Report on the Geophysical Survey at Wrotham Park, Potter's Bar, Barnet, Hertfordshire August-September 2018

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Summary

This report presents the results of the geophysical survey undertaken at Wrotham Park, near Potter's Bar, Hertfordshire, in August and September 2018. It specifies the survey methodology together with an interpretation discussion of the survey results. Magnetometry, ground penetrating radar and earth resistance were carried out across the area of a supposed moated site at the northern end of a field close to the Wrotham Park estate offices. In addition magnetometry was completed across the whole of the field, and a second area of archaeological potential was targeted using ground penetrating radar.

Results of the magnetometry indicated a substantial quantity of ferrous noise in the data, with a series of linear positive anomalies marking geological formations caused by past glacial activity. In addition a series of linear anomalies indicated possible archaeological remains, principally along the supposed line of the Gannick Bank.

The ground penetrating radar indicated sparse remains associated with the possible chantry chapel within the moated area, with the moat of the site being picked out in the lower part of the radar slices. The earth resistance survey indicated the presence of part of a possible building and associated possible pathways and garden features.

A possible building that might be associated with the chantry chapel was found in the results of the survey, although the modern extent of the pond at the site seems to have obliterated part of the structure. Additional associated anomalies were found adjacent to the remains of the building. The possible line of the Gannick Bank was located, together with associated linear anomalies perhaps indicating further structures.

1. Introduction

Between the 27th August and 7th September 2018 a geophysical survey was conducted at Wrotham Park, near Potter's Bar in Hertfordshire (Fig. 1). This formed the second season of survey work undertaken as part of a project investigating the area surrounding a possible chantry chapel associated with the Battle of Barnet (Barker and Wilson 2017). All of the work formed a component of the Battle of Barnet Project directed by the University of Huddersfield, and undertaken with the Barnet Museum.

The survey was undertaken by a team from the University of Southampton, with permission from the Wrotham Park Estate, and funded by the Hadley Trust. The report presented here combines the results of the magnetometer and earth resistance surveys from 2016, and the survey conducted in 2018, continuing the numbering sequence from Barker and Wilson (2017).

1.1 Site Location and Background

The site comprises a roughly triangular pasture field within the southern corner of the Wrotham Park Estate. It is bounded by Kitts End Road to the west, the A1000 to the east and the business park access road and buildings to the north and north east. The western part of the field contains a large pond measuring 70m in length and 24m across. The modern ground level lies at c. 131m aOD (above Ordnance Datum) at the north end of the survey area descending to c. 128m aOD in the south.

The site is underlain by clay, silt and sand of the London Clay Formation, a sedimentary bedrock formed approximately 34 to 56 million years ago in the Palaeogene Period in a local environment previously dominated by deep seas. Superficial deposits of Stanmore Gravel formation are also recorded. These were formed up to three million years ago in the Quaternary Period in a local environment previously dominated by rivers (British Geological Survey., 2017).

Evidence for the prehistoric, Roman and early medieval periods on the site is sparse and the site can be considered to have a generally low archaeological potential for all past periods of human activity, prior to the later medieval period. A number of undated cropmarks are visible on aerial photographs, approximately 350m east and south east of the site and it is possible these represent enclosures of prehistoric date (Barker and Wilson, 2017).

The site lies to the north of the nationally significant Historic Battlefield designation associated with the Battle of Barnet, one of the battles of the Wars of the Roses, which took place on 14th April 1471. The Yorkist army led by Edward IV defeated the Lancastrian army led by the Earl of Warwick, who was killed at the battle. The battle was also notable for the early use of handguns and cannon. This is the only registered historic battlefield in London and is specifically mentioned in Barnet's Core Strategy Policy CS5 (Barnet London Borough, 2012, pp. 21, 63-64, 69, 141). Currently ongoing investigations being undertaken by the University of Huddersfield are examining the possibility that the battle took place to the north of the designated battlefield (English Heritage, 1995) (Historic England, 2017a), within the vicinity of this site.

The location of the designated battlefield area has been guided by contemporary and near contemporary accounts, which referred to a number of landscape features. A 'broad green' (interpreted as Hadley Green) on the high road to St Albans; a 'hedge side' and an area of marshy ground are all mentioned in sources. It was also principally guided by mid-20th century interpretations of the battlefield location by notable military historians such as Alfred Burne (Burne, 1950). All these interpretations are backed up by very little other than circumstantial evidence, and no archaeological proof.

The mentioned landscape features have traditionally been interpreted as being located in the area of Monken Hadley, encompassing the bulk of the Old Fold Manor Golf Course, together with open land to the east. However, the location of the battle has been disputed. While contemporary accounts place the battle approximately one mile beyond High Barnet, associated with the St Albans Road, on a broad green, few other details are known. Von Wesel's account, written a matter of days after the battle, suggests that Edward positioned his men in an area of marshy ground and that the armies faced each other across the St Albans road (Adair, 1968, 68). Furthermore, the battle is known to have been fought from the early morning onwards, in a heavy mist or fog, which confused combatants and have confused any subsequent eye witness reports that contemporary chroniclers may have utilised.

Early maps showing the location of the battle to the north of Barnet, and the placement of the monument to the death of the Earl of Warwick, constructed in 1740 on Hadley Green to the south-east of the site, may have concentrated opinion by 19th century historians that the battle took place in this vicinity. By the late 19th century the battle's location was accepted as Monken Hadley and Barnet, refinement of which contributed to the designation of the battlefield area by English Heritage (now Historic England) in 1995 (CgMs Heritage, 2015, 21-22) (Historic England, 2017a) (Historic England, 2017b) (English Heritage, 1995).

Research undertaken by local historian Brian Warren of the Potters Bar and District Historical Society has identified the possible site of the chapel built to commemorate those killed in the battle, within the present boundary of Wrotham Park. He argues that an extant linear pond within the Estate represents a surviving vestige of the moat that once surrounded the chapel, which is described as moated in a number of accounts (Fig. 2) (Warren, 2009). It is possible that this chapel may have been directly associated with burials or mass graves of those who died in the battle. It is Warren's research that was the principal instigator of the geophysical survey.

Possible battlefield-related archaeological artefacts identified within the site vicinity have included an undated cannonball and lead shot, found opposite Dury Road to the east of the site (Greater London Historic Environment Record MLO16475) and a cannonball found on Hadley Green to the south-east (Greater London Historic Environment Record ELO1229). Subsequent evaluation of a number of these apparent 'cannon ball' finds from the vicinity of the battlefield, now held in Barnet Museum, suggests that they are unlikely to be from the battle due to their method and material of construction (Glenn Foard, pers comm, 2014). However, two lead cannon balls, currently housed in Barnet Museum have been found by an amateur metal detectorist within the Wrotham Park Estate, to the north west of the site. These undoubtedly date from the battle as they are of a construction typically associated with late 15th century cannon balls and comparable with the large assemblage recovered from Bosworth battlefield (Foard & Curry, 2013). A third cannon ball of similar construction was recovered by a metal detectorist during earthmoving on the Shire Golf Course, approximately 1.15km to the west of the site. The Portable Antiquities Scheme also records a number of find spots within Wrotham Park of artefacts which date to the same period as the battle, including a Groat of Edward IV, a French Jetton and a purse bar. Such finds further suggest that the battle may have taken place to the north of the registered area, in accordance with Warren's suggestion.

Archaeological work to try and identify the battlefield site was undertaken by Dr. Tony Pollard and Dr. Neil Oliver in the early 2000's as part of a television series on battlefield archaeology (Pollard & Oliver, 2002). Their work combined test trenches, geophysical survey and metal detecting to test areas within the designated battlefield area around Old Fold Manor and the golf course. Their results were inconclusive, not surprising given the time and access limitations imposed by the television format.

In the post-medieval period, the Wrotham Park Estate was established and grew around the site. It contains a number of listed buildings and other features of post-medieval date. Aerial photographs from the 1940s show what appear to be garden-type features in the western part of the site. Whilst these may be considered relatively ephemeral in nature, it is possible that a trace of them may be picked up by geophysical survey.

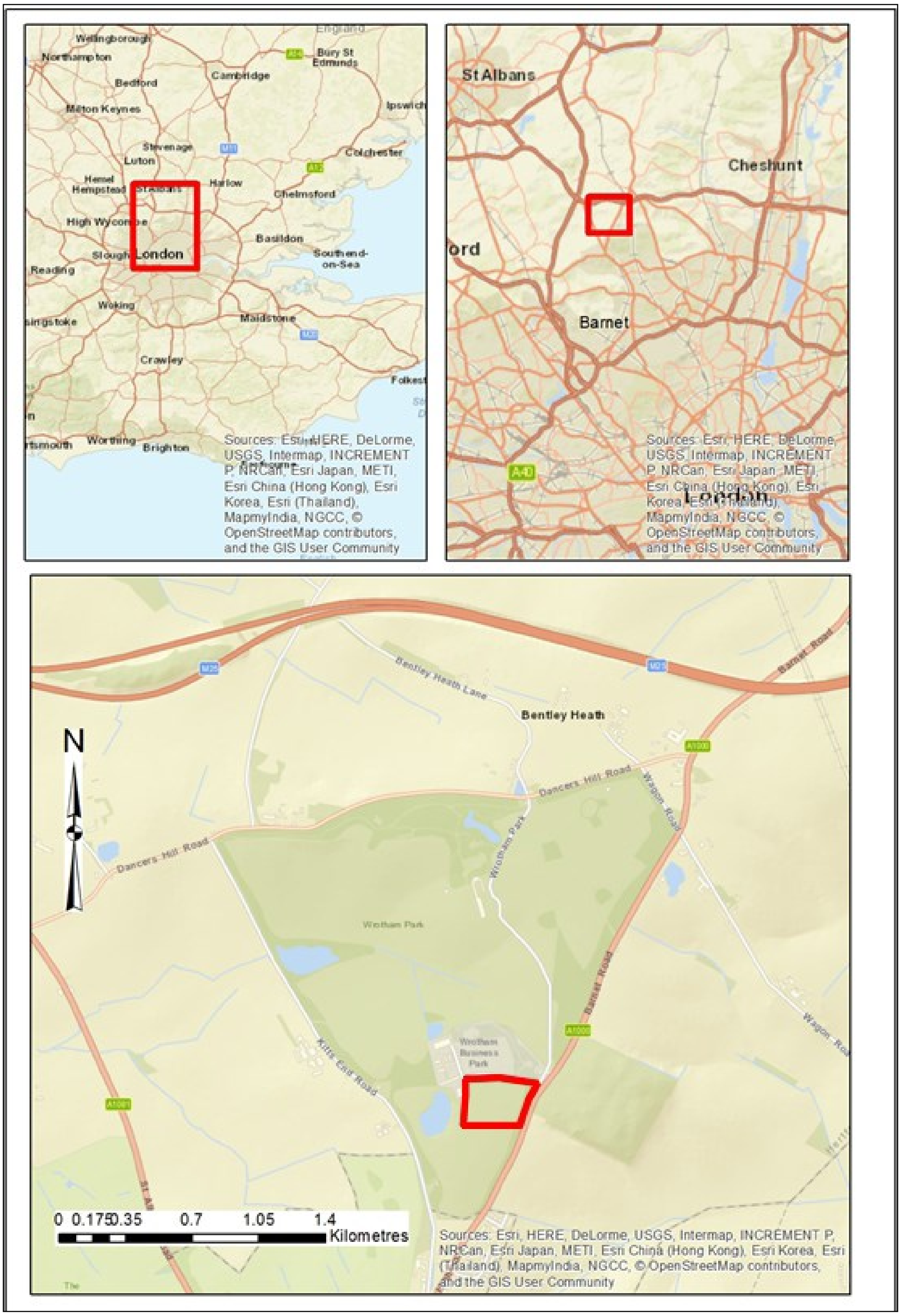

Figure 1Map showing the location of Wrotham Park Estate and the area of the moated site

Figure 2A detail of the South Mimms 1781 enclosure map, showing the moated site

1.2 Aims of the Survey

As part of wider research into the 1471 Battle of Barnet, it was important to investigate the chapel location theory proposed by Warren. Confirming the location of the chapel would have a crucial impact on the wider understanding of the battlefield landscape as a whole and in addition, provide ground breaking new evidence in the understanding of the battle.

The objective of the geophysical survey was to provide information about the archaeological resource within the site, including its presence/absence, character, extent, possible date, integrity, state of preservation and quality. It aimed, as far as is reasonably possible, to determine the nature of the archaeological resource within a specified area using appropriate methods and practices (CIfA 2014). The results of the survey will help in the assessment of the site's potential for archaeological remains, enabling an appropriate strategy of further investigation to be instigated.

The survey followed the Standards and Code of Practice laid down by the Chartered Institute for Archaeologists (Chartered Institute for Archaeologists, 2014), local and regional planning authority archaeology guidance, Historic England/GLAAS Archaeological Guidelines (Historic England 2015) where appropriate and research priorities established in the relevant regional research framework document.

2. Survey Methodology

For the 2018 survey at Wrotham Park a variety of techniques were applied, including magnetometry, earth resistance (ER) and ground penetrating radar (GPR). Results of these techniques are extremely dependent on the geology of the particular area, and whether the archaeological remains are derived from the same materials. Magnetometry is a passive technique which uses sensors to measure variations in the strength of the Earth's magnetic field in nanotesla (nT). Earth resistance is based on the passing of an electrical current through the soil and measuring the resistance to the current. GPR survey utilizes an electromagnetic radar wave propagated through the soil to search for changes in soil composition and structures, measuring the time in nanoseconds (ns) taken for the radar wave to be sent and the reflected wave to return.

As part of the survey these techniques were applied to facilitate a comparison of their effectiveness. The underlying clay geology, and the flint and masonry type of construction generally respond well to the use of earth resistance and GPR survey (Barker, Strutt and Sly 2005; Strutt, Sly, and Barker 2004; Strutt, Barker and Sly 2008). In addition the presence of possible structural and brick features in the archaeological record, and the need for rapid survey over large areas, provided ideal conditions for magnetometry.

2.1 Techniques of Geophysical Survey: Magnetometry, Earth Resistance, and Ground Penetrating Radar (GPR)

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 (Fig. 3). The iron content of a soil provides the basis for its magnetic properties, with the presence of minerals such as magnetite, maghaemite and haematite iron oxides all affecting 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 Teslas (48,000 nanoTesla, or nT). It follows that these instruments are very sensitive indeed.

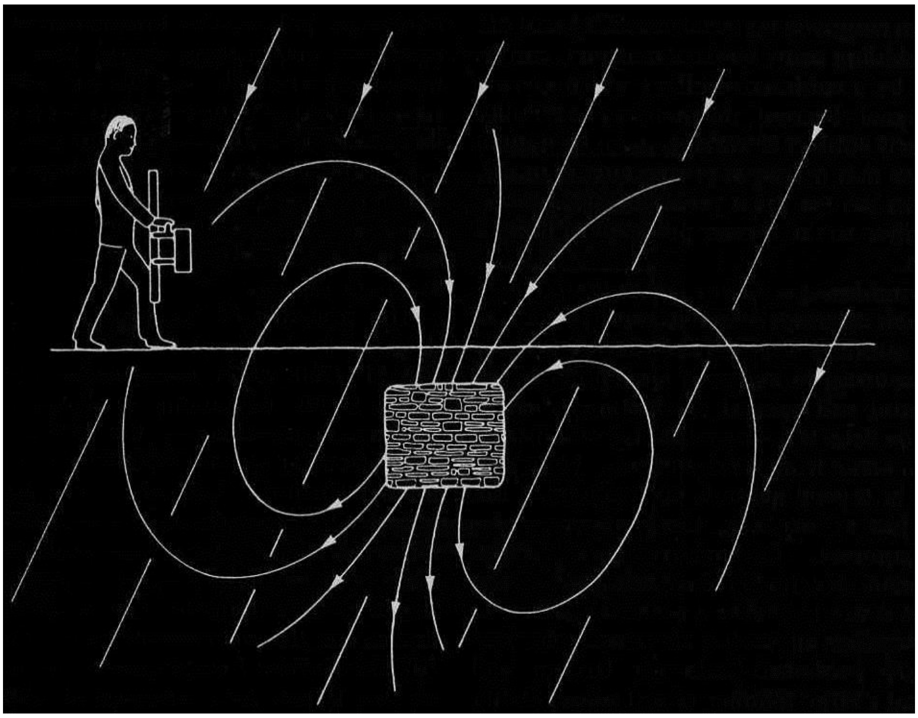

Figure 3Schematic diagram indicating the use of a magnetometer over archaeological remains, and the local magnetic field of the buried objects in relation to the earth's magnetic field (from Clark 1996)

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 instruments are based around a highly permeable nickel iron alloy core, 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 0.1nT 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. Results are however extremely dependent on the geology of the particular area, and whether the archaeological remains are derived from the same materials. Around 1.5 hectares can be surveyed each day.

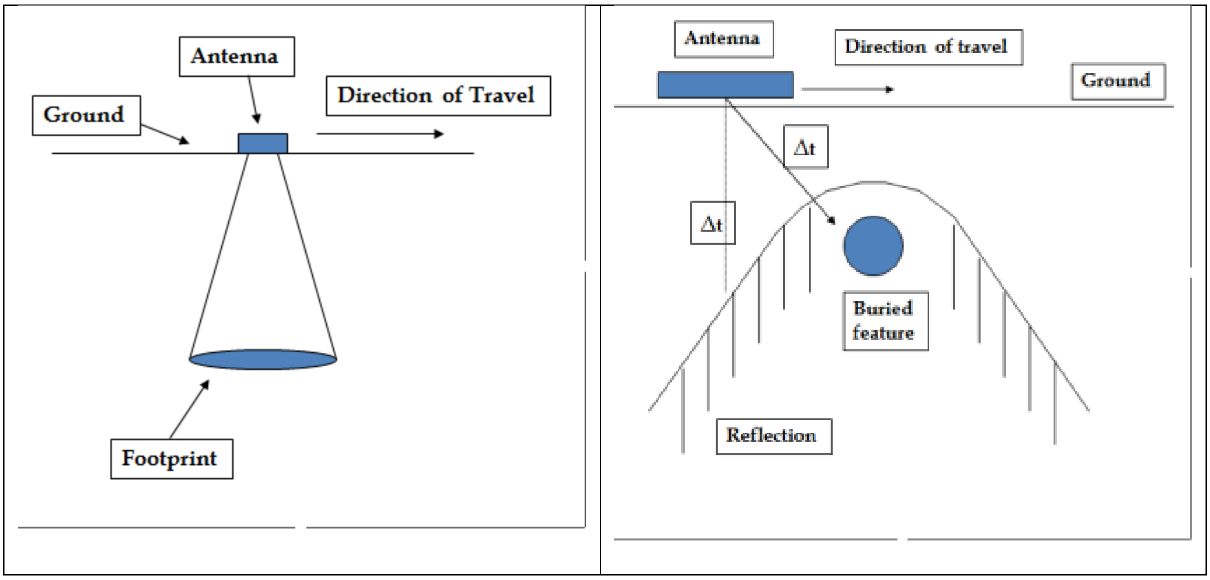

Figure 4Diagram showing the footprint of a GPR radio signal and the response to a spherical object with the resulting hyperbola to demonstrate the propagation of the signal over distance and time (after Conyers and Goodman 1997)

Ground Penetrating Radar (GPR) uses an electromagnetic radar wave propagated through the soil to search for changes in soil composition and structures (Conyers and Goodman 1997, 23ff), measuring the time in nanoseconds (ns) taken for the radar wave to be sent and the reflected wave to return (Fig. 4). The variations in the Relative Dielectric Permittivity (RDP) in different deposits produces reflections in the profile data of the survey. Lower frequency survey antennae (50Mhz or 100Mhz) are generally used for geological survey, whereas higher frequency antennae (250Mhz, 500Mhz or 800Mhz) are utilised for archaeological surveys. The technique has been applied successfully on a range of archaeological sites, in particular over substantial urban archaeological remains (Gaffney et al. 2004, 207ff; Leckebusch 2001, 52ff; Nishimura and Goodman 2000; Neubauer et al. 2002).

Twin probe array earth resistance survey is based on the ability of sub-surface materials to conduct an electrical current passed through them. All materials will allow the passing of an electrical current through them to a greater or lesser extent. There are extreme cases of conductive and non-conductive material (Scollar et al 1990, 307), but differences in the structural and chemical make-up of soils mean that there are varying degrees of resistance to an electrical current (Clark 1996, 27). The technique is based on the passing of an electrical current from probes into the earth to measure variations in resistance over a 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 current and two potential probes. Survey can be undertaken using a number of different probe arrays; twin probe, Wenner, Double-Dipole, Schlumberger and Square arrays.

2.2 Survey Strategy

For the survey grid system was established using a Leica Viva Real Time Kinetic (RTK) GPS with Smartnet (Fig. 5) utilising the Ordnance Survey coordinate system OSGB36. Wooden survey pegs and spray markers were set out at 30m by 30m intervals, and the grids for all areas were georeferenced..

Figure 5Leica RTK GPS with Smartnet being used to grid out (photo: K. Strutt)

Figure 6Magnetometer survey being conducted using a Bartington Instruments Grad 601 fluxgate gradiometer (photo: K. Strutt)

The magnetometer survey was conducted using a Bartington Instruments Grad 601 dual sensor fluxgate gradiometer (Fig. 6). Measurements were taken at 0.25m intervals on 0.5m traverses, with data collected in zig-zag fashion. The survey data were processed using Geoplot 3.0 software. The processing of data was necessary to remove any effects produced by broad variations in geology, or small-scale localised changes in magnetism of material close to the present ground surface. Magnetometer data were despiked to remove any extreme magnetic values caused by metallic objects. A zero mean traverse function was then applied to remove any drift caused by changes in the magnetic field. A low pass filter was then applied to remove any high frequency readings, and results were then interpolated to 0.5m resolution across the traverses.

Earth resistivity was carried out using a Geoscan Research RM15 resistance meter, with measurements taken at 0.5m intervals along traverses spaced 0.5m apart (Fig. 7).

The GPR survey was conducted using a Sensors and Software Noggin Plus system with 500Mhz antenna and Smartcart (Fig. 8) in the outer bailey. Data were collected along traverses spaced 0.5m apart along the x direction of each survey grid across target areas of the sites in the northern, central and southern areas of the survey. Data were processed using GPR Slice software. The different survey profiles were presented in their relative positions, and all profiles were then processed to remove background noise. A bandpass filter was applied to each profile to remove all high and low frequency readings. The presence of hyperbola in the data were utilised to produce an estimation of signal velocity through the deposits at each site, facilitating a calculation of the depth of different features across each site. Profiles were then converted into grid data and were sliced horizontally to produce a series of time slices through each survey area.

The data from each survey were exported as a series of bitmaps, and were imported into and georeferenced in a GIS, relating directly to other salient spatial information such as AutoCAD maps of the site and relevant air photographic imagery. An interpretation layer of archaeological and modern features was digitized deriving the nature of different anomalies in the survey data from their form, extent, size and other appropriate information. As no direct chronological information can be derived from the geophysical survey data, much of this had to be inferred from the morphology of anomalies, and the relationships between different features.

Figure 7Earth resistance survey being carried out using a Geoscan Resesarch RM15 (photo: K. Strutt)

Figure 8GPR survey being conducted in the outer bailey using a Sensors and Software Noggin Plus Smartcart with 500 MHz antenna (photo: D.Barker)

3. The Survey Results

3.1 The Magnetometer Survey

A total area of 8.2 hectares was surveyed covering the large field in the southern area of Wrotham Park (Figs 9 and 14). This included the main area of interest of the postulated site of the moated complex at the north end of the field (Figs 10 and 11), and the southern part of the field (Figs 12 and 13). A series of positive linear magnetic features **[m1], [m2], [m3], [m4], [m5], [m6], [m7], [m8], [m9], [m10], [m18], [m28], [m29], m25]** and **[m26]** was found over the area. They appeared to form a system of abraded polygonal structures and are most likely to be natural, geological features. Their form suggests they are probably from a class of periglacial features known as ice wedges (Huggett, 2011, pp. 296-297, 312) (see discussion below).

A number of discrete clusters or groupings of smaller, less well defined positive magnetic features also occurred across the area of the survey. These were not numbered individually but were rounded up into four groups of positive magnetic features **[pg1], [pg2], [pg3]** and **[pg4]**.

[pg1] consists of a number of features in the area indicated by documentary sources as possibly containing a battlefield memorial chapel. However their form does not appear to indicate structural evidence but more likely a mix of building materials and magnetic enhanced waste material-possibly brick and ferrous material such as pipes, nails bolts etc. The interpretation is made more difficult by the presence of large dipolar features [**m13], [m14] and [m15**] to the north and west which appear to be pipes and that are swamping the results around these features for a significant distance. An historic aerial photograph (Barker and Wilson 2017) shows this area was used as a gardening plot of some description and this maybe the period the pipe [**m13]** is associated with. It should be noted that this area was possibly disturbed during the recent construction of the buildings to the north and north-west of this area. There is no obvious indication of the moated features indicated by documentary sources but again the location of the metal pipes makes identification of such features problematic. In the south of the field the linear positive anomalies associated with periglacial features continue **[m19]**, **[m20]** and **[m21]**. A dipolar anomaly marks a pipeline **[m22]** and **[m23]** running for a distance of over 130m.

[pg2] on the west side of the survey area appears to show a number of linear positive features that might indicate structures of some kind or they are possibly associated with the embankment of the road marked by the dipolar features **[m11]** and [**m12]**.

[pg3] has some linear features but with no obvious structural pattern to them and it may be they are related to the system of periglacial features noted above.

[pg4], located in the south-east corner of the survey, is an interesting outlier of possible structural features. It has number of parallel and perpendicularly aligned linear features with an overall north east alignment. It is possible that these features represent walls, building foundations or ditched subdivisions of an overall enclosure or installation.

Figure 9Greyscale image of the results of the magnetometry at Wrotham Park

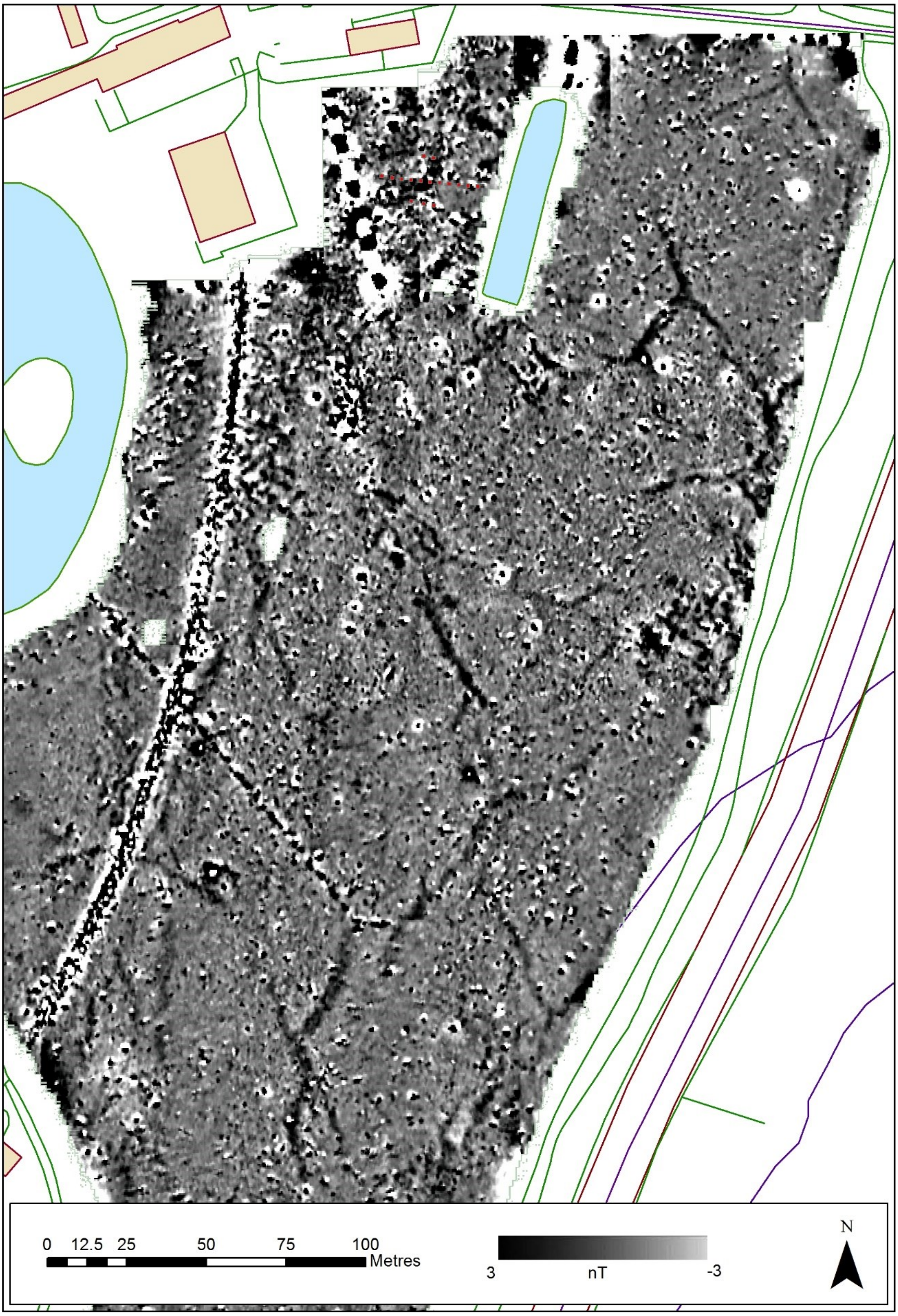

Figure 10 Greyscale image of the results of the magnetometry from the northern part of the field at Wrotham Park

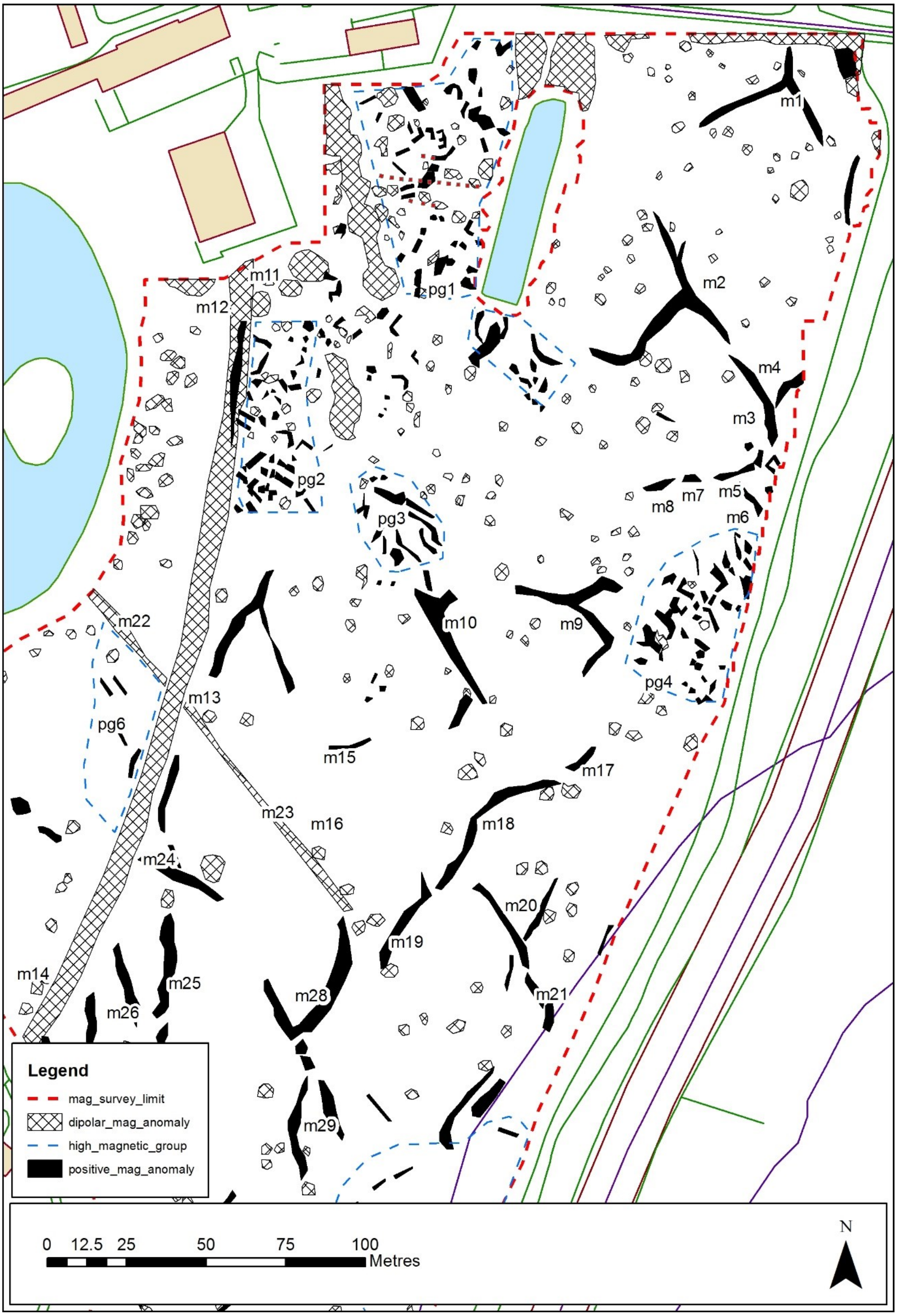

Figure 11 **Interpretation plot of the results of the magnetometry from the northern part of the field at Wrotham Park**

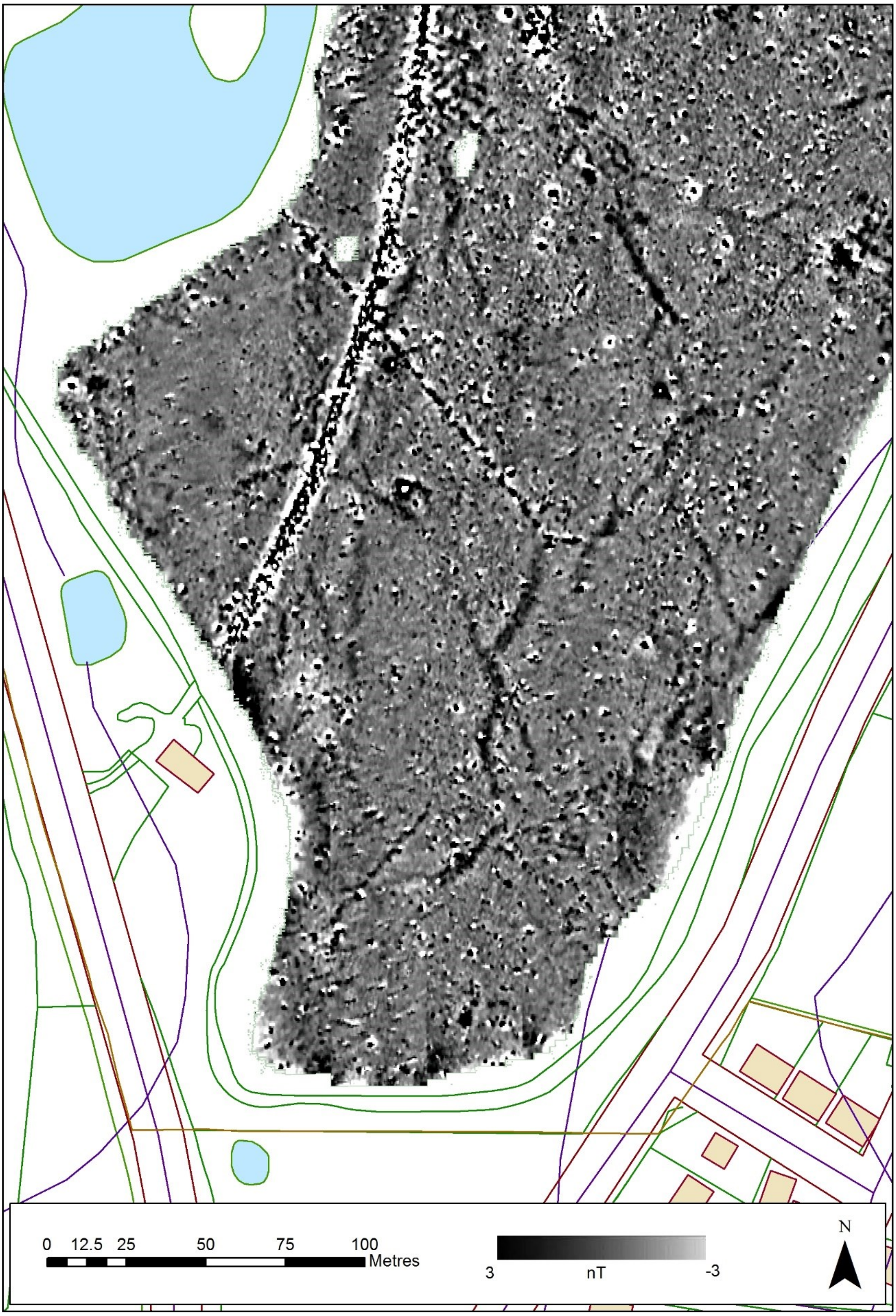

Figure 12 Greyscale image of the results of the magnetometry from the southern part of the field at Wrotham Park

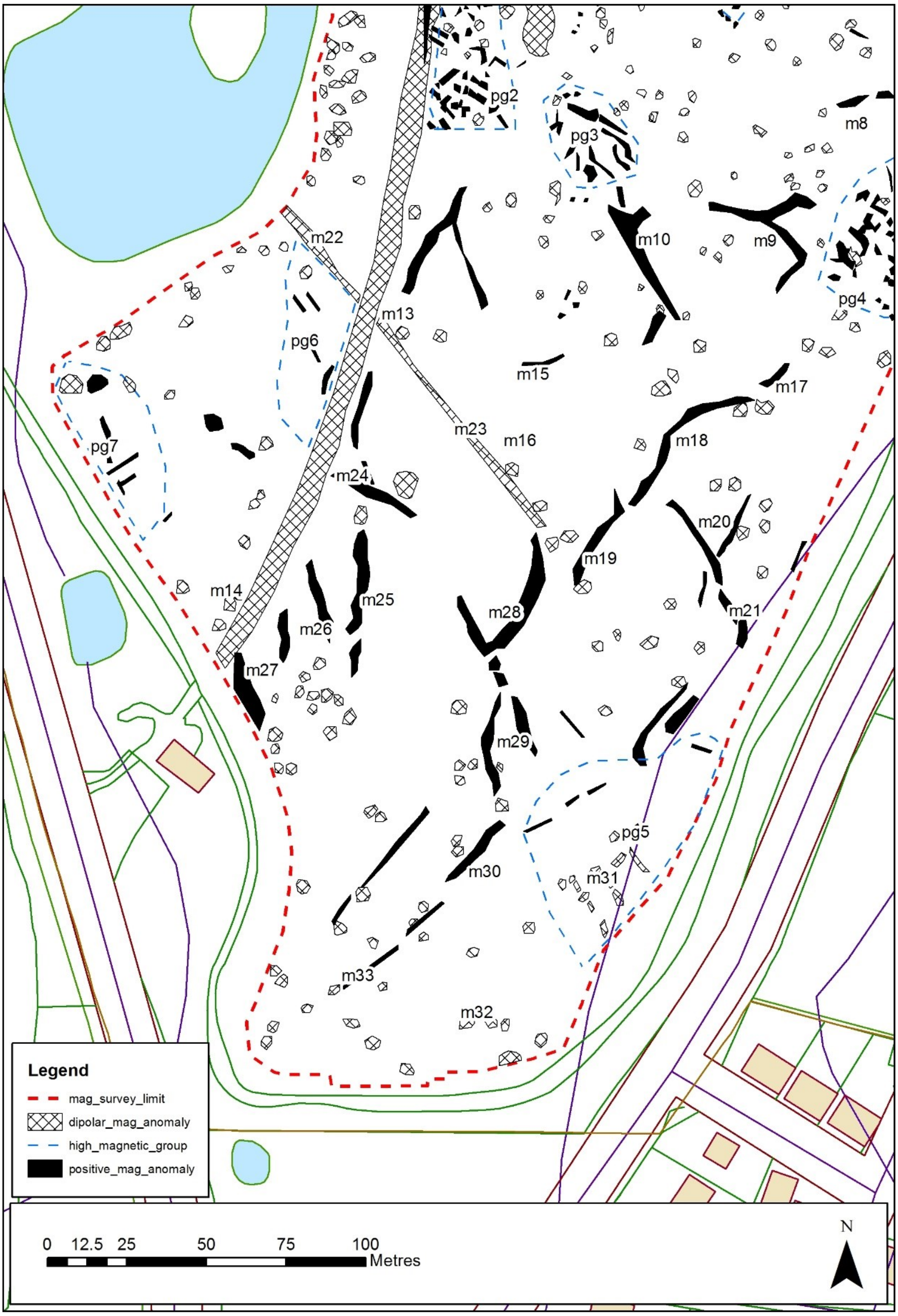

Figure 13 **Interpretation plot of the results of the magnetometry from the southern part of the field at Wrotham Park**

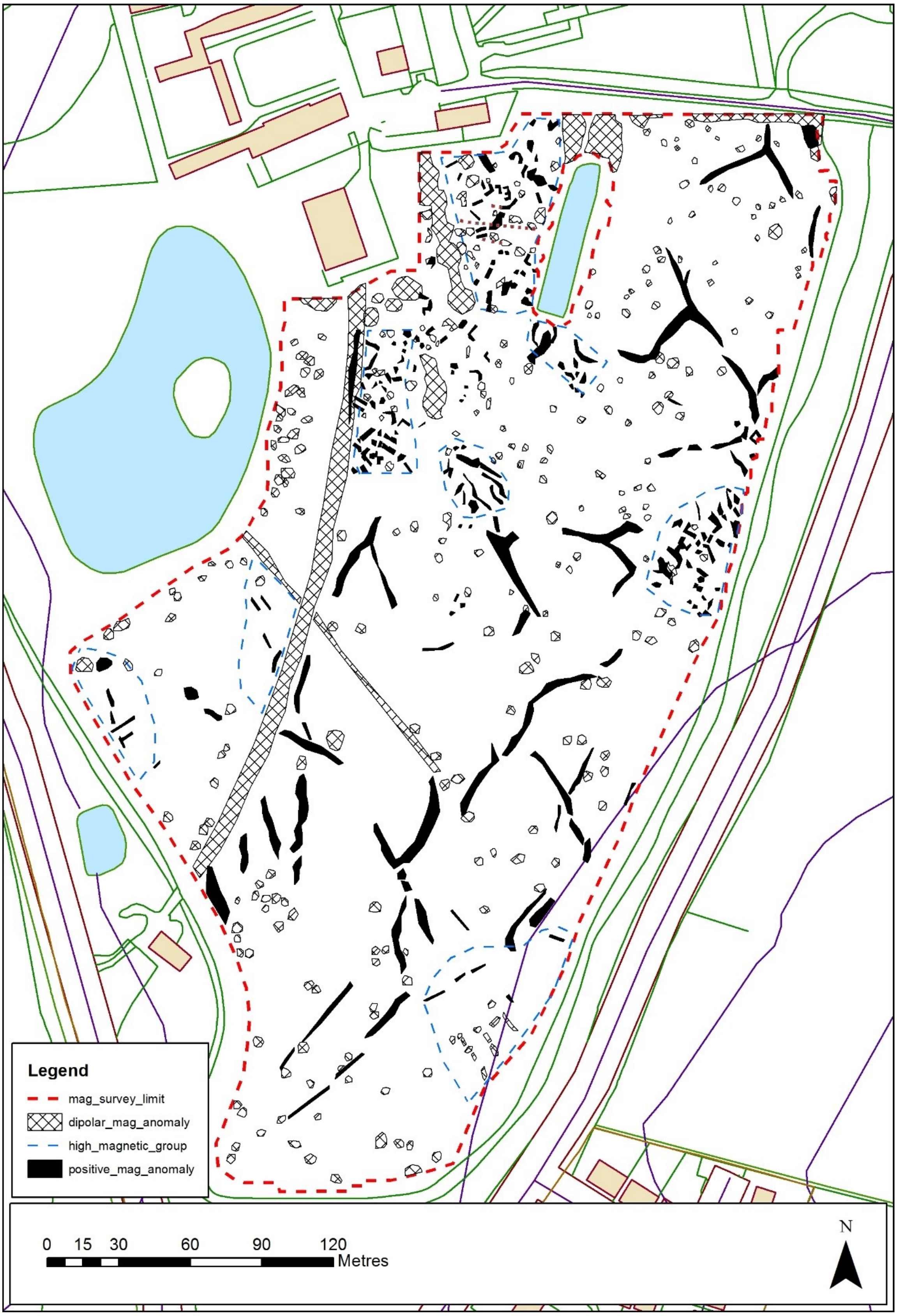

Figure 14 **Interpretation plot of the results of the magnetometry from the field at Wrotham Park**

It is interesting to note the alignment of this concentration in relation to the A1000 road to the east and the postulated route of the Ganwick Bank as plotted from the enclosure map for the area. The exact form of these features and their possible physical and stratigraphic relationship with the bank can only be ascertained by further survey and excavation.

[pg5] consists of a number of linear positive features which like **[pg4]** have may represent building structures or ditched structural elements.

A number of the features located in the 2016 magnetometer survey (Barker and Wilson 2017) continue into the southern part of the field. Most prominent in the results are the features **[m24]**, **[m25]**, **[m26]**, **[m27]**, **[m28]**, **[m29]** and **[m30]** are visible across the entire area. The dipolar linear anomaly marking the track or road **[m13]** and **[m14]** runs to the south, aligned with a building and track to the south-west of the field. A field drain is visible as a dipolar anomaly **[m22]** and **[m23]** running for a distance of 135m from north-west to south-east. Several positive linear anomalies **[m30]**, **[m31]** and **[m33]** mark possible ditch anomalies and structures along the supposed line of the Gannick Bank. Two further groups of linear anomalies are also visible in the south part of the field. The first **[pg6]** is located immediately to the west of the track feature. The second **[pg7]** is located in the south-west corner of the field, marking possible structural remains.

3.2 The Earth Resistance Survey

An area of 0.6 hectares was covered using earth resistance, covering the area within the moated enclosure and a small area immediately to the south of the modern pond (Figs 15 and 16). The survey results indicate a number of anomalies, in particular immediately to the west of the pond. Two linear high resistance anomalies **[r1]** and **[r2]** run from east to west adjacent to the northern end of the pond. A further linear anomaly **[r3]** runs from north to south and these are matched by two broad north-south linear anomalies **[r4]** and **[r5]** marking a possible surface layer to the west. A series of similar linear anomalies continue along the western part of the earth resistance survey area, comprising two discrete anomalies **[r6]** and **[r7]** measuring some 4m in diameter, joined by a faint linear anomaly. A stronger north-south linear anomaly **[r8]** measuring 12m in length is also visible, marking the western edge of a quieter area in the centre of the survey. Several linear and rectilinear high resistance anomalies **[r9]**, **[r10]** and **[r11]** mark possible structural remains, extending southwards **[r12]**. A strong east-west linear anomaly **[r13]** measuring 24m in length with associated linear anomalies runs across the southern part of the survey area.

A strong area of high resistance readings **[r14]** measuring 16m by 3m is located alongside the modern pond. A further series of broad, moderately high resistance readings **[r15]** and **[r16]** demarcate two rectangular areas of moderate readings, measuring 7m by 6m, and 16m by 8m. A similar pattern is produced immediately to the south, with two areas of high resistance **[r17]** and **[r18]** dividing a linear low resistance feature and a further sub-rectangular area. Further high resistance anomalies **[r19]** surrounding a tree, mark possible structural remains.

The area to the south of the pond indicates further anomalies. Two high resistance anomalies **[r20]** and **[r21]**, together with a further anomaly to the east **[r22]** seem to demarcate a low resistance channel feature **[r23]** measuring 36m by 3m. Several variable high resistance anomalies **[r24]** and **[r25]**, **[r26]** and **[r27]** are visible, possibly indicating variations in the clay subsoil. A further low resistance linear anomaly **[r28]** runs to the east, with a low resistance discrete anomaly **[r29]** also visible.

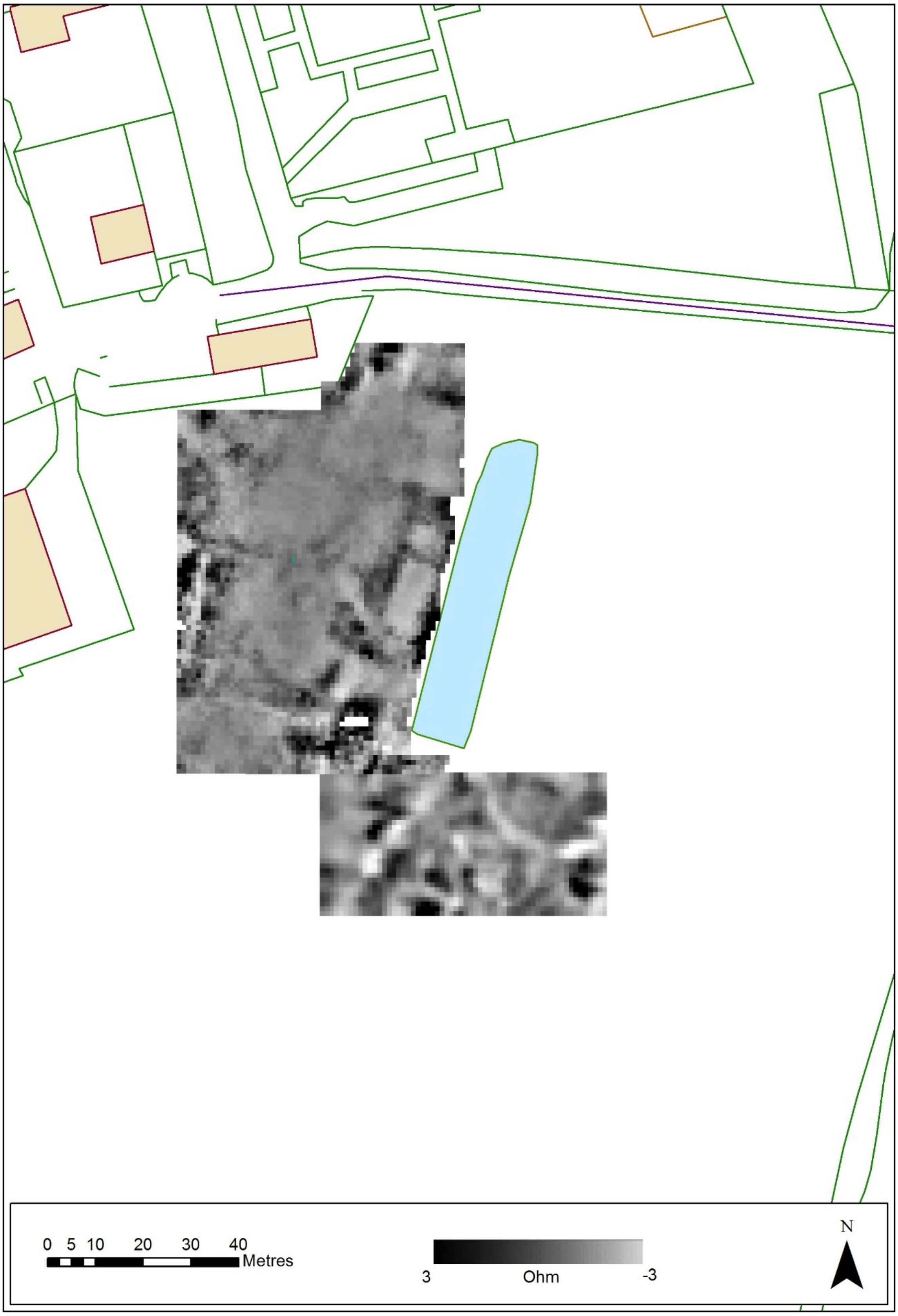

Figure 15 **Greyscale image of the results of the earth resistance survey at Wrotham Park**

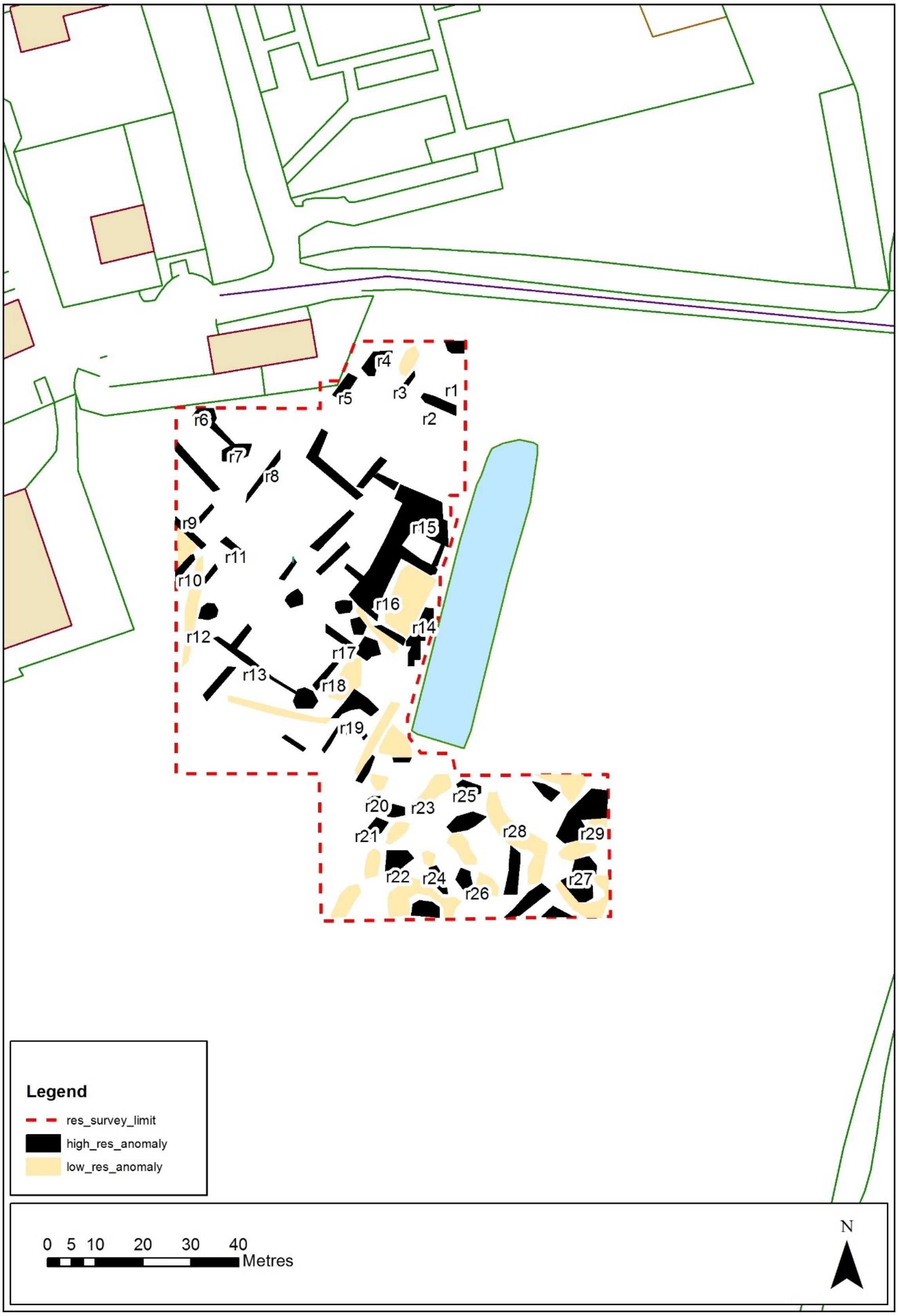

Figure 16 Interpretation plot of the results of the earth resistance survey at Wrotham Park

3.3 The Ground Penetrating Radar Survey

An area of 1.5 hectares was covered with GPR. Two slices of the data were chosen for interpretation; the 0.3-0.5m slice and the 0.7-1.0m slice.

The shallower radar depth in particular shows a varying dataset with a significant distribution of high amplitude anomalies across the different survey areas. These may be associated with variations in the clay geology, and distribution of brick rubble associated with the landscaping of the post-medieval estate grounds.

A number of prominent anomalies are visible in the data at 0.3-0.5m depth (Figs 17 and 18). In the northern area a number of short linear high amplitude anomalies **[g1.1]**, **[g1.2]**, **[g1.3]** and **[g1.4]** seem to indicate features associated with drainage for the estate buildings to the north of the moated site. A series of small (1-2m) discrete anomalies to the west **[g1.5]**, **[g1.6]**, **[g1.7]** and **[g1.8]** seem to indicate possible rubble across the western part of the survey area, with a north-south high amplitude linear anomaly **[g1.9]** measuring some 10m in length marking possible structural remains. The central part of the survey area **[g1.10]** is marked by a series of discrete high amplitude anomalies, indicating rubble.

A strong high amplitude anomaly **[g1.11]** and **[g1.12]** measuring 19m in length and 3m across, is located immediately to the west of the modern pond. Further high amplitude readings to the south **[g1.13]** and **[g1.14]** indicate possible structures or rubble. A linear anomaly **[g1.15]** marks the possible edge of a feature. The western edge of the GPR survey shows evidence of anomalies suggesting a possible road surface and structures. To the north a discrete high amplitude anomaly is visible **[g1.16]**, and two linear anomalies **[g1.17]** and **[g1.18]** measuring around 18m in length also indicate possible road or track surface.

Figure 17 **Greyscale image of the GPR results from 0.3-0.5m depth at Wrotham Park**

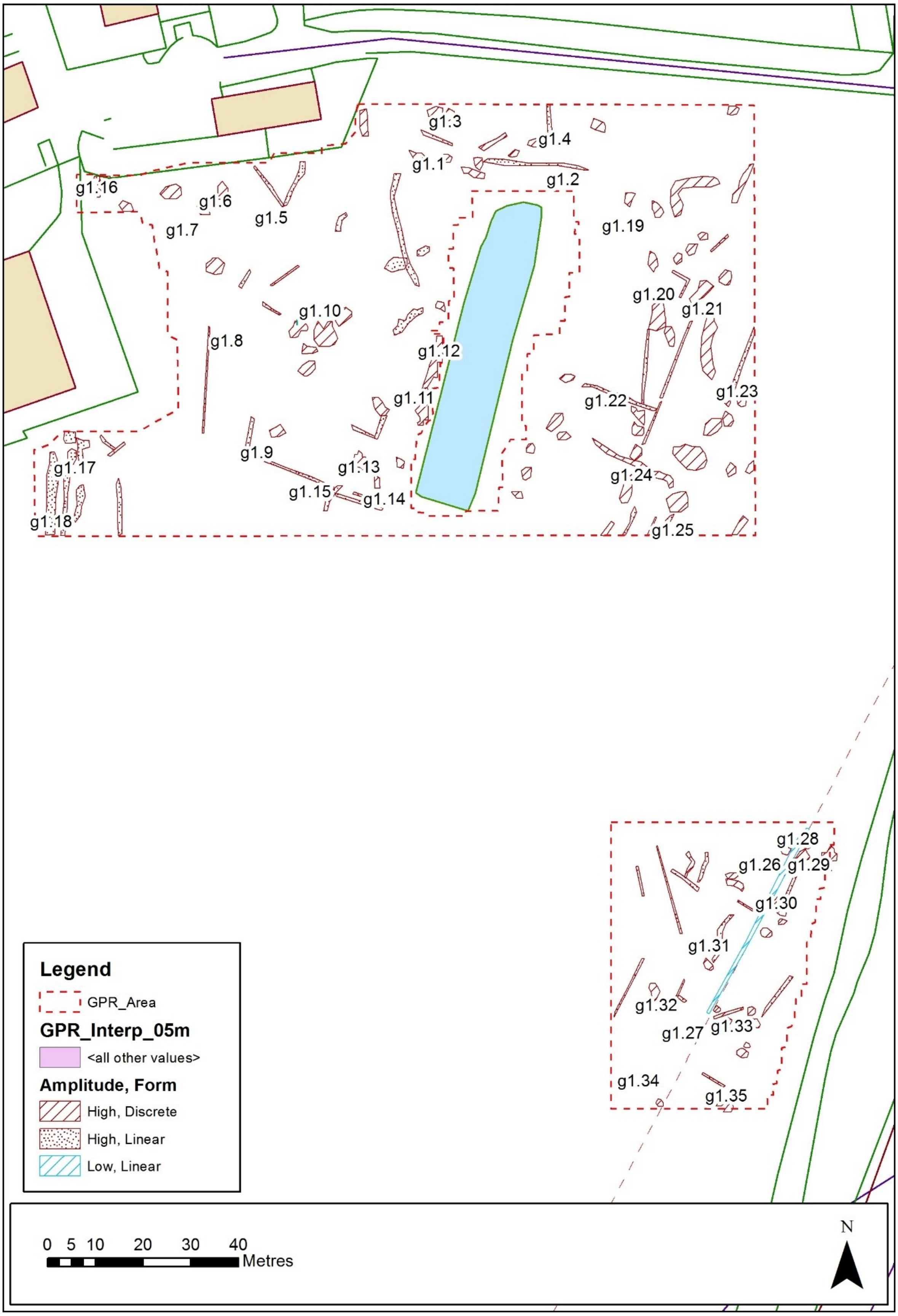

Figure 18 Interpretation plot of the GPR results from 0.3-0.5m depth at Wrotham Park

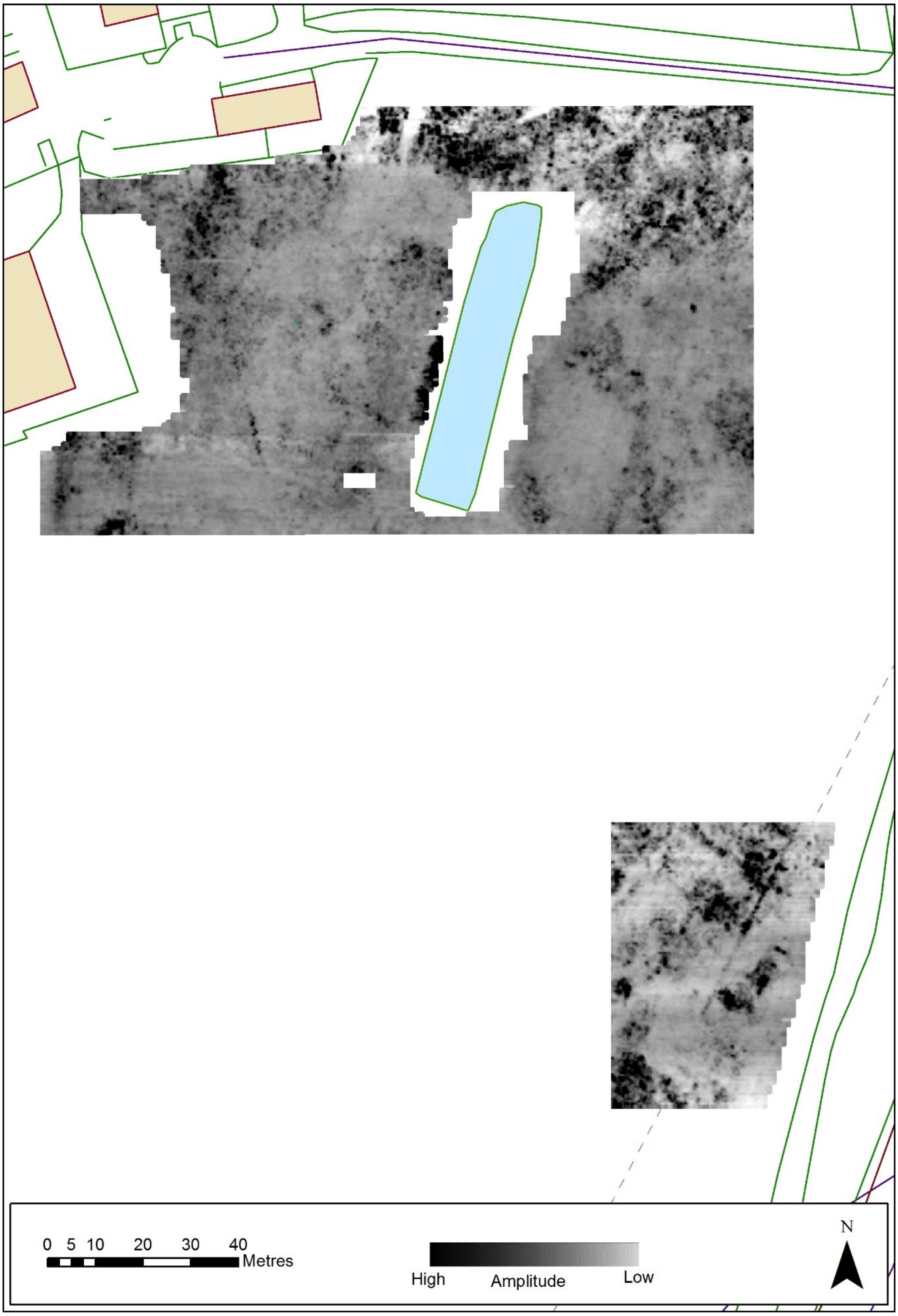

Figure 19 Greyscale image of the GPR results from 0.7-1.0m depth at Wrotham Park

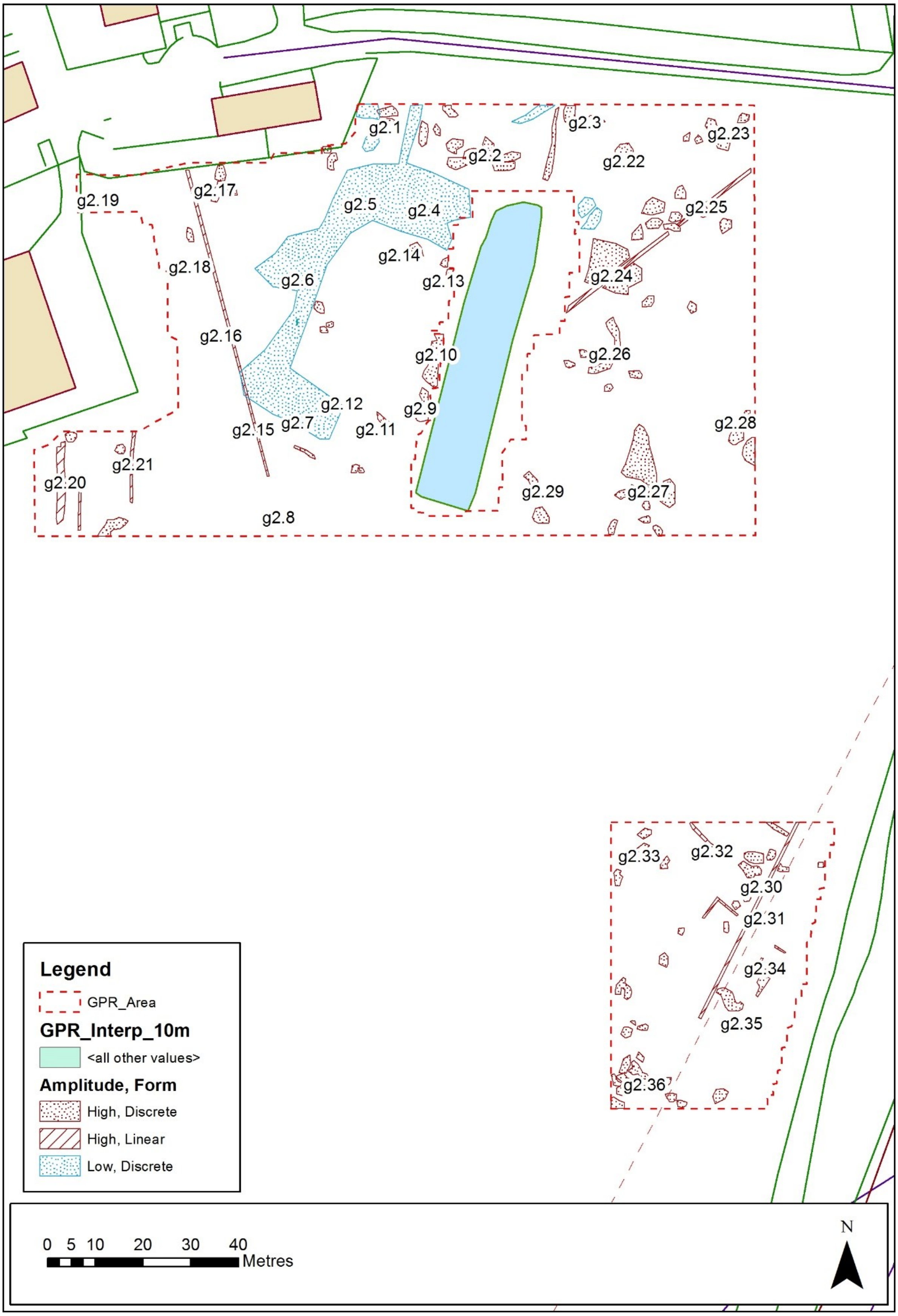

Figure 20 Interpretation plot for the GPR results from 0.7-1.0m depth at Wrotham Park

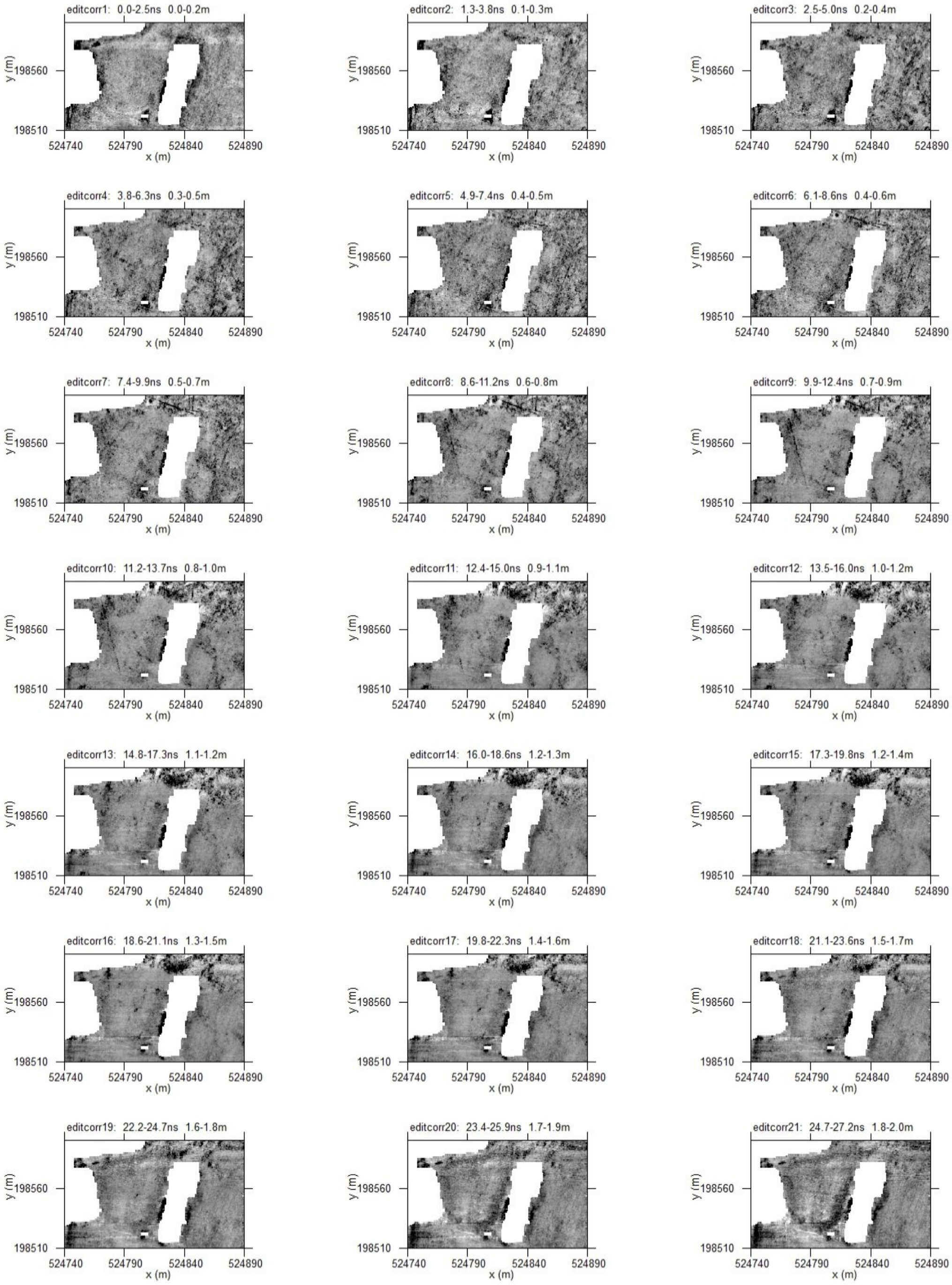

Figure 21 Timeslices of the northern GPR Survey at Wrotham Park

To the east of the pond a large number of discrete high amplitude anomalies mark the area. In addition some discrete anomalies seems to indicate a rectilinear feature **[g1.19]**. A concentration of discrete high amplitude anomalies **[g1.20]** run alongside a linear anomaly **[g1.21]** measuring some 27m in length marking a possible drain or pipeline. A separate linear anomaly **[g1.22]** runs from east to west towards the pond. A further linear anomaly **[g1.23]** is also located close to the eastern edge of the survey area, with discrete high amplitude anomalies **[g1.24]** and **[g1.25]** indicating either rubble or variations in the subsoil.

In the survey area to the south a low amplitude linear anomaly **[g1.26]** measuring over 50m in length marks a possible ditch infilling or drainage feature. Surrounding this several discrete and linear high amplitude anomalies **[g1.27]**, **[g1.28]**, **[g1.29]** and **[g1.30]** seem to mark possible rubble and structural remains. These features extend on both sides of the ditch feature to the south **[g1.31]** – **[g1.35]**.

At 0.7-1.0m depth (Figs 19 and 20) the variation in the subsoil is more visible **[g2.1]**, **[g2.2]** and **[g2.3]** with high amplitude anomalies marking material to the north of the pond. In the central area a quiet zone in the data **[g2.4]**, **[g2.5]**, **[g2.6]** and **[g2.7]** Demarcates a slight difference in the sediment, suggesting fewer high amplitude responses, and therefore fewer instances of rubble or other material, perhaps corresponding to the infilling of the previous moat. Faint high amplitude responses are also visible **[g2.8]** in the area of the tree alongside the south end of the pond.

High amplitude readings are visible along the western side of the pond **[g2.9]** and **[g2.10]** in two segments measuring 7m and 11m in length. A faint series of discrete anomalies **[g2.11]** and **[g2.12]**, together with other anomalies to the north **[g2.13]** and **[g2.14]** mark an area of greater amplitude within the potential curtilage of the moat, measuring 37m by 20m. To the west a linear high amplitude anomaly **[g2.15]** and **[g2.16]** runs for a distance of 70m, marking a possible drain or pipeline. Along the western part of the survey a series of discrete anomalies **[g2.17]**, **[g2.18]** and linear anomalies **[g2.19]**, **[g2.20]** and **[g2.21]** mark road foundations and structural remains running north to south in the area. The north-eastern and eastern sections of the survey area indicate variable readings **[g2.22]** and **[g2.23]** suggesting either rubble material or variations in the sub-soil. A possible pipeline runs from north-east to south-west **[g2.24]** and **[g2.25]** for a distance of 50m. Several discrete high amplitude areas are visible to the south **[g2.26]**, **[g2.27]** and **[g2.28]**.

In the southern survey area a number of discrete high amplitude anomalies **[g2.30]** mark possible structural rubble, with a positive linear anomaly **[g2.31]** measuring 53m in length marks a possible drain or pipeline. Several linear and rectilinear anomalies **[g2.32]**, **[g2.33]**, and **[g2.34]** also indicate possible structural remains, with associated discrete anomalies **[g2.35]** and **[g2.36]** suggesting areas of possible building rubble.

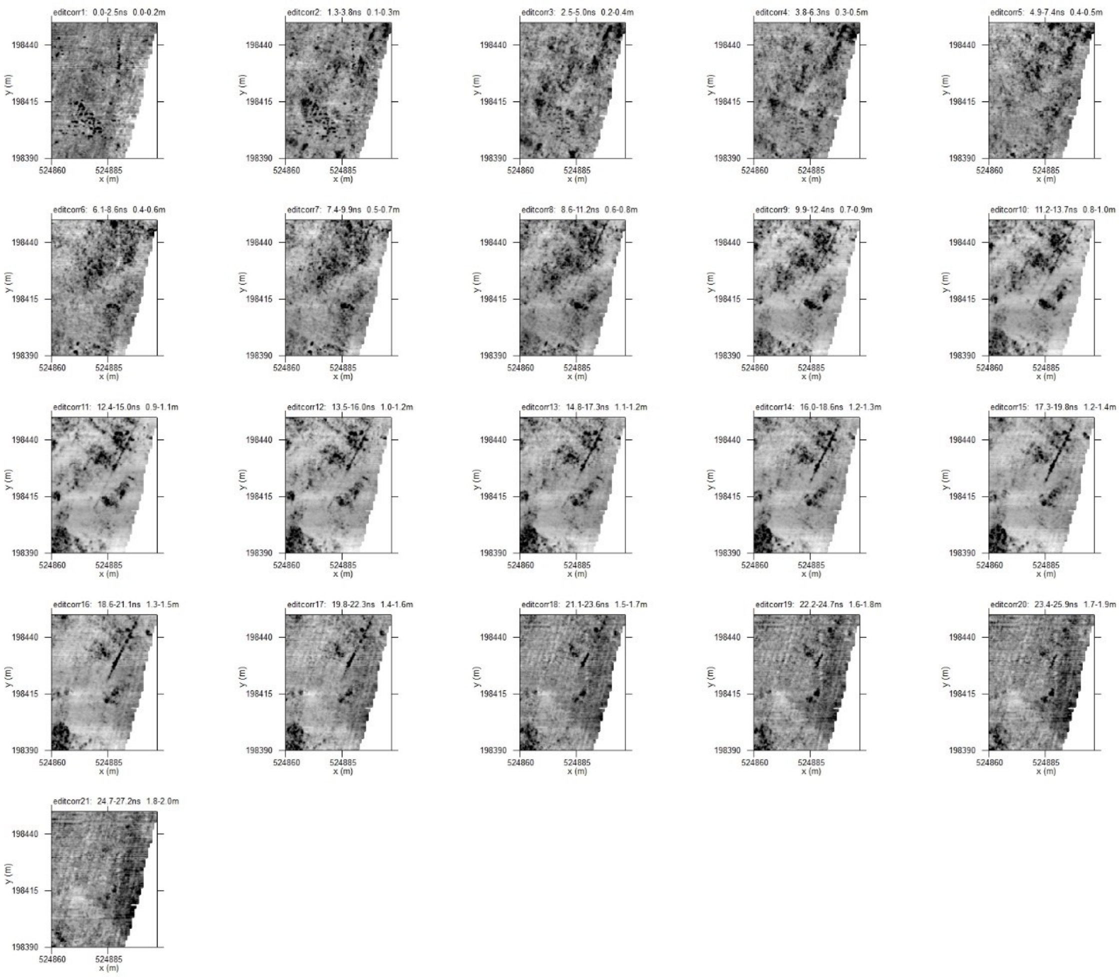

Figure 22 Timeslices of the southernmost GPR survey area at Wrotham Park

4. Discussion

Results of the combined geophysical survey revealed a number of potential areas with material of archaeological importance. The area of greatest interest was found in the vicinity of the pond in the northern part of the field. The high resistance and high amplitude remains immediately to the west of the pond **[r14]**, **[g1.11]**, **[g1.12]**, **[g2.9]** and **[g2.10]** indicate a possible area of structural remains, measuring 16m by 3m. This may indicate the western part of a possible structure that has been cut by the later pond, and the georeferenced enclosure map for the area (Fig. 23) does indicate that the anomalies in the earth resistance and GPR match the western side of the building within the moated enclosure. These features are remarkably close to the building located in the georeferenced historic maps. There is, however, no indication in the result of the geophysics for the presence of a structure with east-west orientation. Inspection of the western side of the pond revealed material eroding out of the edge of the pond, some 0.3m below the modern ground surface (Figs 24 and 25), including an iron-rich sandstone material, and ceramics (Figs 26 and 27) that may indicate flooring or similar made up ground and associated material for a building. The only other possible location for a chapel would be outside of the enclosure area, although this is not visible in the geophysics. The area along the western edge of the survey area marks an overgrown and wooded area that could not be surveyed. In any case it would be highly improbable that the chapel was located in this area.

The rectangular features in the earth resistance survey **[r15]** and **[r16]**, seem to match the area enclosed by the moat in the 1781 map. Anomalies in the GPR **[g1.14]** and **[g1.15]**, **[g2.4]**, **[g2.5]** and **[g2.6]** also seem to match the edges of a break in the circuit of the moat, and moat itself. The anomalies that appear clearly in the earth resistance survey seem to mark variations in the sediment, between sandier deposits in test pits 2 and 3 (Wilson 2017), and the siltier material in other test pits. Wilson (2017, 14-16) notes clayey silt to 0.38m and then silty sand for 0.05m below this in TP 1, corresponding to the low resistance rectangular anomalies in the earth resistance survey **[r15]** and **[r16]**. Test pits TP2 and TP3 were located over the high resistance readings surrounding **[r15]** and **[r16]**. These indicate coarse sand with chert pebbles, starting at around 0.29m depth in TP2, and compact coarse sand with chert pebbles from c. 0.3m in TP3 (Wilson 2017, 14) and this would correlate with high resistance readings. No evidence for any structural material comes from these test pits, and it seems likely that an area of coarse sand with pebbles or similar rubble has been laid out surrounding the two low resistance areas. The form of the anomalies seems to suggest a possible garden area or similarly laid-out terrain, adjacent to the possible remains of the building immediately to the east. Investigation of the GPR data for the deeper timeslices (below c. 1.3m) does not seem to provide any indication of deeper structures within the moated site. The inner and outer moat edges seem to be broadly defined in these slices, presumably due to infilling of the moat with slightly different material.

It must be noted that the area is also marked by anomalies derived from later activity in the area. This includes the higher resistivity responses **[r1]**, **[r2]**, **[r11]** in the centre of the moated area. Several linear anomalies in the GPR seem to indicate field drains or culverts associated with the improvement of the land during the creation of the estate buildings **[g2.24]**, **[g2.25]**,

[g2.16], with similar features noted in the magnetometry. Many of these seem to relate to the walled garden and outbuildings in the area to the north of the estate offices.

The significant positive anomalies visible across the entire magnetometer survey area **[m2]**, **[m4]**, **[m5]**-**[m8]**, **[m18]**, **[m28]** and **[m26]** among others all indicate features, formed in permafrost conditions through the cracking of ground by thawing and freezing and the aggregation of these wedges to form characteristic ice wedge polygons. If the wedges form a trough this may fill with sand or loess material to form ice wedge features (Huggett, 2011, 297), which are possibly what is seen in the magnetometer plots (Fig. 28).

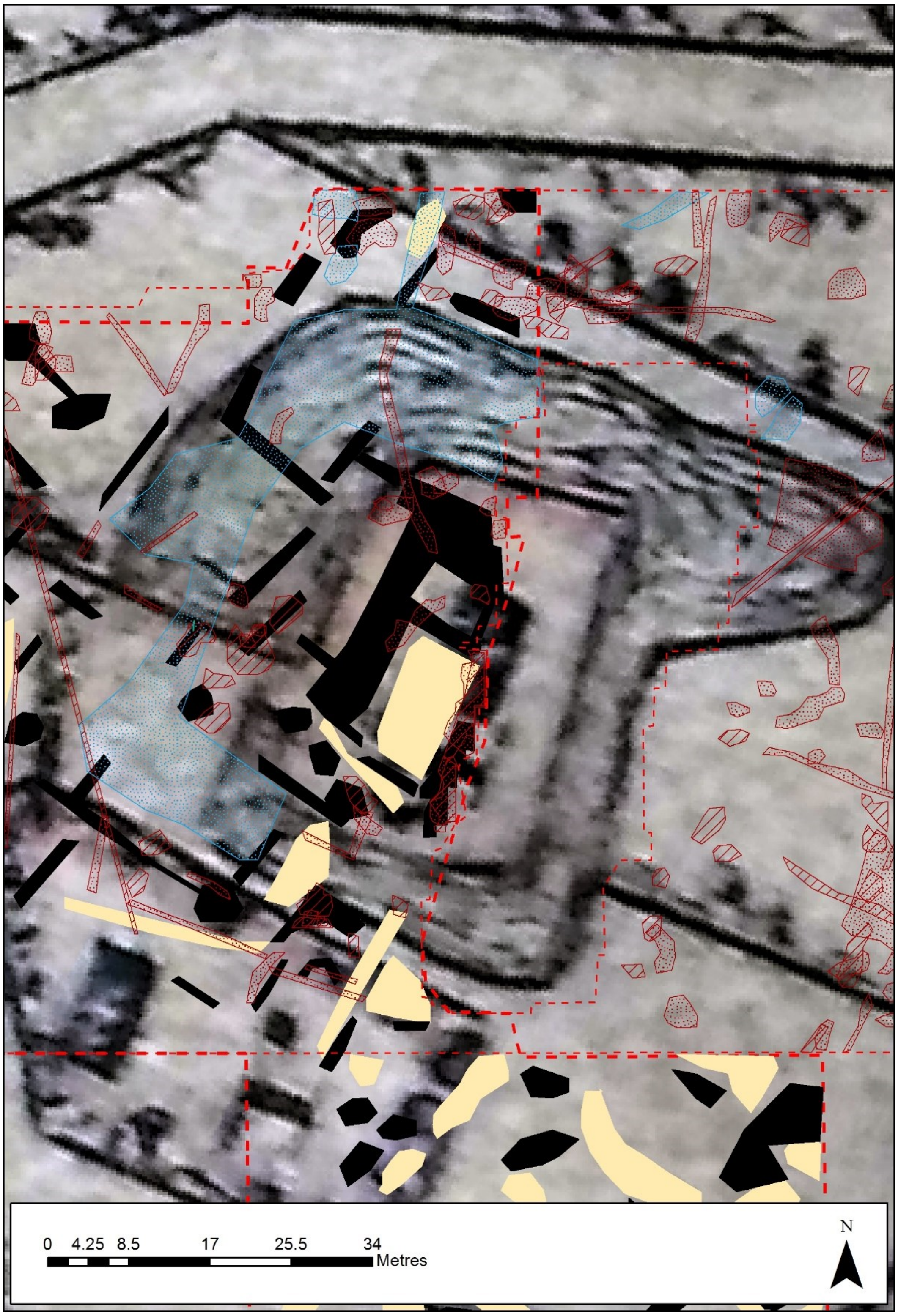

Figure 23 Interpretation plots for the earth resistance and GPR surveys overlaid onto a detail of the 1781 enclosure map

Figure 24 Material eroding from the side of the pond along its western edge

Figure 25 Detail of in situ sandy material eroding from the side of the pond

Figure 26 Sandy stone material eroding from the edge of the pond

Figure 27 Ceramic material eroding from the edge of the pond

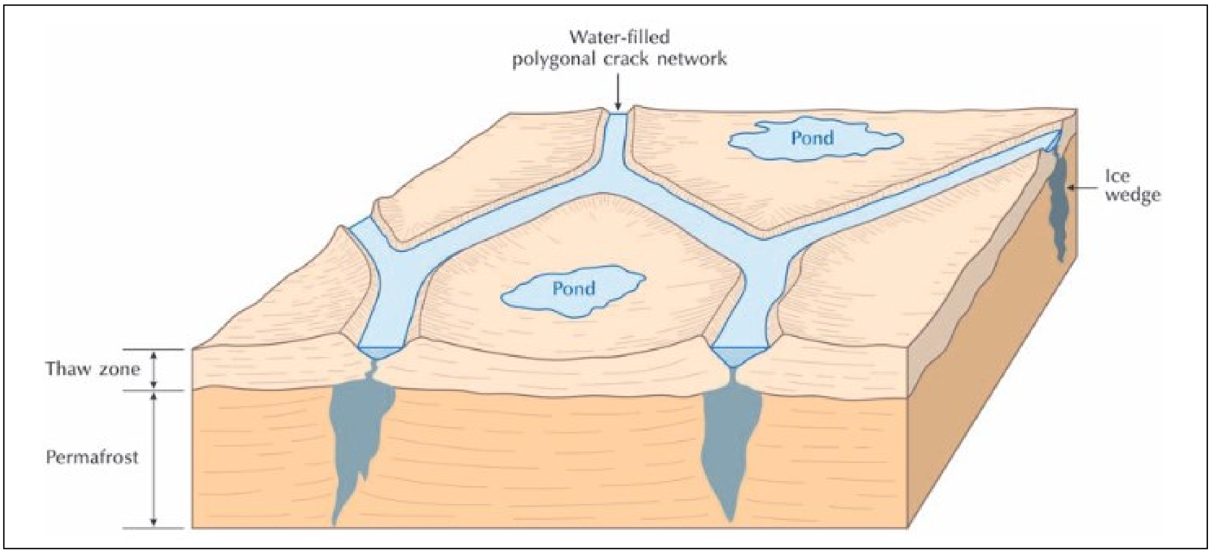

Figure 28 Ice wedge formation and polygons. (Huggett, 2011 Fig 11.3, 297)

The strong magnetic anomaly running from north-south along the western side of the field **[m12]**, **[m13]** and **[m14]** marks a 20th century road or trackway. This seems to be flanked by structures along parts of its length **[pg6]**, **[m11]**, and both track and structures are visible in the GPR **[g1.17]**, **[g1.18]**, **[g2.20]** and **[g2.21]**. These might conceivably be related to activity on the state during World War II, possible extending growing of crops over parts of the estate with appropriate infrasructure.

Faint traces of the possible line of the Gannick Bank were noted in the results of the 2016 magnetometer survey (Barker and Wilson 2017) and similar faint linear anomalies seem to appear in the results to the south **[m33]** although removed from the projected line of the Gannick Bank taken from cartographic evidence.

Evidence for the line of the bank is more visible to the north, where GPR survey indicates a low amplitude linear anomaly **[g1.26]** and a deeper high amplitude linear anomaly **[g2.31]** marking possible infilling of a feature, with a field drain or similar feature using the line. The line of this feature is clear in the GPR, and the georeferenced historic maps show the line of the bank in almost exactly the same location. The feature is surrounded by structural remains **[g2.34]**, **[g1.31]** all indicating possible buildings. A structure is noted on the Warburton map of 1724 (Barker and Wilson 2017, 18) and these features may relate to this building.

5. Conclusions

In contrast to the results of the 2016 survey, use of earth resistance survey and GPR has revealed some features that may be associated with the location of a moated site with a possible building in the north of the survey area. The building seems to have been partly destroyed by the modern pond located in the area, although the foundations or a surfaced area of the building seems to have survived, showing in the geophysics and eroding from the side of the pond. The results also seem to suggest faint variations indicating part of the area of the original moat, presumably back-filled at some stage.

The results of the GPR to the south indicates a linear feature that may indicate the line of the Gannick Bank, although if so the feature has subsequently been used as the line for a field drain. A series of possible structures associated with this feature were also located.

Finally a series of features including a road or track and associated structures from the 20th century were located in the western part of the field.

On the basis of these results, and comparing the data to the evidence from the test pitting (Wilson 2017) and the historic map evidence, the following concluding points can be made:

- The outline of the moated site marked on the historic maps has been located in the results of the geophysics. In addition the line of the Gannick Bank seems to be evident in the results of the GPR.
- While the moated site is present in the survey results, the only potential evidence in the geophysics for a possible structure is in the high resistance and high amplitude anomalies immediately to the west of the present pond, supported by material eroding from the pond edge. In addition there is no evidence for any structure located on an east-west orientation.
- The low resistance rectangular anomalies surrounded by high resistance readings, while being large and rectangular, do not seem to indicate buildings. The geophysics and the results of test pitting indicate low resistance responses from clayey silt, with high resistance responses from coarse sand with occasional chert pebbles. The lack of any structural evidence from these would suggest that these features are not buildings.
- The deeper components of the GPR data do not provide any evidence for a deeper structure that might represent a chapel.

7. Statement of Indemnity

Whilst every effort has been made to ensure that interpretation of the survey presents an accurate indication of the nature of sub-surface remains, any conclusions derived from the results form an entirely subjective assessment of the data. Geophysical survey facilitates the collection of data relating to variations in the form and nature of the soil. This may only reveal certain archaeological features, and may not record all the material present. It must be stressed that accurate interpretation of responses within small areas can prove difficult.

Acknowledgments

Considerable advice and assistance was received from a number of sources in the completion of this survey. Primarily, thanks go to Glenn Foard at the University of Huddersfield and the Hadley Trust for commissioning the geophysical survey. The support and advice of the curators and friends of the Barnet Museum is also gratefully acknowledged, together with the support of Carl Aldous at the University of Huddersfield. Finally thanks go to the Wrotham Park Estate, and the estate managers Charles and Kevin for giving their permission for the survey to take place.

Appendix 1 Details of Survey Strategy

Dates of Survey: 21-24 March 2016; 27th August to 7th September 2018

Site: Wrotham Park

District Parish: Barnet

County: Hertfordshire

Grid Reference: TQ 24838 98518

Surveyor: University of Southampton, University of Huddersfield

Personnel: Dominic Barker, University of Southampton. Sam Wilson, University of Huddersfield.

Geology: Base; clay, silt and sand of the London Clay Formation. Drift; Stanmore Gravel.

Survey Type 1: Earth resistance

Approximate area: 0.6 hectares

Grid size: 30m

Traverse Interval: 1m

Reading Interval: 1m

Instrument: Geoscan Research Resistance Meter RM15

Survey Type 2: Magnetometer

Approximate area: 8.2 hectares

Grid size: 30m

Traverse Interval: 0.5m

Reading Interval: 0.25m

Threshold: 100nT

Instrument: Bartington Grad 601 Single Axis Magnetic Gradiometer

Survey Type 3: Ground penetrating radar

Approximate area: 1.5 hectares

Grid size: 30m

Traverse Interval: 0.5m

Pulse interval: 0.05m

Instrument: Sensors and Software Noggin Plus 500MHz antenna and Smartcart

Appendix 2: Archaeological prospection techniques utilised by Archaeological Prospection Services of Southampton (APSS)

The following appendix presents a summary of prospection methods, implemented by APSS to determine the extent and nature of sub-surface archaeological structures, remains and features. The methodology usually applied by APSS places an emphasis on the integration of geophysical, geochemical and topographic survey to facilitate a deeper understanding of a particular site or landscape.

Geophysical Prospection

A number of different geophysical survey techniques can be applied by archaeologists to record the remains of sub-surface archaeological structures. Magnetometer survey is generally chosen as a relatively time-saving and efficient survey technique (Gaffney *et al*. 1991: 6), suitable for detecting kilns, hearths, ovens and ditches, but also walls, especially when ceramic material has been used in construction. In areas of modern disturbance, however, the technique is limited by distribution of modern ferrous material. Resistivity survey, while more time consuming is generally successful at locating walls, ditches, paved areas and banks, and the application of resistance tomography allows such features to be recorded at various depths. The BSR and APSS also implement topographic surveys over areas of prospection, to record important information concerning the location of the site. A summary of the survey techniques is provided below.

Resistivity Survey

Resistivity survey is based on the ability of sub-surface materials to conduct an electrical current passed through them. All materials will allow the passing of an electrical current through them to a greater or lesser extent. There are extreme cases of conductive and non-conductive material (Scollar *et al*. 1990: 307), but differences in the structural and chemical make-up of soils mean that there are varying degrees of resistance to an electrical current (Clark 1996: 27).

The technique is based on the passing of an electrical current from probes into the earth to measure variations in resistance over a survey area. Resistance is measured in ohms (Ω), whereas resistivity, the resistance in a given volume of earth, is measured in ohm-metres (Ω/m).

Four probes are generally utilised for electrical profiling (Gaffney *et al*. 1991: 2), two current and two potential probes. Survey can be undertaken using a number of different probe arrays; twin probe, Wenner, Double-Dipole, Schlumberger and Square arrays.

The array used by APSS utilises a Geoscan Research RM15 Resistance Meter in twin electrode probe formation. This array represents the most popular configuration used in British archaeology (Clark 1996; 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).

A number of factors may affect interpretation of twin probe survey results, including the nature and depth of structures, soil type, terrain and localised climatic conditions. Response to non-archaeological features may lead to misinterpretation of 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.

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. In addition to the normal twin electrode method of survey, a Geoscan Research MPX15 multiplexer can be utilised with the Resistance Meter, allowing multiple profiles of resistivity to be recorded simultaneously, or resistance tomography to be carried out up to a depth of 1.5m. APSS generally survey, as with the twin electrode configuration, to a resolution of 1 or 0.1Ω, with readings every metre or half metre.

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. Principally the iron content of a soil provides the basis for its magnetic properties. Presence of magnetite, maghaemite 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 nanoTesla (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 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.

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. Results are however extremely dependent on the geology of the particular area, and whether the archaeological remains are derived from the same materials. For fluxgate gradiometer survey, the Bartington Grad601-2 is used. This is a twin array probe, so carries two fluxgate gradiometers which work simultaneously to increase the speed of a survey. Survey is carried out at 0.1nT resolution, with readings taken every 0.5m by 0.25m. In flat and open territory around 1 hectare per day can be surveyed by each instrument.

Ground Penetrating Radar Survey

Ground Penetrating Radar (GPR) 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 of the buried material.

This technique has been applied successfully on a range of archaeological sites, in particular over substantial urban archaeological remains. GPR has been used by APSS at the Domus Aurea in Rome, at Forum Novum, and at Italica in Spain. Use of GPR is more time consuming than using magnetometry. It is more appropriate to apply this method to target particular areas of interest at an archaeological site where magnetometry or resistivity have already been applied, or where there is a potential for deeper archaeological deposits.

APSS operates a Sensors and Software radar system, configured for use with a Smartcart frame and console. This utilises a 500 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.

Topographic Survey

The modern ground surface or topography often contains important information on the conditions and nature of an archaeological site, and the potential existence of structures buried beneath the soil (Bowden 1999). The changes in topography can also have a great influence on determining the nature of features in a geophysical survey. Therefore it is vital to produce a detailed and complete topographic survey as part of the field survey of any given site. This generally entails the recording of elevations across a grid of certain resolution, for instance 5 or 10m intervals, but also the recording of points on known breaks of slope, to emphasis archaeological features in the landscape.

Survey is usually undertaken by APSS using a total station or electronic theodolite, although Global Positioning Satellite systems (GPS) are also utilised, to record the survey points. Computer software is then used to produce Digital Elevation Models of the results. Normally, survey is carried out using a Leica total station (BSR – TC805), with readings taken every 4 metres, and also on the breaks of slope of important topographical features. The resolution can be increased where necessary. Up to 5 hectares per day can be covered.

Integrated Survey Methodology

The survey work carried out by APSS is always produced as part of an integrated survey strategy, designed to affiliate all of the geophysical survey techniques to the same grid system, which would be used for geochemical soil sampling and surface collection. Surveys are normally based on an arbitrary grid coordinate system, tied into a national system or to a series of hard points on the ground corresponding to points on a map. A set of 30m grids are then set out to provide the background for the magnetometry, resistivity, and other survey techniques which will complement the results, for instance fieldwalking and geochemical sampling

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