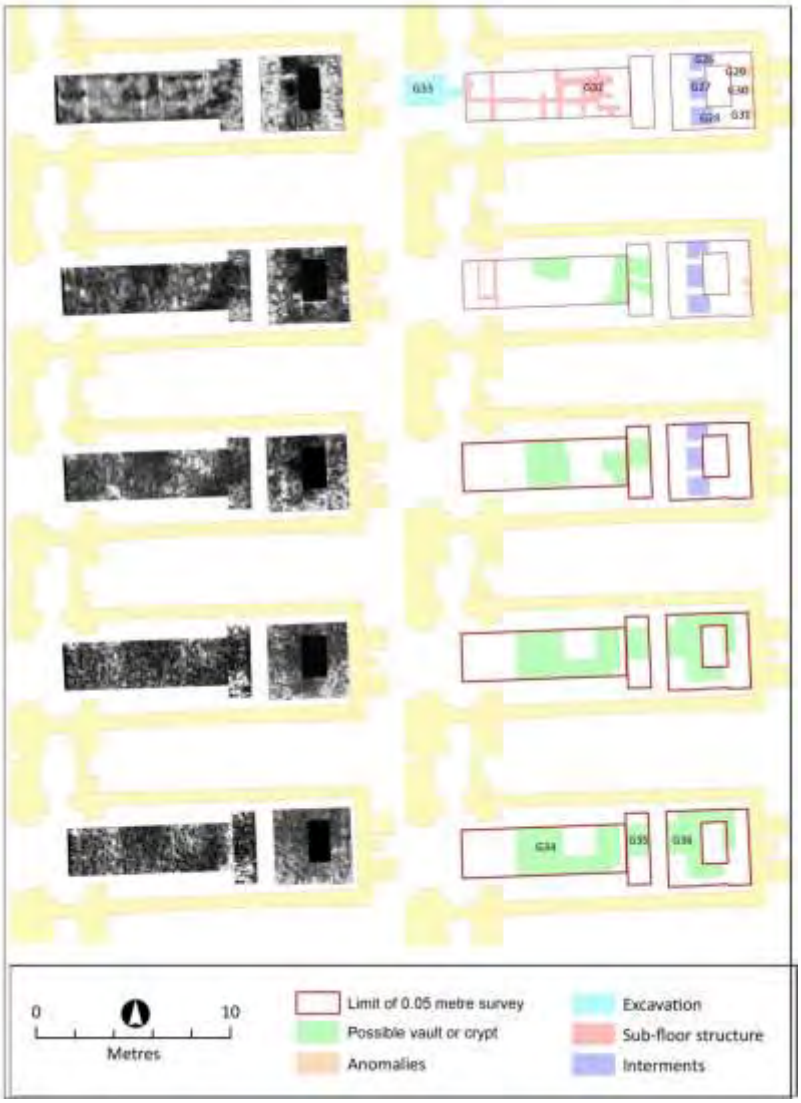
GEOPHYSICAL SURVEYS AT WEARMOUTH AND JARROW 2008-2010



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McCord Centre Report 2014.3

Newcastle University

McCord Centre for Historic and Cultural Landscapes

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Front piece: Internal GPR surveys St Paul's Church, 2010 and 2011. Combined plots and interpretation

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Acknowledgements

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Introduction

A programme of geophysical surveys was undertaken as part of the 'One Monastery in Two Places Project' between 2008 and 2011. These surveys were designed to assess the possible survival of hitherto undiscovered sub-surface archaeological evidence associated with the monastic sites of Wearmouth and Jarrow. Evidence from previous archaeological interventions, particular those of Rosemary Cramp (Cramp 2005), had allowed a detailed picture of the archaeological make-up of the central focus of both institutions but the full geographical extent of each of the monastic sites remained unclear. These surveys were conceived as one strand of a wider holistic attempt to better understand these important early monastic sites in their wider landscape context (Turner *et al.* 2013). The wider study area was divided into a series of nested zones of which only the smallest and most intensely studied was subjected to geophysical survey (Zone 3: *Figure 1*).

Location

Drewett's Park, Jarrow

Drewett's Park, donated to Jarrow Town Council by Alfred Chaytor after he inherited Jarrow Hall in 1910, is located immediately south of the tidal confluence of the River Don and the River Tyne approximately 1 km east of the centre of Jarrow. The area currently functions as a public park and lies between Jarrow Hall and St Paul's Church. The survey area is surrounded by mature trees and shrubs with the greatest density on the northern and eastern edges. A children's playground, with ancillary picnic benches, is located in the northern half of the survey area and is laid to tarmac. The survey area is criss-crossed by a series of paths constructed of brick paviors (*Figure 2*).

St Paul's Church, Jarrow

The church of St Paul's lies immediately to the south of Drewett's Park, separated only by Church Bank road, and is bounded on its southern and eastern sides by the (partially re-routed) River Don (*Figure 3*). Beyond the southern stretch of the River Don lies the in-filled Jarrow Slake, now part of the Port of Tyne. Up until the late 1970s the River Don took a significantly more meandering route in the area to the south of the church but was straightened as part of the infill of Jarrow Slake and the extension of the Port of Tyne.

Immediately adjacent to the church on the southern side are the partially extant remains of the later medieval monastery of Jarrow. The churchyard contains a large number of mature trees and is laid to grass. These are particularly prevalent in the southern half of the churchyard and it is for this reason that this area was excluded from the resistivity survey. The majority of the headstones have now been relocated but some have been laid flat and survive either immediately below or on the current ground surface. The churchyard is divided by the main driveway leading from the B1297, Priory Road, to the western entrance to the church. The churchyard to the north-west contains a number of iron benches and a series of meandering tarmacked footpaths flanked by lighting posts that appear to be redundant. The northeast corner of the churchyard contains a number of active lamp posts and an ancillary building that now operates as a store for the church. At the eastern end of the early chancel the southern churchyard, containing the remains of the monastic complex, is separated by a wall and railings and is also the location for the oil tank that supplies the church heating system. It is also the location of two funerary monuments above the graves of the Drewett family, the former owners of Jarrow Hall and

Drewett's Park. The combination of these factors precluded the inclusion of this area within the geophysical surveys.

St Peter's Church, Monkwearmouth

The church of St Peter's, Monkwearmouth is separated from the River Wear on its southern side by Sunderland University campus and the National Glass Centre (Figure 4). The boundary of churchyard is demarked by St Peter's Way to the south, east and west and by Dame Dorothy Street to the north. The churchyard to the north is largely laid to grass with a few large flower beds and a scattering of trees. With the exception of a one major funerary monument, the majority of the headstones in the churchyard have been removed and re-laid to the east of the church beyond 'Bede's Bakehouse', a modern extension providing café facilities for visitors. The ground to the north and east of the church is up to four metres higher than in the churchyard to the south. The church was, until the clearances of the 1960s, surrounded by Victorian housing that also included the local fire station. This has now given way to an open area of grass and trees with bushes at its edge and the recently added outline of the former monastery in white brick paviors with blue glass infill. This latter feature was an unexpected addition, fortunately after the completion of the GPR surveys but unfortunately before resistivity and gradiometry surveys were undertaken. The addition of this physical outline was a considerable constraint on survey within the area *(Figure 5)*.

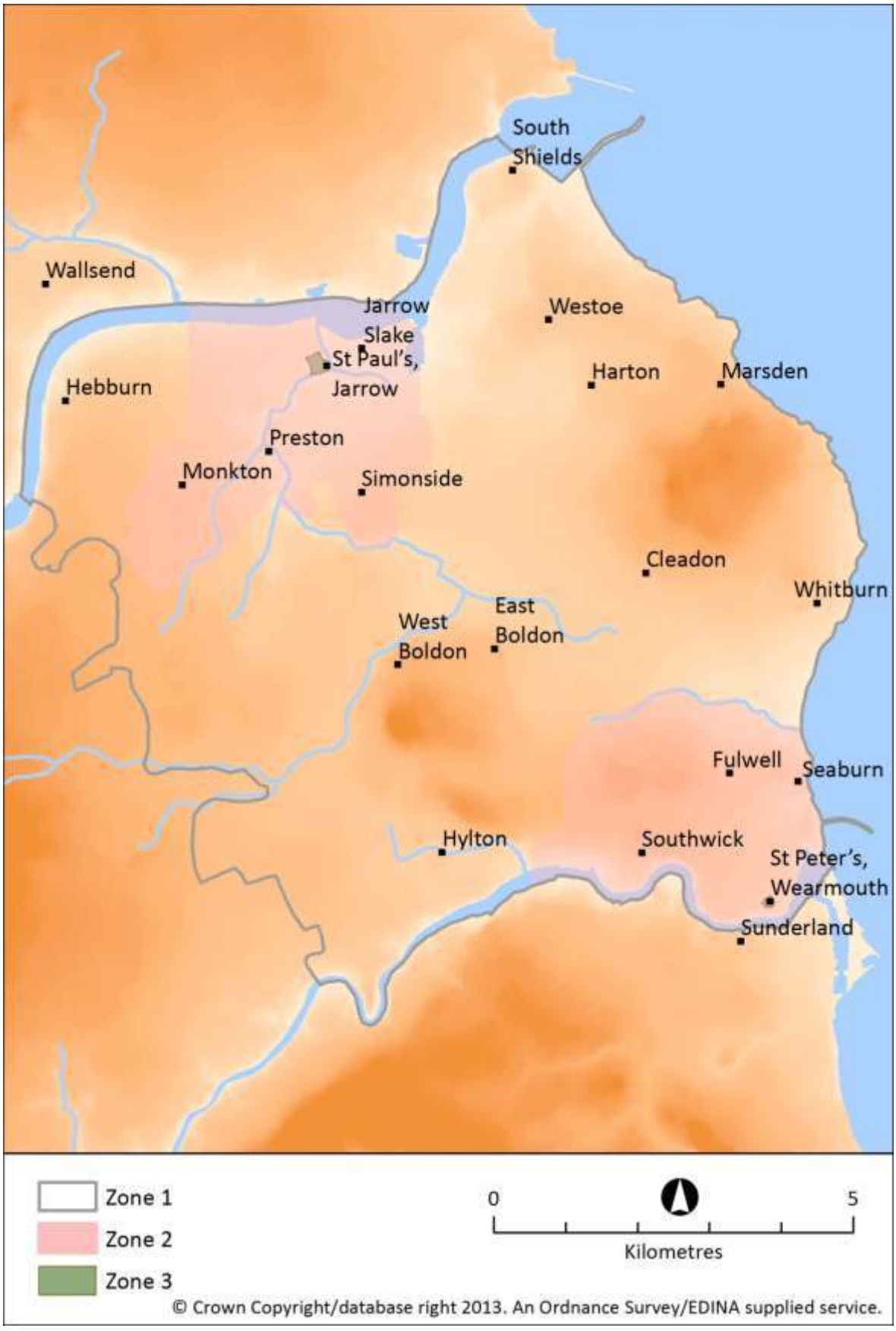


Figure 1: Location of Wearmouth-Jarrow study zones

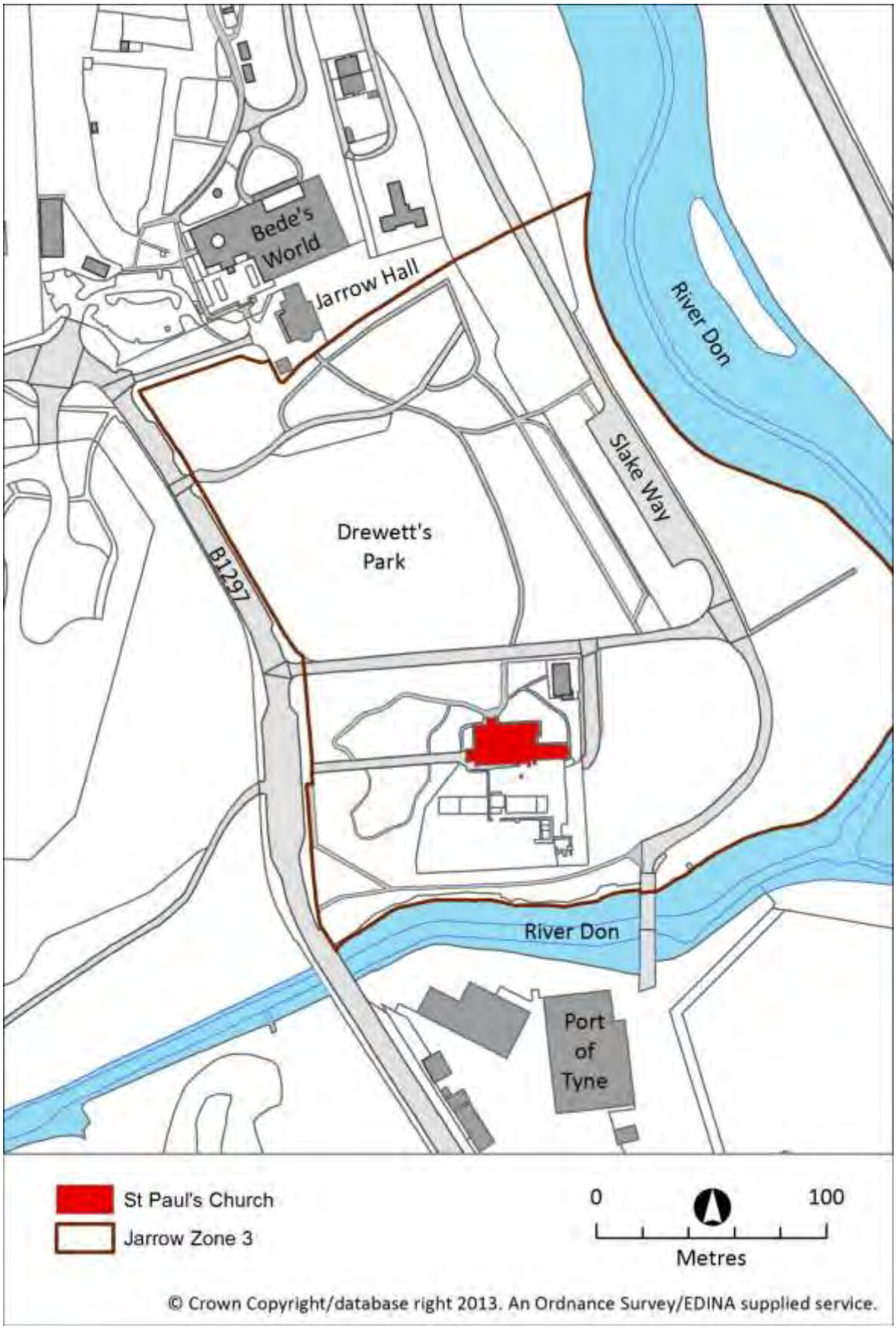


Figure 2: Location of Drewett's Park and St Paul's Church, Jarrow

Figure 3: The changing course of the River Don. Mastermap data shown overlying Ordnance Survey County Series 1st Revision 1895

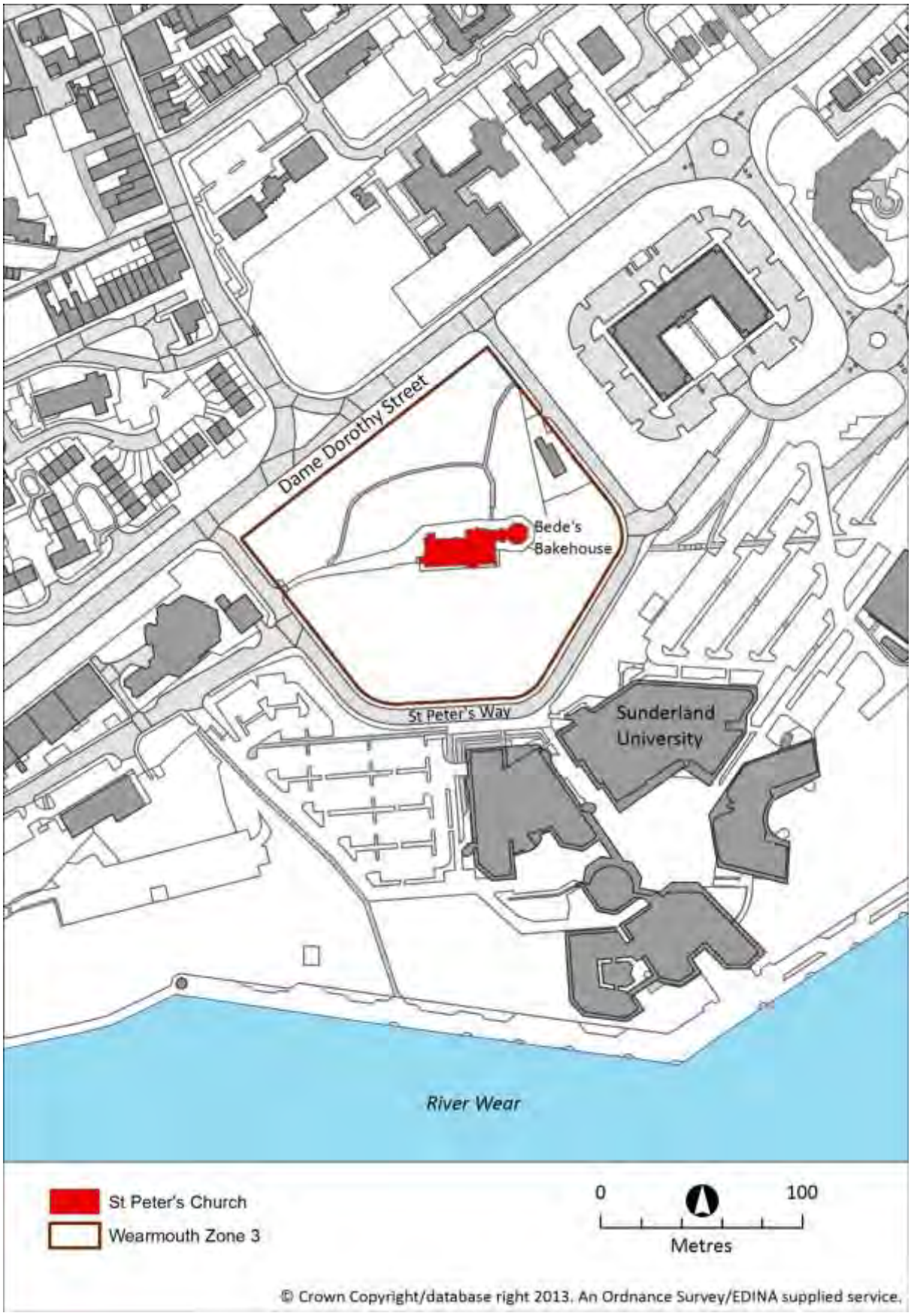


Figure 4: Location of St Peter's Church, Monkwearmouth

Figure 5: The brick outline of the monastery laid immediately before gradiometer and resistivity surveys.

Geology and Topography

Jarrow

The Tyne valley corridor occupies part of the pre-Devensian buried valley system of north-east England. Prior to the last, Devensian ice advance over the region, a much enlarged river system flowed out through land which is now part of the North Sea basin (*Figure 6*). The lower sea-level of the last interglacial period is reflected in the deep burial of the rock-head in the Tyne valley, up to 30m below current O.D. in some locations. The depth of burial of the underlying bedrock geology around the survey site is significant in that at this depth it does not affect the GPR survey data and it is the superficial geology that must be taken into account when analysing the survey results. The superficial geology for the survey area is a mixture of tillites (boulder clays) and fluvio-glacial Quaternary deposits. An examination of the digital geological data also reveals the presence on the eastern edge of the survey of 'made-ground' (Figure 6). This is not unexpected as the low lying tidal reaches around the Jarrow site, particularly Jarrow Slake and the Tyne Docks area have been extensively back-filled with foreign ballast rock and industrial waste. The survey area is located on a spur of ground that slopes in a northwest to southeast direction from Jarrow Hall to the River Don. Alterations to the topography appear to have been carried out in the early 20th century, when the area became a public park, and the eastern edge of the survey area abuts an area much remodelled during the construction of the extension to the Port of Tyne on the site of Jarrow Slake.

Wearmouth

St Peter's Church is situated on Upper Permian Magnesian Limestone covered by a veneer of Quaternary tillite (Boulder Clay) deposits *(Figure 7).* The modern landscape is characterised by modern industrial developments and housing. The immediate topography to the north is largely
Made ground and is the result of the dumping of large volumes, in some cases up to 4 metres deep, of ballast on top of the 18th century churchyard (Turner *et al.* 2013). Today, the surface slopes up sharply away from the church but recent fieldwork, undertaken by Museum of London Archaeology as part of the 'One Monastery in Two Places' project in 2011, has indicated that the church originally stood around 10 metres above sea level on a low spur surrounded by an estuarine landscape (*Figure 8*, Museum of London Archaeology 2012). This significantly altered topography had varying implications for the deployment of geophysical survey techniques. To the north of the church, where the ballast was deepest, only Ground Penetrating Radar (GPR) was capable of penetrating to a sufficient enough depth to yield meaningful results. In contrast the open areas to the south and west of the church, where the ballast was either non-existent or had an average depth of less than a metre, enable the collection of a range of complimentary data using GPR, fluxgate gradiometry and resistivity.

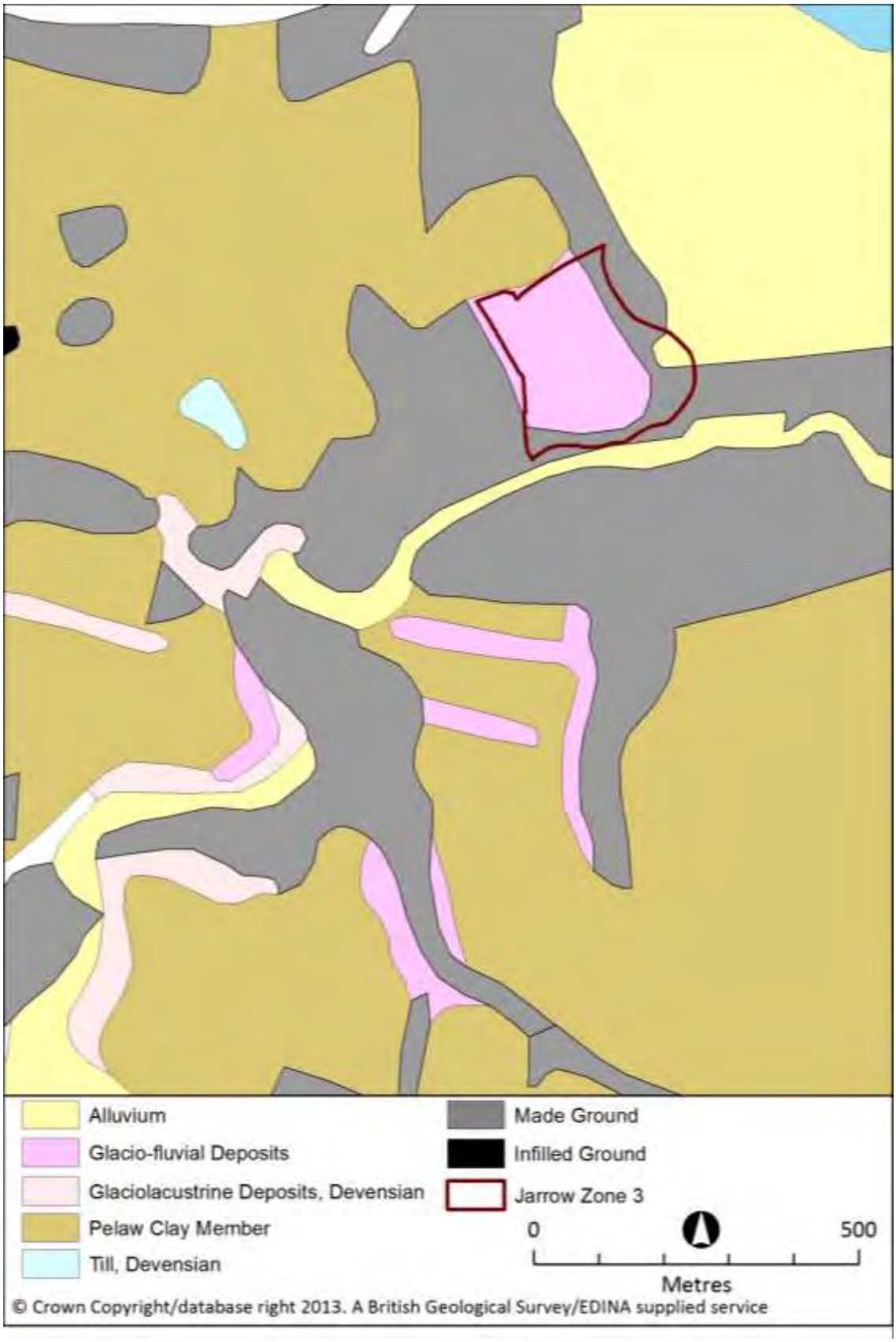


Figure 6: Geology of Jarrow

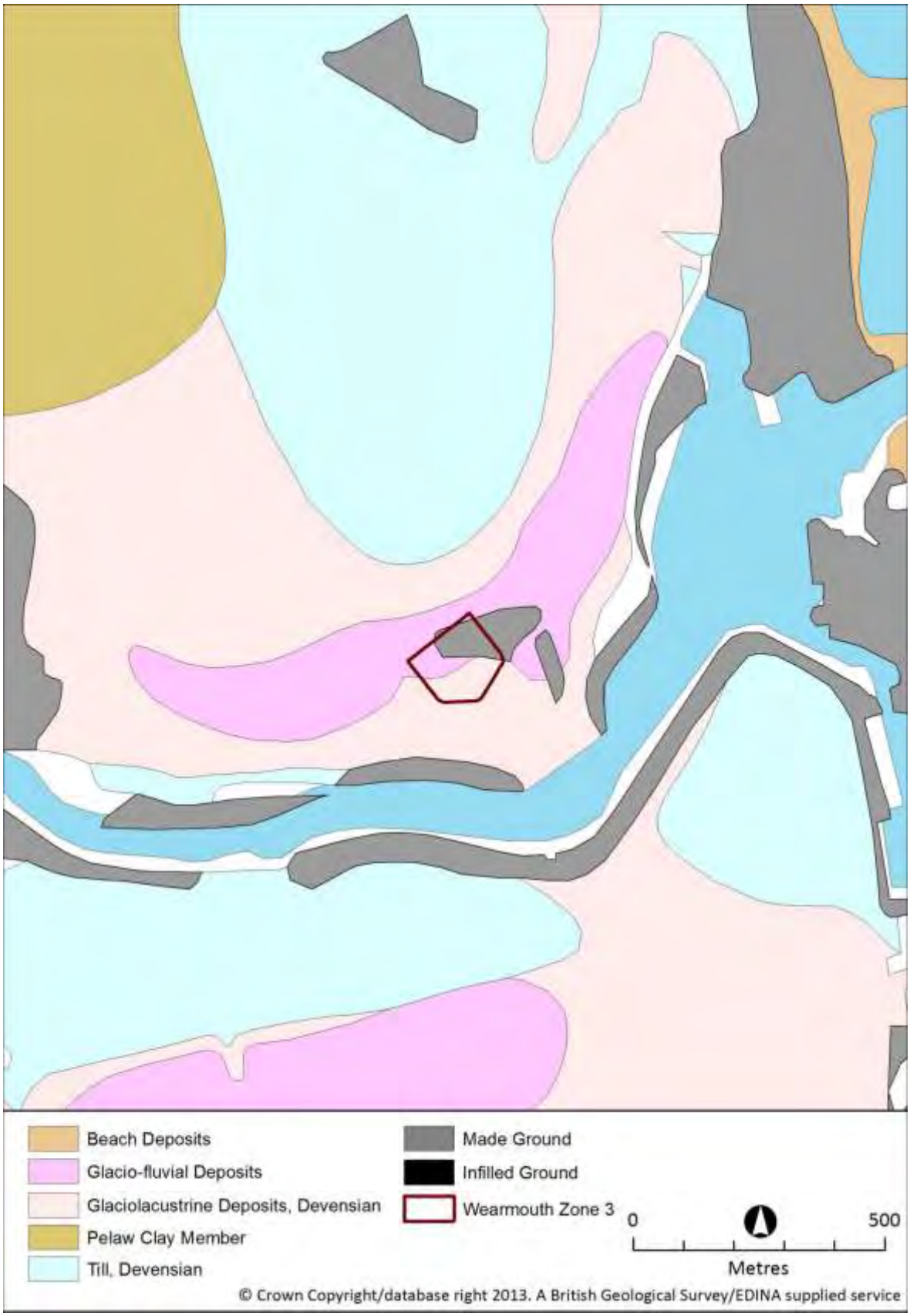


Figure 7: Geology of Wearmouth

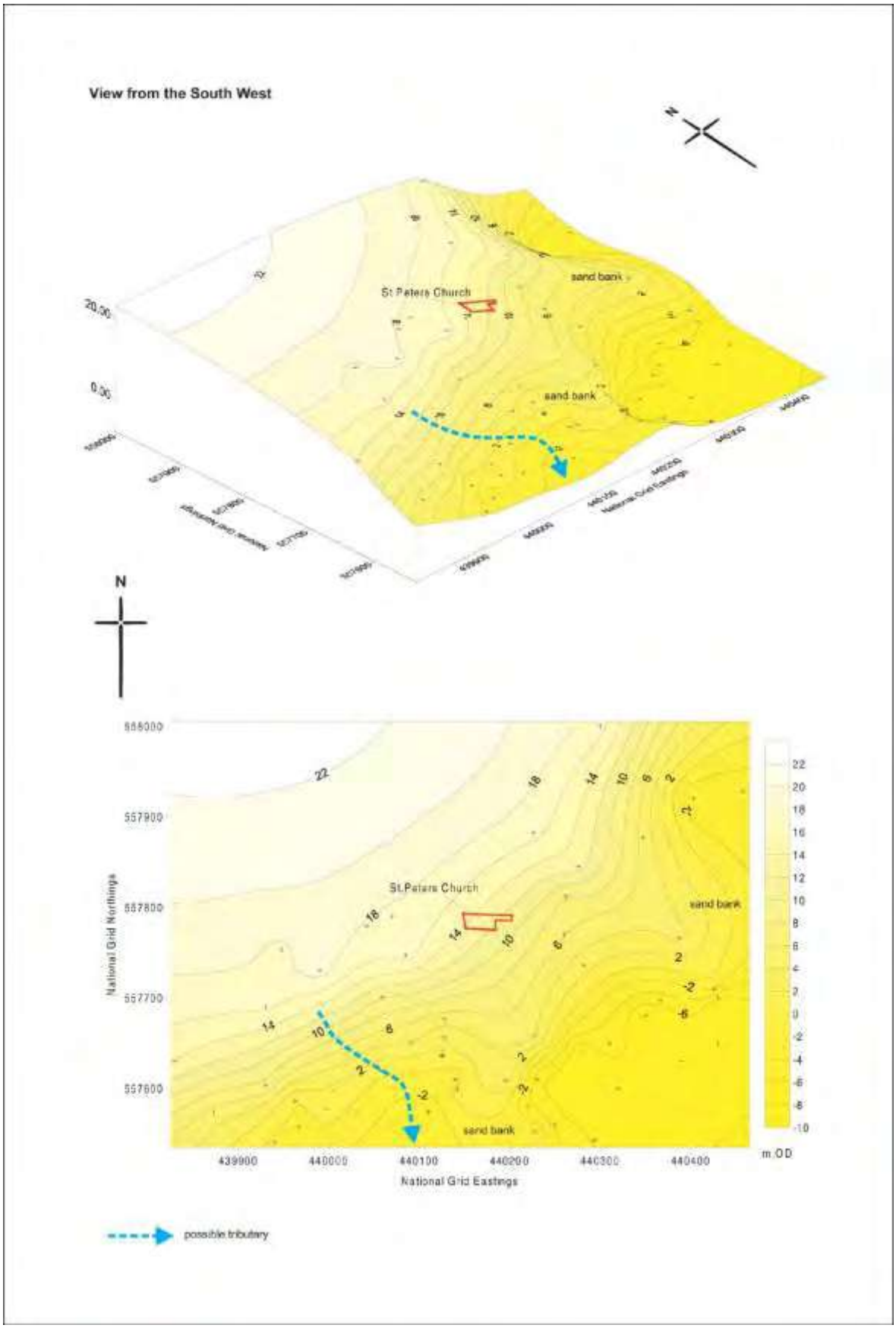


Figure 8: Model of original ground surface at Wearmouth derived from borehole data. Copyright Museum of London Archaeology 2012.

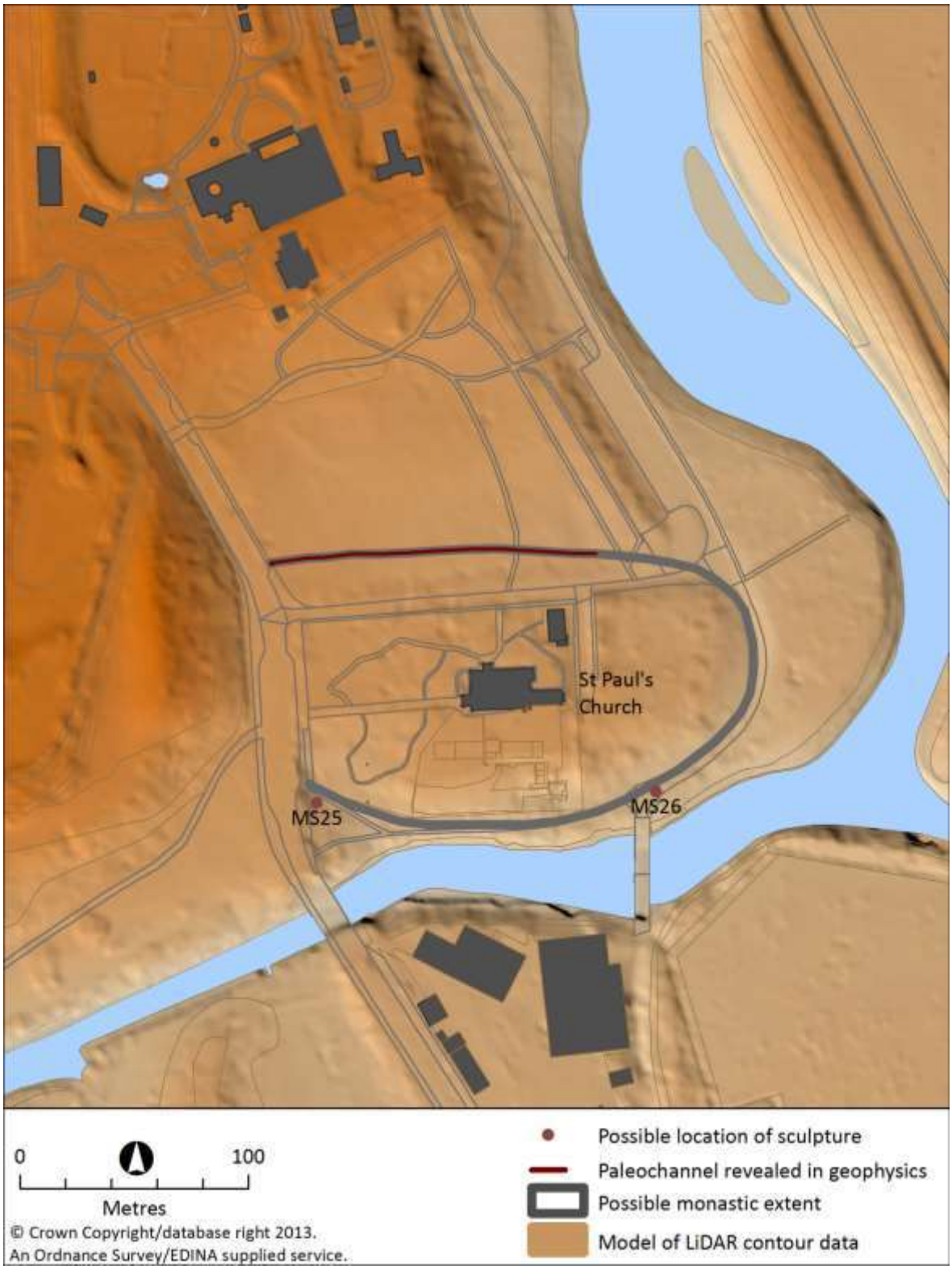


Figure 9: Model of current ground surface at Jarrow derived from LiDAR data. Copyright Geomatics Group, UK Environment Agency.

Survey Methodology

Methods - Survey Grids and Markers

A survey grid size of 30m x 30m was chosen for the gradiometer and resistance surveys and was laid out using a Total Station and tapes. Each survey area was located on the National Grid using a combination of differential GPS and Total Station survey before being transferred to the project GIS. Survey markers were fixed within the tarmac or paved areas of both sites to provide a number of permanent points of reference for the survey. Due to the ferrous content of these markers all magnetically sensitive methods of survey were carried out prior to these being fixed in place. GPR survey was undertaken as a series of transect within the standard 30m x 30m grid but the length of each transect was varied to enable the best fit within the survey area. Internal GPR surveys at Jarrow were initially conducted as a series of transects 30cm apart within the chancel of the church. Upon advice from Neil Linford at English Heritage these transects were reduced to 5cm apart and the area re-surveyed.

As far as was possible the surveys and reporting were conducted in accordance with English Heritage guidelines (*Geophysical survey in archaeological field evaluation,* David *et al.* 2008), *The use of geophysical techniques in archaeological evaluations* (Gaffney *et al.* 2002) and the Archaeology Data Service *Guide to Good Practice: geophysical data in archaeology* (Schmidt & Ernenwein 2011)

Methods – GPR, Jarrow (2008 and 2009)

Ground Penetrating Radar (GPR) is a very high frequency EM technique used to produce high-resolution images from the subsurface. GPR is used for both the detection of material remains and the characterisation of subsurface stratigraphy. The GPR surveys were carried out using a Mala RAMAC X3M equipped with a XV11 monitor and a 500MHz antenna. For the 2008 survey three areas of zigzag traverses (GPR1 - GPR33) were surveyed at one metre intervals within Drewett's Park *(Figures 9)* and for the 2009 survey *(Figure 10)* at one metre and half metre intervals within Drewett's Park (GPR4 - GPR5) and St Paul's Churchyard (GPR6 - GPR9). In both cases samples readings were taken at 0.05 metre intervals along each traverse. Where possible a rough terrain cart, using an on-board calibrated measuring wheel, was employed to enable rapid survey of each traverse. Where conditions allowed variation within the standard 30mx30m survey grid was employed to maximise survey efficiency. As with all GPR survey the computation of depth is reliant on an understanding of the velocity of the electro-magnetic signal through the material being surveyed. Since GPR signal attenuation is greater in soils with a high conductivity (Linford 2006, 2236), reference to soil and geological data was made for each survey area but it is quite clear from the evidence of geotechnical boreholes done in Drewett's Park that there was a significant amount of non-homogenous infill within the park during the early 20th century. GPR was used for both internal and external survey in both Drewett's Park and the Churchyard of St Paul's, Jarrow and subject to the limitations caused by attenuation due to ground moisture, particularly during the 2008 survey, detection of sub-surface features was possible to depths of up to 3.5 metres. GPR was also the only technique capable of detecting sub-surface features within the internal space of the church and external areas laid to concrete or tarmac. GPR survey within the standing structure was problematic due to limitations of space and all efforts were made to ensure that the area available for survey was maximised. Initial survey at Drewett's Park was undertaken in advance of a proposed meeting of ICMOS for the WHS bid and survey conditions for GPR were less than ideal due to the high level of ground water at that time of the year. Further survey work, in 2009, was more carefully timetabled for the summer months to reduce the effects of attenuation, although even these

precautions the maximum penetration depth was only c. 3.5m with a 500 MHz antenna. The proximity of the site to the River Don and the former Jarrow Slake is likely to be a contributory factor to the high water table in the area. However, given the nature of the site and the existing information regarding the depth of burial of remains, penetration to such a depth was probably unnecessary. Calculation of velocity estimates for the sites was done using hyperbola matching during the processing stage. The topographic change for all survey areas at Jarrow was insufficient for antenna tilt to be a problem. Analysis was undertaken using a combination of ReflexW and Reflex3D software. Data within this report is presented as a series of either X or Y scans and combined XY slices.

Methods – GPR internal surveys, St Paul's Church, Jarrow (2010 and 2011)

The internal GPR survey at Jarrow concentrated on the chancel of the present church, the eastern church of the middle Saxon period (*Figure 11*). In addition to testing for the presence of below-ground features it was also part of an overall attempt to link the geophysical survey to the petrological and laser scan surveys of the standing structure. The indoor survey of the chancel was carried out at a much higher resolution than the surveys within Drewett's Park and St Paul churchyard. An initial survey was carried out with traverse intervals of 0.20m, 0.25m or 0.3m (the width of the 500 MHz antenna) depending on the location within the church and sample intervals of 0.05 metres. The initial results suggested the possibility of a void at the eastern end of the church but were slightly ambiguous. Following consultation with Neil Linford at English Heritage a further survey was undertaken with a traverse interval of 0.05 metres in areas (GPR18-GPR22) and a sample interval of 0.05 metres (*Figure 12*). Additionally a survey was also undertaken over the crypt at Hexham (*Figures 13-16*) to provide comparative data for the responses expected from a GPR survey over the known void of an existing empty crypt. The equipment used was the same as that for the external surveys without the addition of the rough terrain cart. This was replaced by a skid plate beneath the antenna along with a smaller measuring wheel attached to the rear it rear. The need for the calibration wheel did restrict the length of some transects, particularly in the area around the altar. Fixed objects that precluded any survey included the altar and Bede's Chair. The latter whilst not fixed in place was too delicate to contemplate moving without damage. Where possible data was collected in both the X and Y directions but this was restricted to areas (GPR19-GPR21).

Methods – GPR, Monkwearmouth (2009)

GPR survey (GPR23-GPR31) was carried at Monkwearmouth using the same equipment and parameters as the 2009 survey of Drewett's Park (*Figure 17*). Although the majority of the site was accessible for survey there was of an area to the east of the main entrance, where Northumbria Water were installing new inspection chambers and pipework, that was unavailable. The northern end of the site is known to have been covered in *c.* 4 metres of ballast and a suitable time of year was therefore chosen to try to ensure maximum depth of penetration with a 500 MHz antenna. It was hoped that this would be sufficient to reach the 18th century churchyard levels known to exist below the ballast. The southern side of the church was less problematic since the geotechnical boreholes (*Figure 18*) and Cramp's excavations of the 1960s had shown that the level of ballast overburden was 1 metre or less in depth (Cramp 2005) within this area. Additionally, a series of boreholes commissioned by the Museum of London, as part of the World Heritage bid process (*Figure 8*), have shown that sands and gravels in the area beyond the topographically lower southern half of the churchyard are beyond the historic tidal reach and are therefore caused by dumping of ballast rather than any tidal deposition (MoLA 2012).

During the snow of December 2010 (*Figure 19*) a further area immediately in front of the western tower was also surveyed with the intention of trying to locate the building shown on a 19th century sketch and reproduced by Cramp (Cramp 2005). Transects were recorded at 0.5 metres intervals in both a north-south and east-west direction with a sample interval of 0.05 metres (*Figure 20*)

Methods - Fluxgate gradiometer survey

Although fluxgate gradiometer survey is an established and trusted technique for the rapid detection of sub-surface archaeology in non-igneous geologies, it had severe limitations in close proximity to the plethora of metallic street furniture found at both Wearmouth and Jarrow. The large number of trees coupled with the abundance of street lighting, ground level lighting and a number of metal benches and signs within the churchyard of St Paul's Church meant that the gradiometer survey for Jarrow was limited to the open area of Drewett's Park. This area (M41) had already been surveyed by Archaeological Services, Durham University, in 2007, as part of the 'Dig Bede' Project (*Figure 21*) and the data, with some re-interpretation in light of the data collected subsequently, is utilised here. At Wearmouth the area chosen for survey was limited to the southern side of the church where the ballast was at its shallowest (*Figure 22*). However, on site problems were encountered with the unannounced use of Harris fencing to enclose an area to mark out the monastic outline with brick paviors (*Figure 5*). Fortunately, an area at the southern and eastern boundaries of the church was clear of obstructions (M42-M43) and this was surveyed as a cross-check of an earlier geomagnetic survey (M44) carried out by Nigel Barker from Durham University in 2003 (*Figure 23*). The data from both surveys was collated and re-interpreted, in light of subsequent information collected by this project and is presented as a composite of the two surveys. The results from the 2009 survey mirrored those obtained in 2003 and only the interpretation of the data differs.

Methods – Fluxgate gradiometer common methodology

Both surveys were carried out using a Geoscan FM256 single sensor fluxgate gradiometer. In accordance with accepted practice initial (EH 2008, 4) initial data collection was done using a 1 metre traverse and 0.25 metre sample within a framework of 30x30 metre grids. A higher data collection rate was subsequently adopted due to the restricted area available for survey and the need to provide a detailed comparison with the results obtained in 2003.

Methods - Resistivity survey

Drewett's Park and St Paul's churchyard, Jarrow

Resistivity surveys were used in a number of key areas at Drewett's Park (R45-R46) and St Paul's Churchyard (R47-R49), Jarrow. The areas chosen at Drewett's Park was informed by the 2008 GPR survey and concentrated on the southern half of the park where there seemed to be less disturbance from WWII activity and the a greater possibility of locating the outer limit of the monastic complex (*Figure 24*). At the southern and eastern edge of the survey a number of mature trees presented a physical obstacle as well as obscuring the results. The area within the churchyard at St Paul's was also limited by a number of mature trees and only a relatively small area to the west of the church was a practical survey proposition. A clearer area was, however, available for survey to the north of the eastern chancel of the church and enable duplication, as far as was possible, of the area covered by GPR survey. An area in the south eastern half of the churchyard was also surveyed but in common with the

other areas around the extant monastic remains was quite clearly disturbed by the Cramp's excavations in the 1960s (Cramp 2005, **)

St Peter's, Wearmouth

The evidence obtained from the geotechnical borehole survey and previous excavation meant that resistivity survey was targeted on the area to the south of the church (R50) where the overburden from ballast dumping was at its shallowest (Figure 25). During the planning stage of the survey the area was open and clear of major obstruction but the unexpected laying of the brick paviors indicating the outline of the former monastic complex severely hampered the collection of data within this area (*Figure 5*). Despite these restrictions there was the opportunity to provide an overlap between resistance, gradiometer and GPR data.

Methods – Resistivity common methods

Resistance survey was carried out using a Geoscan RM15 Advanced equipped with a MPX15 multiplexer. In most instances data was collected on a standard 30m x 30m grid using a series of 1 metre traverses sampled at a rate of one reading per metre. Some smaller selected areas were surveyed with an increased data collection rate of 0.5 metre traverses and 0.5 metre samples. This was based on the results for the preliminary 1 metre survey and due to time limitations was restricted to sampling areas either with the highest archaeological potential or where resistivity was the method least interfered with by services and objects within the survey area.

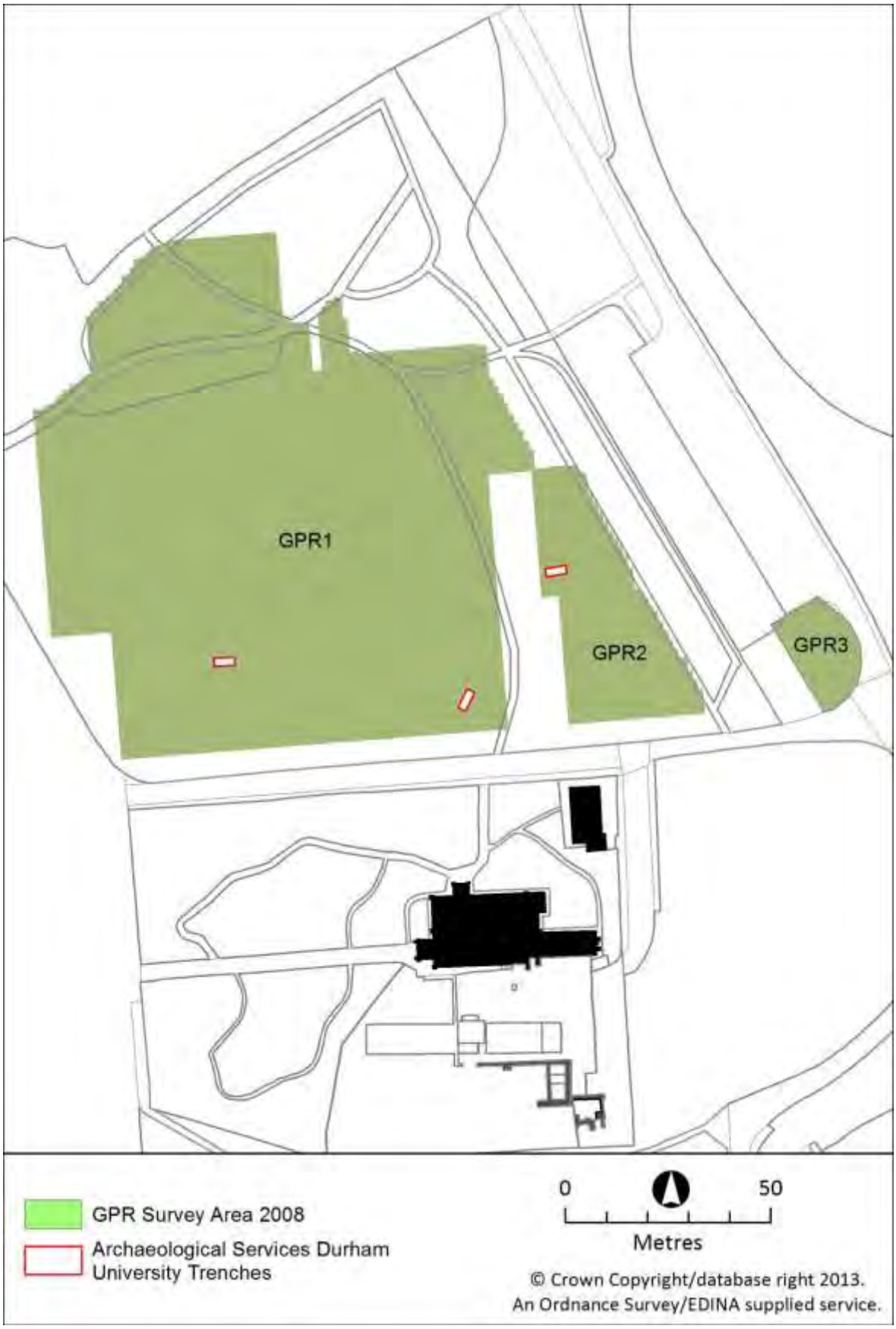


Figure 10: Location of the 2008 GPR survey, Jarrow

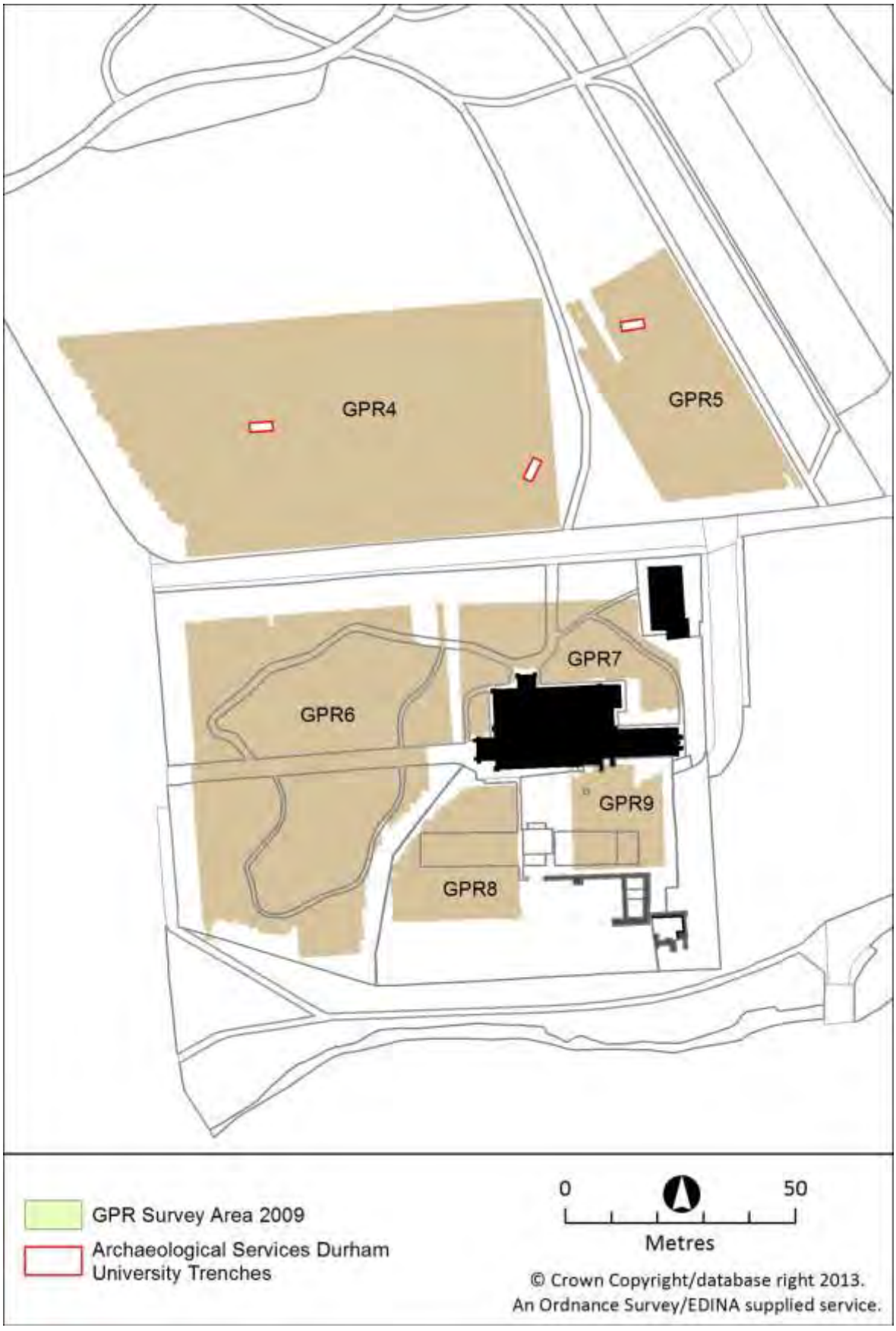


Figure 11: Location of the 2009 GPR survey, Jarrow

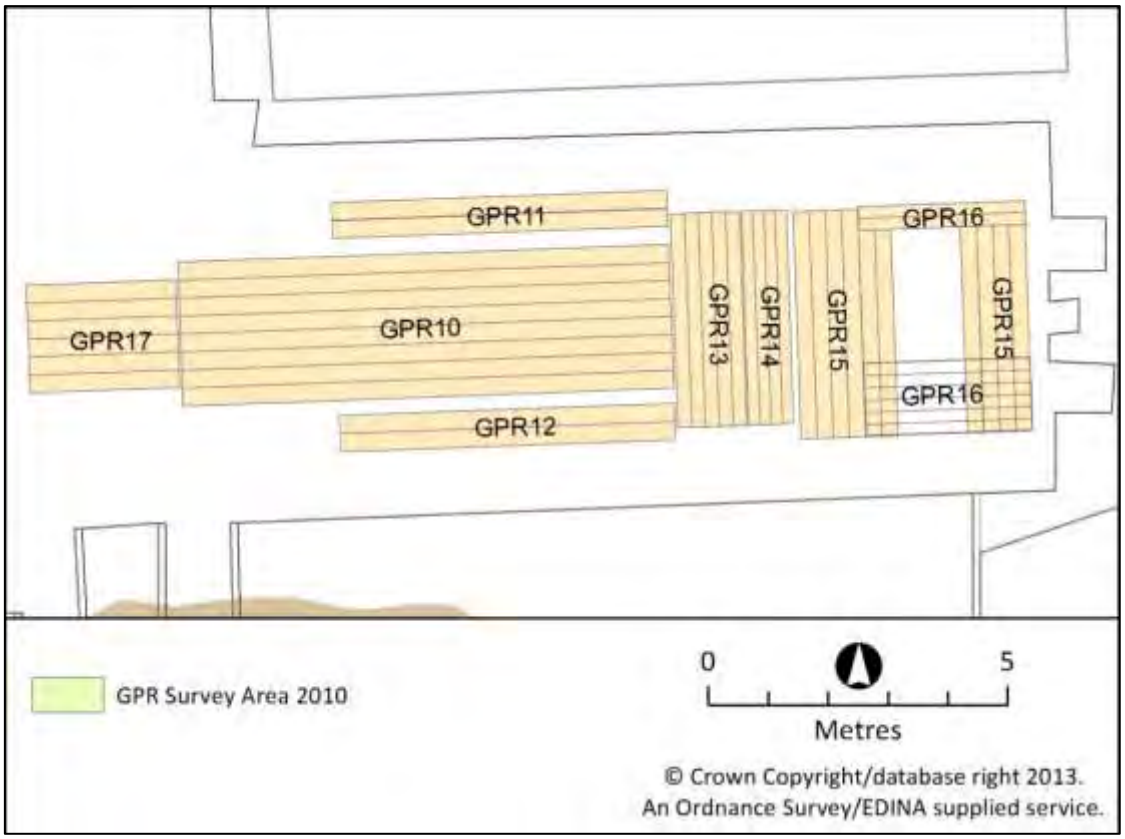


Figure 12: Location of the 2010 internal GPR survey, St Paul's Church, Jarrow

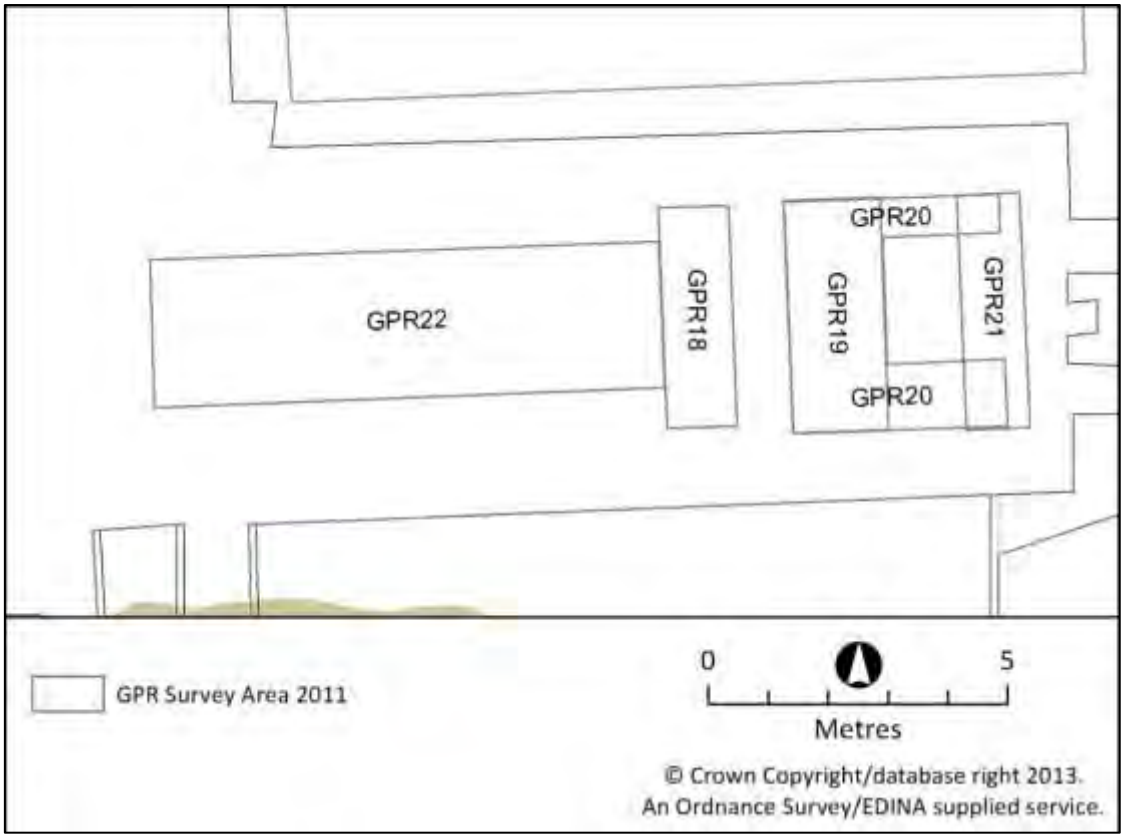


Figure 13: Location of the 2011 internal survey, St Paul's Church, Jarrow

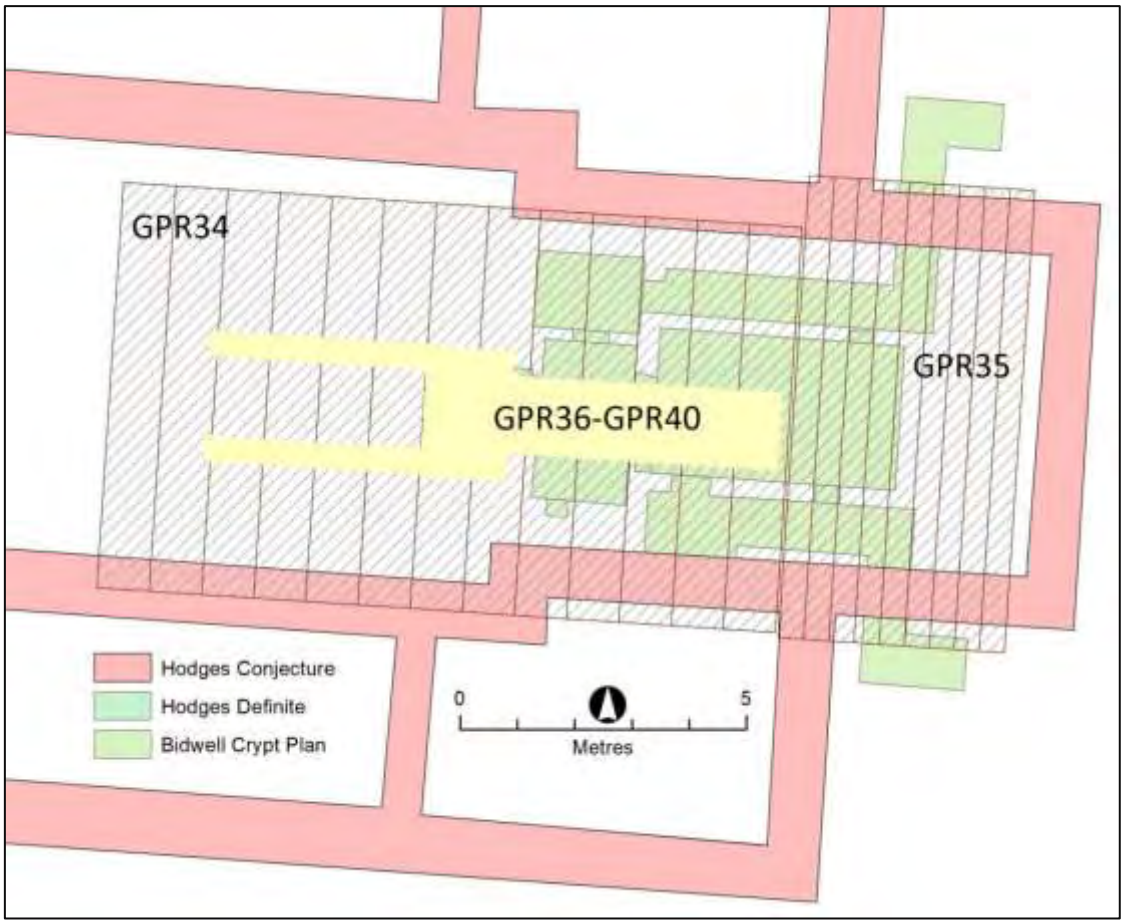


Figure 14: Hexham GPR survey – Location of areas GPR34 andGPR35 with overview of GPR36-GPR40

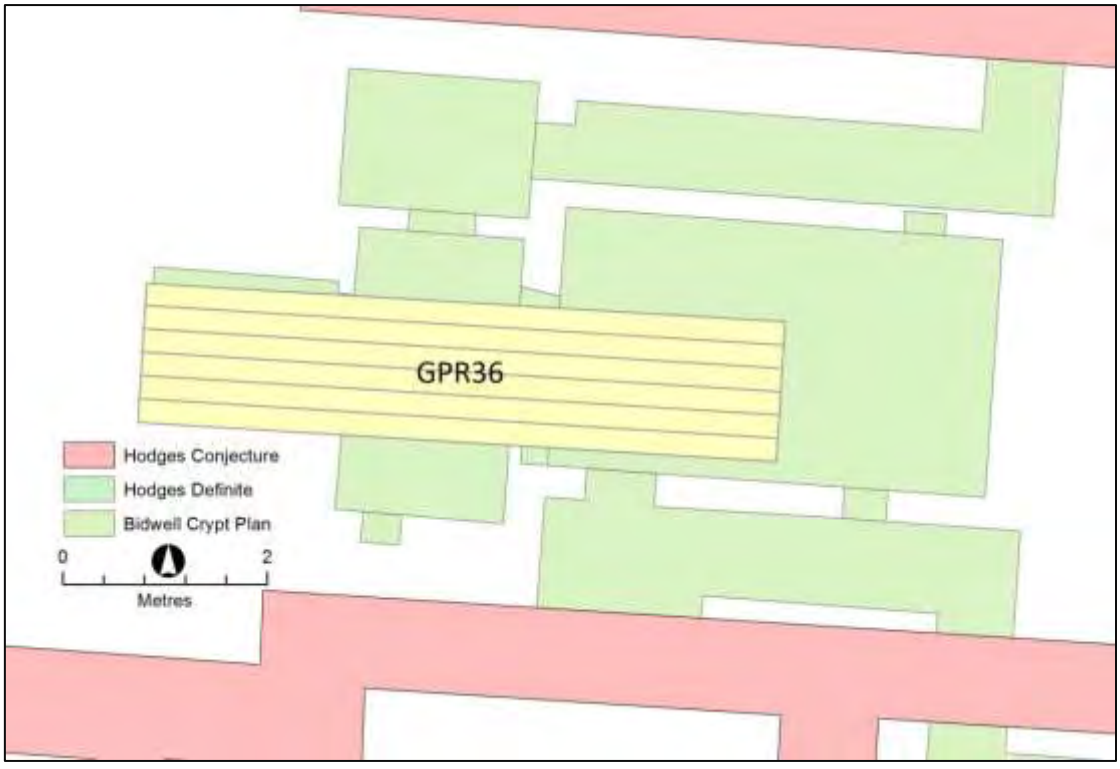


Figure 15: Hexham GPR survey – Detail of Location of GPR36

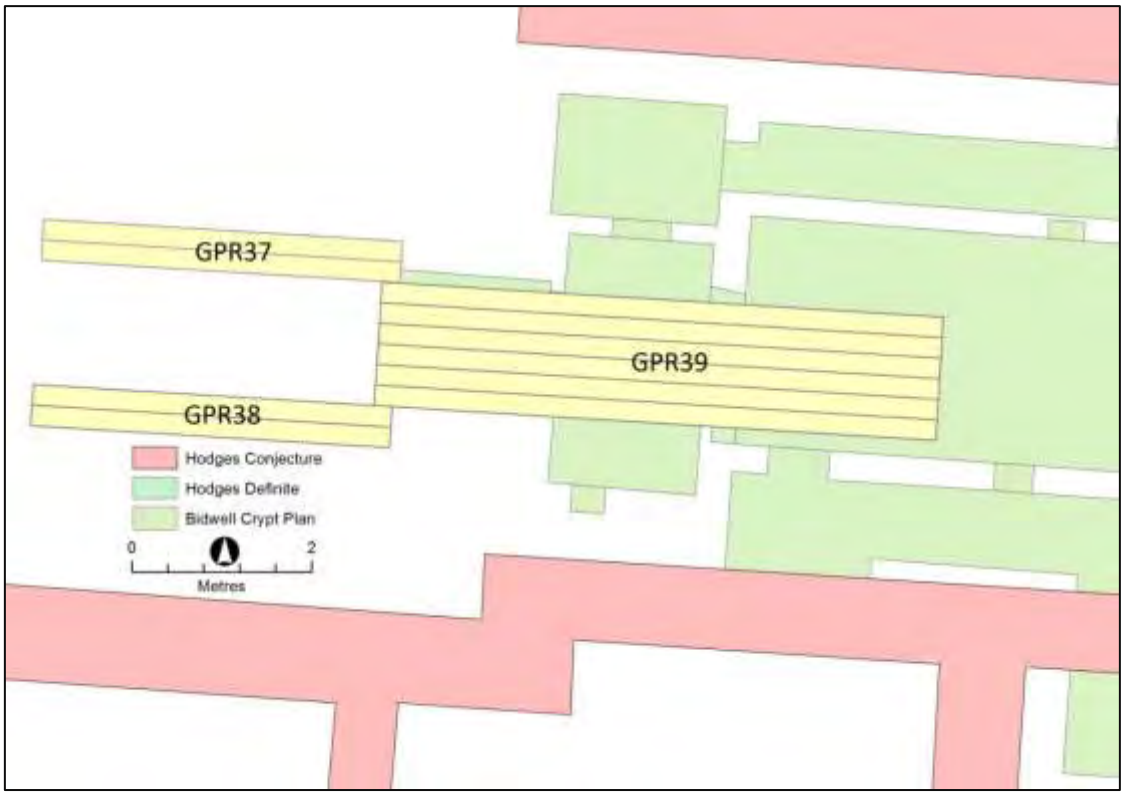


Figure 16: Hexham GPR survey – Detail of location of areas GPR37-GPR39

Figure 17: Hexham GPR survey – Detail of location of GPR40

Figure 18: Location of the 2009 GPR surveys, St Peter's Church, Wearmouth

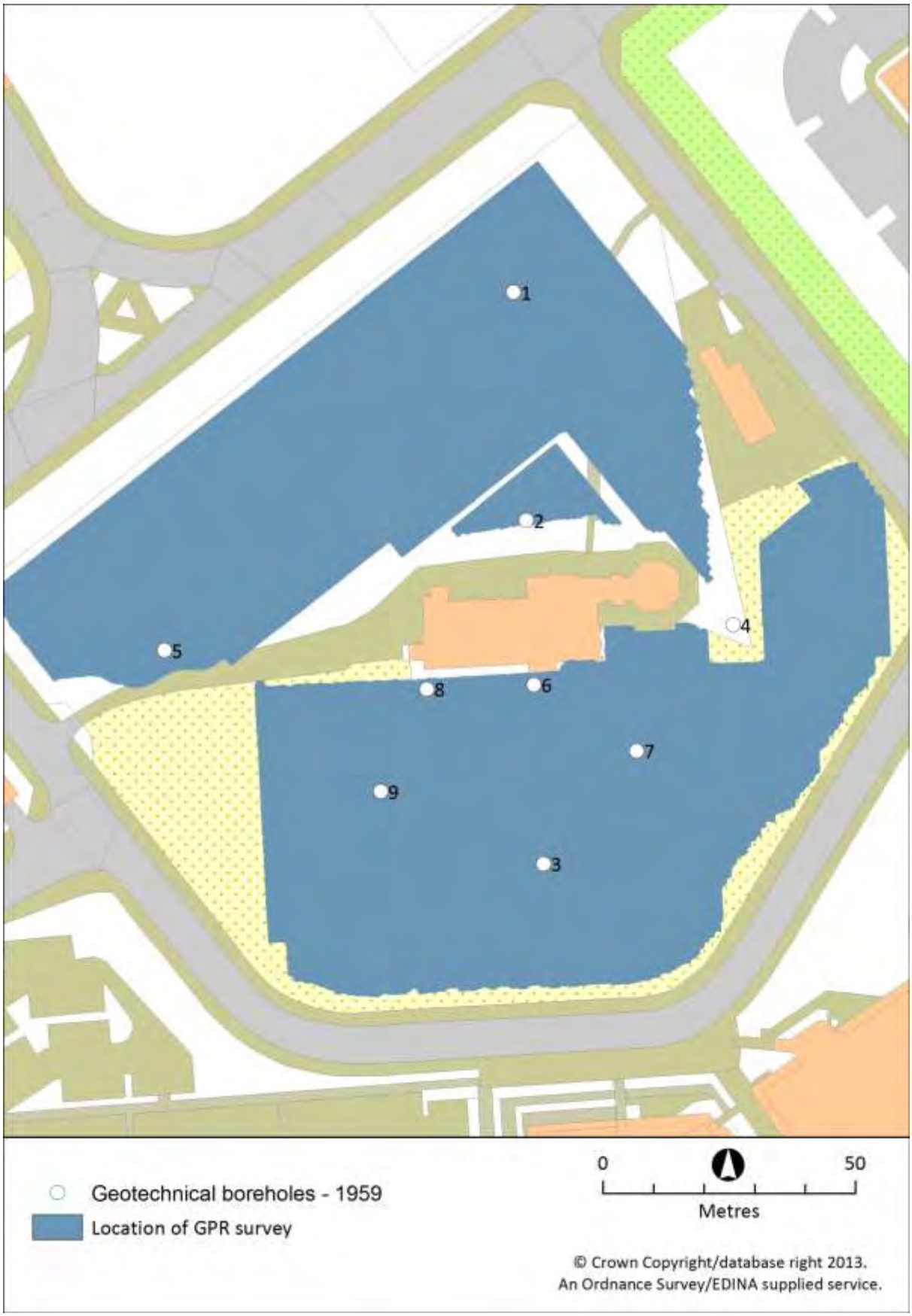


Figure 19: Location GPR 2009 survey and the geotechnical boreholes taken in 1959 prior to housing clearance.

Figure 20: GPR survey Wearmouth 2010

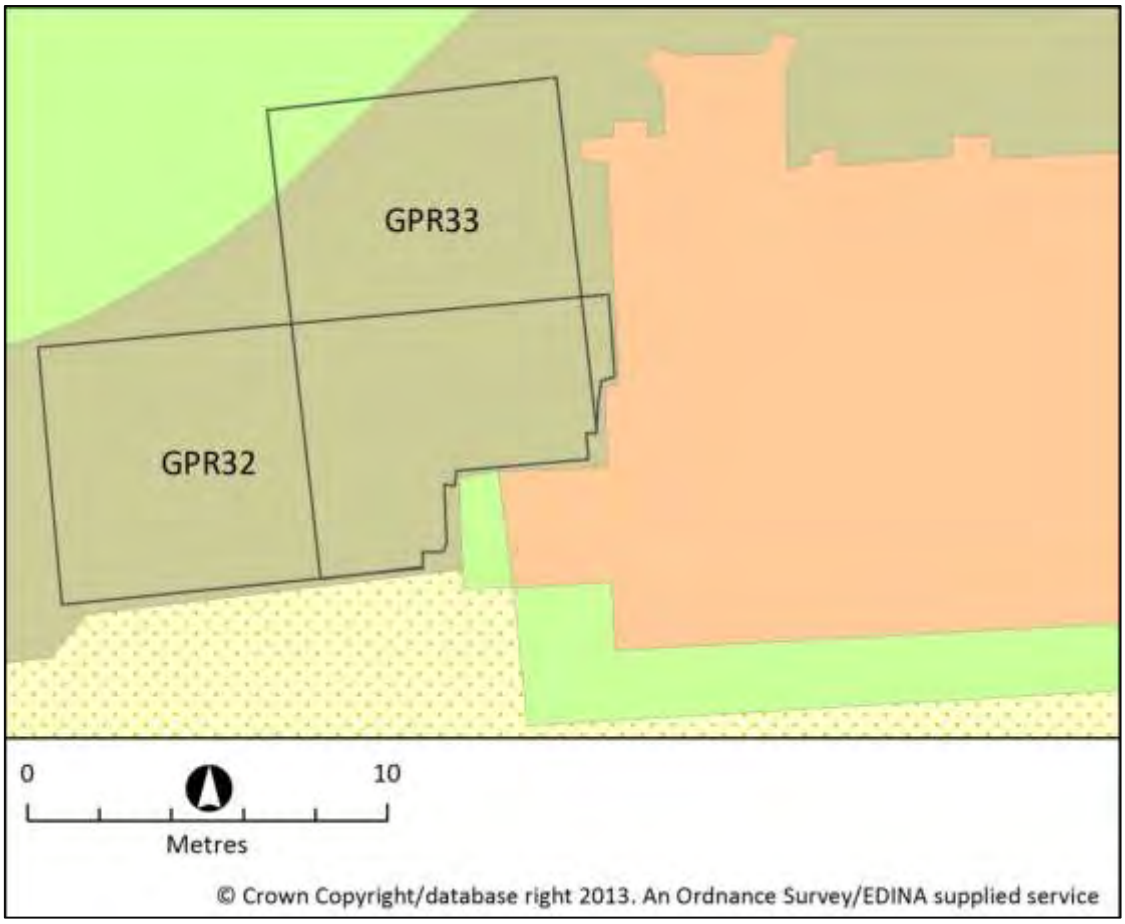


Figure 21: Location of GPR survey Wearmouth 2010

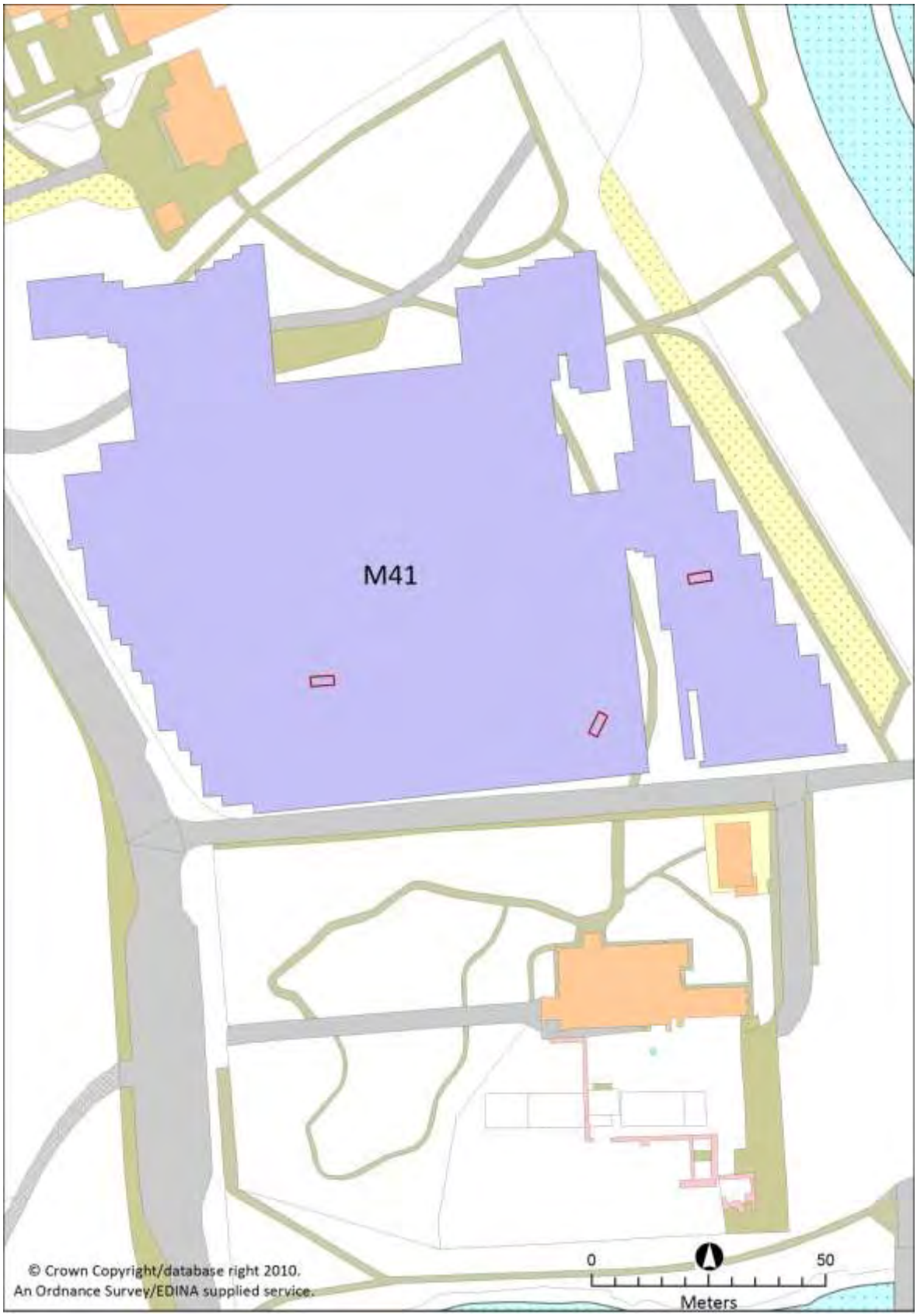


Figure 22: Location of Gradiometer survey Drewett's Park, Jarrow 2007 (Courtesy of Archaeological Services, Durham University. Report 1669)

Figure 23: Location of Gradiometer survey St Peter's Church, Monkwearmouth, 2009

Figure 24: Location of the Barker Gradiometer survey St Peter's Church, Monkwearmouth, 2003

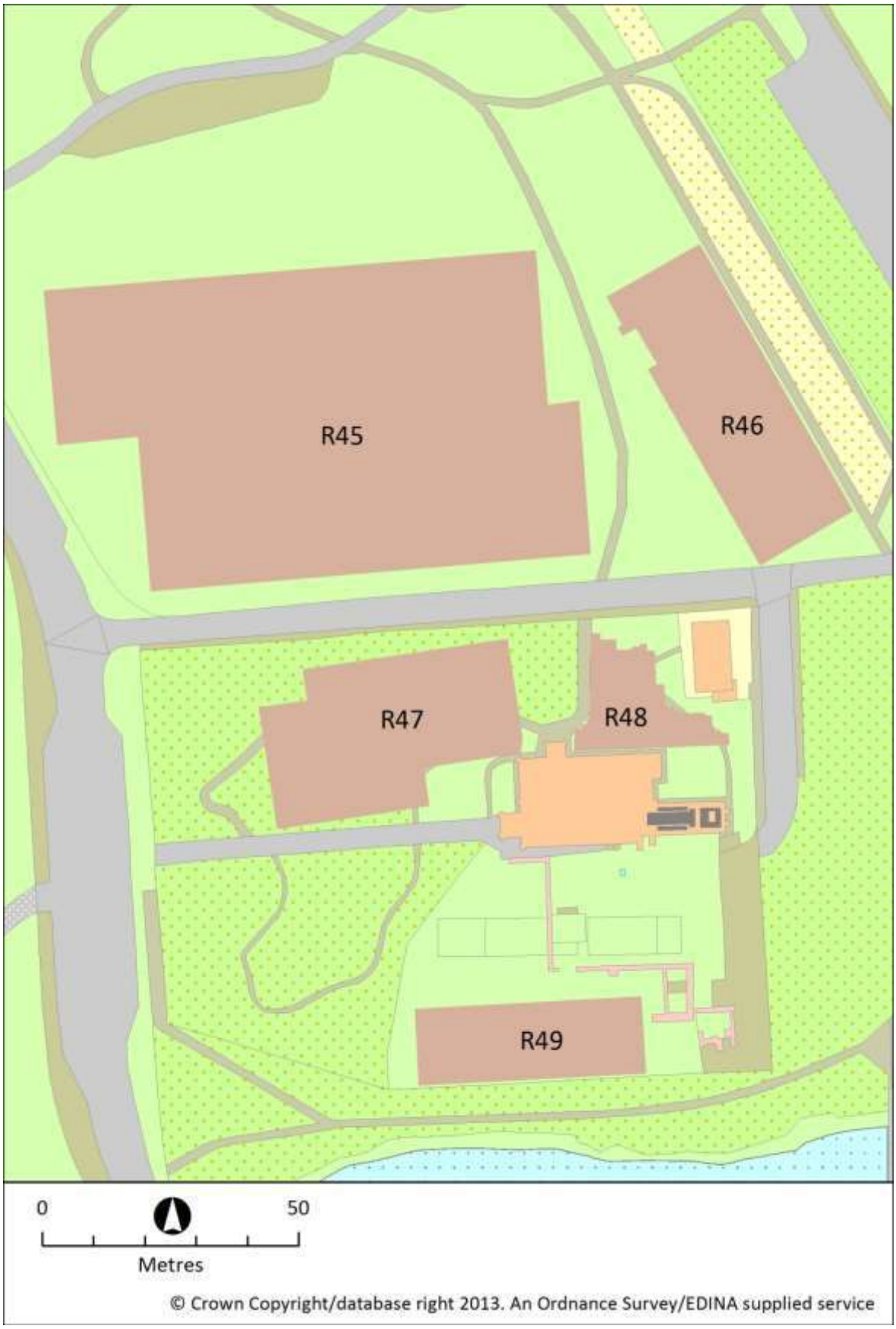


Figure 25: Location of the resistivity surveys at Drewett's Park and St Paul's, Jarrow, 2009

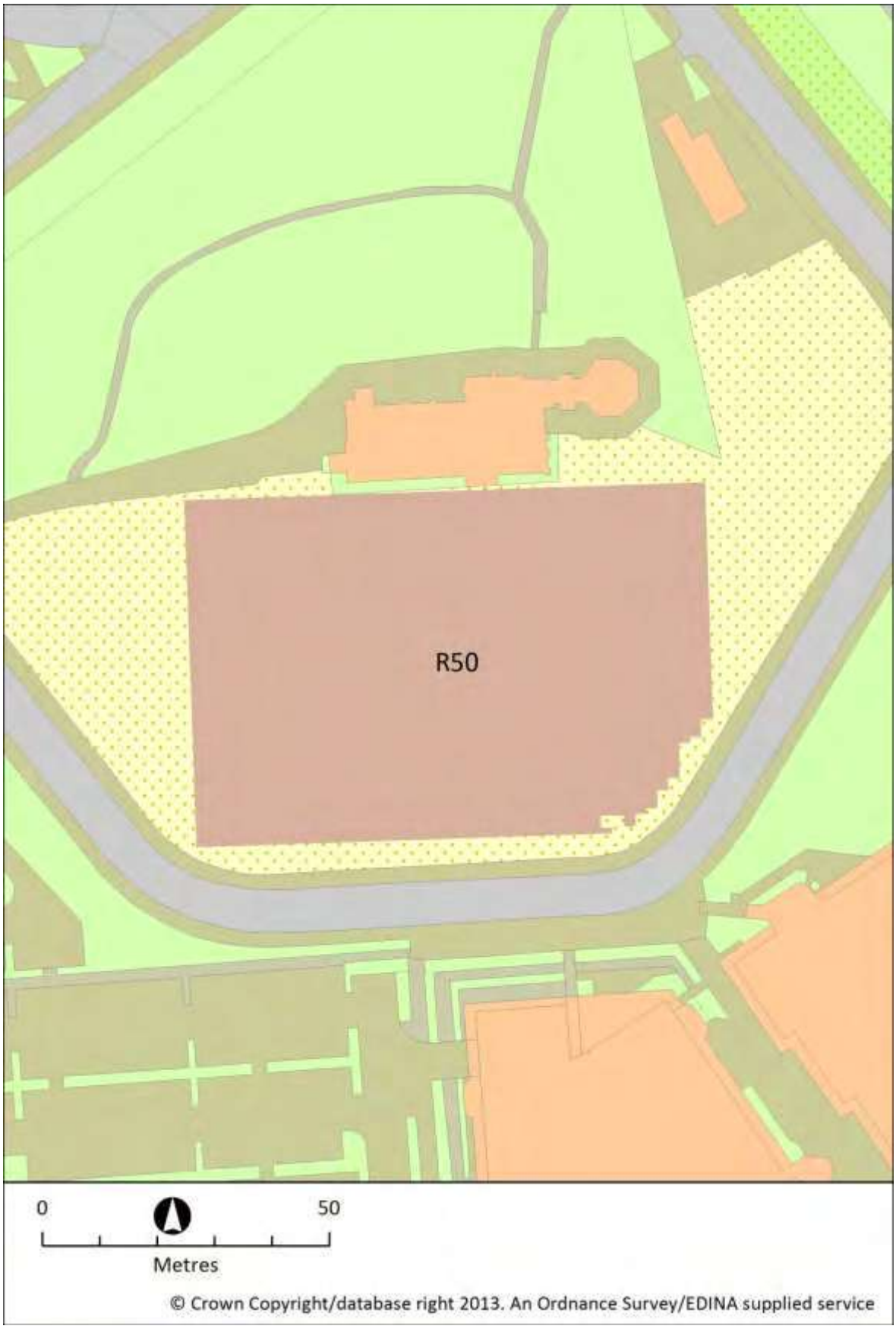


Figure 26: Location of the resistivity surveys at St Peters Church, Monkwearmouth, 2009

Data processing and presentation

Gradiometer and Resistivity survey

The data from both the gradiometer and resistivity surveys was processed and analysed using Geoplot 3.0v in combination with modern and historic mapping data in ArcGIS. The integration of digital output from the geophysical survey with the geospatial and cartographic data within the underlying GIS enable overlay comparison of the results from the different geophysical survey methods. This also enabled the rapid cross-correlation with known features on historic Ordnance Survey and Non-Ordnance Survey maps. The availability of large scale, 1:1250 for the Post WWII national grid and 1:500 for the late 19th century, was particularly useful in identifying known features as was the digital output from the Hadrian's Wall National Mapping Program (EH 2009) and the North East Rapid Coastal Zone Assessment (NERCZA) (EH 2008) which both contributed towards the corrected identification of a number of wartime features in Drewett's Park and at St Peter's Church.

GPR

The GPR data was processed using a combination of Reflexw, Reflex3Dscan and ArcGIS. Representation of the data in relation to topographic models of the sites, obtained using a combination of LiDAR data, terrestrial laser scanning and GPS survey, was also used in the analysis of the combined survey data. British Geological Survey data was used in both the assessment of field survey methodology and the analysis of the final survey data. The output from the GPS survey consisted of a sequence of vertical Z slices from each survey plus a sequence of XY plan slices for each of the survey areas. Both these outputs have been used in the interpretation and are presented as sequenced plots with each of the survey areas. The use of MPG output from Reflex 3D was a particularly useful tool when used in conjunction with Video to Picture Image Convertor, a freeware utility that allows for the rapid production of slices from GPR sequences. Timing of each sequence slice was determined by a combination of the step rate for output from ReflexW and the frame rate for conversion from digital video to digital stills. Correct numbering of each slice with the time/depth estimate was achieved using 'Total Commander' file management software. These sequences are presented with each relevant section.

The results for all methods are presented as an interpretive overlay with feature numbered on the illustrations presented in the text within square brackets []. A number of features are represented in the results of more than one survey methodology. To help comparison of such results a single number is used for each of these common features differentiated by a survey methodology prefix: M for gradiometry, G for GPR and R for resistivity. Overlays are presented for each individual method and are then compiled into a single interpretation of the final results for the combination of survey techniques. Where appropriate these interpretations are also presented with relevant historical maps, copies of excavation plans and aerial photographs derived from the extensive GIS developed as part of the data collection for the project. These are used as backdrops for each interpretation to better emphasise the correlation with already known features and highlight those previously unknown features revealed during the surveys.

Survey Results and Interpretation

Drewett's Park, Jarrow

Fluxgate Gradiometer Survey 2007 – reinterpretation of a survey by Archaeological Services Durham University (Figure 27)

A probable turning circle [M001] is clearly visible as a largely complete substantial anomaly. This feature is clearly visible on the ground as a raised earthwork and shows on aerial photographs as a parch mark. Interestingly, the feature isn't marked on the Hadrian's Wall National Mapping Survey (HWNMP) although it is clearly visible on the 1948 aerial photograph (Figure 30). A series of dipolar ferrous [M002] was detected and is associated with the individual tethers for the barrage balloon (Figure 29) that are clearly marked on the HWNMP transcription of the 1946 RAF post-war aerial photograph (RAF/3G/TUD/UK/125 5185 04-Apr-1946). It is clear that in some cases more than one of the dipolar spikes is associated with the remnants of an individual tethering post since the number of spikes detected exceeds the number transcribed from the aerial photograph (Figure 28). Four former paths share a characteristic response as a broken linear series of positive magnetic anomalies. Two are transcribed in the 2007 report as a continuous sinuous feature crossing the park from north-west to south-east, which does equate to parch marks clearly visible on aerial photographs and satellite imagery from Google Earth (Figure 32) but here they have been re-interpreted as two features, the north-west section [M004] equates to the pathway and a southeastern section [M005] equates partially to the remains of the trackway but also to the positive magnetic response from the rubble infill of the possible palaeochannel revealed in the resistivity survey. This infilled area is also clearly visible as a parch mark on the 1948 aerial photograph and extended into an area not surveyed with any of the methods available due to the planting of a stand of trees after 1948 (Figure 30). It is possible that the area of infill is contemporary with the deployment of the barrage balloon within the park since these balloons were probably transported by a 3 ton Fordson 'Sussex' (Figure 30) winch lorry and would require, at least initially, 30 cylinders of high pressure hydrogen gas, carried on a trailer behind the lorry, to inflate them. Such a weight would have required any soft ground to be reinforced to prevent the risk of the winch lorry and its trailer becoming bogged down during deployment. Two other pathways were detected [M003] and [M006] and these seem to be associated with access to the barrage balloon site. Two dipolar spikes were also recorded [M007] and [M008] that are thought to be associated with the series of air-raid shelters to the west of the survey area. These are clearly marked on the HWMNP survey and probably relate to external activity associated with the air-raid shelter. Indeed, the measurement between the centre of the dipolar spike [M007] and its partner [M009] is the same distance as between the vents that are shown on the HWNMP transcription. Two further dipolar spikes [M009] and [M010] are the remains of WWII Nissen hut platforms that served the barrage balloon site and are clearly marked on the HWNMP aerial transcription. Two features that were visible on the 1948 aerial photograph but not included on the gradiometry interpretation are the children's playground on the eastern edge of the survey (Figure 31, circled in green) and the public toilets in the south-east corner of the survey (Figure 31, circled in orange). Both the former playground area, now relocated to the north of the park, and the former public toilets are either in an areas of scrub or planting and not suitable for survey.

Ground Penetrating Radar (GPR) 2008 Results and Interpretation

c. 0.5 metres (Figures 33 to 35)

The large turning circle [G001] was also a prominent feature in the GPR results. The feature was detected to a depth of c.0.9 metres (Figure 35) and is clearly constructed of substantial metalling. This feature, unlike many of the other paths within the park, does not appear on early maps and may well be associated with access to the barrage balloon site rather than being a part of earlier landscaping of the area. The feature produced a much more pronounced response at its southern edge, some 46 metres from the southern edge of the survey area, than at the northern edge, adjacent to the children's playground and some 75 metres from the survey's southern edge. This feature sits within a slight slope and the stronger response is probably attributable to a thicker layer of metalling at the bottom of this slope. The children's playground to the north of the feature [G012] also seems to have had substantial foundation but was covered with a rubberised compound that prevented proper penetration of the GPR signal. To the east of the turning circle the tethers on the site of a barrage balloon [G002], survived to a depth of c. 0.9 metres (Figure 36) and although they were detected during the GPR survey produced a much weaker response compared to that obtained from either resistivity [R002] or the gradiometry [M002]. The large area of rubble filling the top of the possible palaeochannel [G005] was detected in the top one metre of the survey (Figure 37) and revealed a curvilinear band running in a north-west to south-east direction across the park. Its continuance to the south-east edge of the survey is partially masked by the sub-surface remains from the demolition of the public lavatories and their associated services in the south-east corner of the park. A small section of the air raid shelter [G011] was detected, the majority of this structure being outside the survey area, surviving to a depth in excess of 1.5 metres. The ephemeral remains of the nissen hut platforms [G013] and [G014] were detected in the GPR survey but were revealed more clearly in the vertical slices (Figure 38) and in the plan view. The former path revealed in the resistivity [R004] was also detected by the GPR survey [G004].

c. 0.75 metres (Figures 34, 36 and 38)

All the features present at the 0.5 metre level were also visible at the 0.75 metre level with the addition of a further former path [G015]. The infill of the palaeochannel [G005] was more defined at the 0.75 metre level and the effects of the WWII intervention within the park are clearly shown on its western edge where a rectangular disturbance from the siting of the air raid shelters is the most notable change to this feature. However, the edge of this feature, to the east of the present stand of trees, is no longer discernable in the plan view.

c. 1.00 metres (Figures 38 and 39)

Only features [G001], [G004], [G005] and [G011] were visible in the plan view at the one metre level. The path that appeared in shallower plots to go from northwest to southeast across the park appears at this level to be demarcating the edge of the WWII air raid shelter [G011]. The response for feature [G005] would seem to represent the base of the infill for the possible palaeochannel at this level.

c. 1.25 metres (Figures 40 and 41)

The last vestiges of the infill of the edge of the possible palaeochannel [G005] are visible at this level and the path [G004] continues to delineate the outline of the WWII air raid shelter. At this level the plan view of the GPR image of the northern section of this feature is the result of multiple reflections and not the survival of the path at this level. The probable turning circle [G001] also appears as a series of

multiple reflections on plan view plots at deeper levels with the strongest of these appearing the c.2.0 metres.

c. 1.5 metres – 2.75 metres (Figures 42 to 48)

With the exception of multiple reflections from features [G001] and [G004] the only feature visible through the depth range 1.5m -2.5m is the possible palaeochannel [G005]. The form of this feature at its western end is less clear due to the disturbance from the WWII air raid shelter but as it survives to at least a depth of 2.5 metres it must lie beyond any major construction trench for the shelter. The evidence from the HWMP data (Figure 28) would seem to support this and it is possible that the positioning of these WWII civil defences was significantly influenced by the presence of this channel.

Ground Penetrating Radar (GPR) 2009 - Results and Interpretation (Figures 49 to 60)

The GPR survey undertaken in 2009 repeated the southern half of the area covered in 2008. Interpretative illustrations for these results are only included where there is significant difference from the results obtained in 2008 (Figure 52). The extension of the survey to the south within the present line of trees was carried out with the intention of clarifying the southern boundary of the area thought to contain the palaeochannel [G005]. Unfortunately, in practice any new discoveries were large masked by the trees' extensive root systems [G016]. On advice from the English Heritage Archaeometry Branch an increased sample resolution of 0.05 metres was used along each one metre transect. Despite the increased resolution the number of features revealed was broadly similar to those detected in the earlier survey. However, the definition of the edges of some features was significantly improved and the exact boundary of, in particular, the southern edge of the area of infill over the possible palaeochannel [G005] became clearer. Conversely some features were less well defined within the results from the new survey. One case in particular, the area of impact of the WWII air raid shelters [G011], was virtually impossible to clearly identify. One further feature [G017] was identified in the south-east corner of the survey area and this almost certainly relates to the services connected with the former toilets within the park. The toilets first appear shown on the Ordnance Survey 1:2,500 County Series 3rd revision for 1938-1947 (Figure 53) and the Ordnance Survey 1:10,000 County Series 3rd revision for 1938. They disappear from the mapping between the Ordnance Survey 1:10,560 National Grid 1st revision dated 1957 and the Ordnance Survey 1:10,000 second revision dated 1967. Although the site of the building is beyond the survey area it is difficult to see what else this feature could be.

Resistivity Survey (Figures 61 and 62)

The range of features detected using resistivity survey was broadly similar to those detected using gradiometry. They ranged from the possible palaeochannel [R005] to the remnants of Civil Defence measures from WWII [R011]. The possible palaeochannel [R005] shows up very clearly running northwest to southeast across the survey area. The paleoenvironmental work in this area had suggested that this channel was filled with Victorian and later rubble but the low response from the resistivity confirms the results from the GPR [G005] that showed that this material is only present at a maximum depth of one metre with a significant moisture retentive feature below. The hut platforms [R013] visible on both the gradiometry and GPR plots show up here as a single high resistance feature. The individual tethers for the barrage balloon do not show up on the resistivity plot but are represented by a curvilinear feature [R002] that probably represents a combination of the tethers and the compaction of the ground around the perimeter of the balloon site. The turning circle [R001] was also detected as a high resistance curvilinear anomaly on the northern edge of the survey area with the remains of the footpath [R004] blending into its north-east edge. A more ephemeral higher resistance linear feature [R018] was detected at the eastern edge of the survey and could represent the remains of some earlier landscaping of the park. It is, however, not marked on any of the early maps or detectable on aerial photographs. The response is not strong enough to suggest the survival of sub-surface building remains. Along the southern edge of Drewett's Park the series of high resistance anomalies [R016] represent the roots of the current avenue of trees. One further feature, [R017] equates to the remains of the public toilets also represented on the plots from the GPR survey.

Figure 27: Results of the 2007 gradiometer survey Drewett's Park, Jarrow. (Courtesy of Archaeological Services, Durham University)

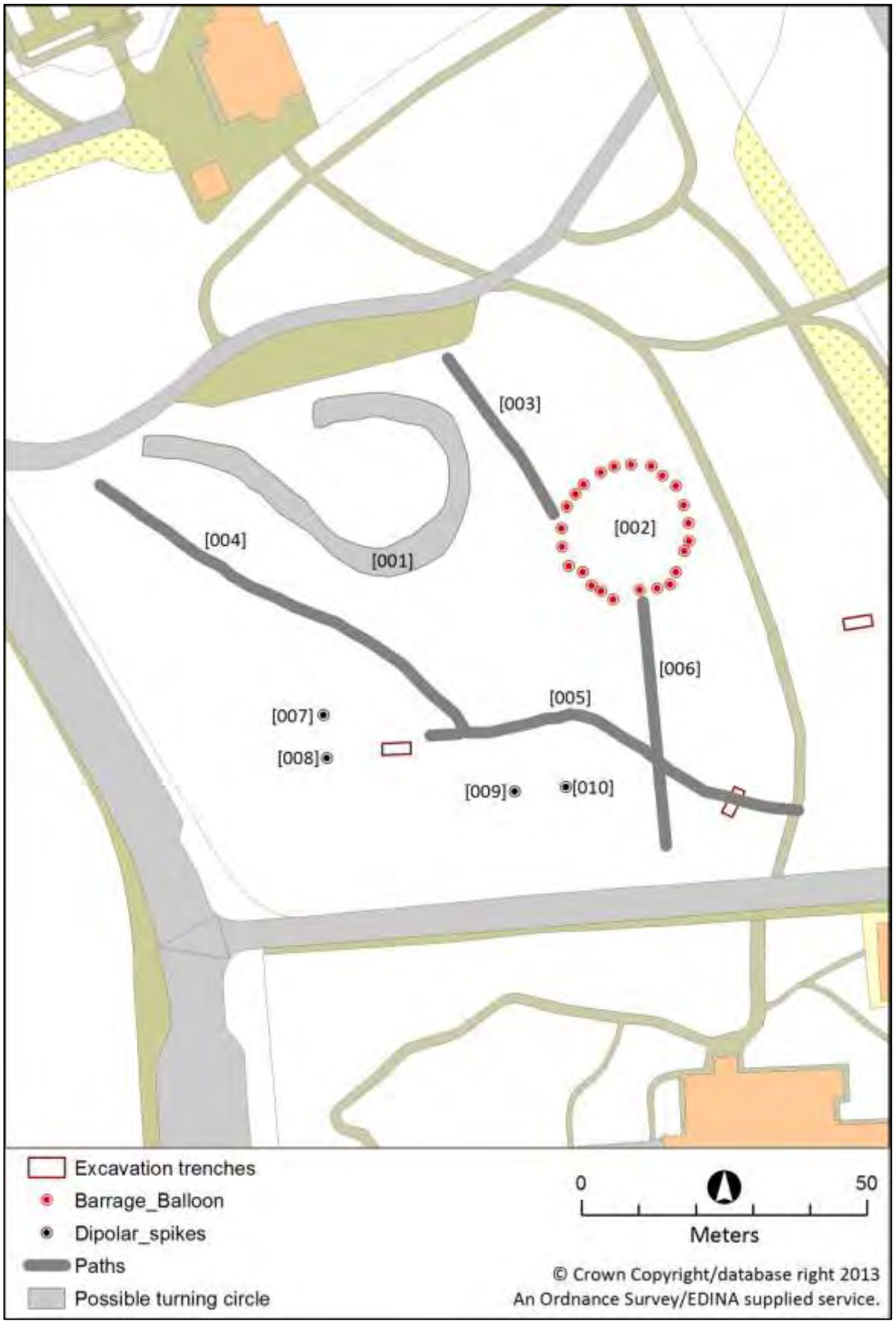


Figure 28: : Re-interpretation of the results of the 2007 gradiometer survey Drewett's Park, Jarrow.

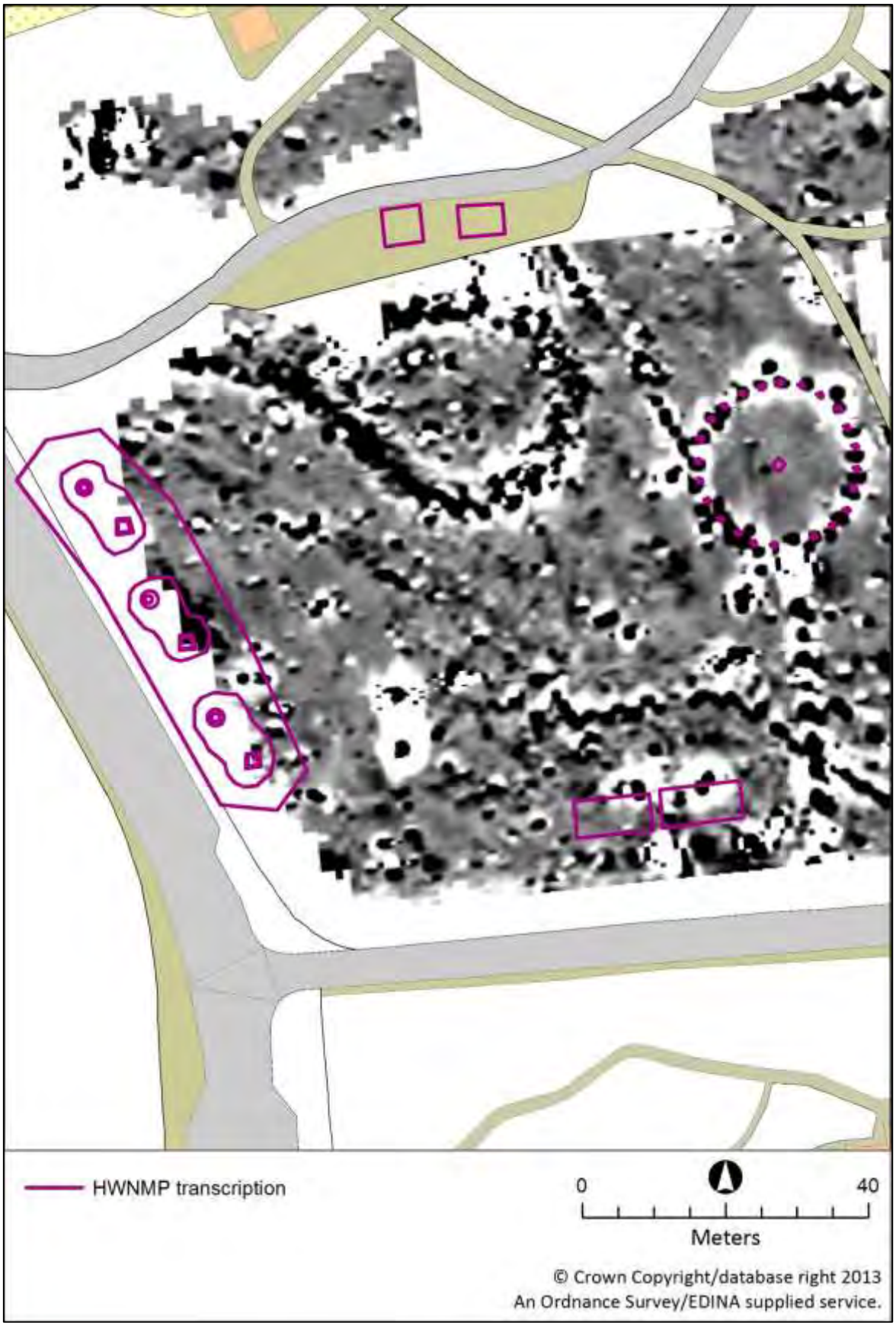


Figure 29: Comparison of the results of the 2007 gradiometer survey and the HWNMP transcription for Drewett's Park, Jarrow.

Figure 30: Example of a WWII barrage balloon tethering anchor. Results from the gradiometry indicate that a substantial part of each of these is still buried under Drewett's Park.

Figure 31: Fordson 'Sussex' barrage balloon transporter.

Figure 32: Comparison of the interpretation of the 2007 gradiometer survey and a rectified 1948 aerial photograph (Copyright Cambridge University BG-75)

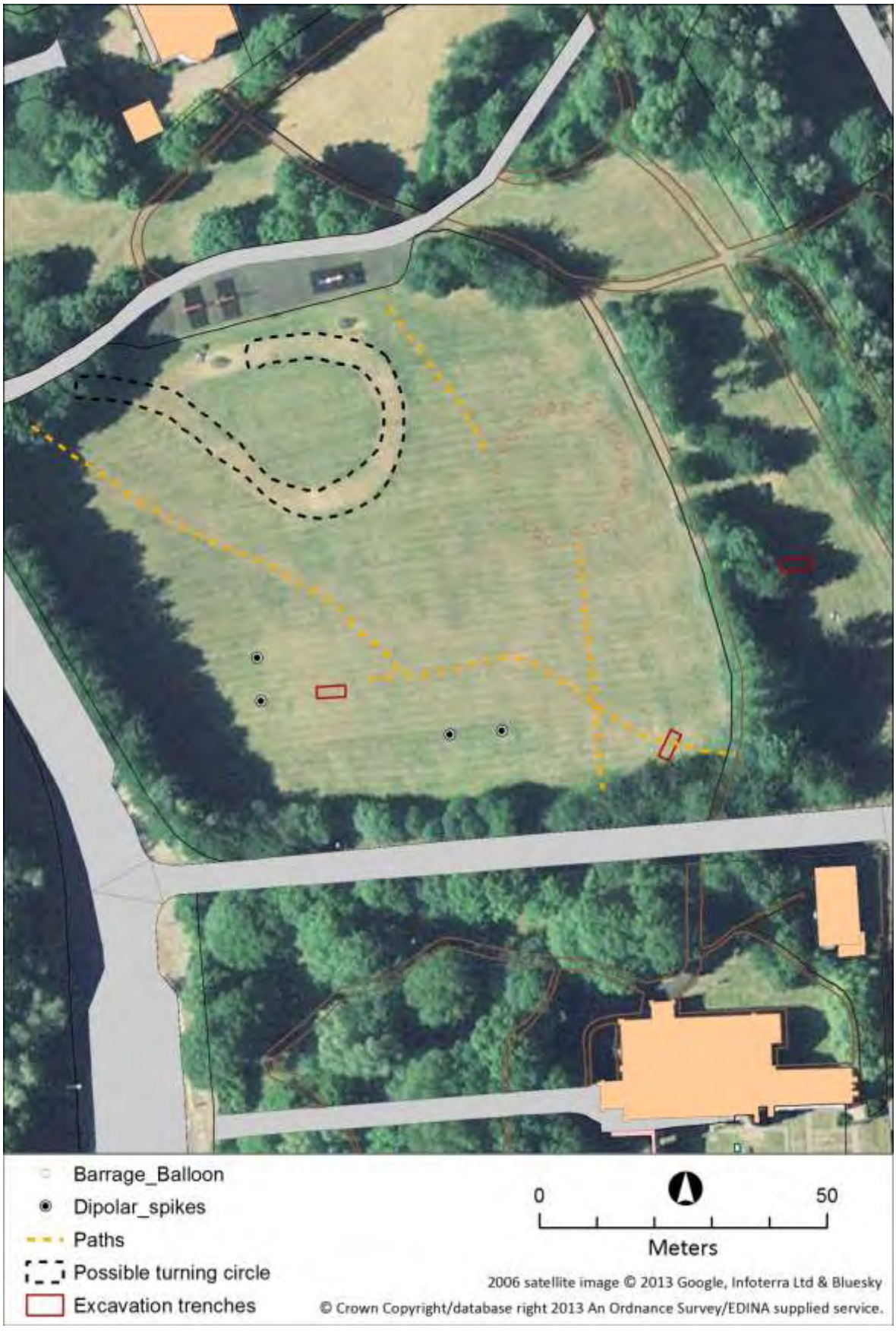


Figure 33: Comparison of the interpretation of the 2007 gradiometer survey and the georeferenced/rectified 2006 Google Earth satellite image.

Figure 34: GPR results Drewett's Park, 2008 – depth c. 0.5 metres

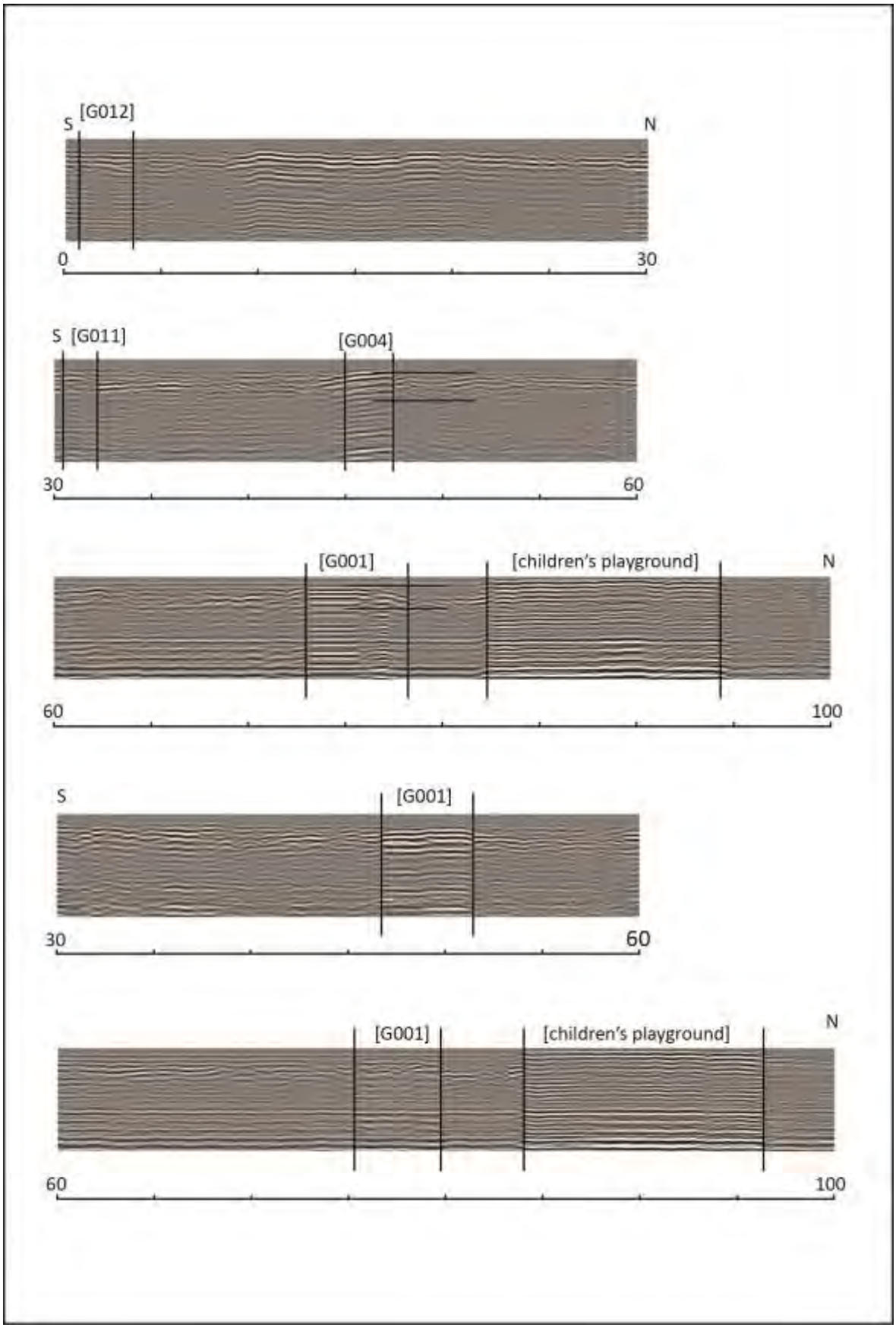


Figure 35: GPR results Drewett's Park, 2008 – vertical profiles intersecting with features [G001],[G004], [G011] and [G012].

Figure 36: GPR interpretation Drewett's Park, 2008 – depth c. 0.5 metres

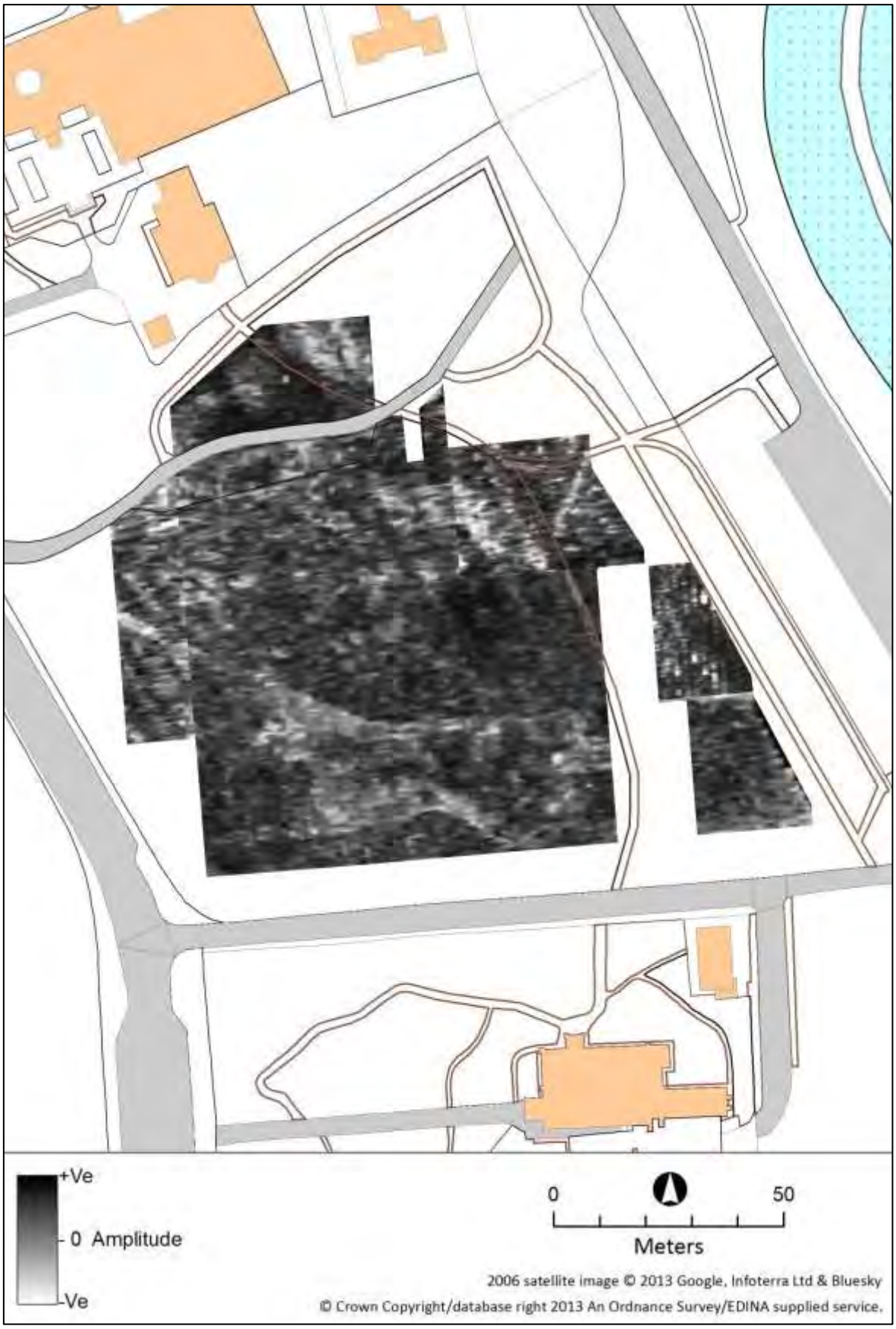


Figure 37: GPR results Drewett's Park, 2008 – depth c. 0.75 metres

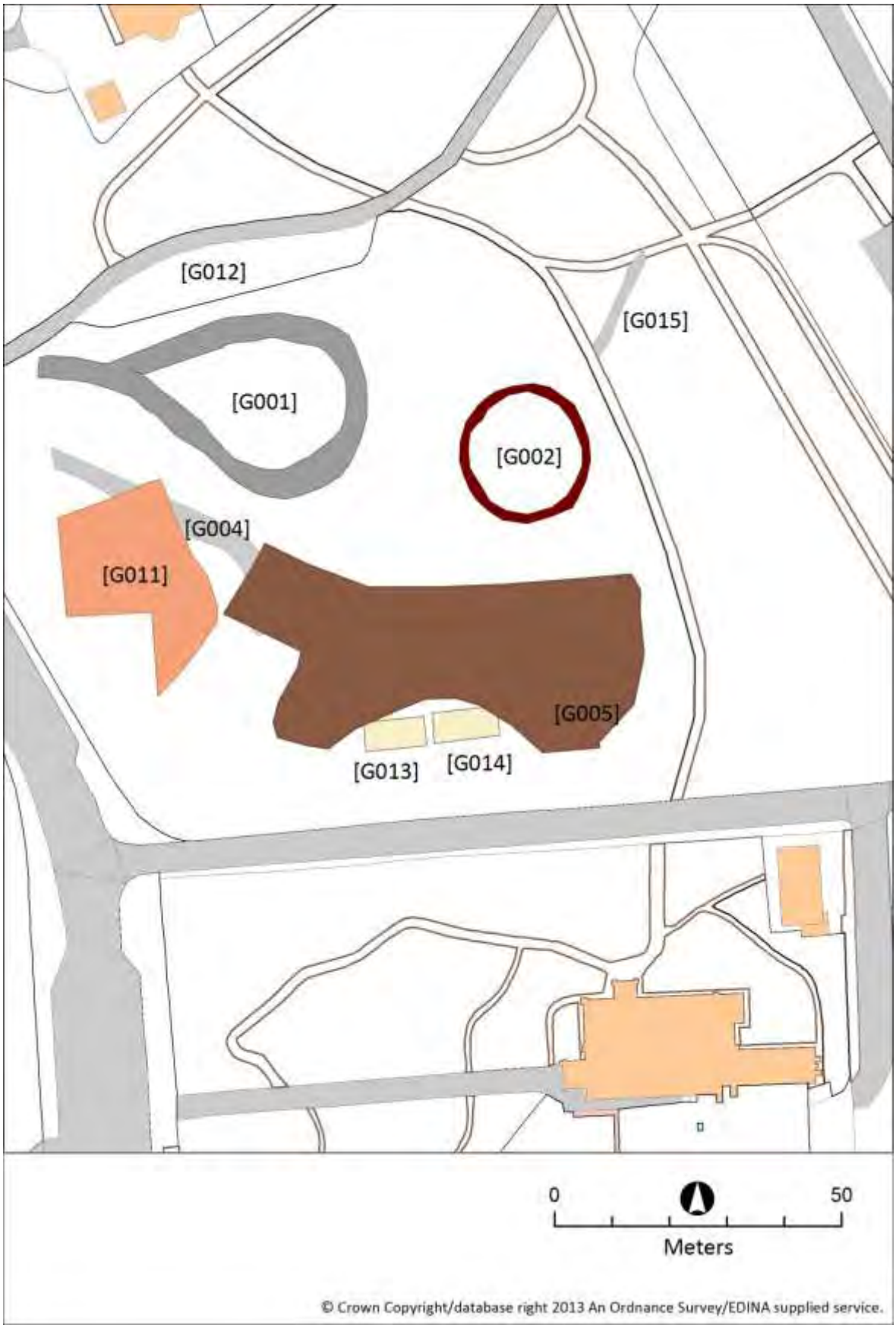


Figure 38: GPR interpretation Drewett's Park, 2008 – depth c. 0.75 metres

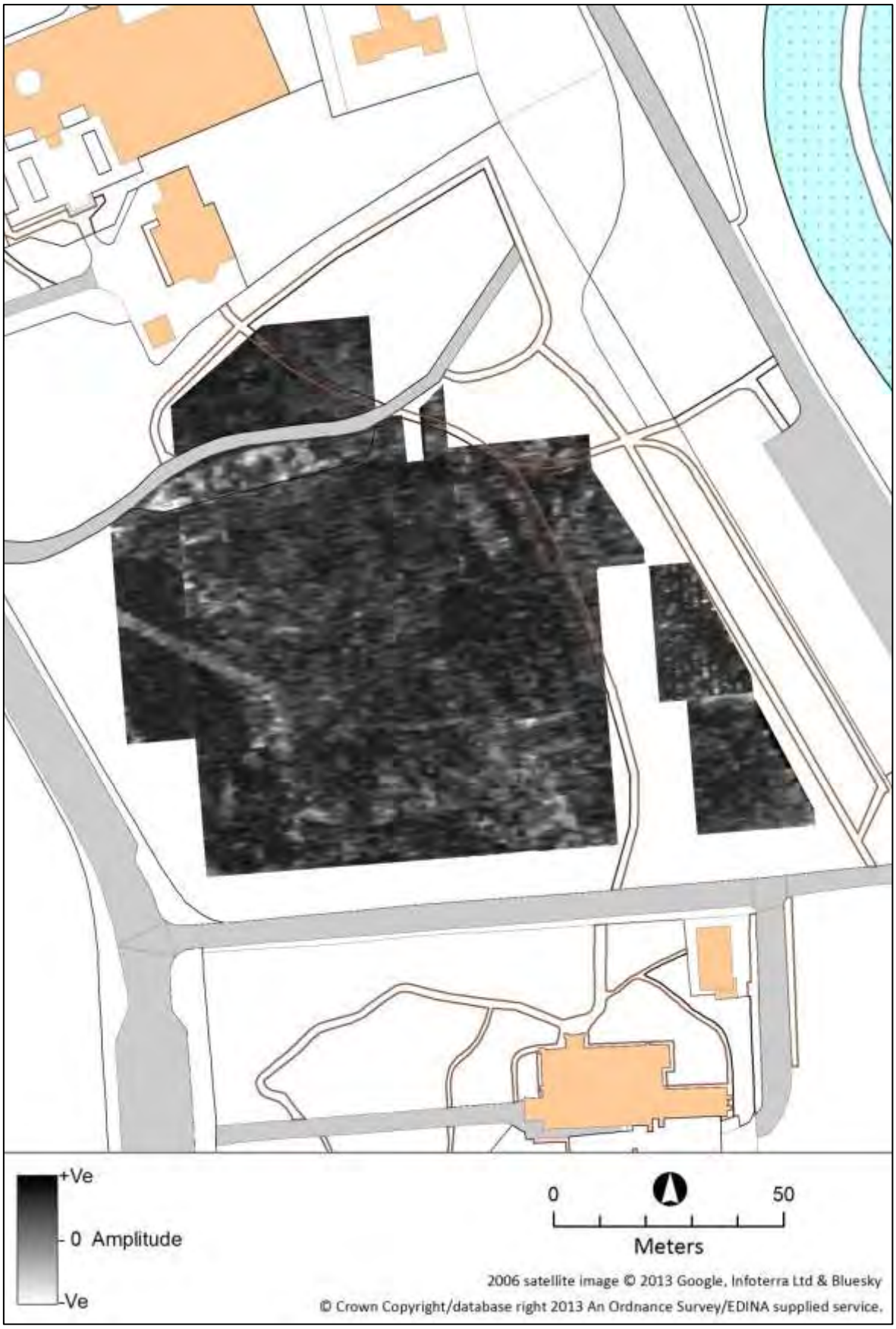


Figure 39: GPR results Drewett's Park, 2008 – depth c. 1.0 metres

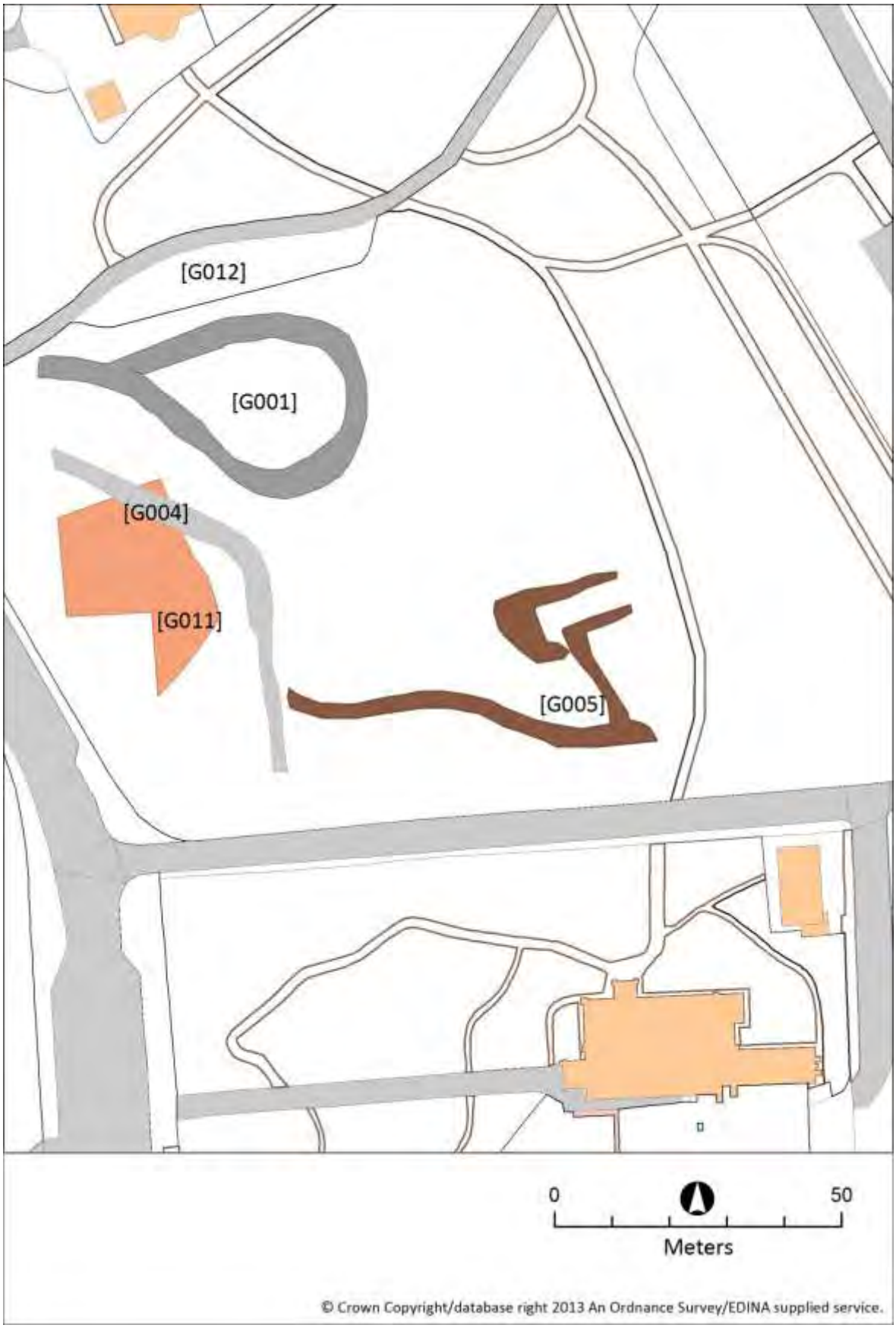


Figure 40: GPR interpretation Drewett's Park, 2008 – depth c. 1.0 metres

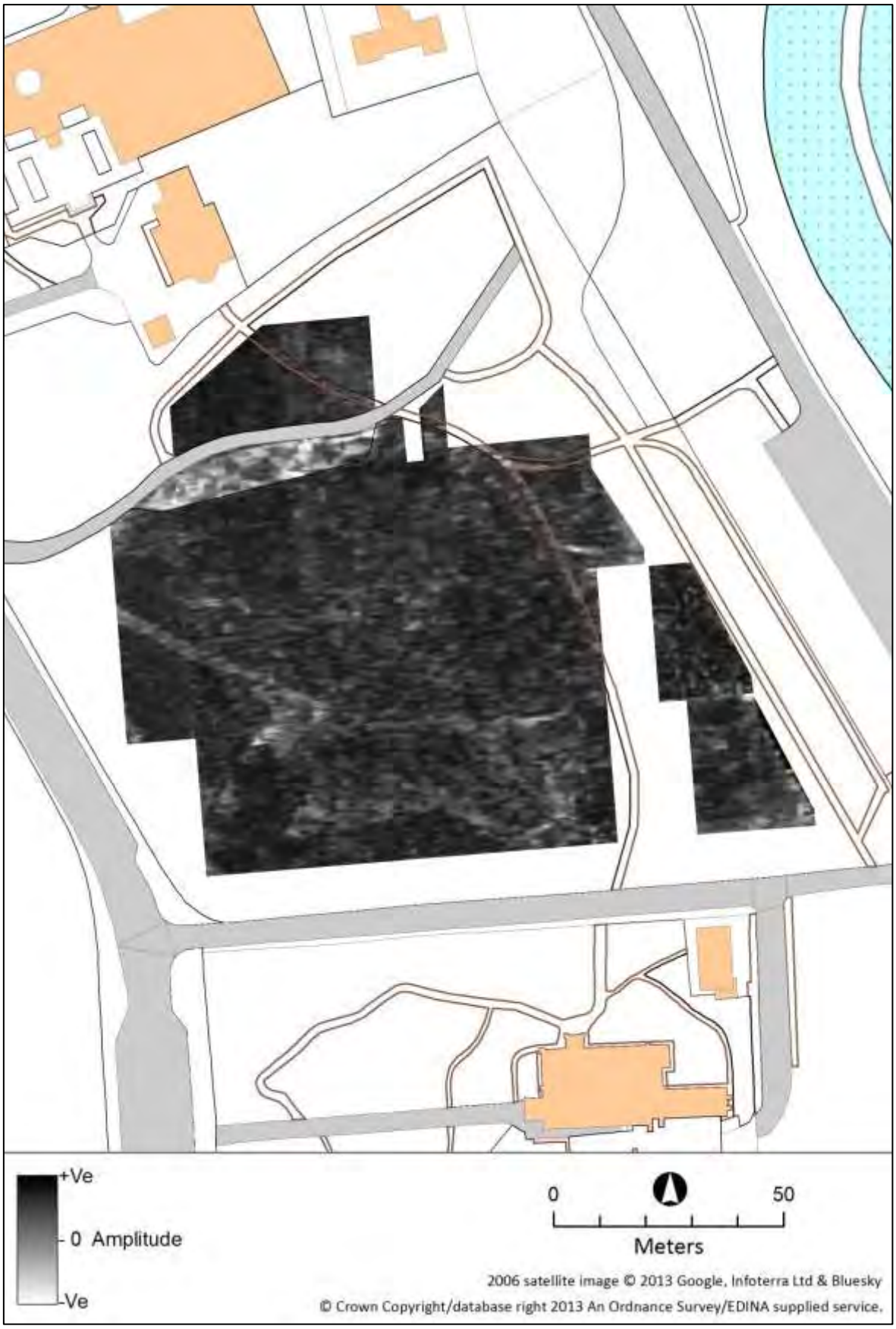


Figure 41: GPR results Drewett's Park, 200 – depth c. 1.25 metres

Figure 42: GPR interpretation Drewett's Park, 2008 – depth c. 1.25 metres

Figure 43: GPR results Drewett's Park, 2008 – depth c. 1.5 metres

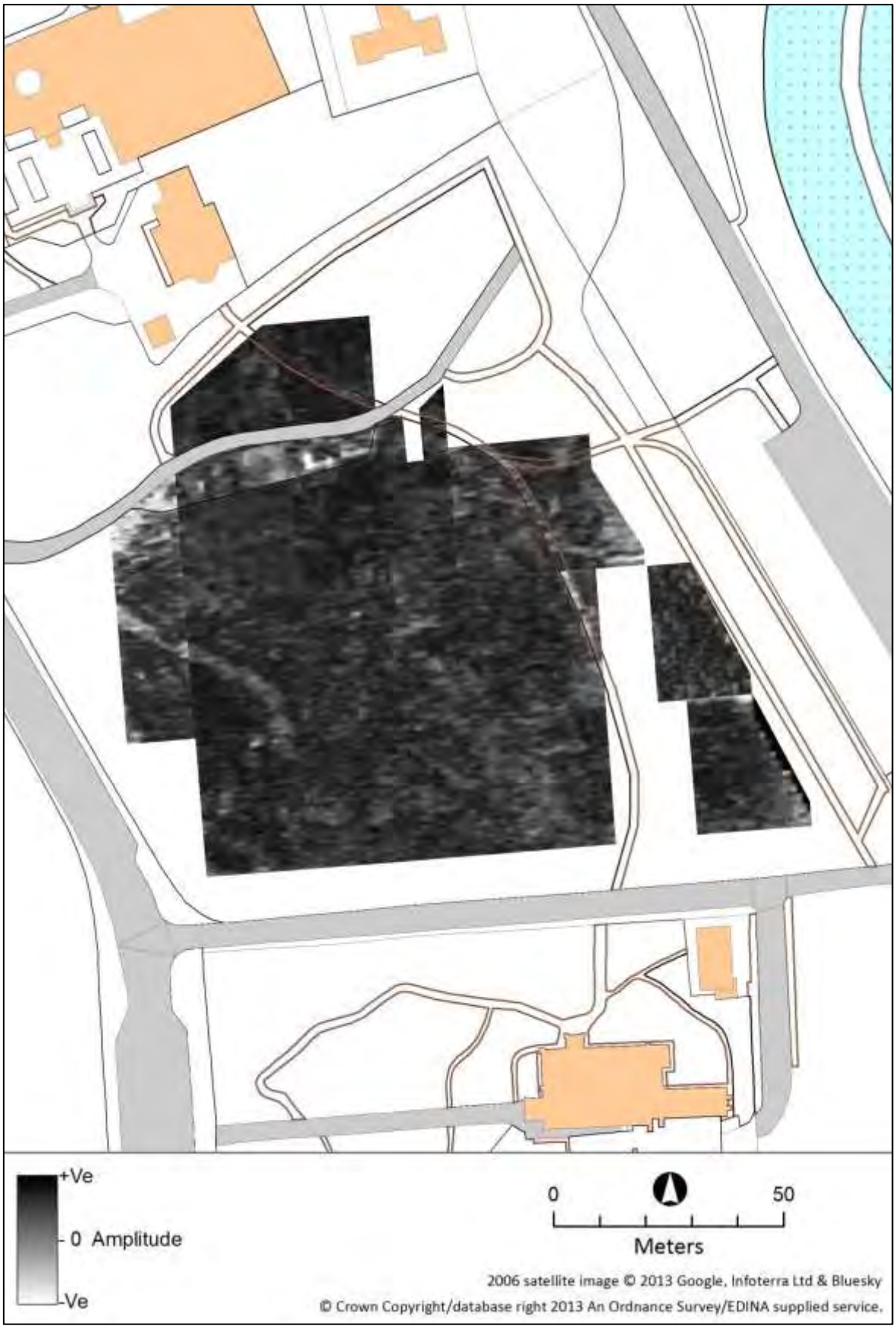


Figure 44: GPR results Drewett's Park, 2008 – depth c. 1.75 metres

Figure 45: GPR results Drewett's Park, 2008 – depth c. 2.0 metres

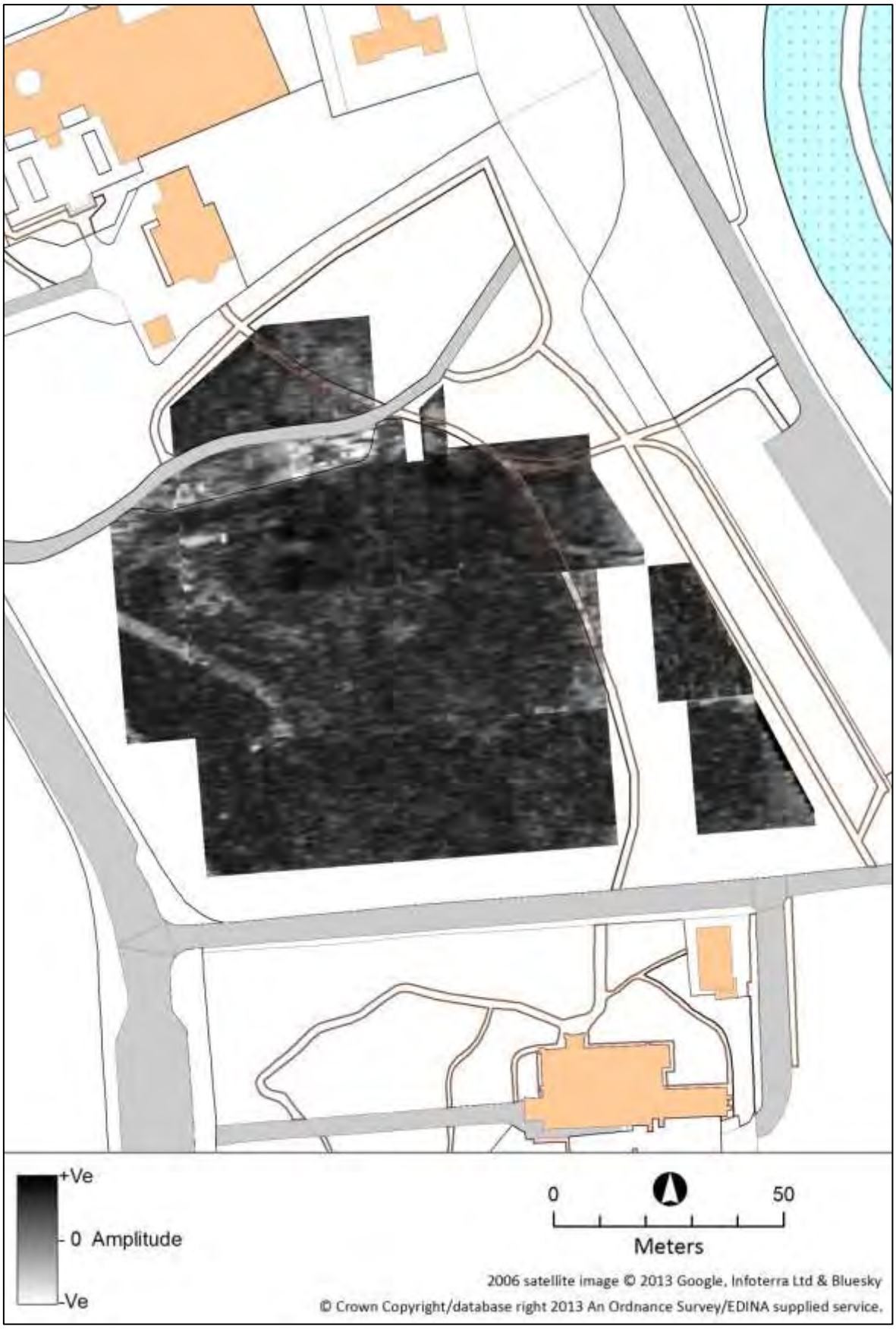


Figure 46: GPR results Drewett's Park, 2008 – depth c. 2.25 metres

Figure 47: Figure 46: GPR results Drewett's Park, 2008 – depth c. 2.5 metres

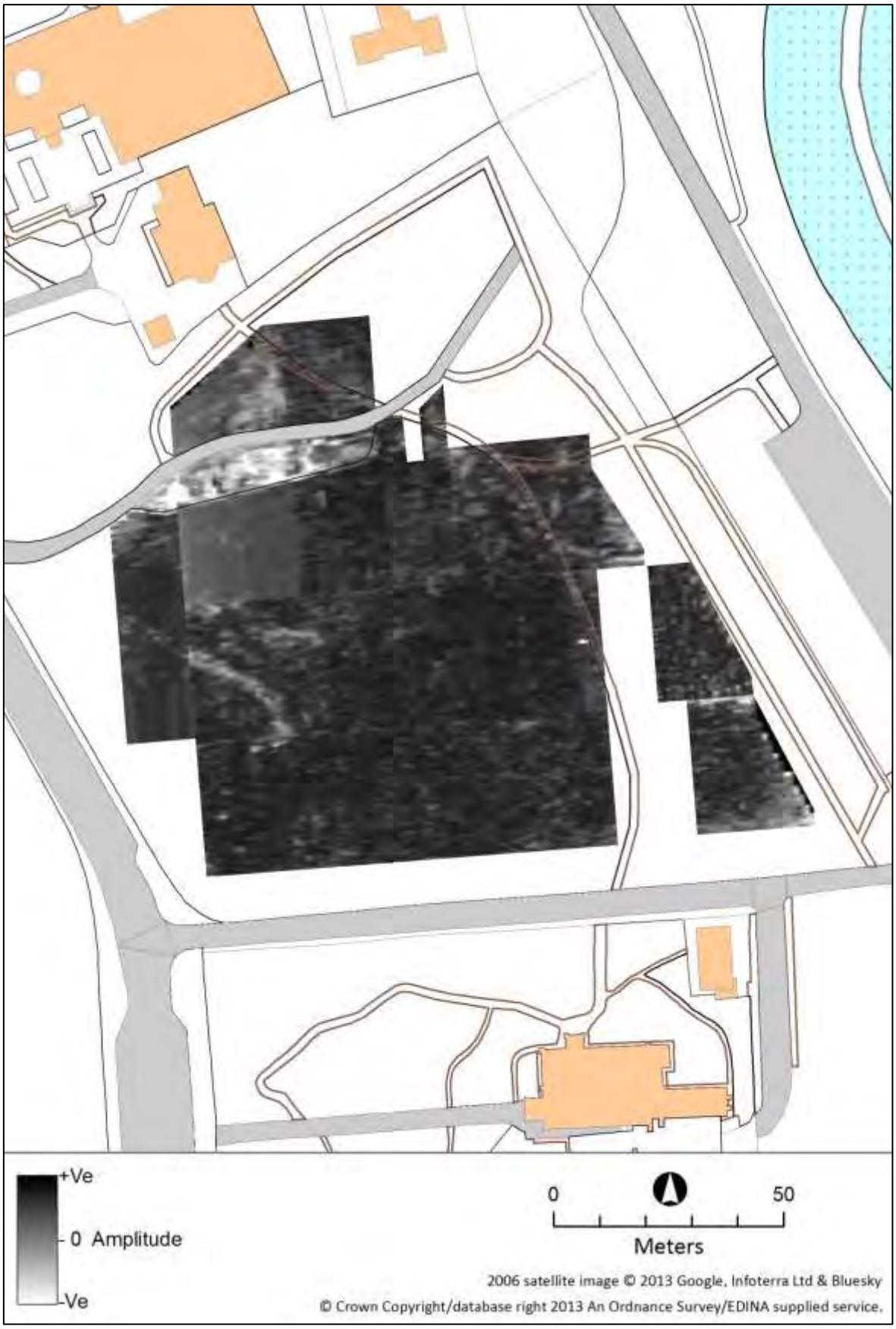


Figure 48: GPR results Drewett's Park, 2008 – depth c. 2.75 metres

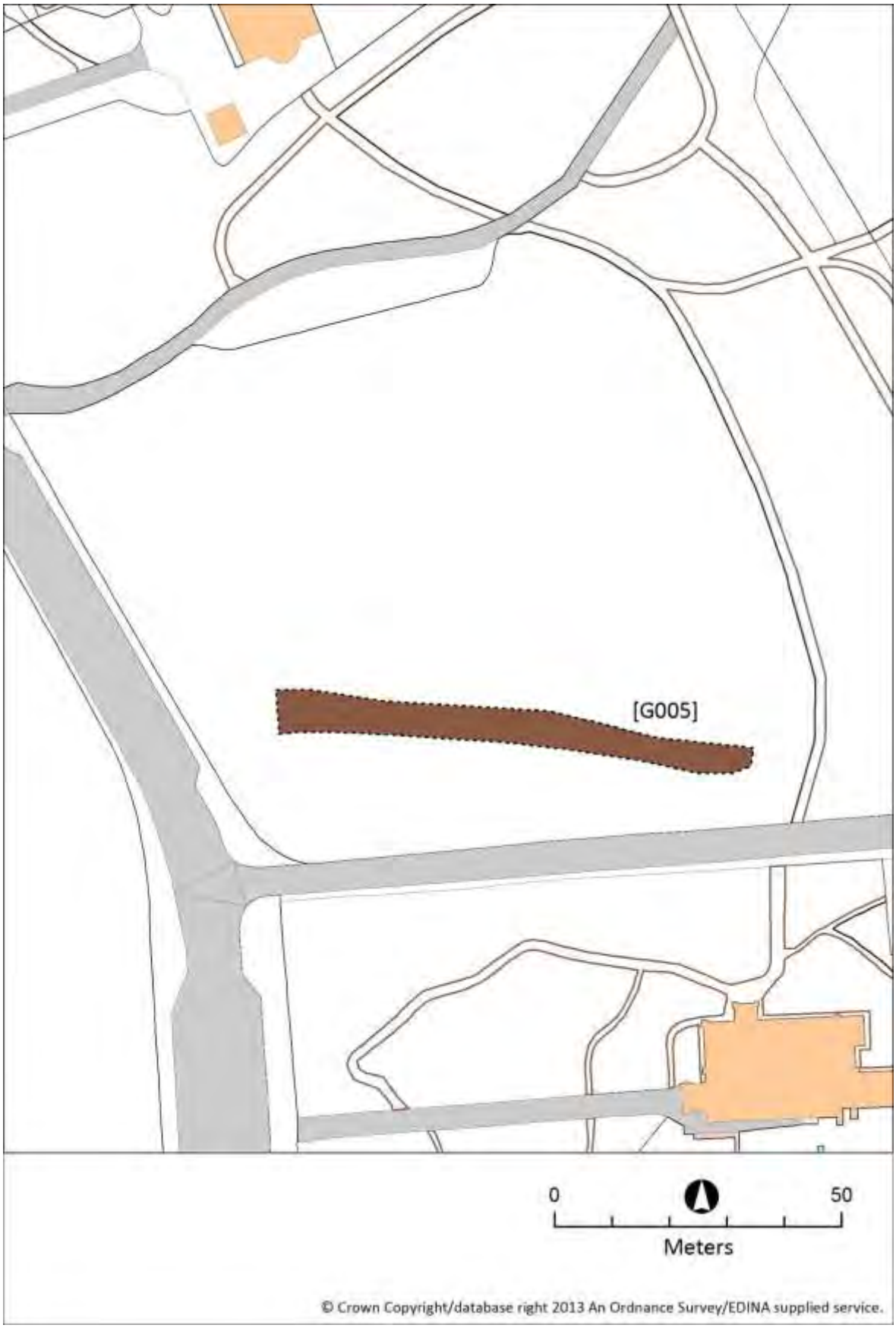


Figure 49: GPR interpretation Drewett's Park, 2008 – depth c. 1.5 – 2.75 metres

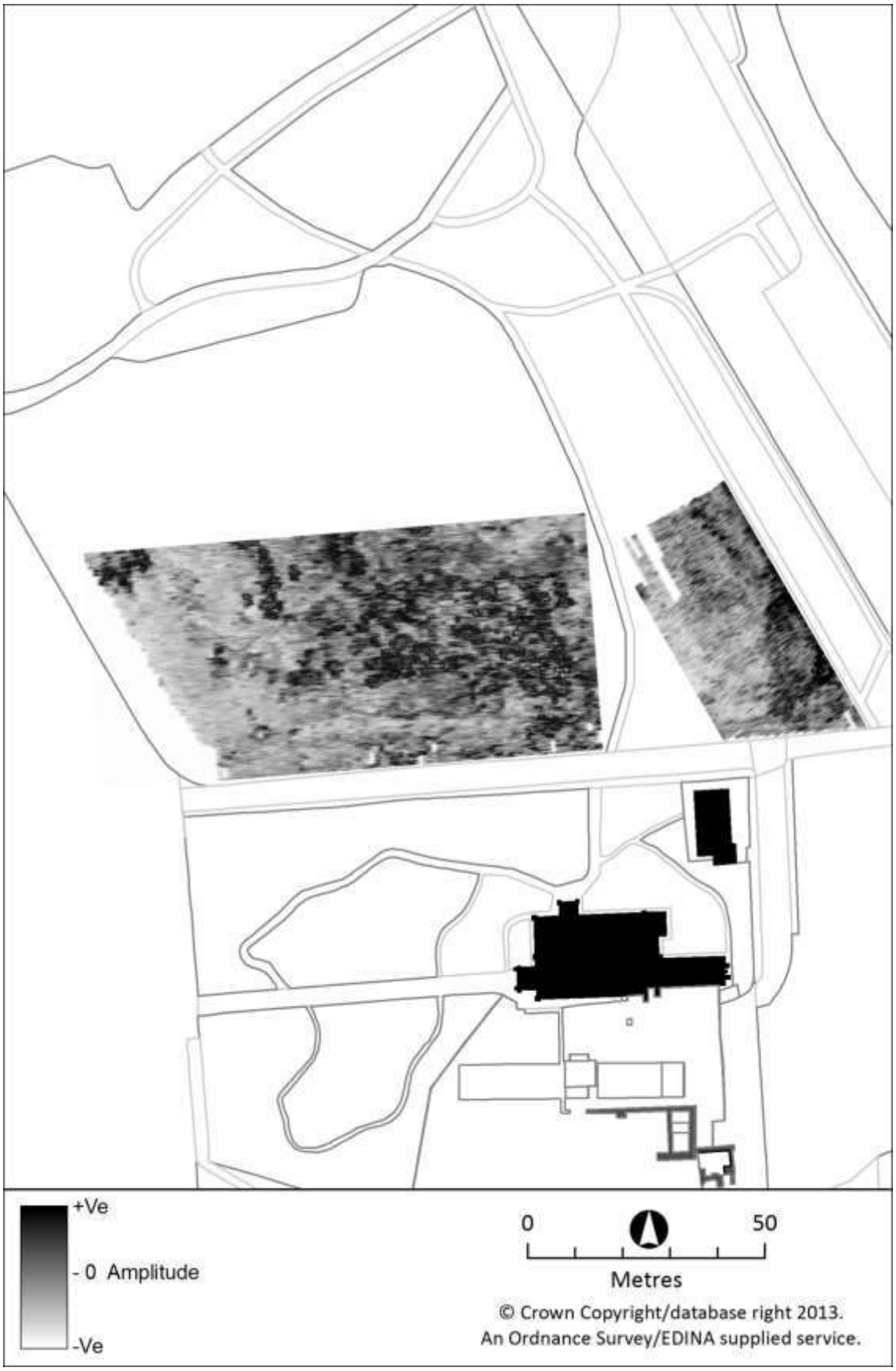


Figure 50: GPR results Drewett's Park, 2009 – depth c.0.5 metres

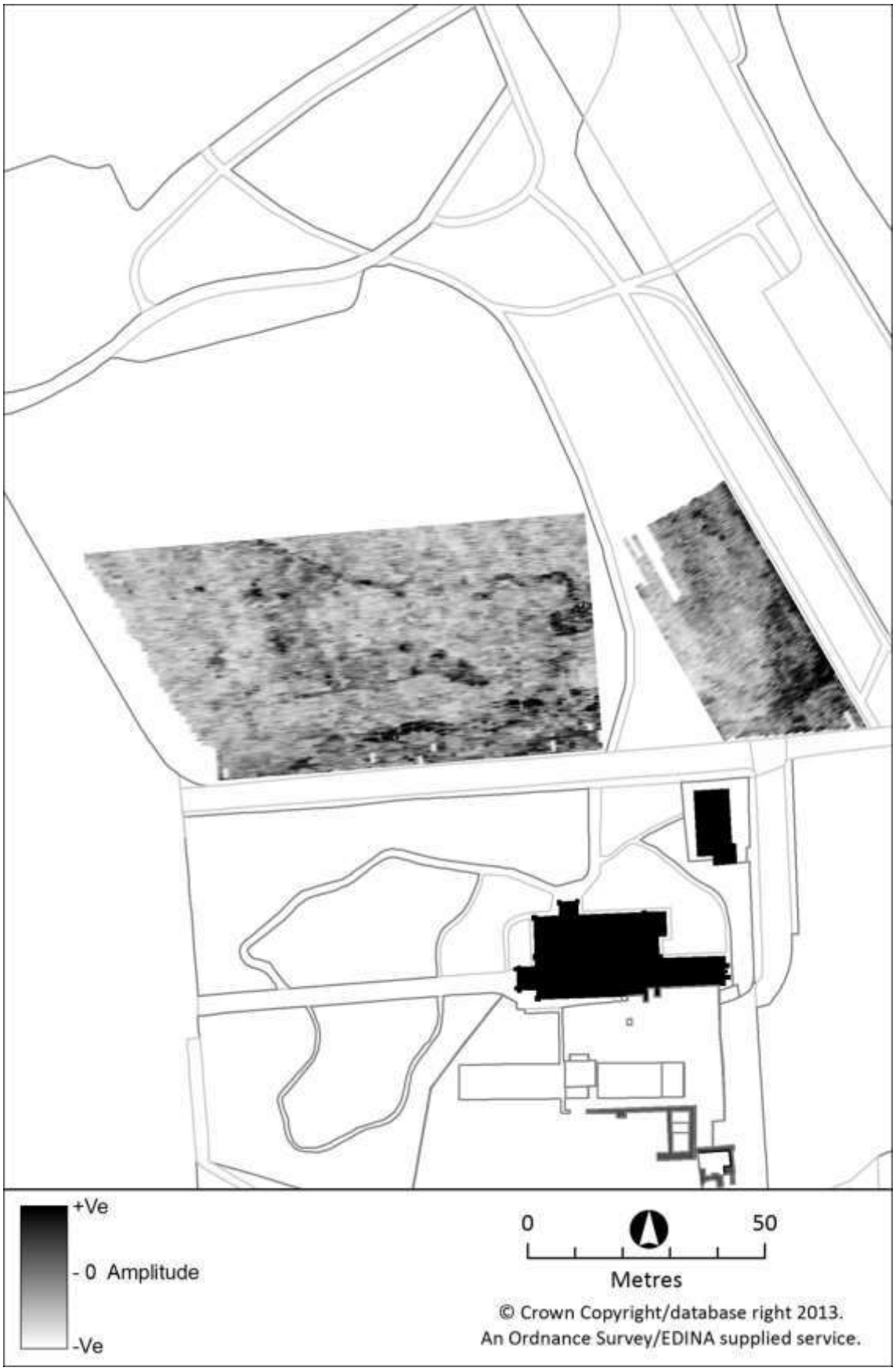


Figure 51: GPR results Drewett's Park, 2009 – depth c.0.75 metres

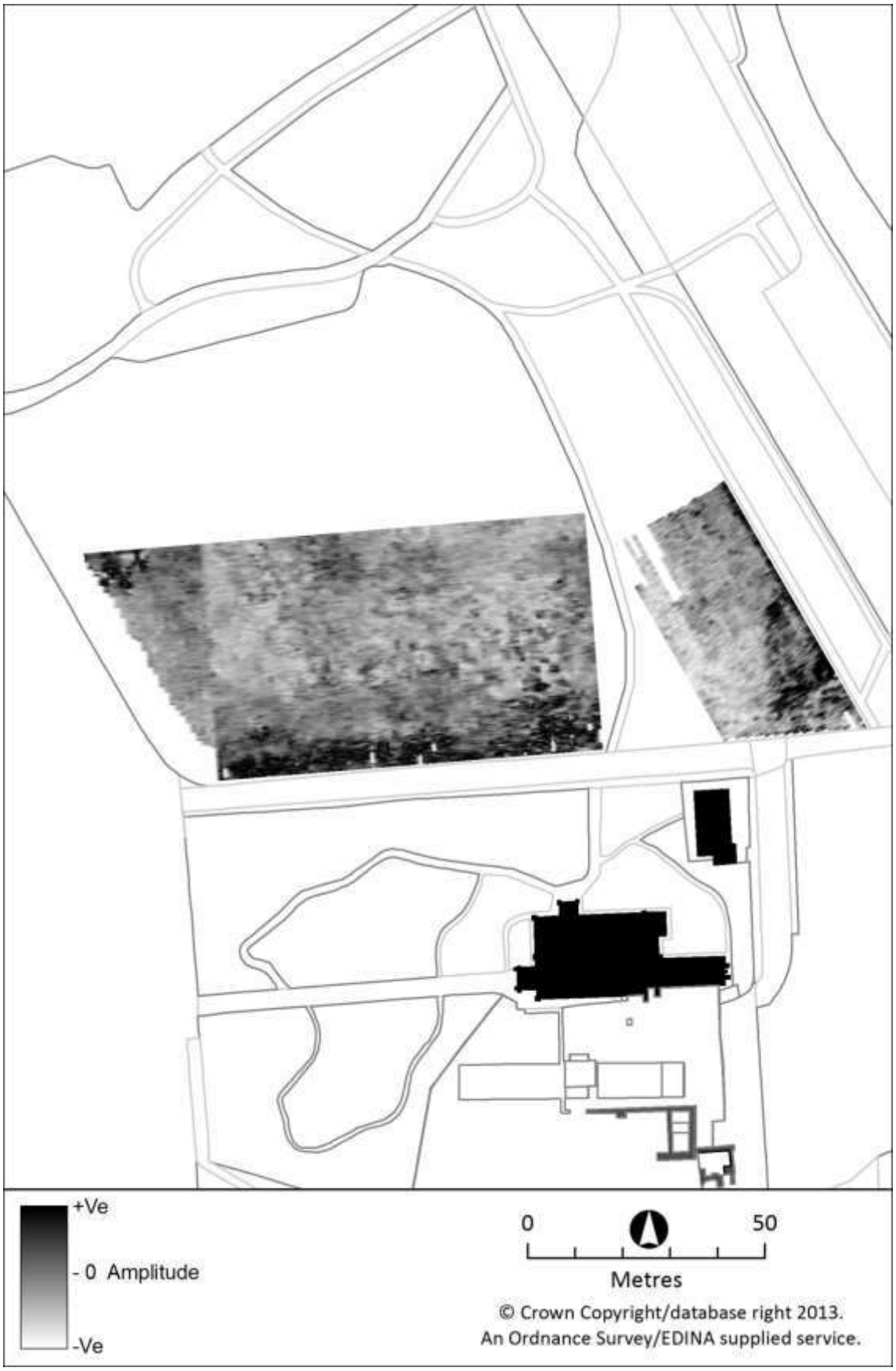


Figure 52: GPR results Drewett's Park, 2009 – depth c.1.0 metres

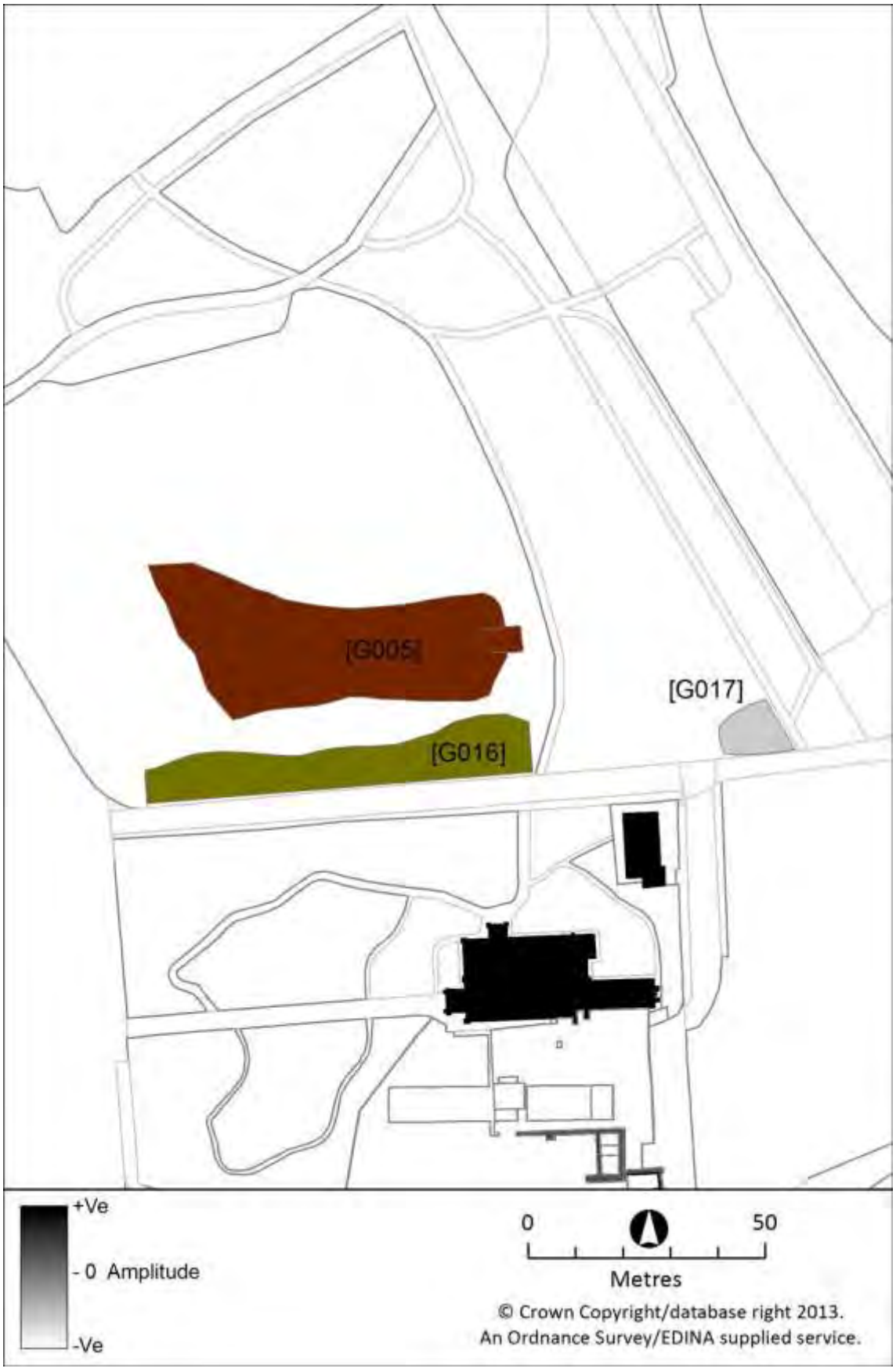


Figure 53: GPR Drewett's Park, 2009 – additional information since the 2008 survey

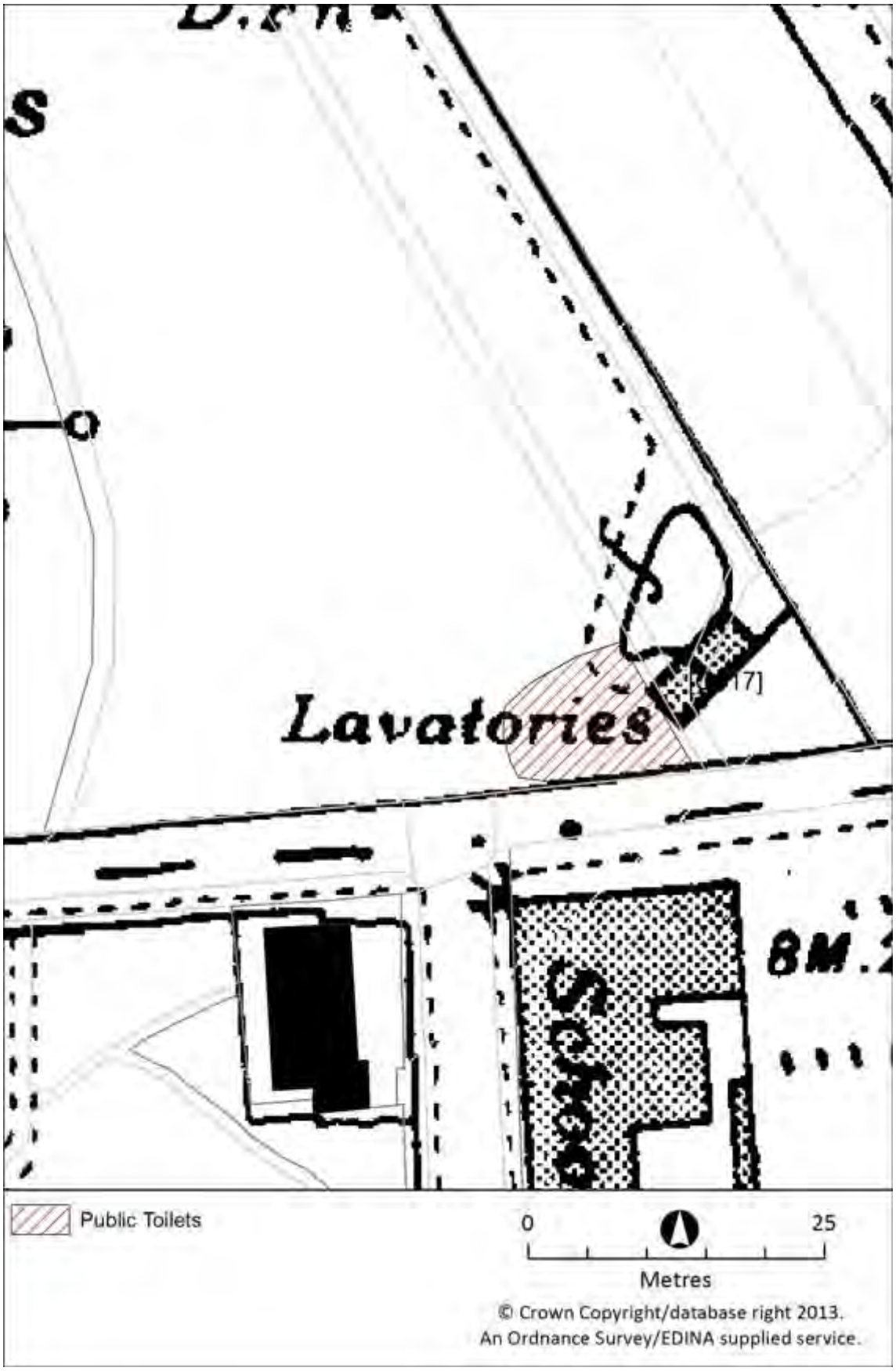


Figure 54: Location of the public toilets, Dreweett's Park 1938-1967.

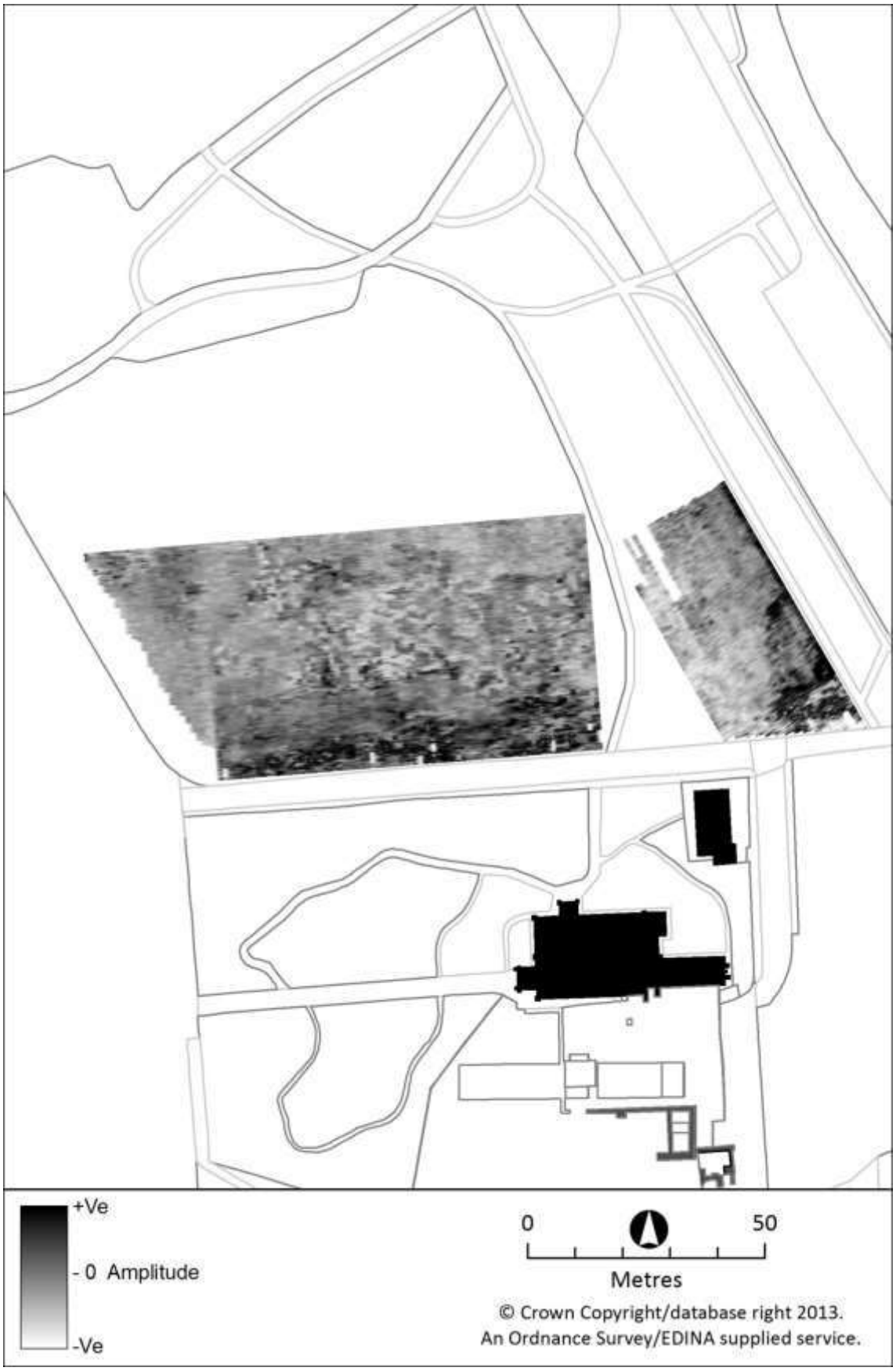


Figure 55: GPR results Drewett's Park, 2009 – depth c.1.25 metres

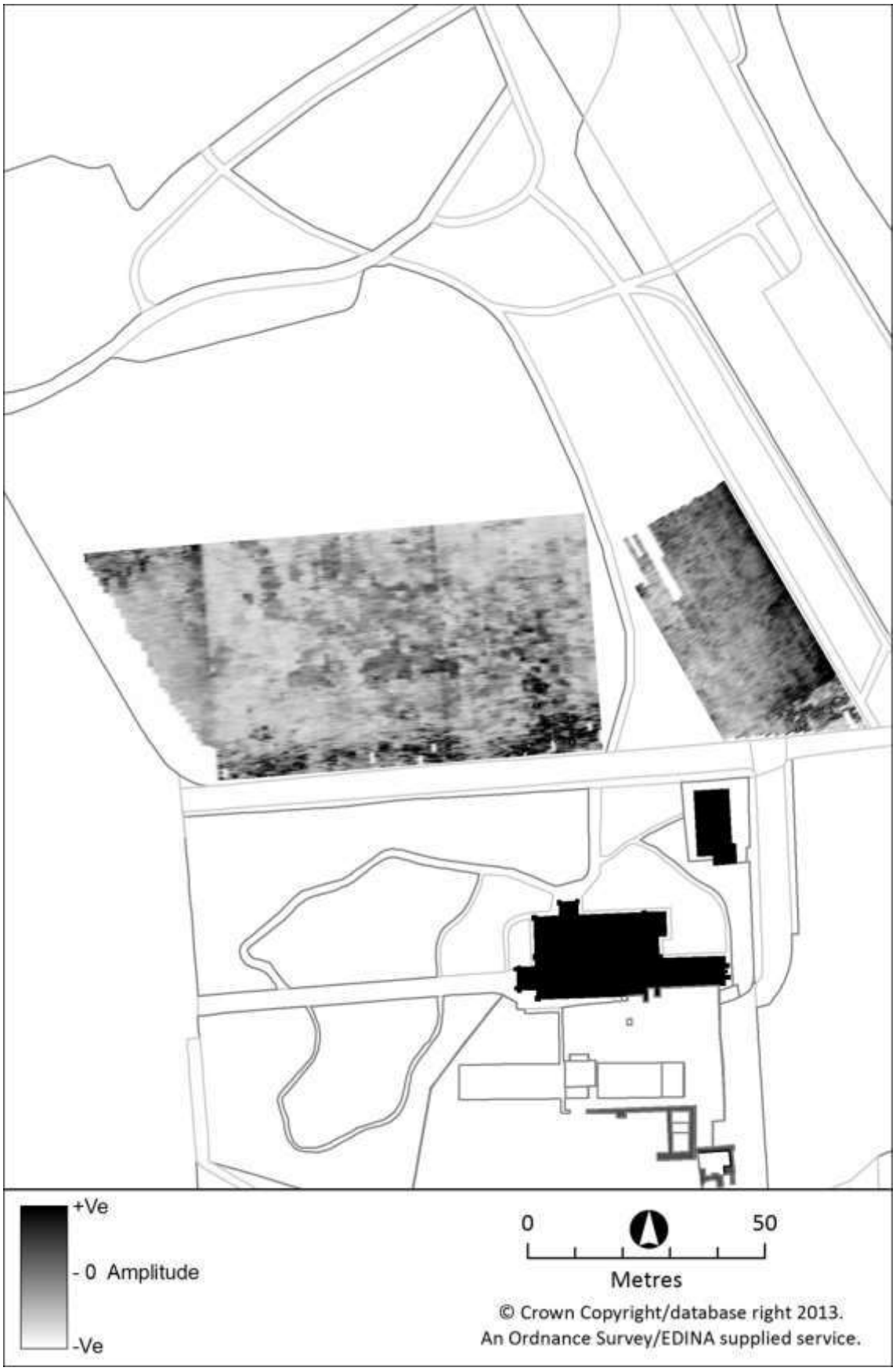


Figure 56: GPR results Drewett's Park, 2009 – depth c.1.5 metres

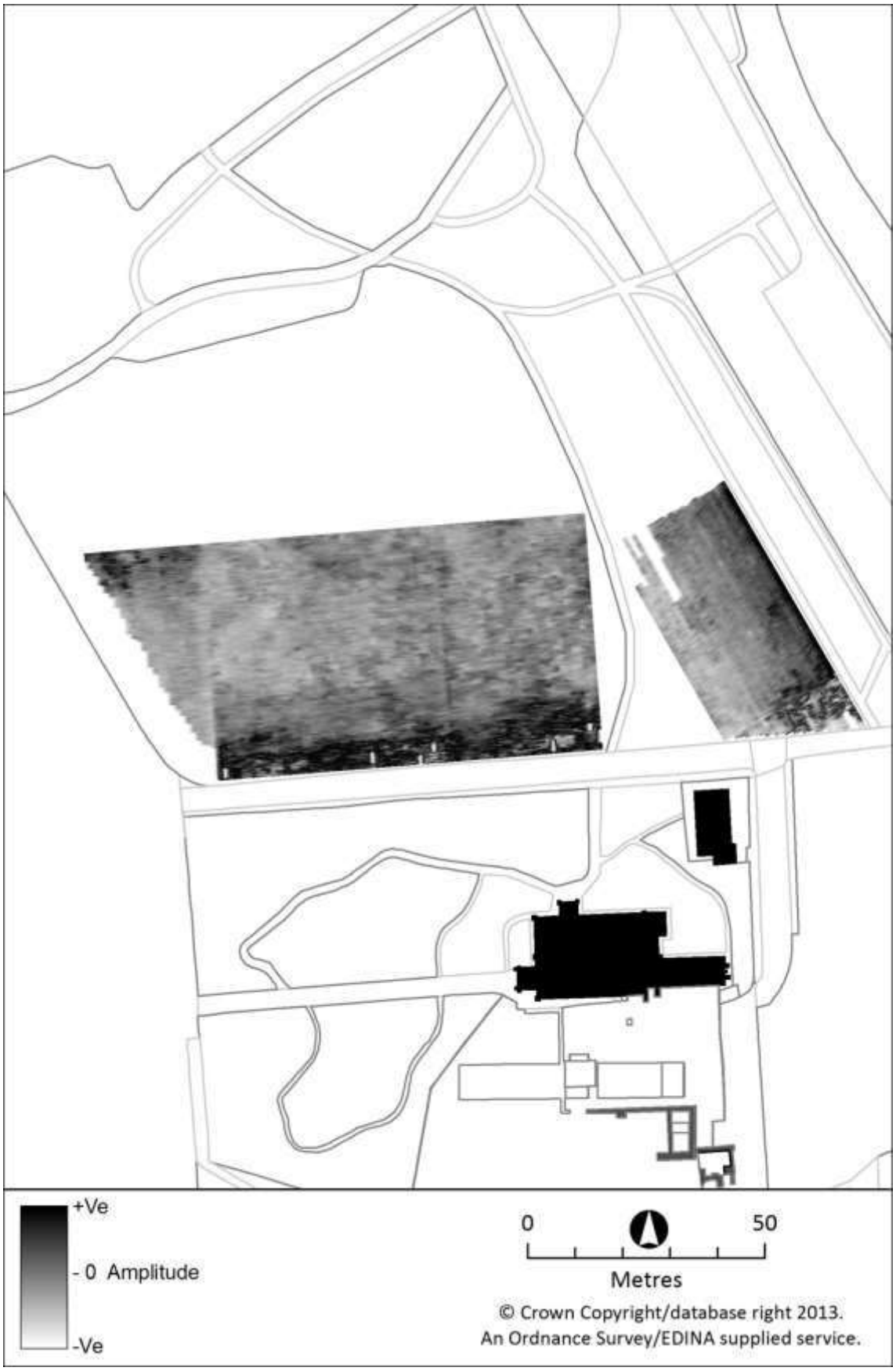


Figure 57: GPR results Drewett's Park, 2009 – depth c.1.75 metres

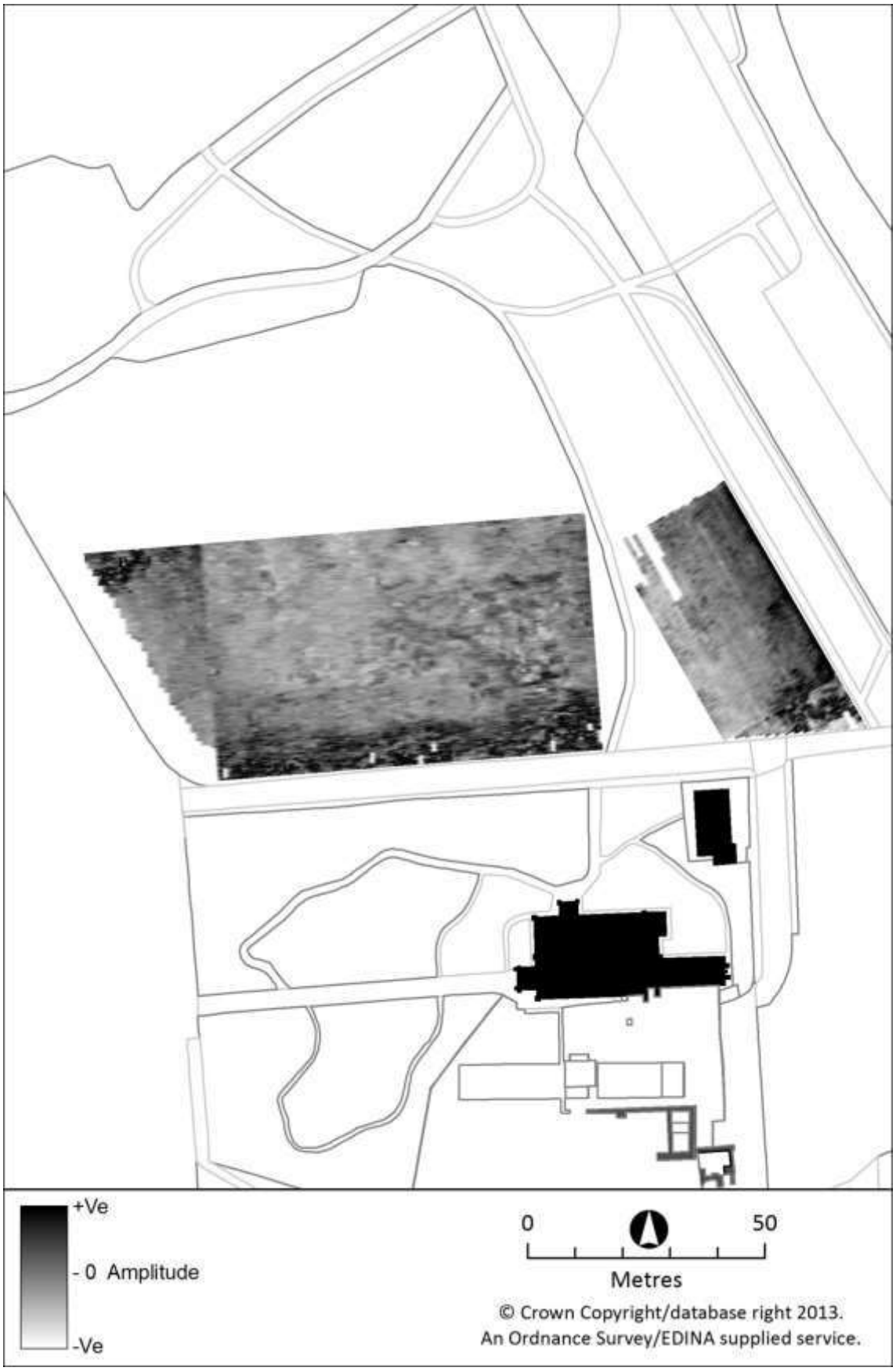


Figure 58: GPR results Drewett's Park, 2009 – depth c.2.0 metres

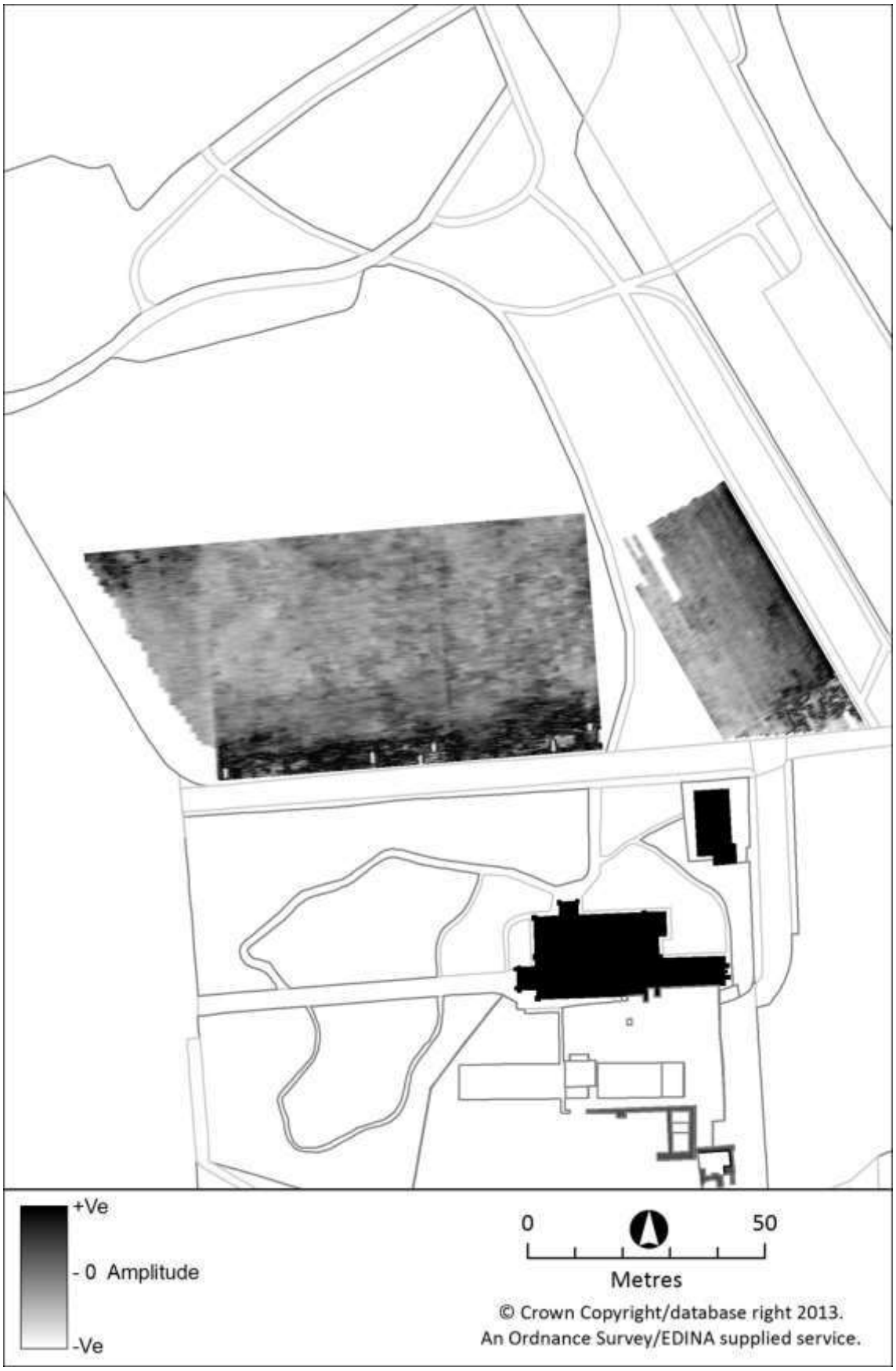


Figure 59: GPR results Drewett's Park, 2009 – depth c.2.25 metres

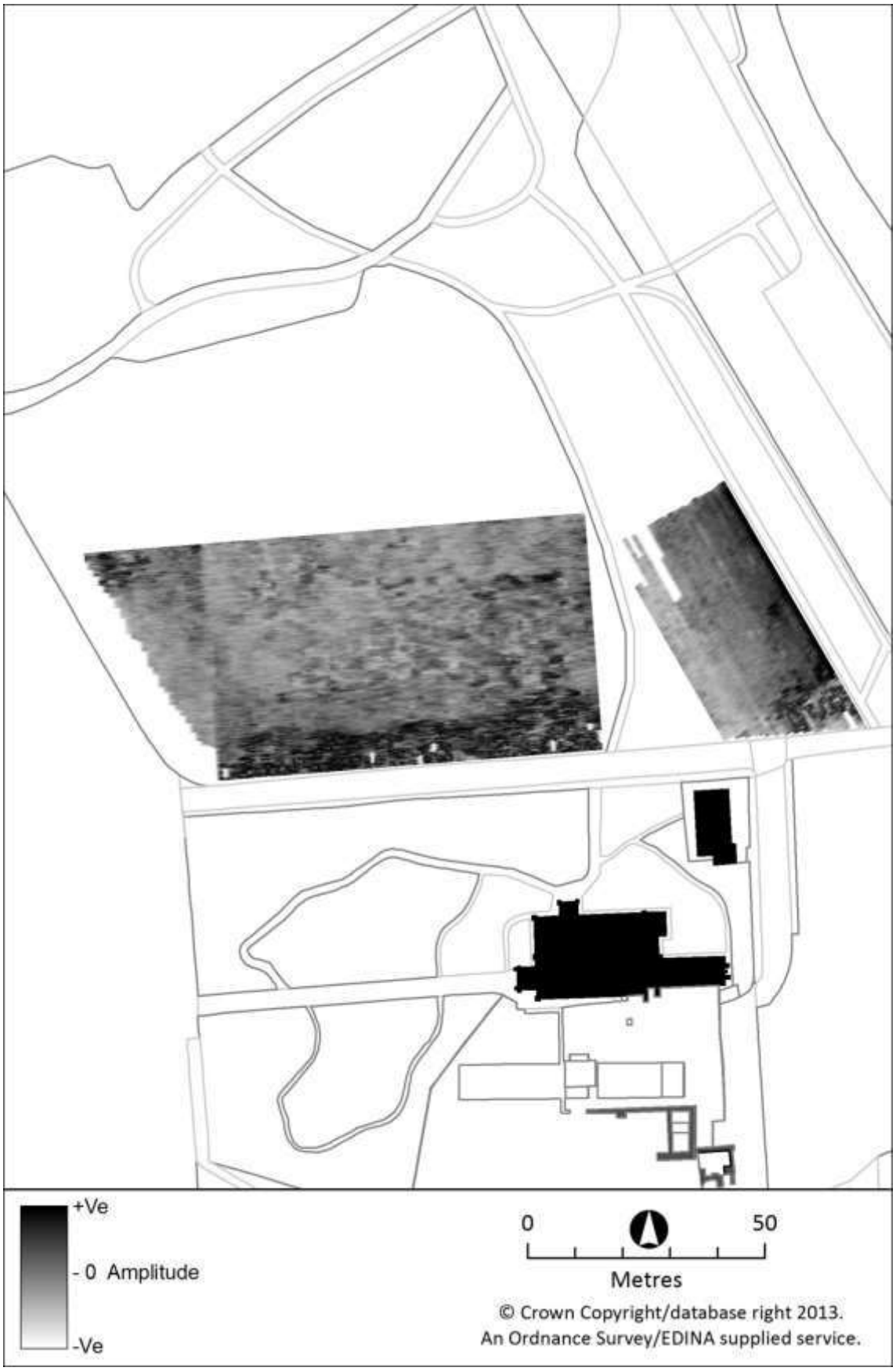


Figure 60: GPR results Drewett's Park, 2009 – depth c.2.5 metres

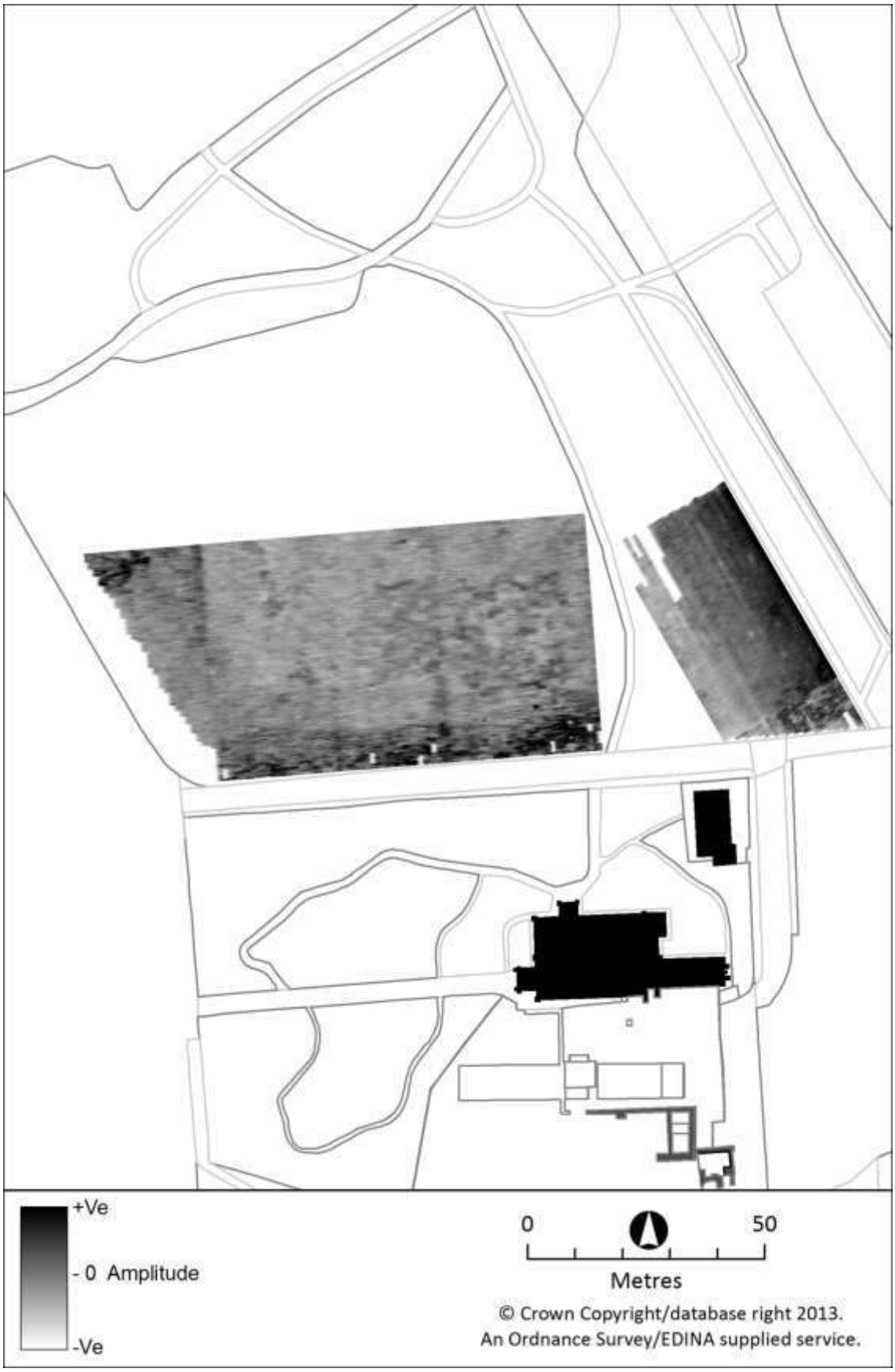
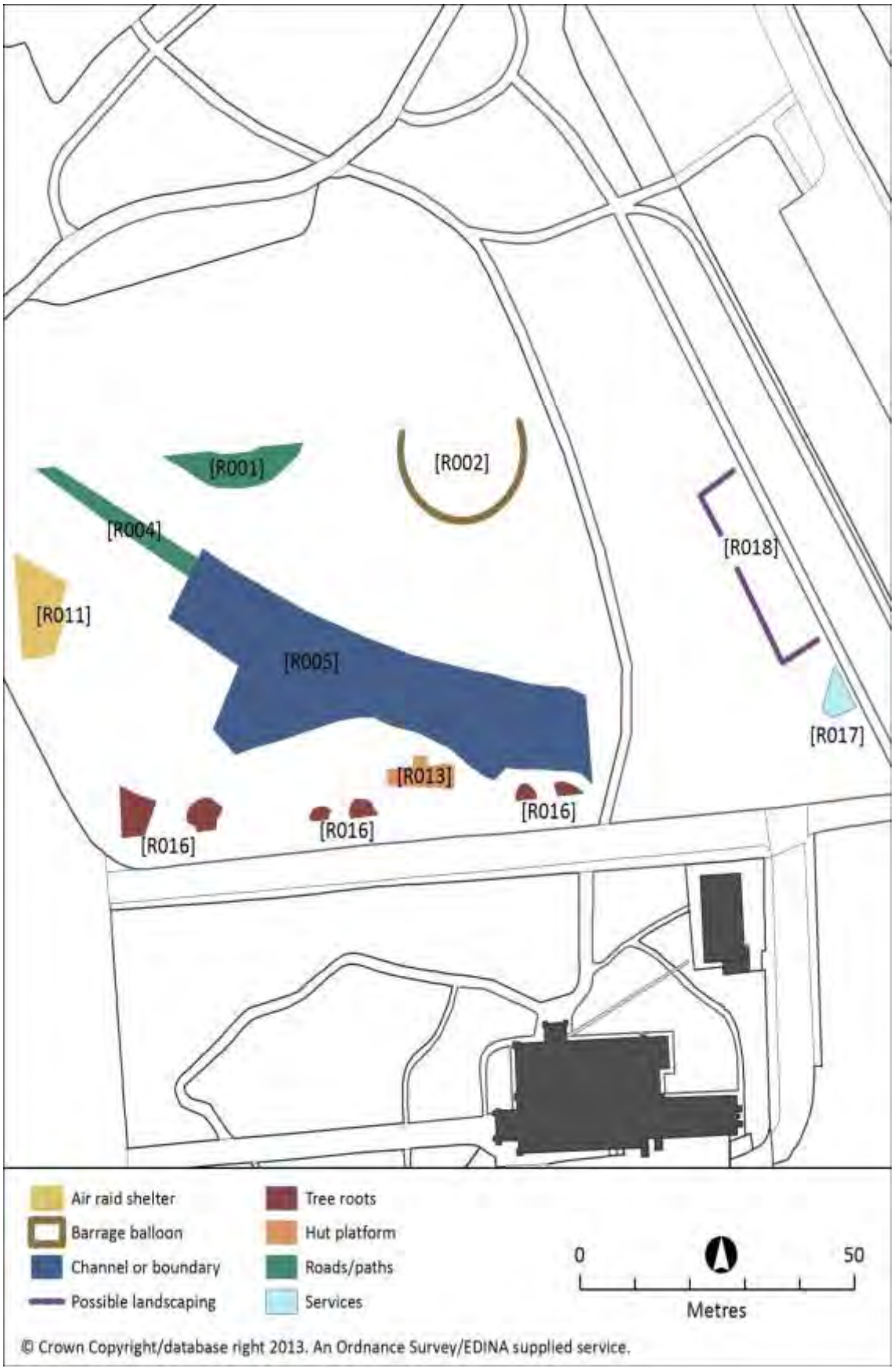


Figure 61: GPR results Drewett's Park, 2009 – depth c.2.75 metres

Figure 62: Resistivity survey results Drewett's Park, 2009


[R001]
[R002]
[R004]
[R005]
[R011]
[R013]
[R016]
[R016]
[R016]
[R017]
[R018]
Air raid shelter
Barrage balloon
Channel or boundary
Possible landscaping
Tree roots
Hut platform
Roads/paths
Services
0
50
Metres
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External Surveys, St Paul's Church, Jarrow

Resistivity Survey 2009 (Figures 63 and 64)

A number of graves [R020] were detected as high resistance anomalies mainly due to the presence of grave slabs buried close to the surface. The survey conducted in the southern half of the churchyard to the south of scheduled monastery remains revealed a number of perpendicular linear features [R021] consistent with the edges of the published excavation trenches (Cramp 2005, Figure 7.4, 74). Three amorphous high resistance anomalies were also detected [R019]. The response from these is consistent with buried masonry.

Ground Penetrating Radar (GPR) 2009 (Figures 65 to 75)

A large number of possible graves were also located during the GPR survey [G022]. Some of these could be related to visible surviving grave markers but a substantial number are clearly the remains of graves whose headstones were removed during the graveyard clearance of the 1960s. A number of former paths within the churchyard were also revealed [G023] and these may again relate to the reorganisation of the churchyard. Despite this intensive survey there was a complete lack of evidence of any structural remains to the north and west of the church. A control area of survey was also undertaken over the layout of the monastic remains to the southwest of the church. This, unsurprisingly, revealed the wall remains [G024] and [G025] documented in Cramp's excavations (Cramp 2005, 219). Analysis of the GPR results also revealed the edges of several trenches which tally with the existing excavation plans. Although no new evidence was brought to light during the survey of this section of the churchyard the presence of known excavated features significantly helped in the calculation of velocity for the GPR signal for the other areas.

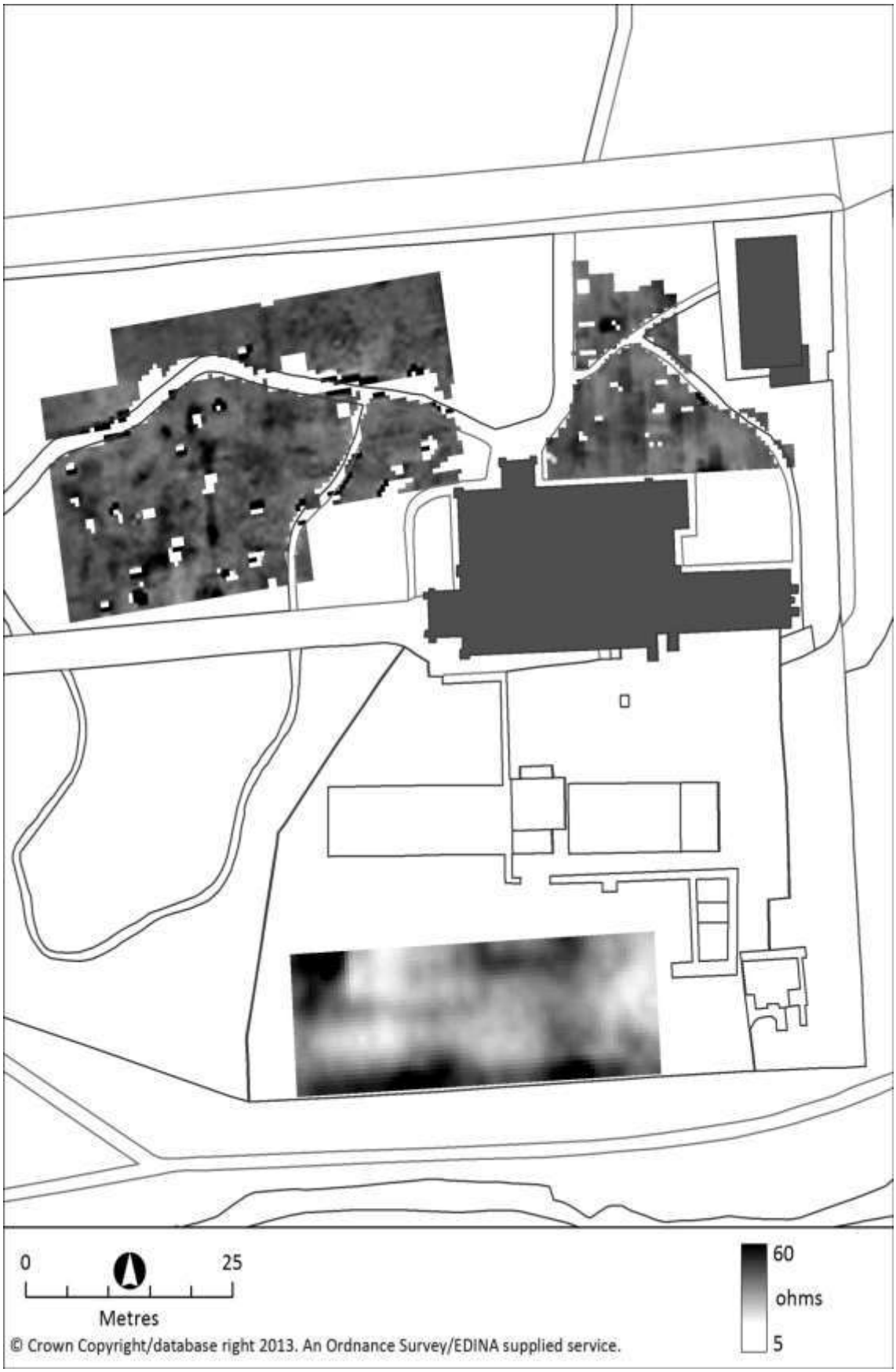

Figure 63: Resistivity survey results St Paul's Church, Jarrow, 2009

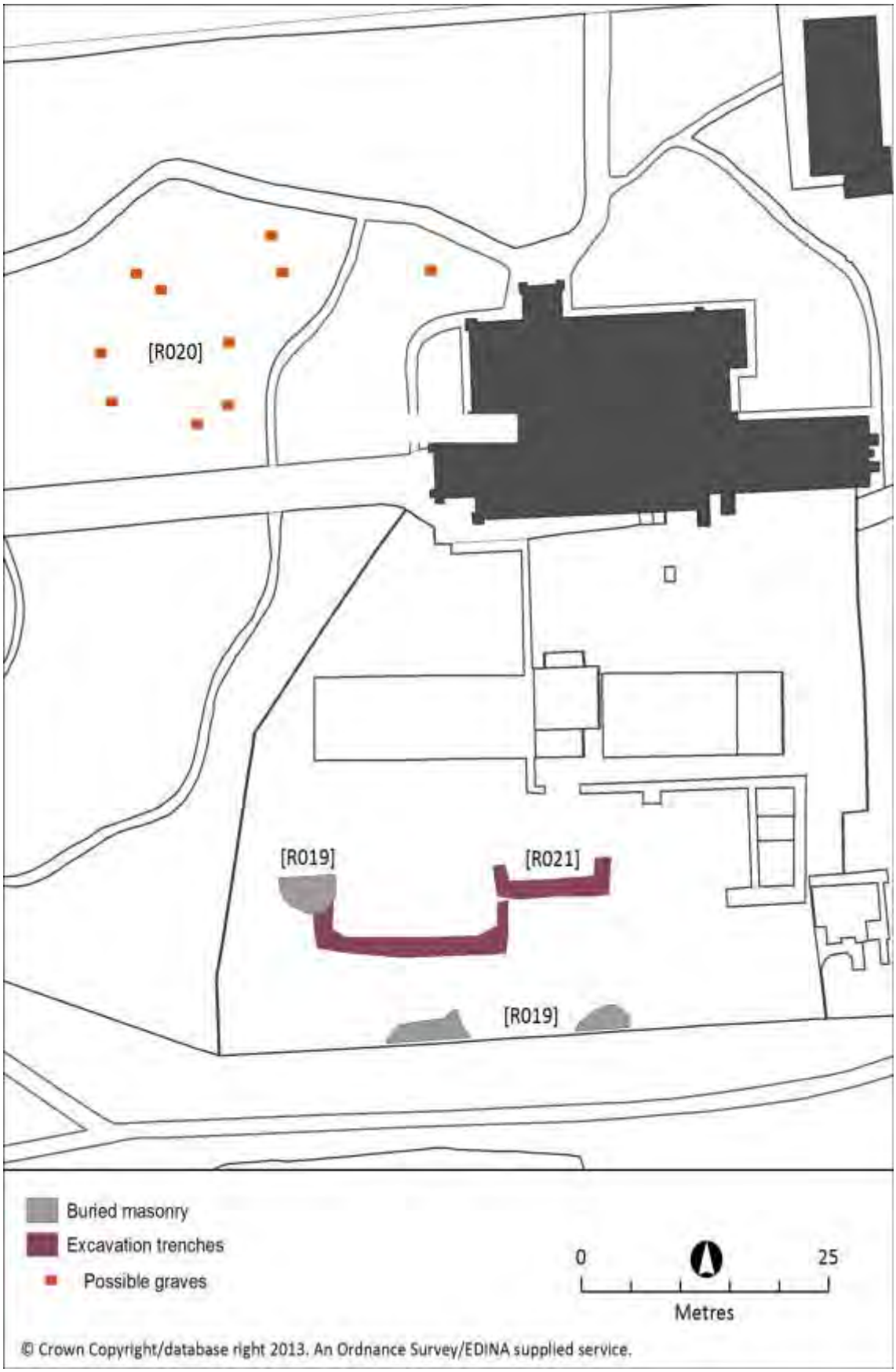

Figure 64: Resistivity survey interpretation St Paul's Church, Jarrow, 2009

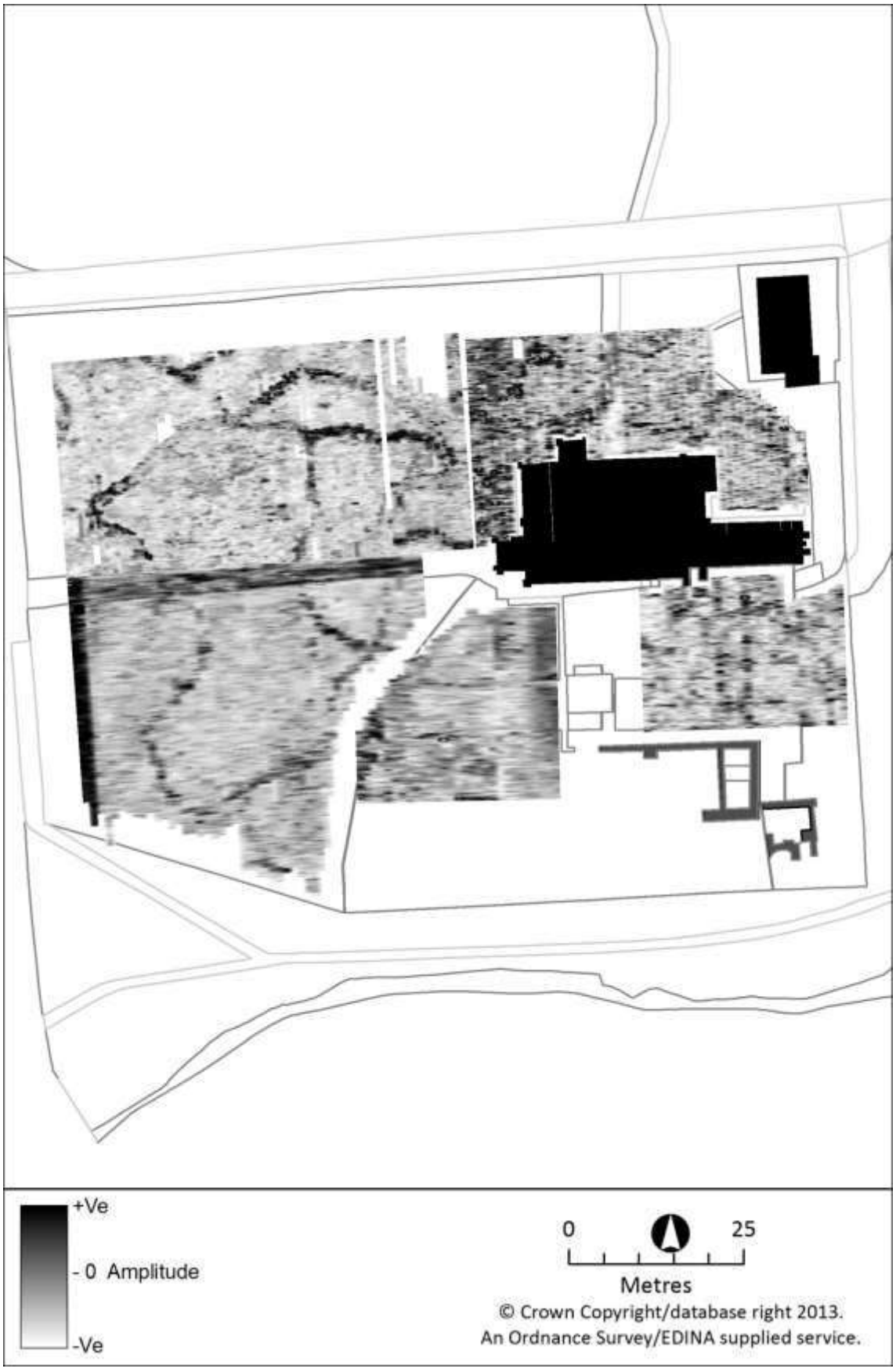

Figure 65: GPR survey results, St Paul's Church, Jarrow, 2009 – depth c.50cm

Figure 66: GPR survey results, St Paul's Church, Jarrow, 2009 – depth c.75cm

Figure 67: GPR survey results, St Paul's Church, Jarrow, 2009 – depth c.100cm

Figure 68: GPR survey results, St Paul's Church, Jarrow, 2009 – depth c.125cm

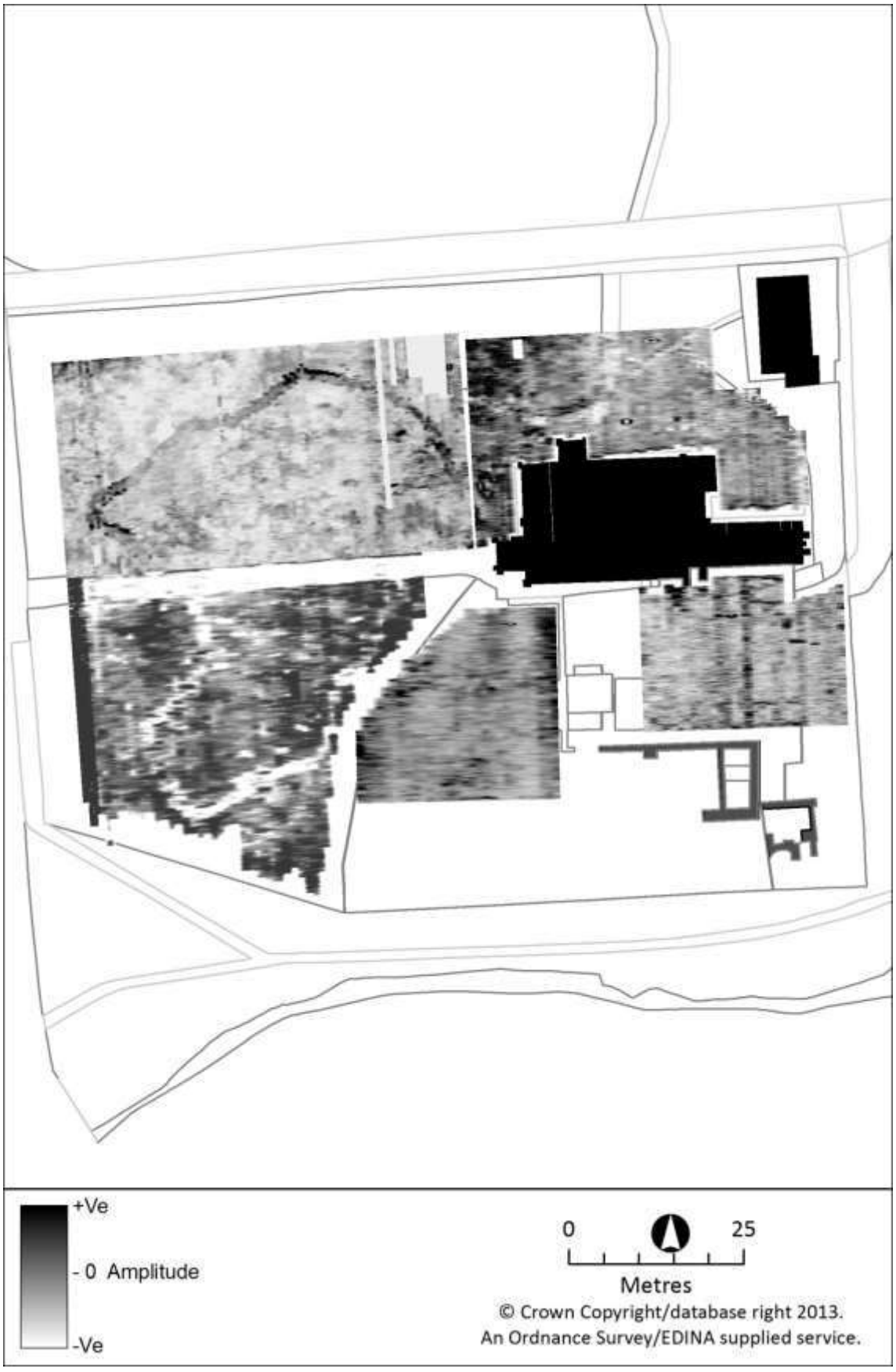

Figure 69: GPR survey results, St Paul's Church, Jarrow, 2009 – depth c.150cm

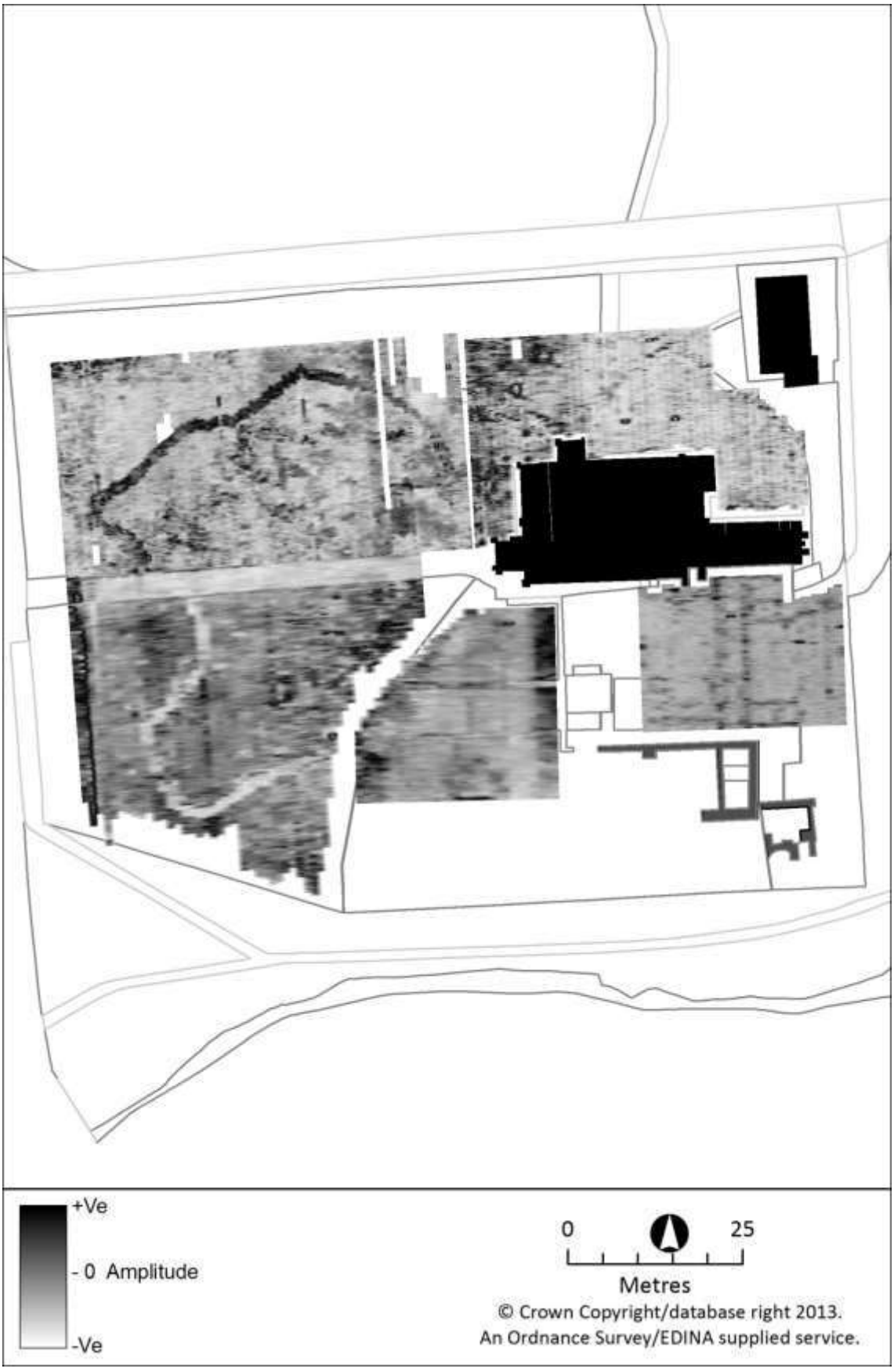

Figure 70: GPR survey results, St Paul's Church, Jarrow, 2009 – depth c.175cm

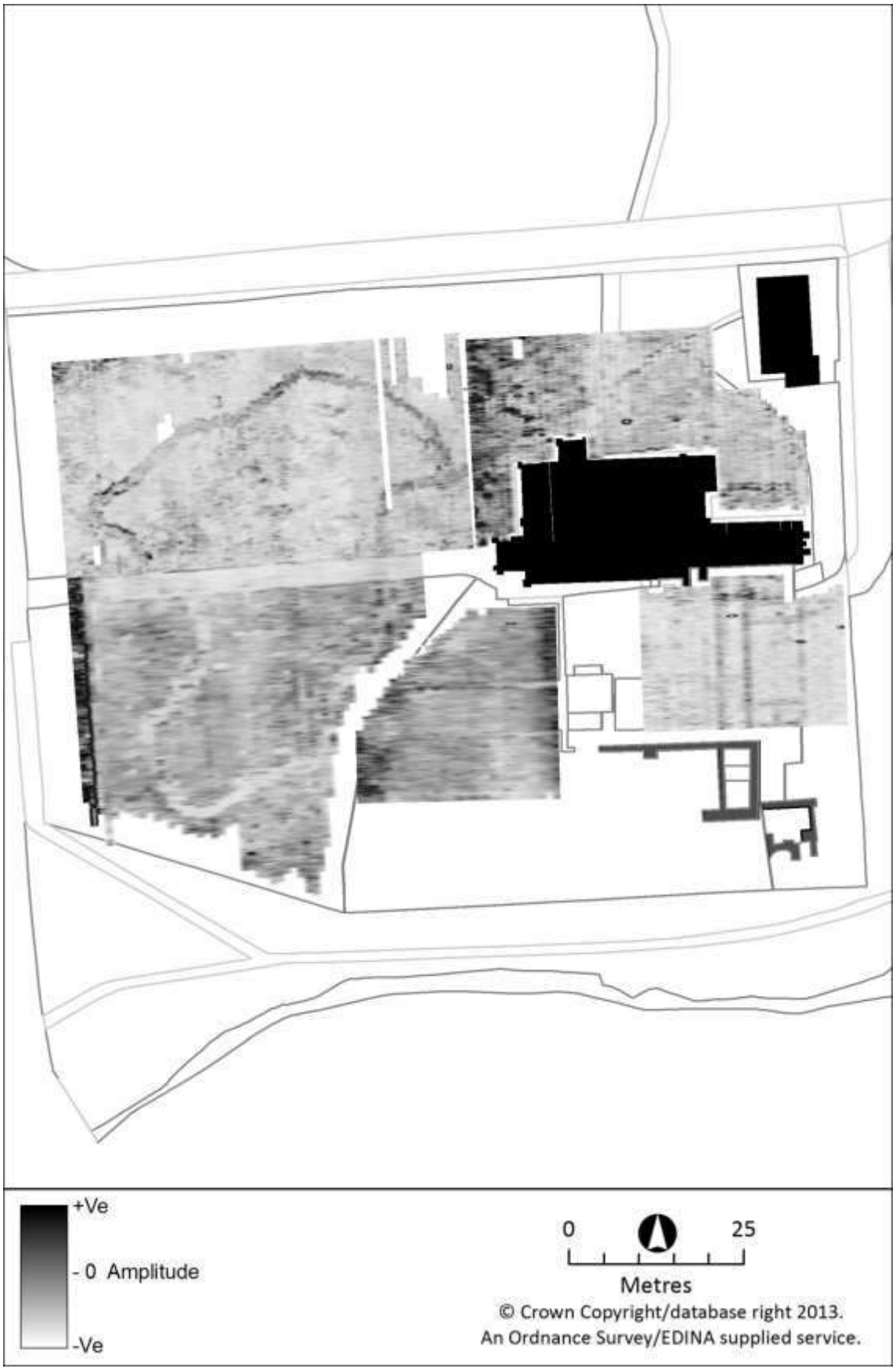

Figure 70: GPR survey results, St Paul's Church, Jarrow, 2009 – depth c.200cm

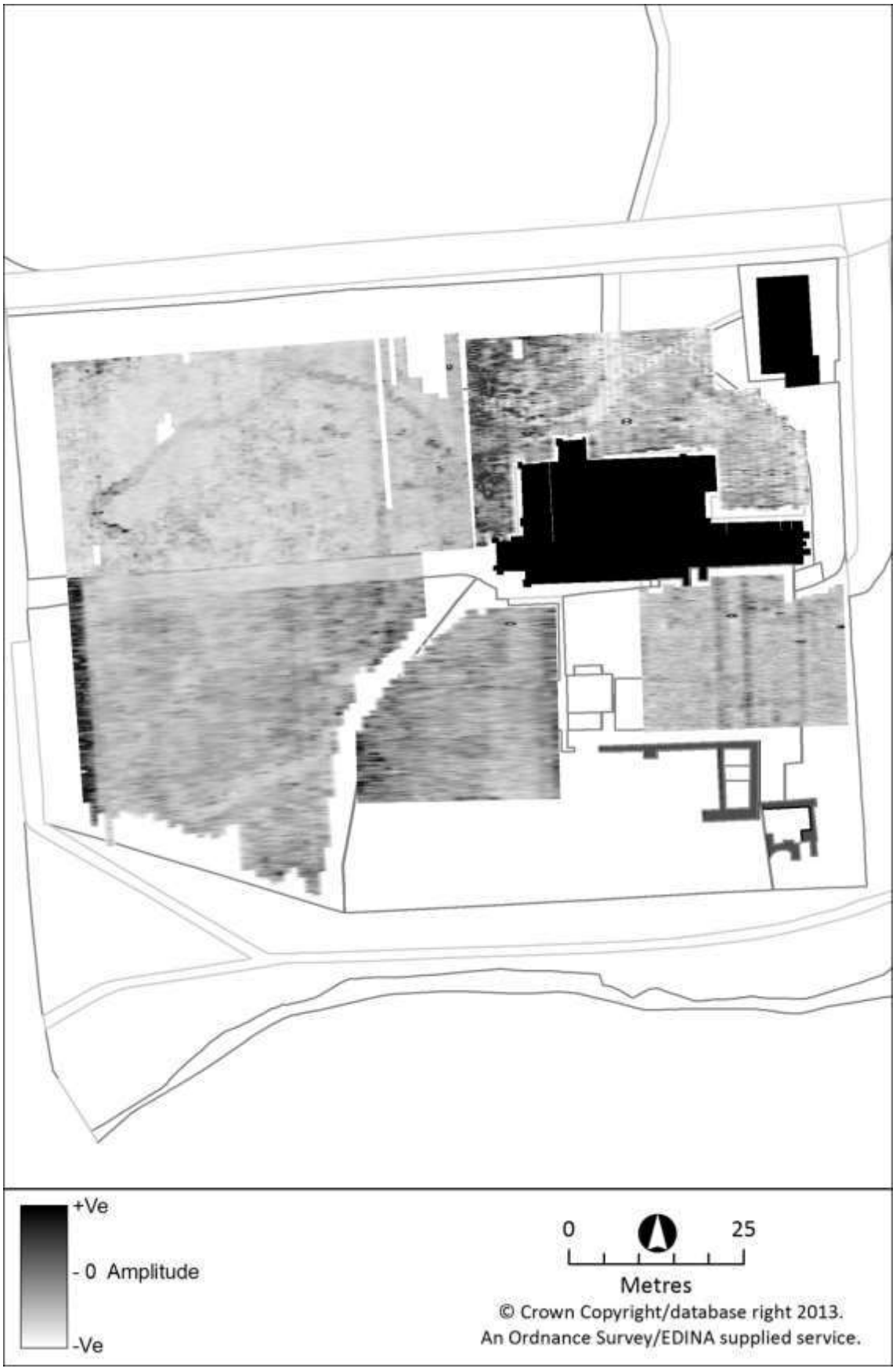

Figure 71: GPR survey results, St Paul's Church, Jarrow, 2009 – depth c.225cm

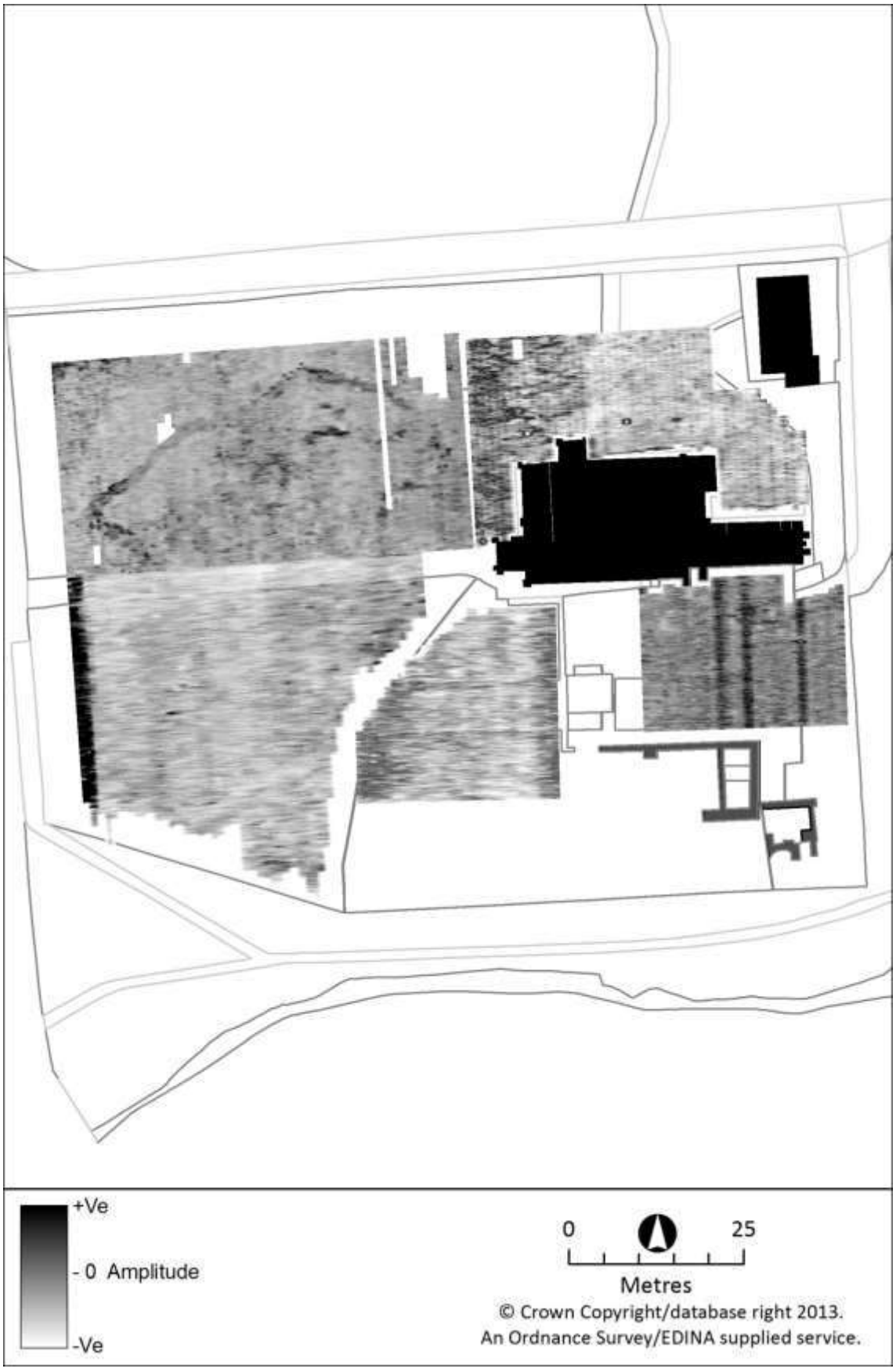

Figure 72: GPR survey results, St Paul's Church, Jarrow, 2009 – depth c.250cm

Figure 73: GPR survey results, St Paul's Church, Jarrow, 2009 – depth c.275cm

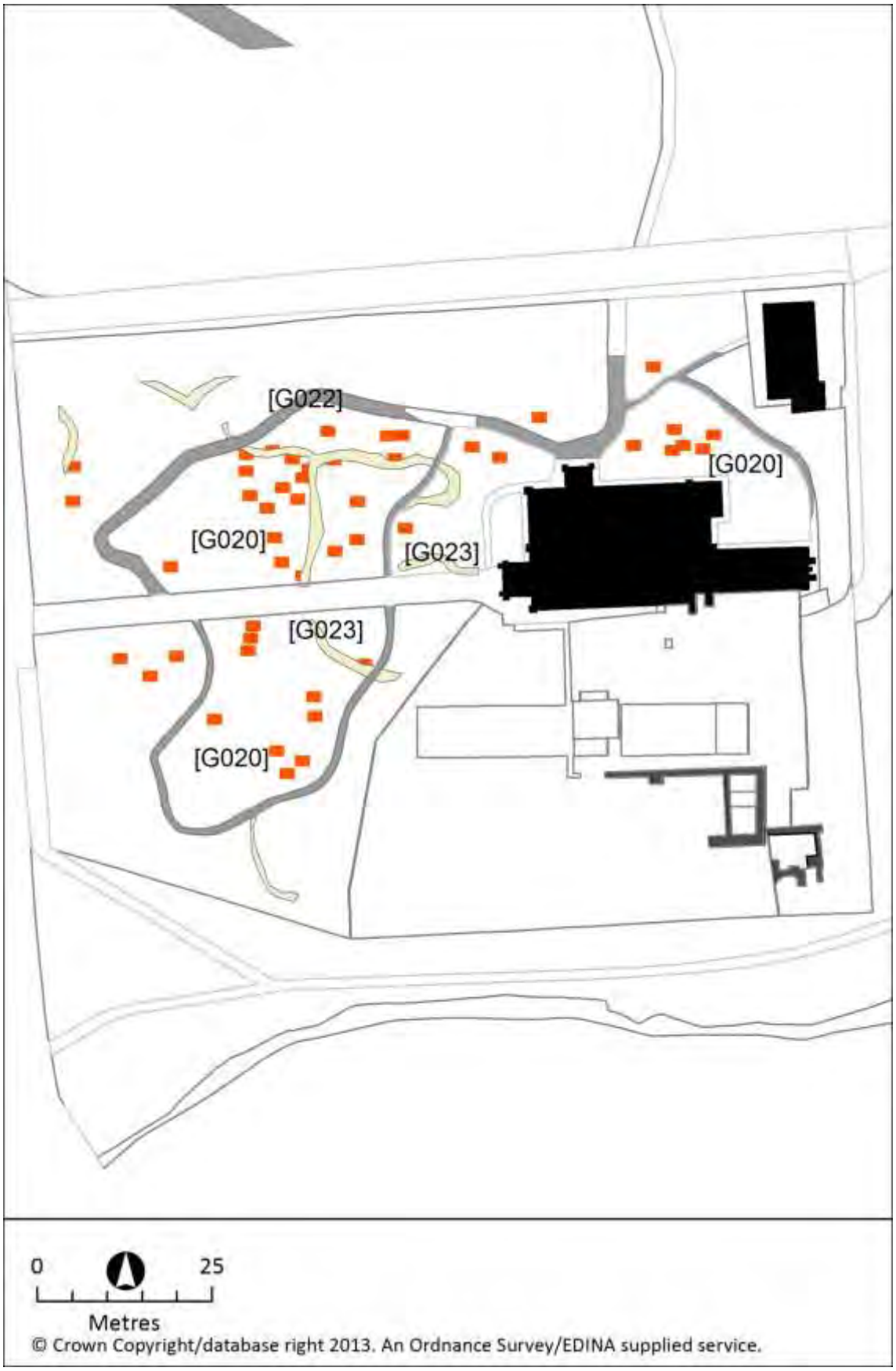

Figure 74: Composite plan of GPR survey results, St Paul's Church, Jarrow, 2009

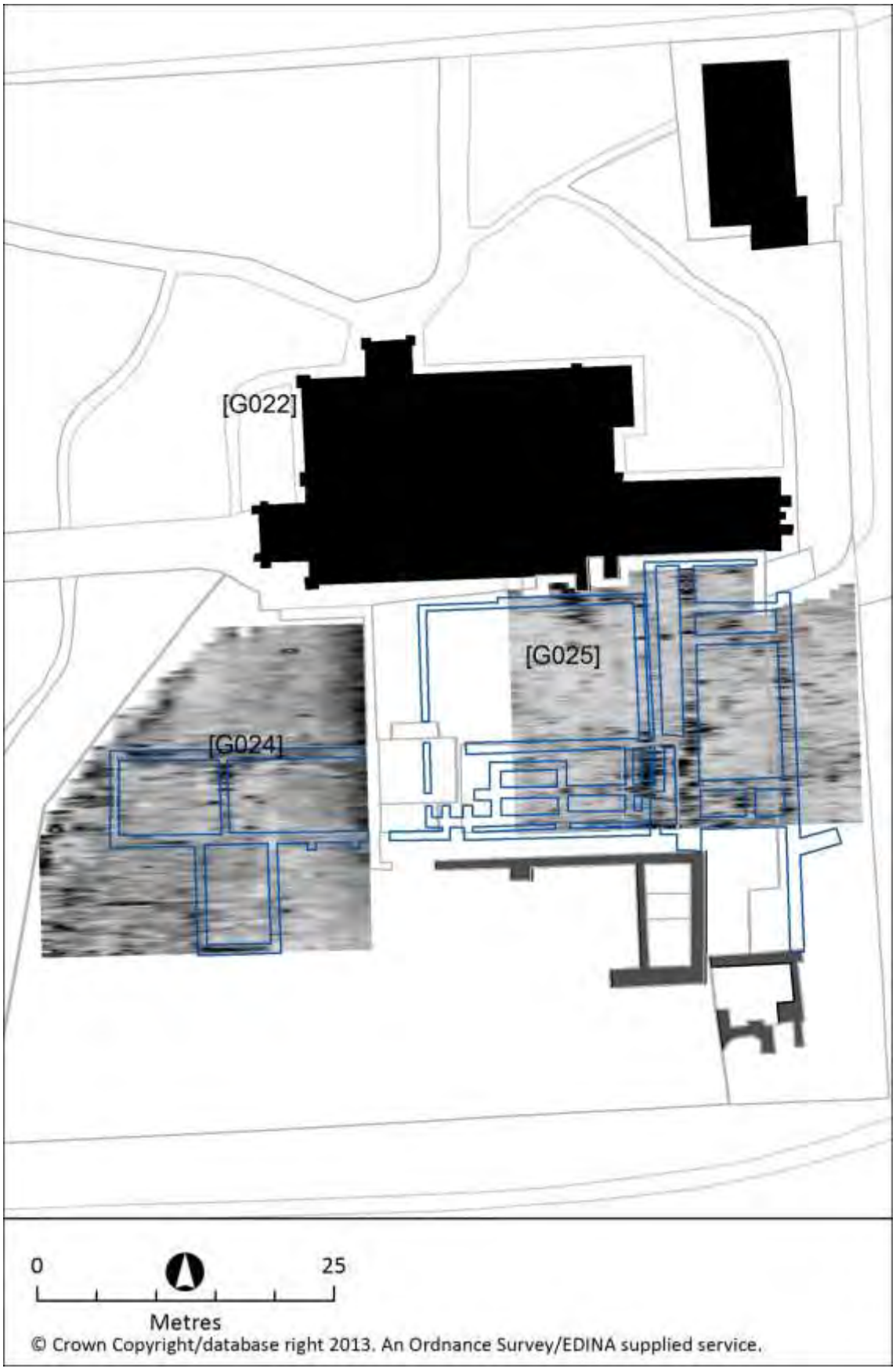

Figure 75: Outline of monastery as laid out at St Paul's Church, Jarrow, overlying the results from the GPR surveys in 2009. Depth c. 1 metre

Internal Surveys, St Paul's Church, Jarrow

Two internal surveys, split into several discrete areas within the chancel of St Paul's, were undertaken in 2010 and 2011. Each survey is illustrated separately. The final section below considers the results and interpretation of these surveys jointly and compares then to the results obtained from a survey over the known crypt at Hexham.

GPR Survey 2010 (Profiles Figures 76 to 82. XY slices Figures 83 to 100)

A number of features were revealed during the first GPR survey that confirmed existing evidence for interventions within the chancel and also presented a series of anomalies that suggested hitherto unknown features at the east end of the church. These were further clarified by the 2011 survey and are discussed below.

GPR Survey 2011 (XY Slices, Figures 101 to 113)

The increase in the traverse measurement helped confirm the nature of a number of features at the eastern end of the chancel. A change in image processing methodology was also adopted for these images due to the significant increase in the amount of data. All plots were exported from Relex3D as TIFF raster images but these were subsequently converted first to raster ASCII files and then to vector polygon files within ArcGIS 10.1. The conversion of these files to polygonal data enabled the employment of the dissolve tool with ArcGIS. This effectively converted all polygons with a common greyscale attribute into a single multi-part polygon. Manipulation of the data including the merging of overlapping areas of survey was then possible using this method. It was also possible to employ statistical techniques to the processing of the data that would not have been possible with the original raster data. The time involved in implementing these additional steps was only thought worthwhile on the larger and more complicated dataset from 2011.

Interpretation (Figure 114)

The three internments, [G26], [G27] and [G28], visible on the floor around the altar as a series of ledger stones were detectable to a depth of approximately one metre (Figures 101 to 104). This would seem to indicate that the formal internments are not present below these stones. By contrast, the response in this area suggests a larger feature in the area around the altar and may also be linked to similar features found in the survey of the chancel aisle [G34], [G35] and [G36]. This has tentatively been interpreted as the possible remains of a crypt with the caveat that this could also be related to later burial vaults of which, as far as is known, no records survive. The three anomalies [G29], [G30] and [G31] that appear to coincide with the external buttressing of the east wall, may be reflections associated with these features. At the uppermost levels the sub-structure of the present floor was detected [G32] and the disturbance from Cramp's excavations in the 1960s [G33] (Cramp 2005, 153).

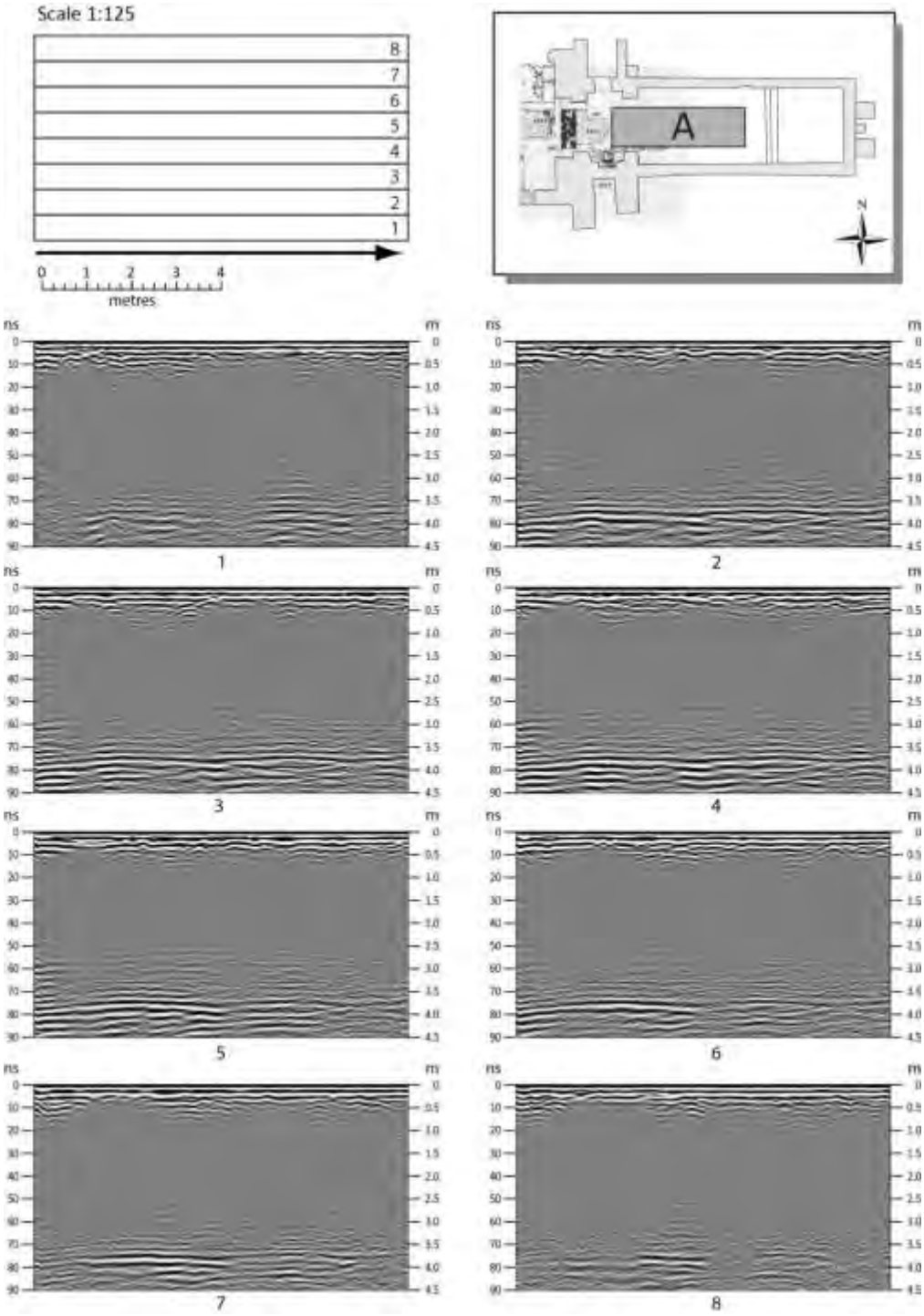

Figure 76: Internal GPR survey St Paul's Church, Jarrow, 2010. Profiles for Area A

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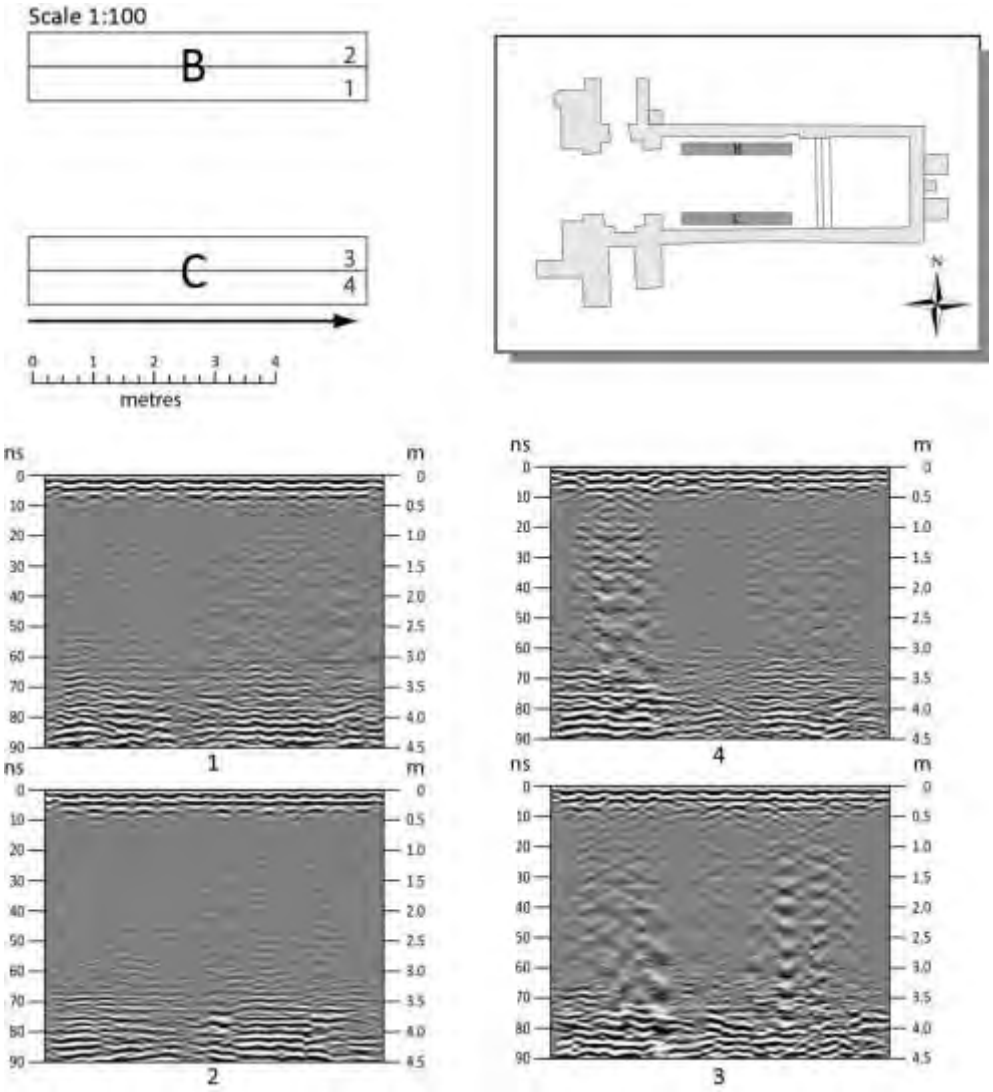

Figure 77: Internal GPR survey St Paul's Church, Jarrow, 2010. Profiles for Areas B and C.

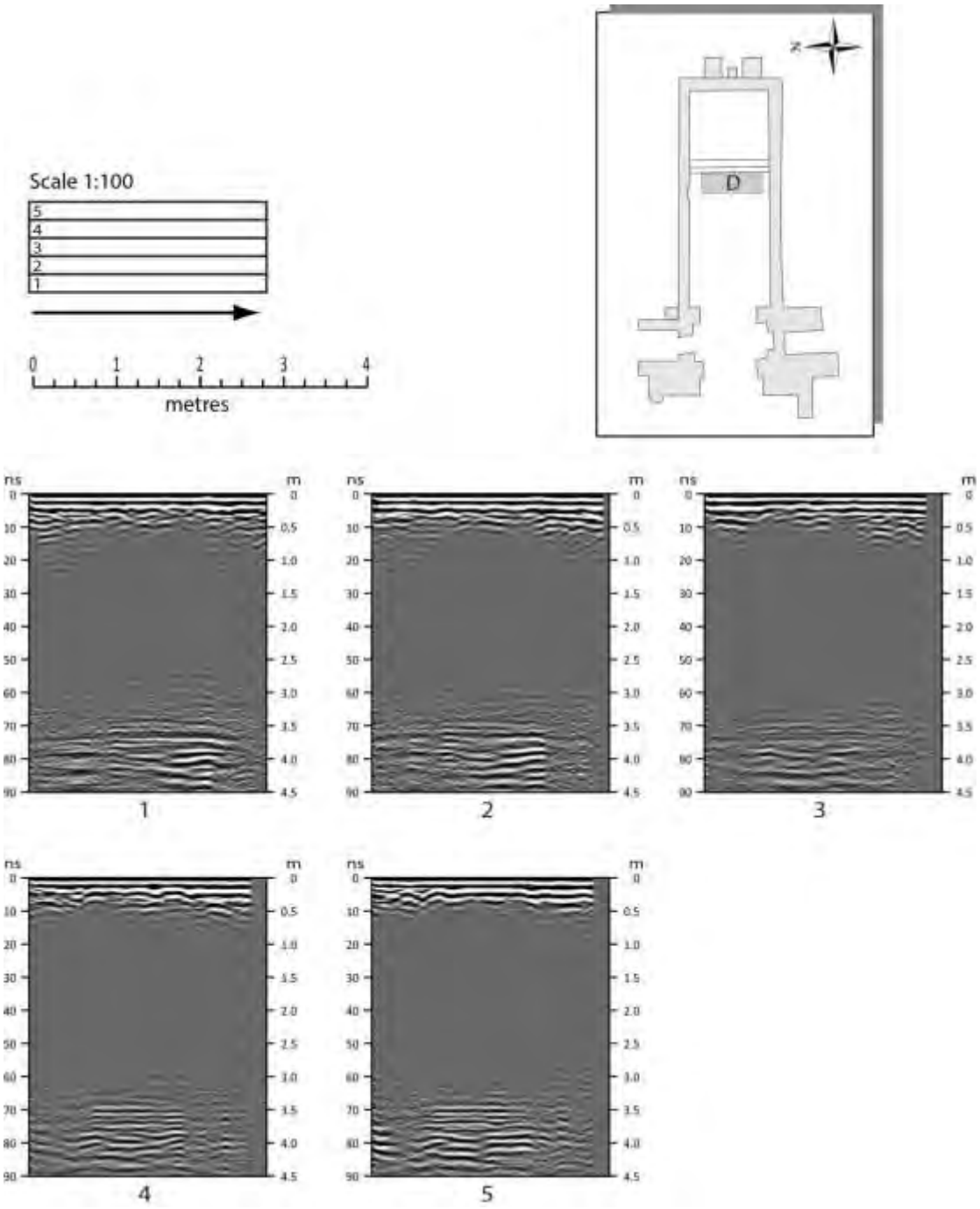

Figure 78: Internal GPR survey St Paul's Church, Jarrow, 2010. Profiles for Area D.

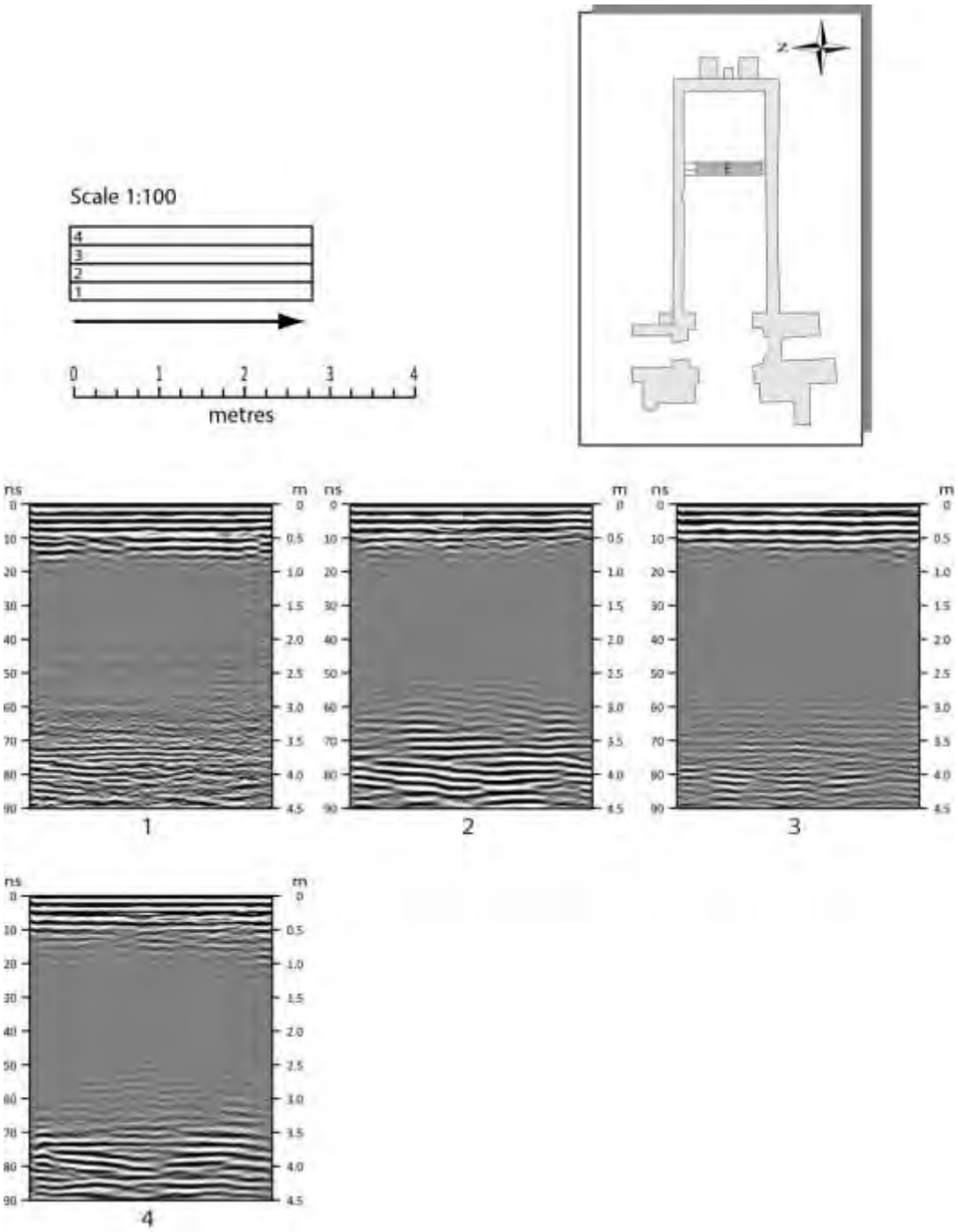

Figure 79: Internal GPR survey St Paul's Church, Jarrow, 2010. Profiles for Area E

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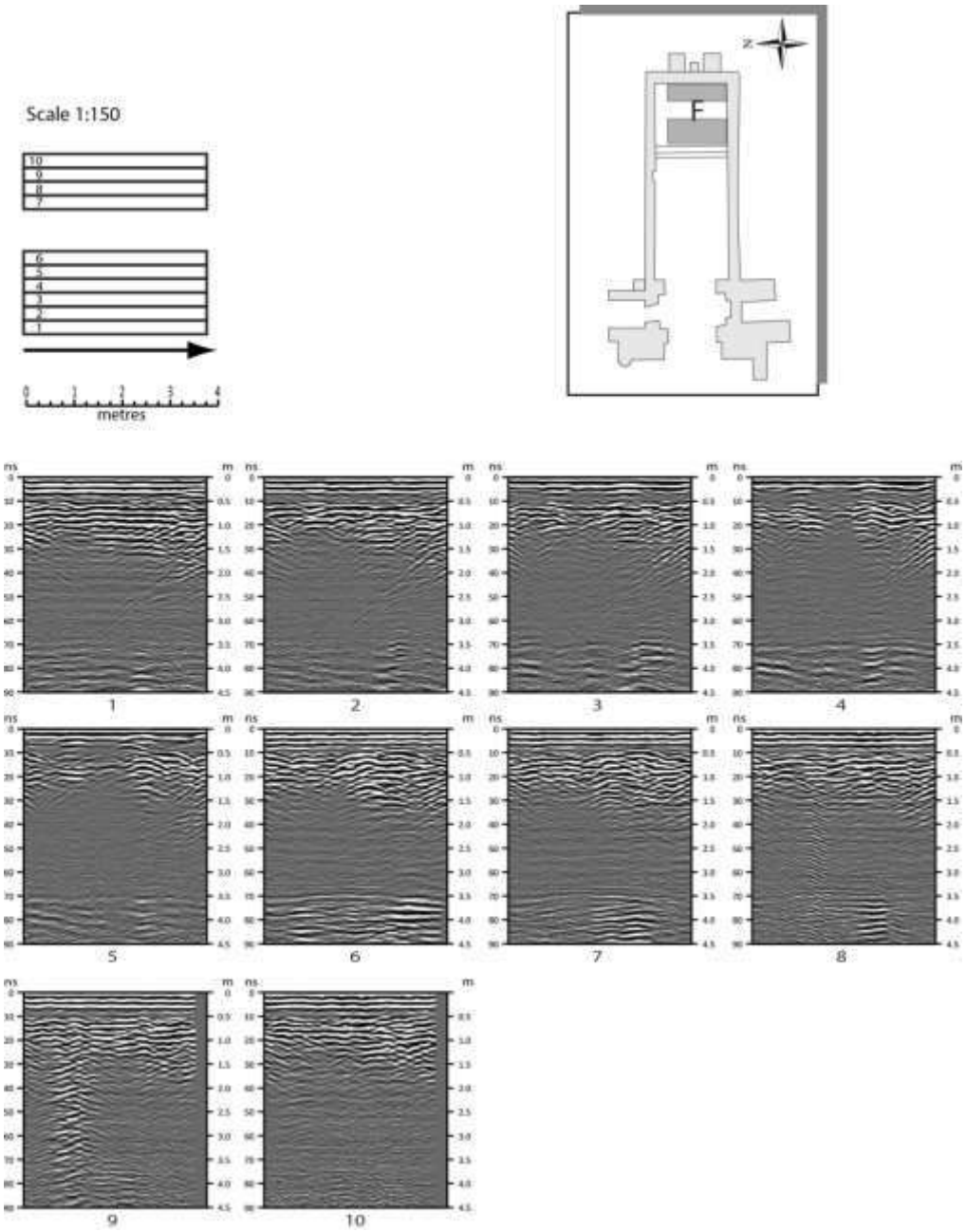


Figure 80: Internal GPR survey St Paul's Church, Jarrow, 2010. Profiles for Area F.

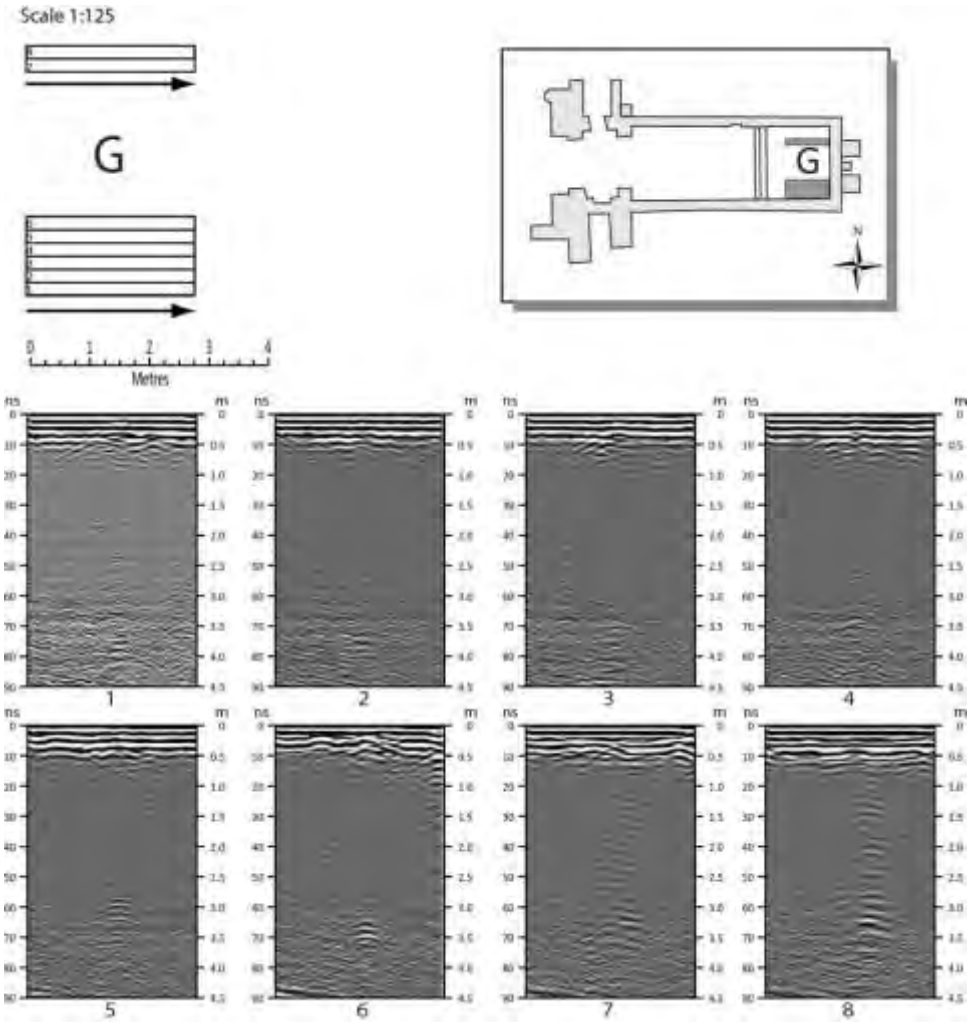


Figure 81: Internal GPR survey St Paul's Church, Jarrow, 2010. Profiles for Area G.

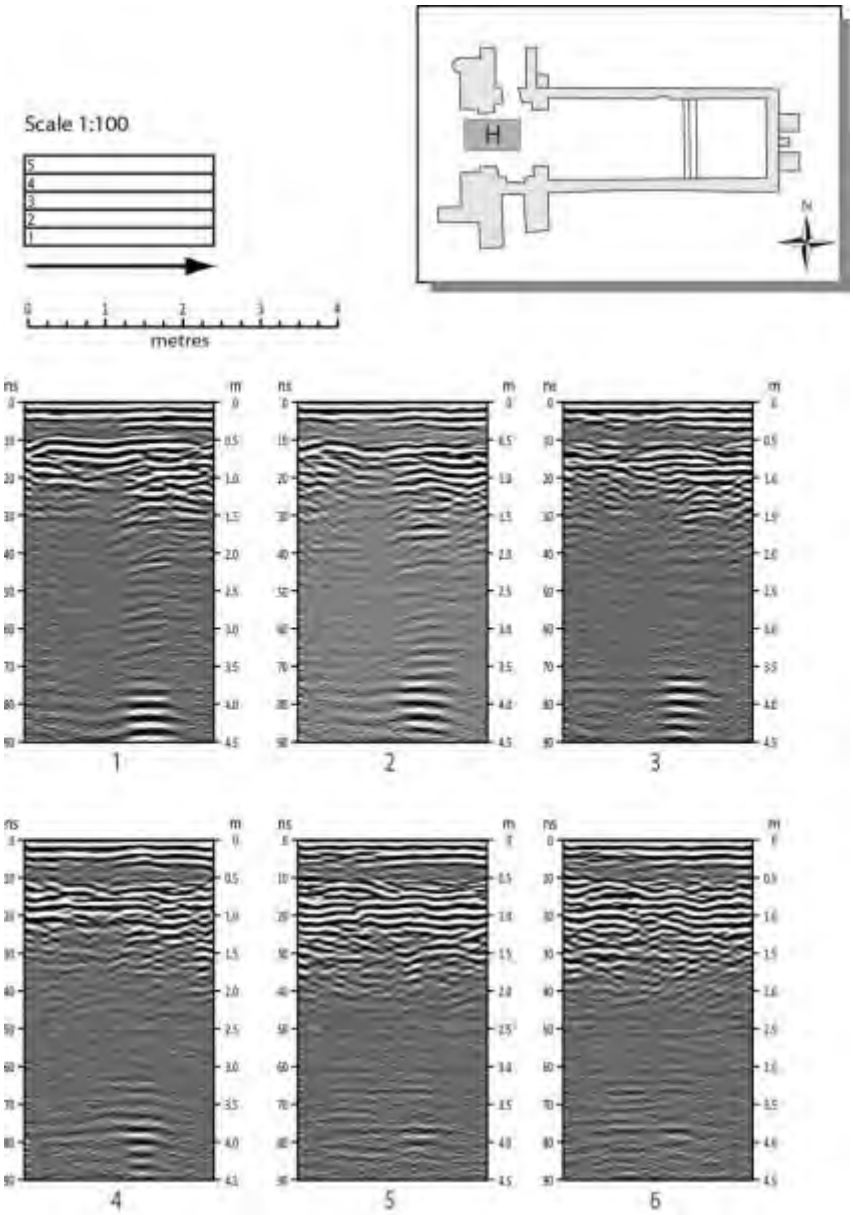


Figure 82: Internal GPR survey St Paul's Church, Jarrow, 2010. Profiles for Area H.

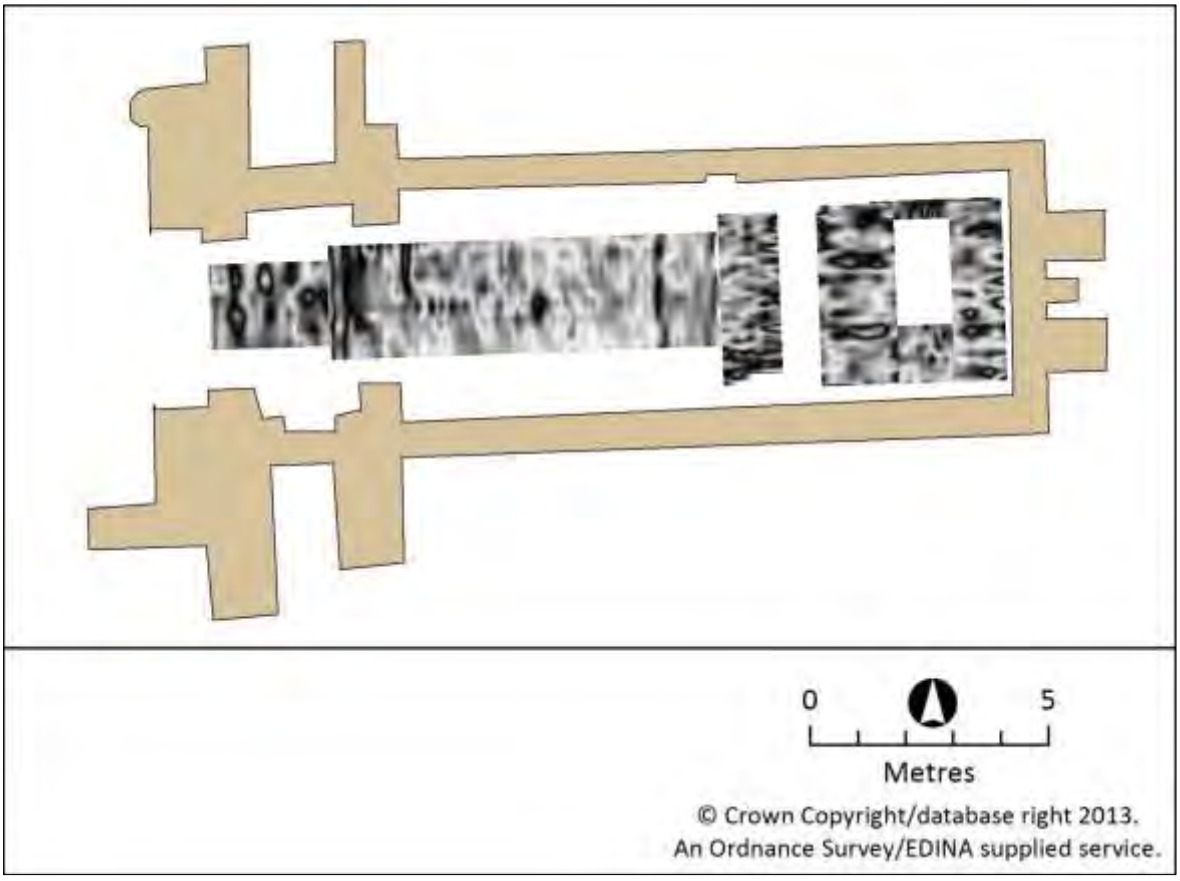


Figure 83: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.25cm

Figure 84: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.50cm

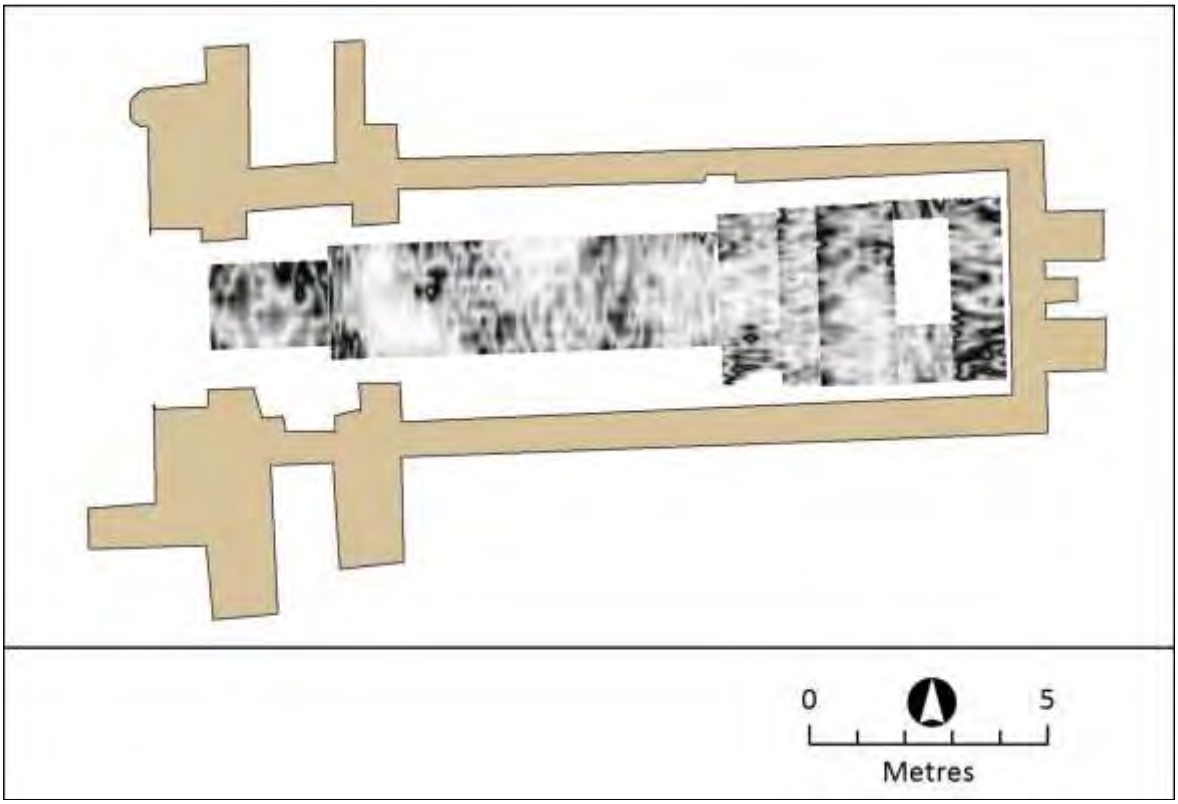


Figure 85: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.75cm

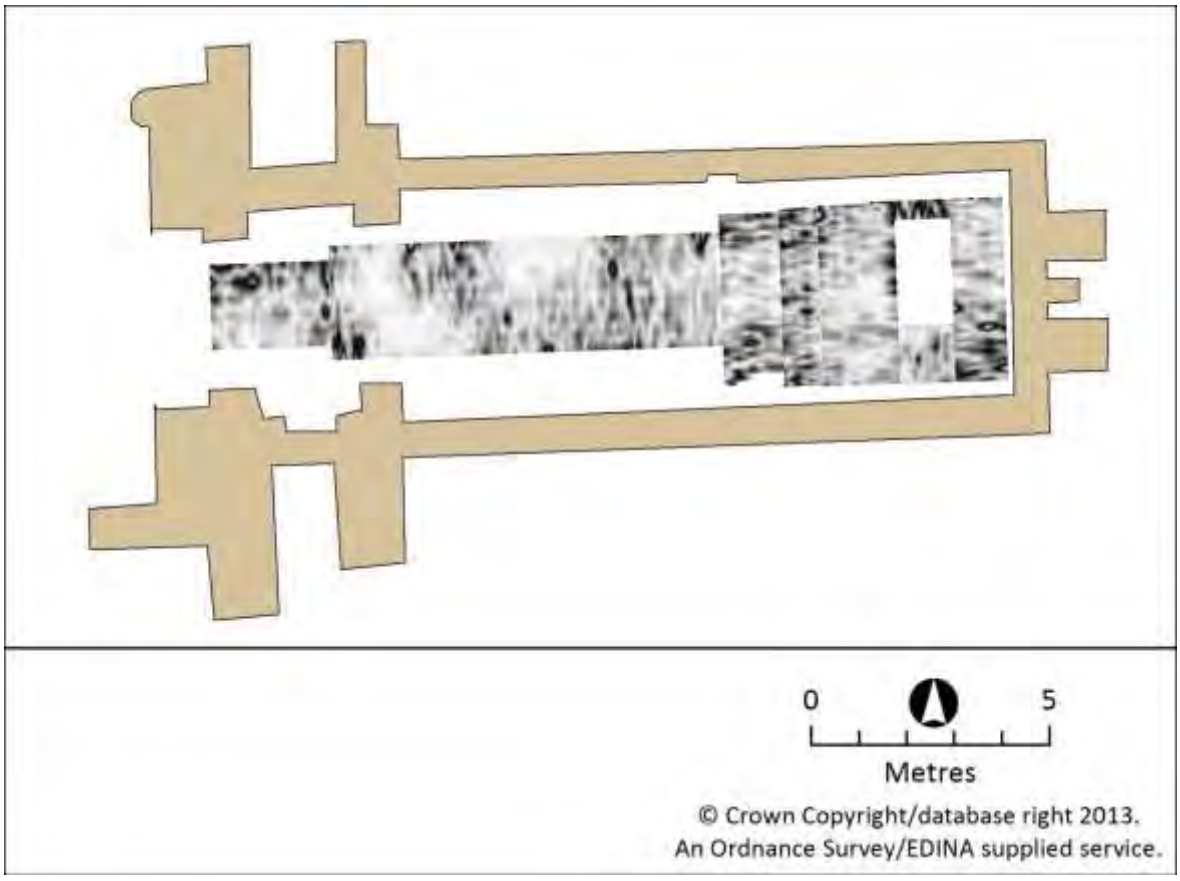


Figure 86: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.100cm

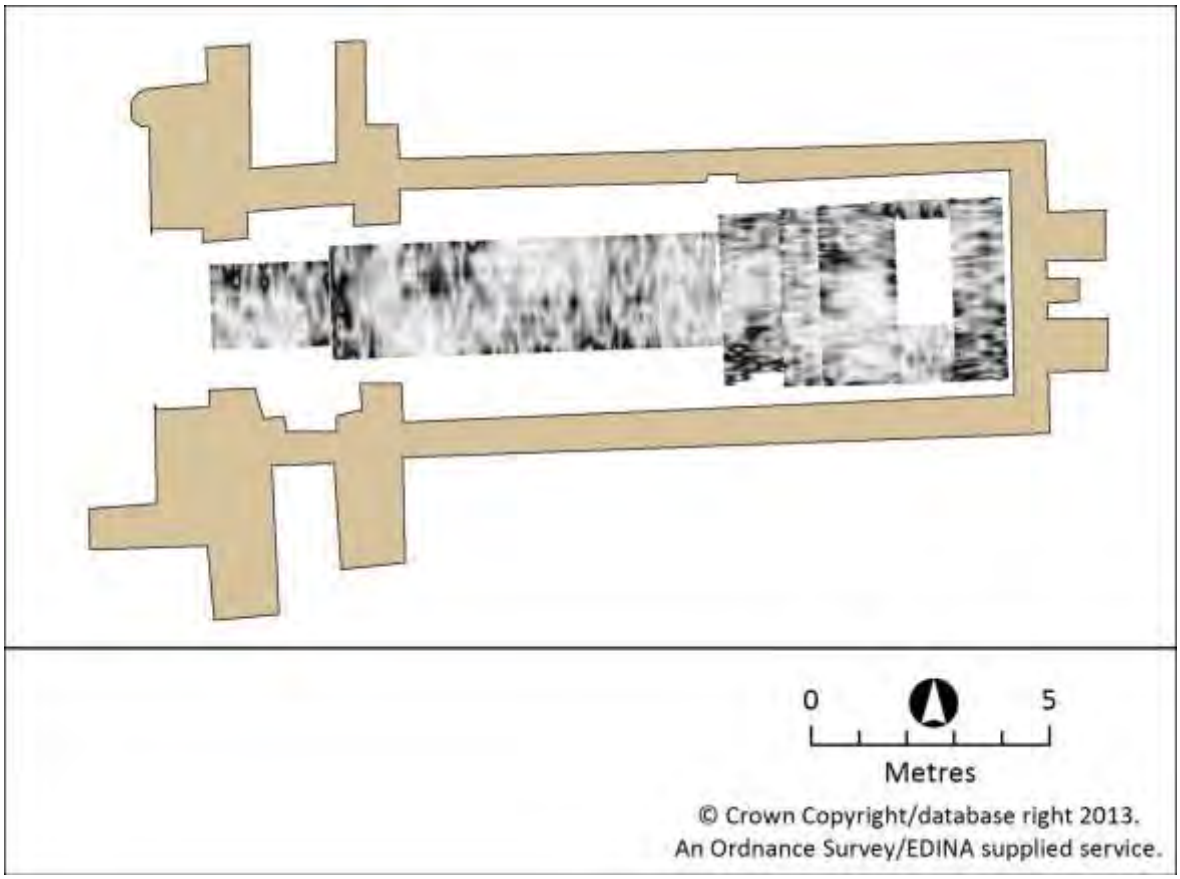


Figure 87: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.125cm

Figure 88: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.150cm

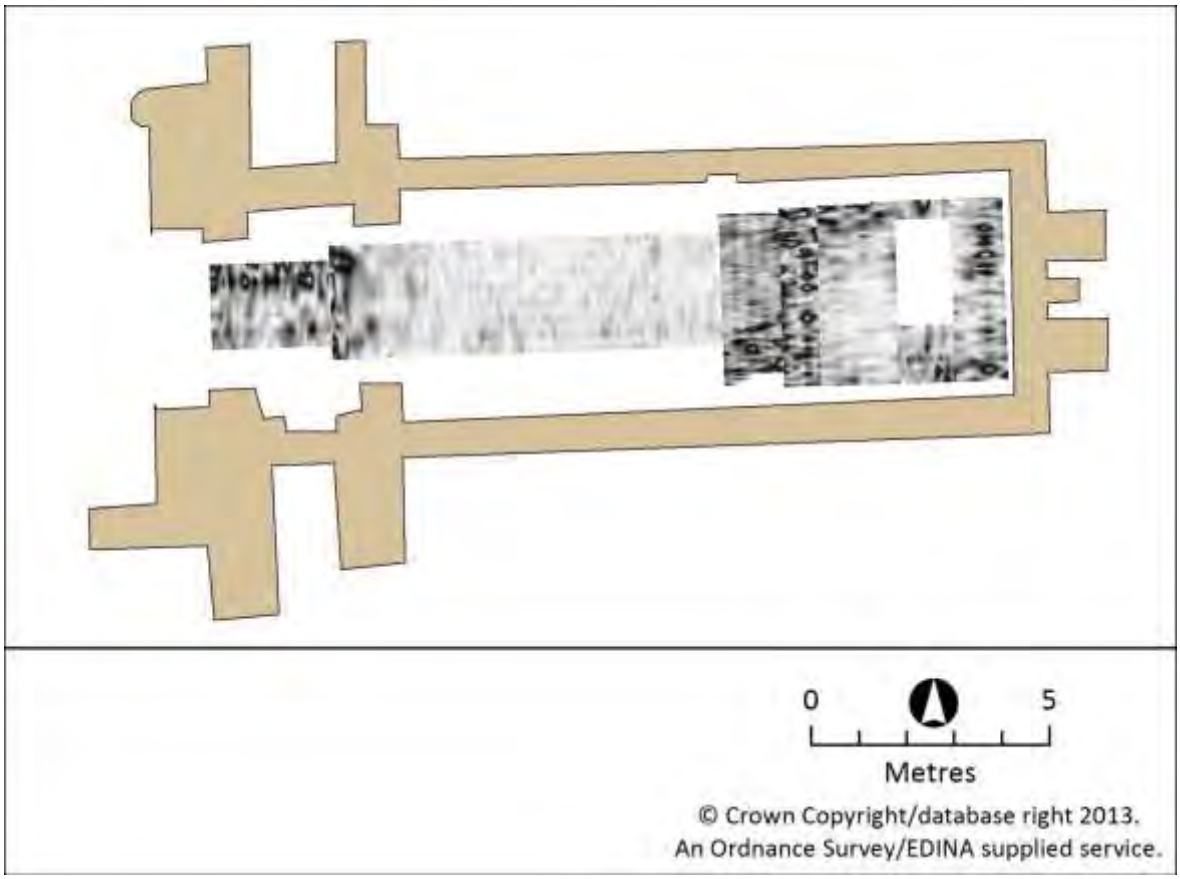


Figure 89: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.175cm

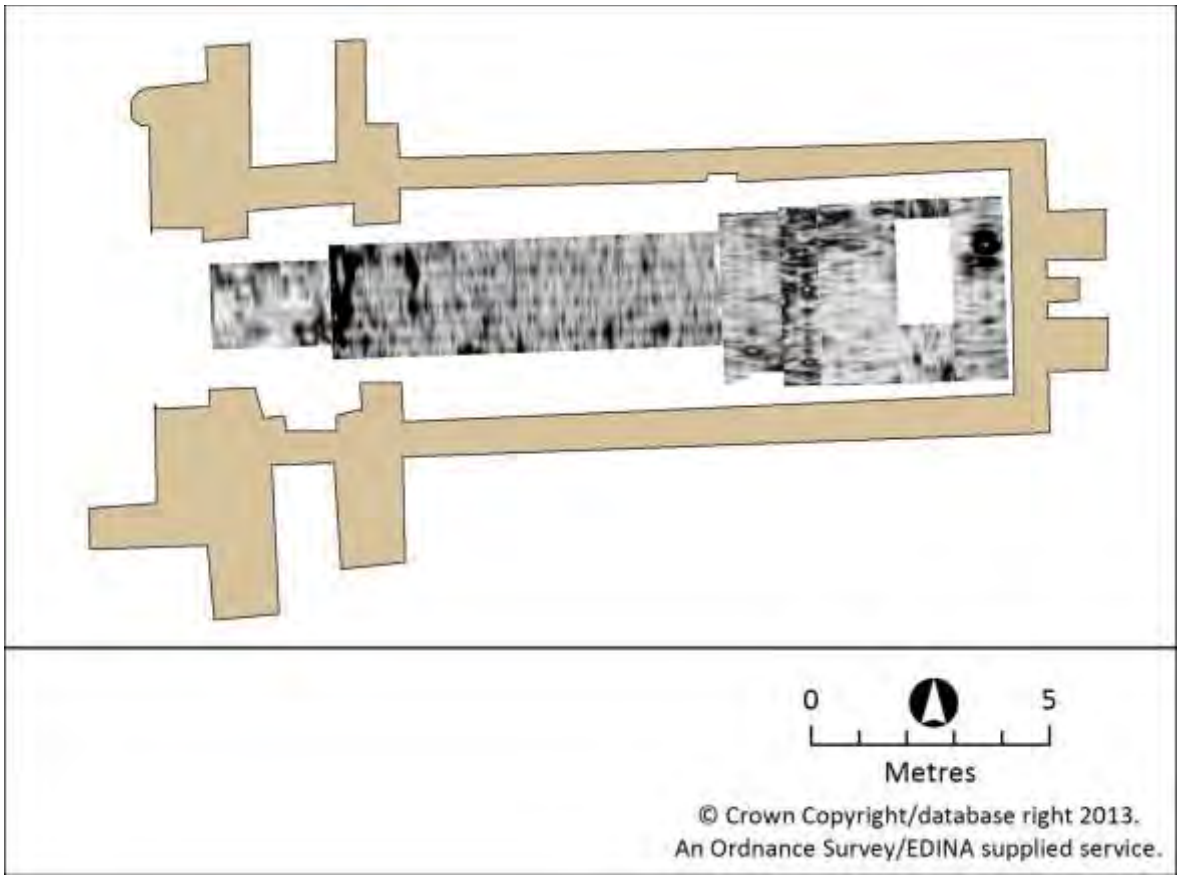


Figure 90: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.200cm

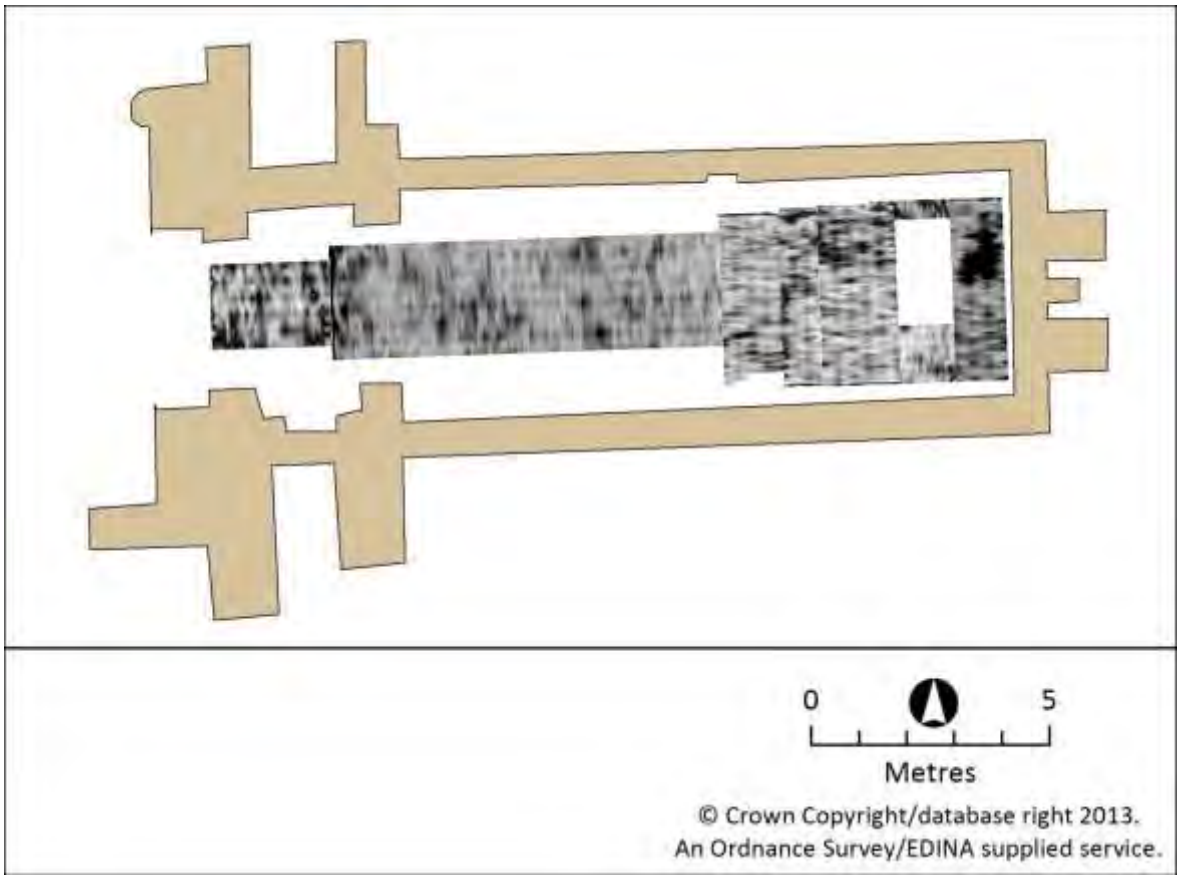


Figure 91: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.225cm

Figure 92: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.250cm

Figure 93: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.275cm

Figure 94: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.300cm

Figure 95: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.325cm

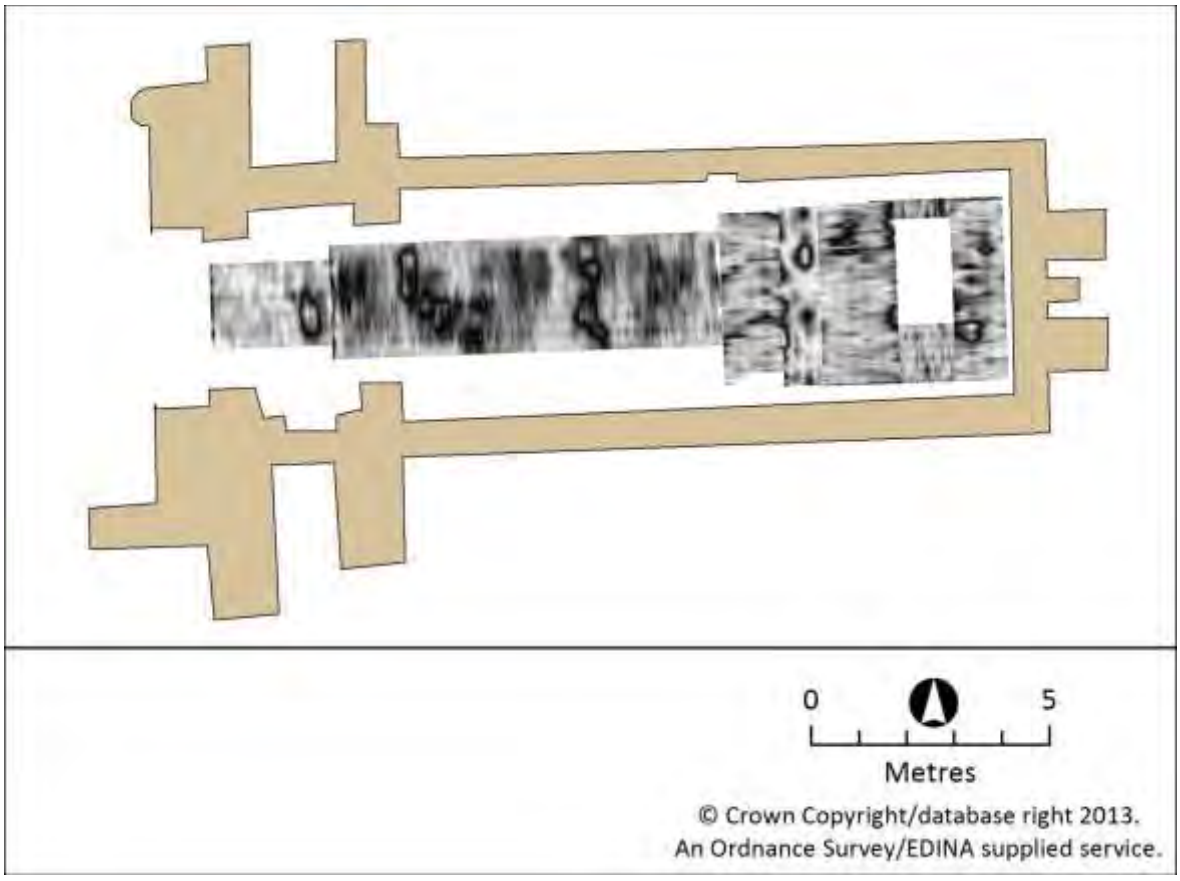


Figure 96: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.350cm

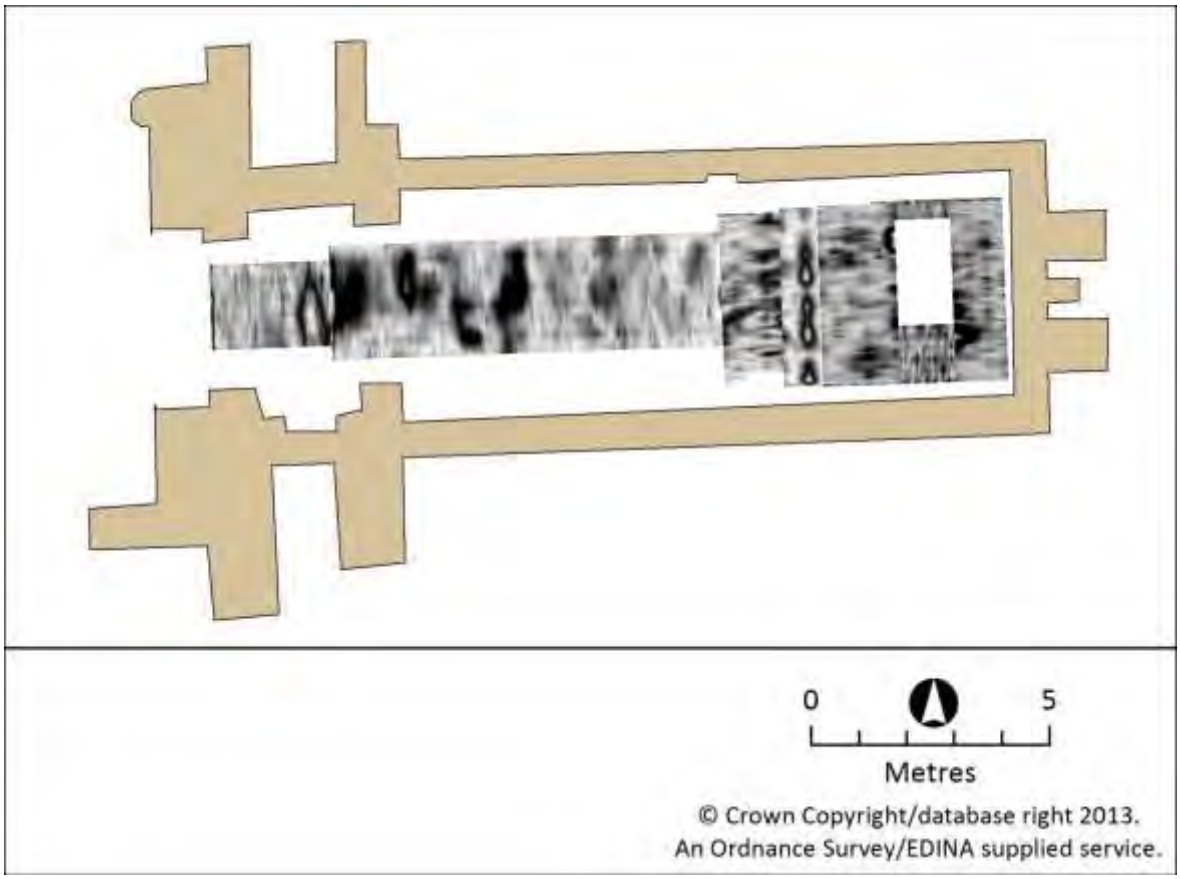


Figure 97: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.375cm

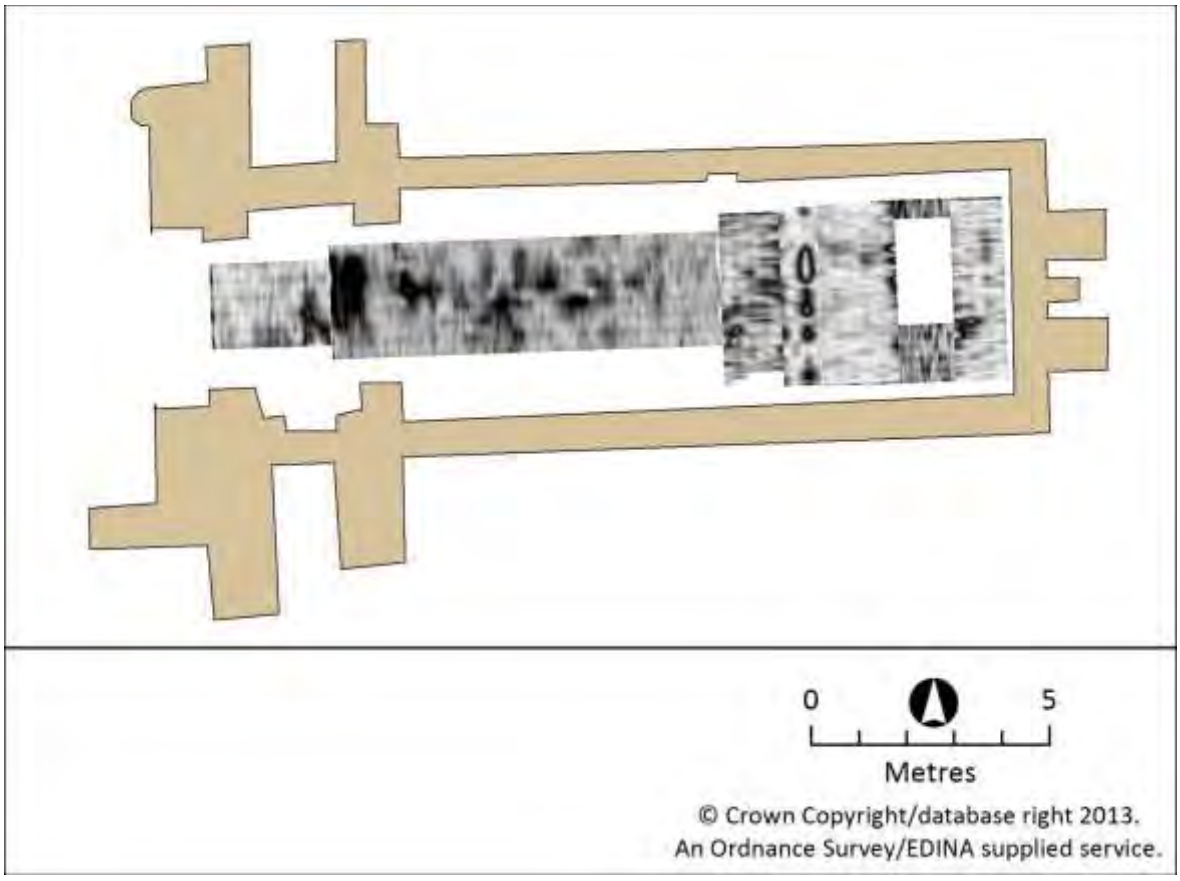


Figure 98: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.400cm

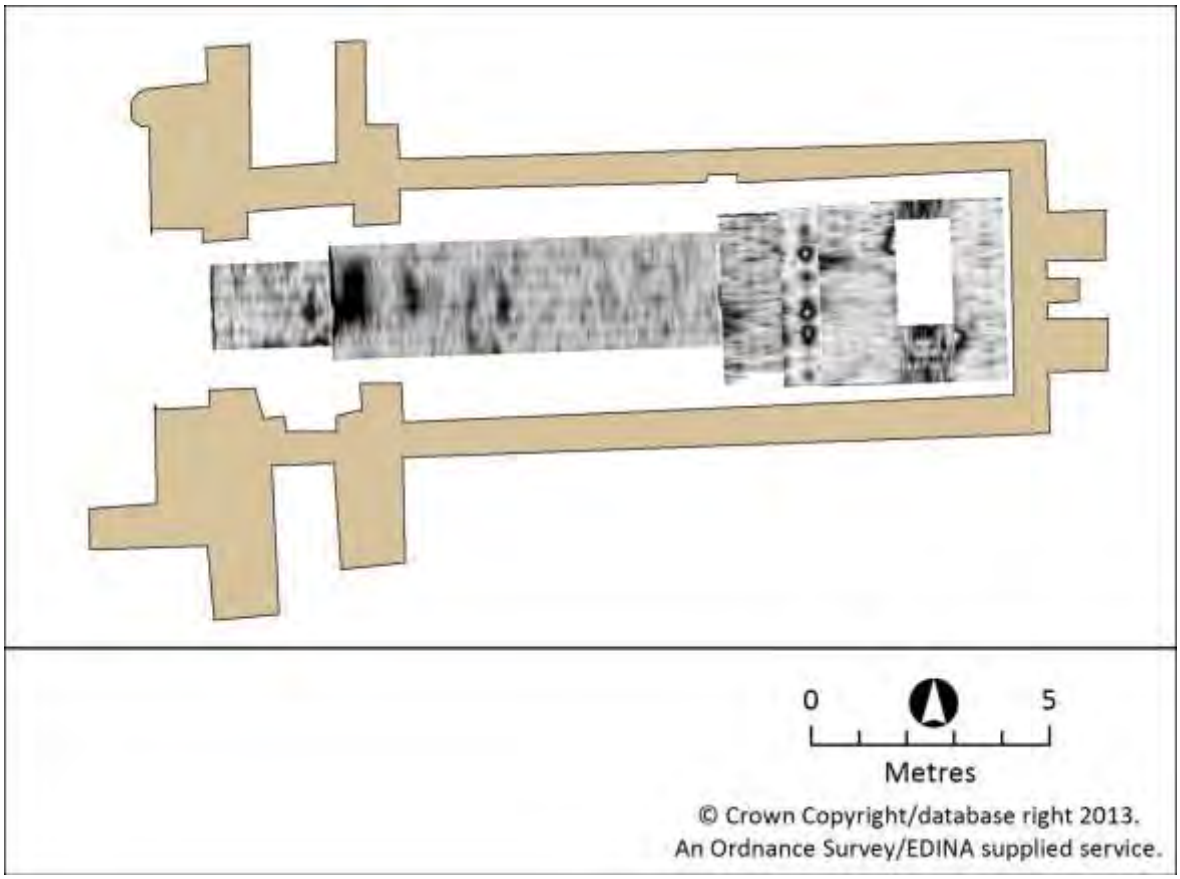


Figure 99: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.425cm

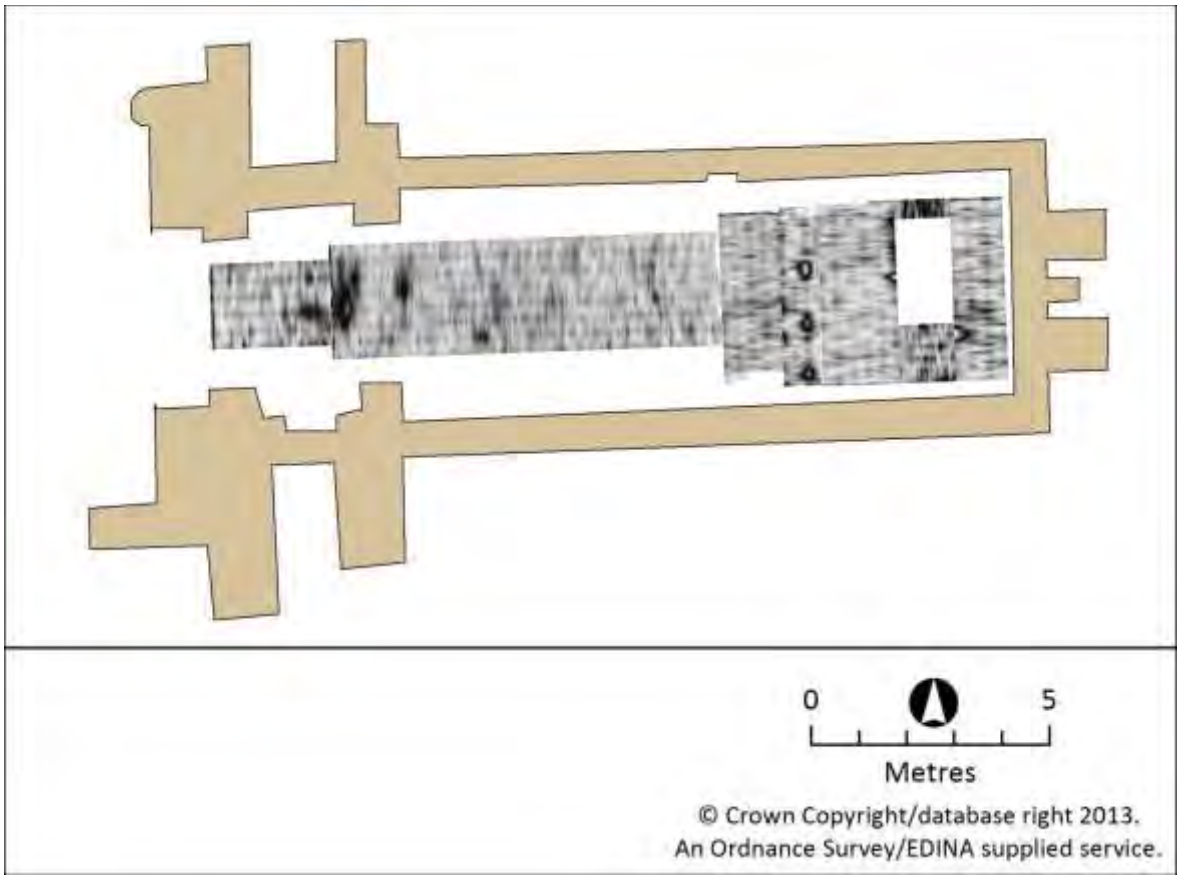


Figure 100: Internal GPR survey St Paul's Church, Jarrow, 2010. Plot at c.450cm

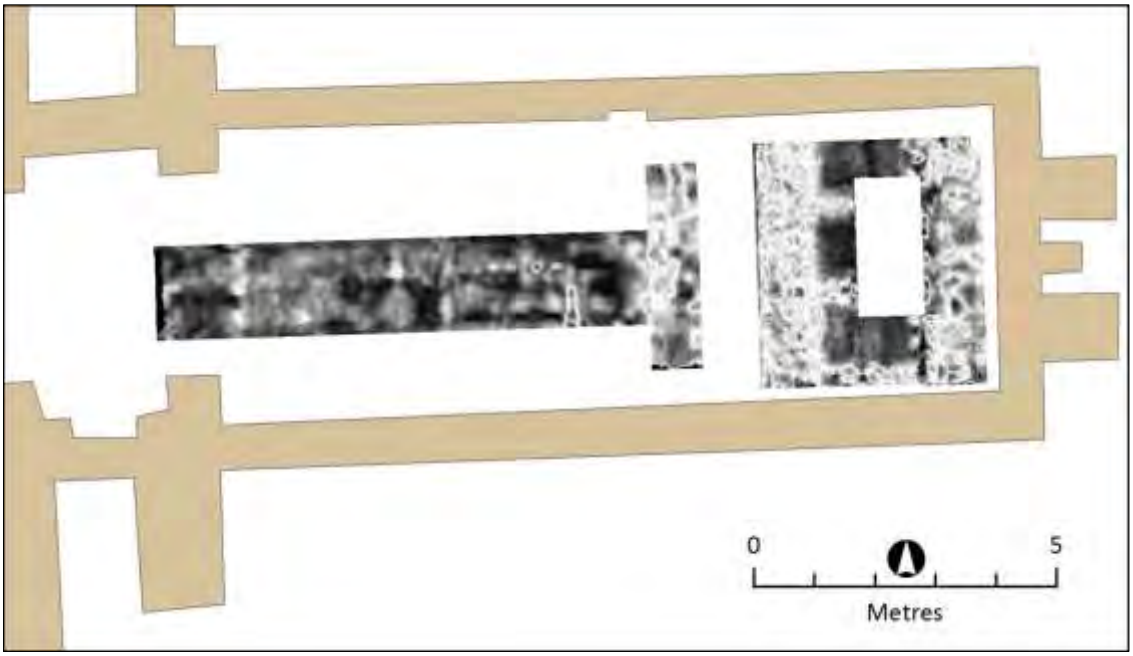


Figure 101: Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.25cm

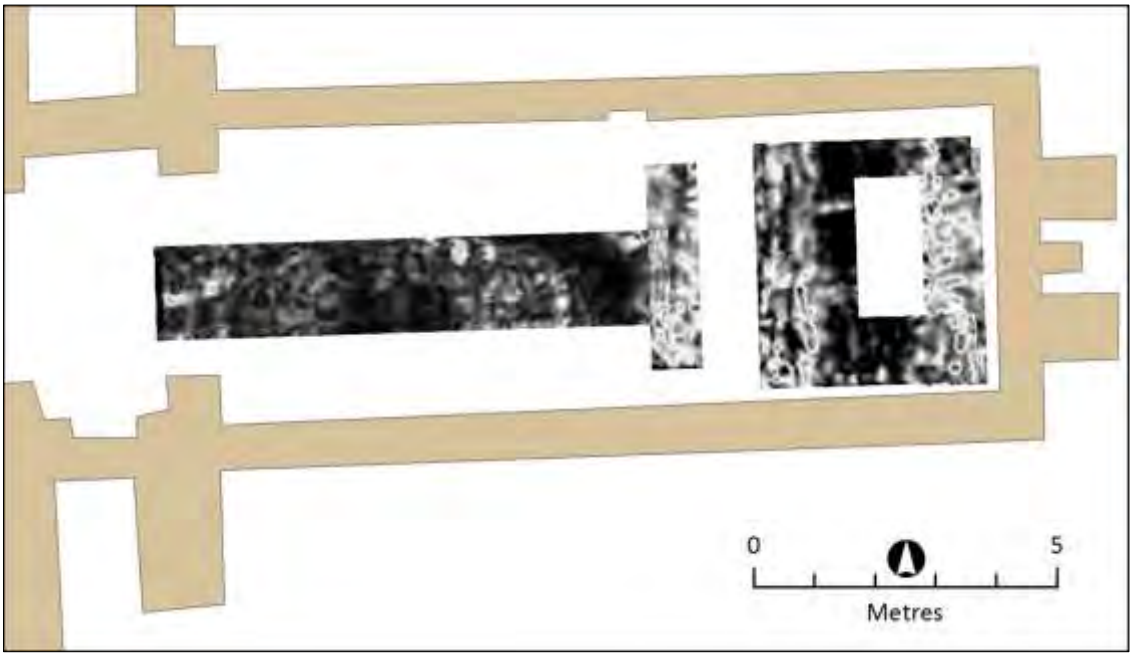


Figure 102: Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.50cm

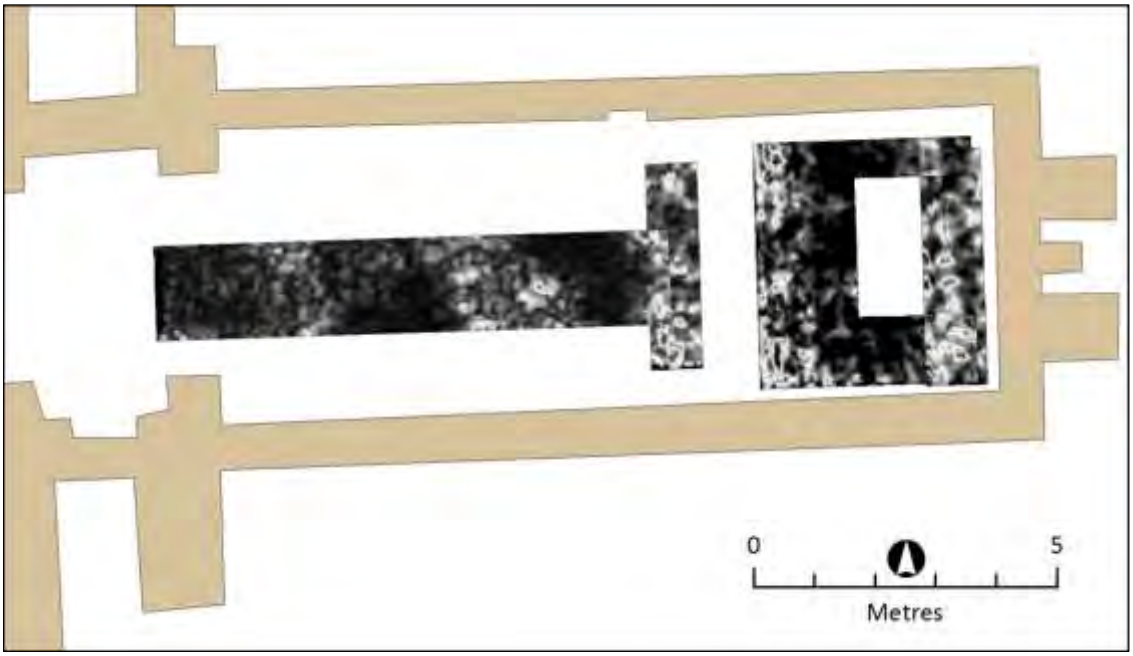


Figure 103: Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.75cm

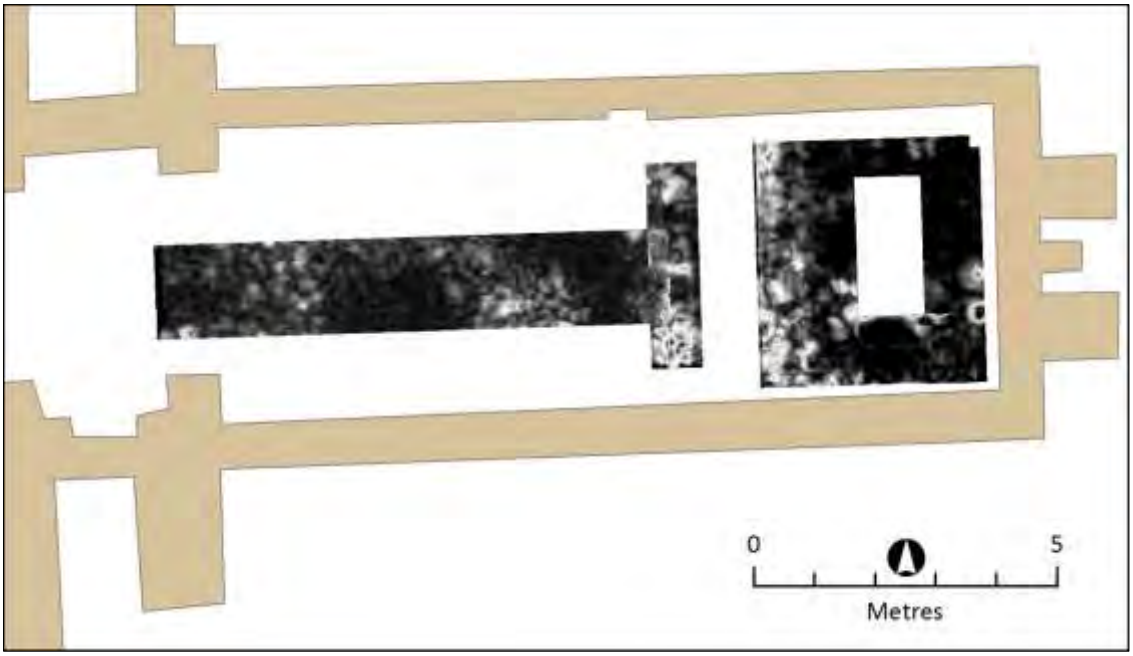


Figure 104: Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.100cm

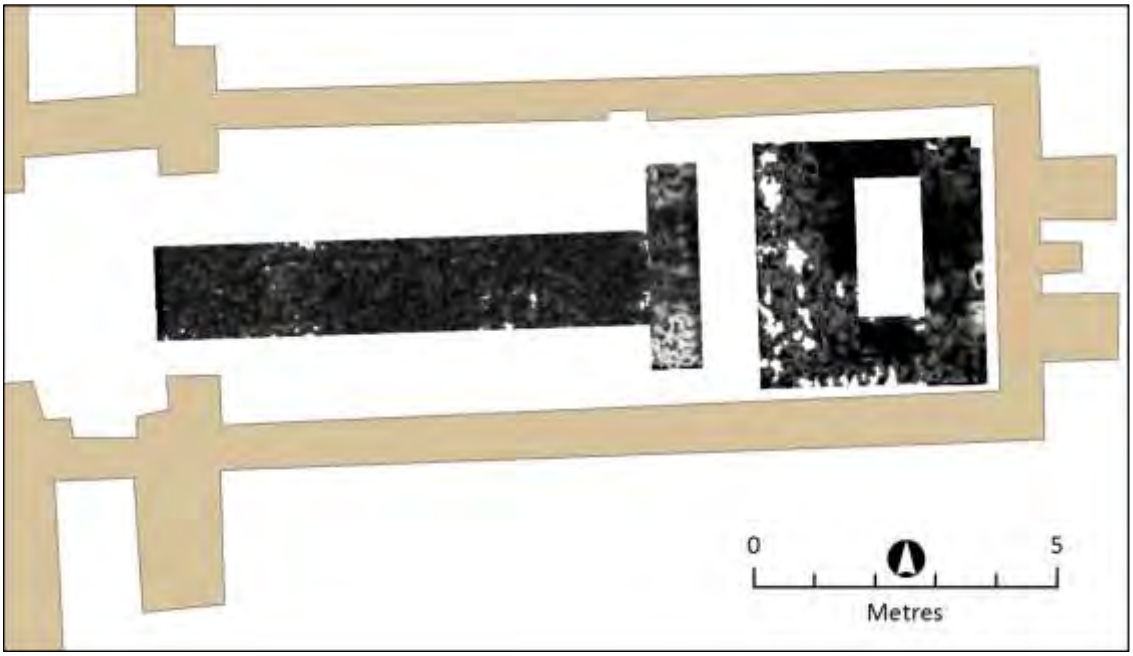


Figure 105: Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.125cm

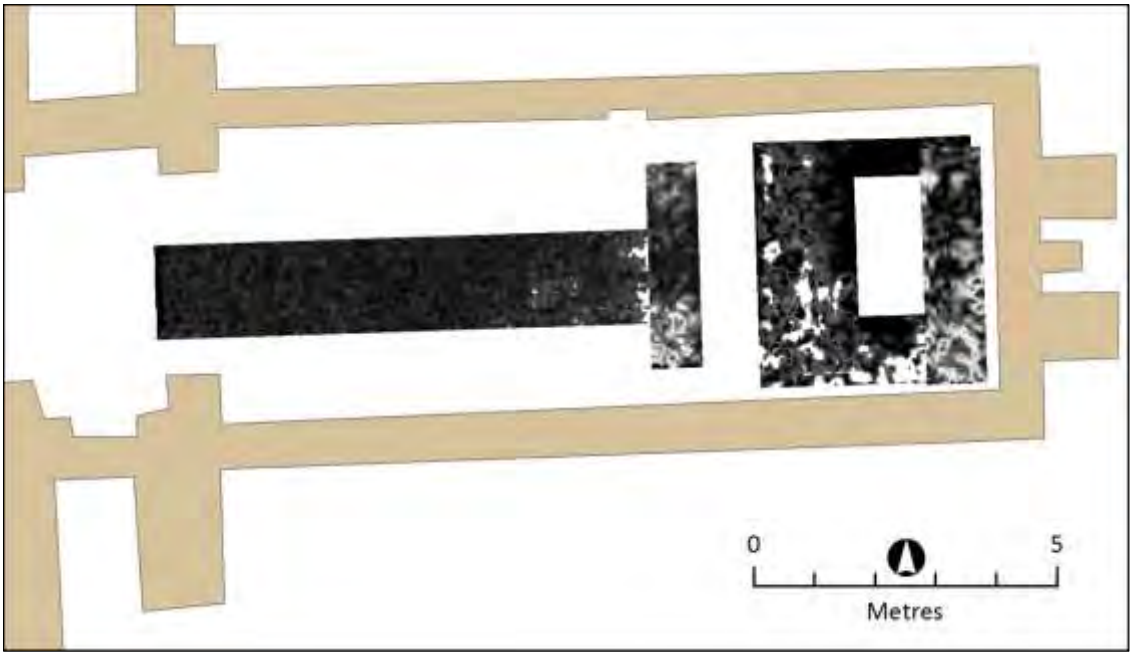


Figure 106: Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.150cm

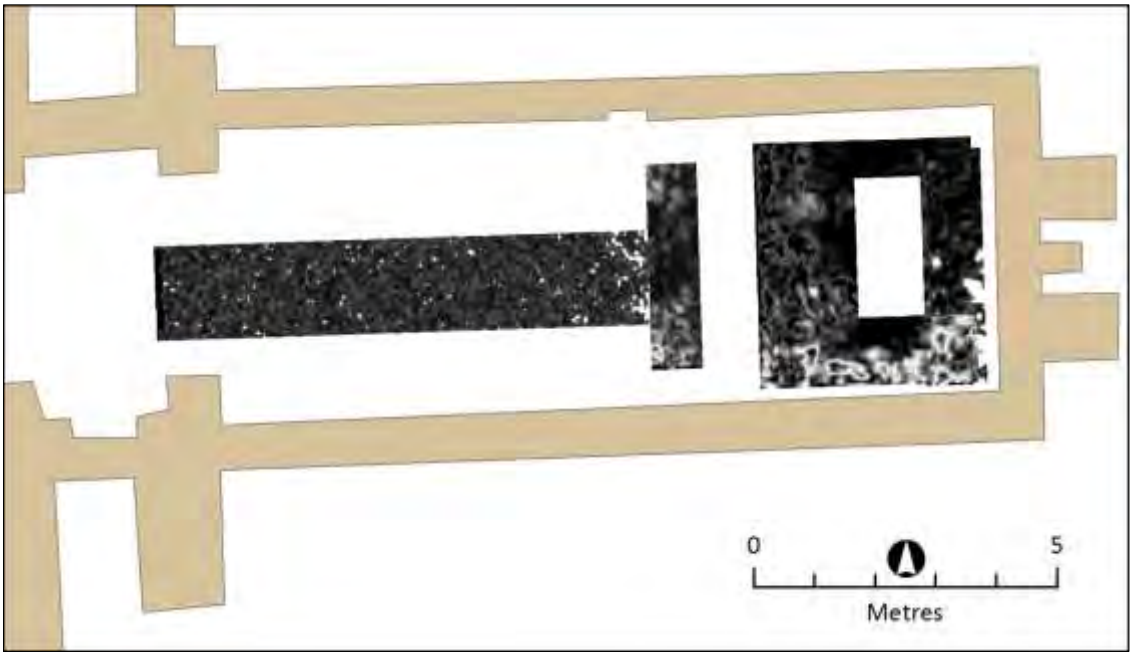


Figure 107:Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.175cm

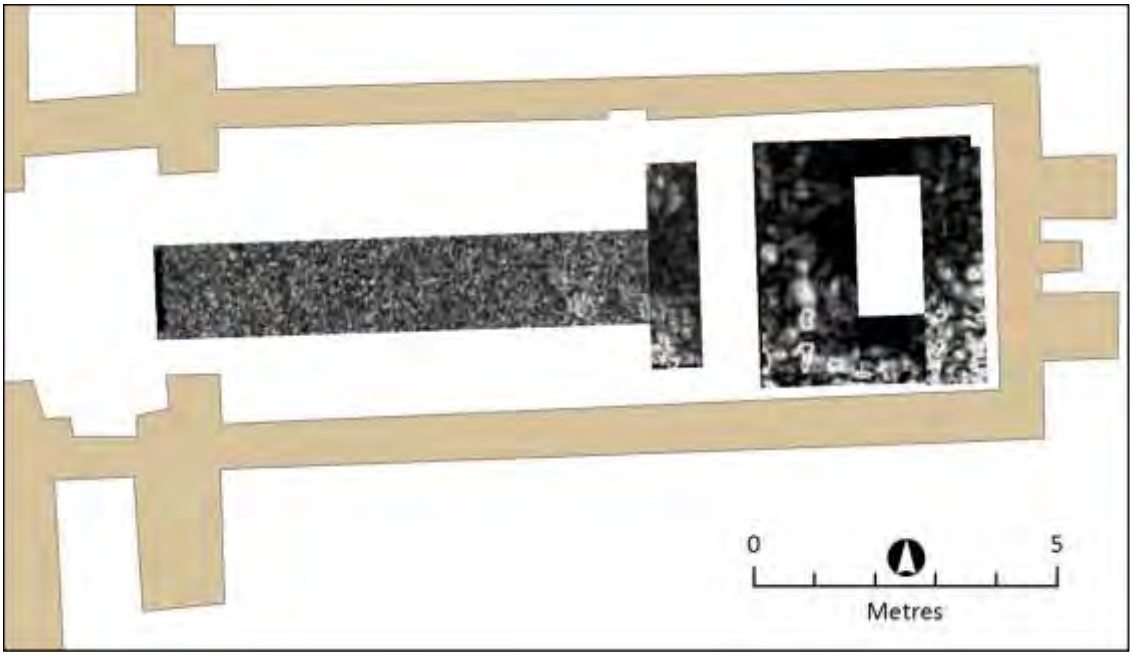


Figure 108: Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.200cm

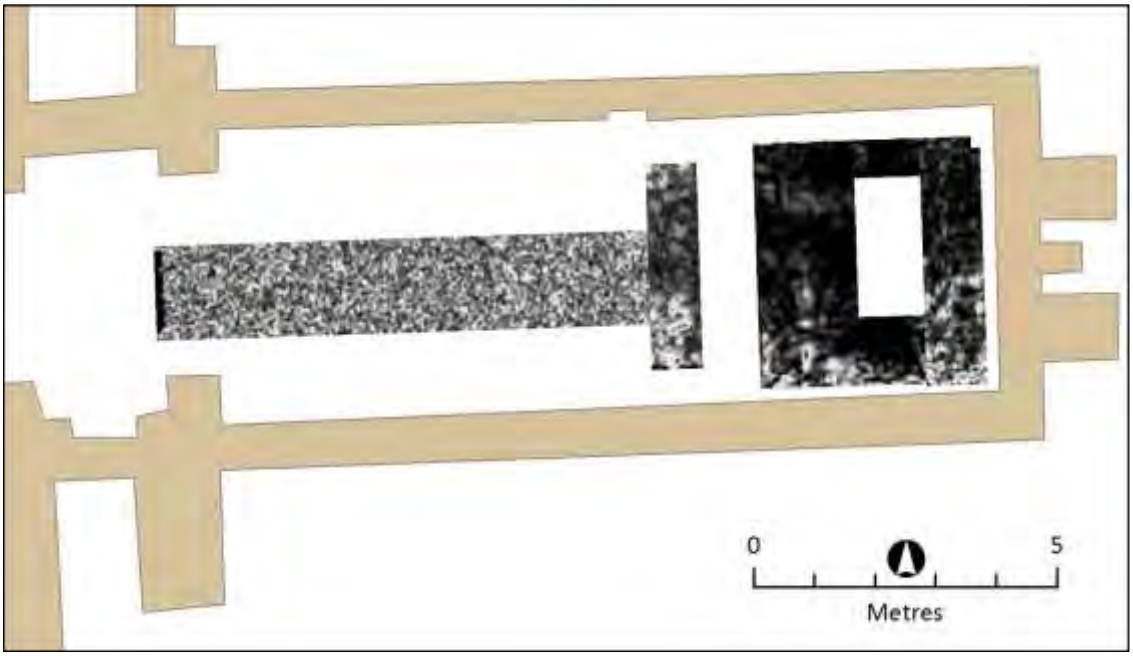


Figure 109: Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.225cm

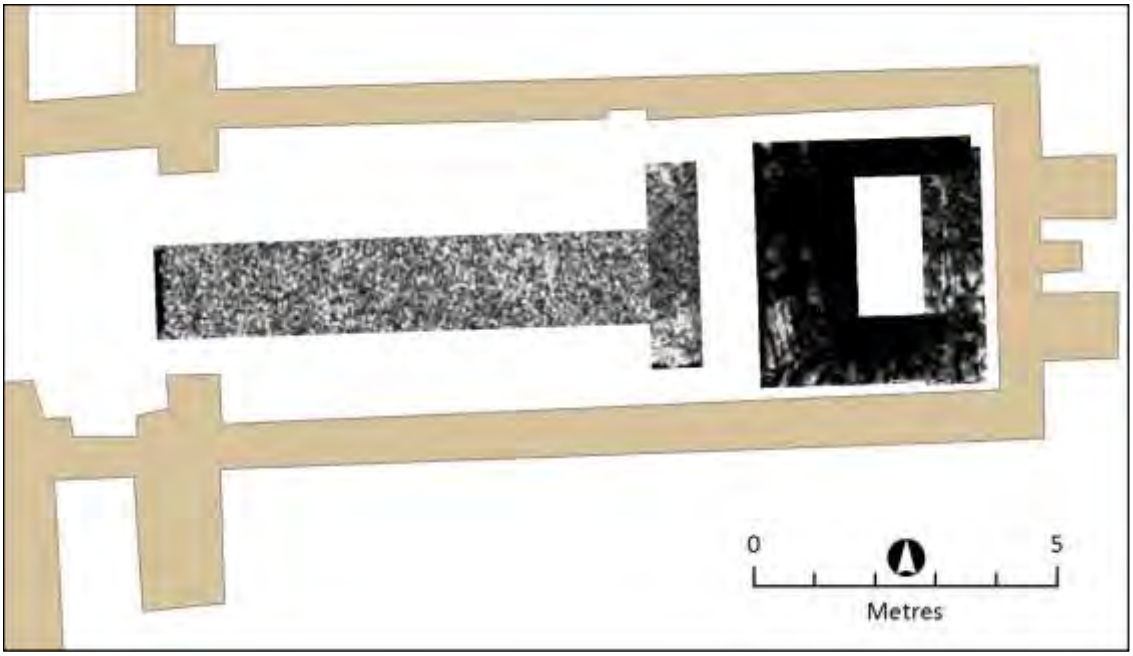


Figure 110: Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.250cm

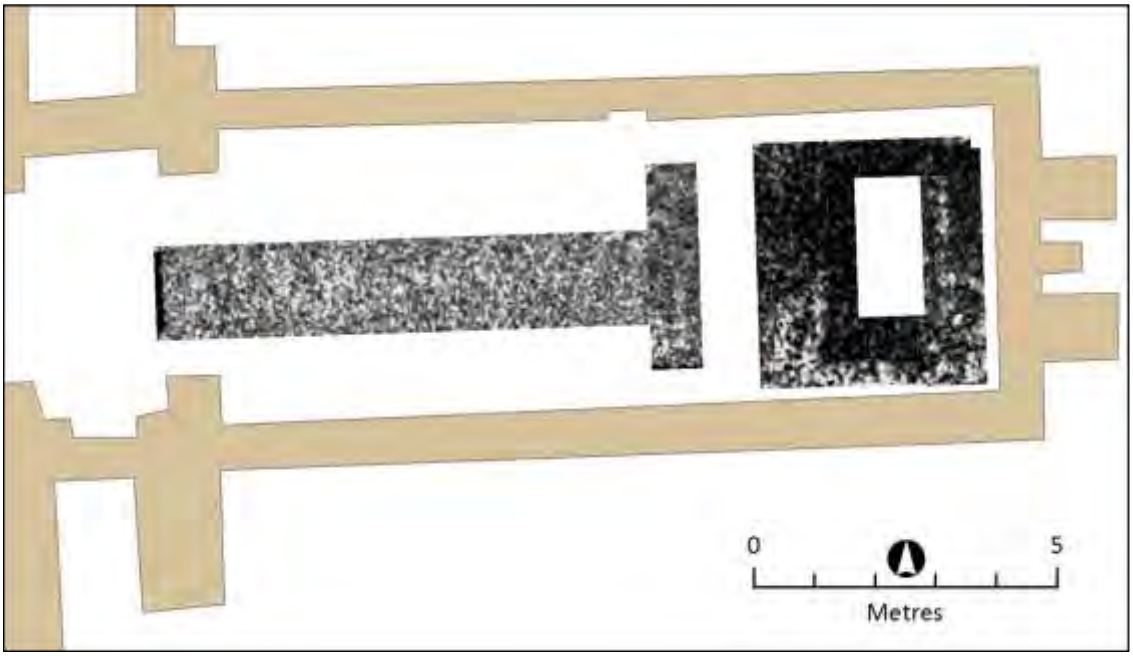


Figure 111: Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.275cm

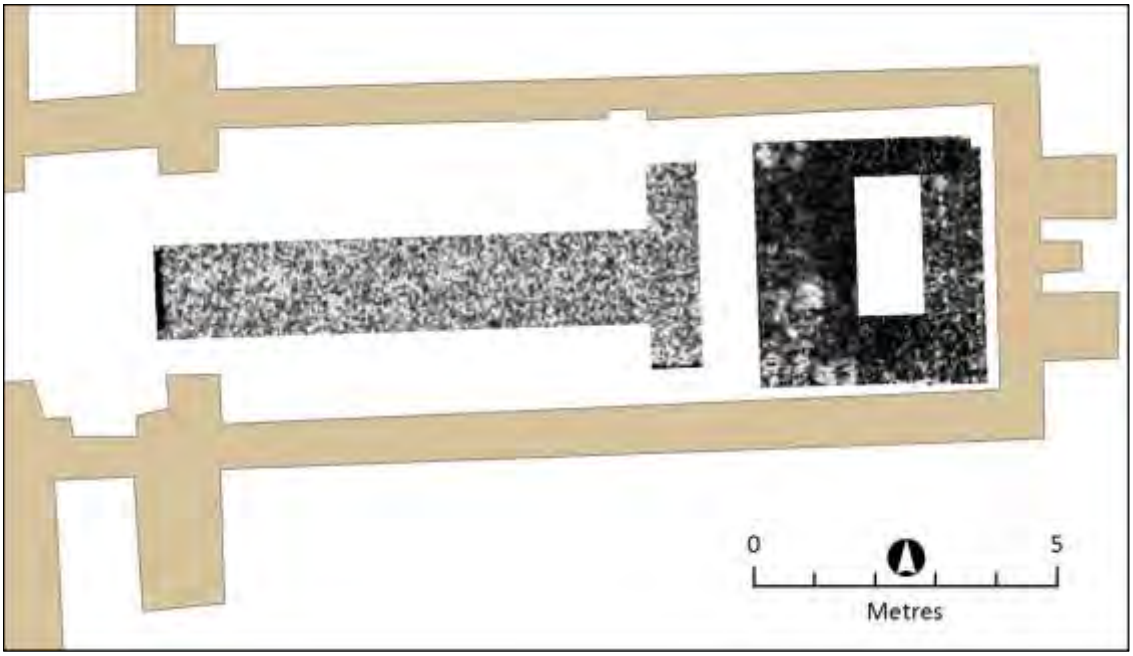


Figure 112: Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.300cm

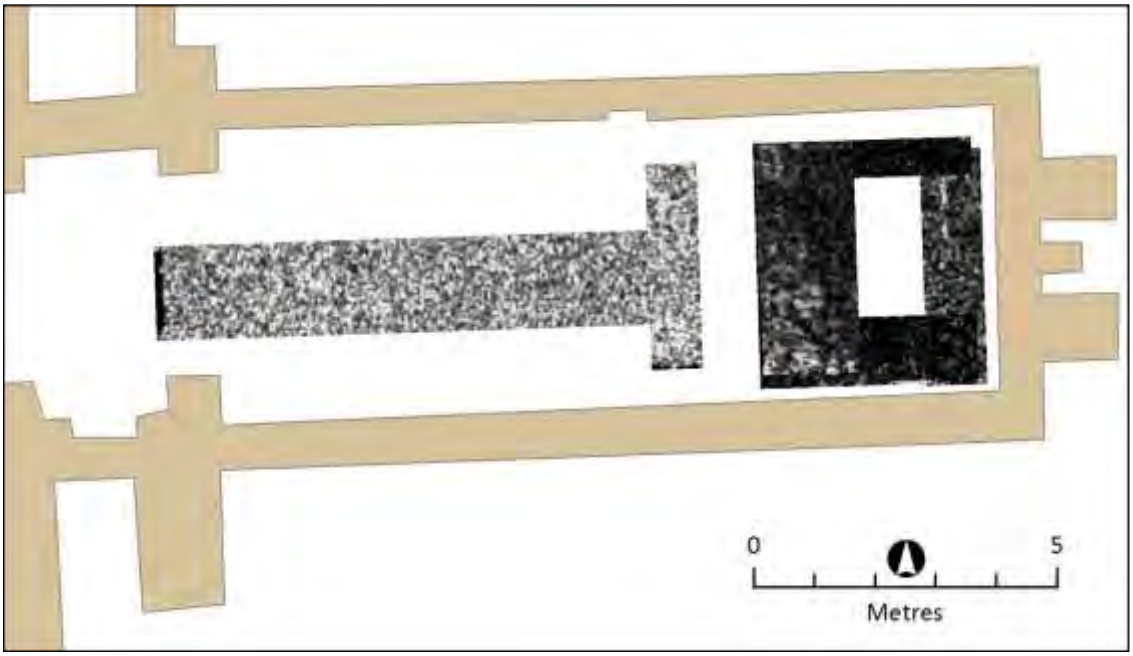


Figure 113: Internal GPR survey St Paul's Church, Jarrow, 2011. Plot at c.325cm

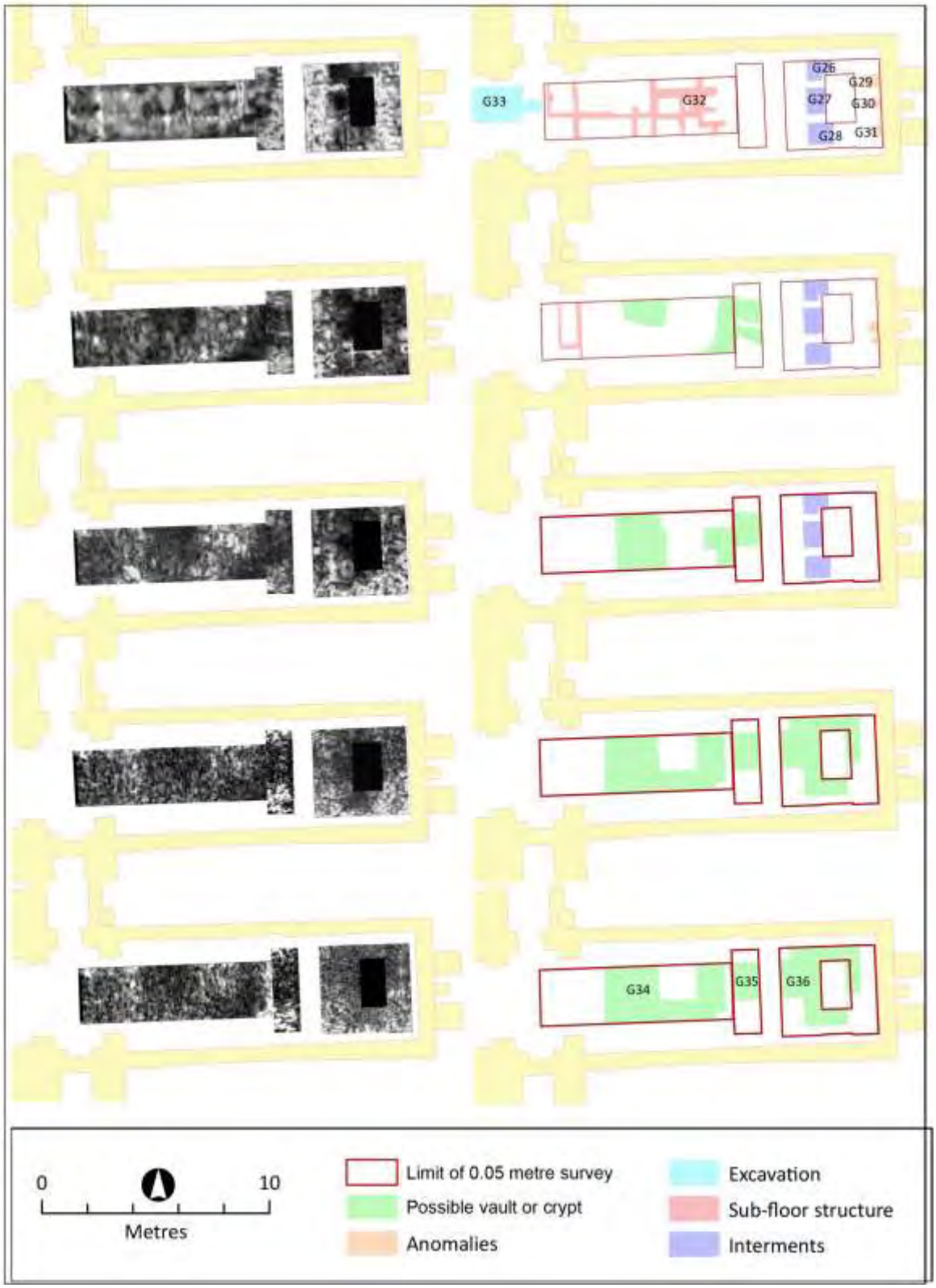


Figure 114: Internal GPR surveys St Paul's Church, 2010 and 2011. Combined plots and interpretation

GPR Survey Hexham (Figures 115 and 116)

The GPR survey over the known crypt at Hexham yielded a much clearer set of results (Figures 114 and 115) and it was possible to plot the profiles against the published cross-section of the crypt structure. The layout of the crypt with its the three cell structure and radiating passageways to the north and south bears only partial resemblance to the possible equivalent at Jarrow but it should be borne in mind that the survey at Jarrow, due to physical constraints within the church, only covered the central portions of the chancel and was restricted in the area around the altar. Additionally, the external survey on the south side of St Paul's, within the area of the monastic excavations of the 1960s, failed to recover any trace of similar external passageways. Crucially the exterior of the eastern end of the chancel was inaccessible due to the later addition of buttresses and the presence of two inhumations with substantial funerary monuments. If a crypt does survive at Jarrow then it is likely that, unlike the empty crypt at Hexham, that it is likely to be at least partially filled. Only further physical intervention, with perhaps the use of an endoscope, will definitively resolve this issue.

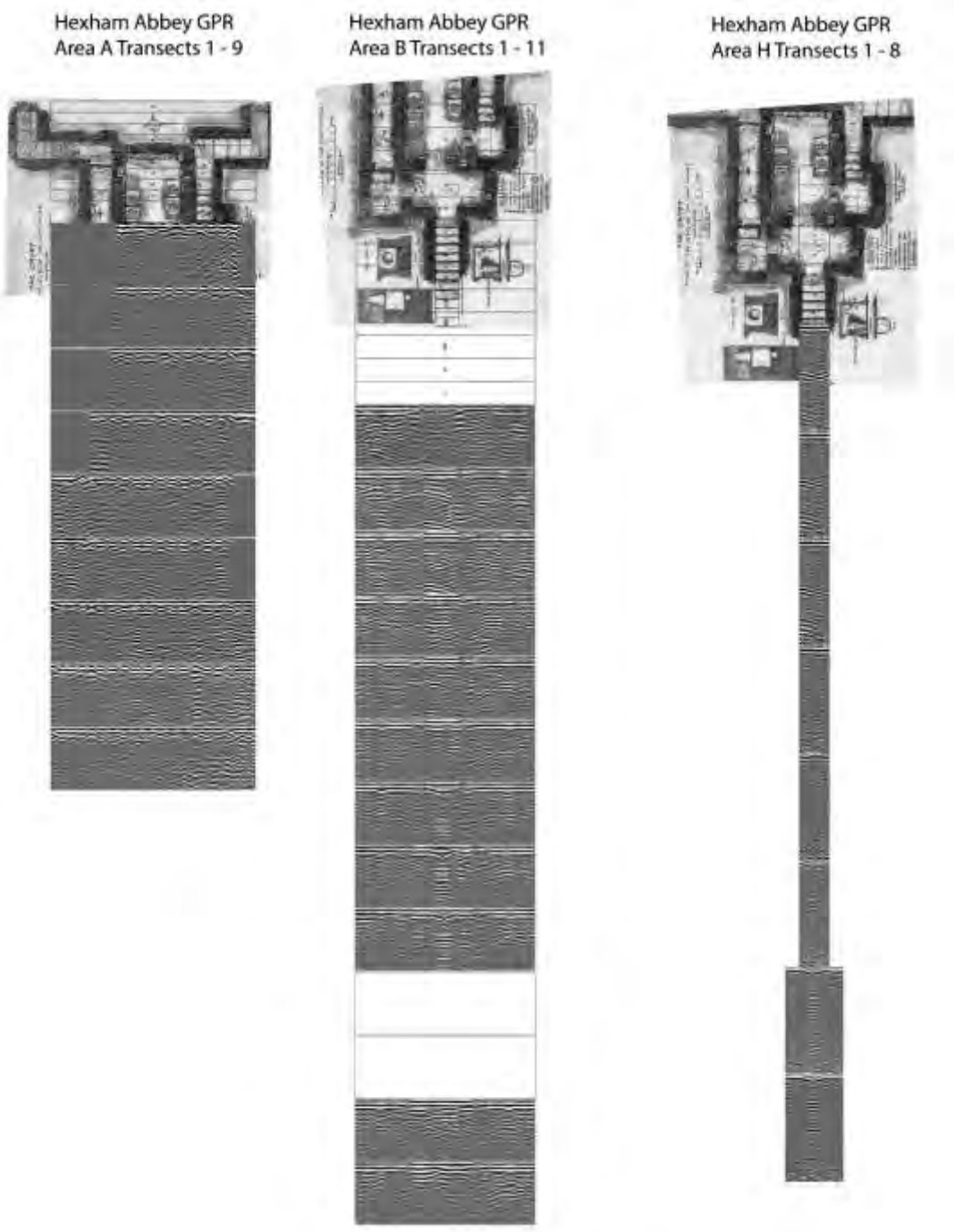


Figure 115: Internal GPR survey Hexham Crypt 2011. Profile areas A, B and H

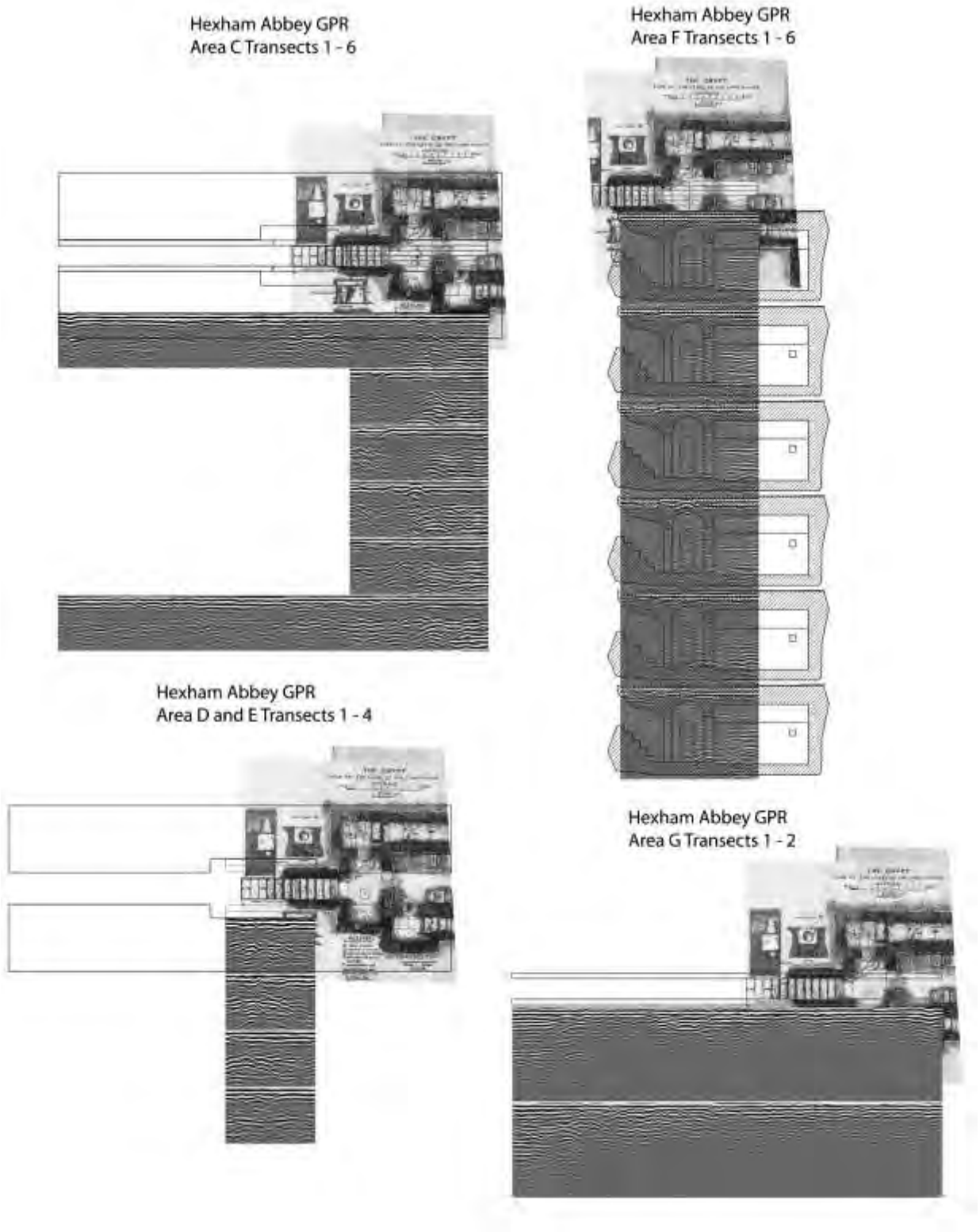


Figure 116: Internal GPR survey Hexham Crypt 2011. Profile areas C,D,E, F andG

St Peter's Church, Wearmouth

Resistivity Survey 2009 (Figures 117, 118)

The resistivity survey to the south of St Peter's Church revealed a number of anomalies, most of which could be reconciled with the available cartographic and excavation evidence. The outline of the monastery, shown as a series of linear blanks on the resistivity plot (Figure 117), represents the recently laid brick outline of the monastic complex based on the results of Cramp's excavations. A number of features could be specifically identified (Figure 118) and these included the circular imprint from the remains of the gasometer [R37], the broad spreads of material from the destruction of the Victorian housing [R49-R52] along with the linear outlines of plot boundaries [R43-R47], a footpath leading from the back of the Victorian housing [R41] and a perpendicular linear feature probably representing the edge of an excavation trench [R38]. Some of the more amorphous high resistance features revealed [R39-R40] are likely to represent disturbance from the installation and infill of the WWII air raid shelter. One possible structure [R48], known to exist in an unexcavated area to the southwest of the church, is likely to be associated with stables serving the Fire Engine House shown on the 1858, 1:500, town plan (Figure 119) and may be the dung pit clearly marked as DP. A modern feature [R42] is associated with utility services running from the road to the church and two other possible modern features [R53] and [R54] are probably electricity cables associated with the modern floodlights to the southwest of the tower. Although resistivity was quite clearly capable of detecting a range of sub-surface features at this site, it seems likely, given the results obtained from this survey, that any as yet undiscovered, surviving features associated with the early church are beyond the maximum depth penetration achievable with resistivity in a standard twin-electrode configuration. Despite ideal surface conditions, the previously attested level of overburden to the north of the church clearly precludes the use of resistivity as a survey method in this area.

Fluxgate Gradiometer Survey (Figures 120 to 123)

Two areas were surveyed to the south of the church using a fluxgate gradiometer in order to test the validity of the 2003 survey undertaken by Barker (Cramp 2005, 363). The results of this initial test (Figure 120) was broadly similar to those obtained in the original survey, although the interpretation differs, and the additional presence of a steel container and metal fence around the newly laid church outline [M61] meant that no further magnetic survey was undertaken. As with the resistivity survey the area to the north of the church was deemed unsuitable for this method due to the depth of the ballast known to exist there. The most obvious feature to be revealed was that of the outline of the WWII air-raid shelter at the southern edge of the current churchyard [M40]. The outline probably represents the rear of this three-celled structure which, given the topography, would have had its entrance facing south towards the shipyards on the banks of the River Wear. The small internal protrusions at the central of the back of each cell are likely to have been sub-divisions for toilet facilities. A plan of a similar structure from Brooklands Aerodrome, albeit on a much larger scale, clearly shows the same arrangement of space (Figure 123). The feature was also mapped as part of the North East Rapid Coastal Zone Survey and is one of a series of such features associated with the shipyards (Figure 136). The structure of the gasometer, seen as a circular anomaly in the resistivity survey was further revealed [M37] with the six large dipolar magnetic anomalies that locate the positions of the support stanchions. This would appear to be an early column-guided type gas holder of about 20 metres (65 feet) in diameter with a maximum height of between 8 and 10 metres and probably dates from the mid-19th century (Thomas 2010). It

was certainly in existence before the 1862 publication of the 1:10,560 Ordnance Survey map. The gasholder is shown on the National Grid 1:10,560 First Edition map published in 1951 but is no longer in existence by the time Cramp undertook the first of her excavations in 1959 (Cramp 2005, 75). These early structures have substantial cast-iron stanchions and the level of response obtained from the magnetic survey would suggest that the stubs of these were not completely removed and still survive below ground (Thomas 2010, 3). The linear dipolar magnetic feature that crosses the north-east corner of the gasometer is a modern service pipe and may be the same as that revealed in the resistivity [M57]. A further dipolar linear anomaly would appear to be a pipe [M60] that is servicing the rectory to the north. The linear anomaly [M59] is a remnant of the division between two now demolished housing plots and is associated with a large area of magnetic disturbance [M58]. Both of these features can be cross-reference to the Ordnance Survey 1:500 Town plan for 1896 (Figure 119). A series of small circular features [M55], [M56] were also discovered demarking the former area of Hallgarth Square. It was initially thought that these could be associated with the fencing that delimited Cramp's excavation of Halgarth Square in the 1960s but superimposition of the outline of her trenches on the results from the gradiometry indicate that this area was south of the opened area (Figure 122). Subsequent comparison with the surviving early Ordnance Survey maps suggests that these anomalies probably represent a line of trees used as a boundary to the square. The 1:500 town plan for 1895 seems to show that the square may have originally been covered by an orchard (Figure 119).

Ground Penetrating Radar (GPR) Survey (Figures 124 to 135)

The GPR survey was carried with the express intention of collecting data for the pre-18th century surface below the ballast to the north of the church and potentially to pick up evidence of further structures in areas not excavated by Cramp to the south of the church. Using a 500mhz antenna produced results from the south of the church that were encouraging but the signal attenuation caused by moisture in the ground coupled with the depth of deposits to the north of the church meant it was not possible to reach the pre 18th century church levels. The plots for the lower levels on the north side of the church (Figures 128 to 134) show broad bands of contrasting material and these are likely to be the levelled dumps of ship ballast documented in the borehole data (Figure 8). In addition to the air-raid shelter at the southern end of Halgarth Square, so prominent on the gradiometer survey, another air raid shelter in the north-east corner is shown on the NERCZA mapping survey (Figure 136). The GPR survey revealed nothing of this feature and it seems likely that the substantial pipe works by Northumbria Water in 2008 may have removed any trace of its remains. A further area, immediately west of the church tower, was investigated with the intention of finding a building revealed in 1912 (Cramp 2005, Figure 5.5, 48). However, despite intensive survey in this area, evidence for the existence of this feature could not be identified. This was largely due a series of underground services with the area that may well have destroyed this feature to the extent that it is unrecognisable from the GPR data.

However, to the south of the church a number of features were revealed. The outline of Hallgarth Square [G40] contrasted very strongly with the demolished buildings, disturbance from the air-raid shelter and most notably the excavations of the 1960s which appear to be visible between 0.5 metres and 2.5 metres on the GPR plots (Figures 124 to 128). As with the other geophysical methods used the outline of the gasometer was clearly visible down to a level of c. 1.0 metre [G37]. Roads and paths associated with demolished houses were also clearly revealed at depths of up to 1.5 metres [G59-G64]. The associated cellared buildings are visible as amorphous patches of rubble down to the 2.5 metre level

and equate to the anomalies found on both the resistivity and gradiometer surveys [G48]-[G52]. The outline of the monastery [G62] was clearly visible to a level of 2.0 metres below ground and tied in with the photographs, plans and sections from the 1960s excavations (Cramp 2005, 73-77). The only exception to this was a wall [G63] which lay within an unexcavated area between the limits of two excavation trenches. The unexcavated area to the west of the church failed to reveal any hitherto undiscovered features and all features detected in the plots from the upper two metres could be equated with features present on the early Ordnance Survey County Series maps and already discovered during the resistivity survey.

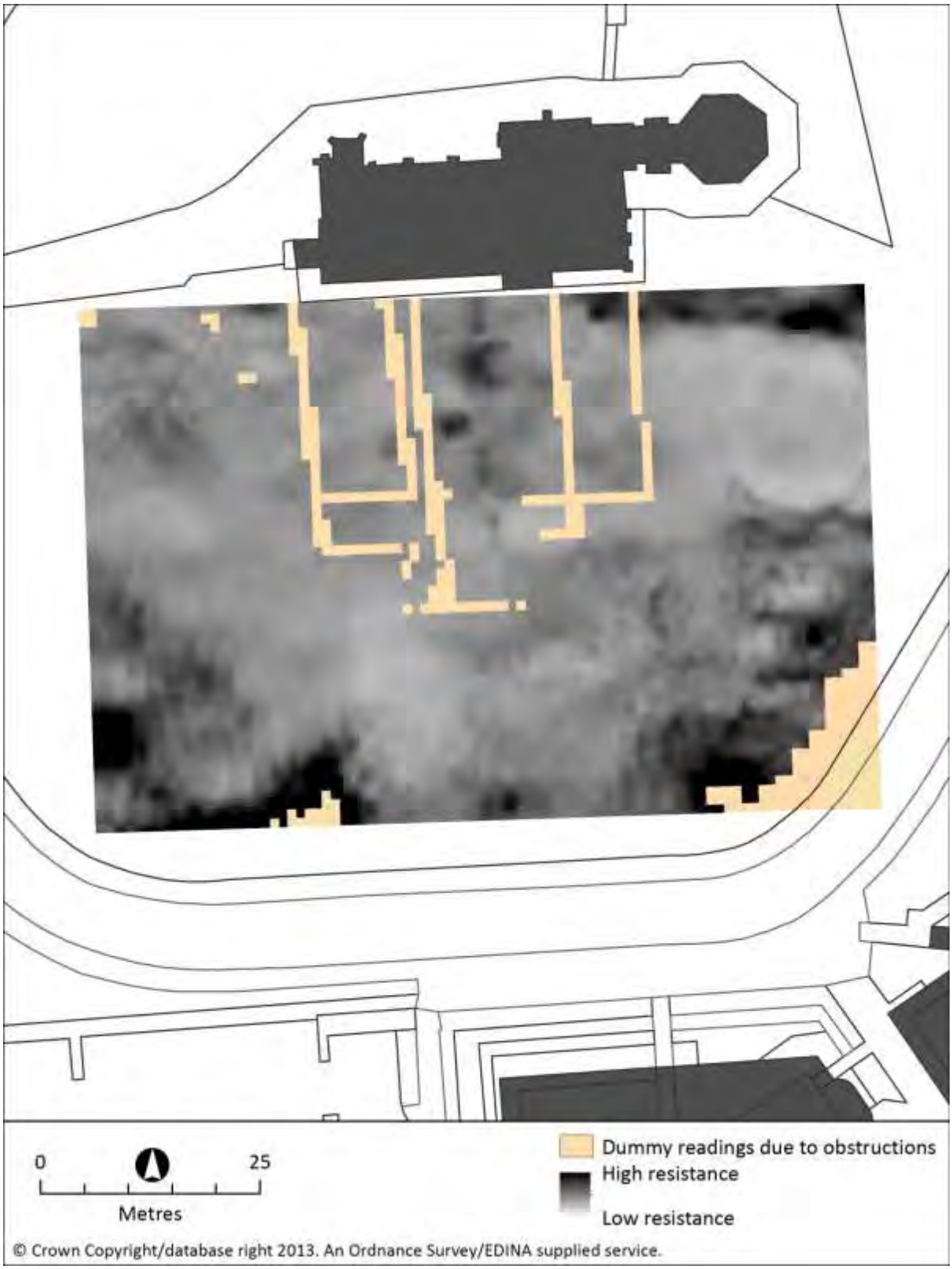


Figure 117: Result of the resistivity survey, Wearmouth

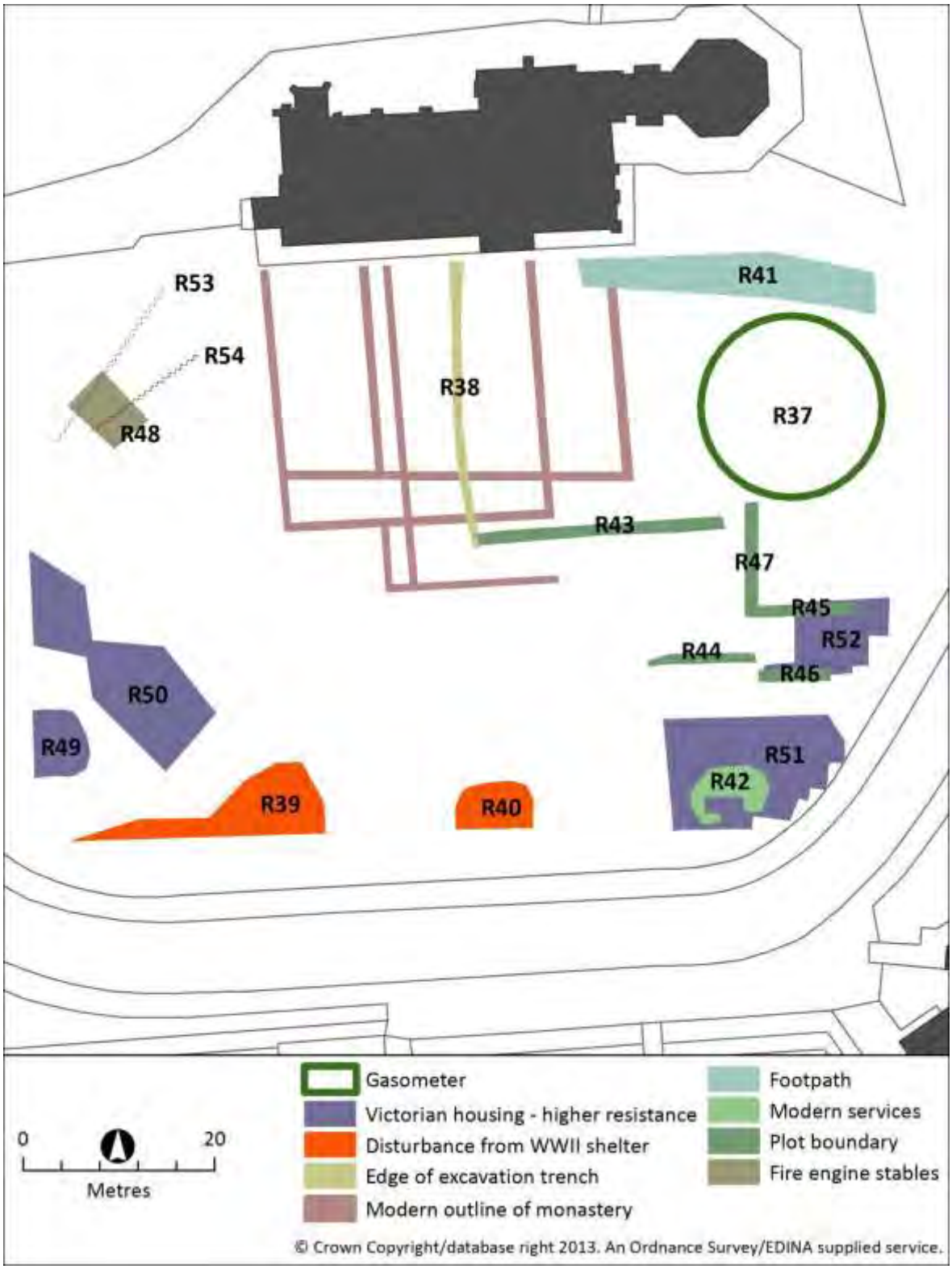
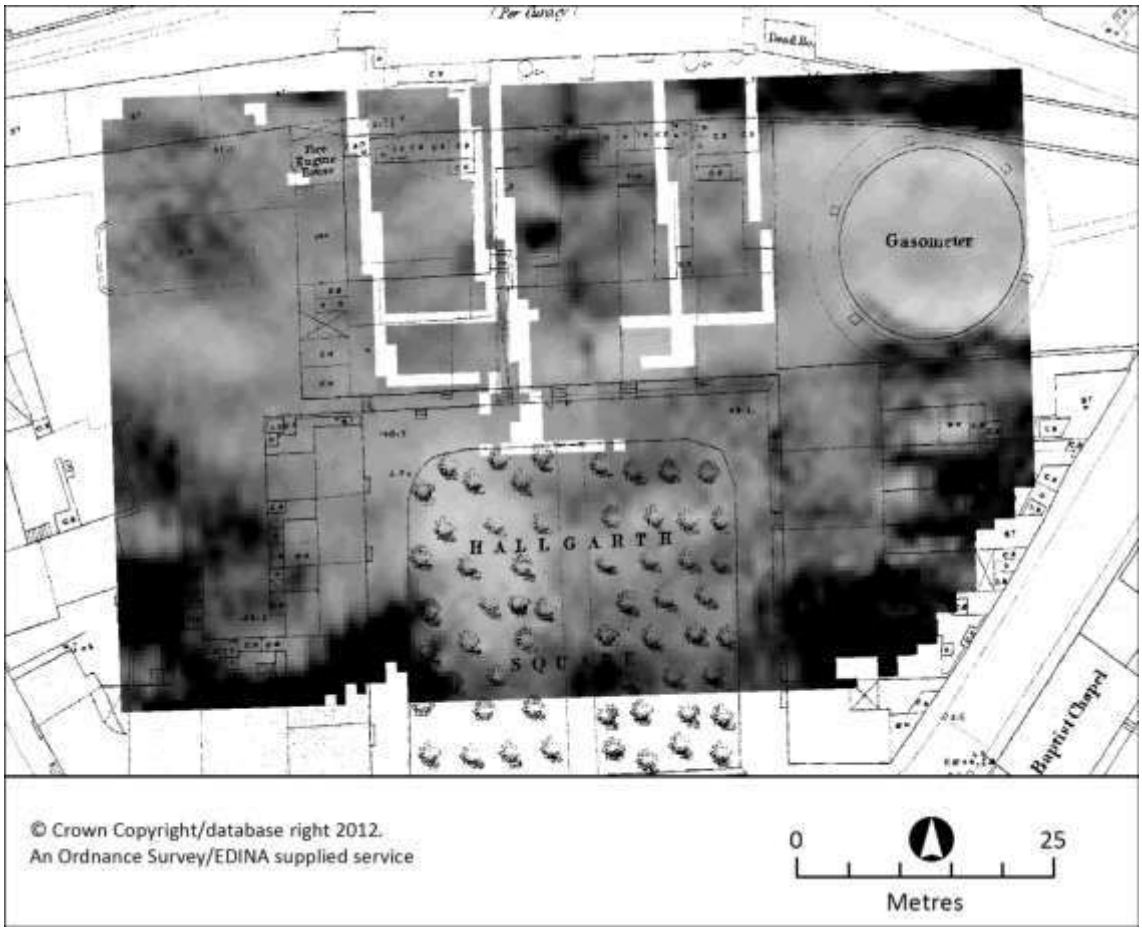


Figure 118: Interpretation of the resistivity survey, Wearmouth



M37

Figure 119: Extract from 1:500 Sunderland Town Plan First Edition overlaid over resistivity survey results for Wearmouth 2009

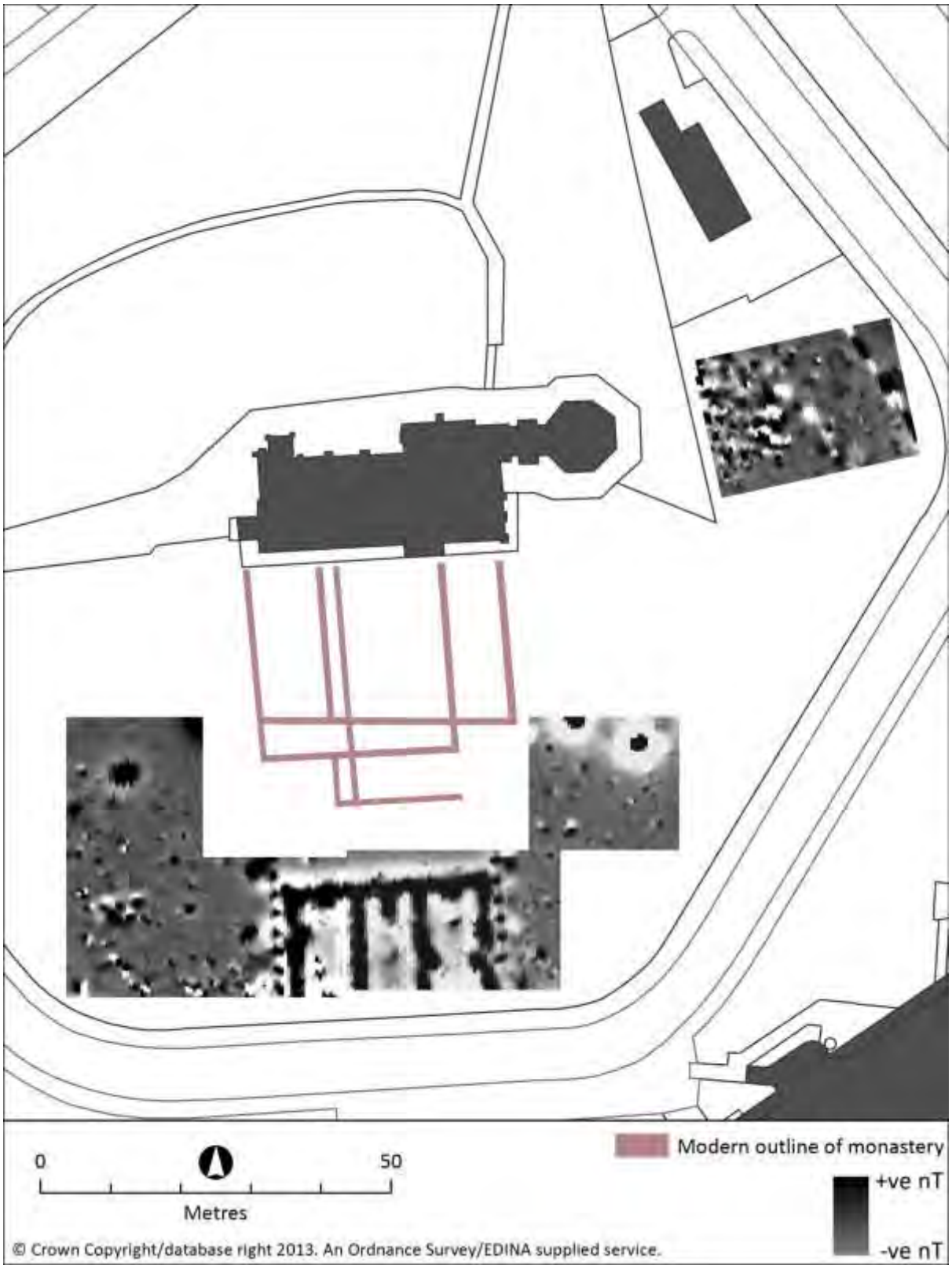


Figure 120: Results of the fluxgate gradiometer survey, Wearmouth 2009

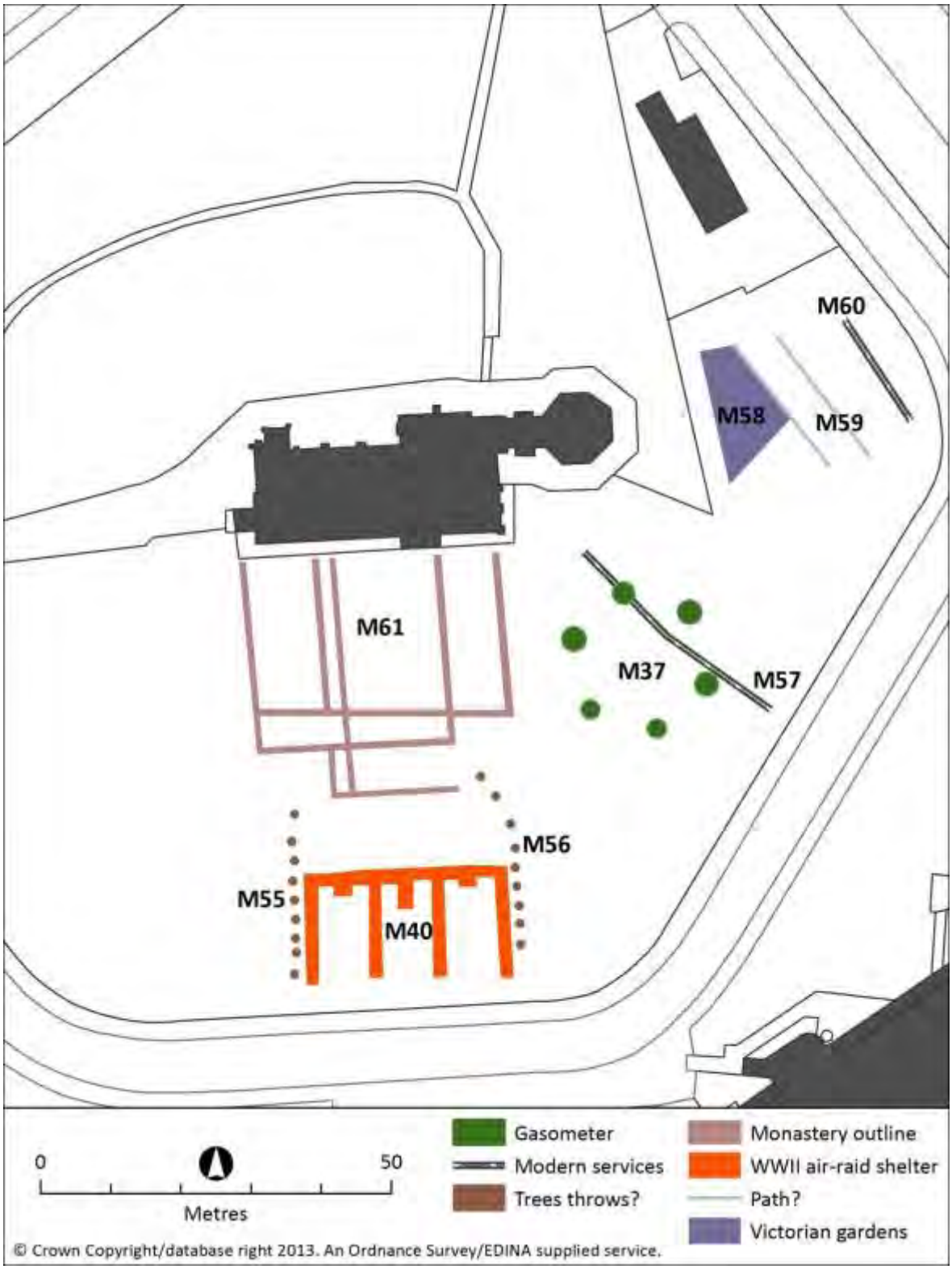


Figure 121: Results of the fluxgate gradiometer survey, Wearmouth 2009

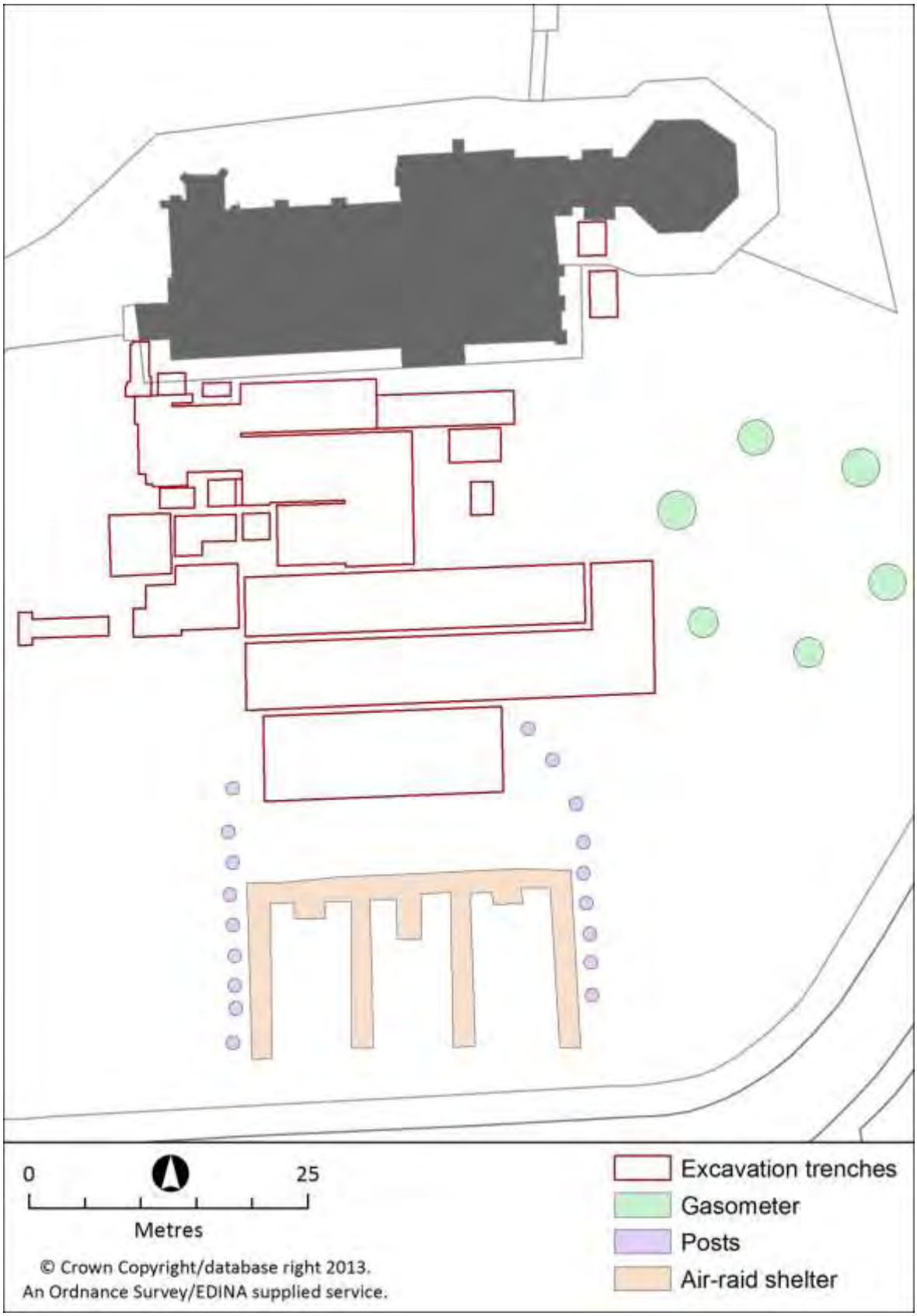


Figure 122: Cramp's excavation trenches with features from gradiometer survey.

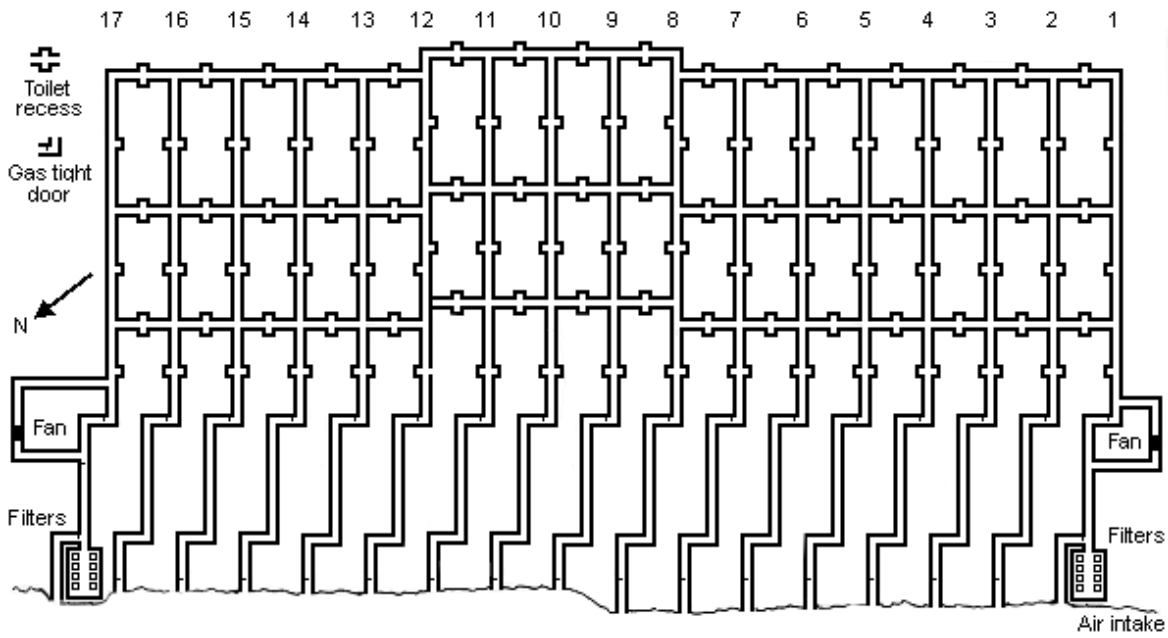


Figure 123: Plan of air-raid shelter- Brooklands Aerodrome

Figure 124: Plot of results from GPR survey 2009 areas A-I. Depth c.0.5m

Figure 125: Plot of results from GPR survey 2009 areas A-I. Depth c.1.0m

Figure 126: Plot of results from GPR survey 2009 areas A-I. Depth c.1.5m

Figure 127: Plot of results from GPR survey 2009 areas A-I. Depth c.2.0m

Figure 128: Plot of results from GPR survey 2009 areas A-I. Depth c.2.5m

Figure 129: Plot of results from GPR survey 2009 areas A-I. Depth c.3.0m

Figure 130: Plot of results from GPR survey 2009 areas A-I. Depth c.3.5m

Figure 131: Plot of results from GPR survey 2009 areas A-I. Depth c.4.0m

Figure 132: Plot of results from GPR survey 2009 areas A-I. Depth c.4.5m

Figure 133: Plot of results from GPR survey 2009 areas A-I. Depth c.5.0m

Figure 134: Plot of results from GPR survey 2009 areas A-I. Depth c.5.5m

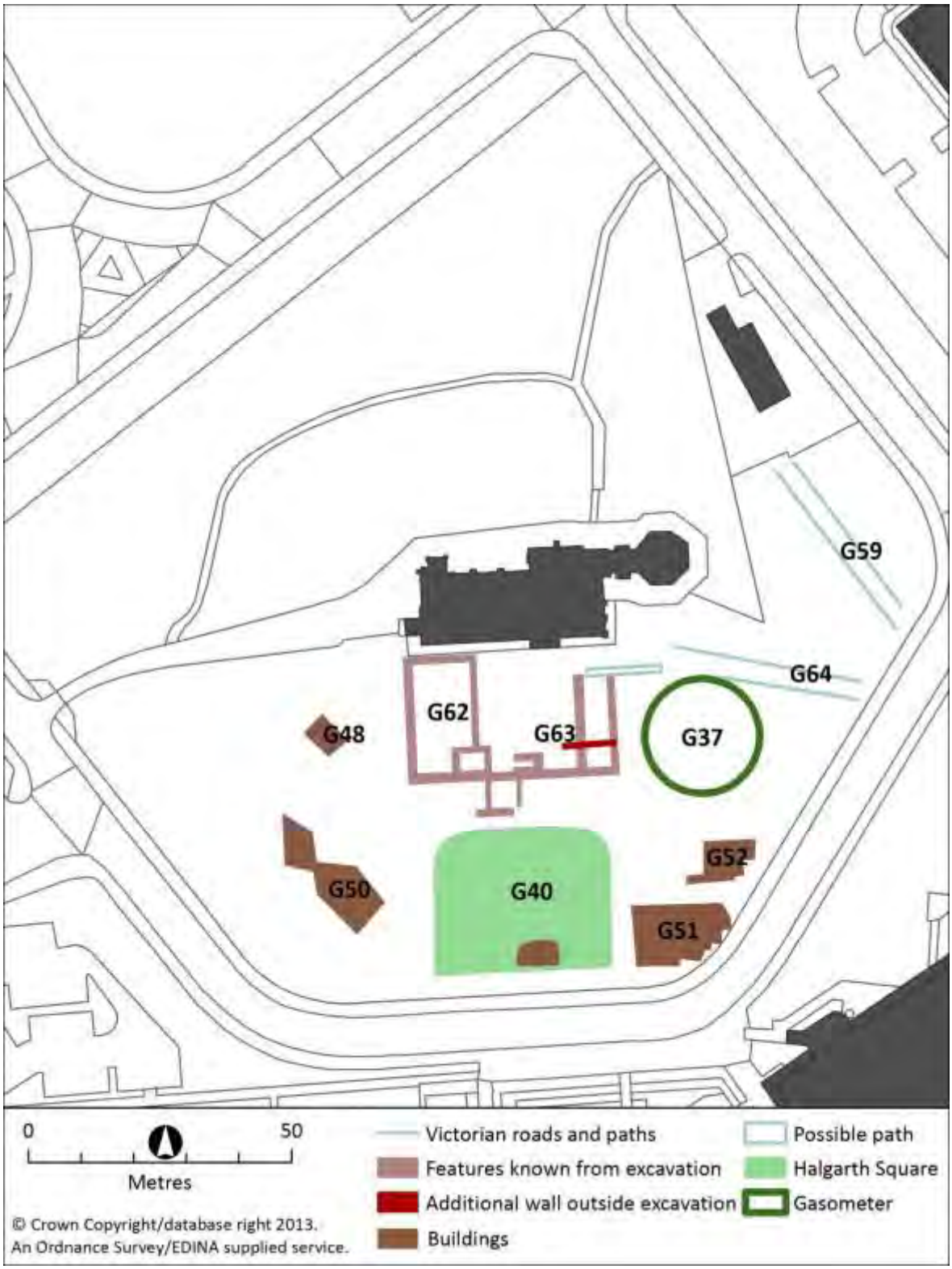


Figure 135: Combined interpretation of GPR plots from Wearmouth survey 2009

Figure 136: NERCZAS mapping of WWII air raid shelters and GPR plot c.1.0 metres

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