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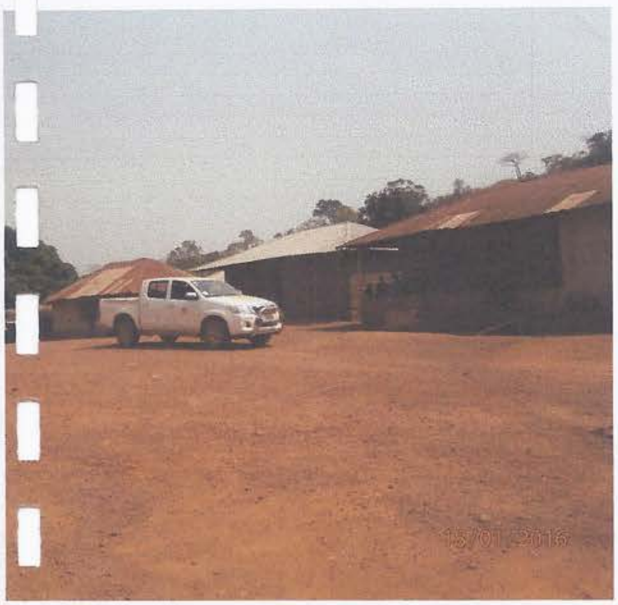
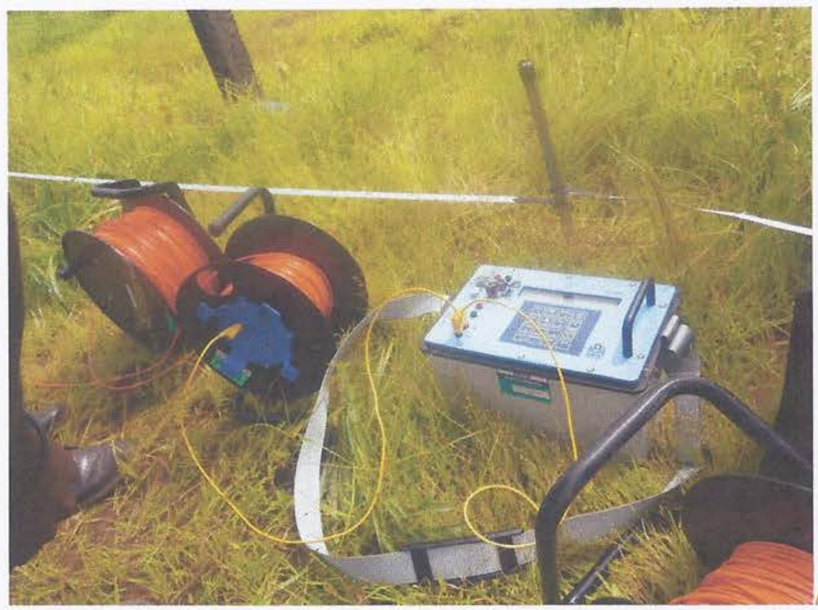


GEOPHYSICAL SITING REPORT

KOINADUGU DISTRICT LOT 2,3



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COMPREHENSIVE SUMMARY

Introduction

This report describes the results of hydrogeological site investigation for Koinadugu District, Northern province Sierra Leone. The aim of the investigations was to locate a suitable boreholes/Shallow well-drilling site of 300m within different areas in the Koinadugu District. To accomplish this, detailed hydrogeological and geophysical investigations have been executed.

Climate

The investigated sites lies within an area that experiences heavy rainfall but the yearly average drops sharply at September. Overall, the climate is hot and oppressive, especially February and March, though on December cool breezed blow with no rain fall. There are two main seasons; the raining season and the dry season.

Geology

The investigated site is found in the Leonean orogenic episode commenced with the intrusion of a basic igneous suite (the Pre-Leonean amphibolites) and by the formation of a greenstone belt represented by the Loko Group which is now deeply eroded. This Group comprises amphibolites, sillimanite quartzites and ironstones. It appears to have formed on a gneiss/granitoid basement in which several granitoid bodies related to an earlier plutonic-orogenic episode, have been distinguished mainly in the northern part of the country. Only the main deformational phase of the Leonean orogenic episode, which resulted in folds and fabrics trending east-west, has been distinguished. Structures that were imparted on the rocks during the older Leonean event were obliterated by the younger Liberian episode and structures. Foliation, banding and veining is a common feature of the synkinematic granites.

Geophysical Fieldwork

Geophysical fieldwork was executed on the 18th December 2015. The Resistivity method was used for the present investigations. Geophysical measurements were used to determine the thickness of the underlying layers, their potential as aquifers, and the expected quantity of groundwater in these formations. Two Vertical Electrical Soundings (VES) was executed at a selected point.

Conclusions

The study concludes that, on the basis of hydrogeological evidence, groundwater prospects in the study area are good. Aquifers are likely to be encountered in the Recent and Pleistocene sediments which form unconfined and semi-confined aquifers and the Tertiary volcanics which form confined aquifers. The aquifers range in depth from 20m to 100m. Groundwater quality in the investigated area is expected to be fairly good.

Recommendations for Drilling

In view of the geophysical results and hydrogeological nature of the study areas, we recommended that a borehole be drilled at the location of VES 1 (pegged with stick) to a maximum depth of 70m.

All the VES sites were pegged during the field investigations and their coordinates were obtained using Global Positioning System (GPS)

Monitoring

Regular monitoring should be done and maintained in the boreholes in order to keep track of groundwater levels.

Borehole Construction

Recommendations are given for borehole construction and completion methods. The importance of correct and comprehensive techniques in this particular aspect cannot be over-emphasized.

TABLE OF CONTENT

GLOSSARY OF TERMS:

Aquifer	A geological formation or structure which transmits water and which may supply water to wells, boreholes or springs.
Confined	Confined aquifers are those in which the piezometric level is higher (that is, at a greater elevation relative to sea level) than the elevation at which the aquifer was encountered.
Recharge	The general term indicating the process of transport of water from surface sources (from rivers or rainfall) to groundwater storage.
bgl	Means below ground level

1. INTRODUCTION

1.1 Background

The Sierra Leone Water Company (SALWACO) which source fund from the Africa Development Bank (ADB) and the Government of Sierra Leone for the implementation of Rural Water Supply Project, contracted Wingin Heavy Duty Machine Company (SL) Ltd., to undertake water exploration in three districts respectively. Namely Kambia 20 boreholes, Koinadugu 31 boreholes and 32 boreholes in Pujehun.

The Client requires detailed information on prospects of drilling production boreholes. The objective of the present study is to assess the availability of groundwater, to recommend borehole drilling sites and comment on aspects of depth to potential aquifers, aquifer availability and type, possible yields and water quantity. For this purpose all available hydrogeological information of the areas have been analyzed, and a geophysical surveys are done.

The investigations involved hydrogeological, geophysical field investigations and a detailed desk study in which the available relevant geological and hydrogeological data were collected, analyzed, collated and evaluated within the context of the Client's requirements.

1.2 Scope of the Work

The scope of works includes:

(i) Site visits to familiarize with the project areas. Identify any issues that might hinder the implementation of works in any of the areas and report to the client.

(ii) To obtain, study and synthesize background information including the geology, hydrogeology and existing borehole data, for the purpose of improving the quality of assessment and preparing comprehensive hydrogeological report.

(iii) To carry out hydrogeological evaluation and geophysical investigations in the selected sites in order to determine potential for groundwater and appropriateness of drilling boreholes at the sites.

2. BACKGROUND INFORMATION

2.1 Location

The study was carried out at Koindugu District, Northern Province of Sierra Leone. The various locality are situated in different villages and chiefdoms, the villages are big, with considerable amount of population and the good part of it is accessible to drilling rig although the road networking is challenging.

The district is situated geological on the Kasila group with different rock formation. The influence of morphology in defining the probability of accumulation of unconsolidated sediments (and therefore potentially suitable layers) cannot be estimated with the same criteria in this area. In that respect, the cross analysis of hydrogeological desk study has being done.

2.2 Physiography, drainage and climate

The District is characterised by a gently undulating landscape, consisting of broad, flat-topped ridges and long and gentle valley slope.

The investigated site lies within an area that experiences two seasons, there is heavy rainfall within the Months of May, June, July and August but the yearly average drops gradually in September, October. Overall, the climate is hot and oppressive, especially in the months of January, February and March, this the time we experience drought.

2.3 Current Water Supply

Currently the communities found within this district found it difficult to get water, people are getting water from unprotected hand dug wells and running streams.

3 GEOLOGY

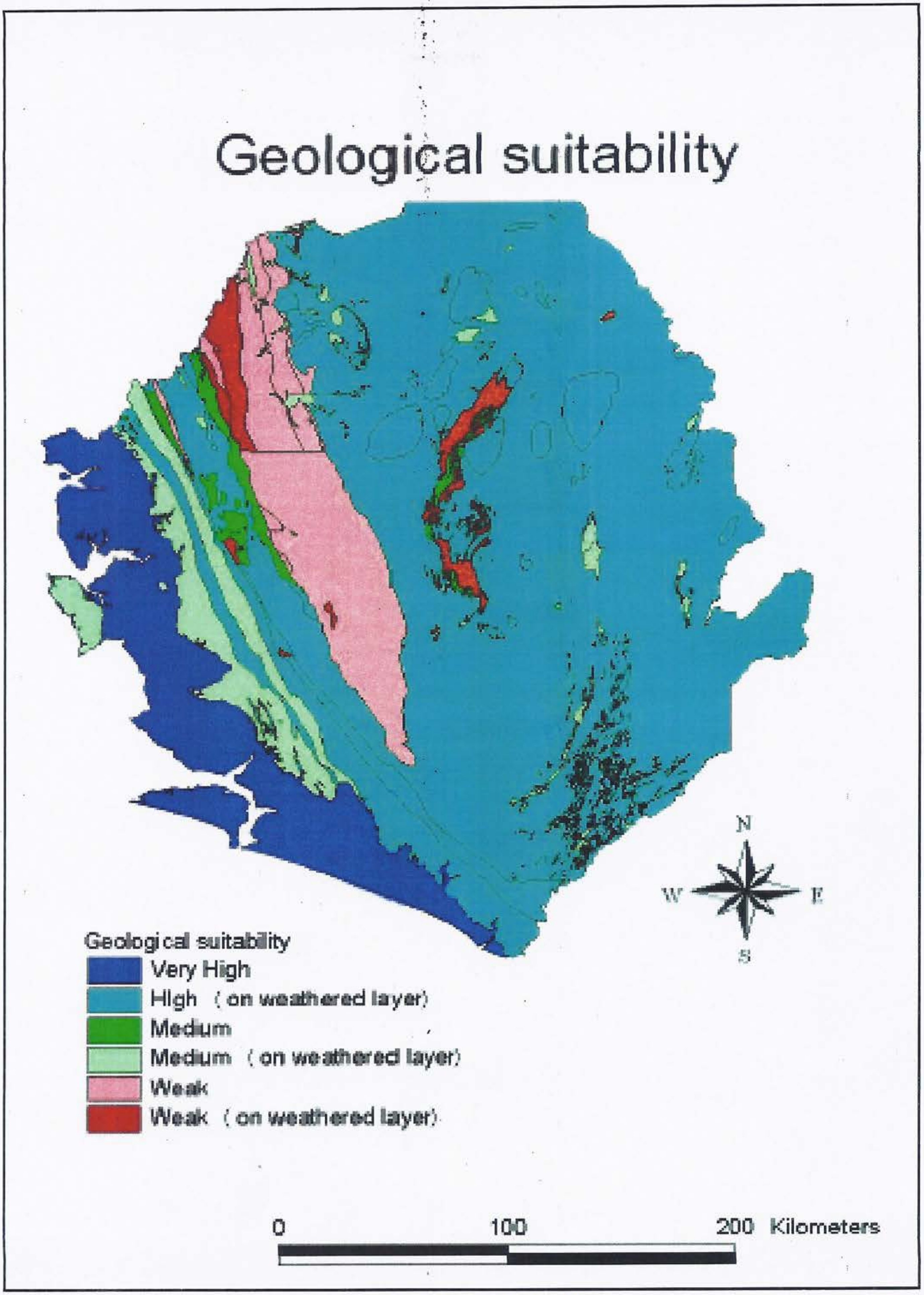
The Kasila Group is a NW–SE trending series of granulites and flanking amphibolites emplaced along the western margin of the West African Craton. It comprises the main outcrop of crystalline schists, gneisses and ganulites of the Liberian complex. The unit is bounded on the east by intrusive granites whilst on the west; it is overlain by sediments, sands and clays of Pleistocene to recent age.

The Kasila Group compries of siliceous gneisses with lesser amounts of charnockites, garnet-hornblende gneisses, garnet-plagioclase gneisses and minor hornblendite and pyroxenite. Protoliths probably included basalt along with siliciclastic and chemical sedimentary rocks metamorphosed to granulite and almandine–amphibolite facies.

The western portion of the group is predominantly amphibolites, gneisses and metasedimentary migmatites , where as the Eastern portion is metabasic and subordinate metasedimentary granulites containing thin layers and lenses of banded iron formation, quartzite and leucogabbro.

3.1Recent

Recent sedimentary deposits that is, debris and fish fauna occurs in the western part of the area and along the main River. The sediments are rather fine grained alluvial and lake deposits consisting of clays and silty sands found at bank of the river.



Map of geological suitability

4. HYDROGEOLOGY.

The hydrogeology of an area is normally intimately dependent upon the nature of the parent rock, structures, weathering process, recharge mechanism and the form and frequency of precipitation.

Drilling in the Leonean Episode within Loko Group rocks and soft sediments in this area has been very successful.

The Amphibolites rocks, owing to their cleavage, easy weathering, and decomposition in general should provide fairly good aquifers.

From the observations made on the existing boreholes in the region, it can be concluded that major water bearing formations are as follows.

Sedimentary deposits along the drainage basins, fault zones in all the rock formations and fractured/weathered rocks.

In general groundwater in volcanic rocks is limited to fractures, weathering and erosional levels (old land surfaces) within the volcanic succession. Lavas are generally not water bearing because of their unfractured and impervious character.

4.1 Hydrogeology of the Investigated Area

The suitability of the formations in the investigated area, which are basically volcanic and volcano sedimentary in origin, as aquifers depend largely on the development of secondary structures mainly faults, their subsurface extent and interconnection to other similar structure on regional scale. Another major factor is the degree of weathering of these Leonean rocks and their porosity. The major aquifers in the area are however confined to weathered Amphibolites. The investigated area is located in a hydrogeological zone, which is characterized by medium to high groundwater potential. The aquifers in the area occur in the syntectonic (Synkenematic) deposits, it appears to have formed on a gneiss/granitoid basement in which several granitoid bodies related to an earlier plutonic-orogenic episode, have been distinguished mainly in the northern part of the country. Weathered and fractured rocks overlying the Basement system rocks at much greater depths. A significant groundwater discharge occurs in the faulted, fractured and weathered zones of these rogks. Shallow aquifers occur at the contact zone between the weathered/fractured rocks.

The occurrence of the aquifers can be summarised as follows:

Weathered layer

Fault and fractured zones

Sedimentary deposits.

4.2 Catchment Area and Rainfall

The catchment area is characterized by the rivers, catchment covering a large area on the north to the west and shares international boundary.

For the purposes of water balance calculations, it cannot be done due to the complexity of the geology of the area and lack of adequate borehole drilling data, which also makes it difficult to estimate the recharge in the project areas.

Groundwater Flow: Although there is no data to draw piezometric maps, it can be deduced that groundwater flows from the Leonean rocks and Basement aquifer to the sedimentary aquifer in the river. During high rainfall, water percolates from the surface down to the groundwater aquifer storage. The groundwater level rises and the aquifer expands both laterally and vertically.

During periods of moderate rainfall, subsurface outflow from the area occurs through base flow along ephemeral drainage channels and groundwater flow from the aquifer into the alluvial plains. During low rainfall periods no surface outflow is observed. The aquifer discharges water only through slow groundwater flow, and evapotranspiration. During the dry season no recharge is experienced and the aquifer maintains its low salinity through hydrodynamic balance in such a way that the aquifer shrinks in size laterally and there is vertical decline in water levels.

4.3 Recharge

Ground water recharge: When rainfall, runoff soil moisture changes and evapotranspiration data is known, the amount of water which is yearly added to the permanent ground can be estimated (recharge). For an accurate water balance calculations very precise and extensive hydrological data of the concerned area is required, which is rarely available. The present water balance study can only be regarded as estimation.

One of the recharge areas for the aquifers is formed from the hills area. Here water percolates directly into the faults and cracks within the rocks through which deeper and adjacent units are recharged over time.

4.4 Discharge

Discharge paths in the investigated area are reflected in geology, land use and cover type, and fall into one of the following categories:

Interception, transpiration and evaporation of rainfall; this covers all losses from rainwater before it leaves the rainfall part of the hydrological cycle and becomes either runoff or percolation water. Transpiration losses (vegetal metabolism) in the area have also a great effect.

1. Direct losses from open water bodies i.e. rivers and streams.

2. Direct losses from human and wildlife activities; in these area, these losses comprise a relatively significant sub – cycle, especially as direct abstraction from shallow wells, Rivers springs and boreholes for irrigation and domestic uses.

3. Deep percolation; it has long been suspected that there is a very deep outlet from the region.

From the hydrogeological study the total effective discharge from the aquifer via either of the above means for this area is not available. However, it should be noted that there is no possibility of irrevocable physical damage to the aquifers resulting from abstraction.

4.5 Groundwater Quality

Water analyses carried out on a large number of ground water samples by the Ministry of Water Resources showed that the physical and chemical quality of the water is generally good and can be used without any treatment in most parts of the investigated area though with increasing human activity, most of the surface and shallow ground water have being contaminated. Occasionally the ground water may contain high concentration of iron and manganese, which gives a bitter taste to the water, and may cause stains on laundry.

5. GEOPHYSICAL INVESTIGATION METHODS.

A variety of methods are available to assist in the assessment of geological sub-surface conditions. The main emphasis of the fieldwork undertaken was to determine the thickness and composition of the sub-surface formations and to identify water-bearing zones.

This information was principally obtained in the field using, Vertical Electrical Soundings (VES)

The VES probes the resistivity layering below the site of measurement. This method is described below.

5.1 Resistivity Method

Vertical Electrical Soundings (VES) were carried out to probe the condition of the sub-surface and to confirm the existence of deep groundwater. The VES investigates the resistivity layering below the site of measurement. This technique is described below.

5.2 Principles

The electrical properties of rocks in the upper part of the earth's crust are dependent upon the lithology, porosity and the degree of pore space saturation and the salinity of the pore water. Saturated rocks have lower resistivity values than unsaturated and dry rocks. Higher the porosity of saturated rocks, or higher the salinity of saturating fluids, the lower the resistivity values. The presence of clays and conductive minerals also reduces the resistivity of the rock. The resistivity of earth materials can be studied by measuring the electrical potential distribution produced at the earth's surface by an electric current that is by passing current through the earth.

5.3 Vertical Electrical Sounding (VES)

When carrying out a resistivity sounding, current is led into the ground by means of two electrodes. With two other electrodes, situated near the centre of the array, the potential field generated by the current is measured.

From the observations of the current strength and the potential difference, and taking into account the electrode separations, the ground resistivity can be determined.

During a resistivity sounding, the separation between the electrodes is step-wise increased (in what is known as a Schlumberger Array), thus causing the flow of current to penetrate greater depths. When plotting the observed resistivity values against depth on software (IX1D), a resistivity graph is formed, which depicts the variation of resistivity with depth. This graph can be interpreted with the aid of a computer, and the actual resistivity layering of the subsoil is obtained. The depths and resistivity values provide the hydrogeologist with information on the geological layering and thus the occurrence of groundwater.

6. FIELDWORK AND RESULTS

6.1 Fieldwork

Fieldwork was carried out. Two Vertical Electrical Sounding (VES) was executed in order to unveil the hydrostratigraphy of the area. The hydrogeological conditions of the investigated site in general are considered to be fairly uniform and the results of the VES are representative of the prevailing stratigraphy of the investigated site.

6.2 Resistivity Soundings Results Interpretation

The VES interpretation results indicate a shallow superficial layer to a depth of less than 5m bgl. The resistivity of this layer ranges between 1000 and 3000 Ohm-m interpreted to be sandy soils and dry clays. This is underlain by a 300 to 400 Ohm-m resistivity layer to a depth of 20m bgl, interpreted to be slightly weathered volcanic rocks at VES 1 and VES 2. Below this layer lies a 4000 Ohm-m to a depth greater than 50m bgl interpreted to be fresh rocks and no water strikes are expected in this layer.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Based on the available information and the geophysical investigations it is concluded that the project area is located in an area, which is considered to have medium to good groundwater potential. Productive aquifers are expected within weathered/fractured rocks. Shallow aquifers are expected above 40m. The water quality is expected to be within the recommended WHO limits.

7.2 Recommendations

7.3 Drilling

In view of the above it is recommended that:

- It is proposed to drill at 40m as normal minimum drilling depth and 70m as normal maximum drilling depth which shall only be exceeded under tropical circumstances and when drilling takes in rocks under sediment found in the drilling site. In the extreme situation, the drill depth may go to maximum of 100m but not beyond.
- There should be an experienced hydrogeologist to monitoring the drilling process for cost effective borehole.

All the VES sites were pegged during the field investigations and their coordinates were obtained using Global Positioning System (GPS) and were shown to the community people.

8. REFERENCES .

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Dobrin M.B. and C.H. Savit 1988. Introduction to Geophysical prospecting, Fourth Edition. McGraw-Hill Books: New York, NY.

Culver and Williams, 1979 S.J. Culver and H.R. Williams, Late Precambrian and Phanerozoic geology of Sierra Leone

Republic of Sierra Leone Ministry of Energy and Water Resources feasibility study for manual drilling, mapping of favourable zones.

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Appendix 1:

Drilling

Drilling Technique

Drilling should be carried out with an appropriate tool - either percussion or rotary machines will be suitable, though the latter are considerably faster. However due to unstable sub ground condition mud drilling is the most suitable method. Geological rock samples should be collected at 2 metre intervals. Struck and rest water levels and if possible, estimates of the yield of individual aquifers encountered, should also be noted.

Borehole Design

The design of the well should ensure that screens are placed against the optimum aquifer zones. An experienced hydrogeologist should make the final design.

Casing and Screens

The well should be cased and screened with good quality material. Owing to the shallow depth of the boreholes, it is recommended to use standard casings and screens of high quality open surface area.

We strongly advise against the use of torch-cut steel well-casing as screen. In general, its use will reduce well efficiency (which leads to lower yield), increase pumping costs through greater drawdown, increase maintenance costs, and eventually reduction of the potential effective life of the well.

Gravel Pack

The use of a gravelpack is recommended within the aquifer zone, because the aquifer could contain sands or silts which are finer than the screen slot size. An 8" diameter borehole screened at 6" will leave an annular space of approximately 1", which should be sufficient. Should the slot size chosen be too large, the well will pump sand, thus damaging the pumping plant, and leading to gradual `siltation' of the well. The slot size should be in the order of 1.5 mm. The grain size of the gravel pack should be an average 2 - 4 mm.

Borehole Construction

Once the design has been agreed, construction can proceed. In installing screen and casing, centralizers at 6m intervals should be used to ensure centrality within the borehole. This is particularly important for correct insertion of artificial gravel pack all around the screen. After installation, gravel packed sections should be sealed off top and bottom with sealing material (2m).

The remaining annular space should be backfilled with an inert material, and the top five metres grouted with cement to ensure that no surface water at the well head can enter the well bore and cause contamination.

Borehole Development

Once screen, pack, seals and backfill have been installed, the well should be developed. Development aims at repairing the damage done to the aquifer during the course of drilling by removing clays and other additives from the borehole walls. Secondly, it alters the physical characteristics of the aquifer around the screen and removes fine particles.

We do not advocate the use of overpumping as a means of development since it only increases permeability in zones which are already permeable. Instead, we would recommend the use of air or water jetting, or the use of the mechanical plunger, which physically agitates the gravel pack and adjacent aquifer material. This is an extremely efficient method of developing and cleaning wells.

Borehole development is an expensive element in the completion of a borehole, but is usually justified in longer borehole-life, greater efficiencies, lower operational and maintenance costs and a more constant yield. Within this frame the pump should be installed at least 2 m above the screen, certainly not at the same depth as the screen.

Borehole Testing

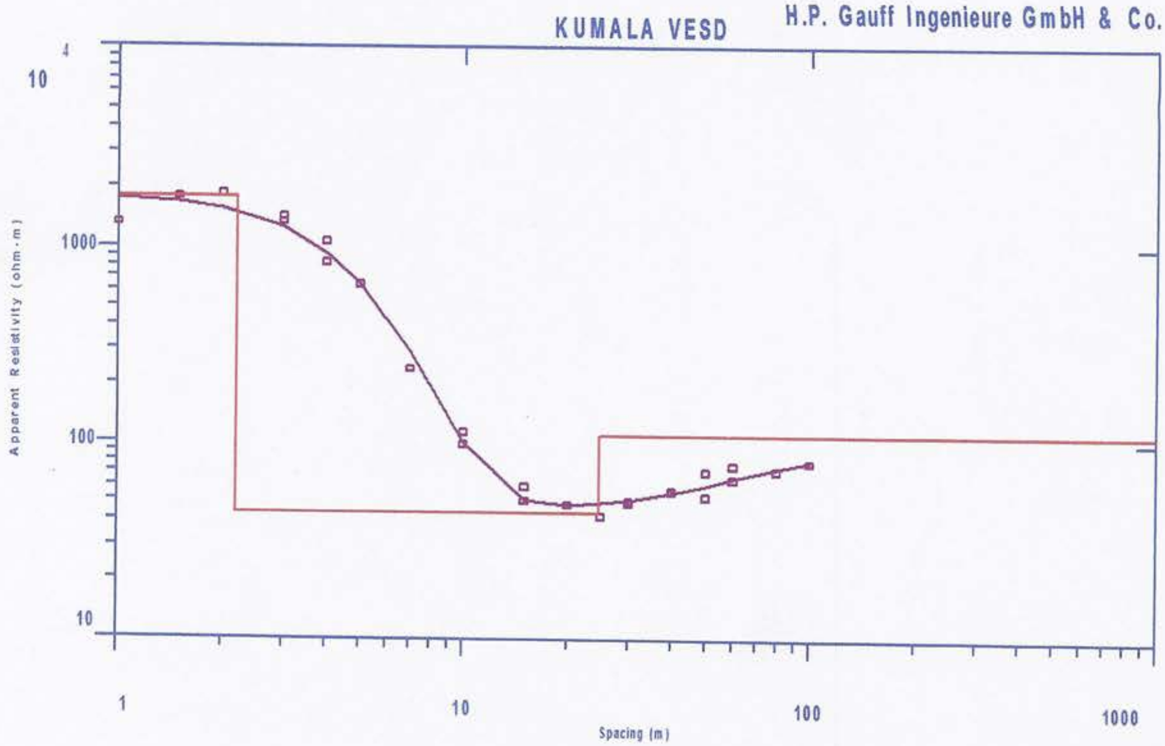
After development and preliminary tests, a long-duration borehole test should be carried out. Borehole tests have to be carried out on all newly-completed boreholes, because apart from giving an indication of the quality of drilling, design and development, it also yields information on aquifer parameters which are vital to the hydrogeologist.

A borehole test consists of pumping a borehole from a measured start level (Water Rest Level - (WRL) at a known or measured yield, and simultaneously recording the discharge rate and the resulting drawdowns as a function of time. Once a dynamic water level (DWL) is reached, the rate of inflow to the well equals the rate of pumping. Usually the rate of pumping is increased step wise during the test. The results of the test will enable a hydrogeologist to calculate the optimum pumping rate, the pump installation depth, and the drawdown for a given discharge rate.

THE TABLE BELOW SHOWS THE GPS COORDINATES OF THE VARIOUS LOCALITIES IN KOINADUGU DISTRICT, NORTHERN PROVINCE

Item	Location	Definate GPS Values(option 1)		Alternative GPS Values(option 2)	
		Northing	Easting	Northing	Easting
1	Fadugu, Kasanko C/dom	0196206	1039379	0196177	1039308
2	Kasanikoro, Kasanko C/dom	0183524	1059940	0183465	1059950
3	Heremakono, C/dom	0215090	1051596	0215130	1051560
4	Koinadugu, Sengbe C/dom	0239988	1054996	0239931	1054976
5	Firawa, Nene C/dom	0247190	1035388	0247206	1035339
6	Yiraia, Sengbe C/dom	0252342	1045700	0252287	1045684
7	Gbenekoro, Sengbe C/dom	0228626	1064867	0228574	1064872
8	Dankawali, Sengbe C/dom	0244413	1065520	0244361	1065527
9	Serekolia, Mongo C/dom	0271922	1054943	0271966	1054905
10	Mongo Bendugu, Mongo C/dom	0285100	1054589	0285135	1054541
11	Kombilie, Mongo C/dom	0270014	1072098	027009	1072198
12	Komdembaya, Diang C/dom	0218244	1037898	0218260	1037823
13	Foria, Diang C/dom	02230086	1023396	0230049	1023427
14	Alkalia, Neini C/dom	02237563	1012692	0237506	1012698
15	Yiffin, Neini C/dom	0250170	1009062	0250145	1009107
16	Kumala, Neini C/dom	0235404	1003083	0235460	1003085
17	Sumbabia, Neini C/dom	0243263	0977116	0243283	0977159
18	Mansofina, Neya C/dom	0276262	1004350	0276288	1004381
19	Kurubola, Neya C/dom	0285958	1017075	0285998	1017118
20	Masadu, Mongo C/dom	0309082	1035577	0309048	1035558

THE TABLE BELOW SHOWS THE GPS COORDINATES OF THE VARIOUS LOCALITIES IN KOINADUGU DISTRICT, NORTHERN PROVINCE					
Item	Location	Definate GPS Values(option 1)		Alternative GPS Values(option 2)	
		Northing	Easting	Northing	Easting
21	Seria, Mongo C/dom	0288758	1046870	0288707	1046871
22	Falaba, Sulima C/dom	0245389	1090128	0245396	1090154
23	Ganya, Sulima C/dom	0249518	1099019	0249550	1099018
24	Sinkunia, Dembelia Sinkunia c/dom	0233572	1091405	0233594	1091441
25	Gbentu, Folosaba Dembelia C/dom	0209996	1100061	0209978	1100021
26	Kambalia, Wara Wara Bafodia C/dom	0188112	1087492	0188074	1087477
27	Bafodia, Wara Wara Bafodia C/dom	0200235	1071898	0200235	1071860
28	Gbindi, Dembelia C/dom	0231997	1097006	0232006	1096968
29	Koromasilaya, Folosaba Dembelia C/dom	0218735	1068767	0218681	10687661
30	Senekedugu, Wara Wara Yagala	0219788	1064799	0219743	1064821
31	Yarawadu, Neya C/dom	0285913	1017050	0285992	1017108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H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
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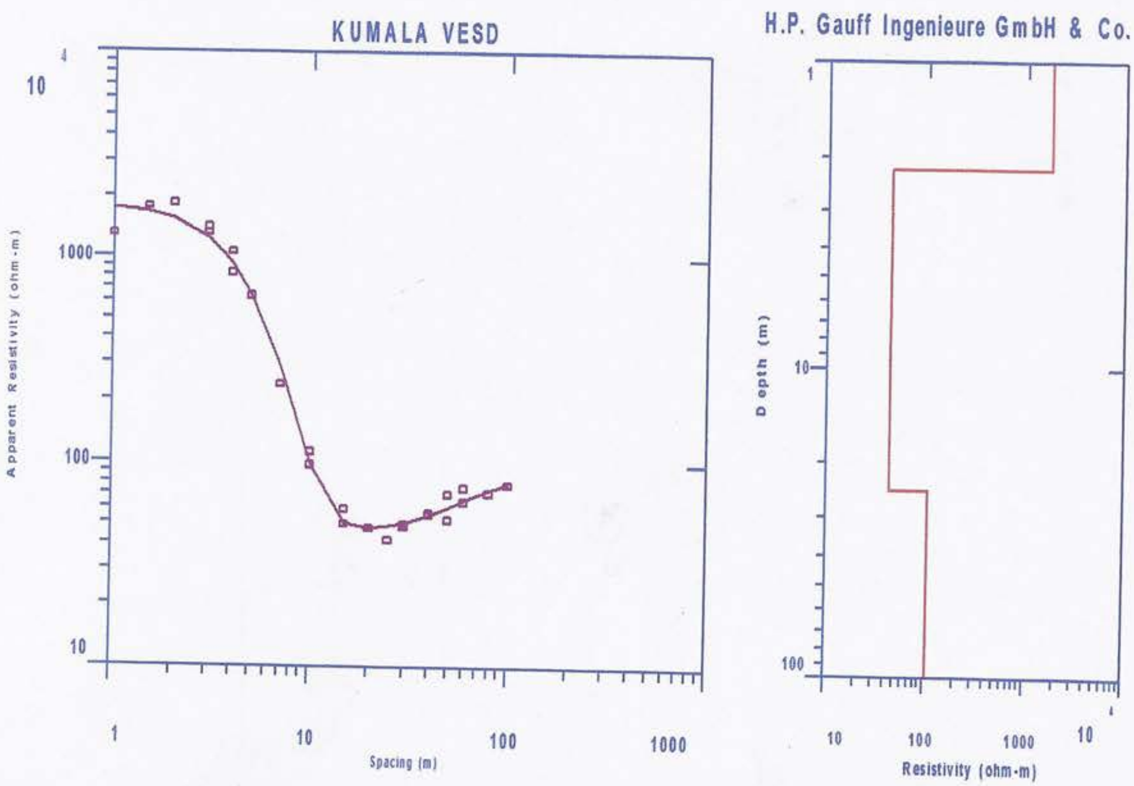
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H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
Spacing (m)
Depth (m)
Resistivity (ohm-m)
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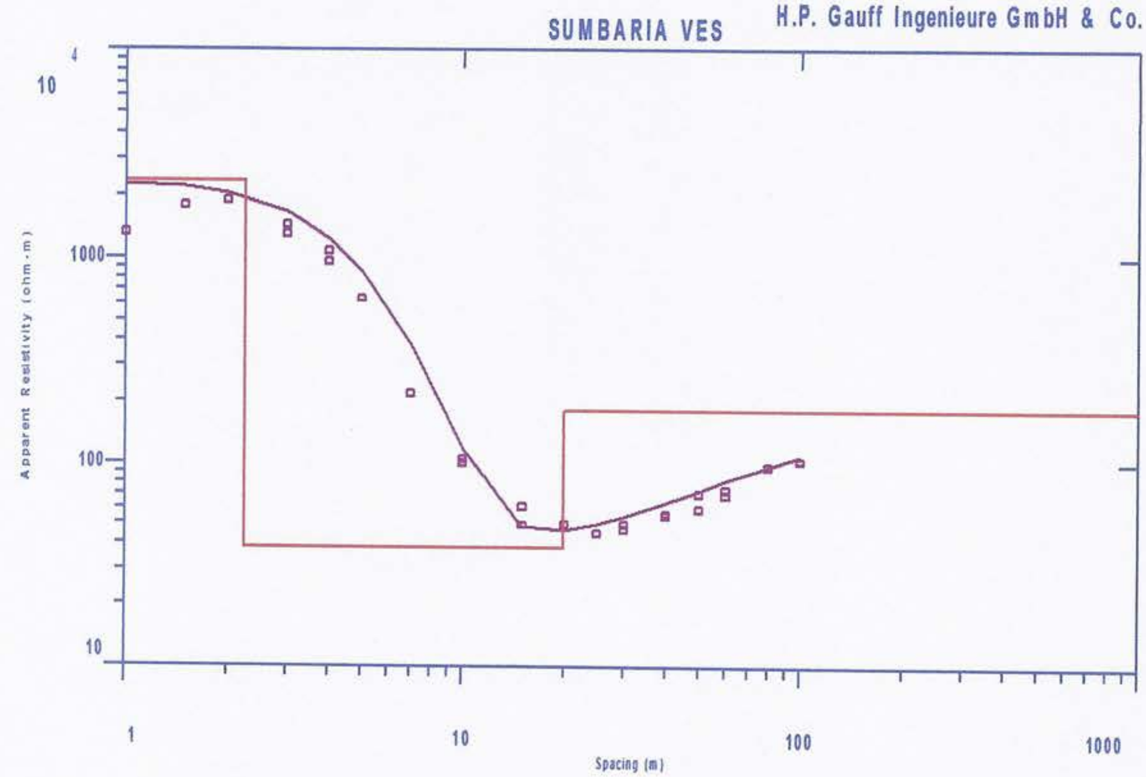
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Apparent Resistivity (ohm-m)
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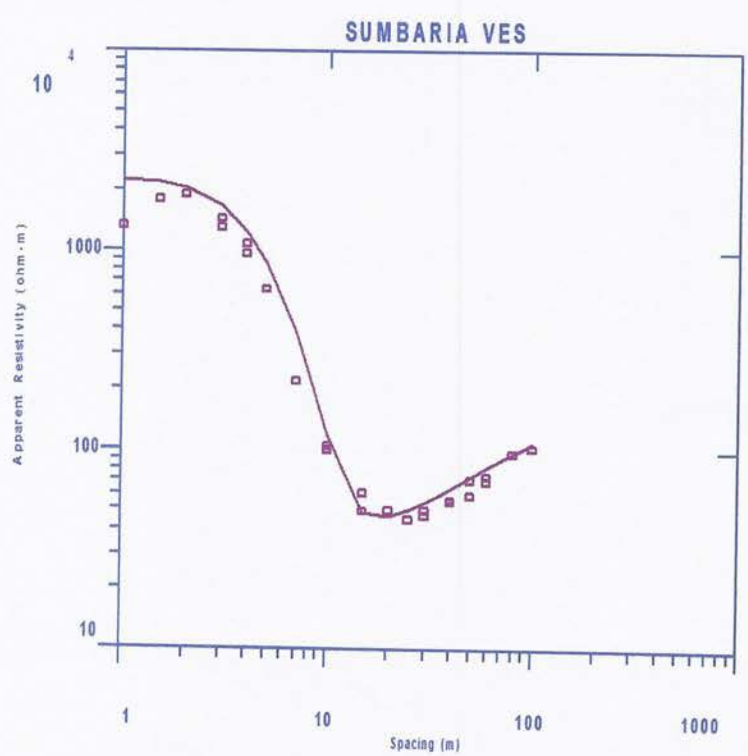
Spacing (m)


SUMBARIA VES
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Apparent Resistivity (ohm-m)
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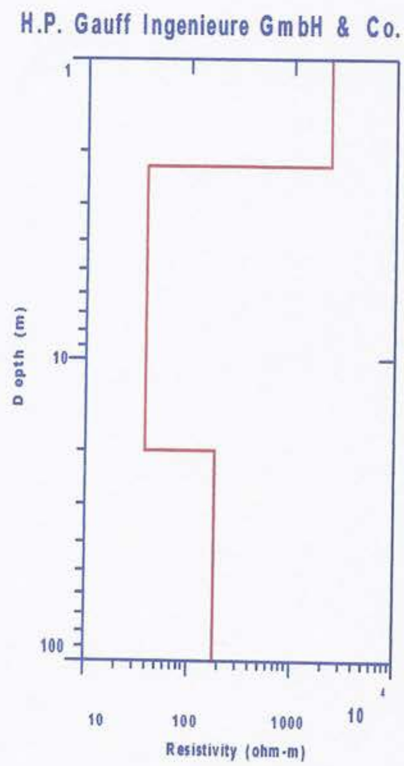
Spacing (m)


H.P. Gauff Ingenieure GmbH & Co.
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Depth (m)
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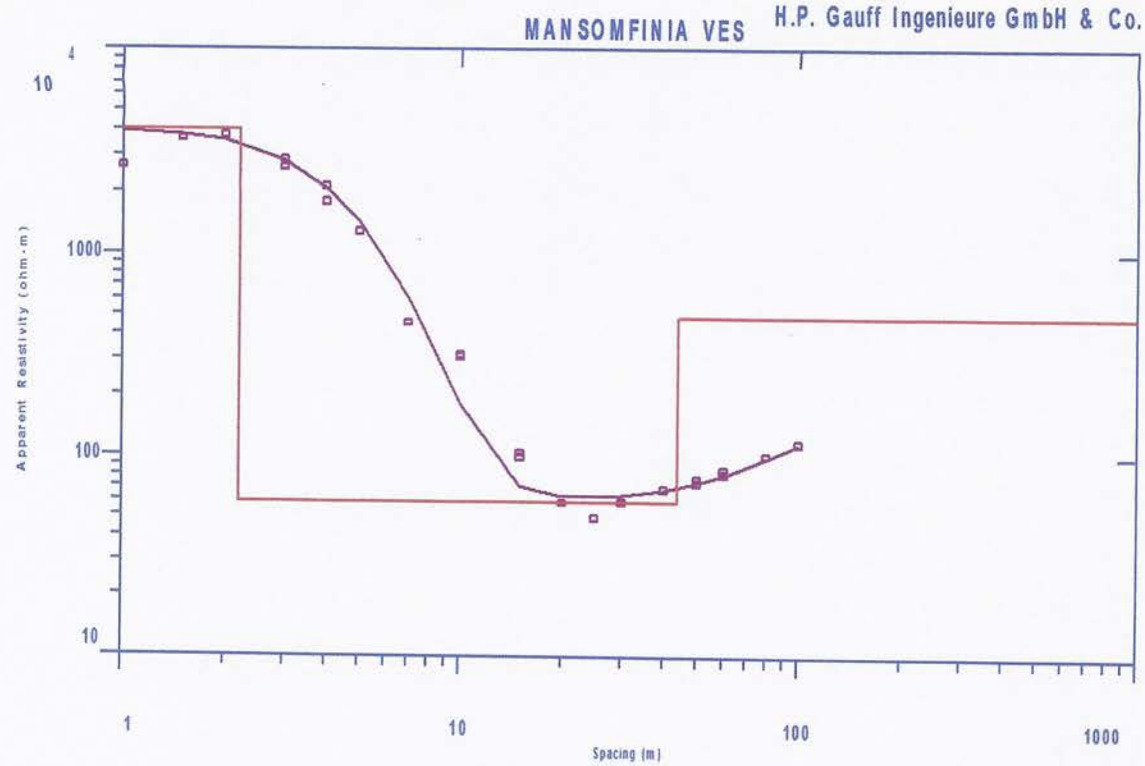
Resistivity (ohm-m)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H.P. Gauff Ingenieure GmbH & Co.
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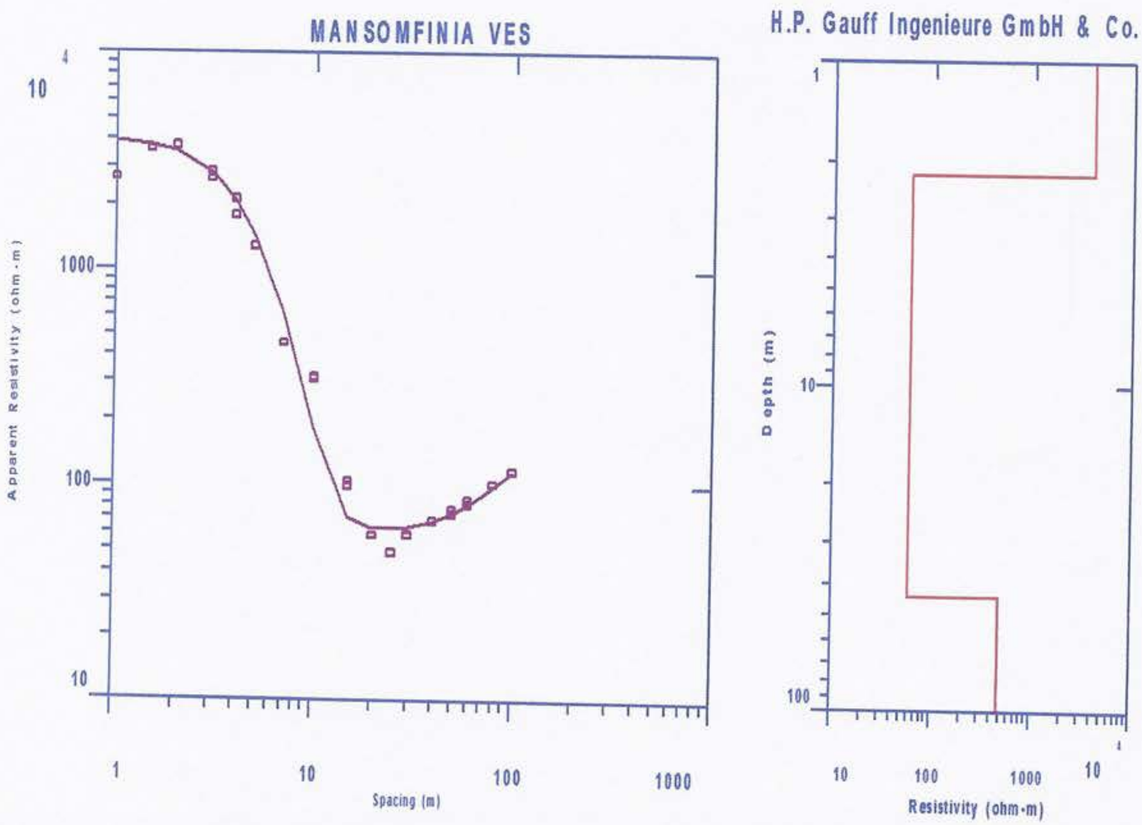
MANSOMFINIA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm·m)
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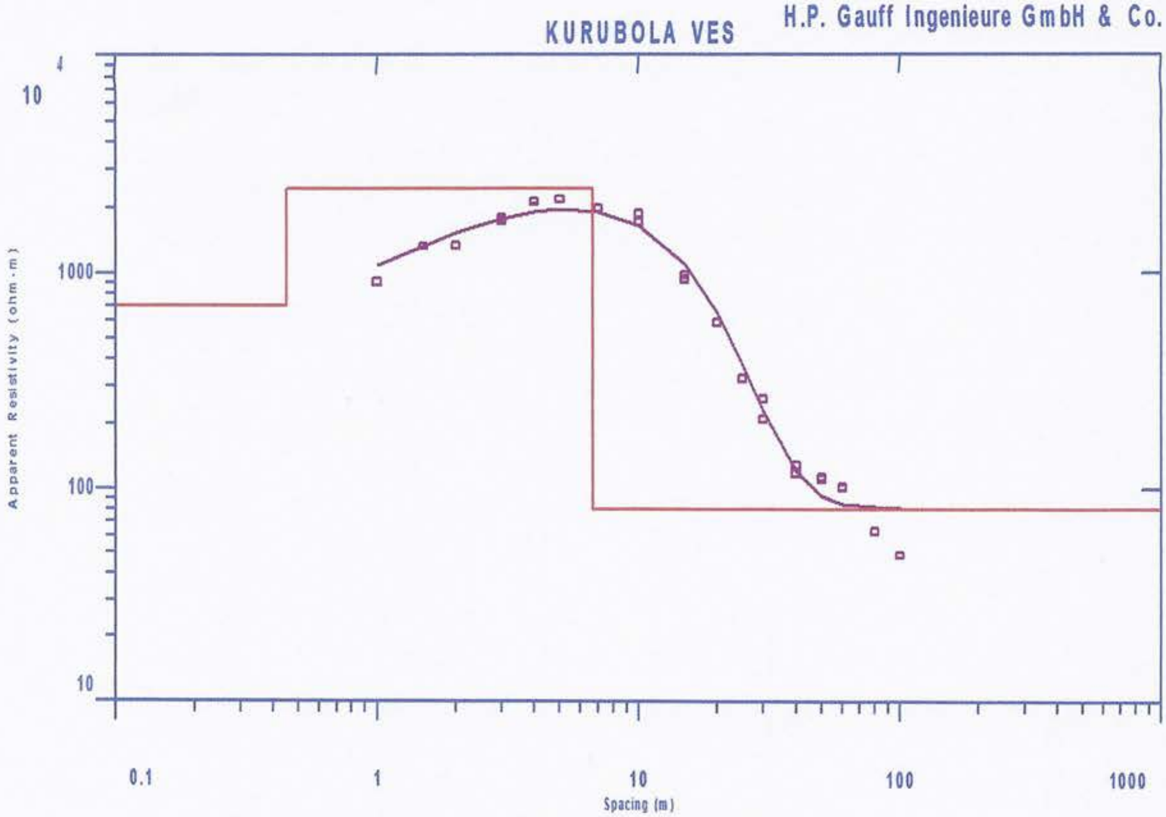
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H.P. Gauff Ingenieure GmbH & Co.
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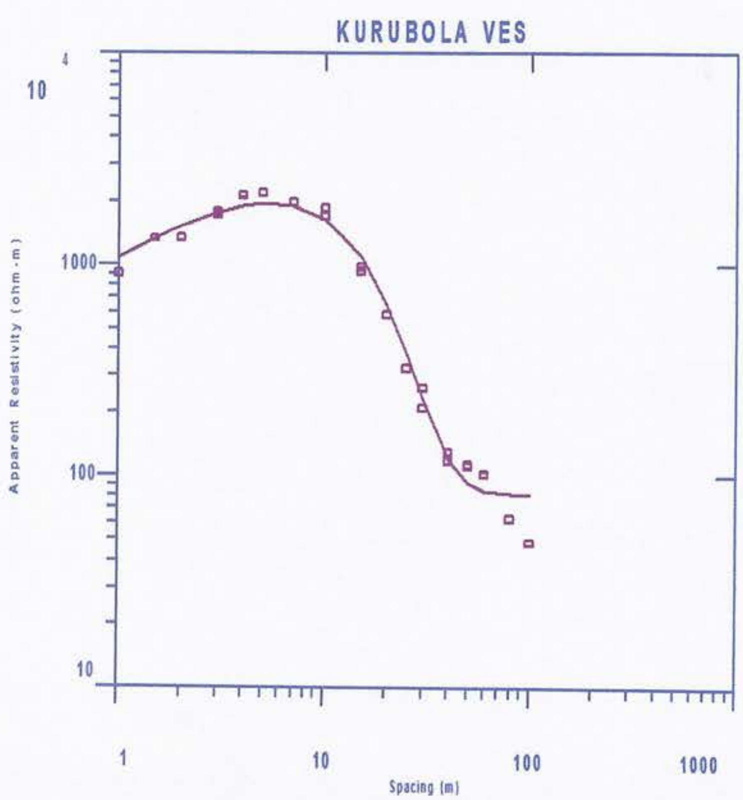
KURUBOLA VES
Apparent Resistivity (ohm-m)
Spacing (m)
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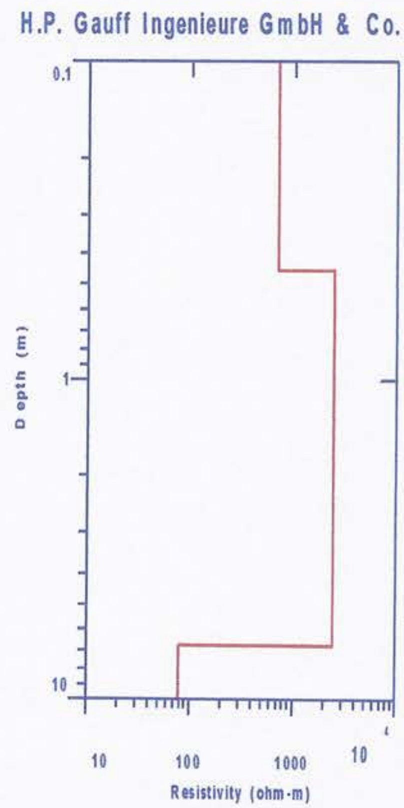
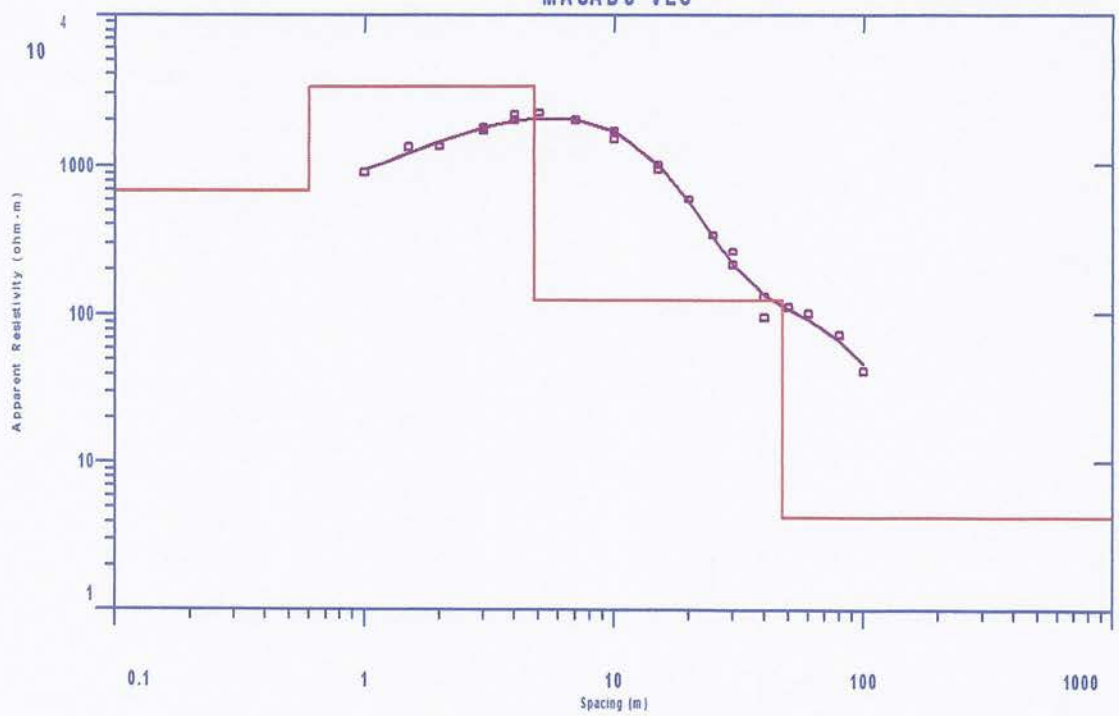
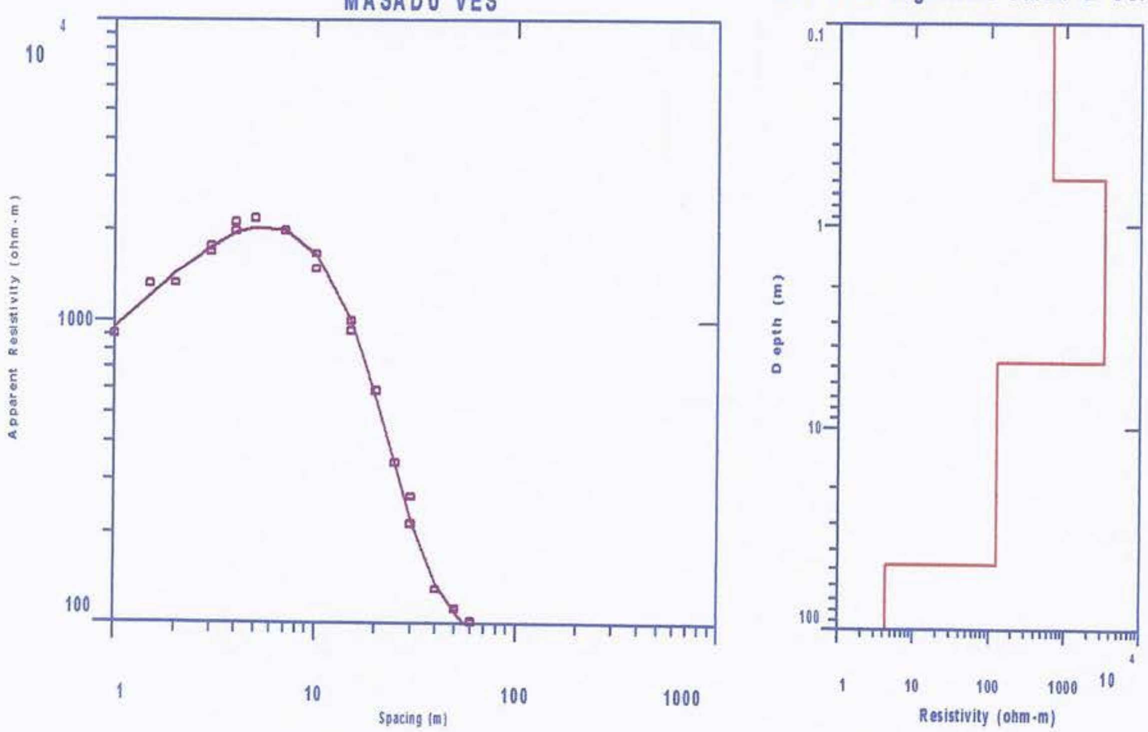
10
100
1000
10
100
1000

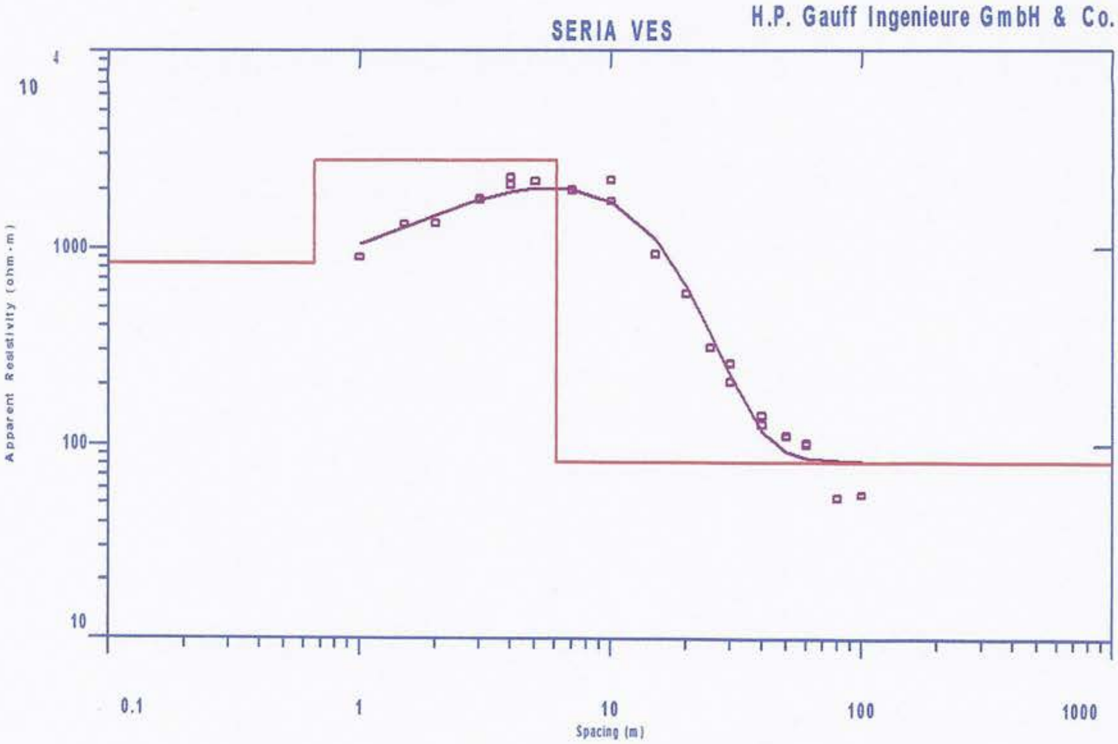

H.P. Gauff Ingenieure GmbH & Co.
Depth (m)
Resistivity (ohm-m)
0.1
1
10
10
100
1000

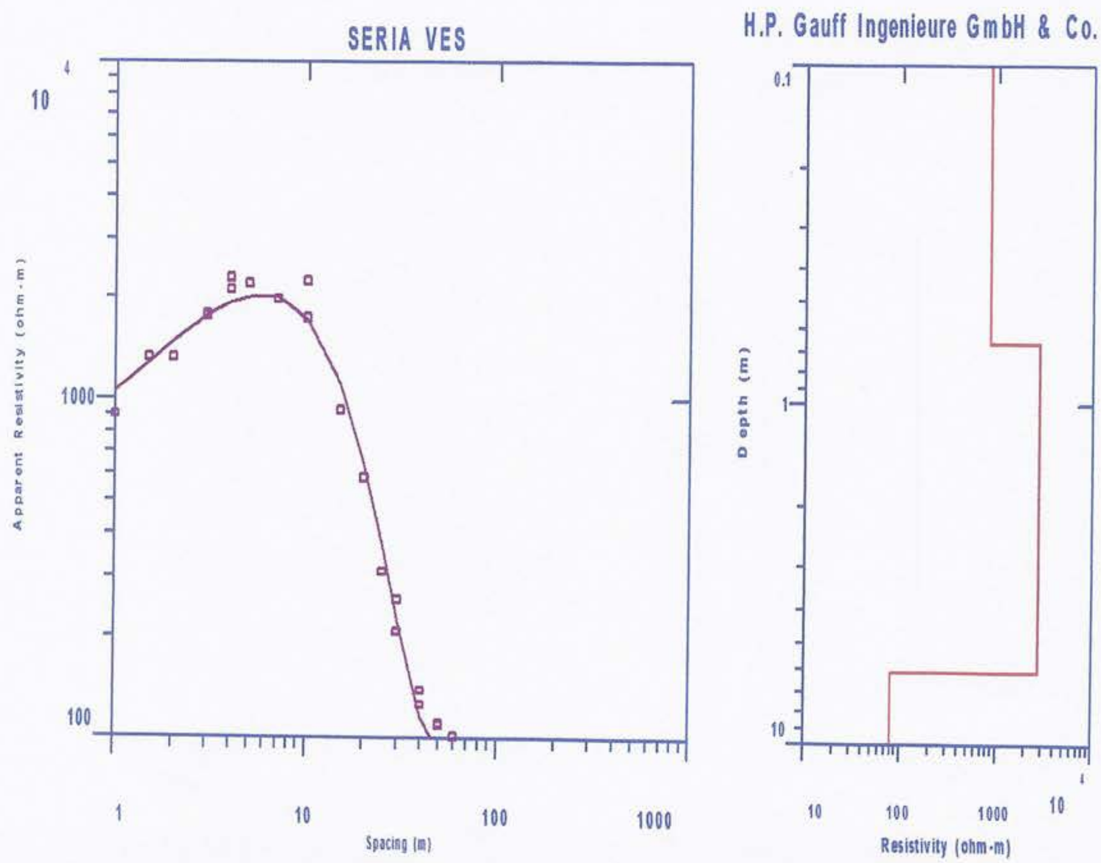
MASADU VES — H.P. Gauff Ingenieure GmbH & Co.



MASADU VES — H.P. Gauff Ingenieure GmbH & Co.

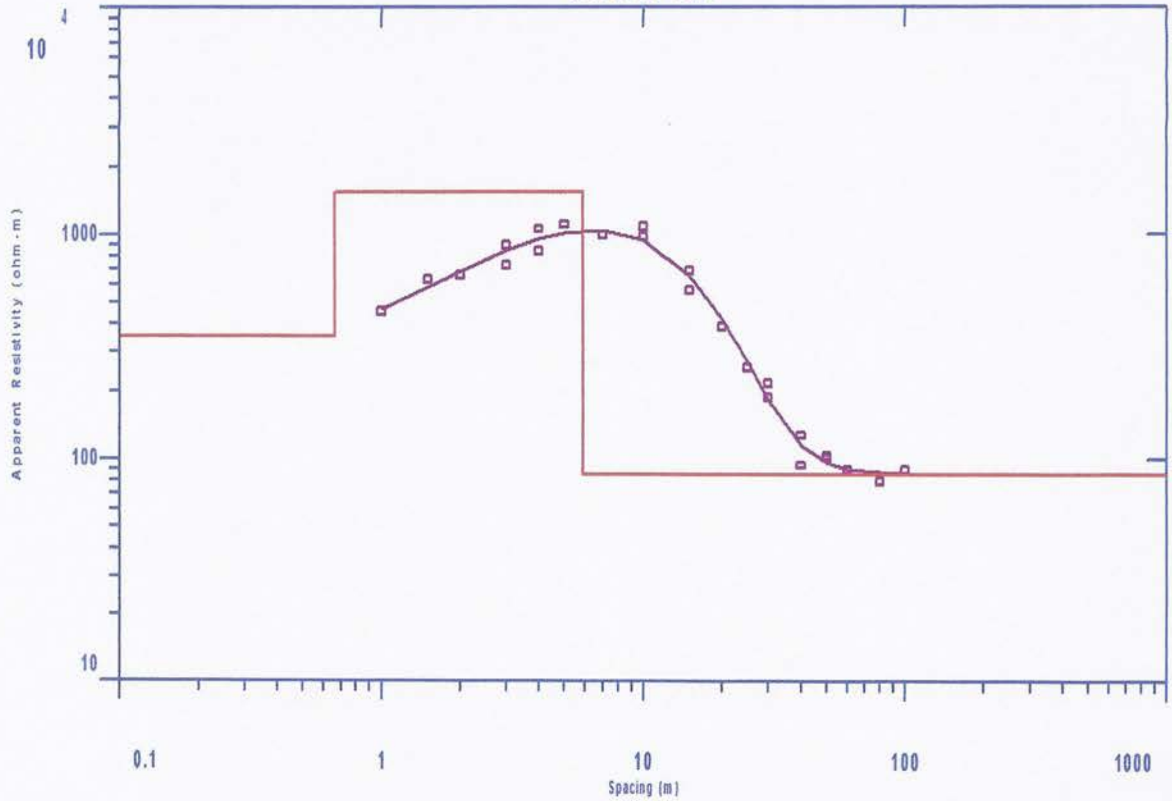



H.P. Gauff Ingenieure GmbH & Co.
SERIA VES
Apparent Resistivity (ohm-m)
10⁴
1000
100
10
0.1
1
10
100
1000
Spacing (m)


SERIA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10⁴
1000
100
1
10
100
1000
Spacing (m)
Depth (m)
0.1
1
10
10
100
1000
10⁴
Resistivity (ohm-m)

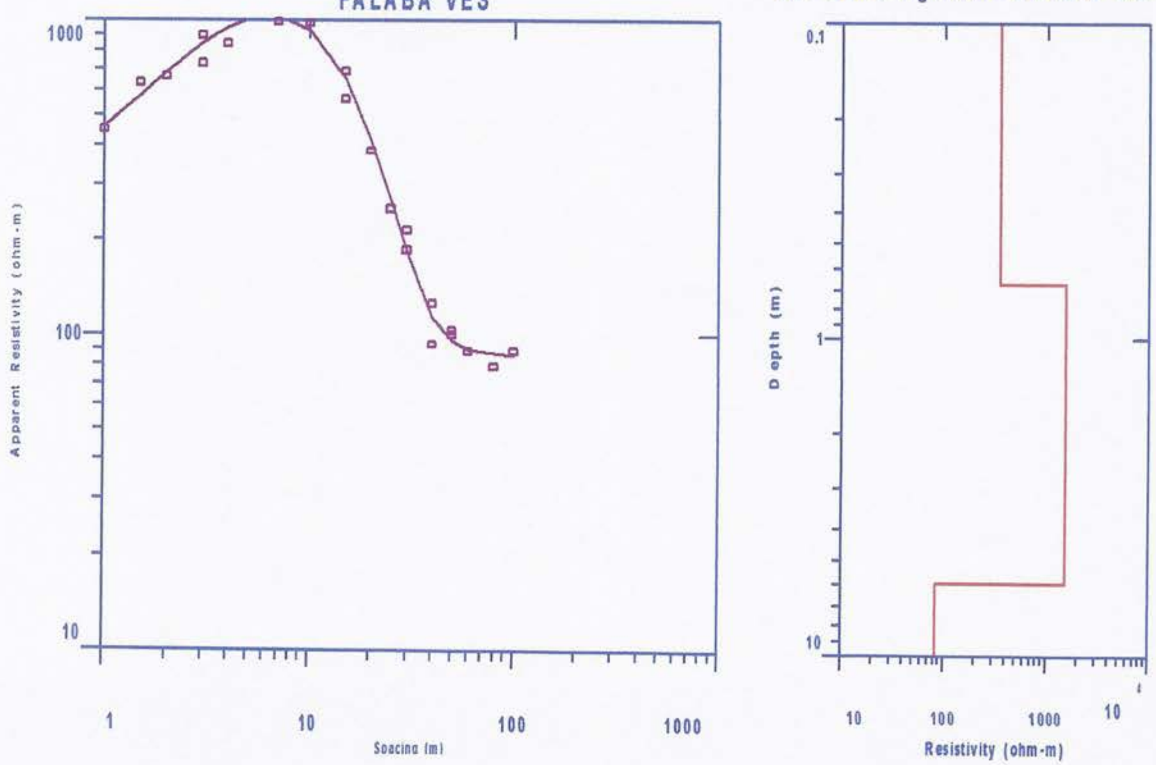
H.P. Gauff Ingenieure GmbH & Co.

FALABA VES



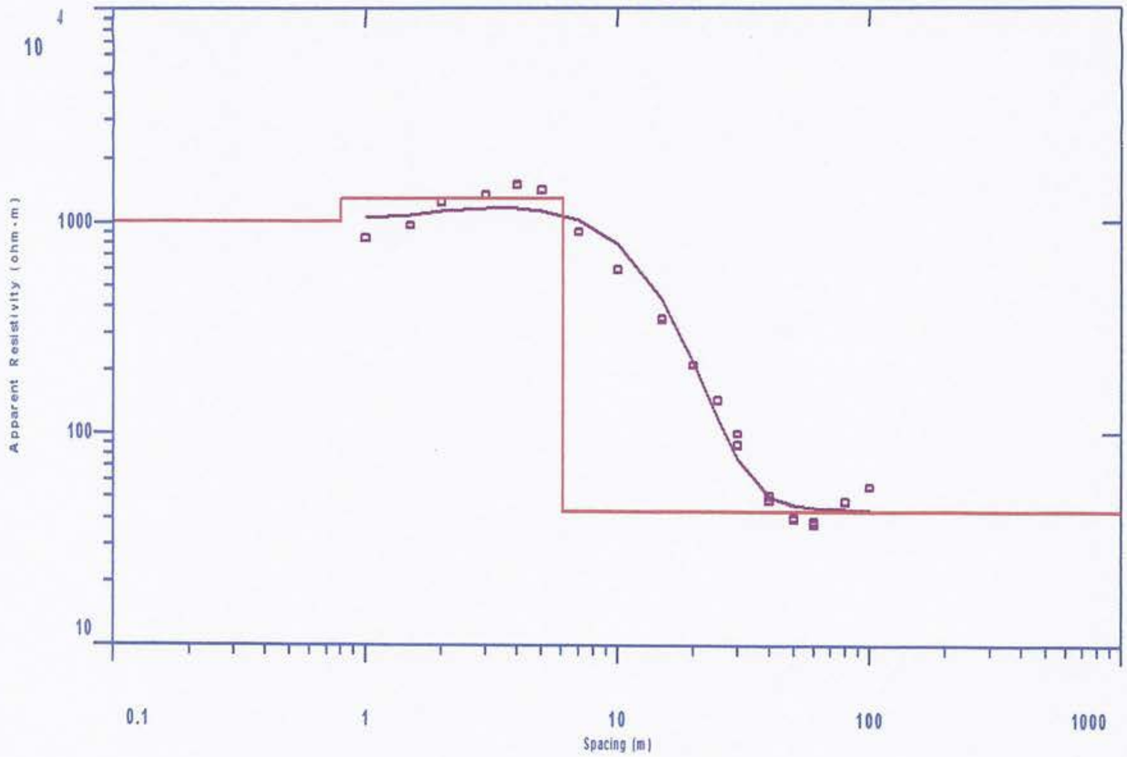
FALABA VES

H.P. Gauff Ingenieure GmbH & Co.



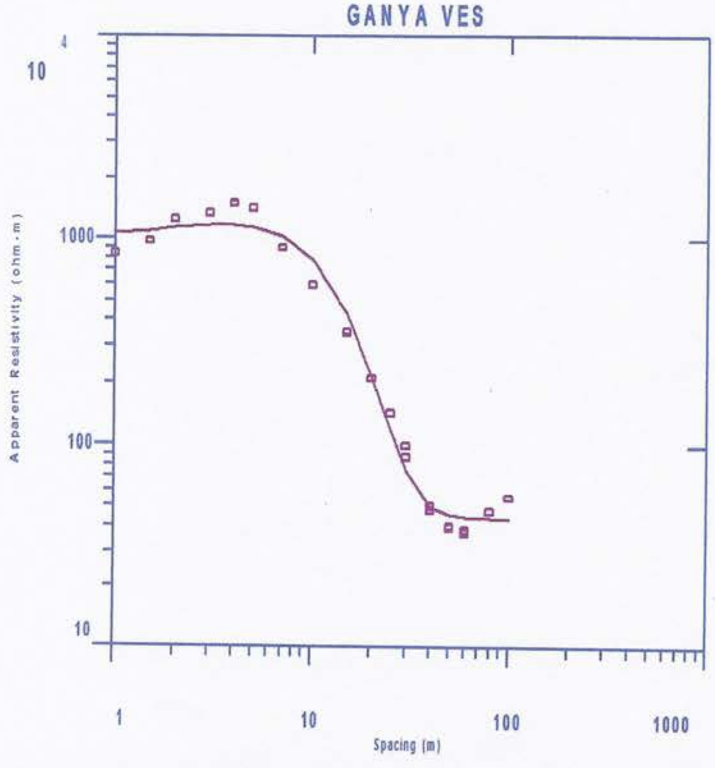
GANYA VES

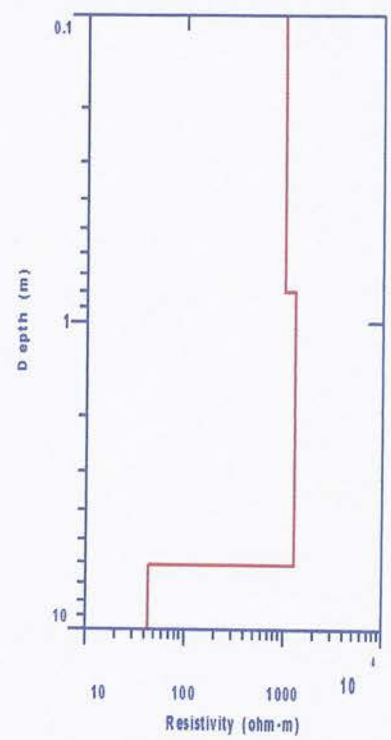
H.P. Gauff Ingenieure GmbH & Co.

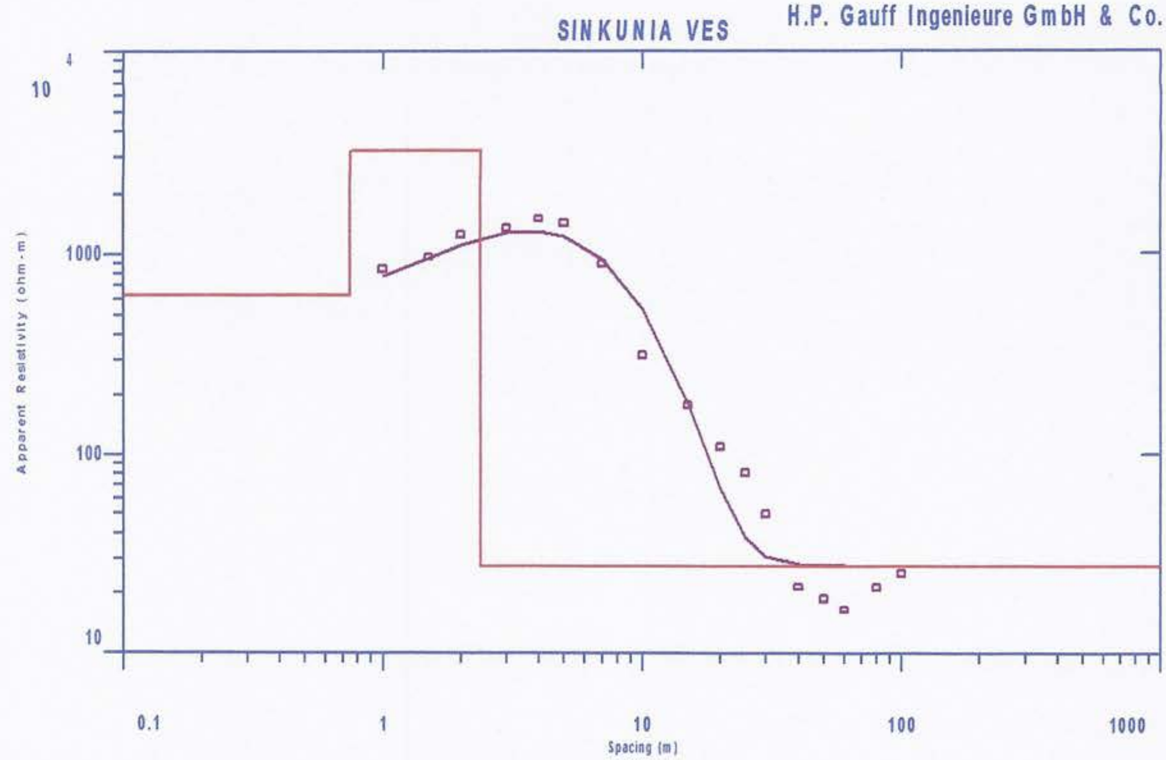


GANYA VES

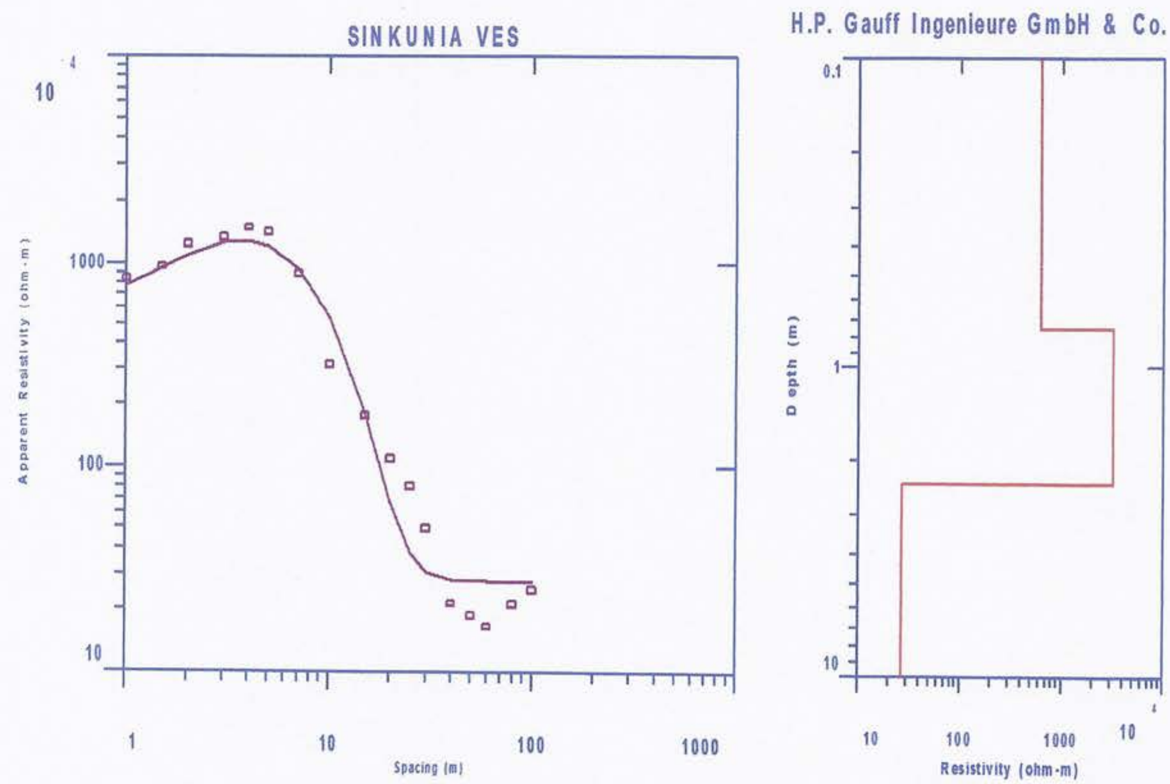
H.P. Gauff Ingenieure GmbH & Co.





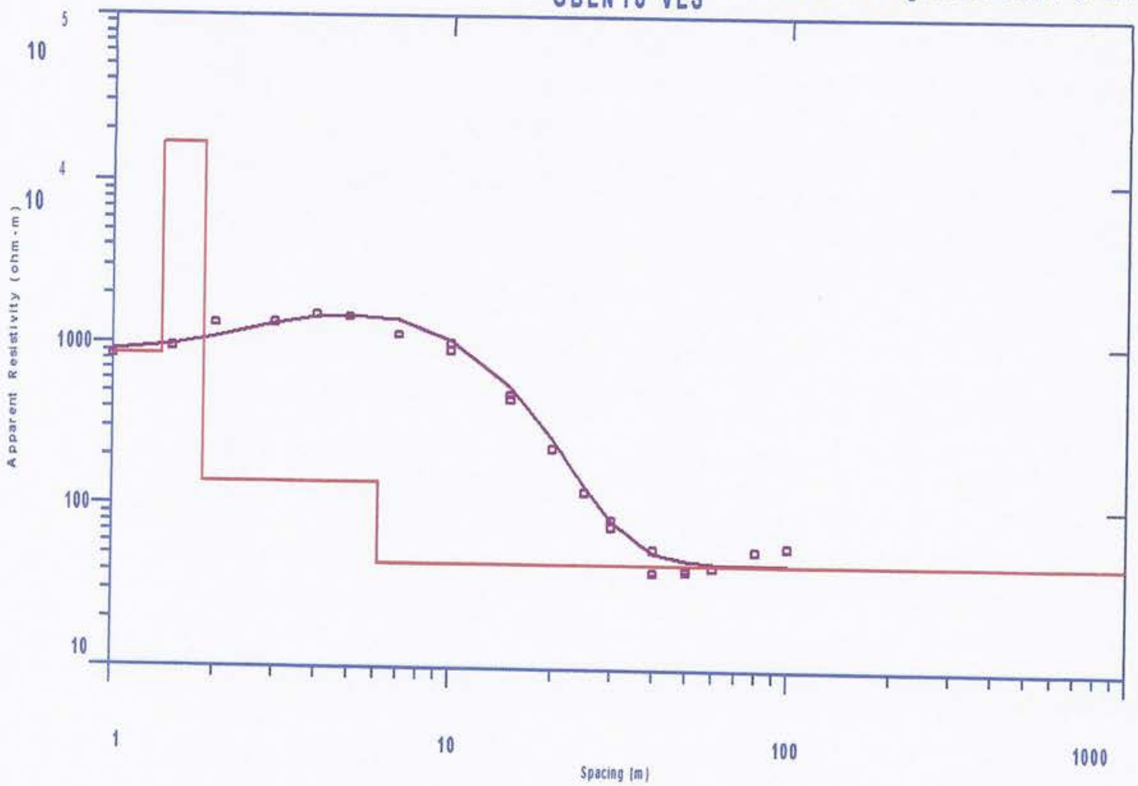


SINKUNIA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10^4
1000
100
10
0.1
1
10
100
1000
Spacing (m)

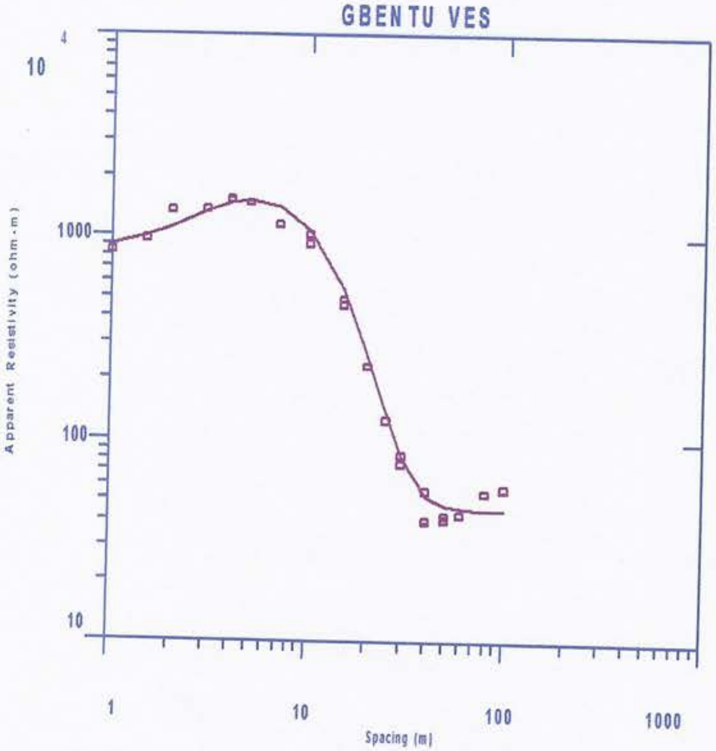


SINKUNIA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10^4
1000
100
10
1
10
100
1000
Spacing (m)
Depth (m)
0.1
1
10
10
100
1000
10^4
Resistivity (ohm-m)

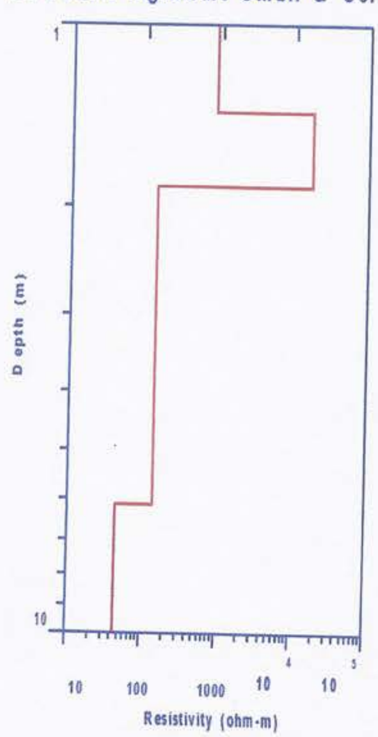
GBENTU VES H.P. Gauff Ingenieure GmbH & Co.

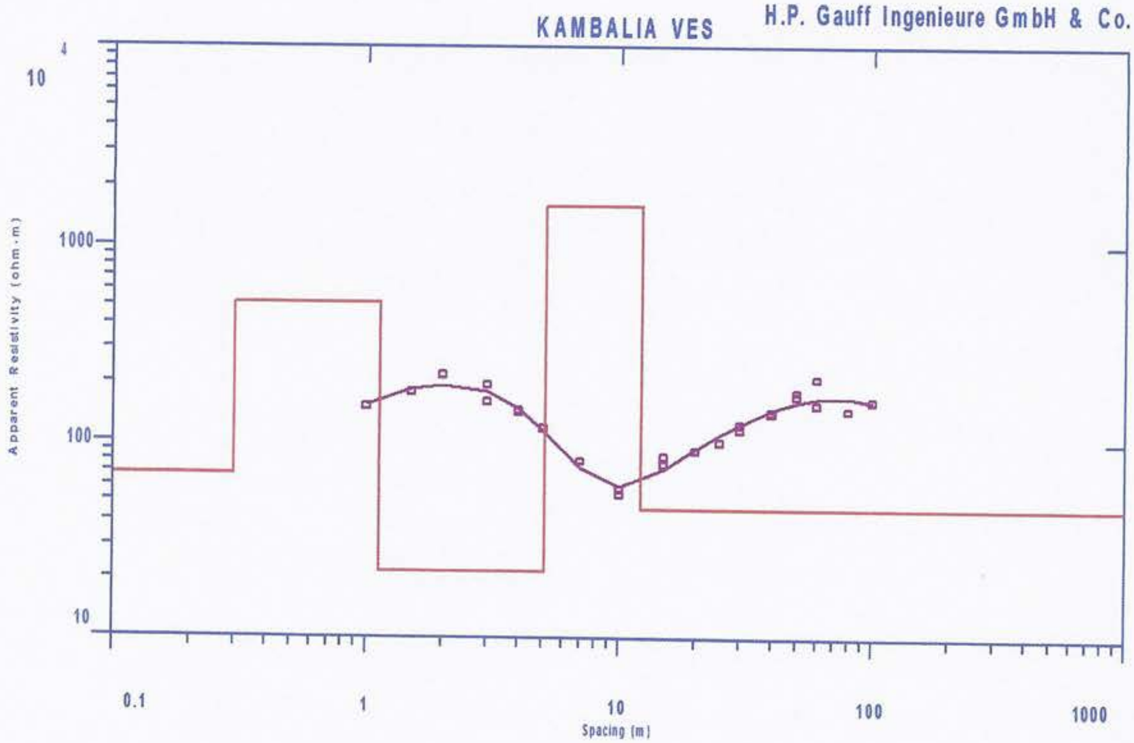


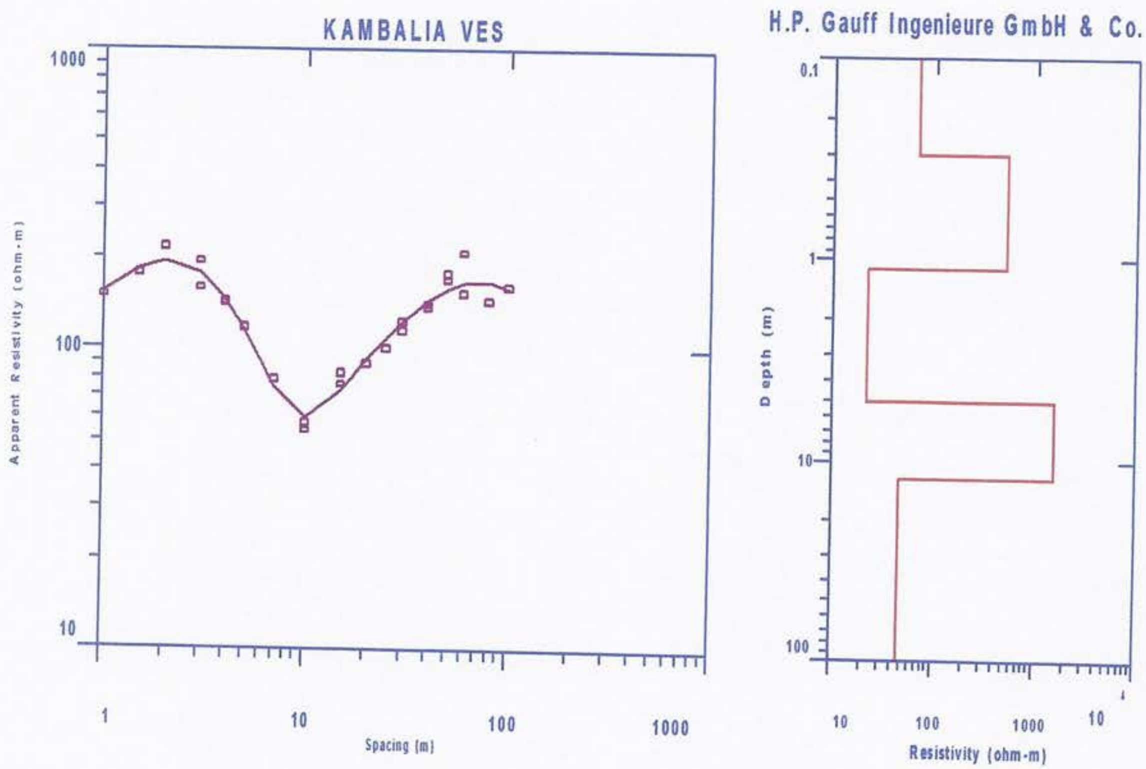
GBENTU VES

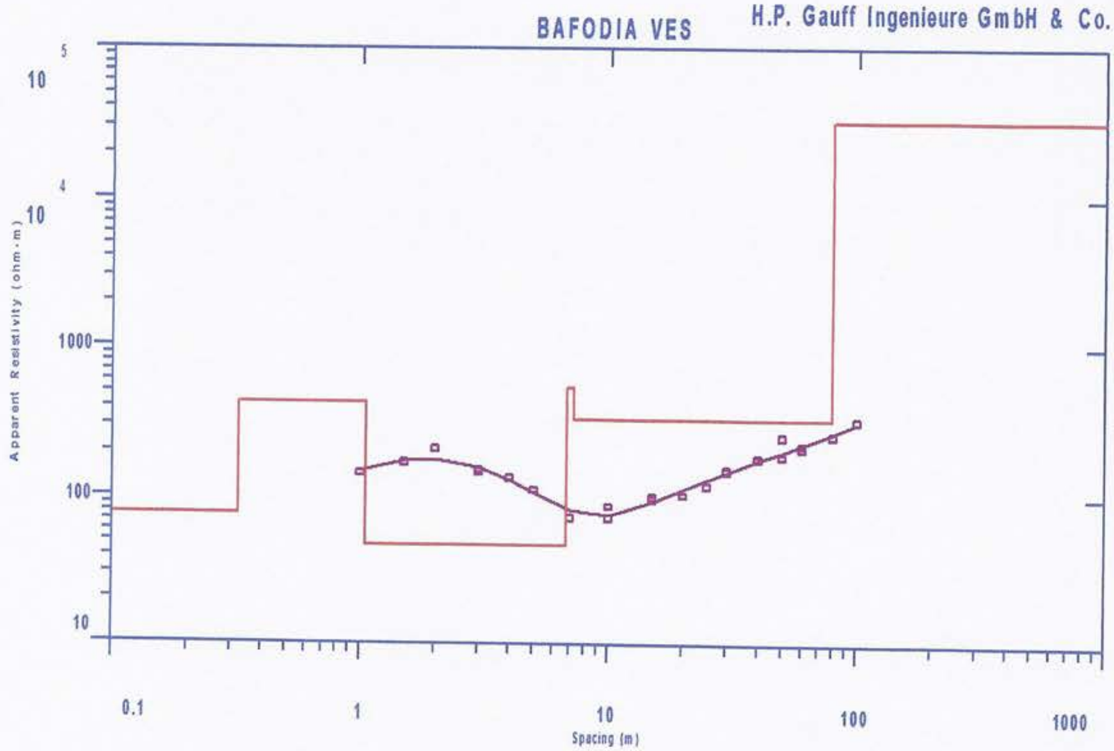


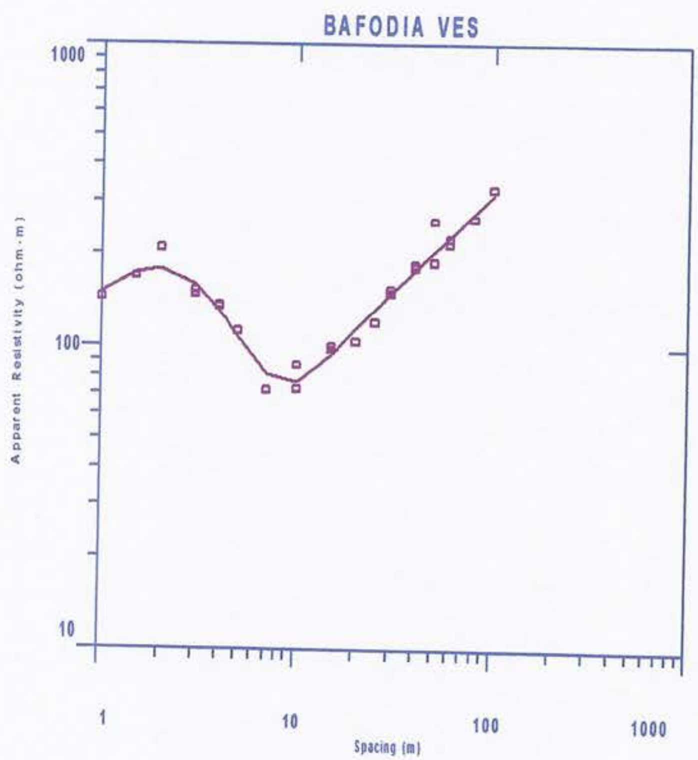
H.P. Gauff Ingenieure GmbH & Co.

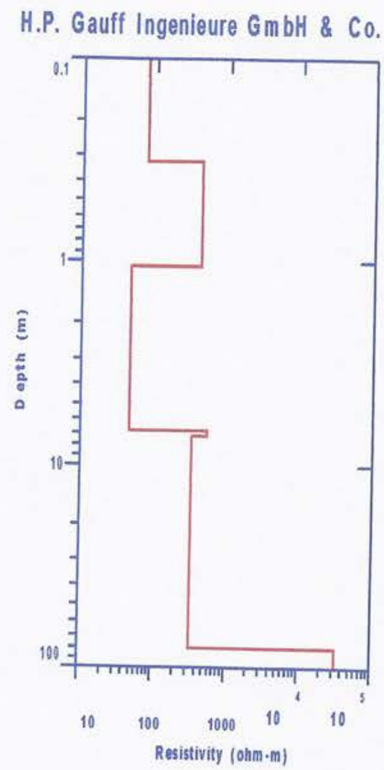


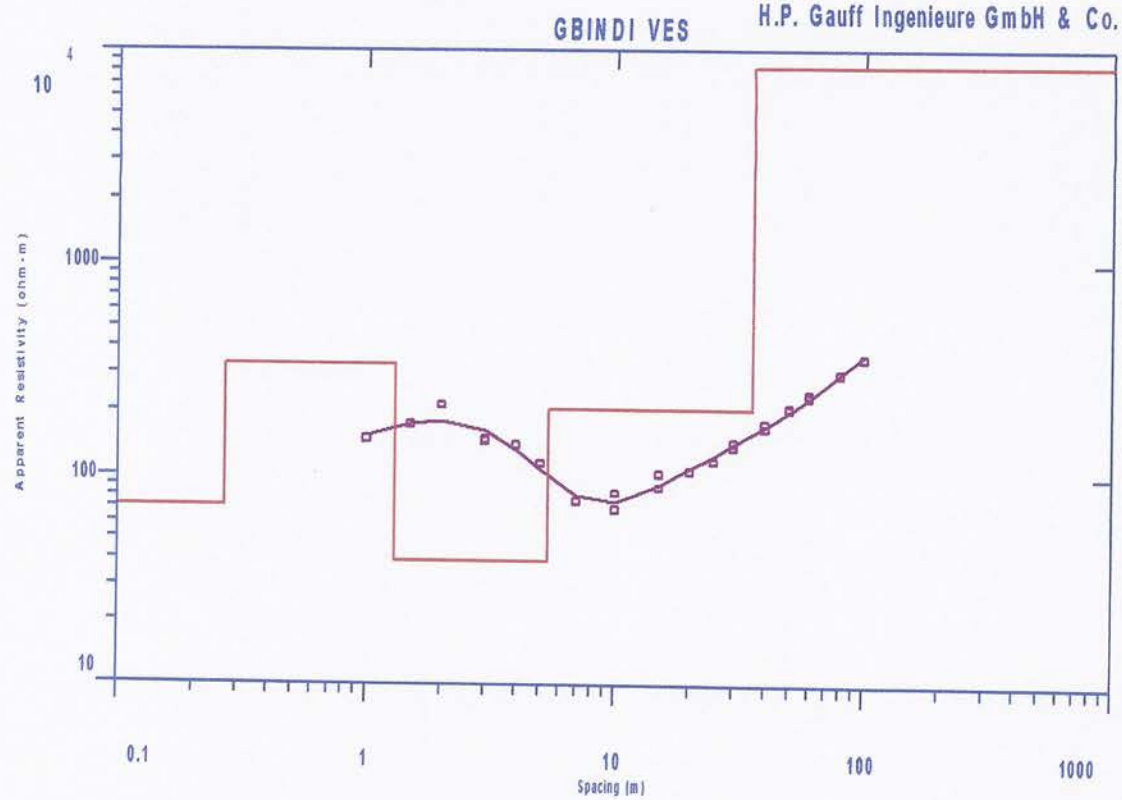

KAMBALIA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10^4
1000
100
10
0.1
1
10
100
1000
Spacing (m)

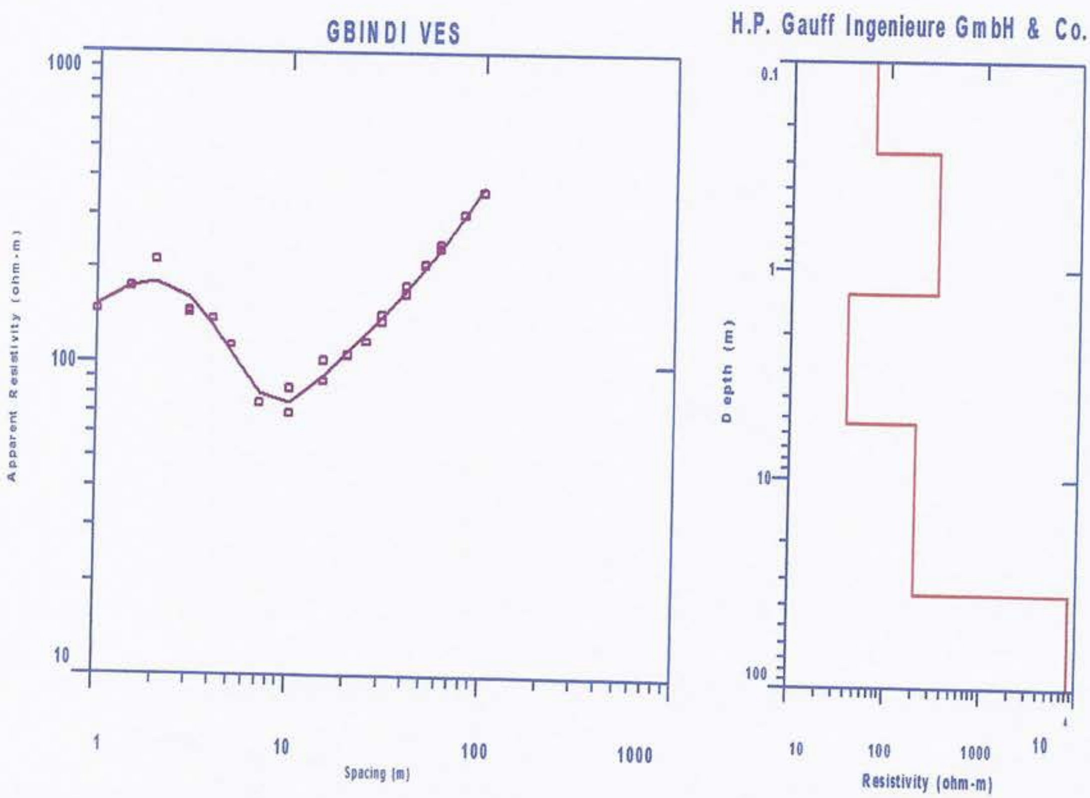

KAMBALIA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
1000
100
10
1
10
100
1000
Spacing (m)
Depth (m)
0.1
1
10
100
10
100
1000
10^4
Resistivity (ohm-m)


BAFODIA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10^5
10^4
1000
100
10
0.1
1
10
100
1000
Spacing (m)

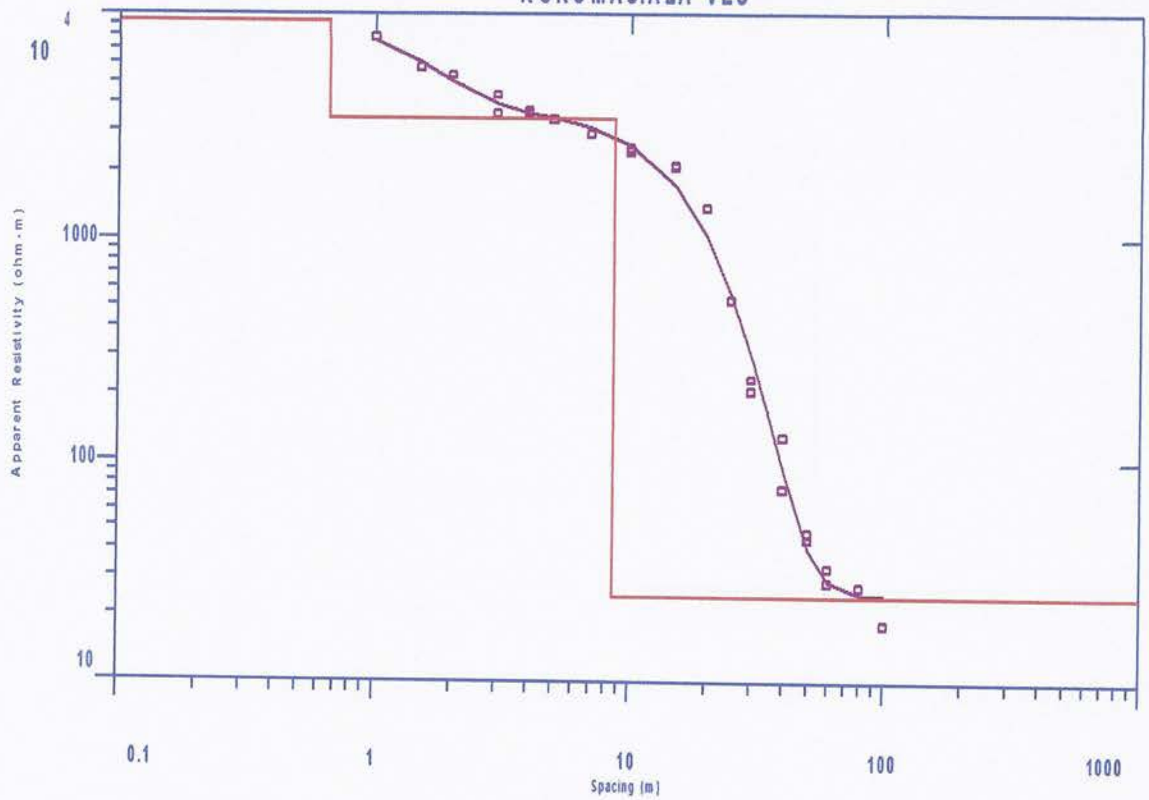

BAFODIA VES
Apparent Resistivity (ohm-m)
1000
100
10
1
10
100
1000
Spacing (m)


H.P. Gauff Ingenieure GmbH & Co.
Depth (m)
0.1
1
10
100
10
100
1000
10^4
10^5
Resistivity (ohm-m)

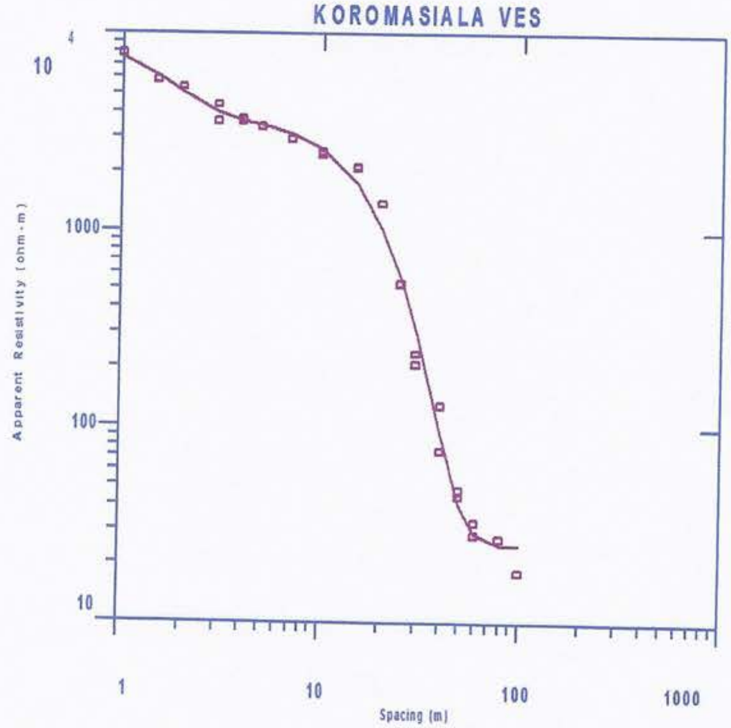

GBINDI VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
Spacing (m)


GBINDI VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
Spacing (m)
Depth (m)
Resistivity (ohm-m)

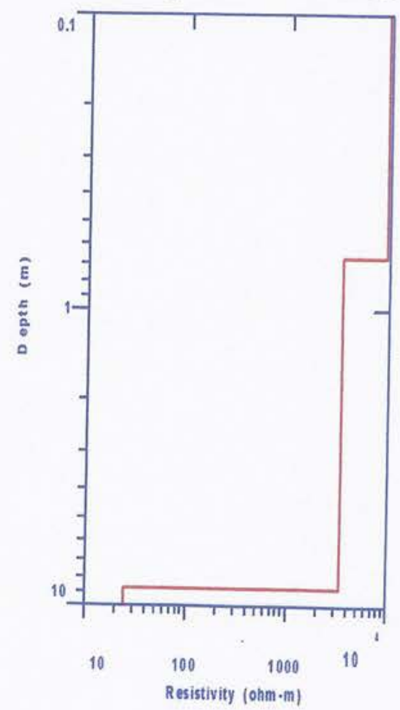
KOROMASIALA VES H.P. Gauff Ingenieure GmbH & Co.



KOROMASIALA VES

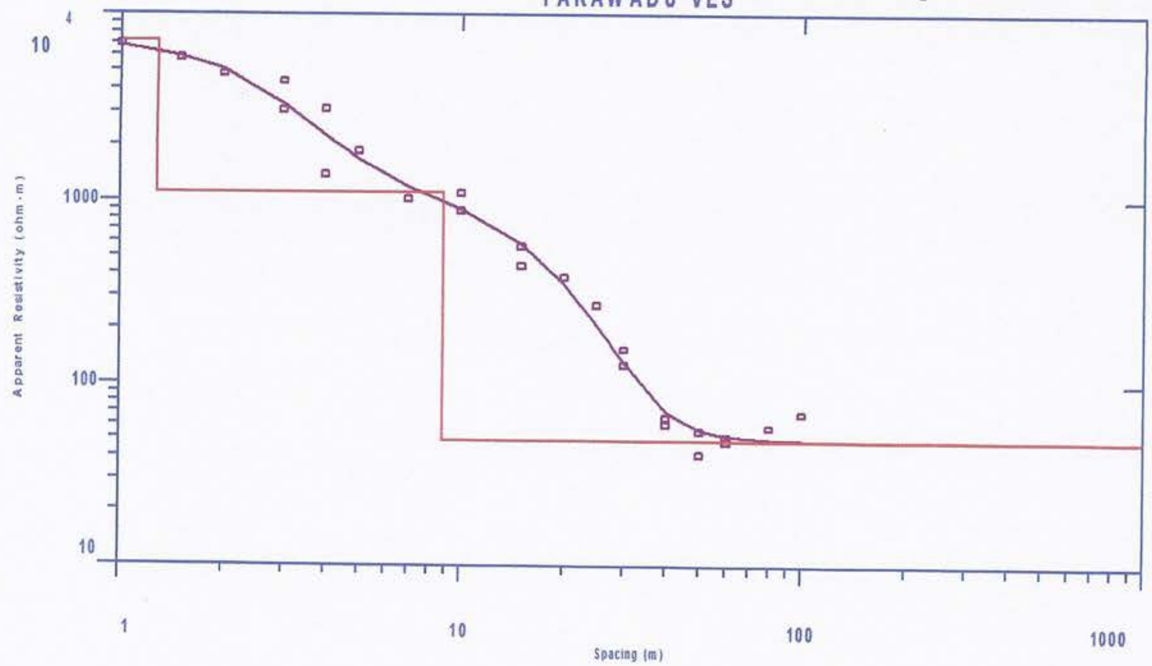


H.P. Gauff Ingenieure GmbH & Co.



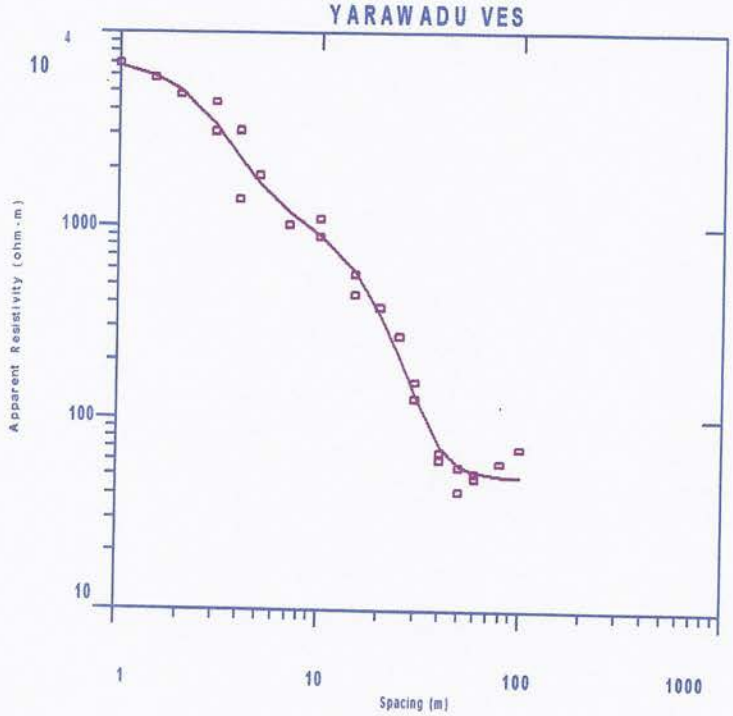
YARAWADU VES

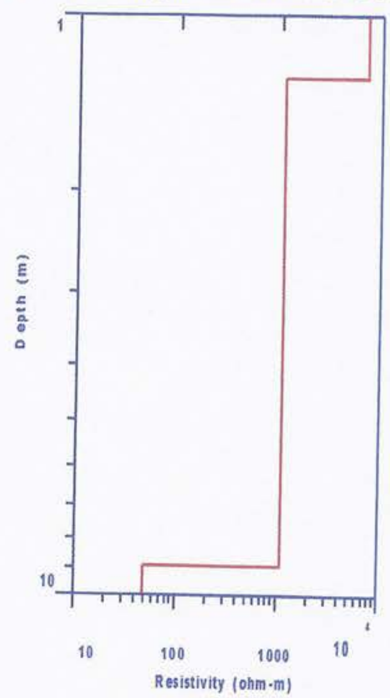
H.P. Gauff Ingenieure GmbH & Co.

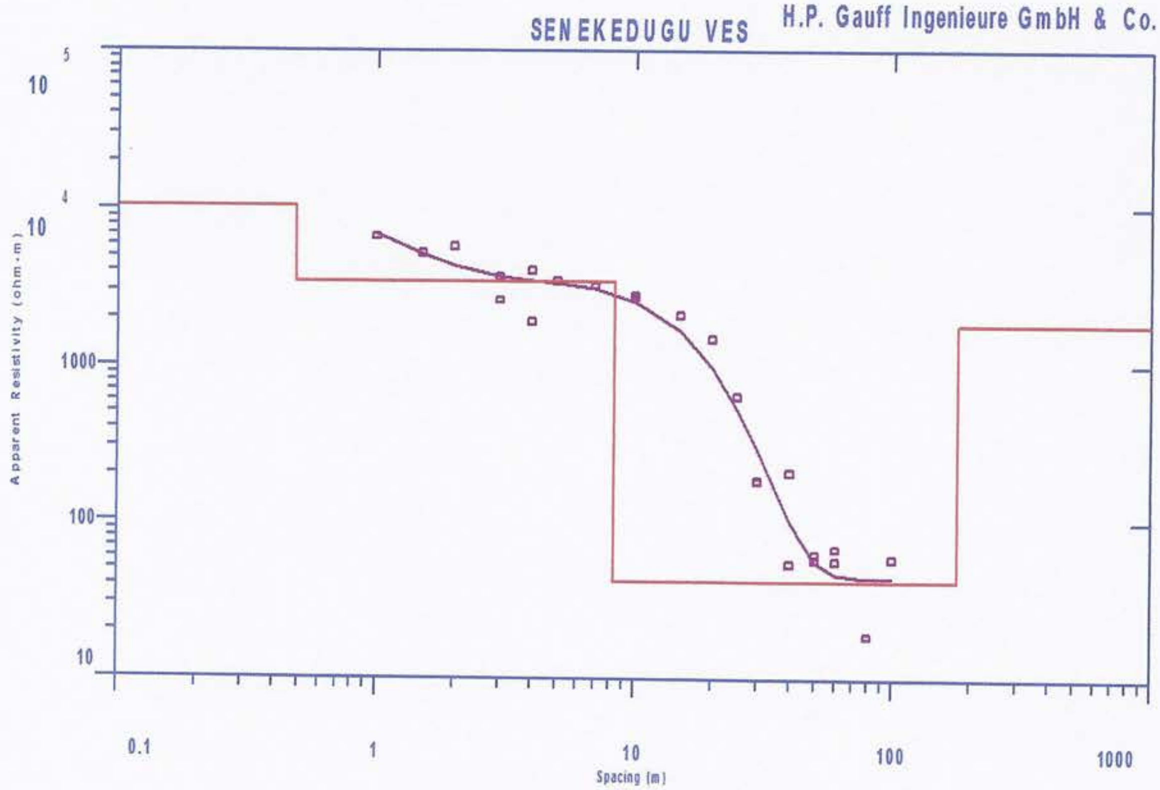


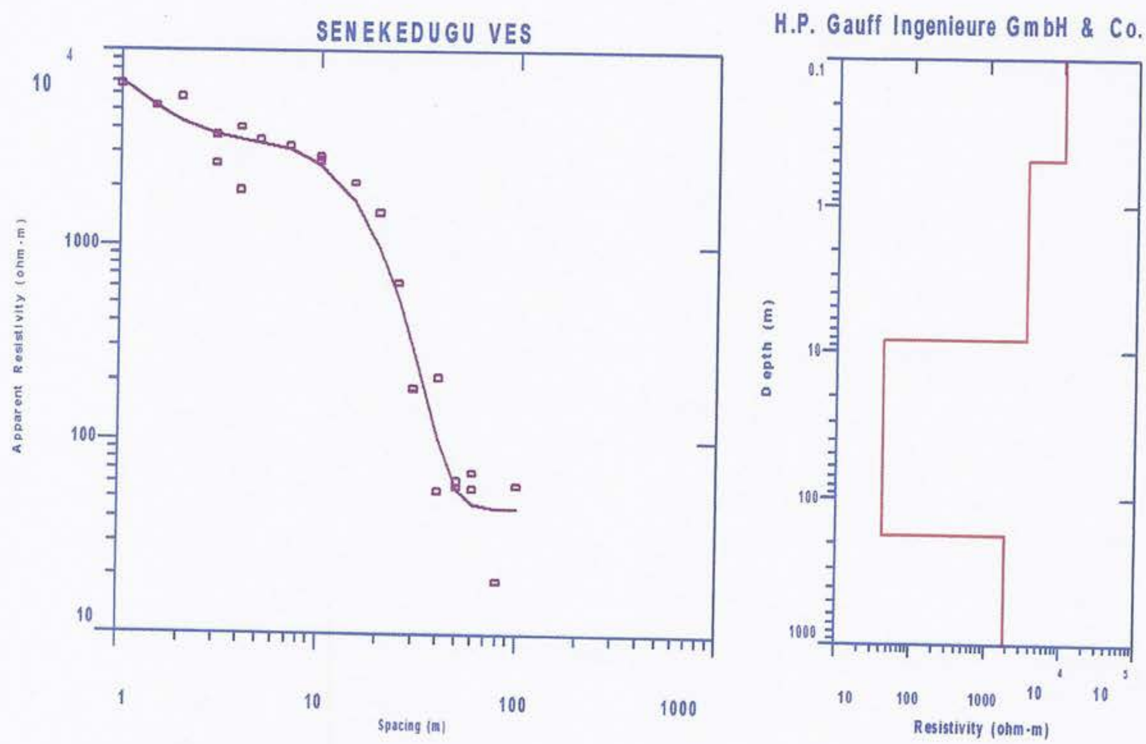
YARAWADU VES

H.P. Gauff Ingenieure GmbH & Co.



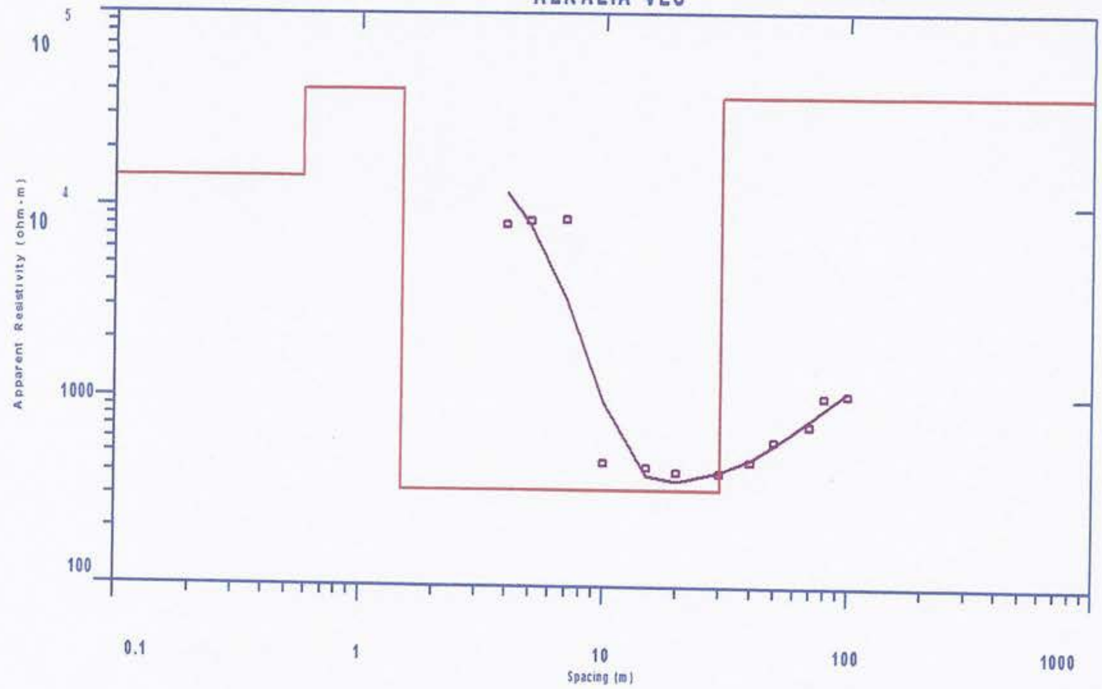



SENEKEDUGU VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10
10
1000
100
10
0.1
1
10
100
1000
Spacing (m)


SENEKEDUGU VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10
1000
100
10
1
10
100
1000
Spacing (m)
Depth (m)
0.1
1
10
100
1000
10
100
1000
10
10
Resistivity (ohm-m)

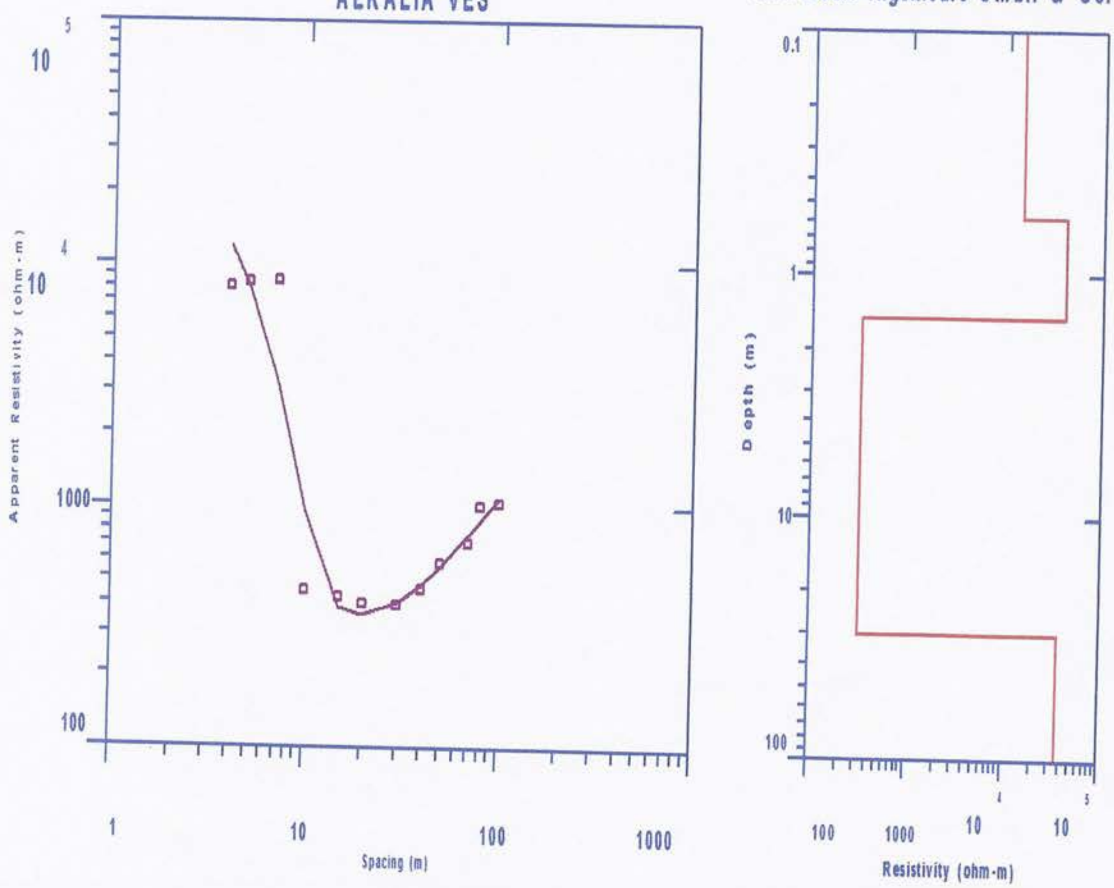
ALKALIA VES

H.P. Gauff Ingenieure GmbH & Co.

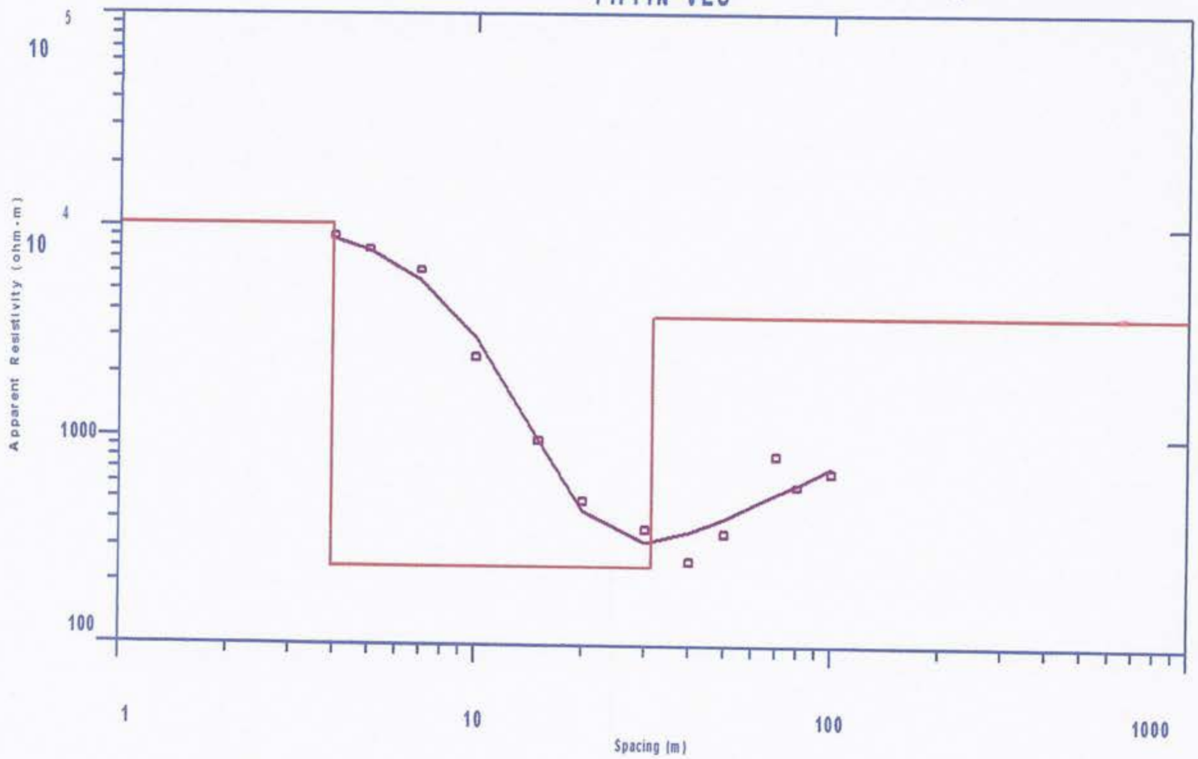


ALKALIA VES

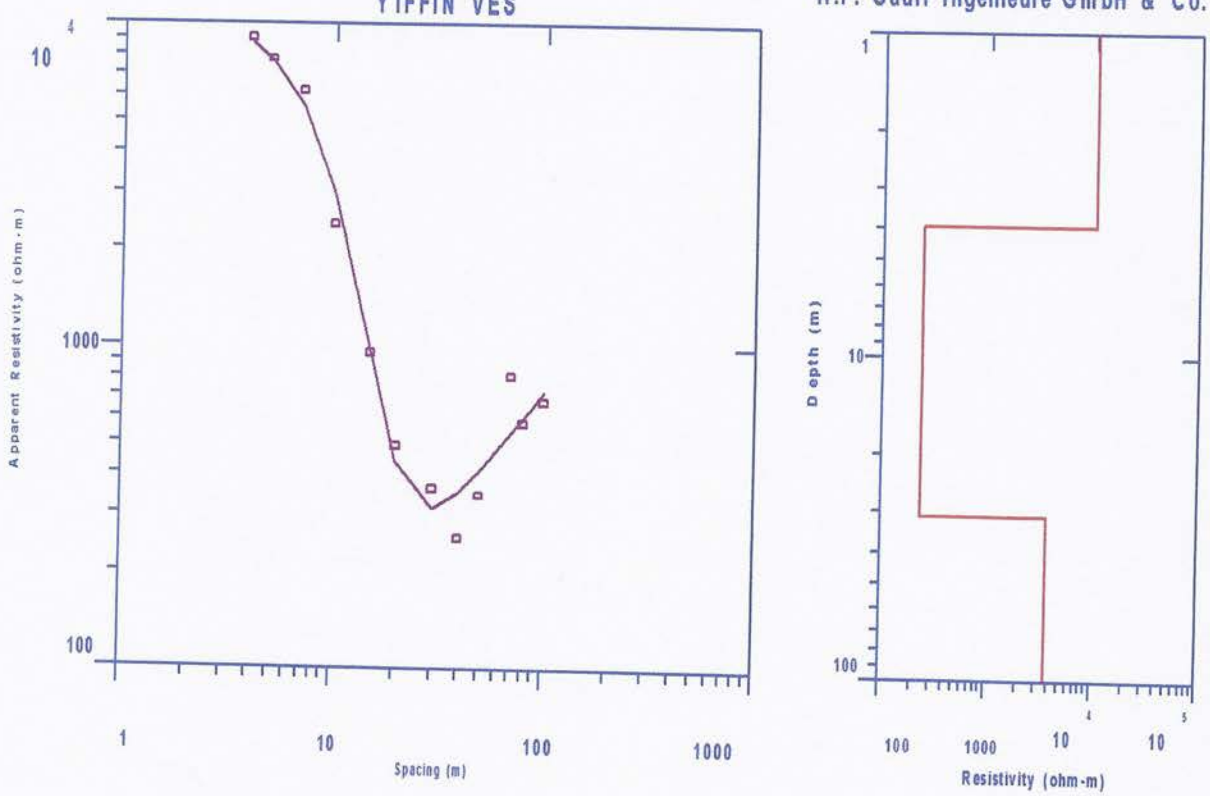
H.P. Gauff Ingenieure GmbH & Co.



YIFFIN VES H.P. Gauff Ingenieure GmbH & Co.

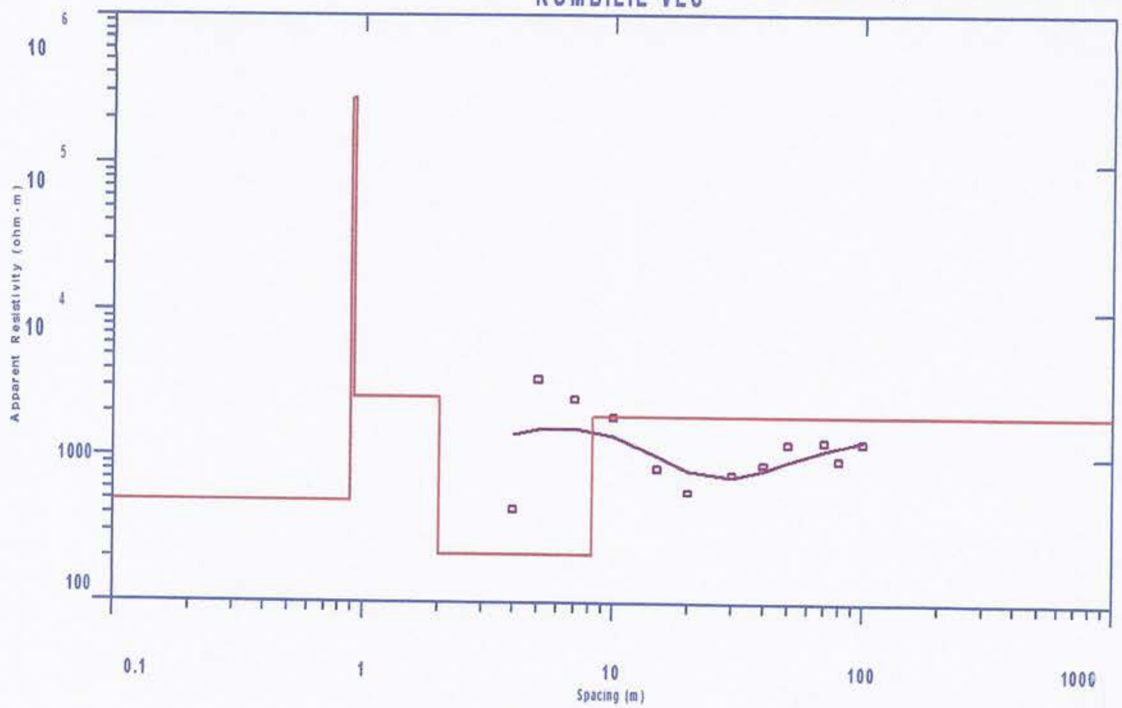


YIFFIN VES H.P. Gauff Ingenieure GmbH & Co.



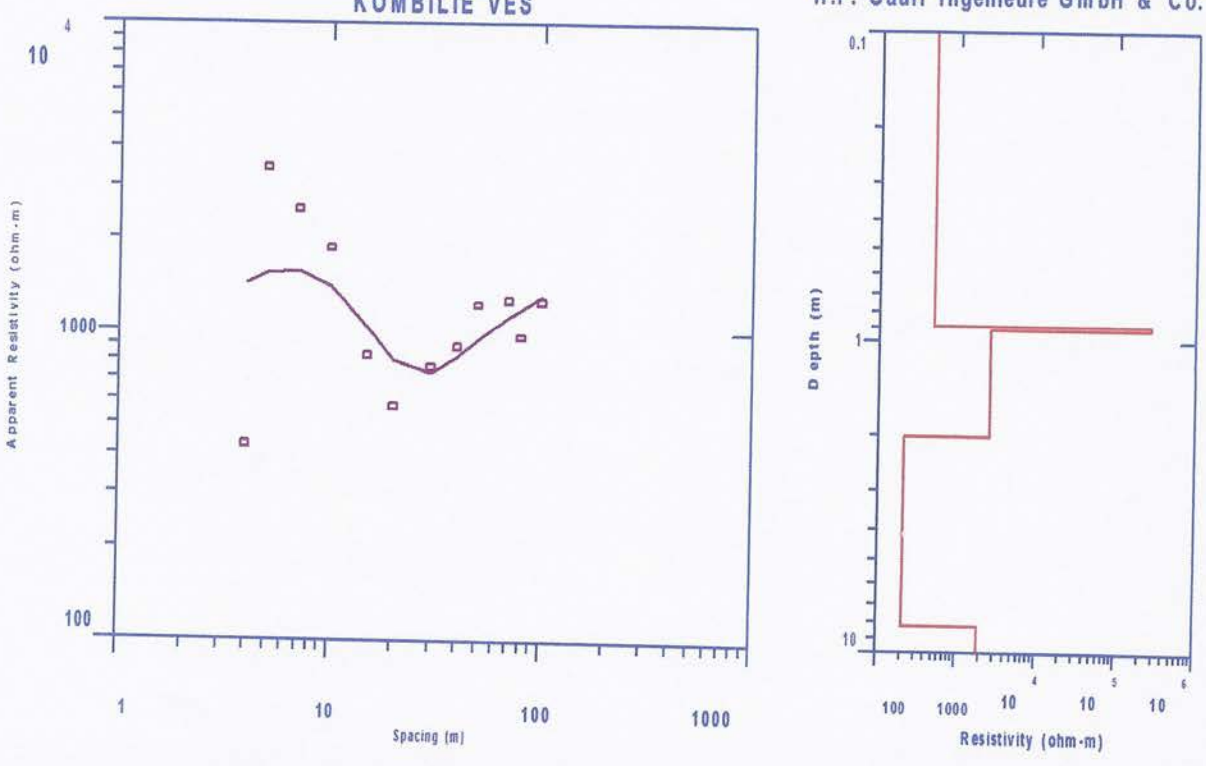
KOMBILIE VES

H.P. Gauff Ingenieure GmbH & Co.

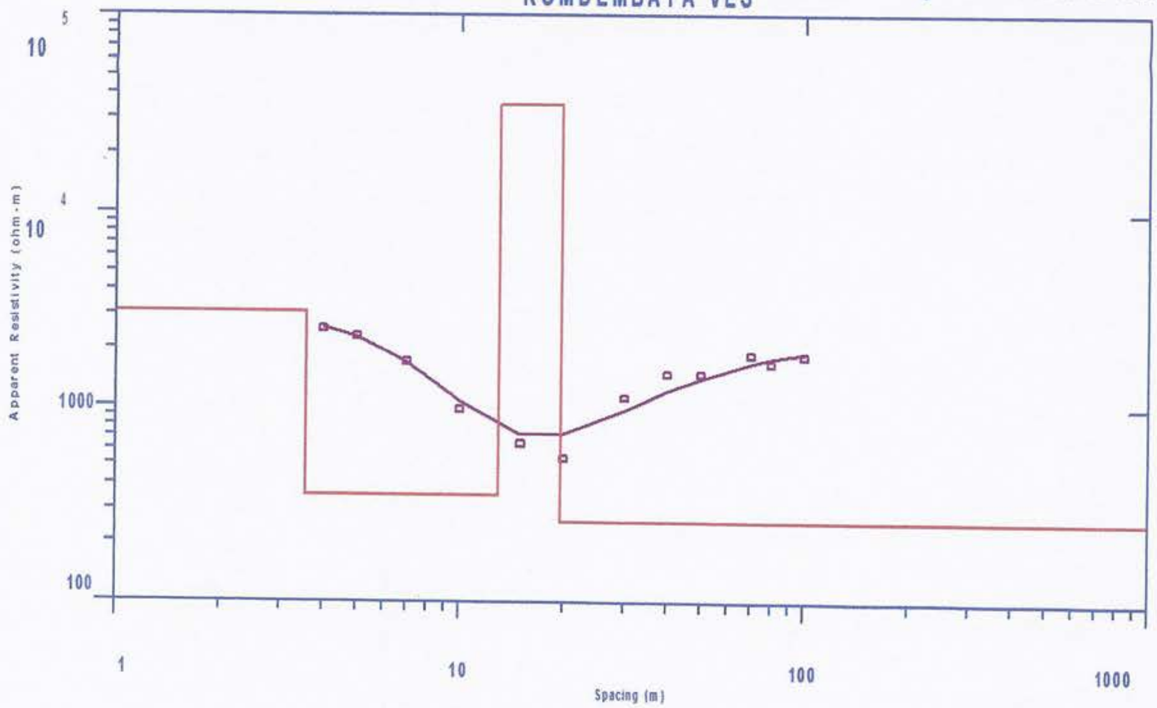


KOMBILIE VES

H.P. Gauff Ingenieure GmbH & Co.

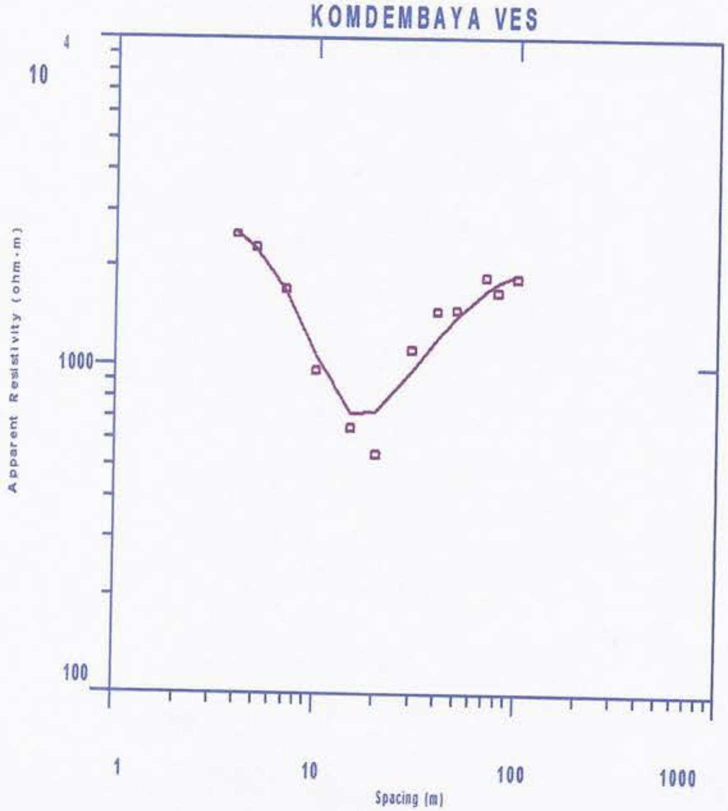


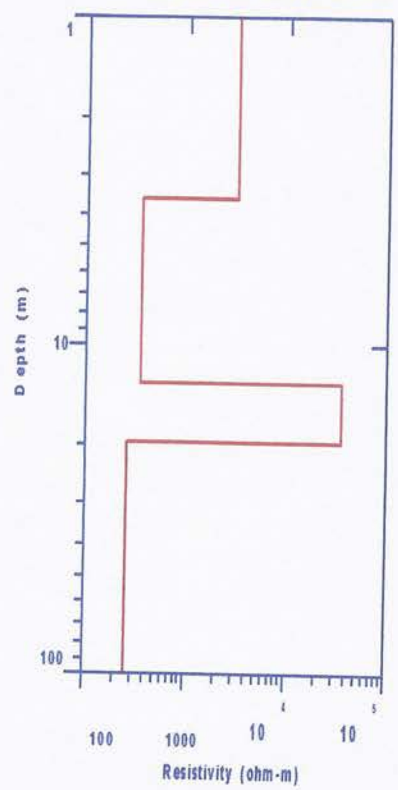
KOMDEMBAYA VES **H.P. Gauff Ingenieure GmbH & Co.**



KOMDEMBAYA VES

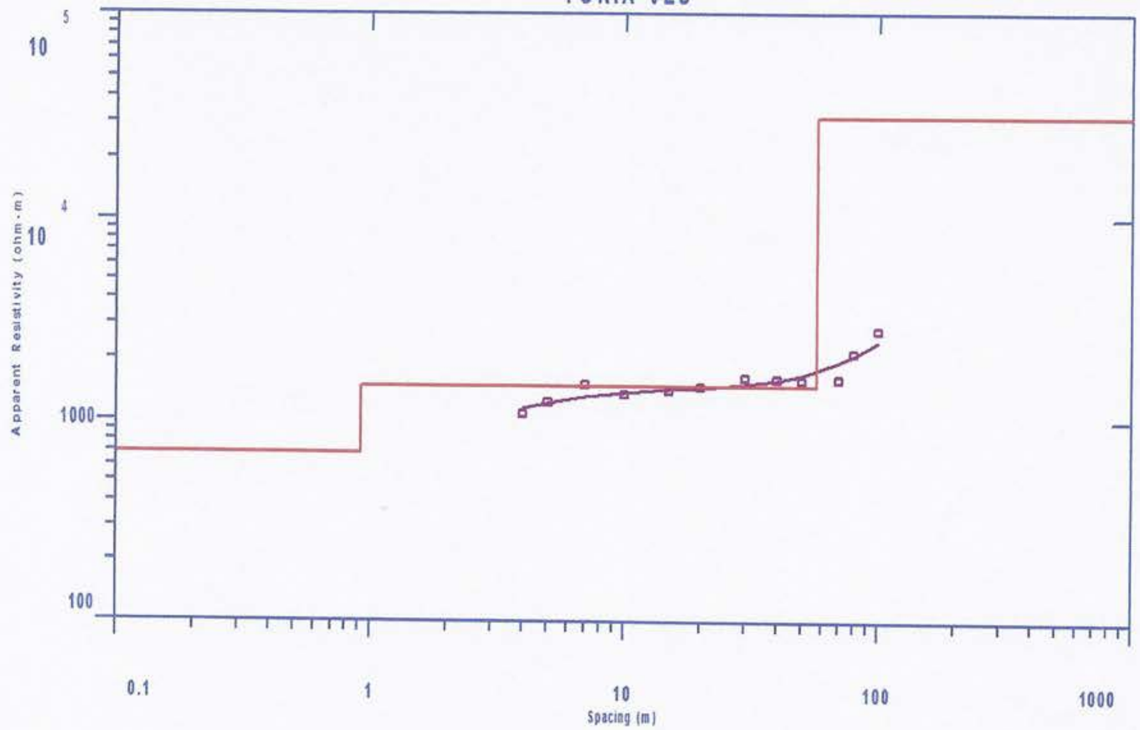
H.P. Gauff Ingenieure GmbH & Co.





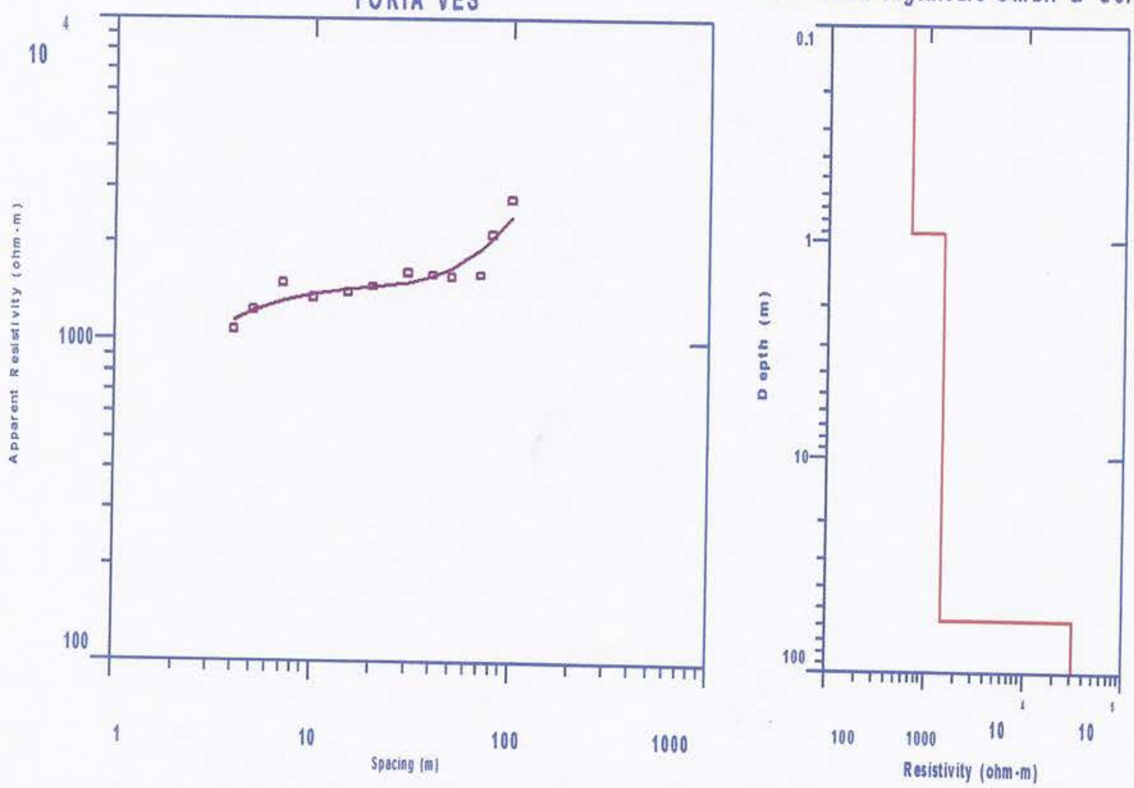
FORIA VES

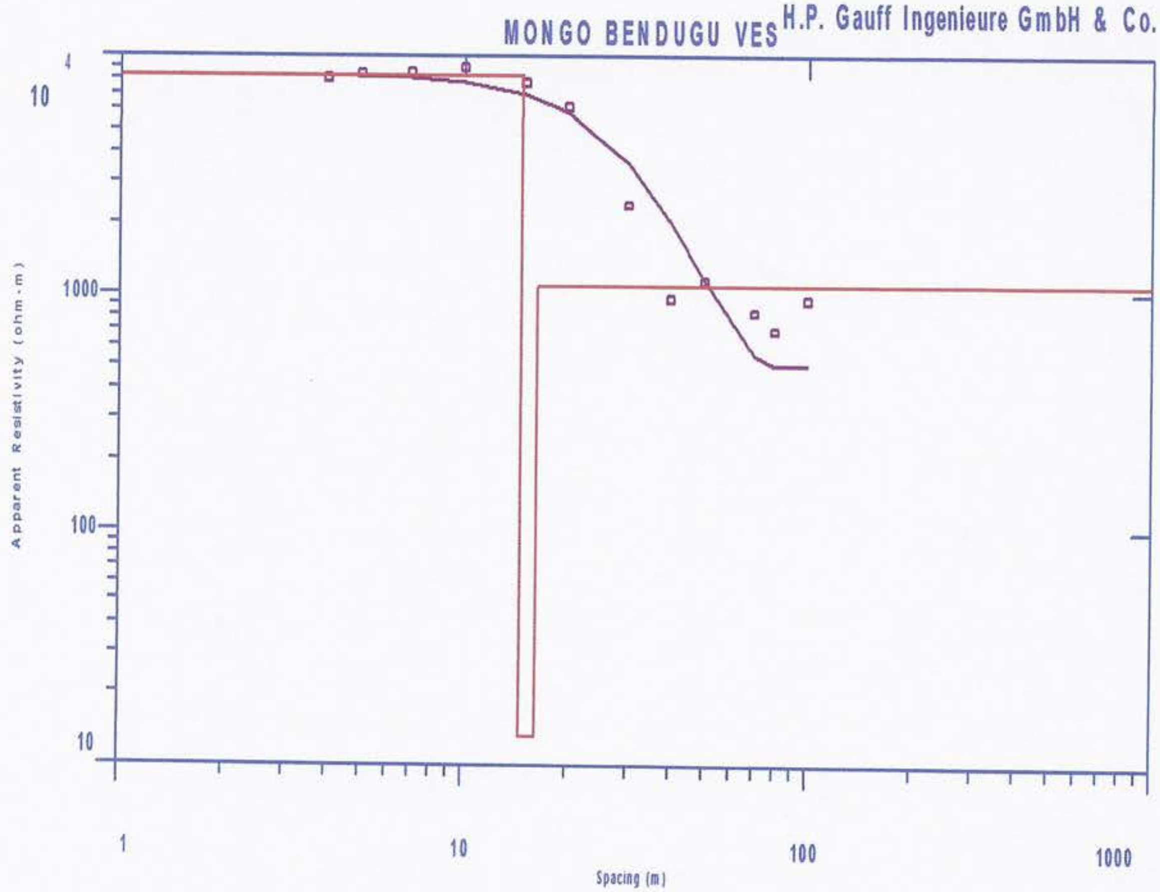
H.P. Gauff Ingenieure GmbH & Co.

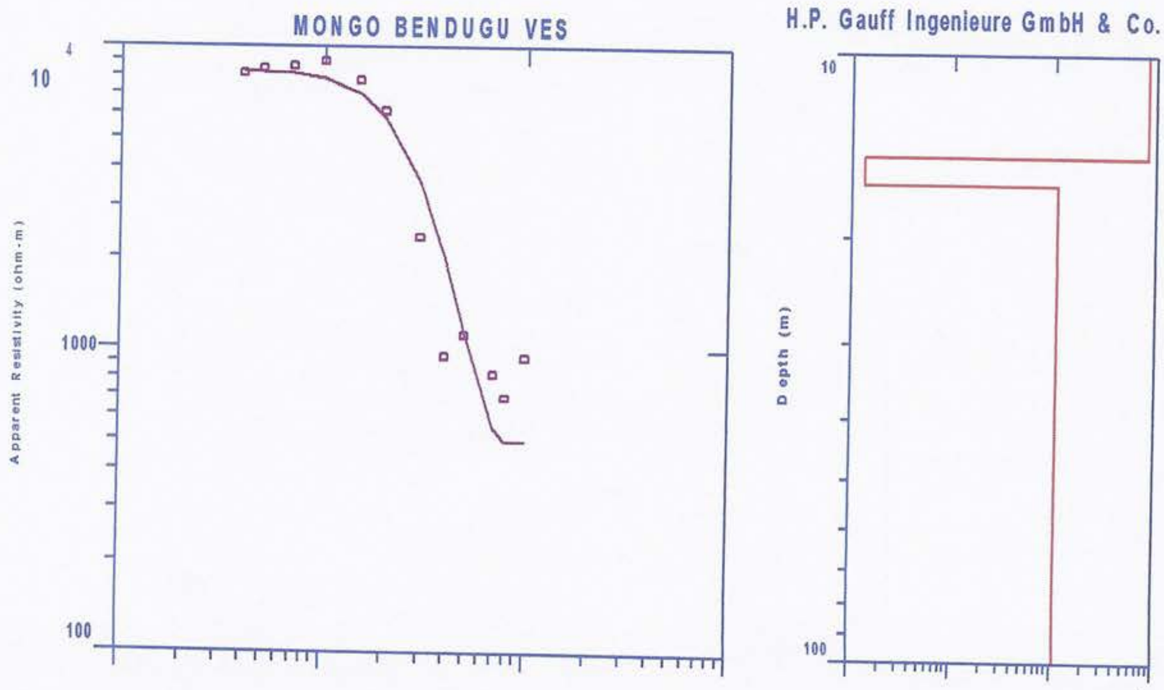


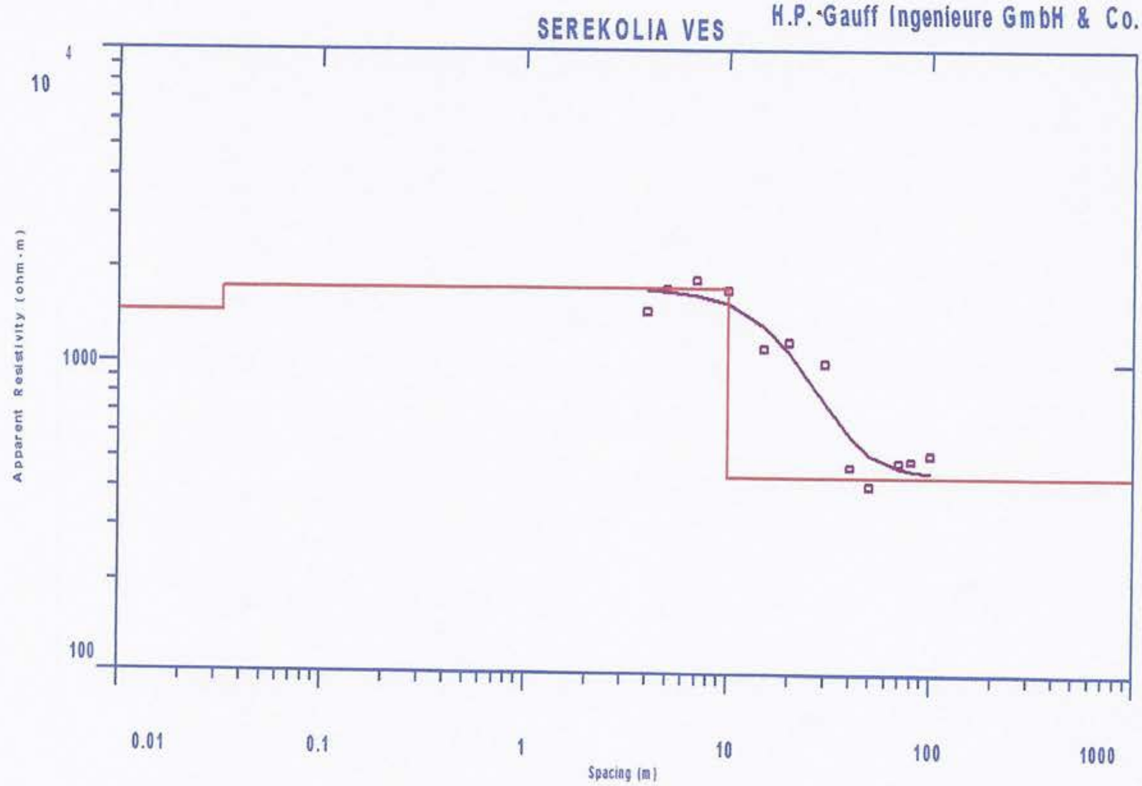
FORIA VES

H.P. Gauff Ingenieure GmbH & Co.

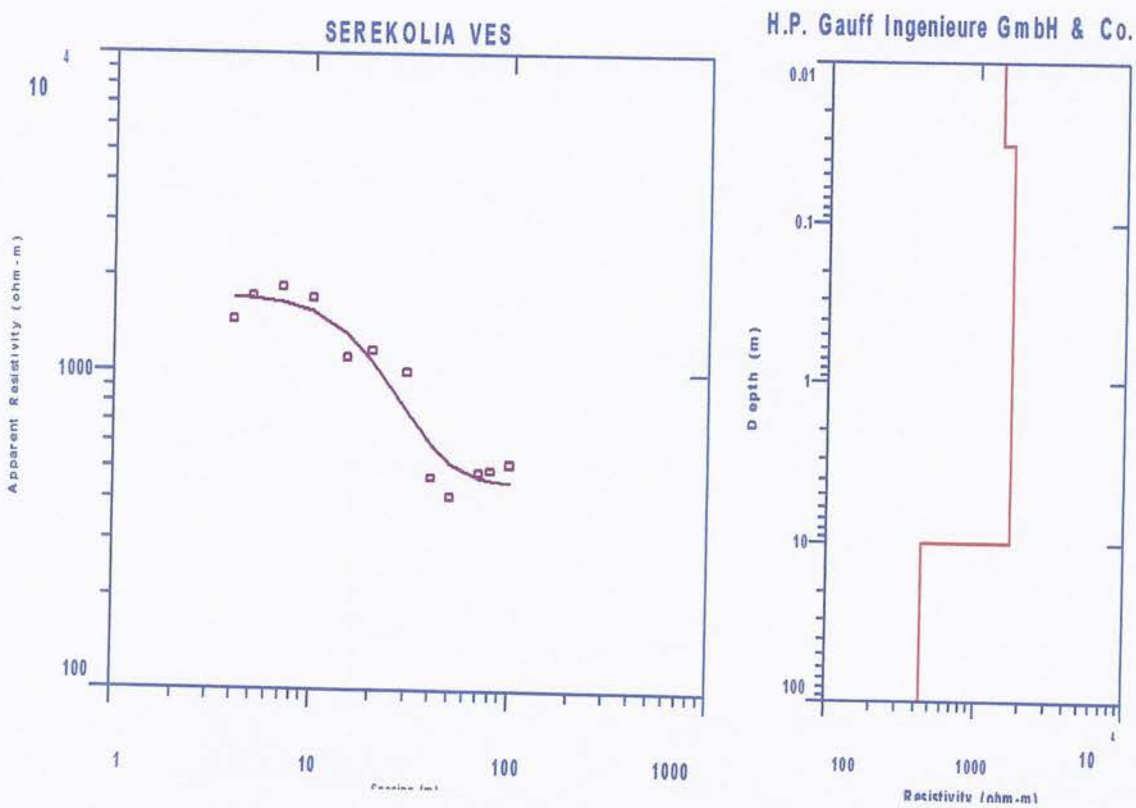



MONGO BENDUGU VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10⁴
1000
100
10
1
10
100
1000
Spacing (m)


MONGO BENDUGU VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10⁴
1000
100
Depth (m)
10
100

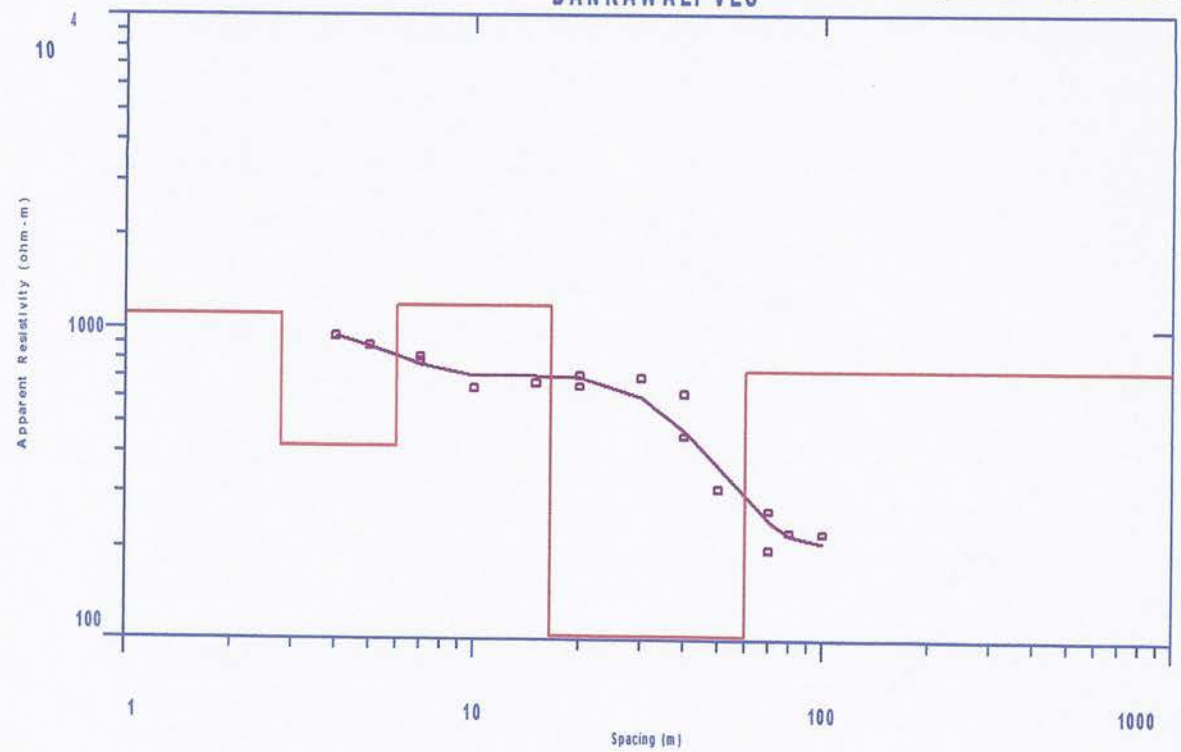


SEREKOLIA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10^4
1000
100
0.01
0.1
1
10
100
1000
Spacing (m)

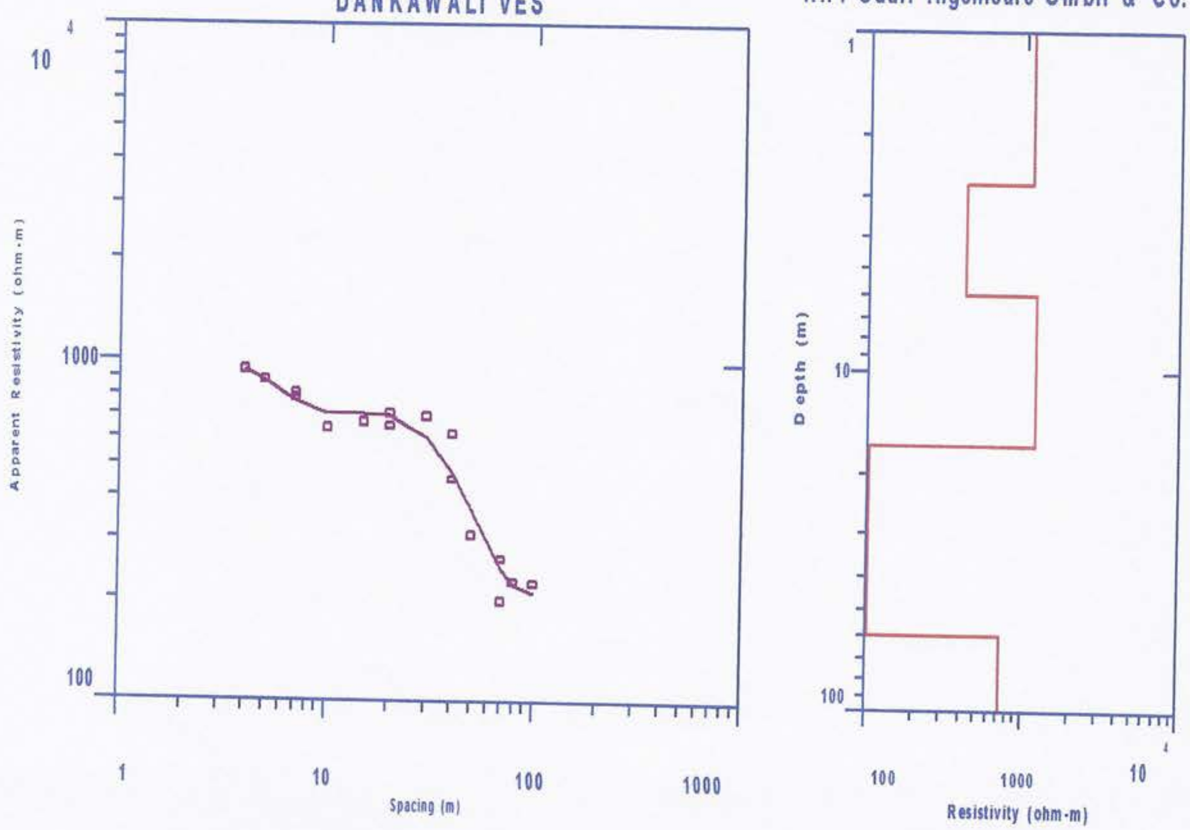


SEREKOLIA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10^4
1000
100
1
10
100
1000
Depth (m)
0.01
0.1
1
10
100
100
1000
10^4

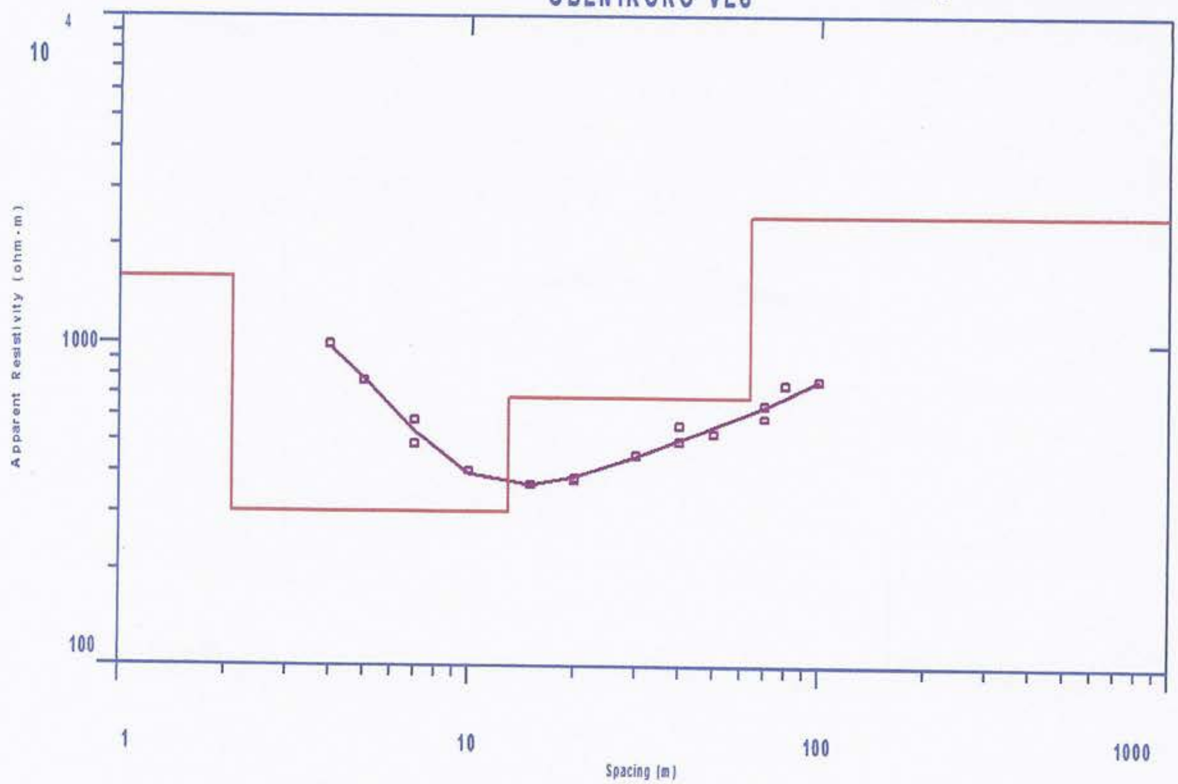
DANKAWALI VES H.P. Gauff Ingenieure GmbH & Co.



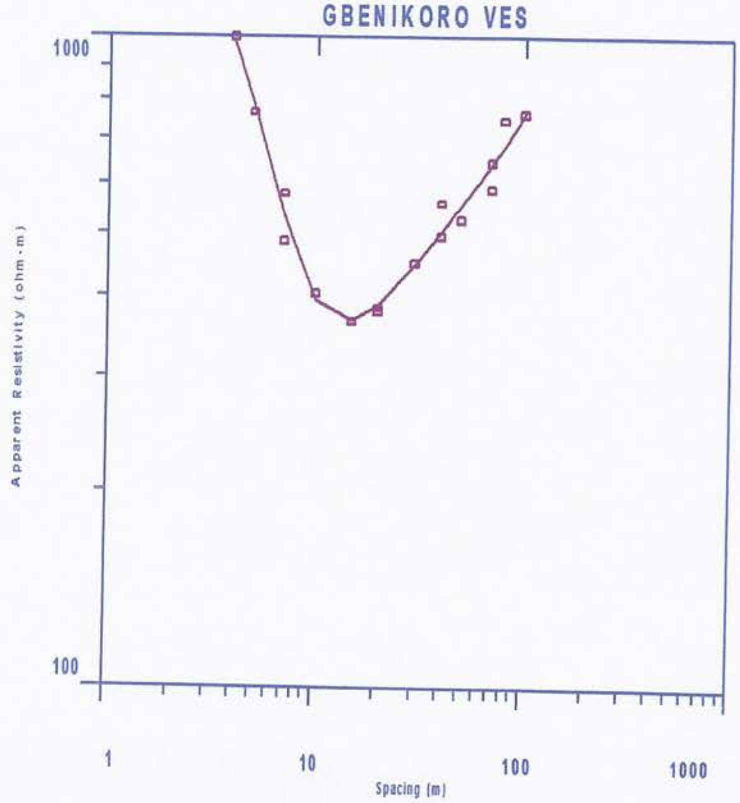
DANKAWALI VES H.P. Gauff Ingenieure GmbH & Co.



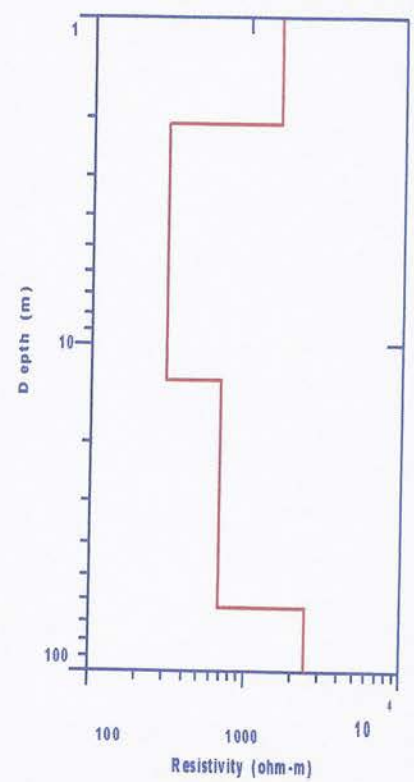
GBENIKORO VES H.P. Gauff Ingenieure GmbH & Co.

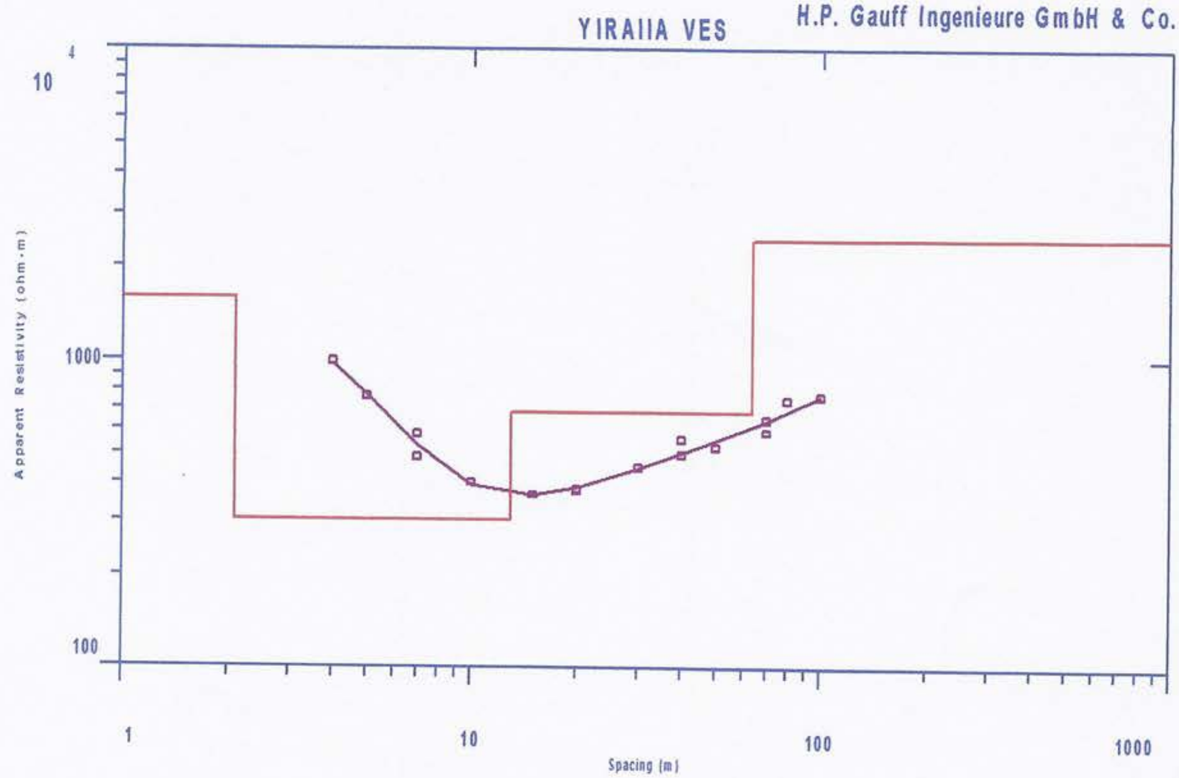


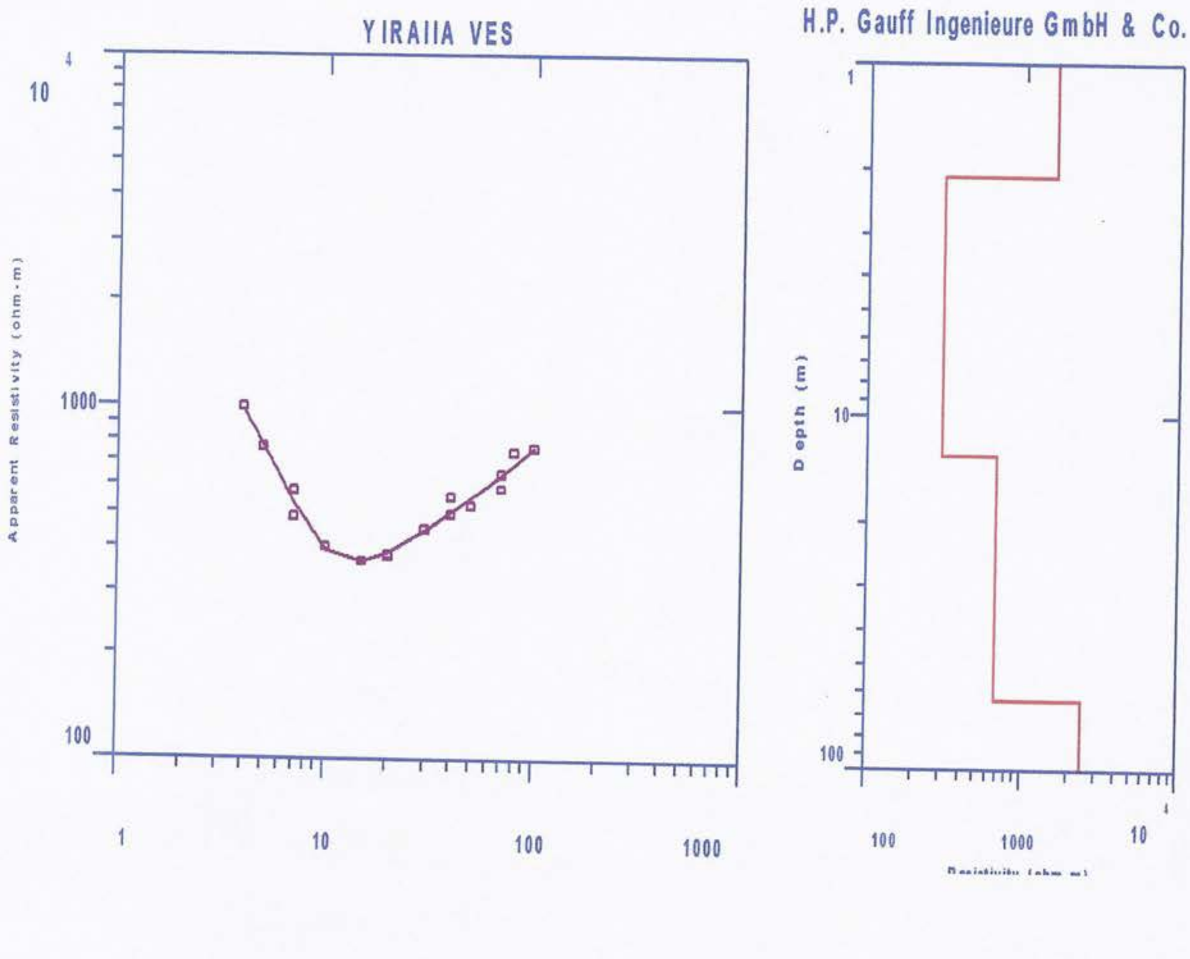
GBENIKORO VES

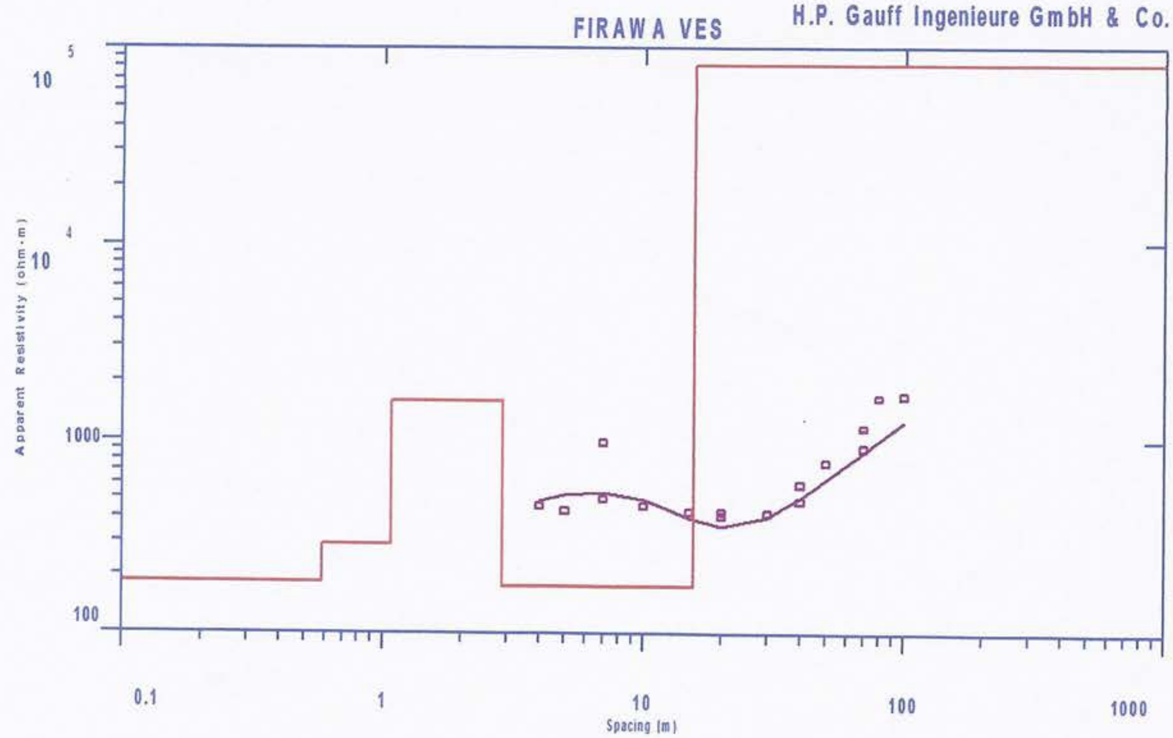


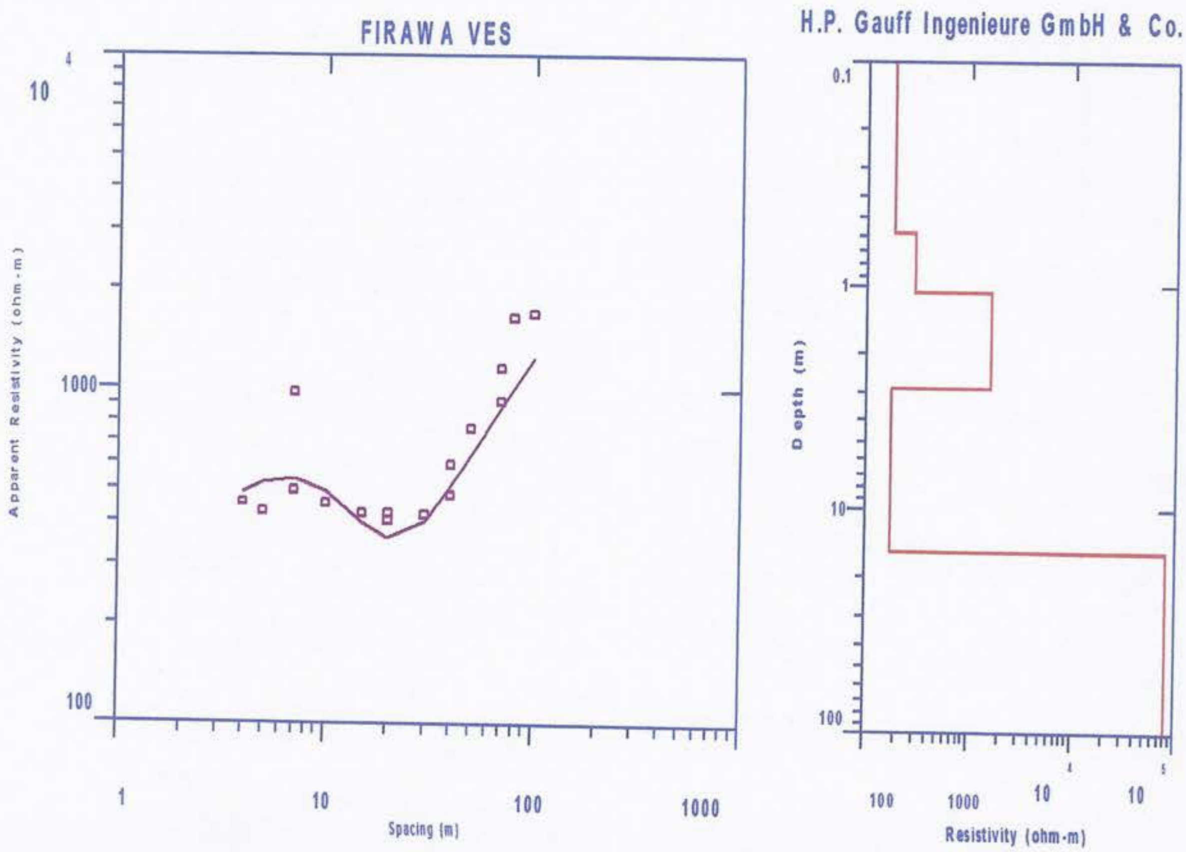
H.P. Gauff Ingenieure GmbH & Co.



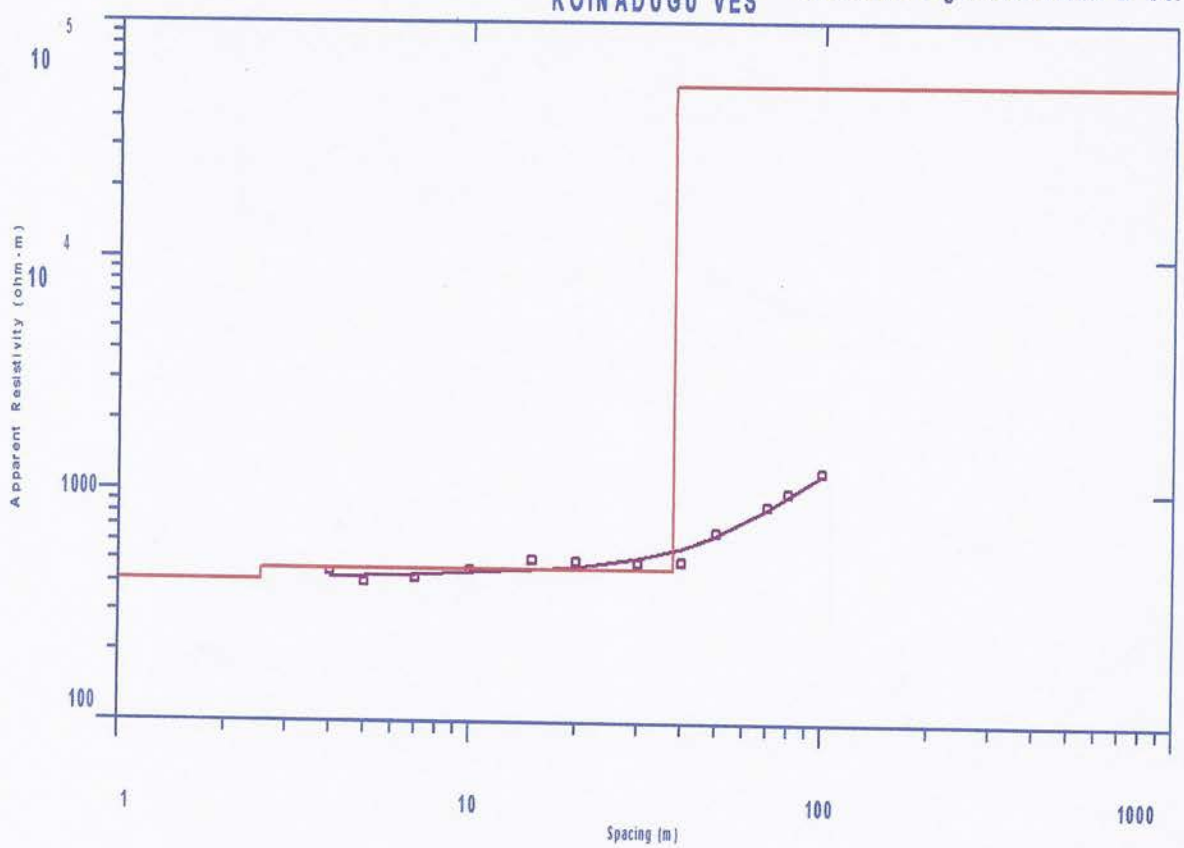

YIRAIIA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10 4
1000
100
1
10
100
1000
Spacing (m)


YIRAIIA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10 4
1000
100
1
10
100
1000
Depth (m)
1
10
100
100
1000
10 4

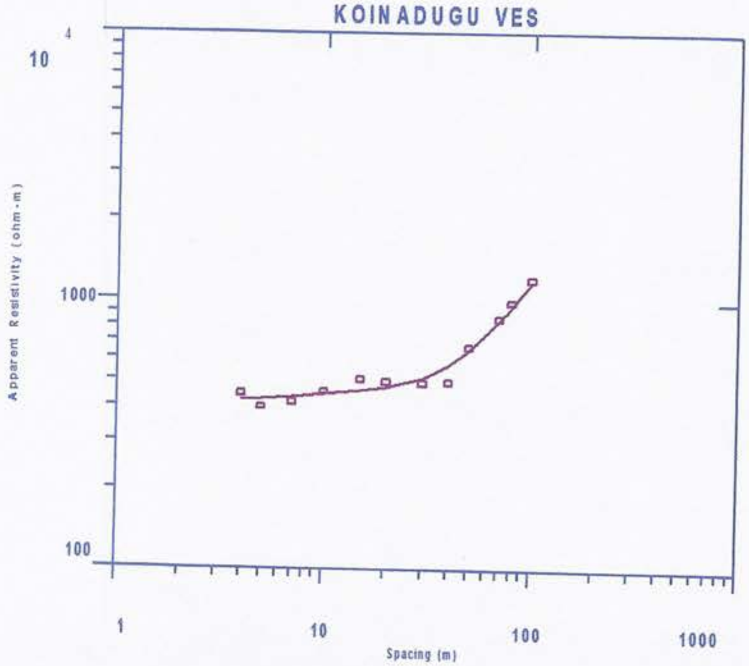

FIRAWA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10^5
10^4
1000
100
0.1
1
10
100
1000
Spacing (m)


FIRAWA VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10^4
1000
100
1
10
100
1000
Spacing (m)
Depth (m)
0.1
1
10
100
Resistivity (ohm-m)
100
1000
10^4
10^5

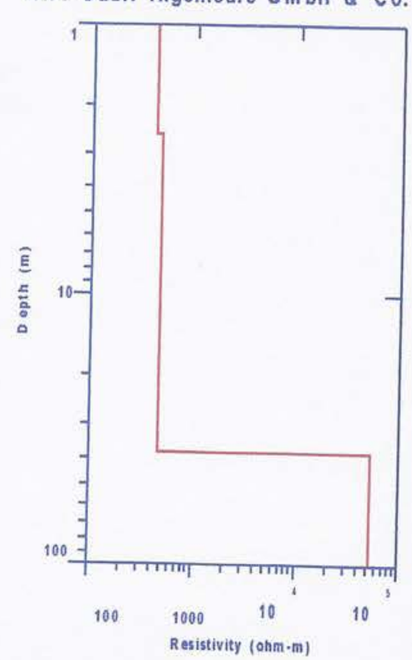
KOINADUGU VES H.P. Gauff Ingenieure GmbH & Co.



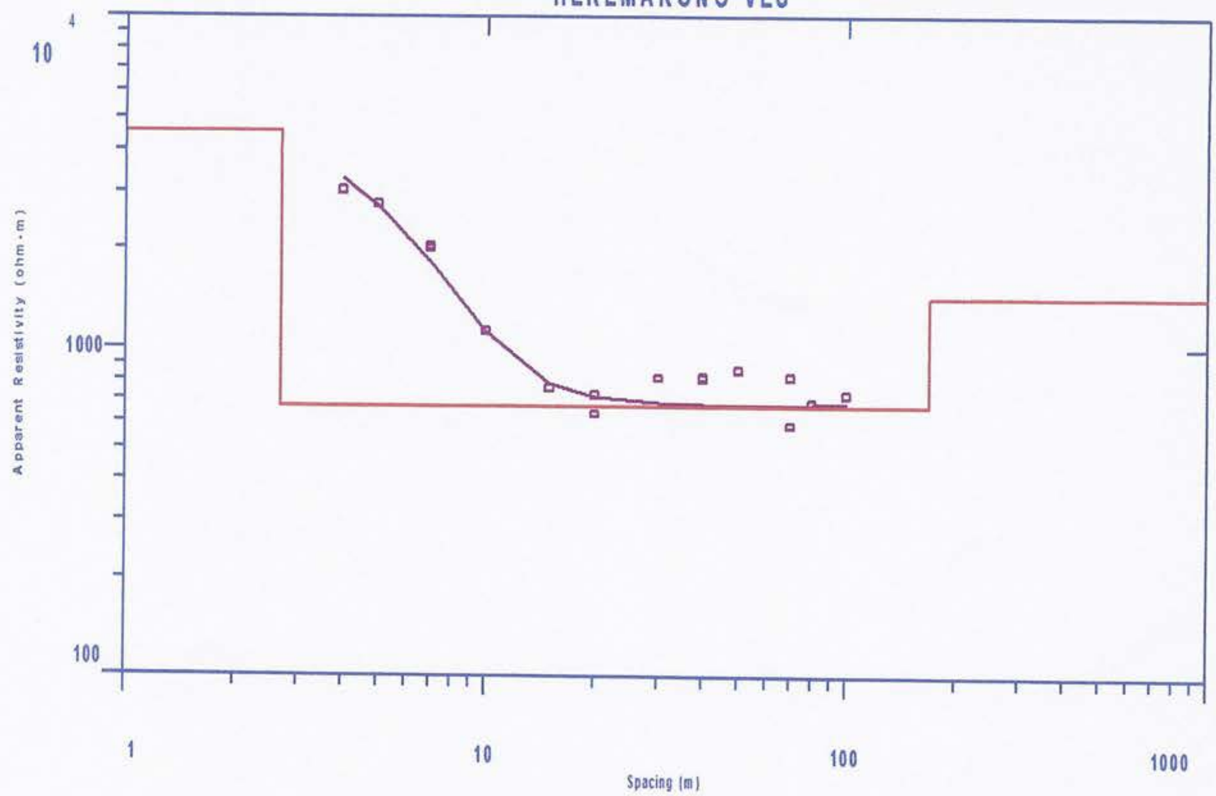
KOINADUGU VES



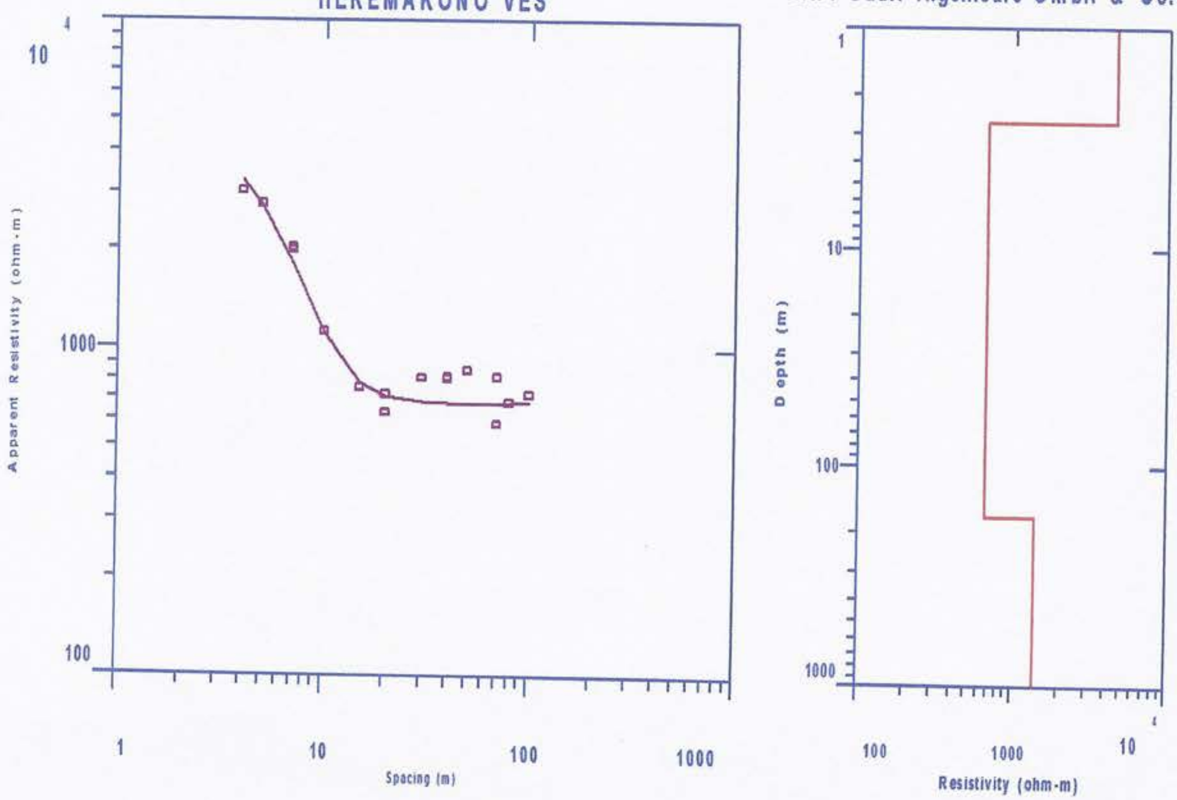
H.P. Gauff Ingenieure GmbH & Co.

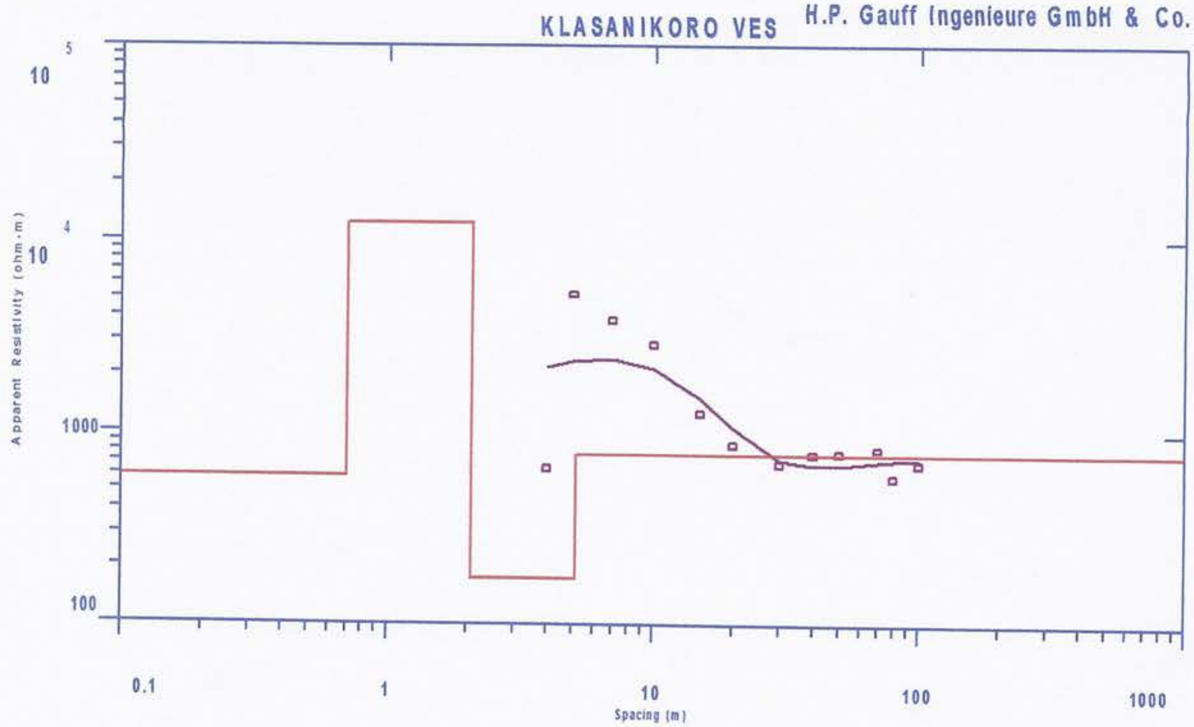


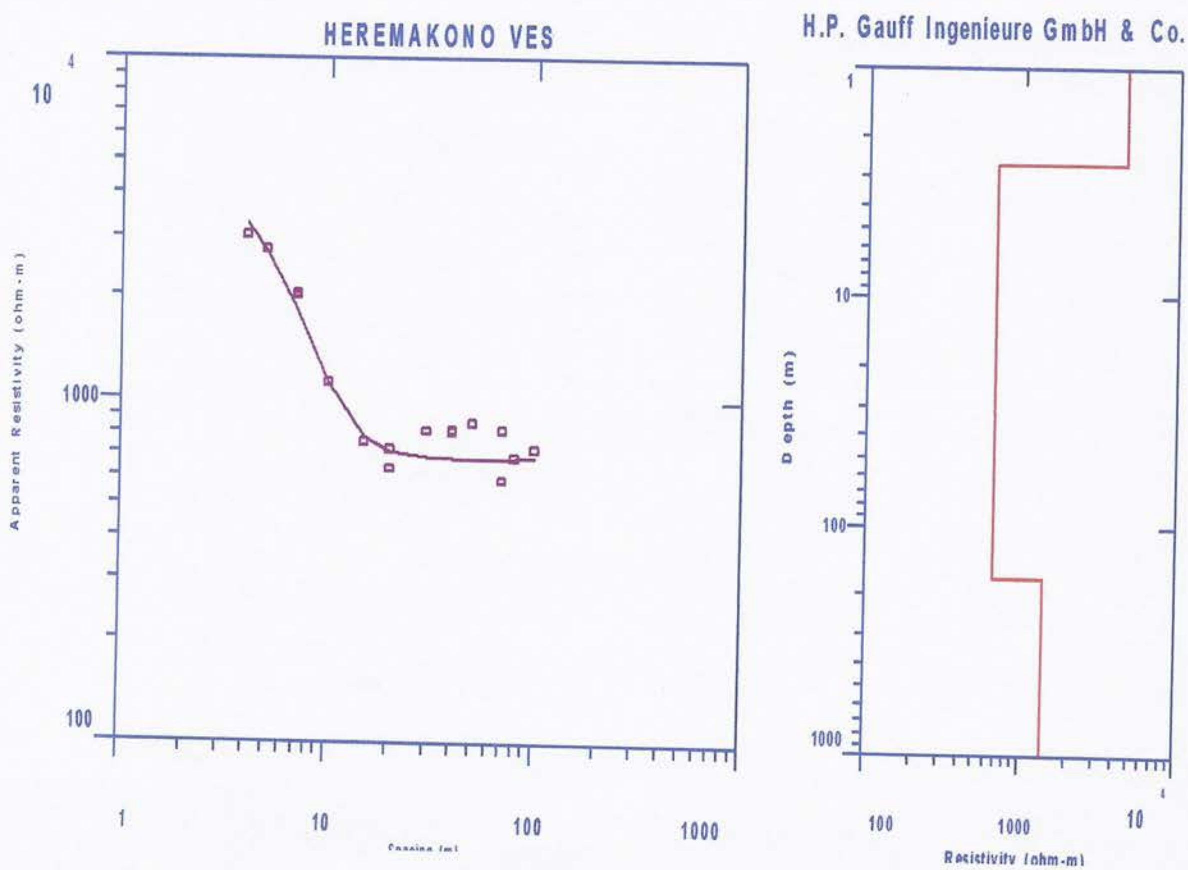
HEREMAKONO VES H.P. Gauff Ingenieure GmbH & Co.



HEREMAKONO VES H.P. Gauff Ingenieure GmbH & Co.

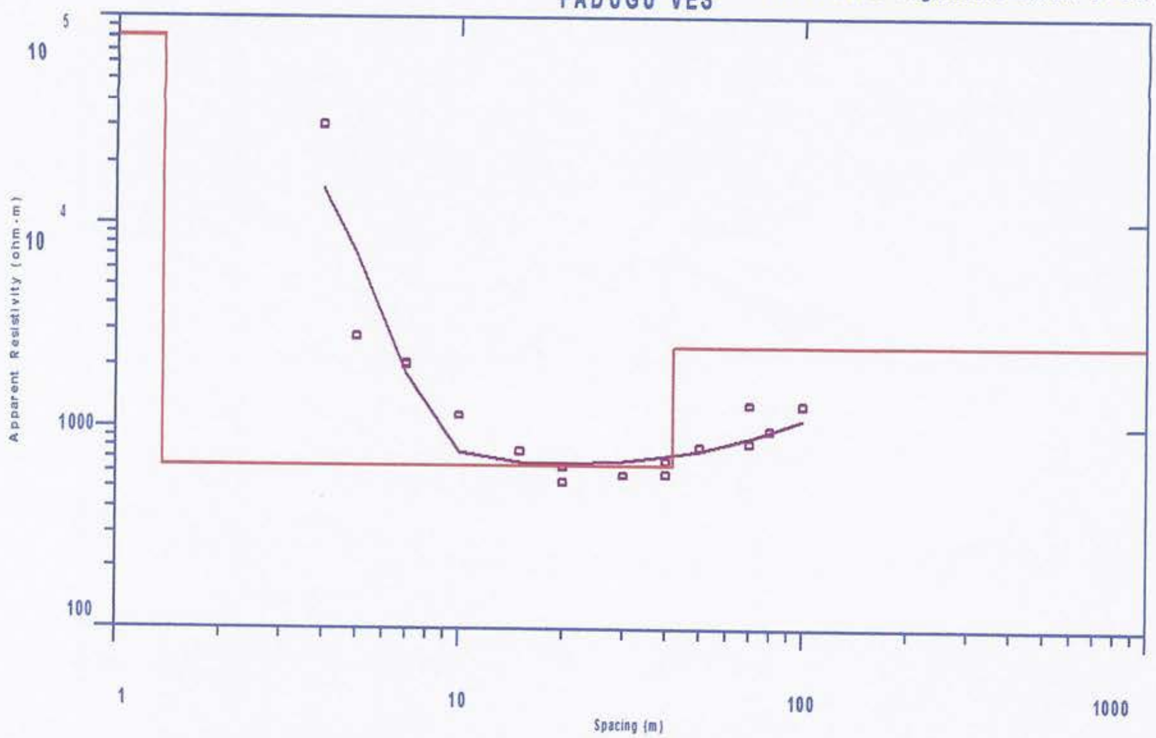



KLASANIKORO VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10^5
10^4
1000
100
0.1
1
10
100
1000
Spacing (m)


HEREMAKONO VES
H.P. Gauff Ingenieure GmbH & Co.
Apparent Resistivity (ohm-m)
10^4
1000
100
1
10
100
1000
Depth (m)
1
10
100
1000
100
1000
10^4
Resistivity (ohm-m)

FADUGU VES

H.P. Gauff Ingenieure GmbH & Co.



FADUGU VES

H.P. Gauff Ingenieure GmbH & Co.