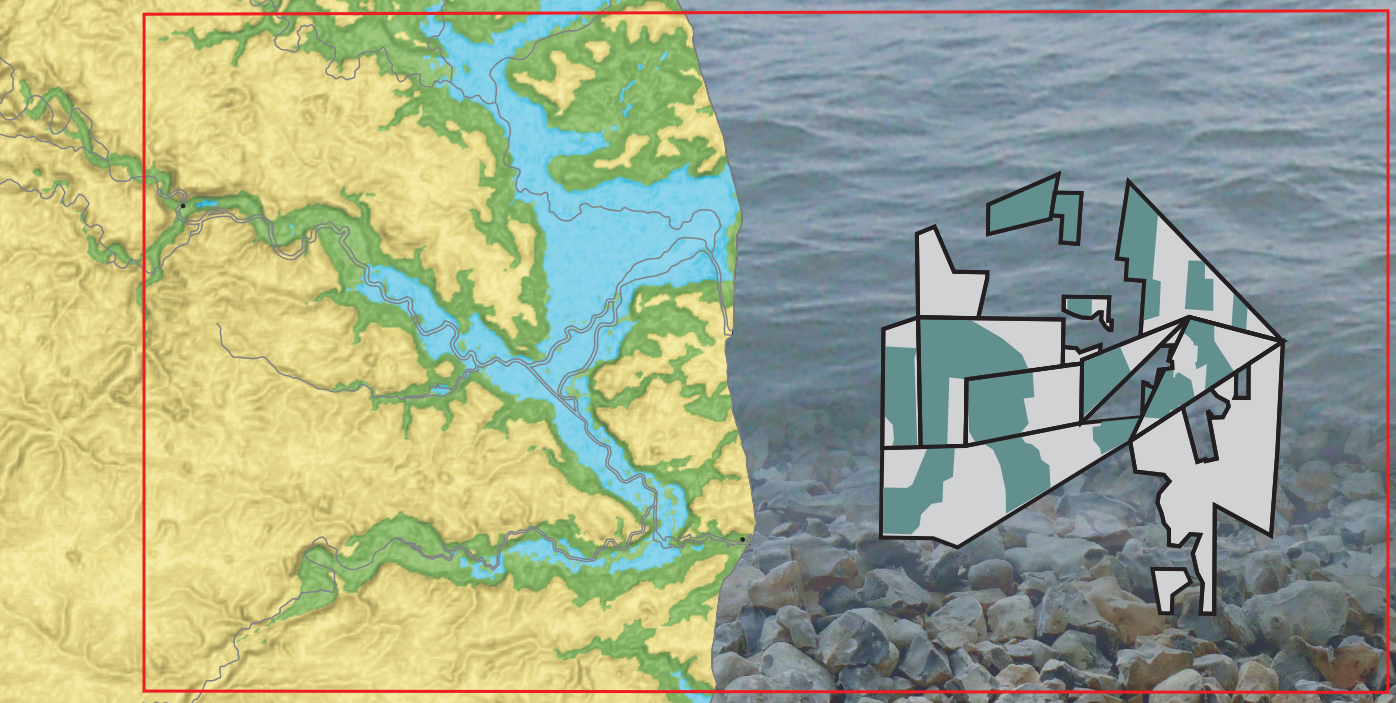
Wessex Archaeology

Palaeo-Yare Catchment Assessment

Addendum Report

Short-Term Licence Areas



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PALAEO-YARE CATCHMENT ASSESSMENT

ADDENDUM REPORT – SHORT-TERM LICENCE AREAS

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PALAEO-YARE CATCHMENT ASSESSMENT

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PALAEO-YARE CATCHMENT ASSESSMENT

ADDENDUM REPORT – SHORT-TERM LICENCE AREAS

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Summary

Wessex Archaeology has been commissioned by the British Marine Aggregate Producers Association on behalf of The Crown Estate, CEMEX UK Marine Limited, Hanson Aggregates Marine Limited, Tarmac Marine Dredging Limited and Volker Dredging Limited, to conduct an assessment of the Palaeo-Yare catchment area, East Anglia. The aim of the project is to delineate, where possible, the regional extents and survival of specific sediment units from which a large number of flint artefacts and faunal remains were recovered. The sediment units and associated finds coincide with a region where long standing production licence areas for marine aggregate dredging have permitted extraction for several decades.

This addendum report supports the Palaeo-Yare Catchment Assessment Technical report (Wessex Archaeology 2012a) and discusses the assessment results specifically for aggregate extraction areas affected by short-term licence conditions. This report also supports the *Provisional Written Scheme of Investigations for the Anglian Region*.

The aim of the Palaeo-Yare Catchment Assessment project is to map, primarily using existing industry data, the extents of the key Palaeo-Yare deposit (Unit 3b), and to develop hypotheses about the archaeological potential of the region in order to support decisions relating to the assessment and management of future marine aggregate operations.

Specific objectives are as follows:

- Map the extent of the Wolstonian floodplain deposit (Unit 3b) within the offshore aggregate dredging areas;
- Assess the archaeological potential of the offshore catchment area within the offshore aggregate dredging areas;
- Assess the known geology of the Palaeo-Yare onshore and its associations with its offshore extension;
- Assess the available information on the onshore archaeology and its possible associations with the artefacts recovered offshore.

Based on the results of the Palaeo-Yare catchment assessment a number of key conclusions with reference to the potential for the presence of archaeological material within the wider East Coast licence area were made. The key conclusions were as follows:

- The Middle Palaeolithic Assemblage is mixed, *i.e.* contains artefacts of *in situ* and secondary context.
- The Middle Palaeolithic Assemblage is primarily associated with Unit 3b within Area 240.
- There is potential for palaeolithic material in secondary context associated with Units 2, 3b, 4, 7, 8 and the bank structures (of unknown age).
- Natural processes throughout transgressions and regressions subsequent to deposition have not completely removed sediment units. With regards to the *in situ* elements of the Middle Palaeolithic assemblage, remnants of *in situ* Unit 3b sediments are present within the region.

- Extensive dredging of the region has not necessarily completely removed Unit 3b sediments within the area.
- There is potential for *in situ* archaeological material to be present elsewhere within the region where remnants of Unit 3b are located.
- Faunal remains and palaeoenvironmental material are likely to be sourced from Units 2, 3b, 4 and 7. These could be *in situ* or secondary context and may be located throughout the region.
- Uncertainties remain due to the data limitations used for the assessment and the degree of dredging undertaken since the geophysics data were acquired.

A set of hypotheses were developed that can be applied to the licence areas within the region in order to test these key conclusions and address the remaining uncertainties. The hypotheses are predominantly focussed on the potential for artefacts within the Palaeo-Yare floodplain deposits (Unit 3b). It is envisioned that these hypotheses will be tested through physical sampling and monitoring of dredge loads. The table below details the hypotheses and the circumstances under which they will be tested.

Hypotheses:		
Inhabitation	**H1a**: Palaeolithic material is recovered only from Unit 3b, which dates to the Wolstonian.	All areas.
	H1b: Palaeolithic material recovered from Unit 3b is predominantly *in situ*.	Only areas containing Unit 3b sediments.
Choice and use of location	**H2a**: Palaeolithic material is recovered only from Unit 3b deposits on the margin of Channel A, not within the Channel itself.	Only areas with Channel A deposits.
	H2b: Palaeolithic material is recovered only from Unit 3b deposits within the limits of the Palaeo-Yare floodplain, and not within the Unit 3b outliers to the north and south of the floodplain	Only Unit 3b outlier deposits.
	H2c: The recovery of Palaeolithic material is clustered in relatively large quantities in discrete locations; material is not recovered from otherwise similar locations.	All areas.
Natural processes	**H3a:** The distribution of recovered Palaeolithic material does not vary according to variations in the sediment structure of Unit 3b.	Only areas containing Unit 3b sediments.
	H3b: Palaeolithic material is not recovered where Unit 3b appears to have been reworked by natural processes in the past.	Only areas which contain reworked bank features or have been reworked by the development of subsequent channels, such as the development of Channel B.
	H3c: Palaeolithic material is not recovered where Unit 3b appears to be covered by major bank structures.	Only areas where major bank structure is observed (Area 361/242 and 328).
Dredging History	**H4a**: Palaeolithic material is not present where the dredging history indicates that a high level of dredging has taken place since the introduction of EMS.	Only areas where cumulative intensity is classified as high.
	H4b: Palaeolithic material is not present where geophysical data indicates that a high level of dredging has taken place.	Only areas where the geophysics data indicates that Unit 3b has been heavily affected or removed through dredging processes.

Operation Sampling methods	**H5a**: Palaeolithic material is found at all wharves where Operational Sampling takes place	All areas.

This addendum report provides details of the palaeogeography and known archaeology for licence areas under short-term licence conditions and addresses the hypotheses to be tested. Specifically, the aims of this addendum report are as follows:

- to assess, in detail, the known presence of Unit 3b in aggregate dredging areas under short-term licence conditions;
- to assess the likely presence of Unit 3b taking into account subsequent dredging in the area since data acquisition;
- to assess whether Unit 3b is the aggregate target;
- to identify the principal hypotheses to be tested by the proposed mitigation (operational sampling).

Unit 3b floodplain deposits were identified in the following areas: Areas 240, 228, 319, 251, 360, 242/361 and 328 (eastern-central and eastern areas only). Unit 3b sediments within the channel were only observed in Area 240, 228, 360 and 251 (eastern area only).

Within the short-term licence areas in which Unit 3b sediments were identified it is considered likely that Unit 3b is the target for dredging, with the exception of Area 242/361 (eastern area). In the eastern area of Area 242/361 the likely aggregate target is the overlying major reworked bank structure. However, in areas where Unit 3b is observed, the unit is not necessarily the only target for dredging. Based on the data the overlying reworked sediments of Unit 8 are also a target, particularly where this unit thickens to more than a veneer of sediment.

In the short-term licence areas where Unit 3b has not been identified (Area 212, 296 and 328 (west and western-central areas), the target for dredging is considered to be the reworked bank structures and Unit 8 (reworked marine sediments).

Natural reworking of Unit 3b sediments is observed in Area 240, 319, 251 and 242/361 (eastern area). In Area 240 Unit 3b sediments have been reworked by the re-activation of Channel A and deposition of Unit 4 sediments, and the development of Channel B and subsequent deposition of Unit 7. The development of Channel B during the early Holocene also caused reworking of Unit 3b deposits in Areas 319 and 251 (western area). In the eastern short-term licence area of Area 242/361 a major reworked bank is observed overlying Unit 3b sediments and there is evidence in the geophysics data suggesting that during the development of the bank some of the underlying Unit 3b sediments were eroded.

In Areas 240, 228 and 242/361 (western area) there is evidence in the geophysics data to suggest that dredging activity has heavily affected or completely removed Unit 3b sediments. In Area 228 it is difficult to discriminate whether Unit 3b has been entirely removed.

The table below provides a summary of the hypotheses that will be tested during dredging within each short-term licence area.

Short-term aggregate licence area	Sub-licences	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
240		✓	✓	✓		✓	✓	✓		✓	✓	✓
228		✓	✓	✓		✓	✓	✓			✓	✓
319		✓	✓			✓	✓	✓		✓		✓
251	West	✓	✓			✓	✓	✓				✓
	Central	✓	✓			✓	✓					✓
	East	✓	✓	✓		✓	✓	✓				✓
360		✓	✓	✓		✓	✓	✓		✓		✓
361/ 242	West	✓	✓			✓	✓				✓	✓
	East	✓	✓			✓	✓		✓			✓
328	West	✓				✓		✓			✓	✓
	West-Central	✓				✓		✓	✓			✓
	East-Central	✓	✓		✓	✓	✓	✓	✓	✓		✓
	East	✓	✓		✓	✓	✓					✓
296		✓				✓		✓		✓		✓
212		✓				✓		✓				✓

The information resulting from the testing of these hypotheses will enhance the knowledge of the presence of Palaeolithic material in the area and will inform the continuing monitoring activity in the licence areas.

PALAEO-YARE CATCHMENT ASSESSMENT

ADDENDUM REPORT – SHORT-TERM LICENCE AREAS

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Acknowledgements

Wessex Archaeology (WA) has been commissioned by the British Marine Aggregate Producers Association (BMAPA) to conduct an assessment of the Palaeo-Yare catchment area, East Anglia. Wessex Archaeology would like to thank Mark Russell (BMAPA) for his assistance throughout the project and Dr Antony Firth of Fjordr Ltd for his contribution.

Wessex Archaeology would particularly like to thank the licensees for their support in providing the data for their respective licences and also providing details on the dredging history of the area. Thanks to Dr Andrew Bellamy (Tarmac Ltd), Will Drake (Volker Dredging Ltd.), Graham Singleton, Dr Rebecca Westlake and Joe Holcroft (CEMEX UK Marine Ltd) and Nigel Griffiths, Emma Beagley, Laura Humphries and Amy Stewart (Hanson Aggregates Marine Limited).

Also, thanks to Royal Haskoning for supplying the Electronic Monitoring System (EMS) data.

Dr Louise Tizzard prepared the report. Kitty Foster prepared the illustrations and the project was managed and QA'd by Euan McNeill.

Data Licences

PALAEO-YARE CATCHMENT ASSESSMENT

ADDENDUM REPORT – SHORT-TERM LICENCE AREAS

Ref: 83740.05

Contents

Tables

Figures

PALAEO-YARE CATCHMENT ASSESSMENT

ADDENDUM REPORT – SHORT-TERM LICENCE AREAS

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1. INTRODUCTION

1.1. PROJECT INTRODUCTION

1.1.1. Wessex Archaeology has been commissioned by the British Marine Aggregate Producers Association on behalf of The Crown Estate, CEMEX UK Marine Limited (CEMEX), Hanson Aggregates Marine Limited (HAML), Tarmac Marine Dredging Limited (TMDL) and Volker Dredging Limited (VDL), to conduct an assessment of the Palaeo-Yare catchment area, East Anglia. The aim of the project is to delineate, where possible, the regional extents and survival of specific sediment units from which a large number of flint artefacts and faunal remains were recovered in 2007/2008 and artefacts subsequently recovered between 2009 and 2011. The sediment units and associated finds coincide with a region where long standing production licence areas for marine aggregate dredging have permitted extraction for several decades.

1.1.2. Previous work relevant to this assessment includes work conducted in the Aggregate Dredging Licence Area 240 (Wessex Archaeology 2011a) on behalf of English Heritage (EH), funded by Aggregate Levy Sustainability Fund (ALSF) and work commissioned by HAML which involved a programme of archaeological monitoring within Licence Area 240 (Wessex Archaeology 2011b).

1.1.3. This addendum report supports the Palaeo-Yare Catchment Assessment Technical report (Wessex Archaeology 2012a) and discusses the assessment results specifically for aggregate extraction areas affected under short-term licence conditions (**Figure 1**). This report also supports the *Provisional Written Scheme of Investigations for the Anglian Region*.

1.2. RATIONALE AND AIMS

1.2.1. The rationale and the aims of the Palaeo-Yare catchment assessment are detailed in the technical report (Wessex Archaeology 2012a). In brief, artefactual material, including handaxes, flakes and cores were recovered, along with faunal remains (including bison, mammoth, horse and reindeer) in 2008 from aggregate extraction Area 240 (licensed to HAML), situated approximately 11km off the coast of Great Yarmouth. The place where the finds were recovered is relatively discrete, and the provenance of the artefacts is secure. Once the finds were reported HAML stopped dredging in the immediate area and voluntarily implemented a rectangular exclusion zone based on dredger trackplots in accordance with the BMAPA *Protocol for Reporting Finds of Archaeological Interest* (BMAPA and EH 2005).

1.2.2. Further seabed sampling work (funded through the Aggregate Levy Sustainability Fund, via English Heritage) and monitoring of dredged material (commissioned by HAML) recovered additional flint artefacts. The Middle Palaeolithic Assemblage comprises a total of 124 flint artefacts including 36 handaxes, 9 cores and 79 worked flakes. At least some of the assemblage, including the handaxes, is thought

to have been *in situ*. There is also evidence of Levallois technique employed at this site.

1.2.3. The flint artefacts are known to be associated with a specific sediment unit (Unit 3b) which was deposited during the Wolstonian (MIS 8/7) and formed a floodplain deposit associated with a channel (Channel A). The floodplain is identified as the (now) offshore extension of the present-day Yare valley system comprising the Rivers Wensum, Yare and Waveney.

1.2.4. A summary of the Middle Palaeolithic Assemblage is provided in **Table 1** and **Figure 2**. Details of the finds are provided in **Appendix I**.

Finds	Handaxes	Cores	Flakes	Total
Original discovery (**WA 2147**)	33	8	47	**88**
EC REC (**WA 2206**)	-	-	1	**1**
Seabed Prehistory: Seabed Sampling (**WA 2192** – **2200, 2203** and **2204**)	-	-	11	**11**
Wharf monitoring (**WA 2207** – **2227**)	3	1	20	**24**
Total	**36**	**9**	**79**	**124**

Table 1. Composition of the Middle Palaeolithic Assemblage

1.2.5. The aim of the Palaeo-Yare Catchment Assessment project is to map, primarily using existing industry data, the extents of the key Palaeo-Yare deposit (Unit 3b), and to develop hypotheses about the archaeological potential of the region in order to support decisions relating to the assessment and management of future marine aggregate operations. Specific objectives were to:

- Map the extent of the Wolstonian floodplain deposit (Unit 3b) within the offshore aggregate dredging areas;
- Assess the archaeological potential of the offshore catchment area within the offshore aggregate dredging areas;
- Assess the known geology of the Palaeo-Yare onshore and its associations with its offshore extension;
- Assess the available information on the onshore archaeology and its possible associations with the artefacts recovered offshore.

1.2.6. The results presented in the Palaeo-Yare catchment assessment technical report illustrated the extents of the sediment units identified in the region, particularly focussing on the known extents of Unit 3b (**Figure 2**).

1.2.7. Based on the results of the Palaeo-Yare catchment assessment technical report a number of key conclusions with reference to the potential for the presence of archaeological material within the wider East Coast licence area were made. The key conclusions were as follows:

- The Middle Palaeolithic Assemblage is mixed, *i.e.* contains artefacts of *in situ* and secondary context.
- The Middle Palaeolithic Assemblage is primarily associated with Unit 3b within Area 240.

- There is potential for palaeolithic material in secondary context associated with Units 2, 3b, 4, 7, 8 and the bank structures (of unknown age).
- Natural processes throughout transgressions and regressions subsequent to deposition have not completely removed sediment units. With regards to the *in situ* elements of the Middle Palaeolithic assemblage, remnants of *in situ* Unit 3b sediments are present within the region.
- Extensive dredging of the region has not necessarily completely removed Unit 3b sediments within the area.
- There is potential for *in situ* archaeological material to be present elsewhere within the region where remnants of Unit 3b are located.
- Faunal remains and palaeoenvironmental material are likely to be sourced from Units 2, 3b, 4 and 7. These could be *in situ* or secondary context and may be located throughout the region.
- Uncertainties remain due to the data limitations used for the assessment and the degree of dredging undertaken since the geophysics data were acquired.

1.2.8. A set of hypotheses were developed that can be applied to the licence areas within the region in order to test these key conclusions and address the remaining uncertainties. The hypotheses are predominantly focussed on the potential for artefacts within the Palaeo-Yare floodplain deposits (Unit 3b).

1.2.9. It is envisioned that these hypotheses will be tested through physical sampling and monitoring of dredge loads. The hypotheses are detailed in **Section 2.4**.

1.2.10. This addendum report provides details of the palaeogeography and known archaeology for licence areas under short-term licence conditions and addresses the hypotheses to be tested. Specifically, the aims of this addendum are as follows:

- to assess, in detail, the known presence of Unit 3b in aggregate dredging areas under short-term licence conditions;
- to assess the likely presence of Unit 3b taking into account subsequent dredging in the area since data acquisition;
- to assess whether Unit 3b is the aggregate target;
- to identify the principal hypotheses to be tested by the proposed mitigation (operational sampling).

1.3. SHORT-TERM LICENCE AREAS

1.3.1. Only aggregate extraction areas to be dredged under short-term licence conditions are assessed as part of this report (**Table 2** and **Figure 1**). The order of the licence areas in the table below is based on geographic location and is in the order in which the areas are discussed in **Sections 3**.

Aggregate licence area	Sub-licences	Area (km^2)	Licensee	Figure
240		20.078	Hanson Marine Aggregate Ltd	**2**
228		10.8111	Volker Dredging Ltd	**3**
319		8.079	CEMEX Ltd	**4**
251	West	9.469	CEMEX Ltd	**5**
	Central	7.766		
	East	2.859		
360		5.223	CEMEX Ltd	**6**

Aggregate licence area	Sub-licences	Area (km^2)	Licensee	Figure
242/361	West	5.037	Hanson Marine Aggregate Ltd	**7**
	Central	4.759		
328	West	1.296	Hanson Marine Aggregate Ltd	**8**
	West-Central	9.569		
	East-Central	3.252		
	East	1.254		
296		6.575	Tarmac Marine Dredging Ltd	**9**
212		3.122	Hanson Marine Aggregate Ltd	**10**

Table 2: Aggregate extraction areas under short-term licence conditions.

2. METHODOLOGY

2.1. INTRODUCTION

2.1.1. As part of the Palaeo-Yare Catchment Assessment approximately 2,500 line km of sub-bottom profiler data from 22 surveys were reviewed. Additionally, 1,171 vibrocore logs and photographs were assessed. Principally, within the aggregate extraction block the data assessed were supplied by the licensees, supplemented by data previously acquired during surveys in the region. The sub-bottom profiler data were interpreted to map the structure of sub-surface features, such as channels and infill sediments, and the vibrocores were integrated into the geophysical interpretation providing details on sediment composition.

2.1.2. The geophysical and geotechnical datasets reviewed for the short-term licence areas are detailed in **Section 3**.

2.2. INTERPRETATION METHODOLOGY

2.2.1. The digital sub-bottom profiler data were processed using Coda Seismic+ software. This software allows the data to be replayed with user selected filters and gain settings in order to optimise the appearance of the data for interpretation. The software then allows an interpretation to be applied to the data. The interpretation tags were exported as text files and imported to GIS.

2.2.2. The analogue data was interpreted from the paper rolls and the interpretation was input into GIS for geospatial analysis.

2.2.3. The sub-bottom profiler data were interpreted with a two-way travel time (TWTT) along the z-axis. In order to convert from TWTT to depth, the velocity of the seismic waves was estimated to be 1,600ms^{-1}. This is a standard estimate for shallow, unconsolidated sediments.

2.2.4. All trackplots (digital and analogue) were georeferenced in ArcGIS to allow an assessment of data coverage. The vibrocore locations were imported into ArcGIS in order to compare the data spatially.

2.2.5. Initially, the vibrocore logs were archaeologically assessed in order to establish the presence and location of sediment units with likely archaeological and palaeoenvironmental potential. The geotechnical data were then integrated with the

geophysical data to aid identification of specific sediment units of interest with regards to the development of the Palaeo-Yare.

2.3. INTERPRETATION CONTEXT

2.3.1. The following section details an overview of the sediment units identified within each short-term licence area. For each area the data has been reviewed to assess, in detail, the known presence of Unit 3b, the likely presence of Unit 3b taking into account subsequent dredging in the area since data acquisition; the known archaeology and provide a list of hypotheses that will be tested by operational sampling within each short-term licence area.

2.3.2. A full review of the palaeogeographic reconstruction of the Palaeo-Yare is provided in the technical report (Wessex Archaeology 2012a). **Table 3** provides an overview of the sediments referred to within the following section.

Unit	Interpretation	Age	Description
8	Marine deposits associated with the last transgression in the Holocene	Holocene	Shelly, gravelly medium to coarse sand.
7	Basal fill of a shallow under-filled channel feature, Channel B, (equivocal to onshore lower Breydon Formation)	Early Holocene	Only observed to the northwest of Area 240 and also a small patch in the south western corner. It comprises a basal unit of peat approximately 0.2 m thick overlain by a unit of sandy or shelly clay. Infilling of Channel B.
6	Glaciofluvial alluvium	Possibly mid-Devensian	Sandy gravel.
5	Possibly represents an estuarine or near coastal depositional environment	Unknown, possibly contemporary with unit 6	Slightly gravelly, slightly silty, fine to medium grained sand infilling depressions.
4	Brown Bank Formation	Early Devensian (110 – 75 ka)	Unit 4 is a very distinctive unit generally associated with the buried channel feature in the north of Area 240 interpreted as the infilling of a cut sequence. It is comprised of fine-grained sediments (sands, silts and clays) deposited in a low-energy environment such as river or estuary.
3b	Reworked glaciofluvial outwash	Wolstonian glaciation (380 to 130 ka)	Unit 3b overlies Unit 3a in the channel and directly overlies Unit 2 throughout the central and western area. It is comprised of sands and gravels.
3a	Reworked glaciofluvial outwash	Wolstonian glaciation (380 to 130 ka)	A channel (Channel A) infill deposit that is associated with a channel feature probably cut into Unit 2 during the Late-Anglian glaciation. Unit 3a is the deepest, and oldest, fill primarily associated with the channel feature in the northeast and comprises gravel and sand.
2a/b	Yarmouth Roads Formation	Cromerian period (478 to 787 ka)	Unit 2a generally comprises silty, gravelly, fine to coarse sands. Observed throughout the majority of Area 240 and generally overlies Unit

Unit	Interpretation	Age	Description
			1.To the south of Area 240 Unit 2b comprises silty sand with very frequent thin beds and laminae of firm to stiff clay and peaty organic clay.
1	Westkapelle Ground Formation	Pliocene/Early Pleistocene	The deepest unit and is observed across Area 240

Table 3: Interpretation of geological units identified throughout the Palaeo-Yare catchment area.

2.3.3. All Units are observed in all the areas with the exception of Units 5 and 6. Units 5 and 6 were identified in Area 240 as infills of small depressions cut into the underlying Unit 3b and are interpreted as estuarine sediments either deposited or at least exposed during MIS 3 (*c.* 35 ka). These units have not been identified in the surrounding area, possibly due to the resolution of the datasets or due to the subtle nature of the features. Equally, there may be no remnants of these features in other areas. As such, Units 5 and 6 are discussed in relation to Area 240 only.

2.4. DREDGING HISTORY

2.4.1. Dredging history of the aggregate areas is an extremely important consideration in aiding the interpretation of the geotechnical and geophysical data given that many of these licence areas represent long standing interests that have been actively worked for 30 years or more.

2.4.2. Electronic Monitoring System (EMS) data was provided for the East Coast region based on a year-on-year basis from 1993 to 2011. The EMS automatically records the date, time and position of all dredging activity and every month this information is supplied to the Crown Estate (Crown Estate and BMAPA 2010).

2.4.3. Qualitative analysis of the EMS data was undertaken and is detailed in the technical report. The data were analysed in terms of cumulative number of years in which dredging has taken place at any one time. Additionally, the data were analysed to assess the cumulative intensity of dredging over the 19 years based on the data provided. The cumulative intensity over the 19 years was classified as follows:

- Very low cumulative intensity – based on consultation (pers. com. M. Russell, May 2012) this group is defined as low intensity dredging for up to 5 years only;
- Low cumulative intensity – low level dredging for greater than 5 years, medium intensity for up to 5 years and no years of high intensity;
- Medium cumulative intensity – Medium dredging for greater than 5 years and high intensity for less than 5 years;
- High cumulative intensity – areas dredged at high levels for greater than 5 years, irrespective of low or medium level dredging.

2.4.4. These levels of cumulative intensity are referred to in this report in relation to the short-term licence areas.

2.5. MITIGATION METHODOLOGY

2.5.1. The mitigation proposed involves operational sampling in the short-term licence areas as detailed in the *Provisional Written Scheme of Investigations for the Anglian Region*. Principally, operational sampling involves the recovery of dredge load from a known location and preferably targeting a single sediment unit which is then made

available for archaeological monitoring. It is proposed that the archaeological monitoring will take place at a licensees wharf and will target the oversize aggregate. This process should allow the archaeologists to observe and retain archaeological material such as flint flakes, handaxes and faunal remains. Operations will be specific to each wharf.

2.5.2. Certain licence areas will lend themselves to certain hypotheses. Each short-term licence area has been assessed, specifically taking into account the following hypotheses (see below).

2.5.3. The information resulting from the testing of these hypotheses by operational sampling will enhance the knowledge of the presence of Palaeolithic material in the area and will inform the continuing monitoring activity in the licence areas.

2.5.4. The hypotheses are divided into 5 groups relating to specific issues, and are detailed below.

Inhabitation

2.5.5. These hypotheses are intended to test if the Palaeo-Yare floodplain was inhabited and if the evidence of inhabitation dates only to the Wolstonian period. These hypotheses primarily assess if archaeological material is *in situ* and associated with the Unit 3b deposits. The assessment of whether the material is *in situ* or recovered from a secondary sediment source will be based on the character and quality of flint material recovered combined with the known geology in the location of the dredge load being monitored.

H1a: Palaeolithic material is recovered only from Unit 3b, which dates to the Wolstonian.

H1b: Palaeolithic material recovered from Unit 3b is predominantly *in situ*.

Choice and use of location

2.5.6. Although there is potential for further artefacts it is difficult to state how much and where they would be found. There is likely to be a cultural element to the use of the landscape and it may be that the area to the southwest of the channel was more preferable to the banks to the north or southeast.

2.5.7. These hypotheses are intended to test whether people inhabited the area represented by Unit 3b according to spatial preferences; and whether activity was focussed or dispersed.

H2a: Palaeolithic material is recovered only from Unit 3b deposits on the margin of Channel A, not within the Channel itself.

H2b: Palaeolithic material is recovered only from Unit 3b deposits within the limits of the Palaeo-Yare floodplain, and not within the Unit 3b outliers to the north and south of the floodplain

H2c: The recovery of Palaeolithic material is clustered in relatively large quantities in discrete locations; material is not recovered from otherwise similar locations.

Natural processes

2.5.8. Although the data indicates that certain areas of Unit 3b have remained undisturbed since their original deposition and contain *in situ* artefacts, some areas of Unit 3b appear to have been heavily reworked. This reworking is due to terrestrial processes such as the development of Early Holocene channel in the west of the area that would have significantly reworked underlying Unit 3b sediments. Also, the erosion and deposition of a large reworked bank in the east of the area have been shown to cause natural reworking of Unit 3b deposits.

2.5.9. Marine processes also cause reworking of sediments during regression and transgression. During transgressions and periods of high sea-level the upper portions of Unit 3b sediments have been reworked and re-deposited with a marine component. Unit 8 which is identified throughout the area as either a veneer or as seabed bedforms will contain sediments eroded and reworked from the underlying sediments.

2.5.10. Hypotheses H3a and H3b are intended to test whether taphonomic processes affect the distribution of Palaeolithic material, where such processes are indicated by changes in the sand/gravel composition of Unit 3b. Changes in the composition of Unit 3b are difficult to assess on a regional scale as the differences are subtle. However, on a localised licence area scale changes in composition are apparent. For example, in Area 240 Unit 3b sediments in the north are noticeably coarser and more gravelly than those in the south.

H3a: The distribution of recovered Palaeolithic material does not vary according to variations in the sediment structure of Unit 3b.

H3b: Palaeolithic material is not recovered where Unit 3b appears to have been reworked by natural processes in the past.

2.5.11. Hypothesis H3c is intended to test whether Palaeolithic material is protected from dredging impacts where the target aggregate is the reworked sediments of the bank features.

H3c: Palaeolithic material is not recovered where Unit 3b appears to be covered by major bank structures.

Human processes, including dredging history

2.5.12. Dredging activity has taken place within the East Coast region over the several decades. Known levels of dredging have been recorded since 1993. This EMS data has been modelled to provide a qualitative assessment of cumulative dredging activity throughout the region and evidence of dredging is observed in the geophysics data in localised areas. The aim of these hypotheses is to test whether evidence for previous dredging, identified through geophysical or EMS data, can be used to indicate an absence of Palaeolithic material.

H4a: Palaeolithic material is not present where the dredging history indicates that a high level of dredging has taken place since the introduction of EMS.

H4b: Palaeolithic material is not present where geophysical data indicates that a high level of dredging has taken place.

Operational sampling methods

2.5.13. In May 2012 WA carried out, on behalf of HAML with agreement from EH, a successful programme of archaeological monitoring of the processing at Frindsbury Wharf, Kent, of aggregate dredged from within dredging licence Area 240 (Wessex Archaeology 2012b). Monitoring was carried out by a team of three archaeologists who monitored *c.* 1500 tons aggregate dredged from a known location. The 40-100mm fraction was observed on a conveyor, prior to being crushed, which was stopped by archaeologists by means of triggering the metal detector whenever pieces with archaeological potential were seen. A piece of bovid animal bone and two items of relatively fresh worked flint in the form of two flakes consistent with previous finds from the area were recovered. These flakes have not been included in the assemblage as this work is still ongoing.

2.5.14. The methods employed during this phase of work proved to be a viable methodology at this particular wharf. However, as all wharves have different set-ups this may not be viable at all wharves. This hypothesis aims to test whether the methodology is effective at all wharves were it is deployed.

H5a: Palaeolithic material is found at all wharves where Operational Sampling takes place.

2.5.15. **Table 4** summarises the situations in which each hypothesis will be tested.

Hypothesis	Areas tested
H1a	All areas
H1b	Only areas containing Unit 3b sediments
H2a	Only areas with Channel A deposits
H2b	Only Unit 3b outlier deposits
H2c	All areas
H3a	Only areas containing Unit 3b sediments
H3b	Only areas which contain reworked bank features or have been reworked by the development of subsequent channels, such as the development of Channel B.
H3c	Only areas where major bank structure is observed (Area 361/242 and 328)
H4a	Only areas where cumulative intensity is classified as high.
H4b	Only areas where the geophysics data indicates that Unit 3b has been heavily affected or removed through dredging processes
H5a	All areas

Table 4: Summary of areas in which hypothesis testing applies.

2.5.16. Not all short-term licence areas will test all hypotheses, as indicated in **Table 4**, and within each short-term licence area the targeting of specific sediment units and palaeogeographic features will test particular hypotheses. This is discussed on an area by area basis in **Section 3**.

3. SHORT-TERM LICENCE AREAS

3.1. AREA 240

3.1.1. Area 240 is licenced to HAML and is situated in the centre of the aggregate extraction block. The short-term licence area excludes the eastern limits of the area including the voluntary exclusion zone implemented after the original discovery of the Middle Palaeolithic Assemblage (**Figure 3**).

Data

3.1.2. Area 240 was first interpreted as part of the *Seabed Prehistory: Site Evaluation Techniques (Area 240)* project (Wessex Archaeology 2011a). The geophysical data were acquired by Andrews Survey Ltd. in 2005 and comprised Reson 8101 multibeam echosounder data and sub-bottom profiler data acquired using an Applied Acoustics Boomer system. Data were acquired in north-south orientation at 100 m line spacing, with cross-lines acquired at 1,000 m line spacing. The data was generally of good quality.

3.1.3. The Area 240 data was re-assessed where necessary as part of this assessment.

3.1.4. Five licensee supplied geotechnical datasets (109 vibrocores) were assessed with 25 vibrocores acquired in 1999 (Alluvial Mining Ltd. 1999), 48 vibrocores in 2000 (Andrews Survey 2000a; 2000b), 38 vibrocores in 2005 (Andrews Survey 2005a) and 9 vibrocores in 2007 (Lankelma Andrews 2007).

3.1.5. The vibrocores acquired in 1999 were undertaken with a 4-m vibrocorer; the remainder were acquired with a 3-m corer. Of the 109 vibrocores in Area 240, 94 are situated in the short-term licence area.

3.1.6. Additionally, geophysical and geotechnical data acquired during the *Seabed Prehistory* project have also been integrated into the interpretation (Wessex Archaeology 2011a).

Interpretation results

3.1.7. Unit 2 is observed throughout the area and is interpreted as Yarmouth Roads Formation. In the short-term licence area the unit generally comprises fine-grained silts and sands and a thin band of clay is observed near the top of the unit. Localised peat and other organic sediments are noted. Similar sediments are observed in Area 228 (**Section 3.2**).

3.1.8. The Area 240 short-term licence area is dominated by channels (Channel A and B) in the north and floodplain deposits (Unit 3b) in the south.

3.1.9. Channel A cuts into Unit 2 sediments and is thought to have first developed at the end of the Anglian Glaciation. Channel A is observed oriented northwest to southeast across the area. The southern edge of the channel is prominent and is approximately 5m deep. The northern edge of the channel is less obvious and is observed as a more gently shoaling rather than a steep cut. The channel feature is up to 2 km wide.

3.1.10. Initial basal infill sediments (Unit 3a) comprise coarse-grained gravel and sand and palaeoenvironmental evidence suggests a fluvio-glacial depositional environment (Wessex Archaeology 2011a). It is considered unlikely that Unit 3a is a target for extraction due to the overlying thickness of sediments within the channel (Unit 3b and Unit 4).

3.1.11. Unit 3b partially infills the channel overlying Unit 3a and forms the floodplain deposits situated to the west and south of Channel A.

3.1.12. Unit 3b generally comprises sands and gravels of varying compositions and vibrocore data indicate that the unit is generally finer-grained to the south of the area. It is from Unit 3b that the Middle Palaeolithic Assemblage artefacts are thought to have been dredged.

3.1.13. Unit 3b overlies Unit 3a in Channel A and directly overlies Unit 2 throughout the central and western area. Within the channel area, Unit 3b is characterised by a series of strong sub-parallel reflectors, whereas in the central area Unit 3b is characterised by a more chaotic unit indicating a lateral change in sediment type. The thickness of this unit is variable across the area, generally between 2 and 4 m thick.

3.1.14. Analysis of the OSL dating indicates that Unit 3b was deposited during MIS 8/7 (250 – 200 ka). There are areas where Unit 3b sediments are not observed either through natural thinning of the unit or, as in most cases, due to dredging of Unit 3b sediments.

3.1.15. Unit 4 is observed in the northeast of the short-term licence area associated with the channel. Unit 4 is observed infilling broad shallow cuts into Unit 3b deposits or as small bank features, primarily associated with the edge of the channel. Unit 4 generally comprises fine-grained sands silts and clays and the palaeoenvironmental analysis indicates deposition in a brackish, estuarine and shallow marine environment. Vibrocores also show evidence of oxidisation which may be a result of weathering and exposure to oxygen and the formation of a horizon of a gley type soil. OSL dating of the unit indicates an early Devensian (MIS 5c: *c.* 100 ka) deposition age (Wessex Archaeology 2011a). OSL dating returned dates of 109 ± 11 ka (GL 10037) and 96 ± 11 ka (GL 10041), both correlating to the early-Devensian.

3.1.16. Unit 5 is observed in the central and southern areas and infills small depressions. Unit 5 comprises up to 2 m slightly gravelly, slightly silty, fine to medium grained sand. Some vibrocores indicate the presence of clays associated with this fine-grained sediment indicating a low-energy depositional environment early in this sequence. The age of this unit is unknown but is thought that it may be contemporary with Unit 6, although could be older.

3.1.17. Unit 6 is observed in the south of the area infilling broad shallow depressions in the surface of Unit 3b. The unit generally comprises up to 3 m sandy gravel and OSL dating indicates a mid-Devensian deposition age (MIS 3; *c.* 35 ka). OSL dating returned a date of 36 ± 3 ka (GL 10044).

3.1.18. In the northwest corner of the short-term licence area a partially infilled channel is observed. The channel (Channel B) is a north to south meandering partially infilled channel that is observed in Areas 240, 319 and 251. The infill of this channel (Channel B) is Unit 7 and comprises up to 2 m of a progressively transgressive sequence from intertidal mudflat/saltmarsh deposited in the Early-Holocene overlain by a shallow marine/ outer estuarine sand, in turn, overlain by a shallow marine lag deposit, deposited during the last transgression (Wessex Archaeology 2011a). Radiocarbon dating returned results of 10,710 – 10,280 cal. BC (SUERC-11978) at the base of the unit and 6730 – 6590 cal. BC (SUERC-32233).

3.1.19. Throughout the area Unit 8 sediments (reworked marine sands and gravels) are observed. The unit is observed forming large scale sandwaves (up to 6 m high) with a veneer of sediments in the troughs of the sandwaves.

3.1.20. Cumulative dredging intensity in the area is predominantly classified as low with significant areas classified as medium cumulative intensity. Localised areas have been dredged to high cumulative intensity.

3.1.21. Areas of heavy dredging where there has been significant removal of sediment units, primarily Unit 3b, are observed in the geophysics data (sub-bottom profiler and multibeam echosounder data). These areas generally co-incide with areas of medium or high cumulative dredging, but not always.

3.1.22. Based on the geophysics interpretation and the EMS data, Units 3b, 4, 5, 6 and 7 are all targets for aggregate dredging. Since the acquisition of the 2005 geophysics dataset dredging has occurred to the west and north of the area.

3.1.23. In addition to the Middle Palaeolithic Assemblage (**WA 2147**, **2206**, **2192** – **2200**, **2203**, **2204** and **2207** – **2227**), as detailed in **Section 1.2**, a further two flint artefacts has been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest* (**WA 2160**). In 2007 – 2008 the two flints, along with two mammoth teeth (**WA 2159**), were recovered from the aggregate reject pile at SVB Flushing Wharf. One of these flints showed possible signs of striking and may have been the waste product during the knapping of a flint tool such as a handaxe (Wessex Archaeology 2008a). Although the exact location of where the flints were dredged is unknown and therefore context is unknown assessment of the geology indicates that the material from which the flakes were dredged was Unit 3b.

3.1.24. In addition to the lithic artefacts, a large number of faunal remains have been recovered from Area 240 (**WA 2145**, **2158**, **2161**). In the original discovery approximately 130 faunal remains (**WA 2146**) were recovered. Approximately 70 % of the faunal remains were attributed to an age between 43,000 and 31,000 BP based on the radiocarbon dating of 5 of the remains and the remaining 30 % of the bones are heavily fossilised, estimated to be older than 500 ka. Faunal remains were also recovered from clamshell grab sampling during the *Seabed Prehistory* project (**WA 2195**, **2196**, **2201**, **2002** and **2005**) and also during the wharf monitoring in dredge loads associated with the flint artefacts.

3.1.25. Furthermore, between October 2010 and 2011 faunal remains were recovered at the wharf in Vlissingen by the Natural History Museum of Rotterdam in agreement with the Wharf (Strijdonk *et al.* 2011; 2012). The aggregate from which the faunal remains were recovered was dredged from Area 240. The remains contain an Early Pleistocene to early Middle Pleistocene assemblage comprising terrestrial mammal bones primarily from species of mammoth and moose. These faunal remains are likely to be associated with either Unit 2 or Unit 3b. In addition, an assemblage of faunal remains dated as Late Pleistocene, which includes woolly mammoth, bison, giant deer, woolly rhinoceros and wild horse, are likely to be associated with Unit 4, 5 or 6. A final group dates to the Early Holocene and are likely to be associated with Unit 7 deposits and include red deer and bovid remains.

3.1.26. Environmental remains, thought to be associated with Unit 7 deposits covering an area of 200 x 130 m in the northeast corner of Area 240 have also been reported (**WA 2148** – **2157**).

3.1.27. The majority of the Middle Palaeolithic Assemblage is situated to the east of the short-term licence area (**Figure 3**) within a voluntary exclusion zone implemented by HAML at the time of the original discovery.

Mitigation

3.1.28. Proposed mitigation is in the form of operational sampling, as detailed in **Section 2.5**. Within the Area 240 short-term licence area five palaeogeographic features are observed that may be the target for dredging activities. **Table 5** details which hypotheses will be tested by targeting each palaeogeographic feature.

Aggregate target	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
Unit 3b deposits (floodplain)	✓	✓			✓	✓			✓	✓	✓
Channel A deposits (Units 3b and 4)	✓	✓	✓		✓	✓	✓				✓
Unit 3b deposits (Channel B)	✓	✓			✓	✓	✓				✓
Other units (Units 5, 6 and 7)	✓				✓						✓
Unit 3b heavily dredged/removed	✓	✓			✓	✓					✓

Table 5: Hypotheses tested by targeting specific palaeogeographic features in Area 240.

3.2. AREA 228

3.2.1. Area 228 is situated adjacent to Area 240 and the short-term licence area is situated to the west of Area 228 (**Figure 4**).

Data

3.2.2. Four geophysics datasets have been acquired in Area 228 since 1989. Partial coverage of the area (south and east) was acquired in 1989 in a survey which covered Areas 319, 251, 228 and 360. The 1989 survey provided full coverage of Area 228, however, the trackchart was not available and in the east data for five lines is missing. Data were acquired at 200 or 400 m line spacing and were or variable quality due to adverse weather conditions.

3.2.3. In 2002 a survey was undertaken by Andrew Survey (Andrews Survey 2002a) and data were acquired on a north-south orientation at 150 m line spacing. In 2005 a survey of two sub-sections of Area 228 (in the central area and the east) were undertaken by Andrews Survey (Andrews Survey 2005b) and lines were acquired at 100 m line spacing, orientated north-south. WA had access to the 2002 and 2005 survey reports and interpreted charts.

3.2.4. The 2011 dataset covered the western portion of Area 228 and was acquired by Gardline Environmental Ltd (2011a). North-south orientated lines were acquired at 100 m line spacing with east-west cross lines at 1,000 m line spacing. The sub-bottom profiler and multibeam echosounder data were assessed by WA as part of an Environmental Impact Assessment (EIA) (Wessex Archaeology 2011c). The interpretation from the EIA was used for this assessment.

3.2.5. The data quality of the 2011 sub-bottom profiler data was variable. A large amount of ringing was observed on all records which masked a large amount of data. Processing was undertaken to reduce this effect but, due to the ringing being created by the seismic source and so being within the same frequency range as the

actual data, only a limited amount could be achieved. As such, discrimination between sediment units was not always possible.

3.2.6. Within Area 228 a total of 144 5-m vibrocores have been acquired in Area 228 from surveys in 1988, 1996, 2002, 2004 and 2011 (Alluvial Mining 1988; 1996; Andrews Survey 2002b; 2004; Gardline Environmental Ltd. 2011b). Of these, 75 vibrocores are situated in the short-term licence area.

Interpretation results

3.2.7. The short-term licence area is situated to the west of Channel A and is situated within the floodplain of the Palaeo-Yare. It is a complex area geologically, particularly in the east near the limits of the channel. The area has also been dredged heavily which further complicates the interpretation. In Area 228 it is difficult to establish how much of Unit 3b remains.

3.2.8. Vibrocore data (2011) indicate the sediments throughout the majority of the area comprise grey and beige coloured sands and gravels with no molluscan inclusions. The gravels comprised flint with quartz, quartzite, basalt, limestone and sandstone. These are interpreted as Unit 3b sediments deposited in a glaciofluvial alluvial environment.

3.2.9. Within the central and eastern areas vibrocores indicate that sediments comprise silts and clays which, in some cases, are sandy, gravelly and shelly. These are interpreted as belonging to estuarine and alluvial deposits and are possibly associated with remnants of overbank deposits of Unit 4 sediments, associated with Channel A. The geophysics data indicates small, isolated minor infilled depressions associated with these finer-grained sediments. However, these depressions are not well defined and have not been mapped for this project.

3.2.10. Throughout the area, Unit 3b overlies Unit 2 sediments which comprise clays and fine grained sands.

3.2.11. In the east of the area the edge of the Late Anglian channel (Channel A) and there is some evidence of Unit 4 sediments overlying Unit 3b sediments within the channel. Vibrocore data in the area indicates that Unit 4 sediments comprise silts and clays overlying a layer of peat.

3.2.12. The uppermost unit observed throughout the site is reworked marine sediments (Unit 8) which range in thickness from a thin veneer to up to possibly 6 m thick beneath a large east – west trending sand wave observed in the northeast of the study area. However, the unit is generally 2 to 4 m thick.

3.2.13. The 2011 bathymetry dataset indicates areas of heavy dredging, particularly in the west of the area. Comparisons between the known water depths at vibrocore locations in these dredged areas in 1988 to the 2011 bathymetry data indicate that as much as 6 m has been removed from the seabed. In these areas it is likely that the majority of the resource has been removed. Although, based on the vibrocore data from 2011 it cannot be stated that the Unit 3b sediments have been completed removed.

3.2.14. Cumulative dredging intensity is predominantly classified as low with two areas classified as medium cumulative intensity. The areas of medium cumulative intensity coincide with areas observed on the geophysical data as being heavily dredged.

3.2.15. No artefacts, faunal remains or environmental remains have been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest* from Area 228.

Mitigation

3.2.16. Proposed mitigation is in the form of operational sampling, as detailed in **Section 2.5**. Within the Area 228 short-term licence area three palaeogeographic features are observed that may be the target for dredging activities. **Table 6** details which hypotheses will be tested by targeting each palaeogeographic feature.

Aggregate target	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
Unit 3b deposits (floodplain)	✓	✓			✓	✓				✓	✓
Channel A deposits (Units 3b and 4)	✓	✓	✓		✓	✓	✓			✓	✓
Unit 3b heavily dredged/removed	✓	✓			✓	✓					✓

Table 6: Hypotheses tested by targeting specific palaeogeographic features in Area 228.

3.3. AREA 319

3.3.1. Area 319 is licenced to CEMEX and is situated in the west of the aggregate extraction block (**Figure 5**).

Data

3.3.2. The geophysics data (sub-bottom profiler) were acquired in 1989 (in a survey covering Areas 319, 251, 228 and 360) by Gardline Survey from the M/V *Profiler*. Data were acquired at 200 or 400 m line spacing. Out of the 11 data lines acquired only nine were available for review. Data were of variable quality. This was partly due to complex geology and partly due to adverse weather conditions.

3.3.3. Geotechnical data for Area 319 was acquired in 1991, 1993, 1999, 2005, 2008 and 2009 (RMC 1991; 1993; 1999a; 1999b; CEMEX 2005; 2008a). A total of 57 vibrocores were acquired of which 46 are situated within the short-term licence area. Data were acquired with a 3- or 4-m vibrocorer.

Interpretation results

3.3.4. Area 319 short-term licence area is dominated by a meandering north-south partially infilled channel (Channel B) which was developed during the early Holocene.

3.3.5. The channel appears to cut through Unit 3b floodplain deposits and is likely to have caused considerable reworking of Unit 3b sediments within the confines of the channel.

3.3.6. On the western bank of the channel within the area sediments comprise a basal shelly sand overlain by interbedded sand clays and silts with some evidence of oxidisation. Palaeoenvironmental analysis indicated deposition in cold estuarine or shallow marine conditions (Limpenny *et al.* 2011). This unit is overlain by sand with occasional silt and some evidence of oxidisation and has been dated to between 222±28.7 ka (at 32.50 mbOD) and 188±19.7 ka at 31.50 mbOD. These dates correlate with those dated in Area 240 (MIS 7/6) for Unit 3b sediments (Wessex Archaeology 2011a). An uppermost date in the unit of 57±5.6 ka at 30.88 mbOD was attributed to sediment exposure to sunlight during the Devensian (MIS 3),

subsequent to its original deposition during the Wolstonian period. The oxidisation noted within the sediments is a result of a fall in the level of the water table, and exposure subsequent to their deposition. The overall environment is of a cold estuarine environment, deposited during the Wolstonian (Limpenny *et al.* 2011).

3.3.7. Vibrocore data indicate that Unit 3b sediments are finer-grained with less gravel content in the west of the area.

3.3.8. On the eastern bank of Channel B the Unit 3b is more difficult to define. Due to the geophysical data quality (partially due to dredging effects) it is difficult to differentiate between Unit 3b and the underlying Unit 2 sediments. Vibrocore data indicate that Unit 3b sediments are variable in thickness in this area and comprise sand and gravel.

3.3.9. Within Channel B Unit 3b sediments have been interpreted at the base of the channel. However, it is possible that the sands and gravels within the channel are reworked and possibly contain later deposited sediments associated with the development of the Channel B. Although there is no evidence of any organic or peat layers as observed elsewhere in the channel (Unit 7) in Area 240, it is possible that the sediments belong to the early Holocene transgressive sequence. Without palaeoenvironmental analysis or dating this cannot be ascertained. It is also possible that any early Holocene Unit 7 deposits have been dredged out leaving the underlying Unit 3b deposits.

3.3.10. Also, within the channel there are two areas where Unit 2 sediments are interpreted and are not overlain by Unit 3b. Unit 2 sediments generally comprise silty sand comparable to Unit 2 sediments observed throughout the region. Unit 2 is overlain by up to 4 m of Unit 8 reworked modern sediments. However, it is possible that the reworked sediments comprise reworked Unit 3b sediments.

3.3.11. Vibrocore data indicates that a veneer of Unit 8 modern reworked sediments is present throughout the area.

3.3.12. The geophysics data indicates that some dredging occurred in the area prior to data acquisition in 1989. EMS data indicates that the area has been dredged in 17 of the 19 years since recording began in 1993. The area has been dredged to low and medium cumulative intensity levels, with localised area of high intensity dredging in the north of the area.

3.3.13. The aggregate target appears to be Unit 3b sediments and the reworked infill sediments from the early-Holocene channel.

3.3.14. Two reports of faunal remains (**WA 2175** and **2176**) have been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest.* **WA 2175** is a fragment of a mammoth tusk and the findspot is an approximate position situated within 1,800 m of the supplied position. **WA 2176** is a left metatarsus of a large red deer and is situated within 1,200 m of the supplied position. It is considered that the faunal remains were recovered from a secondary context and could be associated with Unit 3b or Unit 8 deposits.

Mitigation

3.3.15. Proposed mitigation is in the form of operational sampling, as detailed in **Section 2.5**. Within the Area 319 short-term licence area three palaeogeographic features are observed that may be the target for dredging activities. **Table 7** details which hypotheses will be tested by targeting each palaeogeographic feature.

Aggregate target	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
Unit 3b deposits (floodplain)	✓	✓			✓	✓			✓		✓
Unit 3b deposits (Channel B)	✓	✓			✓	✓	✓				✓
Unit 2 with veneer of Unit 8	✓				✓						✓

Table 7: Hypotheses tested by targeting specific palaeogeographic features in Area 319.

3.4. AREA 251

3.4.1. Area 251 is licenced to CEMEX and is situated in the southwest of the aggregate extraction block (**Figure 6**).

3.4.2. There are three short-term licence areas within Area 251, referred to as west, central and east.

Data

3.4.3. The geophysics data (sub-bottom profiler) were acquired in 1989 (in a survey covering Areas 319, 251, 228 and 360) by Gardline Survey from the M/V *Profiler*. Data were acquired at 200 or 400 m line spacing and 12 lines were missing from the dataset. Data were generally of good quality with some lines of variable quality due to adverse weather conditions.

3.4.4. Geotechnical data for Area 251 was acquired in 1991, 1993, 1999, 2003, 2005, 2008 and 2009 (RMC 1991; 1993; 1999; RMC Marine Ltd 2004; CEMEX 2005; 2008b). A total of 144 vibrocores were acquired of which 87 are situated within the short-term licence area. Data were acquired with a 3- or 4-m vibrocorer.

3.4.5. In the western short-term licence area the area was covered by 13 north-south orientated lines at 200 or 400 m line spacing and 29 vibrocores. Three data lines were missing and as such the maximum gap between two lines in the east of the area is 600 m.

3.4.6. In the central short-term licence area the area was covered by 12 north-south orientated lines at 400 m line spacing with one cross-line and 42 vibrocores. However, the easternmost 5 data lines were missing and the interpretation was based on vibrocore data only.

3.4.7. In the eastern short-term licence area the area was covered by 6 north-south orientated lines at 400 m line spacing with one cross-line and 16 vibrocores. There is a small gap in the interpretation in the east where there is no data coverage.

Interpretation results

Western Area

3.4.8. The western short-term licence area generally comprises Unit 3b sediments overlying Unit 2 sediments. In the western portion Unit 3b sediments form a bank feature up to 5 m high and the bank is cut in the northwest by the early-Holocene channel (Channel B). The bank feature has been interpreted as Unit 3b. However, Unit 3b sediment type is more variable than, for example, the floodplain deposits in Area 240. The bank comprises a veneer of sand and gravel overlying finer-grained silty sand.

3.4.9. To the east Unit 3b sediments comprise up to 2 m coarse-grained sands and gravels overlying Unit 2 (fine-grained sands and silts). The geophysics data indicates that the unit thins and is finer-grained to the south.

3.4.10. Elsewhere, sediments probably comprise a veneer of sands and gravels (probably reworked Unit 8) overlying Unit 2. There is some evidence of dredging on the geophysics data in the central area.

3.4.11. The western short-term licence area has generally been dredged to low cumulative intensity with localised areas of very low and medium intensity. The target aggregate appears to be Unit 3b sediments and Unit 8 in the central portion.

3.4.12. In the western area one find (**WA 2163**) has been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest*. The find is a possible hippopotamus bone, possible of the Ipswichian Interglacial period (MIS 5e). However, the positioning of the findspot is poor and could be associated with Area 102 (off the coast of the Humber).

3.4.13. To the north of the area environmental remains were reported through the protocol (**WA 2164**). Although the findspot is situated to the north of the area it is possibly associated with the infill of Channel B in the northern corner of the short-term licence area.

3.4.14. The peat sample (**WA 2164**) contained relatively high numbers of seeds, as well as substantial numbers of wood fragments. The assemblage indicates the deposition in an ox-bow lake or similar cut-off chute. The presence of opercula of *Bithynia*, a species associated with flowing channels, suggests that some of the material may be derived from overbank flooding. The assemblage suggests the peat was formed on boggy ground, adjacent to a flowing river or stream, with only slight evidence for larger bodies of standing water. The high presence of wood fragments may have been derived from shrubs adjacent to the peat, although the presence certain species indicates some marshland and possibly wet grassland elements.

3.4.15. Although there is no date for this peat deposit and its exact location is unknown, the palaeoenvironmental evidence and the geophysical data evidence indicate that this forms part of the infill of this early-Holocene channel.

Central Area

3.4.16. The central area is dominated by Unit 3b floodplain sediments observed in the geophysics as a bank feature up to 5 m high and thinning to the south and northwest. Sediments are generally coarser-grained than observed in the western short-term area, although the geophysical nature of the bank features are similar.

3.4.17. In the southwest of the area Unit 2 (silts, sands and clays) are observed overlain by a veneer of sand and gravel (probable reworked recent sediments (unit 8)).

3.4.18. The central short-term licence area has generally been dredged to low cumulative intensity with localised areas of very low and medium intensity. The target aggregate appears to be Unit 3b and Unit 8 sediments.

3.4.19. No artefacts, faunal remains or environmental remains have been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest* from this area.

Eastern Area

3.4.20. The eastern short-term licence area is dominated by Channel A sediments. Throughout the area Unit 3b sediments are observed and are overlain in places by Unit 4 sediments. The northern edge of the channel is not clearly defined in the area.

3.4.21. Unit 3b sediments generally comprise sand with some gravel up to 6 m thick in places. The geophysics data indicates that coarser sediments are situated in the south and there is a general fining to sediments to the north.

3.4.22. There are five areas where Unit 4 sediments are observed overlying Unit 3b sediments. Unit 4 is observed infilling cuts into Unit 3b sediments and also forming small bank features. The geophysics data indicates a fine-grained unit and this is confirmed from the vibrocore data. Unit 4 sediments are variable in composition and comprise silts, clays, peat and other organic matter.

3.4.23. Throughout the area a veneer of recent sediment (Unit 8) is observed.

3.4.24. The eastern short-term licence area has been dredged to low cumulative intensity with two areas of medium cumulative intensity. The target aggregate appears to be Unit 3b, however, the EMS data also indicates that Unit 4 sediments are also dredged.

3.4.25. In the eastern area one find (fragment of an auroch metatarsal) has been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest* (**WA 2165**). The positioning of the findspot is the approximate position of the vessel during recovery of the dredge load and could be associated with Unit 3 or 4.

Mitigation

3.4.26. Proposed mitigation is in the form of operational sampling, as detailed in **Section 2.5**. Within the Area 251 short-term licence area five palaeogeographic features are observed that may be the target for dredging activities. **Table 8** details which hypotheses will be tested by targeting each palaeogeographic feature.

Aggregate target	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
Unit 3b deposits (floodplain) (all areas)	✓	✓			✓	✓					✓
Channel A deposits (Unit 3b) (east area)	✓	✓	✓		✓	✓	✓				✓
Channel A deposits (Unit 4) (east area)	✓				✓		✓				✓
Unit 3b deposits (Channel B) (west area)	✓	✓			✓	✓	✓				✓
Unit 2 with veneer of Unit 8 (east and central areas)	✓				✓						✓

Table 8: Hypotheses tested by targeting specific palaeogeographic features in Area 251 (west, central and east areas).

3.5. AREA 360

3.5.1. Area 360 is licenced to CEMEX and is situated in the central region of the aggregate extraction block (**Figure 7**).

Data

3.5.2. The geophysics data (sub-bottom profiler) were acquired in 1989 (in a survey covering Areas 319, 251, 228 and 360) by Gardline Survey from the M/V *Profiler*.

The short-term licence block is situated in the west of the area and was covered by 6 lines of data orientated north-south at 400 m line spacing with two additional cross-lines. Data were generally of good quality with some lines of variable quality due to adverse weather conditions.

3.5.3. Geotechnical data for Area 360 was acquired in 1991, 1999, 2005, 2008 and 2009 (RMC 1991; 1999a; 1999b; CEMEX 2005; 2008b; 2009a). A total of 66 vibrocores were acquired of which 64 are situated within the short-term licence area. Data were acquired with a 3, 4 or 5 m vibrocorer.

Interpretation results

3.5.4. The area is dominated by the floodplain deposits of Unit 3b. Unit 3b generally comprises sands and gravels and varies in thickness between a veneer (<1 m) and 3 m (based on 2008 vibrocore data).

3.5.5. In the south of the area the northern edge of Channel A is observed. The edge of the channel is not particularly distinct with a gentle slope marking the edge of the channel. The channel comprises sands and gravels (Unit 3b) and a secondary cut feature is observed infilled with fine-grained sediment unit (Unit 4).

3.5.6. To the north of the channel edge within certain vibrocores a thin layer of clay and silt is observed overlying sands and gravels and is likely to be associated with Unit 4 either as remnants of deposition in the floodplain or as reworked sediment layers. There is no evidence in the geophysics data that this unit is widespread.

3.5.7. To the east of the area the sediments comprise a veneer (generally <1 m) of reworked shelly sands (Unit 8) overlying fine-grained silty sand (Unit 2).

3.5.8. Three bank features are observed in the area. The southern feature comprises well-sorted sands and gravels up to 3.7 m thick and comprises shelly sands and gravels with organic matter and occasional clay. The northwest bank comprises up to 3.5 m (1999 vibrocore) of sand and gravel with shells and some organic material. The northeast bank is observed infilling a depression in the surface of Unit 3b and is up to 2 m thick. The unit comprises a mix of sediment layers including shelly deposits, clays and some peat.

3.5.9. The banks are interpreted as reworked structures comprising reworked Unit 2, 3b and 4 sediments and are likely to have been formed subsequent to the deposition of Unit 4, most likely during the last marine transgression.

3.5.10. The EMS data indicates that the short-term licence area has been dredged every year between 1993 and 2011. Based on the cumulative intensity model the west of the area has undergone medium to high cumulative dredging intensity and to the east where there is higher fine-grained (silt and clay) content associated with the reworked bank and where the Unit 3b deposit is at its thinnest or absent there has been a low or very low level of cumulative dredging intensity.

3.5.11. Based on the EMS data it is likely that the target aggregate in the area is sand and gravel of Unit 3b. Due to the age of the geophysics data it is not possible to assess how much material has been removed since data acquisition in 1989. However, vibrocores acquired in 2009 in the west of the area indicate at least 2.5 m Unit 3b remaining.

3.5.12. Six reports were made through the BMAPA *Protocol for Reporting Finds of Archaeological Interest* from the short-term licence area in Area 360. The most

prominent report was of a number of mineralised bones, waterlogged wood, peat and a piece of struck flint (**WA 2177 – 2181**). The accuracy of positioning of the finds is referenced as the centre of the dredge lane estimated from a scale drawing trackplot. The dredged area was on the southern boundary of Area 360 orientated southwest – northeast.

3.5.13. Given the location of the dredge tracks and the proximity to the reworked bank in the southwest, it is considered likely that reworked peat was dredged from the bank and it is likely that the faunal remains were also dredged from the bank. Although, the faunal remains could have also been dredged from Unit 3b. The worked flint is an isolated occurrence in Area 360 and no lateral or vertical context can be applied. However, it is possible that the flint is either associated with Unit 3b *in situ*, or in a secondary context associated with Unit 3b or the reworked bank.

3.5.14. Further reports of faunal remains (**WA 2166**, **2182 – 2187**) indicate additional archaeological material within the short-term licence area. Again, the exact dredge locations are not known but it is considered likely that the faunal remains have been dredged from Unit 3b or the overlying reworked marine sediments (Unit 8).

3.5.15. Given the recovery of worked flint from the area, there is potential for further archaeological material within this short-term licence area.

Mitigation

3.5.16. Proposed mitigation is in the form of operational sampling, as detailed in **Section 2.5**. Within the Area 360 short-term licence area four palaeogeographic features are observed that may be the target for dredging activities. **Table 9** details which hypotheses will be tested by targeting each palaeogeographic feature.

Aggregate target	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
Unit 3b deposits	✓	✓	✓		✓	✓			✓		✓
Reworked bank structures	✓				✓		✓		✓		✓
Channel A deposits	✓		✓		✓		✓				✓
Unit 2 with veneer of Unit 8	✓				✓						✓

Table 9: Hypotheses tested by targeting specific palaeogeographic features in Area 360.

3.6. AREA 242/361

3.6.1. Area 242 and 361 are licenced to HAML and are situated in the east of the aggregate extraction block (**Figure 8**). There are two short-term licence areas. The westernmost covers the extreme east of Area 361 and the west of Area 242, and the eastern short-term licence area is situated in the central region of Area 242.

Data

3.6.2. Two datasets were assessed. The first covered Area 361 and was acquired by Andrews Survey in 1999 from the *Bon Accord* (Andrews Survey 1999a). Sub-bottom profiler and single-beam echosounder data were acquired at a line spacing of 200 m, orientated north-south with cross-lines at 1000 m. Data were generally of good quality.

3.6.3. The second dataset covered Area 242 and the easternmost area of 361 (plus Area 328 to the north). The data were acquired by Emu Ltd. in 2010 and comprised data acquired at 100 m line spacing, orientated north-south with east-west cross lines at

1000 m line spacing (Emu Ltd. 2010). Sub-bottom profiler data were provided as paper rolls and were generally of good quality.

3.6.4. Within the western short-term licence area there are 42 vibrocore locations acquired in 1999, 2001, 2003, 2005 and 2007 (Andrews Survey 1999b; 2001a; 2003a; 2005a; Lankelma Andrews 2007). The vibrocores were acquired with 3-m corers in all surveys except in 1999 (4-m corer) and 2003 (6-m corer).

3.6.5. In the central short-term licence area there are 9 vibrocore locations. The vibrocores were acquired with a 4-m corer (Andrews Survey 1999b).

Interpretation results

Western Area

3.6.6. The western area covers the easternmost region of Area 361 and the western region of Area 242. The area is dominated by Unit 3b deposits which are situated to the north of the channel feature, although the northern limit of the channel feature is not clear.

3.6.7. The 1999 dataset in Area 360 indicates that Unit 3b is up to 5 m thick comprising very gravelly sand overlain by a veneer of very shelly sand (reworked sediment). One vibrocore acquired in 2003 (VC3) indicates a more complex sequence of sediments comprising 0.5 m sand and gravel overlying silty sand with organic matter overlying shelly, gravelly sand which in turn overlies clay and sand layers. There is no structural change observed on the 1999 geophysics dataset and it is possible that the clay units may be remnants of Unit 4 associated with the later development of the channel feature. Also, the sediments might be associated with underlying Unit 2. Due to the dredging in the area between 1999 and 2003 it is possible that any apparent reworking of sediment maybe a result of dredging.

3.6.8. In the 2010 dataset it is obvious from the sub-bottom profiler and bathymetry data that the area has been heavily affected by dredging and in a certain area the sub-bottom profiler data indicates that Unit 3b has been mostly removed and Unit 2 is observed sub-cropping the recent marine sediment (Unit 8).To the west there is evidence of heavy dredging but Unit 3b is still observed in the data.

3.6.9. In the north of the short-term licence area the edge of the floodplain deposits are observed and to the north fine-grained silty sand interpreted as Unit 2 deposits are observed overlain by Unit 8 recent marine sediments. Vibrocore data indicates 2 m of shelly sand and gravel overlying fine to medium sands with clay layer.

3.6.10. The EMS data indicates medium cumulative intensity in the west, co-incident with the areas of heavy dredging observed on the sub-bottom profiler data. Less dredging has occurred in the east of the area, generally classified as low to medium cumulative intensity.

3.6.11. Three finds have been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest*. The position of the findspot is situated outside of the short-term area, approximately 10 m to the north. However, the point position is the northern point of the dredge lane and as such it is likely that the finds were dredged from the extensively dredged area in the short-term licence area. The reported finds included fragments of mammoth teeth, mammoth bone and possible deer bone (**WA 2188** – **2190**).

3.6.12. These faunal remains are likely to have been dredged from Unit 3b and probably represent faunal remains washed into the floodplain from further upstream.

Eastern Area

3.6.13. The eastern area is dominated by a large reworked bank feature. The bank is up to 6 m high with numerous phases of development and partially overlies Unit 3b. Unit 3b is observed only in the south of the area. However, prior to, or contemporaneous with the development of this bank the northern limit of the floodplain deposits have been eroded away. It is not clear how much was originally eroded, but the geophysics data shows at least 250 m (lateral extent) has been eroded in places.

3.6.14. The bank comprises a series of sand and gravel units, often shelly, as well as an upper unit of fine-grained silts and clays. The age of this feature is unknown but is not to have thought to have formed under marine conditions since the last transgression and may represent an inter-tidal or nearshore deposit formed during a previous rise or fall of the sea-level. The bank is important in that it shows natural erosion of the floodplain deposit (Unit 3b) that has not also been affected by dredging, indicating that in the east the northern limits of the floodplain were more extensive.

3.6.15. To the north of the area the bank feature overlies Unit 2 sediments (fine-grained silty sand).

3.6.16. EMS data indicates that the bank feature is extensively dredged to a low – medium cumulative intensity. Given the thickness of the bank feature the EMS data indicates that the primary target for aggregate in this area is the sands and gravels of the bank feature. However, to the east of the bank the EMS data indicates that some Unit 3b sediments may be a target.

3.6.17. A single reported find of a faunal fragment (**WA 2162**) has been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest*. **WA 2162** is a fossilised humerus fragment form a large mammal. The position of the findspot is not precise and represents the centre of a dredging lane from which the faunal fragment was dredged. It is likely that the faunal fragment was dredged from the large bank feature and is reworked from underlying sediments (either Unit 2 or Unit 3b). However, due to the accuracy of the position of the find, it is not clear that the faunal remains were dredged from within the short-term licence area.

Mitigation

3.6.18. Proposed mitigation is in the form of operational sampling, as detailed in **Section 2.5**. Within the Area 361/242 short-term licence area four palaeogeographic features are observed that may be the target for dredging activities. **Table 10** details which hypotheses will be tested by targeting each palaeogeographic feature.

Aggregate target	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
Unit 3b deposits (western and eastern areas)	✓	✓			✓	✓					✓
Major bank structure (eastern area)	✓				✓			✓			✓
Unit 3b heavily dredged/removed (western area)	✓				✓	✓				✓	✓

Aggregate target	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
Unit 2 with veneer of Unit 8 (western and eastern areas)	✓				✓						✓

Table 10: Hypotheses tested by targeting specific palaeogeographic features in Area 242/361 (west and east).

3.7. AREA 328

3.7.1. Area 328 is licenced to HAML and is situated in the northwest of the aggregate extraction block (**Figure 9**). Within licence dredge Area 328 there are four short-term licence areas.

Data

3.7.2. The assessed geophysics data comprised two datasets. Initially, a dataset acquired in 1999 was assessed (Andrews Survey 1999c). The data were acquired but Andrews Survey and comprised single-beam echosounder and sub-bottom profiler (boomer) data acquired at 200 m line spacing, orientated north-south with east-west orientated cross-lines at 1,000 m line spacing.

3.7.3. Based on the interpretation of this dataset, the 2010 dataset (Emu Ltd. 2010) was reviewed to assess changes in the seabed condition between acquisition of the datasets.

3.7.4. There are four short-term licence areas within Area 328. The western area is approximately 1.3 km^2. A total of 7 vibrocores are situated within the area acquired during surveys in 1999 and 2007 (Andrews Survey 1999b; Lankelma Andrews 2007). A 3-m corer was used to acquire the samples.

3.7.5. The west-central area is the largest (9.6 km^2) and there are 10 vibrocore locations within the area which were acquired in 1999 and 2001 (Andrews survey 1999b; 2001b).

3.7.6. The east-central area is 3.3 km^2 and there are 22 vibrocore locations within the area which were acquired in 1999, 2001, 2003 and 2007 (Andrews survey 1999b; 2001b; 2003b; Lankelma Andrews 2007). Vibrocores were acquired with 3-m corers with the exception of 2003 when a 6-m corer was used.

3.7.7. The eastern area is the smallest (1.3 km^2). A total of 11 vibrocore locations are situated within the area acquired in 1999, 2005 and 2007 (Andrews survey 1999b; 2005a; Lankelma Andrews 2007).

Interpretation results

Western Area

3.7.8. The sediments in the westernmost area generally comprise Unit 2 with a veneer of recent marine sediment (Unit 8). In the north of the area a bank feature is observed up to 5 m high infilling a slight depression in the surface of Unit 2. The bank feature is a northward prograding bank comprising sand and gravel and is overlain by modern recent mobile sediment, as observed by seabed ripples and sediment accumulation on the edge of the bank. There is little change in lateral and vertical extent between the 1999 and 2010 datasets indicating that the bank is relict and that the bank has not been extensively dredged in the intervening years.

3.7.9. The EMS data supports the geophysics data interpretation. Between 1999 and 2010 the area has only been dredged in three of those years and the cumulative intensity of dredging between 1993 and 2011 is classified as very low or low.

3.7.10. The aggregate target for this area is the recent reworked sediments and the reworked bank structure.

3.7.11. No artefacts, faunal remains or environmental remains have been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest* from this area.

Western-central Area

3.7.12. The western-central short-term licence area is the largest and the geology generally comprises Unit 2 (silty fine- to medium-grained sand) overlain by Unit 8 (predominantly reworked shelly, silty sand). To the south of the area there is a bank structure up to 3 m high comprising layers of silt, shelly sands and gravels. This is the northern extent of the bank observed in the central short-term licence area in Area 242.

3.7.13. In the very north of the area a small bank feature, the base of which infills a depression is observed. The bank comprises 3 m of northerly-dipping reflectors which has been interpreted as sands and gravels. There are no vibrocores acquired in this area so the sediment composition cannot be confirmed. The bank is interpreted as a reworked bank and is probably associated with the reworked bank structure observed in Area 212 to the west. The bank feature is overlain by reworked marine sediments (Unit 8) with occasional small sandwaves (up to 2 m high) observed in the data.

3.7.14. In the north of the short-term licence area the geophysics data (both 1999 and 2010) indicate that dredging has heavily affected and seabed bedforms similar to sandwave structures are observed up to 5 m high. These bedforms are a result of dredging rather than purely natural processes.

3.7.15. EMS data indicates that the area has been dredged in up to 8 years between 1993 and 2011. Predominantly the area has been dredged at very low to low dredging intensity with medium cumulative intensity in the south (targeting the reworked bank structure) and in the north (targeting the thicker Unit 8 reworked sediments).

3.7.16. No artefacts, faunal remains or environmental remains have been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest* from this area.

Eastern-central Area

3.7.17. The eastern-central area predominantly comprises a veneer of recent mobile sediments (Unit 8) overlying Unit 2 sediments comprising silty sands. In the east of the area the Unit 8 sediments thicken to form a bank feature up to 2 m high comprising shelly, silty sands and gravels. In the southwest a large-scale bank feature is observed (a continuation the bank situated in the western-central area).

3.7.18. The bank is composed of sands and gravels and is overlain by a veneer of reworked mobile sediments (Unit 8).

3.7.19. EMS data indicates that the area has been dredged in up to 8 years between 1993 and 2011. Predominantly the area has been dredged at very low to low dredging

intensity with medium cumulative intensity in the south (targeting the reworked bank structure) and in the north (targeting the thicker Unit 8 reworked sediments).

3.7.20. The central area has been dredged to medium cumulative intensity with small localised areas of high cumulative intensity. The dredge target appears to be the reworked Unit 8 sediments. In the north there is a channel feature infilled with up to 5 m well-layered sediments interpreted as Unit 3b outlier. This is overlain by up to 2 m reworked sediment and it appears that it is this sediment that is targeted during dredging, rather than the Unit 3b sediments.

3.7.21. No artefacts, faunal remains or environmental remains have been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest* from this area.

Eastern Area

3.7.22. The eastern area comprises a veneer of up to 2 m of reworked marine Unit 8 sediments overlying Unit 2 sediments. In the north and the south there are two areas interpreted as possible outliers of Unit 3b sediments. The northern feature comprises an infilled depression overlain by a veneer of Unit 8 sediments. There are no vibrocore locations in this area to indicate the composition of the infill sediments.

3.7.23. To the south of the area Unit 3b sediments comprise a gravelly sand up to 3 m thick overlain by up to 1 m reworked clayey, gravelly sand interpreted as Unit 8 reworked sediments.

3.7.24. The EMS data indicates that the area has been dredged over six years between 1993 and 2011. The area has been dredged to medium cumulative intensity over the six years and predominantly targets the veneer of reworked sediments. It is possible that the dredging also targets the two outliers interpreted as Unit 3b sediments.

3.7.25. No artefacts, faunal remains or environmental remains have been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest* from this area.

Mitigation

3.7.26. Proposed mitigation is in the form of operational sampling, as detailed in **Section 2.5**. Within the Area 328 short-term licence area six palaeogeographic features are observed that may be the target for dredging activities. **Table 11** details which hypotheses will be tested by targeting each palaeogeographic feature.

Aggregate target	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
Unit 3b outlier deposits (eastern-central and eastern areas)	✓	✓		✓	✓	✓					✓
Major bank structure (western-central and eastern-central area)	✓				✓			✓			✓
Reworked bank structure (western, western-central and eastern-central)	✓				✓		✓				✓
Unit 3b heavily dredged/removed (western area)	✓				✓					✓	✓
EMS indicates high cumulative intensity (eastern-central)	✓				✓				✓		✓

Aggregate target	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
Unit 2 with veneer of Unit 8 (all areas)	✓				✓						✓

Table 11: Hypotheses tested by targeting specific palaeogeographic features in Area 328 (west, central-west, central-east and east).

3.8. AREA 296

3.8.1. Area 296 is licenced to TMDL and is situated in the north of the aggregate extraction block adjacent to Area 212 (**Figure 10**).

Data

3.8.2. Two geophysical surveys were assessed in 1991 and 2007. In 1991 boomer data were acquired by Geoteam at 300 m line spacing orientated north-south. Boomer data were supplied as paper rolls.

3.8.3. The survey in June 2007 was undertaken by GardlineLankelma onboard the *Nat West II*. Data comprised GeoAcoustics Geo Swath multibeam echosounder data and sub-bottom profiler data acquired with an EG & G Uniboom surface-tow boomer. Data were acquired a 200 m line spacing orientated north-south with cross lines at 450 m line spacing orientated northeast-southwest (GardlineLankelma 2007). The survey area covered Area 296 and Area 494 situated adjacent and to the north.

3.8.4. Both datasets were generally of good quality.

3.8.5. Geotechnical data were acquired in 2000, 2002 and 2008. The survey in 2000 was conducted by Gardline Surveys Ltd. and acquired 35 3-m vibrocores (Gardline Surveys Ltd. 2000). The 2002 survey acquired 25 vibrocores using a 3-m vibrocore and was conducted by Andrews Survey Ltd. on the vessel *Goosander* (Andrews Survey Ltd 2002c). In 2008 10 5-m vibrocores were acquired by GardlineLankelma from the M/V *Flatholm* (GardlineLankelma 2008). All 70 vibrocores are situated in the short-term licence area.

Interpretation results

3.8.6. The short-term licence area is dominated by a large bank feature. In the 1991 data the bank was observed throughout the centre of the area and is observed around 2 m at the edges and up to 6 m high in the central area of the feature. The geophysical data indicates evidence of cross-bedding. Vibrocores indicate that the bank feature comprises layers of shelly sand and gravel.

3.8.7. In the 2007 geophysical dataset three small banks are observed. These are thought to be part of the bank observed in the 1991 dataset. It is clear that much of the 1991 bank feature has been removed by subsequent dredging between 1991 and 2007. However, the banks laterally extend beyond the limits of the bank identified in 1991 primarily due to better quality and better coverage of data (**Figure 10**). This also may be due to re-distribution of sediments during dredging and mobile sediments within the area (as observed by sandwaves).

3.8.8. In the 2007 dataset the western bank is up to 4 m high, the central bank 3 m high and the eastern bank 2 m high.

3.8.9. Beyond the limits of the bank the geophysics data indicates a veneer (<1 m) of shelly sand and gravel interpreted as reworked marine post-transgression sediment

(Unit 8) overlying slightly silty sand (Unit 2). Occasional sandwaves up to 2 m high are observed throughout the area, including on top of the bank feature.

3.8.10. In the northeast corner of the area the southern edge of a large reworked cut and bank feature is observed comprising up to 4 m shelly gravelly sand and overlain, in places, by sandwaves comprising shelly sand.

3.8.11. There is no obvious evidence of dredging activity in the 1991 dataset. However, by 2007 there is clear evidence of dredging activity as described above with the reworked bank the aggregate target. The EMS data indicates that dredging has continued targeting this bank feature since the acquisition of the 2007 dataset between 2008 and 2011.

3.8.12. No artefacts, faunal remains or environmental remains have been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest* from Area 296.

Mitigation

3.8.13. Proposed mitigation is in the form of operational sampling, as detailed in **Section 2.5**. Within the Area 296 short-term licence area two palaeogeographic features are observed that may be the target for dredging activities. **Table 12** details which hypotheses will be tested by targeting each palaeogeographic feature.

Aggregate target	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
Reworked bank structure	✓				✓		✓		✓		✓
Unit 2 with veneer of Unit 8	✓				✓						✓

Table 12: Hypotheses tested by targeting specific palaeogeographic features in Area 296.

3.9. AREA 212

3.9.1. Area 212 is licenced to HAML and is situated in the north of the aggregate extraction block adjacent to Area 296 (**Figure 11**).

Data

3.9.2. Two geophysics datasets were reviewed in Area 212. The first dataset was acquired between 17th and 19th June 1999 by Andrews Survey using the vessel *Bon Accord* (Andrews 1999d). Sub-bottom profiler (boomer source) data were assessed from paper rolls. Data were acquired 200 m line spacing orientated north – south with cross-lines acquired at 1,000 m line spacing. The survey area covered a much larger area (24.615 km^2) than the short-term licence area with the licence area situated in the northwest corner of the survey area (**Figure 11**). The data was generally of good quality.

3.9.3. The second geophysical dataset was acquired in 2008 by EMU Ltd from the RV *Discovery* on 18th February 2008 (EMU Ltd. 2008). The sub-bottom profiler data were acquired using an Applied Acoustics boomer system and data were acquired at 100 m line spacing with north-south orientation. The data were provided as paper rolls and the data were generally of good quality. The 2008 survey dataset covers the short-term licence area.

3.9.4. One geotechnical dataset acquired in 1999 was used in the assessment. The survey comprised 27 vibrocore logs and photographs (Andrews Survey 1999b). The

data were acquired in July 1999 from the *Bon Accord* using a 3-m hydraulic corer. Only 5 vibrocores are situated within the Area 212 short-term licence area.

Interpretation results

3.9.5. Within the short-term licence area the 1999 dataset indicates that the geology generally comprises Unit 2 comprising clayey, slightly gravelly, silty sand.

3.9.6. In places Unit 2 is overlain by a possible localised lag deposit up to 1m thick which possibly comprises re-worked Unit 3b sediments and consists of gravelly sand. The lag deposit is only indicated by the vibrocore logs (VCA21) and is not identified as a feature in the geophysical data. In the north of the area a large re-worked bank up to 4m thick is observed similar to those observed in Area 296. The bank feature is observed in both datasets and comprises a well-structured unit. In the 2008 dataset there is some evidence of dredging of the southern section of the bank and an east-west orientated sandwave is observed on top of the bank. The bank is not targeted by a vibrocore, however is expected to comprise layers of sand and gravel and possibly comprises reworked Unit 3b sediments.

3.9.7. The bank feature is reworked and the timing of this re-working is unknown. Based on the form of the bank and the presence of sandwaves overlying the bank it is thought that the bank may have formed during a transgression of regression period subsequent to deposition of Unit 3 but not during the last transgression.

3.9.8. Throughout the area Unit 2 and reworked Unit 3b sediments are overlain by a veneer of marine sediments which form into reworked bedforms such as sandwaves (Unit 8). The sandwaves are generally up to 2 m high, and are occasionally 5 m high in the southeast of the area. Vibrocores indicate that this unit comprises shelly, slightly gravelly, sands.

3.9.9. Evidence of dredging is observed throughout the area both on the geophysics data (1999 and 2008 datasets) and on the EMS data. EMS data indicates that short-term licence area within Area 212 has been dredged each year between 1993 and 2011.The principal aggregate target appears to be the reworked Unit 3b sediments and the marine sands and gravels.

3.9.10. No artefacts, faunal remains or environmental remains have been reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest* from Area 212.

Mitigation

3.9.11. Proposed mitigation is in the form of operational sampling, as detailed in **Section 2.5**. Within the Area 212 short-term licence area two palaeogeographic features are observed that may be the target for dredging activities. **Table 13** details which hypotheses will be tested by targeting each palaeogeographic feature.

Aggregate target	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
Reworked bank structure	✓				✓		✓				✓
Unit 2 with veneer of Unit 8	✓				✓						✓

Table 13: Hypotheses tested by targeting specific palaeogeographic features in Area 212.

4. CONCLUSIONS

4.1.1. The primary objectives of this report were to detail which short-term licence areas contain Wolstonian floodplain (Unit 3b) sediments, the effects of dredging activities on these sediments and whether Unit 3b is the aggregate target.

4.1.2. Unit 3b floodplain deposits were identified in the following areas: Areas 240, 228, 319, 251, 360, 242/361 and 328 (central-eastern and eastern areas only). Unit 3b sediments within the channel were only observed in Area 240, 228, 360 and 251 (eastern area only).

4.1.3. Within the short-term licence areas in which Unit 3b sediments were identified it is considered likely that Unit 3b is the target for dredging, with the exception of Area 242/361 (eastern area). In the eastern area of Area 242/361 the likely aggregate target is the overlying major reworked bank structure.

4.1.4. However, in areas where Unit 3b is observed, the unit is not necessarily the only target for dredging. Based on the data the overlying reworked sediments of Unit 8 are also a target, particularly where this unit thickens to more than a veneer of sediment.

4.1.5. In the short-term licence areas where Unit 3b has not been identified (Area 212, 296 and 328 (west and central-west areas), the target for dredging is considered to be the reworked bank structures and Unit 8 (reworked marine sediments).

4.1.6. Natural reworking of Unit 3b sediments is observed in Area 240, 319, 251 and 242/361 (eastern area). In Area 240 Unit 3b sediments have been reworked by the re-activation of Channel A and deposition of Unit 4 sediments, and the development of Channel B and subsequent deposition of Unit 7. The development of Channel B during the early Holocene also caused reworking of Unit 3b deposits in Areas 319 and 251 (western area). In the eastern short-term licence area of Area 242/361 a major reworked bank is observed overlying Unit 3b sediments and there is evidence in the geophysics data suggesting that during the development of the bank some of the underlying Unit 3b sediments were eroded.

4.1.7. In Areas 240, 228 and 242/361 (western area) there is evidence in the geophysics data to suggest that dredging activity has heavily affected or completely removed Unit 3b sediments. In Area 228 it is difficult to discriminate whether Unit 3b has been entirely removed.

4.1.8. Based on the results of the Palaeo-Yare catchment assessment (Wessex Archaeology 2012a) a series of hypotheses were developed that could be applied to the licence areas within the region in order to test the key conclusions and address any remaining uncertainties. The hypotheses are predominantly focussed on the potential for artefacts within the Palaeo-Yare floodplain deposits (Unit 3b).

4.1.9. It is envisioned that these hypotheses will be tested through physical sampling and monitoring of dredge loads from the licence areas as detailed in the *Provisional Written Scheme of Investigations for the Anglian Region*. **Table 14** provides a summary of the hypotheses that will be tested during dredging within each short-term licence area.

Short-term aggregate licence area	Sub-licences	H1a	H1b	H2a	H2b	H2c	H3a	H3b	H3c	H4a	H4b	H5a
240		✓	✓	✓		✓	✓	✓		✓	✓	✓
228		✓	✓	✓		✓	✓	✓			✓	✓
319		✓	✓			✓	✓	✓		✓		✓
251	West	✓	✓			✓	✓	✓				✓
	Central	✓	✓			✓	✓					✓
	East	✓	✓	✓		✓	✓	✓				✓
360		✓	✓	✓		✓	✓	✓		✓		✓
361/ 242	West	✓	✓			✓	✓				✓	✓
	East	✓	✓			✓	✓		✓			✓
328	West	✓				✓		✓			✓	✓
	West-Central	✓				✓		✓	✓			✓
	East-Central	✓	✓		✓	✓	✓	✓	✓	✓		✓
	East	✓	✓		✓	✓	✓					✓
296		✓				✓		✓		✓		✓
212		✓				✓		✓				✓

Table 14: Summary of hypotheses tested in each short-term licence area.

4.1.10. The information resulting from the testing of these hypotheses will enhance the knowledge of the presence of Palaeolithic material in the area and will inform the continuing monitoring activity in the licence areas.

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APPENDIX I: GAZETTEER OF KNOWN ARCHAEOLOGY

WAID	UTM31N Easting	UTM31N Northing	Site type	Position accuracy	Geological Context	Assoc. Offshore Unit	Arch. Period	Description	Sources
2145	426683	5822349	FINDSPOT	Centre of N-S orientated dredge lane			Middle Palaeolithic; Upper Palaeolithic	2 sections of de-laminated mammoth tusk recovered from Area 240: Hanson_0126 3 (2007 - 2008)	BMAPA_5103
2146	426460	5822460	FINDSPOT	Centre of dredge tacks in the HAML exclusion zone			Palaeolithic	Mammoth teeth, tusk fragments and antlers. Significant Palaeolithic assemblage. Due to importance not ultimately addressed through implementation service recovered from Area 240: Hanson_0133 3 (2007 - 2008)	
2147	426460	5822460	FINDSPOT	Centre of dredge tacks in the HAML exclusion zone		2,3,5/6	Palaeolithic	88 lithic finds, incl. 28 handaxes. Significant Palaeolithic assemblage. Due to importance not ultimately addressed through implementation service recovered from Area 240: Hanson_0133 3 (2007 - 2008)	
2148	425198	5824420	Environmental	Reported position		7	Mesolithic	Large concentrations of peat recovered from Area 240: Hanson_0150 3 (2007 - 2008)	BMAPA_5153
2149	425215	5824442	Environmental	Reported position		7	Mesolithic	Large concentrations of peat recovered from Area 240: Hanson_0150 3 (2007 - 2008)	BMAPA_5153
2150	425197	5824456	Environmental	Reported position		7	Mesolithic	Large concentrations of peat recovered from Area 240: Hanson_0150 3 (2007 - 2008)	BMAPA_5153
2151	425286	5824478	Environmental	Reported position		7	Mesolithic	Large concentrations of peat recovered from Area 240: Hanson_0150 3 (2007 - 2008)	BMAPA_5153
2152	425211	5824491	Environmental	Reported position		7	Mesolithic	Large concentrations of peat recovered from Area 240: Hanson_0150 3 (2007 - 2008)	BMAPA_5153
2153	425239	5824497	Environmental	Reported position		7	Mesolithic	Large concentrations of peat recovered from Area 240: Hanson_0150 3 (2007 - 2008)	BMAPA_5153
2154	425298	5824504	Environmental	Reported position		7	Mesolithic	Large concentrations of peat recovered from Area 240: Hanson_0150 3 (2007 - 2008)	BMAPA_5153
2155	425321	5824512	Environmental	Reported position		7	Mesolithic	Large concentrations of peat recovered from Area 240: Hanson_0150 3 (2007 - 2008)	BMAPA_5153
2156	425319	5824515	Environmental	Reported position		7	Mesolithic	Large concentrations of peat recovered from Area 240: Hanson_0150 3 (2007 - 2008)	BMAPA_5153
2157	425294	5824588	Environmental	Reported position		7	Mesolithic	Large concentrations of peat recovered from Area 240: Hanson_0150 3 (2007 - 2008)	BMAPA_5153

WAID	UTM31N Easting	UTM31N Northing	Site type	Position accuracy	Geological Context	Assoc. Offshore Unit	Arch. Period	Description	Sources
2158	425192	5824198	Faunal	Centrepoint of dredge lane			Palaeolithic	Mammoth tooth recovered from Area 240: Hanson_0169 3 (2007 - 2008)	BMAPA_5196
2159	425260	5824596	Faunal	Centrepoint of dredge lane			Palaeolithic	2 mammoth teeth recovered from Area 240: Hanson_0180 3 (2007 - 2008)	BMAPA_5179
2160	425260	5824596	FINDSPOT	Centrepoint of dredge lane			Unknown	Struck flint, probable waste flake recovered from Area 240: Hanson_0180 3 (2007 - 2008)	BMAPA_5180
2161	425465	5826119	Faunal	Approximate position of vessel			Palaeolithic	Mammoth tooth recovered from Area 240: Hanson_0268 5 (2009 - 2010)	BMAPA_5336
2162	439002	5825275	Faunal	Centrepoint of dredge lane			Unknown	Fossilised humerus fragment from a large mammal, possibly a mammoth recovered from Area 242_328A_361B_361C_HAML: Hanson_0202 4 (2008 - 2009)	BMAPA_5220
2163	423654	5816000	Faunal	Poor positioning. Could be Area 251 or 102 (Humber)			Middle Palaeolithic	Animal bone, possible hippopotamus (?Ipswichian interglacial) recovered from Area 251: CEMEX_0093 2 (2006 - 2007)	BMAPA_5074
2164	422508	5817821	Environmental	Centrepoint of 1400m N-S track		7	Mesolithic	Peat sample recovered from Area 251: CEMEX_0296 5 (2009 - 2010)	BMAPA_5349
2165	434520	5820104	Faunal	Approximate position of vessel			Unknown	Animal bone, auroch metatarsal recovered from Area 251: CEMEX_0307 5 (2009 - 2010)	BMAPA_5361
2166	434908	5822739	Faunal	Approximate position of vessel			Unknown	Mammoth Bone recovered from Area 360: CEMEX_0340 6 (2010 - 2011)	BMAPA_5394
2167	426144	5827497	Faunal	Centrepoint of dredge lane			Unknown	Fragment of bone, possible deer metatarsus recovered from Area 254: UMD_0041 1 (2005 - 2006)	BMAPA_5016
2168	426144	5827497	Faunal	Centrepoint of dredge lane			Palaeolithic	Upper molar of a woolly mammoth (Mammuthus primigenius). recovered from Area 254: UMD_0045 1 (2005 - 2006)	BMAPA_5024

WAID	UTM31N Easting	UTM31N Northing	Site type	Position accuracy	Geological Context	Assoc. Offshore Unit	Arch. Period	Description	Sources
2169	429984	5832115	Faunal	Centre of Area 296			Unknown	Piece of bone from a large mammal recovered from Area 296: UMA_0076 2 (2006 - 2007)	BMAPA_5062
2170	429984	5832115	Faunal	Centre of Area 296			Palaeolithic	Mammoth tooth, largely unworn so possible milk tooth recovered from Area 296: UMA_0107 2 (2006 - 2007)	BMAPA_5116
2171	429983	5832115	Faunal	Centre of Area 296			Unknown	Femur of a large mammal recovered from Area 296: UMA_0117 3 (2007 - 2008)	BMAPA_5088
2172	429984	5832115	Faunal	Centre of Area 297			Unknown	Degraded animal bone, possibly artiodactyl recovered from Area 296: UMA_0160 3 (2007 - 2008)	BMAPA_5161
2173	429984	5832115	Faunal	Centre of Area 298			Palaeolithic	Fragment of an upper cheek tooth of a fossil mammoth, possibly from a relatively young animal recovered from Area 296: Tarmac_0332 5 (2009 - 2010)	BMAPA_5399
2174	429983	5832115	Faunal	Centre of Area 299			Unknown	Mammoth Tooth recovered from Area 296: Tarmac_0354 6 (2010 - 2011)	BMAPA_5426
2175	423232	5819411	Faunal	Approximate position (within 1800m)			Palaeolithic	Fragment of tusk, possibly mammoth recovered from Area 319: CEMEX_0276 5 (2009 - 2010)	BMAPA_5339
2176	423553	5819963	Faunal	Approximate position (within 1200m)			Unknown	Left metatarsus of a large deer, possibly red deer recovered from Area 319: CEMEX_0281 5 (2009 - 2010)	BMAPA_5341
2177	434832	5822648	Environmental	Centrepoint of dredge lane			Early Mesolithic	c 250 large fragments of waterlogged and mineralised wood, eroding peat layer recovered from Area 360: CEMEX_0039 1 (2005 - 2006)	BMAPA_5044
2178	434832	5822648	Environmental	Centrepoint of dredge lane			Early Mesolithic	4 fragments of fibrous herbaceous peat, containing possible fine comminuted charcoal recovered from Area 360: CEMEX_0039 1 (2005 - 2006)	BMAPA_5045
2179	434832	5822648	Faunal	Centrepoint of dredge lane			Early Mesolithic	12 fragments of mineralised bone, probably large herbivore recovered from Area 360: CEMEX_0039 1 (2005 - 2006)	BMAPA_5046
2180	434832	5822648	Faunal	Centrepoint of dredge lane			Early Mesolithic	3 fragments of deer antler recovered from Area 360: CEMEX_0039 1 (2005 - 2006)	BMAPA_5047

WAID	UTM31N Easting	UTM31N Northing	Site type	Position accuracy	Geological Context	Assoc. Offshore Unit	Arch. Period	Description	Sources
2181	434832	5822648	FINDSPOT	Centrepoint of dredge lane			Early Mesolithic	Fragment of worked flint recovered from Area 360: CEMEX_0039 1 (2005 - 2006)	BMAPA_5048
2182	434823	5822459	Faunal	Approximate position			Palaeolithic	Mammoth tooth recovered from Area 360: Cemex_0265 4 (2008 - 2009)	BMAPA_5338
2183	434823	5822459	Faunal	Approximate position			Palaeolithic	Antler, possible Megaloceros (giant deer) recovered from Area 360: Cemex_0265 4 (2008 - 2009)	BMAPA_5338
2184	434344	5822621	Faunal	Approximate position			Palaeolithic	Elephant, or possibly mammoth, atlas vertebra recovered from Area 360: CEMEX_0284 5 (2009 - 2010)	BMAPA_5346
2185	433476	5822697	Faunal	Approximate position (within 500m)			Unknown	Fossilised Deer Bone recovered from Area 360: CEMEX_0341 6 (2010 - 2011)	BMAPA_5386
2186	433890	5822660	Faunal	Centrepoint of dredge lane			Unknown	Bones and teeth: 1 claw or tooth; 1 large bone - split in two; 2 pieces of bone - one with remains of marrow; and 1 piece of vertebrate recovered from Area 360: CEMEX_0379 7 (2011-2012)	BMAPA_5445
2187	435025	5823016	Faunal	Centrepoint of dredge lane			Unknown	Fossilised bone recovered from Area 360: CEMEX_0405 7 (2011-2012)	
2188	437463	5823517	Faunal	Approximate position			Palaeolithic	Pieces of mammoth bone recovered from Area 361: Hanson_0018 1 (2005 - 2006)	BMAPA_5011
2189	437463	5823517	Faunal	Centrepoint of dredge lane			Palaeolithic	Pieces of mammoth teeth recovered from Area 361: Hanson_0018 1 (2005 - 2006)	BMAPA_5012
2190	437463	5823517	Faunal	Centrepoint of dredge lane			Palaeolithic; Mesolithic	Possible deer bone recovered from Area 361: Hanson_0018 1 (2005 - 2006)	BMAPA_5013
2191	433070	5823801	FINDSPOT	Centre of East Coast Dredging block			Palaeolithic	Flint flake recovered from Area Unknown: UMA_0182 3 (2007 - 2008)	BMAPA_5182

WAID	UTM31N Easting	UTM31N Northing	Site type	Position accuracy	Geological Context	Assoc. Offshore Unit	Arch. Period	Description	Sources
2192	426340	5821854	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	This is a mid-section of a tertiary flake, with well-defined conchoidal rings on the ventral surface. The dorsal surface also has a number of converging negative flake scars. It has a slightly dipping profile. These features, including the way in which it has broken, have been noted on hand axe thinning flakes. Vertebra. Fish. Salmonid?	T1_G22
2193	426244	5821816	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	Flake similar to that from sample T1_G22 (described above). This flake also lacks the proximal and distal ends, so valuable details of the technology are lost. However, the dorsal surface has a number of residual flake scars, which form a radial pattern. This flake is not as convincing as T1_G22, but is still a probability.	T1_G25
2194	426320	5821851	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	This is a stained and patinated primary, hard hammer struck flake. The most convincing feature that indicates human production is the clear striking platform and well positioned point of percussion well back from the edge of the core. Three small flakes, all open to some doubt.	T1_G23
2195	426491	5821890	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	A very thin flake in mint condition and unstained. The point of percussion is located at the edge of the flake. It is possible that this flake was removed by natural processes, however the fact that there are apparent traces of platform preparation, that do not represent edge crushing, and other facets suggest that this is a product of debitage. Centrotarsal. Bovine/Cervid. Fossilised and Fossilised unidentifiable bone.	T1_G5

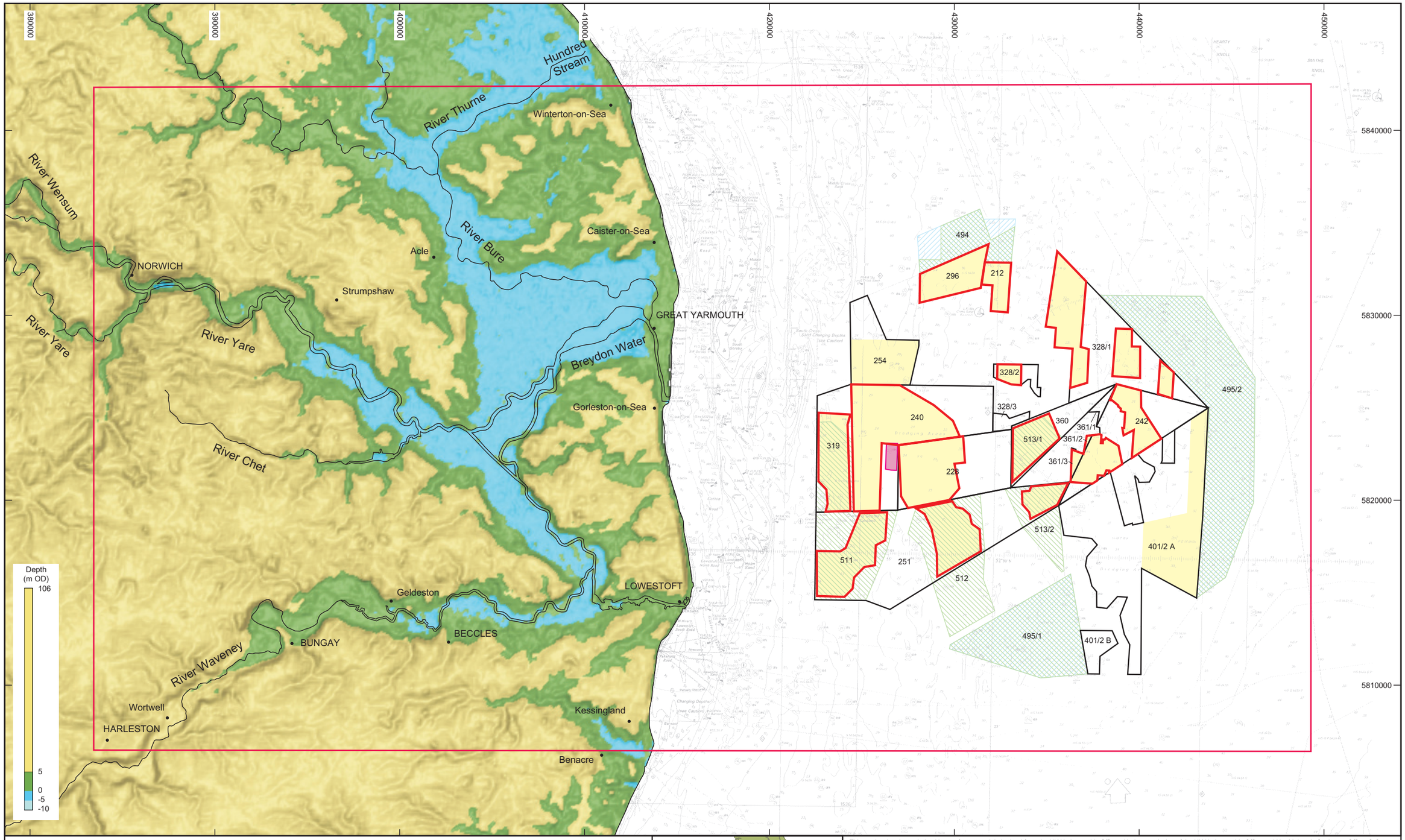
WAID	UTM31N Easting	UTM31N Northing	Site type	Position accuracy	Geological Context	Assoc. Offshore Unit	Arch. Period	Description	Sources
2196	426493	5821897	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	A heavily rolled flake with a glossy finish. It is naturally backed. The proximal end is missing, having been chipped by recent damage; however the presence of clear conchoidal rings on the ventral surface and similar well defined traces on the dorsal surface, indicating a previous removal, suggest that this flake is genuine. 2x unidentifiable small bone fragments. Fossilised.	T1_G5a
2197	426361	5821859	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	This is an elongated hard hammer struck flake. It is unstained and unpatinated. The argument that it is a genuine artefact relates to the presence of other flake scars, which suggest that it is product of deliberate, systematic debitage.	T1_G21a
2198	426537	5821915	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	This is a primary flake that is both patinated and stained. It is hard hammer struck. There is always potential for doubt with a flake of this type; however the striking platform is plain and the point of percussion is well positioned on the striking platform and not a glancing blow.	T1_G6
2199	426529	5821916	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	Clearly hard hammer struck and is part of a 'compound' removal, where a flake was removed with this one at the same time and the same blow. While not certain, it is probably due to human workmanship. Small flint is principally cortical and not convincing.	T1_G9
2200	426286	5821832	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	A small patinated and rolled primary flake, open to some doubt.	T1_G7
2201	426299	5821840	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	Unidentifiable small bone fragments. Recent.	T1_G8
2202	426427	5821879	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	2x bone pieces. The internal structure is mammalian, possibly a terrestrial mammal.	T1_G27
2203	426178	5822054	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	Technically a flake, although open to some doubt.	T2_G1b
2204	426010	5821898	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	Small flake that may well be a product of gravel abrasion.	T2_G5

WAID	UTM31N Easting	UTM31N Northing	Site type	Position accuracy	Geological Context	Assoc. Offshore Unit	Arch. Period	Description	Sources
2205	426715	5823985	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	Vertebra. Aquatic mammal ?dolphin. Recent.	T3_G5
2206	426326	5821823	FINDSPOT	Centrepoint	Unit 3 grab sample	3?	Unknown	During the East Coast REC survey (Limpenny et al. 2011) a flint artefact, identified as a broken secondary flake, was identified during onboard processing of a clamshell sample at station CG6, which is situated to the west of the HAML exclusion zone. The artefact is a broken secondary flake. The surviving dimensions of the piece are approximately 60 x 43 x 9 mm, although a transverse break means that the piece was originally considerably longer.	CG6
2207	426312	5821970	FINDSPOT	Approximate position: mixed load from transect 1A and 1B	Unit 3 target	3?	Palaeolithic	Mixed wharf. Large, mainly cortical flake, unpatinated, unstained, 3 points of impact, hard, slightly rolled, 1 inverse removal; dubious piece primarily thermal and stained but with three negative alternate removals (probably regard as reject)	77860_0000
2208	426312	5821970	FINDSPOT	Approximate position: mixed load from transect 1A and 1B	Unit 3 target	3?	Palaeolithic	Mixed. Cordiform on flake blank, ventral surface flaked sufficient to thin butt, dorsal covering flaking, lightly stained, sharp, 135x95x39mm	77860_1000
2209	426312	5821970	FINDSPOT	Approximate position: mixed load from transect 1A and 1B	Unit 3 target	3?	Palaeolithic	Mixed. Large tertiary flake, hard hammer, plain butt, lightly stained, partially radial flake scars, possibly from Levallois flake core. 95x107x19mm	77860_1002
2210	426312	5821970	FINDSPOT	Approximate position: mixed load from transect 1A and 1B	Unit 3 target	3?	Palaeolithic	Mixed. Large primary flake, unpatinated/unstained, mint/sharp, could be modern on condition but included due to well-placed point of impact 137x106x37mm	77860_1006

WAID	UTM31N Easting	UTM31N Northing	Site type	Position accuracy	Geological Context	Assoc. Offshore Unit	Arch. Period	Description	Sources
2211	426312	5821970	FINDSPOT	Approximate position: mixed load from transect 1A and 1B	Unit 3 target	3?	Palaeolithic	Trip 1 mixed Large flake, stained, sharp/slightly rolled, some modern edge damage. 102x103x23 mm	77860_1007
2212	426312	5821970	FINDSPOT	Approximate position: mixed load from transect 1A and 1B	Unit 3 target	3?	Palaeolithic	Mixed. 1 large primary flake, thermal dorsal surface, cortical butt, stained, slightly rolled/rolled	77860_1008
2213	426312	5821970	FINDSPOT	Approximate position: mixed load from transect 1A and 1B	Unit 3 target	3?	Palaeolithic	Mixed. Stained secondary, hard hammer struck flake, slightly rolled/rolled, cortical butt, clumsy crushed impact 86x82x23mm	77860_1009
2214	426312	5821970	FINDSPOT	Approximate position: mixed load from transect 1A and 1B	Unit 3 target	3?	Palaeolithic	Mixed (wharf). Hand axe with plano-convex cross section, probably made on flake. Both sides with covering flaking. Lightly stained, slightly rolled, tip absent. 113x80x23mm	77860_1011
2215	426312	5821970	FINDSPOT	Approximate position: mixed load from transect 1A and 1B	Unit 3 target	3?	Palaeolithic	Mixed wharf. Core fragment with a pot lid fracture, but with relict flake scars (2 deeply invasive and 1 alternate) that are rolled suggesting the recently formed pot lid may have come from a humanly modified block.	77860_1012
2216	426312	5821970	FINDSPOT	Centrepoint of track 1B	Unit 3 target	3?	Palaeolithic	1 tertiary flake, punctiform butt, possibly natural; rolled secondary flake, butt damaged, rolled, stained, dist part broken; tertiary flake, cortical butt, lightly rolled/rolled, lightly patinated.	77860_1018
2217	426391	5821942	FINDSPOT	Approximate position: mixed load from transect 2A and 2B	Unit 3 target	3?	Palaeolithic	Mixed wharf. Large tertiary flake, stained, slightly rolled/rolled, plain butt, uncertain mode, from flake core 77x114x55mm	77860_1038

WAID	UTM31N Easting	UTM31N Northing	Site type	Position accuracy	Geological Context	Assoc. Offshore Unit	Arch. Period	Description	Sources
2218	426391	5821942	FINDSPOT	Approximate position: mixed load from transect 2A and 2B	Unit 3 target	3?	Palaeolithic	Mixed wharf. Large primary hard hammer struck flake, rolled stained, plain butt 97x112x21mm	77860_1039
2219	424933	5820703	FINDSPOT	Centrepoint of track 2A	Unit 3 target	3?	Palaeolithic	Flake linear butt, mint ventral, unpatinated, unstained, modern; broken thinning/shaping flake, opposed scars, linear butt.	77860_1024
2220	426391	5821942	FINDSPOT	Centrepoint of track 2B	Unit 3 target	3?	Palaeolithic	Both flakes might be anthropogenic	77860_1025
2221	424944	5820639	FINDSPOT	Centrepoint of track 4A	Unit 3 target	3?	Palaeolithic	Large hard hammer secondary flake. Possibly represents a stage of hand axe roughing out/shaping. 3 unidirectional flake scars. Good flint, unstained, slightly rolled, unpatinated. Plain butt, no preparation	77860_1045
2222	426978	5823332	FINDSPOT	Approximate position: mixed load from transect 5A and 5B	Unit 3 target	3?	Palaeolithic	Mixed oversize pile. Hand axe. Ovate/cordiform. Tip absent, well executed bifacial covering flaking, lightly stained, sharp, 87x92x23mm	77860_1085
2223	425017	5820908	FINDSPOT	Centrepoint of track 5A	Unit 3 target	3?	Palaeolithic	Bulk. Tertiary, slightly rolled, lightly stained, no preparation, possible signs of soft percussion	77860_1054
2224	426978	5823332	FINDSPOT	Centrepoint of track 5B	Unit 3 target	3?	Palaeolithic	Broken hard hammer secondary flake, light differential staining, sharp. Unidirectional flaking, plain butt 68x57x22mm; rolled primary flake, probably collision	77860_1058
2225	424979	5820780	FINDSPOT	Centrepoint of track 7A	Unit 3 target	3?	Palaeolithic	Broken flake thermal dorsal, unconvincing butt, probable accidental impact; Flake stained sharp, opposing dorsal scar patterns; flake stained sharp clear butt, hinged dist end	77860_1087
2226	426632	5822423	FINDSPOT	Centrepoint of track 7B	Unit 3 target	3?	Palaeolithic	Broken flake matt, near mint, smashed butt, accident; lightly stained flake, butt unclear, transverse dorsal scars may be anthropogenic; rolled flake with parallel flaking scars lightly patinated. Possibly represents hand axe thinning	77860_1088

WAID	UTM31N Easting	UTM31N Northing	Site type	Position accuracy	Geological Context	Assoc. Offshore Unit	Arch. Period	Description	Sources
2227	425915	5822227	FINDSPOT	Centrepoint of track 8B	Unit 5 target	3?	Palaeolithic	Faceted butt, sharp, lightly patinated, hard, dist tip absent but almost certainly blade, possibly retouched	77860_1096



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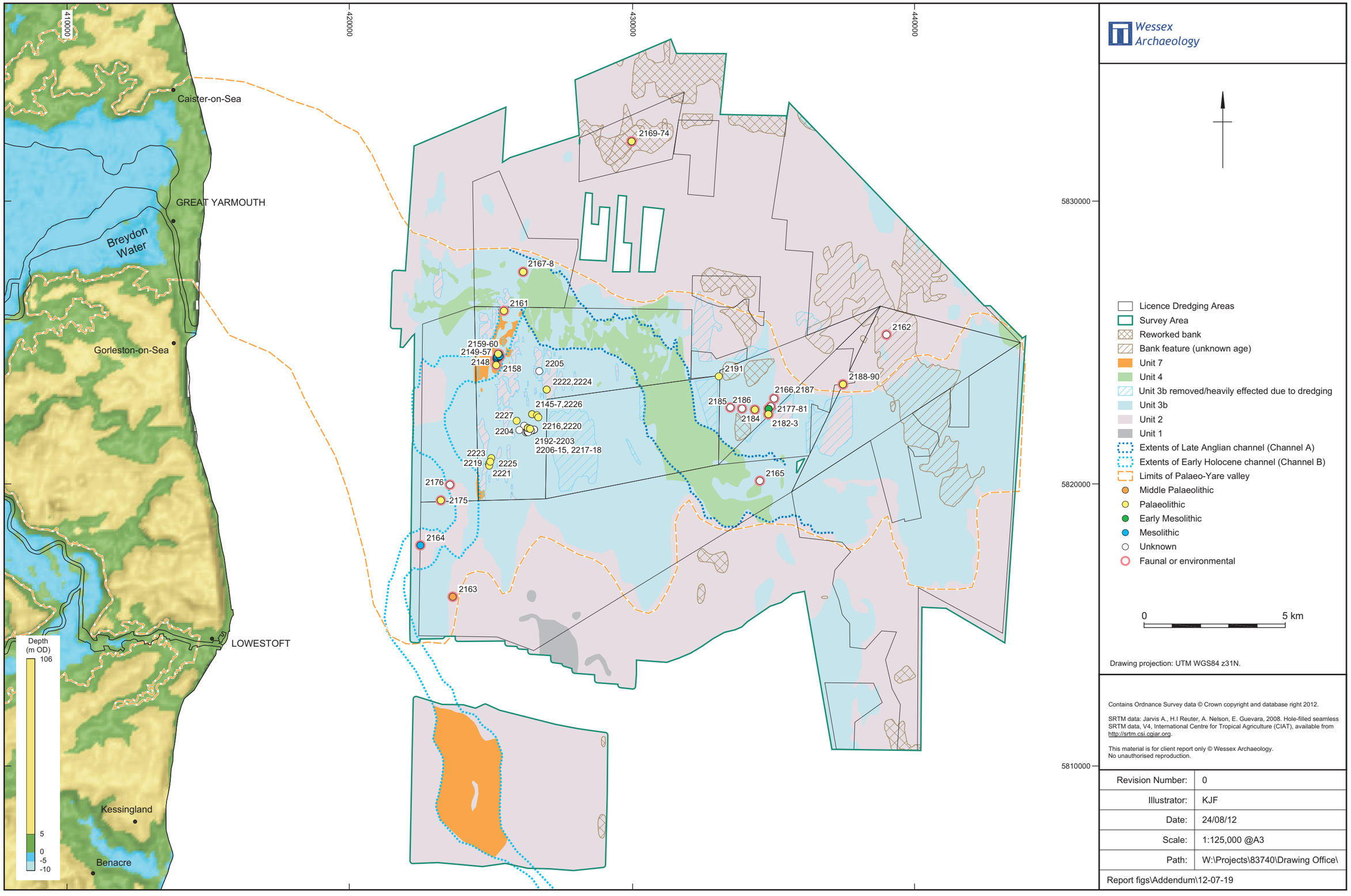
Location map

Figure 1



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Overview of Palaeo-Yare catchment assessment interpretation

Figure 2

Area 240 short-term licence area

Geophysics datasets:

- 2005

Geotechnical datasets:

- 1999
- 2000
- 2005
- 2007

Geology overview:

- Unit 3b is observed throughout the majority of the short-term licence area with exception of where Unit 3b has been removed, principally due to dredging activity.
- Unit 2 is observed throughout the area and subcrops Unit 8 (modern marine sediments) where Unit 3b is absent.
- Unit 4 is confined to the northeast associated with Late Anglian channel and comprises bank features and channel infill deposits.
- Isolated pockets of Unit 5 and 6 are observed infilling shallow seabed depressions.
- Unit 7, an early Holocene peat and transgression sequence is observed in the northwest associated with the infilling of an early Holocene channel (Channel B).

Known Archaeology:

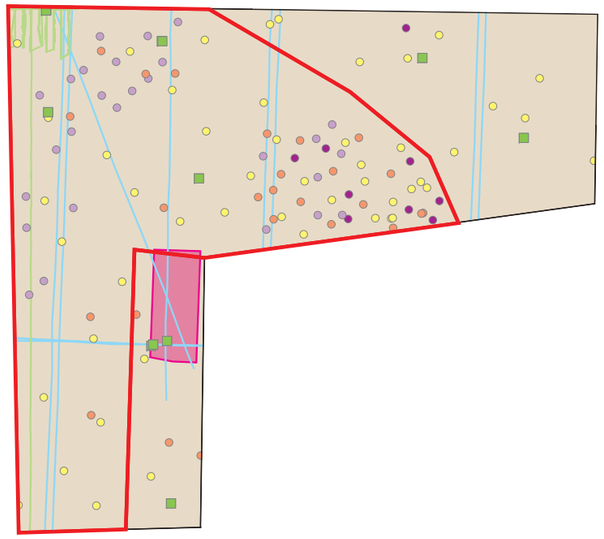
- Flint artefacts comprising the Middle Palaeolithic Assemblage (**WA 2147**, **2206**, **2192 - 2200**, **2203**, **2204**, **2207 - 2227**).
- 16 additional reports through BMAPA *Protocol for Reporting Finds of Archaeological Interest*:
  - Flint (**WA 2160**)
  - Faunal remains (**WA 2145, 2146**, **2158**, **2159**, **2161**)
  - Peat (**WA 2148 - 2157**)
- 5 faunal remains recovered during *Seabed Prehistory* project grab sampling (**WA 2195, 2196, 2201, 2202**, **2205**).

Dredging activity:

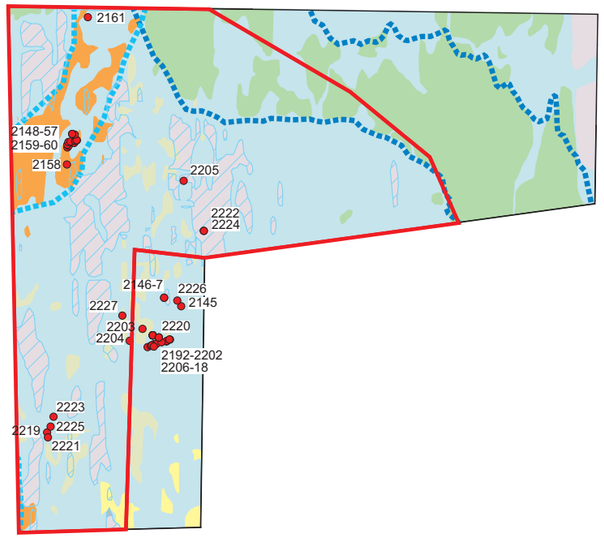
- Dredging activity has occurred throughout the area between 1993 and 2011 with exception of small areas at western edge and in the east.
- Geophysics data indicates that the seabed has been heavily dredged in areas of cumulative low, medium and high intensity dredging.
- Since 2005 data acquisition dredging has occurred in west and north indicating further removal of Units 3b, 5, 6, 7.

Principal hypotheses to be tested by operational sampling:

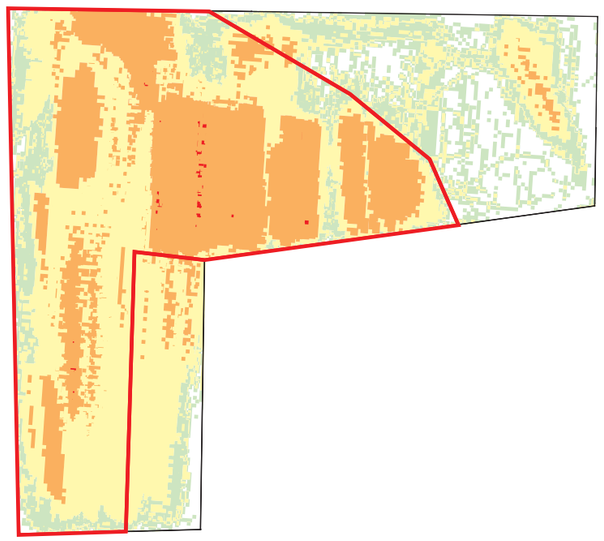
H1a: Palaeolithic material is recovered only from Unit 3b, which dates to the Wolstonian.
H1b: Palaeolithic material recovered from Unit 3b is predominantly *in situ*.
H2a: Palaeolithic material is recovered only from Unit 3b deposits on the margin of Channel A, not within the Channel itself.
H2c: The recovery of Palaeolithic material is clustered in relatively large quantities in discrete locations; material is not recovered from otherwise similar locations.
H3a: The distribution of recovered Palaeolithic material does not vary according to variations in the sediment structure of Unit 3b.
H3b: Palaeolithic material is not recovered where Unit 3b appears to have been reworked by natural processes in the past.
H4a: Palaeolithic material is not present where the dredging history indicates that a high level of dredging has taken place since the introduction of EMS.
H4b: Palaeolithic material is not present where geophysical data indicates that a high level of dredging has taken place.
H5a: Palaeolithic material is found at all wharves where Operational Sampling takes place.



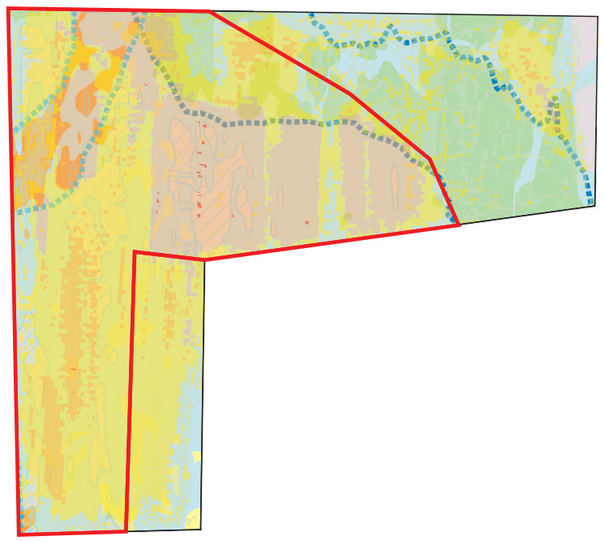
A. Assessed data



B. Interpretation and known archaeology



C. Dredging Activity (1993 – 2011)



D. Known aggregate dredging and palaeogeographic interpretation

Active Dredging Areas under Short Term Licence Applications
Licence Dredging Areas
Area 240 Survey Area 2005
Area 240 exclusion zone
EC REC trackplot
Seabed Prehistory: Great Yarmouth trackplot

Seabed Prehistory: Area 240 vibrocore
Palaeo-Yare licensee vibrocore locations:
1999
2000
2005
2007

Units subcropping surficial sediment (Unit 8):
Unit 7
Unit 6
Unit 5
Unit 4
Unit 3b removed/heavily effected due to dredging
Unit 3b
Unit 2
Unit 1
Extents of Late Anglian channel (Channel A)
Extents of Early Holocene channel (Channel B)
Known archaeology

EMS data analysis: cumulative intensity (1993 – 2011)
High intensity
Medium intensity
Low intensity
Very low intensity

0 5 km

Study Area

Wessex Archaeology

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Figure 3

Area 228 short-term licence area

Geophysics datasets:

- 1989
- 2002 (report only)
- 2005 (report only)
- 2011

Geotechnical datasets:

- 1988
- 1996
- 2002
- 2004
- 2011

Geology overview:

- Area 228 short-term licence area is interpreted as predominantly comprising Unit 3b floodplain deposits. The geophysics data is heavily affected, partly due to dredging activity, and the thickness of the remnant Unit 3b deposits is unknown. Although, vibrocore data indicates the presence of sands and gravels in the area.
- In the central and west areas small isolated cuts and fills are observed and are interpreted as possible remnant overbank deposits or reworked sediments of Unit 4, or remnants of older, infilled sediments within Unit 3b.
- Throughout the area Unit 3b overlies Unit 2 sediments.
- To the extreme east of the area the edge of Channel A is observed and the channel is infilled with Unit 4 deposits comprising clays, silts and sands.
- Throughout the area the uppermost unit generally comprises a veneer to possibly 6 m thick where a large east-west trending sandwave is observed.

Known Archaeology:

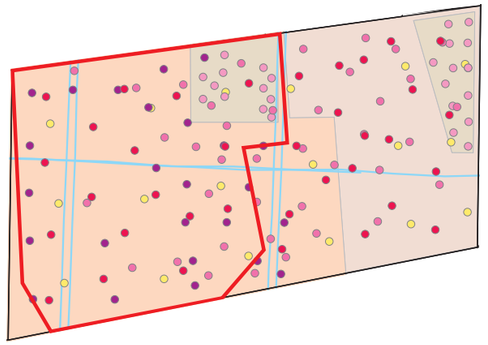
- No finds reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest*.

Dredging activity:

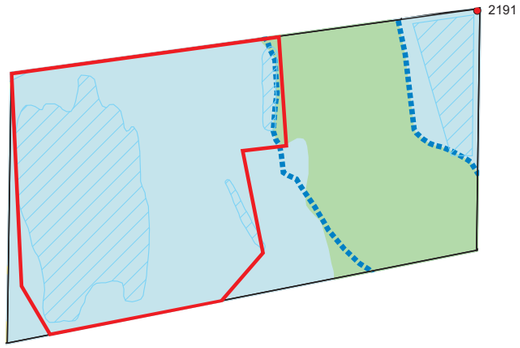
- Dredging has occurred throughout much of the area.
- Localised areas have been dredged in all 19 years (1993 - 2011).
- Predominantly classified as low and medium cumulative intensity.
- Areas of medium cumulative intensity in the west and the east coincide with areas of heavy dredging observed in the geophysical data.
- Evidence of heavy dredging observed in the south in 1989 dataset.
- Target aggregate is interpreted to be Unit 3b. In the west it is difficult to estimate how much of coarse-grained target remains, due to dredging activity.

Principal hypotheses to be tested by operational sampling:

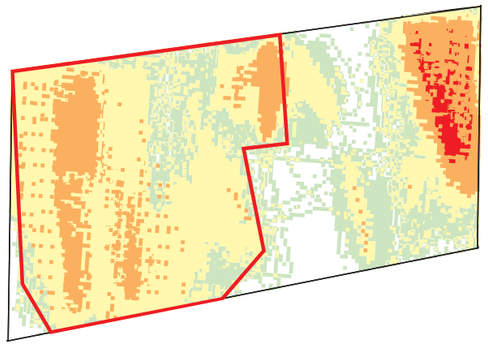
H1a: Palaeolithic material is recovered only from Unit 3b, which dates to the Wolstonian.
H1b: Palaeolithic material recovered from Unit 3b is predominantly *in situ*.
H2a: Palaeolithic material is recovered only from Unit 3b deposits on the margin of Channel A, not within the Channel itself.
H2c: The recovery of Palaeolithic material is clustered in relatively large quantities in discrete locations; material is not recovered from otherwise similar locations.
H3a: The distribution of recovered Palaeolithic material does not vary according to variations in the sediment structure of Unit 3b.
H3b: Palaeolithic material is not recovered where Unit 3b appears to have been reworked by natural processes in the past.
H4b: Palaeolithic material is not present where geophysical data indicates that a high level of dredging has taken place.
H5a: Palaeolithic material is found at all wharves where Operational Sampling takes place.



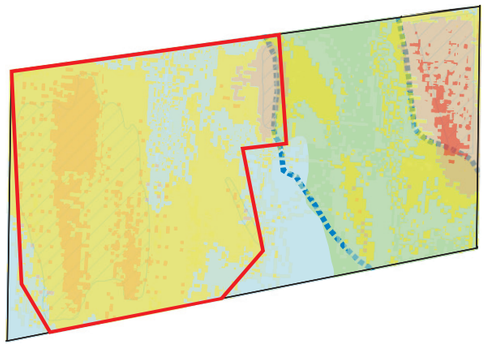
A. Assessed data



B. Interpretation and known archaeology



C. Dredging Activity (1993 – 2011)



D. Known aggregate dredging and palaeogeographic interpretation

Active Dredging Areas under Short Term Licence Applications
Licence Dredging Areas
Area 228 Survey Area 2002
Area 228 Survey Area 2005
Area 228 Survey Area 2011
EC REC trackplot

Palaeo-Yare licensee vibrocore locations:
1988
1996
1999
2002
2004
2011

Units subcropping surficial sediment (Unit 8):
Unit 4
Unit 3b removed/heavily effected due to dredging
Unit 3b

Extents of Late Anglian channel (Channel A)
Known archaeology

EMS data analysis: cumulative intensity (1993 – 2011)
High intensity
Medium intensity
Low intensity
Very low intensity

0 5 km

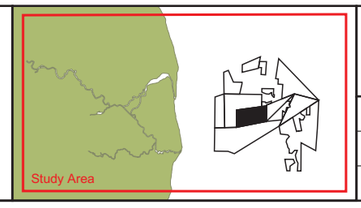


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Figure 4

Area 319 short-term licence area

Geophysics datasets:

- 1989

Geotechnical datasets:

- 1991
- 1993
- 1999
- 2005
- 2008
- 2009

Geology overview:

- Area 319 is dominated by the meandering north-south channel (Channel B) which developed during the early Holocene. The channel cuts into Underlying Unit 3b sediments.
- Unit 3b sediments, generally comprising sands and gravels, are observed throughout the area with the exception of two areas within the channel where it appears that Unit 3b sediments have been completely removed and reworked.
- In the north the sediments are up to 4 m thick. To the east the thickness of Unit 3b sediments is unknown. Some evidence of previous dredging is observed in the geophysics data which obscures the base of Unit 3b sediments.

Known Archaeology:

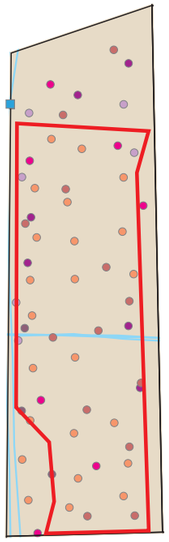
- Two reports of faunal remains (**WA 2175**, **2176**) through the BMAPA *Protocol for Reporting Finds of Archaeological Interest.*

Dredging activity:

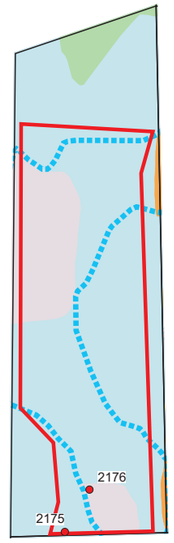
- Area 319 short-term licence area has been dredged over 17 of the 19 years since EMS recording (1993).
- The area has been dredged to low and medium cumulative intensity levels, with localised area of high intensity dredging in the north of the area.
- The aggregate target appears to be Unit 3b sediments and the reworked infill sediments from the early-Holocene channel.

Principal hypotheses to be tested by operational sampling:

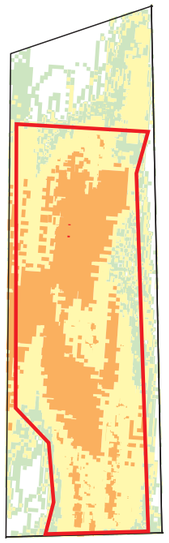
H1a: Palaeolithic material is recovered only from Unit 3b, which dates to the Wolstonian.
H1b: Palaeolithic material recovered from Unit 3b is predominantly *in situ*.
H2c: The recovery of Palaeolithic material is clustered in relatively large quantities in discrete locations; material is not recovered from otherwise similar locations.
H3a: The distribution of recovered Palaeolithic material does not vary according to variations in the sediment structure of Unit 3b.
H3b: Palaeolithic material is not recovered where Unit 3b appears to have been reworked by natural processes in the past.
H4a: Palaeolithic material is not present where the dredging history indicates that a high level of dredging has taken place since the introduction of EMS.
H5a: Palaeolithic material is found at all wharves where Operational Sampling takes place.



A. Assessed data



B. Interpretation and known archaeology



C. Dredging Activity (1993 – 2011)

D. Known aggregate dredging and palaeogeographic interpretation

Active Dredging Areas under Short Term Licence Applications
Licence Dredging Areas
Area 319 Survey Area 1989
EC REC trackplot
ECREC vibrocore locations

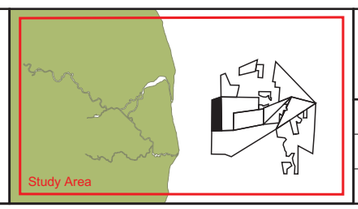
Palaeo-Yare licensee vibrocore locations:
1991
1993
1999
2005
2008
2009

Units subcropping surficial sediment (Unit 8):
Unit 7
Unit 4
Unit 3b
Unit 2

Extents of Early Holocene channel (Channel B)
Known archaeology

EMS data analysis: cumulative intensity (1993 – 2011)
High intensity
Medium intensity
Low intensity
Very low intensity

0 5 km



Wessex Archaeology

Drawing projection: UTM WGS84 z31N.

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Figure 5

Area 251 short-term licence area

Geophysics datasets:

- 1989

Geotechnical datasets:

- 1991
- 1993
- 1999
- 2003
- 2005
- 2008
- 2009

Geology overview:

- The western short-term licence area generally comprises Unit 3b sediments overlying Unit 2 sediments. In the west Unit 3b sediments form a bank feature up to 5 m high and the bank is cut in the northwest by the early-Holocene channel. To the east Unit 3b sediments comprise up to 2 m coarse-grained sands and gravels overlying Unit 2. Elsewhere sediments probably comprise a veneer of recent sediment (Unit 8) overlying Unit 2.
- The central short-term licence area is dominated by floodplain deposits (Unit 3b) which are situated to the west of Channel A. Unit 3b sediments generally comprise up to 3 m sand and gravel and form a cut and bank feature which thins to 1.5 m in the west.
- In the southwest the sediments comprise Unit 2 (fine grained sands and clays) overlain by a veneer of recent sediment (Unit 8).
- The eastern short-term licence area predominantly comprises channel deposits (Unit 3 and 4). Predominantly the sediments comprise up to 6 m fine-grained sands and gravels. Unit 4 sediments are observed and generally comprise up to 3 m fine-grained sediments (including sands, silts and clays) infilling cuts and forming bank features.

Known Archaeology:

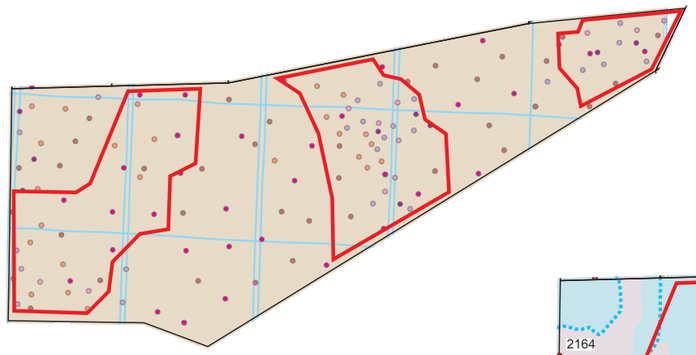
- Three finds reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest*:
  - Faunal remains (**WA 2163** and **2165**) in the western and eastern area, respectively.
  - Environmental remains (**WA 2164**) situated to the northwest of the western short-term licence area.

Dredging activity:

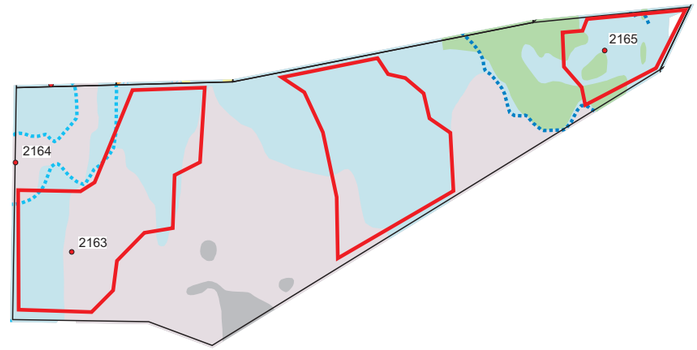
- The western short-term licence area has generally been dredged to low cumulative intensity with localised areas of very low and medium intensity. The target aggregate appears to be Unit 3b sediments and Unit 8 in the central area.
- The central short-term licence area has generally been dredged to low cumulative intensity with localised areas of very low and medium intensity. The target aggregate appears to be Unit 3b and Unit 8 sediments.
- The eastern short-term licence area has been dredged to low cumulative intensity with two areas of medium cumulative intensity. The target aggregate appears to be Unit 3b, however, the EMS data also indicates that Unit 4 sediments are also dredged.

Principal hypotheses to be tested by operational sampling:

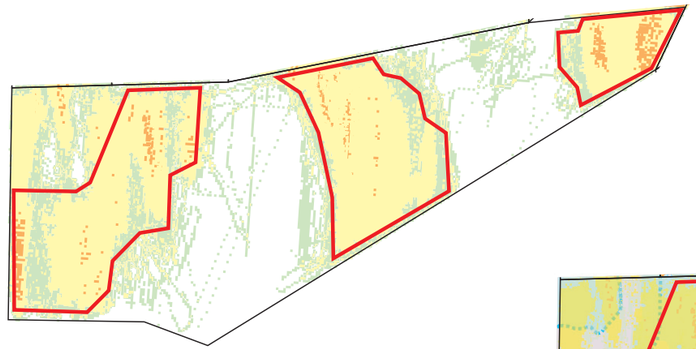
H1a: Palaeolithic material is recovered only from Unit 3b, which dates to the Wolstonian (**all areas**).
H1b: Palaeolithic material recovered from Unit 3b is predominantly *in situ* (**all areas**).
H2a: Palaeolithic material is recovered only from Unit 3b deposits on the margin of Channel A, not within the Channel itself.
H2c: The recovery of Palaeolithic material is clustered in relatively large quantities in discrete locations; material is not recovered from otherwise similar locations (**all areas**).
H3a: The distribution of recovered Palaeolithic material does not vary according to variations in the sediment structure of Unit 3b (**all areas**).
H3b: Palaeolithic material is not recovered where Unit 3b appears to have been reworked by natural processes in the past (**western and eastern areas only**).
H5a: Palaeolithic material is found at all wharves where Operational Sampling takes place **(all areas)**.



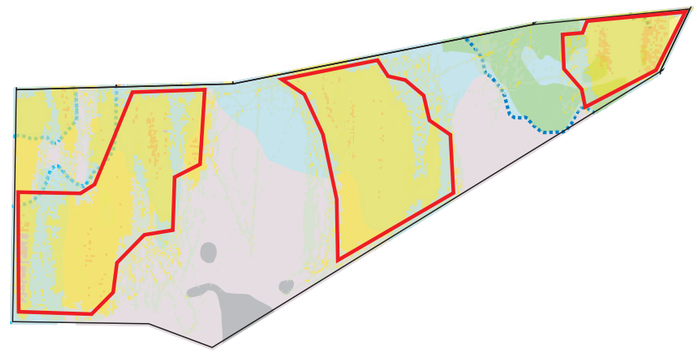
A. Assessed data



B. Interpretation and known archaeology



C. Dredging Activity (1993 – 2011)



D. Known aggregate dredging and palaeogeographic interpretation

Active Dredging Areas under Short Term Licence Applications
Licence Dredging Areas
Area 251 Survey Area 1989
EC REC trackplot

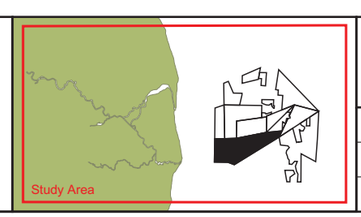
Palaeo-Yare licensee vibrocore locations:
1991
1993
1999
2003
2005
2008

Units subcropping surficial sediment (Unit 8):
Unit 4
Unit 3b
Unit 2
Unit 1

Extents of Late Anglian channel (Channel A)
Extents of Early Holocene channel (Channel B)
Known archaeology

EMS data analysis: cumulative intensity (1993 – 2011)
High intensity
Medium intensity
Low intensity
Very low intensity

0 5 km



Wessex Archaeology

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Figure 6

Area 360 short-term licence area

Geophysics datasets:

- 1989

Geotechnical datasets:

- 1991
- 1999
- 2005
- 2008
- 2009

Geology overview:

- Area dominated by Unit 3b floodplain deposits up to 3 m thick comprising sands and gravels.
- Unit 3b overlies Unit 2 and Unit 2 is observed near the surface in the east.
- Three reworked bank features comprising up to 3.7 m sand, organic material and fine-grained silts and clays. These banks probably contain reworked Unit 2, 3b and 4 sediments and developed post-Unit 4, probably during the last transgression.
- Elsewhere, marine reworked sediments are observed as a veneer.

Known Archaeology:

- Eleven reports of archaeological material through the BMAPA *Protocol for Reporting Finds of Archaeological Interest*:
  - Waterlogged wood and peat, possibly associated with the reworked bank in the southwest (**WA 2177**, **2178**)
  - Worked flint (**WA 2181**)
  - Faunal remains (**WA 2166, 2179, 2180, 2182 - 2187**), although exact positions are unknown

Dredging activity:

- EMS data indicates that the area has been dredged every year between 1993 and 2011.
- Medium to high cumulative dredging activity in the west.
- Very low to low cumulative intensity in the east.
- Dredging targets Unit 3b and overlying reworked bank structures and recent marine sediment (Unit 8).
- Vibrocores indicate that at least 2.5 m Unit 3b still remain as of 2009 (most recent dataset).

Principal hypotheses to be tested by operational sampling:

H1a: Palaeolithic material is recovered only from Unit 3b, which dates to the Wolstonian.

H1b: Palaeolithic material recovered from Unit 3b is predominantly *in situ*.

H2a: Palaeolithic material is recovered only from Unit 3b deposits on the margin of Channel A, not within the Channel itself.

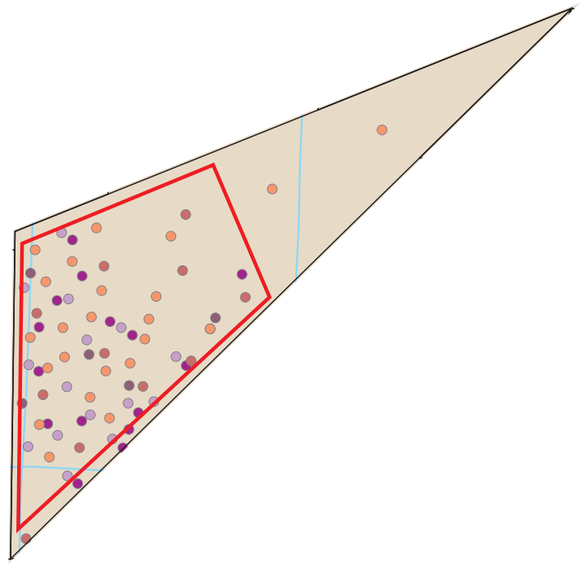
H2c: The recovery of Palaeolithic material is clustered in relatively large quantities in discrete locations; material is not recovered from otherwise similar locations.

H3a: The distribution of recovered Palaeolithic material does not vary according to variations in the sediment structure of Unit 3b.

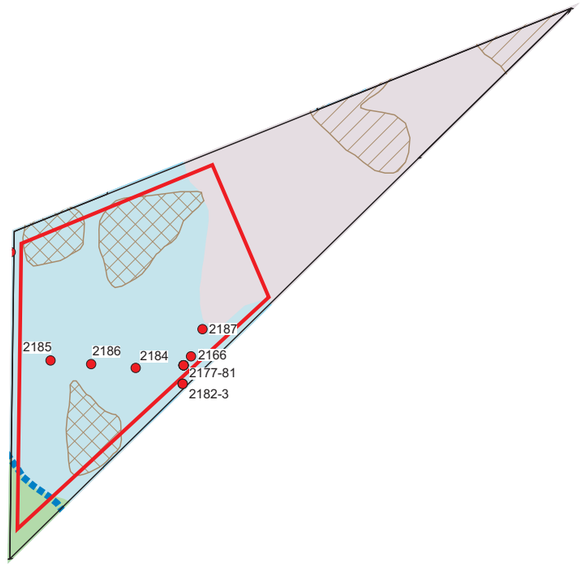
H3b: Palaeolithic material is not recovered where Unit 3b appears to have been reworked by natural processes in the past.

H4a: Palaeolithic material is not present where the dredging history indicates that a high level of dredging has taken place since the introduction of EMS.

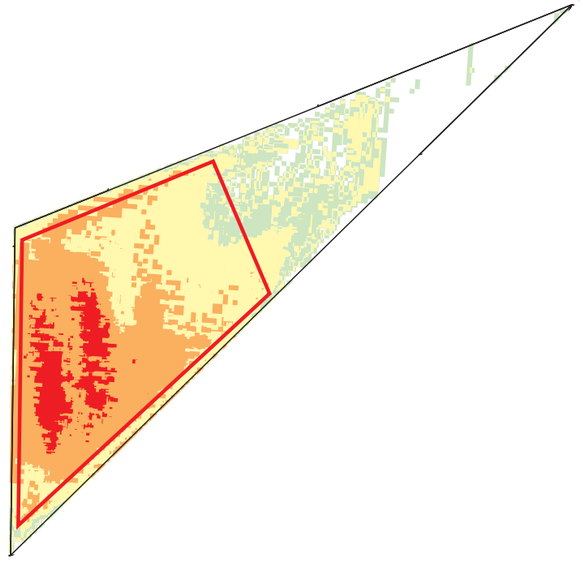
H5a: Palaeolithic material is found at all wharves where Operational Sampling takes place.



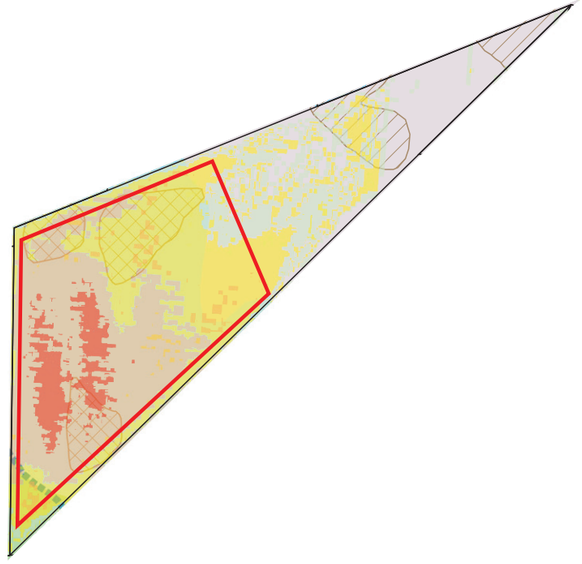
A. Assessed data



B. Interpretation and known archaeology



C. Dredging Activity (1993 – 2011)



D. Known aggregate dredging and palaeogeographic interpretation

Active Dredging Areas under Short Term Licence Applications
Licence Dredging Areas
Area 251 Survey Area 1989
EC REC trackplot

Palaeo-Yare licensee vibrocore locations:
1991
1999
2005
2008
2009

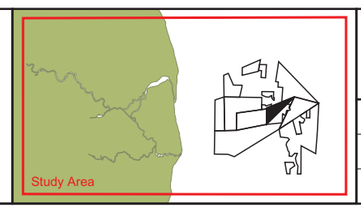
Reworked bank
Bank feature (unknown age)

Units subcropping surficial sediment (Unit 8):
Unit 4
Unit 3b
Unit 2

Extents of Late Anglian channel (Channel A)
Known archaeology

EMS data analysis: cumulative intensity (1993 – 2011)
High intensity
Medium intensity
Low intensity
Very low intensity

0 5 km



Wessex Archaeology

Drawing projection: UTM WGS84 z31N.

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Figure 7

Area 242/361 short-term licence area

Geophysics datasets:

- 1999 (Area 361)
- 2010 (Area 361/242)

Geotechnical datasets:

- 1999
- 2001
- 2003
- 2005
- 2007

Geology overview:

Western area:
- Area dominated by Unit 3b deposits up to 5 m thick representing the floodplain to the north of the channel.
- Some evidence of finer-grained sediments reworked from Unit 2 or nearby Unit 4.
- In the north fine-grained silty sand Unit 2 deposits are observed.
- Veneer of marine reworked sediments observed throughout the area.

Eastern area:
- Dominated by large reworked bank comprising sands, gravels and fine-grained sediments.
- Bank feature partially overlies and has eroded underlying Unit 3b sediments.
- Veneer of marine reworked sediments observed throughout the area.

Known archaeology:

- Western Area: three finds (**WA 2188 - 2190**) comprising mammoth teeth, mammoth bone and possible deer bone reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest*. The findspot is 10 m north of the area but is most likely to be dredged from within the area.
- Eastern Area: Single faunal fragment (**WA 2162**) reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest*.

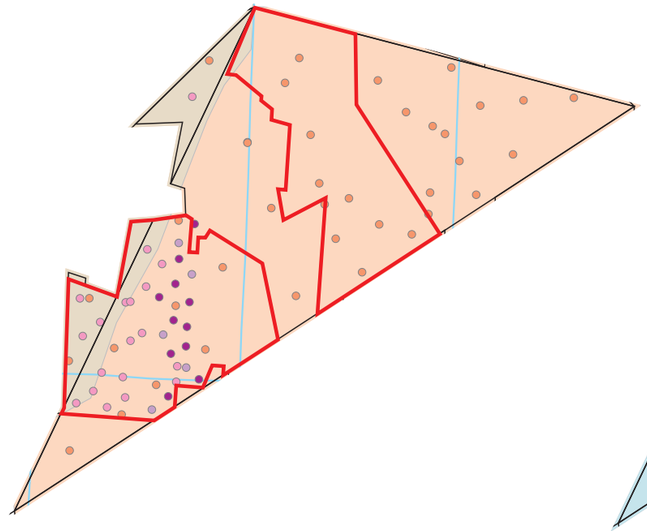
Dredging activity:

Western Area:
- Geophysics data indicates heavy dredging and Unit 3b mostly removed in the east.
- Heavy dredging observed in east but remnants of Unit 3b are present.
- EMS data indicates medium cumulative intensity in the west and low to medium in the west.

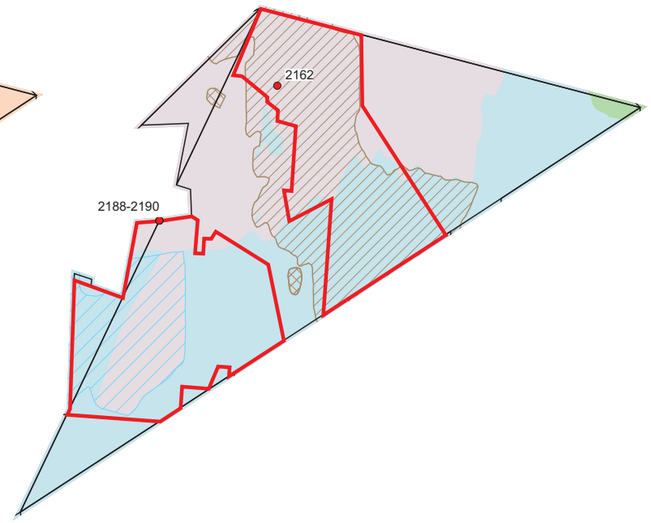
Eastern Area:
- Dredging target is the reworked bank and reworked marine sediments (Unit 8) and has been dredged to low - medium cumulative dredging intensity.
- Small area of Unit 3b may be a target.

Principal hypotheses to be tested by operational sampling:

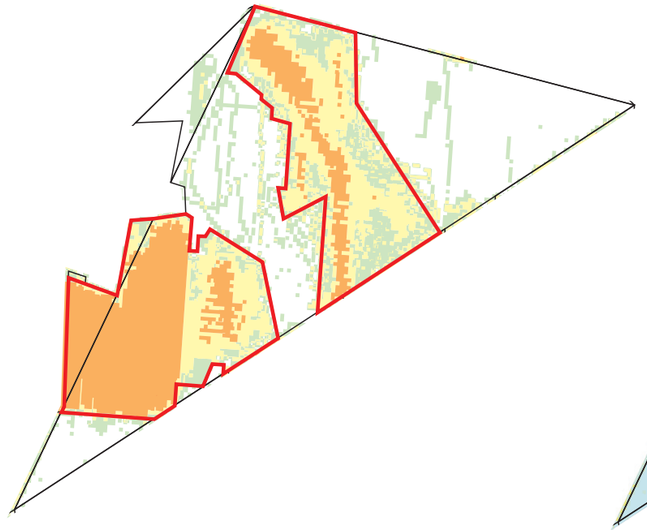
H1a: Palaeolithic material is recovered only from Unit 3b, which dates to the Wolstonian (**all areas**).
H1b: Palaeolithic material recovered from Unit 3b is predominantly *in situ* (**all areas**).
H2c: The recovery of Palaeolithic material is clustered in relatively large quantities in discrete locations; material is not recovered from otherwise similar locations (**all areas**).
H3a: The distribution of recovered Palaeolithic material does not vary according to variations in the sediment structure of Unit 3b (**all areas**).
H3c: Palaeolithic material is not recovered where Unit 3b appears to be covered by major bank structures (**eastern area**).
H4b: Palaeolithic material is not present where geophysical data indicates that a high level of dredging has taken place (**western area**).
H5a: Palaeolithic material is found at all wharves where Operational Sampling takes place (**all areas**).



A. Assessed data



B. Interpretation and known archaeology



C. Dredging Activity (1993 – 2011)

D. Known aggregate dredging and palaeogeographic interpretation

Active Dredging Areas under Short Term Licence Applications
Licence Dredging Areas
Area 361 Survey Area 1999
Area 242 Survey Area 2010
EC REC trackplot

Palaeo-Yare licensee vibrocore locations:
1999
2001
2003
2005
2007

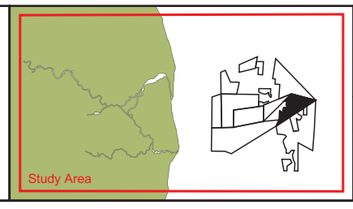
Reworked bank
Bank feature (unknown age)

Units subcropping surficial sediment (Unit 8):
Unit 4
Unit 3b removed/heavily effected due to dredging
Unit 3b
Unit 2

Known archaeology

EMS data analysis: cumulative intensity (1993 – 2011)
High intensity
Medium intensity
Low intensity
Very low intensity

0 5 km



Wessex Archaeology

Drawing projection: UTM WGS84 z31N.

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Figure 8

Area 328 short-term licence area

Geophysics datasets:

- 1999
- 2010

Geotechnical datasets:

- 1999
- 2001
- 2003
- 2007

Geology overview:

- Western area comprises Unit 2 with a veneer of recent marine sediment (Unit 8) with a reworked bank feature up to 5 m high in the north.
- Western-central area generally comprises Unit 2 overlain by reworked deposits (Unit 8). To the south is a major, 3 m high bank structure comprising silt, shelly sands and gravels. To the north is a 3 m high reworked pro-grading bank.
- The eastern-central area is dominated by two reworked banks in the west and east and an outlier of Unit 3b channel infill sediments overlain by up to 3 m reworked sediments (Unit 8) in the north.
- Eastern area is dominated sediment up to 3 m thick interpreted as Unit 3b outlier deposits overlain by a veneer of recent sediment (Unit 8).

Known Archaeology:

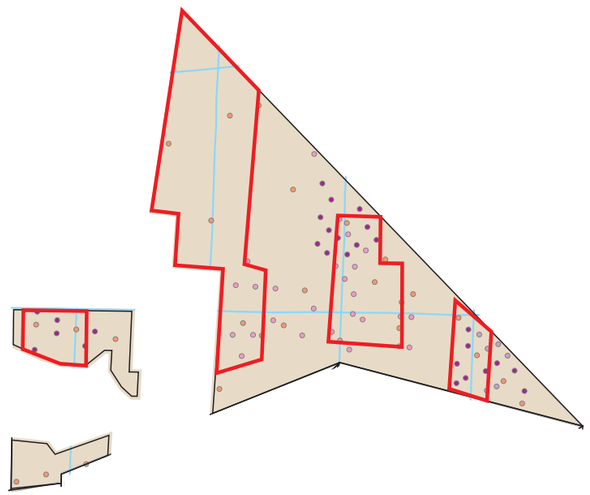
- No finds reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest*.

Dredging activity:

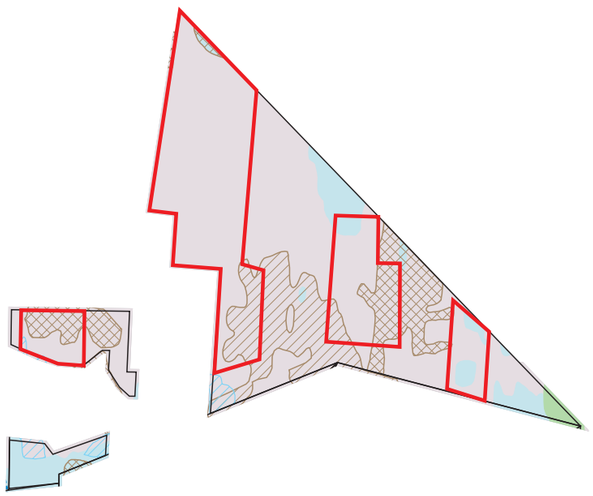
- Western area has been predominantly dredged to very low and low cumulative intensity and the aggregate target appears to be the recent reworked sediments and the reworked bank structure.
- Western-central area is generally low cumulative intensity dredging with localised areas of medium and high cumulative intensity. Aggregate target of large reworked bank in the south and reworked overburden (Unit 8) in the north.
- In the eastern-central area dredging is classified as predominantly medium cumulative intensity and primarily targets reworked bank sediments and overburden (Unit 8). Channel infill deposits (possibly Unit 3b) are targeted in the northwest.
- In the eastern area dredging is classified as predominantly medium cumulative intensity and primarily targets two possible outliers of Unit 3b sands and gravels. Elsewhere aggregate target comprises reworked overburden (Unit 8) deposits.

Principal hypotheses to be tested by operational sampling:

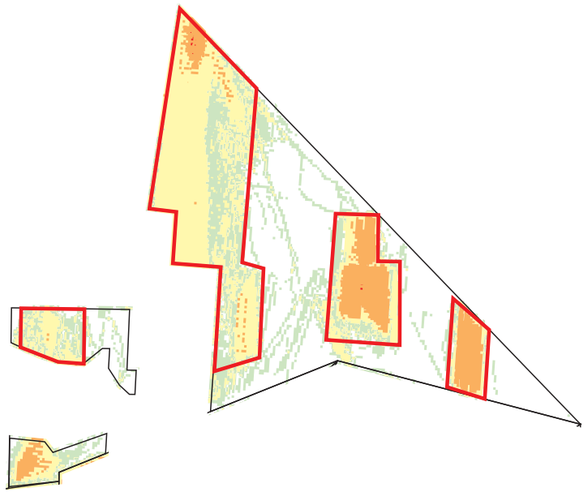
H1a: Palaeolithic material is recovered only from Unit 3b, which dates to the Wolstonian (**all areas**).
H1b: Palaeolithic material recovered from Unit 3b is predominantly *in situ* (**east-central and east areas**).
H2b: Palaeolithic material is recovered only from Unit 3b deposits within the limits of the Palaeo-Yare floodplain, and not within the Unit 3b outliers to the north and south of the floodplain (**east-central and east areas**).
H2c: The recovery of Palaeolithic material is clustered in relatively large quantities in discrete locations; material is not recovered from otherwise similar locations (**all areas**).
H3a: The distribution of recovered Palaeolithic material does not vary according to variations in the sediment structure of Unit 3b (**east-central and east areas**).
H3b: Palaeolithic material is not recovered where Unit 3b appears to have been reworked by natural processes in the past (**west, west-central and east-central areas**).
H3c: Palaeolithic material is not recovered where Unit 3b appears to be covered by major bank structures (**west-central and east-central areas**).
H4a: Palaeolithic material is not present where the dredging history indicates that a high level of dredging has taken place since the introduction of EMS (**east-central area**).
H4b: Palaeolithic material is not present where geophysical data indicates that a high level of dredging has taken place (**west area**).
H5a: Palaeolithic material is found at all wharves where Operational Sampling takes place (**all areas**).



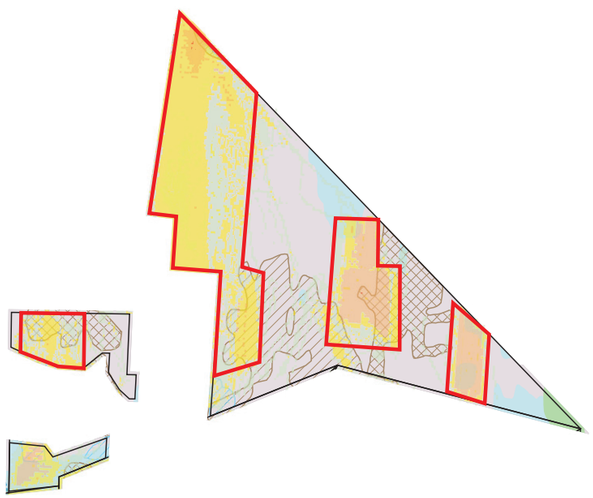
A. Assessed data



B. Interpretation and known archaeology



C. Dredging Activity (1993 – 2011)



D. Known aggregate dredging and palaeogeographic interpretation

Active Dredging Areas under Short Term Licence Applications
Licence Dredging Areas
Area 328 Survey Area 1999
EC REC trackplot

Palaeo-Yare licensee vibrocore locations:
1999
2001
2003
2005
2007

Reworked bank
Bank feature (unknown age)

Units subcropping surficial sediment (Unit 8):
Unit 4
Unit 3b removed/heavily effected due to dredging
Unit 3b
Unit 2

EMS data analysis: cumulative intensity (1993 – 2011)
High intensity
Medium intensity
Low intensity
Very low intensity

0 5 km

Study Area

Wessex Archaeology

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Figure 9

Area 296 short-term licence area

Geophysics datasets:

- 1991
- 2007

Geotechnical datasets:

- 2000
- 2002
- 2008

Geology overview:

- Short-term licence area dominated by large reworked bank structure.
- In 1991 dataset the bank feature was up to 6 m high and comprised shelly, sand and gravel. The bank overlies Unit 2 (Yarmouth Roads Formation).
- In the 2007 dataset three smaller banks remain, with much of the original bank removed through dredging.
- Small cut and bank feature is observed in the northeast corner of the area comprising up to 4 m shelly, sand and gravel.
- Where there are no banks present the sediments comprise Unit 2 overlain by a veneer of reworked sediment with occasional sandwaves, generally up to 2 m high.

Known archaeology:

- Six reports of faunal remains through BMAPA *Protocol for Reporting Finds of Archaeological Interest* (**WA 2169** - **2174**). Position provided is based on centre of the dredging area and is not an accurate recovery position.

Dredging activity:

- The aggregate target is the reworked bank feature and the veneer of sediment overlying Unit 2.
- Dredging activity has occurred in the area every year since 1993 (to 2011) and the main bank area has been dredged to medium cumulative intensity.
- Dredging has continued since the acquisition of the 2007 dataset and as such it is unknown how much of the bank remains.

Principal hypotheses to be tested by operational sampling:

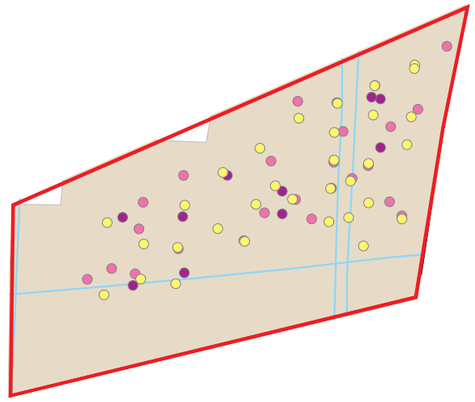
H1a: Palaeolithic material is recovered only from Unit 3b, which dates to the Wolstonian.

H2c: The recovery of Palaeolithic material is clustered in relatively large quantities in discrete locations; material is not recovered from otherwise similar locations.

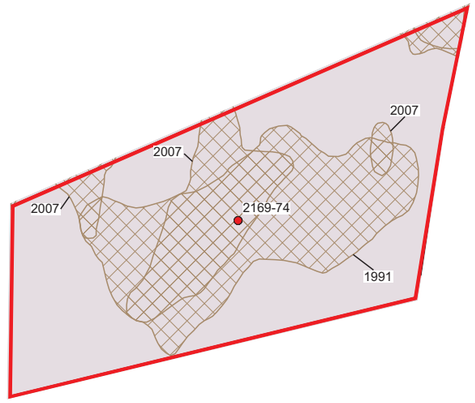
H3b: Palaeolithic material is not recovered where Unit 3b appears to have been reworked by natural processes in the past.

H4a: Palaeolithic material is not present where the dredging history indicates that a high level of dredging has taken place since the introduction of EMS.

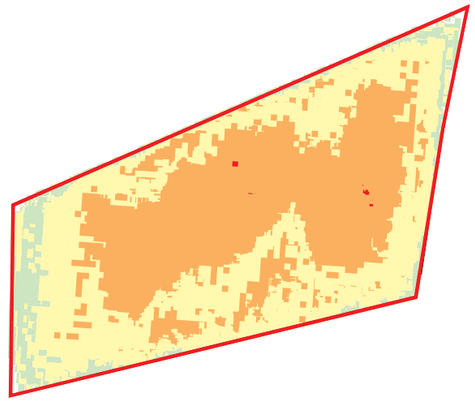
H5a: Palaeolithic material is found at all wharves where Operational Sampling takes place.



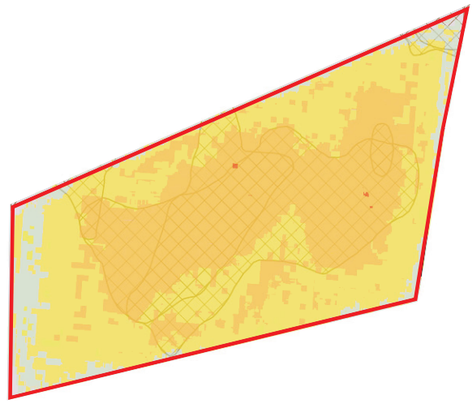
A. Assessed data



B. Interpretation and known archaeology



C. Dredging Activity (1993 – 2011)



D. Known aggregate dredging and palaeogeographic interpretation

Active Dredging Areas under Short Term Licence Applications
Licence Dredging Areas
Area 296 Survey Area 1991
EC REC trackplot

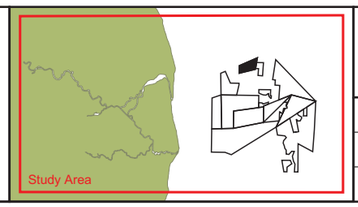
Palaeo-Yare licensee vibrocore locations:
2000
2002
2008

Reworked bank
Known archaeology

Units subcropping surficial sediment (Unit 8):
Unit 2

EMS data analysis: cumulative intensity (1993 – 2011)
High intensity
Medium intensity
Low intensity
Very low intensity

0 2 km



Wessex Archaeology

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Figure 10

Area 212 short-term licence area

Geophysics datasets:

- 1999
- 2008

Geotechnical datasets:

- 1999

Geology overview:

- Generally, Unit 2 overlain by veneer of reworked marine sediments (Unit 8).
- Occasional sediment unit up to 1 m thick comprising possible reworked lag deposit of Unit 3b.
- Bank feature situated in the north up to 4 m high possibly comprising reworked sands and gravels, similar to Unit 3b sediments.
- Sandwaves comprising reworked, post-transgression sediments up to 5 m high are observed within the area.

Known archaeology:

- No finds reported through the BMAPA *Protocol for Reporting Finds of Archaeological Interest*.

Dredging activity:

- Dredging has occurred within the area each year between 1993 and 2011 and is predominantly classified as low and medium cumulative intensity.
- Evidence of dredging is observed on both geophysical datasets.
- Dredging has continued in the centre of the area since the acquisition of the 2008 dataset.
- The target aggregate appears to be the reworked bank deposits and overlying reworked marine sediments.

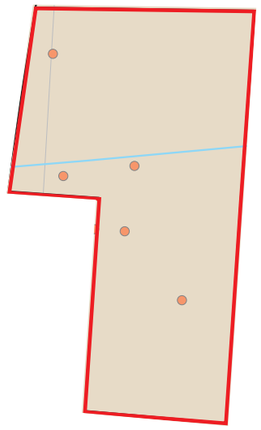
Principal hypotheses to be tested by operational sampling:

H1a: Palaeolithic material is recovered only from Unit 3b, which dates to the Wolstonian.

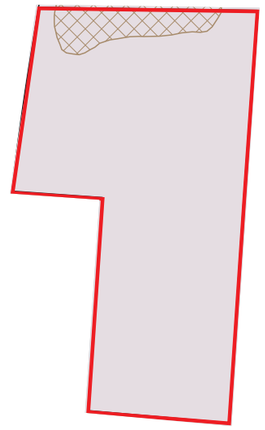
H2c: The recovery of Palaeolithic material is clustered in relatively large quantities in discrete locations; material is not recovered from otherwise similar locations.

H3b: Palaeolithic material is not recovered where Unit 3b appears to have been reworked by natural processes in the past.

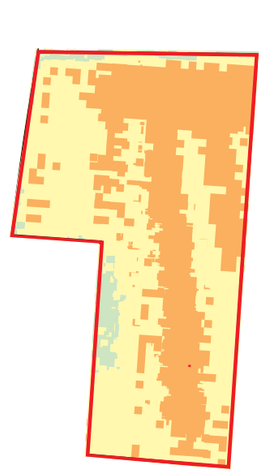
H5a: Palaeolithic material is found at all wharves where Operational Sampling takes place.



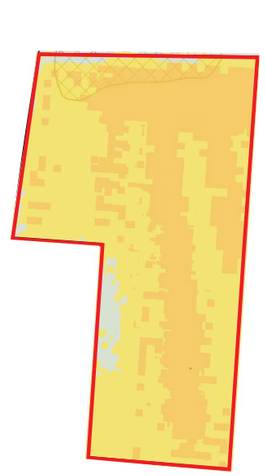
A. Assessed data



B. Interpretation and known archaeology



C. Dredging Activity (1993 – 2011)



D. Known aggregate dredging and palaeogeographic interpretation

Active Dredging Areas under Short Term Licence Applications
Licence Dredging Areas
Area 212 Survey Area 1999 and 2008
EC REC trackplot

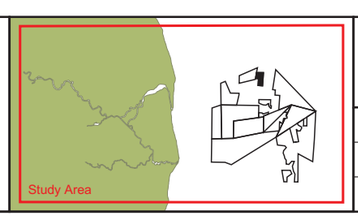
Palaeo-Yare licensee vibrocore locations:
1999

Reworked bank

Units subcropping surficial sediment (Unit 8):
Unit 2

EMS data analysis: cumulative intensity (1993 – 2011)
High intensity
Medium intensity
Low intensity
Very low intensity

0 2 km



Wessex Archaeology

Date:	13/08/12	Revision Number:	0
Scale:	1:40,000 @A3	Illustrator:	KJF
Path:	W:\Projects\83740\Drawing Office\Report figs\Addendum\12-07-19		

Figure 11

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