# RES2DMOD ver. 3.03

## Rapid 2D resistivity and I.P. forward modeling 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 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 an 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.

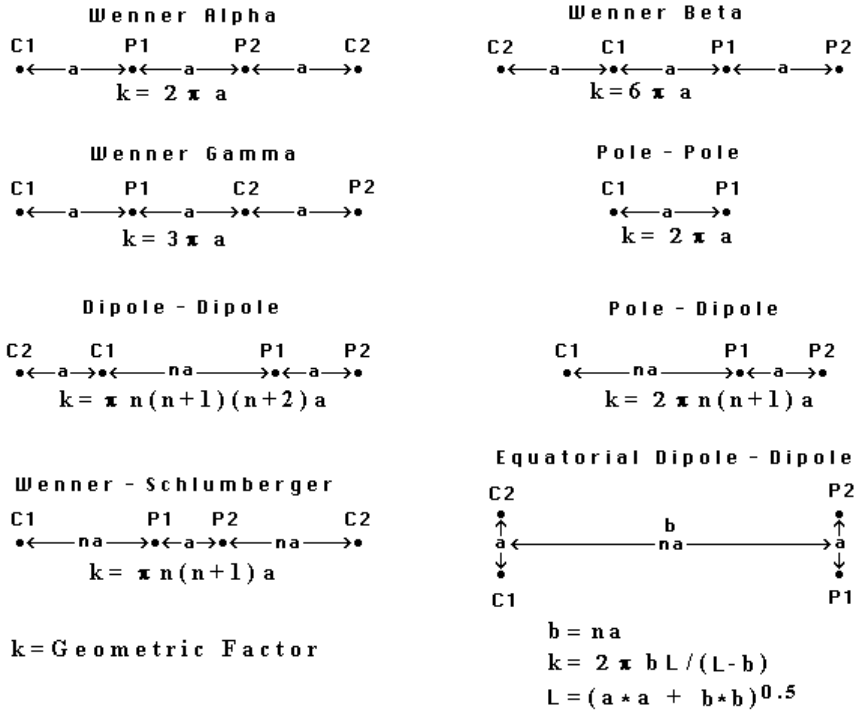



Figure 1 Arrangement of the electrodes for different arrays.

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 XP/Vista/7/8. You will need a microcomputer with an Intel or AMD CPU. This is a 32-bit Windows program that can access up to 2 gigabytes of memory. 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.

Table 1. Partial list of files installed with RES2DMOD program.

| | |
|---|---|
| RES2DMOD.EXE | Main program. |
| RES2DMOD.PDF | Manual in PDF format |
| RES2DMOD.CHM | Help file |
| MODEL41.MOD | Example model file with 41 electrodes survey line. |
| THIN_DIKE.MOD | Model file with dike structure. |
| TIXALL.MOD | File with more complex model. |
| LANDFILL.MOD | Model file for landfill. |
| MODEL101.MOD | Long survey line example. |
| WATER.MOD | Model with water ;ayer |
| ARRAYS.TXT | File with different array configurations. |
| streamer_wsex.txt | Example file with streamer configurations. |

## 3 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.

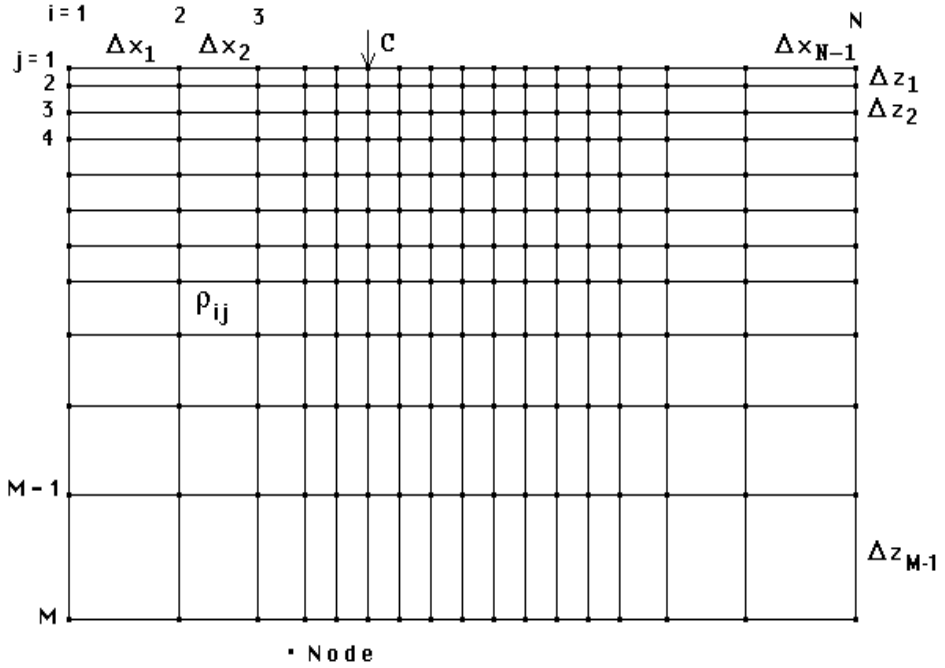



Figure 2 Schematic diagram of the finite-difference or finite-element mesh used by the program.

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 model file is described in section 4. 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.

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 ($\Delta z_j$ in Figure 2) 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.

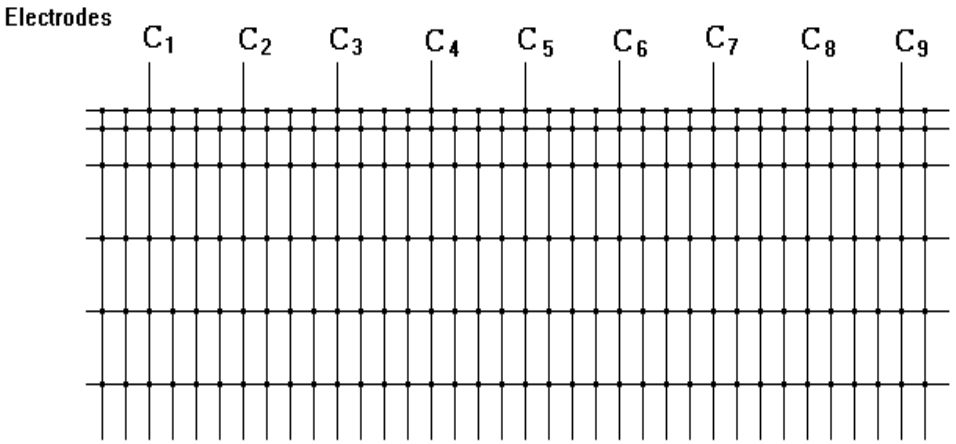
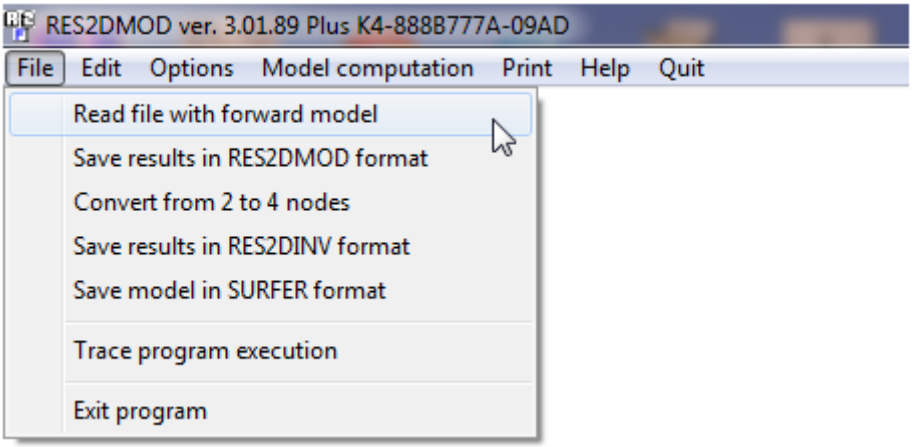



Figure 3 Part of the finite-difference or finite-element mesh showing the location of the electrodes.

## 4 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.

Table 2. Example 2D resistivity model format.

| *MODEL41.MOD file* | *Comments* |
|---|---|
| Blocks | *Title* |
| 41 | *Number of electrodes in survey line* |
| 10 | *Number of pseudosection data levels* |
| 0 | *Flag for underwater survey. Enter 0 for now* |
| 1.0 | *Unit (or smallest) electrode spacing* |
| 2 | *Flag for type of grid model. Enter 2 for user defined depths for the mesh lines.* |
| 0 | *Offset of first block in user-defined model section from the first electrode. Normally enter 0 to avoid problems.* |
| 160 | *Number of blocks in user-defined model.* |
| 10 | *Number of resistivity values in the model (maximum of 16)* |
| 4 | *Number of nodes per unit electrode spacing (2 or 4).* |
| 10.0,100.0,1.0,2.0,4.0,8.0,16.0,32.0,64.0,128.0 | *The model resistivity values.* |
| 14 | *Number of rows of rectangular blocks in the model.* |
| 0.2500,0.5000,0.8125,1.1875,1.6875,2.3125,3.1875, 4.4375,6.4375,10.4375,18.4375,34.4375,66.4375,13 0.4375 | *The depths to the horizontal grid mesh lines.* |
| 00000000000000000000000000000000…. | *The resistivity of the model blocks are given row by row.* |
| 00000000002222000011110000000000…. | *A number "0" means the block has the first resistivity value, "1"* |
| 00000000002222000011110000000000…. | *for the second resistivity value and so on. For the 11th to the* |
| …. | *16th resistivity values, use the letters "A" to "F".* |
| …. | |
| 00000000000000000000000000000022…. | |
| 00000000000000000000000000000022…. | *Last row of resistivity values* |
| 1 | *Type of array. 1 for Wenner* |
| 0,0,0,0 | *End with a few zeros.* |

The array numbers are 1=Wenner, 2=pole-pole, 3=dipole-dipole, 4=Wenner Beta, 5= Wenner Gamma, 6=inline pole-dipole, 7=Wenner- Schlumberger and 8=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.
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. To avoid problems, use this value for the number of model blocks so that it covers all the mesh cells between the first and last electrode. For an example, see the data file MODEL25.MOD.

The file MODELIP.MOD is an example file with model I.P. values as well. The format is similar to that for a resistivity only model, except the I.P. model section is given after the resistivity model section.

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.

**Save results in RES2DMOD format** - In this sub-option, 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. 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.

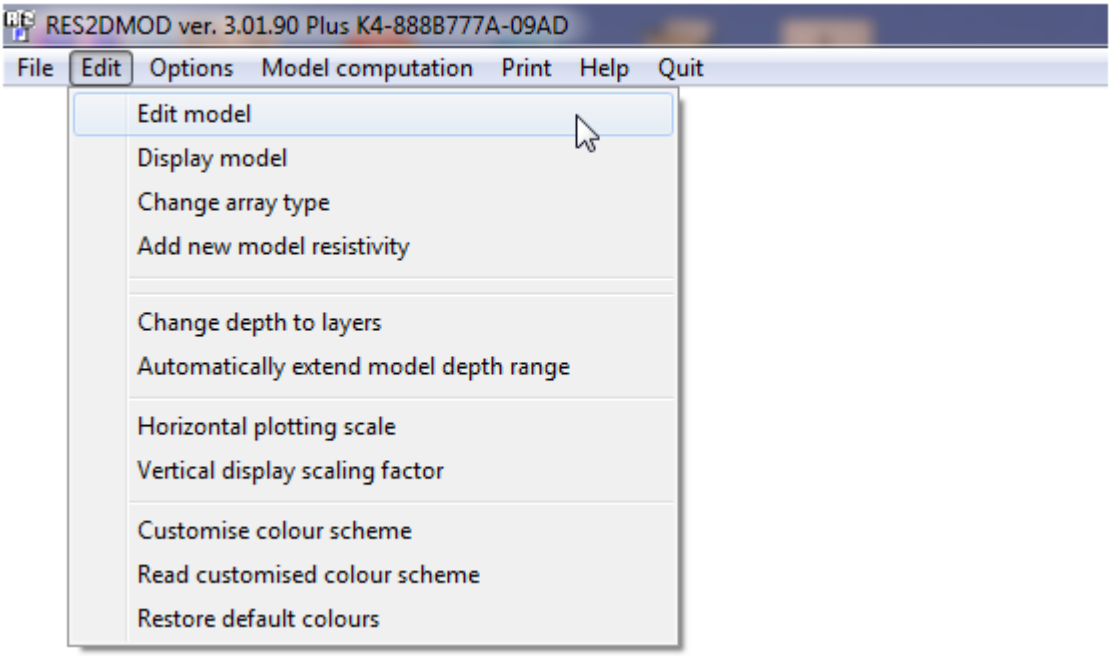
**Convert from 2 to 4 nodes** – This converts a model file originally designed with 2 nodes between adjacent electrodes to one with 4 nodes. It is recommended that you use the 4 nodes option for greater accuracy.

**Save results in 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.

**Save model in Surfer format** – This saves the model values in a format used by Surfer.

## 5 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 if you had calculated the potential values, such as in Figure 4. 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.

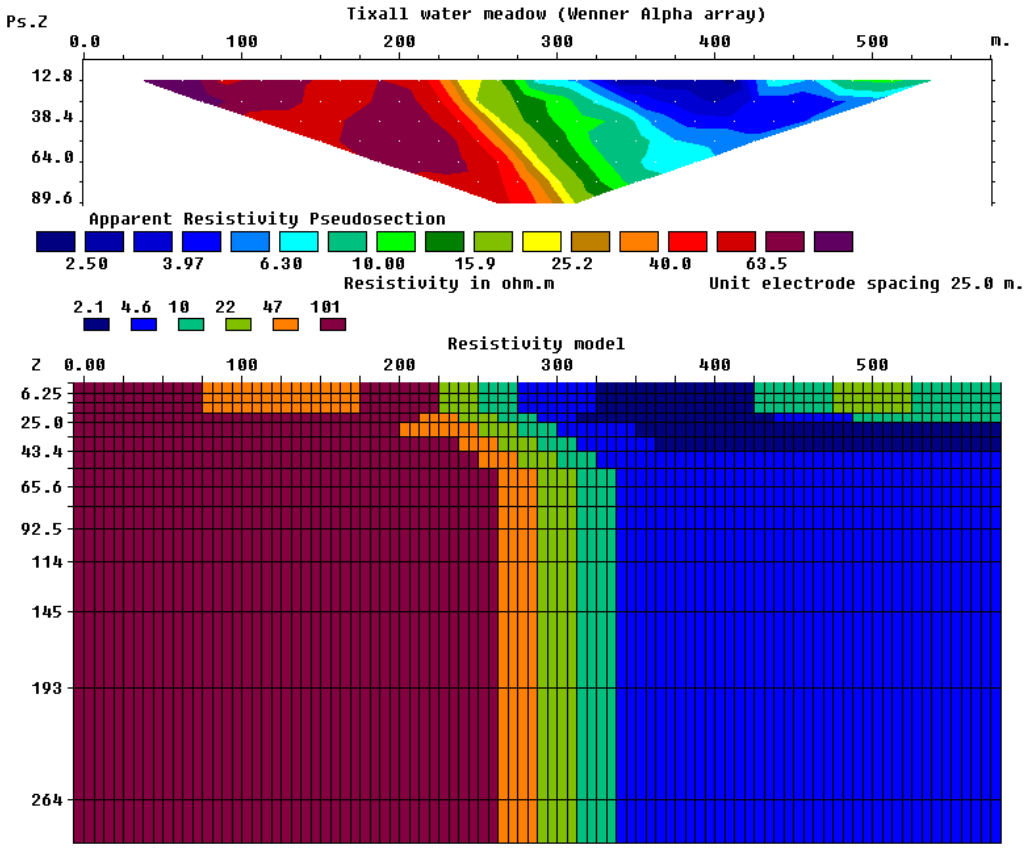
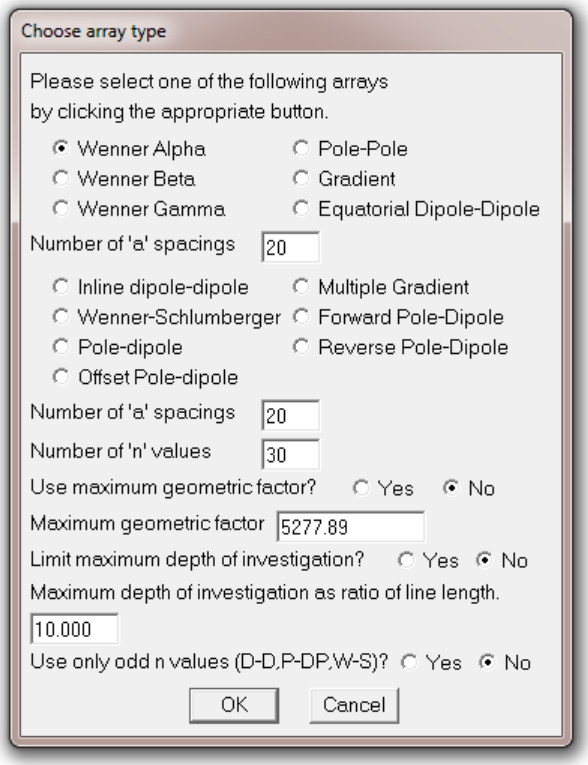



Figure 4 Model with apparent resistivity pseudosection.

**Display model** - Under this option, the model without the grid lines and the apparent resistivity pseudosection will be displayed.

**Change array 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. You can also filter out the possible arrays by setting a maximum limit on the geometric factor or median depth of investigation. For survey lines with a large number of electrodes, the number of possible data points with the dipole-dipole, pole-dipole and Wenner-Schlumberger arrays with all the possible ‘n’ values might be very large. To reduce the number of data points, an option to use only odd ‘n’ values is also available.

**Add new model resistivity** – This adds a new resistivity model value that was not listed in the input model file.

**Change depth to layers** – This allows the user to change the depths to the mesh levels manually.

**Automatically extend model depth range** – To ensure that the bottom boundary of the mesh used is sufficiently far from the surface so that they do not significantly influence the calculated potential values, they should be at least 2 to 3 times the length of the survey line. This option allows the user select whether to automatically extend the model. By default, the model is automatically extended.

**Horizontal 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.

**Vertical 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.

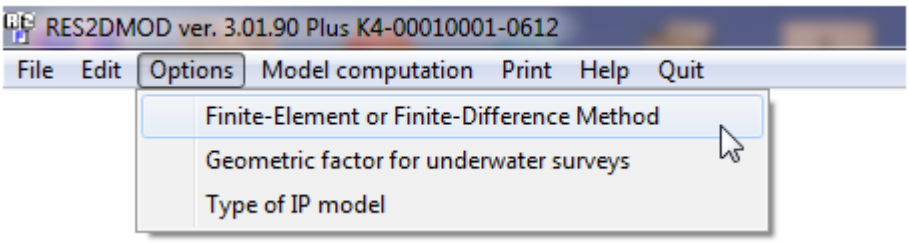
**Customise colour scheme** - This option can be used to manually change the colours used. After changing the values, the colour scheme can be saved into a file so that it can be reused.

**Read customised colour scheme** - You can change the colour scheme to a set of customized colours that was earlier saved in a file.

**Restore default colours** - This will reset the colour scheme used for colouring the sections to a default system used by the program.

## 6 Options

In this option, you can change certain parameters that affect the calculation of the apparent resistivity values.



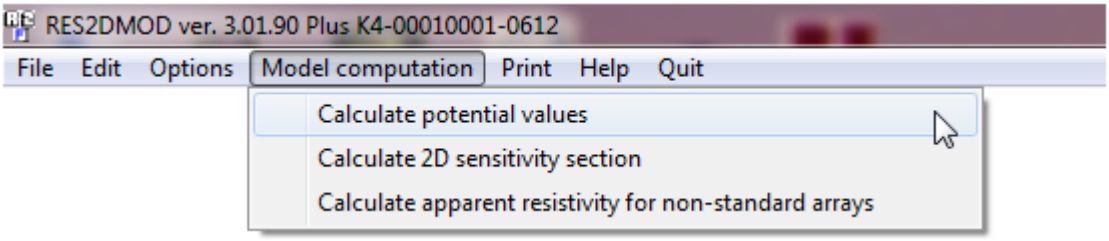

**Finite-Element or Finite-Difference Method** - In this sub-option, you can select to use the finite-element (Silvester and Ferrari, 1990) or finite-difference method that will be used to calculate the apparent resistivity values. The file MODEL2.MOD contains a comparison of the results obtained with 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.

**Geometric factor for underwater surveys** – You can choose to use the geometric factor for electrodes on the ground surface, or the exact geometric factor that takes into account the depth of the electrodes below the water surface. If the thickness of the water layer is large compared to the array length, the exact geometric factor is twice the surface geometric factor.

**Type of IP model** – You can select the 'perturbation' method or the 'complex resistivity' method (Kenma et al. 2000) for the calculation of the apparent I.P. values.

## 7 Model Computation

The following options are displayed on selecting this menu option.




**Calculate potential values** - 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 computers, the calculations probably take less than a minute for most models.

**Calculate 2D sensitivity section** – Please refer to Appendix C for details.

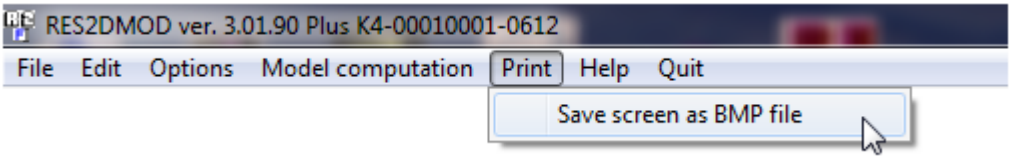
**Calculate apparent resistivity for non-standard arrays** - This allows the user to calculate the apparent resistivity values for non-standard arrays that are not in the list of conventional arrays supported by the program. The program reads in the positions of the electrodes from a text file. It is assumed that the coordinates of the electrodes in the text files correspond to the electrode positions in the model file read in before you read in the text file. The ARRAYS.TXT file with examples with different array configurations is shown in Table 4. When you select this option, the program will first ask for the name of the output file in the RES2DINV 'dat' format, followed by whether you wish to include noise in the apparent resistivity values. Finally it will ask for the 'txt' file containing the array configurations.

Table 3. Example text file with general array configurations

| *ARRAYS.TXT file* | *Comments* |
|---|---|
| Example configurations | *Title* |
| Number of arrays | *Header* |
| 6 | *Number of arrays in this file* |
| Unit electrode spacing | *Header* |
| 1.0 | *Electrode spacing, must be the same as mod file* |
| Coordinates of electrodes (xc1, zc1, xc2, zc2, xp1,zp1,xp2, zp2) | *Header* |
| array 1, dipole-dipole | *Header for 1st array* |
| 1.0,0.0 | *C1 electrode x,z coordinates* |
| 0.0,0.0 | *C2 electrode x,z coordinates* |
| 3.0,0.0 | *P1 electrode x,z coordinates* |
| 4.0,0.0 | *P1 electrode x,z coordinates* |
| array 2 , Wenner | *Header for 2nd array* |
| 1.0,0.0 | *C1 electrode coordinates for 2nd array* |
| 4.0,0.0 | *C2 electrode coordinates for 2nd array* |
| 2.0,0.0 | *P1 electrode coordinates for 2nd array* |
| 3.0,0.0 | *P2 electrode coordinates for 2nd array* |
| array 3, Wenner-Schlumberger | *Start of array 3* |
| .. | *Same format for other arrays* |
| .. | |
| .. | |
| .. | |
| array 5, pole-dipole | *Pole-dipole array example* |
| 0.0,0.0 | *C1 electrode location* |
| -1000.0,0.0 | *C2 electrode, note location is outside survey line* |
| 2.0,0.0 | *P1 electrode location* |
| 3.0,0.0 | *P2 electrode location* |
| array 6, pole-pole | *Pole-pole array example, last array* |
| 0.0,0.0 | *C1 electrode location* |
| -1000.0,0.0 | *C2 electrode, note location is outside survey line* |
| 2.0,0.0 | *P1 electrode location* |
| 1000.0,0.0 | *P2 electrode, note location is outside survey line* |
| Starting and ending x-location to calculate sensitivity values, spacing | *The following lines are used to complete the file format.* |
| -2.0,6.0,0.02 | *They are not used in calculating the apparent resistivity, but only* |
| Starting and ending z-location to calculate sensitivity values, spacing | *for calculating the sensitivity sections.* |
| 0.02,5.0,0.02 | |
| Material resistivity (ohm.m) | |
| 1 | |
| Maximum current (Amp) | |
| 1.0 | |
| Minimum potential (mV) | |
| 0.1 | |

## 8 Print

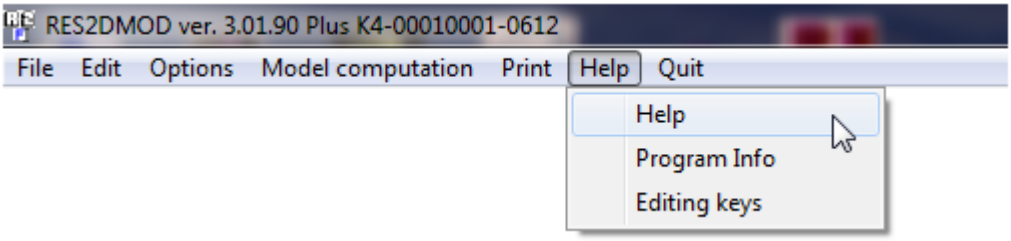
Besides displaying the pseudosections on the screen, you might make a printout of the model sections. On selecting the 'Print' option on the main menu bar, the following list of suboptions will be displayed.




Saving the screen image into the form of a BMP 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.

## 9 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.

**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. 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 geotomo@gmail.com.

## 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.

Kenma, A., Binley, A., Ramirez, A. and Daily, W., 2000. Complex resistivity tomography for environmental applications. Chemical Engineering Journal, 77, 11-18.

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 a possible situation for an underwater resistivity survey.

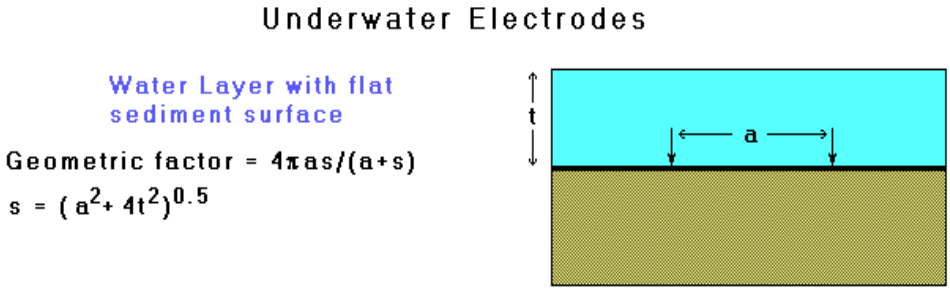



Figure 5 Model with water layer.

The present program only supports the situation with a water layer of constant thickness over a flat sediment surface. The file WATER.MOD is an example model data file with a water layer. The initial part of the file with format used is shown in Table 4.

Table 4. Example 2D resistivity model with water layer format.

| *WATER.MOD file* | *Comments* |
|---|---|
| Model with water layer | *Title* |
| 61 | *Number of electrodes in survey line* |
| 16 | *Number of pseudosection data 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* |
| 1.0 | *Unit (or smallest) electrode spacing* |
| 2 | *Flag for type of grid model. Enter 2 for user defined depths for the mesh lines.* |
| 0 | *Offset of first block in user-defined model section from the first electrode. Normally enter 0 to avoid problems.* |
| 200 | *Number of blocks in user-defined model.* |
| 2 | *Number of resistivity values in the model (maximum of 16)* |
| 4 | *Number of nodes per unit electrode spacing (2 or 4).* |
| 100.0, 2000.0 | *The model resistivity values.* |
| …. | *The rest of the file follows the standard format* |

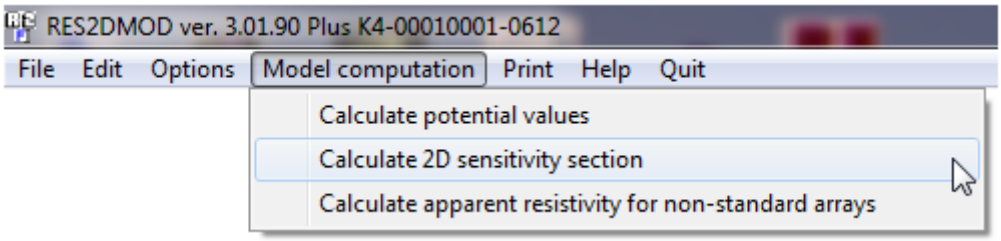
The left and right horizontal limits of the water layer are not used by the present version of the program. It is included for future use with Case 3 where the water layer has a finite horizontal extent. Note that the water layer thickness is given as a negative value. The depths of the electrodes are 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 : Calculation of 2D sensitivity values**

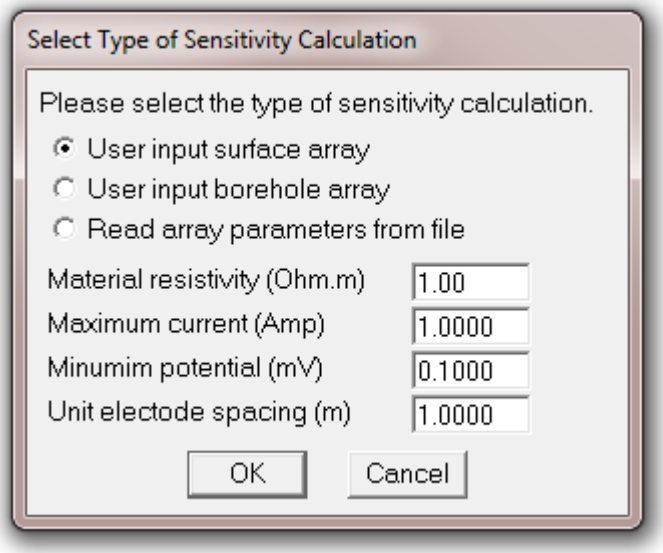
This option calculates the 2-D resistivity sensitivity values for a homogeneous half-space for electrode arrays where the electrodes can be on the surface or underground. The sensitivity pattern shows the areas of the subsurface which have the greatest influence on the apparent resistivity measurement. 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 behaviour 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.

After stating up the RES2DMOD program, click the 'Model computation' option on the top menu bar, and the following menu items should be displayed.

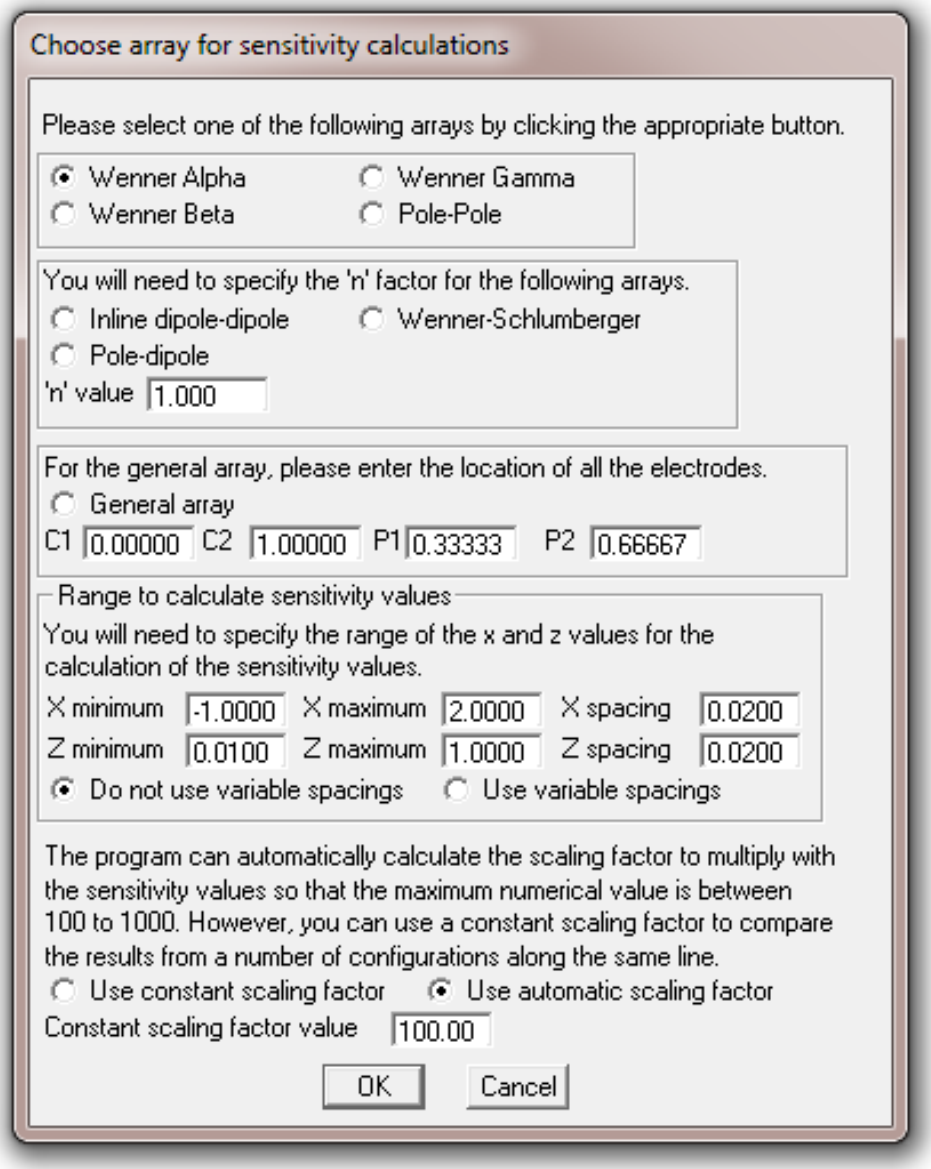



Clicking the 'Calculate 2D sensitivity section' option will bring up the following dialog box. You can choose to type in the parameters for a surface or borehole array, or read in the parameters from a text file. The text file option is particularly useful if you want to calculate the sensitivity values for several array configurations at the same time.




**(a). User input surface array.**

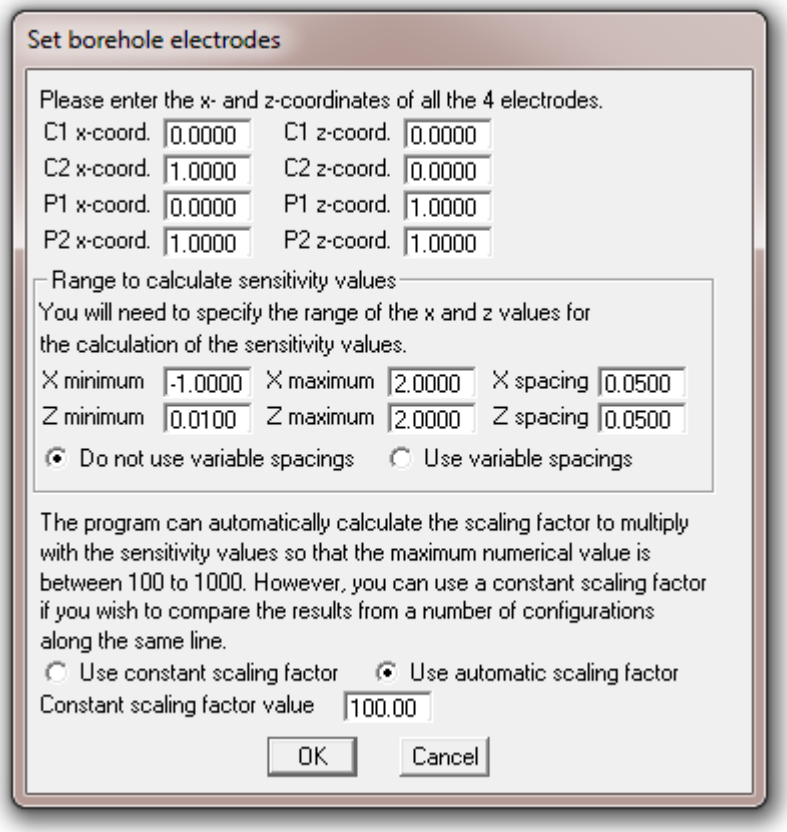
This option is for the calculation of the sensitivity values for a single surface array. When this option is selected, the following dialog box will be shown.



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 and 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.

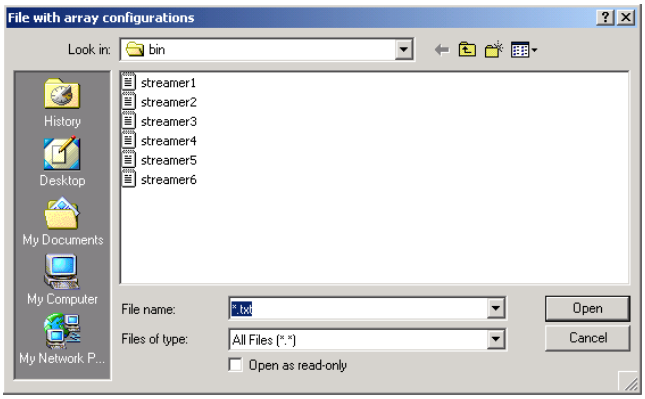
This option is for the calculation of a single borehole array. On selecting this option, the following dialog box is shown.




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.

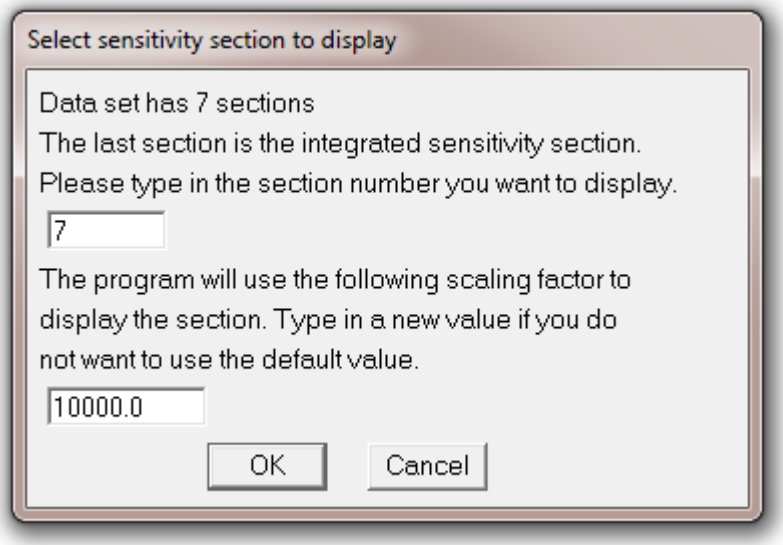
This option allows the user to calculate the sensitivity values of a number of array configurations. The input file must have a TXT extension. When this option is selected, the following input dialog box is shown to prompt the user for an array data file.




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. The file format was described earlier in Section 6.

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.

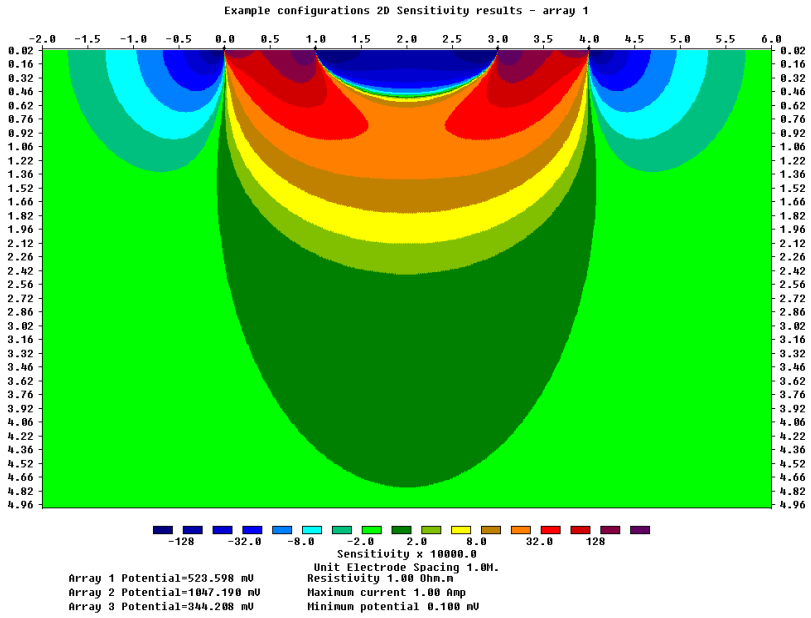


Figure 6 The sensitivity section for the first array configuration in the ARRAYS.TXT file. Note that it is a dipole-dipole array with ‘n’ equals to 2.

**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.

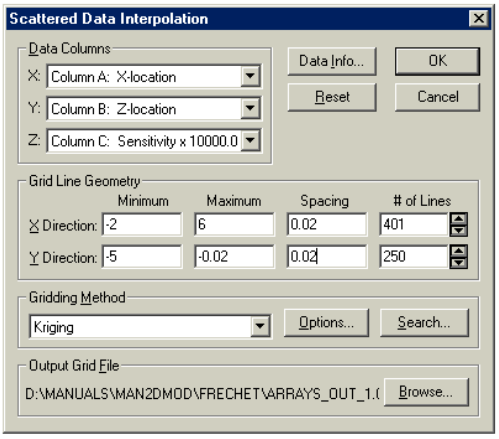
DIPOLES_OM.TXT : A mobile surface survey system, i.e. another type of streamer. In this case there is a limitation that the dipole length is fixed at 1.0 meter. To get vertical resolution, the ‘n’ factor is varied from 0.25 to 2.0.

**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 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.