

Automated Geophysical Field Calculator Using Schlumberger Electrode System

Dannity Oseyande Isiwele^a, Jackson Akpojar^{b*}, Celestine Uche Agwi^c

^{a,b,c}*Department of Mathematical and Physical Sciences, College of Basic and Applied Sciences, Samuel*

Adegboyega University, Ogwa, Edo State, Nigeria

^a*Email: Desolocast@gmail.com*

^b*Email: jakpojar@yahoo.com*

^c*Email: ucheworld2002@yahoo.com*

Abstract

The aim of this paper is to present a fast and direct approach for solving the geometric factor (k) and the Apparent Resistivity (ρ_a) for the Schlumberger electrode configurations in geo-electric field surveys, using the measured quantities of the current electrode and potential electrode spacing respectively. The program is a web-based development based on scripting. Swish script is the major driver alongside the hypertext markup language (html), developed and housed in flash-java containers. The main features are the potential electrode spacing (M,N), current electrode spacing (A,B), the instant resistance reading (V/I (Ω)) (is the reading from the measuring device, usually a resistivity meter), the Geometric factor (k) and the Apparent Resistivity (ρ_a). The ability of the program to modify basic quantities like current electrode spacing, the potential electrode spacing and the V/I to suit individual field practice with respect to the lateral and vertical variations in the inhomogeneous media made it a unique program. On execution of the program, it was found that both the geometric factor (k) and the apparent resistivity (ρ_a) values are automatically displayed once the respective field data were inputted and the execute button clicked accordingly. It was tested for values of $L = 1.0, 1.47, \dots, 100$ and $l = 0.5, \dots, 500$. Finally a standard field sheet was incorporated into the program to reduce the monotony of numbering.

Keywords: Apparent Resistivity (ρ_a); Geometric factor (k); Potential electrode spacing (l); Current electrode spacing (L); flash content; Homogeneous media; Lateral variations.

* Corresponding author.

1. Introduction

Geophysical survey involves the use of one or more of the methods of investigation in probing the earth for some parameters that are diagnostic of the existence of natural or mineral resource for interpretation or outright extraction / exploitation. Invariably, the end result is always a final analysis drawn between the initial calculations and the expertise put into the venture. Electrical resistivity method is one of the most widely used geophysical methods in sedimentary and basement complex terrain. This method is commonly used for detailed geologic and hydrogeological exploration which includes; groundwater, geologic and subsurface foundation studies, aquifer delineation, lithologic boundary differentiation and even geothermal activities [1]. Generally, resistivity survey technique involves the passing of current into the ground by means of a pair of electrodes called current electrodes and measuring the potential difference by means of another pair of electrodes called potential electrodes [2, 12]. Of these methods, the Schlumberger, the Wenner and the Double dipole have come to play a very significant role in their respective usefulness to which they have been well adapted mainly, VES, CVES and profiling. An in-depth analysis of the development was a harmonious assembly between the very many electrode system types with various depth ranges and the investigation to which each was best suited. However, this paper adopts the Schlumberger electrode system based on the generalized Schlumberger field array [3], where the accepted procedure of passing current into the earth by means of a pair of current electrodes and measuring the potential drop through a second pair of potential electrodes was adopted. The study first of all, removes the time delay spent on field data computation of Geometric factor values and apparent resistivity values which are computed manually and fed into the inversion software, thus an on-the-spot automatic computation of both Geometric factor values and apparent resistivity values are obtained from the software. Again, the It also stands as a straight forward method of data integrity check for all reading taken by the resistivity meter, where arbitrarily resistivity results (High, low or negative resistivity values) are instantly seen from the software and retaken or adjusted.

2. Theoretical Background

The theory of electrical resistivity of a layered earth has been studied in [4]. This has also been extensively described by [4] and [5]. The Schlumberger electrode configuration, as used in this work has been described elsewhere in [1], [4] and [7]. Its effectiveness in sedimentary terrain was extensively described by [3]. The configuration has the following quantities based on the generalized system as shown in the Figure 1.

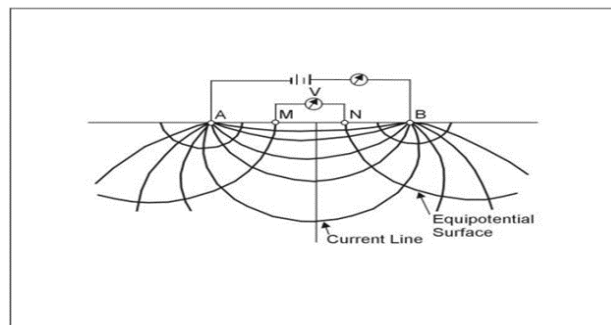


Figure 1: Field Arrangement of the Generalized Schlumberger Electrode Configuration

The variables from Figure 1 are as follows;

A = current electrode 1

B = current electrode 2

M = potential electrode 1

N = potential electrode 2

From Ohms law (Telford and his colleagues 1990) we have;

$$V = IR \text{ (Ohms Law) } \dots\dots\dots (1)$$

$$R = \frac{V}{I} \text{ (Terrameter Reading) } \dots\dots\dots (2)$$

Where;

V = Potential Difference in Volts (v)

I = Current in Amperes (A)

R = Resistance in Ohms (Ω)

$$\frac{AB}{2}(L) \text{ (Current electrode Spacing)}$$

$$\frac{MN}{2}(l) \text{ (Potential electrode spacing)}$$

We rearrange the above relations to get the generalized Schlumberger relation;

$$\rho a = \pi \left[\frac{L^2}{l} - \frac{l}{4} \right] \frac{V}{I} = \pi a \left[\left(\frac{L}{l} \right)^2 - \frac{1}{4} \right] \frac{V}{I} \dots\dots\dots (3)$$

By combining equations (2) and (3), we have the generalized Schlumberger equation, (4).

$$\rho a = (K) \frac{V}{I} \dots\dots\dots (4)$$

In practice, the sensitivity of the instruments limits the ratio of b to a and usually keeps it within the limits of

about 3 to 30, therefore, it is a typical practice to use a finite electrode spacing and equation 2 to compute the geometric factor [9]. The geometric factor (K) is given by;

$$K = \pi \left[\frac{L^2}{I} - \frac{I^2}{4} \right] \dots\dots\dots (5)$$

By simplifying equation (5) with the K relation in equations (6) and (7) respectively, we have,

$$K = k = \frac{\pi^2}{l} \left[1 - \frac{l^2}{4l^2} \right] \dots\dots\dots (6)$$

$$K = \frac{\pi a^2}{b} \left[1 - \frac{b^2}{4a^2} \right] \dots\dots\dots (7)$$

Equations (1), (2), (4), (5), (6) and (7) formed the internal architecture of SESCAL (Schlumberger Electrode System Calculator)

3. Methodology

In conventional field operations, the inner potential electrodes ($M\&N$) remain fixed, while the outer current electrodes ($A\&B$) are adjusted to vary the distance, L . The potential electrode spacing, l is adjusted once a decreasing sensitivity of response is noted from the sensitivity index.

The spacing, l should at most always be less than or equal to $0.4L$, otherwise, the potential gradient assumption is no longer valid. In addition, the l spacing may sometimes be adjusted with L held constant in order to detect the presence of local in-homogeneities or lateral changes in the neighborhood of the potential electrodes [8, 11].

4. Implementation

A generalized Schlumberger field layout model is first developed. It comprises of forms, layouts and measurements. Hence a workable model for the apparent resistivity and geometric factor was obtained after the first testing.

The application was designed using swish program started with declaring of variables, statics, containers and inputs of dynamic quantities etc.

After declaring the current, potential, resistance, geometric factor and apparent resistivity as text objects, the quantities are then given their unique properties that will differentiate them from their respective functions.

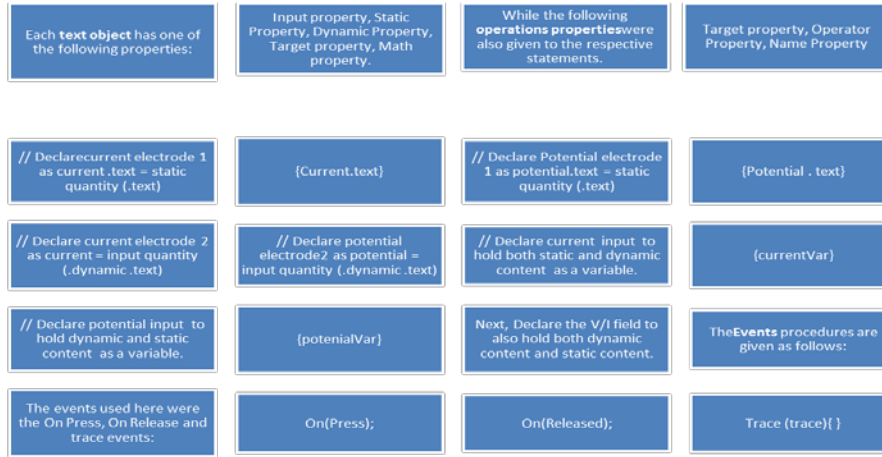


Figure 2: Program flow diagram showing the blocks of the respective operations

The, On-press (or button pressed) works with the trace expression; hence we introduce a container or variable expression below.

$$\kappa = \frac{\pi L^2}{t} \left[1 - \frac{t^2}{4L^2} \right] \dots\dots\dots (8)$$

$$\rho_a = \kappa = \frac{v}{p} \dots\dots\dots ..(9)$$

Once, the On-release, (or button released) action is triggered, the above relations are executed and the containers emptied. Because the super class reference variable can hold the subclass object, but using that variable you can access only the members of the super class, so to access the members of both classes it is recommended to always create reference variable to the subclass [10]. Therefore, in the program, you can instantiate the class as given below.

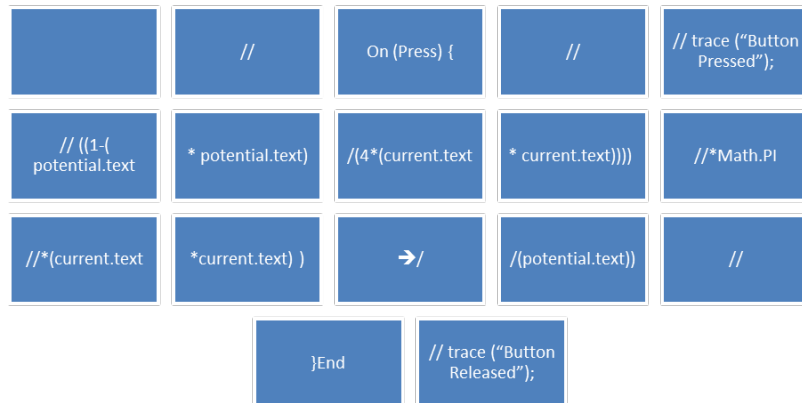


Figure 3: Program flow diagram showing the blocks of the respective operations for the line actions

5. Results and Discussion

SCHLUMBERGER AUTOMATED FIELD CALCULATOR FOR Schlumberger Electrode System (SESCAL)
 BY ISWILE D.O & DR. AKPOJARO J.
 Desolocalist@gmail.com

Current (I) Amperes / milliamperes
 Potential (V) volts / millivolts
 Res (R) ohms / milliohms
 GeoFactor (k) =
 AppaRes (pa) = ohm meter

SESCAL, WESCAL (Alpha, Beta, Gamma) & DIPOCAL are Registered Trade Marks of the Respective TM owners.
 SESCAL & DIPOCAL are TM of DEEPENERGY LTD and WESCALC is a Solocast Accelerated Technologies TM
 DISCLAIMER:
 The readings from this Calculator is correct to two decimal places.

SESCALTM 2016 DGG LTD

Figure 4: A screenshot of the Program on execution (for a single line)

SCHLUMBERGER AUTOMATED FIELD CALCULATOR FOR Schlumberger Electrode System (SESCAL)
 BY ISWILE D.O & DR. AKPOJARO J.
 Desolocalist@gmail.com

Current (I) Amperes / milliamperes
 Potential (V) volts / millivolts
 Res (R) ohms / milliohms
 GeoFactor (k) =
 AppaRes (pa) = ohm meter

SESCAL, WESCAL (Alpha, Beta, Gamma) & DIPOCAL are Registered Trade Marks of the Respective TM owners.
 SESCAL & DIPOCAL are TM of DEEPENERGY LTD and WESCALC is a Solocast Accelerated Technologies TM
 DISCLAIMER:
 The readings from this Calculator is correct to two decimal places.

SESCALTM 2016 DGG LTD

Figure 5: A screenshot of the Program on execution (for the single line; $L = 1.0$, and $l = 0.5$)

Figure 2 shows the program window when there was no measurement inputted. Figure3 captures the inputs of electrode distance of 1.0m, 0.5m of potential electrode distance, and 2.1 Ω resistance value from the resistivity meter. The results show 5.890485 as geometric factor and 12.3700185 Ω m as apparent resistivity. Similarly, Figure 4 is the window-shot of the program when 1.47m , 0.5m and 2.1 Ω is inputted as the current electrode distance, potential electrode distance and the resistivity meter value respectively. It displayed 13.1846333056 as the geometric factor and 27.6877299417 Ω m as the apparent resistivity value.

SCHLUMBERGER AUTOMATED FIELD CALCULATOR FOR Schlumberger Electrode System (SESCAL)
 BY ISWILE D.O & DR. AKPOJARO J.
 Desolocalist@gmail.com

Current (I) Amperes / milliamperes
 Potential (V) volts / millivolts
 Res (R) ohms / milliohms
 GeoFactor (k) =
 AppaRes (pa) = ohm meter

SESCAL, WESCAL (Alpha, Beta, Gamma) & DIPOCAL are Registered Trade Marks of the Respective TM owners.
 SESCAL & DIPOCAL are TM of DEEPENERGY LTD and WESCALC is a Solocast Accelerated Technologies TM
 DISCLAIMER:
 The readings from this Calculator is correct to two decimal places.

SESCALTM 2016 DGG LTD

Figure 6: A screenshot of the Program on execution (for the single line; $L = 1.47$, $l = 0.5$)

**SCHLUMBERGER AUTOMATED FIELD CALCULATOR
FOR
Schlumberger Electrode System (SESCAL)**

Enter the Current and Potential Electrode Spacing
and the Corresponding Resistance from the Terrameter
in the Input boxes and click on the Equal sign to display the Corresponding
Geometric factor and Apparent Resistivity values
respectively.

DISCLAIMER:
The readings from this Calculator is correct to two decimal places.

S/N	AB/2	MN/2	INST READ	GEO F (K)	APP RES (pa)
1	Curr (m) 1.0	Pot (m) 0.5	Res (R) 1.4	GeoFactor (k) = 5.890485	AppaRes (pa) = 8.246679
2	Curr (m) 1.47	Pot (m) 0.5	Res (R) 2.8	GeoFactor (k) = 13.184633	AppaRes (pa) = 36.9169732556
3	Curr (m) 2.15	Pot (m) 0.5	Res (R) 1.8	GeoFactor (k) = 28.651319	AppaRes (pa) = 51.572374272
4	Curr (m) 3.16	Pot (m) 0.5	Res (R) 2.2	GeoFactor (k) = 52.348663	AppaRes (pa) = 137.167058930
5	Curr (m) 4.64	Pot (m) 1.0	Res (R) 3.1	GeoFactor (k) = 66.851821	AppaRes (pa) = 207.240645481
6	Curr (m) 6.81	Pot (m) 1.0	Res (R) 2.1	GeoFactor (k) = 144.90938	AppaRes (pa) = 304.309712177
7	Curr (m) 10.0	Pot (m) 1.0	Res (R) 1.3	GeoFactor (k) = 313.37380	AppaRes (pa) = 407.3859426
8	Curr (m) 14.7	Pot (m) 1.0	Res (R) 2.5	GeoFactor (k) = 578.08121	AppaRes (pa) = 1695.2030432
9	Curr (m) 21.5	Pot (m) 1.5	Res (R) 2.6	GeoFactor (k) = 966.95583	AppaRes (pa) = 2514.08517793
10	Curr (m) 31.6	Pot (m) 1.5	Res (R) 3.2	GeoFactor (k) = 2090.2006	AppaRes (pa) = 6688.64205230
11	Curr (m) 46.4	Pot (m) 1.5	Res (R) 2.3	GeoFactor (k) = 4507.9698	AppaRes (pa) = 10368.3306424
12	Curr (m) 68.1	Pot (m) 1.5	Res (R) 1.4	GeoFactor (k) = 9711.8075	AppaRes (pa) = 13596.5305743
13	Curr (m) 100.0	Pot (m) 2.0	Res (R) 1.9	GeoFactor (k) = 15706.389	AppaRes (pa) = 29842.1394876
14	Curr (m) 147.0	Pot (m) 2.0	Res (R) 2.0	GeoFactor (k) = 33941.759	AppaRes (pa) = 67883.519936
15	Curr (m) 215.0	Pot (m) 2.0	Res (R) 3.5	GeoFactor (k) = 72608.474	AppaRes (pa) = 254129.660064
16	Curr (m) 316.0	Pot (m) 2.0	Res (R) 4.6	GeoFactor (k) = 156651.83	AppaRes (pa) = 721518.439068
17	Curr (m) 464.0	Pot (m) 5.0	Res (R) 2.4	GeoFactor (k) = 135270.51	AppaRes (pa) = 324649.227015
18	Curr (m) 681.0	Pot (m) 5.0	Res (R) 1.1	GeoFactor (k) = 291385.64	AppaRes (pa) = 320524.206763
19	Curr (m) 1000.0	Pot (m) 5.0	Res (R) 1.1	GeoFactor (k) = 526314.47	AppaRes (pa) = 691145.920311
20	Curr (m) 1147.0	Pot (m) 5.0	Res (R) 3.7	GeoFactor (k) = 226617.41	AppaRes (pa) = 3058484.43518

BY
HARVEY D.O. & DR. AKPOJAN J.
desolocal@gmail.com

SESCAL, WESCAL (Alpha, Beta, Gamma) & DIPOCAL are Registered Trade
Mark Names of the Respective TM owners.
SESCAL & DIPOCAL are TM of DEEPENERGY LTD and WESCALC is a
Solocast Accelerated Technologies TM

Figure 7: A screenshot of the Program on execution (for the multi-line, and lateral distance of 2000m)

In case of wrong entry or general miss type, the process to effect change or cancel or reset the whole operation is also very simple and straight forward. In this case, only the On-press is modified with the trace statement. The introduced expression of continuity and the cancel procedure will look like:

On (press) {trace. ("Button Pressed");

resVar = "" ;

currentVar = "" ;

potentialVar = "" ;End

The above script resets the dynamics input of the variables once the action is triggered by the onpress event which handles the cancel procedure. However, the cancel process affects only the dynamic input rather than the dynamic output. The range is found within the following neighborhood;

- Current electrode: 1.0m to 9999.9m

- Potential electrode: 0.1m to 999.9m
- Resistance Reading: 0.1m Ω to Infinity

The Instant reading (V/I) input is designed to hold values in the range of 0.1 milliohms to infinity based on the capability of the measuring device (e.g., terrameter, earth resistivity meter, etc.). Interestingly, the geometric factor (k) and the apparent resistivity (ρ_a), are both unlimited by the output values as a relation to the range of data input at the dynamic input levels which may be beyond the capability of some short programs of its class developed for the same purpose. However, it must be noted that negative resistive reading is as a result of unblended frequency (high noise to signal ratio) hence the negative sign should be ignored when imputing the resistance values from the field.

SCHLUMBERGER AUTOMATED FIELD CALCULATOR
FOR
Schlumberger Electrode System (SESCAL)

Enter the Current and Potential Electrode Spacing
 and the Corresponding Resistance from the Terrameter
 in the input boxes and click on the Equal sign to display the Corresponding
 Geometric factor and Apparent Resistivity values
 respectively.

DISCLAIMER:
 The readings from this Calculator is correct to two decimal places.

S/N	AB/2	MN/2	INST READ	Geo F (K)	AppaRes (pa)
1	Curr (m) 1.0	Pot (m) 0.5	Res (R)	GeoFactor (k)	AppaRes (pa)
2	Curr (m) 1.47	Pot (m) 0.5	Res (R)	GeoFactor (k)	AppaRes (pa)
3	Curr (m) 2.15	Pot (m) 0.5	Res (R)	GeoFactor (k)	AppaRes (pa)
4	Curr (m) 3.16	Pot (m) 0.5	Res (R)	GeoFactor (k)	AppaRes (pa)
5	Curr (m) 4.64	Pot (m) 1.0	Res (R)	GeoFactor (k)	AppaRes (pa)
6	Curr (m) 6.81	Pot (m) 1.0	Res (R)	GeoFactor (k)	AppaRes (pa)
7	Curr (m) 10.0	Pot (m) 1.0	Res (R)	GeoFactor (k)	AppaRes (pa)
8	Curr (m) 14.7	Pot (m) 1.0	Res (R)	GeoFactor (k)	AppaRes (pa)
9	Curr (m) 21.5	Pot (m) 1.5	Res (R)	GeoFactor (k)	AppaRes (pa)
10	Curr (m) 31.6	Pot (m) 1.5	Res (R)	GeoFactor (k)	AppaRes (pa)
11	Curr (m) 46.4	Pot (m) 1.5	Res (R)	GeoFactor (k)	AppaRes (pa)
12	Curr (m) 68.1	Pot (m) 1.5	Res (R)	GeoFactor (k)	AppaRes (pa)
13	Curr (m) 100.0	Pot (m) 2.0	Res (R)	GeoFactor (k)	AppaRes (pa)
14	Curr (m) 147.0	Pot (m) 2.0	Res (R)	GeoFactor (k)	AppaRes (pa)
15	Curr (m) 215.0	Pot (m) 2.0	Res (R)	GeoFactor (k)	AppaRes (pa)
16	Curr (m) 316.0	Pot (m) 2.0	Res (R)	GeoFactor (k)	AppaRes (pa)
17	Curr (m) 464.0	Pot (m) 5.0	Res (R)	GeoFactor (k)	AppaRes (pa)
18	Curr (m) 681.0	Pot (m) 5.0	Res (R)	GeoFactor (k)	AppaRes (pa)
19	Curr (m) 1000.0	Pot (m) 5.0	Res (R)	GeoFactor (k)	AppaRes (pa)
20	Curr (m) 1147.0	Pot (m) 5.0	Res (R)	GeoFactor (k)	AppaRes (pa)

BY
 ISHELE D.O. & DR. AKPOJANRO J.
 ishelecan@gmail.com

SESCAL, WESCAL (Alpha, Beta, Gamma) & DIPOCAL are Registered Trade
 Mark Names of the Respective TM owners.
 SESCAL & DIPOCAL are TM of DEEPGENERITY LTD and WESCALC is a
 Solocast Accelerated Technologies TM

Figure 8: A screenshot of the program on execution (for the multi-line, and lateral distance of more than 2000m)

6. Conclusion

The SESCAL was built as a web-based dynamic program. It was developed using swishmax as its scripting

language, driven by the hypertext markup language (html), embedded in flash-java containers. The four (4) respective electrodes (A,B), (M,N) and the resistance (V/I (Ω)) were built into the program and simulated to run it virtually. The program was developed with the unique ability to modify the basic quantities mentioned above (current electrode spacing, the potential electrode spacing and the V/I) to suit individual field practice with respect to the lateral and vertical variations in an inhomogeneous media. On execution of the program, the Geometric factor (k) and the Apparent Resistivity (ρ_a) were successfully obtained. The equipment was taken to field for experimental survey and the obtained data were fed into the program and it successfully executed itself and gave the geometric and apparent resistivity values for all the obtained data. It was tested for values of $L = 1.0, 1.47, \dots, 100$ and $l = 0.5, \dots, 500$. Finally a standard field sheet was incorporated into the program to reduce the monotony of numbering.

7. Recommendations

For a robust and dynamic program, more field measurements and more electrode array types is recommended to test the program's elasticity, buoyancy and limits, despite the fact that the limit for a homogeneous media has earlier been stated, this is to increase the near-zero percentage error of the program and versatility. Furthermore, there is the need for a dynamic storage for field data in the program; hence a database is to be built into the program using the existing architecture, to make it more robust. Finally, some more lines of the program is also needed for SESCO to enhance its capabilities, especially to the level of graph display as this is its only major limitation for now. Beyond this, SESCO is well suited for any field work in the realm of Schlumberger, Wenner and the Double dipole electrode configurations.

Acknowledgement

We are especially grateful to the members of staff in the ICT Unit of E&P Department of Deep Green Geophysical and Energy Group and Accelerated Technologies for providing the Geophysical Survey Equipment to test run the Program on the field and correlate the results.

References

- [1] M. H. Loke. Electrical Imaging Surveys for Environmental and Engineering Studies. A practical guide to 2- and 3-D surveys, 2000.
- [2] C. W. Montgomery. Environmental Geology (5th Edition.). McGraw Hill. New York, 2000.
- [3] O. M. Alile, S. I. Jegede, and M. O. Ehigior. 'Underground Water Exploration using Electrical Resistivity Method in Edo State'. Asian Journal of Earth Sciences, Vol 1. No. 1, pp. 38-42, 2008.
- [4] B. Sachin, and S. P. Sharma. Groundwater Potential Assessment using Resistivity Sounding method near Kalilkunda, West Bengal, 2008.
- [5] W. M. Telford, L. P. Geldart, and R. E. Sheriff. Applied Geophysics. Second Edition, Cambridge

University Press, 1990.

- [6] P. Kearey, M. Brooks, and I. Hill, I. An Introduction to Geophysical Exploration, (3rd Edition). Blackwell Science Ltd., Oxford, 2002.
- [7] M. B. Dobrin, and C. H. Savit. Introduction to Geophysical Prospecting (4th Ed). McGraw Hill, New York, 1998.
- [8] A. A. R. Zohdy (1989, January). A new method for the automatic interpretation of Schlumberger and Wenner Sounding Curves. [Online]. Available from <https://pubs.er.usgs.gov/publication/70015572>, Geophysics, Vol. 54, No 2, pp. 245-253, [June, 2017].
- [9] W. E. Wightman, F. Jalinoos, P. Sirles, and K. Hanna, K. (2003). Application of Geophysical Methods to Highway Related Problems. Federal Highway Administration, Central Federal Lands Highway Division, Lakewood, CO, Publication No. FHWA-IF-04-021, September 2003
- [10] A. Zara (2014). Java Tutorial Point, Java Easy learning. [Online]. Available from <http://www.tutorialpoint.com> [May, 2017].
- [11] S. Maiti, G. Gupta, V. C. Erram and R. K. Tiwari. 'Inversion of Schlumberger resistivity sounding data from the critically dynamic Koyna region using the Hybrid Monte Carlo-based neural network approach' Nonlinear Processes in Geophysics., Vol. 18, pp. 179-192, 2011.
- [12] E. A. Keller. Introduction to Environmental Geology, Pearson, 2016, pp. 25-28.