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# INVESTIGATION OF IMPACT OF THE USE OF INJECTION WELL ON GROUNDWATER, USING GEOELECTRICAL APPROACH, ALONG BOUNDARY ROAD, BENIN CITY, NIGERIA

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## ABSTRACT

Geoelectrical imaging of the subsurface to investigate the impact of flood injection on groundwater contaminants in a typical flood area in Benin City, Nigeria was carried out. The 2 – Dimensional electrical resistivity survey method for the subsurface imaging was done by engaging the Wenner array configuration using Petrozenith terrameter in the surface measurement. The vertical electrical sounding (VES) was also done by using the Schlumberger array configuaration to determine the depth to the aquifer layer. The DIPRO software and the RES2DINV software were used for the interpretation of the 2-D resistivity data. Physico-chemical analysis of water was carried out to test for the presence of heavy metals. From the VES result, the depth to the aquifer lies around 37.2m of resistivity of 17.3Ωm and the 2-D results showed the resistivity values for DIPRO from 40Ωm to 100Ωm and for RES2DINV from 12.7Ωm to 53.2Ωm respectively showing that the study area has groundwater potential. For the Physico-chemical analysis of water, the result showed the presence of heavy metals such as Nickel (0.09mg/l) and Chromium (0.26mg/l) which when compared with Nigerian Standard for Drinking Water quality (NSDWQ), were found to have exceeded the maximum permitted level, Nickel (0.02mg/l) and Chromium (0.05mg/l). As a result, it was obvious that the presence of Nickel and Chromium, in the Physico-chemical analysis, are likely the cause of the low resistivity values observed in the 2-dimensional electrical resistivity survey results. Besides, both elements are harmful to human beings when ingested because they are carcinogenic, that is, they can cause cancer. Also the boreholes that are not close to the injection well do not have traces of heavy metals which further reveal that as one moves away from the injection well, contamination of groundwater is not obvious.

**KEYWORDS:** Geoeletrical, Contaminant, Imaging, Physico-chemical analysis

## INTRODUCTION

Groundwater is the water below the ground surface which can be found in void spaces (Dawie, 2010). Some of the major sources of contaminants are storage tanks, septic systems, hazardous waste sites, landfills but some of the major sources of groundwater contamination include geophysical aspects, chemical aspects, microbial aspects and man-made aspect (Alile *et al.*, 2012). Groundwater pollution in

Nigeria could not have started from anything else than physical processes and anthropogenic activities.

The Underground Injection Control (UIC) programme defines injection well as a bored, drilled, or driven shaft whose depth is greater than the largest surface dimension. Injection of fluids without control can contaminate groundwater and drinking water. There are different classes of injection wells, namely;

Class I: These wells inject hazardous and non-hazardous waste beneath the lowermost formation containing an underground source of drinking water (USDS) within 1/4mile of the well bore.

Class II: These wells inject fluids associated with oil and natural gas production, for enhanced recovery of oil or natural gas, and for storage of liquid hydrocarbons.

Class III: These wells inject fluids for extraction of minerals from ore bodies that have not been nor cannot be conventionally mined, which includes salts, sulphur and uranium

Class IV: These wells inject hazardous or radioactive waste into and or above a formation containing an USDW. This type is banned unless authorised under other statutes for groundwater remediation.

Class V: These wells include, air conditioning return flow wells, cesspools, draining wells, recharge wells, salt water intrusion barriers wells, septic system for a multiple dwelling, subsidence control wells, spent brine disposal wells e.t.c. The injection well that is used for this study is class iv injection well.

Floods are defined as extremely high flows of river, whereby water overflows the floodplains. Flooding is a situation that results when land that is usually dry is covered with water of a river overflowing or heavy rain. Flood hazard is measured by possibility of occurrence of their damaging consequences, conceived generally as flood risk or by their impact on society, conceived usually as the loss of lives and material damage to society (Henry, 2006).

In a bid to solve the perennial flooding problems being experienced in some parts of Benin City, the Edo State Government in 2005 through the Ministry of Environment and Public Utilities embarked on the use of Injection Wells to channel flood water into the groundwater.

Some private individuals who are involved in small scale fish farming, have also adopted this method to inject their waste water and flood direct into the groundwater. This practice has brought a momentary relief to the affected areas, though Edo State Urban Water Board Benin City advised before the construction of the injection wells, that the practice could be counterproductive as these could lead to groundwater pollution or contamination.

With the recent problem of Lead poisoning in Zamfara state (Medecins Sans Frontieres briefing paper, 2012) and the increasing cases of incidence of Typhoid fever, cancer and other water borne diseases, Benin City which could boast of one of the best groundwater resources could be on the verge of real danger. It is far easier to control flooding than cleaning contaminated or polluted groundwater. Coliform bacteria and heavy metals have been detected in some borehole water samples. High iron concentration has been reported by Ohagi and Akujieze (1989) in some borehole water sources in Benin City and environs. Imeokparia and Offor (1992) indicated high levels of Lead (Pb), Manganese (Mn), Copper (Cu), Iron (Fe) and Nickel (Ni) in Ogba and Ikpoba river sediments. Work by Akujieze and Oteze (1999), and Erah *et al*. (2002) have shown the occurrence and effect of Lead (Pb) and inorganic metals in Benin City groundwater resources.

Most previous works have shown strong correlation between pollution and anthropogenic activities. However, no work has been done on investigation of impact of the use of injection well on groundwater, using geoelectrical approach, along boundary road, in Benin City, South south Nigeria.

The aim of this study is to carry out geoelectrical investigation of the impact of flood injection on groundwater. And the objectives are to:

1. To ascertain the nature of contaminants or pollutants if any.
2. To determine the concentration of contamination or pollution if any
3. To highlight other possible sources of groundwater contamination in the affected area.

**Location of Study Area**

Benin-City is located within the Tropical Equatorial Climate dominated by abundant rainfall with an annual rainfall of over 2000mm. This ensures a large volume of recharge through infiltration by downward displacement all year round with the Benin Formation aquifer having about 30% porosity. This well injection is located at the Boundary road before Adesuwa junction with coordinate 6°18′21.45″ and 5°37′34.63″ which has over 50 injection wells.

**METHODOLOGY**

The equipment used to carry out this survey is Petrozenith Terrameter and other tools are used together with the terrameter such as four steel electrodes (two electrodes used as potential electrodes and the other two electrodes for the current electrodes), measuring tapes, power source (battery) and hammers. Electrodes were driven into the ground using the hammers, and were connected to the terrameter using connecting cables and metal clips. The electrodes are expanded and the electrode spacing is increased between the current electrodes and the potential electrodes, but only at a time, during the course of measurement (Alile *et al*., 2008; Zhdanov and Keller, 1994). The terrameter provides the resistance, voltage and current which are indicated by *R, V, I* respectively. When the values, that is, the resistance, current and voltage are given, the resistivity is calculated by multiplying the resistance by the geometric factor (*K*), that is, ($R \times K$), and $K$ can be calculated by;

$$K = \frac{\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]\pi}{MN} \qquad (1.0)$$

Where, AB is the distance of the current and MN is the distance of the potential. Water sample was collected from borehole near Boundary Road in Benin City.

**Theory of Resistivity Method**

The fundamental physical law used in resistivity surveys is Ohm’s Law that governs the flow of current in the ground. The equation for Ohm’s Law in vector form for current flow in a continuous medium is given by;

$$J = \sigma E \quad (1.1)$$

$$E = -\nabla\Phi \quad (1.2)$$

$$J = -\sigma\,\nabla\Phi \quad (1.3)$$

In almost all surveys, the current sources are in the form of point sources. In this case, over an elemental volume $\Delta V$ surrounding the current source *I*, located at ( $X_S Y_S\ Z_S$) the relationship between the current density and the current (Dey and Morrison 1979a) is given by

$$\nabla.J = \left(\frac{I}{\Delta V}\right)\delta(x-x_s)\delta(y-y_s)\delta(z-z_s) \quad (1.4)$$

Where $\delta$ is the Dirac delta function

$$-\nabla \bullet [\sigma(x,y.z)\nabla\phi(x,y,z)] = \left(\frac{I}{\Delta V}\right)\delta(x-x_s)\,\delta(y-y_s)\,\delta(z-z_s) \quad (1.5)$$

This is the basic equation that gives the potential distribution in the ground due to a point current source.

**Results and Discussion**

The following give the data and the interpretation of the data acquired using the DIPRO software and RES2DINV software for the 2-Dimensional inversion. The 1-D was analysed using Ip2win software. Physico-chemical analysis of water was also carried out in the study area.

**PARALLEL AXIS** (60m away from injection well)

Table 1: ERT Measurement for profile one

| Position | Station Separation (5m) | | | | Apparent Resistivity (Ohm-m) |
|---|---|---|---|---|---|
| 1 | 0 | 5 | 10 | 15 | 167.469 |
| 2 | 5 | 10 | 15 | 20 | 171.239 |
| 3 | 10 | 15 | 20 | 25 | 163.384 |
| 4 | 15 | 20 | 25 | 30 | 170.925 |
| 5 | 20 | 25 | 30 | 35 | 363.844 |
| 6 | 25 | 30 | 35 | 40 | 101.487 |
| 7 | 30 | 35 | 40 | 45 | 117.511 |
| 8 | 35 | 40 | 45 | 50 | 111.855 |
| 9 | 40 | 45 | 50 | 55 | 67.867 |
| 10 | 45 | 50 | 55 | 60 | 213.970 |
| 11 | 50 | 55 | 60 | 65 | 145.160 |
| 12 | 55 | 60 | 65 | 70 | 186.949 |
| 13 | 60 | 65 | 70 | 75 | 171.239 |
| 14 | 65 | 70 | 75 | 80 | 178.780 |
| 15 | 70 | 75 | 80 | 85 | 179.408 |
| 16 | 75 | 80 | 85 | 90 | 182.550 |
| 17 | 80 | 85 | 90 | 95 | 107.771 |

Table 2: ERT Measurement for profile one cont'd.

| Position | Station Separation (10m) | | | | Apparent Resistivity (Ohm-m) |
|---|---|---|---|---|---|
| 1 | 0 | 10 | 20 | 30 | 285.294 |
| 2 | 10 | 20 | 30 | 40 | 213.656 |
| 3 | 20 | 30 | 40 | 50 | 165.898 |
| 4 | 30 | 40 | 50 | 60 | 148.302 |
| 5 | 40 | 50 | 60 | 70 | 185.378 |
| 6 | 50 | 60 | 70 | 80 | 157.100 |
| 7 | 60 | 70 | 80 | 90 | 202.345 |
| 8 | 70 | 80 | 90 | 100 | 208.000 |

Table 3: ERT Measurement for profile one cont'd.

| Position | Station Separation (20m) | | | | Apparent Resistivity (Ohm-m) |
|---|---|---|---|---|---|
| 1 | 0 | 20 | 40 | 60 | 358.188 |
| 2 | 20 | 40 | 60 | 80 | 282.780 |
| 3 | 40 | 60 | 80 | 100 | 248.846 |

| Position | Station Separation (30m) | | | | Apparent Resistivity (Ohm-m) |
|---|---|---|---|---|---|
| 1 | 0 | 30 | 60 | 90 | 5278.560 |

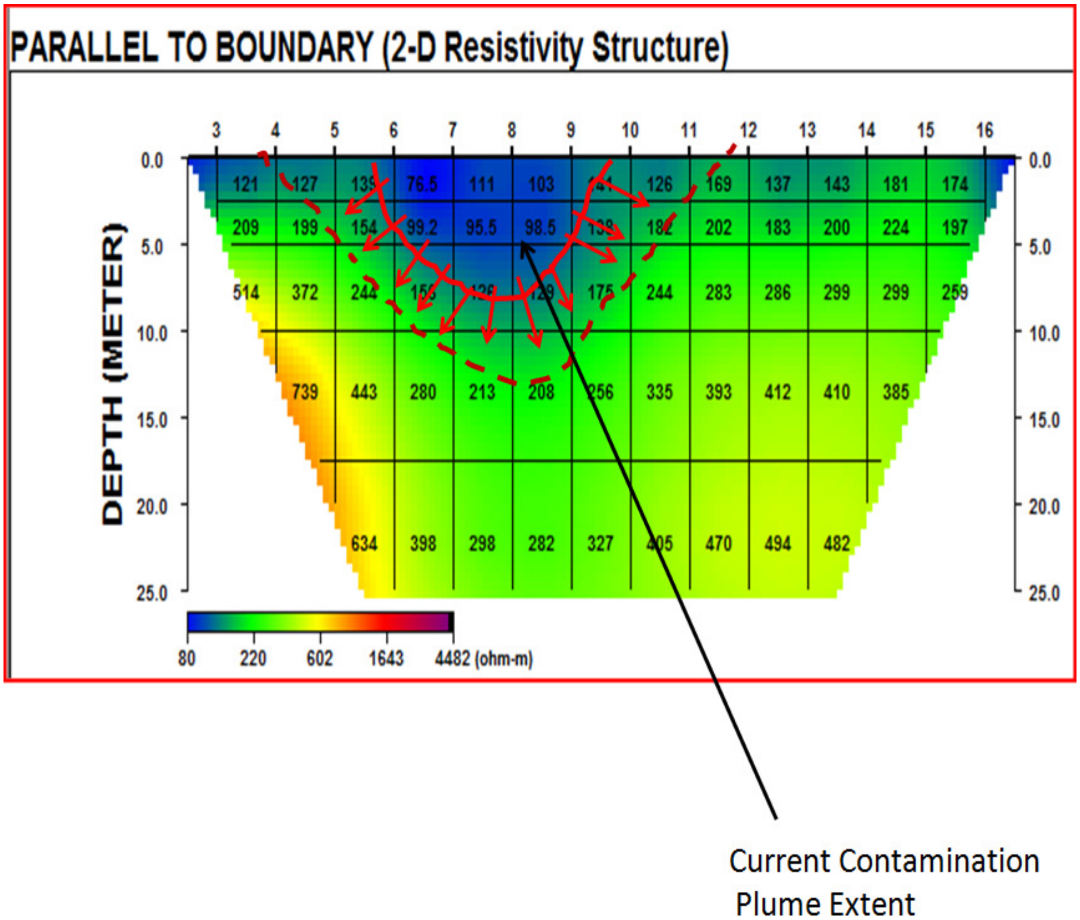


Figure 5: Inversion image of 2-D Resistivity Profile one

The radial pattern indicates spread direction and the depth of infiltration currently is almost 10m (32.8ft).

**Inversion Image of 2-D Resistivity Profile one using Res2Dinv software**

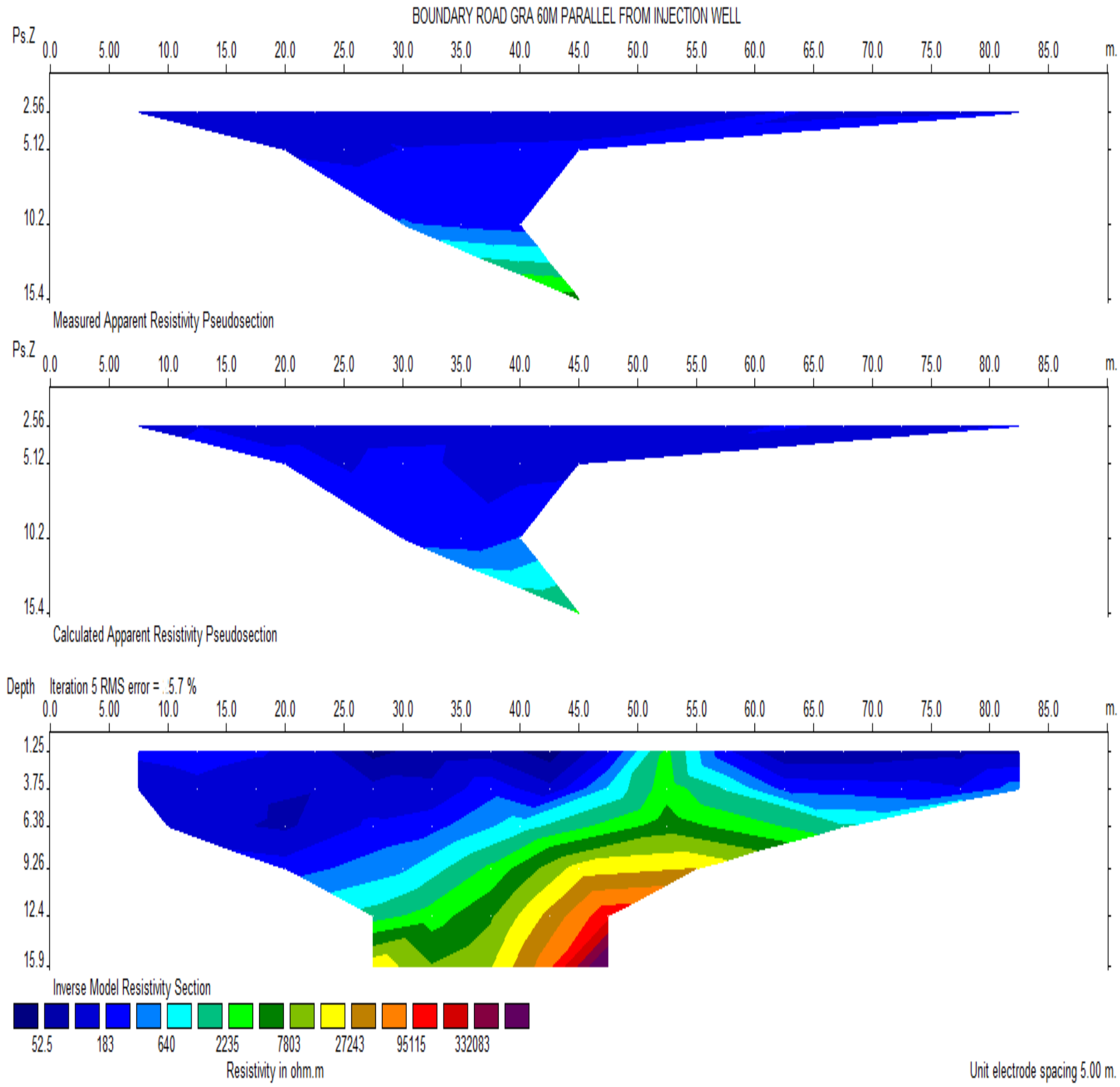


Figure 6: Inversion Image of 2-D Resistivity Profile one

This was confirmed by another software interpretation of the acquired data set which gave a clearer image with pollution infiltration up to a depth of about 10m (32.8ft). Hence all the boreholes inside the injection well with its uncased opening between the depth of zero (0)ft. to about thirty-two (32)ft. have these pollutants moving directly through the injection well into the groundwater.

**PARALLEL AXIS** (120m away from injection well)

Table 4: ERT Measurement for profile two

| S/N | ELECTRODE SEPARATION (a=5m) | | | | APPARENT RESISTIVITY (Ohm-m) |
|---|---|---|---|---|---|
| 1 | 0 | 5 | 10 | 15 | 217.30 |
| 2 | 5 | 10 | 15 | 20 | 195.19 |
| 3 | 10 | 15 | 20 | 25 | 121.84 |
| 4 | 15 | 20 | 25 | 30 | 170.25 |
| 5 | 20 | 25 | 30 | 35 | 283.84 |
| 6 | 25 | 30 | 35 | 40 | 101.87 |
| 7 | 30 | 35 | 40 | 45 | 97.22 |
| 8 | 35 | 40 | 45 | 50 | 91.05 |
| 9 | 40 | 45 | 50 | 55 | 67.67 |
| 10 | 45 | 50 | 55 | 60 | 123.78 |
| 11 | 50 | 55 | 60 | 65 | 145.40 |
| 12 | 55 | 60 | 65 | 70 | 166.99 |
| 13 | 60 | 65 | 70 | 75 | 141.29 |
| 14 | 65 | 70 | 75 | 80 | 178.78 |
| 15 | 70 | 75 | 80 | 85 | 179.08 |
| 16 | 75 | 80 | 85 | 90 | 182.80 |
| 17 | 80 | 85 | 90 | 95 | 194.42 |

Table 5: ERT Measurement for profile two cont'd.

| S/N | ELECTRODE SEPARATION (a=10m) | | | | APPARENT RESISTIVITY (Ohms-m) |
|---|---|---|---|---|---|
| 1 | 0 | 10 | 20 | 30 | 203.66 |
| 2 | 10 | 20 | 30 | 40 | 198.37 |
| 3 | 20 | 30 | 40 | 50 | 145.98 |
| 4 | 30 | 40 | 50 | 60 | 93.29 |
| 5 | 40 | 50 | 60 | 70 | 88.38 |
| 6 | 50 | 60 | 70 | 80 | 157.60 |
| 7 | 60 | 70 | 80 | 90 | 196.64 |
| 8 | 70 | 80 | 90 | 100 | 212.40 |

Table 6: ERT Measurement for profile two cont'd.

| S/N | ELECTRODE SEPARATION (a=20m) | | | | APPARENT RESISTIVITY (Ohms-m) |
|---|---|---|---|---|---|
| 1 | 0 | 20 | 40 | 60 | 532.14 |
| 2 | 20 | 40 | 60 | 80 | 242.60 |
| 3 | 40 | 60 | 80 | 100 | 248.846 |

| S/N | ELECTRODE SEPARATION (a=20m) | | | | APPARENT RESISTIVITY (Ohms-m) |
|---|---|---|---|---|---|
| 1 | 0 | 30 | 60 | 90 | 5278.560 |

Inversion Image of 2-D Resistivity Profile two

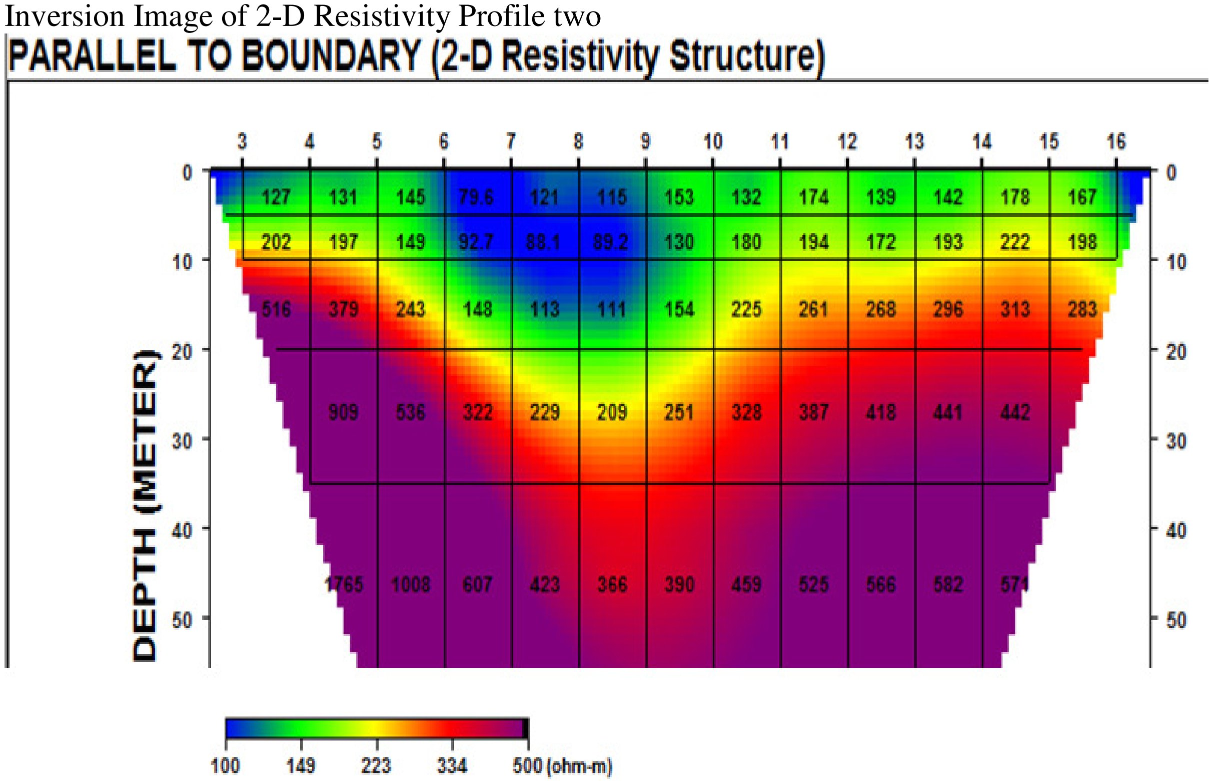


Figure 7: Inversion Image of 2-D Resistivity Profile two

**Inversion Image of 2-D Resistivity Profile two**

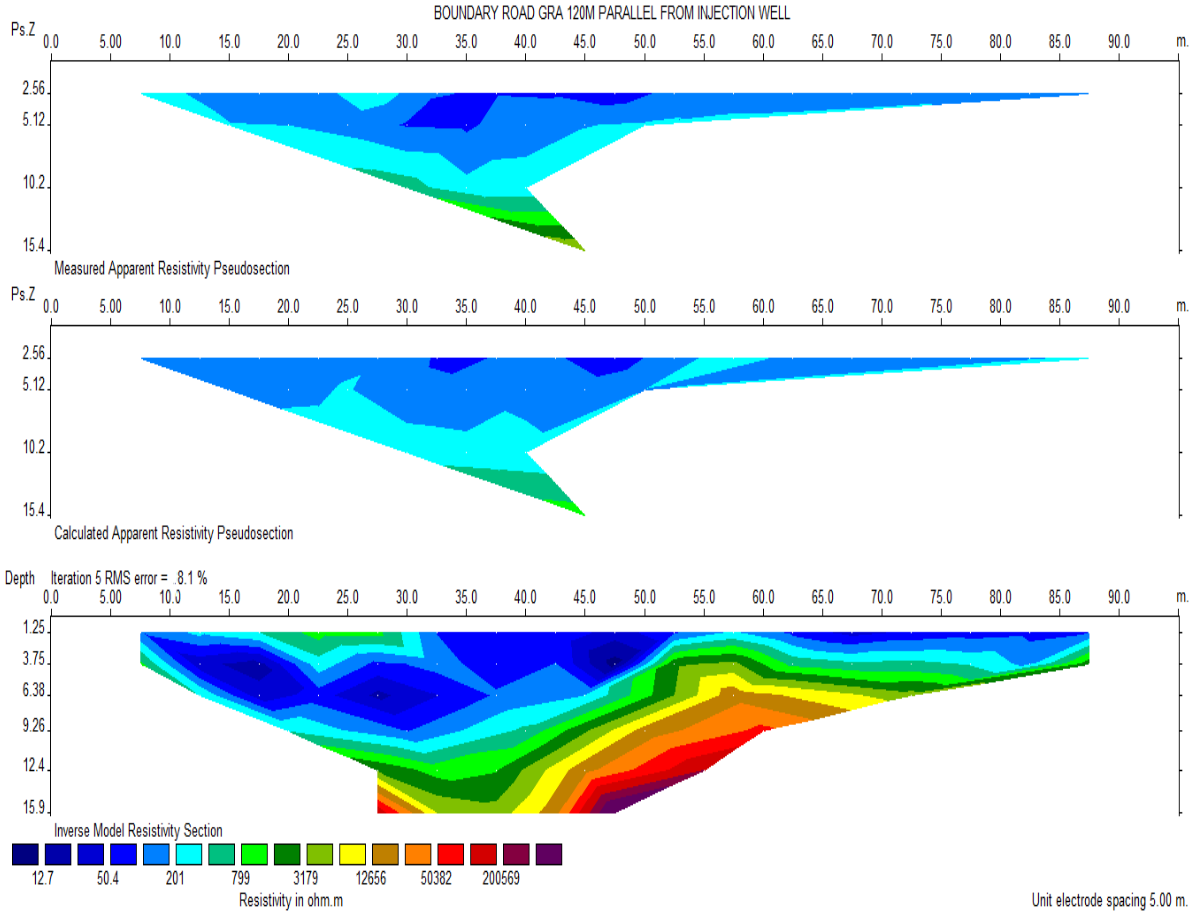


Figure 8: Inversion Image of 2-D Resistivity Profile two

**PERPENDICULAR AXIS** (160m away from injection well)

Table 6: ERT Measurement for profile three

| S/N | ELECTRODE SEPARATION (a=5m) | | | | APPARENT RESISTIVITY (Ohms-m) |
|---|---|---|---|---|---|
| 1 | 0 | 5 | 10 | 15 | 222.54 |
| 2 | 5 | 10 | 15 | 20 | 196.558 |
| 3 | 10 | 15 | 20 | 25 | 399.723 |
| 3 | 15 | 20 | 25 | 30 | 255.735 |
| 4 | 20 | 25 | 30 | 35 | 173.331 |
| 5 | 25 | 30 | 35 | 40 | 216.146 |
| 6 | 30 | 35 | 40 | 45 | 110.491 |
| 7 | 35 | 40 | 45 | 50 | 106.406 |
| 8 | 40 | 45 | 50 | 55 | 157.554 |
| 9 | 45 | 50 | 55 | 60 | 217.717 |
| 10 | 50 | 55 | 60 | 65 | 118.890 |
| 11 | 55 | 60 | 65 | 70 | 179.300 |
| 12 | 60 | 65 | 70 | 75 | 285.899 |
| 13 | 65 | 70 | 75 | 80 | 191.240 |
| 14 | 70 | 75 | 80 | 85 | 87.155 |
| 15 | 75 | 80 | 85 | 90 | 150.793 |
| 16 | 80 | 85 | 90 | 95 | 41.367 |
| 17 | 85 | 90 | 95 | 100 | 113.234 |
| 18 | 90 | 95 | 100 | 105 | 264.533 |
| 19 | 95 | 100 | 105 | 110 | 387.071 |
| 20 | 100 | 105 | 110 | 115 | 213.862 |
| 21 | 105 | 110 | 115 | 120 | 248.739 |
| 22 | 110 | 115 | 120 | 125 | 451.022 |
| 23 | 115 | 120 | 125 | 130 | 649.137 |
| 24 | 120 | 125 | 130 | 135 | 577.500 |
| 25 | 125 | 130 | 135 | 140 | 585.983 |
| 26 | 130 | 135 | 140 | 145 | 579.071 |
| 27 | 135 | 140 | 145 | 150 | 610.491 |

Table 7: ERT Measurement for profile three cont'd.

| S/N | ELECTRODE SEPARATION (a=6m) | | | | APPARENT RESISTIVITY (Ohms-m) |
|---|---|---|---|---|---|
| 1 | 0 | 6 | 12 | 18 | 230.937 |
| 2 | 6 | 12 | 18 | 24 | 237.221 |
| 3 | 12 | 18 | 24 | 30 | 244.762 |
| 4 | 18 | 24 | 30 | 36 | 199.831 |
| 5 | 24 | 30 | 36 | 42 | 169.354 |
| 6 | 30 | 36 | 42 | 48 | 135.420 |

| S/N | ELECTRODE SEPARATION (a=9m) | | | | APPARENT RESISTIVITY (Ohms-m) |
|---|---|---|---|---|---|
| 1 | 0 | 9 | 18 | 27 | 175.009 |
| 2 | 9 | 18 | 27 | 36 | 162.756 |
| 3 | 18 | 27 | 36 | 45 | 136.677 |

Table 8: ERT Measurement for profile three cont'd.

| S/N | ELECTRODE SEPARATION (a=12m) | | | | APPARENT RESISTIVITY (Ohms-m) |
|---|---|---|---|---|---|
| 1 | 0 | 12 | 24 | 36 | 149.245 |
| 2 | 12 | 24 | 36 | 48 | 123.795 |

| S/N | ELECTRODE SEPARATION (a=50m) | | | | APPARENT RESISTIVITY (Ohms-m) |
|---|---|---|---|---|---|
| 1 | 0 | 50 | 100 | 150 | 140.133 |

**Inversion Image of 2-D Resistivity Profile three using Dipro software**

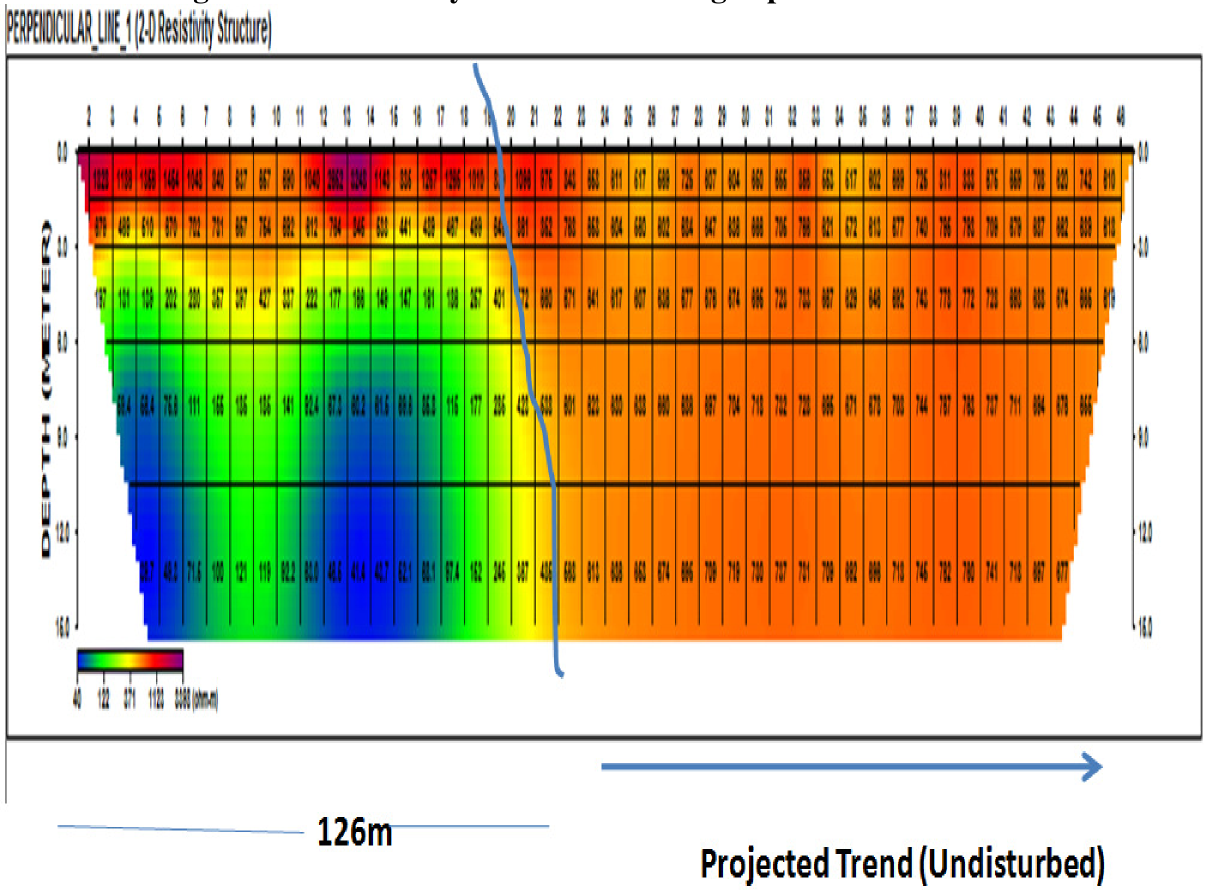


Figure 9: Inversion Image of 2-D Resistivity Profile three

**Inversion Image of 2-D Resistivity Profile three using Res2Dinv software**

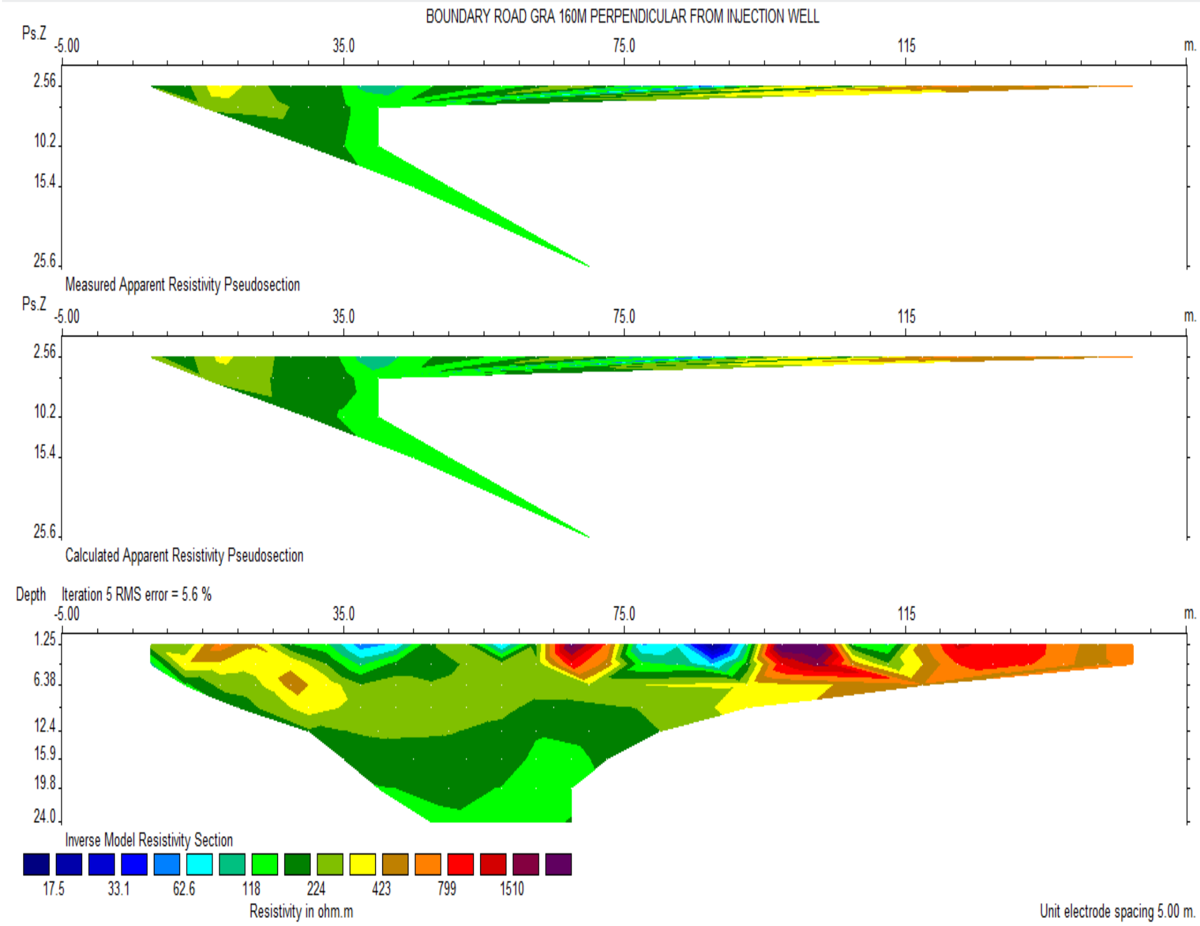


Figure 10: Inversion Image of 2-D Resistivity Profile three

**1-D Vertical electrical sounding result of study area**

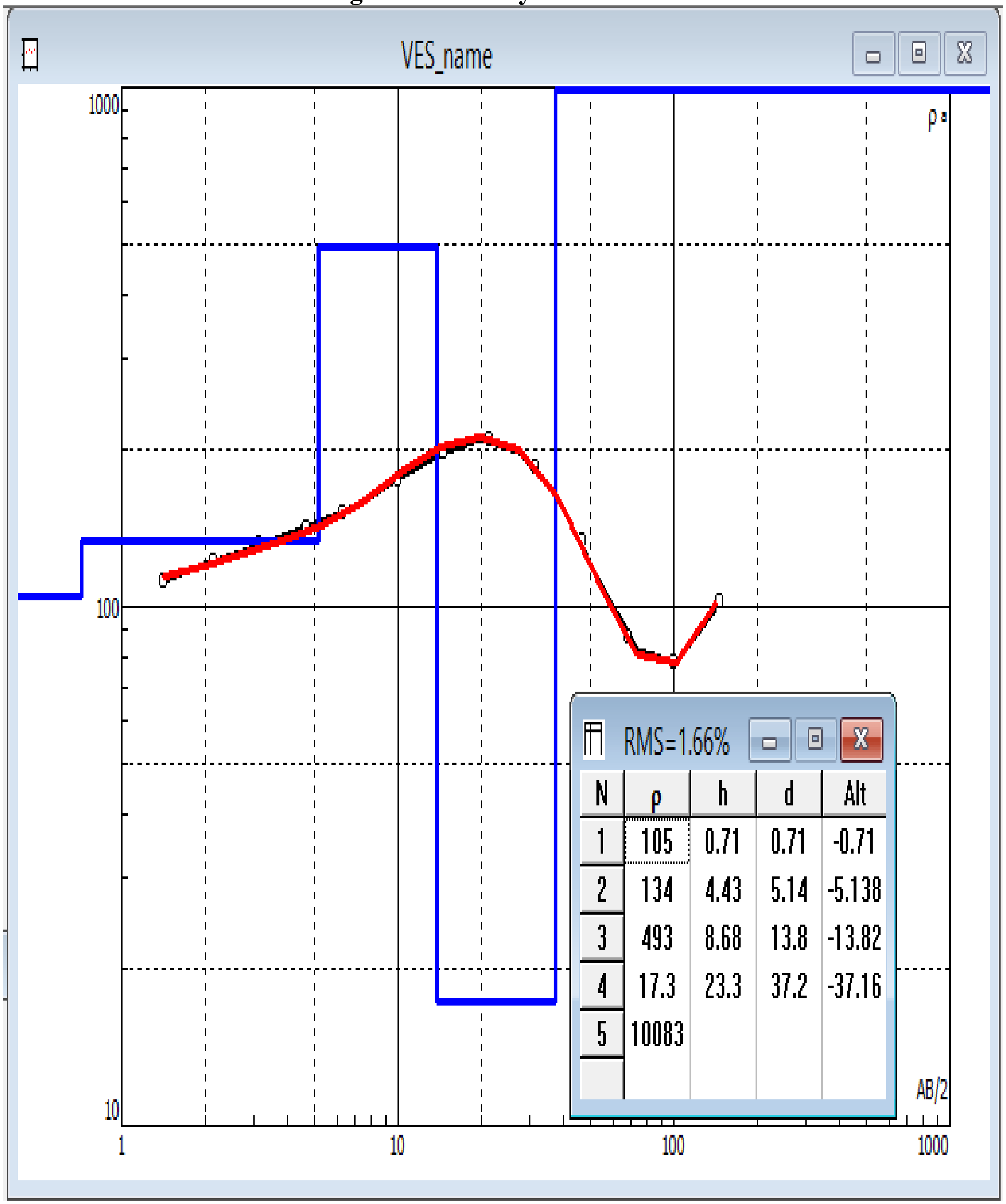


Figure 11: 1-D VES result of the study area

The 1-d result shows five layered earth. The depth to aquifer is about 37.2m which is in the same neighbourhood with the drilled borehole depth of about 40m in the study area.

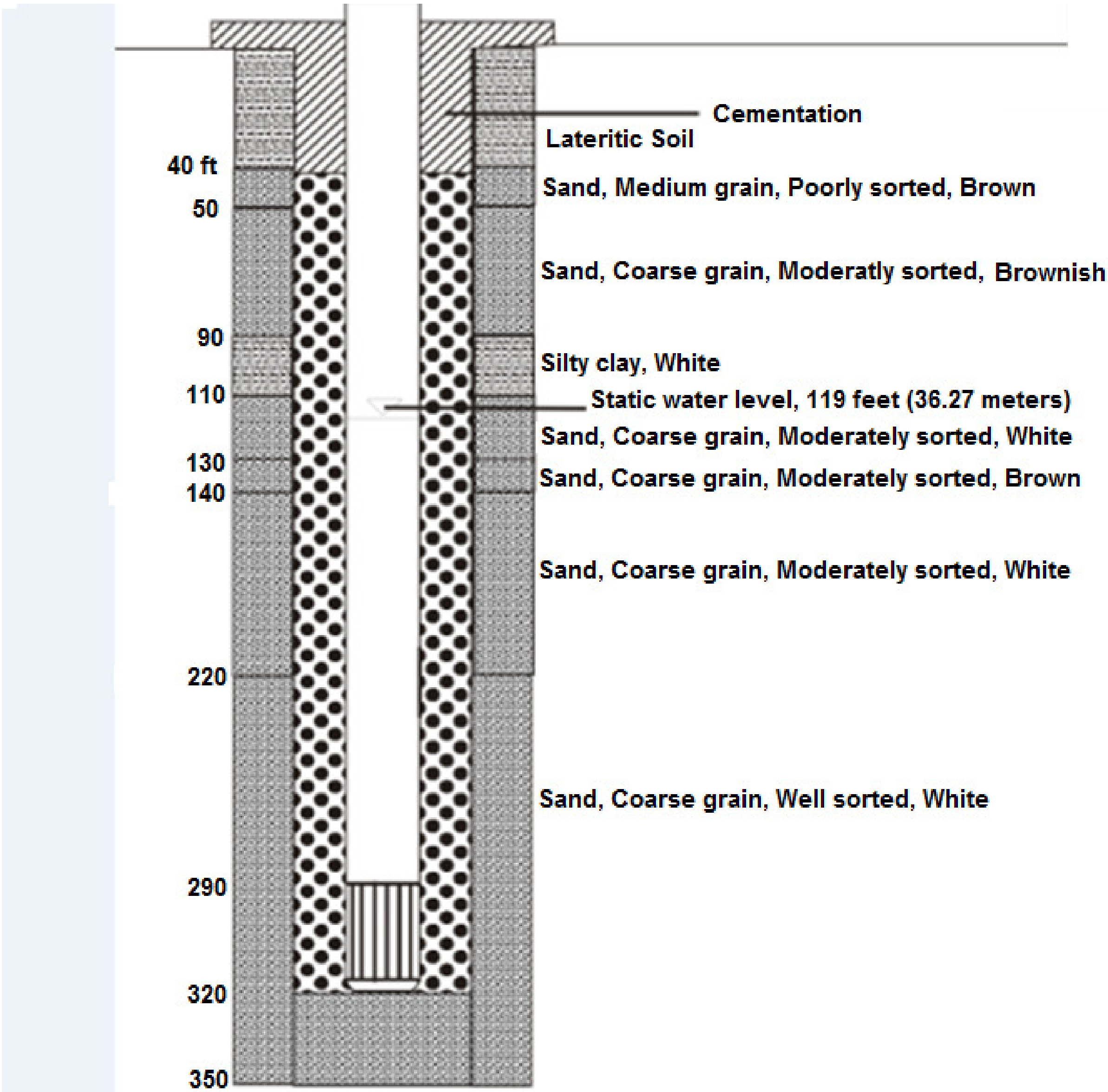


Fig. 12: Boundary Road Borehole lithologic section and well design
Source: pacific Associate, Benin City

Table 9: Physico-chemical analysis of water

| Parameter | Water Analysis Result | Water Analysis Result (Control) | NSDWQ (maximum permitted level) |
|---|---|---|---|
| EC (µs/cm) | 268.00 | 156.00 | 1000 |
| Turbidity (NTU) | 0.24 | 0.15 | 5 |
| Hardness (mg/l) | 0.40 | 0.20 | 150 |
| TDS (mg/l) | 87.00 | 56.00 | 500 |
| pH | 5.67 | 5.53 | - |
| Iron (mg/l) | 0.18 | 0.12 | 0.3 |
| Copper (mg/l) | 0.05 | 0.03 | 1 |
| Lead (mg/l) | BDL | BDL | 0.01 |
| Cadmium (mg/l) | BDL | BDL | 0.003 |
| Chromium (mg/l) | 0.26 | 0.01 | 0.05 |
| Nickel (mg/l) | 0.09 | 0.01 | 0.02 |
| Odour | Unobjectionable | Unobjectionable | unobjectionable |
| Colour (Pt.Co. U) | 5 | 3 | 15 |
| Sulphate (mg/l) | 0.08 | 0.04 | 100 |
| Nitrate (mg/l) | 0.12 | 0.05 | 50 |
| Chloride (mg/l) | 39.2 | 26.0 | 250 |
| Calcium (mg/l) | 5.67 | 4.25 | - |
| Magnesium (mg/l) | 0.05 | 0.03 | 0.20 |
| Manganese (mg/l) | 0.10 | 0.03 | 0.2 |
| Zinc (mg/l) | 0.17 | 0.12 | 3 |

(NSDWQ, 2011)

**CONCLUSION**

Actually the reason for the construction of the injection well is to control flood in the area of study but it has turned out to become a threat to the groundwater in the study area due to the presence of Nickel and Chromium. Both metals are harmful to human beings when ingested because they are carcinogenic, that is, they can cause cancer and other diseases.

The findings of the study are:

1. Low resistivity values were seen in the Inversion Image of 2-D Resistivity Profile, which could be as a result of the presence of plumes from the well injection.
2. The laboratory analysis of the water sample in the study area shows the presence of heavy metals, such as Nickel (0.09mg/l) and Chromium (0.26mg/l). When compared with Nigerian standard for drinking water quality, it was found that Nickel and Chromium exceeded the maximum permitted values which are 0.02mg/l and 0.05mg/l.
3. The presence of Nickel and Chromium can be the cause of the low resistivity values seen in the results above. Besides, both elements are harmful to human beings when ingested because they are carcinogenic, that is, they can cause cancer.

## REFERENCES

Akujieze, C. N. (2004). Effect of Anthropogenic Activities on Urban Groundwater System and Aquifer Vulnerability Assessment in Benin City, Edo State Nigeria. PhD Thesis University of Benin, Benin City, Nigeria.

Akujieze, C. N. and Oteze G. E 1999 Groundwater quality in Benin City Urban of the Pleistocene-Oligecene Benin Formation-Nigeria. A paper presented at National Conference of Nigerian Association of Hydrogeologists (NAH) Abstract pp 4.

Alile, O. M., Amadasun, C. V. O., Evbuomwan, A. L. (2008). Application of Vertical Electrical Sounding Method to Decipher the Existing Subsurface Stratification and Groundwater Occurrence Status in a Location in Edo North of Nigeria. *Int. J. Phys. Sci.*, 3(10): 245–249. Available online at http://www.academicjournals.org/IJPS. ISSN 1992-1950 ©2008 Academic Journals.

Alile, O. M., Oranusi, S. A. and Airen, J. O. (2012). Subsurface Geophysical Investigation and physiochemical/microbial analysis of groundwater contaminant in Ota, south western Nigeria. *Geosciences*, 2(6):179-184. doi:10.5923/j.geo.20120206.05

Dawie, H. (2010). Concise Hydrology. Ventus Publishing APS ISBN 978-87-7681-536-3 groundwater in Northern Nigeria, Geological Bulletin, pp.1-82.

Erah, P. O., Akujieze, C. N. and Oteze, G. E. (2002). The quality of groundwater in Benin City: Baseline study on inorganic chemical and microbial contaminants of health implication in boreholes and open wells, *Tropical Journal of Pharmaceutical Research*, 1(2): 75-82.

Henry, P. (2006). Levees and other raised ground. *Am. Sci*, 94(1): 7-11.

Hill, A. R. (1976). The environmental impacts of agricultural land drainage. *J. Environ. Mgmt.*, 4: 251-274.

Imeopkaria, E. G. and Offor, N. (1992). Heavy metal occurrence in Ikpoba and Ogba River sediments. Paper presented at 10th Annual National Conference of Nigerian Association of Hydrogeologists (NAH), November 1992.

Medecins Sans Frontieres briefing papers, 2012

Ohagi, S. O. and Akujieze, C. N. (1989). Iron in borehole water sources in Bendel State, Nigeria. *Water Resources Journal of Nigerian Association of Hydrogeologists*, 1(2): 192-196.

Zhdanov, M. S. and Keller, G. V. (1994). The geophysical methods in geophysical exploration. Elsevier, Amsterdam-London-New York, Tokyo.