NOTTINGHAM CASTLE OUTER BAILEY, NOTTINGHAM

Report on geophysical survey conducted in April 2014

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SUMMARY

- Trent & Peak Archaeology was commissioned by Nottingham City Council to conduct a geophysical survey within the Outer Bailey of Nottingham Castle, Nottingham, centered on NGR SK 56985 39485 at a height of c. 45m OD (Fig. 1).

- The work was carried out between the 7th and 18th April 2014 following the methodology detailed in the WSI (TPA 2014), in accordance with standard, accepted practices for archaeological geophysical surveys (EH 2008). As Nottingham Castle is a Scheduled Ancient Monument, a Section 42 licence to undertake the survey was obtained by TPA from English Heritage.

- The site is situated on deposits of Nottingham Castle Sandstone Fomation, with superficial Head deposits.

- The site was composed of a single area covering approximately 1Hectare within the Outer Bailey of Nottingham Castle, Nottingham.

- A suite of geophysical survey techniques were employed, earth-resistance, geomagnetic, and ground-penetrating radar were successfully employed to image buried archaeological features and to determine the location and depth of the interface between superficial deposits and the bedrock.

- Geophysical survey demonstrated the presence of potential buried archaeological features, these comprised:

  - Evidence through the earth-resistance survey for possible structures in the shallow sub-surface.

  - Evidence through the GPR survey for possible cave systems.

  - Evidence through the GPR survey for possible post-mediaeval structures.

  - Evidence through the GPR survey for possible 19th century structures.

Report on the geophysical survey of the Outer Bailey at Nottingham Castle, Nottingham.
NGR SK 56985 39485

CONTENTS

LIST OF FIGURES

ACKNOWLEDGEMENTS

The Project Manager for the work undertaken was Paul Johnson. The Project advisor was Lee Elliott. The Project Team comprised Lizzie Richley, Tom Hooley, Povilas Cepauskas, and volunteers from the Nottingham City Council volunteering programme. Neil Linford of English Heritage was consulted on the project design.

1. INTRODUCTION

1.1. Trent & Peak Archaeology conducted a geophysical survey within the Outer Bailey of Nottingham Castle, Nottingham, centered on NGR SK 56985 39485 at a height of c. 45m OD (Fig. 1).

1.2. The work was carried out between the 7th and 18th April 2014 following the methodology detailed in the WSI (TPA 2014), in accordance with standard, accepted practices for archaeological geophysical surveys (EH 2008). As Nottingham Castle is a Scheduled Ancient Monument, a Section 42 licence to undertake the survey was obtained by TPA from English Heritage

1.3. The site is located on deposits of Nottingham Castle Sandstone Formation; Sedimentary Bedrock formed approximately 246–251 million years ago in the Triassic period. The bedrock is overlain by superficial deposits of Head (British Geological Survey).

1.4. Topographically the site is situated to the southeast of the Ducal Mansion at Nottingham Castle (Nottingham). The site is on a slight slope down to the east. The site displays notable localised topographical variation as a result of modern landscaping practices.

1.5. Previous surveys at Nottingham Castle have revealed sections of the curtain wall and structural remains, in addition to probable rubble-spreads and demolition debris along with some evidence for subsurface voids in the area of the Outer Bailey itself (Barker & Mercer 2000; Davies et al. 2013).

1.6. Following consultation with English Heritage, an approved Written Scheme of Investigation was agreed for geophysical survey within the area of the Outer Bailey.

2. PROJECT BACKGROUND

2.1. Potential Remains

2.1.1. Nottingham Castle is a heritage asset of national significance and a Scheduled Monument (English Heritage SM 1006382). As part of Nottingham City Council's recent scoping exercises (in advance of Heritage Lottery Fund applications) a comprehensive impact assessment was undertaken (Kinsley 2012), which provides a detailed description of the heritage assets and a synthesis of all known interventions within the bounds of the Castle (ibid. Appendix B). As this report builds on former work, including the earlier impact assessment, it is not intended to provide a detailed summary of the history and archaeology of Nottingham castle and readers requiring more detailed information are referred to that report.

2.1.2. The archaeological potential of the site is considered to be high and comprises the following possible remains, as indicated in previous reports (Kinsley 2012, Davies et al. 2013).

- ***Mediaeval***
    - The original earthwork castle was constructed in 1067–8 under the instruction of William the Conqueror. The earth and timber defences may have covered the entire extent of the later stone replacements, but this is uncertain (Drage 1989, 36, 43).
    - The earth and timber defences of the Upper Bailey were replaced by a stone curtain wall in 1171–3. A stone keep was in existence by 1188 and a gate tower was constructed in 1373–7.
    - The Middle Bailey earthwork defences were replaced by a stone curtain wall in 1171–89. A great hall and chapel are recorded from the 1230's, and major rebuilding (Richards Tower and the State Apartments) occurred in 1476–80.
    - The Outer Bailey was captured during a siege in 1194. A barbican may have been constructed at the Outer Gatehouse in 1212–13 (Drage 1989, 43) and from 1251 the Outer gatehouse was rebuilt in stone. A stone curtain wall then replaced the outer bailey earthwork and palisade and interval towers possibly during the 1270's (Kinsley 2012, Appendix B, 2.1).
    - One of the numerous caves cut into the sandstone rock beneath the Castle, Mortimer's Hole, is first documented by Leland in 1540 (Drage, 1989, 138).
- ***Post-Mediaeval***
    - Documents dating to the 1620's suggest that some buildings within the castle were beyond repair at this time (Kinsley 2012, Appendix B, 2.1).
    - The 'Ducal Palace' was constructed within the Upper Bailey area in the 1670's, following the purchase of the site by the Duke of Newcastle, and a new passage may have been cut to Mortimer's Hole at this time (ibid). Repairs and alterations (e.g. the windows) were carried out to the Ducal Palace in the early 18th century.

2.2. Previous Fieldwork

2.2.1. Many archaeological interventions have taken place within the castle, perhaps most notably the 'Nottingham Castle Project' campaigns by the Trent Valley Archaeological Research Committee (now Trent & Peak Archaeology) (Drage 1989) which excavated parts of the northern defences of the Middle Bailey, the Middle Bailey bridge, the eastern defences of the Middle Bailey, and a service courtyard with associated buildings within the inner ditch. Subsequent excavations have largely been designed to proceed no further than the first sensitive archaeological horizon.

2.3. Proposed Fieldwork

2.3.1. In order to characterise the potential archaeological remains under the Outer Bailey of Nottingham Castle, the following fieldwork investigation was proposed:

- Geophysics – geophysical survey across an area totalling c. 1 ha.

- Geomagnetic survey, using fluxgate gradiometers, is typically the preferred technique for rapid evaluation of archaeological sites and provides a means of rapidly assessing the potential of the site. In particular this technique can be particularly useful for locating brick-built structures and evidence of burning, whether in domestic or industrial contexts. The instrument used for this survey was a Bartington Grad 601-2 dual-sensor fluxgate gradiometer, able to discern anomalies at a depth of approximately 0.5m-1m.The total area available (approximately 1Ha) was divided into 20m x 20m grid squares, referenced to the Ordnance Survey datum, and each grid was surveyed at 0.5m traverse intervals with sampling along the traverses at a 0.25m interval, equating to 7,200 samples per grid.

- Ground Penetrating Radar survey was conducted across the whole (c. 1Ha) area with close-interval transverse line-spacing of 0.5m and in-line sampling interval of 0.05m. The survey, based on the same grid system as the geomagnetic survey utilised a GSSI single sensor system with both 200MHz and 400MHz antennae to enable both high-resolution mapping of superficially buried features using the 400MHz antenna (to an expected depth of c. 2m), and profiling of the deeper subsurface using the 200MHz antenna.

- Earth-resistance profiling was carried out using a Tigre 64 Electrical Resistance Tomography system. Probe-spacing was determined at 1m in order to focus on imaging the underlying bedrock and all overlying deposits, the Tigre 64 was employed as a result of the relatively short overall length of the transects to be surveyed. The location of ERT transects were georeferenced using the Leica GS15 GPS with SmartNet.

- Earth-resistance mapping was undertaken across the entirety of the available area, using the same grids as the geomagnetic survey, with a Geoscan Research RM85 in dual/parallel twin-probe configuration, with probe-separation of 0.5m in order to image features at a depth of c.0.5m. The survey was conducted on the same gridded basis as the geomagnetic survey with readings taken at intervals of 0.5m between traverses and also along each traverse.

3. OBJECTIVES

3.1. The aim of the present work is to enhance the existing understanding of archaeological evidence by attempting to determine the character of any sub-surface remains prior to any proposed programme of excavation linked to potential developments at the site.

3.2. The survey results will be used to inform future developmental and archaeological work at the site.

4. METHODOLOGY

The geophysical survey grids of 20m by 20m were set out using a Leica GS15 GPS with SmartNet, in the Ordnance Survey National Grid coordinate system. The use of a north-south orientation for the survey grids was employed in the expectation that any surviving remains would be intersected by the survey traverses at an angle of approximately 30º. Details of the survey techniques employed are provided in Appendix B.

4.1. Geophysical Survey: Geomagnetic

4.1.1. The decision to use magnetic gradiometry to survey the site was based on its efficiency as a survey technique suitable for detecting the buried remains of a range of materials based on differences in their magnetic characteristics as compared to the geological background of the area (Gaffney et al. 1991, 6; 2003).

4.1.2. The results of this method are, however, severely restricted in areas of modern disturbance and by the presence of ferrous material (Scollar et al. 1990, 362ff). Objects and known features containing metallic elements were given a wide-berth with an average distance of 3m being allowed to limit their effect on the archaeological data. Magnetometry represented the best compromise between speed and quality of data retrieval for an initial investigation.

4.1.3. The magnetometer survey was undertaken, within the guidelines advocated by English Heritage (David et al. 2008), by a two-person team using a Bartington Instruments Grad 601-2 fluxgate gradiometer. This equipment allowed the survey to be conducted rapidly in the area that was relatively free of obstructions. Readings were taken at 0.25m intervals along traverses of 0.5m spacing walking east. This enabled a sufficiently high density of data for the purposes of archaeological assessment to be collected across the site in the relatively short time allotted for the survey to be completed.

4.1.4. The geomagnetic survey data were processed in Geoplot 3.0 software to remove any environmental disturbances or variations produced in the course of the survey. Firstly data were manipulated to remove any distorting 'spikes' from the survey results. A high-pass filter was then also used to reduce the effect of geological anomalies in the data-set. Low-pass filtering was then used to improve the resolution of larger archaeologically derived anomalies. Finally the data were interpolated to produce uniform data-densities equivalent to 0.25m x 0.25m.

4.1.5. The results were exported as greyscale, raster images and inserted into the AutoCAD plan of the site, generated from Ordnance Survey data, for georeferencing and production of a descriptive, vector overlay. The anomalies presented here were identified visually and manually digitised to produce the vectorised plans which are discussed in the results section of this report. The final print-versions of these plans were elaborated and prepared for printing in Adobe Illustrator CS4.

4.2. Geophysical Survey: Earth-resistance

4.2.1. The decision to use earth-resistance survey on the site was based on its ability to provide relatively precise detail about buried structures and to indicate the presence of both stratigraphically positive and negative sub-soil features without the interference often present in magnetic data as a result of modern disturbance and the presence of ferrous material close to the ground surface (Geoscan Research 1996; Scollar et al. 1990, 362ff).

4.2.2. The results of this method are, however, severely restricted by environmental conditions such as the retention of moisture within the soil (Clark 1990, 27). Earth-resistance survey represented a good compromise between speed and quality of data retrieval for an investigation of possible structures in the immediate sub-surface.

4.2.3. The earth-resistance survey was undertaken, within the guidelines advocated by English Heritage (David et al. 2008), by a two-person team using a Geoscan Research RM85 Resistance meter in parallel twin-probe configuration. This equipment allowed the survey to be conducted relatively rapidly as data from two traverses were collected simultaneously. Readings were taken at 0.5 m intervals along traverses of 0.5m spacing walking west. This enabled a sufficiently high density of data for the purposes of archaeological characterisation to be collected across the site in the relatively short time allotted for the survey to be completed.

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4.4. Geophysical Survey: Electrical Resistivity Tomography

4.4.1. The decision to employ electrical resistance tomography (ERT) was made in order to complement the geomagnetic, earth-resistance, and ground-penetrating radar surveys.

4.4.2. The results of this method are affected by the same sorts of environmental conditions as the earth-resistance survey.

4.4.3. The electrical resistivity tomography profiling was undertaken, within the guidelines advocated by English Heritage (David et al. 2008), by a two-person team using a Tigre 64 Resistance meter in Wenner configuration. Probe separations were determined at 1m in order to provide a compromise between imaging the bedrock/superficial deposit interface and any anomalies within the sub-soil.

4.4.4. The ERT data were processed in Res2D Inv software to create apparent resistivity pseudo-sections and a model of the inversion processed data.

4.4. Geophysical Survey: Ground-Penetrating Radar

4.4.1. The decision to employ ground penetrating radar (GPR) was taken in order to complement the geomagnetic, earth-resistance and Electrical Resistivity Tomography surveys, to provide high resolution data as well as depth information about possible subsurface deposits.

4.4.2. To collect GPR data a radar antenna is pulled or pushed along the surface of the ground, which emits high-frequency radio energy pulses downward into the ground. These waves then reflect off of material in the subsurface and return to a receiving antenna and the two-way travel time can be calculated. Given the strength of the reflected signal the time that it took to return to the surface an accurate model of what lies below the surface can be generated.

4.4.3. Ground penetrating radar survey is based on the use of an electromagnetic radar wave propagated through the soil to search for changes in soil composition and the presence of structures, measuring the time in nanoseconds (ns) taken for the radar wave to be sent and the reflected wave to return. The propagation of the signal is dependent on the relative dielectric permittivity (RDP) of the buried material which is reliant on the geology, which is a value based upon a materials ability to store/conduct electromagnetic energy.

4.4.4. Excess water can negatively impact the effectiveness of a GPR survey with the increased water causing the radar wave to be propagated and attenuated to an extent that very little is reflected back to the antenna. This technique has been applied successfully on a range of archaeological sites, both urban and rural. Use of the GPR is significantly more time-consuming than using a gradiometer.

4.4.5. The survey was undertaken using a combination of a GSSI 400MHZ antenna configured for use with a tricycle cart and a 200MHz antenna on a sledge with survey wheel to enable auto logging of readings.

4.4.6. The 400 MHz antenna, which allows propagation of radar waves down to a depth of approximately 3–4m depending on the nature of the sub-surface materials, was undertaken at 0.5m traverse intervals in order to provide high resolution imaging of the near-surface features. The 200MHz antenna, which permits a depth penetration of up to 10–11m, was initially undertaken at 0.5m traverse intervals. However, as a result of time constraints, the traverse interval was increased to 1m increments to facilitate full coverage of the survey area.

4.4.7. The GPR survey was undertaken using the SIR3000 Interface coupled to, for the first survey, a GSSI 400MHz shielded antenna mounted on the tricycle-cart with odometer, and for the second, to a GSSI 200MHz shielded antenna on a sledge with survey wheel. The use of the cart increased both the speed and accuracy of the survey, while also allowing the antenna to pass between and around obstacles. Because of the larger physical dimensions of the 200MHz antenna, a cart system is not viable and the less manoeuvrable and therefore more time-consuming sled-system was required.

4.4.8. The GPR data were processed in GPRSlice® where the vertical traverses were aligned and then interpolated, sliced and gridded to provide horizontal slices through the ground. A 0ns Radargram editing function was performed on all the slices to minimise the inherent error caused by the uneven ground and a background filter applied to remove extraneous noise from the data. Further processing techniques such as Bandpass (to remove unwanted frequencies in the data) and Migration (correcting hyperbola errors in the data) were applied to the data. The traverses were sliced and gridded together to generate time slices, plans which detail the results at different depths through the ground. Work from individual days were processed independently of each other and then transformed and appended to create a composite image of the full survey area.

4.4.9. The processed GPR data were exported from the software as raster Bitmaps into ArcGIS (ver. 10.1) for georeferencing, interpretation and presentation.

4.5. Ground Conditions

4.5.1. Ground conditions for the survey were generally good, the surface provided no significant problems for survey. Garden ornaments and furniture prevented readings being taken in localised areas. The soil-moisture conditions were noted to be normal and both earth-resistance mapping and GPR survey were successful. Because of the large areas of paving, locations for uninterrupted ERT transects were impossible to find.

5. RESULTS
(Figures 2–24)

5.1. Geomagnetic Survey (Figures 2–3)
5.1.1. Within the area surveyed, the site exhibited a generally poor response to the geomagnetic survey and whilst buried features can be discerned against the geological background there is a high degree of noise in the dataset. As the overall background magnetic response is expected to be low, a result of the nature of the superficial geology, any cut features are likely to show as areas of positive magnetism. In contrast, structural remains are likely to present either positive or negative signals, depending upon the particular materials used and their contrast against the relatively non-magnetic background.

5.1.2. The geomagnetic survey suffered a high degree of disturbance from the presence of modern ferrous/metallic features and the presence of highly magnetic material on or near the surface of the area surveyed. The most notable of these areas of disturbance are discussed in the following text. The overall effect of these strongly magnetic disturbances is to suppress the response of any archaeological features within the dataset.

5.1.3. The results are presented below as a greyscale image of the processed data (Figure 2), and complementary numbered interpretative plan to which the following description relates (Figure 3). This description is organised from west to east, and is largely restricted to discussion of features which have a likely impact on the archaeological understanding of the area.

5.1.4. The northwestern extent of the area surveyed demonstrates large areas of dipolar magnetic noise [m1] and [m2] which are consistent with the lines of current pathways. Positively magnetic maculae [m3] also appear to correlate with the line of a modern path. An alignment of three dipolar maculae [m4] appears to cross the pathway indicated by [m3] at right-angles for approximately 13.5m. A pair of aligned linear, dipolar anomalies [m5], run for c. 23.5m in a southeasterly direction from the northern end of [m4]. This alignment of dipolar anomalies terminates adjacent to a large (c. 89m^2) area of dipolar disturbance [m6] located adjacent to the edge of the survey area in close proximity to the paved area surrounding the bandstand. To the west of this feature are a group of positive and dipolar anomalies [m7] which appear to be coincident with the main path leading towards the gate of the castle and which was also indicate by the anomalies [m3] and [m4]. Approximately 17.5m to the northeast of [m5] is a linear, positive anomaly [m8], which is almost coincident with the location of a modern path. Approximately 7m to the southeast of this feature is a linear, positive anomaly [m9] which runs for approximately 18.25m in a southeasterly direction. This feature shows no obvious correlation to any known modern features and as such can be reasonably expected to be archaeologically significant.

5.1.5. The area to the east of the bandstand is characterised by an absence of significant geomagnetic anomalies. Adjacent to the eastern edge of the survey area is a dipolar macula [m10], coincident with the path around the edge of the Outer Bailey. Approximately 16m southwest of this, adjacent to the western edge of the survey area are a pair of dipolar maculae [m11].

5.1.6. Approximately 16.5m to the south of [m10] is a linear, dipolar anomaly [m12], which runs for c. 13.25m and is conincident with the path along the edge of the Outer Bailey. Further dipolar anomalies [m13] and [m14] also appear to correlate with modern paths and their associated furniture. A pair of positive maculae [m15] may also represent the affect of modern paving/garden furniture.

5.1.7. To the southwest of the area surveyed are a number of dipolar maculae which clearly correlate with modern paths [m16] and [m17]. A swathe of positive maculae [m18] also appear to correlate with the central path away from the bandstand towards the southern curtain wall. Approximately 6m to the west of this path is a group of positive and dipolar maculae [m19] which demonstrate no clear correlation with any known modern features. Immediately to the west of this feature is a complex curvilinear, negative anomaly [m20], representing an apparently penannular feature covering an area of approximately 43m^2.

5.2. Earth-resistance Survey (Figures 4–5)

5.2.1. Within the area surveyed, the site exhibited a generally good response to the earth-resistance survey, a high density of geophysical anomalies are observed across the whole area surveyed, and buried features can be clearly discerned against the geological background with very little noise in the dataset. The overall background resistance is high, largely a result of soil-moisture content, any cut features are likely to show against this as areas of relatively low resistance. In contrast, structural remains and voids are likely to present high-resistance signals.

5.2.2. The results are presented below as a greyscale image of the processed data (Fig. 4), and a complementary numbered interpretative plan to which the following description relates (Fig. 5), this description is broadly organised from west to east.

5.2.3. The northwestern section of the survey shows two anomalies. Firstly a linear, low-resistance anomaly [r1], runs for 19.5m southwest–northeast alongside one of the modern paths. Secondly an area of high-resistance [r2], covers an area of approximately 37m^2 in the centre of the area. Approximately 13.5m to the east of [r2] is a further, 15m^2 area of high-resistance [r3], which is notable as being located within a generally uniform area of resistance. Adjacent to the northeastern edge of the survey area is a curvilinear, “Y-shaped” high-resistance anomaly [r4], measuring c. 14.25m along its long-axis. Possibly associated with this previously described feature is a c. 6m long, curvilinear, high-resistance anomaly [r5] which appears to run beyond the northern edge of the survey area. Approximately 9.5m to the southwest of [r5] is a high-resistance, “L-shaped” anomaly [r6], measuring c. 17m by 6m and conforming to the apparently predominant northwest–southeast alignment of features within the area. Within the corner of the previously described anomaly is a “T-shaped”, low-resistance anomaly [r7], measuring 5m by 3m. Immediately to the southeast of [r6] is a large, “T-shaped”, low-resistance anomaly [r8], measuring approximately 18m by 11m. This anomaly is partially mirrored along its long-axis by another pair of low-resistance anomalies [r9]. Adjacent to the south of [r8] is a pair of rectilinear, high-resistance anomalies [r10], which together describe an “L-shape” measuring 6m by 6m. To the southeast of this feature is a linear, low-resistance anomaly [r11], running northwest–southeast for approximately 16m. To the southwest of this feature is a c. 8m-long curvilinear, low-resistance anomaly [r12] running broadly northeast–southwest. Immediately north of this feature is an “L-shaped” high-resistance anomaly [r13], measuring 5.5m by 3.5m. The line of [r12] appears to be picked up c. 5m to the west by a curvilinear low-resistance anomaly [r14], measuring approximately 8.5m. Possibly associated with the previously described feature is a low-resistance, linear anomaly [r15], measuring approximately 15m and running in a west-northwest–east-southeast direction. Between these previous two low-resistance features is a 5.5m high-resistance anomaly [r16], which appears to conform to the predominant alignment of features observed in the survey results.

5.2.4. Approximately 2m to the east of [r11] is a “distorted-L-shaped” low-resistance anomaly [r17], measuring approximately 14.5m by 5m. Apparently continuing the alignment of [r17] is a 15m-long, linear, low-resistance anomaly [r18]. The line of this anomaly is apparently continued by a curvilinear, 14m-long, low-resistance anomaly [r19], which intersects with the edge of the survey along the modern path from the bandstand to the southeast. Approximately 13.5m to the northeast of [r18] is a “T-shaped”, high-resistance anomaly [r20], measuring c. 10m by 6m. Immediately to the south of this feature are a number of high-resistance anomalies [r21] which cross the survey area for c. 17m from [r18] to the eastern edge of the area surveyed. Broadly parallel to [r19] and located c.15m to the northeast of it, is a linear, high-resistance anomaly [r22], which runs for approximately 5.5m northwest–southeast. Approximately equidistant between [r19] and [r22] is an “L-shaped”, high-resistance anomaly [r23], measuring approximately 8m by 8m. The southeastern corner of the area surveyed is occupied by a cluster of high- and low-resistance maculae [r24].

5.2.5. The southern part of the survey area is characterised by a small number of discrete anomalies. The large irregular, low-resistance anomaly [r25], measuring approximately 16.5m by 18m, could possibly be seen to continue the line of [r19]. The high-resistance maculae [r26] appear to correspond with other areas of high-resistance alongside the paving around the bandstand. Approximately 7.5m west of [r25] is a curvilinear, low-resistance anomaly

[r27], running for c. 14m. to the south of this feature is a high-resistance macula [r28], approximately 7.5m by 3m. The western side of the bandstand demonstrated an alignment of high-resistance anomalies [r29], [r30], running for a total of 29m in a north-northwest–south-southeast direction.

5.3. Electrical-Resistance Tomography

5.3.1. ERT survey was attempted in accordance with the methodology presented above. However, as a result of a combination of environmental factors and technical issues with the equipment, it was not possible to collect any meaningful data within the restricted time available for the application of this technique. Because the 200MHz GPR survey was also capable of imaging the bedrock interface, and was successful in doing so, there was no prejudice to the archaeological or geomorphological information collected through the overall suite of survey techniques employed on the site.

5.4. Ground-Penetrating Radar Survey (Figures 9–24) by L. Richley

5.4.1. Within the area surveyed, the site exhibited a generally good response to the Ground-Penetrating Radar survey, a high density of geophysical anomalies are observed across the whole area surveyed, and buried features can be clearly discerned with very little noise in the dataset. The processed datasets are shown on the left of each figure with the digitised anomalies presented on the right. Presented below are a sample of the layers that show the most interesting/pertinent anomalies.

5.4.2. The 400MHz antenna has provided detailed near surface imagery to an approximate depth of 3.5m. Due to varying weather conditions there are some gain issues between the datasets from individual days that have been corrected with gain corrections in GPRslice, however some residual variances are still present.

5.4.3. The 200MHz antenna enables radar wave propagation to much deeper extents than the 400MHz antenna. As such the time slices presented and discussed below cover much larger segments than those presented in the 400MHz time slices.

5.4.3. 400MHz Results (Figs 9–18).

5.4.3.1. **400 MHz – 7–11ns**

This time slice demonstrates the effect of the paths and tarmac on the antenna as opposed to the grass areas, and the changing intensities of reflectance of the electromagnetic (EM) wave. The modern tarmac paths are clearly visible and are delineated further by the topographical lines (in blue). What is immediately evident is the high amplitude linear feature which runs on the east of the main north-south path. This does not follow the alignment of the path exactly and veers east as it approaches the Victorian bandstand. The southern extent of this anomaly ends/overlaps with a series of high amplitude rectangular features to the north-east of the bandstand. To the west of the main north-south garden path are a series of uncorrelated linear features that do not appear to correspond to each other. There are two parallel lines that run northeast-southwest parallel to the modern path, and may present an earlier layout for this path. A further pair of parallel, high amplitude linear features seem extend northeast from the location of the memorial statue with a single linear on the same alignment extending southwest which is probably related. The southern part of the survey area is largely empty of anomalies that are reconcilable as archaeologically relevant. The southwest has a series of weak, high amplitude linear striations that may be related to the allotments that were located here in the early 1900's. The east is distinguishable for the low amplitude anomalies that bisect that path, and a high amplitude anomaly that follows the alignment of the path and runs for approximately 20m.

5.4.3.2. **400MHz – 10–15ns**

Within this dataset it is possible to see further features to the west and east of the main path. The parallel lines in the west are still present and are much stronger in their readings, so too are the lines extending south and north from the memorial statue. It is possible that these are older paths as mentioned above. To the east of the main path further high amplitude linear anomalies are present. Perhaps signifying earlier land divisions or structures. The rectangular high amplitude features to the north of the Victorian bandstand first identified in the 7–11ns slice continue at this depth and it is now possible to distinguish to parallel linear anomalies on an east-west alignment as a part of this complex of anomalies. Further east a linear feature is evident heading south from a rectangular high amplitude anomaly. There is a band of high amplitude anomalies that runs approximately 2m in from the path that borders the boundary wall. These anomalies match the alignment of the path and curve in west. It is possible that this represents an earlier path or boundary. The Victorian bandstand is surrounding by high amplitude readings which is no doubt related to the construction of the bandstand itself. However, west of the bandstand a line feature can be discerned heading from approximately grid coordinates 456945,339495 for 50m southeast. It is possible that this presents an old path or modern utilities; it is unlikely to be a water pipe associated with the taps due to the location of the nearest brick, water supply tap being 5 meters east.

5.4.3.3. **400 MHz – 13–18ns**
There are distinct linear features present in this time slice. The linear feature that has been apparent in the first two slices discussed is still present but is now intersected by a further linear that exists on the same alignment as the main north-south path. What is particularly interesting is that the high amplitude rectangular features that have persisted in the first two time slices are now longer present at this depth. Instead it is possible to differentiate linear anomalies of both high and low amplitude. The parallel lines are still visible to the west of the band stand however they are less distinct at this level however they have persisted for some 40cm, representing quite substantial features. The linear to the west of the bandstand is now much thinner and it is likely that what was seen in the upper area disturbance above this suggesting that this is indeed utilities that have been inserted in recent years. The linear on the east side of the survey area, identified in the 10–15ns slice, is still present. In this time slice it is possible to identify two clear anomalies that are probably interrelated. There is a square high amplitude anomaly that lies north of a linear that extends south for 15m, however the relevance of this anomaly is hard to discern. The high amplitude anomaly that shadows the outer path continues at this depth. However, where it proceeded to cover west in the previous time slice, the nature of it has now changed and it is now possible to identify two high amplitude rectangular feature the first approximately 5m by 4m and the second, 3m by 10m. In the south west of the survey area there is also two linear features one that runs north–south and the other that runs perpendicular east–west.

5.4.3.4. **400MHz – 16–20ns**
This time slice shows some clearly delineated high amplitude features. The north–south linear anomaly identified in figures 3 and 4 no longer persists at this depth. However a complex of interconnecting linear anomalies that seem to delineate areas, and perhaps represent land divisions from the allotments/pleasure gardens that were present before the formal landscaping can now be discerned. The high amplitude linear feature that has continued from figure 4 in the east of the area is still present at this depth demonstrating that it is a substantial feature at this depth it is approximately 1m in width and 20m in length. To the east of this three further rectilinear features can be identified running perpendicular. Two high amplitude anomalies run parallel to one another on a slight southwest to northwest alignment. These exist below features identified in earlier time slices and likely represent the same anomalies. Further detail is revealed about the distinct rectangular feature identified to the south of the bandstand. In this time slice it is possible to identify the outline of a structure. However the second of the two rectangular feature is less clear. West of this feature are a further two high amplitude features that intersect with each other. The long high amplitude linear anomaly to the west of the bandstand is still faintly visible.

5.4.3.5. **400 MHz – 19–23ns**
This time slice is perhaps the most interesting time slice with several anomalies that could potentially represent archaeological features. The northeast part of the survey area continues to contain interesting linear features. A complex of high amplitude linear anomalies are present in this area, with what could be internal subdivisions. In the northern extent further linear anomalies, on the same alignment as those first identified in the 10–15ns slice are present, it is likely that this represent land divisions for the allotments. There is a band of high amplitude anomalies that exists in the east of the survey area. These lie beneath the strong high amplitude anomalies that were present in the east of the area in figures 4-6. It is likely that these are related.In the southwest area the two linear anomalies identified in the 16–20ns slice are still present and it is possible to differentiate these as a rectangular feature, perhaps relating to an earlier structure with the approximately dimensions of 6m by 5m.

5.4.3.6. **400 MHz – 22–26ns**
A long, 50m high amplitude anomaly is clearly distinct at this depth running from the north extent of the survey area to the middle of the area. The size of this feature suggests it is a modern utility. This intersects the features that run northeast–southwest which persist from when they were first identified in the 16–20ns slice. There is a faint low amplitude rectilinear feature to the west of the main north-south path. Further high amplitude features in southeast area. There is a rectangular area of relative low amplitude readings that is made apparent by the border of strong high amplitude readings. Within this there are faint high amplitude linear features that exist on tangent angles to the modern pathway that rests above.

5.4.3.7. **400 MHz – 26–29ns**
The linear features that have been prevalent in the northeastern part of the survey area have ceased at this depth, leaving little evidence pertinent to the archaeological record of this area. However a rectilinear feature that exists on the same alignment to the linear anomalies identified in the preceding time slices is now visible to the east of the bandstand, with a small area of low amplitude readings within. It is the southern part of the survey area that now shows interesting features in the form of a series of parallel high amplitude lines some 10 meters apart. Once again, much like those in the northern part of the survey area in the high levels, these could be related to the allotments. At a completely different alignment to anything seen before in this area, a square feature can be identified beneath the middle of the three paths in the southern part of the outer bailey. If this is indeed a structure it is likely to be distinct from the other features due to it's 'odd' alignment and may represent an earlier feature.

5.4.3.8. **400 MHz – 28–32ns**
The linear anomalies identified in the previous time slice in the south east of the survey area continue at this depth. The rest of the survey area is categorised by small high amplitude anomalies that could be attributed to the geology or natural/human debris that has been incorporated in the soil matrix from continual habitation on site.

5.4.3.9. **400 MHz – 52–58ns**
This time slice is largely quiet with some high amplitude features to the north and is probably representative of the radar wave penetrating the natural sandstone bedrock.

5.4.3.10. **400 MHz – 81–88ns**
At this depth, it is unlikely that any archaeologically relevant anomalies are being detected. The data is largely quiet and it is likely that the radar has penetrated the bedrock that will be largely unchanging until the caves are met at much deeper levels, beyond the scope of this antenna to detect.

5.4.4. 200MHz Results (Figs 19–24).

5.4.4.1. **200 MHz – 17–25ns**
This time slice covers the same the same extent as those at 7–20ns of the 400 MHz antenna. It is clearly possible to see the same high amplitude linear anomalies that have been identified in the first radar survey. None of which bear any relation to the known location of the caves beneath the castle. The complex of linear readings to the immediate northeast of the Victorian bandstand that were also identified by the 400Mhz survey are also visible in this time slice and appear to show interlinking structures. There is a series of high amplitude readings in the southern part of the survey area on a northwest–southeast alignment, with what also appears to be a rectilinear structure. It is possible that these are the remains of structures, either in the form of foundations or rubble. In the south west of the area there are two parallel high amplitude linear anomalies on the same alignment as those discussed above, however these represent much smaller features with an approximately width of two meters.

5.4.4.2. **200MHz – 22–30ns**
This slice represents the next step down in depth to that discussed above. The complex of linear, high amplitude features remain clearly visible in the north east of the survey area. Intersecting these features a long, thin high amplitude feature can be identified running from the northern edge of the survey for about 50 m south. It is likely that this is a modern utility as opposed to a feature that is archaeological relevant. In the southeastern part of the survey area the high amplitude features that were identified in the preceding time slice are still evident however there is now a feature that curves in from the east towards the bandstand.
The two parallel high amplitude features in the south west of the survey area can still be identified. Their spacing is too far apart to be related to the modern path way and suggests that these are older in origin, however their isolation from other features make them difficult to interpret.

5.4.4.3. **200MHz – 27–36ns**
The long high amplitude linear feature is largely absent at this depth however it is still possible to identify short tracts of it. What is perhaps most interesting at this depth is the development of the complex of linear anomalies that have be prevalent in the dataset from a depth of 18ns. It is possible to distinguish what could be internal subdivisions within these features, giving credence to the theory that they may represent structures. The southern area is less distinct, due in part to the lower resolution of the area. There are hints of the continuation of these linear features but it is hard to define the individual features. There are large areas of high amplitude features across this area which may signify areas of rubble or disturbance. Some of these high amplitude features may be related to each other but difficult to define possible associations.

5.4.4.4. **200MHz – 61–69ns**
This time slice shows large, amorphous high amplitude features however there are no anomalies that are easy to define as structures. These could, therefore, relate to rubble or small intrusions/excavations into the soft sandstone from earlier developments. It is possible that the high amplitude features that border the eastern edge of the survey area relate to known caves. There is a low amplitude linear anomaly that cuts across south of the Victorian bandstand, which is also possibly related to the cave systems below.

5.4.4.5. **200MHz – 71–80ns**
There is little of note in the northern part of the survey area with much of the high amplitude and low amplitude activity showing in the southern part. There is an area of high amplitude readings on the eastern edge of the survey area, which lies directly above known caves and may be related although its orientation is slightly different.

5.4.4.6. **200MHz – 127–135ns**
Once again it is possible to differentiate amorphous, high amplitude anomalies across the south part of the survey area but these are difficult to reconcile with the known locations of the caves nor can they be delineated as structures. It is likely that the results are defining changes in the underlying geology.

6. DISCUSSION

6.1. Geomagnetic and Earth-resistance Survey (Fig. 6)

6.1.1. The discussion of the geomagnetic and earth-resistance surveys will be presented as a single section in this report as both represent information from the immediate subsurface. The overall character of the geophysical anomalies revealed by these survey techniques strongly suggests the presence of archaeological remains within the area surveyed.

6.1.2. In general the geomagnetic survey was considered to be only partially successful in recovering evidence of sub-surface archaeological features. The overall response of the area to the survey was affected by the presence of a great deal of noise in the data, presumably a result of the presence of magnetic material on, or near, the ground surface.

6.1.3. In general the earth-resistance survey produced clearer results than the geomagnetic survey and a large number of smaller-scale features were recognisable within the survey area. The ground-conditions were only partially conducive to the earth-resistance survey, however reasonably clear results were obtained from the majority of the area surveyed. Likely archaeological features were represented by both high- and low-resistance anomalies, being therefore strongly suggestive of voids (tunnels/culverts), structures consisting of masonry or brick walls, and/or possible spreads of demolition debris.

6.1.4. The group of features [r6], [r7], [r4], and [r9], possibly represent the remains of shallow subsurface structures.

6.1.5. The series of low-resistance anomalies [r8], [r11], [r12], [r15] probably represent a shallow trench, possibly related to irrigation or landscaping. This is likely to also be the case for [m8]/[r17], [r18], [r19], [r25], [r27] and possibly [m20].

6.1.6. The features [r2], and [r3] may possibly represent localised concentrations of rubble. Features [r30] and [r28] may also result from the presence of rubble concentrated in the subsoil.

6.1.7. Features [r16], [r13], [r23], [r22], and [r29] are suggestive of the remains of buried structures.

6.1.8. Features [r20], [r21], and [m9] may also represent the remains of buried structures and associated debris, however the nature of these anomalies are more equivocal than those previously discussed.

6.2. Ground-Penetrating Radar Survey

6.2.1. The two complementary GPR surveys have revealed a great deal about the subsurface in the outer bailey of Nottingham castle. It is however, difficult to reconcile the nature of the anomalies with the known historical record, particularly with the plethora of modern utilities in place in this area.

6.2.2. The area of the Outer Bailey of Nottingham Castle, was redeveloped during the last century into landscaped gardens. Previous to this, it was used for privately rented allotments/pleasure gardens, and prior to that it has been theorised that this area contained outbuildings associated with the castle in the form of stable blocks, kitchens and other such service buildings.

6.2.3. It is likely that the long NS feature identified in the survey is related to a pipeline for supplying water to the gardens, as it runs between known water supply locations. Also, due to the nature of the feature, it is likely that the linear to the west of the bandstand that is visible in the shallow 400MHz slices is also a modern feature.

6.2.4. The interesting features representing structures between 50cm and 150cm are visible in both the 400 MHz and the 200 MHz surveys. There is a trend to the alignment of linear anomalies across the survey area with many of them running on a similar northwest to southeast alignment or on a northeast to southwest alignment. These linear features are on a different alignment, and nowhere near, the locations of known caves. It is also prudent to note that they differ from the alignment of the ducal palace however this does not preclude associations. It is possible that these linear features represent land divisions for the late 19th to early 20th century private pleasure gardens.

6.2.5. The presence of possible internal subdivisions development within the linear features mentioned above is interesting. These are, as said, not on the same alignment and also too small to be cave structures but would also seem too complex for gardens suggesting that they might represent structures, still perhaps related to the private allotments, or possibly relating to buildings from the civil war or earlier.

6.2.6. To the south of the Victorian bandstand are several rectangular linear features that are possibly archaeological in origin. However, also in this area is another water pipe for supplying water for the maintenance of the formal gardens. It is possible that the intersecting linear features in this area are related to these and not archaeologically relevant.

6.2.7. In close proximity to the boundary wall of the Outer Bailey on the east of the site, there are some high amplitude anomalies that are not continuous along the path suggesting that they are features independent from the path and possibly representing earlier fortifications. It is possible that these features, are related to the caves below.

7. CONCLUSION

7.1. Geophysical survey demonstrated the presence of potential buried archaeological features.

These comprised:

- Evidence through the earth-resistance survey for possible structures in the shallow sub-surface.
- Evidence through the GPR survey for possible cave systems.
- Evidence through the GPR survey for possible post-mediaeval structures.
- Evidence through the GPR survey for possible 19th century structures.

7.2. The distribution of geophysical anomalies across the areas surveyed should probably be seen as representative of the presence of archaeological features within the survey area and no significant biases in survival/detection of these remains appear to be present within the dataset.

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OS Ordnance Survey 1: 50,000 Landranger Map

Ordnance Survey Maps: All editions 1859-1992

Appendix A: Details of Survey Strategy
Date of Survey: 7th–18th April 2014
Site: NCA6 – Nottingham Castle, Outer Bailey
Region: Nottingham
Grid Reference: NGR SK 56985 39485
Surveyor: Trent and Peak Archaeology
Personnel: Lizzie Richley, Tom Hooley, Povilas Cepauskas, NCC Volunteers
Geology: Nottingham Castle Sandtone Formation/Head

Survey Type 1: Geomagnetic
Approximate area: 1 hectare
Grid size: 20m
Traverse Interval: 0.5m
Reading Interval: 0.25m
Instrument: Bartington Instruments Grad 601-2
Resolution: 0.1nT
Traverse mode: Zig-zag

Survey Type 2: Earth-resistance
Approximate area: 1 hectare
Grid size: 20m
Traverse Interval: 0.5m
Reading Interval: 0.5m
Instrument: Geoscan Research RM85
Resolution: 0.1Ω
Traverse mode: Zig-zag

Survey Type 3: Ground-Penetrating Radar (400MHz)
Approximate area: 1 hectare
Traverse Interval: 0.5m
Samples: 512
Trigger: Cart
Antenna: 400MHz (GSSI)
Time Window: 100n/s

Survey Type 4 :Ground-Penetrating Radar (200MHz)
Approximate area: 1 hectare
Traverse Interval: 1m
Samples: 512
Trigger: Survey Wheel
Antenna: 200MHz (GSSI)
Time Window: 185n/s

Appendix B: Geophysical Prospection Methods
Earth-resistance Survey
Resistivity survey is based on the ability of sub-surface materials to conduct an electrical current passed through them. Differences in the structural and chemical make-up of soils affect the degree of resistance to an electrical current (Clark 1990, 27).
The technique involves the passing of an electrical current through a pair of probes into the earth in order to measure variations in resistance over the survey area. Resistance is measured in ohms (Ω), whereas resistivity, the resistance in a given volume of earth, is measured in ohm-metres (Ωm).

Four probes are generally utilised for electrical profiling (Gaffney et al. 1991, 2), two mobile and two remote probes. Earth-resistance survey can be undertaken using a number of different probe arrays; twin probe, Wenner, Double-Dipole, Schlumberger and Square arrays.

Twin Electrode Configuration:

This array represents the most popular configuration used in British archaeology (Clark 1990; Gaffney et al. 1991, 2), usually undertaken with a 0.5m separation between mobile probes. Details of survey methodology are dealt with elsewhere (Geoscan Research 1996) and so will not be discussed here. The twin probe array configuration utilises two probes on a mobile frame, with two remote probes located at a distance from the mobile frame of least 30 times the separation between the mobile probes.

Alterations can be made to suit different conditions. For extremely dry soils, a range of 0.1mA can be used. If the background resistance is lower than 100Ω, then a gain of x10 should be used. If the background resistance is lower than 10Ω, then a gain of x100 can be used. In urban situations, it may be necessary to alter the range and gain of the instrument to 10mA and x1 respectively.

A number of factors may affect the interpretation of twin probe survey results, including the nature and depth of structures, soil type, terrain and localised climatic conditions. The response to non-archaeological features may lead to a misinterpretation of the results, or the masking of archaeological anomalies. A twin probe array of 0.5m will rarely recognise features below a depth of 0.75m (Gaffney et al 1991). More substantial features may register up to a depth of 1m.

With twin probe arrays of between 0.25m and 2m, procedures are similar to those for the 0.5m twin probe array. However, the distance at which the remote probes are located must for 1-2m twin arrays be greater than that for 0.5m.

Although changes in the moisture content of the soil, as well as variations in temperature, can affect the form of anomalies present in resistivity survey results, in general, higher resistance features are interpreted as structures which have a limited moisture content, for example walls, mounds, voids, rubble filled pits, and paved or cobbled areas. Lower resistance anomalies usually represent buried ditches, foundation trenches, pits and gullies.

Magnetic Survey
Magnetic prospection of soils is based on the measurement of differences in magnitudes of the earth's magnetic field at points over a specific area. The iron content of a soil provides the principal basis for its magnetic properties. Presence of magnetite, maghaematite and haematite iron oxides all affect the magnetic properties of soils.
Although variations in the earth's magnetic field which are associated with archaeological features are weak, especially considering the overall strength of the magnetic field of around 48,000 nano-Tesla (nT), they can be detected using specific instruments (Gaffney et al. 1991).
Three basic types of magnetometer are available to the archaeologist; proton magnetometers, fluxgate gradiometers, and alkali vapour magnetometers (also known as caesium magnetometers, or optically pumped magnetometers).
Fluxgate Gradiometer

Fluxgate instruments are based around a highly permeable nickel iron alloy core (Scollar et al. 1990, 456), which is magnetised by the earth's magnetic field, together with an alternating field applied via a primary winding. Due to the fluxgate's directional method of functioning, a single fluxgate cannot be utilised on its own, as it cannot be held at a constant angle to the earth's magnetic field. Gradiometers therefore have two fluxgates positioned vertically to one another on a rigid staff. This reduces the effects of instrument orientation on readings.
Fluxgate gradiometers are sensitive to 0.5nT or below depending on the instrument. However, they can rarely detect features which are located deeper than 1m below the surface of the ground.
Archaeological features such as brick walls, hearths, kilns and disturbed building material will be represented in the results, as well as more ephemeral changes in soil, allowing location of foundation trenches, pits and ditches. The results are however extremely dependent on the geology of the particular area, and whether the archaeological remains are derived from the same materials.

Ground-Penetrating Radar
Ground-Penetrating Radar prospection of soils is based on the measurement of differences in dialectric permetivity of subsurface soils and deposits. The depth penetration of radar is determined by the electrical conductivity of the ground, the centre-frequency and power of the transmitted radar-wave. As conductivity increases, penetration is attenuated as the electromagnetic energy is dissipated into heat. Higher frequencies of waves offer higher resolution, at the expense of penetration.

Appendix C: GPR return-time/depth correlations

TIME SLICE	DEPTH (CM)	DEPTH (NS)
2	19-35	4-9
3	29-47	7-11
4	42-59	10-15
5	54-71	13-18
6	66-83	16-20
7	77-95	19-23
8	89-107	22-26
9	102-119	25-29
10	114-131	28-32
11	126-143	31-35
12	137-155	34-38
13	149-167	37-41
14	162-179	40-44
15	174-191	43-47
16	185-203	46-50
17	197-215	49-53
18	209-227	52-56
19	222-239	55-59
20	234-251	58-62
21	245-263	61-65
22	257-275	64-68
23	269-287	66-71
24	282-299	70-74
25	294-311	72-77
26	305-323	75-80
27	317-335	78-83
28	329-347	72-86
29	342-359	84-89
30	354-365	87-90

Relative depth in centimetres (cm) to travel-time in nanoseconds (ns) for the 400MHz antenna.

TIME SLICE	DEPTH (CM)	DEPTH (NS)
1	0-35	0-8
2	23-58	5-14
3	47-83	11-19
4	70-106	17-25
5	93-129	22-30
6	116-152	27-36
7	141-176	33-41
8	164-199	39-47
9	187-222	44-52
10	210-245	49-58
11	234-269	55-63
12	257-292	61-69
13	280-315	66-74
14	303-338	71-80
15	328-363	77-85
16	351-386	83-91
17	374-409	88-96
18	398-433	94-102
19	421-456	99-107
20	444-479	105-113
21	467-502	110-118
22	497-527	116-124
23	514-550	121-129
24	537-573	127-135
25	560-596	132-140
26	585-620	138-146
27	608-643	143-151
28	631-666	149-157
29	654-689	154-162
30	678-700	160-165

Relative depth in centimetres (cm) to travel-time in nanoseconds (ns) for the 200MHz antenna.

ENGLISH HERITAGE

English Heritage Geophysical Survey Database Questionnaire

Survey Details

Name of Site: Nottingham Castle Outer Bailey

County: Nottinghamshire

NGR Grid Reference (Centre of survey to nearest 100m): SK 56700 39500

Start Date: 07/04/2014 **End Date:** 18/04/2014

Geology at site (Drift and Solid): Nottingham Castle Sandstone Formation/Head deposits

Known archaeological Sites/Monuments covered by the survey
(Scheduled Monument No. or National Archaeological Record No. if known)

Nottingham Castle, Scheduled Monument Number 1006382

Archaeological Sites/Monument types detected by survey
(Type and Period if known. "?" where any doubt).

Geophysical anomalies, probably relating to shallow sub-surface structures of post-mediaeval date.
Geophysical anomalies, possibly relating to subterranean cave systems.

Surveyor (Organisation, if applicable, otherwise individual responsible for the survey):

Trent & Peak Archaeology

Name of Client, if any:

Nottingham City Council

ENGLISH HERITAGE

Purpose of Survey:

Characterisation of potential archaeological remains under the modern, landscaped surface of the Outer Bailey of Nottingham Castle

Location of:

a) Primary archive, i.e. raw data, electronic archive etc:

Trent & Peak Archaeology, Unit 1, Holly Lane, Chilwell, NG9 4AB

b) Full Report:

Nottingham City HER, Brewhouse Yard Museum, Castle Boulevard, Nottingham, NG7 1FB
English Heritage, East Midlands Office, 44 Derngate, Northampton, NN1 1UH
Trent & Peak Archaeology, Unit 1, Holly Lane, Chilwell, NG9 4AB

ENGLISH HERITAGE

Technical Details

(Please fill out a separate sheet for each survey technique used)

Type of Survey (Use term from attached list or specify other):

Magnetometer

Area Surveyed, if applicable (In hectares to one decimal place):

1 Ha

Traverse Separation, if regular: 0.5m

Reading/Sample Interval: 0.25m

Type, Make and model of Instrumentation: Bartington Instruments Grad 601-2

For Resistivity Survey:

Probe configuration:

Probe Spacing:

Land use at the time of the survey (Use term/terms from the attached list or specify other): Park

ENGLISH HERITAGE

Technical Details

(Please fill out a separate sheet for each survey technique used)

Type of Survey (Use term from attached list or specify other):

Resistivity

Area Surveyed, if applicable (In hectares to one decimal place):

1Ha

Traverse Separation, if regular: 0.5m

Reading/Sample Interval: 0.5m

Type, Make and model of Instrumentation: Geoscan Research RM85

For Resistivity Survey:

Probe configuration: Parallel-twin

Probe Spacing: 0.5m

Land use at the time of the survey (Use term/terms from the attached list or specify other): Park

ENGLISH HERITAGE

Technical Details

(Please fill out a separate sheet for each survey technique used)

Type of Survey (Use term from attached list or specify other):

Resistivity Profile

Area Surveyed, if applicable (In hectares to one decimal place):

N/A

Traverse Separation, if regular: N/A

Reading/Sample Interval: 1m

Type, Make and model of Instrumentation: Tigre64

For Resistivity Survey:

Probe configuration: Wenner

Probe Spacing: 1m

Land use <u>at the time of the survey</u> (Use term/terms from the attached list or specify other):

ENGLISH HERITAGE

Technical Details

(Please fill out a separate sheet for each survey technique used)

Type of Survey (Use term from attached list or specify other):

Ground Penetrating Radar

Area Surveyed, if applicable (In hectares to one decimal place):

1Ha

Traverse Separation, if regular: 0.5m

Reading/Sample Interval: 0.125m

Type, Make and model of Instrumentation: GSSI SIR3000 400MHz antenna

For Resistivity Survey:

Probe configuration:

Probe Spacing:

Land use <u>at the time of the survey</u> (Use term/terms from the attached list or specify other):

ENGLISH HERITAGE

Technical Details

(Please fill out a separate sheet for each survey technique used)

Type of Survey (Use term from attached list or specify other):

Ground Penetrating Radar

Area Surveyed, if applicable (In hectares to one decimal place):

1 Ha

Traverse Separation, if regular: 1m

Reading/Sample Interval: 0.125m

Type, Make and model of Instrumentation: GSSI SIR3000 200MHz antenna

For Resistivity Survey:

Probe configuration:

Probe Spacing:

Land use <u>at the time of the survey</u> (Use term/terms from the attached list or specify other):

Additional Remarks (Please mention any other technical aspects of the survey that have not been covered by the above questions such as sampling strategy, non standard technique, problems with equipment etc.):

ERT (Resistivity Profiling) was attempted with the Tigre 64, however a combination of environmental factors, problems with the equipment and time-pressures resulted in no meaningful data being collected using this technique.

The overall sampling strategy for the project was to collect data at as high a resolution as possible across the entire area of the site in order to provide the best possibility of characterising the nature of buried remains in the Outer Bailey of Nottingham Castle.

List of terms for Survey Type

Magnetometer (includes gradiometer)

Resistivity

Resistivity Profile

Magnetic Susceptibility

Electro-Magnetic Survey

Ground Penetrating Radar

Other (please specify)

ENGLISH HERITAGE

List of terms for Land Use:

Arable
Grassland - Pasture
Grassland - Undifferentiated
Heathland
Moorland
Coastland - Inter-Tidal
Coastland - Above High Water
Allotment
Archaeological Excavation
Garden
Lawn
Orchard
Park
Playing Field
Built-Over
Churchyard
Waste Ground
Woodland
Other (please specify)

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FIGURES

tp
Trent & Peak

Sitecode: NCA6 - Nottingham Castle
Drawn by: PSJ Date: 04/07/2014
Scale at A3: 1:1000

Fig. 1: Location of area surveyed

50m

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Fig. 2: Greyscale plot of geomagnetic survey results

-107nT 119nT

50m

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Fig. 3: Vectorised plan of geomagnetic survey results

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Scale at A3: 1:1000

Fig. 4: Greyscale plot of earth-resistance survey results

-27Ω 55Ω

50m

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Fig. 5: Vectorised plan of earth-resistance survey results

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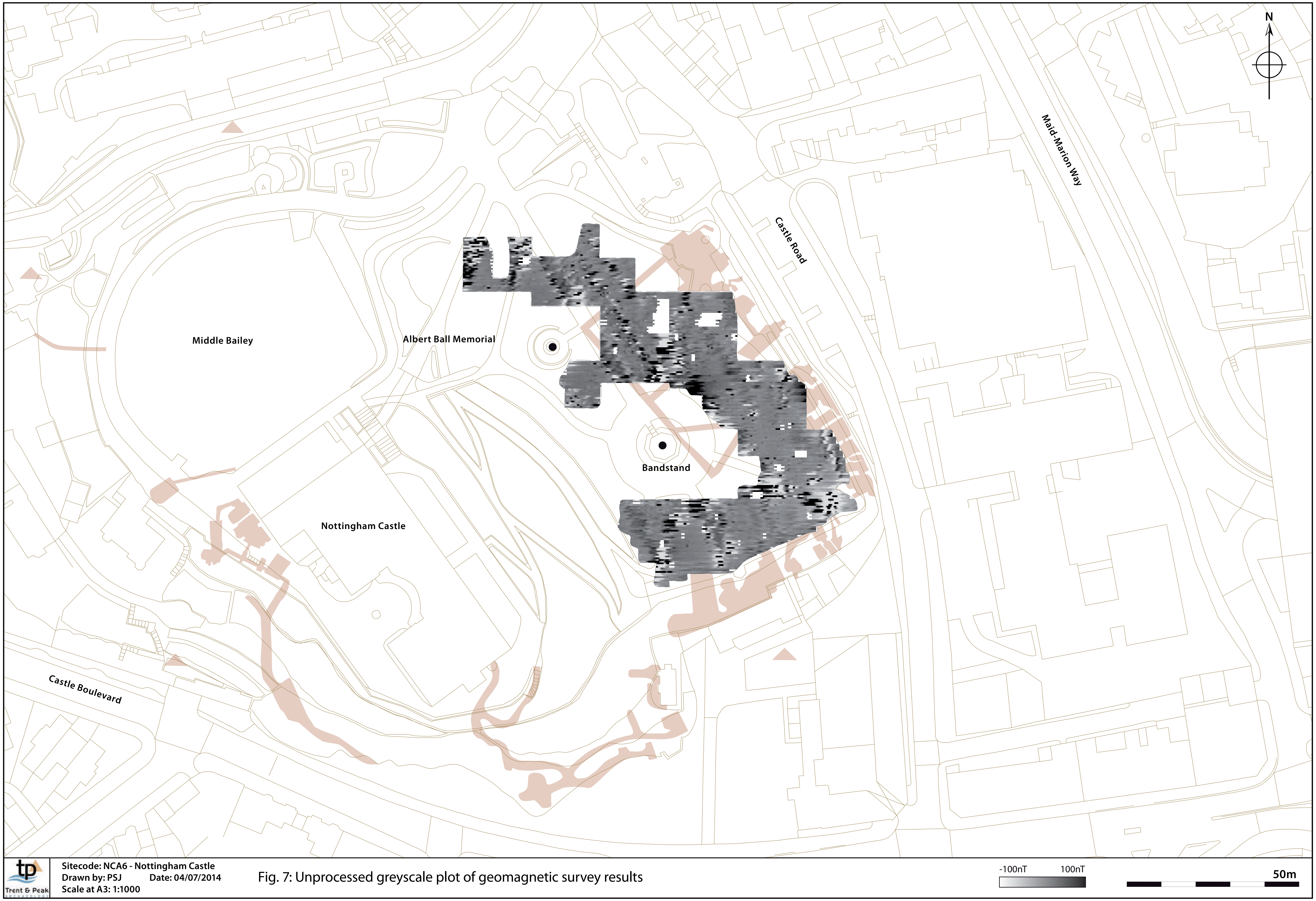
Scale at A3: 1:1000

Fig. 6: Archaeological interpretation plan of geomagnetic and earth-resistance survey results



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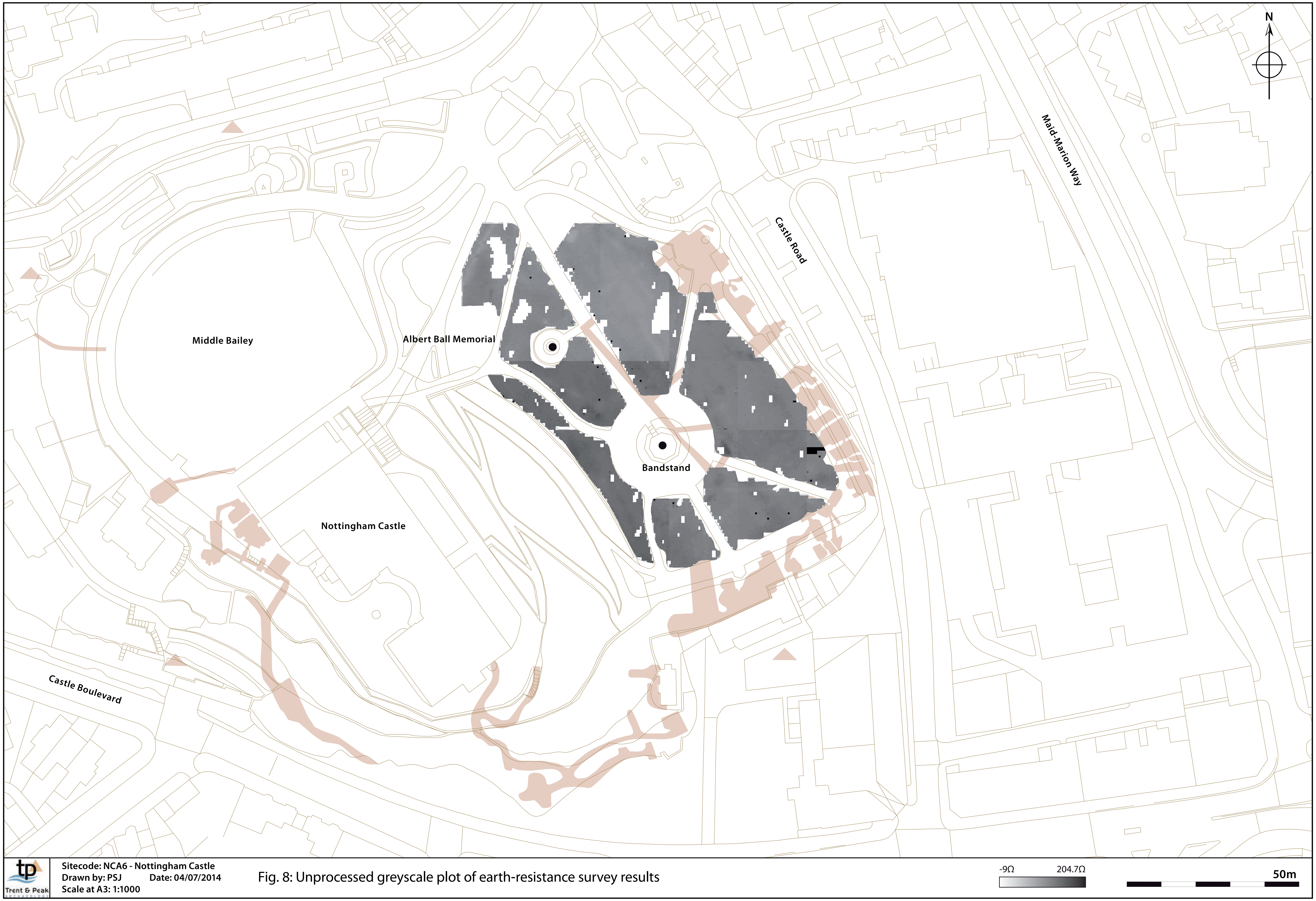
Scale at A3: 1:1000

Fig. 7: Unprocessed greyscale plot of geomagnetic survey results



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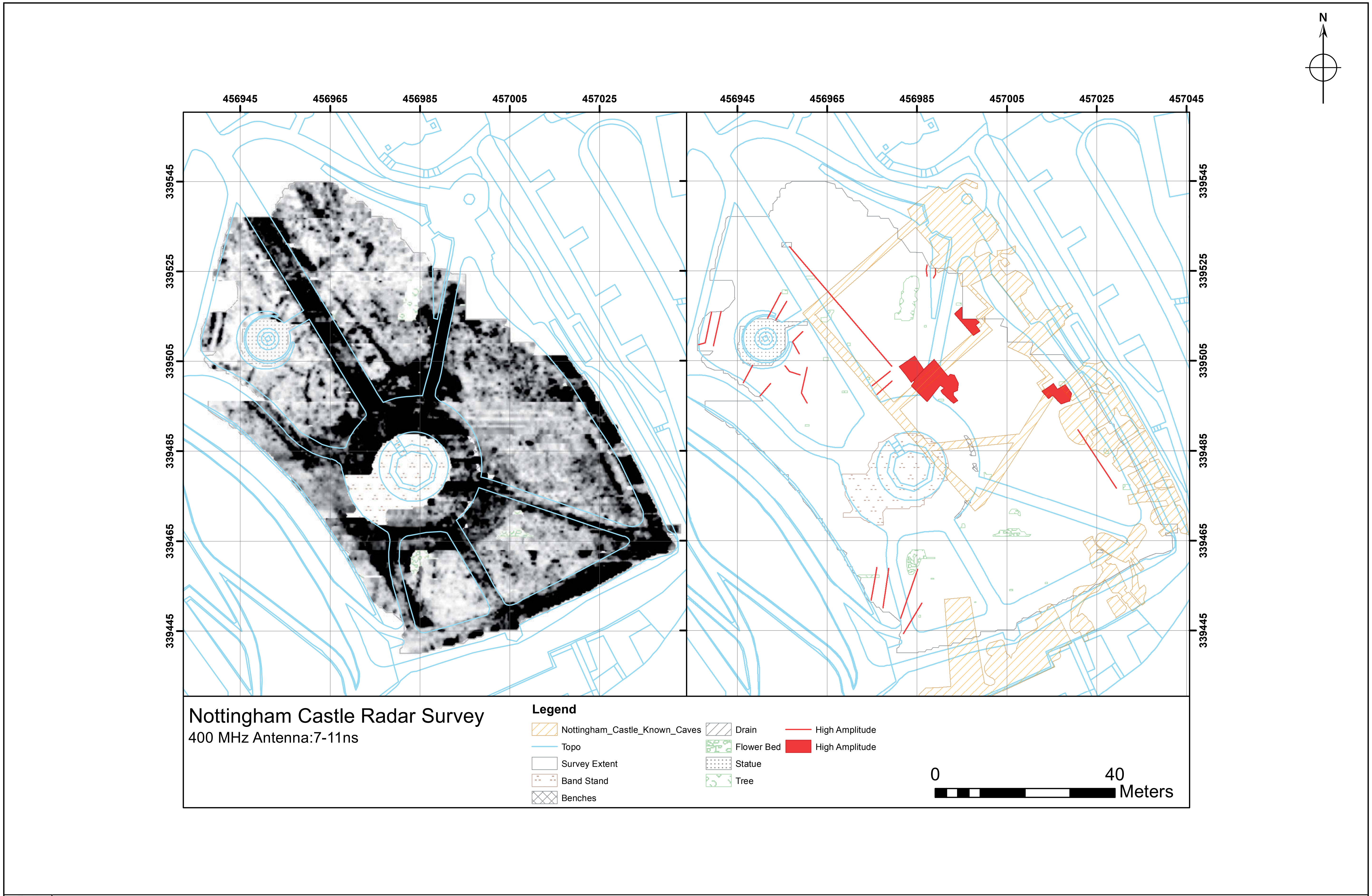
Drawn by: PSJ Date: 04/07/2014
Scale at A3: 1:1000

Fig. 8: Unprocessed greyscale plot of earth-resistance survey results



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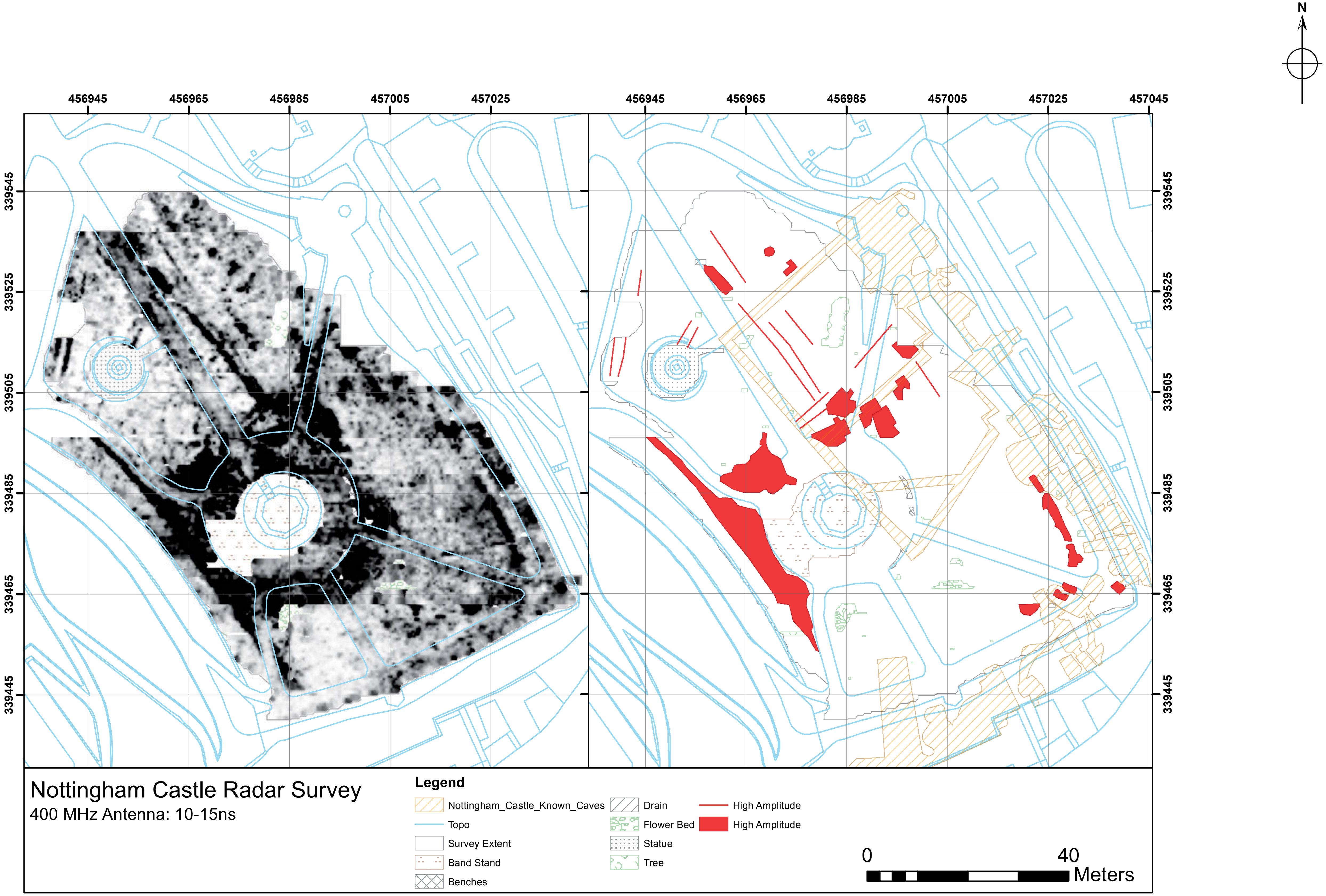
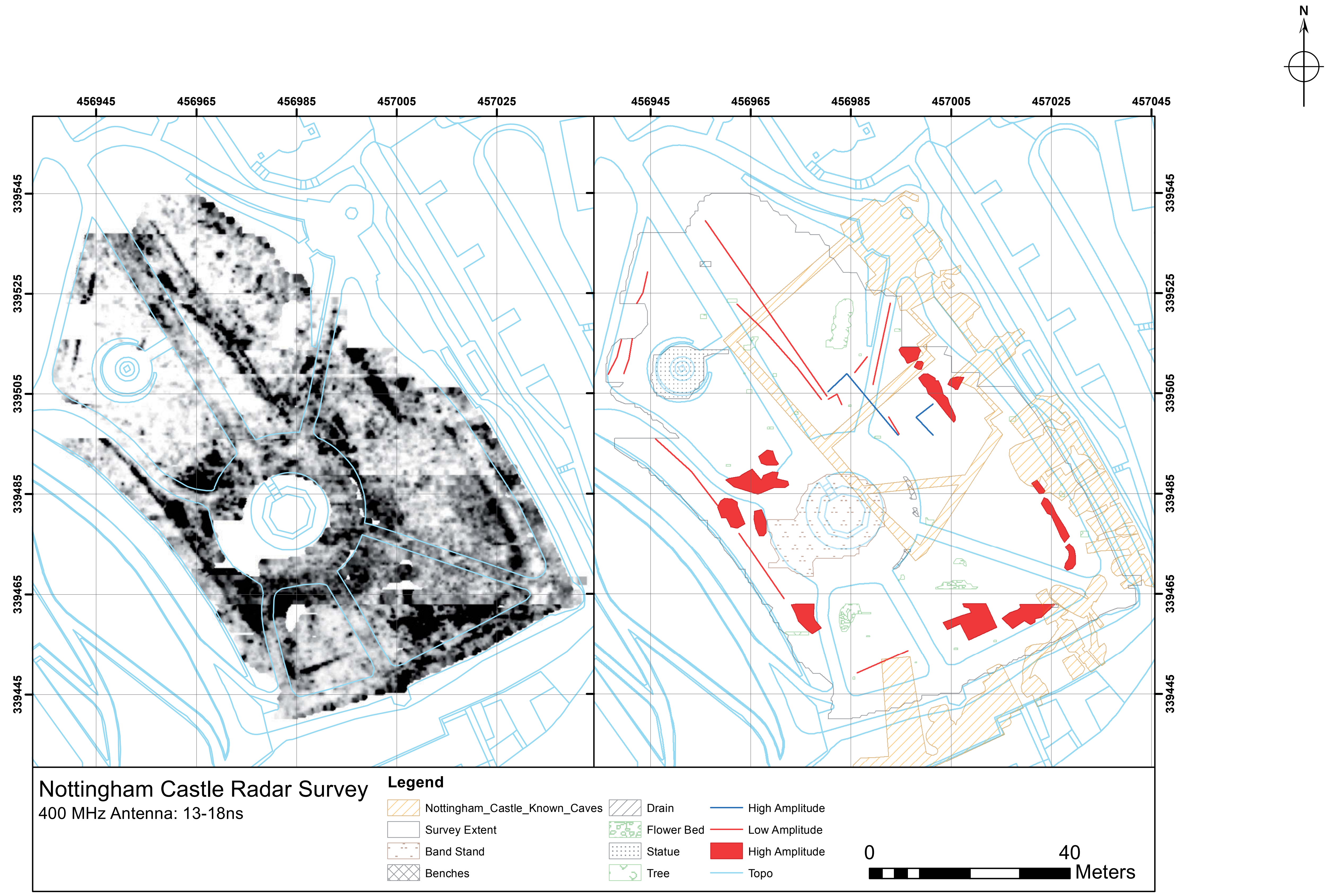
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 9: 7–11ns 400MHz GPR results and interpretation



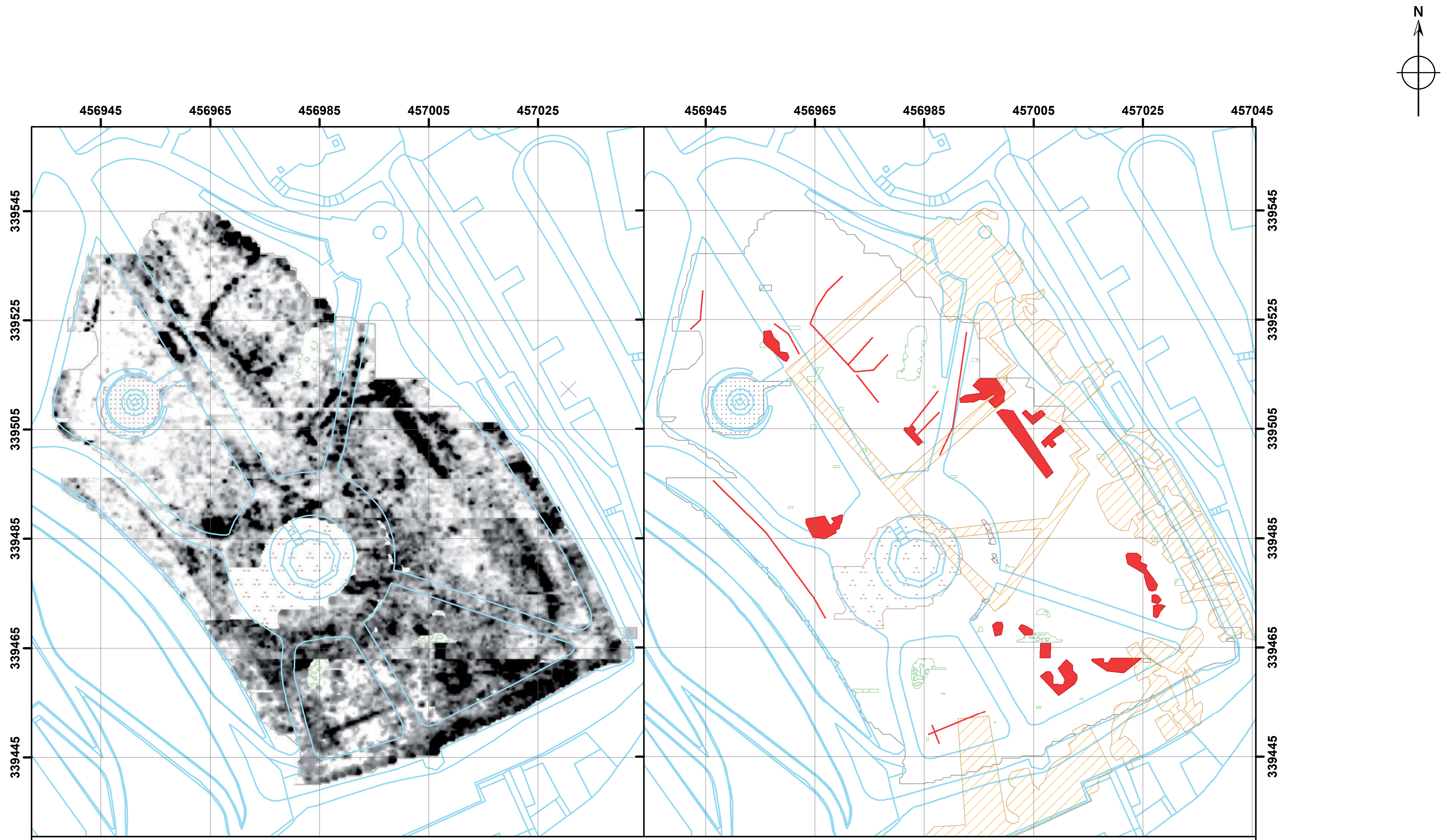
Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 10: 10–15ns 400MHz GPR results and interpretation



Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 11: 13–18ns 400MHz GPR results and interpretation



Nottingham Castle Radar Survey

400 MHz Antenna: 16-20ns

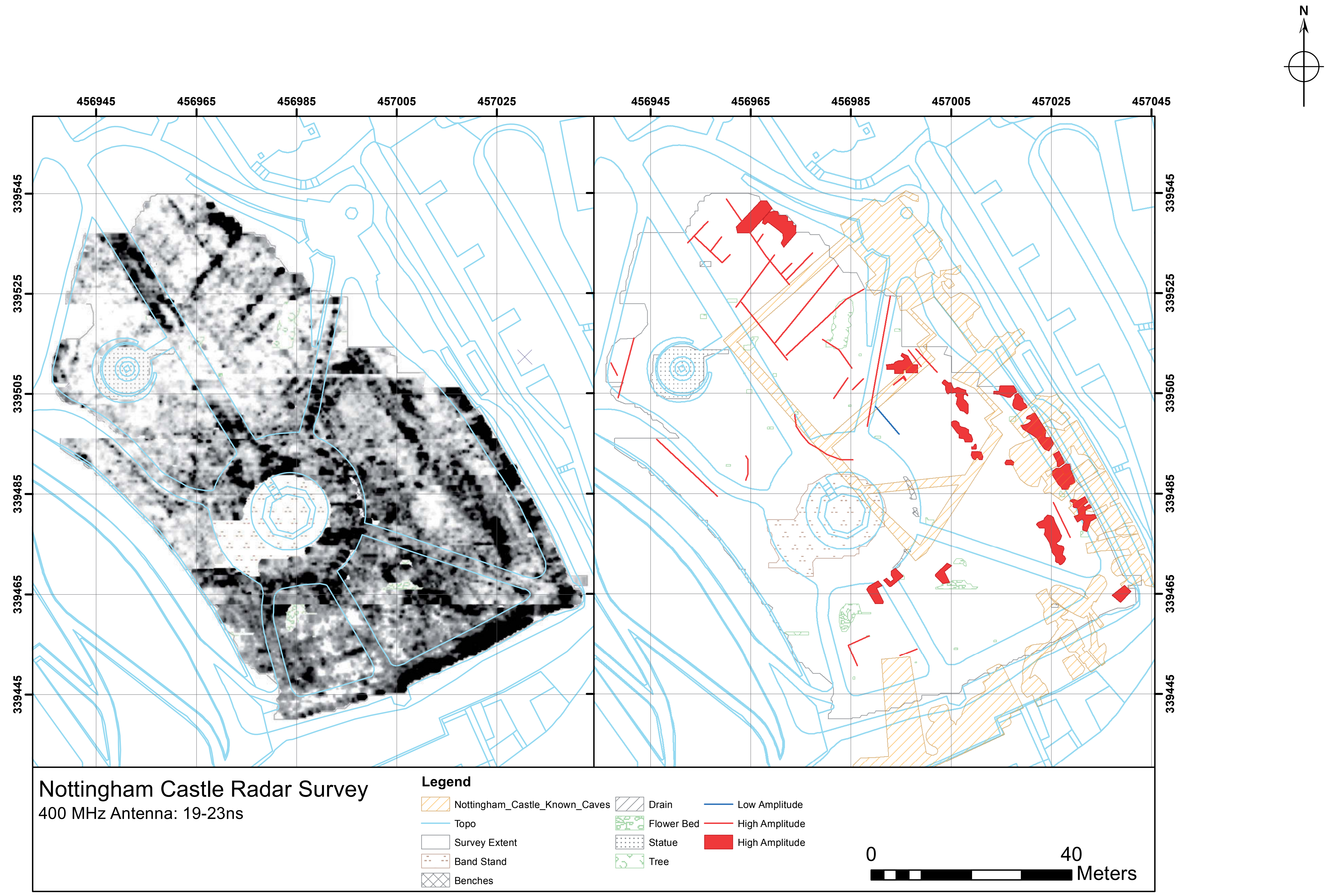
Legend

- Nottingham_Castle_Known_Caves
- Topo
- Survey Extent
- Band Stand
- Benches
- Drain
- Flower Bed
- Statue
- Tree
- High Amplitude (line)
- High Amplitude (area)

0 — 40 Meters

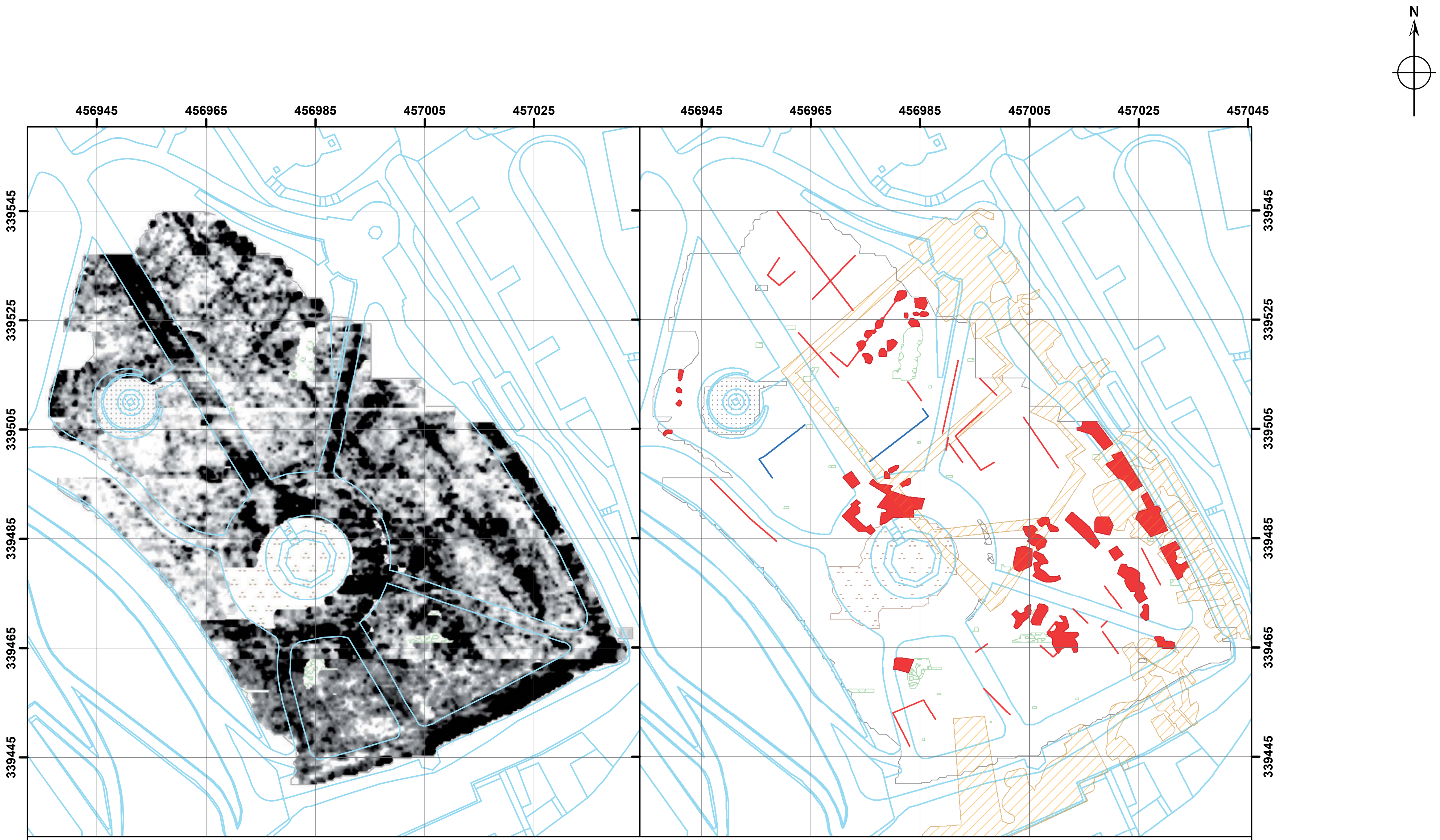
Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 12: 16–20ns 400MHz GPR results and interpretation



Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 13: 19–23ns 400MHz GPR results and interpretation



Nottingham Castle Radar Survey

400 MHz Antenna: 22-26ns

Legend

- Nottingham_Castle_Known_Caves
- Topo
- Survey Extent
- Band Stand
- Benches
- Drain
- Flower Bed
- Statue
- Tree
- Low Amplitude
- High Amplitude
- High Amplitude

0 40 Meters

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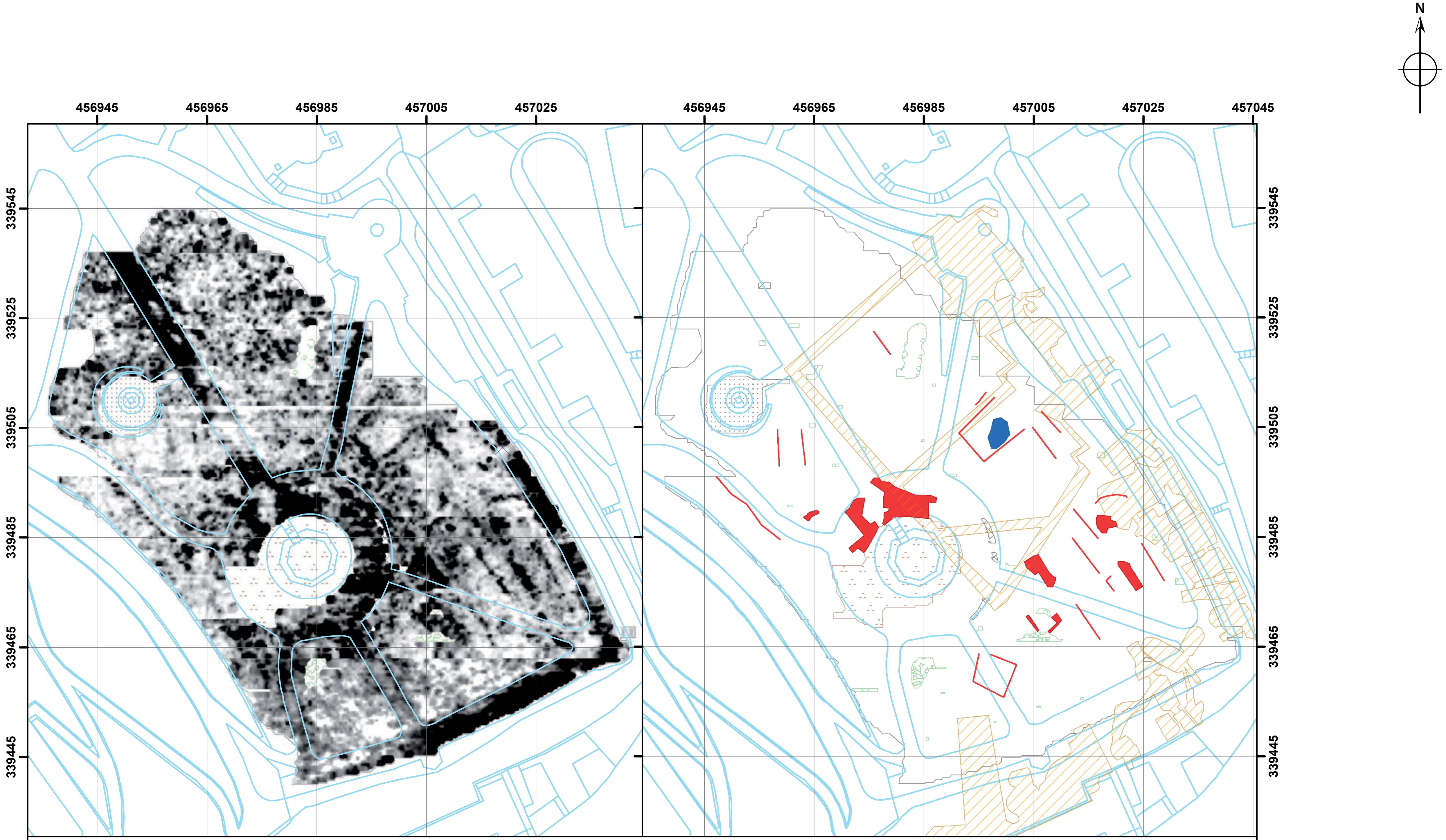
Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 14: 22–26ns 400MHz GPR results and interpretation



Nottingham Castle Radar Survey

400 MHz Antenna: 26-29ns

Legend

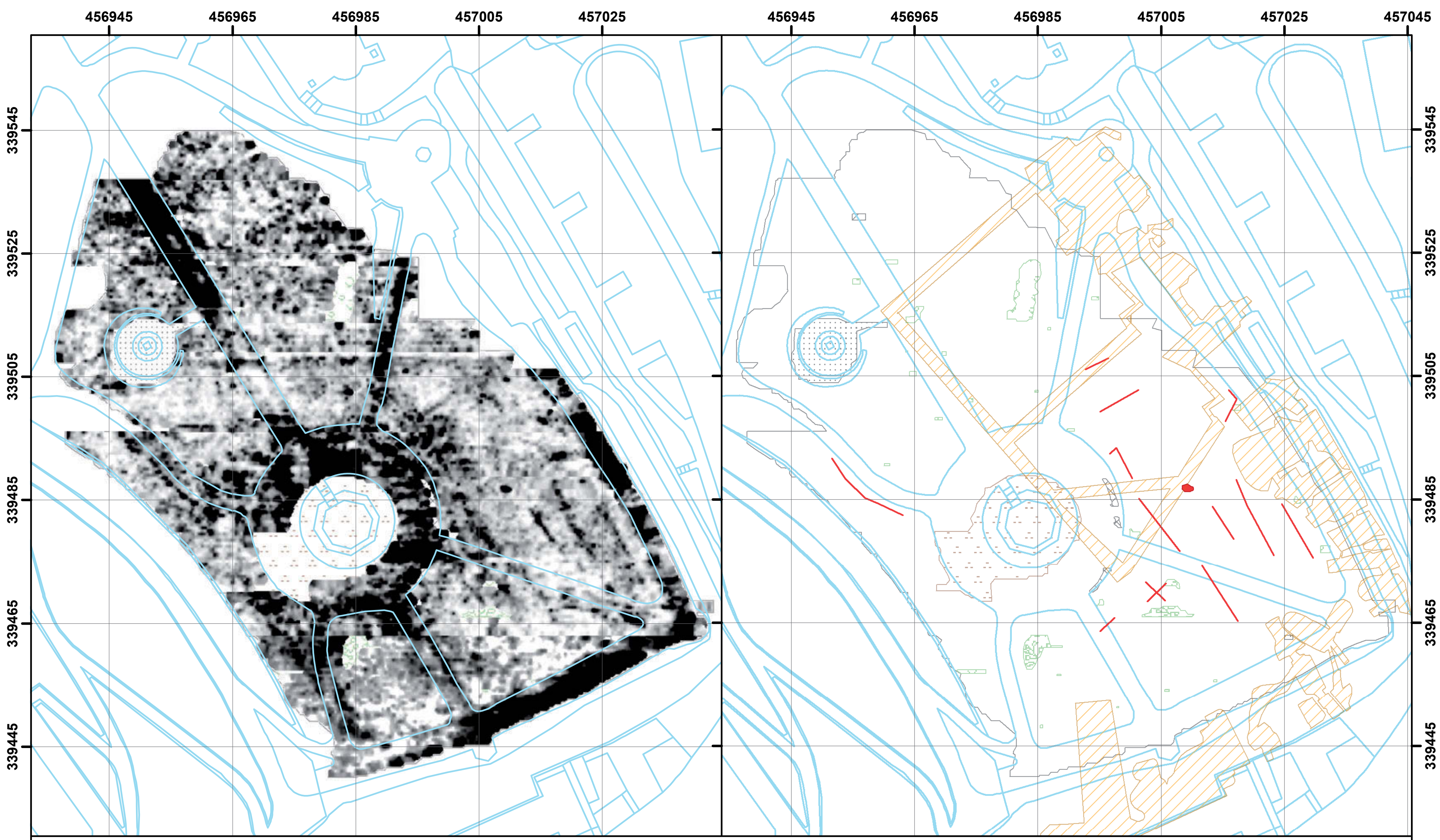
- Nottingham_Castle_Known_Caves
- Topo
- Survey Extent
- Band Stand
- Benches
- Drain
- Flower Bed
- Statue
- Tree
- High Amplitude
- Low Amplitude
- High Amplitude

0 40 Meters

Trent & Peak

Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 15: 26–29ns 400MHz GPR results and interpretation



Nottingham Castle Radar Survey

400 MHz Antenna:28-32ns

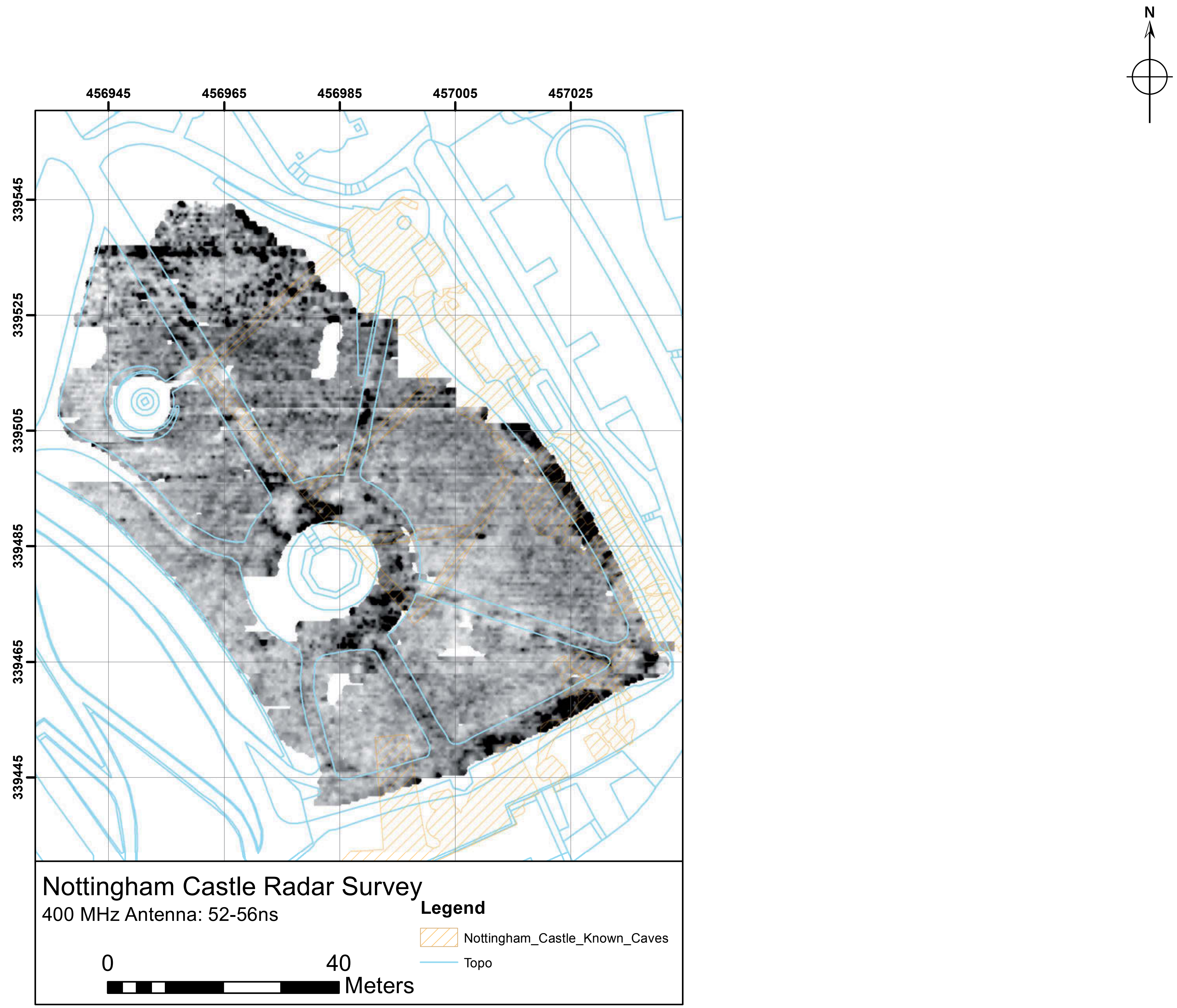
Legend

- Nottingham_Castle_Known_Caves
- Topo
- Survey Extent
- Band Stand
- Benches
- Drain
- Flower Bed
- Statue
- Tree
- High Amplitude
- High Amplitude

0 40 Meters

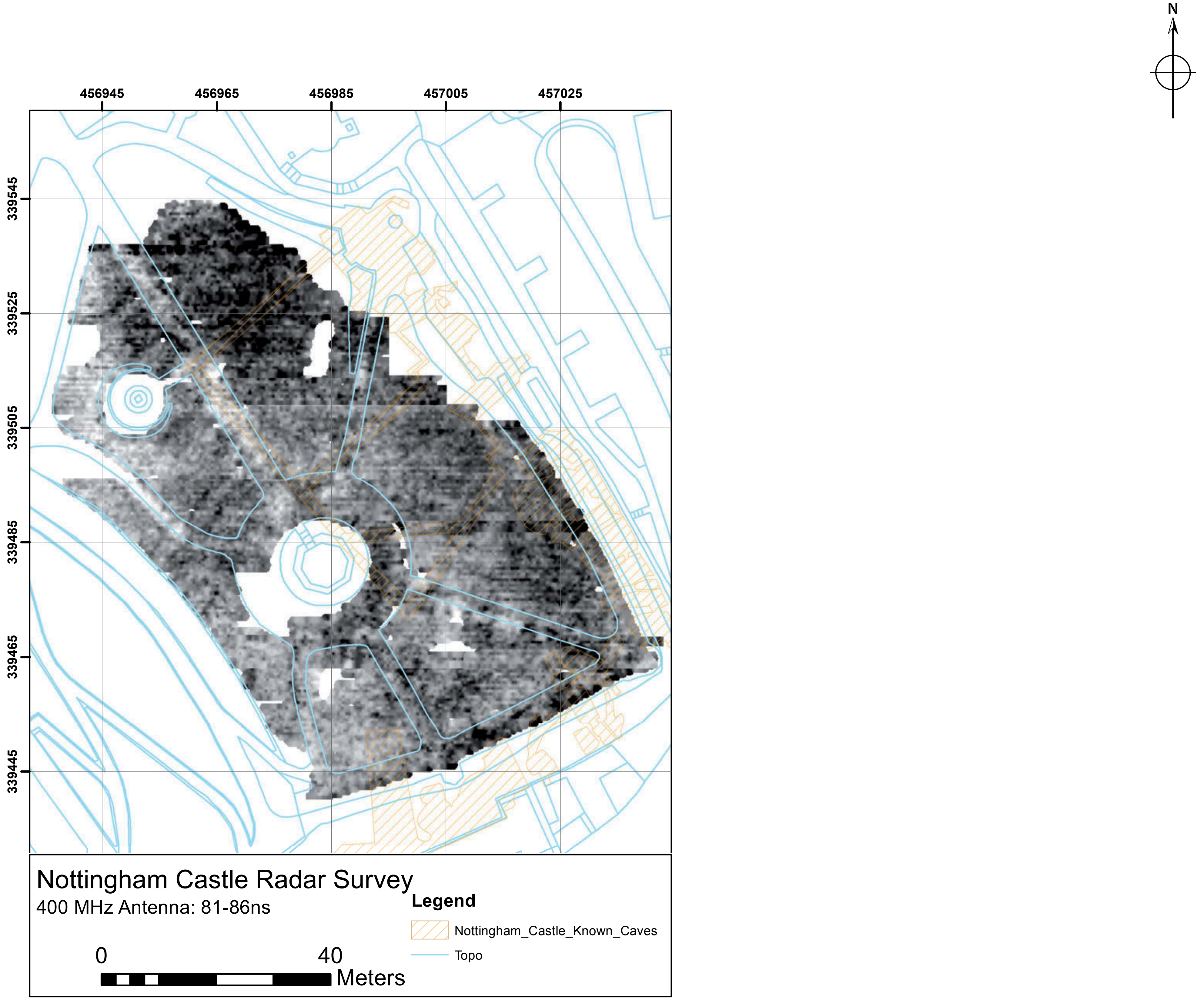
Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 16: 28–32ns 400MHz GPR results and interpretation



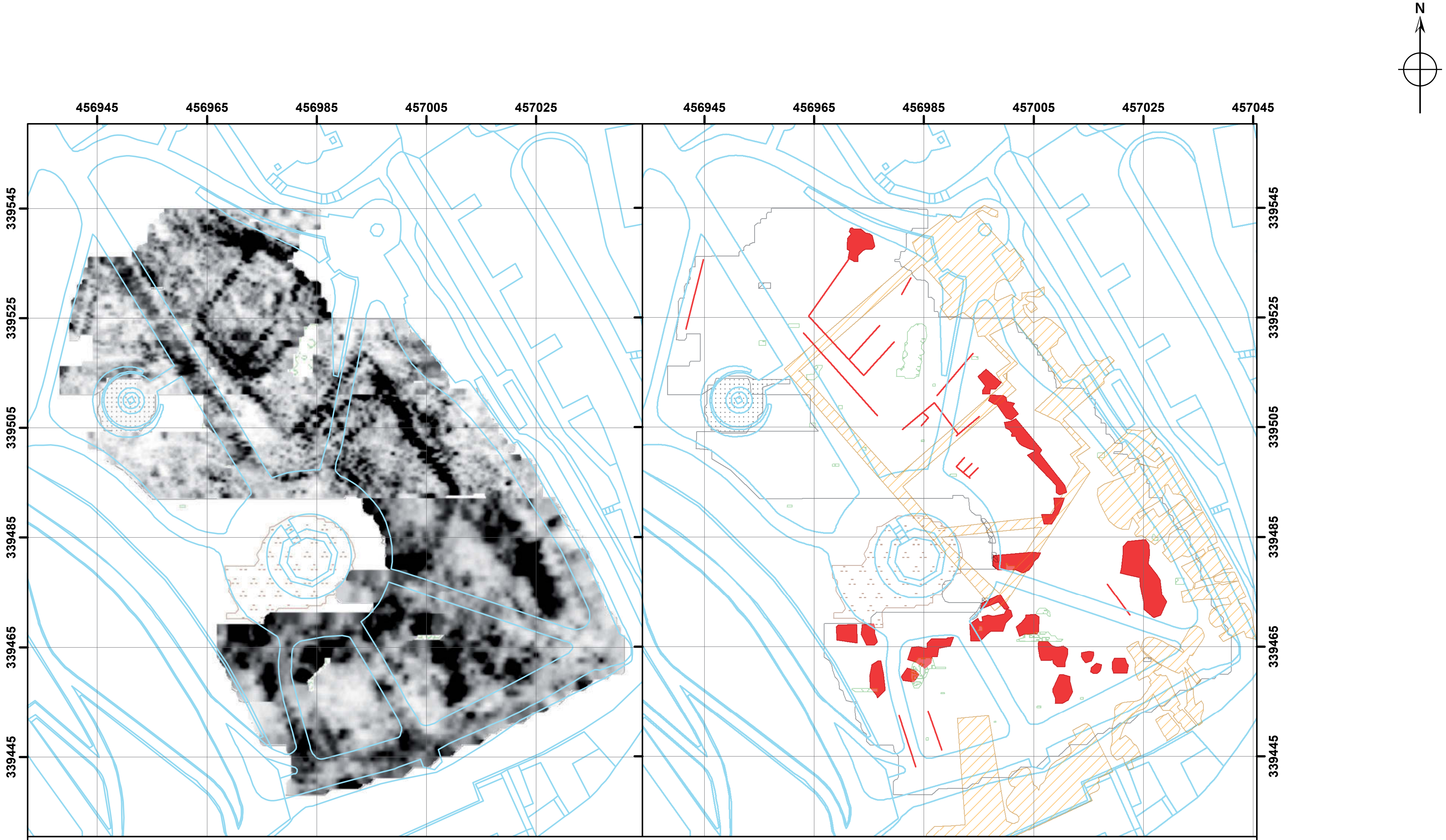
Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 17: 52–56ns 400MHz GPR results



Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 18: 81–86ns 400MHz GPR results



Nottingham Castle Radar Survey

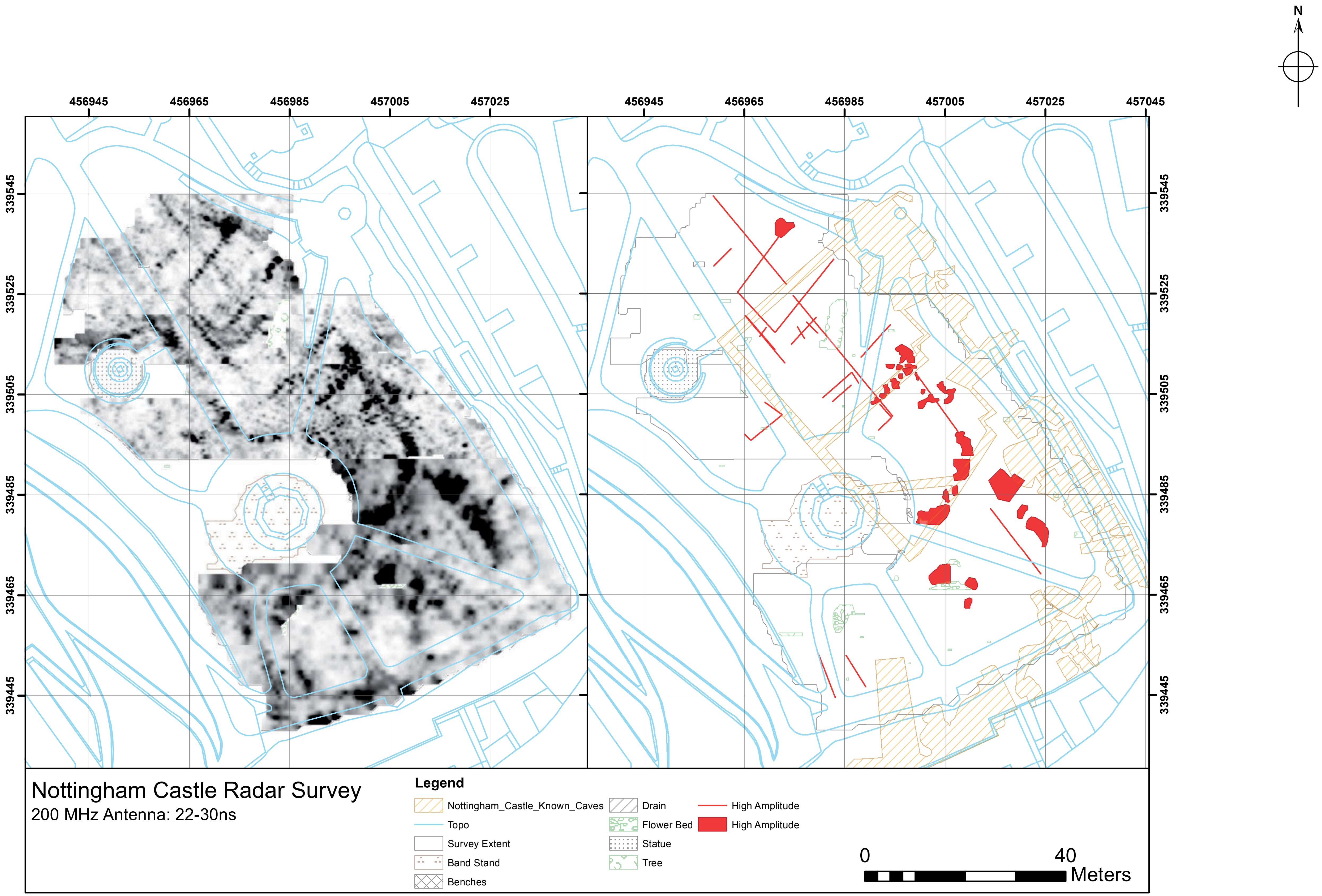
200 MHz Antenna: 17-25ns

Legend

- Nottingham_Castle_Known_Caves
- Topo
- Survey Extent
- Band Stand
- Benches
- Drain
- Flower Bed
- Statue
- Tree
- High Amplitude (line)
- High Amplitude (area)

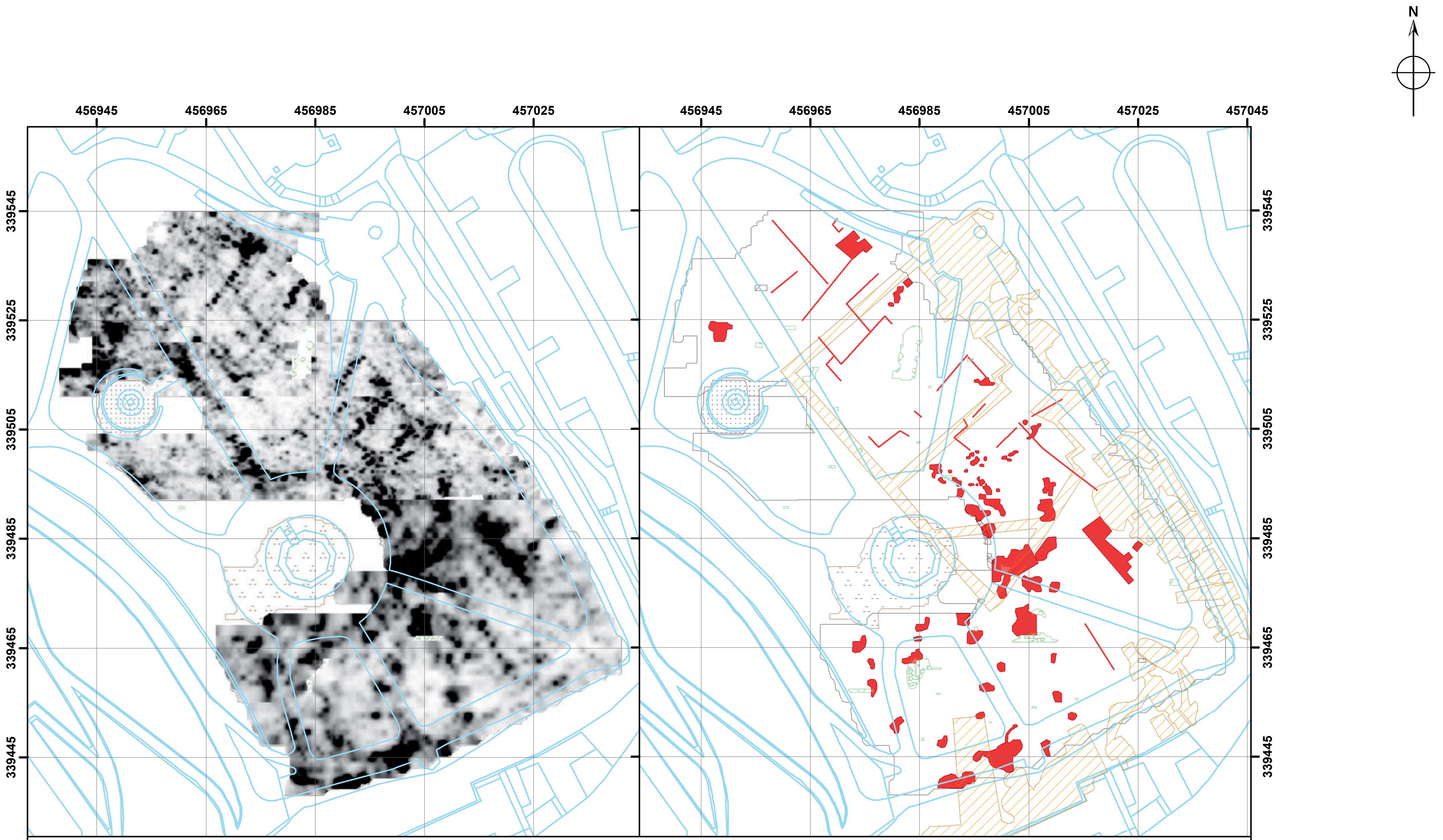
0 40 Meters

Fig. 19: 17–25ns 200MHz GPR results and interpretation



Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 20: 22–30ns 200MHz GPR results and interpretation



Nottingham Castle Radar Survey

200 MHz Antenna: 27-36ns

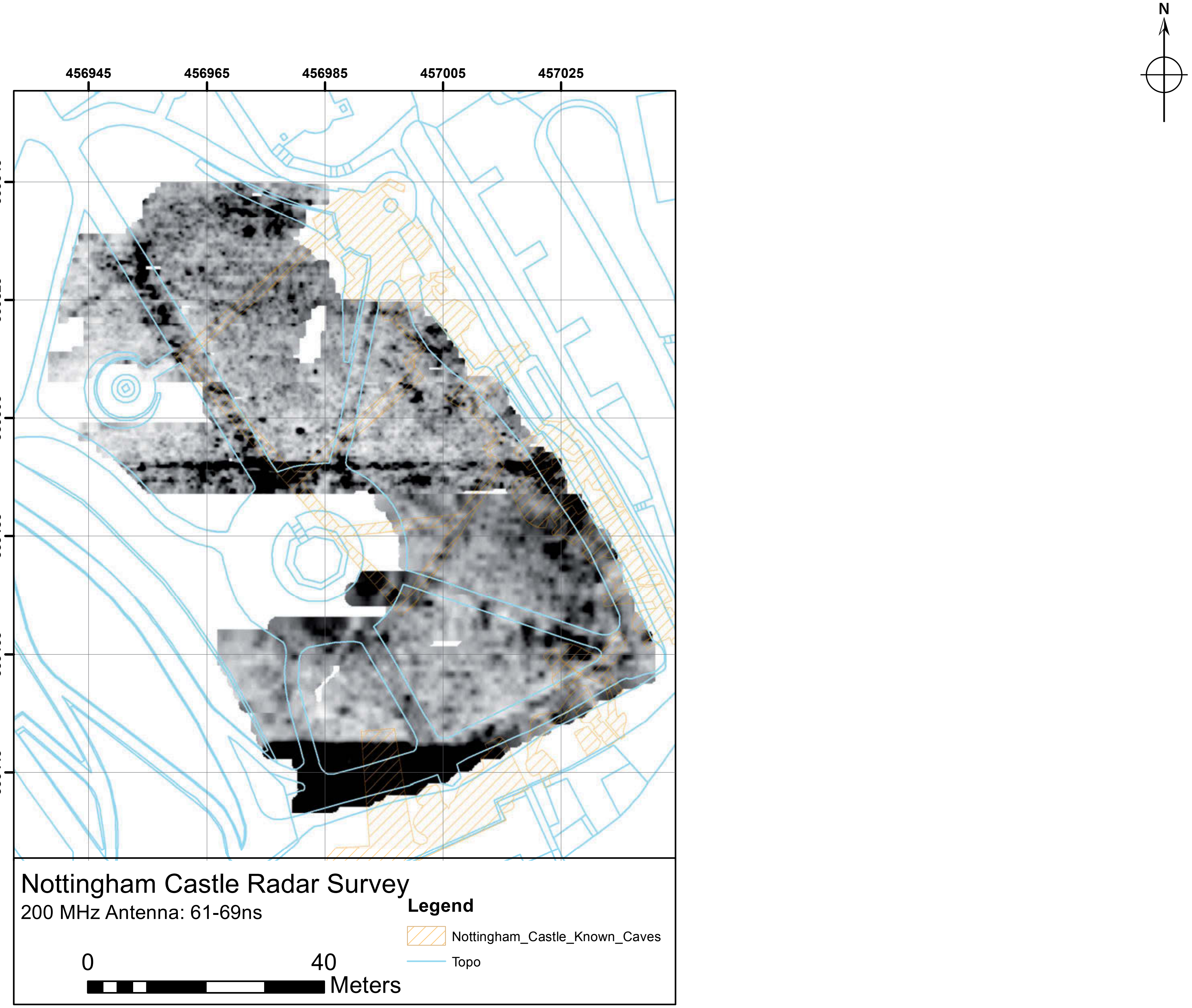
Legend

- Nottingham_Castle_Known_Caves
- Topo
- Survey Extent
- Band Stand
- Benches
- Drain
- Flower Bed
- Statue
- Tree
- High Amplitude
- High Amplitude

0 40 Meters

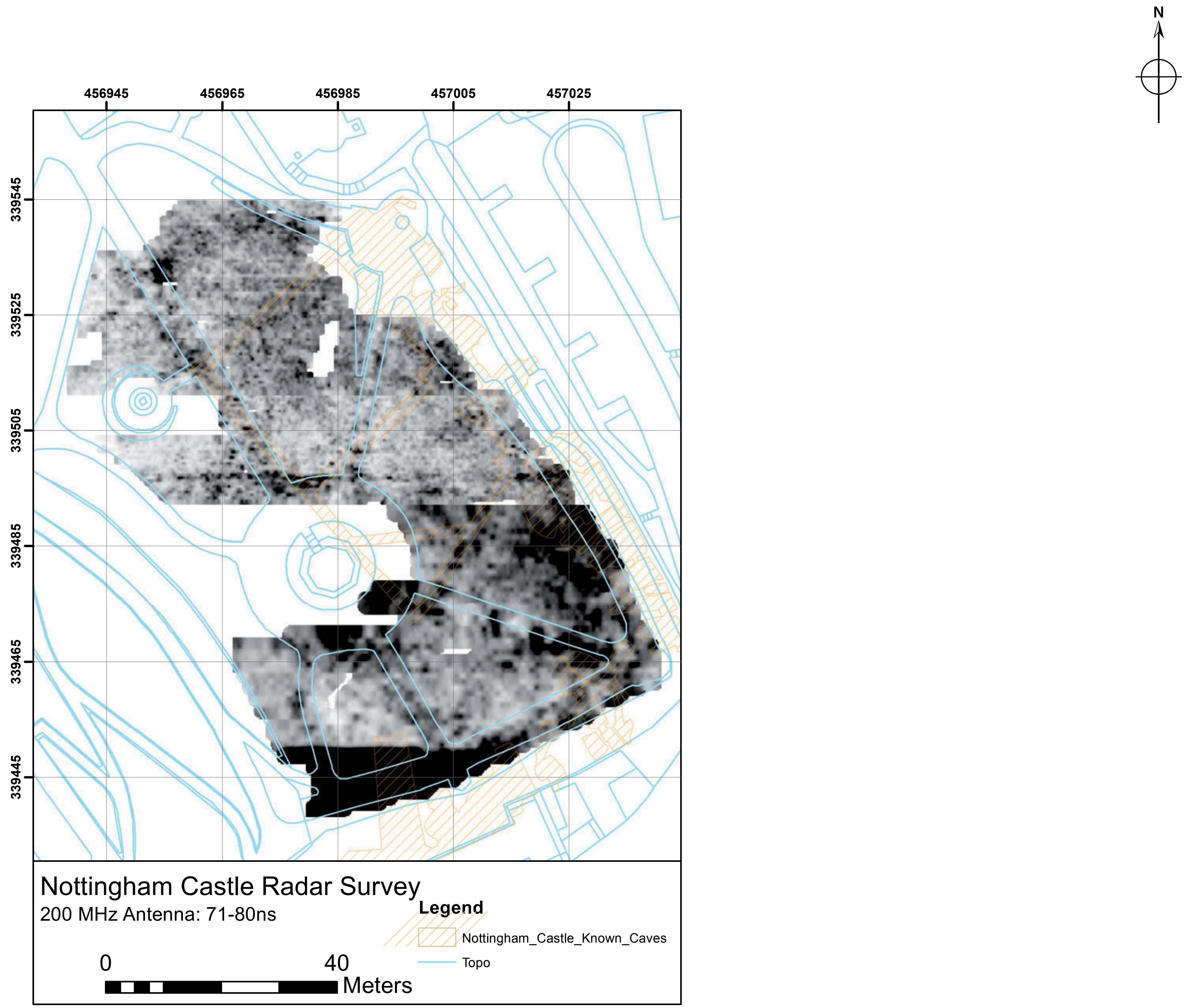
Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 21: 27–36ns 200MHz GPR results and interpretation



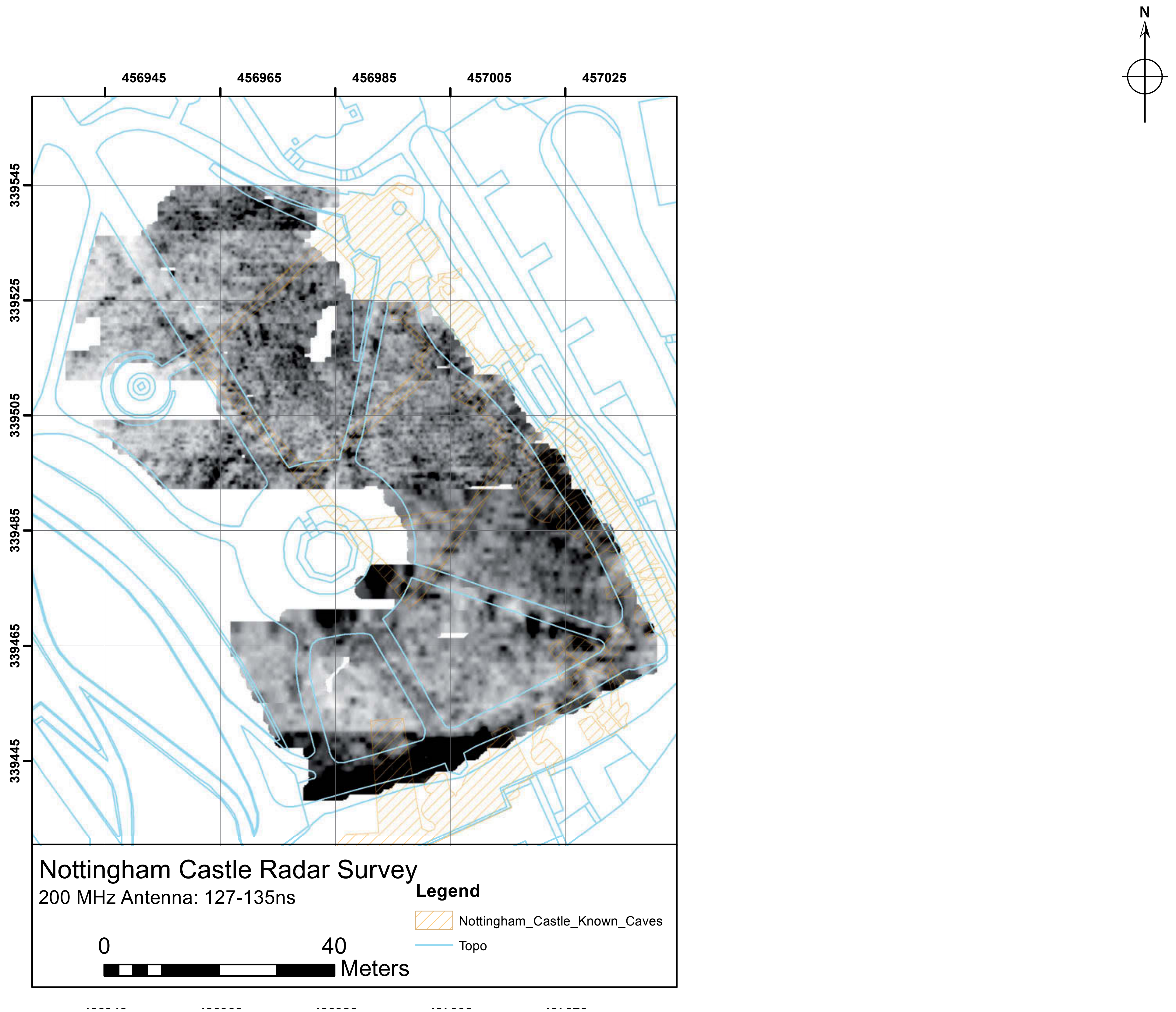
Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 22: 61–69ns 200MHz GPR results



Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 23: 71–80ns 200MHz GPR results



Sitecode: NCA6 - Nottingham Castle
Drawn by: ER Date: 04/07/2014
Scale at A3: 1:800

Fig. 24: 127–135ns 200MHz GPR results