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Research Paper

Evaluation of the Extent of Leachate Contamination of the Subsurface Structures, Using Resistivity Method, In Parts of Minna, Niger State, Nigeria.

[1]Tsado, Jacob [2]Adedokun, Isaac Oludayo, [3]Udensi, Emmanuel E.
[1]Department of Physics, Federal University of Technology, Minna, Niger State, Nigeria.
[2]Department of Physics, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.
[3]Department of Physics, Federal University of Technology, Minna, Niger State, Nigeria.
Corresponding Author: ioadedokun@yahoo.com

ABSTRACT*: This research was undertaken to determine the extent of leachate contamination of underground sediments in Eastern bypass of Minna in Northern Nigeria, Niger State. Abem Terrameter (SAS 1000) was employed to carry out the survey using Schlumberger Vertical Electrical Sounding (VES) configuration for a maximum electrode spread of 200m. Thirty six VES stations were occupied, on an area of about 20000m^2, six on each of the six gridded profiles, spaced 40m apart from each other. Four of the profiles were positioned on the dumpsite while the last two, which served as the control site, were not. RESIT computer software programme was used for the inversion of the derived field data while Suffer 8 was engaged for the Iso-resistivity contour map at 5m, 10m, 12m, and 20m depths. The results from the dump site showed three subsurface layers which are contaminated topsoil and weathered basement, fractured basement and fresh basement. At the control site, four geoelectric and geologic sections were identified; topsoil, weathered basement, fractured basement and fresh basement. Contamination of the first layer and weathered basement was due to the effect of refused dump which percolated down to about 11m, lowering the resistivity to between 9.5Ωm and 39.9Ωm. The apparent resistivity value of the topsoil was higher at the control site which ranged between 150.4 Ωm and 170.5 Ωm without any sign of leachate. Also the results from Iso-resistivity contour maps at 5m and 10m also indicated low resistivity at the dump site and high resistivity at the control site as depicted by the contour lines. It was only at about 12m depth that the contour maps have the same trend on both sides indicating that the effect of leachate has ceased at that depth. The nature of resistivity curves obtained from the study area indicated that resistivity increase continues in the substratum.*

KEYWORDS: *Schlumberger, Iso-resistivity, leachate, RESIT, Abem Terrameter*

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I. INTRODUCTION

Groundwater plays vital roles in human development but has not received commensurate attention. This could be because, water stored in the ground beneath is invisible and so its depletion or degradation due to contamination can proceed without noticed, not like the exposed rivers, lakes and reservoirs, where drying-up or pollution rapidly becomes visible and necessary attention is given. Nowadays, the problem of environmental contamination and waste management is one of the main concerns of earth scientists and researchers from other related fields of science around the globe [1].

Pollution can occur whether discrete, point sources, such as from the land filling of wastes. Waste discarded into landfills and dumpsites undergoes decay, oxidation and corrosion resulting in the release of metal ions causing potential risk to the soil, groundwater and eventually community health. As a result of rapid urbanization, solid waste management has become an endemic problem that characterizes major cities , particularly in terms of environmental nuisance combined with the health hazard and its implication. Earth science investigation using geo-electric method gives a better understanding of the Earth minerals and compositions, its possible subsurface contaminant, transport mechanisms, groundwater flow and general aquifer characteristics [2], [3] and [4].

The electrical conductivity of any geological strata depends on the conductivity of the rock formation. The most important factor is the water content, therefore, a determination of resistivity structure of the substratum might reveal not only the geological structure but also the water bearing layer. Surface resistivity methods have been applied worldwide to investigate the shallow subsurface of the geological, environmental, geotechnical, and hydro-geological problems. They have proven to be efficient and successful in delineating aquifers and mapped subsurface lithology and geological structures [5], [6] and [7]. These methods have been widely applied over the last few decades to address the growing need for a non-invasive and cost effective way to assist in the characterization of the near surface lithology, structures and groundwater aquifers [7]. The method provides mean of mapping to identify and delineate leachate contaminant plumes from dumpsite because the electrical resistivity contrast exists in electrically conductive leachate and the native groundwater. This is as a result of the leachate diminishing the electrical resistivity of the formation containing them [8]

Location of the study area

The study area is located in Minna the capital of Niger State (Figure 1) at the eastern bye-pass, known to be part of Minna North-South. It lies on latitude 9.583555N and longitude 6.546316E. The total area covered for the study is 5x40m x 100m (20000m^2) north- eastern part of Minna..

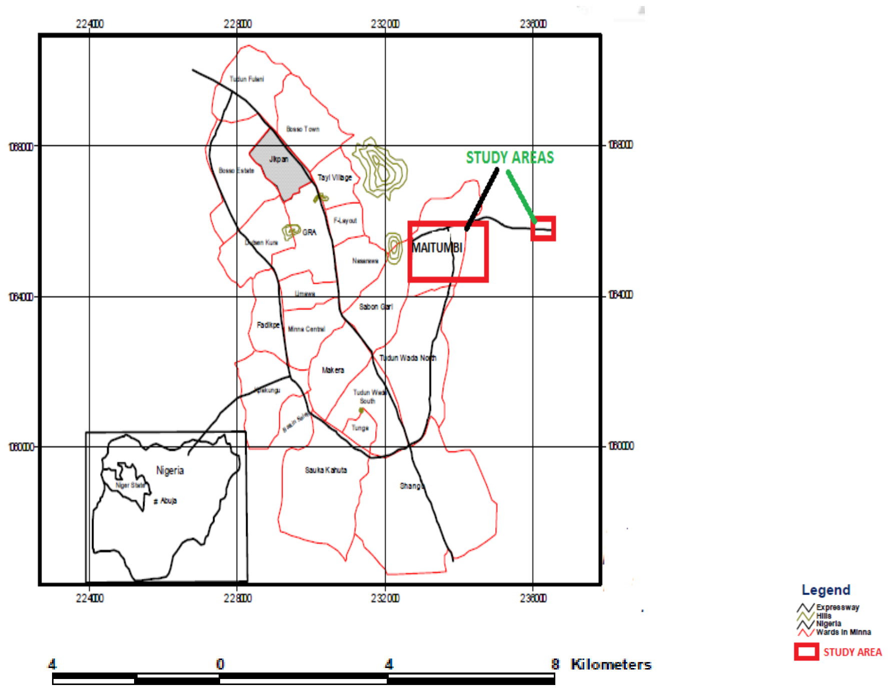


Figure 1: The Map of Minna, showing the study area

Geological and Geographical settings of the study area

Nigeria is underlain by three major sub-divisions of rocks; these are the basement complex, sedimentary basins and the younger granites of the Jos-Plateau. The basement complex covers the western, northern and some parts of the eastern Nigeria. The basement complex rocks were formed during the pre-Cambrian era [9]. Minna, the capital of Niger State is underlain by rocks of the pre-Cambrian basement complex system of Nigeria which is made up of crystalline rocks consisting of gneisses and migmatatites, and meta sedimentary schists. Three formations have been recognized in the area according to [10]. First is the Kusheriki Psamite formation at the base of successions made of rocks of varying lithology, texture and structure and showing different degree of granitization and migmatization. The second classes of rocks are mainly the Kushaka schist formation considered to be the stratigraphic equivalence of the Kushaka Formation. Last ones are the older granites which was first introduced by [11] to distinguish the Pan-African granites in Nigeria from the Mesozoic tin-bearing volcanic granitic ring complexes of the Jos plateau which were emplaced into the migmatite-gneiss complex and the schist belts.

The study area lies within the middle belt of Nigeria with mean rainfall of about 1,334 mm. The highest mean monthly rainfall is in the month of September and monthly temperature is highest in March about 37^{o}c and lowest temperature is in the month of August about 21^{o}c, annual rainfall range 1000mm to 1200mm respectively. The climate is like much of West Africa comprising of a rainy season and a dry season. The seasonal rainfall regime gives rise to a longer wet season of about seven months with an average rainfall of 250mm, and a dry season of about five months with little or no rains at all [12]

II. METHODOLOGY

The area of investigation was gridded into six profiles A to F, each of 100m in length and spaced 40m from each other, along West-East direction. The first four profiles (A-D) were on refuse dump site while the last two (G and F), which served as the control site to profiles (A to D), extended out of the dump site. On each profile, six Schlumberger Vertical electrical sounding (VES) were conducted making it a total of thirty six VES stations on all the profiles which covered an area of 20,000 m^2. Abem Terrameter (SAS 4000) equipment was used with a maximum current electrode separation AB of 200m and potential electrode separation of 30m which corresponds to maximum depth of investigation between 20 and 60m. According to [13], the maximum depth of investigation is between 0.1 to 0.3 times the AB length. The principle is that current (I), is introduce into the ground by means of two current electrodes (A and B) and the potential drop (V) between a second pair of electrodes (potential electrodes M and N) placed in line in between the pair is measured.

The survey method required that the distance between potential electrodes (MN) and current electrodes (AB) are such that 5MN≤ AB. As AB is being expanded while MN remained fixed, the process yields a rapidly decreasing potential differential difference across MN which ultimately exceeds the measuring capabilities of the instrument, Fig. 2. At this point a new value of MN is used, typically two to four times larger than the preceding value and the survey is continued [14]. The product of the resistance R (V/I), read from the equipment, T, and the Geometric factor K which has to do with the arrangement of electrodes (type of array) gives the apparent resistivity and for the arrangement, AM = MN = NB, AT = TB, [15].

$$\ell_{\alpha} = K\frac{\Delta V}{1} = KR$$

(1)

$$K = 2\pi\left[\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right]^{-1} \qquad (2)$$

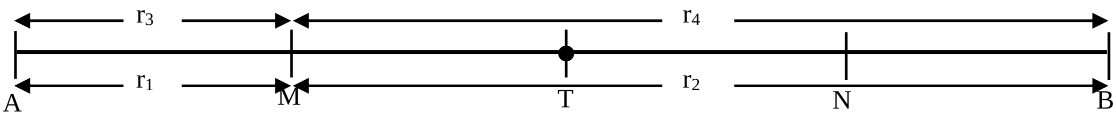
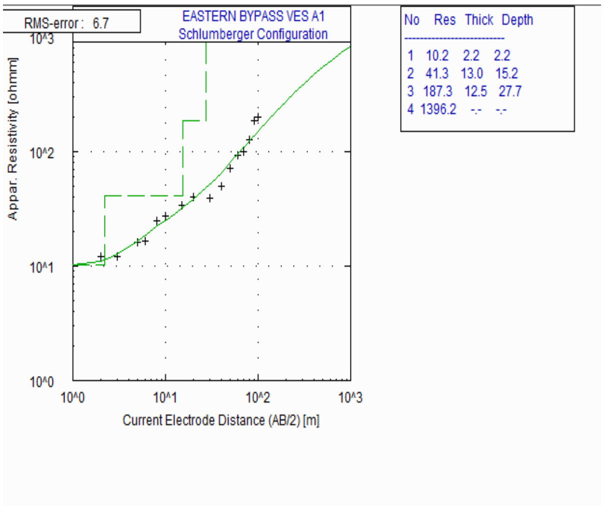


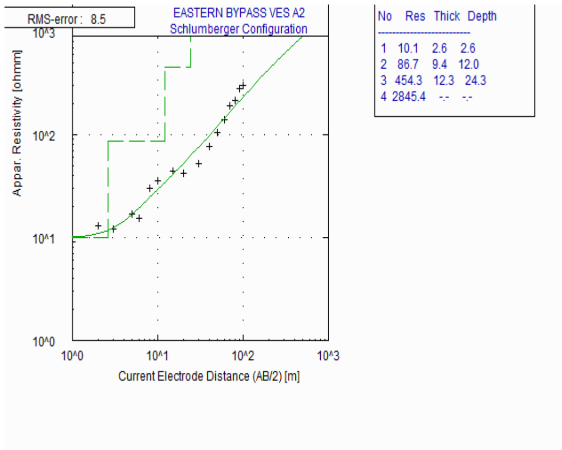
Figure 2: Schlumberger electrode configuration for the survey

value was calculated each time the electrodes were expanded. Computer software programme, RESIT, was employed to invert the field data to 1D resistivity images, where the Apparent resistivity values were plotted against half-electrode spread (AB/2). The inversion was done to interpret the primary resistivity data recorded from the field to obtain the vertical distribution of the beds in the VES stations. Surfer8 software was also used to plot iso-resistivity contour map at 5 m, 10 m, 15 m and 20 m for the thirty-six VES points.

III. RESULTS

The plots obtained for the thirty six VES interpretations, comparison of lithology between the Dump site and the Control site, and Iso-resistivity contour map at 5m,10m, 15m, and 20m are shown in Figures 3, 4 and 5 respectively. On each of the profile six VES stations were occupied and numbered VES A1- VESA6, VES B1-VES B6, VES C1-VES C6, VES D1- VES D6, VES E1- VES E6 and VES F1- VES F6 for profiles A, B, C, D, E and F respectively.


RMS-error : 6.7
EASTERN BYPASS VES A1
Schlumberger Configuration
No Res Thick Depth
1 10.2 2.2 2.2
2 41.3 13.0 15.2
3 187.3 12.5 27.7
4 1396.2 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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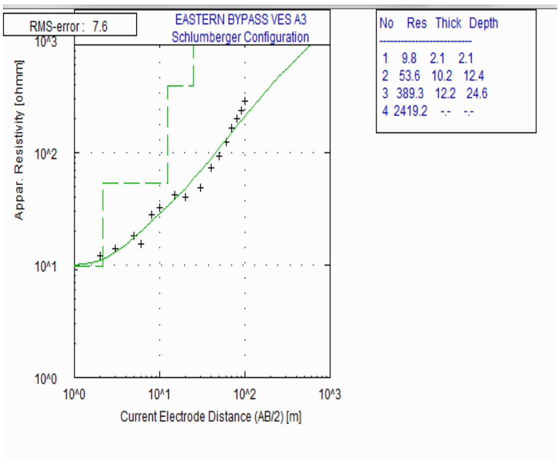
EASTERN BYPASS VES A2
Schlumberger Configuration
No Res Thick Depth
1 10.1 2.6 2.6
2 86.7 9.4 12.0
3 454.3 12.3 24.3
4 2845.4 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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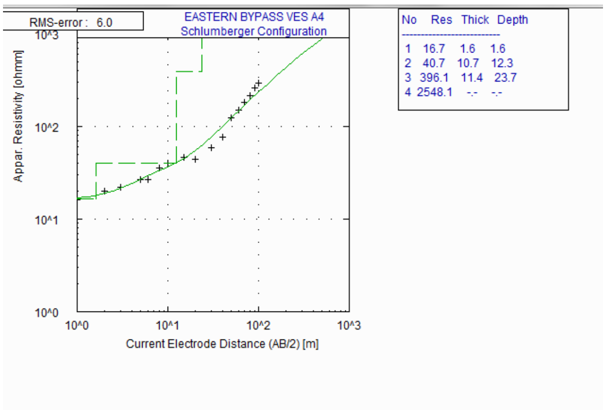
EASTERN BYPASS VES A3
Schlumberger Configuration
No Res Thick Depth
1 9.8 2.1 2.1
2 53.6 10.2 12.4
3 389.3 12.2 24.6
4 2419.2 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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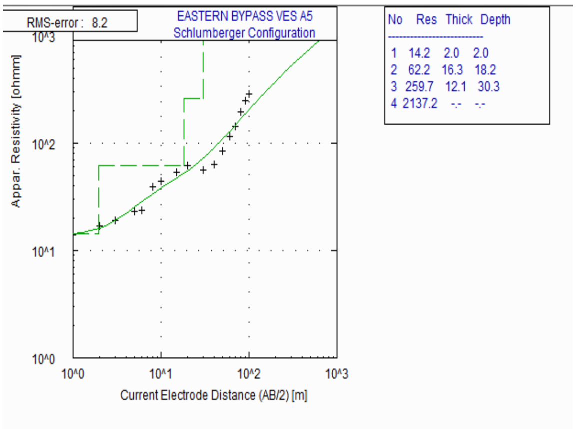
EASTERN BYPASS VES A4
Schlumberger Configuration
No Res Thick Depth
1 16.7 1.6 1.6
2 40.7 10.7 12.3
3 396.1 11.4 23.7
4 2548.1 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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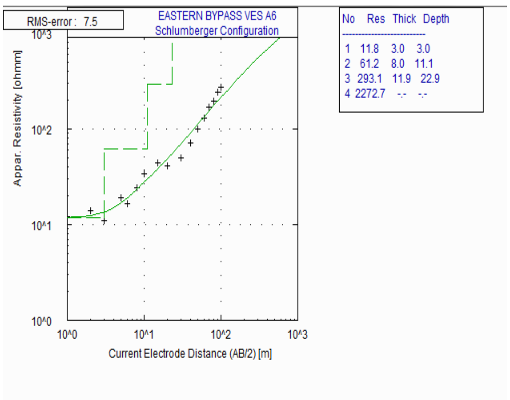
EASTERN BYPASS VES A5
Schlumberger Configuration
No Res Thick Depth
1 14.2 2.0 2.0
2 62.2 16.3 18.2
3 259.7 12.1 30.3
4 2137.2 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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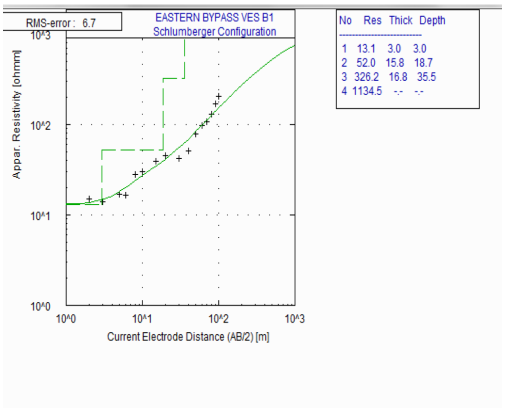
EASTERN BYPASS VES A6
Schlumberger Configuration
No Res Thick Depth
1 11.8 3.0 3.0
2 61.2 8.0 11.1
3 293.1 11.9 22.9
4 2272.7 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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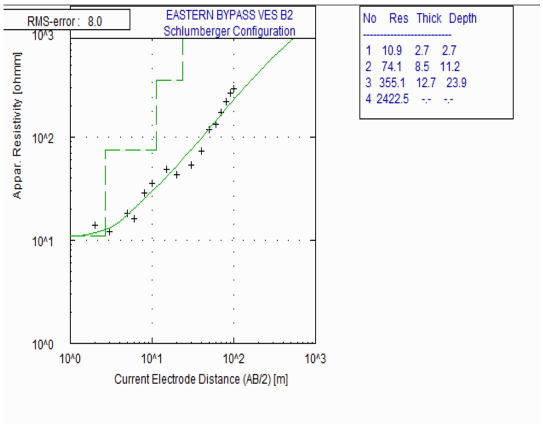
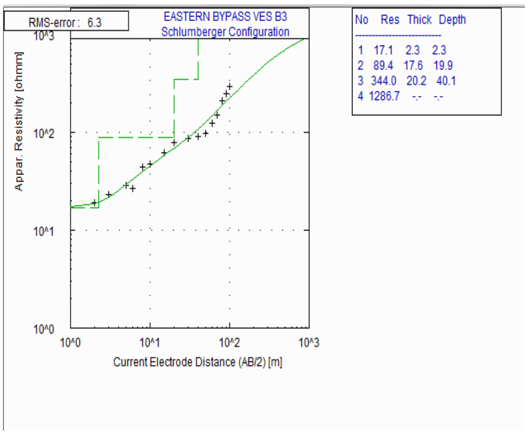
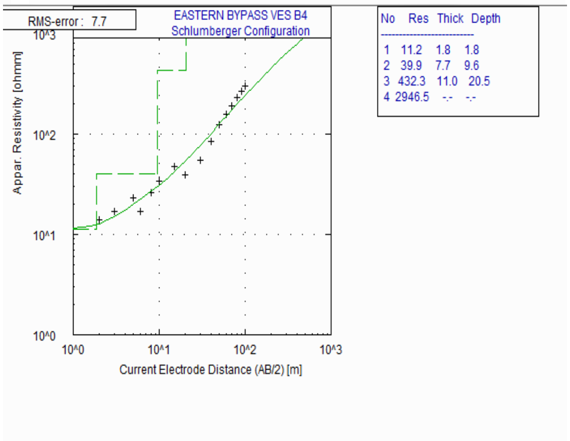
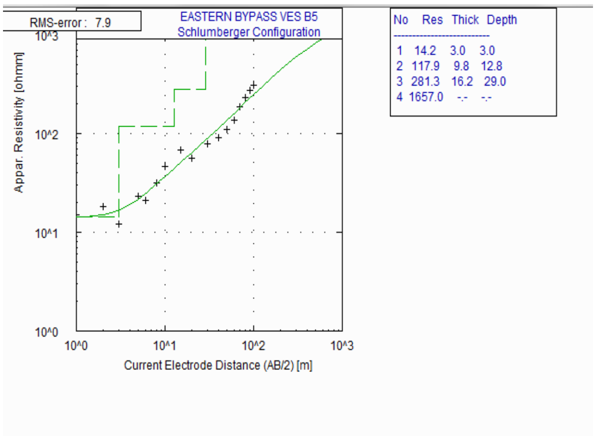
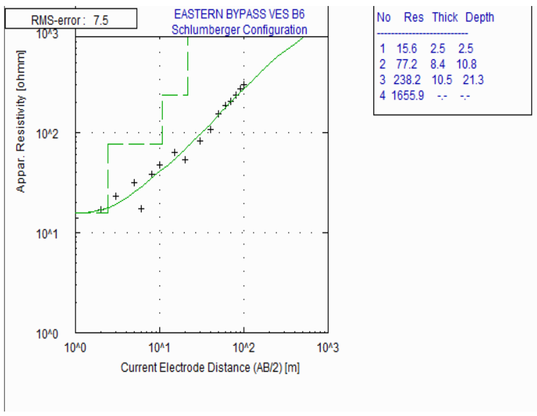
EASTERN BYPASS VES B1
Schlumberger Configuration
No Res Thick Depth
1 13.1 3.0 3.0
2 52.0 15.8 18.7
3 326.2 16.8 35.5
4 1134.5 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]


RMS-error : 8.0
EASTERN BYPASS VES B2
Schlumberger Configuration
No Res Thick Depth
1 10.9 2.7 2.7
2 74.1 8.5 11.2
3 355.1 12.7 23.9
4 2422.5 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]


RMS-error : 6.3
EASTERN BYPASS VES B3
Schlumberger Configuration
No Res Thick Depth
1 17.1 2.3 2.3
2 89.4 17.6 19.9
3 344.0 20.2 40.1
4 1286.7 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]


RMS-error : 7.7
EASTERN BYPASS VES B4
Schlumberger Configuration
No Res Thick Depth
1 11.2 1.8 1.8
2 39.9 7.7 9.6
3 432.3 11.0 20.5
4 2946.5 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]


RMS-error : 7.9
EASTERN BYPASS VES B5
Schlumberger Configuration
No Res Thick Depth
1 14.2 3.0 3.0
2 117.9 9.8 12.8
3 281.3 16.2 29.0
4 1657.0 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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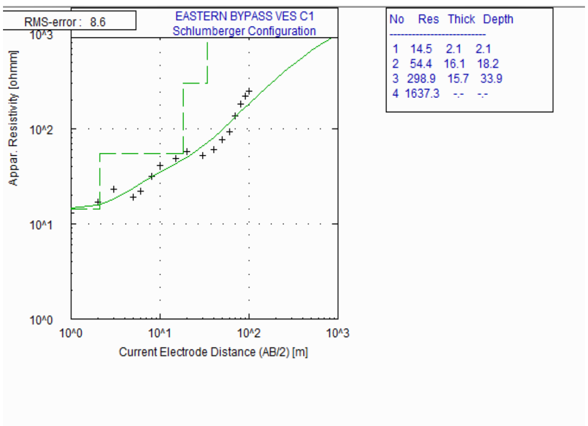
EASTERN BYPASS VES B6
Schlumberger Configuration
No Res Thick Depth
1 15.6 2.5 2.5
2 77.2 8.4 10.8
3 238.2 10.5 21.3
4 1655.9 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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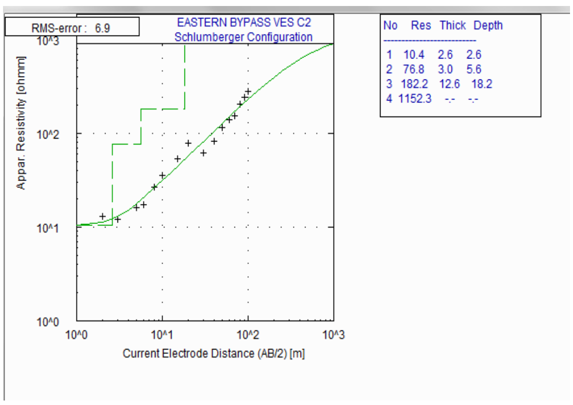
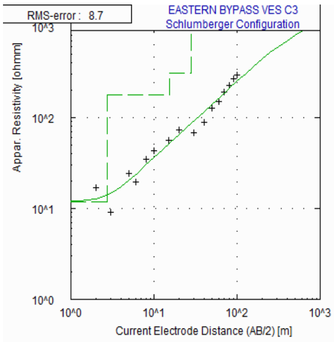
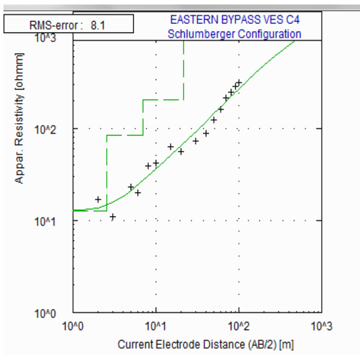
EASTERN BYPASS VES C1
Schlumberger Configuration
No Res Thick Depth
1 14.5 2.1 2.1
2 54.4 16.1 18.2
3 298.9 15.7 33.9
4 1637.3 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]

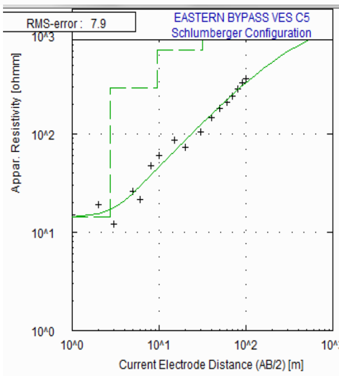

RMS-error : 6.9
EASTERN BYPASS VES C2
Schlumberger Configuration
No Res Thick Depth
1 10.4 2.6 2.6
2 76.8 3.0 5.6
3 182.2 12.6 18.2
4 1152.3 -.- -.-
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]



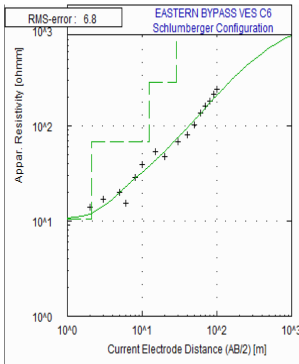
No	Res	Thick	Depth
1	11.8	2.7	2.7
2	176.4	12.6	15.3
3	308.1	12.6	27.9
4	1504.0	-.-	-.-



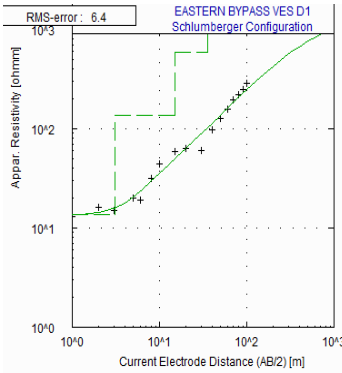
No	Res	Thick	Depth
1	12.8	2.6	2.6
2	84.3	4.4	7.0
3	204.5	14.8	21.8
4	2003.8	-.-	-.-



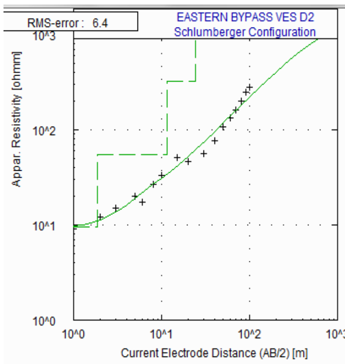
No	Res	Thick	Depth
1	14.2	2.7	2.7
2	292.8	6.7	9.5
3	719.5	22.4	31.9
4	1277.4	-.-	-.-



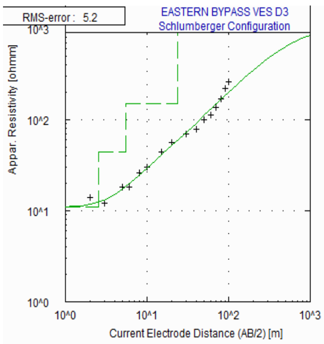
No	Res	Thick	Depth
1	10.6	2.1	2.1
2	68.0	10.2	12.4
3	285.5	16.2	28.6
4	1202.7	-.-	-.-



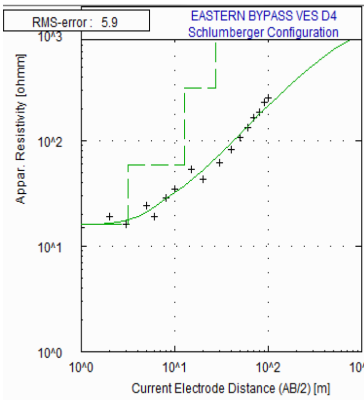
No	Res	Thick	Depth
1	13.5	3.1	3.1
2	138.1	11.8	14.9
3	590.3	20.9	35.7
4	1354.8	-.-	-.-



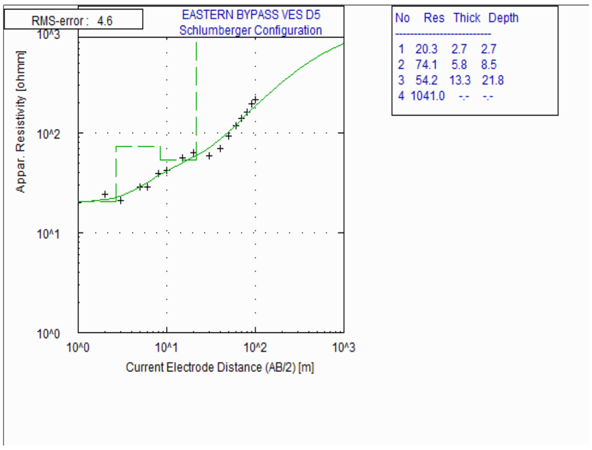
No	Res	Thick	Depth
1	9.5	1.9	1.9
2	55.5	9.6	11.5
3	322.6	12.8	24.3
4	2048.4	-.-	-.-

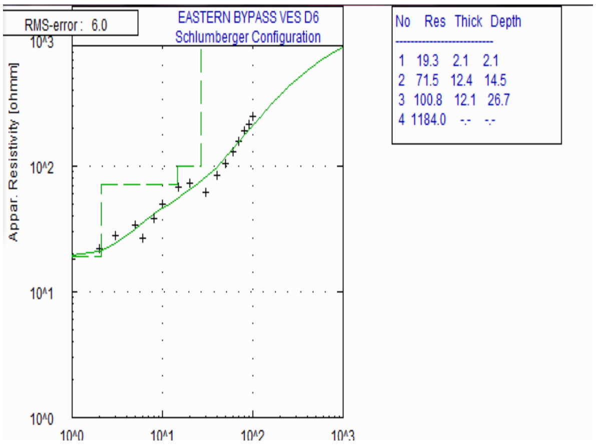


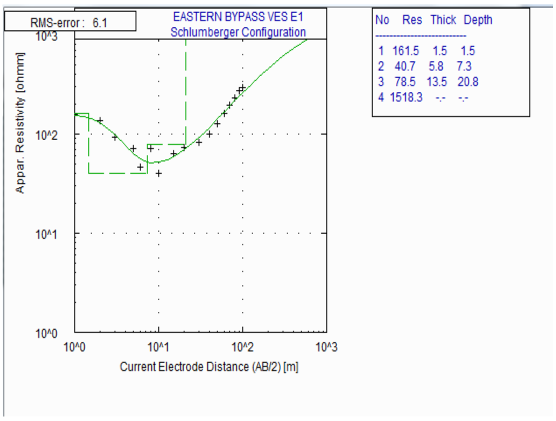
No	Res	Thick	Depth
1	10.9	2.5	2.5
2	44.6	3.0	5.5
3	151.2	18.0	23.5
4	1138.0	-.-	-.-



No	Res	Thick	Depth
1	16.0	3.2	3.2
2	58.3	9.5	12.7
3	319.1	14.5	27.1
4	1517.8	-.-	-.-


RMS-error : 4.6
EASTERN BYPASS VES D5
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 20.3 2.7 2.7
2 74.1 5.8 8.5
3 54.2 13.3 21.8
4 1041.0 -.- -.-


RMS-error : 6.0
EASTERN BYPASS VES D6
Schlumberger Configuration
Appar. Resistivity [ohmm]
No Res Thick Depth
1 19.3 2.1 2.1
2 71.5 12.4 14.5
3 100.8 12.1 26.7
4 1184.0 -.- -.-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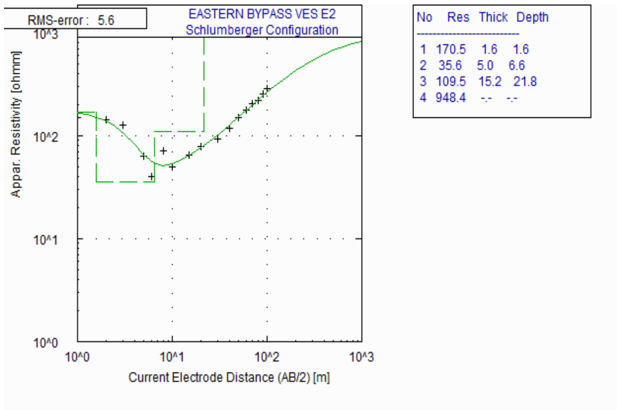
EASTERN BYPASS VES E1
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 161.5 1.5 1.5
2 40.7 5.8 7.3
3 78.5 13.5 20.8
4 1518.3 -.- -.-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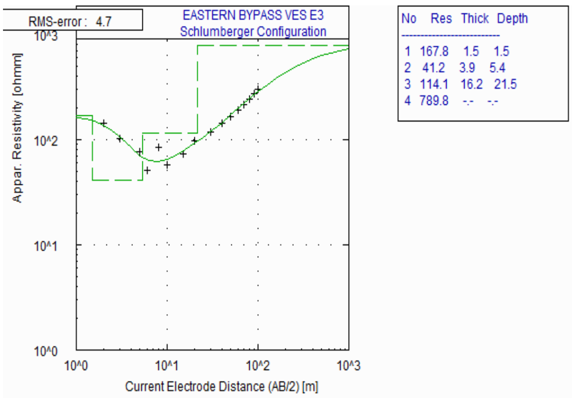
EASTERN BYPASS VES E2
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 170.5 1.6 1.6
2 35.6 5.0 6.6
3 109.5 15.2 21.8
4 948.4 -.- -.-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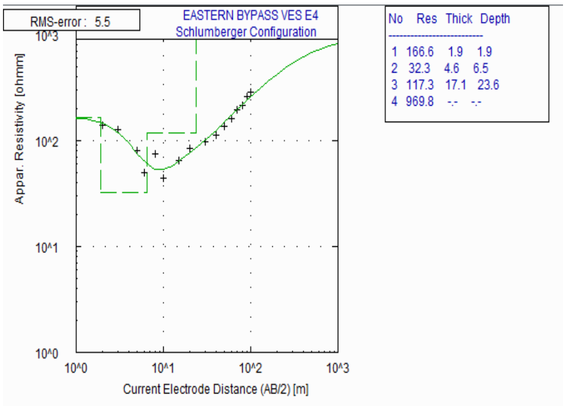
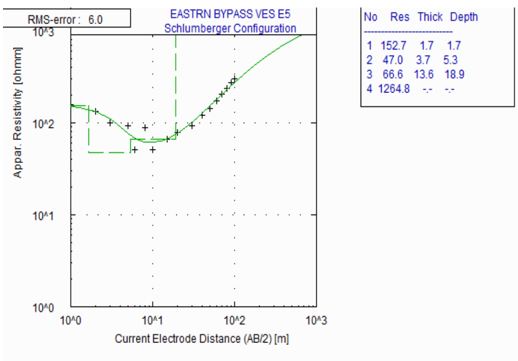
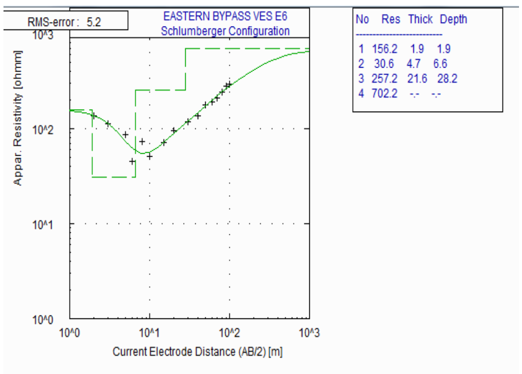
EASTERN BYPASS VES E3
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 167.8 1.5 1.5
2 41.2 3.9 5.4
3 114.1 16.2 21.5
4 789.8 -.- -.-


RMS-error : 5.5
EASTERN BYPASS VES E4
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 166.6 1.9 1.9
2 32.3 4.6 6.5
3 117.3 17.1 23.6
4 969.8 -.- -.-


RMS-error : 6.0
EASTRN BYPASS VES E5
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 152.7 1.7 1.7
2 47.0 3.7 5.3
3 66.6 13.6 18.9
4 1264.8 -.- -.-


RMS-error : 5.2
EASTERN BYPASS VES E6
Schlumberger Configuration
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 156.2 1.9 1.9
2 30.6 4.7 6.6
3 257.2 21.6 28.2
4 702.2 -.- -.-

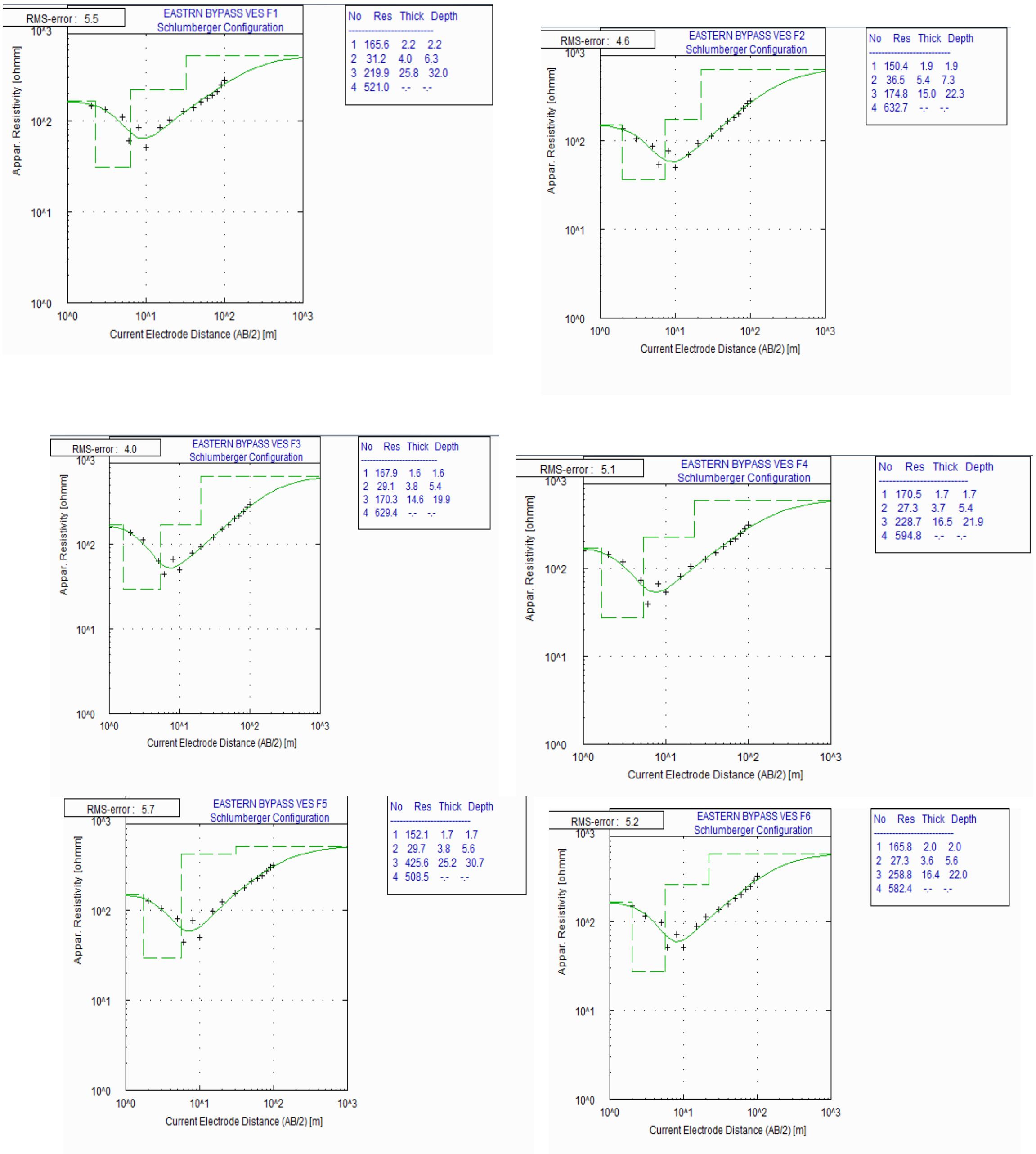


Figure 3: Field and theoretical curves for VES 1- VES 36.

IV. DISCUSSION

Summary of the Vertical electrical sounding (VES) analysis along the profiles.

The geoelectric layers for each of the thirty six VES point on the profiles, are obtained from Fig. 3 are summarised in Tables 1 – 6. Table 1 shows the summary of the VES analysis along profile A. The profile is underlain by four layers. These are humus plus leachate plus humus, weathered basement, fractured basement and fresh basement. The resistivity values ranging from 9.8 to 16.7 Ωm on the first layer, which is the humus plus leachate that percolate into the subsurface with a relative thickness of 1.6 to 3.0 m. The second layer has resistivity values ranging from 40.7 to 86.7 Ωm which is the weathered basement with a relative thickness of 8.0 to 16.3 m The third layer has resistivity values ranging from 187.3 to 454.3 Ωm which is fractured basement with a thickness of 11.4 to 12.5 m. This zone showed low resistivity values, which shows the looseness of the material. The fourth layer has resistivity values ranging from 1396.2 to 2845.4 Ωm which is the fresh competent basement and its thickness is to an infinite depth. From Table 2, the profile is underlain by four layers. These are humus plus leachate, weathered basement, fractured basement and fresh basement.The resistivity values ranging from 10.9 to 17.1 Ωm on the first layer, which is the humus plus leachate that percolate into the subsurface with a relative thickness of 1.8 to 3.0 m.The second layer has resistivity values ranging from 39.9 to 117.9 Ωm which is the weathered basement with a relative thickness of 7.7 to 17.6 m. The third layer has resistivity values ranging from 238.2 to 432.3 Ωm which is fractured basement with a thickness of 10.5 to 20.2 m. This zone showed low resistivity values, which shows the looseness of the material. The fourth layer has resistivity values ranging from 1134.5 to 2946.5 Ωm which is the fresh/competent basement and its thickness is to an infinite depth.

The profile on Table 3 is underlain by four layers. These are humus plus leachate, weathered basement, fractured basement and fresh basement. The resistivity values ranging from 10.4 to 14.5 Ωm on the first layer, which is the humus plus leachate that percolate into the subsurface with a relative thickness of 2.1 to 2.7 m. The second layer has resistivity values ranging from 54.4 to 292.8 Ωm which is the weathered basement with a relative thickness of 3.0 to 16.1 m. The third layer has resistivity values ranging from 182.2 to 719.5 Ωm which is fractured basement with a thickness of 12.6 to 22.4 m. This zone showed low resistivity values, which shows the looseness of the material. The fourth layer has resistivity values ranging from 1152.3 to 2003.8 Ωm which is the fresh/competent basement and its thickness is to an infinite depth.

Table 4 is a summary for profile D which is underlain by four layers. These are humus plus leachate, weathered basement, fractured basement and fresh basement. The resistivity values ranging from 9.5 to 20.3 Ωm on the first layer, which is the humus plus leachate that percolate into the subsurface with a relative thickness of 1.9 to 3.2 m. The second layer has resistivity values ranging from 44.6 to 138.1 Ωm which is the topso with a relative thickness of 3.0 to 12.4 m.The third layer has resistivity values ranging from 54.2 to 590.3 **Ω**m which is weathered/ fractured basement with a thickness of 12.1 to 20.9 m. This zone showed low resistivity values, which shows the looseness of the material to allow seepages of the leachate in the subsurface. BThe fourth layer has resistivity values ranging from 1041.0 to 2048.4 Ωm which is the fresh/competent basement and its thickness is to an infinite depth.

From Table 5, the profile is underlain by four layers. These are topsoil, weathered basement, fractured basement and fresh basement. The lowest resistivity value is 30.6 Ωm which occurs within the second layer of point E_6. The thickest layer in the weathered zone is 5.8 m at E_1 with resistivity of 40.7 Ωm.The thickness of the top layer is at the range of 1.0 m to 2.0 m for all the VES points in the profile with resistivity values ranging from 152.7 to 170.5 Ωm. This suggests that the top layer of all the VES points is lateritic soil. The thickest fractured zone is 21.6 m and this occurs at point E_6 with resistivity of 257.2 Ωm . This presupposes that the point E_6 is the best water bearing zones along profile E. The thinnest weathered zone is 3.7 m which occurs at point E_5 with resistivity value of 47.0 Ωm. The highest resistivity along the profile is 1518.3 **Ω**m which occurs at the fresh basement of VES point E_1.Table 6 is a summary of VES analysis along profile F, which is underlain by four layers. These are topsoil, weathered basement, fractured basement and fresh basement. The lowest resistivity value is 27.3 Ωm which occurs within the second layer of point F_4 and F_6. The thickest layer in the weathered zone is 5.4 m at F_2 with resistivity of 36.5Ωm

The thickness of the top layer is at the range of 1.0 m to 2.5 m for all the VES points in the profile with resistivity values ranging from 150.4 to 170.5Ωm This suggests that the top layer of all the VES points is lateritic soil. The thickest fractured zone is 25.8 m and this occurs at point F_1 with resistivity of 219.9 Ωm This presupposes that the point $F_{1,}$ F_4 and F_6 is the best water bearing zones along profile E. The thinnest weathered zone is 3.6m which occurs at point F_6 with resistivity value of 27.3 Ωm. The highest resistivity along the profile is 632.7 Ωm which occurs at the fresh basement of VES point F_2.

Table 1: Summary of Vertical Electrical sounding (VES), Layer thickness, Depth and Resistivity along profile A (Dumpsite).

VES	Layers	Thickness/m	Depth/m	Resistivity/ Ωm	VES	Layers	Thickness/m	Depth/m	Resistivity/Ωm
A1	1	2.2	2.2	10.2	A2	1	2.6	2.6	10.1
	2	13.0	15.2	41.3		2	9.4	12.0	86.7
	3	12.5	21.7	187.3		3	12.3	24.3	454.4
	4	∞	2	1396.2		4	∞	∞	2845.4
A3	1	2.1	2.1	9.8	A4	1	1.6	1.6	16.7
	2	10.2	12.4	53.6		2	10.7	12.3	140.7
	3	12.2	24.6	389.3		3	11.4	23.7	396.7
	4	∞	∞	2419.2		4	∞	∞	2548.1
A5	1	2.0	2.0	14.2	A6	1	3.0	3.0	11.8
	2	16.3	18.2	62.2		2	8.0	11.1	61.2
	3	12.1	30.3	259.7		3	11.9	22.9	293.1
	4	∞	∞	2137.2		4	∞	∞	2272.7

Table 2: Summary of Vertical Electrical sounding (VES), Layer thickness, Depth and Resistivity along profile B (Dumpsite).

VES	Layers	Thickness/m	Depth/m	Resistivity/ Ωm	VES	Layers	Thickness/m	Depth/m	Resistivity/Ωm
B1	1	3.0	3.0	13.1	B2	1	2.7	2.7	10.9
	2	15.8	18.7	52.0		2	8.5	11.2	74.1
	3	16.8	35.5	326.2		3	12.7	23.9	355.1
	4	∞	∞	1134.5		4	∞	∞	2422.5
B3	1	2.3	2.3	17.1	B4	1	1.8	1.8	11.2
	2	17.6	19.9	89.4		2	7.7	9.6	39.9
	3	20.2	40.1	344.0		3	11.0	20.5	432.3
	4	∞	∞	1286.7		4	∞	∞	2946.5
B5	1	3.0	3.0	14.2	B6	1	2.5	2.5	15.6
	2	9.8	12.8	117.9		2	8.4	10.8	77.2
	3	16.2	29.0	281.3		3	10.5	21.3	238.2
	4	∞	∞	1657,0		4	∞	∞	1655.9

Table 3: Summary of Vertical Electrical sounding (VES), Layer thickness, Depth an Resistivity along profile C (Dumpsite).

VES	Layers	Thickness/m	Depth/m	Resistivity/ Ωm	VES	Layers	Thickness/m	Depth/m	Resistivity/Ωm
C1	1	2.1	2.1	14.5	C2	1	2.6	2.6	10.4
	2	16.1	18.2	54.4		2	3.0	3.6	76.8
	3	15.7	33.9	298.9		3	12.6	18.2	182.2
	4	∞	∞	1637.3		4	∞	∞	1152.3
C3	1	2.7	2.7	11.8	C4	1	2.6	2.6	12.8
	2	12.6	15.3	176.4		2	4.4	7.0	84.3
	3	12.6	27.9	308.1		3	148	21.8	204.5
	4	∞	∞	1504.0		4	∞	∞	2003.8
C5	1	2.7	2.7	14.2	C6	1	2.1	2.1	10.6
	2	6.7	9.5	292.8		2	10.2	12.4	68.0
	3	22.4	31.9	719.5		3	16.2	28.6	285.5
	4	∞	∞	1277.4		4	∞	∞	1202.7

Table 4: Summary of Vertical Electrical sounding (VES), Layer thickness, Depth and Resistivity along profile D (Dumpsite).

VES	Layers	Thickness/m	Depth/m	Resistivity/ Ωm	VES	Layers	Thickness/m	Depth/m	Resistivity/Ωm
D1	1	3.1	3.1	13.5	D2	1	1.9	1.9	9.5
	2	11.8	14.9	138.1		2	9.6	11.5	55.5
	3	20.9	55.7	590.3		3	12.8	24.3	322.6
	4	∞	∞	1354.8		4	∞	∞	2048.4
D3	1	2.5	2.5	10.9	D4	1	3.2	3.2	16.0
	2	3.0	5.5	44.6		2	9.5	12.7	58.3
	3	18.0	23.5	151.2		3	14.5	27.1	319.1
	4	∞	∞	1138.0		4	∞	∞	1517.8
D5	1	2.7	2.7	20.3	D6	1	2.1	2.1	19.3
	2	5.8	8.5	74.1		2	12.4	14.5	17.5
	3	13.3	21.8	54.2		3	12.1	26.7	100.8
	4	∞	∞	1041.0		4	∞	∞	1184.0

Table 5: Summary of Vertical Electrical sounding (VES), Layer thickness, Depth and Resistivity along profile E (control site).

VES	Layers	Thickness/m	Depth/m	Resistivity/ Ωm	VES	Layers	Thickness/m	Depth/m	Resistivity/Ωm
E1	1	1.5	1.5	161.5	E2	1	1.6	1.6	170.5
	2	5.8	7.3	40.7		2	5.0	6.6	35.6
	3	13.5	20.8	78.5		3	15.2	21.8	109.5
	4	∞	∞	1518.3		4	∞	∞	948.4
E3	1	1.5	1.5	167.8	E4	1	1.9	1.9	166.6
	2	3.9	5.4	41.2		2	4.6	6.5	32.3
	3	16.2	21.5	114.1		3	17.1	23.6	117.3
	4	∞	∞	789.8		4	∞	∞	969.8
E5	1	1.7	1.7	152.7	E6	1	1.9	1.9	156.2
	2	3.7	5.3	47.0		2	4.7	6.6	30.6
	3	13.6	18.9	66.6		3	21.6	28.2	257.2
	4	∞	∞	1264.8		4	∞	∞	702.2

Table 6: Summary of Vertical Electrical sounding (VES), Layer thickness, Depth and Resistivity along profile F (control site).

VES	Layers	Thickness/m	Depth/m	Resistivity/ Ωm	VES	Layers	Thickness/m	Depth/m	Resistivity/Ωm
F1	1	2.2	2.2	165.6	F2	1	1.9	1.9	150.4
	2	4.0	6.3	31.2		2	5.4	7.3	36.5
	3	25.8	32.0	219.9		3	15.0	22.3	174.8
	4	∞	∞	521.0		4	∞	∞	632.7
F3	1	1.6	1.6	167.9	F4	1	1.7	1.7	170.5
	2	3.8	5.4	29.1		2	3.7	5.4	27.3
	3	14.6	19.9	170.3		3	16.5	21.9	228.7
	4	∞	∞	629.4		4	∞	∞	594.8
F5	1	1.7	1.7	152.1	F6	1	2.0	2.0	165.8
	2	3.8	5.6	29.7		2	3.6	5.6	27.3
	3	25.2	30.7	425.6		3	16.4	22.0	258.8
	4	∞	∞	508.5		4	∞	∞	582.4

Geo-electric section and hydrology of the Dump site and Control site

From the geo-electric and geologic sections on the tables the dump site (profiles A-D) has three subsurface which are contaminated top soil and weathered basement, fractured basement and fresh basement From the geo-electric section we can deduce that the first layer contaminated top soil and weathered basement is due to the refuse dump and this affect the top soil and the weathered basement, the effect percolates down towards around 11m depth with low resistivity ranging 9.5 to 39.9 Ωm this low resistivity is due to the leachate effect. Getting down to the fractured basement the level or value of the apparent resistivity tends to be at the same range with that of the dump site, ranging from 54.2 to 719 Ωm . This simply explains that the leachate effects affect the top layer down to around 11m. At the second layer (weathered basement) down, the effects stop.

The geo-electric and geologic sections of the Control Sites indicate that the four subsurface, which are top soil, weathered basement, fractured basement and fresh basement. The apparent resistivity value of the top soil is high compare to that of dump site ranging from 150.4 to 170.5 Ωm at 1.5 m depth, which shows no effect of leachate. The weathered and fractured basement which shows low resistivity value is due to the effect of water bearing materials or weathering of the rocks at the depth of 9.3 m down.

Comparison of the Geo-electric section and hydrology from the two sites

By comparing the two geo-electric sections, the dump site has three subsurface and the control site has four, (Fig. 4). The refuse dump at the top of the dump site with lower apparent resistivity affects the weathered basement and tends to also reduce its apparent resistivity. At the control site the first layer which is the top soil has a high apparent resistivity compare to the first layer of the dump site. At the fracture basement of the two sites the effects of leachate disappears, to explain that the leacha te effect stop at around 12m depth below the surface. Deduction from the Iso resistivity map (Fig. 5) also reveals that the effect of leachate at the dump site gives rise to the low resistivity values at 5 m and 10 m respectively compare to the high resistivity at the control site. From the Iso resistivity map, at the 12m depth, the effect of leachate disappears

Table 7: Lithology of the study area from the data

Control site		Dumpsite site	
Lithology	Resistivity /Ωm	Lithology	Resistivity/ Ωm
Topsoil	150.4 – 170.5	Contaminated topsoil	9.5- 20.3
Weathered basement	27 – 47	Weathered basement	20.5 – 98.4
Fractured basement	66.6 – 425.6	Fractured basement	54.2 – 719.5
Fresh basement	508 – 1518.3	Fresh basement	1041.0 – 2946.55

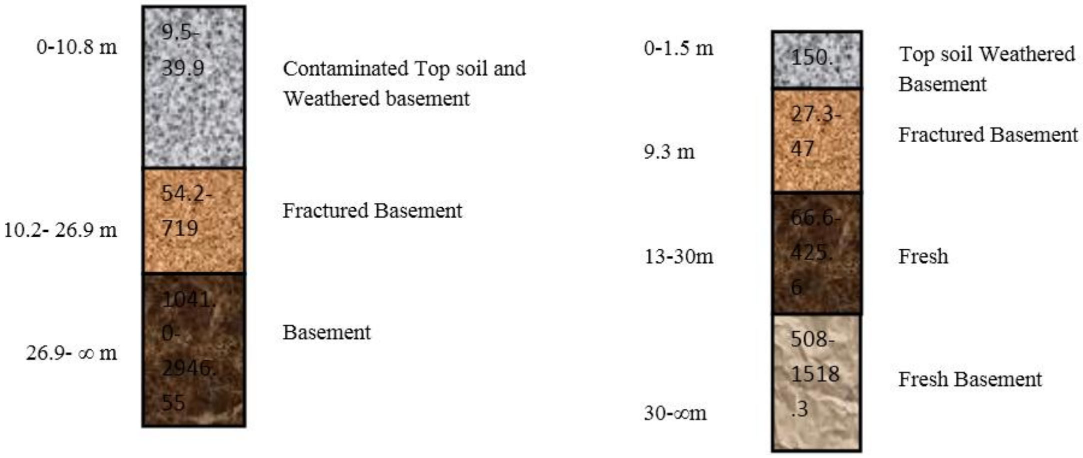


Figure 4: Comparison between (a) Dump site and (b) Control site

Analysis of the Iso-resistivity contour map

From the Iso-resistivity contour map (Fig. 5a) at 5 m depth with contour interval of 10 Ωm shows variation in resistivity values. At the dump site (profile A to D), resistivity value ranges between 0 - 40 Ωm, with consistent increase towards the control site, (profile E and F). The contact boundary between the dump site and control site shows parallel contour lines with resistivity values ranging from 50- 100 Ωm. The control site shows resistivity values ranging from 150 - 180 Ωm The low resistivity values at profile A to D indicate the effect of the leachate on the resistivity values while the high resistivity values profile E and F indicate the absence of leachate.

On Fig. 5b, variation in resistivity values is also observed at 10 m depth with contour interval of 10 Ωm. At the dump site, (profile A to D), resistivity values range from 40-260 Ωm as the resistivity values increases with depth due to decrease in the effect of leachate. The contact boundaries between the dump site and control site also exhibit discontinuity in contour lines, with resistivity values ranging from 150-390 Ωm. The control site shows resistivity values ranging from 400-500 Ω. The effect of leachate is also revealed at the South-western part of the contour map where the resistivity is low. The contour map for Iso-resistivity at 12m depth have low resistivity and similar values at both the dump site and control site, to indicate that no effect of leachate plumes at 12 m depth (Fig. 5c).

The trend at 20 m depth with contour interval of 20 m tends to be consistent as the Iso-resistivity map revealed in Fig.5d. The trends here clearly look the same all through, this explain the total disappearance of the leachates plumes at the refuse dump side. Therefore, both side of the study area, dump site and control site have same trend of contour and no leachate plumes at the depth of 20 m. Towards the lower part of the contour map, Southeastern, shows that the side is viable for good water potential. From the analysis, the dump site has four layers, contaminated topsoil, weathered basement, fractured basement and fresh basement while the control side has four layers also which are, topsoil, weathered basement, fractured basement and fresh basement. The effect of leachates can be seen at the dump site, the first layer (contaminated topsoil) with low resistivity values whose effect penetrates some distance at the second layer (weathered basement). The control site shows high resistivity values in the first and second layers compare to that of dump site and has no effect of leachate.

The iso resistivity maps has also revealed variation in resistivity between the dump site and control site at 5m and 10 m plots of the dump site (profile A to D) which shows low resistivity values compared to the control site (profile E and F). At depth of 12 m depth, the resistivity values at dump site and control site tends to have similar range; an indication that the effect of leachate has disappeared. The lower resistivity values at the control site (Western part) than that of the dump site, explains the effect of water bearing materials or weathering of the rocks at 20 m depth below the surface. Since the effect of leachate on the dump site extends to about around 11 m depth, then the weathered basement is affected and as such the ground water, at the dump site, is affected also.

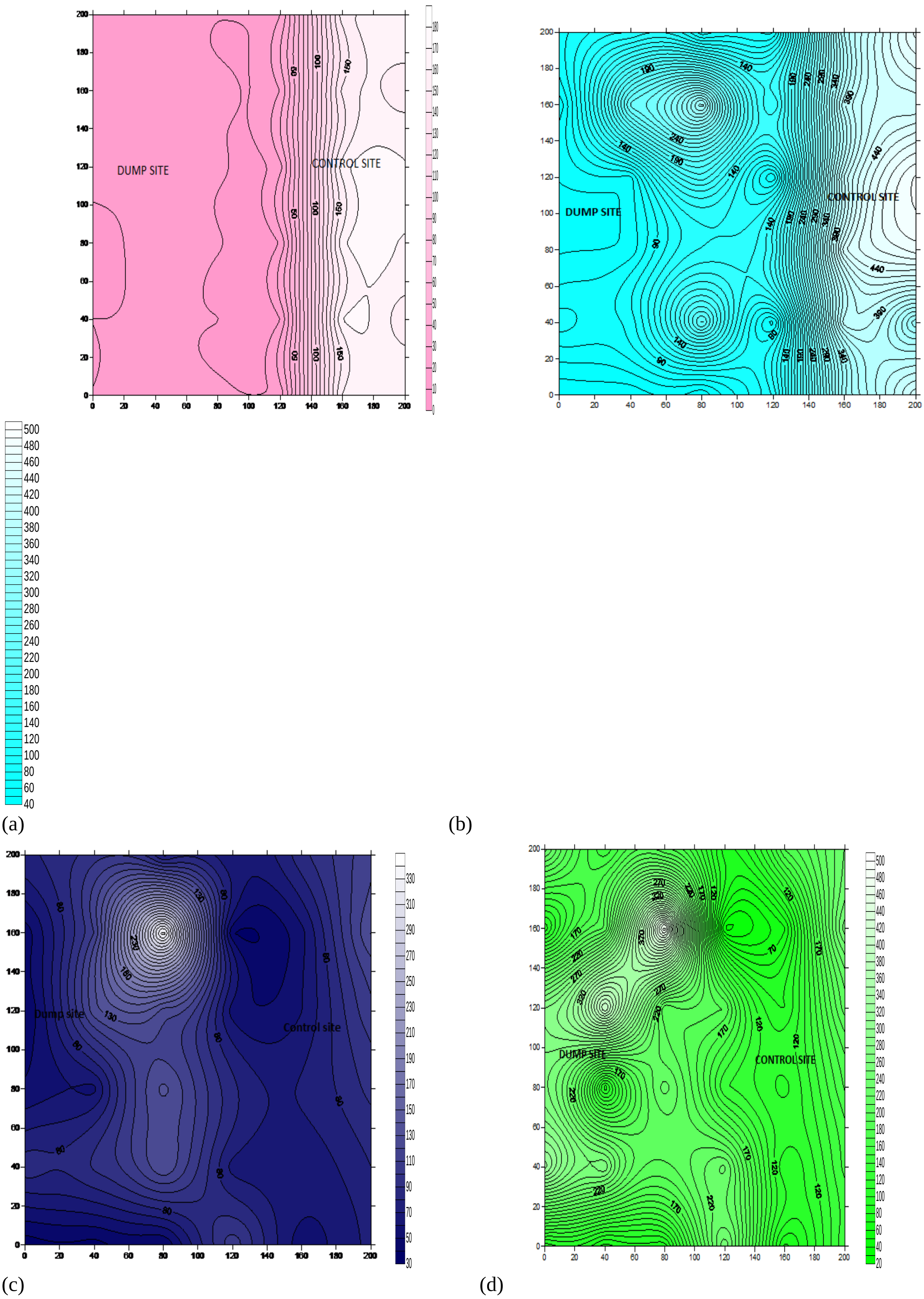


Figure 5: Iso-resistivity contour maps at (a) 5m, (b) 10m, (c) 12m and (d) 20m depths

V. CONCLUSION

This research work has been able to contribute to the efforts of ground water protection, and that Vertical Electrical Sounding can be effectively used to detected the leachate plume and the extent of its influence in terms of depth. Four geologic sections have been delineated: the top most layers which consist of lateritic soil. This formation is followed in succession by weathered/transition zone (which constitutes the main aquifer unit). The results also revealed that the depth of water table varies between 5.3m and 13.2m. The second layer of all the Vertical electrical sounding (VES) points occupied on the dumpsite revealed low resistivity values (9.5 Ωm–20.3 Ωm) which could be attributed to contamination of the ground water as a result of leachate accumulation or presence of in-situ weathered clay material or both. It is shown that the ground water, at the dump site is contaminated as the leachate plume emanates from the dumpsite and migrates, to about 12 m depth, down towards underneath second layer. Therefore, it can be concluded that, leachate plumes contamination affect the groundwater to the depth of 12m in the study area. Location of dumpsites should be well situated from residential site and survey should be carried out when planning for source of drinking water and effective remediation measures must be put in place to reduce further environmental hazard from the refuse dumpsites.

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