DELINEATION OF CONTAMINANT ZONE THROUGH ELECTRICAL IMAGING TECHNIQUE : A CASE STUDY NEAR DINDIGUL, TAMILNADU

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ABSTRACT

Electrical imaging technique was found to be a powerful tool to delineate sub-surface contaminated zone, when there is sufficient resistivity contrast. Electrical tomography (imaging) involves measuring a series of constant separation traverses with the electrode spacing being increased with each successive traverse. Since increasing separation leads to information from greater depths, the measured apparent resistivities will be used to construct a vertical continued section (pseudo section) displaying the variation of resistivities both laterally and vertically over the section. Normally pseudo section contains geometrical effects, geological noise and the distorting effects of near surface lateral changes in resistivities, which occur close to the electrodes (electrode effects). In order to remove geometrical effects as well as to produce an image of true depths and true formation resistivities, inversion technique is used. The inversion technique described by Loke and Barker (1995) was used in the present study for processing pseudo section data to provide contoured image of true depths and true formation resistivity.

Groundwater in and around Dindigul town (Tamilnadu) was contaminated due to untreated tannery effluents. Five profiles were used to measure the apparent resistivity of sub-surface soil. Imaging produced in that condition is difficult to interpret as the resistivities of the weathered overburden may vary due to degree of weathering, saturation and presence of contaminated water. In general, surveys in the shallow basement areas suggest that the regolith (weathered overburden) is characterized by resistivities in the range of 50 to 200 Ω m, whereas in the neighbourhood of tanneries, it is expected thick layer of contaminant zone. In that case, the resistivity of shallow regolith might be expected to have weathered to a greater degree and, therefore, exhibit a resistivity of less than 50 Ω m. Since the water table is shallow and the regolith is largely saturated, any resistivity much below 20 Ω m will indicate groundwater contamination, in the absence of clay. Out of 5 profiles carried out in the polluted area, 4 profiles have shown that the top 10-15 meters of regolith has resistivity of less than 10 Ω m with top 5 m having a resistivity of less than 4 Ω m. This has clearly indicated that the soil is strongly contaminated. One profile has shown low resistivity at low topography of profile and resistivity

of above 100 Ω m in the elevated area is not contaminated. Thus this technique provides useful and interesting information about the polluted zone.

1.0 INTRODUCTION

Electrical imaging technique has been widely used in developed countries to study the subsurface system. New inversion algorithms produce electrical images, which can represent realistic 2D or 3D subsurface systems. As field data have become more reliable with deployment of refined techniques, electrical imaging has become very effective in delineating fracture and contaminated zones. This technique will help in identifying the variable layered thickness of weathered and fractured zones to site drilling locations for a better yield as well to delineate the contaminated zone. This study is mainly focussing on the delineation of subsurface system in Dindigul Town and its surrounding area.

2.0 ELECTRICAL IMAGING

Electrical tomography (imaging) involves measuring a series of constant separation traverses with the electrode spacing being increased with each successive traverse. Since increasing separation leads to information from greater depth, the measured apparent resistivities may be used to construct a vertical contoured section displaying the variation of resistivity both laterally and vertically over the section.

Modern field systems, such as the Campus Imager system, use a multicore cable to which 50 or smore electrodes are connected at takeouts moulded on at predetermined equal intervals. Such a cable is very much like a seismic cable and is used in a similar way. The cable is connected to a switching module and to an earth resistance meter and computer through an RS232 port (Figure 1). With these systems any electrodes may be switched to act as either current A, B or potential M, N electrodes and so within the constraints of the electrodes emplaced, any electrode arrangement can be employed. In practice either the two-electrode (pole-pole), Wenner, pole-dipole or dipole-dipole arrays are often employed. For a fixed line of equally spaced electrodes the arrays have the following advantages and disadvantages:

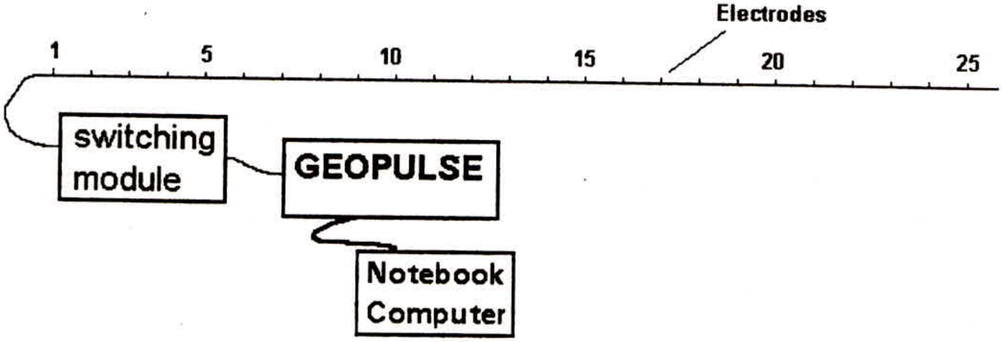

Figure 1. The basic instrument system employed in computer controlled electrical imaging

1. Two-electrode has the greatest depth range, lowest resolution and least sensitivity to geological noise.

2. Wenner covers an intermediate depth range, has intermediate resolution and shows moderate sensitivity to geological noise,

3. Pole-dipole has a good resolution but is more sensitive to noise.

4. Dipole-dipole has the smallest depth range, highest resolution and greatest Sensitivity to noise.

In addition there are practical problems to be overcome with using the two-electrode array and pole-dipole arrays, as these require the use of electrodes placed at considerable distances form the imaging line. Also an important advantage of the Wenner array is that the number of measurements required to construct a pseudosection is much smaller than with the other arrays.

The first stage in the production of an electrical image is the construction of a pseudosection by plotting each apparent resistivity on a vertical section at a point below the centre of the four measuring electrodes and at a depth which is equivalent to the median depth of investigation (Barker 1989, Edwards 1977) of the array employed. The data are contoured to form a pseudo depth-section, which qualitatively reflects the spatial variation of resistivity in cross-section (Figure 2).

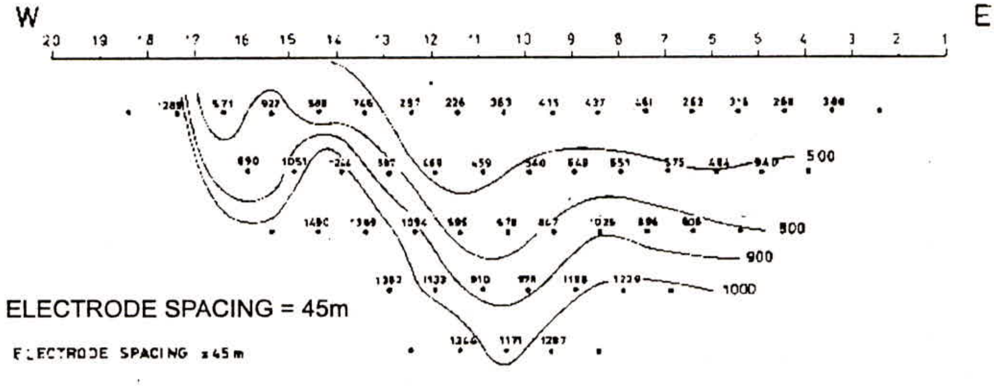

Fig. 2. An example of a Wenner pseudo-section.

Fig. 2 : An example of a Wenner pseudo-section

The contoured pseudosection contains three types of information. It clearly will contain considerable subsurface geological information, which is reflected in the general form of the pseudosection. However, the pseudosection also contains geometrical information so that the anomaly across a simple structure will appear quite different for the different electrode arrays; what appears a simple structure on a two-electrode pseudosection may be quite complex on a dipole-dipole pseudosection. In addition the pseudosection will contain a certain amount of geological noise, the distorting effects of near-surface lateral changes in resistivity, which occur close to the electrodes (often referred to as 'electrode effects'). Although shallower than the depth range of the image they can nevertheless produce spurious resistance readings at any spacing (Barker 1979). Their extreme effect is to produce inverted 'V' anomalies across the pseudosection. The reason why the dipole-dipole array is more sensitive to geological noise is its more complex response to any sub-surface structure.

In order to remove geometrical effects from the pseudosection and produce an image of true depth and true formation resistivity, the observed data must undergo a form of processing known as inversion. The inversion technique recently described by Loke and Barker (1995a,b) appears to be a powerful and effective means of processing pseudosection data to provide a contoured image of true depth and true formation resistivity. It uses a sensitivity matrix of coefficients based on the signal contribution section (Barker 1979) to form the first model. Then, using a finite difference forward modelling algorithm modified from Dey and Morrison (1979), an iterative least squares optimisation technique is applied; an acceptable model is normally arrived at within 5 iterations and the whole process can be carried out in the field on a modern colour notebook computer in less than a couple of minutes.

3.0 FIELD SURVEYS

Electrical imaging technique was applied in Dindigul Town and its surrounding area (Fig. 3). The groundwater system in this area was contaminated due to untreated tannery effluents from 85 tanneries. Nearly 100 km^2 area of agricultural land was affected by the tannery pollution. The present study was to delineate the pollutant zone through electrical imaging method. In the Dindigul surveys a manual imaging system was employed in place of the computer controlled system. A single cable with 25 takeouts at 5m intervals was used together with a simple manual switchbox. In order to speed up the surveys and reduce the number of required measurements, all surveys were done using the Wenner array. The cable and switchbox were connected to SSR MPL resistance meter, manufactured in India by IGIS Ltd. Electrodes were 0.5 metre lengths of stainless steel, which were planted to a depth of 0.4 m. Each electrode was watered to ensure good contact with the ground.

Although data collection was a bit tedious, it did not take much more time than when the same data are collected under computer control, although mistakes were frequently made due to lapses in attention! The resistance meter worked well and managed to measure almost 2000 resistance values in four days!

A total of ten image lines were measured with the images varying in length from 120m to 300m in length. This effectively gave a maximum depth of imaging of 20m.

Two main applications of the technique were investigated – its application in siting boreholes in shallow basement areas, and its application in the study of pollution from the leather tanneries close to Dindigul. A summary of the lines and their locations are given in the following table.

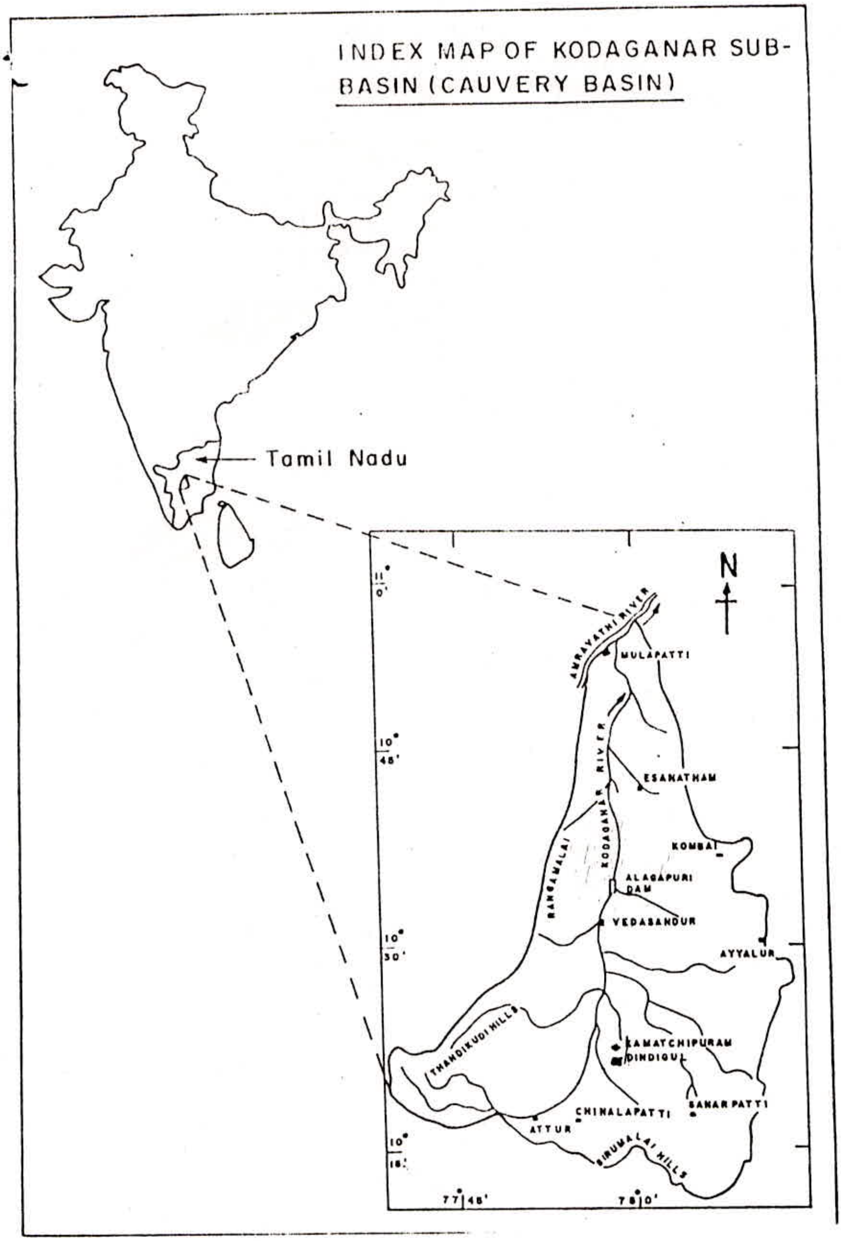

Fig. 3 : Index Map Kodaganar Sub-Basin (Cauvery Basin)

LINE	DATA-FILE	LOCATION	LENGTH m	PURPOSE
Line 1	India1n.dat	Kothapatty	210	Contamination
Line 2	India2n.dat	Ponnimandurai	165	Contamination
Line 3	India3n.dat	Kulaindaipatty	300	Bedrock
Line 4	India4n.dat	Mathinipatty	165	Bedrock
Line 5	India5n.dat	Uirudalaipatty	110	Bedrock
Line 6	India6n.dat	Rajagoundenoor	165	Bedrock
Line 7	India7n.dat	Giriyappa Naiyaknoor	320	Bedrock
Line 8	India8n.dat	Kothapatty	210	Contamination
Line 9	India9n.dat	Pudhupatty Tank	120	Contamination
Line 10	India10n.dat	Kothapatty Tank	120	Contamination

4.0 INVESTIGATION OF CONTAMINATED GROUNDWATER

Five images were measured close to Dindigul in around the leather tanneries in an attempt to provide further information on the extent of groundwater contamination due to the leather tanneries. Such imaging is difficult to interpret as the resistivity of the weathered overburden may vary in response to the following factors:

- degree of weathering
- saturation
- presence of contaminated groundwater.

Surveys in the shallow basement areas suggest that the regolith be characterised by resistivities in the range 50 to 200Ωm. In the region of the leather tanneries the regolith is thought to be much thicker and may be as much as 100m in thickness. In this case the resistivity of shallow regolith might be expected to have weathered to a greater degree and therefore exhibit a resistivity of slightly less than 50Ωm. If it is assumed that the water table is not far below the surface and that the regolith is largely saturated, any resistivities much below 25Ωm might well indicate groundwater contamination.

Line 1 The first line was measured across fairly dry fields at Kothapatty (Fig. 4). The image shows that the top 12 to 15 metres of regolith has resistivity of less than 10Ωm with the top 5m having a resistivity of less than 4Ωm. Therefore it appears that here the soil is strongly contaminated.

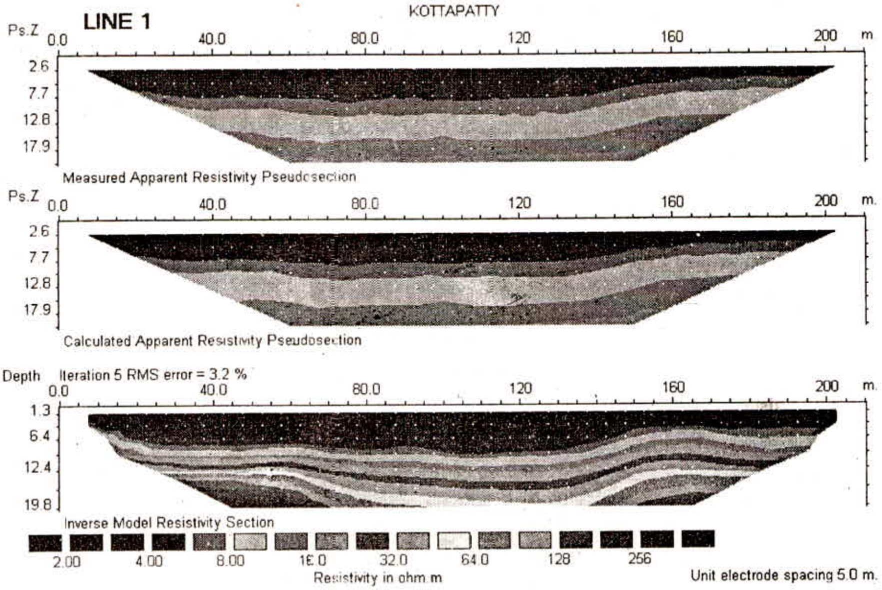

Fig. 4 : Electrical image along Line 1, Kothapatty.

Line 2 An image line was measured near Ponnimandurai, across an area where resistivity soundings had previously been measured and where the villagers claimed groundwater contamination. Here (Fig. 5) there is little indication of strong contamination as the resistivity of much of the subsurface falls within the range expected for uncontaminated ground, i.e. greater than 50Ωm. However towards the right end of the line the surface resistivity falls to just less than 25Ωm and could indicate a slight contamination. However, it is also possible that the low resistivity is just a reflection of the irrigation and clay on the paddy fields, and that contamination in this area has migrated at depth from elsewhere.

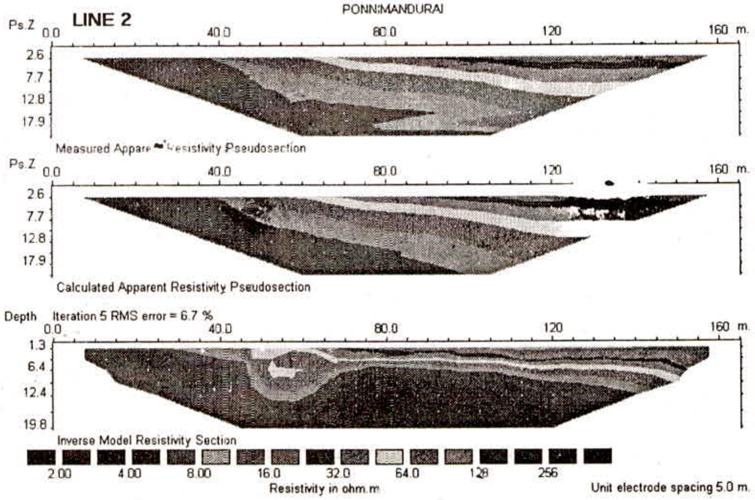

Fig. 5. Electrical image along Line 2, Ponnimandurai.

Line 8 Three lines were measured fairly close to each other near Kothapatty Tank This first one was measured across a variety of fields some of which were being irrigated from dug well half way along the line. Here (Fig. 6) there are signs of contamination as the resistivity of the regolith drops to less than 25Ωm over much of the line. Bedrock appears to be relatively shallow with high resistivities of more than 200Ωm being encountered at depths of 15 to 20m.

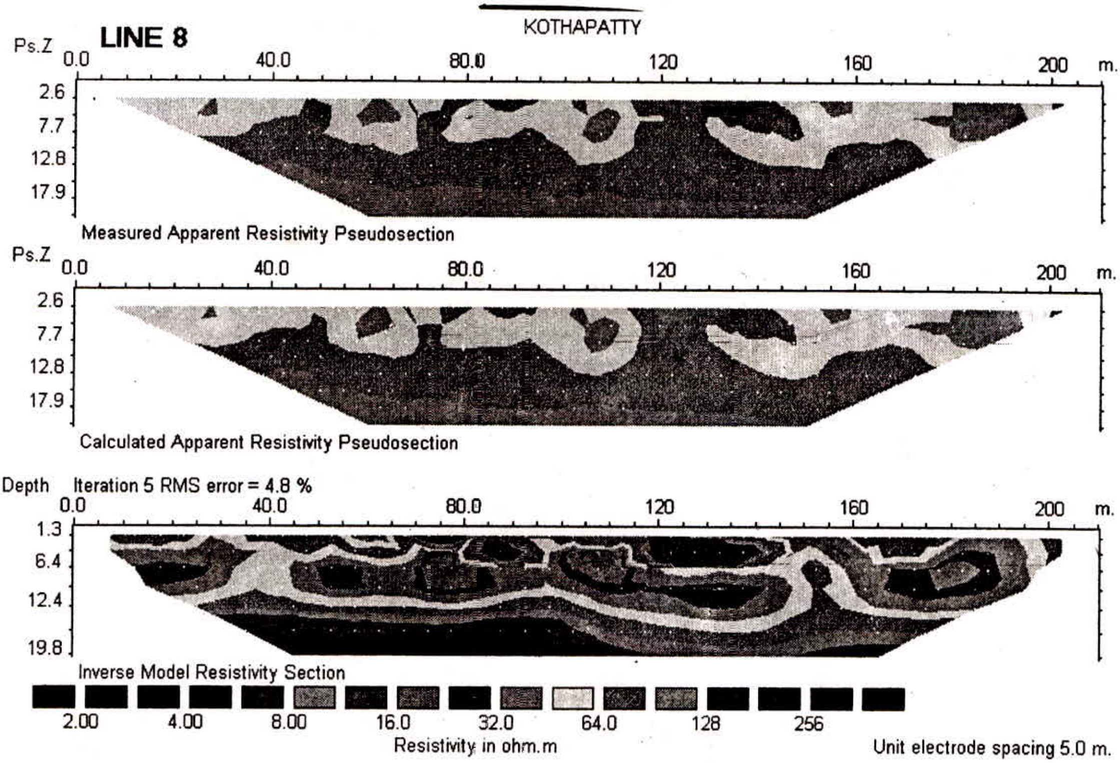

Fig. 6. Electrical image along Line 8, Kothapatty.

Line 9 This image (Fig. 7) was measured directly on the base of the Pudhupatty Tank, a large holding reservoir into which polluted water form the tanneries used to be pumped. At the time of the survey the tank was dry and its surface appeared to comprise thin salty clay. Here the subsurface was characterised by low resistivities with values of less than 10Ωm being seen at the surface and values of less than 50Ωm being apparent down to depths of 15m or more.

Line 10 This line is almost a continuation of Line 9 but into the adjacent overflow Kothapatty Tank. As this area would not have been inundated with contaminated water as frequently as the Pudhupatty Tank, the extent of subsurface contamination was not expected to be as great. And indeed this is what is seen. The low resistivity at the surface (Fig. 8) reflects the presence of a thin layer of surface clay. However, the resistivity increases rapidly with depth suggesting that contaminated water has not affected the subsurface to the extent seen in the adjacent tank.

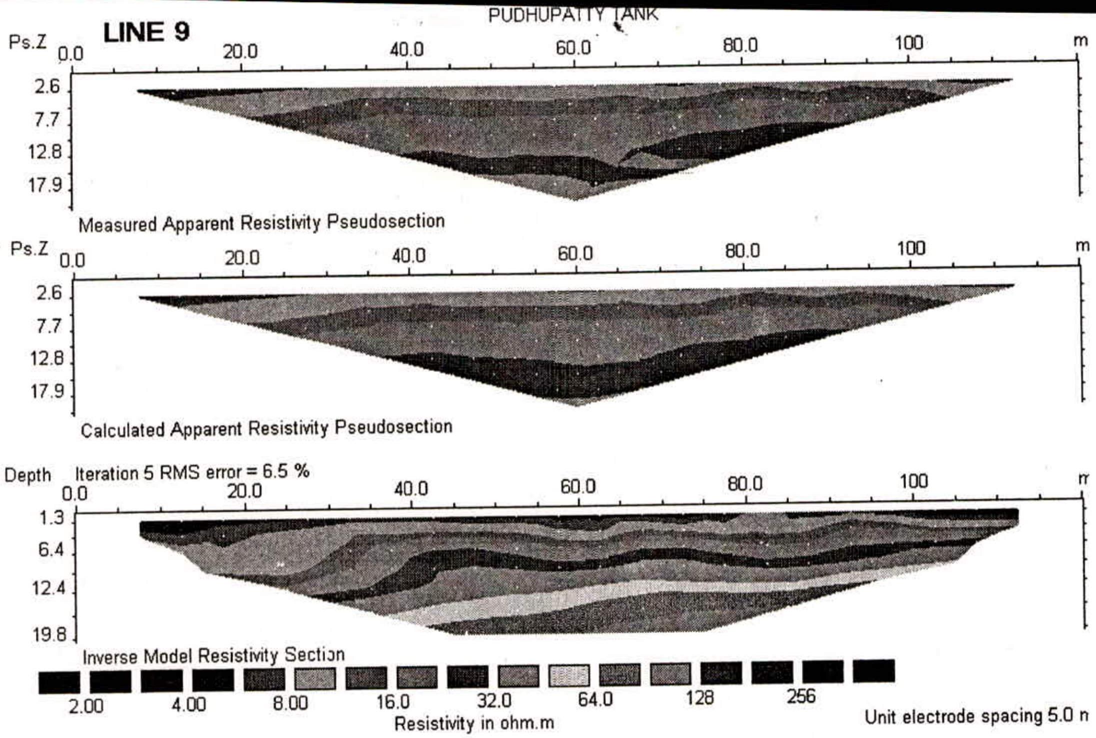

Fig. 7. Electrical image along Line 9, Pudhupatty Tank.

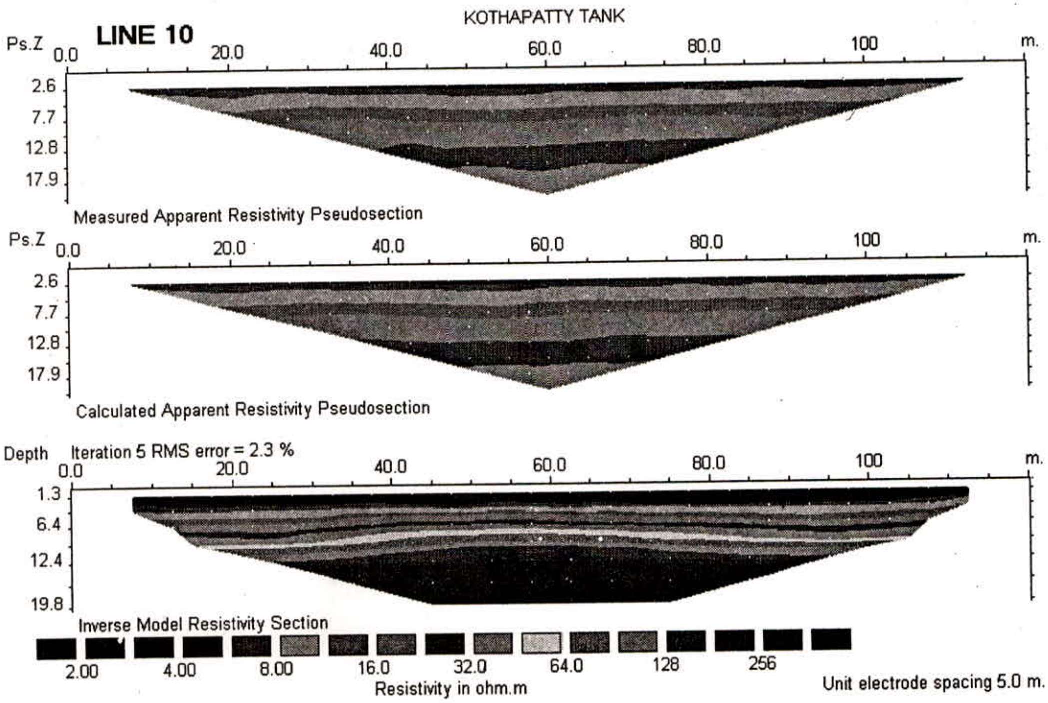

Fig. 8. Electrical image along Line 10, Kothapatty Tank.

5.0 CONCLUSIONS

The imaging over the contaminated areas, although providing interesting information, can only be interpreted qualitatively. As discussed above, the interpretations are ambiguous and can only be improved with other control information from boreholes or chemical sampling. None of the five images measured across the contaminated sites show any strong lateral change in resistivity and it must be admitted that similar information could be obtained with resistivity sounding. A scattering of soundings over the area woald quick indicate where low resistivity regolith and heavy contamination was likely.

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