A Final Report of

ERT Test of 220/132 KV New Butwal Sub-station.

(Pic: author)

[Project location: Bhumai, Nawalparasi]

Submitted by:

Geo-Tech Consult & Research Centre Pvt. Ltd,

New-Baneshwor, Kathmandu.

Submitted to

Tata Projects Ltd, India

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ACRONYMS

Avg	Average
Er.	Engineer
ERT	Earth Resistivity Test
I	Current
kV	Kilovolt
Ltd.	Limited
m	metre
NEA	Nepal Electricity Authority
PIC	Picture
Pvt.	Private
R	Resistance
V	Voltage
=	Equals to
ρ	Resistivity
π	Pi

STUDY TEAM

Mr. Amrit Abhamani Dhakal	Energy Consultant.
Mr. Lalit Singh Rawal	Energy Consultant.

ACKNOWLEDGEMENT

Our study team places on record its profound thanks to N E A for its lead role in Power System Expansion Project under which lies Kaligandaki transmission corridor project.

We are grateful to Geotech Pvt. Ltd, for vesting its confidence on us for carrying out the Earth Resistivity Test (ERT) and their coordination and support in the initial stage of the study.

Our study team is indebted to Mr. Ananda Subedi, Electrical Engineer, NEA; Mr. Srijal Kunwar, Engineer, Jade Consult P. Ltd; Mr. Indranil Banerjee, RCM, Tata Projects Limited for their valuable time and cooperation. The team equally acknowledges contribution of Mr. Meer, Engineer and Mr. Amit, Surveyor from Tata Projects Limited for their unstinted support and cooperation during study.

Finally, we would like to express our thanks to all the other staffs related to this project who helped us in many ways. Special thanks also goes to local people who helped us in field; without whom our study would not have completed in time.

BACKGROUND INFORMATION

Under the SASEC: Power System Expansion Project, Kaligandaki Transmission Corridor Project, work has been initiated for the procurement of plant for design, supply, installation and commissioning of 220/132 kV New Butwal Substation.

*"One of the most important aspects of designing substation is **grounding system design.** Poor grounding system can be very dangerous which also increases the risk of equipment failure. Without an effective grounding system one can be exposed to the risk of electric shock, instrument errors, power factor problems, harmonic distortion issues and a host of possible intermittent dilemmas. If fault currents have no path to the ground through a properly designed and maintained grounding system, they will find unintended paths that could include people; can be fatal. However, good grounding isn't only for safety; it is also used to prevent damage to industrial plants and equipment. A good grounding system will improve the reliability of equipment and reduce the likelihood of damage due to lightning or fault currents. Billions are lost each year in the workplace due to electrical fires. This does not account for related litigation costs and loss of personal and corporate productivity."*

What is necessary in order to design proper grounding system?

Soil Resistivity is one of the most necessary parameter when determining the design of grounding system in order to meet ground resistance requirements. The later chapters will describe the methods used to calculate earth resistivity and the measured values that will be essential for designing proper grounding system for New Butwal Substation.

Objective

The objective of ERT investigation is to find out the horizontal as well as vertical variation of soil resistivity by taking two perpendicular lines parallel to given coordinate axis on proposed substation area at Bhumahi New Butwal, Nawalparasi. Soil resistivity investigation was carried out at 8 different location by taking 8 reading along two perpendicular lines parallel to given coordinate axis. The readings were taking by variation electrode spacing from 0.2m to 50m.

METHODOLOGY

Werner's 4 pole methods have been used in determining the earth resistivity of the allocated site. In this method, 4 electrodes were used (4 electrodes embedded to the ground in straight line) out of which 2 electrodes were responsible for current injection and the remaining 2 electrodes were used for voltage measurement. Basically, the Werner 4 pole arrangement is done as below:

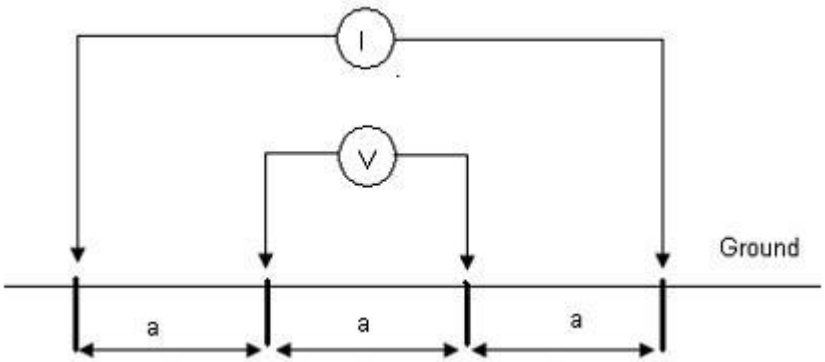


Figure 1: Werner 4 pole arrangement

From the above figure it can be seen that 'a' is the distance between two electrodes. The depth of the electrodes should not exceed 1/20th of electrode spacing 'a'. Using the above arrangement, the resistance can be measured with the help of which resistivity can be calculated using the following equation:

$$\rho = 2.\pi.a.R$$

Equation 1: Where, ρ = resistivity in ohm m, R= resistance in ohm and a= spacing between electrodes in meter.

The following steps were taken in order to measure the earth resistivity for the purposed site, New Butwal Sub-station:

1. The weather condition, soil condition and its type were noted being in the site.
2. The coordinates were checked and marked that were provided by the contractor, in the site. Altogether 8 points were suggested.
3. Keeping the provided point as a reference, the test was conducted along two perpendicular lines parallel to the co-ordinate axis. For one location, 16 readings were taken by putting the spacing of electrodes as 0.2m, 0.5m, 1m, 4m, 8m, 16 m, 32m and 50m in both East-West axis and South-

North axis. The readings were again iterated by using following combination in the connection

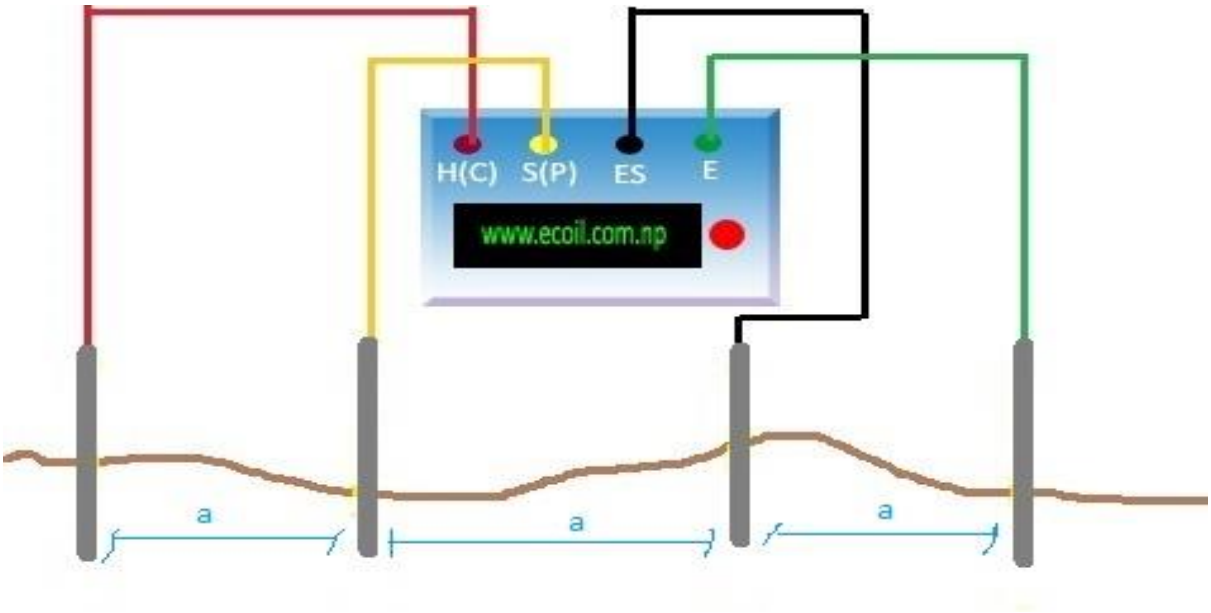


Figure 2: Werner 4 pole arrangement in site using **ST Geomative GD-10 Series**

4. In order to complete a connection for the circuit, water was used frequently to reduce auxiliary earth contact resistance for node S (P) and H (C).
5. Taking the measured value of resistance, the resistivity has been calculated using above equation 1.
6. Finally, the average resistivity for different allocated locations were calculated.
7. The readings for all the 8 locations were verified by the Energy Consultant and witnessed by the responsible personnel in site.
8. Current injection and voltage measurement was in Auto mode.

CLIENTS REQUIREMENT

As mentioned in 2.3.3 of standard technical document (See Snap shot at Annex. 6)

Electrical Resistivity Test: This test shall be conducted to determine the Electrical Resistivity of Soil required for designing safety grounding system for the entire station area. The specifications for the equipment and other accessories required for performing electrical resistivity test, the test procedure and reporting of the field observation shall confirm to the relevant British Standard code (B S Codes)/ equivalent international standard. The test shall be conducted using Wenner's four electrode method as specified in relevant British Standard Codes (B S Codes) / Equivalent International Standards. Unless otherwise specified at each test location, the test shall be conducted along two perpendicular lines

parallel to the coordinate axis. On each line a minimum 8 to 10 reedlings shall be taken by changing the spacing of an electrode from an initial small value of 0.2m up to a distance of 50.0m.

RESULT

Location 1, Coordinate (27.57475°N, 83.69041°E)

From East to West

Spacing(a) (meter)	R [H(C)- S(P)- ES- E] (ohm)	ρ (ohm m)
0.2	8.33	52.34
0.5	2.61	32.80
1	1.085	27.27
4	0.606	22.85
8	0.542	27.24
16	0.328	20.61
32	0.21	15.83
50	0.23	23.12

From South to North

Spacing(a) (meter)	R [H(C)- S(P)- ES- E] (ohm)	ρ (ohm m)
0.2	8.5742	53.87
0.5	2.71	34.05
1	0.87	21.87
4	0.53	19.98
8	0.37	18.60
16	0.29	18.22
32	0.23	17.34
50	0.24	24.13

Location 2, Coordinate (27.57446°N, 83.68972°E)

From East to West

Spacing(a) (meter)	R [H(C)- S(P)- ES- E] (ohm)	ρ (ohm m)
0.2	46.9	294.68
0.5	7.9	99.27
1	2.16	54.29
4	0.82	30.91
8	0.65	32.67
16	0.55	34.56
32	0.261	19.68
50	0.364	36.59

From South to North

Spacing(a) (meter)	**R [** H(C)- S(P)- ES- E **] (ohm)**	**ρ (ohm m)**
0.2	27.9	175.30
0.5	8.8	110.58
1	1.7	42.73
4	0.8	30.16
8	0.46	23.12
16	0.275	17.28
32	0.325	24.50
50	0.241	24.23

Location 3, Coordinate (27.57481°N, 83.68877°E)

From East to West

Spacing(a) (meter)	**R [** H(C)- S(P)- ES- E **] (ohm)**	**ρ (ohm m)**
0.2	18.42	115.74
0.5	10.51	132.07
1	3.07	77.16
4	1.442	54.36
8	0.61	30.66
16	0.45	28.27
32	0.447	33.70
50	0.46	46.24

From South to North

Spacing(a) (meter)	**R [** H(C)- S(P)- ES- E **] (ohm)**	**ρ (ohm m)**
0.2	24.5	153.94
0.5	12.87	161.73
1	2.64	66.35
4	1.95	73.51
8	1.54	77.41
16	1.27	79.80
32	1.01	76.15
50	1.2	120.64

Location 4, Coordinate (27.57577°N, 83.69065°E)

From East to West

Spacing(a) (meter)	R [H(C)- S(P)- ES- E] (ohm)	ρ (ohm m)
0.2	24.1	151.42
0.5	2.68	33.68
1	0.55	13.82
4	0.5	18.85
8	1.1	55.29
16	0.8	50.27
32	0.9	67.86
50	0.6	60.32

From South to North

Spacing(a) (meter)	R [H(C)- S(P)- ES- E] (ohm)	ρ (ohm m)
0.2	21.9	137.60
0.5	6.2	77.91
1	1.83	45.99
4	0.86	32.42
8	0.49	24.63
16	0.54	33.93
32	0.45	33.93
50	0.31	31.16

Location 5, Coordinate (27.57587°N, 83.68983°E)

From East to West

Spacing(a) (meter)	R [H(C)- S(P)- ES- E] (ohm)	ρ (ohm m)
0.2	12.18	76.53
0.5	6.07	76.28
1	3.13	78.67
4	2.82	106.31
8	0.77	38.70
16	0.68	42.73
32	0.46	34.68
50	0.56	56.30

From South to North

Spacing(a) (meter)	**R [** H(C)- S(P)- ES- E **] (ohm)**	**ρ (ohm m)**
0.2	7.17	45.05
0.5	2.69	33.80
1	1.4	35.19
4	0.82	30.91
8	0.59	29.66
16	0.45	28.27
32	0.34	25.64
50	0.27	27.14

Location 6, Coordinate (27.57611°N, 83.68903°E)

From East to West

Spacing(a) (meter)	**R [** H(C)- S(P)- ES- E **] (ohm)**	**ρ (ohm m)**
0.2	11.52	72.38
0.5	4.52	56.80
1	1.58	39.71
4	0.97	36.57
8	0.4	20.11
16	0.37	23.25
32	0.33	24.88
50	0.25	25.13

From South to North

Spacing(a) (meter)	**R [** H(C)- S(P)- ES- E **] (ohm)**	**ρ (ohm m)**
0.2	8.51	53.47
0.5	4.13	51.90
1	1.6	40.21
4	0.83	31.29
8	0.51	25.64
16	0.39	24.50
32	0.28	21.11
50	0.19	19.10

Location 7, Coordinate (27.57532°N, 83.68854°E)

From East to West

Spacing(a) (meter)	**R [** H(C)- S(P)- ES- E **] (ohm)**	**ρ (ohm m)**
0.2	7.15	44.92
0.5	3.48	43.73
1	1.08	27.14
4	0.67	25.26
8	0.45	22.62
16	0.3	18.85
32	0.24	18.10
50	0.2	20.11

From South to North

Spacing(a) (meter)	**R [** H(C)- S(P)- ES- E **] (ohm)**	**ρ (ohm m)**
0.2	10.14	63.71
0.5	4.51	56.67
1	1.54	38.70
4	0.5	18.85
8	0.4	20.11
16	0.31	19.48
32	0.31	23.37
50	0.36	36.19

Location 8, Coordinate (27.575010°N, 83.689510°E)

From East to West

Spacing(a) (meter)	**R [** H(C)- S(P)- ES- E **] (ohm)**	**ρ (ohm m)**
0.2	4.65	29.22
0.5	1.68	21.11
1	1.62	40.72
4	0.97	36.57
8	0.45	22.62
16	0.6	37.70
32	0.44	33.18
50	0.34	34.18

From South to North

Spacing(a) (meter)	R [H(C)- S(P)- ES- E] (ohm)	ρ (ohm m)
0.2	6.77	42.54
0.5	1.63	20.48
1	0.41	10.30
4	0.53	19.98
8	0.32	16.08
16	0.73	45.87
32	0.78	58.81
50	0.49	49.26

Conclusion

Finally, the average resistivity in all the 8 allocated locations were calculated for both east to west (lowest 27.76 to highest 75.33 ohm m) and south to north (lowest 26.01 to highest 101.19 ohm m) measurements. Average resistivity in different location has been plotted as below:

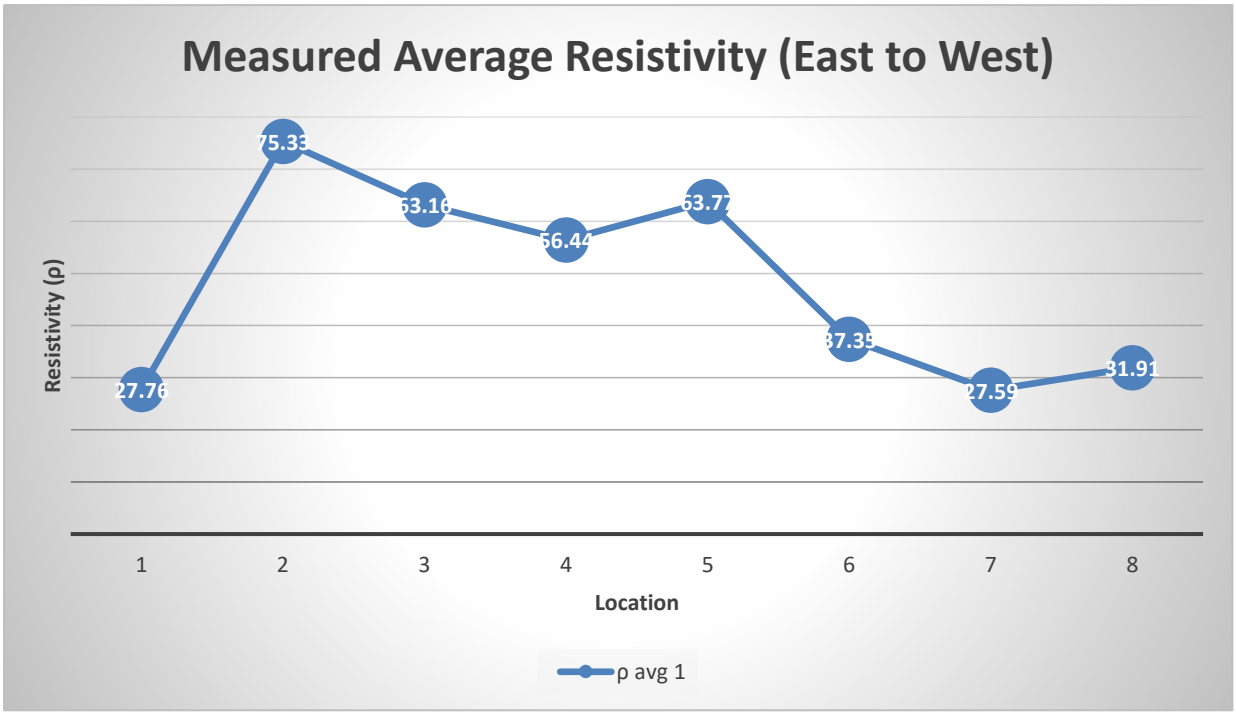


Figure 3: Average resistivity (ρ avg 1)[1] measurement in different 8 locations (East to West)

[1] ρ avg 1 is the resistivity calculated for connection H(C)- S(P)- ES- E .

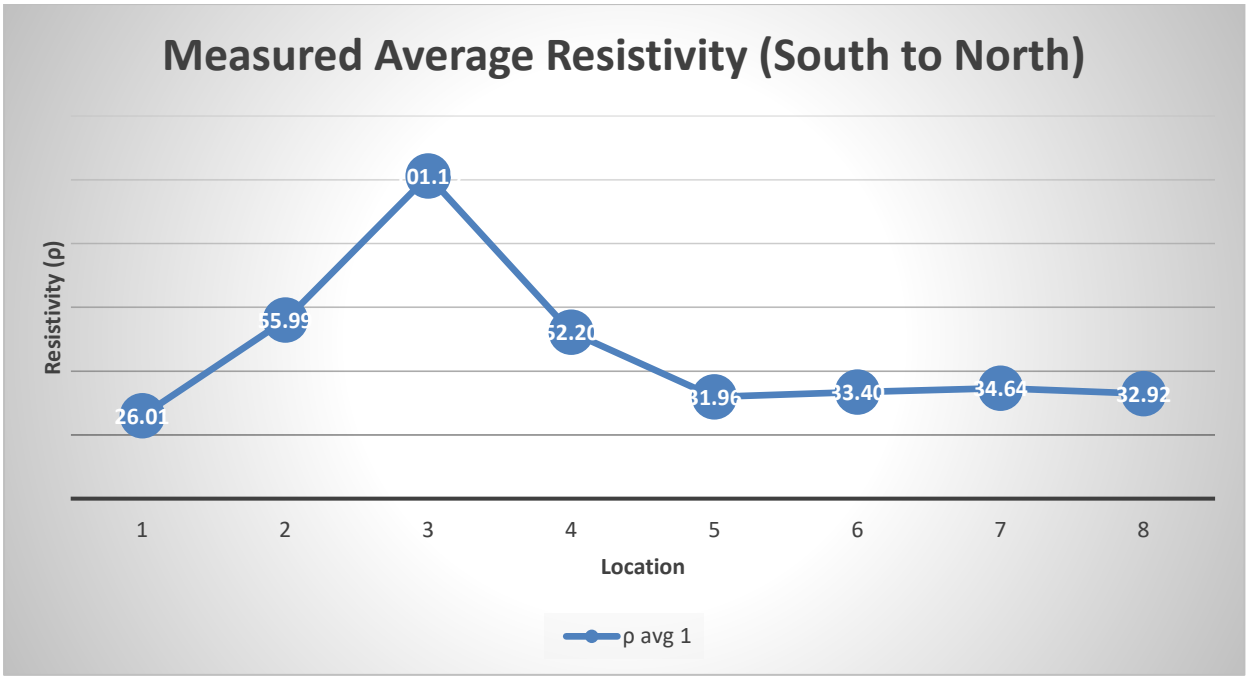


Figure 4: Average resistivity (ρ avg1)[2] measurement in different 8 locations (South to North)

[2] ρ avg1. is the resistivity calculated for connection H(C)- S(P)- ES- E.

ANNEX

Annex: 1: Soil and Weather Conditions

Weather Condition	Soil Condition	Soil Type
Sunny	Arid/ Very Dry	Clayey Silt with fine Soil, at some points there were stones/granite due to crusher factory

Annex: 2: Average resistivity in all allocated 8 locations

	East to West	South to North
Location	**ρ avg1**	**ρ avg1**
1	27.76	26.01
2	75.33	55.99
3	63.16	101.19
4	56.44	52.2
5	63.77	31.96
6	37.35	33.4
7	27.59	34.64
8	31.91	32.92

Annex: 3: Equipment used

Pic: author

Annex: 4: Witnesses on site

Er. Ananda Subedi

Nepal Electricity Authority

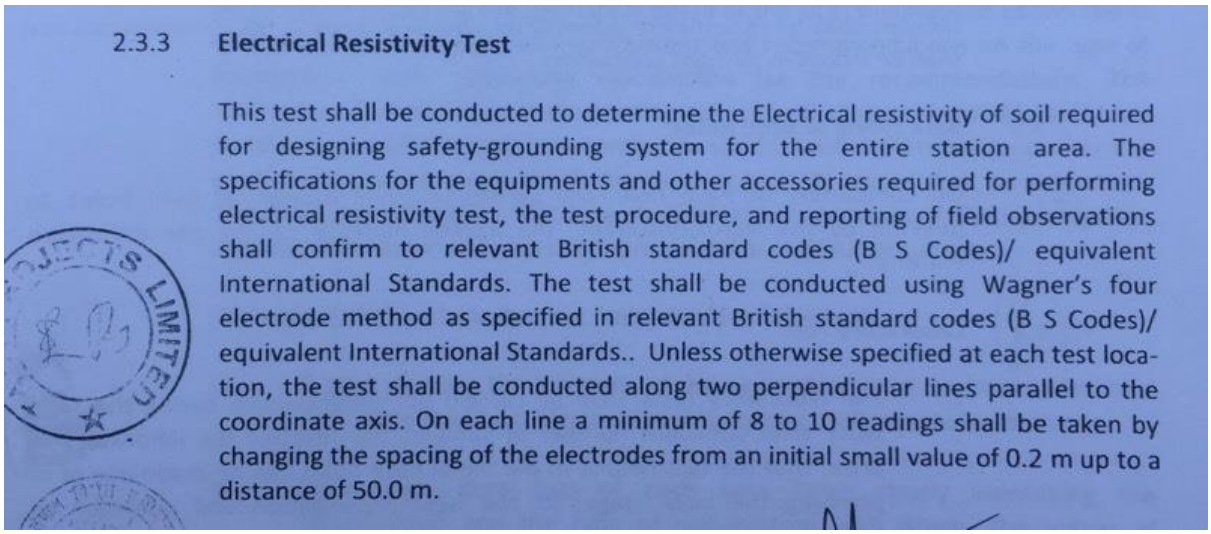
Er. Indranil Banerjee

Tata Projects Limited.

Er. Srijal Kunwar

Jade Consult P. Ltd.

Annex: 5: Snapshot from Standard Technical Document Regarding Electrical Resistivity Test



2.3.3 **Electrical Resistivity Test**

This test shall be conducted to determine the Electrical resistivity of soil required for designing safety-grounding system for the entire station area. The specifications for the equipments and other accessories required for performing electrical resistivity test, the test procedure, and reporting of field observations shall confirm to relevant British standard codes (B S Codes)/ equivalent International Standards. The test shall be conducted using Wagner's four electrode method as specified in relevant British standard codes (B S Codes)/ equivalent International Standards.. Unless otherwise specified at each test location, the test shall be conducted along two perpendicular lines parallel to the coordinate axis. On each line a minimum of 8 to 10 readings shall be taken by changing the spacing of the electrodes from an initial small value of 0.2 m up to a distance of 50.0 m.

Annex: 6: Satellite (Google Earth) Plot of Given Locations

Source: (Google Earth)