ARCHAEOLOGICAL SURVEY OF MINERAL EXTRACTION SITES AROUND THE THAMES ESTUARY

AGGREGATES LEVY SUSTAINABILITY SCHEME
ASSESSMENT REPORT

1. BACKGROUND

1.1 INTRODUCTION

The Thames Mineral Extraction Project was co-ordinated by Kent and Essex County Councils. The work was carried out from April 2003 to March 2004 and was funded by the Aggregates Levy Sustainability Fund, which is administered by English Heritage

The original aim of the project, as stated in the March 2003 project design, was to provide researchers and planning departments with a GIS-related database of important archaeological (including industrial) and geological sites within all known past, present and proposed mineral extraction sites within the area of the Lower Thames Estuary to the east of London (Fig. 1).

In August 2003, the original aim of the project was modified after initial results indicated that the number of mineral extraction sites (c.1600) in the study area was substantially higher than expected. From that point on, it was agreed by all parties concerned that the project would restrict itself to the area that had been selected for 3d modelling by the BGS (see section 1.4.1), and would thus function as a pilot for further work. The 3d modelling area comprised a block of land that included parts of the boroughs of Dartford and Gravesham and the unitary authority of Thurrock (Fig. 1).

Each identified site in the revised study area was examined for Pleistocene and Holocene deposits, Palaeolithic archaeology, post-Palaeolithic archaeology, and mineral-extraction related industrial archaeology. Desk top surveys and/or site visits were used to collect the data for each, which was then entered on to the project GIS-database as a series of layers. Much additional information came from the British Geological Survey, who used existing borehole data to produce 3-dimensional models of the Pleistocene and Holocene geological record.

The GIS-database will make important archaeological and geological information more widely available, and will increase the profile of the archaeological and geological record in the Lower Thames Estuary, parts of which of which are of national or international importance. Increasing development pressure in the Lower Thames region makes the protection and increased management of this important archaeological and geological resource an urgent priority.

1.2 BACKGROUND

1.2.1 Location

The original survey area, as stated in the 2003 project design, was largely comprised of the Thames Gateway sections of the Thames estuary area in the historic counties of Kent and Essex (Fig. 1). Mineral extraction sites were identified in the districts of Castle Point, Basildon and Rochford and the unitary authorities of Thurrock and Southend-on-Sea in Essex, and in the unitary authority of Medway and the Boroughs of Dartford, Gravesham and Swale in Kent.

The reduced survey area (98km^2), to the immediate east of Greater London, straddles the Thames at Dartford and Grays (Fig. 1). The Kent side of it contains Dartford, Northfleet and Swanscombe, and the Essex side contains Grays, Purfleet, Aveley, West Thurrock and South Ockendon. Aveley and Dartford Marshes are on the west edge of the survey area, at the point where the Mar Dyke and the River Darent join the Thames near Purfleet. Most of the survey area is covered by urban development separated by fields and former extraction sites.

1.2.2 Geology and Palaeolithic archaeology

The Pleistocene deposits of the lower reaches of the River Thames and its tributaries are of international significance; they form a framework for this part of the geological record in Britain, and they have important links with the glacial stratigraphy of East Anglia, the fluvial stratigraphy of the Rhine and Seine, and global climatic stratigraphy.

Major advances in understanding the environments in which sediments and fossils were deposited and preserved during the Palaeolithic, and the dating of artefacts and the ability to reconstruct the environments in which early humans existed during that time have put the Lower Thames area at the forefront in Europe in our understanding of late Middle Pleistocene geology and archaeology.

Although some sites are protected by having SSSI or SAM status, many quarries which contain Middle Pleistocene geology and archaeology are no longer active and are now being infilled, landscaped or redeveloped. The potential archaeological wealth of the area and its international importance creates an urgency to avoid destruction of important sequences and exposures by these activities. The current scientific value of the area cannot be over-stressed. Examples of sites under pressure or in need of better management are Greenlands and Botany Pits (Purfleet), Globe Pit (Little Thurrock), Wansunt Pit (Crayford) Swanscombe and the Ebbsfleet Valley. In addition, important issues such as the placing of Wansunt Pit, Dartford Heath are still unresolved (Bridgland *et al*. 1995), and it is crucial that sites such as these are preserved in order to enable the progress of research to continue.

The marshes of the Thames foreshore of both counties contain a Holocene stratigraphy of five peats, alternating with clays and sand, which records a sequence of sea-level change and human occupation during the last 10,000 years. Beneath these are gravels. Examples of potentially vulnerable areas are the marshes around Purfleet, Tilbury and Shell Haven, Dartford and Gravesend. It will become increasingly important that these and other sites remain available for (re-)investigation, because research into the Holocene deposits has been limited to date. The conceptual base for interpreting the deposits is developing and may lead to a significant reappraisal of the rate and nature of sea-level change, with implications for archaeological environmental reconstruction.

1.2.3 Archaeology

Mineral extraction and other forms of large-scale development continue to threaten the rich archaeological heritage of North Kent and south Essex, which is distinctive and often unique, partly due to the Lower Thames, which for nearly 2000 years has served almost continuously as the main artery for communication and trade between the heart of England and mainland Europe (Champion and Overy 1989; Buckley 1980; Bedwin 1996).

The valuable mineral resources of the Lower Thames area, and the important role of the Thames for communication and trade are part of the reason for the large amount of industrial development that has taken place along the banks of the Thames over the last 150 years. Major industries attracted to the area's commercial potential include mineral extraction, cement and gunpowder manufacture, power generation and oil refining.

1.2.4 Planning

The archaeological and geological resource of the Lower Thames area has already come under sustained pressure from the Channel Tunnel Rail link. Further threats to the heritage record are outlined in the government strategic plan, which sees the Thames Gateway area of east London, north Kent and south Essex as a priority spot for regeneration, in order to balance recent growth in west London and the M4 corridor. Threats to the heritage record will come as well from the anticipated growth of Stansted airport, which will have a major effect on the predominantly rural county of Essex. Demand for further mineral resources is also implied in The Mayor of London's spatial development strategy, *Towards the London Plan*. A different form of threat to the archaeological and geological resource is expected to come from the redevelopment of existing quarries, such as the recent Bluewater development and the proposed creation of an 'urban village' within the adjacent Eastern Quarry.

1.3 AIMS AND OBJECTIVES

1.3.1 Aims

In the March 2003 project design, eleven aims (A1 to A11 below) were put forward:

A1 To produce a GIS base map of the Greater Thames area, with which to indicate past, present and future mineral extraction sites and related buildings and features
A2 To show areas of archaeological deposits destroyed by quarrying
A3 To consider the continuing value of the various quarry sites, and any surviving archaeological structures for Palaeolithic and later archaeology
A4 To construct 3-dimensional models of selected mineral extraction sites, based on the GIS
A5 To consider the geological value of the various quarry sites
A6 To assess the archaeological potential of current and potential mineral extraction sites, and to identify future threats to the archaeological and geological deposits
A7 To provide the SMRs with accurate up-to-date information, to assist spatial planning and specific development proposals
A8 To pass relevant information on to the Monuments Protection Program
A9 To increase the profile of heritage issues and to enhance the image of the historic environment in the Greater Thames area
A10 To use the information as part of the planning process, for both current and future spatial planning proposals in the Greater Thames area
A11 To develop further archaeological decision-making and methodologies relating to spatial planning at a trans-national level within north-west Europe, in conjunction with an application for Interreg IIIB funding for the Planarch project

1.3.2 Research objectives

The project addressed the following research objectives, as identified in the Research Framework for the Greater Thames Estuary (Williams and Brown 1999), and repeated in the March 2003 project design:

RO1 The project would meet priorities set out for deposit modelling of the Pleistocene and Holocene geological record (section 4.2.4.2 in Williams and Brown 1999)
RO2 The project would also make a major contribution to meeting the priorities set out for the industrial archaeology survey of the Thames Estuary (section 4.2.4.4 in Williams and Brown 1999)
RO3 The project would assess the nature, extent and survival of archaeological features within the mineral extraction sites, and hence contribute to a greater understanding of the development of the archaeological record around the Thames Estuary

1.4 METHOD

1.4.1 Method

The objective put forward in the project design in March 2003 to investigate all mineral extraction sites (gravel, chalk, brickearth etc) in the survey area was downgraded in August 2003, after preliminary survey results revealed that the project was potentially dealing with *c*. 1600 sites. Because this figure was unexpectedly high and beyond the means of the available resources, it was agreed by the project Steering Committee, that the survey from that point onwards would restrict itself to sites eligible for ALSF funding, namely gravel extraction sites and to sites where the extraction of gravel was of secondary importance to the task in hand. Cut and fill sites along linear projects, such as road and rail schemes, were not included.

The British Geological Survey (BGS) carried out the identification of all eligible past, present and proposed gravel extraction sites within the designated area. Identified sites were mapped using the ArcView Geographical Information System. The geographical data was produced as a series of map layers, with meta data, which could then be directly imported into the Kent and Essex SMRs. The map layers were based on data derived from detailed existing maps and surveys, and were used to produce a customised thematic map showing the extent of worked-out and infilled gravel extraction sites related to past and present gravel extraction and major areas of built-up made ground. The development of the layers involved the examination of OS historical map data (1st, 2nd, 3rd and 4th editions), modern topographic bases, and geological 1:10000/1:10560 scale maps.

Also provided by the BGS were digital files with metadata for use in ArcView of the 1:50000 geological solid, drift and mass movement themes for the study area covering parts of Geological Sheets Romford (257), Southend and Foulness (258, 259), Dartford (271), Chatham (272), Faversham (273), Maidstone (288) and Canterbury (289).

The current land use of the gravel extraction sites was established by a combination of site visits and desk-based research of documentary and cartographic sources and aerial photographs.

In order to enable overall geological and landscape trends to be identified, and also the overall loss of material from, for example, the Thames terraces to be quantified, the ArcView Spatial and 3D Analyst extensions were used to prepare a 3D model of the entire project area, based on Ordnance Survey digital contours at a vertical interval of 5m. More detailed models of selected gravel extraction sites produced using software developed by the BGS were imported into ArcView.

To facilitate the locating of surviving archaeological deposits outside the sites, and to show the locations of known archaeological deposits and the extent of the loss of those deposits in the past, detailed 3D geological models were generated from surface geological linework, DTM and the data from 300 existing boreholes. The area surveyed comprised a 103km2 rectangular block.

ArcView was used to drape the archaeological layers over the geological layers, to analyse the relationships between them, and to estimate the extent of the surviving archaeology.

Following the survey work the Kent and Essex SMRs were updated with all known and new information. Existing SMR information, including back-log sites, were checked and amended where necessary, and new information was added to SMR databases and GIS layers. The SMR sites affected by gravel extraction sites were digitised.

The geological, Palaeolithic, archaeological and industrial significance the identified sites was assessed by individual specialists. Methods statements for each of these can be found in sections 2.1 to 2.4.

1.4.2 Geographical Information System

1.4.2.1 Introduction

The archaeological survey of mineral extraction sites around the Thames estuary was conceived as a largely GIS based project, with a series of digital map layers forming a key output of the project. These layers were used to address the aims and objectives of this project, but will be placed in the respective counties' HERs . They will therefore be able to be used for other projects and considered in light of other datasets as they become available.

GIS layers relating to the general geology of the area were provided by the British Geological Survey. Their data on artificial ground formed the basis of the other layers. Geology, Palaeolithic and industrial specialists compiled their data, which was then passed to the appropriate HER officer (T. O'Connor, P. Cuming) to digitise or append to the polygon data.

1.4.2.2 Data Formats

The digital map layers have been produced as Esri Shapefiles. These were largely created in ArcGIS 8, but will work in earlier versions of ArcView, although there is greater functionality in ArcGIS 8. This means that the data collated as part of this survey will be available to a greater number of end users.

1.4.2.3 Layers

Each topic identified as part of this study has at least one 'layer'. Each of these contain data from the relevant specialist studies, linked to polygons digitised in the artificial ground layer provided by the BGS. This layer provided the initial data as to eligibility, subsequently further refined by querying against eligible geology and map regression.

General Geology (*Datasets provided by the British Geological Survey)*

- Superficial Geology
- Solid Geology

- Artificial ground; extraction sites, roads, railways, sea walls etc (bespoke layer, from historic and modern Ordnance Survey mapping, and historic geology mapping)
- Individual polygons by type eg. Infilled, worked or made ground.
  NB Poygons from this layer were used for each of the following layers

Map Regression

- Data from historic Ordnance Survey Mapping, modern mapping, vertical aerial photographs. Includes identification of type of extraction for eligible sites, and provisional indication of industrial potential.

Geology

- Location of surviving sediments

Palaeolithic

- Potential for analysis of existing Palaeolithic collections
- Potential significance of surviving sediments
- Heritage potential

Desk Based Assessment

- Archaeological references within and in the vicinity of polygons within the 3D core area. Includes 'grey' literature, SAMs, and HER refs. Indication of Archaeological potential. NB Does not include Palaeolithic/Industrial potential, which has been addressed by individual specialists.

Industrial

- Industrial survival and potential significance of sites visited

<u>1.4.2.4 Data Queries</u>

The use of individual layers, each with a polygonal spatial component along with extensive attribute data means that there are a number of options available to query the data. This can be carried out on a single dataset or combinations thereof.

A number of preset spatial queries are available in ArcGIS 8. These include comparison of the location of polygons from different layers and buffering by distance. Data can also be queried by attribute using SQL, an improvement on previous versions, which required a knowledge of Avenue to carry out more complex queries. Spatial and attribute queries can also be combined. The results of queries can be exported as shapefiles.

1.5 WIDER DISPERSAL AND ARCHIVE

1.5.1 Links to other projects

Information has been or will be shared with the following:

- The ALSF funded *Stopes Palaeolithic Project*, which is managed by Dr Francis Wenban-Smith

- Interpretation projects developed for the Swanscombe Skull National Nature Reserve and the Ebbsfleet Valley
- The Oare Gunpowder Works conservation and interpretation project.
- *'The finest prospect in all England'* project, which is designed to enhance public understanding and appreciation of the archaeology of south Essex
- The BUFAU led Shotten project, which is considering protocols for dealing with Palaeolithic archaeology in the West Midlands.

In addition, funding for the project has been used as match-funding for the PlanArch II Interreg project, which involves nine European partners, and is concerned with the role of archaeology within spatial planning. The project is led by Kent County Council with partners in Essex, Netherlands, France and Belgium.

1.5.2 Wider dispersal

Archaeological development control staff, planners, developers and researchers will be able be able to access the information gathered by the project through the Kent and Essex SMRs, which will receive copies of this report, the digital map-layers, and the 3-D modelling layers. Copies of this report will be sent to the archaeological development control officers and minerals planning offices of the relevant counties, unitary authorities and districts. The Essex SMR is online at http://unlockingessex.essexcc.gov.uk.

Popular accounts of the project will appear in the county journals *Essex Archaeology and History* and *Archaeologia Cantiana*, and in the annual newspaper supplement *Essex Past and Present*. Images and text from the project can be found at www.essexcc.gov.uk and www.kent.gov.uk, and *'The finest prospect in all England'* web-site.

The project has produced a travelling exhibition, consisting of four panels in A1 portrait format with text, plans and pictures, in order to publicise the project and to explain the importance of the archaeology and geology of the survey area. A presentation of its results will be given at the annual Thames Estuary Forum.

1.5.3 Archive

Essex and Kent SMRs will receive the digitally generated maps and map-layers for their respective county when the project has been completed. The map-layers will include a geological layer, a Palaeolithic layer, an archaeological layer and an industrial layer. In addition, the Kent and Essex SMRs will receive a layer showing the gravel extraction sites, and the 3D modelling layers.

The rest of the archival material (photographs, plans and drawings, site record sheets *etc.*) will be lodged at Thurrock Museum in Essex, and Dartford Borough Museum in Kent.

2. ASSESSMENT REPORTS

2.1 GEOLOGY

2.1.1 Geological context

2.1.1.1 Introduction to the Pleistocene sequence in the Lower Thames

The term Lower Thames is generally applied to that part of the river's course through and downstream from London (Fig. 5). The Thames has flowed through London only since the Anglian glaciation blocked its former valley, north of the UK capital, and diverted it into the pre-existing Medway-Darent drainage basin (Gibbard, 1977, 1979; Bridgland, 1988, 1999; Bridgland and Gibbard, 1997). Since this event, the Thames has formed a staircase of depositional terraces that provides an exemplary record of the sequence of climatic events since the Anglian. Four terraces can be recognized, with the lowest of these disappearing beneath the modern floodplain downstream from London (Fig. 6).

2.1.1.2 The Quaternary Era

Background information

The Quaternary Era represents the last 2.4 million years of geological time. Its most notable characteristic has been rapid fluctuations of climate, leading to alternating cold and warm episodes, which have been defined as named 'interglacial' and 'glacial' stages within the era (Mitchell et al., 1973). It was considered at that time that the most practical approach, which had widespread applicability, would be to use vegetational change, primarily based on pollen analyses, to define these divisions of the Quaternary. Pollen evidence can be supplemented by information from other fossil groups, especially molluscs, mammals and insects. By the time of the Geological Society's second visit to the Quaternary stratigraphic record (Bowen, 1999), a much wider range of techniques was in use, many of them providing direct means of dating sequences based, for example, on radioactive decay of rare isotopes. Evidence from ocean floor sediments had, by the end of the 20th century, revealed many more climatic fluctuations during the Quaternary than had been recognized on land (see *'The marine oxygen isotope record'* below).

At a coarser scale, the Quaternary can also be divided into the Pleistocene Epoch (2.4 million years to 10,000 years ago) and the Holocene. The Pleistocene can be divided into Early, Middle and Late (Lower, Middle and Upper) Pleistocene. The sequence under consideration in this project is entirely Middle Pleistocene and later, commencing with the diversion of the Thames into its valley through London as a result of the most extensive British Quaternary glaciation, about 450,000 years ago, in the Anglian Stage.

The pollen-based biostratigraphy of the mid-20th century identified just two post-Anglian interglacials, the Hoxnian and Ipswichian (Mitchell et al., 1973), separated by a single glacial episode. The Ipswichian, which can also be called the 'Last Interglacial', was followed by the 'Last Glacial', defined (in the north Midlands) as the Devensian Stage. The Devensian lasted until 10,000

BP (before present). The Middle and Late Devensian are within the range of radiocarbon dating and so are chronostratigraphically as well as biostratigraphically defined, the latter based on pollen and beetles, in particular.

The Holocene (10,000 BP to present) can be regarded as the present-day interglacial, since it has been shorter, so far, than the time-span of typical Quaternary warm stages. It has witnessed the increasing influence on environmental systems of humankind, eventually affecting the vegetational and geological records, with early farmers beginning the process of deforestation and the subsequent loss of soil stability leading to increased erosion in some areas and deposition in others.

The marine oxygen isotope record

The sediments from ocean floors have been found to contain an important globally valid record of Quaternary climatic fluctuation, based on oxygen isotopes within the hard shells of marine planktonic animals that are present in these deposits. Oxygen can exist in three isotopic forms (^{16}O, ^{17}O, ^{18}O). Most oxygen exists as ^{16}O, the most common, or ^{18}O, the ratio between the two being 500:1. As part of the hydrological cycle of evaporation, cloud formation, rain and return of water by rivers to the oceans, during glacial episodes, more and more of the water removed from the oceans gets locked up in global ice and is delayed in its return to the oceans. At such times, because of the preferential evaporation of water containing ^{16}O, the ocean water becomes depleted in the light isotope relative to its condition during interglacials. This effect can be measured by analysing the oxygen isotope content of the calcium carbonate in the shells of planktonic micro-organisms called foraminifera, which are common constituents of ocean floor sediments. It is assumed that their composition is in equilibrium with the sea water at the time they were alive. The results are expressed as a ratio between the two isotopes. It is a measure of global ice volume and, at the same time, an indirect measure of both eustatic sea level and climate. The variations in the ratios between the types of oxygen can be plotted and an oxygen isotope curve drawn up (Fig. 9). The swings on the curve are numbered, the colder periods (^{18}O-rich) being given even numbers and the warmer periods odd. Oscillations in a warm or cold period are given letters, a-c-e being warmer and b-d-f colder.

Oxygen isotope data have been obtained from a number of different ocean cores, each giving a broadly similar record (*e.g*. Shackleton and Opdyke, 1973; Shackleton *et al*., 1990). The global applicability of this marine record has meant that Quaternary scientists have resolved to use it as a global template for the Quaternary. It is, however, difficult to correlate terrestrial sequences with the marine record, generally relying on relative dating methods calibrated by absolute ages from key levels, which can be compared with absolute dates from ocean sediments. Records of global magnetic polarity also represent important globally valid time lines that can be used to correlate marine and terrestrial sequences (see, for example, Patience and Kroon, 1991).

The marine oxygen isotope record has thus become widely accepted as a globally applicable framework for recognising not only over a hundred climatic fluctuations in the last 2.6 Ma, but also the magnitude of those fluctuations.

Correlation of the terrestrial Quaternary stages with the marine oxygen isotope stages has become an important goal of Quaternary science. It is clear that there are more glacials and interglacials recognized within the marine record than had been established previously on land. The extensive Anglian glaciation of 450,000 years ago has been correlated with oxygen isotope stage (OIS) 12 (Bowen et al., 1986), while it is generally agreed that the Last Glacial was coincident with OIS 2. The Last (Ipswichian) Interglacial, however, is thought to equate with OIS 5 or, in fact, with the earliest of three warm peaks within the stage (= substage 5e). The Devensian Stage is therefore not synonymous with OIS 2, but includes OIS 5d-a, OIS 4, OIS 3 and OIS 2 (Fig. 9). The OIS 3 peak appears to represent only a minor climatic amelioration compared to the preceding warm peaks and seems hardly to qualify as a warm stage.

Recent interpretation of the mammalian evidence has suggested that the Hoxnian interglacial correlates with marine OIS 11 (Schreve, 2001), which leaves OIS 10-6 inclusive represented by a single cold episode in the original terrestrial sequence (cf. Mitchell et al., 1973), as mentioned above. Additional interglacials within that interval have, however, been recognized and are identified within the Lower Thames sequence (see Bridgland, 1994, 1995a; Schreve, 2001), but as yet not named.

<u>2.1.1.3 River terraces</u>

Explanation of river terraces and their formation

River terrace sequences are common phenomena all over the World, but particularly at temperate latitudes (*cf*. Bridgland and Maddy, 2002; Westaway *et al*., 2003). They are relatively flat platforms, usually underlain by (or composed of) riverine sediments, that break up the side slopes of river valleys. They are interpreted as fragments of former valley bottoms, or floodplains (since these are where river sediments accumulate) that have been left above river level by fluvial down-cutting. Where the down-cutting has been progressive, which is usual, the terraces (and the sediments forming them) will increase in age with height above the river. There has been considerable debate in the scientific literature as to why rivers should have produced a record of this sort, with a major argument between those who regarded sea-level fluctuation as important (falling sea-level being seen as a trigger for down-cutting) and those envisaging surface uplift of the land as a necessary factor. Others have seen Quaternary climatic fluctuation as a potential trigger mechanism. The importance of uplift has been confirmed recently by the joint consideration of raised beach deposits and the marine oxygen isotope record. Raised beach deposits near Chichester, for example, are 42m above modern sea-level and about 0.5 million years old. The marine oxygen isotope record (see *'The marine oxygen isotope record'* above) shows that global ice volumes were too high at this time to generate a sea-level at this height eustatically (by melting ice), indicating that the raised beach deposits must be uplifted.

Climatic model for the formation of the Lower Thames terraces
Bridgland (1994) has developed an empirical model that explains the formation of the Lower Thames terraces in response to climatic triggering, set against progressive background uplift. The latest version of this model (Bridgland, 2000) is explained in Figure 10. The evidence for this model comes from observations of the sedimentary sequence present within each terrace, which represents a cold-warm-cold sandwich of deposits. Thus each of the Lower Thames terraces is formed by a sequence of lower and upper cold-climate gravels between which temperate-climate, often fossiliferous, sediments occur (Fig. 6; Table 1). This observation has led to the suggestion (Bridgland, 1994, 1995a) that the Lower Thames terraces formed in synchrony with glacial-interglacial climatic fluctuation during the post-Anglian Pleistocene. The sequence potentially provides a record, on land, of the succession of alternately cold and warm episodes recognized from deep ocean cores and established (Shackleton and Opdyke, 1973; Shackleton etal., 1990) as a global template for Pleistocene climatic oscillation (see *'The marine oxygen isotope record'* above). According to Bridgland (1994, 1995a, 2000), there are four terraces in the Lower Thames; the temperate-climate deposits within these four terraces are thought to represent the last four interglacials, correlated with OIS 11, 9, 7 and 5 (Bridgland, 1994; 2000; Schreve, 2001; Figs 6, 7 and 8).

Table 1: Terrace nomenclature and dating in the Lower Thames

Formation	Member	BGS nomenclature	BGS nomenclature	Oxygen Isotope Stage	Climate	Age
(Bridgland 1994, 1995)	***(Bridgland 1994, 1995)***	***(Romford, 1976; Dartford,1977)***	***(Romford, 1996; Dartford,1998)***			***('000 years)***
(Youngest) East Tilbury Marshes Formation	East Tilbury Marshes Upper Gravel	Kempton Park Gravel		5d - 2 Devensian	Cold	
	Trafalgar Square Deposits			5e Ipswichian	Warm	100
	East Tilbury Marshes Lower Gravel			6	Cold	
Downcutting						
Mucking Formation	Mucking Upper Gravel	Taplow Gravel	Flood Plain Gravel	6	Cold	
	Aveley Silts and Sands			7	Warm	200
	Mucking Lower Gravel			8	Cold	
Downcutting						
Corbets Tey Formation	Corbets Tey Upper Gravel	Lynch Hill Gravel	Taplow Gravel	8	Cold	
	Purfleet Silts and Sands			9	Warm	300
	Corbets Tey Lower Gravel			10	Cold	
Downcutting						
Orsett Heath Formation	Orsett Heath Upper Gravel	Boyn Hill Gravel	Boyn Hill Gravel	10	Cold	
	Swanscombe Interglacial Deposits			11	Warm	400
	Orsett Heath Lower Gravel			12	Cold	
(Oldest)	Black Park Gravel	Black Park Gravel	Black Park Gravel	12	Cold	

2.1.1.4 Lower Thames terrace deposits: definitions and brief descriptions of those recognized in the study area

Undifferentiated (High level) terrace gravel

Encountered in the area of Darenth Wood (TQ577721) and Stonewood (TQ 599727), this is part of a multi-level complex of gravel patches bracketed by the BGS with the post-diversionary gravels. However, these deposits are at higher levels than the highest Lower Thames terrace and are therefore likely to be older than the diversion of the Thames into its valley through London (see above). Preliminary results from two stone counts indicate that they consist of c.68% flint and c.32% southern rocks, such as Greensand chert, which makes a Darent origin likely. That would fit well with their location.

Black Park Gravel
This name was applied by Hare (1947) to a newly defined terrace in the Middle Thames. Dated Late Anglian, this was found to be the oldest terrace to follow the post-diversionary route of the river - its immediately post-diversion form, in fact (Gibbard, 1979). Gibbard (ibid) ascribed the gravels covering Dartford Heath (Dartford Heath gravel) to this terrace, thus perpetuating a long-standing controversy over whether the deposits at Dartford and at the famous Swanscombe locality were the same (Hinton and Kennard, 1905; Chandler and Leach, 1907; King and Oakley, 1936; Zeuner, 1945; Cornwall, 1958). The BGS had previously mapped the Dartford gravels as Boyn Hill Gravel, interpreting them as part of the same terrace as the Swanscombe deposits (Dewey et al., 1924). Recent revision of BGS map sheets 257 and 271 have included gravels mapped as Black Park for the first time, but those at Dartford are not included. All are on the Essex side of the river and are at lower heights than the Dartford Heath sites. The rationale for this revision has not been explained in detail, the memoir for the above sheets being awaited (see, however, Smith and Ellison, 1995). The controversy over the Dartford Heath sites was reviewed by Bridgland (1994) and White et al. (1995). Since these were published, new work at Swanscombe has shown that the uppermost deposits there extend much higher than previously recorded, reinforcing the view that they are downstream equivalents of the Dartford Heath deposits (Wenban-Smith and Bridgland, 2001). This does much to undermine the support for a separate higher-level Black Park Terrace in the Lower Thames.

Evidence has also come to light indicating that the entire Dartford Heath sequence is of interglacial origin (see Wenban-Smith and Bridgland, 2001), making a correlation with the Black Park Gravel untenable, but strengthening the correlation with the Swanscombe sequence. Rather than the high-level sedimentation envisaged by some, it is clear that the late Anglian valley east of London, the valley of Black Park times, was eroded to a significant depth, as evidenced by the occurrence of Anglian (OIS 12) glacial deposits beneath the terrace gravels at Hornchurch (Fig. 6) and by the occurrence of late Anglian fluvial sediments in the floor of the Lower Gravel Channel at Swanscombe, now at 23m O.D., the Basal gravel, Bed Ia (Conway and Waecheter, 1977; Bridgland, 1994; Conway et al., 1996; see below).

Nevertheless, the current BGS mapping recognizes the Black Park Gravel as the earliest division of the Lower Thames sequence. This is likely to be questioned, particularly in the light of the evidence from Swanscombe (above) that has come to light since the BGS mapping was undertaken. For the purposes of discussion, therefore, this division will be subsumed under the local term ‘Orsett Heath Formation’ (see *‘Orsett Heath (Gravel) Formation’* below).

Boyn Hill Gravel
Originally applied in the BGS mapping for the highest Thames terrace recognized in the early 20th century (Bromehead, 1912), this unit is named after a site near Maidenhead, in the Middle Thames. Initial New Series BGS mapping applied this name in the Lower Thames also, in which form it is

synonymous with the Orsett Heath Gravel of Bridgland (1988, 1994; Gibbard et al., 1988). As noted above, the most recent BGS sheets 257 and 271 have reclassified certain high-level parts of what was once mapped as Boyn Hill Gravel as the older Black Park Gravel, although the separate existence of this is doubted here. In the region of Moor Hall Farm, Aveley, (TQ 560814), the gravels mapped as Boyn Hill and Black Park Gravels can be demonstrated to be a single body (Wiseman, 1978). In discussion, in order to avoid confusion, this report will use the Middle Thames nomenclature when referring to the current BGS mapped units and the local name Orsett Heath Gravel when referring to the combined 'high terrace' of the Lower Thames, as originally (and probably correctly) envisaged by Dewey et al. (1924).

Orsett Heath (Gravel) Formation

The Orsett Heath Formation (Bridgland, 1994) is the Lower Thames lithostratigraphical term applied to the Boyn Hill terrace as originally mapped by the BGS (Dewey et al. (1924). It includes pre-interglacial, interglacial and post-interglacial members (Fig. 6). The interglacial recorded at Swanscombe is widely accepted as equivalent to OIS 11 of the marine record (Bowen et al., 1989; Bridgland, 1994; Schreve, 2001), which is the same interglacial as at the Hoxnian type locality in East Anglia (West, 1956). Schreve (2001) has recently re-established, on the basis of mammalian biostratigraphy, the correlation between the Swanscombe deposits and the type Hoxnian lacustrine sediments of East Anglia (contra Bowen et al., 1989).

The pre-interglacial (OIS 12) member of the Orsett Heath Formation is recorded only at Swanscombe, where it has been called 'basal gravel' (Bed Ia of Conway and Waechter, 1977; Bridgland, 1994; Conway et al., 1996). The temperate-climate (OIS 11) deposits at Swanscombe were until recently regarded as the only occurrence of the interglacial member of this formation, but it has been realised recently that the Dartford Heath sequence is probably of interglacial origin and equivalent, in its entirety, to the Swanscombe deposits (Wenban-Smith and Bridgland, 2001). The member is named after Swanscombe (Fig. 6). The majority of outcrops mapped as Black Park/Boyn Hill/Orsett Heath Gravel are likely to represent the post-interglacial (OIS 10) member (Fig. 6).

The interglacial sediments at Swanscombe are well known as a source of Palaeolithic artefacts as well as rich mammalian and molluscan faunas, the former including the celebrated early human skull (Ovey, 1964). The deposits in the Swanscombe and Dartford areas are the only interglacial sediments known to have been preserved within the Orsett Heath Formation, although downstream equivalents are recorded in eastern Essex, at Southend, Tillingham and Clacton (Bridgland et al., 1999; Roe, 1999). It was established many years ago, from the evidence at Clacton, that a marine transgression occurred late during this first post-Anglian interglacial, after the climatic optimum, in pollen substage Ho III (Turner and Kerney, 1971; Bridgland et al., 1999). The mouth of the estuary probably remained a considerable distance downstream from the present Lower Thames valley, although the record of dolphin from Ingress Vale, Swanscombe, hints at the relative proximity of the sea.

The Swanscombe Upper Loam, a decalcified and oxidized (and therefore unfossiliferous) clayey silt capping the interglacial sequence at this locality, has hitherto attracted little attention except from archaeologists, who have recorded well-preserved Acheulian bifaces from it (Burchell, 1931; Wymer, 1968). Recent work to the east of the famous Swanscombe localities has shown that this deposit extends up to almost 39m above O.D., nearly 6m higher than previous records (Wenban-Smith and Bridgland, 2001). This suggests that it might be a lateral continuation of a deposit of silty clay at Dartford Heath, the Wantsunt Loam (White et al., 1995). This suggestion is reinforced by the record of twisted ovate bifaces from both these deposits, a typological variation seemingly associated with the latter part of OIS 11 (White, 1998). The sedimentology of both the Swanscombe Upper Loam and the Wansunt Loam is suggestive of low energy floodplain or possibly intertidal deposition, although the absence of fossils precludes palaeoecological corroboration of any such interpretation. At Swanscombe the Upper Middle Gravel was attributed by Kerney (1971) to Ho III-IV, and therefore considered to be coeval with or later than the main Hoxnian transgression recorded at Clacton. The Upper Loam is separated from the Upper Middle Gravel by colluvial deposits and sands, which have been attributed to colder climatic conditions, the sands on the basis of periglacial structures (Conway and Waechter, 1977).

Lynch Hill Gravel

The name Lynch Hill, again taken from a type locality west of London, was given by Hare (1947) to a terrace intermediate between the Boyn Hill and Taplow as originally mapped in the Middle Thames (Bromehead, 1912). The original mapping in the Lower Thames recognized this terrace, but it had been erroneously classified as Taplow. The potential confusion arising from this was a major reason for the application of local nomenclature in the Lower Thames (Bridgland, 1988; Gibbard et al., 1988). The recently revised BGS maps have corrected the earlier error by classifying as Lynch Hill the spreads previously mapped as Taplow, although with minor amendments to the boundaries and with a lower subdivision separately identified as the Hackney Gravel (see below).

The boundaries between the Orsett Heath (Boyn Hill Gravel) and Corbets Tey (Lynch Hill Gravel) Formations shifted between the Dewey mapping and the current revision, especially in the Ockendon area. However, at Mollands Lane (TQ 597823), there is little ground surface height difference between the Lynch Hill Gravel and a patch redesignated as Boyn Hill Gravel. This matter is not addressed further as only a minute part of the redesignated outcrops is involved.

Hackney Gravel

As its name suggests, the Hackney Gravel was originally recognized in East London. This was during the 6 inch resurvey of this area by the BGS and was applied to the North London sheet 256 of 1992 (Smith and Ellison, 1995). It is a lower division of what was formerly mapped as Taplow Gravel on sheets 257 and 271 and was subsequently recognized to be (mainly) a downstream equivalent of the Lynch Hill Gravel of the Middle Thames (see *'Lynch Hill Gravel'* above). The lower division is unrepresented in the study area, but occurs immediately outside its NW corner, at Berwick Manor, near Rainham (TQ 546833). The full rationale for the separate recognition of the Hackney Gravel has yet to be published. If its separate existence is upheld, its accommodation in the climatic model for the formation of the Lower Thames terrace sequence will require future consideration (see *'Climatic models for the formation of the Lower Thames terraces*' above).

Corbets Tey (Gravel) Formation
The Corbets Tey Formation was defined as synonymous with the terrace originally mapped as 'Taplow' east of London, although subsequently identified as the downstream continuation of the Lynch Hill Gravel of the Middle Thames (Bridgland, 1988, 1994; Gibbard et al., 1988; Schreve et al., 2002). The formation is particularly well preserved in the area around and to the north-east of Purfleet, Essex, where it represents an abandoned loop of the Corbets Tey floodplain that was subsequently by-passed by the Thames (Fig. 5). The deposits here have therefore escaped dissection by the main river, although a minor tributary, the Mar Dyke, now drains this loop. The level of Pleistocene activity by the Mar Dyke is a subject of controversy, as some authors have attributed the interglacial deposits at Purfleet to this stream (Palmer, 1975; Gibbard, 1994, 1995), although these are regarded here as Corbets Tey Formation Thames deposits (Bridgland, 1994,1995a; Schreve et al., 2002), as can be demonstrated from mapping of the fluvial deposits over a wider area of southern Essex (Wooldridge and Linton, 1955; Bridgland, 1994, 1995a; Schreve et al., 2002).

As with the Boyn Hill/Orsett Heath, the Corbets Tey Formation incorporates pre-interglacial (Little Thurrock), interglacial (Purfleet) and post-interglacial (Botany) members (Schreve et al., 2002; Fig. 6). The pre-interglacial member has been recognized at Little Thurrock (Bridgland and Harding, 1993, 1994b) and Purfleet (Schreve et al., 2002). At Purfleet, an extensive sequence of Pleistocene fluviatile sediments lies banked against the eroded northern flank of an anticinal chalk ridge, separated by this chalk ridge from the present-day Thames (Schreve et al., 2002). The deposits here, aggraded up to c.19m O.D., are upstream equivalents of the celebrated fossiliferous Thames sediments once exposed in the brickyards of Grays and Little Thurrock. The sediments at Grays, Purfleet and other localities in the Corbets Tey terrace have been attributed recently to an interglacial previously unrecognized in the British Quaternary, thought to correlate with marine OIS 9 (Bridgland, 1994, 1995a; Bowen et al., 1995; Schreve, 1997, 2001; Schreve et al., 2002).
Downstream equivalents of the Purfleet deposits, also attributed to OIS 9, are recognized at Shoeburyness (Roe, 1999), Barling (Bridgland et al., 2001), Burnham-on-Crouch (Bridgland, 1994) and Cudmore Grove (Roe, 1995, 1999), although the last of these represents the Blackwater-Colne tributary system rather than the main Thames (contra Bridgland, 1994). As would be expected, all of these sites preserve sediments with a stronger estuarine signature than the Purfleet deposits.

Taplow Gravel
One of the three original Thames terraces (Bromehead, 1912), this deposit is named after Taplow Station Pit in the Middle Thames, near Slough. As noted above, the name was formerly applied erroneously to the Lynch Hill/Corbets Tey Gravel of the Lower Thames on New Series sheets 257 and 271, on which the true Taplow appeared as 'Floodplain Gravel' (Bridgland, 1988, 1994; Gibbard et al., 1988). This error has now been corrected in the recent revision of these sheets, which apply the term Taplow correctly. The local name 'Mucking Gravel', which was applied to the Lower Thames to obviate the confusion created by the mismatch west and east of London (Bridgland, 1988; Gibbard et al., 1988), remains available (see below).

Mucking Formation
The Mucking Formation is the oldest to follow the modern route of the Lower Thames between Rainham and Grays (Fig. 5). As with the earlier two terrace formations it comprises pre-interglacial, interglacial and post-interglacial divisions, which can be defined as separate members (Fig. 6). The pre-interglacial 'Crayford Member' is recognized at West Thurrock (Bridgland and Harding, 1994a, 1995) and Crayford (Kennard, 1944; Bridgland, 1994). It may well occur elsewhere, but it would be difficult to identify it without superimposed interglacial deposits. The interglacial member has been defined under the name Aveley Silts and Sands, although the term should be restricted to warm-climate sediments within the Mucking Formation (cf. Gibbard, 1994). It includes fossiliferous sediments at several sites east of London, notably at Ilford (Uphall), Aveley, West Thurrock, Crayford and Northfleet (Bridgland, 1994, 1995b; Schreve, 2001), although the last is in the lower reaches of the tributary Ebbsfleet valley. Bridgland (1994) assigned these to OIS 7, but Gibbard (1994) has attributed them to later sedimentation, largely intertidal, during the Ipswichian Stage. The OIS 7 age has been corroborated, however, by data from mammalian faunas (Sutcliffe, 1960, 1964, 1975, 1976; Sutcliffe and Kowalski, 1976; Schreve, 2001), from molluscan assemblages (Keen, 1990; Preece, 1995, 1999) and from amino acid analyses (Bowen et al., 1989; 1995; Bowen, 1991; Hollin, 1996). There is sedimentological evidence for an estuarine influence within the Aveley Member, in particular at West Thurrock (Hollin, 1977; Bridgland and Harding, 1994a, 1995). These sediments are, however, devoid of fossils, although other parts of the interglacial sequence, at West Thurrock and elsewhere, have yielded faunal remains and pollen (Abbott, 1890; Carreck, 1976; Gibbard, 1994). Unlike in the two higher terraces, no supporting evidence can be obtained by tracing the interglacial sediments downstream into deposits in eastern Essex; this is because the downstream continuation of the Mucking Formation falls below modern sea-level and is not represented onshore downstream of Canvey Island.

Kempton Park/East Tilbury Marshes Formation
This terrace formation, formerly known as the Upper Floodplain Terrace in the area west of London (Dewey and Bromehead, 1921), is buried beneath Holocene alluvium in the Lower Thames, where exposures have been few and quarries at this level are invariably flooded. The formal lithostratigraphical name 'Kempton Park Gravel' was applied by Gibbard (Gibbard et al., 1982;

Gibbard, 1985). The usual three divisions - pre-interglacial, interglacial and post-interglacial - can again be recognized (Fig. 6). No interglacial deposits are known from this terrace downstream from London, the most easterly being at Peckham, but studied only from boreholes (Gibbard, 1994). Fossiliferous interglacial sediments from the terrace have been recorded from Greater London at Brentford (Zeuner, 1945) and Trafalgar Square (Franks, 1960; Gibbard, 1985; Preece, 1999) and are attributed, without equivocation, to the Ipswichian Stage (OIS 5e) (Sutcliffe, 1960; Stuart, 1982; Bowen et al., 1989, 1995; Preece, 1995, 1999). No mapped outcrops of this formation occur in the study area, although it may well be present beneath the alluvium of the floodplain; it is mapped in the base of a quarry at East Tilbury, which is the type locality of the Lower Thames synonym, the 'East Tilbury Marshes Gravel'.

Shepperton Formation
The Shepperton Gravel (Formation) is the lithostratigraphical definition (Gibbard et al., 1982; Gibbard, 1985) of the Lower Floodplain Terrace as previously recognized in the area west of London (Dewey and Bromehead, 1921). Lower within the terrace staircase than the Kempton Park Formation, it too is buried beneath Holocene alluvium in the Lower Thames (Fig. 6).

<u>2.1.1.5 Other drift deposits: definitions and brief descriptions</u>

Dartford Silt
A redefinition, on the 1998 edition of BGS sheet 271, of material that was previously mapped as 'brickearth', this division is described on the map as 'sandy clay and silt'. It is shown on the sheet 271 cross section as associated with (overlying) the Boyn Hill Gravel, but from its mapped occurrences. It also occurs associated with the Lynch Hill Gravel in the Darent Valley at Hawley Road (TQ 540726). It is by no means certain that it is always fluvial in origin; aeolian (loessic) 'brickearth' might well have been included. The association with the Boyn Hill terrace suggests that the well-known 'Wansunt Loam', a water-laid silt channelled into the Dartford Heath Gravel at Wansunt Pit, was the inspiration for its definition. The only Dartford Silt mapped on Dartford Heath is at Wilmington (TQ 525731) and Leyton Cross (TQ 528731); the known outcrop of the Wansunt Loam, which has been included above within the Swanscombe (interglacial) Member of the Orsett Heath Formation (see *'Orsett Heath (Gravel) Formation'* above), is not differentiated from the Boyn Hill Gravel (neither was it mapped on earlier editions of the sheet, based on the mapping first published in 1924), though it is described in the literature at Bowman's Lodge Pit (TQ 518736) (see Wymer, 1968) and can be seen in sections between Shepherd's Lane and (Upper) Heath Lane (TQ 523733).

Ilford Silt
The Ilford Silt has been mapped only north of the Thames; on the Kentish side an equivalent unit, the Crayford Silt, has been mapped instead, but does not occur within the study area. Both are shown on BGS Sheet 271 cross section as overlying the Taplow Gravel, which would suggest equivalence with the Crayford Brickearth (Kennard, 1944), which represents the Aveley Silts and Sands Member (see *'Kempton Park/East Tilbury Marshes Formation'* above)

on the south side of the Thames. Likewise, the Ilford Silt is presumably equivalent to the Ilford (Uphall) Brickearth, another lateral equivalent of the Aveley Member (cf. Bridgland, 1994). All these deposits, at the classic localities, are water-laid silts, although other mapped outcrops might include silts of different origins.

Head
Deposits mapped as head are extremely variable. The term is applied to deposits of solifluction (sensu lato) origin, which vary according to their provenance. For instance, where the source material is London Clay capped with gravel, the head will be a gravelly clay, whereas in the dry valleys of the North Downs, including the Dartford - Swanscombe area, the head is a chalky silty deposit of the type previously termed 'coombe rock', as first defined by Reid (1887).

Alluvium
The name alluvium, although meaning 'river-laid deposit', applies specifically to the valley bottom deposits, described by the BGS as 'mainly silt and clay, locally peaty', that have been laid down during the Holocene. The deposits can be coarser grained, with sand and even gravel components. The division has been formally termed 'Staines Alluvial Deposits' in the Middle Thames valley (Gibbard, 1985) and the Tilbury Deposits/Alluvium in the Lower Thames (Gibbard, 1994, 1995). Locally it is a source of molluscan and plant fossils and post-Palaeolithic archaeology. It can be attributed, in the main, to overbank fluvial deposition.

2.1.2 Methodology

<u>2.1.2.1 Desk study selection of sites</u>
Lists of sites and location maps for the appropriate areas of Essex and Kent were supplied by Essex County Council Field Archaeology Unit. All sites on the lists were appraised in a desk study to identify those fulfilling the criterion that gravel had been or was being extracted. All sites on the Black Park, Boyn Hill, Lynch Hill and Taplow Gravels, as mapped by the BGS, were included. Where more detailed descriptions of sites were available in the literature, this information was noted.

Where the geology varied from face to face, the site was divided, e.g. KT 911A, KT 911B, as needed.

This procedure yielded over 400 sites within the project area. However, as there is considerable development pressure, it was decided to visit as many sites as possible, with priority given to those sites from which Palaeolithic material had been recovered. The exception to this was the Thames marshes alluvial area, from which the record of Palaeolithic material was poor.

Other sites, not fulfilling the criteria but on routes to, or near to, qualifying sites, were visited briefly in passing.

A pro-forma (example attached, Table 2) was filled in by hand.

Table 2: Desk study proforma (GD)

ALSF THAMES GATEWAY PROJECT **GEOLOGICAL DESK STUDY (GD)**

Date

Site number

Site name

P.Allen

Location

Grid Reference

GD1 **Quality of geological information**		0 - None	GD2 **Sedimentological or biological material archived**		0 - None/not known
		1 - Regional information only			
		2. - Basic site descript. available			1 - Yes
		3 - Detailed descript. available			

GD3

Formation/ Member (BGS)	**Formation/ Member (Bridgland)**	**Lithology**	**Fossil content**	**Environmental information**	**Archaeological content**	**potential**

GD4 **Areal extent of interest**			North	South	East	West
		0 - None				
		1 - One or two faces				
		2 - Much/whole of area				
		3 - Around periphery				

Summary of geological context

Summary of archaeological context

Principal references

Geological Desk Study Pro-forma (GD)

On the GD pro-forma, the following terminology used is elaborated:

Site number - *e.g*. KT 480. The site number assigned by the FAU Project Officer.

Grid reference - A six figure grid reference was given of a representative spot within the quarry or site.

Quality of geological information :
None - No information available. As the whole area had been mapped by the BGS, there was at least a minimal amount of geological information available for all sites, so none fell into this category.

Regional information. If no site specific information was available, the basic geological properties of each site could be determined from the BGS 1:50000 Sheets 257 (Romford) and 271 (Dartford). In some cases further information could be provided or inferred from nearby sites.

Basic site description. In some cases, a minor amount of geological information was provided in reports or published information. Often this information was derived from archaeological reports in which a rudimentary amount of geological information was recorded.
Detailed site description. In a few cases, detailed geological records were available, usually in the form of detailed sedimentological logs and/or bioenvironmental descriptions of contained Foramifera/Ostracoda, Mollusca, Coleoptera or micro- or macro-vertebrates. In some cases geochronological dating information was available.

Stratigraphy:
Formation/Member. The nomenclature used by on BGS 1:50000 Sheets 257 (Romford) and 271 (Dartford) was used.
Alternative nomenclature. Where alternative terminology was known to be in use, this was given. Mostly this was derived from Bridgland (1994, 1995a).
Lithology. Where known, this was recorded; where inferred, this was indicated by '?'.
Fossil content. Where known this was recorded.
Environment of deposition. Where known, this was recorded; where inferred, this was indicated by '?'.
Archaeology;content. Where known this was recorded.
Archaeology; potential. This was inferred either from the archaeological content record or from an assessment of the palaeoenvironment.

Areal extent of interest:
This is mostly self-explanatory.
Faces. There was a need to follow up this information with site visits to ascertain if the deposits were accessible as in many cases the Pleistocene deposits surmounted, high, steep Chalk faces.
Periphery. In most cases the Pleistocene deposits extend from the quarry edge to the property boundary or beyond. This is particularly important where the quarry is infilled and the peripheral area provides the only resource for further investigation.

The completed GD pro-formas have not been submitted as the material is incorporated into pro-forma GR (see *'Site report pro-forma (GR)'* below).

2.1.2.2 Site visits

As the number of intended visits was high (*c*.400), the visits consisted of (a) locating the site, a surprising difficult feat in some cases, (b) tracing the boundaries of the working zone where possible and (c) noting the nature and location of the sediments present. Sections were not cleared due to time constraints, difficulty of obtaining permissions (particularly where the sites were built on or used for recreational purposes) and where poor accessibility was an issue (e.g. where the Pleistocene sediments surmounted high Chalk faces). However, where possible, opportunity was taken to clear superficial material to verify the presence, and nature, of the sediments present. Note was also made of the present condition of the site and its potential for future archaeological or geological investigation.

Geological site visit pro-forma (GV)

The information was recorded on the GV pro-forma (example attached, Table 3) by hand. The terminology is reasonably self-explanatory, but following are elaborated:

GV3 Physical potential of sediments.

Limited potential. Sediments likely to yield limited information, of a regional rather than site specific, e.g. stone counts and heavy minerals give information about source areas rather than the site itself.

Medium potential. Sediments likely to yield limited site specific information, such as cross-beds indicating direction of ribver flow at the time of deposition.

High potential. Sediments likely to yield more site specific information, such whether the deposits are derived from a river, a lake, a slope, a glacier and whether they have been affected by landslipping, instability due to groundwater saturation, periglacial activity, palaeosol development.

GV4 Bioenvironmental potential of sediments.

Limited potential. Limited amount of fine material, might yield microfossils such as pollen, giving regional information.

Medium potential. Reasonable possibility of fine material yielding at least some of a range of microfossils, such as ostracods or microvertebrates, giving site specific information.

High potential. Sediments likely to yield a range of bioenvironmental information from material such as plant macros, beetles, molluscs, micro- and macro-vertebrates.

Notes

Notes made on a visit provided detail relevant to the site that was not readily incorporated into the pro-forma information.

The completed pro-formas have not been submitted as the information is incorporated into reporting process (see section 2.1.2.3).

Table 3: Site visit pro-forma GV

ALSF THAMES GATEWAY PROJECT **GEOLOGICAL SITE VISIT (GV)**

Date

SITE

Visit by

GV1 **Quantity of Pleistocene sediments present**		0 - None/unknown	GV2 **Location of Pleistocene sediments**		0 - None/Unknown
		1 - Small amount			1 - On site/quarry floor
		2. - Moderate amount			2 - In quarry sides/walls
		3 - Abundant sediments			3 - At land surface adjacent to quarry, within or contiguous with property boundaries

GV3 **Potential of sediments (physical environmental information)**		0 - None	GV4 **Potential of sediments (biological environmental information)**		0 - None
		1 - Limited potential for sedimentological information (stone counts, heavy minerals)			1 - Limited potential for bio-environmental information (microfossils e.g. pollen)
		2 - Medium potential (some measurable features, e.g. x-beds)			2 - Medium potential (e.g. possibility of microvertebrates
		3 - High potential (many measurable features, e.g. x-beds, clast fabrics, deformation structures)			3 - High potential (e.g. macrovertebrates, molluscs, beetles, plant macros)

GV5 **Stratigraphic value of site**		0 - None	GV6 **Accessibility**		0 - No deposit
		1 - Limited (e.g. cold stage gravels only)			1 - Poor: covered by roads or housing; no faces or very inaccessible faces
		2 - Medium (sediments with limited stratigraphic indicators)			2 - Moderate; faces with limited potential for cleaning; restricted or difficult top access
		3 - High potential (e.g. sediments of more than one stage with clear stratigraphic indicators)			3 - Good; direct unrestricted access to face and from above

Notes

2.1.2.3 Reporting

The information was reported in five ways:

Site maps
Site maps were annotated to indicate the areas of interest. Where the site had been divided, to reflect differences in the geology in different parts of the quarry as described in 2.1.2.1 above, the divisions were indicated.

Spreadsheets
The information from all sites visited was recorded on an Excel spreadsheet, under the headings indicated below. This provided essential information in an abbreviated form. The headings are explained as follows:

Area - Essesx (ES) or Kent (KT)
ALSF no. - designated number for site e.g. 908, 911B, etc.
Current status - infilled, open, as appropriate
Sed locale - (sediment locale) location of sediments, on floor of quarry, in faces, at ground surface peripheral to the worked quarry area (whether extant or infilled).
Access - as per GV6.
Access score - as per GV6
Strat 1, 2, 3 - (stratigraphy, from top downwards) as per GD3
Solid geology - (pre-Pleistocene geology) derived from BGS 1:50000 geology map
Varies from BGS - (site visit showed variation from BGS mapping) derived from site visit
Quantity sed - (quantity of sediment present) derived from GV1
Qty-score - derived from GV1
Phys-pot - (physical environmental information potential) derived from GV3
Pp score - physical potential score, derived from GV3
Bioenv-pot - (biological environmental information potential) derived from GV4
Bp score - bioenvironmental potential score, derived from GV4
Geol score - sum of the scores for accessibility, quantity of sediment present, physical potential and bioenvironmental potential.
Sed/bio archived - notes whether any biological or sedimentological material has been archived
Geol-info - (quality of published geological information) derived from GD1.

Overall assessment: Palaeolithic archaeology
Some of the information above was duplicated in the overall assessment sheets for the Palaeolithic archaeology, to provide more comprehensive records of the archaeological situation. The detail of this procedure is shown in Table 4.

Table 4: Overall assessment form; Palaeolithic archaeology (continued on following page)

OVERALL ASSESSMENT: PALAEOLITHIC ARCHAEOLOGY

1 Potential for analysis of existing collections		
1.1 Abundance of artefacts	0 None 1 Single f-spot 2 Several 3 Abundant	3
1.2 Diversity of artefact types	Sum of number of different types present	2
1.3 Artefact depositional history	0 Unknown 1 Significant fluvial transport 2 Minor fluvial/colluvial/solifluction transport 3 Undisturbed	2
1.4 Geological archive (GD2)	0 No archive 1 Sediments or biological material archived	0
1.5 Cut-marked fauna	0 Absent 3 Present	
1.6 Hominid remains	Ditto	
1.7 Biological evidence	Ditto	
1.8 Diversity of biological evidence	Sum of number of different types present	
1.9 History of investigation	0 Collection 2 Controlled collection 4 Controlled excavation	1
1.10 Quality of geological information (GD1)	0.None 1 Regional literature or maps only 2.Basic site description available 3 Detailed site description available	2
1.11 Collection holdings	0 None 1 Single/Several artefacts 2 Abundant artefacts	3
Total	**Sum of #1.1–1.10 multiplied by #1.11**	**30**
2 Potential significance of surviving sediments		
2.1 Sediment survival (within site or at margins) (GV2)	0 None 1 Some present	1
2.2 Sedimentological potential (GV3)	0 No potential 1 Limited 2 Medium 3 High	2
2.3 Abundance of artefacts	As per #1.1 above	3
2.4 Artefact depositional history	As per #1.3 above	2
2.5 Cut-marked fauna	As per #1.5 above	0
2.6 Hominid remains	As per #1.6 above	0
2.7 Bio-environmental potential (GV4)	0 No potential 1 Limited 2 Medium 3 High	2
Total	**Sum of #2.2–2.7 multiplied by #2.1**	**9**

Table 4: Overall assessment form; Palaeolithic archaeology (continued from previous page)

3 Heritage potential		
3.1 Quantity of surviving Pleistocene sediments (GV1)	0 None 1 Small amount 2 Moderate amount 3 Abundant sediments	2
3.2 Accessibility of surviving sediments (GV6)	0 No deposit 1 Poor; covered/no faces/faces inaccessible 2 Moderate; limited cleaning possible, restriced access 3 Good; reasonable or unrestricted access	2
3.3 Abundance of artefacts	As per #1.1 above	3
3.4 Diversity of artefact types	As per #1.2 above	2
3.5 Large mammalian biological evidence	0 None 1 Some 2 Abundant	0
3.6 Collection holdings	0 None 1 Single artefact 2 Several artefacts 3 Abundant artefacts	3
Total	Sum of #3.1–3.6	12

Site report pro-forma (GR)

For each site with archaeological or geological significance, a fuller site report is provided. This is partly in the form of a table repeating GD1 and partly in written form incorporating the qualitative information from the GD and GV hand-written pro-formas. Examples are given in Table 5 and the full complement of reports form section 2.1.3 below.

The information was also used in section 3.1 (Discussion points).

Table 5: Site record form; worked example (continued on following page)

ALSF THAMES GATEWAY PROJECT **GEOLOGICAL REPORT (GR)**

Date

Site number **ES 679**

Site name **Greenlands**

P. Allen

Location **Purfleet**

Grid Reference **TQ**

GD1 **Quality of geological information**		0 - None	GD2 **Sedimentological or biological material archived**		0 - None/not known
		1 - Regional information only		**X**	1 - Yes
		2. - Basic site descript. available			
	X	3 - Detailed descript. available			

GD3

Formation/ Member (BGS)	**Formation/ Member (Bridgland)**	**Lithology**	**Fossil content**	**Environmental information**	**Archaeological content**	**potential**
Lynch Hill Gravel	Corbets Tey Formation	Sequence of coombe rock, gravel, shelly sand, laminated silt, sand and gravel (see below)	Vertebrates, molluscs, ostracods, pollen	Sequence of cold-warm-cold stage fluvial deposits	ClactonianAcheulian and Levallois artefacts found	High

GD4 **Areal extent of interest**			North	South	East	West
		0 - None				
	X	1 - One or two faces	X		X	X
		2 - Much/whole of area				
	X	3 - Around periphery	X		X	X

Table 5: Site record form; worked example (continued from previous page and continued on following page)

Outline description

North Face

Corbets Tey Formation (Bridgland (1994, 1995)

				OIS
C	8.	?Botany Gravel	2 m	8
?T	7.	Grey-brown silty clay	up to 0.75m	8
C	6.	Bluelands Gravel	up to 6m	9
T	5.	Greenlands Shell Bed	up to 2m	9
T	4.	Silty Clay	up to 0.25m	9
T	3.	Shelly gravel	up to 0.75m	9
C	2.	Little Thurrock Gravel	up to 0.4m	10
C	1.	Angular chalk rubble (coombe rock)	1m	10
		Chalk		

C = cold stage; W = warm stage

The above sequence is described from the NW part of the quarry adjacent to the Armor Road entrance to the site, but most/all of the Units can traced along the whole of the north face. The Botany Gravel is better represented in the adjacent Bluelands Quarry.

The ground surface adjacent to the face has some potential for archaeological and environmental information, but the most important strata are at depth.

West Face

The Chalk bedrock rises to the south. Most/all the Units described above occur at the northern end of the west face, now unfortunately, covered by the access road into the QED warehouse complex. As the Chalk rises, the lower sediments are no longer present and only Unit 6 can be seen at the southern end.

The face is immediately adjacent to a public footpath, but (?part of) the field beyond has been/is being designated as part of the SSSI.

South Face

Unit 8, the Botany Gravel, occurs at the extreme western end of this face, yielding abundant artefacts. Unfortunately this part of the face is covered by the access road and protective covering to prevent rock falls. The rest of the face shoes thin gravel affected by cryoturbation, at the top of a vertical Chalk face. There is limited potential on the ground surface between the quarry edge and the boundary fence (and beyond) to investigate the sediments.

East Face

The main part of the east face is similar to the south face, but northern part of the east face, adjacent to the Armor Road extension, shows a steeply dipping Chalk surface covered by coombe rock. Virtually all of this face is close to the property boundary, leaving little potential for surface investigation.

Table 5: Site record form; worked example (continued from previous page)

Interpretation

The whole quarry represents a bank of the Thames, with the dry high ground represented by the south face, the sloping banks by the west (gently sloping) and east (steep) faces and the river deposits by the north face.

The full sedimentary sequence comprises a ‘sandwich’ of cold - warm - cold stage deposits, illustrating a typical Lower Thames terrace sedimentary sequence according to the model of Bridgland (1994, 1995a).

The warm stage deposits have yielded rich molluscan, mammalian, ostracod and pollen assemblages that indicate fully temperate conditions and the distal influence of marine transgression.

Clactonian (Unit 2), Acheulian (Unit 6) and Levallois (Unit 8) Palaeolithic industries are found in superposition, making this a key locality in the understanding of the early human occupation of southern Britain.

Recommendations

The site is part of a complex of quarries, including Bluelands, Botany and the Esso Pits, forming the Purfleet SSSSI, and any work undertaken should be cognisant of this wider context. Specifically to the site, the northern and western faces are the most important.

That part of the **northern face** east of the Armor Road extension is well exposed and active measures are in hand (1003, 2004) to improve access and exposure. West of Armor Road, some landslips have created exposures, but much of the face has been protected by grading and seeding, despite an agreement to leave exposures. An attempt is being made to rectify this situation.

The **western face** has been lost, but a reserve of land beyond the public footpath is being/has been designated as an extension of the SSSI. This has some value, but the most important deposits are at depth.

The **southern face** has important potential at its western end, where the Botany Gravel is immediately below the ground surface. Possibly the Botany Gravel extends into the field reserved as an extension of the SSSI.

Principal references

Schreve *et al*. (2002)

2.1.3 Results: site reports

ALSF THAMES GATEWAY PROJECT **GEOLOGICAL REPORT (GR)**

Date 11/2003

Site number **KT 542**

Site name **Baker's Hole, Ebbsfleet Valley (N)**

(P. Allen)

Location **Swanscombe**

Grid Ref **TQ 608744**

GD1 **Quality of geological information**			GD2 **Sedimentological or biological material archived**		
		0 - None		**X**	0 - None/not known
	X	1 - Regional information only			1 - Yes
		2. - Basic site descript. available			
		3 - Detailed descript. available			

GD3

Formation/ Member (BGS)	**Formation/ Member (Bridgland)**	**Lithology**	**Fossil content**	**Environmental information**	**Archaeological content potential**	
Boyn Hill Gravel	Dartford Heath Gravel Orsett Heath Formation	Gravel	None known	Fluvial terrace	None known	High

GD4 **Areal extent of interest**			North	South	East	West
		0 - None				
	X	1 - One or two faces		X		X
		2 - Much/whole of area				
	X	3 - Around periphery		X		X

Summary of geological context
At top of slope, slope to east. Chalk pit exposed Boyn Hill/Dartford Heath Gravel to west and south.

Summary of archaeological context
No record of finds specific to site, but finds nearby at Galley Hill (KT 552, 574, 575) and Swanscombe NNR (KT 911), all within 1 km.

Notes
Chalk quarry on platform above KT 581. Now heavily vegetated, but reasonable access to faces on west and south sides + margin on south side, of variable width, at original ground surface occurs adjacent to footpath from Stanhope Road/Herbert Road.

Principal references
Wymer (1968, 1999)
BGS 1:50000 Sheet 271 Dartford (1998)

ALSF THAMES GATEWAY PROJECT **GEOLOGICAL REPORT (GR)**

Date 11/2003

P. Allen
F. Wenban-Smith

Site number	**KT 585A, B, C (KT 553)**	
Site name	**Rickson's Pit** **Baker's Hole, Ebbsfleet Valley (S)**	
Location	**Swanscombe**	
Grid Reference	**KT 585 A** **B** **C**	**TQ 609743** **TQ 612741** **TQ 615735**

GD1			GD2		
Quality of geological information		0 - None	**Sedimentological or biological material archived**		0 - None/not known
		1 - Regional information only		X	1 - Yes Majority in Natural History Museum
		2. - Basic site descript. available			
	X	3 - Detailed descript. available			

GD3

Formation/ Member (BGS)	**Geol code (BGS)**	**Formation/ Member (Bridgland)**	**Lithology**	**Fossil content**	**Environmental information**	**Archaeological content**	**potential**
Head (KT 585B, C)	HEAD		Coombe Rock (Angular chalk clasts in chalk matrix)	Mollusca and vertebrates	Solifluction deposits	Arefact-rich in KT 585B (see FWS)	High
Boyn Hill Gravel (KT 585A)	BHT	Orsett Heath Formation	X-bedded sand and gravel Horiz-bedded sand & grave Sandy gravel Coarse gravel	Unspecified shells recorded	Fluvial terrace	Many artefacts recovered from both the basal Coarse rravel and the X-bedded sand and gravel.	High
Chalk							

Summary of geological context Ground slopes to east. Chalk pit exposed Boyn Hill Gravel in western part (KT 585A) and Coombe Rock to the east (KT 585B). KT 585C possibly has Coombe Rock along its eastern (KT 553) and southern margins.

Summary of archaeological context Boyn Hill Gravel - river side (described as a beach). Possible correlations with the Swanscombe NNR deposits.

Coombe Rock has artefacts, Mollusca and vertebrates (KT585B). This is the most famous and most prolific Levallois site in Britain. Kt 585C has been severely affected by CTRL works.

Notes KT 585A. Rickson's Pit has/had a full sedimentary and archaeological sequence, comparable to the Swanscombe NNR sequence. Site is now infilled to above original ground level, but margin of variable width of original ground surface occurs along north-west boundary, adjacent to footpath from Stanhope Road/Herbert Road. Sediments will also be present in eastern area, under properties in Stanhope Road.

KT 585B. Parts preserved as Baker's Hole SSSI which comprises 'islands' of original sediment.

KT 585C. Former Chalk quarry with Coombe Rock and eastern edge. Now infilled to above original ground surface in northern area, with infill overlapping on to undug Coombe Rock (KT 553). However, whole area now compromised by CTRL works.

Principal references

Wymer (1968, 1999)
BGS 1:50000 Sheet 271 Dartford (1998)

2.1.4 GIS 3-D MODELLING OF GEOLOGICAL DATA

2.1.4.1 Scoping

The British Geological Survey (BGS) was commissioned to provide geological mapping- and borehole-derived spatial and altitude data for the geology of the study area. This included line mapping data for the whole Thames area, and more detailed mapping and borehole data modelling for the project area around Dartford, Northfleet, Purfleet and Grays (Fig. 11).

2.1.4.2 BGS methodology

The BGS provided geological maps (linework) and 3-D modelling.

Geological linework

The information was provided as digital files for use in Arcview with metadata, as indicated below.

Thames Gateway

The linework for the Thames Gateway covered :
Essex: Thurrock, Basildon District, Castle Point District, Southend on Sea, Rochford District
Kent: Dartford District, Gravesham District, Medway Towns and Swale District.

The linework comprised 1:50000 geological solid, drift and mass movement themes for the study area covering parts of Geological Sheets Romford (257) Southend and Foulness (258, 259), Dartford (271), Chatham (272), Faversham (273), Maidstone (288) and Canterbury (289). The dates of survey vary across the project area most of the Kent area was surveyed in the 1950s-1970s whereas much of the Essex area dates from 1970s-90s.

Project area

The linework comprised an artificial geology layer based on data derived from the most detailed (1:10000 or 1: 10560 scale) maps and surveys for the whole area to produce a customised thematic map showing the extent of worked out and infilled sites related to past and present mineral extraction (sand and gravel, chalk, brickclay, etc) and major areas of built up-made ground. The cut and fill along linear routes and structures (roads, rail, canals, dams and seawall defences etc) are clearly shown on topographic bases and would not be included. The development of this layer involved the examination of OS historical map data, modern topographic bases, geological 1:10 000/1:10560 maps, and the Chelsea Speleological Society database of chalk workings-deneholes across the area. An index map was provided listing metadata about the sources consulted.

The artificial ground layer shows areas of worked out ground, infilled ground and made ground. This data is based on 1:10000-10560 topographic maps published since the late 19TH Century, the BGS surveyed geological 1; 10000 master maps and records of deneholes from the Chelsea Speleological Society archives.

Project area; Geological modelling

For the project area, detailed 3D geological models were provided, using surface geological linework, subsurface Digital Elevation model (DEM) and borehole data, assessed by an experienced geologist. From several thousand records for that area, the best and most representative 300 or so were coded up to produce the model.

Nature of data provided.
The data was provided on a single CD containing c. 600mb of data in c. 490 files. Of the data that were on the CD the geological map provided by the BGS and the subsurface models require further discussion.

The subsurface models were well documented, providing each DEM in a number of different raster formats. This facilitated easy integration into the GIS software. The only criticism of these data, at this stage, is that they did not contain accurate project information.

On the other hand, the geological map data provided by the BGS was poorly structured. These directories contained a number of ESRI shapefiles and an ESRI grid. Many of these shapefiles were intermediary copies of working files. It was therefore difficult to establish which were the definitive data files. It was finally decided to employ *Join_geology.shp* as the definitive version of the 1:50,000 geological map. The attributes metadata for this shapefile was well-documented in the associated Word documents (*Geology_fields* and *Artificial_fields*). The 1:10,000 linework discussed in *'Project area'* above did not appear to exist on the CD provided. These comments are not intended to be critical of the BGS data, but to indicate the difficulties encountered.

The model is in .xml format, consisting of thematic layers for manipulation in a GIS using Arcview or similar.

Summary of digital visualisation techniques
Each of the subsurface DEMs were converted into Erdas Imagine (.img) raster format and projection information was added in ArcCATALOGUE. An extent mask was created by reclassifying each DEM. A 'base of drift' model was created by combining the highest points of the Thames group, Lambeth group and Thanet sand formation models.

Fence diagrams were produced in ArcSCENE using a block diagram script available from the ESRI website (www.esri.com). Isopach models were created in ArcMAP by subtracting the appropriate gravel terrace from the 'base of drift' model. The resultant illustrations were exported as tiff files. Titles, keys and other illustrative content were added in Adobe Illustrator. The final illustrations were exported as jpeg files.

2.1.4.3 Project utilization of BGS modelling

Aims
It was hoped that the 3-D modelling would enable the Thames Pleistocene sediments to be better characterized than is possible from map data alone or, indeed, from map data supplemented with borehole records. Particular aims were:

- characterization of the terrace deposits

- exploration of issues and areas of interest - *e.g.* investigation of controversial sites or areas of deposit

- identification of anomalous data - *e.g*. steeper or thicker stretches of the terraces; patches of deposits at anomalous heights

Constraints of the data
The 3-D data as supplied provides upper surface levels of the various terrace units, other drift units, and the Tertiary bedrock units. Bases of units are defined only by the tops of the underlying units. Unfortunately no data was supplied for the Chalk, which meant that thicknesses of Pleistocene beds could be modelled only where they are overlying Tertiary bedrock. For this reason there was a restricted choice of areas in which the terraces could be characterized, and of problems and anomalies that could be investigated.

Furthermore, as discussed in *'Corbets Tey Gravel at Globe Pit SSSI Palaeolithic locality, Little Thurrock'* below the 3-D data did not always show the horizontal superposition of beds. The incorporation of this information would have allowed the formation sequences in the study area to be rigourously re-evaluated. This would have enabled a more rounded re-appraisal of the palaeo-archaeological potential in the zone. It is, however, likely that this data is available from the BGS. Hence, for similar projects in the future it is recommended that close communication is maintained between the data providers and data analysts to ensure that the most appropriate models are being used.

Finally, there was no breakdown into lithologies within mapped units. Thus the various loams and gravels within the Swanscombe sequence are not definable separately within the 3-D data. This means that the 3-D form of the interglacial members within terrace formations (see Fig. 6) cannot be modelled, let alone individual beds within complex sequences such as at Swanscombe.

Characterization of key terrace deposits
The 3-D data was used in attempt to characterize the sinuous linear sediment bodies forming the Orsett Heath (Boyn Hill Gravel), Corbets Tey (Lynch Hill Gravel) and Mucking (Taplow Gravel) Formations (as defined by Bridgland, 1994 - see section 2.1.1.4), all three being important contexts for Palaeolithic archaeology. The chosen method was to construct a linearly-connected fence type diagram along the palaeodrainage course for each of these, with cross-sections at selected points (chosen to coincide with optimal preservation of terrace deposits overlying Tertiary bedrock. This type of pragmatic approach is required for dissected sediment bodies of this sort, which survive reasonably intact in certain areas but have been removed by erosion elsewhere. The Mucking Formation, although containing important (Levallois) archaeological material at sites such as West Thurrock and Northfleet (Ebbsfleet tributary), could be characterized only to a very limited degree because, given its lower elevation within the valley, it mostly overlies Chalk rather than Tertiary bedrock (The gently dipping Chalk - Tertiary contact crosses the study area at about the height of the Corbets Tey Formation, which, for example, cuts across this boundary at Globe Pit, Little Thurrock

(Bridgland and Harding, 1993, 1994b. No meaningful modelling of the Mucking Formation was achieved.

Orsett Heath Formation/Black Park and Boyn Hill Gravels
Characterization of the Orsett Heath Formation required the Boyn Hill and Black Park gravels, as mapped by the BGS, to be modelled in combination (see section 2.1.1.4). The separate distinction of these mapped units, of doubtful validity on grounds outlined in *'Black Park Gravel'* above, was investigated using the 3-D data in the Aveley vicinity (see *'Distinction of Black Park and Boyn Hill Gravel'* below). The results provide no support for the separate mapping and, therefore, justification for the modelling of these two units in combination. In actuality the largest spreads of the Black Park Gravel, as redefined by the BGS, occur in the Dartford area and are all mapped as Boyn Hill Gravel

The long profile fence diagram of the gravels (Fig. 12) shows their thickness to vary, being greater in Essex in the Aveley area, on Dartford Heath and Orsett Heath. As the centre line of the fence diagram was taken along the outcrops, it does not necessarily coincide with the deeper part of the channel and it is possible that the thinner gravels between Dartford and Swanscombe reflect the river edge. However, the data does not include the thicker gravels now worked out, as at the Wansunt Pit and Swanscombe, so the fence diagram will not be too accurate a reflection of the initial condition of the gravels. Near Crayford, a steep channel edge to the Boyn Hill Gravel can be seen, captured by the centre line, possibly reflecting the a steep outer bank on the curve of the river. Further east on Dartford Heath, the base of the gravel rises slowly to the south, suggesting a feathering out of the gravel rather than a well defined channel edge. A further a steep rise in the underlying Tertiary beds (base of drift) can be seen in the Swanscombe area, again on a bend in the river, but unfortunately with little Pleistocene sediment present. Thicker sediments occur again at Orsett Heath, lying within a well defined channel. There is no evidence in the fence diagrams for the channel that Dewey et al. (1924) thought existed beneath Dartford Heath.

The crowded nature of the fence diagram is a product of the angle of view and the area is considered in more detail below (see *'Distinction of Black Park and Boyn Hill Gravels'* below).

The isopachs (thicknesses) of the Black Park and Boyn Hill Gravels (Fig. 13) support and elaborate on the fence diagrams. The thickness of the Black Park and Boyn Hill Gravels gravels in the Aveley area can be seen to increase in an orderly manner to the northwest rather than in the stepped fashion that would be expected of two separate members of a terrace sequence.

The steep bank noted near Crayford (see above) can be seen to have a north-south trend (TQ [5]505 [1]730), possibly associating it with a tributary of the Cray, coinciding with a present-day dry valley originating in Joyden's Wood. The east-west feature indicated by thicker gravel at TQ[5]515 [1]735 is not a valley, but thicker gravel banked against an east-west trending slope. The gravel immediately to the north is thinner because the ground surface if falling rapidly to the north (the contours are isopachs, not altitudinal). The gravels and loam at the Wansunt Pit are part of this thicker outcrop.

The isopachs of the Boyn Hill Gravel on Orsett Heath show an east-west trend, suggesting flow in that direction. Thus the deep channel of the Thames between Northfleet and Orsett may have been further west than the centre line of the fence diagram, sweeping round to flow eastwards across Orsett Heath. The isolated patches of Black Park Gravel around the Lion Pit (TQ [5]595 [1]788) belong to the northward-flowing stretch of the Thames as it crossed back into Essex from Kent.

Corbets Tey Formation/Lynch Hill and Hackney Gravels
Characterization of the Corbets Tey Formation required the Lynch Hill and Hackney Gravels, as mapped by the BGS, to be modelled in combination (see *'Orsett Heath (Gravel) Formation'* above). In actuality, no Hackney Gravel is mapped within the study area, so the exercise in effect was to model the Lynch Hill Gravel. This could be carried out less readily than for the Orsett Heath Formation because in parts of the area the unit rests on Chalk (see *'Constraints of the data'*). Indeed, along the well-preserved sinuous course of the Corbets Tey Formation

between Ockendon and Purfleet its southern flanks rest on the Chalk of the Purfleet anticline, whereas its northern flanks rest on Tertiary beds.

The Formation could be represented on fence diagrams for its full width only in the South Ockendon area. Beyond that the Formation could be represented only partially along the centre line and cross-sections to Purfleet. Beyond that again, the Formation is not represented on the fence diagram. A cross-section through the deposits at the Globe Pit, Little Thurrock failed to detect the Formation at the site. This was to be expected as the Formation is not mapped at the site. A further difficulty is that the Formation is not represented where it has been worked out. This particularly affects the first cross-section, near South Ockendon.

Examination of fence diagram (Fig. 14) suggests there might be a slightly deeper feature running to the east of the centre line in the Ockendon area and north of the line in the Purfleet area. This feature only partly coincides with the present Mar Dyke, so it might be an old feature. All of the sections indicate a considerably deeper area centred on Aveley village. This may represent a deeper part of the channel on the inside of the bend as the Thames of the time swung around, in an acute angle, the high ground at the junction of Sandy Lane and Romford Road (TQ 561808).

Isopachs of the Formation (Fig. 15) show the minor channel only in the South Ockendon area. The deeper channel centred on Aveley village is clearly shown. The isopach contours do not show any thinning towards the inner edge of the bend. Possibly this is an artefact of data availability and/or of the data processing.

Investigation of particular issues and sites

During this survey, there were many cases of anomalies between the geological information, either already published by the BGS (1:50000 sheets 257 and 271) or supplied for this project, and the situation on (under) the ground. Drift mapping, particularly at boundaries, is notoriously difficult and the following are offered as examples of the problems that archaeologists may encounter and as indicators to the BGS where it may consider altering its procedures to accommodate these problems.

Distinction of Black Park and Boyn Hill Gravels

The only area where these two mapped units are juxtaposed within the area of 3-D data availability is to the west of Aveley village, at and around the northern part of the erstwhile Sandy Lane Quarry. This quarry was much visited by the authors during its period of working and was described in some detail in an MSc student dissertation supervised by P. Allen (Wiseman, 1978). It was also described as part of the Aveley GCR site by Bridgland (1994). The 1996 edition BGS Sheet 257 (Romford) shows Black Park Gravel capping the highest ground here, as exposed in the south-eastern part of the former workings (ES 629B), whereas the lower areas to the immediate north-west are mapped as Boyn Hill (ES 629A). This means that the Black Park - Boyn Hill boundary would have passed through the quarry and could be exposed on its north side (ES 629A). There is, however, nothing in the available descriptions of the quarry to suggest that two separate terraces were exposed in this area nor were any indications noted during visits to the quarry in the 1970s.

This anomaly was investigated by using the 3-D data to construct a section through the surviving Black Park and Boyn Hill Gravel (Fig. 16). The resultant section shows the base of the deposits rising steadily to the south-east without a step and the Boyn Hill and Black Park Gravels forming a single gravel body, with no separation into two terraces. The ranges of altitude are within the envelope established for the Orsett Heath Formation on the basis of the record in the areas of less dissection around Dartford and Swanscombe (see *'Orsett Heath (Gravel) Formation*' above). The conclusion is that the 3-D data provide no support for the distinction of two separate terrace units here and that the more parsimonious interpretation would be that a single terrace formation is represented. The slope to the north-west could be the result of natural variation in base height combined with an erosional surface or, given that the bedrock is London Clay, could result from cambering. Evidence that the Orsett Heath deposits here have been cambered has, in fact, been described from the Sandy Lane quarry, in which the gravels were disrupted by collapse structures, possibly associated with faulting (gulls), overlying upward injections (diapers) of London Clay (Fig. 17; Allen, 1991).

Investigation of mapping anomaly at Southfleet Road, Swanscombe
A known mapping anomaly occurs at Southfleet Road, Swanscombe, where an archaeological excavation in 1999/2000 found Palaeolithic gravels, identified as parts of the Swanscombe interglacial sequence, in an area mapped as Thanet Sand (Wenban-Smith and Bridgland, 2001).

The aim was to investigate the 3-D nature of the mapped units in this area, to see whether the mapping could be corrected by reinterpreting the data. This aim was largely thwarted by the non-availability of data for the top of the Chalk, which precluded thickness modelling of the sediments mapped as Thanet Sand. A grid fence diagram covering the area in question was produced from the 3-D data (Fig. 18). The diagram was constructed so that the central north-south line intersected the most southerly east-west line at Swanscombe Community School, where excavations had revealed the presence of the Boyn Hill Palaeolithic Gravel. No gravel was indicated at the intersection.

Investigation of mapping anomalies at Bexley Hospital, Dartford Heath
A second area of mapping anomaly occurred in the well-preserved Boyn Hill/Orsett Heath outcrop covering Dartford Heath. This was investigated (a) by using the 3-D data to produce a grid-fence diagram (Fig. 19) and (b) a comparison of the 1:10000 (Fig. 19) and 1:50000 (Fig. 20) line mapping provided for the project and the published 1:50000 sheets 271 (1971 and 1998).

The 1971 edition of sheet 271 shows a boundary running east-west through the hospital, with Boyn Hill Gravel to the north and Thanet Sand to the south. The 1998 Geology map shows the same boundary but with Head on the south side and isolated patches of Boyn Hill Gravel to the south (not present on the earlier geology map). An implication of this at there is Boyn Hill Gravel beneath the Head. This appears in part to be supported by the fence diagram (Fig. 19) which shows the Gravel to extend further south intermittently across an area mapped as bedrock on the older Geology map. The southerly extension was proven by an archaeological investigation of the hospital site in 1999/2000 that involved trial pit excavation on both sides of the boundary. This showed that the Boyn Hill Gravel extends south of the original mapped boundary.

The line mapping provided for the project indicated further anomaly in that the 1:10000 and 1:50000 distributions did not fully coincide. The former showed the Boyn Hill Gravel extending further to the west on Dartford Heath and the latter marginally further to the east (Fig. 20).

Corbets Tey Gravel at Globe Pit SSSI Palaeolithic locality, Little Thurrock
Neither of the BGS mappings of sheet 271 (1971, 1998) show the small outcrop of Corbets Tey Gravel at the Globe Pit (ES 476). Head is shown on the 1998 edition. The 3-D modelling also failed to show up the Corbets Tey Gravel (Fig. 21), but this was to be expected as it is not mapped at the site.

Detailed investigation of this site in the 1980s (Bridgland and Harding 1993, 1994a) recorded bedded gravels at the surface here, although the thin uppermost material in places might be colluvially reworked (Bridgland et al., 2003). Although there might be some justification for the mapping of head, it is considered unhelpful to show thin overburden of this type rather than more significant underlying bedded (fluvial) drift.

A further problem brought out by the 3-D modelling was that the modelling procedures did not always show horizontal superposition beds but a vertical relationship. The cross-sections at Little Thurrock showed Boyn Hill Gravel (lying to the north of the site) giving way laterally to Head, rather than the Head being in superposition on the Gravel. The sections also failed to show the interglacial deposits (Ilford Brickearth) as lying horizontally between the Lower and

Upper Corbets Tey Gravel, though this was more of a failure to recognise that the Brickearth was a constituent member of that Gravel.

Mucking Formation at Lion Pit SSSI Palaeolithic locality, West Thurrock
This is another instance in which precise mapping of boundaries can affect important contextual sediments at a Palaeolithic locality. The Mucking Formation deposits at this site were described by Bridgland and Harding (1994b; 1995). The Formation was previously mapped as Coombe Deposits and Brickearth, with Flood Plain Gravel adjacent (Dartford sheet 271, 1971). On the revised BGS map it appears as Taplow Gravel (Dartford sheet 271, 1998). The SSSI/archaeological site lies north of the mapped boundary of the Taplow Gravel and close to a minor outcrop of Boyn Hill Gravel. Thus it would be easy to associate the site the latter, with consequent stratigraphic error.

Potential future investigations
A number of further points of interest were identified for possible future investigation. To carry out this work would require (a) the addition of data for the Chalk surface and/or (b) the extension of the 3-D data area.

Black Park - Boyn Hill boundary in the Ockendon area
Following up the investigation of this junction at Aveley (see *'Distinction of Black Park and Boyn Hill Gravels'* above), which found little to support its existence, it could be further investigated at North Ockendon (TQ 593852), although the units do not abut one another there. This is beyond the present coverage of the 3-D data.

Boyn Hill - Lynch Hill boundary in the Ockendon area.
This boundary has been moved during the revision of sheet 257, possibly as part of the incorporation of the higher Black Park division. Juxtaposed deposits at South Ockendon (TQ 600823) could be investigated (beyond the present coverage of the 3-D data). Surface heights on the map raise a question mark about the distinction of higher Boyn Hill Gravel here (see 'Lynch Hill Gravel' above).

2.2 PALAEOLITHIC

2.2.1 Introduction

2.2.1.1 The Palaeolithic
The initial human occupation and subsequent settlement of Britain and northwest Europe has taken place against the backdrop of the Quaternary period, characterised by the onset and recurrence of a series of glacial-interglacial cycles. The Palaeolithic covers the time span from the initial colonisation of Britain in the Middle Pleistocene, *c.* 500,000 years ago, to the end of the Late Pleistocene, corresponding with the end of the last ice age *c.* 10,000 years ago. Thus the Palaeolithic period occupies almost 500,000 years. This period of time includes at least six major glacial-interglacial cycles (reflected in the global geological record as Oxygen Isotope stages, identified from changes in the proportions of the oxygen isotopes O^{18} and O^{16}) accompanied by dramatic changes in climate, landscape and environmental resources. At the cold peak of glacial periods, ice-sheets 100s of metres thick would have covered most of Britain, reaching on occasion as far south as London, and the country must have been uninhabitable. At the warm peak of interglacials, mollusc species that now inhabit the Nile were abundant in British rivers, and tropical fauna such as hippopotamus and forest elephant were

common in the landscape. For the majority of the time, however, the climate would have been somewhere between these extremes.

When climatic conditions allowed, and when access from the continent was possible — after the formation of the Channel, probably some time in the later Middle Pleistocene, access was only possible during periods of cold climate when sea levels were lower — early hominids were periodically present in Britain, which was at the northern margin of the inhabited world. The archaeological evidence of the period mostly comprises flint tools, and the waste flakes left from their manufacture. These are very robust and resistant to decay, and, once made and discarded, persist in the landscape, eventually becoming buried or transported by sedimentary processes related to climatic change and landscape evolution. Other forms of evidence include faunal dietary remains of large animals, sometimes cut-marked reflecting the stripping of flesh for food or broken open for marrow extraction and, very rarely, wooden artefacts. These forms of evidence are, however, more vulnerable to decay, and it is only very rarely that burial conditions were suitable for their preservation through to the present day. Hominid skeletal remains have also been found on occasion although, again, these are very rare and require exceptional conditions for their preservation.

The Palaeolithic has been divided into three broad, chronologically successive stages — Lower, Middle and Upper — based primarily on changing types of stone tool. This framework was developed in the 19th century, before any knowledge of the types of human ancestor associated with the evidence of each period, and without much knowledge of the timescale. This tripartite division has nonetheless broadly stood the test of time, proving both to reflect a general chronological succession across Britain and northwest Europe, and to correspond with the evolution of different ancestral human species.

The earlier, Lower and Middle, parts of the Palaeolithic period (Table 6) saw the gradual evolution of an Archaic hominid lineage from the first colonisers of Britain (*Homo heidelbergensis*) into Neanderthals (*Homo neanderthalensis*) during the period of almost 500,000 years up to the middle of the last glaciation (*c.* 35,000 BP). Very broadly speaking, the Lower Palaeolithic is associated with early Archaics and handaxe manufacture (Acheulian), and the Middle Palaeolithic with the development of Neanderthals and increasingly sophisticated flake-tool based lithic technology (Levalloisian and Mousterian), alongside one distinctive form of handaxe, the *bout coupé*.

It has, however, become clear with improved dating of several key sites, that the definition and distinction of Lower and Middle Palaeolithic is less clear-cut than was originally thought. While most early evidence is indeed dominated by the manufacture of handaxes, there are a number of contemporary early sites without handaxe manufacture that can be included as Lower Palaeolithic — particularly the manifestations of crude cores, flakes and notched flake-tools that occur at several sites in Kent and East Anglia and are labelled as Clactonian. It is also uncertain to what extent the manufacture of handaxes persisted alongside the uptake of "Middle Palaeolithic" technology, whether different human groups were involved, and whether a transition from Lower to

Middle Palaeolithic took place contemporaneously across the whole of Britain. Handaxes are scarce, but present, at most of the few Levalloisian sites known in Britain. These may be derived from earlier deposits, or contemporary with the Levalloisian material. The problem is that our understanding of the Lower and Middle Palaeolithic archaeological record is restricted by:

● Poor provenance of most finds

● Difficulty of dating deposits of this age

● Uncertainties over the extent of earlier derived material in assemblages

Despite these caveats and uncertainties, the traditional orthodoxy outlined in Table 6 was, as far as possible, applied in the survey. The majority of Pleistocene sediments identified as affected by mineral extraction in the survey were Middle and early Late Pleistocene, dating to the Lower and Middle Palaeolithic; and all Palaeolithic evidence identified from the sites studied dated to these periods.

After 35,000 BP, Neanderthals were suddenly replaced in Britain and northwest Europe by anatomically modern humans (*Homo sapiens sapiens*), who are associated with the later, Upper part of the Palaeolithic. The Upper Palaeolithic is also characterised by cultural changes such as the development of bone and antler tools and the representation of images of animals painted on cave walls or as small antler or bone carvings. The suddenness of this change and the physiological differences between Neanderthals and modern humans, as well as recent DNA studies, suggest that modern humans did not evolve from Neanderthals, but evolved elsewhere, probably in Africa or western Asia *c.* 125,000 BP, before colonising other parts of the world. In contrast to the Lower and Middle Palaeolithic periods, the relatively recent age of the Upper Palaeolithic, and the fact that, at least in Britain, the period is within the range of radiocarbon dating, means that our understanding of the period is good. It is clear that, at least in Britain, there is a well-defined and clear break between the Middle and the Upper Palaeolithic.

Britain was only occasionally inhabited during the Upper Palaeolithic, much of which co-incided with the cold climax of the last glaciation, and no evidence of the period was identified in any of the survey sites.

Table 6. Palaeolithic period in Britain

Archaeological period	*Human species*	*Lithic artefacts and other material culture*	*OI Stage*	*Date (BP)*	*Geological period*
Upper Palaeolithic	Anatomically modern *Homo sapiens sapiens*	Dominance of blade technology and standardised tools made on blade blanks, personal adornment, cave art, bone/antler points and needles	2–3	10,000–35,000	Late Pleistocene
Middle Palaeolithic	Early pre-Neanderthals initially, evolving into *Homo neanderthalensis* after OI stage 5e	Growth of more standardised flake and blade production techniques (Levalloisian and Mousterian), the development of a wider range of more standardised flake-tools, and towards the end, the development of *bout coupé* handaxes	3–5e	35,000–125,000	
			5e–8	125,000–250,000	Middle Pleistocene (later part of)
Lower Palaeolithic	Archaic Homo — *Homo* cf *heidelbergensis* initially, evolving towards *Homo neanderthalensis*	Handaxe dominated, unstandardised flake core production techniques and simple unstandardised flake-tools Occasional industries without handaxes, based on large flake blanks made by unstandardised core-reduction techniques	8–13	250,000–500,000	

2.2.1.2 The Palaeolithic in the Thames Estuary

The Thames Estuary is a key region for Palaeolithic archaeology in Britain. It remained to the south of the ice-sheets that periodically covered most of Britain during the Pleistocene. Therefore deposits from throughout the Middle and Late Pleistocene, contemporary with Palaeolithic occupation, are better preserved than in most other parts of the country. The Thames Estuary region contains a range of Pleistocene deposits that contain Palaeolithic evidence. Foremost among these, and of particular relevance in relation to aggregate extraction, are fluvial deposits laid down by early courses of the Thames and its lower tributaries, particularly the Medway, Cray and Darent. Colluvial/solifluction deposits are also present in several locations, formed by downslope sediment movement, and often covering fluvial sediments in lower-lying parts of the landscape or on the sides of valleys. Finally, residual Clay-with-flint deposits cap the high ground on the Kent side of the Thames Estuary, although the areas where these are present are a) outside the present study region, and b) have not generally been subject to aggregate extraction.

Fluvial deposits

Pleistocene fluvial deposits survive as terraces on the flanks of the Lower Thames in north Kent and south Essex, as well as of smaller tributaries such as the Cray, the Darent and even the Ebbsfleet. The combination of the cyclical cold-warm climatic changes of the Pleistocene and progressive tectonic uplift of the region have led to staircases of terraces, with older deposits higher and younger ones progressively lower. The deposits in these terraces mostly constitute sands and gravels laid down by flowing water, and thus the artefacts within them are not found undisturbed, but have been transported for a certain distance. Artefacts of different periods may also have entered the same river channel at different times, and ended up in apparent association. Nonetheless, these river deposits represent (within the context of the whole Palaeolithic period) a relatively restricted time capsule of Palaeolithic evidence from a well-defined spatial region. Any contained Palaeolithic evidence can, therefore, make a useful contribution to building up our understanding of behaviour and cultural change through the Palaeolithic. These fluvial sequences can also contain horizons where a hiatus in fluvial activity followed by low energy deposition of fine-grained sediment has led to preservation of a landsurface containing undisturbed evidence of early human activity. Such sites complement the wider picture provided by the transported fluvial evidence, by a) providing accessible details of early human behaviour at specific locations in the landscape, and b) providing high integrity samples of material culture without derived material from earlier periods.

Colluvial/solifluction
This group of deposits includes a variety of sediment types from coarse-grained solifluction gravels to fine-grained silty sands mapped as brickearth. Such sediments have formed under differing depositional processes and consequently the Palaeolithic archaeological material they contain has different taphonomic history and interpretive potential. They occur at the base of slopes, on the surface of valley-sides, in dry valleys and in hollows in the landscape — anywhere in fact where sediment destabilised by severe climatic conditions and/or devegetation has accumulated. Despite their coarse nature, many colluvial/solifluction deposits have slipped only a short distance, leading to the relatively gently burial of archaeological material. Colluvial/solifluction deposits often cap fluvial deposits, or occur as horizons within them, marking breaks in fluvial deposition. Thus they are often intrinsic parts of bodies of sediment affected by aggregate extraction.

Key sites
The Pleistocene deposits around the Thames Estuary are a nationally significant archaeological resource, representing a sequence of deposition from shortly after the first colonisation of England through to the end of the Pleistocene, and being rich in Lower and Middle Palaeolithic archaeological evidence (Wymer 1968 & 1985). The deposits in northwest Kent and south Essex are of particular significance, and finds from a few sites have made a disproportionately high contribution, in numbers as well as quality of information, to current knowledge of the Lower Palaeolithic in Britain (Table 7). Sites from throughout the Lower and Middle Palaeolithic are represented, containing a diversity of artefactual and biological information, often on undisturbed palaeo-landsurfaces. Furthermore, the only hominid skull known from this period found in Britain comes from Barnfield Pit, Swanscombe, on the Kent side of the Thames Estuary, found in three separate pieces between 1933 and 1955. The Swanscombe Skull shows some Neanderthal-type features, suggesting physical evolution from *Homo* cf *heidelbergensis* towards Neanderthals had already begun at the time of deposition of the Swanscombe sequence, although to what extent this was

accompanied by behavioural change remains unknown, and a major research question in Palaeolithic archaeology.

Many other significant sites are also present in the region. In fact it is somewhat invidious to isolate a few as being more significant, since small pieces of information from all the sites combine to create a greater understanding of the Palaeolithic than would be possible from any single site, however well-preserved or rich in evidence. On the Essex side of the Thames Estuary, 17 Palaeolithic sites are recorded within the study area by the recent English Rivers survey (Wessex Archaeology 1996). On the Kent side, 36 were recorded in the preceding Southern Rivers survey (Wessex Archaeology 1993). These sites are for the most part found within areas of previous aggregate extraction, often of heavy extraction where only vestiges of deposits that once were rich in artefacts and faunal remains survive. This survey has identified the extraction sites that have produced the most abundant and diverse Palaeolithic evidence of various types and periods, and has identified so far as possible where deposits containing evidence of potential significance survives. It is hoped that this will sustain protection against the threats posed by expansion and development in the region, and lead to renewed investigations in areas where the potential is highest to address current research questions.

Table 7: Key Thames Estuary Palaeolithic sites

County	*Site*	*Formation*	*Biological evidence*	*Undisturbed landsurface*	*Hominid remains*	*Archaeology*
Essex	Purfleet — Greenlands, Bluelands, Botany Bay Pits	Lynch Hill/ Corbets Tey	Abundant mammalian, molluscan, pollen & ostracods	-	-	Abundant Acheulian and Levalloisian evidence
	Globe Pit, Little Thurrock	Lynch Hill/ Corbets Tey?	Mammalian and pollen	-	-	Abundant Clactonian
Kent	Barnfield Pit	Boyn Hill/ Orsett Heath	Abundant mammalian (some cut-marked) and molluscan	Refitting evidence from undisturbed landsurface with Clactonian material	Skull	Abundant Acheulian (pointed handaxes) & Clactonian
	Wansunt Pit	post-Boyn Hill/ Orsett Heath	-	Refitting evidence and possible multiple landsurfaces in Wansunt Loam	-	Abundant Acheulian (ovate handaxes),
	Bakers Hole	Taplow/ Mucking, and possibly later	Abundant mammalian and molluscan	Refitting evidence from at least two locations	-	Abundant Levalloisian

2.2.1.3 Palaeolithic archaeology and aggregate extraction

There is a strong and unavoidable correspondence of interest between Palaeolithic archaeology and aggregate extraction. The great majority of sands and gravels that have use as aggregates were formed during the Pleistocene; and Pleistocene deposits were formed during the Palaeolithic period, and so contain all of our evidence of the Palaeolithic. In some cases the Pleistocene sands and gravels themselves have been the target of extraction. In other cases there has been a major impact on Pleistocene deposits that overlie other valuable aggregate resources, such as Chalk for the cement industry. In the Thames Estuary, the impact has been exacerbated by the presence of substantial aggregate deposits, their location in the major area of urban expansion of southeast England and their proximity to the navigable Lower Thames. These factors have combined to make them prime targets of industrial exploitation, and there has been substantial extraction in the region since the second half of the 19th century.

It should be emphasised that, while aggregate extraction has inevitably impacted upon the Palaeolithic archaeological resource, it has also provided the necessary exposures of the sediments that have led to our current understanding of the period, and there is a long history of co-operation and tolerance between Palaeolithic investigators and commercial quarrying. Early hand-digging and screening of gravel provided ideal conditions for the recognition and recovery of artefacts, and quarry owners such as the Associated Portland Cement Company in Swanscombe provided resources to facilitate archaeological investigation on numerous occasions at several key sites, such as Barnfield Pit and Bakers Hole, in Kent. These initiatives took place in the early 20th century, well before the advent of any legislation or planning guidance that required archaeological impacts to be considered and mitigated. Our current understanding of the Palaeolithic would be much reduced without the opportunities afforded by previous aggregate extraction. Far from being in conflict with the needs of Palaeolithic archaeology, ongoing and future aggregate extraction can be of benefit, so long as appropriate mitigating investigations are carried out.

2.2.2 Aims and objectives

The overall aims of the project are listed in the main introduction, and are aimed at informing current and future land-use proposals, and education and leisure initiatives. For the mineral extraction sites covered in the survey, records of Palaeolithic archaeological remains, their continuing presence and (if present) their potential for further investigation are relevant to a number of the eleven specific aims (A1–11) and three research objectives (RO1–3) listed:

A 3 Considering the continuing value of the sites for Palaeolithic and later archaeology

A 6 Assessing the archaeological potential of the sites, and adjacent un-extracted areas, and identifying future threats to archaeological or geological deposits

A 7 Provision of accurate and up-to-date information for Sites and Monument Records

A 8 Feedback into English Heritage's Monuments Protection Programme

A 9 Contributing to raising the profile of heritage issues and enhancing the image of the historic environment in the Thames Gateway region and its adjacent areas [*taken as including in relation to community, education and leisure initiatives*]

A 10 Use of the information as part of the planning process in relation to proposals for specific areas

RO 3 Assess the nature, extent and survival of archaeological features [*taken to include Pleistocene deposits containing Palaeolithic evidence*] within ME sites

2.2.3 Methods

The Palaeolithic was just one of a number of aspects of archaeological information considered in the survey. These also included Pleistocene geology. There is clearly a strong overlap in the presence of Pleistocene deposits and the presence/potential for Palaeolithic archaeological remains. However the Pleistocene and Palaeolithic aspects were initially considered independently, in light of the divergent criteria involved in assessing the importance of Pleistocene deposits in their own right in relation to the project aims. Relevant data from the Pleistocene assessment was ultimately combined with data from the Palaeolithic assessment to produce an integrated Palaeolithic/Pleistocene assessment of mineral extraction sites.

The starting point for the collation of Palaeolithic information was the overall synthesis of *eligible* mineral extraction sites within the project area. The eligible sites were presented on hard copy paper maps as shape polygons covering mutually exclusive areas, numbered separately for Kent [KT nnn] and Essex [EX nnn] with each sequence commencing at 1. These were presented on separate maps for Kent and Essex, showing current OS landline data with the OS 1km grid overlaid.

The assessment of Palaeolithic potential was based initially on a *desk-based synthesis* of existing recorded information. This was followed up by *field visits* for 29 sites, selected as of potential high significance or under specific threats from information collected in the desk-based study. The information gathered during these studies directly addresses aims A7, A8 and RO3. This information was then collated and combined with relevant Pleistocene geological information (RO3), and the full range of relevant data evaluated to provide *overall assessment* in three areas, prepared ultimately as separate Palaeolithic GIS layers:

- Layer 1 — Palaeolithic potential in relation to analysis of existing collections (A3, A6, A10)
- Layer 2 — Palaeolithic potential in relation to surviving sediments (A3, A6, A10)
- Layer 2 — Heritage potential (A3, A9)

Desk-based study
For each mineral extraction site, four sources were consulted for information on recorded Palaeolithic archaeological remains:

- Southern Rivers Palaeolithic Project (Wessex Archaeology 1993)
- English Rivers Palaeolithic Project (Wessex Archaeology 1996)
- Sites and Monuments Records
- Unpublished site reports in Kent and Essex County Council archives

Primary published references for each site were collated from these sources and checked for relevant information. In addition to these sources, relevant information recovered during archival and bibliographic research carried out for the concurrent Stopes Palaeolithic Project were included (Wenban-Smith 2004).

Palaeolithic archaeological remains were taken as comprising direct evidence of human activity or presence, such as hominid skeletal material, flint artefacts or cut-marked faunal material, and related material relevant to researching the Palaeolithic, such as mammalian remains and other biological evidence (including molluscs, pollen, diatoms and plant macro-fossils), which are central both for providing palaeo-environmental reconstruction of the hominid landscape and for dating. Evidence from within each extraction area, and from their immediate environs, were both recorded. Hence the same Palaeolithic remains have on a few occasions been recorded as affecting more than one site, where they were found in between two adjacent sites — for instance the Palaeolithic handaxe find at Moor Hall Farm, Rainham, is recorded for both EX 620 and EX 629, and those from Dierden's Pit, Greenhithe have been recorded as part of EX 870, the northwestern part of the Barnfield Pit complex.

For each site, the relevant data on Palaeolithic remains were collated onto a standard proforma (APPENDIX 1), which was ultimately incorporated into the GIS end-product of the project. The information gathered is obviously constrained by the limitations of a desk-based study, in that it summarises what is already known. Lack of information on a specific site, or in a specific category of evidence, does not necessarily imply absence of Palaeolithic material. The information recorded merely highlights the proven presence of various categories of evidence, with a view to identifying sites with potential for further recoveries, possibly of better quality material and under more controlled conditions.

Field visits
Based on the data recorded in the desk-based Palaeolithic and Pleistocene studies, a number of sites (29) of high Palaeolithic interest were selected for field visits by both the Palaeolithic archaeological specialist (Francis Wenban-Smith) and the Pleistocene geological specialist (Peter Allen). A range of data was recorded during the site visits, concerning the current status of the site, the survival of Pleistocene deposits, the vulnerability of any surviving sediments and key issues for further research at the site. These were summarised in a proforma (APPENDIX 2), and ultimately have been incorporated into the GIS end-product of the project.

The criteria for selecting sites for field visits were:

- Survival of Pleistocene sediments (within site or at margins)
- Abundance of Palaeolithic evidence
- Quality of Palaeolithic evidence (degree of disturbance)
- Diversity of Palaeolithic evidence (range of categories represented)

Overall assessment
For overall assessment, Palaeolithic and Pleistocene geological data were combined into a single proforma (APPENDIX 3). The overall assessment was aimed at identifying value and potential of Palaeolithic remains and mineral extraction sites in three areas:

- Potential for analysis of existing collections
- Potential of surviving sediments
- Heritage potential

The approach to assessment in each of these areas was a simple collation of scores reflecting the prevalence or quality of material in categories of data thought relevant (Table 8) and weighted accordingly (*cf*. details in APPENDIX

3). Some categories of data are relevant in more than one of these areas, and so their score contributes to the total in each area of relevance. The combined scores in each area of assessment are thus a crude initial indicator of sites of potential interest. The numeric outcome of this system is not intended to provide a definitive means of relative ranking of sites in relation to each other, but to broadly identify sites with higher potential interest and significance. The scoring and weighting protocols adopted for this stage of the analysis can, if desired, be very easily adjusted in the future to use different combinations or weighting of the raw data from the desk-based study and field visits. The particular characteristics and potential of higher scoring sites then need to be considered more carefully, and each site treated on its own particular merits, in relation, for instance, to development threats.

Table 8. Categories of desk-based and field visit data from Palaeolithic and Pleistocene (Pleist.) studies contributing to overall assessment in different areas

Potential for analysis of existing collections	*Potential of surviving sediments*	*Heritage potential*
● Abundance of artefacts ● Diversity of artefact types ● Sedimentological record (Pleist.) ● Artefact depositional history ● Cut-marked fauna ● Hominid remains ● Biological evidence ● Diversity of biological evidence ● History of investigation ● Quality of geo information (Pleist.) ● Size of collection holdings	● Survival of any Pleistocene sediments (Pleist.) ● Sedimentological record (Pleist.) ● Abundance of artefacts ● Artefact depositional history ● Cut-marked fauna ● Hominid remains ● Bio-environmental evidence	● Quantity of surviving of Pleistocene sediments ● Accessibility of surviving Pleistocene sediments ● Abundance of artefacts ● Diversity of artefact types ● Large mammalian biological evidence ● Size of collection holdings

2.2.4 RESULTS

2.2.4.1 Essex

In total eighteen mineral extraction sites on the Essex side of the Thames Estuary had Palaeolithic remains recorded, and eight were visited as part of the Palaeolithic survey (Table 9). The majority of sites (eight) were single handaxe finds of uncertain provenance, although probably mostly originating from deposits of either the Boyn Hill/Orsett Heath or the Lynch Hill/Corbets Tey formation. Otherwise three major areas of Palaeolithic significance were identified:

● The area of Lynch Hill/Corbets Tey deposits around Bluelands, Greenlands, Botany and Esso Pits that abuts the northwest facing side of the Purfleet anticline (EX 653, 659, 670, 675 679 & 681)

● The Lion Pit Tramway cutting (EX 649)

● The Globe Pit, Little Thurrock (EX 476)

Bluelands, Greenlands, Botany and Esso Pits (EX 653, 659, 670, 675 679 & 681)

This area is already well-known as a key area for Palaeolithic and Pleistocene research. However the survey highlighted the unique combination of abundant and diverse archaeological *and* bio-environmental evidence that is present. The archaeological material includes Acheulian, Clactonian and Levalloisian industries in distinct stratigraphic horizons, and the biological evidence includes large mammals, small vertebrates, molluscs, pollen and ostracods, all abundant and well-preserved. The survey also highlighted the extent to which the area of these valuable deposits has already been affected by aggregate extraction, and continues to be further degraded by industrial and infrastructural development, particularly the Channel Tunnel Rail Link.

Reasonably representative areas of intact sediment are preserved, most of which are protected as a Site of Special Scientific Interest. Given the deep stratigraphic sequence of artefact-bearing deposits, and their varied archaeological content, the substantial collections from Botany Pit are of questionable value, considering their lack of stratigraphic provenance.

[Key references: Schreve *et al.* 2002; Bridgland *et al.* 2003]

Lion Pit Tramway Cutting (EX 649)
The most important aspect of this area is the undisturbed Levallois working floor, found at the northern end of the extraction area, deeply buried beneath sands and silts. The survey highlighted the range of biological evidence — ostracods, pollen and molluscs — that is also present, although relatively unresearched, at the site. A handaxe is also recorded from the site, and the relationship of any handaxe-bearing deposit to the Levallois working floor (if not the same horizon) is a question for future research. Another important issue is how the Lion Pit Levallois floor correlates with that on the south side of the Thames, found in a superficially stratigraphically analogous situation by Spurrell at the base of the Crayford Brickearth (Spurrell 1880). The Lion Pit area is currently undergoing housing development and infrastructural improvement, and areas of Pleistocene sediment either side of the tramway cutting, particularly at its northern end near the Levallois floor, are clearly vulnerable to development. The banks of Pleistocene sediment along the length of the tramway cutting are also exposed and vulnerable to degradation by natural causes and human activity, although their exposure also makes them more easily accessible for Palaeolithic/Pleistocene investigation. Some of the area is protected as an SSSI, and consideration needs to be given to whether this area is adequate (or the most appropriate) and to mitigating the vulnerability and ongoing degradation of the Palaeolithic/Pleistocene resource.

[Key reference: Bridgland & Harding 1994]

Globe Pit, Little Thurrock (EX 476)
This is an important locality for Clactonian material, which is abundant in a small patch of gravel preserved in the northeast corner of the extraction area, beyond the margins of the quarried brickearth spread. Biological evidence — mammalian and pollen — is reported from the brickearth in the vicinity of the site, but a) it is not totally clear how the brickearth relates stratigraphically to the Clactonian horizon, and b) there is no biological material with sufficiently good provenance to help in dating the Clactonian material or understanding the contemporary environment. The small remaining area of the site has been subject to three phases of excavation — Wymer (1957), Snelling (1964) and Bridgland & Harding (1993) — and the traces of these projects are still visible, although much overgrown and degraded. Access to the site is a problem, being primarily through a private residence by the grace of the occupant. The growth of woodland on the site poses a threat to the surviving sediments through root impact, and, although much of the area is an SSSI, potentially significant deposits extend outside the SSSI to the east, where they are vulnerable to impact from development. The key archaeological issue at the

site is the date of the Clactonian horizon. Other British Clactonian sites date to the early part of the Hoxnian interglacial, whereas the gravel containing the Clactonian deposit at Globe Pit is thought to date much later, to the following glacial–interglacial cycle. Thus archaeologically the site is problematic, and confirming, or re-attributing, its date has a major bearing on our understanding and interpretation of the Lower Palaeolithic archaeological record.

[Key references: Wymer 1957; Snelling 1964; Bridgland *et al.* 2003]

Table 9: Essex mineral extraction sites with Palaeolithic remains

ME site	*Site-name*	*Desk-top data*	*Site visit (Pal.)*
EX 207 EX 630	Stifford	✓	-
EX 466	Sockets Heath, Deneholes Roundabout	✓	-
EX 468	Dell Road, Grays	✓	-
EX 473	Whitehall Lodge, Grays	✓	-
EX 476	Globe Pit, Little Thurrock	✓	✓
EX 477	Grays, Thurrock	✓	-
EX 620	Moor Hall Farm, Rainham	✓	-
EX 628	Buckles Lane, South Ockendon	✓	-
EX 629	Moor Hall Farm, Rainham	✓	-
EX 647	Thames Board Mills Car Park	✓	-
EX 649	Lion Pit, Tramway Cutting	✓	✓
EX 653	Esso Pit A, Purfleet	✓	✓
EX 659	Starlands RDX, Esso Garage	✓	-
EX 662 EX 671	Lion Pit	-	✓
EX 670	Bluelands Pit, Purfleet	✓	✓
EX 675	Esso Pit B, Purfleet	✓	✓
EX 679	Greenlands Pit, Purfleet	✓	✓
EX 681	Botany Pit, Purfleet	✓	✓
EX 684	West Thurrock	✓	-
Total		18	8

2.2.4.2 Kent

The Kent part of the study area, on the south side of the Thames Estuary, was richer in Palaeolithic sites than the Essex part, possibly reflecting the increased quantity of archaeologically rich gravels of the Boyn Hill/Orsett Heath formation, as well as the larger number of extraction sites. In total 35 sites had Palaeolithic archaeological evidence recorded, and 21 sites were visited for the Palaeolithic survey (Table 10). Sixteen of the sites were isolated finds of handaxes or low quantities of debitage. The remainder include two of the most significant Palaeolithic sites in Britain — Barnfield Pit (KT 510, 870 & 911) and Bakers Hole (KT 542, 581 & 585), both of which have abundant archaeological evidence from different periods, undisturbed horizons, faunal remains and diverse and abundant palaeo-environmental evidence — and a number of other highly significant sites, one more — Wansunt Pit (KT 708 & 729) — with evidence of undisturbed Palaeolithic occupation horizons, and several — The Brent (KT 484), Eastern Quarry (KT 567), Hawley Road (KT

732 & 848) and Res 1, Stone (KT 855 & 874) — with diverse bio-environmental evidence.

One major new site came to light in the course of the survey, namely Eastern Quarry, Swanscombe (KT 541, 567, 583, 584, 915 & 916). Recent field evaluation (Wenban-Smith 2002) had identified that archaeologically rich deposits of the Boyn Hill/Orsett Heath formation were present in the unquarried deposits immediately adjacent to the northeast of the quarry. Concurrent work on the Stopes Palaeolithic Project (Wenban-Smith 2004) had established that substantial numbers of Palaeolithic handaxes were recovered both from within the central quarried area of the site, and from the smaller quarried area (KT 567) on its eastern side, originally known as Bevans Washpit. Finally, the site visit carried out as part of this survey identified potentially significant surviving Pleistocene deposits exposed by Channel Tunnel Rail Link works at the eastern margin of the site, adjacent to Southfleet Road. Subsequent, and ongoing, investigation of these deposits has identified that they contain an undisturbed landsurface, possibly with Clactonian occupation, as well as a deep sequence of sediments with excellent pollen preservation, making them potentially critical in correlating the key sites and deposits in the Swanscombe area with those in Essex and East Anglia — such as Clacton, Hoxne and Beeches Pit — which are already integrated into the detailed Hoxnian pollen sequence.

Table 10: Kent mineral extraction sites with Palaeolithic remains (continued on following page)

ME site	*Site-name*	*Desk-top data*	*Site visit (Pal.)*
KT 471	Bexley Hospital (Phase III)	✓	-
KT 480	Smith's Pit (Mitchell Close)	✓	✓
KT 484	The Brent	✓	-
KT 510 KT 911	Barnfield Pit, Swanscombe	✓	-
KT 541	Blue Circle Conveyor Belt, Eastern Quarry	✓	-
KT 542 KT 581	Baker's Hole, Ebbsfleet Valley (N)	-	✓
KT 552	Galley Hill Pit (NW) [Higgins Pit]	✓	✓
KT 554	Northfleet (1/4 mile west of church)	✓	-
KT 567	Bevan's Wash-pit, Eastern Quarry	✓	-
KT 568 KT 795	Craylands Lane Pit (East)	✓	✓
KT 570	Galley Hill Pit (SE)	-	✓
KT 574	Galley Hill Pit (SW)	✓	✓
KT 575	Botany Bay Pit, Galley Hill	✓	✓
KT 583 KT 584 KT 915 KT 916	Swanscombe Wood Clay Pit, Eastern Quarry	✓	-
KT 585	Baker's Hole, Ebbsfleet Valley (S)	✓	✓
KT 671	Dartford Golf Club, Pit B [Dartford Heath Brickyard]	-	✓

Table 10: Kent mineral extraction sites with Palaeolithic remains (continued from previous page)

KT 674 KT 815	East Hill, Romano-British Cemetery	✓	-
KT 688	St James Road, Dartford	✓	-
KT 692	Dartford Adult Education Centre	✓	✓
KT 700	Dartford Golf Club, Pit A [Dartford Heath Brickyard]	-	✓
KT 706	Heath Lane Retail Park	-	✓
KT 708	Wansunt Pit (E), Dartford Heath	✓	✓
KT 709	Brotherwood's Pit [Clubb's HO]	✓	✓
KT 711	King Edward Avenue	✓	-
KT 713	Dartford Golf Club, Pit C	-	✓
KT 723	Wood's Pit, Dartford Heath	-	✓
KT 725	Pearson's Pit [Heath Lane Open Space]	✓	✓
KT 727	Dartford Heath Park	-	✓
KT 729	Wansunt Pit (W)	✓	✓
KT 731	Bowman's Lodge, Dartford Heath	✓	✓
KT 732	Powdermill Lane, Hawley Road	✓	-
KT 733	Mill Pond, Dartford Mill	✓	-
KT 823	Ingress Abbey, Old Garden (Embleton's)	✓	-
KT 844	Darent Road Pit	✓	-
KT 848	Hawley Road, A2/A282 Improvement	✓	-
KT 855	Res 1, Stone, Dartford	✓	-
ME site	*Site-name*	*Desk-top data*	*Site visit (Pal.)*
KT 864	Darenth Wood, A2/A282 Improvement	✓	-
KT 870	Barnfield Pit (NW) [adj. Dierden's Pit]	✓	-
KT 871	Ingress Abbey, Old Garden (Embleton's)	✓	-
KT 874	Res 1, Stone, Dartford	✓	-
KT 890	Stonewood Brickyard	✓	-
KT 903	Globe Pit, Greenhithe	✓	✓
KT 966	Dartford Tunnel (South Portal?)	✓	-
Total		35	21

In summary, eight main sites, or groups of sites, were identified as of particular Palaeolithic significance in the Kent part of the survey area.

● Barnfield Pit, Swanscombe (KT 510, 870 & 911)

● Baker's Hole, Ebbsfleet Valley (KT 542, 581 & 585)

● Dartford Heath Gravel — Pearson's Pit (KT 725)

● Dartford Heath, superficial deposits — Wansunt Pit (KT 708 & 729), Bowman's Lodge (KT 731), Wood's Pit (KT 723), Dartford Heath Park (KT 727) and Dartford Golf Club (KT 671, 700 & 713)

● Eastern Quarry, Swanscombe (KT 541, 567, 583, 584, 915 & 916)

● Globe Pit, Greeenhithe (KT 903)

● Craylands Lane East (KT 568 & 795)

- Darent Valley terrace deposits — Smith's and Brotherwood's Pits, Wilmington, (KT 480 & 709) and Hawley Road (KT 732 & 848)

Barnfield Pit, Swanscombe (KT 510, 870 & 911)
This site was not specifically visited for this survey, since it had already been recently visited during the detailed survey by Wessex Archaeology (2004). The site is recognised as of international archaeological significance, as well as being designated an SSSI on Quaternary geological grounds. The main sequence of deposits (Table 11), which was present across most of the area, and which survives within the southern part and at the southeastern margin of the site, contains lithic and faunal remains incorporated in stratified fluvial sand and gravel units, accompanied by biological palaeo-environmental evidence (mammalian remains and molluscs). Undisturbed archaeological horizons preserving intact evidence of Lower Palaeolithic activity were present in one of the lower deposits — the Lower Loam. And one horizon within the middle phase of the Barnfield Pit sequence — the Upper Middle Gravel — has also produced an early human fossil skull (the Swanscombe Skull) making it one of only two sites in England with Lower or Middle Palaeolithic hominid skeletal evidence. Substantial bodies of sediment survive in the southern part of the site, and are protected as an SSSI.

At the northwestern margin of the site, Pleistocene deposits are preserved close to the location of the Ingress Vale Shell Bed, investigated at Dierden's Pit in the early 20th century. This problematic site produced abundant sharp condition ovate and cordate handaxes, quite different to those from Phase II of the main Barnfield Pit sequence. The site also produced abundant molluscan and mammalian remains, but detailed investigation of the mollusc and mammal bearing deposits (Smith & Dewey 1914) showed that they contained Clactonian material only, without any handaxes, and were equivalent to the Lower Loam from Barnfield Pit. Therefore the source and date of the unusual handaxe assemblage remain a mystery, and one that can only be solved by rediscovery of another part of the handaxe-bearing deposit.

The deep sequence at Swanscombe, presumed to date from the post-Anglian interglacial, provides a base-line against which to correlate other shorter sequences of deposits in the region. There is still further archaeological/Quaternary work that could usefully be done on the surviving deposits to study the archaeological and palaeo-environmental evidence at the site, to improve our understanding of hominid behaviour and the dating of the deposits. While deposits of Phases II and III of the sequence are widespread in the Swanscombe region, the lower deposits of Phase I (Lower Gravel and Lower Loam) are much more restricted, and particular attention should be paid to identifying where they are present, and restricting/mitigating impact upon them. Key conservation issues at the Swanscombe site are avoiding degradation of surviving sediments by leisure use, natural erosion and woodland growth.

[Key reference: Conway *et al.* 1996]

Table 11: Stratigraphic and archaeological summary of Barnfield Pit sequence, Swanscombe

Phase	*OI Stage*	*Stratigraphic unit*	*Height OD*	*Palaeolithic archaeology*
III	11–10/ 10/ 10–8?	Upper Gravel	*c.* 33–34m	Occasional ovate handaxes, often with twisted profiles and tranchet sharpening, debitage — "Acheulian"
		Upper Loam	*c.* 32–33m	
		Upper Sand	*c.* 29.5–32m	None known
II	11	Upper Middle Gravel	*c.* 28.5–32m	Pointed handaxes with thick partly trimmed butts (often large and well-made but also small and crude), cores, debitage and *ad hoc* flake-tools — "Acheulian" (Swanscombe Skull level)
		Lower Middle Gravel	*c.* 26.5–28.5m	
I	11	Lower Loam	*c.* 25–26.5m	Cores, debitage, *ad hoc* flake tools, and very occasional crude proto-handaxes — "Clactonian"
		Lower Gravel	*c.* 22–26.5m	

Baker's Hole, Ebbsfleet Valley (KT 542, 581 & 585)

The sequence of deposits down the western margin of the site mostly represents a continuation of that from Barnfield Pit, which is only *c.* 1.5km to the northwest. These have produced extensive quantities of archaeologically similar Lower Palaeolithic material. In the southwest corner of the site there is an isolated group of sediments that are probably broadly similar in age to those from Barnfield Pit, but whose correlation with the Barnfield Pit sequence is uncertain. These contain mammalian and well-preserved pollen evidence, as well as an undisturbed Palaeolithic landsurface, possibly containing evidence of Clactonian occupation. The central part of the site originally — before quarrying and later development — contained a major accumulation of sediment that post-dated the Barnfield Pit sequence, and therefore complements that from Barnfield Pit by documenting a different period of the Palaeolithic. These later deposits, now mostly quarried away but investigated in the first half of the 20th century, produced abundant Middle Palaeolithic Levalloisian material, from a range of sediments thought to date to between 250,000 and 100,000 years old. Abundant mammalian and molluscan remains were also recovered from a number of deposits. The presence of refitting artefacts in the surviving collections confirms that undisturbed landsurfaces were once part of the sequence, although whether any remnants of these now survive is doubtful.

Most of the Pleistocene sediments in the Ebbsfleet Valley were removed by quarrying between 1890 and 1970. A substantial proportion of those that survived quarrying have now been removed or buried by development in relation to the Channel Tunnel Rail Link and the Ebbsfleet International Station, although this impact was mitigated by Palaeolithic/Pleistocene archaeological investigations. These investigations confirmed how significant the site could have been if fully investigated before quarrying. Abundant biological evidence was present at a number of horizons, including mammalian (large and small), molluscan and ostracod remains. Fresh condition Levallois material was also recovered, although not from undisturbed horizons. The sequence of deposits was shown to be very complex and to vary over short distances, which makes interpretation of the stratigraphic provenance of the early Levalloisian collections even more problematic.

Despite the level of quarrying and development, important Pleistocene sediments survive as small remnants in several places, and continuing protection/management of these must become a priority, particularly in view of their future location within, or adjacent to, the car park of a major international railway station. Two of these key remnants are already protected as a Scheduled Ancient Monument (Kent 267a and b) and an SSSI. And finally, a third (Wenban-Smith 1995, Area E) is unprotected formally, but has been recognised as of value, and has been avoided in the course of the current CTRL development, although attention needs to be paid to its future protection. Besides these, the whole of the western side of the extracted area represents a cross-section through one of the classic sequences of deposits in Britain. The northern half of this section represents a continuation of the Barnfield Pit sequence, with, at some unknown point, the continuation of the Lower Gravel/Lower Loam channel. At some point along the section, again unrecorded, is the southern margin of the main (phase II and III) Boyn Hill/Orsett Heath formation. And finally, further to the south along the section are the newly discovered Pleistocene lake-fill and fluvial sediments that contain pollen evidence and an undisturbed Palaeolithic landsurface, which continue into the adjacent Eastern Quarry (cf. below).

Key research questions in the Ebbsfleet Valley are to improve understanding of the sequence and three-dimensional geometry of these Pleistocene sediments, and of the evolution of the Pleistocene landscape, and to improve understanding of the archaeological content of the surviving sediments, and of the behaviour associated with the Palaeolithic occupation at different periods. Conservation issues are to assure the continuing protection of the surviving remnants of sediment, in the face of continuing development of the area around them, and the likelihood of it becoming an increasingly busy urban area. As things stand, the important sediments of SAM 267b are becoming overgrown, and some of the most important sediments, comprising the miniscule remnants of the Temperate Bed, which are immediately beneath the topsoil, are in the process of being compromised by root damage and plant growth.

[Key reference: Wenban-Smith 1995]

Dartford Heath Gravel — Pearson's Pit (KT 725)
Pearsons Pit is of interest for several reasons. First, it is part of the problematic body of Dartford Heath Gravel, for which there is dispute over whether it contains one or two major gravel formations. Second, it contains a substantial lower body of gravels filling a channel sealed by an upper body of gravel and brickearth, and it has been suggested that the lower body may be an upstream continuation of the Lower Gravel/Lower Loam channel, although there are no records of recovery of similar Clactonian material from the lower gravel body. And third, contemporary reports refer to ovate handaxes being present in the upper gravel, in contrast with the predominance of pointed handaxes in the main Phase II gravel at Barnfield Pit, with which the upper

gravel is generally correlated. A substantial number of fresh condition cordate handaxes are known from the site, although their provenance is uncertain, and they may come from the brickearth over the gravel rather than the gravel itself, or even from the lower channel.

Key questions at the site concern establishing the stratigraphic sequence and documenting the archaeological content of different horizons, and correlating the sequence with other Dartford Heath Gravel sites and with the Barnfield Pit sequence. The site is currently in use as an Open Space leisure amenity, and although the site is entirely landfilled to the level of the original groundsurface, the original sediments are present around the site margins, and possibly survive in a strip 5–10m wide within the site perimeter, as well as under the surrounding road network. Consideration should be given to the possible archaeological impact of road repairs and services maintenance around the site perimeter, as well as of any development of the surrounding properties, and whether any mitigating recording is required.

[Key references: Shephard-Thorn 1971; Wymer 1968: 328, 330; Bridgland 1994: 189, 191]

Dartford Heath, superficial deposits — Wansunt Pit (KT 708 & 729), Bowman's Lodge (KT 731), Wood's Pit (KT 723), Dartford Heath Park (KT 727) and Dartford Golf Club (KT 671, 700 & 713)
This group of Dartford Heath sites have been distinguished from Pearsons Pit on the basis that their archaeological content and potential is known to relate to fine-grained deposits that overlie the Dartford Heath Gravel, rather than the gravel itself — although there is a possibility that the fresh condition material from Pearsons Pit also comes from fine-grained deposits overlying the upper gravel. At Wansunt Pit, numerous small ovate and cordate handaxes, as well as refitting handaxe-manufacturing debitage, have been recovered from several horizons throughout a fine-grained deposit labelled the Wansunt Loam, which overlies the gravel and reaches several metres thickness in places. The origin of this deposit is uncertain, and it is generally regarded as a fluvial deposit equivalent to the Barnfield Pit Upper Loam, although a partly colluvial origin cannot be ruled out. Key surviving remnants of the Wansunt Loam in the eastern extension of the Wansunt Pit (KT 708) are protected as an SSSI, although they are restricted in extent, highly exposed and vulnerably to degradation by natural processes, human leisure activity, as well as regular section-cleaning as part of the maintenance at the site of a representative section.

The Wansunt Loam is known to wedge out within the eastern part of Wansunt Pit, and does not continue directly into the nearby Bowman's Lodge pit, so even if the fine-grained deposits at each site are equivalent, they are not part of the same body. The archaeological material at Bowman's Lodge is broadly similar to that from Wansunt Pit, although with an increased element of cores and flakes, possibly reflecting less selective collecting rather than a different archaeological industry. In contrast, however, it comes from a specific horizon on the surface of the Dartford Heath Gravel, and at the base of the overlying fine-grained brickearth. Although the Bowman's Lodge Pit is now entirely landfilled back to its original ground level, substantial bodies of original sediment are preserved around its perimeter, and investigation of these has the potential to address a number of outstanding issues. It remains to carry out formal archaeological excavation and section recording at the site, which can identify the full sequence of deposits, the horizons where archaeological material is present, and the full range of artefacts and micro-debitage present. This could then help in interpretation of the mode of formation of the sequence, and its correlation with the Wansunt Loam, the Barnfield Pit sequence and the wider chrono-stratigraphic framework.

No archaeological material is known from the remaining group of Dartford Heath pits — Wood's Pit, Dartford Heath Park and the three pits now contained within the northern part of Dartford Golf Club. Recent geological mapping (British Geological Survey 1998) has identified the presence at, or adjacent to, all these pits of a distinctive fine-grained body of sediment labelled "Dartford Silt", overlying the Dartford Heath Gravel. The Dartford Silt may be equivalent in nature and origin to the Wansunt Loam and the fine-grained brickearth of Bowman's Lodge, and consequently may contain similar archaeological material, or may contain biological evidence (which is lacking at Bowman's Lodge and Wansunt Pit) that helps date the deposit and explain its mode of formation.

[Key references: Tester 1951 & 1975; Wymer 1968: 326–329; Bridgland 1994: 185–193; British Geological Survey 1998]

Eastern Quarry, Swanscombe (KT 541, 567, 583, 584, 915 & 916)
A substantial number of handaxes were recovered in the 19th century from the high ground, now quarried away, in the centre of the site. The stratigraphic context of these remains a mystery, since they could not, at the height and position they were found, have originated from any manifestation of the Boyn Hill/Orsett Heath formation. Most likely they were residual finds, from a deposit capping the hilltop. Pleistocene sediments from the Boyn Hill/Orsett Heath formation, equivalent to Phases II and III of the Barnfield Pit sequence, are present immediately to the northeast of the main extraction area, in the vicinity of the small extraction area (KT 541) representing the route of the old conveyor belt from Eastern Quarry to the Blue circle Northfleet Cement Works. These are of interest as representing the most southerly extent known of deposits of the Boyn Hill/Orsett Heath formation, and they must be close to the valley-side margin of the main fluvial sediments of Phase II, of which they are a part. The deposits are rich in handaxes, although the presence, range and quality of biological evidence remain to be established.

At the eastern end of the site, immediately to the south of the extraction area KT 567, and adjacent to Southfleet Road, a sequence of lake-fill deposits with excellent pollen preservation has recently been identified. These include a palaeo-landsurface with possible Clactonian occupation, and are capped, and truncated, by a body of gravels that contain evidence of handaxe manufacture. A well-made white-patinated ovate was also found at the site, probably originating from the brickearth that caps the gravel deposit. The extent, date and stratigraphic correlation of these deposits is at present uncertain, although under investigation in conjunction with the impact on these sediments due to construction of road infrastructure associated with the CTRL and the Ebbsfleet development area.

Key questions over the Boyn Hill/Orsett Heath deposits in the northeastern quadrant of Eastern quarry concern their distribution and maximum southerly extent, the possible presence within them of undisturbed archaeological occupation horizons associated with their valley-side margin and the presence of biological evidence. Key questions over the newly discovered sediments to the south of KT 567 concern the nature of the full sequence, the base of which has to date not been reached, their lateral extent and variability, the nature of the archaeological occupation and content at different horizons, and their date and correlation, both with nearby manifestations of the Boyn Hill/Orsett Heath formation, and with key archaeological sites further afield, such as Clacton-on-Sea, Hoxne and Beeches Pit, where archaeological horizons are tightly dated in relation to the Hoxnian pollen sequence.

Eastern Quarry is currently earmarked for major mixed urban and housing development, and priority should be given to ensuring that appropriate archaeological mitigation takes place in conjunction with any impact upon these important Palaeolithic remains.

[Key references: Wenban-Smith 2002 & 2004]

Globe Pit, Greeenhithe (KT 903)
This site was investigated in the early 20th century, and produced large numbers of fresh condition cordate handaxes, a sizeable collection of which are preserved in the Stopes collection in Cardiff (Wenban-Smith 2004). Although the quarry is within the mapped area of the Boyn Hill/Orsett Heath formation, the recorded sequence is a disturbed combination of brickearth and gravel, and does not appear to correlate directly with the Barnfield Pit sequence. The provenance of the handaxes, and their stratigraphic relation with better-provenanced assemblages in the region remains, therefore, problematic. Typologically the closest parallels are with the Dierden's Pit handaxe collection (*cf*. Barnfield Pit, above), which also have uncertain provenance, and both sites may represent a post-Boyn Hill phase of occupation whose remains are, in certain places, contained within sediments that overlie, or are in places interworked with, the eroded surface of the Boyn Hill/Orsett Heath formation.

The site is now entirely landfilled, forming a central turfed mound reaching well above the original landsurface. The original sediment sequence presumably is still present immediately to the south and east of the extracted area, although these areas are covered by domestic housing and gardens. Key issues at the site concern the more detailed recording of the Pleistocene sequence, the identification of the horizon from which the main handaxe assemblages have come, the identification of the archaeological content of whichever horizons are present, investigation for the presence of bio-environmental evidence, and the dating and correlation of the sequence in relation to the local Barnfield Pit framework.

[Key reference: Wymer 1968: 332–333]

Craylands Lane East (KT 568 & 795)
This site occurs immediately to the northeast of Barnfield Pit, on the other side of Craylands Lane, and is generally thought to contain a continuation of the same deposits. However, the only recorded section (Smith & Dewey 1914) is not immediately recognisable as showing an equivalent sequence, and the recorded archaeological content is entirely different. An assemblage consisting entirely of ovate and cordate handaxes, many with twisted profiles, was recovered in the early 20th century from one horizon within the gravel sequence (in contrast to the predominantly pointed material from the Middle Gravels at the same height in Barnfield Pit), and a deposit 1m thick of pale, contorted clayey gravel capping the sequence produced an abundant assemblage of Levallois material. More recently, archaeological investigations on the northwest side of the quarried area, carried out in conjunction with the construction of the housing development that now fills the site, identified the presence of a body of fluvial sands and gravels at a much lower level, between 23 and 35m OD, that extend under Craylands Square. A fresh condition flint artefact was found in these gravels, but this was insufficient to characterise their archaeological content. There are clearly unaddressed problems concerning the extent, sequence and archaeological content of the deposits at Craylands Lane East, and their correlation with the immediately adjacent Barnfield Pit sequence.

[Key reference: Wymer 1968: 346–351; Wenban-Smith 1999]

Darent Valley terrace deposits — Smith's and Brotherwood's Pits, Wilmington, (KT 480 & 709) and Hawley Road (KT 732 & 848)
Large numbers of handaxes have been found from the Darent terrace gravels at Smith's and Brotherwood's Pits, which were immediately adjacent to each other and exploiting the same gravel deposit. The handaxes are mostly pointed, and are in fresh condition. The terrace gravel at this point is thought to be equivalent in age to the Middle Thames Lynch Hill formation, and extends south on the western flank of the Darent Valley as a well-defined strip of terrace deposits for several km. Further down the valley side in the same area is a lower terrace deposit, that has produced biological evidence at the two locations along Hawley Road (KT 732 & 848), as well as sparse artefactual evidence. This terrace unit is mapped as equivalent to the Taplow terrace, and may also be equivalent to the deposits that produced the undisturbed Levallois flaking site further downstream, in the Crayford brickearths at the mouth of the Darent, just outside the study area.

These sites emphasise the potential of the post-Boyn Hill/Orsett Heath terrace sequences in Thames tributary valleys, such as the Darent and the Cray, to provide information on the Palaeolithic occupation of the region *after* the period represented by the classic Barnfield Pit sequence. Despite being younger, we actually have fewer deposits, and know less about their archaeological content for periods after that represented at Barnfield Pit, where the extensive deposits have been thoroughly researched over a long period. A key issue in the study region is to recognise that Thames tributary valleys, and even minor now-dry tributaries of these tributaries, contain terrace sequences of Pleistocene deposits, and that they have as much potential as better-known deposits such as the Boyn Hill/Orsett Heath deposits at Swanscombe to contain Palaeolithic remains. In fact such deposits, due to their smaller scale, are likely to contain less transported and more tightly chronologically controlled archaeological remains than those of a major river such as the main Thames. Therefore they may be of greater value in documenting material cultural change in the region through the Palaeolithic.

[Key references: Wymer 1968: 331; Oxford Archaeology 2002; Oxford Archaeology 2003a, b]

2.3 ARCHAEOLOGY

2.3.1 Introduction

An Archaeological Desk Based Assessment (DBA) was carried out as an integral part of the survey of mineral extraction sites around the Thames Estuary. This assessment contributed to a number of the tasks outlined in the Project Design (as outlined in section 2.3.3 below).

Although the survey emphasised the geological, Palaeolithic and industrial aspects of the study it was clear that the Thames Estuary area is an important for all periods of archaeology. The nature of this resource has been outlined most recently in the 'An Archaeological Research Framework for the Greater Thames Estuary' (Williams and Brown eds, 1999) and as such is only briefly summarised here.

Extensive quarrying in the study area in the 19th and 20th centuries led to the identification of a wide range of archaeological sites, particularly of the prehistoric period. These include important collections of Palaeolithic material, Bronze Age and Neolithic landscapes, and, along the Thames-side marshes, valuable environmental material. Later periods are also well represented, these include Late Iron Age and Roman field systems, settlements and associated industry (for example salt working). Saxon activity is also represented, although the major site at Mucking lies outside the core 3D study area.

It should be noted that this desk-based study excludes geology, Palaeolithic, and Industrial archaeology (as specified in the Project Design Task 5) as these are being addressed by appropriate specialists.

This assessment was deliberately designed to result in a series of GIS layers (ArcView shapefiles) in order that it could be amended and expanded on in any future phases of work. The GIS layers therefore should be considered to be the results of the work, a summary of some of the data obtained is presented below. Details of the data contained in the layers can be found in Appendix 4. Illustrative examples can be found on figures 2 to 4 and 22 to 25.

2.3.2 Aims and objectives

The DBA was to contribute to the aims and research project as a whole but had particular relevance to the following aims (as outlined in the Project Design):

A2 Mapping areas where quarrying has destroyed archaeological deposits

A6 Assessing the archaeological potential of current and potential mineral extraction sites and identifying future threats to the archaeological or geological deposits.

2.3.3 Method

In order to further this survey the first task was to establish the nature of the minerals being extracted from the extraction sites identified by the BGS. The BGS provided an 'artificial ground' layer for use in ArcView. This layer included former extraction sites, major areas of made ground (largely reclaimed marsh), road and rail cuttings and embankments and sea banks. This data was queried spatially by the respective county SMR officers in order to identify which of the polygons in this layer coincided with, or were within a reasonable distance of, eligible deposits. It was clear at this stage that a) there were an extremely large number of sites (c.1600) and b) that a number of the sites on the layer were not 'extraction' sites and needed to be excluded.

Each of the polygons identified was therefore subject to a map regression exercise. This also formed part of the DBA. Each edition of the Ordnance Survey 6" map (or equivalent scale) was examined and the results added as attributes to an ArcView shapefile (EX_MR and KN_MR; see Appendix 4 for attributes). Although problems were noted with the extents of excavation shown by the BGS in some case it was not feasible given the numbers of sites and the project timescale to re-digitise the polygons. This stage of work also examined modern maps and vertical aerial photographs. This exercise concluded by attempting to identify the type of activity represented.

This initial rapid assessment enabled a refined list of polygons to be produced, which was provided to the appropriate specialists as Excel spreadsheets, Access databases, shapefiles and paper copies.

Further assessment was carried out to place the polygons in their archaeological context. This was applied to **<u>EVERY</u>** polygon identified as eligible. This examined:

Local HERs (data provided digitally by relevant SMR officers)
Readily available archaeological material (i.e. published/development control reports)
Aerial Photographs (ECC NMP and 2000 verticals; KCC)
General archaeological studies of areas, including site visits

The potential of the sites was then assessed in very broad terms. It should be noted that the assessment of potential necessarily refers to the areas in the immediate vicinity of the sites which have not been subject to mineral extraction.

Yes: *Within an already identified area of archaeological potential, close to a SAM, proximity to areas of potential (e.g. The Mar Dyke)*
Possible: *Reasonable number of HER references in the vicinity suggesting at least the possibility that there may be archaeological material in the immediate vicinity of the area*
Low: *No HER references within 200m*

Each polygon has the relevant DBA data attached, along with the assessment of potential (EX-DBAA and KN_DBAA; see Appendix 2 for attribute data)

2.3.4 Results

The numbers of eligible sites was far higher than anticipated. After map regression this can be summarised as follows:

Kent: 242 polygons
Essex: 105 polygons

It should be noted that as BGS polygons were used as the basis for the project one quarry can be made up of numerous polygons depending on map sheet, and type (*e.g.* open ground and infilled ground in each quarry which would be digitised separately).

These were made up of a number of different artificial ground types:

Type of Ground Identified by the BGS	**Number of polygons by type; Essex**	**Number of polygons by type; Kent**
Worked Ground	37	89
Infilled Ground	31	92
Made Ground	27	53
Landscaped Ground	0	5
No Data	7	3

Spatially the made ground is typically, although not exclusively, along either the Thames-side marshes, river sides, or road/rail embankments. Infilled ground is widely distributed although the degree of infill is unknown.

The map regression identified various types of extraction which had taken place in the polygons:

Type of activity Identified by map regression	Number of polygons by type; Essex	Number of polygons by type; Kent
Pit *As labelled on historic mapping*	47	160
Quarry *As labelled on historic mapping*	16	3
Brickfield *As labelled on historic mapping*	1	1
Other *Unidentified extraction area*	4	24
Denehole *As labelled on mapping*	0	4
Works *Industrial works*	0	3
Bank *embankment assoc with extraction*	1	2
Unknown *No extraction area shown on sources examined as part of map regression and therefore type is unknown*	32	46

The map regression shapefile contains information with regard to which edition of the Ordnance Survey the extraction areas are shown on. Through querying this data it will be possible to get a general pattern of use and disuse of the various extraction sites within the study area.

Ordnance Survey Edition	Number of polygons by edition; Essex	Number of polygons by edition; Kent
1st Edition (1870s/80s)	18	67
2nd Edition (1890s)	26	107
3rd Edition	30	129
4th Edition	> 30	146

2.3.5 Archaeological potential

The archaeological potential of each polygon has been assessed using a variety of criteria. An outline of the sources consulted in the course of this study can be found in the method statement above. As the initial data was digital in nature it was possible to combine this with various other datasets which were available in order to assess potential. It was for example possible to use spatial queries to identify HER records which lay within a certain distance of any given polygon. The same could be used in relation to the sites of SAMs.

In addition to the readily available datasets a further shapefile was created containing information from grey literature and other sources. Each polygon could therefore be queried against this data in addition to that in the HER.

In terms of archaeological potential the level of disturbance within the extraction areas themselves is likely to have either severely damaged or destroyed any archaeological remains. The assessment of potential therefore relates to the immediate vicinity of the extraction area.

The assessment of potential carried out as part of this study is necessarily broad brush in nature given the large number of sites involved, and the limitations of the sources. It should not be taken as a stand alone final result but rather a general indication. This is particularly the case with those polygons assessed at this stage as having low potential. This criteria reflects to some degree an absence of archaeological information rather than an absence of archaeology.

As the data outlined above shows a large number of the polygons were subject to mineral extraction in the late 19th and early 20th centuries. Although valuable artefact collections were made and some note made of features of interest the numbers of modern interventions has been limited. The most extensive have been work carried out in the last 20 years associated with road and rail schemes.

The following criteria were used to assess potential:

Yes: *Within an already identified area of archaeological potential, close to a SAM, proximity to areas of potential (e.g. The Mar Dyke)*
Possible: *Reasonable number of HER references in the vicinity suggesting at least the possibility that there may be archaeological material in the immediate vicinity of the area*
Low: *No HER references within 200m*

The results in terms of potential can be summarised as follows:

Potential	Number of polygons; Essex	Number of polygons; Kent
Yes	23	76
Possible	61	36
Low	18	131

2.3.6 Areas where quarrying has destroyed archaeological deposits

In order to identify areas where mineral extraction has led to the destruction of archaeological deposits a spatial query was carried out to identify the polygons which contained an HER record or information relating to archaeological material not yet noted on the relative HERs. Where the two locations coincided it was thought reasonable to assume that extraction had destroyed the archaeological context from which this material had derived.

The results of this can be summarised as follows:

	Essex	Kent
Total number of polygons	105	242
Number where archaeological deposits have been destroyed	31	69

2.3.7 Historic Environment Record enhancement

The DBA has been able to contribute to the enhancement of the HERs for the relevant counties. The map regression has identified a number of features which should be included on the HER. These are largely post-medieval and modern in date.

In Kent map regression identified five deneholes, and a group of tumuli on Dartford Heath, along with various post medieval and/or industrial sites.

The DBA used the HER as the main source of data and as such there are no new records to be added other than updates from ongoing work such as that associated with the CTRL. In examining the records however some points which needed either correction or clarification were noted.

Data relating to the HERs was entered in a field for both the map regression and DBA shapefiles. These have been issued to the relevant SMR officers.

	Essex	Kent
SMR Updates identified during map regression	11	30
SMR Updates identified during DBA	9	4

2.3.8 Discussion

Although some alterations had to be made to the methodology of the DBA the aims of the study have been achieved. The primary aim, of assessing archaeological potential, has been addressed although further work would be advantageous in order to build on this basic assessment.

The use of the GIS methodology also has advantages. Although the layers used have been designed to address the aims and objectives of this project they can be used independently. All the statistical data outlined in the above sections was obtained by querying either the attributes of the data or spatial queries, or indeed a combination of both. The raw data contained in the original files has a spatial dimension.

2.4 INDUSTRIAL

2.4.1 Introduction

This report details the results of an extensive survey undertaken to identify, record and assess Industrial heritage assets, within former mineral extraction or associated sites, which at present, due to development initiatives such as the Thames Gateway, face an uncertain future. The importance of the Thames Estuary, particularly the growth and decline of those industries exploiting the estuary's communication and natural aggregate resource, is well acknowledged. The survey targeted the highly industrialised landscape of the Thames Estuary and particularly those areas comprising Thurrock, Swanscombe and Northfleet, which saw huge industrial growth, founded upon innovative and important developments within cement production, from the early 19th century onwards. Quarry sites supplying gravel, sand and chalk to industry, principally cement and whiting works, were once widespread within the survey area, and although the built heritage has seen significant levels of loss, many of the workings are still visible within the modern landscape.

2.4.2 Background

The development of the cement industry, particularly that of Portland Cement, initially during the 1820s by James Frost at his Swanscombe works and a truer artificial 'wet mill' cement patented by 1843 William Aspdin at Northfleet, led to a marked increase in the extraction of chalk, clay and aggregate and the foundation of the Thameside industry along the south shore of the river. By the 1870s the Portland cement industry was established in Essex with works at Purfleet and Grays (Brown, 1916, Davies, 1943). Developments in manufacturing technology, lower cost and a wider adoption of the product led to a boom in the industry during the 1870-80s and accordingly greater levels of extraction. A depression in the building industry during the early 1890s, led to a period of consolidation, although the slump was short lived and by the mid-late 1890s the industry expanded once more with new build or the enlargement of existing complexes within the industries heartland along the Thames and Medway. Despite this revival, the turn of the century saw a gradual decline and in attempt to stabilise the industry, increased levels of consolidation, such as the formation of the Associated Portland Cement Manufactures (APCM) and ultimately the closure of less profitable works. European imports placed further pressures on the British markets, with a period of decline, closure and contraction further exacerbated by the Great War (Eve, 1999). The interwar and post war periods saw more site closure and concentration of assets, to a point were the majority of the modern works are operated by a small number of dominant producers.

2.4.3 Aims and methodology

The aim of this survey is to provide a basic assessment of the surviving resource, to identify form, location, extent, potential and quality of any remains. Furthermore, by using comparative assessment, the relative significance of each site, by form and regional standing will be established, as will the priorities for future survey and/or management. Each site, identified through BGS survey data, MPP survey material and a local desk-based assessment were visited during a period of extensive surveys covering the Purfleet-Thurrock-Grays to Dartford-Swanscombe-Northfleet areas of Essex and Kent. An individual site record was created for each site and the information gathered during the extensive survey, comprising site/architectural descriptions, supported by geographic location and a photographic record of any surviving resource, was collated and interrogated to provide recommendations on comparative significance and future management as outlined above. Ultimately the information on each site will be added to the relevant Sites and Monuments Record in the form of a conventional data entry and as an Industrial layer on a GIS (arcview) application.

2.4.4 Essex

The survey of the Essex Industrial sites targets a series of former extraction sites from Purfleet in the west to Grays and South Ockenden in the east and north respectively. In total 18 separate sites were visited, ranging from small quarries (EX 576 or 453) through to huge former Industrial sites such as the former Tunnel Cement Works (EX 684). Of the 18 sites, six already have an Industrial entry on the Essex Sites and Monuments Record, while one of the six (EX 681) includes four (non-industrial) grade II listed buildings, of which, three are semi-derelict and currently designated ‘at risk’ (Garwood, 2003).

Of the 18 sites, 10 sites (56%) have been extensively redeveloped or cleared to the extent that no remains survive, or have a very low potential for sub-surface archaeological survival. These sites comprise EX659, 670, 680, 453, 474, 473, 465, 205, 555 and 576.

From the remaining eight sites, five (27%) including the former Tunnel Cement Works EX 684, the Thames Cement Works (EX 683), Grays Quarry EX475, Tank Lane Quarry EX 681 and the Globe Cement, Brick, Whiting and Chalk works have undergone similar levels of systematic clearance and redevelopment, but have retained industrial features or have a higher potential for surviving sub-surface technological and/or structural evidence. However, typically these remains are peripheral structures or cuttings that due to subsequent modernisation or reuse, are of low technological importance and accordingly of little significance.

Two, former tramway cuttings/routes, linking the quarry to the Harrison wharves on the foreshore, can still be recognised, to the north of London Road, at (EX 681). A former Office/administration building attached to the Globe works (EX 476) remains along Whitehall Lane while a tunnel (now blocked) passing under Hoggs Lane and a tramway cutting, used to transport lime, burnt on site, to the riverside, survive within quarry (EX 475). Both the Former Thames Works (EX 683) and the Tunnel Works (EX 684) have been extensively demolished leaving no buildings or structures. While the Tunnel Works site has been redeveloped and now lies below the modern Tunnel Estate to the west of Lakeside Retail Park, the site of the Thames Works (EX 683) at present, is predominantly unbuilt, although the site is under threat by a large residential development immediately to the north and east. These two sites both retain potential for sub-surface archaeological remains and a chance to study, through intervention, the function and technologies of a large 19th cement works.

Three sites (16%) of the sample retain some form of structure or combination of features associated with a former industrial use. The former Grays Chalk Quarry (EX 477) has undergone considerable redevelopment with large residential schemes built within its boundaries to the north and south and a large chemical plant to the west, reusing the main quarry tramway for vehicular access. The residential development has significantly reduced the potential for future research, however, the unbuilt north-eastern quarry presently is used as a nature reserve and is untouched by recent redevelopment. Despite the density of the undergrowth, a limited inspection uncovered the remains of a ruined tram shed, depicted on the second edition OS map (1897) and several lengths of tram track. Although once more the remains are ancillary, the reserve presents possibly the best potential for surviving structures and technologies, and should be targeted for a more systematic survey.

Quarry (EX 649) is a large linear cut formerly supplying the Lion Cement Works to the south. The northern ‘head’ end is water filled, however the deep tramway cutting, to the south, survives in a well preserved state. At the London Road junction is a contemporary road bridge while 40m north and on the eastern side of the cutting is a section of a solid brick and flint revetment. The eastern bank was strengthened at this point as it was the junction of two tramways, with a higher tramway cut into the bank on the eastern side only. The upper tramway originates from a later (interwar) working face to the east of the older working. Retaining original form and character this cutting survives as one of the better examples of tramway encountered during the survey and as such merits a more comprehensive survey.

The remnants, comprising 3 large concrete silos and 8 smaller silos, of the former Metropolitan Works (EHCR 15540) to the east of Stonehouse Lane, West Thurrock, were recorded during an MPP site assessment (Gould, 1996). All have since been demolished (c.1998) and the site re-landscaped to the extent that the former land surface now lies below c. 3-4 metres of made ground. The only surviving evidence of the works are tunnels which pass below Stonehouse Lane to the quarry to the west. These have been reused for vehicular access or have been blocked. Immediately to the east is the modern cement works of La Farge established at Thurrock in 1923. The northern and western parts of the complex are clearly modern works, but the south-eastern buildings, comprising a single-storey range and a tall iron clad steel and shuttered concrete furnace house, date from the 1930s. Within an industry which has been obliterated by consolidation and modernisation, these works retain the most extensive and possibly the only pre WWII cement works buildings in Essex. As such they are at least of regional importance and should benefit from an internal survey to establish levels of technological survival.

2.4.5 KENT

The Kent industrial survey targeted 21 former extraction/cement work sites in Northern Kent from Dartford in the west through to Swanscombe and Northfleet in the east . In total 18 separate sites visits (three sites comprising two components) were visited, many of which, particularly those associated with cement industry works, have already been recorded as part of the Kent Sites and Monuments Record Enhancement Project on the Kent Cement Industry (Eve, 1999). One site, Ingress Abbey (KN871/961), also includes 12 grade II listed buildings/structures/features (non-industrial) within its grounds.

Of the 18 sites visited, 9 sites (50%) have been extensively redeveloped or relandscaped to the extent that no remains of any significance survive, or that they present a very low potential for sub-surface archaeological survival and therefore a low industrial value. These sites comprise KN 729/708, 714, 731, 871/961, 554, 832, 542/581, 585 and 570.

From the remaining nine sites, five (27%), including J.B. Whites Swanscombe Works (KN552), Dartford Cement Works (KN701), quarry supplying The London Portland Cement Works (KN 582) and quarries at Craylands Lane (KN 574) and Bevans Wash (KN 567), have been subjected to extensive redevelopment, but still retain industrial features or a higher potential for sub-surface technological and/or structural remains.

J.B. Whites' Swanscombe works (KN552) along with Aspdins works at Northfleet, was one of a small band of pioneering companies responsible for the development of Portland cement. The main cement works was situated to the north of London Road and east of Manor Way (KN552). By 1897 the site expanded into Craylands pit (KN 574) to the south and by 1910 extended north of Manor Way. The majority of the cement works and adjacent whiting works were demolished by Blue Circle when the site was closed in 1990. The Swanscombe works were one of the most innovative and important cement production sites within the Thames Estuary, and although predominantly demolished, the original and peripheral sites may still retain important structural and technological evidence relating to pioneering developments within cement production. An assessment such potential and an internal inspection of two interwar buildings on site should be undertaken prior to any future development.

The Dartford Cement Works (KN701), in common with the Swanscombe works, has potential for below ground survival although on a much smaller scale. An early 20th century tramway cutting integrating the quarry at Bevans Wash (KN 567) to a much larger extraction site at Swanscombe Park, survives intact possibly due to its re-use as a public footpath. A substantial late 19th century tunnel linking quarry (KN 582) to the former London Portland Cement Works site, at some distance to the north, still remains as does a second later tunnel constructed between1920-30, to the west. The southern part of the site is used as a reservoir while CTRL works have impacted upon the majority of the site.

Four sites (22%) retain a more extensive survival of structural, earthwork or combination of features associated with a former industrial use. The Craylands Gorge was created following the backfilling of Barnfield Pit during the 1950s-60s. The gorge remained open as a conduit linking quarries, through tramways and a series of tunnels, to the Swanscombe Cement works to the north. The gorge retains a number of features associated with its industrial past including tunnels, the tramway bed, dewatering pipes and a footpath/bridge traversing the gorge. Although individually these remains present a limited heritage value, they are important in that as a group together they provide a flavour of the areas industrial past, which has already and still is facing a high rate of attrition.

The Northfleet Paper Mills were established on present Kent Kraft Estate during the later 19th century and rebuilt during the 1930s as the New Northfleet Paper mills. The sites continued industrial use has resulted in the demolition of the majority of the older industrial buildings. However, a factory unit belonging to the 1930s rebuilding remains intact and in use and a small gatehouse/ancillary building, predating the factory lies toward the eastern boundary. Along the northern boundary lie two derelict warehouses built at the turn of the last century as part of the Thames Tar Distillery. Both are fire-damaged, roofless and in a poor condition. Future redevelopment pressures, particularly the wider impact of the CTRL may see the future loss, or increased pressure upon all these buildings.

Established at the Grove Road site, Northfleet by mid19th century Aspdins Portland Cement Works (KN 558) was famed for the operation of nine bottle kilns producing a product named nine-kiln cement. The works continued until the earlier 20th century and was incorporated into the modern cement works (now Blue Circle) to the east. By the 1930s the former works to the north were reduced significantly and the original site, to the east of Grove Road cleared of it older structures, apart from one of the nine bottle kilns (TQ61750 74890), which has since been scheduled and the truncated remains of another kiln. The core of a small late 19th century ancillary ?cement store survives within the northern site, although it urgently requires structural works. Although the building and truncated kiln present a limited heritage value, together with the scheduled kiln they still represent all that is known to survive of one of the most significant cement works sites on a regional and national level. The potential for survival of important below ground technologies and structures, specifically those associated with the other kilns, further augment the importance of this site for future research.

The largest of three sand and gravel quarries situated within Dartford Heath, designated a Site of Nature Conservation Interest (SNCI), quarry (KN727) retained no evidence of structures or related technologies. However, a remarkable series of regular linear banks, locally known as ‘Glory Bumps’ covered the quarry floor. Appearing on the second edition OS maps much as they do today, they comprise discarded capping material removed in strips to gain access to higher quality Boyn Hill gravels below. When the gravel was exhausted the quarry was simply abandoned. It is possible that the sites remoteness from Dartford urban has been a major factor influencing the survival of these 19th century earthworks, of which isolated examples are unusual, but what appears to be the entire workings, is very rare. No other quarries were encountered retaining such features, and it is predicted that few if any sites within or beyond the scope of this initial survey retain the extent or quality of these remains. In a local and regional context these earthworks are unparalleled and as such can be assessed as holding regional if not national importance, worthy of further survey, study and statutory protection.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 GEOLOGY

3.1.1 Sites of high potential or in need of protection

As a result of the survey, the following are identified as sites with particularly high potential for further investigation of their geology or in need of immediate protection to ensure their preservation.

<u>3.1.1.1 Essex</u>

ES 653 Esso Pit
The Esso Pit SSSI lies within a warehouse complex that is being developed at the moment. Site markings suggest that the central area of the pit (outside the SSSI boundary) might be developed in some way also. Access to this area will involve crossing, possibly removing, ground that will be rich in artefacts. This access point is probably outside the SSSI. The creation of this crossing point is not necessarily opposed, but a controlled excavation or, at a minimum, a watching brief should be in place. The sedimentology revealed will help reconstruct the physical palaeoenvironment of the site.

ES 681 Botany Pit
This site has yielded an unusually high number of Levallois artefacts. The east face of Botany Pit is still extant, though landscaped. It lies close to a property boundary and is not likely to be in any immediate danger of damage. The face has the potential to provide a cross-section from a high point above the Lynch Hill Terrace Gravels, through much of the terrace. Thus the face can provide a chance to conduct an unusually full palaeoenvironmental reconstruction through the terrace, as well as providing a full context for the archaeology.

Greenlands
This site has reasonably good exposures immediately east of the Armor Road emergency exit and matters are in hand for a limited degree of enhancement of the exposure. The face west of the emergency exit is partly subject to landslipping and, within the QED warehouse development, has been landscaped without leaving representative exposures as had been agreed as part of the development. Action is needed (a) to further improve and conserve the eastern exposures, (b) to ensure the landslipping and any remedial action do not damage the exposures and (c) to make good the lack of representative exposures in the QED complex.

Bluelands
The future of this site is not known. All four faces expose potentially important sediments. The north and east faces surmount high Chalk faces above deep water. Currently access to them is impossible. The south face is particularly important as it is known to show the former Chalk river cliff and has sedimentology important deposits containing a range of fossil material and two artefact industries. However, this face again is very steep and is covered by thick vegetation including mature trees, making access almost impossible.

The west face is reasonable accessible and has been investigated by Palmer (1975), Hollin (1977) and Lonsdale (1978). Any future development of the pit for housing, for commercial purposes, recreation or biological conservation will need to pay due heed to the very important geology and archaeology present.

Globe Pit
The poor condition of the Globe Pit SSSI makes the finding of a replacement site a matter of importance. The Grays Brickearth (Ilford Silt) was worked at various sites to the west (EX 473, 474, 476) and they are being investigated at the moment. Further Silt is mapped to the east in Rookery Vale and may be present in a spur of high ground immediately south of EX459.

Purfleet Road, Aveley
This is part of, or closely adjacent to, the Aveley SSSI. Its boundaries are not yet fixed. It lies on the north-east side of the A13 road cutting immediately south-east of the Purfleet Road bridge (TQ 550799). Investigations during creation of the cutting exposed a varied varied sedimentological sequence randing from main channel gravels to river side mudflats yielding. vertebrates, beetles, plant macros and pollen. On the south side of the road a limited number of flakes were recovered from an upper gravel. This site is not yet recorded for its archaeological interest.

Lion Pit Tramway cutting
The west side of the cutting is subject to landslipping and has been undermining gardens and garage access, so there are no proposals to investigate the face furtherm beyond keeping a watching brief when remedial work is carried out.

The east side of the cutting shows a remarkable sedimentological sequence of approximately 300 m from a steep Chalk river cliff out into mudflats and sandflats. At the base of the palaeocliff, gravels represent a beach and within the gravels several artefacts including refits. Thus this is an exceedingly important site both archaeologically and geologically.

Matters in hand to remove some of the vegetation and improve access at various points along the face. However, the critical area by the palaeocliff is steep, high and subject to rapid build up of talus with minor cliff falls. Safety is major issue here and any work to create either temporary or permanent exposures will require careful consideration. The importance of this part of the site makes creating exposures an imperitive.

<u>3.1.1.2 Kent</u>

KT 727 Dartford Heath
Within KT 727, the southern peripheral area of an area known as the ‘Glory Bumps’ shows several exposures of sandy, silty loam overlying gravel corresponding early descriptions of the stratigraphy of the archaeological find spots in the adjacent Bowman’s Lodge pit (see Site Report KT 731). As this site appears to provide a similar stratigraphy to that at Bowman’s Lodge, but a

contrasting one to that in the Wansunt Pit, it is important not only for its archaeology, but for its potential to provide further evidence for a palaeoenvironmental reconstruction of the Dartford Heath area.

KT 708 Wansunt Pit, Crayford
This site is in a reasonably good state of conservation. The floor of the pit was infilled to a greater height than agreed and in some cases the lower parts of the sections are obscured, but could be cleared. Careful monitoring will be needed to ensure the current sections are kept in good order and free of tree roots and that the programme letting sections degrade and new ones opened is adhered to.

KT 484, 486, 681, 815 Dartford Brent
The site where Newton recovered Mollusca and vertebrates is not known with certainty, but KT 486A and 474 (possibly the one location, but not precisely located) are likely candidates, while other sites have been located nearby. KT 484, 486A, 681 and 815 are all capable of excavation. The sites are not under immediate threat, but being in a dense residential area, landscaping and other improvements might cause a potentially important site to be lost.

KT 874 Stone
In the central area of the Boyn Hill Gravel outcrop in Kent there are few exposures left and none are easily accessible apart from this upstanding small ridge of gravel with clear exposures at ground level. Being a cold stage coarse gravel it is less likely to yield artefacts, but it is important for as an exemplar of the sedimentology of the Gravel. The site is vulnerable because it is not imposing and it does not appear significant. The main dangers facing the site are vandalism or unintentional landscaping or other earthworks.

KT 910 Stone
At the western end of Steele Avenue, within a recreation ground, there exposures of bedded head, 100 m long by 5 m high. The amount of exposure, the variation in the sediments and the alkaline environment indicate a high possibility of finding bioenvironmental information, particularly molluscs and vertebrates. Levallois artefacts have also been found in similar deposits from Baker's Hole. There is no immediate threat to the site.

KT 954 Stone
Bedded head is exposed in a former entrance at the eastern of this abandoned Chalk quarry. The site is heavily overgrown. The exposure is c.30 metres long and 3-4 m high. The site is very close (c. 0.5 km) to Ingress Vale. Again, the similarity of the outcrop to Baker's Hole should be noted. The quarry is abandoned, but there are limited signs of remedial activity in the bottom of the quarry and it is in an area subject to intense housing development.

KT 911C Swanscombe
The whole of the Swanscombe site is currently under consideration for further conservation work. Of particular note is area C where infilling has covered the face. This part of the site had been investigated by Conway and shown to

reveal the sequence from the Upper Middle Gravel, through solifluction deposits, the Upper Sand, Upper Loam and Upper Gravel and the Higher Loam. The solifluction deposits and Higher Loam are known only from this area. Thus re-exposure of this part of the site will be particularly important.

KT 567 Southfleet Road washing plant, Swanscombe
Associated with the former washing plant in Southfleet Road, there is a former quarry immediately to the south. Although mapped as Thanet Sand, recent re-evaluation of the geology, showing implementiferous Boyn Hill Gravel, at Swanscombe Community School (c.0.5 km to the north) and the current investigations of a sequence of head, gravels and lacustrine deposits 100-200 m to the south, again with associated artefacts, make this an important site for further evaluation.

3.2 PALAEOLITHIC

3.2.1 CONCLUSIONS

3.2.1.1 Future threats and curatorial priorities

Many of the aggregate extraction sites in the survey area have no Palaeolithic remains. Of those that do, there is great variety in the degree and imminence of future threats to the remaining Palaeolithic archaeological resource. Several sites that are entirely landfilled have undisturbed sediments around their margin, often beneath urban road networks and domestic housing/gardens. To some extent this serves to protect the deposits against degradation from exposure and human activity, although in the long run one must consider the possible impact of chemical leaching from the landfill into the surrounding sediments. Consideration should also be given to the ongoing impact of highways maintenance, excavations in relation to services, and small-scale domestic development at individual house-plots. As it stands these are generally carried out without archaeological mitigation, yet they could be impacting upon a scarce resource of Pleistocene sediment fringing certain key sites. This is a particular issue in heavily quarried areas such as Swanscombe, where key sequences of deposits are in many places only surviving under private housing and the road network between quarried areas.

In other sites, significant sediments are exposed, but not apparently under threat of development, either due to their protection as an SSSI or SAM, or due to their location in an undesirable area. Nonetheless these sediments are vulnerable. First, the pressure for new housing and the general level of urban expansion in the region means that no site can be expected to be without potential for development for very long. Second, even sites that are protected from development are still suffering degradation of their Palaeolithic remains. Exposed sections are vulnerable to erosion by the elements, and to interference from wildlife, such as birds, wasps, badgers and foxes. The growth of plants and tree roots can also significantly damage surviving sediments. This is a particular and obvious problem at the key site of the Ebbsfleet Valley, where the last surviving remnants of the Temperate Bed at SAM 267b, which occur immediately beneath the ground surface, are heavily overgrown by shrubs and young trees. Exposed sequences are also vulnerable to human interference, whether incidental such as biking or fly-tipping, or deliberate such as archaeological investigation and section-cleaning. Despite the academic value of maintaining certain key sections, consideration should be given to the long-term impact on, and degradation of, the resource if subjected to repeated section-cleaning. At the least, archaeological recording should take place of any finds made in the course of section-cleaning, and consideration should be given to other methods such as sieving spoil for micro-debitage, if appropriate at a specific site.

Finally, several sites are undergoing present or imminent development, and this clearly poses a threat to the Palaeolithic resource. While steps have usually been taken to mitigate the Palaeolithic impact, it is important to regularly review whether these steps are sufficient, or whether improvements could be made in the curation of the Palaeolithic resource. In general, Kent and Essex archaeological authorities have led the way in recognising the nature and needs of the Palaeolithic heritage, and in making Palaeolithic archaeological investigations in advance of development a condition of planning consent. However such work is often focused on sites with known Palaeolithic remains, and there continues to be an emphasis within the wider curatorial community on the identification and investigation of undisturbed evidence. It should be emphasised that Palaeolithic sites are regularly discovered unexpectedly during construction at locations without prior records. Increased attention should maybe be paid to evaluation and watching briefs at sites where Pleistocene deposits are known to occur in the area, even if there is no prior indication that they are present at a specific development location. Second, while undisturbed evidence is without doubt important, it is necessary to recognise the contribution to understanding of the Palaeolithic that can be made by two other significant categories of evidence: a) disturbed Palaeolithic remains contained in sealed Pleistocene fluvial deposits, and b) biological palaeo-environmental evidence, even at sites lacking artefactual evidence.

In summary, threats to the surviving Palaeolithic resource can be grouped into two main categories: human/active degradation and natural/passive degradation (Table 12). The impact of aggregate extraction and development are well-recognised and curatorial structures are in place to address them. However there remain a number of present threats that are less well-recognised, and require curatorial attention.

Recognition and mitigation	*Human/active degradation*	*Natural/passive degradation*
Mitigation and curatorial structures in place	● Aggregate extraction ● Housing and infrastructural development	
Relatively unmitigated and needing curatorial attention	● Highways maintenance ● Services impacts ● Leisure impacts ● Dumping, fly-tipping ● Repeated section-cleaning	● Erosion ● Plant growth ● Wildlife impact ● Groundwater drainage ● Chemical leaching

Table 12. Threats to the Palaeolithic resource

3.2.1.2 Research framework and priorities

The survey has highlighted the quantity of significant sites in the survey area that have outstanding issues requiring further research. Many of these sites have not been investigated for a number of years, often several decades, and recent advances in areas such as Optically Stimulated Luminescence dating, amino acid dating, small vertebrate recovery and bio-stratigraphical interpretation make them ripe for further archaeological investigation. Whether this is done as independently funded research or as mitigation in the face of impact from development, this research needs to be carried out in relation to clearly defined aims and objectives, as outlined in national and regional Palaeolithic research frameworks.

Widely agreed core objectives for national Palaeolithic research include:

- Documentation and dating of regional sequences of material cultural change

- Dating artefact-bearing deposits within regional, national and international Quaternary frameworks

- Behaviour of Archaic (pre-anatomically modern) hominids a) at specific sites, b) across the wider landscape

- Behaviour of anatomically modern hominids a) at specific sites, b) across the wider landscape

- Contrasts in Archaic and anatomically modern human behaviour and adaptations

- Patterns of colonisation, settlement and abandonment through the Pleistocene

- The climatic and environmental context of Archaic settlement, and the relationship between climate/environment and colonisation

- Improved documentation and understanding of hominid physiological evolution

● Investigation of the relationship between evolutionary, behavioural and material cultural change

● Social organisation

Within the broad context of these national objectives for Palaeolithic research, a number of regional priorities have become apparent during the survey, both in Essex (Table 13) and Kent (Table 14). It should also be remembered that the Pleistocene deposits on both Kent and Essex sides of the study area are a key part of the national Palaeolithic resource, and so issues in these regions are usually by definition of national Palaeolithic significance.

Essex
Grays, Thurrock (Globe Pit) ● Extent of artefact-bearing gravels ● dating/correlation of same ● Presence of handaxes or handaxe manufacturing debitage in same ● Identification of surviving brickearths ● Recovery of biological palaeo-environmental evidence from brickearths ● Dating/correlations of same
Lion Pit, Tramway Cutting ● Dating/correlation of gravel deposits mapped as "Black Park" ● Correlation of sequence with Crayford and Ebbsfleet brickearths ● Correlation of Levalloisian occupation with Crayford and Ebbsfleet Levalloisian horizons ● Comparison of Levalloisian technology with that of Crayford and Ebbsfleet ● Recovery of biological palaeo-environmental evidence
Corbets Tey/Lynch Hill deposits at Purfleet ● Extent, continuity and correlation of deposits between Bluelands, Greenlands, Esso and Botany Pits ● correlation of deposits with key Kent and East Anglian sequences ● Archaeological characterisation of different horizons, particularly in relation to: – presence of Levalloisian – presence of Clactonian – handaxe typology ● Dating of Levalloisian horizons, and correlation with Levallois occupation at Crayford, Lion Pit Tramway Cutting and Ebbsfleet ● Investigation of whether there is evidence of more intensive occupation at channel-bank

Table 13. Palaeolithic research priorities in the Thames Estuary (Essex)

Kent
Dartford Heath Gravel ● Presence of one or two major fluvial terraces within Dartford Heath Gravel ● Dating/correlations of same ● Characterisation of archaeological content of same ● Recovery of biological palaeo-environmental evidence
Fine-grained sediments overlying Dartford Heath Gravel ● Mapping, dating and correlation of Wansunt Loam, Bowman's Lodge Brickearth & Dartford Silt ● Characterisation of archaeological content ● Recovery of biological palaeo-environmental evidence ● Understanding of mode of formation
Darent, Cray and Ebbsfleet Valleys ● Mapping, dating and correlation of Pleistocene terrace deposits ● Characterisation of archaeological content ● Recovery of biological palaeo-environmental evidence ● Date and environmental context of Levalloisian occupation
Swanscombe area ● Mapping, dating and interpretation of different phases of Barnfield Pit sequence, particularly: – course of Lower Gravel/Lower Loam channel – southern margin of Lower/Upper Middle Gravels – transition from Upper Middle Gravel to Upper Loam ● Characterisation of archaeological content of different levels of Barnfield Pit sequence, particularly: –Lower Gravel or Lower Loam – quantity and typology of handaxes in Upper Loam – presence or otherwise of Levalloisian in Upper Gravel ● Identification and investigation of ovate/cordate handaxe-bearing deposits in vicinity of Greenhithe

Table 14. Palaeolithic research priorities in the Thames Estuary (Kent)

3.3 ARCHAEOLOGY

3.3.1 Assessment of future threat

The study area lies within one of the most densely populated areas in the country and also an area with a rich mineral resource. There is therefore the threat of both further mineral extraction and development/regeneration of these areas.

In order to identify the potential threats, policy statements relating to the area have been examined. These include

- Minerals local plans
- Regional Planning Guidance
- Local Authority development/strategy plans

These threats have, where possible, been digitised as shapefiles. This data was then compared to that contained on the layers relating to the mineral extraction sites, which have formed the basis of this study in order to assess where threats and sites coincided.

Section 3.3.2 summarises the results of this study.

3.3.2 Identification of future threats

3.3.2.1 Minerals

Kent

The Kent Minerals Local Plan Construction Aggregates Written Statement for 1993 (draft Second Review project report produced May 2000) sees no major problem in maintaining a 10 year landbank for sandstone derived gravel, concreting sand, ragstone and building sand, but does see difficulties in securing a 10 year landbank for silica sand and flint-based gravels. The known deposits of the former lie within areas of high landscape value, whilst the main sources of the latter, the lower reaches of the Darent, Medway and Stour are approaching exhaustion. In the medium term, areas of high agricultural quality in the Hoo peninsula and in north east Kent and alongside the River Thames may be exploited but, in the long term, significant changes in the supply pattern are envisaged with further increases in the contribution from imports (crushed rock or marine dredged materials), recycled materials, and possibly limestone mining in East Kent.

The minerals policy for Kent is set out in:

- *Kent Minerals Local Plan: Construction Aggregates Written Statement Adopted Dec 1993*
- *Kent Minerals Local Plan: Chalk and Clay/ Oil and Gas Adopted Dec 1997*
- *Kent Minerals Local Plan: Brickearth Written Statement Adopted May 1986*

In addition to existing minerals permissions the minerals local plans identify 'areas of search for future minerals extraction'. This identifies areas which may be possible minerals extraction sites in the next few years. This data was provided as a shapefile by KCC.

There are ten areas of 'future search' which lie within the 3D core area, five of these are sites of gravels, sands and/or construction aggregates. Three of these are located in the north west of the county, to the north and west of Temple Hill, Dartford. The remaining two are to the south of Dartford, in the area of the Dartford Trade Park and a small area to the east of the A228 at Blackdale Farm.

Essex

The Essex Minerals Local Plan (Adopted First Review 1997) states that Essex is the largest producer of land-won sand and gravel in the South-East Region, contributing over 20% of the region's total production. At the end of 1991 there was a landbank of permitted sand and gravel reserves in Essex equivalent to over eleven years production. It was however foreseen that the depletion of resources and environmental constraints, coupled with the Regional demand for aggregates, would in the long-term need to be met from imported material, marine-dredged gravel and recycled materials. There are three extraction sites with Permission for working brickearth in Rochford District. In addition the Minerals Local Plan identifies eight sites (largely on old industrial sites) along the Thames foreshore as potential Rail and Marine Depots for the importation of aggregates. The Draft Second Review which began in July 2002 states that the landbank still contains over seven years worth of aggregates. None of the preferred sites to maintain the landbank lie within the Thurrock area at present although this may not be the case after review of the MLPs which will take place every five years.

Data provided by ECC identifies forty-five minerals sites within the 3D core area, one currently active and the remainder 'dead' or disused. Most of the sand and gravel reserves in Thurrock had been extracted by the late 1980s and early 1990s, with few continuing into this century. Chalk extraction had also ceased by this time (Thurrock UDP Chapter 12).

Although there are no extant or expected minerals extraction sites within Thurrock there is likely to be development along the riverside to create wharves for the importation of aggregates.

3.3.2.2 Regional and Local Planning Policy

The Thames Gateway, as defined in Regional Planning Guidance Note 9, runs on both sides of the Thames, from Docklands in London at the west end, to Southend and the Isle of Sheppey at the east. The regeneration of this area, and consequently potential threat to the historic environment, is identified as "… a regional and national priority" (RPG 9 Para 4.9).

This framework, which covers the period up to 2016, provides a regional framework for local authority development plans. Further strategic guidance is provided in RPG 9a 'Thames Gateway Planning Framework'.

The study area lies within Thurrock (a unitary authority), Gravesham and Dartford (collectively known as Kent Thames-side). A number of documents issued by these authorities identify areas of priorities in terms of development:

- Gravesham Borough Council information on major development sites (www.gravesham.gov.uk)
- Dartford Borough Local Plan Review (2nd Deposit Draft Written Statement Sept 2002)
- North Kent Area Investment Framework (Thames Gateway Kent Partnership, April 2002)
- Thurrock Unitary Development Plan (Written Statement, March 2003)

3.3.2.3 Gravesham

Gravesham is located to the east of Dartford Borough, with which it shares boundary running along the Ebbsfleet. The River Thames forms its northern boundary. Only a small part of this borough lies within the 3D core area, with fifteen identified polygons of mineral extraction sites within its boundaries. Of these eight were identified as sites with archaeological potential. This is particularly the case for those in proximity to the Ebbsfleet valley which is known to be an area of archaeological potential, as shown by the discoveries made during the construction of the Channel Tunnel Rail Link (CTRL).

The key major development areas identified by the Borough are the Springhead/ Ebbsfleet area which is proposed for mixed use development. Development is also proposed along the Thames side are, the Northfleet part of which lies within the 3D core area. Particularly identified are the Former Northfleet Power Station and the Northfleet Cement Works; the latter particularly may be of interest for industrial archaeology.

Of the fifteen mineral extraction polygons that lie within Gravesend, 11 either intersect with, or lie in close proximity to, these major development sites and therefore could be under threat.

3.3.2.4 Dartford

Dartford Borough, along with Gravesham, makes up North Thames-side. The Rivers Darent, Cray and Dartford Creek form the western boundary of the borough and the Ebbsfleet the east. The majority of the 3D core area is within Dartford, 222 of the mineral extraction sites lie within its boundaries. It includes the archaeologically significant area of the Ebbsfleet Valley, parts of which have scheduled status.

Dartford lies at the heart of the Thames Gateway area, and is one of the largest growth areas in the UK. Consequently there are at least eight large areas proposed for mixed use development in the borough. Plans for the development of the area are set out in *Dartford Borough Local Plan Review; 2nd Deposit Draft Written Statement Sept 2002.*

The following summarises the larger development sites in the area. These have been digitised in order to allow spatial queries to be carried out.

Ebbsfleet

Development in the Ebbsfleet area involves the construction of the CTRL, along with a domestic and international railway station, and a further rail connection to the North Kent Line. Associated with this is mixed development with associated infrastructure. Works on the CTRL are ongoing. The archaeological works associated with this scheme have investigated a number of sites, including areas of Palaeolithic interest, the Springhead Roman settlement at the southern end of the valley, Northfleet Roman villa and a previously unknown Saxon watermill. This is clearly an area of significant archaeological potential. Development has been approved in principle by Dartford and Gravesham Councils. Master plans are in preparation (www.dartford.gov.uk/services/planning/majorapps Jan 2004).

Eastern Quarry

To the west of the Ebbsfleet valley lies Eastern Quarry. This is the largest of the Kent Thameside development sites at some 300ha, and is proposed as a mixed use area with the capacity for some 7250 homes. Given the size and scale of the area development would need to include both primary and secondary schools (North Kent Area Investment Framework).

Swanscombe Peninsula (West and East)
Swanscombe peninsula is also a key site, particularly as it straddles the CTRL and would serve to link existing development on the Greenhithe riverside (Ingress Park) and development in the Ebbsfleet valley. This too is identified as mixed use, but with a greater emphasis on housing. The proximity of this site to the Thames means that the land is likely to have to be raised (North Kent Area Investment Framework).

Land at North Dartford
Land at North Dartford is one of the largest Kent Thameside development sites, located to the north of the Temple Hill area, and the west of the Dartford river crossing (North Kent Area Investment Framework). The site includes part of the former Joyce Green Hospital, and the Littlebrook Nature Reserve;a series of water filled former quarries. Outline planning permission has been issued (www.dartford.gov.uk/services/planning/majorapps).

West Hill Hospital
The site of the former West Hill Hospital is also likely to be developed. A planning brief has been issued by Dartford Borough Council, for residential/mixed use development (Dartford Borough Council Sept 2003).

Stone Castle
Stone Castle lies to the north of Bluewater. The Local Plan identifies the site for mixed use. There are however a number of environmental issues which would need to be addressed prior to any development. This is particularly the case in the areas of former quarries which have been infilled.

3.3.2.5 Thurrock
The Essex part of the 3D core area lies in Thurrock, a Unitary Authority. As with Dartford and Gravesham part of the area lies within the Thames Gateway (as defined in RPG 9, 2001), defined as Essex Thameside. Unlike Kent Thameside much of the redevelopment potential in Thurrock has already been taken up by the completion of existing permissions. The authority's development plan however does stress the further regeneration of sites '… especially the chalk quarries to the west of the M25' for commercial; development and housing (Thurrock Unitary Development Plan Chapter 1)

The Thames Gateway Strategic Executive identified 'zones of change' where opportunities for major development exist. In Thurrock these are the riverside zone; running from Purfleet to Tilbury including Lakeside, Chafford Hundred and South Stifford/Grays, and the Canvey/Shell Haven zone which lies outside the 3D core area (Thurrock Unitary Development Plan Chapter 1).

The UDP lists nine development sites which have outstanding planning permissions (as of 31 March 1998). The majority of these are small to medium sites for between eight and 255 dwellings. The largest of these, Brooks Works and Bruces Wharf in Grays, are former industrial sites. The only large scale development, with capacity for a remaining 3173 dwellings, is Chafford Hundred. The majority of this development lies within previously extracted areas but there are areas, particularly to the south, where archaeological horizons may survive.

Phase 1 of re-development of non residential land for housing identifies twenty-one potential sites within the 3D core area for development between 1998 and 2006. Again the majority of these are small to medium developments. These include land North of Tank Lane, The Dipping, north of Hloow Cottages and the Eurolink Esso North Site, all within Purfleet. Phase 2, between 2006 and 2011, includes further development in the Chafford Hundred area. Other sites include the Globe and Titan Works in Grays, and the Mardyke Magazine site in Purfleet. Phase 3, 2011 to 2016, includes further work at the Globe Works, and the Eurolink Esso North Site.

3.3.3 Assessment of future threat

3.3.3.1 Kent

Development
Of the 242 minerals extraction polygons within the Kent 3D core area 221 lie within the designated boundaries of the Thames Gateway.

Seventy of the polygons lie either within or immediately adjacent to proposed development sites, as identified in section 2.3 above. Twenty-seven of these are thought to have archaeological potential (as identified by the DBA) and include the nationally important Ebbsfleet Valley and Bakers Hole area, Eastern Quarry (where Palaeolithic and other archaeological horizons may survive), and the Galley Hill Pit.

Although the primary focus of the development in the area is the regeneration of former industrial sites, such as the quarries and pits this study is concerned with, the development areas in many cases extend outside those areas previously extracted, for example at Eastern Quarry . There is also the threat posed by associated infrastructure which may impact on undisturbed areas.

Minerals
The areas of future search for minerals sites lie within or immediately adjacent to thirty-two of the mineral extraction sites polygons. These include the nationally important sites at Bakers Hole/Ebbsfleet Valley, Galley Hill, and Bevans Wash Pit.

3.3.3.2 Essex

Development
The development threats to the Essex Thameside are not as extensive as those identified in Kent. As these were smaller scale developments, largely only identified in the development plans by address, it was not possible to digitise them. Some general comments as to threats can however be made.

The main area identified for re-development is that to the west of the M25. This area contains some of the most significant sites within the Essex section of the 3D core area. These include Botany Pit, Esso pit and Bluelands/Greenlands Pits.

Minerals
The sources consulted would suggest that there is no direct threat from mineral extraction in this part of the study area. It is however possible that the redevelopment or restoration of former extraction sites may have an impact. There is a potential threat from the development of marine wharves along the riverside and presumably associated infrastructure.

3.4 INDUSTRIAL

3.4.1 Discussion

The survey confirmed what was generally expected, the poor survival rate, given the extent of industrial growth on both sides of the Thames estuary during the 19th and earlier 20th century, of any significant industrial structures, workings or related technological features. The steady decline within the cement, lime and brickmaking industries combined with the development pressures from both industry and latterly urban regeneration through retail and residential schemes, has seen rapid and continued change.

All the large 19th century concentrations of cement works have been systematically demolished and redeveloped, to the extent that only one site (Aspdins Northfeet works) retains 19th century structural remains of any technological significance. Generally, structural survival was poor, mainly turn of century or later and characteristically ancillary, while the survival of industrial plant was non-existent. The modern La Farge works in West Thurrock, is the only significant example of a pre Second World War cement works, to remain in use, however, survival of original technology is unlikely due to the buildings continued use. Survival within the more built-up industrialised areas was shown to be paltry, however, the rural quarries, apart from the complete 19th century earthworks on Dartford Heath, were equally as poor. These quarries were by no means under the same levels of developmental pressure but nonetheless were cleared, possibly as a consequence of a recreational re-use.

Apart from the actual excavated faces of the quarry, the features most commonly encountered were former tramway cuttings and associated road bridges, access routes or the tunnels used to inter-connect adjacent quarries below roads or railways. The condition of these components was largely dependent upon use, many tunnels were maintained for vehicular access, as were some of the former tramway cuttings and road bridges. Preservation through use can be broadly applied to many of the remains, from buildings remaining in industry to cuttings used for footpaths of local public spaces. Damage through dis-use and neglect is adequately demonstrated by the derelict buildings at Tank Lane Quarry and the Kent Kraft Estate.

The statistics from the survey, comprising a broadly equivalent number of sites visited in Kent and Essex, show a remarkably similar pattern of survival. Approximately half of sites visited were so extensively redeveloped that they merited no, or a very low archaeological significance. 27-28% of the sites visited were those which retained some industrial features or had a higher potential for below ground survival and were of a low-medium significance, while (16-22%) of the sites were of a medium significance retaining structures or combination of features associated with the sites industrial use. Of these only two, the scheduled kiln at Northfleet and the earthworks at Dartford Heath, were assessed as having national importance, the latter at present without specific statutory protection.

Two sites, particularly the remains at Dartford Heath and the nature reserve at Craylands Gorge, present due to higher levels of amenity excellent educational opportunities for local schools. The Victorians and the 19th century are studied at Key Stage 2 and Key Stage 3, and projects based upon these former Industrial sites and their impact upon the local landscape, could be integrated into the curriculum. They form a tangible link with the areas industrial heritage and through study and direct involvement may engender a greater sense of local importance.

Although all of the historic cement production sites have been cleared they may still retain important below-ground archaeological evidence relating to the development of the technologies used within the industry, particularly at pioneering sites such as the Swanscombe and Northfleet works. These sites hold immense research potential and arguably present the last chance to analyse and study the development of innovative large scale 19th century cement works, within the industries heartland. Further site assessment and targeted archaeological intervention should be used as mitigation in future planning proposals.

3.5 GIS

3.5.1 Further work

A key part of any further work should be the re-digitising of the polygons upon which the study has been based. The time constraints of this first phase of ALSF work meant that the data obtained by the specialists was appended to the polygon data provided by the BGS on the ‘artificial ground’ layer. There are however some limitations with this data as it was not specifically designed for this purpose. These can be summarised as follows:

- As data was digitised per 1:10,000 quarter sheet (*e.g.* TQ 57 SW) multiple polygons exist for a single site where they cross sheet boundaries. Although each has been cross-referenced simplification would be advantageous.
- In some cases the areas of excavation shown on the 1:10,000 artificial ground layers and the general geology layers do not coincide. This is likely to be an inevitable result of digitising differing scales of map. This could however cause problems where trying to identify the limits of extraction, which is particularly important when considering the extent of surviving sediments
- The attribute data for individual polygons does not identify the edition or type of map which the actual shape was digitised from.
- On some occasions the limits of individual polygons do not match limits shown on historic maps (presumably because they were digitised from a different edition). This means that on occasion extents of excavation are greater than those shown.

Re-digitisation using the method outlined below would be considered appropriate. In order to progress the ALSF project any further areas of study should also be re-digitised prior to commencement. This would not greatly delay any project as map regression needs to take place as part of the identification of eligible sites and the desk based assessments.

It is suggested that each edition of the Ordnance Survey (1870s to 1980s and modern mapping) should be examined and areas of excavation digitised at a standard scale. These should be saved as individual layers for each edition. The 1st to 4th editions are available digitally for each county, later editions would need to be consulted in the respective records offices, the data added to paper maps then digitised.

The layers created above could then be overlaid. Polygons could then be joined in order to identify the limits of extraction.

The above exercise would not only be advantageous in identifying areas of extraction but could conceivably contribute to more specialist studies. As each edition would be digitised separately the development and spread of the extractive industry, and the earliest sites could be identified. The identification of 'time specific' areas of extraction could also possibly narrow down the location of chance finds.

It would also be considered advantageous to develop links to the Historic Landscape Characterisation Project, which may well have data sets which could contribute to further study.

Assuming that the 1st – 4th editions of the Ordnance Survey are available digitally it is estimated that this would take approximately fifty person days for an area equivalent to that of the 3D core area. This would vary depending on the complexity of extraction in any given area.

Seminars
A large number of GIS layers have been created as part of this project. Part of the reason for this, in addition to fulfilling the aims and objectives of the study, was to provide a tool which could be used by archaeologists in managing the resource that these sites represent, particularly given the clear future threat of the extensive proposed Thames Gateway development. It is also a tool which could be used in conjunction with other data sets, for example that of the Historic Landscape Characterisation programme, which could aid research.

It would therefore be appropriate to provide a number of seminars for relevant staff to introduce the data available, clearly explain the sources the data is drawn from and suggest ways that it could be used. As part of this process end-users could be asked if they have any comments to make on the usefulness of the layers and suggest improvements. This could then be fed back in to any further stages of work.

3.6 SUMMARY

Summarised below in sections 3.6.1 to 3.6.4 are the main conclusions and recommendations of the assessment reports.

3.6.1 Preservation and management of sites

3.6.1.1 Geology and Palaeolithic
Key Palaeolithic and Pleistocene sites within the study area with high potential and/or in need of protection from further degradation are listed below.

Although well-established mitigation and curatorial procedures are available to address the threat to the known Palaeolithic/Pleistocene resource from large-scale development (e.g. mineral extraction, road and housing schemes etc), no mitigation/curatorial procedures are available to protect it from active and passive degradation (e.g. small-scale development, erosion, wildlife and tree impact etc) (Table 12). The addressing of this flaw is seen as an urgent priority.

Essex

- Esso Pit (EX653)
- Botany Pit (EX681)
- Greenlands
- Bluelands
- Globe Pit (EX476)
- Purfleet Road, Aveley
- Lion Pit Tramway cutting (EX649)

Kent

- Barnfield Pit, Swanscombe (KT510, KT870 and KT911)
- Bakers Hole, Ebbsfleet Valley (KT542, KT581 and KT585)

- Parsons Pit (KT725)
- Wansunt Pit (KT708 and KT729)
- Bowmans Lodge (KT731)
- Woods Pit (KT723)
- Dartford Heath Park (KT727)
- Dartford Gold Club (KT671, 700 and 713)
- Dartford Brent (KT484, KT486, KT681 and KT815)
- Eastern Quarry, Swanscombe (KT541, KT567, KT583, KT584, KT915 and KT916)
- Craylands Lane East (KT568 and KT795)
- Smiths and Brotherwoods Pits, Wilmington (KT480 and KT709)
- Hawley Road (KT732 and KT848)
- Stone (KT874, KT910 and KT954)

3.6.1.2 Industrial

Large-scale modern development has ensured that relatively few significant industrial structures of the 19th and earlier 20th centuries are still present in the project area. Existing planning procedures would ensure that most of the identified sites listed below would be subject to detailed assessment prior to development.

Essex

Sites with significant structural and technological standing remains

- La Farge Cement works, Thurrock

Sites with less technologically significant remaining structures or possible sub-surface remains

- Tunnel Cement Works (EX684)
- Thames Cement Works (EX683)
- Grays Quarry (EX475)
- Tank Lane Quarry (EX681)
- Globe Cement, Brick, Whiting and Chalk works
- London Road (EX681)
- Globe Works (EX476)
- Quarry EX475
- Former Thames Works (EX683)
- Tunnel Works (EX683)
- Grays Chalk Quarry (EX477)
- Quarry EX649
- Metropolitan Works (EHCR 15540)

Kent

Sites with significant structural and technological standing remains

- Aspdins Northfleet Works
- Dartford Heath (KN727)

Sites with remaining structures or possible sub-surface remains

- J.B. Whites Swanscombe Works (KN552)
- Dartford Cement Works (KN701)
- The quarry supplying the London Portland Cement Works (KN582)
- Craylands Lane (KN574)
- Bevans Wash (KN567)
- The Northfleet Paper Mills site

3.6.2 Research objectives

3.6.2.1 Geology and Palaeolithic

Section 3.2.1.2 and Tables 13 and 14 list nationally important research questions which, with the aid of new technological innovations, the identified Palaeolithic/Pleistocene resource in the study area has the potential to address. Continued research and progress in the discipline, however, is dependant on the effective preservation and maintenance of the existing resource. The profile of the internationally important sites identified in this report needs to be increased, and effective mitigation and curatorial practices for the preservation of the Palaeolithic/Pleistocene resource in the Lower Thames area need to be developed and implemented.

3.6.2.2 Industrial

Although much above ground evidence for the development of the cement industry in its industrial heartland in the 19th century has already been lost, significant evidence for it probably still exists below ground at pioneering sites like Swanscombe and Northfleet. Relatively little is known about the development and organisation of this innovative industry, and every opportunity should be taken to preserve and investigate what little remains.

3.6.3 Technical and organisational issues

Progress in the project was bedevilled by technical and organisational problems, mostly related to the geological modelling of the study area and the presentation of accurate data on the GIS-database (sections 2.1.4.2 and 3.5.1). Consequently, expansion of the GIS-database to include information from neighbouring areas should not been undertaken before the identified problems have been rectified.

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