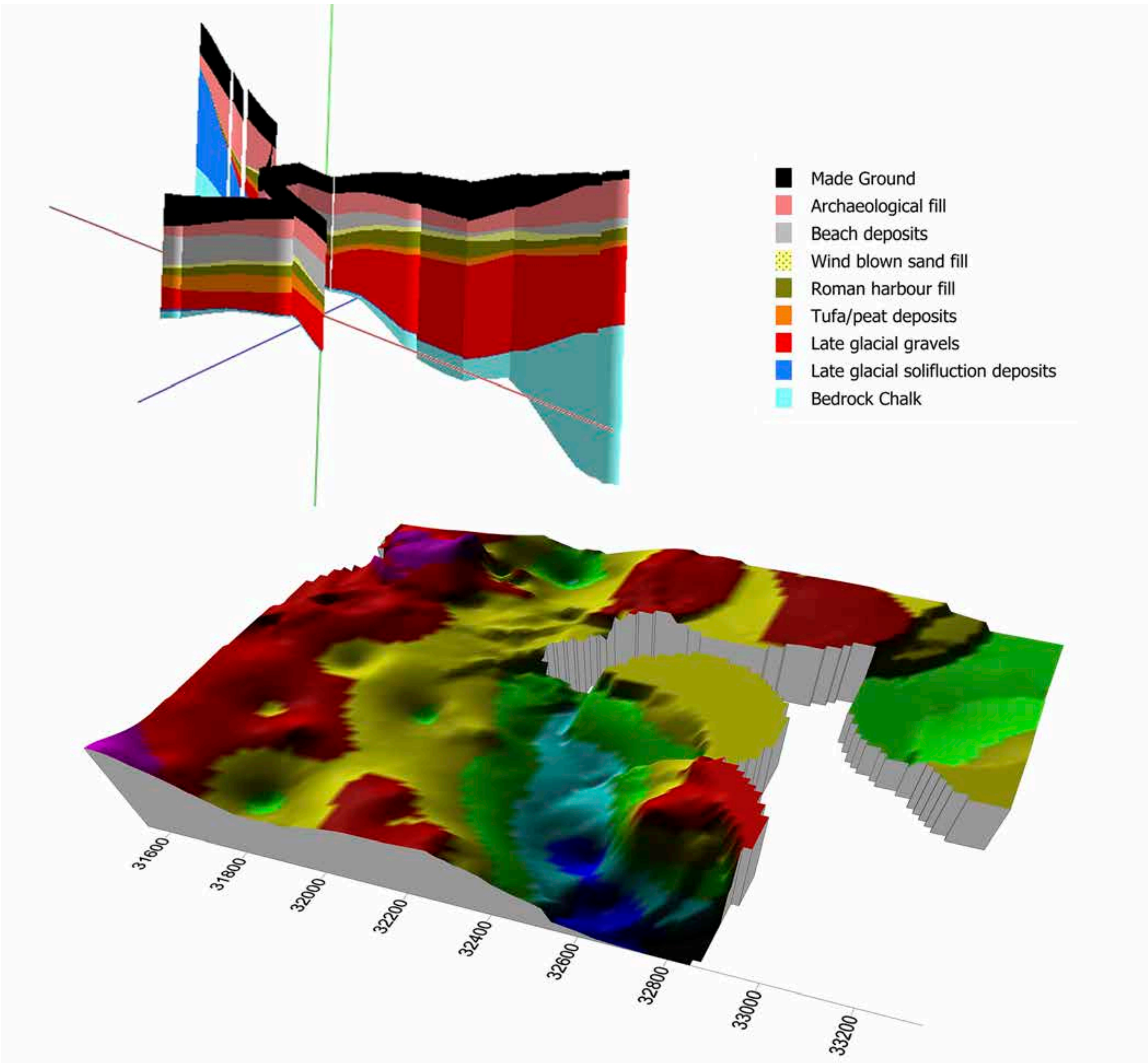
Historic England

Deposit Modelling and Archaeology

Guidance for Mapping Buried Deposits



Summary

This guidance is written to help archaeologists working within the context of development-led projects to understand what deposit models are and the benefits that can be gained by using them. It is also relevant to any archaeological work where the intention is to characterise deep sequences of deposits.

Deposit models use existing information to map the distribution of buried deposits of archaeological interest across a site or landscape. By interpreting when the deposits accumulated and what they represent, areas of greater and lesser archaeological potential can be identified. This enables subsequent fieldwork to be focused and the context of archaeological remains to be better understood.

A deposit model can:

- avoid blanket coverage in evaluation trenching
- identify areas of low archaeological potential
- identify areas of high archaeological potential
- guide the selection of appropriate evaluation and mitigation techniques
- aid communication with construction professionals
- facilitate the reconstruction of the palaeoenvironment

Using a deposit model as a desk-based technique early in the planning process can reduce risks, as well as inform mitigation by design.

For best value, a model will be constructed at the start of a project and will subsequently be refined and updated as additional data are collected during the project lifespan.

This guidance provides an overview of the deposit modelling process: where and when to use them, the information needed, how they are constructed, and what outputs to expect, as well as good practice for archiving and re-use. Case studies provide examples of using deposit models in a range of situations.

Practical information is provided in three appendices:

Appendix 1 illustrates how deposit modelling fits into the planning process

Appendix 2 sets out how to establish the scope for a deposit model

Appendix 3 gives a guide specification for deposit modelling

Additional details are set out in an accompanying technical monograph *Deposit Modelling and Archaeology* (Carey *et al* 2018), which provides a series of in-depth case studies written by deposit modelling practitioners.

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Front cover: Stratigraphy of Dover town centre illustrated in a fence diagram, with topographic plot of gravel surface.

Contents

1 Introduction

1.1 About this guidance

Deposit models are conjectural maps and cross-sections that can be used to investigate the archaeological significance of buried deposits.

To construct a deposit model, information about the buried soils and sediments at different locations across a site is examined and interpreted. Known information is extrapolated across areas not directly examined, in order to build up a picture of the buried deposit sequence. The results can be used to guide further work.

A deposit model enables decisions to be made early on in the planning process. By providing an early warning of what archaeological deposits and sediments exist, archaeological significance and the potential impact of the proposed development can more reliably be assessed.

The initial deposit modelling process can be desk-based. Value can be added by updating the model, as new information is recovered from fieldwork, thereby informing later project stages.

Deposit models are most useful where archaeological remains survive within or beneath deep sediment sequences, especially where they lie below the range of shallow geophysical survey.

This guidance is designed to lead the reader through the process of deposit modelling. It is written with the non-specialist archaeological ‘end-user’ in mind. It explains when to use, request or commission a model and how to understand its outputs and limitations. Although it is not intended to be a ‘how to’ guide for deposit model construction, the sections on assembling and building a model and its outputs will be useful to any archaeologist who uses geotechnical data.

Hyperlinks are given to case studies, most of which are described in detail in a supporting technical monograph (Carey *et al* 2018). A Glossary is provided for less-familiar terms.

Focus is on the terrestrial rather than marine environment. For complementary guidance on the investigation of submerged landscapes readers are referred to the off-shore guidance (Gribble and Leather 2011).

For archaeological investigations of the intertidal zone, which forms the boundary between fully-terrestrial and marine landscapes, it is advisable to consult both documents prior to commencing work.

1.2 Who should read it?

Construction and use of a deposit model requires input from a range of archaeologists, each with a different role to play:

Heritage managers (planning archaeologists) employed by local and national government organisations or by other quasi-national agencies are responsible via the planning process for assessing threats posed to archaeological deposits by development. They provide advice within the context of relevant legislation and planning policy, which forms the basis for establishing project briefs and broad criteria for evaluation and mitigation. This underpins the tendering process and requirements for deposit modelling.

Historic Environment Record (HER) officers working for local authorities or other public bodies, are responsible for maintaining databases of sites and finds for counties or unitary authorities, which can be a source of information for deposit models. As they can be the likely receiving officers of the completed model, they need to be consulted regarding file format to facilitate re-use of the model.

Archaeological consultants often provide the interface between contractors and clients. They engage with planning archaeologists, interpret project briefs, select contractors to undertake the proposed archaeological investigations, and draft specifications and Written Schemes of Investigation (WSIs) for tendering processes. These documents need to be sufficiently explicit to make sure all contractors cost against the same scope, which will assist in the selection of an appropriately-experienced contractor.

Project managers in contracting organisations are responsible for interpreting project briefs and specifications provided by the client or their consultants. They design and cost appropriate programmes of work to address these requirements, so it is important that they understand when a deposit model will benefit a project. Effective use of a deposit model by a project manager can assist the development of a more tightly-focused and reliably-costed project, and can help clients visualise the potential impacts of development upon the archaeological resource.

Supervising archaeologists working for contracting organisations are responsible for directing fieldwork, making sure that work is undertaken in line with the WSI and collating the results. They are also responsible for interpreting the archaeological stratigraphy and are best placed to integrate this with the results of deposit modelling. Understanding the deposit modelling process and its outputs will ensure suitable field records are made to feed into deposit model updates and that full use is made of deposit modelling to guide field strategies and to assist analysis and reporting.

Deposit modellers are typically geoarchaeologists and are responsible for creating the deposit model in a way that addresses the archaeological questions and meets the requirements of the WSI. Deposit modellers need to collaborate with supervising archaeologists, project managers and consultants, heritage managers and HER officers to ensure that the deposit models can be understood, used and re-used.

2 Deposit models: what, why and where?

A deposit model provides a visual representation of the vertical and lateral distribution of sediment units beneath the modern ground surface. It interprets the past environments, landscape processes and human activities represented by these buried deposits and provides an enhanced understanding of the archaeological potential (both cultural and palaeoenvironmental) of the **sub-surface stratigraphy**.

Using a deposit model is no more than an extension to established good practice, given that archaeologists already review pre-existing geotechnical reports to gain knowledge of ground conditions before designing and costing a project.

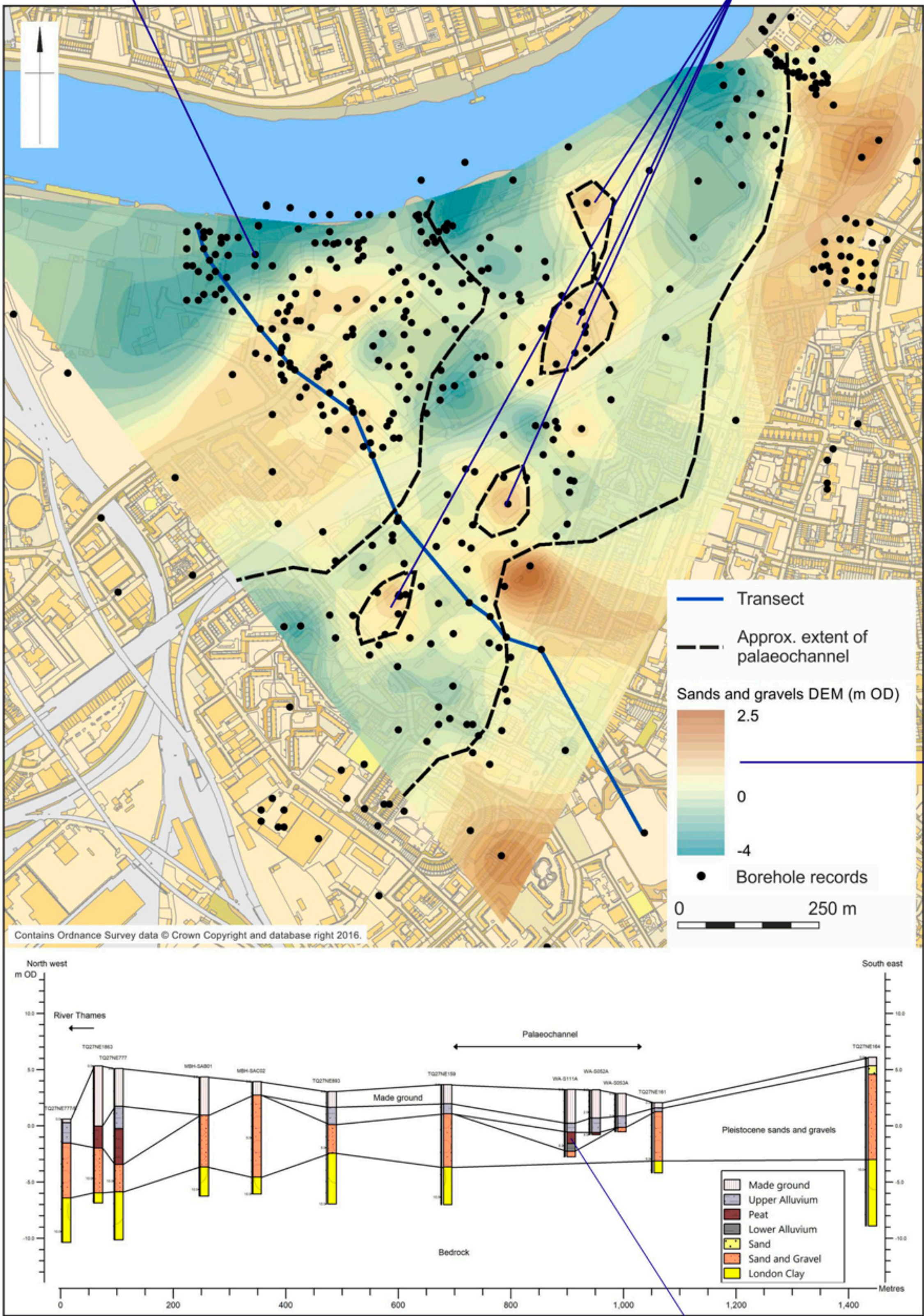
2.1 What does a deposit model look like?

A deposit model consists of maps, cross-sections and supporting text. A typical deposit model is illustrated in Figure 1. The aim of the modelling was to locate areas with the greatest potential for prehistoric archaeology below the modern urban street pattern of Wandsworth. Previous work nearby had found plough marks scoured into the sandy subsoil. Existing information from previous geotechnical boreholes and archaeological investigations (illustrated as black dots in Figure 1) recorded a deposit sequence of gravel overlain by sand and modern made ground, with peat and clay variably sandwiched in-between. By comparing the relative locations and heights of these deposits a pattern emerges. The surface of the sand is irregular and where it is low, peat and clay are present. This information is the crux of this model, allowing the modeller to identify a channel containing sandy islands within it.

The outputs illustrated in Figure 1 were selected by the modeller (Wessex Archaeology) to explain the findings of the modelling process to the end-user (planning archaeologist, developer, archaeological consultant and contractor). By superimposing the modelled surface of the sand over the street map, the location of islands (where the surface of the sand is at a higher elevation) can be identified. By drawing a schematic cross-section across the area, the likely depth of the sandy islands below modern ground level can be determined. The presence of peat in the channel areas also gives advance warning of the potential for waterlogged archaeology and palaeoenvironmental evidence, which could complement any evidence of dryland activity on the sandy islands. The map and the cross-section are

Borehole Locations
The modelled surface is more reliable where the boreholes are closer together'

Islands identified as potential foci of past activity



The street map allows the location of modelled deposits and features to be defined

Buried features are identified by mapping the underlying topography **(in this example a sand and gravel deposit surface)**

The cross-section (transect) is located on the map and shows the depth and distribution of deposits of interest

Peat within the palaeochannel is likely to preserve environmental remains, waterlogged artefacts or structures

Figure 1: A typical deposit model, with explanatory text. © Wessex Archaeology

supported by clear text explaining the findings of the model and making its limitations (such as the uneven borehole spacing) clear. Chapter 7 in *Deposit Modelling and Archaeology* (Carey *et al* 2018) provides more detail about this model.

Section 6 gives more information about what a deposit model looks like.

2.2 Why use them?

Where archaeological deposits do not lie immediately below the modern ground surface, but are buried by other sediments (eg **alluvium**), they can be invisible to standard methods of prospection (such as geophysical survey) and are likely to be poorly represented on Historic Environment Records (HERs). However, if previous geotechnical information exists, or is likely to be commissioned, this can be used to look at the types of buried deposits, to identify when they accumulated, what they represent and their archaeological potential. Done as a desk-based assessment (DBA) or preliminary site evaluation exercise, this can be a cost-effective method of predicting archaeological potential. In many cases no previous information exists, but deposit models can still be constructed from minimally-intrusive fieldwork: boreholes, deep geophysical survey or test pits, ideally in conjunction with geotechnical site investigations.

Constructing a deposit model at an early stage in any project means that subsequent field- and post-excavation work can be:

- targeted on areas, depths and locations most likely to preserve archaeological evidence
- more effectively communicated to a curator, consultant or developer
- understood and interpreted more robustly within its wider context
- costed realistically because:
  - likely depths to deposits of interest are known
  - the general character of the buried deposits is understood
  - the likelihood and extent of deposits requiring specialist input are identified at an early stage (eg organic and waterlogged deposits; a buried landsurface with the potential for preserving lithic artefact scatters)
  - areas of limited or no potential can be identified

By improving understanding of the significance of the buried deposits, a model can reduce risk to developers and can inform the design and location of the proposed development.

At a strategic level, the local, national and international importance of archaeological remains can be enhanced by the improved understanding of their environmental setting and spatial context provided by a deposit model. This emphasises its role as an essential component of management and decision-making for the historic environment.

Constructing a deposit model can also be the first step in large-scale, long-term archaeological projects involving multi-disciplinary teams, such as those investigating the preservation of waterlogged archaeological remains. This is explained in more detail in chapter 15 of *Deposit Modelling and Archaeology* (Carey *et al* 2018).

Section 7 gives further examples of using deposit models.

2.3 Where can they be used?

Deposit models can be applied in any landscape where sediments accumulate, either through natural or anthropogenic processes.

Natural sediments have been deposited by various landscape processes during the **Quaternary** and are described in more detail in the Historic England Geoarchaeology guidance (Historic England 2015). The Quaternary coincides with the period of human evolution from the Palaeolithic to the present. In any location where sediments have accumulated during this time, they may contain, or be interleaved with, evidence for past human activity. Where development sites are located on Quaternary deposits, the project is likely to benefit from deposit modelling as sediments could have built up since the archaeological remains were deposited. Quaternary sediments are mapped by the British Geological Survey (BGS) as Superficial (formerly known as Drift) geology. However, **geological maps** should be treated as indicative only for Quaternary geology. They provide a guide to the type of sediments that may be encountered in an area, but superficial geology of archaeological interest is often encountered outside the areas mapped by the BGS and with characteristics that differ from those mapped.

Anthropogenic deposits include sediments that have accumulated through the build-up of urban stratigraphy and where processes are triggered by human activity: for example, soil erosion associated with deforestation and agriculture causing **colluvium** and alluvium to be deposited.

Most deposit models have focused on the potential for prehistoric archaeology to be found in natural deposit sequences. Such modelling is best done by geoarchaeologists, who understand landscape processes and the characteristics of natural deposits. Even in urban areas (such as east London) deposit models tend to focus on the deep **Holocene** alluvial sediments or the **Pleistocene** river terraces, rather than the complex overlying archaeological stratigraphy that has built up from the Roman period onwards.

The current development of **Urban Archaeological Databases (UADs)**, enhanced HERs and **Heritage Action Zones**, which focus on historic archaeology, has emphasised the need for models for later periods based on anthropogenic deposits. The principles and the outputs discussed later in this guidance are equally relevant to these models, but their sources of information will draw more heavily on the archaeological records held in HERs and archaeological archives. It is essential that whoever designs the methodology and interprets the data has a good understanding of the types of deposit being modelled.

In addition to cultural evidence, sediments may preserve palaeoenvironmental remains that can be used to reconstruct past landscapes. An aim of deposit modelling can be to identify and model the spatial distribution and thicknesses of sediments that may contain biological remains such as pollen, insects and plants, providing proxy records of past climate, vegetation and land-use history. See the Environmental Archaeology guidelines for more information (English Heritage 2011).

2.4 What size of area can be modelled?

There is no minimum or maximum area for the application of a deposit model. The effectiveness of modelling depends far more on the availability, distribution and quality of information on which the model will be based than on size.

Most models used to illustrate this guidance are larger scale. The use of software makes it possible to store and manipulate information from big datasets, which has proved very effective on larger infrastructure schemes. The same software can also be used to model smaller datasets, although this can also be undertaken by hand drawing a cross-section. Where deposits of archaeological interest are likely to be buried at depth, a deposit model is likely to be a cost-effective approach to assessing the archaeological potential of any site, irrespective of size. On small sites, it is important for the model to include existing information from the surrounding area, so it provides a context for reliably interpreting information from the site.

Deposit models can be used at landscape or multi-site scales. On large-scale, long-running projects where a site-wide stratigraphic overview is required, a preliminary overarching deposit model can help to place discrete pieces of work in context. This can be especially useful if multiple contractors are involved. One of the earliest and most successful large-scale and long-term modelling projects was constructed for High Speed 1. The model that was developed formed the overarching framework for subsequent archaeological investigations along the entire route (Bates and Stafford 2013).

MOLA-PCA developed a similar model for the Olympics site in the Lower Lea Valley. The initial model formed a scheme-wide, low-resolution map of key deposit types and zones of different archaeological potential. This was updated, with each individual construction package feeding back into the scheme-wide model, as work was undertaken on each development site. The post-excavation work on the Olympics site, which involved a further revision of the model to inform analysis, was conducted by Wessex Archaeology (Powell 2012).

Similar strategies work well on housing development sites, where separate phases of development take place over long timespans and are often conducted by different contractors, but where each might be better understood in the context of the wider landscape. Sites earmarked for quarrying also benefit from this approach, especially as here the impact is likely to remove all archaeological evidence, from the ground surface to the base of the Quaternary sequence. Further information can be found in the Mineral Extraction and Archaeology practice guide (Historic England 2020).

If datasets are comparable, models made by contractors working on different sites at variable scales can be amalgamated or projects can be designed to build overarching models. A good example, the Battersea Channel project, is described in more detail in chapter 11 of *Deposit Modelling and Archaeology* (Carey *et al* 2018). Here, deposit modellers working on a swathe of sites in Battersea for different clients and archaeological contractors collaborated to develop a landscape deposit model, accessible to and updatable by all archaeological units working in the area.

3 Deposit models and planning

This section explains how deposit models fit into the various stages of development-led projects undertaken within the planning context. A similar process of updating to refine the model, as new information is collected throughout the life of an archaeological project, is relevant for models created as part of research projects.

3.1 The planning context

Development-led archaeology takes place within a planning context consisting of national, regional and local planning policy. The general principle of the current planning policy framework is sustainable development and the understanding of significance, which includes protecting and enhancing the historic environment, as set out in section 16 of the National Planning Policy Framework (MHCLG 2019).

Deposit models can help archaeological projects to deliver positive outcomes within this planning context. In particular they can inform:

- decision-making, by identifying sediments with potential for archaeological interest, the likely nature of their significance and the likely impact on them of development
- development design, by identifying how impacts to sediments with potential for archaeological interest can be minimised
- past landscape reconstructions, which can inform initiatives that create a sense of place and local distinctiveness, increasing the public value of a development

By modelling buried deposits, a greater understanding is gained of where archaeological sites might be discovered in the future. This is an important aspect of the evidence base provided by the Historic Environment Record (HER) (NPPF 2019, Para 187) and justifies deposit modelling being undertaken as part of HER enhancement projects, particularly in the development of Urban Archaeological Databases (UADs).

A deposit model can provide a proportionate technique for assessment and evaluation of archaeological significance (NPPF 2019, Para 189).

This is applicable to all sites, but is especially relevant on sites where the archaeological deposits lie at depth and might only be impacted by deep construction techniques (eg piling and attenuation tanks).

3.2 The planning process

Deposit modelling is most effective in the earliest stages of the planning process. A model constructed from existing information as part of a desk-based assessment (DBA) acts as a preliminary stage of site investigation. It may then guide subsequent evaluation, either at the pre-determination stage of the planning process or when secured by planning condition.

Appendix 1 provides a flowchart illustrating the scope of deposit modelling within the planning process.

3.3 Archaeological project stages

This section sets out key inputs that deposit models can make to different stages of archaeological projects.

3.3.1 Desk-based assessment (DBA)

A DBA determines from existing records, the nature, extent and significance of the historic environment resource and the impact on this of the proposed development. Deposit models address these objectives by providing a preliminary understanding of the character, spatial extent and depth of deposits of archaeological interest. Using the model, the potential impact of development can be examined and archaeological questions can be framed, both of which inform the design of evaluation and mitigation strategies.

At this stage of a project, the information is likely to be limited to geotechnical borehole logs. Current DBA practice often presents these borehole logs as a table, but more can be gained from this information irrespective of whether an archaeologist or geoarchaeologist examines it. Simple schematic cross-sections across a site show the depth of the archaeological deposits and the location of any key horizons. An indicative map, zoning the site into areas of differing potential and deposit character, can also be presented.

On large or deep sites it is more appropriate for a geoarchaeologist to construct the model. In the case of complex, urban stratigraphy an experienced urban archaeologist should work in partnership with a geoarchaeologist to create the model. For very large schemes, a deposit model provides a valuable overview for the scheme as a whole; this can be essential for the planning archaeologist to determine appropriate approaches to separate phases of development.

In some cases, the deposit model may be the first archaeological and geotechnical assessment of an area and will require new data. For all sites, construction of a deposit model during the DBA stage makes sure that consideration is given to the full sequence of deposits and their archaeological potential, thus helping to minimise the risk of unexpected discoveries. It also provides an opportunity to liaise with geotechnical engineers and for archaeological input to the design of all site investigations.

3.3.2 Evaluation

Deposit modelling is often conducted in a series of stages during evaluation. As a first step, any existing model is updated, using the results of recent geotechnical site investigations. On sites where the archaeological deposits are likely to be deeply buried, it is good practice for any geotechnical groundworks for development purposes to be designed and undertaken in collaboration with a geoarchaeologist.

Where gaps exist or questions remain unanswered in any desk-based model, purposive geoarchaeological boreholes and/or test pits and (on large open sites) deep geophysical survey should be undertaken as an early stage of evaluation. This improves the reliability of the model because:

- data coverage is now determined archaeologically (rather than by development requirements) and can infill any gaps in previous datasets
- deposits will have been examined by a geoarchaeologist and locations can be selected to clarify issues raised by the previous data
- finds and samples are likely to be available for dating, which will provide chronological control

Figure 2: Deep evaluation shaft on the Thames floodplain

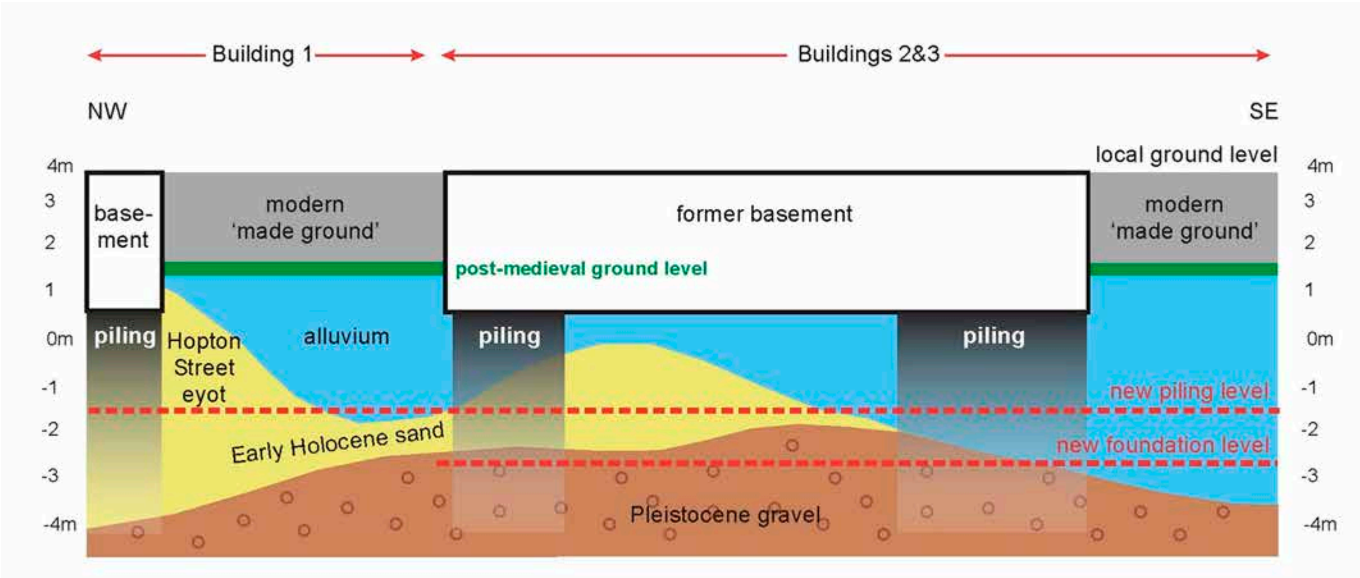


Figure 3: Schematic section illustrating potential development impacts to non-archaeologists © MOLA

The sediment sequence from any cores taken is recorded and provisionally interpreted, including scientific dating where necessary. More detailed assessment is rarely required at this stage of investigation. Therefore, any cores with potential for further work can be retained for examination at a later project stage. The updated deposit model should be sufficiently robust to inform evaluation trenching strategies and to provide information for reliable costing (eg depth of the deposit sequence, types of deposit and the range of archaeological evidence and specialist input that may be expected). Where natural deposit sequences of archaeological interest are exceptionally deep, as in floodplains and estuarine areas, the high cost of excavation makes the deposit model critical in determining where evaluation should occur (Figure 2).

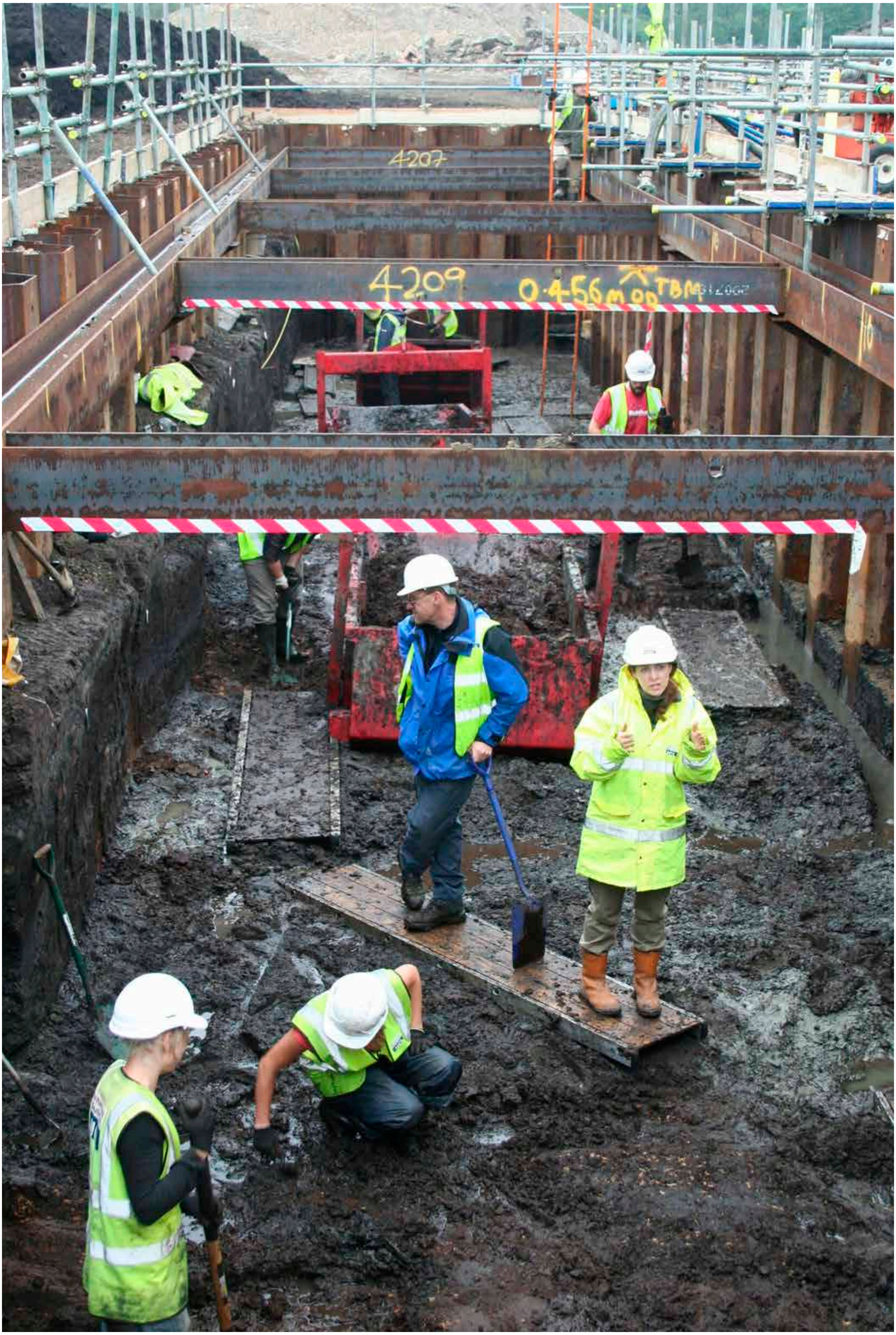
During trench evaluation, the recording of sections and augering from trench bases provides more data to feed into an updated model. Superimposing foundation design, service runs, lift pits, attenuation tanks and other proposed intrusive works on schematic cross-sections also provides a useful visual tool for the likely impact of development (Figure 3).

Deposit modelling can be integrated with **Building Information Modelling (BIM)** so that everyone involved in the project can view the impact of development. This aids dialogue within the project team on designing-out impacts prior to construction.

3.3.3 Excavation

A deposit model is not redundant when excavation begins, but its purpose shifts to developing a context for the archaeological remains. Information on the sediment sequence collected during excavation ensures that archaeological data can be reliably linked to evidence for site formation and landscape change. Opportunities need to be created during the mitigation stage for geoarchaeological recording of sections, boreholes and other deposit sequence profiles to collect appropriate information for updating the deposit model and linking it with the archaeological sequence (Figure 4).

Figure 4 (page 14): Running section maintained during excavation of floodplain deposits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4209
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Creating a deposit model is also the first step where the preferred option is to retain the archaeological deposits *in situ*, rather than to excavate. Changes to the burial environment brought about by the development might cause potential harm to the archaeological remains and a deposit model provides the sedimentary context, against which potential changes in hydrology, compaction and chemistry can be examined (see Preservation of Archaeological Remains guidance (Historic England 2016)).

3.3.4 Post-excavation assessment and updated project design (UPD)

The deposit model is updated with information collected during excavation. This updated model helps in the selection of samples for environmental assessment and dating and in the interpretation of the results. Liaison between the site supervisor and the modeller must also take place to integrate the model effectively with the site sequence. Discussion about the role of the model in the analysis and publication stage is also needed, and the tasks and resources that are needed to achieve this should be specified in the UPD.

3.3.5 Post-excavation analysis

Refinements to the model are made following dating, stratigraphic and palaeoenvironmental analysis. Liaison between the site supervisor and geoarchaeologist takes place to achieve full integration of the deposit modelling results with the site archaeological stratigraphy. It might also be necessary to incorporate information from nearby sites for which archaeological and geoarchaeological data exist in order to contextualise the information from the site itself (see Figure 10).

3.3.6 Publication and archiving

Outputs from a deposit model can provide the basis for reconstructions of past landscape evolution and the changing environment of a site; these are often vital for contextualising the archaeological evidence. The visual products of deposit models provide, in addition, valuable opportunities for wider engagement (Yendell 2018).

The deposit model forms part of the site archive. Early discussion is needed to establish where and how the model is curated; for example, with the Archaeology Data Service (ADS) or the HER. This confirms standards and any other requirements, such as cost. The database created for the model has great potential for re-use, especially on adjacent or nearby sites and in projects mapping wider areas. Everyone involved should aim to make the data underpinning deposit models accessible for re-use.

Section 8 sets out best practice for archiving and re-use of deposit models.

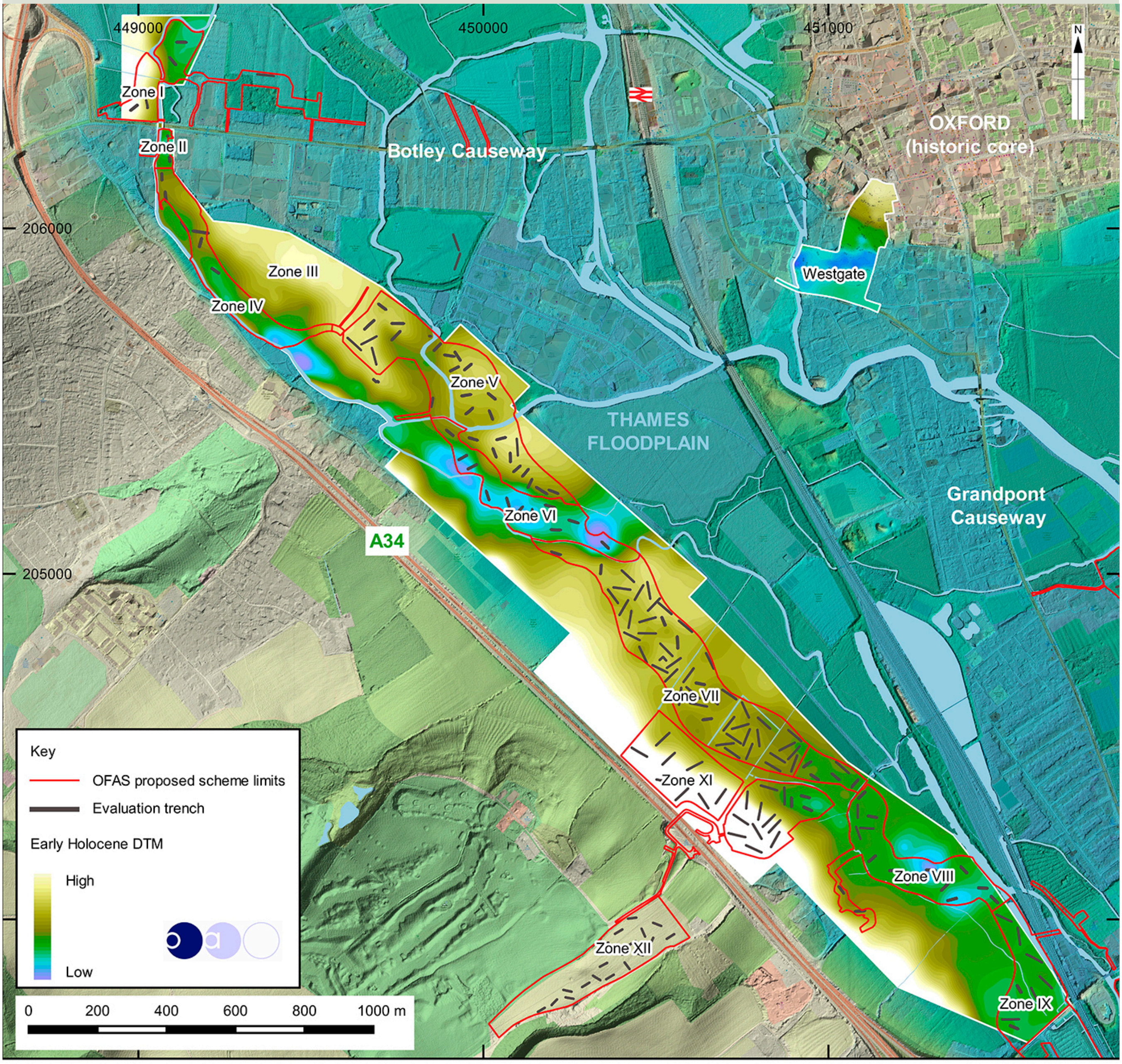
Sharing deposit models with engineers and developers

At every project stage, deposit model outputs provide a means of communicating the distribution, depth and thickness of archaeological deposits to non-archaeological clients, providing a link between archaeology and engineering.

Oxford Flood Alleviation Scheme

The Environment Agency’s plans for a major scheme to reduce flood risks to homes and businesses in Oxford includes proposals for a new *c* 5 kilometre channel across floodplain meadows. To support the Environmental Impact Statement, Oxford Archaeology carried out a series of staged geoarchaeological surveys, culminating in an extensive programme of evaluation trenching to investigate archaeological potential within and beneath a thick swathe of alluvium that blankets the route.

Figure 5: Plot of gravel surface used to explain trenching strategy to project partners
© Oxford Archaeology



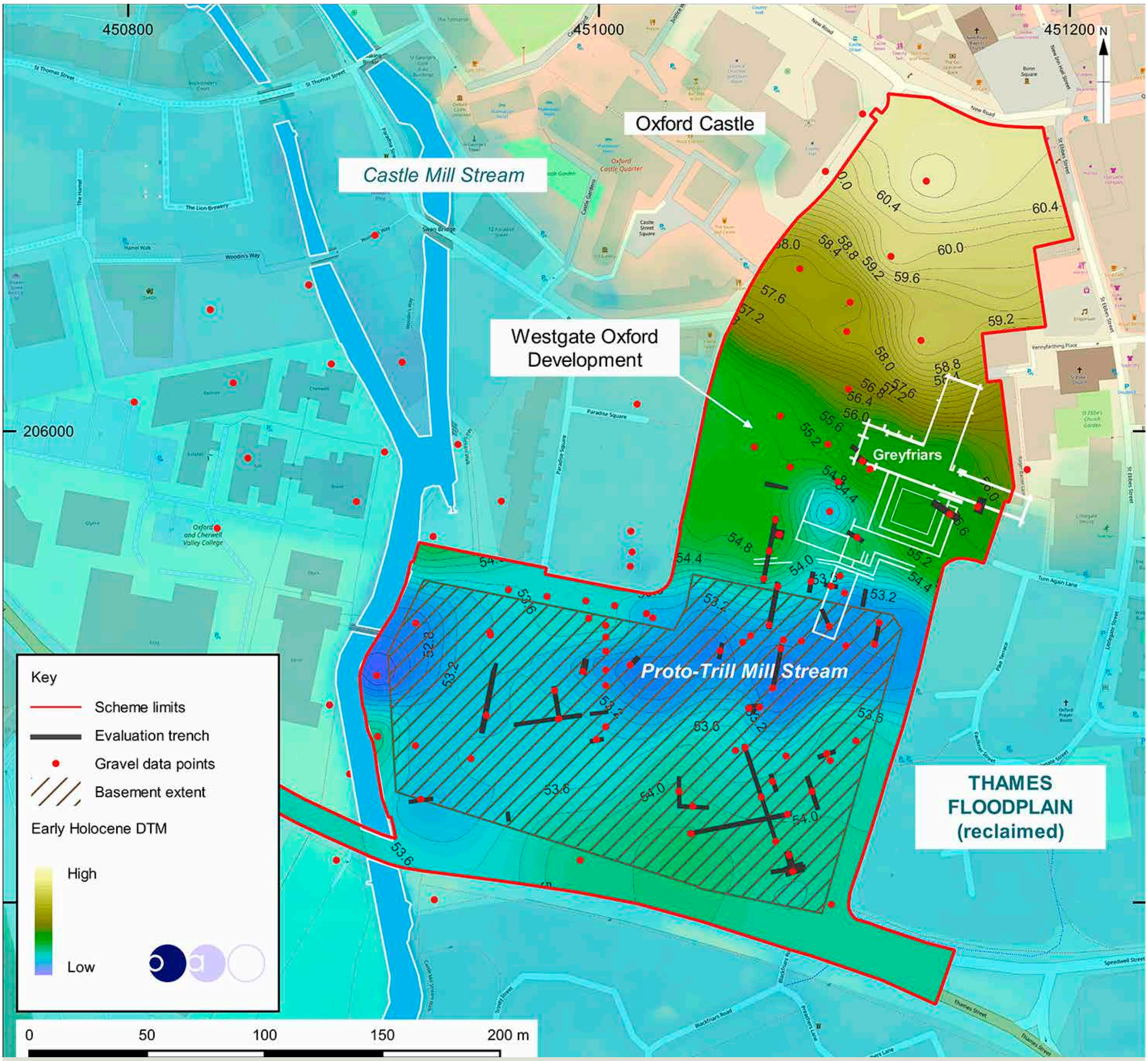


Figure 6: Gravel surface model used by engineers in BIM to design basement cofferdam
© Oxford Archaeology

At all reporting stages, survey results were accompanied by digital data, including spreadsheets, cross-sections, 3D models, surface and thickness plots in both metres OD and depths below ground level as CAD (computer aided design) and GIS (geographical information systems) shape files. This allowed for full quantitative use of the data to be made while designing the evaluation trenches. Through a series of presentations, the deposit modelling helped to illustrate the basis for the evaluation strategy to the Environment Agency, scheme designers (Ch2M), Historic England and planning archaeologists. The high-quality sub-surface data also contributed to non-archaeological aspects of the scheme, with buried palaeochannels and varying thicknesses of alluvium guiding locations for additional phases of geotechnical investigations. The ‘added value’ of the deposit modelling also resulted in a reciprocal watching brief being carried out by the scheme designers during the evaluation trenching.

Oxford Westgate

Prior to construction of the new Westgate shopping complex, Oxford Archaeology carried out extensive geoarchaeological deposit modelling to reconstruct the early Holocene topography, including plotting of an early course of the Trill Mill Stream. It also characterised the overlying alluvial sequences and deposits resulting from centuries of urban occupation and expansion across the Thames floodplain and adjacent river terrace. Based on this work, the site was divided into zones of archaeological potential to aid formulation of the mitigation strategies.

The aims and design of the excavations relied heavily on the results of the deposit modelling, enabling the construction impacts of a two-storey basement carpark on buried waterlogged deposits to be assessed in detail. The model, along with a programme of targeted purposive boreholes, helped to pinpoint optimal locations for 4–5 metre deep, stepped trenches to expose the full sequence across the Trill Mill Stream and the adjacent Thames floodplain for detailed recording and sampling. The excavation team included a full time geoarchaeologist tasked with collecting additional data and samples to enhance the deposit model and to enable detailed landscape reconstruction during post-excavation analysis.

Communication and data exchange between archaeologists and the main contractor was crucial to avoid delay to the construction programme. The engineers incorporated data from the 3D model of the floodplain gravel surface (Early Holocene Digital Terrain Model) and underlying Oxford Clay into their Building Information Modelling (BIM) to help design the perimeter cofferdam, enabling dewatering of the area for the excavations and ultimately construction of the basement car park.

4 Collecting the data

The need for a deposit model might be identified by the archaeological contractor or might be a requirement of a brief or tender. In either case, the checklist (Appendix 2) and the indicative specification (Appendix 3) are recommended to help in deciding what is likely to be required and what questions need to be asked before a deposit model is commissioned.

Once it has been agreed that a project would benefit from a deposit model, conversations begin with a geoarchaeologist to ensure that the technique is used to gain maximum benefit for the project.

From the outset, it should be recognised that deposit models ARE models.

They:

- are only as good as the data underpinning them
- provide a conceptual framework and act as an aid to decision-making
- do not provide definitive representations of buried stratigraphy
- provide a starting point for discussion
- should be refined as part of an **iterative process**, as additional data are collected

4.1 Assembling existing information

The building blocks of any deposit model are geoarchaeological and geotechnical borehole logs, together with previous archaeological records. This information can be mined from several repositories, the majority of which offer some degree of open-access (Table 1). In addition, the client or their consultant might have relevant geotechnical data. It is good practice to collect data beyond the immediate site. This reduces the loss of information through 'edge effects' and helps to contextualise the deposit model, especially if the site is of small extent.

Source	Value
BGS (National Geosciences Data Centre)	Provides a repository for geotechnical data deposited by various organisations. This includes borehole records: key data sources for constructing deposit models. Some are confidential, but open-access borehole scans are available via the Geology Viewer and a wider range of BGS data is searchable via the GeoIndex. BGS also produces a series of memoirs in support of mapping activities, which are available to purchase online. Older memoirs provide detailed descriptions of key Quaternary sites and deposits.
ADS and HERs	Local HER officers are best placed to advise on the availability of previous and nearby models and the data underpinning them. Digital data, including that from deposit models might be archived with ADS (search on geoarchaeology). Archaeological records (especially derived from trench sections) may also provide useful data and can be obtained from unpublished archaeological reports, which may also include geoarchaeological information. These are available from the local HERs. Not all of this information is open access or free of charge.
Quaternary Research Association	Produces a series of regional field guides containing valuable geological and archaeological information, which are available to purchase online.
Academic Community	Relevant published literature may be found in regional, national and international journals, as well as in monographs and unpublished postgraduate theses. Recent articles can be purchased but older literature and theses may be available through online portals (eg JSTOR; eTheses).
Historic England	Regional Research Frameworks do not include data but help to refine research questions for deposit models.
Joint Nature Conservation Committee (JNCC)	The Geological Conservation Review (GCR) series, support the statutory protection of nationally and internationally important geological sites, many of which have an archaeological value. These volumes provide background information for deposit models (particularly those of Palaeolithic or wetland interest) but they are not key sources of data.

Table 1: Sources of data for deposit models

Lidar can provide valuable information on landforms, helping interpretation of depositional environments and geomorphological processes. Environment Agency lidar data can be downloaded from the National Library of Scotland website.

4.2 Data quality

The availability of borehole logs does not equate with availability of useable data. Review of data quality will determine whether a model can be constructed or whether more information needs to be collected before modelling can take place.

Most pre-existing borehole data will have been described by geotechnical contractors who base their stratigraphic descriptions on intermittent samples taken to characterise the engineering properties of key sedimentary units. In contrast, geoarchaeologists need to see continuous sequences of deposits, as described in greater detail in the Historic England guidelines for Geoarchaeology (Historic England 2015). This allows them to examine the interfaces between sediment units and to reliably interpret the past environments represented by these deposits.

Although standards exist (BS:5930:2015 and BS EN ISO 14688-1) to encourage consistent description of sediments as part of ground investigations (based on grain size and inclusions), drillers and geotechnical contractors do not all interpret the same units consistently. It might be difficult to integrate data collected by different contractors. A single gravel deposit might be called Glaciofluvial by one and River Terrace by another; in urban contexts, the same fine-grained deposit with pottery, brick or tile inclusions might be called Alluvium or Made Ground. Compared with modern logs, those drilled in the last century might also have scant, uninformative or variable descriptions, depending on their original purpose.

The Association of Geotechnical & Geoenvironmental Specialists (AGS) has recently published guidance for drillers and geotechnical contractors on the description of anthropogenic sediments (AGS 2018), with the aim of standardising recording of the different types of deposit that might have a bearing on ground contamination. However, it does not differentiate modern deposits from those of archaeological interest. Geotechnical engineers commonly use the term Made Ground to describe any unit that is derived from human activity. Therefore it is likely to include both modern and archaeological deposits. Made Ground is included by the British Geological Survey in the term Artificial Ground.

Critical limitations to data quality include missing or imprecise spatial coordinates and locations based on mapped features that no longer exist. Lack of information about the ground level the borehole was drilled from is also a frequent issue. Even where this might be inferred from nearby current ordnance datum, there is no guarantee that the ground surface at the time of drilling was the same as today.

Borehole depth can also be an issue. Some geotechnical logs might be based on shallow test pits and not give information about the full Quaternary sequence. Deeper boreholes might appear to provide useful information, but on examination may describe a bedrock sequence. Apparently good borehole coverage might in reality provide no more information than various depths of made ground over truncated bedrock, from which little useful information can be derived.

With all pre-existing data, it is necessary to review, clean and standardise the information prior to creating a deposit model.

4.3 Spatial coverage

Since deposit models extrapolate heights between stratigraphic data points, the most robust models are produced where these points are distributed evenly across a site, ideally on a grid. Software may offer a choice of algorithms to aid the smoothing of surfaces between data points, but these will achieve little where data points are very widely spaced or in irregular discrete clusters.

The choice of appropriate spacing intervals between data points depends on the questions being asked of the model, the likely nature and complexity of the buried deposits, and the size of any features that the model is aiming to identify. For example, to reconstruct the stratigraphy of a 2 kilometre wide floodplain containing several palaeochannels, each around 50 metres wide, an interval spacing of significantly less than 50 metres would be required to examine their internal stratigraphy and distribution. In these cases it can be appropriate to construct nested models at different spatial scales and with different divisions or groupings of deposits, which enable a more subtle range of questions to be addressed.

4.4 Collecting new data

If existing information is not available or is inadequate, bespoke geoarchaeological data must be collected before a model can be constructed. The method employed will depend on the estimated depth of the sedimentary sequence, the likely sediment characteristics and whether samples are needed for recording, dating or palaeoenvironmental assessment.

4.4.1 Boreholes

Coring, either manually or with a mechanised rig, is the most usual technique for obtaining new data. More information about different types of borehole is provided in the Historic England geoarchaeology guidance (Historic England 2015). Selection of the appropriate coring method will be site-specific and advice should be sought from appropriate specialists such as geoarchaeologists or by contacting the Historic England Science Advisors.

It is good practice to drill boreholes that record the full Quaternary sequence (ie to the top of bedrock). It can be difficult to interpret a deposit if the underlying sediment is ignored, and this will impact on the reliability of the model. Therefore, it is not recommended that boreholes are drilled only to the depth of proposed development impact.

Boreholes can be recorded on- or off-site, and the cores can be retained or discarded after sampling. The choice will depend on the amount of detail and information required from them and whether they are likely to be needed in later project stages. Cores should be described with enough detail to interpret the deposit sequence and its archaeological potential (which usually requires outline dating to be obtained).

The scope for environmental remains assessment as part of a deposit modelling exercise, and when it should take place, will depend on the purpose of the model. This purpose is likely to change as the model is updated during the life of a project. Assessment of environmental remains to establish their range and state of preservation is rarely required in early project stages, except where the model's purpose is to establish palaeoenvironmental potential. However, such assessment is generally needed to inform analysis as part of a mitigation strategy and it is needed if the purpose of the model is to inform decision-making in the preservation of archaeological remains.

Where geotechnical site investigations are planned ahead of development, the client should be encouraged to allow geoarchaeologists to work alongside geotechnical specialists so that both parties are able to collect information from the same sedimentary sequences, albeit for different purposes. Such an approach negates the need for different specialist teams to access the site at different times, and ultimately will save the client both time and money.

4.4.2 Other techniques

On sites where the sequence is shallow and the focus is on the characteristics of Made Ground or the potential for Palaeolithic archaeology, it can be more effective to use test pits rather than boreholes. This gives more opportunity for finds to be recovered, and is more reliable for coarse non-consolidated sediment which is not easy to recover in borehole cores.

Where it is not necessary to obtain cores for dating, palaeoenvironmental assessment or detailed deposit description, geophysical methods are routinely used to characterise the buried deposit sequence (see chapter 8 in *Deposit Modelling and Archaeology* (Carey *et al* 2018). Deeply penetrating geophysical techniques include:

- electromagnetic survey for sequences 0–6 metres Below Ground Level (BGL)
- electrical resistivity surveys for sequences 2–25 metres BGL
- ground penetrating radar for sequences 2–8 metres BGL

In all cases when geophysical survey data are used, it is good practice to ground-truth the resulting interpretations with boreholes. The effect of groundwater on the signal should also be considered.

5 Building the model

Key things to remember:

- robust deposit models rely on good data
- software is useful, but a good understanding of the type of deposits being modelled and an informed geoarchaeological interpretation are more important
- avoid preconceptions about site stratigraphy: examine the deposits, their context and topographic position before they are ascribed to a stratigraphic sequence

5.1 Data inspection: looking at a single deposit sequence

The starting point for any deposit model is the division of the sediment sequence at each data point (typically boreholes) into vertical units based on a range of descriptive physical attributes (eg texture, sorting, structure, colour and inclusions). These attributes represent the key physical characteristics of the sediments, allowing an interpretation of depositional environments.

In Figure 7 the logs from three boreholes drilled on a small site are drawn alongside each other, with short descriptions about their sediment characteristics. Modern inclusions in the uppermost deposits have led them to be identified as recent Made Ground, but the lowest of these might well have archaeological significance. Given the location of the site on a floodplain, with river terraces on the valley side, the sands and gravels towards the base of each sequence have been interpreted as Pleistocene river deposits. This and the following three figures have been adapted from illustrations previously prepared for geoarchaeological work carried out at Luther Court, Oxford by Oxford Archaeology, to help illustrate the steps involved in building a model.

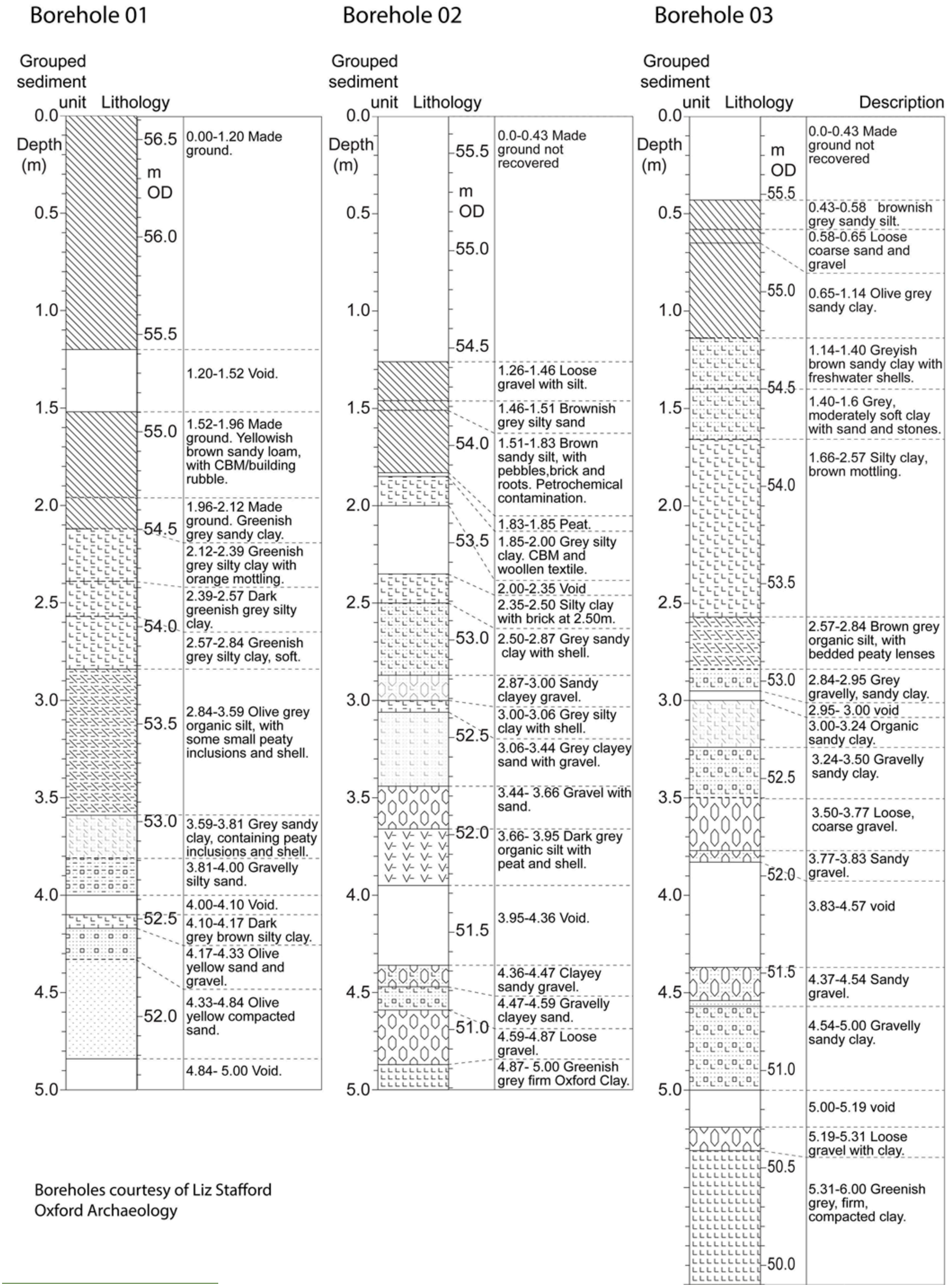
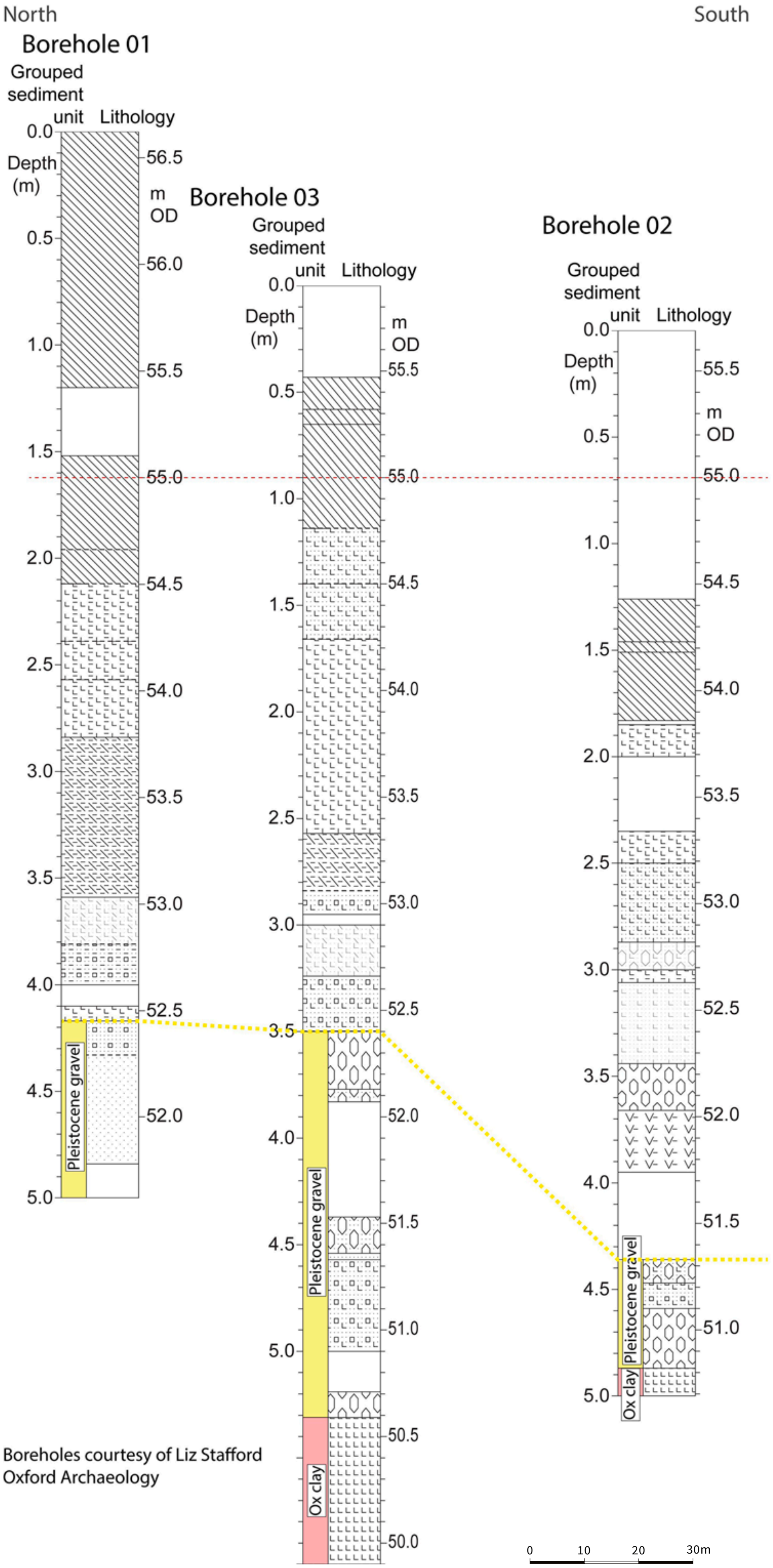


Figure 7: Deposit characteristics described in typical borehole logs



Place the boreholes in order relative to height OD and positioned according to spacing on the ground.

The sediment descriptions can now be grouped into wider deposits. In this case the Pleistocene sands and gravel are defined and the interface of this deposit is correlated between boreholes.

Figure 8: Identifying the buried topography

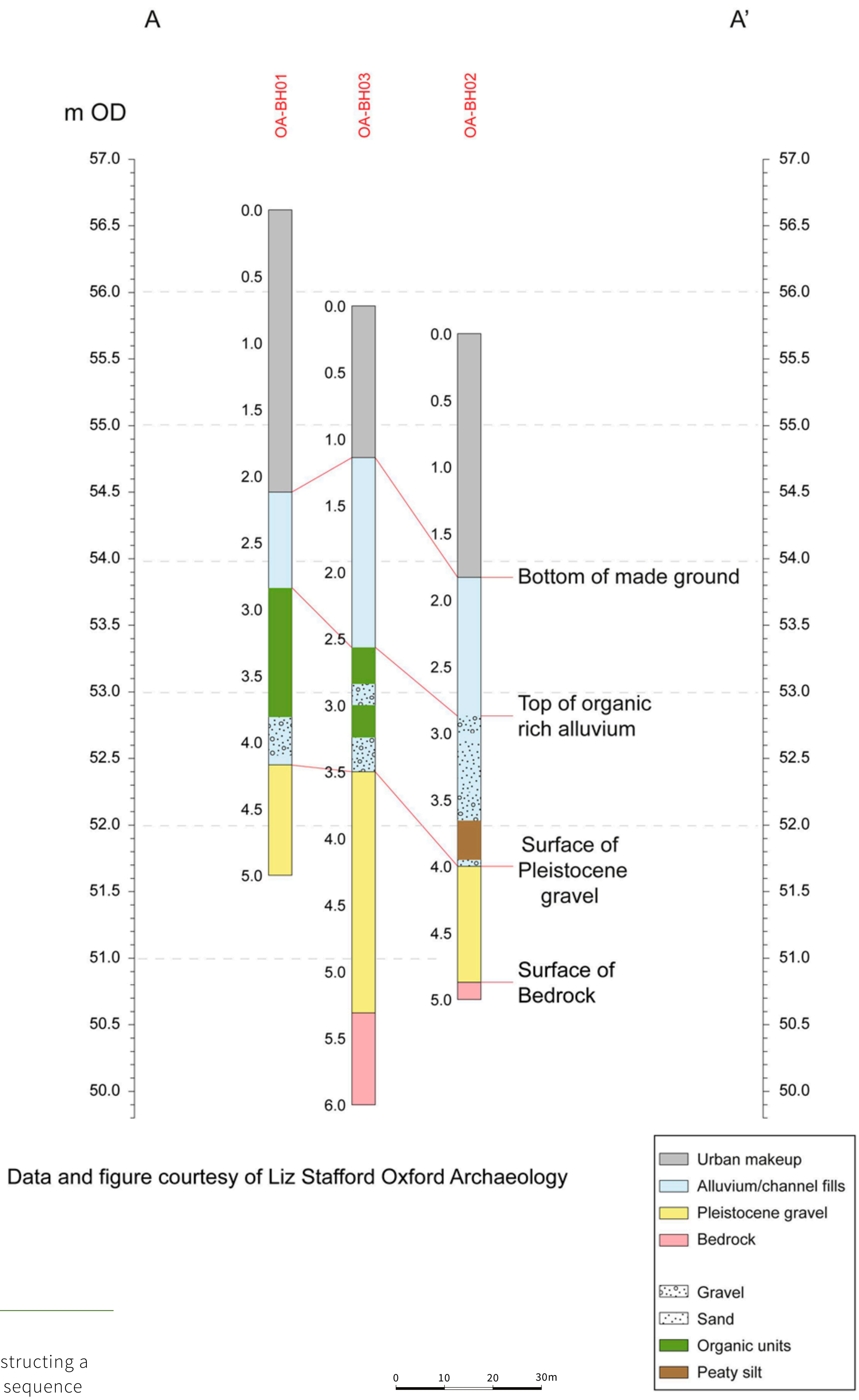


Figure 9: Constructing a stratigraphic sequence

5.2 Linking deposit sequences across a site

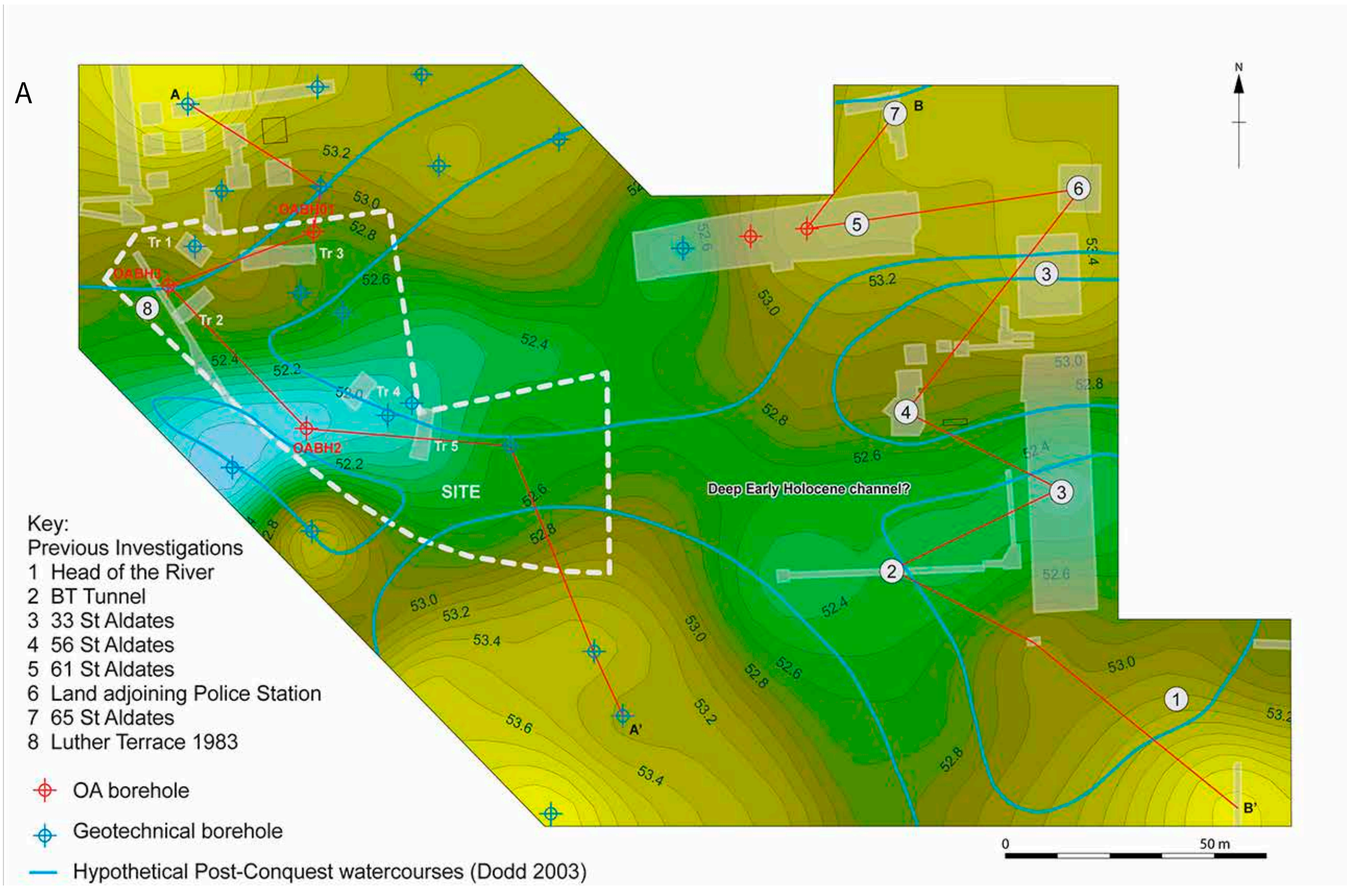
Laterally-equivalent units across the site are then identified by comparing adjacent boreholes: a process known as correlation. The boreholes are typically drawn (by hand or using computer software) next to each other, spaced to scale and at relative heights, covering the full sequence to the top of the bedrock. The depositional environment of each sediment unit is more easily interpreted if its topographic position is known. Therefore the first step is usually to construct a baseline topographic template. This is typically the surface of bedrock if Pleistocene deposits are being examined, or the surface of the uppermost unit pre-dating the Holocene in each borehole, if the interest is the Holocene deposit sequence.

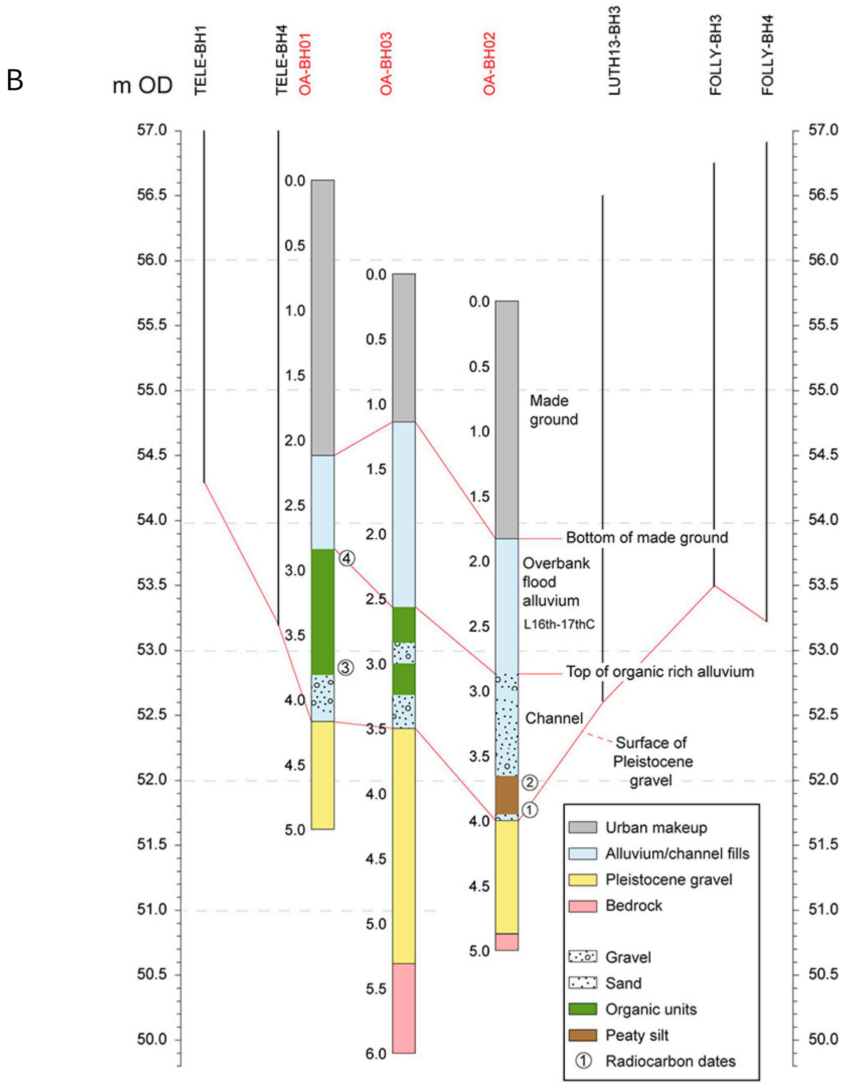
In Figure 8 the top of the Pleistocene gravel (which has been shaded) in each borehole has been correlated. This shows that the gravel surface is dipping from north to south across the site.

The sediment units in each borehole are then grouped into wider stratigraphic units, which are likely to relate to similar depositional environments and are compared with those in adjacent boreholes. Where possible these are linked to form a stratigraphic sequence that has meaning across the whole site. In Figure 9, the lowest deposits above the Pleistocene gravel in each borehole appear to be organic and are interspersed with coarser sandy sediment. These deposits might be grouped together and could represent fast-flowing, shifting channels across a well-vegetated valley floor. In contrast, the overlying deposits are silty clays, more likely to represent sluggish water flow and overbank flooding, characteristic of a sediment-laden river. These lower and upper deposits might therefore be grouped into two different stratigraphic units, which can be linked between the boreholes.

Once stratigraphic layers have been identified across the entire site, the heights (OD) of the upper and lower bounding surfaces of each stratigraphic unit can be calculated and entered into a spreadsheet, together with easting and northing coordinates. If using software, each type will have particular specifications about how data are inputted. The outcome is the same: levels for each borehole for the upper and lower bounding surfaces of stratigraphic units, from which thicknesses, surface plots and cross-sections across the site can be produced.

Although a good transect can be constructed from the three boreholes used here as an example, these do not provide enough data for a surface or thickness plot. On small sites like this it is helpful to include pre-existing boreholes from the surrounding area, if use of these can provide sufficient data points for modelling. The level for the top of the Pleistocene gravel from previous geotechnical boreholes excavated on and around the site has been added to the database and its surface modelled in Figure 10. Figure 10A shows that the dip in the surface of the gravel and the recorded fluvial deposits relate to a significant channel feature that cuts across the site.





Data and figure courtesy of Liz Stafford Oxford Archaeology

Figure 10: Including data from beyond the site improves interpretations of topography (A) and channel profile (B)

In Figure 10B the transect across the site (Figure 9) has been expanded to show how the boreholes from the site relate to the full width of the channel. This information was used to locate three evaluation trenches (Tr1-3) on the higher ground in the northern part of the site, to investigate whether archaeological remains survived in the Made Ground. As mitigation for piled foundations, radiocarbon dates and palaeoenvironmental evidence were later obtained from the borehole cores from the channel area.

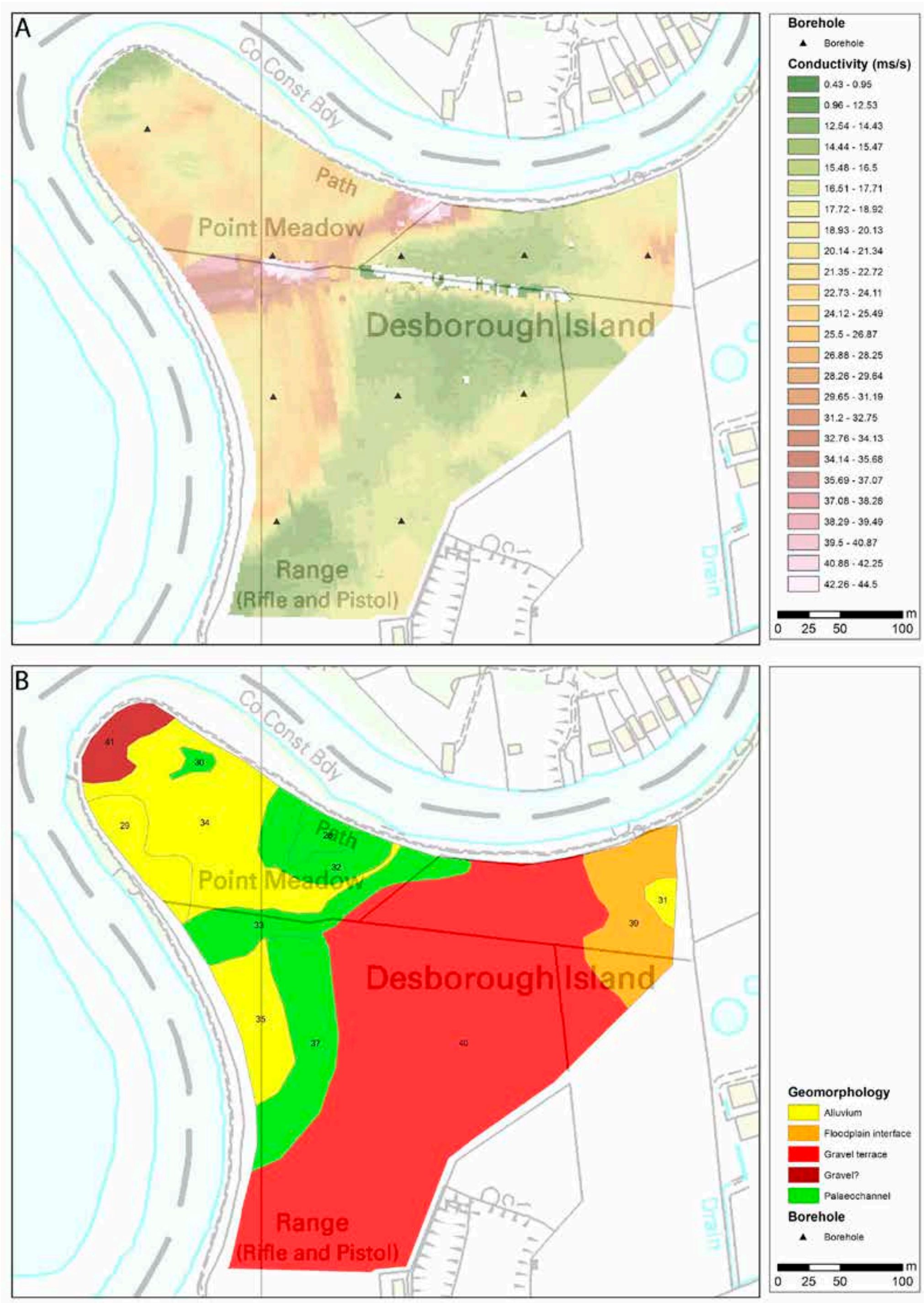


Figure 11: Using conductivity data in a deposit model (A) and channel profile (B) © Trent & Peak Archaeology

5.3 Using data from deep geophysics

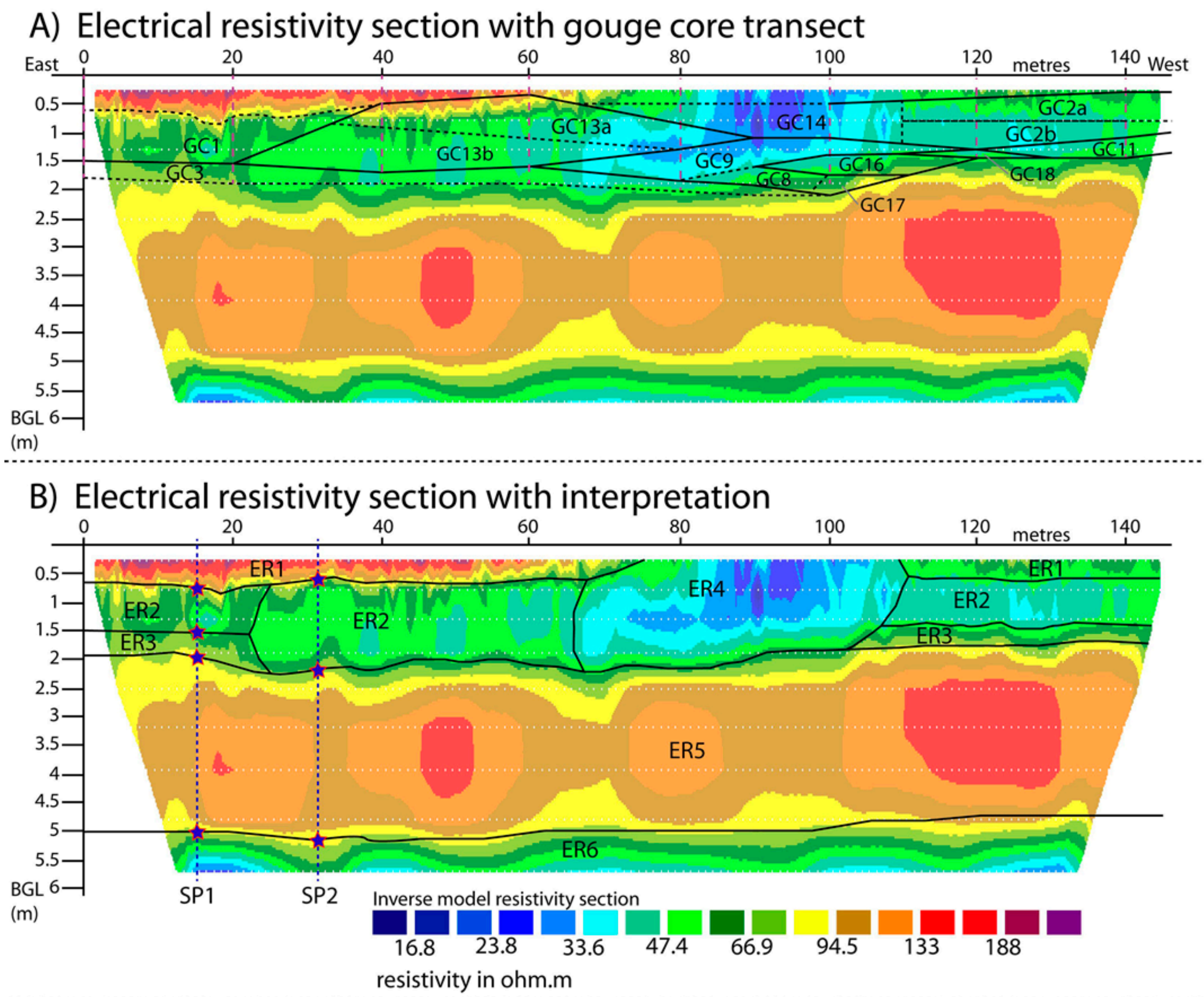
The data from deep geophysical survey can be used in a variety of ways during the construction of a deposit model, with modern geophysical software allowing the input of borehole data for accurate calibration of depth. The data from electromagnetic survey (conductivity mapping) can be used to produce a site-wide model, showing bulk variation in sediment deposits in the top 0-6m BGL, allowing a simple geomorphological compartmentalisation of the site. The data from GPR and resistivity transects require translation to enable their addition to the deposit model using a process called 'surface picking'.

Figure 11 illustrates the outputs of conductivity mapping. Figure 11A shows the **interpolated** map of conductivity values across the study area, with clear variations in electrical conductivity, which in turn can be taken to represent differences in sediment types (often but not always due to grain size variation). The boreholes have been located to ground-truth the conductivity results. Figure 11B shows the interpretation of geomorphological features, based on the conductivity readings.

A resistivity transect surveyed across a floodplain with the results of a gouge core transect superimposed is illustrated in Figure 12A, while an interpretation of the resistivity transect is shown in Figure 12B. The data are interpreted and subdivided into key sediment units. The boundaries and thicknesses of these interpreted sediment units can then be 'picked' at different locations, giving the location, upper and lower surface and thickness of different deposits. Ground truth boreholes are used to identify which sediment interfaces the picked surfaces in the geophysical data relate to; and then the geophysical picks of surfaces can be used to create the deposit model. Alternatively, virtual boreholes can be placed anywhere along the transect recording the XYZ locations of the interfaces of the stratigraphic units, as illustrated in Figure 12B and these data points can be added into the deposit model.

5.4 Generating models from the database

Once stratigraphic interpretations have been determined, models can either be constructed by hand as relatively simple 2D diagrams or can be generated using computer software. Interrogating the database and generating models is an iterative process. Working models showing the buried topography, the distribution of overlying deposits and their thicknesses are created and can be viewed in plan and in sections crossing the site in a variety of directions. They help the modeller understand the landscape evolution, archaeological context and potential of the site. If available, the modeller will also want to incorporate any available evidence for dating and palaeoenvironmental remains; these might clarify deposit interpretation and archaeological potential.



Gouge core data:

GC1 = Red brown silty clay (unit 1)
GC2a = Yellow grey clayey silt (unit 2)
GC2b = Yellow grey silty clay (unit 2)
GC3 = Sand and gravel in red clay matrix (unit 3)
GC8 = Blue grey clayey silt with organic matter
GC9 = Blue grey silty clay with organic matter
GC11 = Red grey clay
GC13a = Light brown clayey silt
GC13b = Light brown silty clay
GC14 = Red brown clayey silt
GC16 = Blue grey clay
GC17 = Light grey clayey silt with organics
GC18 = Grey brown gravelly, silty sand

Resistivity interpretation:

ER1 = Terrace alluvium (high resistivity) = Unit 1
ER2 = Terrace alluvium (low-medium resistivity) = Unit 2
ER3 - Medium resistivity unit, clay/gravel interface
ER4 = Palaeochannel
ER5= Sand and gravel
ER6 = Bedrock

Interpreted sediment boundary
Gouge core location

Surface picking 'virtual' borehole:

Virtual borehole
Surface pick recording XYZ of interpreted sediment interface

Figure 12: Using resistivity data in a deposit model © Oxford Archaeology and Chris Carey

Deposit modelling is increasingly making use of powerful software packages to interrogate and display data to generate sophisticated models. The apparent authority of these modelling products, however, makes it all the more important that the modeller understands the deposits and is able to make sound judgements on what looks robust and what is simply a construct of the modelling algorithm.

Geographical Information Systems (GIS) ranging from commercial products such as ArcGIS to open-source software such as QGIS can be used to manipulate the stratigraphic data and create pseudo-3D surfaces. Alternatively, a range of software has been developed by the geological community to map stratigraphic sequences; two of the most popular commercial products used in archaeology are RockWorks and Surfer. RockWorks is often used to create and interrogate the database in section and to produce transects. It can model surfaces and thicknesses but it is more usual for the interpreted data to be exported to GIS for modelling and for creating more user-friendly and useful outputs. Surfer is used for constructing surface plots and 3D block diagrams, often in conjunction with hand-drawn sections. The British Geological Survey has recently launched an open-source modelling software package known as Groundhog.

This guidance does not endorse any single software, and it is stressed that the key aim of any deposit modelling exercise is to generate outputs that are clear and informative for all end-users.

6 Modelling outputs

Maps and cross-sections are typical outputs from a deposit model. These outputs must be supported by clear text explaining what they represent and their limitations.

A model constructed for a commercial project is likely to be produced in standard report format, with its supporting database archived with other digital records from the site.

A model constructed as a management tool to support a Historic Environment Record (HER) is more likely to be viewed onscreen and has potential for updating as more information is obtained. The database will be integrated into the HER but the model should still be supported by text describing the outputs and their limitations. Explanation should not rely on metadata alone, but include text documents linked to the deposit model outputs.

6.1 Reporting

The results from a deposit model should be presented in a report with text and illustrations. This might be a separate document or form a section of a desk-based assessment, written scheme of investigation, evaluation, post-excavation assessment and updated project design or other archaeological report. In all cases its purpose, outputs and findings should be referred to in the main archaeological text.

The following information is required in a deposit model report:

- location, geology and topographic setting
- aims and objectives (to include text addressing the purpose of the model)
- data sources, distribution and assessment of quality
- methods used to build the model
- chronological control

- reliability of the model and the confidence that can be placed in it
- text explaining the site-wide deposit sequence and supporting the illustrations
- recommendations for how the model should be used and archived
- relevant illustrations. As a basic minimum, these should have appropriate annotations and explanations, be clearly related to base mapping and show:
    - site location and setting
    - distribution of data points
    - location of transects (schematic cross-sections)
    - one or more transects, selected and prepared to address the model objectives
    - key surface plot (eg top of bedrock or pre-Holocene surface)
    - **isopach maps**, where relevant
    - zones of different archaeological potential (character maps)

Collaboration between the modeller and project manager is needed to make sure that the outcomes of the study are integrated within the wider results of the project and are used to inform the questions that the deposit model was commissioned to address.

Where software has been used, the report might be supplemented by layers of interpreted information that can (subject to copyright) be imported as shape files into project or HER databases for examination against other datasets. Any digital dataset underpinning the model should be made available upon request in a generic open-source format that can be used by clients and other parties (eg local HER).

6.2 Illustrations

Illustrations derived from deposit models are powerful outputs. Suitable figures allow those who have not been involved in modelling to understand the significance of the sediment sequences and the potential for the sediments to contain archaeological evidence.

Remember:

- be selective in the images used and ensure each figure conveys a key point highlighted in the text
- simple cross-sections and plots that relate the depths and locations of archaeological deposits to modern and historic mapping and the footprint of any proposed development are essential
- deposit models which are not clearly related to base mapping may have little practical use
- direct outputs from deposit modelling software are likely to need improvement by the geoarchaeologist and/or graphics specialist to create user-friendly illustrations
- each image used in a deposit model report should be adequately annotated to ensure that its meaning and relevance are easily understood by the end-user.

6.2.1 Cross-sections (transects)

A fundamental method for displaying deposit modelling results is to use 2D cross-sections, which display the relationship of different sediment units to each other, vertically and laterally across a site. It is good practice for the data points along the line of the transect to be shown on an accompanying map or plan (see Figure 10). In Figure 13, the deposit sequence examined and interpreted in boreholes is projected across the site to better understand the extent of a reclamation layer and its relationship to the former environment of the site.

As well as representing the relationships of sediments, transects can also be used to identify key geomorphological features within an area, such as palaeochannels, cliff-lines, terraces or gravel islands.

Transects can be illustrated in many ways. The most appropriate method for one model might not work well for another. Often both sediment characteristics and stratigraphy are illustrated. In Figure 14, the sediments in each borehole are shown (see key) and the stratigraphy is superimposed as blocks of colour, annotated with their interpretation. This helps a user to visualise the depth and character of the deposits of interest and in this instance relate them to the proposed development impact (indicated by the superimposed red line).

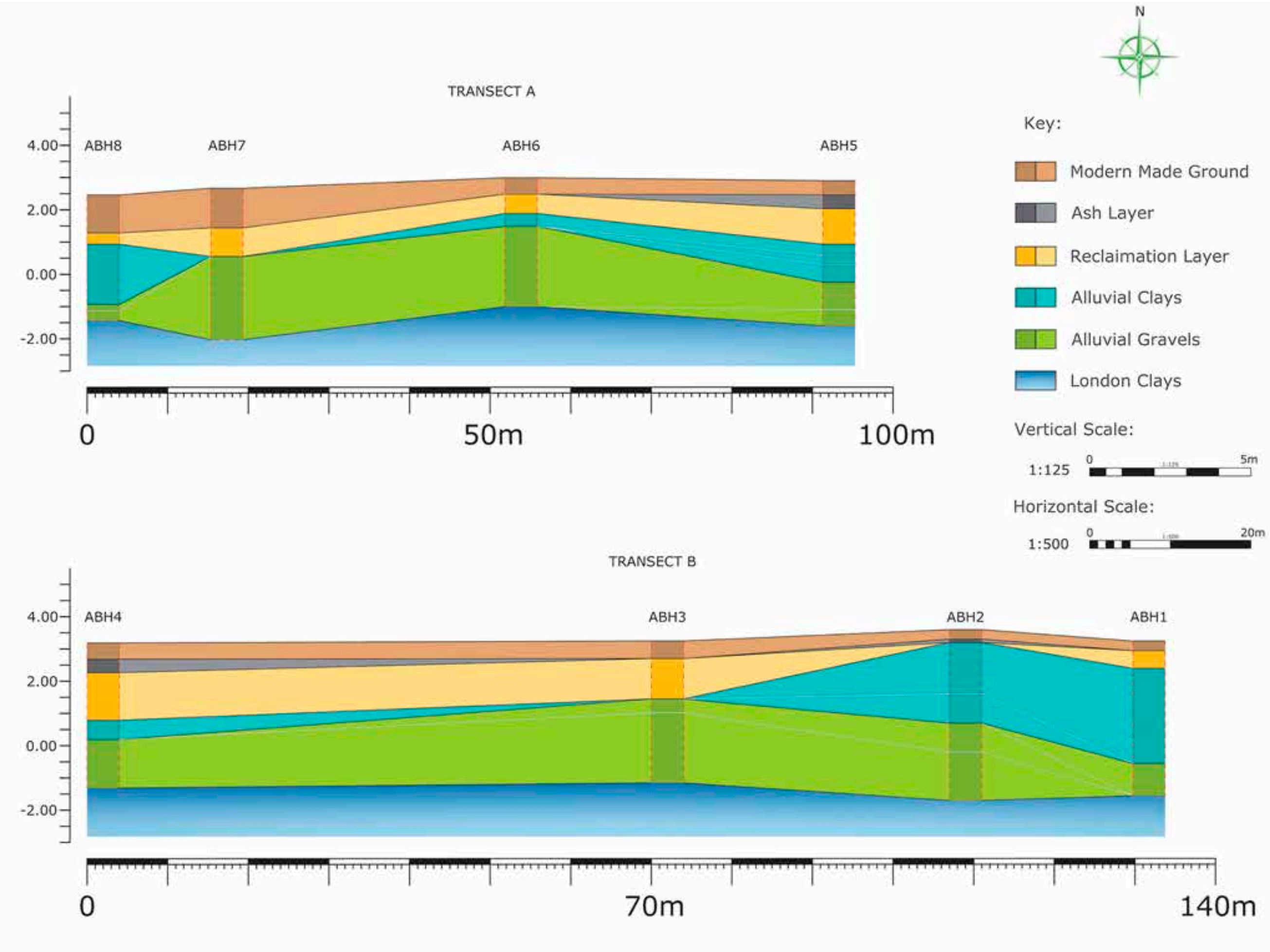
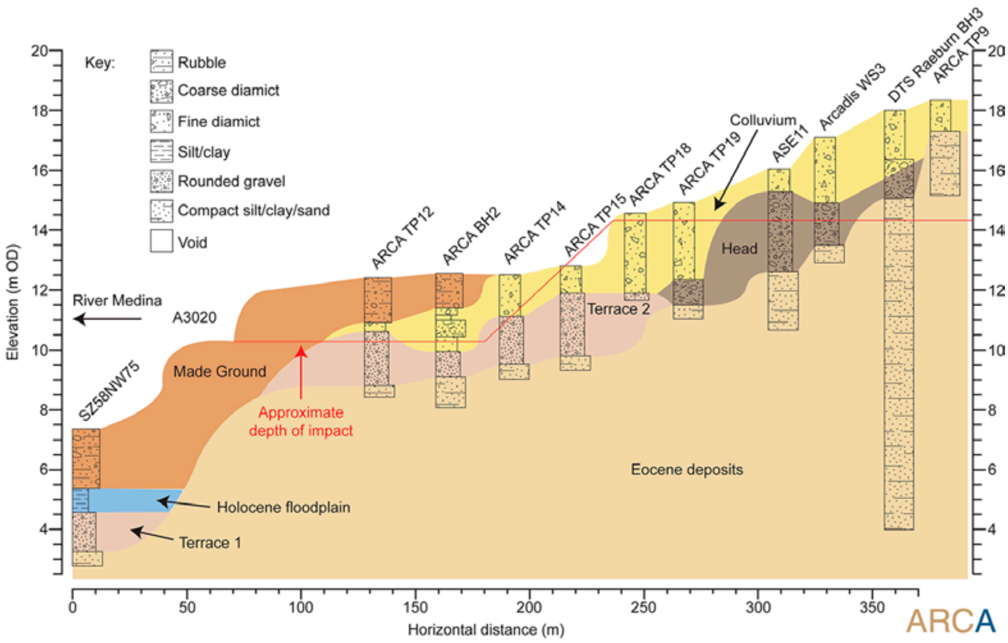


Figure 13 (above): Simple transect: different colours highlight interpreted and conjectured stratigraphy © Britannia Archaeology

Where detailed relationships between the data points cannot be made, they might be shown as discrete logs.

Fence diagrams are used to show cross-sections in a variety of intersecting axes, highlighting the characteristics of sediment deposition across an area. Software enables them to be tilted and rotated so that the modeller can select a good perspective for illustrating key aspects of the model. They can

Figure 14 (right): Transect illustrating deposit characteristics, stratigraphy and proposed development impact © ARCA



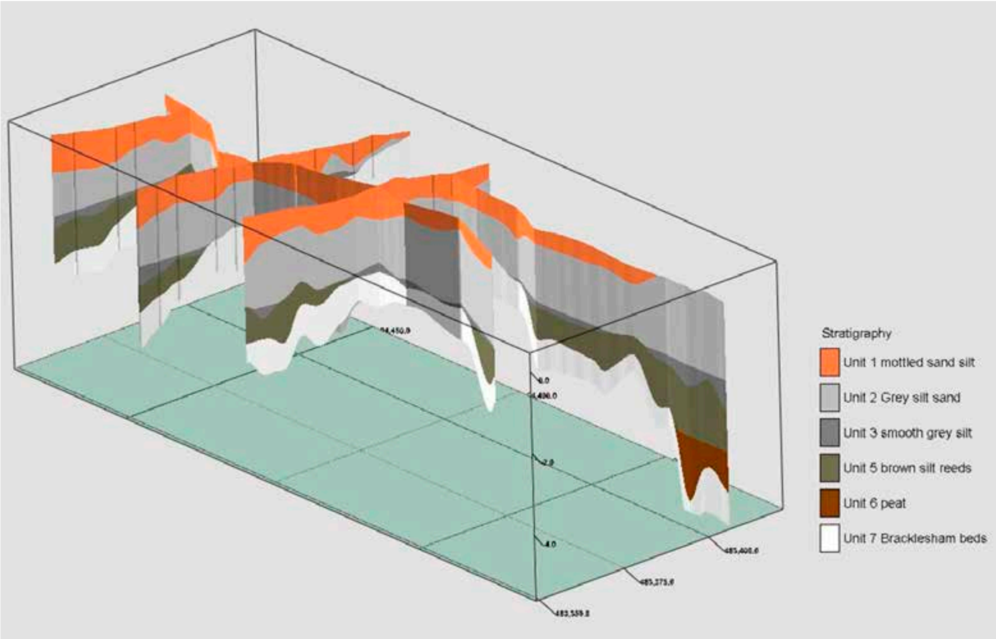


Figure 15: 3-dimensional fence diagram from Medmerry © Archaeology South East and Kristina Krawiec

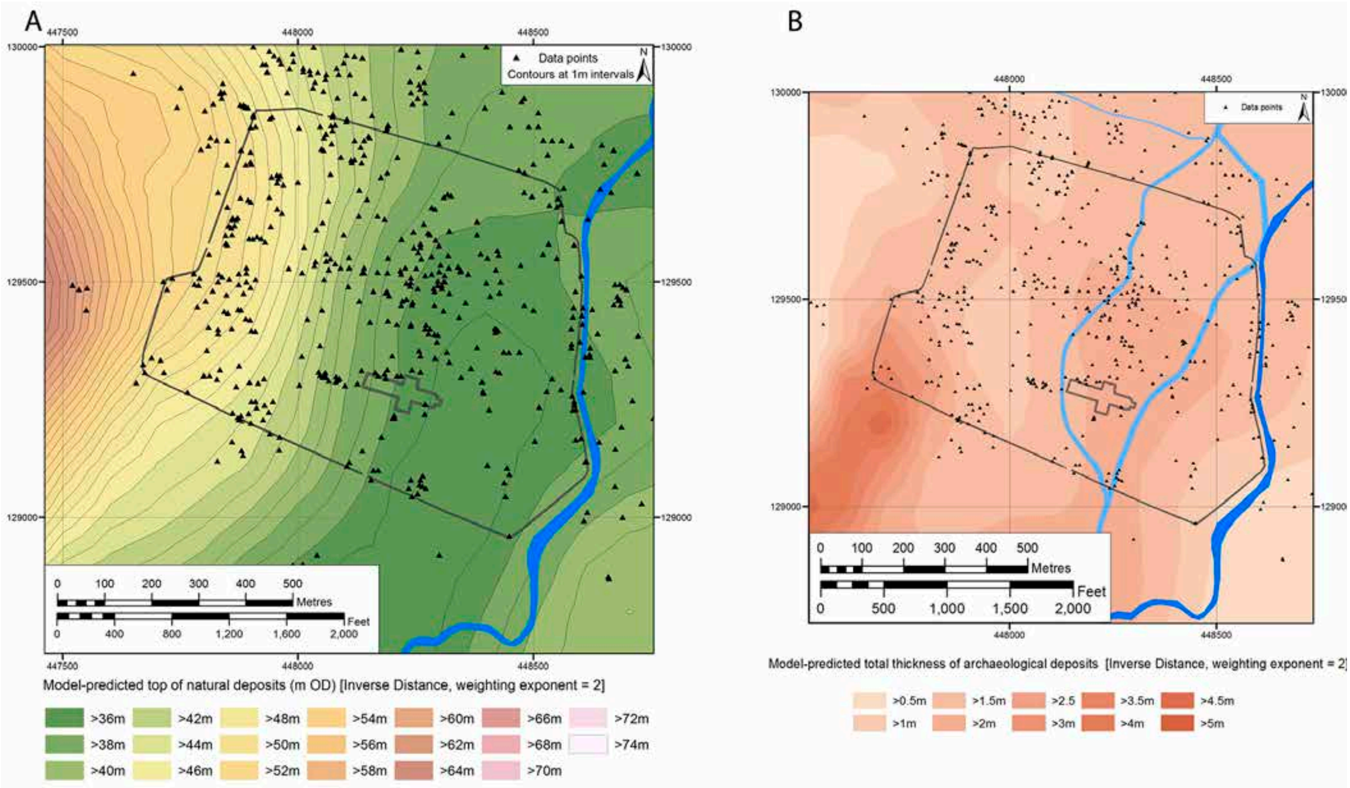
be difficult to relate to base mapping, but can convey an impression of the extent of a deposit or feature, in tandem with more clearly located cross-sections and surface plots (see front cover). The fence diagram in Figure 15 clearly shows the relationship of the peat and organic silt with low areas of the underlying bedrock (Bracklesham Beds) topography.

6.2.2 Surface plots

Software programmes provide an opportunity to display the spatial dimensions of the lower and upper contacts (interfaces) of key stratigraphic units as digital elevation models (DEMs) and to extrapolate thicknesses of key units as **isopach maps.** Unlike cross-sections, these plots will generally only model one sediment unit at a time; they are most useful, therefore, when examined in conjunction with each other, as well as with cross-sections. They are used to illustrate the topography of buried landsurfaces and the thicknesses of archaeological deposits or overlying sediment units (such as colluvium or alluvium), which might conceal archaeological deposits.

Figure 16 shows layers from a broad-brush deposit model constructed for the Winchester UAD. The surface of the underlying natural geology is predicted in Figure 16A and the thickness of the overlying archaeological deposits in Figure 16B. When examined together these outputs identify a deep archaeological sequence both on the valley floor and on the higher ground overlooking the river.

Surface plots can also be shown three-dimensionally, as block models, which are useful for visualising buried topography. Figure 17A shows a 3D representation of the Early Holocene topography of the Lower Walbrook Valley in the City of London. This shows the shape of the valley more clearly than the 2D map (Figure 17B), but can be difficult to relate to other mapping.



Contour maps: (A) surface plot and (B) isopach map from Winchester UAD

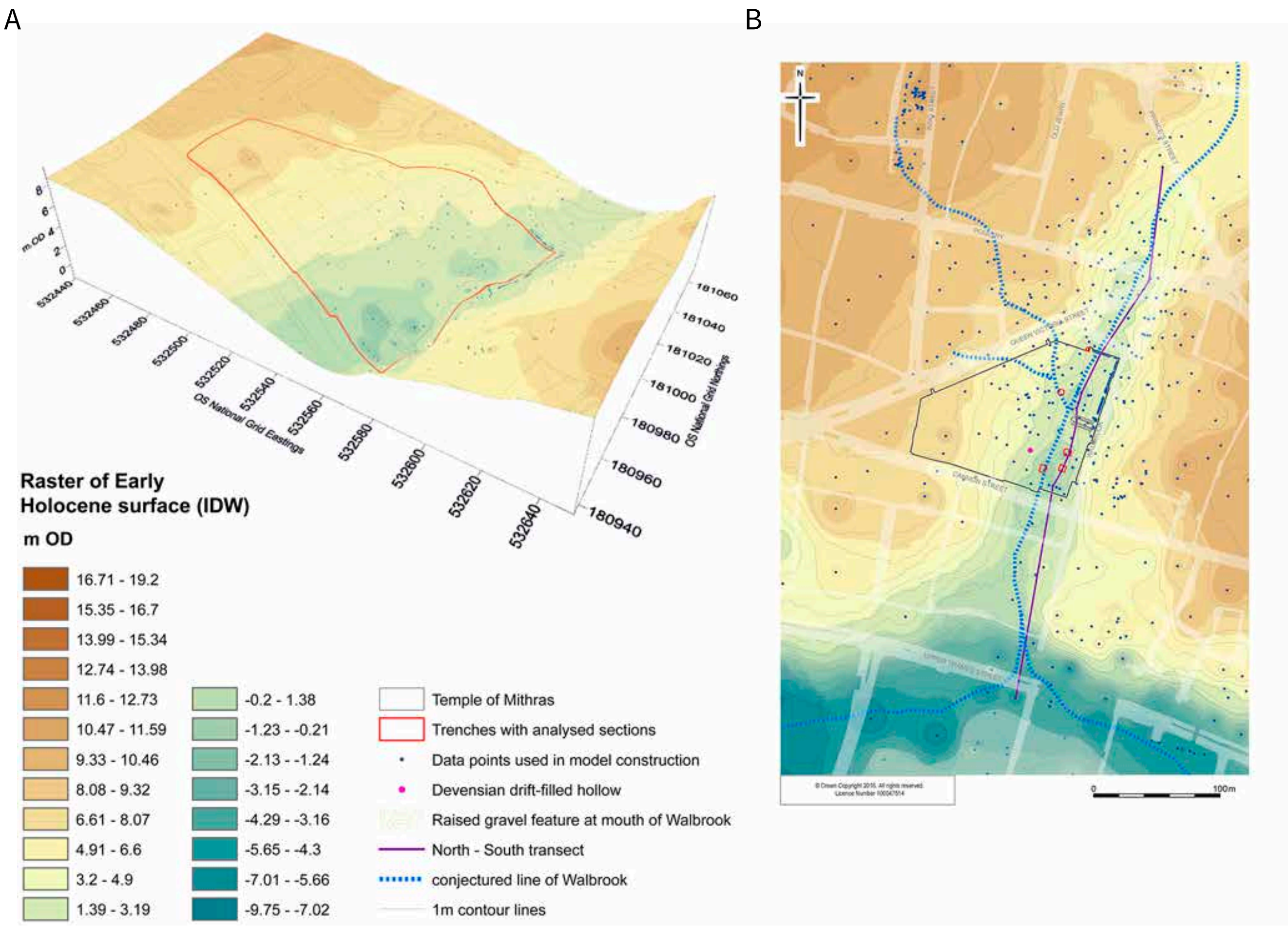


Figure 16 (top, page 39): Contour maps: (A) surface plot and (B) isopach map from Winchester UAD © Winchester CC

Figure 17 (bottom, page 39): The shape of a feature can be easier to see in a 3D block model (A) than a 2D map (B) © MOLA

6.2.3 Confidence in the model

The borehole distributions in Figures 16 and 17 help the user to gauge the reliability of the models, which will be less robust in areas where data points are further apart. Adding data point distributions to modelled surfaces and thicknesses is a simple and effective way of illustrating confidence in a model, especially where accompanied by a clear statement that reliability increases when data points are close together and evenly spaced. Statistical methods for expressing confidence are less accessible to end-users (and most modellers). Given the premise that archaeological deposit models are working models and will almost always be tested and updated through fieldwork, statistical testing is not necessary for most archaeological purposes. Where data points are sparse or unevenly distributed across an area, it can sometimes be appropriate to use a graphical cut-off filter to illustrate the modelling; this can highlight limitations of the model, but using cut-off filters has both advantages and disadvantages.

Cut-off filters provide a means of limiting the interpolation of a deposit model to a set distance from any given point. For example, if a cut-off filter is set to 50 metres, the model will not interpolate beyond 50 metres from any data point. Beyond this, a ‘gap’ will be shown in the model (Figure 18). These blank areas with insufficient data for modelling can help in making the case for additional geoarchaeological boreholes; especially where features such as palaeochannels, archaeological cut features or gravel islands with a relatively small spatial footprint might be overlooked if data are too widely spaced. Because cut-off filters limit the modelling to areas close to where

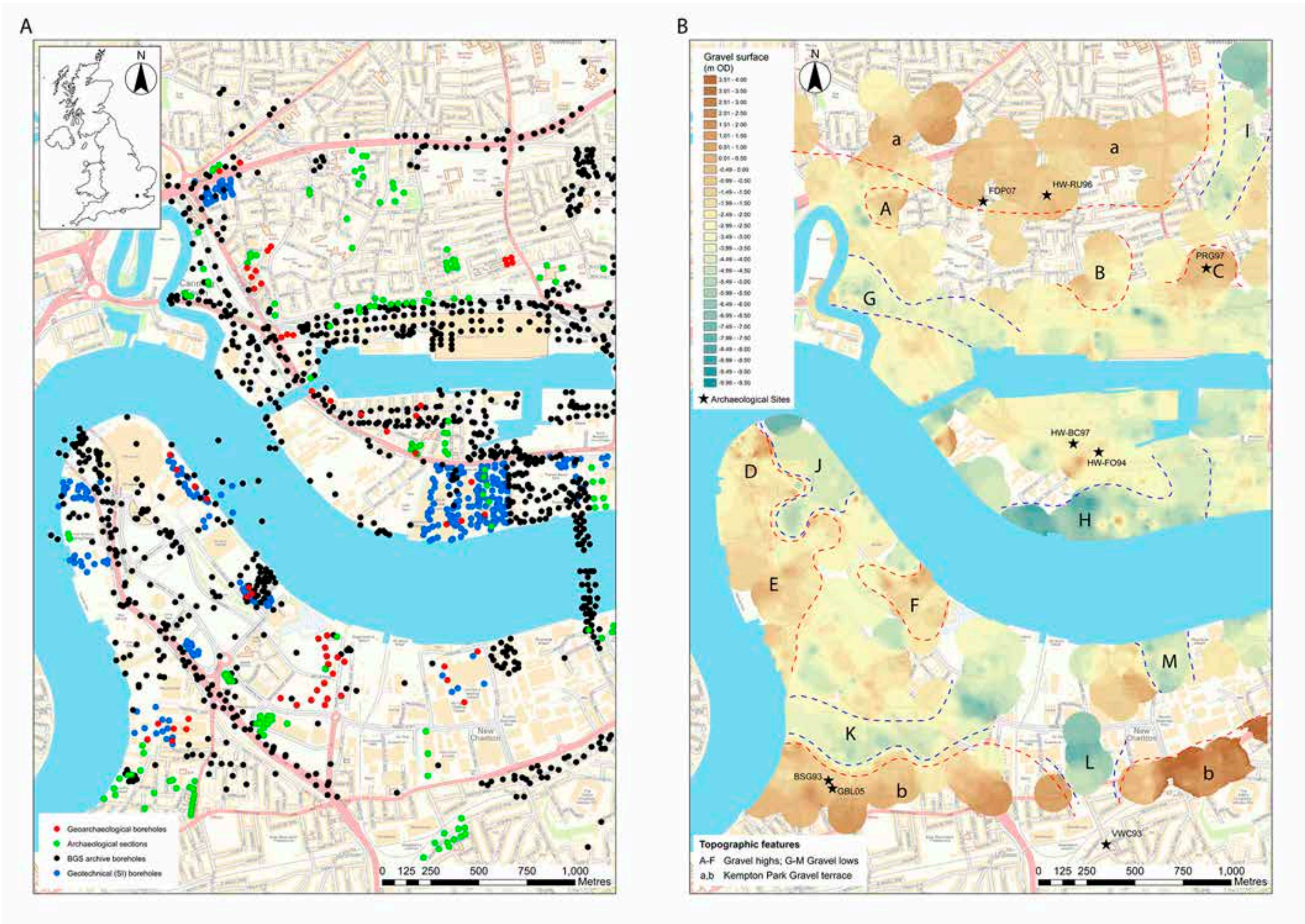


Figure 18 (below): Limitations in data coverage (A) illustrated with a cut-off filter (B) © QUEST data are present, they potentially make the outputs more reliable. However, inappropriate or arbitrary cut-off distances can be counterproductive and falsely reassuring. Their pros and cons need to be understood by the end-user and the justification for using them must always be stated.

Given that modelled layers can be used as illustrations, separately from their supporting text, figure captions should be explicit about reliability (eg with a statement such as less reliable in areas with fewer data points).

6.2.4 Character maps

A summary diagram of the outcomes from the deposit model, across a site or development area, is a convenient way of describing the main characteristics of the sediment sequence in different parts of a site. By dividing the site into landscape or geomorphological zones, differences in archaeological potential and significance can be easily explained (Figure 19). These diagrams aid decision-making and can be linked to a tabulated dataset providing further information. They can act as archaeological constraint maps for a site and feed into developers' risk models.

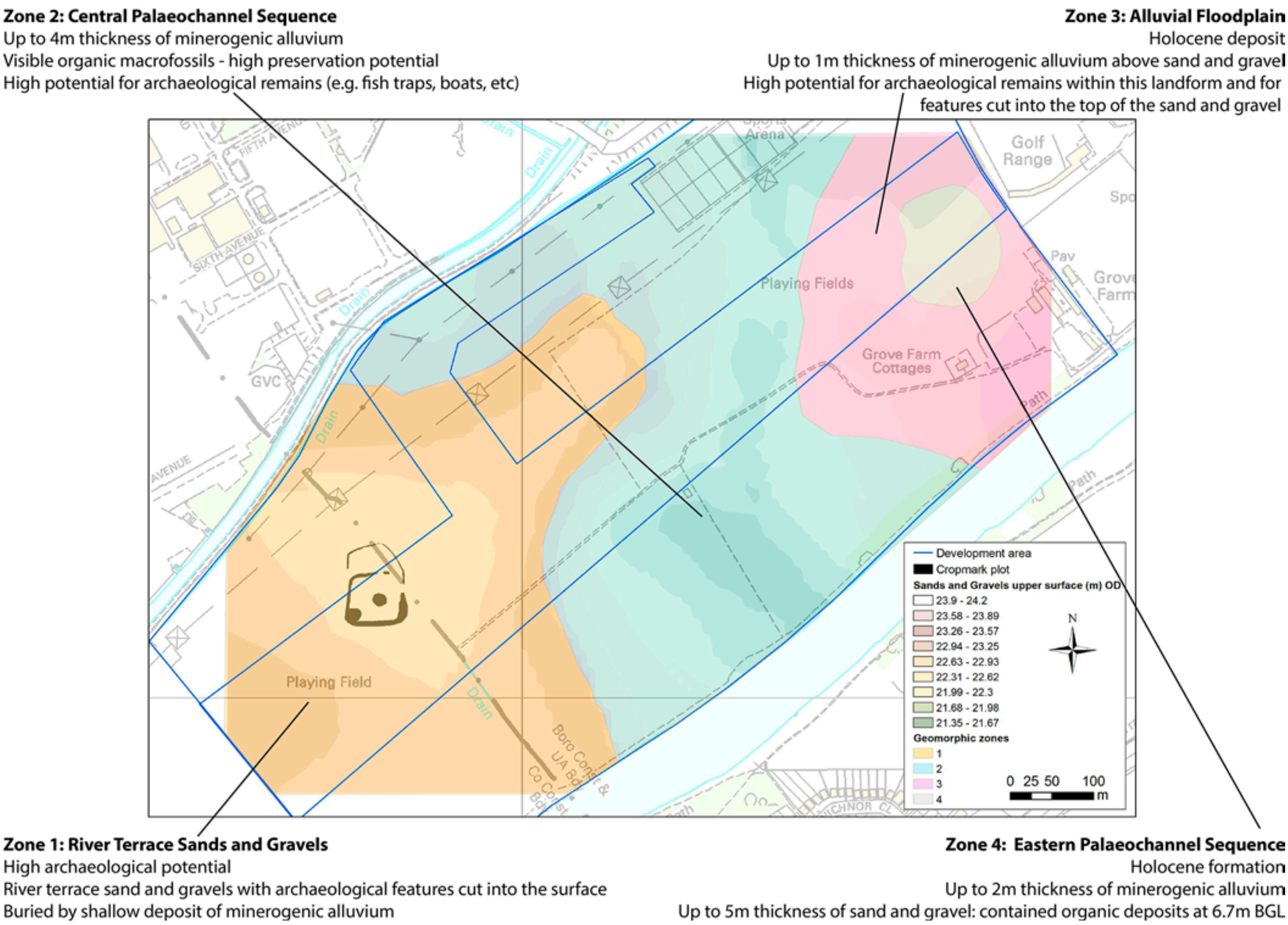


Figure 19: Character maps zone a site into areas of different archaeological potential © Trent & Peak Archaeology

7 Using the model

A deposit model is likely to be used if it is clear and comprehensible to non-specialists and addresses the archaeological questions it was commissioned to answer. In all cases:

- the archaeologist who commissions the model must be clear about its purpose
- the modeller must make the model understandable, relevant and useful to non-specialist end-users
- a deposit model should never be constructed as a 'box-ticking' exercise

The outputs of a model and how it is used will depend on its purpose. Although this is likely to change through the life of a project, it should be the first question asked when the scope of a model is considered.

Five case studies (CS1 to CS5) have been selected to illustrate the positive outcomes that deposit models can achieve. Three are development-led projects: CS1 is a big scheme; CS2 is a small urban site; and CS3 is a site where the archaeological interest lies within a sequence of natural sediments. Two are non-commercial and have been constructed within the context of heritage management: CS4 was undertaken as a research project; and CS5 was prepared during HER enhancement, re-using and updating earlier models. Two further examples have been used in Section 3 to illustrate ways in which deposit models can help communicate archaeological information to non-archaeologists at different stages of a project.

Many uses of deposit models are not discussed in this guidance, especially newer and more complex approaches, which are currently being developed. For example Sturt *et al* (2016), using the Somerset Levels as a case study, illustrate a number of GIS techniques, including potential limitations, for use with deposit models in generating predictive models. Later work utilised the same deposit modelling dataset to demonstrate how it could be integrated with Bayesian analysis of radiocarbon dates and palynological modelling to understand the timing of landscape-scale Neolithic clearances within the Somerset Levels (Farrell *et al* 2019).

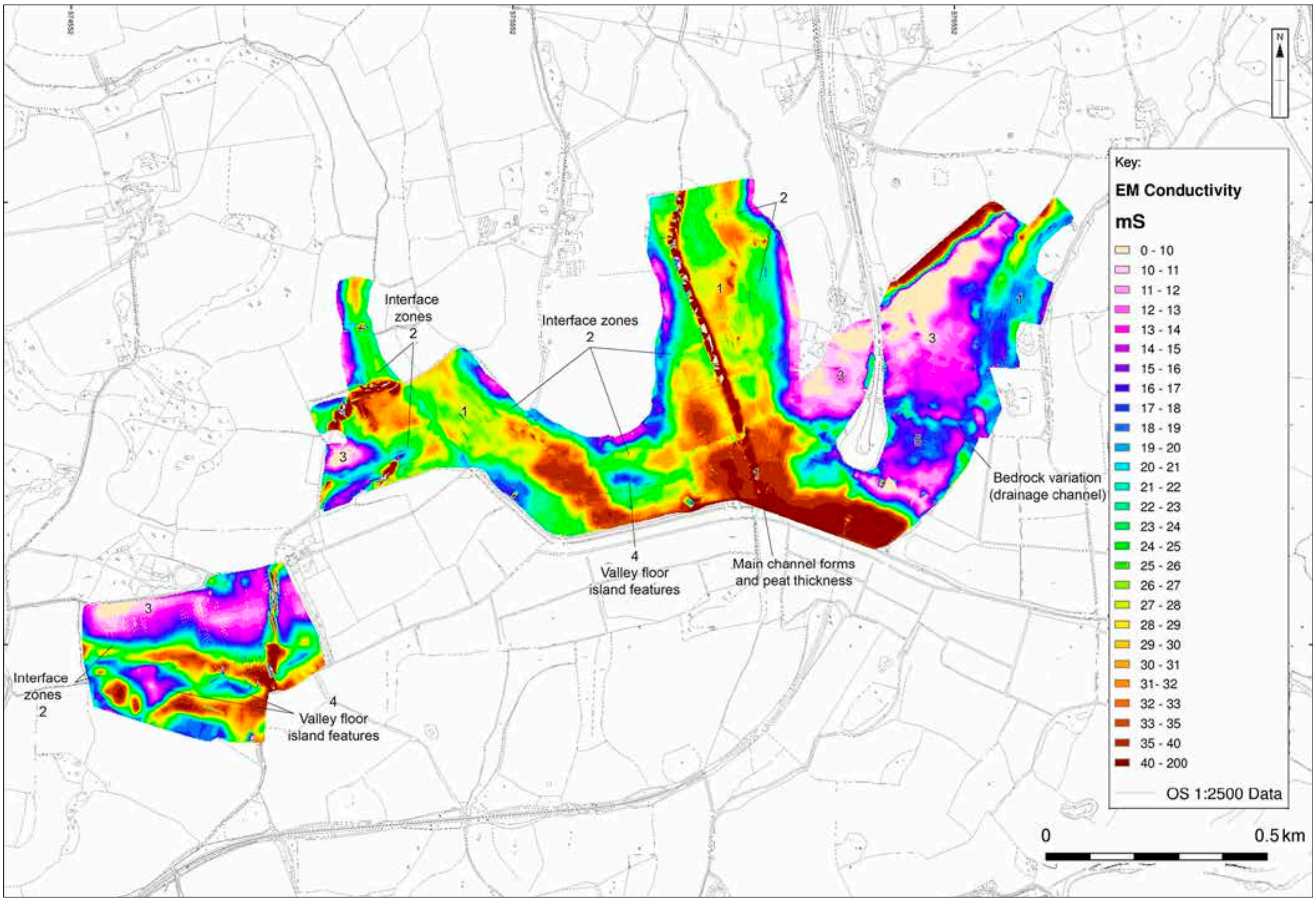
7.1 CS1: a large scheme

Deposit modelling provided the overarching framework for the archaeological investigation of the Bexhill-Hastings Link Road. It helped Oxford Archaeology communicate the archaeological potential to project partners throughout the project and ensured that steps could be taken to reduce risks and to avoid delays due to the discovery of unexpected archaeological remains.

A preliminary deposit model was constructed by the geoarchaeologist from existing geotechnical data for the entire 5.6 kilometre length of the scheme, as part of an initial Environmental Impact Assessment. This desk-based assessment gave early warning of the potential for wetland and dryland archaeology and for palaeoenvironmental evidence along the route.

To better understand the archaeological risk, the model was refined by the results of geoarchaeological investigation during a preliminary stage of evaluation. Boreholes were located where deep deposit sequences had been predicted and test pits were excavated in shallow areas. This enabled samples to be collected for dating. It also allowed first-hand examination of the deposits, which revealed lithic scatters, confirming the archaeological potential of the scheme. A subsequent geophysical survey, using magnetometry in shallow areas and electrical conductivity where the sequence was deep, identified islands and archaeological features. The browns and yellows in Figure 20 show areas of high conductivity, equating to

Figure 20: Conductivity survey enabled the entire site to be characterised © Oxford Archaeology



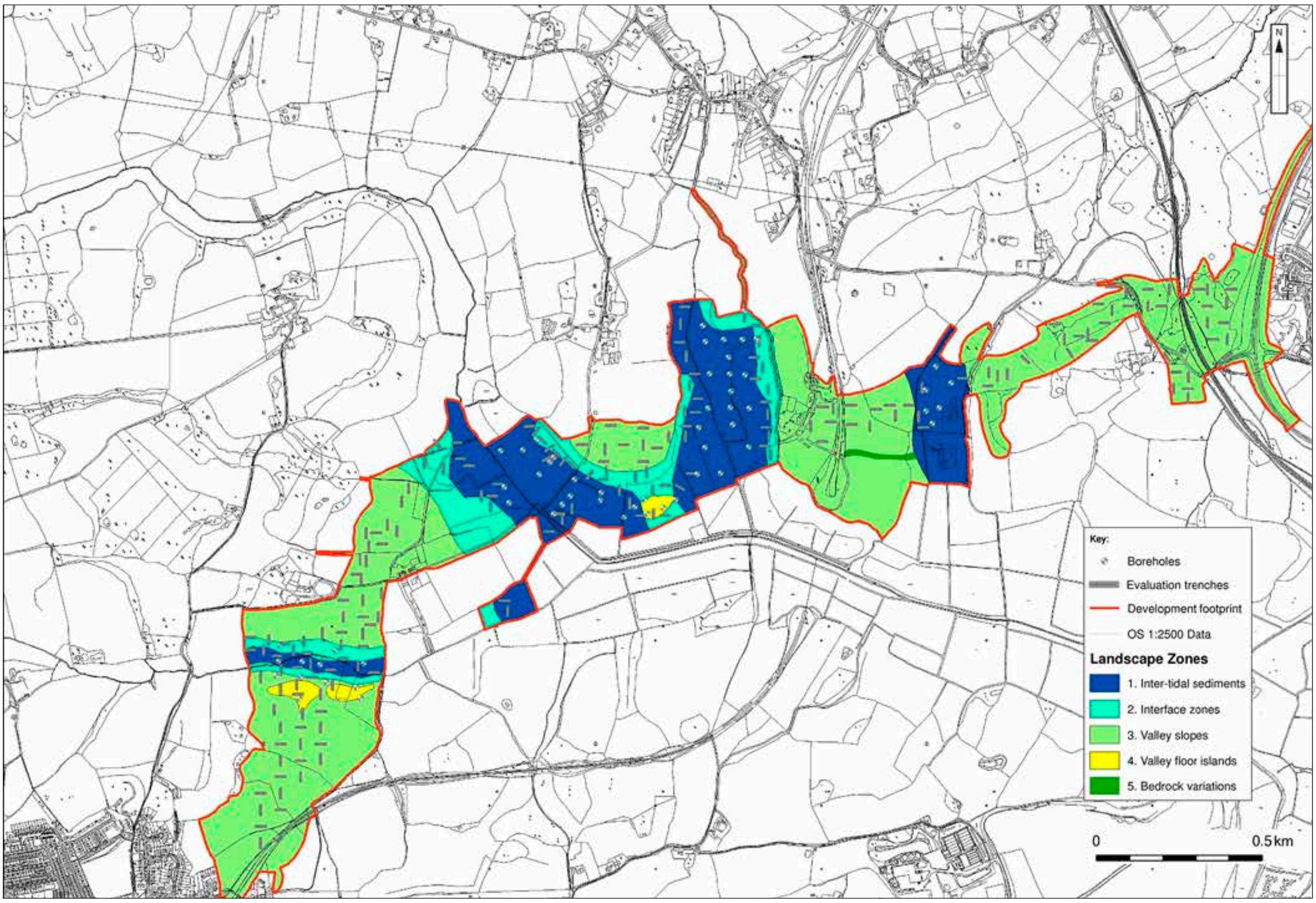
waterlogged riverine and estuarine deposits; the blues and purples pick out areas of low conductivity where the bedrock, or colluvium derived from it, lies close to the surface.

A character map of the site was constructed from the information in order to define zones of different archaeological potential. This is shown in Figure 21, where the map is overlain with the trenching (and borehole) evaluation strategies designed to reflect the likely depths of deposits of archaeological interest.

The trenching recorded lithic scatters and evidence for burnt mounds in areas modelled as lying at the wetland–dryland interface. This horizon was projected scheme-wide in an update to the model, which underpinned development of a mitigation strategy. Where possible the scheme design was modified to avoid the potentially very rich archaeological resource of the wetland-dryland interface. Where this was not possible, area excavation took place.

Across the deep wetland areas that would be impacted by ground consolidation techniques, mitigation was achieved by geoarchaeological boreholes. Their assessment and analysis provided a reconstruction of the changing environment of the site, creating a past landscape context for the excavated archaeological remains. For more detail about the project see chapter 5 in *Deposit Modelling and Archaeology* (Carey *et al* 2018).

Figure 21: Landscape zones guide the location of evaluation trenches and boreholes © Oxford Archaeology



7.2 CS2: a small urban site

Appropriate use of boreholes and associated deposit modelling can be challenging in an urban environment, as complex archaeology does not have the lateral integrity of natural deposits (eg alluvium, river gravels and buried soils). Therefore, correlation of deposits between boreholes is usually focused on the broad characterisation of sediments, rather than the identification of archaeological features and contexts.

Wellington House and its adjacent buildings form a parcel of land next to historic Kingsgate in Winchester, one of the entrances into the walled city. When redevelopment of the area was proposed, the northern part of the site was anticipated to preserve evidence for the town's Roman, Saxon and medieval defences. Planning permission was granted, subject to various conditions. These required archaeological evaluation (including a borehole survey) to assess the nature and significance of the buried archaeological remains in relation to the proposed development and to inform any subsequent mitigation that might be required.

A borehole survey carried out by Wessex Archaeology provided information about the sub-surface stratigraphy prior to evaluation trenching. Fifteen boreholes were drilled (at *c* 3 metre spacing) in two intersecting transects; these were designed by the geoarchaeologist to provide a cross- and longitudinal-section through the ditch, based on documentary evidence and previous archaeological information. The aims were to define the depth and extent of the medieval ditch, assess the nature of its fills and establish its potential to contain waterlogged remains. It also aimed to characterise the sequence of sediments and patterns of accumulation across the site and to collect samples that could be used for palaeoenvironmental and dating work at a later project stage.

The results identified a general site-wide deposit sequence comprising (from the top down):

- Made Ground (generally loose soil with relatively modern building rubble)
- anthropogenic deposits (a catch-all term for general archaeological deposits found across the site)
- alluvial ditch fills
- gravelly soil
- gravels (the underlying floodplain gravels of presumed Late Pleistocene date)

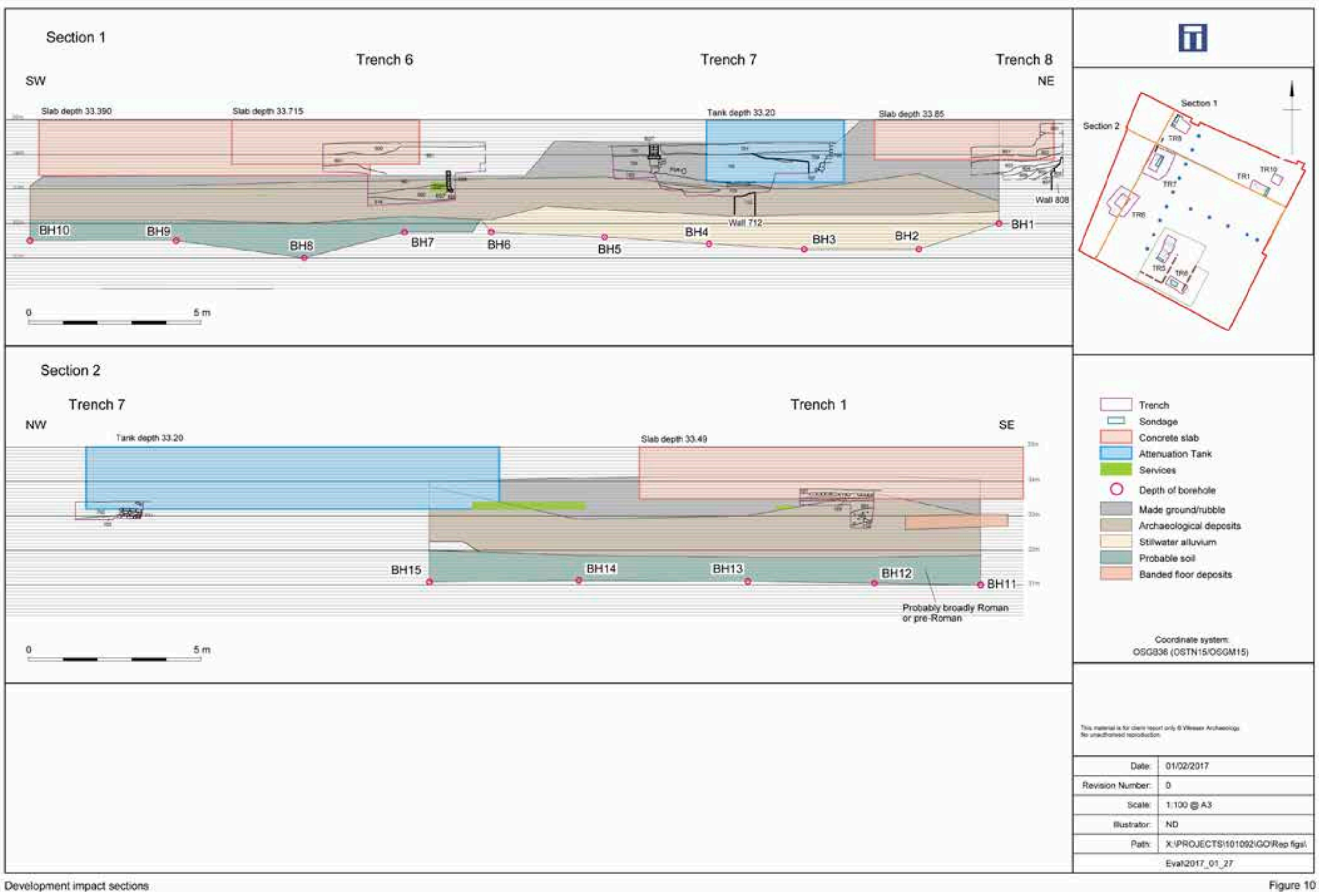


Figure 22: Schematic section illustrating site-wide deposit sequence overlain by key archaeological remains and development impact © Wessex Archaeology

These results contributed to the assessment of archaeological potential that was presented in the evaluation report. They provided broad site-wide layers of different deposit types, illustrated as schematic sections, on which were superimposed the proposed development impacts and the archaeological remains recorded in the evaluation trenches (Figure 22). This information was used to inform a mitigation strategy.

Mitigation involved an additional transect of boreholes drilled on pile locations. This ran parallel with the evaluation transect across an area where the ditch was conjectured but had not been identified from earlier geotechnical logs (Figure 23). These boreholes confirmed the evaluation interpretation that no ditch was present in this area, as the gravelly pre-ditch soil extended across it. Elsewhere on site, where the ditch was found and its waterlogged fills survived, they were left preserved *in situ* below the development. Borehole cores taken through the ditch deposits were retained for post-excavation assessment and analysis in view of their importance for providing a dated framework for the ditch fill sequence, as well as information about the changing character of the ditch and its environmental setting. Shallow archaeology that would be impacted by the scheme was the subject of area excavation.

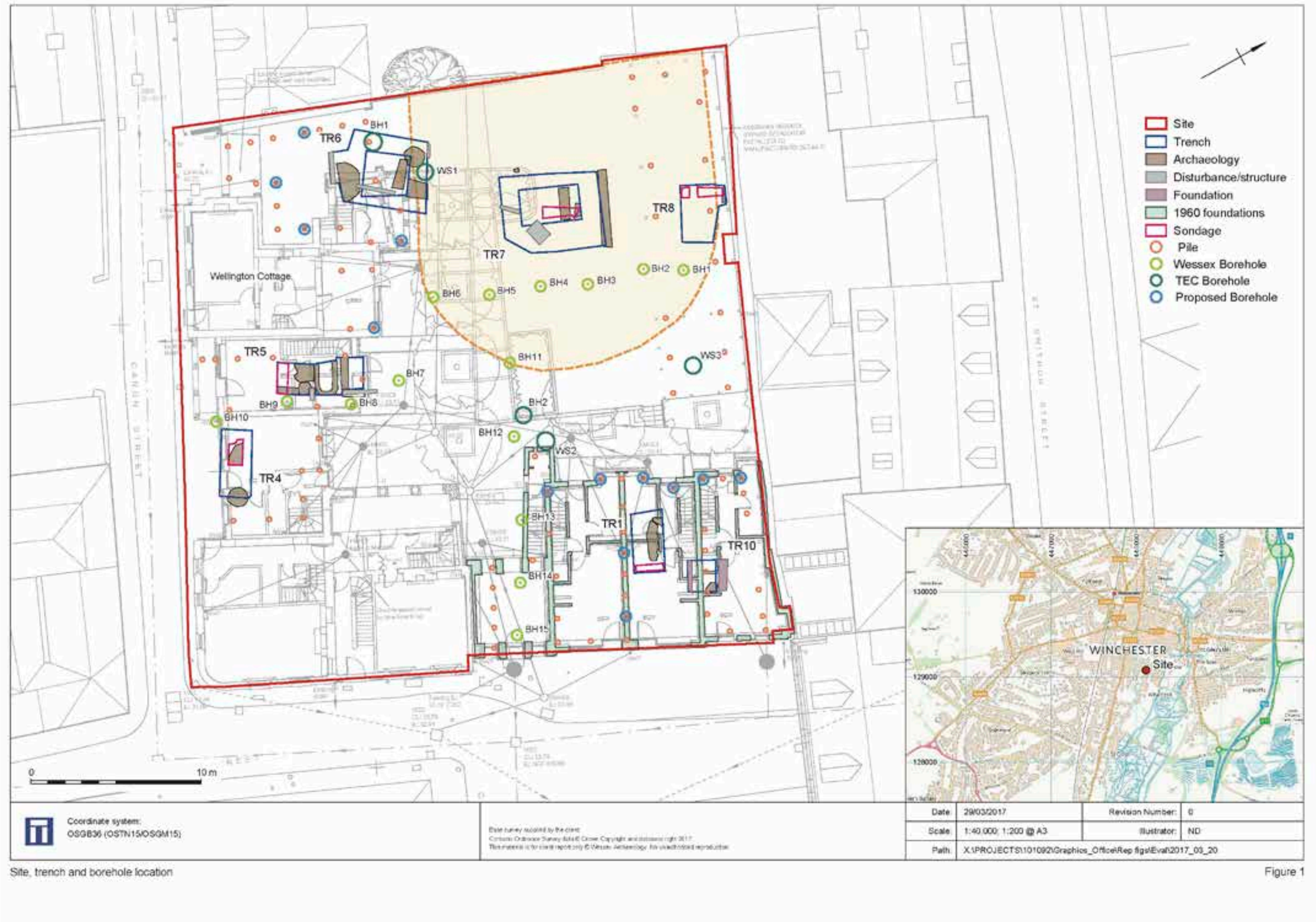


Figure 23: Location of evaluation and mitigation boreholes against conjectured ditch extent and proposed piling layout © Wessex Archaeology

7.3 CS3: archaeology in a natural deposit sequence

Significant Palaeolithic archaeology has previously been found in the lowest river terraces of the River Medina (Isle of Wight). Therefore, there was a need to establish whether Pleistocene deposits of Palaeolithic interest were present in advance of the construction of a new superstore proposed at Pan Lane, Newport, which was to be cut into the valley side. To achieve this, ARCA was commissioned to produce a geoarchaeological deposit model as part of an evaluation required to discharge the archaeological planning condition.

The aim was firstly to better understand the depth and distribution of Quaternary deposits across the site and establish their Palaeolithic potential, and secondly to assess the impact of the development on these deposits. It was anticipated before the geoarchaeological work took place that the superstore would require comprehensive excavation for Palaeolithic archaeology, especially upslope where its footprint would cut up to 4 metres into the valley side and where Pleistocene river terraces were thought to exist. Downslope, the existing ground level would need to be raised and levelled with the excavated spoil.

An initial deposit model, based on the results of previous archaeological interventions and geotechnical investigation was prepared; this guided the location of 12 test pits and three geoarchaeological boreholes. Updating the deposit model with the new information, together with the results of luminescence dating, demonstrated that a significant river terrace existed only in the north west corner of the site and was unlikely to be impacted by the development. The footprint of the store lay entirely over truncated bedrock and scoured channels infilled with Head (Pleistocene slope deposits) which the test pits indicated was not (on this site) of Palaeolithic significance.

By superimposing the proposed development footprint onto a distribution map of the Quaternary deposits, the equivalent of a character map (Figure 24) and onto a schematic section (see Figure 14), the impact of the development was made clear to all stakeholders. More detail is provided in chapter 4 of *Deposit Modelling and Archaeology* (Carey *et al* 2018).

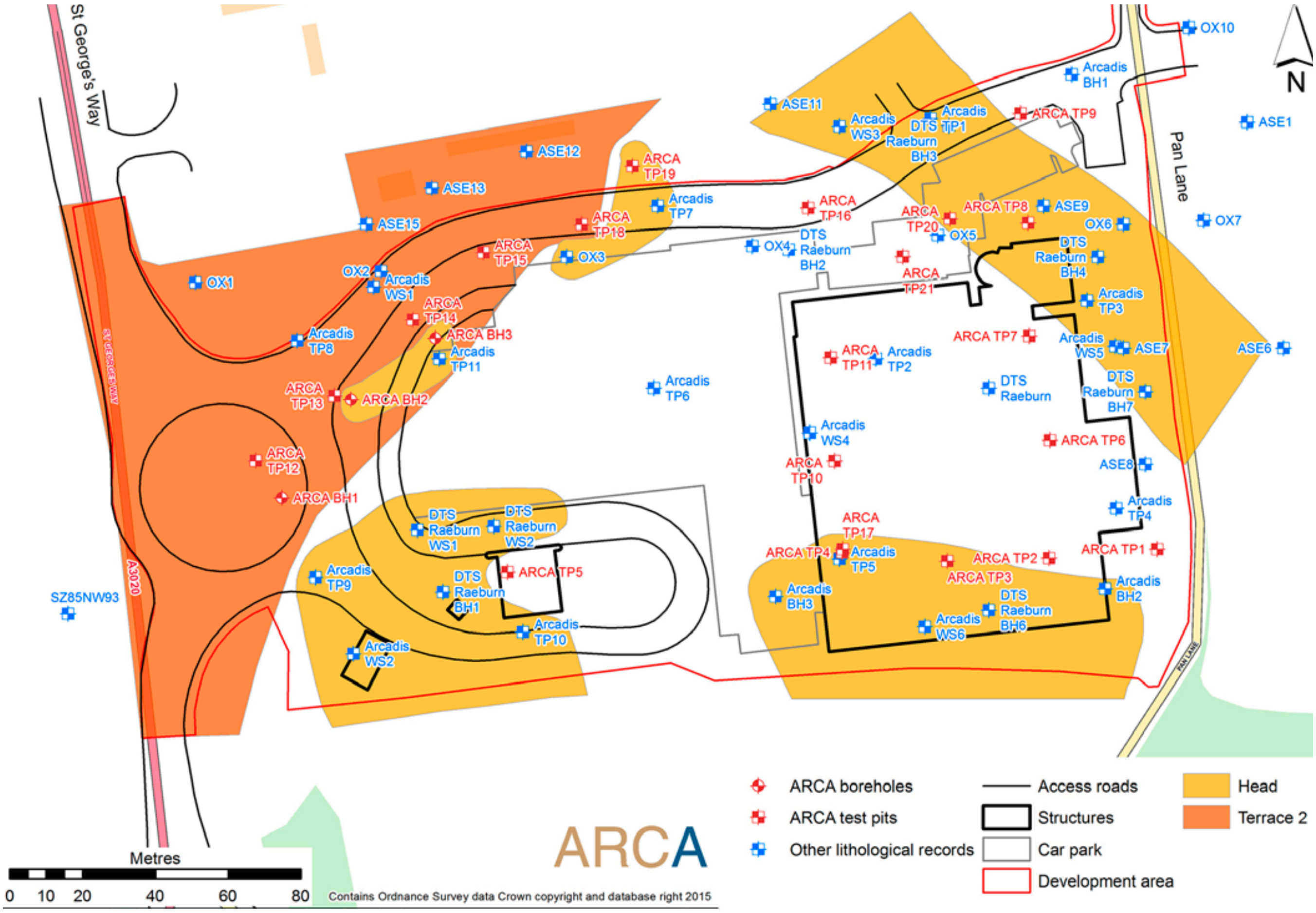


Figure 24: Extent of deposits of likely significance, with development footprint superimposed © ARCA

7.4 CS4: furthering archaeological research

Geoarchaeologists who work frequently within a town or region accumulate their own database of borehole logs, which provides a sound basis for generating new models when work on future developments takes place. MOLA, for example, has a dataset of over 13,000 data points for central London, stretching from Westminster to Rainham and up the Lea Valley as far as Enfield (Figure 25). This formed a sound starting point for the collaborative modelling work undertaken through the planning process as part of the Battersea Channel Project, for which MOLA, Wessex Archaeology and Reading University (QUEST) each contributed between 300 and 600 data points. More information on this project can be found in chapter 11 of *Deposit Modelling and Archaeology* (Carey *et al* 2018).

Where data have not been synthesised previously, integrating the information from previous work into a landscape-scale model is usually beyond the remit of modelling undertaken as part of a development-led project. Yet such an overarching deposit model could inform requirements and prevent unnecessary work as part of the planning process. Considerable development is taking place in the London boroughs of Newham and Greenwich, which lie either side of the Thames in east London. The need to understand this buried landscape for heritage management purposes prompted QUEST to undertake a deposit modelling research project and publish the results.

Today, the prehistoric and early historic topography of the area is imperceptible and deeply buried below both urban sprawl and a significant accumulation of riverine and estuarine deposits. In prehistory, however, it consisted of a network of small islands, stream channels and fens that lay between the higher ground in the north (Newham) and south (Greenwich), where Pleistocene river terraces cropped out above the floodplain. Based on geoarchaeological data obtained from their own site investigations and previous models, supplemented by that held in the HER and by the British Geological Survey, QUEST collected a database of over 2,000 geoarchaeological records across the area located in Figure 25 and illustrated in Figure 18A. From these data a deposit model was constructed for the Late Pleistocene landsurface Figure 18B and overlying Holocene deposits of the floodplain and adjacent river terraces.

A number of topographic features were identified, including gravel highs that remained as dry islands above the waterlogged valley floor as river levels rose throughout prehistory. Comparison with the known archaeological record allows the deposit model to be used as a predictive tool. To date, all known prehistoric archaeological sites are demonstrably associated with sand or gravel highs, with key locations for both cultural and past environmental evidence following palaeochannel margins. While it might be expected that the thickest peat deposits would be associated with the lowest topographic features, the relationship is far less clear than this, as the peat was clearly forming at different times in different places, most likely as a result of differing environmental factors. This is demonstrated in Figure 26, where each borehole log indicates a similar sequence of deposits that vary in date and archaeological significance.

This project demonstrates the role that landscape-scale modelling can play in the development of research questions and strategies that inform development-led archaeology. The findings are explained in more detail in chapter 10 of *Deposit Modelling and Archaeology* (Carey *et al* 2018).

Figure 25: Distribution of MOLA datapoints for London © MOLA

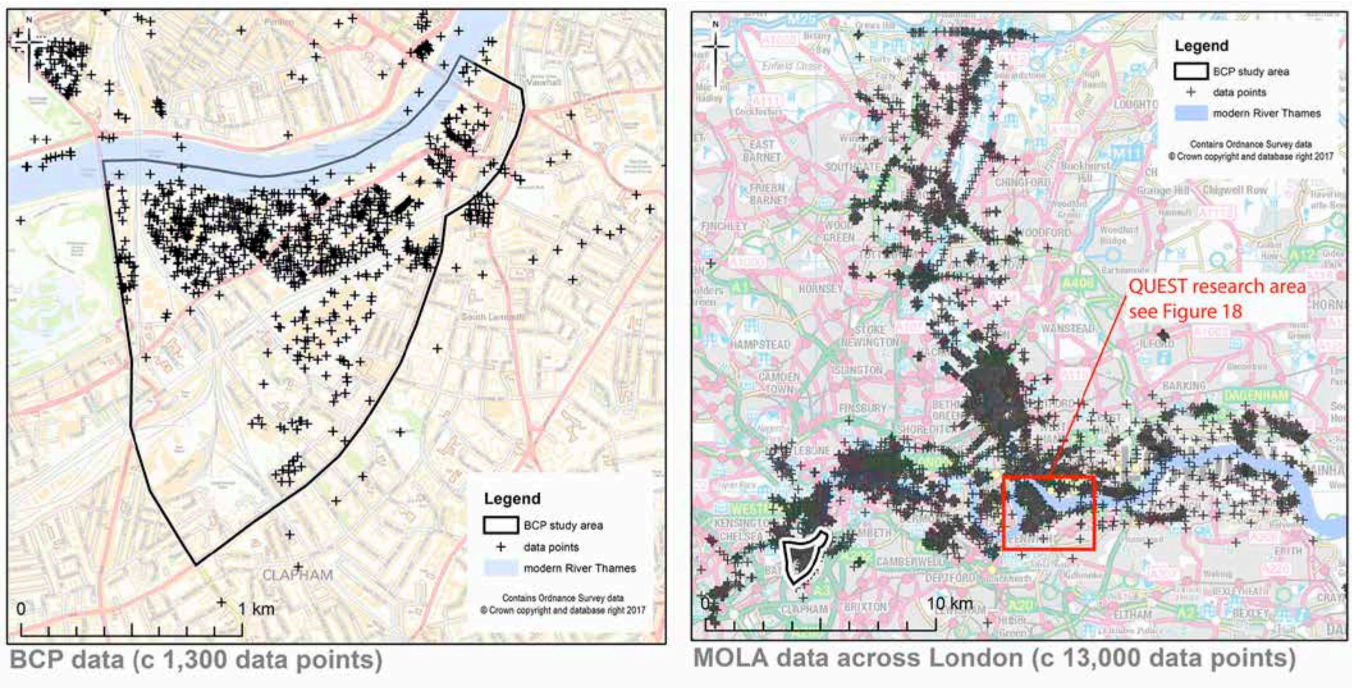
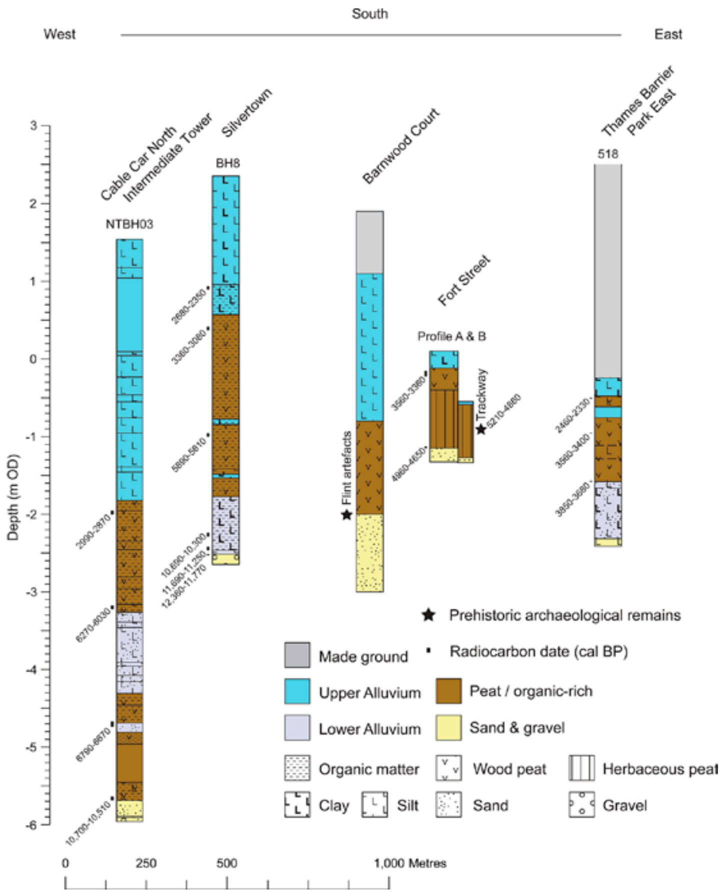


Figure 26: Comparision of deposit sequences across the Silvertown area of Newham © QUEST



7.5 CS5: HER enhancement

Datasets for deposit models are not redundant when a project is completed. Their value is enhanced when they are re-used. This premise has been central to modelling in Dover, where initial models constructed 30 years ago continue to be updated with new information and now form part of the HER.

Dover is underlain by a thick sequence of marine, freshwater and terrestrial deposits that document the evolution of the Dour estuary, which encompassed a Roman harbour. A dynamic geomorphological environment has buried archaeological remains with alluvial sediments, as well as other deposits, for example wind-blown sand (Figure 27). A deposit model constructed in 1990, using borehole records and excavation data, produced simple contour plots and meshed surfaces to define the outline shapes of the inner and outer harbours. This initial model was refined and re-evaluated as part of major sewage and other works within the town centre, which led to the discovery of significant environmental deposits of peat and tufa and a Bronze Age boat.

Until recently the model has mostly been updated through personal research. However, extensive regeneration is planned for Dover, prompting the need for the modelling outputs to be more widely available and used for decision-making within the planning process. The model is currently being integrated into the Dover UAD, so that its results and data can be accessed via the HER. The UAD project has enabled recording of the nature and depth of archaeological deposit sequences (obtained from excavation reports and borehole logs) within the HER (as Events), providing a useful resource for the development control process. The model has also been extended beyond the town centre to other parts of the Dour catchment, as well as into the modern harbour, where bathymetric and seismic profile data have been incorporated.

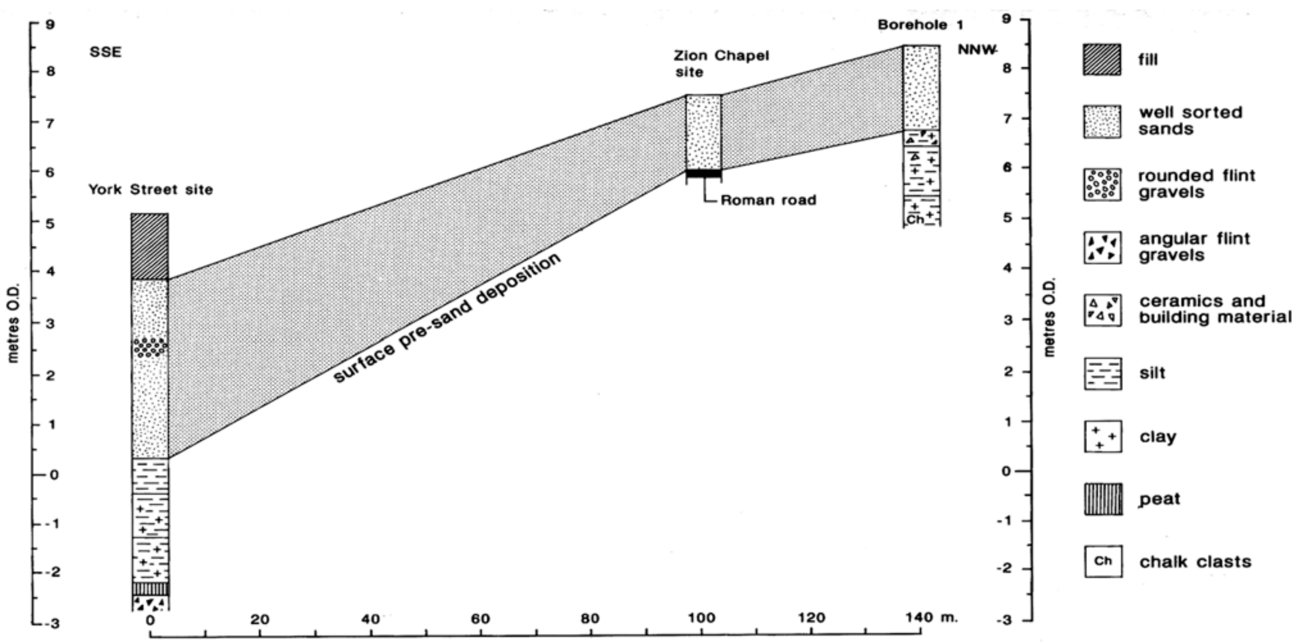


Figure 27: Transect identifying a potential Roman landsurface, buried by wind-blown sand © Martin Bates

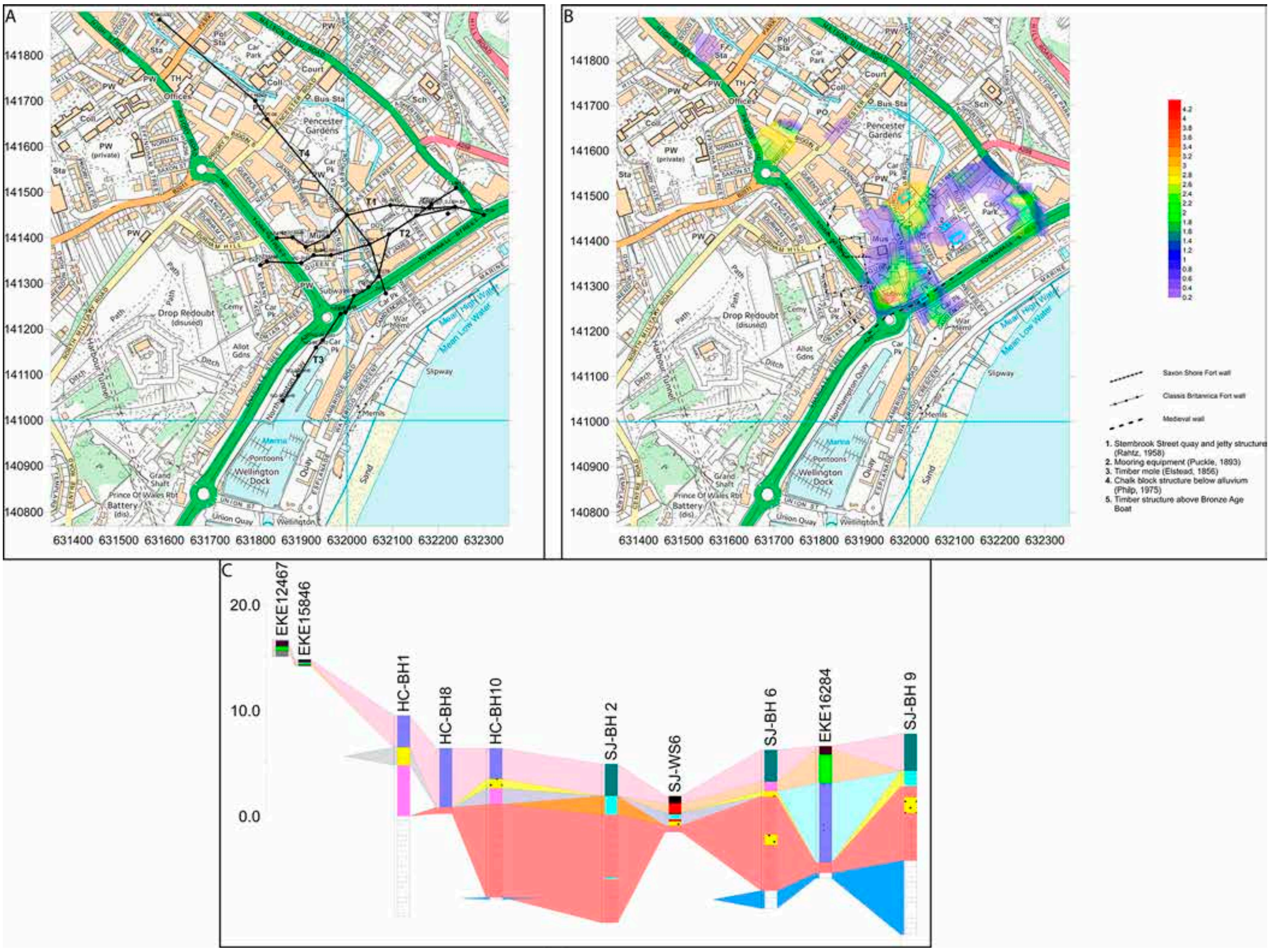


Figure 28: Deposit model outputs displayed as layers in Dover's UAD (explanation in main text) © Martin Bates and Kent CC

Data entry is undertaken by the HER officers. Deposits are ascribed to a pre-determined stratigraphic sequence based on the previous models and agreed by the steering group (HER officers, development management team and geoarchaeologist [Dr Martin Bates]). These stratigraphic data are taken directly from Excel into Surfer 12 and allow the geoarchaeologist to model surfaces and thicknesses, with transects prepared in RockWorks. The digital outputs (with transects as PDFs) are then brought back into the HER GIS for display against other layers of information. As an example, the thickness of harbour fills and location of indicative transects are superimposed on street mapping in Figures 28A and 28B respectively, alongside a draft of Transect 2 (minus its key; Figure 28C).

Updating the database forms part of the standard HER data entry process, but updates to the modelled layers and representative transects need external geoarchaeological input. The modelling layers will be supported by a text commentary (currently in preparation) that reviews the findings and provides a how-to-use guide for researchers and curatorial staff. This will also identify areas where additional data are needed to make the model more robust and will help to ensure that future projects provide for relevant data gathering in those areas. More information about the deposit modelling work that has been done in Dover is provided in chapter 2 of *Deposit Modelling and Archaeology* (Carey *et al* 2018).

8 Future Use and Archiving

The deposit modelling process ends with ensuring that the information is stored and made easily accessible for future use.

Archiving is a necessary stage that must be completed at the end of a project to meet planning or funding requirements. It is essential that the records created are not retained solely by the organisations that have done the work, but are available to others working nearby in future.

8.1 Planning requirements

It is a requirement of planning policy (NPPF 2019, Section 16, 199) for local authorities and developers to make archaeological records and the archive generated from archaeological work publicly accessible. Reports should be deposited with the Historic Environment Record and any archives with a local museum or other public depository (such as the Archaeology Data Service).

8.2 Archaeology Data Service

The Archaeology Data Service (ADS) is a secure digital archiving facility, where data can be curated appropriately and maintained for the future. All data should be deposited with the ADS, including raw data, the interpretation of those data and the outputs from the model(s). This would include: borehole logs; spreadsheets of interpreted stratigraphic units including XYZ information; geophysical data and their interpretation; and resultant GIS files of various deposit and surface parameters.

8.3 Historic Environment Records

All reports and illustrations must be deposited with the relevant Historic Environment Record (HER). Some HERs will be capable of holding digital data. Discussion with the local HER officer is essential at the beginning of the project to know whether they can accept data, curate them and make them publicly available. At this point the HER officer will confirm their local standards (eg format and file structure).

Some HERs, especially those with a UAD, have deposit model layers and/or borehole records (as Events). In these cases it is sometimes possible for new work to extract and use data from the existing model. Depending on the skillset of the HER officer and available software, the new modelling might be able to feed into and update the existing evidence base.

In general, HERs will require the data to be supplied in two forms:

- interpreted layers (shape files) that will help planning archaeologists, consultants and contractors who consult the HER understand the findings from the site
- point data that might more easily be incorporated into future models

8.4 Future development

Data generated from work undertaken as part of the planning process are held in the public domain. However, data created by deposit modelling can often be challenging to find. Research and development is needed to create tools that make it easier and more efficient to understand what work has been done and where, what the results showed and how to extract the raw data for re-use.

Typically, the deposit model is an appendix in a site report. The site is identified by a polygon on the HER, but the existence of a deposit model (unless it is recorded as a separate Event) cannot always be seen from a HER search. Usually, the information has to be extracted from the site report and data inputted from scratch into a new database to re-use it. This is time-consuming, not cost-effective and rarely undertaken, and thus much existing information that could contribute to new deposit models remains unused.

A step-change in how deposit modelling is used requires the distribution of the numerous deposit modelling data points (geoarchaeological boreholes; profile logs from archaeological sections/test-pits; archaeologically-interpreted geotechnical logs) to be visible in a HER search, or by other open-access means. Ideally this information would be digitally downloadable, for re-use in new deposit models. This would not replace the requirement for archiving the data with the rest of the site records, but would supplement it with a tool that allowed the spatial distribution of the datasets to be interrogated.

At the very least, individual site and wider area deposit models should be visible collectively as a layer on the HER, so that their availability is clearly evident. For now this is an aspiration, but we recommend that the sector works towards achieving this ambition, to make sure that the value of every deposit model is maximised.

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10 Glossary

Aeolian – Natural processes driven by wind action that can lead to both the erosion and deposition of sediments.

Alluvium – Sediment deposited by running water, usually a river or stream. Generally, the term is not used for sediments deposited in lakes or marine environments. In archaeology, the term is often used in association with fine-grained sediments (eg silts and clays).

BIM - Building Information Modelling is a process for creating and managing information on a construction project during the lifecycle of the individual scheme.

Colluvium – Material moved naturally on slopes by a combination of gravitational processes (mass movement) and hillwash. The sediments are usually locally derived; in the archaeological record, their development has often been exacerbated by human activity.

Correlation – The process of comparing two geological records to identify similarities and differences that allow the connection of events in both space and time.

Geological maps – Geological maps produced by the British Geological Survey (BGS) are deposit models in their own right. Until the relatively recent past, the emphasis of geological mapping was placed on the detailed understanding of economically-significant deposits rather than the superficial sediments. Therefore, not all Quaternary sediments have been recorded and mapped in detail, although they may be of significant archaeological interest.

Heritage Action Zones – A Historic England initiative launched in 2017 and funded by central government that aims to use local heritage assets to drive economic growth and social cohesion in cities, towns and villages across England.

Historic Environment Records (HERs) – Databases, often held within local authorities, which provide sources of information relating to landscapes, buildings, monuments, sites, places, areas and archaeological finds. They are used for planning and development control, but they also fulfil educational and research purposes. They were formerly termed Sites and Monuments Records (SMRs).

Holocene – The youngest part of the Quaternary period, encompassing the last 11,000 years of geological time. It is often referred to as the postglacial period.

Isopach – A line (contour) joining points of equal value. An isopach map is a contour map illustrating thickness variations within a sediment body over an area. It is used colloquially in this guidance to cover both its correct meaning, the perpendicular distance between the upper and lower boundary of a stratigraphic unit (true stratigraphic thickness), and the vertical thickness of a deposit (true vertical thickness, which is correctly displayed as an isochore map).

Iterative process – The process of repeating an action to allow the review of previous findings and conclusions.

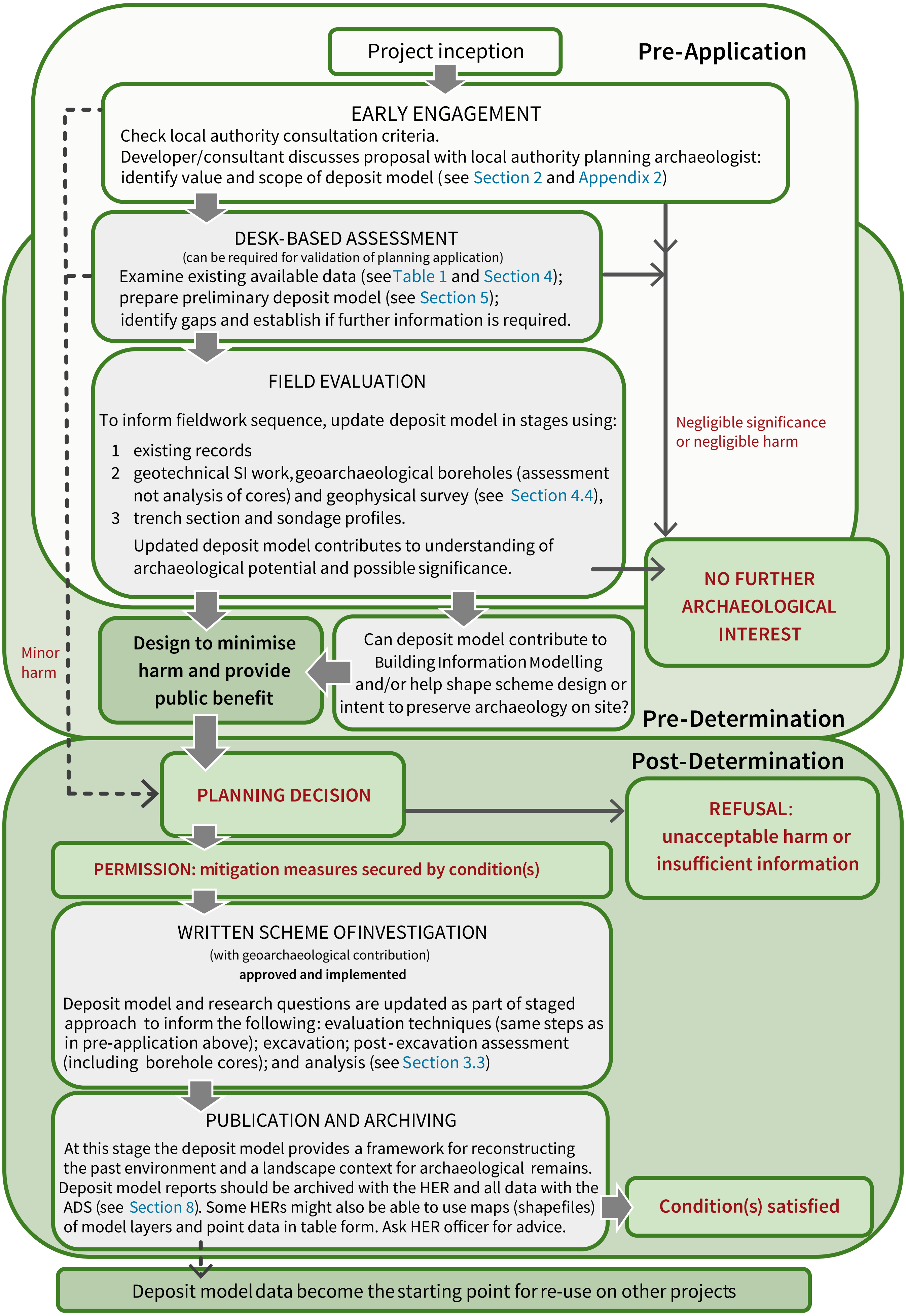
Pleistocene – The oldest part of the Quaternary period, preceding the Holocene and extending back to around 2.6 million years ago. It is characterised by major alternating warm and cold stages defined respectively as interglacials and glacials.

Quaternary – Approximately the last 2.6 million years of geological time, encompassing both the Pleistocene and Holocene epochs and extending to the present day. It is characterised by profound climatic changes and provides a timeline along which modern humans evolved from primate ancestors.

Sub-surface stratigraphy – The individual layers of sediment identified below a defined ground surface and their study, which usually involves spatial and temporal correlation.

UADs – Urban Archaeological Databases provide detailed Historic Environment Record coverage for areas that have rich and complex below-ground archaeology; they have been created so far for about 30 historic towns and cities across England. They provide descriptions and maps of all individual pieces of archaeological work (‘Events’) which have taken place within a defined geographical area, along with a summary of all the ‘Monuments’ which have been identified by that work.

11 Appendix 1: Deposit models in the planning process


Project inception
Pre-Application
EARLY ENGAGEMENT
Check local authority consultation criteria.
Developer/consultant discusses proposal with local authority planning archaeologist: identify value and scope of deposit model (see Section 2 and Appendix 2)
DESK-BASED ASSESSMENT
(can be required for validation of planning application)
Examine existing available data (see Table 1 and Section 4); prepare preliminary deposit model (see Section 5); identify gaps and establish if further information is required.
FIELD EVALUATION
To inform fieldwork sequence, update deposit model in stages using:
1 existing records
2 geotechnical SI work, geoarchaeological boreholes (assessment not analysis of cores) and geophysical survey (see Section 4.4),
3 trench section and sondage profiles.
Updated deposit model contributes to understanding of archaeological potential and possible significance.
Negligible significance or negligible harm
NO FURTHER ARCHAEOLOGICAL INTEREST
Minor harm
Design to minimise harm and provide public benefit
Can deposit model contribute to Building Information Modelling and/or help shape scheme design or intent to preserve archaeology on site?
Pre-Determination
Post-Determination
PLANNING DECISION
REFUSAL: unacceptable harm or insufficient information
PERMISSION: mitigation measures secured by condition(s)
WRITTEN SCHEME OF INVESTIGATION
(with geoarchaeological contribution)
approved and implemented
Deposit model and research questions are updated as part of staged approach to inform the following: evaluation techniques (same steps as in pre-application above); excavation; post-excavation assessment (including borehole cores); and analysis (see Section 3.3)
PUBLICATION AND ARCHIVING
At this stage the deposit model provides a framework for reconstructing the past environment and a landscape context for archaeological remains. Deposit model reports should be archived with the HER and all data with the ADS (see Section 8). Some HERs might also be able to use maps (shapefiles) of model layers and point data in table form. Ask HER officer for advice.
Condition(s) satisfied
Deposit model data become the starting point for re-use on other projects

12 Appendix 2: Scoping a deposit model

Working through this checklist (Table 2) will provide a clear idea of the scope for a deposit model and should be undertaken by any curator, consultant or project manager before they prepare a Brief, Specification or costing.

Question	Consider	Next steps
1 Why do you want a deposit model?	a deposit model will map buried deposits – do you need this information to: ■ assess archaeological potential? ■ develop an evaluation or mitigation strategy? ■ assess development impact? ■ inform development design? ■ communicate with non-archaeologists? ■ understand archaeological context? ■ understand the burial environment?	None of these: take project in another direction Yes to any of these: go to Question 2
2 Where is the site?	is it in an area where [Section 2.3]: ■ natural sediments have accumulated over archaeological time? ■ the archaeological interest is likely to be deeply buried? ■ deep urban stratigraphy is expected? ■ varied buried characteristics are likely to exist?	No: take project in another direction Yes to any of these: go to Question 3
3 Does suitable data exist for the model?	there may be geotechnical records available for the site and other data sources are listed in Table 1. How good are these data? Do they have: ■ OD levels? ■ OS Grid co-ordinates? ■ useable descriptions? ■ good coverage and even distribution? ■ adequate depth? ■ reliable dating control? Sections 4.2 and 4.3 might help you decide.	If No to any of these: go to Question 4 If Yes: go to Question 5 If you are unsure: contact a geoarchaeologist or HE Science Advisor.
4 Will more data be needed?	section 4.4 explains how new data might be collected, either as independent geoarchaeological fieldwork or as part of geotechnical site investigation. Is there scope for such work at this stage of the project?	If No: consider a deposit model at a later project stage (Section 3.3). If yes: go to Question 5.
5 What outputs do you want?	this will depend on the purpose of the model (Question 1). Examples are given in Section 6. At this stage you should discuss the deposit modeling approach with a geoarchaeologist. Do you need contact details for a geoarchaeologist?	If Yes: contact HE Science Advisor If No: go to Question 6
6 What else is needed?	■ before you write a Brief or Specification look at Appendix 3. ■ Make sure a geoarchaeologist writes or inputs to the WSI. ■ Be clear from the outset how the model will be re-used as part of the project (Section 3.3) and how it will be archived (Section 8)	

Table 2: Checklist for scoping a deposit model

13 Appendix 3: Guide specification for deposit modelling

Given that the majority of commercial archaeological tenders are submitted on a competitive basis, it is essential that detailed Specifications are provided for deposit modelling by the planning archaeologist or by the consultant as part of a tender package. This will make sure that costed bids are broadly comparable and will deliver a similar level of information.

Specifications should include:

- why a deposit model is required and how it will be used and updated during the life of the project
- nature of the site and the type of deposits likely to be encountered
- the need to engage specialist advice early in the design of the project
- whether the deposit model is to be constructed from pre-existing data* or will require the design of a fieldwork strategy for further recording and sampling**
- expected outputs and illustrations from the deposit model
- reporting requirements
- expected archive destination, process and expected format

*If pre-existing information is used, specify what baseline datasets the deposit modellers are expected to use. This should include information from beyond the site boundaries in order to provide an appropriate context for the deposit model. A buffer zone for data collection should be specified.

**If the construction of a deposit model requires further data collection by way of fieldwork, it is important to specify:

- type of fieldwork
- spatial resolution
- maximum depth to which detailed recording is expected
- whether it is expected that core samples will be logged on- or off-site
- whether cores will be retained for subsequent assessment and analysis or whether they will be photographed, sub-sampled and discarded
- additional techniques and sampling that might be required to accompany the work
- broad outline of the number of samples and types of techniques to be used (eg types of dating and palaeoenvironmental assessment)

The checklist provided in Appendix 2 will help you tackle most of the bullet points above and point you towards the appropriate sections of this guidance document.

14 Where to get advice

Within Historic England, the first point of contact for general archaeological science enquiries, including those relating to deposit modelling, should be the Science Advisors, who provide independent, non-commercial advice. For contact details see:

HistoricEngland.org.uk/scienceadvice

14.1 Acknowledgements

Illustrations

Thanks to Liz Stafford and Oxford Archaeology for permission to modify illustrations from Luther Court in Figures 7–10

Thanks to Mark Stevenson for the GLAAS template for Appendix 1 and for comments (with Sandy Kidd) on its content in the context of deposit models

More information about most of the figures and case studies can be found in an accompanying monograph *Deposit Modelling and Archaeology* (Carey *et al* 2018).

Text

Sharing deposit models with engineers and developers (Section 3): Oxford Flood Alleviation Scheme text supplied by Liz Stafford (Oxford Archaeology); supported by Catherine Charman (Environment Agency). Oxford Westgate text supplied by Liz Stafford (Oxford Archaeology); archaeological mitigation funded and facilitated by the developer, Westgate Oxford Alliance (Landsec and The Crown Estates) and the main contractor Laing O'Rourke in consultation with Oxford City Council.

Case Study 2, based on work summarised in reports and emails from Dave Norcott (Wessex Archaeology). The archaeological investigation was commissioned from Wessex Archaeology by Wilson Large, on behalf of Beam Design Limited.

Case Study 5, thanks to Paul Cuming (Kent County Council) for permission to include current work on Dover UAD.

Confidence in the model (Section 6.2), based on text supplied by Dan Young (QUEST) and Virgil Yendell (MOLA)

Reference for geoarchaeological work on HS1 (Section 2.4): Bates, M and Stafford, E 2013 *Thames Holocene: A geoarchaeological approach to the investigation of the river floodplain for HS1, 1994–2004* (Oxford Wessex Archaeology)

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Final text prepared following comments from Jane Sidell and Hannah Fluck (Historic England).

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