USING GEOPHYSICAL TECHNIQUE TO DETERMINE GROUNDWATER YIELD FOR SOME PART OF FIKA LOCAL GOVERNMENT AREA OF YOBE STATE.

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ABSTRACT

Water as a sustainable development in rural area can improve the lives of individuals in any locality. Providing potable water has been a major concern to the people of Fika Local government area of Yobe State. This study is aimed at determining groundwater yield using geo-electrical resistivity data to determine the groundwater distribution of the study area. Thirteen vertical resistivity sounding (VES) was carried out in some selected regions of Fika local government area of Yobe state. The data obtained were processed using the WinSev6.4 software to display results in log-log graph. Based on the geology of the area, the hydro geophysical parameters of transmissivity and hydraulic conductivity were computed using the Dar Zarrouk formulations. The transmissivity values recorded is within a range of 3.00 m^2/day to 17.02 m^2/day with an average value of 5.83 m^2/day, the hydraulic conductivity value recorded is also within the range of 4.4395x10^{-6} m/s to 7.4771 x10^{-6} m/s with an average of 6.2438 x10^{-6} m/s. From the analysis of the result, the best groundwater yield in the study area is just enough for community and private consumption.

KEY WORDS: *Resistivity, Dar Zarrouk, Transmissivity, Groundwater*

INTRODUCTION

Groundwater is described as water which exists below the earth surface within saturated layers of sand, gravel and pore spaces in sedimentary as well as crystalline rocks (Oseji and Ofomola, 2010). Todd (2004) explains groundwater to mean the water occupying all the empty spaces within a geologic stratum. It is among the natural resources of prime importance to man throughout the world. Oseji et al., (2005) noted that groundwater occurs in many types of geologic formations. Those known as aquifer are the most important and are defined as formations containing sufficient saturated permeable material to yield significant quantities of water to wells and spring (Abiola et al., 2009).

In exploration geophysics or geophysical prospecting, practical applications of geophysical methods; electrical, seismic, magnetic, gravitational, and electromagnetic are employed to measure the physical properties of the earth's subsurface, to ascertain the subsurface geological, hydro-geological conditions and aquifer characteristics in other to detect or infer the presence of structures and minerals of interest (Dobrin, 1976). Under groundwater is of interest in this work andcan be explored using geophysical techniques or methods. Geophysical methods which depend of the physical properties of rocks (being measured directly like; resistivity, density, susceptibility, thermal or radioactive properties, etc.) can further be used to infer other indirect properties (conductivity, transmisivity) targets of interest.

Fika a Local government in Yobe is faced with an increased demand of water as a result of population growth. The wells usually dry up during the dry seasons leaving a very few boreholes with coloured waters as the only source of water for the people. Its therefore necessary to determine the ground water potential of the study area and identify in it a location where good quantity of water can be harvested. The most popular and common method of determining the underground water potential is by carrying out a pump test which is very expensive for the common man to afford. A much faster and less expensive method of estimating the underground water yield is by using the geophysical and Dar Zarrouk parameters to determine the existence of water in an unknown area for exploration.

GEOLOGY AND LOCAL HYDROGEOLOGY OF THE STUDY AREA

Fika is a Local Government Area in Yobe State, Nigeria is bounded by latitude 11°18′N and 11°38′N and longitude 11°22′ E and 11°32′E and covers an area of approximately 2,208 km² (figure 1) which includes towns like Dole, Ramarama, Gana, Maiduwa, Fokkel, Toke.t.c.

Yobe state falls within the basin of deposition known as the chad basin described as the second largest area of inlands drainage in Africa. This basin occupies part of Nigeria, Central African Republic and Cameroon. The Nigeria sector of the basin slopes gently towards the Lake Chad, which is the main geographical feature. It consist of six distinct formations that overlie the basement each characterized by a particular depositional environment. There are also intrusions of tertiary basalts and Jurassic younger granites at the southern and north eastern parts of the state respectively. Fika falls within the northeastern end of the state,an area characterized by intrusions of younger granites within the relatively flat sedimentary cover.

Groundwater occurs in the quaternary deposits of the Chad basin, (sometimes referred to as the Chad formation) in perched aquifer, confined water or semi confined water. Normal groundwater is the most common source of water supply which is tapped from dugged wells in Yobe portion of Chad formation. Occasional semi-confined aquifers in the zone of normal groundwater are tapped by boreholes and wells and provide sub-artesian supplies.

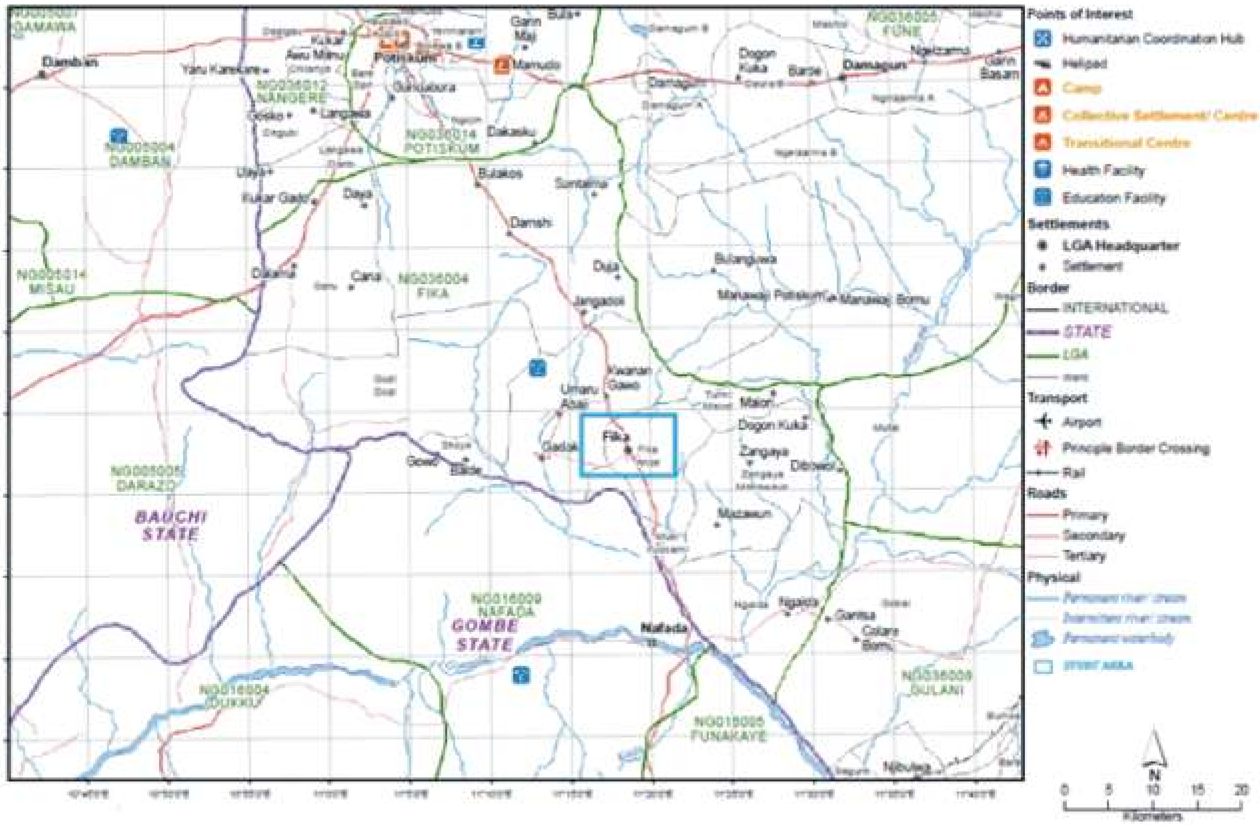


Figure 1: Yobe state map showing the Location of the study area in box (Sources: DTM RXVII, DWC, eHealth Africa, IHP, ITOS, Government of Nigeria (OSGOF), OSM, UNCS, WFP)

THEORETICAL BACKGROUNDS

To avoid drilling abortive wells, geophysical investigation is imperative because it helps to delineate aquifer (or potential water bearing geological units) while on the other hand, assessment of Water yielding capacity of aquifer are traditionally determined from parameters obtained from well pump tests and well log data (Singh, 2005). These are time consuming and very expensive. A rapid and cost effective means of determining these parameters; hydraulic conductivity and transmissivity, is with resistivity data (Kelly,1977; Singhal and Niwas, 1981; Singh, 2005,Kudamnya and Osumeje, 2015), particularly where bore wells are not sufficient (Dhakate and Singh, 2005) or not available like in the present study area. In an attempt to infer on the potential of the aquifer of the study area, the relationship established by Singh (2005), Singhal and Niwas (1981) and the standard set by Krasny (1993a) were adapted.

According to Singhal and Niwas (1981), the analytical relationship between aquifer transmissivity (T), hydraulic conductivity (K) and aquifer thickness (h) is given by:

$$T = K h$$

And in accordance with Singh (2005)

$$K = 8 \times 10^{-6} e^{-0.0013\rho}$$

Where ρ is resistivity of the aquifer.

The relation above was used to estimate hydraulic conductivity (K) and the unit is sandwiched by resistive layers (Singh, 2005). In hydro-geologic maps, transmissivity has been the best hydraulic property to clearly express groundwater potential (Krasny, 1993a as cited in Kudamnya and Osumeje, 2015)

Table 1 Classification of transmissivity magnitude and yield (Source:Kudamnya and Osumeje, 2015)

S/N	Transmissivity values (m^2/d^{-1})	Designation of Transmissivity	Groundwater Yield
1	1000 and above	Very high	Withdrawals of great regional importance
2	100 – 1000	High	Withdrawal of lesser regional importance
3	10 – 100	Intermediate	Withdrawal of local water supply (communities, plants)
4	1 – 10	Low	Smaller withdrawals for local water supply (private consumption)
5	0.1 – 1	Very low	Withdrawal for local water supply with limited consumption
6	Below 0.1	Imperceptible	Source for local supply are difficult

MATERIAL AND METHODS

The schlumberger technique which is the best for probing vertical depth was used to acquire the vertical electrical sounding (VES) data using the Mc-ohms resistivity meter, electrodes, and other necessary accessories for the instruments. Fourteen points were randomly sounded around the study area. The VES data collected was processed and analyzed to reveal the aquiferous zones and their respective thicknesses. Based on the above equations, we calculated the transmissivity and hydraulic conductivity of the study area as shown in table 3 below.

RESULTS AND DISCUSSION

The results from the processed VES data, with its resistivity and numbers of layers is shown in table 2.

The results are discussed and interpreted based on the hydraulic parameters calculated and supported by the geology of the study area.

Table 2: Vertical Electrical Sounding Results

VES NO	LAYERS	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)
1	1	8261	1.8	0.0
	2	4753	0.18	1.8
	3	2317	1.8	2
	4	453	11	3.8
	5	906	4.6	15
	6	2302	9.9	20
	7	5311	∞	30
2	1	698	0.86	0.0
	2	178	8.5	0.86
	3	2588	∞	9.4
3	1	531	1.7	0.0
	2	126	29.3	1.7
	3	8578	∞	31
4	1	2060	0.62	0.0
	2	375	1.4	0.62
	3	207	8	2
	4	80	8.7	10
	5	2186	∞	19
5	1	900	3.1	0.0
	2	138	14	3.1
	3	517	15	17

	4	5185	∞	32
6	1	280	0.57	0.0
	2	52	4.7	0.57
	3	150	1.7	5.3
	4	258	29	7
	5	418	∞	36
7	1	419	0.38	0.0
	2	138	1.6	0.38
	3	268	1.1	2
	4	60	7.6	3.1
	5	1259	∞	11
8	1	1103	2	0.0
	2	585	0.9	2
	3	155	6.6	2.9
	4	285	11	9.5
	5	3950	∞	20
9	1	1648	1.7	0.0
	2	1582	0.2	1.7
	3	703	11	1.9
	4	168	5.5	13
	5	6416	∞	18
10	1	796	0.6	0.0
	2	186	16	0.6
	3	439	12	17
	4	1073	134	29
	5	1135	∞	163
11	1	3193	0.72	0.0
	2	3100	2.4	0.72
	3	327	19	3.1
	4	4936	∞	22
12	1	1122	0.72	0.0
	2	476	1.4	0.72
	3	379	7.1	2.1
	4	733	20	9.2
	5	4888	∞	29
13	1	2060	0.62	0.0
	2	375	1.4	0.62
	3	207	8	2
	4	80	8.7	10
	5	2186	∞	19

From table 2 above, most VES points have five geo-electric layers with some extending up to seven. The average resistivity value of the first geo-electric layer is about 1,771.69Ωm. The average resistivity value of the second geo-electric layer is about 928.00 Ωm. The average resistivity value of the third layer is about 1,295.00 Ωm. The average resistivity value of the fourth geo-electric layer is about 1,210.09 Ωm. The average resistivity value of the fifth geo-electric layer is about 2,593.78 Ωm.Comparing the above resistivity values with the standard resistivity values as given by Loke (1999) the following inference where drawn. Layer 1 consists of sand and shale except for VES 1 which consist of marble. Layer 2 consists of clay alluvium. Layer 3 and 4 consists of fresh groundwater stored in unconfined aquifers with an exception of VES 2. Layer 5 consists of clay alluvium. The study area can geologically be classified into three distinct layers of overburden, weathered and fresh basement.

Table 3: VES points with calculated Hydrologic parameters

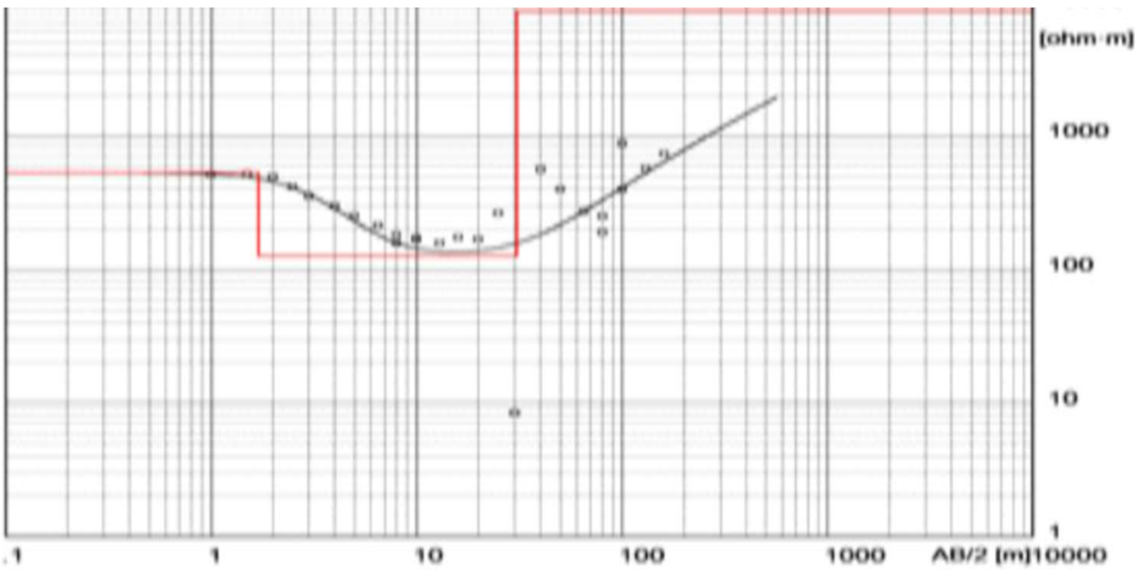
VES points	Coordinates VES		Aquifer thickness (m)	Resistivity (m)	Hydraulic Conductivity (m/s)	Transmissivity (m^2/day)
	LONG.(°)	LAT. (°)				
1	11.0274	11.2356	11	453	4.4395 X 10^{-6}	4.219
2	10.9905	11.3211	8.5	178	6.3474 X 10^{-6}	4.662
3	11.0935	11.3660	29	126	6.7913 X 10^{-6}	17.016
4	10.9177	11.4473	8.7	80	7.2098 X 10^{-6}	5.419
5	10.9744	11.3414	14	138	6.6862 X 10^{-6}	8.088
6	11.1930	11.5648	4.7	52	7.4771 X 10^{-6}	3.036
7	11.2540	11.5593	7.6	60	7.3997 X 10^{-6}	4.859
8	11.2617	11.3432	6.6	155	6.5400 X 10^{-6}	3.729
9	11.1930	11.5648	5.5	168	6.4304 X 10^{-6}	3.056
10	11.2927	11.3474	16	186	4.5210 X 10^{-6}	4.687
11	10.9974	11.2999	19	327	5.2296 X 10^{-6}	8.585
12	11.2927	11.3474	7.1	379	4.8878 X 10^{-6}	3.004
13	10.9177	11.4473	8.7	80	7.2098 X 10^{-6}	5.419
COMPUTED TOTAL			146.4	2382	81.1696 x10^{-6}	75.779
COMPUTED AVERAGES			11.26	183.2	6.2438 x10^{-6}	5.829

From table 3, the transmissivity values recorded are within a range of 3.00 m^2/day to 17.02 m^2/day with an average value of 5.829 m^2/day. Aquifer thickness recorded a range of value between 5.50 m to 29.00 m with an average thickness of 11.26 m. Based on the range of transmissivity values (from 3.00 m^2/day to17.02 m^2/day) on table 1, the study area can be classified to have "low transmissivity", with an exceptional point at VES 3 whose transmitivity value suggested a better ground water potential. This area around the VES 3 is an area predominantly with better yield for local supply or basically for private consumption. The hydraulic conductivity values is moderate and shows that the rock types in the study area are mainly silty sand and sandstones (Singhal and Gupta, 1999) which is confirmed by the geology of the study area. This shows that points around VES 3, like the VES 5 and VES 8 would produce good yield of the underground water and hence recommended for citing a borehole to a depth of between 25 m to 30 m.

CONCLUSION

The applied technique had enabled us to obtain the hydrological parameters from which an estimate the groundwater yield for the study area was obtained. From the study it is obvious that the area around VES 3 gives the best yield which is surrounded with VES 5 and VES 8 that also have good water yield. The average Transmissivity values of 5.829 m^2/day shows that the yield may only be sufficient for local uses in communities and private consumption. We recommend citing a borehole at VES 3, VES 5 and VES 8 to obtain the best yield. This study has encouraged the use of this technique to determine the hydraulic parameters of the earth's subsurface which can be used to determine the underground water potential of an area.

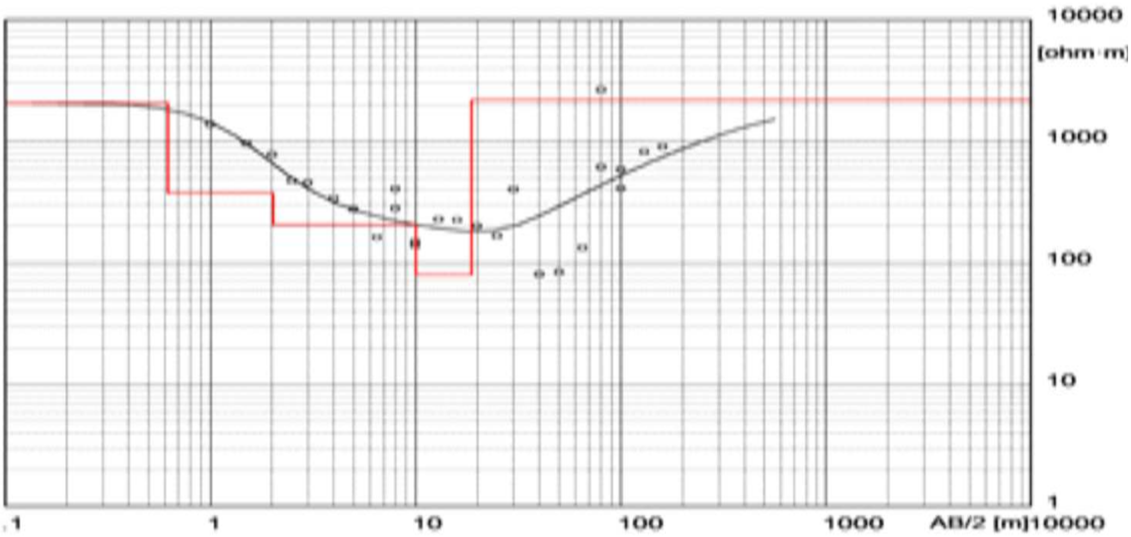
Some Iterated Field Curve Of The Vertical Electrical Sounding (ves)points



Location X = 011.09345 Y = 11.36633

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
531	1.7	
126	29	1.7
8578		31

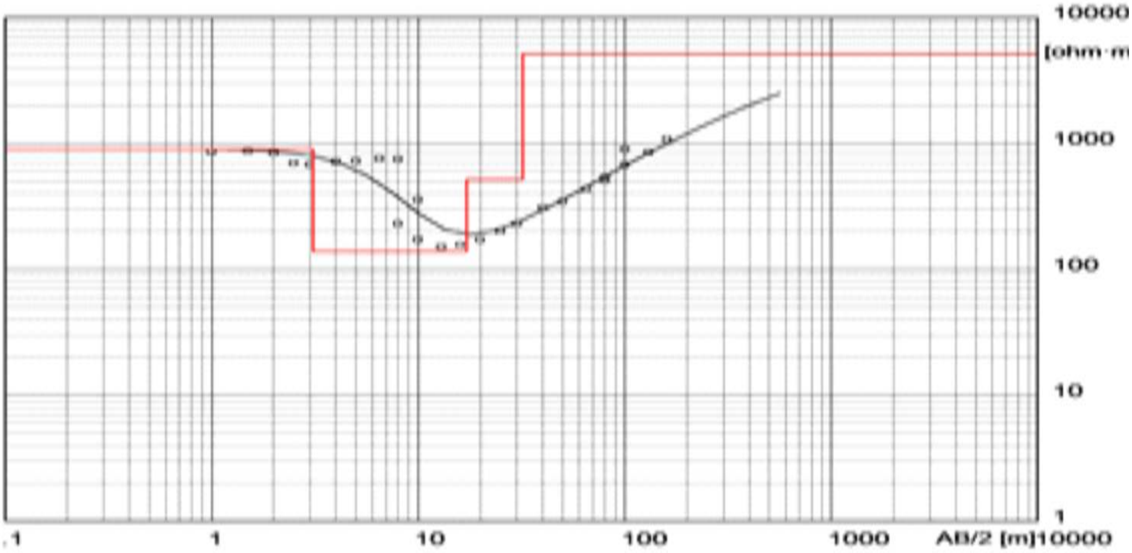
VES 3



Location X = 010.91766 Y = 11.44725

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
2060	.62	
375	1.4	.62
207	8	2
80	8.7	10
2186		19

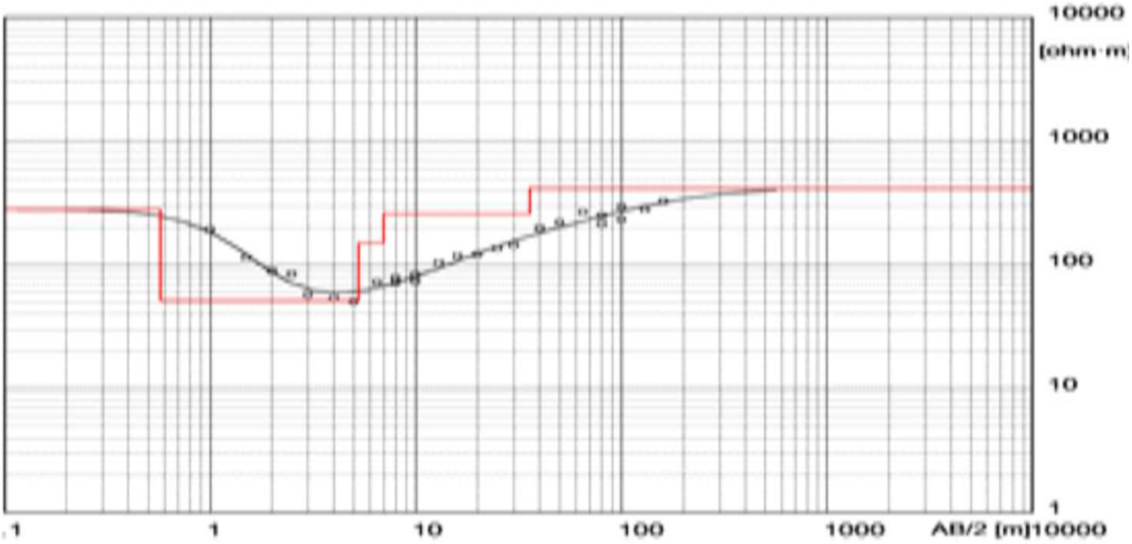
VES 4



Location X = 10.97441 Y = 11.34136

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
900	3.1	
138	14	3.1
517	15	17
5185		32

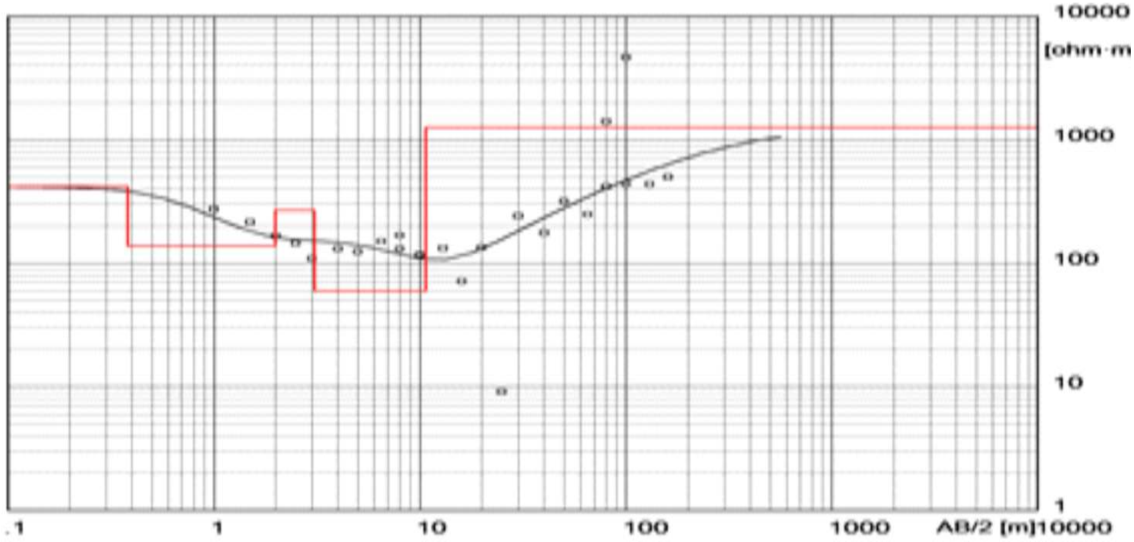
VES 5



Location X = 11.19299 Y = 11.56480

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
280	.57	
52	4.7	.57
150	1.7	5.3
258	29	7
418		36

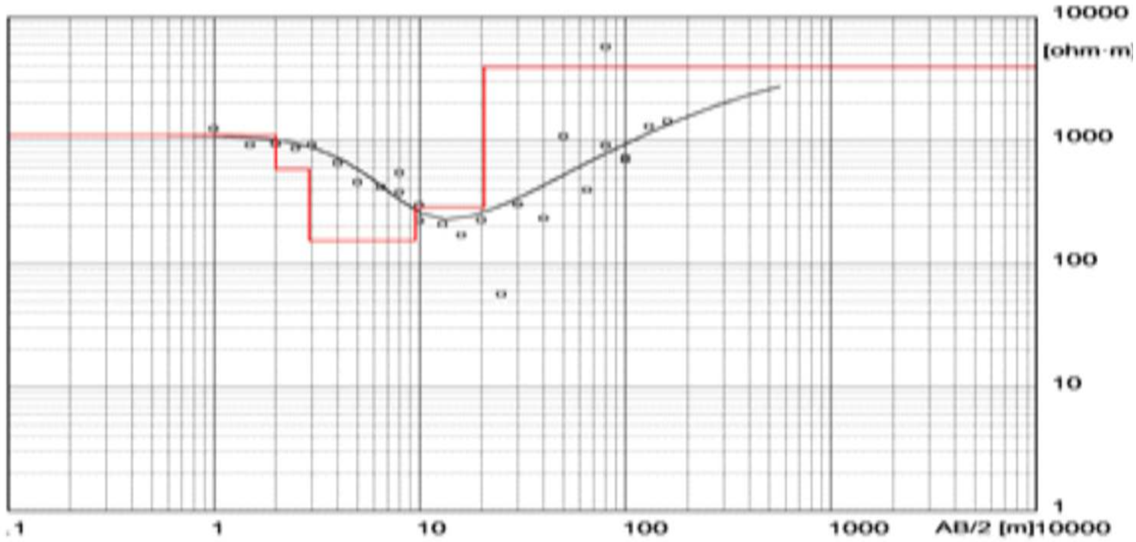
VES 6



Location X = 11.25402 Y = 11.55931

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
419	.38	
138	1.6	.38
268	1.1	2
60	7.6	3.1
1259		11

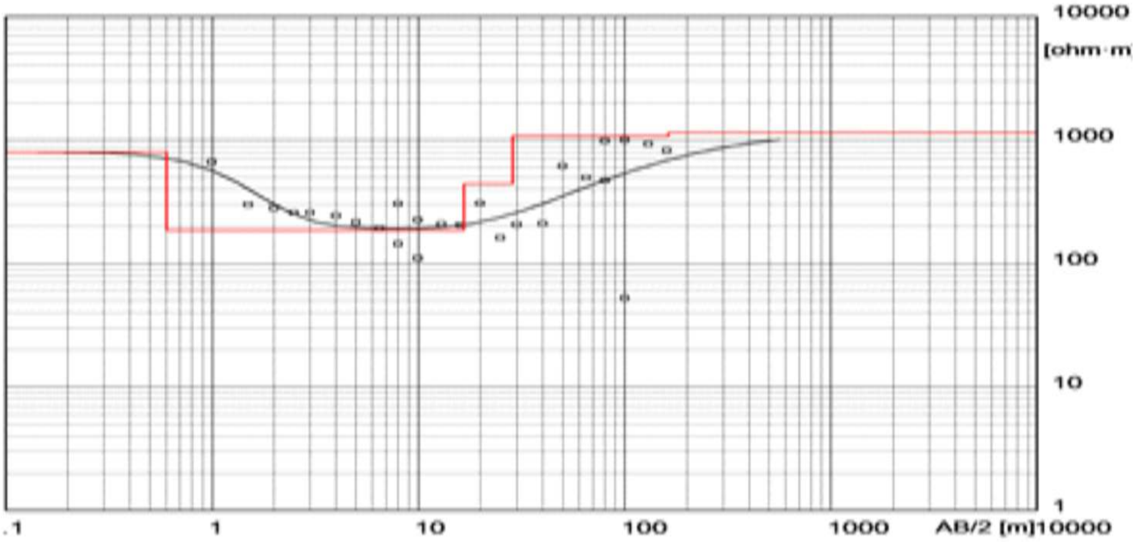
VES 7



Location X = 11.26168 Y = 11.34324

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
1103	2	
585	.9	2
155	6.6	2.9
285	11	9.5
3950		20

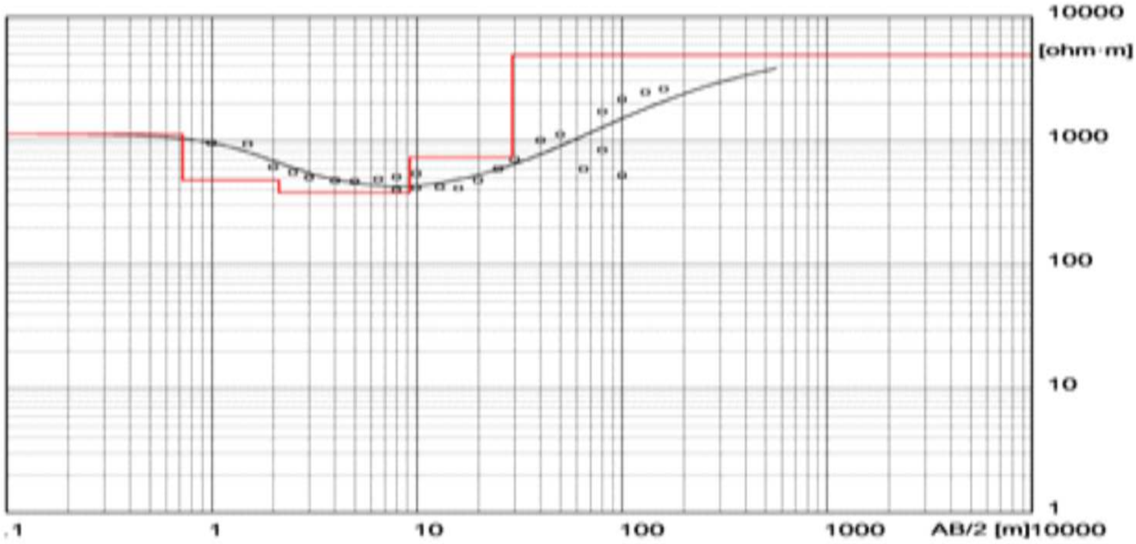
VES 8



Location X = 11.29265 Y = 11.34741

VES 10

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
796	.6	
186	16	.6
439	12	17
1073	134	29
1135		163



Location X = 11.29265 Y = 11.34741

VES 12

Model Resistivity [ohm·m]	Thickness [m]	Depth [m]
1122	.72	
476	1.4	.72
379	7.1	2.1
733	20	9.2
4888		29

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