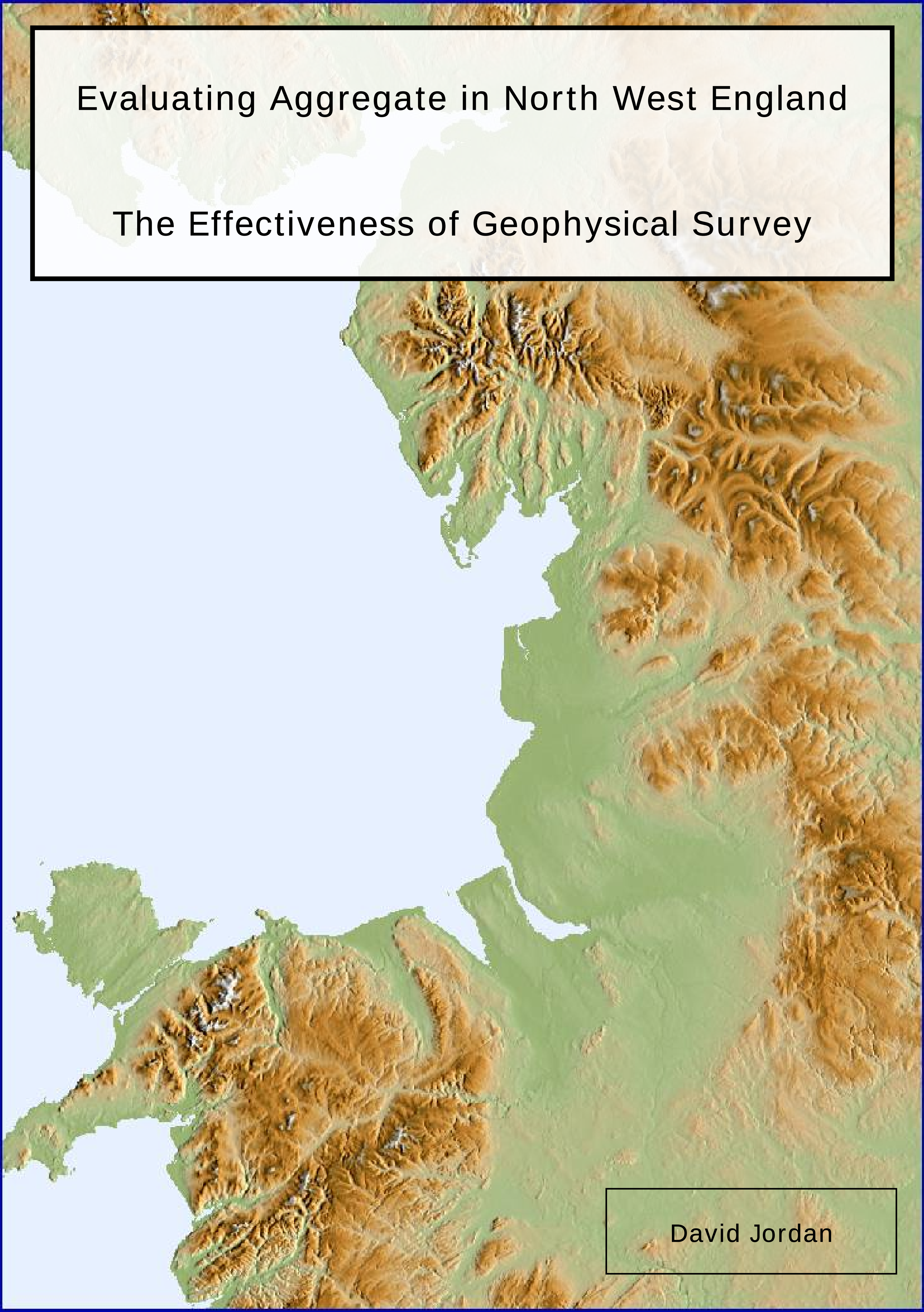
Evaluating Aggregate in North West England

The Effectiveness of Geophysical Survey



David Jordan

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The Effectiveness of Geophysical Survey

This report presents the results of a study of geophysical surveys carried out for archaeological site evaluation in the North West of England.

It discusses the effectiveness of such methods and considers what might be done to improve the way that they are used.

David Jordan

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Contents

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Summary

Questions have been raised about the effectiveness of geophysical techniques as a means of evaluating archaeological remains in the North West of England. There have been sufficient doubts, in the judgement of some professional archaeologists, to abandon its use altogether. Others, however, regard geophysical survey as one of the key evaluation techniques and commission its use on many of their projects. Concerns over the effectiveness of geophysical survey in the North West are particularly significant since there are often no good alternatives.

This project investigated the uses and products of geophysical surveys carried out for archaeological evaluation in the North West, concentrating on commercial projects since 1990.

It gathered information about the methods, sites, natural contexts and outcomes of all surveys for which information was available. It then analysed these data to reach conclusions about the use and effectiveness of such survey in the roles chosen for it.

The project concludes that:

1 Geophysical survey in the North West of England usually produces results which meet the needs of those who commission it. It deserves a key role in archaeological site evaluation and to be applied more often and more widely.

2 Only about 10% of surveys fail entirely to meet the need for which they were commissioned, for example by failing to detect substantial remains.

3 We might expect that the reasons why surveys fail will be complex but this does not appear to be so. In the North West, at least, surveys fail

because the archaeological remains are too deeply buried, are masked by other (usually modern) anomalies or because there is too little geophysical contrast between remains and their surroundings – though this latter only appears to seriously affect sites on a very limited range of parent materials. The causes and effects of all these problems are already well understood.

4 If we can predict where such problems occur we can avoid them, substantially raising the effectiveness of surveys by targeting them more effectively. Detecting such problems in advance of survey should not be difficult, with a simple preliminary study or, at the very least, a simple assessment of the geological and historical context of the site. This should become a routine part of the preparation for survey.

5 Despite the numbers of routine surveys, very little money is being spent on research in archaeological geophysics. Such research needs to be promoted at the national level and built into the normal fabric of archaeological projects from which, at present, we learn very little from which we can improve survey itself. A small investment here could reap significant rewards in better techniques, better instruments, more precisely tailored survey methods and more informative interpretations.

6 The range of survey methods, instruments and field techniques being applied in geophysical survey is surprisingly restricted, given the diversity of remains and their natural soil contexts. One reason is that existing techniques are quite effective in their current role, as this project has shown. Another is a tendency for the planning system to favour conservative options, to avoid risk. A wider range of techniques, and a wider role for geophysical survey, might serve archaeology well.

7 The planning system fails to reward skilful survey. Basic data standards need to be set to reverse what conscientious surveyors see as a race to the bottom. The national bodies and local authorities need to ensure that survey data reach adequate standards, though such

standards, and the protocols used to ensure they are met, will only be accepted if they are developed and adopted by surveyors themselves.

8 The skills of expert surveyors are being wasted, and surveys inadequately designed, because briefs are formulaic and guidelines, intended as minimum standards, have become a very restrictive norm. Instead briefs should define the aims of a survey and require that the survey design created in response should explicitly show that it can acquire the data required to meet them. In doing this briefs should explicitly state the purposes of a survey, and thus the targets that must be detectable by it. This will require that surveyors are given a greater say in, and a greater responsibility for, survey design.

In creating briefs of this kind Curators need to ensure that the natural desire of archaeological consultants to save their clients money does not mean that a broad initial brief is automatically translated into a minimal survey specification. Briefs need also to require that surveyors are provided with adequate data and time to design surveys which are as well adapted as possible to sites. All too many surveys are being commissioned to unrealistic – indeed unprofessional – deadlines and with neither crucial supporting information nor the requirement that it be provided. No wonder that surveyors choose the safe survey options.

9 The standard survey spacings of 1x0.5m for magnetometry and 1x1m for electrical resistance survey are often only just adequate and denser data gathering may often be more cost-effective on sites with geophysically complex soils and weakly-defined archaeological anomalies. There seems little reason, in particular, not to reduce the normal magnetometer survey spacing to 1x0.25m. A staged approach to survey, gathering further data and applying other techniques after an initial sparse survey, may often be a good way to achieve this extra data density where it is most needed.

10 This survey-of-surveys has reached conclusions by inference, comparing surveys and excavation data to identify what has been found, and what missed. Indeed, for lack of excavation data from key sites some of the conclusions here have had to be based on survey results alone – although only where such conclusions are clear-cut.

It would be useful to develop a further research project which will examine survey and excavation data by actively taking part in commercial projects, though with non-commercial funding, and gathering the data needed to quantify and then explain the relative performance of survey through a combination of geophysical and geoarchaeological methods. One explicit purpose of this project would be to develop protocols by which such research could be adopted more widely, as a small but normal part of commercial archaeological practice.

Magnetic gradiometer survey of the Roman Vicus at Maryport[1]

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[1] Biggins, J. A. and Taylor, D. J. A., 2004, 'The Roman Fort and *vicus* at Maryport: geophysical survey, 2000 - 2004', in R. J. A. Wilson and I, Caruana (eds.), *Romans on the Solway*, CWAAS for the Trustees of the Senhouse Museum, Maryport, 102-133.

Introduction

Companies quarrying aggregate are required to record archaeological remains before they are destroyed. New applications to extract must identify significant remains so that appropriate action can be taken to record or preserve them. Thus the availability of means to find buried remains is a key part of aggregate planning, as it is in the wider planning process.

Some professional archaeologists have concluded that geophysical survey may not be an effective way to find and map remains in North-West England. This might have a serious effect on the measures we take to conserve remains because geophysical survey is widely used to find and map buried archaeological sites throughout England. Moreover where pasture predominates, as in much of the North West, our other main survey techniques work much less well than in arable areas and geophysics often becomes the only alternative.

This project was designed to find out whether geophysical survey is an efficient and effective way to assess archaeological remains in the North West and to suggest means by which it might be improved. It considers the technical matters which influence the outcome of surveys by looking at a selection of survey results in the light of subsequent excavation. It also considers how the practice and administration of archaeology influences the use and outcomes of surveys.

The project design was developed during an initial survey of projects and of opinions among surveyors and survey users. It became clear, during the project itself, that the structure of the report would differ from that initially intended, because of unforeseen constraints and opportunities. The project was constrained by the scarcity of comparable survey and excavation data, the difficulties of comparing results from diverse sites, in diverse environments, and the paucity of informative air-photograph records for most of the sites with geophysical surveys. The project was, however, enhanced by the chance to look more closely at a number of sites where survey and excavation were in progress.

As a consequence this report compares survey and excavation results, in the light of the environment of each site and of the methods used, as originally intended. But it then looks in greater detail at a series of diverse case-studies in which the reasons for survey outcomes are related to the nature of the site.

The result is therefore a discussion of the underlying causes of survey behaviour and a description of how they impact on particular projects.

The survey and excavation projects chosen for study include many which are not associated with aggregate extraction, except insofar as sites in the North West often overlie hard rocks suitable for aggregate. While the project aims to consider how geophysics should be applied in aggregate-related archaeological mitigation, to restrict the project to sites already associated with aggregate extraction would mean that we would have very few cases and little comparable data.

The report therefore looks at other cases so that the wider lessons learnt can be applied to aggregate extraction mitigation. The project did, nonetheless, examine one aggregate extraction area in detail (New Cowper and Overby in Cumbria) and draws wider conclusions about how the lessons learned from this and others should influence our use of geophysics in aggregate mitigation projects.

Context

Aggregate and Archaeology in the North-West

About 13 million tonnes of aggregate is extracted in North-West England each year. About 10 million tonnes of this is crushed limestone, sandstone and igneous rocks and the remainder is sand and gravel[2]. The area affected and the potential to destroy buried remains is considerable.

The distribution of extraction and of potential extraction of the various types of aggregate is uneven between the authorities of Cheshire, Greater Manchester, Merseyside, Lancashire and Cumbria. Most of the crushed-rock aggregate comes from Cumbria and Lancashire, most of the gravel and sand from Cheshire.

The North-West is unusual because it produces a much higher proportion of crushed-rock aggregate than more lowland areas. Much of this quarrying takes place on the upland margin, in areas where the density of known archaeological remains is lower and its character more ephemeral and more difficult to detect than in much of the rest of England. Complex, glacial drift soils and a predominance of pasture tend to make remains even harder to find. The techniques we most rely on to find buried remains elsewhere, especially air-photography and field-walking, are usually ineffective.

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[2] North West Regional Aggregates Working Party Annual Report 2002, Cheshire County Council. Figures refer to the extraction statistics for 2001.

Geophysics might therefore be the approach of choice, and is so widely used throughout England that we might expect it to be a common part of the strategy to find buried remains, whatever the threat. Some North Western archaeologists report, however, that the results of geophysical survey have proved disappointing – even that geophysics "doesn't work" - and a review of its use and the potential for its improvement was therefore urgently requested.

The picture of geophysical survey success is bound to be uneven across a region of such diverse landscapes. The absolute performance of geophysics, and its performance relative to other approaches, will be different around hard rock quarries in the acid upland soils of Cumbria than around gravel quarries in the lowlands of Cheshire, especially since the soils overlying lowland aggregate deposit do support significant areas of arable crops where Air Photography and Field Walking can be successful.

If we are going to consider the archaeological role of geophysical survey in all the counties of the North-West together we must remain aware of these important regional differences.

The significance of archaeological remains in the North West is no less than in other regions. The MARS report[3] showed that the density of known monuments and the rate of their discovery is relatively low but it also made it clear that in areas where pasture and semi-natural environments are common, as here, sites stand the best possible chance of survival, increasing their potential significance.

[3] T Darvill and A Fulton, 1995 *The Monuments at Risk Survey of England 1995*, English Heritage

The MARS report also indicates that the number of sites destroyed in the North West by mineral extraction, as opposed to other risks, is the lowest in England but, when we take the low concentration of known sites into account, the proportional loss is very much higher. Moreover, professional archaeologists, interviewed during this project, suggested that many pre-medieval sites remain to be discovered. It is therefore possible that the current bias towards relatively recent sites, in the archaeological record, is not truly representative of the resource. This suggests that aggregate extraction, and other development, may be destroying unrecognised, earlier sites simply because they are hard to find. Thus assessing our site detection methods, such as geophysics, is crucial in considering how we can better protect the past in a challenging environment.

Method

The basic data for this report was compiled by soliciting survey and excavation reports from all the principal commercial archaeology contractors working in the region, and from others, as well as by searching Local Authority archives. It had been intended to compare these datasets using original, digital geophysical data but few survey reports could be accessed in this way and it was considered more important to increase the numbers of projects examined than to spend a lot of time obtaining small amounts of digital data from busy survey contractors.

The project concentrated on commercial surveys carried out for Development Control because it is on these that the practical importance of effective evaluation methods has most day-to-day impact. Other surveys were recorded but a small number carried out by universities and local archaeological societies have undoubtedly been missed. Site management surveys, carried out for the National Trust, were also excluded but are recorded in other databases.

A total of 111 surveys were identified as having been carried out since 1990, in addition to the 63 post-1990 surveys in the North West already entered in the English Heritage (EH) database[4] and the 24 post-2000 surveys recorded by the Archaeological Investigations Project (AIP) at Bournemouth University[5].

Information on the method, survey instrument, date and the state of the ground were obtained for each site where possible. Topographic maps, geological maps, soil maps and air-photographs were obtained for each site and digital elevation models obtained both from the NASA Shuttle

[4] EH Geophysical Survey Database http://sdb2.eng-h.gov.uk/
[5] AIP Database http://csweb.bournemouth.ac.uk/aip/aipintro.htm

Radar Topographic Mission (SRTM) and from Ordnance Survey datasets. Land-use was identified from survey reports, air-photographs and, occasionally, from site visits.

Survey and excavation data were compared visually, from reports, since the lack of digital data made more formal comparison, by overlay, much more difficult to achieve accurately – and accurate overlay is crucial to such comparison[6].

Meetings were held with almost all of the principal geophysical survey contractors, the excavation contractors and Local Authority Development Control teams. Those few with whom it was not possible to meet were contacted by phone. A few discussions were also held with aggregate extraction companies, their staff and agents. All of those interviewed were asked about their experience of the effectiveness and efficiency of geophysical survey in the North West, and of the way it is applied. On an understanding of anonymity, many strong views were expressed and these are distilled in the discussions below.

Of the 111 newly identified surveys, 76 were not studied further. Some had been carried out too recently or too long ago for records to be obtained. Others were interesting but clearly of little wider significance because the site was atypical (such as Williamsons Tunnels, under central Liverpool).

Study of the surveys was prioritised if:

1 the site had also been excavated

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[6] Gill Hey and Mark Lacey, 2001 *Evaluation of archaeological decision making processes and sampling strategies* Oxford Archaeology Unit

2 the survey and excavation were extensive and recorded large quantities of remains

3 the survey and excavation records were detailed

4 the site and project could be taken to typify a number of others, and therefore provide a useful example

Some surveys, without accompanying excavation, were also considered in detail because they had proved particularly good, or poor records of remains known from other data, or because they spoke for themselves.

Of the remaining 35 surveys, 17 had extensive, detailed records with which survey and excavation results could be compared.

All of the 35 surveys were examined in detail and the nature of the survey, soil, geology, topography and landuse noted. Survey results were compared with excavation results where possible. More detailed comparisons were made for the 17 sites for which most data was available and an attempt was made to relate the degree of survey “success” to the nature of the remains and the site context.

These comparisons were then, themselves, compared so that more general patterns of relationships between site variables and survey outcomes might be distinguished. These were then considered in the light of what we currently know about influences on survey performance.

The absolute performance of geophysical methods, in mapping buried archaeological sites, depends on four things:

1 the natural characteristics of the soil, especially texture, structure, mineralogy and moisture

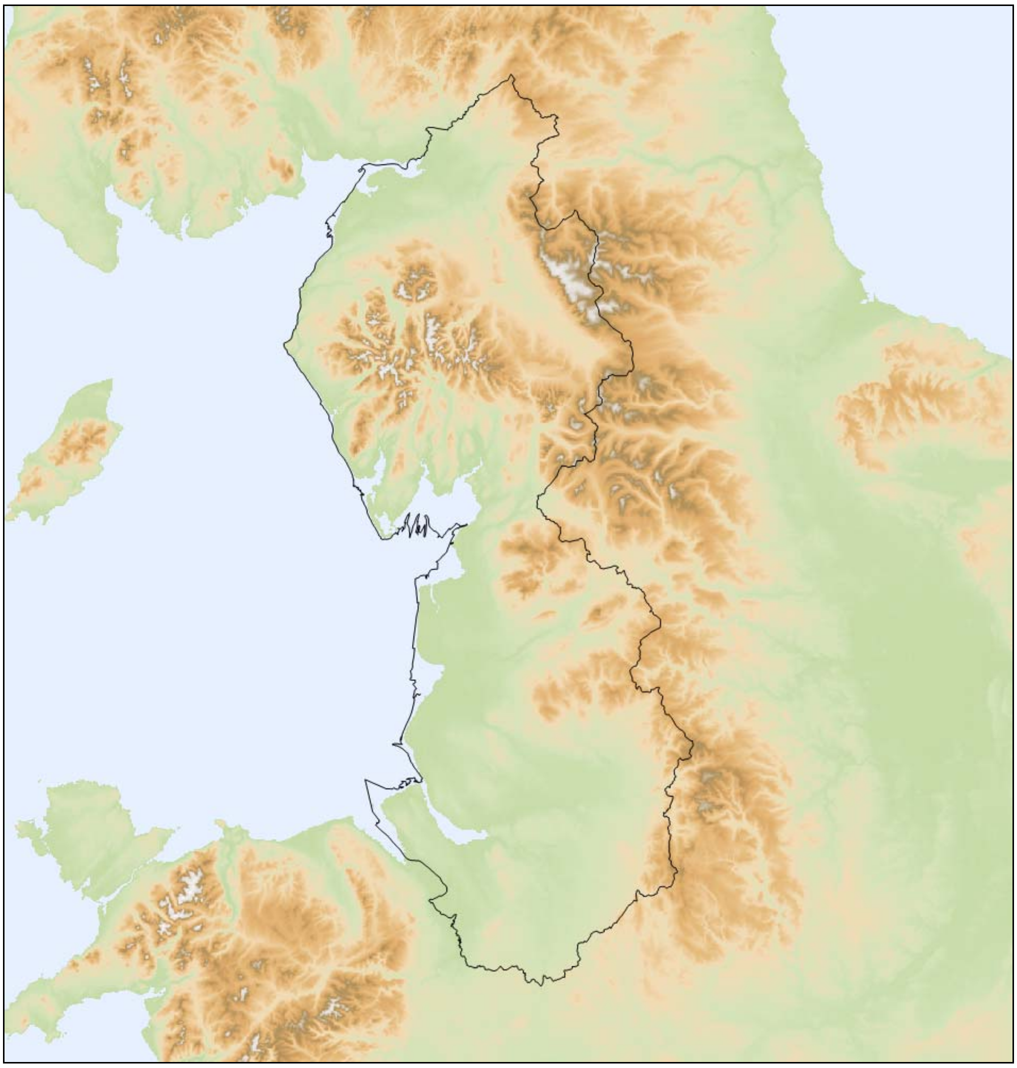
2 the characteristics of the remains themselves, as with natural soils, and their area, volume, depth of burial, boundaries and any geophysically significant artefacts (such as those made of metal)

3 the nature of the ground surface – whether it is in short-cropped pasture, ploughed, under concrete and so on

4 the geophysical measurements taken and the instruments and field methods used

The performance of geophysical methods in relation to other approaches, such as air-photography, is equally important in judging how they can and should be used. Geophysics is just one of a number of potential survey methods, which we can use separately or together and, in commercial projects, choices have usually to be made between them. The most frequently used methods, other than geophysics, are air-photography. fieldwalking and trenching – shallow, strip excavations using the backhoe of a mechanical excavator.

As with geophysics, the effectiveness of other methods depends on the nature of the site. Most air-photographic information is gathered on sites under arable crops, although records of sites from photographs under low-light and snow-cover and of soil marks are important. The high proportion of sites identified from arable crop mark photographs means that the extent of arable agriculture significantly affects the quality of our archaeological records. Arable agriculture is also crucial to the use of our other key technique – fieldwalking. If the ground is rarely if ever ploughed, we have no opportunity to find artefacts and soil colour variations brought up to the ground surface which is often key evidence for the presence of buried remains.

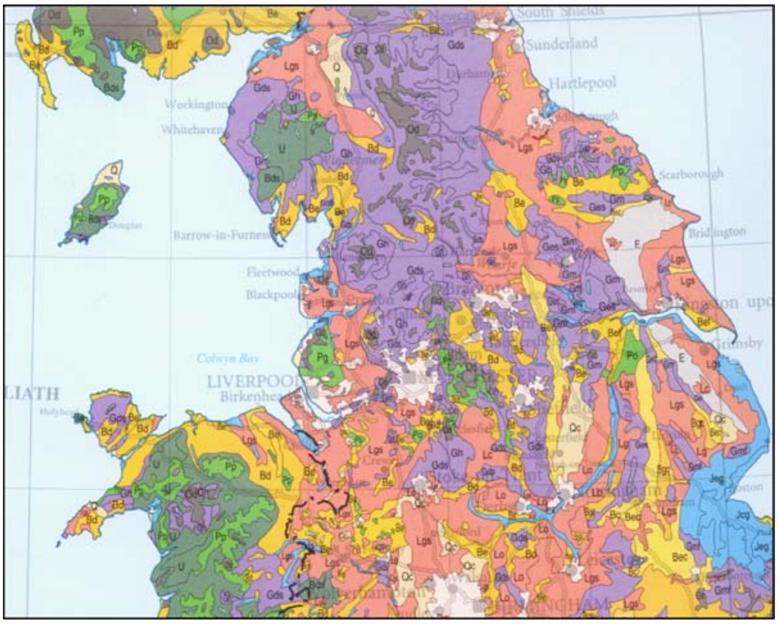


The topography of the study region, from Cheshire to the Scottish border[7]

[7] This map is derived from SRTM topographic data (http://srtm.usgs.gov/ and http://srtm.csi.cgiar.org/). The geographical data for this project were processed using the Manifold GIS system http://www.manifold.net/

The use of trenching is governed by other constraints. Its effectiveness in finding remains is less affected by soil and surface type than alternatives but, since only a small proportion of any one site may be trenched (as opposed to a usually much larger proportion of geophysical survey) it may miss most remains entirely and give, on some kinds of site, a misleading impression of the remains. It's effectiveness, and that of other approaches, has been assessed by Hey and Lacy[8].

The soils of the North West are diverse and range from calcareous lowland Gleys, through sandy Brown Earths to acid upland peats. The full range of those factors which most affect soil geophysical properties is represented – and thus we may expect to find a wide range of geophysical survey outcomes.



***The soils** of the North West of England, showing the contrast between the abundant acid upland soils of the north (mainly Gleysols G, Umbrisols U and Histosols O) and the lowland, base-rich and finer-textured soils of the south (mainly Luvisols L)* [9]

The North West differs, however, from most areas to the south in the abundance of upland and the high proportion of soils formed in Devensian till. While glaciation has smoothed the landscape at a large scale, it has

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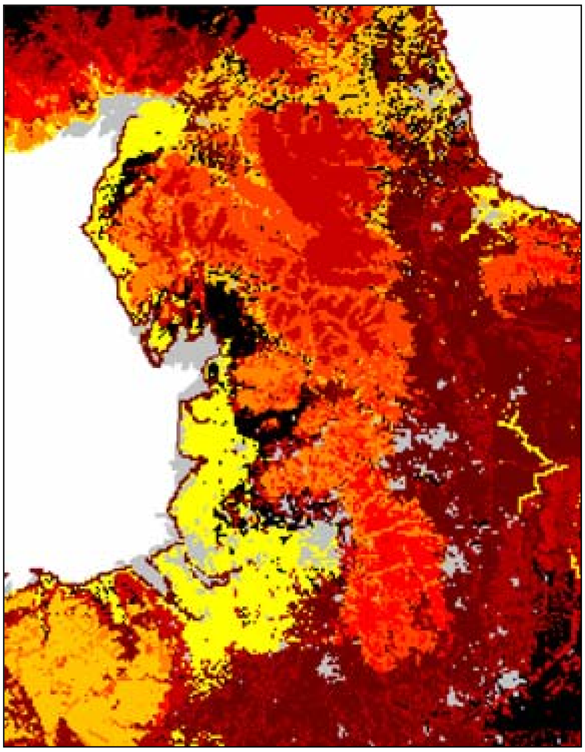
[8] Gill Hey and Mark Lacey, 2001 *ibid*

[9] This useful simplification of the soils is derived from the 1:2500000 Soil Atlas of Europe, European Soil Bureau Network, European Commission, 2005

left a complex micro-topography of drumlin fields, ice-scars, kettle-holes and the like which mean that large areas are covered in soil patterns of immense complexity, in particular in drainage. The scale and degree of variation itself varies greatly between areas of hard and soft rocks, and between the uplands, upland valleys, the broad lowland valleys (such as the Vale of Eden) and the plains.

The geology of the Northwest is, likewise, complex and contains rocks which impose a wide variety of geophysical properties on soils derived from them. The distribution of mineral textures and mineralogy has been greatly complicated by the presence of till and large areas of alluvia derived from it, which have crushed, mixed and moved the bedrock minerals over very large areas. While there is often a close correlation between bedrock and till lithology, contaminants are almost ubiquitous. One important consequence is that finer tills derived from soft rocks may contain an abundance of pebbles and cobbles derived from harder rocks, which have often been reworked in fluvioglacial deposits. The significant impact that this has on geophysical survey outcomes is discussed below.

The ground surface across the North West is just as variable. With the exception of the major conurbations it is, on average, less encumbered by roads, buildings and the debris of modern human activity than areas to the south. The Local Authorities south of Cumbria, however, have areas of dense and of dispersed development similar to the West Midlands. While the lowlands and plains are intensively farmed, the large areas of upland are mostly in rough pasture and heath where archaeological threats, and thus evaluations, are rare. The North West has a higher proportion of pasture than the South Eastern regions which, as noted above, tends to limit the effectiveness of evaluation by air-photography and fieldwalking.

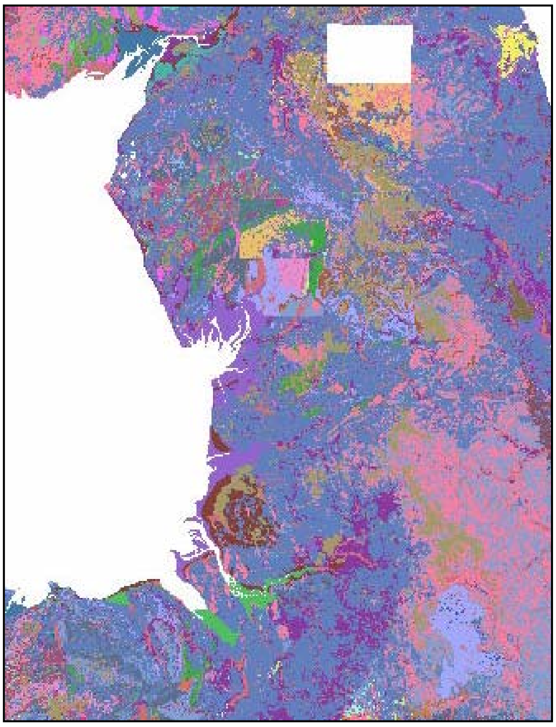


***Landuse classification** of the North West of England*[10]*.*

This map illustrates the complexity of the landscape mix across the region.

***Superficial geology** of the North West showing the abundance of till (light blue) and the extensive spreads of sand and gravel (pink), peat (brown) and Holocene alluvium (yellow)*[11]*.*

[10] This is an extract from the Land Cover Map 2000 produced by the Centre for Ecology and Hydrology (NERC 2000) and uses a combined classification of ten broad landscape groups generated using the software CIS v.8
[11] Great Britain, Quaternary (BGS 1977)



Parent material *map of the North West from the BGS provisional national Parent Material map[12].*

Soil parent material is distinct from superficial geology, as previously mapped, because it specifically considers the material within which soils have formed rather than the predominant deposits overlying bedrock. It is thus more relevant to the distribution of soil geophysical properties

The known **archaeological remains** in the North West are more sparse and more ephemeral than those elsewhere in England[13]. Almost all types of sites are represented but they vary considerably in density and complexity between the different landscapes of the region. Thus, while the archaeological character of Cumbrian mountains is distinct, that of the Cheshire plain is similar to that to the south and east.

Putting this all together - although, *on average*, the absolute and relative merits of each available archaeological survey method undoubtedly different in the North West than in other parts of the country, the diversity of soils, surfaces and sites is such that all such techniques should have their place in archaeological projects because good conditions for air-photography, fieldwalking, geophysics and others can be found.

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[12] British Geological Survey 2007
[13] T Darvill and A Fulton, 1995 *The Monuments at Risk Survey of England 1995*, English Heritage

Thus if we do not commission geophysical survey because we think it does not “work”, we are likely to be wasting opportunities to detect and protect sites.

Indiscriminate use of geophysics may, however, prove less effective than in some other parts of England because the geophysical behaviour of the soil is variably, and more often, distributed in a complex pattern related to the complexities of the landscape. Thus for every site where good results can be obtained, there is likely to be another site, nearby, where very different soil properties make for less good results – for any one survey technique, at least.

The challenge is therefore to learn how to identify the conditions under which good results can be obtained and thus use geophysical survey discriminatingly – to work out which techniques and field methods to apply and how to interpret the results at a particular site, so that geophysical survey is as successful as possible and so that it is not used, wastefully, where it will produce nothing useful.

The problem is that our use of geophysics is, at present, more indiscriminate than it needs to be. We know too little about the conditions (soil, mineralogy, landuse ...) at any particular site, and the effect this has on our survey methods, and give surveyors too little time to make use of such information, where it is available, for discrimination to be possible.

The use of geophysics is, moreover, subject to the complexities of the planning system as applied, with large variations, across the region. Survey success depends on a combination of technical matters and on the context of commercial practice and planning policy within which it is used.

Tackling the technical problems which limit survey success is likely to be difficult. Tackling the problems which arise from the operation of the archaeological survey market and from planning policy, even more so because many of these problems are due to deeper issues about the way in which we manage archaeological conservation nationally.

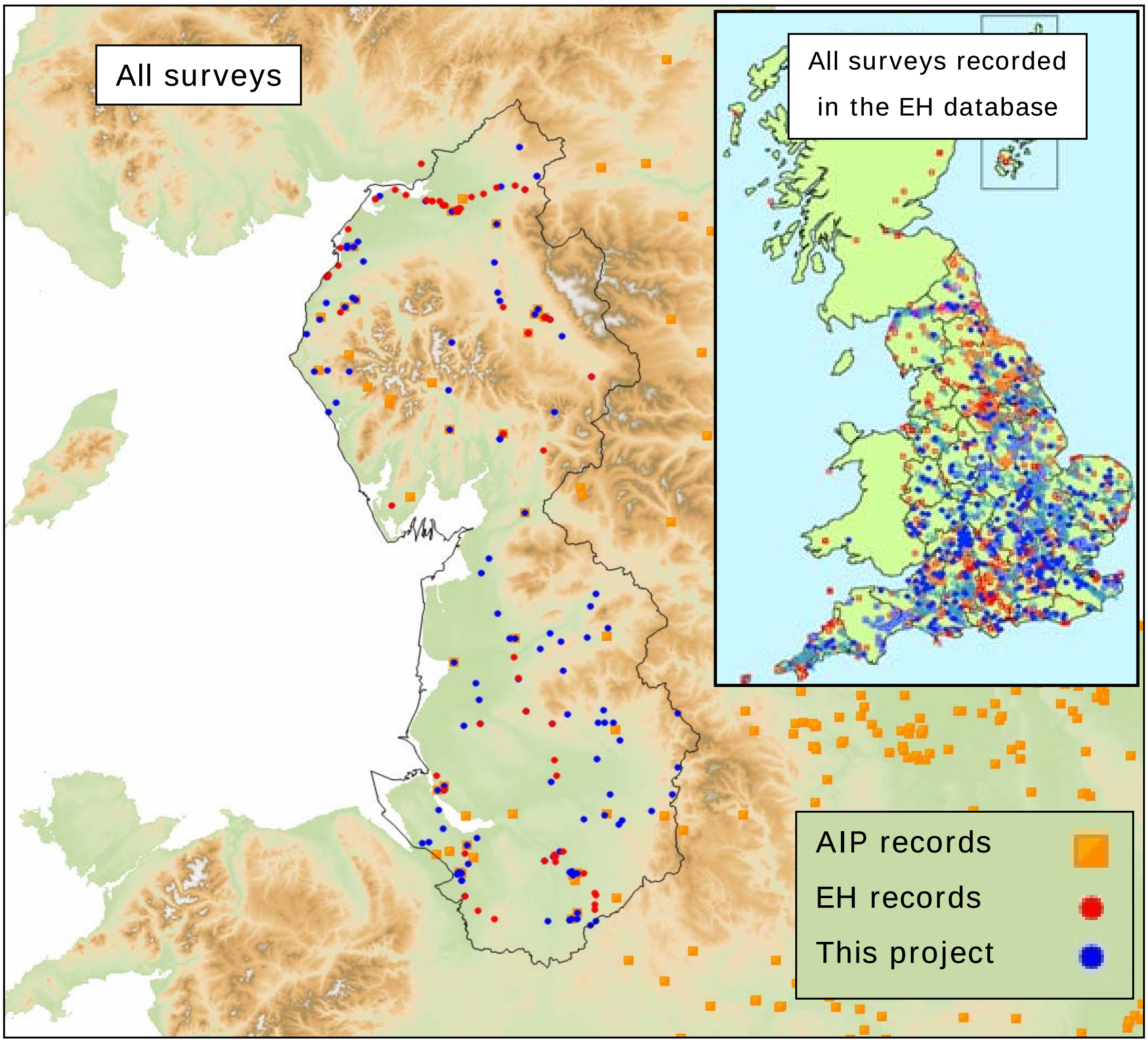
The complex question of what we mean by survey "success" and the steps we might take to achieve it more frequently are discussed below.

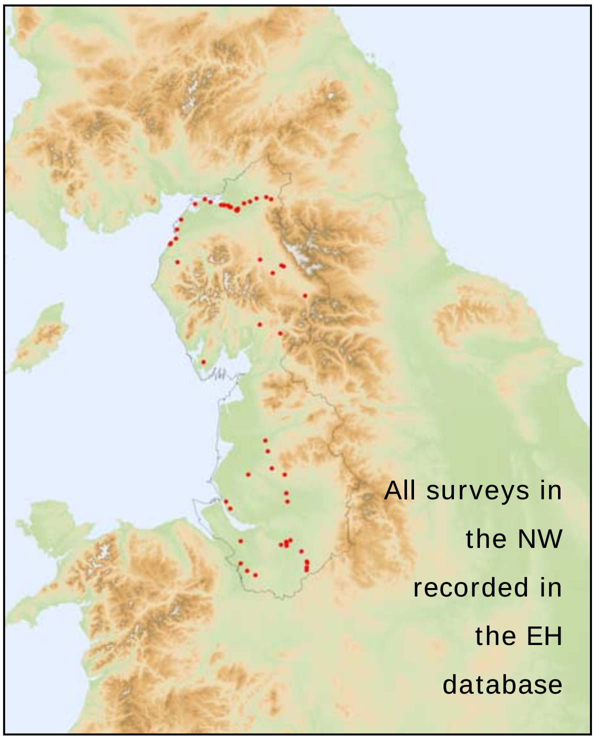
The distribution of Geophysical surveys

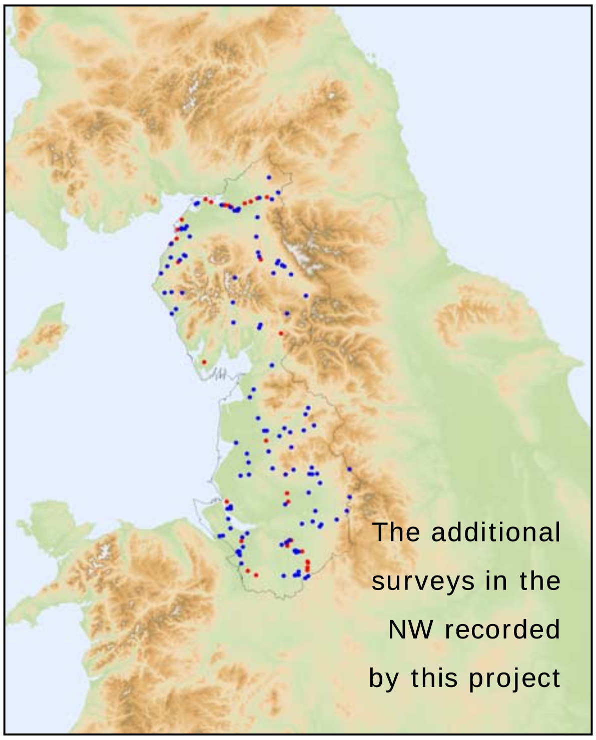
Records of surveys reported since 2000 are held by the Archaeological Investigations Project (AIP) at Bournemouth University and earlier surveys have been recorded by English Heritage. A comparison shows that the surveys reported here add to these significantly, and omit very few recorded by EH and AIP. This suggests that this project has been successful in capturing geophysical survey records. It also suggests that the combined EH and AIP records for the rest of England are likely to be significantly incomplete, since we have found them to be so for the North West.

The records show that there have been a lower density of geophysical surveys in the NW than in most other areas of England although there are some other areas, the West Midlands for example, where surveys have been relatively sparse.

Unsurprisingly these records also show that most surveys have been carried out in lowland areas of the North West with a few on the upland fringe. There is an understandable concentration of surveys along Hadrian's wall and on the associated Roman coastal defences almost all of which were carried out for research and site management. It appears that a higher proportion of surveys have been carried out for research and conservation in the North West than in areas to the south, perhaps because of the relative rarity of commercial, prospective evaluation surveys and the abundance of monuments in public hands.







The distribution of geophysical surveys carried out in the NW of England

We can compare the proportion of archaeological projects which used geophysical survey across the country from the AIP datasets. The comparison is limited to surveys and other evaluations since 2000, from when both sets of data are available. From this we can see that the proportion of evaluation projects in which geophysics has been applied varies considerably between regions. On average, a lower proportion of evaluations have made use of geophysical surveys in the North West than in the rest of England. Surveys in the North West, and in some other parts of England, also appear poorly distributed, with large areas having few surveys.

This might be taken to indicate that different purposes and policies, amongst those commissioning survey, has had an affect on survey distribution. If, however, we include the surveys which are known to have been carried out before 2000 the distribution becomes much more even and the relative frequency of geophysical survey and the use of other evaluation methods less clear. Thus, while we now have a good understanding of the distribution of geophysical surveys, we do not have a sufficiently good record of other evaluations to make a fair comparison.

The methods in use

The majority of surveys in our records for the North West have been carried out by magnetic gradiometry (87 of 127 surveys). Most of these surveys have made use of a single type of instrument – the Geoscan FM series fluxgate gradiometer – and a spacing between readings of 1x0.5m.

The situation is changing, as new instruments become available. Fluxgate gradiometry still dominates but newer instruments tend to be used as pairs (or larger multiples) thus increasing survey speed. Caesium Vapour Magnetometer surveys are becoming more common across the whole country but remain rare.

Looking at the area, rather than just the numbers of surveys, magnetometry is even more dominant because of a relatively few but very large magnetometer “scan” surveys (9 of 127). The average standard (recorded) magnetometer survey covers 3.1 Ha while the average magnetometer scan covers 23.8 Ha.

Electrical resistivity surveys are less common (34 of 127) and much smaller, averaging only 1.3 Ha. Almost all have been carried out using the Geoscan RM15 resistance meter and a twin-electrode array at a fixed electrode spacing of 0.5m and a reading spacing of 1x1m.

Finally very few Ground Penetrating Radar (5 of 127) and Magnetic Susceptibility (2 of 127) surveys appear in our new records. This is, perhaps, a surprisingly low proportion and might suggest a tendency to conservative choices in project design.

Geophysical surveys in the North West – types of surveys and areas covered

Site name	County	Total area	Mag scan area Ha	Mag Scan	Mag Sus area Ha	Mag Sus	Mag area Ha	Mag	Res area Ha	Res	GPR area Ha	GPR
Bewcastle	Cumbria	10	0		0		10	y	0		0	
Birdoswald	Cumbria	27	0		0		15	y	12	y	0	
Holmes Chapel Rd, Middlewich	Cheshire	0.57	0		0		0.57	y	0		0	
Kingsley Fields, Nantwich	Cheshire	40	30	y	0		10	y	0		0	
Low Plains Quarry	Cumbria	0.6	0		0		0.6	y	0		0	
Manchester Airport	GM	4	0		0		2	y	2	y	0	
Mellor	GM	6.65	0		0		5.8	y	0.8	y	0.05	y
Middlewich - Buckely Fields	Cheshire	1.2	0		0		0.6	y	0.6	y	0	
Middlewich Eastern Bypass	Cheshire	18.6	12.6	y	0		6	y	0		0	
New Cowper Farm, Aspatria	Cumbria	6	0		0		6	y	0		0	
Overby Quarry, Aspatria	Cumbria	6	0		0		6	y	0		0	
Peel Place Quarry	Cumbria	13.2	0		12	y	1.2	y	0		0	
Plasketlands	Cumbria	0.8	0		0		0.8	y	0		0	
Ulgill	Cumbria	3.5	0		0		1.5	y	2	y	0	
Uni Lancs SW Campus	Lancashire	1	0		0		1	y	0		0	
Aspatria, West Street	Cumbria	1	0		0		0.5	y	0.5	y	0	
Bowscar, Inglewood Road	Cumbria	9	0		0		9	y	0		0	
Burgh by Sands	Cumbria	10	0		0		10	y	0		0	
Carrs Field, Carlisle	Cumbria	8	0		0		4	y	4	y	0	
Castle Steads	Lancashire	1	0		0		1	y	0		0	
Castlesteads, Brampton	Cumbria	17	0		0		17	y	0		0	
Cumwhitton	Cumbria	3	0		0		3	y	0		0	
Egremont	Cumbria	0.3	0		0		0		0.3	y	0	
Hoole P&R	Cheshire	23.04	10	y	10	y	0.24	y	2.8	y	0	
Lathom House, Ormskirk	Lancashire	1	0		0		0		1	y	0	
Long Marton	Cumbria	1	0		0		1	y	0		0	
Pasture House Farm	Cumbria	5.4	0		0		5.4	y	0		0	
Samlesbury Hall	Lancashire	0.22	0		0		0.06	y	0.16	y	0	
Temple Sowerby Bypass	Cumbria	15.5	0		0		15.5	y	0		0	
Tendley Quarry, Cockermouth	Cumbria	1	0		0		1	y	0		0	
Baguley Hall, Wythenshawe	GM	1	0		0		0		1		0	
Basford Sidings, Crewe	Cheshire	17.6	16	y	0		1.6	y	0		0	
Bolton, Smithills Hall	GM	1	0		0		0		1		0	

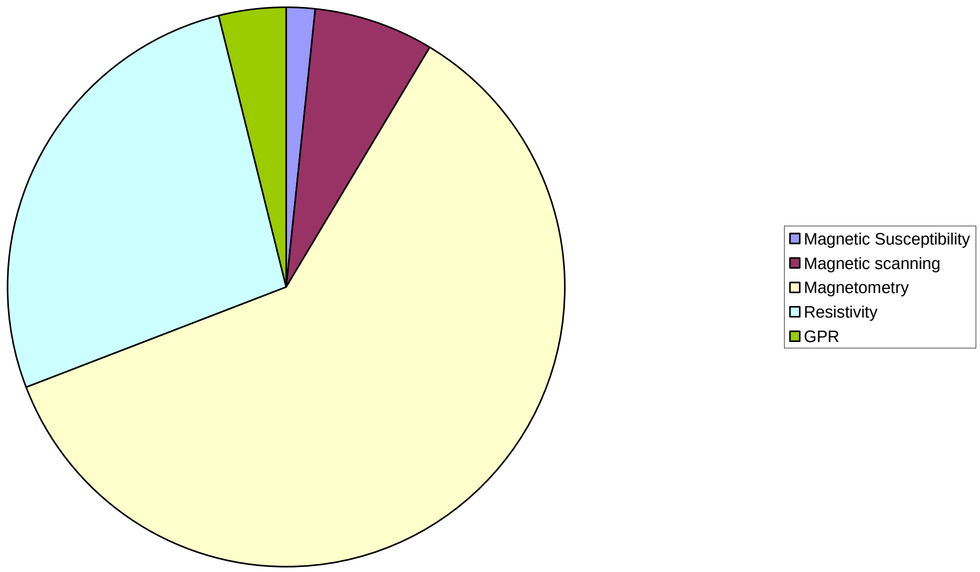
Clayton Hall, Clayton-le-Woods	Lancashire	1	0		0	0		1		0	
Hopecarr Hall	Lancashire	2	0		0	2	y	0		0	
Kinderton Lodge, Middlewich	Cheshire	63	60	y	0	3	y	0		0	
Kirkby Stephen	Cumbria	3	0		0	1.5	y	1.5	y	0	
Middlewich - Centurion Way	Cheshire	1	0		0	1	y	0		0	
Radcliffe Cemetry	GM	1	0		0	1	y	0		0	
Whitehall Moated Site	Cheshire	1	0		0	0.5	y	0.5	y	0	
A500 Crewe South	Cheshire	10	0		0	10	y	0		0	
A500 Crewe South	Cheshire	10	0		0	10	y	0		0	
A69	Cumbria	2	0		0	1	y	1	y	0	
Acorn Bank, Penrith	Cumbria	1.75	0		0	0		1.75	y	0	
Appleby	Cumbria	0.08	0		0	0		0		0.08	y
Audley to Alrewas pipe	Cheshire	3.32	0		0	3.32	y	0		0	
Basford West	Cheshire	52.6	50	y	0	2.6	y	0		0	
Belman Quarry	Lancashire	5	0		0	5	y	0		0	
Billsborrow	Lancashire	22.6	21	y	0	1.6	y	0		0	
Birdoswald	Cumbria	0.9	0		0	0.8	y	0.1	y	0	
Branthwaite Road, Penrith	Cumbria	2	0		0	1	y	1	y	0	
Broughton Tower	Lancashire	0.52	0		0	0.28	y	0.24	y	0	
Burton Manor	Cheshire	1	0		0	1	y	0		0	
Castle Stede	Lancashire	0.88	0		0	0.44	y	0.44	y	0	
Castleshaw	GM	0.5	0		0	0.5	y	0		0	
Chapel Field	Cheshire	6.7	0		0	5.7	y	1	y	0	
Cheshire Castle	Cheshire	0.8	0		0	0		0.8	y	0	
Chester Amphitheatre	Cheshire	0.5	0		0	0		0		0.5	y
Chester Northgate	Cheshire	0	0		0	0		0		0	
City Walls, Rufus Court, Chester	Cheshire	0	0		0	0		0		0	
Clifton Hall, Great Clifton		1	0		0	1	y	0		0	
Cockerham	Lancashire	0	0		0	0		0		0	
Crewe Green Link Road	Cheshire	15.2	12.5	y	0	2.7	y	0		0	
Cunsey Forge	Cumbria	0.02	0		0	0.02	y	0		0	
Davenham By-pass	Cheshire	0	0		0	0		0		0	
Drigg	Cumbria	2.25	2	y	0	0.25	y	0		0	
Eccles	Lancashire	0	0		0	0		0		0	
Edderside	Cumbria	0.6	0		0	0.6	y	0		0	
Egremont	Cumbria	1.5	0		0	1.5	y	0		0	
Gadbrook Park	Cheshire	0.78	0		0	0.78	y	0		0	
Glencoyne Farm, Ullswater	Cumbria	0.36	0		0	0.36	y	0		0	
Grange Quarry, Wilton	Cumbria	1	0		0	1	y	0		0	

Grant Gardens	Merseyside	0	0	0	0		0		0	
Greenbank, Ambleside	Cumbria	0.28	0	0	0		0.28	y	0	
Hadrians Wall - 3	Cumbria	2	0	0	0		2	y	0	
Heaton Park	GM	1.6	0	0	0.8	y	0.8	y	0	
Heronbridge - 1	Cheshire	0	0	0	0		0		0	
Heronbridge - 2	Cheshire	0	0	0	0		0		0	
Higham	Lancashire	0	0	0	0		0		0	
Ince	Cheshire	0	0	0	0		0		0	
Kirkby Thore	Cumbria	1.2	0	0	0.7	y	0.5	y	0	
Ladyewell Shrine	Lancashire	0.8	0	0	0.8	y	0		0	
Linen hall Stables, Chester	Cheshire	0	0	0	0		0		0	
M6 Widening	Cheshire	6.2	0	0	6.2	y	0		0	
Marthome	Lancashire	1	0	0	0		1	y	0	
Mickle Trafford pipe	Cheshire	1.2	0	0	1.2	y	0		0	
Mottram to Tintwistle Bypass	Cheshire	0	0	0	0		0		0	
Newby Hall	Cumbria	0.5	0	0	0.25	y	0.25	y	0	
Oakenhurst Farm	Lancashire	1.25	0	0	1.25	y	0		0	
Old Dock, Liverpool	Merseyside	0.14	0	0	0		0		0.14	y
Ormskirk	Lancashire	0.54	0	0	0.27	y	0.27	y	0	
Papcastle	Cumbria	1.2	0	0	0.6	y	0.6	y	0	
Pilsworth Quarry, GM	GM	1	0	0	1	y	0		0	
Poynton Bypass	Cheshire	0	0	0	0		0		0	
Port Sunlight	Merseyside	0	0	0	0		0		0	
Ribchester	Lancashire	2.5	0	0	1.3	y	1.2	y	0	
Risley	Lancashire	0.04	0	0	0.04	y	0		0	
Roodee Racecourse, Chester	Cheshire	0	0	0	0		0		0	
Rufford Park	Lancashire	0	0	0	0		0		0	
Shotwick to Bridgewater	Cheshire	2.4	0	0	2.4	y	0		0	
Showley Court	Lancashire	0.64	0	0	0.32	y	0.32	y	0	
Spen Moor, Bury	GM	1.2	0	0	1	y	0.2	y	0	
Tarleton	Lancashire	0	0	0	0		0		0	
Tatton Park	Cheshire	0	0	0	0		0		0	
Vicarage Drive, Kendal	Cumbria	0.5	0	0	0.5	y	0		0	
Warton Marsh	Lancashire	0.16	0	0	0.16	y	0		0	
Watercrook, Kendal	Cumbria	0.5	0	0	0.5	y	0		0	
Williamson's Tunnels	Merseyside	0.01	0	0	0		0		0.01	y
Wilmslow	Cheshire	0	0	0	0		0		0	
Winscales	Cumbria	2	0	0	1	y	1	y	0	
Wordsworth House	Cumbria	0.025	0	0	0		0.025	y	0	

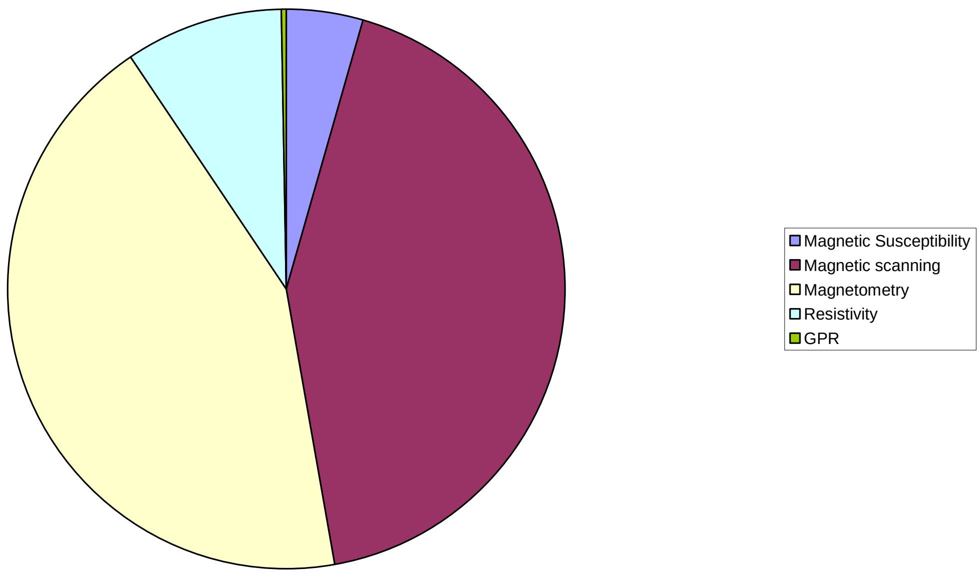
Summary

Total survey area (Hectares)	Magnetic Susceptibility	Magnetic scanning	Magnetometry	Resistivity	Ground Penetrating Radar
499.925	22	214.1	217.11	45.935	0.78
Total survey numbers					
127	2	9	77	34	5

Survey types by numbers of surveys



Survey types by total area surveyed



How do we judge survey outcomes?

This project considers how effective geophysical surveys are for archaeological evaluations in the North West of England.

Thus we must ask what we mean by effectiveness. Effective at what and for whom?

This is a complex and sensitive question because many of the survey contractors interviewed for this project do not feel that the effectiveness of their work is fairly judged. Such issues concern contractors because they directly affect their livelihoods. They are particularly concerned that survey failures are assumed to be due to their lack of competence and thus they carry an unreasonable burden for failures which they may consider are actually due to poor survey design by consultants and curators, pressure for unreasonably quick results and low prices which have forced down survey standards, since standards high enough for success are not enforced.

When surveyors and survey consumers were asked, during interviews for this project, what they mean by a “successful” survey their definitions depended on their own role and responsibilities.

It is natural that the definition of success will vary with survey aims. To the archaeologist concerned with research and conservation successful surveys are those which provide detailed information on which to build new archaeological knowledge and conservation policy. Thus successful survey will be that which reveals sufficient detail to make this possible. To the archaeological consultant or curator success is usually a matter of resolving a planning question by prospection - finding out if there are any remains present at all or defining the limits of a known site, and broadly characterising its contents. Every site and project, however, is different.

Given this range of aims, no one definition of “success” will do. The key criterion against which success must be judged is the degree to which a survey met its original aims, especially since this will, or should, have defined the survey approach which was used. Thus the explicit statement of aims, and sufficient time and resources for project design, should be key elements of survey projects – yet our interviews clearly showed that surveyors believe that these corners must be cut, all too often, if they are to win work and meet project schedules. They see this as an assault on their professionalism.

Surveys may, of course, succeed in other terms, by providing information which proves of interest later and this information may prove more significant than that originally sought. But this does not remove the need for the survey to succeed in its original purpose if they are to be judged successful.

Most of the surveys examined during this project were commissioned for planning purposes and must be judged by planning criteria, rather than research criteria. Did the survey results help to decide a specific planning question about a development or not?

Thus a survey which was designed to decide where to build a warehouse and which maps a Roman villa in one half of a site but does not detect a Saxon settlement in the other half will have failed for most practical planning purposes because the true threat to the buried remains will have been misunderstood and further planning decisions may be incorrect, as a consequence – especially if the clarity of the villa image gives the surveyor confidence that there is nothing else to find.

Calling this outcome a failure may seem a bit harsh – after all, a good survey of a Roman villa is valuable – but the purpose of the survey was to assess a potential planning constraint. If the resulting planning advice is that development should be permitted, without constraint, on the half of the site outside the villa then the survey has clearly failed in its purpose.

In practice development may not be permitted unless further evaluation steps have been taken but it is here that the frequent lack of alternative methods in the North West becomes particularly important. If geophysics does not meet the needs of planners and developers necessary steps towards development may simply have to take place without adequate archaeological mitigation and this introduces a new pressure on all involved – especially in an area with a weakened economy where costly evaluation may make a development impossible to finance. Thus the ability of Geophysical survey to solve planning problems becomes a key issue for development, even more so before planning permission has been determined and when the land in question may simply not be available for intrusive evaluation by trenching.

A further complication arises because surveys are often commissioned for several explicit and implicit purposes. It is natural to want to find, in a single volume of data, the answer to several questions such as “where are the limits to this settlement?” and “where are the principal archaeological features within it?”. This may mean that the survey methodology is designed as a compromise between two or more aims because insufficient funds may be available to address each aim individually. This is one of the reasons why survey design so often returns to the usual default of 1x0.5m-spaced fluxgate gradiometry. Success in achieving several aims is always a little less likely using surveys designed as a compromise rather than surveys designed specifically for a single purpose.

For these reasons this project defines “success” in terms of the original aims of those who commissioned the survey – but it notes that these are often not made explicit and are often complex and multiple.

Judging whether a survey has succeeded in these terms, however, does not tell us why it has done so. Nor, crucially – and to restate the points made above - is it a judgement on the competence of surveyors. Those who carried out a survey are often never drawn sufficiently into the project design stage to be aware of the real purposes of the survey nor put in a position to influence an inappropriately simplistic, cheap methodology imposed on them. They may have been required to provide answers to complex questions without having the freedom to apply the range of techniques this would realistically require or the time needed to apply them. None of these reasons would mean that the failure of a survey is a judgement on their competence.

Finally, the value of many survey results, equivocal results especially, only becomes apparent when they are tested in excavation – not only because the user then knows if they correctly predict the presence of remains, but also because they can be used to extend excavation results into unexcavated areas. Thus the success achieved by a survey may be transformed by the evaluation steps which follow from it.

Survey outcomes

An overview of survey outcomes cannot do justice to the complexity of the issues involved. Thus you are referred to the detailed discussion of individual sites below.

In brief, however, of the seventeen sites for which we have detailed, comparable records, nine produced unequivocal success. These surveys produced results which, demonstrably, met the need for which they were carried out. Four are surveys of major, protected sites which produced clear, informative geophysical images on which conservation and management decisions could be based. The remaining five either identified remains, or the absence of remains, which were subsequently confirmed in excavation.

Five of the remaining eight surveys produced equivocal results. Four identified remains, but only some of those later located in excavation and one located features which proved not to be archaeological. In practice, many surveyors err on the side of caution in interpreting coherent patterns within survey images as being potentially of archaeological origin, knowing – and usually stating – that they might have other origins. Thus such results might reasonably considered successful. The problem for the user, however, is that such caution does not give them the confidence they need if they are then, themselves, to make confident decisions about the consequences of survey results. This need for confidence, rather than just knowledge, is one of the key matters for survey users and a major reason for the difference in perspective on survey results between those who produce them and those who have to make planning and commercial decisions based on them.

The remaining three surveys were demonstrably unsuccessful. They failed to locate extensive archaeological remains later proved in excavation. In none of these cases could this reasonably have been anticipated, given the way that surveys are currently planned, and the failures occurred despite the surveys having been carried out to standards and with methods in line with currently accepted practice.

Of the 18 sites for which we have less complete records fifteen were successful in correctly identifying remains, or their absence. Two were unsuccessful, failing to detect known remains and one were partially successful, detecting some remains but missing others of importance.

This overview is too crude to be really useful because it conflates the purposes and contexts of surveys, the nature of the remains, their environment and the survey methods used. It shows, nonetheless, that a high proportion of surveys achieve their aims and that many of the remainder provide useful information. Outright failures, where significant remains are missed, are rather rare, though important when they occur. Those listed here can be attributed to a limited range of effects which might sometimes be anticipated.

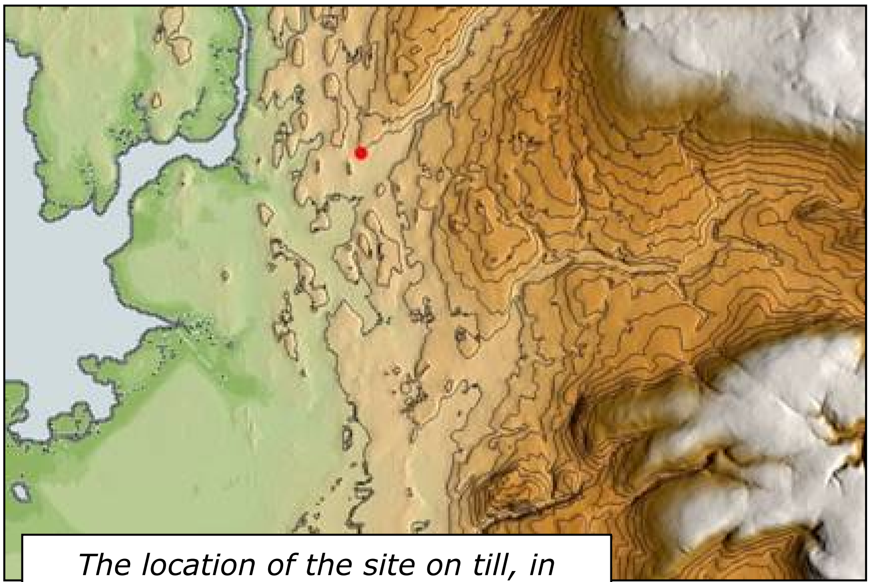
Geophysical survey has also proved good at correctly identifying the absence or very low density of remains – a particularly difficult test. This project has identified a few surveys where an apparent absence was actually due to difficulties in detecting remains, but it has also shown that many surveys give correct, negative evidence of archaeological sites – despite the common assumption that they cannot be used reliably for this purpose. The difficulties of using geophysical survey results as negative evidence, and the potential for its wider use are discussed below.

In this section of the report you will find a detailed discussion of six case histories, and four brief discussions, chosen to illustrate key issues which affect geophysical survey in the North West, although they are not intended to give a balanced impression of survey outcomes.

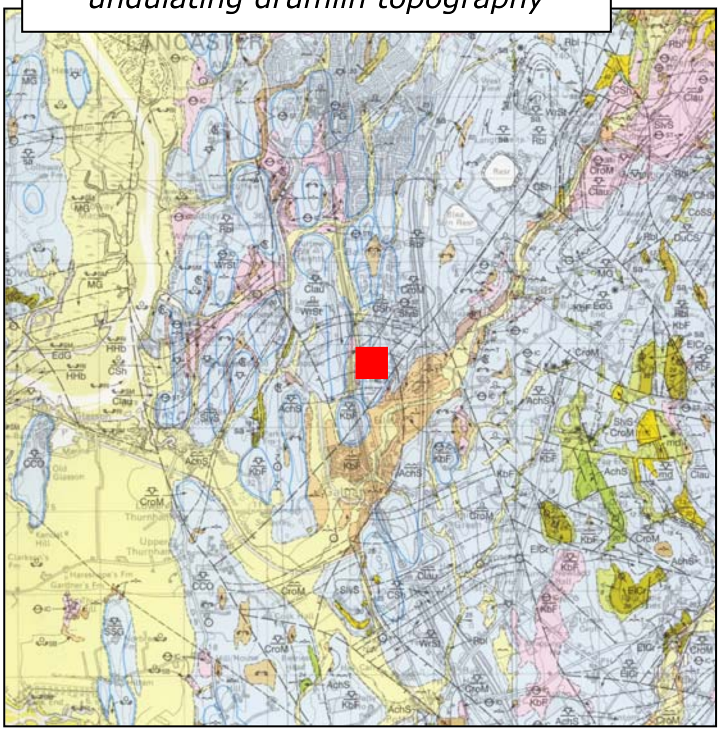
Location	SD 4836 5694
Curatorial Authority	Lancashire County Council
Context	Development control
Consultant	Oxford Archaeology North
Survey Contractor	GSB
Excavation Contractor	Oxford Archaeology North
Geology	Till, forming drumlins, over complex sandstones, siltstones, shales, mudstones and thin coal seams of the upper Carboniferous coal measures (Crofts 1992). The till is stony, containing well-rounded pebbles and cobbles apparently (since the author did not study them on site) of a broad metamorphic lithology.
Soil	Cambic stagnogley of the Brickfield 2 association (Jarvis et al 1984).
Hydrology	Slowly permeable soil and parent material on a very gently sloping site. Thus water ponding is reflected in redoximorphic colouring in the lower soil profile and archaeological sections.
Topography	Very gently sloping site on the south western toe of a drumlin.
Land Use	Pasture.
Survey Method	Magnetic gradiometry covering 1Ha at a traverse spacing of 1m and a reading spacing of 0.5m using a Geoscan FM36 fluxgate gradiometer.
Survey Date	30 July 2002
Survey Conditions	Not known
Excavation Approach	Evaluation by trenching followed by an open area excavation.

Discussion

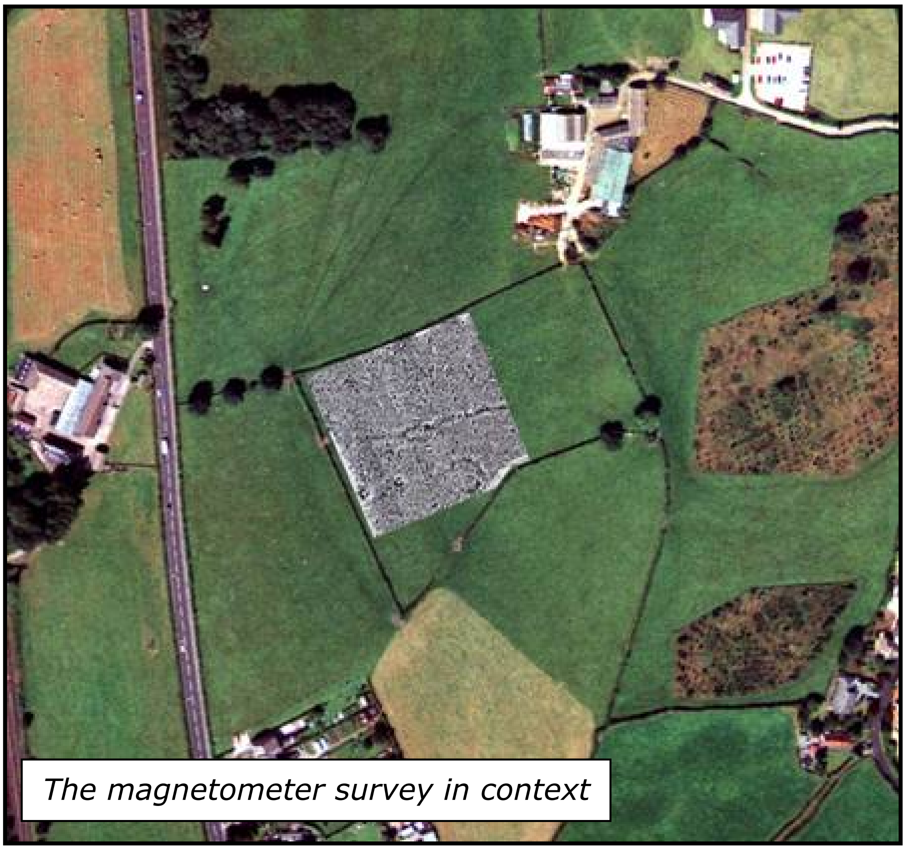
The archaeological study at Barker House Farm consisted of a magnetometer survey of 1ha and trial trenching, over an area of about 20ha, followed by open-area excavation of 0.5ha along a strip running through the southern part of the site.



The location of the site on till, in undulating drumlin topography



The trial trenching located a number of archaeological pits and ditches. The magnetometry did not locate these but did identify a previously unknown enclosure ditch. Thus area excavation was undertaken to further explore features identified by both evaluations in the area to be most affected by the development.



The magnetometer survey in context

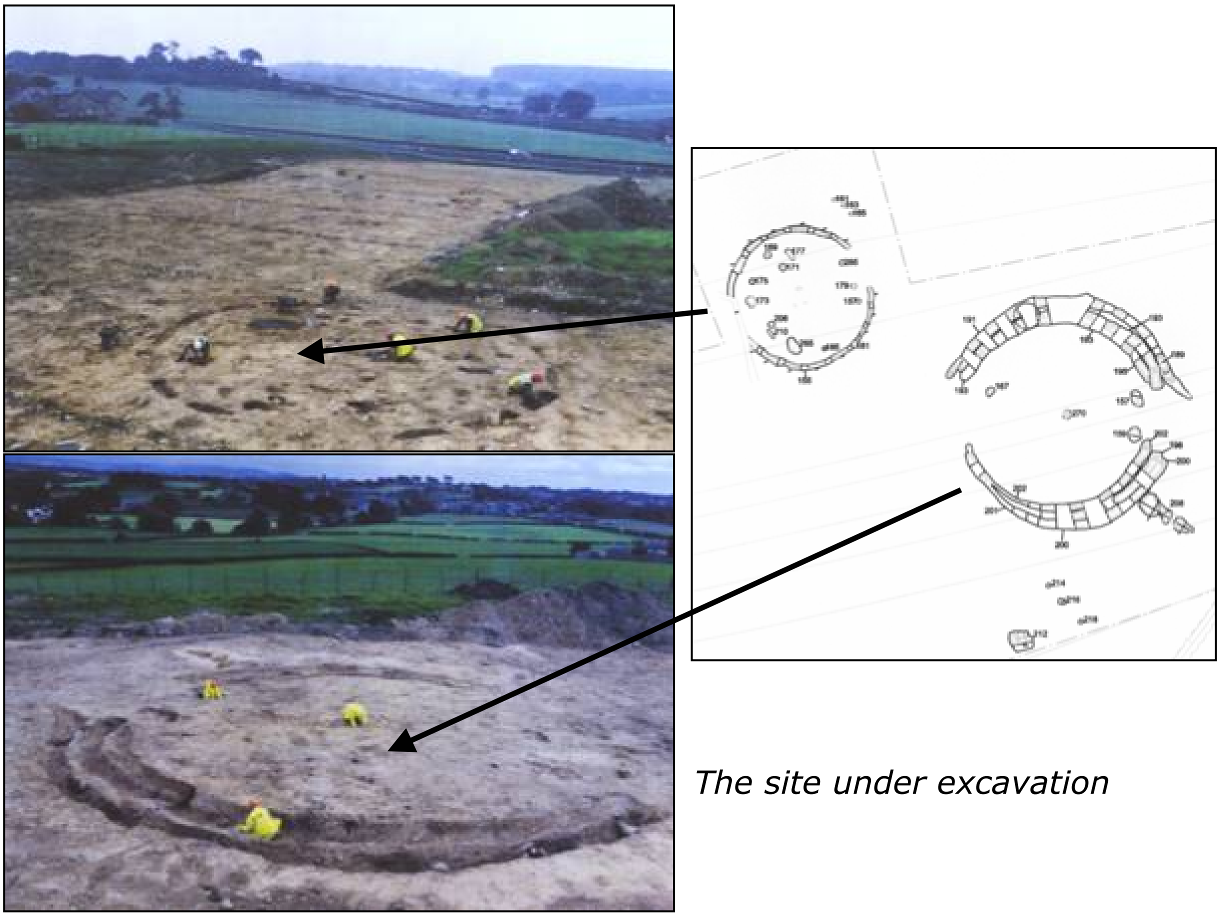
This excavation confirmed the findings of both the trenching and magnetometry evaluation – showing that both had found, and missed, important features. It also found a second, smaller ring ditch which the magnetometry had not identified.

Thus the magnetometry had proved a partial success and a closer examination of the site and survey approach suggests why.

The geological Drift mapping of the site proved correct, if imprecise. The archaeological remains, and natural soil, were formed in till but the key details of till origin and type, that we need to predict soil magnetic mineralogy, stone content and stone lithology, are not given – and indeed neither given on such maps nor usually available from any other source. The soil mapping was misleading because while the soil indeed appears to be loamy, as mapped, it is also very stony and compact, a vital influence on its geophysical properties and on those of archaeological remains formed from it. These details are likewise absent from existing soil maps in Britain.

That these key variables are not recorded on the geology and soil maps is a function of the low precision of the mapping and the inherent variability of till, and thus of soils formed from it – conditions that apply across most of the North West of England.

The stoniness and variations in other soil properties, typical of many till soils, is probably the reason for a dense pattern of low-amplitude variations in magnetic field angle which give the greyscale survey plot a “spotty” appearance at the range of +/-1nT used by the survey contractor. Even the larger enclosure ditch is hard to discern within this pattern, and the smaller features are indistinguishable. This suggests that their fills have not greatly influenced the earths magnetic field angle above them, relative to their surroundings, and, therefore, that the magnetic susceptibility contrast between them is low and that they do not have a significant remnant magnetic field of their own (hardly likely in such circumstances in any case).



The site under excavation

A simulation of the survey pattern shows that, at a reading spacing of 1x0.5m, approximately 280 magnetic gradient readings will have been recorded above the broader enclosure ditch and only about 36 above the narrow ring ditch – nearly 5 times fewer per linear metre of ditch ($4.5m^{-1}$ as against $0.96m^{-1}$). This is only a rough indication of what the magnetometer will have been able to detect, which is affected by the volume and profile shape of the remains as well as the distribution of magnetic properties within them. It nonetheless shows just how much influence the combination of feature shape and survey density can have. This is likely to be crucial at a site such as this where low magnetic susceptibility enhancement and variable soil components mean that feature fill and background might be much better distinguished by a greater sample density.

One simple way to improve the chances of detecting weakly-defined and narrow remains such as these is to increase the density of readings along each survey traverse. Doubling the density of readings to 0.25m approximately doubles the number which overlie each feature but increases survey time much less because magnetometers can record at such survey densities without any loss of speed. The only time lost is in the extra frequency of data downloading required, which varies considerably between different magnetometers. The more recent magnetometers have such large memories that downloading can take place once or twice a day, and thus the time-cost of increasing density to 0.25m or less is negligible. For less recent designs, with smaller memories and slower download speeds, the time-cost of the extra downloads is significant and this will be a consideration, though not necessarily crucial, for many contractors who have made a heavy investment in technically competent magnetometers which suffer from these memory limitation and who would therefore suffer some extra cost in carrying out surveys specified at higher linear densities.

The narrower ditch under excavation

The stoniness of the till, and ditch fill derived from it, is evident

It would also be possible to improve the chances of detecting small, weak remains in complex backgrounds by increasing the density of survey lines. This requires a nearly proportional increase in survey time and thus a similar increase in time costs in the field. The increase in detection likelihood, however, is also considerable, and more certain than if we increase density only along each traverse, because the density of points by which linear features are detected increases almost irrespective of the form and angle of the remains.

The choices that are made about survey layout also depend on the priorities of those commissioning the work. These are all-too-often implied rather than stated. If an archaeologist commissions a survey to detect archaeological remains what, precisely, do they want? If the archaeologist needs to find small, weakly contrasting remains but does not provide resources for a survey which is likely to do so it is hardly surprising that geophysical survey does not give them what they need. The problem here is that the needs of Development Control evaluation and the potential of geophysics under commercial conditions have become detached from each other by a market and by commissioning mechanisms which do not allow much interaction and feedback between surveyors and archaeologists before survey takes place. Removing the barriers to this, getting surveyors more routinely and fully involved in project development, will be an important step in the better use of geophysics.

To clarify: if an archaeologists requirement is to detect all remains, in whatever circumstances, then only open-area excavation will do – and sometimes not even that will find heavily lessivated remains which have lost their upper stratigraphic boundaries. If an archaeologist needs only to be able to find linear features such as ditches around occupation enclosures then the scale of such ditches, and the frequency with which their fills have a significantly enhanced magnetic susceptibility, imply that magnetic gradiometry, using standard instruments and methods, will usually be sufficient. If, however, the key issue is to distinguish two types of such enclosed site – one with and one without small storage pits, for example – then standard magnetometry may be able to find the sites but not to answer the key archaeological question because it cannot find the pits.

If the process of survey commissioning were interactive, and the archaeologist clear about their needs, then the surveyor could tell the archaeologist what kind of survey method, instrument and density would be required.

Such consideration of the archaeological priorities for a survey, and their implications in terms of the kind or remains which have to be detected, are generally absent from survey designs – except in the choice of method (resistivity over magnetometry for detecting buried stone walls, for example). This is particularly so where the survey is prospective and intended to detect and define previously unknown remains, as is generally the case with developer funded projects. It would be possible, however, to bring together research priorities and local site information to clarify survey briefs by stating explicitly the kinds of remains which are to be detectable, given specific environmental circumstances. This might be very helpful to surveyors and archaeologists because it will focus survey design on the key issues – but it would take a change in the way archaeologists and surveyors relate to each other within commercial projects.

At Barker House Farm one more issue needs to be considered. Anomalies as weak as that from the enclosure ditch can only be identified if the magnetometer survey is carried out with care and skill – especially using standard fluxgate magnetic gradiometers. The crucial detection of the ring ditch here is only possible because the survey was carried out with a correctly regulated (balanced) magnetometer carried smoothly and without significant changes in pace, since any survey errors introduced by such effects were small enough to be ignored or removed in post-processing. If the magnetometer had been poorly regulated and the survey badly carried out the ditch would not have been detected.

There is no requirement, however, that surveyors produce data that meet quality standards and thus no requirement that such remains must be detectable. This is a complex and sensitive matter. Surveyors are uncomfortable with outside regulation of standards, especially where it might reduce their freedom to use their judgement in producing good surveys – quite the opposite of what is required. Low survey standards, however, benefit only those who lack the skills and materials to do better, within a system that gives them little incentive to improve. A requirement for higher standards – and thus regulation of data quality - is likely to benefit all concerned if it means that the elimination of poor survey outcomes produces better results and encourages the wider use of geophysics.

Regulation might take the form of requirements to reach certain data quality criteria on standard test sites, on each site surveyed or both. The problem with the former approach is that it is detached from the issues which affect survey outcomes on individual sites. The problem of the latter is that sites are so geophysically variable that it would be difficult to design criteria which could apply to all.

Finally, of course, the degree to which quality criteria are required depends very much on the method and instrument used and this depends on the commercial investment decisions made by different surveyors in their equipment. It is a particular issue at present because most surveys are carried out by magnetic gradiometry using fluxgate instruments which only give good data if they are used well. Other magnetometers, however, are much less sensitive to the skills of the surveyor and instruments used for other kinds of survey will produce adequate results, however skilled the operator, if the survey has been correctly designed and laid-out in the field. Thus standards need to focus on the quality of the product, not the means used to obtain it.

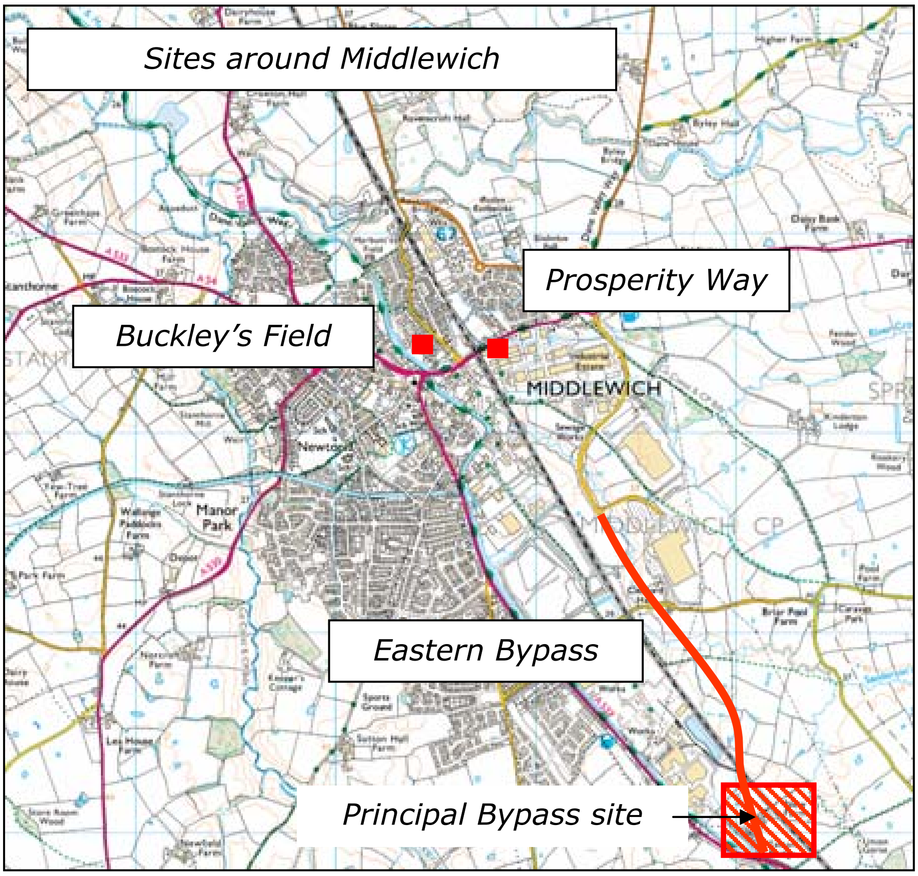
This brings us back to the magnetometer survey at Barker House Farm where a well-performed magnetometer survey, using standard methods, identified one important feature, but not another, because of the nature of the soil and of the remains. Denser survey may have made the smaller ditch, and other features, detectable but the amount of background noise and the stoniness of the soil suggests that other instruments and other methods are not likely to have given a better result.

Buckley's Field, Middlewich

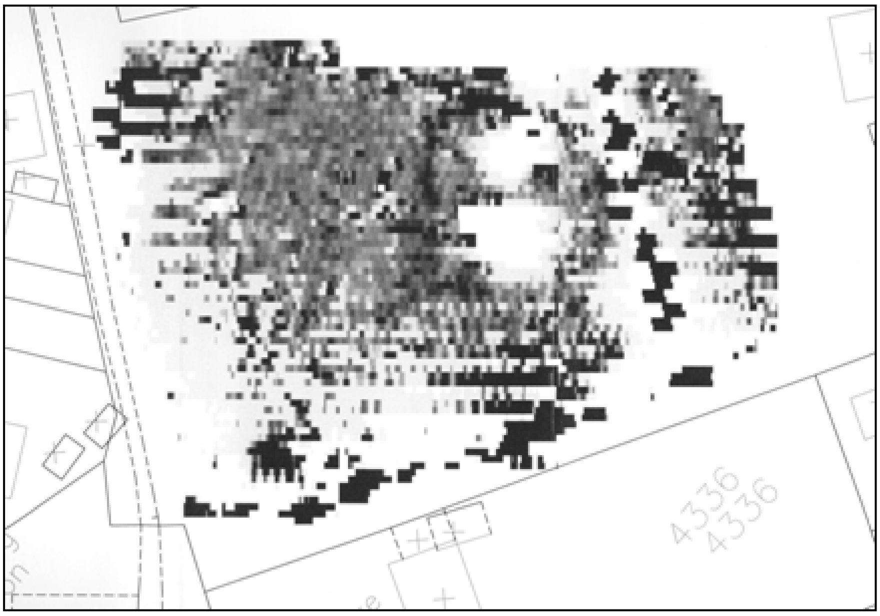
Location	SJ 705 665
Curatorial Authority	Cheshire County Council
Context	Research
Consultant	Gifford and Partners, Chester
Survey Contractor	Stratascan
Excavation Contractor	Middlewich Archaeological Society supervised by Giffords
Geology	Triassic Mudstone
Soil	Typical stagnogley of the Salop association.
Hydrology	Slowly permeable soil and parent material, on a flat site without underdrainage. Thus water ponds within the soil profile and the soil remains waterlogged throughout the later autumn, winter and spring.
Topography	Flat site with steep slope to modern river terrace to the South West.
Land Use	Rough pasture
Survey Method	Fluxgate Magnetic gradiometry: 90x70m at 0.25x1m. Bartington Grad 602 twin fluxgate gradiometer. Electrical Resistivity: 90x70m at 1x1m. RM15 with 0.5m twin-electrode array.
Survey Date	23/6/2005
Survey Conditions	Hot and dry
Excavation Approach	Stripped in narrow trenches then excavated and enlarged to clarify.

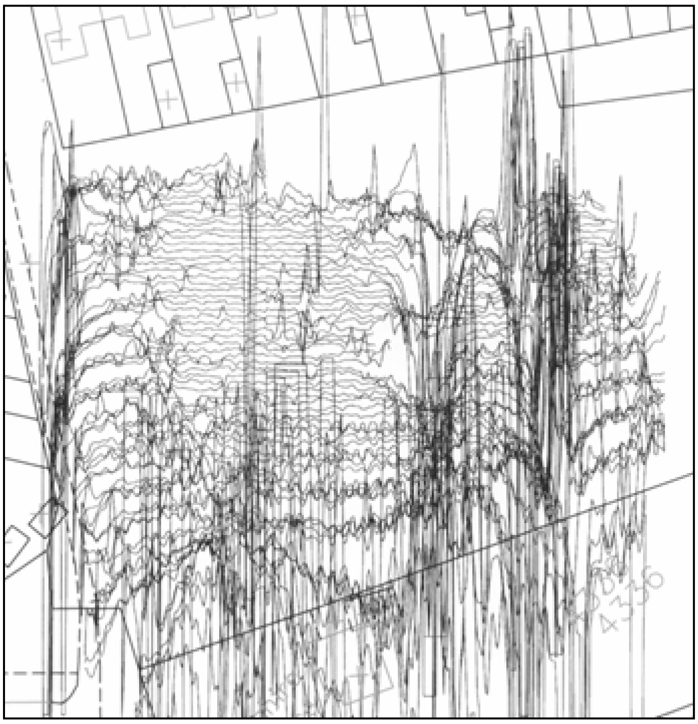
Discussion

This site occupies an open, grassy field within the town of Middlewich. The survey was commissioned as research, to find any significant remains, in support a community archaeology project.



The magnetometer survey detected very strong magnetic gradient anomalies due to metal objects around the perimeter and debris within the site. Disturbance was also caused by brick and other construction debris along one side of the site. Despite this a number of potentially archaeological anomalies were also reported by the surveyors. The resistivity survey showed that the site is divided into two zones, each containing abundant, strong soil electrical resistance variations. The surveyors interpreted a number of more linear anomalies as having a potentially archaeological origin.

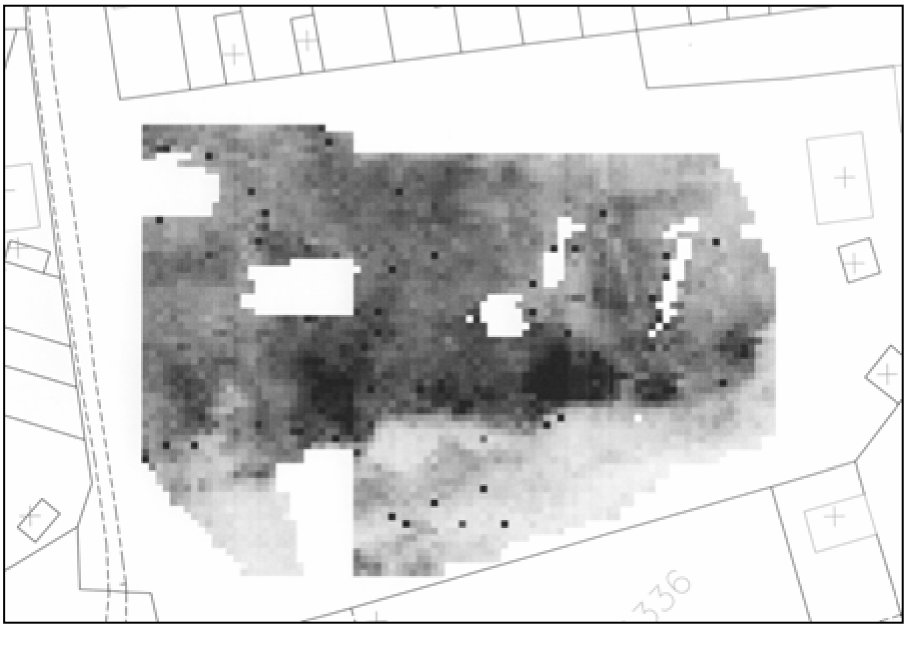




Magnetic gradiometer survey at Buckley's Field

+/-13nT greyscale plot and trace plot (300nT from top to bottom of this image) showing very strong magnetic gradients and abundant strong, sharply defined dipoles.

These are due to a combination of larger metal objects (fences …) and abundant brick and metal debris in the soil.



Electrical resistance survey

17 to 139 Ω greyscale plot showing that the site is divided into two zones, each with abundant, strong resistivity variations.

The geophysical surveys were followed by the excavation of 11 trenches. These showed that the strong resistivity difference between the two zones were due to the modern build-up of debris-laden material, which was also the cause of the strong magnetic disturbances in the same area. The anomalies suggested as potentially archaeological by the surveyors proved to have other origins.

Abundant and varied Roman remains

But

1 deeply buried
2 broad spreads
3 overlain by debris

The excavations found an abundance of archaeological remains none of which were represented in the geophysical survey results.

We can identify three reasons for this:

1 the abundance of disturbance, debris and metal constructions around the site produced a strong pattern of anomalies which made it impossible to resolve the smaller anomalies due to archaeological remains nearby.

2 the excavation showed that the archaeological remains, though extensive, were buried to a depth of more than 50cm and many of the strongest geophysical boundaries lay at significantly greater depths. The stratigraphy was also quite complex and three-dimensional, which tends to obscure the detail of individual features when conflated to the 2-dimensions of a standard geophysical survey, even where they lie close to the surface – and even more so where they lie at depth. The result is that the detectable anomaly contrast, due even to these significant remains, will have been weak at the ground surface whatever 2-dimensional technique was used.

3 Many of the archaeological remains here are broad spreads of material with only diffuse vertical boundaries. Our normal geophysical survey techniques detect these much less well than boundaries between cut (ditch, pit) or built (wall) structures within contrasting materials, most often the natural soil.

These effects, taken together, provide sufficient reasons why the remains were not detected. Could this have been anticipated and could an alternative, successful strategy been designed?

The abundance of metal around the perimeter of the site was known and we can presume that records, and local memory, would have identified the area of dumped materials over nearly 30% of the site. Thus the difficulties caused by these anomalies could be anticipated, though on there own they would not be sufficient reason not to carry out a geophysical survey because any strong archaeological anomalies might still have been detectable.

The depth to which the remains are buried may be due to post-Roman flooding which has spread alluvium across the site and this can be readily predicted from the topography of the site. Such deep burial is not common except at the base of easily eroded slopes and on floodplains, and it can be anticipated in both cases. Certain coarse soils also tend to accumulate deeper upper strata or to loose stratigraphic definition in the upper 50cm due to lessivage (the downward movement of fine soil matter through suspension in water draining through pores) and this has a similar effect on the detection of archaeological remains beneath.

The nature of archaeological remains, however, is much harder to predict – but this, of course, is the purpose of the survey itself and shows how useful it would be state explicitly what we require geophysical survey to be able to find in any particular case.

Thus, in brief, strong clues did exists that the site might be hard to map geophysically due to surface debris and deep burial but to do so would require a different approach to survey design, and a significant application of resources in anticipating such problems.

Two factors make this difficult to achieve.

1 Archaeological geophysicists are expected to know a great deal about their instruments, survey and processing methods but they are often neither trained nor expected to be trained in soil science and geoarchaeology. Thus anticipating complex matters of geomorphology or pedology – such as deep alluvium - is neither possible nor expected. Many surveyors do have considerable excavation experience and some have other earth science training but soil science is now a rarely taught discipline and most archaeologists receive less than one day of earth science training during their entire degree course[14]. Overcoming this really requires the much closer integration of geophysics and geoarchaeology which is likely to have much wider benefits.

[14] Telephone survey of all UK departments teaching single-honour archaeology. Conducted 10/11/2005 by Terra Nova Ltd.

2 Geophysical surveyors are usually required to prepare survey designs very quickly and, while they may have regional scale soil and geological mapping available, they do not have time to find out about the detailed geology, geomorphology and soils at a particular site. Indeed, it is a common problem across all archaeological contract practice that, while other members of a development team may have access to detailed geological and historical mapping, geotechnical, environmental and archaeological Site Investigations are often so divided that the teams do not share such basic resources.

Designing alternative strategies presumes that we will anticipate that standard approaches will not give what the archaeologist needs and we have shown that this requires that we give the surveyor more time, resources and better earth science training with which to prepare.

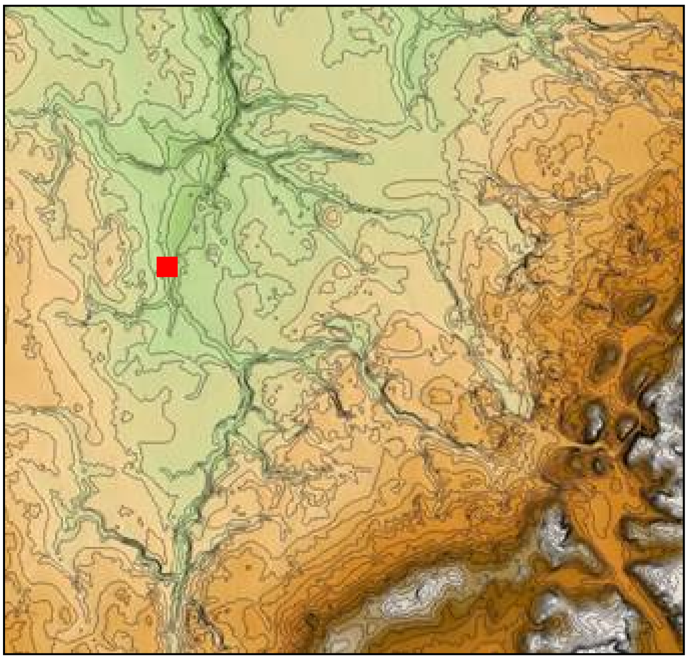
One way to ensure that alternative strategies are applied is to make multiple survey techniques the norm – though the current assumption in commercial practice is that the cost of this requires exceptional justification. In this case, however, two very different techniques were used without remains being detected and thus a third would have been required. Knowing that the remains were quite deeply buried, however, would have altered the surveyor to the need of a quite different approach, since they would know that magnetic gradiometry and standard electrical resistivity survey were likely to fail. They might therefore, for example, have used ground penetrating radar, which might have proved successful.

Whether the probably much greater cost of such an approach have been acceptable would depend on a balance of needs and resources that could only be considered for each project. Such costs are usually regarded as too high since geophysical survey appears all too often to be seen, by those who commission it, to be a quick, low cost option and its considerable potential, when used analytically, is much more rarely explored.

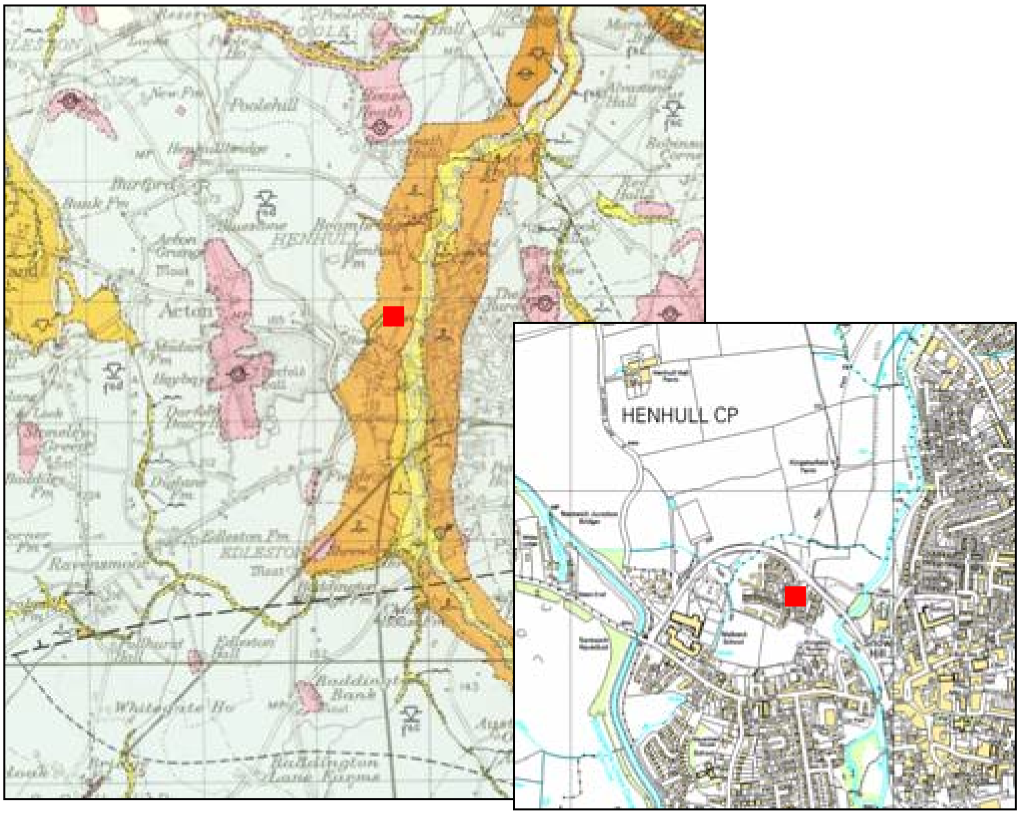
Location	SJ 6455 5260
Curatorial Authority	Cheshire County Council
Context	Development Control
Consultant	University of Manchester Field Archaeology Unit
Survey Contractor	Geoquest
Excavation Contractor	University of Manchester Field Archaeology Unit
Geology	Fine grained Holocene alluvium and adjacent till. The solid geology is Triassic Upper Keuper salt-bearing beds.
Soil	Typical sandy gley of the Blackwood association grading into cambic gleys similar to the Wigton Moor association (SSEW 1986).
Hydrology	Moderately permeable soil and parent material with variable groundwater depth, on a largely flat site with some underdrainage. Water ponds within the soil profile.
Topography	Largely flat site on a low (2nd) river terrace
Land Use	Pasture
Survey Method	Fluxgate magnetic gradiometry: 30 % of the site by magnetic “scanning” then more than approximately 60000m^2 with readings recorded at 1x0.5m intervals.
Survey Date	September 2001
Survey Conditions	Not recorded
Excavation Approach	Trenching followed by extensive open area excavation of approximately 1ha.

Discussion

The magnetic gradiometer survey at this site found areas of magnetic field gradient disturbance and some drains but very little of obvious archaeological significance, though two groups of potential features within the magnetic gradient plots were picked out by the surveyor.



The site is in low-lying topography on a fine-grained alluvial terrace on the valley side, close to the edge of the till.



The excavations, which covered about 1ha, found abundant archaeological remains, including large brine storage tanks, which were not detected by the magnetometer survey.

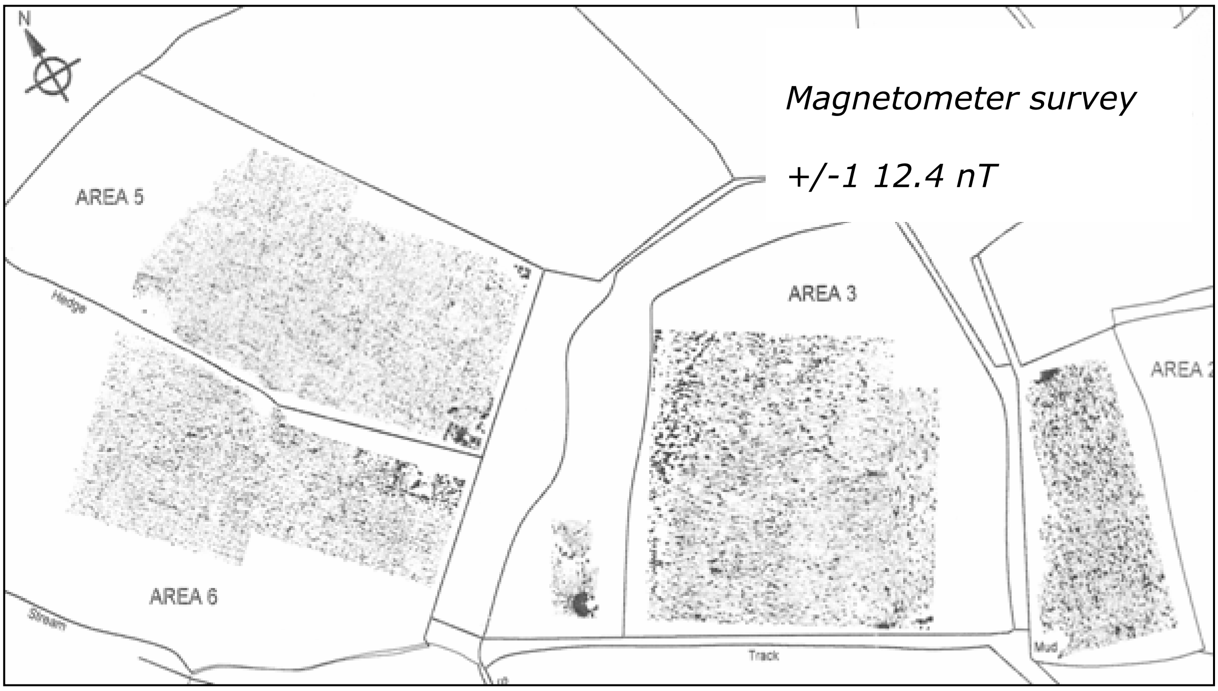
Brine tanks under excavation and a general view across the site.

The excavation report and publication suggest why the magnetometer survey did not find the archaeological remains.

1 The remains were deeply buried and truncated beneath a formally cultivated soil, often more than 50cm deep.

2 While some of the remains contained ceramic fragments and other archaeological debris, the fills of the larger features, the brine tanks especially, were composed of material very similar to the natural

deposits around and the tanks were built of wood, which is not detectable magnetically. Thus there would be no reason to expect a magnetic contrast between the tanks and their surroundings, making them invisible to magnetometer survey.



It might have been possible to detect the brine tanks using other methods. Electrical resistance tomography or electromagnetic conductivity survey might have been effective if used across the whole site. But the former, in particular, would be costly and would therefore require that the consulting archaeologist and geophysical contractor anticipate the nature of the remains and their soil context.

It is reasonable to suppose that the presence of deep topsoil, due to medieval cultivation, can be anticipated in superficial deposits such as these. Indeed the deep burial of weakly contrasting remains is a common characteristic of sites in soils, such as this, which contain a high proportion of both sand and clay because they have often been favoured for cultivation and tend to be affected by deep bioturbation and lessivage.

To develop an awareness of the risks this poses to geophysical survey, however, requires an degree of interaction between archaeological geophysics and soil science or geoarchaeology which is currently uncommon. It would also require new research designed specifically to identify such risks, which is unlikely to happen, given how little such background research is currently taking place in British archaeological geophysics.

Location	SJ 713 656 to SJ 723 638
Curatorial Authority	Cheshire County Council
Context	Development Control
Consultant	Oxford Archaeology North
Survey Contractor	GSB
Excavation Contractor	Oxford Archaeology North
Geology	Till with small areas of fluvial and fluvioglacial alluvia overlying Triassic Upper Keuper salt-bearing beds.
Soil	Typical stagnogley of the Salop association with areas of typical brown alluvial soils (SSEW 1986).
Hydrology	Moderately permeable upper soil horizons over slowly permeable parent material with variable groundwater depth, in a gently undulating area with some surface drainage. Water ponds within the profile of the Salop association soil.
Topography	Gently undulating interfluve crossed by a small stream valley.
Land Use	Pasture
Survey Method	Fluxgate magnetic gradiometry: 12.6ha of scanning followed by 6ha with readings recorded at 1x0.5m intervals.
Survey Date	March 2003
Survey Conditions	Not recorded
Excavation Approach	Evaluation by trenching, based on geophysical survey results, followed by excavation of selected areas.

Discussion

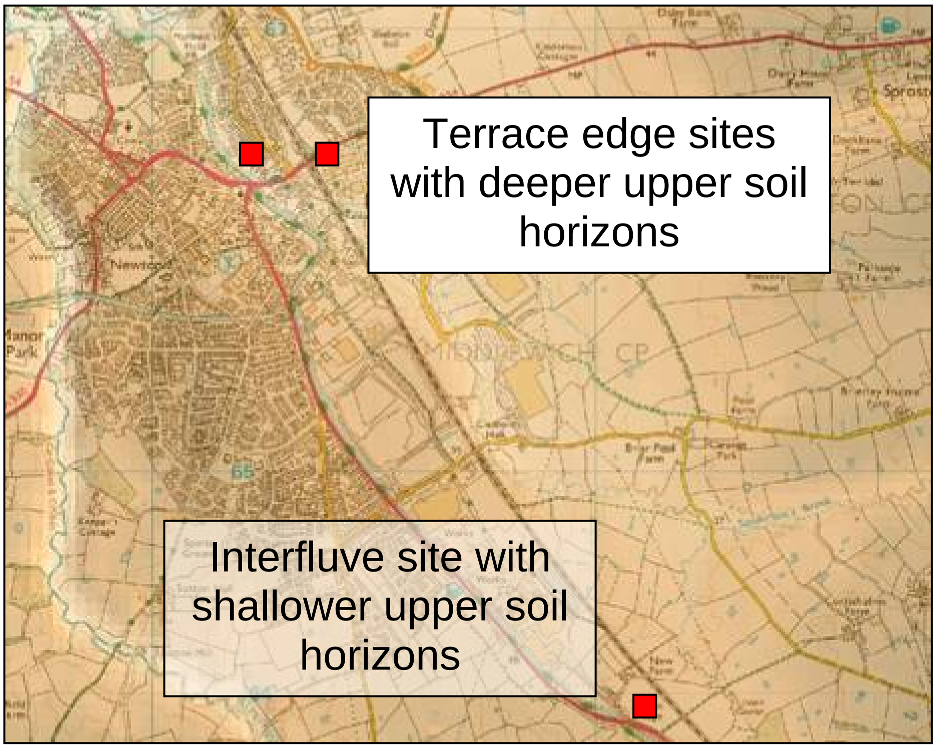
The magnetic gradiometer survey, in 10 blocks along the route, failed to identify a small number of archaeological features which were found by trenching and identified a number of potential archaeological remains which were not confirmed by trenching. It also, however, found a complex of anomalies which trenching confirmed as being due to buried ditches.

Thus, while the survey gave some misleading positive and negative evidence, it succeeded in the more important task of locating a significant group of remains.

This positive result came about because there were no significant reason why it should *not* be possible. The route is mostly on interfluve without deep soil accumulations. Thus archaeological remains lie immediately below the plough-soil. The remains themselves are filled with material which contrasts sufficiently, physically, with its surroundings, thus making it possible for anomalies to be detected. Finally, the site is uncontaminated with surface debris and is not close to modern constructions which might otherwise produce complex magnetic interference.

Magnetometer greyscale plot of the principal site located on the Middlewich Eastern Bypass

This plot, at -1 to +2 nT, shows a very well defined ditched enclosure later identified in excavation



The location of three sites around Middlewich in relation to topsoil depth.

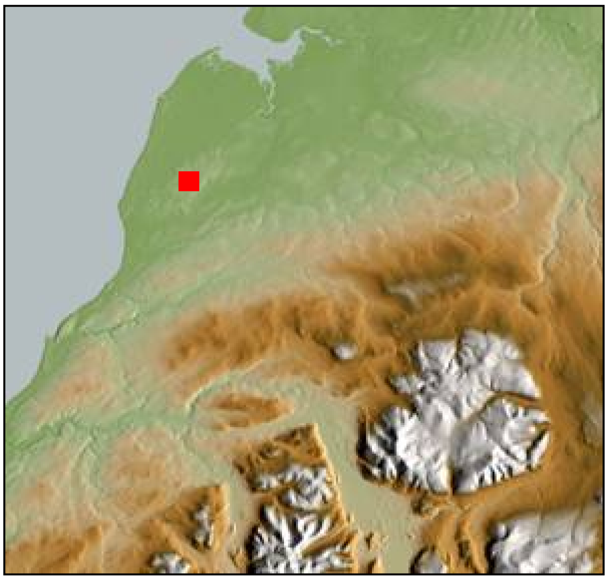
The two sites, to the north, which lie close to watercourses, have deep topsoils which are likely to include post-occupation alluvium. Surveys of these sites did not detect the buried archaeological remains. It is likely that the topsoil depth is one of the principal reasons in both cases, although surface contamination also caused significant interference.

The single site to the south, on the Eastern bypass, lies on an interfluve with no significant accumulation of Holocene alluvium. Thus the archaeological remains are close to the surface and correctly located by magnetometry.

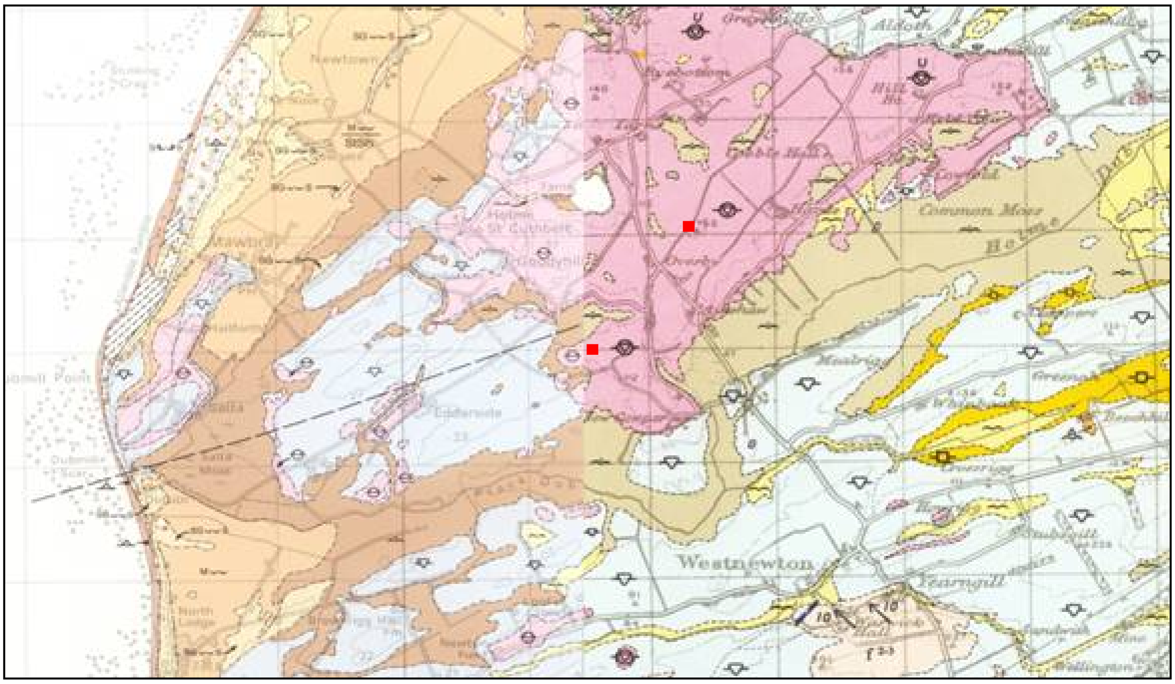
Location	NY 110 450 to NY 135 500
Curatorial Authority	Cumbria County Council
Context	Development Control
Consultant	Headland Archaeology and NP Archaeology
Survey Contractor	Archaeological Services WYAS and Bartlett-Clark Consultancy
Excavation Contractor	NP Archaeology
Geology	Quartz sand ridge
Soil	Typical Brown Sands of the Newport 1 association
Hydrology	Very well drained throughout due to high permeability
Topography	Gentle slopes and plateaux
Land Use	Pasture
Survey Method:	
New Cowper Farm	Fluxgate magnetic gradiometry: 6ha with readings recorded at 1x0.5m intervals.
Overby	Fluxgate magnetic gradiometry: 2 areas of 0.5ha Caesium magnetic gradiometry: 2 areas of 0.5ha Electromagnetic survey (EM38) Phase: 2 x 0.5ha Electromagnetic survey (EM38) Quad: 2 x 0.5ha Magnetic susceptibility (MS2/D): 2 x0.5ha Electrical resistivity: 2 x 500m^2
Survey Date	September 2005
Survey Conditions	Dry, settled
Excavation Approach	Strip and record of the whole quarry extension.

Discussion

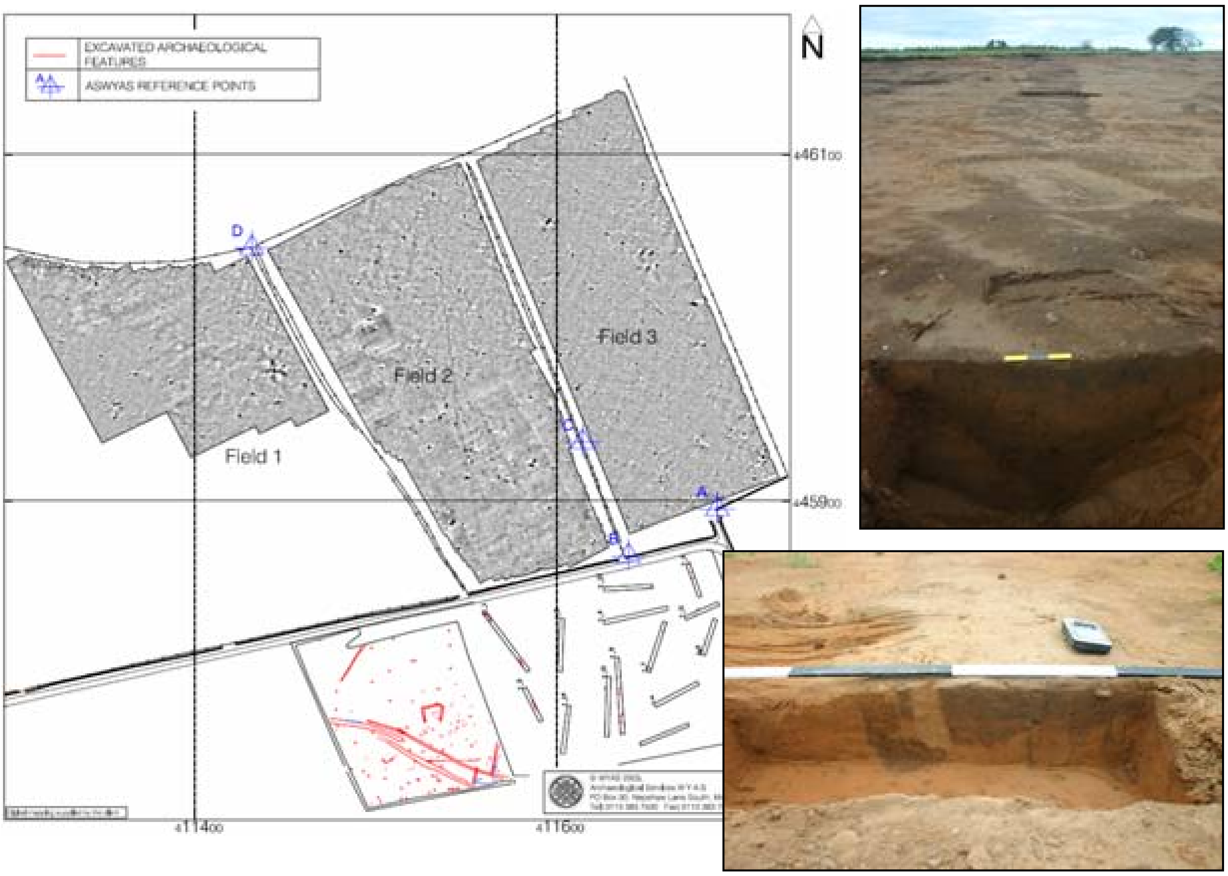
A number of archaeological sites have been recorded by air-photography on the sand ridge near New Cowper Farm and Overby. An application to extend the New Cowper Farm sand quarry, and similar applications to extend the quarries at Overby, provided the opportunity to examine the geophysical properties of archaeological remains in detail.



The sites lie on an undulating ridge, mostly composed of sand with some gravel (shown in pink on the geological map below)



The area was originally included for more detailed study in this project because the initial 6ha magnetic gradiometry survey at New Cowper Farm had located few of the remains which were found when the fields were stripped. Thus the reasons for this were immediately relevant to the project.



Magnetometer survey at New Cowper Farm and photographs of ditches. The uppermost photograph shows the ditch which is represented by a linear anomaly running N-S through field 2. The very small ditch in the photograph below was not identified. Greyscale magnetometer plot at -1 to +2nT

Since further topsoil stripping was planned, it was possible to study the soils in more detail to find out why the detection of remains had proved so difficult by fluxgate magnetometry, and to explore alternatives.

The site was visited twice and measurements made of magnetic susceptibility, using a portable MS2 meter and type E sensor coil, in a variety of newly exposed ditches and pits. The soil profile was also recorded and further observations made wherever relevant.

A series of 20 boreholes were drilled across several fields close to Overby quarry, to a depth of 3m. The soil profiles were recorded and magnetic susceptibility recorded.

The soil profile at New Cowper Farm, coring and magnetic susceptibility measurements. Similar profiles were found over the whole ridge-top.

Finally, trial surveys were undertaken at Overby using fluxgate and caesium magnetic gradiometers, an electromagnetic conductivity meter (the Geonics EM38) and a resistivity meter in 0.5 and 1m twin-electrode configuration. The results of these surveys were compared with air-photographs of the same areas showing crop marks.

The sandy soils which cover this area are quite easily eroded and, even where stable, develop deep, homogeneous topsoils through bioturbation and lessivage. Thus many archaeological features in such sites tend to be truncated, deeply buried or both. The soil profile exposed by stripping along the edge of one of the fields at New Cowper Farm showed this very clearly, with a topsoil accumulation of more than 50cm on flat and concave slopes and shallower profiles over convex slopes – presumably due to erosion.

The magnetic susceptibility contrast between the feature fills and the natural sand to each side is almost always low and sometimes undetectable, whereas the susceptibility of the topsoil above is often significantly higher. Many of the archaeological features, moreover, are shallow and truncated. Thus the magnetic anomalies to be expected from such features would be small and easily masked by variations in topsoil depth and composition.

The sand which makes up the bulk of the soil and feature fills is quartz-rich and well-sorted. Thus it is almost certainly poor in the iron minerals which, directly or when altered, produce higher magnetic susceptibilities. Reductive and then oxidative heating of samples of sand, topsoil and feature fills did result in increases in magnetic susceptibility but values still remained relatively low (a sand sample changing from 4 to 8x10^{-7}SI and a pit fill from 5 to 15 x10^{-7}SI for example – as against topsoil susceptibility typically between 10 and 20 x10^{-7}SI). Moreover it was the samples with the finer textures, and thus which had the greater non-sand component, which became most enhanced.

Experienced archaeological surveyors usually expect poor magnetometer survey results from sandy sites because of the lack of the finer, less silica-rich mineral matter which can be more magnetically susceptible – and thus provide a detectable magnetic contrast. Many of the sandy materials from which soils form, however, contain finer matter and, although they may be mapped as sands and sandy soils, can produce good magnetic survey results. The mineralogy of the sand itself is important. While most fluvioglacial or sub-glacial sands, like those at New Cowper, are largely quartz (which is inherently of low susceptibility), some contain a wider mineral suite and are inherently more susceptible, as well as producing more susceptible weathering products.

Thus, once again, our ability to predict the quality of survey outcomes on sandy sites will depend partly on the quality of the mapping we have available – their ability to resolve the extent of sand bodies, and the amount of information they can give us about the mineralogy and textural purity of the sand. Current geological maps are inadequate for confident prediction of such properties because they are too spatially imprecise and give too little mineralogical information about the soil parent material. Moreover, geological survey in Britain has traditionally ignored the most superficial materials from which soils form. Thus the true extent and nature of drift deposits is often incorrectly mapped because the most superficial deposits, from which soils form, are often different from those beneath. It is very common, for example, to find that the uppermost deposit of a fluvioglacial sand and gravel is finer, and may be predominantly silty rather than sandy. Likewise, the true extent of loess in soils would be underestimated if we took only drift geological data.

The effect of these uncertainties, and how they might be addressed, is discussed below.

The caesium magnetometer test results did not prove significantly better than those produced by the fluxgate magnetometer, perhaps because both principally recorded variations in topsoil rather than the presence of archaeological structures beneath. Electrical conductivity recorded by the EM survey showed no interpretable patterns over remains known from air-photographs but Electrical resistance survey, using a 1m twin-electrode array was more effective, though very much slower and thus more difficult to justify over a large evaluation area.

The survey results at New Cowper Farm and at Overby confirm the expectation that magnetometry, over sands, tends to produce poor results. Our study shows, however, that there can be several reasons for this, including the masking effects of the depth and susceptibility of overlying soil horizons, as well as the inherent lack of susceptibility contrast between feature fills and the natural soil. The positive results of the electrical resistivity survey test, and positive ER survey results from other sites, should encourage the use of ER survey, under appropriate conditions, especially if the latest developments of multi-channel, multiplexed and moving contact ER instruments increase survey speed and thus reduce costs to those of magnetometry. Likewise the potential for better magnetometer results might encourage the use of caesium magnetometry on sandy sites (with convex surfaces especially) where deep surface horizons are less likely to accumulate, taking advantage of the often very flat magnetic background against which weak anomalies may be detectable.

Location	NX 987 211
Curatorial Authority	Cumbria County Council
Context	Development Control
Consultant	Oxford Archaeology North
Survey Contractor	ArchaeoPhysica
Excavation Contractor	Oxford Archaeology North
Geology	Till and alluvium overlying Coal Measures
Soil	Varied. Mapped as Cambic Stagnogley soils of the Brickfield 3 association. The site also probably contains Brown Alluvial soils and variants.
Hydrology	The parent material and till derived from it is inherently poorly drained. The valley bottom deposits are, likewise both poorly drained and subject to groundwater. The degree of drainage, however, is reported to vary great across the slopes of the site and within accumulations of colluvium. The site is crossed by a spring-line and partly underdrained.
Topography	Moderate slopes, valley floor and plateau
Land Use	Pasture
Survey Method	Caesium magnetic gradiometry: 4ha with readings recorded at 1x<0.25m intervals. Electrical Resistivity: 4ha at 0.5x1m using 0.5m twin-electrode array. Metal detecting: 4ha, traverses at 3m intervals
Survey Date	June 2005
Survey Conditions	Not recorded
Excavation Approach	Trenching targeted on geophysical anomalies

Discussion

This is one of several geophysical surveys designed to evaluate linear routes in the North West, most of which are bypasses. Several such bypasses, along the A66 and here at Ulgill, lie close to Roman remains - which makes effectiveness of detection imperative - yet cover a large area – which requires that they are not costly.

The solution applied here was a combination of denser survey (1x0.25m magnetometry, 1x0.5m resistivity) and a more sensitive magnetometer (a caesium vapour magnetometer set up as a 1.2m vertical gradiometer) than are usually used.

The results show a variety of buried remains associated with agriculture – primarily drainage. They also very clearly show natural variations in soil physical properties due to drainage and soil composition. They do not, however, show more significant archaeological remains nor, in particular, any Roman remains.

Excavation confirmed these results in detail, finding precisely those structures anticipated from the geophysical survey, and not finding other structures which the geophysics had missed.

Surveys on other bypasses, on the A66, have used standard fluxgate magnetometers and reading spacings. As at Ulgill, these largely found only features associated with drainage and land-divisions, most of which are post-medieval. Not all those features detected geophysically have been confirmed in excavation, and not all those found in excavation had been detected by geophysics, but the overall scarcity of remains of greater *planning significance*, identified in the geophysical surveys was, essentially, confirmed.

In all of these cases – and despite the complexity of the soil physical property distribution at Ulgill – a largely negative survey result (from a planning perspective) proved reliable because there was sufficient geophysical contrast between features and their surroundings and because there was no other reason why such features would be obscured, especially by surface debris and deep surface horizons. The same is likewise true for a number of area surveys in the region, such as at Low Plains Quarry and the area evaluated to the west of the recent Manchester airport extension.

It is widely assumed that geophysical surveys are useful only to provide positive evidence of archaeological remains. Yet, for many planning purposes, it is the positive confirmation of the absence of remains which is most significant. Such negative results are to be frequently expected in a region where remains have already been found to be relatively sparse.

It is therefore, perhaps, significant that those sites in the North West where an apparent absence of remains proved incorrect have particular characteristics (geology, soils and site history) which could be identified in advance. Thus it may be possible, though at present we can say no more, that geophysical surveys can be used to provide reliable evidence of absence, especially if accompanied by a few simple soil tests which show that the surface horizon is not likely to mask remains.

It is reasonable to suppose, also, that denser and multi-technique survey will increase the reliability of such negative results further and should clearly be considered where negative evidence is explicitly sought – as is often the case in commercial site evaluation. Whether the use of more precise survey instruments (such as caesium magnetometers) makes a significant difference to survey outcomes will depend on the nature of the soil and its parent material. On quiet magnetic backgrounds – fine, uniform alluvium, for example – the higher magnetic field resolution of such instruments may enable them to distinguish weaker archaeological anomalies. On the many North Western soils, however, where igneous and metamorphic stones are common, the disturbed magnetic field background will make the additional sensitivity of such instruments redundant.

It is also possible to reproduce some of the sensitivity advantages of the caesium magnetometer using fluxgate magnetometers by more precisely controlling instrument position and orientation, by slower survey and by recording only in a single traverse direction and instrument orientation. The exceptional clarity of results from fluxgate gradiometer surveys, which used such methods, at a number of major sites in the North West (Maryport, Birdoswald and others) certainly shows why it would be useful to increase the frequency of such variations in survey method into routine professional practice. This principally requires that surveyors are given greater freedom to develop survey designs in response to the needs of a particular site and project, and are less constrained by formulaic survey designs in which they have little say – now too often the case.

Maryport Roman Fort and Vicus

The unusual clarity of the magnetic gradiometer survey results at Maryport, in Cumbria, may be a result both of the strong magnetic susceptibility variations down the natural soil profile and of the careful field technique used to gather the data. It, and a number of similar surveys on major sites along Hadrian’s Wall, show that magnetometry can produce data of exceptional value in site management and research – especially where such surveys cover large areas. This hardly needs restating in light of the many successful surveys around the country, but it emphasises that surveys in the North West can be just as good. It also shows that, where there is a specific need for dense survey and an unusually careful field method (single-direction walking, which avoids systematic variations between survey lines) these can and should be adopted. This, in particular, should persuade curators and consultants to move away from briefs that stick too narrowly to the accepted minimum standards and, in consultation with survey contractors, prescribe higher standards of work where a higher standard of outcome is likely to be important.

Manchester Airport

A number of surveys were carried out in areas to the west and south of Manchester airport in advance of its extension. Most of these surveys found only relatively recent land divisions, and this was largely confirmed in evaluation excavations. One field, however, at Stock-in-Hey farm, contained curving features identified in an electrical resistivity survey. These proved, in excavation, to be former natural stream courses thus demonstrating both the difficulties of distinguishing some archaeological and natural features and the potential of geophysics to identify potential sources of palaeoenvironmental and palaeo-geomorphological evidence.

There is considerable potential for the wider use of geophysical survey in this role but it requires a greater awareness of the potential, on the part of those commissioning and carrying out survey, as well as the closer integration of geophysics and geoarchaeology. This, in turn requires that all concerned – curators, consultants and contractors – receive more than the minimal geomorphology and soil science training currently on offer in most universities, as a routine part of their undergraduate foundation studies. It also suggests that advice be sought from palaeoenvironmental scientists on the potential use of geophysical survey, or the palaeoenvironmental interpretation of survey results, where promising deposits are likely to be found.

Thus, for example, where a valley bottom site lies on Holocene alluvia a project geoarchaeologist should recognize that it may be relatively straightforward for a short geophysical survey and coring project (using appropriate methods – which are different from those best adapted for mapping shallow remains) to trace the principal palaeochannels and thus identify bodies of buried peat in former meanders. Such strategic input early in the development of a project, may prove valuable for research and better value than a piecemeal recovery of peat samples as deposits are encountered.

There is a particular coincidence of interest, here, between aggregate quarry companies who want accurate data about overburden depths and archaeologists who need to know about the palaeoenvironmental and archaeological potential of that same overburden. Coordinated coring and geophysical survey campaigns can be designed to meet both interests.

Mellor

The prehistoric ridge-top site at Mellor, Greater Manchester, has been both excavated and the subject of extensive survey using magnetometry, electrical resistivity and ground penetrating radar. Mellor is unusual, however, in that this work has been led by a group of local enthusiasts with the assistance of the Local Authority archaeology team. The largely successful results of the surveys are instructive because they point out what can be achieved by those who have the advantage of time and the ability to keep on returning to the same site – which most professional surveyors and excavators cannot. They also show the benefits of a local, non-professional team which is able to draw on the substantial skills of its members in other fields. Thus, while the Mellor community team does not include a geophysicist, it includes quite as much relevant scientific expertise as most professional survey contractors. This expertise, and the time that non-professionals can often make available, might be well used in strategic research and Curators might bear in mind the potential which such groups may offer other than in digging and pot-washing.

Sawley Abbey

Sawley Abbey is typical of monastic sites in the North of England, in widening valleys on the upland fringe, which were built on Holocene alluvium over fluvioglacial valley floor deposits. Such sites, including, for example, Furness and Fountains Abbeys, consist of upstanding banks and platforms some of which have stone construction or rubble cores. Buried wall footings survive beneath the ground as stone constructions as well as lined and unlined drains and ditches.

Such prominent sites are in guardianship and protected by a management regime that keeps them under permanent pasture, but there are many other sites, including Country Houses like Lostock Hall, Moston Hall and

Lathom House, which share an abundance of earthworks and buried stonework, set in poorly drained soils.

The lower soil horizons of the major monastic sites tend to be wet throughout the year because of the high groundwater levels in such valley bottoms, but upper horizons, and the whole soil profile around valley side sites, are likely to vary greatly in wetness between winter and summer because of the changing depth of ground water and volumes of surface water flow.

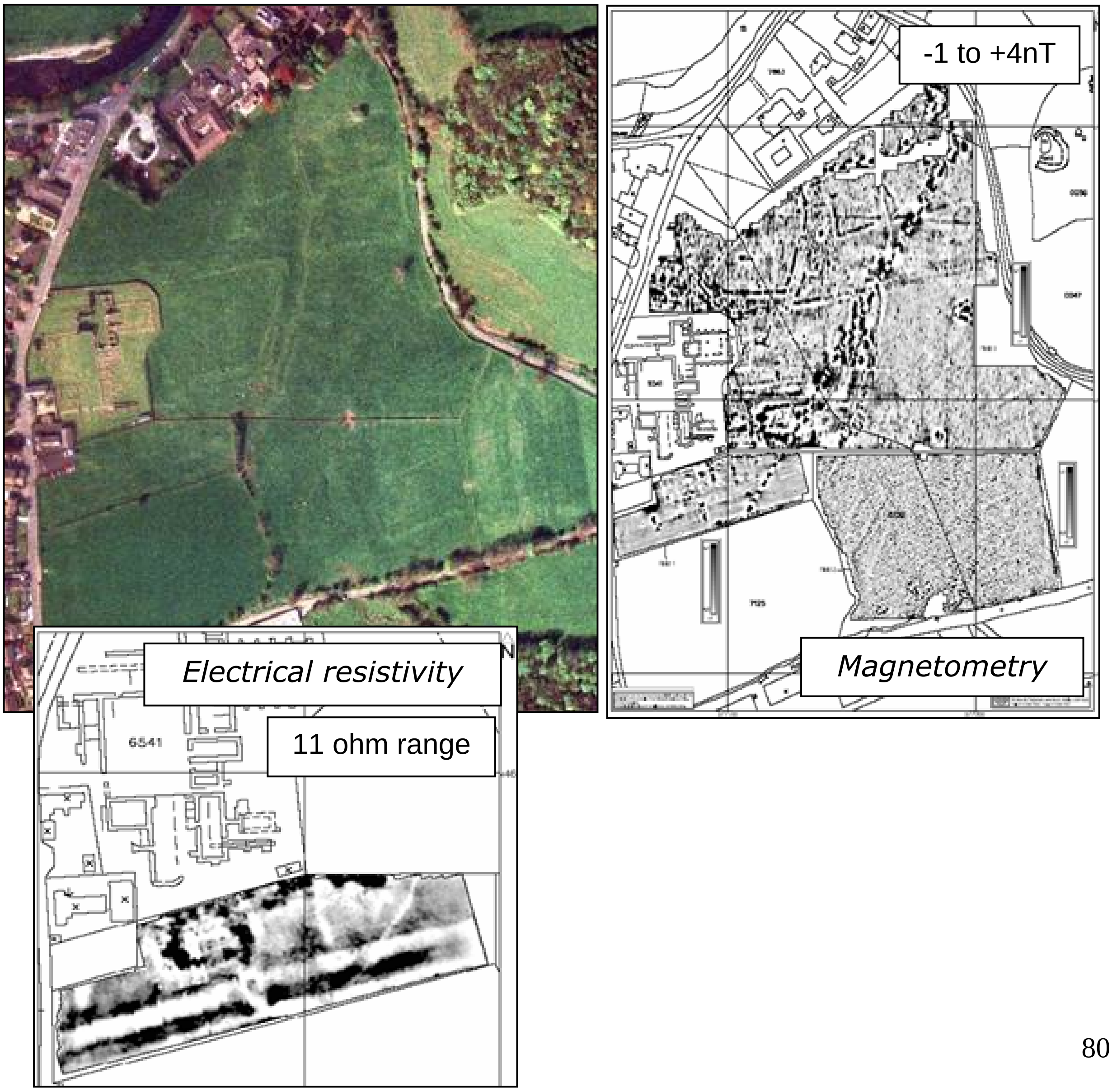
This combination of site and soil characteristics is significant because it both constrains and provides opportunities for successful survey, as the Sawley Abbey results show.

A particular problem arises in distinguishing between anomalies due to earthworks and due to the material that lies buried within them. Upstanding earthworks can create geophysical anomalies because they contain archaeological structures, such as wall cores. But their shape alone creates anomalies both as a result of their topography (which, for example, distorts the flow of electric current, in Electrical Resistance survey, and alters the distance between sensor and ground in Magnetometry). Earthworks also create anomalies, irrespective of whether they *contain* remains (rather than *being* remains) because they alter the physical properties (such as moisture content) of the soil within them.

It is interesting that it has proved consistently difficult to distinguish between these three distinct geophysical effects in surveys carried out over such sites in the North West.

It is, in theory, possible to record the shape of the ground surface and use this to calculate the anomaly which it, alone, might cause. In most practical cases, however, this is impossible because sufficiently detailed topographic records are not available, because such modeling is too time consuming and because it relies on a uniformity of substrate and a control of the survey method (such as where, precisely, readings were taken) which cannot be achieved.

A better solution is to combine survey methods so that the results of each give insights into the meaning of the others. Thus it may be best for all sites of this general character to be subject to surveys using several methods, for GPR survey to be considered as part of this wherever deep stratigraphy may be expected (since it is likely to be particularly worthwhile) and for electrical resistance survey to be carried out when the soil is at its driest to increase the probability of contrasts between the natural soil and relatively conductive archaeological deposits.



Discussion

1 Does geophysical survey meet the needs of archaeologists in the North West?

Of the 35 sites for which we can reach clear conclusions:

24 unequivocally met the need for which they were commissioned. They found the remains later located by excavation or provided detailed images of major monuments in care, from which management could be planned.

6 did not meet the need for which they were commissioned. They failed to find important remains later found in excavation.

5 produced partial success. They found a useful proportion of the remains later found in excavation but, also, missed important features.

Moreover:

A high proportion of surveys which record nothing which is likely to be a major archaeological planning constraint (only post-Medieval land-divisions, for example) were likewise supported by later excavation which show that there was nothing more significant to find.

Thus where conditions allow (in other words, where there are no reasons why survey should *not* succeed) geophysical surveys in the North West appear capable of giving reliable evidence for the absence of remains as well as for their presence.

Clearly geophysical survey has proved effective and deserves a key role in archaeological evaluation in the region.

2 Where does geophysical survey fail and why?

Since this project is largely a review of past evaluations, most of the evidence for the reasons for survey outcomes have been inferred rather than directly ascertained. The exception is the area around New Cowper Farm and Overby, in Cumbria, where we have direct measurements to explain what can and cannot be detected geophysically.

Survey failures, where they occur, can be significant but, in most cases are easily explained.

This project suggests that there are only a few causes (risk factors) behind most survey failures:

I. The remains lie too deeply buried to be detected
II. The remains are masked by natural or man-made debris
III. The geophysical anomalies due to remains are masked by nearby surface structures such as metal-clad buildings, fences and vehicles
IV. The remains and natural soil do not contrast geophysically

Occasionally, also, remains are simply too small to be detected, either (as with small pits) because they are not likely to be sufficiently sampled by the survey instrument or (as with many timber beam slots) because they do not have enough volume to create a geophysical anomaly detectable against background variations.

Finally, Electrical Resistance survey results are sensitive to soil moisture conditions. Survey is less likely to succeed under wet, rather than dry conditions, for most types of remains, and some results might therefore have been clearer if survey had take place when the site was at its driest, in the late summer.

Sometimes two or three factors coincide. Thus, at Welsh Row, Nantwich, and New Cowper Farm the remains are both quite deeply buried and probably lack magnetic contrast with their surroundings. At Buckley Fields, Middlewich the remains are both deeply buried and within a geophysically noisy environment due to man-made debris and nearby structures. At Prosperity Way, Middlewich, the remains are deep, the soil contaminated by modern debris and the site adjacent to metal structures.

The presence of natural “debris” within the soil is particularly important in much of the North West. The structure of many soils can produce geophysical anomalies of the scale of archaeological remains, which are therefore masked. Most fine-grained soils, however, are relatively uniform at this scale and probably, under most conditions, produce relatively flat geophysical backgrounds against which archaeological anomalies can be easily distinguished. Metamorphic and igneous stones are, however, abundant in some of the tills which cover so much of the region and these produce magnetic and other geophysical anomalies which can mask buried remains – as, for example, at Barker House Farm, Lancaster. Most of the surveys over till-derived soils in the region do not seem to have been significantly affected by this (hence the exceptional clarity of magnetometer surveys at Birdoswald, Maryport, Bewcastle and elsewhere, all of which overlie till). Surveys over fluvioglacial gravels elsewhere, however, have often proved unsuccessful because the strong natural background anomalies mask the rather weaker ones due to archaeological remains.

Thus the identification of igneous and metamorphic-rich coarse gravels and stony tills would be very valuable in predicting where survey results may be obscured by a noisy geophysical background.

3 What improvements might make geophysical survey more effective in the North West?

Avoiding the most common survey problems

Successful geophysical surveys in the North West have been carried out across a wide variety of soils, on arable and pasture land and on a variety of site topographies and hydrologies.

This suggests that, except where there are specific risk factors which cause surveys to fail, they are likely to succeed in their original aims, even if they do not produce results of exceptional clarity.

Thus it follows that survey outcomes will be most quickly improved by identifying areas where survey results are likely to be degraded by one or more of the four risk factors (I to IV) identified above. We can then either avoid survey in such areas or use alternative geophysical survey strategies.

I *Deep topsoils*

Surveying the risk of deeper top-soils, over large areas, may be feasible by combining soil survey, parent material and geomorphological data.

The three sites in Cheshire obscured by deep topsoils (Buckleys Field and Prosperity Way, Middlewich and Welsh Row, Nantwich) all lie on erodable soils and within the range of the higher floods of nearby streams. Thus these deep topsoils are likely to incorporate alluvium, as is widely the case elsewhere.

Thus some sites at risk of deep burial could be identified by the extent of recent alluvium from soil and geological mapping. Site evaluation might then begin with a hand-auger traverse to gain an impression of depth to the first non-organic horizon – or the first significant colour change from darker topsoil to lighter parent material (what archaeologists would refer to as the “natural”). Where the topsoil is more than 50cm deep either geophysics should be reconsidered or advice should be sought on an appropriate geophysical survey design, able to map at least larger features at such depth. Standard magnetometry and electrical resistivity are unlikely to be successful.

Surveys to detect sites made up of discrete archaeological remains, on deep, mineral alluvium, where sites may lie buried at greater depth, are unlikely to succeed under any but exceptional circumstances. Survey intended to identify the buried structure of such alluvium – the presence of former islands, for example – can allow excavation to be targeted, even if sites are not directly detected.

The surveys at New Cowper Farm and Overby demonstrated that sandy soils tend to develop deep topsoils on lower slopes and in concavities – as we would expect. Other soils vulnerable to erosion and the accumulation of deep colluvium are not very common in the North West. They can be identified from soil mapping but over almost all of the area, such maps are imprecise and local enhancement of soil map data from slope and geological or parent material mapping may be required to achieve useful degrees of confidence in identifying areas where colluvium and alluvium may bury sites.

Thus soil, geological and topographic mapping might be combined to provide a first approximation of the risk of sites being buried too deeply for successful geophysical survey using standard methods. Local information could then specifically consider this, and other risk factors, before survey is commissioned.

IIa *Stoniness*

The risk of poor survey results due to the abundance of igneous and metamorphic stones is very much harder to estimate because we lack the basic map data on which it might be based. Some maps of coarse gravel bodies are available but the stoniness of till is particularly hard to predict and yet can, as at Barker House Farm, have a significant effect on survey results because individual stones cause a complex pattern of individual anomalies.

Till stoniness does, however, vary with the underlying rock. Thus most of the tills across the Cheshire Plain are less stony than those in Cumbria simply because they have been formed largely from softer rocks.

Clearly, while soil stoniness is a risk to survey success, this has not stopped excellent results being obtained from both magnetometry and resistivity survey on till. Thus we may presume that geophysical surveys can be recommended on till soils but we should take steps to learn more about the distribution of till textures, and their effects. The complex distribution of till mineralogies is likewise an influence on soil magnetic properties, and thus magnetometry survey success, but is, at present, only known in part. Current research which will enhance our knowledge of soil magnetic property distributions is welcome but we still have a great deal to learn about the origins of soil magnetic behaviour if we are to understand, model and thus predict its local distribution to a useful degree of confidence.

One way to improve our understanding of the distribution of soil geophysical properties, crucial to survey outcomes, will be for archaeologists and archaeological surveyors to join in the current efforts to improve soil parent material mapping, under the BGS Parent Material Mapping Programme. Geologists have now appreciated how valuable soil parent material data is for many potential clients. Traditional geological survey has, however, ignored the most superficial deposits, although some notes on these are found on survey field sheets. Archaeologists would find such parent material data very valuable. They are also in an unusually strong position to obtain it, under reciprocal agreements, since they can feed data on parent materials back into the mapping programme. Few other professionals expose the range and extent of parent material as do archaeologists. Thus there is a great deal for both archaeologists and geologists to gain if excavation recording included a little, standardised recording of site parent materials by suitably trained excavators. Likewise, archaeological geophysicists could make a strong case to be given relevant parent material data to plan surveys if they fed a small amount of standardised geophysical and soil data back to BGS – and this might be achieved at minimal cost.

Whether the scarcity of earth science skills in archaeology and the great commercial pressures on excavators would allow this to happen is another matter.

IIb *Man-made debris*

Metal debris, slag and brick is often found in the topsoils of urban and urban-fringe sites. The geophysical effects of these can dominate survey results, making weaker anomalies due to archaeological remains uninterpretable, as is seen in the highly disturbed magnetic gradient survey results from Prosperity Way, Middlewich. Likewise modern dumps of make-up material obscure remains beneath because they are often very inhomogeneous and produce strong magnetic and electrical resistance anomalies of their own, as at Buckleys Field, Middlewich.

Mapping the extent of such debris, to provide advanced warning of these effects at a regional scale, is not realistic. There are, on the other hand, clear indications where sites might be at risk of such effects, both in the historical record – especially through historic mapping, and from local sources.

One enduring problem of archaeological evaluations is that, although they often form only one of three site investigations, with a geotechnical and environmental investigation, data and field resources are often not well shared between them. This reduces the effectiveness of much archaeological work, not just geophysics, and there is a case for local authorities to take a very active role in ensuring that SIs are coordinated so that all the desktop data, historic mapping and results of test pitting, for example, are made available to archaeological surveyors so that they can plan survey as effectively as possible.

It should be an explicit task of desktop evaluation to identify where contamination by recent brick, tile, metal, slag and similarly magnetic debris might contaminate the soil over sites. That this is, in retrospect, identifiable (as at Prosperity Way, Middlewich, for example) suggests that it should also be identifiable as a risk at the outset.

III *Metal constructions around the site*

The proximity of fences and other metal constructions to a site is only of concern where they are large enough to produce extensive magnetic anomalies, which can obscure weaker archaeological anomalies. In our study this was only a problem at Buckleys Field and Prosperity Way, Middlewich and could be easily anticipated in both cases.

IV *Lack of geophysical contrast*

It is widely understood that the outcome of geophysical surveys depends, to some extent, on the nature of parent material on which it takes place. Apart from the interfering effects of debris (such as stones, discussed above), and soil structure, one of the main reasons for this is that the strength of geophysical anomalies, and thus our ability to resolve them against natural background variations, depends on the contrast in properties between the remains and the natural soil around them.

Thus soils which have large changes in magnetic susceptibility down the profile, or which develop enhanced susceptibility through human activity, tend to contain archaeological remains associated with strong magnetic anomalies. Likewise, soils on well-drained substrates often produce much clearer electrical resistance anomalies, under the right conditions, than those on poorly-drained clays where little contrast exists between the resistivity if the clay and an archaeological feature fill.

One of the interesting findings from this project is that successful geophysical surveys have taken place across a wide variety of substrates across the North West, suggesting that substrate type is not the limiting factor that it might be expected be in survey success – despite the obvious differences in the clarity of survey results over different substrates across the country. The principal exception is the area around New Cowper Farm and Overby, where magnetic susceptibilities are low because of the relative purity of the sand, and thus the lack of susceptible minerals.

It may be, of course, that the small study has simply not encountered other sites where such effects might have become apparent. It is possible, for example, that some of the surveys which have failed to find remains in areas which excavation proved to be truly empty of significant remains would not, in fact have found such remains because of a lack of geophysical contrast. Yet the variety of sites and soils where features *have* been clearly identified suggests otherwise.

This is not to say, however, that substrates have proved equally responsive to survey. The clarity of the magnetometer survey results at Maryport, for example, is a result of a particularly careful field technique. It is also, however, the result of a very strong contrast between the high natural magnetic susceptibility of the surface horizons (20-35x10^{-7}SI) and that of the parent material (5-10x10^{-7}SI) which is likely to have considerably enhanced the bulk susceptibility of the buried remains, and thus the anomalies they create. Susceptibility values, and consequent magnetic anomaly amplitudes are, for example, much lower on sites over coal measures (as at Barker House Farm, for example).

Thus one tentative conclusion from this study is that we may need only identify the extent of a few, specific parent materials (clean, well-sorted sands especially) in order to be forewarned of sites where magnetic susceptibility contrasts will be too low for surveys to succeed, at least in achieving narrow planning goals, even if not in the more demanding task of providing very clear geophysical images.

Doing better surveys

If the first approach to improving survey outcomes is to identify and respond to risk factors, the second is to improve the quality of the surveys themselves – the capabilities of the instruments and the methods used.

This is not likely to happen very often unless the context within which survey is commissioned changes. Although, nationally, more, large geophysical surveys are now being commissioned, the pressures are for quicker survey turnaround, lower prices and cheaper methods. The conscientious commercial geophysical surveyor faces an uncomfortable dilemma. With increasing competition, do they cut corners to stay in the market?

The risk is that, if survey standards fall, the effectiveness of survey will be reduced – and there is then even less chance that non-standard instruments and denser surveys will be used, even where cost-effective. Yet surveyors interviewed for this project said that, if they maintain their standards, and object to briefs they consider inadequate and timetables that place them under unreasonable pressures, they fear that they will simply not be asked to tender again because there is no independent body ensuring that standards are maintained on their behalf.

Part of the answer must surely be to set standards that all must meet – yet this will be hard to achieve, not least because surveyors themselves are suspicious of anything which reduces their freedom of action.

For this reason standards should be designed by surveyors themselves and should prescribe only the quality of data and not how it is obtained, nor how surveys are designed to meet a planning need. Quality standards might, for example, include the repeatability of readings during multiple resurvey of representative traverses. We also suggest that the data received by surveyors, the data returned to clients and perhaps the process of initial planning and consultation should be subject to standards.

Magnetic “scanning” – unrecorded, sparse magnetometer survey, usually over large areas - is a particularly instructive example of how the current system has compromised surveyors. Scanning has been an accepted part of survey practice for many years and, as our survey shows, it has come to form a significant proportion, by area, of geophysical surveys. Yet privately none of the archaeological contractors interviewed during this studied were comfortable with its use. They would rather it was dropped entirely from briefs. Yet several explained that they felt unable to challenge what they consider professionally inadequate briefs because, if they were to do so, somebody else would get the work and they would not be asked to tender again. Thus the impression has persisted that scanning is acceptable when, clearly, the most informed professional opinion is that it is not.

This seems likely to change because recent advice issued by English Heritage recommends that only recorded magnetometer surveys should be carried out, even on large sites, and that these cover whole sites, rather than samples of sites, where possible. This advice will be widely welcomed by surveyors but the fundamental problem remains. Unless mechanisms are found to reward surveyors for going beyond the bare minimum, the bare minimum will remain the norm and all will be forced towards it by the need to turn a profit. Likewise, unless surveyors become more equal partners in the over-rigid process of evaluation design and tendering, then they will not be able to feed their expertise into a system that could clearly benefit from it.

One problem with national survey guidelines, in particular, is that they tend to form the core of survey briefs and thus become proscriptive rather than enabling. This is wasteful because it has encouraged formulaic surveys using only standard approaches.

It is interesting to note that those surveys carried out with non-standard, more sensitive magnetometers, denser survey grids or unusually careful field techniques, have often been rewarded by excellent results. Under current conditions, however, a developer or their consultant may well not be willing to pay more for such a service since the value gained from it will often not be judged and recognised – thus the extra costs involved will not be repaid – even though a fair appraisal would show that it represented good value as well as good practice.

Better survey standards need a more subtle understanding of the value of good, professional survey amongst those who define projects and judge their outcomes. This is a tall order for a Development Control Officer in a Local Authority who is unlikely to have specialist training in survey. One of the concerns, raised by a number of the survey contractors interviewed, is that their expertise is insufficiently used. Local Authority archaeologists said that they do, sometimes, approach the best established survey contractors for advice in setting briefs but those same contractors said that they were disappointed at how rarely this happened. Likewise many in both groups said that they only rarely ask advice of the English Heritage geophysics team, despite its acknowledged expertise.

Some of the geophysical surveyors we contacted expressed concern that, if raising standards raises costs then sceptical consultants and curators, unconvinced of the value of geophysics, will commission it less often and the market will therefore shrink. Some were concerned that this project might, by identifying the weaknesses of surveys, persuade those who commission it to do so less often. They would rather that the boat was not rocked.

The project has, by contrast, established the strengths of survey and shown that it would be wise for it to be commissioned more often and more consistently. Our case studies have shown, however, that it would also be wise for survey to be designed using a greater range of options – of method, instrument and survey density – so that they are more efficient and produce results capable of deeper interpretation.

The survey at Barker House farm shows, for example, that a survey at a standard spacing of 1x0.5m might have been better – and more cost effective – if carried out at 1x0.25m or, better still, at 0.5x0.25m. These denser surveys would have been much more likely to detect the second ring-ditch and, potentially, other features. This might well have been cost-effective since it would have given the archaeologists more information and a better basis for project planning – thus allowing better cost planning at the next evaluation stage.

One of the biggest barriers to this is that geophysical survey has become narrowed down into a minimum set of options so that neither surveyors nor the archaeologists who commission them, can demonstrate the benefits of alternatives. Thus the restrictions placed on survey design are, to some extent, self-perpetuating.

A key reason for this is the lack of feedback from excavators to surveyors about how survey results compared with the features found in excavation. Survey contractors repeatedly said that they request excavation results with which to review their work, but rarely receive them (though one senior excavator also remarked that he had never been asked).

Some excavators, who had been asked to routinely return excavation result to surveyors did not do so, they said, on the grounds of cost. Since it is not *required*, under planning regulations, that they give excavation reports back to surveyors, why should their clients pay for them to do so? Under PPG16 are not such *post-hoc* costs excluded? This is a surprising argument. The cost of sending an excavation report, by e-mail or on DVD, is trivial within the costs of most projects, yet for the lack of this surveyors are not given the opportunity to learn where surveys work and where they do not – and why. Such feedback should be a basic requirement of projects and written into briefs and yet a surprising range of archaeologists asked specifically about this issue (including some in local and national government) seem to think it an unreasonable burden on developers.

One difficulty of comparing excavation and survey results is that there are key soil variables which the excavator will rarely record but which the geophysicist would find very useful in order to understand their results. The most important of these, in terms of survey data volumes, is magnetic susceptibility – usually the key determinant of the magnetic anomalies detected by magnetometry. This is, in fact, recorded by some surveyors who get a chance to visit excavations and there is a large amount of susceptibility data which has been accumulated, over the years, by English Heritage and others. Much of this is, however, taken from the bulk soil and parent material and not tied to individual buried remains – and this is what we really need.

We could learn a great deal about how to improve survey, and better interpret its results from individual research projects which look at the origins of site geophysical behaviour, and funding for such projects should be a priority for the research Councils and English Heritage. We would learn as much, however, by incorporating some simple geophysical recording into many more routine archaeological excavations, so that we gather the basic data which tells us about the results of surveys and how they relate to the nature of soils and remains. While excavators have neither the equipment nor the expertise to carry this out, the growing number of geoarchaeologists servicing excavation projects are in a better position. The equipment, capable of measuring magnetic susceptibility, electrical resistivity, dielectric permittivity and so on, is not likely to be acquired by most excavators but it might be made available by County and Unitary Authorities with grants from government. Other bodies, such as BGS, would undoubtedly be interested in such data and might support the costs of acquiring it, since archaeological excavations give them a unique opportunity to do so.

One further consequence of the narrowing of briefs is the rarity of surveys using several methods. The combined magnetometer, resistivity and metal detecting surveys at Ulgill, for example, shows how valuable they can be because they not only gave greater confidence in archaeological interpretation, but also clarified the nature of the ground conditions, and thus of the detectability and survival of remains. Combined survey might have been cost effective on a much higher proportion of sites – including those, as at Ulgill, which find little significant archaeology, since multiple surveys can give greater confidence about the absence of remains, just as they can give further details of remains which have been found.

The restriction of geophysical survey to a few techniques and field methods is wasteful because geophysics is, in fact, capable of giving archaeologists a great deal more information than they commonly obtain from it, and to do so cost-effectively. While there are still major questions about the use of data from Ground Penetrating Radar and Electrical Resistance Tomography, such 3-dimesional survey techniques can give us unique insights into the structure of remains and the degree to which they are preserved.

These, and other techniques, can also map the buried geomorphic context of remains – the former land surfaces on which the were constructed, for example – and by repetition, allow us to monitor changes within sites and thus their long-term survival.

Curators have therefore good reasons to make wider use of such geophysical techniques because they can help them to discharge there duties in finding and protecting remains. It would thus make sense for geophysics to be given a much wider role in developer-funded projects, and not only in prospection – though this will require a closer collaboration between geophysicists, geoarchaeologists and other specialists.

But, yet again, the current compartmentalisation, short timescales and straight-line structure of archaeological evaluation means that more thoughtful use of geophysics is likely to require a change in the wider structure of the planning process, and geophysics is only rarely used as an element in projects, after evaluation, although it could play a useful interactive role, with excavation, in extending excavation data into unexcavated areas.

Conclusions

Key conclusions:

1 Geophysical survey often meets the needs of archaeologists in the North West. It deserves a key role in evaluation and research.

The idea that it often “does not work” is not borne out by the evidence. Indeed it seems unexpectedly capable of providing reliable evidence for the *absence* of significant remains, as well as their presence – a particularly difficult test.

2 Some surveys fail, but only about 10%. The reasons are often easily understood and potentially predictable and avoidable. Survey needs, in particular, to be considered carefully on sites with deep surface horizons, interfering structures (such as metal buildings, in the case of magnetometry) and modern debris contamination. This should not prove difficult and thus there is a real prospect of further reducing the chances of failure.

Those designing briefs should, first of all, take steps to find out if a site is likely to have a deep topsoil or modern debris contamination – if necessary (in other words, where this is not already clear) by including a simple 30-minute coring survey in the very first site investigations, using the very simplest criteria.

A more strategic approach will be to find out more about the distribution of the four main factors which place surveys at risk of failure (and of those which give them the best chance of success), and then develop modelling tools to give curators, consultants and survey contractors an objective basis on which to decide how sites should be evaluated. There is no reason to restrict this to geophysical methods – indeed, to do so would be a distortion since geophysics is always considered as a part of our evaluation options, rather than alone and all evaluation methods have constraints which can be modelled using geographical data.

The data required to predict how best to prospect for sites, and how to avoid those particular conditions which cause surveys to fail, can partly be obtained from soil and geological maps but these are usually too coarse, and lack the right details for confident prediction at any particular site. The new Parent Material Mapping initiative at BGS may help to correct this because it could provide the kind of data required by prediction and could be gradually improved to the spatial resolution archaeologists need.

Archaeologists and surveyors are in a good position to participate in the BGS mapping programme because archaeological excavations produce data – and could easily produce much more data – of immense value to it, and this value is at present unrealised. Thus English Heritage might consider developing a programme for the large-scale exchange of geophysical, geological and geoarchaeological data between archaeologists and the BGS, under agreed standards, and with minimal costs.

Archaeologists will need to agree with BGS what mapping information and precision they require but this kind of tailored data product could be provided if it is agreed in advance. In particular archaeological surveyors need to have classifications of parent materials by mineralogy and lithology and by texture, at mapping scales of 1:25000 or better.

There is a very wide range of evaluation practices and attitudes towards evaluation techniques, geophysics especially, between those who design project briefs and commission surveys in different areas and organisations.

This reflects differences in local planning realities – there are good reasons why the balance of evaluation methods used in one landscape or economic zone will differ from those in another, but it also reflects a significant lack of consensus about the objective potential of evaluation methods.

The efforts being made through the English Heritage Roadshows, in particular, to inform archaeologists about the potential of survey methods is welcome, and the new guidelines, due out later this year, will no doubt help. Yet there is an urgent need for decisions about evaluations to have a more objective, transparent basis. Who can blame a Developer, in particular, for a little scepticism about archaeologists in adjacent counties who have widely differing, but strongly held views on the right way to map buried remains – with consequent differences in impact on the economics of development?

3 To improve survey practice, and widen the role of survey, we need to know more about the national distribution of geophysical properties in archaeological sites and natural soils. To enhance the national Parent Material Mapping programme, therefore, archaeologists might incorporate some simple geophysical measurements (magnetic susceptibility, electrical resistivity and dielectric permittivity especially) into a much higher proportion of routine excavations than at present, since this would be an efficient way to generate a large, national database of soil geophysical properties. Such analyses could be quickly carried out on a small sample of contexts, and natural soils, perhaps making use of the growing number of

geoarchaeologically trained staff, or local volunteers, to do so. Measuring equipment might be made available by Local Authority archaeology teams, assisted by national funding.

Standard protocols for such recording could easily be produced to take account of the data quality required and the practicalities of excavations.

Clearly, such data must be analysed and archived and it could form part of the standard survey archiving which should be enforced (and developer-funded) for each project.

4 There is surprisingly little archaeological geophysics research in progress at a national level, given the importance of the sector to archaeological practice. This needs to be challenged and funding from the Research Councils and others encouraged. We need, in particular, to connect geophysical and geoarchaeological research so that we understand the causes of geophysical properties in remains in greater detail. This will allow us, in particular, to make fuller use of the complex 3-dimensional geophysical datasets which we can now gather, and thus widen the range of archaeological information which geophysics can provide.

5 The planning system has flaws which seriously affect the way in which geophysical survey is used in archaeological mitigation.

While planning guidance and legislation has allowed the development of a vigorous market in archaeology, the operation of that market and its relationship to the planning process means that geophysical surveys are designed with too little reference to the surveyors who carry it out. Thus the skills of experienced surveyors are being wasted because they are often not brought in, to give advice, at an early stage in evaluation design. Surveyors find themselves tendering for briefs which they find inadequate to timetables that they find unrealistic. Prices have been driven down to levels which can only sustain formulaic rather than thoughtful survey by a tendering process which places insufficient emphasis on skill.

Archaeology would be better served by an interactive process of evaluation design in which an experienced geophysical survey contractor acted as consultant and in which briefs required developers to give surveyors the freedom to recover the data required for a particular site, not just meet minimum, standard requirements based on national guidelines. It should be recognised, in particular, that guidelines must be adapted to each and every site, and such adaptations explained, and they should be written to encourage good survey practice, rather than to tell surveyors what to do. It is then up to the Curator to ensure that survey designs and results give a particular archaeological project what it needs.

Downward commercial pressures on survey price must be better balanced by upward profession pressures on survey quality. Conscientious surveyors need to be better rewarded and all surveys need to reach basic standards of data quality.

Thus English Heritage, ALGAO and the national professional bodies (IFA, CBA, ISAP ...) need to work with surveyors to define what is, and what is not acceptable data quality, and how to measure it. It should not be impossible to design quick tests, to be applied on every survey, which show that the a few lines of survey data can be replicated to within certain tolerances, and that the common problems of instrument adjustment, line stagger and so on are sufficiently controlled.

For the lack of such standards we now have a wide range of data quality, with a significant effect on survey results and on the costs and profits of surveyors. A raised and levelled playing field would be of benefit to all.

Surveyors need better prior data about sites and the time required to make use of it in survey planning. It would be helpful if invitations for survey tenders were accompanied by a set of standard documentation including geological, soil and historical mapping and documentation from any prior Site Investigations. Developers and consultants who want to improve the effectiveness of geophysical surveys might also be encouraged to gather some simple data, on site, concerning soil depth and parent material. This need require nothing more than 30 minutes with a hand-auger and a checklist, as previously described.

6 Better briefs will require that those who write them get more advice from specialists. The first source for such advice should be commercial surveyors who should be routinely brought into survey design, as consultants. The second source is the EH Archaeological Science Advisors and Geophysics team who have a wealth of expertise to offer. Our discussions with Curators, consultants and contractors suggests that this is not used as much as it might be. Giving EH staff more time and resources would allow them to better support local Authorities and result in better briefs and better surveys.

7 Many surveys record data which is widely spaced in relation to the size of the remains sought and the resolution required. It make sense for magnetic gradient data to be routinely gathered at spacings of 1x0.25m or less. Survey costs will rise only slightly and, with modern instruments, hardly at all. Many sites would benefit from surveys at

closer spacings and surveys where the surveyor anticipates weak anomalies (such as well-sorted sands), or complex geophysical backgrounds (such as stony till) should be surveyed at 0.5x0.25m as a routine, rather than as an exception, as now. The extra cost of this is often likely to be balanced by the extra value of the data gathered. Such surveys could, in marginal cases, be staged so that the extra data is only gathered, by repeating survey with a 50cm offset, once an initial 1x0.25m data set has been assessed.

The adequacy of any particular survey spacing, however, depends on what the archaeologist needs to find. This is not often made explicit. A brief which allows a magnetometer survey spacing of 1x0.5m implicitly accepts that many small or more ephemeral features will not be detected – but how often do surveyor and curator actually discuss, in advance, the effect of this on achieving research priorities? If the archaeological priority is to identify sites in which pits, or narrow gullies, are a defining feature, then survey spacings need to be defined to reflect this.

Briefs should, therefore, state what the archaeologist needs to find and allow the survey contractor and consultant to define – and state - how this will be done.

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