Site: **Keresforth Close, Barnsley.**

Project Title: **Geophysical Survey.**

Survey Period: 3rd to 5th October 2022

Client: **Curtins**
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DISCLAIMER

THIS REPORT REPRESENTS THE BEST PROFESSIONAL OPINION OF THE AUTHOR. EVERY EFFORT HAS BEEN MADE TO ENSURE ACCURACY AND RELIABILITY OF GEOPHYSICAL SURVEY DATA.

GEOPHYSICAL SURVEY DATA SHOULD NOT BE USED AS THE SOLE MEANS OF SITE ASSESSMENT. GEOPHYSICAL DATA CAN BE INFLUENCED BY A COMBINATION OF MANY SUB-SURFACE FACTORS LEADING TO NON-UNIQUE INTERPRETATIONS. SURVEY RESULTS MUST BE COMBINED AND VERIFIED WITH INTRUSIVE METHODS FOR DEFINTIIVE CONFIRMATION.

A GEOPHYSICAL SURVEY MAY NOT LOCATE ALL SUB-SURFACE TARGETS SINCE DETECTION LIMITS WILL APPLY. A LACK OF GEOPHYSICAL TARGETS WITHIN THIS REPORT DOES NOT WARRANT THAT ALL TARGETS WITH POTENTIAL CONSEQUENCE FOR COSTS HAVE BEEN LOCATED.

ANY CHANGE IN SITE CONDITIONS POST-SURVEY, SUCH AS REDUCTION IN ELEVATION AND REMOVAL OF SURFACE OBSTRUCTIONS, MAY LEAD TO DISCOVERY OF UNFORESEEN GROUND CONDITIONS WHICH WERE BEYOND DETECTION AT THE TIME OF THE GEOPHYSICAL SURVEY. IT IS THE RESPONSIBILITY OF THE CLIENT TO UNDERSTAND AND ADVISE THAT NO COMBINATION OF GEOPHYSICAL SURVEY, INTRUSIVE WORKS OR DESK STUDIES CAN ELIMINATE ALL SUBSEQUENT CONSTRUCTION RISKS.

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1 Introduction

This report contains the results and conclusions following a geophysical investigation within the former playing field off Keresforth Close, Barnsley, South Yorkshire.

The purpose of the survey was to obtain a site-wide electromagnetic conductivity and magnetometry dataset. The survey output was intended to indicate the position of geophysical anomalies which might relate to mining relicts, natural or man-made changes in infill or sub-surface composition and other potential man-made influences. A further survey using ground penetrating radar was undertaken in the north of the site within an area close to a collapse which occurred in 2014. Three tunnels with their crowns at around 2.5m below surface were noted within the collapse running along alignments of SE, SW and NE.

The survey was undertaken between the 3rd and 5th October 2022.

2 Site Details

The Keresforth Close site lies 1.4km south-west of Barnsley centre with the site centre at National Grid coordinates 433351, 405486. Figure 1 shows the site location and key site details. Figure 2 shows some site photographs taken during our visit.

The site area covers approximately 2.7Ha and comprised flat lying short grass. The site was a former playing field and was well drained at the time of our visit. The site is bounded to its north by a metal fence and a steep slope beyond which was the road leading into Keresforth Close. The site is bounded to its west by a metal fence and the A6133, to its south by an embankment leading down to a footpath and to its east by a hedge and fence above the lower section of Keresforth Close.

Close to the site centre a horded off area marked the location of shaft 433405-008.

A collapse in the north of the site, recorded and treated by the Coal Authority in 2014 lay close to the fence line south of Keresforth Road at coordinates 433300, 405590 (Figure 1). The Coal Authority report states that during treatment three tunnels were noted with crown levels at around 2.5m below surface. The tunnels are described as roadways and these were noted on alignments of SE, SW and NE. The SE aligned tunnel if present, may run towards shaft 433405-008.

Within the site the ground surface was uniform with no obvious visual evidence for sub-surface disturbance or man-made relicts. The exception to this lay around the entrance gate at the north of the site where the ground surface was disturbed possibly due to the passage of vehicles in wet weather.

According to the British Geological Survey online resources, the likely geological sequence at the site is as follows:-

1. Superficial deposits. None recorded. Likely to be a thin topsoil with imported materials for levelling the playing field.
2. Solid Geology. The majority of the site is underlain by the Pennine Middle Coal measures comprising sandstone, mudstone and siltstone sequences. A small area at the north of the site is underlain by Pennine Middle Coal measures sandstone, possibly a unit termed Barnsley Rock.

3 Geophysical Survey

3.1 Survey Objectives

The objectives of the survey were to:

- Cover the full accessible area of the playing field to produce a map of conductivity and magnetic gradient anomalies or zones to enable later targeting of anomalies likely to be of significance. This aim fitted with the need to attempt to locate evidence of the tunnels/road ways noted in the 2014 collapse and unrecorded mine workings such as shafts.
- Undertake a GPR survey in a specified survey area at the north of the site where the 2014 collapse and its associated tunnels / roadways were noted.
- These aims were to be covered where access and practical limits were deemed suitable. Note that at the very north of the site a wire fence and a steep embankment prevented access and affected the conductivity and magnetic instruments.

3.2 Electromagnetic (EM) Ground Conductivity Measurements

Electromagnetic measurements can be used to map out the variations in conductivity of sub-surface materials. Ground conductivity is measured in SI units of milli-Siemens per metre (mS/m). Ground conductivity variations can be caused by:-

- Changes in geology. For example changes in the type of superficial cover and/or changes in its thickness.
- Changes in made ground composition
- Variations in moisture/water content
- The presence of in-situ structural remains
- The presence of metals within buried structures

3.3 Electromagnetic (EM) Ground Conductivity Equipment

The survey was undertaken using a Geophex GEM2. The instrument consists of a flat “ski” containing the transmitter, receiver and balancing coils together with the required control electronics.

The GEM2 is carried by an operator with data being continuously collected at linear intervals of around 0.15m. The instrument was located using a Hemisphere A101 dGPS system with an accuracy of ±0.5m. Raw data were recorded onto a Trimble Nomad field logger. As the site was open, dGPS position quality was always in excess of the minimum requirements.

The GEM2 can collect data simultaneously using a number of frequencies which can permit the results to be tailored to a particular depth range. The depth range covered is not a fixed relationship to a particular frequency. Based upon many previous surveys we *estimate* that the equipment may have recorded data over a depth range of 0 to 4/5m.

3.4 Electromagnetic (EM) Ground Conductivity Processing

During each survey period, survey data were periodically downloaded from the Trimble logger to ensure data security and to undertake a check on data quality. During each day the survey instrument was setup over the same location to ensure that daily repeatability was maintained. Additionally a comparison of the instrument readings and dGPS locations between beginning and end of each day was made to check for drift. In each case the variance in instrument readings was minimal with drift also minimal such that no further corrections were necessary.

After each data file was downloaded, the raw binary data were inverted to EM conductivity values using WinGEM2. Subsequently, spreadsheet editing of null values and conversion of geodetic coordinates into OS National Grid using the OSTN02 transform within OS utility Grid InQuest were undertaken. Golden Surfer 20 was then used to combine the survey data, grid each data file, filter and colour code the data as contour plots.

3.5 Magnetic Measurements

Magnetometer surveys map out localised variation in the Earth's magnetic field which can be caused by the presence of magnetic objects and variations in ferrous content of drift, infill or solid geology.

3.6 Magnetic Equipment

Sensitive instruments can measure the total magnetic field at any one place on the Earth's surface. These instruments are known as magnetometers and they can measure field variations of 0.01nT (nanoTesla). For comparison, the strength of the Earth's magnetic field is around 50nT but this can vary according the location on the globe and due to local geological variations.

This survey utilised a Geometrics G-858 caesium vapour magnetometer. This instrument can sample the field at up to 10 times per second with a sensitivity of ~0.01nT.

The system operates using the optical pumping principle in which circular polarised light forces spin alignment of gas atoms. The degree of alignment is proportional to the local field strength.

At the site the system was set up such that the total magnetic field was measured using two sensors, one above the other. In this configuration the data collected can show the upper sensor measurements which can be more sensitive to larger deeper targets or the lower sensor data which can be more sensitive to shallow targets. Using the data from both sensors, the vertical magnetic gradient can be calculated which can help filter out near-surface noise whilst indicating the variation in the rate of change of the magnetic field below the sensor pair. After processing the most appropriate sensor properties are used for interpretation purposes.

During the survey the dGPS receiver data and the magnetic field data were recorded by the G-858 console which was worn around the operator's waist. Once the survey setup had been programmed into the data logger all accessible areas of the survey area were covered.

Magnetometer readings were collected at a fixed point at the beginning and end of the survey period to check for instrument drift and diurnal magnetic field variation. Over the short survey duration diurnal variations were minimal and instrument drift was considered negligible.

3.7 Magnetometer Data Processing

Once in the office, data were downloaded from the G-858 console using Magmapper software. The software allows the user to view the raw data and make an initial assessment of its quality and to account for the dGPS and magnetometer offset. Some limited smoothing and filtering operations are also possible.

The dGPS data downloaded with the magnetic data were converted to Ordnance Survey eastings and northings. Once the combined dataset is processed the data were output in a format suitable for gridding using Surfer.

The data were gridded using Golden Software Surfer. Appropriate filtering and contour levels were chosen to illustrate the magnetic characteristics of the site by removal of noise and survey artefacts. The most informative magnetic parameter (gradient or total field) was then chosen for final interpretation and presentation. In this case we chose to present the data as magnetic gradient which can pick out more subtle magnetic variations.

3.8 Ground Radar Measurements

Ground penetrating radar (GPR) uses pulsed electromagnetic waves emitted into the ground via a screened antenna, to build up a 2-dimensional image of the subsurface.

A single pulse consists of a wave train of electromagnetic energy propagating from the transducer into the subsurface. At an interface between materials with differing electromagnetic properties, a proportion of the electromagnetic energy is reflected and the remainder continues into the subsurface. The amount of reflected energy is governed by the dielectric constant (contrast) between the materials at any interface.

The reflected signal pulses are measured by the receiving transducer in the antenna and the relationship between reflection time and remaining energy can be used to build up a 2-dimensional subsurface image using successive pulses as the system moves along the ground surface.

In terms of voiding and subsidence, GPR characteristics include high amplitude ringing within voids, a stronger reflector from the base of depressions, chaotic reflections from infilled zones and when viewed in map form, the ability to trace suspected fractures or zones of voiding.

3.9 Ground Radar Equipment Used During this Survey

The survey was undertaken using a GSSI SIR 4000 radar system. Having trialled several antenna at the site we chose to complete the survey using a 270MHz antenna.

3.10 Ground Radar Data Processing

In our offices the raw GPR data are reviewed using Radan 7. Radan is specifically designed to process data obtained from GSSI radar systems. The data are processed to a point where the results are sufficiently clear for the purposes of the survey. The processing steps are typically:

1. Time zero correction. Move surface reflection to 0ns.
2. Apply a gain function to enhance signal clarity over the useable time range.
3. Apply a background removal. Removes flat lying multiples and frequency effects.
4. Apply band-pass filters to reduce noise.
5. Choose an appropriate colour mapping.
6. Combine individual survey grid blocks into a single composite data block for interpretation and visualisation.

4 Survey Layout

Baselines were installed at the northern and southern ends of site. Marker flags were placed at 2m intervals along each baseline to act as aiming points to assist the operator to maintain parallel survey lines.

The GEM2 and G-858 magnetometer were traversed back and forth at ~2m line separations until the full site had been covered. Linear sampling rates obtained a sample at intervals of around 0.15m locally dependent upon traverse speed.

The GPR survey was undertaken within the specified survey area at the north of the site. Baselines were installed at the eastern and western side of the survey area and survey data was collected along survey lines spaced at 2m intervals with linear sampling at 0.05m.

5 Results

Figure 3 shows the results for the full site survey with conductivity and magnetic gradient data being plotted on the OS grid.

We can summarise the conductivity results as follows:-

1. Overall the conductivity data has a low overall range between 0 and 11mS/m. This suggests the presence of near-homogenous ground conditions. In this case we suggest the conductivities reflect minimal superficial cover over Pennine Middle Coal Measures.
2. Despite the low conductivity ranges there are some obvious zonal variations and some more localised anomalies within the conductivity distribution.
3. At the north end of the site we note a near-regular shaped area with higher conductivity. The regular shaped nature of this zone may suggest that:
    a. the sub-surface materials reflect human influence such as excavation or possibly the location of a former building. The potential for being related to mining cannot be excluded without intrusive confirmation.
    b. We note from the BGS online geological database that there is a small area within this locality of the site which comprises Barnsley Rock, a sandstone.
4. There is a slight conductivity variation over and adjacent to the 2014 collapse. This may reflect the infill materials.
5. A zone of increased conductivity is noted along the SW boundary of the site adjacent to the A6133. The zone appears to posses some degree of regularity in its shape.
    a. The area could reflect human influence on sub-surface materials, for example excavation and reinstatement. The potential for being related to mining cannot be excluded without intrusive confirmation.
    b. The conductivity could reflect, in part the influence from passing vehicles and the metal railings in the fence. However this zone is only noted in the SW corner of the site and does not continue along the full extent of the western site boundary.
    c. The zone could reflect a local geological change or even a change in ground water content.
6. Anomaly C1 in the SE corner of the survey area is a high conductivity, very localised anomaly. Without the benefit of intrusive confirmation and considering the site context it may represent:-
    a. A localised natural change in materials properties
    b. A localised man-made influence such as debris, imported infill or
    c. A possibility that it relates to infill in a former shaft
    d. We note no equivalent magnetic gradient anomaly suggesting that no or minimal ferrous materials are present.
7. Anomalies C2, C3 and C5 are also localised conductivity anomalies. The amplitude of these zones is considerably less that anomaly C1. Taking the site context into account but without the benefit of intrusive confirmation they may relate to:-
    a. Natural sub-surface geological variations
    b. Disturbed or infilled ground relating to former human use, including mining
    c. Localised variations in ground water content.
    d. Anomaly C5 lies along the possible route of a tunnel trending SE from the 2014 collapse. No linear anomaly can be determined within the conductivity or magnetic gradient data in this area.
8. Anomaly C4 displays a regular shaped, minor increase in conductivity. We speculate that it may be related to:-
    a. Natural geological or moisture content changes or
    b. A man-made influence such as an in-situ or removed structure
    c. We note that this anomaly coincides with a subtle but well defined square magnetic gradient anomaly (Figure 3).
9. We note some evidence for a north to south trending linear anomaly defined by some very subtle increases in conductivity (dotted line Figure 3). Some intrusive works may be

required to confirm whether this anomaly is real or simply a ghost feature. No equivalent magnetic gradient anomaly is noted.

10. There is an area of low conductivity at the west of the site centred on coordinates 433300, 405500. Without the benefit of intrusive confirmation this could represent:
    a. A change in geological composition
    b. Very shallow rockhead depths.
11. There is no clear geophysical evidence for tunnels trending from the 2014 collapse within the conductivity data.

We can summarise the magnetic gradient mapping as follows:-

1. There is a very low overall range in the magnetic gradient aver the site. This suggests that there is a near-homogenous sub-surface material which would be expected with a shallow rockhead level.
2. In-situ goal post sleeves remaining within the sub-surface have been indicted as "GP" on Figure 3 after reference to aerial photographs.
3. A faint linear anomaly is noted trending SE from the general area of the 2014 collapse. Taking the site context into account this could be:-
    a. A tunnel or
    b. A coincidentally located service
    c. A field drain?
4. Two further faint linear gradient anomalies are noted within the site. One is located in the north of the site and trends SW to NW, north of shaft 433405-008. A second faint linear gradient anomaly is noted south of shaft 433405-008 and trends E to W. Taking the site context into account these linear segments could relate to
    a. in-situ remains of structures,
    b. truncated services or
    c. field drains?
5. South of shaft 433405-008 we note a square shaped magnetic gradient anomaly which also coincides with a regular shaped area of increased conductivity. This anomaly could represent the outline of a former building? Intrusive works will be required to confirm the identity of the anomaly.
6. Remaining anomalies within the magnetic gradient data appear to be localised. Each anomaly has been referenced on Figure 3. Intrusive works will be required to confirm their identity. Localised anomalies can represent items of ferrous debris but a connection with former mining such as shafts cannot be excluded since rudimentary shaft "capping" often included metal rails to block the shaft opening.
7. We note the presence of a significant magnetic gradient anomaly immediately north of the hording around shaft 433405-008. A steel gate providing access into the horded off area is likely to have influenced the magnetic field in this area making an interpretation impossible.

Figure 4 shows the GPR data collected within the specified survey area at the north of the site. The data are shown separately on the left and as an overlay on the magnetic data on the right. This area is marked by a green dashed outline on Figure 3. The GPR data can be summarised as follows:-

1. The overall penetration of the GPR system as poor. Signal to noise ratios meant that the maximum useful depth of penetration was around 1.5 to1.75m.
2. Within the useable penetration depth, the GPR returns were typical of those expected for compact homogenous material as would be expected within rockhead close to the surface.
3. Despite the quiet nature of the GPR mapping, we noted a clear linear higher amplitude anomaly running from the general area of the 2014 collapse towards the SE. This linear anomaly closely aligned with the magnetic anomaly.
4. The GPR data also show a slight increase in amplitude along the survey areas southernmost extent. Within these slightly elevated amplitudes we note a single localised area of maximum amplitude reference G1 on Figure 4. Intrusive works will be required to

confirm this target which appears to lie at a depth of around 0.5m based on an estimated time-depth calibration for the GPR signal velocity.

6 Discussion and recommendations

6.1 Discussion

The conductivity and magnetic gradient survey have covered the full accessible areas within the former playing field at Keresforth Close. The output data provide high resolution coverage of conductivity and magnetic gradient changes within the site, which will permit targeted intrusive works to be undertaken as this will be the only means to confirm the physical nature of each anomaly or zone.

The GPR data have provided some degree of coverage at the north of the site over and adjacent o the 2014 collapse. The GPR penetration depths were poor in this area possibly due to the higher pore water contents. Despite this, the GPR survey element confirmed the orientation of a linear anomaly trending south from the general area of the former collapse.

In terms of possible geophysical evidence for tunnels or roadways within the data we note a relatively narrow linear anomaly within both the magnetic gradient data and the GPR data. The GPR data suggests that the target lies at shallow depth (<1m). However as this linear anomaly appears to originate from the 2014 collapse we suggest this is a potential tunnel target until proven otherwise.

The tunnels noted within the collapse running to the NE and SW have no obvious geophysical signature within the data. However we point out that the wire fencing which will have affected both conductivity and magnetic data. In addition, the presence of a steep embankment below the Keresforth Close access road prevented survey access as far as the site boundary. Both these site characteristics mean that no effective survey was possible in these areas. As such, the NE and SW tunnels may not have been passed over.

Other than the narrow linear magnetic anomaly trending SE along the site length and the very faint conductivity anomaly running N to S there is no further geophysical evidence for the presence of tunnels. Note that a lack of geophysical evidence does not indicate a lack of tunnels since they may be beyond detection limits.

6.2 Recommendations

Table 1 below contains the OS coordinates of the localised and linear anomalies noted within the survey data. We recommend that these are investigated using trial pits.

We recommend that the square shaped anomaly noted within the magnetic gradient data has its identity confirmed via slit trenches crossing its boundary. The regular nature of this anomaly may reflect the presence of a structure.

We recommend that the linear anomaly running south from the 2014 collapse is investigated via trial pit. The two further linear anomalies could be checked similarly.

We recommend that if desired the various conductivity zones noted on Figure 4 could be investigated to understand the sub-surface characteristics but this may not be necessary based on the intended site use. Figure 2 can be used to target these works as they are more widespread.

We also recommend that a further geophysical technique might be worthwhile in the north of the site whilst the opportunity is available. We would suggest that Electrical Resistivity Tomography (ERT) could be used to measure the electrical properties of the sub-surface along linear transects running perpendicularly to the possible SE trending tunnel. The resultant output from the method is a vertical profile showing the resistivity distribution which can indicate stratigraphic relationships but can also indicate the locations of tunnels as localised resistivity highs. Two profiles running E to W and spaced around 20m apart may be useful as a further check for any Se trending tunnels entering the site. Unfortunately the geometry of the site and its northern boundary conditions means that this method would not be suitable to detect tunnels running parallel to or along that boundary. Intrusive works will be required in these locations as the current geophysical output is inconclusive in the area.

Anomaly ID	Easting/Northing	Notes
C1	433449.0, 405460.6	Possible shaft cap?
C2	433406.6, 405440.2	Conductivity localised zone
C3	433422.0, 405458.5	Zone localised zone
C4 / Square magnetic anomaly. Four corners	NW 433363.8, 405503.9 NE 433386.2, 405519.6 SE 433403.0, 405494.9 SW 433379.9, 405481.1	Defined by both conductivity and magnetic gradient
C5	433337.0, 405544.7	North of hording around shaft 433405-008
M1	433372.2, 405585.0	Localised magnetic anomaly
M2	433297.2, 405577.6	Localised magnetic anomaly - near linear magnetic and GPR anomalies
M3	433302.4, 405572.5	Localised magnetic anomaly - near linear magnetic and GPR anomalies
M4	433289.5, 405570.3	Localised magnetic anomaly
M5	433352.6, 405562.2	Localised magnetic anomaly - on linear magnetic anomaly
M6	433326.8, 405544.6	Localised magnetic anomaly - on linear magnetic anomaly
M7	433400.7, 405550.2	Localised magnetic anomaly
M8	433260.7, 405535.1	Localised magnetic anomaly
M9	433291.2, 405532.6	Localised magnetic anomaly
M10	433342.3, 405514.5	Localised magnetic anomaly
M11	433326.0, 405474.2	Localised magnetic anomaly
M12	433319.5, 405467.7	Localised magnetic anomaly
M13	433398.1, 405476.7	Localised magnetic anomaly
M14	433384.0, 405437.2	Localised magnetic anomaly
Magnetic and GPR Linear. Start / End coordinates	433301.6, 405578.9 to 433357.8, 405430.8	Linear anomaly. Coincident with reported SE tunnel in 2014 collapse.
Magnetic SW-NE trending linear north of shaft 433405-008	433326.8, 405547.1 to 433376.7, 405575.8	Linear anomaly. Field drain, structure, tunnel?
Magnetic W-E trending linear south of shaft 433405-008	433334.2, 405500.7 to 433293.4, 405489.3	Linear anomaly. Field drain, structure, tunnel?

6.3 Survey limitation statement

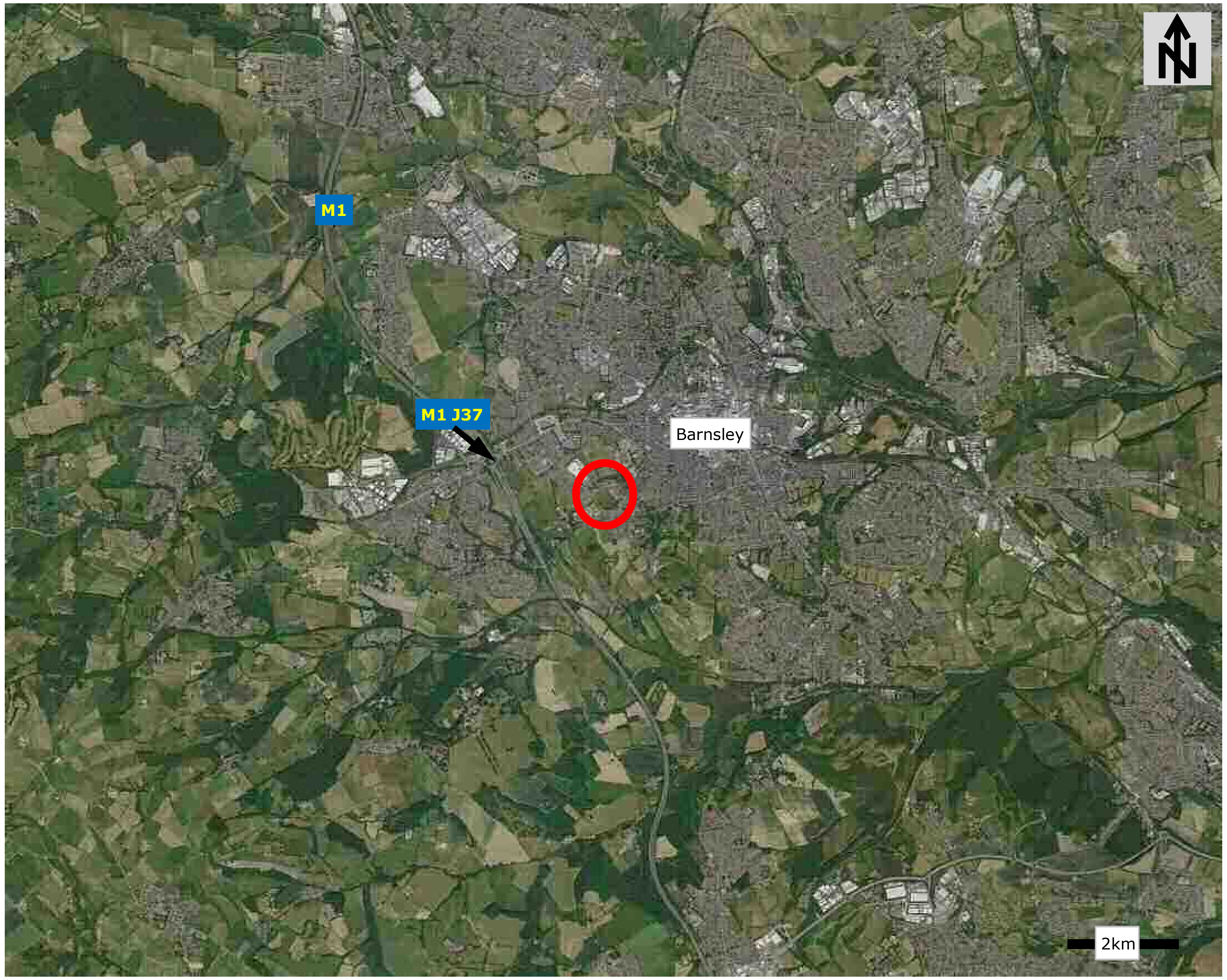
1. Geophysical methods rely on detecting contrasts in materials properties. Where complex relationships exist or where there is an insufficient geophysical contrast between materials or targets, the detection of sub-surface targets will lie beyond the working limits of any geophysical instrumentation or interpretation. As such a lack of geophysical targets cannot therefore be used to infer that there is no risk to future construction methods or related costs.
2. Geophysical survey data must not be used as the sole means of a site assessment. Survey data must be combined with desktop studies and intrusive site investigation methods in order to provide the ultimate client with the best possible understanding of sub-surface

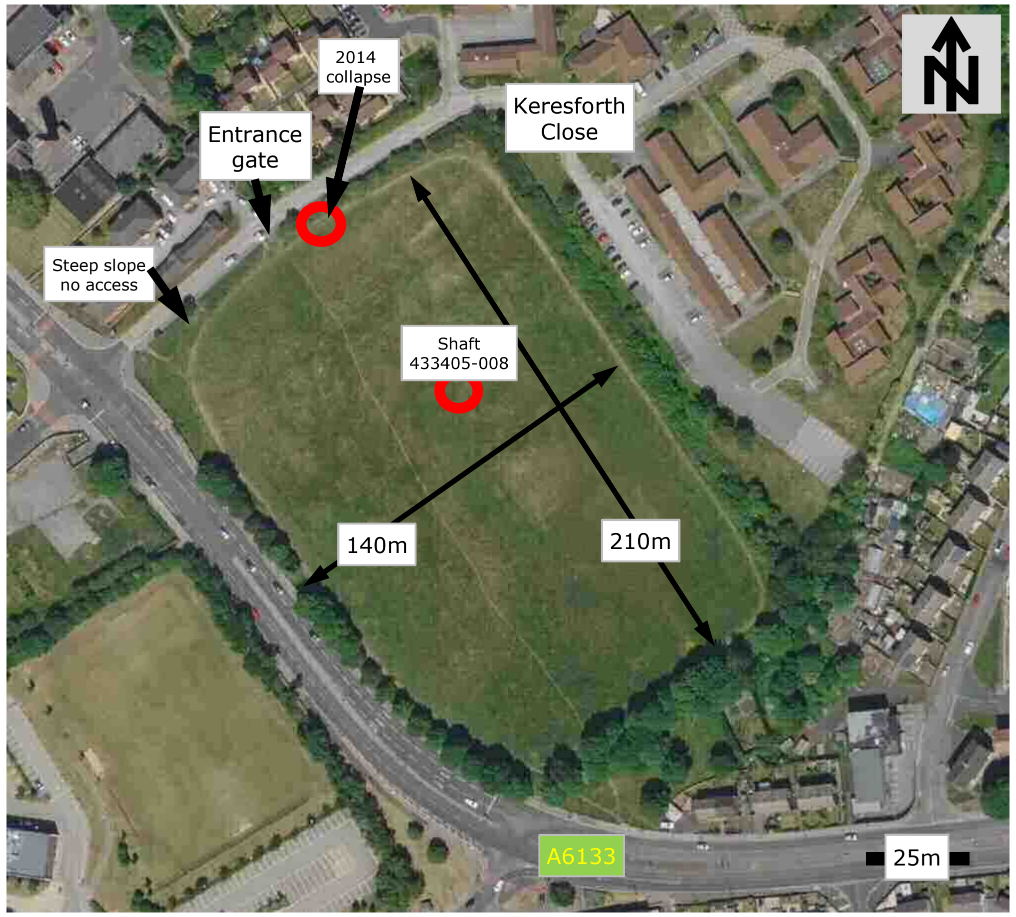
conditions and risks. This understanding and the assessment of risk will based upon the volume of investigative works undertaken, coupled with the limitations of all site investigation strategies.
3. The remit for this survey and the methodologies used will not meet those required by a PAS128 utility survey.
4. The survey data reflect the geophysical conditions offered by the site at the time of the survey. Reduction is elevations, deeper excavations and operations such as piling, will reach depths beyond the effective range of surface-based geophysical methods. Risks to these operations must be considered.
5. The survey data reflect only those areas covered and the results cannot be used to imply sub-surface characteristics elsewhere within the site.

Dr Steven Openshaw (BSc, PhD, FGS)

Director
For Bentham Geoconsulting Limited
October 17th 2022

Figure 1: Site Location





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Keresforth Close

Figure 1. Site location

Site : Keresforth Close, Barnsley
Survey Dates : 3rd to 5th October 2022

Figure 2: Site Photographs


View towards the south-east over the 2014 collapse area.
The boarded area is shaft 433405-008


View towards the north-east over the 2014 collapse area.


GPR survey underway within the specified search area north of shaft 433405-008

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Figure 2. Site photographs

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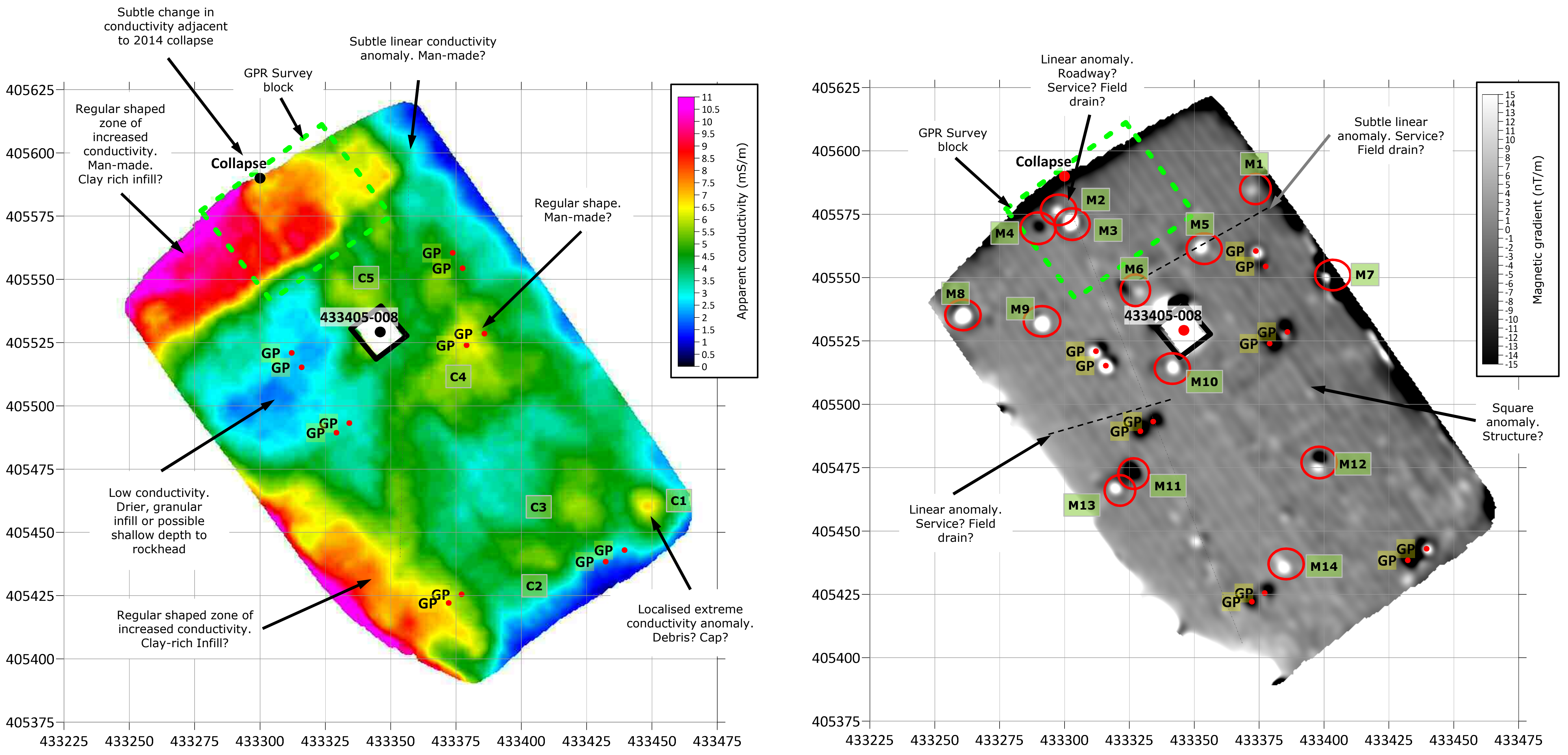
Figure 3: Magnetic and Conductivity Survey Mapping.



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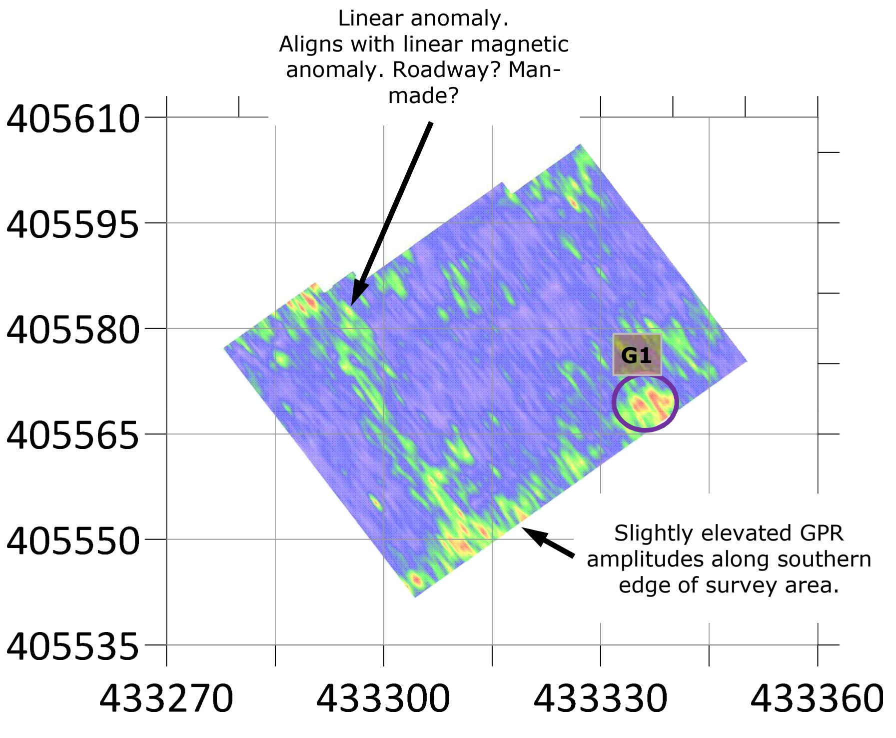
- Goal Post (Location obtained from historic aerial photographs)
- Localised anomaly - debris? Cap?
- Collapse

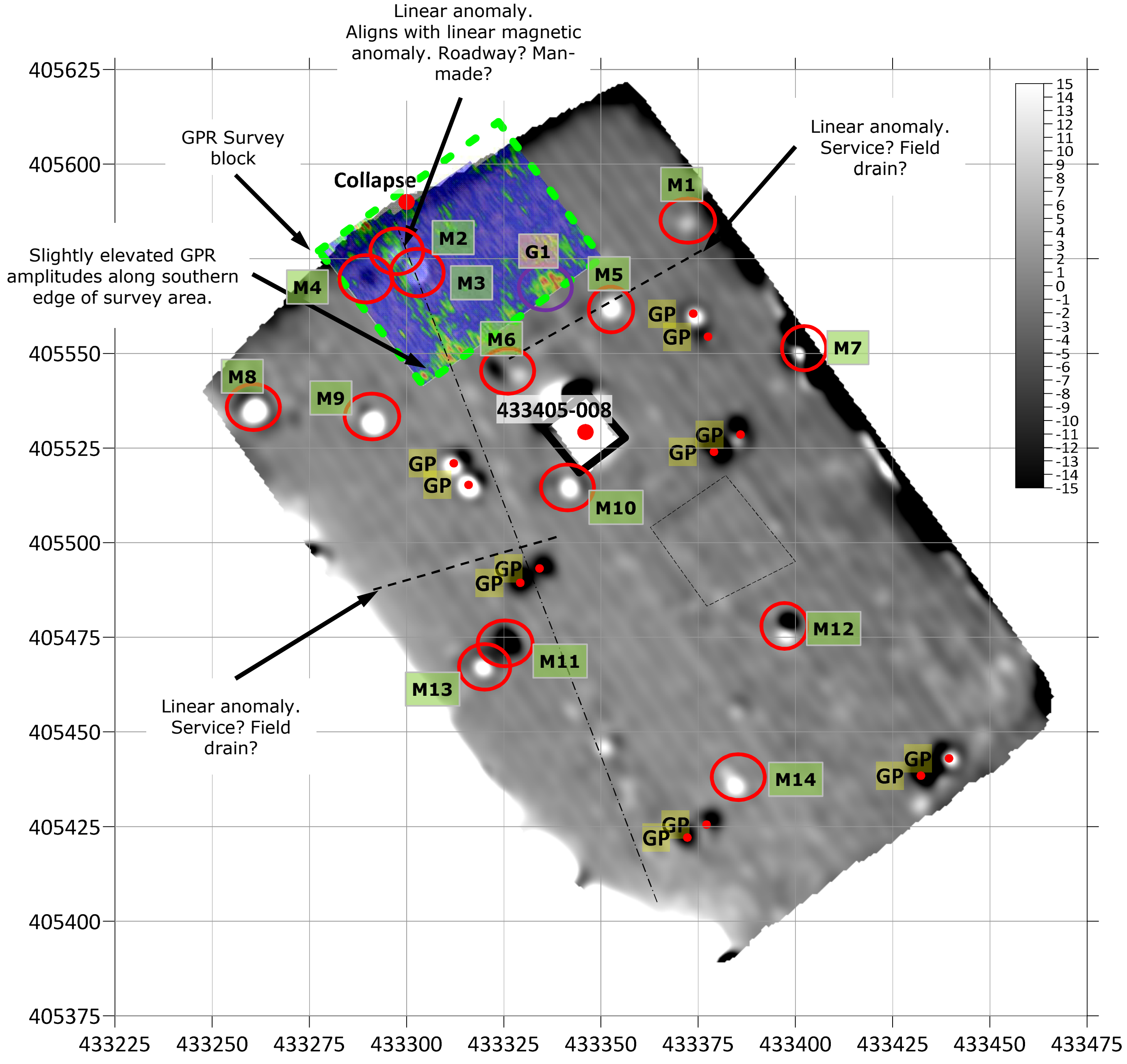
Figure 3. Magnetic and Conductivity Survey Mapping.

Site : Keresforth Close, Barnsley
Survey Dates : 3rd to 5th October 2022

Figure 4: GPR Survey data with overlay on magnetic gradient mapping data.



GPR



GPR DATA ON MAGNETIC

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Goal Post (Location obtained from historic aerial photographs)
Localised magnetic anomaly
Collapse
GPR anomaly

Figure 4. GPR Survey data with overlay on magnetic gradient mapping data.

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