



Land off Hillock Lane, Gresford, Wrexham

Specification for Geophysical Survey (Caesium Vapour Magnetic – Archaeology)

Version 1.0

Project code: HLG191

Produced for: Icení (on behalf of Norris Jones
Developments Ltd)

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Table of Contents

1 Introduction.....	1
1.1 Overview.....	1
1.1.1 Environment.....	1
1.2 Geology and soil.....	2
1.3 Other site effects.....	2
1.4 Archaeology.....	2
2 Discussion.....	3
2.1 Objectives.....	3
2.2 Principles – magnetic survey.....	3
2.2.1 Resolution.....	3
2.2.2 Soil properties.....	3
2.2.3 Instrumentation.....	4
3 Methodology.....	4
3.1 Introduction.....	4
3.2 Magnetic survey.....	4
3.2.1 Technical equipment.....	4
3.2.2 Monitoring & quality assessment.....	4
3.2.3 Envisaged process stages.....	4
3.2.4 Note on magnetic data handling from different instrument types.....	5
3.3 Deliverables.....	5
3.3.1 Reporting content.....	5
3.4 Archiving and dissemination.....	5
3.5 Caveats.....	6
3.6 Bibliography and selected reference.....	6
4 Supporting information.....	8
4.1 Standards and quality (archaeology).....	8
4.2 Key personnel.....	9
4.3 Ensuring safety.....	10

1 Introduction

1.1 Overview

A geophysical survey has been commissioned by Iceni (on behalf of Norris Jones Developments Ltd) to prospect for buried features of potential archaeological interest on a parcel of land off Hillock Lane, Gresford, Wrexham.

Country	Wales
County	Wrexham
Nearest Settlement	Gresford
Central Co-ordinates	336029,354478
Proposed Survey Area (ha)	6.1

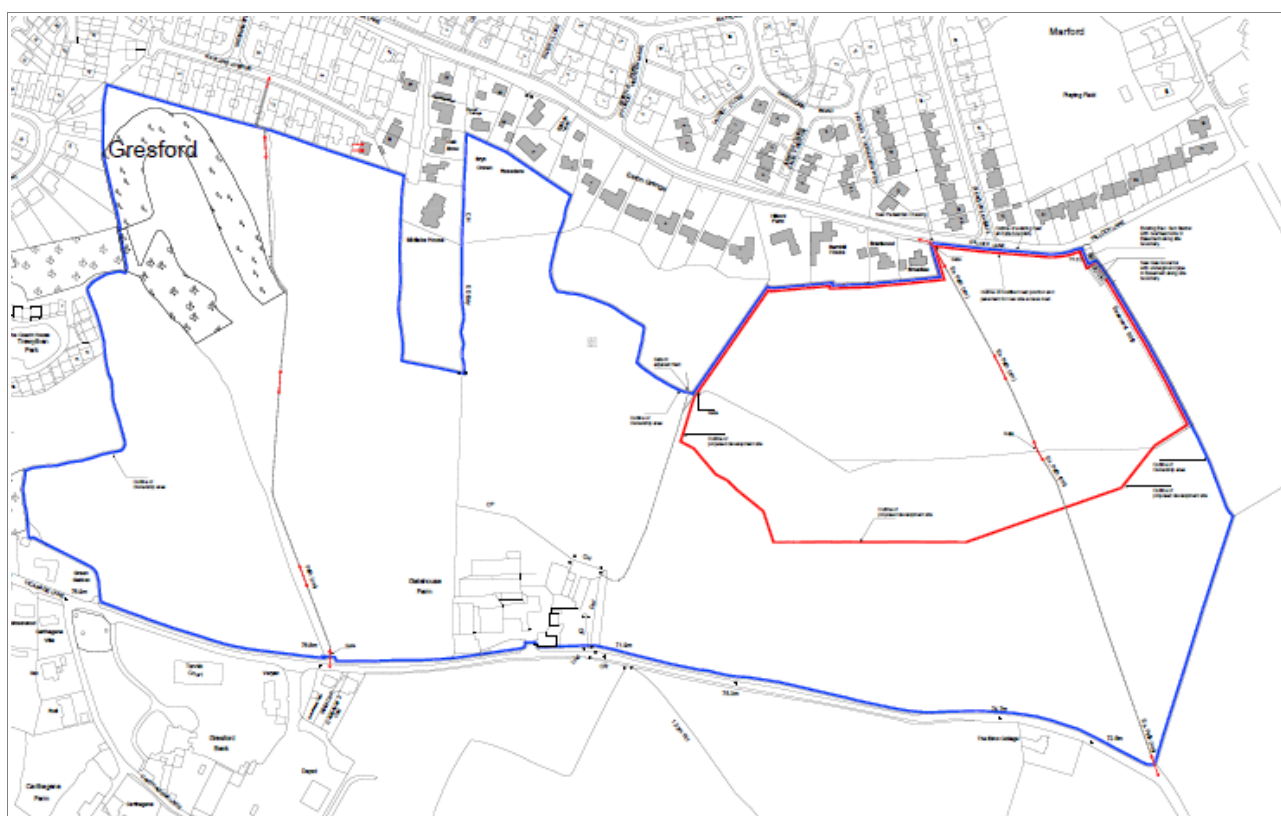


Figure 1: Extract from map supplied by the client showing the proposed survey outlined in red

1.1.1 Environment

Soilscapes Classification	Freely draining slightly acid sandy soils (10)
Superficial 1:50000 BGS	Glaciofluvial Sheet Deposits, Devensian - Sand And Gravel (GFSDD)
Bedrock 1:50000 BGS	Salop Formation - Mudstone, Sandstone And Conglomerate (SAL) Kinnerton Sandstone Formation – Sandstone (KNSF)
Topography	Flat
Hydrology	Freely draining
Current Land Use	Agricultural – Pastoral
Historic Land Use	Agricultural – Mixed

Soilscapes Classification	Freely draining slightly acid sandy soils (10)
Vegetation Cover	Grass
Sources of Interference	Potential ferrous interference from residential properties and vehicular movement adjacent to the northern boundary, and a small sub-station on the north corner and overhead cables from this along the eastern boundary, agricultural and other ferrous debris and potential below ground services.

1.2 Geology and soil

The dominant character within the data is likely to be due to the superficial deposits, with the sand and gravel of the Glaciofluvial deposits likely uneven and containing pockets of soil and sometimes magnetic glacial erratics. The magnetic field will thus be variable and to what extent weak anomalies from buried features of interest will be detected will vary locally.

The BGS (British Geological Survey) G-Base soil iron content is 2.6% (5km resolution) and is not particularly high but is likely to be sufficient for the soils to support magnetic enhancement, therefore allow detection of variations in topsoil depth, including those relating to features of potential archaeological interest

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1.3 Other site effects

The proposed survey area is open and full survey coverage is anticipated. There is some potential for ferrous interference along the northern boundary, but this will be localized and will not impact overall data quality. There is a public footpath running roughly north-south through the survey area.

1.4 Archaeology

The proposed survey has previously been subject to a heritage assessment (BWB, 2019). The recommendations of this state that:

"..... within the wider study area there are known assets of prehistoric, Roman, medieval and post-medieval activity. The assessment has considered that there is potential for undiscovered archaeological assets dating to the Roman period based on the finds found within the site/ within its immediate area. On this basis it is recommended that a geophysical survey is undertaken to further assess the potential for Roman activity to occur within the site."

The assessment also contains a map regression, which shows the location of former field boundaries within the proposed survey area.

2 Discussion

2.1 Objectives

The basic objective is to detect and define the extent of buried structures of archaeological interest. The resolution must be such that structures perhaps only 0.5m wide or diameter have a chance of being detected and that the anomalous field from them is sufficiently sampled so as to permit analysis of characteristics potentially diagnostic of different materials and structures.

2.2 Principles – magnetic survey

2.2.1 Resolution

Routine magnetic survey for general archaeological assessment purposes in the UK is traditionally specified with a 1.0m line separation as a compromise between resolution (and hence the detectability of features) and the time required for survey. A 0.25m along line interval for magnetic survey is widely accepted practice and in line with English Heritage guidance (David, 2008).

2.2.2 Soil properties

Magnetic survey for any purpose relies upon the generation of a clear magnetic anomaly at the surface, i.e. strong enough to be detected by instrumentation and exhibiting sufficient contrast against background variation to permit diagnostic interpretation. The anomaly itself is dependent upon the chemical properties of a particular volume of ground, its magnetic susceptibility and hence induced magnetic field, the strength of any remanent magnetisation, the shape and orientation of the volume of interest and its depth of burial. Finally the choice and configuration of measurement instrumentation will affect anomaly size and shape.

Archaeological sites present a complex mixture of these factors and for some the causative affects are not known. However, depth of burial and size are usually fairly constrained and background susceptibility can be estimated (or measured). The degree of remanent magnetisation is harder to predict and depends on both the natural magnetic properties of the soil and any chemical processes to which it has been subjected. Fortunately heat will raise the susceptibility of most soils and topsoil tends to be more magnetic than subsoil, by volume.

It is hard to draw reliable conclusions about what sort of geology is supportive of magnetic survey as there are many factors involved and in any case magnetic response can vary across geological units as well as being dependent upon post-deposition and erosional processes. In general a relatively non-magnetic parent material contrasting with a magnetisable erosion product, i.e. one which contains iron in the form of oxides and hydroxides, will allow archaeological structures to exhibit strong magnetic contrast against their surroundings and especially if the soil has been heated or subjected to certain processes of fermentation. In the absence of either, magnetic enhancement becomes entirely reliant upon the geochemistry of the soil and enhancement will often be weaker and more variable.

The principal magnetic iron mineral is the oxide magnetite which sometimes occurs naturally but is more often formed during the heating of soil. Subsequent cooling yields a mixture of this, non-magnetic oxide haematite and another magnetic oxide, maghaemite. Away from sources of heat, other magnetic iron minerals include the sulphides pyrite and greigite while in damp soils complex chemistry involving the hydroxides goethite and lepidocrocite can create strong magnetic anomalies. There are thus a number of different geochemical reaction pathways that can both augment and reduce the magnetic susceptibility of a soil. In addition, this susceptibility may exhibit depositional patterns unrelated to visible stratigraphy.

Most structures of archaeological interest detected by magnetic survey are fills within negative or cut features. Not all fills are magnetic and they can be more magnetic or less magnetic than the surrounding ground. In addition, it is common for fills to exhibit variable magnetic properties through their volume, basal primary silt often being more magnetic than the material above it due to the increased proportion of topsoil within it. However, a fill containing burnt soil may be much more magnetic than this primary silt and sometimes a feature that has contained standing water can produce highly magnetic silts through

mechanical depositional processes (depositional remanent magnetisation, DRM).

A third structural factor in the detection of buried structures is the depth of topsoil over the feature. As fills sink, the hollow above accumulates topsoil and hence a structure can be detected not through its own magnetisation but through the locally deeper topsoil above it. The volume of soil required depends upon the magnetic susceptibility of the soil but just a few centimetres are often sufficient. Such a thin deposit can, however, easily be lost through subsequent erosion by natural factors or ploughing.

2.2.3 Instrumentation

Instrumentation plays a significant part in the performance of magnetic survey in an archaeological context and it is the instrument configuration that governs the form and strength of an anomaly. Vertical gradiometers are in particular insensitive to laminar structures, e.g. broad lenses of topsoil within the upper fills of features. Their response is strongly governed by the depth of a material below the lower sensor and hence topsoil with a significant payload of magnetic debris can appear as a mass of noise. However, they respond sharply to the lateral edges of features, more so than non-gradiometric instruments.

Non-gradiometric instruments are considerably more sensitive to both laminar and deeply buried structures and are less strongly affected by surface magnetic sources, with a slight theoretical loss of horizontal resolution. In practice this last characteristic is not an issue within archaeological survey.

3 Methodology

3.1 Introduction

The proposal is that the whole development area will be surveyed using non-gradiometric magnetic survey. From experience this is probably most efficient way of covering the requested area with geophysical survey at this site. Some classes of feature may escape detection by this method alone but this is probably the most effective route to an overview of possible archaeological remains and their context.

3.2 Magnetic survey

3.2.1 Technical equipment

Measured variable	Magnetic flux density / nT
Instrument	Array of Geometrics G858 Magmapper caesium magnetometers
Configuration	Non-gradiometric transverse array (4 sensors, ATV towed)
Sensitivity	0.03 nT @ 10 Hz (manufacturer's specification)
QA Procedure	Continuous observation
Spatial resolution	1.0m between lines, 0.25m mean along line interval

3.2.2 Monitoring & quality assessment

The system continuously displays all incoming data as well as line speed and spatial data resolution per acquisition channel during survey. Rest mode system noise is therefore easy to inspect simply by pausing during survey, and the continuous display makes monitoring for quality intrinsic to the process of undertaking a survey. Rest mode test results (static test) are available from the system.

3.2.3 Envisaged process stages

All data processing is minimised and limited to what is essential for the class of data being collected, e.g. reduction of orientation effects, suppression of single point defects (drop-outs or spikes) etc.

The initial processing uses proprietary software developed in conjunction with the multisensor acquisition system and includes sensor and GNSS data alignment and reduction of temporal variations through application of 1D temporal or 2D spatial filters depending upon what is required. Gridded data is ported as

data surfaces into Manifold GIS for final imaging and detailed analysis. Additional specialist analysis is undertaken using proprietary software.

TigerGeo uses more advanced processing for magnetic data using potential field techniques standard to near-surface geophysics. Details of these can be found in Blakely, 1996, "Potential Theory in Gravity and Magnetic Applications", Cambridge University Press.

General information on processes commonly applied to data can be found in standard text books and also in the 2008 English Heritage Guidelines "Geophysical Survey in Archaeological Field Evaluation" at http://www.helm.org.uk/upload/pdf/Geophysical_LoRes.pdf.

All archived data includes process metadata.

3.2.4 Note on magnetic data handling from different instrument types

With total field instruments (like caesium vapour) each sensor measures the total magnetic intensity (c. 48000nT) and the minimal processing stages must include a removal of large-scale trends (some of which are temporal) to allow the data to be usefully visualised for archaeological purposes. This can be achieved in different ways, e.g. by subtracting a reference sensor (stationary base station or higher-mounted sensor) or by using a high-pass temporal filter to take out the large-length variation that isn't wanted.

Fluxgate magnetometers, because they are always constructed in pairs as gradiometers, effectively do this internally, so this minimal processing stage isn't needed. If the sensors of a total field instrument are configured as a vertical gradiometer and the output from that is used, the same applies.

3.3 Deliverables

Primary delivery of report items is as PDF files comprising the text and also the report images exported from the project GIS. In addition, digital report elements are available as vector and raster components exported from the GIS as geo-referenced objects. Images are available in GeoTIFF format and purely vector elements in AutoCAD R12 DXF format. Spatial database data is available in SHP file format.

3.3.1 Reporting content

All reporting is in line with English Heritage (David, 2008: Section 4) and Chartered Institute for Archaeologists (Standard and guidance for Archaeological Geophysical survey - 2016) recommendations.

The illustrations will include: a location plan at 1:10000, showing the survey extent; large scale plots of total magnetic intensity data (including of raw / semi-processed data); the same with diurnal and other large background trends removed; and interpretation plan. Where multiple methods of geophysical survey have been carried out, more detailed data extent maps will be shown. Where further processing has been beneficial, additional plots may be included.

The data will be presented as a series of greyscale images overlaid onto map data geo-referenced to Ordnance Survey grid throughout. Additional plots using other visualisation methods will included where appropriate. Partial contour plots may be used to clarify presentation in some cases and to assist visualisation of the interpretation. A separate catalogue map will graphically highlight the most significant anomalies regardless of their origin, also the numerical key to a detailed anomaly catalogue included within the text.

Alongside this catalogue the text includes a non-technical summary in English and Welsh and a detailed methodological description, justification and analysis of the geophysical environment and its impact upon or presence within the data. Significant aspects of the result are discussed within the text.

3.4 Archiving and dissemination

TigerGeo maintains an archive for all its projects, access to which is permitted for research purposes. Copyright and intellectual property rights are retained by TigerGeo on all material it has produced, the client having full licence to use such material as benefits their project.

The archive contains all survey and project data, communications, field notes, reports and other related material including copies of third party data (e.g. CAD mapping, etc.) in digital form. Many are in proprietary formats while report components are available in PDF format. In addition, there are paper elements to some project archives, usually provided by the client. Nearly all elements of the archive that are generated by TigerGeo are digital.

The client will determine the distribution path for reporting, including to the end client, other contractors, local authority etc., and will determine the timetable for upload of the project report to the OASIS Grey Literature library or supply of report or data to archiving services. A high resolution PDF copy of the report and associated digital elements will then be supplied to Historic Environment Record in accordance with the Welsh HERs submission guidance (WATs, 2018).

TigerGeo reserves the right to display data rendered anonymous and un-locatable on its website and in other marketing or research publications.

3.5 Caveats

Geophysical survey is reliant upon the detection of anomalous values and patterns in physical properties of the ground, e.g. magnetic, electromagnetic, electrical, elastic, density and others. It does not directly detect underground features and structures and therefore the presence or absence of these within a geophysical interpretation is not a direct indicator of presence or absence in the ground. Specific points to consider are:

- some physical properties are time variant or mutually interdependent with others;
- for a buried feature to be detectable it must produce anomalous values of the physical property being measured;
- any anomaly is only as good as its contrast against background textures and noise within the data.

TigerGeo will always attempt to verify the accuracy and integrity of data it uses within a project but at all times its liability is by necessity limited to its own work and does not extend to third party data and information. Where work is undertaken to another party's specification any perceived failure of that specification to attain its objective remains the responsibility of the originator, TigerGeo meanwhile ensuring any possible shortcomings are addressed within the normal constraints upon resources.

3.6 Bibliography and selected reference

Aspinall, A, *et al*, 2008, "Magnetometry for Archaeologists", Geophysical Methods for Archaeology, Altamira Press

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Tarling, D H, *et al* (ed.), 1999, "Palaeomagnetism and Diagenesis in Sediments", Geological Society, London, Special Publications, 151

Telford, W M, *et al*, 1990, "Applied Geophysics", 2nd Edition, Cambridge University Press

The Welsh Archaeological Trusts (WATs), 2018, reviewed 2019, "Guidance for the Submission of Data to the

Welsh Historic Environment Records (HERs)"

4 Supporting information

4.1 Standards and quality (archaeology)

TigerGeo is developing an Integrated Management System (IMS) towards ISO certification for ISO9001, ISO14001 and OHSAS18001/ISO45001. For work within the archaeological sector TigerGeo has been awarded CIfA (Chartered Institute for Archaeologists) Registered Organisation status.

A high standard of client-centred professionalism is maintained in accordance with the requirements of relevant professional bodies including the Geological Society of London (GeolSoc) and the Chartered Institute for Archaeologists (CIfA). Senior members of TigerGeo are professional members of the GeolSoc (FGS), CIfA (MCIfA & ACIfA grades) and other appropriate bodies, including the European Association of Geoscientists and Engineers (EAGE) Near Surface Division (MEAGE) and the Institute of Professional Soil Scientists (MISoilSci).

In addition TigerGeo is a member of EuroGPR and all ground penetrating and other radar work is in accordance with ETSI EG 202 730.

TigerGeo meets with ease the requirements of English Heritage in their 2008 Guidance "Geophysical Survey in Archaeological Field Evaluation" section 2.8 entitled "Competence of survey personnel". The management team at TigerGeo have almost 50 years of combined experience of near surface geophysical project design, survey, interpretation and reporting, based across a wide range of shallow geological contexts. Added to this is the considerable experience of our lead geophysicists in a variety of commercial and academic roles. All geophysical staff have graduate and in many cases also post-graduate relevant qualifications pertaining to environmental geophysics from recognised centres of academic excellence.

During fieldwork there is always a fully qualified (to graduate or post-graduate level) supervisory geophysicist leading a team of other geophysicists and geophysical technicians, all of whom are trained and competent with the equipment they are working with. Data processing and interpretation is carried out by a suitably qualified and experienced geophysicist under the direct supervision and guidance of the Senior Geophysicist. All work is monitored and reviewed throughout by the Senior Geophysicist who will appraise all stages of a project as it progresses.

Data processing and interpretation adheres to the scientific principles of objectiveness and logical consistency. A standard set of approved external sources of information, e.g. from the British Geological Survey, the Ordnance Survey and similar sources of data, in addition to previous TigerGeo projects, guide the interpretive process. Due attention is paid to the technical constraints of method, resolution, contrast and other geophysical factors.

There is a strong culture of internal peer-review within TigerGeo, for example, all reports pass through a process of authorship, technical review and finally proof-reading before release to the client. Technical queries resulting from TigerGeo's work are reviewed by the Senior Geophysicist to ensure uniformity of response prior to implementing any edits, etc.

All work is conducted in accordance with the following standards and guidance:

- David et al, "Geophysical Survey in Archaeological Field Evaluation", English Heritage, 2008;
- "Standard and guidance for Archaeological Geophysical survey", Chartered Institute for Archaeologists, 2014 (Updated 2016);

and undertaken in accordance with the high professional standards and technical competence expected by the Geological Society of London and the European Association of Geoscientists and Engineers.

4.2 Key personnel

Martin Roseveare, MSc BSc(Hons) MEAGE FGS MCIfA	Senior Geophysicist, Director
Martin specialised (MSc) in geophysical prospection for shallow applications and since 1997 has worked in commercial geophysics. Elected a GeolSoc Fellow in 2009 he is now working towards achieving CSci. A member of the European Association of Geoscientists & Engineers, he has served on the EuroGPR and CIfA GeoSIG committees and on the scientific committees of the 10th and 11th Archaeological Prospection conferences. He has reviewed papers for the EAGE Near Surface conference, was a technical reviewer of the Irish NRA geophysical guidance and is a founding member of the ISSGAP soils group. Professional interests include the application of geophysics to agriculture and the environment, e.g. groundwater and geohazards. He is also a software writer and equipment integrator with significant experience of embedded systems.	
Anne Roseveare, BEng(Hons) DIS MISoilSci	Operations Manager, Environmental Geophysicist - Data Analyst
On looking beyond engineering, Anne turned her attention to environmental monitoring and geophysics. She is a Member of the British Society of Soil Science (BSSS) and has specific areas of interest in soil physics & hydrology, agricultural applications and industrial sites. Amongst other contributions to the archaeological geophysics sector over the last 20 years, Anne was the founding Editor of the International Society for Archaeological Prospection (ISAP) and is a founding member of the ISSGAP soils group. Specifications, logistics, safety, data handling & analysis are integral parts of her work, though she is happily distracted by the possibilities of discovering lost cities, hillwalking and good food.	
Jennifer Smith, MSc	Fieldwork Manager, Environmental Geophysicist
Jen developed an interest in all aspects of topographical and geophysical survey whilst studying for a MSc in Archaeological Science at the University of Bristol. During her studies she obtained valuable experience in the use of and data analysis for various terrestrial geophysical techniques as well as develop her interest further by adding marine geophysical techniques to her working theoretical knowledge. She has worked as a near-surface geophysicist within archaeology for several years and has developed a good knowledge of UK geology. Outside of work, Jen is currently learning Java code but is easily distracted by keeping fit, exploring the world or some other hobby.	
Daniel Lewis, MA BA(Hons) ACIfA	Consultant Archaeologist
Daniel studied archaeology at the University of Nottingham and worked in field archaeology for many years, managing urban and rural fieldwork projects in and around Herefordshire. When the desk became more appealing he jumped into the world of consulting, working on small and large multi-discipline projects throughout England and Wales. At the same time, he returned to University, gaining an MA in Historic Environment Conservation. With over 15 years' experience in the heritage sector, Daniel has a diverse portfolio of skills. Here he ensures that geophysical work within the heritage sector is well grounded in the archaeology. His spare time includes much running up mountains	
Luigi Benente, MSc	Consultant Environmental Geophysicist
Luigi is an experienced geologist specialized in geophysics, who gained a blend of practical and technical experience within explorations carried out in Italy, Peru, Colombia, Ecuador, Mexico, Uzbekistan, Thailand and Nigeria. Resourceful and hardworking with a positive attitude in problem solving, he has the ability to lead a team through challenging tasks, organizing people and equipment in order to hit the goal in safety and with time conscious professionalism. He is attracted to discover hidden things within the earth and after celebrating with friends, good wine, good beer and lots of food he is able to repair most broken things...	
Alexandra Gereia, MSc, BSc, PhD Candidate	Geophysical Processor & Analyst

Alexandra has a BSc in Geophysics and an MSc in Applied Geo-biology and started a PhD in the UK after living in Portugal for six months working on her master's degree. Since 2008 she has used most mainstream processing applications across electrical, magnetic and radar methods. She combines a love of nature and science and is currently studying plant roots in agricultural environments using geophysical methods. When not doing that she enjoys travelling, hiking, nature, yoga, books, foreign languages and cats. Two years ago she found a passion for electronics and started building different devices including intelligent gardening systems and coding in Python.

4.3 Ensuring safety

A site specific RAMS will be produced for this project and the following notes serve only as an introduction to our safety policy.

We are starting the process of achieving ISO certification for OHSAS18001/ISO45001 through production of an Integrated Management System (IMS). We prefer to use Alan Ward of Bigfoot Services as our external safety advisor as he has a proven track record in outdoor working, a NEBOSH Certificate in occupational health and safety, an IOSH licence to deliver IOSH Working Safely and Managing Safely courses, a IEMA Associate Certificate and is an IOSH Technical Member.

We have adopted the IAGC document "Land Safety Manual" (version 10) as our safety manual, making due allowance for UK-specific regulations and guidance.

Our Operations Manager has a current IOSH Managing Safely qualification and all surveyors have REC 1st Aid Level 2 or 3 and LANTRA CLVA06X(ATV) training; most also have CSCS cards. Our safety procedures take into account the following guidance with site and application-specific documents being additionally adopted as required.

- AFAG701 ATV quad bikes
- Health and Safety Executive (HSE) Health and safety made simple – The basics for your business
- Health and Safety Executive (HSE) Welfare at work – Guidance for employers on welfare provisions
- Health and Safety Executive (HSE) The health and safety toolbox – How to control risks at work
- Health and Safety Executive (HSE) First aid at work – The Health and Safety (First-Aid) Regulations 1981
- Health and Safety Executive (HSE) First aid at work – Your questions answered
- Health and Safety Executive (HSE) AIS33 Safe use of all-terrain vehicles (ATVs) in agriculture and forestry
- Health and Safety Executive (HSE) GS6 Avoiding danger from overheard power lines
- Health and Safety Executive (HSE) AIS Working safely near overhead power lines
- Health and Safety Executive (HSE) HSG144 Safe use of vehicles on construction sites
- Health and Safety Executive (HSE) INDG139 Using electric storage batteries safely
- Health and Safety Executive (HSE) INDG163 Risk assessment
- Health and Safety Executive (HSE) INDG136 Working with substances hazardous to health
- International Association of Geophysical Contractors (IAGC) Land Safety Manual Version 10
- Kawasaki Tips and Practice Guide for the ATV Rider
- Lyme Disease Action Ticks in Britain
- Lyme Disease Action Ticks and Lyme Disease
- Lyme Disease Action Tick-borne diseases in Britain
- Prospect Union Driving and Roads

- Prospect Union Lone Working
- Royal Commission on Environmental Pollution 2005 Crop spraying and the health of residents and bystanders

All PPE in use is to the relevant standards, e.g. safety boots meet EN ISO 20345:2011 S3 SRC, head protection meets EN12492:2012 and FS/ATV1 for ATV use, otherwise BS EN397, high visibility clothing meets BS EN471 class 2 or 3 and eye protection meets EN166.

Each project has a nominated first-aider and all vehicles carry first aid kits.