

### Short Guide for EM4Soil users

## A- Preparation of the data

The data from EM400P should be converted in a format readable for EM4Soil. To do that run the program PROFTOEMS (clicking twice in the name of the program). The following screen will appear:



Go to Input and click on Input Profiler file.

Input Data File				<u>?</u> ×	
Procurar em:	C Mahfooz	•	+ 🗈 💣 📰 -		
Os meus documentos r Mabiente de trabalho Os meus documentos	<pre>EMP400_005 EMP400_012</pre>				
O meu computador S meus locais na rede	Nome do ficheiro: Ficheiros do tipo:	  Mask (".EMI)   Abrir em modo só de leitura	×	Abrir Cancelar	

Choose the file (\*.EMI) to be converted. Clicking twice in the file name the program will import the data informing you the amount of values.

	www.emtomo.c	com emtomog@gmail.com	
	PROFiLERtoEM45 files	Sava Abark	_O×
E	o, ango, anorunisticoscup Display	PROFILERROEM45 files X Done Number of sites: 147 OK	

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Clicking in OK will finish the importing. Go now to the Instrument Setup to give the height of the equipment during the acquisition and the name of the survey:





After importing the data you can display a graphic with your data. Go to Display and press the display data:



Then you can have an idea about the quality of your data and to decide which frequencies do you want to save for inversion on EMS4Soil. To do that, go to Save:



And choose the frequencies:



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PROFILERtoEM45 files	
Ext hout indument Song Dougly Sove About	BR 6 51,1 56,4 66,7 73,0
B- B- B- B- B- B- B- B- B- B-	73.0

And click in OK, and save the file in a folder.

Save the file for	EM4Soil program						?	×		
Procurar em:	C Mahfooz		•	← 🗈	r 🔁	•				
Os meus documentos r Com Ambiente de trabalho Os meus documentos Os meus computador	<ul> <li>proftoems</li> <li>emp-005</li> <li>emp-012</li> <li>p1</li> <li>p2</li> <li>p4</li> <li>treta</li> <li>gfgf</li> <li>proftoems</li> <li>EMP400_005</li> <li>EMP400_012</li> <li>ewe</li> <li>dualtoems</li> </ul>	명 PROFtoEMS.f90 G proftoems.obj 편 PROFtoEMS-readme 및 proftoems	9							Data
Os meus locais na rede	Nome do ficheiro: Ficheiros do tipo:	surveyP.DAT Mask (*.*) Abrir em modo só de leitr	ura			•	Abrir Cancelar		-7	
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That file will be import by EM4Soil for processing and inversion. The file is an ASCII one and the first rows will be like the example below:

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XY	Z ECa40	00 ECa600	00 ECa	15000 L	at Long tir	ne			
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0.0000	000 0.	.500000	0.00	738.36	494.87	538.12	0.00	0.00	0.00
0.0000	000 1.	.000000	0.00	819.56	748.57	617.46	0.00	0.00	0.00
0.0000	000 1.	.500000	0.00	869.47	835.96	617.76	0.00	0.00	0.00
0.0000	000 2.	.000000	0.00	848.91	861.21	546.57	0.00	0.00	0.00



Close the program and start the EM4Soil one, clicking twice in the name.

## **B-** Using the EM4Soil program

The program will display the following screen:



The program needs you select the equipment used for acquisition. Go to Input and Input Sensor and choose the PROFILER. After click OK.

	EM4Soil-	v1: EM I	Laterally Constra	ained Inve	rsion						
Exit	Survey	Input	Data Processing	Inversion	Display Settings	Save	Print	Help	About		
A	ction:										
	Plo	t Raw	Data								
	Plot I	Filtere	d Data		📑 Input Senso	or			_ 🗆 ×	1	
	Plot De	ecimat	ed Data		Choose se	nsor					
Γ	Plot N	oise A	nalysis		DUALEM-1 DUALEM-2						
ſ	Plot N	leg.Co	rrected		DUALEM-2	1					Λ٦
Ē	Plot E	3-L Co	rrected		DUALEM-4	21					
Ē	Plot	Initial	Model		EM38	42					
Ē	Plot In	verter	1 Model		EM31 EM34						
	Plot D	ata/Da	chance		GEM PROFILER						
	PIULD	ataine	sponse				<u>ч</u>				
	-	Plot D	DI								
		Quit									

If your data has been collected in several profiles it is considered a Area survey and should be import in Input, Input Data, Area:



Choose the file to input (probably you need to modify the type of file from DAT to All files):

Input Data File						? ×	
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Os meus documentos r Ambiente de trabalho Os meus documentos O meu computador	<pre>proftoems emp-005 emp-012 p1 p2 p4 p4 proftoems PEMP400_005 PEMP400_0012 ewe dualtoems</pre>	료 PROFtoEMS.f90 료 proftoems.obj 편 model 편 PROFtoEMS-readme 로 proftoems					Л <sup>-</sup>
Os meus locais na rede	Nome do ficheiro: Ficheiros do tipo:	emp-012 All Files (*.*) Abrir em modo só de leitura			•	Abrir Cancelar	

Clicking twice in the file name the program will input the file and you will be informed about the data: Equipment you have chosen; number of values; number of frequencies and if you have negative values. In any case "No initial model will be made", because you have input a AREA survey NOT a line survey.



Clicking in OK the program will open the MAP Module where you can see the data and select the profiles to be inverted. The following screen will be displayed:

EM4Soil - Map module		
Exit Display Profile mode Save Print	Help About	
Quit	ЕМТОМО	
	BHTOMO - Software for ElectroMagnetic Tomography	

You can go to Display, Survey Layout to see the location of your data:



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EM45oil - Map module Exit Display Profile mode Save Print Help About						
Quit						
			Sites			
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2.5 -						· -
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0.8 -						• L
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_0.8 _						
-0.0-	0.2 0.3	0.9	1.4	1.9	2.3	2.8
			Distance X	(m)		

Or display the Data, Cond/Res and see your data:





You can see the maps of all frequencies clicking on the right button of the mouse.



The Model slices only can be used after the inversion of the profiles (will see this feature latter).

The entrance settings will allow you to do some alteration on the map display:

Exit Display Profile mode Save Print Help About       Quit     Raw Data       Exit    <       Data     Grid geometry       • Raw Data     Xmin       • O.1500     Sites       Sites     Xmax       • Plot sites     Ymin       • No sites     Ymin       • Conductivity       • Resistivity       Contour type       • Linear
Quit       Raw Data            EM45oil - Map module
EM45oil - Map module       Image: Constraint of the system o
EM4Soil - Map module       Image: Construct of the system of
Data       Grid geometry            • Raw Data       Xmin         • 0.1500          Sites       Xmax       3.1500             • Plot sites        Ymin        - Map             • No sites        Ymin        -0.8333             • Display        Ymax        10.8333             • Conductivity        - Resistivity        - Map             • No        - Map        - Map             • No           • Ymax        10.8333             • Conductivity           • Expected               • Linear           • Linear           • Linear
<ul> <li>Raw Data Xmin -0.1500</li> <li>Sites Xmax 3.1500</li> <li>Plot sites Ymin -0.8333</li> <li>NO sites Ymax 10.8333</li> <li>Conductivity</li> <li>Resistivity</li> <li>Contour type</li> <li>Linear</li> </ul>
Sites Xmax 3.1500 Plot sites Ymin -0.8333 Display Ymax 10.8333 Conductivity Resistivity Contour type © Linear
<ul> <li>Plot sites</li> <li>NO sites</li> <li>Ymin</li> <li>-0.8333</li> <li>Display</li> <li>Ymax</li> <li>10.8333</li> <li>Conductivity</li> <li>Resistivity</li> <li>Contour type</li> <li>Linear</li> </ul>
Display Ymax 10.8333 Conductivity Centour type Contour type Chinear
© Conductivity © Resistivity Contour type © Linear
<ul> <li>Resistivity</li> <li>Contour type</li> <li>Linear</li> </ul>
Contour type Einear
Inear
C Logarithmic
Rescale axis
© YES
ок

You can print any Map going to the Save menu.

# Let's see how to define and export profiles for inversion.

First display again the Survey layout. After go to the profile mode, Add Profiles:

EM4Soil - Map module										
Exit Display Profile mode Sav	/e Print	Help	About							
Add profile										
Qan										
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							Sites			
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							Jistance X (;	nn.)		



When you click in Add Profile the arrow of the mouse modifies into a cross. Go to the beginning of the profile and click on the left mouse button. After go to the end of the profiles and click on the left mouse button. Without to move, click on the right mouse. This finish the profile selection and open the following screen:

		10.8 +
EM4Soil - Map	module _ 🗖	× i
Exit		9.2 -
Profile ends		-
×0	0.0079	7.5 -
YO	0.0035	-
XE	-0.0007	5.8 -
YE	10.0452	
Profile:	no name	4.2 -
Search radius	s (m) 2.0	2.5 -
New Profile?		
• YES		
O NO		- 8.0
	ОК	
		-0.2

Give a name for the profile and choose the search radius (should be a little smaller than the distance between measured data). If you do not want more profiles select NO.

EM4Soil - Map module Exit Display Profile mode Save Print Help Al	oout		-				
Quit							
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	10.0						
EM4Soil - Map module	92-						•
Profile ends	0.11				•		•
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Profile: line5					:		:
Search radius (m) 0.6	2.5 -	1 1					
New Profile?		1 1					:
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	-0.2	0.3	0.9	1.4	1.9	2.3	2.8
				Distance	X (m)		

After, the selected profiles should be saved. Go to Save, Save Profiles:





Select the profile you want to save and do that clicking in OK.

🔲 EM4Soil - Map	module									
Exit Display Prof	Save Selected P	rine Mole Alexae rofile			?   ×	al				
Quit	Procurar em:	C Mahfooz		+ 🗈 💣 💷 -						
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	Os meus locais na rede	Nome do ficheiro: Ficheiros do tipo:	line3.tx   Mask (".")   ∏ Abrir em modo só de leitura		Abrir Cancelar				•	-
		2.5 0.6 -0.8	line1		ine3	•	line5	• • •		-

After you have saved the profiles, quit the Map Module clicking in QUIT. You can back to the Map module at any time using the entrance Input, Go to Map of the EM4Soil:

	EM4Soil-v	1: EM I	aterally Constra	ained Inve	rsion					
Exit	Survey	Input	Data Processing	Inversion	Display Settings	Save	Print	Help	About	
A	tion:	Inp	ut Sensors							
		Inp	ut Data	•						
	Plot			-						
E	Input inversion results(*.INVr)									
	Plot F									
		Sele	ect sites (EMSoundi	ing)						
_	PIULDE			-						
	Plot No	Gol	to Map			_				
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	Plot N	eg.Co	rrected							
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	Plot B	-L Cor	rected							
	Plot I	nitial I	Model							



## C- Inverting (Q2D) and Displaying results

Now you must invert the profiles you have saved. To do that, go to EM4Soil program and input the first profile using the Input, Data, Line option:

	EM4Soil-v	1: EM L	aterally Constra	ained Inve	rsion				
Ex	it Survey	Input	Data Processing	Inversion	Display Settings	Save	Print	Help	About
	Action.	Inpu	ut Sensors			_			
	icuon.	Inpu	ut Data	۱.	Line				
	Plot				Area				
		Inpu	ut inversion results	(*.INVr)	EM Sounding				
	Plot F								
	Plot De     Select sites (EMSounding)								
ſ		Go t	ю Мар			ı			
	PIOTING	лэс А	iaiyoio		-				
	Plot N	eg.Co	rrected						

During the input you can see this warning:



In general you do not need to go for decimation (only if you have a significant data redundancy). After input the data will be displayed:





If the display is like the following, it means that your search radius was too large. You must reselect the profile.



After importing the profile you can filter, try to correct negative values etc...

If the data did not have any negative value, an initial model was saved (you have been informed about it during the data input) and you can use it for the inversion. If it is the case, go to the inversion and select the Inversion Parameters:



After that, go to the Inversion, Inversion Q2D, Inversion calculation (FS):





Select the data you want to invert:



The following warning will appear:



Click on YES (SIM is yes in Portuguese language). The program will start the inversion. You can follow the inversion in the DOS windows opened when the EM4Soil program started.



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Clicking in OK the program save all the needed files and you can now see the inversion results and save the model for further processing.

Use the buttons on left of the screen to display the data/results misfit and the model also:



In this particular case the misfit is very high. There are several factors that affect the misfit values: data quality (the most important), initial conductivity, number of



iterations, damping factor...etc. This model was made using the default parameters. A better model can be calculated using a damping of 0.02 and 15 iterations.

After to calculate a satisfactory model, this should be saved. Go to Save option:

EM4Soil-v1: EM Laterally Constra	ained Inve	rsion							
Exit Survey Input Data Processing	Inversion	Display Settings	Save	Print	Help	About			
Action:		Freq.	Sav Sav	e Initia e Initia	l Model I Model	(1D)   (Q2D)			
Plot Raw Data Plot Filtered Data		4000. 6000.	Sav	e Proce	essed D	Data	۲		
Plot Decimated Data	Δ	15000.	Sav Sav	e Inver e Inver	rse Moo rsion M	del isfit			1
Plot Noise Analysis		(m)	Sav 	e Mode	Resp Result	onse -			
Plot Neg.Corrected		S A	Sav	e Medi	um Proj	- p,	•	•	
Plot Initial Model		) pu	; 9; ; 9;	3.9 - 6 1 -			<u>ہ</u>	 2	<mark>9</mark>

**NOTE:** if your data have negative values (even if they have been corrected) the program does not do an initial model. In such case before the inversion you must define an initial model. Go to Inversion, define initial model (see the sequence of screens):

📄 EM4Soil-v1: EM Laterally C	onstra	ined Inve	rsion					
Exit Survey Input Data Proce	essing	Inversion	Display Settings	Save	Print	Help	About	
Action: Plot Raw Data Plot Filtered Data			Freq. — 4000. — 6000. — 15000.	lin	e: n	0		1
Plot Noise Analysis Plot Neg.Corrected			,   1	29 29 24 24	2.6 - 6.3 - 0.0 -		- <del>-</del>	~
Plot B-L Corrected	 Ini	tial Mode		15 	17- 14-		*	<b></b> €
Plot Inverted Model	Exit	Manually Automati	y (1-D) ic		2 - 9 -		-	<u> </u>
Plot Data/Response Plot DOI	0	Open Fil	e (1-D) OK		4 - 0	0.0	1.	0
Quit								



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Therefore an initial model of uniform conductivity of 130 mS/m was defined. Now you can do the inversion.

#### **D-** Using the Map Module to display the models

After to have the models calculated you can back to the Map Module going to the Input, Go to Map option. Then go to Display, Models. The following warning appears:



Clicking in Yes you will input the models file:

Input models			<u>? ×</u>
Procurar em:	C Mahfooz	-⊞ *≏ 🖬 →	
Os meus documentos r Os meus Ambiente de trabalho Os meus documentos Os meus o meu computador	proftoems emp-005 emp-012 line1 line3 line6 line7 modl1 modp1 modp2 modp4 p1	<ul> <li>p2</li> <li>p4</li> <li>pf</li> <li>proftoems</li> <li>gfgf</li> <li>proftoems</li> <li>EMP400_005</li> <li>EMP400_012</li> <li>ewe</li> <li>dualtoems</li> <li>PROFtoEMS.f90</li> <li>proftoems.obj</li> <li>model</li> <li>PROFtoEMS-readme</li> </ul>	
Os meus locais na rede	Nome do ficheiro: Ficheiros do tipo:	modl1     Abri       All Files (*.*)     Cance       Abrir em modo só de leitura     Cance	r lar
			11.

All the files should be input in sequence. After importing the last model file click in Cancel and the program will display the first level of your models.

ЕМТОМО www.emtomo.com emtomog@gmail.com 10.8 -4.0 3.6 Distance Y (m) 1.8 1.4 1.0 0.5 -0.4 -0.8 0.3 0.9 1.4 1.9 Distance X (m) 2.3 2.8 -0.2

In same cases it is better to display the values in a Log scale. This can be selected in the Settings entrance:

Elev.

EM4Soil - Map module		_ 🗆 ×			
Exit					
Data	Grid geometr	у			
Raw Data	Xmin	-0.1500			
Sites	Хтах	3 1500			
Plot sites		5.1300			
○ NO sites	Ymin	-0.8333			
Display	Ymax	10.8333			
Conductivity	Denths (m) <sup>.</sup>				
C Resistivity	Depuis (iii).				
Contour type		-0.0			
• Linear		-1.5			
C Logarithmic		-2.1			
Rescale axis	Minimum ele				
• NO	Movimum old	Minimum elev2.0			
O YES	Maximum en	CYU.I			
ОК	1				

You can also select the depth (elevations) of the slices to be shown. To display the next slice use the right mouse button. Print the correspondent figures using the Print entrance in the menu bar.



# E- Preparing data for the Q3D inversion

Data from a survey (area) can be inverted using the Q3D algorithm. The data should firstly correct from negative values.



In the next step, before gridding the data, the user should decide about the rotation of the survey in order to optimize the mesh for the inversion.

1	by barroy, borroovaa_aavo
,	Survey Rotation
-	Exit
it	Rotation:
	Automatic
	C Angle
	Clockwise rotation in Degrees:
	angle 0.0
	ОК







The rotated result can be saved for future use. However, the gridding of a rotated survey can be done immediately the rotation with saving the results.

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Grid Geometry		
Exit Gridding Method: Inverse Distance Input Data: Raw data Rotated OK	Grid geometry: Mean distance Xmin Xmax #Xlines	14.88 0.0000 439.0770 100
	Ymin Ymax #Ylines	0.0000
	Smoothing: #Xlines #Ylines	3
	Weight	2.0

Note: after selection of "rotated" click in OK to accept the selection (this is not necessary selecting "raw data"). Select the number of #Xlines and #Ylines and click OK. The gridding process can take a while for surveys with a high number of measurements. Wait till the program finish. The mean distance value that appears in the screen is an average value of the diagonal of the mesh (sqrt( $dx^2 + dy^2$ )).

The user should inspect the gridding result using the option Display/Grid/Filtered data. In the example below the #Ylines value of 100 is too high originating several zones without any data with consequences in the inversion results.





After the gridding the filter of the topography or of the apparent conductivity values can now be applied.

The data are now ready to be inverted. To do that, select the parameters . inversion (number of iterations, damping factor and the algorithm to use. )

node	Inversion	Zoom	Save	Print				
anid.	Paramel	ters						
(FIIG	Input initial model							
	Inversion Q3D							
	Trace Ir	nversion						
ш)	Apprais	al inversi	on (Q3E	)) ▶				

Inversion Parameters		
Exit		
Damping factor :	0.07	
Number of iterations :	10	
Data error :	1.00	
Misfit target :	0.20	
C Algorithm S1		
Algorithm S2		
C Algorithm S3		
ОК		

Higher damping factor will smooth the model. Algorithm S1 allows more variability in the model than algorithm S2. Algorithm S3 is for 1D inversion without any spatial constraint (a 1D model of 2 or 3 layers should be selected as initial model for this option).



The Manual option is good for algorithm S3. Automatic and Uniform medium are options that use the default layered model and can be used with care. The user should prepare a 1D model file according his experience and input it.



The start and finishing RMS corresponding to each section will be presented in a table for evaluation.

Exit           Section         Niter         1stRMS         endRMS         Repeat           1         10         38.678         11.212         NO           2         10         54.339         13.051         NO           3         10         46.269         7.004         NO           4         10         30.528         5.312         NO           5         10         44.196         13.629         NO           6         10         49.828         14.097         NO           7         10         46.615         7.693         NO           8         10         27.195         5.508         NO           9         10         47.433         14.822         NO           10         10         46.406         9.566         NO           11         10         46.406         9.566         NO           12         10         32.119         5.150         NO	🔲 Q-3D inversion-Results		
Section         Niter         1stRMS         endRMS         Repeat           1         10         38.678         11.212         NO           2         10         54.339         13.051         NO           3         10         46.269         7.004         NO           4         10         30.528         5.312         NO           5         10         44.196         13.629         NO           6         10         49.828         14.097         NO           7         10         46.615         7.693         NO           8         10         27.195         5.508         NO           9         10         47.433         14.822         NO           10         10         46.406         9.566         NO           11         10         46.406         9.566         NO           12         10         32.119         5.150         NO	Exit		
1         10         38.678         11.212         NO           2         10         54.339         13.051         NO           3         10         46.269         7.004         NO           4         10         30.528         5.312         NO           5         10         44.196         13.629         NO           6         10         49.828         14.097         NO           7         10         46.615         7.693         NO           8         10         27.195         5.508         NO           9         10         47.433         14.822         NO           10         10         46.406         9.566         NO           11         10         46.406         9.566         NO           12         10         32.119         5.150         NO	Section	Repeat	
2         10         54.339         13.051         NO           3         10         46.269         7.004         NO           4         10         30.528         5.312         NO           5         10         44.196         13.629         NO           6         10         49.828         14.097         NO           7         10         46.615         7.693         NO           8         10         27.195         5.508         NO           9         10         47.433         14.822         NO           10         10         46.406         9.566         NO           11         10         46.406         9.566         NO           12         10         32.119         5.150         NO	1	NO	
3         10         46.269         7.004         NO           4         10         30.528         5.312         NO           5         10         44.196         13.629         NO           6         10         49.828         14.097         NO           7         10         46.615         7.693         NO           8         10         27.195         5.508         NO           9         10         47.433         14.822         NO           10         10         46.406         9.566         NO           11         10         46.406         9.566         NO           12         10         32.119         5.150         NO	2	NO	
4         10         30.528         5.312         NO           5         10         44.196         13.629         NO           6         10         49.828         14.097         NO           7         10         46.615         7.693         NO           8         10         27.195         5.508         NO           9         10         47.433         14.822         NO           10         10         46.406         9.566         NO           12         10         32.119         5.150         NO	3	NO	
5         10         44.196         13.629         NO           6         10         49.828         14.097         NO           7         10         46.615         7.693         NO           8         10         27.195         5.508         NO           9         10         47.433         14.822         NO           10         10         46.406         9.566         NO           11         10         46.406         9.566         NO           12         10         32.119         5.150         NO	4	NO	
6         10         49.828         14.097         NO           7         10         46.615         7.693         NO           8         10         27.195         5.508         NO           9         10         47.433         14.822         NO           10         10         46.406         9.566         NO           11         10         46.406         9.566         NO           12         10         32.119         5.150         NO	5	NO	
7         10         46.615         7.693         NO           8         10         27.195         5.508         NO           9         10         47.433         14.822         NO           10         10         48.220         18.146         NO           11         10         46.406         9.566         NO           12         10         32.119         5.150         NO	6	NO	
8         10         27.195         5.508         NO           9         10         47.433         14.822         NO           10         10         48.220         18.146         NO           11         10         46.406         9.566         NO           12         10         32.119         5.150         NO	7	NO	
9         10         47.433         14.822         NO           10         10         48.220         18.146         NO           11         10         46.406         9.566         NO           12         10         32.119         5.150         NO	8	NO	
10         10         48.220         18.146         NO           11         10         46.406         9.566         NO           12         10         32.119         5.150         NO	9	NO	
11         10         46.406         9.566         NO           12         10         32.119         5.150         NO           12         10         51.022         14.052         NO	10	NO	
12 10 32.119 5.150 NO	11	NO	
	12	NO	
13 10 51.022 14.052 NU	13	NO	
14 10 52.740 20.118 NO	14	NO	
15 10 49.663 9.180 NO	15	NO	
16 10 38.728 4.646 NO	16	NO	
ОК			





The final model can be displayed in different ways.











The user can save (mainly the MAP file) and print the results using the Save and Print options in the menu bar.