Appraisal of Electrode Configuration Characteristics in Resistivity Surveying

Kankanamge B.U., Chathuranga S.M.S., Ruwanika I.L.D., Palamure P.K., Abeysinghe A.M.K.B., Samaradivakara G.V.I. and *Jayawardena C.L.

Department of Earth Resources Engineering, University of Moratuwa, Sri Lanka

*Corresponding author – chulanthaj@uom.lk

Abstract

Non-destructive subsurface exploration methods could reveal subterranean characteristics with minimal consumption of time and resources. However, validity of such interpretations could vary depending on the appropriate use of the controllable parameters in the geophysical method, with respect to the subsurface complexities. Accordingly, this study evaluates the sub subsurface characteristics of several locations revealed by the interpretation of resistivity data to understand the performance of different electrode configurations used in resistivity surveying. The electrode spacings maintained at each configuration was also critically assessed to identify the most appropriate for a particular instance of surveying. Furthermore, subsurface profiles were computed using three different interpretation methods to identify any influences from the interpretation method on the accuracy of the resultant profile. The results reveal a strong dependency of interpretations on the array configuration and maintained electrode spacing. And it was determined a suitable electrode spacing for improved subsurface interpretation. In order to improve accuracy of interpretations, it also suggests the need of developing an upper limit for current electrode spacing (AB) of the Schlumberger Array Configuration, given the general electrode spacing is maintaining a lower limit as AB ≥ 5 (potential electrode spacing).

Keywords: Electrode spacing, Geophysical exploration, Vertical Electrical Sounding, Electrical profiling, Array configurations

1 Introduction

The Electrical Resistivity method is a prominent technique out of many non-invasive subsurface investigation methods [1]. It determines the resistance of subsurface layers to conduct a direct current (DC) flow [2] and computes the respective apparent resistivity values. This method reveals the resistivity variations in horizontal and vertical directions of the subsurface strata along the line of traverse or at a particular point of interest, to accurately interpret subsurface characteristics mainly associated with stratification and discontinuities [3].

However, the accuracy of such interpretations could be largely influenced by the array configurations used, electrode spacings maintained and the method of interpretation, in addition to the equipment specific controllable parameters such as the amount of DC flow, time delay, no of stacks etc. Hence, an attempt to assess the discrepancies generated by each electrode configuration and mode of interpretation for a location with a known subsurface profile could provide the degree of influence by each component on the interpreted profiles.

2 Methodology

Seven selected sites [Table 1] with known subsurface profiles were used to collect resistivity data with varying electrode configurations and spacings. The different array configurations included both Wenner and Schlumberger arrangements (profiling and sounding) and several pre-determined electrode separations.

Table 1: Resistivity Surveying Locations.

Location	Description
1	University of Moratuwa (Playground)
2	Matale, Raththota (near Tubewell MA 182)
3	Matale, Raththota (near Tube well MA 183)
4	Matale, Raththota (near Tube well MA 122)
5	Matale, Ambuldeniya 1
6	Matale, Ambuldeniya 2
7	Badulla, land subsidence

2.1 Resistivity Survey

The resistivity survey was conducted using the equipment (Resistivity Meter) Terrameter SAS1000, which was powered by a 12V external battery and supported by four steel electrodes with connecting wires. The direct current was introduced to the ground using electrodes A & B and the resultant potential difference between a separate pair of electrodes (M & N) were recorded for each attempt [4]. The potential values recorded for each known current, is used to calculate the resistivity and corresponding apparent resistivity of the subsurface layers.

Schlumberger and Wenner array configurations were used, where the four electrodes were aligned in a straight line along the traverse, in the sequence of A, M, N, B respectively. Current electrode spacing (AB) and potential electrode spacing (MN) were managed according to spacing values [Table 2], which increases as the survey proceeds. The increasing electrode separations usually maintained as, AB ≥ 5MN for Schlumberger and AB = 3MN for Wenner arrangement [4].

Table 2: Electrode Spacing Combinations Used for the Study.

Schlumberger				Wenner
S1: Uni. of Moratuwa		S2: Water Board		W
AB/2 (m)	MN/2 (m)	AB/2 (m)	MN/2 (m)	Electrode spacing (m)
1.5	0.5	1.5	0.5	33
2	0.5	2.1	0.5	30
3	0.5	3	0.5	25
3	1	4.4	0.5	15
5	1	6.3	0.5	10
7	1	9.1	0.5	5
10	0.5	13.2	0.5	
10	1	13.2	5	
12.5	2.5	19	0.5	
15	2.5	19	5	
16	2.5	27.5	0.5	
20	2.5	27.5	5	
30	2.5	40	0.5	
40	2.5	40	5	
40	2.5			
50	2.5			
50	10			

The electrode spacing combinations given in Table 1 indicates S1 & S2 Schlumberger spacings commonly used by the University of Moratuwa and the Water Board of Sri Lanka respectively. 'W' indicates the Wenner arrangement.

2.2 Data Interpretation

A total of twenty two resistivity data tables were recorded for seven locations with varying electrode configurations. Obtained resistivity data was interpreted using three different methods namely; curve fitting and inverse slope manual methods as well as "IPI2win" computer software. The subsurface information (layers, water table and bedrock) generated was validated using borehole data from known locations. These subsurface profiles were then compared among each other to determine their ability to represent the subsurface information accurately. This enabled building up a performance appraisal on electrode configurations and interpretation methods.

Interpretations using inverse slope method, the graphs were plotted for (AB/2)* Resistivity against AB/2 (for Schlumberger) and 1/Resistivity against electrode spacing (for Wenner). The varying gradients indicated on the graph was used to identify the changes in subsurface characteristics [5] and this method had been used to obtain rough idea of number of layers and layer depth in general.

In contrast, curve fitting and computer software methods mainly used to determine the groundwater table and depth to the bedrock. The computer assisted method, "IPI2win" software was used to process and interpret resistivity data [6].

Curve fitting method was used to interpret resistivity data obtained from Schlumberger array configuration. The graphs were plotted for apparent resistivity against (AB/2) and interpretation on these sounding curves were done by matching them with the corresponding master curves [7].

Finally, available borehole data from each location was used to check the accuracy of the interpreted profiles. These profiles were intended to be identical when at least one of the interpreted profiles among three different configurations mentioned in Table 1, and matched with borehole log data. In places where borehole logs were not available, a comparison was made among interpreted profiles obtained from three different array configurations, to extract a better approximation for subsurface characteristics.

3 Results and Discussion

Irrespective to the capabilities of the resistivity method, there can be significant discrepancies on subsurface interpretations for a particular location, when the readings were taken with different electrode configurations and spacing [3]

Apparent resistivity against Electrode spacing plot (Figure 1), resistivity cross section and pseudo cross section (Figure 2) for the location at University of Moratuwa which was generated by "IPI2win" software reveals the number of layers, water table depth and bedrock depth with percentage of error. The summary of the interpretation is given in Table 3.

Similar analysis was carried out for the all locations investigated in this study.

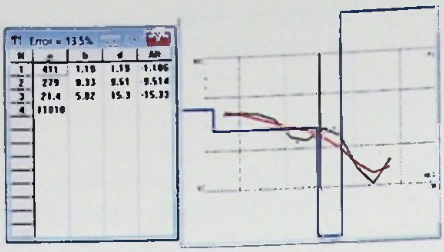

Figure 1: Apparent Resistivity Against Electrode Spacing Plot for University of Moratuwa Location.

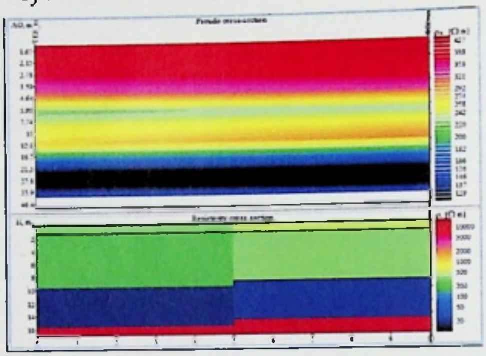

Figure 2: Pseudo Cross Section and Resistivity Cross Section for University of Moratuwa Location.

Table 3: Summary of the Interpretations of "IPI2win".

Criteria	Schlumberger Array		Wenner Array (Table W)	Borehole
	Table A	Table B		
No. of Layers	4	4	4	4
Water Table Depth (m)	9.51	8.72	5.21	~ 6.3
Bed Rock Depth (m)	15.3	14.7	10.2	11

Additionally, the curve-fitting method was also used for interpretations at each location but only for Schlumberger array configurations. This disclosed the subsurface characteristics such as; number of layers, layer thicknesses and the corresponding apparent resistivity values of the sub surface layers. A selected example of the results of this interpretation is given in Table 4.

Table 4: Curve Fitting Results for University of Moratuwa Ground.

Apparent resistivity, ρ(Ωm)	Thickness (m)
480	1.3
720	0.65
288	

Furthermore, interpretations from Inverse Slope method for the same location revealed subsurface characteritics as in Figure 3. The number of layers are indicated from the straight-line segments on the graph. The resistivity values were calculated from the reciprocal of slopes and the depths were determined using intersection points on abscissa [5].

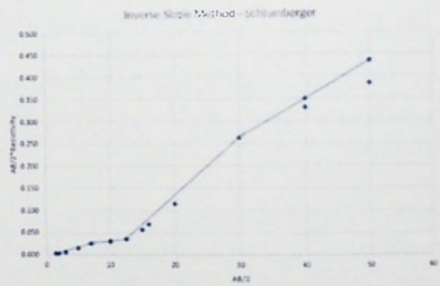

Figure 3: AB/2R Against AB/2 Plot of Data Obtained from Resistivity Survey (Schlumberger Array) Using Inverse Slope Method for University of Moratuwa Ground.

The reliability of the software-based interpretation was evaluated using the outcomes of the curve-fitting method and Inverse Slope method. A summary of interpreted profiles for each location with respect to the field data collection tables (A, B and W), and borehole data are given in Table 5, 6 and 7 respectively.

Table 5: Summary of Results Generated from Table A Validated with Borehole Logs, Table B and Table W Results.

Location	1	2	3	4	5	6	7
No. of Layers	√	X	X	√	-	-	-
Water Table Depth	√	X	X	√	√	-	-
Bed Rock Depth	√	√	X	X	-	-	-

√ Identical; X Different; - Borehole logs not available or comparisons not possible

According to Table 5, interpretation done by "IPI2win" resulted in reasonably acceptable profiles compared to borehole logs. The inverse slope interpretation showed the ability to determine correct number of layers better than the others.

Table 6: Summary of Results Generated from Table B Validated with Borehole Logs, Table A and Table W Results.

Location	1	2	3	4	5	6	7
No. of Layers	√	X	√	√	-	-	-
Water Table Depth	√	X	X	X	√	-	-
Bed Rock Depth	√	X	X	X	-	-	-

√ Identical; X Different; - Borehole logs not available or comparisons not possible

Table 6 reveals that field measurements recorded by Table B given under Table 3 and interpretation carried out using the software generated compatible results with borehole logs. The comparison indicates the ability of identifying correct number of layers in 3 out of 4 cases (where borehole logs available) using this method.

Table 7: Summary of Results Generated from Table W Validated with Borehole Logs, Table A and Table B Results.

Location	1	2	3	4	5	6	7
No. of Layers	√	X	X	√	-	-	-
Water Table Depth	√	√	√	X	√	-	-
Bed Rock Depth	√	X	X	X	-	-	-

√ Identical; X Different; - Borehole logs not available or comparisons not possible

The profiles generated for the field measurements recorded using Wenner Array configuration showed identical water table depths three profiles out of four with respect to the borehole logs. Thus, it is evident that, for the studied conditions Wenner configuration has accurately identified the water table depth. For locations 5, 6 and 7 (where borehole logs were not available) it was difficult to obtain a reasonable comparison of subsurface characteristics for the interpreted results from Table A, B or W given under Table 3. However, water table depth at location 5 was available from all three configurations.

Due to the degree of discrepancies disclosed among generated profiles during comparisons, electrode configurations were considered. The Schlumberger electrode configuration which was used to record measurements on both tables A and B in Table 3 indicated that AB < 20(MN) as reasonable upper limit as Table A in Table 3 records are reasonably accurate compared to Table B in Table 3. However, to determine the validity and applicability of an upper limit for AB through a proper empirical relationship, further studies are required.

4 Conclusions

The study reveals the possible discrepancies among interpretations based on different array configurations used, method of interpretation and environmental parameters although survey was carried out under identical conditions.

Although, Schlumberger array configurations were used in Table A and Table B presented under Table 3, there are significant discrepancies on interpreted profiles which implies the need of finding the proper AB to MN ratio to improve accuracy.

From the analysis done on the data tables of this study 5MN ≤ AB ≤ 20MN would be the most suitable for the locations under examination.

However, to evaluate the appropriateness of the above findings, it is recommended to conduct surveys to collect comprehensive set of records to satisfy minimal statistical requirement while maintaining consistent range of electrode spacing.

Acknowledgement

The authors are thankful to Mr. S. Weerawarnakula for providing the resistivity instrument to record data. Assistance from Ms. D.R.T. Jayasundara for statistical analysis of data was very helpful. Contributions from Mr. Shenal De Silva during resistivity surveying at various stages of this study and field support by Ms. Pathma Dissanayake and Mr. SD Sumith, is very much appreciated.

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