Date: 14/02/2019

Installation and training Report of Lippmann Earth Resistivity-meter Against IIT Roorkee PO No. 1100000668/MM-17/IITR/2018-19/Resistivity meter/CED/343 dated 10/12/2018

Introduction:

1) Resistivity sounding, also known as Vertical Electrical Sounding (VES)

Vertical Electrical Sounding (VES) is by far the most used method for geoelectric surveying, because it is one of the cheapest geophysical method and it gives very good results in many area of interest.

This method uses two current electrodes situated at the end points with the two measuring electrodes continuously spreading in the line. This yields depth-wise resistivity variations, which are interpreted in terms of aquifer aquitards at depth and salinity of water in the aquifers.

The field measurements technique is adjustable for the different topographic conditions and the interpretation of the data can be done with specialized software, with a primary interpretation immediately after the measurements. The results of VES measurements can be interpreted qualitatively as well as quantitatively.

The technology is applicable on rivers and lakes also, making it possible to find out the geology of underwater terrain. This method has proven efficient in designing vertical guided boreholes and other engineer projects.

2) Resistivity imaging, also known as electrical resistivity tomography (ERT)

Resistivity imaging technique is a new development in recent years to image the subsurface having moderately complex geology and wide variations in aquifer occurrences. It combines resistivity sounding and profiling, incorporates the effects of lateral variations in resistivity on sounding, and produces a two- or three-dimensional subsurface resistivity image, thus leading to the three-dimensional geometry of the aquifers.

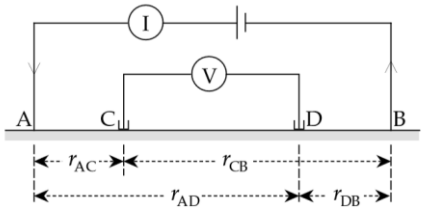
Multi-electrode resistivity meter is used for such kind of survey where surveys are carried out automatically using a large number of equally spaced collinear array of electrodes connected to a multi-core cable. A laptop microcomputer together with an electronic switching unit is used to automatically select the relevant electrodes for each measurement. The major time is taken only in planting the electrodes. The result so produced after processing of data gives complete subsurface information of the target area.

Theory:

The general four-electrode method Consider an arrangement consisting of a pair of current electrodes and a pair of potential electrodes (Fig. 1). The current electrodes A and B act as source and sink, respectively.

The potential difference measured by a voltmeter connected between C and D is:

$$V = \frac{\rho I}{2\pi}\left\{\left(\frac{1}{r_{AC}} - \frac{1}{r_{CB}}\right) - \left(\frac{1}{r_{AD}} - \frac{1}{r_{DB}}\right)\right\}$$



All quantities in this equation can be measured at the ground surface except the resistivity, which is given by:

$$\rho = 2\pi\frac{V}{I}\left\{\left(\frac{1}{r_{AC}} - \frac{1}{r_{CB}}\right) - \left(\frac{1}{r_{AD}} - \frac{1}{r_{DB}}\right)\right\}^{-1}$$

Special electrode configurations

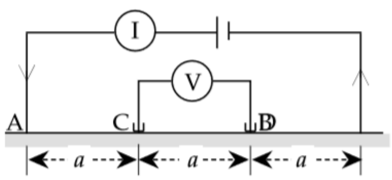
The general formula for the resistivity measured by a four-electrode method is simpler for some special geometries of the current and potential electrodes. The most commonly used configurations are the Wenner, Schlumberger and double-dipole arrangements. In each configuration the four electrodes are collinear but their geometries and spacings are different.

In the **Wenner** configuration (Fig. 2) the current and potential electrode pairs have a common mid-point and the distances between adjacent electrodes are equal, so that rAC=rDB=a, and rCB=rAD=2a. Inserting these values in Eq. gives.

(a) Wenner

$$\rho = 2\pi\frac{V}{I}\left\{\left(\frac{1}{a} - \frac{1}{2a}\right) - \left(\frac{1}{2a} - \frac{1}{a}\right)\right\}^{-1}$$

$$\rho = 2\pi a\frac{V}{I}$$



$r_{AC} = a \quad r_{AD} = 2a$

$r_{CB} = 2a \quad r_{DB} = a$

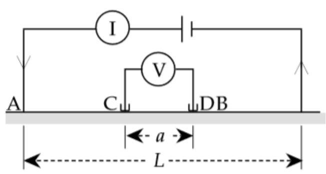
$$\boxed{\rho_a = 2\pi\frac{V}{I}a}$$

In the **Schlumberger** configuration (Fig. 3) the current and potential pairs of electrodes often also have a common mid-point, but the distances between adjacent electrodes differ. Let the separations of the current and potential electrodes be L and a, respectively. Then rAC= rDB= (L – a)/2 and rAD=rCB=(L+a)/2. Substituting in the general formula, we get:

(b) Schlumberger

$$\rho = 2\pi\frac{V}{I}\left\{\left(\frac{2}{L-a} - \frac{2}{L+a}\right) - \left(\frac{2}{L+a} - \frac{2}{L-a}\right)\right\}^{-1}$$

$$= \frac{\pi}{4}\frac{V}{I}\left(\frac{L^2 - a^2}{a}\right)$$



$r_{AC} = (L-a)/2 \quad r_{AD} = r_{CB}$

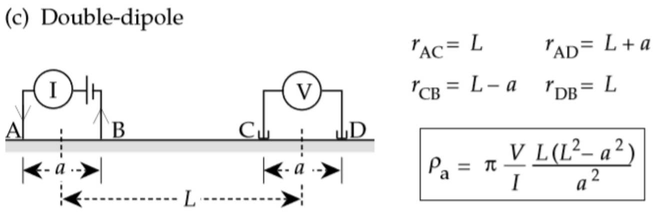
$r_{CB} = (L+a)/2 \quad r_{DB} = r_{AC}$

$$\boxed{\rho_a = \frac{\pi}{4}\frac{V}{I}\frac{(L^2 - a^2)}{a}}$$

In the **double-dipole** configuration (Fig. 4) the spacing of the electrodes in each pair is a, while the distance between their mid-points is L, which is generally much larger than a. Note that detection electrode D is defined as the potential electrode closer to current sink B. In this case rAD=rBC=L, rAC=L+a, and rBD=L – a. The measured resistivity is

$$\rho = 2\pi \frac{V}{I}\left\{\left(\frac{1}{L} - \frac{1}{L-a}\right) - \left(\frac{1}{L+a} - \frac{1}{L}\right)\right\}$$

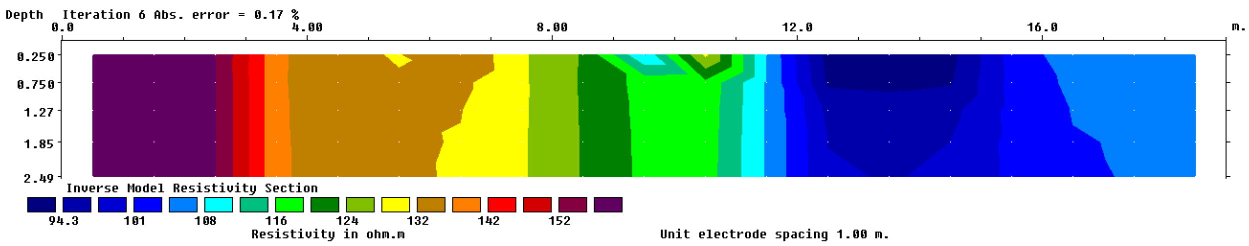
$$\rho = \pi \frac{V}{I}\left(\frac{L(L^2 - a^2)}{a^2}\right)$$



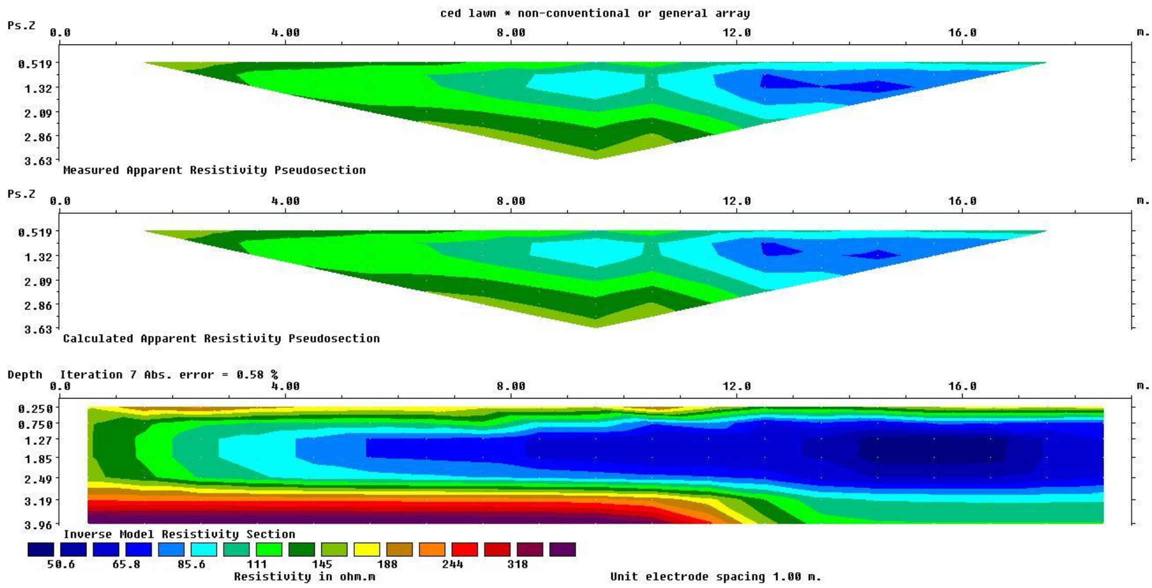
Results and Discussions:

4 resistivity surveys were carried out by the team near the Solani river side, Roorkee. The screenshots of the settings and the final results after inversion and modelling is shared below.

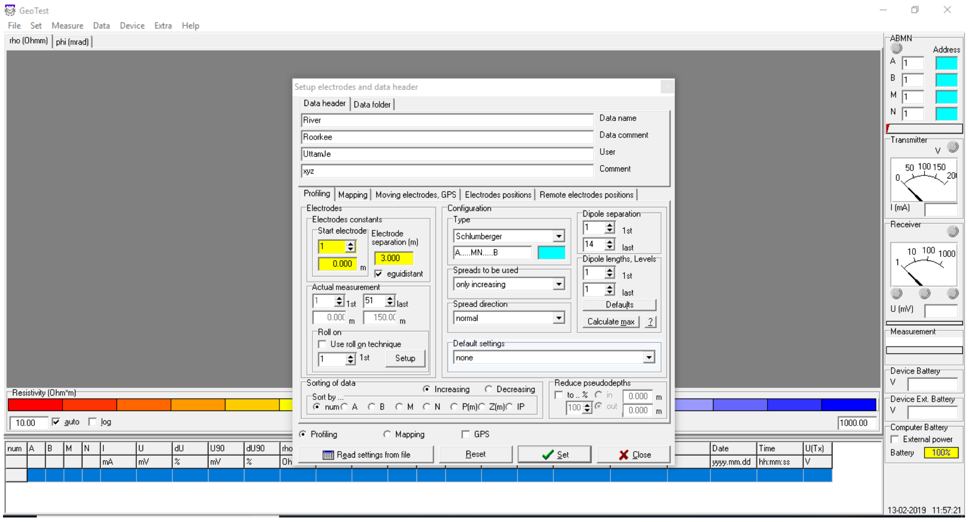
Wenner: (12/02/2019), no. of electrodes – 20, profile length 19m

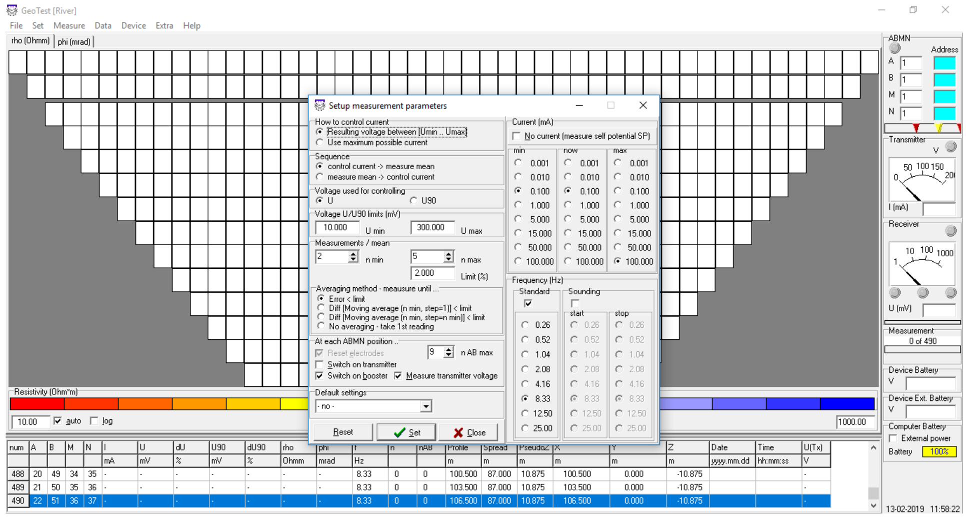


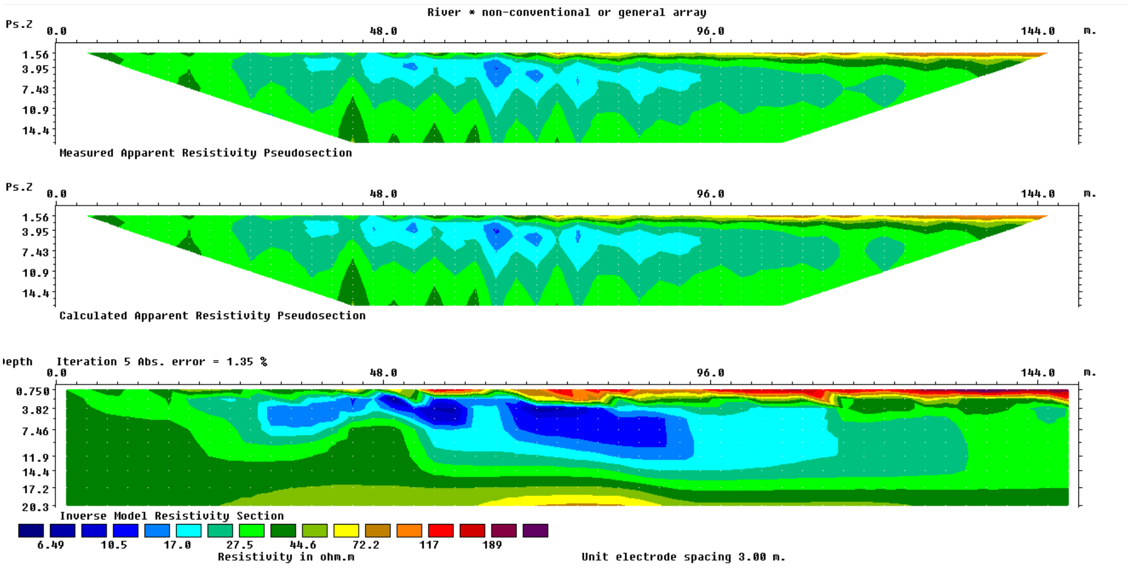
Schlumberger (12/02/2019) no. of electrodes- 20, profile length -19m.



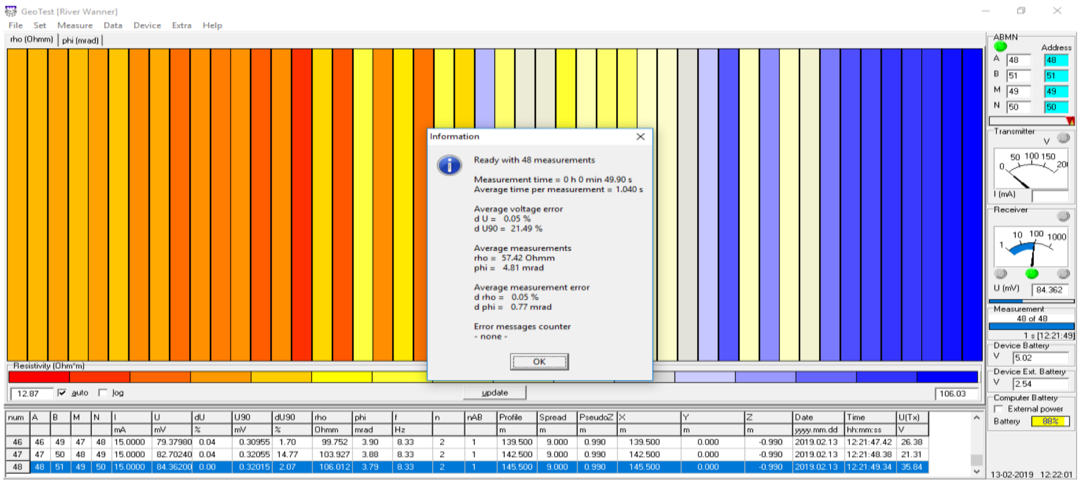
Schlumberger (13/02/2019) No. of elecrodes-50, Profile length-150m.

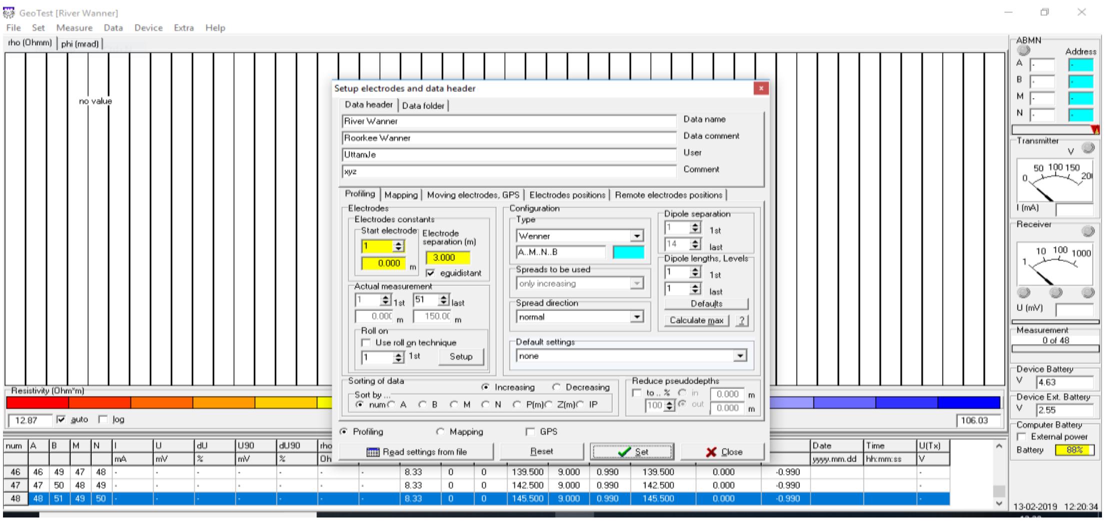


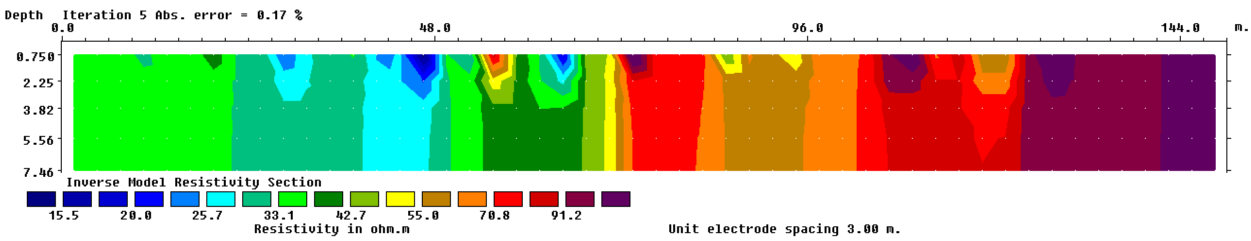




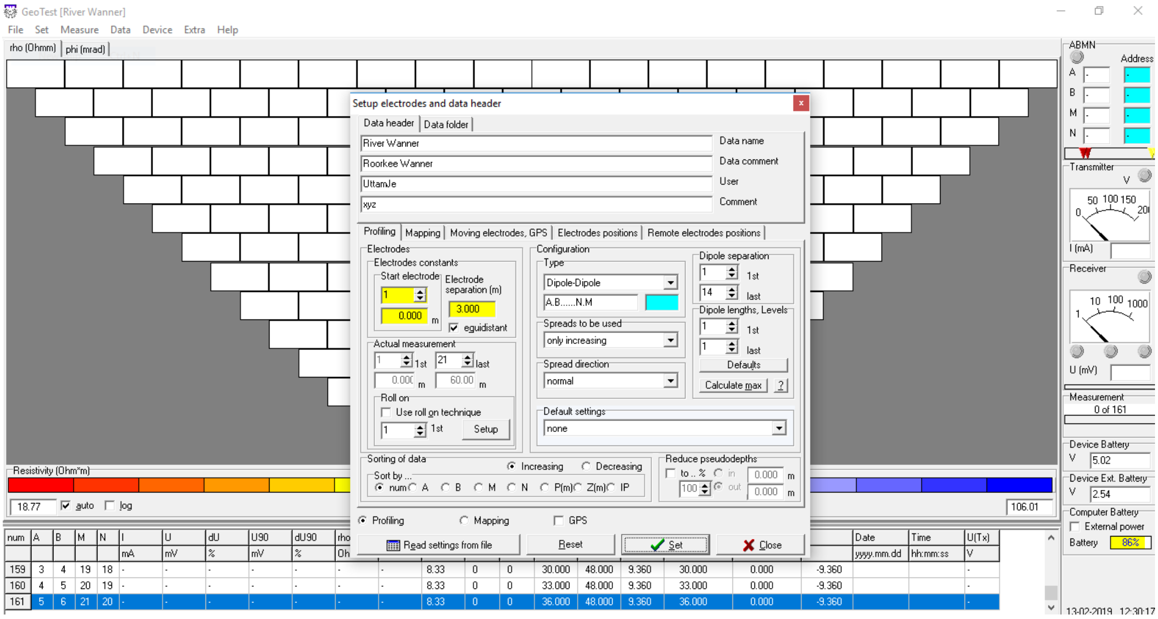
Wenner(13/02/2019)- No. of electrodes-50, Profile length -150m.

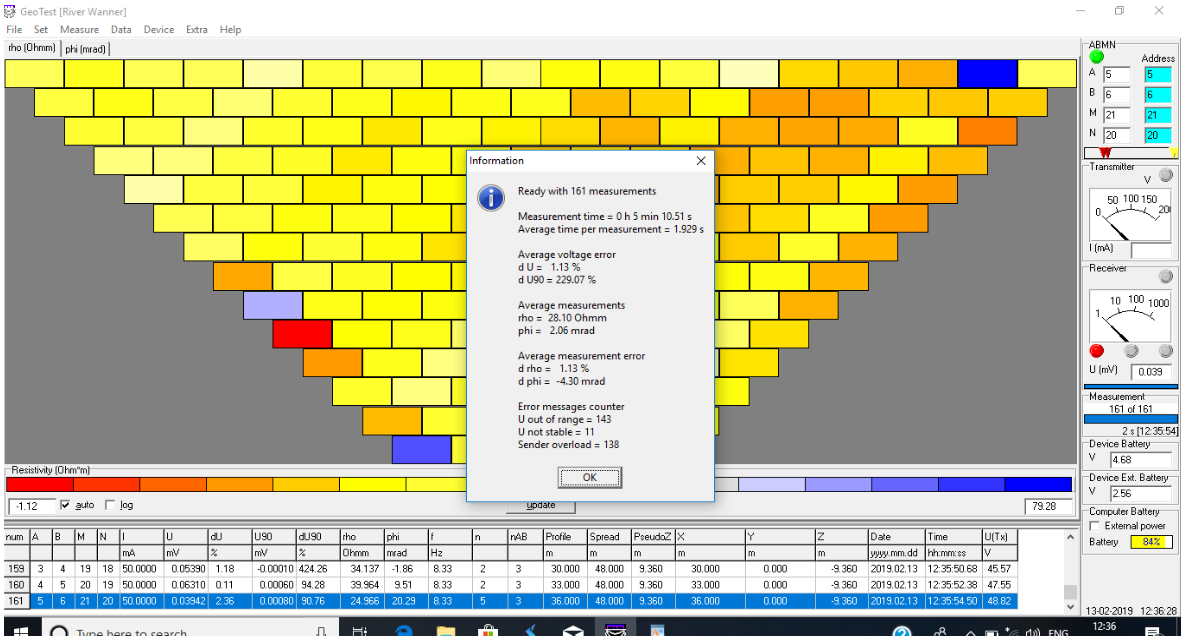


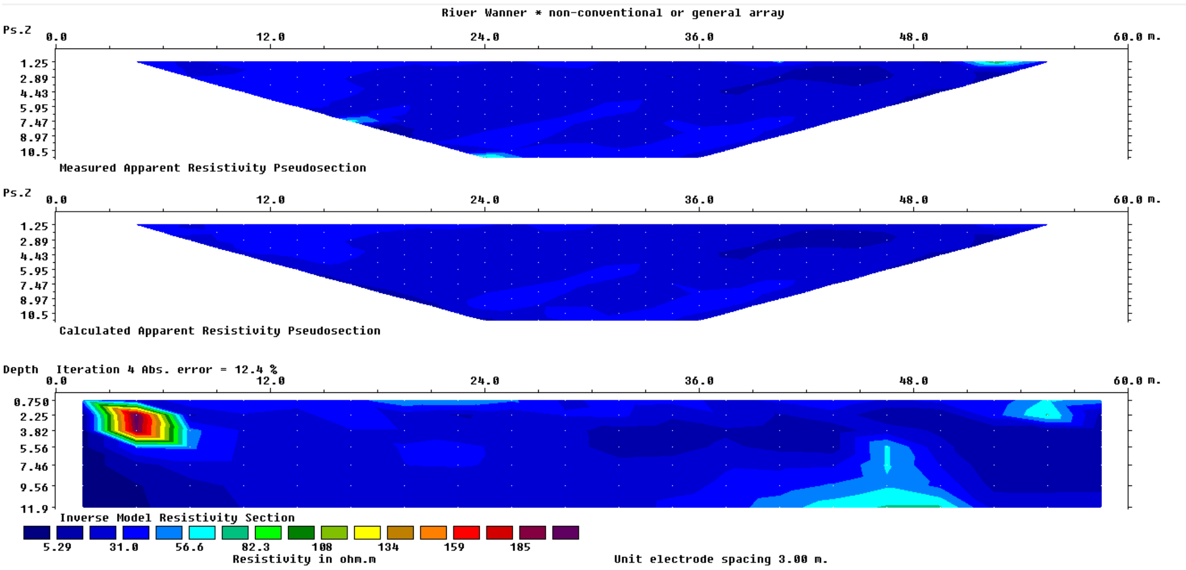




Dipole-Dipole (13/02/2019)- No. of electrodes -20, Profile length – 60m.


GeoTest [River Wanner]
Setup electrodes and data header
River Wanner
Data name
Roorkee Wanner
Data comment
UttamJe
User
xyz
Comment
Dipole-Dipole
Resistivity [Ohm*m]


GeoTest [River Wanner]
Information
Ready with 161 measurements
Measurement time = 0 h 5 min 10.51 s
Average time per measurement = 1.929 s
Average voltage error
d U = 1.13 %
d U90 = 229.07 %
Average measurements
rho = 28.10 Ohmm
phi = 2.06 mrad
Average measurement error
d rho = 1.13 %
d phi = -4.30 mrad
Error messages counter
U out of range = 143
U not stable = 11
Sender overload = 138
OK
Resistivity [Ohm*m]


River Wanner * non-conventional or general array
Ps.Z
0.0
12.0
24.0
36.0
48.0
60.0 m.
1.25
2.89
4.43
5.95
7.47
8.97
10.5
Measured Apparent Resistivity Pseudosection
Calculated Apparent Resistivity Pseudosection
Depth
Iteration 4 Abs. error = 12.4 %
0.750
2.25
3.82
5.56
7.46
9.56
11.9
Inverse Model Resistivity Section
5.29
31.0
56.6
82.3
108
134
159
185
Resistivity in ohm.m
Unit electrode spacing 3.00 m.

This is to confirm that Installation and training completed successfully be Pan India Consultants Pvt Ltd, Gurgaon team and IIT Roorkee team found that Lippmann earth resistivity meter is working satisfactorily.

<u>Pan India Team</u>:

Mr. Umesh Kumar

Mr. Naman Agarwal

Mr. Saksham Arora

Mr. Rishabh Chandra

<u>IIT Roorkee Team:</u>

Prof P.K. Sharma, Asso. Prof

Mr. Uttam Singh, Research Scholar

TABLE 1 Source:IEEE142/BS 7430

Soil Type	Average Resistivity
	Ωm
Well graded gravel	600-1000
Poorly graded gravel	1000-2500
Clayey gravel	200-400
Silty sand	100-800
Clayey sands	50-200
Silty/clayey sand with slight plasticity	30-80
Fine sandy soil	80-300
Inorganic clays of high plasticity	10-55
Surface soils	1-50
Clay	2-100
Sandy clay	100-150
Moist gravel	50-700
Dry gravel	700-1200
Limestone	5-10000
Porous limestone	30-100
Quartz, crystalline limestone	100-1000
Sandstone	20-2000
Granites	900-1100
Concrete	300-500