STRATASCAN

Geophysical Survey Report

Tutbury Glassworks
Staffordshire

For

Birmingham Archaeology

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J2076

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1 SUMMARY OF RESULTS

A ground probing radar (GPR) survey was carried out at Tutbury Glassworks in Staffordshire. The radar data has produced a wide range of GPR anomalies with a higher concentration situated in the northwest of survey Area 2. A large area of strong complex anomalies possibly represents the structural remains and debris of a building known to have existed on the site during the early 1900's. A large number of possible structural remains are situated throughout Areas 1 and 2 and may relate to previous buildings associated with the glassworks complex. Areas of reinforced concrete has been identified along the western edge of Area 2 and in the southwest corner of Area 1. Area 3 has a considerable reduction in radar anomalies compared to the other survey areas, possibly representing a decrease in structural remains.

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 Birmingham Archaeology.

2.2 Site location

The site is located at Tutbury Glassworks, Tutbury, Staffordshire at OS NGR ref. SK 213 287

2.3 Description of site

The site consists of three survey areas. Area 1 is situated in two rooms within the main factory building. Area 2 is situated within the car park and entranceway of the factory complex. Area 3 is situated towards the south of the site within a small building. All survey areas consist of hard standing. A number of obstructions are present within survey Areas 1 and 3 in the form of modern debris.

Plate 1: Looking east of the north of Area 2

Plate 2: Looking north towards the glassworks entrance

The underlying geology is Triassic Mudstone (British Geological Survey South Sheet, Fourth Edition Solid, 2001). The overlying soils have not been comprehensively mapped due to the sites urban environment but are likely to consist of Worcester soils, which are typical argillic pelosols. These consist of slowly permeable non-calcareous and calcareous reddish clayey soils (Soil Survey of England and Wales, Sheet 3 Midland and Western England).

2.4 Site history and archaeological potential

Birmingham Archaeology has provided the following information:

An estate map of 1810 (see Figure 13) shows a number of buildings that relate to the Glassworks at this time. The land was sub-divided into four plots. Two existed on Ludgate Street frontage, a plot situated along Burton Street in the form of terrace housing and a larger plot to the rear, with access from Burton Street.

By 1840, a series of extensions were added to the present buildings and an L-shaped building was constructed to the rear of the Glassworks complex. The 1st Edition Ordnance Survey map (1888) of the area shows an amalgamation of the glassworks plot into a single unit. The units along Ludgate Street were extended with little other alterations visible throughout the end of the 19th century (2nd Edition Ordnance Survey map 1900, see Figure 13).

Sometime before 1948 the terrace houses on the corner of Ludgate and Burton Street where demolished and replace by a single unit. Buildings to the rear of the main range were demolished and the land subdivided. A single building was constructed on Burton Street frontage with extensions added onto the rear of the Ludgate building complex.

2.5 Survey objectives

The objective of the survey was to locate any anomalies that may be of archaeological significance to aid in the archaeological investigation carried out by Birmingham Archaeology.

2.6 Survey methods

Ground probing radar was chosen due to its ability to survey over hard standing and within an urban environment achieving high resolution data.

More information regarding these techniques is included in the Methodology section below.

3 METHODOLOGY

3.1 Date of fieldwork

The fieldwork was carried out over 3 days from the 24th to the 26th October when the weather was wet.

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 survey was 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 0.095/nsec which is typical for the type of sub-soils on the site. With a range setting of 60nsec this equates to a maximum depth of scan of 2.8m respectively 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. A filter was applied to the data to remove background noise.

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.

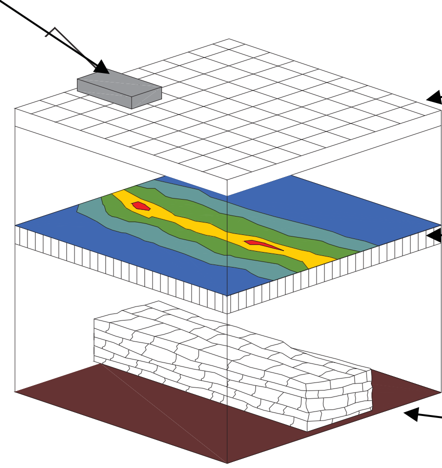
iii. Point diffractions.
These may be formed by a discrete object such as a stone or a linear feature such as a small diameter pipeline being crossed by the radar traverse (see also the second sentence in 4. below).

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 3-7). 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 3-7).

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

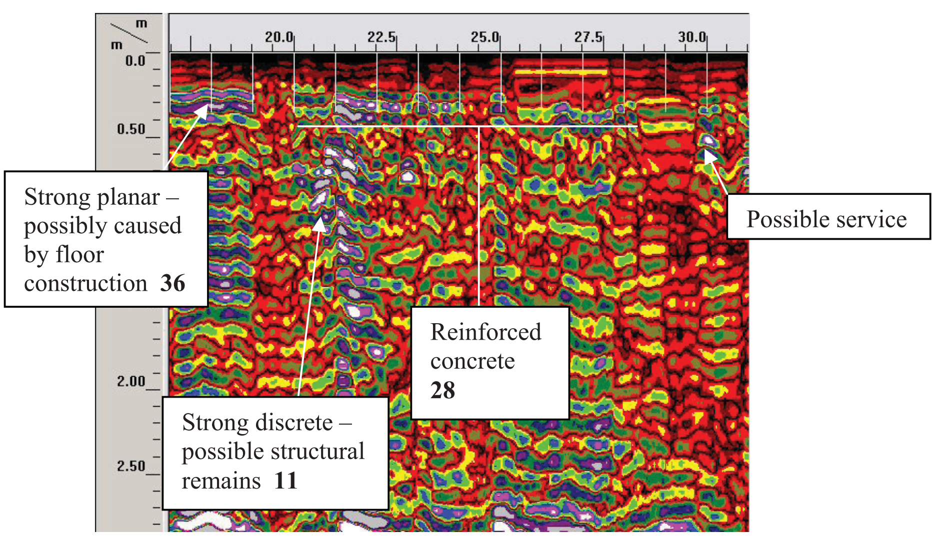
The radar data in all three survey areas have produced a wide range of anomalies with Area 2 generating the most complex of anomalies, suggesting a large area of structural remains and debris.

The anomalies have been classified into the following categories (see Figure 10-13):

- Linear anomalies – possible services and structural supports
- Strong complex and discrete responses – possible structural remains and debris
- Weak complex and discrete responses- possible structural debris and areas of ground disturbance
- Discrete and complex responses – possible evidence of fragmented structural remains
- Broad crested anomalies – possible structural remains
- Strong planar and complex anomalies – may relate to a buried surface with interspersed structural remains
- Weak planar and complex anomalies – may relate to a buried surface with interspersed structural remains
- Weak discrete anomalies – possibly relating to structural remains
- Modern anomalies

Linear anomalies – possible services and structural supports
Situated across the north of survey Area 2 are a number of linear anomalies at varying depths from 0.2 to 0.6m. These anomalies may represent services possibly associated with the nearby electrical substation.

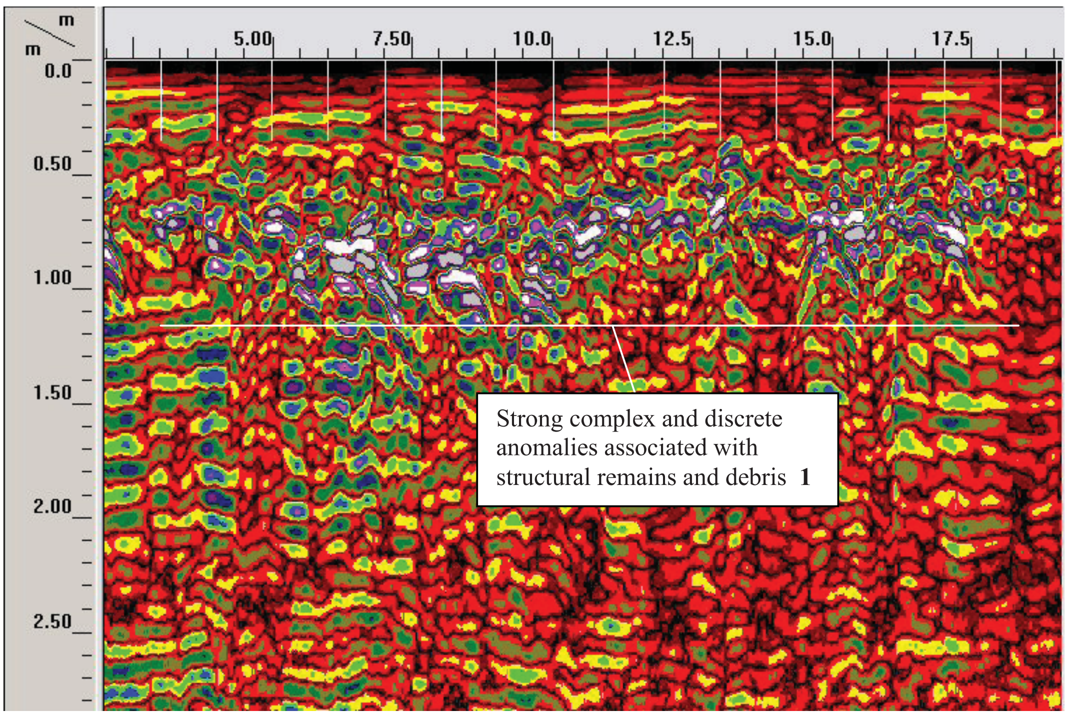
A number of possible services have also been identified across Areas 1 and 3. A large area of reinforced concrete has been identified in the southwest of Area 1; a number of larger structural supports possibly associated with the nearby glass furnaces can be identified in the form of linear anomalies (Example Radargram 1).



Example Radargram 1: Area 1 along traverse 10W, 17-31S. Showing reinforced concrete, a possible service and a discrete anomaly possibly represent structural remains

Strong complex and discrete responses – possible structural remains and debris
A large area of strong complex anomalies has been identified at varying depths of 0.5-1.1m situated in the northeast of Area 2 (**1**). This large complex response is interspersed with strong discrete anomalies and is likely to represent structural remains and debris relating a previous building illustrated in the Second Edition Ordnance Survey (Figure 13 and Example Radargram 2 and 4).

Two smaller areas of strong complex anomalies have been identified within Area 2. Anomalies **2** and **44** may represent further structural remains; however anomaly **44** may be associated with the car park construction and nearby earthen bank.

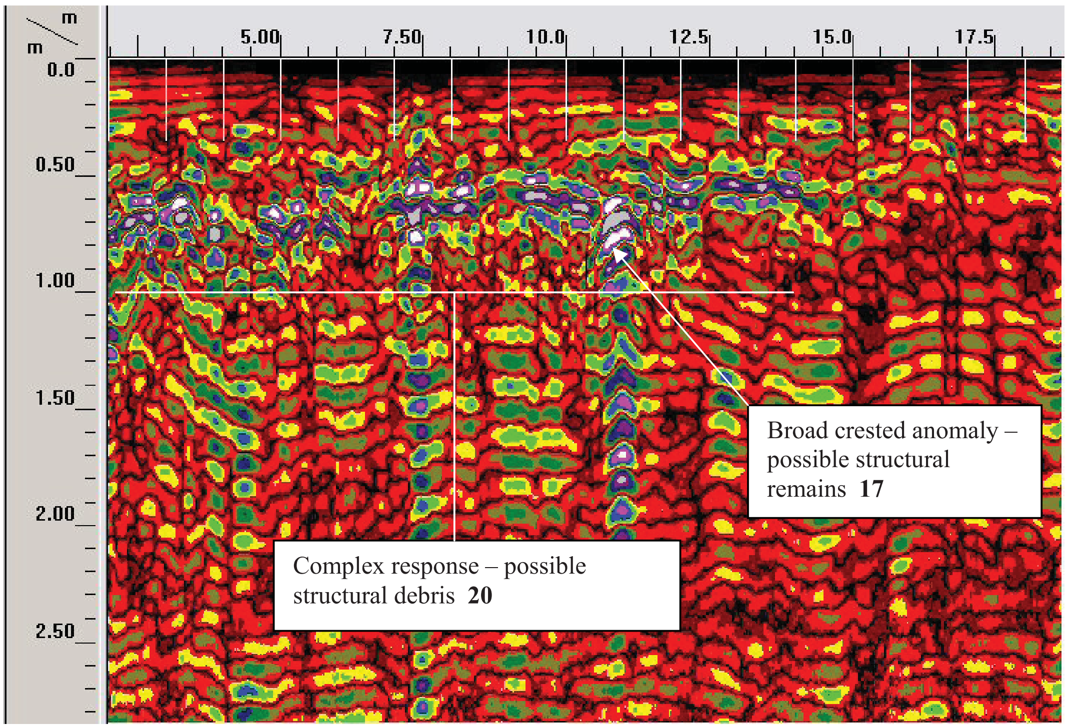


Example Radargram 2: Area 2 along traverse 9.5W, 2-19S. Showing strong complex and discrete anomalies associated with structural remains and debris

Weak complex and discrete responses- possible structural debris and areas of ground disturbance
Three areas of weak complex response have been identified across Area 1. As mentioned above, anomaly **28** is likely to be associated with an area of reinforced concrete (Example Radargram 1). Anomalies **27** and **29** may relate to ground disturbance or areas of structural debris.

Within Area 2, a large number of weak complex anomalies have been identified across the survey area. Anomaly **20** is situated in the east of survey and may represent an area of structural debris. There appears to be a marked drop in GPR anomalies along the eastern edge of anomaly **20**. This may indicate the western front of a building identified with the 1810 estate map (see Figure 13 and Example Radargram 3).

Anomalies **21** – **23**, situated within the centre of the survey area, may indicate areas of structural debris associated with previous buildings. Anomalies **24** and **25** situated within the northwest corner of Area 2 may represent ground disturbance possibly associated with the nearby services. Anomaly **30** may indicate structural remains or a possible service trench. Anomaly **26**, situated in the south of Area 2 may indicate an area of ground disturbance from the nearby car park boundary but may also represent structural debris of archaeological origin.

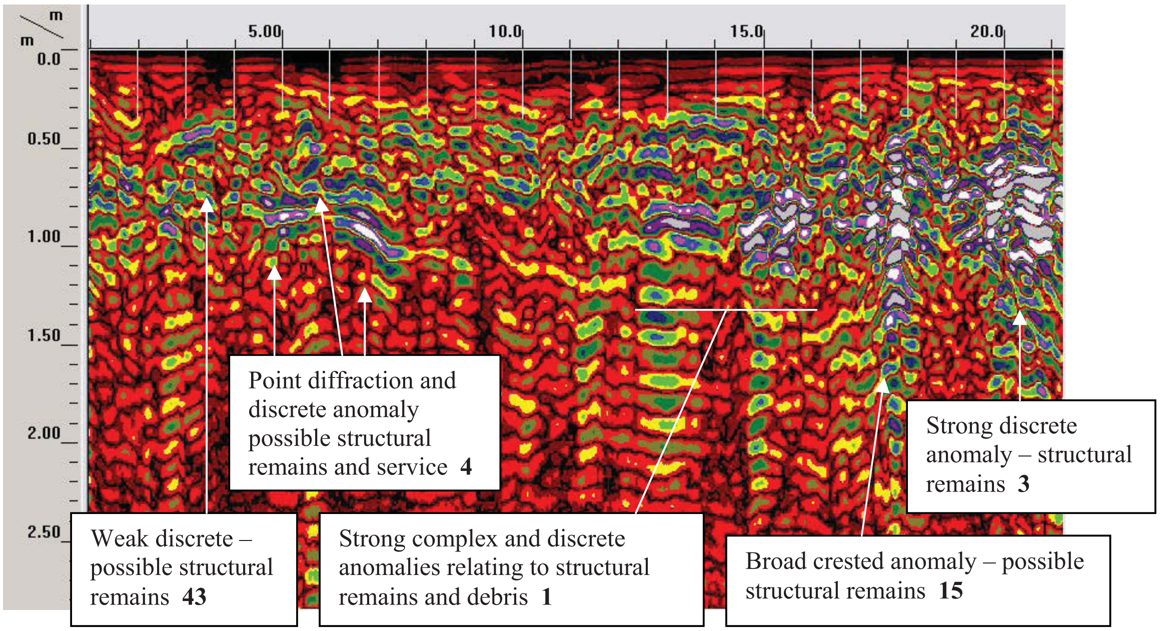


Example Radargram 3: Area 2 along traverse 6W, 2-18.5S. Showing complex, discrete and complex anomalies possibly associated with structural remains and debris

Situated in the northwest corner of Area 3 is a small area of weak complex response (**45**). This anomaly may represent an area of ground disturbance or structural remains possibly associated with a previous structure present within the 1900 Ordnance Survey map (Figure 13).

Discrete and complex responses – possible evidence of fragmented structural remains
Two strong discrete anomalies have been identified with survey Area 1 (**10** and **11**). These anomalies may represent previous structural remains (Example Radargram 1).

A large number of strong discrete and complex anomalies have been identified mainly within the northern and central areas of survey Area 2. Anomaly **3** may represent possible structural remains relating the building illustrated in the 1810 estate map (Figure 13). Anomaly **4**, situated in the north of Area 2 may also represent structural remains relating to the 1810 building. However, this anomaly may also indicate a service trench running in the direction of the electric substation, as a number of anomalies situated within the strong discrete response may represent a service (Example Radargram 4).



Example Radargram 4: Area 2 along traverse 19.5W, 1-21S. Showing strong complex and discrete anomalies possibly associated with structural remains

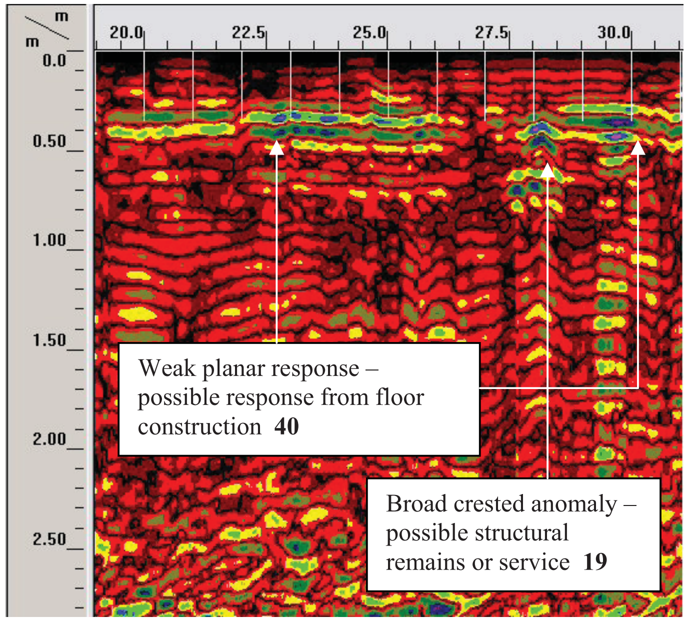
Anomalies **5-7** appear at depths of 0.6-1.3m and may represent structural remains and debris, these anomalies appear at a greater depth than the large anomaly **1**. Possibly suggesting that these anomalies (**5-7**) may predate the structural remains of anomaly **1**.

Anomalies **8** and **9** may also represent possible structural remains, however they may also be associated with ground disturbance caused by the nearby bank and car park boundary and its construction. Anomalies **12** and **13** may also represent small areas of structural remains (Example Radargram 6).

Broad crested anomalies – possible structural remains

One broad crested anomaly has been identified in the south of survey Area 1 (**19**). This anomaly may represent weak evidence for structural remains or may be a possible service (Example Radargram 5).

Five broad crested anomalies have been identified mainly situated in the central area of survey Area 2 (**14-18**). These anomalies may relate to structural remains of archaeological origin. Anomalies **14**, **15**, **17** and **18**, may identify structural remains associated with the 1810 building (see Figure 13).

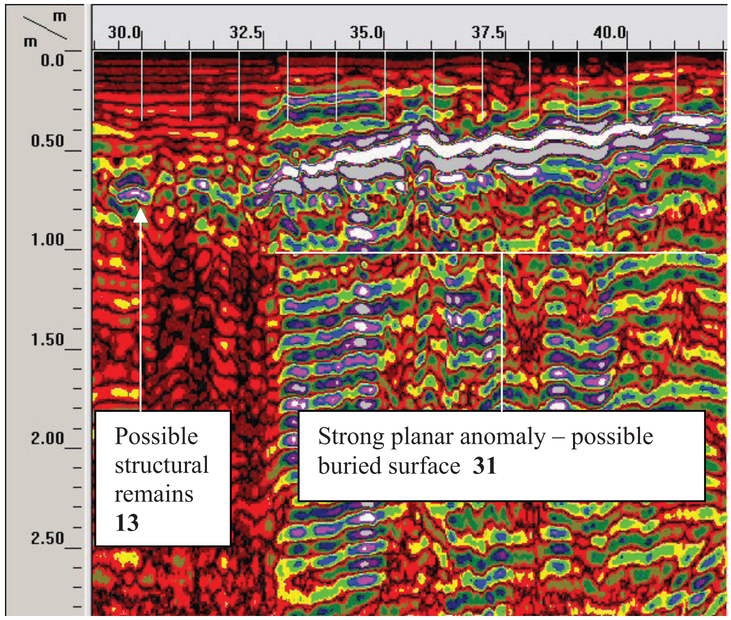


Example Radargram 5: Area 1 along traverse 3W, 19-31S. Showing weak planar anomalies and a broad crested anomaly possibly represent structural remains or a service

Strong planar and complex anomalies – may relate to a buried surface with interspersed structural remains

Two small areas of strong planar response have been identified towards the central edges of survey Area 1 (**35** and **36**). These anomalies may be caused by the present floor construction or indicate a previous floor level (example Radargram 1).

A large area of strong planar response has been identified in the south of survey Area 2 (**31**). This anomaly may represent a possible buried surface at approximately 0.4m deep. Anomaly **31** has clearly defined edges, and may be associated with a building identified on the 1810 estate map, possibly representing a cobbled or paved courtyard. Further areas strong planar anomalies situated within Area 2 may also represent previous floor levels of possible archaeological origin (**32-34**) (Example Radargram 6).



Example Radargram 6: Area 2 along traverse 27.5W, 29-42S. Showing a strong planar anomaly – possibly indicating a previous floor level

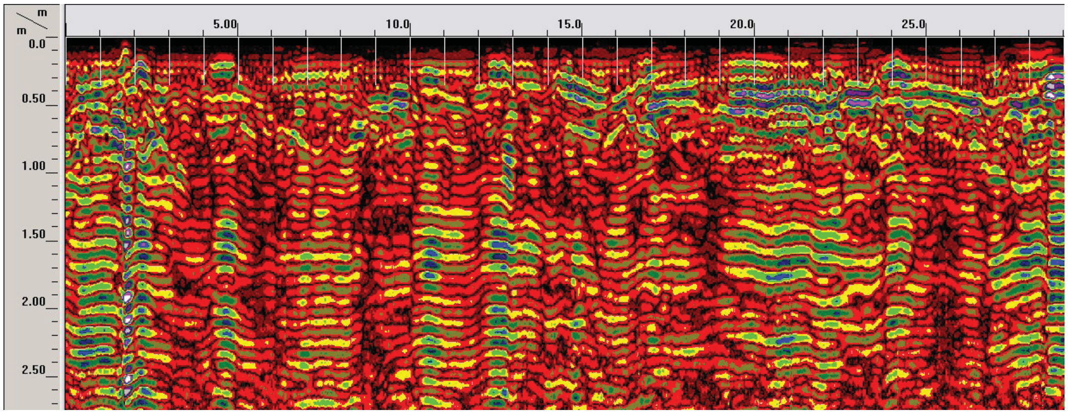
Weak planar and complex anomalies – may relate to a buried surface with interspersed structural remains
A number of weak planar anomalies have been identified throughout survey Area 1 (**39** and **40**). These anomalies may be caused by the present floor construction and appear at an approximate depth of 0.25m (Example Radargram 5).

Weak planar anomalies situated within Area 2 appear mainly in the west of the survey area. Anomaly **37** may represent the continuation of anomaly **31**. Anomaly **38** may indicate an area of buried surface towards the western edge of the survey area.

Weak discrete anomalies – possibly relating to structural remains
Situated across survey Area 2 are a number of weak discrete anomalies that may provide weak evidence for structural remains (**41- 43**). Anomalies **41** and **43** may be associated with the 1810 structure.

Two areas of weak discrete anomalies have been identified within the north of survey Area 3 (**46**). These anomalies may represent weak evidence for structural remains or ground disturbance possibly relating to the previous structure present on the Ordnance Survey map of 1900 (Figure 13).

Modern anomalies
A number of manhole covers and drainage gulling have been identified in the form of conductive surfaces. Two areas of reinforced concrete have also been identified within survey Areas 1 and 2 (see example Radargram 1 and 7).



Example Radargram 7: Area 2 along traverse 36.5W, 0-29S. Showing evidence for reinforced concrete at approximately 20cm centres in the form of small point diffractions

5 CONCLUSION

A large area of possible structural remains and debris has been identified in the northwest of Area 2. These anomalies are likely to represent the structural remains of a building known to have existed on the site during the early 1900's (Figure 13). A larger area of strong planar response has been identified in the south of survey Area 2 and may represent a buried surface relating to the glassworks complex. Area 1 provides a number of anomalies that may relate to structural remains, whereas Area 3 has revealed less substantial anomalies, producing weaker evidence for structural remains. Areas of reinforced concrete have been identified within the south of Area 1 and along the entrance driveway within Area 2.