, with thickness in the range of 29-54m, probably attributed to moderately fractured rocks. A depth, the presence of low resistivity layers of 5-10 Oh-m is evident from VES data. These low resistivity layers are found below the depth range of 70-90m, and may constitute highly weathered water bearing rock . The thickness of this interpreted water bearing layer is also variable being in the range of 38-78m.

Figure 5a. Location map of VES points and HRP lines, Goremti.

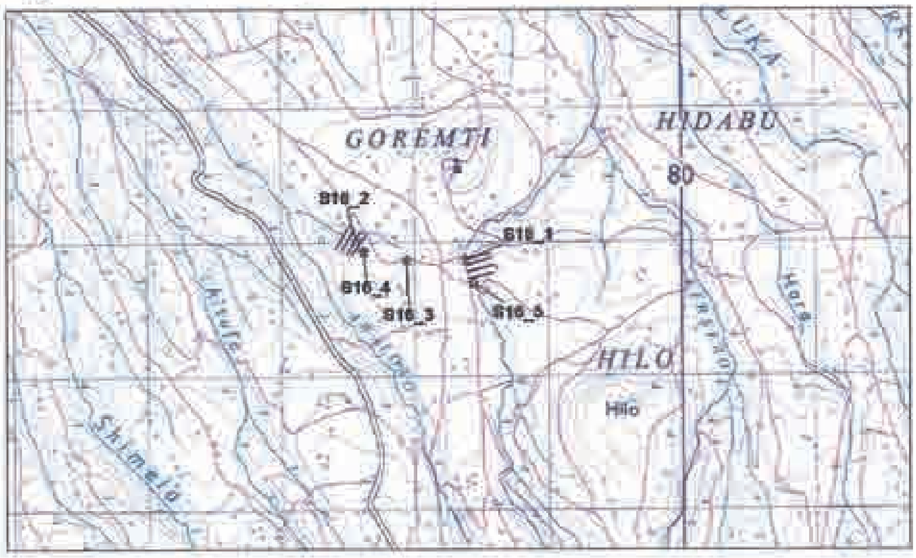


Figure 5b. Apparent Resistivity Map, Site I, Goremti.

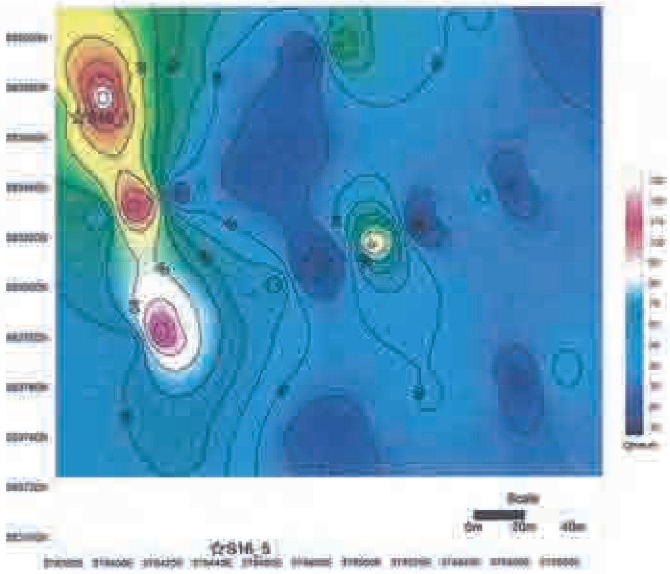


Figure 5c. Apparent Resistivity Map, Site II, Goremti.

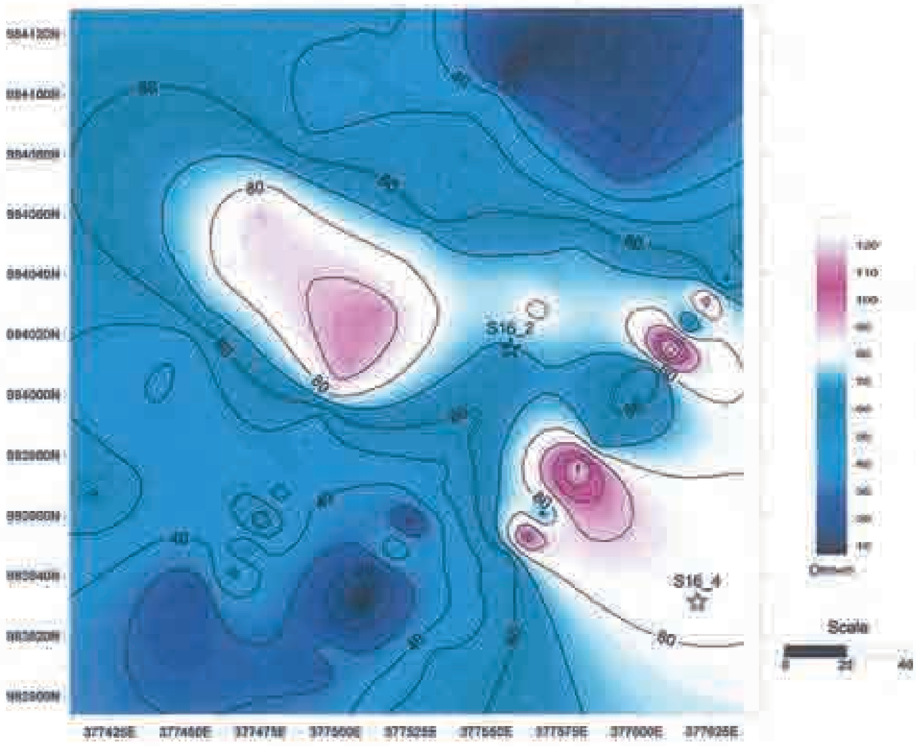
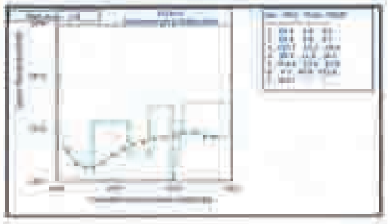


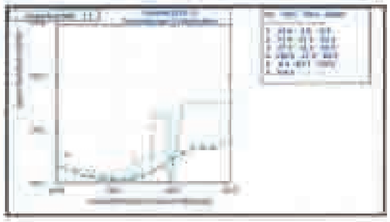
Figure 5d. Interpreted Layer Parameters, Goremti.

(a) VES- S16-1				
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	76.6	1.9	1.9	Top soil
2	295.1	8.5	10.4	Moderately to slightly fractured rock
3	26.5	26.4	36.8	Loose sediment and/or pyroclastics, probably saturated
4	217.5	44.9	81.7	Moderately fractured rock
5	10.7	37.8	119.5	Highly weathered rock and/or pyroclastics, probably saturated
6	335.1			Moderately to slightly fractured rock

(b) VES-S16-2				
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	97.4	0.5	0.5	Top soil
2	14.6	3.6	4.1	Silty clay
3	133.1	12.2	16.3	pyroclastics
4	30.4	21.9	38.2	Loose sediment and/or pyroclastics, probably saturated
5	274.4	53.9	92.1	Moderately fractured rock
6	7.1	60.6	152.7	Highly weathered rock and/or pyroclastics, probably saturated
7	303.7			Moderately to slightly fractured rock



(c) VES-S16-3				
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	22.6	0.9	0.9	Top soil
2	11	21.3	22.2	Silty clay
3	27.6	23.3	45.5	Loose sediment and/or pyroclastics, probably saturated
4	196.8	41	86.5	Moderately fractured rock
5	6.4	64.1	150.6	Highly weathered rock and/or pyroclastics, probably saturated
6	306.8			Moderately to slightly fractured rock



(d) VES-S16-4				
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	20.6	0.7	0.7	Top soil
2	5.6	4.2	4.9	clay
3	126.4	12.2	17.1	pyroclastics
4	27.3	23.1	40.2	Loose sediment and/or pyroclastics, probably saturated
5	142	28.9	69.1	Moderately fractured rock
6	5.2	78.7	147.8	Highly weathered rock and/or pyroclastics, probably saturated
7	290.8			Moderately to slightly fractured rock

(e) VES-S16-5				
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	107.3	1.1	1.1	Top soil
2	27.7	13.2	14.3	Sandy clay
3	38.5	19.7	34	Loose sediment and/or pyroclastics, probably saturated
4	245.1	48.7	82.7	Moderately fractured rock
5	9.1	45.3	128	Highly weathered rock and/or pyroclastics, probably saturated
6	320.2			Moderately to slightly fractured rock

3.1.5 Gosu Qora

A total of three VES were measured in Gosu Qora area (Fig 6a). The results of the soundings show that the subsurface is constituted by five resistivity layers (Fig 6b). The first two layers (three in the case of VES S24-1) are characterized by low resistivities of 4-37 Ohm-m, which together makeup the top 2-27m and are interpreted as silty/clayey soil and highly weathered pyroclastics. The largest thickness (27m) occurs at VES S24-1. These low resistivity layers are underlain by moderately high resistivities of 160-176 Ohm-m, having thickness of 25-31m and probably corresponding to moderately weathered rock or pyroclastics. The high resistivity layer pinches out towards the east and is totally absent under VES S24-1.

The fourth layer is represented by very low resistivity of 5 to 13 Ohm-m, probably indicating the presence of water bearing highly weathered rock and/or pyroclastics, the thickness of which vary between 20-50m; the thickest section is found below VES S24-1. The bottom layer is characterized by moderate to high resistivities (75-243 Ohm-m), which may attributed to moderately to slightly fractured rock.

Figure 6a. Location map of VES points, Gosu Qora.

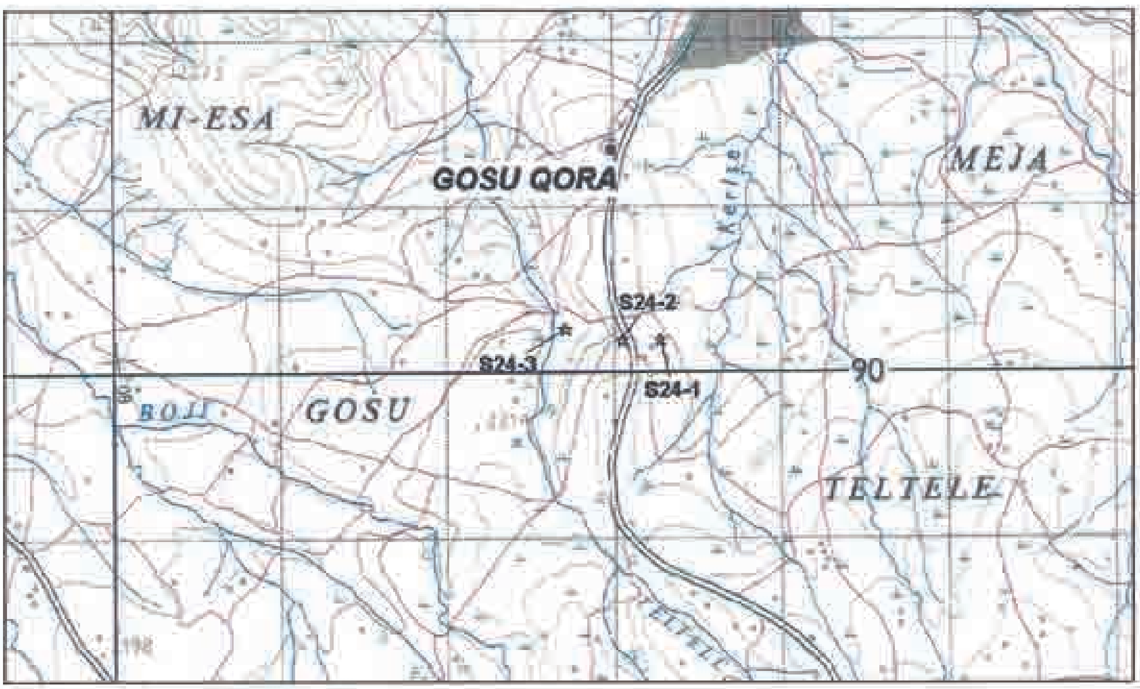
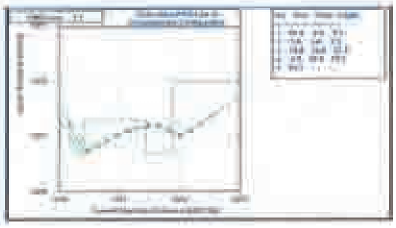


Figure 6b. Interpreted Layer Parameters, Gosu Qora.

(a) VES- S24-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	66	0.5	0.5	Top soil
2	3.9	2	2.5	Clayey soil
3	18.8	24.9	27.4	Weathered pyroclastics
4	4.9	49.4	76.8	Highly weathered rock and/or pyroclastics, probably saturated
5	95.7			Moderately fractured rock



(b) VES-S24-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	22.3	1	1	Top soil
2	36.9	16.8	17.8	Weathered pyroclastics
3	160.8	25.4	43.2	Moderately weathered rock or pyroclastics
4	7.3	38.5	81.7	Highly weathered rock and/or pyroclastics, probably saturated
5	75.4			Moderately fractured rock

(c) VES-S24-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	34	0.8	0.8	Top soil
2	16.2	5.2	6	Silty soil
3	175.9	31.4	37.4	Moderately weathered rock or pyroclastics
4	13.1	19.8	57.2	Highly weathered rock and/or pyroclastics, probably saturated
5	242.7			Moderately to slightly fractured rock

3.1.6 Kolu Gelan

At Kolu Gelan, both VES and HRP surveys were undertaken (Fig 7a). The VES survey encompasses a large area as the soundings were nearly a kilometer apart. But the HRP survey was completed in a limited area of VES S12-3. The apparent resistivity map (Fig 7b) shows, that the northwest corner of the area is underlain by very high resistivities of greater than 100-700 Ohm-m probably corresponding to slightly weathered rock, whereas the central and southern part are underlain by low resistivities of less than 50 Ohm-m attributed to weathered/fractured rocks.

The low resistivity zone has a nearly elliptical shape. VES S12-3 is located just at the southwestern border of this low resistivity zone. Although the sounding shows a four layer earth (Fig 7c) the top three layers are characterized by low resistivities of which the third layer with the lowest resistivity of 11 Ohm-m has about 55m thickness, and is interpreted as a water bearing layer. Totally, the low resistivity layers are about 73m thick. The other soundings show similar results, with the overall thickness of the highly weathered rock being in the range of 50-60m.

Figure 7a. Location map of VES points and HRP lines, Kolu Gelan.

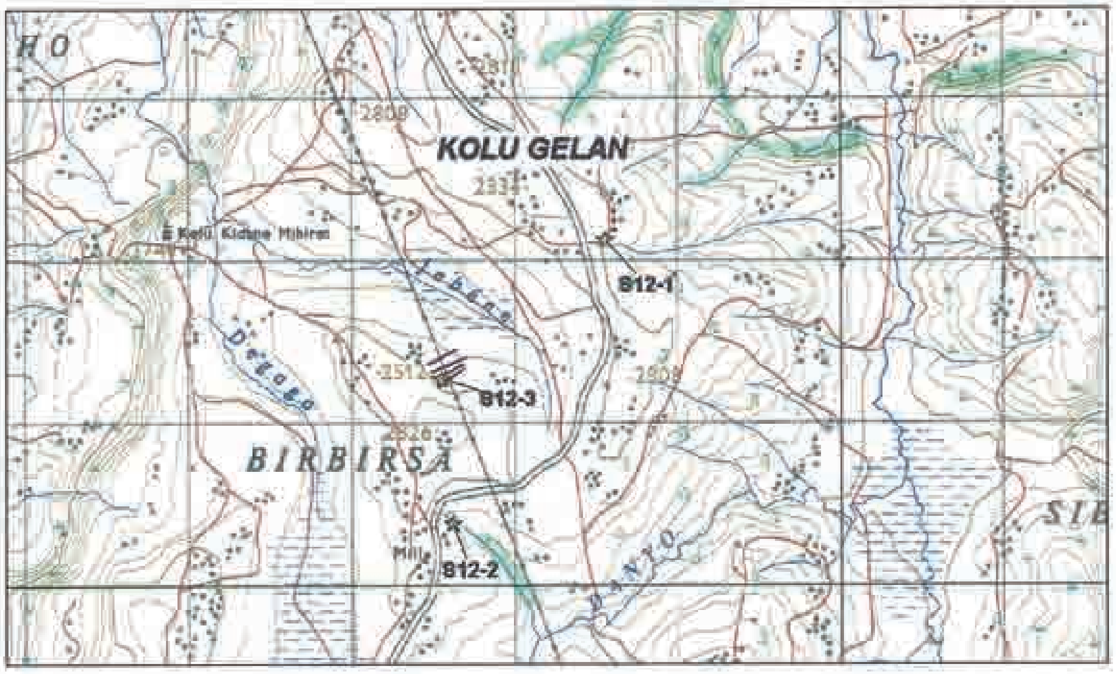


Figure 7b. Apparent Resistivity Map, Kolu Gelan.

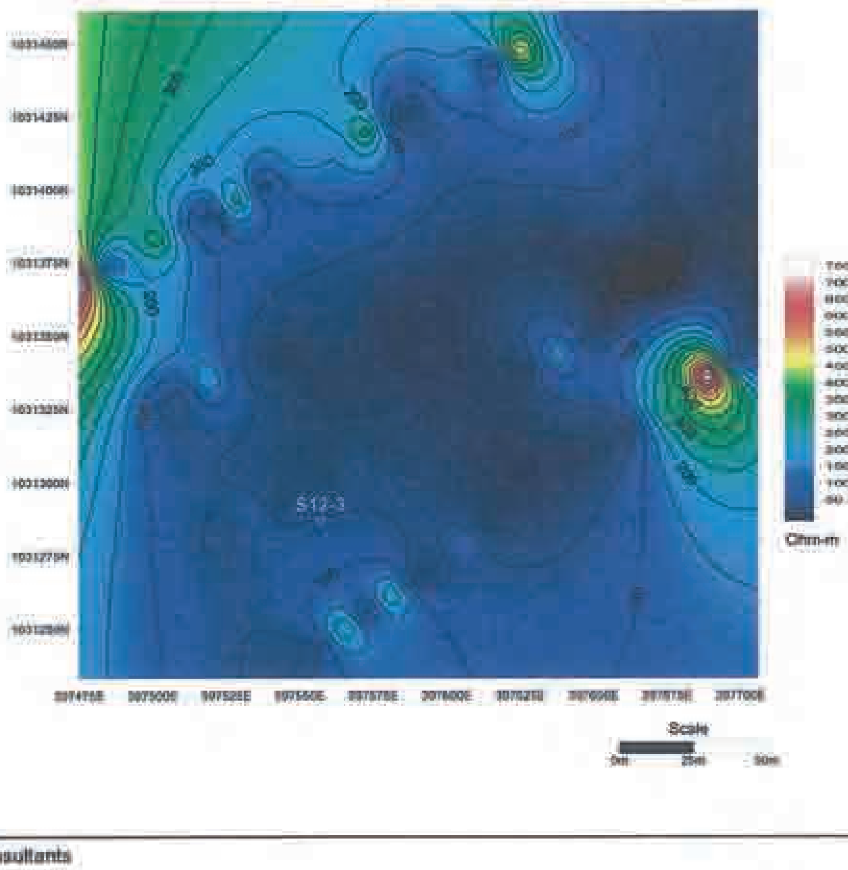
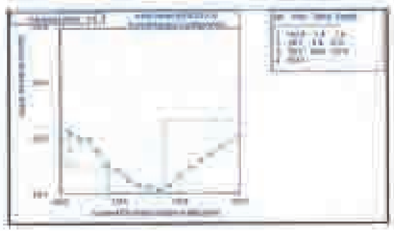


Figure 7c. Interpreted Layer Parameters, Kolu Gelan

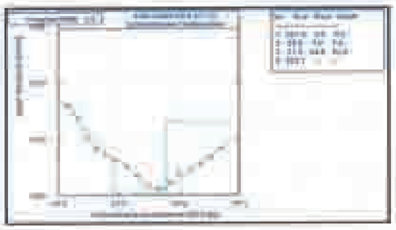
(a) VES S12-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	143.8	1.4	1.4	Top Soil
2	29.1	4.9	6.3	Highly weathered rock, clayey material
3	10.2	46.6	52.9	Highly weathered, fractured rock-probably water
4	193.5			Moderately weathered rock



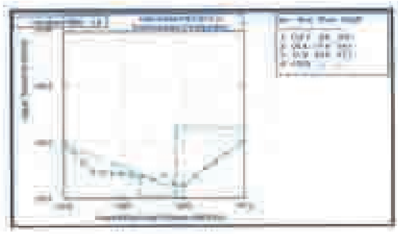
(b) VES S12-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	641.8	0.8	0.8	Top Soil
2	50.8	7	7.8	Highly weathered rock, Gravelly clay material
3	11	54.6	62.4	Highly weathered, fractured rock-probably water
4	203.1			Moderately weathered rock



(c) VES S12-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	114.7	0.6	0.6	Top Soil
2	26.4	17.4	18	Highly weathered rock, clayey material
3	11	54.6	72.6	Highly weathered, fractured rock-probably water
4	196.8			Moderately weathered rock



3.2 Horo Guduru Zone

3.2.1 Dedu

The Dedu site is located adjacent to the existing well currently supplying the town (Fig 8a). The depth of the borehole is said to be about 50m. In the area, the local geology is completely hidden from view by thick soil. From the regional geology, however basalt is expected to underlie the surface which would be followed by Adigrat sandstone.

The apparent resistivity map at the site (Fig 8b) shows an interesting resistivity response. The marginal areas to the northwest and southeast are characterized by high resistivity values more than 160-380 Ohm-m, whereas the central part is represented by relatively low resistivity of less than 100 Ohm-m trending in the NE-SW direction and having width of more than 100m. The former zone may be interpreted as the response of slightly weathered to massive rock at relatively shallow depth whereas the latter zone may be attributed to highly weathered rocks.

The VES points were fairly distributed over the area covered by the HRP survey. The first sounding, VES H 15-1 was measured near the existing Dedu well, which is about 50m deep. The interpretation of the sounding first showed no water bearing horizon within the depth of the borehole as the low resistivity interpreted to be water bearing was detected well below 90m. Although no borehole data was available, it was assumed based on the regional geological knowledge, that the borehole could be tapping water bearing horizons at the basalt-sand stone contact situated above the 50m depth of the borehole. Forward modeling incorporating the above assumption led to the interpretation result for VES H15-1 presented in Fig 8c , which show a low resistivity layer of 45 Ohm-m, and about 15m, thickness appearing in the middle of two high resistivity layers, the upper being the overlying basalt and the lower being the underlying sandstone layer. Such interpretation was applied to the rest of the soundings (i.e. VES H15-2 and H15-3). However, at VES H15-4 and H15-5, the sharply rising branches of the curves do not fit the model. Rather these two soundings were interpreted as representing only a thin cover of clayey material of 5 to 7m thickness underlain by a very massive basalt characterized by high resistivities in excess of 2700 Ohm-m.

The irony is that these two soundings (i.e. H15-4 and H15-5) lie at the center of the low resistivity zone mapped by the HRP survey. The first three soundings show a well defined descending resistivity curve as their last branch/segment. This descending part was modelled as the bottom resistivity layer which was characterized by resistivities of 17-37 Ohm-m. The depth to the top of these low resistivity layers varied between 81 and 98m, and they were interpreted as highly weathered and/or fractured water bearing sandstone. It was observed that the resistivity of the top layers has a profound effect on the apparent resistivity at the intermediate parts of the VES curve. That was misleading because in effect the HRP map did not show what it was supposed to.

Figure 8a. Location map of VES points and HRP lines, Dedu.

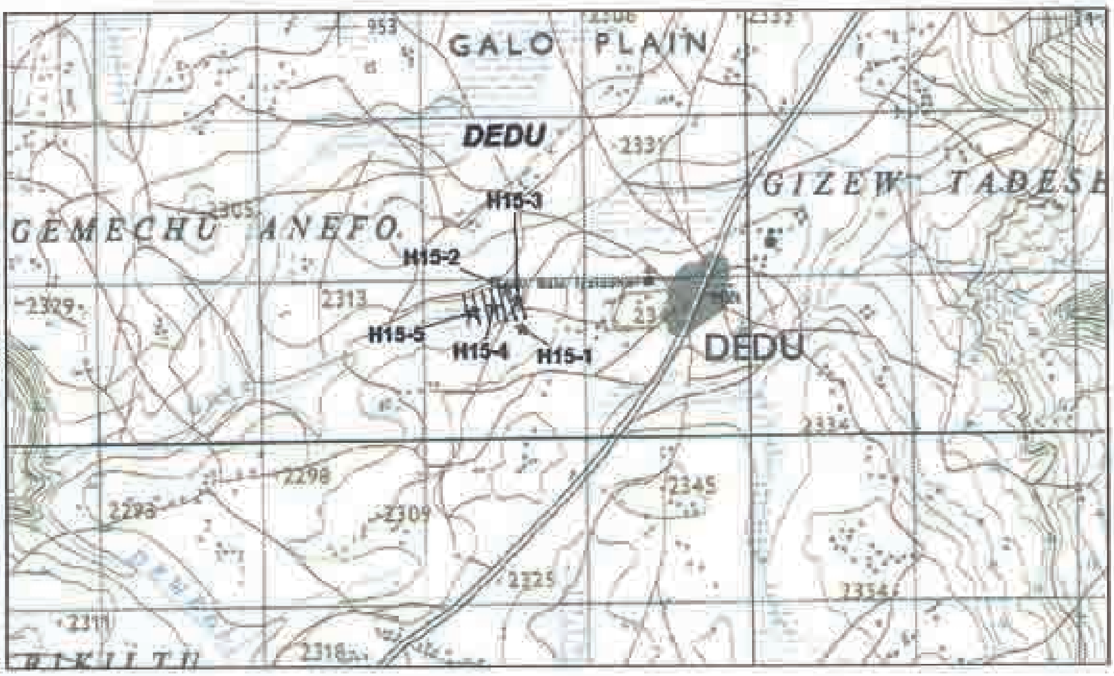


Figure 8b. Apparent Resistivity Map, Dedu.

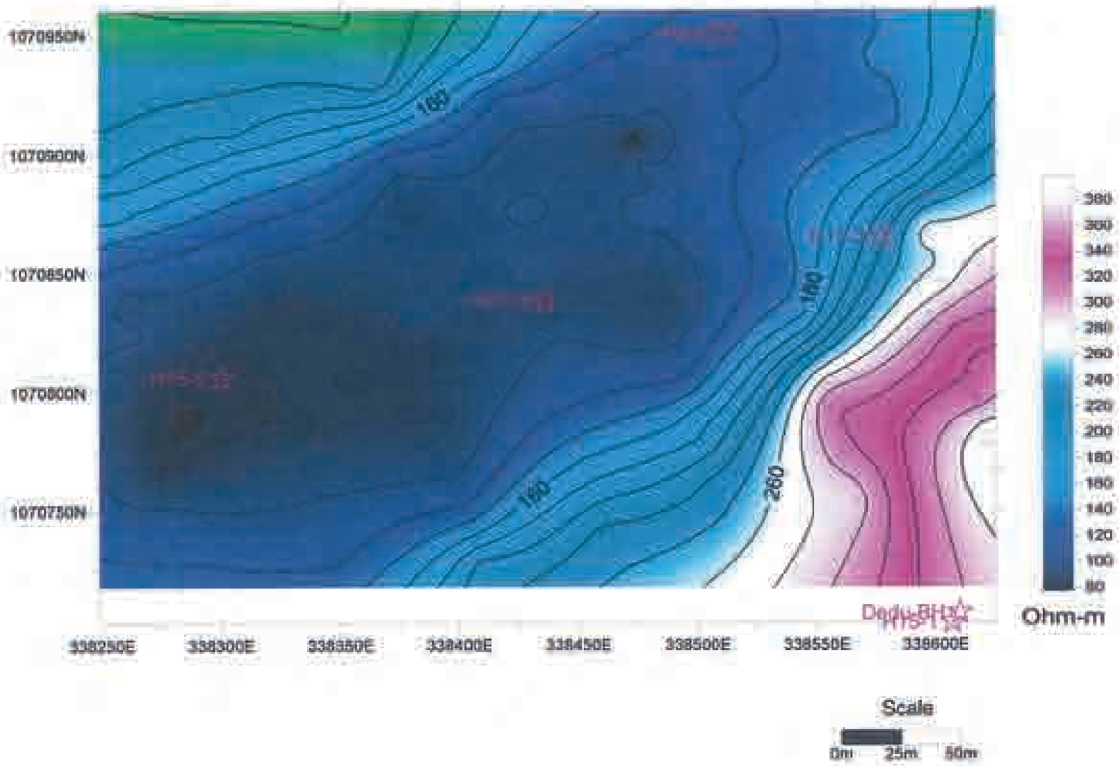
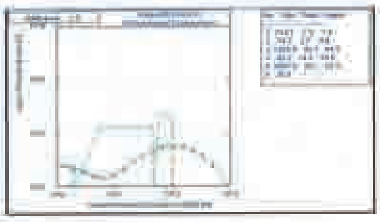


Figure 8c. Interpreted Layer Parameters, Dedu.

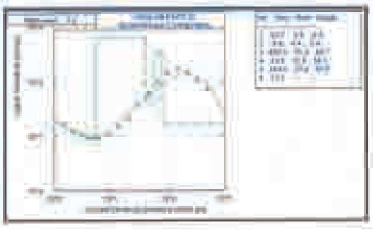
(a) VES-III5-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	243.1	1.9	1.9	Top Soil
2	74.2	3.7	5.6	Clay
3	1259.4	39.3	44.9	Fresh Basalt
4	45.3	14.8	59.7	Highly weathered fractured Basalt and/or Sandstone-probably water bearing
	2087.9	38.1	97.8	Massive Sandstone
5	36.7			Highly weathered and/or fractured Sandstone-probably water bearing



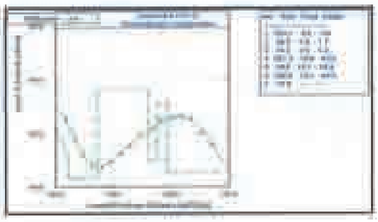
(b) VES-III5-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	20.7	0.9	0.9	Topsoil
2	6.8	4.4	5.3	Clay
3	652.5	35.3	40.6	Slightly weathered Basalt
4	41.2	15.4	56	Highly weathered fractured Basalt and/or Sandstone probably water bearing
5	343.4	25.4	81.4	Moderately fractured Sandstone
6	17.2			Highly weathered and/or fractured Sandstone-probably water bearing



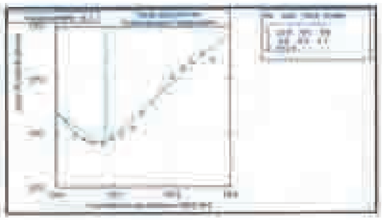
(c) VES-III5-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	510.7	0.6	0.6	Topsoil
2	35.5	1	1.6	Clay
3	14.2	3.6	5.2	Highly weathered decomposed Basalt
4	652.3	34.8	40	Massive Basalt
5	29.8	15.7	55.7	Highly weathered fractured Basalt and/or Sandstone probably water bearing
6	369.6	29.1	84.8	Moderately fractured Sandstone
7	18.8			Highly weathered and/or fractured Sandstone-probably water bearing



(d) VES-III5-4

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	33.8	0.6	0.6	Topsoil
2	5.6	6.5	7.1	Clay
3	2774.5			Massive Basalt



(e) VES-III5-5

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	47.2	0.5	0.5	Topsoil
2	4.6	4.6	5.1	Clay
3	2876.7			Massive Basalt

3.2.2 Jardega

The Jardega site is located north-northeast of the village in the western part of Jarmet marsh (Fig 9a). The apparent resistivity map (Fig 9b) reveals that the whole area is underlain by very low resistivity material of less than 40 Ohm-m, except the north western cover where high resistivity in the range of 50-120 dominate. The high resistivities in the northwest corner are found in the foothill area, and thus can be the response of shallow bedrock. There is a progressive decrease in resistivity towards the east, and the lowest resistivity below 20 Ohm-m is found near the southeast corner of the area. The low resistivities in the eastern half of the area may be due to loose unconsolidated sediments saturated with water or due to thick clay layers.

The results of the VES survey (Fig 9c) clearly show that the top two or three layers exhibit high resistivities of 94 to 555 Ohm-m attributed to dry gravelly material the thickness of which range between 4 to 14m. Underlying these layers, there is low resistivity formation with resistivity of 9 to 40 Ohm-m probably related to the aquifer in the area. Generally, the thickness of the low resistivity material overlying the slightly weathered bedrock increases from 68m at VES H13-5 near the foothill to more than 133m towards the eastern end of the site. The bottom layer has resistivity more than 400 Ohm-m, indicating its slightly weathered to massive nature.

Figure 9a. Location map of VES points and HRP lines, Jardega.

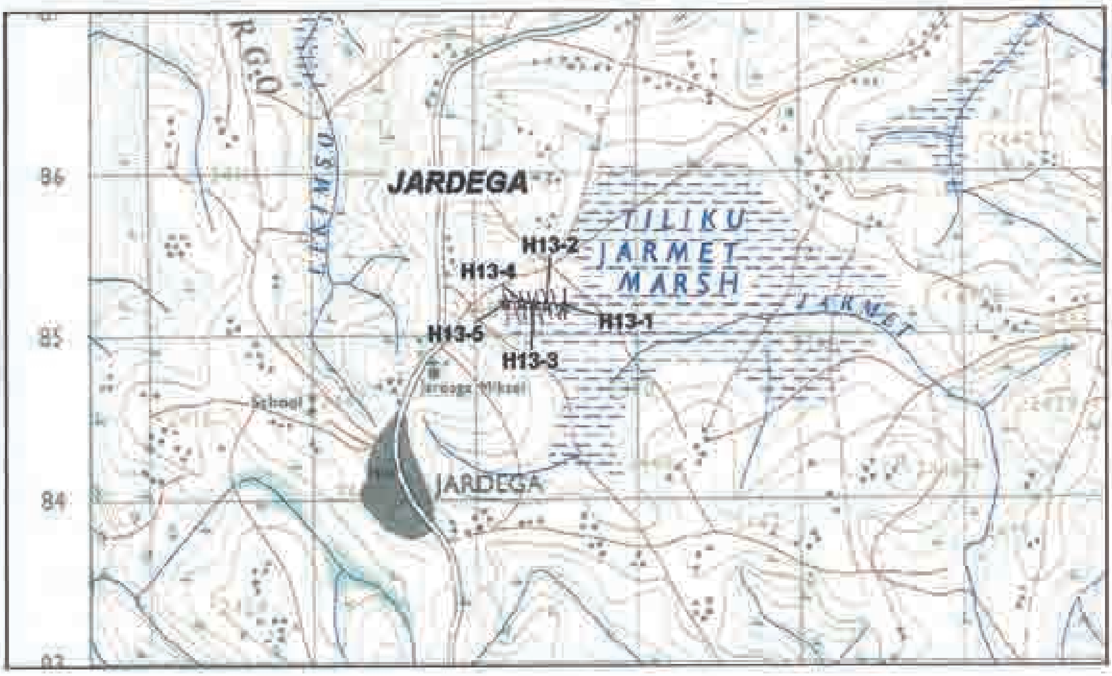


Figure 9b. Apparent Resisitivity Map, Jardega.

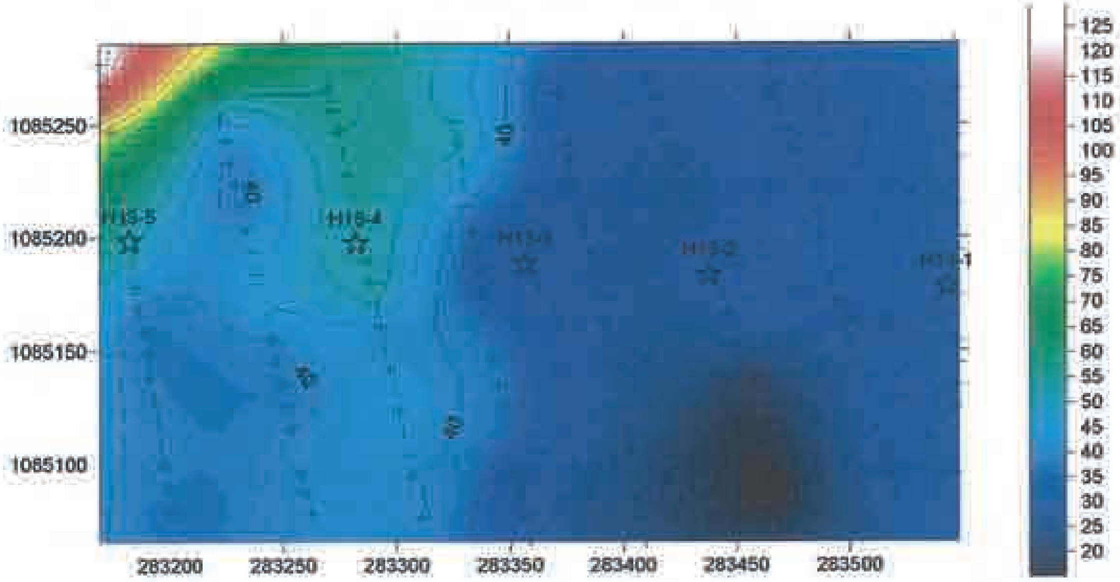
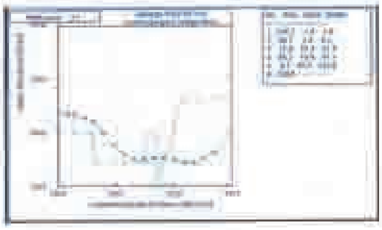


Figure 9c. Interpreted Layer Parameters, Jardega.

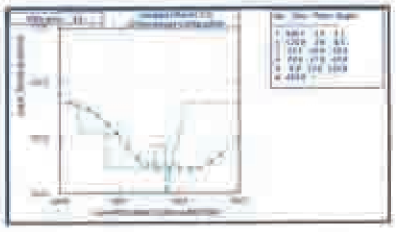
(a) VES-H13-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	236.7	1.8	1.8	Top Soil
2	94.1	2.3	4.1	Unconsolidated Sediments, Gravelly
3	27	27.4	31.5	Unconsolidated Sediments, probably water bearing
4	88.2	19.6	51.1	Highly to moderately weathered rock (Sandstone?)
5	9.1	81.7	132.8	Highly weathered and/or fractured rock (Sandstone?)-probably water bearing
6	399.8			Moderately to slightly weathered and/or fractured rock-probably Sandstone



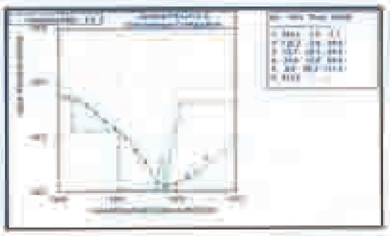
(b) VES-H13-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	408.1	2.1	2.1	Top Soil
2	125.9	3.9	6	Unconsolidated Sediments, Gravelly
3	27.7	33.5	39.5	Unconsolidated Sediments, probably water bearing
4	73	17.5	57	Highly to moderately weathered rock (Sandstone?)
5	9.8	72.8	129.8	Highly weathered and/or fractured rock (Sandstone?)-probably water bearing
6	402.9			Moderately to slightly weathered and/or fractured rock-probably Sandstone



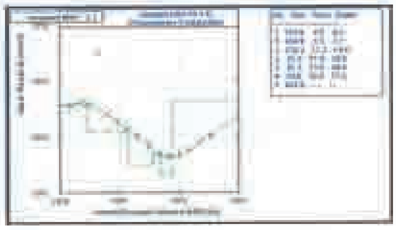
(c) VES-H13-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	555.1	1.7	1.7	Top Soil
2	128.2	8.8	10.5	Unconsolidated Sediments, Gravelly
3	10.7	38.3	48.8	Unconsolidated Sediments, probably water bearing
4	39.5	10.8	59.6	Highly weathered rock (Sandstone?)
5	8.9	58.3	117.9	Highly weathered and/or fractured rock (Sandstone?)-probably water bearing
6	412.5			Moderately to slightly weathered and/or fractured rock-probably Sandstone



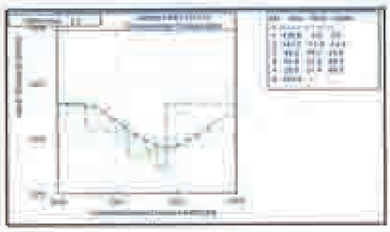
(d) VES-H13-4

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	315.6	0.5	0.5	Top Soil
2	430.8	2.2	2.7	Unconsolidated Sediments, Gravelly
3	125.3	11.3	14	Unconsolidated Sediments, Gravelly
4	31.3	21.9	35.9	Unconsolidated Sediments, probably water bearing
5	51.1	12.4	48.3	Highly to moderately weathered rock (Sandstone?)
6	20.6	29	77.3	Highly weathered and/or fractured rock (Sandstone?) probably water bearing
7	437.7			Moderately to slightly weathered and/or fractured rock probably Sandstone



(e) VES-H13-5

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	438.6	3	3	Top Soil
2	141.1	11.9	14.9	Unconsolidated Sediments, Gravelly
3	48.3	19.1	34	Unconsolidated Sediments, probably water bearing
4	61.8	12.2	46.2	Highly to moderately weathered rock (Sandstone?)
5	29.5	21.9	68.1	Highly weathered and/or fractured rock (Sandstone?) probably water bearing
6	434.4			Moderately to slightly weathered and/or fractured rock-probably Sandstone



3.2.3 Mazoria-Achane

The Mazoria-Achane site is selected to serve both communities of Mazoria and Achane. The geology is exposed at the site and is entirely of Adigrat sandstone. Figure 10a shows the location of VES points and HRP lines; and Figure 10b shows the apparent resistivity map of the site. The HRP lines were laid out into two perpendicular directions, i.e. in NNW-SSE and ENE-WSW direction, to detect any fracture systems, if any, which could be favorable zone for groundwater movement and storage.

As a result, the apparent resistivity map (Fig 4b) depicts large resistivity variation in the area varying between 300 and 1300 Ohm-m. The areas in the north and east of the site are characterized by very high resistivities of greater than 600 Ohm-m, indicating the presence of slightly fractured to massive sandstone.

However, in the central and southwest part of the map resistivities below 500 Ohm-m are commonly found, with two general trends in the NE-SW and NW-SE direction. At the intersection of these two trends, there is a broad low resistivity zone represented by resistivities less than 400 Ohm-m, possibly caused by water saturation.

The VES points were evenly distributed within the low resistivity zone mapped by the HRP. The VES results (Fig 10c) show large resistivity variation, with very high resistivity dominating the top layers and resistivity monotonously decreasing with depth.

The soundings indicate that the subsurface is underlain by 4 to 5 resistivity layers, of which the top 3 to 4 layers are highly resistive, at place reaching more than 2000 Ohm-m. These high resistivity layers may be attributed to massive to Slightly fractured sandstone. Within the massive section, there exist highly to moderately fractured zones at certain locations (e.g. VES H10-3, H10-4 and H10-5) having thickness in the order of 20m, and within depth range of 15 to 40m which is probably water bearing. However, the last, bottom layer with resistivity in the range of 109-277 Ohm-m found below the depth range of 80 to 100m could form the major water bearing layer in the area.

Figure 10a. Location map of VES points and HRP lines, Mazoria-Achane.

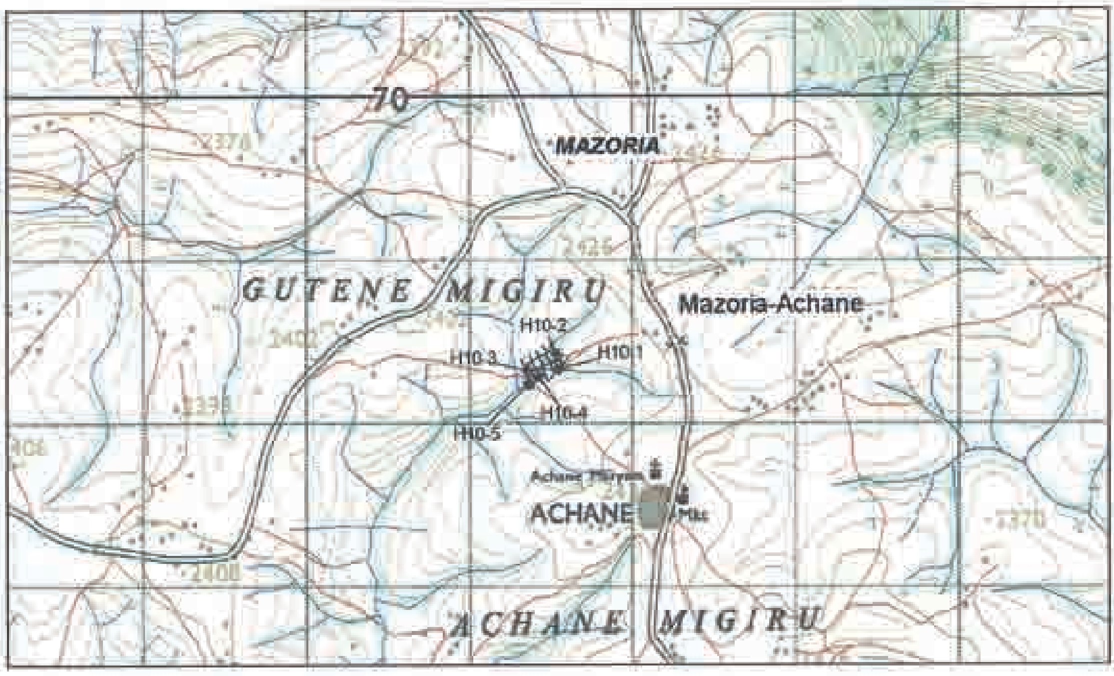


Figure 10b. Apparent Resistivity Map, Mazoria-Achane.

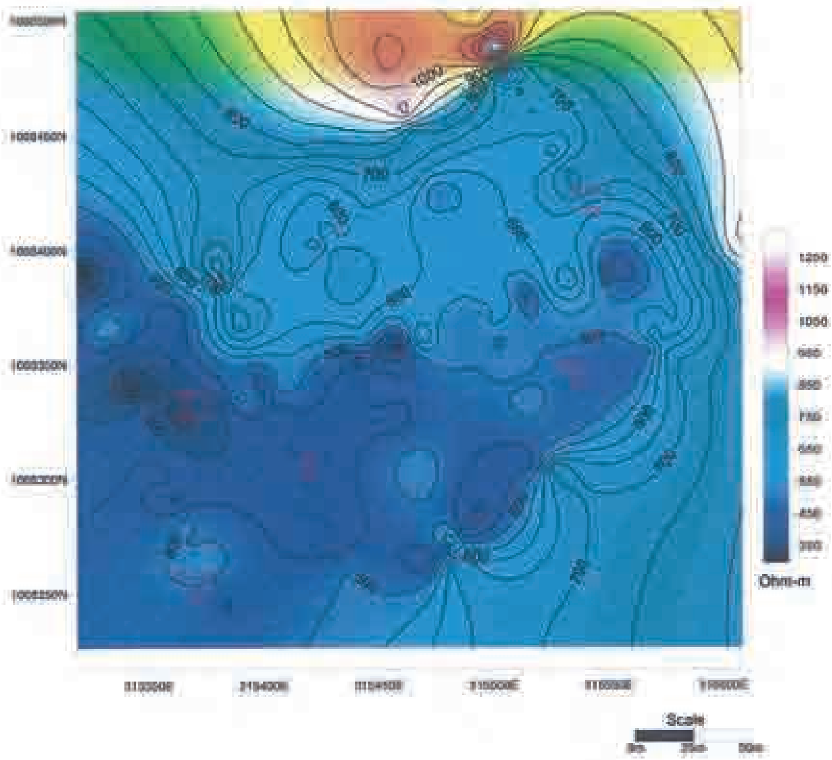
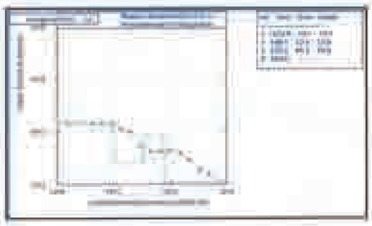


Figure 10c. Interpreted Layer parameters, Mazoria-Achane.

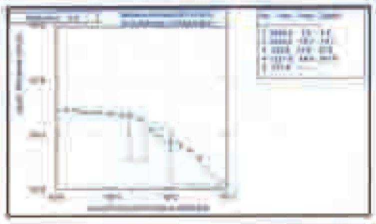
(a) VES-H10-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	1470.8	10.1	10.1	Massive Sandstone
2	288.1	22.9	33	Highly to Moderately Fractured Sandstone
3	832.2	46.5	79.5	Slightly Fractured Sandstone
4	109			Highly weathered and/or fractured Sandstone-probably water bearing



(b) VES-H10-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	3699.6	2.4	2.4	Massive Sandstone
2	2462	16.7	19.1	Massive Sandstone
3	333.6	17.9	37	Moderately Fractured Sandstone
4	1221.9	64.6	101.6	Slightly Fractured to massive Sandstone
5	121.4			Highly weathered and/or fractured Sandstone-probably water bearing



(c) VES-H10-3

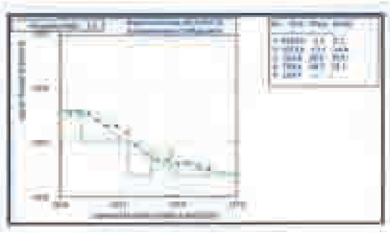
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	2867.7	2.9	2.9	Massive Sandstone
2	1396.6	16	18.9	Massive Sandstone
3	178.5	23	41.9	Highly to moderately fractured Sandstone-probably water bearing
4	826.7	44.9	86.8	Slightly Fractured Sandstone
5	132.4			Highly weathered and/or fractured Sandstone-probably water bearing

(d) VES-H10-4

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	4664.1	1.2	1.2	Massive Sandstone
2	1630.5	19.3	20.5	Massive Sandstone
3	255.1	20.1	40.6	Highly to moderately fractured Sandstone-probably water bearing
4	1231.6	61.8	102.4	Slightly Fractured to massive Sandstone
5	277.3			Highly to moderately fractured Sandstone-probably water bearing

(e) VES-H10-5

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	3910.8	2.3	2.3	Massive Sandstone
2	1073.9	12.1	14.4	Slightly Fractured to massive Sandstone
3	215.9	20.6	35	Highly to moderately fractured Sandstone-probably water bearing
4	709.4	39.2	74.2	Slightly Fractured Sandstone
5	250.7			Highly to moderately fractured Sandstone-probably water bearing



3.2.4 Chala Foka

The Chala Foka site is very identical to the Dedu site in many aspects such as geology and geomorphology. The site is located on the swampy plain about 600m west of the village (Fig 11a). There is a thick soil cover, hiding the underlying geology from view.

Eight profiles all along an east-west direction were measured by the HRP method. The apparent resistivity map (Fig 11b) shows a clear linear low resistivity zone of less than 100 Ohm-m, in a region surrounded by high resistivity greater than 300 to 500 Ohm, trending in NE-SW direction and having a with of about 100-120m, which gets wider further southwest wards. The low resistivity zone may be related to highly weathered and decomposed rocks at shallow depth. Higher resistivities (greater than 200 Ohm-m) underlie the northern and southeastern part of the area, may be due to shallow massive to slightly weathered rocks.

The sounding points were distributed within the low resistivity zone identified from the HRP. The results of the soundings (Fig 11c) generally show 5 to 7 resistivity layers. The soundings conducted in the center of the low resistivity zone (e.g. VES H05-3 and H05-5), typically show the existence of massive rock below the top 7 to 10m of the subsurface as the curves rise sharply. In contrast, the soundings at the margins of the low resistivity zones (e.g. VES H05-1, H05-2 and H05-4) show an HK type of curve where resistivity is set to decrease with depth caused by the presence of highly weathered/fractured rock possibly forming the water bearing layer in the area.

Figure 11a. Location map of VES points and HRP lines, Chala Foka.

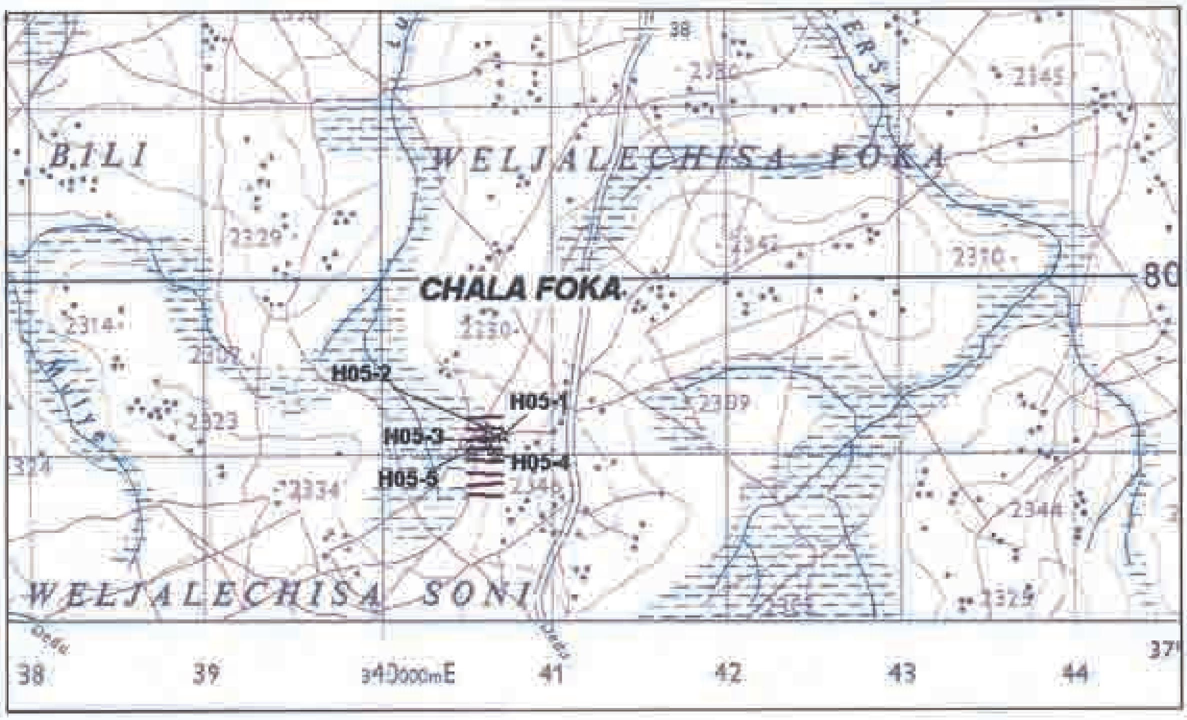


Figure 11b. Apparent Resistivity Map, Chala Foka.

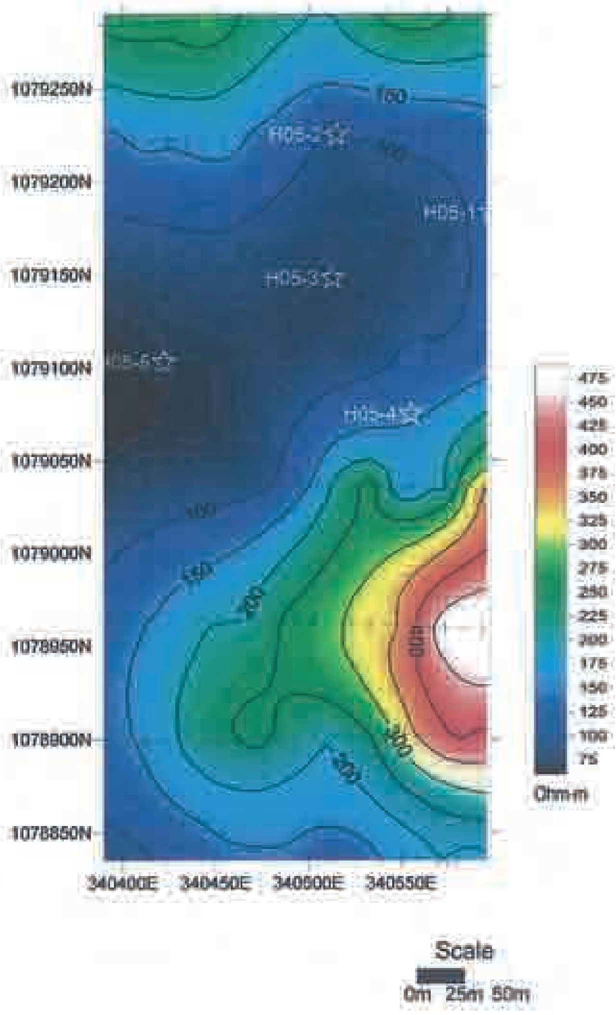
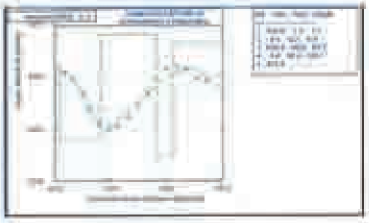


Figure 11c. Interpreted Layer parameters, Chala Foka.

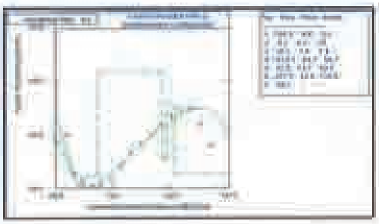
(a) VES-H05-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	149.9	1.2	1.2	Top Soil
2	4.1	5.2	6.4	Clay
3	2905.7	53.7	60.1	Highly weathered Basalt
4	14	21.2	81.3	Highly weathered fractured Basalt and/or Sandstone-probably water bearing
	276.8	32.4	113.7	Weathered Sandstone
5	15			Highly weathered and/or fractured Sandstone-probably water bearing



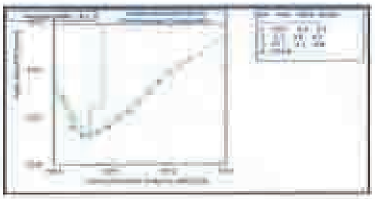
(b) VES-H05-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	701.5	0.4	0.4	Topsoil
2	8.1	2.4	2.8	Clay
3	16.1	2.6	5.4	Highly weathered, decomposed Basalt
4	1519.3	63.3	68.7	Massive Basalt
5	32.9	14.7	83.4	Highly weathered fractured Basalt and/or Sandstone-probably water bearing
6	371.9	33.4	116.8	Weathered Sandstone
7	18.2			Highly weathered and/or fractured Sandstone-probably water bearing



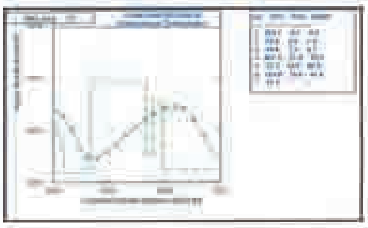
(c) VES-H05-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	139.1	0.5	0.5	Topsoil
2	3.3	3.8	4.3	Clay
3	17.1	2.7	7	Highly weathered, decomposed Basalt
4	1376.8			Massive Basalt



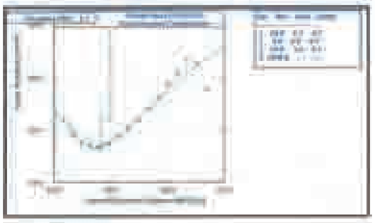
(d1) VES-H05-4

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	363.1	0.7	0.7	Topsoil
2	53	0.8	1.5	Clay
3	13.6	3.2	4.7	Highly weathered, decomposed Basalt
4	861	41	45.7	Massive Basalt
5	32.2	14.9	60.6	Highly weathered fractured Basalt and/or Sandstone-probably water bearing
6	354.8	30.8	91.4	Weathered Sandstone
7	18.3			Highly weathered and/or fractured Sandstone-probably water bearing



(e) VES-H05-5

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	29	0.7	0.7	Topsoil
2	4	6	6.7	Clay
3	16	3	9.7	Highly weathered, decomposed Basalt
4	1000			Massive Basalt



3.2.5 Bedo Gidami

The three soundings conducted at Bedo Gidami were distributed around the village (Fig 12a). The first sounding was measured on the bank of Goraso River and the third sounding close to Hine River in the north of the village.

The interpretation results (Fig 12b) reveal 6 to 7 resistivity layers. Except minor differences near the top, the subsurface resistivity structure is more or less similar among the three soundings.

In general, the resistivity distribution in the area below the top soil is dominated by low resistivities in the range of 7-16 Ohm-m suggesting the presence of highly weathered and fractured rocks which are potentially water bearing; the little variation being the occurrence of a high resistivity layer at shallow depth of 4 to 9m under VES H08-1 correlated to sandy/gravelly alluvium.

However, in the middle of the low resistivity layers, there is an interbed of high resistivity (118-197 Ohm-m) material with thickness varying between 26-32m, and interpreted as moderately weathered rock.

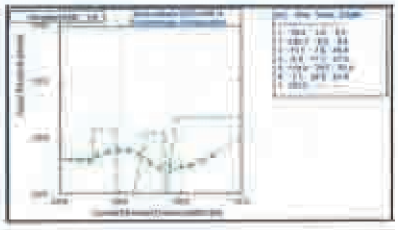
The above two formations make up the top 60-80m of the subsurface overlying the bottom high resistivity layer (227-363 Ohm-m) interpreted as moderately to slightly weathered rock.

Figure 12a. Location map of VES points, Bedo Gidami.

Figure 12b. Interpreted Layer parameters, Bedo Gidami.

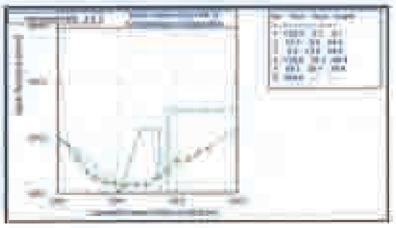
(a) VES-H08-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	39.4	3.5	3.5	Top Soil
2	136.3	5	8.5	Sandy material
3	11.1	7.6	16.1	Highly weathered fractured rock -probably water bearing
4	8.4	11.3	27.4	Ditto
5	118.4	25.7	53.1	Moderately weathered rock
6	7.1	28.9	82	Highly weathered, fractured rock-probably water bearing
7	227.5			Moderately to slightly weathered rock



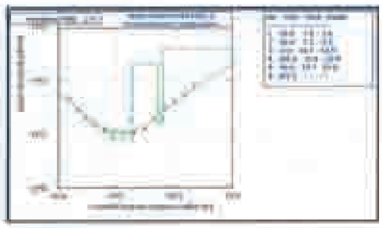
(b) VES-H08-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	129.3	0.7	0.7	Topsoil
2	15.1	9.9	10.6	Silty material
3	9.2	13.4	24	Highly weathered fractured rock -probably water bearing
4	139.8	26.3	50.3	Moderately weathered rock
5	10.1	20.1	70.4	Highly weathered, fractured rock-probably water bearing
6	304.8			Moderately to slightly weathered rock



(c) VES-H08-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	99.9	1	1	Topsoil
2	10.4	7.2	8.2	Silty material
3	8	10.7	18.9	Highly weathered fractured rock -probably water bearing
4	196.9	31.9	50.8	Moderately weathered rock
5	16	12.7	63.5	Highly weathered, fractured rock-probably water bearing
6	362.8			Moderately to slightly weathered rock



3.2.6 Kelala Didimtu

The soundings at Kelala Didimtu were carried out on margins of swampy grounds to the south and north of village (Fig 13a).

The interpreted layer parameters presented in Fig 13b show that 5 to 6 resistivity layers underlie the area. Low resistivity layers of 8-13 Ohm-m underlying the topsoil, and ranging in thickness between 15 and 27 m probably constitute the shallowest water bearing horizon in the area. Below the low resistivities, moderately high resistivity layer of 108-131 Ohm-m is identified, which has a nearly constant thickness of about 24m, and attributed to moderately weathered rock.

This layer is again underlain by a low resistivity formation of 5-12 Ohm-m, and thickness of 17-37m, probably comprising the second and deeper water bearing formation. The thickness of this aquifer varies from 37m at VES H09-3 to 17m below VES H09-2.

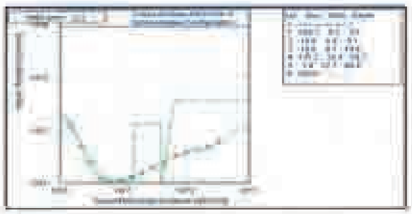
The last layer observed has very high resistivity of 350-395 Ohm-m pointing out its slightly weatherd nature. Depth to the top of the slightly weathered rock varies between 66 and 75m.

Figure 13a. Location map of VES points, Kelala Didimtu.

Figure 13b. Interpreted Layer parameters, Kelala Didimtu.

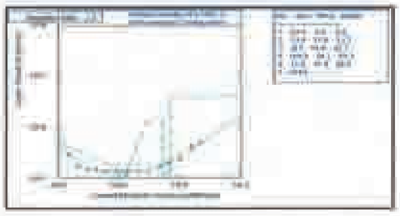
(a) VES-H09-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	348.3	0.7	0.7	Top Soil
2	10.6	14.1	14.8	Highly weathered, fractured rock -probably water bearing
3	131.2	24.4	39.2	Moderately weathered rock
4	7.4	27.1	66.3	Highly weathered, fractured rock-probably water bearing
5	360			Moderately to slightly weathered rock



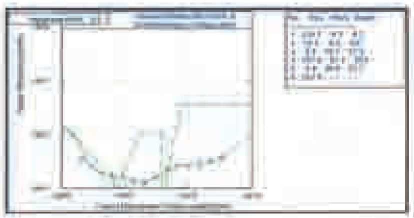
(b) VES-H09-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	67.5	0.5	0.5	Topsoil
2	13.5	11.8	12.3	Silty material
3	9.1	14.8	27.1	Highly weathered, fractured rock -probably water bearing
4	119	24.2	51.3	Moderately weathered rock
5	11.6	17.4	68.7	Highly weathered, fractured rock-probably water bearing
6	394.6			Moderately to slightly weathered rock



(c) VES-H09-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	232.7	0.7	0.7	Topsoil
2	16.5	6	6.7	Silty material
3	8.3	10.7	17.4	Highly weathered, fractured rock -probably water bearing
4	107.9	21.2	38.6	Moderately weathered rock
5	5.4	36.6	75.2	Highly weathered, fractured rock-probably water bearing
6	332.9			Moderately to slightly weathered rock



3.2.7 Loya Dilelo

At Loya Dilelo, the soundings were conducted in two areas, to the right and left of the village separated by about one kilometer (Fig 14a). The results of interpretation (Fig 14b) show five to six resistivity layers of which the top 2 to 3 layers (3 in the case of VES H14-2) below the topsoil show relatively low resistivity of 18-49 Ohm-m interpreted as highly weathered rock of 11 to 28m thickness, and which could at places be (eg. under VES H14-2) water bearing.

A high resistivity layer of 203-235 Ohm-m, which is about 10m thick underlies the highly weathered layer, which again overlies a low resistivity layer of 19-37 Ohm-m, and 10-19m thickness. The thickness of this low resistivity layer is generally small, but at VES H14-1 it attains the largest thickness of 19m.

The bottom part of the subsurface is characterized by very high resistivity in the range of 597-906 Ohm-m, probably indicating slightly weathered to massive rock. Depth to the top of the high resistivity bottom layer is in the range of 30-48m.

Figure 14a. Location map of VES points, Loya Dilelo.

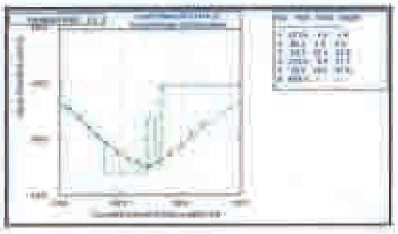
Figure 14b. Interpreted Layer parameters, Loya Dilelo

(a) VES-H14-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	572.6	0.8	0.8	Top Soil
2	48.9	12.4	13.2	Highly weathered rock, sandy material
3	234.7	11.4	24.6	Moderately weathered rock
4	18.7	19.2	43.8	Highly weathered, fractured rock-probably water bearing
5	596.6			Moderately to slightly weathered rock

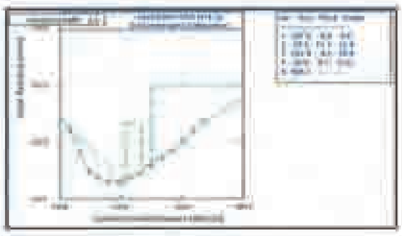
(b) VES-H14-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	472.5	1	1	Topsoil
2	86.2	4.4	5.4	Highly weathered rock, sandy material
3	25.3	22.4	27.8	Highly weathered fractured rock probably water bearing
4	225.9	9.9	37.7	Moderately weathered rock
5	35.5	10.1	47.8	Highly weathered, fractured rock-probably water bearing
6	878.3			Slightly weathered rock



(c) VES-H14-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	407.9	0.6	0.6	Topsoil
2	18.2	11.1	11.7	Highly weathered rock, silty material
3	202.9	9.2	20.9	Moderately weathered rock
4	38.9	9.7	30.6	Highly weathered, fractured rock-probably water bearing
5	906.1			Slightly weathered rock



3.2.8 Genji Ketala

The Genji Ketala site is situated about 2 km north of the northern shore of Lake Chomen (Fig 15a). The VES interpretations (Fig 15b) show a simple resistivity structure consisting of four resistivity layers underlying the subsurface.

At the three sites, the topsoil has high resistivity of 252-660 Ohm-m, probably due to sandy soil, and thickness of 1-3m. Below the topsoil, a moderately high resistivity layer of 65-133 Ohm-m with 5 to 9m thickness is found, which is interpreted as dry highly weathered rock lying above the local water table.

The third layer is characterized by low resistivity of 20-30 Ohm-m, and thickness of 30 to 50m, probably representing highly weathered and potentially water bearing formation. The substratum has resistivity ranging between 100-161 Ohm-m, indicating its moderately fractured nature. Depth to the top of the moderately weathered layer varies between 42 and 61m, the largest depth being found at VES H07-3.

Figure 15a. Location map of VES points, Genji Ketala.

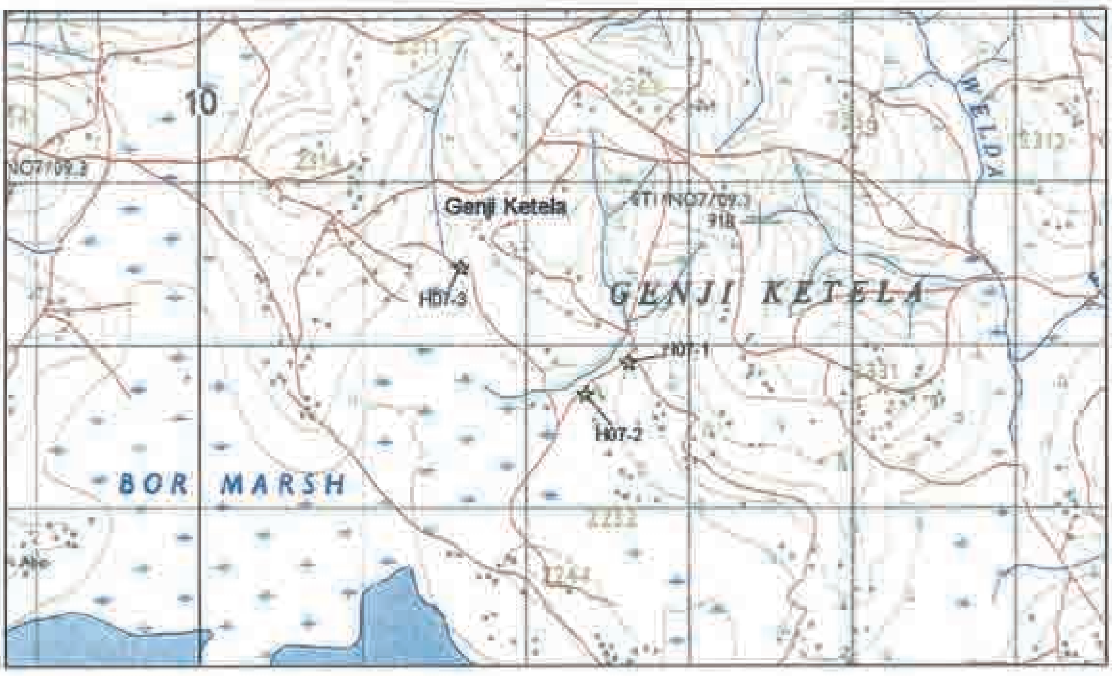
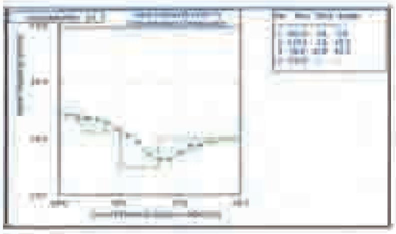


Figure 15b. Interpreted Layer parameters, Genji Ketala

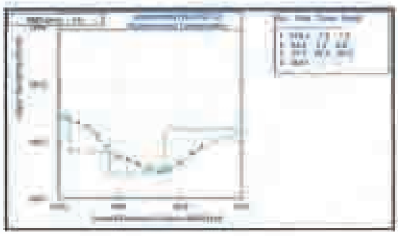
(a) VES-H07-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	252	2.6	2.6	Top Soil
2	133	7.6	10.2	Highly weathered rock, sandy material
3	30	32	42.2	Highly weathered, fractured rock-probably water bearing
4	100			Highly to moderately weathered rock



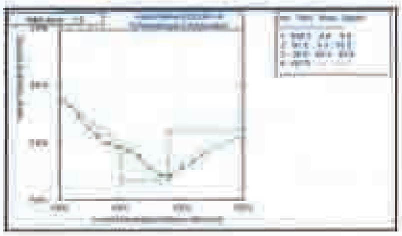
(b) VES-H07-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	270.3	1.5	1.5	Top Soil
2	64.6	5.3	6.8	Highly weathered rock, sandy material
3	27.7	48.8	55.6	Highly weathered, fractured rock-probably water bearing
4	180.1			Moderately weathered rock



(c) VES-H07-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	660.3	0.9	0.9	Top Soil
2	91.5	9.3	10.2	Highly weathered rock, sandy material
3	20.8	50.3	60.5	Highly weathered, fractured rock-probably water bearing
4	161.5			Moderately weathered rock



3.2.9 Burka Hobo

The Burka Hobo site is located on the northern extension of the Chomen Swamp. VES H12-1 and H12-2 were conducted on the western margin of a wide marshy plain traversed by the Erer stream, and VES H12-3 was done on the eastern bank of Wango swamp about 1.4 km to the west of the other soundings (Fig 16a). The sounding interpretation (Fig 16b) show shallow bedrock at the location of the first two soundings, i.e. within 3 to 9m depth moderately weathered rock may be reached; but at VES H12-3, the moderately weathered rock may be reached at a depth of 23m, where the overlying material comprising low resistivity of 19 Ohm-m could be locally water bearing.

In both cases, the moderately weathered layer is characterized by moderate to high resistivity of 170-299 Ohm-m and 23 to 35m thickness. Below these layer, a relatively low resistivity formation in the range of 22 to 78 Ohm-m, and thickness varying between 26 and 52m is observed, which is interpreted as a water bearing highly weathered or fractured rock.

The bottom layer has high resistivity response in the range of 346-393 Ohm-m, which may be attributed to slightly weathered to fresh rock.

Figure 16a. Location map of VES points, Burka Hobo.

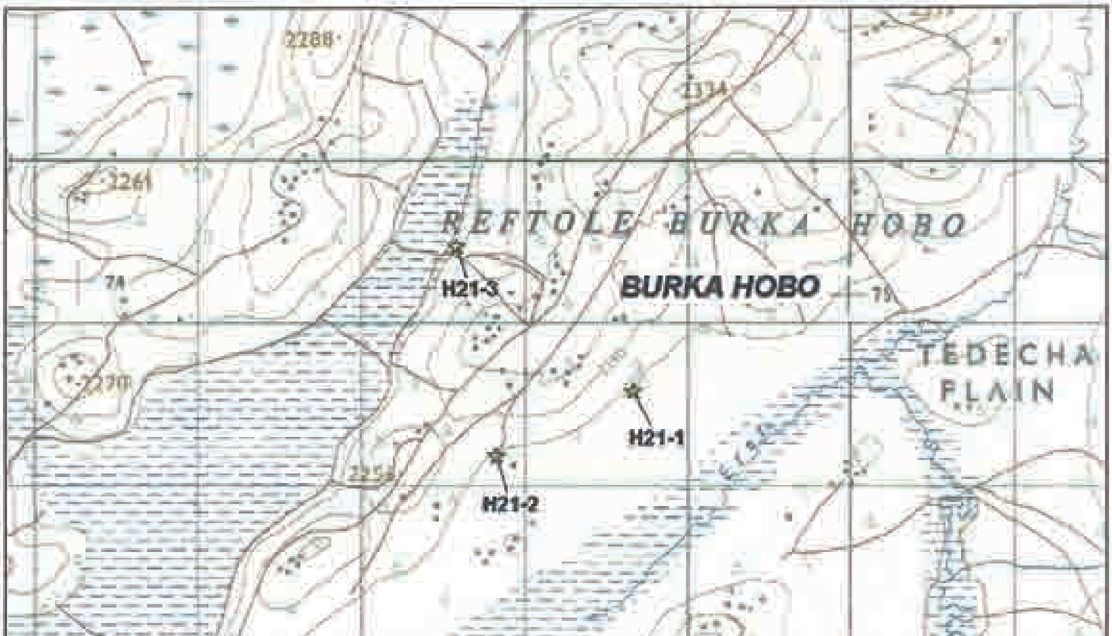
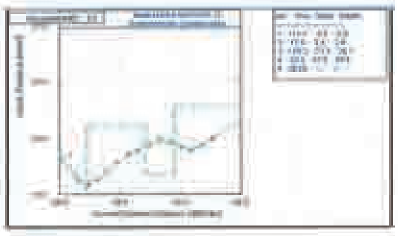
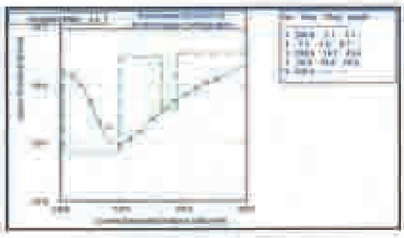


Figure 16b. Interpreted Layer parameters, Burka Hobo.

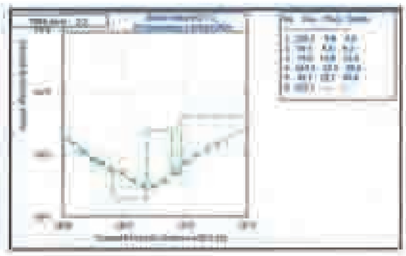
(a) VES H21-1				
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	111.7	0.5	0.5	Top Soil
2	11.6	2.4	2.9	Silty material
3	170.3	23.3	26.2	Moderately weathered rock
4	22	52.5	78.7	Highly weathered, fractured rock-probably water bearing
5	365.8			Slightly weathered rock



(b) VES H21-2				
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	200.6	1.1	1.1	Topsoil
2	7.1	7.6	8.7	Clayey material
3	298.6	34.7	43.4	Moderately to slightly weathered rock
4	36.9	33.3	76.9	Highly weathered, fractured rock-probably water bearing
5	346.5			Slightly weathered rock



(c) VES H21-3				
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	206.7	0.9	0.9	Topsoil
2	58.7	5.5	6.4	Sandy material
3	19	16.9	23.3	Highly weathered, fractured rock-probably water bearing
4	243.4	35.4	58.7	Moderately to slightly weathered rock
5	48.1	26.1	84.8	Highly weathered, fractured rock-probably water bearing
6	393.1			Slightly weathered rock



3.2.10 Haro Habo

At Haro Habo two sites were identified for the VES survey. The first site is located on the bank of Dimtu River/swamp, where two soundings (H22-1 & H22-2) were measured, and at the second site about 600 m to the southeast near Negasa stream, the third sounding (H22-3) was measured (Fig 17a)

The nature of the sounding curves show slight variation in the subsurface setting of the two sites. At both sites, the top three layers are characterized by relatively higher resistivity response varying between 65 and 572 Ohm-m indicating the dominance of moderately to slightly weathered rocks . Together these layers are about 30m thick.

Below the high resistivity layers, there is a formation represented by low resistivities in the range of 18-33 Ohm-m, the top of which may be found at about 30m below the surface. This layer probably comprises the aquifer in the area. The thickness of the low resistivity layer was found to be about 31m at the site of H22-3, but could not be determined at H22-1 and H22-2 as it forms the bottom layer. At VES H22-3, the highly weathered formation is underlain by a high resistivity layer of 251 Ohm-m, which may be related to slightly weathered rock.

Figure 17a. Location map of VES points, Haro Habo.

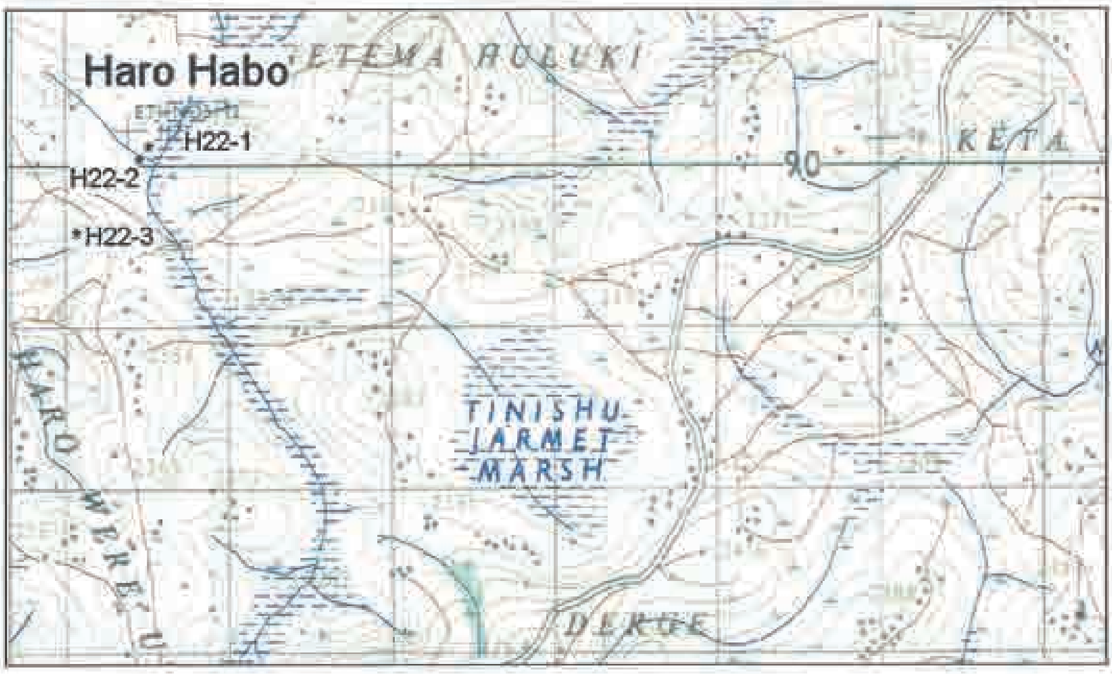


Figure 17b. Interpreted Layer parameters, Haro Habo.

(a) VES H22-1

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	190	2.2	2.2	Top Soil
2	101.3	6.3	8.5	Highly weathered rock, sandy material
3	372.7	20.1	28.6	Slightly weathered rock, may be sandstone?
4	32.6			Highly weathered, fractured rock-probably water bearing

(b) VES H22-2

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	348.8	2.3	2.3	Top Soil
2	69.4	8.5	10.8	Highly weathered rock, sandy material
3	343.8	20.1	30.9	Slightly weathered rock
4	18.5			Highly weathered, fractured rock-probably water bearing

(c) VES H22-3

Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	340.6	12.3	12.3	Top Soil
2	65	8.4	20.7	Highly weathered rock, sandy material
3	231.8	9.4	30.1	Slightly weathered rock
4	33.9	30.8	60.9	Highly weathered, fractured rock-probably water bearing
5	251.3			Slightly weathered rock

3.2.11 Tulu Gana

The Tulu Gana site is the only site underlain by Precambrian basement rocks, although due to the thick weathering mantle, no exposures of the underlying rock is found.

Three sounding were conducted at the site, separated by about 300 to 700 m, and four resistivity layers were identified from the interpretation of the soundings (Fig 18a). The top three layers are characterized by variable resistivity response of low to moderate value, which represent rocks affected by high to moderate degree of weathering and/or fracturing.

For example, the top layers of VES H18-3 are characterized by very low resistivity in the range of 13-27 Ohm-m, indicating highly weathered and/or fractured rock, the bottom part of which is probably water bearing. This layer is underlain by a very high resistivity of more than 1100 Ohm-m, attributed to slightly fractured to almost massive basement rock.

At VES H18-1, the third layer marked by resistivity 80 Ohm-m has about 25m thickness. This layer may indicate high to moderate degree of weathering and fracturing, and thus may consist of a shallow water bearing layer. The bottom substratum is characterized by resistivity of more than 2100 Ohm-m indicating massive rock.

Figure 18a. Location map of VES points, Tulu Gana.

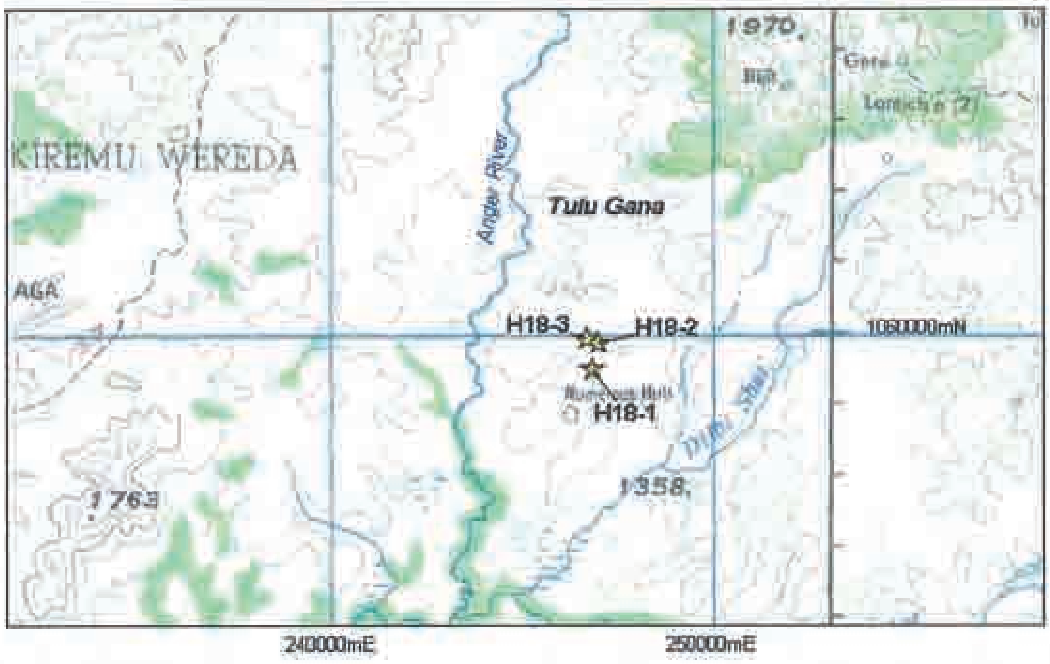
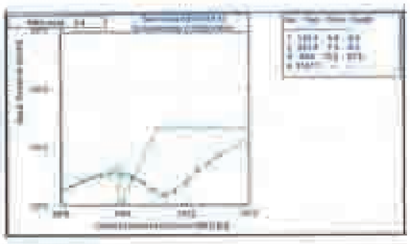
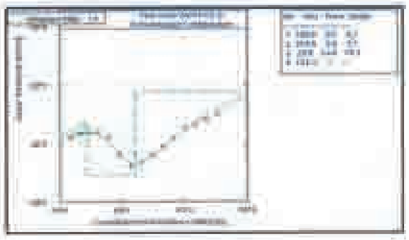


Figure 18b. Interpreted Layer parameters, Tulu Gana.

(a) VES-H18-1				
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	158.4	0.8	0.8	Top Soil
2	451	7.4	8.2	Moderately weathered rock, sandy material
3	80.6	25.6	33.8	Highly weathered, fractured rock-probably water
4	2107.7			Massive Basement rock



(b) VES-H18-2				
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	108	0.7	0.7	Top Soil
2	218.8	2	2.7	Moderately weathered rock, sandy material
3	28.9	13.6	16.3	Highly weathered, fractured rock-probably water
4	744.3			Massive Basement rock



(c) VES-H18-3				
Layer Number	Resistivity(Ohm-m)	Thickness(m)	Depth(m)	Inferred formation
1	27.5	0.7	0.7	Top Soil
2	19.2	4.9	5.6	Highly weathered rock, Clayey sand material
3	13.1	9.5	15.1	Highly weathered, fractured rock-probably water
4	1131.3			Massive Basement rock