Caerphilly Castle
Caerphilly, Glamorgan

Multichannel Ground Penetrating Radar Survey

Grade I Listed Building (Cadw) Ref: 13539
Scheduled Monument (Cadw) Ref: GM002
Ref: 228023.03
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Summary

A Multichannel Ground Penetrating Radar (GPR) survey was conducted over two areas at Caerphilly Castle, Caerphilly, Glamorgan (centred on NGR 315611 187078) on 10 – 11 August 2020 and 28 September. The survey forms part of an ongoing programme of archaeological works being undertaken in support of the redevelopment of the Great Hall and adjacent areas within the South Domestic Range to improve its functionality and the provision of a greater range of visitor facilities adjacent to the Outer Main Gatehouse.

The GPR survey was successful in identifying a range of features in each area that are considered likely to be archaeological in origin. Within the areas surrounding the south-western Drum Tower (Area 1) and in the Central Eastern Platform (Area 2), numerous high amplitude responses were detected that relate to structural remains. Most of these relate to foundations for the existing castle structure.

Within Area 1, a single wall and a surface may relate to a small building within the Middle Ward, to the east of the West Gateway. There is also evidence for the foundations of the Inner Ward wall or levelling of ground for its construction. Within the State Apartment buildings, there is evidence for further foundations adjacent to the existing walls, but generally, there are no other internal features.

Within area 2, the remains of a structure have been located directly north-east of the Mill. It is probable that this has been heavily demolished and that the material from this structure has been utilised to level the area to the north. It is estimated from the GPR data that there is 1 – 1.2 m of made ground overlying this area. This is most likely associated with landscaping works during the latter part of the 19th century and the first half of the 20th-century.

The remainder of the anomalies are predominantly associated with modern activity and a series of probable modern services.

Crynodeb

Cynhaliwyd arolwg Radar Treiddio Tir Amlsianel dros ddwy ardal yng Nghastell Caerffili, Caerffili, Morgannwg (wedi'i ganolfan ar NGR 315611 187078) ar 10 – 11 Awst 2020 a 28ain Medi. Mae'r arolwg yn rhan o raglen barhaus o waith archeolegol i gefnogi ailddatblygu'r Neuadd Fawr ac ardaloedd cyfagos o fewn Ystod Ddomestig y De i wella ei swyddogaethau a darparu ystod ehangach o gyfleusterau i ymwelwyr gerllaw'r Prif Borthdy Allanol.

Roedd yr arolwg GPR yn llwyddo i nodi ystod o nodweddion ym mhob ardal yr ystyrir eu bod yn debygol o fod yn archeolegol. O fewn yr ardaloedd sy'n gysylltiedig â Thŵr Drum de-orllewinol (Ardal 1) ac yn Platfform Canol y Dwyrain (Ardal 2), canfuwyd nifer o ymatebion digonedd o uchder sy'n ymwneud ag olion strwythurol. Mae'r rhan fwyaf o'r rhain yn ymwneud â sylfeini ar gyfer strwythur presennol y castell.

O fewn Ardal 1, gall un wal ac arwyneb ymwneud ag adeilad bach o fewn y Ward Ganol, i'r dwyrain o Borth y Gorllewin. Ceir tystiolaeth hefyd ar gyfer sylfeini wal Ward Fewnol neu lefelu tir ar gyfer ei hadeiladu. O fewn adeiladau Aprhydment y Wladwriaeth, ceir tystiolaeth ar gyfer sylfeini pellach sy'n gyfagos i'r waliau presennol, ond yn gyffredinol, nid oes unrhyw nodweddion mewnol eraill.

O fewn ardal 2, mae olion strwythur wedi'u lleoli'n uniongyrchol i'r gogledd-ddwyrain o'r Felin. Mae'n debygol bod hyn wedi'i ddymchwel yn helaeth a bod y deunydd o'r strwythur hwn wedi'i ddefnyddio i lefelu'r ardal i'r gogledd. Amcangyfrifir o ddata'r GPR bod 1 – 1.2 m o dir wedi'i or-orddyled ar y maes hwn. Mae hyn yn fwyaf tebygol o fod yn gysylltiedig â gwaith tirlunio yn ystod rhan olaf y 19eg ganrif a hanner cyntaf yr 20fed ganrif.

Mae gweddill yr anghysonderau yn gysylltiedig yn bennaf â gweithgarwch modern a chyfres o wasanaethau modern tebygol.

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The fieldwork was undertaken by Brett Howard, Scott Chaussee, Rok Plesnicar and Nancy Dixon. Rok Plesnicar processed and interpreted the geophysical data, wrote the report and prepared illustrations. The geophysical work was quality controlled by Nicholas Crabb and the project was managed on behalf of Wessex Archaeology by Tom Richardson.

Caerphilly Castle, Caerphilly, Glamorgan

Multichannel Ground Penetrating Radar Survey Report

1 INTRODUCTION

1.1 Project background

1.1.1 Wessex Archaeology was commissioned by Mace Group Ltd, on behalf of Cadw, to carry out a geophysical survey at Caerphilly Castle, Caerphilly, Glamorgan (**Figure 1**). The survey forms part of an ongoing programme of archaeological works being undertaken in support of the redevelopment of the Great Hall and adjacent areas within the South Domestic Range to improve its functionality and the provision of a greater range of visitor facilities adjacent to the Outer Main Gatehouse.

1.2 Scope of document

1.2.1 This report presents a brief description of the methodology followed by the detailed survey results and the archaeological interpretation of the geophysical data.

1.3 The site

1.3.1 The geophysical survey area is located within Caerphilly Castle, which is located in the centre of the town of Caerphilly, 10 km north of Cardiff. The site is centred on National Grid Reference (NGR) 315611 187078 and lies within the administrative boundary of Caerphilly County and the historic borders of Glamorgan. The survey area is bounded by the castle buildings as well as the castle moat.

1.3.2 The survey comprises two areas of 0.28 ha. Area 1 is located at the south-western corner of the castle, surrounding the Drum Tower and also covers part of the South Domestic Range of the Inner Ward within the State Apartments. Area 2 is located to the east of the moat in the Central Eastern Platform, west of the Outer Main Gatehouse. The grounds currently comprise a mixture of grass, loose gravel surfaces, and pathways.

1.3.3 The castle is situated on a low-lying formerly marshy site surrounded by hills to the north, south, and west. The ground lies at an elevation of 88 m above Ordnance Datum (aOD). The interior of the fortifications, the Inner Ward, lies at a height of 95 m aOD.

1.3.4 The solid geology comprises mudstone, siltstone, and sandstone of the Grovesend Formation with superficial glaciofluvial deposits of sand and gravel (British Geological Survey 2020).

1.3.5 The soils underlying the site are recorded as unsurveyed due to the urban nature of the site (SSEW SE Sheet 5 1983) but are likely to be favourable for GPR survey based on the geological parent material.

2 ARCHAEOLOGICAL BACKGROUND

2.1 Introduction

2.1.1 The archaeological and historical background of the site has been investigated in a prior desk-based assessment (DBA) (Wessex Archaeology 2020), which considered the recorded historic environment resource within a 500 m study area of the proposed

development. The DBA used information from Cadw and the National Monuments Record of Wales (NMRW). Additional sources of information are referenced, as appropriate. Although not exhaustive, the following section summarises the findings of this DBA, which are considered relevant for the interpretation of this geophysical survey.

2.2 Summary of the archaeological resource

2.2.1 The castle at Caerphilly (Cadw 13539, GM002; GGATHER 00696m) was originally constructed between 1268 and 1271 by Gilbert de Clare (1245-95), Earl of Gloucester and Hertford and Marcher Lord of Glamorgan, in response to the threat posed by Llywelyn ap Gruffudd, Prince of Wales. After war broke out in 1276 further fortification was undertaken of the southern and western sides of the defences. Major works were also undertaken to the eastern part of the castle after this time in a different style. Caerphilly marks the beginning of a new trend in castle design, having no traditional keep but instead built on lines of concentric defence, although the Inner East Gatehouse could be isolated and defended. By the mid-14th century, the castle was effectively disused though it continued to be maintained.

2.2.2 The Great Hall is documented as being rebuilt between 1325-6 by Hugh Despenser the Younger and it is likely that other works were carried out on other parts of the castle at this time. However, no substantial work to the castle complex is thought to have taken place after 1326.

2.2.3 The town of Caerphilly (GGATHER 02328m) was established after the construction of the castle, outside the eastern barbican of the castle (Pugh 1971, 340). Skirmishes in 1294-5 and 1316 led to widespread destruction of the town but only limited damage to the castle itself. Although Caerphilly was a relatively small settlement at this time there is some surviving evidence for the town to the east and south of the castle including the 17th-century courthouse (Cadw 13568; GGATHER 01842m) along with several properties along Castle Street and Market Street (GGATHER 02618m-02642m).

2.2.4 The castle was largely ruinous by the early 16th century with the lakes now merely marshy areas. Further depredations occurred in the late 16th century when the property was leased to Thomas Lewis of Van, who used the stone dressings in the enlargement of his house.

2.2.5 By the 18th century, houses had been constructed adjacent to the south embankment of the castle confirming the obsolescence of the structure. However, the restoration of the castle was started in the 1870s by the third Marquess of Bute, who re-roofed the Great Hall and rebuilt the retaining wall on the north side of the North Lake. This work was continued by his son in the 1920s and 1930s.

2.2.6 In addition to the castle, a Roman fort is located to the north-west of the castle but still within the scheduled monument boundary. It was constructed on a glacial mound and consisted of a rampart and a double ditch. Three main phases of activity were identified with occupation from *c.*AD 75 into the latter part of the 1st century. A Roman road connected the fort to the legionary fortress at Caerleon and the fort at Cardiff.

2.3 Previous investigations.

2.3.1 Several small-scale investigations have been undertaken within the castle and Scheduled Monument Boundary. These are summarised in detail in the DBA (Wessex Archaeology 2019; Figure 4), but those located closest to Area 1 and 2 are summarised below.

Area 1 – South Western Drum Tower and State Apartments

2.3.2 Previous GPR surveys have been undertaken by SUMO Survey in 2019 over the Inner Ward, Great Hall, and north of the North-West Tower of Caerphilly Castle. This detected a number of linear and areal anomalies possibly associated with structural remains such as walls or foundations, buried surfaces, and disturbed ground. The GPR survey of the interior of the hall did not locate any archaeological features of note but did identify the below floor system of concrete ducts that contain the radiator pipework.

2.3.3 In 2007 a trench was located within the western area of the state apartments, to the west of the Great Hall (CAP Ltd 2007). This was dug to a depth of around 0.3 m below current ground levels, at which depth foundation stones of the northern wall were exposed and a deposit determined to be natural geology was uncovered at the southern end of the trench. It was therefore concluded that no medieval floor levels survive within this area of the castle.

2.3.4 A single trench was excavated in advance of the proposed installation of a new underfloor heating system in the Great Hall to a depth of 0.75 m (Archaeology Wales 2020). No evidence of an original floor surface or the remains of either a cross wall or screen passage were identified. Burnt material, a post hole, and linear feature along with three concrete features were thought to relate to later reconstruction works.

Area 2 – Central Eastern Platform

2.3.5 An archaeological evaluation of nine trenches was undertaken prior to the construction of the visitor centre to the west of the East Gateway (CAP Ltd 2001b). Excavations in the centre of this area revealed a buried medieval ground level (88.25 m aOD) but no floor surfaces or other structural remains. The whole of the area had undergone landscaping works during the latter part of the 19th century and the first half of the 20th century, which has resulted in the ground level being raised above the medieval ground surface. Three trenches south of the Main Gatehouse, which were only excavated to a relatively shallow depth, located a buried medieval soil at a depth of around 89 m aOD and a dump deposit thought to represent backfill within the construction cut for the wall.

2.3.6 An archaeological watching brief was carried out in three areas in advance of i) the proposed new visitor centre located west of the Outer East Gatehouse, ii) the establishment of a temporary contractor's compound east of the mill and south of the Outer Main Gatehouse, iii) the new toilet block in the south-east corner of the Inner Ward (CAP Ltd 2002). Within the new visitor centre groundworks comprised stripping the footprint to approximately 0.3-0.4m below the stepped footings of the curtain wall as well service trenches. Rubble and mortar rich deposits were thought to represent 19th-century levelling deposits. An undated linear feature was also thought to be associated with 19th-century reconstruction works. A small area of flat angular stones was also uncovered, and a possible ditch cut and charcoal spread was identified within the service trenches.

3 METHODOLOGY

3.1 Introduction

3.1.1 The geophysical survey was undertaken by Wessex Archaeology's in-house geophysics team on 10 – 11 August for the multichannel radar survey. Field conditions at the time of the survey were good throughout the period of survey. An overall coverage of 0.21 ha was achieved. A steeper area deemed inappropriate for the multichannel survey could not be surveyed at the northern part of the Gatehouse area. This area was revisited on the 28 September with a single channel antenna. The ground conditions at the time of the survey

were good. An overall coverage of 0.07ha was achieved. In total 0.21 ha of the 0.28 ha area was surveyed. The remaining areas were unsuitable for survey due to obstructions.

3.1.2 The methods and standards employed throughout the geophysical survey conform to that set out in the Written Scheme of Investigation (WSI) (Wessex archaeology 2020), as well as to current best practice, and guidance outlined by the Chartered Institute for Archaeologists' (CIfA 2014) and European Archaeologiae Consilium (Schmidt *et al.* 2015).

3.2 Aims and objectives

3.2.1 The aims of the survey comprise the following:

- To determine, as far as is reasonably possible, the nature of the detectable archaeological resource within a specified area using appropriate methods and practices; and

- To inform either the scope and nature of any further archaeological work that may be required; or the formation of a mitigation strategy (to offset the impact of the development on the archaeological resource); or a management strategy.

3.2.2 In order to achieve the above aims, the objectives of the geophysical survey are:

- To conduct a geophysical survey covering as much of the specified area as possible, allowing for on-site obstructions;

- To clarify the presence/absence of anomalies of archaeological potential; and

- Where possible, to determine the general nature of any anomalies of archaeological potential.

3.3 Fieldwork methodology (Mala MIRA multi-channel array)

3.3.1 The GPR survey was conducted using a Malå Imaging Radar Array (MIRA). This multi-channel GPR system uses separate shielded transmitter and receiver antennae mounted within a rough terrain cart setup. The MIRA system contains 5 transmitter and 4 receiver antennae with a central frequency of 400 MHz to form 8 channels for data collection. The data were recorded every 4 cm with a horizontal profile spacing of 8 cm within a time window of 60 ns.

3.3.2 Multi-channel ground penetrating radar (GPR) systems provide real-time positioning enabling full site coverage without the need to set up individual grid nodes across the survey areas. This allow positions to be determined with sub-decimetre accuracy and therefore exceeds EAC recommendations (Schmidt *et al* 2015). However, in order to ensure survey accuracy, the boundaries of the survey extent were established using a real-time kinematic (RTK) Global Navigation Satellite System (GNSS) instrument. In addition, several further grid notes were established on site to ensure that the area was covered in regular swathes.

3.3.3 Data were collected in the zigzag method, with 8 profiles collected simultaneously along each 0.64 m swathe.

3.4 Fieldwork methodology (Impulse Radar Crossover 4080)

3.4.1 The GPR survey was conducted using an Impulse Radar Crossover 4080 system with a dual shielded antenna. This was mounted on a rough terrain cart which is fitted with an odometer to measure horizontal distance along the ground surface. This was deployed across all of the GPR areas with data collected along traverses spaced 0.5 m apart. Data

with the 400 MHz antenna was collected every 0.02 m with an effective time window of 100 ns. This was collected in the zigzag method.

3.4.2 A field test of the antenna frequency was undertaken prior to the commencement of the survey using 400 and 800 MHz antennae. This established that the 400 MHz antenna was likely to provide the most information regarding the nature of archaeological remains within each area and therefore no further survey was undertaken using an alternative antenna.

3.5 Data processing

3.5.1 Data from the GPR survey has been subjected to common GPR signal correction processes. These comprise amplitude and wobble correction of the radar profile to correct for variance in temperature and soil moisture content, normalisation of the first response and background and bandpass filtering to remove noise in the data from the surrounding area. These steps were applied to all datasets collected across the Scheme.

3.5.2 Multi-channel systems require additional signal processing to compensate for small differences in the frequency responses between the individual channels. This was achieved by applying a Hilbert Transformation, which reduces the oscillating components of the individual GPR pulses.

3.5.3 The approximate depth conversions for the 400 MHz antennae data for both Area 1 and 2 are shown in **Table 1**, **2** and **3**. These have been calculated on the assumption that the GPR pulse through the ground occurred at a certain velocity. This was established through analysis of the radargrams for suitable hyperbolic reflections, which can be used to determine the velocity of the GPR pulse through the subsurface deposits. For Area 1, it was calculated that this was 0.1 m/ns, and Area 2 was 0.106 m/ns when surveyed with Mala MIRA multi-channel array. In the second part of Area 2, a speed of 0.088 m/ns was calculated for the Impulse radar Crossover 4080 antennae. It is possible to determine more precisely the average velocity of the GPR pulse through the ground if known features can be related to a specific response at a known depth can be identified.

3.5.4 Further details of the geophysical and survey equipment, methods and processing are described in **Appendix 1**.

Table 1 Relative velocity to depth conversion in Area 1, based on a dielectric constant of 9 for the Mala MIRA multi-channel array, 400 MHz antenna

Time Slice	Time (ns)	Depth (cm)	Time Slice	Time (ns)	Depth (cm)
1	0.-1.76	0.-0.09	14	22.69-24.45	1.13-1.22
2	1.75-3.51	0.09-0.17	15	24.43-26.19	1.22-1.3
3	3.49-5.25	0.17-0.26	16	26.18-27.94	1.3-1.39
4	5.24-7.	0.26-0.35	17	27.92-29.69	1.39-1.48
5	6.98-8.74	0.35-0.44	18	29.67-31.43	1.48-1.57
6	8.73-10.49	0.43-0.52	19	31.42-33.18	1.56-1.65
7	10.47-12.23	0.52-0.61	20	33.16-34.92	1.65-1.74
8	12.22-13.98	0.61-0.7	21	34.91-36.67	1.74-1.83
9	13.96-15.72	0.7-0.78	22	36.65-38.41	1.82-1.91
10	15.71-17.47	0.78-0.87	23	38.4-40.16	1.91-2.0
11	17.45-19.21	0.87-0.96	24	40.14-41.9	2.-2.09
12	19.2-20.96	0.96-1.04	25	41.89-43.65	2.09-2.17
13	20.94-22.7	1.04-1.13			

Table 2 Relative velocity to depth conversion in Area 2, based on a dielectric constant of 8.01 for the Mala MIRA multi-channel array, 400 MHz antenna

Time Slice	Time (ns)	Depth (cm)	Time Slice	Time (ns)	Depth (cm)
1	0.-1.76	0.-0.09	14	22.55-24.31	1.2-1.29
2	1.73-3.5	0.09-0.19	15	24.29-26.05	1.29-1.38
3	3.47-5.23	0.18-0.28	16	26.02-27.78	1.38-1.47
4	5.2-6.97	0.28-0.37	17	27.76-29.52	1.47-1.57
5	6.94-8.7	0.37-0.46	18	29.49-31.25	1.56-1.66
6	8.67-10.44	0.46-0.55	19	31.23-32.99	1.66-1.75
7	10.41-12.17	0.55-0.65	20	32.96-34.72	1.75-1.84
8	12.14-13.9	0.64-0.74	21	34.7-36.46	1.84-1.93
9	13.88-15.64	0.74-0.83	22	36.43-38.19	1.93-2.03
10	15.61-17.37	0.83-0.92	23	38.17-39.93	2.02-2.12
11	17.35-19.11	0.92-1.01	24	39.9-41.66	2.12-2.21
12	19.08-20.84	1.01-1.11	25	41.64-43.4	2.21-2.3
13	20.82-22.58	1.1-1.2			

Table 3 Relative velocity to depth conversion in Area 2, based on a dielectric constant of 11.51 for the Impulse radar Crossover 4080, 400 MHz antenna

Time Slice	Time (ns)	Depth (cm)	Time Slice	Time (ns)	Depth (cm)
1	0.-2.15	0.-0.09	14	27.58-29.73	1.22-1.31
2	2.12-4.27	0.09-0.19	15	29.71-31.85	1.31-1.41
3	4.24-6.39	0.19-0.28	16	31.83-33.98	1.41-1.5
4	6.37-8.51	0.28-0.38	17	33.95-36.1	1.5-1.6
5	8.49-10.64	0.38-0.47	18	36.07-38.22	1.59-1.69
6	10.61-12.76	0.47-0.56	19	38.19-40.34	1.69-1.78
7	12.73-14.88	0.56-0.66	20	40.31-42.46	1.78-1.88
8	14.85-17.	0.66-0.75	21	42.44-44.58	1.88-1.97
9	16.97-19.12	0.75-0.85	22	44.56-46.71	1.97-2.07
10	19.1-21.24	0.84-0.94	23	46.68-48.83	2.06-2.16
11	21.22-23.37	0.94-1.03	24	48.8-50.95	2.16-2.25
12	23.34-25.49	1.03-1.13	25	50.92-53.07	2.25-2.35
13	25.46-27.61	1.13-1.22			

4 GEOPHYSICAL SURVEY RESULTS AND INTERPRETATION

4.1 Introduction

4.1.1 The GPR survey was undertaken over the majority of Area 1, but it was not possible to survey the Water Gate Entrance at the eastern edge of the area. There were also minor reductions at the edges of the survey to allow for the manoeuvring of the equipment. This was also the case in Area 2, where steep terrain in the north prevented survey. This was surveyed with a single channel antenna on 28 September.

4.1.2 The 400 MHz antennae have the potential of detecting features to a depth of 2 – 3 m in optimal conditions. However, the total depth reached varies depending on the specific conditions of each area.

4.1.3 All features are described in terms of their geophysical character. It is important to stipulate that all of the depths referred to in this report are approximate levels below the current ground surface.

4.1.4 It should be noted that small features and waterlogged features may produce responses that are below the detection threshold of the GPR antenna. Excessive ground disturbance can also impede the ability of geophysical techniques to detect archaeology. It may therefore be the case that more archaeological features are present than have been identified through this geophysical survey.

4.1.5 For ease of interpretation, the most representative timeslices have been selected for presentation with the interpretation image detailing the salient results from each relevant slice. For the dataset 30 slices of 0.08 – 0.1 m thickness were generated. These are followed by a graphical summary of the timeslices to allow a more complete understanding of how these features may relate to each other.

4.1.6 Results are presented as a series of greyscale plots, and archaeological interpretations at a scale of 1:500 (**Figures 2** to **5**). The data are displayed from Lower Amplitude (white) to Higher Amplitude (black) responses.

4.2 Ground-penetrating radar results and interpretation

Area 1 – South-western Drum Tower and State Apartments

4.2.1 Area 1 was collected as four separate blocks but were all characterised by similar ground conditions. The largest block surrounds the area to the south and west of the Drum Tower and was covered with a loose gravel surface, with a small lawned area in the north-west corner. The smaller block within the State Apartments at the western end of the Southern Domestic Range was also covered with a gravelled surface, albeit slightly more compacted.

4.2.2 The GPR survey of Area 1 has been successful in identifying a range of high amplitude responses, some of which may relate to structural remains associated with the castle (**Figures 2, 3, 7, 8**).

4.2.3 In the north of the area, there is a high amplitude linear response at **4000** that measures 0.6 m in width and 5.6 m in length. It is aligned north-south and runs roughly parallel to the wall surrounding the Inner Ward. It can be identified in Timeslices 4 – 9 (0.26 – 0.7 m) and is most likely associated with a short section of wall. Directly to the east of this, there is a strong planar response at **4001** which covers a 2.5 by 1.5 m rectangular area. This is visible between Timeslice 5 – 7 (0.35 m – 0.61 m) and is associated with a former surface, most likely relating to a floor or compacted area to the east of the wall at **4000**.

4.2.4 Below **4000** – **4001**, a larger L-shaped area of high amplitude response is visible at **4002**, although this is poorly defined. It covers a rectangular area of 4.8 by 2 m at the northern part and expending into a square area for an additional 2.2 by 2.2 m at the southern edge. It is visible in Timeslice 7 – 18 (0.61 – 1.57 m) but is variable in form. It is perhaps most clearly identified in Timeslice 10 (0.78 – 0.87 m). The corresponding radargrams of the areas are characterised by an increased amount of hyperbolic responses that may indicate a more variable composition. This is suggestive of infilling or levelling of the area and may be related to the construction of the Inner Ward wall.

4.2.5 Taken collectively, the anomalies at **4000** – **4002** probably relate to a former structure in this location. This comprises a relatively complex arrangement of levelling, a structure, as well as a possible floor surface.

4.2.6 In the north-western corner of the survey, to the south of the Western Gatehouse, there is a high amplitude response at **4003**. This is relatively square in plan and measures 2.8 m in width and 2.6 m in length. It is visible in Timeslices 4 – 13 (0.26 – 1.13 m) and indicates possible backfill or a rubble deposit. This could be connected with levelling of the ground for construction of Western Gatehouse.

4.2.7 Within the State Apartment rooms, in the north-eastern corner of Area 1, there are a series of high amplitude responses that are interpreted as possible structural remains. This

comprises two linear, responses at the outer edges of the larger room in the east (**4004** and **4005**). They are immediately adjacent to the standing walls and extend as far as 0.8 m into the room. This response is visible in Timeslices from 4 – 17 (0.26 m – 1.48 m) and indicates an area of compacted material, likely associated with foundations for the walls.

4.2.8 Within these rooms, there are also several high amplitude responses (**4006** and **4007**). These are more irregular in shape, but the largest measure up to 2.7 m by 2.3 m. Some of this is located in the uppermost timeslices, between Timeslices 3 – 6 (0.17 m – 0.52 m) and is most likely associated with building debris (**4006**). Those located deeper are either related to the levelling of the area or variation in the composition of the underlying natural geology (**4007**).

4.2.9 Approximately 10 m to the south-west of **4002**, there is a moderately high amplitude response at **4008**. This is visible between Timeslices 9 – 17 (0.7 m – 1.48 m) and measures up to 3 m by 3.8 m. The anomaly shifts laterally from north to south as the timeslices descend. Another similar response (**4009**) is located about 10 m to the south-east of it in Timeslices 9 – 21 (0.7 m - 1.83 m), which gradually shifts from west to east. These probably relate to further levelling deposits comprising compacted or stony material providing firm ground for the construction of the Drum Tower. Within the corresponding radargram (**Figure 6**; Transect 353) several diagonally dipping planar responses are visible that may relate to the tipping of material or to variable layers of this deposition (**4009**).

4.2.10 Several linear responses were identified, traversing the site (**4010** – **4015**). They are characterised by hyperbolic responses which typically indicate modern services, such as cables and drains. Most of these are visible in the uppermost timeslices, but some are only apparent within the corresponding radargrams and are very faint within the timeslices.

Area 2 – Central Eastern Platform

4.2.11 Area 2 comprises a single area occupying the southern half of the Central Eastern Platform, to the north of the former Millhouse and south-east of the Outer Main Gatehouse. It is predominantly covered with short grass, with a path traversing through the western part of the area.

4.2.12 The GPR survey of Area 2 has been successful in identifying a large number of high amplitude responses. Most of these are associated with possible structural remains but it is also likely that they comprise a significant amount of demolition debris (**Figures 2, 3, 7, 8**).

4.2.13 Alongside the southern edge of the survey, adjacent to the outer fortification wall. there is a complex broad linear response (**5000**). This is orientated east – west and is 20 m long by 3 m wide. It can be detected in Timeslice 2 – 13 (0.9 m – 1.1 m). This is likely associated with the foundation for the outer wall.

4.2.14 Directly north of the Mill, in the south of Area 2, there is a clear rectilinear arrangement of high amplitude responses at **5001**. This is only visible within the lower portion of the dataset between Timeslice 12 – 42 (1.1 m – 3.47 m) and covers a total area of 21 x 10 m. This represents the footprint of a former building, which has not been previously noted or recorded on any mapping of the area. The definition of the walls is poor within some timeslices but is quite substantial measuring 2.5 m wide. This suggests that it represents a substantial structure, which has been demolished.

4.2.15 The building at **5001** is orientated askew from the predominant east – west alignment of the castle and its walls. Although it appears to extend north-east from the extant Mill structure in the south-west corner of Area 2, it also does not respect this alignment. As such it is suggested that it relates to a different phase of construction.

4.2.16 The north-western corner of **5001** appears to be better defined than much of the eastern part of the structure. There is also a notable gap close to the north-eastern corner, which is

1 m wide. This implies that the wall does not continue and that there is a genuine break in the structure in this location.

4.2.17 Within the structure at **5001**, there is a further high amplitude response which may relate to an internal division or wall (**5002**). This is visible between Timeslice 7 and 30 (0.55 m – 2.76 m) and forms an L-shaped area, covering a 6 m by 5.5 m area.

4.2.18 Much of the area enclosed by the structure at **5001** is characterised by a lower amplitude response, particularly within the lower timeslices between Timeslice 22 – 30 (1.93 m – 2.76 m; **5003**). This suggests that there are no or few internal features or structural remains at this depth. The low amplitude nature of the response also suggests that the area comprises a more conductive material, such as silty-clay sediment. One possibility is that was deposited during activity associated with the Mill, but further investigation would be required to confirm this.

4.2.19 Within the radargrams for the area, it is possible to identify a series of strong hyperbolic responses that relate to the structural remains at **5001** and **5002**. Although they are relatively clear, in places, they are notably complex over the eastern part of the structure, suggesting that they may be heavily disturbed (**Figure 6**; **Transect 97**). Within the eastern part of this, it is also possible to identify the lower amplitude response at **5003** as a relatively 'quiet' area.

4.2.20 Extending north from the structure at **5001**, close to the short gap, there is a possible north-easterly extension to the structure at **5004**. This is poorly defined but is most apparent within Timeslice 20 (1.75 – 1.84 m). This may relate to a further structural element of the building, but it is equally possible that it relates to its demolition.

4.2.21 In the middle of Area 2, there are widespread areas of high amplitude responses within the upper timeslices. These lack coherent form but are concentrated in two areas at **5005** and **5006**. They are visible between Timeslices 5 – 13 (0.37 m – 1.2 m) and measure up to 15 m by 8 m. These indicate possible layers of demolition rubble and suggest that there is a significant level of material deposited over the structure at **5001**. At the northern part of Area 2, there is an amorphous high amplitude anomaly (**5007**) identifiable in the lower timeslices. It is visible in Timeslices 13 – 30 (1.13m – 2.28m), measuring up to 15m by 9m on a north-west to south-east orientation. This is consistent with the area undergoing landscaping works during the latter part of the 19th century and the first half of the 20th century, which has resulted in the ground level being raised above the medieval ground surface.

4.2.22 At the north-western side of Area 2 is a complex high amplitude response (**5008**) that correspond to the steep incline in terrain. It is visible in the Timeslices 9 – 22 (0.75m – 2.35m) and measures 16m by 8m. This is likely caused by the steep incline and landscaping associated with it.

4.2.23 Although it is considered that the upper 1.2 m of Area 2 is characterised by made ground and demolition rubble, it is possible to identify other features that likely relate to more modern activity. For example, there are 10 circular high amplitude responses (**5009**) that are orientated on a north – south linear alignment. These are located within the same area as **5001** and are thought to be associated with a series of 0.8 m diameter fenceposts, spaced between 1.6 m – 2 m apart. However, as they are only visible in a limited number of timeslices (9 – 11 (0.74 m – 1.01 m)), it is likely that little of the features remain.

4.2.24 Elsewhere, within the uppermost timeslices, there is a low amplitude linear response at **5010**, which corresponds with the modern path at the site. There is also a low amplitude linear anomaly (**5011**) that traverses the site on a north – south orientation and branches into two parts at the southern part of the survey. These are indicative of modern services such as pipes, cables, or drains. At the north-eastern corner of the survey there are several

high amplitude responses (**5012**) that are related to the modern services at the site such as manholes and drains.

5 DISCUSSION

5.1.1 The multichannel GPR survey at Caerphilly Castle was successful in identifying a range of features in the area that are considered likely to be archaeological in origin. Within the area surrounding the south-western Drum Tower (Area 1) and in the Central Eastern Platform (Area 2), numerous high amplitude responses were detected that relate to structural remains, most of which relate to foundations for the existing castle structure.

5.1.2 Within Area 1, a single wall and a surface may relate to a relatively small building within the Middle Ward, to the east of the West Gateway. There are also numerous high amplitude responses close to the wall of the Inner Ward, which likely relate to foundation or levelling deposits prior to its construction. Within the State Apartment buildings, there is evidence for further foundations adjacent to the existing walls, but generally, there are no other internal features.

5.1.3 Within area 2, the remains of a substantial structure have been located directly north-east of the Mill. It is probable that this has been heavily demolished and that the material from this structure has been utilised to level the area to the north. It is estimated from the GPR data that there is 1 – 1.2 m of made ground overlying this area. This is most likely associated with landscaping works during the latter part of the 19th century and the first half of the 20th century resulting in the ground level being raised above the medieval ground surface.

5.1.4 The remainder of the anomalies are predominantly associated with modern activity and a series of probable pipes or cables have been identified.

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Old Maps (accessed September 2020) https://www.old-maps.co.uk

APPENDICES

Survey Methods and Equipment

The ground penetrating radar (GPR) data were collected using a cart mounted shielded antennae with central frequencies suitable for the types of target being investigated. Lower frequency antennae are able to acquire data from deeper below the surface, whereas higher frequencies allow high resolution imaging of near-surface targets at the expense of deep penetration. The exact make and model of equipment varies.

The depth of penetration of GPR systems is determined by the central frequency of the antenna and the relative dielectric permittivity (RDP) of the material through which the GPR signal passes. In general, soils in floodplain settings may have a wide range of RDPs, although around 8 may be considered average, resulting in a maximum depth of penetration c. 2.5m with the GPR signal having a velocity of approximately 0.1m/ns.

The GPR beam is conical in shape, however, and whilst most of the energy is concentrated in the centre of the cone, the GPR signal illuminates a horizontal footprint, which becomes wider with increasing depth. At the maximum depth of the antenna, it becomes impossible to resolve any feature smaller than the horizontal footprint for the corresponding depth. The size of the footprint is dependent upon central frequency, and its size increases as the central frequency decreases.

The vertical resolution is similarly dependent upon the central frequency; for the 500MHz antenna, features of the order of 0.05m can be resolved vertically. Antennae with lower frequencies might penetrate more deeply but are less resolute in both horizontal and vertical directions. Choice of antenna frequency is guided largely by the anticipated depth to the target and the required resolution.

GPR data for detailed surveys are collected along traverses of varying length separated by 0.5m with cross lines collected running perpendicular to these traverses at wider separations. The data sampling resolution is governed by the data logger and a minimum separation of 0.05m between traces is collected for all surveys.

Post-Processing

The radar data collected during the detail survey are downloaded from the GPR system for processing and analysis using commercial software (GPR Slice). This software allows for both the data and the images to be processed in order to enhance the results for analysis; however, it should be noted that minimal data processing is conducted so as not to distort the anomalies.

Typical data and image processing steps may include:

- Gain – Amplifies GPR data based upon its position in the profile, which boosts the contrast between anomalies and background. A wobble correction is also applied during this step
- Background Filter - is used to remove banding noises that are seen across the radargrams
- Bandpass – Removes GPR data lying outside a specified range, which removes high- and low-frequency noise.

Typical displays of the data used during processing and analysis:

- Timeslice – Presents the data as a series of successive plan views of the variation of reflector energy from the surface to the deepest recorded response. The variation in amplitude is represented using a greyscale with black indicating high amplitude and white indicating low amplitude responses

- Radargram – Presents each radar profile in a vertical view with distance along the profile expressed along the x axis and depth along the y axis. The amplitude variation is expressed using a greyscale

Appendix 2: Geophysical Interpretation

The interpretation methodology used by Wessex Archaeology separates the anomalies into four main categories: archaeological, modern, agricultural and uncertain origin/geological.

The archaeological category is used for features when the form, nature and pattern of the anomaly are indicative of archaeological material. Further sources of information such as aerial photographs may also have been incorporated in providing the final interpretation. This category is further sub-divided into three groups, implying a decreasing level of confidence:

- Archaeology – used when there is a clear geophysical response and anthropogenic pattern.
- Possible archaeology – used for features which give a response, but which form no discernible pattern or trend.

For the interpretation of GPR datasets two additional categories are also employed:

- High Amplitude – used for features which give a notably high amplitude response but display no discernible pattern.
- Low Amplitude – used for features which give a notably low amplitude response but display no discernible pattern.

The modern category is used for anomalies that are presumed to be relatively modern in date:

- Modern service – used for responses considered relating to cables and pipes. GPR is known to be very effective at locating buried utilities and they are often identifiable within the radargrams as strong hyperbolic reflectors.

The agricultural category is used for the following:

- Former field boundaries – used for ditch sections that correspond to the position of boundaries marked on earlier mapping.
- Ridge and furrow – used for broad and diffuse linear anomalies that are considered to indicate areas of former ridge and furrow.
- Ploughing – used for well-defined narrow linear responses, usually aligned parallel to existing field boundaries. These can sometimes repeat or ‘ring’ through GPR datasets, particularly if there are ploughing furrows on the surface.

The uncertain origin/geological category is used for features when the form, nature and pattern of the anomaly are not sufficient to warrant a classification as an archaeological feature. This category is further sub-divided into:

- Trend – used for low amplitude or indistinct linear anomalies.
- Superficial geology – used for diffuse edged spreads considered to relate to shallow geological deposits. They can be distinguished as areas of high and/or low amplitude response but are commonly amorphous in form.

Appendix 3: OASIS form

Project Details:

Project name	Caerphilly Castle, Caerphilly, Glamorgan				
Type of project	GPR survey (Field evaluation)				
Project description	The survey at Caerphilly Castle has identified anomalies consistent with structural remains surface responses and a water channel. Majority of these were located at the Outer Main Gatehouse, although some features identified at the South Domestic Range were also indicating underground remains. There is evidence for a structure located at the Outer Main Gatehouse. Although the walls could not be clearly defined, the occupied/ disturbed area in the ground indicates a possible outline for a building. Connected to it is a water channel that was recognised at the deeper slices. The area of several high amplitude responses that is located across the water channel could also represent some structural remains that could relate to the watermill. In addition, a buried surface was detected alongside the southern wall that could indicate a paved area. The additional paved area with a supporting wall on a side was probably a side entrance to the Southern Domestic Range between the Western Gate and south-western Drum Tower. Planar responses to the west of the Drum Tower are indicating to a past surface level, but the time of the making it to today's level would need to be confirmed with further investigations. Similar responses are present on the southern side of the Drum Tower that indicates a ditch that could be in use as a defensive feature but could as well be backfilled at the construction of the castle.				
Project dates	**Start:** 10-08-2020		**End:** 11-08-2020		
Previous work	DBA, Geophysical research				
Future work	Trial trenching/excavation				
Project Code: 228023	**HER event no.**	If relevant	**OASIS form ID:**	wessexar1-403003	
	NMR no.	N/A			
	SM no.	GM002			
Planning Application Ref.					
Site Status	Scheduled Monument (SM				
Land use	Public building				
Monument type	Castle	**Period**	Early medieval		

Project Location:

Site Address	Castle St, Caerphilly			**Postcode**	CF83 1JD
County	Glamorgan	**District**	MARITIME	**Parish**	Caerphilly
Study Area	0.3 ha	**Height OD**	88 –95 m aOD	**NGR**	ST 15611 87078

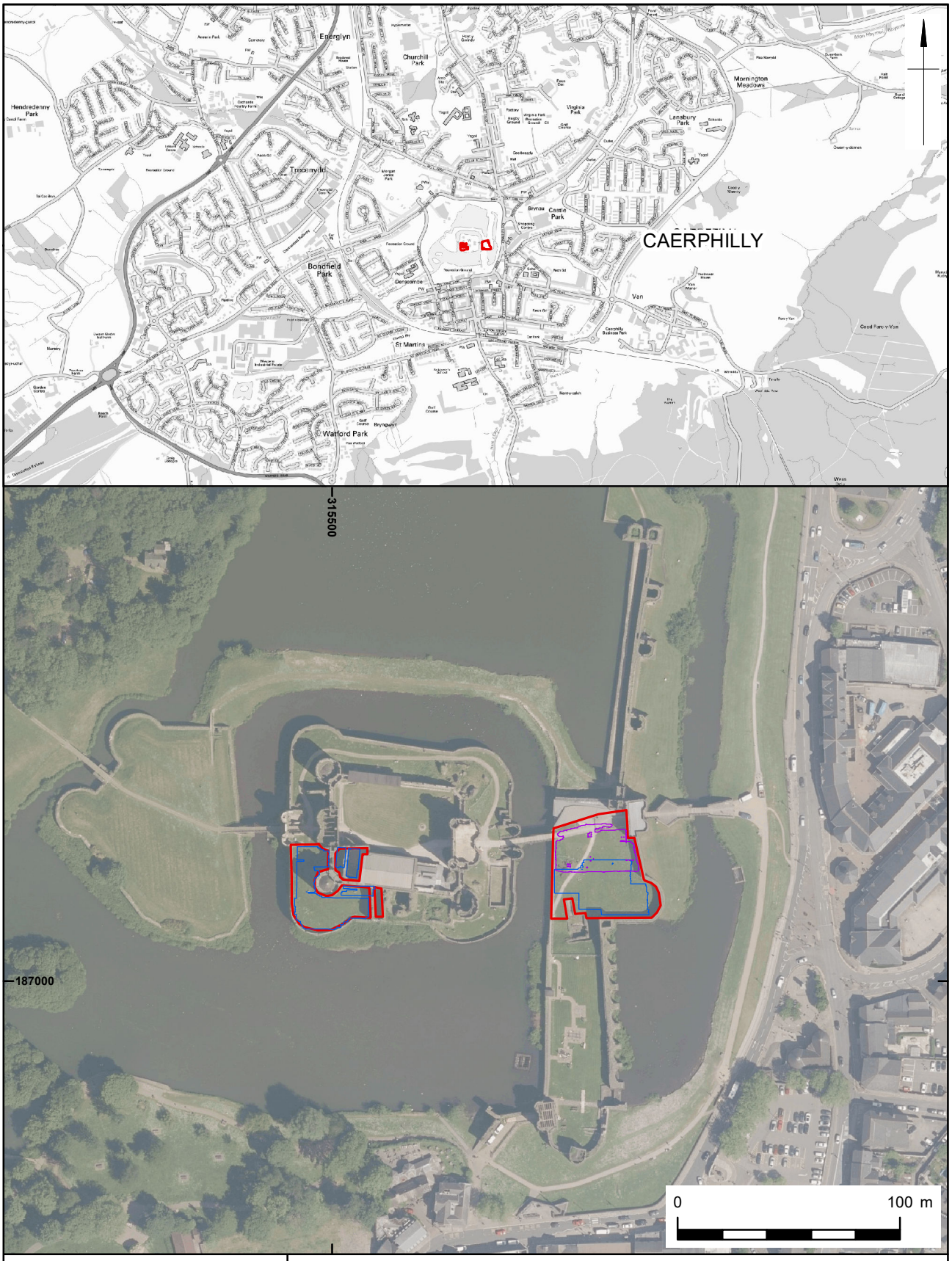
Project Creators:

Name of Organisation	Wessex Archaeology		
Project brief originator	Mace Group	**Project design originator**	WA
Project Manager	Tom Richardson	**Project Supervisor**	Brett Howard
Sponsor or funding body	Mace Group	**Type of Sponsor**	Client

Project Archive and Bibliography:

Physical archive	N/A	**Digital Archive**	Geophysical survey and report	**Paper Archive**	N/A

Report title				**Date**	2018
Author	Wessex Archaeology	**Description**	Unpublished report	**Report ref.**	228023.03



MIRA Survey Extents

Crossover Survey Extents

Survey area

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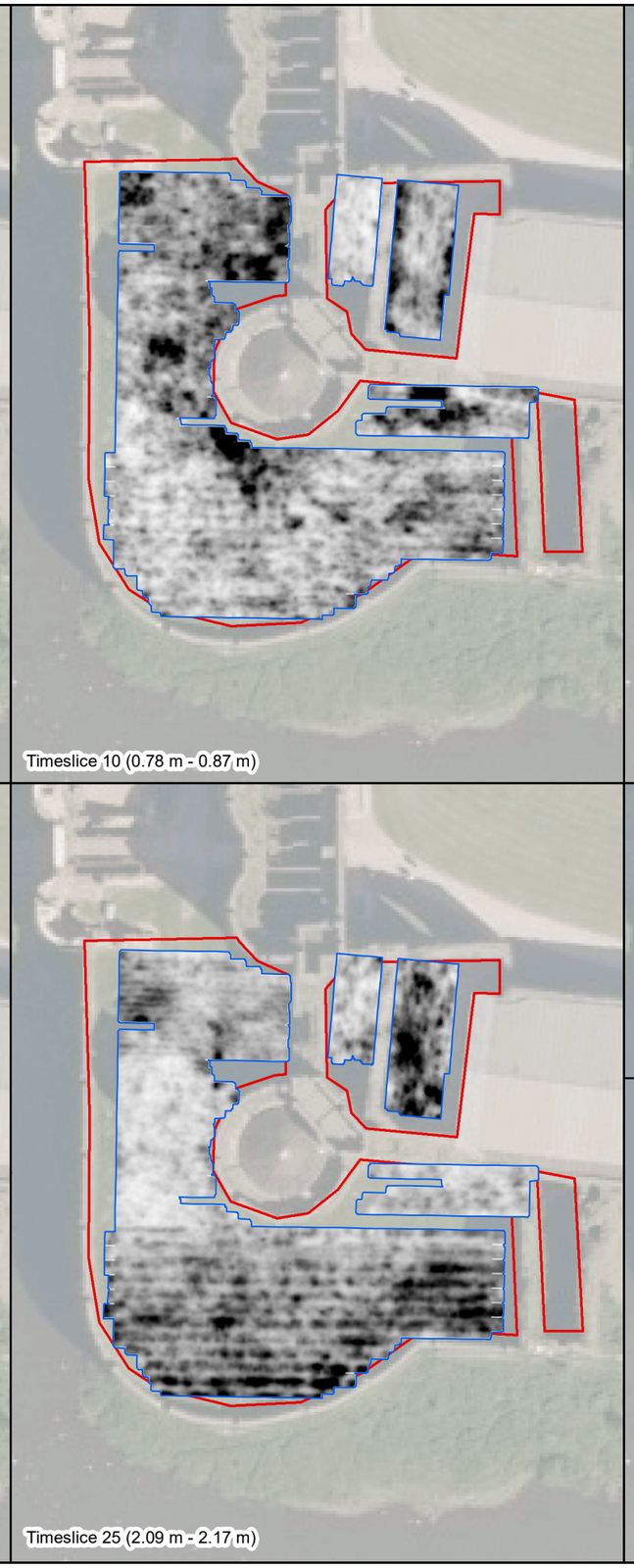
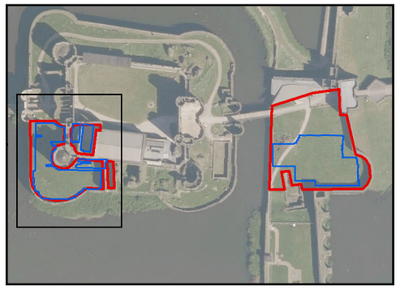
Site location and survey area

Figure 1





GPR Transects
Detailed Survey Extents
Survey area

Low Amplitude — High Amplitude

0 — 25 m

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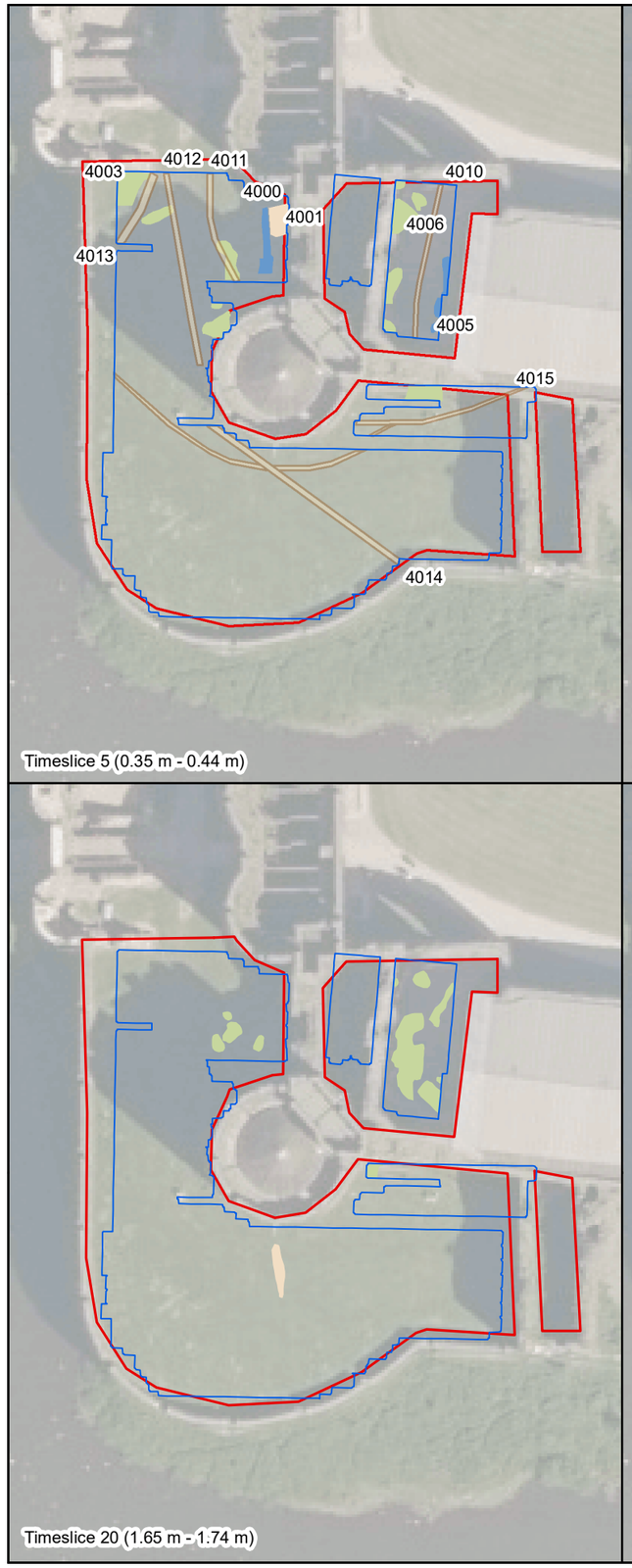
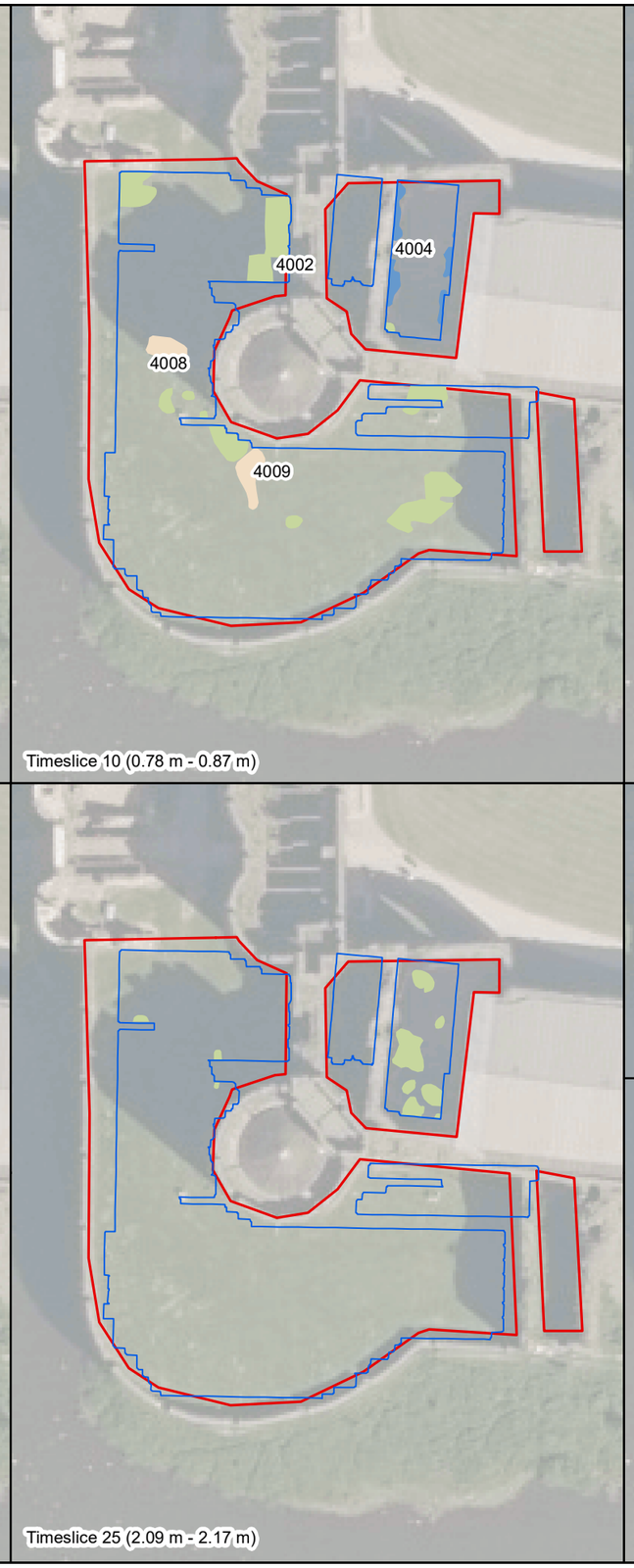
Geophysical survey results: Greyscale plot; Area 1 – Southwestern Drum Tower and State Apartments

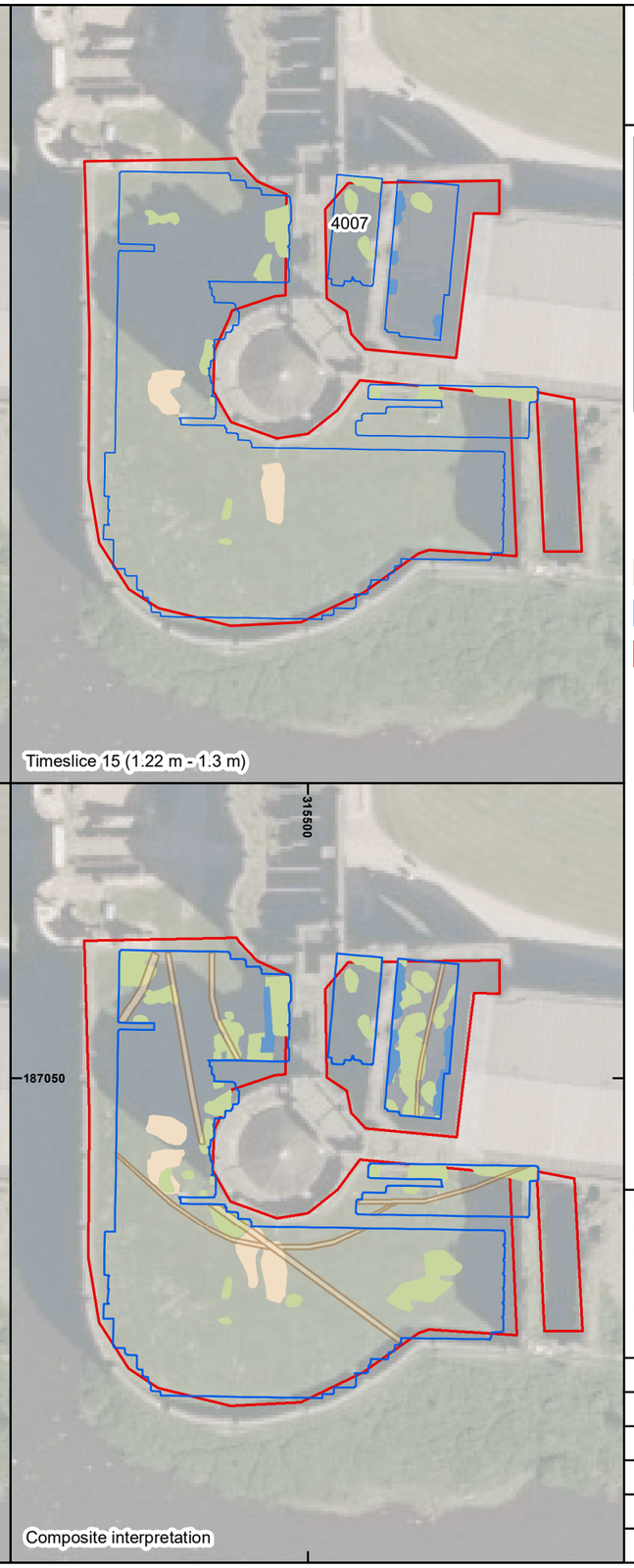
Figure 2



Timeslice 5 (0.35 m - 0.44 m)



Timeslice 10 (0.78 m - 0.87 m)

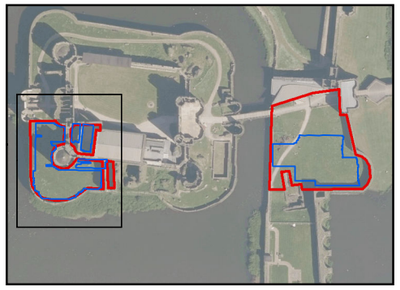


Timeslice 15 (1.22 m - 1.3 m)

Timeslice 20 (1.65 m - 1.74 m)

Timeslice 25 (2.09 m - 2.17 m)

Composite interpretation



- Possible Archaeology
- High Amplitude
- Buried Surface
- Modern Service
- Detailed Survey Extents
- Survey area

0 25 m

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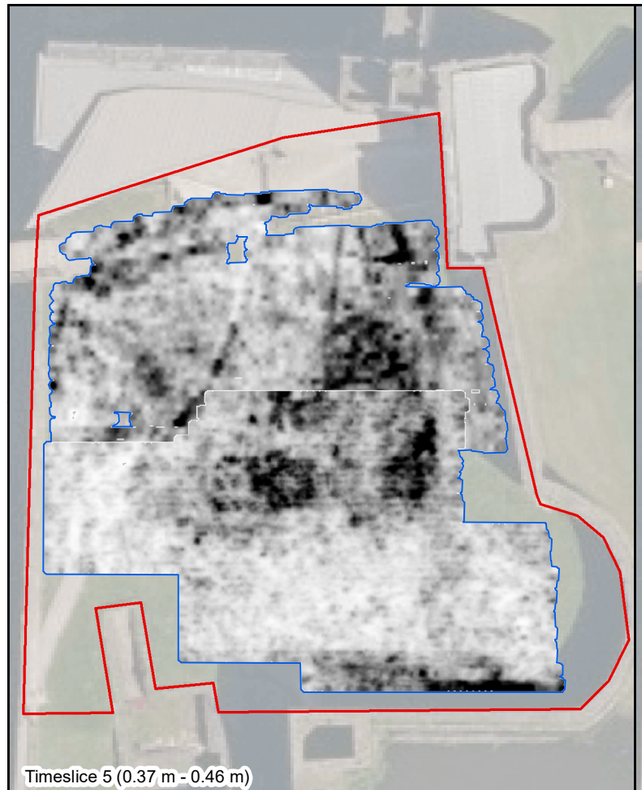
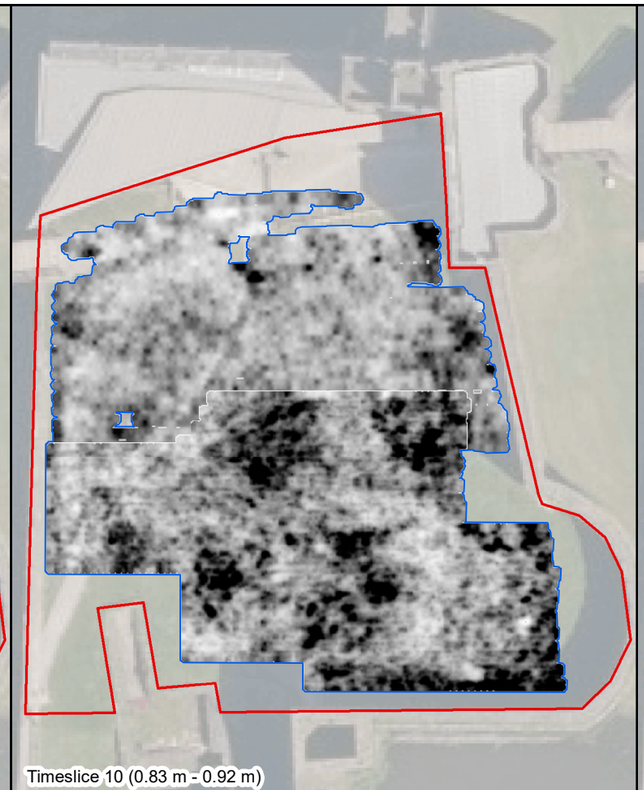
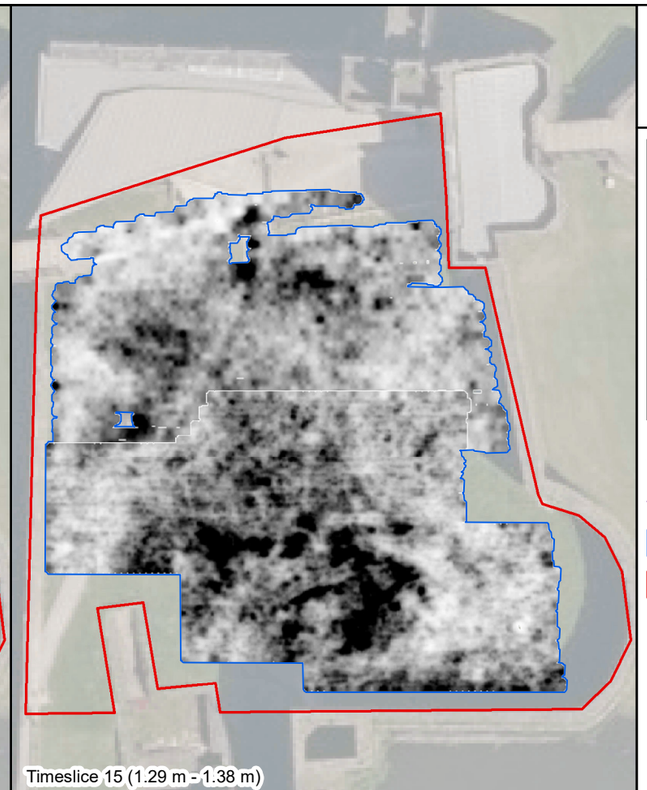
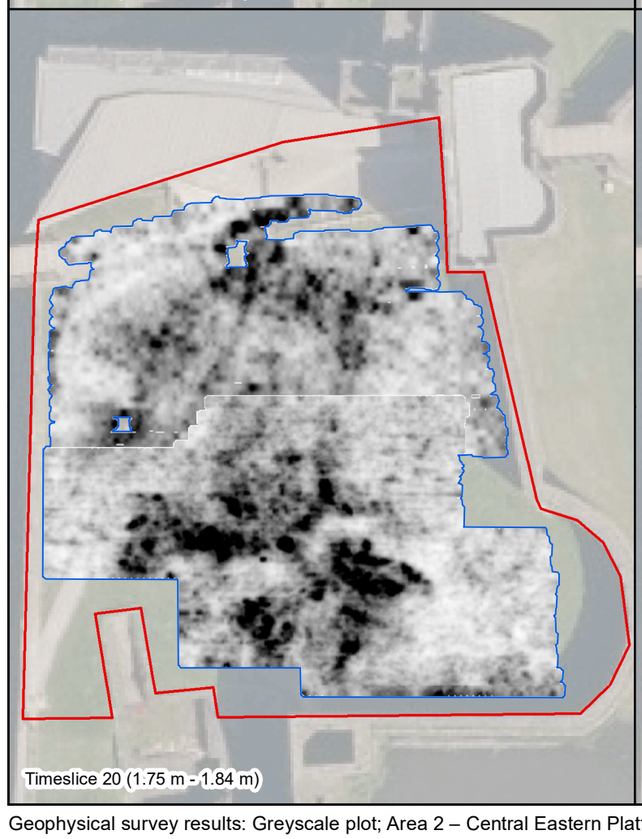
Geophysical survey results: Interpretation; Area 1 – Southwestern Drum Tower and State Apartments

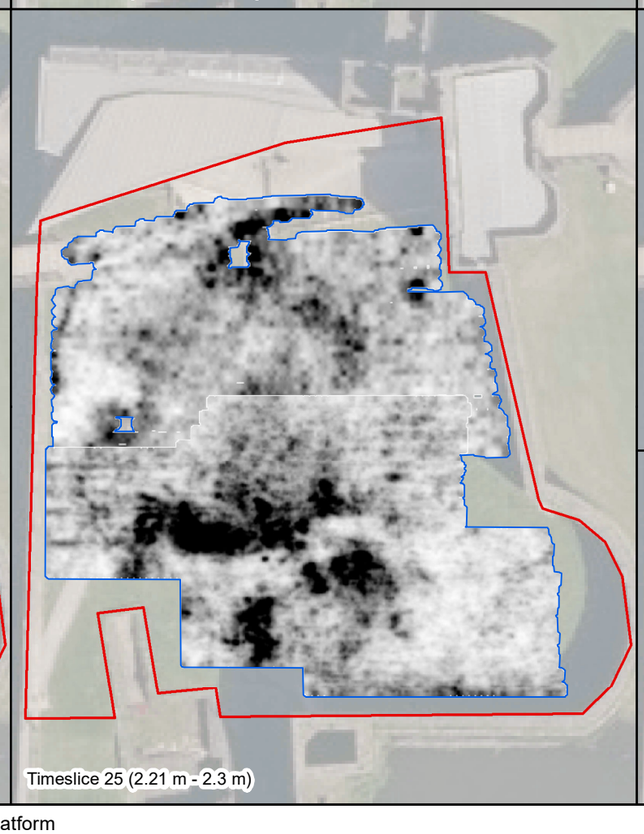
Figure 3

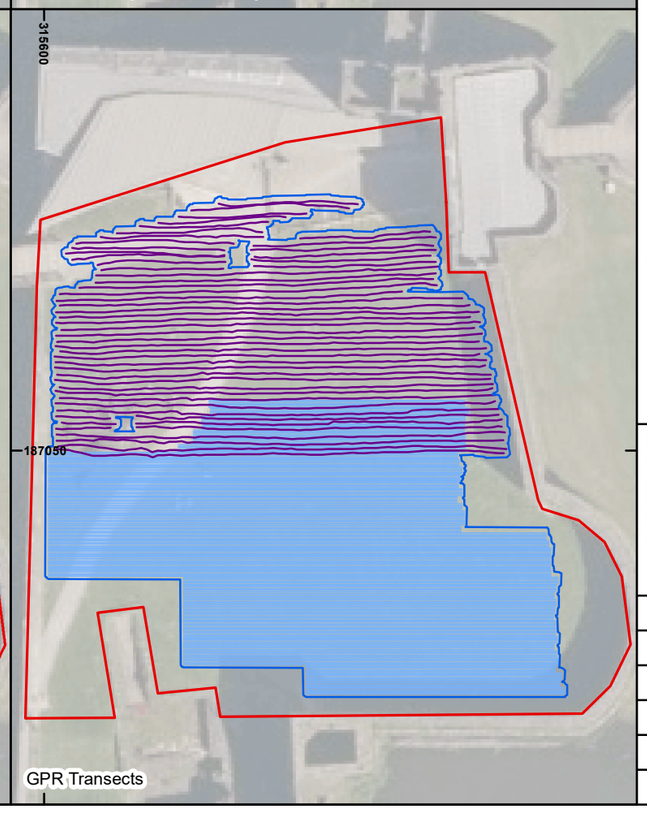


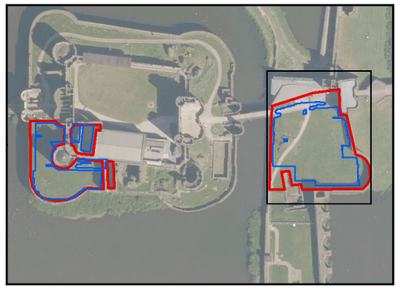












GPR Transects MIRA

GPR Transects Crossover

Detailed Survey Extents

Survey area

Low Amplitude — High Amplitude

0 — 25 m

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Revision Number:	0
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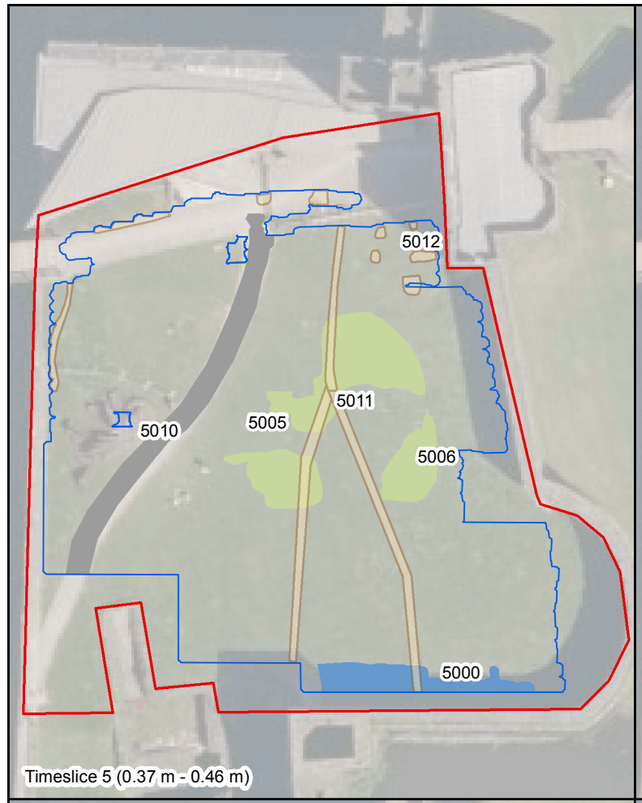
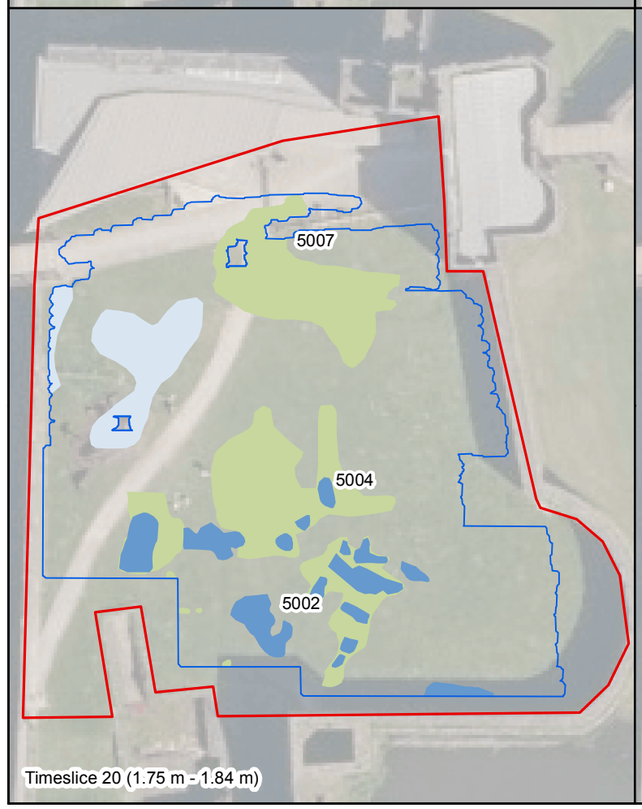
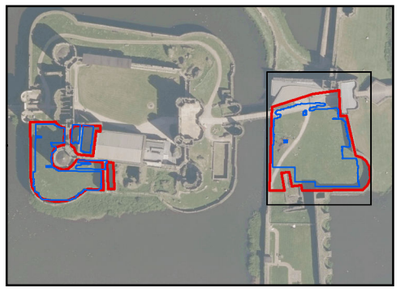
Geophysical survey results: Greyscale plot; Area 2 – Central Eastern Platform

Figure 4







Possible Archaeology
High Amplitude
Superficial Geology
Modern Service
Detailed Survey Extents
Survey area

0 25 m

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Geophysical survey results: Interpretation; Area 2 – Central Eastern Platform

Figure 5

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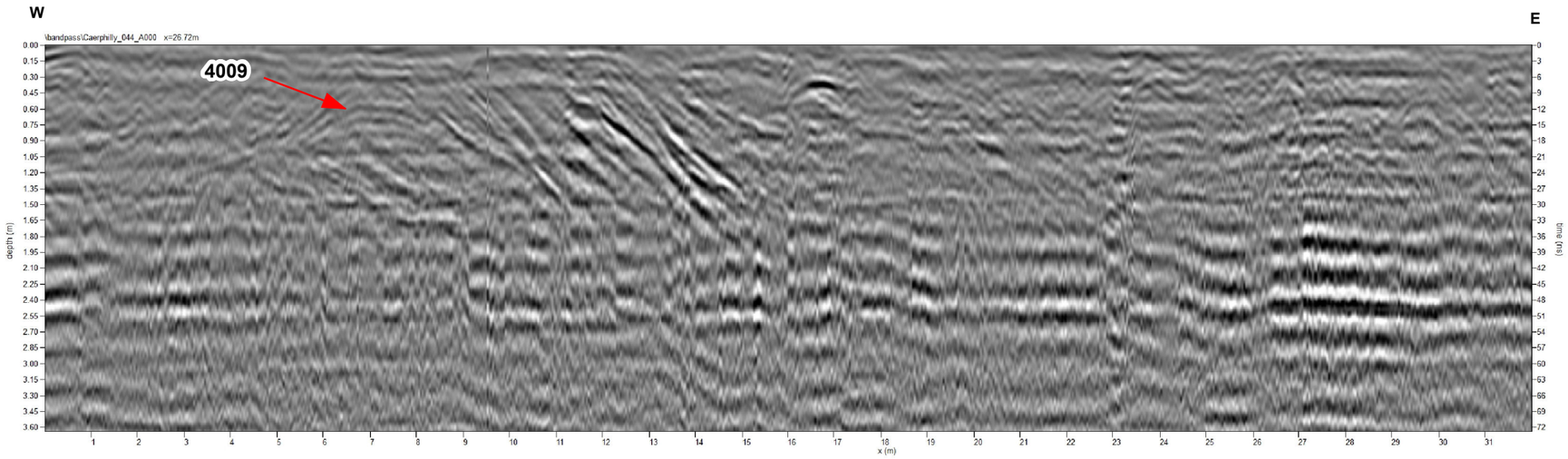

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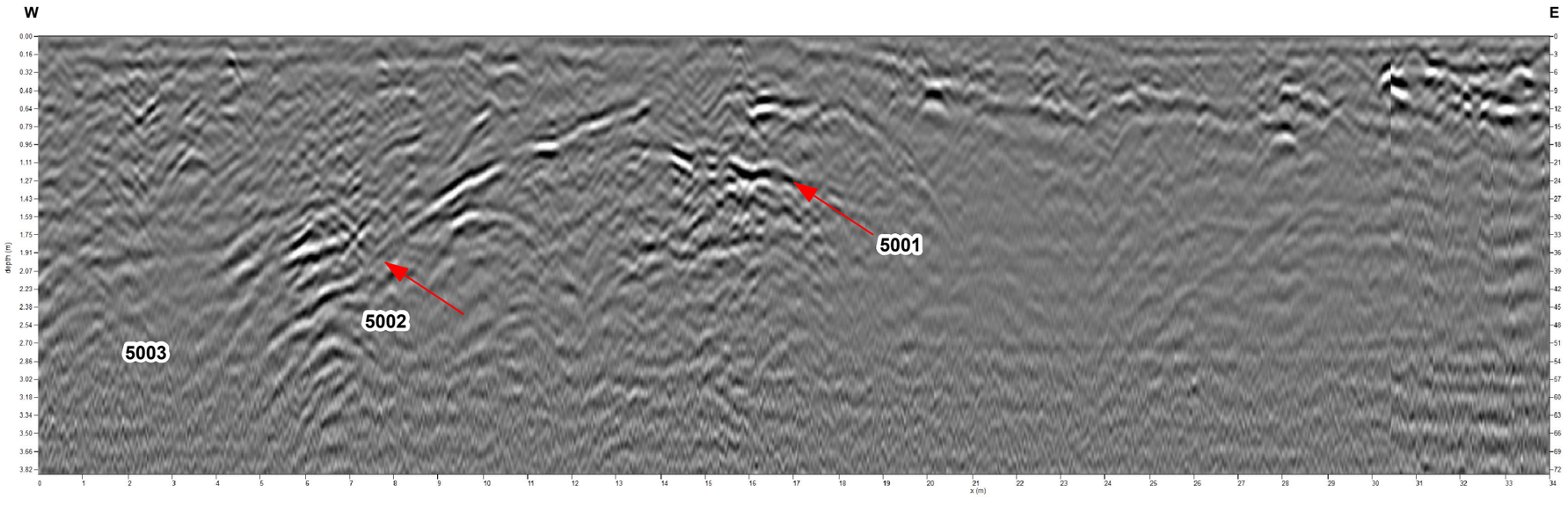
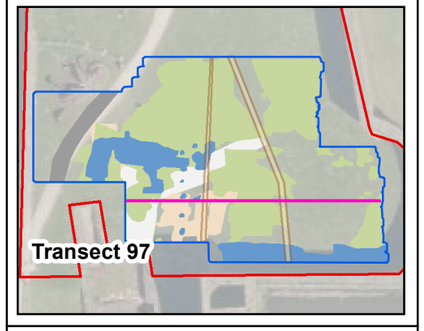


Low Amplitude — High Amplitude



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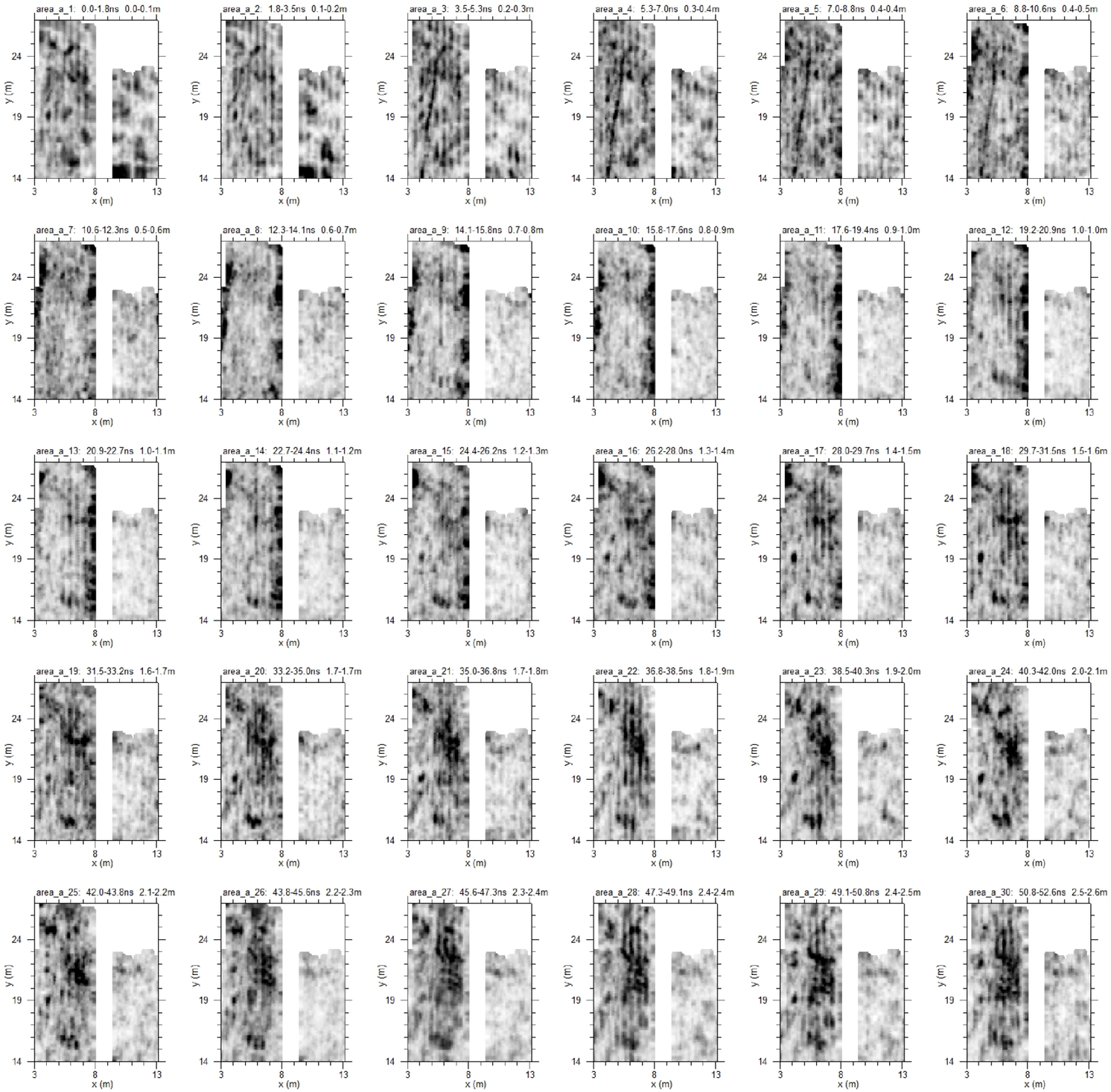
Geophysical survey results: Select Transects

Figure 6



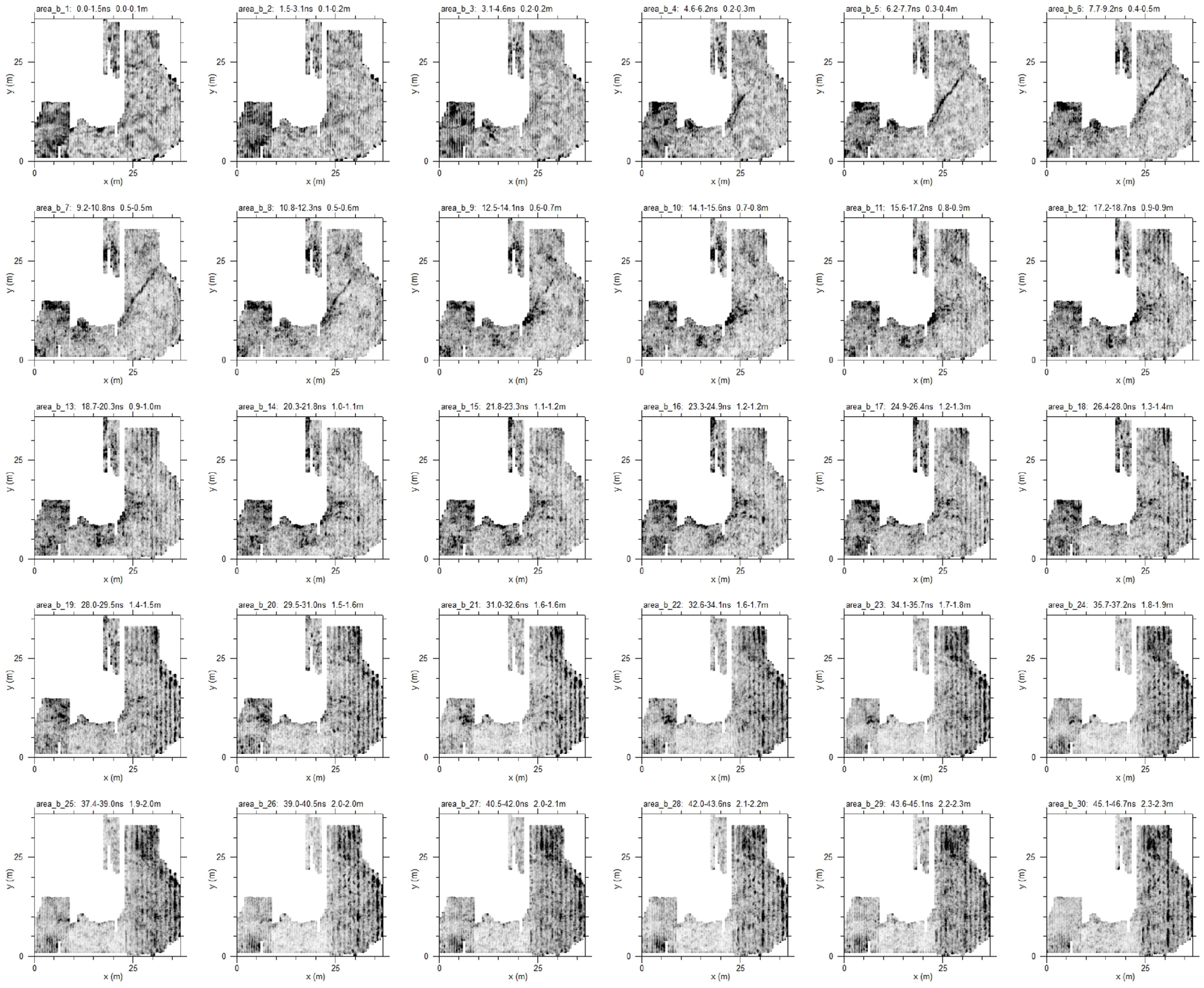
Low Amplitude — High Amplitude

Coordinate system:
OSGB36 (OSTN15/OSGM15)

Date:	07/09/2020
Revision Number:	0
Scale:	N/A
Illustrator:	RP
Path:	X:\PROJECTS\228023\ \GIS\FigsMXD

Geophysical survey results: Greyscale mosaic; Area 1 – State Apartments

Figure 7



Low Amplitude — High Amplitude

Coordinate system:
OSGB36 (OSTN15/OSGM15)

Date:	07/09/2020
Revision Number:	0
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Path:	X:\PROJECTS\228023\
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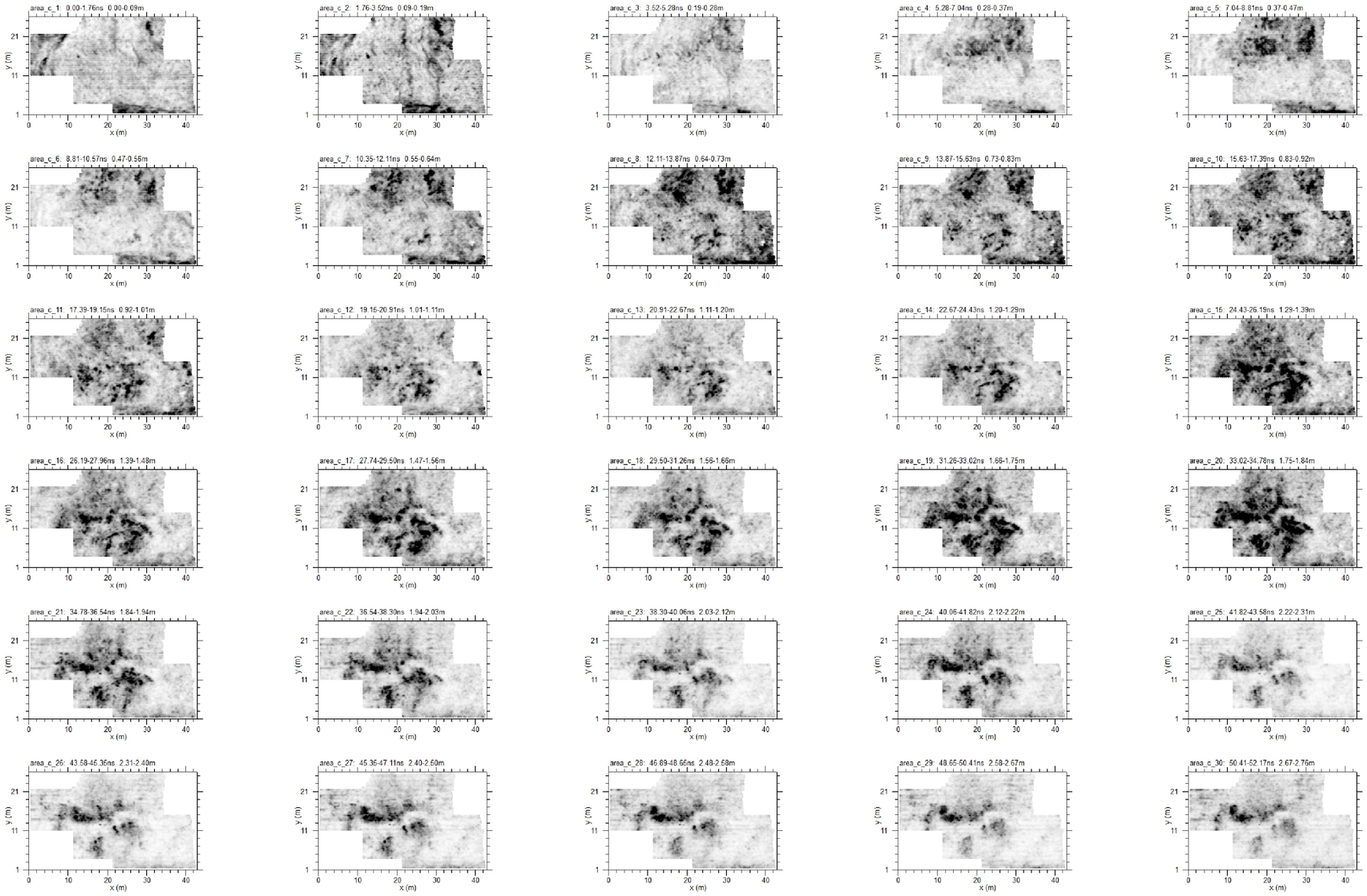
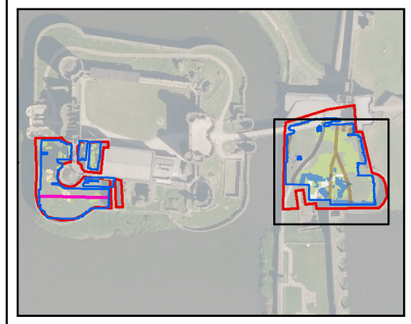
Geophysical survey results: Greyscale mosaic; Area 1 – Southwestern Drum Tower

Figure 8





Low Amplitude — High Amplitude

Coordinate system:
OSGB36 (OSTN15/OSGM15)

Date:	07/09/2020
Revision Number:	0
Scale:	N/A
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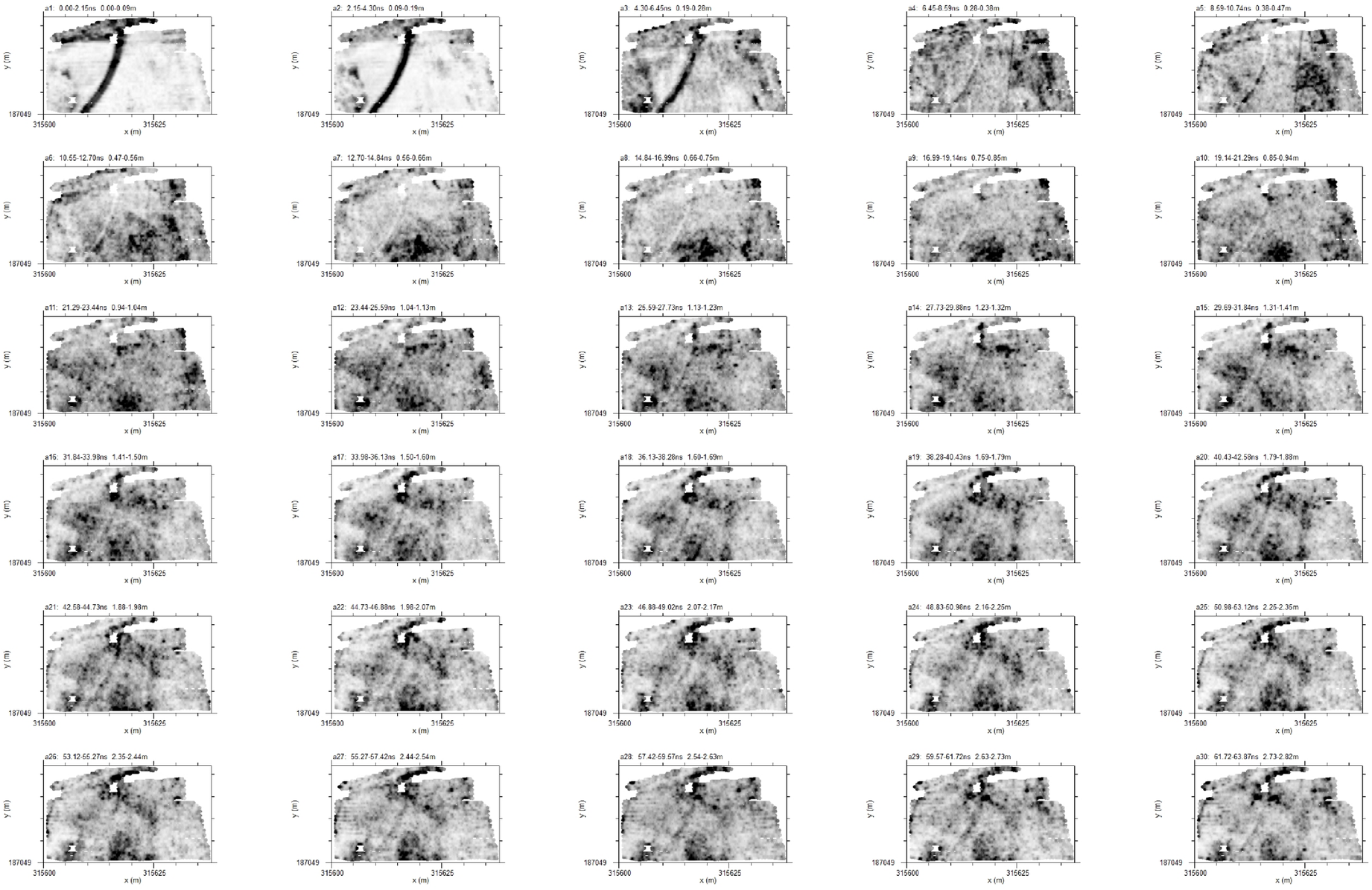
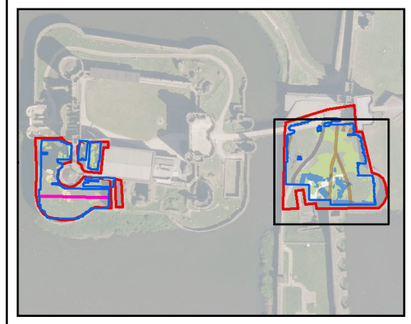
Geophysical survey results: Greyscale mosaic; Area 2 – Central Eastern Platform: Multichannel MIRA

Figure 9





Low Amplitude — High Amplitude

Coordinate system:
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Date:	30/09/2020
Revision Number:	0
Scale:	N/A
Illustrator:	RP
Path:	X:\PROJECTS\228023\ \GIS\FigsMXD

Geophysical survey results: Greyscale mosaic; Area 2 – Central Eastern Platform: Single channel Crossover

Figure 10

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