FORTRAN code to convert resistivity Vertical Electrical Sounding data to RES2DINV format

R. Rajesh* and R.K.Tiwari

CSIR-NGRI, Hyderabad, India,

* Corresponding Author: rekapalli@gmail.com

ABSTRACT

We present the conversion of multiple vertical electrical resistivity sounding data measured at equal intervals along a profile into '*.DAT' 2D data file, which is compatible with Res2D.INV to obtain 2D resistivity inverse model. For this, we have developed a FORTRAN code. We applied the code on real time resistivity sounding data acquired using Dipole-Dipole array and obtained the 2D data file. Finally, we have inverted the converted 2D data using Res2D.INV program to obtain the 2D resistivity subsurface model. Thus, the code helps to generate the 2D resistivity model of the subsurface from sounding data obtained using four electrode setup (Wenner, Dipole-Dipole, Schlumberger arrays), where the usage of advanced equipment and financial supports are limited, to provide two dimensional interpretation on groundwater resources, soil pollution etc. The conversion and analysis of available past resistivity data helps to study the time-lapse resistivity changes through the comparison of present data within the limits of data errors and resolutions. The weathered water bearing zone and fractures identified on the 2D resistivity inverse model obtained from the converted 1D sounding data from Boneikela village, Sundargarh district, Orissa clearly matches with regional hydrogeology.

Key words: Vertical Electrical Sounding, Res2D.INV, 2D inverse model, FORTRAN code, Groundwater, Time lapse resistivity.

INTRODUCTION

Electrical resistivity tomography is a non-invasive geophysical technique, which researchers have been practicing rigorously for the investigations of groundwater, environmental pollution, and site characterization (Loke et al., 2013), since past five decades. Although the researchers have been employing advanced multi electrode systems to carryout 2D, 3D and 4D resistivity studies, the basic electrode configurations used in the data acquisition are the same conventional arrays commonly used for vertical electrical sounding (VES) and profiling techniques (Griffiths and Barker 1993; Loke and Barker, 1996; Dahlin, 2001; Loke, 2010; Loke et al., 2013). However, the quality of data acquired using such automatic multi electrode systems is adequate because of the stacking procedure employed in the acquisition (Loke et al., 2013). In view of the cost involved in the purchase, maintenance and depth of investigation limitations of high-resolution electrical resistivity data acquisition systems, researchers are still using the conventional four-electrode operation for ground water mapping, bed rock detection, pollution studies etc., where the input of economic resources is limited.

Hence, the main objective of this study is to present a FORTRAN code that coverts the sounding data to '*.DAT' file, compatible with Res2D.INV (Loke, 2010) inversion software. Since the 2D resistivity imaging is a robust geophysical tool, the conversion of multiple VES data acquired along a profile with fixed traverse interval will help the research community, where the availability of the economic resources is limited. Apart from this, the research organizations and academic institutions have acquired sounding /profiling data since late seventies. Archiving such an enormous data has become difficult and time consuming. Therefore, the proper conversion of such large amount of sounding /profiling data into a format in which it can be processed using advanced resistivity tomography software (Res2D.Inv) will help to obtain the resistivity inverse model from the available past data. This also helps to compare the 2D cross section obtained from the data acquired now with the 2D cross sections obtained from the converted data to assess the temporal variations in the subsurface resistivity. This enhances precision of data interpretation as well as facilitates to study the time-lapse resistivity imaging up to decadal scales. We present an example of format conversion of VES data acquired using Dipole-Dipole array to '*.DAT' along with its inverse 2D resistivity model.

Development and application of FORTRAN code

Following the file format information provided by Loke (2010), the following FORTRAN code is developed and presented to covert the multiple sounding data acquired using Wenner, Dipole-Dipole (Inline) and Schlumberger electrode arrays into '*. DAT' file.

Table 1. Sample input data file of Dipole –Dipole.

Location % Name of the Survey File or area%			
Array type	Center location(m)	na (m)	Apparent Resistivity (ohm-m)
Dipole-Dipole	0	10	223.8359 |First data point
Dipole-Dipole	0	20	219.2669
Dipole-Dipole	0	30	200.4101
-	-	-	-
-	-	-	-
Dipole-Dipole	240	110	1434.010 |Last data point

Code:

```
!*PROGRAM TO COVERT SOUNDING DATA TO 2D
RESISTIVITY DATA FILE *!
!-------------------------------------------------------------------------!
     IMPLICIT NONE
     REAL::A,X,R,L,LN,N1,N2,LT
CHARACTER :: HEAD
CHARACTER(Len = 20) :: FNI,FNO,LOC
INTEGER :: I,N,SP,SPN, AT
!-------------------------------------------------------------------------!
WRITE(*,*) 'ENTER INPUT FILE NAME (CASE
SENSITIVE):'
READ(*,*) FNI
WRITE(*,*) 'ENTER OUTPUT FILE NAME:'
READ(*,*) FNO
WRITE(*,*)'For Wenner=1;Dipole-
Dipole=3,Schlumberger=7'
WRITE(*,*)'ENTER ARRAY TYPE:'
READ(*,*) AT
WRITE(*,*) 'ENTER NO OF DATA POINTS:'
READ(*,*) N
WRITE(*,*) 'ENTER MINIMUM SPACING:'
READ(*,*) A
     OPEN (1,FILE=FNI,STATUS='OLD')
OPEN(2,FILE=FNO,STATUS='NEW')
READ(1,'(A)') LOC
WRITE(2,*) LOC
READ(1,'(A)') HEAD
WRITE(2,*) A
WRITE(2,*) AT
WRITE(2,*) N
WRITE(2,*) '1'
WRITE(2,*) '0'
     SP=0
     N2=0
     DO 10 I=1,N
       READ (1,*) LT,LN,X,R
       N1=X/A
       IF (N1.LT.N2) THEN
        SP=SP+1
       ENDIF
       L=SP*A
       N2=N1
      IF (AT.EQ.1) THEN
WRITE(2,*) L,A,R
      ENDIF
      IF (AT.GT.1) THEN
WRITE(2,*) L,A,N2,R
      ENDIF
 10 CONTINUE
WRITE(2,*) '0'
WRITE(2,*) '0'
WRITE(2,*) '0'
CLOSE(1)
CLOSE(2)
     END
!-------------------------------------------------------------------------!
```

Vertical Electrical Sounding data from Boneikela village, Sundargarh district, Orissa acquired using Dipole-Dipole array configuration are saved as a text file in the prescribed format as shown in the Table 1.

The first column of the file is 'Array type', second column is 'x co-ordinate of the array center ', third column is the 'dipole separation factor (n)', and the last column is the apparent resistivity value. Table 1 depicts an example of input file format.

When we run the FORTRAN code, it takes the user input parameter like input file name, output file name, array type (1 for Wenner, 3 for Dipole Dipole, 7 for Schlumberger), number of data points, and minimum electrode separation (a). The successful execution of the program converts the VES data into the 2D file in format as shown bellow and writes to the output file with the given output file name. A sample output of the program is given bellow.

Output file format

```
Location | Location or survey file name
10.0000 | Minimum electrode separation 'a'
3       | Type of the electrode array (1 for Wenner, 3
              for Dipole Dipole, 7 for Schlumberger)
275     | Total number of data points
```
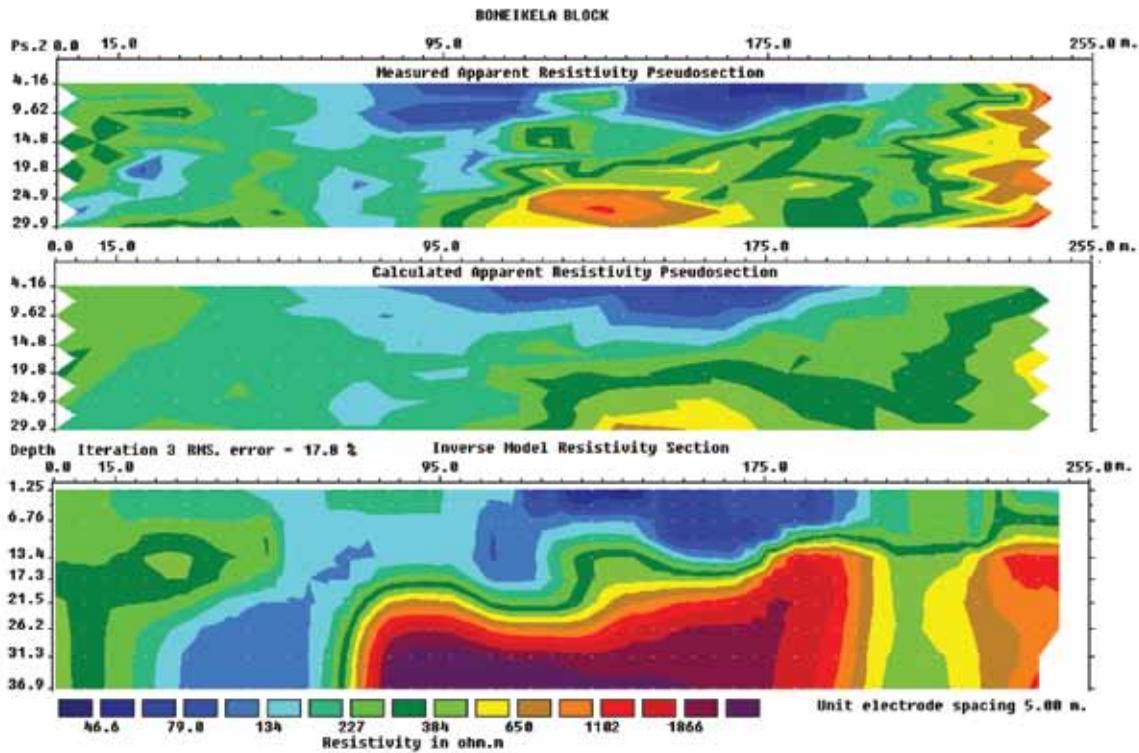
Figure 1. Dipole-Dipole 2D cross section image obtained from the converted data of multiple soundings from the Boneikela village, Sundargarh district, Orissa.

```
1          | 1 Formidpointlocation; 0 for starting electrode
             location
0          | 0 For apparent resistivity data

0.00000 10.0000  1.00000  223.836  |First data point
                                    (x location,
0.00000 10.0000  2.00000  219.267  |minimum
                                     electrode
                                     separation (a),
0.00000 10.0000  3.00000  200.410  |n and apparent
                                     resistivity)
0.00000 10.0000  4.00000  269.916
0.00000 10.0000  5.00000  334.812
-
-
240.000 10.0000 10.0000  1081.10
240.000 10.0000 11.0000  1434.01  |Last data point
0                                 |Three zeros
                                   indicating enf of
                                   file
0
```

The output file was processed using Res2D.INV software (trail version) to get the 2D resistivity model of the subsurface. The processed output of least square inversion after 3 iterations is shown in Figure 1. The model refinement (a=5m) is used in the processing to reduce the misfit due to huge resistivity variation near the shallow depth. Although the output has shown 17.8 RMS error, processing the data using Res2D.INV software full version with statistical filtering and more iterations will reduces the error.

The groundwater availability varies from place to place depending upon nature of broad category of hydrological units like consolidated, semi consolidated and unconsolidated formations with high heterogeneity in character, showing both vertical and lateral variations in Sundargarh district, Orissa (CGWB Repot, 2013). Highly weathered mica schist, highly jointed and well foliated carbonaceous phyllites, highly jointed metabasic rocks (Amphibolites), Lime stone, Dolomite, Granite, Granite gneiss, Quartzites are the major water bearing litho units within 4 to 18m depth. The recharge occurs mainly in the secondary porosity resulting from weathering and fracturing of the rocks in the consolidated formations comprising Precambrian metasediments of Gangpur series and Iron ore series and also granite gneiss, metasediments like amphibolite, epidiorite. CGWB report (2013) clearly indicated two to four water bearing fracture zones down to a depth of 100 m bgl. The sand stone, shales, conglomerates, grits belonging to Talcher, Barakar and Kamthis of lower Gondwana are the semi consolidated formations in this region. Among them the Barakar formations are the potential aquifer rocks in the area with water level depth varying between 7 to 18m (CGWB report, 2013).

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Laterites and alluvium of Sub-recent to Recent age form the unconsolidated formations in this region. Laterites occurring as capping over older formations are highly porous in nature and form good aquifers to be tapped through dug wells. The limited alluvial deposit strips of recent origin along the prominent drainage channels are also the potential aquifers of unconfined to semi-confined condition. The shallow low resistivity zone between spatial location 100 to 200m and depth range 4to 14m is the water bearing weathered formation (Bottom panel of Figure 1). We can also notice a high resistive rock formation beyond 14m with a fracture around spatial location at 45m.

CONCLUSION

We present a FORTRAN code to convert multiple vertical electrical sounding data recorded along a profile into '*.DAT' file. The conversion allows us to process the data in Res2D.INV to generate inverse resistivity model of the subsurface. The code developed here helps the research community to generate the 2D resistivity model cross section images for the 2D interpretation of ground water, environmental pollution, bedrock studies etc., from sounding (Deep resistivity sounding) data, where the operational cost and advanced instrumentation facilities are limited. The conversion of the past sounding data that is available from late seventies will allow estimating the temporal variability (even up to decadal scales) by comparing with the present data. We have clearly identified the weathered aquifer zone within 4m to 13m depth in the 2D section of selected example data from Boneikela village, Sundargarh district, Orissa. The deep fracture in the high

resistive rock formation is also clearly visible in the 2D section. The aquifer identified in the 2D section obtained from the multiple 1D soundings using the code is agreeing well with regional geology of the study area.

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REFERENCES

Dahlin, T., 2001. The development of DC resistivity imaging techniques. Computers & Geosciences, v.27, no.9, pp: 1019-1029.

Griffiths, D.H., and Barker, R.D., 1993. Two-dimensional resistivity imaging and modelling in areas of complex geology. Journal of Applied Geophysics, v.29, no.3, pp: 211-226.

Loke, M.H., and Barker, R.D., 1996. Rapid least-squares inversion of apparent resistivity pseudosections by a quasi-Newton method. Geophysical prospecting, v.44, no.1, pp: 131-152.

Loke, M.H., 2010. Res2DInv ver. 3.59.102 Geoelectrical imaging 2D and 3D.Instruction manual.Geotomo Software. www. geoelectrical. com.

Loke, M.H., Chambers, J.E., Rucker, D.F., Kuras, O., and Wilkinson, P.B., 2013. Recent developments in the direct-current geoelectrical imaging method. Journal of Applied Geophysics, v.95, pp: 135-156.

CGWB Report, 2013, Central Ground Water Board, South Eastern Region, Bhubaneswar.