# GEOPHYSICAL SURVEY REPORT

## Swan Lane Car Park, Evesham

Client

**Ecus Ltd on behalf of Churchill Retirement Living**

Survey Report

**05571**

Date

**August 2022**

**Survey Report 05571: Swan Lane, Evesham**

| | |
|---|---|
| **Survey Date** | 14th July 2022 |
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| **Report Date** | 23rd August 2022 |
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## 2 SURVEY METHODOLOGY

Ground Penetrating Radar (GPR) was chosen as the most efficient and effective geophysical method for locating the type of archaeological anomalies that might be expected at this site.

| | | | |
|---|---|---|---|
| GPR | Mala MIRA High Density Array | Traverse Interval 0.08m parallel | Sample Interval 0.05m |

## 3 EXECUTIVE SUMMARY

3.1 A ground penetrating radar (GPR) geophysical investigation was conducted over a car park in Swan lane, Evesham. The survey objective was to search for evidence of archaeological features to inform the scope of further archaeological investigations.

A Mala MIRA high density array GPR system was used for the survey acquiring data at standard 0.08 metre spaced parallel lines.

Seven distinct categories of anomalies were detected by the GPR survey, with four types – possible structures, anomalous layers, disturbed ground and linear anomaly have possible archaeological associations.

The GPR survey did not find any features of genuine archaeological significance. Most of the anomalies detected appear to be associated with industrial buildings that occupied the site in the second half of the 20th century.

## 4 INTRODUCTION

4.1 **SUMO Geophysics Ltd** were commissioned to undertake a geophysical survey of a car park in Swan Lane, Evesham. The work is being undertaken to inform the scope of further archaeological investigation. The planning application 21/02252/FUL has been allowed at appeal and this survey is to be used to inform subsequent archaeological fieldwork.

4.2 **Site details**

| | |
|---|---|
| **NGR / Postcode** | SP03844405 / WR11 4PA |
| **Location** | The site is located on Swan Lane in Evesham, Worcestershire, c. 230 m north of the historic town centre (Figure 1). |
| **HER** | Worcestershire |
| **District** | Wychavon |
| **Parish** | Evesham |
| **Topography** | Flat hardstanding |
| **Current Land Use** | Car park |
| **Geology (BGS 2022)** | **Solid:** Mudstone of the undifferentiated early Jurassic Blue Lias Formation and Charmouth Mudstone Formation (182 - 209 Ma)<br>**Superficial:** Sand and gravel of the Quaternary New Inn Sand and Gravel Member |
| **Soils (CU 2022)** | Soilscape 6: Freely draining slightly acid loamy soils |
| **Archaeology (ECUS 2022)** | The site lies within Evesham, which has a rich archaeological record. However, the potential for remains of archaeological significance within the site is considered to be negligible. There are no scheduled monuments on the site. The site has been subject to two previous |

investigations, a watching brief in 1989 and an excavation in 1995, and whilst these recorded evidence of prehistoric through to post-medieval activity, the site has since been subject to recent extensive disturbance and impact associated with the construction of the existing buildings and car park. Any remains surviving as pockets between areas of disturbance would have been significantly disrupted and compromised resulting in them having low heritage significance.
The very northern extent of the Site is considered to have more potential for surviving buried archaeological remains as it has been subject to less disturbance/impact. Any such remains are likely to relate to agricultural, horticultural and gardening activity and would constitute heritage assets of low to negligible heritage significance depending upon date of origin. Any remains relating to recent activity would not be of heritage interest.

**Survey Methods** Ground penetrating radar (GPR)

**Study Area** *c. 0.3ha*

### 4.3 Aims and Objectives

To locate and characterise any anomalies of possible archaeological interest within the study area that may be impacted by the planning application.

## 5 SURVEY PROCEDURE

5.1 A survey grid was established by total station as a reference for the site work. A Mala MIRA High Density Array Radar was used for the survey. The MIRA has an array of 8 x 400MHz antenna units spaced at standard intervals of 0.08m, with readings taken at 0.05m intervals. A parallel series of radar profiles was carried out with the MIRA system over accessible parts of the site. The positions of the radar profiles are presented in Figure 1.

Further information about the GPR method is given in Appendix A.

## 6 INTERPRETATION OF RESULTS

### 6.1 Introduction

Most ground conditions contain electrically contrasting layers which produce reflection events on the GPR profiles. Features such as soil or fill boundaries provide the background signals around unusual features such as buried structures or voids. Processing and interpretation procedures are designed to separate reflections into various target categories and then map the different reflection types on to a plan diagram.

The raw data was initially processed using rSlicer software manufactured by Mala, to produce a series of regularly spaced timeslices at 0.1 m intervals within the survey depth range of 0.1 to 1.0 metres, which are presented in Figures 2 - 4. An interpretation of each individual time slice was carried out to identify any moderate to high amplitude anomalies that formed discrete or linear consistent patterns that repeat within the data set.

The second stage of data interpretation involved reprocessing of the MIRA raw data using GPR Slice processing software manufactured by Screening Eagle Technologies. The GPR Slice software can separate the data set into individual radar data profiles, allowing further analysis of the primary anomalies abstracted from the rSlicer timeslices. The second stage of data interpretation used the GPR Slice radar profiles to further categorise the primary

MIRA anomalies into eight significant categories of reflection targets, which are described below:

i) Possible structure
ii) Possible void
iii) Anomalous layer
iv) Disturbed ground
v) Undifferentiated anomaly
vi) Probable reinforced concrete
vii) Possible service/linear feature
viii) Linear feature of uncertain origin

6.2 **Possible Structure**

The possible structure reflection category consists of discrete, moderate to high amplitude, well defined reflections with margins characterised by edge scattering. The top surfaces of the possible structure reflections vary between flat, curved or more irregular in appearance.

6.3 **Possible Void**

Possible voids appear as discrete, high amplitude reflections, typically with a curved, flat or more irregular top surface, showing a marked contrast against the background. The possible void reflections are often associated with reverberations producing characteristic ringing on the GPR record. It is important to note that GPR can identify the presence and cover depth of a void, but normally cannot determine the internal vertical dimension. Pulse ringing usually masks any reflections from the base of the void.

6.4 **Anomalous Layer**

Anomalous layers occur as well defined, moderate to high amplitude, planar, sub-horizontal sometimes more irregular reflections, with little evidence of edge scattering at the margins of the anomalies.

6.5 **Disturbed Ground**

Areas of disturbed ground generally appear as zones of moderate to high amplitude irregular, reflections displaying broken layering. In some cases, a more chaotic internal structure may be evident, resulting from interaction between individual reflections.

6.6 **Undifferentiated Anomalies**

Primary rSlicer anomalies that could not be clearly identified or clearly categorised on the individual radar profiles have been left as undifferentiated anomalies.

6.7 **Probable Reinforced Concrete (limited signal penetration)**

Single rebars within concrete normally appear as high amplitude reflections on GPR records, caused by the strong electrical contrast between concrete and steel. A radar profile perpendicular or at a high angle to the length of a single rebar, produces a reflection with a characteristic hyperbolic geometry. Reinforcing mesh reflection responses are generally more complicated, due to interference from overlapping reflections between adjacent rebars. With decreasing rebar spacing, the hyperbolic patterns merge into a composite pattern and resolution correspondingly decreases. In areas of very dense reinforcing, virtually no signal penetration is possible beyond the level of the reinforcing.

6.8 **Possible Service/Linear Feature**

The possible pipe/linear structure category is associated with fairly high amplitude, well defined, steeply curved or hyperbolic reflections, with margins generally characterised by edge scattering. The position is located at the apex of the curve, with the tracks identified by alignments of similar reflections between adjacent parallel profiles. It is not always possible

to determine whether a linear anomaly is produced by a service or a narrow linear feature such as a strip foundation or wall footing.

### 6.9 Linear Feature of Uncertain Origin

Linear features of uncertain origin are characterised as linear anomalies that are clearly visible on the timeslices, which were not consistently identifiable on individual radar profiles. The anomalies are generally wider than a service related anomaly, but may correspond to service trenches or linear structures such as footings.

## 7 DATA APPRAISAL & CONFIDENCE ASSESSMENT

### 7.1 Ground Penetrating Radar

The Mala MIRA high density array system was selected as the optimum method for producing high resolution time slices of an archaeological site. The maximum depth penetration over most of the site was restricted to approximately 1.1 metres only. However, at least three categories of anomalies potentially associated with archaeological features were identified from the data, suggesting that the survey has been moderately effective.

## 8 SUMMARY OF RESULTS

8.1 The interpreted results of the GPR survey are presented as a GPR plan interpretation in Figures 5. Figure 6 presents a series of historic maps of the site between 1885 to 1994 taken from the ECUS Desk based Assessment (Taylor 2022) . A final archaeological interpretation of the GPR data is presented in Figure 7. A summary of the main findings is given below. Specific anomalies have been given labels [A], [B] etc for the description below.

Eight distinct categories of anomalies were detected by the GPR survey, which are shown on the plan interpretation in Figure 5. Four types – possible structures, anomalous layers, disturbed ground and linear feature of uncertain origin have possible archaeological associations.

The most significant findings were detected in the northern half of the site. A cluster of variably shaped anomalous layers [A, B] surround two east-west oriented linear structures [C] , with two undifferentiated anomalies [D] nearby to the east. These features grouped together may correspond the remains of the garage first seen on the 1965-1968 historic map. Alternatively, they may be associated with older archaeological features that precede the earliest available historic map.

A large rectangular strip of disturbed ground [E] running the eastern site boundary correlate to the remains of a former printing works seen on the 1965 – 1968 historic map.

Numerous possible services/linear features are present within the northern half of the site with a generally bimodal north-south and east west trends. It was not possible to further distinguish whether the linear features are related to services or other types of narrow linear structures. The bimodal trend roughly aligned to the site boundaries suggests some of these features may be associated with the former garage.

Three scattered possible structures [F, G, H] near the middle of the site are of uncertain origin. A possible structure and adjacent void [I] in the north-west corner of the site are likely to be service related.

A substantial part of the southern half is obscured by reinforced concrete surfacing [J]. Numerous closely spaced linear features were identified to the south of the reinforced concrete. At least four of these linear features potentially correspond to services. Three irregular shaped areas of disturbed ground [K, L] in the south-east corner may be former excavations or demolition rubble.

Most of the linear features in the south-west corner have a NW/SE orientation, but are of uncertain origin. The possible voids [M] beneath the driveway entrance at the southern end of the site may be service related.

## 9 CONCLUSIONS

9.1 A GPR survey was carried out of Swan Lane Car park, Evesham. Few features of genuine archaeological significance were detected by the GPR survey, with most of the anomalies detected related to industrial buildings that occupied the site in the second half of the 20th century.

## 10 REFERENCES

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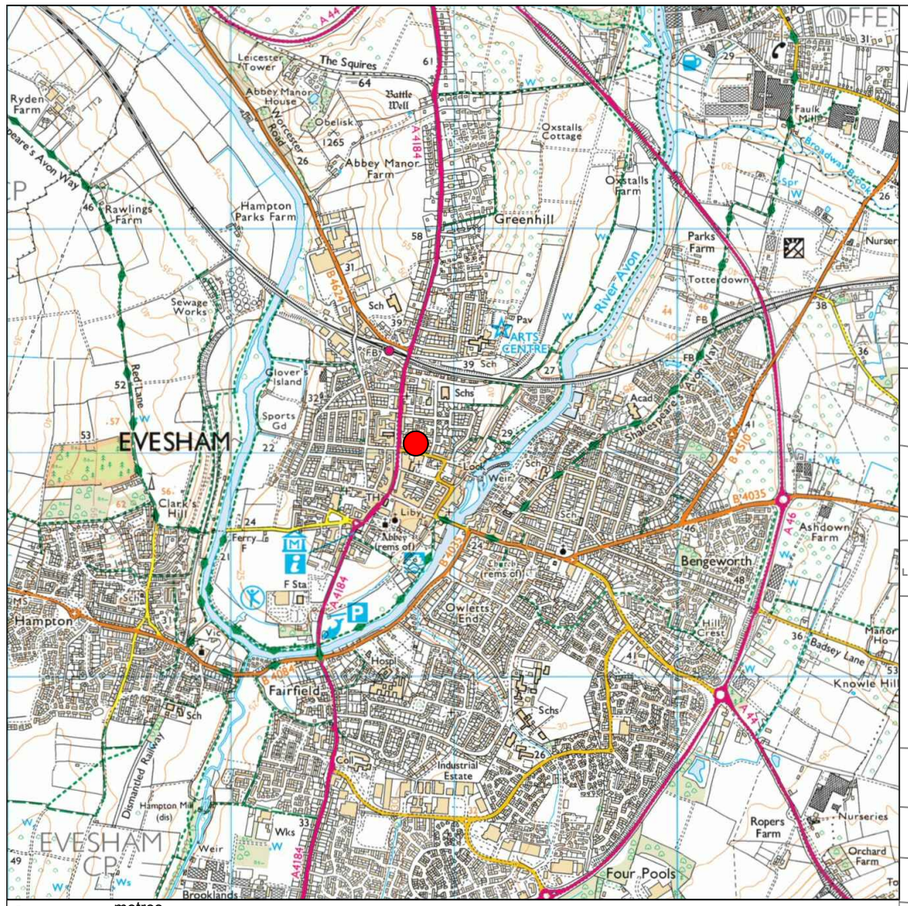



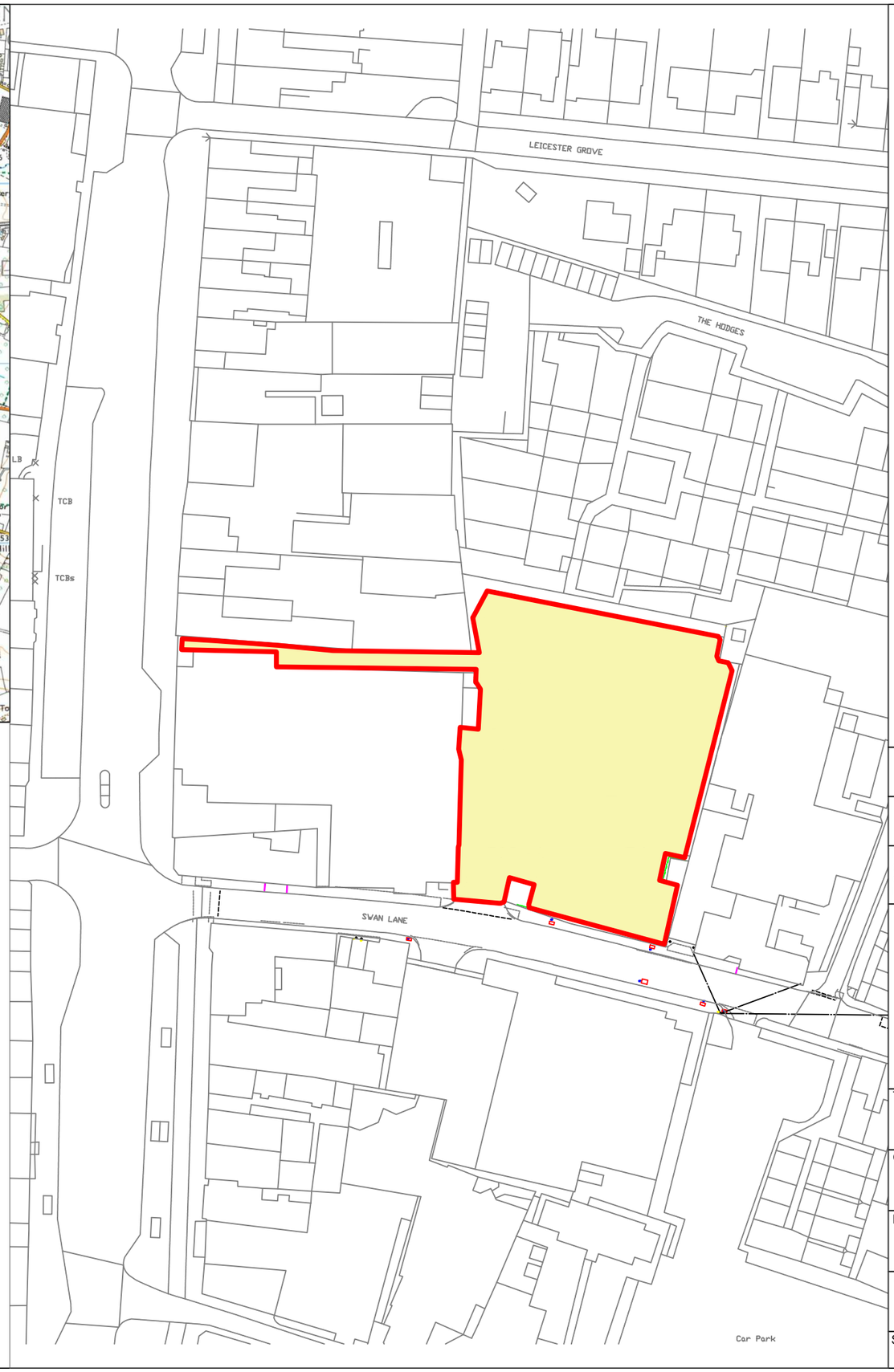


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Site Location

Survey Area GPR Coverage



sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
Site Location, Map of Survey Area and GPR Survey Coverage

Client:
ECUS

Project:
05571 - Swan Lane Car Park, Evesham
Worcestershire

Scale: metres 0m 10 20 30 40 50
1:1000@ A3

Fig No: 01

| Survey date | Drawn by | Checked by |
|---|---|---|
| July 2022 | DMH | PB |

10cm depth


20cm depth


N

30cm depth


40cm depth


sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Timeslices at Depths 0.1m, 0.2m, 0.3m and 0.4m

Client:
ECUS

Project:
05571 - Swan Lane Car Park, Evesham Worcestershire

Scale:
1:750 @ A3

0 metres 37.5

Fig No:
02

50cm depth


60cm depth


N

70cm depth


80cm depth


sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Timeslices at Depths 0.5m, 0.6m, 0.7m and 0.8m

Client:
ECUS

Project:
05571 - Swan Lane Car Park, Evesham Worcestershire

Scale:
1:750 @ A3

0 metres 37.5

Fig No:
03

90cm depth


100cm depth


N

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Timeslices at Depths 0.9m and 1.0m

Client:
ECUS

Project:
05571 - Swan Lane Car Park, Evesham
Worcestershire

Scale:
1:750 @ A3

0 metres 37.5

Fig No:
04


**The performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside of Sumo's control. Whilst Sumo uses all due diligence and reasonable endeavours it does not warrant that 100% detection can be achieved. Irrespective of the information provided by a geophysical survey, any ground works should be undertaken with extreme caution.**

KEY

| | |
|---|---|
| | Possible structure |
| | Possible void |
| | Anomalous layer |
| | Disturbed ground |
| | Undifferentiated anomaly |
| | Probable reinforced concrete |
| | Possible service/linear feature |
| | Linear feature of uncertain origin |
| 0.6 | Depth to the top of the feature (in m) |

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: GPR Survey Plan Interpretation

Client: ECUS

Project: 05571 - Swan Lane Car Park, Evesham Worcestershire

Scale: metres 0m 4 8 12 16 20m
1:400 @ A3

Fig No: 05

| Survey date | Drawn by | Checked by |
|---|---|---|
| July 2022 | DMH | PB |


**The performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside of Sumo's control. Whilst Sumo uses all due diligence and reasonable endeavours it does not warrant that 100% detection can be achieved. Irrespective of the information provided by a geophysical survey, any ground works should be undertaken with extreme caution.**

N

KEY

| | |
|---|---|
| | Combined anomalies of possible archaeological origin |
| | Possible demolition remnants of former printing works |
| | Disturbed ground of uncertain origin (demolition rubble?) |
| | Scattered possible structures of uncertain origin |
| | Possible voids of uncertain origin (service related?) |
| | Undifferentiated anomalies of uncertain origin |
| | Possible pipe |
| | Possible service or linear feature of uncertain origin |
| | Probable reinforced concrete |
| 0.6 | Depth to the top of the feature (in m) |

sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title:
GPR Survey
Archaeological Interpretation

Client:
ECUS

Project:
05571 - Swan Lane Car Park, Evesham
Worcestershire

Scale: metres
0m 4 8 12 16 20m
1:400 @ A3

Fig No:
06

| Survey date | Drawn by | Checked by |
|---|---|---|
| July 2022 | DMH | PB |

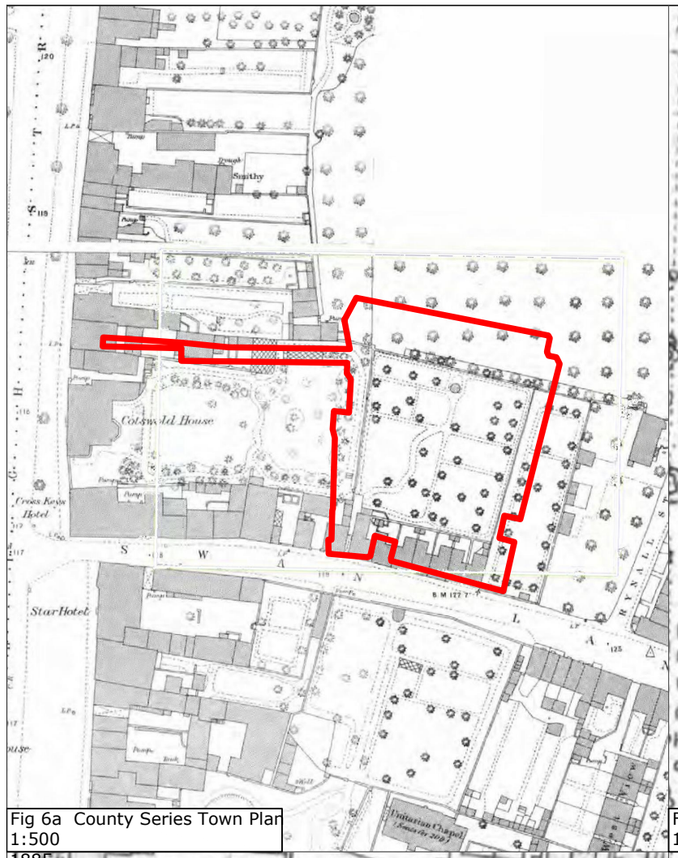



Fig 6a County Series Town Plan 1:500 1885


Fig. 6b County Series 1:2500 1923-1927

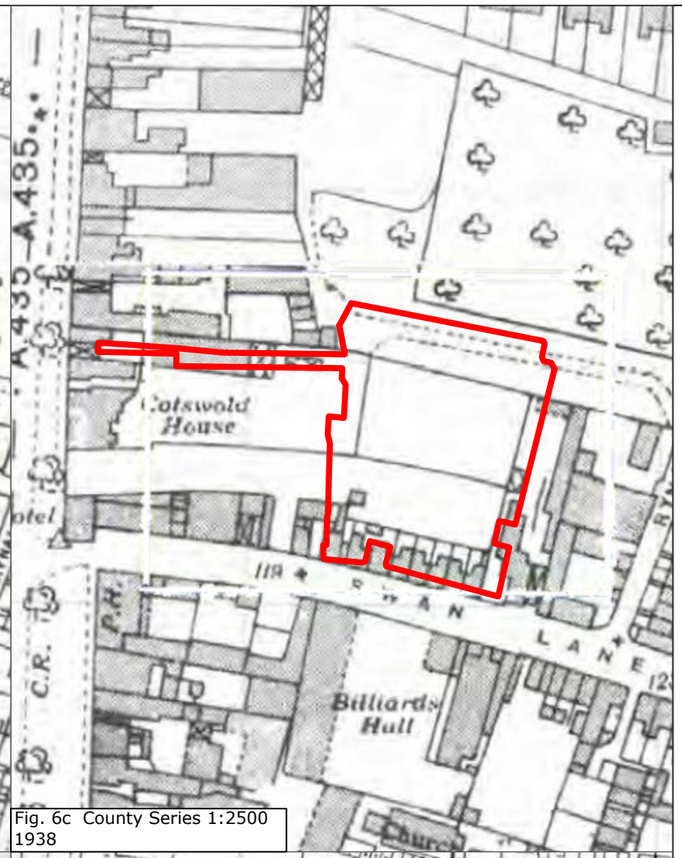



Fig. 6c County Series 1:2500 1938


Fig. 6d National Grid 1:2500 1965-1968

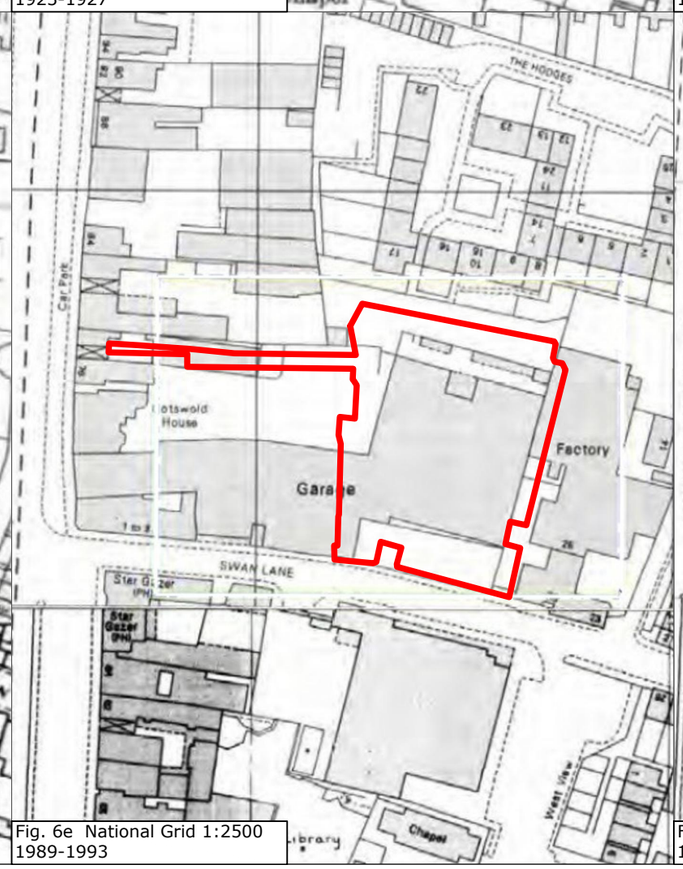



Fig. 6e National Grid 1:2500 1989-1993

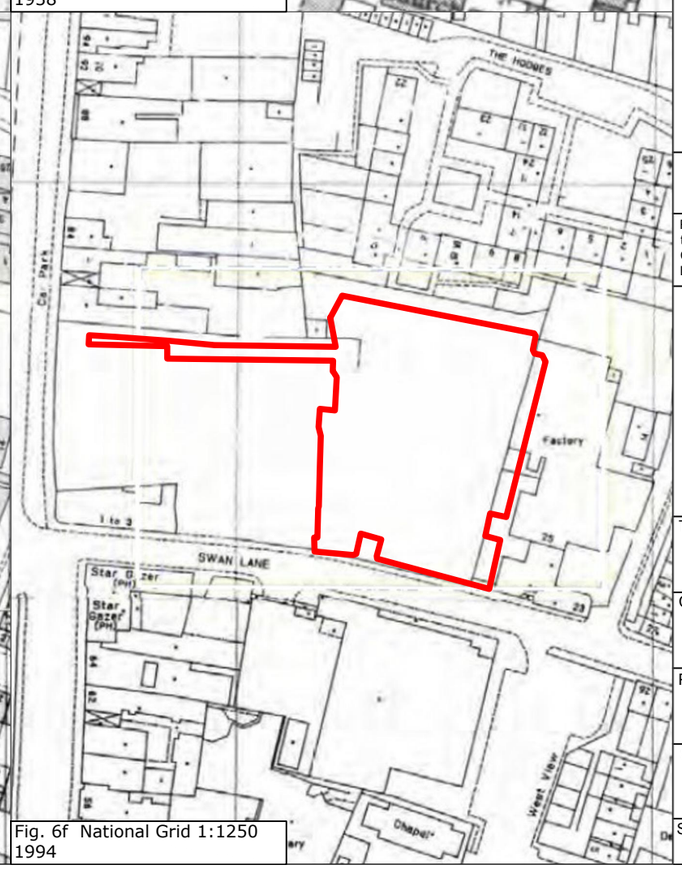



Fig. 6f National Grid 1:1250 1994

N

Survey Area Outline



sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: Historic Maps (obtained from *ECUS DBA, Taylor 2022*)

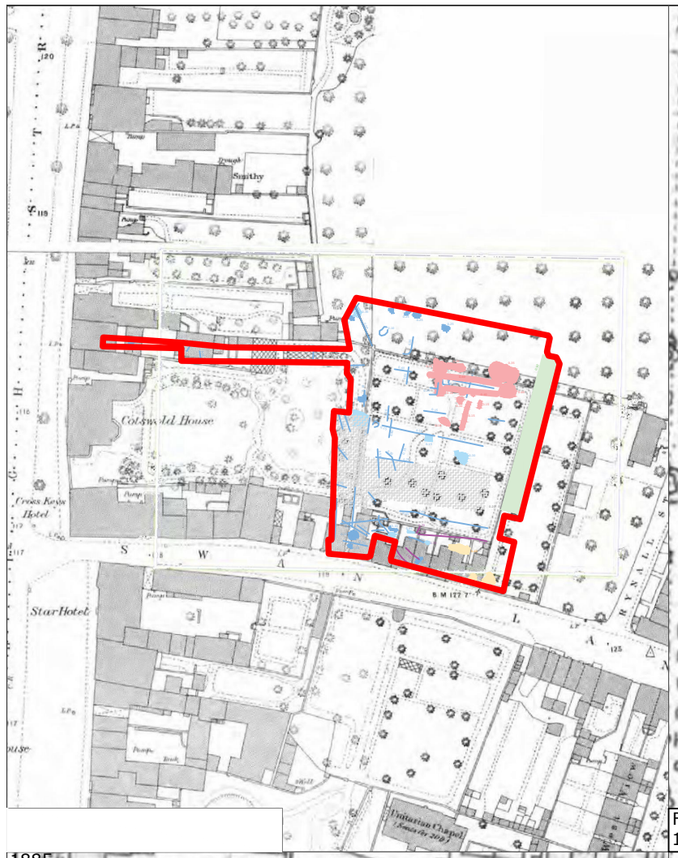
Client: ECUS

Project: Swan Lane Car Park, Evesham, Worcestershire

Scale: metres 0m 10 20 30 40 50m 1:1500@ A3

Fig No: 07

| Survey date | Drawn by | Checked by |
|---|---|---|
| July 2022 | DMH | PB |




1885


Fig. 6b County Series 1:2500
1923-1927


Fig. 6c County Series 1:2500
1938


Fig. 6d National Grid 1:2500
1965-1968

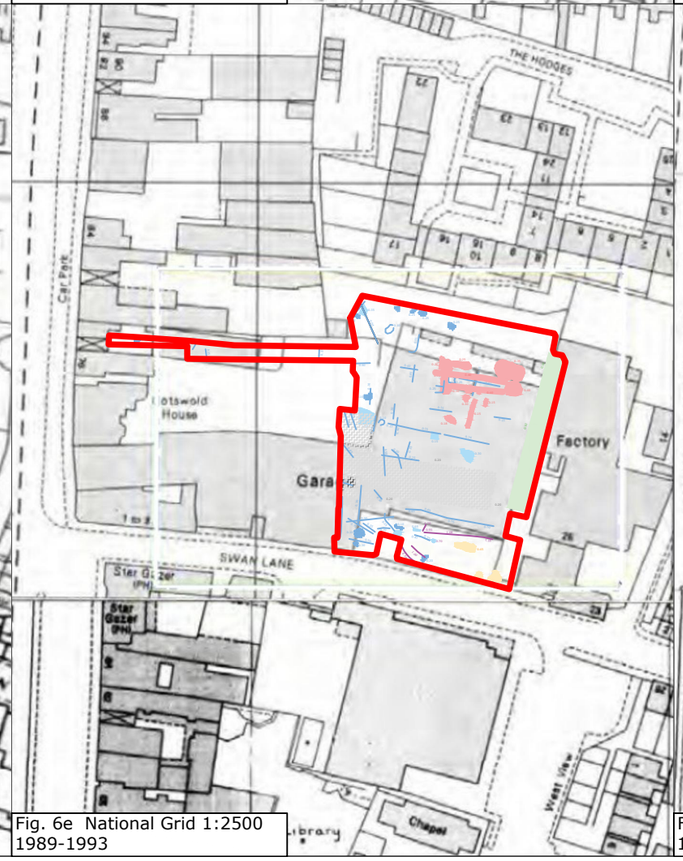



Fig. 6e National Grid 1:2500
1989-1993

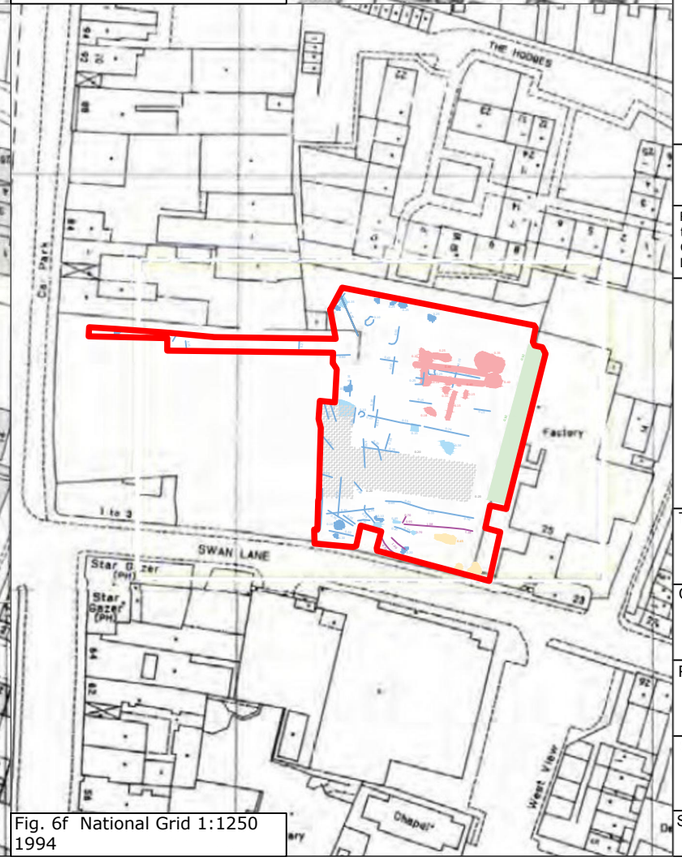



Fig. 6f National Grid 1:1250
1994

N

Survey Area Outline



sumo Survey
GEOPHYSICS FOR ARCHAEOLOGY & ENGINEERING

Title: Archaeological Interpretation Overlain on Historic Maps

Client: ECUS

Project: Swan Lane Car Park, Evesham, Worcestershire

Scale: metres 0m 10 20 30 40 50m
1:1500@ A3

Fig No: 08

| Survey date | Drawn by | Checked by |
|---|---|---|
| July 2022 | DMH | PB |

**Appendix A - Ground Penetrating Radar (GPR) Method**

***Introduction***

Two of the main advantages of radar are its ability to give information of depth as well as work through a variety of surfaces, even in cluttered environments which normally prevent other geophysical techniques being used.

A typical GPR system consists of an antenna unit, together with a signal control and processing unit with built in monitor. The system is powered from a 12V DC battery source. During survey operations, the antenna is moved in parallel traverses over the ground or material under investigation.

A short pulse of electromagnetic energy in the UHF frequency band is emitted into the ground and reflections are returned from the interfaces between different materials in the subsurface. The amplitude of these returns depends on the change in velocity of the radar wave as it crosses these interfaces. A measure of these velocities is given by the dielectric constant of the material under investigation. The travel times are recorded for each return on the radargram and an approximate conversion made to depth by calculating or assuming an average dielectric constant (see below).

Drier materials such as sand, gravel and rocks, i.e. materials which are less conductive (or more resistant), will permit the survey of deeper sections than wetter materials such as clays which are more conductive (or less resistant).

As the antennae emit a "cone" shaped pulse of energy an offset target showing a perpendicular face to the radar wave will be "seen" before the antenna passes over it. A resultant characteristic *diffraction* pattern is thus built up in the shape of a hyperbola. A classic target generating such a diffraction is a pipeline when the antenna is travelling across the line of the pipe. However, it should be pointed out that if the interface between the target and its surrounds does not result in a marked change in velocity then only a weak hyperbola will be seen, if at all.

The resolution and depth range of a GPR system is principally dependent on the frequency of the antenna units used. Higher frequency antennas provide the optimum resolution of hidden features, but generally have a limited depth range. Conversely, low frequency antenna units have greater depth range, but lower resolving power.

***Survey equipment and configuration - Mala MIRA High Density Array***

The Mala MIRA High Density Array Radar uses a multichannel 8 x 400MHz antennae.

*Sampling interval*
Individual radar profiles are spaced at standard intervals of 0.08m, with readings taken at 0.05m intervals. All survey traverse positioning was carried out using a Trimble S6 Robotic Total Station.

*Depth of scan and resolution*
The average velocity of the radar pulse ranges between 0.10 - 0.12m/nsec in most UK ground conditions. The MIRA has a variable range setting of up to 60nsec equating to a maximum depth penetration of up to 3.6m, although this figure could vary by ± 20%.

Under ideal circumstances the minimum size of a vertical feature seen by a 400MHz (intermediate frequency) antenna in a damp soil would be 0.05m (i.e. this antenna has a wavelength in damp soil of about 0.25m and the vertical resolution is one quarter of this wavelength).

*Data capture*
Data is displayed on a monitor as well as being recorded onto an internal hard disk. The data is later downloaded into a computer for processing.

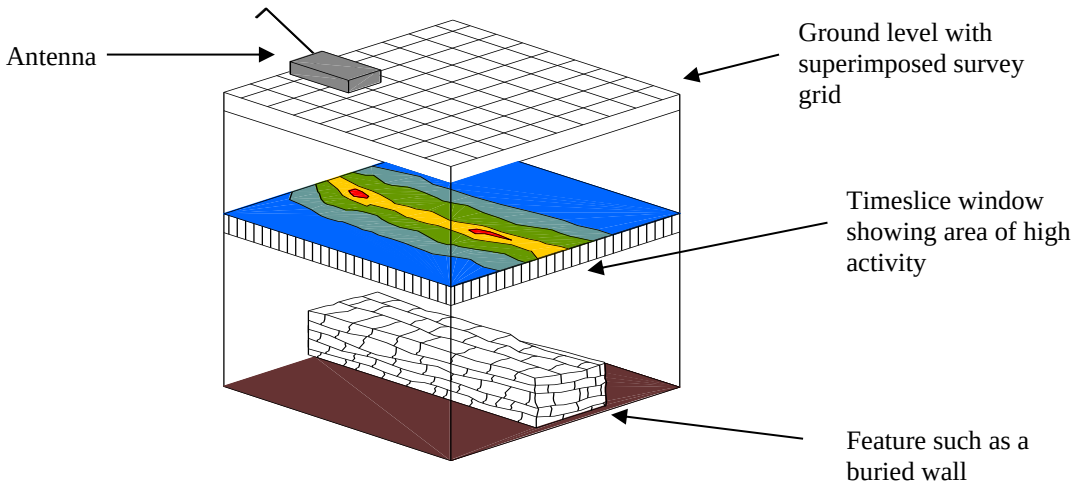
***Data processing***

Processing is performed using specialist software (Mala Rslicer). There are a wide range of filters available, the application of which will vary depending on the project. The table below shows the typical processes used for this data:

| | |
|---|---|
| Gain | Amplification to correct for weakening of signal with depth. |
| DC-Shift | Re-establishes oscillation of the radar pulse around the zero point) |
| Dewow / Ringdown Removal | Removes low frequency, down-trace instrument noise |
| Bandpass Filtering | Suppresses frequencies outside of the antenna's peak bandwidth thus reducing noise |
| Background Removal | Can remove ringing, instrument noise and minimize the near-surface 'coupling' effect |
| Migration | Collapses hyperbolic tails (also known as 'diffractions') back towards the reflection source |
| Amplitude Envelope | Simplifies pulses for production of time-slice maps by summing peak values, regardless of polarity, over a given time-window. |

*Timeslice plots*

The MALA radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots. In this way it is easy to see if the high activity areas form recognisable patterns.




The GPR data is compiled to create a 3D file. This 3D file can be manipulated to view the data from any angle and at any depth within a range. The 3D file can be sampled to produce activity plots at various depths. As the radar is measuring the time for each of the reflections found, these are called "time slice windows". Plots for various time slices have been included in the report. Based on an average velocity calculation have been made to show the equivalent depth into the ground.

The weaker reflections in the time slice windows are shown as light grey colour. The stronger reflections are represented by colours such black and dark grey.

Reflections within the radar image are generated by a change in velocity of the radar from one medium to another. It is not unreasonable to assume that the higher activity anomalies are related to marked changes in materials within the ground such as foundations or surfaces within the soil matrix.

***Survey equipment and configuration - GSSI Dual Frequency (DF) system***

The GSSI Dual Frequency (DF) system manufactured by GSSI collects two channels of data using 300MHz and 800MHz antennae simultaneously

*Sampling Interval*

Readings were taken at 0.05m intervals. All survey traverse positioning was carried out using a Trimble S6 Robotic Total Station.

*Depth of scan and resolution*

The resolution and depth range of the GPR system is dependent on the frequency of the antenna units used. Higher frequency antennas provide the optimum resolution of hidden features, but generally have a limited depth range. Conversely, low frequency antenna units have greater depth range, but lower resolving power.

The average velocity of the radar pulse ranges between 0.10 - 0.12m/nsec in most UK ground conditions. The Dual Frequency 800MHz has a range setting of 20.95nsec this equates to a maximum depth penetration of 1.1m but it must be remembered that this figure could vary by ± 20% or more. The 300MHz has a range setting of 41.9nsec equating to a maximum depth of scan of 3.3m. Very shallow features are lost in the strong surface response experienced with this frequency.

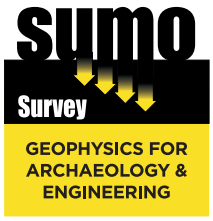
Under ideal circumstances the minimum size of a vertical feature seen for instance by a 300MHz (relatively low frequency) antenna in a damp soil would be 0.075m (i.e. this antenna has a wavelength in damp soil of about 0.3m and the vertical resolution is one quarter of this wavelength). Comparing this with the higher frequency 800MHz antenna, which has a wavelength in the same material of about 0.1m and a theoretical resolution of 0.025m.

Data capture

Data is displayed on a monitor as well as being recorded onto an internal hard disk. The data is later downloaded into a computer for processing.

***Warning***

SUMO use non-invasive survey techniques to detect sub-surface features. However, the performance of the technologies employed in non-invasive surveys can be adversely affected by factors outside SUMO's control, such as ground conditions. Also, it should be understood that the interpretation of ground penetrating radar data are opinions based on inferences from electromagnetic measurements, factors and assumptions, and that such inferences are not infallible. Therefore, because of the uncertainty of variable ground conditions, SUMO does not warrant that 100% detection can be achieved. Irrespective of information provided by a detection survey, any ground works should be undertaken with extreme caution and in accordance with the Health and Safety Executive guidelines HSG47 - Avoiding Danger from Underground Services.




- Archaeological
- Geophysical
- Laser Scanning
- Measured Building
- Topographic
- Utility Mapping

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