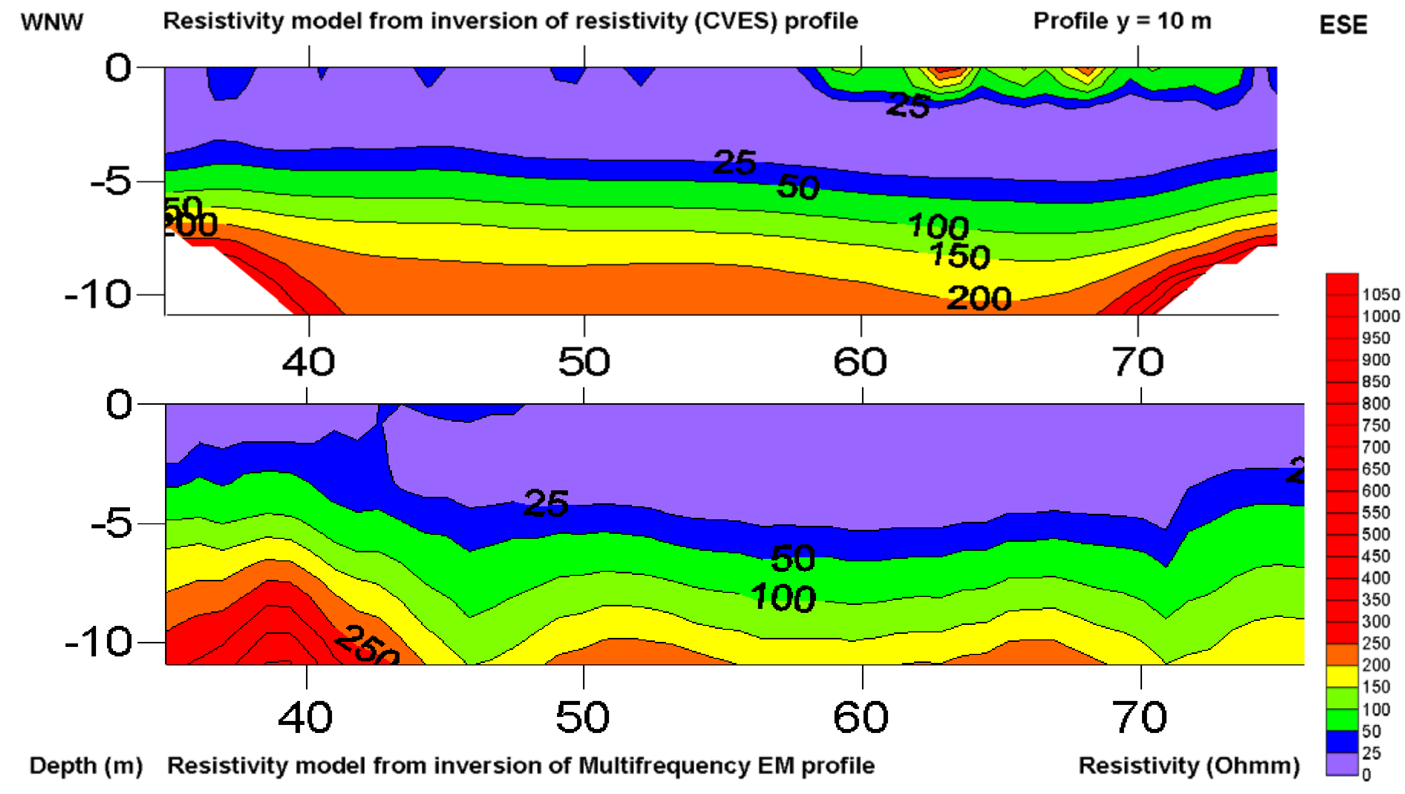
GMD

GMD - Geo- & MiljöData

Geo- & Environm.Data

Modelling of multi-frequency EM and resistivity profiles in a conductive waste



Guy C de Caprona

www.gmd.se

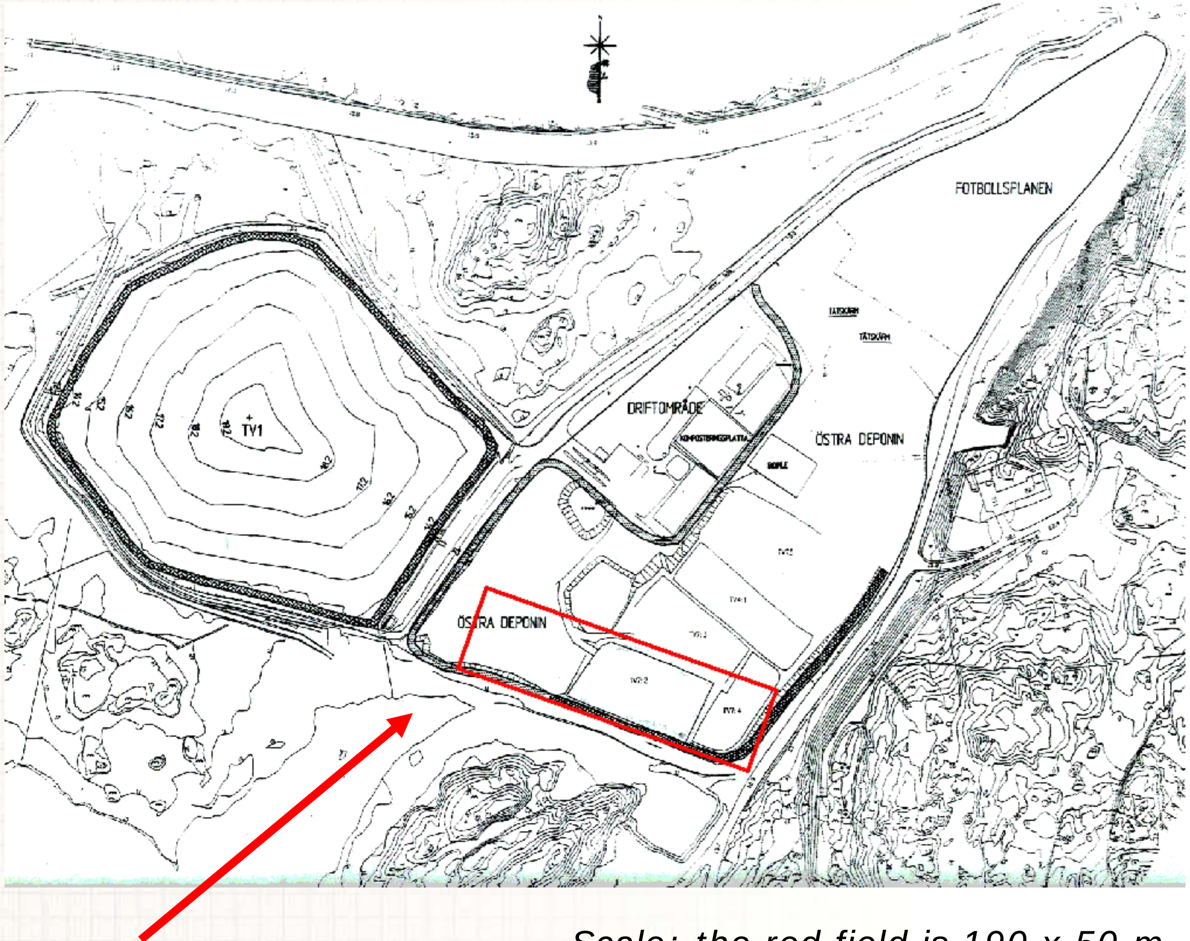
2004

Objective

In inversion modelling of multi-frequency electromagnetic (EM) data, models are constructed providing an EM field as close as possible to the measured data.

GMD is currently carrying out inversions in various geological environments to assess the depth of penetration, the resolution and accuracy (conductivity, suscep-tibility and layering). In the present example, modelling of EM data is compared with the inversion results of resistivity soundings.

The objective is to quickly carry out volume mappings of layerings, depth to bedrock and the case may be, soil or gound water contaminations.

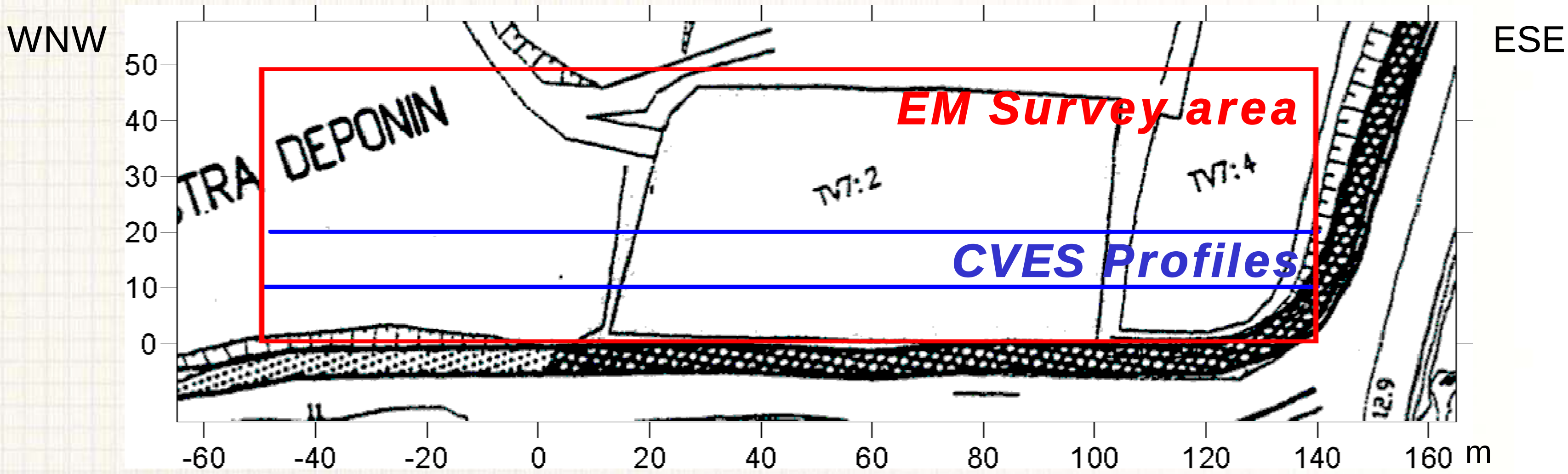


Scale: the red field is 190 x 50 m

At the Torsviken waste landfill in Göteborg the red rectangle was chosen as compartment TV7:2 was expected to contain conductive material from the car industry.

The survey was carried out in July 2004 and consisted of a multi-frequency electromagnetic surface mapping and of two continuous vertical electrical soundings (CVES).

Description of the surveys



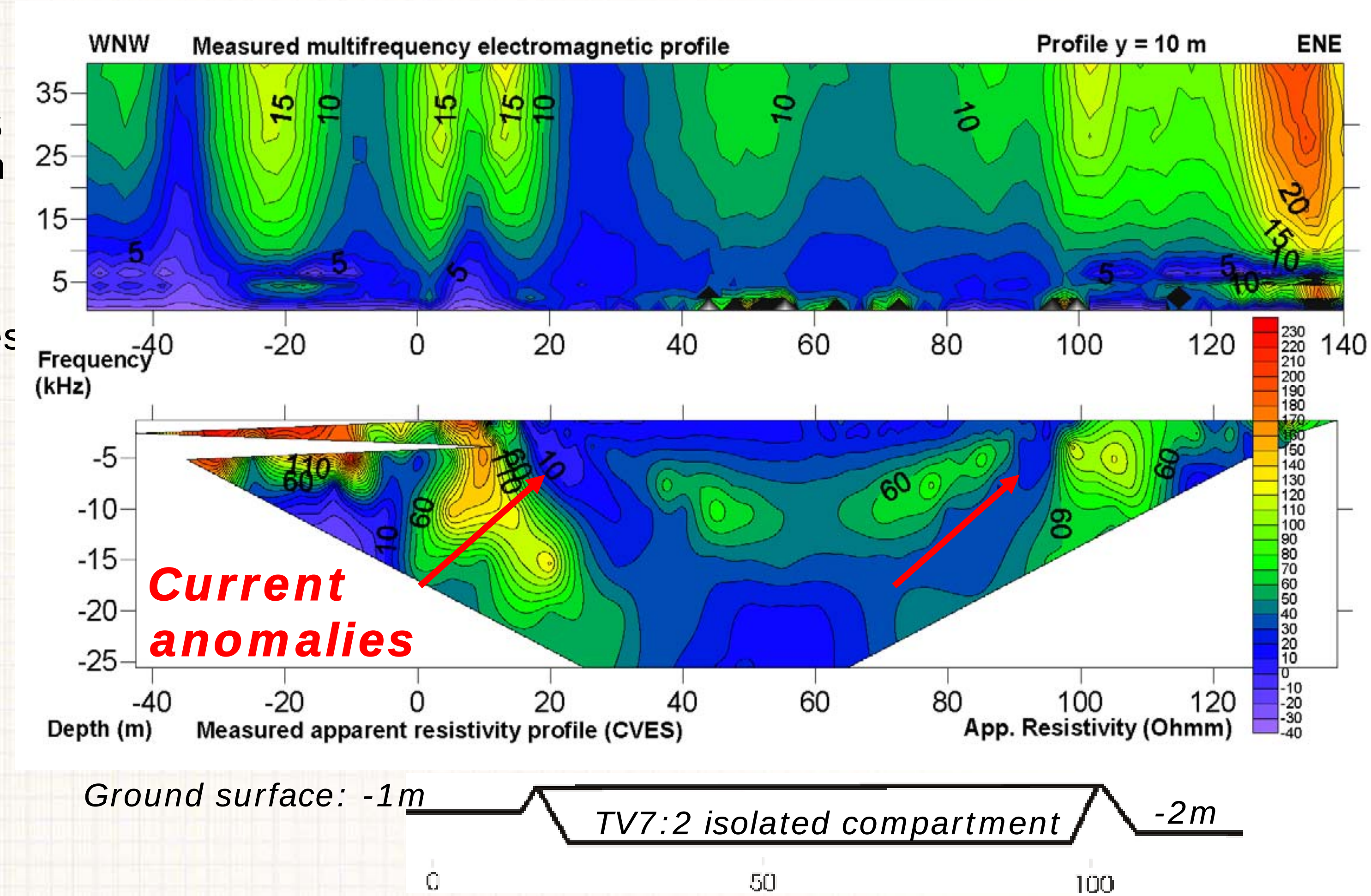
- The EM equipment used was a frequency domain instrument GEM-2 from Geophex (see description). The area was surveyed in two runs with frequencies chosen to obtain an even spreading of the logarithm of the induction number: first run 0.6-5 kHz (575, 925, 1 775, 3 175, 5 325); second run 5-40kHz (5 325, 10 025, 16 775, 27 275 och 39 775 Hz).

- A Terrameter SAS4000 from ABEM was used for the resistivity profiles with two configurations: a Wenner short (2.5 m electrode separation) for a detailed resolution to 10 m and and a Wenner long (5m separation) for penetration up to 60 m depth.

- The electromagnetic survey area is shown in red with a line separation of 2 m in the WNW-ESE direction and of 10 m in the ENE-WSW direction. The two resistivity profiles (y= 10 och 20 m) are shown in blue.

Pseudo-profiles, line 10

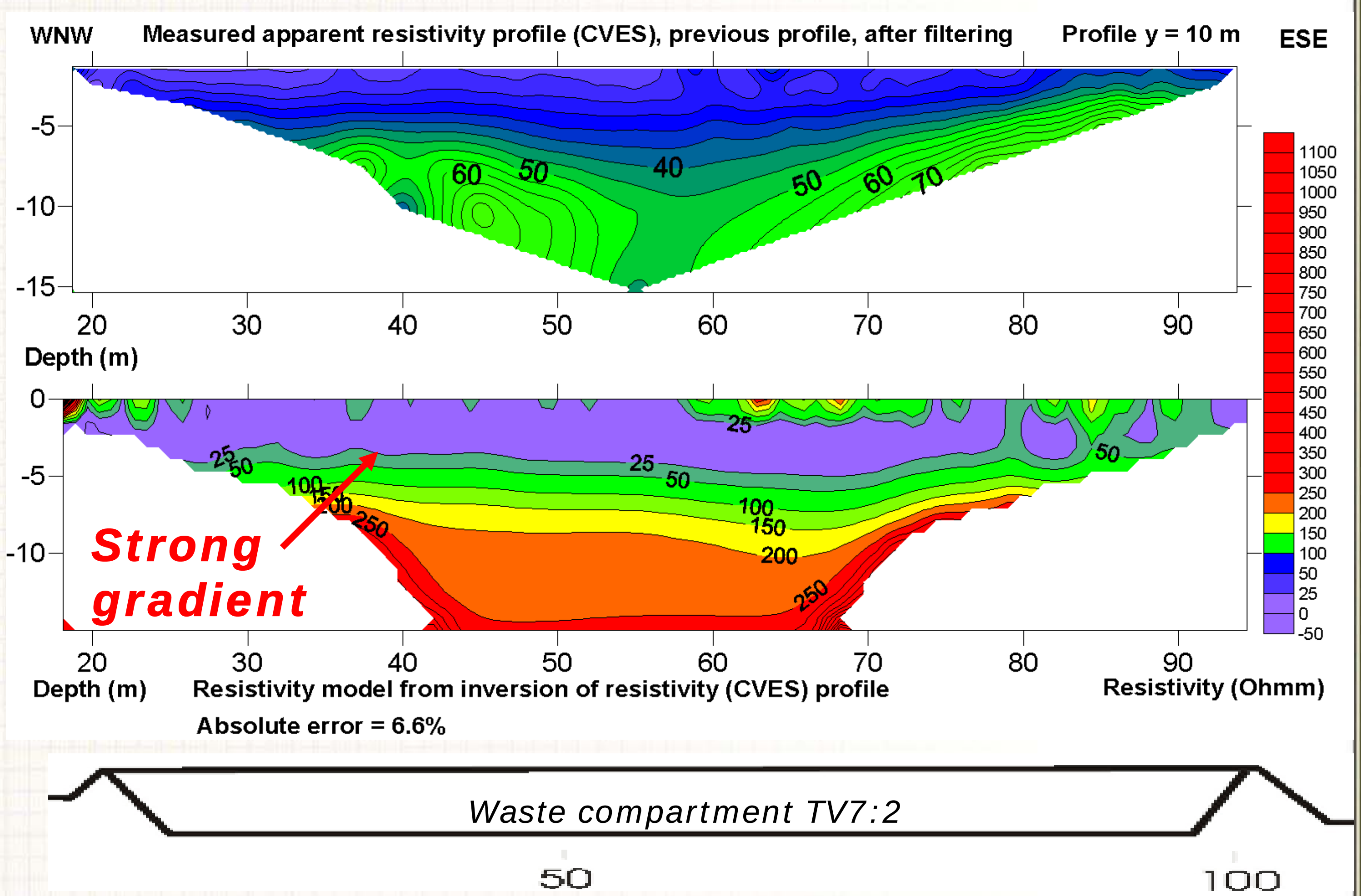
- The apparent resistivity profiles, top EM (vert. axis in frequency), CVES underneath (vert. axis in m) and an approximate topography profile, bottom.
- The EM and CVES profiles are coherent, showing anomalies at the same surface location: weak over the landfill, strong at the edges
- The EM profile shows a weakening of the readings under 5 kHz (the first run with low frequencies is more power consuming)



- The CVES profiles show strong so called current anomalies where the rubber isolation sheet comes to the surface between or close to the current electrodes and alters the current density. These anomalies overlay readings in the resistive material outcropping at the edges of the landfill compartment. These current anomalies could not be properly filtered so only the central part of the profile is inverted. The topography is not included in the profile with 1 m denivellation at the western and 2 at the eastern end.

Inversion of resistivity profile 10

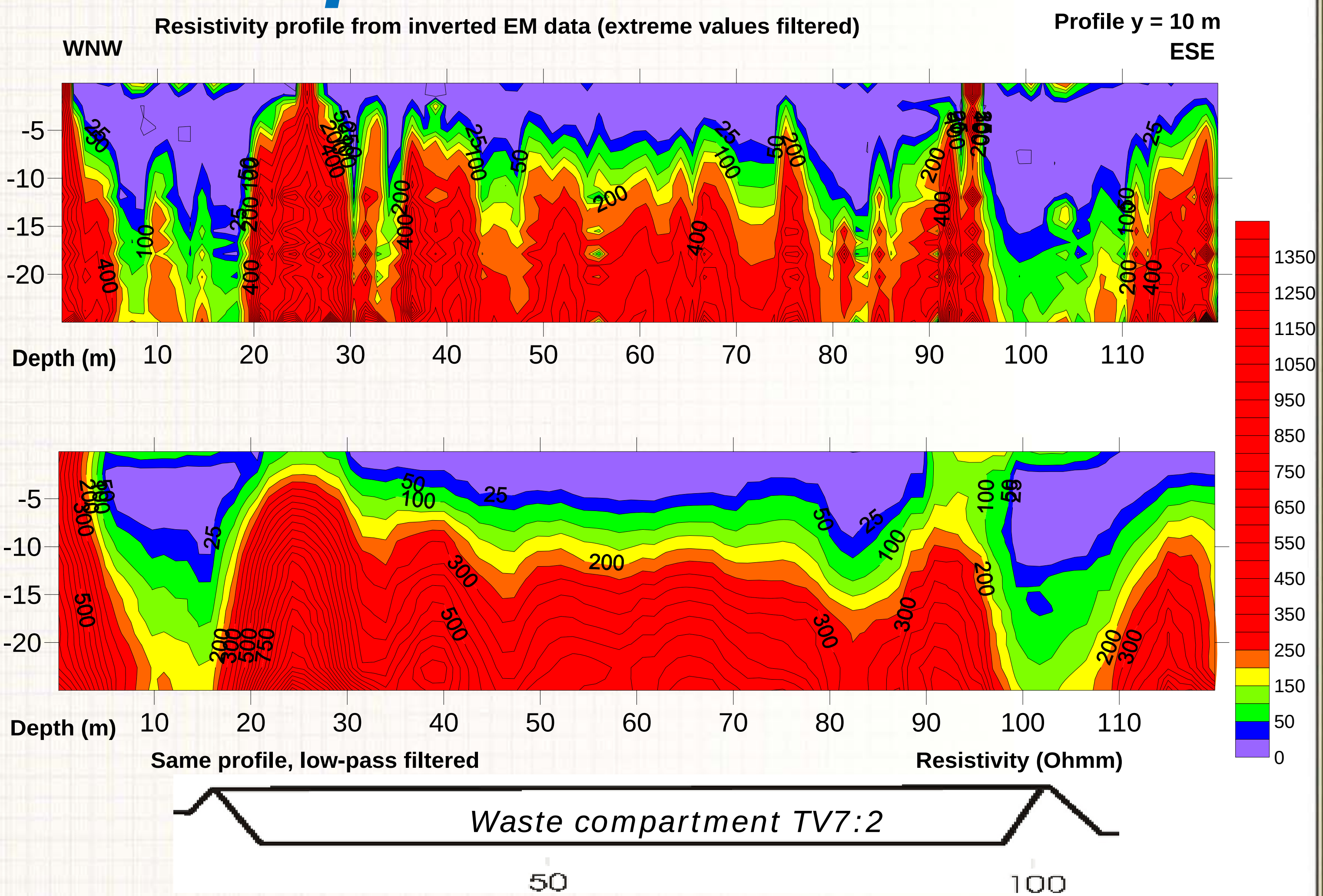
- The apparent resistivity after editing and filtering, top, an inversion modell underneath. The profiles have the same scale.
- In the central part of line 10, good quality inversions could be obtained after correcting for the remaining anomaly effects: a strong resistivity gradient of a few meters thickness at some 5 m depth under an upper layer of 0-25 ohmm and over soils of a few hundred ohmm. At the surface a few high resisitvity spots.



- The strong gradient coincides with the isolation material under the landfill.
- After correction for the current anomaly effects, the topography of the bottom of the landfill is flattened at its edges, at 20 and 80 m.

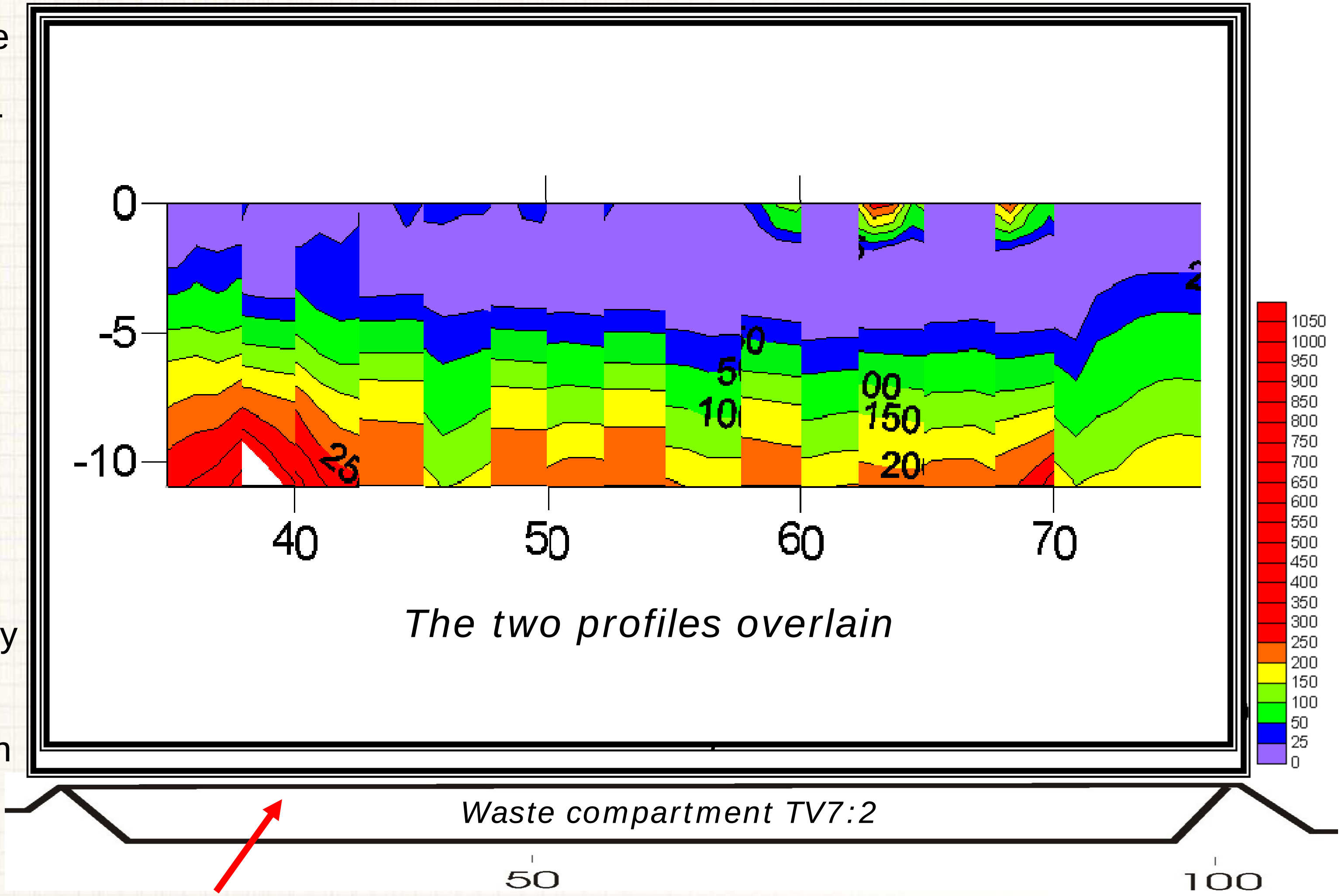
Inversion of EM-profile 10

- The secondary EM field is controlled by the electric conductivity and magnetic suscepti-bility of soils. Both pro-perties are modelled when carrying out inversions.
- Top, inverted EM profile with a so called General Cross Validation criteria. Underneath, same profile after low-pass filtering. The profiles have the same scale in ohmm.
- Bottom, the approx. 5 m thick landfill com-partment.
- The inversion shows a low resistive layer (0-25 ohmm) between 5 and 10 m thick and underneath a strong gradient down to 25 m. The extent of the low resistive layer coincides with the lanfill compartment. The depth seems to increase towards its eastern end.
- The low resistive areas West and East of the compartment do not seem to be caused by the denivellations (see maps on slide 10)



Comparison between CVES and EM inversions of profile 10

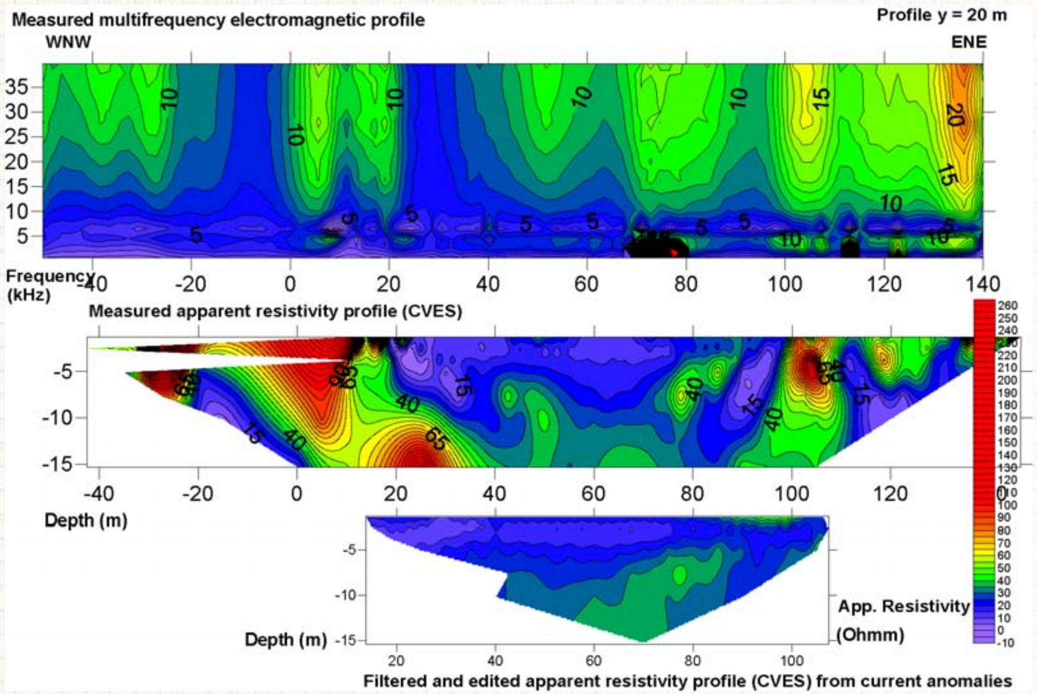
- Inversion model of the resisitivity profile, top and of EM data underneath. The scale is common.
- Both models display between 35 and 75 m a comparable upper layer of 0-25 ohmm, underlain by a strong gradient.
- At the western and eastern edges of the landfill compartment, the apparent resistivity of the CVES profile showed a pinch-out but the filtered version is strongly flattened does not show the same dips as the EM.

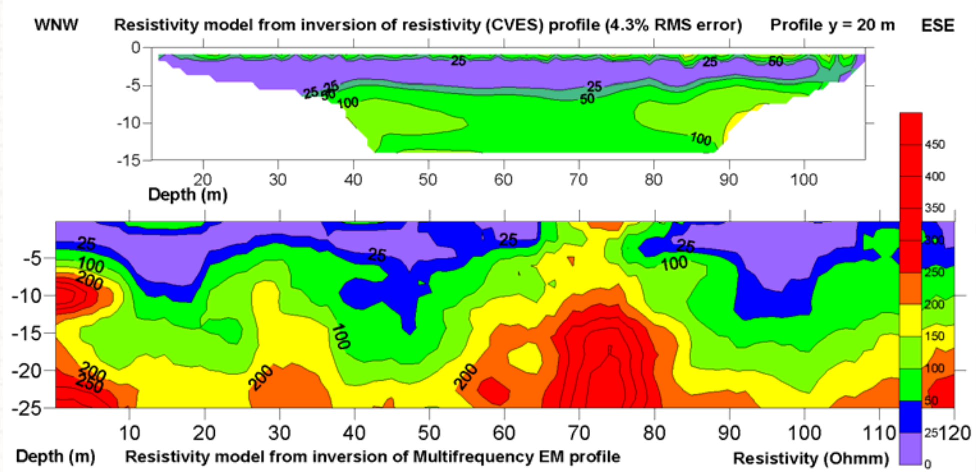


The two profiles overlain

- Within the limited stretch 35 –75 m, the correlation is good for the layer of low resistivity and the underlaying gradient to approximately 10 m.

Comparison between CVES and EM inversions of profile 20





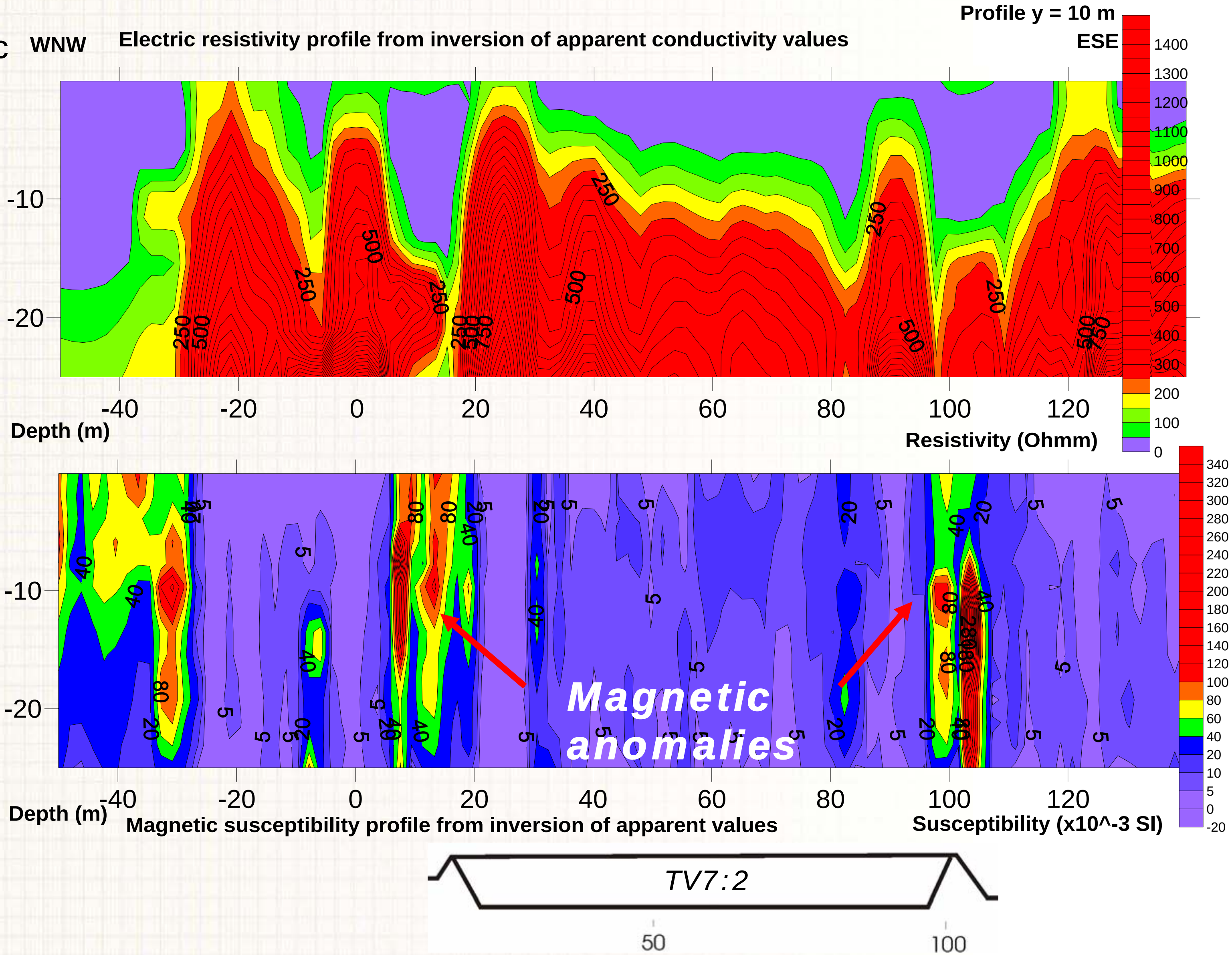
Left: Pseudo-sections

Right: Inversion models

- <u>Left</u>: Pseudo-profiles of apparent resistivity, EM top, complete CVES profile underneath and reduced to its central part and filtered for current anomalies, bottom. Common scale. Similar current anomalies are visible as in profile 10.
- <u>Right</u>: Inversion models of the resistivity profile, top (4.3% RMS error) and same EM profile under. Except for the low resistive surface layer (0-25 ohmm), the match between the models is not as good as in line 20.
- In the EM data only, this layer thins out at the compartment edges at 20 and 100 m. The resistive material subcrop at 70 m is indicated in the apparent resistivity section and in the previous section. In the CVES model, the subcrop is flattened after correcting for current anomalies.

Inversion of el. cond. & magn. susc.: Profile 10

- Lower profile: Magnetic susceptibility anomalies at the compartment edges and at the western end
- The magnetic anomalies at the edges of the landfill compartment correspond to those on the resistivity profile.
- There appears to be a mutual influence at extreme values: at high resistivity values, the susceptibility is close to zero and vice versa.
- As expected, the penetration does not go beyond the conductive surface layer.



Compilation of EM 1D inversions

- The inversion modelling is carried out over the entire surveyed area. The isodepth maps, right, have the same scale as the profiles. They are edited for extreme values (>2500 ohmm) and low-pass filtered.
- The compilation of the inversions show a good lateral coherency.
- The low resistivity surface layer (0-25 ohmm) extends down to 5 m and along the compartment edges to 7 m, locally to 10 m depth. At the western end, the layer stretches down to beyond 10 m.
- The small steeps of 1 and 2 m at the edges of compartment TV7:2 do not cause noticeable anomalies

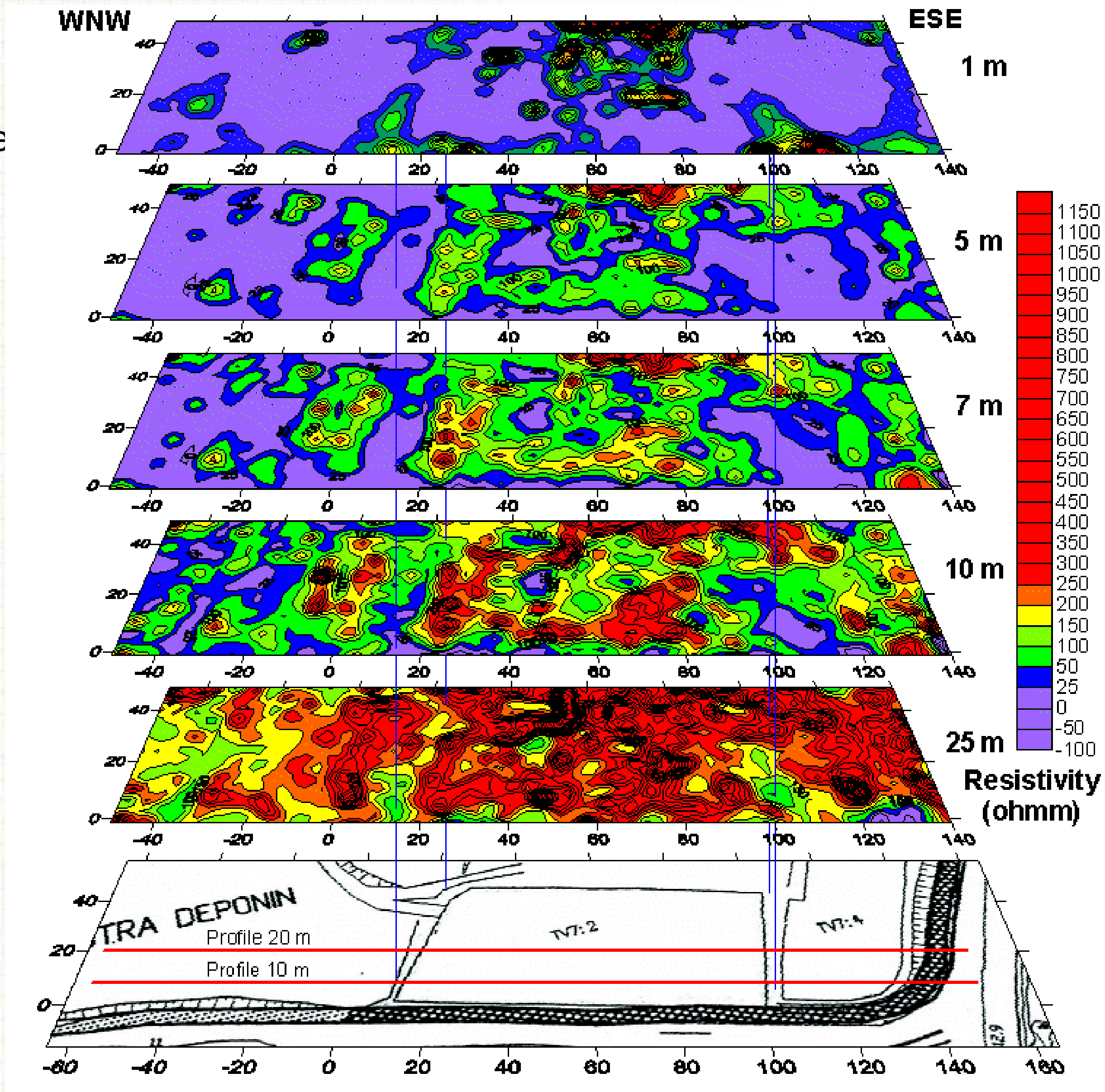


Figure: result of the inversion modelling of the EM data over the entire survey area. Modelled resistivitities at different depths between 1 and 25 m.

Conclusions

- With both EM and CVES the penetration depth is limited to a low resistive layer (0-25 ohmm) of some 5 m thickness. It is underlain by a strong gradient to a few hundred ohmm. The bottom topography of the surface layer matches well in in the central part of the profiles.
- The low resistive surface layer is isolated with a rubber membrane. This sheet causes strong current anomalies on the resistivity soundings (CVES). The profiles have therefore been edited and filtered but at the expense of a flattening of subcropping events.
- At the compartment edges where the rubber membrane crops out and where the low resistive layer pinches iut, the EM data show a better correspondance with visual observations than the CVES models because of the strong current anomalies.
- The results from the inversion modelling of EM data would have been of better quality if the chosen frequencies in the two measurement runs had been intertwinned rather than having a low frequency and a high frequency run. The outgoing energy would have been sufficient for all frequencies.
- Inversion modelling of multi-frequency EM is generally of poorer quality than CVES but is “good enough” in the present low resistive environment.
- *One man-day with CVES corresponds to 10 minutes with multi-frequency EM, i.e. EM is 50 times faster. EM can be used for screening and for extrapolation of CVES profiles.*

Software used

Software used:

1. For the resistivity data:
   1. Editing and filtering: X2IPI from the University of Moscow and IRD
   2. Inversion modelling: Res2DInv Geotomo

2. For EM inversion modelling: EM1DFM from the University of British Columbia

We wish to thank Renova AB, owner of the Torsviken waste landfill for the opportunity to carry out this modelling comparison, the geological department of the university of Göteborg for lending us the resistivity equipment and to ABEM for lending us the Res2Dinv software of Geotomo and last but not least my friend Aldo Cataldi, TRX Consulting for his excellent advice.