RES2DMOD ver. 3.01

Rapid 2D resistivity forward modelling using the finite-difference and finite-element methods

Wenner (alpha, beta, gamma), inline & equatorial dipole-dipole, pole-pole, pole-dipole and Wenner-Schlumberger

by

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1 Introduction

RES2DMOD is a free 2D forward modelling program that calculates the apparent resistivity pseudosection for a user defined 2D subsurface model. It is largely intended for teaching undergraduates and postgraduate students about the use of the 2D electrical imaging method. The program might also assist the user in choosing the appropriate array for different geological situations or surveys.

The arrays supported by this program are the Wenner (Alpha, Beta and Gamma configurations), pole-pole, gradient, inline dipole-dipole, pole-dipole and equatorial dipole-dipole (Edwards 1977). Each type of array has its advantages and disadvantages. This program will hopefully help you in choosing the "best" array for a particular survey area after carefully balancing such factors as the cost, depth of investigation (or equivalent depth), resolution and practicality.

The following figure shows an overhead view of the arrangement of the electrodes for the different arrays.
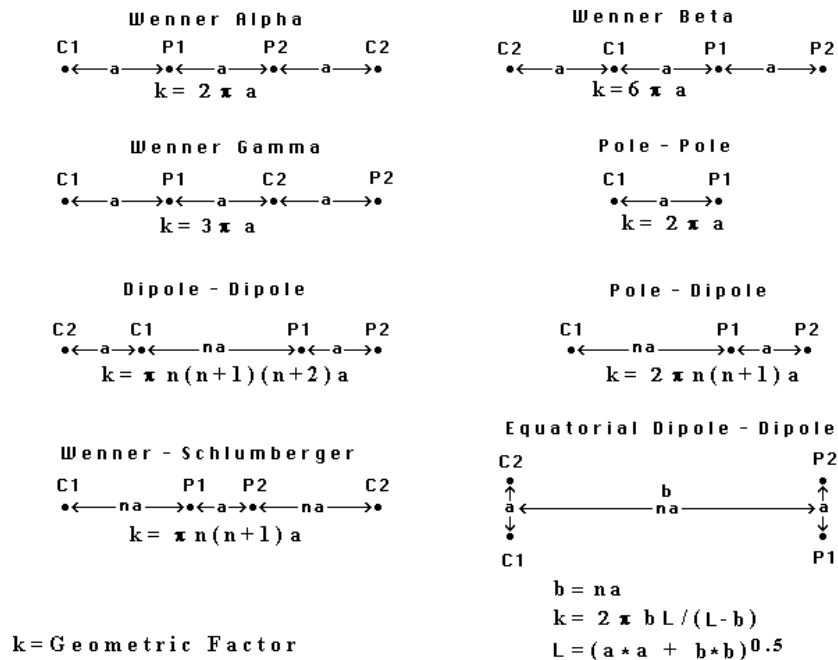

Figure 1 Arrangement of the electrodes for different arrays.

You can use a model with a maximum of 151 electrodes (with 2 nodes per unit electrode spacing) or 75 electrodes (with 4 nodes per unit electrode spacing). This limit is set by the resolution of the computer graphics display.

2 Computer System Requirements

RES2DMOD is a 32-bit Windows based program that will run under Windows 95/98/Me/2000/NT. You will need a Pentium, Pentium Pro, Pentium II, Pentium III, or Pentium 4 (or compatible) based microcomputer to run this program. The minimum amount of RAM is 32 megabytes, but 64 megabytes is recommended! You will also need about 128 megabytes of free hard-disk space that the program can use to store temporary swap files. If you have more than one hard-disk drive, the program will automatically select the drive with the largest amount of free space as the drive to store the swap files. This is a 32-bit Windows program that can access up to 4 gigabytes of memory.

It is also recommended that you use the 800 by 600 (for 14 and 15 inch monitors), or the 1024 by 768 (for 17 inch monitors), or the 1280 by 1024 (for 21 inch monitors) with 256 colours SVGA graphics mode. If you are using the SuperVGA modes with 16-bit or 24-bit colours, you should switch the display mode to 256 (i.e. 8-bit) colours using the Display option in the Control Panel folder in Windows 95/98/NT if you encounter problems. Graphics operations with the 256 colours mode will be faster, and more memory will be available to your programs.

The RES2DMOD package comes in a single compressed installation file SETUP.EXE. It is a Windows based installation program that will install the program files. In Windows 95/98/ NT, click Start, and then Settings followed by Control Panel. Then click the icon to Add/Remove programs. After that, navigate to the subdirectory where the SETUP.EXE file is located.

3   Freeware

This program is released as freeware. However, I am not liable for any problems or possible damages arising from the use of this program. If you find this program useful, please send an email to me at mhloke@pc.jaring.my. I will try to fix bugs, and provide more features in future versions, but that will depend on my free time.

4 Theory

The 2-D model used by the finite-difference or finite-element method divides the subsurface into a number of blocks using a rectangular mesh (Figure 2). Some improvements were made to the Dey and Morrison (1979) finite-difference formulation to improve the accuracy of the calculated apparent resistivity values (Loke 1994). The finite-difference method basically determines the potential at the nodes of the rectangular mesh that consists of L nodes in the horizontal direction and M nodes in the horizontal direction.
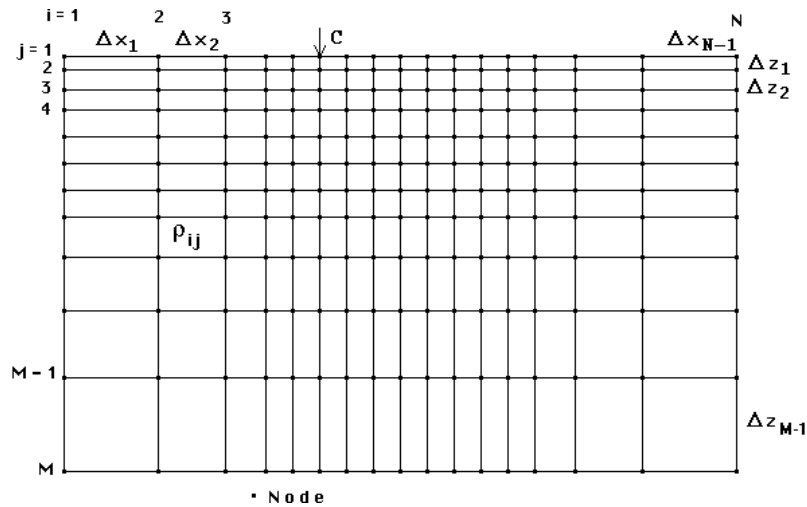

Figure 2 Schematic diagram of the finite-difference or finite-element mesh used by the program.

Note that the grid model has L-1 columns and M-1 rows of rectangular blocks. The blocks can have different resistivity values. By using a sufficiently fine mesh, complex geological structures can be modelled. The program uses a mesh with two or four horizontal nodes per unit electrode spacing for a multi-electrode array (Figure 3).

The program requires you to supply the resistivity values of the rectangular blocks in between the mesh lines (and other information) using an input data file. The format of the input data file is described in section 5. In general, you should try to use "reasonable" model resistivity values that are not too small or too large.

The first electrode is placed at the 12th horizontal node from the left edge of the mesh. Similarly there are 12 nodes between the last electrode and the right edge of

the mesh. Table 1 shows the vertical depths and horizontal offsets of the mesh lines for an electrode spacing of 1 meter for the default model used by this program. Note this example has 4 vertical mesh lines between adjacent electrodes.

You can also set your own depths for the mesh lines. If you choose to set the depths of the grid lines, use a smaller vertical spacing (Δz_j in Figure 1) between adjacent horizontal mesh lines near the surface and larger spacings for the deeper mesh lines to ensure that the results will be sufficiently accurate. In particular, the vertical spacings between the top 3 horizontal mesh lines should not be greater than the horizontal spacings between adjacent vertical mesh lines. The files FAULT.MOD and MODEL41.MOD are example model files with user defined depths for the mesh lines.

If this is the first time you are using the program, try reading in the example model data file TIXALL.MOD provided with the program using the "File" option in the Main Menu. Then select the "Model Computation" option to calculate the apparent resistivity values for this model. After that, use the "Edit/Display" option to take a look at the 2-D model and the apparent resistivity pseudosection. In the following sections, a more detailed description of each item in the above menu is given.
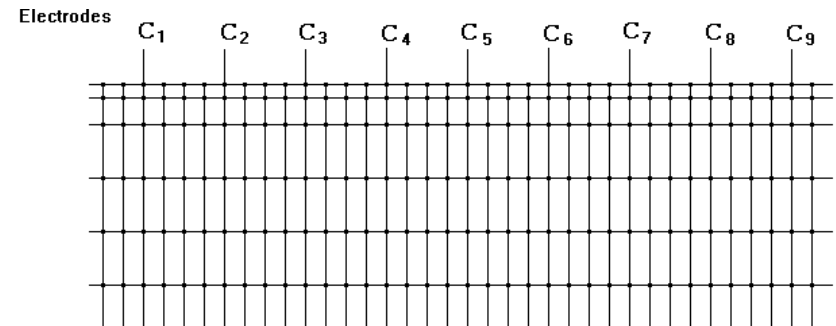

Figure 3 Part of the finite-difference or finite-element mesh showing the location of the electrodes.

Table 1 : Locations and spacings between the nodes in the 2-D finite-difference grid model using a predefined set of depths for the horizontal mesh lines. The first electrode on the surface is located at the 12th horizontal node. Subsequent electrodes are placed at 4 horizontal nodes apart. The electrode spacing is 1 metre. The horizontal spacings between the last 11 nodes after the last electrode are the same as that for the first 12 nodes (except in reverse order).

Index	Horizontal Location	Node Spacing	Index	Vertical Depth	Node Spacing
i	x_i	dx_i	j	z_j	dz_j
1	0.00	64.0	1	0.25	0.25
2	64.00	32.0	2	0.50	0.25
3	96.00	16.0	3	0.75	0.25
4	112.00	8.0	4	1.00	0.25
5	120.00	4.0	5	1.55	0.55
6	124.00	2.0	6	2.16	0.61
7	126.00	1.0	7	2.82	0.67
8	127.00	0.50	8	3.55	0.73
9	127.50	0.50	9	4.36	0.81
10	127.75	0.25	10	5.24	0.89
11	128.00	0.25	11	7.02	1.77
12	128.25	0.25	12	10.56	3.54
13	128.50	0.25	13	17.64	7.09
14	128.75	0.25	14	31.82	14.17
15	129.00	0.25	15	60.16	28.35
16	129.25	0.25	16	116.85	56.69
17	129.50	0.25	17	230.23	113.38

5   File operations

On clicking the 'File' option on the top Main Menu bar, the following submenu will be displayed.
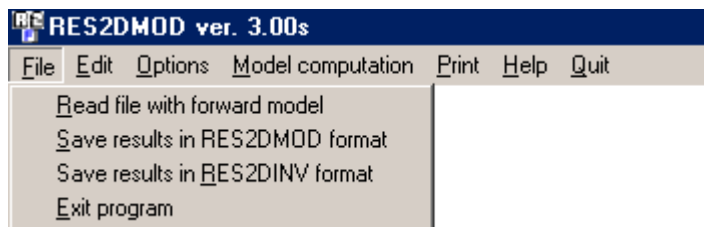
Read data file with forward model - In this option, you read in a model data file. When you select this option, the list of files in the current directory (or the last subdirectory from which you read in a model file) which has an extension of .MOD will be displayed.

The program requires the resistivity model values to be typed in separately in a text file. For an example of the input data format, you should make a printout the MODEL41.MOD data file. The parameters for the finite-difference model are arranged in the following format.

Line 1 - Name of model

Line 2 - Number of electrodes (Maximum of 101)

Line 3 - Number of pseudosection data levels (Absolute maximum of 32 but also depends on the type of array and the number of electrodes).

Line 4 - Flag for underwater survey. Enter 0 for now.

Line 5 - Unit (or smallest) electrode spacing

Line 6 - Flag for type of grid model. Enter 0 or 1 for a grid model with the default depths for the mesh lines. Enter 2 for user defined depths for the mesh lines (see the file MODEL41.MOD). The file MODEL25.MOD gives an example of a model file which uses the default (option 0) depth values given in Table 1. If option 1 is used, the depths are scaled according to the depth of investigation of the array used.

Line 7   - Offset of first block in user-defined model section from the first electrode. Normally enter 0 to avoid problems.

Line 8 - Number of blocks in user-defined model. To avoid problems, use a value of (Number of electrodes - 1) * Number of nodes/unit electrode spacing which will cover all the blocks between the first and last electrode.

Line 9 - Number of resistivity values in the model (maximum of 16)

Line 10 - Number of nodes per unit electrode spacing (2 or 4). You can use a value of 4 for up to a maximum of 75 electrodes.

Line 11 - The model resistivity values.

Line 12 - Number of rows of rectangular blocks in the model (maximum of 29). Note that the number of vertical mesh lines is equals to the number of rows of blocks plus one.

Line 13 - The depth to the horizontal grid mesh line.

Lines 14 to 27 - The resistivity of the model blocks are given row by row. A number "0" means the block has the first resistivity value, "1" for the second resistivity value and so on. For the 11th to the 16th resistivity values, use the letters "A" to "F".

Lines 28 - Type of array. 1 for Wenner, 2 for two-pole, 3 for dipole-dipole, 4 for Wenner Beta, 5 for Wenner Gamma, 6 for inline pole-pole, 7 for Wenner-Schlumberger and 8 for equatorial dipole-dipole array. For the equatorial dipole-dipole array, you will also need to enter the separation between the current electrode pair. It is assumed that the potential electrode pair will have the same separation. Please refer to the file MODELEQ.MOD for an example of this array format.

Lines 29 and 30 - Enter 0 for both. These are flags for calculated apparent resistivity and potential values which are used for the output data file produced by this program.

Lines 31, 32 and 33 - Enter 0 for now. They are reserved for possible new features in future versions of this program.

Note that you only have to set the resistivities for a limited section of finite-difference grid model. The program assumes that the resistivity of the blocks to the left side of the first electrode is the same as that of the first model block for which you have set the resistivity value. Similarly the resistivity of the blocks on the right side are set to be the same as that of the last block of the rightmost column in the user-defined model section. Normally it would probably be most convenient to set the resistivities of all the blocks between the first and last electrode of the multi-electrode array. In this case, the offset of the first block in your model from the first electrode is 0 (data for line 7 above). If the total number of electrodes is E and the number of nodes per unit electrode spacing is n, then the number of blocks between the first and last electrode is (E-1)*n. For an example, see the data file MODEL25.MOD.

As an example of model file where the depths to the mesh levels are specified, the upper part of the FAULT.MOD file with comments are given as follows.

Data in FAULT.MOD file	Comments
Fault and block model	Title
51	51 electrodes in line
15	15 data levels
0	Normal land survey, i.e. not underwater
1.0	Unit electrode spacing
2	2 for user defined mesh lines depths
0	Offset of first block form first electrode
200	Total number of blocks in user model
3	Indicates three model resistivity values
4	Four nodes between adjacent electrodes
10.0,50.0,100.0	The model resistivity values
14	Fourteen rows of model blocks
0.2500,0.5000,0.8125,1.1875,	The depth to the base of each row starting from the
1.6875,2.3125,3.1875,4.4375,	top. Note the smaller distance between the top
6.4375,10.4375,18.4375,34.4375,	two mesh lines, and the large spacings near the
66.4375,130.4375	bottom
0000000000000000000000000000000	The usual model codes start here

The file LANDFILL.MOD gives an example of an input model file which also contains measured apparent resistivity values from a field survey. The required information is placed in after the value for the type of array. Below is part of this model file with comment about the format of the data (the format is similar to that used by the RES2DINV inversion program).

Data in LANDFILL.MOD	Comments
9999999999999999999999999	Last part of
9999999999999999999999999	model codes.
1	Wenner array flag
0	Put 0's in these 2 lines. These are flags used by
0	RES2DMOD for the output file it produces.
2	Put 2 here for only measured app. resis. values.
334	Number of datum points
1	0 for location of first electrode, 1 for midpoint
0	Put zero here, will be used later for I.P. flag
4.50000, 3.00000, 84.90	The following lines give the field data, arranged
7.50000, 3.00000, 62.80	as x-location of datum point, electrode spacing,
10.50000, 3.00000, 49.20	apparent resistivity value. See manual for inversion
13.50000, 3.00000, 41.30	program for details. At the end of the file, put four 0's.

One common problem encountered in using this program is mistakes in the input data file. If the program stops with an error message it could be due to a mistake in the input data file. First check that the data in the file is arranged according to the format described above.

It is important that you do not edit the output files produced by the program. The program saves the apparent resistivity and potential values calculated in the 'Model Computation' option in its own format.

Save results in RES2DMOD format - In this suboption, you can save the apparent resistivity values into a file with the format used by the RES2DMOD program. Besides the model information, the apparent resistivity and potential values will be saved. By reading this file again, you can display the apparent resistivity values without having to recalculate the potentials.

Use RES2DINV format - This will save the apparent resistivity values into the format used by the RES2DINV inversion program. Note that you cannot read this output file with the RES2DMOD program since it is intended for the RES2DINV program.

6 Editing and displaying models

On selecting the 'Edit' option on the main menu bar, the following menu will be displayed.
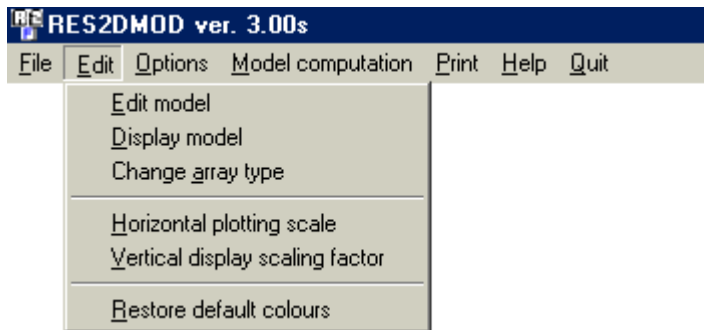
Edit model - Under this option, you can change the resistivity of the blocks in the model interactively using the mouse or keyboard. The individual rectangular blocks and the finite-difference grid together with the apparent resistivity pseudosection are displayed.

To change the resistivity of a single block, move the "+" shaped cursor with the mouse to the centre of the block. Then click the right mouse button. The colour of the block should change to white. After that move the cursor to one of the rectangular blocks in the legend just above the top left of model grid section. Press the left mouse button and the colour of the small rectangular block within the model should change to the colour you have chosen. You can change the resistivity of several blocks to the same resistivity value by first clicking them with the left mouse button, and then click the appropriate block on the legend. The following keys are also used :-

Left mouse button or "4" key - Change the resistivity of 4 blocks to the right of the cursor.

"D" key - Change the resistivity of a whole column of blocks downwards to the bottom edge of model.

"]" key - Change the resistivity of a whole row of blocks rightwards to the right edge of model.

"[" key - Change the resistivity of a whole row of blocks leftwards to the left edge of model.

"}" key - Change the resistivity of all the blocks to the right and below the cursor.

"{" key - Change the resistivity of all the blocks to the left and below the cursor.

After editing the model, use the "Model Computation" option in the Main Menu to calculate the apparent resistivity pseudosection. After the calculations are completed, you can use the "Edit/Display" option again to take a look at the apparent resistivity pseudosection as well as the model section. Figure 4 shows an example of a model with its apparent resistivity pseudosection.
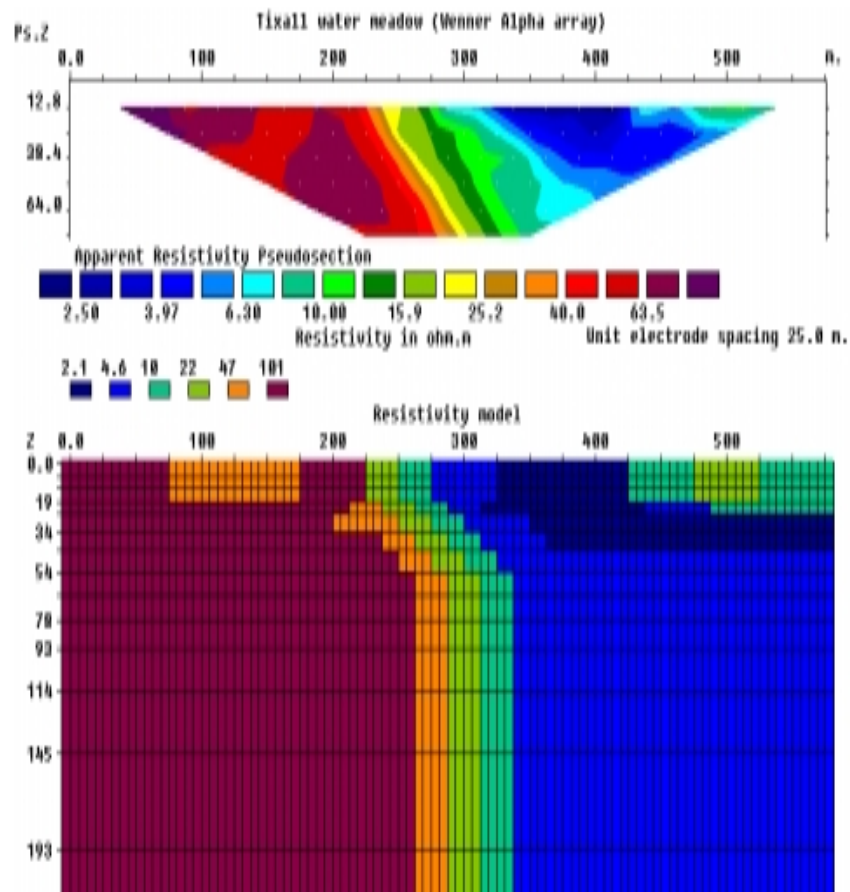
Figure 4. Model with apparent resistivity pseudosection.

<u>D</u>isplay model - Under this option, the model without the grid lines and the apparent resistivity pseudosection will be displayed.

Change <u>a</u>rray type – This option enables you to change the array type, as well as the number of 'a' spacings, and the 'n' values (for the pole-dipole, dipole-dipole and Wenner-Schlumberger arrays). On selecting this sub-option, the following dialog box will be shown.
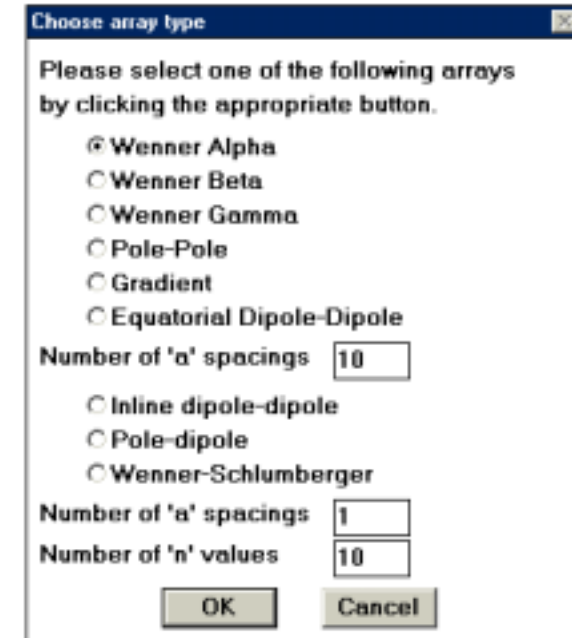
To change the array type, just click the button next to the appropriate array type. This is useful to investigate the effect of the type of array used on the shape of the anomalies in the apparent resistivity pseudosection. This will hopefully assist you in selecting the "best" array for a particular problem.To change the number of 'a' spacings or 'n' values, just type in the number needed inside the relevant box.

<u>H</u>orizontal plotting scale - This allows you to change the horizontal scale, in terms of number of pixels per unit electrode spacing. This option is useful when you want to plot the results from different survey lines with different numbers of electrodes, with the same scale.

<u>V</u>ertical display scaling factor - This option allows you to specify the ratio of the vertical scale to the horizontal scale, i.e. the vertical exaggeration factor, in the display. Convenient values to use are 2.0, 1.5 and 1.0. If you enter a value of 0.0, the program will use a default scaling factor so that the display can fit into the display screen.

<u>R</u>estore default colours - This will reset the colour scheme used for colouring the sections to a default system used by the program.

7 Options

In this option, you can change certain parameters which affects the calculation of the apparent resistivity values.
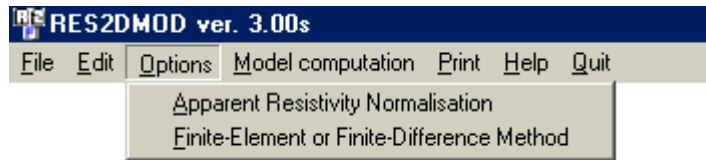
Apparent Resistivity Normalisation - If this option is enabled, the program will first calculate the potentials for a homogeneous earth model. These values will then be used as correction factors for the potentials calculated for the input model. In most cases, there will be a slight increase in the accuracy of the calculated apparent resistivity values.

Finite-Element or Finite-Difference Method - In this suboption, you can select the finite-element (Silvester and Ferrari, 1990) or finite-difference method which will be used to calculate the apparent resistivity values. The file MODEL2.MOD contains a comparison of the results obtained with the finite-difference and finite-element methods for a two-layer model. For most models, there is not much difference in the apparent resistivity values calculated by the two methods. However, some of the older finite-element implementations contain an interesting error whose effect shows up more prominently for certain arrays (see the lower section of the MODEL2.MOD file).

8 Model Computation

After making the necessary changes to your model, select this option to calculate the apparent resistivity values. The model section will be displayed when the calculations are being carried out. After calculating the apparent resistivity values, you can save the results in a disk file in a format that can be read by this program. If you read this file at a later time, it will not be necessary to recalculate the apparent resistivity values. With present day Pentium class and faster computers, the calculations probably takes less than a minute for most models.

9 Print

Besides displaying the pseudosections on the screen, you might make a printout of the model sections. On selecting the 'Print' option on the main menu bar, the following list of suboptions will be displayed.
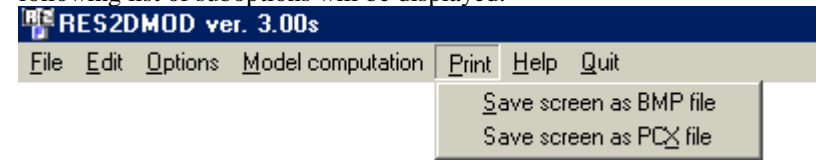
Saving the screen image into the form of a BMP or PCX graphics file allows you to edit the picture with a bit-mapped graphics program, such as the Windows PaintBrush program, before printing it. The graphics file can also be embedded into most word processor documents such as Microsoft Word for Windows.

10 Help

The following list will be displayed when this option is selected.
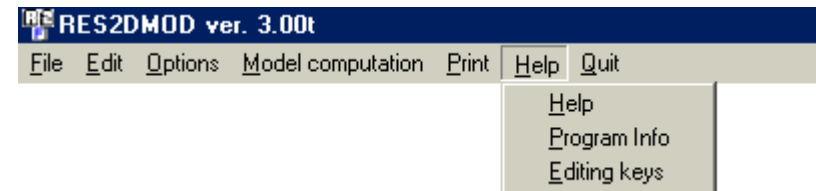
Help – This brings up the online Windows Help file.

Program Info – This displays some information about the program.

Editing keys – This displays the keyboard keys that can be used in the 'Edit' model mode.

12 Pitfalls

While this program will show you the apparent resistivity pseudosection for a given model and array, there are many other factors that should be considered before selecting an array for actual field measurements. One important factor is the potential that will be measured by the potential electrodes. All field instruments have a finite accuracy in measuring the potential caused by the input current used. This is further degraded by the presence of random noise. This is particularly an important factor for the inline dipole-dipole, equatorial dipole-dipole, pole-dipole and Schlumberger arrays. You can determine the potential by dividing the apparent resistivity value by the geometric factor (see Figure 1) for the array and multiply this by the current used. An interesting and common mistake, particularly in North America, is the use of the inline dipole-dipole array in many situation where it is not suitable (especially with "n" values exceeding 6). Please refer to Appendix A in the RES2DINV manual, or the free lecture notes "Electrical imaging surveys for environmental and engineering surveys" or the more technical tutorial notes on electrical imaging). You can download these documents from the www.geoelectrical.com web site.

Disclaimer

This software is provided "as is" without any express or implied warranties including its suitability for a particular purpose. Neither the author nor the distributor will assume responsibility for any damage or loss caused by the use of this program.

Since this is a free program, no warranties are given. I will be grateful for bug reports and every effort will be made to correct the bugs. If you wish to contact me, please send an email to mhloke@pc.jaring.my or geotomo@tm.net.my.

References

Dey, A. and Morrison, H.F., 1979, Resistivity modelling for arbitrary shaped two-dimensional structures. Geophysical Prospecting, 27, 1020-1036.

Edwards, L.S., 1977, A modified pseudosection for resistivity and induced-polarization. Geophysics, 42, 1020-1036.

Loke, M.H., 1994, The inversion of two-dimensional apparent resistivity data. unpubl. Ph.D. thesis, Un. of Birmingham (U.K.).

Loke, M.H. and Barker, R.D., 1995. Least-squares deconvolution of apparent resistivity pseudosections. Geophysics, **60**, 1682-1690.

McGillivray, P.R. and Oldenburg, D.W., 1990. Methods for calculating Frechet derivatives and sensitivities for the non-linear inverse problem : A comparative study. Geophysical Prospecting, **38**, 499-524.

Silvester P.P. and Ferrari R.L., 1990. Finite elements for electrical engineers (2nd. ed.) . Cambridge University Press.

Zhou, B. and Greenhalgh, S.A., 2000. Cross-hole resistivity tomography using different electrode configurations. Geophysical Prospecting, **48**, 887-912.
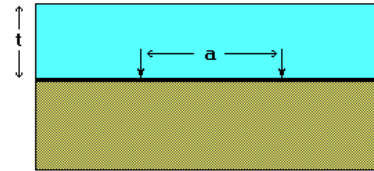
Appendix A : Underwater surveys
The following diagram shows the various possible situations for underwater resistivity surveys.
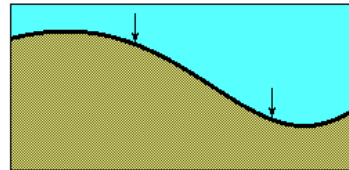
Underwater Electrodes

Case 1 : Water Layer with flat sediment surface
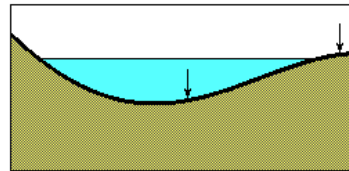
Geometric factor = $4\pi as/(a+s)$

$s = (a^2 + 4t^2)^{0.5}$

Case 2 : Water Layer with undulating sediment surface but with all electrodes below the water surface.

Case 3 : Survey across a channel with some of the electrodes above the water level.

The present program only supports the situation shown in Case 1 with a water layer of constant thickness over a flat sediment surface (although the inversion program RES2DINV supports all 3 cases). The file WATER.MOD is an example model data file with a water layer. The initial part of the file with format used is as follows :-

WATER.MOD file	Comments
Model with water layer	| Title
51,16	| 51 electrodes, 16 datum levels
1	| 1 to indicate water layer, normally 0
50.00,-100.00,200.00,-4.0	| Water resistivity, left limit of water layer,
	| right limit, water thickness
1.00	| Unit electrode spacing
2	| Number of model resistivity values
	| The rest of the file follows the standard format

The left and right horizontal limits of the water layer is not used by the present version of the program which only supports Case 1 in Figure 5. It is included for future use with Case 3 where the water layer has a finite horizontal extent. Note that the water layer thickness is given as a negative value. The depth of the electrodes are set at 0 m., i.e. the depth datum level, and the depth values are positive downwards. Since the top of the water layer is above the 0 datum level, following this convention, the water thickness has a negative value.

Appendix B : I.P. models

The file MODELIP.MOD gives an example of a model file where the I.P. values (note in terms of chargeability with units of V/V which is 1000 times smaller than the more usual unit of mV/V). Essentially an extra section is included following the section with the model resistivity values. The lower part of the MODELIP.MOD file is shown below with comments.

| WATER.MOD file	Comments
111111111111111111111	Last line of model resistivity codes
IP present	keyword 'IP present' to indicate IP model
3	Three model IP values
0.00,0.10,0.20	The chargeability values
000000000000000000000	The IP codes

Appendix C : Calculation of 2D sensitivity values (limited availability)

This option is currently undergoing tests, and its present use is limited to registered users of the RES2DINV software. You will need to attach the RES2DINV dongle to the computer in order to use this feature.

This option calculates the 2-D resistivity sensitivity values for a homogeneous half-space for electrode arrays where the electrodes can be on the surface or underground. The sensitivity pattern shows the areas of the subsurface which have the greatest influence on the apparent resistivity measurement. This essentially shows the regions mapped by an array. The sensitivity function basically tells us the degree to which a change in the resistivity of a section of the subsurface will influence the potential measured by the array. The higher the value of the sensitivity function, the greater is the influence of the subsurface region on the measurement. Mathematically, the sensitivity function is given by the Frechet derivative (McGillivray and Oldenburg 1990). For a homogeneous half-space, the 3-D and 2-D forms of the sensitivity function can be calculated analytically (Loke and Barker 1999).

There are two main situations this type of calculation is useful. The first situation is in understanding the behavior of borehole arrays (Zhou and Greenhalgh, 2000). It will show the area 'scanned' by a borehole array, and hopefully lead better designs for cross-borehole surveys. The second situation is in designing streamers for mobile surveying systems, such as in water covered areas. In this problem, the number of nodes in the cable is very limited (usually less than 10) and the current electrodes are fixed at two of the nodes. The challenge is to design a measurement sequence that gives the most information about the subsurface within limitations imposed by the available equipment.

To use this option, the appropriate dongle must be attached to the computer before starting up the RES2DMOD program. After stating up the RES2DMOD program, click the 'Model computation' option on the top menu bar, and the following menu items should be displayed.
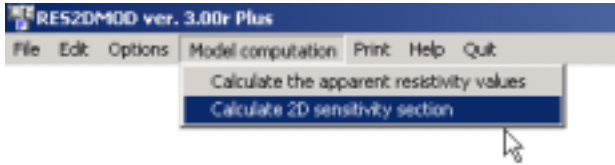
Clicking the 'Calculate 2D sensitivity section' option will bring up the following dialog box.You can choose to type in the parameters for a surface or borehole array, or read in the parameters from a text file. The text file option is particularly useful if you want to calculate the sensitivity values for several array configurations at the same time.
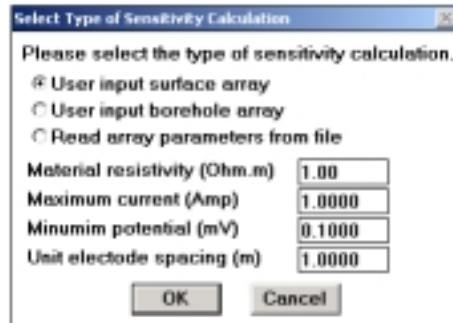
(a).   User input surface array.
This option is for the calculation of the sensitivity values for a single standard surface array. When this option is selected, the following dialog box will be shown.

The standard arrays supported are the Wenner Alpha, Wenner Beta, Wenner Gamma and Pole-Pole; as well as the dipole-dipole, Wenner-Schlumberger and pole-dipole. For the dipole-dipole, Wenner-Schlumberger and pole-dipole arrays, the value of the 'n' dipole separation factor is also needed. The general array format where the locations of the C1, C2, P1 and P2 electrodes are specified by the user is also supported. By default, the program sets the locations of the electrodes such that the array length is 1 meter with the first electrode at the 0 meter mark and the last electrode at the 1.0 meter mark. Next the range of the x (horizontal) and z (vertical) values of the subsurface to calculate the sensitivity values is needed, as well as the spacing between the calculation points. To avoid the singularity at the electrodes, the minimum z value must be greater than 0.0 meter.

For plotting purposes, the program multiplies the sensitivity values by a numerical scaling factor, usually between 100 to 100000, so that the final maximum sensitivity value is between 100 and 1000. By default, the program will calculate the scaling factor automatically, but the user can also fix the scaling factor.

(b).   User input borehole array.
This option is for the calculation of a single borehole array. On selecting this option, the following dialog box is shown.
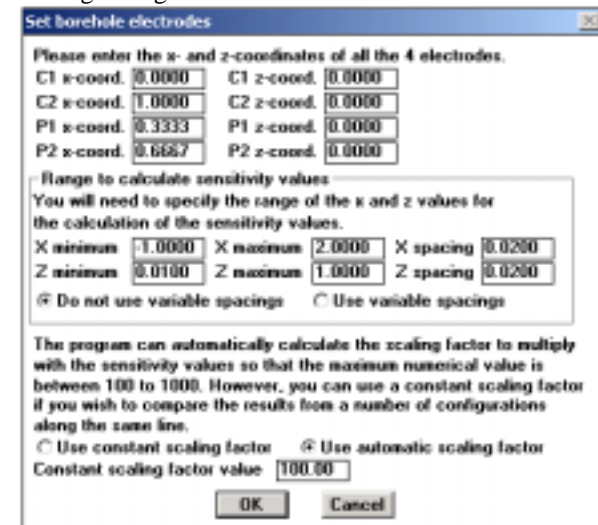
In this case, both the x and z coordinates of the four electrodes must be specified by the user.

(c).   Read array parameters from file.

This option allows the user to calculate the sensitivity values of a number of array configurations. The input file must have a TXT extension. When this option is selected, the following input dialog box is shown to prompt the user for an array data file.
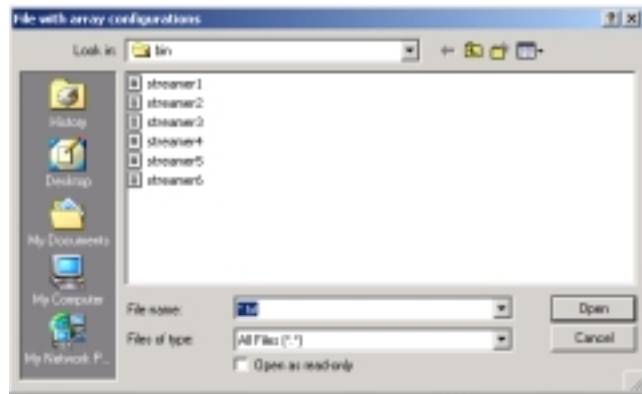

Basically, the x and z coordinates of each array configuration is typed into a text file. The ARRAYS.TXT file is an example input file. Below is a description of the file format .

ARRAYS.TXT file	Format Description
Example configurations	Title
Number of arrays	Header for number of arrays data
3	The number of configurations in this file
Unit electrode spacing	Header
1	The unit electrode spacing value
Coordinates of electrodes (xc1,zc1,xc2,zc2,xp1,zp1,xp2,zp2)	Header
array 1 = surface dipole-dipole	Header for first array
1,0	x and z location of C1 electrode
0,0	x and z location of C2 electrode
3,0	x and z location of P1 electrode
4,0	x and z location of P2 electrode
array 2 = surface pole-dipole	Header for second array (pole-dipole)
0,0	x and z location of C1 electrode
-1000,0	C2 electrode, note very large x distance
2,0	x and z location of P1 electrode
3,0	x and z location of P2 electrode
array 3 = borehole to surface bipole-bipole	Header for third array (borehole array)
0,1	x and z location of C1 electrode (in borehole)
0,2	x and z location of C2 electrode (in borehole)
2,0	x and z location of P1 electrode (on surface)
3,0	x and z location of P2 electrode (on surface)

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Starting and ending x-location to calculate sensitivity values, spacing	Header
-2.0,6.0,0.02	The x calculation range and spacing
Starting and ending z-location to calculate sensitivity values, spacing	Header
0.02,5.0,0.02	The z calculation range and spacing
Material resistivity (ohm.m)	Header
1	The subsurface resistivity
Maximum current (Amp)	Header
1.0	The maximum current value
Minimum potential (mV)	Header
0.1	The minimum potential value

Note that in theory, the C2 electrode for the pole-dipole array is at infinity. For calculation purposes, it can be placed at a large distance from the other electrodes. After the program has completed the calculations, it will prompt the user for the name of the output files to store the sensitivity values. The purpose of the files is described in the following section. After saving the sensitivity values, the program will then ask the user to select an array configuration to plot the sensitivity section. For example, after calculating the sensitivity values for the ARRAYS.TXT file, the following dialog box will be shown.
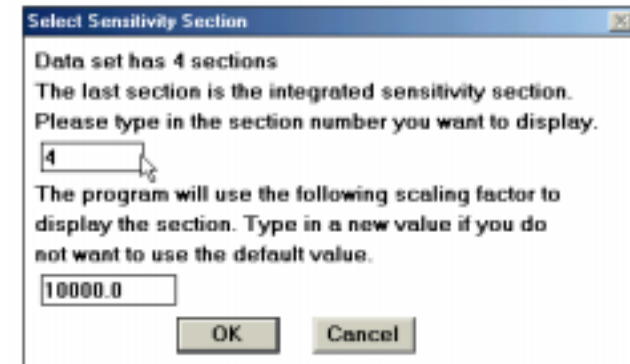
Note that although the file has only three array configurations, there are four sections. The fourth section has the integrated sensitivity values of the first three individual arrays. After selecting the appropriate array number, the program will then plot a contour section for the sensitivity values, such as in Figure 2 for the first array configuration in the ARRAYS.TXT file. The program will automatically select a scaling factor so that the sensitivity values when multiplied by this factor will have a reasonable range. However, you can change the scaling factor if the resulting contoured section is not suitable.

If you want to display the section for another configuration, you will need to read the output file containing the sensitivity values (for this example, the output file will be ARRAYS_OUT.TXT) by using the "Read array parameters from file" option described earlier. The program will detect that the output file already has the sensitivity values and will not carry out the sensitivity calculations again.
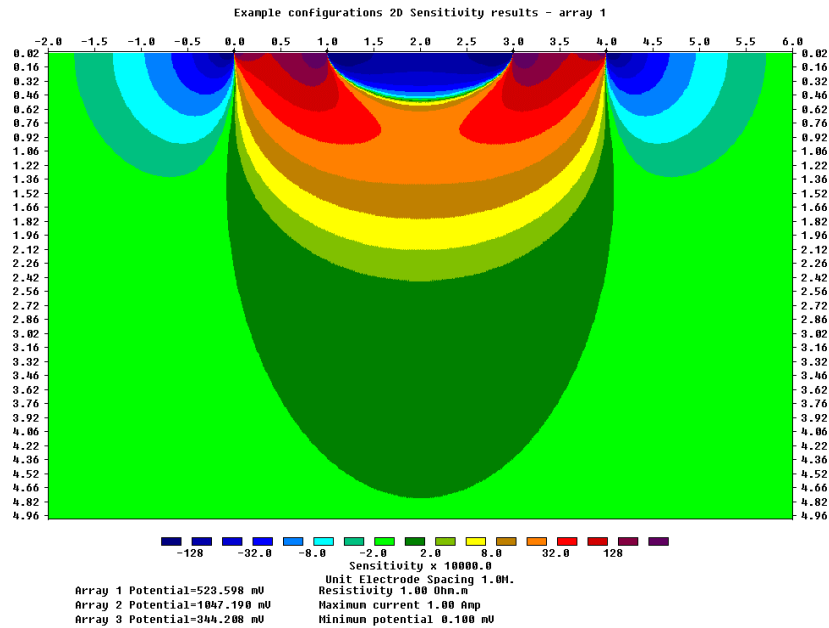

Figure 2. The sensitivity section for the first array configuration in the ARRAYS.TXT file. Note that it is a dipole-dipole array with 'n' equals to 2.

Example array files

Besides the ARRAYS.TXT file, the following example files might be of interest for various applications.

DIPOLES.TXT : The dipole-dipole array with large 'n' values ranging from 7 to 11. Shows that the dipole-dipole (and pole-dipole) becomes less sensitive to deeper parts of the subsurface as the 'n' values becomes too large.

BOREHOLES.TXT : Various cross-borehole array configurations.

STREAMERS_WSEX.TXT : A streamer with 11 nodes, with all electrodes on the ground or water surface. This streamer is based on the Schlumberger type of configuration. The integerated sensitivity section that shows the section of the subsurface mapped by the streamer system is of interest.

STREAMERS_WSEX_UW.TXT : The same streamer but underwater. For those planning an underwater survey with the cable dragged along the river/lake/sea bed.

DIPOLES_OM.TXT : A mobile surface survey system, i.e. another type of streamer. In this case there is a limitation that the dipole length is fixed at 1.0 meter. To get vertical resolution, the 'n' factor is varied from 0.25 to 2.0.

Output files

After calculating the sensitivity values, the program will save the data into a number of files. One file stores all the data into the internal format used by the RES2DMOD PLUS program, while the rest stores the sensitivity values for each array configuration in the format used by the SURFER 2D plotting program. As an example, for the ARRAYS.TXT input file, the program will store the sensitivity values for all the arrays into an ARRAYS_OUT.TXT file. This file can be read by the RES2DMOD PLUS program with the 'Read array parameters from file' option described earlier. In this case, the program will by-pass the step of calculating the sensitivity values. There will also be three other output files (ARRAYS_OUT_1.DAT, ARRAYS_OUT_2.DAT and ARRAYS_OUT_3.DAT for the ARRAYS.TXT input file) which has the sensitivity values in the SURFER format. A fourth file, ARRAY_OUT_TOTAL.DAT, has the integrated sensitivity values in the SURFER format.

Use of Surfer format data file

For each array configuration, the program will store two files that can be used by the SURFER 2D contouring program. As an example, the files ARRAYS_OUT_1.DAT and ARRAYS_OUT_1_POST.DAT are generated for the first array configuration in the ARRAYS.TXT file. To create a contour plot, follow the following steps.

1). Create contour file. Click 'Grid' on the top menu bar, and then 'Data' to read in the ARRAYS_OUT_1.DAT file. After reading in the data file, SURFER will show the 'Scattered Data Interpolation' dialog box. In the 'Grid Line Geometry' section, the number of lines that SURFER uses to interpolate the data values into a rectangular grid is shown. For this data set, the default values are probably 50 lines in the X direction and 31 lines in the Y direction. You will need to change the X and Y spacing values to the values used in calculating the sensitivity values (as given in the ARRAYS.TXT files). In this example, both values are 0.02. After changing the spacings, the following dialog box should be shown.
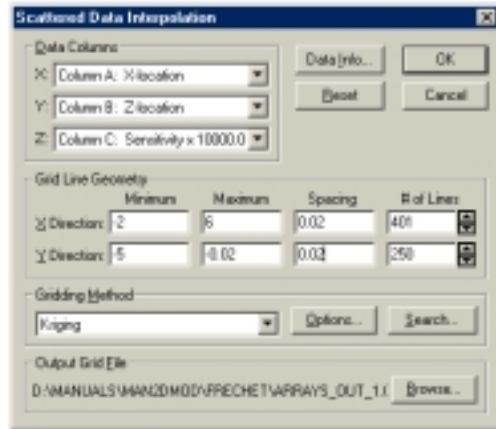
The SURFER program will create a grid file ARRAYS_OUT_1.GRD. Next click 'Map' on the top menu bar and then 'Contour'. In the 'Contour' option, read in the default file ARRAYS_OUT_1.GRD. Next the 'Contour Map' dialog box will be shown. In this dialog box, click the 'Fill Contours' option. Next click the 'Load' button, and then read in the FRECHET1.LVL file to set the contour values and colours. If you wish to display the colour scale and smooth the contours, click the 'Color Scale' and 'Smooth Contours' options. Next click OK, and SURFER should start drawing the contour section.

If you want to plot the positions of the electrodes as well, click the 'Post' command in the 'Map' menu, and then read in the ARRAYS_OUT_1_POST.DAT file (which contains the location of the electrodes) in the 'Open Data' dialog box. After reading in this file, the 'Post Map' dialog box will be shown. In this dialog box, select the symbol shape and size and other options you want to use, and then click OK. After that, press F2, and then click the 'Overlay Maps' command in the 'Map' menu. Next click the figure and then the 'Edit Overlays' command in the 'Map' menu. Click 'Post' and the 'Move to Front', and the electrodes will be drawn on top of the model section.

After drawing the section in the SURFER window, you can use other options within SURFER to improve the model section, such as changing the font, labels, titles etc., before printing the results or exporting it to another format. SURFER supports a large variety of formats, including bit-mapped graphics formats such as PCX, BMP, GIF etc.; and well as vector-based formats such as the AUTOCAD DXF format.

Preview – What is this?
Have you carried out this type of survey?
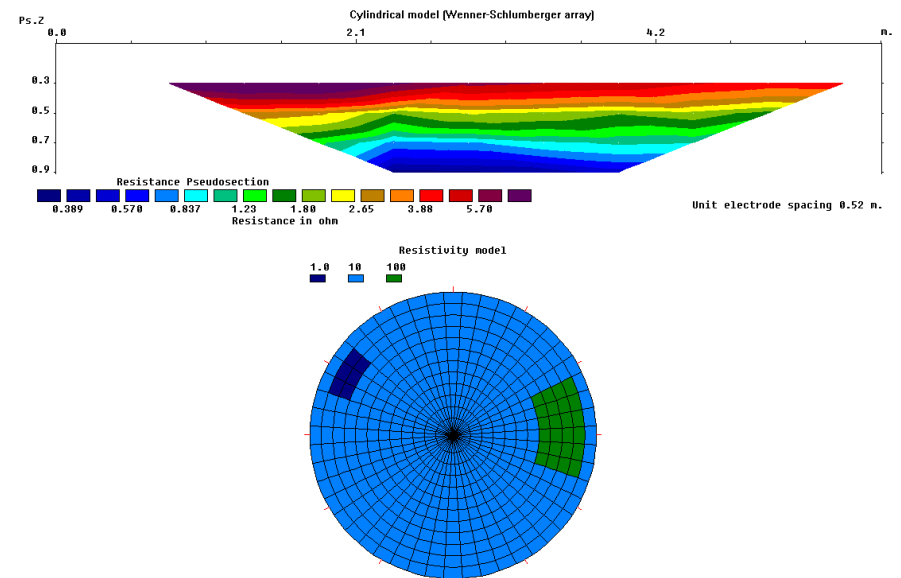
What's New
Version 1.x - Old version using expanded memory.

Version 2.0 - New version using a DOS extender and more friendly user interface. The rectangular (equatorial dipole-dipole) array has been added.

Version 2.10 - An option to read the inversion results files produced by the RES2DINV.EXE program was added to the RES2DMOD program. An option to use the Finite-Element method (with first order triangular elements) was also included.

Version 2.20 - Support for underwater surveys with a water layer of constant thickness was added.

Version 3.00 - Windows version.

Version 3.01 – Calculation of 2D sensitivity sections added. Only available to registred RES2DINV users.