NIKU OPPDRAGSRAPPORT 176/2015

GEORADARUNDERSØKELSE VED ÅSKOLLEN

Tønsberg kommune, Vestfold fylke

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Sammendrag

In October 2015 archaeological geophysical prospection was carried out in the framework of ongoing development of the industrial estate at Åskollen, Tønsberg kommune. A motorized MIRA GPR system was deployed for the fieldwork and a total area of 5.4 ha was investigated. This report includes a technical description, archaeological interpretation and the resulting GPR data images. In general the surveys provided good results. The data images are clear and a suffiecient depth penetration for the detection of buried archaeology could be achieved. However, very few remains of possible archaeological interest could be detected.

Emneord
georadar

Avdelingsleder

Knut Paasche

Content

1 Aims of the survey

In November 2015 the Norwegian Institute for Cultural Heritage Research (NIKU) carried out geophysical surveys at Åskollen, Tønsberg municipality on behalf of the archaeology team from Kulturarv, Vestfold fylkeskommune. The surveys were initiated as part of archaeological evaluations of the respective area. The aim of the survey was to investigate agriculturally used areas by motorized high-resolution ground penetrating radar (GPR). Currently, the further development of the industrial estate at Åskollen is going to affect areas of possible archaeological interest. The geophysical surveys were carried out to map and interpret all detectable traces of human-induced activities ranging from single pits and postholes to graves, buildings, cemeteries, settlements and other man-made structures of archaeological interest prior to further planning decisions.

Fig. 1: Overview map, the area at Åskollen is marked with the red dot. Map source: Statens kartverk, Geovekst og kommuner.

Fig. 2: Detailed map of the survey area at Åskollen, Background map: Norge i bilder, Geovekst.

2 Survey area

Åskollen lies in Tønsberg municipality, Vestfold County, about 5km north-west of Tønsberg (fig. 1). The survey area is situated directly north of the industrial estate at Åskollen and directly west of the E18. Towards the north and west the survey area is delimited by further arable land, the area lies between 11 and 14 m above MSL. The Auli river is situated about 400 m from the survey area in western direction and the survey area is part of the river plain.

No archaeological remains have been previously registered directly in that area but several mound cemeteries and settlement remains from the Bronze- and Iron Age have been registered on the elevated N-S ridge to the east of the survey area (http://www.kulturminnesok.no/).

Two separate areas (fig. 2) have been surveyed at Åskollen. Subarea A1 is situated in the southern corner of the survey area. The area was recently (after 2012) converted into a car park and lies c. 1m higher than the surrounding area. The edges of the car park indicate that the former arable land was filled up with boulders and gravel in order to create the parking. The total size of the surveyed subarea is 2,456 m^2.

The larger subarea A has a rather flat surface, only towards its eastern edge the surface rises slightly towards the E18. The area was cultivated in 2015 with two different types of crop, leading to slightly different surface conditions. The total size of the survey area amounts to 53,763 m^2.

3 Methodology

Over the past years geophysical prospection methods have developed to become an indispensable set of tools in archaeology and have seen increasing popularity. From the numerous available methods, in particular magnetic prospection, earth resistance and GPR (ground penetrating radar) measurements have proven to be of particular use for archaeological applications. These methods permit the detection and mapping of buried man-made structures by measurement of the physical properties of the subsurface. In the case of archaeological prospection applications, dedicated measurement configurations are used for the spatial, gridded sampling with dense sample spacing for the investigation of several hectares of area in a short period of time. The data analysis and visualisation is conducted using specially developed processing algorithms and software.

The potential of the methods used is primarily determined by the contrast of the physical properties of the soil in comparison to the present archaeological structures. From experience, under suitable conditions, the magnetic prospection method is able to detect a diverse range of structures of archaeological interest (for example pits, postholes, trenches, hearths, furnaces, walls, track ways, palisade trenches).

GPR prospection can be used to detect stratigraphic interfaces, trenches, pits and post holes, masoned architecture and stone structures (e.g. walls, hearths, stone lining in post holes) as well as modern utilities in three dimensions. The GPR method can be adversely affected by high soil humidity and soils rich in clay, or in dry climates where the topsoil can be rich in minerals due to evaporation. While traditional GPR measurements are conducted using single antenna systems, with coverage rates of some 2,500 square metres per day at 25 cm crossline spacing, modern motorized surveying systems permit a considerably increased spatial coverage at very dense profile spacing.

Both in the case of magnetic and GPR measurements, a preliminary data analysis is possible on site for quality control and further planning of the survey. For detailed data analysis, powerful computer and special processing software are used. The visualised data of the individual measurements are combined in the form of georeferenced images that are subsequently interpreted archaeologically including all available information (e.g. terrain models, aerial images, previously registered archaeological remains, soil maps, written sources etc.) in the framework of a Geographical Information System (GIS) by experienced experts. Experiences gained during the last years throughout the county of Vestfold have shown that high resolution GPR prospection achieves the best results and was therefore chosen to be used for the investigations at Åskollen.

3.1 Principles of ground penetrating radar

The GPR method is a variant of radar technology based on the reflection of electromagnetic waves in the subsurface. An electromagnetic pulse with maximum amplitude of a certain frequency is emitted into the subsurface using a transmitter antenna. This pulse is travelling through the ground with a velocity dependent on the traversed material, and it is reflected from individual objects or interfaces with differing physical properties (i.e. dielectric permittivity, electric conductivity). The returning part of the emitted signal is recorded with a receiver antenna and digitized in form of a so-called reflection trace. When many of these single traces are recorded next to each other a vertical GPR profile is produced along the line the antennas where moved. The changes in signal amplitude and frequency carry information about the composition of the subsurface (soil humidity, porosity, clay content) and contained structures. The traveltime of the electromagnetic signal is proportional to the distance of reflecting objects or interfaces.

It is mainly the dielectric permittivity of the medium, its electric conductivity, the radiation characteristics of the antennas used, and the frequency content of the emitted GPR pulse that govern its propagation in the subsurface (maximum signal penetration depth, vertical and horizontal resolution).

The contrast of the dielectric permittivity of two media determines the amount of energy reflected from objects or at layer interfaces. In the upper soil layers strong reflection coefficients are caused by changes in the substrate, by strong inhomogenities due to varying soils humidity, and by contained anthropogenic objects or structures (e.g. utilities, foundation walls).

The absorption of the electromagnetic energy transmitted into the ground depends on the transversed medium (material dependent absorption loss). The reduction in signal amplitude of the transmitted energy pulse depends mainly on the electrical conductivity of the medium and the travelled distance, with the conductivity being the determining factor for the actual penetration depth of the electromagnetic pulse. By comparing amplitudes it is possible to differentiate areas according to their absorption properties.

GPR antennae emitting a low frequency signal (e.g. 100 - 200 MHz) permit a greater depth of investigation at reduced resolution, due to the longer wavelength of the signal. High-frequency signals (e.g. 800 - 1000 MHz) offer the greatest resolution, but only limited signal penetration (< 1 m). GPR antennas commonly used for archaeological prospection typically operate with signal frequencies between 400 - 500 MHz, offering penetration depths of 1.5 - 3 m and sufficient vertical resolution.

Material	ϵ_r	σ [mS/m]	v [m/ns]
Air	1	0	0.30
Sweet water	81	1 – 300	0.03
Salt water	81	4000	0.03
Dry sand	3 – 5	0.5 – 1.5	0.13 – 0.17
Wet sand	20 – 30	5 – 20	0.05 – 0.17
Dry clay	10 – 50	20 – 200	0.08 – 0.17
Wet clay	2 – 30	10 – 100	0.05 – 0.07
Peat	20 – 40	100 – 300	0.04 – 0.06
Granite	4 – 6	0.3 – 2	0.11 – 0.16
Limestone	4 – 8	0.1 – 2	0.1 – 0.14
Sandstone	4 – 12	1 – 10	0.08 – 0.13

Table 1: Approximate values of the relative dielectric permittivity ϵ_r, the electric conductivity δ and the GPR signal velocity v for several common materials (modified from Davis and Annan 1989).

In general, GPR data are very substantial and contain a large amount of information. The visualisation of GPR data is commonly realized in the form of greyscale images showing the amplitudes of the recorded signals as a function of space and time.

Within the individual GPR sections, representing vertical cuts through the subsurface, typical reflection and diffraction patterns of the signals can be observed that are generally very difficult to interpret. However, the use and visualisation in the form of vertical GPR sections is today rather uncommon in geophysical archaeological prospection and outdated, with exception of special applications.

The individual GPR sections collected manually or with motorized survey systems are merged after the fieldwork in the computer using specially developed software solutions. Through interpolation a virtual three-dimensional data volume is generated. If the velocity of the GPR signal in the subsurface is known or estimated (a value commonly used is a constant velocity for the entire subsurface of 10 cm/ns; however, variations between 5 and 15 cm/ns can be encountered), it is possible to convert the vertical axis of the data volume from time to depth.

This digital block of data can be cut into horizontal slices, so called GPR time-slices or GPR depth-slices. Slices of different thickness can be computed, e.g. at 5 cm, 10 cm, 20 cm, 30 cm, 40 cm and 50 cm, averaging variable amounts of information contained in the data volume.

Using these slices it is possible to map and image archaeological structures that occur at approximately the same depth, considerably facilitating their archaeological interpretation since the spatial context becomes clear to the observer. By scrolling through a stack of thin GPR depth- or time-slices in form of a quick succession of images or an animation, it becomes possible to understand the spatial extent of structures contained in the data. While the relative depth of structures imaged using the GPR method is correctly imaged, it should be kept in mind that the absolute depth of the structures can vary by approximately +/- 20% due to the lack of knowledge of the exact GPR signal velocity distribution in the imaged volume.

4 Fieldwork and Equipment

The fieldwork at Åskollen was carried out on the 12th and 13th of November 2015 when a total area of 56,219 m^2 could be surveyed. The survey and weather conditions were good, and only small areas in the western part were rather wet causing some difficulties when driving there. The driving direction in the field was chosen along the ploughing direction allowing a faster surveying speed and better ground contact of the radar antennas. The different types of crop cultivated in the field provided different surface conditions and therefore small differences can be observed in the GPR data.

4.1 GPR instrumentation

A motorized 16-channel GPR array (MIRA 3) has been applied for the fieldwork at Åskollen. The MIRA 3 ground penetrating radar system is a high-resolution multichannel radar system based on the *MALÅ Imaging Radar Array* (MIRA). The GPR array consists of 8 receiver and 9 transmitter antennas with a centre frequency of 400 MHz. Transmitters and receivers are mounted in two rows with an offset of half an antenna width in a ruggedized box. Each receiver antenna records the signal of the two neighbouring transmitter antennas. The cross line spacing between the resulting 16 channels therefore amounts to 10.5 cm. In total a 178 cm wide swath of 16 single GPR sections is recorded for each driven line. The antenna box is mounted to the front hydraulics of a Kubota mini tractor (RTV-X900), which allows a floating position and hence ideal ground contact of the antenna box during the entire survey.

Surveys at Åskollen were conducted with each channel constantly recording 40 single measurements per second leading to an average in-line trace spacing of 4 cm depending on the actual driving speed (usually between 7 and 9 km/h). The resulting minimum spatial resolution for this survey therefore amounts to 10.5 x 4 cm. Each recorded GPR trace is averaged from 4 actually measured traces (4 stacks). The record time of the system was set to 70 ns allowing for a maximum penetration depth of 3.5 m (at an assumed GPR signal velocity of 0.1 m/ns). A ruggedized industrial computer (TANK-700) equipped with software products MIRAsoft (MALÅ Geoscience), NetView (Javad) and LoggerVIS (LBI ArchPro) is mounted in the Kubota minitractor and is used for data acquisition, measurement control and navigation. The centimetre accuracy for positioning and navigation is provided by a Javad Sigma GNSS system with CPOS subscription.

4.2 Processing

A first processing of the GPR data was carried out immediately after fieldwork in order to control for data quality and sufficient coverage. Further processing and visualization steps were carried out using the software ArchProSoft, developed by ZAMG ArcheoProspection*ns*® and the LBI ArchPro. A 3D data block was created from the individual GPR sections. This data block was then cut into horizontal slices (GPR depth-slices) of 5 cm thickness displayed as greyscale images. A constant GPR signal velocity of 0.085 m/ns was used for the time - depth conversion according to the results of a hyperbola adaption analysis of several single GPR sections carried out in Reflexw, leading to a maximum recorded depth of 260 cm. Due to GPR signal attenuation there are no more features visible below a depth of c. 130 – 150 cm. It has to be considered that the GPR signal velocity may vary throughout different parts of the area, therefore an error of +/- 20% in the calculated depth information is possible.

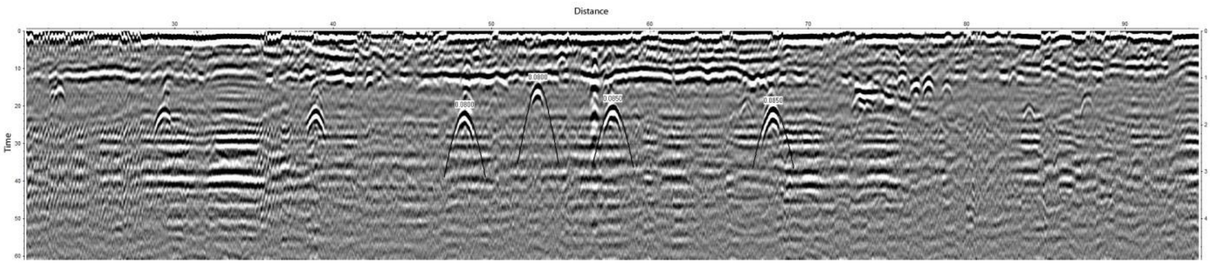

Fig. 3: Cross-section view of survey line 002 / channel 08, showing clear reflection hyperbolas used for the velocity adaption analysis.

Various common GPR processing steps (trace interpolation; band-pass frequency filtering; spike removal; de-wow filter; average-trace-removal; amplitude gain correction; amplitude balancing and Hilbert transformation) have been applied with different settings prior to the 3D data block computation, leading to different result images. Archaeological structures might therefore be clearly visible in one of these datasets, whereas they could be almost invisible on another one. That is why all resulting images need to be analysed and used for the interpretation. The two subareas were processed separately, but were eventually combined to produce the final images.

The resulting images were embedded into an ArcMap (ESRI) geodatabase. Data analysis, archaeological interpretation and the creation of maps were conducted in the framework of the GIS using the ETRS1989 UTM zone 32N coordinate reference system and a special ArcMap extension developed for the archaeological interpretation of geophysical data (ArchaeoAnalyst, LBI ArchPro).

5 Results

5.1 Modern features

A large number of straight linear features can be observed all across the surveyed area at Åskollen. These features generally appear at a depth between 30 and 130 cm, but are most distinguishable at a depth of c. 70 – 90 cm. Most of them show a two way appearance: At a depth of c. 30 - 40 cm they show absorbing properties, displayed as white or light grey in the depth-slices. In the lower slices they switch to reflective properties displayed in dark grey or black. Due to their appearance and spatial distribution these features are interpreted as drainage diches and pipes.

All along the eastern edge a reflective band of c. 20 m width can be observed running parallel with the E18 a bit further to the East. Aerial images from 2012 show that this area was affected by road works for the new E18, and the reflective band might therefore represent modern debris or simply compacted soil from the road works.

5.2 Archaeology

Very few features originating from human activities can be observed in the dataset from Åskollen. These are circular or approximately circular features with diameters between 0.8 and 2.5 m, and are limited to the south-western corner of the survey area. They first show up directly beneath the plough soil at c. 25 cm depth and some of them remain visible down to c. 80 cm, however, the larger number is limited to a depth range of c. 25 – 45 cm. Most of them show absorbing properties in the depth range of approximately 25 – 35 cm and reflective properties further down. The features are clearly a disturbance of the natural layering in that area and are potentially caused by human activities. Some kind of archaeological pits (cooking pit, storage pit, etc.) are a conceivable interpretation. However, other rather recent human activities like stone extraction for clearance purposes could also cause such anomalies; furthermore these could have natural causes like specific tree root systems. In the case of Åskollen, an aerial photograph from the 1950s shows a former forest exactly in the area with the larger number of the pit-like structures, indicating that they might be caused by remaining tree roots or pits derived from the removal of tree trunks.

5.3 Paleoenvironmental observations

The larger parts of the survey area show rather homogeneous subsoil probably caused by the marine sediments present in the area. In the north-western part of the area the remains of several palaeochannels cut into the marine sediment can be observed. The large, reflective areas between the channels are probably caused by deposits formed by the former creeks or simply display water logged areas in the landscape from former meandering streams.

The large reflective band alongside the eastern border of the survey area (described in 5.1 Modern features) could also be caused by geological processes. An erosion layer originating from the N-S running ridge east of the present day E18 appears to be another possible interpretation for that feature.

5.4 Subarea A1

No relevant features could be detected in subarea A1. This is simply explained by the rather modern filling-up of the area with stones and gravel. The material reaches a thickness of approx. 1 m, and due to signal attenuation no features could be detected below this layer.

Fig. 4: Overall interpretation map of the surveyed areas at Åskollen, Background map: Statens kartverk, Geovekst og kommuner

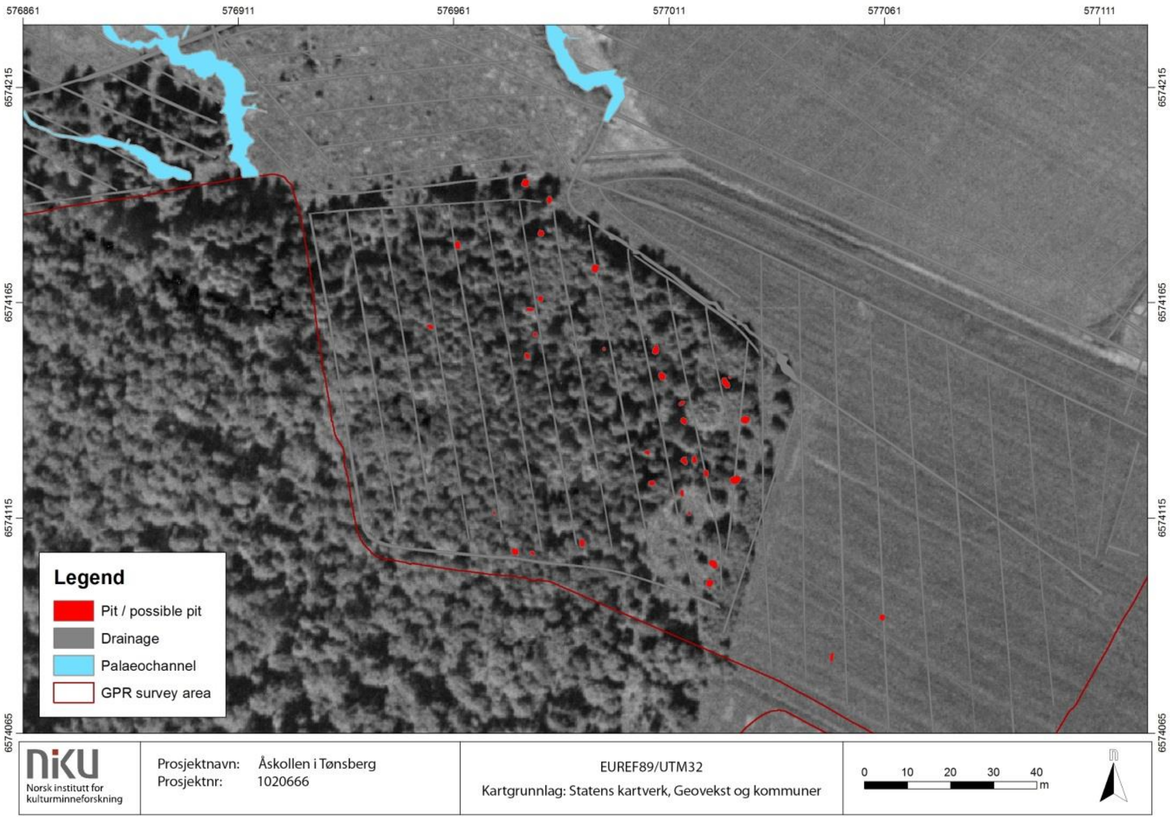

Fig. 5: Aerial image from 1954 (source: Norge i Bilder, Geovekst) overlain with the interpretations and showing the congruence between the pit-like structures and the former forest.

6 Conclusion

In general, the GPR investigations at Åskollen provided good results, the depth-slice images are clear and the positioning is accurate. Especially the case of the large number of drainage diches and pipes show that a strong contrast between the natural soil and human-made structures is present. The maximum reached depth-penetration of 1.4 m is sufficient to detect possible buried archaeology. However, no clear features of archaeological relevance could be detected. The interpreted pits/possible pits could have other origins than being human made or could display human interference in the soil with little or no archaeological relevance.

7 Bibliography

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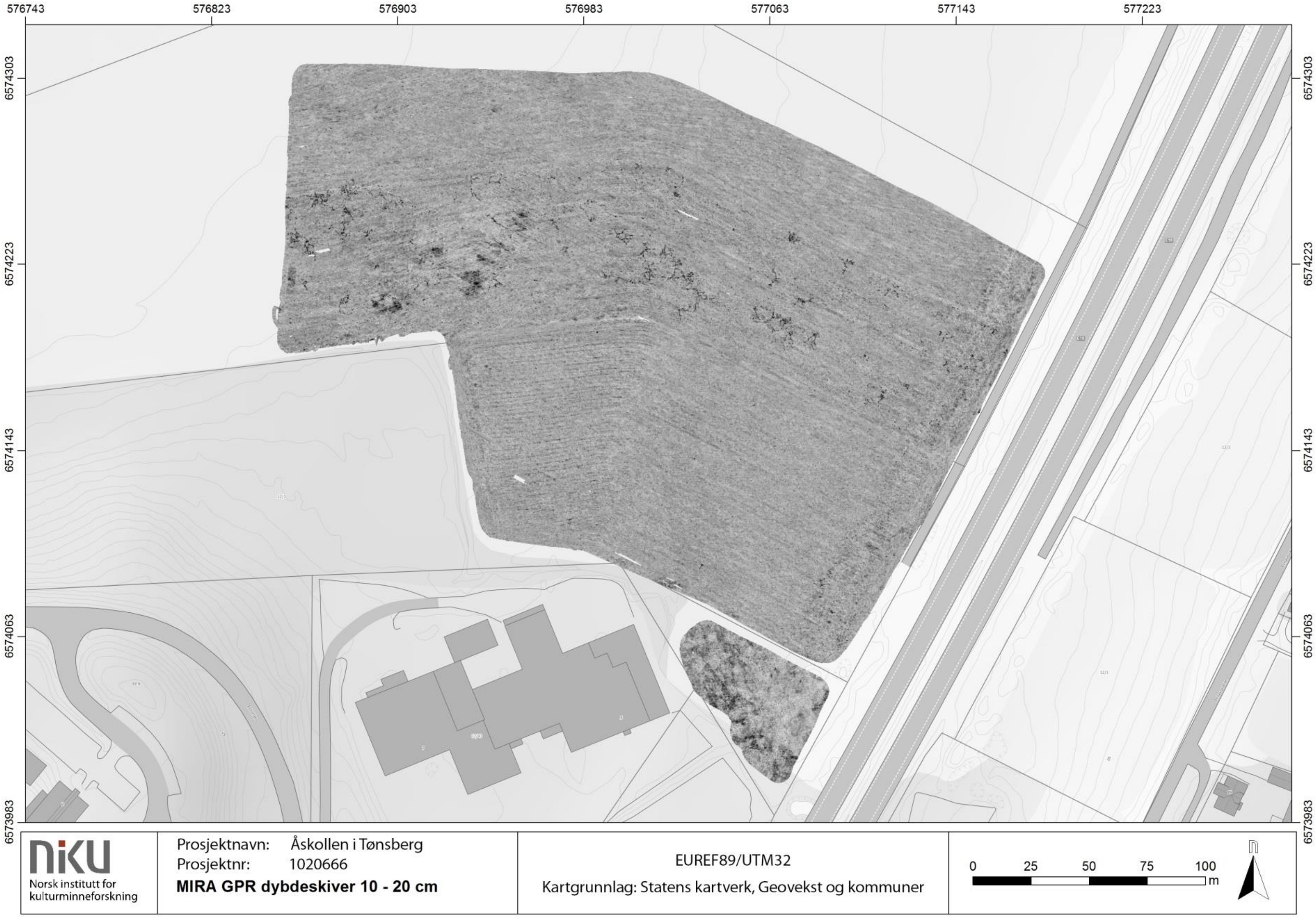
Davis, Les J., Annan, Peter.	Ground penetrating radar for high resolution mapping of soil and rock stratigraphy. Geophysical prospecting, Vol. 37, p. 531-551, 1989.
Trinks, Immo, et al.	Efficient, large-scale archaeological prospection using a true 3D GPR array, Archaeological Prospection 17, p. 175-186, 2010

Appendix – MIRA GPR depth-slices

niku Norsk institutt for kulturminneforskning	Prosjektnavn: Åskollen i Tønsberg Prosjektnr: 1020666 **MIRA GPR dybdeskiver 0 - 10 cm**	EUREF89/UTM32 Kartgrunnlag: Statens kartverk, Geovekst og kommuner	0 25 50 75 100 m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Norsk institutt for kulturminneforskning
Prosjektnavn: Åskollen i Tønsberg
Prosjektnr: 1020666
MIRA GPR dybdeskiver 10 - 20 cm
EUREF89/UTM32
Kartgrunnlag: Statens kartverk, Geovekst og kommuner
0 25 50 75 100
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NIKU Norsk institutt for kulturminneforskning	Prosjektnavn: Åskollen i Tønsberg Prosjektnr: 1020666 **MIRA GPR dybdeskiver 20 - 30 cm**	EUREF89/UTM32 Kartgrunnlag: Statens kartverk, Geovekst og kommuner	0 25 50 75 100 m

Norsk institutt for kulturminneforskning

Prosjektnavn: Åskollen i Tønsberg
Prosjektnr: 1020666
MIRA GPR dybdeskiver 30 - 40 cm

EUREF89/UTM32
Kartgrunnlag: Statens kartverk, Geovekst og kommuner

0 25 50 75 100 m


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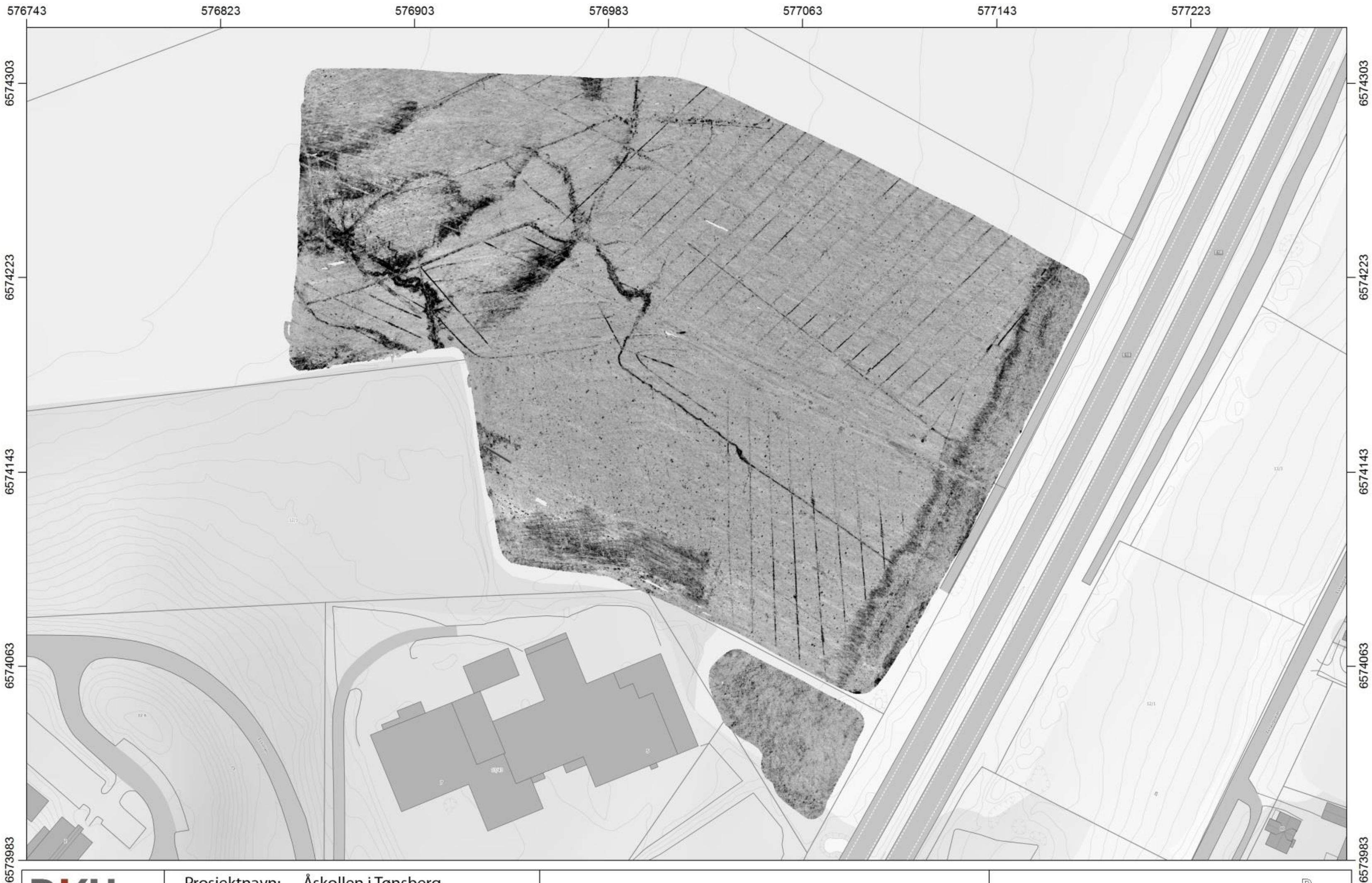
Prosjektnavn: Åskollen i Tønsberg
Prosjektnr: 1020666
MIRA GPR dybdeskiver 40 - 50 cm
EUREF89/UTM32
Kartgrunnlag: Statens kartverk, Geovekst og kommuner
0 25 50 75 100 m

niku Norsk institutt for kulturminneforskning	Prosjektnavn: Åskollen i Tønsberg Prosjektnr: 1020666 **MIRA GPR dybdeskiver 50 - 60 cm**	EUREF89/UTM32 Kartgrunnlag: Statens kartverk, Geovekst og kommuner	0 25 50 75 100 m



NIKU Norsk institutt for kulturminneforskning	Prosjektnavn: Åskollen i Tønsberg Prosjektnr: 1020666 **MIRA GPR dybdeskiver 60 - 70 cm**	EUREF89/UTM32 Kartgrunnlag: Statens kartverk, Geovekst og kommuner	0 25 50 75 100 m

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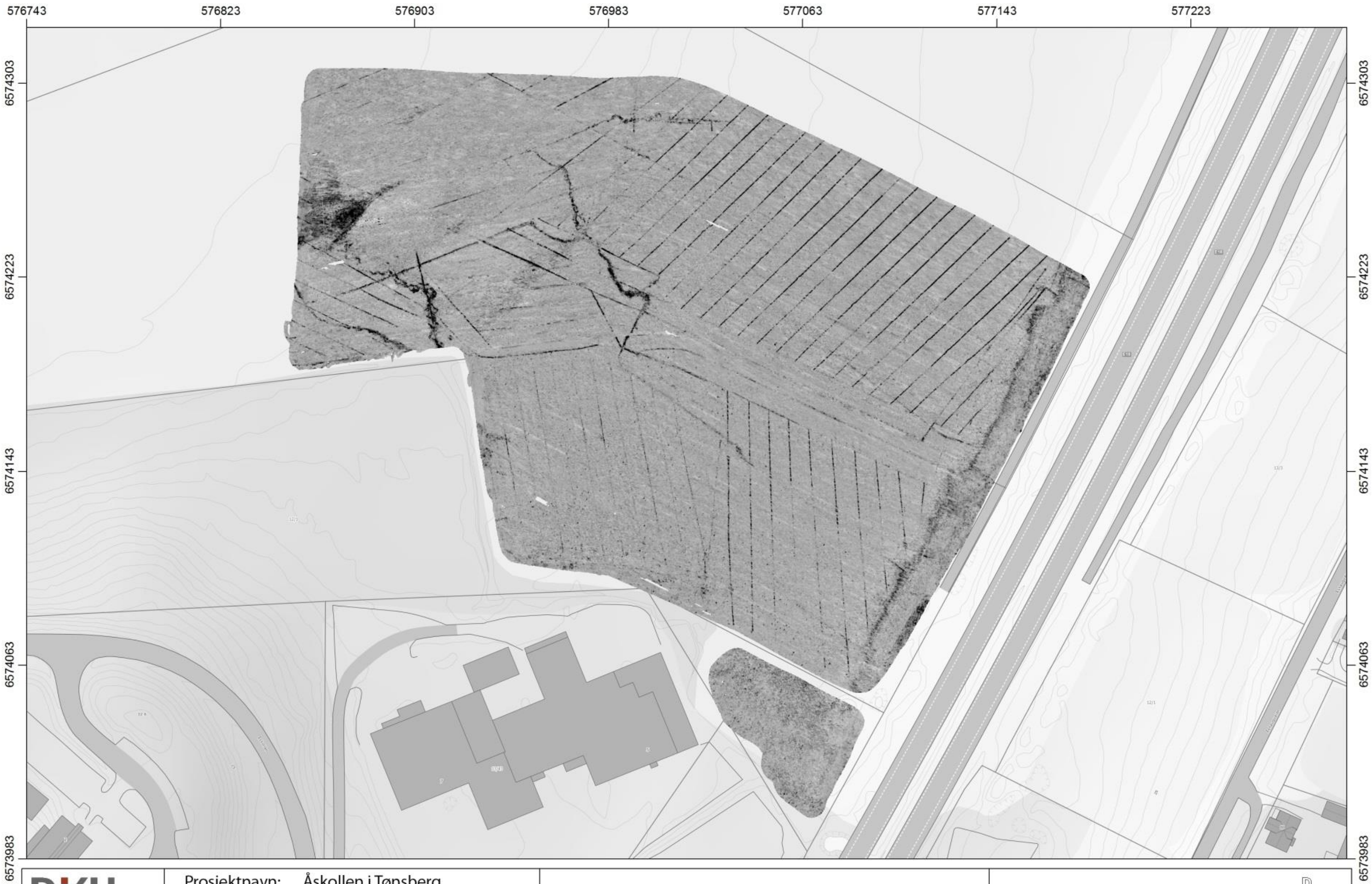
Prosjektnavn: Åskollen i Tønsberg
Prosjektnr: 1020666
MIRA GPR dybdeskiver 70 - 80 cm

EUREF89/UTM32
Kartgrunnlag: Statens kartverk, Geovekst og kommuner

0 25 50 75 100 m

niku Norsk institutt for kulturminneforskning	Prosjektnavn: Åskollen i Tønsberg Prosjektnr: 1020666 **MIRA GPR dybdeskiver 80 - 90 cm**	EUREF89/UTM32 Kartgrunnlag: Statens kartverk, Geovekst og kommuner	0 25 50 75 100 m



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Prosjektnr: 1020666
MIRA GPR dybdeskiver 90 - 100 cm

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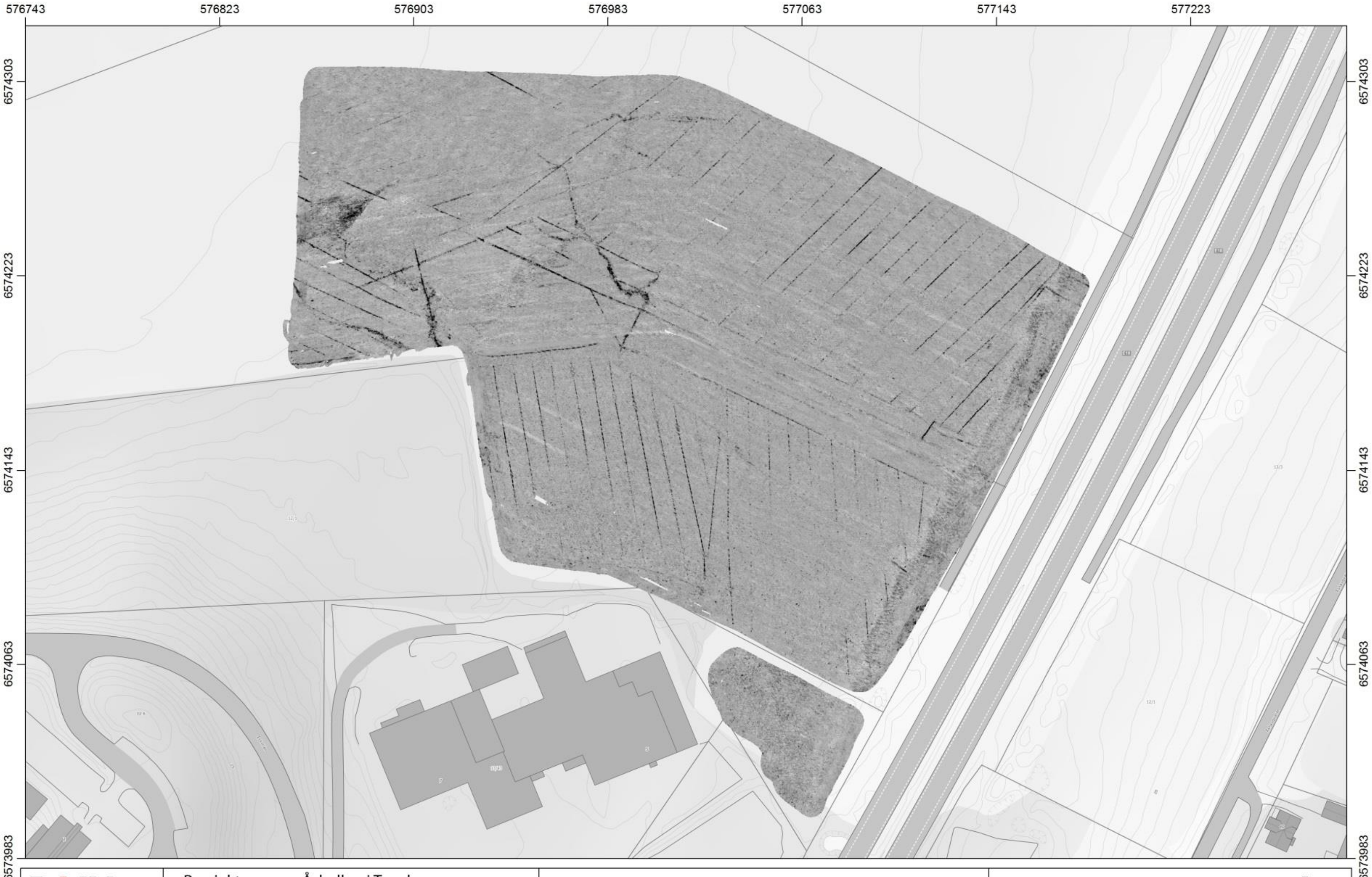

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MIRA GPR dybdeskiver 100 - 110 cm

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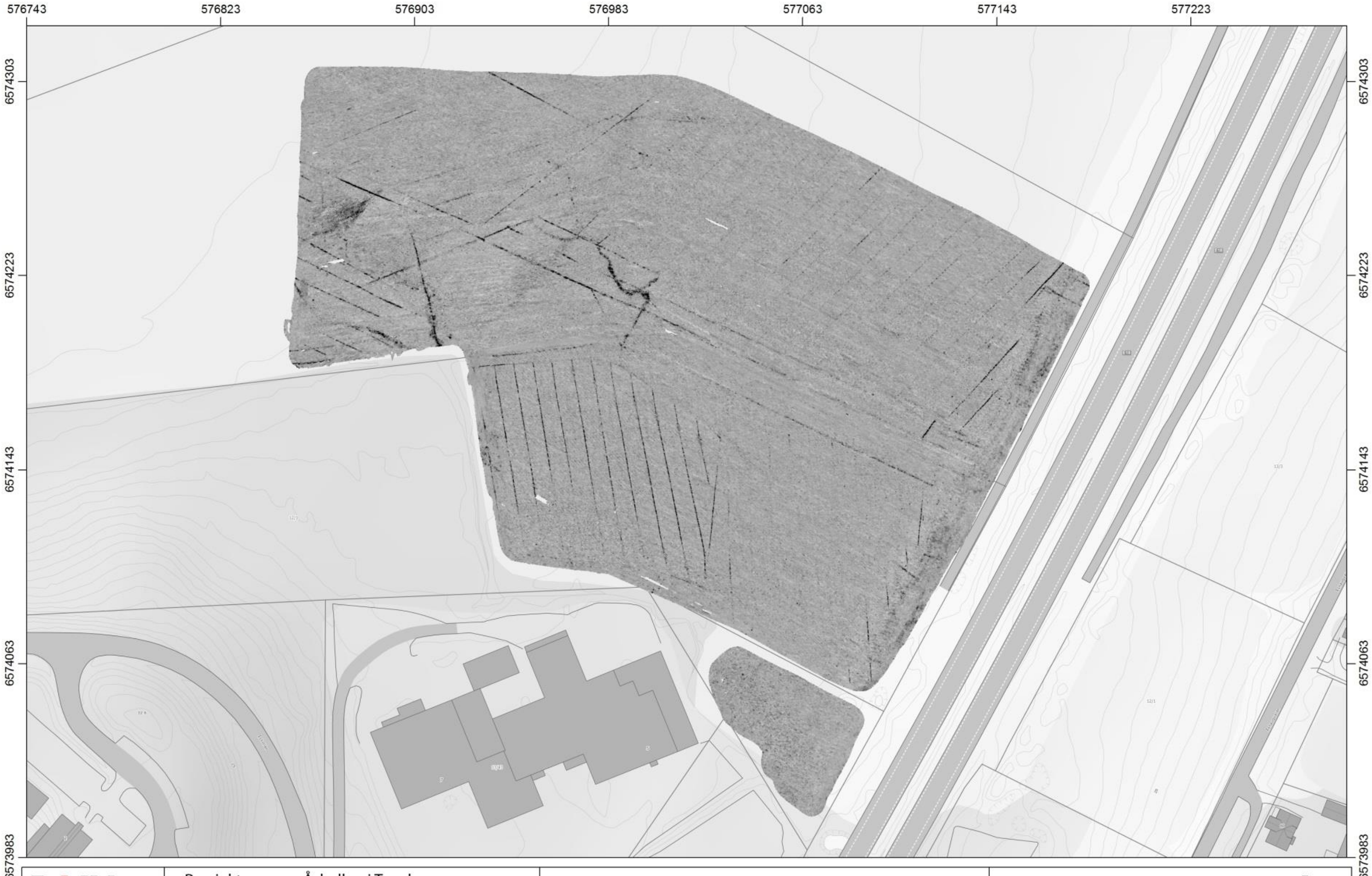

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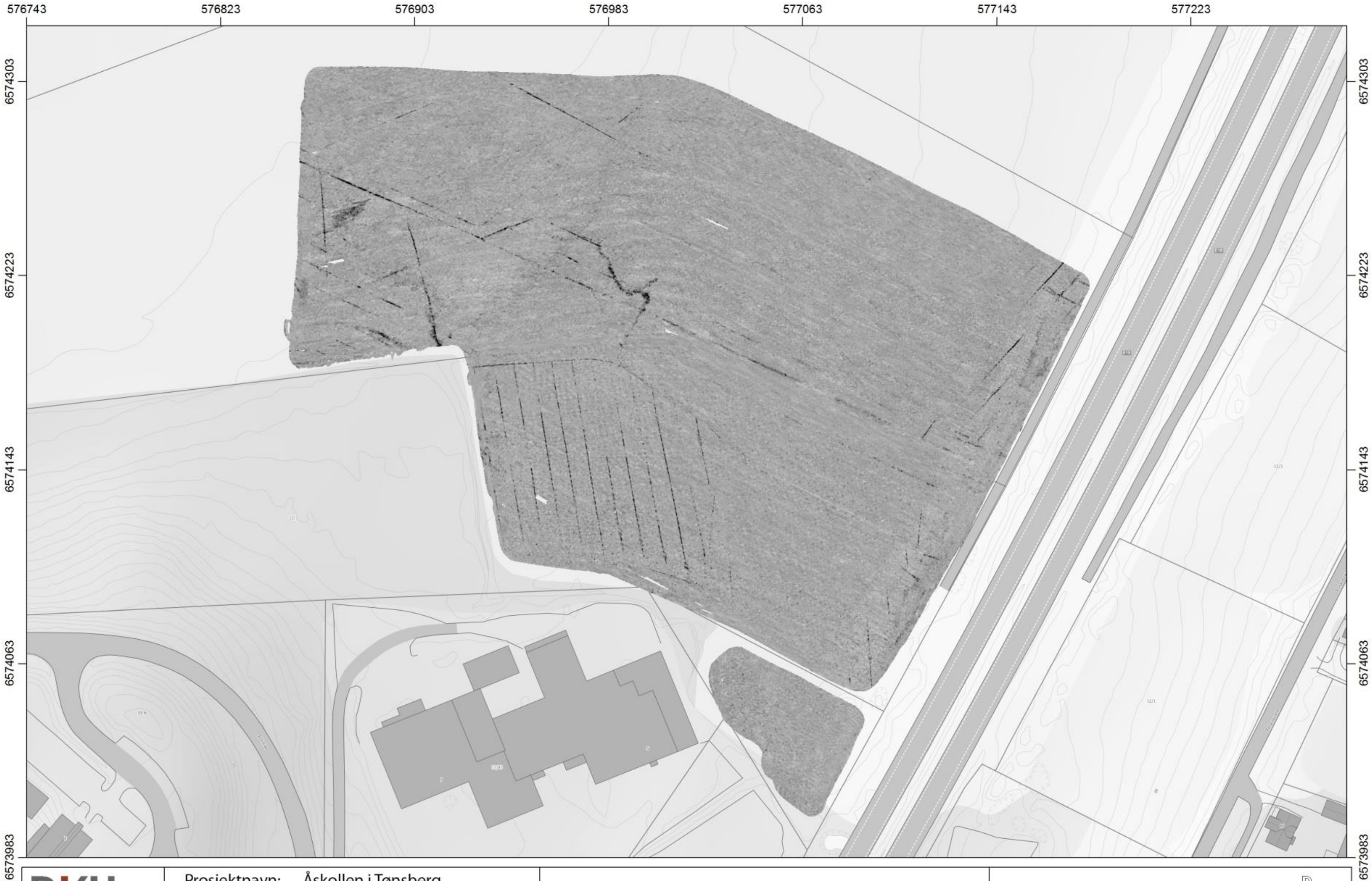

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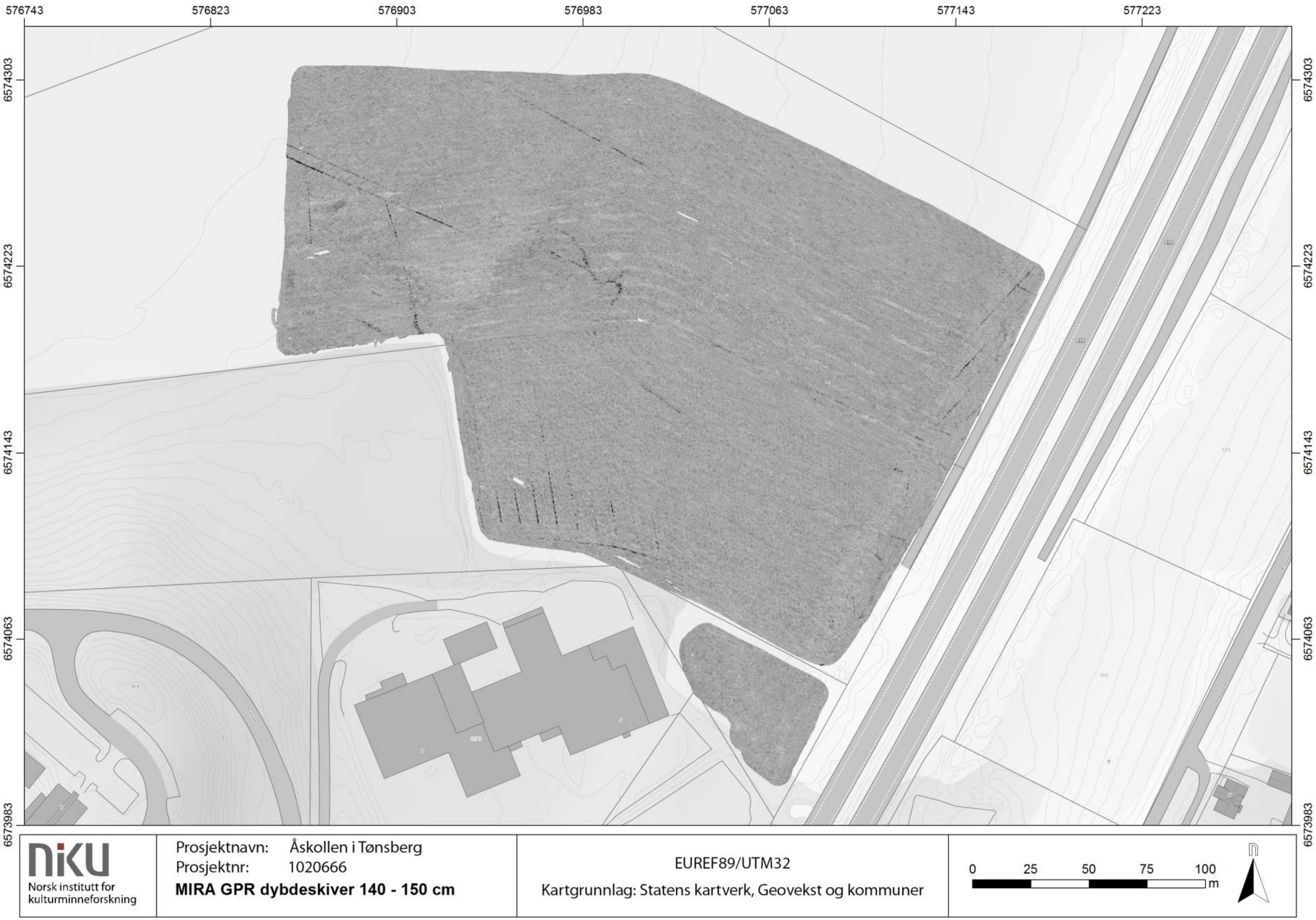
Prosjektnavn: Åskollen i Tønsberg
Prosjektnr: 1020666
MIRA GPR dybdeskiver 120 - 130 cm

EUREF89/UTM32
Kartgrunnlag: Statens kartverk, Geovekst og kommuner

0 25 50 75 100 m

niku Norsk institutt for kulturminneforskning	Prosjektnavn: Åskollen i Tønsberg Prosjektnr: 1020666 **MIRA GPR dybdeskiver 130 - 140 cm**	EUREF89/UTM32 Kartgrunnlag: Statens kartverk, Geovekst og kommuner	0 25 50 75 100 m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Prosjektnavn: Åskollen i Tønsberg
Prosjektnr: 1020666
MIRA GPR dybdeskiver 140 - 150 cm
EUREF89/UTM32
Kartgrunnlag: Statens kartverk, Geovekst og kommuner
0 25 50 75 100 m

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