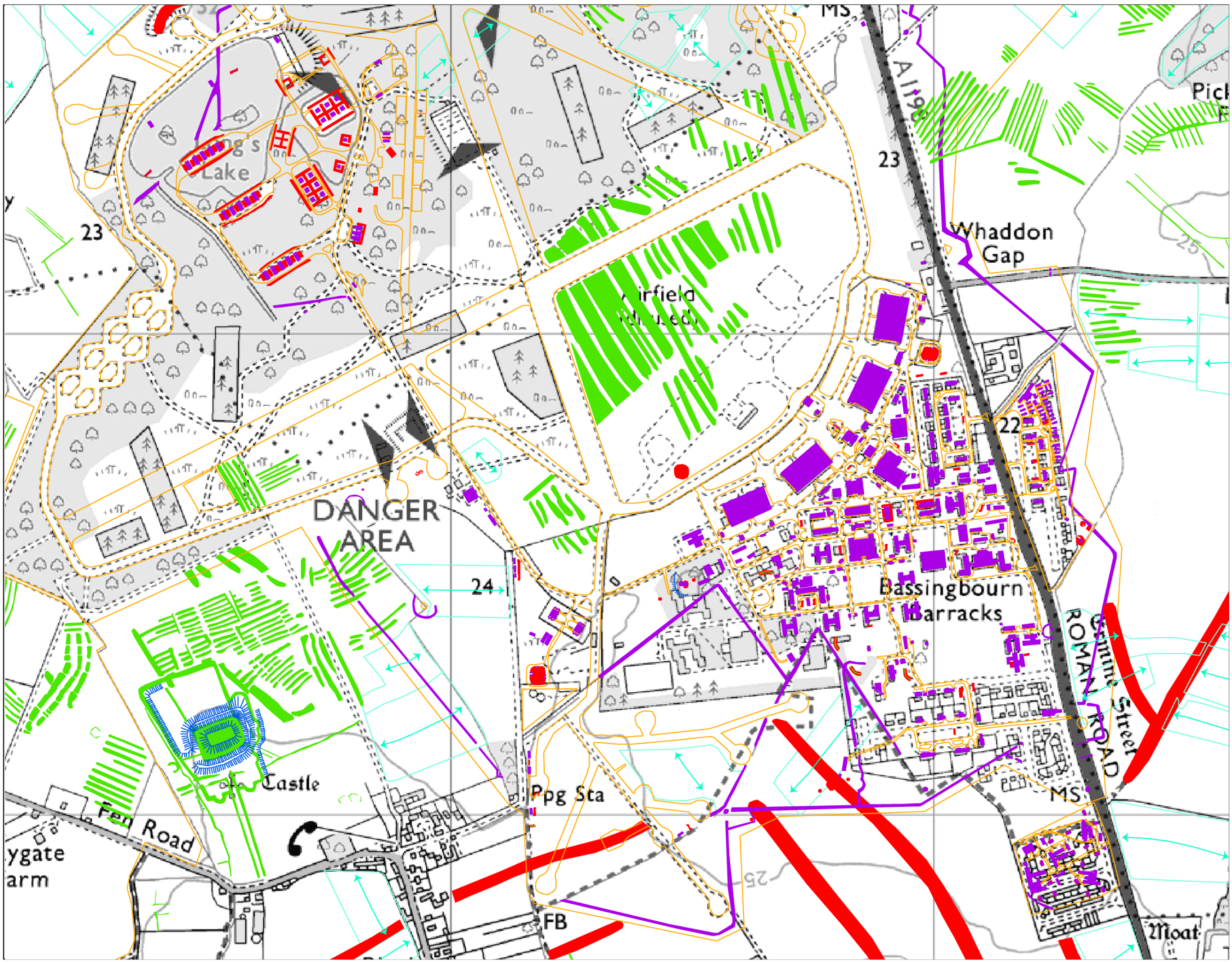
Historic England

Historic England Aerial Investigation and Mapping (formerly National Mapping Programme) Standards Technical Review

Sally Evans

Discovery, Innovation and Science in the Historic Environment



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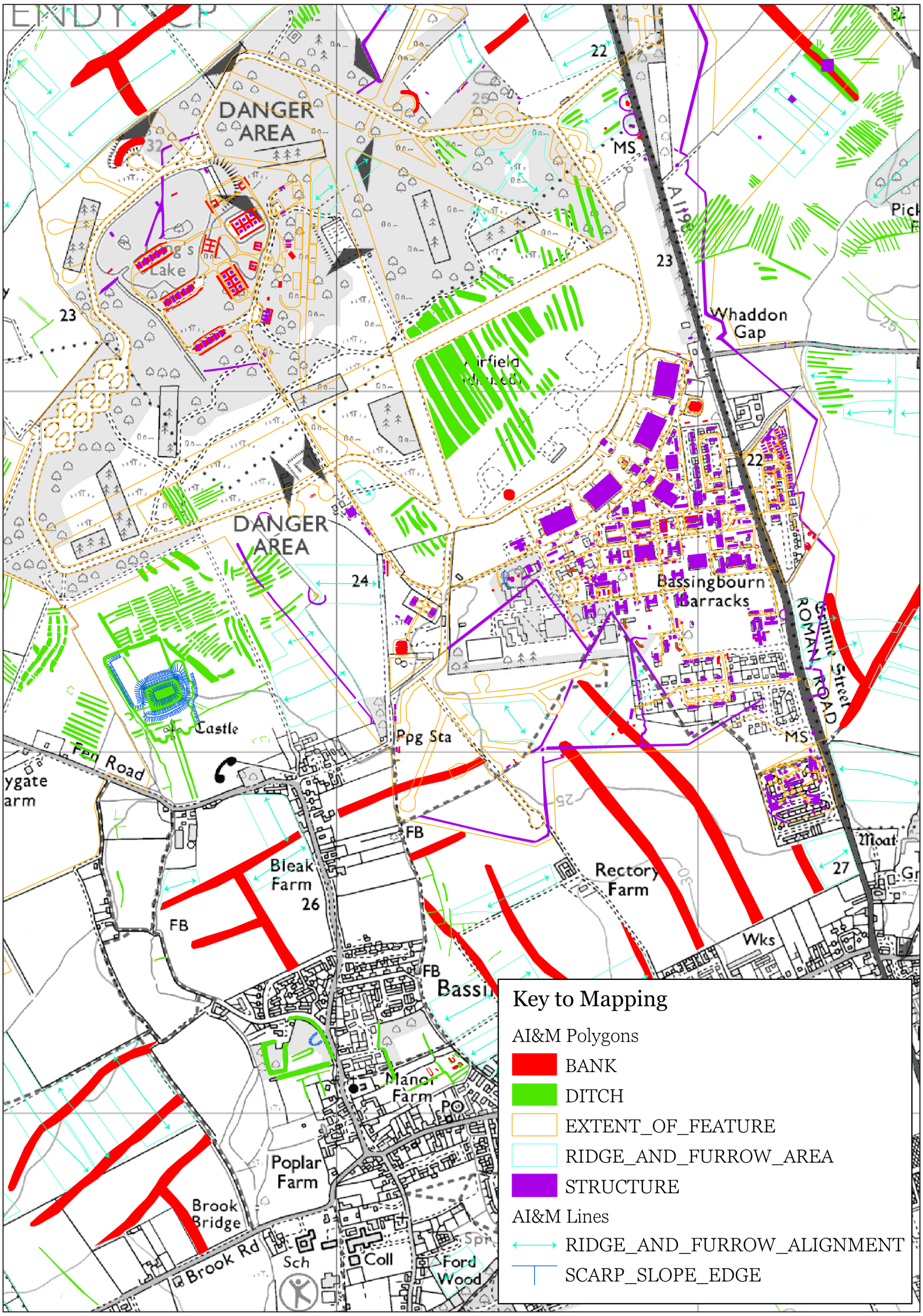
For more information contact Res.reports@HistoricEngland.org.uk
or in writing to:
Historic England, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD



Frontispiece and Cover Image: Aerial Investigation & Mapping results from South-West Cambridgeshire, providing a key to digital mapping conventions. © Historic England. Base map © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100019088.

SUMMARY
Historic England, and its predecessors, developed standards (formerly called National Mapping Programme (NMP)) to ensure effective use of aerial photographs and lidar to identify, map, record and better understand archaeological sites and landscapes. Since their inception, projects using these standards have provided significant enhancement to the historic environment record, with the creation of tens of thousands of monument records and archaeological mapping for over half of England. Although embedded in national and local historic environment records, these previous projects' results have great potential for the reuse and repurposing of their datasets. Technological advancements provide increasing opportunities for better ways of gathering information, sharing data, and increasing the potential for innovative analyses and studies.

This technical review aims to promote understanding and use of existing data and to develop methods for gathering and sharing project results in the future. The results of a user and producer survey are presented in this report. Other outputs include a user's guide to older and current products and an updated standards document. The review was undertaken by Sally Evans of Historic England's Aerial Investigation and Mapping (AIM) team with input from those working on Historic England funded projects and other key stakeholders.

ACKNOWLEDGEMENTS
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CONTACT DETAILS
Historic England, 37 Tanner Row, York, YO1 6WP
Sally Evans, 01904 601940, sally.evans@HistoricEngland.org.uk

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BACKGROUND

Historic England and its predecessors have used aerial photograph interpretation and mapping to record and understand landscapes since the 1960s. In the 1990s this was formalised into a set of standards known as the National Mapping Programme (NMP). These were developed to ensure effective and consistent use of aerial photographs and latterly airborne laser scanning data (lidar) to identify, map, record and better understand archaeological sites and landscapes. Just over half of England has been covered by over 100 large-area Aerial Investigation and Mapping (AI&M) projects. The projects were carried out by Historic England (and predecessors) staff and contractors. These projects continue to be carried out in areas where development, climatic impact such as coastal change or lack of knowledge, is a potential threat to archaeological remains.

As a result of Historic England AI&M projects there has been a significant enhancement of the historic environment record, leading to improved protection and management. Over 120,000 archaeological sites have been discovered and each year thousands more are added to the record from such projects. The benefits to society accruing from past and future mapping projects are great: stimulating further discovery, extending knowledge, understanding, protection and good management.

There are a number of key components that make up an AI&M project. They are typically areas of 100 square kilometres or more, as this enables efficiencies in resources and impact over a significant area for strategic planning. The AI&M approach uses all readily available aerial sources to map multi-period archaeological remains visible as cropmarks, earthworks, stonework and selected structures. This results in a sophisticated spatial dataset, produced to a consistent standard, which depicts the precise form and extent of archaeological remains. This distinguishes it from traditional monument recording that consists of simple point or polygon spatial data. AI&M projects create and enhance historic environment records that comprise a textual description of the archaeological features and sources. A report, typically including a landscape analysis of the area of study, is produced and published online. These products are used for planning and research across the heritage community. The cumulative benefit of multiple AI&M projects produced to a consistent standard allows for local, regional and national studies.

Historic England is committed to clear and readily understandable names for its processes. In consequence, the term *NMP Standards* has now been replaced by the new name of '*Historic England Aerial Investigation & Mapping (AI&M) Standards*', which more accurately describes the approach. These standards are essential as they allow project teams to deliver high quality work to an agreed timescale and cost. The reader should be aware that AI&M methodologies and NMP are synonymous. For consistency throughout this report the term AI&M projects will be used, except when describing specific past project names or in direct quotes from correspondents.

Historic England undertakes and funds AI&M projects that meet corporate goals. In practice this means projects are targeted to address key threats and opportunities within regional and national contexts. They must also improve understanding and appreciation of the historic environment and have a proven contribution to regional research and planning frameworks. This approach makes best use of the considerable expertise that resides with a small number of practitioners in Historic England's Aerial Investigation and Mapping (AIM) team and several external partner organisations.

Aerial investigation and mapping projects, using AI&M standards, are undertaken by Historic England's AIM team or by contractors funded through Heritage Protection Commissions and, on occasion, Heritage Lottery Fund or Universities. The Historic England AIM team also plays a crucial role in developing standards, maintaining quality, and carrying out innovative work using aerial sources. This review is required to ensure that the AIM team continue to be intelligent clients and further develop effective, efficient and innovative ways of working.

Aerial investigation and mapping standards are largely unchanged since the early 1990s, and the basic approaches have proved to be highly effective. However, changes in technology mean there is variation in the products produced by projects. Current and future developments in technology, alongside changes in organisational policy and goals, present key opportunities for AI&M projects to continue to play an important role in the heritage information landscape in England. For example, the use of Geographic Information Systems (GIS) provides increasing sophistication and efficiency in gathering information, recording, sharing data, and comparative analyses. Furthermore, changes to Historic England's existing infrastructure including the new model for the National Record of the Historic Environment (NRHE) and other corporate goals identified in the Heritage Information Access Strategy (HIAS) should increase the visibility and potential for online access to information.

Historic England therefore needs to ensure that the most is made of technological changes. With every new project, ever increasing numbers of sources are available, including lidar, online sources and new accessions to the Historic England Archive (HEA) of both new and older photography; effective flow lines for their use need to be reviewed.

To make the most efficient and effective use of resources we need to identify how future projects can have the greatest impact in terms of discovery, understanding and appreciation of project results. AI&M projects need to use the most suitable methods to disseminate results to Historic Environment Records (HERs), partner agencies, academic audiences and the general public.

This review explores how past projects are used within the historic environment sector, by whom, and how often. It provides case studies and an assessment of positive impact, but also considers issues of accessing, understanding and using AI&M project data. Accordingly, this report looks to the future of AI&M and identifies the opportunities for making existing results accessible to a wider audience and methods for improving flow lines for new projects.

AIMS AND METHODS

The technical review aimed to deliver the following outcomes:

- Review existing working methods and tools to highlight future opportunities for how we may best develop AI&M methods.
- Review processes and technical tools to improve efficiency and streamline processes; while also extending and enriching interpretation and recording of features.
- Explore methods of public access to all large-area AI&M products to ensure that they are a more effective heritage management and research tool. This includes exploring the possibility of creating a single consolidated dataset available for heritage protection/planning, for assessment of national significance and for strategic research.

This technical review is primarily based on the results of three main datasets reviewed and compiled as part of the project:

- From 1985 onwards project management data were recorded. These documented statistics from 112 completed AI&M projects. This dataset includes information such as start date, size of area mapped, numbers of records created and the time taken for mapping and recording. For this review, these project data were enhanced by a review of all past project reports, project designs or project reviews to include additional information on project methods and to confirm scope and sources. Some project data were unavailable or incomplete so these were excluded from analyses. For the full updated metadata table see Appendix 1.
- The results of a survey circulated to AI&M data producers. The data producer survey was completed by 22 respondents, accounting for 88% of personnel currently working on AI&M projects. This survey focussed on current methods and ways to streamline processes going forward.
- The results of a survey targeted at AI&M data users. The user survey was completed by 67 respondents from a variety of archaeological backgrounds, including Historic Environment Record (HER) staff, academics, contracting units, volunteers and national bodies. This survey focussed on usability of the existing corpus of AI&M data to ensure the potential of past project data were being fully realised and to use any feedback to ensure increased public value for future work.

Following on from the surveys, a number of case studies were undertaken with participants from the two surveys to provide additional clarity and detail to the review. Pertinent quotes from both surveys and case studies are included within the report as a way of highlighting particular points and issues.

Although the review will consider various methods to increase methodological efficiency, it is outside the scope of the review to implement infrastructure or technological changes. The recommendations of the review will be applied when suitable infrastructure and/or technology are available.

IMPACT OF AI&M PROJECTS ON THE HERITAGE SECTOR

"[AI&M mapping] is used on a daily basis to inform our development control role, is an integral part of the HER and forms the basis of any landscape or period based study [...]."

"[AI&M mapping is] really useful for me to put designated archaeology in context and sometimes to identify areas of significant archaeology not yet designated."

"As a largely agricultural county the development control team use the NMP data on a daily basis for our advice. Without this data many of the rural areas would have little or no archaeological knowledge."

"We need the confidence that the full potential of the AP [aerial photographic] record has been explored and is represented on the HER. NMP projects give us that confidence (up to the date of the project)."

"I can use it [NMP/AI&M mapped data] with the HER or with MapInfo layers used for developmental control, with summary data that triggers a need for further research."

"We use the data supplied to create HER records. We use the shapefile to create the GIS layer and the attribute table to inform an HER record."

"If NMP/AI&M data can be integrated into the HER it is of direct use in our development and management role and in providing advice under countryside stewardship schemes, as well as maximising public benefit of the data."

"[AI&M/NMP project data are] supplied in a useful vector format, with additional information in monument records, plus a good report. Not sure what else anyone could really wish for!"

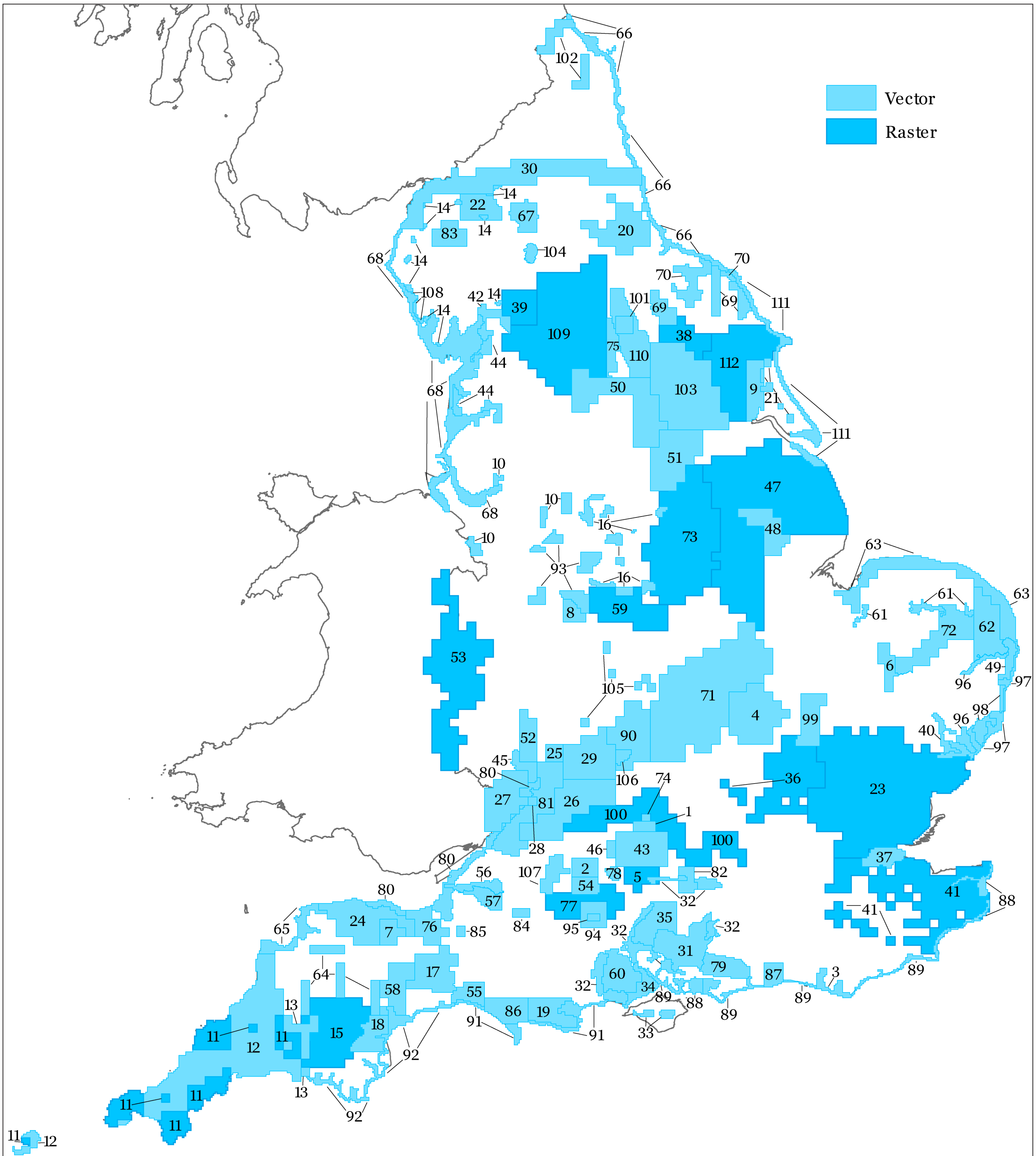
"A vital and unique resource that should be more widely available."

"It is an extraordinary resource available in a format that is easily usable in GIS platforms."

"NMP - comprehensive and consistent interpretation of aerial data in a very flexible format."

"You know that the mapping and analysis has been undertaken in a systematic way with all available sources and using highly-skilled staff members – you can be confident in the products."

(Quotes taken from AI&M User Survey)



1 Abingdon Reservoir
2 Avebury World Heritage Site
3 Beachy Head
4 Bedford Borough
5 Berkshire
6 Breckland - Norfolk and Suffolk
7 Brendon Hills
8 Cannock Chase Staffordshire
9 Chalk Lowlands and the Hull Valley
10 Cheshire - Peak Fringe, Cheshire Plain and Mersey Valley
11 Cornwall & Isles of Scilly
12 Cornwall & Isles of Scilly
13 Cornwall/Devon
14 Cumbrian Minerals
15 Dartmoor
16 Derbyshire and Peak District ALSF
17 Devon - Blackdown Hills
18 Devon - Haldon Ridge to Dart valley
19 Dorset -Wild Purbeck
20 Durham Limestone ALSF
21 East Yorkshire ALSF
22 Eden-Petteril-Caldew Transect Project
23 Essex
24 Exmoor National Park
25 Gloucestershire - Carrant Valley
26 Gloucestershire - Cotswold Hills
27 Gloucestershire - Forest of Dean
28 Gloucestershire - Frampton ALSF
29 Gloucestershire - North Cotswolds
30 Hadrian's Wall
31 Hampshire - South Downs
32 Hampshire ALSF
33 Hampshire ALSF - Isle of Wight
34 Hampshire ALSF - New Forest
35 Hampshire Downland
36 Hertfordshire
37 Hoo Peninsula
38 Howardian Hills
39 Howgill Fells
40 Ipswich & Shotley Peninsula
41 Kent
42 Lakes and Dales - NAIS Upland Pilot
43 Lambourn Downs
44 Lancashire
45 Leadon Valley ALSF
46 Liddington Environs
47 Lincolnshire
48 Lincolnshire - Witham Valley
49 Lothingland, Lowestoft and North Suffolk Coast and Heaths
50 Lower Wharfedale
51 Magnesian Limestone ALSF
52 Malvern Hills AONB
53 Marches Uplands
54 Marden Henge
55 Marshwood Vale
56 Mendip Hills AONB (GCC)
57 Mendip Hills AONB ALSF (SCC)
58 Mid-Devon Rivers
59 National Forest
60 New Forest Remembers
61 Norfolk ALSF
62 Norfolk Broads
63 Norfolk Coast
64 North Devon
65 North Devon AONB
66 North East RCZAS
67 North Pennines AONB
68 North West RCZAS
69 North York Moors
70 North York Moors 2
71 Northamptonshire
72 Norwich - Thetford A11
73 Nottinghamshire
74 Oxfordshire - Frilford
75 Pennine Dales Fringe
76 Quantock Hills AONB
77 Salisbury Plain Training Area
78 Savernake Forest
79 Secrets of the High WoodS
80 Severn Estuary RCZAS
81 Severn Vale
82 Silchester Environs
83 Skiddaw Massif
84 Somerset ALSF - East Mendip
85 Somerset ALSF - Levels
86 South Dorset Ridgeway
87 South Downs Pilot - Worthing Weald
88 South East RCZAS - Wessex
89 South East RCZAS (CCC & GCC)
90 South East Warwickshire and Cotswolds HLS
91 South West coast RCZAS - Dorset
92 South West RCZAS - Devon
93 Staffordshire - eastern river confluences and Gnosall, Kidgrove and Talke
94 Stonehenge WHS: Landscape Survey South of A303
95 Stonehenge World Heritage Site
96 Suffolk ALSF
97 Suffolk Coast
98 Suffolk Coast and Heath AONB
99 SW Cambridgeshire - NAIS
100 Thames Valley
101 Thornborough Henges
102 Till Tweed
103 Vale of York
104 Warcop Army Training Estate
105 Warwickshire ALSF
106 Warwickshire Pilot
107 West Wiltshire - NAIS
108 Western Lake District
109 Yorkshire Dales
110 Yorkshire Henges
111 Yorkshire RCZAS
112 Yorkshire Wolds

Fig 1: AI&M project areas

To provide context for the technical review, it is important to highlight the impacts of AI&M products to clarify why the process and getting it right is so important to the heritage sector. AI&M projects have had a major impact on knowledge of the archaeological resource. A total of 112 large-area AI&M projects have been completed, with over 120,000 additions to the archaeological record. The coverage is vast, with over 51% of England having been mapped, equating to over 70,000 square kilometres (Fig 1).

Key Performance Indicators (KPI) for Historic England are agreed by the Department for Digital, Culture, Media and Sport (DCMS) and set out a framework that allows Historic England to report on its performance against those priorities (Historic England 2018, 7). KPI 12: Historic sites newly identified through our work and added to Historic Environment Records (Historic England 2018, 12) is the key indicator for AI&M projects, with such work identifying most of the 14,500 archaeological monuments recorded over the last three years. These sites are new discoveries, with no previous record in the national or local HER.

One of the key achievements of AI&M projects has been to produce mapping data which can be used by a wide range of users and for a variety of situations. The use of AI&M projects across the entire spectrum of the heritage community has always been a desired outcome. However, establishing who has been using the data, for what purpose and the extent of reuse (ie how often) has always been difficult to fully assess, with case studies often restricted to anecdotal evidence and personal feedback.

The AI&M project data are available via the HEA as well as the relevant local HERs. The results of the survey of users suggests that although most data consumers are based in local HERs (with whom project data are deposited), it is also used by academics, local government planning advice, Historic England (planning, listing and research colleagues), consultants, contracting archaeological units and community groups and volunteers (Fig 2). Emphasis on targeting efforts to increase use and access by these non-HER users should remain a priority, especially towards the academic and commercial sectors where the data are less well known and used, but could have a major impact.

The User Survey has confirmed that the data fulfil a wide range of heritage management requirements; planning, academic research, professional research, commercial work and HER enhancement. Perhaps most importantly AI&M data, some of which is now 30 years old, is used by 37% of respondents every day with a further 27% using it at least once a week. This shows the impact and longevity of the project data and really emphasises the long-term value of the products.

The User Survey also confirmed that satisfaction with the data is high. Overall, 74% of users are satisfied or very satisfied with the format of AI&M mapping. Dissatisfaction with mapping was generally linked to having only the older project data or resulting from formatting issues. Users are also satisfied with monument recording with 71% of users satisfied or very satisfied. 63% of users were satisfied with the format of the final project reports, though a further 34% were on the fence, largely due to a perceived lack of usefulness compared with the spatial mapping data and monument records. This could partly be a reflection in the variability in format and content of reports as they range from resource assessments to more in-depth landscape analysis.

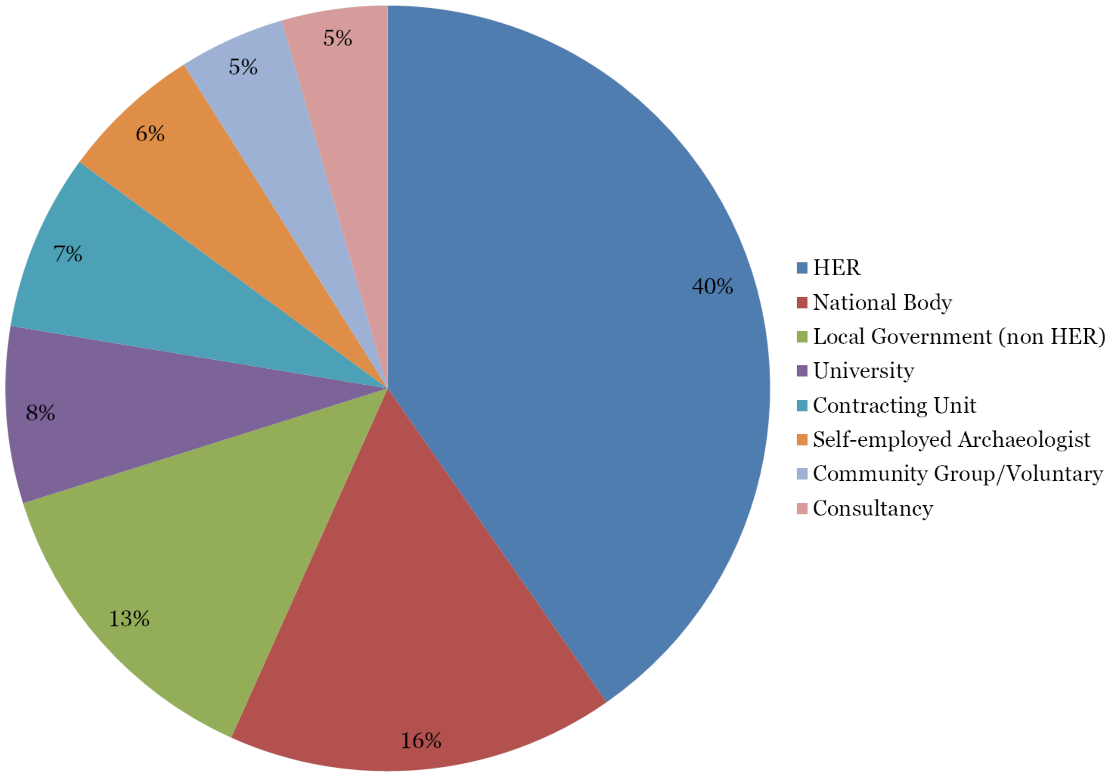


Fig 2: Chart revealing users of AI&M project data.

When asked overall how well AI&M data met users' needs, 60% responded very well, with a further 10% responding extremely well, though 27% suggested that AI&M data only met their needs somewhat well. Users were generally impressed with the consistency of the data over large areas and its ability to fill in gaps that may otherwise be overlooked. They felt confident that AI&M data were generally to a high standard with expert interpreters and that it saved them time in not having to assess the aerial resource in-house. 70% of AI&M data users wanted additional AI&M coverage.

The AI&M User Survey results strongly suggest that the project products are fit for purpose. However, there are areas for improvement in terms of data sharing and accessibility. There were a number of concerns raised by the User Survey, mostly methodological, and these are discussed below, though only those relating to current practice are explored in detail.

AI&M Data User Highlights:

- AI&M data are used mainly by HERs, but also academics, local government planning advice, Historic England (planning, listing and research colleagues), consultants, contracting archaeological units and community groups and volunteers.
- 74% of users use AI&M data at least once a week, with over half of those using it every day.
- 70% of users feel that, overall, AI&M products meet their needs very or extremely well.
- Confidence in AI&M products was high, and users felt it saved them time in not having to assess the aerial photographic resource in-house.
- 70% of users wanted additional coverage.

HISTORY AND CURRENT POSITION

The aim of Historic England's AI&M projects is to enhance our understanding of past land use. This is achieved by providing the primary information and syntheses for all archaeological sites and landscapes visible on aerial photographs, lidar and other remotely sensed data from the Neolithic to the 20th century. This includes recording sites visible on aerial photographs and lidar as cropmarks, soilmarks, earthworks and some structures (Winton and Horne 2010, 7).

This method had its origins in the Yorkshire Wolds survey (Stoertz 1997) which mapped cropmark sites only, and Dartmoor (Soffe 1985) which mapped earthwork and stonework sites. In 1987 four pilot projects, designed to map, interpret and record archaeological information from aerial photographs were begun for Kent (Edis 1989), Hertfordshire (Fenner 1992) and the Thames Valley (Fenner and Dyer 1994). These projects focussed on cropmark landscapes but in 1989 the Yorkshire Dales (Horne and MacLeod 1995) expanded the scope to include earthwork and stonework sites. AI&M projects, under the banner of NMP, began in earnest in 1992 after the successful completion of those pilot projects. The Lincolnshire project became the first full NMP (Bewley 1998, 9) which saw a definition of the scope still in use. This effectively extended the remit from the buried, mainly prehistoric or Roman landscapes, to include medieval and later remains surviving as earthworks. The inclusion of other structures was a specific response to growing interest in 20th-century military remains (Winton and Horne 2010, 8). The AI&M Standards remain a minimum requirement that allows a consistent national approach; however, the scope can be enhanced and developed depending on the client or context. For example, the Thornborough Henges Aerial Photograph Mapping Project (Deegan 2005) extended the scope to include mapping palaeochannels in order to assess the interplay between the archaeological and geological landscape.

Prior to the formal definition of AI&M projects, aerial photograph interpretation projects in the Yorkshire Wolds and Kent dealt exclusively with cropmarks and used mainly specialist oblique photography (Winton and Horne 2010, 8). The technology and methods used in interpretation and mapping from aerial sources, and the scope, have developed since 1992 but the fundamental principal of AI&M projects remains to look at all readily available aerial sources (Winton and Horne 2010, 11). The widening of the sources used more or less coincided with the start of acquisition by the National Monuments Record (now the HEA) of large amounts of historic and more recent vertical aerial photographs. The HEA now holds vast oblique and vertical aerial photograph collections and these are consulted for every AI&M project. Other typical sources include the Cambridge University Collection of Aerial photographs (CUCAP) and catalogued local collections, usually held in county based HERs or SMRs. Lidar was first used by the Stonehenge World Heritage Site (WHS) mapping project in 2001 (Crutchley 2013, 139) but its inclusion into AI&M projects only became standard when Environment Agency data became freely available for much of England in 2015. Orthophotography, available as a complete georeferenced mosaicked image of England since 2008, was incorporated into almost all AI&M projects from then on, the first being an Aerial Survey in the Cotswold Hills (Janik *et al* 2011). Use of Google Earth and Bing online imagery also began at this time.

Although initially NMP began as a programme with national aims, it was always undertaken as a patchwork approach, to target resources in a flexible way to maximise the impact of results (Winton and Horne 2010, 7). They comprise a suite of projects targeted to address specific strategic needs. Some early projects were intended to enhance the English Heritage Monument Protection Programme (MPP). Others surveyed areas subject to major change – such as the proposed National Forest (MacLeod 1995). A suite of projects combined non-intrusive techniques, including analytical earthwork and aerial survey, to provide information to enhance management of the historic environment in protected landscapes such as the Areas of Outstanding Natural Beauty (AONBs) covering the Malvern Hills (Bowden 2005), Quantock Hills (Riley 2006) or Mendip Hills (Jamieson 2015). An acknowledgement of the potential national impact of mineral extraction led to a number of projects funded by the Aggregates Levy Sustainability fund. These used AI&M standards to redefine baseline knowledge of the ancient landscapes in areas with options or potential for mineral extraction. These included the Magnesian Limestone geology in South and West Yorkshire (Roberts *et al* 2010) and areas with a range of minerals across Hampshire (Young 2008; Trevarthen 2010). AI&M projects also contributed considerable information to an English Heritage national programme of Rapid Coastal Zone Assessment Surveys (RCZAS) to inform the impacts of coastal change on the historic environment. A series of projects used multiple survey techniques to identify and assess archaeological remains in inter-tidal and coastal areas. A major theme emerging from the aerial components of these projects was the ephemeral and surviving aspects of the 20th-century wartime landscape, such as coastal defences, airfields, training areas and camps. Virtually the whole coast has been covered and examples of AI&M work include The Yorkshire Coast and Humber Estuary (Deegan 2007) or the south east coast (Dickson *et al* 2012).

AI&M projects continue to be targeted at areas with a patchwork of issues or threats and some are also exploring different ways of engaging with professional and other communities. For example, the National Archaeological Investigation Survey (NAIS): South West Cambridgeshire project (Knight *et al* 2018) explored the opportunities and problems associated with carrying out landscape survey in an area of on-going development pressure with considerable development-led excavation in multiple locations. The recently completed Cannock Chase project was a partnership between Historic England, Staffordshire County Council and the Heritage Lottery Fund (Carpenter *et al* 2018). The project was developed to provide a framework for further survey, management and promotion of the historic environment with local communities specifically in mind. The AI&M aspects explored innovative ways of engaging volunteers with lidar data and the results from the aerial investigation and mapping. Workshops and other activities provided training in documentary research, geophysical survey and analysis of archaeological earthworks. Combined, these aim to ensure enduring engagement with and care for the archaeological remains on the Chase.

The standard products of AI&M projects have developed over time but now comprise a digital archaeological map with linked archaeological descriptions and a synthesis of the archaeological results. The spatial data are an accurate morphological depiction of the archaeological remains seen on the available aerial sources, rather than just a point or polygon as is commonly used for archaeological monument recording. This detail of depiction is unique in that it builds up a visual representation of the archaeological landscape by combining information from multiple sources. AI&M data are fully interrogatable making it a powerful tool for heritage management. In addition to the spatial data, monument records are produced in either the NRHE or relevant local HER. Every AI&M project provides a synthesis of archaeological information, commonly in the form of a report, or occasionally a publication. These also provide background on methods, scope and sources to aid future use of the AI&M data. All available AI&M reports are available in print or to download via the Historic England website. The mapping from a recent project The Chase Through Time (Carpenter *et al* 2018) is available as online web mapping services.

Initially pre-NMP and pilot-NMP projects were undertaken by Royal Commission on the Historical Monuments of England (RCHME) staff (who later merged with English Heritage, now Historic England), but from the early 1990s in-house and external contract staff were employed linked to specific projects. Currently aerial investigation and mapping projects, using AI&M standards, are mostly undertaken by contractors funded by Historic England and, more rarely, Heritage Lottery Fund or Universities. Historic England's AIM team plays a crucial role in developing standards and maintaining quality, as well as carrying out innovative work using aerial sources.

Aerial photograph interpretation and mapping is a specialism and there are very few expert practitioners in England (for details see Aitchison 2017, 586). Due to the landscape scale of the work, the archaeological remains encountered are very varied, both in date and form and it takes a long time to develop the confidence and experience to become a proficient aerial photograph interpreter. Confusing geology, photograph blemishes or recent human activity can easily throw off the untrained eye. The methodology required to produce accurate archaeological mapping is also complex, with a large number of stages required. Many staff working on AI&M projects are very experienced and continuity of experience is essential when training or guiding new or inexperienced staff. Currently, most staff working to AI&M Standards have over 10 years' experience, with some of those having over 20 years' experience. The experience of staff and robust quality assurance of all mapping products allows users to have confidence in the data.

This review is interested in large area based AI&M projects only. There are a number of specialist site-based projects carried out by Historic England and its forebears that used varied scope and techniques. Recent examples include work developed to enhance the presentation and interpretation of English Heritage properties. This included a survey of Birdoswald (Knight and Jecock forthcoming) which comprised Structure from Motion (SfM) photogrammetric techniques, or Belsay Awakes (Oakey 2017), a multidisciplinary programme of work looking at Belsay Hall and environs. Other work may address similar issues to promote understanding and presentation of the site and setting of scheduled monuments such as Snodhill Castle, Herefordshire (Bowden *et al* 2017).

The aerial components of these projects often use different conventions, techniques and scales of approach to large-area AI&M work, depending on the archaeological remains and wider requirements. This report excludes site-based aerial investigation and mapping work carried out by commercial units in planning contexts.

DEVELOPMENT OF AI&M METHODS

When considering some of the results of the technical review, it is worth considering how and why methods have changed over time. The methods used directly affect accuracy and usability of the individual project data. Changes in project scope can lead to confusion as to why certain features were not depicted. The individual project reports, which should include an overview of methods, provide context for the mapped results. This section provides a brief overview of the major changes and acts as a brief user's guide. The relevant sections should be consulted for additional detail relating to current methods. The changes in methods discussed below were adopted by different AI&M project teams at different times so the projects highlighted are not the starting point for universal upgrades but were some of the first to make the changes.

The earliest projects, from 1985 onwards, were hand-drawn with the archaeological features manually transcribed onto overlays to a 1:10,560 or 1:10,000 Ordnance Survey (OS) base map. The overlays were first produced in pencil, and included notes, before being traced onto a clean overlay using technical pens and a range of line types and symbols. Both the pencil and inked overlays were routinely archived. Sketch plotting was the most commonly used manual transcription method. This relies on reaching an informed estimate of where the archaeological remains were located on the paper map, for example within the north-east corner of a field. In areas with lots of boundaries to delimit an area, accuracy could be reasonably high, conversely in areas of very open ground with fewer landmarks on which to orientate and locate an archaeological feature, accuracy was often reduced. The Yorkshire Dales project, undertaken between 1989 and 1992, reports "Position and accuracy was largely dependent on the quality of the mapping on the OS base maps, combined with the skills of the aerial photograph interpreter. In intake areas the positional accuracy is estimated to be in the order of 5-15m but on open moorland the limited background information may result in errors of 50-100m" (Horne and MacLeod 1995, 10). The network method, paper strip method or proportional dividers (see Wilson 1982, 198) were used in some instances to increase accuracy.

The earliest hand-drawn projects helped develop and standardise the mapping conventions that were later incorporated into AI&M projects. The Yorkshire Wolds mapping project was relatively straight forward, only cropmarks were recorded and therefore the 2D version of the archaeological remains could be adequately drawn as seen (Fig 3). By contrast, the Yorkshire Dales mapping project was an upland area with extensive earthwork survival and industrial remains. Therefore, mapping conventions had to be developed to differentiate the various earthwork features (Fig 4). The project used two sets of conventions during its lifetime. However, these developments resulted in the recommendation to map all archaeological features as seen and to use standard conventions for future projects (Horne and MacLeod 1995, 149-156). The recommended conventions were first used for the Lincolnshire mapping project, using solid lines for ditches and stipple for banks and continuing with schematised depiction of ridge and furrow. There conventions became the standard for NMP.

Fig 3: A sample of the Yorkshire Wolds survey depicting buried archaeological remains seen as cropmarks surrounding the present day village of Rudston. The mapping was hand drawn. ©Historic England. Base map © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100019088.

As computer technology became more widely available, mapping moved into the digital environment. The Northamptonshire project, undertaken in MapInfo in 1994, was the first NMP project to be implemented in an entirely digital environment (Deegan 2002, 2). The Avebury WHS project, which began in 1997, was the first AI&M project to be mapped in AutoCAD. One OS quarter sheet was entirely mapped digitally using AutoCAD while the remaining eight maps were sketch plotted and then the final drawn map digitized using AutoCAD (Small 1999, 10). From 1998, successive versions of AutoCAD Map became the primary means of mapping (Crutchley 2013, 138) largely due to the corporate availability of that software within Historic England and the GIS-like options available as part of the Map package. The North Devon AONB NMP (Knight *et al* 2014), starting in 2011, became the first AI&M project to be completed in Esri ArcGIS. The use of ArcGIS has continued since then with some external AI&M contractors, and as of 2017 has been rolled out within Historic England for such projects. Recent projects were undertaken in AutoCAD Map, ArcMap, MapInfo, QGIS and INK (HEROS).

Limited use of Aerial, specialist rectification software, began with early hand-drawn projects such as Yorkshire Wolds, which started in 1985 (Stoertz 1997), or Nottinghamshire, which started in 1992 (Deegan 1999), though the majority of archaeological remains were sketch plotted. Using Aerial at this time was a laborious, staged process, with increased potential for error. The fully digital Northamptonshire project, which started in 1994, was the first where all the aerial photographs used for mapping were digitally rectified. This digital rectification greatly improved the accuracy of the mapping and allowed smaller features to be mapped in detail. Digital Terrain Models eventually became incorporated into selected rectifications from 2000 onwards in projects such as the Malvern Hills AONB (Winton 2005), Vale of York (Kershaw 2001) or Quantock Hills AONB (Riley 2006). These further increase the accuracy of the resultant rectifications and mapping as it accounts for height displacement caused by steep or undulating terrain.

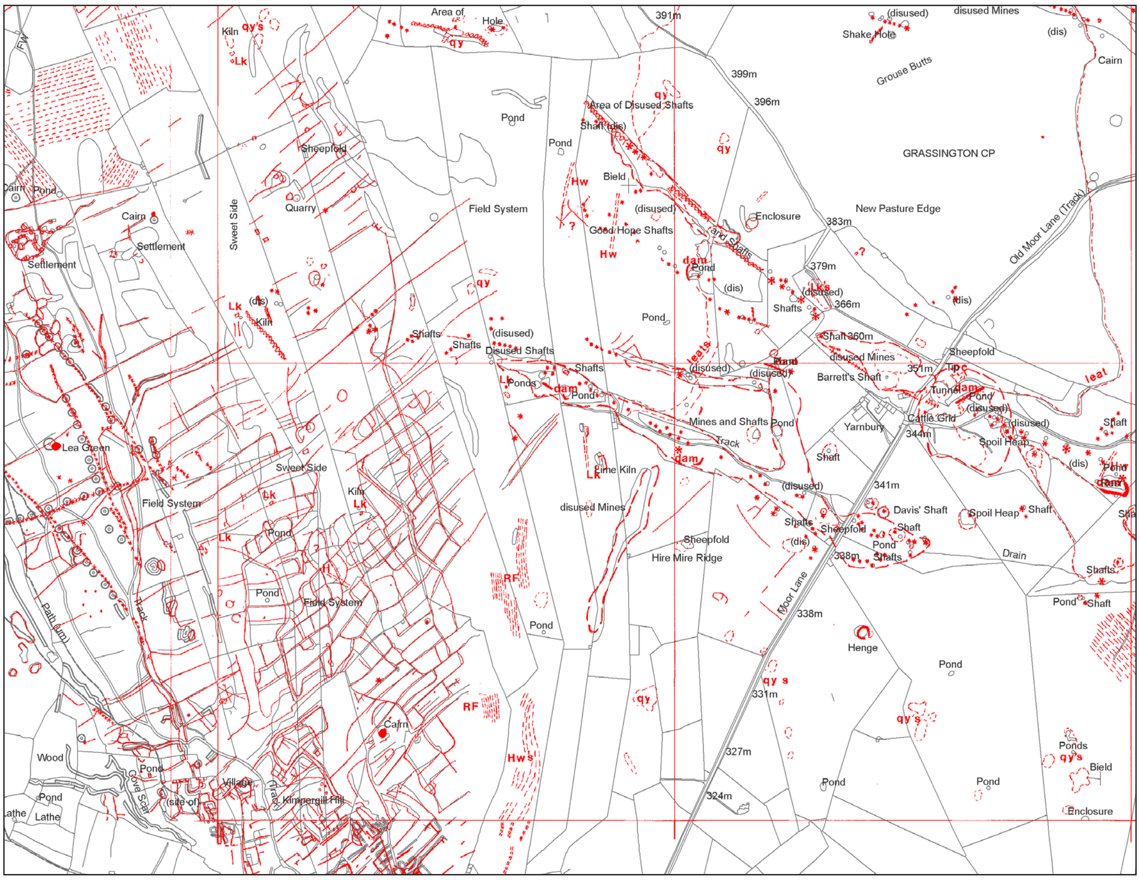


Fig 4: A sample of The Yorkshire Dales mapping, north-east of Grassington. This data has been rasterised from a hand-drawn product. The Yorkshire Dales archaeological remains include earthwork and stonework sites and symbols were developed to aid differentiation between the various forms of archaeological remains. This example shows banks depicted as solid lines, asterisks for shafts and trackways shown with a parallel dashed line.

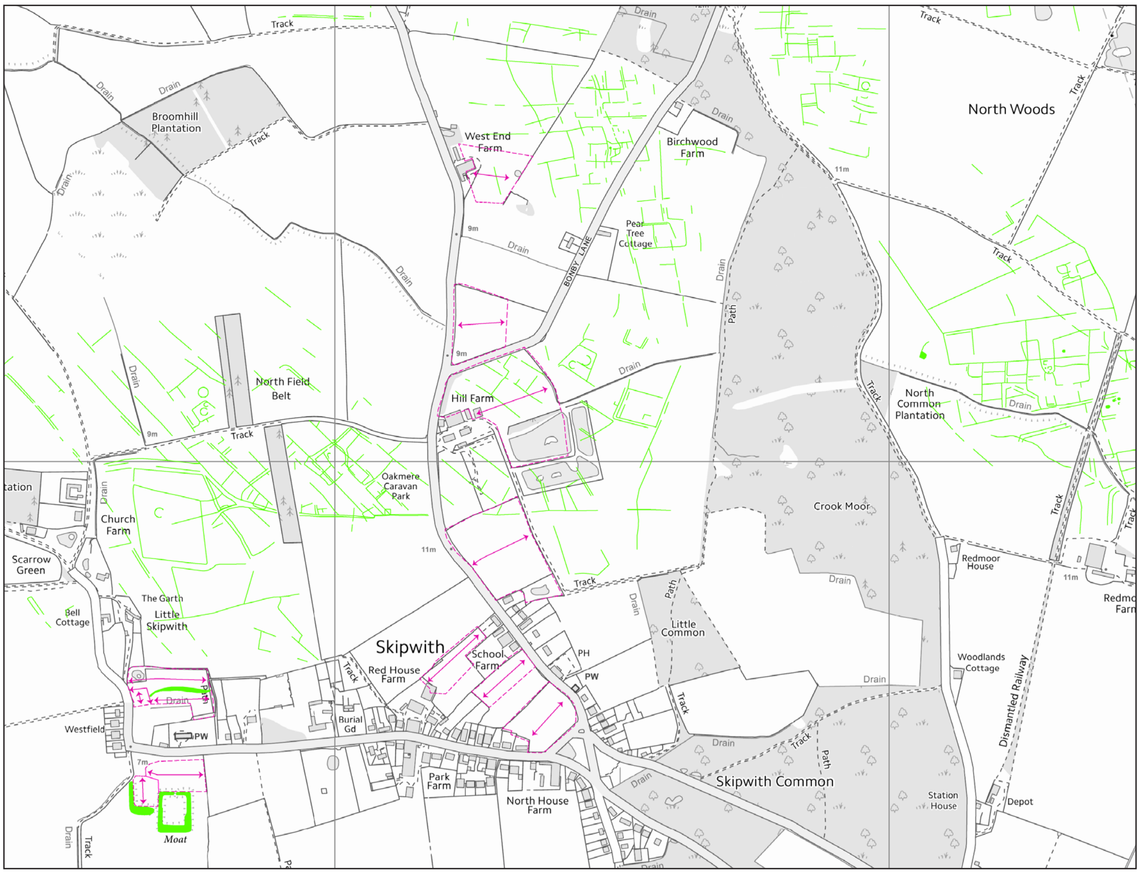


Fig 5: A sample of digital mapping from Vale of York NMP using single line depictions for features narrower than 2m. The moat, to the west of Skipwith, is the only feature drawn using a polygon. © Historic England. Base map © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100019088.

The first digital projects tried to recreate the hand-drawn conventions as some archive customers still required black and white products (Winton pers comm). This meant creating polygons with stippled fill for banks and solid fill for ditches, and also using different line types for levelled or earthwork ridge and furrow. Most early digital projects used single line depictions for features less than 2m in width (Fig 5). In reality, this meant a single line drawn along the centre of the feature, making it difficult to measure the true extent of some archaeological features. Lower Wharfedale NMP (Deegan 2004), starting in 2002, was the first project to use only closed polygons (except for ridge and furrow alignment and slope). This change coincided with the increased availability of 1:2,500 scale OS mapping as a source for rectification. These combined improvements have increased accuracy, detail and usability of the products and provide clarity on how different archaeological features interact (Fig 6).

Changes in recording practise have also occurred; with the earliest pre-NMP project, Dartmoor starting in 1985, producing no records at all whilst the Yorkshire Wolds produced a gazetteer. Starting in 1987, the Classification of Cropmarks in Kent project (Edis 1989) embarked on morphological recording of archaeological cropmarks, undertaken in a stand-alone database known as MORPH (later MORPH2). This recording system sought to record features based on their size, shape, aspect and pattern as well as period, type and form (Edis *et al* 1989, 114; Bewley 2001, 79). As a stand-alone database this was a less usable as a tool for heritage management as this typically requires a wider set of information and textual descriptions. Consequently, the recording practise shifted to the use of the NRHE and its forebears. This began in late 1997 with the Avebury WHS mapping project (Small 1999). At the same time, some of the earlier MORPH2 records were also converted and enhanced to be batch loaded into records within the NRHE. For a while, the two recording systems were concurrent, but morphological recording eventually became redundant and the stand-alone software became obsolete. The original MORPH2 data is still stored by the Historic England AI&M team. Currently AI&M projects input into either the NRHE or the local HER and the NRHE data are always supplied to the relevant HERs.

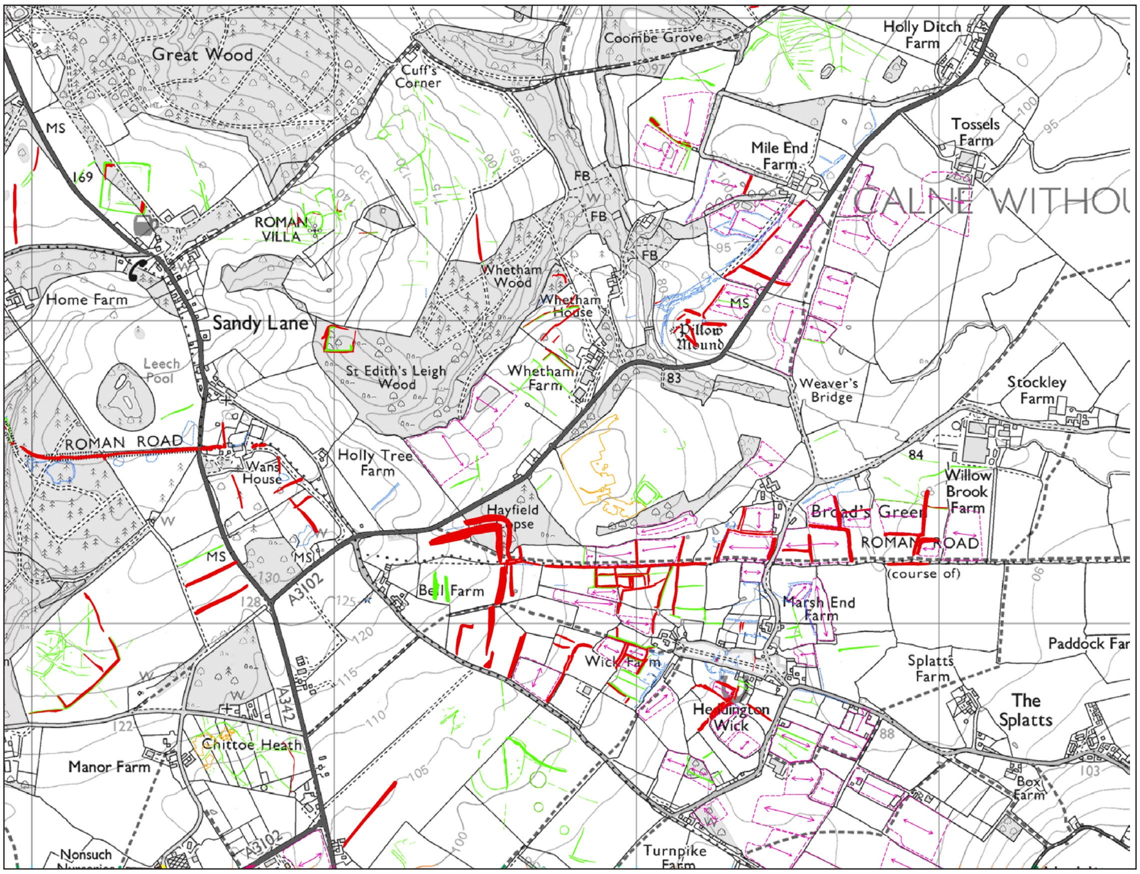


Fig 6: A sample of mapping from the West Wiltshire NAIS, where each archaeological feature is depicted to its true extent, using polygons. Note the use of 'T' hachure for slopes (blue).

Attribute or object data, the text classifications attached to spatial data in GIS, has also become a key method of recording monuments. Its use has developed on an *ad hoc* basis into the current situation where it is a key output of the mapping data for most AI&M projects. Although some of the attribute data replicate data in the textual monument record, the benefit of this dual recording is its flexibility to end users, allowing easy data exchange, without the need for bespoke monument recording systems.

The growth of the HEA (and its predecessors) has a symbiotic relationship with the growth in the number of sources used for AI&M projects. The HEA aerial photograph collection began in 1965 in order to rapidly build up a record of field monuments throughout England (Barber 2011, 221). The aerial photograph collection expanded in the 1980s to include a number of important vertical photograph collections, including Royal Air Force (RAF) photographs taken since the start of the Second World War and Meridian Airmaps Ltd (MAL) photographs usually flown in advance of infrastructure projects or for census purposes. The advantage of vertical photographs is that they offer blanket coverage and can be viewed in 3D. This 3D viewing was a key aspect in the move to recording earthworks and also allowed the topography of the area to be fully appreciated.

The upland landscape of the Yorkshire Dales mapping project was the first to include vertical photographs as standard. In 1991, OS vertical photographs dating from 1951 onwards were transferred to the HEA and their use allowed landscape change to be assessed over large areas.

The other national collection, CUCAP, was established in 1948 (Barber 2011, 217). Although initially the collection consisted of only oblique photographs, later vertical survey was undertaken. CUCAP photographs have been used for almost all AI&M projects, with the exception of some of the earliest hand-drawn projects. Unfortunately CUCAP was closed for review temporarily in 2010 and then again since August 2016 meaning that any projects undertaken during these times could not access the aerial photographs. There are a number of local photograph collections across England, usually held by the HER/SMR. The numbers of photographs held within these collections can vary considerably and sometimes contain unique material taken by a local flyer. However, they often hold duplicates of those held within the HEA and CUCAP collections acquired to help with local research and management.

Lidar was first used by the Stonehenge WHS mapping project in 2001 (Crutchley 2013, 139) but due to a lack of capacity to process the data in-house, the project relied on a number of pre-processed single-lit images provided by Cambridge University (ibid). The Witham Valley NMP, undertaken in 2004, evaluated some lidar images covering part of the project area, but this was carried out subsequent to the mapping from aerial photographs (Boutwood 2005, 8). By 2006, the Environment Agency provided lidar derived imagery at 2m resolution tiles, lit from one direction for use in AI&M projects (Fig 7). Although the use of this imagery became standard the usefulness was limited, largely due to the low resolution (typically 2m per pixel) of the data (Deegan 2007, 2; Bacilieri *et al* 2008, 10), and also because of the risk of missing features that lie parallel to the light source (Crutchley 2013, 139). Bespoke lidar was trialled for projects such as Savernake Forest (Crutchley *et al* 2009) and the North Pennines AONB project (Oakey *et al* 2012). These became the first projects to systematically use lidar visualised as raster surface data over a wide area. Both projects used AutoCAD Map, which includes the facility to view raster surfaces with interactive hill shading and vertical exaggeration in a 2D model space. Additionally, the ASCII data were processed in Applied Imagery's Quick Terrain Reader and used alongside to view and manipulate the lidar in a pseudo-3D environment. The downside of this methodology for lidar use was the time taken to carry out the constant manipulation to get the best view for mapping every feature as well as practical issues with using raster surfaces in AutoCAD Map which could be unstable at that time.

In 2015, Environment Agency data became freely available for much of England at resolutions of up to 25cm in some areas and is now a standard resource where available. Most producers visualise this lidar data in Relief Visualisation Toolbox (RVT) 1.1 (Kokalj *et al* 2011; Zakšek *et al* 2011) starting with South West Cambridgeshire National Archaeological Identification Survey (NAIS) in 2015 (Knight *et al* 2018). RVT is a free to use software that allows multiple visualisations proven to be effective for identification of small scale features. Lidar has had a major impact on AI&M projects, particularly in upland areas, where earthwork survival is extensive due to limited ploughing. The North Pennines AONB NMP (Oakey *et al* 2012) really showed the impact lidar could have in such landscapes, with the discovery of 30 later prehistoric settlements and associated field systems, and the impressive mapping of extensive lead mining landscapes. Lidar can impact in lowland areas too, even those under intensive ploughing, for example as part of the South West Cambridgeshire NAIS (Knight *et al* 2018). Here lidar revealed extensive networks of linear earthwork boundary banks, that when viewed on traditional photography, appeared levelled. Lidar is particularly useful in wooded areas for recording archaeological earthworks. The recent Aerial Investigation and Mapping of part of the Norfolk and Suffolk Breckland Region recorded archaeological earthwork remains surviving in forested areas in a lowland zone. Discoveries included mounds, likely Bronze Age round barrows, and medieval to post-medieval boundaries and enclosures, the latter often associated with warrens (Horlock and Tremlett 2018, 13).

National coverage georeferenced orthophotography has been available to AI&M projects since 2008 and was first used by an archaeological survey in the Cotswold Hills (Janik *et al* 2011). An orthophotograph has had all distortions removed and combines a number of photographs into a single mosaicked image. Digital orthophotographs are supplied to Historic England funded AI&M projects through an agreement with the Aerial photographgraphy for Great Britain (APGB) initiative. The APGB orthophotography is often the latest available aerial imagery for many archaeological sites, providing an excellent resource, combined with lidar, to assess current condition. It also acts as a highly accurate base map.

Online orthophotography, such as Google Earth, Bing maps and others offer seamless vertical aerial photograph coverage of England. Google Earth has the advantage of temporal depth added by multiple years of coverage. Marden Henge and Environs (Carpenter and Winton 2011), undertaken in 2009, was the first AI&M project to include these online sources, though it took until 2012 for their use to become standard, mainly due to access issues for some project teams.

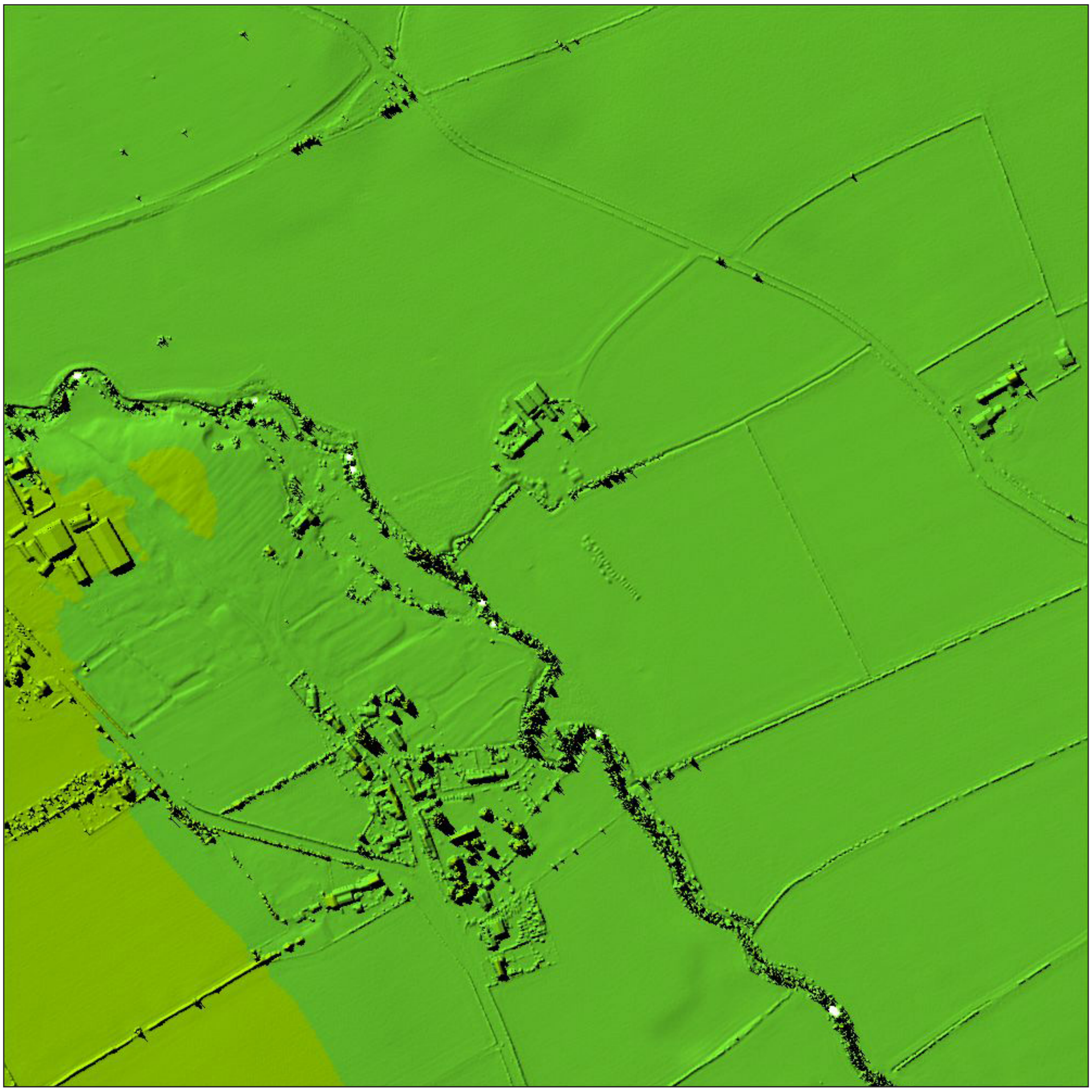


Fig 7: Example of an Environment Agency 2m resolution jpeg lidar tile, visualised using a single direction hillshade. The image shows the earthwork remains of the medieval settlement of Thornton le Street in North Yorkshire. This was the first lidar dataset that was widely incorporated into AI&M projects, but has been superceeded by higher resolution gridded data. LIDAR SE4186 Environment Agency D0112148 01-JUN-2007 © Environment Agency copyright 2019. All rights reserved

REVIEW OF SOURCES

This section provides an overview of the aerial sources currently used by AI&M projects. It will assess issues with the use of these sources and highlight any potential workflows that may improve processes. There is some variation in the sources used between projects and project teams but generally all readily available sources are consulted. For every archaeological feature, the best source is chosen to map from. However, the nature of the archaeological remains will affect the usefulness of different sources, for example Second World War military remains are almost always identified using historic RAF vertical photographs, whereas archaeological cropmarks are almost always identified using specialist oblique photographs. Lidar is often useful in areas that have escaped the plough, where archaeological remains survive as earthworks. For most projects all sources are useful. The following table reveals the slight variation between individual respondents to the producer survey in sources used (Fig 8). Some of this variety is due to access issues, or variation in approach. Standardisation of sources has always been a priority and includes non-aerial material such as historic maps, HER records and other relevant data.

The standard aerial sources for AI&M projects include digital and print photographs from national and local archives, government digital data sets such as the Environment Agency lidar, photos and height data from the APGB and free to view online sources such as Google Earth.

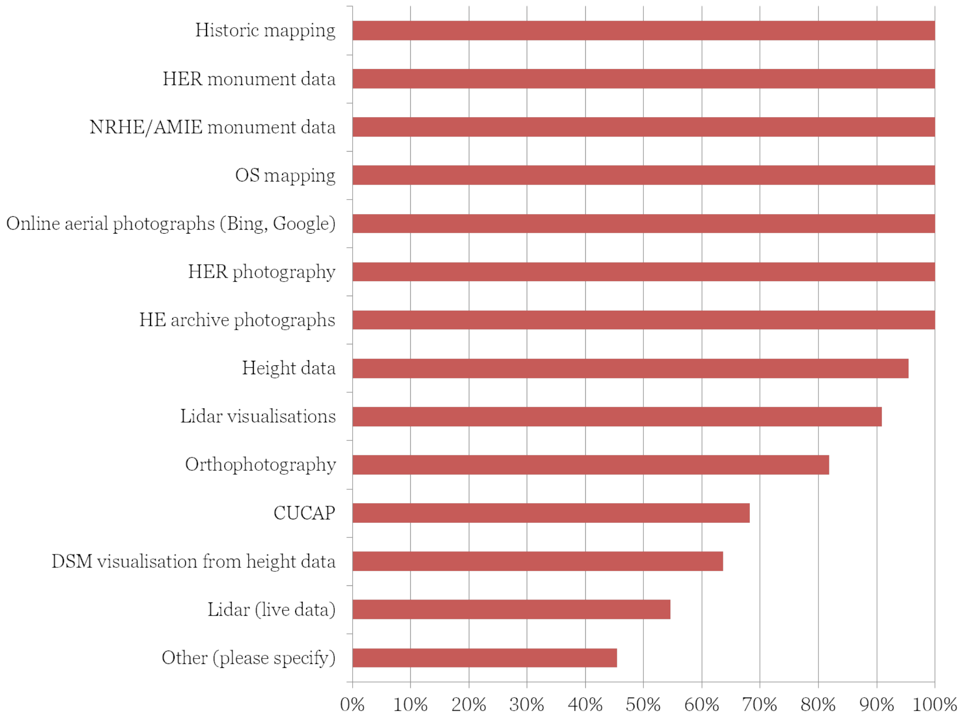


Fig 8: Responses from the producer survey show the extent to which different sources were used during recent AI&M projects.

Aerial photographs and archives

The main source for Aerial Investigation & Mapping projects is the HEA but each project may also use other archives if the sources are catalogued and/or readily accessible. Project planning requires a good understanding of the nature of the archive material and access arrangements.

Historic England Archive

The Historic England Archive in Swindon is one of the largest publicly accessible archives in the UK. Four million aerial photographs, covering the whole of England and dating from the early 20th century to the present day, make up part of the archive's collection. The aerial photograph collection contains vertical and oblique prints and born-digital imagery in colour and black and white. It is the main source for projects using AI&M standards.

Large area AI&M projects require access to considerable amounts of physical archive material. These projects are a proven method of unlocking and synthesising the archaeological potential held within the disparate aerial photographs held by the archive; revealing monuments that would otherwise remain unidentified.

In order to work efficiently and effectively, and to improve archaeological interpretations, it is essential that all the available aerial photographs are examined for a particular area. The archive provides considerable support and allows access to tens of thousands of oblique and vertical photographs for AI&M projects each year. Currently, most producers of AI&M data reside within a Historic England office, with four full-time mappers in York (two of those being contractors) and four in Swindon (two being contractors). The remaining eight contractors work in three local authority offices. Loan provision, both in-house and to external offices, is based on meeting care and storage criteria agreed by the HEA.

Digitisation of photographic material is beneficial to the HEA as it reduces the handling of this archival material and will improve access. However, until digital 3D viewing technology greatly improves there is still a need to view vertical prints using a hand-held stereoscope, as this remains the most efficient way to view them quickly in 3D. Currently, only a small proportion of the archive's imagery is available digitally.

Oblique photographs

Oblique photographs are a key source for archaeological interpretation and mapping and the images were usually taken for heritage management purposes. The exceptions to this are those taken by the RAF during and after the Second World War and the Aerofilms collection which mainly focussed on urban areas and buildings from the 1930s onwards.

Fig 9a: An example of a digital oblique photograph in a lowland setting, held by the Historic England Archive. Cropmarks revealing an Iron Age/Roman settlement in Bedford. 27106_010 01-JUL-2011 © Historic England Archive

Fig 9b: A digital oblique photograph of an upland landscape, held by the Historic England Archive. The earthwork remains of a settlement enclosed and defended by a bank and ditch in Leck, Lancashire. 28364_001 11-DEC-2012 © Historic England Archive

Fig 9c: An example of a black and white oblique print of cropmarks, taken in the Hull valley. NMR 2116_2116 02-JUN-1982 © Crown copyright. Historic England Archive

Oblique photographs are taken at an angle to the ground, most-often with a handheld camera. The plane orbits around an archaeological site so that the monument can be photographed from multiple angles. This maximises the visibility of the archaeological remains and provides sufficient viewpoints in order to correlate the photo to a base map. An oblique photograph provides a perspective view of the ground with varying scale from foreground to background and therefore requires transformation to a plan view for mapping purposes. When oblique photographs are taken with an appropriate overlap between frames then they can be viewed in 3D using a stereoscope or for digital obliques by using a 3D screen and appropriate viewing software.

The bulk of the oblique collection postdates 1965 when the RCHME Aerial Photograph Unit resolved to "use photography to build up a record of field monuments throughout England" (Barber 2011, 221). At first they did this by acquiring aerial photographs to build up a library of images of archaeological sites. By 1967 the RCHME began its own oblique photography in support of fieldwork.

Although most of the oblique aerial photograph collection is focussed on archaeological monuments, the scope has expanded since the late 1980s to include a broader definition of heritage assets, such as urban areas, buildings, parks and gardens, and monitoring of scheduled sites and landscape change. Most of the collection consists of black and white and colour prints (Fig 9). Since 2003 digital photography was more common and in 2006 the last physical negative film aerial photographs were taken by the Historic England reconnaissance team. The HEA now holds nearly a million aerial photographs taken by HE staff and other regional fliers; over 200,000 of those are digital photographs. The scanned oblique photographs from the Aerofilms collection are routinely supplied digitally.

Vertical photographs

Vertical photographs make up most of the material loaned for AI&M projects. A vertical photograph is taken using a fixed camera pointing straight down at the ground. The resultant photograph provides a plan view of the ground at a nominally uniform scale. The aeroplane is flown on a prescribed course, at a predetermined speed and altitude, with overlap between frames.

Vertical photographs are captured in such a way that they can be viewed in stereo, due to this overlap between frames. This affords a 3D aspect and sense of topography and landscape that, until the invention of lidar, was largely unavailable in other sources (though there are some stereo obliques).

The suitability of vertical photographs for archaeological prospection is variable as few were taken specifically to record archaeological features. However, due to the quantity of sorties over many decades, photographs were often taken in the right conditions to serendipitously record archaeological earthworks and cropmarks.

Another key benefit of vertical photographs is they record large areas of urban or rural landscape change at intervals from the 1940s (and sometimes earlier) onwards. These changes can include the impact of major development and urban expansion, conversion of pasture to arable and the resultant levelling of earthwork features, or destruction of archaeological monuments through quarrying or other major extraction. They are an essential resource for the recording of short-lived archaeological features such as 20th-century military remains, and indeed AI&M projects were at the forefront in mapping the physical remains of these landscapes (Winton and Horne 2010, 10).

The vertical photograph collections held by the HEA mainly range in date from the 1940s to the 1990s, though there are some earlier images. Most are black and white but there are a small number of colour runs. The vertical collection was acquired from different sources, and includes photographs taken by the RAF, United States Army Air Forces (USAAF), OS or commercial archives such as Hunting Surveys and MAL (Fig 10). These provide large area coverage at a variety of scales. There are regional variations in the density of cover of aerial photographs available, which mean some projects have multiple sorties spanning a broad date range, whilst others will have fewer.

Fig 10a: An example of an RAF vertical photograph held by the Historic England Archive: a vertical frame taken of the Cherhill area to the north-west of Avebury reveals Oldbury Hillfort, a field system and barrow cemetery. CPE/UK/1821 V 3070 04-NOV-1946 Historic England Archive (RAF Photography)

Fig 10b: An example of an Ordnance Survey vertical photograph held by the Historic England Archive: a vertical image taken over Mollington, Cheshire serendipitously recording medieval earthworks. OS/89139-001 05-MAY-1989 © Crown copyright. Ordnance Survey

Accessing aerial photographs from the Historic England Archive

There is a slightly different flow line for acquiring and viewing archive material for Historic England funded AI&M projects compared to those for commercial and public users of the archive. Commercial and public users usually view the aerial photographs in the public search room in Swindon.

At the planning stage, a shapefile of the relevant area is sent to the HEA. This is used to provide a 'coversearch' with information from the AirPhotonet database that lists all material catalogued for that particular area.

The coversearch selects any oblique photographs where the centre point of the photograph is within the project area. The oblique photographs are plotted in AirPhotonet as a series of points corresponding to the centre point of the frame. This provides a consistent location in reference to the area covered by the photograph but this may not be exactly the same location as the archaeological site or main subject of the photograph especially if it is a wide view. Oblique photographs are provided as either prints, scans of negatives (or prints) or as born-digital image files.

The footprint of each vertical frame is recorded within GIS, so the full geographic extent of each photograph is known. The scale of the vertical photography used for AI&M projects is usually limited to 1:15,000 or larger due to the increasingly small size of archaeological features at lesser scales, but this accounts for 92% of the photographs held in the archive. Where projects have used vertical photographs at all scales, they were a complementary source for recording the evolving wartime landscape where changes, if not great detail, were recorded (Winton and Horne 2010, 15). Therefore this approach should be considered for those projects likely to contain military archaeological remains as a major component.

The number of loaned photographs can be significantly less than the initial coversearch suggests as the archive holds films for a number of photographs but not the prints. Most significantly, more recent OS photography (from 2000-2010) is usually not printed nor is it held digitally so is unavailable for loan, unless specially requested. However, there are alternative sources of photographs for this period.

Vertical and oblique aerial photographs with no negative or film, or with damaged prints or film, are ineligible for loan outside the Archive building due to the inability to reproduce the print in cases of loss or damage. In these instances laser copies are supplied. These are suitable for a basic assessment but archaeological features are not always clearly visible. They are also often unsuitable for stereo viewing because of the effect of scan lines.

For past projects this has only affected a small proportion of prints (those with repository codes FDR/FDM ie film destroyed). However, an assessment of repository code MOD in 2017 revealed that the film was not held for many of these sorties so they were reclassified as FNH (Film Not Held) and are consequently ineligible for loan (Luke Griffin pers comm). For example, there are no negatives for 6% and 15% of the total vertical prints for two recent projects. At project planning stage, the archaeological potential of those prints with no negative should be assessed. If the archaeological potential is high then they can be viewed at the archive or high resolution scans can be arranged.

Providing hundreds of laser copies is a significant time investment for the archive and forthcoming projects will need to assess their value. Past experience with laser copies has shown them to be of poor quality for interpretation and mapping, especially once scanning and rectification has occurred (Bacilieri *et al* 2008, 22; 2009, 17 and Dickinson *et al* 2012, 29).

Another issue that can affect supply of images to AI&M projects is the backlog of accessioning to the archive, this mostly relates to oblique images. Where possible, areas with mapping projects are prioritised for cataloguing. Otherwise, project teams negotiate with the reconnaissance team to acquire relevant photographs directly.

This issue will largely be resolved once the HE Oblique Aerial Photographs (OBAP) application, currently in development, is rolled out. It will allow users to view digital oblique aerial photographs in relation to their approximate location and, once verified by the HEA Cataloguing Team, accurate location against a background map. It will allow users to download images in jpeg format. The immediate plan is for OBAP to be made available to Historic England based staff, however a web-based service is the longer term aim.

Constraints and Issues

- Assessment of the available archive material is essential at project planning stage.
- Potential loss of archaeological information where there is no access to prints because there is a negative only or they cannot be loaned outside the Archive. This usually accounts for a small percentage of a loan.
- Need to assess archaeological potential of this non-loanable material and decide whether they should be used for a project. This should be balanced against the potential impact on limited archive resources.
- In areas where there are non-accessioned oblique images extra time is required to acquire these from the reconnaissance team.

Opportunities

- Consider loaning vertical images at all scales, especially for projects with a high military component as they can provide a wider range of dates during and after the Second World War.
- Locating some oblique images to their true ground position can be difficult but the new OBAP portal locates pre-catalogued material more efficiently.

Historic England Archive loans

"I generally find the service [loan provision] efficient and the loans easy to use."

"I find the delivery of HEA loans to be very efficient and have not had any problems in the last 5 or more years."

"Loan requests back to the archive can be extremely disruptive when working in some areas and have a [negative] impact on project timetable."

(Quotes taken from AI&M Producer Survey)

Although there are a relatively low number of projects in each year, the numbers of loans relating to them is significant as a limited number of prints are allowed in each loan (Fig 11). For each loan, time is required to pull prints and then file on return. Each loan includes all sources in part of a project area as they need to be assessed simultaneously. Vertical prints are stored by sortie, not by location, so this means that multiple areas in the archive store need to be visited to collate all the prints for a given area.

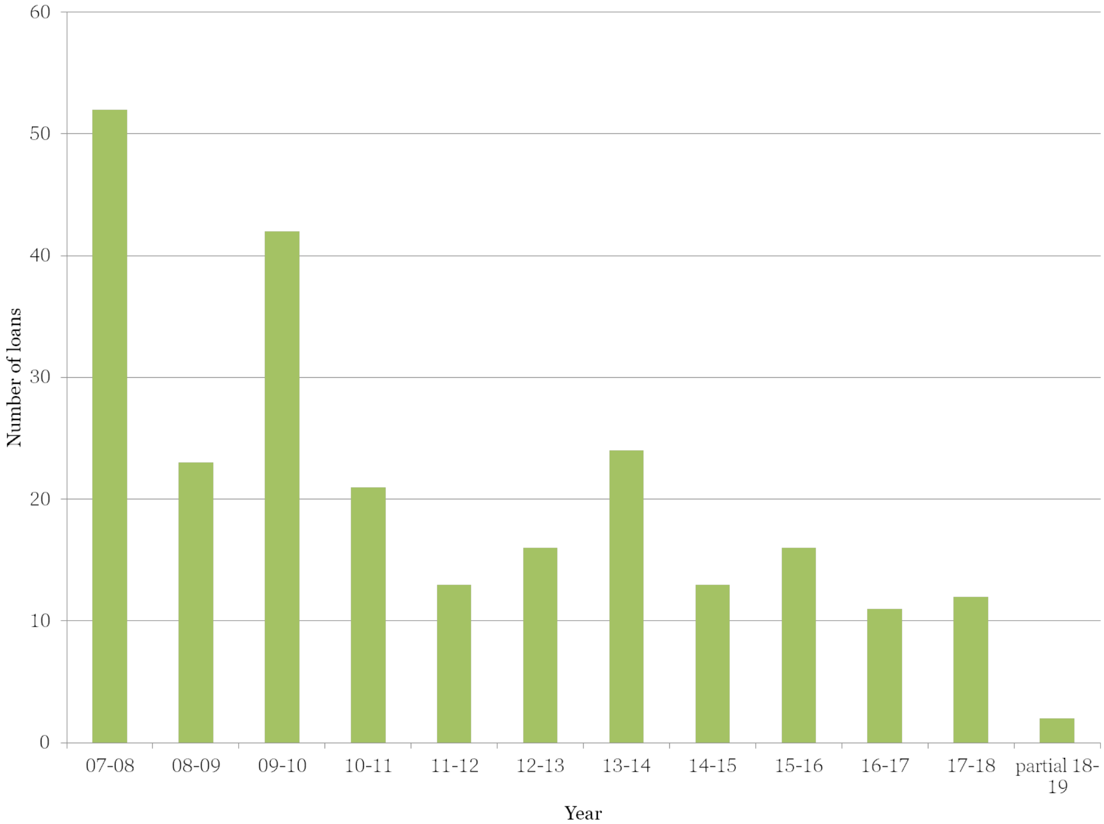


Fig 11: The number of aerial photograph loans provided by the Historic England Archive each year for AI&M projects.

Figure 12 charts the considerable numbers of photographs loaned in the last decade. To support provision of photographs for commissioned AI&M projects to an agreed timetable for both parties, Historic England Grants team fund an Archive Support Officer. To facilitate delivery of loans, discussions with the HEA are undertaken at the outset of any new project. A loan can consist of no more than 2,000 vertical prints and 2,000 oblique prints (including photocopies of material where appropriate), 4,000 prints in all. This ensures a manageable workload for the archive team and ensures that prints are out of the archive for the minimum time possible. This means that many projects have to be split into smaller areas or blocks. Each project is allowed a maximum of two blocks or 8,000 prints to allow a full assessment of the photographic material for the adjoining blocks and to ensure continuity of work. Occasionally this restriction on photograph numbers might hinder larger, and therefore quicker, teams if mapping allocations aren't carefully managed. However, for the most part the loan sizes are easily managed.

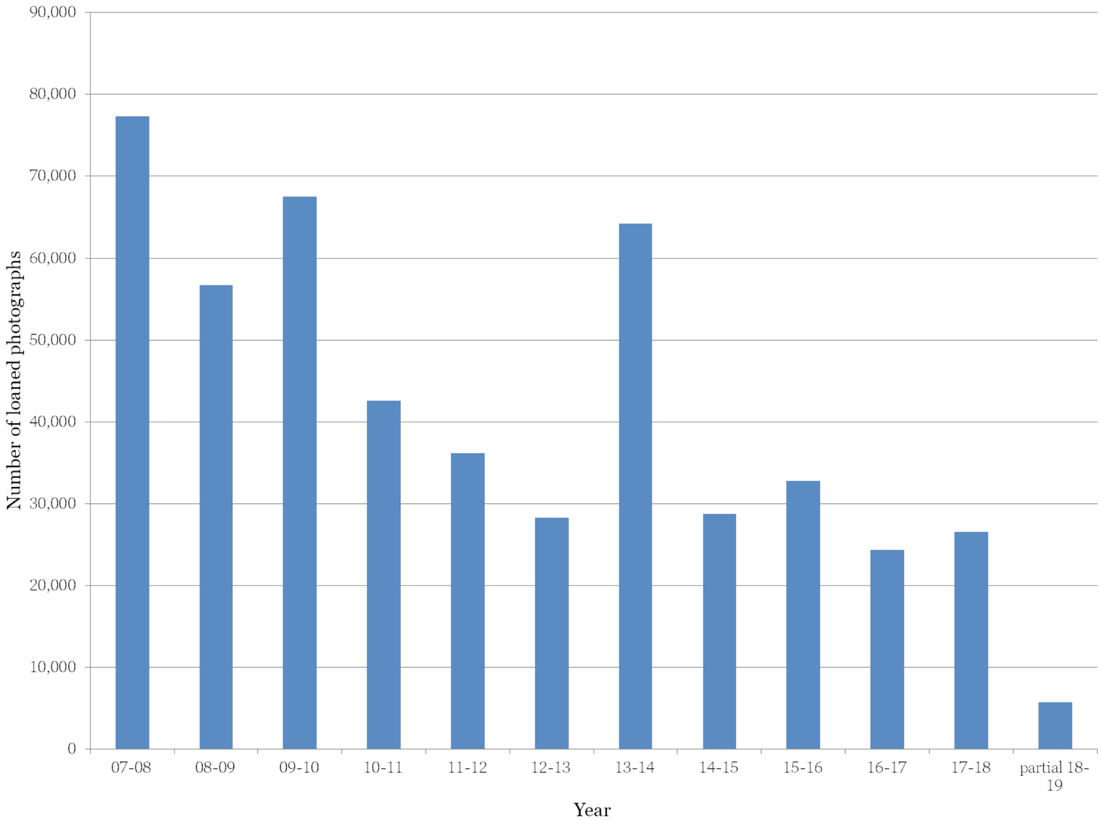


Fig 12: The number of images loaned by the Historic England Archive each year for AI&M projects.

To facilitate delivery of aerial photographs to other customers there is a requirement for AI&M project teams to return relevant material within 48 hours of receipt of a request. This requirement varies between projects but is usually a small proportion of project time. For example, during the Lowland NAIS eight loan requests took 1.5 days in total to process, for the SW Cambridgeshire NAIS there were 16 loan return requests taking 1.8 days to process. Conversely, for the Upland NAIS project no requests were received. These figures are fairly low, but anecdotally it seems that for some projects the impact can be higher. Project planning should include contingencies to ensure project workflows and to take into account the time and cost required to return small parts of loans for other customers of the Archive.

Constraints and Issues

- Loan provision is an essential process for AI&M projects especially as all sources should be assessed simultaneously for each area.
- Project planning should assess the likely impact of processing loan requests on project timetables.

CUCAP – Cambridge University Collection of Aerial Photographs

CUCAP is the result of airborne survey campaigns by JK St Joseph, starting in 1948 (Barber 2011, 217). The collection presently holds almost 500,000 oblique and vertical aerial photographs in black and white, colour and infra-red. The aerial sources cover the British Isles, with the oblique images depicting a wide variety of landscapes and archaeological features (Fig 13).

Fig 13a: An example of a colour CUCAP image revealing a Bronze Age barrow cemetery at Standlake, Oxfordshire. This image is one of 1,500 high resolution images now available to download for non-commercial use via the Cambridge University Digital Library website. CUCAP KE51 26-JUL-1948.

Fig 13b: A black and white print CUCAP image showing multi-period cropmarks at Mucking, Essex, including the prehistoric 'South Rings' and Iron Age/Roman enclosures. This image is held by the Historic England Archive and reproduction is restricted. CAP_7601_8 1962 Cambridge University Collection of Aerial Photography © Copyright reserved.

This archive is a valuable resource for archaeological work with Historic England funded projects having a long history of using CUCAP imagery. Where past projects have not consulted the CUCAP collection it is usually the result of a temporary closure. Unfortunately, since August 2016 the CUCAP archive has been closed and is currently undergoing review.

The closure of the archive was a key issue for respondents to the AI&M Producer Survey, with 74% expressing concern about this lack of access. The aerial photographs held by CUCAP can represent over 20% of the total aerial photographs loaned for any particular project. Figure 14 shows 30 AI&M projects where numbers of loaned aerial photographs are known and compares those available from HEA and CUCAP (oblique and vertical numbers were combined). Unfortunately, given the *ad hoc* nature of cropmark formation sometimes the photographs held in the

CUCAP archive will be the only source that shows a particular site. Recent work by Cara Pearce (forthcoming) has shown that for a sample area of the Yorkshire Wolds a significant number of archaeological features were only identifiable on CUCAP photography. This highlights the problems faced by aerial photograph interpreters when access to the full resource is not possible.

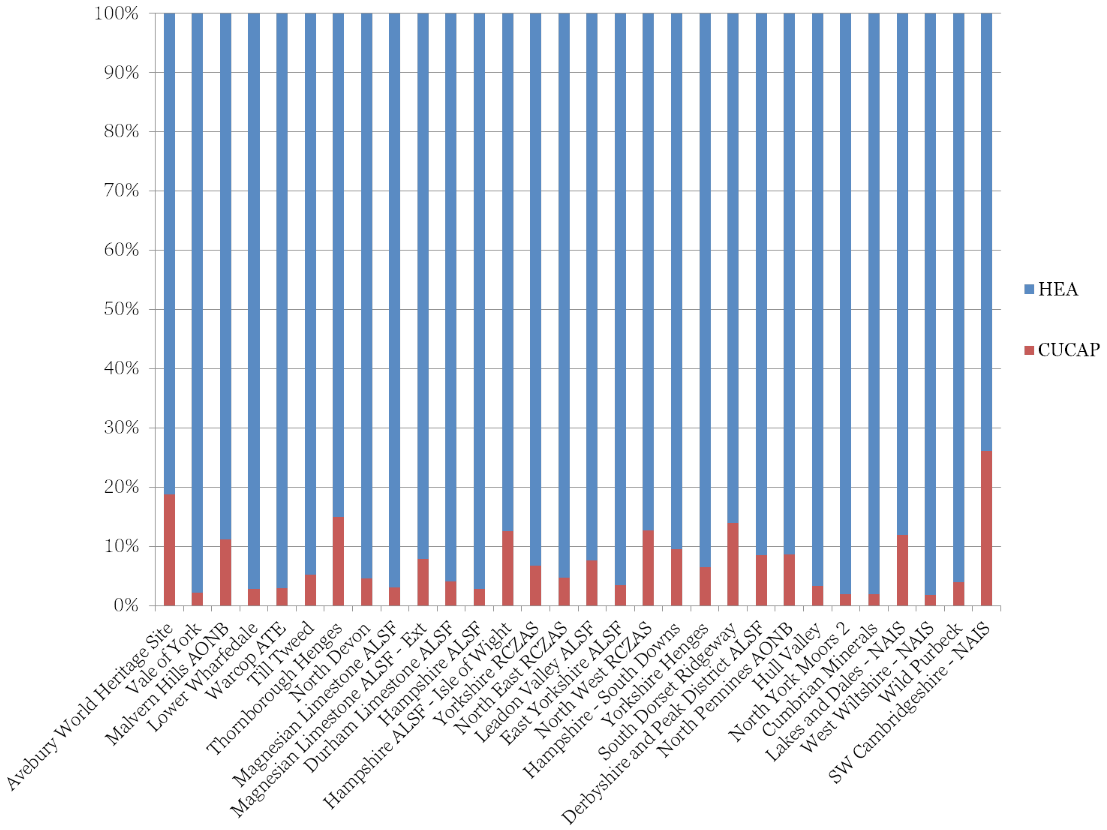


Fig 14: The proportion of CUCAP aerial photographs, compared with Historic England Archive aerial photographs loaned for individual projects.

Prior to the closure of the CUCAP archive, Historic England had an excellent long-standing arrangement for acquiring imagery. Loans were issued or interpreters viewed prints at the library. Even now, a web-based, searchable map (https://www.cambridgeairphotos.com/map/) can be interrogated and a .csv file downloaded to provide a full list of the aerial photographs available within a particular area. As the CUCAP online catalogue is still accessible an assessment of the number of CUCAP images within that project area is still possible, in order to assess the potential of the collection and the extent to which archaeological information may not be available.

Access to a limited number of CUCAP photographs is possible. Currently, a sample 1,500 (of half a million) CUCAP images are downloadable at lower resolution for research via the Cambridge Digital Library http://cudl.lib.cam.ac.uk/, though there is no facility to search by project area. However, the launch of this subset is an exciting development, with the stated aim being the digitization of the entire collection.

Alternatively, the CUCAP photographs are sometimes held in other collections, such as the HEA or local HERs. However, these represent only a small subset of the CUCAP collection. Permission must be sought from CUCAP to copy or reproduce their images in other repositories.

The loss of such an important national collection for archaeological and other research is a serious setback and it is imperative that the collection is secured for the future.

Constraints and Issues

- Incomplete archaeological information in the historic environment as CUCAP aerial photographs are inaccessible.

Opportunities

- Access to a small proportion of CUCAP collection via other archives and online.
- Explore ways to ensure the prints become available.

Local photographic collections

There are a number of local photograph collections across England, usually held by the HER/SMR. The numbers of photographs held within these collections can vary considerably and they sometimes contain unique material taken by a local flyer. However, they often hold duplicates of aerial photographs held within the HEA and CUCAP collections, acquired to help with local research and management.

As such, an assessment of the collections is made at the project design stage for each project to assess whether a visit to the collection is worthwhile. Assessing these collections can be difficult as they are often not catalogued and require consultation with the relevant archive/HER officer for clarity. Access to the collection needs to be negotiated on a case by case basis. Occasionally the images in local collections will be loaned or provided digitally, but more often a visit to the collection is required. Permission to scan any images is usually granted but again this is on a case-by-case basis per HER; it also depends on any copyright agreements with the original photographer.

Smaller collections of aerial photographs are held by some museums, universities, the Forestry Commission and archaeological societies. These often represent the archive of an individual photographer, such as the Derrick Riley collection held by The University of Sheffield. Privately owned aerial photograph collections, taken by independent aerial archaeologists, can occasionally be made available. Public access to these smaller collections may be more limited than those held by Local Authorities or public archives.

Constraints and issues

- Difficult to quantify utility of local collections as it varies across different collections.
- Project planning should assess any collections that require visits and include

resources in the project design as additional cost may be needed to acquire or view aerial photographs in private collections.
- Copyright issues need to be carefully assessed especially where it is not held by the collection.

Working with traditional imagery (vertical and oblique photographs)

The sheer numbers of aerial photographs supplied at the start of a project means it is essential to have a system for efficient workflow. HEA oblique photograph prints are easy to use and site (locate on the base map) as they are catalogued by kilometre square. HEA vertical photographs are supplied by sortie and organised by library number. As it is essential to compare photographs of the same area taken at different times, the usual workflow involves reorganising the loans by geographical area. This siting is usually done as one of the first tasks for any AI&M project. All aerial photographs have to be returned in the order they were supplied on completion of the project.

The usual approach is to locate the vertical run using an OS map and mark the area covered on a label featuring a reduced scale OS map or grid of the project area (Fig 15). The type, date and mapping block (if applicable) is also noted. Bundles of photographs are then placed in glassine bags, with a label indicating the area they cover. The glassine bags cost approximately £100 for 500 bags but are reusable.

Once the siting process is complete all the prints are collected into geographical areas and placed in archive boxes. Although sorting by geographical area requires an investment of time, relevant photographs for a particular area can be identified quickly.

The siting process also aids landscape familiarisation and provides a rapid overview of the quality and quantity of sources. Modern digital orthophotography and lidar mean that the landscape can also be viewed on screen. However, if the landscape has changed significantly then the siting process provides a good overview of major changes and can avoid confusion when using later sources.

This siting and loan management process is a very important part of the AI&M project process and needs to be planned very carefully to ensure efficient use of the large numbers of aerial photographs. Sorting and siting has to be done for every photograph or run of photographs irrespective of their containing archaeological remains or not.

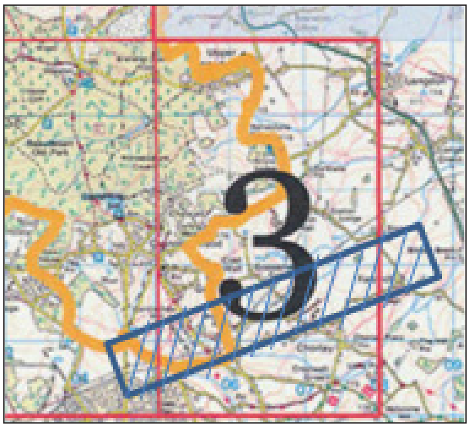


Fig 15: Example of siting label for block 3 of the Cannock Chase AI&M project. The blue hatched rectangle shows the location of a particular run of vertical photographs. OS mapping © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100019088

Project teams have developed different approaches to organising photographs to suit their circumstances. The methods vary slightly but elements of each technique are broadly similar.

Alison Deegan (Aerial Photograph & Lidar Interpreter) uses a formula in Microsoft Excel to produce X, Y data taken from the loan coversearch so that it can be input into a GIS (MapInfo in this instance) as points. The X, Y data equates to the centre of an individual vertical photograph that can be viewed in any GIS. The resulting points can then be selected by location for a particular area or block and the list of frames printed. The photographs are then pulled from the loan, which is maintained in loan order, and ticked off as they have been assessed. This approach allows comparison of all sources for a given area but removes the need to repackage the loan and saves time at the end of a project as the photographs should still be in loan order. Deegan estimates that pulling the photos for the first area from a loan takes the longest (700 vertical prints from a 2,500-3,000 print loan would take three to four hours) but that subsequent areas take less time because there are fewer prints left in the loan boxes. This approach has the advantage that it does not require re-sorting back into loan order at the end of the project and also, going through loose photographs rather than bagged photographs, is quicker. If these figures are correct then this would equate to a large time saving compared with the labelling approach. As a very experienced aerial photograph interpreter working on projects alone, this method clearly works. However, a project with several team members working on different but potentially overlapping areas may require a different approach.

Sophie Tremlett (Senior Aerial photograph Interpreter, Norfolk County Council), has developed a similar approach using the GridRefMapper tool in MapInfo that automatically converts the eastings and northings from the loan list into six-figure grid references that can be plotted as point data in MapInfo. These data are then used to create thematic maps to highlight the different runs, or to distinguish between digital and print obliques. Like Deegan, the photographs are selected by location, usually by mapping block plus a buffer. The individual runs of photographs are then placed in hanging files within archive boxes, so loan order is not maintained. Tremlett is unsure if the method actually saves time, particularly as she works as part of a project team (Deegan works as an individual).

> "I am in two minds about whether or not this system is better than our old one [label method described above]. I find it harder to work out or remember where a photo is of and whether it's relevant. The advantages [are] it cuts down significantly on the time spent sorting the loan out for mapping, and putting it back together again, and the Excel spreadsheet is really useful for keeping track of what you have/haven't looked at (but this could be used in any system, provided you have a plot of the APs). The disadvantage is the time spent pulling the photos for the specific area you want. I find that this is particularly onerous where you are spanning a loan block and/or someone else's mapping area - no matter how we plan it, we always end up mapping next to each other at some point and needing the same photos. I think in these instances I would find it

> quicker to find the ones I need by looking at one of our old labels showing the sortie in relation to a grid square, but that may not be the case for everyone.
> I think overall that in our experience there isn't an awful lot in it in terms of saving time, it will to some extent be dependent on individual preference/aptitude, and how your project is organised in terms of how many team members are using the photos and when."

Cain Hegarty (NMP Project Manager, AC Archaeology) combines the various approaches described above and generates points from the loan list in ArcMap to select the images by location and then display by individual sortie to speed up the siting/label generation for the glassine bags (Cain Hegarty pers comm).

Going forward, project teams may benefit from trialling these approaches to assess efficiency of each method.

Constraints and Issues

- Handling vast numbers of aerial photographs and siting them for use is essential to ensure that sources can be compared and used efficiently.
- The sorting process can feel time consuming so aids such as GIS should be used where possible to streamline the process and ensure all photos are reviewed effectively.

Opportunities

- Explore with the HEA the possibility of providing shapefiles of vertical photograph locations with loan list to avoid AI&M team having to re-create this existing data using coordinates provided on loan list (for siting photographs).
- Compare individual approaches to siting photographs to confirm most efficient method.

Viewing vertical photographs

The benefit of printed vertical photographs is that they can be viewed quickly in 3D using a hand-held stereoscope (Fig 16). The stereoscope is a device for viewing a pair of separate images, depicting left-eye and right-eye views of the same scene from slightly different angles that allows convergence of the separate images as a single 3D image. The use of a stereoscope for viewing stereo pairs is mandatory for AI&M projects as it is essential for effective archaeological survey. The view provided through the stereoscope both magnifies the image and exaggerates the height so identification of archaeological earthworks is easier. Investigators generally use a stereoscope at 2x magnification, though occasionally may swap to a higher magnification if the earthworks are very slight or the visibility of the features is poor on a pair of images.

Every vertical frame is viewed in 3D using the stereoscope. This is the only way to fully assess the source and ensure that all archaeological features are identified. It is good practice to study the vertical photographs in date order with the earliest photographs first. This allows the investigator to fully understand how the landscape has changed over time. Once an archaeological feature has been identified the usual approach is to make a quick note in the chosen mapping software (as spatial data with attribute in GIS or as a simple notes layer in AutoCAD). However, if working on small areas at a time a mental note only may be required.

Once all the photographs have been assessed for a small area, the most suitable photograph (or other source) will be chosen for mapping each archaeological feature. If it is a photograph, it is scanned using a desktop flatbed scanner at an appropriate resolution. In practice, this means black and white photographs are scanned as 8-bit grayscale at a minimum of 400dpi, but for smaller details a higher resolution may be appropriate. Colour images are scanned as 24-bit colour image files. The file is saved as an uncompressed Tagged Image File (.tif) used for storing high quality raster images. For efficient file management each scan should be systematically named using the photo reference (eg RAF_540_642_RS_0093.tif). The scan can be edited in Adobe Photoshop or equivalent software to enhance the image if required.

Fig 16: An investigator views vertical photographs in 3D using a stereoscope.

Viewing oblique photographs

Most oblique photographs are assessed, usually by kilometre square or each archaeological monument. Some oblique photographs were taken as stereo pairs and these are viewed in 3D using a hand-held stereoscope. As with vertical images, only the best photograph for each site will be scanned, using the process described above.

Digital oblique images have to be viewed on screen. For internally based teams this is usually done in Adobe Bridge, which is useful software for finding, managing, editing and organising images.

Viewing digital images in 3D

Historic England investigators have 3D monitors and NVIDIA 3D Vision Photo Viewer Software that allows 3D viewing of digital stereo imagery, both vertical and obliques. Although it is not used regularly due to the lack of digital stereo pairs, it is likely that as more digital aerial photographs are provided for projects that its use will become more widespread. Scans of negatives can also be viewed in 3D using this software. Currently, external teams do not have access to this software and equipment, meaning that they cannot view digital oblique imagery in 3D.

Risks and Constraints

- External teams unable to view digital oblique photographs in 3D.

Rectification

The distortions inherent in vertical and oblique aerial photographs mean that to produce accurate plans it is necessary to transform proportionally (rectify) and georeference each aerial photograph to a suitable base map before tracing off the archaeological features. Specialist rectification software is used to achieve this. The results of the Producer Survey showed that all project teams currently use Aerial 5.36 although there is an alternative software package called AirPhoto.

The latest version of the Aerial rectification software is designed to run under 32-bit versions of Windows, including XP and Version 7. It was developed by John Haigh and the University of Bradford and was last updated in 2015. John Haigh has since retired and the intellectual property rights for the software have been transferred to Historic England, Historic Environment Scotland and the Royal Commission on the Ancient and Historical Monuments of Wales. No further development of the software is planned so alternatives are discussed below.

There is a short manual covering technical aspects of Aerial but training is usually provided by project team members or Historic England guidance. It is important that anyone using rectification software has an understanding of the underlying process.

The success of rectifying an aerial photograph depends largely on the availability of accurate control information. Control points are locations that are visible on both the aerial photograph and the source for control, either a 1:2,500 scale map or orthophotography. The source of control used by AI&M projects has changed over time with the earliest projects relying on printed OS maps at 1:10,560, and later 1:10,000 scale. The current source for control is the digital OS 1:2,500 scale MasterMap (or equivalent) which became the standard in 2007, though some projects used it prior to that. Orthophotography at 25cm resolution, supplied through the APGB agreement, has also been used since 2008. This affords the advantage of being able to use features that are not depicted on OS mapping, such as boulders or the intersections of field drains, as control but caution is required to ensure that the true ground position of control features is used.

The use of orthophotography as a source for control is not an AI&M standard as the 'fit' between the aerial photograph and the source for control is harder to assess. Within Aerial you can view the rectified image overlain with the OS map, but this cannot be replicated with the orthophotography. To use orthophotography images as a source for control within Aerial they have to be uncompressed in Photoshop and resaved. This loses the geotiff tagging, though fortunately the geo-information is not totally lost as a world file (.tfw) is provided as standard. Batch processing in recent versions of Adobe Photoshop or similar software makes this uncompression process relatively efficient, though not all external teams have access to this.

The use of a 5m digital terrain model (DTM) to employ a 3D geometric transformation has been standard since 2005. The use of a DTM allows aerial to produce a rectification that takes into account variations in surface height.

The acceptable tolerance for rectification of aerial photographs is normally within ±2m of the source used for control. Control points need to be well placed and evenly spread to surround all of the archaeological remains that are to be mapped (Fig 17). Only the area of the photograph within the control points is accurately rectified. Rectifications should ideally use at least six or seven control points, though Aerial will produce a rectification if five control points are placed. Using too many control points or too few can result in increased errors and poorer accuracy of the resulting rectification. For best results and to offset issues of height displacement (on vertical photographs) the archaeological remains are best located centrally within the image frame (Fig 18).

The source for control has a significant impact on the accuracy of the resulting rectification. The stated accuracy for OS 1:2,500 scale mapping is an absolute accuracy of 1.1m root mean square error (RMSE). The absolute accuracy is how closely the coordinates of a point in the dataset agree with the coordinates of the same point on the ground. The relative accuracy, positional consistency of a data point or feature in relation to other local data points or features within the same or another reference dataset, is 1.1m +1.0m (up to 100m) RMSE. This contrasts with the 1:10,000 scale map where the absolute accuracy is RMSE 4.1m with a relative accuracy of ±4.0m (up to 500m) RMSE. APGB orthophotography is georeferenced and accurate to ±1.25m RMSE. This means that we can expect that any features mapped by projects using the 1:10,000 scale mapping as a source for control will be less accurately geo-located in the real world than those using the 1:2,500 scale mapping or orthophotography.

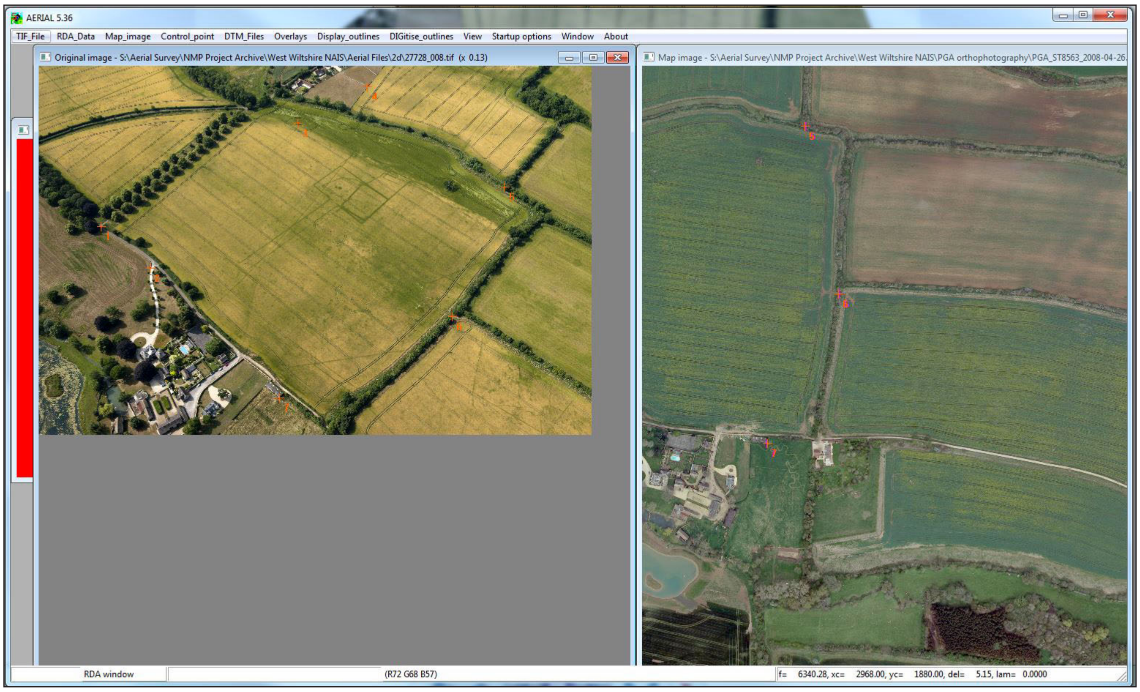


Fig 17: Using Aerial software for rectification of an oblique photograph (left). In this example the source for control is the geo-referenced APGB orthophotography (right). Control points are placed on the oblique photograph and on the orthophotography. Image HEA 27728_008 12-JUL-2013 ©Historic England and RGB Aerial Photography – ©Bluesky International/Getmapping PLC

Fig 18: The rectified and geo-referenced oblique image overlain by OS mapping to check the fit. The rectified image can be inserted into any GIS mapping software. Image HEA 27728_008 12-JUL-2013 © Historic England and OS mapping © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100019088.

Accuracy in the real world

Aerial photographs rectified in Aerial using digital OS mapping or orthophotography as a source for control and a DTM to account for height distortions are highly accurately located. This means that the derived digital mapping is also extremely accurate to its true ground position. As part of the West Wiltshire NAIS geophysical survey was included in the project to complement the initial AI&M stage. This geophysical survey focussed on selected sites in the project area, where ground-based methods could potentially enhance the assessment of the archaeological evidence. Navigation and positional control for the geophysical survey was achieved using a Trimble R8 series Global Navigation Satellite System (GNNS) receiver (Linford *et al* 2014a; 2014b; 2015). Neil Linford (pers comm) suggests that assuming you have decent satellite cover and a base station in the field then accuracy should be sub decimetre.

At Little Chalfield an extensive Iron Age/Roman multi-phased settlement, consisting of a number of intercutting rectilinear enclosures with an adjoining trackway or avenue and an extensive field system, was discovered via the AI&M element of the West Wiltshire NAIS within a large arable field. The position of the AI&M mapping and the geophysical results are largely identical, confirming that rectification to modern standards can provide excellent locational accuracy (Linford *et al* 2014, fig 5; reproduced here Fig 19). At Kellaways Farm a discrete early Roman enclosure was identified within a relatively small field. For those features identified by both the geophysical survey results and AI&M mapping there is an excellent match when the two techniques are superimposed on one another (Linford *et al* 2015a, fig 6 & 7). At Paxcroft, Iron Age/Roman enclosures were identified as part of the West Wiltshire NAIS (Linford *et al* 2015b, fig 7). Here, although the match between the AI&M mapping and the geophysical survey mapping is good, there are a couple of areas of drift of between 1 to 2m, probably due to the quality of the available control on the aerial photograph and OS map.

The absolute accuracy of the archaeological mapped features for older projects will generally be lower. This is because these projects used earlier OS products as a source for control that had a lower stated accuracy than is currently available. Additionally, before georeferenced vector data were available, raster maps had to be manually registered in Aerial, increasing potential errors. The evidence from excavations and geophysical survey that followed the Magnesian Limestone NMP corroborate this, with some areas matching extremely well and others where there is variation in both size and location of the features (for examples see Roberts *et al* 2010; Martin *et al* 2013). Control information for this project was mostly derived from the OS Land-Line ™ 1:2,500 scale vector maps with accuracy for the OS 1:2,500 maps in the range of ±2m. The specified error for the rectification of the photographs was within ±2.5m (Deegan 2006, 3). Ian Sanderson (West Yorkshire Joint Services) describes his experiences using the Magnesian Limestone NMP data; he also highlights some of the issues cropmark sites face:

> "Plotting accuracy is a little variable, sometimes very accurate, sometimes rather less so (but it is consistently good enough for us to consider it to be a reliable resource) & we appreciate the

limitations that are inherent in plotting cropmarks from a variety of aerial photographs taken over a varied period of time.
The [follow-on work] confirmed some features visible on the aerial photographs and added some detail as well. In our view the techniques are complementary and sometimes the reverse happens. One factor that you might want to consider is that the NMP work in WY was done in 2003-4 using aerial photographs taken over the previous 50 years (but mainly ones taken in the 1980-mid 1990s), so it is something of a historical snapshot in that there has often been 20 years plus subsequently of ploughing on these sites. Some sites that we are seeing excavated are very heavily truncated now & geophysical survey is not always very good at picking up such features."

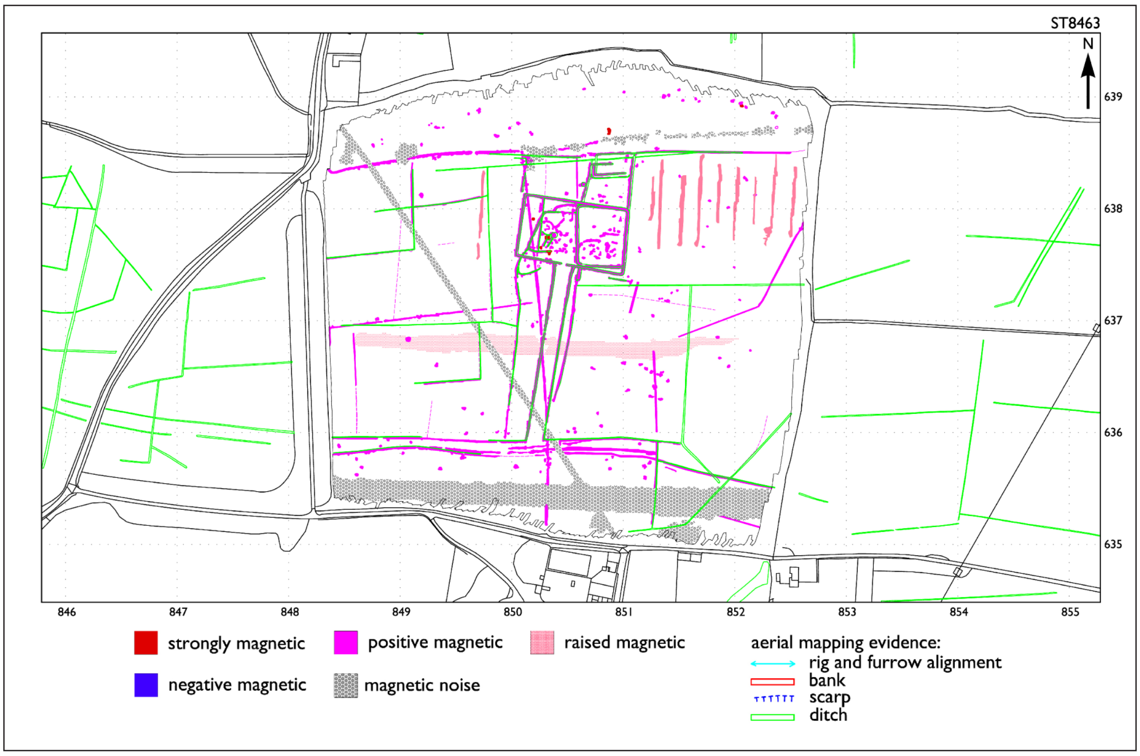


Fig 19: Little Chalfield, Atworth, Wiltshire. Geophysical results (pink) and AI&M results (green) revealing the geo-locational accuracy of AI&M products © Historic England. OS mapping © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100019088

Should rectified images be retained?

The archive material used for AI&M projects is publically available imagery. The photographs used for mapping each archeological feature are stated in the monument record and repeated in the spatial data. As such, the source material is accessible to users, but only via the appropriate archive. For copyright reasons, on completion of a project no scanned or rectified images are archived in any way. The scans are neither supplied to the HEA nor retained by AIM. Historically this was due to digital storage issues, though this is less of a problem with current IT systems. For images where HEA do not hold copyright these cannot be retained.

One respondent to the User Survey would like the aerial photographs supplied as part of the AI&M project data:

> "It would always be useful to have access to the APs [aerial photographs] themselves in digital form, as you are otherwise heavily dependent on the interpretations of those who did the digitising."

However, as the scans vary considerably in resolution, contrast and crop they are not an archival product. Therefore they are not suitable for supply through the HEA. However, if a quick and simple method were devised, it could be possible to provide these snapshots as part of a monument record or mapping data. Copyright and reproduction rights would still need to be resolved. As a note of caution, a single image on screen should never be used in isolation for making an archaeological interpretation as the mapping will in many cases be derived from multiple sources.

Opportunities

- Look for opportunities to link mapping data or monument records with source aerial photograph, particularly for born-digital imagery.

Alternatives to Aerial

The likely redundancy of Aerial over the next few years, aligned to the release of future operating systems (post-Windows 10) is a cause for concern. Aerial software is used by most professionals in the UK and by all staff working on projects conforming to Historic England's AI&M standards.

AirPhoto

The AirPhoto rectification software forms part of the Bonn Archaeological Software Package, which has been developed cooperatively since 1973. It has the advantage that it is freely available to download and like aerial can incorporate a DTM. It is popular in Europe as it is designed to be used with different map projections. Past trials of this software at Historic England have suggested that whilst the software is satisfactory, it offered no real benefits over Aerial at that time, particularly as it was difficult to assess errors.

ArcMap

ArcMap and other GIS programmes have the facility to undertake a transformation of aerial photographs via a number of control points. However this method is not a true rectification and the transformation cannot account for height variation at present and so are not a suitable alternative for AI&M projects.

Risks and Constraints

- Redundancy of Aerial and potential future need for updated or replacement software.

Opportunities

- Explore alternative rectification software to assess usability.
- Compare accuracy of rectifications using different software packages.

Copyright

Even when an aerial photograph is supplied to an AI&M project, it does not mean that the HEA necessarily holds the copyright to that photograph. For HEA loaned material, the copyright holder is included as part of the photographic loan list, but there may still be restrictions on use. The archive provides advice on the use of this material. In collections mainly sourced from other archives, such as local authority HERs, it can be difficult to determine copyright. In some cases, additional costs may be required for the right to scan or reproduce aerial photographs. In instances where there is a third-party copyright holder, written permission must be sought before an image is used or reproduced.

Copyright is a complex issue for such a large and diverse collection and therefore a key part of project planning is to ensure what level of permission there is for use of photographs. As with any other source, the copyright and reproduction of images for project reports or other publications needs to be checked with the Archive.

Risks and Constraints

- Cost to reproduce copyrighted imagery may be prohibitive.
- Inability to scan an image making accurate archaeological mapping very difficult.

Photo References

The aerial images supplied by the HEA and other archives have to be referenced in a standard way for ease of identification and retrieval from the archive. This allows anyone using AI&M data to find the original source photograph and anticipates a future scenario where datasets are linked and available on the web (ie Airphotonet and Heritage Gateway). These photo references are used in the digital mapping attribute data table, for NRHE or HER monument records, and in the project report or other publicity. There are numerous variations in reference types reflecting the great number of different sources (and copyright) of material in the archive.

The current loan lists output from Airphotonet do not provide references in the formats required by the archive for recording and referencing. Guidance is provided by the archive, but the variation in formats is high. Changes in formats usually occur with organisational restructures (with accompanying name change) or when a new type of source is introduced, such as born-digital aerial photographs or lidar. This can be hard to manage across multiple projects and teams as changes mid-project are not desirable, and ensuring that each team is up to date relies on looking at guidance at the start of each project. The current AI&M standards document (Winton 2018) provides the reasons behind formats and examples of photo references, but the Producer Survey suggests that more guidance is required.

In future, a change in the format of loan lists to include the correct photo reference would ensure that project teams are using correct references as defined by the Archive. This could then be used as a pick list for AI&M projects and other customers. This would maintain standardisation and ensure that up-to-date references are used. Users of AI&M data also note confusion over which archive the photographs are held in and the format of photograph (digital or print), so additionally this information may be useful to include in any future updates.

The photograph (and other source) references shown below illustrate the variety of formats required. Standard components include a minimum of film/frame or sortie/frame and the date. Date of image is crucial for those assessing the age of the evidence and the other reference numbers should be sufficient for the source archive to identify the image for a customer. In future the source archive will also be included.

The following shows how the reference is compiled from a number of columns within the HEA loan list and helps illustrate the problems of maintaining standardisation given the variation in formats:

Vertical examples

The reference includes sortie number, camera position, frame number and date flown.

ADA/099 V 108 22-JUL-1982

MAL/71170 V 106 13-NOV-1971

OS/74041 V 41 22-APR-1974

RAF/541/23 RS 4176 16-MAY-1948

Oblique reference examples

For those taken by Historic England (or precursors) the reference includes source code, film number, frame number and date flown.

NMR 12033/46 19-NOV-1990 (non-digital example)

NMR 28985_003 22-FEB-2018 (digital example – the frame number must always be expressed as three digits, and underscores used to enable searching of the digital archive)

Military Oblique examples

The reference includes source code, original number, frame number and date flown.

RAF 30162/PSFO-0013 01-MAR-1963

For those oblique photographs not taken by Historic England (or precursors) but held in HEA.

The reference includes source code, film number, frame number, date flown (and original number where applicable).

TMG 4559/55 15-JUL-1988

CAP 7938/42 07-APR-1949 (XYZ123)

AFL 60009/EPW000041 JAN-1920

CCC 5208/06729 1930s (no exact date known in this example)

There are also photo reference formats for aerial photographs supplied by CUCAP

CUCAP BW13 23-JUL-1982

CUCAP RC8HP 076 30-MAY-1985

There are no standard formats for aerial photographs supplied by HERs or SMRs so an appropriate format is agreed by the project team. The reference typically includes information to identify the source organisation and allow them to identify the image for supply to an enquirer.

Issues and Constraints

- Process for recording photo references is subject to error when all or partly free-text – copy and paste requires use of standard list of photo references per project and requires a separate stage in the project.
- Copyright of material remains a complex issue – a 'self-service' method of checking would be desirable.
- In some recording systems, such as the NRHE, the source archive is not always easy to determine.

Opportunities

- Standardisation of the basic format of sources could avoid confusion due to organisation changes etc.
- Explore with Archive Team the possibility of inclusion of correct photo references in loan list to avoid mistakes and reduce time costs to projects.
- Include source organisation in reference.
- Explore opportunities for developing Aerial software.

Orthophotography

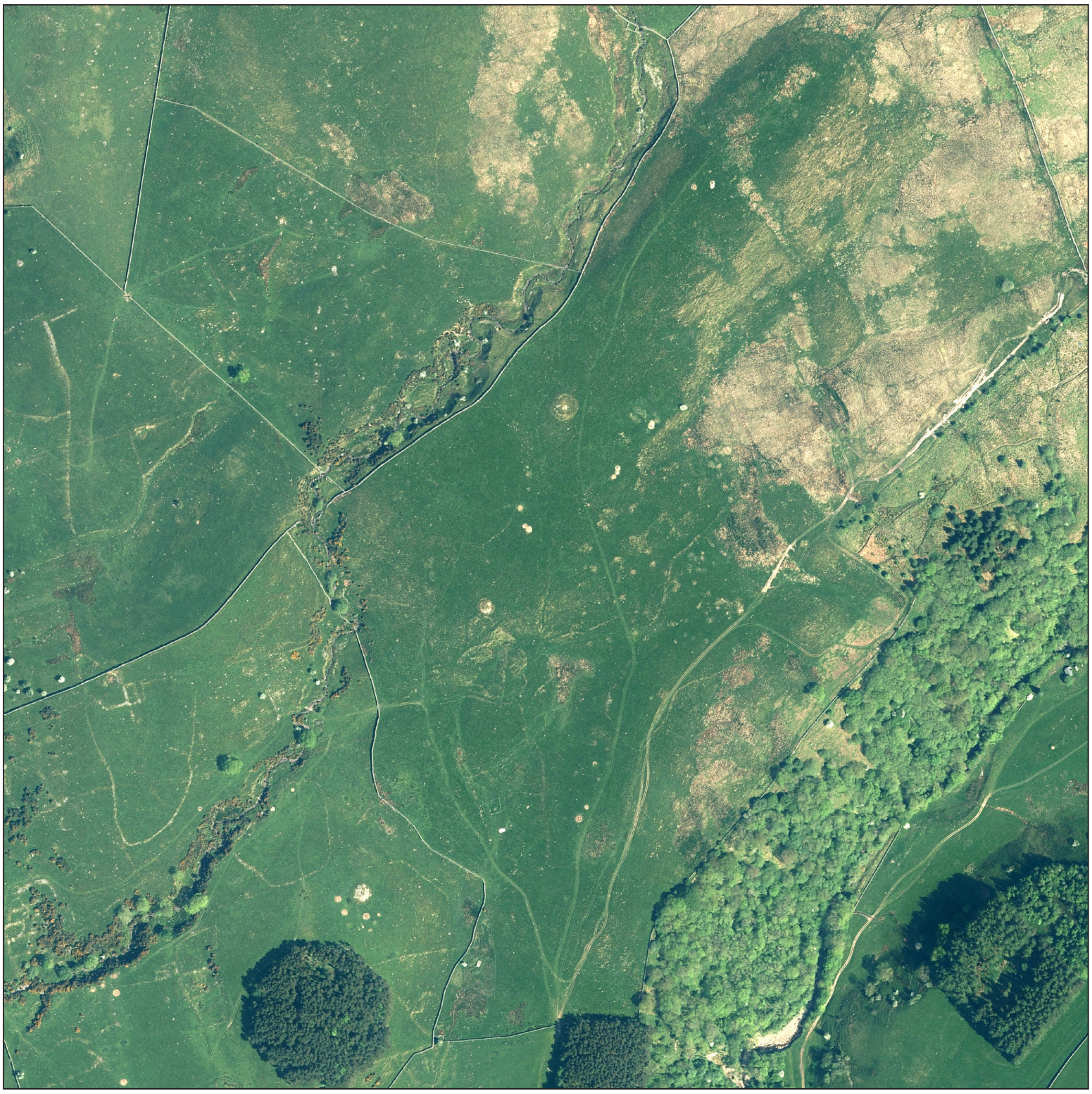


Fig 20: Example of 25cm resolution APGB orthophotograph. This one square kilometre tile shows multi-phased archaeological remains visible as earthworks and stonework at High Park, Lancashire. APGB NY6478 15-JUL-2017 RGB Aerial Photography – ©Bluesky International/Getmapping PLC

An orthophotograph is a georeferenced photomosaic which is uniform in scale, with all distortions such as height displacement removed. The pre-processing by the supplier means that there is no need to rectify the image. The imagery can only be viewed on screen as a 2D image. Orthophotography has been used as a source for Historic England archaeological mapping since 2008. Archaeological features mapped using this source are very accurately placed in relation to their true ground position. Where necessary, some projects use it as a base map for rectifying traditional aerial photographs.

National orthophotography is currently supplied by APGB. This is a consortium called Next Perspectives made up of three companies – Airbus Defence and Space, Bluesky International and Getmapping. APGB provide full coverage of Great Britain flown at 25cm and 12.5cm resolution divided into 1km tiles (Fig 20). The photography is captured between 1st April and 31st October each year, meaning that it can show archaeological remains as cropmarks in optimal conditions as it is flown over the spring/summer months. It is generally less suited to recording archaeological earthworks, where the long shadows associated with winter are more appropriate, although earthworks can be visible if photographed early or late in the day. Historic England and HERs can access and use the images and other products until Spring 2020 as part of the Public Sector Mapping Agreement. There is a risk of losing access to this essential resource if these agreements are not maintained, due to cost or lack of use.

APGB images are acquired from a web-based service into which a project area shape file is uploaded in order to select the relevant 1km^2 tiles. These will then be delivered via direct download, USB storage device or DVD, dependent on the size of the request. Until recently, both the tile name and the date of the photograph were included in the filename for each image, but now the filename is just the tile reference. As it is important to record the date of any photographs used, the interpreter must spend time cross-referencing the photographs and the .xml data provided by APGB in order to confirm the date.

The APGB website currently only provides full coverage of the latest orthophotography and in some cases a limited selection of previous years' coverage, though this is constantly improving. It would be advantageous to have the complete dataset for multiple years of photography, as this increases the chance of identifying archaeological remains, which in turn may also cut down on the number of rectifications of other photography required. The APGB data can be directly inserted into any GIS software.

Going forward, the imagery would ideally be pre-loaded as a dataset within the Historic England corporate GIS. This would significantly reduce the time impact of importing this source for those based within Historic England offices and providing the data to non-HE/HER AI&M project teams may also be quicker.

Issues and Constraints

- Time taken to uncompress the files for use in Aerial.
- The time impact of providing data to third parties on HE AIM team.
- Lack of date on filenames, causing additional processes for interpreter.

Opportunities

- Inclusion of the APGB orthophotography within the Historic England corporate GIS.
- Likelihood of increased temporal coverage of APGB orthphotographs.
- Explore re-inclusion of the date of the orthophotography in the filename.

Online aerial photographic coverage

Google Earth and BING provide photomosaics based on aerial photographs. These images are sometimes the same coverage as available through APGB. As with most vertical photographs, the images are not flown with archaeological remains in mind, which may mean that they are not flown at the best time of year for cropmarks or the sun is too high in the sky to best show earthwork features. The key benefits of these resources are their availability and the extensive coverage they provide. Google Earth has multiple years of photography available as part of its time-slider functionality, though the amounts of coverage can vary considerably with some areas only having one year's coverage. The resolution of the imagery is also variable depending on the location, with some upland areas having very poor resolution coverage. However, the imagery is updated regularly and therefore the potential for more coverage is high. Dates of photographs are not consistently recorded and often include defaults such as 1st January or 31st December. This can be problematic when trying to pinpoint key timings of landscape change.

Web-based imagery has been used as a source for mapping since 2009. Most producers of AI&M data have the Google Earth programme on their computers and most of those are currently in the process of moving over to Google Earth Pro. This provides the option to save higher resolution images than standard Google Earth. Unfortunately some organisations restrict the use of Google Earth and so some teams cannot access the imagery, unless via Google maps which only shows a single layer of photographs.

BING and Google maps are accessed via a website on any internet browser. Viewing the imagery is easy, notwithstanding the inability to view the imagery in 3D, but unfortunately using the data for mapping is slightly more problematic. Although there are methods to directly link map imagery to ArcGIS or AutoCAD this requires a robust network connection (as you are constantly feeding in live data from their servers) and the appropriate permissions to allow this. Furthermore, the georeferencing of Google and Bing is very variable it cannot be relied upon for mapping purposes.

Alison Deegan has trialled Bing in MapInfo but found that switching coordinate systems to match BINGs to be problematic and also the resolution of imagery to be low. Therefore, the usual method is to save or simply screen grab an image and then align it within a GIS. The resultant imagery is of lower resolution than can be viewed on screen, making mapping of the archaeological remains difficult, but the enhanced locational accuracy is beneficial. The date of BING photography is not included so this can be a major issue when assessing change over time.

Issues and Constraints

- Reduction in resolution and clarity of photograph due to method of use.
- The stated date of the photograph is often incorrect or not available.

Opportunities

- Explore using direct links to web-based imagery via mapping software.

Satellite imagery

Satellite imagery is not currently used for AI&M projects. Freely available satellite imagery is usually of lower resolution than terrestrial imagery. Higher resolution imagery is available to purchase, but whilst multiple temporal coverage is available, it is difficult to acquire useful runs of photographs, ie those without cloud. It is likely that satellite imagery will be incorporated into AI&M projects in the future but this will require an assessment of the cost and time outlay compared with the usefulness of this source.

The key advantage of satellite data, over and above the possibility of capturing data over very large areas at any given time, is the fact that most of the recent satellites possess sensors beyond the visible spectrum. At the very least they have one additional sensor, beyond the RGB, to record the Near Infra-Red (NIR); many have between six and ten sensors ranging from the edge of the ultra violet to near thermal bands. The use of airborne multispectral (M/S) data has been proven to be beneficial in recording changes in plant, growth indicating the presence of buried remains, before this appears in the visible spectrum. Less work has been done with satellite imagery, and where analyses have been carried out with regard to cultural heritage, it tends to have been done outside the UK. There is, however, certainly potential to use the M/S data available from satellites, though this will require a degree of training.

Although higher resolution data has only been available to purchase, making it largely inaccessible to archaeologists, this will change in the next year or so. A government backed project the Space for Smarter Government Programme (SSGP) aims to provide access to high resolution imagery to government agencies so as to improve their effectiveness. HE is one of the agencies that will be testing the use of these data to assess its applicability to our work. Again there will be a requirement for training, but this is part of the SSGP.

Opportunities

- Explore use and effectiveness of satellite imagery as a source for AI&M projects.

Lidar

Lidar stands for 'light detection and ranging', which describes a method of determining three dimensional (3D) data points by using a laser (Crutchley 2018, 1). Lidar usually involves an aircraft-mounted pulsed laser beam, which scans the ground from side to side. The laser pulses bounce off the ground, and the features on it, and the speed and intensity of the return signal is measured. 'First return' is the term used to describe the first beams to bounce back, whether they hit the ground, a rooftop or the tree canopy. Other beams will follow a path between the leaves and branches, possibly bouncing back from the ground within woodland (known as last return). This information is used to create a precise Digital Elevation Model (DEM) of the ground and the features on it and is a broad term that covers Digital Surface Models (DSM) and Digital Terrain Models (DTM). For landscapes, the DTM represents the 'bare earth' surface resulting from the filtering out of features such as buildings and trees, while the DSM is the surface including features such

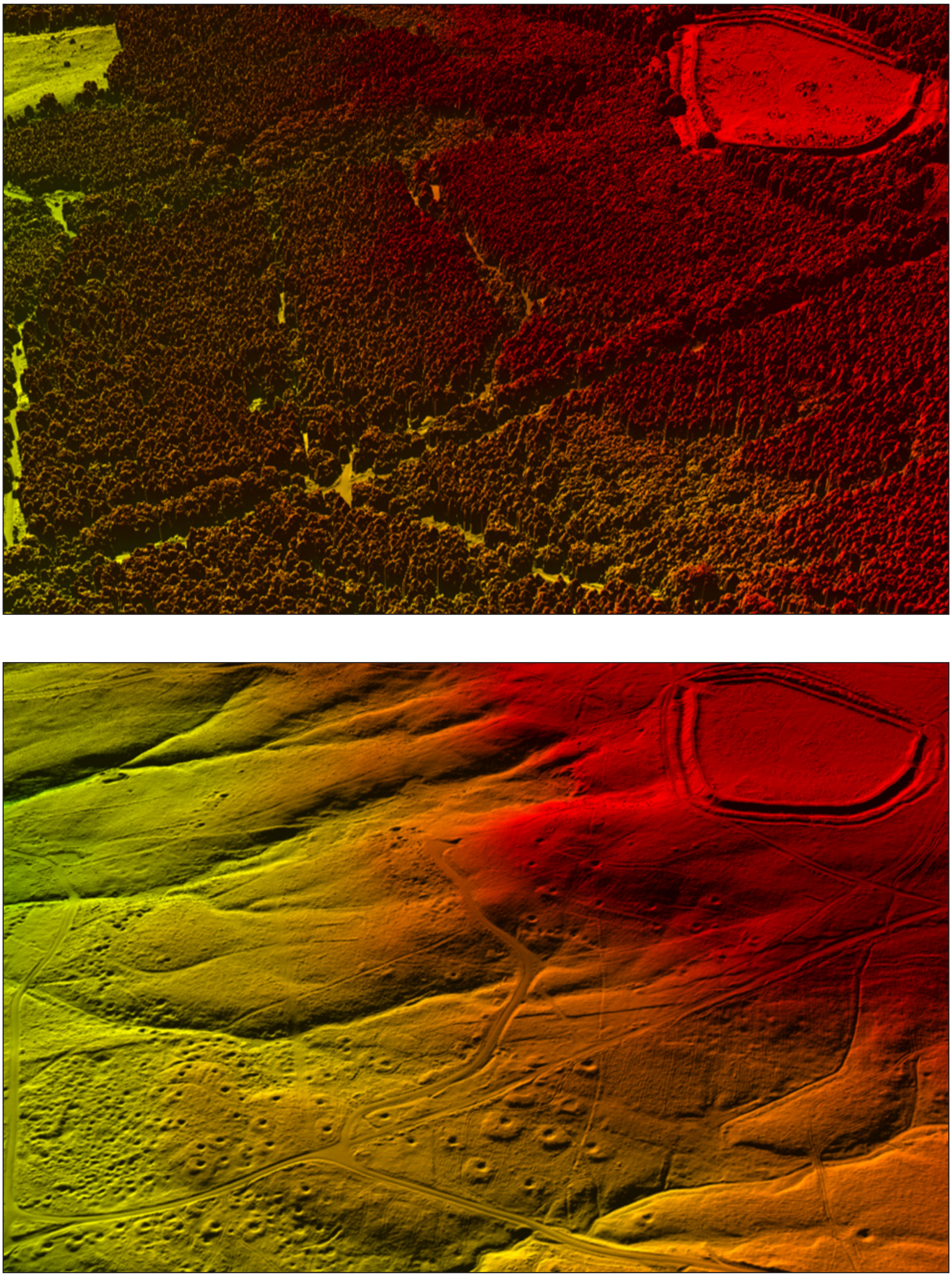


Fig 21: Examples of lidar Digital Surface Model (DSM) and Digital Terrain Model (DTM). The DSM is a model of the landscape including all surface features such as buildings and vegetation. The DTM is processed using an algorithm to virtually remove surface features and create a bare-earth model, allowing identification of archaeological features obscured by woodland on Cannock Chase, Staffordshire. © Historic England. Source: Chase Through Time Staffordshire CC/Bluesky LTD

that it can show archaeological remains as cropmarks in optimal conditions as it is flown over the spring/summer months. It is generally less suited to recording archaeological earthworks, where the long shadows associated with winter are more appropriate, although earthworks can be visible if photographed early or late in the day. Historic England and HERs can access and use the images and other products until Spring 2020 as part of the Public Sector Mapping Agreement. There is a risk of losing access to this essential resource if these agreements are not maintained, due to cost or lack of use.

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The APGB website currently only provides full coverage of the latest orthophotography and in some cases a limited selection of previous years' coverage, though this is constantly improving. It would be advantageous to have the complete dataset for multiple years of photography, as this increases the chance of identifying archaeological remains, which in turn may also cut down on the number of rectifications of other photography required. The APGB data can be directly inserted into any GIS software.

Going forward, the imagery would ideally be pre-loaded as a dataset within the Historic England corporate GIS. This would significantly reduce the time impact of importing this source for those based within Historic England offices and providing the data to non-HE/HER AI&M project teams may also be quicker.

Issues and Constraints

- Time taken to uncompress the files for use in Aerial.
- The time impact of providing data to third parties on HE AIM team.
- Lack of date on filenames, causing additional processes for interpreter.

Opportunities

- Inclusion of the APGB orthophotography within the Historic England corporate GIS.
- Likelihood of increased temporal coverage of APGB orthphotographs.
- Explore re-inclusion of the date of the orthophotography in the filename.

Online aerial photographic coverage

Google Earth and BING provide photomosaics based on aerial photographs. These images are sometimes the same coverage as available through APGB. As with most vertical photographs, the images are not flown with archaeological remains in mind, which may mean that they are not flown at the best time of year for cropmarks or the as buildings and trees. The DTM is generated by filtering the last return of the laser pulse using an algorithm to calculate where features exist above the natural ground surface and removing them (Fig 21).

This allows the identification of archaeological features, normally obscured on traditional imagery. The resulting models can then be visualised in various ways to maximise discovery of archaeological earthworks, especially when combined with photographic sources to provide clarity.

As lidar is a georeferenced dataset it does not have to undergo the process of rectification necessary for oblique and vertical photographs. It also provides a ready-made on-screen 3D view – vertical aerial photographs are usually viewed with a hand-held stereoscope, or require processing to view in 3D on screen. Lidar can also be used to determine the most recent condition of archaeological earthworks, as it often post-dates most vertical photographic coverage. Where stereo pairs of vertical photographs are unavailable (eg on Google Earth) the lidar also provides a 3D view. Use of lidar has significantly increased the numbers of monuments that we are able to identify and record in certain areas.

Some AI&M projects use lidar flown especially for a project. A recent example was The Chase through Time project (Carpenter *et al* 2018) where 25cm spatial resolution lidar was purchased by Staffordshire County Council through the Heritage Lottery Fund to aid the interpretation of very complex First World War military remains and other sites visible as earthworks. Although lidar costs are reducing it is still a significant outlay. Therefore bespoke lidar is used only for project areas where there will be considerable return on the investment. Another example of this was the recent South Downs National Park Authority 'Secrets of the High Woods' project (Carpenter *et al* 2016). Historic England usually works with third parties who fund acquisition of lidar data such as National Parks, the English Heritage Trust or the Heritage Lottery Fund. Bespoke lidar therefore should be considered for areas lacking Environment Agency lidar cover but only if it is felt it will significantly facilitate recording of archaeological earthworks. It also is useful in heavily wooded areas, where the standard 1m resolution Environment Agency lidar does not give the density of points required to produce a useful DTM and a 25cm resolution or higher survey is required (Simon Crutchley pers comm).

Most projects use Environment Agency lidar via the Survey Open Data portal, where it is available to download for free. The portal has a zoomable map that allows the user to identify what resolution data are available for a particular area. The portal then allows download of DSM and DTM data in gridded ASCII format. These data are provided as one kilometre squares, but these can be mosaicked in ArcMap to form larger areas.

There is EA lidar data for approximately 75% of the country, but they have plans for full coverage. The current gaps in data are usually due to its original focus on flood plains, urban areas and coastal zones. Therefore the gaps often coincide with upland areas which often have high archaeological potential due to the increased likelihood of survival of archaeological earthworks or structures. The absolute spatial error in our LIDAR data is ±40cm. For our datasets at 2m, 1m and 50cm resolution, this error is effectively absorbed in the pixels of the raster image. The absolute spatial error in the data is +40cm so for datasets at 2m, 1m and 50cm this error is absorbed in the pixels of the raster image. The vertical accuracy is +15cm RMSE (Environment Agency 2018). This means that any features mapped from lidar will be very close to their true ground position. The spatial resolution of Environment Agency lidar varies significantly; between 25cm and 2m, with 1m or better being most appropriate for identifying archaeological features. Most of the coverage is at 1m or 2m resolution, with 50cm and 25cm often only available along the narrow corridors of waterways etc. 2m resolution lidar is usually too poor quality to detect anything but the largest of earthworks.

Fortunately, the degree and quality of coverage is changing. The Environment Agency are undertaking a three year programme of lidar survey and hope to have surveyed the whole country by mid-2020 to 1m resolution or higher (Environment Agency 2017). These new survey data are released half yearly, to avoid delay in availability. All AI&M surveys use the most up-to-date lidar data available at the time of the project.

Lidar is available from other sources, such as the Channel Coastal Observatory, Tellus SW, the Forestry Commission and others. These will be used if appropriate to a project and readily accessible. These surveys are usually not extensive and are targeted on specific sites and areas, and it can be difficult to know where these lidar surveys have occurred as there is no central repository. Alison Deegan highlights the issue:

> "There is an increasing number of drone photography and lidar surveys posted all over the internet [with] no centralised map of where and when [they were undertaken]. I think this could cause a problem in the future when monuments identified by these projects are found to be missing from AI&M projects undertaken after these ad hoc surveys were published."

Working with lidar

Most producers now visualise the ASCII data in Relief Visualisation Toolbox 1.1 (RVT). This is a free to use software that allows multiple visualisations of GeoTIFF and ASCII data to create 2D raster images. These visualisations aid the aerial interpreter to identify earthwork features. Development of RVT was part financed by the European Commission's Culture Programme through the ArchaeoLandscapes Europe project. Relief Visualisation Toolkit 2.0 is launching soon, developed by the Research Centre of the Slovenian Academy of Sciences and Arts with the intention of continued support and development for the application going forward. If external funding becomes available then the plan is to recode it into Python and publish it as open-source (Kokalj pers comm), thereby reducing the risk of software redundancy.

There is not a standard set of visualisations required for AI&M projects (RVT offers eight), largely because not all the visualisations work well in hilly environments (Kokalj *et al* 2013, 102) but multiple direction hillshade, Principal Component

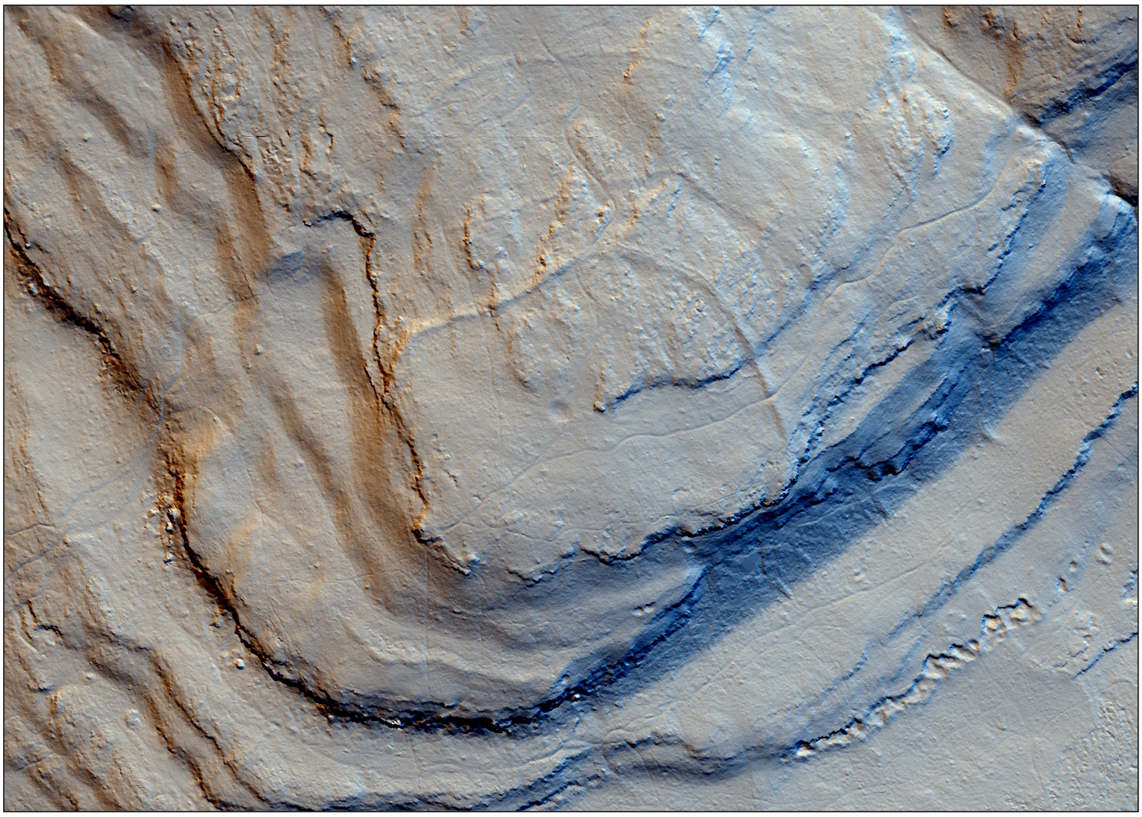


Fig 22: Example of a multiple direction hillshade visualisation revealing the Warton Crag hilltop enclosure, Lancashire. Produced using RVT software. © Historic England

Analysis of hillshading, simple local relief model etc have all been successfully used. Multiple direction hillshading is the most consistently used as it is user friendly (Fig 22). The RVT software is fast and efficient and can produce multiple visualisations at once working with datasets of several gigabytes. A full summary of the benefits of various visualisations is beyond the scope of this report, but Kokalj and Hesse (2017) provide an excellent overview. RVT 2.0 will enable combining of various visualisations (Kokalj pers comm).

The resulting 2D GeoTIFF visualisations are georeferenced and can be simply inserted into GIS/AutoCAD, requiring no further manipulation. For those teams with access to Quick Terrain Reader (mostly Historic England based teams) this can provide a 3D view of the lidar data, using Geotiff files created by RVT.

Constraints and Issues

- Availability of lidar data: Environment Agency data are currently at 75% of England, but some is 10 years old and of low resolution.
- Cost of purchasing bespoke lidar data at higher resolutions.
- Multiple visualisations should be used to best enhance the visibility of archaeological remains within a specific area.
- Move to using multiple visualisations needs to be appropriate as lidar data may not be the key source in some areas.

- Spatial resolution of lidar data needs to be 1m or higher to aid identification of archaeological features, though lower resolutions data can still be assessed to identify larger earthwork features.
- Lidar should be used in conjunction with the aerial photograph evidence, including if possible a near contemporary source, to improve identification and interpretation.
- Lack of access to smaller or ***ad hoc*** survey data.

Opportunities

- Full UK coverage of Environment Agency lidar by mid-2020 at 1m resolution or higher.
- Update to RVT 1.3, which provides 11 lidar visualisations and RVT 2.0 when available.

APGB height data

Height data are available via the APGB DTM. This is a photogrammetrically derived digital terrain model of the whole of Britain, meaning it is derived from stereo aerial photographs. As with a DTM derived from lidar, the photogrametically-derived DTM is processed to remove ground artefacts such as trees, vegetation, buildings and other manmade structures. However, unlike lidar, there is no "ground" data, so those objects that are removed often leave blank areas, instead of revealing the underlying topography. The data are downloaded as 1km x 1km tiles via the APGB website as ArcGRID, the data can be mosaicked in ArcMap. The 5m data are solely used for increasing the accuracy of rectifications in Aerial, as described in the rectification section above.

APGB also provide a 2m DSM, again derived from stereo aerial photographs (photogrammetry). The DSM is an accurate representation of the earth's surface including vegetation, buildings and manmade structures. The data can be downloaded from the APGB website as ArcGRID files and mosaicked in ArcMap if required. The individual tiles or mosaicked data can then be visualised using RVT, in the same way as lidar. The resulting 2D GeoTiff visualisations can be useful in areas lacking in Environment Agency lidar. This can be used as a substitute to a lidar DSM when the latter is unavailable. The APGB height data DSM is only 2m in resolution, so the clarity of archaeological remains is poor. This approach was trialled as part of the SW Cambridgeshire NAIS and the models were described as adequate for the identification of larger earthwork features (Knight *et al* 2018), though others have found the outputs to be "useless and misleading" (Producer Survey 2018) due to the issues described above. However, the use of visualised 2m DSM height data will become redundant by 2020 when the Environment Agency lidar coverage is completed.

Constraints and Issues

- APGB DSM can be visualised in areas missing lidar, but outputs are at 2m resolution which only provides data on larger earthworks.

Structure from Motion for DSMs and orthophotography

DSMs and othorphotographs can be created using traditional oblique and vertical photographs using a digital photogrammetric process, known as Structure from Motion (SfM) – for more information see Historic England (2017). The process works best where photographs have been taken specifically for this purpose, with photogrammetric principles; namely ensuring that the photographs have sufficient overlap and coverage, sharpness and focus. The software used by Historic England is Agisoft Metashape (formerly Agisoft Photoscan). This performs photogrammetric processing of digital images by aligning and matching points on the images to generate 3D spatial data. In order to insert the resulting models into a GIS/AutoCAD, they have to be georeferenced. This can be undertaken by adding control from known georeferenced data, such as lidar or the APGB datasets, or more accurately by collecting reference co-ordinates in the field using a Global Navigation Satellite System (GNSS).

The Hadrian's Wall: Birdoswald Sector Survey (Milecastle 48 to Turret 51A) became the first project to trial using SfM on a landscape scale (Knight and Jecock forthcoming). Nearly 1,200 oblique photographs were taken at the outset of the project by Historic England's Aerial Reconnaissance team. In this instance, the aeroplane made a series of east-west runs across the project area and the photographer achieved as much overlap as possible between photographs to maximise the SfM outputs (Fig 23). These images were processed in-house using Agisoft Photscan, The resulting orthophotography and DSM outputs covered an area measuring 16.8 square kilometres. Survey grade hand-held terrestrial GNSS, with an accuracy of between 10-40mm under normal conditions (Historic England 2017, 46), was used to provide ground control points. This resulted in the model having a relative spatial accuracy of approximately 30cm (Knight and Jecock forthcoming). This means that features mapped from the SfM outputs are more accurately located than those mapped from traditionally rectified aerial photographs. This model was then exported as a DSM with a resolution of 18cm. The photogrammetric process also created a 9cm resolution orthophotograph of the project area.

The Birdoswald project was the first time that HE undertook a large-scale landscape survey using specially taken oblique aerial photographs processed using SfM. The resulting model provided a useful mapping tool in the absence of high resolution lidar data. The orthophotograph provided a detailed image of the landscape. There are issues with using SfM on larger areas. The processing time is high, the above project took over eight days to process, though it is largely an automated process that can be left. Hardware and software must be of appropriate capacity to handle, visualise and store large datasets; for this project a total of 1,137 high resolution .tif images, each 106MB in size were processed and the working files were over 300GB. It should be assessed in advance whether existing lidar and othophotographs would successfully meet project requirements.

For the AI&M element of the Stockton and Darlington Railway Heritage Action Zone (HAZ) Agisoft Photoscan was trialled to create a series of orthophotographs using historic vertical photographs of different dates. Initial attempts using scanned

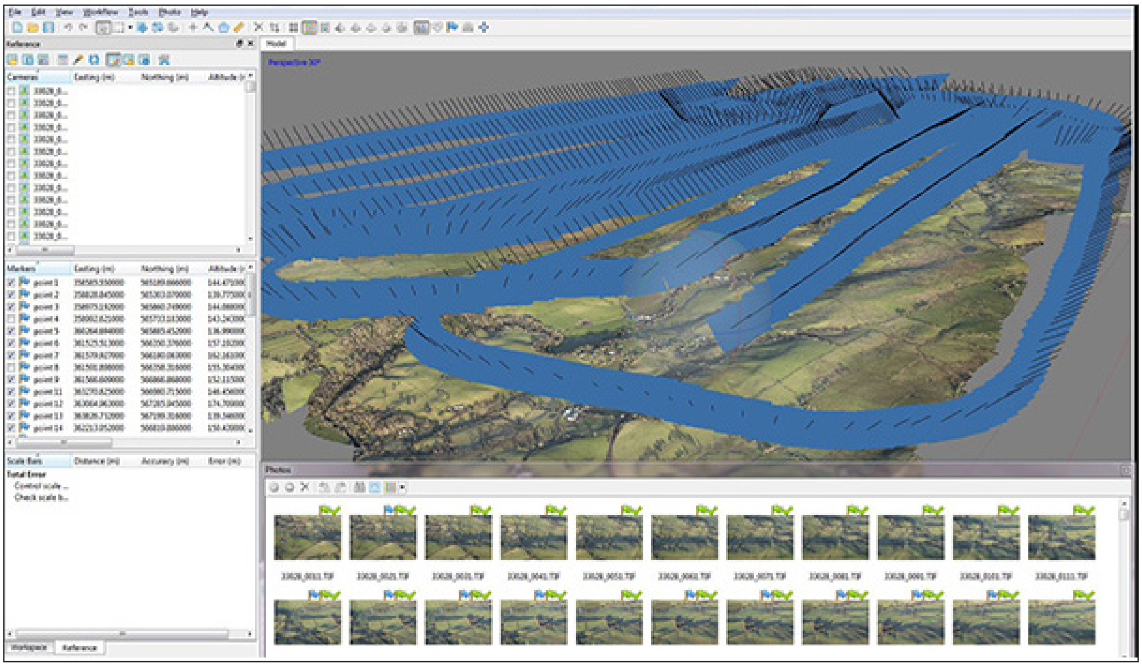


Fig 23: Agisoft Photoscan, aligning the individual oblique frames to create a DSM and an orthomosaic. The blue rectangles show the positions the photographs were taken from. © Historic England.

RAF vertical photographs have had mixed results due to the low quality of the prints, scale of the photographs and photo blemishes etc, meaning that the images do not always align successfully. Selection of the most appropriate images will be the biggest challenge to ensure that time is not wasted scanning photographs that will not process successfully. It is also important to consider which run of vertical photographs will be the most useful for the mapping of archaeological remains. Where the process worked most successfully, the images were large scale, with little cloud cover and with good clarity. The orthomosaic output has proven to be very useful for mapping purposes as it reduces the number of individual rectifications required. X,Y,Z control for the resulting outputs was derived from APGB orthophotography and height data, and while it is less accurate than control gathered in the field using GNSS, it is analogous to siting control points in Aerial. DSM outputs were of limited use as the scale of the photography is most commonly 1:10,000 or smaller, meaning archaeological earthworks aren't modelled.

The HE reconnaissance team is in the process of installing vertical cameras. This will enable more rapid collection of photographic material targeted on archaeological monuments and landscapes. The uniformity of the vertical photographs and overlap between images should provide excellent material for undertaking SfM.

Issues and Constraints

- The SfM process works best when images have been taken with good overlap and clarity so bespoke photography may be required.
- Processing times can be long and the quality and usability of the outputs variable, if the input imagery is poor.

- Large files sizes require large amounts of computer storage space and high spec computers for processing and use.

Opportunities

- Increasing use of photomosaics from historic photographs, reducing the need for multiple rectifications.
- HE reconnaissance vertical photographs will provide increased imagery for trialling SfM.
- Explore the opportunities for trialling production of DTMs using SfM.
- Establish improved methods for establishing control, especially increasing the use of ground control points.

Secondary sources

Although the following sources are not usually directly used for mapping, they are essential for providing context when undertaking AI&M projects.

OS mapping provides the framework on which AI&M hangs. OS data are available as a 1:2,500 scale OS digital map. OS map data are one of the Historic England corporate datasets and for HE staff there are a series of GIS templates with the OS data preloaded reducing set-up time. Historic OS data are also available, including pre-war County Series mapping at 1:10,560 and 1:2,500 scales, post war mapping at 1:1,250, 1:2,500 and 1:10,000 scales and original OS one inch old series mapping dating to 1805-1869. Modern 1:2,500 scale OS digital mapping is essential for providing control points for rectification. Historic maps show how the landscape has changed over time. It also cuts down on the number of features AI&M projects are required to map, as features depicted on first edition mapping, such as field boundaries (since removed), are normally excluded unless deemed archaeologically significant for a project area.

Monument and Event data from both national and regional sources are essential to AI&M projects and provide archaeological background, aiding dating and identification of features. It provides a starting point for the known distribution of archaeological monuments and can be used to assess the likely timetabling for the project. Monument and Event Records are available via the NRHE and the relevant HERs or SMRs. The Event Records provide information about any archaeological events within the areas ie excavations, geophysical surveys etc. The monument record provides details of any known archaeological sites, including period, form, type and source. Full NRHE monument records must be accessed. These data are a Historic England corporate dataset and are available as shapefiles with limited attribute data and PDFs for the full text summary. As with OS mapping data, for those working in ArcMap within a Historic England office, there are a series of GIS templates with the NRHE monument data and OS mapping data preloaded.

The level and detail of data available from HER/SMRs varies but full monument records and shapefiles with attributes are usually available. The most efficient method for accessing the data are usually by direct requests to the HER/SMR, but this is only practicable if there is a resident HER officer and they have the time and ability to output the data. Recently there has been a cost associated with some data requests, though AIM teams still provide the results of AI&M mapping in return for free. Occasionally, projects may have to access monument data via the Heritage Gateway website but this only has a sub-set of monument data. Heritage Gateway is an online aggregator that allows the cross-searching of over 60 local and national records. However, the interface and underlying technology are over a decade old, with consequential impacts on the interface.

The national and local systems for monument and event recording in England (and the UK) are currently being overhauled with the HIAS (see below). Heritage Gateway will be improved and expanded as part of this work.

Project teams will also consult readily available published and unpublished sources, depending on access to this material, to support interpretation and report writing.

Issues and Constraints

- Continued access to monument and event data is essential for AI&M projects.
- Continued access to OS mapping data is essential for AI&M projects.

Too many sources?

Time is a factor, but it is necessary to use as many sources as possible to get a full picture."

"It would be very difficult to justify not using a particular source and then still claim to have conducted a comprehensive survey."

"I think there are too many [sources]. It would be ideal to continue to use all available, but increasing numbers of sources make time pressures unrealistic. Some rationalisation of hard-copy images could reduce those that cover [the] same area in high density or a national assessment of the least frequently used sorties could inform less productive sources to leave out".

"Possibly worth rationalising some of the later APs [aerial photographs] such as the 1980s and 1990s which cover the same area."

(Quotes taken from AI&M Producer survey)

The number of sources used for AI&M projects has increased over time; especially with the introduction of lidar and orthophotographs, but also due to the increased volumes of photographic material now held in the HEA. However, 81% of individuals working on AI&M projects feel that they remain appropriate albeit with the caveat of uncertainty regarding the ability to produce mapping to an agreed timescale. Project planning includes a mandatory timetable assessment partly based on a review of the available sources intended to mitigate the risk of over-running on mapping time.

Attempts to rationalise the vertical photographs, and thus avoid repeated cover of the same areas, were trialled for the South East RCZAS (Hamel and Lambert 2011, 4; Dickson *et al* 2012, 26). RCZAS projects used multiple techniques, including Aerial Investigation and Mapping, to evaluate the archaeological remains on the coast and intertidal zone. In general, the RCZASs were large projects, but for the SE RCZAS this coincided with very high densities of aerial photographs and consequently the archive could not deliver that volume of material within the timeframe required by the project. The decision was taken to filter the loan based on experience of previous RCZAS projects where most of the archaeological data came from 1940s vertical photographs, ie those that showed wartime coastal defences, and specialist obliques. The reduced loan therefore included all oblique photographs (as normal) and all vertical photographs taken up to 1950, and a single complete vertical layer for each subsequent decade (Dickson *et al* 2012, 26). The footprint of each vertical photograph is available as a layer via AirPhotonet and can be viewed and queried in ArcMap making the filtering process reasonably simple. There had been plans to filter the data based on time of year etc to maximise archaeological potential, but unfortunately the date range of the photographs was too limited (Winton pers comm). This approach undoubtedly reduced the time impact for the HEA and was therefore successful in this aim. However, there was an increased chance that some archaeological features were missed. As there were exceptional circumstances this approach has not been repeated.

Case studies

The following case studies compare the sources used across a variety of projects in order to identify the most effective sources and those that may be less useful depending on the area. The relative usefulness of different sources often correlates to the nature of the archaeological remains; earthworks are more easily mapped from lidar or historic vertical photographs, whereas cropmarks are more likely to be recorded on specialist oblique photographs. The case studies were chosen to include a variety of landscape types, such as upland, lowland, coastal and woodland. The figures were calculated using attribute data where sources were recorded in the mapping so only those projects with such information were assessed. The figures for each project were calculated in the same way, looking at the unique aerial sources used to map an archaeological monument. Some monuments are adequately recorded from one source, but a complex cropmark site may be recorded from multiple sources, so all the noted sources were incorporated. As the Secrets of the High Woods project was only recorded to the monument level, rather than individual mapped features, the analysis for this project is based on the main source for mapping only. The impact of the landscape on the range of sources is interesting, with very diverse patterns emerging.

South Downs National Park: Secrets of the High Woods

The Secrets of the High Woods project covered part of the South Downs National Park from the Queen Elizabeth Country Park in the west to the River Arun in the east. It was a community-focussed project and the aerial component was part of a data gathering exercise to facilitate further research on the ground. In contrast to much of the chalk downs in the south of England, this area has a high proportion of broadleaf woodland and this led to the preservation of extensive archaeological earthworks. The archaeological remains ranged from Neolithic funerary monuments through to military remains of the 20th century (Carpenter *et al* 2016).

With support from the Heritage Lottery Fund, the lidar data were collected especially for the project and visualised to aid archaeological interpretation (*see* Fig 24). This was the key source for the project and 81% of the archaeological features were mapped using lidar. This demonstrates the value of lidar as an aerial source in areas with high survival of archaeological earthworks and where tree cover prevents identification of archaeological remains on traditional aerial imagery. HEA oblique photographs and RAF vertical photographs were the next most used sources. Both were used to identify military remains, buried features revealed as cropmarks, and earthworks that had been plough-levelled since the time of photography.

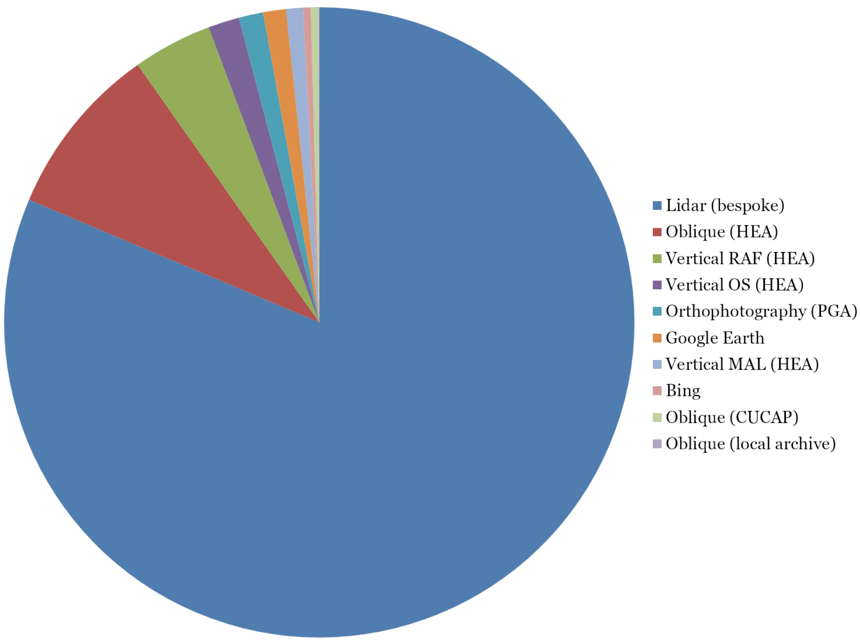


Fig 24 Sources used for mapping archaeological remains for the Secrets of the High Woods Project

Cannock Chase, Staffordshire: The Chase through Time, Historic England Contribution

This project covered Cannock Chase AONB and a small contextual area in south Staffordshire. This was also a community-focussed project with the aerial component informing field survey and volunteer training activities on the ground. The Chase occupies a plateau of high ground, subdivided by minor streams and valleys. The Chase is a mix of open heathland, consisting of heather, gorse, bilberry and bracken and woodland including scrub, deciduous and coniferous plantations. Multi-period archaeological remains are visible there, including one of the best preserved First World War training landscapes in England. However, much is hidden in woodland and heathland vegetation. With support from the Heritage Lottery Fund, high resolution lidar was flown for the project (Carpenter *et al* 2018).

The results of the project would have been very different without the use of lidar, which revealed the extensive archaeological earthwork remains within the heath and woodland areas. Due to vegetation cover in these areas the visibility of archaeological features on aerial photographs was practically zero. Overall, 53% of archaeological features were mapped using lidar (Fig 25). The second most commonly used source was the RAF vertical photographs. These photographs dating from the 1940s onwards were used to map 'lost landscapes', providing views of sites that have since been demolished or destroyed. These features were generally located on the lower lying land surrounding the Chase. Examples included collieries around the edge of the Chase and Second World War camps. APGB orthophotography was used to record the plough-levelled remains of later prehistoric and medieval field systems, visible only as cropmarks.

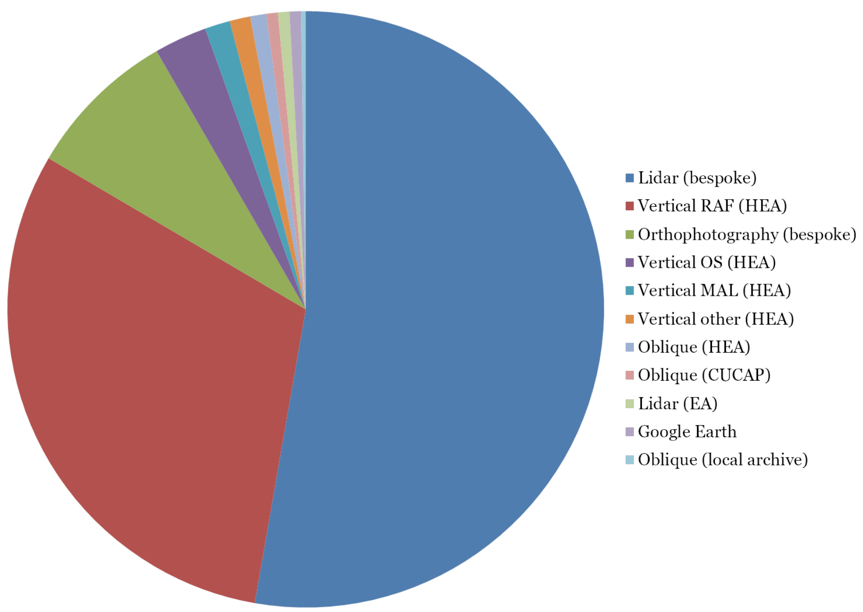


Fig 25: Sources used for mapping archaeological remains for the Cannock Chase project.

Chalk Lowland and the Hull Valley

The Chalk Lowland and the Hull Valley project covered the valley of the River Hull and the Yorkshire Wolds chalk edge. The terrain is largely low-lying but rises up towards the dip-slope of the Wolds edge. The region has been intensively ploughed and most archaeological earthworks recorded on aerial photographs in the 1940s and 1950s were plough levelled during the second half of the 20th century. The archaeological landscape is varied and includes a high proportion of later prehistoric features visible as cropmarks as well as 20th-century military features linked to coastal defences, particularly focussed around . The Hull Valley was one of the earliest projects to use Environment Agency lidar, although only for a small area and at a resolution of one metre (Evans *et al* 2012).

The mix of sources is interesting (Fig 26). The biggest contribution comes from RAF photography; 88% of archaeological features were mapped and recorded using this source. These recorded the many medieval earthworks that have been plough levelled and which are unlikely to appear on more recent sources. The mostly short lived Second World War military remains were also recorded from post-war RAF photographs. Oblique photographs were the second greatest source used for mapping as they recorded an abundance of buried archaeological remains revealed as cropmarks. This was made possible due to the large amount of arable in this high-grade agricultural landscape. Lidar was little used, due to the small area covered and its low resolution. Analysis of the attribute data comparing it with the project loan lists revealed that nearly 8% of the oblique photographs loaned by the HEA were used for mapping and over 9% of the verticals.

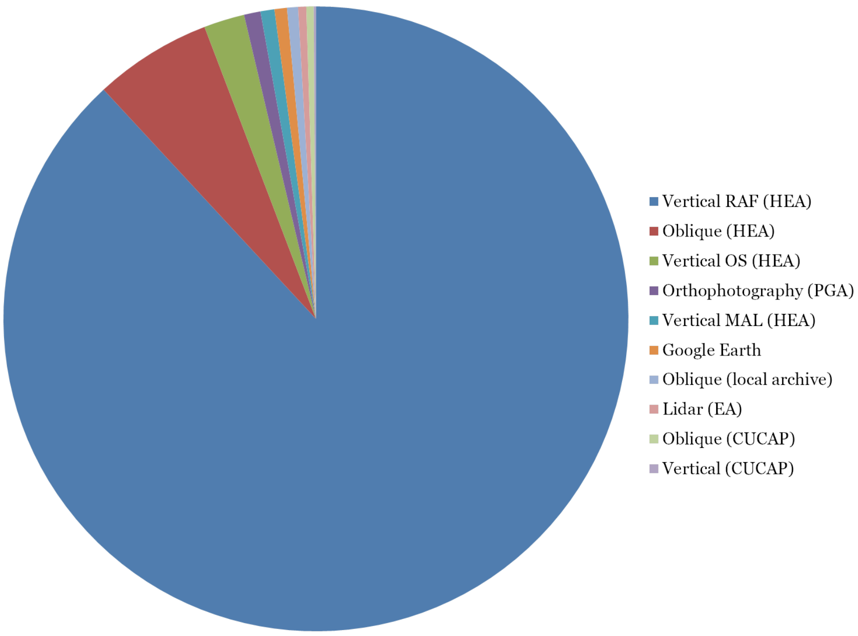


Fig 26: Sources used for mapping archaeological remains for the Chalk Lowland and the Hull Valley NMP project.

National Archaeological Identification Survey: South West Cambridgeshire

The AI&M element of the NAIS: SW Cambridgeshire project covered an area west of Cambridge, from the historic fen edge at Fenstanton, across the west Cambridgeshire claylands down to the chalk downs south of Royston. The overall project aimed to address the impact of aerial assessment for planning purposes, in an area under intense development pressure. It combined aerial investigation with some ground-based work and analysis of excavation evidence from a number of urban expansion and infrastructure projects. This low-lying area is high quality arable agricultural land with potential for buried remains to show as cropmarks, especially on the gravels and alluvial deposits flanking the River Rhee. There are also extensive field systems, furlong boundaries and ridge and furrow surviving as low earthworks. The most striking industrial impact within this part of Cambridgeshire is the 19th-century coprolite workings on the Gault, Greensand and Chalk geologies, visible as cropmarks and soilmarks. Specialist oblique photography of the Cambridgeshire clay lands, taken in excellent conditions at the start of the project, resulted in the discovery of levelled Iron Age or Roman settlements on soils not typically conducive to cropmark formation.

Analysis demonstrates the use of multiple sources; the most used sources were the Environment Agency lidar and HEA oblique photography each accounting for 18% of the features mapped (Fig 27). The lidar was a key source for earthworks and comprised Environment Agency and APGB lidar at various scales as well as visualised 2m height data to fill in any gaps in coverage (Knight *et al* 2018). Even though ploughing is extensive across the area resulting in the levelling of earthwork

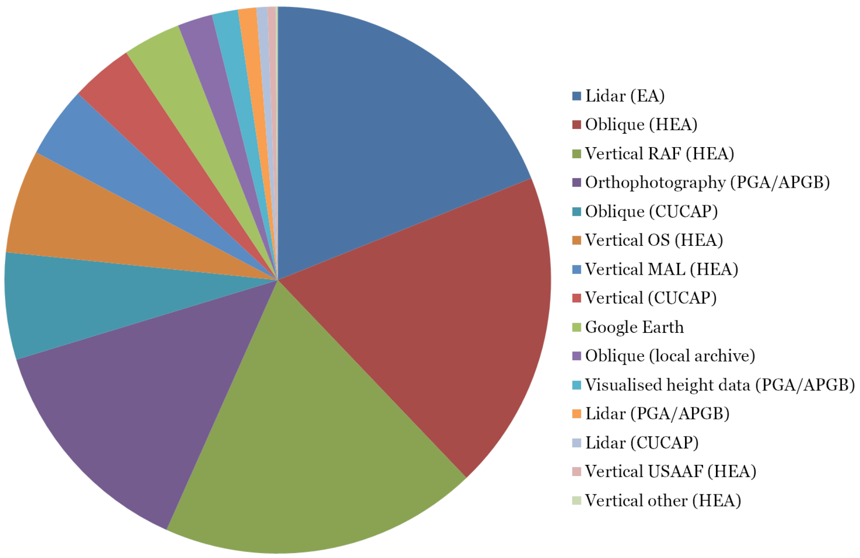


Fig 27: Sources used for mapping archaeological remains for the South West Cambridgeshire NAIS.

features, the lidar highlighted the remains of low earthworks. The lidar and OS vertical photographs were crucial for mapping the extensive furlong boundaries, which survive as low-lying earthworks, cropmarks and soilmarks. This area of Cambridge has had a long history of aerial reconnaissance, mainly concentrated on the free draining chalk soils. However, reconnaissance in in recent years over the clay and tilley-clay soils recorded numerous previously unknown settlements revealed as cropmarks. The APGB orthophotography was flown when the fields were bare, so no cropmarks were visible, but some archaeological features were serendipitously recorded as soilmarks. Analysis of the attribute data, comparing it with the project loan lists, revealed that over 9% of the oblique photographs loaned by the HEA were used for mapping and over 12% of the verticals.

Bedford Borough Phase 1 (further project phases are ongoing)

This project covers Bedford Borough and a small contextual area extending into adjoining counties to inform management and planning in advance of an extensive patchwork of different developments in the area. The topography to the north of Bedford is typically undulating, open and exposed lowland giving extensive vistas, with scattered woods and dispersed settlement (Adams and Crowther 2016, unpublished). Extensive swathes of medieval and/or post-medieval ridge and furrow cultivation, remnants of the former common open-field system, extend throughout the project area, but become more scattered in the southeast corner on the slopes of the Greensand Ridge. The more recent agricultural regime is dominated by arable cultivation, which lends itself to cropmark formation.

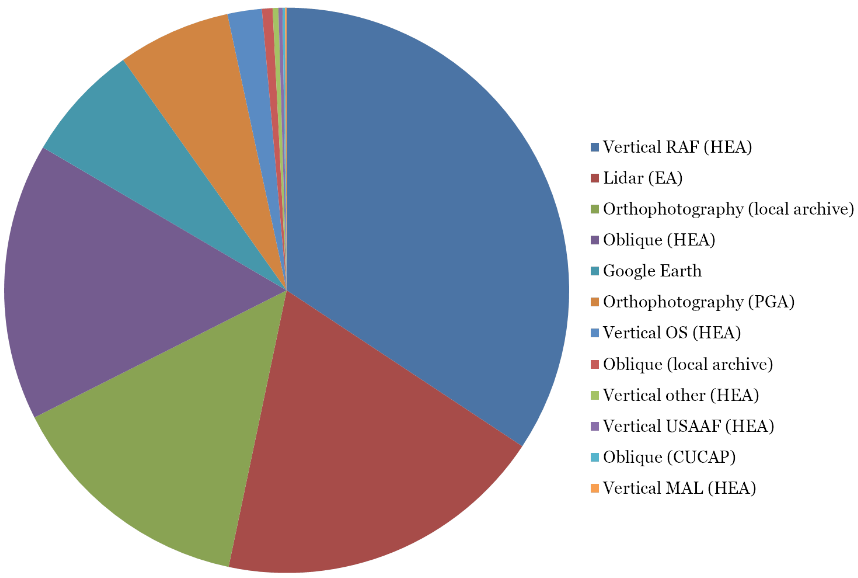


Fig 28: Sources used for mapping archaeological remains for the Bedford Borough project.

An important source for this area was the RAF vertical photographs; accounting for 34% of the archaeological features mapped (Fig 28). These included multiple medieval and post medieval earthwork features such as moats, but also a variety of Second World War military features such as an airfield, bomb depots etc. Many of the ridge and furrow blocks recorded by the survey had been plough-levelled before the 1950s. The denuded cultivation earthworks have revealed underlying earlier cropmark features. Bedford Borough composite orthophotography serendipitously recorded a large number of archaeological cropmarks and had the added benefit that the photos were georeferenced. This complemented archaeological information gained from recent HEA oblique photographs (Amanda Adams and Stephen Crowther pers comm).

National Archaeological Identification Survey: Upland Pilot

The NAIS: Upland Pilot was located in Cumbria and Lancashire. The project aimed to develop methods for landscape analysis, including aerial investigation and various targeted ground based techniques. The AI&M project area comprised a transect from Brigsteer in the north-west to Kirkby Lonsdale in the south-east, but also included an area to the west of the M6 as far south as Carnforth. The project sampled a range of topography covering the coastal fringe, the lowland river valleys and the upland zone of the Yorkshire Dales. The project had almost complete Environment Agency lidar coverage. The archaeological remains dated from the later prehistoric period to the 20th century, with particularly extensive Iron Age/Roman co-axial field systems and settlement sites surviving as earthworks on the Yorkshire Dales fringe. Only one cropmark site was recorded for the whole of the project, an Iron Age or Roman D-shaped enclosure. There were very few military features.

Environment Agency lidar was the key source used for the project (Fig 29) with over 55% of archaeological features being mapped from that source. Most of these were in the east of the project area, especially on the edge of the Yorkshire Dales National Park. Vertical photographs (RAF and OS) were another key resource and these were used for recording additional earthwork features in lower lying areas, many of which have been plough-levelled since the time of the photography. Analysis of the attribute data, comparing it with the project loan lists, revealed that nearly 6% of the oblique photographs loaned by the HEA were used for mapping and 5% of the verticals.

In the project report (Oakey *et al* 2015, 19) notes that a gap in lidar coverage coincides with the lowest density of vertical photographs and has very few archaeological features recorded. It is suggested that it is possible that the distribution and nature of archaeological remains mapped from aerial photographs in this area has thus been biased by the lack of adequate coverage and confirms the importance of having good availability of a number of sources. The mainly pastoral land use and soil types mean this area has low potential for discovery of buried remains from cropmarks. Therefore the oblique photographs provided key illustrative material in terms of landscape views and aspects of known sites but were not used extensively for mapping.

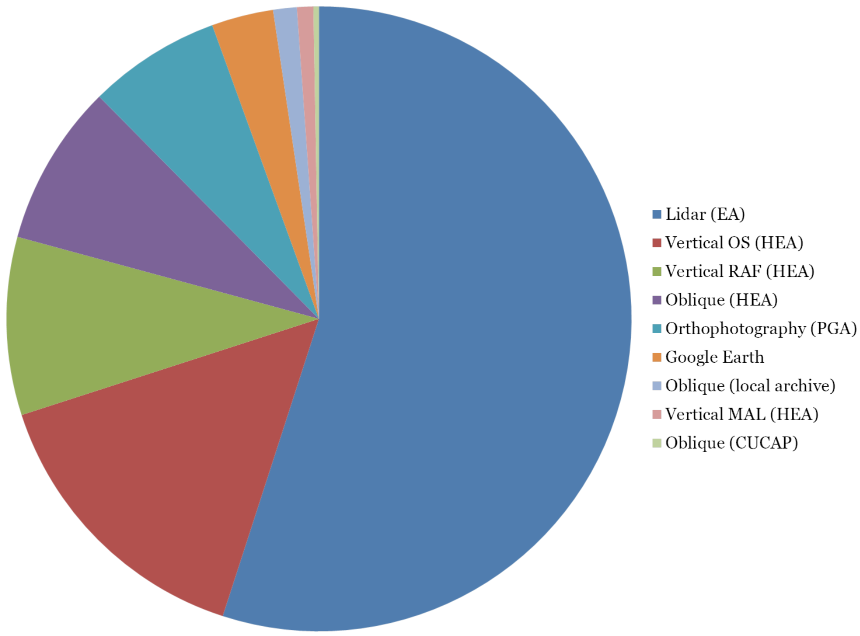


Fig 29: Sources used for mapping archaeological remains for the Upland NAIS project.

The importance of a variety of sources

The results of the case studies above clearly show that each source provides different opportunities, depending on past and current land use. Upland areas, areas of dense vegetation or simply those that have escaped the plough or are largely unchanged over the last century are best served by using high resolution lidar data. This becomes the main source for mapping, with traditional aerial photography having less of a role, but still an important source. The Environment Agency's aim to achieve full coverage by 2020 will greatly facilitate archaeological aerial survey in upland areas with no current lidar cover. Revisiting a sample of upland projects undertaken prior to the invention/use of lidar, such as the Yorkshire Dales, could assess the impact of this new source.

In contrast, lowland areas, particularly areas under the plough or those with significant landscape change, require a mixture of sources and particularly traditional photography. The historic vertical photographs are a key source for mapping short-lived features, such as Second World War defences. Oblique photographs are usually the main source for the identification of cropmarks but can be used for discovery of earthwork sites too. Lidar can be used to identify archaeological remains in small pockets of woodland or ploughed down archaeological features surviving as low earthworks, but also islands of extant earthworks that may have escaped the plough, for example scheduled monuments which have received additional conservation and protection.

Across every project, the key resources are lidar and traditional aerial photographs. RAF vertical photographs are the most commonly used photographs. This is because they offer extensive coverage and usually the earliest view of a landscape. They often provide evidence of archaeological earthworks and structures that have since been levelled. More recent photographs reveal the extent of levelling of archaeological earthworks due to conversion of pasture areas to arable. However, the arable land use provides the context for the discovery of buried archaeological remains as cropmarks. BING and Google Earth images are the least used for mapping across the various projects, but are occasionally serendipitously very useful.

It is important to note that for all the case studies above, only the sources that were used for mapping were recorded. This does not reveal the sources for assessing the landscape generally or for informing interpretation of other sources such as lidar. Latest condition of the archaeological remains is typically assessed using Environment Agency or bespoke lidar, APGB orthophotography, Google Earth imagery and HEA digital oblique photography, as these tend to be the most recent sources available for a project area.

Summary of findings

- It is impossible to discount any particular source in any particular landscape. All are useful in all landscapes, though some are more useful than others.
- Consider key sources at outset of project and consider using these as a primary source, particularly if georeferenced, with additional sources to fill in any gaps.

Issues and Constraints

- Future aerial investigation projects where lidar is a key source (upland areas, vegetation covered) should not proceed without full lidar coverage at a resolution of 1m or above. The Environment Agency is due to fulfil national coverage by 2020.

REVIEW OF PROCESS/ORGANISATION OF WORK

During the execution stage of any project, the aerial photographs, and other remote-sensed data, should be viewed together for the same site or area, so that the maximum amount of information can be extracted efficiently from the most appropriates source(s). A suitable workspace is required for viewing aerial photographs and other sources. This should have good natural light and a desk lamp. Glare on computer screens should be minimised. Desk space should be generous to allow aerial photographs to be laid out in pairs to allow stereoscopic viewing, and also for computer equipment, two monitors and scanner.

Tailoring the approach to the sources is beneficial depending on the project. For example, traditional aerial photographs are often the first source assessed. Assessing these from earliest to latest provides an appreciation of how the landscape has changed over time and which photographs are key sources. However, in an upland zone with very little ploughing or landscape change, lidar will often be the primary source with the other sources being used to aid interpretation of the lidar data and to fill in any additional details. In a lowland area, lidar is less likely to be the primary source, so traditional photographs should be looked at first. The project area is usually sub-divided into 'blocks' to allow team members to work on a project simultaneously. These should be of a suitable size so that the time between identification, mapping and monument recording is short enough to remain efficient.

All relevant data sources should be available to the project from the outset. For digital sources it is good practice to set up a project template in the mapping software. This template should have the secondary sources pre-loaded such as historic map data, spatial monument data etc. All the available visualised lidar tiles and orthophotographs are added into the workspace as these provide an excellent means of orienting within the landscape and provide the latest evidence for many of the archaeological monuments.

Sources should be reviewed simultaneously for a small area and the best source(s) chosen for mapping. If necessary, relevant photographs are rectified. Archaeological remains are traced off a rectified and georeferenced aerial photograph, orthophotograph or lidar image in a GIS software package. Attribute data are added to assist with monument recording.

The following section lists the equipment used by current AI&M projects. Not all teams have access to the same hardware and software. Appropriate mapping software should be used according to the circumstances of the project team but this should be set up to common standards and be easily transferred between systems.

Equipment

- Stereoscope 2x magnification or higher
- 3D screen and glasses (if using digital stereo-viewer)
- Glassine bags, storage boxes, secure storage for archive material as specified by HEA

Hardware

- Computer suitable for moderate data processing
- Two high-quality monitors
- Scanner

Software

Image viewing/scanning/manipulation software

- Adobe Photoshop CS6
- Adobe Bridge CS6
- NVIDIA 3D Vision Photo Viewer

Specialist photo transformation software

- Aerial 5.36 or equivalent
- Agisoft Photoscan

Specialist software to process and visualise lidar data.

- Relief Visualization Toolbox
- QT Modeler/Reader
- AutoCAD Map 3D
- Esri ArcMap

Mapping software

- AutoCAD Map 3D
- Esri ArcMap
- MapInfo
- QGIS
- Ink (HEROS)

Set up to enable direct input to the relevant HER/SMRs or the NRHE and to allow analysis of data

- Oracle database via CITRIX (for NRHE)
- Exegesis HBSMR (HER)
- HEROS (HER)
- Microsoft Access database (HER)

Word processing or publishing package for report writing

- Microsoft Word
- Adobe InDesign

Other

- Microsoft Excel
- GridRefMapper
- Web browser
- Microsoft PowerPoint
- Google Earth Pro

REVIEW OF MAPPING

"Our HER is largely point data, the NMP provides the extent of the visible remains, this is incredibly useful."

"For recent projects [...] the mapping is clear and helpful. For older projects and mapping created in AutoCAD the lack of polygons makes combining and copying problematic."

"We only seem to get it [AI&M/NMP data] as AutoCAD files; shapefiles would be more preferable. I'm not sure if this is available but we haven't been aware of it, or if AutoCAD is the standard format."

"The output types are so variable and many professionals struggle to understand the NMP conventions."

"A good balance between coherent visual understandability and detail."

"The vector format [mapping] of later surveys with the attached data are very good, the older raster [hand-drawn mapping] not so but still enough to show what we need for interpretation."

"The most recent projects which split information up into different layers [contain attribute that can be symbolised] is generally more helpful. This can allow aspects to be switched off or changed – this is useful, for example, where there are extensive records of ridge and furrow which need to be acknowledged, but where there is a mix of them masking other features and cropmarks."

(Quotes taken from AI&M User Survey)

Mapping software

The software used for mapping varies considerably between those working in AI&M teams. Although most (77%) use AutoCAD, this is changing. Costs of software and the need for more integration of data in a GIS means that GIS packages (ArcMap at Historic England) are increasingly being used. Other commonly used software includes QGIS, MapInfo and Ink (HEROS).

The most efficient system for mapping would include a spatially enabled database with excellent digitisation and analysis tools and interoperability across different systems. None of the current software packages entirely fulfils the needs of the AI&M projects teams and numerous products in a variety of formats make it difficult to share data with project partners. Most current AI&M mapping is supplied as shapefiles to best suit the requirements of our users, usually local authority HERs or HEA customers. However, AutoCAD files, MapInfo files and ArcGIS geodatabases are also occasionally supplied. The HER is consulted ahead of data exchange to confirm in advance which format to supply the data in. Although conversion between file types is relatively straight forward, with good compatibility between the various systems, it still requires some project time for AI&M teams to undertake the conversion.

Despite the multiple formats, providing regional and national overviews of the mapping alone is fairly straight forward and a national dataset has been compiled in the HE corporate GIS. A key issue is combining the mapping with the relevant textual data held in the HER or NRHE monument record. Recent projects have used attribute data in the mapping to allow analysis of the mapping. This is described in more detail below.

Mapping methods

The individual elements within an archaeological monument are drawn using a series of conventions mostly defined by form of remains. These are often referred to as 'layers' (a hang-over from working exclusively in AutoCAD), but in a GIS environment these are simply an attribute that is used to symbolise the dataset. The 'layers' were set up as these formed the basic interpretation of the parts of a monument that were unlikely to change (in contrast to the date or condition) and comprised bank, ditch, or structure. These are usually distinguished by colour but on the hand-drawn maps different conventions were used. The digital conventions are a useful standardised depiction so that it should be easy to read the form of a range of archaeological remains based on their colour.

Additionally, there are some schematic drawing conventions such as those for slopes (T-hachure), ridge and furrow, or extent of feature, which is used to indicate large areas of quarrying or to depict the maximum extents of complex or military sites (Fig 30).

Some teams still add additional 'layers' but this should be unnecessary as they are usually a monument type that can be adequately recorded in the monument types attribute field. As these non-standard layers have to be removed for supply to Historic England, their use is discouraged.

All features should be drawn as closed polygons, with the exception of the T-hachure convention for depicting slope and the single line used to depict ridge and furrow alignments. In the past, it was common for some banks and ditches, those less than 2m wide, to be drawn as polylines but this has been phased out as it becomes difficult to fully understand the extent of a feature and the relationships between individual elements (Fig 31). It also causes problems with inclusion into the corporate GIS datasets.

The results of the AIM producer survey revealed that some teams still use polylines for narrow banks and ditches (those less than 1m) to "speed up progress" for prevalent feature such as catch meadows and braided trackways. To test the impact of mapping using polylines or polygons, the projects database was assessed. It has conclusively shown that there is minimal difference in mapping rate; on average 1.1 days per square kilometre for those project mapped as closed polygons, compared

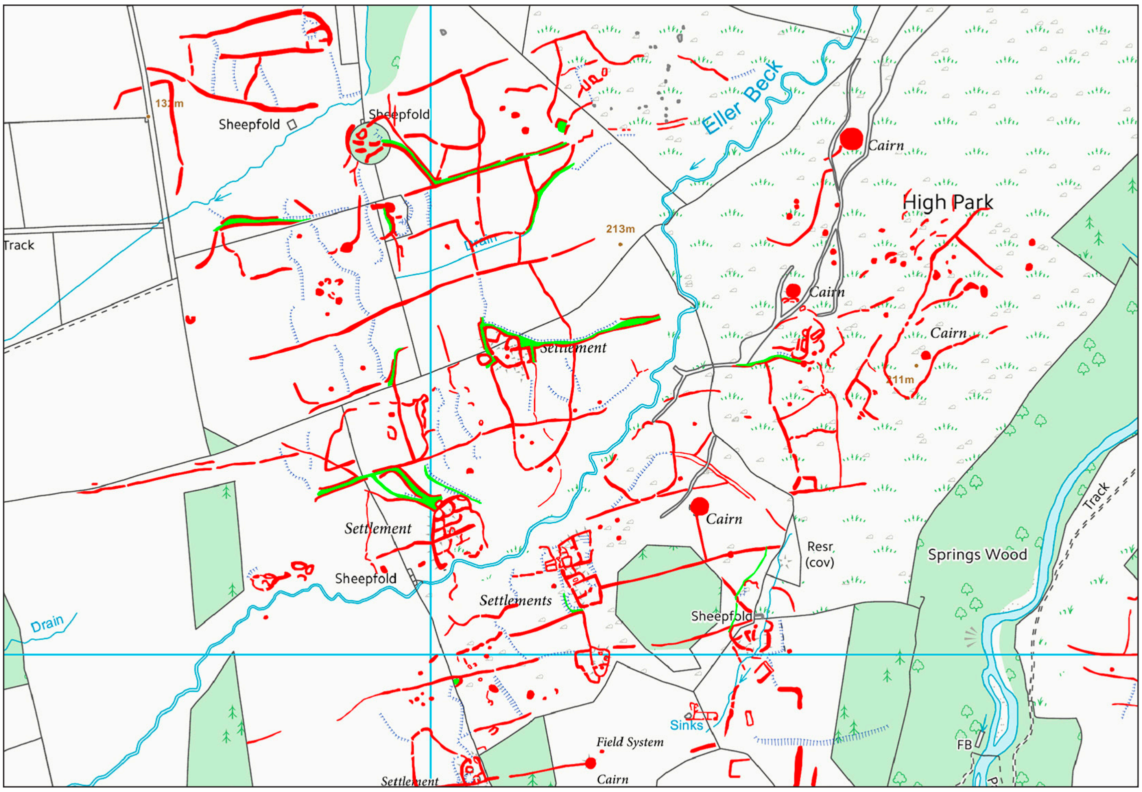


Fig 30: Example of AI&M mapping showing later prehistoric/Roman settlement and field systems. Mapped as part of the Upland NAIS, the archaeological remains are located at High Park, Lancashire. © Historic England. Base map © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100019088.

with 1.2 days per square kilometre for those projects mapped using some single line depictions. The number of monuments per square kilometre does not appear to be a significant factor here as, on average, those projects mapped using closed polygons contained on average 5.3 monuments as compared with 4.4 monuments per square kilometre for those using single line depictions. It is therefore recommended that single line depictions are not used for future projects, given the increased usability of the product and the lack of impact on project timetables.

The T-hachure convention was developed for schematically depicting slope and, for speed, is a much-simplified version of the hachures used in larger scale analytical earthwork survey or non-digital OS mapping. The top of the 'T' indicates the top of slope and the body indicates the length and direction of slope. The drawing and adjusting of T-hachures is time consuming. A macro was developed for use in AutoCAD which speeds up the process and allows the length and direction of the individual arrows to be adjusted. This means that issues with crowding on the concave side of a bend can be relatively easily adjusted. However, in ArcMap and other GISs there is not currently an adequate solution. Within ArcMap a line can be symbolised to appear as a line of hachures, however it is a uniform scale throughout the entire project drawing with no adjustments to the scale, length, width or orientation possible. This means that the T-hachures are the same size for a castle motte as for a small house platform and the issues of T-hachures colliding with one

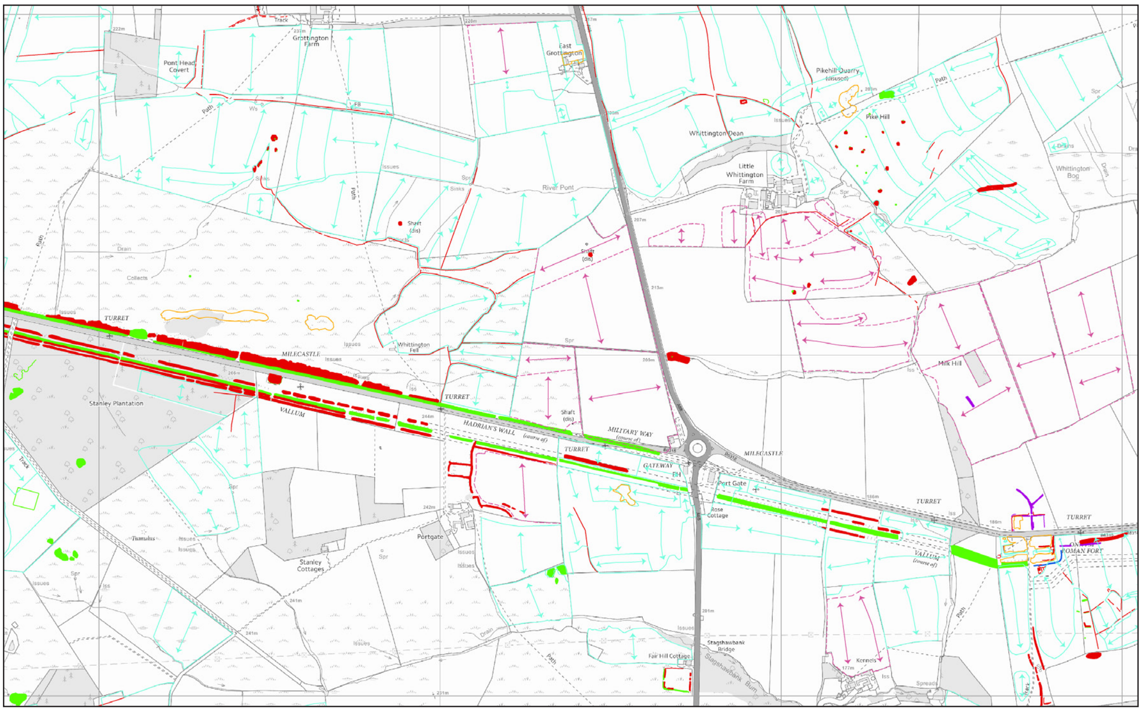


Fig 31: Example of mapping from Hadrian's Wall World Heritage Site, The features depicting the wall are mapped as polygons as they are over 2m in width, but the finer banks used to depict the post medieval sod-cast boundaries to the north of the wall were drawn using single line depictions as they were ubiquitous and less than 2m wide. © Historic England. Base map © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100019088.

another are extreme. The top of slope and bottom of slope are not depicted as the length of the 'T' is standard and symbolised from the middle of the polyline. As such, the work-arounds are as follows:

- Those with access to AutoCAD but who are working in ArcMap draw a line for top and bottom of slope in ArcMap, export the lines as shapefiles that can be imported into CAD where they are T-hachured as normal. The T-hachures are then imported back into ArcMap. A laborious process that relies on having another expensive software package.
- Some teams draw a bank polygon at the top of a slope as they have no other means of depicting slope due to lack of access to AutoCAD, but this is a less effective way of depicting scarps and slopes. However, beyond a certain scale the T-hachure has the appearance of a polygon anyway.
- The OS digital products now use polylines only to depict top and bottom of slope. This could be a methodology we could consider as it is relatively quick, but our experience of using this OS mapping shows us that the final visual output is virtually unreadable.

The current standard for ridge and furrow is a polygon outlining the extent of a block of ridge and furrow and a single polyline depicting the direction of the furrows within that block. Some practitioners augment these alignments with hand-drawn arrowheads, but this involves drawing at least three polylines for each alignment instead of one. The ridge and furrow alignment polylines can be symbolised in GIS to create a dashed symbology (such as that used in field survey drawings) or to have arrow heads, but they do not function well at varying zoom scales, so while it may be appropriate to symbolise them for illustrative purposes, for viewing data they are largely a hindrance. Projects managed by Cain Hegarty (AC Archaeology) depict ridge and furrow with at least two alignments, to indicate both the direction and width of the cultivation. The early digital projects used two colours and line types to distinguish levelled ridge and furrow from surviving earthworks, but latterly this information is recorded within the attribute data.

Attribute or object data

"Attribute data is essential - as I use this to style the mapping to appear with the standard NMP symbologies. You can also then use this to filter by date/monument type etc - as we're often dealing with massive datasets & this helps to make our interrogation of the data manageable. I also then always refer to the full monument records, for any additional information".

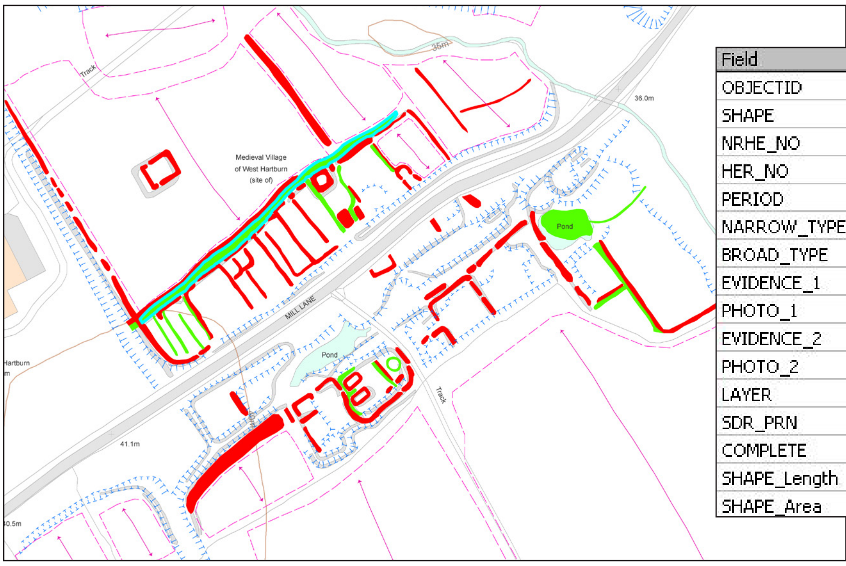
"Which of these [Attribute data or full monument records] is most useful is really dependent on the level of engagement with the data. For the majority of users, I find that the interpretive text in the HER. Monument records are what they need, along with the visual representation of the individual objects. However, for anyone undertaking detailed professional/academic work the individual attribute data is vital for compiling new interpretations".

"I've generally found that the quality of the attribute data limits the type of queries you can undertake so I haven't used it very successfully, but I realise this probably varies depending of the nature of the archaeology and particular projects".

"The mapping is great but only when attribute data is included".

(Quotes taken from AI&M User Survey)

Each element of the mapping should have GIS attribute data or AutoCAD object data attached (Fig 32). HER or NRHE monument record number is the minimum standard as in theory this can be used to automatically populate the attributes in the mapping with data from the monument record. However, in practice this is difficult to achieve to the right level of detail and is not carried out as standard. In recent AI&M projects, attribute data typically repeats information in the monument record such as period, monument type and source, but is also used to provide details such as latest evidence or details at a sub-monument level. It therefore allows features within a monument to be recorded individually. For example, with a medieval settlement, the individual elements that make up that site might have croft or toft values for the Monument Type fields. The two features may have been recorded from two different sources and that can be recorded in the Photo field. The earthworks of a single croft may have been levelled and this can be noted in the Latest Evidence field. This allows detailed interrogation of the spatial data at the reporting stage and in the future.



Field	Value
OBJECTID	1776
SHAPE	Polygon
NRHE_NO	25649
HER_NO	209
PERIOD	MEDIEVAL
NARROW_TYPE	HOLLOW WAY
BROAD_TYPE	FISHPOND
EVIDENCE_1	EARTHWORK
PHOTO_1	OS/74006 V 16 17-MAR-1974
EVIDENCE_2	EARTHWORK
PHOTO_2	LIDAR Environment Agency FI
LAYER	DITCH
SDR_PRN	<null>
COMPLETE	<null>
SHAPE_Length	413.538555
SHAPE_Area	762.972186

Fig 32: Example of an archaeological monument with attribute data. The mapping depicts the medieval settlement of West Hartburn, Darlington. The attribute data reveals additional details about the features that make up the settlement; in this case the hollow way (highlighted in turquoise).The latest evidence reveals that the feature is extant on recent aerial sources. © Historic England. Base map © Crown Copyright and database right 2019. All rights reserved. Ordnance Survey Licence number 100019088.

This contrasts with the monument record which will focus on the overall interpretation (such as settlement) and although there will be reference to details (such as croft or toft) this is not spatially linked to the individual features that make up the depiction of the monument.

A key benefit of embedding data in the digital drawing is that it can function as a stand-alone dataset, which can be used independently of textual monument records (HERs or the NRHE). The Cannock Chase project in Staffordshire demonstrated the effectiveness of this approach with the use of an online GIS with the attribute data to share AI&M mapping with volunteers and stakeholders.

If this can be achieved for all projects then it will greatly facilitate regional and national analysis. However, it should be noted that attribute data has only been intermittently created over the last 15 years, some teams always include it, others only the minimum. Work is on-going for those projects to extract attribute data from the monument records but this will be less refined than data attached to individual elements of a site. In future, every project should include attribute data, at a consistent minimum standard, until an integrated mapping and monument recording method is available.

Data Standards and issues of variability

"I've found that the attribute data could be improved -perhaps by trying to improve consistency but I realise this is a challenge in large projects with multiple people involved."

(Quote taken from AI&M User Survey)

The results of the producer survey show that there is variability in the use of attribute or object data, particularly the number of fields, with some teams only adding the minimum standard of monument UID and Layer. This variability is mainly because attributes were originally designed to suit the needs of the individual project in the hope of an integrated recording system in the near future. This, perhaps unrealistic, aspiration meant that no data standard was defined other than that the data in the fields chosen should match that in the monument record. Additionally, as some teams simply use the data as a means of note taking, there is currently no standardised method of quality control for input and common errors include typos, values added to the wrong field, use of non-standard data, or missing data.

Attribute	Description	Sample data
PERIOD	Date of feature (HE Thesaurus). Single or dual indexed terms	MEDIEVAL
NARROW_TYPE	Monument Type (HE Thesaurus). Specific monument type for individual features	RIDGE AND FURROW
BROAD_TYPE	Monument Type (HE Thesaurus). Broader monument type to enable grouping of individual features	RIDGE AND FURROW
EVIDENCE_1	Form of remains (HE Thesaurus) as seen on PHOTO_1	EARTHWORK
PHOTO_1	Source feature was mapped from (aerial photograph or lidar)	OS/67307 V 0065 20-AUG-1967
EVIDENCE_2	Latest form of remains (HE Thesaurus) as seen on PHOTO_2	LEVELLED EARTHWORK
PHOTO_2	Latest available source (aerial photograph or lidar) to give indication of current state of preservation. Not applicable for cropmark sites	LIDAR English Heritage Trust DSM 03 & 14-MAR-2016
NRHE No	NRHE Unique Identifier (UID)	23092
HER/SMR No	HER/SMR number for those features concorded with existing HER/SMR records	10928

Table 1: Example of standard attribute data table

As it is unlikely that the monument recording system and the AI&M spatial data will ever be fully integrated, the attribute data should become a data standard for AI&M projects. Minimum standards should include the following fields (Table 1) and every element should have data attached, additional fields can be used to address the needs of a specific project. The attribute data should be fully compliant with the Forum on Information Standards in Heritage (FISH) thesaurus terms. For those projects working in GIS systems that allow picklists, these should be used to help prevent typing errors.

Issues and Constraints

- Polygonisation of banks and ditches should be mandatory.
- Standardise AI&M conventions and resolve issues with ridge and furrow and T-hachures.
- Standardise attribute information would be best achieved by using domains (picklists) in ArcMap or similar.
- Make use of templates (or create new ones) to reduce setting up time.

Comparing mapping processes in AutoCAD Map and ArcMap

The processes for mapping in AutoCAD Map and ArcMap are largely comparable once an investigator has grown accustomed to the software. In terms of drawing and editing spatial data, AutoCAD is preferable as the drawing tools allow greater speed, precision, flexibility and ease of use. ArcMap is perfectly adequate for most of our needs, except for the T-hachure symbol, which at present is not possible.

Use of GIS is more efficient when using standardised digital datasets. Templates can be set up to contain most source material (eg modern and historic OS mapping, NRHE monument records etc). Replicating this in AutoCAD requires setting up and linking to data multiple times. Networked AutoCAD is a possible solution but GIS performs the same function. For HE staff it is also part of a corporate GIS package, with various templates available and secondary sources pre-loaded.

Attaching object data in AutoCAD Map can be problematic as occasionally, the sheer numbers of objects with data causes instability and loss of data. More significantly, values cannot be added automatically for each field, they have to be typed in, potentially leading to incomplete datasets and mistakes. Assessing the object data, confirming everything is correct or querying data are also more complex than in GIS.

Using attributes in ArcMap is straight forward. A file geodatabase is set up in advance of mapping and the picklists are created at this early stage. The attribute values are taken from the FISH thesaurus terms, ensuring standardisation. The attributes for each feature class can easily be assessed by opening the attribute table. It is a simple process to amend or interrogate the attribute data. Therefore it is easier to manage and attach data using a GIS package.

- However, it would be preferable to have an integrated mapping and recording system that could populate fields in both the spatial AI&M mapping data and the monument record simultaneously, but at present no such system is available.

Pros and cons of ArcMap and AutoCAD

Function

- AutoCAD Map has excellent drawing tools. ArcMap drawing tools have more limited functionality.
- The creation of appropriate T-hachures is not currently possible in ArcMap.
- Creating and editing donuts (a donut is a polygon containing an inner and outer boundary) is simpler in ArcMap. In AutoCAD Map, the donut cannot be edited once drawn and if drawn incorrectly the fill will not display correctly on conversion to shapefile.
- The cutting/trimming tool is simple in both programmes. However ArcMap has the advantage as the attribute data remains intact on all remaining segments. In AutoCAD Map, only one element of the cut feature retains the object data.
- Both systems manage raster data (aerial images) very well although both software programmes need to be managed to avoid slowing the programme.

Data management

- Querying and selecting features by attributes is simple in ArcMap.
- Manual window selection process in ArcMap is difficult, especially complex of features. Manual window selection in AutoCAD is straightforward.
- ArcMap allows attribute data to be constrained to set values for a particular field, improving data integrity. AutoCAD relies on free text input only leading to increased data errors.

Data Exchange

- Both programmes provide export to multiple formats, but outputting shapefiles from ArcMap is quicker than converting .dwg from AutoCAD.

REVIEW OF ARCHAEOLOGICAL MONUMENT RECORDING

A key component of AI&M projects is that monument data are input to the local or national historic environment record. These data should be available online – a function currently performed by the Heritage Gateway and Pastscape. These data are used for local and national planning decisions and research. The National Planning Policy Framework asserts that for proposals affecting heritage assets, as a minimum the relevant HER should have been consulted and the heritage assets assessed (Gov.uk 2018, 55).

In future all terrestrial monument data will be supplied to the local authority HERs through processes developed as part of the Historic England Heritage Information Access Strategy (HIAS) which aims to disperse all non-marine NRHE data to local providers. Therefore, the current preferred option for AI&M projects is direct input to the HER. This is a challenge for the AI&M experts distributed around the country as remote access to HERs is highly variable but works well when available, such as the set-up used for the Cannock Chase project in Staffordshire.

Overall, 59% of AI&M projects were input direct to the NRHE. Since the 1990s, these data (along with the mapping) have always been supplied to the relevant local authority HER, but full integration of these data is variable. The results of the AI&M producer survey revealed that just under half (45%) of recent projects input data directly to the local HER or SMR. Two projects used a stand-alone database, the South Downs Secrets of the High Woods project and part of the South East RCZAS, but the data were supplied to the relevant HERs. AI&M projects use stand-alone databases in exceptional circumstances only such as on the South Downs where it was required for online access for project staff and volunteers across multiple HER areas.

Prior to the digitisation of the National Monuments Record (predecessor of the NRHE) some projects used a morphological system of recording in the MORPH (latterly MORPH2) database. This was developed to try to standardise approaches to recording, especially for sites seen as cropmarks (Edis *et al* 1989). This was superseded by the development of digital national and local historic environment records, which were more understandable and useful as they included textual descriptions and details of sources.

All recording must follow HE/MIDAS Heritage (the UK Historic Environment Data Standard) and Association of Local Government Archaeological Officer (ALGAO) guidelines (available online at https://archaeologydataservice.ac.uk/ifp/). Minimum requirements for contents are set out in the Historic England AI&M standards (Winton 2018) and additions or minor variations are set out in project designs.

Monument records derived from aerial sources should be detailed enough to provide the user with a clear understanding of the features but should not aim to provide an intricate 'word picture' of the site, as this is provided by the mapped spatial data.

The monument record should include the following information (there will be variation in the fields used depending on the monument recording system available, some information may be automatically recorded):

- Location – for most sites an eight-figure NGR (accurate to within 10m) should be used to record the approximate centre point.
- Monument type – this can be qualified with 'probable', 'possible' or 'potential' but these terms should only be used when there is a genuine degree of uncertainty.
- Period – as above, qualifiers should be used judiciously.
- Form – how the features were seen (cropmark, soilmark, earthwork or structure).
- Source – the photograph or lidar dataset should be referenced in the text and properly indexed in the sources field.
- Latest form – if the features were seen on historic imagery, include information on the latest observable condition.
- Longer descriptive text may also include the location – for most sites an eight-figure NGR (accurate to within 10m) should be used to record the approximate centre point. This should include the location and approximate size of significant components of the site. Key relationships can be described but avoid detailed descriptions of every single element.
- Where appropriate, additional sources of information should be referenced, particularly when they support the interpretation of date and function, examples include historic OS maps, archive material or bibliographic references.
- Other monument numbering schemes –concords disparate numbering schemes for those monuments recorded in NRHE and HERs or other identifiers such as National Heritage List for England (formerly scheduled monument) number.
- Compiler details

Accurate referencing information is essential as it allows users to access the original source if required. It will also enable those undertaking aerial interpretation and mapping in the future to have certainty over whether they are assessing the same source as you. This is particularly important when alternative interpretations are being made.

Currently 84% of AI&M data users access the full monument records (via either the NRHE or the HER) to fully understand any mapped archaeological monuments and its recording history, but the remainder rely on attribute data alone. The vast majority of users were satisfied with the format of the monument records. Those users who were very dissatisfied were using very old NMP data which used morphological recording rather than archaeological monument recording which meets the current standards.

NRHE

"Records on NRHE are good!"

"Using Pastscape there is enough information to understand the feature and to find other primary sources if needed."

"Our HER records are pretty variable. The NMR [NRHE] records are perhaps more consistent. "

"Usually detailed records, including interpretations which are useful to reference."

(Quotes taken from AI&M User Survey)

The NRHE is held in an old version of the Oracle database (Oracle 10g) but this platform is no longer fit for purpose. Geospatial data for the NRHE is held in ArcMap and was linked via a custom built tool, developed in-house at Historic England. Even with this link there is no direct link between textual monument data and AI&M spatial mapping. There are also issues with managing and updating the links between the two systems. Although the database was originally designed as a sophisticated dataset (linking monuments, archive catalogue, event records, and library catalogue) the system has been gradually devolved to off-the-shelf packages leaving monuments and events only.

The NRHE database interface (AMIE) is now out of date. For example, there is no spellcheck facility and certain information has to be manually entered for every monument record, such as event, archive, role, date and office. Spatial data also has to be entered manually such as grid reference, county, district and parish. This is extremely inefficient for large projects that cumulatively enter thousands of records per year.

NRHE records are made available via the Pastscape website. The records are updated every two weeks so newly created monuments will be available to the public almost instantaneously. A hyperlink to Pastscape can be added to the attribute data in ArcMap (via a rapid automated process) so that any users of AI&M data can access the full monument records reasonably easily. This is a key benefit due to the detachment between the mapped data and the monument records. The AI&M spatial data and NRHE spatial data can be viewed together within the HE corporate GIS but this is only visible to staff working within HE offices at present. The consistency of the NRHE records is appreciated by AI&M data users.

The HIAS Principle 1 that 'Local Authority HERs should be the first point of call for and primary trusted source of investigative research data and knowledge' means that the way AI&M projects record monument data will change and the NRHE monument and event records will transfer to the HERs and the NRHE will cease to exist (*see* HIAS section below).

Issues with data exchange and concordance between NRHE & HER/SMR

"Mechanisms need to be fully in place to ensure integration into the HER as well as into NRHE. We understand that more recent initiatives (particularly NMP projects) have sought mechanisms for direct entry into HER systems, but it is clear that this has not always been universal. As outlined above, recent experiences with other non-NMP AI&M projects has demonstrated the value of timely integration of the outputs into the local as well as the National Record. We understand that this particular issue is being considered as part of HIAS, but as an interim measure, ensuring HERs are fully appraised of upcoming projects would be incredibly useful."

"When we obtained data in 2012, HE (or EH as it was then) was only able to supply the records as shapefiles with minimal information and PDFs of detailed information (including the all-important period/type data). The PDFs were a very difficult thing to process, as they required a two-step reprocessing to make machine readable and the end results were slightly imperfect. The data was usable in the end but took considerable expertise and processing to make so."

"We add them ad-hoc, when one becomes relevant. We would love to add them all in, but the resource required to import and concord them with current HER records precludes this at the moment."

"This is a complete mess and has resulted from a lack of forward planning on behalf of HE. The data exchange issue has always been there from the early 2000s yet there has been little progress to address this."

"Too much data and not enough resource to fully incorporate it into the HER database. The GIS layer acts as the trigger to consider the data in any planning matters."

"VERY partially. Percentage wise it's probably less than 5%. There are links to each other, but not integration of data."

"In this HER we work extremely closely with our NMP team and have evolved formats that work for the HER as well as for HE's aims."

(Quotes taken from AI&M User Survey)

The HERs are currently the key user of AI&M data, but data exchange of monument records has always been a challenge. To date, just under half of AI&M projects were input directly to the relevant HER. However, over half were input to the NRHE and required export to the HERs. There are a number of export routines from the NRHE via Oracle Discoverer. None of these are ideal and usually involve full monument summaries supplied as PDFs, and various subsets of the monument data output as XLS or XML files. The HER monument record number is recorded as a matter of course. However, supply of data is a source of much frustration to those working in the HERs who struggle to find the time to fully integrate it. Feedback from

HER-based users of AI&M data suggests that most monument records have **not** been integrated into the HER (Fig 33) but instead rely on the GIS spatial data and accessing the NRHE full monument summaries via Pastscape or as PDFs where necessary.

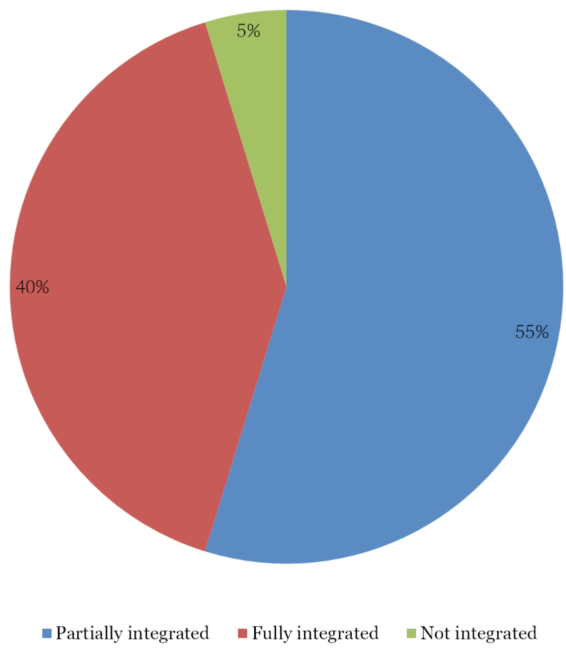


Fig 33: Feedback from HER respondents detailing integration of AI&M NRHE monument records into HER monument record.

AI&M data producers expressed concern about how the NRHE records are incorporated into the relevant HER and expressed fears of monuments being reinterpreted or lost through secondary accessioning. This is a known issue, and an extreme example occurred when an HER officer deleted all the military archaeological remains discovered by an AI&M project, presumably because it was not felt to be in the scope of the HER.

Recording in HER/SMR

A variety of methods have been used to ensure that monument records are input directly into the HER/SMR databases. In most cases, a project team was set up in the HER to avoid the issues of backlog.

A number of teams are co-located within the HER and therefore can directly input to the HER's monument record. The advantages and disadvantages of this set-up, for both the AI&M interpreters and the Local Authority HER, are described below:

Advantages

- Not adding to HER backlog increases goodwill; the HER would not have the resources to ensure that AI&M data were accessioned promptly.
- Records created directly by AIM specialist are more efficient, with less potential for meaning to be lost or changed through secondary accessioning.
- Direct maplink between GIS and database; creation of linked monument polygons.
- Data are ultimately for HER use, so it is a great benefit to work with HER Officer (using most up-to-date HER procedures, increased liaison with HER officer, ability to export and query database very easily).
- Ensures that up to date information is on the HER (and DCC Environment Viewer and Heritage Gateway) for all users – development management, spatial planning, land management, academic and local research. Numerous instances where freshly input AI&M information has been used for all the above.
- Liaison with colleagues helps raise awareness of AI&M projects in HER team and improve interpretations based on shared expertise and experience.
- Tap directly into host organisation dissemination and promotion activities eg websites and events.
- Working in GIS environment effective and efficient.

Disadvantages

- Licensing, access and desk space have to be made available, and committed to by host authority (all potentially have cost implications); high level of uncertainty exist in Local Government and changes can be announced with little warning.
- Admin eg Procurement procedures in host authority; can be arbitrary and slow, which can cause issues on project timescale.
- Fitting into host organisation ICT systems eg upgrades, changes can be imposed with no consultation and at short notice and with limited training opportunities, potentially limited availability (or lack) of 'specialist' applications eg Google Earth, Adobe Photoshop (with issues arising from slow ICT processes and procurement).
- Working in GIS environment, transcriptions may be less intuitive to 'read' - ie not able to use hachures to depict earthworks.

Bill Horner (Historic Environment Manager and County Archaeologist, Devon County Council) describes the great value of AI&M teams recording directly into the HER monument record:

- It ensures that up-to-date information is on the HER (and DCC Viewer and Heritage Gateway) for all users. It is used for development management, spatial planning, land management, academic and local research. I could cite numerous instances where freshly input NMP information has been used for all the above.
- If it was to be done as a backlog project, although it would likely be a priority, we would not have the resources to ensure that it went on to the HER monument record promptly. The North Devon AONB baseline data and several other large area surveys were delayed.
- A cash contribution towards HER inputting is less useful than direct input

by AI&M teams as it usually results in delays. These include problems of data exchange with consultants, incompatibility of data and difficulties lining up HER contractors or backfill staff to complete the work.

- Direct inputting leads to added quality and efficiency of the HER entry by those who are doing the AP interpretation as they have increased understanding of the site, its interpretation, the sources used etc.
- Embedded staff within HER also gives quality enhancement due to 'instant' multi-way dialogue between NMP team and HER, DM and other HET staff.

Where projects are not carried out with direct access to the HER, remote access can sometimes be set up. For example, Cornwall Archaeological Unit have completed several projects using remote access facility to the Dorset county Exegesis HBSMR. A similar set up was used by Historic England for the recent Cannock Chase project where access to Staffordshire County Council HER (Exegesis HBSMR) was available using Netscaler Gateway and Citrix software. In both cases the link was liable to crash but the reasons behind this were not entirely clear.

Suzy Blake (Staffordshire Historic Environment Records Officer, Staffordshire HER) describes her experiences of receiving monument data for three separate AI&M projects:

> "We have had three phases of NMP undertaken for our county in recent years. We are still trawling through adding data to the HER from the first two phases, which is a lengthy and time consuming process. For the most recent project we did, however, provide remote access to the HER for the NMP team, who created data directly in the HER. This provided access to the data for heritage management purposes as it was created (rather than having to wait until the end of a two-year project for data supply) and also means that there is no back-log of data waiting to be added to the HER. If this approach can be adopted for all future NMP projects then that would be really helpful and save duplication of effort.
> There were quite a lot of steps to go through for both our own internal ICT and Historic England's ICT departments, including completing a 'Thirds Party Access Policy' which sets out various security protocols, plus the individual mapping officers at Historic England completing Acceptable Use Policy documents and then in trying to get Citrix working within Historic England's ICT environment. We were fortunate that we had sufficient user licences for our HER system (which is the Exegesis HBSMR system working with ArcMap) to allow the four staff from Historic England to have a login (though factoring in additional licence costs might be something to consider for other HERs). Once access had been granted and the correct Citrix set up achieved I think everything was generally straight forward for the four Historic England staff, though you may wish to discuss with them their experience of using the system remotely.
> The benefits of having the data added directly to the HER far outweighed the downside to having it as separate datasets. The data

was ready to access and use immediately that it was created and has saved massively in terms of time re-entering or importing data. Due to the time constraints of the NMP project it was agreed between ourselves and Historic England that point data only would be added to the system, but we are in the process of integrating the polygon and line data to give us the detailed mapping within the HER. Ideally for any future NMP projects we would prefer to build in sufficient time to allow the full mapping to be undertaken directly in the HER.

> There are, of course, some slight differences in how we would perhaps group or split monument data within the HER compared to the NMP approach, (for example, we would perhaps not grouping vast swathes of disparate fields or ridge and furrow surviving in different condition (levelled earthwork, earthwork, cropmark) under a single HER record), but on the whole this is not a major issue and is something we would perhaps look at discussing the approach to in more detail should we embark on another NMP project following this approach. I think what made the remote inputting so successful was the experience and skill of the mapping team, who obviously understand the process of creating good, accurate and detailed data which meant that from a quality control point of view there have been very few issues that have arisen."

Due to the great variety in systems and IT infrastructure used by the HERs remote access is not always achievable or can be costly. Some project teams have chosen to travel to the HER to input, with mixed results. As well as inefficiencies caused by separating the mapping and recording into different phases this set up increases costs for travel and familiarisation with each different HER system. Furthermore, many HERs have limited IT set-ups and access can only be arranged when the HER staff members are elsewhere. As such HER visits to input data are not likely to become the norm.

Sophie Tremlett's AI&M team, based in Norfolk, have inputted to both Norfolk and Suffolk HERs as part of their AI&M projects. Her thoughts are as follows:

> "Our main experience has been of directly inputting records into the Norfolk HER. We also have experience of working in Suffolk, where we initially entered records into a duplicate HER, which were then migrated into the live HER by Exegesis (the same process that Cain and Sarah used for earlier Suffolk projects); more recently, we have created Word documents for each record, and gone to Suffolk County Council's office in Bury to input them in batches. As we tend to write our summaries and descriptions in Word documents anyway, even when directly inputting into the Norfolk HER, the process for Suffolk didn't significantly alter what we were doing. The advantage of doing the text in Word is that it is more user friendly (in terms of the clarity of the text on screen, and being able to quickly check what you have written for errors). For both HERs, we keep track of records using a spreadsheet, with a sheet for

new records – for which the HERs issue us blocks of numbers as required, a sheet for amended records, and another for split records – the latter is so that the HERs have something to refer to that details how we have split an existing site up (splitting cropmarks from finds, for example)."

The following compares the use of HBSMR and HEROS for HER monument recording. The HER systems have direct links to GIS software, such as ArcMap, QGIS or Mapinfo. HEROS InkGIS has a built in GIS:

Exegesis HBSMR

- Slightly more time consuming than HEROS, but quality of data better, for example no free text in UIDs etc.
- A more intuitive workflow through monument records.
- Time saving options are available ie ability to copy entire record and amending details when recording multiple similar monuments.
- Straightforward to query or export data.
- Compared to previous DCC bespoke system HBSMR has good support from supplier when issues encountered; annual updates and development guided by HBSMR user group forum.
- Current version more readily used remotely.

HEROS

- It is accessed remotely via the web.
- However, onscreen annotations are not possible; we had to double up on tasks using DCC GIS and HEROS in parallel – less efficient.
- Free text in several fields allows typos ie UID, which is problematic to spot and fix.
- Process seems less intuitive over multiple panes and fields. Cannot copy and paste entire records, only sections, with potential copy errors due to free text issue.
- Visually less user-friendly.
- Less straightforward to query than HBSMR; Somerset typically use their online HER access for basic queries. More technical expertise required to query or export data for analysis and would require more time and training or knowledge of SQL/Python.
- More clicks per GIS function, including several stages to export and load rectified images.
- Generally less stable than HBSMR; development is ongoing and limited. Some users had bugs, others didn't and fixes largely reliant on a single developer.
- Lidar display poor and with less functionality than ArcMap.

The most efficient solution is for monument recording and mapping to take place in the same system (GIS with a monument database) directly input to the HER. However, this is not possible for many HER set-ups due to technical and/or practical reasons. AI&M projects are targeted to areas where they will have the greatest impact and this means that they will need access to many different HER set-ups depending on current issues and may be working across HER boundaries.

Although direct entry to the HER monument records is excellent for the HER and making the data accessible quickly to local planning teams, it does have some issues for other users not based within that HER. A data exchange process needs to be agreed at project outset and even then the team may not always have access to the full monuments records. It also means that although the AI&M mapping will appear on the Historic England corporate GIS, there will be no monument records. In the Norfolk example described above, the project team do not have attribute data either so have to rely on access to the HERs GIS to undertake any analysis of their project data. This also limits its usefulness for data users based outside of the HER.

Heritage Gateway in its current form is an online portal for a number of HERs and the NRHE, (and other datasets). This allows simple searches of multiple databases based on area, monument type or period etc. The results are viewable but not downloadable and therefore it is not suitable for undertaking national or regional analyses. However, an improved Heritage Gateway is planned as part of HIAS (see below) and therefore it will become the key system for such research.

Issues and Constraints

- Lack of interoperability between monument recording systems.
- Serious delays in inputting AI&M data into HERs.
- Reinterpretation and deletion of some AI&M data.

Heritage Information Access Strategy (HIAS)

HIAS is a business and culture change programme for those involved in the production and handling of heritage information. The HIAS programme is recognised in the Culture White Paper which says: We will ask Historic England to work with local authorities to enhance and rationalise national and local heritage records over the next ten years, so that communities and developers have easy access to historic environment records. Of particular relevance is HIAS principle 1, as agreed by sector stakeholders, which states that local authority HER should be the first port of call for and primary trusted source of investigative research data and knowledge.

One strand of HIAS involves the transfer of the current AMIE monument and event database (NRHE) into an Arches system to ensure security of the data in an increasingly failing AMIE set-up. Arches is an open source software developed by the Getty Conservation Institute and World Monuments Fund. It is an open-source, geospatially-enabled software platform for cultural heritage inventory and management. This will facilitate a key component of HIAS which is the transfer of all terrestrial monument data to the relevant local authority HER. The remaining intertidal and marine data will form part of a new National Marine Heritage Record. Thereafter, the HERs will act as the primary point of access for investigative research data, with a proposed revamped Heritage Gateway providing access to the national overview.

Provision of an internal HE research recording tool is the focus of a further HIAS work package and this is in development. It is highly likely that this will also use the Arches system and this will overcome a number of the issues discussed above by providing a modern efficient recording system with a map based interface. The on-going transfer of project data to HERs should also be addressed by functionality developed within the Arches system to support the transfer of NRHE data to the HERs.

The implications of HIAS for AI&M monument recording is covered in additional detail in the section below.

REVIEW OF REPORTING

“I think they are generally really good, particularly the ones where real effort has been made to integrate the data with other available archaeological information; these reports really demonstrate the value of NMP.”

“I think the reports I’ve seen are a judicious summary of the data and obvious highlights are clearly presented.”

“NMP reports are usually excellent – very informative and a really valuable research resource. There are a few that are a lot more brief, but they’re still useful.

“Varies depending on age of project – modern project reports are much better in terms of providing context/detail (including images) while older projects are merely methodological statements, making the project results as a whole, harder to understand.”

“Didn’t use them.”

“I never bothered [accessing the report]. The report isn’t relevant".

(Quotes taken from AI&M User Survey)

A report is written on completion of every AI&M project (Fig 34). The reports provide an overview of the archaeological remains as well as providing a summary of the sources and methods that were used for that project. Earlier project reports tended to include limited methodological statements and gazetteers of sites. Most provide a good overview of the archaeological landscape.

The current standards ensure that the reports are issued in Historic England’s Research Report Series (RRS) and are made available as a free PDF via the Historic England website. A new online interactive map (Fig 35), makes searching for reports much simpler as it provides a map of England with each project depicted with a hotlink to the appropriate downloadable report https://services.historicengland.org.uk/access-to-research-reports/. Alternatively, they can be searched for via the Research Reports database http://research.historicengland.org.uk/.

RRS reports are now uploaded onto the Archaeology Data Service (ADS) via OASIS and this is likely to increase their visibility going forward, as well as signposting the existence of the project spatial data. The advantages of upload to ADS are that:

- Each report is given a Digital Object Identifier (DOI) with metadata uploaded to the British Library, with consequent benefits for citation and resource discovery.
- Reports are archived in perpetuity by the only accredited heritage digital repository in the UK.
- HE reports can be found in the ADS Library, alongside an ever increasing number of unpublished fieldwork reports and e-prints of traditional published literature.
- Report metadata are shared with other organisations including ARIADNE

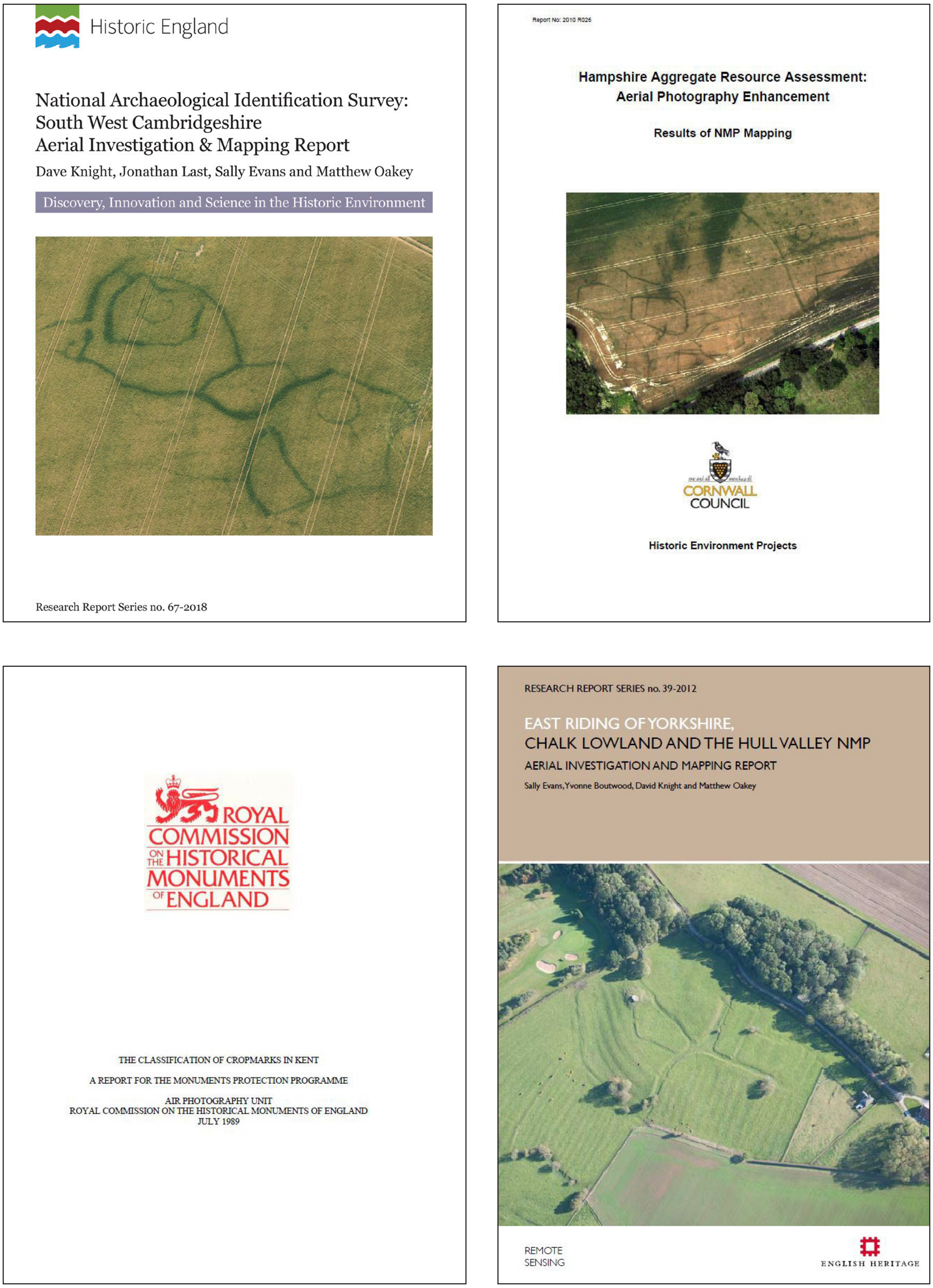


Fig 34: A selection of Aerial Investigation and Mapping reports, available to download via the Historic England website.

(the European portal for heritage inventories) and MEDIN (maritime records), exposing reports to a much wider audience.
- OASIS records can be accessed by the relevant HER, allowing them to include the report in any associated monument, event or source records. (Tim Evans pers comm).

A limited run of hard-copy reports are printed and supplied to the relevant HER and other stakeholders.

The results of the User Survey showed that most project reports are accessed via the HE website (46%), with some (16%) being provided by the HER. The numbers of RRS downloads for AI&M projects are reasonably good with the top title, Chalk Lowlands of the Hull Valley NMP being downloaded 336 times in the year 2018 to present (31st July 2018). Only 5% of users currently access the project report via ADS but this is likely to improve as the addition of RRS reports to ADS is relatively recent. The reported download figures for AI&M projects are relatively low. However, Tim Evans (pers comm) suggests that these figures are likely to under represent true numbers of downloads as the ADS are currently changing the methods by which their usage statistics are gathered.

Unfortunately, a further 10% of users did not know there was an AI&M project report, suggesting that more work is needed to highlight their availability. As the reports are grey literature they are often overlooked, especially by academics. Krystina Truscoe (University of Reading) highlights the issue:

> *"I keep coming across references to ancient surveys which are cited in relatively modern academic work, because they have appeared in a book, when I know that there has been a more recent [and comprehensive AI&M] survey in the same area carried out as part of NMP which is not referred to. I've noticed a bit of a change in academics when it comes to using other grey literature, generally excavation reports, but nothing as regards NMP reports. I was looking at the Thames Valley report, which truth be told is fairly impenetrable, but still acts as a decent enough signpost to the mapping. They had highlighted features usefully which had either been missed or just not referred to in the published survey by Gates from 1975, yet this is generally the only AP work cited for the area."*

As well as the project report, each project has a webpage hosted on the HE website. The webpage is usually launched at the start of a project as a way of signposting the work. It is then usually updated again on completion of the project and is available for approximately two years. The webpage provides a reasonably brief summary of the key findings of each project with a selection of high quality illustrations and aerial images to engage the viewer. Robin Page, digital coordinator at HE, suggests that traffic to new AI&M projects is up 300% on the same period in the previous year; for example the Chase Through Time page has had over 600 page (public) views.

Although not a standard product, some AI&M projects have led to the publication of books and articles. Books include *Suffolk's Defended Shore* (Hegarty and Newsome 2007), *Mapping Ancient Landscapes in Northamptonshire* (Deegan and Foard 2007) or *Understanding the Cropmark Landscapes of the Magnesian Limestone* (Roberts *et al* 2010). Examples of articles include The *National Mapping Programme in Cornwall* (Young 2006, 109–16) or the multi-disciplinary report *Recent Work on Urchfont Hill, Urchfont Wiltshire* (Roberts *et al* 2017, 134–70). Traditional publication methods may provide improved sign-posting for AI&M projects rather than RRS reports alone.

Issues and constraints

- RRS reports are not being used by all AI&M data users and especially not by academics.

Opportunities

- Increase signposting and use of RRS reports to maximise impact.
- Trial a variety of publication methods to assess impact on AI&M data use.

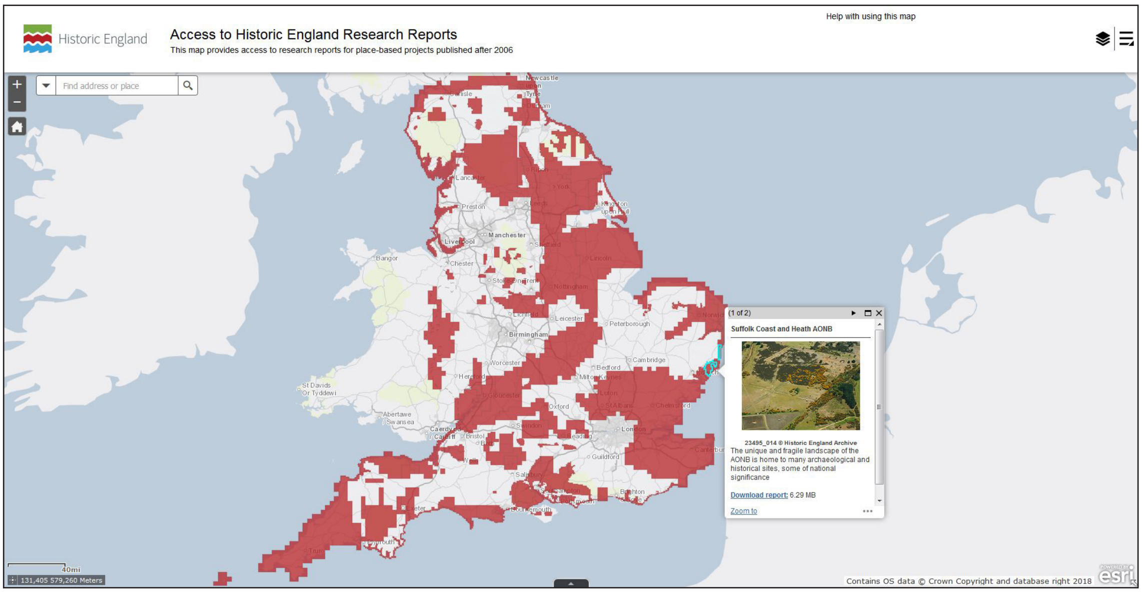


Fig 35: Historic England Research reports can be searched for and downloaded using the online web mapping service.

REVIEW OF DISSEMINATION & ARCHIVE

"I know to ask the HER/HE archive to check for NMP coverage – otherwise it is often not highlighted. Sometimes users then only realise and area has been covered by an NMP project when they find an HER/NRHE record referring to it."

"The Suffolk RCZA data I've used has no attribute data at all (no HER number/ unique identifier) [it does, but has obviously not been provided]

"Form of mapping is great, but accessibility is not – NMP should be nationally available as open data."

"I was charged a considerable sum by the NMR [HEA] because the 1:10,000 sheets I needed had to be copied by the Photographic Services Team. Why couldn't they have just been scanned and attached to an email, like in the modern world? It was so inefficient and old-skool civil service that I began to see the organization as a total waste of space. The plots turned out to be less than useful anyway."

"Other [HERs] seem to undervalue the [AI&M/NMP data. [the] HER have converted the NMP polygons to points."

"It's a massively useful dataset (due to the enormous number of heritage assets identified/highlighted by it) & receiving it as shapefiles with attribute data attached is absolutely ideal. The only fly-in-the-ointment is when HERs occasionally insist that they cannot issue the vector data, as they don't own the copyright/licence for it. Because I'm aware of this, having come across it a couple of times, I know to request it straight from the Historic England Archive right at the start of the project. It's annoying to have to pay twice for this though when we've already paid for an HER search. Most HERs are fine though - it's just a few who still seem to be confused as to why they have this dataset in the first place."

"Clarification statements about copyright would be useful."

"The Suffolk RCZA data I've used had no attribute data at all (no HER number/ unique identifier), but the digital Essex Data has full attribute data (HER number, interpretation etc)." [NB the attribute data are available]

"The output types are so variable, and many professionals struggle to understand the NMP conventions, even those who are close to the data such as HER staff."

(Quotes taken from AI&M User Survey)

On completion of an AI&M project the mapping and associated records are provided to the relevant HER(s). The formats that the data are supplied in vary, but shapefiles are the most commonly requested by the HERs and current AI&M project teams aim to supply data in the most suitable format for the HER. For historical reasons the copyright of AI&M projects is complex and depends on the context of the project. It may reside with Historic England, a contractor, or the main project stakeholder. This causes confusion with provision of data to third parties.

Improved signposting of AI&M data is an area that could be addressed, particularly if AI&M data are to impact on commercial and academic work. The AI&M User Survey revealed that currently the HER (28%) and AI&M RRS reports (16%) are where most first learn about AI&M projects (Fig 36). No users discovered an AI&M project through the event record – this may be because the NRHE events module (and perhaps also HERs) do not adequately record the extent of large area projects and therefore they do not appear in searches. Additionally, although NRHE monument records are shown on Pastscape or Heritage Gateway, the event (the AI&M project) that created that record is not shown. AI&M projects would be significantly better signposted if the named project was included on every monument record on these websites.

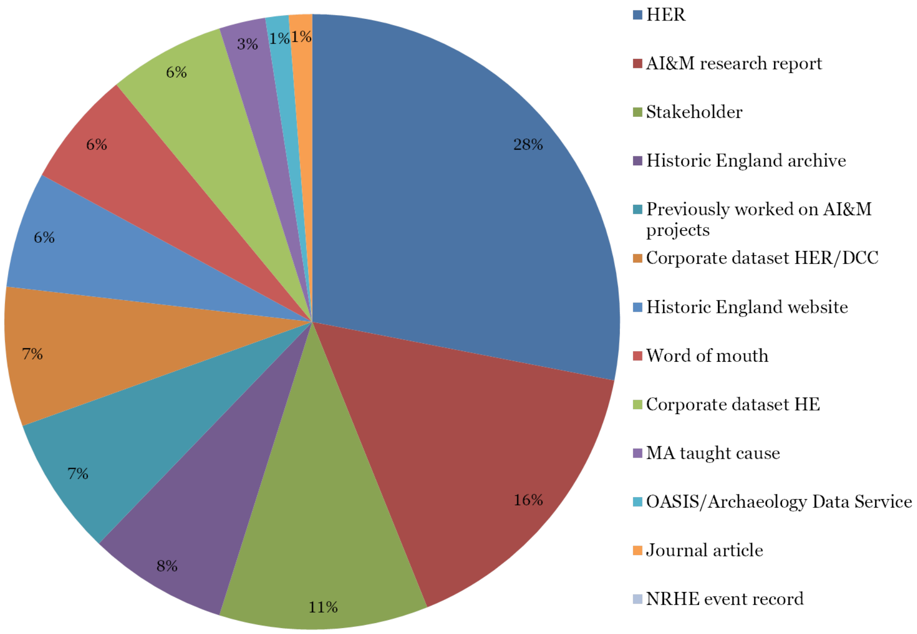


Fig 36: Feedback from AI&M data users detailing where they first heard about such projects.

Copies of current project data are deposited with Historic England's digital archive, with shapefiles and AutoCAD files now being deposited as standard for internal projects. However, not all project data are supplied to archive for various reasons. As discussed above, monument records may be held in the NRHE, HER or both. This archived AI&M spatial data are accessible to the general public, but this is not usually the first point of contact, with most acquiring it via the HER. Lindsay Jones (Archive Services Manager, HEA) reports that NMP (AI&M) data were requested 105 times for the year 2017-2018, though this may include areas where there was no data available. For non-HE AI&M projects, much of the project data are not archived within the HEA and as such is at risk of data redundancy in the future.

The AI&M User Survey revealed that AI&M data provision is poor and confusing, with users unaware of what formats are available or what the data should include.

A lot of AI&M data users want shapefiles, but most projects were produced in AutoCAD. The files are therefore mainly supplied as AutoCAD files, with conversion to shapefiles only taking place on request. The very oldest projects are held as film copies but have been rasterised and georeferenced so that they can be provided digitally, again if the user knows to request this.

The following chart shows different data formats provided to users (Fig 37). The User Survey also reveals that project data are being compromised by being supplied without the attribute data, even when that data exists. This can be extreme – numerous users describe being provided recent digital AI&M mapping (by an HER) without monument UIDs, making it extremely time consuming for the user to correlate the mapping to the relevant monument record and undertake any type of assessment. In most instances, the user will be unaware that they do not have the full information. Occasionally, data requested as shapefiles will be taken from the Historic England corporate GIS rather than by converting the original files, but these data has had its attributes stripped out, except for UID and Layer, so again its usability is limited.

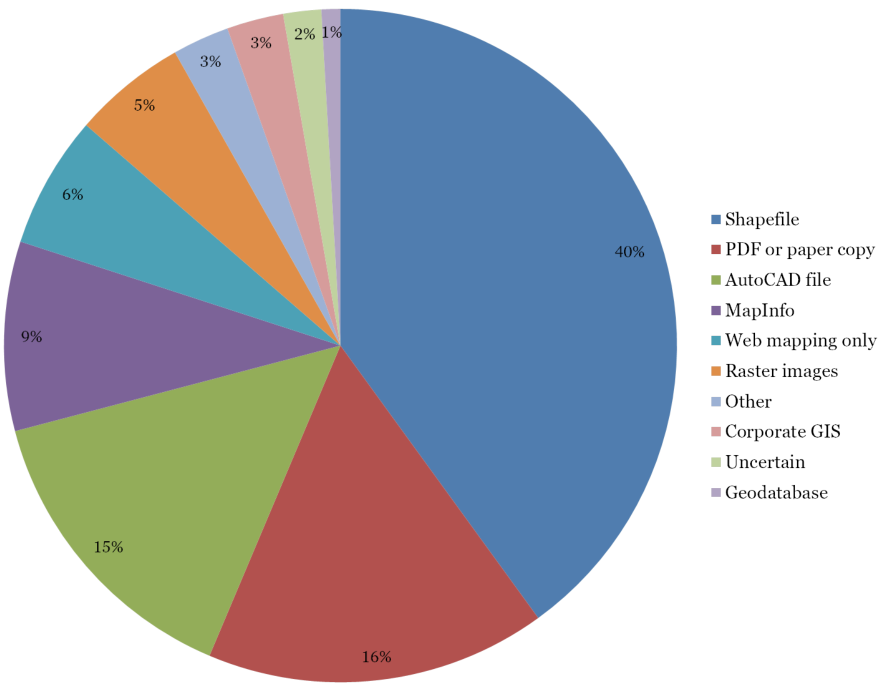


Fig 37: Feedback from AI&M data users detailing the formats of AI&M mapping they have received.

It is clear that provision of AI&M data needs to be better coordinated and standardised to ensure users get the data they need. With the exception of data provided directly by AI&M teams as part of the standard transfer to HERs, it is being provided by third parties with less understanding of the dataset. This is a key issue to be addressed as provision of incomplete data affects the perception of AI&M data as a whole and adds unnecessary complication for users.

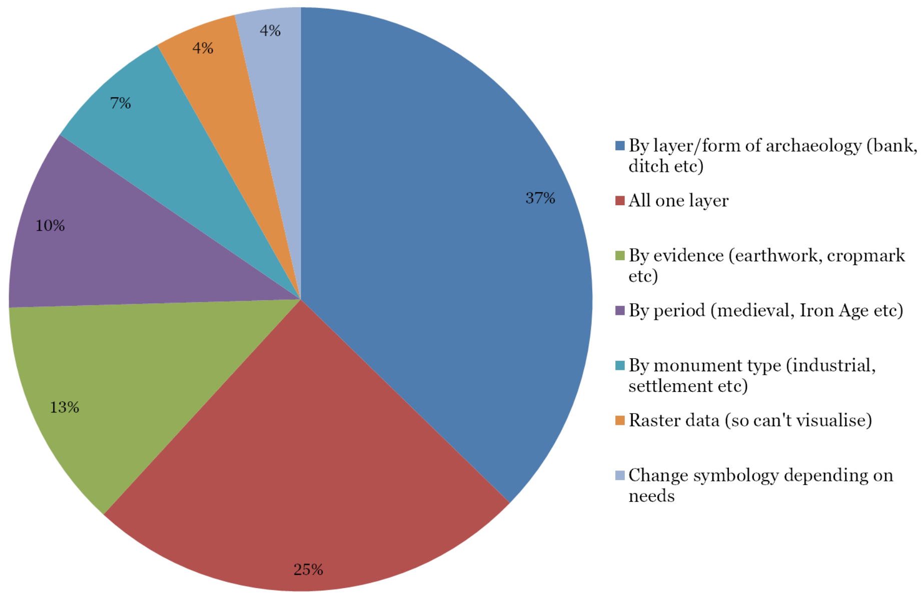


Fig 38: Feedback from AI&M data users regarding symbolising data. AI&M data is best symbolised by 'layer'. Those users who do not symbolise the data are missing out on much of the detail of AI&M products.

An additional problem was highlighted by the User Survey. Responses show that AI&M data users are not always symbolising their digital AI&M data, only 37% report symbolising by Layer/Form (as is the most appropriate) or Period etc (Fig 38) even though this is prescribed in the metadata provided with all AI&M projects. Unfortunately, 25% of users have the data as a single layer making it difficult to interpret and use, as large monument polygons will often hide finer detailed features (Fig 39). It is heartening to see that some users are changing the symbology of the AI&M data depending on their requirements and this should be encouraged going forward to aid archaeological landscape analyses and to elucidate trends.

A short overview of NMP projects and a user's guide to products is planned as part of this review. This will be a web-based document that is used alongside AI&M products, so that users can better understand their character and aims to promote understanding and use of existing data. This should hopefully limit expectations of the project data, especially for the earliest projects. Going forward there are a number of methods to increase accessibility, usability and uniformity of AI&M products, particularly if an up-to-date national map is produced (*see* Opportunities below).

Issues and constraints

- Ensure all AI&M projects are correctly archived.
- Within HE, ensure the HEA have the tools and skills to provide AI&M data easily, rather than the current arrangement where the AIM team supply data to HEA.
- Improve dissemination flow lines for AI&M data to ensure users are receiving the

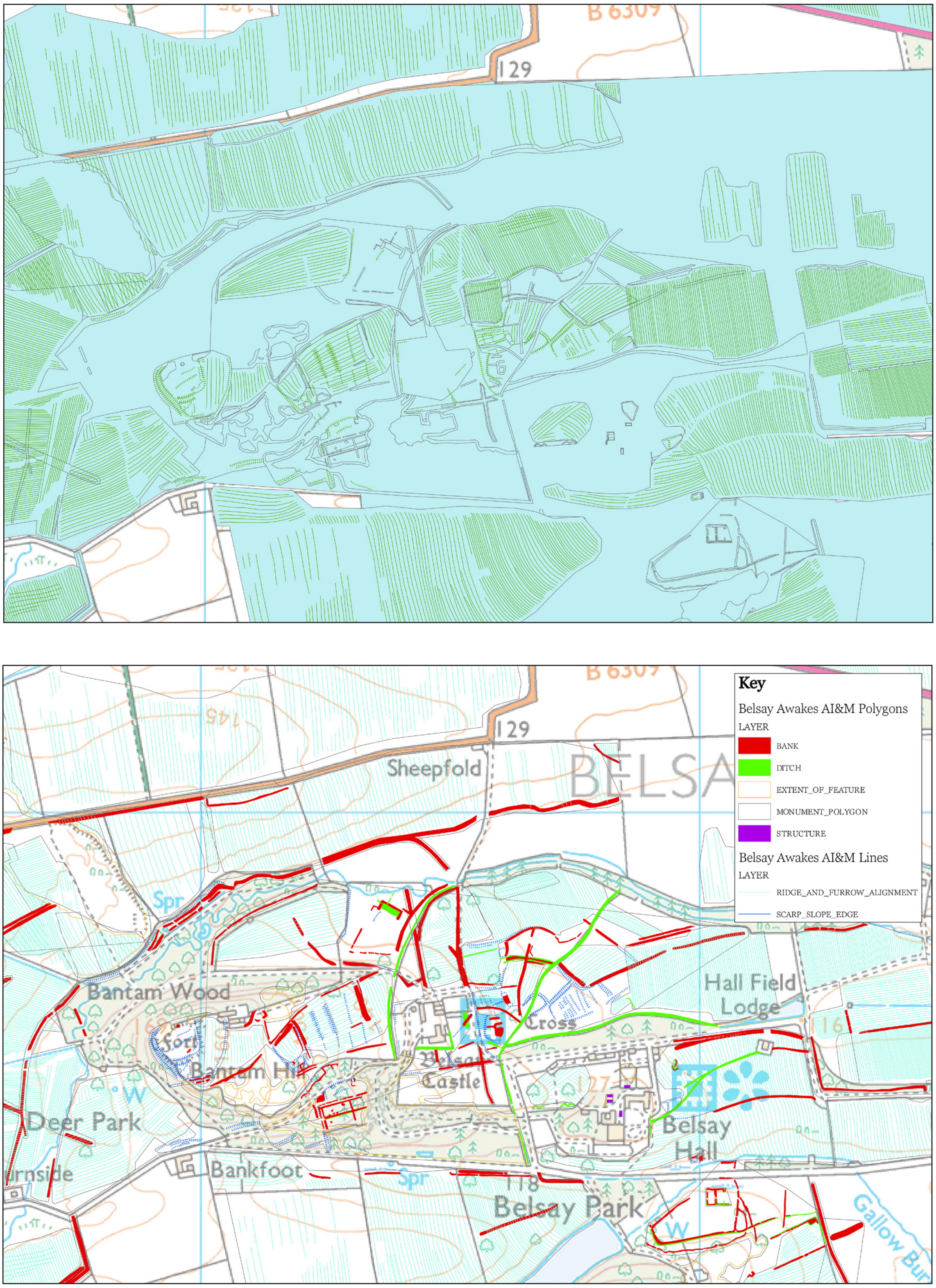


Fig 39: Mapping taken from the Belsay Awakes project. The first image shows the mapping without symbology, simply visualised as polygons and lines. The monument polygon for the formal park obscures the detailed mapping. The second image shows the same data, but symbolised using the layer attribute, greatly improving its usefulness and readability.

complete dataset.
- Provide clarification to AI&M data users on what the data consists of and the variation in products. Disseminate this clarification to all dataset providers so that a consistent level of information is given to users.

Opportunities

- Increased use of AI&M products.
- Improved user experience of AI&M products

REVIEW OF PROJECT PLANNING

Mapping produced to AI&M Standards produces high quality data by collating all the archaeological information available on aerial photographs and lidar. Although initially AI&M projects were targeted at county level with projects such as Northamptonshire (Deegan and Foard 2007) or Cornwall and the Isles of Scilly (Young 2007), this was soon abandoned and a more targeted approach was adopted. This allows resources to be more carefully focussed on specific issues. At first this was often based on management needs, with projects such as Hadrian's Wall WHS NMP (Oakey 2009), undertaken to enhance the understanding and assist the management of the WHS through consistent and accurate recording of both the WHS and its setting zone (Kershaw 2002, 6). Increasingly, AI&M projects have been undertaken in response to planning issues. The West Wiltshire NAIS focussed on an area with a relative lack of previous investigation compared to the adjacent North Wessex Downs and Cotswolds, combined with potential development around the major towns (Last *et al* 2016, 11). The Chalk Lowlands and the Hull Valley project focussed on an area under threat due to arable agriculture, with a large number of scheduled monuments on Historic England's Heritage at Risk Register (Evans *et al* 2012, 7).

There are Historic England guidance documents relating to Management of Research Projects in the Historic Environment (MoRPHE). MoRPHE PPN7: Interpretation and mapping from aerial photographs and other remote sensed data (update forthcoming) mainly provides guidance on the planning and management of large area projects to AI&M standards. This forms the basis of planning for all AI&M projects. The PPN sets out the importance of consultation with relevant stakeholders, including the relevant local authority and the aerial photograph archives. Another key issue is the definition of the project area and clearly stated objectives that explain how the work will contribute to understanding and protection of the historic environment in that area. Products for AI&M projects are usually a georeferenced digital map, archaeological monument records and a research report providing an overview of archaeological discoveries, but also wider landscape observations. A robust quality assurance phase is built into all AI&M projects allowing users to have confidence in the data.

Due to the large areas involved, a key stage in project planning is the timetable assessment used to determine the extent to which certain factors may affect the time required for the project. These factors usually include aspects that may affect the potential for discovery of archaeological remains from the air such as soils, geology, and land use but also include the potential complexities of access to source material. Therefore, the time required for a project is usually based on previous experience of the team, quantification of aerial photographs and other data, access arrangements at the archives, quantification of existing archaeological knowledge and likely density of new discoveries, as well as resources needed for other non-mapping and recording tasks.

The HEA will provide a coversearch quantifying the number of aerial photographs they hold for a particular area and other sources are assessed as appropriate. This provides information on the nature and distribution of the sources allowing planning of workflows but can also highlight areas with high potential for discoveries, such as those with a lot of oblique cover. Heritage Gateway is a good starting point for accessing information about local aerial photograph collections, as it provides contact details for England's HERs. To quantify the archaeological knowledge, the NRHE and local HERs monument records are routinely consulted. Regional research agendas provide good overviews of current knowledge and perceived physical and conceptual gaps. Online aerial photographs, soil maps and geology data provide information on current land use and the potential for discovery from the air.

A review of time allocations

The following sections identify trends within past projects in order to highlight key variables and so improve the effectiveness of planning future projects. Most of the examples provided below focus on digital projects only so that the statistics apply to current standards. The analysis was carried out using the project management data recording statistics from 123 completed AI&M projects. This dataset includes information such as start date, size of area mapped, numbers of records created and the time taken for mapping and recording. These data were supplemented by a review of project methods extracted from individual project reports.

A key benefit of AI&M standards is the relatively small amount of time it takes to assess and understand large areas, thus providing a framework for more time-intensive ground based work. The recent multi-disciplinary project for the West Wiltshire NAIS presents a good example of this benefit in practice. In this case the AI&M results formed the basis for targeting ground-based work, but also highlighted the different scale and rapidity of the approaches used within the project. Inevitably, fieldwork was targeted at a small proportion of the project area: about 50ha of geophysical survey (0.25% of the project area) and less than 0.2ha of excavation (under 0.001%) (Last *et al* 2016, 134–5).

Although AI&M is a relatively rapid method, Historic England need to ensure that it remains efficient and continues to provide value for money. Current project designs are timetabled based on an average calculated from previous projects of 0.8 to 1 day per square kilometre to prepare, interpret, map and record all the archaeological remains visible on aerial sources (henceforth summarised as 'to map one square kilometre'). Although project designs have carefully set out task lists and include timetable assessments which aim to take account of anticipated archaeological complexity, the time pressures faced by those working on AI&M projects was one of the key concerns of respondents to the Producers Survey and so is addressed here.

The following chart shows the projects in the order that they began, and the average time taken for each to map one square kilometre (Fig 40), those without this information are excluded. Although this chart provides an overview of project timescales, it does so without considering any variables that may account for that change eg number of monuments or number of sources etc. That being said, this broad analysis is helpful for showing that there has been a demonstrable increase in the time taken to map one square kilometre since the first projects began. The

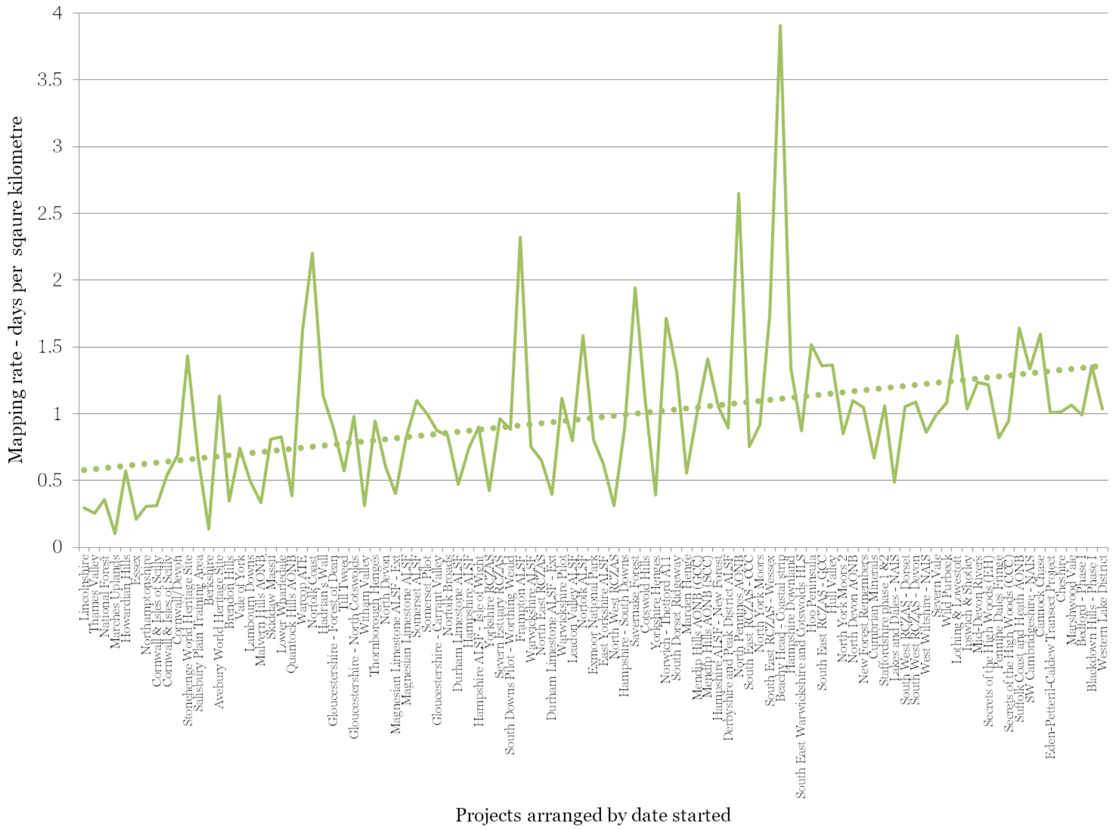


Fig 40: Time taken to map one square kilometre for all AI&M projects, the projects are arranged by date with the earliest to the left.

major increase in project time has coincided with, or been caused by, the move from hand drawn to digital. The standard time used in project planning for hand-drawn projects was 10 days per quarter sheet or 0.4 days per square kilometre. This tallies well with the available project statistics which suggest an average of 0.3 days per square kilometre (this figure should be considered with caution as we don't hold statistics for most hand-drawn projects). In an early attempt at digital projects, some were hand drawn and digitised in AutoCAD, which saw the mapping rate increase to 0.7 days per square kilometre. For those projects undertaken purely in a digital environment the mapping rate increases to 1.05 days per square kilometre or 1.1 days per square kilometre for digital projects using lidar. This general trend, of projects taking longer to complete, does appear to have levelled off over the last few years, with projects achieving a more consistent mapping rate over the last eight years, likely due to the increased standardisation of the methodology brought about by the introduction of the AI&M Standards documents as well as increased clarity in project planning and project designs. Additionally, although the methodological changes have brought a significant increase in the mapping rates this has to be contrasted with the relative values of the hand-drawn or digital products produced in terms of increased accuracy, usability and functionality for the later digital projects.

The current guidance of up to one day per square kilometre is therefore about right but should be adjusted to reflect the methods used. Regardless of the average, more or less time may be required depending on the density and complexity of the archaeological remains, the number of aerial photographs and the scope of the project (Historic England forthcoming MoRPHE PPN7). However, consideration needs to be given as to whether non-methodological variables can cause additional time impacts. This would allow project teams to more accurately anticipate time costs going forward and to identify potential efficiencies. It seems likely that average mapping rates could be reduced with rigorous project planning and improved flow lines.

Size of project area

The size of a project area can impact on a project's preparation, interpretation, mapping and monument recording rate, but this has never been definitively assessed. It is important to achieve a balance between size of areas large enough for economies of scale and those that are so large they are unwieldy and too long running. AI&M projects are usually limited to one to two years (preferably one year). By limiting the time frame this allows more flexibility to respond to changing priorities and to allocate resources where they are most needed. Limiting the project area also reduces the risk of project fatigue. People need a mix of data collection/ analysis with overall landscape analysis and report writing to maintain interest and different skills. The size of the project team impacts the project area, with a

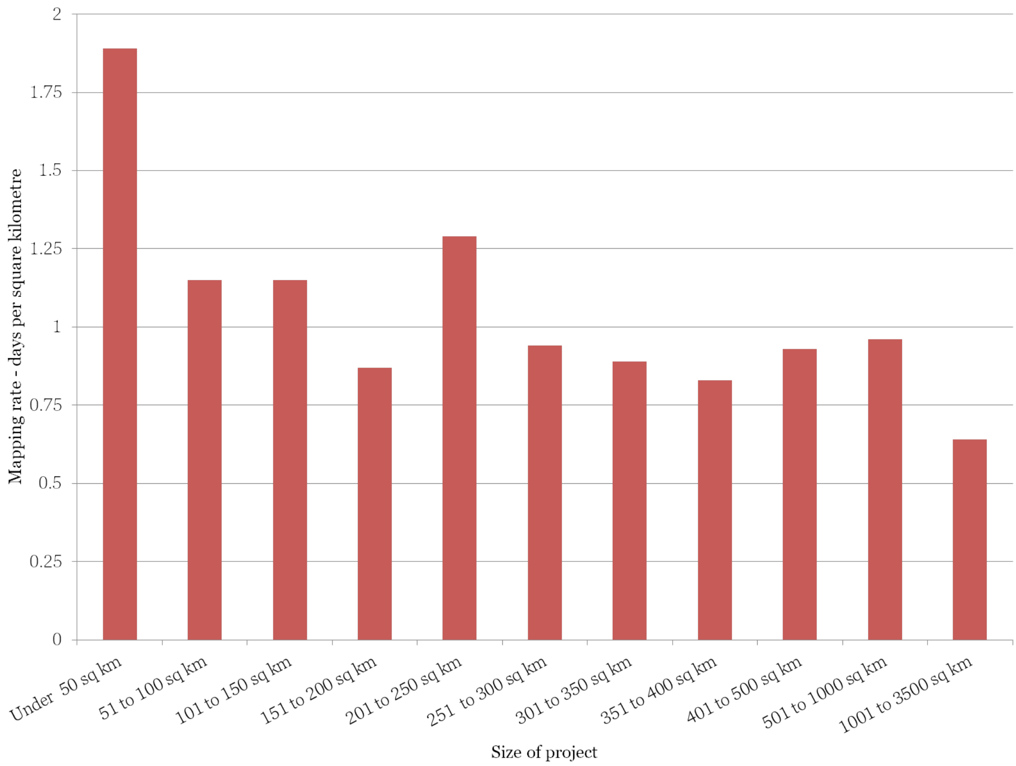


Fig 41: The relationship between project size and mapping rate. Smaller projects take longer to map one square kilometre than larger projects

preference for two or more investigators to ensure larger areas are covered within a year. Project teams also facilitate archaeological and methodological discussion and generally provide mutual support.

As the purpose of this section is to help finesse future AI&M project planning the following chart examines digital projects only (ie those aligned with current practice) and compared the area mapped by the projects against the mapping rate. The chart reflects the 70 digital projects where the statistics were available and they are grouped by size and the average mapping rates calculated (Fig 41).

The general trend revealed is that those projects covering smaller areas take longer on average to map than larger ones. Although most AI&M projects are large areas, over 100 square kilometres, the few projects of less than 50 square kilometres have taken significantly longer. The reasons behind this trend are a little harder to explain, but could include:

- Landscape familiarisation – it takes a little while at the start of each new project to become comfortable with the archaeological remains in a new landscape and that this familiarisation is proportionally larger in a smaller project area than a larger one. Once an investigator has gained confidence in understanding the landscape the mapping rate will improve.
- Project set-up time – setting up the project drawing, (such as incorporating all the disparate secondary datasets, visualising lidar, inputting orthophotography) has to be done at the start of the project. For smaller projects the time taken to achieve this is proportionally more than for larger projects.
- Scale and complexity of archaeological remains – a smaller project area may have been chosen due to the high density and complexity of the archaeological remains.

They don't include:

- Size of mapping and recording – in smaller areas it was thought that interpreters may unconsciously split the archaeological landscape into smaller parcels when monument recording, thus taking longer overall. If there was a correlation you may expect to see a higher number of monument records per square kilometre in smaller projects than larger ones. This was assessed for 90 digital projects and there was no correlation between size of project and numbers of records (ie number of monuments) per square kilometre (Fig 42), suggesting that, in general, the size of the project does not impact on record numbers.

Size of project area must be considered when setting up new projects, especially with the trend of decreasing size of project areas. It appears that projects over 150 square kilometres are more efficient. Single contiguous project areas are more efficient than a 'sampling' strategy of several discreet blocks, especially as AI&M methods are designed specifically to assess contiguous landscapes. Additionally, projects are often subdivided into 'blocks' for ease of photographic loan delivery and to subdivide projects between team members. The shape of the blocks should also be considered as the more regular the shape the more efficient the print retrieval for HEA staff

(Luke Griffin pers comm). It seems likely that this sub-division of projects will also impact on mapping rates and should be considered at project set-up.

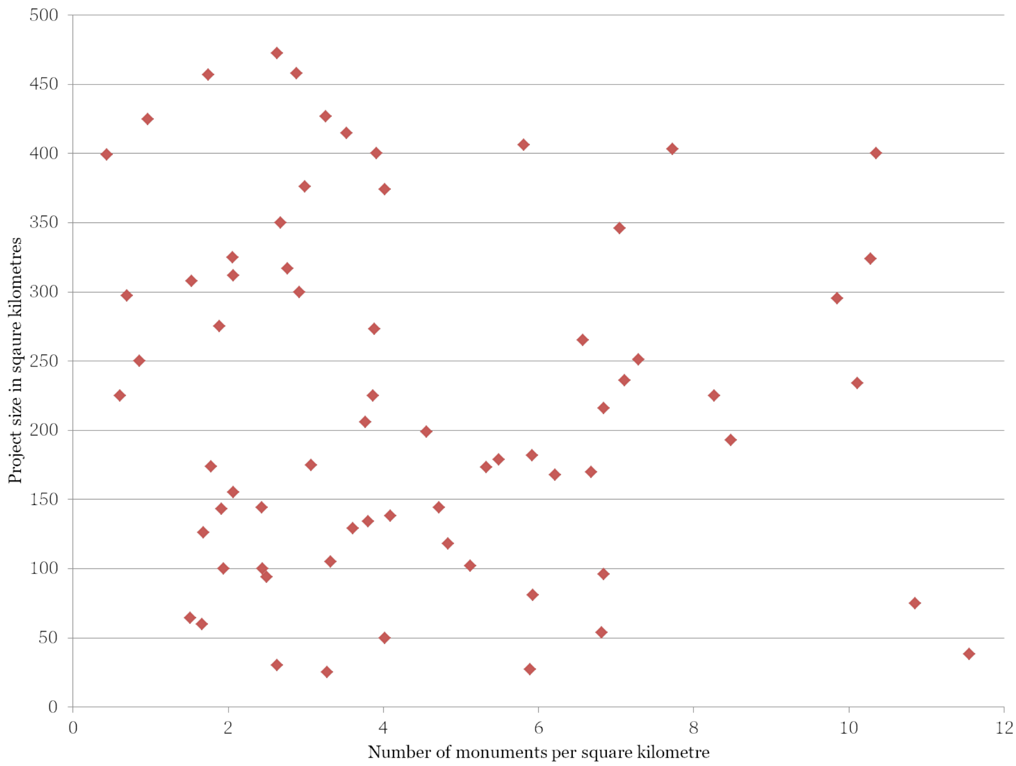


Fig 42: This chart shows that the size of an AIM project does not appear to affect numbers of monuments recorded per square kilometre.

Sub-division of a project area should be appropriate to the team members' work patterns, with the gap between mapping and recording of monuments as short as possible to increase efficiency and reduce the need for note taking etc. This might mean that for full time staff, a mapping block of between 10 and 20 square kilometres may be appropriate (equating to approximately 10 to 20 days to complete the area), whereas a team consisting of part time staff, or investigators with other work priorities, may find smaller mapping blocks more efficient. Equally, the number of archaeological monuments anticipated in a block should be assessed and those busier areas could be sub-divided into smaller mapping blocks, again to decrease the time between mapping and recording of archaeological monuments and thus increasing efficiency.

Number of monuments and nature of the archaeological remains

The density of archaeological remains is the key factor in terms of time required to map a particular square kilometre. This should be estimated at project planning stage through an assessment of the number and nature of archaeological monuments in the NRHE and the local HER (alongside other factors such as number and nature of sources, soils, geology and land use). Amending existing monument records is often more difficult and time consuming than creating new ones. Consideration of these factors elucidates the potential for new discoveries and the likely complexity of archaeological remains.

NRHE or HER archaeological monument data usually consists of a single point, polygon or line for each archaeological monument. The digital data produced by AI&M projects is much more complex and nuanced as it depicts the form and extent of the archaeological site. The archaeological 'site' described in each monument record will vary greatly in date, size and complexity. This might include one burial mound or an extensive coal mining landscape straddling many kilometres and comprising hundreds of individually mapped features with varying attribute data. This means that the timetable assessment can only provide a broad indication of potential and sometimes areas, especially those where little previous archaeological work or where little specialist aerial photography has taken place, can be unexpectedly 'busy'.

The following chart compares 92 previous projects where data are available for average monuments per square kilometre and average days to map one square kilometre (Fig 43). This clearly demonstrates the link between monument density and time required for mapping and recording. Time required is less for projects with fewer archaeological monuments per square kilometre whilst for busier areas with more archaeological monuments per square kilometre it takes longer on average to map and record that square kilometre.

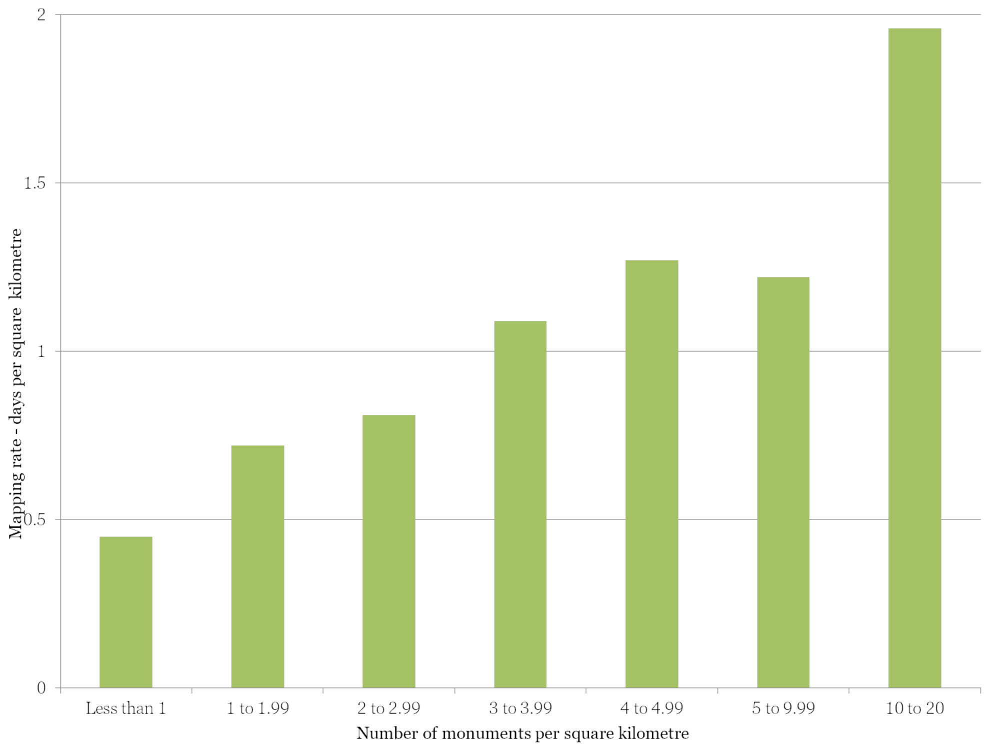


Fig 43: This chart demonstrates that the average number of archaeological monuments per square kilometre has a significant impact on the mapping rate.

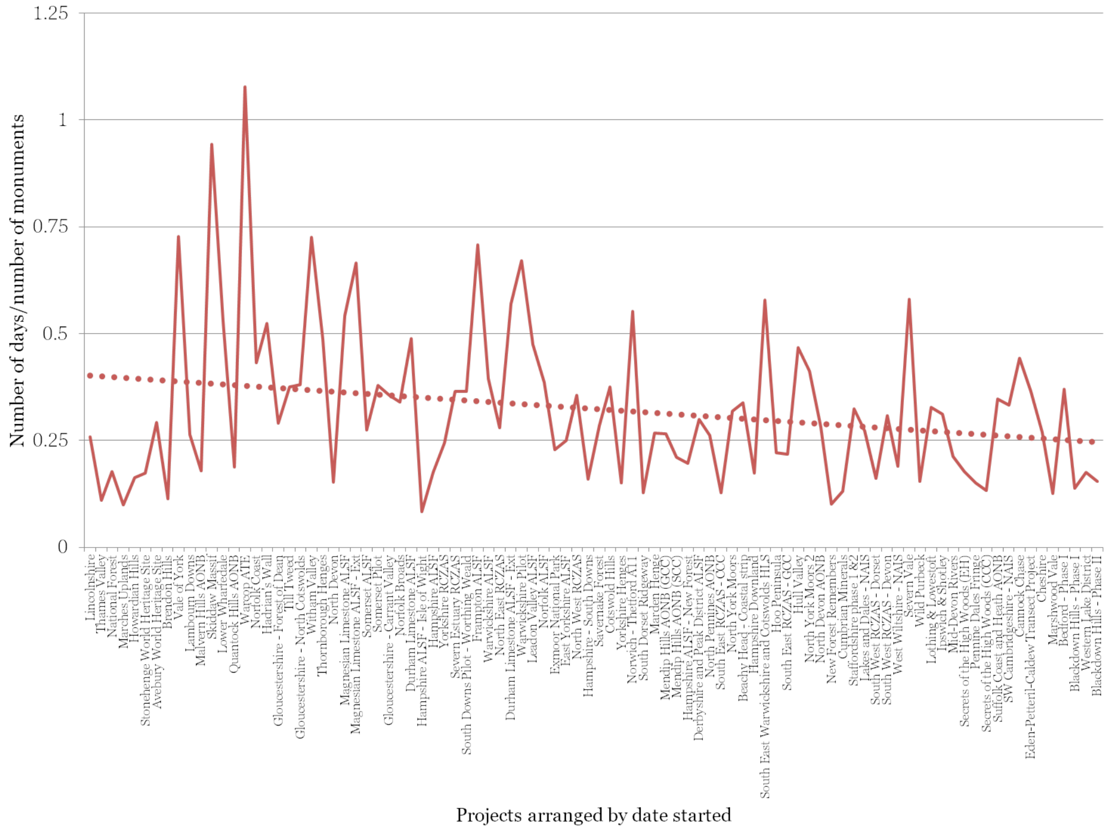


Fig 44: The changing rates in the graph show that AI&M projects are now mapping and recording monuments quicker. The projects are arranged by date with the earliest to the left.

On a positive note, a comparison of the total number of records against the number of days for each individual digital project shows that the time taken to map and record an individual monument has actually decreased over time, with an average of 0.33 days per monument (Fig 44). Given that the projects are generally taking longer to map per square kilometre, the only explanation is that more monuments per square kilometre are being identified and recorded; the following chart (Fig 45) confirms this to be true. Presumably, the increase in numbers of archaeological features per square kilometre is a direct result of the increase in sources used – particularly lidar and orthophotography, but also reflects a widening of archaeological scope such as the inclusion of military remains or, for some projects, widespread small-scale extractive features.

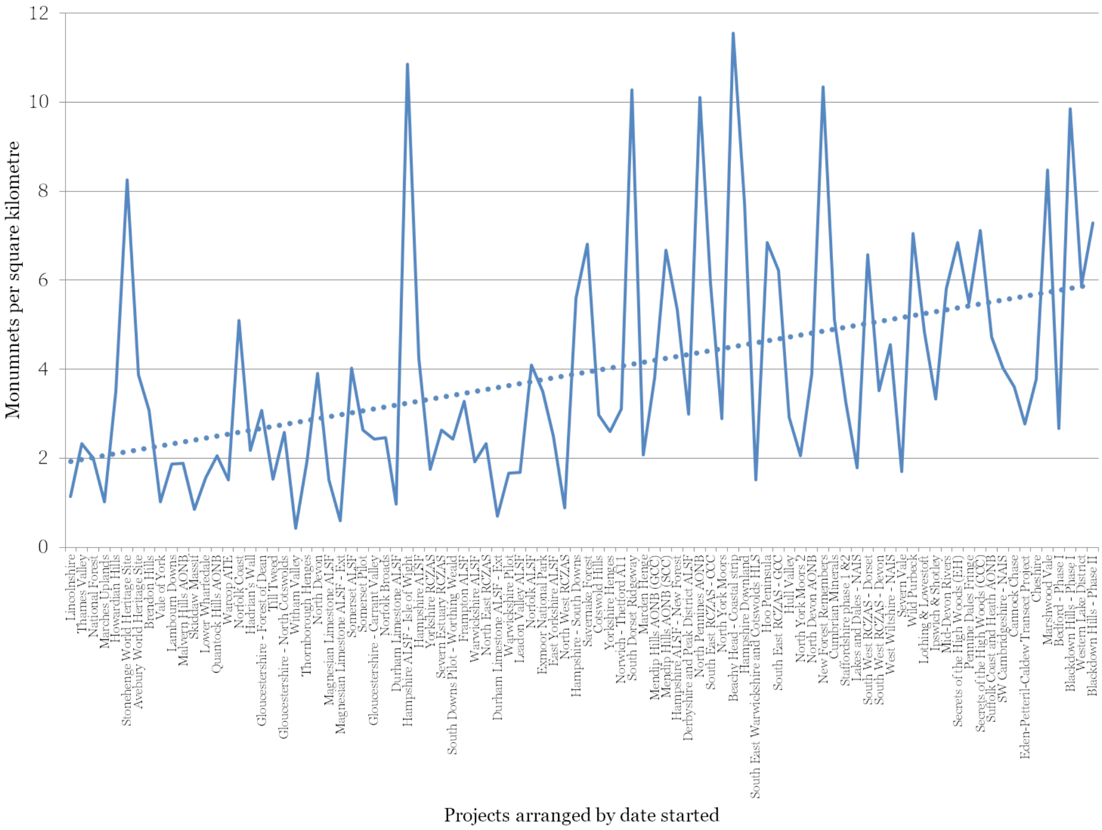


Fig 45: The number of monuments recorded per square kilometre has increased over time. The projects are arranged by date with the earliest to the left. This increase is probably due to a number of factors including a greater range of sources and widening of archaeological scope.

Team and Individual

The team or individual undertaking the project work may impact mapping time, but this is hard to be certain of in most cases. The most significant factor is likely to be the level of experience. Although project time is set aside for training new starters, there is still likely to be an impact on a trainer's mapping rate due to having to provide on-going support and the interruption that causes. As well as needing training, new staff will be slower at first as they develop both an understanding of multi-period archaeological landscapes and also learn the practical steps required to complete a mapping project.

The variety of archaeological landscapes or regions a team may be working in cause bias too. For example, Team A may work mainly in a rich archaeological landscape, compared with Team B who mainly works in less rich areas. Therefore Team A will on average have more archaeological remains to map and record and will therefore take longer. Project planning and review must focus on the nature of the area rather than comparing average times taken by each team.

The circumstances of the team may also have an impact on mapping rates. For example, network speed, reliability of software, access to online resources such as Google Earth, and general technical support can vary greatly. Anecdotally, those working for government bodies (local or national) can experience greater difficulties than those with more direct control over IT resources.

The following charts focus on digital projects only and compare the average time taken to map one square kilometre by each project team. Some teams have undertaken multiple AI&M projects, whilst others have undertaken very few, even though a team may have been in place for a long time, the individuals making up that team could have changed entirely over the years. If looking at the average time taken for each team, there does appear to be a trend for some teams to take longer than others to map one square kilometre (Fig 46). If the figures are broken down into individual projects however, still comparing teams, it reveals that there is considerable variation within teams across projects suggesting that while the team does have an impact on the timetable, other variables are also at play, such as the nature of the projects undertaken.

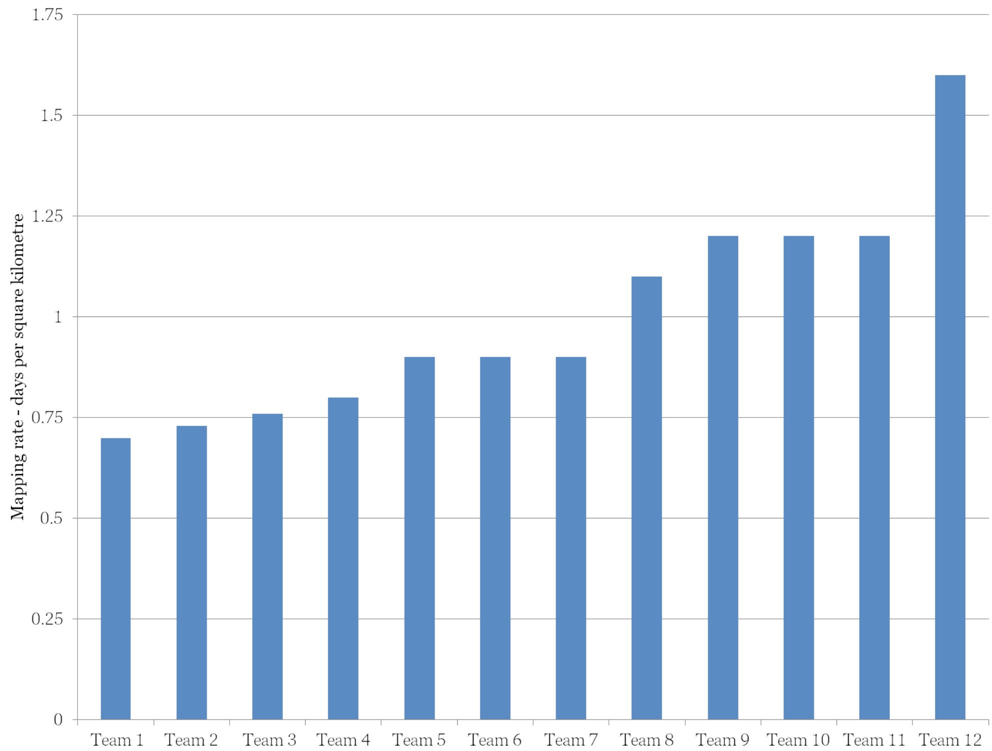


Fig 46: The variation in mapping rate across the various project teams (not all current). The mapping rate was calculated per square kilometre for digital projects and is averaged across each team's projects.

The following data looks at individuals working on two recent Historic England projects to assess what impact the individual can have on timetable. Methods and team members were the same for both projects so many of the variables described previously are eliminated. The figures are skewed slightly by an increased monument

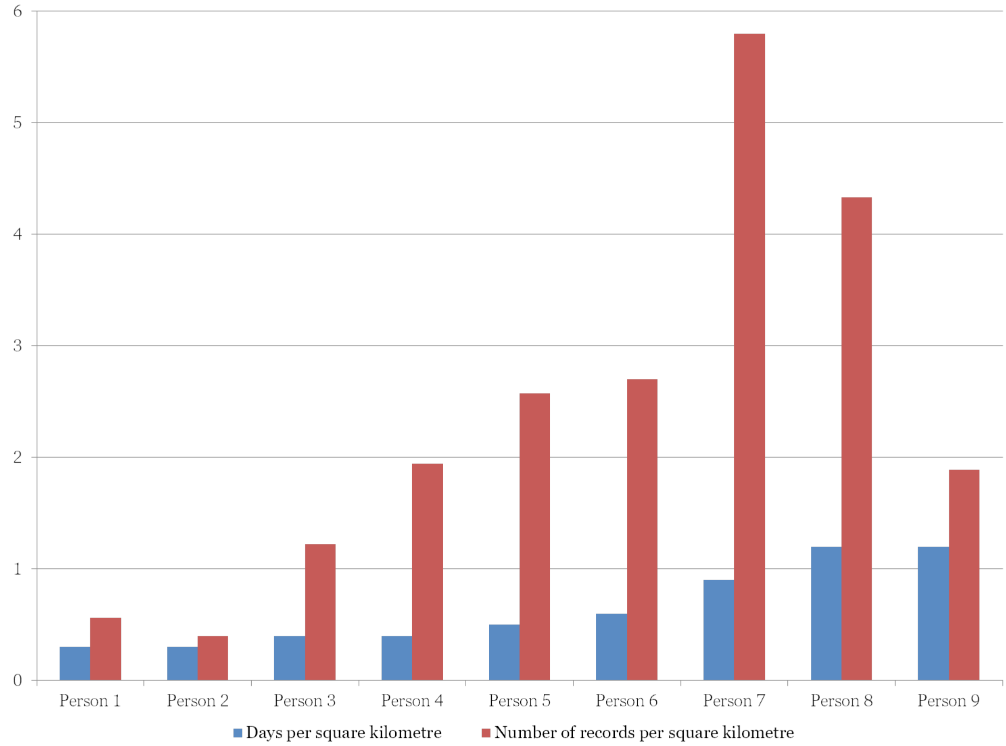


Fig 47: The variation in mapping rate per square kilometre for individuals working on the the recent Upland and Lowland NAIS projects. The numbers of monuments per square kilometre that these individuals recorded as part of these projects are also shown.

numbers per square kilometre in certain individual's areas (Fig 47). The results clearly show that there is variety in the time taken between individuals. Interestingly, the two persons who mapped the least, only three square kilometres and nine square kilometres respectively, are also the people who took the longest. This suggests that mapping smaller areas is not effective and actually impacted mapping rate more than the number of archaeological monuments per square kilometre. In this instance, the reason that these individuals mapped less was due to additional work commitments impacting on their time, leading to an inefficient approach to mapping. This needs to be factored in to any project planning, with a solid block of time set aside in work programmes.

Number of photographs

At the project planning stage the numbers and types of aerial photographs are reviewed for the timetable assessment. The following chart focuses on the number of aerial photographs per square kilometre and the mapping rate. The chart is based on the 64 projects where the number of vertical and oblique photographs assessed by the project was recorded (Fig 48). The photograph numbers are limited to the HEA, so CUCAP and HER archives and online or APGB are not included. However, these sources are a small proportion of all used as the HEA is the main supplier of aerial photographs for AI&M projects. The number of photographs appears to have less of an impact on timetable than anticipated. There is no correlation between project times and number of aerial photographs both for vertical and oblique frames.

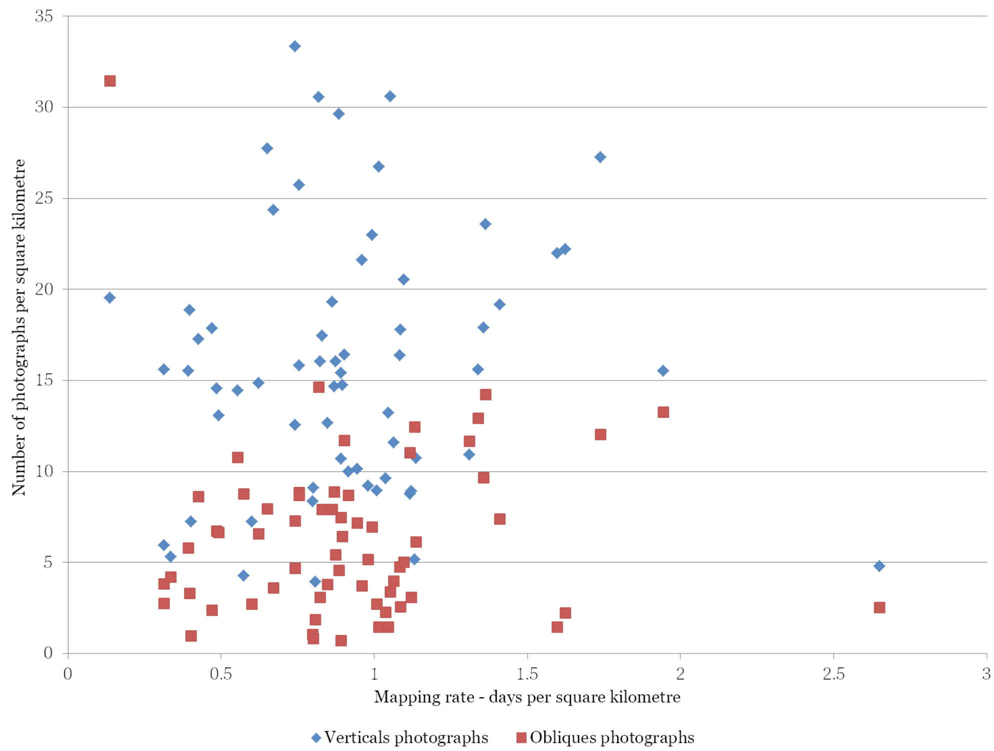


Fig 48: The chart demonstrates that there is no correlation between numbers of photographs and mapping rate.

Presumably, this can be explained as the time taken to locate and assess a particular frame is relatively small compared to the time taken to locate, assess, rectify, interpret, plot and record a single monument on a photograph. As you would only be undertaking the latter if an archaeological monument was visible on the frame, the majority of photographs will reflect a very insignificant time cost. This is reassuring for those projects with a higher density of photography, in that although the sorting, siting (locating) and assessing stage will take a little longer this impact is relatively insignificant over the lifetime of the project. However, for project planning purposes, the nature of the sources should be carefully assessed to determine the likely complexity and density of archaeological remains.

Rectifications and timetabling impact

As rectification of an aerial photograph *can* be a time-consuming process it is important that the number of rectifications per archaeological monument is kept as low as possible without compromising on detail or the accuracy of the mapping. Where an archaeological monument is clearly visible on a georeferenced dataset then that source should be the primary source for mapping. This is why it is important that sources are assessed together to ensure the best images for mapping are identified.

The source used for mapping is usually recorded in the attribute data for digital projects. By calculating the number of different photo references for each monument, this gives a reasonably reliable method of calculating the number of sources used to map each monument and in turn the number of rectifications. It is unlikely that a photograph was rectified and then not used as a source for mapping.

The following chart is based on a sample of attribute data from 15 projects. The projects chosen were across a variety of project teams (where project data with attributes could be accessed) and landscapes. Ridge and furrow was excluded from these calculations as it is recorded in large parcels which may include lots of sources (Fig 49). The results are encouraging as they suggest similar working practices across project teams. Combining the results of the 15 projects, 75% of archaeological monuments were mapped from one source alone, a further 15% were mapped from two sources. In all just over 98% of features were mapped from five sources or fewer. Where the number of sources used appears extreme, for example SW Cambridgeshire had one monument that was recorded from 42 different sources, further investigation shows that this feature was a very extensive field system covering many kilometres. Similarly Hull Valley has one monument with 34 sources recorded in the attribute data, but this turned out to be a coaxial field system, again covering many kilometres.

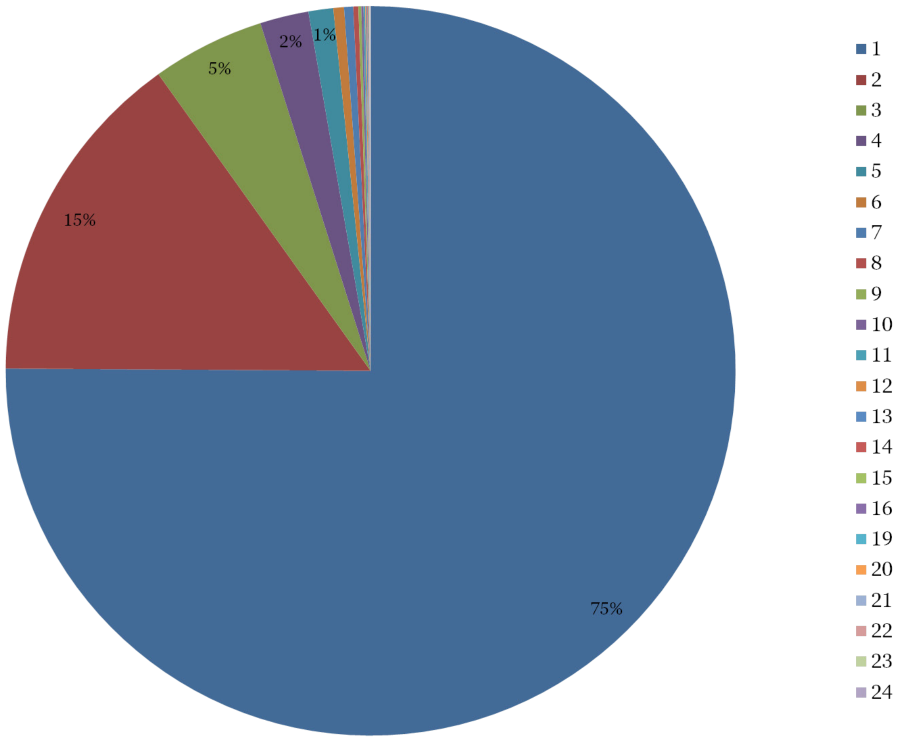


Fig 49: A sample across 15 projects assessing the number of sources used for mapping an individual monument. The results suggest that all project teams are keeping number of rectifications to a minimum.

These analyses are important as they identify that AI&M project teams across the board are consistently relying on as few rectifications as possible to map individual monuments. Across the various projects there is little variation with each project team undertaking a broadly similar approach. As such, it seems unlikely that there are any key time savings to be found in terms of numbers of rectifications. The preferential use of georeferenced datasets should be encouraged to avoid unnecessary rectifications of traditional imagery if it is appropriate to do so (if the archaeological remains are clearly visible on both sources).

Use of lidar

Use of lidar has a small impact on some project timetables, with the average rising to 1.1 days per square kilometre for those projects using raster surface visualisations of Environment Agency lidar, usually produced in Relief Visualisation Toolbox 1.1. This compares with past projects not using lidar that take on average 0.86 days per square kilometre. The adoption of RVT as a standard has allowed lidar data to be integrated into AI&M project flow lines with minimal impact on timetable. This is the current standard approach to using lidar in a time effective manner for AI&M projects. Although lidar tiles do not need to be rectified, as they are already a georeferenced dataset, they do need to be visualised. However, since the introduction of the RVT software, this has been a relatively quick process and so unlikely to be the root cause of the time increase. The time impact must therefore be a direct result of the increased clarity of earthwork archaeological features, and the statistics back this up. For projects without lidar, there are on average four monuments per square kilometre, for those using the Environment Agency lidar visualisations this increases to 4.6 monuments per square kilometre.

The adoption of lidar into AI&M projects has seen a variety of methods trialled (*see* Lidar section for details) and lessons learned. Projects such as Savernake Forest (Crutchley *et al* 2009, 45) or North Pennines AONB (Oakey *et al* 2012, 65) trialled the use of 'live' raster surface data where hillshading and vertical exaggeration could be changed in a 2D environment within AutoCAD Map 3D. The mapping rate using this method rises to 1.4 days per square kilometre, and therefore the impact of this approach was too great to be sustainable.

Summary of key findings

- Smaller projects take longer per square kilometre to map than larger ones. Going forward it seems that a project size of 150 square kilometres or over leads to increased efficiency.
- The number of monuments per square kilometre is the key time impact. Fewer monuments take less time, more monuments take more time. However, project planning should take into account the anticipated complexity of the archaeological remains.
- The average mapping rate is one day per square kilometre for lidar and aerial photograph projects.
- Average time taken to map an archaeological monument has decreased.
- Teams and individuals do have some impact on mapping rates.
- Quantity of aerial photographs has a relatively low impact on project timetable. However, for project planning purposes, the nature of the sources should be carefully assessed to determine the likely complexity and density of archaeological remains.

- For efficiency, the time between mapping and recording of monuments should be at a minimum. In practice this means that the size of mapping blocks should be appropriate to the individual or team, as should the number of anticipated archaeological monuments in an area. Project duration should not be greater than 2 years and ideally about one year.
- Single contiguous project areas should be encouraged unless there are strong reasons for sampling multiple geologies or topographies in a region – even then the areas should be of a size to ensure significant results.
- A single project area with straight sides is more efficient for archive retrieval and re-filing and is a more efficient use of sources.

OPTIONS, OPPORTUNITIES AND RISKS FOR THE FUTURE

"Gradually make all project datasets available for free download - although making sure it's tied into NRHE/HER/HIAS is essential for understanding context. A combined and streamlined national dataset - perhaps as WMS - would be good, at least for a quick and easy way to have a look at what has been done for an area. Could also produce specialized and curated WMS eg Roman Roads."

"1) If you are not willing to make it freely downloadable, at least make it freely viewable on line, so that it's not so often a case of paying handsomely up front for data that turns out to be of relatively little use.

2) Develop more streamlined and efficient systems for reproduction of the data

3) Have a member of staff in the Public Search Room who understands the nature of survey data and has in-depth knowledge of the coverage and parameters of each NMP project."

"Make it more accessible. Make it easier to check coverage."

(Quotes taken from AI&M User Survey)

One of the key messages to come out of the User and Producer Surveys was the perceived lack of accessibility to the data linked with the desire for a single dataset of all projects. Nearly 80% of users felt that this should be available as a downloadable national dataset. A curated AI&M dataset would provide an unparalleled view of the archaeological landscape, adding detail to the very broad overview given by HER records. This national dataset would be beneficial in a number of ways:

- It would combine the disparate projects into a single entity.
- It would resolve some of the dissemination issues.
- If the data could be made available (and downloadable) via the web it would significantly increase use of the data due to better signposting. It would also signpost HER data.
- It would be the only AI&M dataset with a national scope; promoting national, regional and local archaeological studies.

As AI&M projects have been produced over a long period of time using a variety of methodologies and recording systems, it is difficult to combine them into a single dataset. There has been some progress towards achieving this aim, and Simon Crutchley in combination with the Historic England corporate GIS team has been instrumental in turning the multitude of projects into a single corporate dataset, available via webGIS and ArcMap to internal users. The numerous AI&M project datasets were difficult to collate within the corporate GIS due to a variety of technical difficulties, some of which included inconsistencies within the dataset. Unfortunately, the system that was developed for the collation exercise involved the stripping out of attribute information, with the exception of 'layer' (for symbolising the data) and 'NRHE UID'. This was because the full benefit of attribute data were not fully realised as a standalone means of querying data, but also because it was always thought that the AI&M data would link directly to the NRHE spatial data, so that attribute data would become redundant. It was also difficult to load any projects that undertook monument recording directly with HERs as the GIS corporate tools require the mapping to have an AMIE UID.

Simon Crutchley is leading discussions for a system that will import all AI&M data (internal and external; current and historic) irrespective of whether there is an NRHE UID and, where available, including the import of attribute data. This would rely on the existing data having all the attribute data correctly attached. Time would need to be set aside to resolve these issues, but in most cases it is relatively simple to fill in the gaps based on surrounding data, or occasionally by referring to the NRHE monument record. For the more recent projects, there is less likelihood of missing data. For those earlier AI&M projects without attribute data it is slightly more difficult to resolve, though relatively simple to attach all the options from NRHE to all the features with that UID. This would not be an equivalent to the later projects, where attributes are attached to individual elements, and would have to be made clear to anyone doing research, but it would be better than the current situation and could provide a workable solution.

Several existing examples demonstrate practical and innovative dissemination of HE AI&M data online on a smaller scale. The Northamptonshire NMP results are available to download via the ADS website https://archaeologydataservice.ac.uk/archives/view//nnmp_eh_2003/index.cfm. From an HER perspective, the Cornwall Council Interactive Map https://map.cornwall.gov.uk/website/ccmap/ has the 'National Mapping Programme lines' as a single layer, with the HERs monuments records also visible and colour coded by period. The Devon County Council Environment Viewer http://map.devon.gov.uk/DCCViewer/ includes 'NMP transcriptions' symbolised by 'layer' with limited attribute data available, as well as numerous other historic environment datasets. The recent Cannock Chase AI&M project is available online via the HE website http://services.historicengland.org.uk/cannock-chase-map/index.html using Esri GIS online. The archaeological mapping spatial data and the source lidar data are visible, as well as a number of selected ground shot photographs. The mapping can be clicked on and attribute information is visible, though the data are not queryable, making landscape analyses difficult.

In Scotland, CANMORE https://canmore.org.uk/map/about (the online Scottish national record of the historic environment) includes the results of airborne mapping. The 'known site extents' of monuments (equivalent to AI&M data monument polygons or NRHE monument polygons) are available to view within a Web Mapping interface, and for download as a shapefile. Though the air survey has very limited coverage compared with the English AI&M data it provides an exemplar of what is achievable. Pastmap https://pastmap.org.uk/map allows viewing of CANMORE data alongside numerous other secondary sources and provides information about the archaeology, architecture and landscapes of Scotland on one single map. Both websites are managed by Historic Environment Scotland (HES) along with partners from local government and archaeological curators. The data are equivalent to that held by Historic England as part of the corporate GIS. These existing systems perhaps best highlight the opportunities that the overhauled Heritage Gateway and HIAS offer.

Historic England has been collaborating with the Getty Conservation Institute to develop the Arches system for internal use for HE's inventory requirements. The Arches project aims to develop, for the international heritage field, an open source, web- and geospatially based information system that is purpose-built, to inventory and manage immovable cultural heritage. Arches incorporates widely adopted standards (for heritage inventories, heritage data, thesauri, and information technology) so that it will offer a solid foundation that heritage institutions may customize to meet their particular needs.

Arches will be used for monument recording for Historic England internal AI&M projects when NRHE input ceases and the AMIE system is retired. Arches can also be used as a basic GIS, though this needs to be thoroughly tested to assess its utility for AI&M projects. If not, it can be linked with other GIS systems such as ArcMap or QGIS. The system has been used successfully for Lincoln's HER and despite issues with data migration has proven extremely useable. Greater London HER is currently changing over to Arches and the NRHE monument and event records are due to transfer in spring 2019. The Arches system has the benefit for users that it is inherently web based and allows textual and spatial data to be interrogated in combination. Arches also allows users to export data, which could be a chargeable service if required. Arches offers a good opportunity to get AI&M data into a usable format and provides that ability to share the data more widely. AI&M spatial data, once fully collated, should be retained as one of Historic England's national datasets.

A single monument recording system, such as Arches, could be used by multiple teams working on AI&M or other non-HER based projects, on the proviso that data were made available online near-instantly through the Heritage Gateway. Arches has inbuilt heritage standard, meaning standardisation of AI&M and other projects would be easily achievable. This data could then be integrated into the multiple HER systems using the protocols established as part of the HIAS NRHE to HERs data transfer programme.

The disparate HER systems and the current incomplete cover on Heritage Gateway mean there are serious technical issues in presenting the AI&M GIS data as a single data set online alongside the monument records. However, as described above, the GIS data could be presented as another layer on the Heritage Gateway. The attribute data includes monument UID (NRHE and/or HER) to enable a link to the relevant HER record.

Heritage Gateway could provide a viewable GIS dataset, with clickable attributes (as in the Cannock Chase example above), but this would still be a vast improvement on what is currently available. The AI&M projects could therefore 'go live' on Heritage Gateway as soon as they are complete. If users wanted the data for inclusion into their own GIS, they would need to be provided that data by HE, but this would be a simple matter of extracting the appropriate area from the corporate GIS in the short term.

Going forward, a monument recording strategy needs to be agreed but this is somewhat dependent on the direction taken by HIAS and the technical solutions available. The chosen recording decision would impact on the future of attribute data. Would it be needed going forward, or can it be superseded by use of a spatially enabled database? A few options are as follows, with the first two options being preferable:

- Direct input into HER monument records so records can be created and amended 'live'.

This method would avoid the HER having to verify each record. However, it is only possible where the HER has facilities for remote access and requires AI&M project teams to learn each of the many systems used by HERs.

- Create records in an interim Arches system, which publishes to the Heritage Gateway and can be downloaded by HERs at a later stage following the NRHE to HER flowline.

This is a compromise option and will allow project data to be available online if HERs cannot accommodate remote access, until such a point as the data is published in the HER's own Heritage Gateway feed. This option is better for work with a national geographic scope, such as reconnaissance recording (from recently taken aerial photographs) or thematic projects where it is not practical to enter records to multiple HERs.

- Stop monument recording altogether, just use extended attribute tables in GIS and supply these data.

This would save time, but could reduce the usability of AI&M data for local planning purposes. Consistency for attribute data would have to be maintained to make the dataset usable and past projects would need to be updated to include attributes.

CONCLUSION

This review demonstrates the broad range of benefits of AI&M project data and the impact it has within the heritage sector. It is used by HERs, academics, local government planning advice, Historic England (planning, listing and research colleagues), consultants, contracting archaeological units and community groups and volunteers. The use and re-use of AI&M data are significant with such data, in daily or weekly use across the majority of users, even for the oldest projects. This shows the impact and longevity of the project data and really emphasises the long-term value of the products. The User Survey also confirmed that satisfaction with the data is high and that many wanted additional coverage, suggesting that AI&M data remains a useful resource for heritage management.

Areas for improvement have also been highlighted; to gain new audiences for such data, particularly the academic and commercial sectors but also for non-heritage professional audiences. Redundancy of specialist software, especially Aerial, is an area of concern and the proactive trialling of alternatives could reduce the impact. The review has highlighted some of the fundamental issues with regard methodologies and the significant impact that non-connected systems are having on the efficiency of the workflow. If these issues can be addressed, then there is the potential for improved productivity and an overall reduction of project timetables. As a first step, improved data standards and consistency will ensure increased usability of AI&M project data. HIAS and the implementation of Arches offers a significant change to working routines within Historic England and beyond, which if implemented correctly could increase visibility, availability and utility of the AI&M data to HERs and the wider heritage sector. There is significant support within the heritage community for making all the AI&M data available online. Such an outcome would resolve the variability in dissemination, which sees incomplete provision of data but also significantly enhance the public value of this unique dataset by allowing local, regional and national studies.

Plan of action

Immediate goals

- Produce a guide to using AI&M products and promote their use.
- Produce an updated AI&M Standards document and ensure that standards are applied consistently.
- Ensure accurate and consistent use of attribute data.
- Develop AI&M project flowline and monument recording in Arches as part of HIAS developments.
- Use ArcMap for mapping purposes (internal staff).
- Trial alternative rectification software.
- Ensure all AI&M projects are adequately archived for long term preservation and that the data are supplied by HEA when requested by archive customers.

Medium-term goals (1 to 5 years)

- Collate all AI&M project data into a single dataset of with mapping and monument data (as attributes) in a single GIS available online.

- Decide on recording strategy post-HIAS and retain AI&M monument records for past projects.
- Dependent on new recording strategy and Arches development, decide on use of attribute data for AI&M projects.
- AI&M spatial and textual records available as a single identifiable dataset on Heritage Gateway.
- All AI&M project teams working on a multi-user GIS.

GLOSSARY OF TERMS

Aerial 5.36: A rectification programme that allows aerial photographs to be transformed proportionally (rectified) and georeferenced. Aerial uses a DTM to employ a 3D geometric transformation.

AIM (Aerial Investigation and Mapping): The Historic England team name.

AI&M standards (Aerial Investigation & Mapping standards): large area aerial investigation and mapping (formerly NMP). A set of standards developed by Historic England to ensure effective use of aerial photographs and lidar to identify, map, record and better understand archaeological sites and landscapes.

AMIE: See NRHE below.

APGB (Aerial Photography for Great Britain): a GeoStore allowing the download of a number of geospatial data products, including 25cm resolution aerial photography, height data terrain products etc.

CUCAP (Cambridge University Collection of Aerial Photography): An aerial photograph collection holding over 500,000 images. Currently closed.

DSM (Digital Surface Model): a representation of the earth's surface including all the objects on it. This represents the first return of the laser received for each laser pulse sent out, and represents the tops of buildings, trees, and other objects, or the ground, if unobstructed.

DTM (Digital Terrain Model): a representation of the earth's surface without any objects on it. Elevations of vegetation and cultural features, such as buildings and roads, are digitally removed.

HE (Historic England): the public body that looks after England's historic environment.

HEA (Historic England Archive): publically accessible archive, holding a large collection of aerial photographs and other archive material, including digital and/or paper copies of AI&M mapping products.

HER (Historic Environment Record): sources of, and signposts to, information relating to landscapes, buildings, monuments, sites, places, areas and archaeological finds spanning more than 700,000 years of human endeavour. Based mainly in local authorities, they are used for planning and development control but they also fulfil an educational role.

Lidar (Light detection and ranging): Airborne laser scanning data or lidar (light detection and ranging) measures the height of the ground surface and other features in large areas of landscape with a very high resolution and accuracy. It provides highly detailed and accurate models of the land surface at metre and sub-metre resolution.

MIDAS Heritage (the UK Historic Environment Data Standard): The standard was developed for and on behalf of the Forum on Information Standards in Heritage (FISH), a discussion forum aimed at helping to resolve standards and recording issues for the whole of the heritage sector.

NMP (National Mapping Programme): (now AI&M) a series of projects with a common set of standards using aerial photographs and lidar to identify, map, record and better understand archaeological sites and landscapes.

NRHE (National Record of the Historic Environment): a database originally designed to record monuments, archives, events and bibliographic data. First developed by the Royal Commission on the Historical Monuments of England (RCHME) it was called MONARCH and then AMIE. It continued after the merger with English Heritage and then was used by Historic England. It was reduced to monument and event records only as the other components were transferred to off-the-shelf systems.

Orthophotograph(y): an aerial photograph that has been geometrically corrected (orthorectified) such that the scale of the photograph is uniform, meaning that the photo can be considered equivalent to a map.

PastScape: an online portal for searching the NRHE.

SfM (Structure from Motion): a photogrammetric ranging technique for producing a 3D point cloud (DSM) from 2D sequential (aerial) photographs.

SMR: (Sites and Monuments Record): former name for HERs (though some retain SMRs).

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APPENDIX 1 - AI&M PROJECT DATABASE

AI&M Project Name	Start date	Finish date	Team	Scale	Monument Recording database	How drawn?	Rectification Method	Source for control	DTM used	HE Verticals	HE Obliques	CUCAP Verts	CUCAP Obliques	HER/specialist oblique images	Orthophotography	Bespoke Live lidar	Bespoke visualisations	EA lidar jpeg tiles	EA Lidar visualisations	Web aerial imagery	SfM DEM & ortho	Attribute/Object data
Abingdon Reservoir	01/04/1992	31/12/1998	RCHME/English Heritage	2500	Gazeteer	Hand drawn	Aerial	1:10000/1:2500 OS	N	N	Y	N	N	N	N	N	N	N	N	N	N	N
Avebury World Heritage Site	22/10/1997	01/11/1998	RCHME	10000	AMIE	Hand drawn then digitised in AutoCAD	Manual/Some Aerial	1:10000 OS	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	UID only
Beachy Head	30/09/2012	30/11/2010	English Heritage	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Some	N	N	Y	N	Y	N	Y
Bedford Borough	20/03/2016	30/06/2018	Skylarkeology	2500	AMIE	AutoCAD	Aerial 5.35 - 5.36	1:2500 OS	Y	Y	Y	N	N	Y	Y	N	N	Y	Y	Y	N	Y
Berkshire	27/09/1996	01/04/1998	RCHME/training project	10000	MORPH2	Hand drawn some digitised in AutoCAD	Aerial	1:10000 OS	N	Y	Y	U	U	U	U	U	U	U	U	U	U	U
Breckland - Norfolk and Suffolk	01/02/2016	Ongoing	Norfolk CC HES	2500	exeGesIS HBSMR	AutoCAD exported to MapInfo	Aerial 5.36	1:2500 OS	Y	Y	Y	Some	Some	Y	Y	N	Y	N	Y	Y	N	UID only
Brendon Hills	20/02/1998	01/10/1998	RCHME	10000	AMIE	Hand drawn then digitised in AutoCAD	Manual/Some Aerial	1:10000 OS	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	UID only
Cannock Chase Staffordshire	01/07/2015	01/01/2017	English Heritage	2500	exeGesIS HBSMR	AutoCAD	Aerial	1:2500 OS /APGB	Y	Y	Y	N	N	Y	Y	Y	Y	N	Y	Y	N	Y
Chalk Lowlands and the Hull Valley	26/10/2011	21/08/2012	English Heritage	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	Y
Cheshire - Peak Fringe, Cheshire Plain and Mersey Valley	09/10/2015	22/12/2016	ARS	2500	AMIE	AutoCAD	Aerial	1:2500 OS /APGB	Y	Y	Y	N	Y	Y	Y	N	N	N	Y	Y	N	Y
Cornwall & Isles of Scilly	26/06/1994	01/02/1999	Cornwall CC HES	10000	MORPH2/Cornwall HER	Hand drawn	Manual/Some Aerial	1:10000 OS	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N
Cornwall & Isles of Scilly	26/06/1994	01/04/2006	Cornwall CC HES	10000	MORPH2/exeGesIS HBSMR	AutoCAD	Aerial 4.2-5	1:10000 OS	Some	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Some
Cornwall/Devon	26/06/1994	01/04/2006	Cornwall CC HES	10000	MORPH2/exeGesIS HBSMR	AutoCAD	Aerial 4.2-5	1:10000 OS	Some	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Some
Cumbrian Minerals	18/03/2013	13/09/2013	A Deegan	2500	AMIE	MapInfo exported to AutoCAD	Aerial 5.33	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	Y
Dartmoor	01/09/1985	01/09/1985	RCHME	10560	No records	Hand drawn	Manual	1:10560 OS	Some	Some	Y	N	N	N	N	N	N	N	N	N	N	N
Derbyshire and Peak District ALSF	15/06/2009	01/06/2010	ARS	2500	AMIE	MapInfo exported to AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y	N	Y
Devon - Blackdown Hills	18/04/2016	24/06/2018	Devon CC HES	2500	exeGesIS HBSMR	ArcMap	Aerial 5.29	1:2500 OS	Y	Y	Y	N	N	Y	Y	N	N	Y	Y	Y	N	UID only
Devon - Haldon Ridge to Dart valley	01/01/2018	01/05/2019	Devon CC HES	2500	exeGesIS HBSMR	ArcGIS	Aerial 5.30	1:2500 OS	y	y	y	N	N	Y	Y	N	N	N	Y	Y	N	UID only
Dorset -Wild Purbeck	23/11/2013	18/11/2014	Cornwall CC HES	2500	exeGesIS HBSMR	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	N	Y
Durham Limestone ALSF	21/04/2006	31/08/2007	ARS	10000	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
East Yorkshire ALSF	29/10/2007	01/02/2008	A Deegan	2500	AMIE	MapInfo exported to AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Eden-Petteril-Caldew Transect Project	18/07/2015	03/03/2017	A Deegan	2500	AMIE	MapInfo exported to AutoCAD	Aerial 5.36	1:2500 OS	Y	Y	Y	Some	Some	Y	Y	N	N	N	Y	Y	N	Y
Essex	17/10/1993	01/02/2003	Essex CC HES	10000	MORPH2/Essex HER	Hand drawn	Manual/Some Aerial	1:10000 OS	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N
Exmoor National Park	22/10/2007	01/06/2009	Exmoor National Park	10000	AMIE	AutoCAD	Aerial 5.3	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Gloucestershire - Carrant Valley	01/03/2006	01/04/2007	English Heritage	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	Y	N	N	UID only
Gloucestershire - Cotswold Hills	01/06/2008	01/08/2010	Gloucestershire CC AS	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	N	Y
Gloucestershire - Forest of Dean	29/11/2002	01/01/2004	English Heritage	10000	AMIE/selected ASRM	AutoCAD	Aerial4.2 & 5/some Manual	1:10000 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	UID only
Gloucestershire - Frampton ALSF	04/07/2006	01/08/2006	Gloucestershire CC AS	10000	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Gloucestershire - North Cotswolds	15/07/2003	01/07/2008	English Heritage	2500	AMIE	AutoCAD	Aerial 5	1:2500 OS	Some	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Hadrian's Wall	17/11/2002	01/08/2008	English Heritage	2500	AMIE	AutoCAD	Aerial 5.29	1:10000/1:2500 OS	Y	Y	Y	Y	Y	Y	Some	N	N	N	N	N	N	Y
Hampshire - South Downs	12/01/2008	01/03/2011	Cornwall CC HES	2500	exeGesIS HBSMR	AutoCAD	Aerial 5.29	1:10000 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Hampshire ALSF	08/05/2006	01/01/2008	Cornwall CC HES	10000	exeGesIS HBSMR	AutoCAD	Aerial 5.2	1:10000 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Hampshire ALSF - Isle of Wight	08/05/2006	01/12/2009	Cornwall CC HES	2500	exeGesIS HBSMR	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Hampshire ALSF - New Forest	22/05/2009	01/09/2009	Cornwall CC HES	10000	exeGesIS HBSMR	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	N	N	N	Y	N	N	N	N	Y
Hampshire Downland	14/10/2010	05/02/2013	Cornwall CC HES	2500	exeGesIS HBSMR	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	N	N	Y	Y	N	N	N	N	Y	N	Y
Hertfordshire	01/11/1990	01/11/1991	RCHME	10000	MORPH2	Hand drawn	Manual	1:10000 OS	N	Some	Y	N	Y	N	N	N	N	N	N	N	N	N
Hoo Peninsula	21/01/2011	23/02/2012	English Heritage	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	y	y	y	Y	N	N	Y	N	N	N	Y
Howardian Hills	23/07/1993	01/01/1994	RCHME	10000	AMIE/MORPH2	Hand drawn	Manual	1:10000 OS	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N
Howgill Fells	01/07/1992	01/01/1993	RCHME	10000	AMIE/MORPH2	Hand drawn	Manual	1:10560 OS	N	Y	Y	N	N	Y	N	N	N	N	N	N	N	N
Ipswich & Shotley Peninsula	13/04/2014	15/03/2015	Essex CC HES	2500	exeGesIS HBSMR	ArcGIS	Airphoto	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	Y
Kent	01/02/1987	01/05/1988	RCHME	10000	AMIE/MORPH	Hand drawn	Manual	1:10000 OS	N	Some	Y	Y	Y	N?	N	N	N	N	N	N	N	N
Lakes and Dales - NAIS Upland Pilot	19/04/2013	30/06/2013	English Heritage	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS/25cm PGA	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	Y
Lambourn Downs	14/02/1999	01/04/2000	English Heritage	10000	AMIE/selected ASRM	AutoCAD, some hand-drawn then digitised	Aerial 5.11	1:10000 OS	Some	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	UID only
Lancashire	01/03/2017	31/07/2018	ARS	2500	AMIE	AutoCAD	Aerial	1:2500 OS /APGB	Y	Y	Y	N	Y	Y	Y	N	N	N	Y	Y	N	Y
Leadon Valley ALSF	26/06/2007	01/08/2007	Gloucestershire CC AS	10000	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Liddington Environs	01/11/2000	30/09/2001	Training Placements	10000	AMIE	AutoCAD			Some								N					
Lincolnshire	22/06/1992	01/12/1996	English Heritage	10000	AMIE/MORPH2	Hand drawn	Manual	1:10000 OS	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N
Lincolnshire - Witham Valley	14/09/2004	01/03/2005	English Heritage	10000	AMIE/selected ASRM	AutoCAD	Aerial 5.24	1:10000 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	Y*	N	N	Y
Lothingland, Lowestoft and North Suffolk Coast and Heaths	09/02/2014	18/09/2014	Norfolk CC HES	2500	exeGesIS HBSMR	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	N	UID only
Lower Wharfedale	12/04/2002	01/03/2004	WYAS	10000	AMIE/selected ASRM	AutoCAD	Aerial 5.18-5.24	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Magnesian Limestone ALSF	02/03/2005	01/12/2006	WYAS	10000	AMIE	AutoCAD	Aerial 5.18- 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Malvern Hills AONB	19/09/2000	01/01/2001	English Heritage	10000	AMIE/selected ASRM	AutoCAD	Aerial 5	1:10000 OS	Some	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	UID only
Marches Uplands	28/06/1993	01/10/1994	RCHME	10000	AMIE/MORPH2	Hand drawn	Manual/Some Aerial	1:10000 OS	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N
Marden Henge	22/02/2009	01/11/2009	English Heritage	2500	AMIE	AutoCAD	Aerial 5	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	Y	N	Y
Marshwood Vale	27/11/2015	22/12/2016	Devon CC HES	2500	exeGesIS HBSMR	AutoCAD/ArcGIS	Aerial 5.36	1:2500 OS	Y	Y	Y	N	N	Y	Y	N	N	N	Y	Y	N	Y
Mendip Hills AONB (GCC)	01/03/2009	01/05/2009	Gloucestershire CC AS	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y
Mendip Hills AONB ALSF (SCC)	23/03/2009	01/01/2008	Somerset CC HS	10000	Somerset SMR	MapInfo	Aerial 5.29	1:10000 OS	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	N	N	N
Mid-Devon Rivers	29/07/2014	01/11/2015	Devon CC HES	2500	exeGesIS HBSMR	ArcGIS	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	UID only
National Forest	30/11/1992	01/08/1993	RCHME	10000	AMIE/MORPH2	Hand drawn	Manual/Some Aerial	1:10000 OS	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N
New Forest Remembers	30/01/2012	29/11/2012	Cornwall CC HES	2500	exeGesIS HBSMR	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y
Norfolk ALSF	15/08/2007	01/03/2008	Norfolk CC HES	10000	exeGesIS HBSMR	AutoCAD, exported to MapInfo	Aerial 5.29	1:2500 OS	Some	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Norfolk Broads	19/04/2006	01/08/2007	Norfolk CC HES	10000	exeGesIS HBSMR	AutoCAD, exported to MapInfo	Aerial 5.29	1:10000 OS	Some	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Some
Norfolk Coast	02/07/2002	01/12/2006	Norfolk CC HES	10000	exeGesIS HBSMR	AutoCAD, exported to MapInfo	Aerial 5.17-5.29	1:10000 OS	Some	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Some
North Devon	18/12/2004	01/11/2005	Cornwall CC HES	10000	ACCESS/Devon HER	AutoCAD	Aerial	1:10000 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
North Devon AONB	01/12/2011	28/02/2013	Devon CC HES	2500	exeGesIS HBSMR	ArcMap	Aerial 5.3	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y
North East RCZAS	25/03/2007	01/07/2008	ARS	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
North Pennines AONB	13/08/2009	01/06/2011	English Heritage	2500	AMIE	AutoCAD	Aerial 5.29	25cm orthophoto	Y	Y	Y	Y	Y	N	Y	Y	Y	N	N	Y	N	Y
North West RCZAS	07/12/2007	01/04/2009	ARS	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
North York Moors	26/06/2010	01/05/2011	ARS	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS/25cm PGA	Y	Y	Y	N	N	Y	Y	N	N	N	N	N	N	Y
North York Moors 2	12/12/2011	25/01/2013	ARS	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS/25cm PGA	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	N	Y
Northamptonshire	01/01/1994	01/08/2001	Northamptonshire CC	10000	MORPH2/Northamptonshire HER	MapInfo	Aerial 4 to Aerial 5.14	1:2500 OS	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Some
Norwich - Thetford A11	20/09/2008	26/02/2013	Norfolk CC HES	2500	exeGesIS HBSMR	AutoCAD, exported to MapInfo	Aerial 5.29	1:2500 OS	Some	Y	Y	Y	Y	Y	N	N	N	Some	N	Y	N	Y
Nottinghamshire	01/01/1992	01/01/1997	Air Photo Services	10000	MORPH2	Hand drawn	Manual/Some Aerial 4.2	1:10000 OS	N	N	Y	Y	Y	N	N	N	N	N	N	N	N	N
Oxfordshire - Frilford	19/01/2010	01/06/2010	Training Placement	2500	AMIE	AutoCAD	Aerial	1:2500 OS	Some	y	y	y	y	N	N	N	N	N	N	Y	N	UID only
Pennine Dales Fringe	13/11/2014	11/02/2015	A Deegan	2500	AMIE	MapInfo exported to AutoCAD	Aerial 5.33	1:2500 OS/25cm PGA	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	N	Y
Quantock Hills AONB	25/06/2002	01/02/2003	English Heritage	10000	AMIE	AutoCAD	Aerial		Some								N					

AI&M Project Name	Start date	Finish date	Team	Scale	Monument Recording database	How drawn?	Rectification Method	Source for control	DTM used	HE Verticals	HE Obliques	CUCAP Verts	CUCAP Obliques	HER/specialist oblique images	Orthophotography	Bespoke Live lidar	Bespoke visualisations	EA lidar jpeg tiles	EA Lidar visualisations	Web aerial imagery	SfM DEM & ortho	Attribute/Object data
Salisbury Plain Training Area	08/01/1995	01/09/2005	RCHME	10000	MORPH2	Hand drawn	Manual/Some Aerial	1:10000 OS	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N
Savernake Forest	10/02/2008	01/07/2008	English Heritage	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	Y	Y	N	N	N	N	Y
Secrets of the High Woods	03/11/2014	30/09/2015	Cornwall CC HES/Historic England	2500	CMS	HEROS	Aerial 5.29	1:2500 OS/25cm PGA	Y	Y	Y	Y	Y	N	Y	N	Y	N	N	Y	N	UID only
Severn Estuary RCZAS	12/06/2006	01/04/2008	Gloucestershire CC AS	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	N	N	Y
Severn Vale	16/09/2013	29/01/2016	Gloucestershire CC AS	2500	AMIE	AutoCAD	Aerial 5.29-5.36	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	N	Y
Silchester Environs	16/06/2016	16/06/2016	Reading University	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	N	Y
Skiddaw Massif	28/08/2001	01/12/2001	English Heritage	10000	AMIE/MORPH	AutoCAD	Aerial 5.18	1:10000 OS	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	Y
Somerset ALSF - East Mendip	18/11/2005	01/03/2006	Somerset CC HS	10000	Somerset SMR	MapInfo	Aerial 5	1:10000 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	UID only
Somerset ALSF - Levels	06/01/2006	01/03/2006	Somerset CC HS	10000	Somerset SMR	MapInfo	Aerial 5	1:10000 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	UID only
South Dorset Ridgeway	29/11/2008	01/09/2010	Cornwall CC HES	2500	exeGesIS HBSMR	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	N	N	Y
South Downs Pilot - Worthing Weald	19/06/2006	01/09/2008	English Heritage	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	N?	N	N	N	N	N	N	N	Y
South East coast RCZAS - Wessex	30/06/2010	01/06/2010	Wessex Archaeology	2500	exeGesIS HBSMR	ArcMap	Aerial 5.33	1:2500 OS	Y	Y	Y	N	N	N	Y	N	N	Y	N	Y	N	Y
South East coast RCZAS (CCC & GCC)	19/03/2010	01/08/2011	Gloucestershire CC AS/Cornwall CC HES	2500	AMIE/exeGesIS HBSMR	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	N	N	N	Y	N	N	Y	N	Y	N	Y
South East Warwickshire and Cotswolds HLS	19/11/2010	16/04/2013	Gloucestershire CC AS	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	N	Y
South West coast RCZAS - Devon	17/05/2013	01/06/2014	Devon CC HES	2500	exeGesIS HBSMR	ArcView	Aerial 5.3	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	y	N	Y
South West coast RCZAS - Dorset	26/04/2013	23/12/2013	Cornwall CC HES	2500	exeGesIS HBSMR	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	Y	N	Y
Staffordshire - eastern river confluences and Gnosall, Kidgrove and Talke	31/03/2013	30/06/2015	ARS	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS/25cm PGA	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	N	Y
Stonehenge WHS: Landscape Survey South of A303	27/04/2016	13/08/2018	Historic England		AMIE	AutoCAD	Aerial 5.35	1:2500 OS	Y	Y	Y	N	N	Y	Y	N	N	Y	Y	Y	N	Y
Stonehenge World Heritage Site	20/12/1994	01/08/2001	English Heritage	2500	AMIE/selected interim MORPH module	AutoCAD	Aerial 5	1:10000/1:2500 OS	Some	Y	Y	Y	Y	Y	N	N	Y	N	N	N	N	UID only
Suffolk ALSF	01/01/2005	01/03/2007	Sufffolk CC AS	10000	exeGesIS HBSMR	MapInfo	Aerial 5	1:2500 OS	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	UID only
Suffolk Coast	01/01/2005	01/01/2005	Sufffolk CC AS	10000	exeGesIS HBSMR	MapInfo	Aerial 5	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	UID only
Suffolk Coast and Heath AONB	29/01/2015	06/05/2016	Norfolk HES	2500	exeGesIS HBSMR	AutoCAD, exported to MapInfo	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	N	UID only
SW Cambridgeshire - NAIS	17/05/2015	17/03/2016	English Heritage	2500	AMIE	AutoCAD	Aerial 5.36	PGA/APGB/1:2500 OS	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	N	Y
Thames Valley	20/09/1992	01/12/1993	RCHME	10000	AMIE/MORPH2	Hand drawn	Manual/Some Aerial	1:10000 OS	N	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N
Thornborough Henges	11/12/2004	01/02/2005	WYAS	2500	AMIE	AutoCAD	Aerial 5.24	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Till Tweed	12/04/2003	01/09/2003	WYAS	10000	AMIE/selected ASRM	AutoCAD	Aerial 5.18	1:10000 OS	Some	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	Y
Vale of York	17/05/1998	01/11/2000	English Heritage	10000	AMIE/selected ASRM	AutoCAD, some hand-drawn then digitised	Aerial 5.12	1:10000 OS	N?	Y	Y	N	Y	Y	N	N	N	N	N	N	N	UID only
Warcop Army Training Estate	01/07/2002	20/09/2002	English Heritage	10000	AMIE	AutoCAD	Aerial	1:10000 OS	Y	Y	Y	N?	Y	Y	N	N	N	N	N	N	N	Y
Warwickshire ALSF	06/12/2006	01/03/2008	Warwickshire CC MS	10000	exeGesIS HBSMR	MapInfo	Aerial 5	1:10000 OS	Y	Y	Y	Y	Y	N	N	N	N	Y	N	N	N	N
Warwickshire Pilot	09/05/2007	01/06/2007	Warwickshire CC MS	10000	exeGesIS HBSMR	AutoCAD	Aerial 5	1:2500 OS	Some													
West Wiltshire - NAIS	27/07/2013	11/11/2013	English Heritage	2500	AMIE	AutoCAD	Aerial 5.29	1:2500 OS/25cm PGA	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	Y
Western Lake District	21/05/2016	30/09/2016	A Deegan	2500	AMIE	MapInfo exported to AutoCAD	Aerial 5.36	1:2500 OS	Y	Y	Y	N	N	Y	Y	N	N	N	Y	Y	N	Y
Yorkshire Dales	01/01/1989	01/04/1992	RCHME	10560	MORPH2	Hand drawn	Manual	1:10560 OS	N	Y	Y	N	N	Y	N	N	N	N	N	N	N	N
Yorkshire Henges	09/08/2008	30/11/2016	A Deegan	2500	AMIE	MapInfo exported to AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	N	N	Y
Yorkshire RCZAS	15/05/2006	01/04/2007	WYAS	10000	AMIE	AutoCAD	Aerial 5.29	1:2500 OS	Y	Y	Y	Y	Y	Y	N	N	N	Some	N	N	N	Y
Yorkshire Wolds	01/10/1985	01/10/1990	RCHME	10560	Gazeteer	Hand drawn	Manual/Some Aerial	1:10560 OS	N	Some	Y	Y	Y	N	N	N	N	N	N	N	N	N

*post mapping from APs

APPENDIX 2 - AI&M RESEARCH REPORTS

Report Number	Title	Author
01/1985	The Archaeology of Dartmoor: an air photographic Survey	Soffe, G
137/1989	The Classification of Cropmarks in Kent : A report for the Monuments Protection Programme	Edis, J
89/1992	Cropmarks in Hertfordshire: A report for the National Mapping Programme	Fenner, V
70/1994	The Thames Valley Project: A report for the National Mapping Programme	Fenner, V; Dyer, C
66/1995	Howardian Hills Mapping Project: A report for the National Mapping Programme	Carter, A
67/1995	The National Forest Project: A Report for the National Mapping Programme	MacLeod, D
68/1995	The Yorkshire Dales Mapping Project: A report for the National Mapping Programme	Horne, P; MacLeod, D
85/1999	The Nottinghamshire Mapping Project: A report for the National Mapping Programme	Deegan, A
94/2000	Salisbury Plain Training Area: A report for the National Mapping Programme	Crutchley, S
135/2001	Vale of York National Mapping Programme Project Review	Kershaw, A
132/2002	The Lambourn Downs: A Report for the National Mapping Programme	Small, F
133/2002	Stonehenge World Heritage Site Mapping Project: Management Report	Crutchley, S
134/2002	Warcop Army Training Estate NMP: Summary Report	Boutwood, Y
135/2002	Northamptonshire NMP Project: management report	Deegan, A
119/2003	Essex National Mapping Programme Project: Management Report	Ingle, C; Saunders, H
120/2003	Till-Tweed ALSF NMP Project.	Deegan, A

95/2004	The Marches Uplands Mapping Project: A report for the National Mapping Programme	Stoertz, C; Small, F
96/2004	West Yorkshire Lower Wharfedale NMP Project Summary Report (2957)	Deegan, A
78/2005	Hadrian's Wall NMP Project: Bowness on Solway to Carlisle	Boutwood, Y
79/2005	Malvern Hills AONB: A Report for the National Mapping Programme	Winton, H
80/2005	Witham Valley NMP - Summary Report	Jones, D; Boutwood, Y
81/2005	The Archaeology of the Suffolk Coast and Inter-tidal Zone: A report for the National Mapping Programme	Hegarty, C; Newsome, S
82/2005	Aggregates Levy Sustainability Fund Thornborough Henges: Air Photo Mapping Project (3897)	Deegan, A
28/2006	The Forest of Dean Mapping Project, Gloucestershire: A Report for the National Mapping Programme	Bishop, S; Carpenter, E; Small, F; Stoertz, C; Winton, H
91/2006	Frampton On Severn Aggregate Levy Sustainability Fund: Archaeological Aerial Photograph Interpretation National Mapping Programme Report	Dickson, A
92/2006	The Magnesian Limestone in South and West Yorkshire Archaeological Assessment Project (3860)	Deegan, A
93/2006	The Aggregate Landscape of Somerset: Predicting the Archaeological Resource - Interim Report for Aerial Photograph Interpretation Component Block 1: Eastern Mendip	Truscoe, K
94/2006	The Aggregate Landscape of Somerset: Predicting the Archaeological Resource - Report for Aerial Photograph Interpretation Component Block 2: Somerset Levels	Truscoe, K
111/2007	Cornwall and Isles of Scilly Mapping Project: A Report for The National Mapping Programme	Young, A

112/2007	National Mapping Programme: The Leadon Valley Sand and Gravel Aggregate Area (4832)	Priest, R; Crowther, S; Dickson, A
113/2007	The Archaeology of Norfolk's Broads Zone: Results of the National Mapping Programme - English Heritage Project No: 2913	Albone, J; Massey, S; Tremlett, S
115/2007	North Devon Mapping Project: A Report for the National Mapping Programme (3899)	Young, A; Turner, S
116/2007	The Yorkshire Coast and Humber Estuary Rapid Coastal Zone Assessment Project (3729)	Deegan, A
11/2008	The South Downs NMP Pilot Area 1 - Worthing to the Weald: National Mapping Programme Report	Carpenter, E
69/2008	Hadrian's Wall NMP Project - Brampton to Birdoswald: National Mapping Programme Report	Small, F
96/2008	Durham: Assessment of Archaeological Resource in Aggregate Areas - Revised Interim Report	Radford, S; Pallant, G
97/2008	Desk-Based Resource Assessment and Research and Management Framework of Aggregate-Producing Landscapes in the East Riding of Yorkshire	Deegan, A
98/2008	Archaeological Aerial Photograph Interpretation in the Northern Mendip Hills: A Highlight Report for the National Mapping Programme	Priest, R; Dickson, A
99/2008	The Aggregate Landscape of Somerset: Predicting the Archaeological Resource (3994) - Archaeological Aerial Photograph Interpretation in the Central Mendip Hills	Truscoe, K
100/2008	The Archaeology of Norfolk's Aggregate Landscape	Albone, J; Massey, S; Tremlett, S
101/2008	North East Coast Rapid Coastal Zone Assessment Survey (3929) - Air Survey Mapping Report	Bacillieri, C; Knight, David; Radford, S

102/2008	Severn Estuary Rapid Coastal Zone Assessment Survey: National Mapping Programme	Crowther, S; Dickson, A; Truscoe, K
29/2009	Savernake Forest : A Report for the National Mapping Programme	Bowden, M; Crutchley, S; Small, F
30/2009	The Carrant Valley Landscape NMP: National Mapping Programme Report	Bishop, Sharon
31/2009	Tarrant Launceston 15 & Environs, Air photo survey and analysis, Special Project Report	Bishop, Sharon
73/2009	Hadrian's Wall World Heritage Site - National Mapping Programme Project: NMP Summary Report	Oakey, M
107/2009	Exmoor National Park National Mapping Programme: Management and Summary Report	Hegarty, C; Toms, K
108/2009	North West Coast Rapid Coastal Zone Assessment Survey (4548) - Air Survey Mapping Report	Bacillieri, C; Knight, D; Williams, S
111/2010	Skiddaw Massif National Mapping Programme: Management Summary and Project Review.	MacLeod, D
112/2010	Derbyshire and Peak District Aggregates Assessment Project, Air Survey Mapping Summary Report, National Mapping Programme	Bacillieri, C; Knight, David
113/2010	The Aggregate Landscape of Hampshire: Results of NMP Mapping (ALSF 4766)	Trevarthen, E
114/2010	Assessment of Archaeological Resource in Aggregate Areas on the Isle of Wight: Results of NMP Mapping (ALSF 5783)	Royall, C
115/2010	The Archaeology of Norwich 'Growth Point' & Environs: Results of the Norwich Growth Point NMP Project - English Heritage Project No. 5313	Bales, E; Cattermole, A; Horlock, S; Tremlett, S

116/2010	The Aggregate Landscape of Suffolk: The Archaeological Resource Interim report for Aerial Photograph Interpretation component Areas One & Two: The Felixstowe Peninsula (ALSF 3987)	Hegarty, C
117/2010	The Aggregate Landscape of Suffolk: The Archaeological Resource Interim report for Aerial Photograph Interpretation component Areas Four & Five: The Waveney Valley (ALSF 3987)	Hegarty, C
123/2011	An Archaeological Aerial Photograph Interpretation in the Cotswold Hills: A Report for the National Mapping Programme	Janik, J; Dickson, A; Priest, R
124/2011	The National Mapping Programme: Hampshire South Downs NMP Mapping Project	Young, A
125/2011	North York Moors National Mapping Programme and Assessment: Aerial Photograph Interpretation Mapping Summary Report - National Mapping Programme	Knight, David; Sutcliffe, T J; Bax, S
126/2011	The Archaeology of Thetford 'Growth Point' & Environs	Bales, E; Cattermole, Alice; Horlock, S; Tremlett, S
127/2011	The National Mapping Programme: South Dorset Ridgeway Mapping Project: Results of NMP mapping	Royall, C
128/2011	South East Rapid Coastal Zone Assessment Survey National Mapping Programme Report Components 1 and 2 (Blocks B-C & L-M)	Hamel, A; Lambert, V
04/2012	Alston Moor, North Pennines, Miner-Farmer landscapes of the North Pennines AONB NMP: Aerial Investigation and Mapping Report	Knight, David; Oakey, M; Radford, S
17/2012	The North Cotswolds: A Highlight Report for the National Mapping Programme	Stoertz, C

39/2012	East Riding of Yorkshire, Chalk Lowland and the Hull Valley NMP: Aerial Investigation and Mapping Report	Evans, S; Knight, David; Oakey, M
55/2012	South East Rapid Coastal Zone Assessment Survey National Mapping Programme Components 1&2 (Blocks A, D-H & J-K)	Dickson, A; Janik, J; Priest, R; Royall, C
22/2013	South Downs Beachy Head to the River Ouse: Aerial Investigation and Mapping Report	Barber, M; Carpenter, E; Small, F
41/2013	Stoke Hammond, Buckinghamshire: Aerial Investigation and Mapping of Two Possible Neolithic Enclosures	Edwards, Z
64/2013	Cumbria Terrestrial Mineral Resource: Air Photo and Lidar Mapping and Interpretation	Deegan, A
65/2013	Results of NMP air photo analysis in the central Hampshire chalk downs	Royall, C
66/2013	North York Moors NMP 2: Aerial Photograph Interpretation Mapping Summary Report - National Mapping Programme	Knight, David; Bax, S
67/2013	The Archaeology of the A11 Corridor: Results of the 'A11 Corridor' Study Area for the Norwich, Thetford and A11 Corridor National Mapping Programme (NMP) Project: English Heritage Project No. 5313	Cattermole, Alice; Ford, E; Horlock, S; Tremlett, S
68/2013	Using Air Photo Mapping for Strategic Planning in Growth Areas: A case study from the Norwich, Thetford and A11 Corridor National Mapping Programme (NMP) Project: English Heritage Project No. 5313	Cattermole, Alice; Ford, E; Horlock, S; Tremlett, S
69/2013	Yorkshire Henges and their Environs Air Photo Mapping Project (3908 MAIN)	Deegan, A
10/2014	NAIS Upland Pilot, Burton-in-Kendal and Dalton, Cumbria and Lancashire: An Archaeological Landscape Investigation	Hardwick, Ian

80/2014	The National Mapping Programme: New Forest Remembers: Results of NMP Mapping	Royall, C
81/2014	North Devon Area of Outstanding Natural Beauty NMP Project: A National Mapping Programme Report - English Heritage Project 6083	Knight, S; Hegarty, C; Tait, Graham
82/2014	South East Warwickshire and Cotswolds Higher Level Stewardship (HLS) Target Areas NMP	Priest, R; Dickson, A
83/2014	Rapid Coastal Zone Assessment Survey National Mapping Programme for South-West England - South Devon Coast: A Report for the National Mapping Programme - English Heritage Project No. 6046	Hegarty, C; Knight, S; Sims, R
84/2014	Rapid Coastal Zone Assessment Survey for South West England - South Coast Dorset: Component One: National Mapping Programme (6673)	Royall, C
85/2014	Staffordshire National Mapping Programme - Phase 1 Eastern River Confluences: Aerial Photograph Interpretation Mapping Summary Report	Bax, S
95/2014	Essex Grazing Marshes Project	Gascoyne, Adrian; Medlycott, Maria
10/2015	National Archaeological Indentification Survey: Upland Pilot*	Oakey, M; Jecock, M; Hazell, Z; Linford, N; Linford, P; Payne, A
100/2015	National Mapping Programme Project for Lothingland, Greater Lowestoft and North Suffolk Coast and Heaths	Ford, E; Horlock, S; Tremlett, S
101/2015	Pennine Dales Fringe NMP: Air Photo and LiDAR Mapping and Interpretation Project Report (EH Project No. 6626)	Deegan, A

102/2015	Staffordshire National Mapping Programme - Phase 2 Gnosall, Kidsgrove and Talke: A National Mapping Programme Project Report	Bax, S
38/2016	National Archaeological Identification Survey Lowland Pilot Project Report*	Last, J; Carpenter, E; Evans, S
63/2016	East and Mid Devon River Catchments National Mapping Programme Survey Phases 1 and 2 Final report	Hegarty, C; Knight, S; Sims, R
64/2016	An Archaeological Survey in the Severn Vale, Gloucestershire: A Highlight Report for the National Mapping Programme NMP	Crowther, S; Dickson, A
66/2016	Suffolk Coast And Heaths AONB NMP	Horlock, S; Tremlett, S; Ford, E
67/2016	Western Lake District: Air Photo and LiDAR Mapping Project	Deegan, A
68/2016	National Mapping Programme Mapping of Wild Purbeck: Historic England Project Number 6600	Royall, C
64/2017	NMP Mapping of the Marshwood Vale, Dorset AONB	Flemming, F; Royall, C
68/2017	Cheshire NMP and Lidar Project: Sampling the Peak Fringe, Cheshire Plain and Mersey Valley A National Mapping Programme Project Report	Hardwick, Ian
24/2018	The Blackdown Hills Area of Natural Beauty: The Blackdown Hills AONB and East Devon River Catchments Aerial Investigation and Mapping Survey	Hegarty, C; Knight, S; Sims, R
67/2018	National Archaeological Identification Survey: South West Cambridgeshire Aerial Investigation & Mapping Report	Knight, D; Last, J; Evans, S; Oakey, M
	*multi-disciplinary report with large AI&M component	






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