Assignment of VES application in Breevenen area

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A) Process the borehole descriptions of 12G-B40, 12G-B119 and 12G-B78. Do this by schematizing the given borelog descriptions (known as "log-grouping") so that they can be entered into GEWin-Excel.

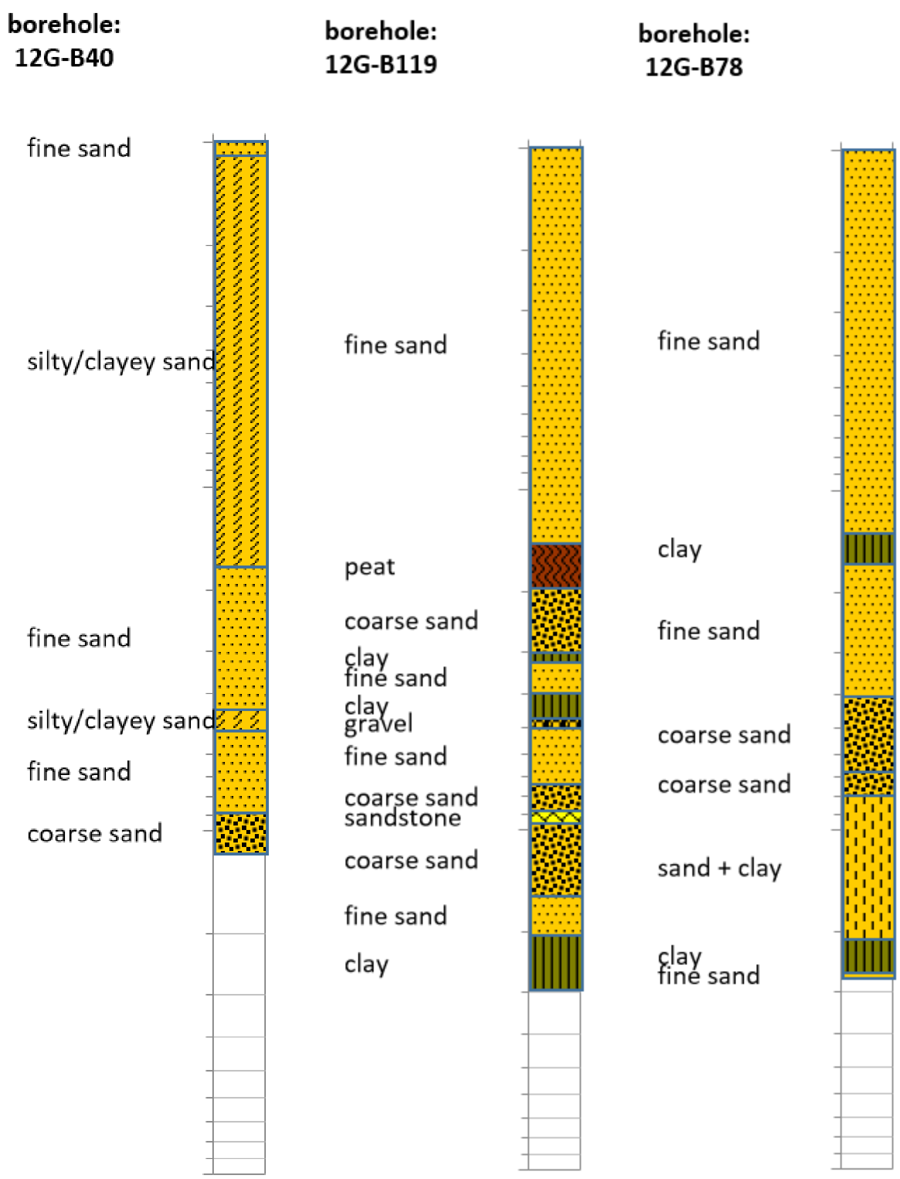

Figure 1. Borelog description of three boreholes

B) Enter the processed (log-grouped) borehole descriptions in GEWin-Excel by presenting them on the borelog-graph, adding the coordinates and name and saving each borelog within the GEWin-Excel database.

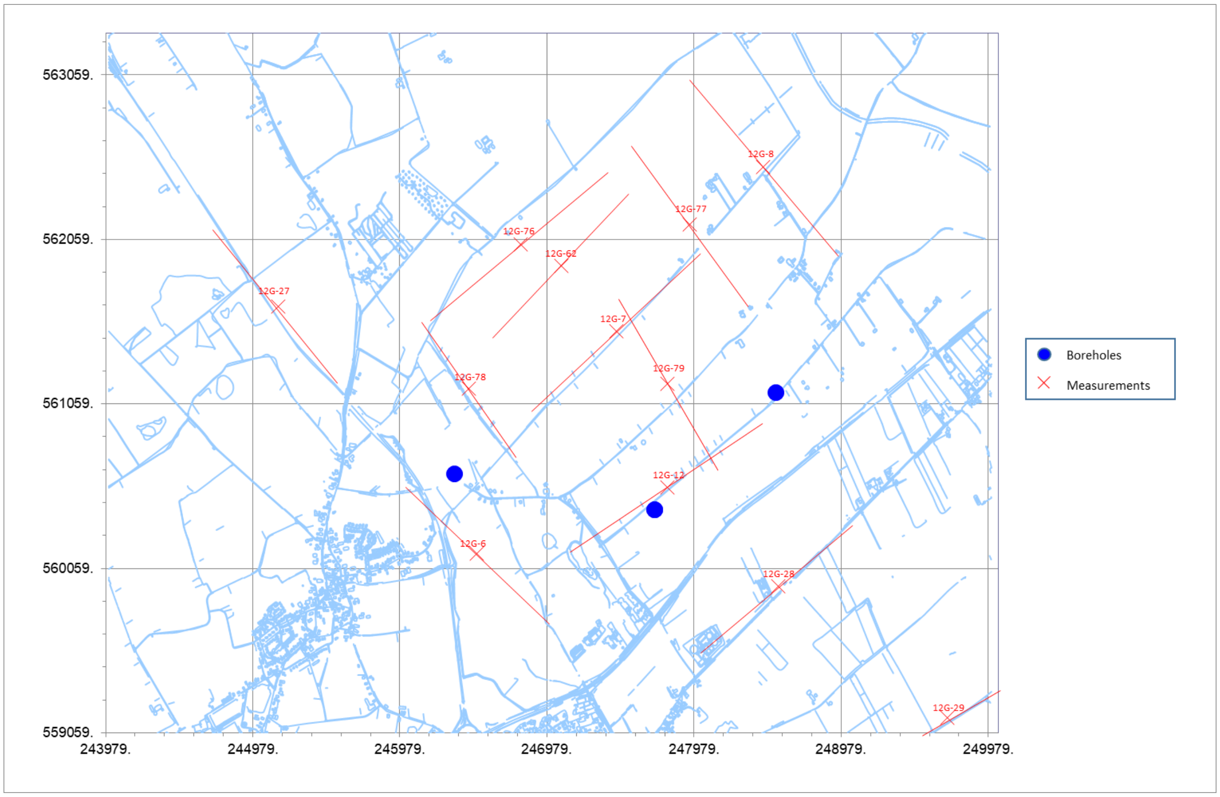

Figure 2. The locations of three boreholes

C) Draw a West-East cross-section through the boreholes in the following order: 12G-B40, 12GB119, and 12G-B78. Post-process the cross-section, using the standard Excel "drawing tools". Connect (known) clay, fine sand and coarse sand layers in the cross-section. Where information is not available in depth, do not continue the lines, or add question marks.

The cross-section is shown in Figure 3 below through three boreholes. It reflects the distribution of rocks in this section. From the borehole exploration giving information, we can identify there are mainly four layers in this area. The first one is the layer of fine sand, the second one is coarse sand, and the third one is also fine sand. Finally, the last layer is the layer of marine clay. And at the west part with high elevation, there are some fine rocks (clay or silt) over the top layer of fine sand. However, some parts unavailable to determine the lithology still exist, which are labeled by the marks in the figure. The depth of borehole logging 12G-B40 is too shallow to reach the thick layer of marine clay. Thus, the lithology of the rocks, which are below 100 meters in the west part, cannot be identified. Moreover, at the location of borehole logging 12G-B119, there are some peat, coarse sand, and clay layers in the first fine sand layer, while these layers do not occur in the other two boreholes. The lithology of this part cannot be identified only by the geophysics surveying method. A thin clay or peat layer is possible to exist in this part. Another situation is just some clay mixed in the fine sand layer.

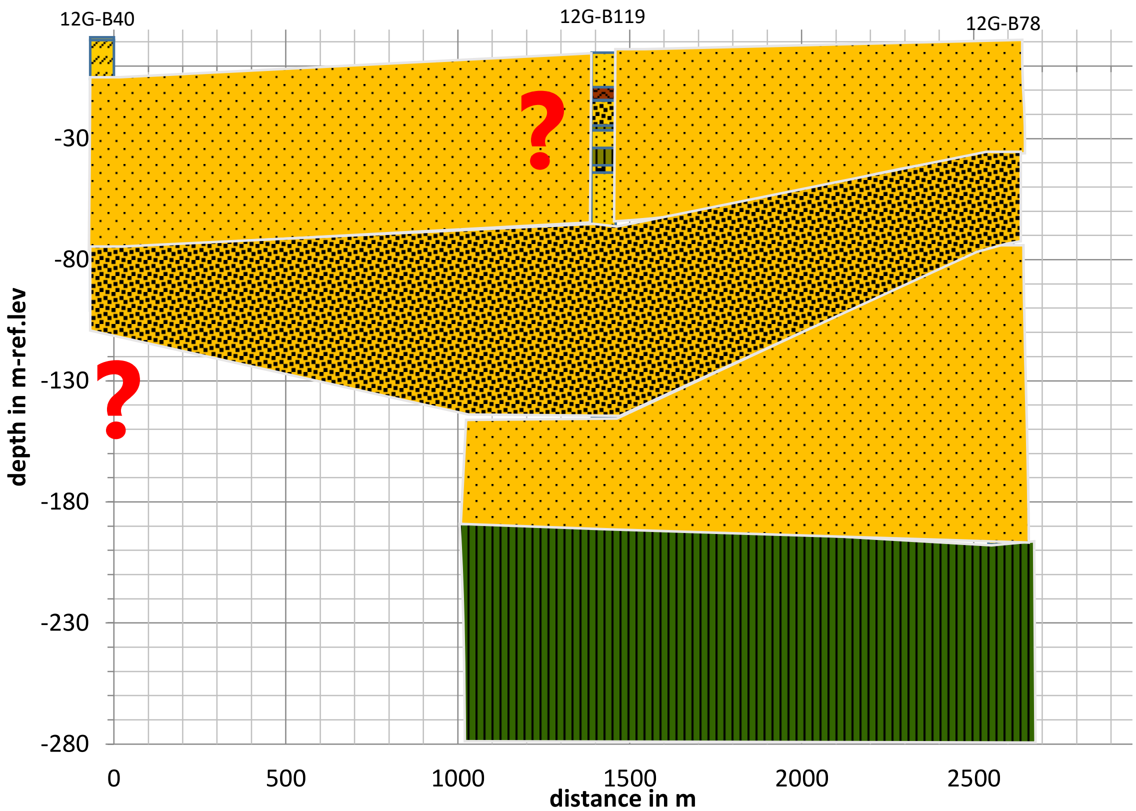

Figure 3. West-East cross-section through three boreholes

D) What value will you use for the end-resistivity in the VES models? Why will you use this value?

The value I used for the end-resistivity is 2Ωm in the VES models.

It is known that the geo-hydrological base of Breevenen is a thick layer of marine clays. Since these clays have been deposited in a marine environment, they are saline. As we know, the saline water conducts electric currents fairly well. And the formation resistivity of the clay layers is much less than the formation resistivity of the overlying sand layers. Therefore, the combination of salinity and clay results in the end-resistivity of 2 Ωm.

E) For each of the three borehole descriptions try to estimate some of the formation resistivities based on the available data. Include the grouped boreholes and estimated resistivities in a table in your report and briefly explain why you included or neglected certain layers and how you estimated the resistivity. For 12G-B119 also use the geophysical well log of the borehole given in Annex 8.

The principle of including or neglecting layers is to keep the lithological characteristics of the subsurface soil. So I keep the obviously gathered similar soil as layers, and include the obviously changed layers, such as the gravel layers at 45-48 meter depth in the B119 borehole because it cannot lose any information in this group procedure. And some details will be neglected due to the equivalence and suppression in the procedure of interpretation of the VES models. The information from measurement should be maintained in this part. But some similar soil should be grouped together to form layers, such as when a very thin layer of clay occurs between two thick fine sandy layers, the three layers should be grouped as a layer of fine sand.

The method of estimating resistivity is translating the electrical conductivity of pore water to the formation resistivity. The EC value of pore water, which is obtained from other measurements, can translate to the resistivity of pore water. And then, this resistivity multiplying the formation factor results in the estimation formation resistivity of layers. Meantime, for 12G-B119, the resistivity can be reached by reading the geophysical log figure directly. While for 12G-B40, there are no available data to estimate the formation resistivity, thus here I estimate it based on thumb rules. The results of grouped boreholes and estimated resistivity are listed in Table 1.

Table 1. Grouped boreholes and estimated resistivity

Borehole	**Top**	**Bottom**	**Main type of sediment**	**Estimated resistivity**
	m-SL	m-SL		
B40	0	1.1	fine sand	60-120
	1.1	16.6	silt sand	20-80
	16.6	42.5	fine sand	60-120
	42.5	49	silt sand	20-80
	49	84	fine sand	60-120
	84	110	coarse sand	120-160
B119	0	14	fine sand	70-110
	14	19	peat	20-100
	19	29	coarse sand	100-160
	29	31	clay	20-80
	31	38	fine sand	80-120
	38	45	clay	20-80
	45	48	gravel	100-200
	48	70	fine sand	100-180
	70	83	coarse sand	100-180
	83	91	sandstone	160-200
	91	147	coarse sand	100-160
	147	192	fine sand	80-120
	192	276	clay	2
B78	0	13	fine sand	60-120
	13	16	clay	20-80
	16	39	fine sand	60-120
	39	64	coarse sand	120-160

64	75.5	coarse sand	100-140
75.5	196.5	sand + clay	20-80
196.5	245	clay	2
245	255	fine sand	-

F) Interpret geo-electrical (VES) measurement 12G-6, based on the log-grouped lithological sketch of borehole 12G-B40 that you can add underneath the GEWin graph of the VES.

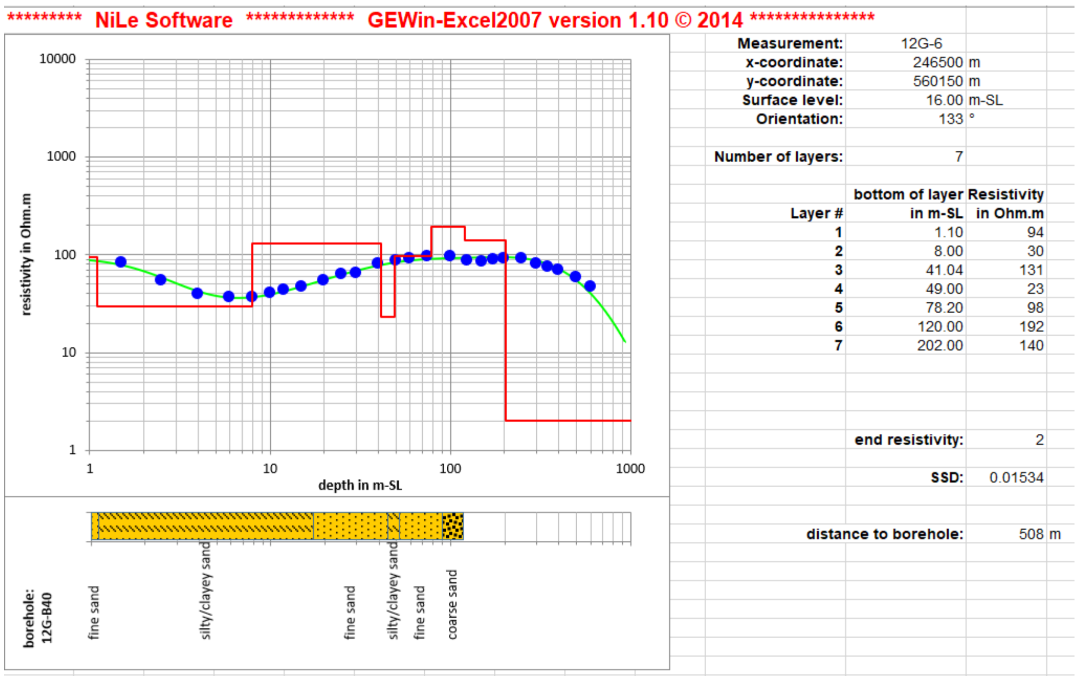

Figure 4. Interpretation of geo-electrical measurement 12G-6

G) Now interpret geo-electrical measurement 12G-78. Load the geo-electrical model for geoelectrical measurement 12G-6 as an initial geo-electrical model for this measurement. Which borehole log will you add for comparison?

Since borehole 12G-B40 is the nearest borehole of the measurement site 12G-78, 12G-B40 is carried out for comparison.

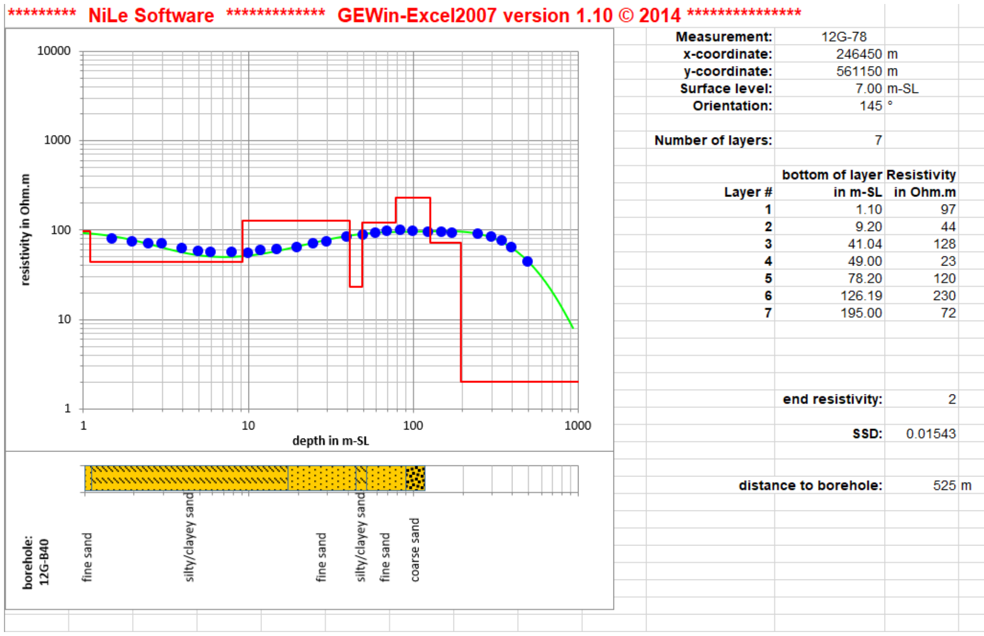

Figure 5. Interpretation of geo-electrical measurement 12G-78

H) Interpret geo-electrical (VES) measurement 12G-12 based on the log-grouped lithological sketch of borehole 12G-B119 that you can add underneath the GEWin graph of the VES.

To keep the detail information of lithology, I divide the soil into a lot of layers. However, in the interpretation of geo-electrical measurement due to the equivalence and suppression influence, the layers will be combined, and the number of layers will decrease. In this interpretation, the difference between the peat layer and the coarse sand layer is neglected.

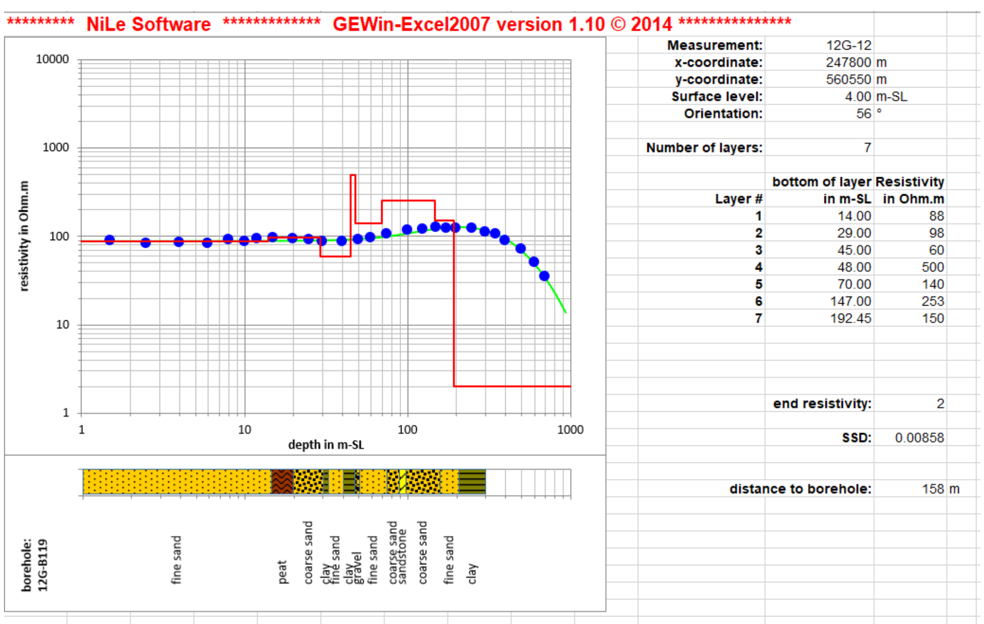

Figure 6. Interpretation of geo-electrical measurement 12G-12

I) now interpret geo-electrical measurement 12G-7. See if you would like to start with any previously built geo-electrical model and/or add any borehole log.

The nearest borehole log for 12G-7 is 12G-B119. Thus, start with the previously built model for 12G-12 and compare with borehole ‘hard’ data from 12G-B119.

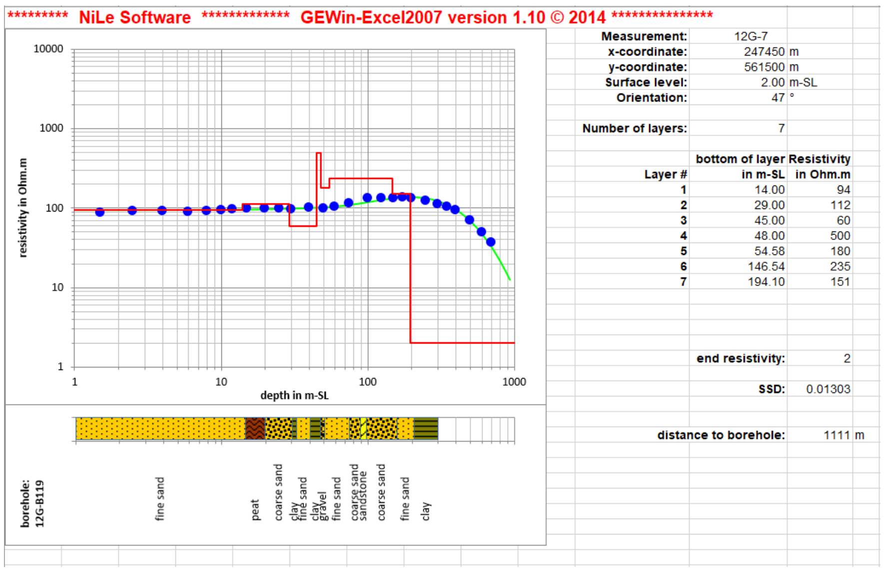

Figure 7. Interpretation of geo-electrical measurement 12G-7

J) Next, interpret geo-electrical measurement 12G-27. See if you would like to start with any previously built geo-electrical model and/or add any borehole log.

The site of 12G-27 is far away from any previously built models or boreholes. And the field resistivity of this site is very high. It indicates 12G-27 is located on an area with unsaturated subsurface. Synthesizing all the information, no model and borehole are added into this interpretation.

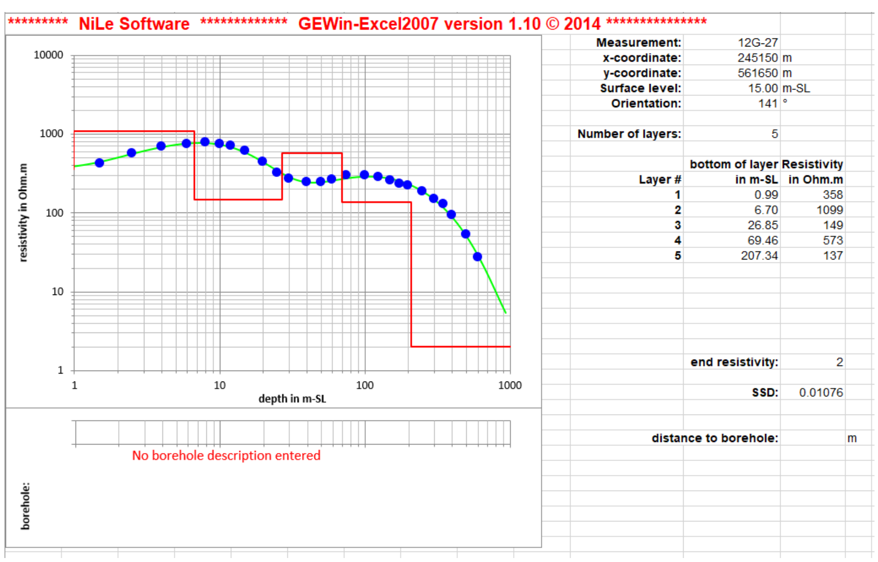

Figure 8. Interpretation of geo-electrical measurement 12G-27

K) Finally, interpret geo-electrical measurements 12G-28. See if you would like to start with any previously built geo-electrical model and/or add any borehole log.

The nearest borehole log for 12G-28 is 12G-B119. Thus, start with the previously built model for 12G-12 and compare with borehole 'hard' data from 12G-B119.

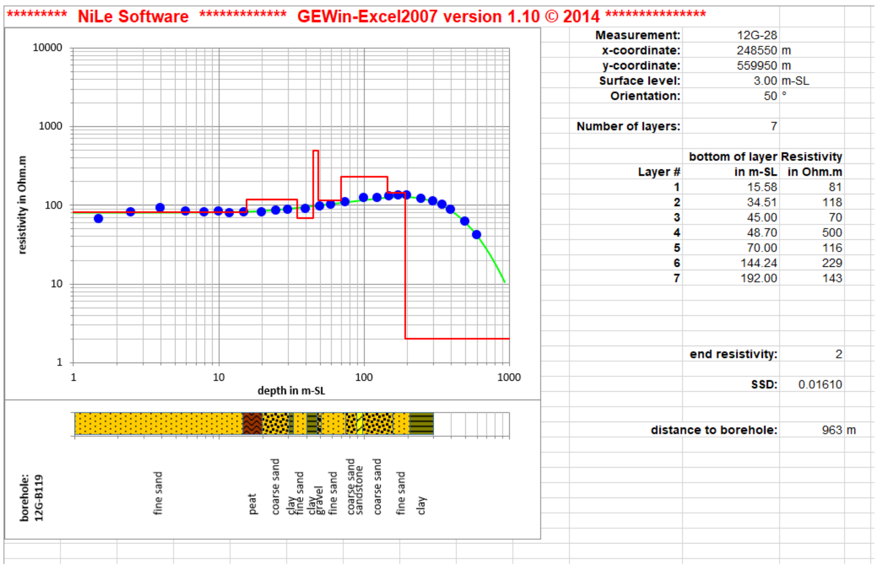

Figure 9. Interpretation of geo-electrical measurement 12G-28

L) Create a map of the geo-electrical base in meters minus NAP (i.e. mean sea level), based on the interpreted VES and borelogs. Check the map for measurements that disturb a smooth and logical geo-hydrological pattern. Redo the interpretation of the measurements that disturb the pattern (in other words, you are now in the "redo-loop" of the interpretation procedure; in reality you would do this for all layers). When you are satisfied with the results (i.e. the map shows logical patterns) you are ready. You are asked now to enter the final map in your report and briefly comment on the obtained results.

The final smooth and logical map is shown in Figure 10. This is a contour map of the geo-hydrological base in the study area. This contour map is based on the interpolation values by the Kriging method. It should be noted that borehole 12G-B40 is not applied for interpolation since the shallow depth of this borehole cannot identify the depth of the marine clay layer. Totally, this resulting map is smooth, and the trend of hydrological base elevation change is consistent with the surface topography, which is higher in the southwest part and lower in the northeast part. And the contour map performs well near the two boreholes, which are considered the actual values of the base layer elevation. The lack of data will increase the error of the Kriging method. Therefore the worse performance of this figure occurs in the northeast part of the area, which is a lack of data, especially the borehole data. In conclusion, the smooth and logical pattern indicates the rationality of the interpretation of geo-electrical measurements.

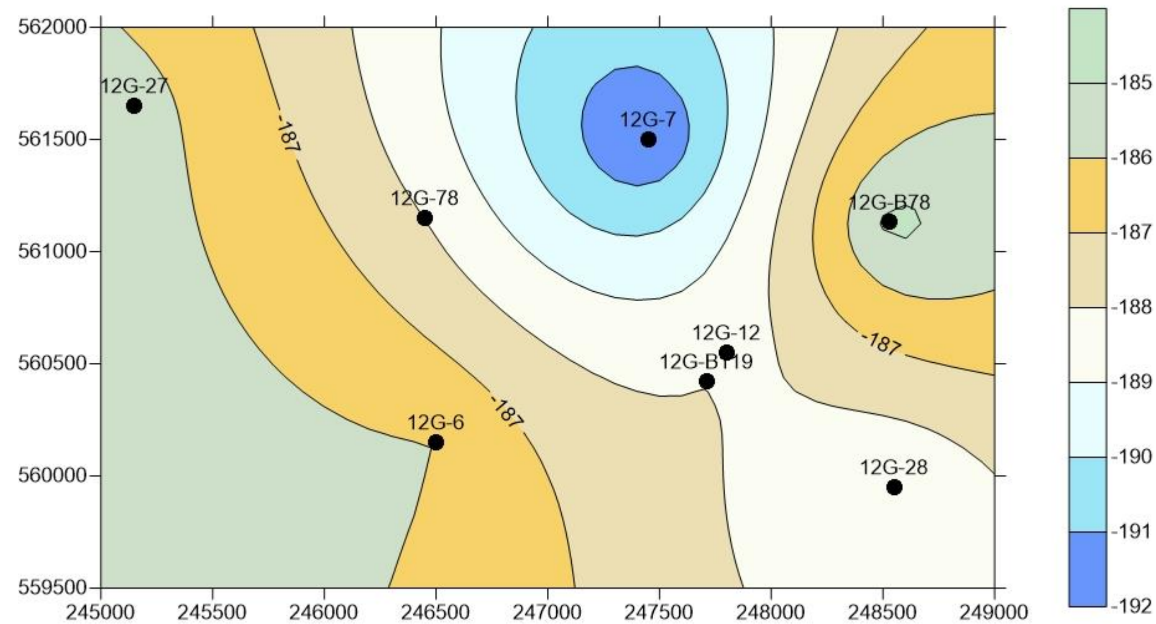

Figure 10. Contour map of geo-electrical base

M) Draw a West-East cross-section through the interpreted geo-electrical measurements and boreholes in the following order: 12G-27, 12G-B40, 12G-6, 12G-B119, 12G-12 and 12G-B78.Post-process the cross-section, using the standard Excel "drawing tools". Connect (known) clay, fine sand and coarse sand layers in the cross-section and indicate the geo-electrical/geo-hydrological base. Where information is not available in depth, do not continue the lines, or add question marks. Briefly comment on the results.

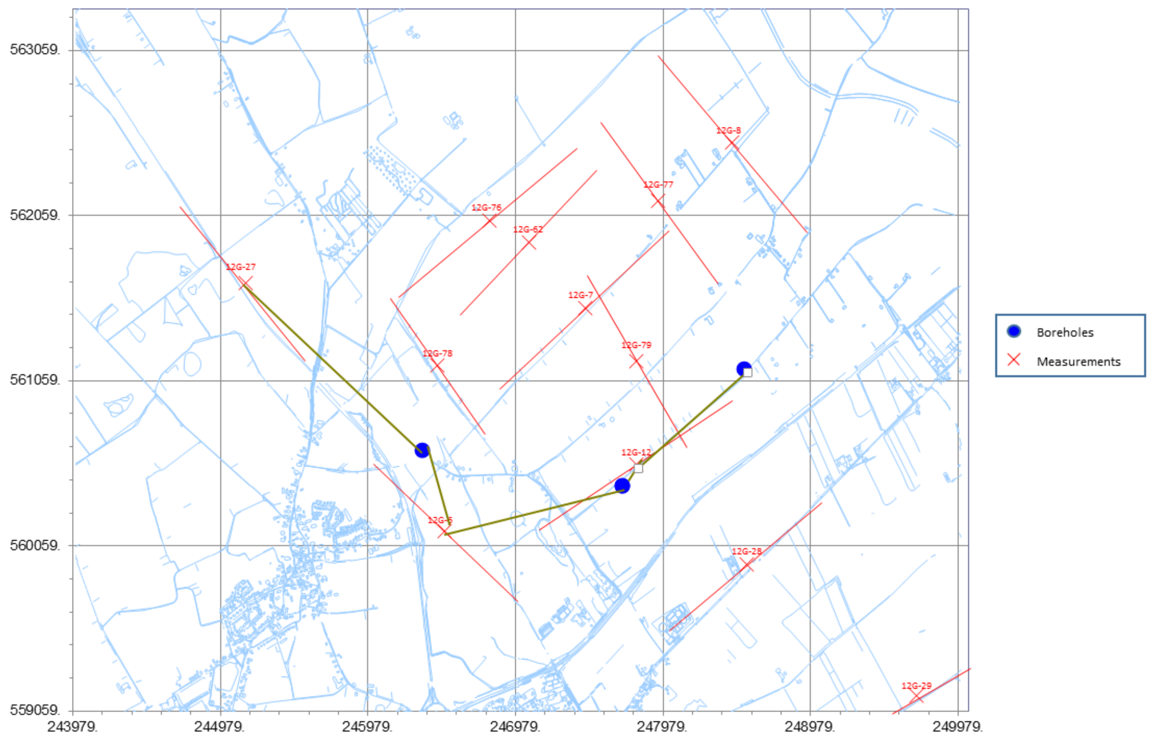

Figure 11. The locations of measurements and boreholes in the west-east section

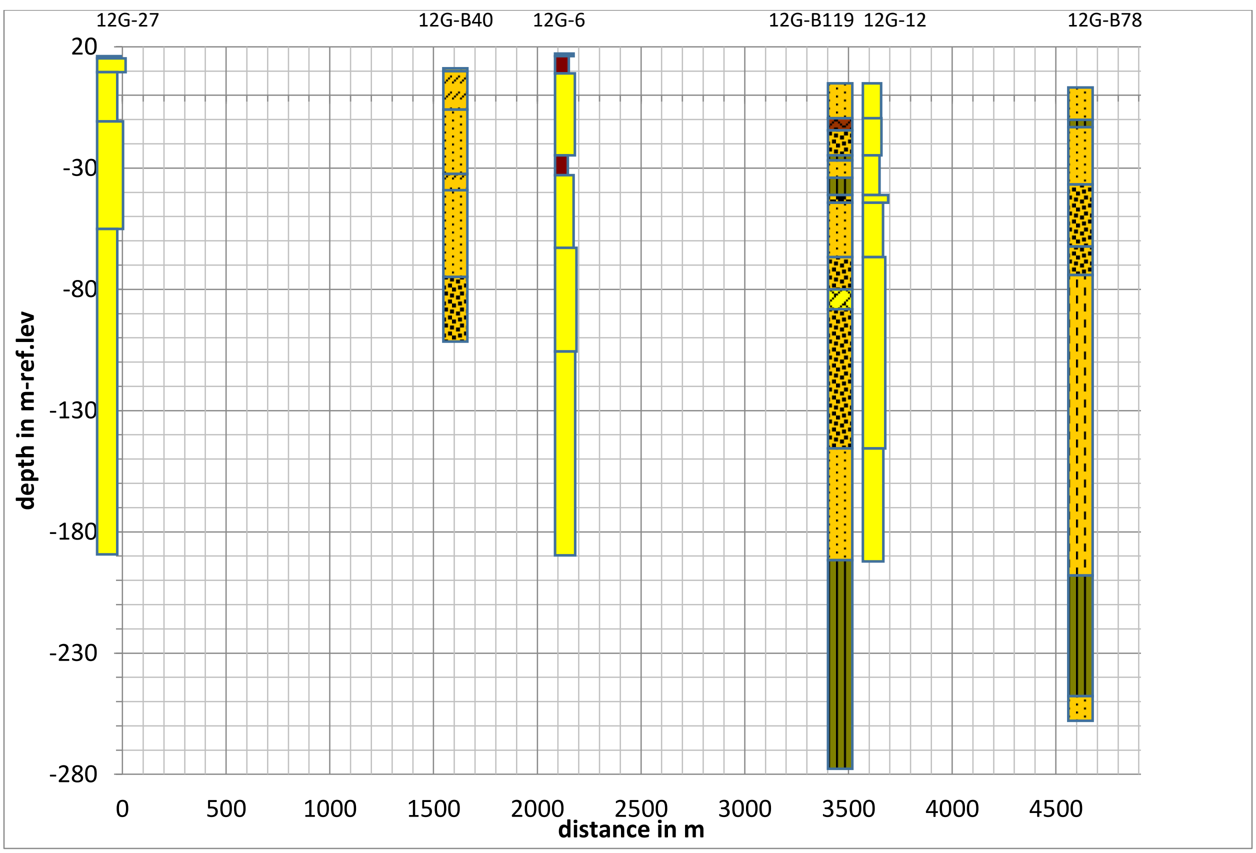

Figure 12. The resistivity and lithology in the west-east cross-section

The above two figures present the location and cross-section of the west-east section line. And Figure 13 shows the interpretation results after combing the geo-electrical measurement results and all the ‘hard’ data. The total distribution of rocks is similar to the distribution given in question c before interpreting the VES values. The top layer and third layer are the fine sand layer, the second layer is the coarse sand layer, and the base layer is the marine clay layer. Uncertain clay layer in the top fine sand layer can be identified through the measurement values. However, there are still some uncertain components in the subsurface soil. The first one is that the coarse sand and peat at 12G-B119 is still strange. I guess they are just some mixture between the sand and clay layer. This is not a big problem for the whole section. Another two problems are more important. Since the soil at 12G-27 is unsaturated, the divide between fine sand and coarse sand is difficult to identify. Therefore my recommendation is to identify the layers accurately the borehole logging near 12G-27 should be carried out. The last problem is the remaining problem of the lack of borehole 12G-B40 data under 100-meter depth. The recommendation is increasing the logging depth in 12G-B40.

From the hydrogeology perspective, the water level in this area is very shallow, because the formation resistivity reflects the most part area is saturated area. The only one unsaturated area is at 12G-27. This may be because 12G-27 is not at the discharge part of this aquifer, while other sites are at the discharge part, which is consistent with the topology indicates the front mountain area is the discharge area.

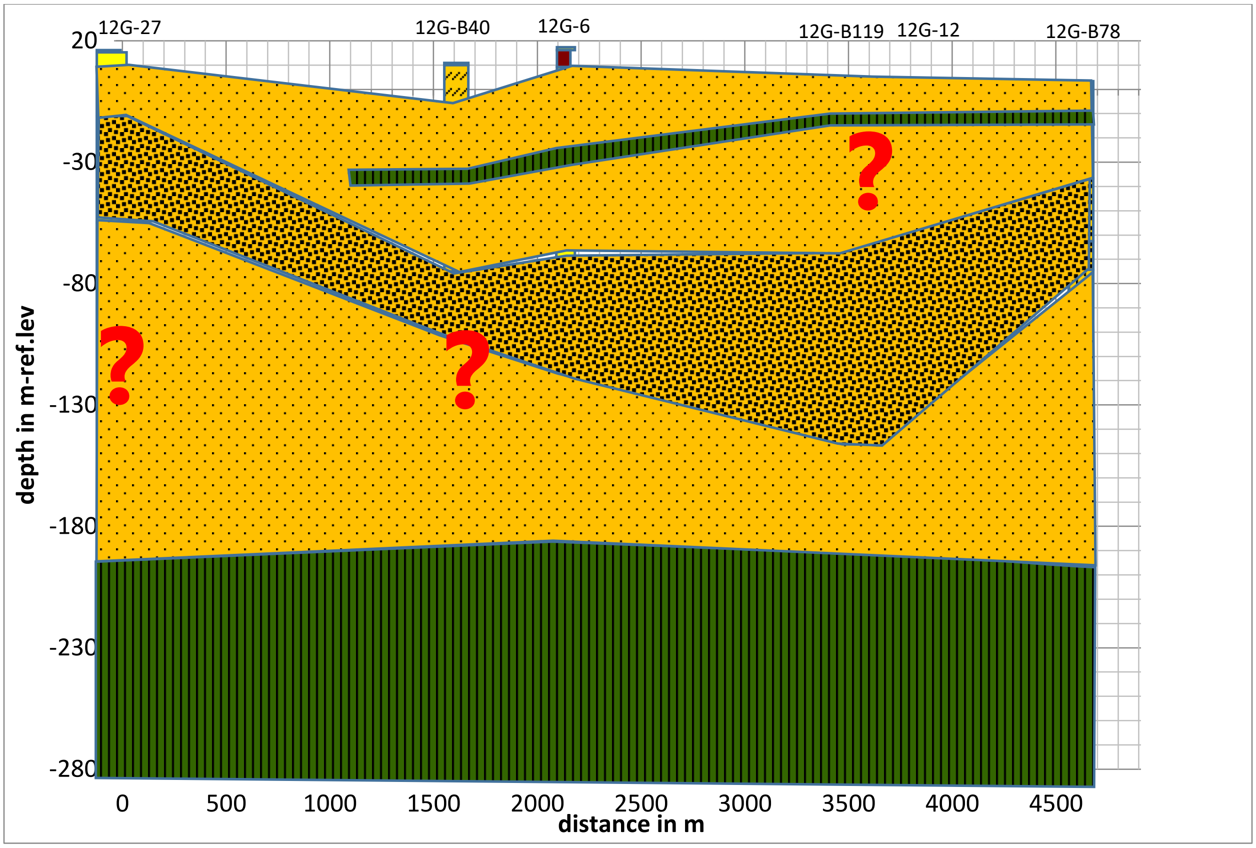

Figure 13. The interpretation of the west-east cross-section

N) Prepare a calibration table for the study area.

Combining all the available data, including VES values, all 'hard' data, and pore water resistivity data, the 'one to one' relationship between rock type, formation resistivity, and formation factor can be established. And the relationship between rock type and formation resistivity is influenced by the water content. All the relationship is listed in Table 2, which is called the calibration table. In the forward study and project, the calibration table is used to identify the type of rock during the geo-electrical survey without specific borehole logging. The calibration table below still needs to be improved by solving the problems above. Actually, the more borehole used for establishing the calibration table, the calibration table is more accurate.

Table 2. The calibration table for Breevenen area

Rock type	Water content	Pore water	Formation resistivity	Factor
Fine sand	Saturated	30-40	60-150	3-5
Coarse sand	Saturated	30-40	140-240	5-6
Clay	Saturated	30-40	<45	<2
Marine clay	Saturated (saline water)	-	2	-
All	Unsaturated	-	>500	-
Gravel	Saturated	-	>500	-