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Helmsley Castle, Helmsley, North Yorkshire

Report on Geophysical Survey, June 2023

Megan Clements and Neil Linford

Geophysics

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Summary

A ground penetrating radar (GPR) survey was conducted across the Inner Bailey and South Barbican of Helmsley Castle, Helmsley, North Yorkshire, at the request of the English Heritage Trust, primarily to confirm the presence of soakaway drains serving the West Range thought to have been installed in the 1980s. The survey (0.48ha) was extended beyond the immediate area of interest to provide a wider archaeological context and aid the future management of Helmsley Castle. The results broadly confirm the location of the soakaway and, in addition, reveal significant structural remains possibly associated with an original keep or hall and the previous location of the chapel. Several service buildings have also been identified together with anomalies suggesting different phases of activity within the castle than are currently indicated in the extant remains, evident for example within the Kitchen range and South Barbican. Evidence for more recent recreational activity may also have been detected.

Contributors

The geophysical fieldwork was conducted by Neil Linford and Megan Clements.

Acknowledgements

The authors are grateful for the help provided by colleagues from the English Heritage Trust on site and at the English Heritage Hemsley Archaeology Store. The cover image shows the ground penetrating radar equipment facing the Chapel in the foreground looking towards the Gallery, West Tower and Chamber Block of the West Range (photo taken by Neil Linford).

Archive location

Fort Cumberland, Fort Cumberland Road, Portsmouth, PO4 9LD

Date of survey

The fieldwork was conducted between the 27th and 29th of June 2023 and the report completed on 22nd of August 2023.

Contact details

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Introduction

A ground penetrating radar (GPR) survey was conducted at Helmsley Castle, Helmsley, North Yorkshire, at the request of the English Heritage Trust, primarily to confirm the presence of soakaway drains serving the West Range thought to have been installed in the 1980s. Rainwater drainage problems identified in this area together with limited invasive investigation (Florence Spaven *pers comm*) questioned whether the soakaways shown on a 1988 design plan had been fully installed and were still functioning (Fenton 1988; Linford 2023). The survey was extended to cover accessible areas within the Inner Bailey and South Barbican to provide a wider archaeological context to inform both the interpretation and future management of the site. The work was agreed under the Shared Services Agreement and addresses Historic England corporate plan activity “5.2 Work with English Heritage Trust to support the National Collection”.

Helmsley Castle evolved from the 12th to late 16th centuries and comprises a formidable double ditch, hewn from solid rock on the west side, surrounding an oblong inner bailey (Historic England 1992). The initial concentric rectangular ringwork is generally attributed to Walter l'Espec, who held the site from 1120 to 1153, and the massive earthen rampart between the deep ditches is believed to have been originally surmounted by a timber stockade. A stone castle was raised by Robert de Roos sometime between 1191 and 1227, with a curtain wall enclosing the Inner Bailey, circular towers protecting three of the four corners, two semi-circular towers flanking the northern gatehouse, and a larger projecting D-shaped tower keep located on the eastern curtain.

On the western side the curtain wall is sharply set back roughly halfway along its length and a square tower is situated in the angle. A simple gate tower provided access on the southern side with the entrances strengthened in the mid-13th century with the addition of an outer northern gatehouse and a large barbican beyond the South Gate. A range of domestic buildings including a possible great hall were situated on the west side of the Inner Bailey. During the 14th century the South Barbican was strengthened, two upper floors were added to the West Tower and a new hall built in the south-west corner.

In the 1560s Edward Manners, 3rd Earl of Rutland, built a house in the shell of the West Tower which survives largely unaltered. In November 1644 following a three month siege the castle surrendered to the Parliamentary commander Sir Thomas Fairfax and its subsequent slighting was severe. Most of the curtain wall and towers survive only as footings although the courtyard front of the keep stands almost extant. In 1695 the castle and its lands were sold to Charles Duncombe. The castle gradually fell into disrepair and was taken into State guardianship in 1923.

Helmsley Castle is a Grade 1 listed building (National Heritage List for England (NHLE): 1175226), scheduled ancient monument (NHLE: 1009963) and part of Duncombe Park, a registered Park and Garden (NHLE: 1001061). Helmsley Castle has the North Yorkshire Historic Environment Record Number MNY24416.

The site lies over Oxfordian Age Upper Limestone of the Corallian Oolite formation (Malton Oolite and Coral Rag) with no superficial geology recorded (Geological Survey of Great Britain 1882; British Geological Society 2023). Shallow calcareous or fine loamy over clayey soils of the ELMTON 2 (343b) association are recorded, although destruction deposits and made ground seem more likely within the castle ward (Soil Survey of England and Wales 1983). The surface conditions were cut grass interrupted by extant remains of the castle and the weather across the survey days was cloudy with intermittent light rain.

Method

A 3d-Radar (Kontur) MkIV GeoScope Continuous Wave Step Frequency (CWSF) Ground Penetrating Radar (GPR) system was used to conduct the survey collecting data with a hand operated multi-element DXG0908 ground coupled antenna array (Linford *et al.* 2010; Eide *et al.* 2018). A roving Trimble R8s Global Navigation Satellite System (GNSS) receiver was mounted on the GPR antenna array, that together with a second R8s base station was used to provide continuous positional control for the survey collected along the instrument swaths shown on Figure 2. The GNSS base station receiver was adjusted to the National Grid Transformation OSTN15 using the Trimble VRS Now Network RTK delivery service. This uses the Ordnance Survey's GNSS correction network (OSNet) and gives a stated accuracy of 0.01-0.015m per point with vertical accuracy being half as precise.

Data were acquired at a 0.075m x 0.075m sample interval across a continuous wave step frequency range from 40MHz to 2.99GHz in 4MHz increments using a dwell time of 5ms. A single antenna element was monitored continuously to ensure data quality during acquisition together with automated processing software to produce real time amplitude time slice representations of the data as each successive instrument swath was recorded in the field (Linford 2013).

Post-acquisition processing involved conversion of the raw data to time-domain profiles (through a time window of 0 to 75ns), adjustment of time-zero to coincide with the true ground surface, background and noise removal, and the application of a suitable gain function to enhance late arrivals. Representative profiles from the full GPR survey data set are shown on Figure 4. To aid visualisation amplitude time slices were created from the entire data set by averaging data within successive 2.5ns (two-way travel time) windows (e.g. Linford 2004). An average sub-surface velocity of 0.112m/ns was assumed following constant velocity tests on the data and was used as the velocity field for the time to estimated depth conversion. Each of the resulting time slices therefore represents the variation of reflection strength through successive ~0.14m intervals from the ground surface, shown as individual greyscale images in Figures 3 and 5 to 8. Further details of both the frequency and time domain algorithms developed for processing this data can be found in Sala and Linford (2012).

Results

A combined graphical summary of significant GPR anomalies from throughout the data set, [**gpr1-70**] discussed in the following text, is shown superimposed on the base Ordnance Survey (OS) mapping data, in Figure 9. In addition, for greater clarity, individual graphical summaries of significant anomalies found between 0.0 and 15.0ns, 15.0 and 30.0ns, 30.0 and 45.0ns, and 45.0 and 60.0ns are provided in Figures 10 to 13 respectively.

Reflections have been recorded throughout the 75ns two-way travel time window, although there are few significant responses beyond a two-way travel time of ~60.0ns (3.42m) where the signal is more heavily attenuated. The very near-surface data between 0.0 and 2.5ns (0.0 to 0.14m) contains responses due mainly to the surface micro-topography of the site, compacted foot paths evident in the vicinity of the access bridge to the North Barbican, and mole burrows within the South Barbican.

Inner Bailey

A large 17.5m by 23.5m rectangular high-amplitude anomaly [**gpr1**] is visible between 15.0 and 57.5ns (0.84 to 3.28m) and is indicative of substantial wall footings measuring between 2m and 2.5m in width. While it is difficult to suggest a precise interpretation from the geophysical data alone, [**gpr1**] could certainly represent an early phase of masonry construction, possibly even an original keep or a vaulted hall built by Walter l'Espec. There does not appear to have been any previous record of building remains in this location and, perhaps due to the depth of overburden, the formation of parch marks or any topographic representation has been suppressed.

Five circular high-amplitude anomalies [**gpr2**] found between 15.0 and 45.0ns (0.84 to 2.52m) within [**gpr1**] are likely to be structural pillars perhaps supporting a vaulted under croft, with the diffuse right angle spread of debris [**gpr3**] possibly associated with a former wall or flooring. Towards the east [**gpr1**] appears to form a separate section that may represent an entrance [**gpr4**] with the large circular anomaly [**gpr5**] possibly forming part of a defensive feature. Low-amplitude anomaly [**gpr6**] is found parallel to the walls of [**gpr1**] and is likely to be associated with those building structures.

To the immediate south of [**gpr1**], a high-amplitude anomaly [**gpr7**] shares the same approximate east-west alignment and rectangular form as the extant Chapel, suggesting [**gpr7**] may represent the location of the original chapel. It is possible from the proximity and similar orientation that [**gpr1**] and [**gpr7**] were contemporary structures, with the 1.0m wide walls of [**gpr7**] extending slightly deeper from between 15.0 and 60.0ns (0.84 to 3.42m). More discrete anomalies [**gpr8**] detected within [**gpr7**] could, tentatively, suggest

the location of graves. A high-amplitude anomaly [**gpr9**] bisects [**gpr7**] and is visible in the data between 15.0 and 30.0ns (0.84 to 1.85m). The course of [**gpr9**] follows the Ministry of Works (MoW) concrete surface marker indicating the location of the outer wall of the late 13th to early 14th century Hall.

*Plate 1: photo looking towards the Hall and the West Range from the Kitchen Range. The outer wall and MoW concrete marker [**gpr9**] is evident in the centre of the photo (Source: Historic England Archive 1970).*

It can be assumed the original keep was demolished by Robert de Roos, who held Helmsley Castle between 1191 and 1227, to make way for his new castle, the layout of which is largely as it stands today. The original chapel [**gpr7**] may have continued in use until the recorded dedication of the new chapel in 1246. However, it would have been challenging to retain a chapel at [**gpr7**] while demolishing the adjacent sizable building shown by the wall foundations [**gpr1**]. Clearing the Inner Bailey may have also been a strategic defensive choice by Robert de Roos, who had a colourful political career, and may suggest the original chapel was also demolished by 1227 during this period of renovation. This would leave a gap of at least 20 years, before the dedication of the new chapel, where the status of the chapel of Helmsley Castle is in question. It is possible rooms within the main residential part of the castle were used for this purpose until the next lord, William de Roos, added the 13th century chapel. This may also help to explain the perhaps unusual placement of the new chapel adjacent to the East Tower.

A large diffuse, high-amplitude response [**gpr10**] is likely to be a floor layer within the Hall, with the right-angled anomaly [**gpr11**] a wall footing of an internal room. The low-amplitude anomaly at [**gpr12**] is more difficult to interpret, perhaps either a robbed-out wall footing or drainage conduit. It is possible [**gpr11**] and [**gpr12**] formed the wall of an original, smaller hall, or [**gpr11**] represents a small corridor associated with the late 13th to early 14th century remodelling that created the current Hall.

A faint response to a spread of debris [**gpr13**] east of the East Tower could be a paved or gravelled pathway to the Well. It is probable the adjacent anomaly at [**gpr14**] is either the continuation of the pathway or, given the greater depth extent, the foundations of the outer wall.

Further possible wall foundations are found with the same depth range and orientation as [**gpr1**], extending to the north [**gpr15**], and west [**gpr16**] and [**gpr17**]. Extant rectangular masonry of unknown date appears to adjoin the west end of [**gpr16**] and a discrete anomaly [**gpr18**] seems to mirror this masonry block to the east of [**gpr17**]. A high-amplitude wall-type anomaly [**gpr19**] continues south of the rectangular masonry block to meet with a surviving wall extending from the West Tower, attributed to Walter l'Espec and given a date of 1122-53. It is possible that [**gpr20**] and [**gpr21**] are debris from a former southern and eastern wall respectively, and [**gpr22**] a possible pillar base. Anomaly [**gpr23**] is likely to be debris from either the extant 1122-53 wall, or the room formed by anomalies [**gpr16**] and [**gpr19-23**]. Together anomalies [**gpr15-22**] appear to represent a demolished range of rooms.

The linear, low-amplitude anomalies [**gpr24**] appear to share the orientation of the surrounding high-amplitude responses [**gpr1**], [**gpr16**] and [**gpr19-21**] and are possibly either cut ditch-type features or robbed-out walls. The more discrete low-amplitude anomaly [**gpr25**] may either be associated with the adjacent Well or the walls of [**gpr1**], [**gpr15**] or [**gpr17**].

A high-amplitude rectangular anomaly [**gpr26**] is found between 7.5 and 60.0ns (0.43 to 3.42m) and suggests substantial masonry remains, possibly associated with the room formed by [**gpr16**] and [**gpr19-22**] immediately to the east. The two low-amplitude responses [**gpr27**] on either side of [**gpr26**] could indicate cut ditch-type features or robbed-out walls.

To the north of [**gpr26**], a broad rectilinear anomaly [**gpr28**] extends north-west from the extant masonry block towards the 16th century Gallery but is on a different alignment to [**gpr1**] and the possibly associated rooms of [**gpr16-22**]. This suggests [**gpr28**] was built during a different, possibly later, phase. Spreads of debris [**gpr29**] within the area could indicate the approximate footprint of a former building comprising anomalies [**gpr28**] and

[**gpr29**]. However, the responses of [**gpr28**] and [**gpr29**] are limited to the near-surface, between 0.0 and 15ns (0.0 to 0.86m), suggesting more recent activity, such as landscaping associated with the Helmsley Tennis Club active during the 19th and early 20th centuries (Kenyon 2017).

To the south a strong, diffuse response [**gpr30**] dips gently to the south-west and appears with greatest clarity between 12.5 and 27.5ns (0.71 to 1.71m), although the anomaly does continue to 60ns (3.42m). While [**gpr30**] shares a similar alignment to [**gpr28**], it seems more likely [**gpr30**] represents either a deeper rubble deposit or is a response to the underlying geology.

A possible spread of debris [**gpr31**] has been detected between the masonry wall extending from the West Tower and stairs that lead down to the basement. A confident interpretation of [**gpr31**] is difficult, although it could represent building rubble associated with structural remains in the vicinity of the West Tower. A similar, amorphous high-amplitude anomaly [**gpr32**] is found on the other side of the projecting wall from the West Tower at the entrance to the Chamber Block and is continuous from the near-surface to 60ns (3.42m). While this area is complicated by recent interventions, including possible drainage works and gravel input to reduce surface wear at the visitor entrance (Fenton 1988, Florence Spaven *pers comm*), fragmented linear responses sharing a similar orientation to the Chamber Block are evident within [**gpr32**] and could be indicative of potential foundations, possibly of the original fortifications.

A linear low-amplitude anomaly [**gpr33**] appears to act as either a drain for the central Inner Bailey, or is potentially a continuation of the soakaway [**gpr67**], with water possibly accumulating at [**gpr34**].

A series of fragmented high-amplitude anomalies [**gpr35**] in the north-west of the Inner Bailey, are suggestive of structural remains that could possibly be associated with internal room divisions and additional buildings extending beyond the extant masonry. More discrete responses [**gpr36**] are found across this area, particularly within the near-surface data between 10.0 and12.5ns (0.57 to 0.71m), and may represent midden pits from when the castle grounds were used for refuse disposal. However, the apparent linear arrangement of some of [**gpr36**] may suggest a more deliberate placement or function than simple midden pits.

Two dividing walls [**gpr37**] extend to a limited depth, suggesting these may be associated with post-medieval renovations to the castle. An additional anomaly [**gpr38**] has been identified in the north-east corner of what is proposed to be the 16th century Stables. The response could indicate either a floor layer or an additional small wall. A deeper response at the corner of the Chamber Block [**gpr39**] continues to 60ns (3.42m) and is suggestive of

more substantial structural remains. The linear anomaly [**gpr40**] is found parallel to the extant Bakehouse and Brewhouse wall and may possibly be a corridor for access from the Chamber Block. Two high-amplitude responses [**gpr41**] and [**gpr42**] are quite substantial in size with a diameter of 2m and 2.5m respectively. Anomalies [**gpr41**] and [**gpr42**] could possibly represent structural remains, such as pillars to a room enclosed by [**gpr40**] and the extant wall to the west, although their size perhaps suggests a more significant origin.

Spreads of debris [**gpr43**] and [**gpr44**] possibly represent building rubble, flooring or areas of hard-standing. Anomaly [**gpr45**] follows the same gentle dip to the south-west as [**gpr30**] and seems likely to represent a continuation of the response to either a deeper rubble deposit or the underlying geology. A high-amplitude linear anomaly in the very near-surface [**gpr46**] could possibly be associated with compacted ground as a result of visitor footfall towards the access bridge, with the apparent continuation of the response into later time slices due to multiple air-wave reverberation, although interpretation as shallow structural remains is also possible. Anomalies [**gpr47**] and [**gpr48**] could either be flooring or rubble given the location within or in close vicinity to extant building remains. The large diffuse anomaly [**gpr49**] is possibly structural remains related to the East Tower, or perhaps the footprint of a former building.

A complex anomaly [**gpr50**] within the Bakehouse and Brewhouse is formed from a central low-amplitude response, possibly a drain or area of moisture retentive soil, with structural walls to either side. This suggests a causative feature directly related to the baking or brewing processes.

A high-amplitude linear anomaly [**gpr51**] is found towards the east end of the 13th century Chapel and continues to a depth suggestive of substantial masonry remains. While [**gpr51**] may be associated with the later 16th century fireplace, when it is thought the Chapel became a Tudor kitchen, it could also be related to the ecclesiastical phase of use, perhaps a raised alter dais. A more diffuse anomaly [**gpr52**] is found approximately parallel to [**gpr51**], although again it is difficult to determine whether it is associated with the chapel or kitchen phase of use.

Further low-amplitude anomalies could possibly indicate linear drainage conduits [**gpr53**] related to the kitchen, while [**gpr54**] is more likely to be a robbed-out masonry void associated with [**gpr51**] and [**gpr52**]. A large, diffuse spread of debris [**gpr55**] is found in the centre of the Chapel between 15.0 and 30.0ns (0.86 to 1.85m) suggesting a substantial amount of material, possibly flooring. The individual more discrete anomalies [**gpr56**], of both high and low-amplitude response, have the potential to be grave cuts or marker stones due to the size and placement of the anomalies within a known former chapel.

Three linear high-amplitude anomalies [**gpr57**] within the Kitchen indicate the presence of former walls, that appear quite substantial to the north and south of the Kitchen, with the response to the north extending west beyond the extant remains. It seems likely anomalies [**gpr57**] represent an earlier range or phase of buildings pre-dating the 13th-14th century remains. High-amplitude anomalies [**gpr58**] found in the vicinity of the entrances to the Kitchen, Pantry and Buttery are likely to be structural remnants of doorways, while the more diffuse responses may be due to either rubble spreads or flooring. The low-amplitude anomalies [**gpr59**] detected in the Buttery could be due to more moisture retentive soil or the underlying open void space.

South Gate and South Barbican

The high-amplitude anomalies [**gpr60**] are probably associated with the compacted access route into the castle. It was observed during the survey that these areas have been significantly worn away to expose the bare limestone. Two linear spreads of debris in the east-wing of the South Barbican [**gpr61**], suggest the presence of former walls with further, better defined, linear anomalies [**gpr62**] perhaps forming a small room. The spread of high-amplitude material [**gpr63**] may also be rubble from structural remains, perhaps to support upper floors. The low-amplitude anomalies [**gpr64**] are more difficult to interpret, but may indicate drains, robbed-out masonry or even a small water source. Former walls [**gpr65**] and the response to possible flooring or debris material [**gpr66**] are also located in the west-wing of the South Barbican. This indicates the South Barbican has undergone stages of renovation and suggests this range had more substance than the open-backed curtain wall and towers of the early 13th century.

Soakaway Drain

Figure 14 shows a detail of the site in the vicinity of the West Range Chamber Block, including an extract from the plan view of the proposed soakaways drawn in May 1988 scaled with the OS mapping data (Fenton 1988). The presumed location of the two soakaways are shown as grey hachured boxes on the graphical summary of significant GPR anomalies (Figure 14(B)).

There are significant anomalies associated with both water chutes from the roof (marked S1 and S2 on Figures 14(A) and 14(B)) at the approximate location and expected depth of the soakaways proposed on the design plan. However, the anomalies do not appear to match the dimensions or orientation of the proposed soakaways. To the south, a mixed amplitude anomaly [**gpr67**] heads due east from the West Range from a depth of approximately 0.6m with an adjacent low-amplitude response [**gpr68**] immediately to the north-west.

The water chute to the north, S2, is associated with a less well-defined high-amplitude anomaly [**gpr69**] and a smaller low-amplitude response [**gpr70**]. It is possible that [**gpr67**] and [**gpr68**] represent a response to the underlying hardcore supporting the perforated drain and were constructed to remove water away from the West Range while avoiding surviving masonry remains shown in the photograph of the site Figure 14(A). Photographs showing limited invasive investigation conducted in March 2022 suggest the trial trench did not, necessarily, extend over the location and depth of the relevant anomalies (Plate 2).

*Plate 2: exploratory excavation trench in the vicinity of [**gpr67**] facing south-west towards the West Range Chamber Block with the grooved paving stone to the immediate right of the ranging rod receiving discharge from water chute S1 above (Source: Historic Property Restoration ltd 2022).*

Conclusions

The ground penetrating radar survey has successfully identified a palimpsest of anomalies across the Inner Bailey that greatly enhance the current interpretation of Helmsley Castle. Substantial masonry remains have been revealed within the Inner Bailey and may suggest the location of a substantial original keep or vaulted hall, and a potential chapel possibly belonging to the time of Walter l'Espec. Evidence for rooms and buildings beyond the visibly extant wall lines have been identified together with indications of previous structural remains within the Kitchen, South Barbican and Hall. Additional interventions from more recent recreational activities and utilities have been detected.

Anomalies have also been found in the expected location of the 1980s soakaways installed to receive water discharged from chutes in the roof of the West Range. The form of the anomalies appears different to the design plan, perhaps taking account of the local soil conditions and avoiding extant masonry remains. The GPR survey also suggests that the previous trial trenching to identify the soakaways did not, necessarily, extend over the location and depth of the relevant anomalies.

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Figure 4: Representative topographically corrected profiles from the GPR survey shown as greyscale images with annotation denoting significant anomalies. The location of the selected profiles can be found on Figures 2, 3 and 12.

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Figure 6: GPR amplitude time slices between 15 and 30ns (0.86 to 1.71m) (1:1500).

Figure 7: GPR amplitude time slices between 30 and 45ns (1.71 to 2.57m) (1:1500).

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Figure 9: Graphical summary of significant GPR anomalies between 0 and 60ns (0 to 3.42m) (1:500).

Figure 10: Graphical summary of significant GPR anomalies between 0 and 15ns (0 to 0.86m) (1:750).

Figure 11: Graphical summary of significant GPR anomalies between 15 and 30ns (0.86m to 1.71m) (1:750).

Figure 12: Graphical summary of significant GPR anomalies between 30 and 45ns (1.71 to 2.57m) (1:750).

Figure 13: Graphical summary of significant GPR anomalies between 45 and 60ns (2.57 to 3.42m) (1:750).

Figure 14: Detail of the GPR data in the vicinity of the West Range soak-away including (A) a photograph showing the location of the rain water

chutes and (B) graphical summary of significant GPR anomalies superimposed over the presumed location of the drainage works (1:100), together with selected west east orientated GPR profiles from across the area.

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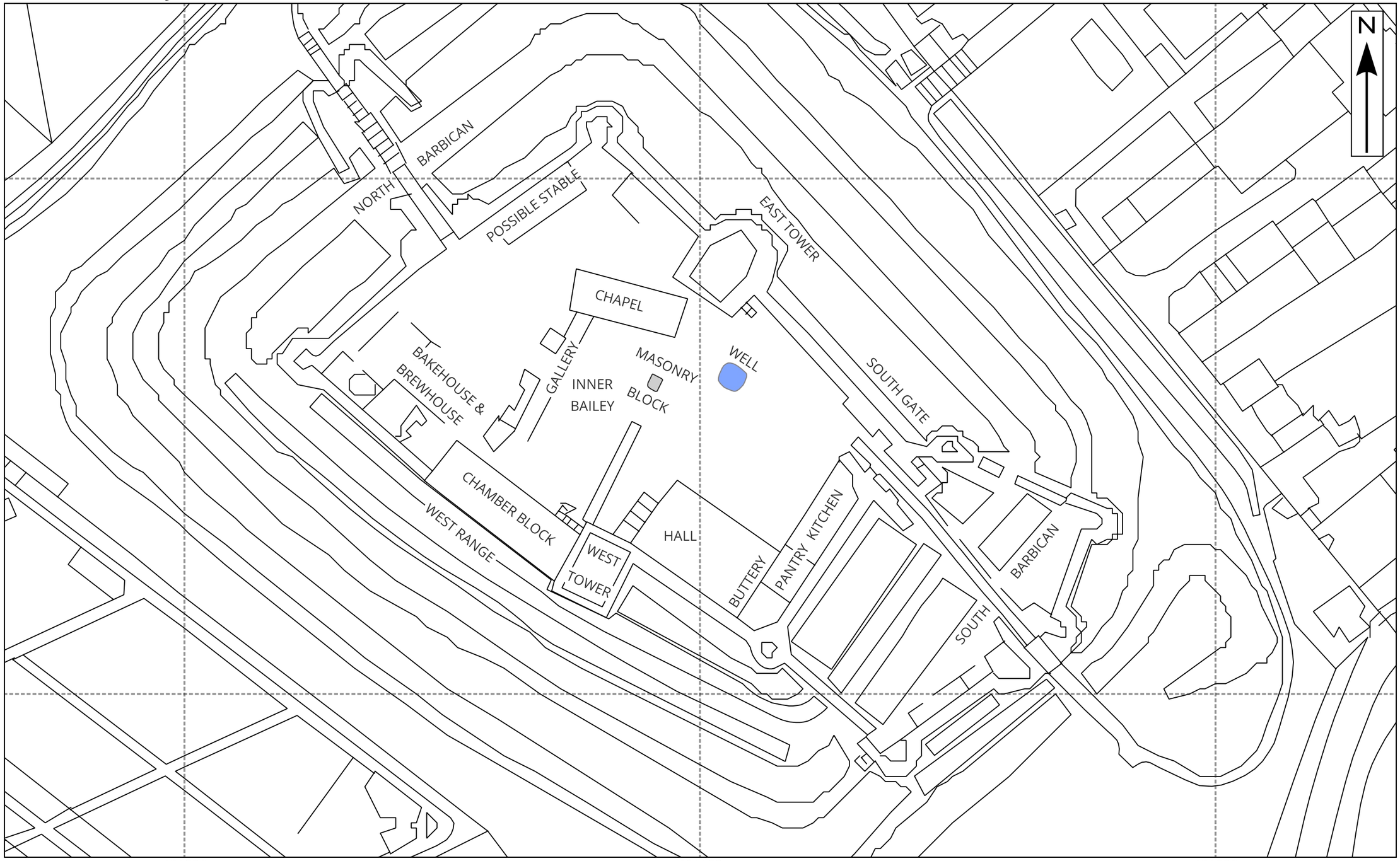
HELMSLEY CASTLE, HELMSLEY, NORTH YORKSHIRE

Figure 1

Plan of Castle, June 2023



0 25 50 75 m

1:750

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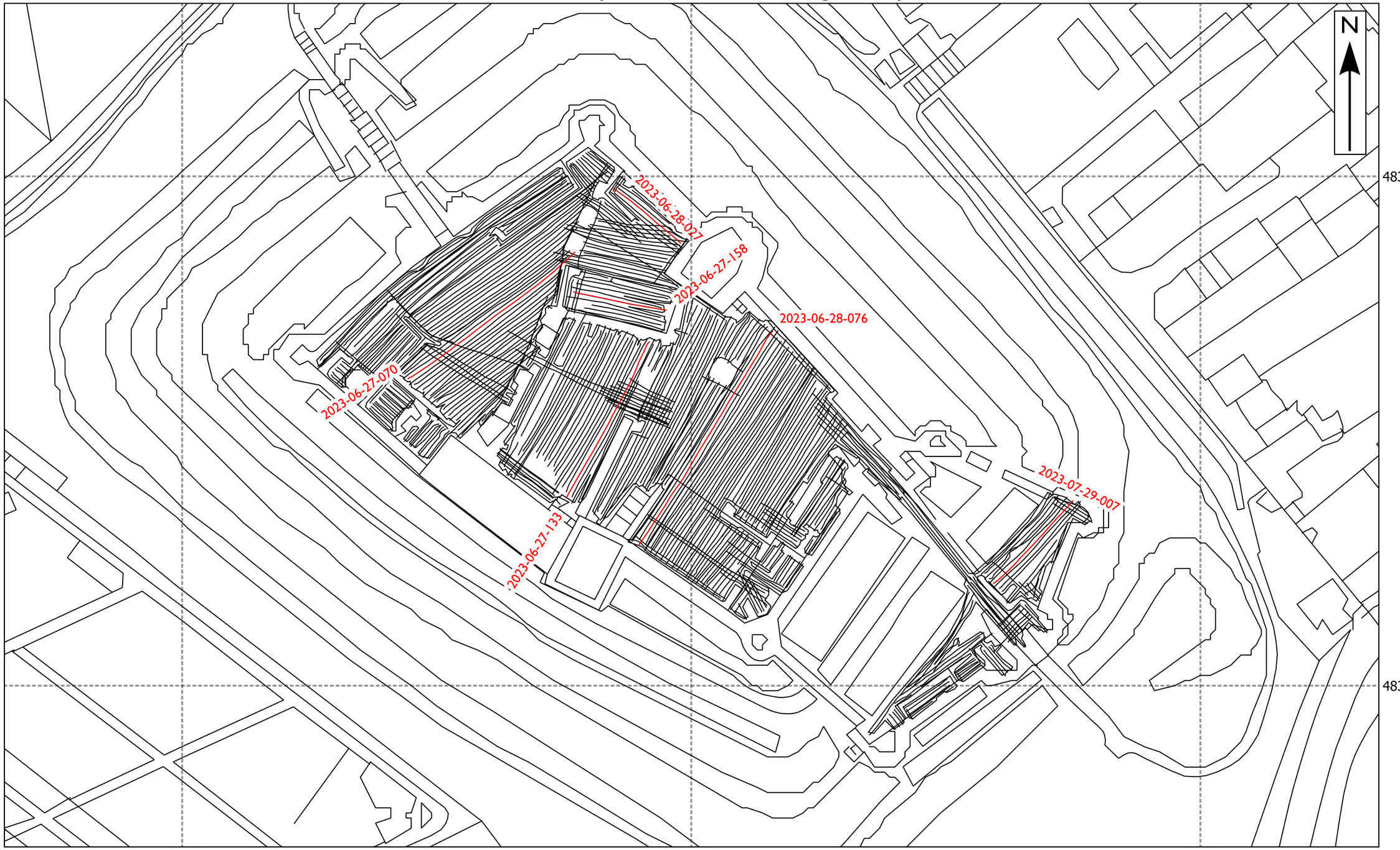
Historic England

HELMSLEY CASTLE, HELMSLEY, NORTH YORKSHIRE

Figure 2

Location of GPR instrument swaths and selected GPR profiles shown on Figure 4, June 2023



0 25 50 75 m

1:750

GPR Survey Swaths

Location of selected GPR profiles shown on Figure 4

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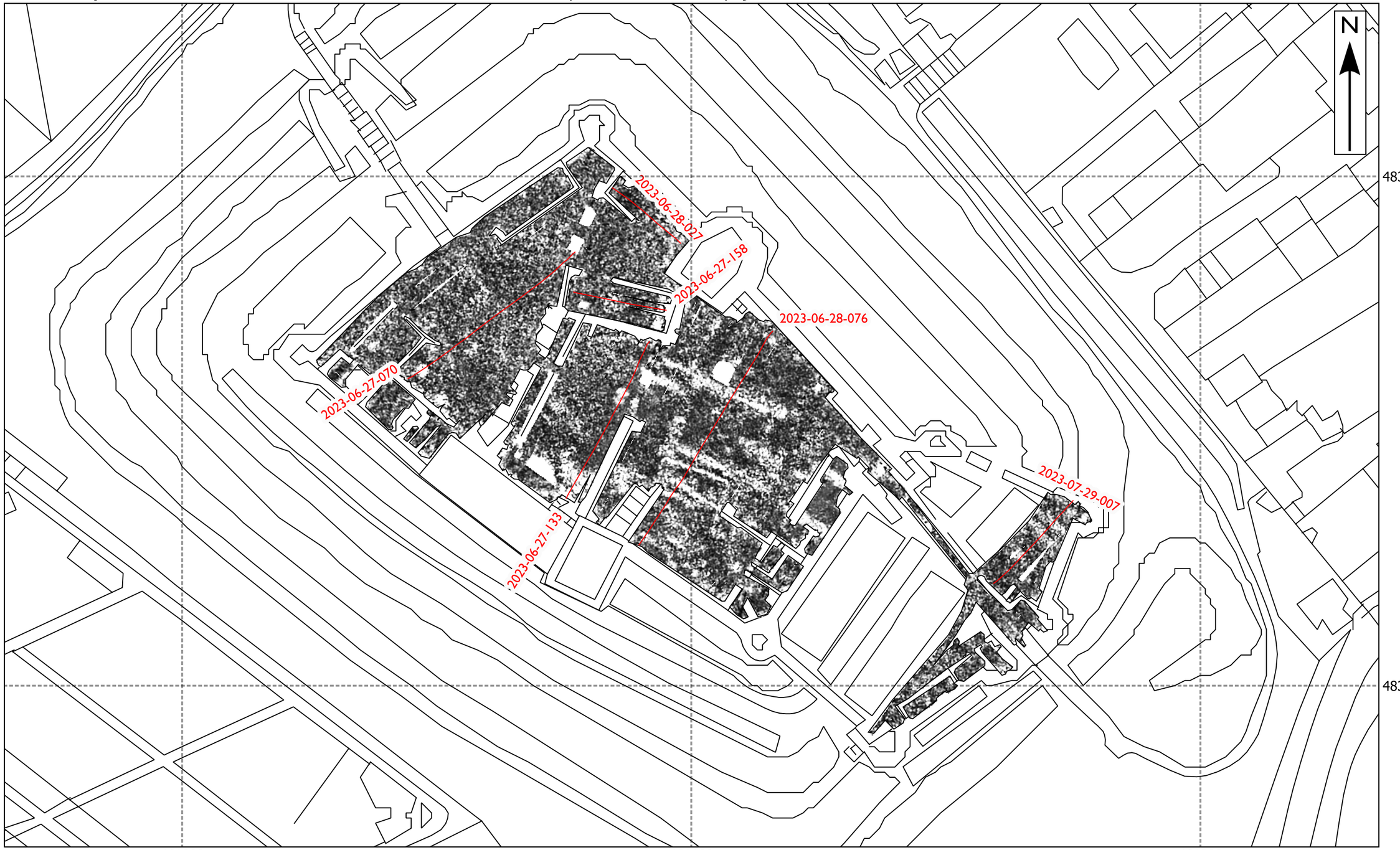
HELMSLEY CASTLE, HELMSLEY, NORTH YORKSHIRE

Figure 3

GPR amplitude time slice between 27.5 and 30.0ns (1.57 to 1.71m), June 2023



0 25 50 75 m

1:750

Low High
relative reflector strength

Location of selected GPR profiles shown on Figure 4

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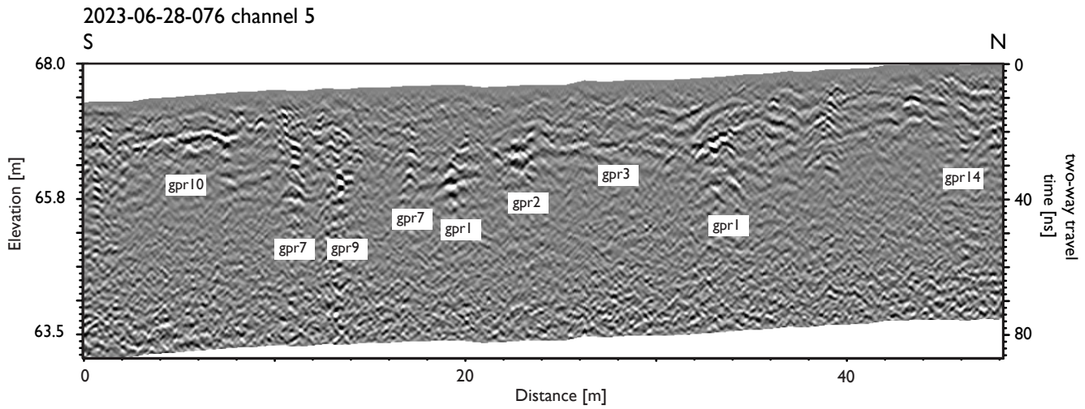
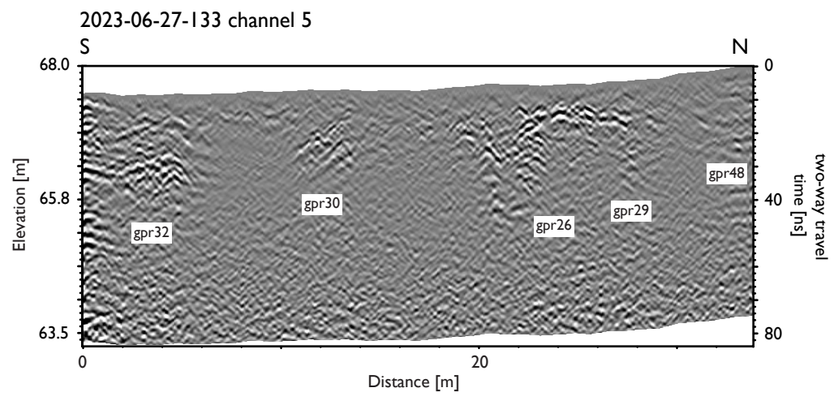
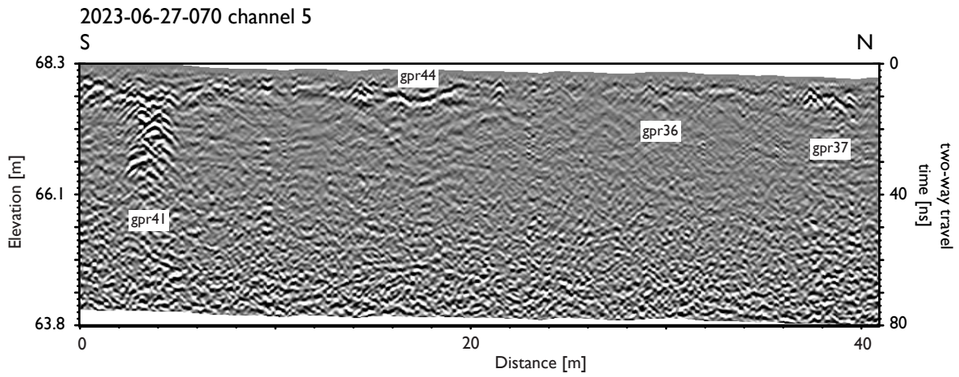
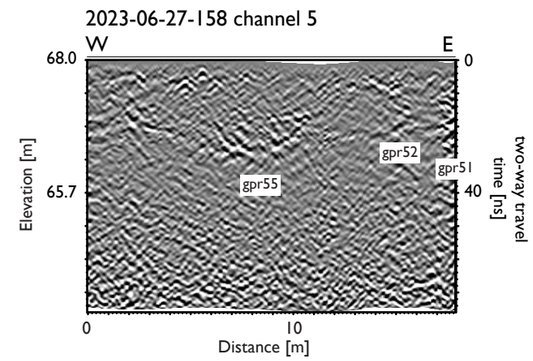
HELMSLEY CASTLE, HELMSLEY, NORTH YORKSHIRE
Representative topographically corrected GPR profiles, July 2023

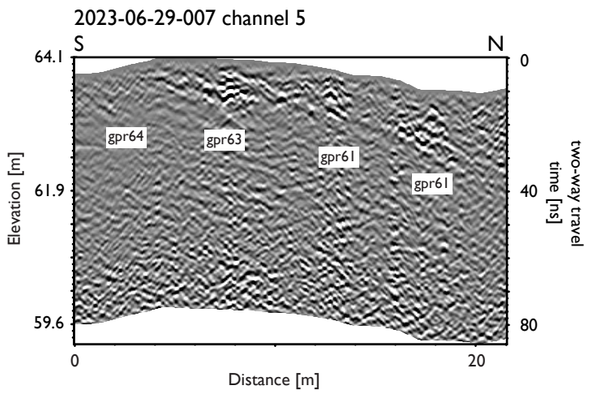
Figure 4











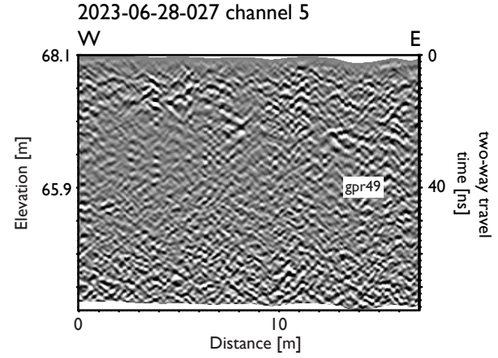


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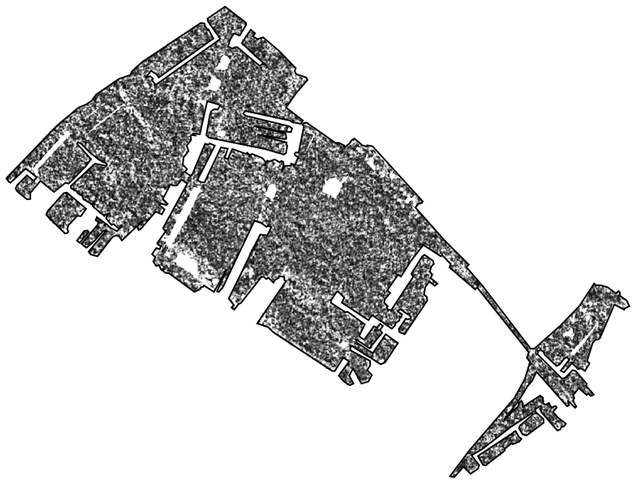
Figure 5

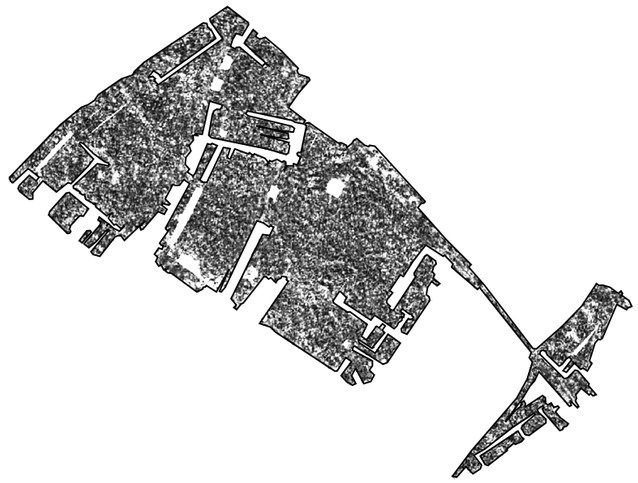
GPR amplitude time slices between 0.0 and 15.0ns (0.0 to 0.86m), June 2023

N

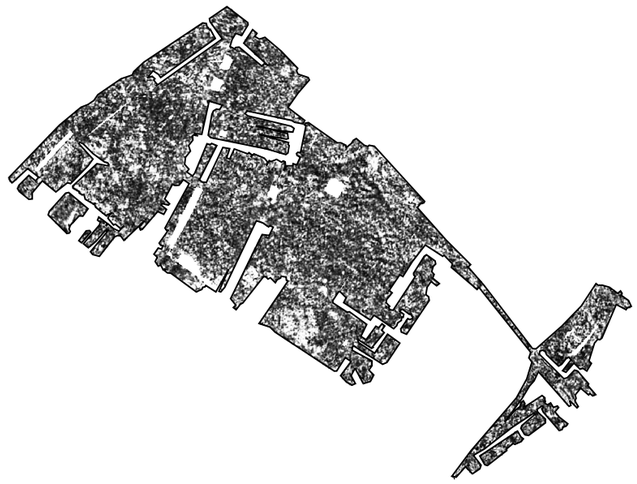
0.0 - 2.5ns (0.0 - 0.14m)



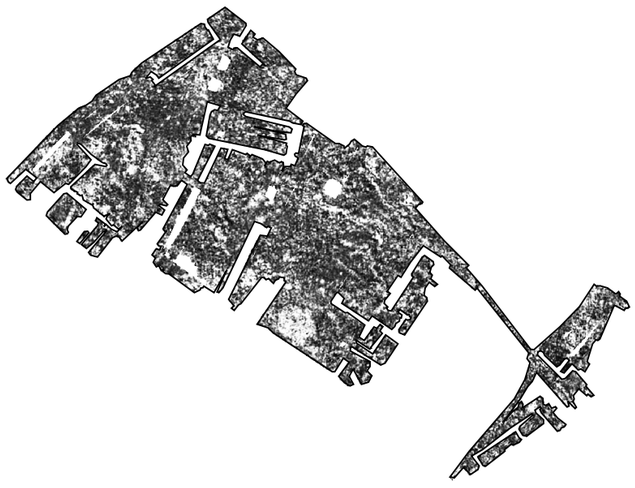
2.5 - 5.0ns (0.14 - 0.29m)



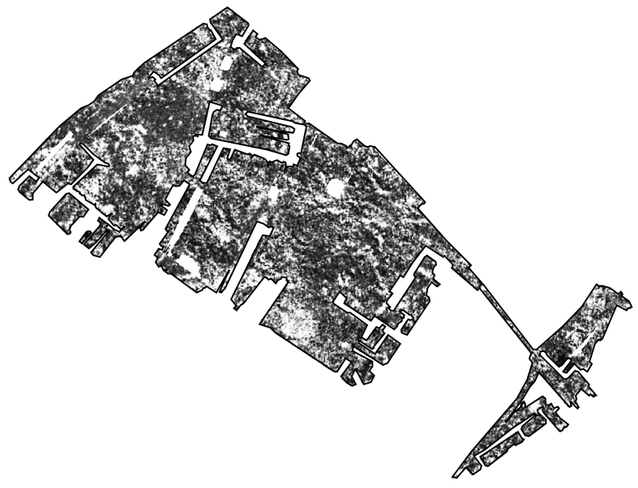
5.0 - 7.5ns (0.29 - 0.43m)



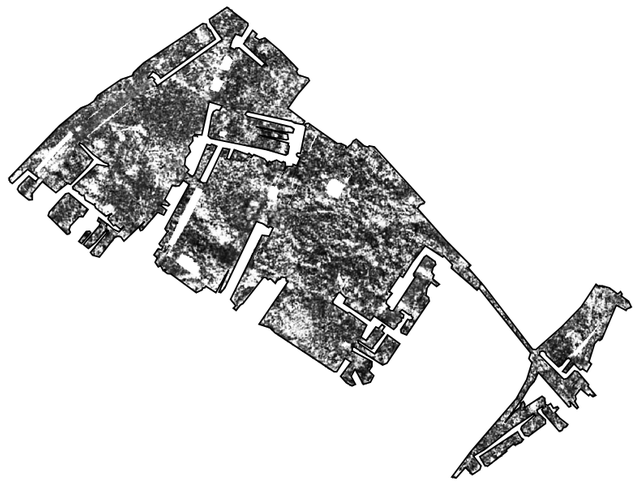
7.5 - 10.0ns (0.43 - 0.57m)



10.0 - 12.5ns (0.57 - 0.71m)



12.5 - 15.0ns (0.71 - 0.86m)



0 50 100 150 m

1:1,500

Low High

relative reflector strength

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Historic England

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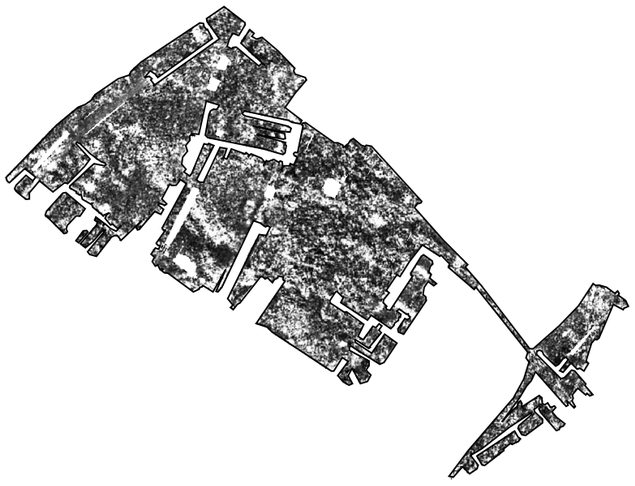
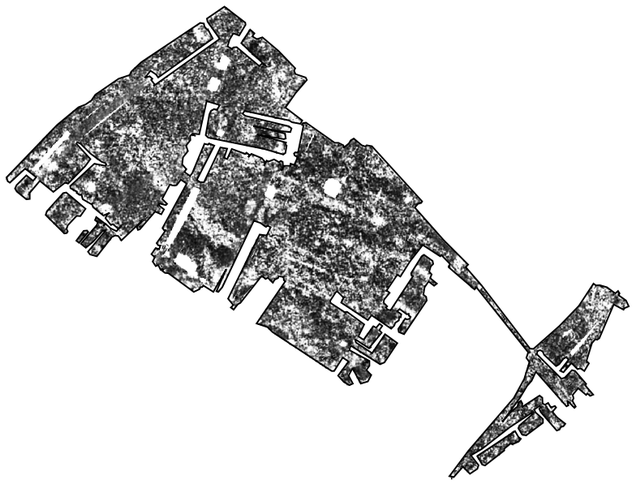
Figure 6

GPR amplitude time slices between 15.0 and 30.0ns (0.86 to 1.71m), June 2023

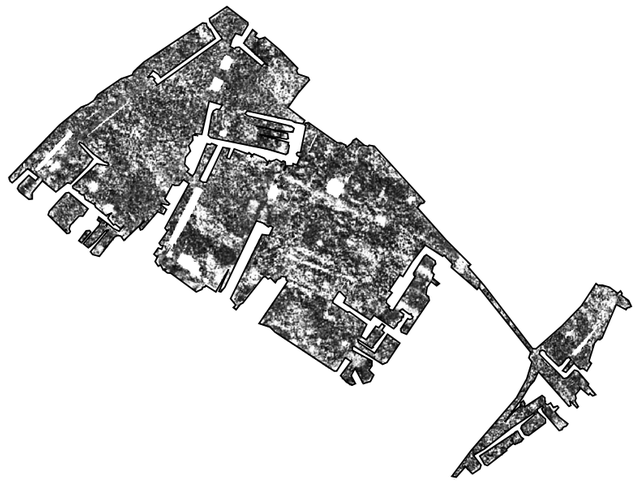
15.0 - 17.5ns (0.86 - 1.00m)



17.5 - 20.0ns (1.00 - 1.14m)

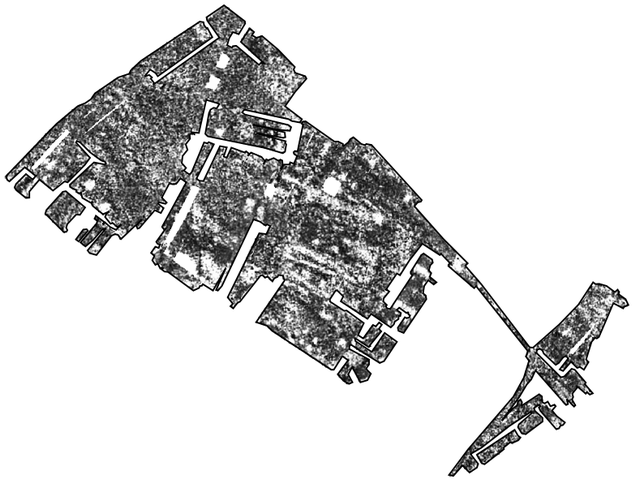


20.0 - 22.5ns (1.14 - 1.28m)

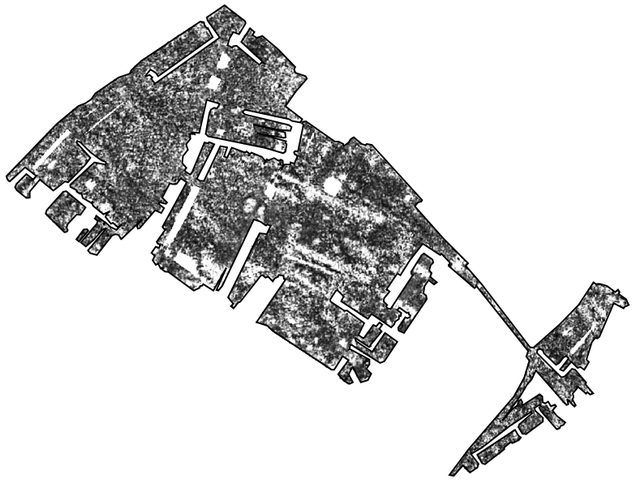


N

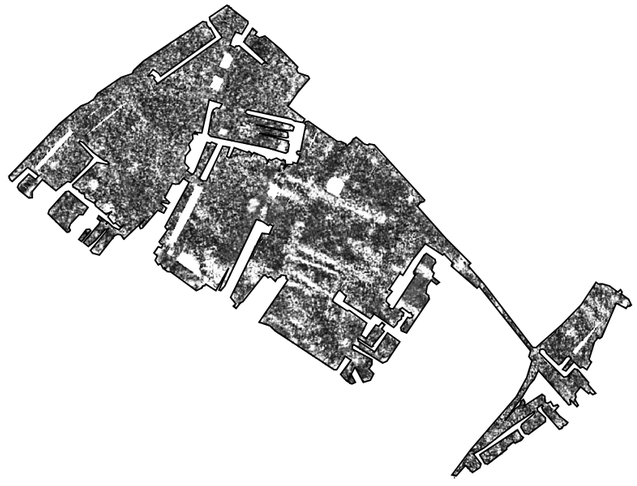
22.5 - 25.0ns (1.28 - 1.43m)



25.0 - 27.5ns (1.43 - 1.57m)



27.5 - 30.0ns (1.57 - 1.71m)



0 50 100 150 m

1:1,500

Low High

relative reflector strength

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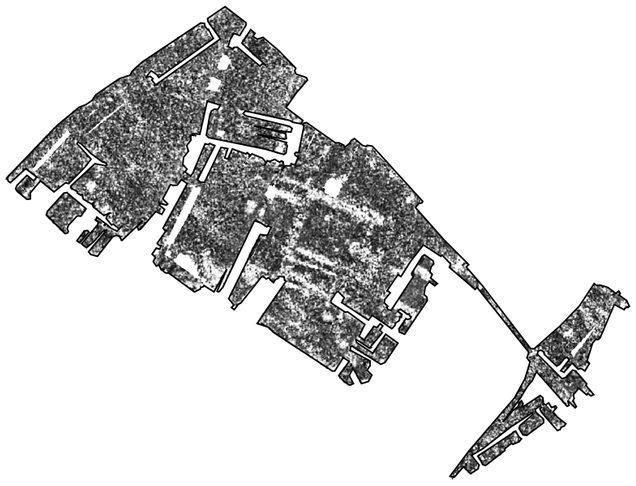
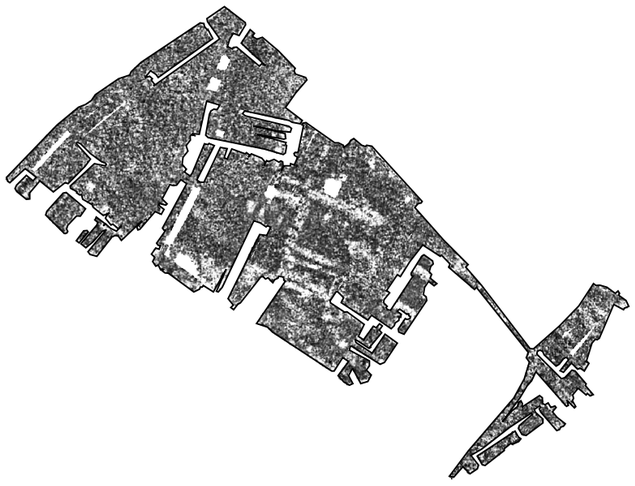
Figure 7

GPR amplitude time slices between 30.0 and 45.0ns (1.17 to 2.57m), June 2023

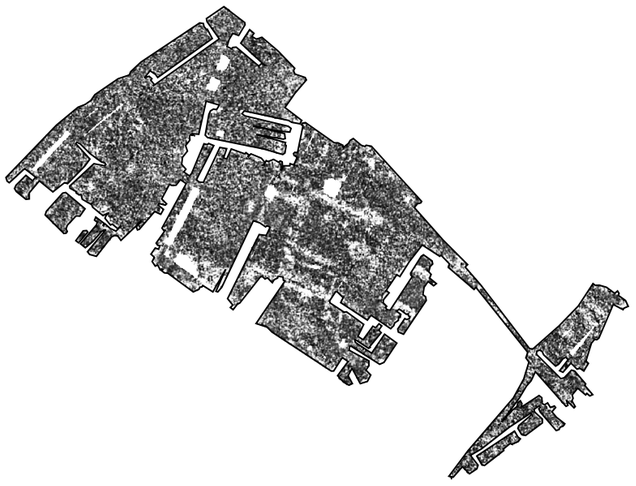
30.0 - 32.5ns (1.71 - 1.85m)



32.5 - 35.0ns (1.85 - 2.00m)

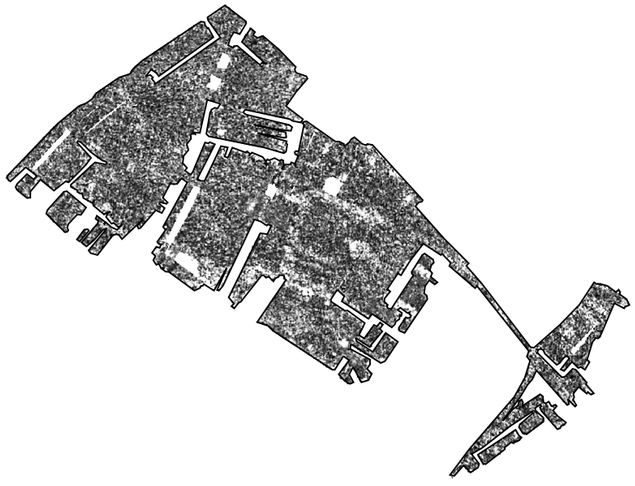


35.0 - 37.5ns (2.00 - 2.14m)

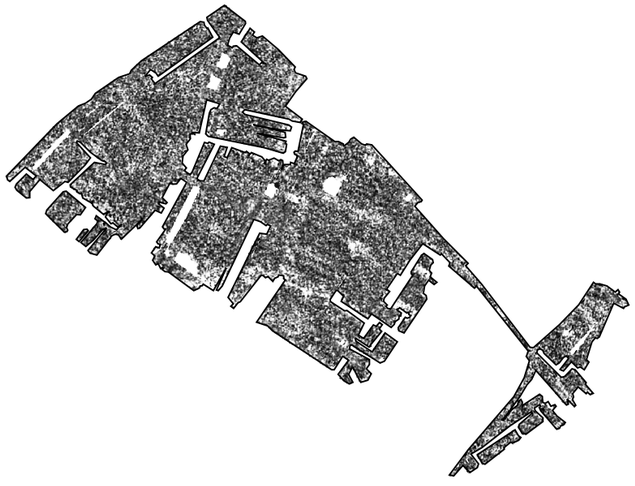


N

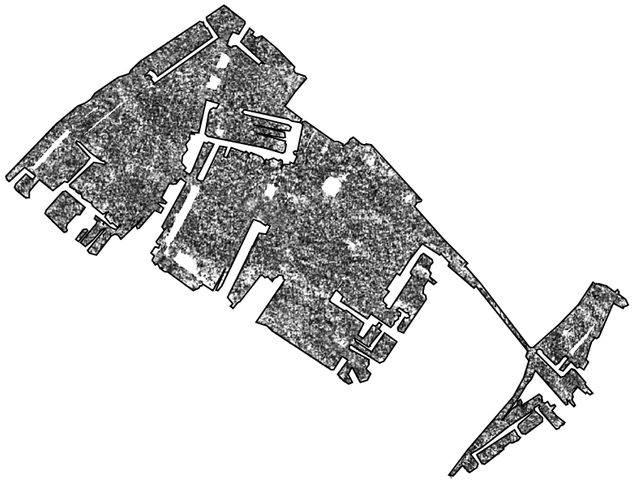
37.5 - 40.0ns (2.14 - 2.28m)



40.0 - 42.5ns (2.28 - 2.42m)



42.5 - 45.0ns (2.42 - 2.57m)



0 50 100 150 m

1:1,500

Low High

relative reflector strength

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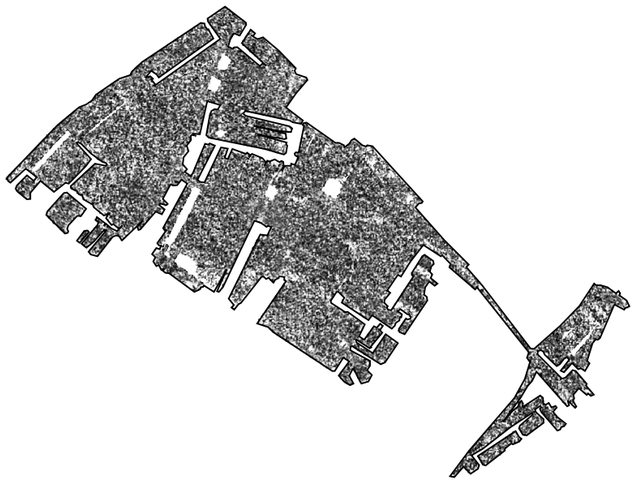
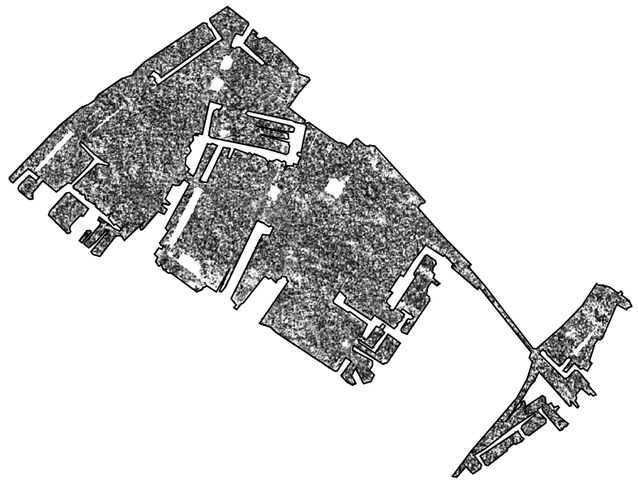
Figure 8

GPR amplitude time slices between 45.0 and 60.0ns (2.57 to 3.42m), June 2023

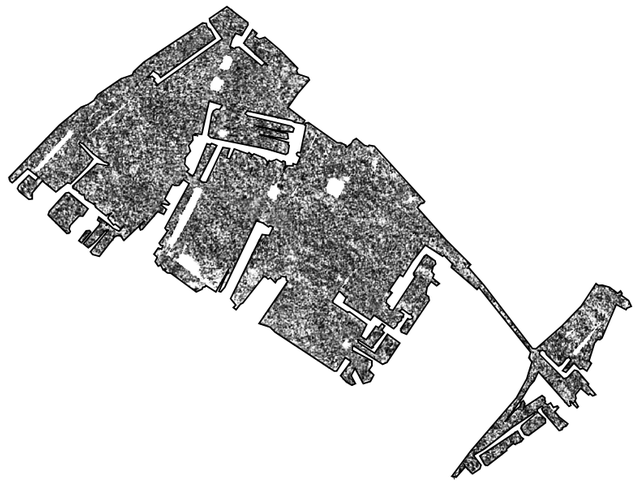
45.0 - 47.5ns (2.57 - 2.71m)



47.5 - 50.0ns (2.71 - 2.85m)

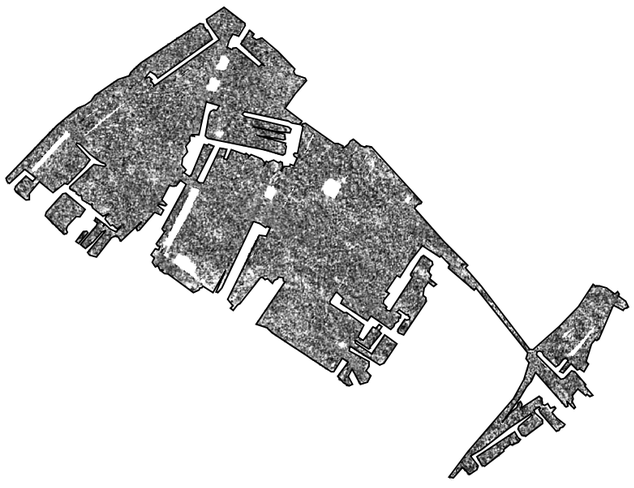


50.0 - 52.5ns (2.85 - 2.99m)

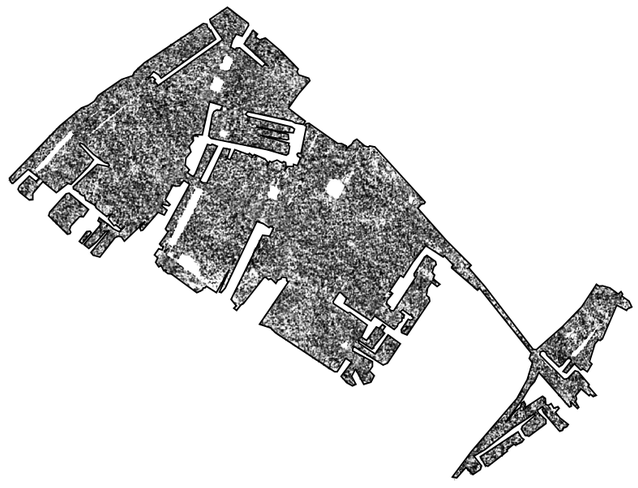


N

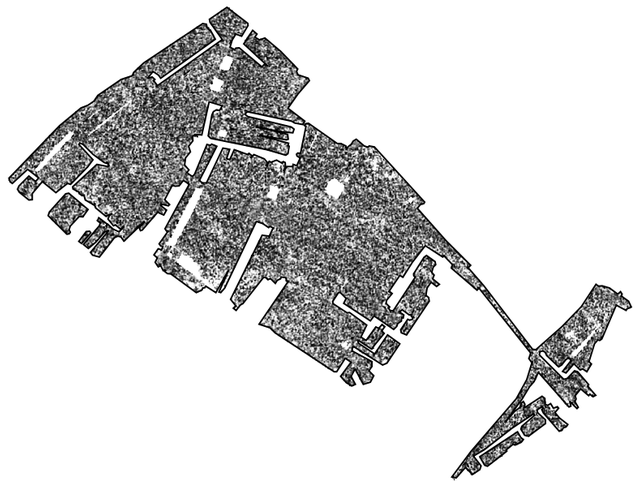
52.5 - 55.0ns (2.99 - 3.14m)



55.0 - 57.5ns (3.14 - 3.28m)



57.5 - 60.0ns (3.28 - 3.42m)



0 50 100 150 m

1:1,500

Low High

relative reflector strength

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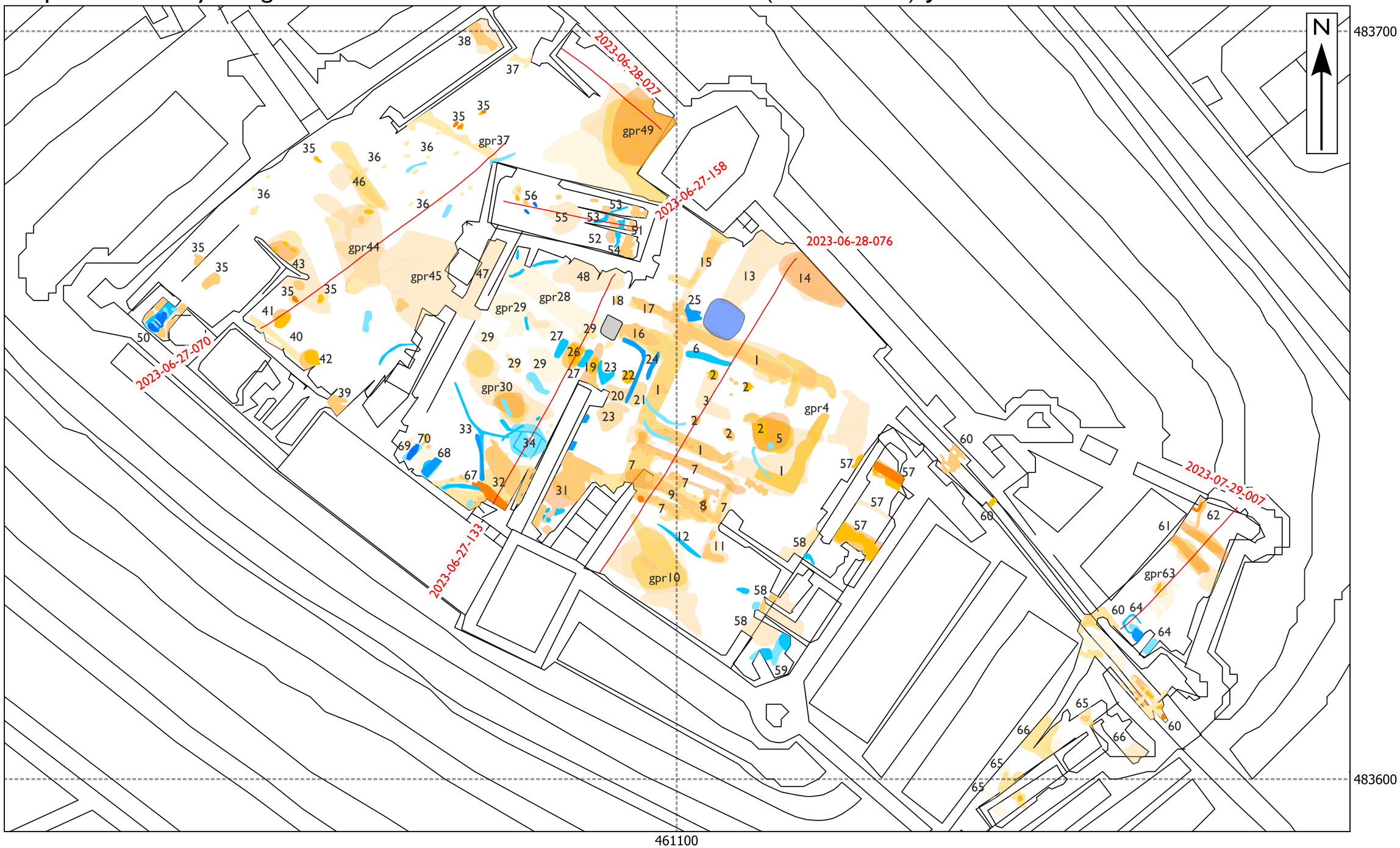
Figure 9

Graphical summary of significant GPR anomalies between 0.0 and 60ns (0.0 to 3.42m), June 2023



0 20 40 60 m

1:500

High Amplitude Reflectors: 0 - 15ns; 15 - 30ns; 30 - 45ns; 45 - 60ns

High Amplitude Reflectors (diffuse): 0 - 15ns; 15 - 30ns; 30 - 45ns; 45 - 60ns

Low Amplitude Reflectors: 0 - 15ns; 15 - 30ns; 30 - 45ns; 45 - 60ns

Location of selected GPR profiles drawn on Figure 4

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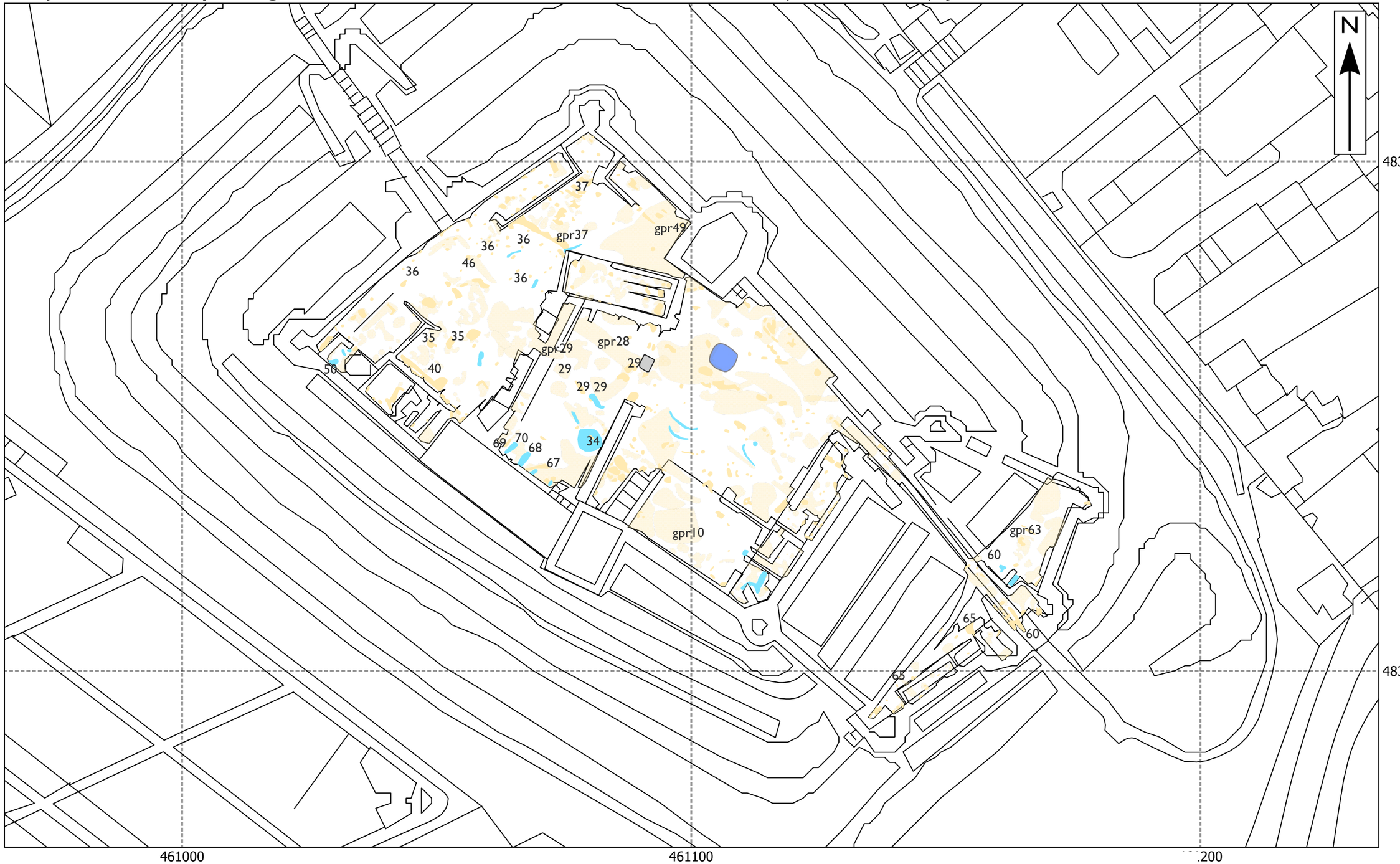
Figure 10

Graphical summary of significant GPR anomalies between 0.0 and 15ns (0.0 to 0.86m), June 2023



High Amplitude Reflectors 0 - 15ns

High Amplitude Reflectors (diffuse) 0 - 15ns

Low Amplitude Reflectors 0 - 15ns

0 25 50 75 m

1:750

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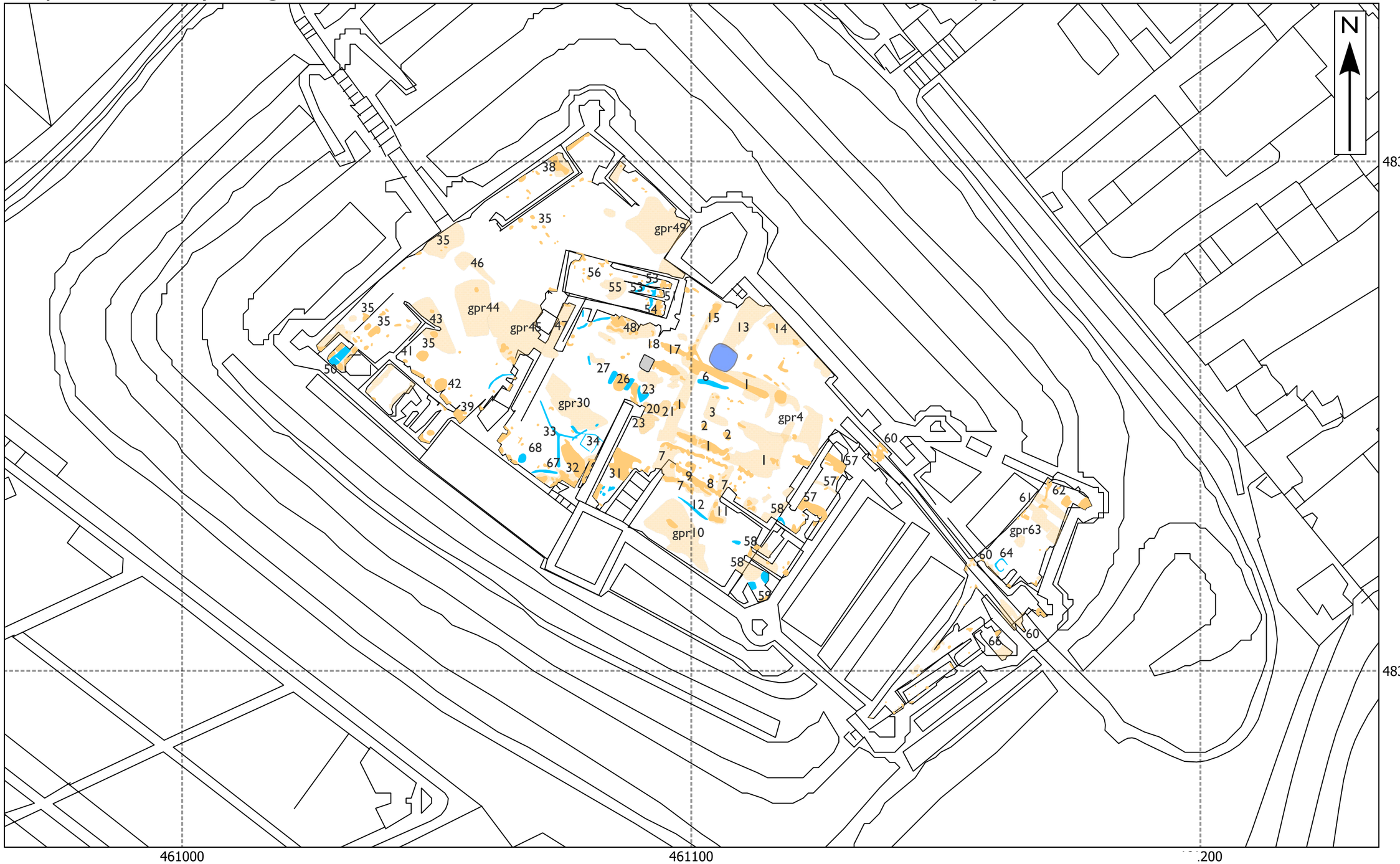
Figure 11

Graphical summary of significant GPR anomalies between 15.0 and 30.0ns (0.86 to 1.71m), June 2023



High Amplitude Reflectors 15 - 30ns

High Amplitude Reflectors (diffuse) 15 - 30ns

Low Amplitude Reflectors 15 - 30ns

0 25 50 75 m

1:750

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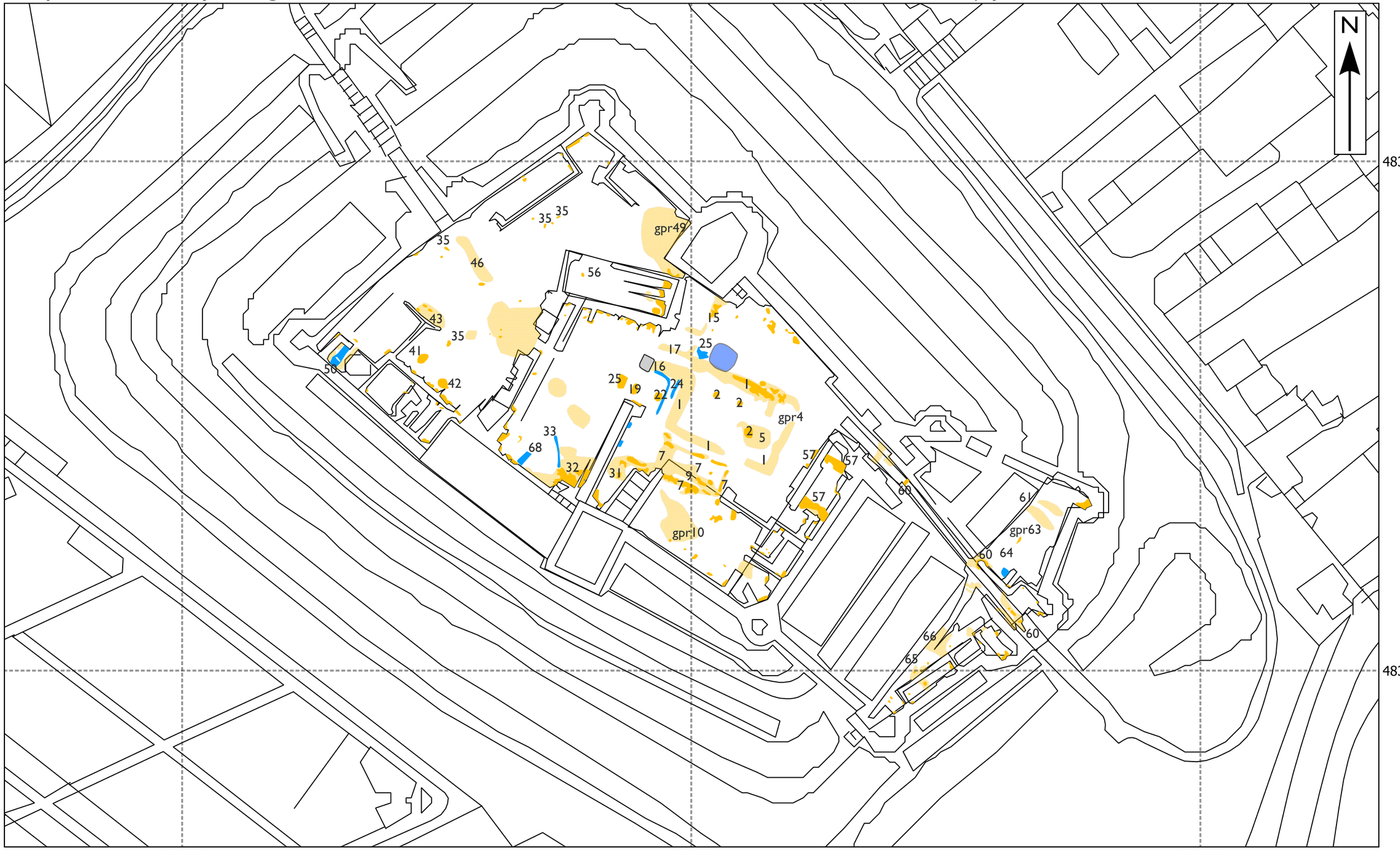
Figure 12

Graphical summary of significant GPR anomalies between 30.0 and 45.0ns (1.71 to 2.57m), June 2023



High Amplitude Reflectors 30 - 45ns

High Amplitude Reflectors (diffuse) 30 - 45ns

Low Amplitude Reflectors 30 - 45ns

0 25 50 75 m

1:750

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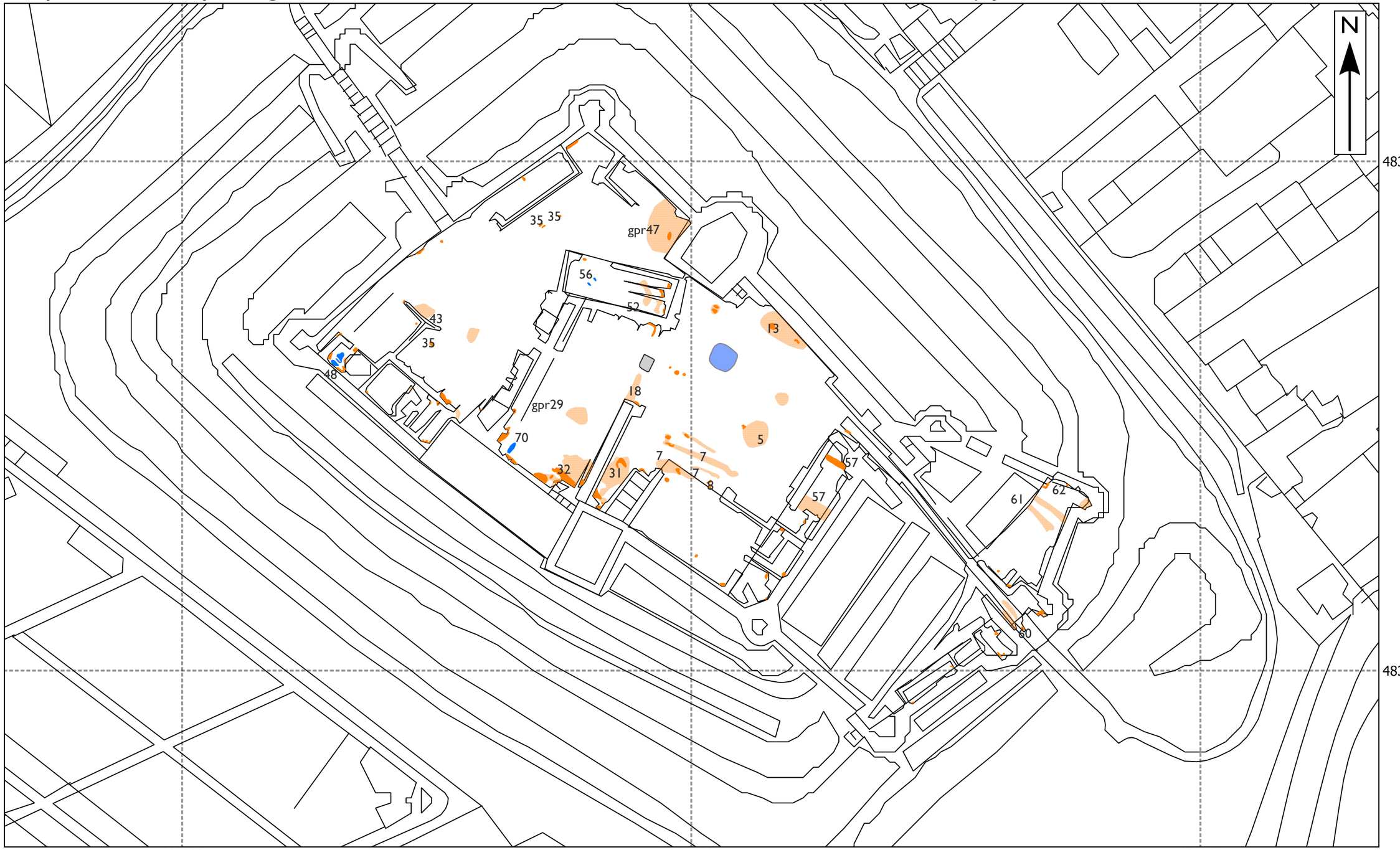
Figure 13

Graphical summary of significant GPR anomalies between 45.0 and 60.0ns (2.57 to 3.42m), June 2023



High Amplitude Reflectors 45 - 60ns

High Amplitude Reflectors (diffuse) 45 - 60ns

Low Amplitude Reflectors 45 - 60ns

0 25 50 75 m

1:750

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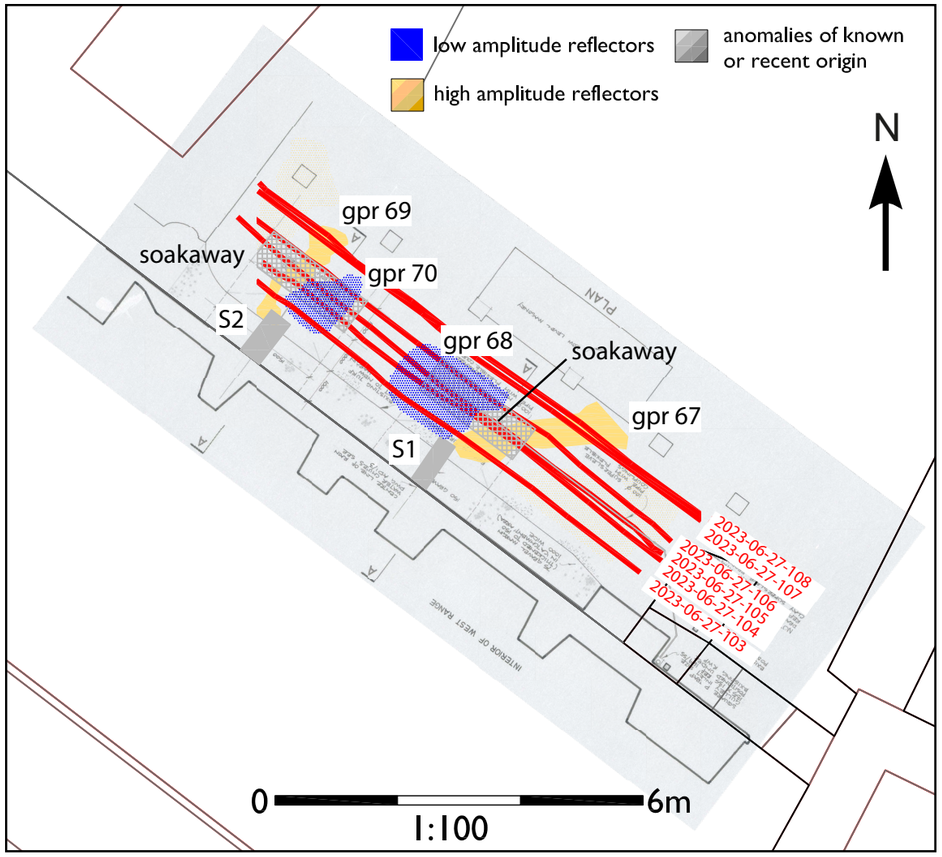
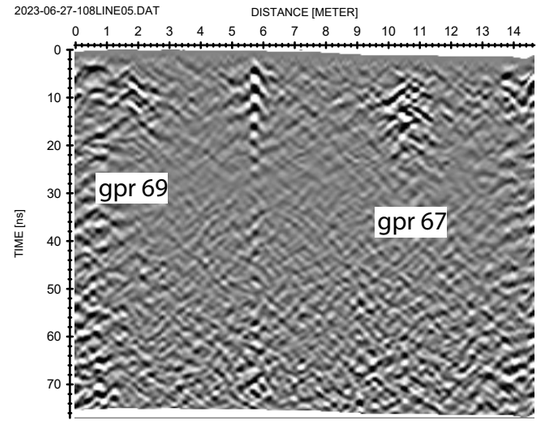
West Range soakaway GPR profiles, June 2023

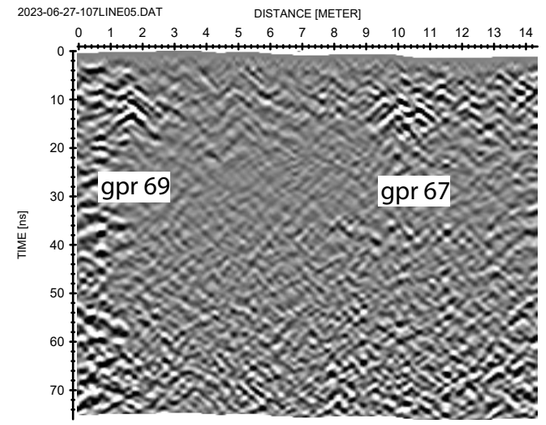
Figure 14

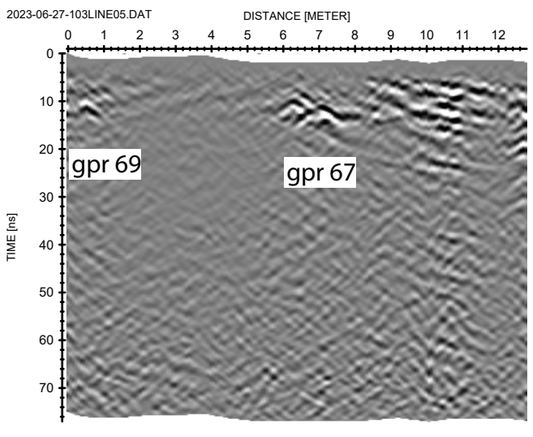
(A) West Range facing north showing location of water chutes

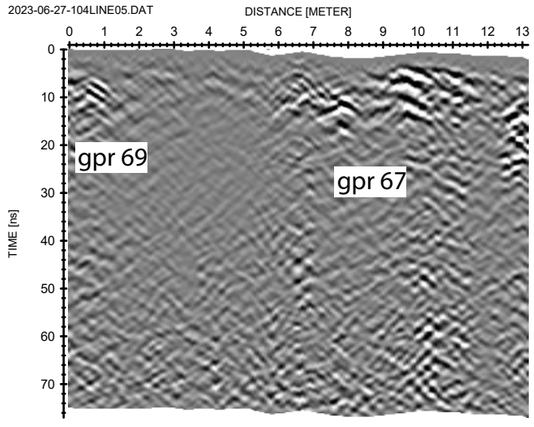
(B) Graphical summary of significant GPR anomalies

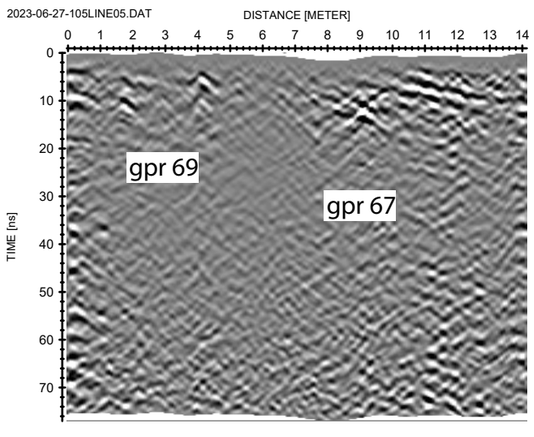


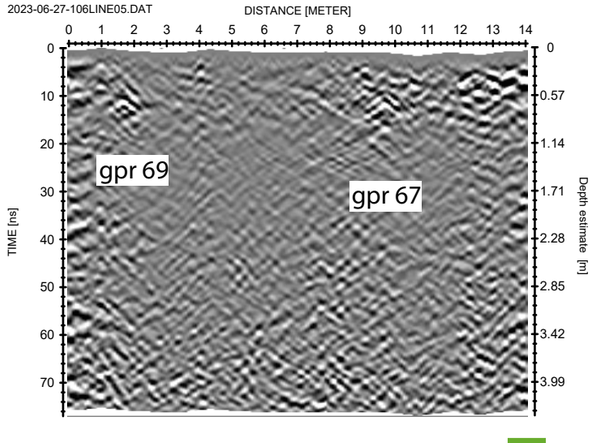












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