Chapter 10. Conclusions and methodological Implications

10.1 Conclusions

- Stratigraphic modelling has showed the limitations of borehole modelling at the scale of an individual floodplain and how it could be improved with increased core density. The integration of exposure/section data with such models is possible but still presents technical problems.

- Radiocarbon dating of the cores and exposures has shown that there is a relationship between channel ages and ground surface height (OD) and a consistent spatial pattern produced by the history of channel change. Generally, older palaeochannels have a higher topography, whilst younger palaeochannels have a lower topography. From this the archaeological potential of palaeochannels can be estimated.

- OSL dating, which was largely successful, showed a greater Holocene age range than the radiocarbon dating indicating both earlier occupation of palaeochannels (i.e. indicating later re-occupation) and overbank deposition at times when no channel fills were being deposited or were deposited but since have been eroded (e.g. the Mesolithic).

- Dendrochronological dating of the tree trunks of Warrens Farm Quarry suggests that all the channels are of late Neolithic – early Bronze Age date (c. 2700-2500 BC) and several may have been felled at the same time. Apart from providing excellent dating of the channel activity it may also be archaeologically significant as it clearly represents floodplain deforestation, whether natural or human induced.

- The use of standard sedimentological analyses (e.g. LOI, CaCo3, magnetic susceptibility) illustrated well the complex nature of some of the channel fills and hiatuses caused by channel abandonment and re-occupation.

- The beetle assessment showed considerable variation in the preservation of sclera but a clear relationship with pH, preservation being better at the lower pH's in the dataset. Also important is depositional environment and sample size, as it appears that the combination of these factors are the most important in producing high quality data.

- The beetles data also indicated a predominantly species-rich grassland with grazing animals surrounded the channels during the Bronze Age at Warrens Farm Quarry with alder carr adjacent to one of the palaeochannels. A reconstruction of the thermal regime is made from the Devensian palaeochannel.

- Pollen and spore preservation and concentration is highly variable, with % damaged varying from 0 to nearly 100% and concentration varying from <743 grains ml^{-1} to 199,581 grains ml^{-1}. The only correlation with an environmental variable is with mean core pH and this is probably indirect. There is clearly a complex relationship between damaged grain concentration and depth although this is difficult to explore further given the variation in the depths of the sequences.

- Studies using NIR scanning of parts of the floodplain with the idea of detecting buried archaeological features through variations in soil moisture were not successful due primarily to technical limitations.

- The transect surveys showed that ER is a valuable tool for investigating the depth and internal stratigraphy of palaeochannel fills and is complimentary to the GPR survey used in Phase I.

- Comparison of the chronostratigraphic model with the observed dates from the palaeochannel fills revealed a good correspondence but with a slight tendency to misclassify Neolithic and Bronze Age channels as early Holocene. This would have been rectified easily if only the dendrochronological, or exposed face radiocarbon dates had been used in the initial chronostratigraphic model.

- Using all the data presented in Phases I and II a developmental/diachronic model of channel change is presented and it is suggested that it is driven by avulsion and palaeochannel re-occupation rather than channel migration.

- Lastly a methodological statement is presented which suggests a coherent and ordered set of tasks that can be used in an assessment and evaluation of a large floodplain area prior to intrusive studies and excavation which will maximise pre-intervention knowledge and set any intervention into its full environmental and geoarchaeological context.

- There is a strong predictable element in the results as in effect the chronostratigraphic model and associated environmental potential hypothesises in Phase I from LiDAR is largely proven by the analytical results in Phase II. Indeed with only the LiDAR and some subsurface information from boreholes, cores or combined GPR/ER a model of the archaeological potential could be proposed which would have been substantially correct. In this case the archaeological potential is defined by a combination of the age and type of deposit.

10.2 New research directions

This phase of the project has suggested a number of future directions for both research and management. The research directions are largely technical but not exclusively so. The research directions are:

- More work is definitely needed on the core density required to be able to produce subsurface models of an appropriate resolution for geoarchaeological purposes in conjunction with modelling packages such as ROCKWORKS.

- An illustrative application of both radiocarbon (including AMS fraction dating) and OSL of a single complex palaeochannel as exposed in a gravel quarry would be very useful as it could identify the optimum locations for future sampling.

- Core scanning (using Xray dispersive energy – e.g. ITRAX) needs to be investigated as a much faster and possibly cost effective method of characterising palaeochannel fill cores.

- Ground scanning has to be undertaken either from a height of 10+m and nearly vertical or new scanners need to be used which have technical fixes to the problem of range induced intensity variations.

- More research is required on improving the sensitivity of ER and coupling it with dGPS.

The management and implementation future directions are:

- The routine use of LiDAR for areas of floodplain assessment and evaluation and its use as the DEM basemap.
- Coupled use of GPR and ERGI to characterise palaeochannel and terrace deposits observed in the LiDAR data.
- The use of powered coring with automatic geolocation should be encouraged.
- Routine analyses (LOI and magnetic susceptibility) should be required of a selection of palaeochannel fills prior to other environmental analyses.

10.3 Methodological Statement for Archaeological Prospection in Confluence Zones

This report has demonstrated that river confluences are significant zones of archaeological activity. However, the evolution of confluences is complex (Best, 1988) and understanding their development is essential to identifying and managing the archaeological record. As with all alluvial environments, the key to elucidating their development and hence the character of the archaeological record is to understand the nature and timing of physical processes.

A number of research papers and other documents already exist, which provide generic methodologies for investigating alluvial valley floors (Howard and Macklin, 1999; Passmore et al., 2002; Passmore et al., 2006; Waddington and Passmore, 2006) as well as other best practice sampling strategies (e.g. Hey and Lacey 2001). Therefore, this document does not seek to repeat this corpus of information, but rather focuses on two key aspects of this work:

- Providing a methodological statement for confluence zones, which merit discussion in their own right.
- Demonstrating the value of taking an integrated approach to geoprospection using a combination of non-invasive remote sensing and geophysical techniques, calibrated through invasive coring and other field investigations.

1. Step 1. Desk-Based Assessment (DBA) of the Study Area

DBA should involve the collation of all relevant data and information in existence relating to the physical, cultural and environmental landscape. Preferably, this information should be collated and stored within a project GIS; for this study, we used ARC GIS, but it should be recognized that other systems are available. A key consideration when choosing a GIS should be compatibility of systems between project partners and end users, especially local government.

<u>Key datasets to collect</u>:

1a. Geological Data

Information relating to the solid and superficial geology of all of the British Isles has been collected by British Geological Survey (BGS) field geologists since the earlier 20th century. Originally produced as paper maps at varying scales, it is now also available as digital (Raster and Vector) datasets for capture within a GIS framework. In some cases, it may be that the solid geology is of relevance to the study, but in most cases, it will be the superficial (i.e. soft) sediments that are of interest. These will include the distinction of river terraces, alluvium, peats and other deposits such as colluvium and may allow major landforms such as palaeochannels to be identified and delimited; mapped data at a scale of 1:50,000 are of greatest use for reach scale geoarchaeological studies.

Assessment of stratigraphy and three-dimensional architecture of sediments can be obtained through the analysis of site-investigation boreholes and test pits where no surface exposures are available. The National Geosciences Data Centre collects site investigation information generated by the BGS and its precursors, as part of its national strategic mapping programme, in addition to data provided by external organizations (e.g. mineral companies, public utilities). In some cases, not all the information will be publically available and even if accessible, the quality of these records does vary; nevertheless this data provides a valuable source of information.

Contact: British Geological Survey (www.bgs.ac.uk)

1b. Soils Data

Information relating to the soils developed on both solid and superficial geologies in England and Wales is now held by National Soils Resources Institute (previously collected by the Soil Survey of England and Wales). Traditionally published as paper maps of varying scale, this information is now available in a digital format.

Contact: National Soils Resources Institute (www.silsoe.cranfield.ac.uk/nsri)

1c. Hydrological Data

The NERC-funded Centre for Ecology and Hydrology at Wallingford (UK) holds a 'National Water Archive' comprising the 'National River Flow Archive' and the 'National Groundwater Level Archive'. This information may be used to model groundwater flows and in the case of extraction areas, can often be supplemented by groundwater data collected by individual mineral companies as part of their programmes of environmental monitoring.

Contact: Centre for Ecology and Hydrology (www.ceh.ac.uk)

1d. Historic Map Data

Since rivers are often laterally mobile, collation of the available historic map data will provide an indication of the position and character of former channels. 1st edition Ordnance Survey (OS) maps are available for the British Isles from approximately 1850 and can be purchased in digital format for collation within a project GIS. The position of former administrative boundaries may indicate the position of palaeochannels.

In addition, to OS sheets, Tithe maps and other cartographic sources provide additional information and full lists of such resources are usually available through county HERs.

Contact: Local government Records Office/HER

1e. Aerial Photographs (APs)

For identifying the natural landscape features of any study area including river terraces and palaeochannels, both oblique and vertical aerial photographs form an invaluable resource. The majority of county HERs holds multiple runs of both black and white and colour APs taken over several decades; the earliest are often attributable to the RAF in the immediate post WWII years. Given local meteorological conditions, especially the presence of cloud, it may be necessary to use multiple sets of APs; as with cropmarks (see below), the identification of landforms, especially wetter palaeochannels may vary from year to year depending on climatic conditions. As with other data sources, APs should be geo-rectified and incorporated within the GIS framework to allow the delimitation and plotting of landforms as discrete GIS layers.

If working in some more remote parts of the world, declassified (CORONA) aerial photography collected by US military satellites between 1960-1972 may prove particularly valuable (see Challis et al., 2004).

Contact: Local government HER

1f. Archaeological Data

All data relating to the 'known' archaeological resource of any area will be held within the local government HER (formerly the SMR). English Heritage has a supplementary database (MONARCH), which often includes additional records.

Traditionally, this information has taken the form of paper records and maps, but it is increasingly available in digital format. Whilst a valuable starting point, the robustness of these datasets are often lacking in several key respects:

- The distribution of data often shows spatial biases usually associated with interested amateurs/groups.
- The distribution of data does not take account of our present understanding of landscape evolution and geological filtering.
- The data usually is illustrated as single points, yet archaeological sites can cover several hectares.
- The location of and information relating to data points is often inaccurate and/or duplicated. HER data often requires significant cleaning within a GIS framework before meaningful assessments and interpretations can be made. This is especially true when attempting to dovetail HER-MONARCH databases.

In addition to the point data, the HER will also collate grey literature relating to archaeological interventions within the area of interest. If desired, this information can be collated and linked via a database (ACCESS) to a project GIS.

As part of English Heritage's National Mapping Programme (NMP), cropmarks have been systematically recorded across extensive tracts of English landscape. Traditionally produced in paper form, it is now available digitally for inclusion within GIS frameworks. The addition of this information to point data can considerably improve our understanding of the spatial extent of archaeological sites. It is unfortunate that in the majority of cases, aerial archaeologists have not mapped features relating to the natural landscape (e.g. landforms) since this would add considerably to these rich archaeological datasets.

Contacts: Local government HERs & English Heritage (www.english-heritage.org.uk).

1g. LiDAR Data

LiDAR provides a tool for the rapid and accurate mapping of topography and geomorphology over large areas of valley floor (Challis, 2006). The technique uses the properties of coherent laser light, coupled with precise kinematic positioning provided by a differential global positioning system (dGPS) and inertial altitude determination provided by an inertial measurement unit (IMU), to produce horizontally and vertically accurate elevation measurements. An aircraft mounted laser projects a coherent beam of light at the ground surface with the reflections recorded by a receiver. Travel times for the pulse/reflection are used to calculate the distance from the laser to the reflecting object. The vertical resolution of LiDAR is estimated to be 10cm-15cm.

Post-survey processing of the simultaneously recorded laser, location and altitude data allows reconstruction of elevation values for the ground surface. Raw survey data in the form of a three dimensional point-cloud are projected to a local map datum, sorted, filtered and used to generate a regular grid of elevation values. The laser receiver is able to record multiple returns for a single pulse, recording a partial return from the top of a semi-opaque object such as a woodland canopy (FP) and from the opaque ground beneath the canopy (LP). Other information, such as the intensity (amplitude) is also recorded. Intensity data provides a record of the backscattered intensity of reflection of each laser pulse. Backscattered intensity values vary according to changes in the reflectance of differing earth surface materials at NIR wavelengths (Wehr and Lohr, 1999).

As part of flood risk management studies, the Environment Agency (EA) has owned a LiDAR sensor for a number of years and flown the majority of river valley corridors in the England. This data can be bought in a standard processed format from the EA. In the past couple of years NERC has also acquired its own sensor and its services can be sought in the usual NERC equipment bidding rounds. In addition, private companies such as Infoterra have their own instrumentation and can provide a bespoke data collection service.

Contacts: Environment Agency (www.environment-agency.gov.uk; NERC (www.nerc.ac.uk); Infoterra (www.infoterra-global.com).

1h. Multi-Spectral Imagery Data

For a number of years, NERC has generated multi-spectral imagery using two airborne scanners: the Daedalus 1268 Airborne Thematic Mapper (ATM) and the Compact Airborne Spectographic Imager (CASI).

The Daedalus 1268 ATM records spectral reflectance and infrared radiation in 11 discrete bands; these range in wavelength from visible blue to thermal infrared. In contrast, the CASI–2 is a configurable hyper-spectral scanner capable of recording spectral reflectance in up to 288 spectral channels at varying spatial resolution.

Both instruments have produced data stored as digital archives by NERC. Such datasets offer potential to identify contrasts in vegetation, which may be related to discrete landforms such as palaeochannels, however, the potential of neither has been rigorously investigated by the archaeological community.

Contacts: NERC (www.nerc.ac.uk).

1.1. End Product of DBA Stage 1 of Project

At the end of the desk-based assessment, any project should have a robust GIS containing information that allows a preliminary understanding of the following issues:

- The geological evolution of the study area including the character of the sediments, landforms and the major geomorphological processes operating through time.
- A LiDAR generated Digital Terrain Model of the project area allowing the identification of major landforms with respect to the archaeological record. This will produce a 'Landform Assemblage Map' (see Passmore et al., 2002).
- Preliminary assessment and mapping of the spatial distribution of archaeology by period and type with respect to both landforms and geologies.
- A relative chronology of recent landscape development based on successive maps and other resources (e.g. APs).
- An assessment of the three dimensional geological record and its implications for archaeological prospection and preservation.

2. Step 2. Collection of Field Data of the Study Area

2a. Ground Truthing of Landform Assemblage Map

Whilst the identification and mapping of landforms can be undertaken within a GIS framework from the datasets collated in Stage 1, it is essential that ground truthing and additional geomorphological and geological field mapping is undertaken in order to determine the precise stratigraphic relationships between landforms and key sedimentological units. If necessary additional information about landforms and other units such as their further extent can be delimited and spatially referenced using a GPS to augment other data already held within the project GIS.

2b. Non-Invasive Stratigraphic Investigations

The application of GPR and ER prospection have a pivotal role to place in future geoarchaeological investigations. Both ER and GPR can be used to provide 2D sections, to look at the cross sections and stratigraphic relationships of different floodplain components, and also 3D surveys to produce volumetric diagrams of different features, such as palaeochannels or areas of terrace. GPR has proved itself to be reliable in identifying sediment sequences within gravel bodies and of overlying alluvial deposits, where the alluvium has low clay and water contents. In such instances basic stratigraphy can be modelled and inferences made on sediment composition based on the intensity of reflection. GPR is ineffective at revealing the stratigraphy of palaeochannel fills, when sediments are clay rich or have high water contents. Typically a 200MHz antenna can give good data resolution to c. 3m depth.

ER can be effectively coupled with GPR survey, to provide information on palaeochannel fills. ER does not define stratigraphy as well as GPR on areas of terrace, but major floodplain components can be defined, such as palaeochannels. In addition information can be gained on the nature of palaeochannel fill, such as the where areas of highest biotaphonomic potential are. In addition ER has a greater depth penetration potential than GPR using a 200MHz antenna and can be used to investigate the nature of gravel deposits, to locate/investigate deposits within the gravel body of higher biotaphonomic potential. The use of ER and GPR is strongest when the two techniques are used in conjunction. In addition, the use of gouge core survey (see below) can provide additional complimentary data that is useful for interpretation of the ER and GPR sections.

1c. Invasive Stratigraphic Investigations - Augering

Where sedimentary exposures are unavailable, augering can be used to record stratigraphy, calibrate instrumentation and provide samples for environmental analysis and landscape reconstruction. If collected on (relatively) regularly spaced grid intervals, such subsurface information can be used for 3d modelling of valley floor architecture using a range of software linked to a GIS framework (see Bates, 2003; Challis & Howard, 2003).

1d. Geochronology

As with all alluvial environments, the key to elucidating their development and hence the character of the archaeological record is to understand the nature and timing of physical processes. It is essential that the investigation of any site is accompanied by a well-designed and robust dating programme. Depending on the timescale and nature of datable materials, this may include the use if Radiocarbon techniques or other developing methods such as Optically Stimulated Luminescence (OSL) or Amino Acid Racemization. The possibilities for dating of sediments etc should be discussed early in any programme of work with suitable qualified dating specialists.

2.1. End Product of Fieldwork at Stage 2 of Project

At the end of fieldwork, any project should have a robust dataset that allows an understanding of the following issues:

- The geological evolution of the study area including the character of the sediments, landforms and the major geomorphological processes operating through time.
- A through understanding of the three dimensional geological record and its implications for archaeological prospection and preservation.
- A ground truthed Landform Assemblage Map that provides a thorough understanding of major landforms with respect to the archaeological record.
- A thorough understanding of the spatial distribution of archaeology by period and type with respect to both landforms and geologies.
- An absolute chronology of landscape development and the timing of key geomorphological events (e.g. erosion and sedimentation) and an assessment of the impacts of landscape evolution on the archaeological record.