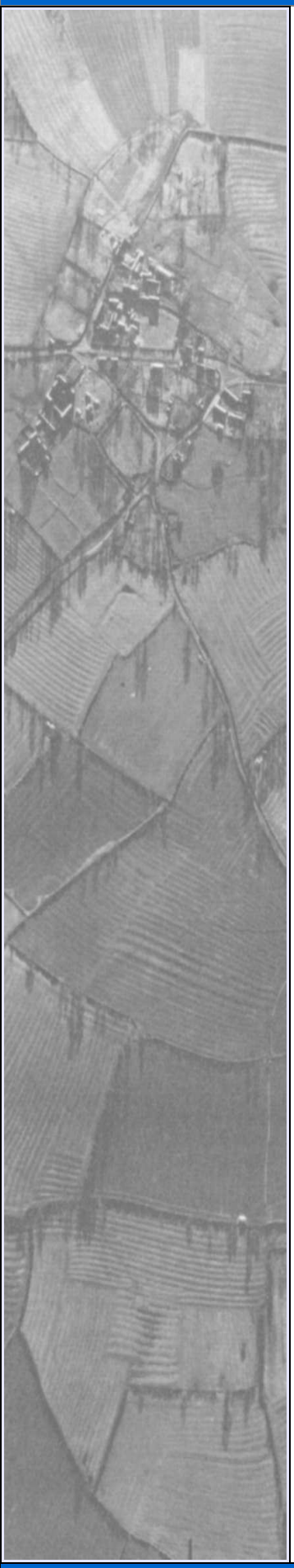

Former Bus Depot
Friars Street
Hereford

A REPORT ON A GROUND PENETRATING RADAR SURVEY

for

Cotswold Archaeology

David Sabin and Kerry Donaldson

September 2017

Ref. no. J728

ARCHAEOLOGICAL SURVEYS LTD

Former Bus Depot
Friars Street
Hereford

Ground Penetrating Radar Survey

for

Cotswold Archaeology

Fieldwork by David Sabin
Report by David Sabin BSc (Hons) MCIfA and Kerry Donaldson BSc (Hons)

Survey date - **7th September 2017**
Ordnance Survey Grid Reference - **SO 50625 39841**

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SUMMARY

Ground penetrating radar (GPR) survey was carried out at a former bus depot to the west of Friars Street, Hereford. The survey was commissioned by Cotswold Archaeology, ahead of the proposed redevelopment of the former bus depot site. Strong GPR reflectors relate to modern tarmac surface layers and the associated subsurface. Significant reflection of GPR energy from these layers may have limited penetration across parts of the site. A discrete feature approximately 1.5m by 1.5m was identified within time slices and associated radargrams show a hyperbola profile possibly consistent with a vaulted feature extending between depths of approximately 0.4m and 0.9m. The archaeological potential of the anomaly should be considered, although a modern feature is also possible. Complex, planar and dipping reflectors are widespread across the site, although the majority are located near to the surface; however, it is possible that some relate to former structures or structural debris.

1 INTRODUCTION

1.1 Survey background

1.1.1 Archaeological Surveys Ltd was commissioned by Cotswold Archaeology to undertake a ground penetrating radar (GPR) survey. The site is located at the former bus depot, Friars Street in Hereford which has been proposed for redevelopment. The survey forms part of a wider archaeological assessment of the site.

1.1.2 The geophysical survey was carried out in accordance with a Written Scheme of Investigation (WSI) produced by Archaeological Surveys (2017) and approved by Julian Cotton, Archaeological Advisor to Herefordshire Council, prior to commencing the survey.

1.1.3 A former late 17th century Quakers' Meeting House and burial ground is recorded within the site and there is potential for associated buried archaeological remains to still exist beneath the more modern ground make-up.

1.2 Survey objectives and techniques

1.2.1 The objectives of the survey were to use GPR survey to help to establish the presence/absence and extent of any potential remains associated with the Quakers' Meeting House and associated burial ground along with any other features or structures that may be of archaeological origin within the eastern part of the proposed development area.

1.2.2 The methodology is considered an efficient and effective approach to archaeological prospection. The survey and report generally follow the

recommendations set out by: English Heritage, 2008, *Geophysical survey in archaeological field evaluation;* Institute for Archaeologists, 2002, *The use of Geophysical Techniques in Archaeological Evaluations*. The work has been carried out to the Institute for Archaeologists (2011) *Standard and Guidance for Archaeological Geophysical Survey.*

1.3 Site location, description and survey conditions

1.3.1 The site lies to the east of Friars Street, Hereford within a car park associated with the former bus depot. The central OS Grid Reference is SO 50625 39841. The area covered by the site is approximately 40m by 25m (1000m²), see Figs 01 and 02.

1.3.2 The survey area was bounded by Heras fencing on the eastern side with permanent steel mesh fencing along the northern and southern sides. The western limit of the survey area was defined by the front of the former bus depot. The surface consisted of tarmac with a kerb running through the southern part of the site and three recently excavated and infilled trenches, presumed to be associated with geotechnical investigations, located within the survey area. Two of the infilled trenches were located at the southern edge of the area and were too rough to traverse, the third trench was located in the central western part of the area and was even enough to survey with the GPR system. Several inspection chambers were noted within the survey area.

1.3.3 The ground conditions across the site were generally considered to be favourable for the collection of ground penetrating radar data. Weather conditions during the survey were fine.

Plate 1: Survey area looking south-east

1.4 Site history and archaeological potential

1.4.1 A document outlining the heritage impacts within the site has been compiled (Hall & Sambrook, 2017). It indicates that during a number of small scale archaeological investigations along Friars Street, medieval pits, gullies and a furnace have been identified. Post medieval cultivation had truncated several of the features, and mapping shows much of the area to contain orchards and gardens beyond the medieval walls of the city, located 85m to the east.

1.4.2 Within the north-eastern part of the survey area is the site of the former Quakers' Meeting House (HER: 26935) with the associated burial ground to the rear. The meeting house was built in 1689 fronting on to Friars Street, but it was later replaced in the early 18th century, by another building set back off Friars Street and located to the south-west of the original building. It was sold in 1807 and converted into three dwellings which were demolished by 1970. In the north-western corner of the survey area projected the south-eastern corner of a 19th century saw mill, and later this part of the site contained a Drill Hall for the Herefordshire (1st) Rifle Volunteers and the 1st Battalion Herefordshire Regiment Territorial Force.

1.4.3 The site lies immediately west of Friars Street which is the western boundary of the Hereford Area of Archaeological Importance, designated as such under the Ancient Monuments and Archaeological Areas Act 1973.

1.4.4 The Quakers' Meeting House with later buildings and associated garden features, as well as the saw mill and drill hall in the north-western corner, indicates that there has been considerable development across the site. If there are any undisturbed areas that contain burials it is possible that the ground penetrating radar survey could locate them, although this depends on the mode of burial and construction of the grave.

1.5 Geology and soils

1.5.1 The underlying solid geology across the site is interbedded siltstone and mudstone from the Raglan Mudstone Formation (Silurian) with overlying Devensian glaciofluvial deposits (BGS, 2017).

1.5.2 The overlying soil across the survey area is unmapped due to the urban location but likely to come from the Escrick 1 association and is a typical argillic brown earth. It consists of a deep, well drained, reddish, coarse, loamy soil (Soil Survey of England and Wales, 1983).

1.5.3 Due to urban location and number of former structures within the site, the ground make-up may have little relationship to local soils and solid geology. The penetration of GPR signals through the modern tarmac and near surface material may be a more significant factor with regard to depth penetration.

2 METHODOLOGY

2.1 Technical synopsis

2.1.1 Ground penetrating radar systems transmit an electromagnetic wave into the ground and record the time delay and amplitude of reflections from buried features. Reflections occur from changes in conductivity or dielectric permittivity.

2.1.2 Electromagnetic waves are increasingly attenuated as frequency increases and, therefore, lower frequencies provide greater penetration into the subsurface. However, the longer wavelengths associated with lower frequencies reduce the resolution of buried features. Typical frequencies chosen for archaeological prospection are around 400 and 250 MHz.

2.2 Equipment configuration and data collection

2.2.1 Ground penetrating radar data were acquired using an Utsi Electronics Groundvue 3A system running with a 400MHz and a 250MHz shielded antenna. The system utilises a wheeled encoder system on a small cart. A dielectric constant of 10 was used in the field to set up the instrument and view data. The value is for display purposes only and does not affect the recorded data. A value of 100ns (nanoseconds) was chosen for the time sweep (two way GPR signal travel time) in order to balance potential depth of penetration and resolution.

2.2.2 Data were collected from scans recorded at 0.0295m along traverses separated by 0.25m for the 400MHz antenna and at 0.059m along traverses separated by 0.5m for the 250MHz antenna. The data captured along each traverse were logged to an internal disk drive to allow further processing and analysis. Positional information along each traverse is derived from the wheeled encoder. Survey traverses were collected parallel from north to south.

2.3 Survey grid and base mapping

2.3.1 Ground penetrating radar data were collected along traverses originating from a common baseline at the northern end of the survey area. Digital base mapping was supplied by the client and baselines with traverses were mapped from site measurements, see Fig 02. A high level of positional accuracy was achieved.

2.3.2 The survey baseline and parallel southern line were set out to the Ordnance Survey OSGB36 datum using a Leica GS10 RTK GPS used in conjunction with Leica's Smartnet service where positional corrections are sent via a mobile telephone link. Positional accuracy of around 10 – 20mm is possible using the system. The instrument is regularly checked against the ETRS89 reference framework using Ordnance Survey ground marker C1ST7784 (Horton). The parallel survey traverses were positioned using tapes.

2.4 Data processing

2.4.1 Ground penetrating radar data were analysed using REFLEX v8 software. Each traverse was analysed as an individual profile to allow a manual assessment of anomalies. In addition, profiles across each survey area were combined and processed in order to create time slices showing the variation in reflector amplitude at various depths. The following processing has been carried out on GPR data captured during this survey:

- background removal - improves the appearance of the data by removal of strong horizontal bands;
- gain - increased with time in order to amplify weaker reflections from deeper features;
- bandpass filtering - lowers noise by the removal of energy above and below specified frequency limits.

2.4.2 Time slices were analysed using both absolute and envelope reflectivity strengths. The latter use a square root function of the energy at an instant in time and is generally the preferred option; however, occasionally the absolute values provide more detailed anomalies.

2.5 Data presentation

2.5.1 An abstraction and interpretation is offered for the anomalies located by the survey. A brief summary of each anomaly, with an appropriate reference number, is set out in list form within the results (Section 3) to allow a rapid and objective assessment of features within each survey area. Approximate depths to anomalies is added to the abstraction and interpretation plot.

2.5.2 The main form of data display prepared for this report are colour time slice plots derived from Reflex as JPG files. Anomalies are abstracted using colour coded points, lines and polygons. All plots are scaled to landscape A3 for paper printing.

2.5.3 The raster images are combined with base mapping using ProgeCAD Professional 2016 creating DWG file formats. All images are externally referenced to the CAD drawing in order to maintain good graphical quality. A digital archive, including raster images, is produced with this report, see Appendix A below.

3 RESULTS

3.1 General overview

3.1.1 The GPR survey located numerous complex and planar reflectors within the

survey areas. The majority of these are associated with the modern surface and sub-surface make-up, and their high magnitude may indicate limited penetration by the GPR waves as a significant proportion of the energy is reflected as shallow depths. Some areas show complexity and variable responses from slightly increased depths and these may be associated with structural debris. Only one discrete feature was interpreted as having archaeological potential, although other anomalies of uncertain origin should also be considered.

3.1.2 A velocity of 0.08m/ns was calculated using hyperbola matching. There were very few clear hyperbola that could be used for the analysis and velocity is likely to be very variable. As a result the depths indicated in the report and associated plots are approximations only.

3.2 Statement of data quality

3.2.1 The GPR data were collected with due consideration given to surface conditions, obstructions and area constraints. GPR signals appear to have achieved moderate penetration and a maximum depth is likely to be approximately 1.2m. Penetration is likely to be limited by loss of energy in the near surface make-up that has caused high magnitude planar reflections.

3.2.2 Antenna ground coupling was mainly very good due to smooth tarmac surfaces. However, coupling was poor over small areas of spoil adjacent to geotechnical trenches and over a length of kerbing. Some additional surface noise is also associated with cracked tarmac that was occasionally encountered.

3.3 Data interpretation

3.3.1 The list of sub-headings below attempts to define a number of separate categories that reflect the range and type of features located during the survey. A basic explanation of the characteristics of the radar anomalies is set out for each category in order to justify interpretation, a basic key is indicated to allow cross referencing to the abstraction and interpretation plot. CAD layer names are included to aid reference to associated digital files (.dwg/.dxf). Sub-headings are then used to group anomalies with similar characteristics.

Report sub-heading CAD layer names and plot colour	Description and origin of anomalies
Anomalies with archaeological potential AS-ABST GPR STRUCTURAL ARCHAEOLOGY	Anomalies have the characteristics of a range of archaeological features such as walls, structures, vaults, etc..
Anomalies with an uncertain origin AS-ABST GPR STRUCTURAL DEBRIS AS-ABST GPR LINEAR UNCERTAIN AS-ABST GPR AREA UNCERTAIN AS-ABST GPR PATH	The category applies to a range of anomalies where there is not enough evidence to confidently suggest an origin. Anomalies in this category may well be related to archaeologically significant features, but equally relatively modern features features should be considered.
Anomalies with a modern origin AS-ABST GPR SERVICE AS-ABST GPR ROAD	Reflections clearly related to modern features such as services, inspection chambers, kerbs, demolition rubble, former road/car park surfaces etc.

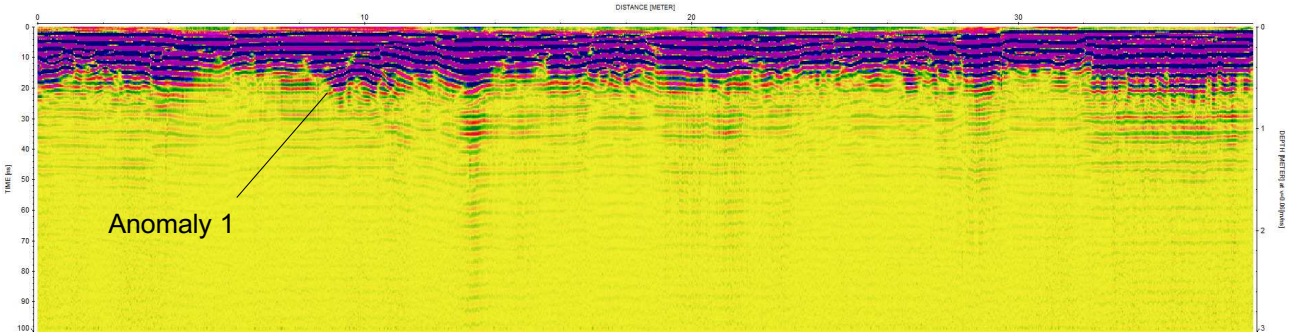
Table 1: List and description of GPR interpretation categories

3.4 List of ground penetrating radar anomalies

Area centred on OS NGR 350625 239841, see Figs 03 - 05.

Anomalies with archaeological potential

(1) - Time slices indicate the presence of a rectangular or square feature with approximate dimensions of 1.5m by 1.5m and depth of 0.4m to 0.9m. The central part of the feature appears disturbed, although GPR profiles indicate a broad hyperbola. The anomaly does not appear in the near surface make up suggesting that it may be an earlier feature of archaeological potential. The response could be consistent with a former vaulted structure, although a truncated inspection chamber may give a similar response.



Radargram 1: File HA040 indicating part of anomaly 1

Anomalies with an uncertain origin

(2) - Several possible linear features revealed in the north-eastern part of the survey area. Approximate depths are 0.3 - 0.6m. The anomalies do not appear at shallower depths which may indicate they are related to structural remains.

(3) - Weak reflectors with a broad linear trend are resolved in the time slice at approximately 0.4m depth and do not appear related to strong shallow reflectors in the vicinity.

(4) - Complex and variable reflectors within a broad linear zone at approximately 0.3 - 0.7m depth. The anomalies may indicate buried structural debris.

(5) - A zone of planar and complex reflectors that may represent some structural debris relating to former buildings. However, many of the planar reflectors have probably been caused by multiple reflections within the near surface make-up. A linear feature just to the north of the zone is revealed at an approximate depth of 0.4m and may be associated.

(6) - The north-west part of the site contains variable reflectors with many planar and dipping forming amorphous or rounded features. They originate at the surface or near surface suggesting they are associated with infilled dips and hollows; however, deeper more complex reflectors may relate to structural debris.

(7) - Complex reflectors probably associated with subsurface make-up for the modern surface.

Anomalies with a modern origin

(8) - Near surface planar reflectors possibly associated with a former path or part of the Drill Hall.

(9) - Near surface planar reflectors that may relate to former paths.

(10) - Near surface planar reflectors indicating previous layouts to the car park and bus depot access.

(11) - Possible service/drain at southern end of survey area.

(12) - Extant and removed kerb.

(13) - Multiple reflectors associated with inspection chambers.

4 CONCLUSION

4.1.1 The results of the GPR survey indicate the presence of widespread planar and complex reflectors associated with the modern surface and near surface make-up. High magnitude near surface reflectors can indicate that a significant proportion of the GPR energy is lost and may not penetrate to depth.

4.1.2 A single anomaly (1) in the northern part of the survey area has been

interpreted as having archaeological potential based on both its depth below the surface and subsurface make-up, and its reflection profile visible in corresponding radargrams. The time slice indicates an approximately square-shaped feature in plan while in GPR radargrams it appears as a hyperbola. This type of response may indicate a vaulted structure although a disused inspection chamber is also a possibility.

4.1.3 Several zones contain planar, complex and dipping reflectors (4 & 5), and it is possible that they represent structural debris associated with former buildings. However, many of the reflectors are shallow and probably indicate infilled depressions and undulations. Many other near surface reflectors (10 & 12) indicate changes in the layout of car park and bus depot access routes.

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Appendix A – digital archive

Archaeological Surveys Ltd hold the primary digital archive at offices in Wiltshire (see inside cover for address). Data are backed-up onto an on-site data storage drive and at the earliest opportunity data are copied to CD ROM for storage on-site and off-site.

Surveys are reported on in hardcopy using A4 for text and A3 for plots (all plots are scaled for A3). A PDF copy of the report will be supplied to the Herefordshire Historic Environment Record (HER) with printed copies on request. The report will also be uploaded to the Online AccesS to the Index of archaeological investigationS (OASIS). Should the data need archiving with the Archaeology Data Service (ADS), this will be subject to an additional charge to the client to cover the ADS costs.

This report has been prepared using the following software on a Windows XP platform:

- Reflex v8 (GPR data analysis)
- ProgeCAD Professional 2016 (report plots),
- OpenOffice.org 4.1.1 Writer (document text),
- PDF Creator version 0.9 (PDF archive).

Appendix B – basic principles of ground penetrating radar survey (GPR)

GPR survey records reflected radio waves that are pulsed into the ground as the radar antenna is dragged along the ground surface. Changes in the ground make-up, such as from soil to stone, provide conditions where some of the transmitted energy is returned to the surface. In this way, subsurface features can be mapped. Careful timing of the returned radio waves along with calculation of their velocities allows an estimate of depth to be made.

The transmitted radio energy is very wide in bandwidth but peaks at the resonant frequency of the antenna. As resolution is a function of the transmitted wavelength, a 400MHz system will have a higher resolution than a 200MHz system; however, the lower frequency system may have superior penetration which may be critical in certain conditions. 200 and 400MHz systems are typical of those used for archaeological prospection.

Damp clay soils may present problems at times and it is not uncommon for conditions to be so poor that no penetration below a few centimetres is possible. It is also worth noting that rarely can GPR be used to locate graves. Exceptions exist, particularly if disturbance is recent or if there are buried voids or associated structural features.

Data are logged with positional references derived from an odometer, GNSS or total station. Processing is required in order to allow abstraction and interpretation; typically this involves filtering of strong near surface reflections and increasing the gain of weak reflections from greater times/depths. The reflections are often complex and data are assessed as vertical profiles and time slices that may reveal features in plan.

Appendix C – copyright and intellectual property

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Survey location

N

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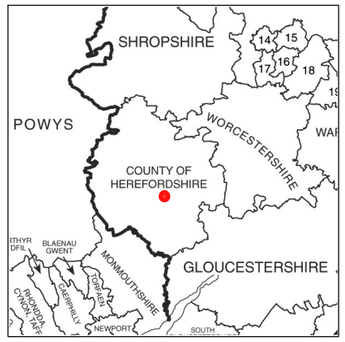
Map of survey area



● Survey location

Site centred on OS NGR
SO 50625 39841

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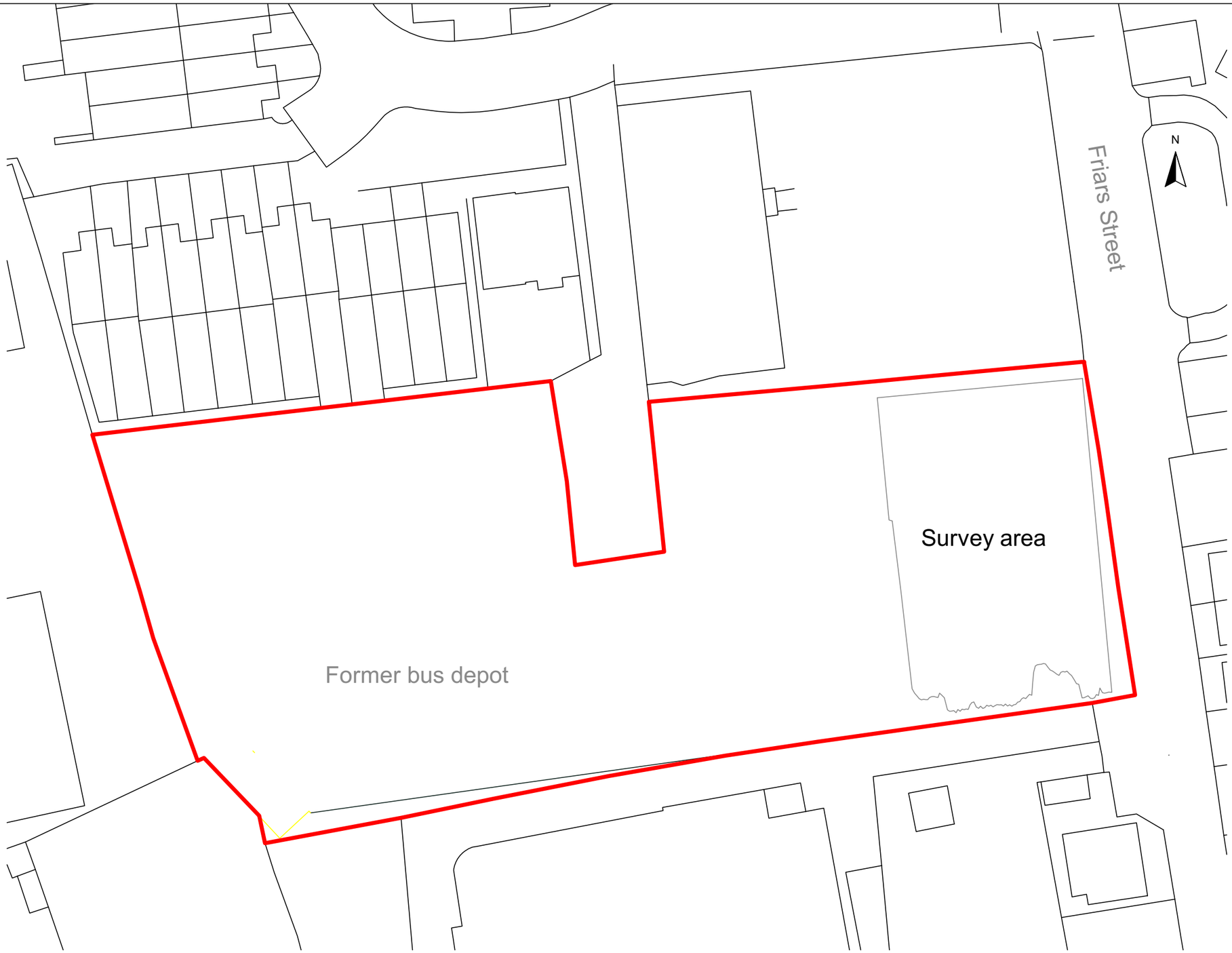
FIG 01



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Former Bus Depot
Friars Street
Hereford

Site location and survey area

Site boundary

SCALE 1:500

0m 5 10 15 20 25m

SCALE TRUE AT A3

FIG 02

Referencing 400MHz

Survey progresses from E to W at 0.25m separation between parallel traverses and data collected N - S

Files HA001 - HA100 (HA074 deleted)

350610.49

350634.89

239858.53

239860.81

HA100

HA001

trench and spoil

trench and spoil

trench and spoil

Referencing 250MHz

Survey progresses from E to W at 0.5m separation between parallel traverses and data collected N - S

Files HB001 - HB054

N

350610.49

350634.89

239858.53

239860.81

HB054

HB001

trench and spoil

trench and spoil

trench and spoil

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Geophysical Survey
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Friars Street
Hereford

Referencing information

Grid coordinates based on Ordnance Survey OSGB36 datum

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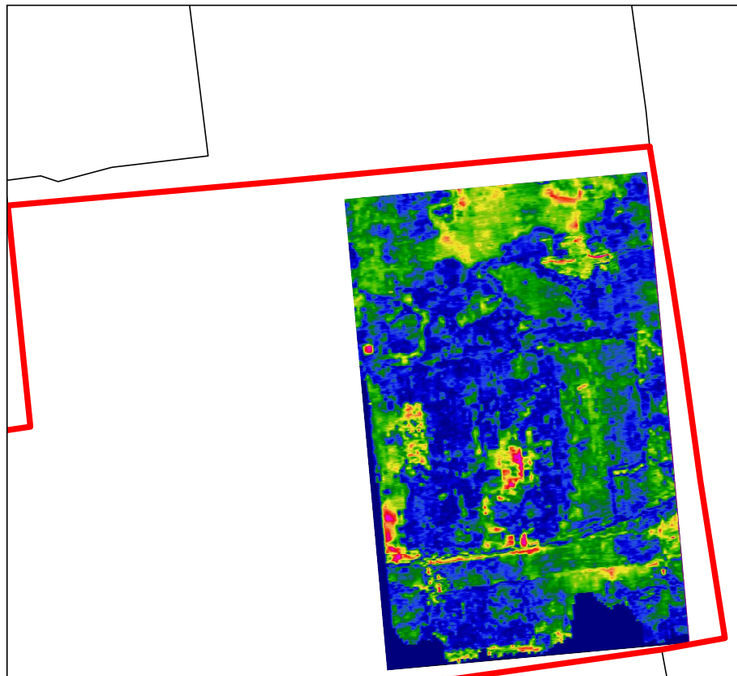
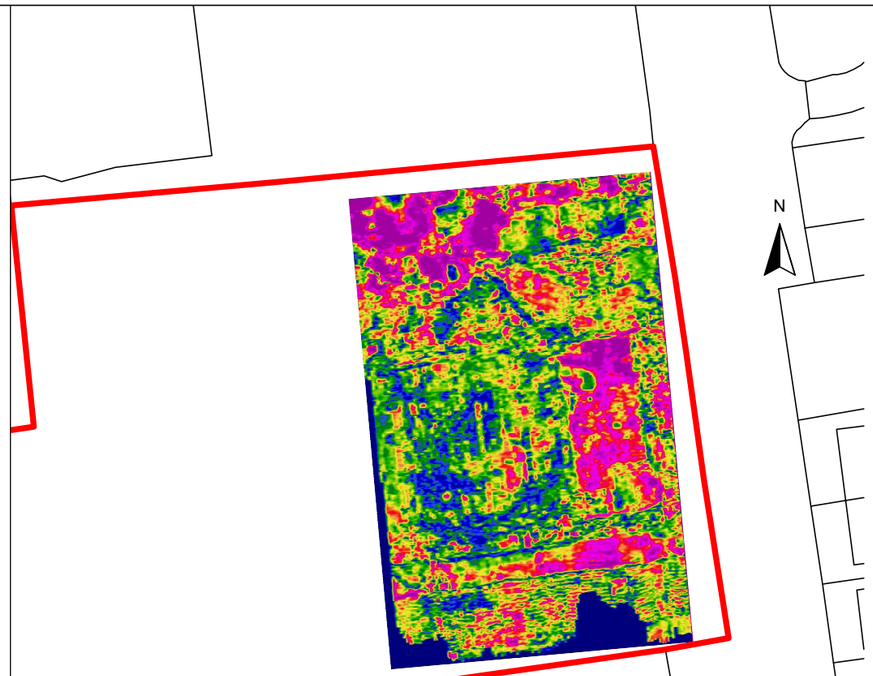
SCALE TRUE AT A3

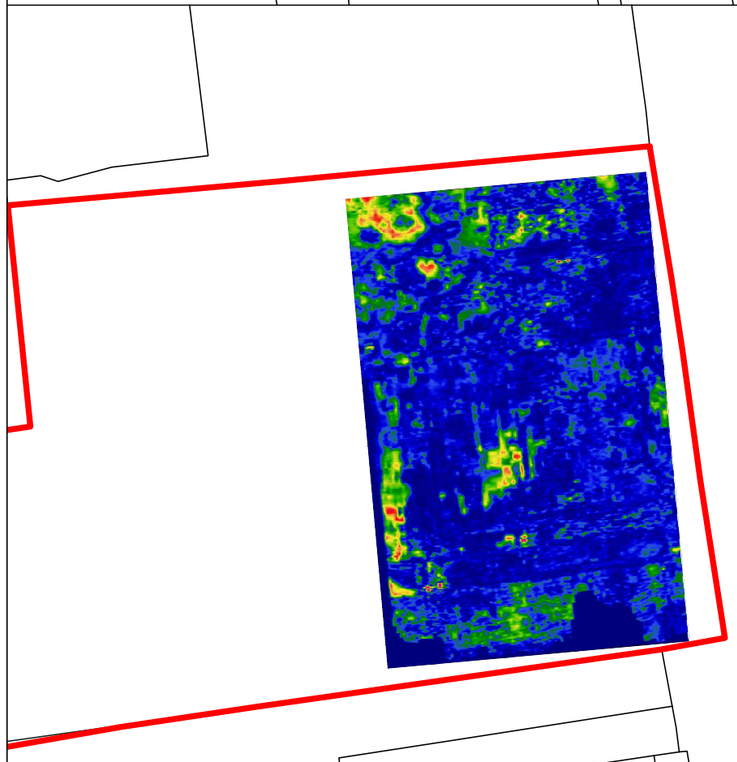
FIG 03



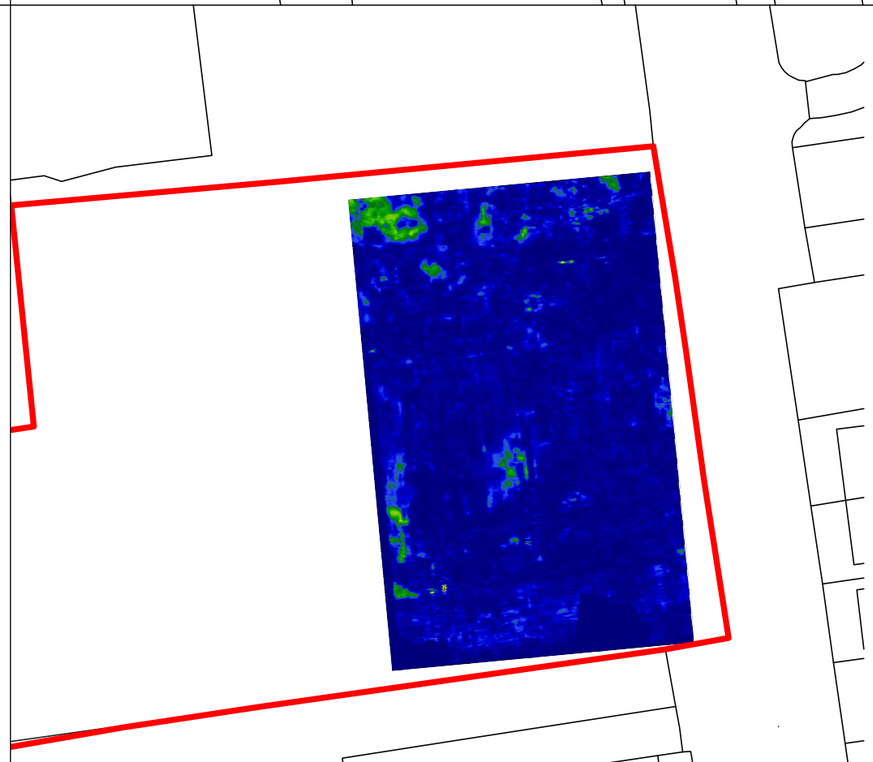
400MHz GPR Time slice at 2.73ns
(approx. 0.1m depth)



400MHz GPR Time slice at 6.25ns
(approx. 0.25m depth)



400MHz GPR Time slice at 12.5ns
(approx. 0.5m depth)



400MHz GPR Time slice at 16.01ns
(approx. 0.64m depth)

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Ground penetrating radar time slices - 400MHz

high amplitude reflection

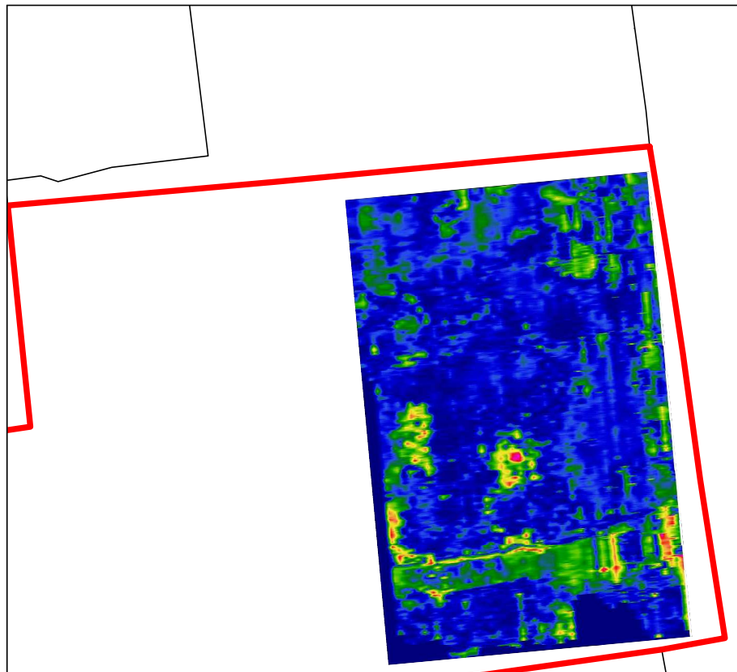
low amplitude reflection

SCALE 1:500

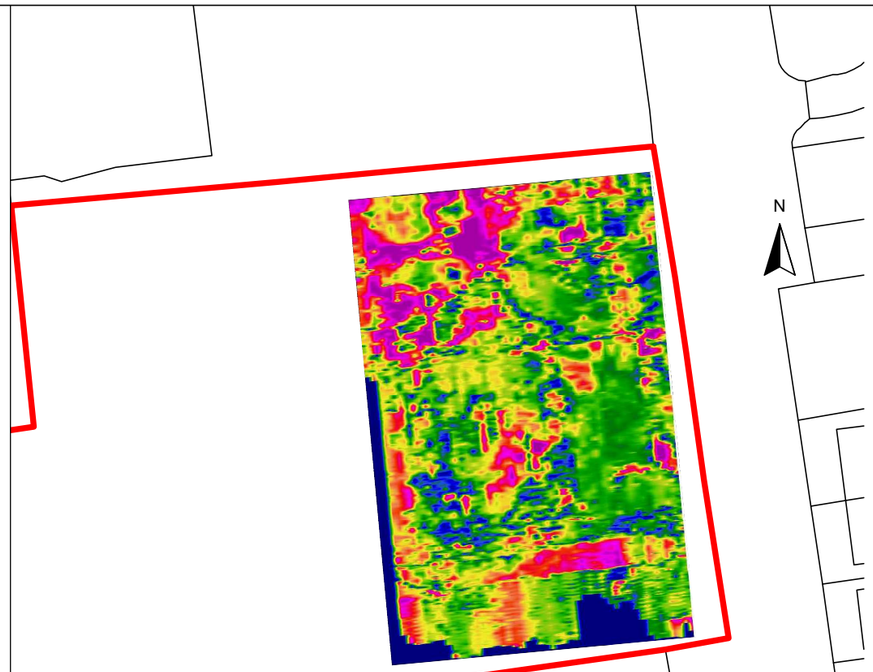
0m 5 10 15 20 25m

SCALE TRUE AT A3

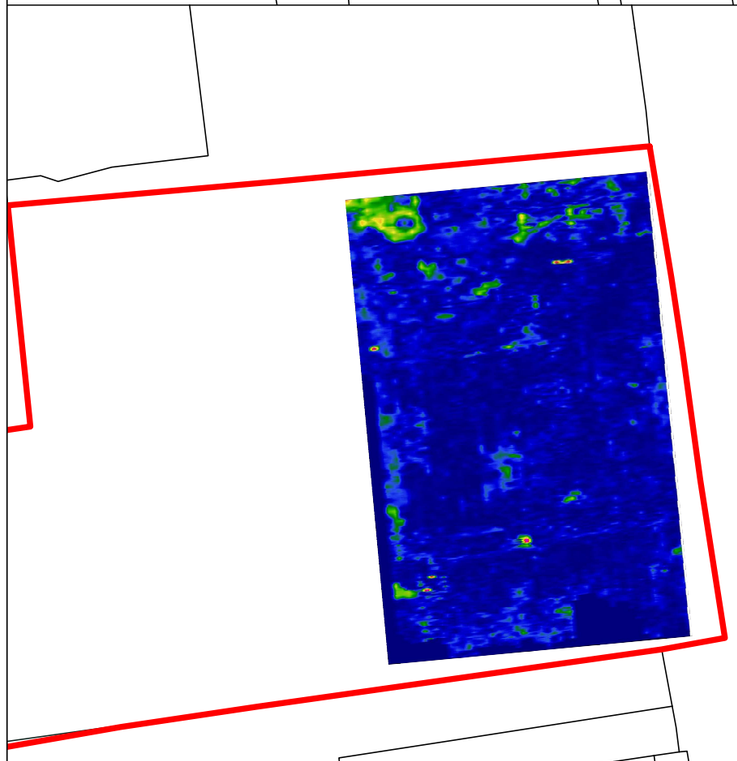
FIG 04



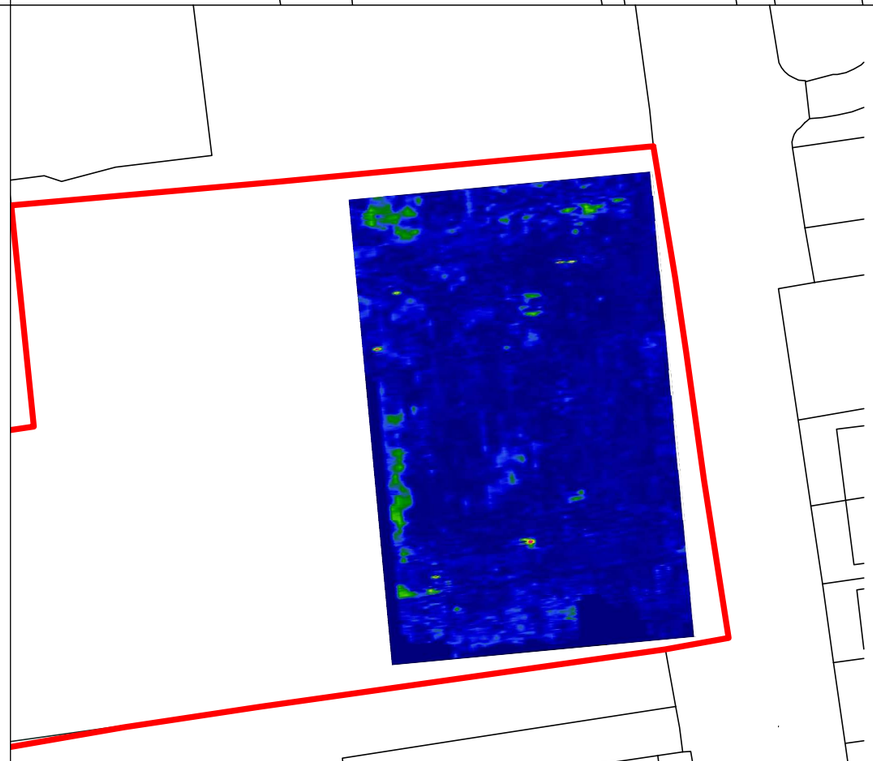
250MHz GPR Time slice at 2.73ns
(approx. 0.1m depth)



250MHz GPR Time slice at 6.25ns
(approx. 0.25m depth)



250MHz GPR Time slice at 16.79ns
(approx. 0.67m depth)



250MHz GPR Time slice at 21.09ns
(approx. 0.84m depth)

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Ground penetrating radar time slices - 250MHz

high amplitude reflection

low amplitude reflection

SCALE 1:500

0m 5 10 15 20 25m

SCALE TRUE AT A3

FIG 05

N

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Former Bus Depot
Friars Street
Hereford

Abstraction and interpretation of ground penetrating radar anomalies

- GPR reflectors of archaeological potential
- Complex and planar reflectors possibly associated with former structures
- Variable reflectors associated with subsurface make-up
- Planar GPR reflectors - path/track
- Planar GPR reflectors - previous car park and access routes
- Complex GPR reflectors - disturbed ground associated with possible service
- Possible structural remains
- GPR linear anomaly - kerb
- Strong GPR anomaly - inspection chamber
- 8 GPR anomaly label
- 0.4m Approximate depth of GPR anomaly

SCALE 1:200

0m 2 4 6 8 10m

SCALE TRUE AT A3

FIG 06