STRATASCAN

Geophysical Survey Report

EXETER CASTLE, EXETER

For

Exeter Archaeology

July 2006

J2157

Richard Smalley BA (Hons) AIFA

REGISTERED IFA ORGANISATION

Document Title:	**Geophysical Survey Report** **Exeter Castle, Exeter**
Client:	**Exeter Archaeology**
Stratascan Job No:	**J2157**
Techniques:	**Ground Probing Radar**
National Grid Ref:	**SX 921 930**

Field Team:	**Claire Graham BA (Hons)** **Richard Elliot BA (Hons)**
Project Manager:	**Simon Stowe BSc. (Hons)**
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LIST OF FIGURES

1 SUMMARY OF RESULTS

The ground probing radar survey undertaken at Exeter Castle has located a number of features. Planar, discrete, broad crested anomalies as well areas of complexity have indicated the presence of modern services and associated trenches within the survey area. Any subtle features of an archaeological nature may have been masked by this modern activity.

2 INTRODUCTION

2.1 Background synopsis

Stratascan were commissioned to undertake a geophysical survey of an area outlined for development. This survey forms part of an archaeological investigation being undertaken by Exeter Archaeology.

2.2 Site location

The site is located at Exeter Castle, Exeter at OS NGR ref. SX 921 930.

2.3 Description of site

The site consists of approximately 2500m^2 of Tarmac car park at Exeter Castle, Exeter.

The underlying geology is Namurian millstone grit (British Geological Survey South Sheet, Fourth Edition Solid, 2001). The overlying soils have not been surveyed due to the urban nature of the site (Soil Survey of England and Wales, Sheet 5 South West England).

2.4 Site history and archaeological potential

No specific details were available to Stratascan

2.5 Survey objectives

The objective of the survey was to locate any anomalies that may be of archaeological significance prior to trenching.

2.6 Survey methods

Ground Penetrating Radar (GPR) was considered to be the most suitable method for the survey due to the urban nature of the survey area

More information regarding this technique is included in the Methodology section below.

3 METHODOLOGY

3.1 Date of fieldwork

The fieldwork was carried out over 3 days from 15th May 2006 when the weather was fine and dry.

3.2 Grid locations

The location of the survey grids has been plotted in Figure 2.

3.3 Description of techniques and equipment configurations

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 and which normally prevent other geophysical techniques being used.

A short pulse of energy is emitted into the ground and echoes are returned from the interfaces between different materials in the ground. 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 that material. 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). Penetration can be increased by using longer wavelengths (lower frequencies) but at the expense of resolution (see 3.4.2 below).

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 Ground Probing Impulse Radar used was a SIR2000 system manufactured by Geophysical Survey Systems Inc. (GSSI).

The radar surveys were carried out with a 400MHz antenna. This mid-range frequency offers a good combination of depth of penetration and resolution.

3.4 Sampling interval, depth of scan, resolution and data capture

3.4.1 Sampling interval

Radar scans were carried out along traverses 0.5m apart on a parallel grid as shown in Figure 2. Data was collected at 40 scans/metre. A measuring wheel was used to put markers into the recorded radargram at 1m centres.

3.4.2 Depth of scan and resolution

The average velocity of the radar pulse is calculated to be 0.08m/ns which is typical for the type of sub-soils on the site. With a range setting of 60ns this equates to a maximum depth of scan of 2.4m but it must be remembered that this figure could vary by ± 10% or more. A further point worth making is that very shallow features are lost in the strong surface response experienced with this technique.

Under ideal circumstances the minimum size of a vertical feature seen by a 200MHz (relatively low frequency) antenna in a damp soil would be 0.1m (i.e. this antenna has a wavelength in damp soil of about 0.4m and the vertical resolution is one quarter of this wavelength). It is interesting to compare this with the 400MHz antenna, which has a wavelength in the same material of 0.2m giving a theoretical resolution of 0.05m. A 900MHz antenna would give 0.09m and 0.02m respectively.

3.4.3 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.

3.5 Processing, presentation of results and interpretation

3.5.1 Processing

The radar plots included in this report have been produced from the recorded data using Radan software. No processing was undertaken.

3.5.2 Presentation of results and interpretation

Manual abstraction
Each radargram has been studied and those anomalies thought to be significant were noted and classified as detailed below. Inevitably some simplification has been made to classify the diversity of responses found in radargrams.

i. Strong and weak discrete reflector.
These may be a mix of different types of reflectors but their limits can be clearly defined. Their inclusion as a separate category has been considered justified in order to emphasise anomalous returns which may be from archaeological targets and would not otherwise be highlighted in the analysis.

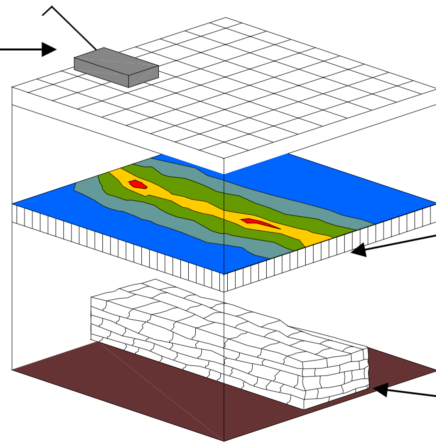
ii. Complex reflectors.
These would generally indicate a confused or complex structure to the subsurface. An occurrence of such returns, particularly where the natural soils or rocks are homogeneous, would suggest artificial disturbances. These are subdivided into both strong and weak giving an indication of the extent of change of velocity across the interface, which in turn may be associated with a marked change in material or moisture content.

iii. Point diffractions.
These may be formed by a discrete object such as a stone or a linear feature such as a small diameter pipeline being crossed by the radar traverse (see also the second sentence in 4. below).

iv. Convex reflectors and broad crested diffractions.
A convex reflector can be formed by a convex shaped buried interface such as a vault or very large diameter pipeline or culvert. A broad crested diffraction as opposed to a point diffraction can be formed by (for example) a large diameter pipe or a narrow wall generating a hybrid of a point diffraction and convex reflector where the central section is a reflection off the top of the target and the edges/sides forming diffractions.

v. Planar returns.
These may be formed by a floor or some other interface parallel with the surface. These are subdivided into both strong and weak giving an indication of the extent of change of velocity across the interface which in turn may be associated with a marked change in material or moisture content.

Timeslice plots
In addition to a manual abstraction from the radargrams, a computer analysis was also carried out. The radar data is interrogated for areas of high activity and the results presented in a plan format known as timeslice plots (Figures 5, 6, 7 and 8). 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 range. The data was then modelled to produce activity plots at various depths. As the radar is actually 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 calculations have been made to show the equivalent depth into the ground. The data was sampled between different time intervals effectively producing plans at different depths into the ground.

The weaker reflections in the time slice windows are shown as dark colours namely blues and greens. The stronger reflections are represented by brighter colours such as light green, yellow, orange, red and white (see key provided in Figures 5, 6, 7 and 8).

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.

4 RESULTS

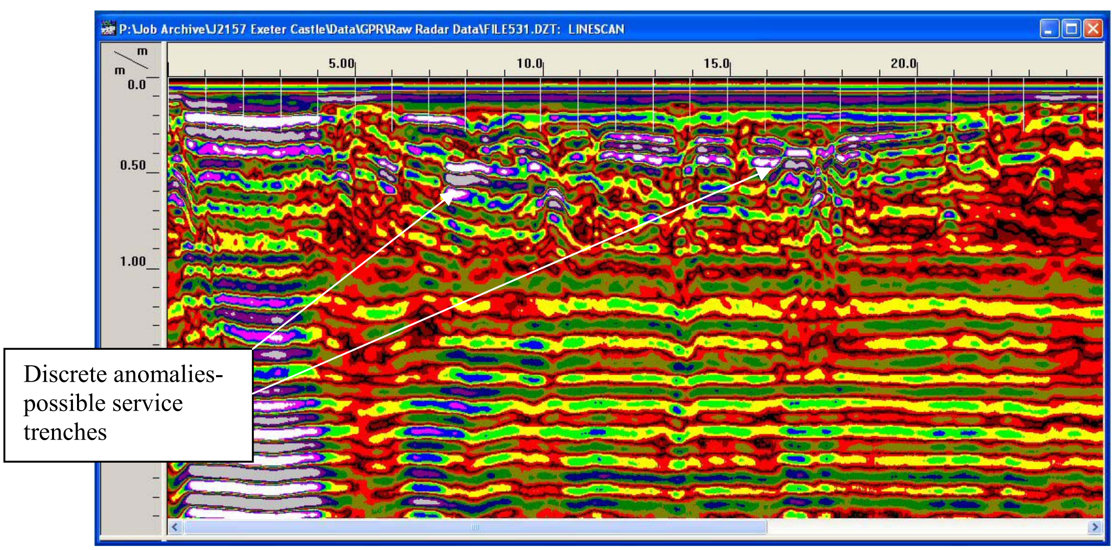
The ground probing radar survey undertaken at Exeter Castle, Exeter has located a number of anomalies that seem to be related to modern services. Four types of anomaly have been identified including: discrete, planar and broad crested anomalies along with areas of complexity.

4.1 Discrete Anomalies.

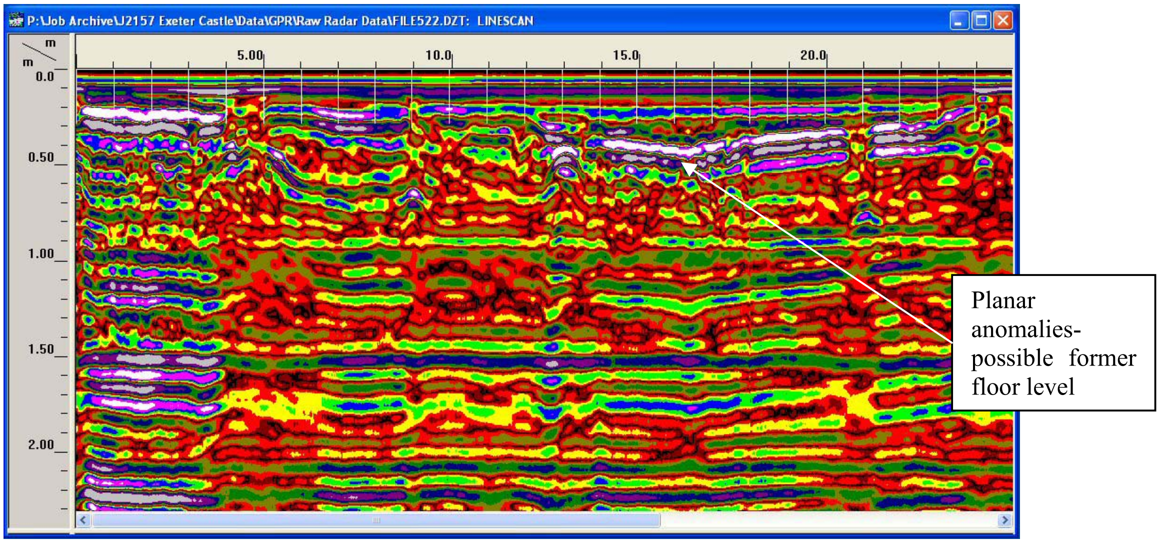
A number of discrete anomalies with a linear nature have been identified within the survey area. These anomalies may indicate the presence of a service trench. The fact that a number of these features run towards or in close proximity to manholes adds weight to this interpretation (See Example Radargram 1).

4.2 Planar Anomalies.

Shallow planar anomalies can be noted across the survey area and are likely to relate to the construction of the car park. However, a number of planar anomalies are evident in the north of the survey area that have a depth of around 0.4m-0.6m. These anomalies may indicate a former floor level and may be of archaeological origin (See Example Radargram 2).



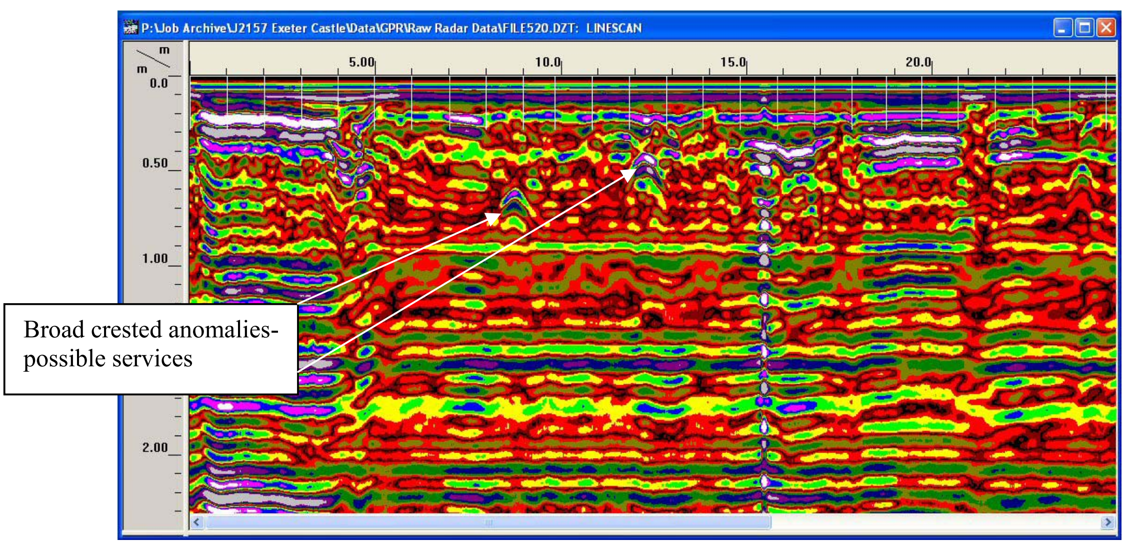
Example Radargram 1: 43S 16E – 53E Discrete anomalies- possible service trench



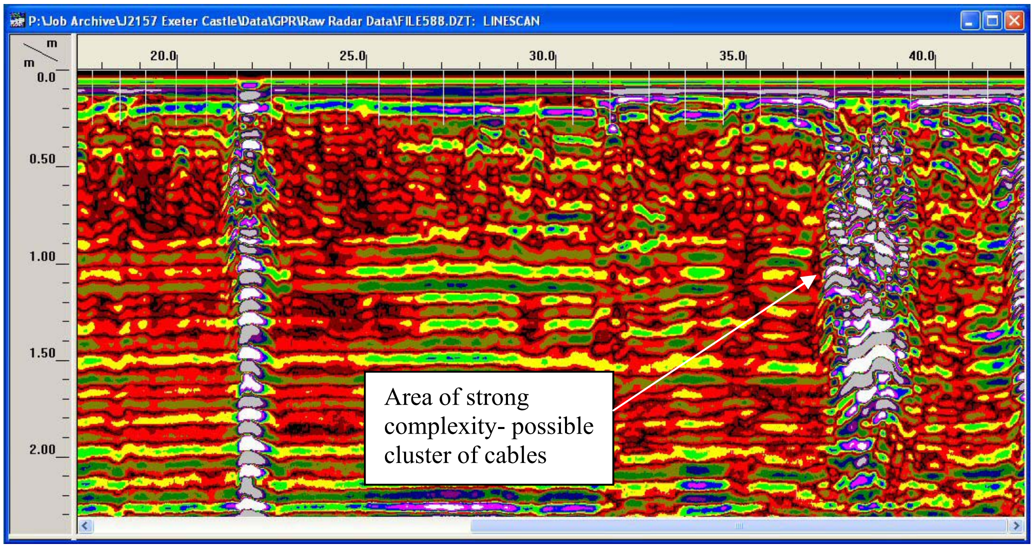
Example Radargram 2: 38S 16E – 53E Planar anomalies

4.3 Broad Crested Anomalies

Broad crested anomalies dominate the data collected at Exeter Castle. Their linear arrangement and close proximity to manholes suggests that the majority of these features relate to modern services within the survey area.



Example Radargram 3: 37.5S 16E – 56E Broad crested anomalies- possible services



Example Radargram 4: 49S 17.5E – 64.5E Strong complexity- clusters of cables

4.4 Areas of Complexity

Complexity within the radar data can often relate to sub-surface rubble or possible structural remains. However, the complex areas within this survey area are all in close proximity to manholes and therefore may be related to clusters of services or their related backfill (Example Radargram 4).

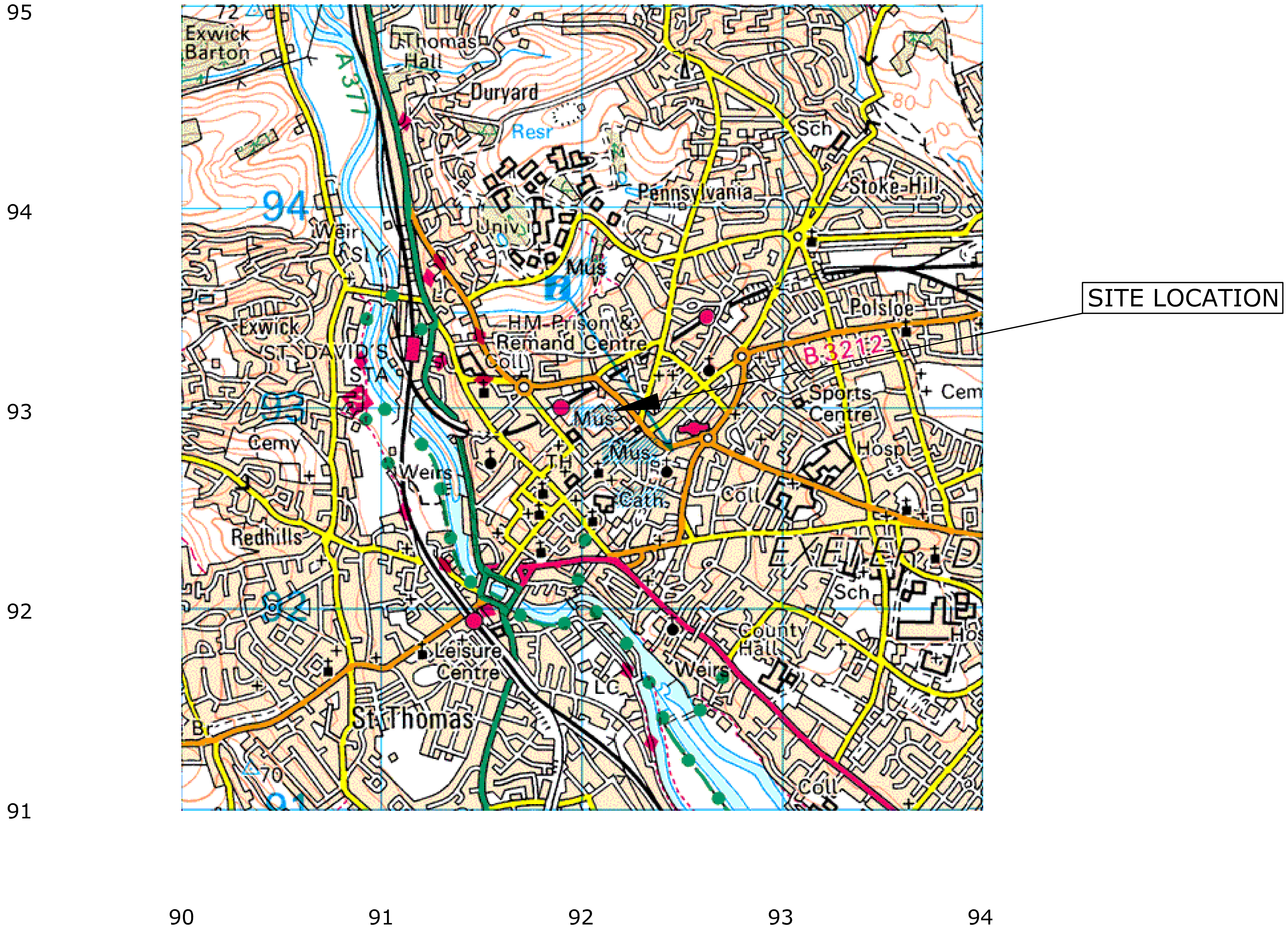
5 CONCLUSION

The majority of anomalies detected through the use of ground probing radar at Exeter castle, Exeter seem to be related to modern service activity. Broad crested anomalies indicate the presence of subsurface pipes or cables and discrete anomalies represent the trenches cut for laying services. Areas of complexity have been located in close proximity to manholes and seem to be related to clusters of cables.

A number of planar anomalies are evident across the survey area. Many of these anomalies are related to the construction of the car park. However, in central northern limits of the site planar anomalies can be noted with a depth of around 0.30m. These anomalies may represent a former floor level and therefore may be of archaeological origin.

Other, more subtle features of possible archaeological origin that may be within the survey data are likely to have been masked by the high amplitude modern activity present on site.

OS 100km square = SX



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Amendments		
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Site centred on NGR SX 921 930

Client
EXETER ARCHAEOLOGY

Project Title — Job No. 2157
GEOPHYSICAL SURVEY - EXETER CASTLE

Subject
LOCATION PLAN OF SURVEY AREA

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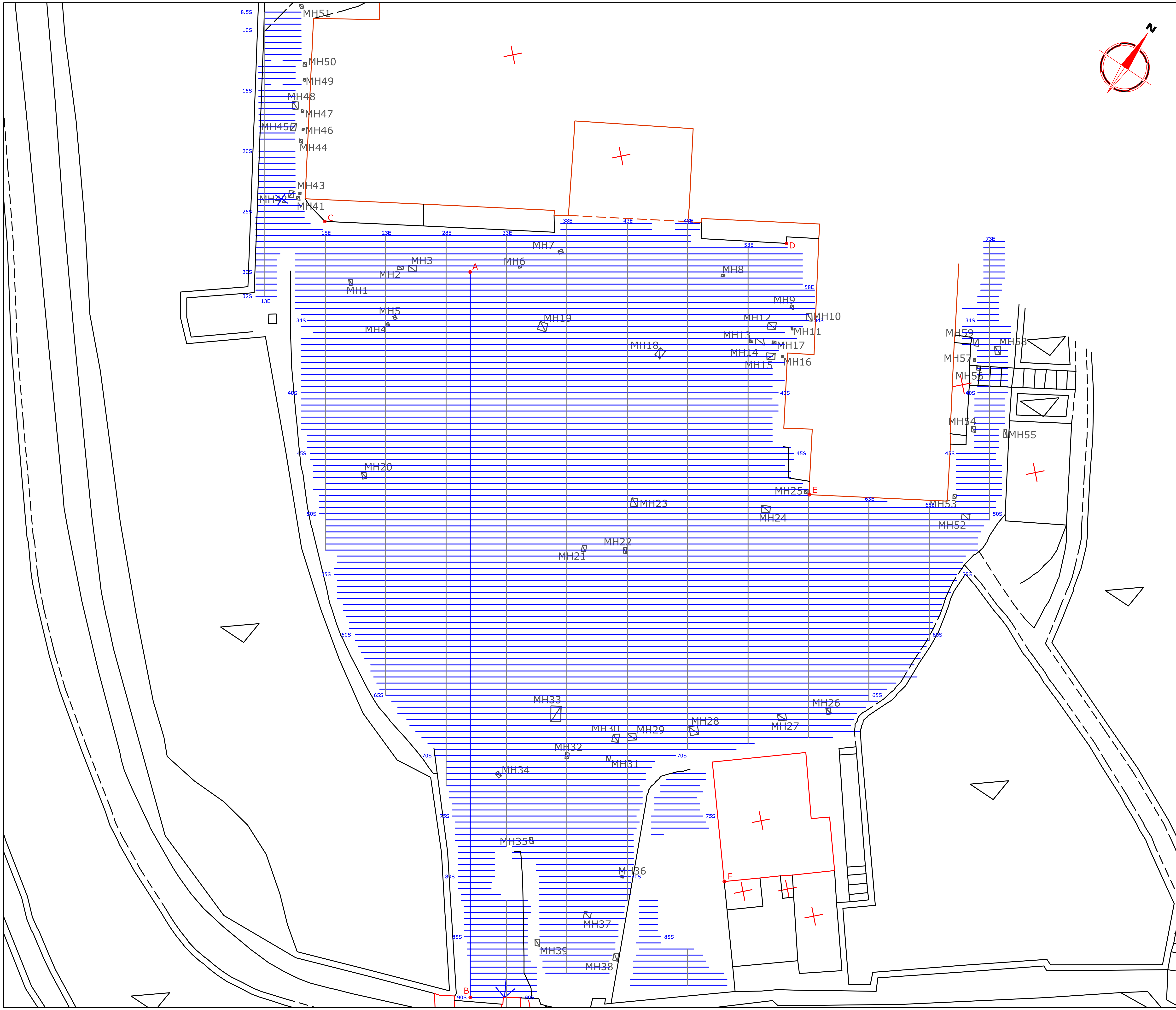
Scale 1:25 000 — 0m 500 1000m

Plot	Checked by	Issue No.
A3	SAS	01
Survey date	**Drawn by**	**Figure No.**
MAY 06	NG	01



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REFERENCING INFORMATION

A-B	60m	A-C	12.74m	A-D	26.29m
A-E	33.57m	B-C	65.30m	B-D	67.64m
B-F	23.10m				
A-B	Base line				
C,D, E, F	Referencing points				
——	Radar transect				

Client

EXETER ARCHAEOLOGY

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GEOPHYSICAL SURVEY - EXETER CASTLE

Subject

SITE PLAN SHOWING LOCATION OF RADAR TRANSECTS AND REFERENCING

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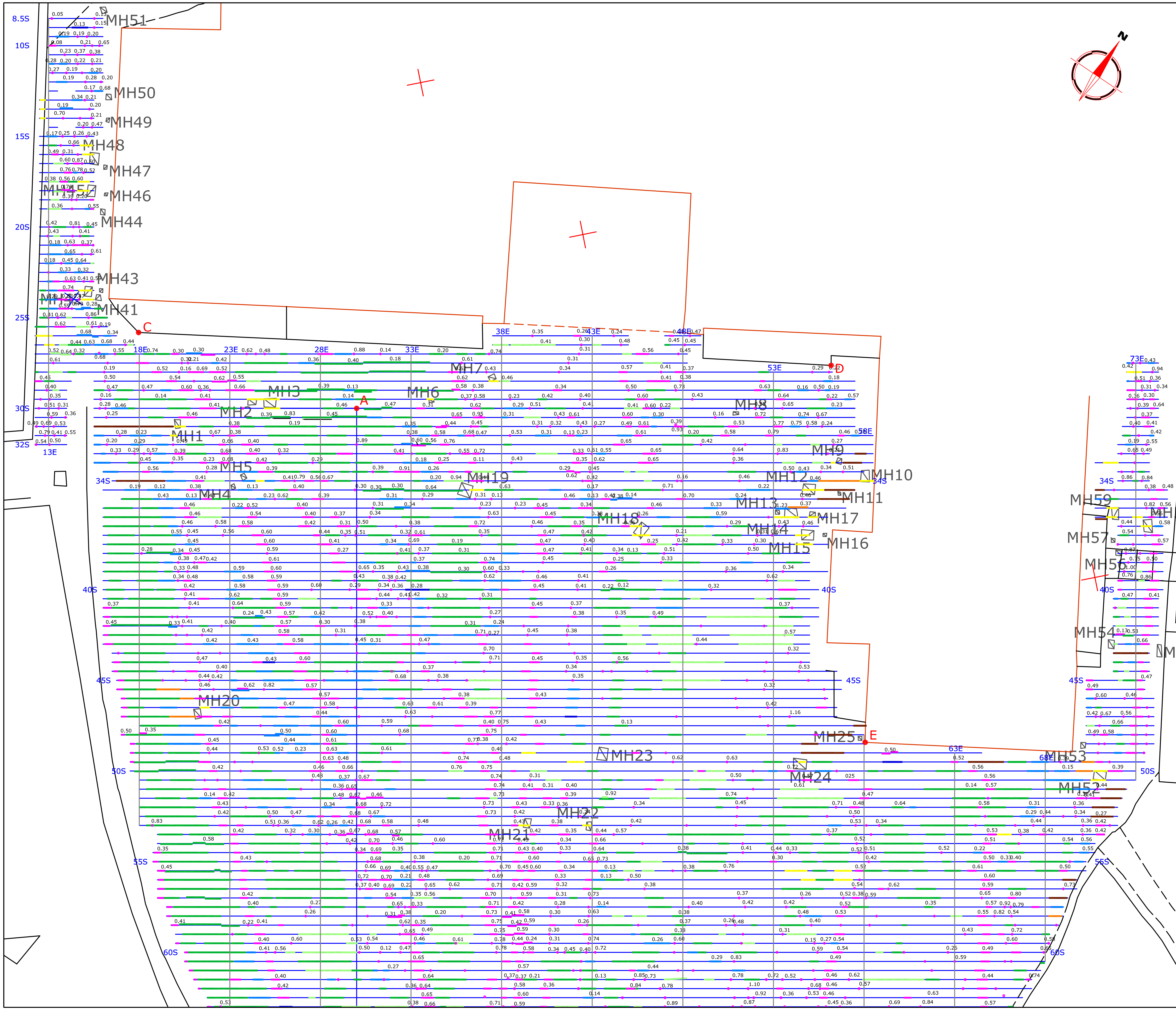
Survey date MAY 06	Drawn by RAJS	Figure No. 02



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RADAR ABSTRACTION KEY

	Strong Discrete
	Weak Discrete
	Strong Complex
	Weak Complex
	Point Diffraction
	Broad Crested
	Strong Planar
	Weak Planar
	Focused Ringing
	Conductive Surface
	Inclined Event
0.25	Depth to top of feature [m]

Client

EXETER ARCHAEOLOGY

Project Title — Job No. 2157

GEOPHYSICAL SURVEY-
EXETER CASTLE

Subject

ABSTRACTION OF GROUND
PENETRATING RADAR DATA -
400MHz- NORTH

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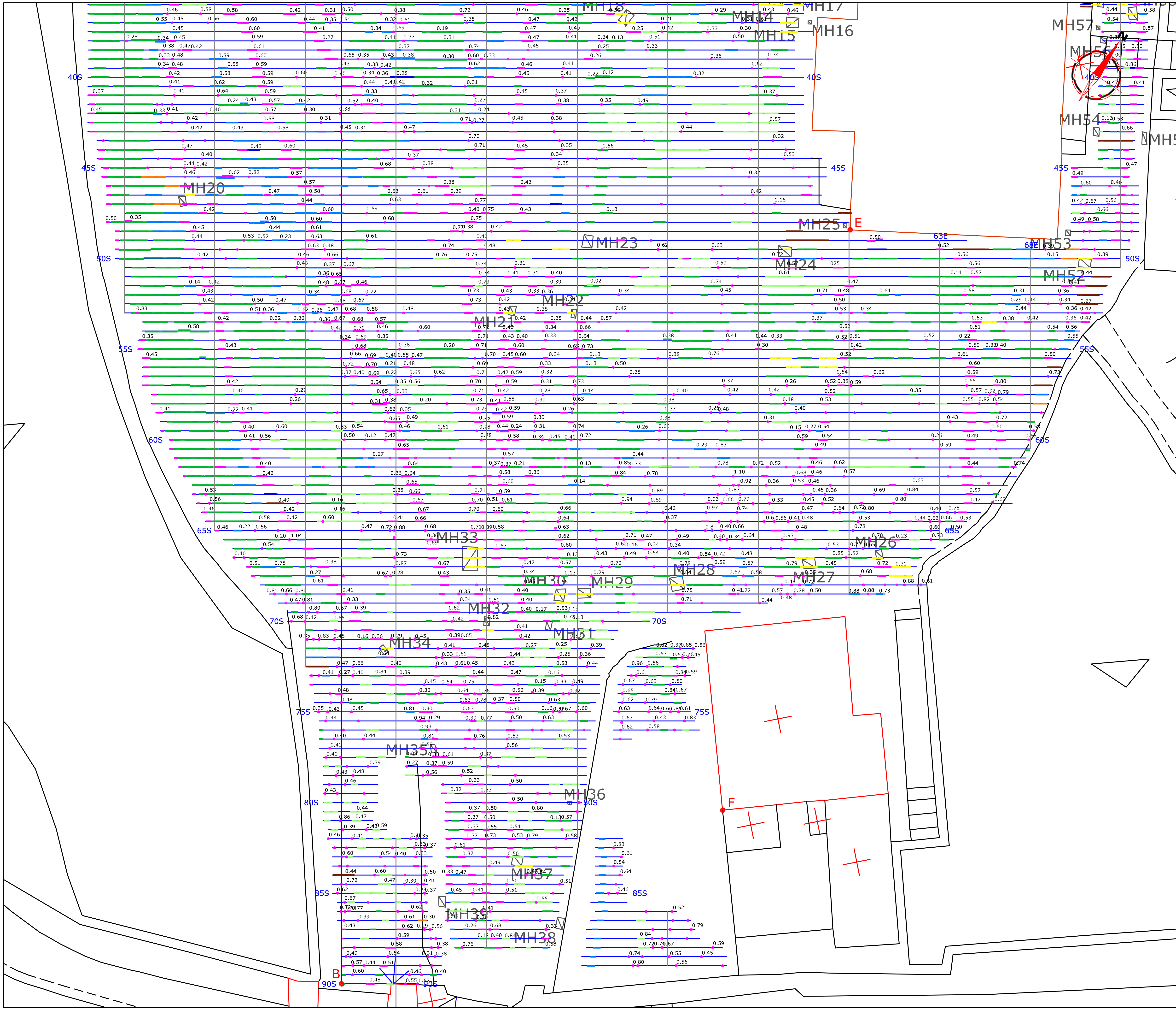
Survey date MAY 06	Drawn by SH	Figure No. 03



Amendments		
Issue No.	Date	Description
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RADAR ABSTRACTION KEY

(dark blue line)	Strong Discrete
(light blue line)	Weak Discrete
(brown line)	Strong Complex
(orange line)	Weak Complex
(magenta dot)	Point Diffraction
(magenta line)	Broad Crested
(green line)	Strong Planar
(light green line)	Weak Planar
(grey line)	Focused Ringing
(yellow line)	Conductive Surface
(thin black line)	Inclined Event
0.25	Depth to top of feature [m]

Client
EXETER ARCHAEOLOGY

Project Title — Job No. 2157
GEOPHYSICAL SURVEY-
EXETER CASTLE

Subject
ABSTRACTION OF GROUND PENETRATING RADAR DATA - 400MHz- SOUTH

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Scale 1:200 (0m 2 4 6 8 10m)

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A3	SAS	01
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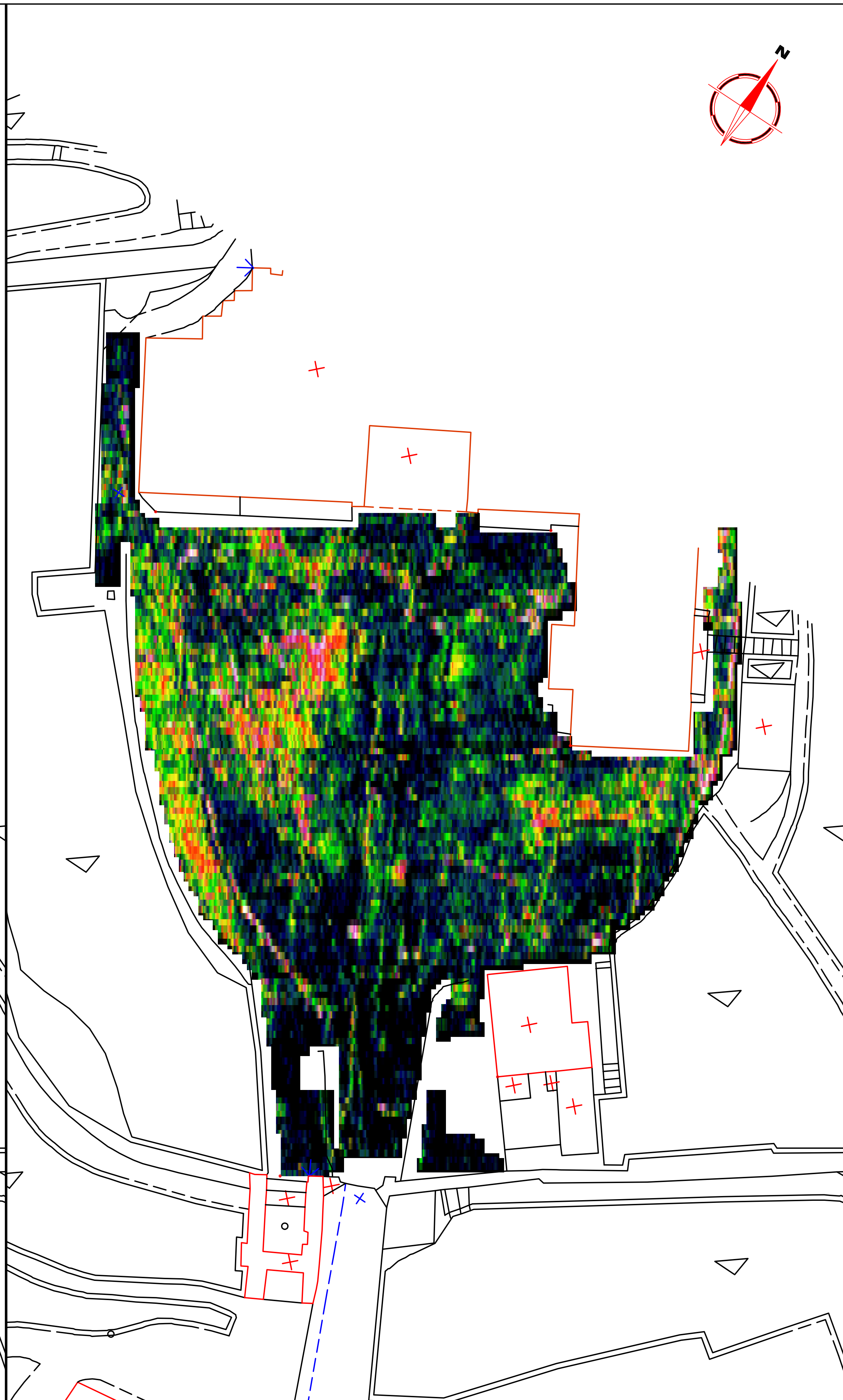
Amendments

TIMESLICE AT A DEPTH OF 0.25m



TIMESLICE AT A DEPTH OF 0.5m

Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING

ENERGY LEVEL

DECREASING

High Energy Return
-Possible Archaeological Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

Client

EXETER ARCHAEOLOGY

Project Title — Job No. 2157

EXETER CASTLE

Subject

GPR TIMESLICE PLOTS AT 0.25m AND 0.5m DEPTH AT A WIDTH OF 0.25m

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Scale 1:500 — 0m 5 10 15 20 25m

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A3	SAS	01
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MAY 06	HH	05

Amendments

Issue No.	Date	Description
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Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING / ENERGY LEVEL / DECREASING

High Energy Return
-Possible Archaeological Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

Client
EXETER ARCHAEOLOGY

Project Title — Job No. 2157
EXETER CASTLE

Subject
GPR TIMESLICE PLOTS AT 0.6m AND 0.725m DEPTH AT A WIDTH OF 0.25m

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Scale 1:500 — 0m 5 10 15 20 25m

Plot	Checked by	Issue No.
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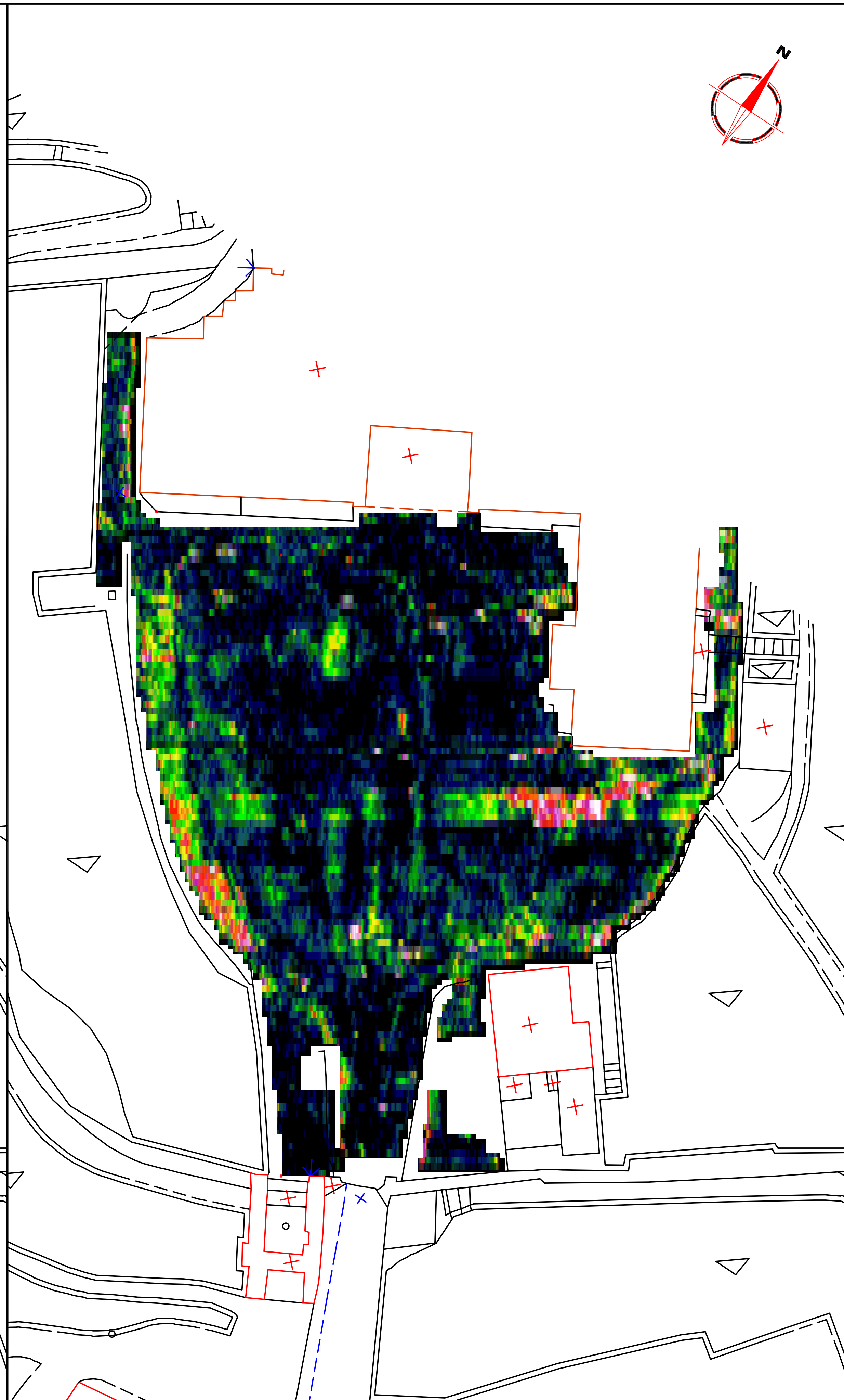
MAY 06	HH	06

TIMESLICE AT A DEPTH OF 0.875m



TIMESLICE AT A DEPTH OF 1.2m

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Issue No.	Date	Description
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Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING

ENERGY LEVEL

DECREASING

High Energy Return -Possible Archaeological Target

Medium Energy Return -Mixed Ground

Low Energy Return -Homogenous Ground

Client

EXETER ARCHAEOLOGY

Project Title — Job No. 2157

GEOPHYSICAL SURVEY- EXETER CASTLE

Subject

GPR TIMESLICE PLOTS AT 0.875m AND 1.2m DEPTH AT A WIDTH OF 0.25m

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Scale 1:500 — 0m 5 10 15 20 25m

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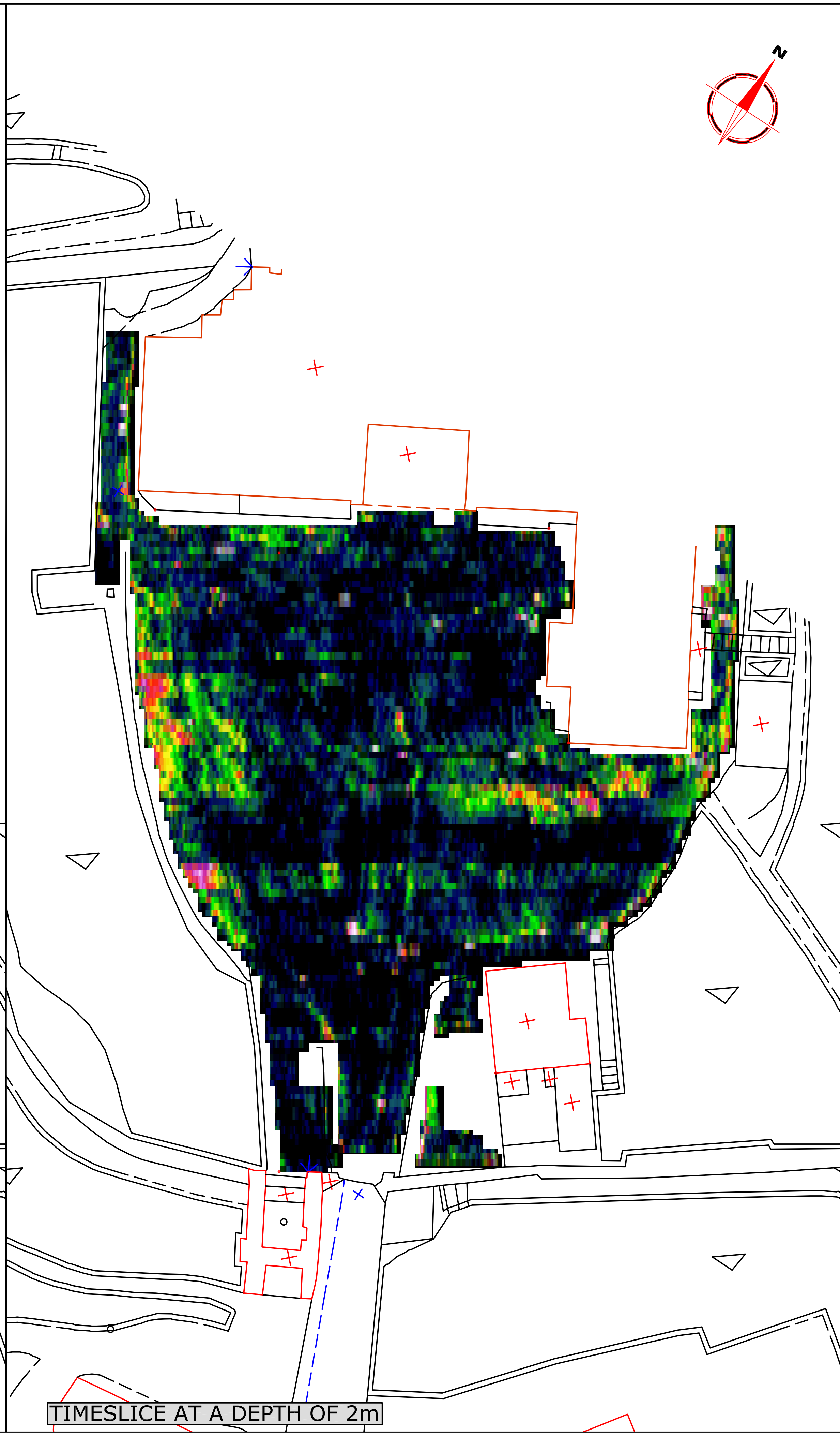

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Issue No.	Date	Description
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Colour Scale for Timeslice 'Activity' Plots and Simplified Key

INCREASING — ENERGY LEVEL — DECREASING

High Energy Return
-Possible Archaeological Target

Medium Energy Return
-Mixed Ground

Low Energy Return
-Homogenous Ground

Client
EXETER ARCHAEOLOGY

Project Title — Job No. 2157
GEOPHYSICAL SURVEY-
EXETER CASTLE

Subject
GPR TIMESLICE PLOTS AT 1.5m AND 2m DEPTH AT A WIDTH OF 0.25m

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A3	SAS	01
Survey date	Drawn by	Figure No.
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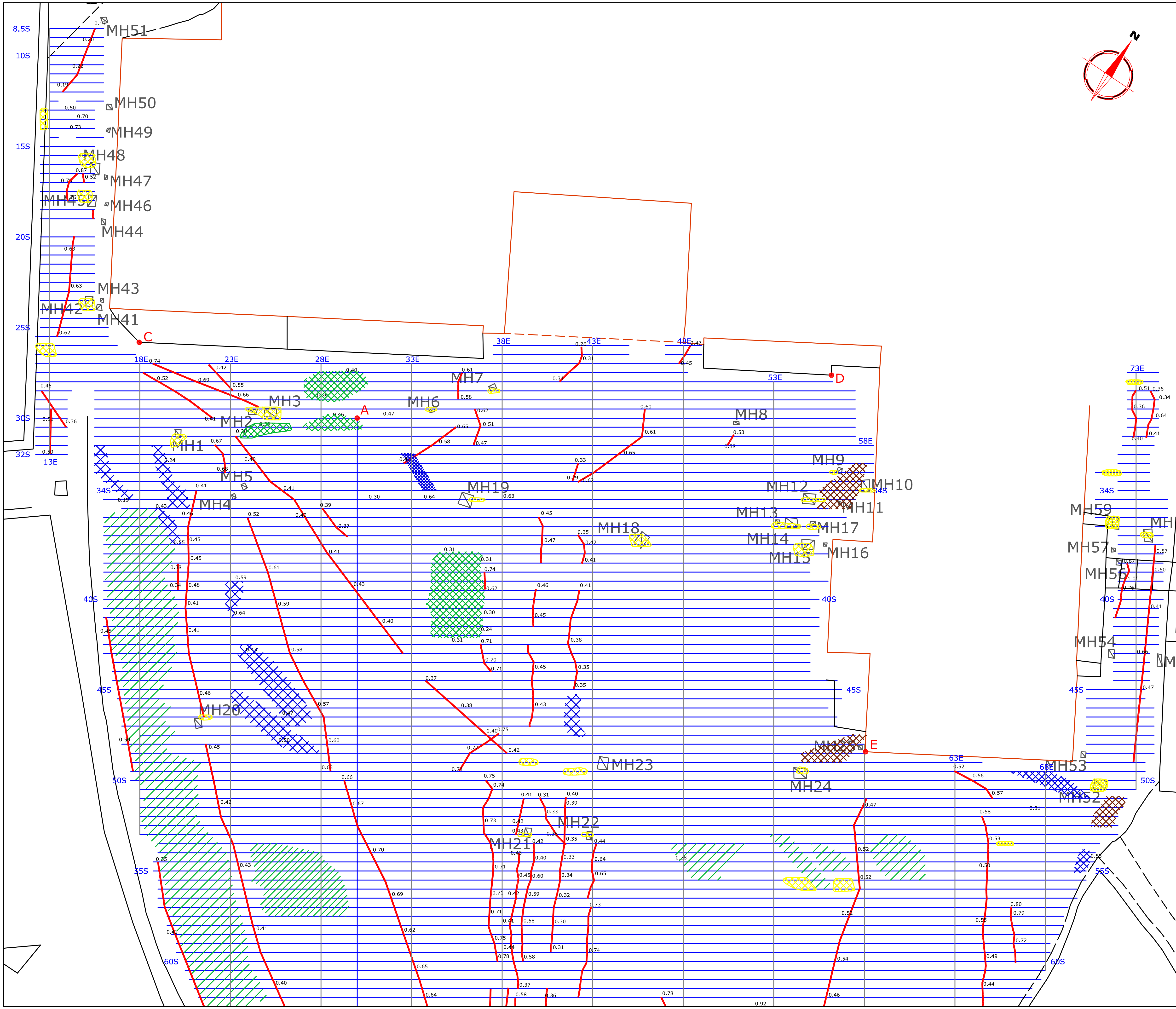

Amendments

Issue No.	Date	Description
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KEY

- Linear anomalies possibly relating to services
- Discrete anomalies- possible service trench
- Planar anomalies - related to construction of modern surface
- Planar anomalies at depth- possibly related to former ground level
- Areas of strong complexity in close proximity to manhole- possibly relating to nests of cables
- Conductive Surface- probably relating to manhole

Client

EXETER ARCHAEOLOGY

Project Title — Job No. 2157

GEOPHYSICAL SURVEY- EXETER CASTLE

Subject

INTERPRETATION OF GPR DATA

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Scale 1:200 — 0m 2 4 6 8 10m

Plot	Checked by	Issue No.
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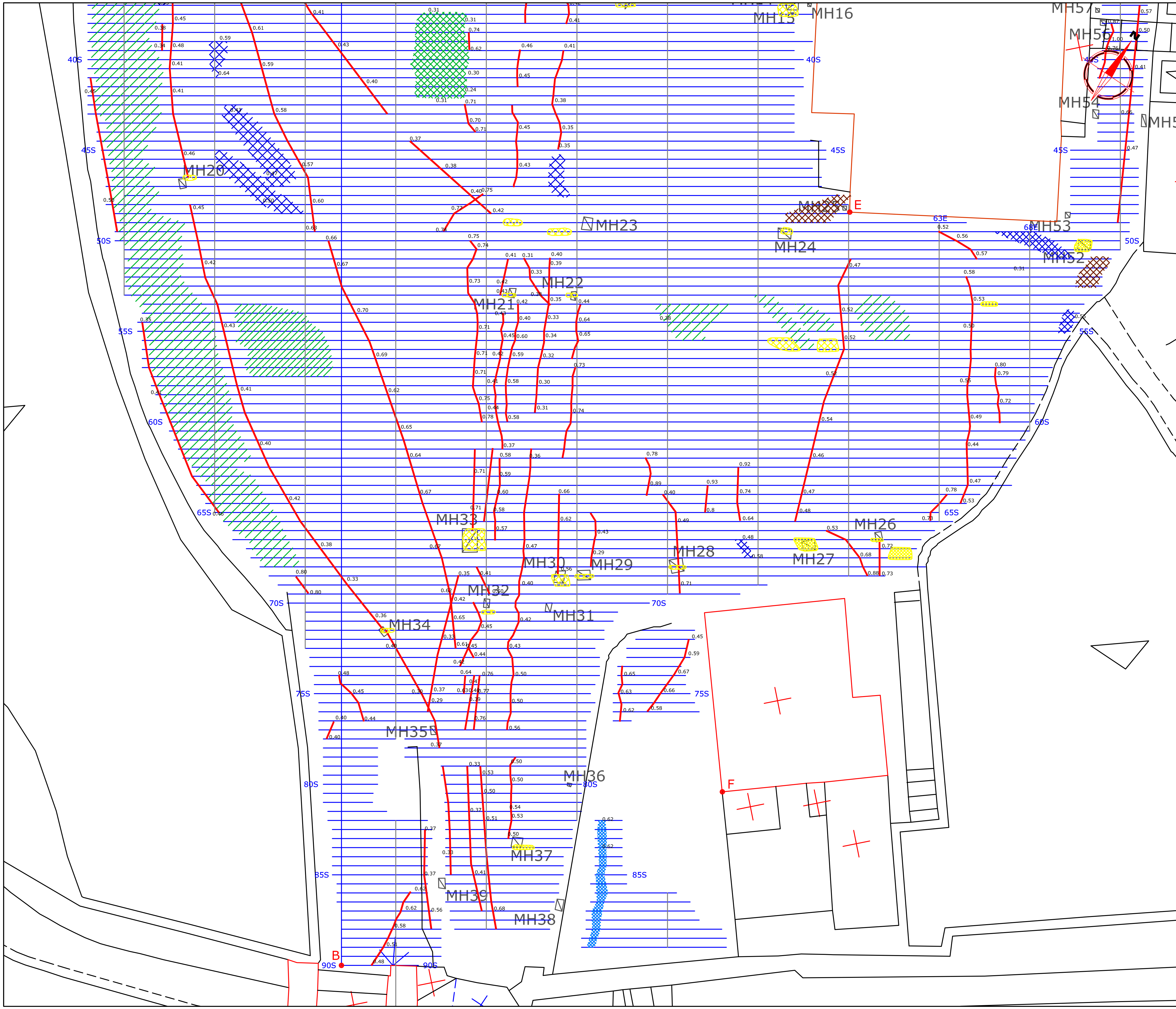
Survey date	**Drawn by**	**Figure No.**
MAY 06	RAJS	09



Amendments		
Issue No.	Date	Description
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KEY

- Linear anomalies possibly relating to services
- Discrete anomalies- possible service trench
- Weak discrete surface response
- Planar anomalies - related to construction of modern surface
- Planar anomalies at depth- possibly related to former ground level
- Areas of strong complexity in close proximity to manhole- possibly relating to nests of cables
- Conductive Surface- probably relating to manhole

Client

EXETER ARCHAEOLOGY

Project Title Job No. 2157

GEOPHYSICAL SURVEY- EXETER CASTLE

Subject

INTERPRETATION OF GPR DATA- SOUTH

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Scale 1:200	0m 2 4 6 8 10m	
Plot A3	Checked by SAS	Issue No. 01
Survey date MAY 06	Drawn by RAJS	Figure No. 10