tTEM mapping Salten - HydroGeophysics Group - Aarhus University

tTEM Mapping Salten

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HydroGeophysics Group
AARHUS UNIVERSITY

TABLE OF CONTENTS

1. Introduction **2**

2. Data Collection **3**
2.1 The Survey Area 3
2.2 The towTEM System 4
2.3 tTEM - Technical Specifications 6
2.4 Calibration of the tTEM System 7
2.5 The resistivity of various soil types 8

3. Processing of the tTEM Data **10**
3.1 Data Processing – Workflow 10
3.2 GPS-Positioning 10
3.3 Voltage Data 11
3.4 Processing - Technical Specifications 13

4. Inversion of the tTEM Data **14**
4.1 Spatially Constrained Inversion 14
4.2 Smooth and sharp Inversion 16
4.3 Depth of Investigation 16
4.4 Inversion - Technical Specifications 17

5. Thematic Maps and Cross Sections **18**
5.1 Mean Resistivity Maps 18
5.2 Profiles 19
5.3 Location Map, QC-maps 19
5.4 Deliverables 20

6. Conclusion **22**

7. References 23

Appendix I: Location maps, QC maps **1**

Appendix II: Cross Sections **2**

Appendix III: Mean Resistivity Maps **3**

1. INTRODUCTION

In October, 2017, a geophysical mapping with the groundbased transient electromagnetic method tTEM was carried out in the Salten, Denmark. The mapping project was conducted in a cooperation between the HydroGeophysics Group, Aarhus University, Denmark and SEGES, Denmark.

The aim of the project "Afvanding, klimatilpasning og fremtidens vandløbsregulering" is to secure farmers higher and more stable yield on fields, which, today, are facing issues due to excess water. This will be done on the basis of an example from Salten (Løvenholt Gods), were we will investigate causes and solutions to poor draining/dewatering of wet spots on the fields. This is done together with farmers and consultants.

In this context, HGG, AU have mapped a 26 hectare big area close to Salten (Løvenholt gods) by means of geophysical methods. The aim of the mapping was to map the shallow soil layers (upper 5-8 m) and in depth (upper 30 m). This was done with a 10 m line distance with the GCM (DualEM) and tTEM (towTEM) methods.

This report primary presents the geophysical results (resistivity maps and cross sections) and documents the data collection, processing and inversion of the tTEM data. Chapters 2 - 4 describe the data collection, processing and inversion. Chapter 5 explain the various types of geophysical maps and cross section placed in Appendix I: - III.

This report does not address a geological interpretation of the obtained geophysical mapping results.

tTEM survey, Salten	
Client	SEGES
Key persons	**HGG, Aarhus University, Denmark** *Jesper B. Pedersen, Pradip Maurya, Rune Kraghede & Kim Engebretsen* **SEGES, Denmark** *Rikke Laursen*
Locality	Salten, Denmark
Survey period	The 7th of October, 2017
Line km acquired	25 km
Line spacing	10 m

2. DATA COLLECTION

2.1 The Survey Area

The tTEM survey was carried out the 7th of October, 2017, and covers a total of 25 line km of data (Figure 1). The lines strike south-north with a line spacing of 10 m. The average driving speed was 10-15 km/h.

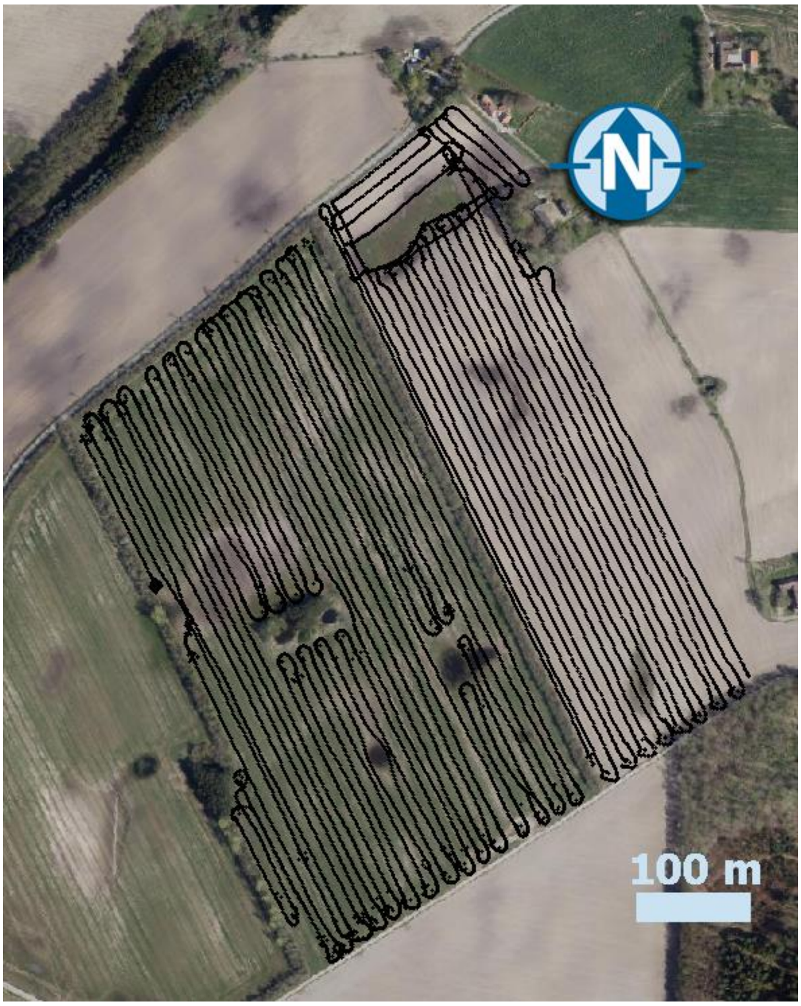

Figure 1. Survey area, with tTEM lines in black. Each black dot corresponds to one tTEM sounding/resistivity model. The model spacing along the lines is ~10 m.

2.2 The towTEM System

towTEM (tTEM) is a time-domain electromagnetic system designed for hydrogeophysical and environmental investigations. The tTEM system measures contiously and especially designed for a unique near-surface resolution with a early time gates and a high repetition frequency. The following contains a general introduction to the tTEM system. A more thorough description of TEM methods can be found in Christiansen et al., 2006 .

Figure 2. The tTEM system. For a detailed instrument setup see ***Error! Reference source not found.***.

Instrument

Error! Reference source not found. shows the tTEM system. The TEM is using an off-set configuration, with the z-receiver coil (RX-coil) approximately 7.0 m behind the trasmitter coil (TX-coil). The tTEM-sytem is towed by an ATV and the distance between the ATV and the TX coil is 2.5 m. The TX-coil is situated within a 2 m x 4 m rectangular frame (TX-frame) which is placed on two sledges. GPS's is placed at the front of the TX-frame, and at the RX-coil, for positioning of the data. The RX-coil is palced on a small sledge, suspended in the air to avoid high frequency motion induced noise. The instrumentation: Transmitter, receiver, power supply, ect is placed on the ATV.

During data collection the the driver can motitor key data parameters in real time on a tablet placed in the front of the ATV.

Measurement Procedure

Measurements are carried out with one or two transmitter moments, depending on the target geology. The standard configuration uses a low and a high transmitter moment applied sequentially. A high and low moment sequence typically takes 0,5 seconds and includes several hundreds of individual transient measurements.

The driving speed can be adjusted to the survey area and target, up to a maximum speed of approximately 20 km/h.

Apart from GPS and TEM data, a number of instrument parameters are monitored and stored, in order to be used for quality control when the data are processed. These parameters include transmitter temperature, current level, and voltage of the instrument.

Penetration Depth

The penetration depth for the tTEM system depends on the transmitter moment, the geological settings, the background noise level and driving speed. Normally, a penetration depth of 60-70 m can be achieved in a setting with an average resistivity model of 40 ohm-m, but it depends on primarily the geological setting. During the inversion a depth of investigation is estimated for each resistivity model (see section 4.3).

2.3 tTEM - Technical Specifications

This section holds detailed technical specifications of the tTEM system setup for this survey.

The tTEM system is configured in a standard two-moment setup (low moment, LM and high moment, HM).

The system instrument setup is shown in **Error! Reference source ot found.**. The positioning of the instruments and the corners of the transmitter coil are listed in Table 1. The origin is defined as the center of the transmitter coil.

The specifications of the LM an HM moment are summarized in Table 2.

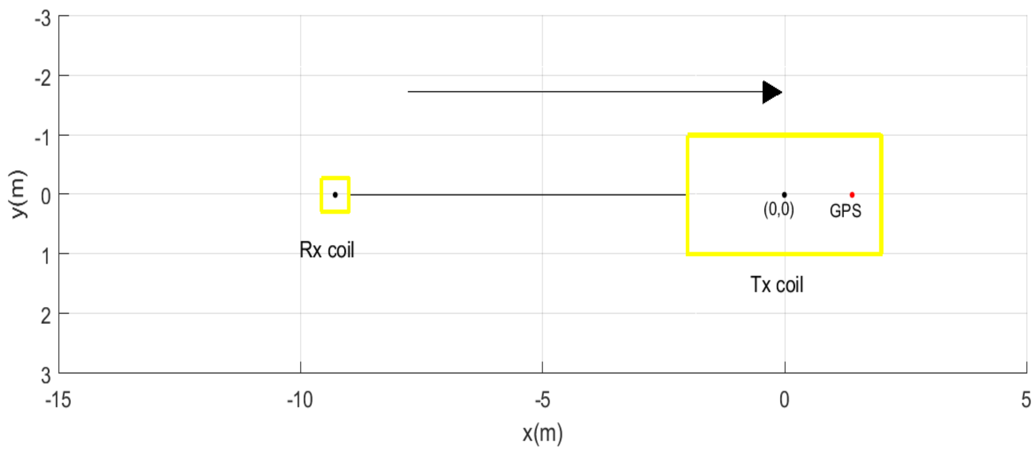

Figure 3. Instrument setup for the tTEM system used. Rx Coil are the receiver coil and Tx is the transmitter coil.

Device Position

Unit	X (m)	Y (m)	Z(m)
GP_TX (GPS)	1.40	0.00	-0.20
RxZ (Z-receiver coil)	-9.18	0.00	-0.20
Tx (center transmitter coil)	0.00	0.00	-0.29
Loop corner 1	-02.00	-01.00	0.00
Loop corner 2	02.00	-01.00	0.00
Loop corner 3	02.00	01.00	0.00
Loop corner 4	-02.00	01.00	0.00

Table 1. Summary of equipment and transmitter coil corner positioning. The origin is defined as the center of the transmitter coil. Z is positive towards the ground.

Transmitter, Receiver Specifications

Parameter	LM	HM
No. of turns	1	1
Transmitter area (m^2)	8	8 m^2
Tx Current	~ 2.8 A	~ 30 A
Tx Peak moment	~ 22.4 Am^2	~ 240 Am^2
Repetition frequency	1055 Hz	330 Hz
Raw Data Stack size	422	264
Tx-on-time	0.12 ms	0.45 ms
Tx Ramp down time	2.5 µs at 2.8 Amp	4.0 µs at 30 Amp
Number of gates	18	33
Gate time interval	4.1 µs – 33.1 µs	10.0 µs – 900.0 µs

Table 2. Summary of low moment (LM) and high moment (HM) specifications.

2.4 Calibration of the tTEM System

Prior to the survey, the tTEM equipment was calibrated by at the Danish national TEM test site near Aarhus, Denmark (Foged et al., 2013). The calibration is performed to establish the absolute time shift and data level in order to facilitate precise data modeling. No additional leveling, or drift corrections are applied subsequently.

In order to perform the calibration, all system parameters (transmitter waveform, low pass filers, etc.) must be known to allow modeling of the used tTEM configuration.

The calibration constants are determined by comparing a recorded tTEM response on the test site with the reference response. The reference response is calculated from the test site reference model for the used tTEM configuration.

Acceptable calibration was achieved with the calibration constants stated in Table 3.

Moment	Time Shift	Scale Factor
LM	-0.55 µs	1.00
HM	-0.7 µs	1.03

Table 3. Calibration constants.

2.5 The resistivity of various soil types

With the tTEM method the resistivity of the soil is measured. The measured resistivity depends on several factors like lithology, water content and the ion content in the water. Figure 1 shows the relative resistivity of different lithology's and the relation to water quality. Figure 2 shows the values of typical resistivity's of Danish lithology's. Due to the chemical composition clay deposits are characterized by having a low resistivity while layers of sand or gravel have a high resistivity.

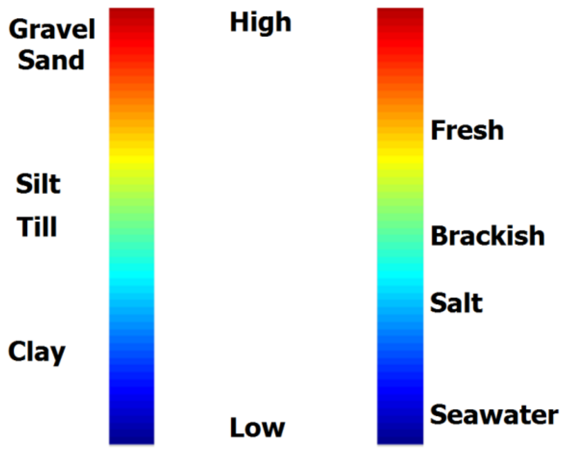

Figure 1. Relative resistivity of various lithologies and the relation to water quality.

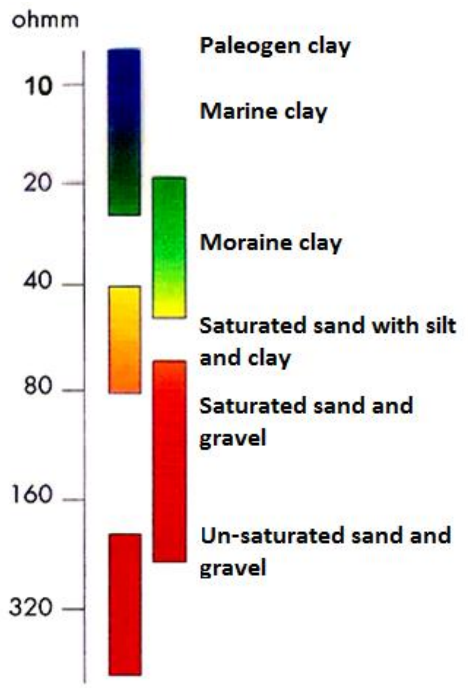

Figure 2. The resistivity of different Danish lithology's.

3. PROCESSING OF THE TTEM DATA

3.1 Data Processing – Workflow

The software package Aarhus Workbench is used for processing the tTEM data.

The aim of the processing is to prepare data for the geophysical interpretation. The processing primarily includes filtering and averaging of data as well as culling and discarding of distorted or noisy data.

The data processing can be divided into four steps:

1. Import of raw data into a fixed database structure. The raw data appear in the form of .skb-, .sps- and .geo-files. Skb-files contain the actual transient data from the receiver. Sps-files contain GPS positions, transmitter currents etc. and the geo-file contains system geometry, low-pass filters, calibration parameters, turn-on and turn-off ramps, calibration parameters, etc.
2. Automatic processing: First, an automatic processing of the four data types is used. These are GPS-, and TEM data. This automatic processing is based on a number of criteria adjusted to the survey concerned.
3. Manual processing: Inspection and correction of the results of the automatic processing for the data types in question.
4. Adjustment of the data processing based on preliminary inversion results.

All data is recorded with a common time stamp. This time stamp is used to link data from different data types. The time stamp is given as the GMT time.

In the following, a short description of the processing of the different data types is shown. A more thorough description of the TEM data processing can be found in Auken et al., 2009.

3.2 GPS-Positioning

The position of the tTEM-system is recorded continuously with two independent GPS receivers. Furthermore, the GPS data are shifted to the optimum focus point of the tTEM system.

3.3 Voltage Data

The voltage data are gathered continuously along the mapping lines (Figure 4) and alternately with low and high moments. The processing of voltage data is carried out in a two-step system: an automatic and a manual part. In the former, a number of filters designed to cull coupled or noise influenced data are deployed. Furthermore, raw data are stacked to increase the signal-to-noise ratio using a trapezoidal averaging core (Figure 5). The averaging width of late-time data is wider than that of early-time data, as seen in Figure 5. The data uncertainty is calculated from the data stack, with an additional 3% uniform data uncertainty. Typically, the stacked data (soundings) are generated for every 10 m depending on mapping speed, tTEM setup and target. Each sounding location will produce a 1D resistivity model when data is inverted.

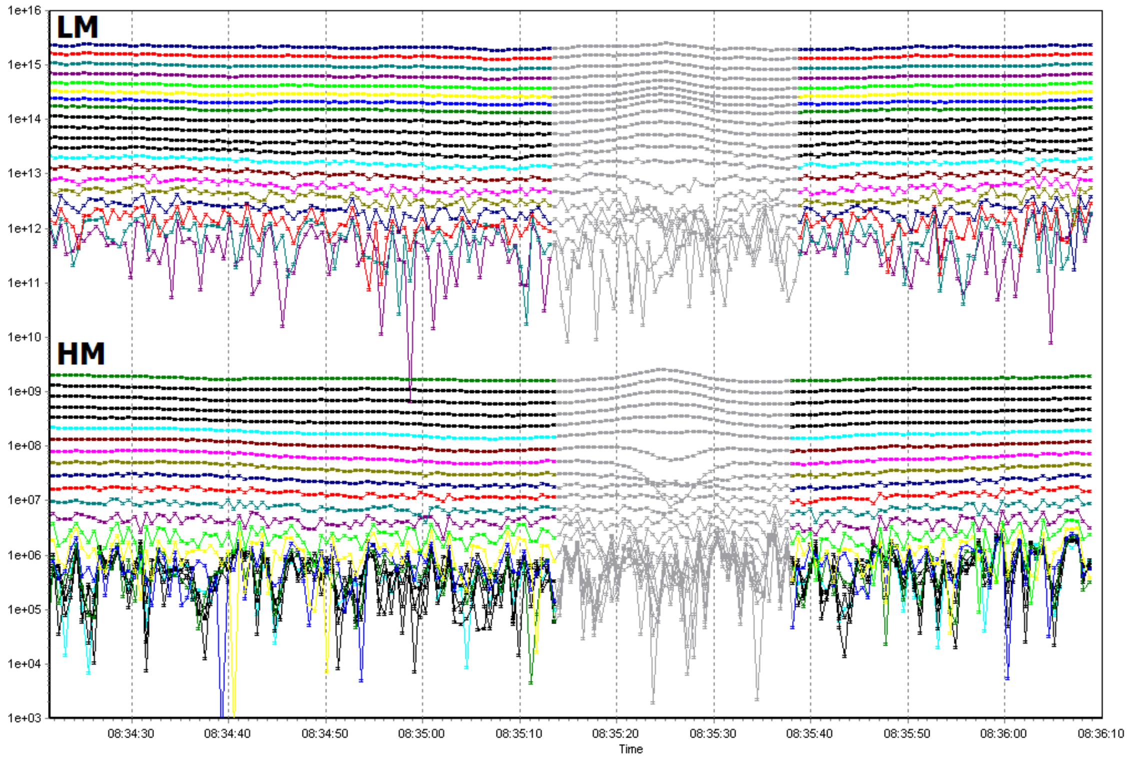

Figure 4. Data section example with coupled data. The section displays 2 minutes (~0.5 km) of data. Each of the curves shows raw low-moment or high-moment data for a given gate time. The green line represents gate 1 of the high moment, the black line gate 2 etc. The grey lines represent data that have been removed due to couplings. A coupling can clearly be identified at 08:35:12 to 08:35:37. In this case the coupling are associated with buried power cables.

The automatic processing is always followed by a manual inspection and correction. Survey areas are typically crossed by a number of power lines, roads, railroads etc. As data near such installations often are heavily disturbed (couple to the installations), it is necessary to remove these data, in order to produce geophysical maps without artifact from these manmade installations. The manual inspection and removal of coupled data is therefore essential to obtain high quality end results. In some cases it is not possible to identify the source of the coupling even though it is evident in the data.

Figure 4 shows an example of strongly coupled data. First the coupled data parts are removed. Then data are stacked into soundings, and finally the late-time part of the sounding curves below the background noise level is excluded.

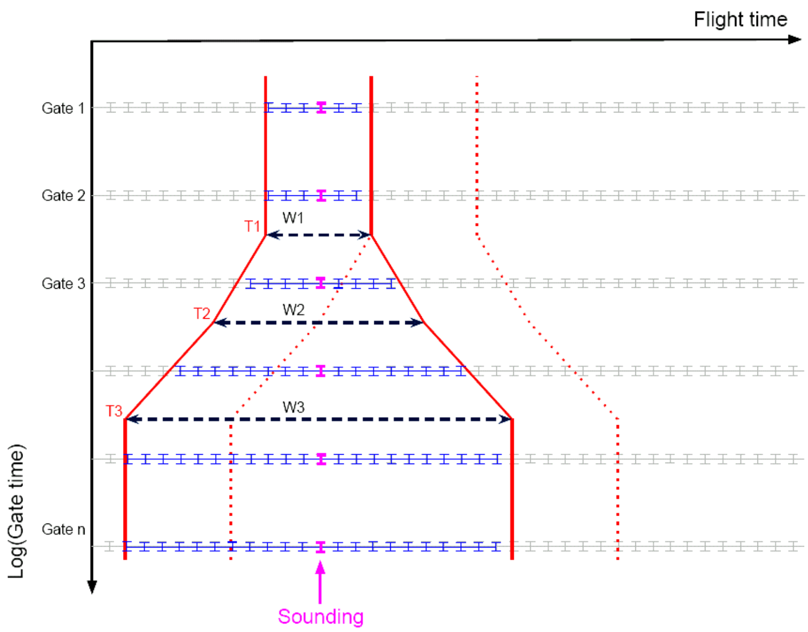

Figure 5. Trapezoid averaging of TEM-data. Raw data (blue error bars) within the red lines are averaged yielding the sounding marked by magenta error bars. The averaging trapezoid is subsequently moved (red dashed line), and a new sounding is created. The times T1-T3 and widths W1-W3 define the trapezoid.

3.4 Processing - Technical Specifications

Table 4 shows key processing settings in the Aarhus Workbench, used for this survey.

Item		Value
Noise Processing	Data uncertainty: Uniform data STD	From data stack 3%
Trapezoid filter	Sounding distance LM, times: T1, T2, T3 [s] LM, width: W1, W2, W3 [s] HM, times: T1, T2, T3 [s] HM, width: W1, W2, W3 [s]	2.5 s (~10 m) 1e-5, 1e-4, 1e-3 2.5, 2.5, 2.5 1e-5, 1e-4, 1e-3 2.5, 5, 10

Table 4. Processing settings.

4. INVERSION OF THE TTEM DATA

Inversion of the dataset and evaluation of the inversion results are carried out using the Aarhus Workbench software package. The underlying inversion code (AarhusInv) is developed by the HydroGeophysics Group, Aarhus University, Denmark (Auken et al., 2015).

The inversion is a 1D full non-linear damped least-squares solution in which the transfer function of the instrumentation is modeled. The transfer function includes turn-on and turn-off ramps, front gate, low-pass filters, and transmitter and receiver positions.

4.1 Spatially Constrained Inversion

The spatially constrained inversion (SCI) (Viezzoli et al., 2008) scheme is used when inverting the tTEM data. The SCI scheme uses constraints between the 1D-models, both along and across the mapping lines, as shown in Figure 6. The constraints are scaled according to the distance between soundings.

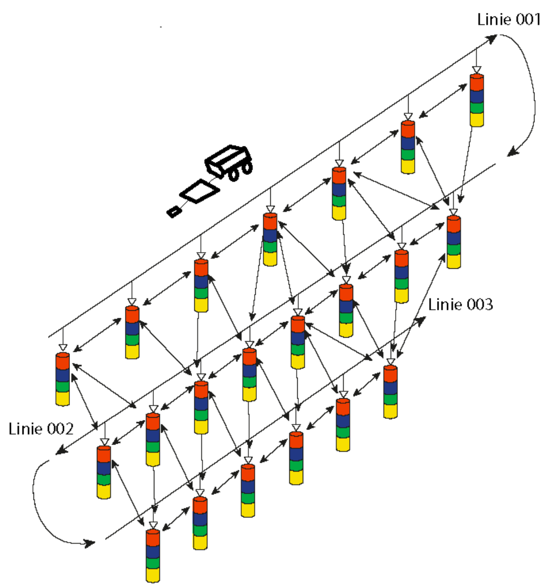

Figure 6. Schematic presentation of the SCI setup. Constraints connect not only soundings located along the mapping lines, but also those across them.

The connections pattern of the constraints is designed using a Delaunay triangulation, which connects *natural* neighbor models. For line oriented data the Delaunay triangulation results in a model being connected to the two neighbor models at the mapping line and typically 2-3 models at the adjacent mapping lines, (see Figure 7). The SCI constraints are the preliminary condition for breaking down the line orientation in the dataset.

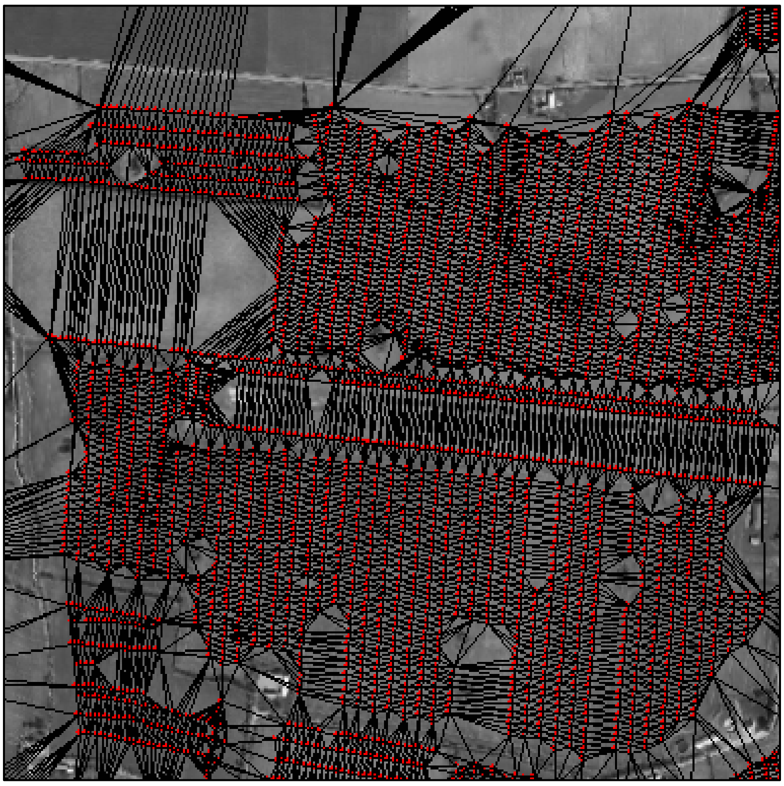

Figure 7. Example setup of SCI-constraints. The red points are the model positions. The black lines show the constraints created with the Delaunay triangles. The line distance in this example is 20 m and the area is approximately 1 x 1 km.

Constraining the parameters enhances the resolution of resistivities and layer interfaces, which are not well resolved in an independent inversion of the soundings.

SCI-setup parameters for this survey are listed in section 4.4.

4.2 Smooth and sharp Inversion

Both a smooth and a sharp model inversion have been carried out. Both inversion types use the SCI-setup, but the regularization scheme is different.

The smooth regularization scheme penalizes the resistivity changes, resulting in smooth resistivity transitions both vertical and horizontal, as seen in Figure 7. The sharp regularization scheme penalizes the number of resistivity changes of a certain size, resulting in model sections with few, but relative shape resistivity transitions, as seen in see Figure 7. Normally the tTEM data are fitted equally well with the model types.

Assuming a geological layered environment, picking geological layer boundaries, will be less subjective in a sharp model result compared to a smooth model.

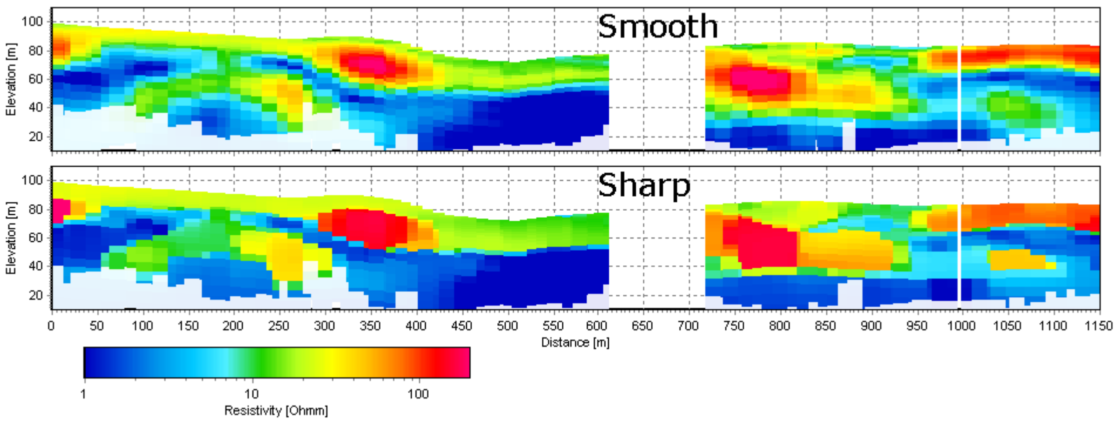

Figure 8. Profile examples of a smooth and sharp inversion of the same tTEM data set.

4.3 Depth of Investigation

For each resistivity model a depth of investigation (DOI) is estimated, as described in Christiansen and Auken, 2012. The DOI calculation takes into account the tTEM system transfer function, the number of data points, the data uncertainty, and the resistivity model.

EM fields are diffusive, and there is no discrete depth where the information on the resistivity structure stops. Therefore, we provide a conservative and a standard DOI estimate. As a guideline, the resistivity structures above the DOI conservative value are well consolidated by the tTEM data, and resistivity structures below the DOI standard value are very weakly founded in the data and should normally be disregarded.

The DOI conservative and DOI standard estimates are included as point themes map in Appendix I: The cross sections in Appendix II: are blanked in depth at the DOI standard values. Furthermore, the resistivity models are blanked below the DOI- standard value when compiling the mean resistivity maps.

4.4 Inversion - Technical Specifications

The inversion settings for the smooth and sharp inversions in Aarhus Workbench are listed Table 5.

Item		Value
Model setup	Number of layers	30
	Starting resistivities [Ωm]	40 ohmm
	Thickness of first layer [m]	1.0
	Depth to last layer [m]	150.0
	Thickness distribution of layers	Log increasing with depth
Smooth model: Constraints/ Prior constraints	Horizontal constraints on resistivities [factor]	1.3
	Reference distance [m]	10
	Constraints distance scaling	(1/distance)[1]
	Vertical constraints on resistivities [factor]	3.0
	Prior, thickness	Fixed
	Prior, resistivities	None
	Minimum number of gates per moment	3
Sharp model: Constraints/ Prior constraints	Horizontal constraints on resistivities [factor]	1.03
	Reference distance [m]	10
	Constraints distance scaling	(1/distance)[1]
	Vertical constraints on resistivities [factor]	1.08
	Prior, thickness	Fixed
	Prior, resistivities	None
	Minimum number of gates per moment	3
	Sharp vertical constraints	200
	Sharp horizontal constraints	300

Table 5. Inversion settings, smooth and sharp SCI setup

5. THEMATIC MAPS AND CROSS SECTIONS

To visualize the resistivity structures in the mapping area, a number of geophysical maps and cross sections have been created. Furthermore, a location map and a number of maps made for quality control (QC-maps) are found in the appendices.

5.1 Mean Resistivity Maps

To make depth or horizontal slices, the mean resistivity in the depth or elevation intervals is calculated for each resistivity model and then interpolated to a regular grids.

Figure 9 shows how the resistivities of the layers in a model influence the calculation of the mean resistivity in a depth interval [A, B]. d_0 is the surface, d_1, d_2 and d_3 are the depths to the layer boundaries in the model. ρ_1, ρ_2, ρ_3 and ρ_4 are the resistivities of the layers.

The model is subdivided into sub-thicknesses Δt_{1-3}. The mean resistivity ($\rho_{vertical}$) is calculated as:

$$\rho_{vertical} = \frac{\rho_1 \cdot \Delta t_1 + \rho_2 \cdot \Delta t_2 + \rho_3 \cdot \Delta t_3}{\Delta t_1 + \Delta t_2 \cdot \Delta t_3}$$

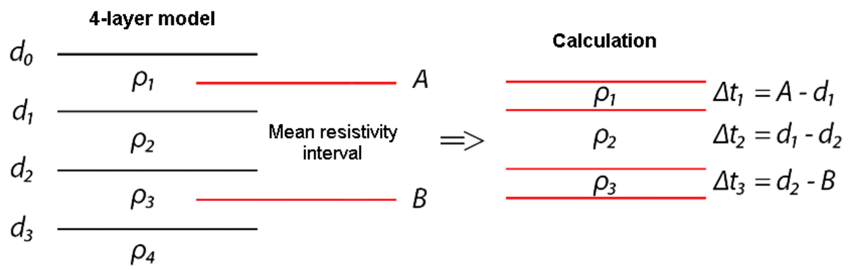

Figure 9. The figure illustrates how the resistivities of the layers influence the mean resistivities in a depth interval [A:B]

In the general term the mean resistivities in a depth interval is calculated using the equation below:

$$\bar{\rho} = \frac{\sum_{i=1}^{n} \rho_i \cdot \Delta t_i}{\sum_{i=1}^{n} \Delta t_i}$$

where i runs through the interval from 1 to the number of sub-thicknesses. The mean resistivity calculated by the above formula ($\rho_{vertical}$) is named the vertical mean resistivity - equal to the total resistance if a current flows vertically through the interval.

By mapping with a TEM method, the current flows only horizontally in the ground. It is therefore more correct to perform the mean resistivity calculation in conductivity in the space, then named the horizontal mean resistivity ($\rho_{horizontal}$). The horizontal mean resistivity is equal to the reciprocal of the mean conductivity (σ_{mean}) and is calculated as:

$$\rho_{horizontal} = \frac{1}{\sigma_{mean}} = \left[\frac{\sum_{1=1}^{n}\left(\frac{1}{\rho_i}\right) \cdot \Delta t_i}{\sum_{i=1}^{n} \Delta t_i}\right]^{-1}$$

For this survey, horizontal mean resistivity themes have been generated from the smooth model inversion result in 5 m depth intervals from 5 to 30 m, and in 10 m intervals from 30 to 50 m. The resistivity models have been blanked at the DOI standard value prior to the interpolation regular mean resistivity grids.

The interpolation of the mean resistivity values to regular grids is performed by Kriging interpolation (Pebesma and Wesseling, 1998), with a node spacing of 5 m and a search radius of 30 m, and with additional pixel smoothing in the presented bitmaps images. The mean resistivity maps are placed in Appendix III:

5.2 Profiles

Cross sections of selected mapping lines are included in Appendix II: Each section holds the model bars, which are blanked at the DOI- standard value. Cross section of all mapping lines are available in the delivered Workspace.

5.3 Location Map, QC-maps

A location map and quality control maps (QC) described below are included in Appendix I:

Model Location and Lines

This map shows the actual mapped lines. Black dots mark where data are disregarded due to line turns, low signal or coupling. Red dots mark where data is kept and inverted to a resistivity model.

A decent amount of data is disregarded due to coupling and low signal, and the coupled data are primarily associated with electrical cables, roads and the railway.

Data Residual

The data residual tells how well the obtained resistivity models explain the recorded data (how well the data is fitted). The data residual values are normalized with the data standard deviation, so a data residual below one corresponds to a fit within one standard deviation.

The data residual map in Appendix I: is for the smooth inversion result. The data residual for the sharp inversion is similar. Some areas have relatively high data residual values (>2), this is primarily due to noise data, which again is associated to low signal ground responses (resistive ground). In general, the data residuals are really good, which is expected for this type of environment and geological setting.

Depth of Investigation (DOI)

This map shows the DOI estimates for the smooth model inversion result (see section 4.3 for a description of the DOI-calculation). DOI maps in elevation and depths are included in the appendix.

5.4 Deliverables

Digital

- This report incl. theme maps and profiles as PDF-files.

- Aarhus Workbench workspace holding raw data, processed data, inversion results, theme maps and profiles..
  The workspace holds both the smooth and the sharp inversion results.
  The workspace can be delivered upon request.

- Mean resistivity maps in depth intervals as GeoTIFF files.
  …\MRESD_##_##.tif

- QC-maps in ArcGIS shape format.
  *…\QC_maps***.shp*

- Resistivity models in xyz-ascii files, for both the sharp and smooth model.
  …\xyz_ascii\sharp_model.xyz, Smooth_model.xyz.

Note: All digital maps and data are geo-referenced to coordinate system WGS84, UTM zone 32N.

6. CONCLUSION

A total of 6 boreholes, drilled to 1,5 m depth, has also been carried out in the area by Casper Szilas from GPS agro. These boreholes have been plotted on top of the profiles. For a detailed description the boreholes and their good agreement with the GCM/EMI and tTEM data we refer the user to the paper "Notat vedr. profilundersøgelser ved Løvenholt" by Casper Szilas, GPS Agro. In the paper there is a detailed comparison of the EMI results and the boreholes.

To summarize the results, the geophysical mapping reveals that on the eastern field we see very high resistivity's almost at ground surface, which corresponds well with meltwater sand, which has a high resistivity of more than 100 ohm-m. In some areas it is so resistive that we don't get a signal with the tTEM method and hence the data had to be discarded. In these areas we still have GCM data. From 10 m depth and to more than 70 meters depth the tTEM results reveal a large meltwater sand aquifer. This aquifer extends below both the western and eastern field.

The shallow geology is much more complex on the western field. There are large variations in the area from resistive strongly sandy deposits (meltwater sand) to conductive clay/organic matter rich deposits (meltwater clay). This is especially evident in the mean-resistivity maps based on the GCM results. These are made in 0.5 to 1 meter slices from 0-5 meters depth. The local lows in the fields have been superimposed on the mean-resistivity maps as black contours. It is very clear from these maps that there is a strong correlation between the areas were there is standing water on the fields and the spots were there is a local low and meltwater clay in the upper 1-5 meters. The thick meltwater clay sequence acts as a barrier so the water can't infiltrate.

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APPENDIX I: LOCATION MAPS, QC MAPS

This appendix includes maps of:

- Model location and mapping lines
- Data residual
- Depth of investigation, in depth

SEGES

HydroGeophysics Group
AARHUS UNIVERSITY

tTEM Salten 2017

Location, tTEM lines

Red: 1D model Black: Discarded data

UTM 32N WGS84

250 m

SEGES

LANDBRUG FØDEVARER

HydroGeophysics Group
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0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4

Data Residual

Below one corresponds to a fit within one standard deviation

UTM 32N WGS84

250 m

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0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10

Depth [m]

Depth of Investigation, Conservative

Depth, Meters

UTM 32N WGS84

250 m

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Depth of Investigation, Standard

Depth, Meters

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10

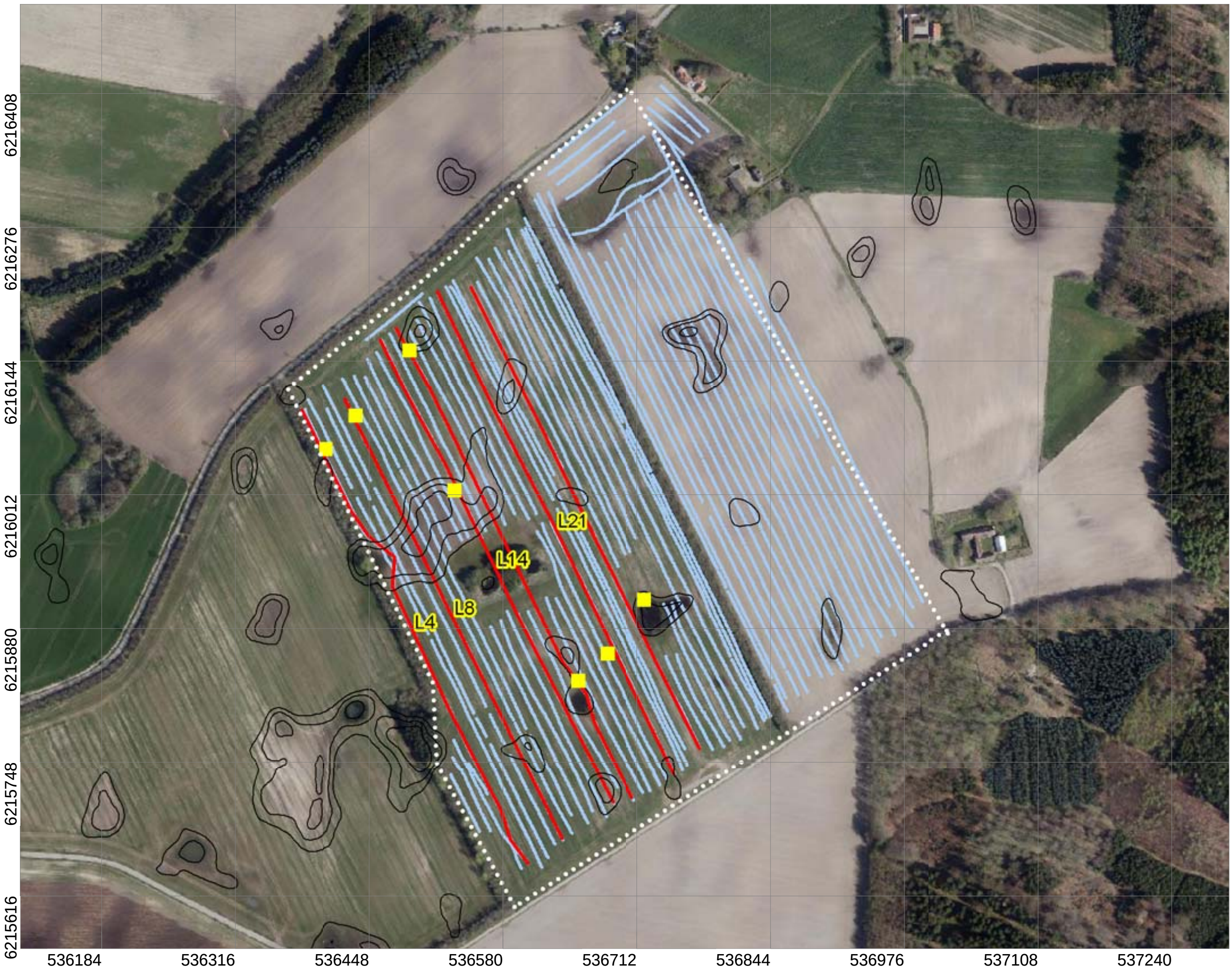
Depth [m]

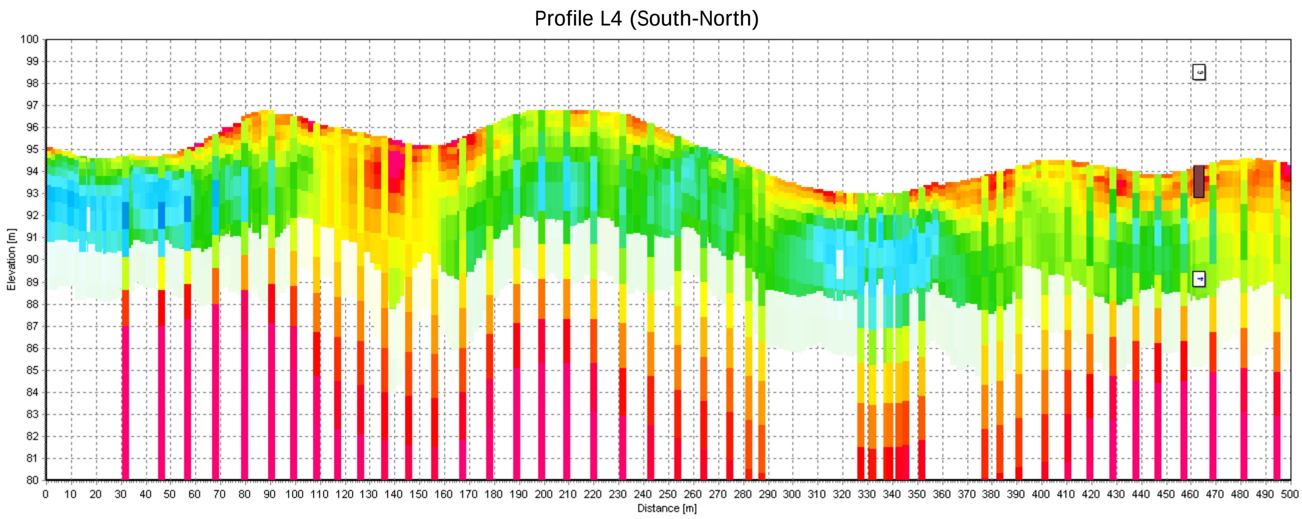
UTM 32N WGS84

250 m

APPENDIX II: CROSS SECTIONS

Selected cross sections for the smooth inversion are included. Each section holds the model bars blanked at the DOI- standard value. Sections for all the mapping lines are available in the delivered Workspace.





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10 100 [Ohmm]

Resistivity Profiles (ohmm)

Smooth SCI Model

GCM results is shown as model bars.
tTEM results has been plotted on top of the GCM results as model bars.
Boreholes have been plotted on top as well.

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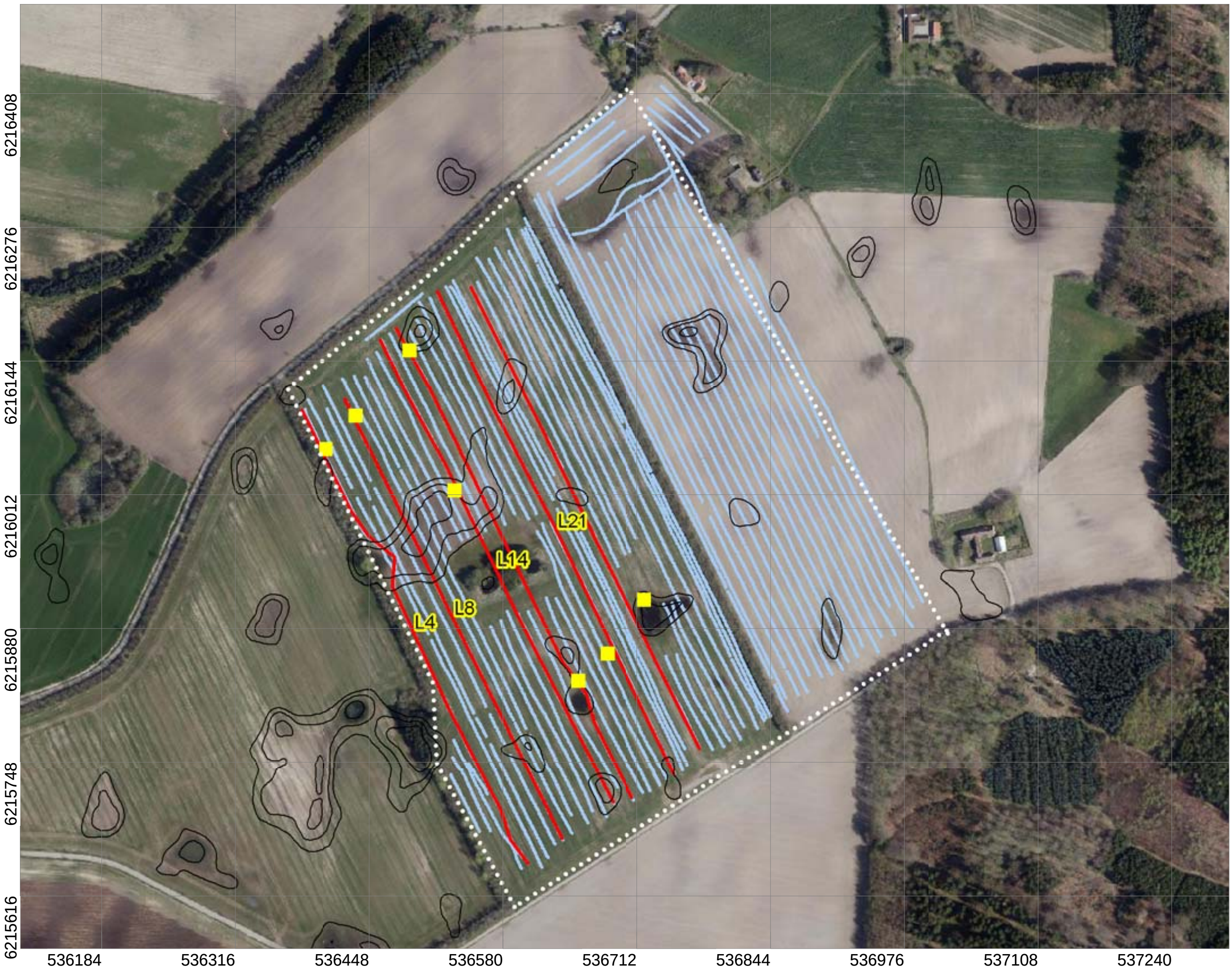

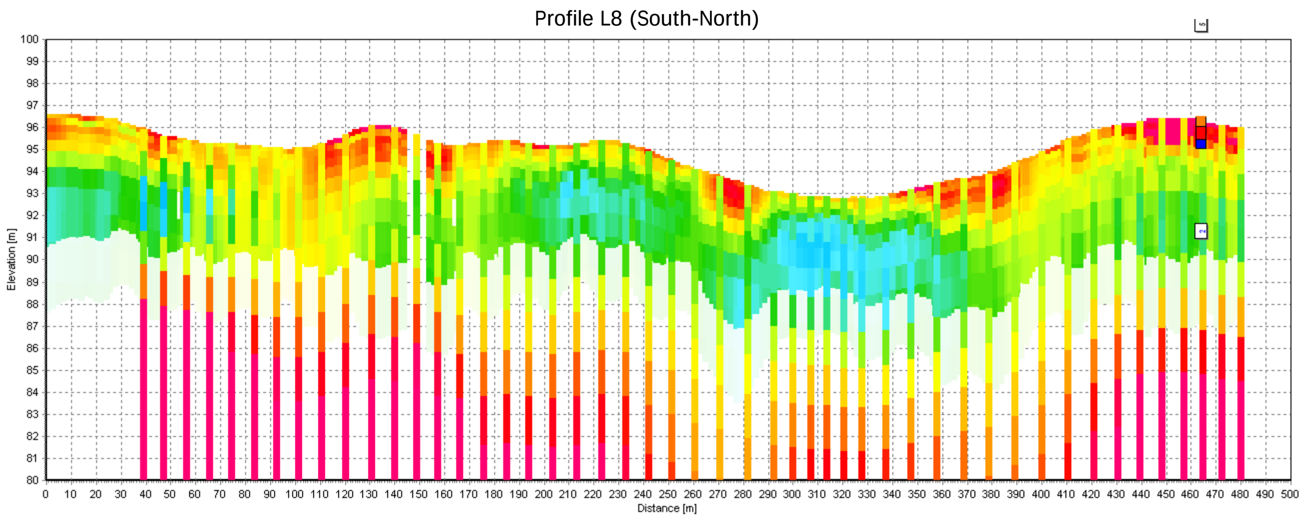

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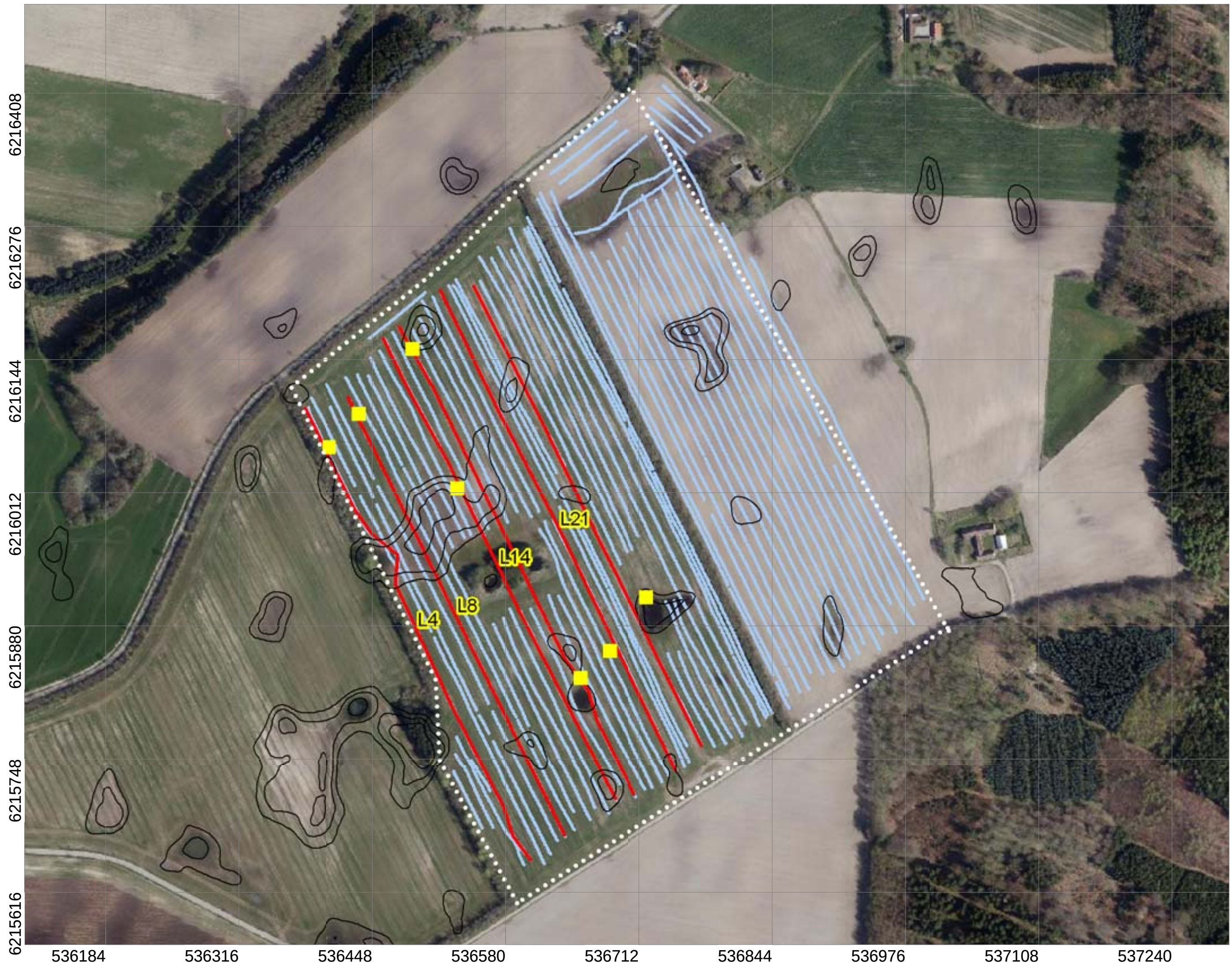
GCM tTEM Salten 2017

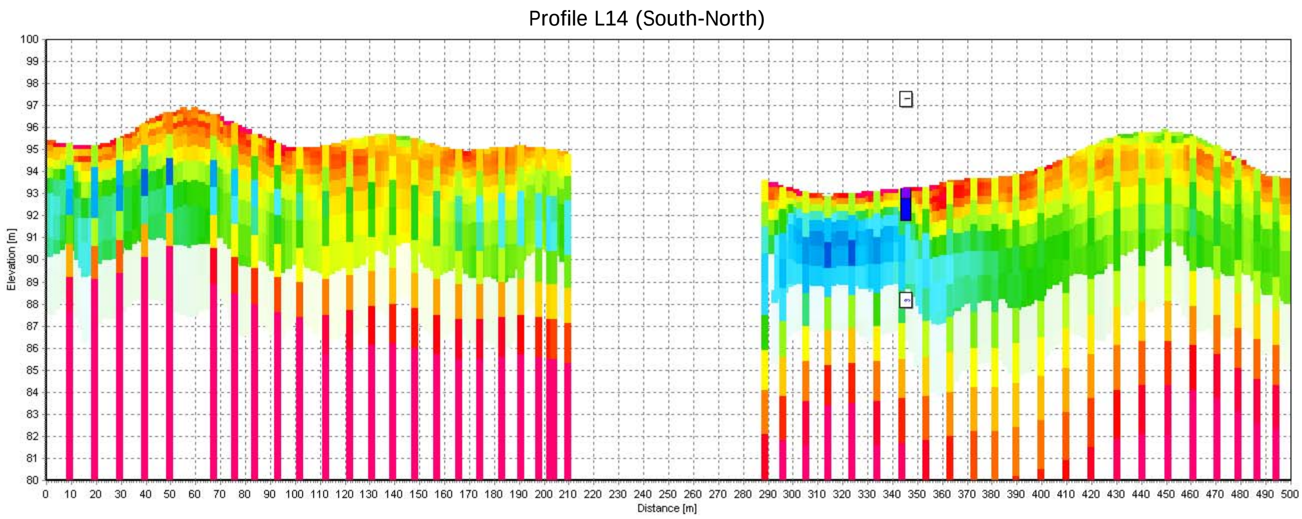
Resistivity Profiles (ohmm)

Smooth SCI Model

10 100
[Ohmm]

GCM results is shown as model bars.
tTEM results has been plotted on top of the GCM results as model bars.
Boreholes have been plotted on top as well.





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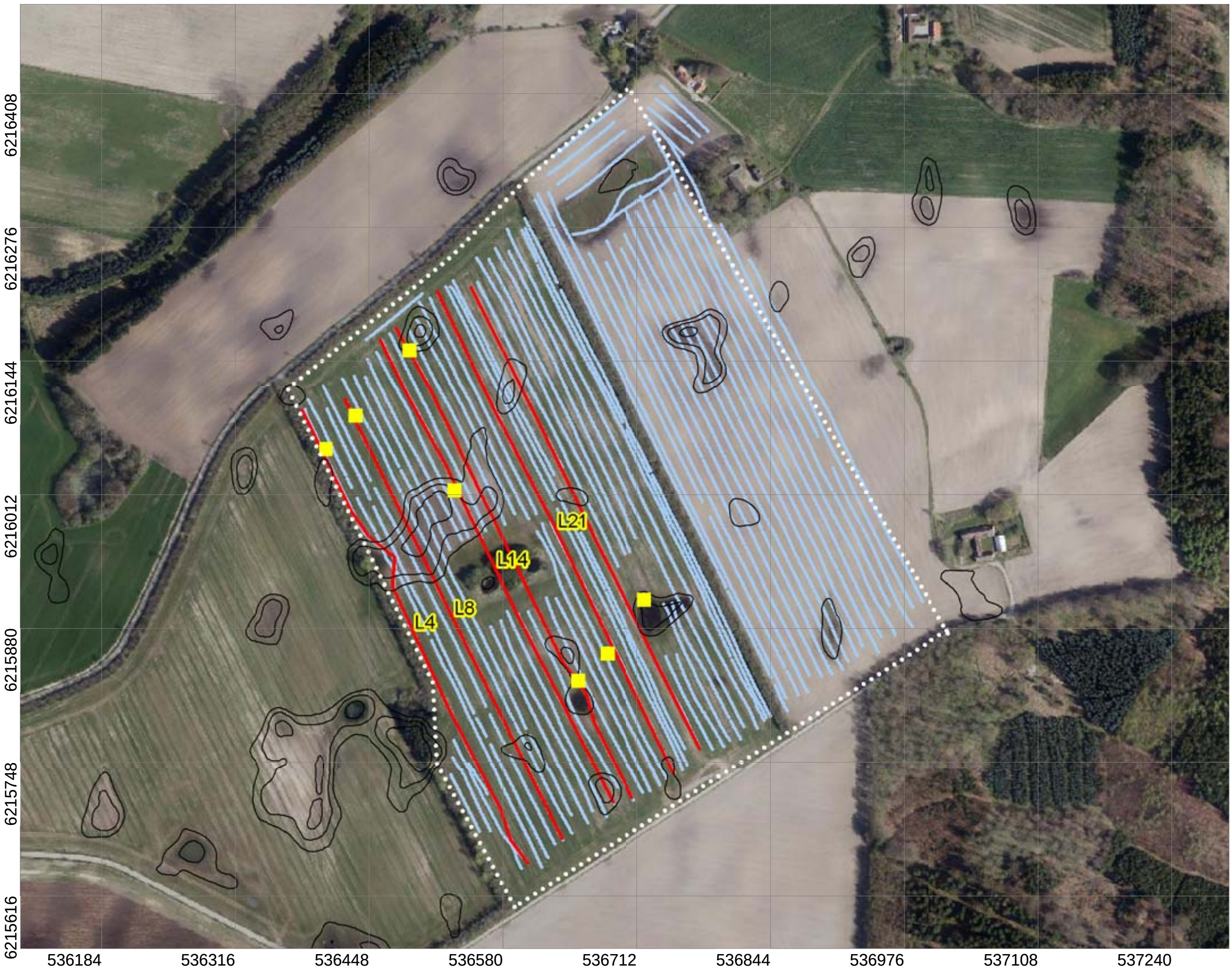
10 100 [Ohmm]

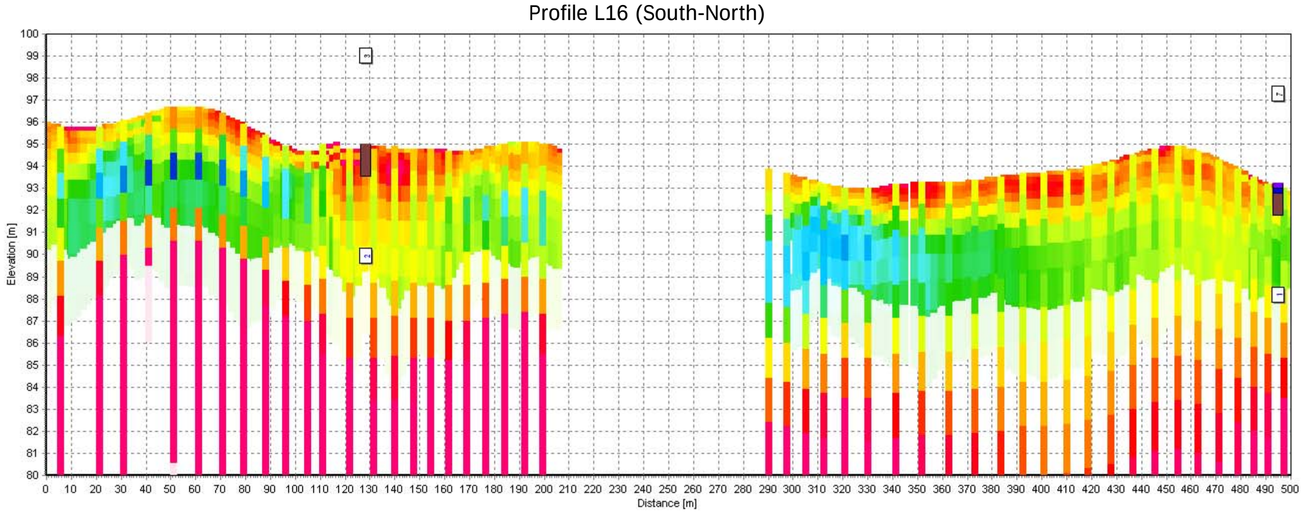
Resistivity Profiles (ohmm)

Smooth SCI Model

GCM results is shown as model bars.
tTEM results has been plotted on top of the GCM results as model bars.
Boreholes have been plotted on top as well.



Profile L16 (South-North)



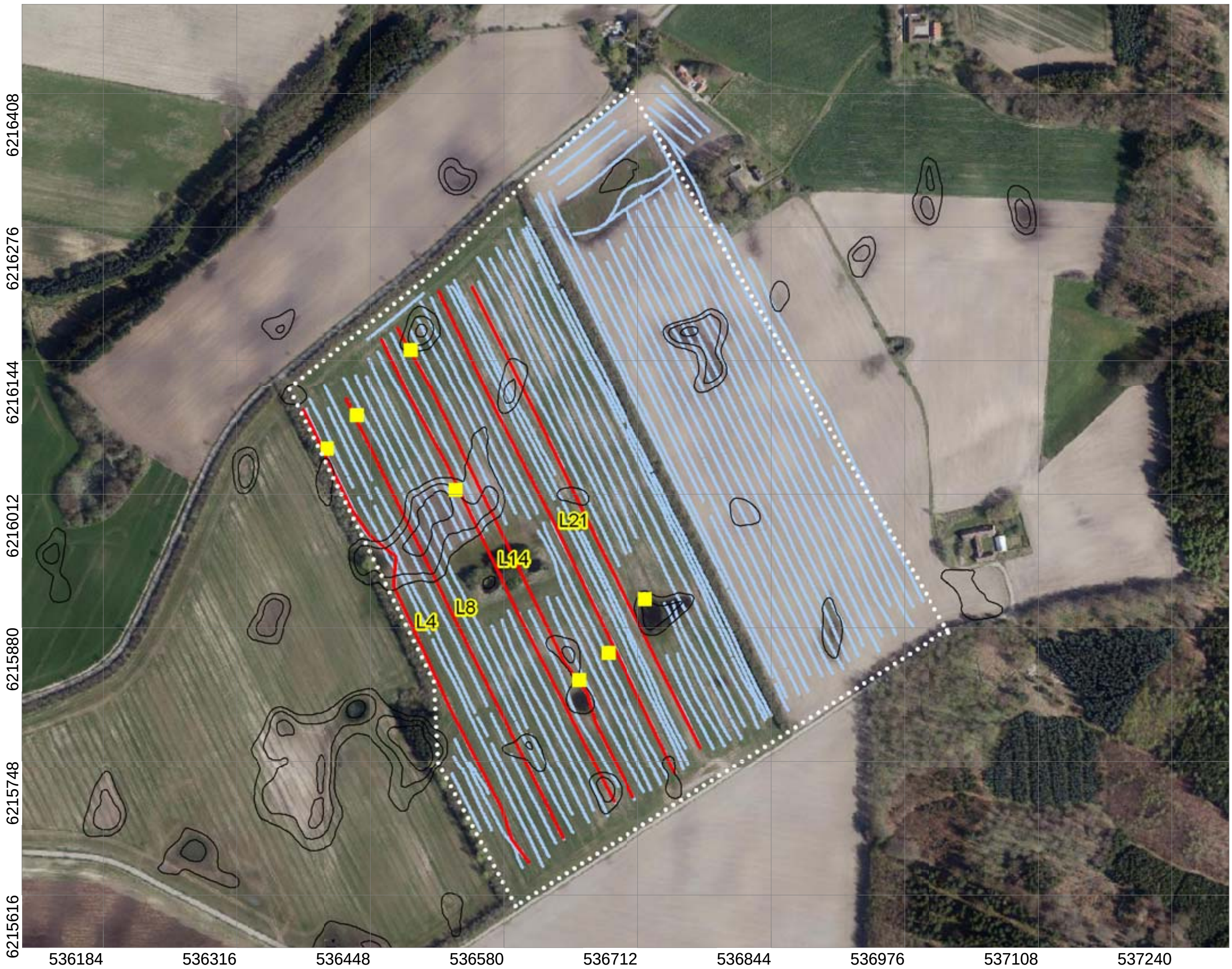
GCM tTEM Salten 2017

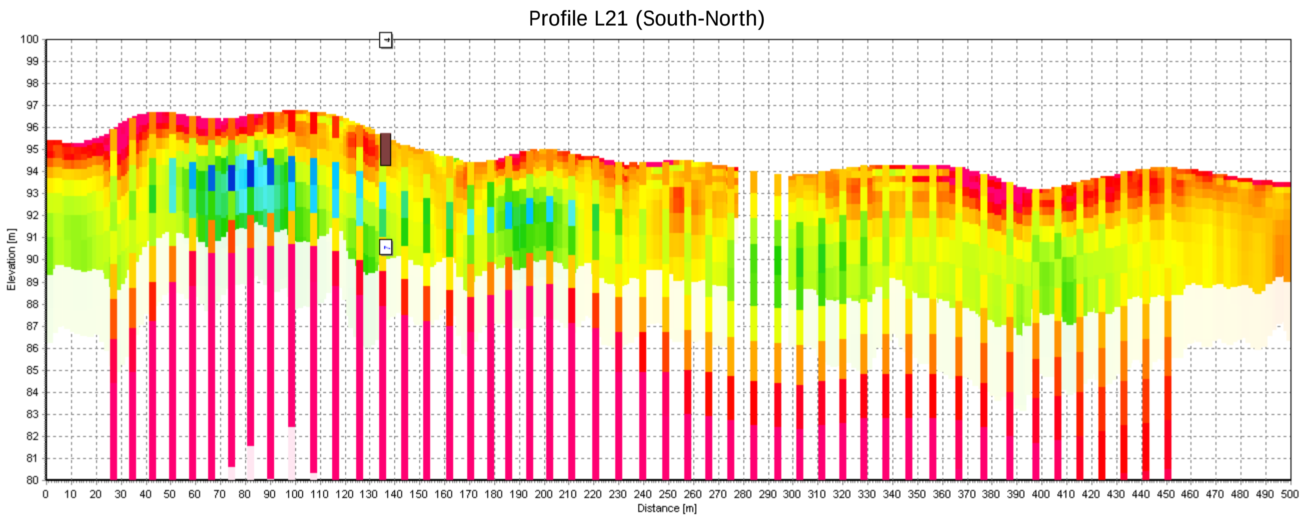
10
100
[Ohmm]

Resistivity Profiles (ohmm)

Smooth SCI Model

GCM results is shown as model bars.
tTEM results has been plotted on top of the GCM results as model bars.
Boreholes have been plotted on top as well.





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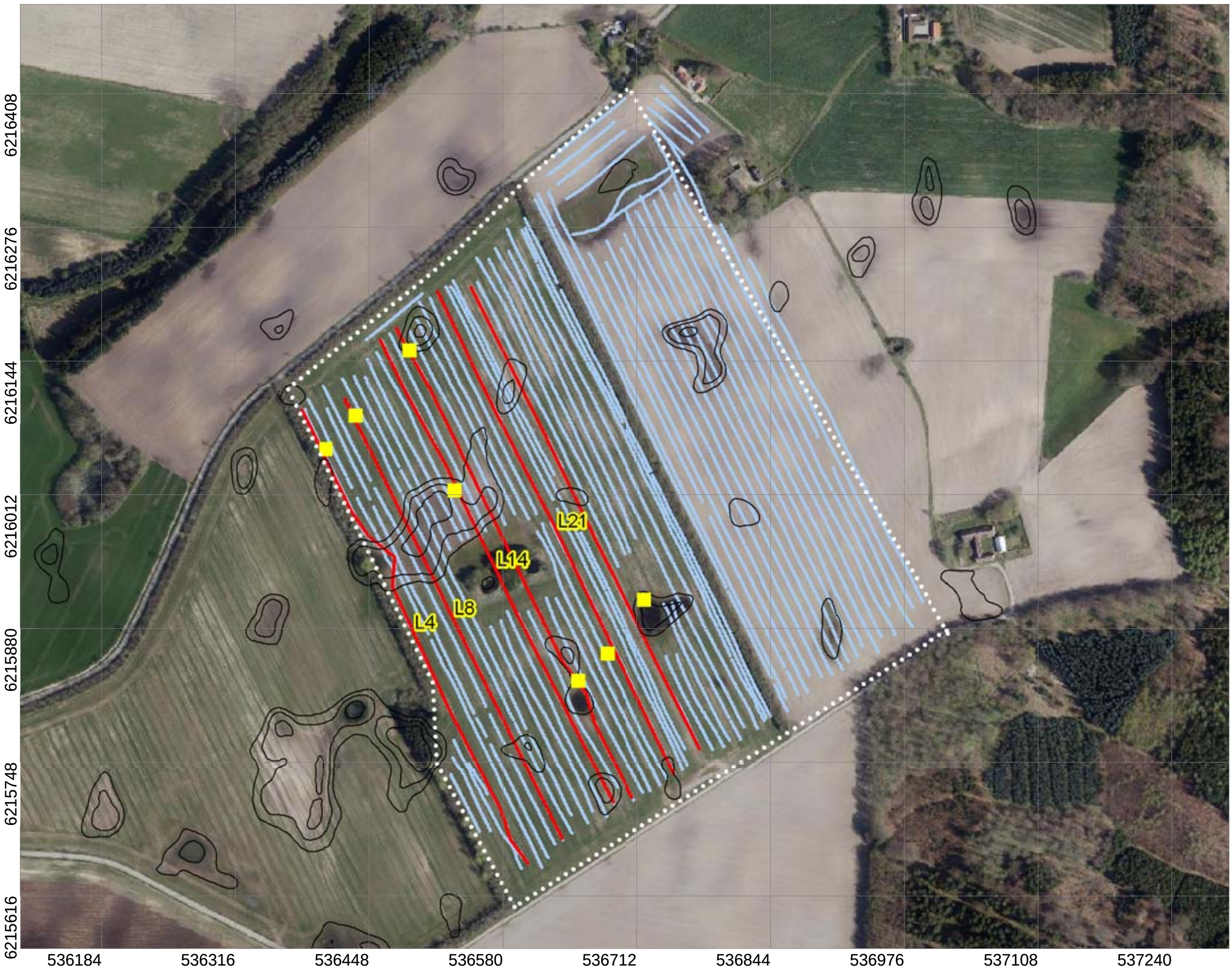
Resistivity Profiles (ohmm)

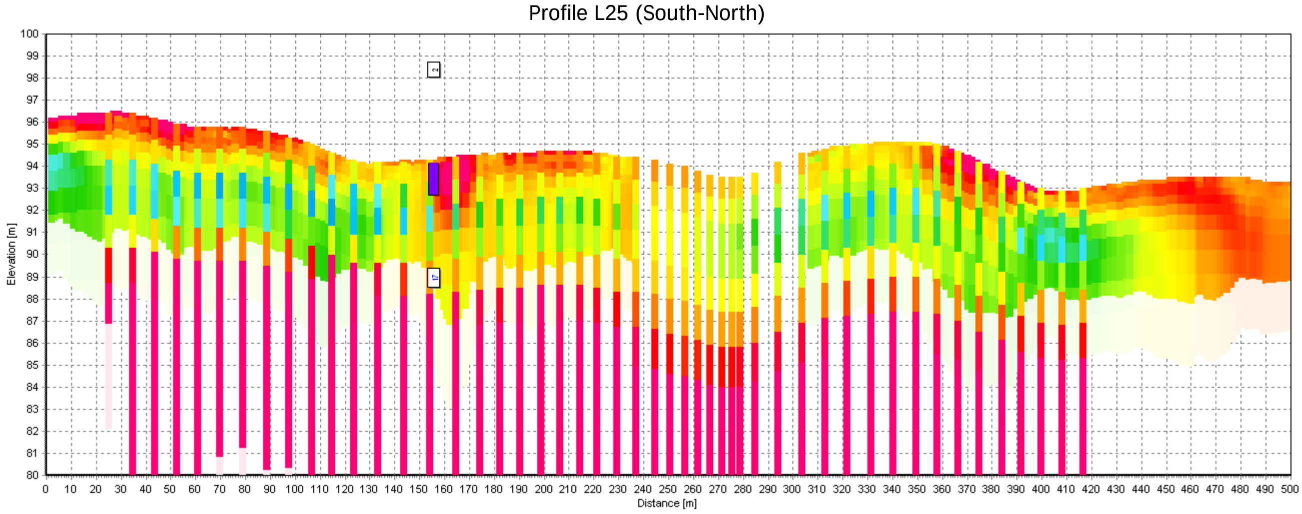
Smooth SCI Model

10 100 [Ohmm]

GCM results is shown as model bars.
tTEM results has been plotted on top of the GCM results as model bars.
Boreholes have been plotted on top as well.



Profile L25 (South-North)



GCM tTEM Salten 2017

Resistivity Profiles (ohmm)

Smooth SCI Model

10 100 [Ohmm]

GCM results is shown as model bars.
tTEM results has been plotted on top of the GCM results as model bars.
Boreholes have been plotted on top as well.

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APPENDIX III: MEAN RESISTIVITY MAPS

This appendix includes mean resistivity maps generated from the smooth model inversion result in 5 m depth intervals from 0 to 30 m, and in 10 m intervals from 30 to 50 m. The resistivity models have been blanked at the DOI standard value prior to the interpolation to regular mean resistivity grids.

The interpolation of the mean resistivity values is performed by Kriging interpolation, with a node spacing of 5 m, a search radius of 100 m, and with additional pixel smoothing in the presented bitmaps images.

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Mean-resistivity, Depth 0 m - 0.5 m (ohm-m)

SCI Smooth Model - Kriging Search Radius 30 m

UTM 32N WGS84

250 m

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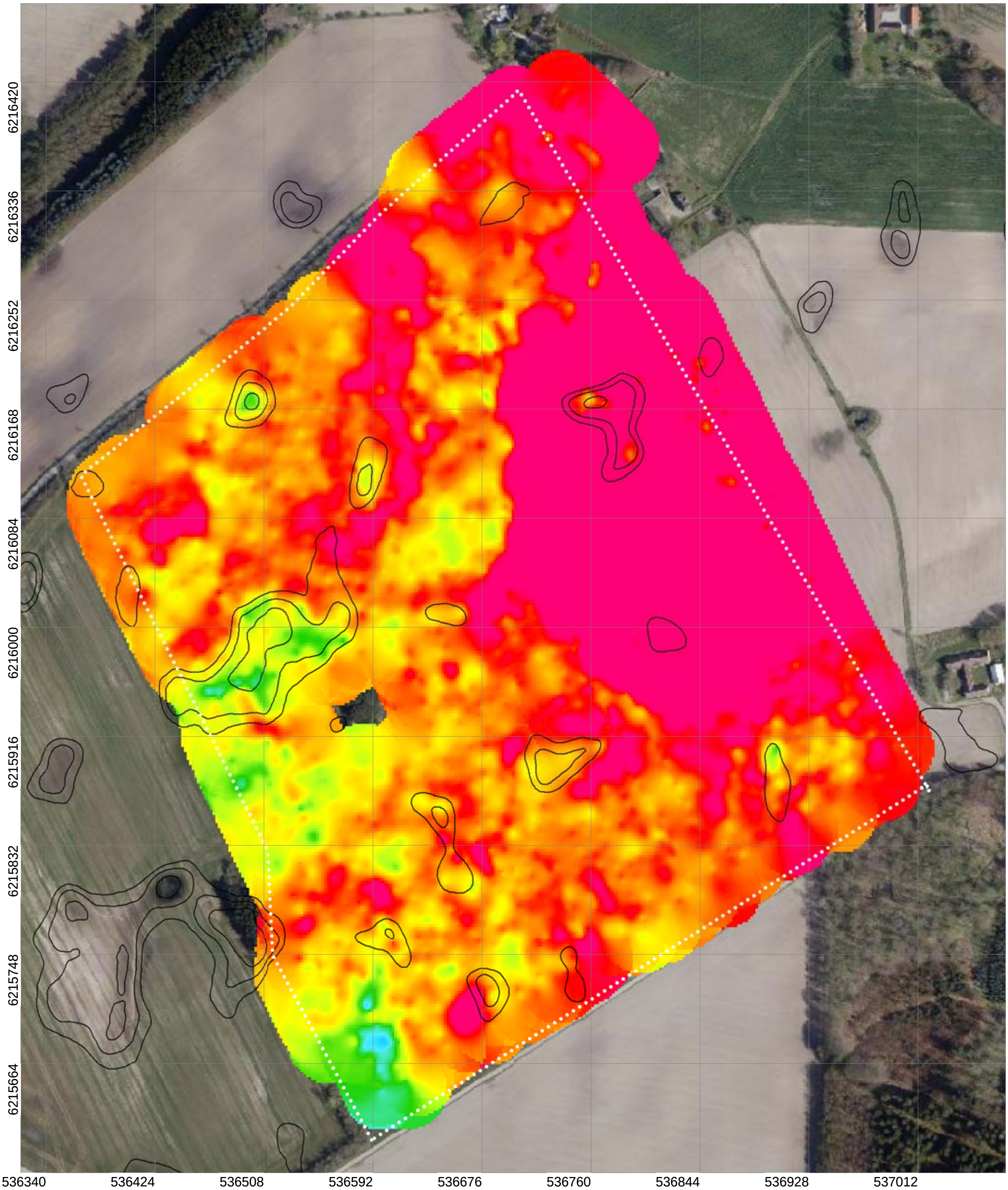

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Mean-resistivity, Depth 0.5 m - 1.0 m (ohm-m)

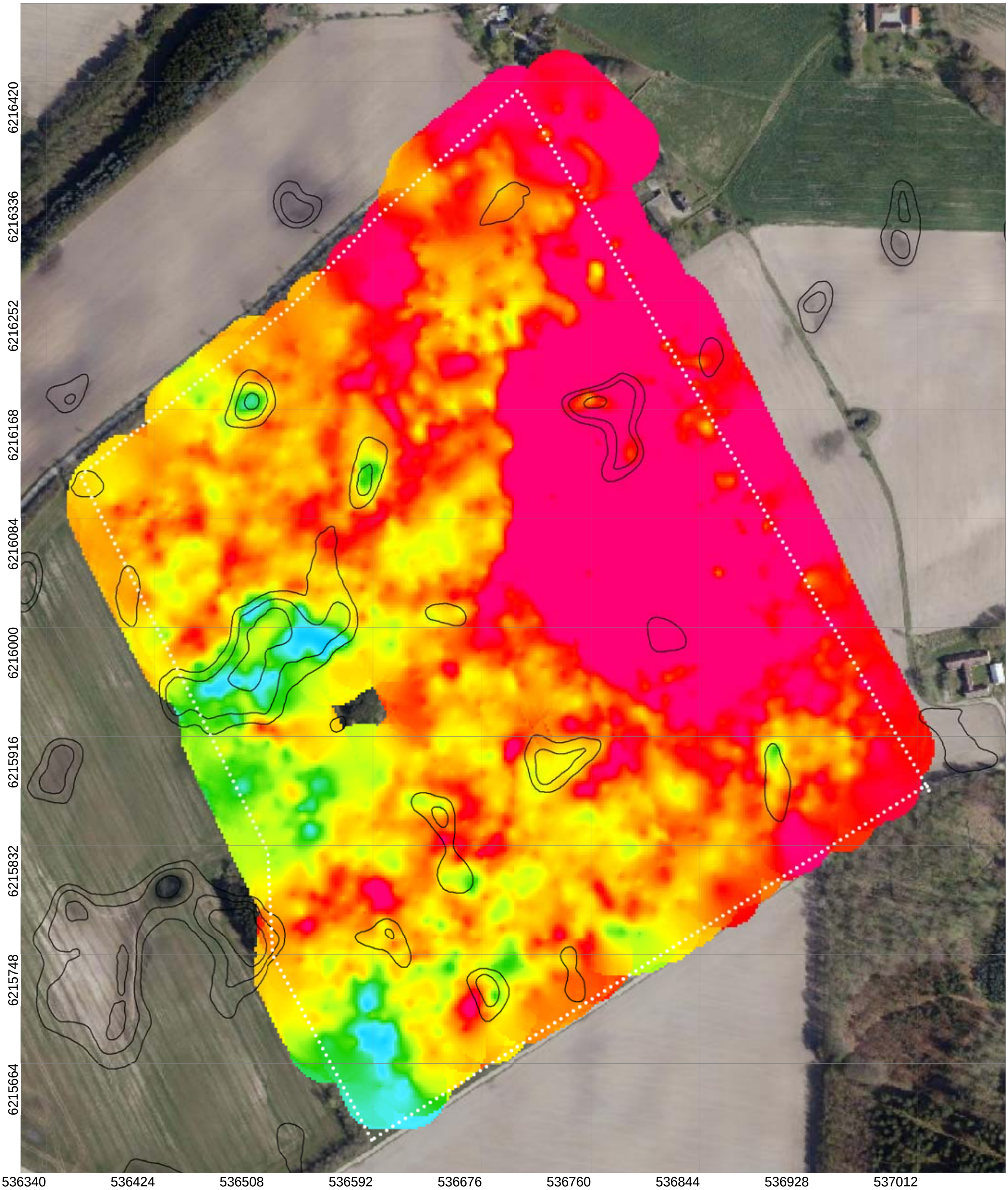
SCI Smooth Model - Kriging Search Radius 30 m

10 100

Resistivity [Ohmm]

UTM 32N WGS84

250 m



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GCM Salten 2017

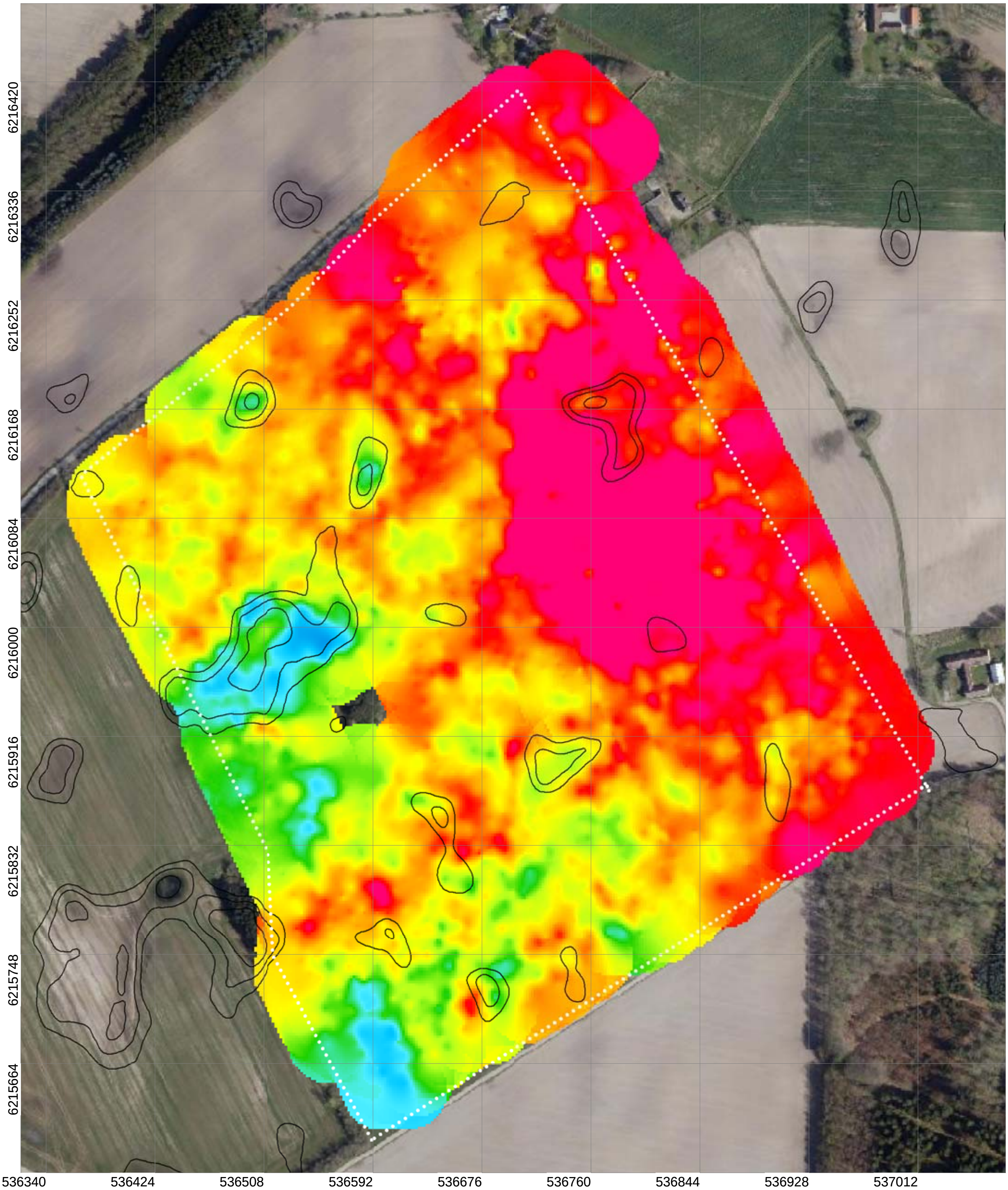
Mean-resistivity, Depth 1.0 m - 1.5 m (ohm-m)

SCI Smooth Model - Kriging Search Radius 30 m

10 100
Resistivity [Ohmm]

UTM 32N WGS84

250 m



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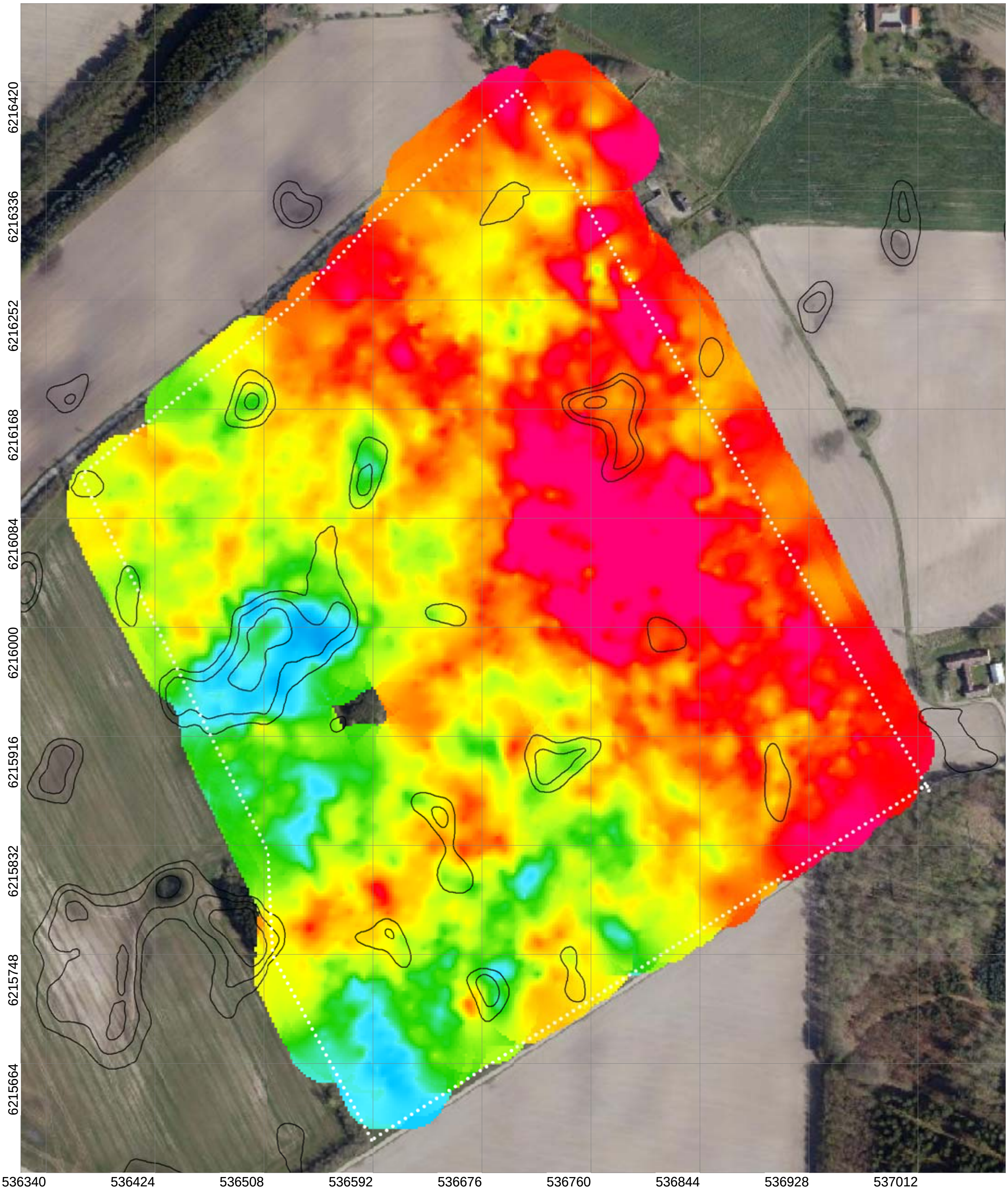
10 100
Resistivity [Ohmm]

Mean-resistivity, Depth 1.5 m - 2.0 m (ohm-m)

SCI Smooth Model - Kriging Search Radius 30 m

UTM 32N WGS84

250 m



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GCM Salten 2017

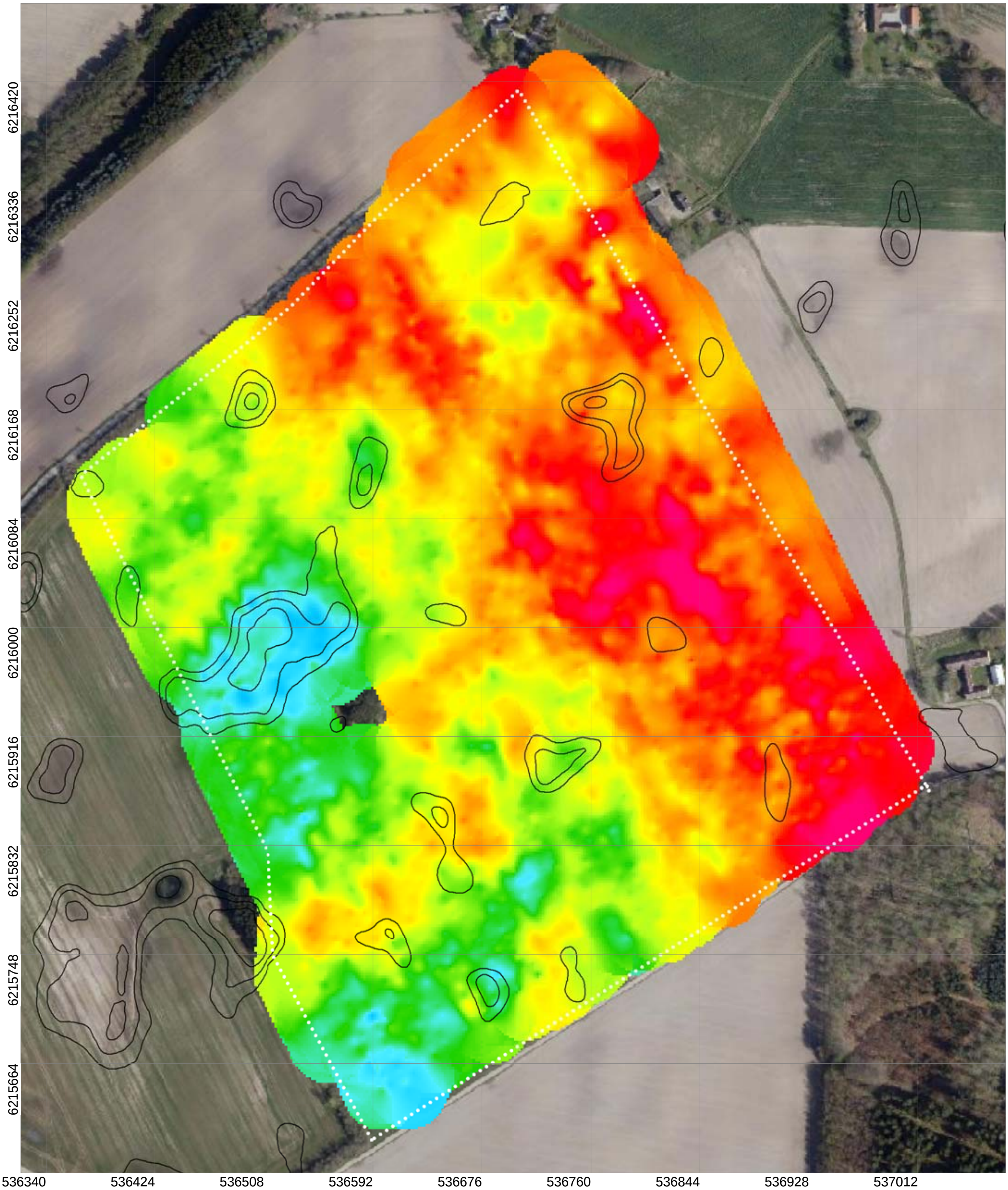
Mean-resistivity, Depth 2.0 m - 3.0 m (ohm-m)

SCI Smooth Model - Kriging Search Radius 30 m

10 100
Resistivity [Ohmm]

UTM 32N WGS84

250 m



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GCM Salten 2017

Mean-resistivity, Depth 3.0 m - 4.0 m (ohm-m)

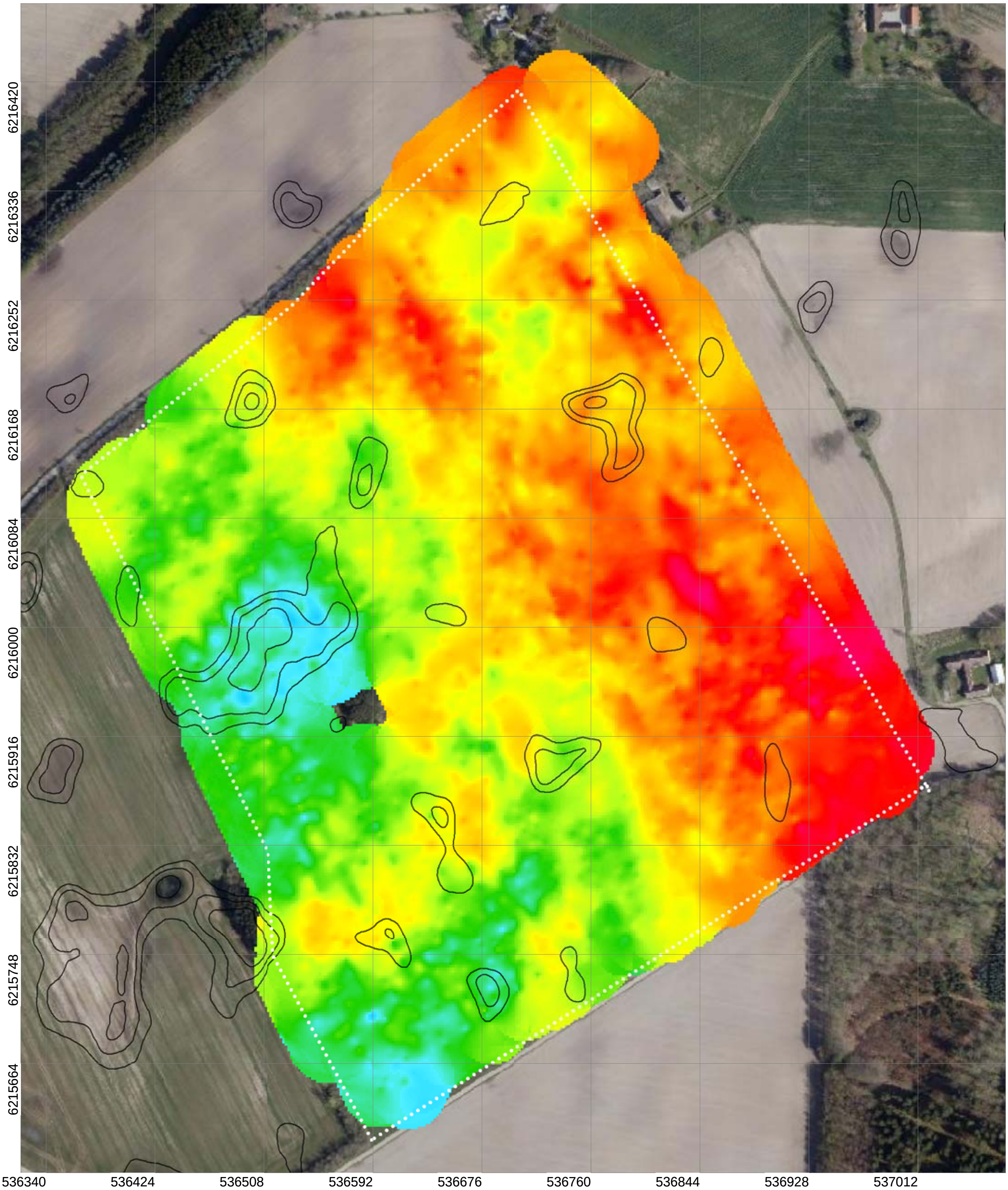
SCI Smooth Model - Kriging Search Radius 30 m

10 100

Resistivity [Ohmm]

UTM 32N WGS84

250 m



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GCM Salten 2017

Mean-resistivity, Depth 4.0 m - 5.0 m (ohm-m)

SCI Smooth Model - Kriging Search Radius 30 m

10 100

Resistivity [Ohmm]

UTM 32N WGS84

250 m

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Mean-resistivity, Depth 5.0 m - 10.0 m (ohm-m)

SCI Smooth Model - Kriging Search Radius 30 m

10 100

Resistivity [Ohmm]

UTM 32N WGS84

250 m

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Mean-resistivity, Depth 10.0 m - 15.0 m (ohm-m)

SCI Smooth Model - Kriging Search Radius 30 m

UTM 32N WGS84

250 m

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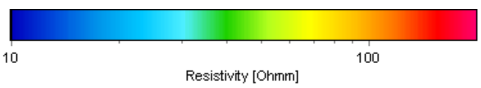
Mean-resistivity, Depth 15.0 m - 20.0 m (ohm-m)

SCI Smooth Model - Kriging Search Radius 30 m



UTM 32N WGS84

250 m

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Mean-resistivity, Depth 20.0 m - 25.0 m (ohm-m)

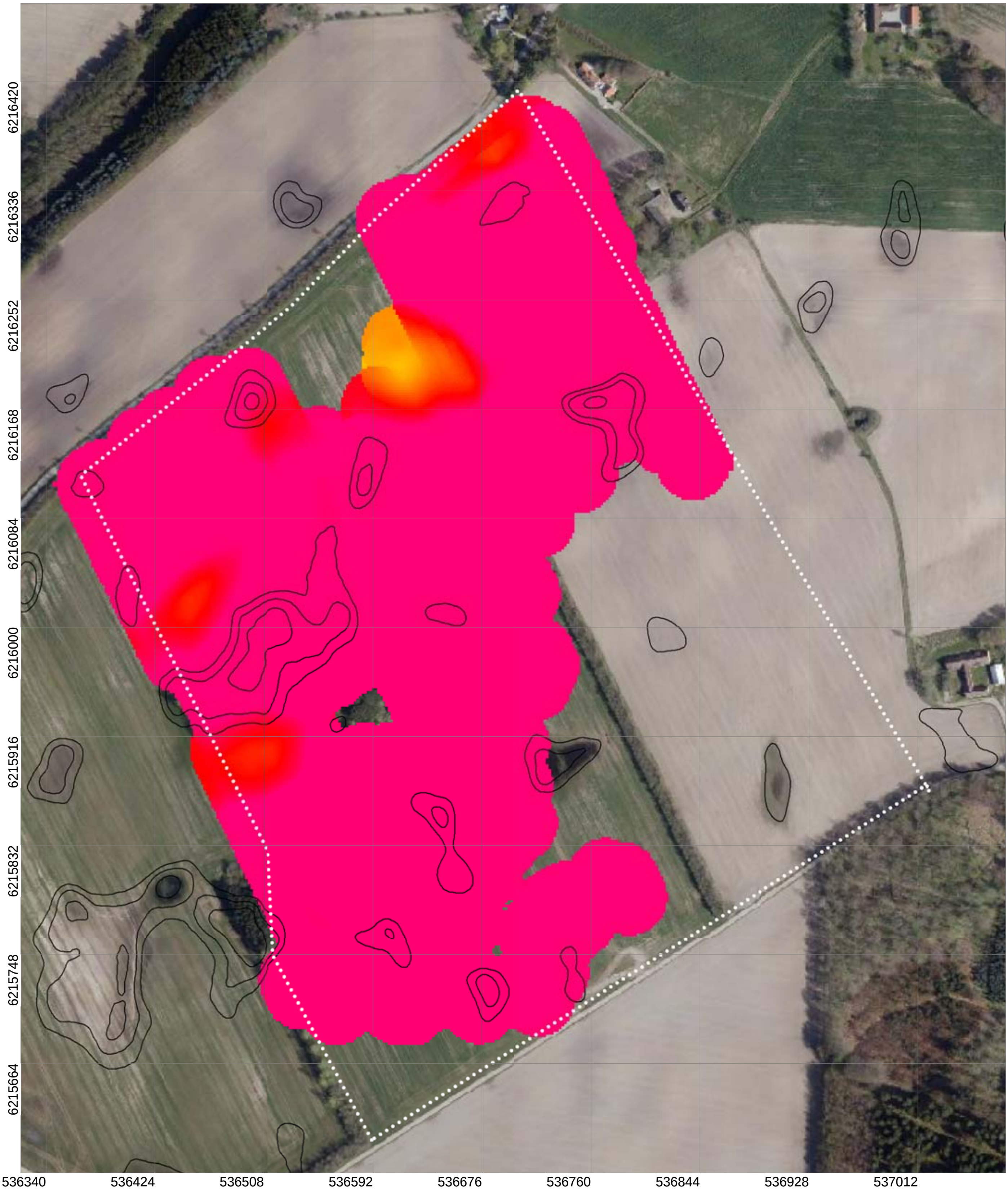
SCI Smooth Model - Kriging Search Radius 30 m

10 100

Resistivity [Ohmm]

UTM 32N WGS84

250 m



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Mean-resistivity, Depth 30.0 m - 40.0 m (ohm-m)

SCI Smooth Model - Kriging Search Radius 30 m

UTM 32N WGS84

250 m

tTEM Salten 2017

Mean-resistivity, Depth 40.0 m - 50.0 m (ohm-m)

SCI Smooth Model - Kriging Search Radius 30 m

UTM 32N WGS84

250 m