Analysis of the Effectiveness of Airborne Lidar Backscattered Laser Intensity for Predicting Organic Preservation Potential of Waterlogged Deposits

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Revised Submission, March 2006

PNUM 4782

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EXECUTIVE SUMMARY

This project aims characterise landforms, such as abandoned river channels, where palaeoenvironmentally-rich sediments and associated cultural remains may be preserved, by using backscattered laser intensity data to assess their degree of preservation.

AIMS and OBJECTIVES

The proposed project has three components:

- Determining the soil proprieties characterized by backscattered laser intensity through use of terrestrial laser scanning;
- Systematic investigation of the backscattered laser intensity component of airborne laser scanning;
- Investigation of archive laser altimetry data held by EA to determine its usefulness.

OUTPUTS

It is anticipated that the project will produce at least the following generic products:

- A workshop aimed at aggregate industry stakeholders and others from the Heritage sector communicating project results.
- A generic good practice guidance document communicating the benefits that can be achieved through analysis of lidar backscattered laser intensity data; it will also set out a clear method for analysis. The document will include contact details and procedures for bodies able to supply lidar data.
- A publication in an international peer-reviewed journal, *Archaeological Prospection*, *The Photogrammetric Record* or *IJPRS*.

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1 INTRODUCTION

1.1 STATEMENT OF RELEVANCE TO ALSF CORE THEMES

This project has emerged from the applicants own work with lidar (EH PNUM 3357, 3850, 3307) and through helpful discussion with colleagues at English Heritage (principally, Dr David Earle Robinson, Peter Horne, Simon Crutchley and Dr Jim Williams). It aims to complement other English Heritage funded work considering the applications of lidar for mapping archaeological landscapes (e.g. the Heritage-3d project (EH PNUM 3789) and Stonehenge landscape (Bewley *et al*, 2005)) and comparing lidar with other sources of airborne remote sensing (Multi-spectral imaging and thermal-decay mapping on sands and gravel bearing sub-soils, EH PNUM 3841). The project proposes the systematic investigation of the potential of backscattered laser intensity data from airborne laser altimetry to remotely determine soil properties, including organic content and moisture levels. If successful, this should allow the identification of areas of preferential organic preservation within regions affected by aggregate extraction and provide information related to wider issues of catchment management (e.g. impacts of climate change and changing hydrological conditions).

In most aggregate-rich areas the *greatest* potential for organic preservation is usually associated with palaeochannels, whose position within the landscape is already known from the analysis of aerial photographs and historic maps. Information gained from analysing lidar data is unlikely to identify new areas of organic preservation, but may help in the rapid assessment of valley floor corridors, preventing the need for costly investigations prior to the submission of planning proposals and provide an indication of the preservation potential and degree of waterlogging.

The proposed project has three components: firstly aimed at determining the soil proprieties characterized by backscattered laser intensity through use of terrestrial laser scanning; secondly at systematic investigation of the backscattered laser intensity component of airborne laser scanning; and thirdly (and finally) at investigation of archive laser altimetry data held by EA to determine its usefulness.

This project seeks to address the ALSF objective two criteria:

- research to enhance understanding of the scale and character of the historic environment in aggregate producing areas in order to provide the baseline information necessary for effective future catchment management.
- support for the development of management and conservation strategies for the historic environment in aggregate producing areas.

It also seeks to address two of the additional ALSF criteria outlined by English Heritage in the *Science Coordinator's Review of Land-Based ALSF Research in England, 2002 – 2005* (Thompson 2005, 31) namely:

- Increased use of 'lidar imagery to enhance/upgrade Historic Environment Records'.
- Continued development of prediction, evaluation, and mitigation techniques (continual improvement of methods and techniques is of paramount importance).

1.2 PROJECT RATIONALE

Airborne remote sensing techniques have traditionally been employed to great effect in mapping cultural archaeology and to a lesser extent the geomorphology of valley floor landscapes. Archaeologists have largely focused their attention on the comprehensive mapping of cropmarks and other features of the archaeological landscape revealed from aerial photographs (eg. Riley 1980; Whimster 1989), and large areas of England have been comprehensively mapped as part of the National Mapping Programme undertaken by English Heritage (Bewley 2003). Aerial photographs have also been employed in mapping geomorphology in alluvial landscapes, for example in extensive studies of the valleys of the Rivers Trent (Baker 2003; Garton and Malone 1998) and Thames (Lambrick 1992; Robinson and Lambrick 1994). Such mapping of fluvial geomorphology provides a context for past cultural landscapes and assists in identifying topographical features of high archaeological potential (for example relict river channels) and isolating areas of past river erosion where little in the way of archaeological material might be expected to survive (*cf* Brown 1997). The systematic reconnaissance, mapping and classification of aggregate bearing valley floor landscapes in this way has played a significant role in the strategic management of the geoarchaeological resource and intimately associated archaeological remains (e.g. fishweirs, bridges, platforms, trackways, etc.) in the face of growing impacts from aggregate extraction and other development pressures (Bishop 2003).

More recently, such information relating to former fluvial regimes is also being increasingly used in understanding wider issues of floodplain management, particularly with respect to assessing the impacts of changing flood frequency and magnitude with respect to future climate (Thompson and Clayton, 2002).

While the two dimensional record of air-photography provides an approach to mapping the quantity of archaeological material (both cultural and geoarchaeological) within aggregate bearing landscapes, it provides no indication of the state of preservation of that material or the associated cultural evidence. In particular, aerial photography provides no indication of the moisture level and the potential for the preservation of organic sediments. This is a significant shortfall in the usefulness of the data, since the presence of moist, organic-rich sediments may greatly increase the archaeological value of deposits.

The generic potential of this research are:

- It will create a tool to allow the rapid assessment of valley floor corridors to provide baseline information on the environmental potential of organic sediments, usually preserved within palaeochannels. Such information may prevent the need for costly environmental investigations of potential extraction areas prior to the submission of planning proposals.

- It may provide information on the hydrological condition of valley floor sediments prior to aggregate extraction, an important issue in the consideration of the effects of artificial pumping and draw-down on the water table.

In addition to the benefits this work may provide for the aggregates industry in their consideration of the archaeological record, this study may also produce important data that can be used in wider environmental management themes, for example, consideration of catchment management with respect to changing flood frequency and magnitude associated with future climate change, the Water Frameworks Directive.

Airborne Laser Altimetry provides access to high resolution, high accuracy terrain information and as a secondary output a laser "image" of the land surface derived from measurements of the intensity of reflection of each backscattered laser pulse. A detailed description of Lidar is provided in Wehr and Lohr (1999). Archaeological applications of Lidar have focused largely on its ability to provide a high resolution record of terrain variation, allowing the detection and mapping of subtle archaeological features (Bewley *et al*, 2005), mapping of fluvial geomorphology (Challis 2005b and in press) and its unique ability to penetrate vegetation cover to map underlying archaeological earthworks (Devereux, *et al*, 2005).

Backscattered laser intensity measurements have largely escaped attention, and indeed do not form a part of the standard data product supplied by EA (although intensity data is collected on each EA flight and can be accessed by reprocessing original flight data). The lidar system used by EA, NERC and many UK-based commercial lidar providers (an Optech Airborne Laser Terrain Mapper) operates in the near infra-red (NIR: 1047nm) and so backscattered intensity is in-effect a record of the reflectance of earth surface materials at this wavelength.

While it is recognised that other airborne remote sensing techniques (ATM, CASI, etc. *cf* Figure 1) may be equally or more effective than lidar at detecting geoarchaeological and anthropogenic features, this study focuses on lidar for a number of reasons. Principally lidar has been chosen as the basis of this study because it is an emerging technology, still poorly understood within the archaeological community. There is a growing demand for and supply of commercial lidar providers. National agencies such as EA already operate lidar, while Ordnance Survey are actively investigating a move into ownership or a lidar system for data acquisition to assist national mapping. Some good work has been done of understanding the parameters of lidar terrain mapping required for archaeological purposes (Challis 2005, Crutchley, pers comm) and so archaeologists are equipped to specify such work when commissioning survey. However, little or no work has been undertaken to investigate intensity, which until now has been largely ignored both by archaeologists and by the lidar industry as a whole.

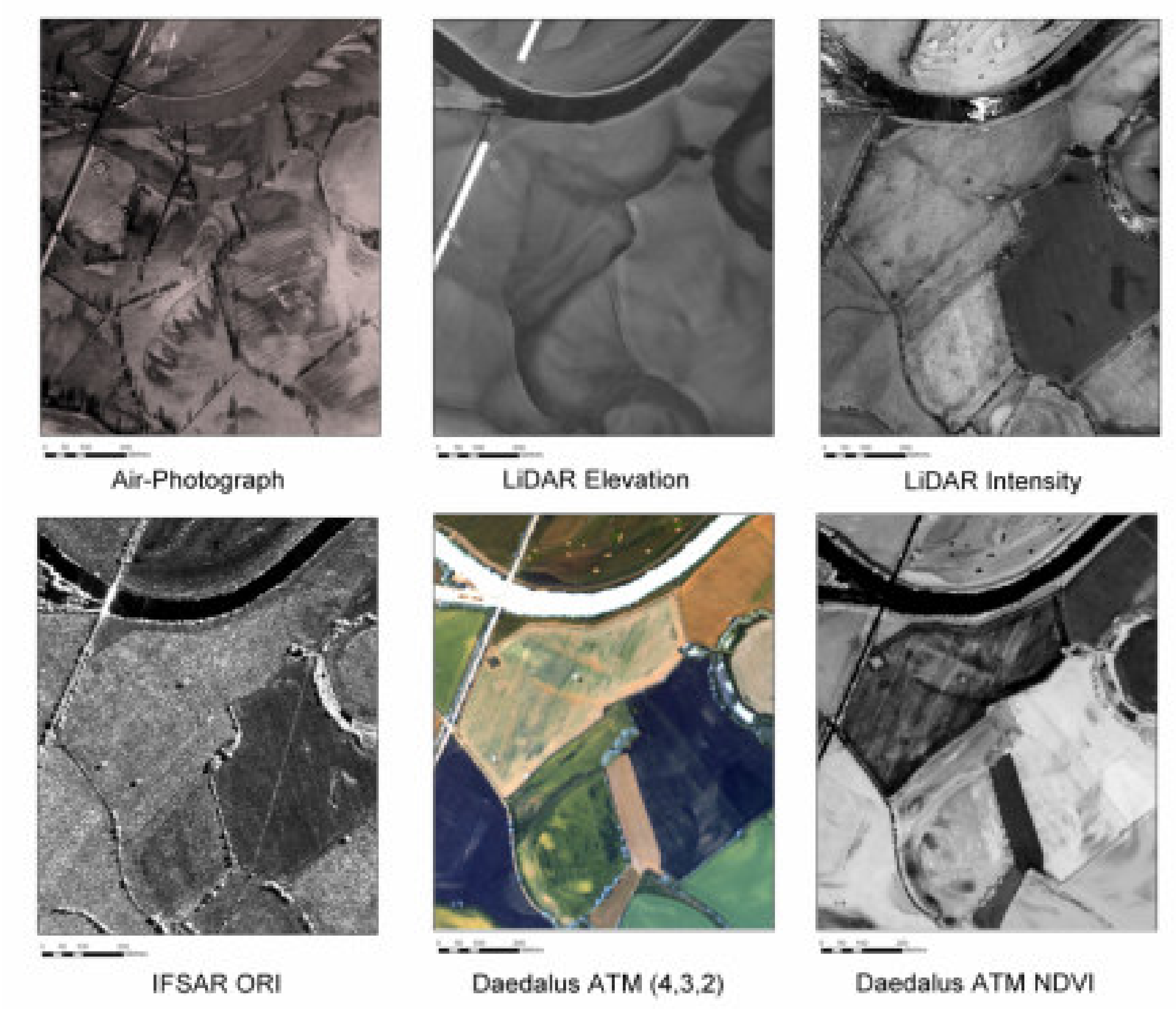

Figure 1 Comparison of various airborne remote-sensing techniques, including lidar, on a test site on the River Trent at Lockington (after Challis 2005).

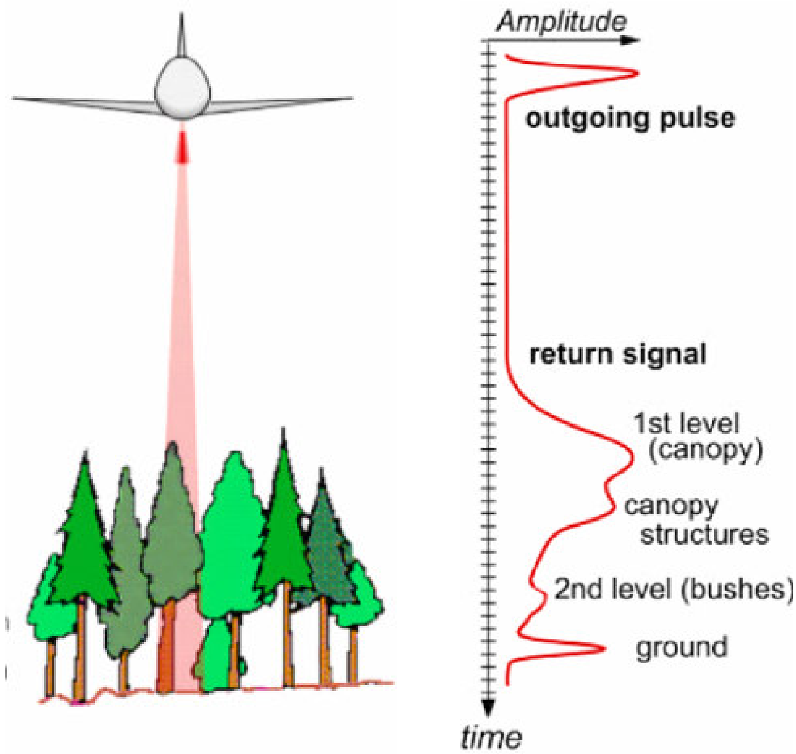

Figure 2. Graphical representation of the lidar principal. Partial reflections of a single laser pulse are detected from each of the surfaces it encounters. The analogue signal is used to generate discrete digital returns usually stored as a first pulse and last pulse return. The amplitude of the return varies because of a number of factors; Optech sensors store the amplitude value as a measurement of intensity.

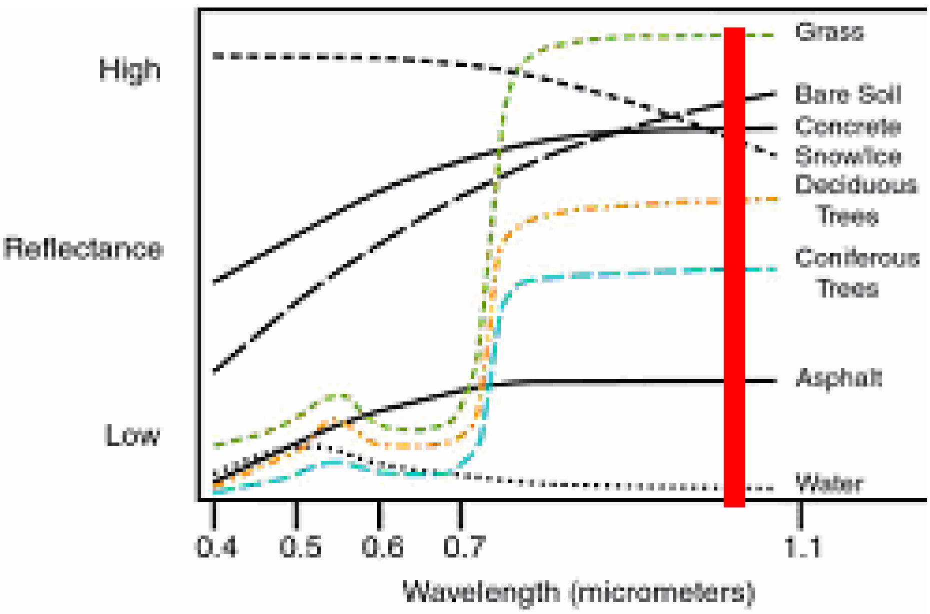

Figure 3. Graph showing the spectral reflectance of various earth surface materials. Materials are clearly distinguished in the near infra red (lidar 1047nm, shown by red bar).

Initial examination of backscattered laser intensity data by the applicants (Challis, 2005) suggests that a fall-off in the intensity of the reflected light corresponds with the position of sediment filled landform features such as palaeochannels. Variations in the reflectivity of various earth surface materials to laser light of differing wavelength are well-documented (for example, see Wehr and Lohr 1999, 74) and damp soil conditions are known to reduce reflectivity. It is possible that the increased soil-moisture associated with palaeochannels, and perhaps other associated variations in soil and vegetation properties, are responsible for the reduced reflection of the laser pulse. This phenomenon is largely untested but demands further examination as if reflected laser intensity is closely related to soil moisture it may provide a useful means of identifying areas of preferential organic preservation. The rigorous examination of lidar intensity data, both to identify geoarchaeological and anthropogenic features and to remotely determine wetness and other soil and sediment properties forms the core of the proposed project.

1.3 ANTICIPATED KEY BENEFITS

The project aims to benefit stakeholders within the aggregates industry, from quarries companies submitting planning applications through to individuals and bodies responsible for commissioning archaeological investigations within the framework of PPG 16, and curatorial archaeologists also working within the PPG16 framework. Project work will benefit these groups by providing an authoritative assessment of the use of lidar backscattered laser intensity as a tool for detecting archaeological features and remotely predicting organic preservation of waterlogged deposits in aggregate bearing environments. Such rapid assessment may save aggregate companies the expense of prospection within areas that have high potential for organic preservation, or paying for expensive mitigation strategies in areas where the organic potential of organic deposits is low. It may also provide information on the condition of valley floor deposits prior to dewatering Results of the proposed work will be communicated via a workshop, in a good practice guidance document and in peer-reviewed publication.

It is anticipated that the project will produce at least the following generic products:

- A workshop aimed at aggregate industry and heritage sector stakeholders communicating project results.

- A generic good practice guidance document communicating the benefits that can be achieved through analysis of lidar backscattered laser intensity data and setting out a clear method for analysis. The document will include contact details and procedures for bodies able to supply lidar data.

- A publication in an international peer-reviewed journal, either *Archaeological Prospection* , *The Photogrammetric Record* or *IJPRS* as appropriate.

1.4 PROPOSED STUDY AREAS

The underlying control on the evolution of river valley floors and floodplain development is the contrasting geomorphological settings of the upland, piedmont and lowland landscape zones (see Howard and Macklin, 1999). In order to assess the effectiveness of this methodology, it is essential that river systems from these contrasting geomorphological contexts are assessed. The study areas selected for further research (Figure 4) have been chosen since they represent contrasting styles of floodplain evolution. They are also well known by the project team who have undertaken much landscape archaeology research in these areas, much of it funded by the ALSF, since all areas are the focus of intensive mineral extraction.

1.4.1 Study Area 1, The Trent Valley around the Trent – Soar confluence

Upland and piedmont river systems have been characterised by high rates of lateral channel mobility throughout the Holocene, leaving a series of abandoned palaeochannels across the valley floor. The Middle Trent between Tamworth and Newark is characteristic of a high-energy upland / piedmont system.

The Trent Valley has been the focus of intensive geoarchaeological study as part of a number of components of the ALSF *Trent Valley Geoarchaeology* 2002 (PNUM 3307). In addition, the evolution of its major tributaries, the Dove and the Idle are currently the focus of a further ALSF study (*The Trent Tributaries Project*, PNUM 3850). In the middle Trent Valley, further collaborative research by the Universities of Birmingham and Exeter, funded by the ALSF (PNUM 3357) has resulted in a detailed archaeological investigation of the landscape and underlying deposits around the confluence of the River's Trent and Soar. Stage 1 of this project involved the collation and dovetailing of datasets collected using a combination of aerial (lidar, IFSAR) and ground-based remote sensing techniques (ground penetrating radar); this information allowed the construction of a preliminary model of confluence evolution. Stage 2 of the project (currently underway) is refining this model by dating key stratigraphic units, including palaeochannels, which in turn are being assessed for their environmental potential and consideration of taphonomic issues. Ground penetrating radar proved excellent in identifying structures within the terrace sediments, but poor in determining the internal structure of waterlogged, fine grained fills of palaeochannels; therefore, during Stage 2, further geophysical data is being collected for the palaeochannels using ERGI.

1.4.2 Study Area 2, The Idle Valley around Misterton Carr

The River Idle is a lowland river that has been generally stable within the landscape for the majority of the Holocene and has deposited fine-grained, organic rich sediments across the floodplain through vertical accretion.

The Misterton area has been the focus of geoarchaeological studies as part of a number of English Heritage funded initiatives including the Humber Wetlands Survey and the Trent Tributaries Project, both of which have utilised the expertise of members of the project team. Only a few kilometres upstream, close to Misson, the floodplain is also the focus of an intensive survey of groundwater dynamics being undertaken by the University of Hull (PN 3557).

1.4.3 Study Area 3, The Thames Valley around Port Meadow, Oxford

The River Thames around Port Meadow, a few kilometres north of the City Centre is a rich archaeological landscape. Although the archaeological remains identified at Port Meadow itself form part of a Scheduled Ancient Monument, the area to the north has been the focus of significant aggregate extraction, archaeological survey and excavation (notably, the Yarnton project undertaken by Oxford Archaeology and funded by English Heritage; http://www.oxfordarch.co.uk/micro_sites/yarnton/index.htm). The Thames around Port Meadow is also a lowland river, but in contrast to the Idle, it vertically accreted sediments are less organic than the peatlands of the River Idle. Historic map evidence suggests greater lateral channel migration, which may explain this contrast between these two lowland river systems. Although the project team has not worked in this area, the team have had discussions and are liasing with the Oxford City Council archaeologist (Mr Brian Durham), who is supportive of our proposed study.

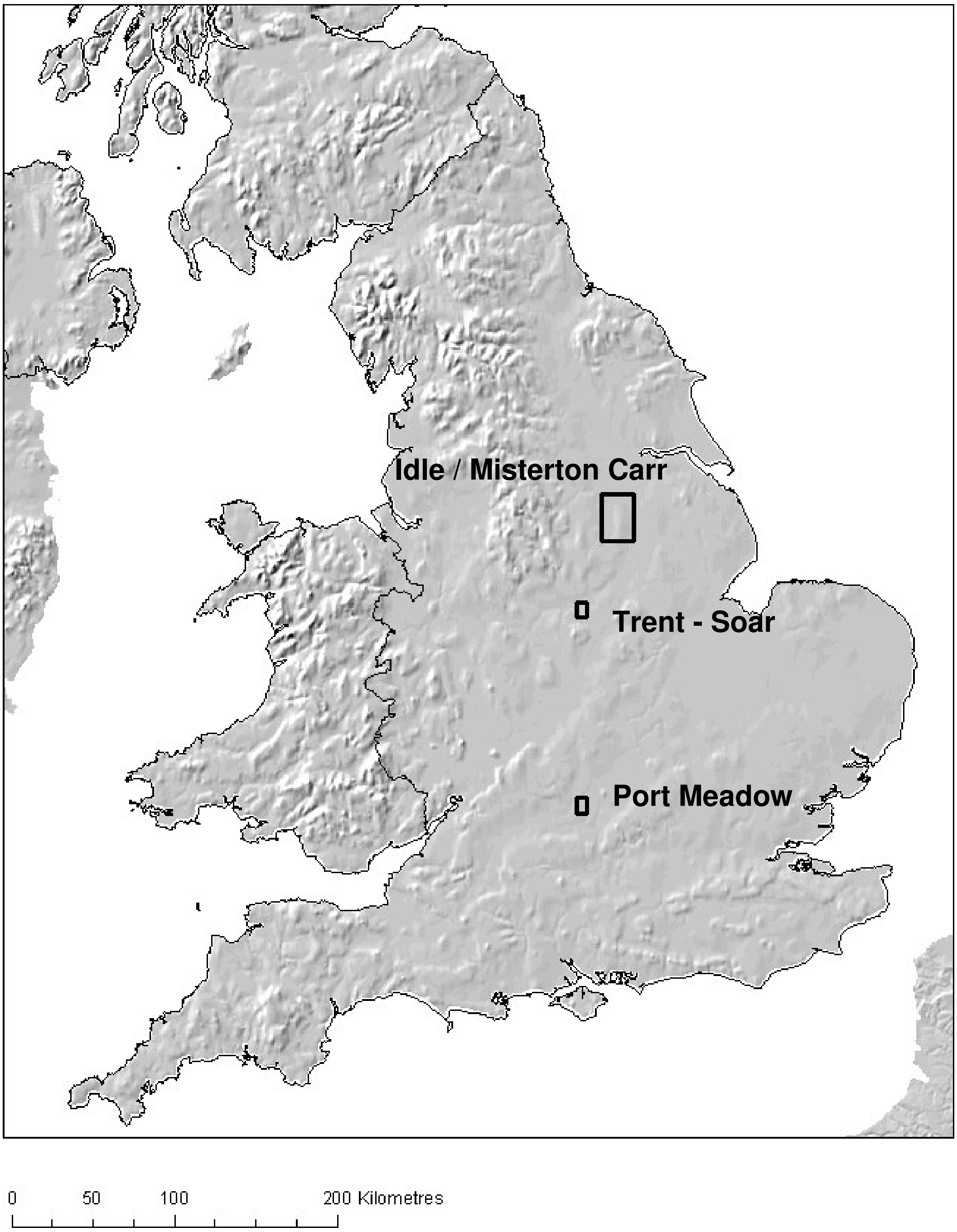

Figure 4. Proposed study areas.

2 AIMS AND OBJECTIVES

2.1 INTRODUCTION

The proposed project aims to rigorously investigate and document the use and potential of lidar to identify and characterise geoarchaeological and anthropogenic features where palaeoenvironmentally-rich sediments and associated cultural remains may be preserved by using backscattered laser intensity. The objectives of the project may be broken down into three themes:

1: Investigation of laser intensity.
2: Investigating backscattered intensity of airborne lidar.
3: Investigating EA off the shelf lidar for assessment of organic preservation.

Detailed aims and objectives for each theme are set out below.

2.2 THEME 1: INVESTIGATION OF LASER INTENSITY

This stage of the proposed project aims to investigate the land cover and properties influencing backscattered laser intensity. Since mobilisation of an airborne system is both costly and time consuming, with no guarantee that data can be collected to suite specific soil and vegetation conditions, work on this stage of the project will make use of a NIR terrestrial lidar with appropriate deployment and data manipulation to simulate airborne lidar.

The aims of this stage of the project are both to investigate the extent to which intensity data might allow identification of buried archaeological remains through their physical expression at the earth surface as crop or soil marks (including those not otherwise evident in the visible portion of the spectrum), and to examine and quantify the aspects of land cover, soil and sediment properties affecting intensity values.

It is axiomatic that lidar backscatter values reflect only land cover and soil properties evident at the surface. For lidar to provide a reliable indicator of the presence and state of preservation of buried archaeological remains it will be necessary to demonstrate that surface properties are influenced in a uniform and readily determined way by buried remains. This will be accomplished through a programme of systematic investigation of land cover properties (e.g. spectral properties of vegetation), soil and sediment character, both at the surface and within buried archaeological horizons so that, for example, it will be possible to demonstrate whether enhanced soil moisture at the surface reliably indicates the presence of wet buried features beneath.

The project will aim to investigate the impact of ground conditions and vegetation on lidar backscatter through examination of a variety of ground cover types. Briefly, work will aim to collect intensity data for sites with bare earth such as ploughed fields, equating to conditions where archaeological soilmarks may be evident, growing crops, where light crop cover is unlikely to give any indication of buried features using conventional techniques, and areas of mature crop where cropmarks might be expected to form. Areas of permanent pasture will be similarly investigated to determine to what extent archaeological remains may be detected and analysed through lidar backscatter in such conditions. Where possible test sites will be resurveyed on at least three occasions to capture data reflecting seasonal variations in soil, crop and vegetation cover. Information on weather conditions prior to each survey will be collected from the nearest Metrological Office ground station so that some attempt at gauging impact of prevailing conditions on soil properties may be made.

Fieldwork will collect laser backscatter data using a NIR terrestrial lidar to scan the ground surface at selected test sites (Figure 4). The use of a ground-based lidar will allow collection of dense data (100s points / m2) which can be resampled to reflect typical point densities for airborne lidar at varying resolutions. Use of a highly mobile ground-based lidar will allow rapid collection of multiple data on each survey visit to allow for example, the investigation of factors such as scan direction, angle of incidence, and short term environmental conditions on intensity values.

The project will examine a variety of site types, including geoarchaeological phenomena such as palaeochannels and anthropogenic features such as archaeological ditches and pits.

Backscattered intensity data will be compared with simultaneously collected information on land cover, soil and sediment properties. This will include analysis of the spectral properties of vegetation and soil cover and physical properties of soils through the analysis of sediment samples from each test site in order to assess organic content, moisture, geochemical signature and particle size. The level of preservation of a range of environmental indicators (pollen, insects, macroscopic plant remains) from underlying buried archaeological materials will also be assessed. Where possible sites where some or all of the palaeoenvironmental data exist from previous fieldwork will be selected to minimize the amount of new environmental data collection (and hence cost) of executing this task. Where new palaeoenvironmental assessments are to be made the degree of preservation will follow classifications developed by English Heritage specialists.

The condition of the groundwater table at each study area will be assessed through the measurement of soil moisture conditions at each site. In addition, hydrogeologists from Capita Symonds led by Dr Alan Thompson will provide advice on the overall condition of the water table around each test site and the potential implications of these conditions for our research. Initially, as part of this study, we planned to model groundwater conditions using aggregate company borehole records around each site. However, discussions between key members of the aggregates industry, Dr Howard and Dr Thompson have proved delicate and at this stage, the industry is reticent about providing access to these records. It appears that our requests have come at a rather sensitive time, especially given the wider discussions associated with the NIAN. Since both the PIs and Dr Thompson envisage that this research has potentially significant implications for the management of floodplains and therefore should form part of a longer term research strategy, we have decided against pursuing industry for these records at this point in time. However, we hope to stimulate their interest and support for this research in the future, once we can present some of the data to them.

The main aims of this theme are therefore:

- To assess the role that the physical characteristics of sediments and moisture conditions affect the backscattered laser intensity data.
- To assess the role that vegetation characteristics and the time within the growth cycle affects the backscattered laser intensity signal.

- To assess the degree of organic preservation revealed by multi-proxy environmental indicators (pollen insects, plant remains) in key depositional environments.

This theme comprises the following tasks, method statements for which are described in section 3.1.

1A: Selection of contrasting test sites
1B: Mobilising and training in terrestrial lidar
1C: Collection of terrestrial lidar data
1D: Collection of metrological data
1E: Collection of land cover spectral data
1F: Collection of data describing soil properties and environmental remains
1G: Processing and analysis of field data

2.3 THEME 2: INVESTIGATING BACKSCATTERED INTENSITY OF AIRBORNE LIDAR

This stage of the project aims to determine to what extent the properties of lidar intensity predicted though use of a terrestrial system hold true for airborne lidar. Airborne data for one or more test sites will be collected and similar calibration with land cover, soil and sediment properties undertaken as in stage one. In order to avoid the cost of new commissioned flights the team will liase with the EA airborne remote sensing facility and with commercial lidar providers to identify areas that will be flown in the future and co-ordinate field data collection with over flights in appropriate areas.

If possible, airborne data will be collected for one or more of the test sites examined in stage one of the project. Should this prove impossible, other test sites with equivalent geological, geomorphological and archaeological attributes will be selected from the flight areas available.

Intensity data from Optech airborne systems has a number of recognised but undocumented issues each of which will require careful investigation and consideration. Intensity values are not constant as sensors may be adjusted from flight to flight to provide different data collection parameters. Within any single flight, intensity values vary markedly depending upon the direction of the flight path so that for example, adjacent flight paths may exhibit different intensity values for similar earth surface materials (Figures 5 and 6). Since this means that intensity values are not recorded on an absolute scale and vary across or even within flights analysis will focus on change of intensity value within individual survey flights, and within flights on analysis of intensity values within individual flight lines. Analysis will focus on examination of the point cloud data from last pulse returns from the ground, not on examination of continuous surfaces interpolated from the point-cloud.

As with Theme 1 of the project, data related to land cover, soil and sediment properties will be collected allowing the direct comparison of data between Themes 1 and 2. In addition information on weather conditions prior to each flight will be collected from the nearest Metrological Office weather station so that some attempt at gauging impact of prevailing conditions on soil properties may be made.

The main aims of this theme are therefore:

- Compare the results of ground-based and airborne lidar backscatter intensity datasets
- Compare the results of ground condition parameters (vegetation, soil properties etc).

The following task groups are anticipated, method statements for which are described in Section 3.2.

2A: Identification of potential test sites
2B: Collection of land cover spectral data
2C: Collection of data describing soil properties and environmental remains
2D: Collection of metrological data
2E: Analysis of airborne lidar

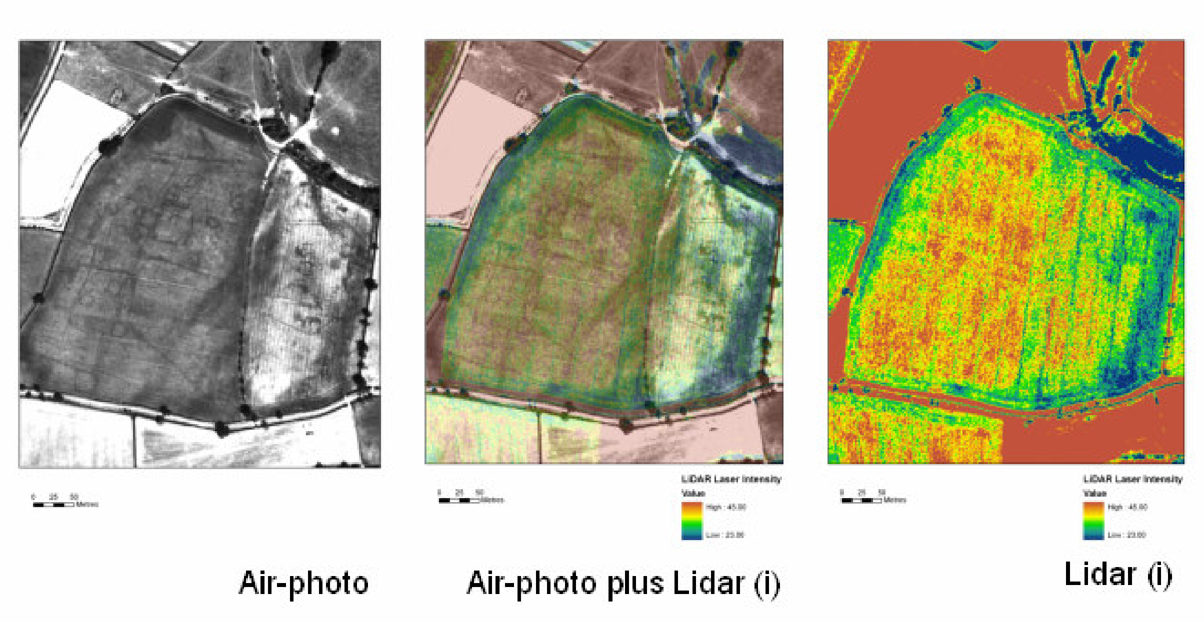

Figure 5. Comparison of an air photograph showing cropmarks and lidar intensity data on a test site at Roman villa on the River Trent at Lockington (after Challis 2005).

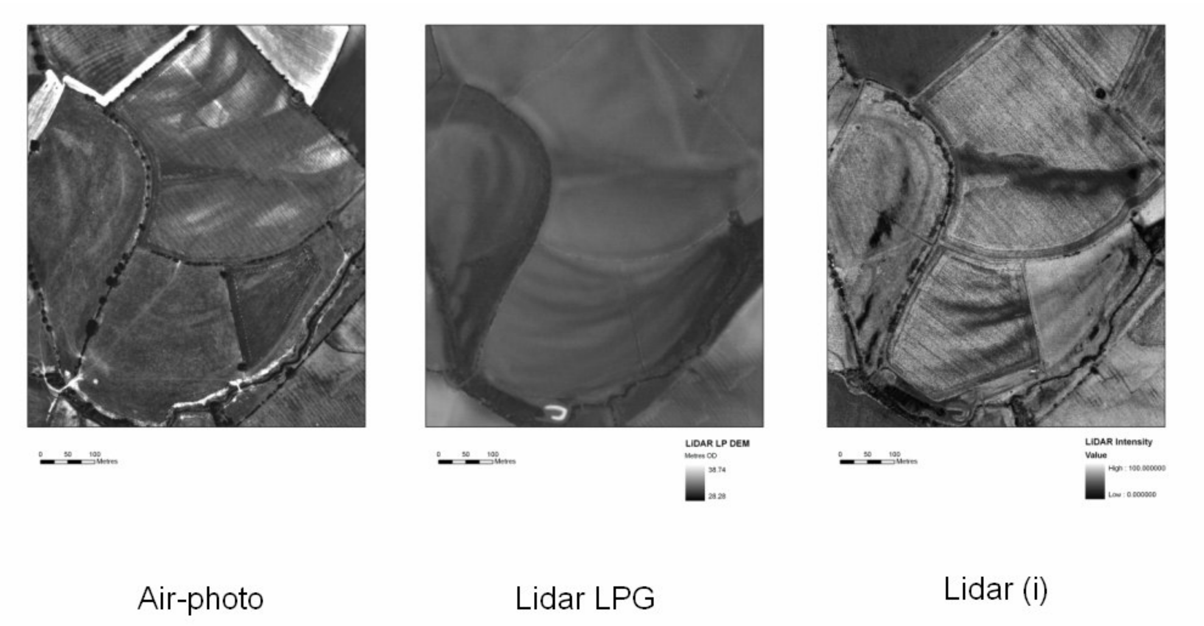

Figure 6. Comparison of air-photographic evidence, lidar last pulse surface model and last pulse intensity for a part of the Lockington test site (after Challis 2005).

2.4 THEME 3: INVESTIGATING ENVIRONMENT AGENCY OFF THE SHELF LIDAR DATA

The Environment Agency holds a considerable archive of lidar data for river corridors and coastal areas of England and Wales (Figure 8). These data have been collected over number of years (EA acquired its first lidar system in 1999) using a variety of Optech sensors (Brown et al, 2003).

In general flights were organised to collect 5 – 10 points m^2 and after appropriate processing these data were used to generate continuous surface models at 2m grid posting. Both point cloud and intensity data do not form part of EA's lidar data product; however, access to both is possible through reprocessing of original flight data (Figure 9), though this can be both time-consuming and costly.

This stage of the project aims to determine to what extent reprocessing of EA data to gain access to intensity measurement will provide any meaningful benefit for archaeological prospection and wider issues of catchment management. To this end, a number of study areas will be selected, wherever possible coincident with those investigated in stages one and two of the project. EA will be asked to reprocess original flight data to provide access to point cloud xyzi last pulse data. In order to assess variations in intensity data over time (using different Optech sensors) data from both early and more recent flights will be selected.

In each case information on weather conditions prior to each flight will be collected from the nearest Metrological Office weather station so that some attempt at gauging impact of prevailing conditions on soil properties may be made.

Should it prove necessary further information on soil and sediment properties at new test sites will be recovered to duplicate that information collected in stages one and two of the project.

The main aims of this theme are therefore:

- To assess the potential for reprocessing existing lidar data to provide meaningful data related to laser intensity

This theme comprises the following tasks, method statements for which are described in section 3.3.

3A: Selection of test sites
3B: Collection of land cover and soil property data from test sites.
3C: Collection of metrological data
3D: Analysis of airborne lidar data

Figure 7. Grey-scale image showing last pulse lidar intensity values for a part of the Idle Valley near Retford, illustrating the problem of variations in intensity caused by different flight-line orientation.

2.5 DISSEMINATION, REPORTING AND ARCHIVE

The principal aim of the dissemination stage of this project is to generate *generic* information of direct benefit to stakeholders in the aggregates industry and heritage sector. This will be accomplished by providing materials and information describing in non-technical terms the use and benefits of lidar intensity as a data source for assessing the presence, extent and character of environmental remains preserved within valley floor environments. Such information may help the aggregates industry to rapidly determine the environmental potential of any selected area of valley floor or the conditions of sediments prior to extraction and dewatering.

Indirectly, the collection of this data may provide a platform for considering more general issues of catchment management, particularly related to flood risk, climate change and the Water Frameworks Directive.

It is envisaged that information will be provided in a format suitable to inform those with a strategic management responsibility for archaeological resources (such as local authority archaeological officers) and those with an interest in assessment and evaluation of archaeological remains (the aggregates industry itself, archaeological consultants and contractors).

Information will be provided in the form of a succinct, non-technical document providing and explanation of the principles of lidar and the meaning and applicability of using data related to lidar intensity, advice on specifying lidar surveys for archaeological and catchment management purposes and good practice guidance on the analysis and presentation of lidar data. The completed document will be widely distributed and a summary will be offered for publication in *The Field Archaeologist* and *Quarrying Today.*

The document will be supported by a series of one-day workshops, aimed at key individuals in the stakeholder group, which will be held at Birmingham University and elsewhere.

A secondary aim will be to promote the research to the academic community, both as a contribution to advancing the research agenda for lidar and to gain critical peer review by the wider science community. At the completion of the project, a paper will be submitted for publication to an appropriate peer-reviewed journal: either *Archaeological Prospection*; *The Photogrammetric Record;* or *International Journal of Photogrammetry and Remote Sensing*. Further academic papers may be prepared for additional publication after the completion of the project if results warrant.

At the completion of project work, a well-ordered archive of digital data generated during research will be prepared. The archive will be presented to the archaeological data service for long-term storage.

The main aims of this theme are therefore:

- Dissemination and communication of the results of this research to key stakeholders through the preparation of a good practice document and one-day workshop.

- Dissemination and communication of the results of this research to the wider science community through peer-reviewed academic journals.

- Collation and presentation of project archive to the Archaeological Data Service.

This theme comprises the following tasks, method statements for which are described in section 3.4.

4A: Production of Good Practice Guide
4B: Workshops
4C: Academic Journal Paper
4D: Archiving of Project Data

3 METHOD STATEMENTS FOR FIELDWORK, DATA COLLATION, AND ASSESSMENT

3.1 THEME 1: INVESTIGATION OF LASER INTENSITY

3.1.1 1A: Selection of Contrasting Test Sites

The underlying control on the evolution of river valley floors and floodplain development is the contrasting geomorphological settings of the upland, piedmont and lowland landscape zones. In order to assess the effectiveness of this methodology, it is essential that river systems from these contrasting geomorphological contexts are selected and assessed. The study areas will consist of well-studied areas of river valley in the middle Trent Valley (Trent-Soar confluence, Leicestershire), the Idle Valley, Nottinghamshire (including for example Newington Quarry, where EH are presently funding detailed hydrological investigations Hull (PN 3557)) and Thames Valley (around Port Meadow, Oxford).

Product
The products of this project component will comprise:

- Landform assemblage maps for each of the study areas illustrating the key physiographic (terraces, palaeochannels) and archaeological features.
- Identification of experimental transects within each study area.

3.1.2 1B: Mobilising and Training in Terrestrial Lidar

Terrestrial lidar survey will be undertaken using a Measurement Devices Ltd (MDL) LaserAce scanner. The MDL scanner is lightweight, robust and easy to operate. Usefully it combines a reflectorless total station with an automatic scanning function, making geo-location of individual scans and stitching of multiple scans relatively easy. The LaserAce operates at 905nm providing an effective analogue of the Optech airborne lidar.

Training in use of the LaserAce scanner will be provided to project staff at the MDL UK base in York. In addition to instruction in operation of the scanner, MDL will assist in developing a suitable survey procedure, mounting system for the scanner and software to allow export of xyzi data for analysis and correction of range distance on intensity readings (allowing simulation of a near vertical scanner position using oblique survey data).

Product
The products of this project component will comprise:

- Training of project staff in use of the MDL LaserAce
- Development of a survey procedure and software routines.

3.1.3 1C: Collection of Terrestrial Lidar Data

Terrestrial lidar data will be collected from each study area on at least three occasions, where possible, reflecting bare earth (winter), light vegetation (spring) and mature vegetation (summer) conditions. Within each of these study reaches, intensity will be measured across a range of natural and archaeological features (e.g. palaeochannels to ditches) and substrates (e.g. terraces gravels to alluvium covered floodplains).

Product
The products of this project component will comprise:

- Collection of multi-season, xyzi terrestrial lidar data for suitable study zones within each study area.

3.1.4 1D Collection of Metrological Data

In order to assess the impact of short-scale variations in weather conditions, in particular rainfall, on soil properties information on weather conditions prior to each survey will be collected from the nearest Metrological Office surface weather station. Archive Met Office surface station data are freely available to academic researchers via the NERC British Atmospheric Data Centre (badc.nerc.ac.uk).

Met Office surface station data usually include at least indices of minimum and maximum temperature, rainfall and hours of sunshine. Data for the four weeks prior to each survey and the monthly averages for ten years prior to the survey will be collected and assessed. These will be used to determine prevailing conditions at the time of survey, and in particular whether soils are likely to be unusually dry (little preceding rainfall) or unusually wet (substantial preceding rainfall) or are likely to be seasonally wetter or dryer than the ten year average.

Product
The products of this project component will comprise:

- Collection of Met Office surface weather station data and analysis to determine possible impact of prevailing weather conditions on soils and survey results.

3.1.5 1E: Collection of Land cover Spectral Data

Data on the spectral reflectance of sunlight from the ground surface/vegetation in each surveyed area will be collected simultaneously with the terrestrial lidar data. This will provide a means of calibrating results from the terrestrial lidar (905nm) with those at precisely the wavelength of the airborne lidar (1047nm) as well as examining reflectance across the full spectral range. Spectral data will be collected using an ASD FieldSpec Pro spectroradiometer. This instrument offers a robust, easy to operate data collection system within the range 350-2500nm (visible blue to near infra-red).

Product
The products of this project component will comprise:

- Solar reflectance data for ground surface and land cover within each study area.

3.1.6 1F: Collection of Data Describing Soil Properties, Environmental Remains and Moisture Conditions

In order to understand precisely what affects laser intensity, the soils across experimental transects of each study area will be subjected to a number of basic sedimentological tests to determine their physical character. These tests will be undertaken on the top 1m of sediment and are required for quantitative data analysis. Provision has been made in the project budget for the full analysis of up to 30 samples (spread as required over tasks 1F, 2C and 3B).

- Particle size analysis: grain size will be measured by a grain size analyser. Grain size is known to affect water movement and moisture retention through soil.

- Loss on Ignition: this is a quick and effective way of measuring the organic matter content. We will use a two temperature LOI (550^{o}C and 850^{o}C) and the difference between the two is a measure of carbonate content and loss of water from clay minerals. In this case, due to the geochemical nature of the area it will be a measure of clay content. This work will be undertaken by Dr Chris Carey, Dept of Geography University of Exeter.

- The geochemical (elemental) signature of the sediment will be measured using ICP-MS. Major and minor trace elements we would look for include SiO_2, Al_2O_3, Fe_2O_3, MnO, CaO, MgO, Na_2O, K_2O, TiO_2, P_2O_5, Ba, Co, Cu, Ni, Sc, Sr, V, Y, Zn, Cr, Pb. This work will be undertaken by Dr Chris Carey, Dept of Geography University of Exeter.

- Soil moisture will be measured at multiple depths using a soil moisture probe and has been successfully trailed in the Trent-Soar area as part of the previously described combined Birmingham-Exeter project (ALSF PNUM 3357).

- Hydrologists and hydrogeologists from Capita Symonds will provide a broad assessment of groundwater conditions within each reach and comment on the implications of their assessment for this research. This group, led by Dr Alan Thompson, has worked closely with the aggregates industry on a number of groundwater projects and are currently designing a catchment management plan for the Trent Valley as part of an Environment Agency strategic review. Their input to this project and the close linkages they bring with the aggregates industry are viewed as essential for future stakeholder liaison.

- The preservation potential of organic sediments identified at key localities in the experimental parts of the study areas will be assessed. Where necessary, sediment cores will be collected to a depth of 1m and sub-samples of organic material will be analysed from the top, middle and bottom to assess the state of preservation of pollen, insect remains and plant macrofossils. The nature of preservation will be assessed with respect to well-established schemes designed by English Heritage specialists (Kenward and Large, 1998; Murphy and Wiltshire, 1994). In addition the group will liaise with Richard Brunning of the MARiSP project to ensure that as yet unpublished methodological refinements devised through his work are adopted.

3.1.7 1G: Processing and Analysis of Field Data

Terrestrial lidar data will be processed using proprietary software developed by MDL to allow accurate geo-location of each scanned area, stitching together of overlapping scans and correction of intensity values for range distance effects. XYZI point cloud data will be imported into suitable image-processing and GIS software for analysis.

Analysis of the lidar data will seek to determine to what extent cultural and geoarchaeological features are evident in both z and i values and to what extent soil and vegetation properties influence intensity.

Analysis will comprise visual inspection of the point cloud z and i values to identify topographical features of archaeological interest. Surveyed lidar data will be compared with the locations of known archaeological features and deposits and intensity values compared with data on soil properties and spectral characteristics of soils and vegetation cover.

Multivariate statistical analysis will be undertaken to determine which soil and vegetation properties influence lidar intensity, the degree of influence and its statistical significance.

In order to simulate the response of airborne lidar, regular grid arrays at 1m and 2m resolutions will be generated from the point cloud data through appropriate interpolation. The process of analysis will be repeated using the raster data in order to determine to what extent relationships evident in the raw point cloud are affected by interpolation to a regular grid.

Product

The products of this project component will comprise:

- Corrected xyzi point clouds for each survey area
- 1m and 2m resolution gridded data for each survey area (simulating airborne lidar)
- Analysis of point cloud and gridded data through visual and multivariate statistical comparison with the simultaneously recorded physical and spectral properties of soil and vegetation.

3.2 THEME 2 INVESTIGATING BACKSCATTERED INTENSITY OF AIRBORNE LIDAR

3.2.1 2A: Identification of Potential Test Sites

Access to airborne data for this project stage is dependent on establishing a good working relationship with lidar providers. Both Environment Agency (EA) and the commercial contractor Network Mapping (NM) have presented themselves as willing to participate in the project through providing advanced information on flight plans and access to airborne data.

Both EA and NM will be provided with information on the locations of test sites so that if possible, the sites used in stage one of the project will be investigated using airborne lidar.

In addition, should further suitable test sites be identified within the areas flown by EA and NM as part of their normal flying programme, opportunity will be taken where possible to investigate one or more of these sites and to collect ground-based data at the time of the lidar overflight.

Product
The products of this project component will comprise:

- Airborne lidar survey of one or more test sites identified by the project team in collaboration with EA and NM

3.2.2 2B: Collection of Land Cover Spectral Data

Data on the spectral reflectance of sunlight from the ground surface/vegetation in each surveyed area will be collected simultaneously with the airborne lidar data. Data collection will used the same equipment and method as described for terrestrial lidar in Section 3.1.4.

Product
The products of this project component will comprise:

- Solar reflectance data for ground surface and land cover within each study area.

3.2.3 2C: Collection of Data Describing Soil Properties, Environmental Remains and Moisture Conditions

In order to understand precisely what affects laser intensity, the soils across experimental transects of each study area will be subjected to basic sedimentological tests (as described in section 3.1.5) to determine their physical character. These tests will be undertaken on the top 1m of sediment and are required for quantitative data analysis. Full method statements for these tests are contained in section 3.1.6.

Product
The product of this component will comprise for each test site:

- Particle size analysis

- Loss on Ignition

- Assessment of soil moisture and groundwater conditions
- Sediment geochemistry
- Assessment of the preservation potential of organic sediments.

3.2.4 2D Collection of Metrological Data

In order to assess the impact of short-scale variations in weather conditions, in particular rainfall, on soil properties information on weather conditions prior to each survey will be collected from the nearest Metrological Office surface weather station. Archive Met Office surface station data are freely available to academic researchers via the NERC British Atmospheric Data Centre (badc.nerc.ac.uk). The method will follow that set out in section 3.1.4.

Product
The products of this project component will comprise:

- Collection of Met Office surface weather station data and analysis to determine possible impact of prevailing weather conditions on soils and survey results.

3.2.5 2E: Analysis of Airborne Lidar

Analysis of airborne lidar data will focus on establishing the extent to which known cultural and geoarchaeological features may be identified within z and i values and the relationship between varying soil and vegetation properties and intensity. Analysis will be undertaken using both point last pulse z and i values and regular grid arrays at 1m and 2m spatial resolutions generated from the point cloud.

Analysis will comprise visual inspection of the relationships of z and i values with known physical features and multivariate statistical analysis of the relationships between intensity and the various physical properties of the soils and vegetation.

Assessment will also consider the impact of flights at different seasons and in different types of ground cover on the ability to identify archaeological remains and the impact on the relationships between intensity and archaeology.

Attention will be given to the impact of flight direction on intensity values and the ability to resolve archaeological features.

Product
The products of this project component will comprise:

- 1m and 2m resolution last pulse gridded data for each survey area.
- Analysis of point cloud and gridded data through visual and multivariate statistical comparison with the simultaneously recorded physical and spectral properties of soil and vegetation.

- Assessment of the impact of different seasons and ground cover on the relationship between intensity values and archaeological remains.

- Assessment of the impact of flight direction on intensity values.

3.3 THEME 3: INVESTIGATING EA OFF THE SHELF LIDAR FOR ASSESSMENT OF ORGANIC PRESERVATION

3.3.1 3A: Selection of Test Sites

The EA hold an extensive archive of lidar data for England and Wales (Figure 9) collected using a variety of Optech sensors since 1999. The selection of test sites for analysis of archive EA data will include both coverage for the test sites investigated in stages 1 and 2 of this study and a selection of other test sites meeting project criteria. The selection of these latter sites will be undertaken in conjunction with the EA and allow the investigation of EA lidar collected with different generations of Optech sensor and at different seasons.

The EA will reprocess original flight data on behalf of the project team in order to provide access to last pulse z and i values.

Product

The products of this project component will comprise:

- Point cloud last pulse xyzi data for selected test sites extracted from the EA lidar archive

3.3.2 3B: Collection of Data Describing Soil Properties, Environmental Remains and Moisture Conditions

In order to understand precisely what affects laser intensity, the soils across experimental transects of each study area will be subjected to the basic sedimentological tests described in section 3.1.5 to determine their physical character. These tests will be undertaken on the top 1m of sediment and are required for quantitative data analysis. Full method statements for these tests are contained in section 3.1.6.

Product

The product of this component will comprise for each test site, assessment of:

- Particle size analysis
- Loss on Ignition
- Soil moisture and groundwater
- Sediment geochemistry
- Assessment of the preservation potential of organic sediments

3.3.3 3C Collection of Metrological Data

In order to assess the impact of short-scale variations in weather conditions, in particular rainfall, on soil properties information on weather conditions prior to each survey will be collected from the nearest Metrological Office surface weather station. Archive Met Office surface station data are freely available to academic researchers via the NERC British

Atmospheric Data Centre (badc.nerc.ac.uk). The method will follow that set out in section 3.1.4.

Product
The products of this project component will comprise:

- Collection of Met Office surface weather station data and analysis to determine possible impact of prevailing weather conditions on soils and survey results.

3.3.4 3C: Analysis of Airborne Lidar Data

Analysis of airborne lidar data will focus on establishing the extent to which known cultural and geoarchaeological features may be identified within z and i values and the relationship between varying soil and vegetation properties and intensity. Analysis will be undertaken using both point last pulse z and i values and regular grid arrays at 1m and 2m spatial resolution generated from the point cloud.

Analysis will comprise visual inspection of the relationship of z and i values with known physical features and multivariate statistical analysis of the relationship between intensity and the various physical properties of soils and vegetation.

Assessment will also consider the impact of flights at different seasons and in different types of ground cover on the ability to identify archaeological remains and the impact on the relationship between intensity and archaeology.

Attention will be given to the impact of flight direction on intensity values and the ability to resolve archaeological features.

Assessment will also consider the effectiveness of different generations of Optech sensor for resolving archaeological features.

Product
The products of this project component will comprise:

- 1m and 2m resolution last pulse gridded data for each survey area.
- Analysis of point cloud and gridded data through visual and multivariate statistical comparison with the simultaneously recorded physical and spectral properties of soil and vegetation.
- Assessment of the impact of different seasons and ground cover on the relationship between intensity values and archaeological remains.
- Assessment of the impact of flight direction on intensity values.
- Assessment of the effectiveness of different Optech sensors.

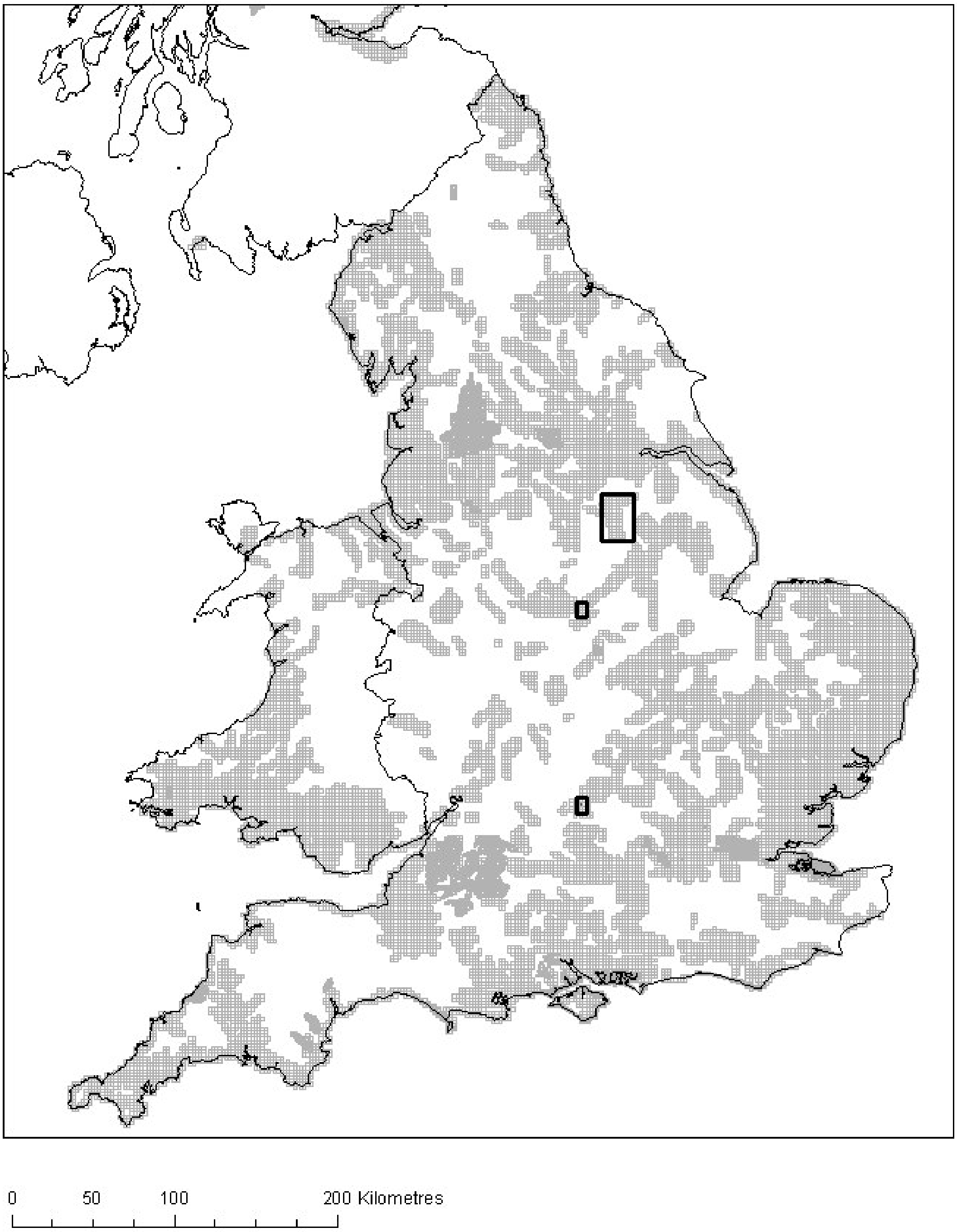

Figure 8. Map showing the extent of lidar coverage held by Environment Agency as of 2005. Proposed study areas are highlighted in bold.

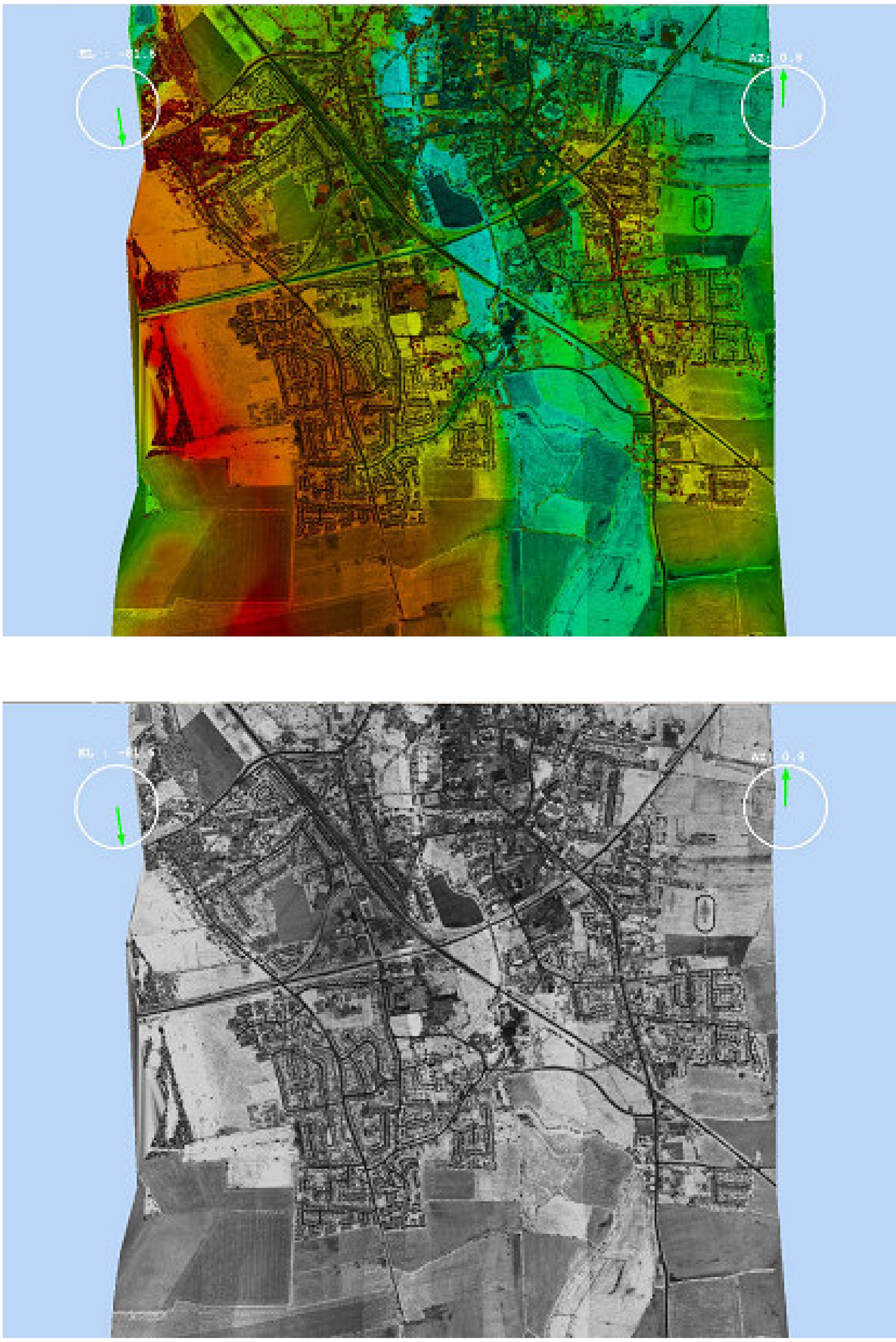

Figure 9. EA lidar data reprocessed to give access to a first pulse DSM (top) and first pulse intensity (bottom).

3.4 DISSEMINATION, REPORTING AND ARCHIVE

3.4.1 4A: Production of Good Practice Guide

A good practice document, aimed at stakeholders and written in a non-technical style will be produced at the end of the project. It will outline: (1) how to obtain Lidar data; (2) basic information on processing; (3) how this is applicable to the stakeholder community in general; (4) specific information related to intensity and its applicability to the stakeholder community. Once approved by English Heritage the document will be widely and freely distributed, initially to members of the Association of Local Government Archaeological Officers (ALAGO) and to selected stakeholders (eg EH Science Advisors) via a mail shot. A summary of the document will be offered for publication in *The Field Archaeologists* and *Quarrying Today* the magazine of the Quarry Products Association.

Website

Information about the project will be disseminated via the Trent Valley GeoArcheology website (www.tvg.org.uk) which is maintained by the project principal investigators and is located on a University of Birmingham server. This portal is already used for the dissemination of a number of ALSF projects being undertaken at Birmingham. Digital versions of the good practice guide will be made available for download in Adobe portable document format (PDF), as well as a copy of the PowerPoint presentation and accompanying notes used in the workshops (see below). Users will be required to complete a short registration process before downloading reports. This process will follow the model successfully implemented for TVG2002 reports. By November 2004, 42 registered users had downloaded TVG2002 reports including users from the UK, USA and continental Europe.

Product

The products of this project component will comprise:

- A good practice document distributed free to stakeholders
- Publications in *The Field Archaeologists* and *Quarrying Today*
- Creation of a link page to the project via the TVG website
- Reports in Adobe PDF and PowerPoint formats available for download from the project website.

3.4.2 4B: Workshop

A series of workshops will be held, initially at the University of Birmingham and subsequently at two regional venues (York and Southampton) inviting key members of the stakeholder community (aggregates representatives, heritage managers, other academics etc) to view the results of this work and its applicability to the minerals and archaeological communities. In essence, the workshop will take the stakeholders through the Good Practice Guide and offer the opportunity for comment and question.

Product

The products of this project component will comprise:

- Three workshop sessions at the University of Birmingham, York and Southampton.
- Literature and PowerPoint presentations; they also form a product of 3.4.1.

3.4.3 4C: Academic Journal Paper

The project team will produce an academic paper summarising the research undertaken as part of the project for publication in a suitable peer-reviewed journal. The paper will reflect both the archaeological and remote sensing aspects of the project. Briefly, it will consider:

1. Use of terrestrial lidar as an analogue for airborne lidar
2. Analysis of terrestrial and airborne intensity
3. Relationship of intensity to soil and vegetation properties
4. Relationship of intensity to archaeological deposit preservation.

Product
The products of this project component will comprise:

- At least one academic paper in an appropriate peer-reviewed journal

3.4.4 4D: Archiving of Project Data

A digital archive of data generated by the project ream will be prepared. The archive will be accompanied by full metadata using the standards recommended by ADS; it will be deposited with ADS at the completion of project work. Note that copyright and licensing issues prevent airborne lidar and other third party data forming part of the final product archive.

Product
The products of this project component will comprise:

- A digital archive of original data generated by the project team.

4 RESOURCES AND PROGRAMMING

4.1 WORKPLAN AND TIME MANAGEMENT

4.1.1 Task List and Time Allocations

	KDC	AJH	BRG	DM	Ano	DS	Task Total
1A: Selection of Contrasting Test Sites	1	1	1	1	1	1	**6**
1B: Mobilising and Training in Terrestrial lidar	-	-	-	5	-	-	**5**
1C: Collection of Terrestrial lidar Data	5	-	-	10	2	-	**17**
1D: Collection of metrological data	-	-	-	5	-	-	**5**
1E: Collection of Land Cover Spectral Data	2	-	-	5	2	-	**9**
1F: Collection of Data Describing Soil Properties…	2	1	-	-	15	1	**19**
1G: Processing and Analysis of Field Data	5	-	4	10	10	3	**32**
2A: Identification of potential test sites	1	-	0.5	1	1	0.5	**4**
2B: Collection of Land Cover Spectral Data	2	-	-	10	2	-	**14**
2C: Collection of Data Describing Soil Properties…	-	-	1	-	20	1	**22**
2D: Collection of metrological data	-	-	-	5	-	-	**5**
2E: Analysis of airborne lidar	5	-	-	15	-		**20**
3A: Selection of test sites	1	-	0.5	1	1	0.5	**4**
3B: Collection of land cover and soil property data	2	-	1	5	20	1	**29**
2D: Collection of metrological data				5			**5**
3D: Analysis of airborne lidar data	5	-	-	10	-	-	**15**
4A: Production of Good Practice Guide, etc.	5	1	1	15	10	1	**33**
4B: Workshop	2	1	1	2	2	-	**8**
4C: Academic Journal Paper	5	1	1	10	10	1	**28**
4D: Archiving of Project Data	1	-	-	5	4	-	**10**
Capita Symonds Groundwater Consultancy	-	-	-	-	-	-	**5**
Project Administration	6	-	-	-	-	-	**6**
Total	**50**	**5**	**10**	**120**	**100**	**10**	

4.1.2 Milestones and Monitoring

Four project milestones are proposed for the purposes of monitoring satisfactory progress on the project. These are as follows:

Milestone 1: Completion of first phase of terrestrial lidar surveys, June 2006.

Milestone 2: Completion first phase of airborne lidar surveys, Sept 2006.

Milestone 3: Selection of EA test sites, Dec 2006.

Milestone 4: Completion of draft good practice document, Feb 2007.

4.1.3 Project Management and External Validation

The project will be managed on behalf of the HP Vista Centre, Birmingham Archaeology, by Keith Challis. It is proposed to set up a steering group for the project, with the aim of meeting once mid-way through the research, comprising representatives from the following organisations:

- English Heritage (Mr Simon Crutchley)
- English Heritage (Dr Jim Williams)
- ALAGO (tbc)
- Mr B Durham (Oxford City Council)
- Environment Agency (tbc)
- Network Mapping Ltd (Mr Nick Hanmer)
- Infoterra Global Ltd (tbc)
- Institute of Archaeology and Antiquity University of Birmingham (Prof V L Gaffney)
- Landscape Research Centre (Mr D Powlesland)

Periodic reports on progress will also be presented for peer review to the lidar special interest group of the Remote Sensing and Photogrammetric Society (RSPSOC). Note that KDC is a member of the steering committee of this group.

4.1.4 GANNT Chart

Task	Months from Project Start											
	01	02	03	04	05	06	07	08	09	10	11	12
1A: Selection of Contrasting Test Sites	■											
1B: Mobilising and Training in Terrestrial lidar	■											
1C: Collection of Terrestrial lidar Data		■	■	■	■	■	■	■	■	■		
1D: Collection of Metrological Data		■	■	■	■	■	■	■	■	■		
1E: Collection of Land Cover Spectral Data		■	■	■	■	■	■	■	■	■		
1F: Collection of Data Describing Soil Properties…		■	■	■	■	■	■	■	■	■		
1G: Processing and Analysis of Field Data		■	■	■	■	■	■	■	■	■		
2A: Identification of potential test sites	■											
2B: Collection of Land Cover Spectral Data		■	■	■	■	■	■	■	■	■		
2C: Collection of Data Describing Soil Properties…		■	■	■	■	■	■	■	■	■		
2D: Collection of Metrological Data		■	■	■	■	■	■	■	■	■		
2E: Analysis of airborne lidar		■	■	■	■	■	■	■	■	■		
3A: Selection of test sites								■	■	■		
3B: Collection of land cover and soil property data								■	■	■		
3C: Collection of Metrological Data								■	■	■		
3D: Analysis of airborne lidar data								■	■	■		
4A: Production of Good Practice Guide, etc										■	■	■
4B: Workshop										■	■	■
4C: Academic Journal Paper										■	■	■
4D: Archiving of Project Data										■	■	■

The proposed start date for the project is 28th March 2006. Given a start data in March 2006, project work will be completed by 16th March 2007.

4.2 PERSONNEL

Keith Challis, BA MPhil MSc
Birmingham Archaeology
Keith Challis is GIS and Remote Sensing Manager with Birmingham Archaeology and a Research Fellow in the Institute of Archaeology and Antiquity, University of Birmingham. He specialises in archaeological applications of GIS and remote sensing in alluvial environments, he is a member of the Remote Sensing and Photogrammetric Society and serves on the steering committee of the Lidar Special Interest Group. Keith will take responsibility for the terrestrial and airborne lidar aspects of the project and will also be the principal point of contact for the project and will act as project manager.

Dr A J Howard, BSc PhD
Institute of Archaeology and Antiquity, University of Birmingham
Dr Andy J Howard is a lecturer in geoarchaeology in the Institute of Archaeology and Antiquity, University of Birmingham. His research interests include geoarchaeology and fluvial environmental change (both Pleistocene and Holocene histories). Andy will supervise the characterisation of the study areas, the physical characterisation of the sediments and liaise with the groundwater analysis team.

Dr Ben Gearey, BA, MSc, PhD
Senior Environmental Research Fellow, Birmingham Archaeology
Dr Ben Gearey is a Senior Environmental Research Fellow within Birmingham Archaeology and the IAA and specialises in pollen and plant macrofossil analysis. His current research interests include: the palaeoenvironmental and archaeological record of wetland landscapes, in particular raised mire systems, the geoarchaeology of alluvial landscapes and palynological approaches to Holocene landscape change. He has worked extensively across the UK and Europe. Ben will co-ordinate and supervise the palaeobotanical studies.

Dr David Smith, MA (Cantab), MA, PhD
Institute of Archaeology and Antiquity, University of Birmingham
Dr David Smith is a lecturer in the IAA specialising in Palaeoentomology. He has worked extensively on Pleistocene to late Holocene insect assemblages from floodplains throughout the UK. David will co-ordinate and supervise the palaeoentomological studies.

Research Assistant Remote Sensing
The project proposes to appoint Derek Moscrop as the GIS and remote sensing RA. Derek has already worked with the project team on the Trent Tributaries project. He has a post-graduate qualification in GIS and remote sensing.

Research Assistant Geomorphology and Palaeoenvironments
The person appointed as the geoarchaeology RA should have a well-balanced background in either environmental archaeology or geomorphology and be educated to at least Masters level. A full job description will be forwarded to EH if funding for this project is granted.

Dr Alan Thompson, BSC, PhD
CAPITA SYMONDS
Dr Alan Thompson is an Associate Director and Head of Earth Sciences at Capita Symonds Ltd., responsible for a team of 15 environmental and engineering geologists, hydrologists and hydrogeologists, working primarily for Central Government Departments and Agencies,

mineral operators, and private developers. Dr Thompson and his team will advise the project with respect to groundwater issues.

5 REFERENCES

Baker, S. (2003). *The Trent Valley: Palaeochannel Mapping from Aerial Photographs*. Trent Valley Geoarchaeology Research Report. Nottingham: Trent & Peak Archaeological Unit.

Bewley, R.H. Crutchley, S.P and Shell, C.A. (2005). New light on an ancient landscape: lidar survey in the Stonehenge World Heritage Site. *Antiquity* Volume: 79 Number 305: 636–647

Bewley, R. H. (2003). Aerial survey for archaeology. *The Photogrammetric Record* 18 (104): 273-292.

Bishop, M. (2003). Issues and agenda in archaeological research and management: a case study from the Trent Valley, UK. In Howard, A.J., Macklin, M.G. and Passmore, D.G. (eds) *Alluvial Archaeology in Europe.* Lisse: Balkema: 123-131.

Brown, A.G. (1997). *Alluvial Geoarchaeology. Floodplain archaeology and environmental change.* Cambridge: Cambridge University Press.

Brown, K., Duncan, A., O'Dwyer, C., Davison, B., Hogarth, P,. Butler, D. & Sampson, E. (2003). Integrated airborne data collection by the Environment Agency. In Aplin P. and Mather, P.M. (eds) *Proceedings of RSPSoc 2003: Scales and Dynamics in Observing the Environment, Nottingham, 10-12 September 2003*. Nottingham: The Remote Sensing and Photogrammetry Society.

Challis, K. (in press). Airborne laser altimetry in alluviated landscapes. *Archaeological Prospection.* DOI: 10.1002/arp.272. http://dx.doi.org/10.1002/arp.272

Challis, K. 2005a. *Predictive Modelling of Multi-Period Geoarchaeological Resources at a River Confluence Airborne Remote Sensing. Analysis of the Effectiveness of Aerial Photography, Lidar and IFSAR.* English Heritage PNUM3357.

Challis, K. 2005b. Airborne Lidar: A Tool for Geoarchaeological Prospection in Riverine Landscapes. in Stoepker, H. (ed) *Archaeological Heritage Management in Riverine Landscapes.* Rapporten Archeologische Monumentenzorg, 126: 11-24

Devereux, B.J. Amable, G.S. Crow, P. and Cliff, A.D. (2005) The potential of airborne lidar for detection of archaeological features under woodland canopies. *Antiquity*, Volume: 79 Number: 305: 648–660

Garton, D. & Malone, S. (1998). Geomorphology from aerial photographs in the Trent Valley. In Challis, K. (ed) Fieldwork by Trent & Peak Archaeological Trust in Nottinghamshire, 1996-7. *Transactions of the Thoroton Society of Nottinghamshire* 102: 139-141.

Kenward, H.K. and Large, F. 1998. Recording the preservation condition of archaeological insect fossils. *Environmental Archaeology* 2, 49-60.

Lambrick, G., 1992. Alluvial archaeology of the Holocene in the Upper Thames basin 1971-1991: a review, in Needham, S., and Macklin, M.G., eds., *Alluvial Archaeology in Britain*: London, The Society of Antiquaries of London, 209-225

Murphy, P.L. and Wiltshire, P.E.J. 1994. A proposed scheme for evaluating plant macrofossil preservation in some archaeological deposits. *Circaea* 11 (1), 1-7.

Riley, D.N. (1980). *Early Landscape from the Air. Studies of cropmark sites in South Yorkshire and North Nottinghamshire.* Sheffield: Department of Archaeology and Prehistory, University of Sheffield.

Robinson, M., and Lambrick, G., 1984, Holocene alluviation and hydrology in the Upper Thames basin: *Nature* (London), v. 308, 809-814.

Wehr, A. and Lohr, U. (1999). Airborne laser scanning – an introduction and overview. *ISPRS Journal of Photogrammetry & Remote Sensing* 54: 68-82.

APPENDIX 1: CURRICULUM VITAE OF PRINCIPAL INVESTIGATORS

Andy J. Howard BSc (CNAA), PhD (CNAA)

Appointments

Sept 2004 -	Institute of Archaeology and Antiquity, University of Birmingham
July 2002-August 2004	Senior Research Associate, University of Newcastle
Jan. 1998-June 2002	Research Fellow, School of Geography, University of Leeds.
Jan. 1997-Jan. 1998	Temporary lecturer, School of Geography, University of Leeds.
Jan. 1993-Dec. 1996	Geomorphologist/geoarchaeologist. Trent and Peak Archaeological Unit, Department of Archaeology, University of Nottingham.
Jan. 1989-Dec. 1991	Research Assistant. Department of Geology, University of Derby
June 1988-Dec. 1988	Water Resources Officer. Lee Valley Water Company, Harlow, Essex.

Key Research Areas

- The location, preservation, prospection and interpretation of archaeological resources in Holocene temperate and semi-arid alluvial landscapes.
- Deciphering climatic and cultural signals of environmental change in temperate and semi-arid alluvial basins.
- Pleistocene landscape development of eastern and northern Britain and the environmental setting of Palaeolithic communities.

Publication Record

I Books and Monographs

Knight, D. and **Howard, A.J.** (2004). *Trent Valley Landscapes*. Heritage Marketing and Publications Ltd, Kings Lynn.

Howard, A.J., Macklin, M.G. and Passmore, D.G. (2003) (eds) *Alluvial Archaeology in Europe*. Swets, Rotterdam

Howard, A.J. and Macklin, M.G. (1998) (eds) *The Quaternary of the Eastern Yorkshire Dales. Field Guide. The Holocene Alluvial Record*. Quaternary Research Association, London.

Knight, D. and **Howard, A.J.** (1995) *Archaeology and Alluvium in the Trent Valley: An Archaeological Assessment of the Floodplain and Gravel Terraces*. Trent and Peak Archaeological Unit, University of Nottingham.

II Chapters in Books and Monographs (Selected)

Howard, A.J., Whyman, M., Challis, K. and McManus, K.B. (Submitted). *The prospection and management of regional archaeological resources in the alluvial Vale of York, UK: the impact of the Aggregates Levy Sustainability Fund*. World Archaeological Congress 5, Conference Series. Routledge.

Macklin, M.G., **Howard, A.J.** and Passmore, D.G. (2003). The condition of Holocene alluvial archaeology in the UK: constraints and opportunities. In Howard, A.J., Macklin, M.G. and Passmore, D.G. (eds) *Alluvial Archaeology in Europe*. Swets, Rotterdam. 3-14.

Challis, K. and **Howard, A.J.** (2003). GIS based modelling of sub-surface deposits for archaeological prospection in alluvial landscapes. In Howard, A.J., Macklin, M.G. and Passmore, D.G. (eds) *Alluvial Archaeology in Europe*. Swets, Rotterdam. 263-275.

Howard, A.J., Challis, K. and Macklin, M.G. (2001) Archaeological resources, preservation and prospection in the Trent Valley: The application of Geographical Information Systems to Holocene Fluvial Environments. In Maddy, D., Macklin, M.G. and Woodward, J.C. (eds) *River Basin Sediment Systems: Archives of Environmental Change*. Balkema, Rotterdam. 405-419.

Howard, A.J., Smith, D.N., Garton, D., Hilliam, J. and Pearce, M. (1999) Middle to Late Holocene Environments in the Middle to Lower Trent Valley. In Brown, A.G. and Quine, T. (eds) *Fluvial Processes and Environmental Change*. Wiley, Chichester. 165-178.

III Papers in Refereed Journals (selected)

Howard, A.J., Whyman, M., Macklin, M.G., Challis, K., Coulthard, T. and McManus, K.B. (Submitted) Archaeological prospection and preservation in large alluvial basins: a case study from the Vale of York, UK. *Geoarchaeology*.

Howard, A.J. (In Press) The contribution of geoarchaeology to understanding the environmental history of the Trent Valley, UK. *Geoarchaeology*.

Smith, D.N. and **Howard, A.J.** (2004) Identifying changing fluvial conditions in low gradient alluvial archaeological landscapes: can Coleoptera provide insights into changing discharge rates and floodplain evolution? *Journal of Archaeological Science* **31**, 109-120.

Howard, A.J., Macklin. M.G., Bailey, D.W., Mills, S and Andreescu, R. (2004) Late Glacial and Holocene river development in the Teleorman Valley on the southern Romanian Plain. *Journal of Quaternary Science*.

Bailey, D.W., Andreescu, R., **Howard, A.J.**, Macklin, M.G. and Mills, S. (2002). Alluvial landscapes in the temperate Balkan Neolithic: transitions to tells. *Antiquity* **76**: 349-355.

Howard, A.J., Macklin, M.G., Black, S. and Hudson-Edwards, K.A. (1999). Holocene river development and environmental change in Upper Wharfedale, Yorkshire Dales, England. *Journal of Quaternary Science* 15 (3), 239-252.

Howard, A.J. and Macklin, M.G. (1999) A generic geomorphological approach to archaeological interpretation and prospection in British river valleys: a guide for archaeologists investigating Holocene landscapes. *Antiquity* **73 (281)**, 527-541.

Conference Convening

Knight, D. and **Howard, A.J.** (1995) *Man and environment in the Trent Valley since 10,000 BC*. University of Nottingham and Trent and Peak Archaeological Unit, Nottingham.

Howard, A.J. and Macklin, M.G. (1998) *Holocene Alluvial Systems in the eastern Yorkshire Dales*. Quaternary Research Association Short Field Meeting.

Howard, A.J., Macklin, M.G. and Passmore, D.G. (2000) *The Alluvial Archaeology of North-West Europe and the Mediterranean*. University of Leeds.

Membership of Professional Research Organisation Executive Committees

2001-2004	Member of Executive Committee, Quaternary Research Association.
2001-2004	Publications Secretary for the Quaternary Research Association.
2001-2003	Member of Executive Committee, Association of Environmental Archaeologists.
2002-	Member (Geoarchaeology) of the Scientific Advisory Committee for York Archaeological Trust and City of York.

KEITH CHALLIS BA(Hons) MPhil, MSc

PROFILE

Keith Challis is GIS and remote sensing manager for Birmingham Archaeology. His research interests lay in the use of GIS for archaeological and geological deposit modelling, particularly for archaeological prospection in alluvial landscapes, archaeological applications of airborne laser altimetry and use of GIS for landscape analysis and cultural resource management. Outside of the UK Keith has pursued research into the use of high-resolution satellite remote sensing for archaeological prospection and landscape analysis in arid environments.

Beyond remote sensing and GIS Keith has a research interest in the archaeology of the medieval English countryside, in particular rural settlement and land use. His excavations including a medieval settlement at Thurvaston, Derbyshire, medieval iron smelting site at Stanley Grange, Derbyshire, extensive landscape survey in Nottinghamshire and on-going research and survey at the open-field village of Laxton, Nottinghamshire

Keith's background is in commercial archaeology and he has managed archaeological excavation, research and consultancy in the East Midlands for fourteen years, first for Trent & Peak Archaeological Unit and more recently for York Archaeological Trust.

Key Interests

- Archaeological applications of Geographical Information Science and Remote Sensing
- The use of GIS for archaeological and geological deposit modelling, particularly for archaeological prospection in alluvial landscapes
- Archaeological applications of airborne laser altimetry
- Archaeological applications of GIS for landscape analysis and cultural resource management
- Use of high-resolution satellite remote sensing for archaeological prospection and landscape analysis in arid environments
- The archaeology of the medieval English countryside, in particular rural settlement and land use
- Assessment of archaeological impact of development
- Archaeological site investigation

RELEVANT QUALIFICATIONS

MSc (Distinction) Geographical Information Science. University of Nottingham 2001
MPhil Archaeology (Thesis title: *Early and Middle Saxon Essex*). University of Nottingham 1992
BA (Hons) Archaeology. University of Nottingham 1987

MEMBERSHIP OF SOCIETIES

Member of the Association of European Archaeologists
Member of the Remote Sensing Society
Member of the Council for British Research in the Levant
Member of the Medieval Settlement Research Group
Member of the Society for Medieval Archaeology

ARCHAEOLOGICAL CAREER HISTORY

2004 – Present	**HP Vista Centre**, Birmingham Archaeology, Institute of Archaeology and Antiquity, University of Birmingham. GIS and Remote Sensing Manager
2003 – 2004	**York Archaeological Trust** Project Officer / Field Officer
2000 – 2003	**Department of Archaeology University of Nottingham** Research Associate, Remote Sensing and Geographical Information Science. (Seconded from TPAU part-time)
1991 – 2003	**Department of Continuing Education University of Nottingham** Lecturer in archaeology and heritage conservation
1987 – 2003	**Trent and Peak Archaeological Unit** Field Archaeologist

1985-1986 **Museum of London DGLA**
Field technician

PUBLICATIONS

Papers in Refereed Journals
HENDERSON, J., **CHALLIS, K.**, MILWRIGHT, M., LARSSON, S., SAUNDERS, T. and TOWLE, A. in review "An Abbasid ceramic workshop at Tel Aswad al-Raqqa, Syria. Excavations 1998 – 2001". *Levant*.

HOWARD, A.J., WHYMAN, M., MACKLIN, M.G., **CHALLIS, K.**, COULTHARD, T. and MCMANUS, K.B. submitted. Archaeological prospection and preservation in large alluvial basins: a case study from the Vale of York, UK. *Geoarchaeology*.

CHALLIS, K. 2005. Airborne Lidar: A Tool for Geoarchaeological Prospection in Riverine Landscapes. *Rapporten Archeologische Monumentenzorg.*

CHALLIS, K. 2005. Airborne laser altimetry in alluviated landscapes. *Archaeological Prospection.*

HENDERSON, J., **CHALLIS, K.,** O'HARA, S., MCLOUGHLIN, S., GARDNER, A., and PRIESTNALL, G. 2005 "Experimentation and Innovation: Early Islamic Industry at Al-Raqqa, Syria." *Antiquity*.

CHALLIS, K., PRIESTNALL, G., GARDNER, A., HENDERSON, J. and O'HARA, S 2004 "Corona Remotely-Sensed Imagery in Dryland Archaeology: The Islamic City of al-Raqqa, Syria" Journal of Field Archaeology, 29.

CHALLIS, K. 2002 "A Medieval Iron Smelting Site at Stanley Grange, Derbyshire, UK" Historical Metallurgy 36 No 1.

HENDERSON, J., **CHALLIS, K.,** GARDNER, A., O'HARA, S. and PRIESTNALL, G. 2002 "The Raqqa Ancient Industry Project". *Antiquity,* 76.

Chapters in Books and Monographs
MCCAFFREY, C., **CHALLIS, K**., CRANSTONE, D., TRUEMAN, M., and NATHANAIL, C.P. 2005. *Guidance on Assessing the Risk Posed by Land Contamination and its Remediation on Archaeological Resource Management*. English Heritage. London.

CHALLIS, K. and HOWARD, A.J. 2003 "GIS-based modelling of sub-surface deposits for archaeological prospection in alluvial landscapes" in Howard, A.J. and Passmore, D. (eds) *The Alluvial Archaeology of Europe*." Balkema, Rotterdam.

HOWARD, A.J., **CHALLIS, K**. and MACKLIN, M. 2001 'Archaeological resources, preservation and prospection in the Trent Valley: The application of Geographical Information Systems to Holocene Fluvial Environments.' In Maddy, D., Macklin, M.G. and Woodward, J.C. (eds): *River Basin Sediment Systems - Archives Of Environmental Change.* Balkema. Rotterdam.

Papers in Other Journals
WHYMAN M., HOWARD, A.J., **CHALLIS K**. AND MCMANUS, K. submitted. Landscape and Settlement in the Vale of York. *Yorkshire Archaeological Jounrnal*.

CHALLIS, K. 2005. "Drowned in "a whyrlepytte": Nottingham Coroners' inquests and the late medieval River Trent." *Transactions of the Thoroton Society of Nottinghamshire*.

CHALLIS, K. 2004. "Airborne laser altimetry. Looking at the archaeology of river valleys inYorkshire and beyond." *Yorkshire Archaeology Today,* 6.

BESWICK, P. and **CHALLIS, K**. 2004. "Pottery from the medieval iron smelting site at Stanley Grange, Derbyshire" *Derbyshire Archaeological Journal,* 124.

CHALLIS, K. and BISHOP, M. 2003 "Risk Assessment" *GEOWorld* Vol 16.

CHALLIS, K. 2003 "Settlement Morphology and Medieval Village Planning: A Case Study at Laxton, Nottinghamshire" *Transactions of the Thoroton Society of Nottinghamshire,* 106.

CHALLIS, K., PRIEST, V., ALLEN, C. and KINSLEY, G. 2003 "A Roman Road At Belle Eau Park, Bilsthorpe, Nottinghamshire" *Transactions of the Thoroton Society of Nottinghamshire,* 106.

CHALLIS, K. and PRIESTNALL, G. 2002 "An Early Islamic Cityscape Revealed: Mapping The Historic Landscape Of Raqqa, Syria " - *GEOWorld* Vol 15.

CHALLIS, K. 1999 'Excavation of a medieval structure at Hemp Croft, Thurvaston, Derbyshire' *Derbyshire Archaeological Journal*, 119.

BISHOP, M. and **CHALLIS, K**. 1998 'Village Earthwork Survey in Nottinghamshire' *Medieval Settlement Research Group Annual Report,* 13.

CHALLIS, K. 1997 'Rescue excavation of a Medieval monastic iron smelting site at Stanley Grange, Derbyshire' in Crew, P. and Crew, S., (eds) *Early Iron Working in Europe; Archaeology and Experiment.*

CHALLIS, K. 1995 "Recent Excavations at Laxton, Nottinghamshire" *Medieval Settlement Research Group Annual Report,* 10.

GUILBERT, G. and **CHALLIS, K**. 1993 'Excavations across the supposed line of "The Street" Roman road, south-east of Buxton 1991.' *Derbyshire Archaeological Journal,* 113.

CONTRIBUTIONS TO CONFERENCES

Remote Sensing and Environmental Modelling in Alluvial Landscapes. Session convener. European Association of Archaeologists. Cork, September 2005.

Extending the Remote Sensing Record: Using Declassified Intelligence Satellite Imagery for Landscape Reconstruction in the Middle East. Forensic Remote Sensing and Geophysics Conference Joint EIGG (Environmental & Industrial Geophysics Group) and RSPSoc Meeting (The Remote Sensing & Photogrammetry Society) Geological Society, Burlington House, Piccadilly, London December 2004

Airborne Laser Altimetry in Alluviated Landscapes. BGS/RSPSoc Meeting Laser Scanning of the Environment Using Both Airborne and Terrestrial Techniques, British Geological Survey, Keyworth, Nottingham. November 2004.

Airborne Lidar: A Tool for Geoarchaeological Prospection in Riverine Landscapes. European Association of Archaeologists. Lyon. September 2004.

Floodplain Archaeology in Three Dimensions. Using Lidar and Boreholes Records to Map and Model the Geoarchaeology of the River Trent. Trent Valley GeoArchaeology. British Geilogical Survey. March 2004.

Airborne Scanning Laser Altimetry (Lidar) and Geographical Information Science (GIS) Some Thoughts on Applications for ALSF Project. English Heritage ALSF Technical Meeting. British Geological Survey. October 2003.

Wetlands at River Margins: Archaeological Preservation and Potential in Alluvial Environments. European Association of Archaeologists. St Petersburg. September 2003.

Mapping Floodplain Geoarchaeology using Airborne Laser Altimetry. World Archaeological Congress 5. Washington DC. June 2003.

GIS-based modelling of sub-surface deposits for archaeological prospection in alluvial landscapes. The Alluvial Archaeology of Europe and the Mediterranean. University of Leeds, December 2000.

Rescue excavation of a Medieval monastic iron smelting site at Stanley Grange, Derbyshire. Early Iron Working in Europe; Archaeology and Experiment. Plas Tan y Bwlch September 1997.

BENJAMIN RICHARD GEAREY BA, MSc, PhD

PROFILE

Ben Gearey is an environmental archaeologist with especial interest in palynology and the analysis of 'on site' and 'off site' deposits from a wide range of archaeological and landscape contexts. Other areas of experience include the geoarchaeology of alluvial landscapes, the archaeoenvironmental record of raised mires, the identification of palaeohydrological changes in mires using testate amoebae and plant macrofossil based approaches, with particular reference to the identification of autogenic and allogenic changes and the implications for past human activity in and around these landscapes. Current projects include investigation of the archaeology and environment of the raised mire complexes of Thorne and Hatfield Moors, South Yorkshire, funded by English Heritage and English Nature. Other ongoing projects include The Sutton Common Project (with the University of Exeter), funded by English Heritage and the Domuztepe Environments Project, SE Turkey, in collaboration with the University of Manchester and the University of California, Los Angeles.

RELEVANT QUALIFICATIONS

Ph.D. *'Human-Environment Relations on Bodmin Moor During the Holocene.'* Department of Geographical Sciences, University of Plymouth, (1992-1996)
M.Sc. (Distinction) *Environmental Archaeology and Palaeoeconomy*, Department of Archaeology & Prehistory, University of Sheffield (1991-1992), funded by Science and Engineering Research Council 'QUOTA' Award Competition
B.A. (Hons.) *History* (2.1), Department of History, University of Leeds (1988-1991).

ARCHAEOLOGICAL CAREER HISTORY

September 2005 - Present
Research Fellow in Environmental Archaeology, Institute of Archaeology and Antiquity, University of Birmingham.

August 2000- August 2005
Research Fellow and Part-time Lecturer, Wetland Archaeology and Environments Research Centre, Department of Geography, University of Hull.

March 1998-August 2005
Research Officer/Palaeoenvironmentalist, Centre for Wetland Archaeology (CWA), Department of Geography, University of Hull.

October 1996-March 1998
Research Fellow, School of Geography and Archaeology, University of Exeter.

OTHER APPOINTMENTS

June-October 1996
Research Assistant, Department of Geographical Sciences, University of Plymouth.

RECENT CONFERENCE PAPERS

***2000: December*:** Archaeology Under Alluvium, Department of Geography, University of Leeds. Paper presentation (with M.C.Lillie and H.P.Chapman): *High resolution geo-archaeological survey of the river Hull and its environs, England: the Late-glacial and Holocene record*.
Theoretical Archaeology Group, University of Oxford. Paper presentation (with H.P.Chapman) *Digital Gardening.*
***November*:** Recent Palaeoenvironmental Research in Ireland, Association for Environmental Archaeology, Queens University Belfast. Paper presentation: *Palaeohydrological Investigations at Derryville*.
People, Landscape and Cultural Environment, College of Ripon and St.John, York: Paper presentation (with J.R.Kirby) *Wetland and Dryland Vegetation Dynamics in the Humber Lowlands.*
***2001*: *December*:** Theoretical Archaeology Group, University College Dublin. Chaired session (with H.P.Chapman): *Palaeoecology and Phenomenology.*
***September*:** Changing Wetlands, University of Sheffield. Paper presentation (with M.J.Bunting). *Causes of retrogressive succession: a case study at Askham Bog, Yorkshire, England.*

***2002*: *September*:** Holocene Environmental Catastrophes and Recovery INQUA/PAGES, University of Brunel. Paper presentation (with C.Caseldine) *Getting wetter all the time: Palaeohydrological Investigations at Derryville Bog, Co.Tipperary, Ireland.*
***2003: April*:** Association for Environmental Archaeology, Queen's University Belfast. Paper presentation (with N.Bermingham and H.P.Chapman) *Towards an holistic approach to the archaeo-environmental record from raised mires.*
2004: September: Wetland Archaeology Research Project, University of Edinburgh. Paper presentation (with H.P.Chapman)

REPORTS and PUBLICATIONS

B.R.Gearey & C.J.Caseldine (2006 in press). Archaeological Applications of Tetstate Amoebae Analyses: A Case Study from Derryville Bog, Co.Tipperary, Ireland. *Journal of Archaeological Science.*
B.R.Gearey, A.R.Hall, H.Kenward, M.J.Bunting, M.C.Lillie & J.Carrott (2005 in press). Recent palaeoenvironmental evidence for the processing of hemp (*Cannabis sativa* L.) in eastern England during the medieval period. *Medieval Archaeology* **49**. *42*
B.R.Gearey & H.P.Chapman (2005 in press) *In situ* preservation, PPG16 and wetland archaeology in the United Kingdom: Some current concerns. *Conservation and Management of Archaeological Sites.*
C.J.Caseldine & **B.R.Gearey** (2005) Evaluation of a multi-proxy approach to reconstructing surface wetness changes in a complex raised mire system at Derryville Bog, Co.Tipperary, Ireland: identification of responses to a series of prehistoric big bursts. *The Holocene* **15, 4**, 585-601.
H.P.Chapman & **B.R.Gearey** (2004) The Social Context of Seafaring in the Bronze Age Revisited. *World Archaeology* **36, 4**, 452-458.
B.R.Gearey & H.P.Chapman (2004) Towards realising the full archaeoenvironmental potential of raised (ombrotrophic) mires in the British Isles. *Oxford Journal of Archaeology* **23, 2**, 199-208.
H.P.Chapman & **B.R.Gearey** (2003) Archaeological predictive modelling in raised mires: some concerns and approaches for their interpretation and management. *Journal of Wetland Archaeology* **2**, 77-88.
D.J.Charman, C.Caseldine, A.Baker, **B.R.Gearey** & J.M.Hatton (2001) Palaeohydrological Records From Peat Profiles And Speleothems In Sutherland, Northwest Scotland. *Quaternary Research* **55**, 223-234.
H.P.Chapman & **B.R.Gearey** (2000) Palaeoecology and the perception of prehistoric landscapes: some comments on visual approaches to phenomenology. *Antiquity* **74**, 316-319. (This article was reprinted in *Megaliths From Antiquity* (2003), T.Darvill &
C.Malone (eds), Cambridge, Antiquity Publications Ltd, 377-381).
B.R.Gearey, D.J.Charman & M.Kent (2000) Palaeoecological Evidence for the Prehistoric Settlement of Bodmin Moor, Cornwall, South-West England: Part I – The Status of Woodland and Early Human Impacts. *Journal of Archaeological Science* **27**, 423-438.
B.R.Gearey, D.J.Charman & M.Kent (2000) Palaeoecological Evidence for the Prehistoric Settlement of Bodmin Moor, Cornwall, South-West England: Part II - Land-Use Changes from the Neolithic to the Present. *Journal of Archaeological Science* **27**, 493-508.
B.R.Gearey, S.West & D.J.Charman (1999) The Landscape Context of Medieval Settlement on the South-Western Moors of England - Recent Palaeoenvironmental Evidence from Bodmin Moor and Dartmoor. *Medieval Archaeology* **41**, 195-208.
B.R.Gearey & D.D.Gilbertson (1997) Pollen Taphonomy of Trees in a Windy Climate: Northbay Plantation, Barra, Outer Hebrides. *Scottish Geographical Magazine* **113,** 2, 113-120.

Peer Reviewed Book Chapters and Conference Proceedings

C.J.Caseldine & **B.R.Gearey** (in press 2006) Multi-proxy Approaches to Palaeohydrological Investigations of Raised Bogs in Ireland: A Case Study from Derryville, Co.Tipperary. In N.Whitehouse and E.Murphy (eds) *Environmental Archaeology in Ireland*. Oxbow, Oxford.
M.C.Lillie, **B.R.Gearey** & H.P.Chapman (2003) Geoarchaeological Evidence for Holocene Landscape Evolution in the Hull Valley, Eastern England, UK. In A.Howard, M.Macklin & D.Passmore (eds) *Alluvial Archaeology in Europe - Proceedings of the Alluvial Archaeology of North-West Europe and Mediterranean Conference, Leeds, 18-19 December 2000.* A.A.Balkema, Rotterdam, 69-80.

Other Book Chapters

B.R.Gearey & H.P.Chapman (in press 2005) Digital gardening: a method for simulating elements of palaeovegetation and its implications for the interpretation of prehistoric landscapes. In P.Daly, T.Evans & V.Trifkovic (eds) *Archaeological Theory for a Digital Past.* Routledge, London.
B.R.Gearey & W.G.Fletcher (2004) Butterbump Barrow Cemetery, Lincolnshire Marsh: issues of investigation, interpretation and preservation in a wetland landscape. In E.Carver & O.Delong (eds) *Modern Views – Ancient Lands*. BAR 377. Archaeopress Ltd, Glasgow.

C.Caseldine, **B.R.Gearey**, J.Hatton, E.Reilly, I.Stuijts & W.Casparie (2001) From the 'Wet' to the 'Dry' - Palaeoecological Studies at Derryville, Co.Tipperary. In B.Raftery & J.Hickey (eds) *Recent Developments in Wetland Research*. Seandalaiocht: Mon 2, Dept. Archaeology UCD and WARP Occ.Paper 14, Dublin. Dept of Archaeology, UCD, 99-115.

B.R.Gearey & M.C.Lillie (2001) Routh Quarry. In M.D.Bateman, P.C.Buckland, C.D.Friedrick, N.J.Whitehouse (eds) *The Quaternary of East Yorkshire and North Lincolnshire*. Field Guide, Quaternary Research Association, London, 69-73.

M.D.Bateman, P.C.Buckland, R.Carpenter, S.Davies, C.D.Frederick, **B.R.Gearey**, N.J.Whitehouse (2001) Cove Farm. In M.D.Bateman, P.C.Buckland, C.D.Friedrick, N.J.Whitehouse (eds) *The Quaternary of East Yorkshire and North Lincolnshire*. Field Guide, Quaternary Research Association, London, 141-161.

J.R.Kirby & **B.R.Gearey** (2001) Wetland and Dryland Vegetation Dynamics in the Humber Lowlands. In M.A.Atherden (ed) *Wetlands In the Landscape: Archaeology, Conservation and Heritage.* PLACE Research Centre, York, 41-68.

D.J.Charman, **B.R.Gearey** & S.West (1998) New Perspectives on Prehistoric Human Impact on the Uplands of Devon and Cornwall. In M.Blacksell, J.Matthews & P.Sims (eds) *Environmental Management and Change in Plymouth and the South West*. University of Plymouth Publication, 1-21.

B.R.Gearey & D.J.Charman (1996) Testing Archaeological Hypotheses with Landscape Palaeoecology at Rough Tor, Bodmin Moor. In D.J.Charman. & D. Croot (eds) *Devon and East Cornwall: Field Guide.* Quaternary Research Association, London, 101-120.

Humber Wetland Project Monographs

In S.Ellis, M.C.Lillie, H.Fenwick & R. Van de Noort (eds) (2001) *Wetland Heritage of the Lincolnshire Marsh*. Humber Wetlands Project, University of Hull:

M.C.Lillie & **B.R.Gearey** Introduction to the Palaeoenvironmental Survey M.C.Lillie & **B.R.Gearey** The Palaeoenvironmental Survey of the Lincolnshire Marsh

In R.Van de Noort & S.Ellis (eds) (2000) *Wetland Heritage of the Hull Valley*: Humber Wetlands Project, University of Hull

M.C.Lillie & **B.R.Gearey** Introduction to the Palaeoenvironmental Survey: 21-31.

M.C.Lillie & **B.R.Gearey** The Palaeoenvironmental Survey of the Hull Valley and Research at Routh Quarry: 31-87.

In R.Van de Noort & S.Ellis (eds) (1999) *Wetland Heritage of the Vale of York*. Humber Wetlands Project, University of Hull:

B.R.Gearey & M.C.Lillie (1999) Aspects of the Vegetational History of the Vale of York: palaeoenvironmental investigations at Askham Bog: 35-79.

M.C.Lillie & **B.R.Gearey** (1999) The Palaeoenvironmental Survey of the Rivers Aire, Ouse, Wharfe and Derwent: 109-125.

A.Bayliss, C.Bronk-Ramsey, G.Cook, **B.R.Gearey**, R.Sparks and R. Van de Noort (1999) The Radiocarbon Dates: 289-297.

Dr. David Smith MA (Cantab) M.A. Ph.D.

Current position Lecturer, Institute for Archaeology and Antiquity, University of Birmingham

Qualifications

- *October 1989 - October 1992:* PhD in Palaeoentomology. Department of Archaeology and Prehistory, The University of Sheffield.
- *October 1988 - September 1989:* MA in Environmental Archaeology and Palaeoeconomy. Department of Archaeology and Prehistory, The University of Sheffield.
- *October 1985 - June 1988.* BA Honours Degree. Archaeology and Anthropology. Cambridge University. MA awarded 1990.

Key publications

Smith, D., Osborne, P. and Barratt, J. 2000. Chapter 14. Beetles and evidence of past environments at Goldcliff. In M. Bell, A. Caseldine, and H. Neumann (eds.), *Prehistoric Intertidal Archaeology in the Welsh Severn Estuary.* CBA Reserch Report 120. London: Council for British Archaeology. 245-260.

Brown, A.G., Copper, L., Salisbury, C.R. and Smith, D.N. 2001. Late Holocene Channel Changes of the Middle Trent: Channel Response to a Thousand Year Flood Record. *Geomorphology*. 39. 69-82.

Smith, D.N. and Howard, A.J. 2004. Indentifying changing fluvial conditions in low gradient alluvial archaeological landscapes: can Coleoptera provide insights into changing discharge rates and floodplain evolution? *Journal of Archaeological Science*. 31. 109-120.

Smith, D.N., Roseff, R., Bevan, L., Brown, A.G. Butler, S, G. Hughes, A. Monckton. 2005. Archaeological and Environmental Investigations of a Late Glacial and Holocene River Valley Sequence on the River Soar, at Croft, Leicestershire. *The Holocene*. 15.2.

Key skills

Dr. Smith has 15 years experience of both research and contract based palaeoentomology. He has participated in the planning of a number of large-scale environmental archaeology projects where the integration of a wide range of proxy environmental indicators, beyond his specialisation in insect remains, is necessary. This includes the analysis of considerable numbers of sites in the Trent and Severn River basins, close involvement with the Goldcliff and Redwick projects and large urban excavations in central London. Dr. Smith has a long record of completing projects to deadlines and producing integrated reports and publications.

APPENDIX 2: HEALTH AND SAFETY STATEMENT

POLICY AND IMPLEMENTATION

Birmingham Archaeology as part of the University of Birmingham, follows the requirements of the University's 'Safety Policy Statement'. This concerns general policy and principles, and is supplemented by codes of practice and guidance notes relating to specific activities. These include, of particular relevance to archaeology, 'Rules and Guidance for the Safe Conduct of Fieldwork, Expeditions and Outdoor Activities' and 'Health and Safety Guidance when Working Overseas'. For further guidance on health and safety issues specific to archaeology the manual 'Health and Safety in Field Archaeology' (Standing Conference of Archaeological Unit Managers, 1999) is used.

This Health and Safety policy is implemented and monitored according to the attached hierarchy of responsibilities. Each fieldwork project is co-ordinated by the Project Manager, who is responsible for the preparation of a risk assessment in compliance with the Management of Health and Safety at Work Regulations 1992 and the Construction (Design and Management) Regulations 1994, as appropriate. Supervisory staff are required to be familiar with these and the four documents listed in the paragraph above, and in addition are issued with a summary of their duties and responsibilities (*BUFAU Health and Safety Responsibilities of Supervisors July 1998*). They are responsible for maintaining health and safety standards during fieldwork. Site assistants and other staff in non-supervisory positions are issued with separate brief guidelines on safety standards, including instructions on what action to take in the event of any concern which may arise over safety procedures (*Birmingham Archaeology Health and Safety Guidelines for Employees*). Overall responsibility for monitoring the implementation of health and safety policy in the field lies with the Manager, with day-to-day responsibility delegated to the Health and Safety Co-ordinator. In situations where professional advice is required, inspections are undertaken by appropriate officers of the University's Safety Unit. The monitoring of safe working practices on Birmingham Archaeology's premises on the University Campus is the responsibility of the Health and Safety Co-ordinator, the Trade Union representative, and appropriate officers of the University's Safety Unit.

Training in health and safety issues is undertaken through the University's various training programmes. Field staff undergo training and examination in First Aid through the St. John Ambulance organisation. Training in safety awareness for staff using dumper trucks or other light plant is undertaken through the Construction Industry Training Board.

RELEVANT UNIVERSITY HEALTH AND SAFETY POLICY DOCUMENTS

- Health and Safety Policy Statement/Organisation and Arrangements: UHSP/0/97 (revised 1997)
- Management of Health and Safety within Budget Centres: UHSP/1/MHSCBC/94
- Risk Assessment: UHSP/3/RA/94 (incl. Assessment Form)
- Fire Safety: UHSP/4/FS/94 (incl. Fire Report Form, Induction Fire Training Checklist)
- Checking, Inspection and Testing of Electrical Equipment (Equipment Rated up to 240 volts): UHSP/5/CITEE/95
- Manual Handling Operations: UHSP/6/MHO/95 (incl. Assessment Form)
- Display Screen Equipment Use: UHSP/7/DSE/96
- Safety Footwear - Policy and Procedures: USP/90/SF/17
- Rules and Guidance for the Safe Conduct of Fieldwork: USP/90/FW/18
- Arrangements for COSHH Assessments: USP/91/ACA/20
- Accident/Incident Report Form: USP/92/AI/21
- Guidance on Equipment Provided for Use at Work: GUIDANCE/1/EPUW/97
- Guidance on Health and Safety Responsibilities: Undergraduate and Postgraduate Project Work: GUIDANCE/4/HSRUPP/98
- Work Station Design: GUIDANCE/5/WD/98
- Guidance for Work Experience Placements for Young Persons at The University: GUIDANCE/6/WEPYPU/98
- Guidance on Risk Assessment in Offices: GUIDANCE/7/RAO/98
- Guidance on Safe Work in Confined Spaces: GUIDANCE/8/SWCS/98
- Health and Safety, General Guidance: GUIDANCE/9/HSGG/98

HEALTH AND SAFETY RESPONSIBILITIES

Head of Budget Centre
(Prof. Shearer West)

Director of the Institute of Archaeology and Antiquities
(Prof. Ken Dowden)

Director of Birmingham Archaeology
(Dr Alex Jones)

Birmingham Archaeology Health and Safety Co-ordinator
(Jo Adams)

Project Managers

Site Supervisors

Site Assistants
Work Placements

Admin. And
Secretarial Staff

Finds Officer

Finds Managers and Supervisors

Finds Processors
Work Placements

Drawing Office Staff