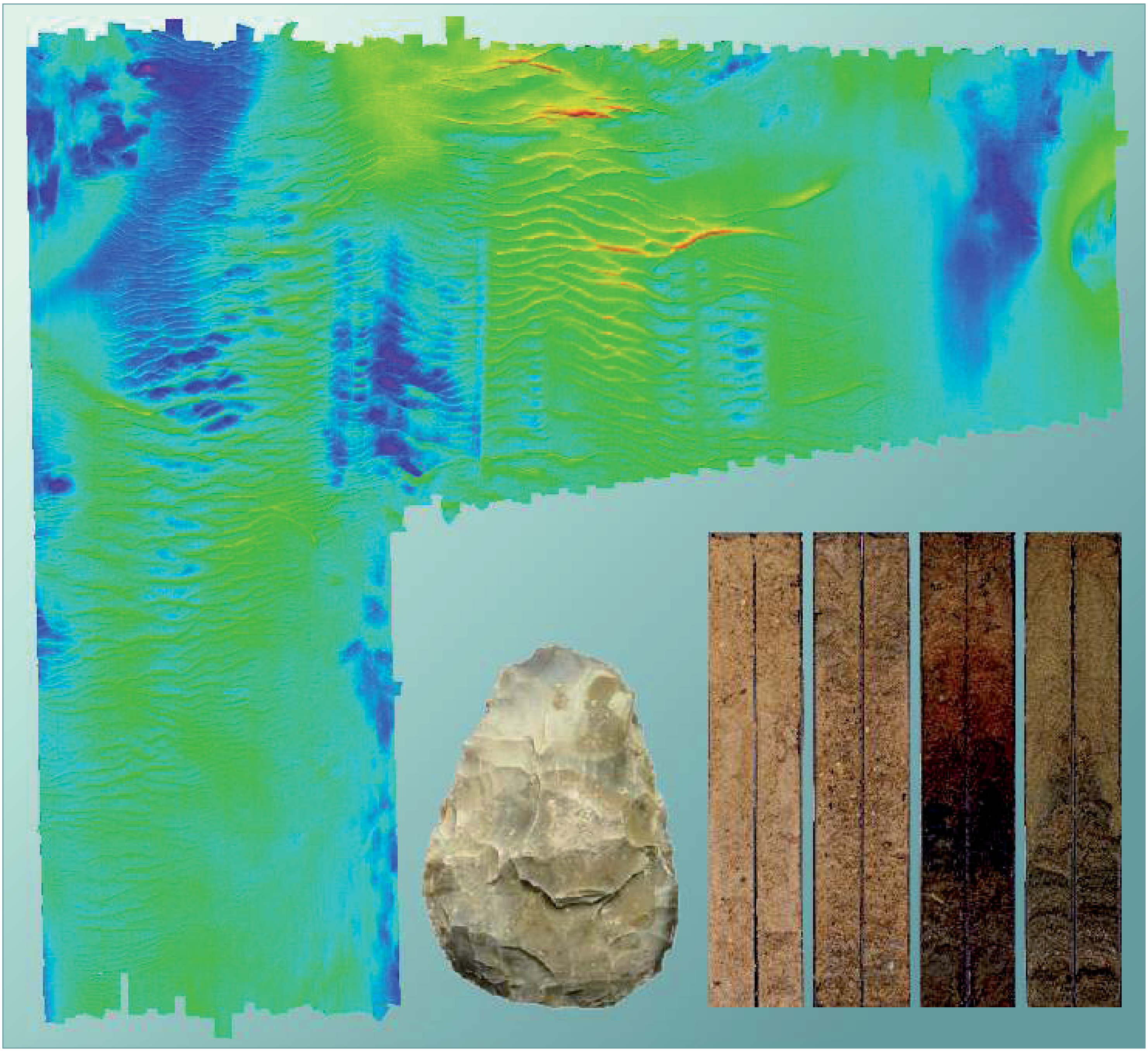
Wessex Archaeology

Seabed Prehistory:
Site Evaluation Techniques (Area 240)

Existing Data Review

Draft Report



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July 2009

SEABED PREHISTORY:
SITE EVALUATION TECHNIQUES (AREA 240)

EXISTING DATA REVIEW

DRAFT REPORT

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Summary

Wessex Archaeology (WA) was commissioned by English Heritage (EH) to conduct a project concerning the application of geophysical and geotechnical/seabed sampling methodologies to marine aggregate deposits that have been demonstrated to contain potential pre-Devensian or Devensian artefactual material.

Artefactual material, including hand axes, flakes, cores and faunal remains, were recovered from dredging licence Area 240 (licensed to Hanson Aggregates Marine Ltd.) in 2008, situated approximately 11km off the coast of Great Yarmouth. The findings show that significant archaeological material can be present in deposits that are being targeted for marine aggregate extraction. The place where the finds were dredged is relatively discrete, and the provenance of the artefacts is secure. The area where the hand axes were recovered is currently subject to a rectangular exclusion zone based on dredger trackplots, implemented voluntarily by Hanson Aggregates Marine Ltd in accordance with the BMAPA/EH Protocol.

The principal aim of the project is to improve the future management of the potential effects of aggregate dredging on the marine historic environment by developing techniques to evaluating the source of prehistoric artefactual material discovered in the East Coast region.

This report presents the findings of *Stage 1: review of existing data* and discusses the re-interpretation of geophysical and geotechnical data acquired on behalf of HAML for the assessment of aggregate reserves.

The geophysics data reviewed included multi-beam bathymetric data and sub-bottom profiler (boomer source) data acquired by Andrews Surveys Ltd (now Gardline Surveys Ltd) during June and July 2005. The geotechnical data included 158 vibrocore logs and photographs acquired between 1999 and 2007.

The review of the geophysical and geotechnical indicate a complex history of deposition and erosion within Area 240. This history is further complicated by dredging operations conducted over the last 20 years. Eight sediment units were identified in the data, dating from the Late Pliocene/Early Pleistocene (Unit 1) to marine deposits associated with the last transgression in the Holocene (Unit 8). The area is dominated by two channel features, one possibly dating to the Late Anglian (*c.* 480,000BP), the other a shallow meandering channel infilled with peats, possible deposited as late as the Mesolithic (*c.* 10,000 – 7,500 BP).

Within the area where the artefacts were dredged, three particular sediment units were identified sub-cropping the surficial sediment unit. Based on the artefact appearance and the initial dating of faunal material, the artefacts may be associated with particular units (Units 2, 4 and 6). The two channels lie to the north of this area, indicating that the artefacts, if associated with the channel, are associated with the channel edge rather than immediately adjacent to the channels.

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Acknowledgements

The Seabed Prehistory: Site Evaluation Techniques (Area 240) Project was commissioned by English Heritage.

Wessex Archaeology would like to thank Helen Keeley and Gareth Watkins of English Heritage for their assistance throughout the project; Rob Langman from Hansons Aggregates Marine Limited for the provision of data; Dr Ian Selby of the Crown Estate for his contributions, particularly concerning the dredging history and overall interpretation of the area. Further thanks are extended to Vince Grove from Gardline Surveys Ltd and James Williams of Swathe-Services for their contributions concerning technical aspects of the geophysical data.

Wessex Archaeology would also like to thank Mr Jan Meulmeester, Mr Hans Peeters of Rijksdienst voor Archeologie, Cultuurlandschapp en Monumenten (RACM) - Dutch government organization for archaeology, culture landscapes and monuments -, and Dr Jan Glimerveen for their contributions concerning the artefacts and faunal remains.

Louise Tizzard prepared the report with contributions from Jack Russell. Kitty Brandon prepared the illustrations. The project was managed for Wessex Archaeology by Paul Baggaley and Antony Firth developed the project design.

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1. INTRODUCTION

1.1. PROJECT BACKGROUND

1.1.1. Wessex Archaeology (WA) was commissioned by English Heritage (EH) to conduct a project concerning the application of geophysical and geotechnical/seabed sampling methodologies to marine aggregate deposits that have been demonstrated to contain potential pre-Devensian or Devensian artefactual material.

1.1.2. Artefactual material, including hand axes, flakes, cores and faunal remains, were recovered from dredging licence Area 240 (licensed to Hanson Aggregates Marine Ltd. (HAML)) in 2007/2008. Area 240 is situated approximately 11km off the coast of Great Yarmouth situated towards the west of a large area of aggregate licence areas covering an area of around 250km^2 (**Figure 1**).

1.1.3. The discoveries showed that significant archaeological material can be present in deposits that are being targeted for marine aggregate extraction.

1.1.4. Major questions remain about the complexity of deposits within Area 240; the susceptibility of such deposits to geophysical investigation; and the capability of various seabed sampling methods to enable observations of prehistoric artefacts, palaeoenvironmental material and their spatial distributions.

1.1.5. This report discusses the re-interpretation of geophysical and geotechnical data that were acquired on behalf of HAML for the assessment of aggregate reserves.

1.2. RATIONALE

1.2.1. In 2007/2008, 75 Palaeolithic artefacts, including hand axes, flakes and cores as well as a series of bones (woolly mammoth, woolly rhino, bison, reindeer and horse) were discovered by Mr Jan Meulmeester in stockpiles of gravel at the SBV Flushing Warf. The finds were identified from stockpiles and reject piles between the 7th December 2007 to the 18th March 2008, dredged from Area 240 between the 7th December 2007 and 5th February 2008. The fresh condition of some of the hand axes indicated that they came from relatively undisturbed deposits.

1.2.2. A lithics specialist from WA reviewed photographs of the artefacts taken during the expert meeting for the North Sea Prehistory Research and Management Framework in Amersfoort on 13 March 2008. Their provisional view, based on the photographs alone, was that the finds seem to indicate several different depositional histories. For example, some appear to have spent a considerable period in iron-rich gravels, while others retain edge and surface conditions suggestive of inclusion in a fine, soft-grained sediment. This suggests that the dredger impacted a range of deposits containing artefacts, rather than one single coherent deposit.

1.2.3. These observations based on photographs were confirmed by Hans Peeters of Rijksdienst voor Archeologie, Cultuurlandschapp en Monumenten (RACM) - Dutch government organization for archeology, culture landscapes and monuments - , who prepared an initial inventory of the artefacts. He commented that the hand axes could be divided roughly into three groups (pers. com. 15/05/08):

1. artefacts in 'mint' condition (no/slight colour patination, no gloss, no edge abrasion); among these are many hand axes forming a homogeneous typological/technological group; it seems that this group originates from a primary context;

2. artefacts in partially 'fresh' condition (colour patination but no gloss and abrasion on one side, and colour patination, slight to medium gloss and slight to medium edge abrasion on the other); this group mainly consists of flakes; it would seem that these items originate from an eroding surface (at the seafloor?);

3. artefacts in weathered condition (colour patination, medium to heavy gloss, edge abrasion on both sides); some hand axes, flakes and cores; this material originates from secondary contexts and in view of the presence of 'acorn shell' (or some other sea creature) traces on one of the hand axes, the material (not necessarily all) derives from the sea floor.'

1.2.4. The inventory listed numerous flakes and cores, including Levellois flakes and cordate hand axes. It is not possible to estimate the age of the artefacts based on the photographs and initial inventory and the collection of artefacts could date from 500,000 to 22,000 BP. Images of some of these hand axes are presented in **Plates 1 - 4**.

1.2.5. Also, although it is very difficult to assess the hand axes by photographs, particularly in terms of identifying diagnostic features, the WA lithic specialist has suggested likelihood of the Levallois technique evident (250,000 to 40,000BP). Cordate hand axes are generally thought to be Mousterian of Acheulian Tradition (MAT). The MAT is broadly 60,000 to 35,000 BP, however cordate hand axes have also been found at Hoxne, Suffolk (MIS 9; 300,000 BP).

1.2.6. Provisional results of the analysis and radiocarbon dating of the faunal rermains have been made available by Mr Jan Glimmerveen (pers. com. 30/03/09). Radiocarbon dating was conducted on six bones. The results indicated that five of the bones were dated to between 31,000 and 43,000 BP and one sample was older than 46,000 but younger than 65,000 BP. Meulmeester found in excess of 100 bones and around 70% of these have been attributed the same age as those mentioned above, based on their appearance and degree of fossilisation. The remaining 30% of the bones are heavily fossilised, estimated to be older than 500,000 BP.

1.2.7. Given the limits of radiocarbon dating on remains older than around 50,000 years the date of 46,000 to 65,000 BP should be considered approximate.

1.2.8. The place where the finds were dredged is relatively discrete, dredged specifically for aggregates for SBV Flushing. This part of Area 240 has only been dredged (at least in recent times) during the period that Mr. Meulmeester was monitoring the wharf. The correlation between the stockpiles inspected by Mr. Meulmeester and the source of the aggregate, confirmed by the correspondence between the dates of his visits and the dates of aggregate dredging in Area 240, means that the provenance of the artefacts is quite secure. Moreover, a review of trackplots of dredging for the relevant dates has established the extent of a quite limited area within which the artefacts are most likely to have been recovered (**Figure 2**).

1.2.9. The area where the hand axes were recovered is currently subject to a rectangular exclusion zone based on dredger trackplots, implemented voluntarily by HAML in accordance with the BMAPA/EH Protocol for Finds of Archaeological Interest (**Figure 2**).

1.2.10. The dredging history within Area 240 in discussed in detail in **Section 4**.

1.2.11. The discovery of these artefacts has raised two issues in understanding and dealing with potential impacts of marine aggregate extraction on the marine historic environment.

1.2.12. Primarily, the potential early (Devensian and pre-Devensian) age of the artefacts, their number, their apparently little-disturbed context and their association with faunal material indicate that the archaeological potential and special interest of the region may be older than previously thought.

1.2.13. Furthermore, although considerable advances have been made in the use of geophysical data (both through acquisition of new data and re-use of industry data), techniques are as yet under-developed for successfully ground-truthing geophysical data and relating such data to the actual presence of archaeological material.

1.2.14. As such, this project endeavours to refine a range of techniques for prehistoric site evaluation, including geophysical techniques, seabed sampling techniques, and techniques of palaeo-environmental analysis, dating and reconstruction, as well as generating additional data about the hand axe site and the site in terms of its implications for the wider region.

1.2.15. These data and interpretations will inform the Anglian Marine Aggregates Regional Environmental Assessment (MAREA) and interpretation of data from the accompanying Regional Environmental Characterisation (REC) survey. The Anglian MAREA will provide the general environmental framework for subsequent marine aggregate licensing procedures off East Anglia, so this project is likely to inform future aggregate licensing both through the MAREA and through individual licence applications.

1.2.16. This project is likely to result in significant data about the context of the hand axes and other material recovered from Area 240, which are currently subject to several strands of research. The hand axe assemblage itself is going to be examined in the course of research based at the University of Leiden, and the faunal remains recovered with the hand axes are currently being catalogued and subject to an ongoing programme of radiocarbon dating, also in the Netherlands. As well as providing geoarchaeological and palaeo-environmental context, both locally and regionally, to support these studies, this project is also likely to contribute case material to support the development of the North Sea Prehistory Research and Management Framework (NSPRMF), which is being led by RACM (Netherlands Heritage Agency).

1.2.17. The results are also likely to inform a number of other initiatives relating to the prehistory of the North Sea and of European Continental Shelves, including the European Cooperation in Science and Technology (COST) Action on Submerged

Prehistoric Landscapes and Archaeology of the Continental Shelf (SPLASH), and the Ancient Human Occupation of Britain (AHOB) projects.

1.3. AIMS AND OBJECTIVES

1.3.1. The aim of the project is to improve the future management of the potential effects of aggregate dredging on the marine historic environment by developing techniques to evaluating the source of prehistoric artefactual material discovered in the East Coast region.

1.3.2. In order to achieve this aim the following objectives were devised (Wessex Archaeology 2009):

O1 Refine practical techniques for establishing the presence or absence of prehistoric archaeological material (artefacts, deposits, faunal and other palaeoenvironmental material) on the seabed and for establishing the character, date, extent, quality, preservation and special interest of such material, if present;

O2 Improve the understanding of the character of the historic environment in the East Coast region, specifically its potential for prehistoric material;

O3 To pass on the knowledge gained to the archaeological and scientific community, to industry, and to the general public.

1.3.3. The structure of the project has been split into nine stages, as detailed in **Table 1**.

Stage	Task description
1	Review of existing geophysical and geotechnical data
2	Geophysical survey
3	Seabed sampling
4	Visual inspection/palaeo-environmental sampling
5	Palaeo-environment assessment and dating
6	Palaeo-environmental analysis
7	Synthesis
8	Dissemination, knowledge transfer and outreach
9	Archive deposition

Table 1. Project stages

1.3.4. This report presents the findings of *Stage 1: review of existing data*. This stage contributes to the project aim of improving management by developing techniques to evaluate artefactual material in the East coast region in two ways:

- Firstly, the review of existing data seeks to obtain maximum benefit from pre-existing datasets, ensuring efficient and informed targeting of resources and methods for the subsequent stages listed in **Table 1**.

- Secondly, the review provides a wider context for the subsequent detailed localised investigations of the hand axe site, ensuring that the localised investigations take place in the knowledge of their broader context and that the results have relevance beyond their immediate confines.

1.3.5. The review of existing data focuses upon Objective 2 – improving understanding of the character of the historic environment in the East Coast region – by providing a wider palaeogeographical context than would be apparent from the localised field investigations proposed for Stage 2. Additionally, insofar as the existing survey data relates to an aggregate licence area, then Stage 1 also makes a direct link between improved understanding and enhanced management of aggregate dredging.

1.3.6. As part of a planned series of meetings, English Heritage and Crown Estate attended a progress meeting on 20th May 2009 to discuss the preliminary results of this report, the 2009 geophysics survey (Stage 2) and the proposed sampling survey (Stage 3).

2. METHODOLOGY

2.1. INTRODUCTION

2.1.1. This report is concerned with the review of existing geophysical and geotechnical datasets within Area 240. The project design (Wessex Archaeology 2009) indicated that three datasets would be used: two analogue datasets from 2002 and a digital dataset from 2005. All three datasets were acquired by Andrews Survey Ltd. In the event, the analogue datasets were not available to WA; only the 2005 digital dataset was used. As this data was the latest available dataset acquired prior to the 2007 dredging when the artefacts were dredged, is in a digital format suitable for reprocessing, and is the best quality dataset (I. Selby, pers. com.), it is the most appropriate dataset to review.

2.1.2. The following section details the methodologies used to interpret the geophysical and geotechnical data and also details previous data acquired by WA that has been used to further aid the interpretation of the Area 240 data with regards to its context within the wider area.

2.1.3. As part of the geotechnical data review 158 vibrocore logs and photographs were reviewed (**Figure 4**).

2.1.4. Throughout the report, the Universal Transverse Mercator (UTM) Zone 31 co-ordinate system based on the WGS 84 datum is used. Where necessary, co-ordinates were transformed and projected using the Quest Geodetic Calculator by Quest Geo Solutions Limited.

2.2. GEOPHYSICAL DATA REVIEW

2.2.1. As part of the review of existing data, a previously acquired dataset from 2005 was processed and reviewed. The data were acquired by Andrews Survey Ltd (now Gardline Surveys Ltd) and comprised sidescan sonar data, sub-bottom profiler (boomer source) and swathe bathymetry data.

2.2.2. The sub-bottom profiler data were acquired using an EG&G 230 surface tow system with an EG&G boomer plate with an EG&G 234 power source. An 8-element SIG hydrophone was used and the data were recorded on a TSS 760 system, in Coda (*.cod) file format. The plate was powered at 200J at a firing rate of 375ms (2.67Hz).

2.2.3. The bathymetry data were acquired using a Geoswath system. The data were supplied to WA in raw, tidally uncorrected format and also as a tidally corrected gridded SD file. The SD file was gridded at 2m and is the file format generated by IVS Fledermaus software.

2.2.4. Sidescan sonar data were acquired using an Edgetech 4200 digital towfish at low (100kHz) and high (500kHz) frequencies at 100m range.

2.2.5. All data were acquired on north-south orientated lines at 100m line spacing, with cross-lines acquired at 1km line spacing (**Figure 3**).

2.2.6. For the purpose of this data review, the sub-bottom profiler and bathymetric data were reviewed. The sidescan sonar dataset provided to WA had no navigation data attached to the files and as such was not used for the review.

2.2.7. Additional lines providing context were also reviewed. These included a review of the prospection lines and main survey geophysical data acquired during the Seabed Prehistory Round 2 project: Great Yarmouth (Wessex Archaeology 2008). These survey lines are illustrated in **Figure 3**.

Geophysical data processing and anomaly characterisation

2.2.8. The 2m gridded bathymetry dataset was used for interpretation purposes, as provided to WA. The 2m sample grid is acceptable for the interpretation of seabed features such as sandwaves. The data were provided referenced to chart datum (Lowestoft). In order to associate the offshore deposits with terrestrial sediments, the bathymetry data were reduced from chart datum to Ordnance Datum (OD) Newlyn. Chart datum relative to OD (Newlyn) is -1.5m (Admiralty Chart number 1543).

2.2.9. The sub-bottom profiler data were processed by WA using Coda Geosurvey 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.

2.2.10. The data were generally of very good quality, particularly the north-south orientated lines. The east-west orientated lines are of slightly poorer quality, likely caused by the strong cross-currents in the area having an adverse affect on the data.

2.2.11. The data were processed on a line by line basis with filters and trace mixing adjusted accordingly in order to maximise the quality of the data. Generally, a band pass filter of 800 to 1800Hz was applied.

2.2.12. The sub-bottom profiler data were interpreted with 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 1,600m/s. This is a standard estimate for shallow, unconsolidated sediments (Sheriff and Geldart 1983).

2.2.13. The main aim of the geophysical data review was to provide geological context for Area 240 with regards to the sediments from which the artefacts may have been dredged. As such, a geological interpretation of the area was conducted focussing on those sediments thought to have been deposited within the timescale of the human occupation of Britain. Each sedimentary boundary was tagged along each line. Additionally, sediment sub-units thought to be of archaeological interest, i.e. fine-grained sediments, were also tagged.

2.2.14. Interpolations between the sediment boundaries and features interpreted from different lines were mapped and georeferenced using ArcView GIS software.

2.2.15. The depth of boundaries sub-seabed were also exported and gridded into layers using IVS Fledermaus software, referenced to the seabed depths acquired during the bathymetry survey (reduced to metres below OD).

2.2.16. The geophysics review was conducted in two phases. Firstly, the data within the vicinity of the site in Area 240 where the hand axes were found were reviewed.

These results enabled the development of the geophysical survey plan (Stage 2), which comprises a 3x1km area around the known dredged area. The second phase involved a review of all the data from Area 240 in order to arrive at an overall interpretation and provide context over the wider area.

2.3. GEOTECHNICAL DATA REVIEW

2.3.1. The data received for geoarchaeological review consisted of five reports containing geotechnical logs, photographs and test results (Alluvial Mining Ltd. 1999; Andrews Survey 2000a; 2000b; 2005; Lankelma Andrews 2007). These surveys were commissioned by HAML in order to assess the economic viability of extracting sand and gravel from within the first few metres of sediment of Area 240.

2.3.2. In order to compare the data, the locations were manually entered into a database and, where necessary, converted to WGS84 datum UTM z31 projection. For each vibrocore a unique Wessex Archaeology Vibrocore Identification number (**WA_VC**) was generated in order to compare them easily. The depths of the vibrocores relative to Ordnance Datum (OD) were generated by comparing the manually entered positions to the 2005 multibeam echosounder data using IVS Fledermaus software (**Section 2.2**). For all the vibrocores, with exception to those acquired during September 2005 (**WA_VC74-100**), the depths provided for the vibrocores should be treated as indicative only. Due to dredging activities and natural movement of mobile sediments (ripples and sandwaves) there will be differences in the water depths. As the quantity of sediments dredged is unknown, fully accurate conversions can not be made. There are a further 12 vibrocores (**WA_21, 22, 33, 37, 38, 44, 42, 41, 43, 70, 72 and 158**) that lie outside of known dredged areas. The water depths of these vibrocores should be considered approximate. The dredging history of Area 240 is discussed in greater detail in **Section 4**.

2.3.3. The **WA_VC** number, location, depth, original reference number, aggregate dredging area and report reference is given in **Appendix I**.

2.3.4. For the purpose of this report vibrocores **WAVC_101** to **WA_VC 149** are not referred to in this report as they are located outside of Area 240 see **Figure 4**.

2.3.5. Vibrocores within Area 240 (**Figure 4**) were also compared to the vibrocore survey undertaken as part of the Round 2 ALSF Seabed Prehistory project (Wessex Archaeology 2008) in Area 254, adjacent and to the northwest of Area 240. The assessment of the vibrocore data and the integration with the geophysics data are discussed in detail in **Section 5**.

2.3.6. The data were correlated with the geophysics data. However, correlation between vibrocore logs into a system of units is complicated by a number of factors:

- The sediment incorporated within more recent sandwaves and lag deposits are likely to have been originally brought to Area 240 by shallow marine/fluvial/glacial processes and sediments from these sources are difficult to differentiate in photographs;
- Dredging activity has likely disturbed the top *c.*2m of sediment in some areas (**Section 4**);
- The mode of deposition of sand and gravel either by marine, coastal, fluvial and/or glacial processes cannot be determined by reviewing geotechnical vibrocore logs;

- The degree of sorting, sedimentary structure, and gravel type have been either not recorded or recorded intermittently within the logs, thus increasing the difficulty in comparison.

2.3.7. As part of the review of the vibrocores it was hoped that some, if still intact, could be geoarchaeologically recorded and potentially subsampled for scientific dating. Therefore a list of cores suitable for this purpose was generated. Those cores thought suitable are listed in **Table 2** in order of preference:

Area	Easting	Northing	Report	Original VC no.	WA_VCID no.
240	424562	5819754	Andrews Survey 2000b	VC39	**WA_VC072**
240	425836	5825537	Andrews Survey 2005	VC13	**WA_VC086**
240	426248	5825874	Andrews Survey 2005	VC17	**WA_VC090**
240	426441	5825533	Andrews Survey 2005	VC18	**WA_VC091**
240	428235	5824511	Alluvial Mining Ltd 1999	VC6	**WA_VC006**
240B	426606	5825385	Alluvial Mining Ltd 1999	VC1	**WA_VC016**
240B	426526	5820572	Alluvial Mining Ltd 1999	VC6	**WA_VC021**
240B	426940	5820402	Alluvial Mining Ltd 1999	VC7	**WA_VC022**
240B	425510	5820928	Alluvial Mining Ltd 1999	VC8	**WA_VC023**
240B	426099	5822240	Alluvial Mining Ltd 1999	VC9	**WA_VC024**
240B	425500	5822211	Alluvial Mining Ltd 1999	VC10	**WA_VC025**
240	429034	5824194	Andrews Survey 2000a	VC3	**WA_VC028**
240	424546	5825776	Andrews Survey 2000b	VC1	**WA_VC033**
240	431173	5824803	Andrews Survey 2000b	VC9	**WA_VC041**
240	424950	5824808	Andrews Survey 2000b	VC28	**WA_VC061**
240	425541	5821926	Andrews Survey 2000b	VC32	**WA_VC065**
240	425579	5819748	Andrews Survey 2000b	VC38B	**WA_VC071**
240	424701	5822498	Andrews Survey 2005	VC1	**WA_VC074**
240	424667	5823373	Andrews Survey 2005	VC2	**WA_VC075**
240	424659	5823780	Andrews Survey 2005	VC3	**WA_VC076**
240	428863	5823487	Lankelma Andrews 2007	VC39C	**WA_VC150**
240	429672	5824239	Lankelma Andrews 2007	VC44	**WA_VC155**
240	429619	5825977	Lankelma Andrews 2007	VC45	**WA_VC156**
240	430054	5823722	Lankelma Andrews 2007	VC47A	**WA_VC158**
240	426992	5825822	Andrews Survey 2000b	VC3	**WA_VC035**
240	426205	5821661	Andrews Survey 2000b	VC33A	**WA_VC066**
240	425054	5824391	Andrews Survey 2005	VC6	**WA_VC079**
240	428873	5823807	Lankelma Andrews 2007	VC40C	**WA_VC151**

Table 2. Vibrocores with the potential for sub-sampling for scientific dating.

2.3.8. At the time of writing (July 2009), information on whether these cores are available for geoarchaeological recording or subsampling is unavailable.

3. BASELINE ENVIRONMENT

3.1. GEOLOGICAL AND GEOMORPHOLOGICAL BASELINE

3.1.1. The flowing section provides a brief account of the sea-level changes, climatic variations and geology for Area 240 and its surrounding area. For simplification, these factors are discussed in terms of glacial and interglacial chronologies with reference to their Marine Isotope Stage (MIS) number. Correlation between onshore deposits and those mapped offshore are also included.

3.1.2. The Quaternary (Pleistocene and Holocene) has been a period of fluctuating climate with corresponding fluctuations in sea-level. During interglacials sea-levels were high, sometimes comparable to present day, whereas at the climax of glacial periods sea-levels fell to more than 100m below present levels. During these glaciations the majority of the North Sea continental shelf would have been dry land.

3.1.3. Stone artefacts have long been found in sediments associated with river channels, either in sand and gravels layers or associated fine-grained sediments and peats (e.g. Wymer 1999). Fluvial sequences are also an important source of mammalian and molluscan fossils that have great potential for identifying interglacials (Preece 1995). Furthermore, as many of these fluvial sequences can be shown to have existed continuously throughout the Quaternary (or at least large parts of it) their sedimentary records provide an important framework for Quaternary stratigraphy (Bridgland 2002:27).

3.1.4. For a large percentage of the Middle and Late Pleistocene rivers have extended beyond present day shorelines onto the continental shelf (Bridgland 2002:25). These extensions of existing rivers, enlarged by confluences that are now submerged, and swollen by glacial meltwater, would have been drainage systems of considerable size (Bridgland 2002:25). It should also be borne in mind that remnants of rivers systems may be submerged which have no direct correlation onshore today.

3.1.5. **Table 3** provides an approximate indication of relative sea level variations in the southern North Sea during the last *c.*800,000 years. The table presents information derived from several references. The Marine Isotope Stages are from Wymer's projection in *The Lower Palaeolithic Occupation of Britain* (1999:4) and from compilations by Dix and Westley (2004:95) and the Ancient Human Occupation of Britain (AHOB) project (AHOB 2006; Barton 2005:18). The sea levels from the Pleistocene period are drawn from discussions by Funnel (1995:4), Dix and Westley (2004:67-80) and Lee *et al.* (2006:173-176). More data is available for the sea levels during the Holocene, particularly with regards to the east and the south coasts. However, it must be noted that as sea level fluctuations are the result of numerous factors, projected sea level curves must be regarded as projections of general tendencies rather than representations of exact figures.

3.1.6. Major archaeological periods and significant archaeological discoveries and events are shown within the table to illustrate the relationship between these periods and the relative sea level stands. The glacial maximum of the last ice age, the Devensian, is marked by shading.

Relative Sea Level	Approximate Age	Marine Isotope Stage	Chronozone/ Biozone	Archaeology
0m+ to -10m+	5,500 BP 7,200 BP	-	Atlantic pollen zone	Late Mesolithic to Early Neolithic. Area 240 inundated at approximately 7,500 BP
-15m+	- 8,500 BP	-	Boreal pollen zone	Beginning of Late Mesolithic. Start of inundation in the southern North Sea
-30m+	- 9,500 BP	-	Boreal pollen zone	Early Mesolithic

Relative Sea Level	Approximate Age	Marine Isotope Stage	Chronozone/ Biozone	Archaeology
-40m+	- 10,000 BP	-	Preboreal pollen zone	Beginning of Early Mesolithic
-50m+	- 11,000 BP	1	Loch Lomond stadial	Final Upper Palaeolithic
-60m+	- 13,500 BP	1	Windermere interstadial/ Late glacial	Late to Final Upper Palaeolithic, Re-colonisation of Britain from *c.* 12,500 BP; Creswellian cave sites and 'straight-backed blade' open air sites at Brockhill and Hengistbury Head
-80 to -100m+	- 18,000 BP	2	Dimlington stadial/ Late Devensian glaciation	Mid to Late Upper Palaeolithic, Britain probably not occupied
-120m+	- 40,000 BP	2	Devensian glacial maximum *c.* 18,000 BP	Early to Mid Upper Palaeolithic, appearance of modern humans in Europe *c.* 40-30,000 BP; Britain probably not occupied from *c.* 22,000 BP
-60 to -90m+	- 110,000 BP	3-5a-d	Devensian glaciation, Upton Warren/Chelford interstadials	Late Middle Palaeolithic; Kempton Park/East Tilbury gravel terraces deposited; Britain probably not occupied until 60,000 BP
5m+	- 130,000 BP	5e	Ipswichian interglacial	Early Middle Palaeolithic; Britain is an island and probably not occupied; raised beach deposits, e.g. Pagham
-120m+	- 186,000 BP	6	Wolstonian glaciation	Taplow/Mucking gravel terraces deposited; Britain probably not occupied from 180,000 BP
0m+	- 245,000 BP	7	(Aveley) interglacial	Pontnewydd (Homo neanderthalensis); Britain is an island; Norton raised beach
-120m+	- 303,000 BP	8	Wolstonian glaciation	Lynch Hill/Corbets Tey gravel terraces deposited – possibly related to the particularly artefact rich Taddiford Farm Gravel of the Solent; Levallois technology appears
0m+	- 339,000 BP	9	(Purfleet) interglacial	Sparsity of sites; Britain probably an island for at least part of this stage
-120m+	- 380,000 BP	10	Wolstonian glaciation	Boyn Hill/Orset Heath gravel terraces deposited; many Lower Palaeolithic sites
0m+	- 423,000 BP	11	Hoxnian interglacial	Swanscombe (Homo heidelbergensis); Aldingbourne raised beach (? possibly early MIS 7); Britain is an island during late Hoxnian

Relative Sea Level	Approximate Age	Marine Isotope Stage	Chronozone/ Biozone	Archaeology
-130m+	- 478,000 BP	12	Anglian glaciation	Sea level probably at its lowest recorded level around the British Isles; first breach of continental land-bridge during late Anglian
+/-0m	- 528,000 BP	13	Cromerian Complex, including Cromer Forest-bed formation (possibly confined to MIS 17-19) and Happisburgh glaciation (MIS 16?)	Boxgrove (Homo heidelbergensis); Slindon raised beach
-50m	- 568,000 BP	14		
+/-0m	- 621,000 BP	15		
-90m	- 659,000 BP	16		
-10m	- 712,000 BP	17		Happisburgh artefacts
-80m	- 760,000 BP	18		
-?m	- ?	19		Pakefield freshwater deposits and artefacts (MIS 17 or 19?)
+/-0m	- 787,000 BP			Pakefield estuarine deposits and artefacts (MIS 17 or 19?)

Table 3. Relationships between age, archaeology and relative sea level from the Cromerian Complex to post-Devensian

3.1.7. During the multiple cycles of transgressions and regressions, associated with the transitions between glacial and interglacial phases, various areas of the southern North Sea and English Channel have been repeatedly exposed. During these transitions, sediments would have been reworked, primarily through the repeated combination of fluvial action, glacial and permafrost melts, followed by marine transgression. Moreover, glacial cycles did not follow a regular pattern and within the transition from glacial to interglacial, with its progressive warming of the environment, there would have been short periods of cooling. As a consequence, the pattern of inundation and exposure would have occurred irregularly at varying rates, within an overall transgression or regression trend.

3.1.8. The consequence of these multiple cycles of transgression and regression is that in some cases deposits within the seabed around the UK have been truncated and sequences of earlier deposits have been isolated. The present day seabed stratigraphy does not necessarily represent a complete chronological sequence as deposits may have been completely or partially eroded before subsequent deposition. As well as the possibility of some periods of deposition not being represented in the sedimentary record, some deposits may have been reworked and modified by flooding events.

Pre-Anglian (MIS 13 upwards; >480,000 BP)

3.1.9. For the purpose of this report pre-Anglian sediments are discussed in terms of known occupation in Britain, i.e 700,000 BP, from the Cromerian Complex (from 787,000 BP) to the onset of the Anglian Glaciation.

3.1.10. The Cromerian Complex is recognised as having at least six temperate phases (Preece 2001). With the exception of MIS 16 and MIS 14 which are thought to represent colder phases (Wymer and Robins 2006:464-466), when sea level fell to approximately 90m below its current level, the Cromerian has been described as having a warm climate, similar to that of the present day Mediterranean.

3.1.11. One of the most important archaeological discoveries in recent times was at Pakefiled on the east coast of East Anglia. The Pakefield site is thought to be on the course of the Bytham River, which has produced a series of Lower Palaeolithic sites along its length. The Bytham River ran along a general course from Midland England to Great Yarmouth and beyond into the North Sea plain (Rose *et al.* 2001*;* 2002:50; Wymer 1999:130).

3.1.12. Archaeological excavations at Pakefield have uncovered 32 worked flints, including a simple flaked core, a crudely retouched flake and a quantity of waste flakes (Parfitt *et al*. 2005). The artefacts were all found in clear stratigraphical contexts relating primarily to the interglacial infill of a channel, comprising extensive deposits of organic muds and clays (Cromer Forest Bed Formation) incised into late Pliocene and Early Pleistocene marine sediments, known as Crag deposits. The Cromer Forest-bed Formation are overlain by the terraced river deposits of the Bytham sands and gravels (AHOB 2006; Rose *et al* 2002:50).

3.1.13. The floodplain deposits containing flint artefacts are the earliest indication of human occupation in Britain, *c.* 700,000 BP (Parfitt *et al*. 2005:1011; Lee *et al*. 2006:174-176). The discovery of artefacts at Pakefield demonstrates a longer human occupation of north-west Europe than hitherto thought, pre-dating other evidence by as much as 200,000 years. These sediments have also yielded a rich fauna of elephants, deer and other large mammals (Wymer 1999:129; Stringer 2006 and references therein).

3.1.14. The Cromer Forest Bed Formation and associated Bytham River sands and gravels are partially equivalent of the Yarmouth Roads Formation offshore. The Yarmouth Roads Formation comprise sediments deposited as part of a complex delta-top sequence forming part of the Ur-Frisia delta plain, consisting of sands with pebbles (including chalk), abundant plant debris and peat clasts (Cameron *et al*. 1992:107).

3.1.15. The Yarmouth Roads Formation is of Praetiglian to Cromerian age (approximately 2.3MA – 480,000BP). The age of the formation around Area 240 is difficult to assess: environmental data from vibrocores 8km off the coast of Lowestoft suggest a Praetiglian to Tiglian age (1.9 to 2.4 Ma) coeval with the Westkapelle Ground Formation or is possibly coeval with the Markham Hole Formation (1.2 to 1.4 Ma).

3.1.16. However, sediments to the north are of Cromerian Complex age 790,000 – 480,000 BP) (Cameron *et al* 1992:107) and pollen analysis of a core in the Dutch Sector indicates that the deposition of the sediments at a similar latitude occurred during the Cromerian III Interglacial, around 690,000 to 720,000BP (Zagwijn 1983). Deposition of this formation occurred though to the end of the Cromerian Complex with a basin-wide marine transgression progressing south to the around 52° latitude by 400,000 BP. It was during this transgression phase that the Cromer Forest Bed Formation was deposited. There may be remnants offshore of these sediments, although it has been suggested that the uppermost parts of the Yarmouth Roads Formation have probably been eroded (Cameron *et al* 1992:108).

3.1.17. Within Area 240 the Yarmouth Roads Formation overlies the Westkapelle Ground Formation. The Formation comprises clays, muddy sands and sands deposited in an open marine environment (Cameron *et al*. 1992:105), and are partially equivalent to the Crag deposits recorded onshore (Arthurton *et al* 1992:32).

Anglian (MIS 12; 480,000 – 423,000 BP)

3.1.18. The Anglian glaciation represents the most extensive glaciation of the British Middle Pleistocene, with ice sheets reaching down as far as the north Cornish coast and the Thames Valley (Wymer 1999:17). The trapping of water within the extensive Anglian ice sheets resulted in a fall in sea level thought to be the lowest recorded around the British Isles and estimated at 130m below the present level.

3.1.19. Extensive remodelling of the landscape took place, with old river courses such as the Bytham River destroyed or buried. The Thames and its tributaries were diverted southwards and a large ice-dammed lake developed in the southern North Sea - directly to the south of the ice-front -into which the Thames, and other major European rivers flowed (Gibbard 1988; 2001).

3.1.20. Onshore deposits around Great Yarmouth from this period are till deposits belonging to the Corton and Lowestoft Till Formations (Arthurton *et al*. 1994). No Anglian till deposits are known to be preserved offshore, as they were thought to be eroded by the subsequent sea-level rise during the Hoxnian interglacial.

Hoxnian (MIS 11; 423,000 – 380,000 BP)

3.1.21. The Hoxnian interglacial followed the Anglian glacial period. During the interglacial, Britain is likely to have become a peninsula of north-western Europe and remained so until the onset of the Aveley Interglagical (*c.* 245,000 BP). During the Hoxnian interglacial, the glacial meltwater from the Anglian ice sheet ran down the Thames-Medway channel, increasing its size and causing it to divert once again southwards in a course approximating the current position of the Thames Estuary (Bridgland 1994:295).

3.1.22. Sediments of possible Hoxnian age were observed in a section during the construction of sea defences at Caister-on-Sea. The sediments comprise channel fill sands cut into Lowestoft Till Formation. These sands were overlain by sands and gravels of the Devensian Yare Valley Formation (Athurton 1994:68).

3.1.23. There are no documented Hoxnian deposits offshore.

Wolstonian (MIS 10 – 6; 380,000 – 130,000 BP)

3.1.24. The Wolstonian Glaciation had comparable effects to those seen in the previous Anglian Glaciation (Gibbard 1988; 2001), causing major drainage diversion and landscape remodelling. The limits of the ice sheet during the Wolstonian Glaciation remain a contentious issue. It has been tentatively suggested that the ice sheet extended through Lincolnshire and the Midlands (Wymer 1999:18). In the North Sea the limits extended from the Wash eastwards and then north before heading south and west. Sea levels are estimated to have been approximately 120m below their current level during the Wolstonian glaciation (Wymer 1999). However, Gibbard (2007) has proposed that the ice sheet dammed a lake in the southern North Sea with the lake water level remaining close to present sea-level. The major rivers of the Rhine and Meuse were forced to flow to the southwest into this ice-marginal lake (Gibbard 2007). British faunas from this period are dominated by cold species such as mammoths, woolly rhino, reindeer and arctic fox.

3.1.25. Area 240 would not have been covered by an ice sheet during this glacial phase, and may have been situated on the western edge of the glacial lake. The landscape would be have been a vegetational mosaic of cold tundra and open steppe (Barton 2005:26).

3.1.26. During this period there were two interglacials known as the Purfleet (MIS 9) and the Averly (MIS 7), duering which times the sea-level was at similar levels as today and Britain was an island.

3.1.27. There are no documented Wolstonian sediments offshore within the region of Area 240.

3.1.28. There is no evidence of human inhabitation from MIS 6.

Ipswichian (MIS 5e; 130,000 – 110,000 BP)

3.1.29. For the purpose of this report the Ipswichian interglacial is referred to as MIS 5e only. Certain authors integrate MIS 5a-d with the interglacial and mark the start of the Devensian Glaciation at MIS 4 (60,000 to 75,000 BP) as it is at this point in the faunal record that animals are cold-adapted (Currant and Jacobi 1997). However, more generally, MIS 5d is referenced as the onset of the Devensian after the maximum stage of the interglacial (Wymer 1992; Kukla *et al* 2002 etc.).

3.1.30. The onset of MIS 5e (110,000 – 130,000 BP) was marked by an abrupt climatic transition from the end of the Wolstonian. The climate was similar of that today, possibly a bit warmer with hot summers and mild winters (Barton 2005). The southern North Sea was submerged during this time with the sea level 5-6m higher than it is today.

3.1.31. There is little evidence of Ipswichian interglacial sediments remaining in the Great Yarmouth and Lowestoft areas. Given the rise the sea-level during this time, much of the coastal areas would have been inundated. At Great Yarmouth and its surrounding areas, of the Pleistocene stages following the Anglian, only the Devensian sediments are considered to be widespread (Arthurton 1994:68). To the south in the Lowestoft area, there are Ipswichian deposits at Wortwell, interpreted as having been deposited in a low energy fluvial backwater within the Waverney Valley (Moorlock *et al* 2000; 68).

3.1.32. There is no evidence of human occupation during the Ipswichian.

Devensian (MIS 5d – 2; 110,000 – 13,500 BP)

3.1.33. The Devensian Glaciation was the last glacial stage to occur before the present climate amelioration. The Devensian maximum, when the glaciation was at its greatest extent, occurred *c.*18,000 BP with the southern extent of the ice sheet extending in a line from the Severn to the Wash (Flemming 2002:7). Area 240 would thus have been outside the limits of the ice but within the peri-glacial zone. At the height of the Devensian, the water locked up in ice sheets caused a lowering of sea level to approximately 120m lower than its current level.

3.1.34. During MIS 5a – 5d (70,000 – 117,000 BP) there was a general deterioration in climate characterised by interstadial (5c and 5a) and stadial (5d and 5b). Periglacial conditions prevailed during the stadials but pollen indicates that this did not limit tree growth altogether (Barton 2005).

3.1.35. Offshore, sediments from the early Devensian (MIS 5a-d; 110,000 – 75,000 BP) ae ascribed to the Brown Bank Formation. This formation was deposited during the marine regression at the onset of the glacial stage. Generally, sediments comprise brackish-marine grey-brown silts which are extensively bioturbated with a thin layer of shelly gravelly sand towards the base (Cameron *et al* 1992:113; 1989:125). However, in the region of Area 240 the Brown Bank Formation may comprise more fluviatile current-bedded silt and finely laminated clays filling late Ipswichian/ early Devensian channels, up to 20m deep (British Geological Survey 1991).

3.1.36. MIS 4 (75,000 – 60,000 BP) marked the onset of very cold conditions in Europe with the advancement of the Scandanavian ice sheet. However, southern Britain probably remained ice free.

3.1.37. The first evidence of human inhabitation following the Wolstonian (MIS 6) occurs in MIS 3, indicating a 120,000 year period in which Britain was uninhabited (Currant and Jacobi 1997; Barton 2005; AHOB 2006).

3.1.38. MIS 3 (60,000 – 25,000 BP) is typified by a sharply oscillating climate – short cooling episodes and milder climatic events are recorded. In Britain, cool dry conditions encourage the development of rich arid grasslands (mammoth steppe) which supported large mammals such as mammoth, woolly rhino, lion, bear etc. The migration of these animals probably also coincided with the arrival of the Late Neanderthals (Mousterian culture). From around 31,000 BP, anatomically modern humans are recorded habiting the British Isles (Barton 2005:28).

3.1.39. Onshore, possible Devensian sediments are ascribed to the Yare Valley Formation and are only recognised from boreholes. The formation occupies the floor of a buried valley system underlying the marshland and river valleys of the present day. It is generally observed overlying Crag deposits or London Clay to the West. Immediately offshore Newtown sands and gravels interpreted as this formation are observed overlain by the Late Devensian Breydon Formation.

3.1.40. The Yare Valley Formation comprises fine to coarse gravel, with variable amounts of fine to coarse grained sand. The gravel fraction is predominantly flint. Some silty gravel is recorded, as well as shell fragments and chalk cobbles. The type-borehole comprises grey, silty, fine to coarse gravel passing in the top-most metre to grey-brown gravelly, medium grained sand (Arthurton *et al.* 1994).

3.1.41. There is no direct evidence for the age of the formation. Coxon (1979) suggests Devensian; Cox *et al* (1989) suggest Late Devensian. Arthurton *et al.* (1994) supposes at least some of the deposits to be Late Devensian/early Holocene age, deposited by rivers flowing within the now buried valley system and draining central parts of East Anglia to the contemporary southern North Sea Basin.

3.1.42. There is also speculation to the maximum age of the deposits. Funnell (1990) has argued that the general characteristics of the deposits imply a late Anglian age. The formation postdates the Anglian succession (Lowestoft and Corton tills) but it is possible that it includes the glaciofluvial deposits of Late Anglian age.

3.1.43. Interestingly, the Yare Valley Formation occurs below the river terrace deposits around Postwick in the Yare Valley, regarded by Coxon (1979) as either Anglian or Wolstonian; Cox *et al* (1989) postulated a possible late Hoxnian age for these sediments.

3.1.44. The Yare Valley Formation is tentatively recognised in offshore seismic profiles (Arthurton *et al* 1994).

3.1.45. The gravel deposits identified by Bellamy (1998) within dredging Area 254, directly adjacent to the north of Area 240 were tentatively identified as analogous to the terrestrial Yare Valley Formation. These sands and gravels identified during the Seabed Prehistory: Great Yarmouth project (Wessex Archaeology 2008) were interpreted as fluvial sediments with Optically Stimulated Luminescence (OSL) dates suggesting deposition during the Wolstonian period.

3.1.46. There are no documented sediments present off the coast of East Anglia attributed to the periglacial landscape present at the height of and continuing after the Devensian Glaciation. To the northeast of the dredging areas the Twente Formation is documented. The Twente Formation is composed of periglacial sediments deposited throughout much of the southern North Sea from the Devensian and into the Early Holocene. These sediments are largely reworked during the Holocene transgression, and are now only preserved as scattered outliers (Cameron *et al* 1989:129).

Late Devensian and Early Holocene (MIS 2 – 1; 13,000 – 7,500 BP)

3.1.47. Water depths within Area 240 are between 18.2m and 35.0m below OD. According to existing models of sea-level change this area would have remained exposed as dry land following the retreat of the Devensian ice sheet. Inundation probably occurred *c.* 7,500 to 8,000 BP (Jelgersma 1979; Shennan *et al.* 2000; Shennan and Horton 2002).

3.1.48. Onshore, the confluence of the Rivers Bure and Tare at Great Yarmouth has resulted in a large complex of alluvium, peat and Fen silts adjacent to the coast (Geological Survey of Great Britain, Sheet 12). Peat of freshwater and brackish origins is a major component in the valleys of the River Yare and overlies the Yare Valley Formation gravels (Arthurton *et al.* 1994:72).

3.1.49. These post-glacial peats are identified as the Breydon Formation, a fill of the buried valley system underlying present-day marshland. The formation is dominated by silt and clay. Associated with the formation are three peat layers: the basal, middle and upper peat. Of these peat layers the basal peat is the one of interest with regards to Area 240; the middle and upper peat were deposited onshore after the inundation of Area 240 (Boomer and Godwin 1993; Arthurton *et al.*1994).

3.1.50. The basal peat is recorded to have formed *c.* 7580+/- 90 BP at a depth of around 23m below OD and is up to 2m thick (Arthurton *et al.* 1994:77). Based on seismic data of the near coastal area, the Breydon Formation is thought to be preserved offshore in two distinct areas off Great Yarmouth to the limit of the Cross Sand area, approximately 6km offshore, to the northwest of Area 240.

3.1.51. It has been suggested that these sediments continue offshore to Area 254 and then south into Area 240 (Bellamy 1998).

3.1.52. To the north of The Wash remnants of Mesolithic landscape have been documented including a dendritic channel network of potential fluvial, estuarine or intertidal origin (Fitch *et al* 2005:185) and remnant peat deposits (Ward *et al* 2006; Hazell 2008). Also, to the south of the aggregate areas the Elbow Formation is documented. This is an intertidal peat deposited at the onset of the transgression. However, there is no documentation of any remnant Mesolithic landsurfaces in the region of Area 240.

Mid Holocene (transgression; 7,500 BP)

3.1.53. Offshore, within Area 240, Holocene sediments generally form a thin veneer over Pleistocene formations. The present-day bathymetry of this area of the North Sea is comparable to the morphology of the pre-Holocene land surface with exceptions where accretion and erosion has occurred (Cameron *et al* 1992;116). Within Area 240 the seabed sediments are documented as sandy gravel and mobile sandwaves are numerous across the area (British Geological Survey 1988).

3.2. FINDS IN THE OFFSHORE AREA

3.2.1. The recovery of Palaeolithic stone artefacts and Pleistocene faunal remains from the southern North Sea has a long history predominantly associated with the fishing industry and, more recently the dredging industry.

3.2.2. Numerous mammal remains have been reported from a relatively restricted area in the southern North Sea between the Brown Bank area and the Norfolk coast. Between sandwaves in this area, there are a number of outcrops of the Yarmouth Roads Formation which yield Early and Middle Pleistocene mammal fossils (van Kolfschoton and Laban 1995; De Wilde 2006:239).

3.2.3. Documented faunal finds indicate four terrestrial fossil fauna-associations from the southern part of the North Sea. These indicate that at least part of the area was dry land during the Pre-Pastorian, Early Cromerian, Late Ipswichian – Early Devensian and Early Holocene (van Kolfschoton and Laban 1995).

3.2.4. Findings of artefacts such as flints, spear-heads, and reworked or carved fossil mammal bones are documented (Coles 1998; Flemming 2002). Ongoing studies in the southern North Sea are also contributing to the accumulation of artefacts.

3.2.5. Area 240 lies within the extents of the current East Coast Regional Environmental Characterisation (REC) area, which has resulted in geophysical data becoming available for the region. During May and June 2009 the East Coast REC Survey conducted its benthic sampling stage, focusing on ecological and geotechnical issues. Also, archaeologists were on board the survey vessel to obtain sub-samples for archaeological processing and to intercept any archaeological finds.

3.2.6. A possible flint artefact was identified during onboard processing of a clamshell sample at station CG6, which is situated to the west of the HAML exclusion zone (**Figure 5**). The sample was described as clean gravelly sand with occasional flint/quartz cobbles/pebbles on top. An unsieved 20 litre sample from CG6 (and comparable samples from other stations) is due to be delivered to WA for processing in the near future.

3.2.7. The artefact has subsequently been confirmed by Matt Leivers of WA as a broken secondary flake (**Plate 5** and **6**). The surviving dimensions of the piece are approximately 60mm by 43mm by 9mm, although a transverse break means that the piece was originally considerably longer. Although formal retouch is absent, both lateral margins have been used. The right margin has light edge damage towards the distal end; the proximal two thirds however show evidence of more robust use. The left margin is almost entirely cortical, but one short section comes to a cortex-free point, which appears to have been used as a piercing tool. The butt is facetted, and the platform edge has been prepared.

3.2.8. Flake debitage is difficult to date, but these traits are suggestive of a potentially Late Glacial date. However, Phil Harding (WA) has also commented that such a flake could also result from hand axe preparation, and thus be linked with Mr. Meulemeester's discoveries. One facet on the dorsal surface has a light patina; otherwise the piece is unpatinated and in very good condition, showing no signs of rolling, staining or damage congruent with its having been redeposited or having undergone any disturbance subsequent to its original loss/discard. In this sense it can be regarded as in situ.

3.2.9. This discovery has confirmed that prehistoric artefacts are present within the area targeted by this project, and that clamshell grabs are capable of recovering artefacts in a way that is suitable for archaeological recording and processing.

3.2.10. In addition, numerous finds have been reported via the BMAPA/EH protocol for reporting finds of archaeological interest.

3.2.11. Between 2005 and 2009 (at the time of writing) 49 finds have been reported as part of the protocol within the aggregate dredging areas offshore East Anglia (**Figure 5**). The reported finds comprise a variety of archaeological material covering prehistoric, marine and aviation archaeology. Prehistoric finds reported through the protocol are detailed in **Table 4**. Those highlighted in bold are of particular interest with regards to worked flint artefacts.

Area	Find	Description	Date	Report and year
240	**Hand axes and bones**	**>28 hand axes and bone fragments (as discussed in detail in Section 1.2).**	**Bones dated between 31,000 and 65,000 BP; and >500,000 BP**	**Hanson_0133_A (2007 – 2008)**
254	Fragment of bone	10cm long bone fragment identified as a possible deer metatarsus		UMD_0041_A (2005 – 2006)
360	**Eroding peat layer**	**A collection of dark decaying waterlogged pieces of wood, peat, mineralised bone, antler and a piece of struck flint**	**Charred wood and an eroded peat ball both radiocarbon dated to >47000BP**	**CEMEX_0039_A (2005 – 2006)**
361	Ice Age Mammal remains	Fragments comprising mammoth teeth and bone, and a piece of deer bone.	Woolly Mammoth: *c.* 380,000 to 10,000 BP	Hanson_0018_A (2005 – 2006)
251	Animal Bone	35cm long complete bone was identified by WA as a similar size to that of a horse, red deer or cattle; EH have suggested that it may be a hippopotamus radius bone.		Cemex_0093_A (2006 – 2007)
296	Animal bone	Suggested end of a long bone from a large mammal, possible one bigger than a horse.		UMA_0076_A (2006 – 2007)
296	Mammoth tooth	Possible milk tooth due to its size and unworn nature.	Woolly Mammoth: *c.* 380,000 to 10,000 BP	UMA_0107_A (2006 – 2007)
240	Mammoth tusk fragments	Two curved sections of tusk	Woolly Mammoth: *c.* 380,000 to 10,000 BP	Hanson_0126_A (2007 – 2008)
240	Peat concentrations	Three large concentrations of peat were discovered at various locations across three dredging lanes, indicating 200m by 130m area.		Hanson_0150_A (2007 – 2008)
240	**Mammoth teeth and flint**	**Two mammoth teeth and two flint finds. The teeth measure 17cm and 12cm, respectively. One of the flint artefacts showed possible signs of striking and may have been the waste**	**Mammoth: *c.* 380,000 to 10,000 BP**	**Hanson_0180_ A (2007 – 2008)**

Area	Find	Description	Date	Report and year
		product during knapping.		
296	Femur fragment	Large fragment (approximately 26cm long) of a right-sided femur. High degree of rolling and abrasion on the seabed. Derived from either a large bovid, such as a cow, or a cervid such as a giant deer.		UMA_0117_A (2007 – 2008)
296	Bone	Heavily degraded and damaged bone, possibly pig, goat or cattle		UMA_0160_A (2007 – 2008)
Unknown	Struck flint flake	Flint struck by human action rather than during dredging or b natural processes. Probably waste flake with smooth worn surfaces		UMA_0182_A (2007 – 2008)
430	Bone fragment	7cm long fragment identified as a partial distal end of the humerous bone. Mammalian in origin		UMA_0144_A (2007 – 2008)
361	Animal bone	Fossilised humerous fragment (22cm across) possible belonged to a large mammal, such as a mammoth	Mammoth: *c.* 380,000 to 10,000 BP	Hanson_0202 (2008 – 2009)

Table 4. Possible Prehistoric finds reported through the BMAPA / English Heritage Protocol for Reporting Discoveries of Archaeological Interest

3.2.12. The majority of the reported finds comprises fragments of bones and the context of these finds is unknown. The fragmented remains of ice age mammals such as deer or woolly Mammoth may end up in marine contexts having been washed from terrestrial deposits by rivers or eroded from cliffs or beaches. Alternatively, they may date to a time when the seabed was dry land.

3.2.13. Of particular note are the eroding peat layer, waterlogged wood and flint (CEMEX_0039_A) reported in February 2006.

3.2.14. The eroding peat layer, waterlogged wood and flint were reported in 2006 from Area 360, to the east of Area 240 (**Figure 5**). A range of remains were recovered comprised 4 samples of fibrous herbaceous peat, containing possible fine comminuted charcoal, in excess of 200 large (>50mm) waterlogged and mineralised wood fragments, one large definite (and one possible) fragment of partially charred wood, 12 fragments of mineralised bone, 3 fragments of antler and one worked flint. The single struck flint indicates the high archaeological potential of the assemblage.

3.2.15. Identification of the wood fragments suggested dominance of pine then birch indicating a relatively open canopy woodland, with deciduous types present but not important. The presence of hazel, elm and oak was thought to indicate a date after c. 9,300 BP, but potentially quite soon after given the importance of pine. However, radiocarbon dating of a large fragment of elm and a sample of peat both gave dates earlier than 47,000 BP. Although this collection of material was not from a secure context, it may provide circumstantial evidence of former landsurfaces and human activity relevant to Area 240.

3.2.16. Further evidence of former landsurfaces was identified in Area 240 where extensive concentrations of peat were reported (Hanson_0150_A) covering an area measuring 200m in length and 130m in width. These peat concentrations were dredged from an area adjacent to where mammoth teeth and flint were reported (Hanson_0126_A).

Although not identified in context, these finds further highlight the potential importance of Area 240.

4. DREDGING HISTORY

4.1.1. The extraction of marine sand and gravel to supply the construction industry started in earnest in the early 1960s with small vessels dredging relatively close to their marketplace. Business expanded in the 1990s with larger vessels used capable of dredging in deeper waters. In 1993 the Crown Estate deemed it compulsory that all vessels dredging on their licences should be fitted with an Electronic Monitoring System (EMS). The EMS automatically records the date, time and position of all dredging activity and every moth this information is supplied to the Crown Estate (Crown Estate and BMAPA 2002).

4.1.2. It was the interrogation of the EMS data that allowed the areas where the hand axes where dredged from to be constrained and formed the basis for the creation of the exclusion zone.

4.1.3. Within Area 240 the dredging history needs to be taken into account when analysing geophysical data and interpreting the depositional history of an area. Obviously, dredging has an impact on the seabed and effectively creates an additional post-transgression erosion surface.

4.1.4. **Figure 6** illustrates the coverage of dredging that has occurred over the past 10 years, between 1998 and 2007 and the HAML exclusion zone that has been in place since 2008. Area 240 covers an area of 31.5km^2, of this the 10 year dredging review indicates approximately 78% of the area has been dredged since 1998. However, only certain areas have been systematically dredged. To the west of the area, it is unlikely that more than the occasional dredge has occurred (Ian Selby, pers. Comm. 02/07/2009).

4.1.5. Evidence of dredging can be seen on the bathymetry data in places (**Figure 7**). However, it should be noticed that for the majority of the area, there is no direct evidence on the seabed. This is possibly due to the small amounts dredged from the seabed, or if the area was not dredged in recent years then bedforms may have formed disguising any visible effects from dredging. Furthermore, the type of dredging used in this area generally does not leave the dredge scars that are observed in other areas of the seabed (Ian Selby, pers. com. 21/05/09).

4.1.6. Although, there is no visible evidence of this dredging on the seabed, the dredging activities complicate the interpretation of the geophysical data and have to be taken into account when assessing deposition and erosion of sediment bodies within the area.

5. DATA REVIEW RESULTS AND DISCUSSION

5.1. INTRODUCTION

5.1.1. The following section presents the results and interpretation of the geophysics and geotechnical data review. As detailed in **Section 3**, Area 240 has a potentially long and complex history of deposition and erosion through numerous glacial and interglacial periods. Attempts have been made in the interpretation to identify these units and apply a chronological model to the units identified. Where this is not achievable based on these datasets, reasons have been given.

5.1.2. The results provide a broad palaeogeographic background to Area 240, as well as focussing on the area in which the artefacts were dredged.

5.1.3. The features tagged and referred to in the following section are listed in a gazetteer (starting at 7000) in **Appendix II**.

5.2. PALAEO-GEOGRAPHY OF AREA 240

5.2.1. Water depths in the 2005 area vary between 18.2m and 35.0m below OD (16.7 and 33.5m below CD). There are numerous features identified on the bathymetry data. Areas of previous dredging activities are observed in the central area and to the east, as discussed in **Section 4** (**Figure 8**). This dredging occurred prior to 2005. The most heavily dredged area is known to have been dredged in 2001, 2003 and 2004 (Crown Estate 2001, 2003 and 2004).

5.2.2. Sandwaves are observed throughout the majority of the area generally with an east-west trend. To the west and south of the area the sandwaves are generally up to 3m high; in the north of the area they are up to 6m high.

5.2.3. There are two distinct areas of lower-lying seabed that are observed with only some evidence of small bedform features (generally less than 1m high), and therefore not affected by present-day currents in the same manner as the rest of the area. These are located to the northeast (Channel A) and to the northwest (Channel B). Both low-lying areas are orientated northeast to southwest (**Figure 8**). These are possibly channel features that extend beyond the limits of Area 240. In the northwest channel a small bank is observed orientated along the length of the channel, towards the northern edge, and notably lies perpendicular to the offshore sandbanks observed to the west of Area 240.

5.2.4. These seabed features will be discussed in conjunction with the sub-bottom sediment units below.

5.2.5. Additionally, on the bathymetry data two wrecks were identified (**Figure 8**). One of the wrecks is situated within the vicinity of the dredging in 2007. Both these wrecks are listed by the UKHO as live wrecks. A further six wrecks are documented in the area by the UKHO and are listed as dead wrecks. These wrecks are not observed on the bathymetry data.

5.2.6. Using the geophysical data eight units were identified based on their seismic characteristics. These are illustrated in simplified schematics (**Figure 9**). **Figure 9a** illustrates a scheme of units south to north; **Figure 9b** from west to east.

5.2.7. **Unit 1** (**7000**) is the deepest unit and is observed across Area 240. Seismically, it generally comprises a series of faint, sub-parallel reflectors. To the west, pro-grading sediments/dipping reflectors are observed. The top of **Unit 1** is a well defined reflector in the west becoming fainter and less well defined to the east. The top of the unit is observed at 2.2 to 29.3m sub-seabed (32.2m to 61.0m below OD), as illustrated in **Figure 10**. This unit is interpreted as the Westkapelle Ground Formation which is dated to the LatePliocene/Early Pleistocene and predates the occupation of Britain. As such, these sediments are of no archaeological interest.

5.2.8. **Unit 2** (**7001**) is observed throughout the majority of Area 240 (**Figure 10**) and generally overlies **Unit 1** and as such the base of the unit is observed dipping to the east (**Figure 10**). **Unit 2** thickens to the east as **Unit 1** deepens. **Unit 2** is absent in the southeast corner of the site and to the northwest corner of the site where the sediments have been eroded away and subsequent overlying sediments have been deposited.

5.2.9. Seismically, **Unit 2** has a varying character. Predominantly it is an acoustically transparent unit with occasional faint reflectors; to the southwest and west of the area faint, southerly dipping reflectors are observed. Vibrocores **WA_VC025**, **065** and **071** indicate that these faint reflections are indicative of thin beds of clay laminae and silts (**Figure 11**). Throughout the remainder of the area the vibrocores (**WA_VC55**, **057** and **068**) indicate that the unit comprises silty, gravelly, fine to coarse sands.

5.2.10. Based on its seismic character this unit is interpreted as the Yarmouth Roads Formation. The Yarmouth Roads formation is known to comprise a complex delta-top sequence forming part of the Ur-Frisia delta plain, consisting of sands with pebbles (including chalk), abundant plant debris and peat clasts (Cameron *et al*. 1992:107). The Yarmouth Roads Formation was deposited between 2.3MA and 480,000 years ago; although the earliest deposits are of no archaeological interest, the later depsoits equate to the Cromer Forest Bed Formation which have been associated with archaeological material at Pakefield.

5.2.11. The base of **Unit 2** is an undulating surface with some broad shallow channels observed across the site. The general trend of this layer is illustrated in **Figure 10**.

5.2.12. **Unit 3** (**7002**) is only observed to the south of the site (**Figure 12**). The base of the unit is observed between 1.0 and 11.3m sub-seabed (29.9 to 39.2m below OD) and is either overlain by surficial lag deposit (<1m) to the east or up to 7m of **Unit 4**. There are no bedforms in this area. Unit 3 is up to 11m thick and is composed of a series of very strong, southerly dipping reflectors (**Figure 12**).

5.2.13. To the northern limit of the unit the sediments look as though they could be cutting **Unit 2**. However, as **Unit 2** in this area is generally transparent with few reflectors no evidence of this cut is no apparent. Also, the base of the dipping reflectors onlap the underlying **Unit 1**.

5.2.14. **WA_VC022** indicates that the sediments comprise a silty sand with very frequent thin beds and laminae of firm to stiff clay and peaty organic clay. These sediments are very similar to those described above for **Unit 2** (**WA_VC025**, **065** and **071**) and **Unit 3** is interpreted as part of the Yarmouth Roads succession. The enhanced reflectors are likely caused by the high organic content in the unit here compared to further west. It is likely that in this part of Area 240 the depositional environment was of lower energy that to the north of the site and formed part of the delta plain described by Cameron *et al* (1992:107).

5.2.15. **Unit 4** (**7003 – 7006; 7090 - 7093**) is observed across the majority of the site (**Figure 13**). The unit generally comprises sands and gravels of varying compositions. There is some difficulty in interpreting these units due to their complex seismic signatures.

5.2.16. The base of **Unit 4** is observed between 0.5m to the west and central areas, and 15.4m sub-seabed, to the east associated with the base of a channel (25.9 and 43.6m below OD). The thickness of the unit varies and in many places is observed at or close to the seabed. In the east associated with the channel it is up to 10m thick, although in this area it is interspersed with **Unit 5**.

5.2.17. Across the central portion of Area 240 a relatively thin unit (up to 4m thick) of chaotic reflections are observed (**Unit 4a** in **Figure 9**). The basal reflector of this unit varies and is sometimes observed as an obvious strong reflector, elsewhere it is diffuse (**Figure 13** and **14**). The diffuse boundary probably reflects a grading of sediments into the underlying silty sands and gravels of **Unit 2**. Within the dredged areas particularly to the southeast of the area the unit is very diffuse and difficult to identify. These areas are highlighted in **Figure 13**. Furthermore, due to the nature of the overlying sands and gravels of the surficial unit (**Unit 8**) it is difficult to interpret where the edges of this unit sub-crop **Unit 8,** or where the base of the unit becomes so indistinct that the basal reflector cannot be accurately tagged. The areas where the unit boundary is represented by a solid line in **Figure 13** represent areas where the base of **Unit 4** sub-crops beneath the surficial sediments and as such the underlying **Unit 2** is present at the seabed overlain by **Unit 8**. **Figure 13** also illustrates areas where **Unit 4** is absent, cut by overlying units.

5.2.18. Elsewhere in Area 240, particularly to the east of area this unit is marked by strong reflectors with a strong basal reflector marking a definite change in sediment type with the underlying **Unit 2**. This is **Unit 4b** and **4c** in **Figure 9**.

5.2.19. A major feature of **Unit 4** lies to the north of the area where a channel (**7090**) (Channel C) cut into **Unit 2** is observed marked by the strong basal reflector of **Unit 4** (**Figure 15**). The channel feature is observed orientated northwest to southeast across the area. The southern edge of the channel is prominent and can clearly be seen on the Fldermaus model in **Figure 15**. The channel edge cut 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 to the south.

5.2.20. Within the northern section of the area and associated with the channel and channel edges is a strong reflector (**Reflector A** in **Figure 9**). This is a strong reflector (**Figure 16**) which marks a particular horizon within the channel fill deposits. It is interpreted as marking a hiatus in the infilling of the channel cut. However it is not always observed in all parts of the channel (**Figure 16**). This layer is observed between 0.3 and 12.6m sub-seabed (23.8 to 36.6m below OD), generally deepening to the east. It is observed underlying **Unit 4c**, but also is observed marking the base of **Unit 5**, which is described in more detail below.

5.2.21. **Reflector A**, where present, marks the top of **Unit 4b** and the base of **Unit 4c**. **Unit 4b** comprises strong reflectors, sometimes chaotic sometimes sub-parallel. **Unit 4c** is seismically very similar to **Unit 4a** observed to the west and south of the area, strong, more chaotic reflectors observed. Based on seismic character, where **Reflector A** is absent there is no observed difference in the seismic character of **Units 4b** and **4c**.

5.2.22. The base of **Unit 4** appears continuous across the site (where observed) with no structural evidence to suggest that the channel cuts through any existing deposits of sands and gravels. Throughout the area the **Unit 4** fill sediments exhibit subtle seismic characteristic changes, hence the reference to **4a**, **4b** and **4c** in **Figure 9**. However, there appears on the geophysics data to be lateral continuity across the area with structural evidence to suggest different depositional environment, with the exception of localised areas where **Reflector A** appears to mark the top of a channel gravel deposit.

5.2.23. **Unit 4** is interpreted as comprising sands and gravels and is confirmed by the vibrocores. The sands and gravels recorded in the vibrocore logs were predominantly orange, yellow and brown in colour although occasionally grey. The sand was often noted to contain crushed shell. The gravels were predominantly subangular to subrounded flint with noteable amounts of quartz, quartzite, sandstone and occasional siltstone. It should be noted that the level of detail recorded varied between the reports and therefore attempts to characterize these sands and gravels, particularly with regard to their inclusions, is difficult.

5.2.24. Although difficult, an assessment was made to see if there was any spatial pattern to those vibrocores documented as containing flint, flint and quartz, and flint, quartz and sandstone. No discernable patterns were apparent. The vibrocores do not penetrate **Reflector A**, as such any differences in the sediments of **Units 4b** compared to **4a** and **4c** are not known.

5.2.25. The strong reflectors associated with the channel infill may form part of the fluvatile Brown Bank Formation sequence (Early Devensian) as detailed by (British Geological Survey 1991).

5.2.26. **Unit 5** is a very distinctive unit generally associated with **Unit 4b** and **4c** to the north of the site, although is associated with **Unit 4a** to the south of the area (**Figure 17)**. It is generally a seismically transparent unit, generally up to 2m thick, occasionally thickening in channels to up to 6m.

5.2.27. **Unit 5** is observed at various layers stratigraphically within **Unit 4** and also in a variety of forms. It is observed infillng broad shallow depressions to the south of the area (**7020 – 7025**) (**Figure 17**). To the northwest it is observed forming small bank like structures up to 3m high (**7018** and **7019**) (Bank A on **Figure 8**). Further banks of **Unit 5** are observed to the east associated with the edges of the channel (**7028**, **7030**, **7036** and **7038**). This type of feature is illustrated in **Figure 17**. **Unit 5** is also observed infilling shallow channel-like structures sometimes marked by **Reflector A** (**Figure 17**) (**7026**, **7027**, **7029**, **7031 – 7035**, **7037**, **7039 – 47**).

5.2.28. Based on the geophysics **Unit 5** is interpreted as comprising fine-grained (sands, silts and clays) deposited in a low-energy environment such as river or estuary. The vibrocore data confirms this. The vibrocores penetrating this unit indicate clay with occasional shells (**WA_VC090**, **091**, **016**, **044**, **041**, **150** and **158**) overlain by a thin unit of clayey sand (**WA_VC016** and **150**). **WA_VC090** and **091** show evidence of oxidisation and may be a result of weathering and exposure to oxygen and the formation of a horizon of a gley type soil. Black clay recorded in **WA_VC158** may have the colour due to a high organic content although no organic material was recorded on the vibrocore log. Given the mode of deposition, i.e. low energy fluvial/estuarine, the presence of organic matter is not unexpected.

5.2.29. Channel B, observed on the bathymetric data (**Figure 8**) is observed draped with Unit 4 sediments and although appears channel-like on the bathymetric data this is not substantiated by the sub-bottom profiler data.

5.2.30. **Unit 6** (**7048 – 7079**) is observed throughout the southern and central areas and in pockets to the northwest (**Figure 18**). The seismic character is generally transparent indicating a finer composition than the underlying **Unit 4. Unit 6** infills small depressions; there is no significant evidence to suggest that these sediments infilled channels. The base of the unit is observed between 0.4 and 6.3m sub-seabed (25.4 to 34.4m below OD).

5.2.31. The geotechnical data indicates that the unit comprises slightly gravelly, slightly silty, fine to medium grained sand (**WA_VC88** and **064**). Vibrocores **WA_VC23**, **024** and **074** indicate the presence of clays associated with this fine-grained sediment indicating a low-energy environment deposition early in this depositional sequence. Within vibrocores **WA_VC023** and **WA_VC024** clay is interbedded with shelly silty sand which may be an indication of tidal rhythmitic deposition suggesting an estuarine or near coastal depositional environment.

5.2.32. **Unit 7** is only observed to the northwest of Area 240 and also as a small patch in the southwestern corner (**Figure 19**). This unit is generally characterised by very strong sub-parallel reflectors (**Figure 19**) and is associated with the channel observed on the bathymetry data (Channel A, **Figure 8**). The base of the unit is observed between 0.6 and 6.3m sub-seabed (27.7 to 36.2m below OD). The top of the unit is observed at the seabed with only a thin veneer of surficial sediments (less than 1m).

5.2.33. The small bank (Bank B) on the northern edge of this channel observed on the bathymetry data also marks the northern limit of **Unit 7**.

5.2.34. The vibrocores containing peat are **WA_VC061**, **WA_VC072** and **WA_VC086** (**Figure 11**) and are associated with **Unit 7**. In **WA_VC061** the 0.2m thick peat is recorded in the bottom of the core and not fully penetrated. Its surface is at 32.5m below OD and it is overlain by sandy clay. The peat in vibrocore **WA_VC086** is 0.75m in thickness, elevated between 30.05 to 30.81m below OD; and overlain by a shelly, silty clay. The peat in **WA_VC072** is 0.24m in thickness and elevated between 30.18 and 31.2m below OD. The peat has formed above a deposit of sand and is overlain by a shelly clay containing bivalves. **WA_VC076** is also associated with **Unit 7** and comprises clay at the base of the core similar to that in **WA_VC086** at similar elevations (**Figure 20**).

5.2.35. Further known occurrences of peat have been dredged up from this area within the vicinity of **Unit 7** (**7083** and **7088**) deposits (**Figure 5**). These reports indicate that the peats may be more extensive than this geophysics data indicates, or that due to the relatively thin character of the peat layer, it has been removed in the area by dredging activity (when the peats were reported).

5.2.36. The peats and clays of **Unit 7** and the presence of a very shallow channel indicate low-energy deposition in a fluvial or marshland environment, either freshwater or intertidal environments.

5.2.37. **Unit 8** represents the uppermost unit identified in the geophysical and geotechnical data and are observed across the entire site either in the form of a lag deposit or in mobile sediment forming mobile bedforms such as sand ripples and larger sandwaves. Where observed the lag deposit generally comprises shelly, gravelly medium to coarse sand. Those vibrocores containing a shelly well sorted sand (**WA_VC010**, **011**, **012**, **038** and **048**) form part of a mobile seabed sediment or sandwave.

5.2.38. The above section describes the general descriptions of the seismic units identified within Area 240, their relationships to each other and their general composition based on the vibrocore data. Additionally certain features identified in the vibrocores deserve particular mention.

5.2.39. Of particular note were the fine grained deposits in **WA_VC006** which contained a sandy clay which appeared a mottled pink colour in the photograph, recorded as grey on the vibrocore log (Alluvial Mining Ltd 1999). It is noted that amongst the sediment recovered from the reject piles in Holland in association the hand axe finds, some “reddish clay” – sample no.<5> was recorded. At the location of **WA_VC006** the geophysics data indicates the presence of **Unit 5**: a fine grained unit as described above.

5.2.40. A number of the vibrocores contained silty sands and clays which appeared from the photogtaphs and logs to have oxidised surfaces, these included **WA_VC023**, **024 (Plate 12)**, **062**, **068**, **071**, **074**, **090** (**Plate 8**), **091** (**Plate 9**), **155** and **156**. This may be a result of weathering and exposure to oxygen and the formation of a horizon of a gley type soil.

5.2.41. When compared to the geophysics data, the oxidised surfaces are associated with three units. **WA_VC068** are situated in areas interpreted as likely **Unit 2** deposits, **WA_VC90** and **091** are **Unit 5** (as discussed above) and the remainder are associated with **Unit 6**.

5.2.42. The organic freshwater silts and overlying estuarine silty clays from the Great Yarmouth seabed prehistory project (Wessex Archaeology 2008) are visually similar to some of those vibrocores in this study. Some examples are shown in **Plates 6 - 9**. Of particular note is the organic sediment in **VCGY1** from the Seabed Prehistory project (**Plate 10**; **Figure 21**) which is elevated at similar levels to the peats recorded in vibrocores **WA_VC061** (**Plate 11**), **WA_VC072** and **WA_VC086** (**Plate 7**); elevations are illustrated in **Figures 20** and **21**. Oxidised fine grained sediment seen in vibrocores **WA_VC090** and **WA_VC091** (**Figure 21**) are also similar to sediment within vibrocore **VCGY1** from the seabed in prehistory project (see **Plates 7**, **8** and **9**).

5.2.43. Although visually similar, the geophysics data indicates that the peats observed the in vibrocores **WA_VC061**, **WA_VC072** and **WA_VC086** are likely to belong to **Unit 7** (**Figure 18**), whereas **VCGY1** and the oxidised sediments observed in **WA_VC090** and **WA_VC091** are likely to be **Unit 5**.

5.2.44. There are definite comparisons in the geophysics data between the Seabed Prehistory Great Yarmouth geophysics data and the dataset reviewed for this report. Direct comparisons between the seismic unit stratigraphy can be made, as shown in **Table 5**.

Area 240 Unit	Area 254 Unit	Interpretation
Unit 8	Unit 4	Holocene seabed sediments
Unit 7	Not observed	Fine-grained peat deposits
Unit 6	Not observed	Estuarine fin-grained sediments
Unit 5	Unit 3	Fine-grained sediments (estuarine/freshwater)
Unit 4	Unit 2	Sands and gravels
Unit 3	Not Observed	?Deltaic fine-grained sediments
Unit 2	Unit 1	Shallow marine sands and gravels
Unit 1	Not recorded	Open marine clays and sands

Table 5. Comparison of sediment unit identified in this survey and the Seabed Prehistory: Great Yarmouth survey

5.3. CHRONOLOGY

5.3.1. The chronology of Area 240 is difficult, particularly in terms of the complexity of the seismic data in differentiating the sands and gravels of **Unit 4**.

5.3.2. Also of particular note are the peats and organic silts and clays contained within **Units 5**, **6** and **7**. It is often assumed that offshore sequences of fine-grained deposits and peats near the seabed surface in the Southern North Sea and English Channel are the result of Holocene estuarine and saltmarsh development respectively. However, the sequences of fine-grained and organic deposits are cyclical throughout the Pleistocene cold and warm stages as the following examples demonstrate:

- Silts and clays investigated as part of the Happisburgh and Pakefield Round 2 Seabed in Prehistory Project thought to form part of the Bytham River offshore are thought to be *c.*1 million years old (Wessex Archaeology 2008);

- Along the coast, fine-grained deposits thought to date to MIS17 *c.*700,000 BP associated with the Cromer Forest Bed Formation have recently yielded human artefacts (Parfitt *et al*. 2005);

- During the Seabed Prehistory Round 2 project to the north of Area 240, organic sits and clays were dated by OSL dating. These results combined with environmental analyses seemed to suggest that the deposits were probably Ipswichian MIS 5e in date. There were however some conflicting dates arising from radiocarbon dating which suggested these intertidal sediments were *c.* 40,000kyr ago or MIS3 (Wessex Archaeology 2008);

- The “Breydon Formation”, an onshore sequence near Great Yarmouth of peats, silts and clays dating to *c.*8,000 to 6,000BP has been previously suggested to be continuous offshore (Arthurton *et al* 1994; Bellamy 1998).

5.3.3. **Unit 1** is interpreted as the Westkapelle Ground Formation of Late Pliocene/Early Pleistocene age. This is overlain by **Units 2** and **3** which are interpreted as Yarmouth Roads Formation. Dating of this formation in this area is difficult as explained in **Section 3.1**. The sediments observed in the vibrocores could belong to the Cromerian Complex around 700,000 BP, similar to those sediments found at Pakefield, but they could be older.

5.3.4. There is then a gap in the sequence until the initial channel cut (Channel C) into the Yarmouth Road sediments marked by the base of **Unit 4**. Given the large scale extensive landscape remodelling that occurred during the Anglian Glaciation that forced the Thames further south, it is thought that the channel cut into the Yarmouth Roads unit is likely to have formed during the Late Anglian at the earliest.

5.3.5. The relative chronology of **Unit 4** infill sediments is difficult. The unit comprises a series of sands and gravels of varying compositions which are all seismically similar. The relative ages of these sediments is based on the structure observed at the edge of the cut. If the channel cut was observed to the seabed then it would post-date the deposition of the sediments **Unit 4a**. However, in the absence of any cuts through this unit it seems likely that across the site the seabed was modified (erosion) when the channel was cut to the layer that has been marked the base of **Unit 4**. The channel then subsequently infilled with sands and gravels deposited at the edges of the channels either contemporaneously or later. It is likely that the sediments of **Unit 4b** are the oldest in the sequence, observed at the base of the channel.

5.3.6. There then appears to be a hiatus in deposition (**Reflector A**) which was then subsequently remodelled (observed as channels and undulations in this layer). Fine –grained deposits of **Unit 5** were then deposited. The numerous small channels and meandering nature indicate a large low energy channel, with the **Unit 5** deposits developing both temporally and spatially as the channel continued to flow and fill. Evidence from Area 254 suggests that **Unit 5** comprises a freshwater deposit at the base, becoming increasing estuarine and then marine influenced, indicative of sea level rise (Wessex Archaeology 2008). The sand and gravel deposits of **Unit 4a** and **4c** could be contemporary and associated with higher-energy estuarine deposition at the onset of a transgression. However, Area 254 indicates that some of these sands and gravels from **Unit 4a** are likely to be older than **Unit 5**. It is possible that **Units 4** and **5** indicate a cyclic sequence of deposits indicating changing environments. Based on the geophysical data, **Unit 4** may be pre-date, be contemporary with the deposition of **Unit 5**, or younger than **Unit 5** towards the top of the sequence.

5.3.7. If these sands and gravels are the equivalent of the Yare Valley Formation (**Section 3.1**) then the interpretation agrees with the hypothesis that the succession of sands and gravels may be as old as Late Anglian (Funnell 1990) and at least some of the deposits as young as the Late Devensian (Cox *et al* 1989; Arthurton *et al*. 1994).

5.3.8. Much further work would be required to establish the dates associated with these sediments. As stated above, during the Seabed Prehistory Round 2 project sediments dated by OSL dating and combined with environmental analyses seemed to suggest that **Unit 5** deposits were probably Ipswichian (MIS 5e) in date. There were however some conflicting dates arising from radiocarbon dating which suggested these intertidal sediments were c. 40,000kyr ago or MIS3. The differences in these dates have implications on the relative ages of the cut of the channel and the sands and gravels of **Unit 4**, and thus have an influence on the likely ages of the sediments in which the hand axes were dredged from.

5.3.9. Based on the dates of **Unit 5** from the Seabed Prehistory: Great Yarmouth Project (Wessex Archaeology 2008) two hypotheses can be suggested.

5.3.10. The first hypothesis is based on a MIS 5e date for **Unit 5**. The date of the channel formation is unknown, but would probably post-date the Anglian Glaciation. OSL dates of sediments from Area 254 indicate tentative Wolstonian date for the sands and gravels directly underlying **Unit 5** deposits which would indicate that the deposition of these sediments occurred in the base of the channel flowing towards the ice marginal lake situated to the east and southeast of Area 240 (Gibbard 2007). With climate amelioration at the onset of the Ipswichian, the channel fills were deposited in lower-energy freshwater environments, that become more estuarine and then tidally influenced. The **Unit 4a/c** sediments would likely be deposited either during this transgression or during the Devensian, deposited no later than MIS 2. Data from Area 254 indicates that the top sediments of **Unit 5** would have been exposed to air during MIS2, although not necessarily deposited as late as this.

5.3.11. Interestingly, there are no deposits of Ipswichian age documented onshore. If these sediments are MIS 5e then the offshore sediments may aid in the understanding of the regions stratigraphy both on- and offshore.

5.3.12. The second hypothesis is based on a MIS 3 date for **Unit 5**. In this hypothesis the channel was down cut during the marine regression at the onset of the Devensian (MIS 5d) (British Geological Survey 1991). The channel would then be infilled between the date of incision and during the climatic fluctuations during the Early Devensian (MIS 5a-d and 4) with **Unit 5** deposited during MIS 3 and **Unit 4a/c** deposited at or just after this time, no later than MIS 2. Given that the environmental data would indicate an intertidal succession for **Unit 5** this would indicate a transgression during MIS 3 where the sea level would be around 30m below present. Sea levels during MIS 3 are documented at lower than this (between 60 and 90m below present levels).

5.3.13. There are issues are regarding both hypotheses with current documented theories, particularly concerning sea-levels at times of sediment deposition. Further dating evidence, in the form of absolute dating techniques and further environmental analysis would be required in order to establish the dates of these sediment units. What can be said is that the sediments generally form a continuously younging sequence from the initial incision into the Yarmouth Roads sediments (**Unit 2**).

5.3.14. The relative chronology of **Unit 6** and **7** is also difficult. Both units are younger than **Units 4** and **5**, but as there are no areas where the two units (**6** and **7**) are situated together no direct relationship can be made. **Unit 6** was likely deposited in a tidal estuary, whereas the peats and clays of **Unit 7** were deposited in a low-energy riverine marshy environment. It is possible that **Unit 7** could be as young as the Early Mesolithic (MIS 1) and is an offshore extension of the Breydon Formation (Arthurton *et al* 1994; Bellamy 1999). Onshore the basal peat of the Breydon Formation is observed at 23m below OD and around 6km offshore Great Yarmouth clays of the Breydon Formation are observed at a depth of 27m below OD. These are comparable depths to **Unit 7** peats and clays in area 240 between 30 and 32m below OD (Figure 20). The basal peat of the Breydon Formation is overlain by the Lower Clay composed of soft silty clay which becomes firm with depth (Arthurton *et al*. 1994), which may be comparable with the thin unit of sandy, shelly clay observed overlying the peats in vibrocores **WA_VC061**, **072** and **086**.

5.3.15. If **Unit 7**, associated with Channel A, is Mesolithic in age then it is likely that when these peat deposits were being deposited the larger, older channel (Channel C) to the east would have filled up by this time.

5.3.16. Dating and further investigation of the composition of the peats would be required in order to confirm that remnants of a Mesolithic landscape exist offshore in this area.

5.3.17. Unit 8 comprises the uppermost unit associated with the last transgression and is the subject of present-day marine processes.

5.4. RELATION TO THE AREA 240 FINDS

5.4.1. A 3 x 1km block has been constructed around the dredging tracks from which the artefacts were dredged (**Figure 22**). It is this area that was surveyed as part of the 2009 geophysics survey which forms Stage 2 of this project (Wessex Archaeology 2009a).

5.4.2. All units, except **Units 5** and **7,** are observed within the area. **Figure 22** illustrates those sediment units that are observed subcropping the surficial sediment unit (**Unit 8**) within the 2009 survey area. These include **Units 2**, **3**, **4** and **6**. When compared to the 2007 dredging tracks each of these units could have contained the hand axes, flakes and bones.

5.4.3. The flakes were described as being in mint condition from a primary context, fresh condition from a possible erosion surface and weathered condition from secondary sources or the seafloor.

5.4.4. The weathered material is almost certainly from a secondary context either deposited with the sands and gravels of **Unit 4** or in the surficial lag deposits reworked during the last marine transgression. The presence of 'acorn shell' (or some other sea creature) traces on one of the hand axes would indicate that at least some of the hand axes are situated on the seabed. As there are strong currents in the area that cause sandwaves to move, it is likely that the lag deposit forms a reworked surface of the sands and gravels below rather than sediments transported during the transgression. Therefore, it is possible that the artefacts were deposited in this area (either in primary or secondary contexts) prior to the transgression.

5.4.5. Those artefacts exhibiting fresh condition are possibly associated with **Unit 4** or the edges of **Unit 6**. There is a possibility that they may also be associated with the top of **Unit 2**/base of **Unit 4** where the base of **Unit 4** is close to the surface. Interestingly, Ian Selby (pers. Comm.) has stated that the flint in the gravel is generally small (40mm or less) and is not large enough to make handaxes. However, some of the vibrocores indicate ‘cobbles’ at depth and the sediments in the EC REC clamshell grab 6 indicate flint cobbles up to 150mm long in the upper 0.5m of sediments. As such, there is a possibility of material available for making hand axes *in situ*, particularly to the south of this area.

5.4.6. Those in fresh condition are likely associated with **Unit 6**. Given the depositional environment of **Unit 6** is unclear, it is difficult to state how likely the hand axes are to be found associated with this unit. **Unit 5** deposits are associated with the edge and within a channel and given their fine-grained (silts and clays) nature, would preserve the artefacts.

5.4.7. Also, it was noted that amongst the sediment recovered from the reject piles in Holland in association the hand axe finds, some “reddish clay” – sample no.<5> was recorded, similar to that recorded in **WA_VC006** which the geophysics data indicates the presence of **Unit 5**. However there is no **Unit 5** present within the dredging area.

5.4.8. The distribution of the sediment units close to the surface would indicate that the artefacts, regardless of condition, are most likely to be dredged from **Units 4** and **6**.

5.4.9. **Units 4** and **6** are interpreted as Mid to Late Devensian age (MIS 3 – 2) which would tie-in with the re-occupation of Britian after long human absence from the Wolstonian through to the start of MIS 3. However, as discussed above the age of **Unit 4** may prove to be older, possibly Wolstonian and as such deposition of the hand axes may pre-date this absence.

5.4.10. Provisional results of the analysis and radiocarbon dating of the faunal remains indicated that bones were dated to between 31,000 and 43,000 BP and one sample was older than 46,000 but younger than 65,000 BP (MIS 3). 70% of the bones have been attributed the same age as those mentioned above, based on their appearance and degree of fossilisation. The remaining 30% of the bones are heavily fossilised, estimated to be older than 500,000 BP.

5.4.11. The heavily fossilised bones are likely to have been associated with areas where **Unit 2** subcrops the surficial sediments. This is primarily the eastern and northernmost dredge tracks (based on this dataset). The bones dated between 31,000 and 65,000 BP are likely to be associated with **Unit 4** or **6** within this area

5.4.12. **Units 4** and **6** are likely to date to the Mid to Late Devensian (depending on date hypothesis discussed above). The bones are considered likely to have dredged from the sand and gravels of **Unit 4**. It is likely that mammoth teeth found in the area (Hanson_0180_A; **Figure 5**) were dredged from **Unit 4**.

5.4.13. Further analysis of the bones and identification of any faunal assemblages may narrow this down and provide useful information to establish the chonology of sediments within the area.

5.4.14. As part of the EC REC project a worked flint was found in a clam shell grab. The clamshell grab was situated within the 3 x 1km block around the survey area and within the bounds of the HAML exclusion zone (**Figure 22**). At this position the 2005 geophysics data indicates an undulating seabed surface with no bedforms in the area. The uppermost unit indicates a lag deposit of approximately 1.4m depth overlying a shallow infilled depression (**Unit 7**) to 4m sub-seabed.

5.4.15. Initial results indicated that the grab comprised gravelly sand with cobbles and flint and coarse sand. It is possible that the flint was retrieved from the upper lag (seabed sand and gravel layer) **Unit 8**. It is possible that the flint flake was found associated with the underlying **Unit 7** deposits, but it is unlikely that the clamshell grab would have penetrated the 1.4m of surficial sediments to reach this unit. However, in order to truly evaluate this recent sub-bottom profiler data from the 2009 survey needs to be looked at as any subsequent dredging between 2005 and 2008 may have altered the sediment levels under discussion.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1.1. A long and complex history of erosion, and deposition is apparent in Area 240. Two channels have been identified, one possibly dating to the Late Anglian, the other a shallow meandering channel possible as young as the Mesolithic.

6.1.2. There are, however, major uncertainties regarding the age of the sediments. Two hypotheses have been proposed in this report and it is acknowledged that further dating and environmental analysis would be required to establish the dates of the units identified. The geophysical and geotechnical data data indicate a cyclic sequence of fluvial, estuarine and intertidal sediments deposited throughout the Pleistocene.

6.1.3. Initial results of the dating of animal bones found with the hand axe artefacts indicate two distinct groups (Jan Glimmerveen pers. comm.). The majority of the bones are thought to be between 70,000 and 23,000 BP; the remainder are heavily fossilised and are though to be greater than 500,000BP. The heavily fossilised bones are likely to be associated with **Units 1** and **2**, the remainder associated with **Units 4** and **6**. Based on both the artefact appearance and the initial dating evidence it is possible that the artefacts may be associated with a range of sediments deposited in a range of environments (**Units 2**, **4** and **6**).

6.1.4. The two channels lie to the north of the HAML exclusion zone, indicating that the artefacts, if associated with the channel, are associated with the channel edge rather than immediately adjacent to the channels.

6.1.5. The initial results of this report and the position of the HAML dredge tracks were used to establish a 3 x 1km survey area to target with geophysics survey in Spring 2009 (Stage 2). The results are present in a separate report (Wessex Archaeology 2009) and include an update on the geophysical units identified within the area taking into account dredging that has occurred since the acquisition of the 2005 dataset. The report also makes recommendations for sampling sites for the upcoming Stage 3 of the project (Summer 2009). From a sampling point of view, based on the 2005 data, each sediment type (**Units 2**, **4** and **6**) within the 2009 survey area warrants sampling.

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APPENDIX I VIBROCORE POSITIONS

Vibrocores shaded in light gray are those where the depth values correlate accurately with the processed bathymetry data (both 2005 datasets); those shaded in dark grey are vibrocores were the depth values are likely to be approximate, as they lie outside the dredged area; for the remainder of the vibrocores the depth values an not be deemed accurate as the amount of dredging from acquisition to the 2005 acquisition of the bathymetry dataset is unknown.

WA_VC Idendification Number	Easting	Northing	Depth m below OD	Area	Original Vibrocore Number	Report reference
WA_VC001	427886	5823863	27.96	240	VC1	Alluvial Mining Ltd 1999
WA_VC002	427891	5823483	26.79	240	VC2	Alluvial Mining Ltd 1999
WA_VC003	427688	5823772	27.3	240	VC3	Alluvial Mining Ltd 1999
WA_VC004	427988	5824071	26.13	240	VC4	Alluvial Mining Ltd 1999
WA_VC005	427806	5824599	26.05	240	VC5	Alluvial Mining Ltd 1999
WA_VC006	428235	5824511	25.15	240	VC6	Alluvial Mining Ltd 1999
WA_VC007	428668	5824110	24.62	240	VC7	Alluvial Mining Ltd 1999
WA_VC008	428244	5823711	27.18	240	VC8	Alluvial Mining Ltd 1999
WA_VC009	428644	5823418	25.68	240	VC9	Alluvial Mining Ltd 1999
WA_VC010	429061	5823677	28.23	240	VC10	Alluvial Mining Ltd 1999
WA_VC011	429450	5823371	26.74	240	VC11	Alluvial Mining Ltd 1999
WA_VC012	429841	5823565	26.27	240	VC12	Alluvial Mining Ltd 1999
WA_VC013	429819	5823558	25.83	240	VC12a	Alluvial Mining Ltd 1999
WA_VC014	429421	5824077	29.43	240	VC13	Alluvial Mining Ltd 1999
WA_VC015	429003	5824547	26.38	240	VC14	Alluvial Mining Ltd 1999
WA_VC016	426606	5825385	26.72	240B	VC1	Alluvial Mining Ltd 1999
WA_VC017	426221	5825378	28.88	240B	VC2	Alluvial Mining Ltd 1999
WA_VC018	425640	5825678	31.93	240B	VC3	Alluvial Mining Ltd 1999
WA_VC019	425236	5824824	30.63	240B	VC4	Alluvial Mining Ltd 1999
WA_VC020	426458	5823633	28.24	240B	VC5	Alluvial Mining Ltd 1999
WA_VC021	426526	5820572	28.1	240B	VC6	Alluvial Mining Ltd 1999
WA_VC022	426940	5820402	29.49	240B	VC7	Alluvial Mining Ltd 1999
WA_VC023	425510	5820928	25.67	240B	VC8	Alluvial Mining Ltd 1999
WA_VC024	426099	5822240	26.66	240B	VC9	Alluvial Mining Ltd 1999
WA_VC025	425500	5822211	27.22	240B	VC10	Alluvial Mining Ltd 1999
WA_VC026	429450	5823709	28.55	240	VC1A	Andrews Survey 2000a
WA_VC027	429811	5823971	26	240	VC2	Andrews Survey 2000a
WA_VC028	429034	5824194	26.38	240	VC3	Andrews Survey 2000a
WA_VC029	428650	5823735	24.43	240	VC4	Andrews Survey 2000a
WA_VC030	428283	5823287	25.68	240	VC5	Andrews Survey 2000a
WA_VC031	429690	5823878	25.89	240	VC6	Andrews Survey 2000a
WA_VC032	429218	5823498	24.81	240	VC7	Andrews Survey 2000a
WA_VC033	424546	5825776	31.26	240	VC1	Andrews Survey 2000b
WA_VC034	426017	5825672	28.56	240	VC2	Andrews Survey 2000b
WA_VC035	426992	5825822	23.61	240	VC3	Andrews Survey 2000b
WA_VC036	427842	5826026	23.86	240	VC4	Andrews Survey 2000b
WA_VC037	429015	5825536	26.05	240	VC5	Andrews Survey 2000b
WA_VC038	429639	5825582	27.34	240	VC6	Andrews Survey 2000b
WA_VC039	430050	5825885	27.34	240	VC7	Andrews Survey 2000b
WA_VC040	431362	5825322	31.68	240	VC8	Andrews Survey 2000b

WA_VC Idendification Number	Easting	Northing	Depth m below OD	Area	Original Vibrocore Number	Report reference
WA_VC041	431173	5824803	30.98	240	VC9	Andrews Survey 2000b
WA_VC042	430753	5824959	28.8	240	VC10	Andrews Survey 2000b
WA_VC043	432071	5824247	25.55	240	VC11	Andrews Survey 2000b
WA_VC044	430247	5824359	26.75	240	VC12	Andrews Survey 2000b
WA_VC045	429891	5823894	26.15	240	VC13	Andrews Survey 2000b
WA_VC046	429426	5823494	26.17	240	VC14	Andrews Survey 2000b
WA_VC047	429444	5823500	26.34	240	VC14A	Andrews Survey 2000b
WA_VC048	429083	5823977	26.97	240	VC15	Andrews Survey 2000b
WA_VC049	428828	5824483	23.55	240	VC16	Andrews Survey 2000b
WA_VC050	428295	5823979	24.91	240	VC17	Andrews Survey 2000b
WA_VC051	427996	5823515	27.94	240	VC18	Andrews Survey 2000b
WA_VC052	427930	5824522	24.11	240	VC19	Andrews Survey 2000b
WA_VC053	427762	5825005	25.89	240	VC20	Andrews Survey 2000b
WA_VC054	426567	5825169	26.58	240	VC21	Andrews Survey 2000b
WA_VC055	427011	5824631	30.81	240	VC22	Andrews Survey 2000b
WA_VC056	427593	5824050	28.96	240	VC23	Andrews Survey 2000b
WA_VC057	427253	5823574	28.89	240	VC24	Andrews Survey 2000b
WA_VC058	426671	5823455	29	240	VC25	Andrews Survey 2000b
WA_VC059	426076	5823833	26.5	240	VC26	Andrews Survey 2000b
WA_VC060	425714	5824321	28.11	240	VC27	Andrews Survey 2000b
WA_VC061	424950	5824808	31.09	240	VC28	Andrews Survey 2000b
WA_VC062	424903	5823725	25.53	240	VC29	Andrews Survey 2000b
WA_VC063	425128	5823191	26.32	240	VC30	Andrews Survey 2000b
WA_VC064	425914	5822669	25.59	240	VC31	Andrews Survey 2000b
WA_VC065	425541	5821926	26.96	240	VC32	Andrews Survey 2000b
WA_VC066	426205	5821661	27.55	240	VC33A	Andrews Survey 2000b
WA_VC067	424891	5821160	27.49	240	VC34	Andrews Survey 2000b
WA_VC068	425633	5820836	27.06	240	VC35	Andrews Survey 2000b
WA_VC069	425155	5820202	26.94	240	VC36	Andrews Survey 2000b
WA_VC070	426290	5820130	27.42	240	VC37A	Andrews Survey 2000b
WA_VC071	425579	5819748	25.97	240	VC38B	Andrews Survey 2000b
WA_VC072	424562	5819754	29.36	240	VC39	Andrews Survey 2000b
WA_VC073	429551	5824417	27.63	240	VC40	Andrews Survey 2000b
WA_VC074	424701	5822498	28.27	240	VC1	Andrews Survey 2005
WA_VC075	424667	5823373	28.59	240	VC2	Andrews Survey 2005
WA_VC076	424659	5823780	27.69	240	VC3	Andrews Survey 2005
WA_VC077	424892	5822678	26.91	240	VC4	Andrews Survey 2005
WA_VC078	424839	5825101	28.57	240	VC5	Andrews Survey 2005
WA_VC079	425054	5824391	30.5	240	VC6	Andrews Survey 2005
WA_VC080	425277	5823631	25.79	240	VC7	Andrews Survey 2005
WA_VC081	425254	5824626	30.69	240	VC8	Andrews Survey 2005
WA_VC082	425246	5825313	30.37	240	VC9	Andrews Survey 2005
WA_VC083	425441	5825428	30.92	240	VC10	Andrews Survey 2005
WA_VC084	425625	5825869	31.54	240	VC11	Andrews Survey 2005
WA_VC085	425648	5825097	30.2	240	VC12	Andrews Survey 2005
WA_VC086	425836	5825537	29.41	240	VC13	Andrews Survey 2005
WA_VC087	425846	5824939	28.18	240	VC14	Andrews Survey 2005
WA_VC088	426045	5825157	28.41	240	VC15	Andrews Survey 2005
WA_VC089	426255	5825319	28.42	240	VC16	Andrews Survey 2005

WA_VC Idendification Number	Easting	Northing	Depth m below OD	Area	Original Vibrocore Number	Report reference
WA_VC090	426248	5825874	27.24	240	VC17	Andrews Survey 2005
WA_VC091	426441	5825533	27.82	240	VC18	Andrews Survey 2005
WA_VC092	427754	5824306	25.84	240	VC19	Andrews Survey 2005
WA_VC093	428467	5823537	25.97	240	VC20	Andrews Survey 2005
WA_VC094	426642	5826056	24.99	240	VC21	Andrews Survey 2005
WA_VC095	427795	5823350	27.56	240	VC22	Andrews Survey 2005
WA_VC096	428466	5824032	24.66	240	VC23	Andrews Survey 2005
WA_VC097	428447	5824533	24.92	240	VC24	Andrews Survey 2005
WA_VC098	428655	5824719	25.13	240	VC25	Andrews Survey 2005
WA_VC099	428786	5823539	26.28	240	VC26	Andrews Survey 2005
WA_VC100	428773	5824338	26.57	240	VC27	Andrews Survey 2005
WA_VC150	428863	5823487	26.58	240	VC39C	Lankelma Andrews 2007
WA_VC151	428873	5823807	27.25	240	VC40C	Lankelma Andrews 2007
WA_VC152	428572	5824407	25.43	240	VC41	Lankelma Andrews 2007
WA_VC153	428167	5824281	25.54	240	VC42	Lankelma Andrews 2007
WA_VC154	429655	5823609	26.2	240	VC43A	Lankelma Andrews 2007
WA_VC155	429672	5824239	26.05	240	VC44	Lankelma Andrews 2007
WA_VC156	429619	5825977	27.51	240	VC45	Lankelma Andrews 2007
WA_VC157	429968	5823473	26.7	240	VC46C	Lankelma Andrews 2007
WA_VC158	430054	5823722	26.64	240	VC47A	Lankelma Andrews 2007

APPENDIX II GAZETEER

WA ID	Unit	Feature	Area (km^2)	Notes
7000	Unit 1/Unit 2	Basal reflector	30.730	Reflector marking top of Unit 1. Observed across the area between 2.2 to 29.3m sub-seabed deepening to the east of the site. The reflector is well defined in the west becoming fainter in the east at depth. Unit 1 comprises a series of faint, sub-parallel reflectors. To the west, pro-grading sediments/dipping reflectors are observed.
7001	Unit 2	Sediment unit	30.148	7001 represents the coverage of Unit 2 within the Area 240 site. The base of the Unit is 7000. The top of the unit is primarily unit 4, sometimes Units 7 or the surficial unit (Unit 8). 7001 is absent in the southeast corner of the site and to the northwest corner of the site where the sediments have been eroded away and subsequent overlying sediments have been deposited. It is not present where Unit 3 is observed (7002). Comprises faint sub-parallel or dipping reflectors
7002	Unit 3	Sediment unit	0.888	Only observed to the southeast of the site. Base of unit between 1.0 and 11.3m sub-seabed. Unit is up to 11m thick and is composed of a series of very strong, southerly dipping reflectors
7003	Unit 4	Sediment unit	25.351	Base of unit interpreted as sands and gravels covering the majority of Area 240. Almost continuous unit to the east. In the west there are areas where the unit is missing either at the seabed or because base of the unit is ephemeral and not always observed. Base of unit observed from the surface to 15.4 associated with the base of the channel (7090).
7004	Unit 4	Sediment unit	0.755	Base of Unit 4 exhibiting a diffuse basal reflector observed between 0.8 to 8.3m sub-seabed. Fill interpreted as sands and gravels. Edges of unit are diffuse not necessarily pinching out at the surface. Numerous large sandwaves in the area.
7005	Unit 4	Sediment unit	0.697	Base of Unit 4 exhibiting a diffuse basal reflector observed between 1.0 to 6.3m sub-seabed. Fill interpreted as sands and gravels. Edges of unit are diffuse not necessarily pinching out at the surface. Numerous large sandwaves in the area.
7006	Unit 4	Sediment unit	0.159	Small outlier of Unit 4. Diffuse basal reflector observed between 1.8 and 5.6m sub-seabed. Fill observed to the seabed with a possible thin lag layer on top. Edges of unit are diffuse not necessarily pinching out at the surface. Numerous large sandwaves in the area.
7007	Reflector A	Strong reflector	0.605	Strong reflector generally associated with the channel feature. Strong reflector observed between 1.0 and 10.3m sub-seabed.

WA ID	Unit	Feature	Area (km^2)	Notes
7008	Reflector A	Strong reflector	4.296	Strong reflector generally associated with the channel feature. Strong reflector observed between 0.3 and 12.6m sub-seabed. Predominantly marks the base of the Unit 5 channel features.
7009	Reflector A	Strong reflector	0.072	Strong reflector generally associated with the channel feature. Strong reflector observed between 1.0 and 10.3m sub-seabed. The layer generally deepens in the central part of the channel.
7010	Reflector A	Strong reflector	0.082	Strong reflector generally associated with the channel feature. Strong reflector observed between 1.0 and 10.3m sub-seabed. The layer generally deepens in the central part of the channel.
7011	Reflector A	Strong reflector	0.083	Strong reflector generally associated with the channel feature. Strong reflector observed between 1.8 and 4.2m sub-seabed.
7012	Reflector A	Strong reflector	0.044	Strong reflector generally associated with the channel feature. Strong reflector observed between 1.8 and 4.6m sub-seabed.
7013	Reflector A	Strong reflector	0.006	Strong reflector generally associated with the channel feature. Strong reflector observed between 2.6 and 3.3m sub-seabed. Shallow feature only observed on 1 line.
7014	Reflector A	Strong reflector	0.205	Strong reflector generally associated with the channel feature. Strong reflector observed between 1.1 and 8.6m sub-seabed.
7015	Reflector A	Strong reflector	0.006	Strong reflector generally associated with the channel feature. Strong reflector observed between 2.0 and 4.0m sub-seabed.
7016	Reflector A	Strong reflector	0.001	Small area of strong reflector generally associated with the channel feature. Strong reflector observed between 2.5and 2.6m sub-seabed.
7017	Reflector A	Strong reflector	0.005	Strong reflector generally associated with the channel feature. Strong reflector observed between 4.0 and 6.0m sub-seabed.
7018	Unit 5	Fine-grained bank feature	0.047	Thin unit observed close to seabed. Some evidence of cut to the south. Observed on a gravel bank rise. Base observed between 1 and 3.8m sub-seabed. Thickness up to 1.9m overlain by thin layer of lag deposit. Small sdandwaves (<0.5m) only.
7019	Unit 5	Fine-grained bank feature	0.011	Thin unit observed close to seabed. Observed on a gravel bank rise to northwest of area. Undulating base observed between 1.6 and 3.6m sub-seabed. Thickness up to 1.9m overlain by thin (<1m) layer of lag deposit.
7020	Unit 5	Fine-grained unit	0.155	Thin unit with undulating base close to seabed, slight channel to the north. Base observed between 0.3 and 4.4m sub-seabed. Max fill of3.1m overlain by <1m lag deposit (no bedforms). Base of unit cuts through base of underlying Unit 4
7021	Unit 5	Fine-grained unit	0.034	Thin unit observed close to seabed. Base observed between 1.1 and 2.7m sub-seabed. Thickness up to 1.7m overlain by thin (1m) layer of lag deposit.
7022	Unit 5	Fine-grained unit	0.050	Southeast corner of area. Base observed between 1.8 and 4.5m sub-seabed.

WA ID	Unit	Feature	Area (km^2)	Notes
				Undulating base, possibly infilling a depression. Fill up to 2.5m thick overlain by up to 1.5m
7023	Unit 5	Fine-grained unit	0.032	To the west of the anomaly two small cuts and fills of Unit 5 are observed, this merged into 1larger fill to the east. Base observed between 2.4 and 3.9m sub-seabed. Fill overlain by up to 2m sediments (?seabed pulse or true sediment).
7024	Unit 5	Fine-grained unit	0.035	Undulating base between 1.4 to 4.0m sub-seabed. Fill up 2.6m overlain by up to 1.5m lag deposit (no bedforms)
7025	Unit 5	Fine-grained unit	0.019	Small sub-circular feature to the south. Infilling a slight depression. Base observed between 1.9 and 4.1m sub-seabed. Infilled with up to 2m overlain by up to 2m lag deposit (no bedforms)
7026	Unit 5	Fine-grained unit	0.018	Small thin remnant unit protected by sandaves. Base of unit between 2.1 and 5.0m sub-seabed. Fill up to 1.5m thick overlain by a series of sandwaves up to 4.2m high.
7027	Unit 5	Cut and fill	0.075	Fill unit infilling channel. Base of reflector between 1.1 and 4.9m sub-seabed. Up to 2.8m fill overlain by up to 2m lag deposit (no bedforms).
7028	Unit 5	Fine-grained bank feature	0.136	Fine-grained bank deposit of variable thickness. Top of unit observed directly beneath mobile sand unit. Base observed between 2.1 and 7.2m sub-seabed. Numerous sandwaves observed covering the feature up to 3m high.
7029	Unit 5	Cut and fill	0.622	Series of channel like fill observed over 11 adjacent lines. Undulating base not marked by Reflector A. Base of unit between 2 and 8.2m sub-seabed. Overlain by minimum of 2m surficial sediments.
7030	Unit 5	Fine-grained bank feature	0.207	Bank of fine-grained sediments overlying undulating surface marked in part by Reflector A. Base of unit between 2.0 and 7.7m sub-seabed. Fill varies - generally 3 to 4m thick overlain by sandwaves up to 5m high.
7031	Unit 5	Cut and fill	0.374	Series of channel fills observed on 10 adjacent lines. Base marked by strong reflector (Reflector A). Base observed between 1.8 and 10.7m sub-seabed. Fill overlain by a gravel unit up to 2.4m thick, in turn overlain by sandwaves up to 5m high.
7032	Unit 5	Fine-grained bank feature	0.239	Fine-grained bank feature. Base marked by strong reflector (Reflector A) and undulating between 1.5 and 11.7m sub-seabed. Fill varies, generally around 5m thick overlain by sandwaves up to 4.5m high.
7033	Unit 5	Cut and fill	0.028	Small feature observed over three lines. Base observed between 1.1 to 7.1m sub-seabed. Base marked by Reflector A. Fill up to 2.2m overlain by sand and gravel unit up to 2.6m in turn overlain by 3.8m sandwave
7034	Unit 5	Fine-grained bank feature	0.021	Small feature observed over two lines. Base observed between 2.1 to 6.5m sub-seabed. Fill up to 2.7m overlain 4m sandwave
7035	Unit 5	Cut and fill	3.105	Largest continuous feature for Unit 5. Seies of channels with various fill thickness.

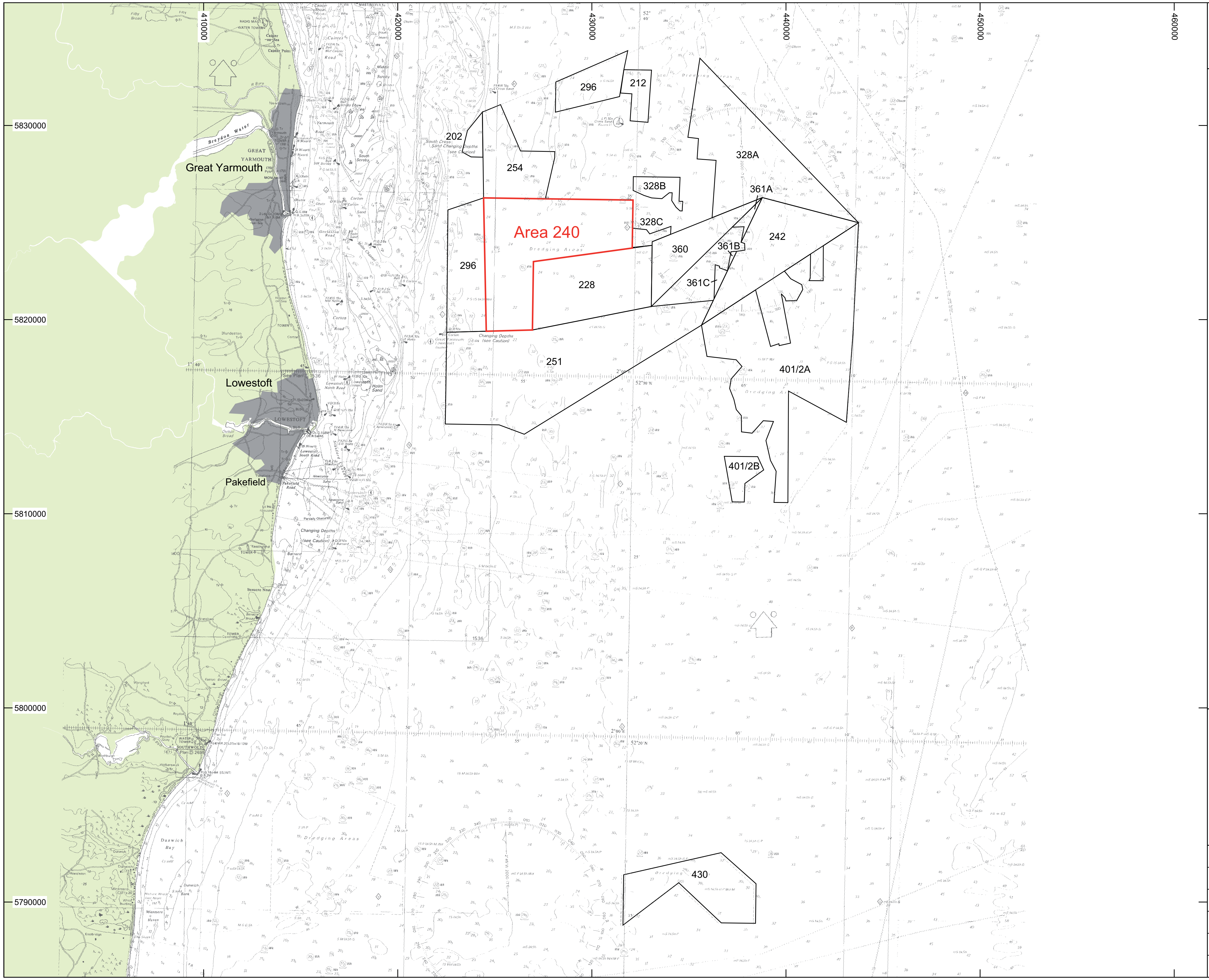
WA ID	Unit	Feature	Area (km^2)	Notes
				In part the base is marked by strong reflector (Reflector A). Overlain by sands and gravels and a series of sandwaves up to 6m high. Base of unit between seabed to 12m sub-seabed.
7036	Unit 5	Fine-grained bank feature	0.767	Fine-grained bank feature observed over 8 lines. Base observed between 1.4 and 5.3m sub-seabed. Generally fill is approximately 2 - 4m overlain by lag deposit (no bedforms)
7037	Unit 5	Cut and fill	0.128	Fine-grained unit close to seabed. Undulating base between 1.7 and 3.7m sub-seabed. Up to 2.7m fill overlain by up to 1m lag deposits (no bedforms).
7038	Unit 5	Cut and fill	0.302	Cut and fill observed on 11 lines. Base on cut between 1.8 and 4.8m sub-seabed
7039	Unit 5	Fine-grained bank feature	0.009	Small feature observed on two lines. Base of unit between 1.2 and 6.3m sub-seabed. Fill up to 3.4m overlain by up to 2.3m sand and gravel unit and surficial lag deposit.
7041	Unit 5	Fine-grained channel fill	N/A	Only observed on one line. Feature 0.199km long. Base of channel observed between 2.6 and 7.3m sub-seabed. Fine-grained fill of 2.9m overlain by a series of small sandwaves up to 3.3m high.
7042	Unit 5	Fine-grained unit	N/A	Only observed on one line. Feature 0.156km long. Outlier to 7031.Thin unit observed close to the seabed. Strong base and top reflector approximately1.2m thick overlain by sandwaves up to 3.7m high.
7043	Unit 5	Depression and fill	N/A	Only observed on one line. Feature 0.132km long. Strong reflector and fill up to 1.2m overlain by 2.9m sandwave.
7044	Unit 5	Fine-grained unit	N/A	Only observed on one line. Feature 0.282km long. Base observed between 3.7 and 9.6m sub-seabed with a transparent fill of 3.3m Overlain by up to 2m sands and gravels (Unit 4) and small sandwaves up to 1.7m high. Base of unit marked by Reflector A
7045	Unit 5	Cut and fill	N/A	Only observed on one line. Feature 0.245km long. Base of feature marked by strong reflector observed between 2.2and 6.2m sub-seabed. Up to 3.7m of fill overlain by 2.2m lag deposit and small sandwaves.
7046	Unit 5	Fine-grained unit	N/A	Only observed on one line. Feature 0.138km long. Thin transparent unit up to 1.2m thick. Base observed between 2.1 and 3.1m sub-seabed. Overlain by <1m lag deposit.
7047	Unit 5		N/A	Only observed on one line. Feature 0.138km long. Base observed between 1.8 and 3.3m sub-seabed. Up to 1.8m thick overlain by about 1m of lag deposit (no bedforms).
7048	Unit 6	Cut and fill	0.041	Small cut orientated west to east. Base observed at 1.1 to 3.4m sub-seabed.1.3m transparent (fine-grained) fill overlain by up to 3.2m high sandwave.
7049	Unit 6	Depression and fill	0.014	Small, sub-circular depression to the southeast of 7048. Base observed up to 3.9m sub-seabed. Cut with transparent fill to the south with erosion layer to the east and north. Fill up to 2.5m thick overlain by up to 1.5m surficial sediments.

WA ID	Unit	Feature	Area (km^2)	Notes
7050	Unit 6	Fine grained unit	0.045	Thin, up to 1.8m thick transparent (fine-grained) unit. No cut observed. Possible remnant of shallow depression. Overlain by up to 4.9m surficial sediment (sandwave).
7051	Unit 6	Depression and fill	0.222	Large irregular shaped depression filled with transparent fill. Base of feature observed between 1 and 6.3m sub-seabed. Situated in centre of 3x1 area.
7052	Unit 6	Cut and fill	0.044	Small irregular shaped feature on edge of 3x1 area. Base of unit observed from seabed to 4.6m sub-seabed. Undulating cut with strong basal reflector. Transparent fill up to 2.2m thick overlain by up to 3.1m surficial sediment (sandwave).
7053	Unit 6	Cut and fill	0.070	Irregular shaped feature comprising 2 cuts and fill features merging to one to the west. Strong basal reflector between 0.8 to 5.6m sub-seabed. Fill of faint chaotic reflectors up to 3m thick overlain by up to 2.4m surficial sediments (small sandwaves)
7054	Unit 6	Fine grained unit	0.007	Small thin unit of transparent fill. Fill up to 1.6m thick overlain by up to 1m lag deposit (no bedforms).
7055	Unit 6	Depression and fill	0.011	Small unit to west of Area 240. Strong basal reflector between 1.4 to 3.4m sub-seabed. Maximum fill of 1.7m overlain by surficial sediments up to 1.7m high (small sandwave).
7056	Unit 6	Depression and fill	0.230	Large irregular shaped depression filled with transparent fill. Intermittent remnants of sediment units or filled shallow depressions. Base of feature observed between 1 and 3.8m sub-seabed. Fill of up to 2.8m overlain by around 1m of lag deposit (no bedforms)Situated to the south of 3x1 area.
7057	Unit 6	Cut and fill	0.079	Linear feature orientated south to north. Thicker fill to the south of the feature, generally more of an erosion surface to the north. Base observed between 1.0 to 4.1m sub-seabed marked by strong reflector. Fill up to 2.1m overlain by surficial sediment up to 2.5m sandwave.
7058	Unit 6	Depression and fill	0.012	Small linear undulating depression close to the seabed. Stong basal reflector between 2.0 to 7.6m sub-seabed. Overlain by surficial sediments up to 2.4m (sandwave).
7059	Unit 6	Cut and fill	0.067	Meandering feature orientated west to east. Basal reflector observed between 1.5 to 4.7m sub-seabed. Shallow fill up to 1.5m overlain by surficial sediments up to 3.5m (sandwave).
7060	Unit 6	Cut and fill	0.357	Irregular shaped feature situated to the south within the 3x1km area. Form varies within the feature but generally a cut form observed. Deepest observed in the centre of the feature. Base observed between 1.0 and 5.4m sub-seabed. Top of unit observed at the seabed (no bedforms).
7061	Unit 6	Fine grained unit	0.085	Strong undulating basal reflector between 0.9 and 4.4m sub-seabed. Thin unit of fill up to 1.6m overlain by surficial sediments (up to 2.8m sandwave).

WA ID	Unit	Feature	Area (km^2)	Notes
7062	Unit 6	Fine grained unit	0.012	Small feature orientated northwest to southeast. Thin unit beneath sandwaves. Basal reflector between 1.4 to 3.9m sub-seabed. Sandwaves up to 2.4m high.
7063	Unit 6	Depression and fill	0.007	Small sub-circular cut into unit 4. Base observed at 1.5 to 4.1m sub-seabed. Fill up to 1.4m overlain by up to 2.8m sandwave.
7064	Unit 6	Cut and fill	0.025	Sub-circular depression with strong basal reflector observed between 1.0 and 3.8m sub-seabed. Fill up to 1.7m overlain by 2.3m surficial sediments (sandwaves).
7065	Unit 6	Cut and fill	0.074	Undulating basal surface observed between 1.1 and 4.3m sub-seabed. Fill thickness varies with the undulations up to 2.2m overlain by a series of small sandwaves up to 2.7m high.
7066	Unit 6	Cut and fill	N/A	Linear feature approximately 0.108 km long. Base observed between 1.6 and 3.9m sub-seabed. Thin transparent fill up to 2.3m thick overlain by 1.6m surficial sediments.
7067	Unit 6	Cut and fill	N/A	Linear feature approximately 0.169 km long. Base observed between 0.9 and 5.4m sub-seabed. Thin transparent fill up to 2.6m thick overlain by up to 3.6m surficial sediments (sandwave).
7068	Unit 6	Cut and fill	N/A	Linear feature approximately 0.092 km long. Base observed between 1.4 and 3.5m sub-seabed. Small cut with thin transparent fill up to 1.9m thick overlain by up to 3.0m surficial sediments (sandwave).
7069	Unit 6	Cut and fill	N/A	Linear feature approximately 0.026km long. Base observed between 1.8 and 5.0m sub-seabed. Small undulating cut with 2 deeper sections. Fill of sands up to 2.4m thick overlain by up to 2.8msurficial sediment (sandwave).
7070	Unit 6	Cut and fill	N/A	Linear feature approximately 0.150 km long. Base of cut observed between 2.4 and 4.5m sub-seabed. Fill composed of sub-parallel reflectors interpreted as fine sands. Up to 2.3m thick overlain by up to 4.0m of surficial sediment (sandwave).
7071	Unit 6	Cut and fill	N/A	Linear feature approximately 0.103 km long. Basal reflector cuts through base of underlying Unit 4 (7003 and 7092) into Unit 2 (7001). Base observed between 3.6 and 4.8m sub-seabed. Transparent (fine-grained) fill up to 2.1m thick overlain by up to 3.5m surficial sediment (sandwave).
7072	Unit 6	Cut and fill	N/A	Linear feature approximately 0.103 km long. Small cut into Unit 4 (7003). Base observed between 1.8 and 3.4m sub-seabed. Up to 1.7m transparent fill overlain by up tp 1.3m surficial sediment (small sandwave feature).
7073	Unit 6	Cut and fill	N/A	Linear feature approximately 0.114 km long. Small shallow cut. No fill observed due to reflecor resolution. Base observed between 1 and 3.6m sub-seabed. Overlain by up to 2.4m sandwave.

WA ID	Unit	Feature	Area (km^2)	Notes
7074	Unit 6	Cut and fill	N/A	Linear feature approximately 0.182 km long. Small cut feature cutting into base of underlying Unit 4 (7003). Base observed at 1.4 to 3.6m sub-seabed, with up to 1.5m transparent (fine-grained) fill overlain by up to 3.6m sandwave
7075	Unit 6	Cut and fill	N/A	Linear feature approximately 0.049 km long. Small cut with up to 3.2m of transparent fill overlain by thin (<1m) of lag deposit (no bedforms).
7076	Unit 6	Cut and fill	N/A	Linear feature approximately 0.132 km long. Undulating but with up to 2.9m transparent fill overlain by <1m lag deposit (no bedforms).
7077	Unit 6	Cut and fill	N/A	Linear feature approximately 0.227 km long. Broad shallow cut. Base observed between 0.7 and 3.8m sub-seabed. Up to 2.5m fill overlain by less than 1m lag deposit. Cut through base of underlying Unit 4 (7003).
7078	Unit 6	Cut and fill	N/A	Linear feature approximately 0.139 km long. Shallow undulating cut. Base observed between 1.0 and 2.2m sub-seabed overlain by <1m lag deposit.
7079	Unit 6	Cut and fill	N/A	Linear feature approximately 0.182 km long. Small cut with strong basal reflector. Base observed between 1.3 and 4.0m sub-seabed. Fill up to 1.2m thick overlain by sandwave up to 3.4m high.
7080	Unit 7	Cut and fill	0.083	Broad, shallow channel structure. The base of the feature is observed between 0.6 and 5.3m subseabed. Predominantly overlain by a thin veneer of surficial lag deposit. Fill comprises strong, sub-parallel reflectors. Associated with low-lying area (channel) on bathymetry in the southwest of the area.
7081	Unit 7	Cut and fill	0.007	Small outlier of Unit 7 south of the main channel feature to the northwest as observed on the bathymetry data. Small, shallow channel structure. The base of the feature is observed between 1.6 and 3.5m sub-seabed. Predominantly overlain by a thin veneer of surficial lag deposit up to 1m thick. Comprises strong, sub-parallel reflectors.
7082	Unit 7	Cut and fill	0.786	Broad, shallow channel structure orientated southwest to northeast associated with the base of the shallow channel observed on the bathymetry data. The base of the feature is observed between 0.6 and 6.3m sub-seabed. Predominantly overlain by a thin veneer of surficial lag deposit. Comprises strong, sub-parallel reflectors. Thicker sediments observed to the to the west of the channel.
7083	Unit 7	Depression and fill	0.137	Shallow depression feature, sub-circular in shape associated with the base of the shallow channel observed on the bathymetry data. The base of the feature is observed between 1.25 and 6.1m sub-seabed. Predominantly overlain by a thin veneer of surficial lag deposit. Comprises strong, sub-parallel reflectors. Thicker sediments observed to the centre of the feature. Fill comprises strong, sub-parallel reflectors.

WA ID	Unit	Feature	Area (km^2)	Notes
7084	Unit 7	Cut and fill	0.001	Small linear cut (only observed on one geophysics data line) approximately 60m long and comprising a strong dark reflector at the surface. The base of the unit was observed at 1.3 to 2.7m sub-seabed, overlain by a thin veneer of surficial sediment
7085	Unit 7	Cut and fill	0.191	Shallow channel feature and fill associated with the bathymetric channel observed in the northwest corner of Area 240. Feature is orientated southwest to northeast. Fill comprises strong, sub-parallel reflectors. Base of the feature observed at 0.9 to 5.0m, deepest int he centre of the feature. unit overlain by less than 1m of surficial lag deposits.
7086	Unit 7	Depression and fill	0.053	Shallow depression feature, sub-circular in shape associated with the base of the shallow channel observed on the bathymetry data. The base of the feature is observed between 0.9 and 4.0m sub-seabed. Predominantly overlain by a thin veneer of surficial lag deposit. Comprises strong, sub-parallel reflectors. Thicker sediments observed to the to the central south area of the feature. Fill comprises strong, sub-parallel reflectors.
7087	Unit 7	Cut and fill	0.021	Small cut feature associated and in alignment with 7086 and 7082 - associated with bathymetric channel feature. Base of feature observed between 1.5 and 3.7m sub-seabed, with approximately 1.5m fill of strong reflectors.
7088	Unit 7	Cut and fill	0.005	Small linear cut (only observed on one geophysics data line) approximately 154m long and comprising a strong dark reflector at the surface. The base of the unit was observed at 0.8 to 3.1m sub-seabed, overlain by a thin veneer of surficial sediment
7089	Unit 7	Cut and fill	0.003	Small linear cut (only observed on one geophysics data line) approximately 130m long and comprising a strong dark reflector at the surface. The base of the unit was observed at 1.8 to 4.5m sub-seabed, overlain by a thin veneer of surficial sediment
7090	Unit 4	Channel cut	9.176	Channel cut into Unit 2 (7001) sediments in the north of the area and is marked by a strong basal reflector. Channel cut is up to 5m deep on the southern edge. Channel feature is orientated northwest to southeast across the area.
7091	Unit 4	Sediment unit	0.019	Thin unit of sediment close to the seabed. Limits of unit pinch out to the north and south. Unit approximately 2m thick overlain by a series of small sandwaves up to 2.6m high.
7092	Unit 4	Sediment unit	0.650	Small area of sediment unit 4 observed pinching out at the seabed. Strong basal reflector observed between 1.7 and 5.7m sub-seabed.
7093	Unit 4	Sediment unit	0.130	Small linear feature only observed on one line. Up to 1.1m thick. Unit is cut into by 7066. In turn overlain by sandwaves.



Wessex Archaeology

Area 240
Other Licence Areas

0 10km

Drawing Projection: UTM WGS84 z31N.
Admiralty Chart 1543 (dated 2000).

Revision Number:	0
Illustrator:	KJB
Date:	09/07/09
Scale:	1:200,000 @A3
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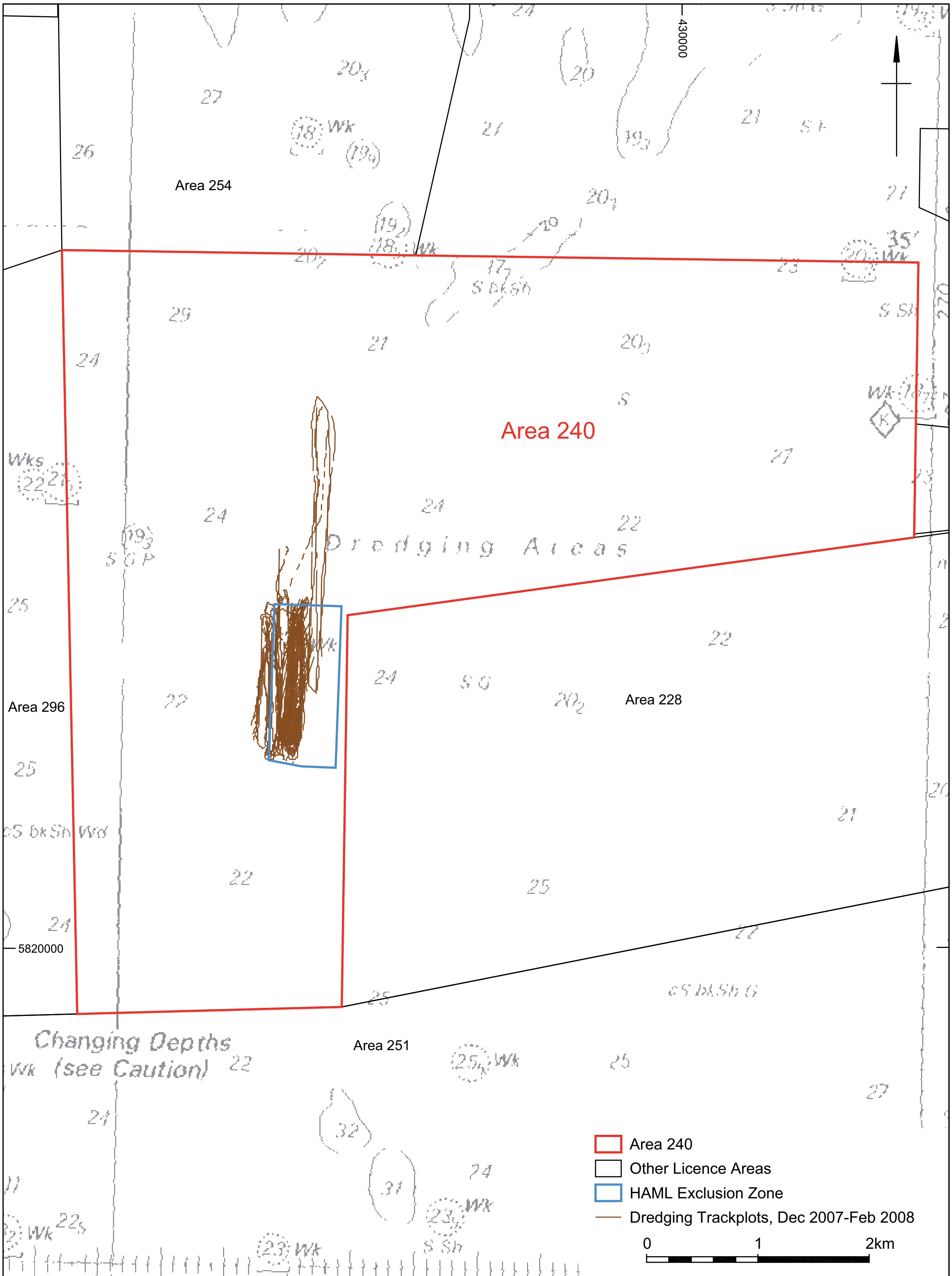
Area 240 location

Figure 1



Drawing Projection: UTM WGS84 z31N.
Admiralty chart 1543ac (dated 2000).

Date:	09/07/09	Revision Number:	0
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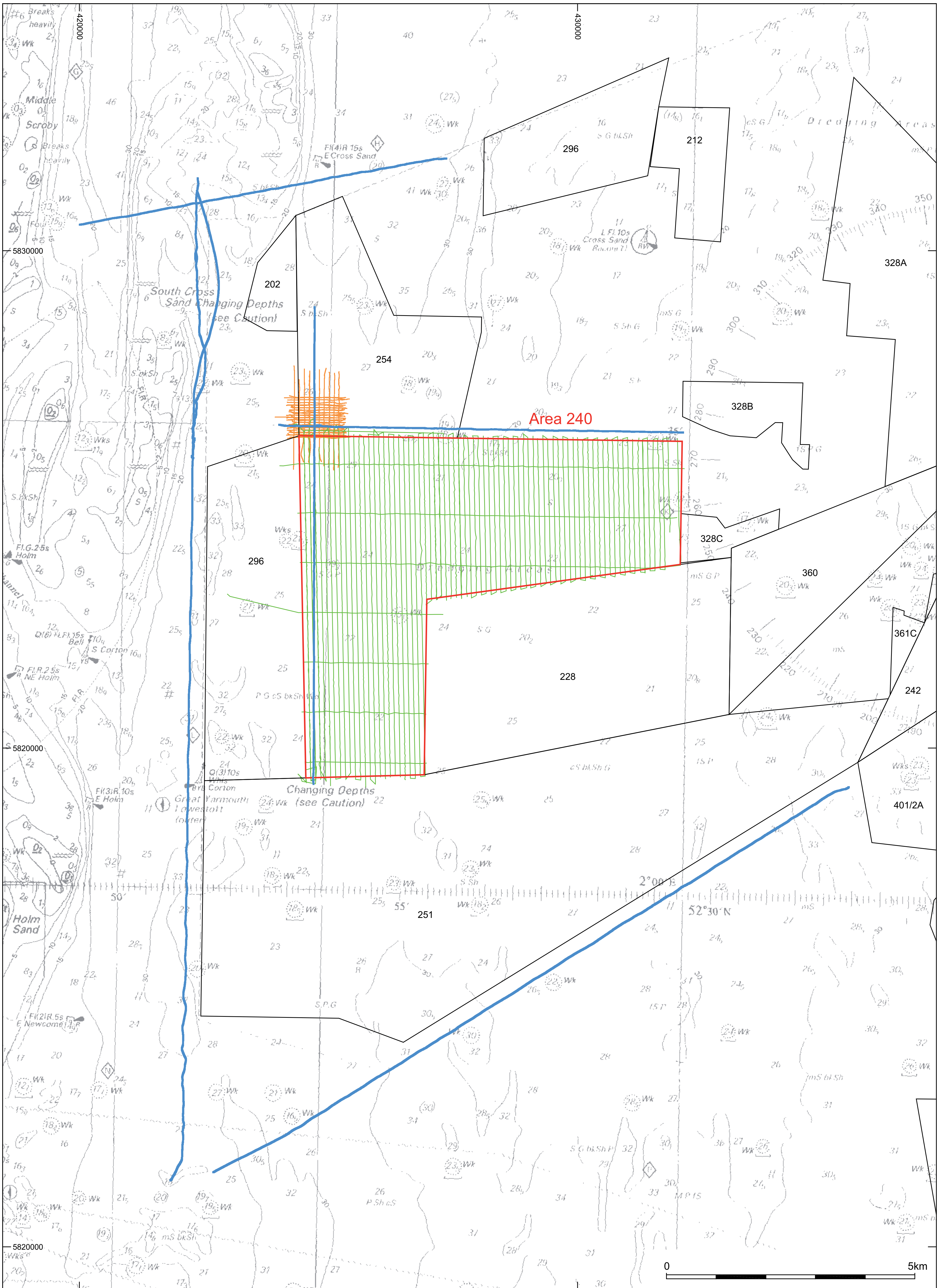
Area 240 Exclusion Zone

Figure 2



Drawing Projection: UTM WGS84 z31N.
Admiralty chart 1543ac (dated 2000).

- Area 240
- Other Licence Areas
- Geophysics survey lines, 2005 survey
- Seabed Prehistory: Great Yarmouth main survey, Oct 2005
- Seabed Prehistory: Great Yarmouth prospection lines, Oct 2005

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Date:	10/07/09	Revision Number:	0
Scale:	1:75,000 @A3	Illustrator:	KJB
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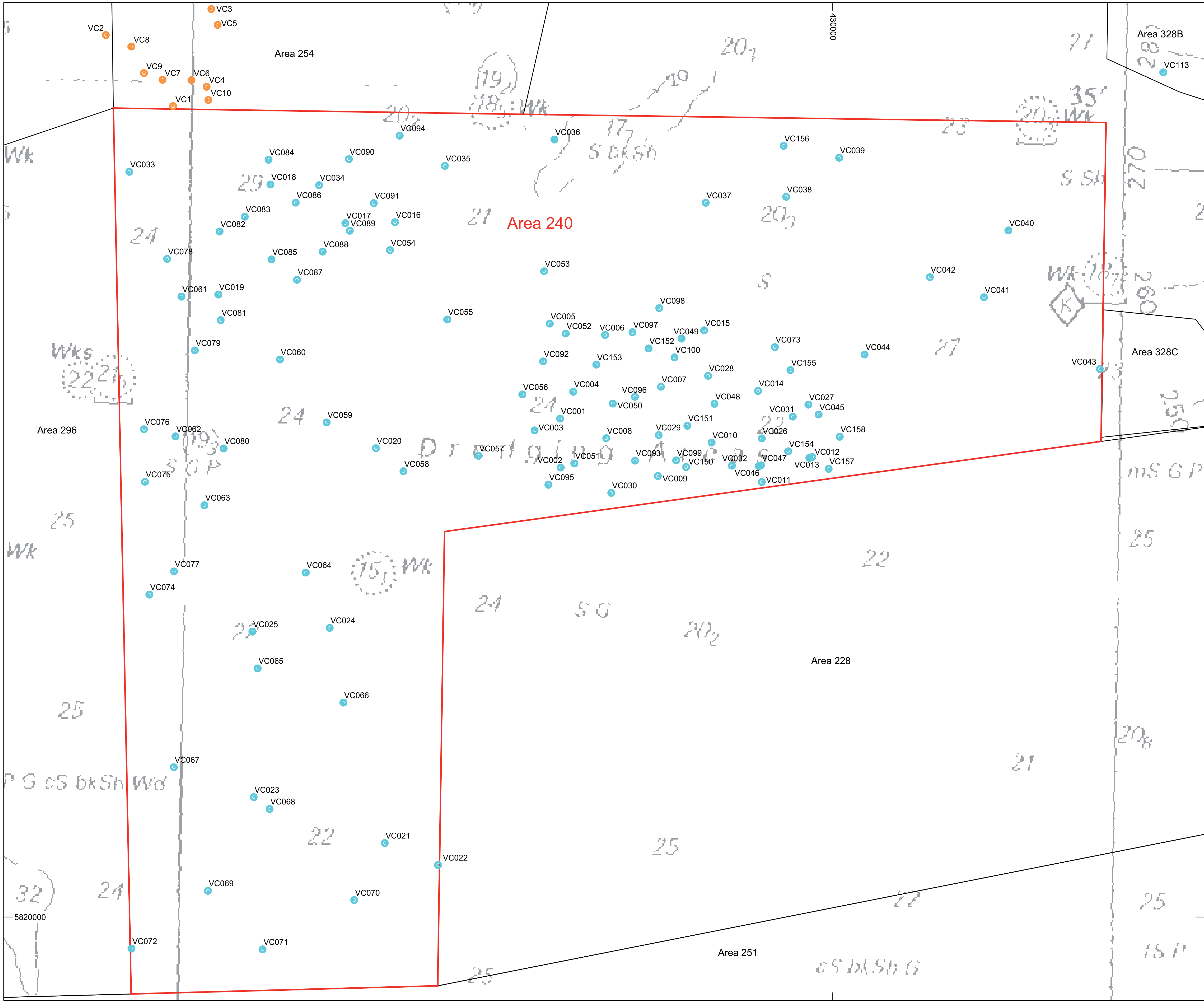
Survey lines

Figure 3



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- Area 240
- Other Licence Areas
- Vibrocore locations (this project)
- Seabed Prehistory: Great Yarmouth vibrocore locations

0 1km

Drawing Projection: UTM WGS84 z31N.
Admiralty chart 1543ac (dated 2000).

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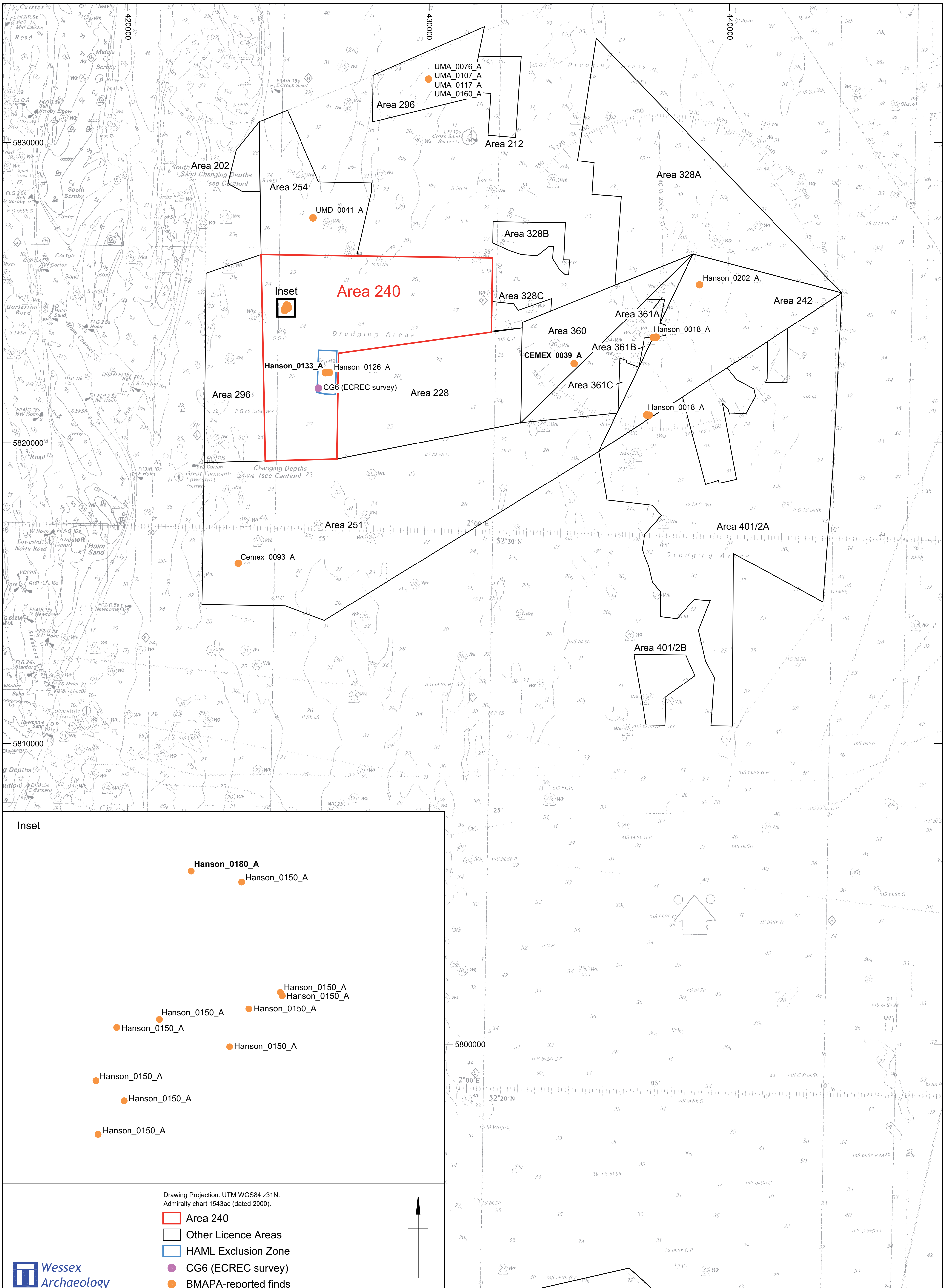
Vibrocore locations

Figure 4



Drawing Projection: UTM WGS84 z31N.
Admiralty chart 1543ac (dated 2000).

- Area 240
- Other Licence Areas
- HAML Exclusion Zone
- CG6 (ECREC survey)
- BMAPA-reported finds

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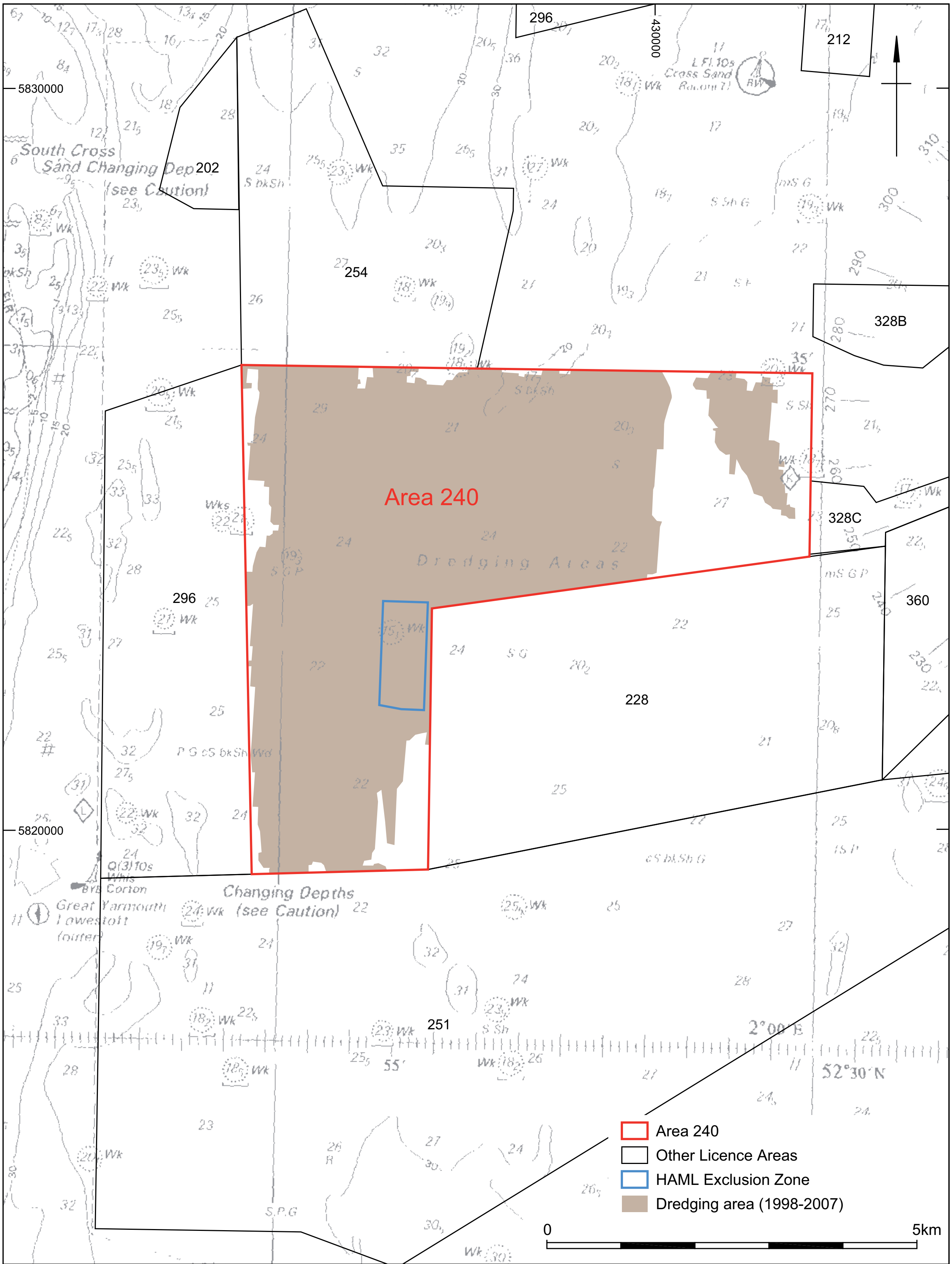
Finds within the offshore area

Figure 5



Drawing Projection: UTM WGS84 z31N.
Admiralty chart 1543ac (dated 2000).

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Scale:	1:75,000	Illustrator:	KJB
Path:	W:\Projects\70751\Drawing Office\Report Figs\Data review\09-07-09\70751_01		

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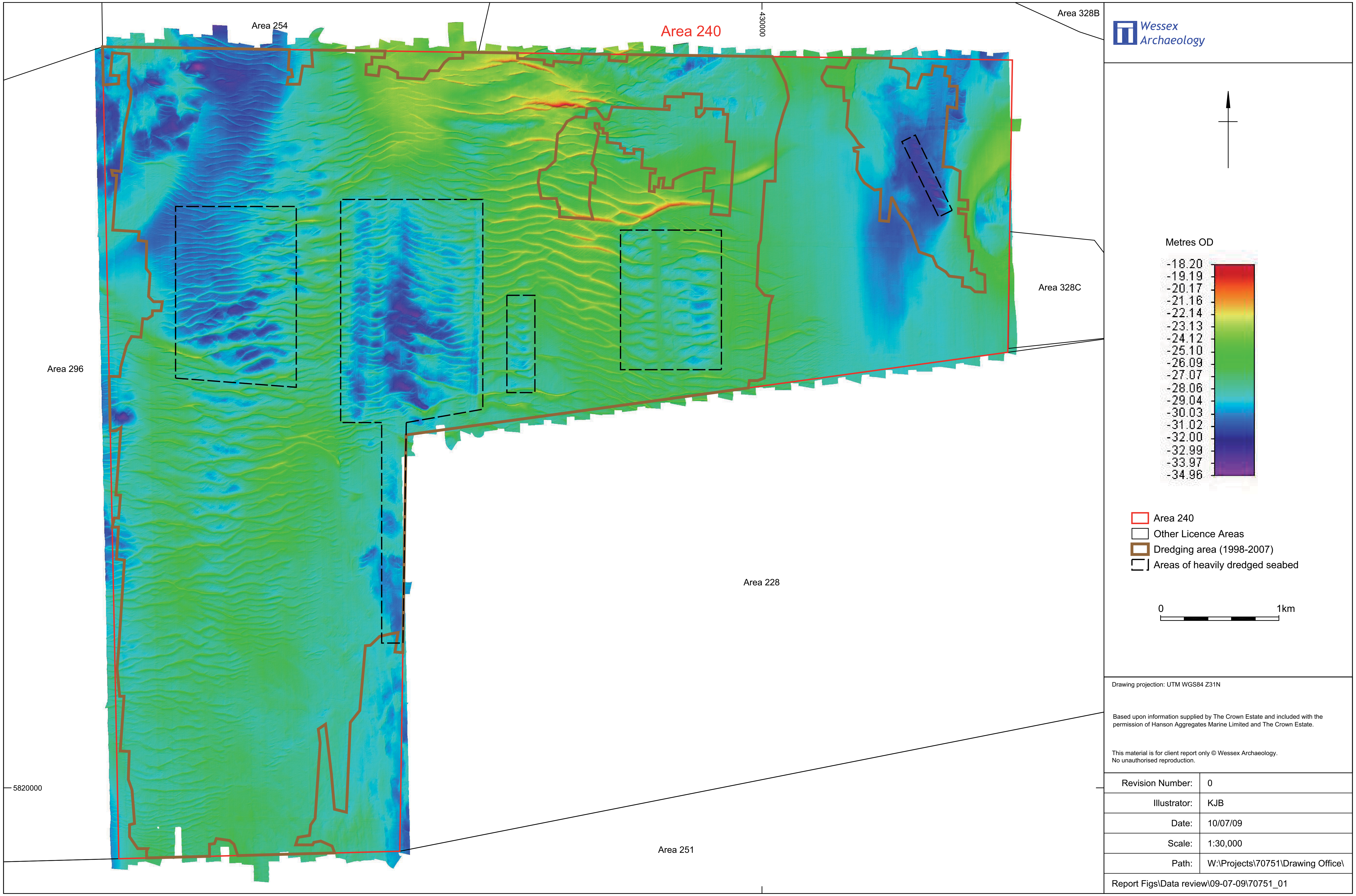
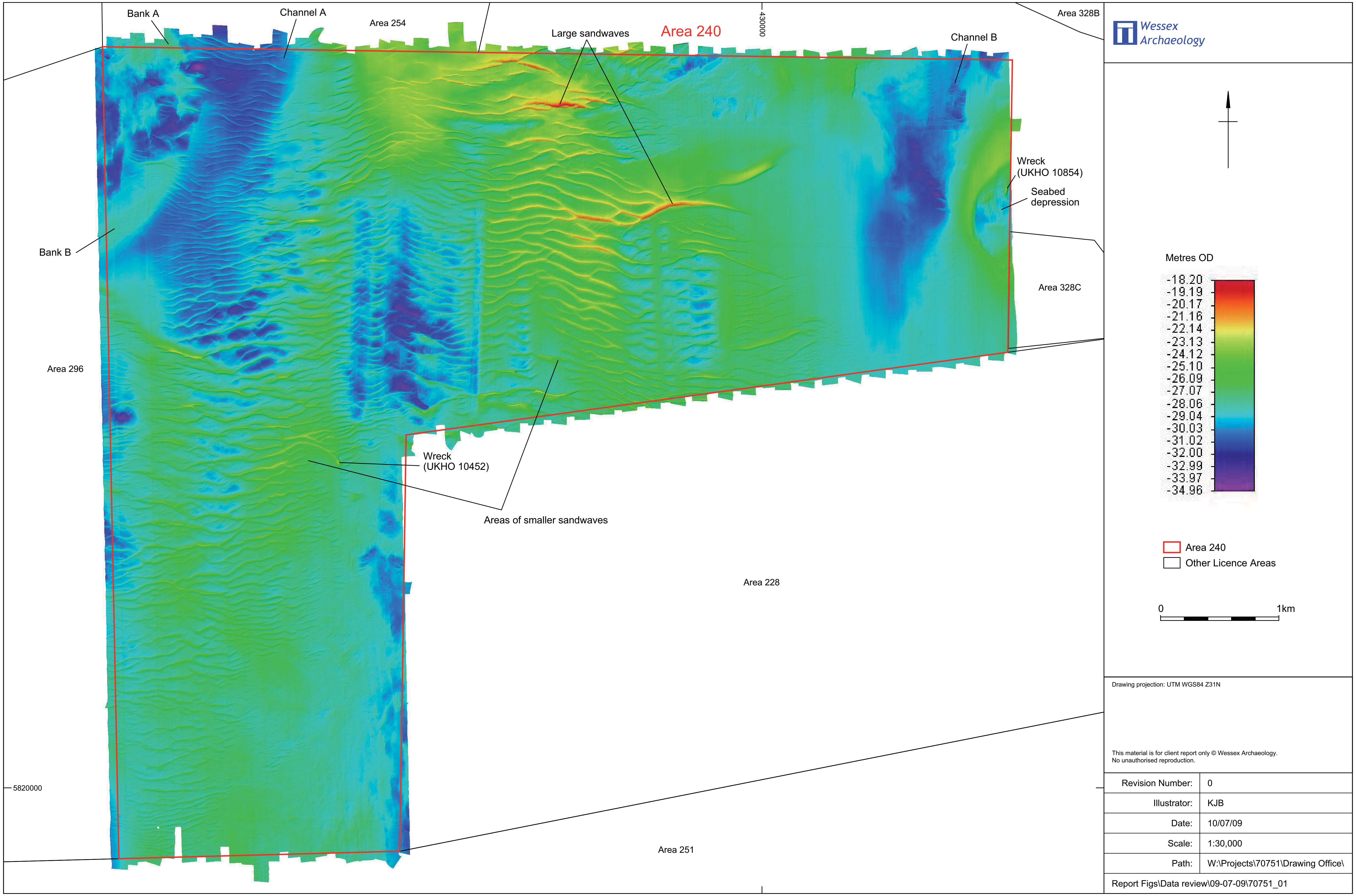
Dredging history within Area 240

Figure 6



Evidence of dredged areas on the seabed

Figure 7



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Drawing projection: UTM WGS84 Z31N

Revision Number:	0
Illustrator:	KJB
Date:	10/07/09
Scale:	1:30,000
Path:	W:\Projects\70751\Drawing Office\

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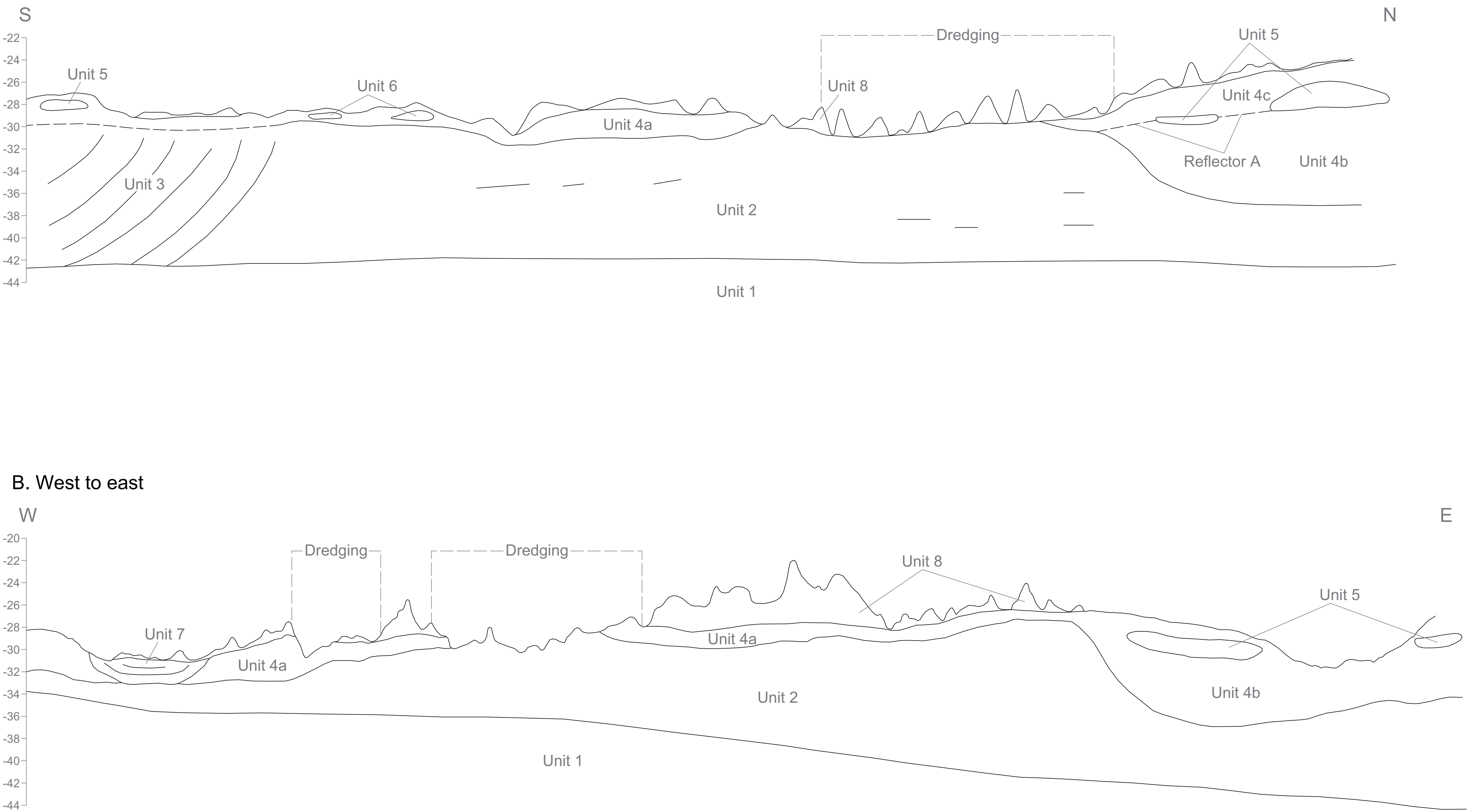
Area 240 bathymetry

Figure 8

A. South to north



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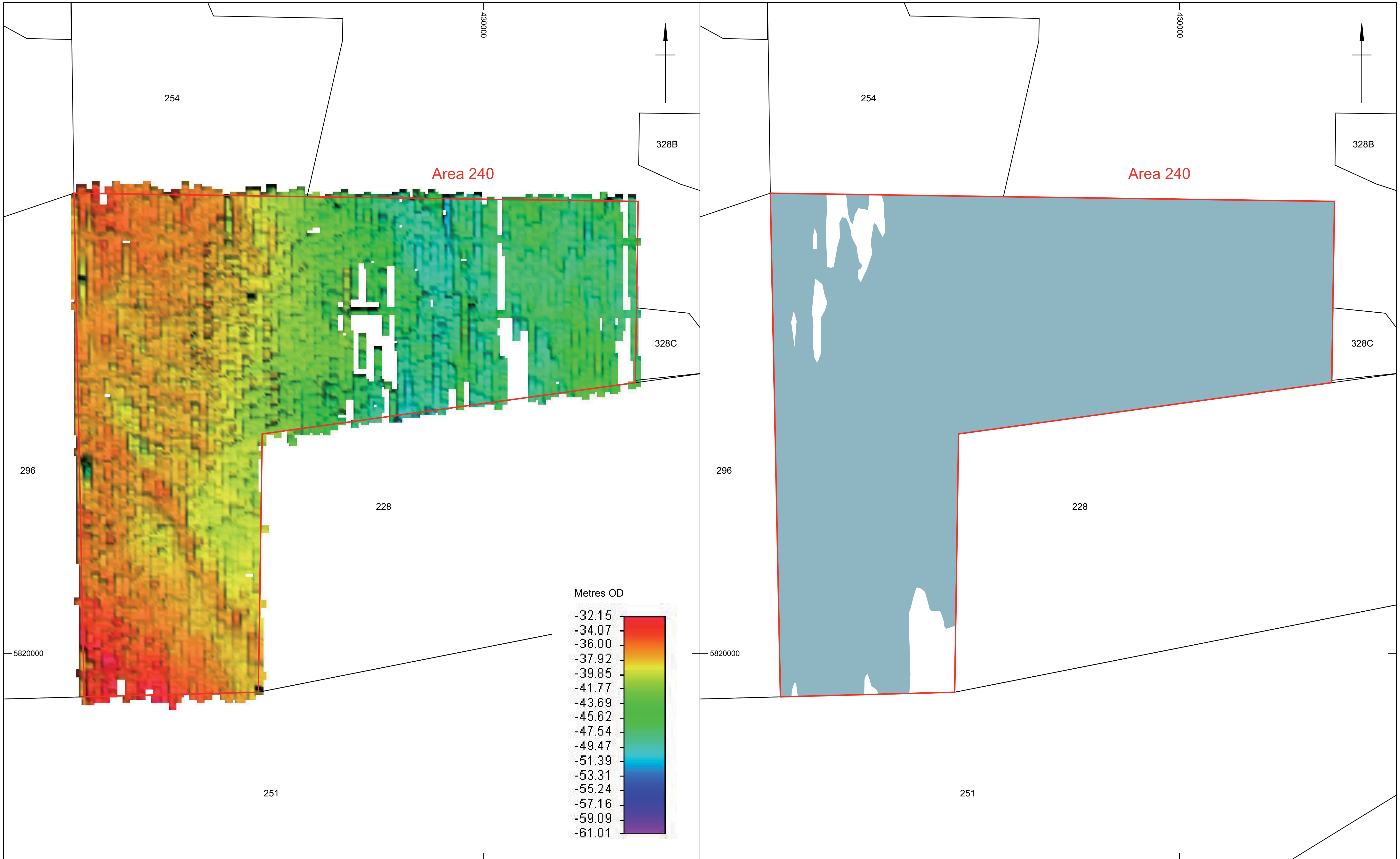
Scale:	1:500 vertical @A4	Illustrator:	KJB
Path:	W:\Projects\70751\Drawing Office\Report Figs\Data review\09-07-09\70751_01		

Schematics of seismic units identified in Area 240

Figure 9



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0 1 2km

Area 240
Other Licence Areas
Distribution of Unit 2

Drawing projection: UTM WGS84 Z31N.

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Scale:	1:50,000 @A3	Illustrator:	KJB
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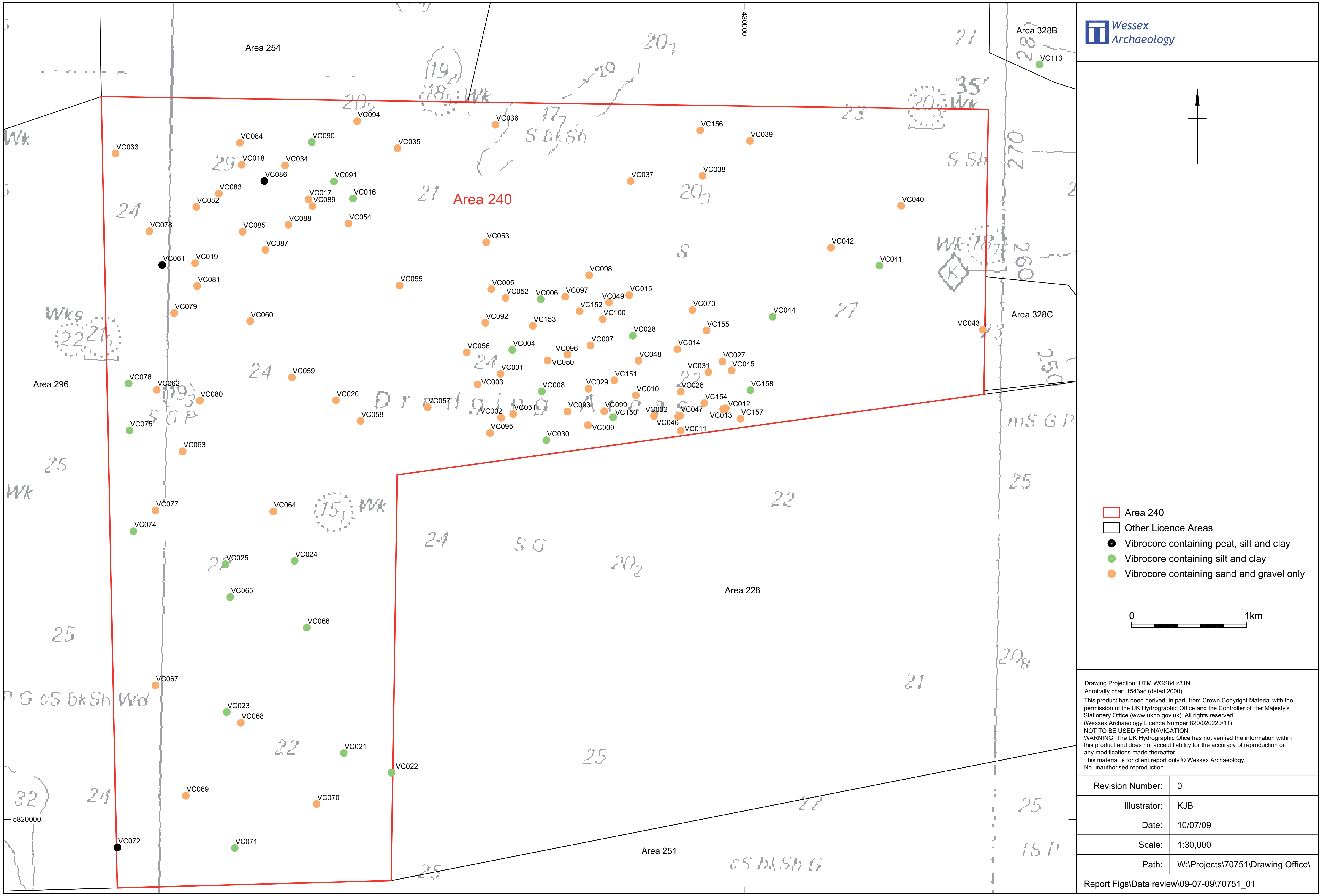
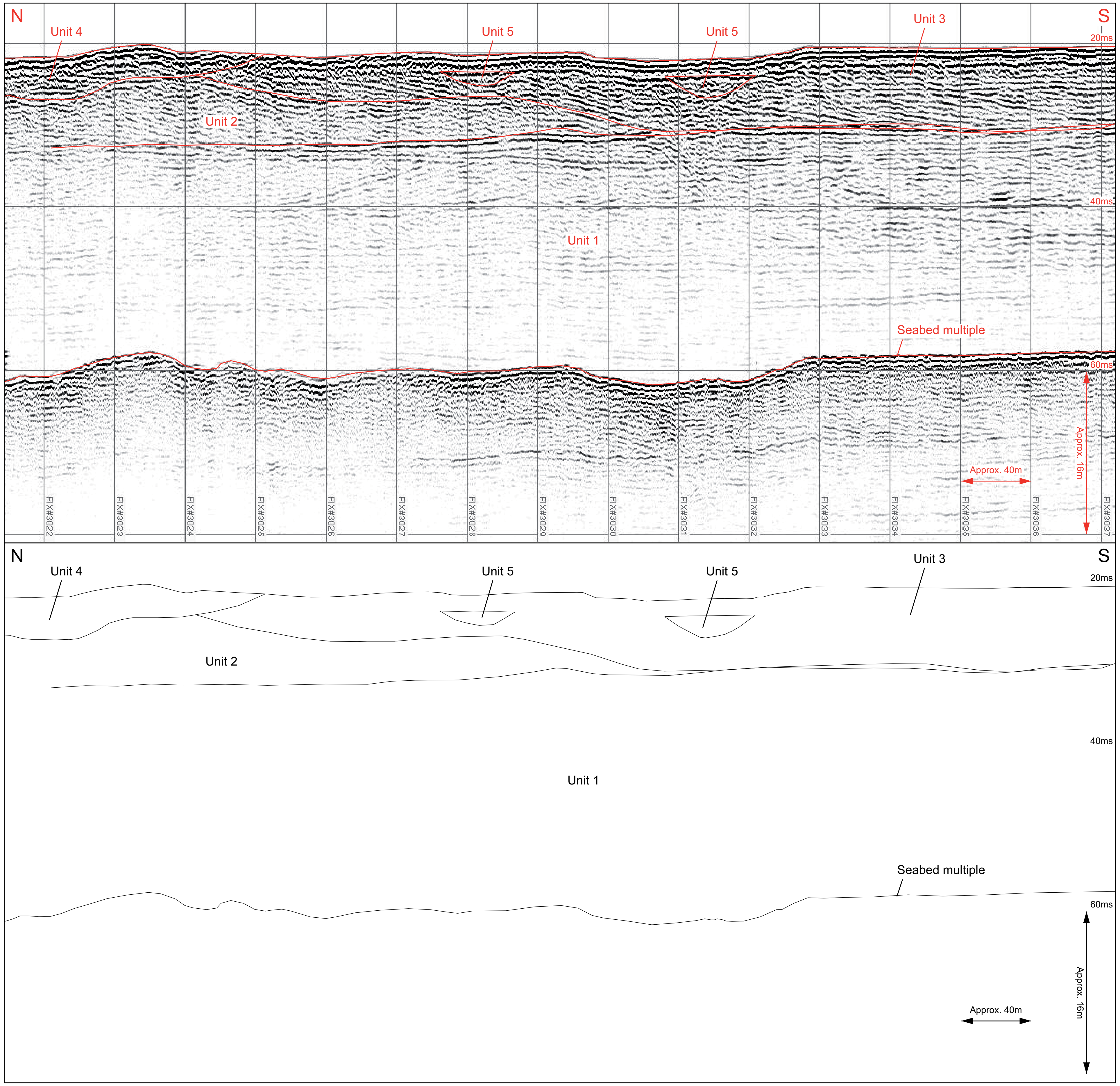
Top of Unit1/Base of unit 2 and distribution of Unit 2

Figure 10



Area 240 vibrocore sediments

Figure 11



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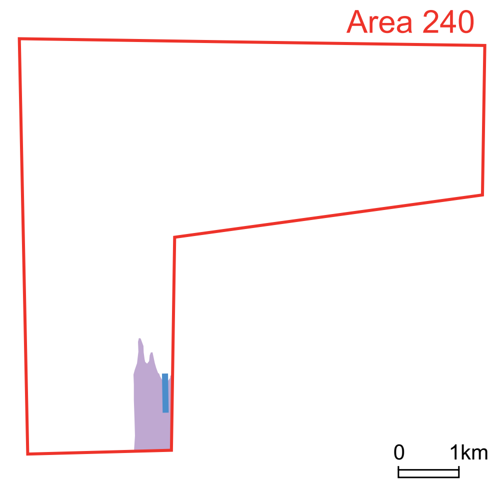

Area 240
Distribution of Unit 3
Location of SBP data example

Drawing Projection: UTM WGS84 z31N.

Revision Number:	0
Illustrator:	KJB
Date:	13/07/09
Scale:	1:2,500 horizontal (Inset 1:125,000)
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Sub-bottom profiler data example illustrating seismic character of Unit 3

Figure 12

Drawing Projection: UTM WGS84 z31N.

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Scale:	1:50,000	Illustrator:	KJB
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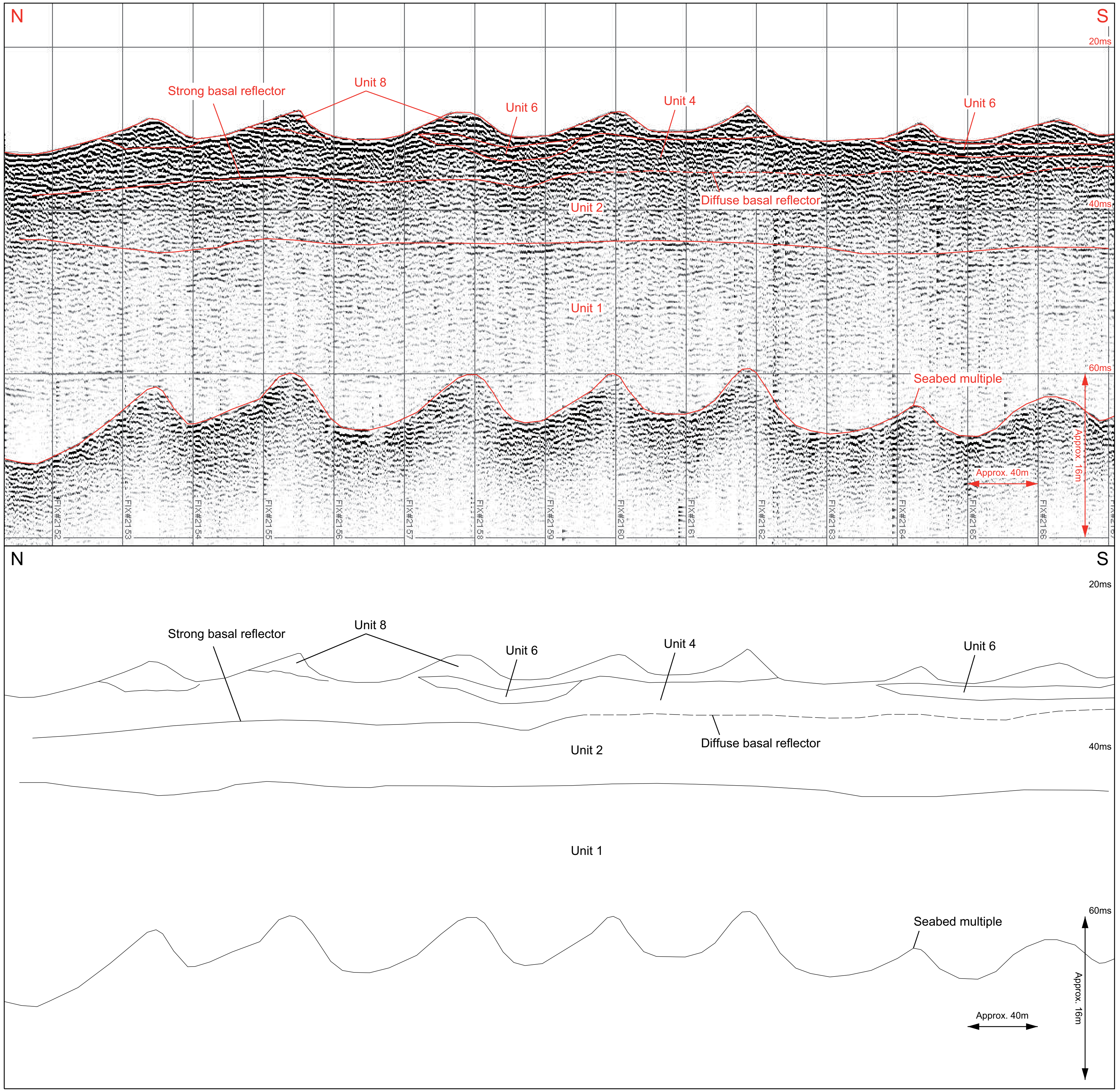
Distribution of Unit 4

Figure 13



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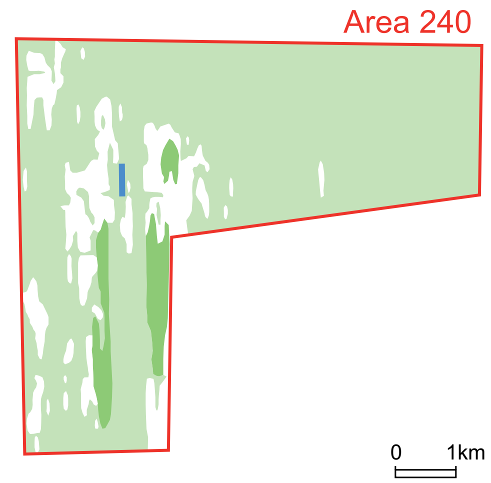

Area 240
Location of SBP data example
Unit 4 - strong basal reflector
Unit 4 - indistinct basal reflector

Drawing Projection: UTM WGS84 z31N.

Revision Number:	0
Illustrator:	KJB
Date:	13/07/09
Scale:	1:2,500 horizontal (Inset 1:125,000)
Path:	W:\Projects\70751\Drawing Office\

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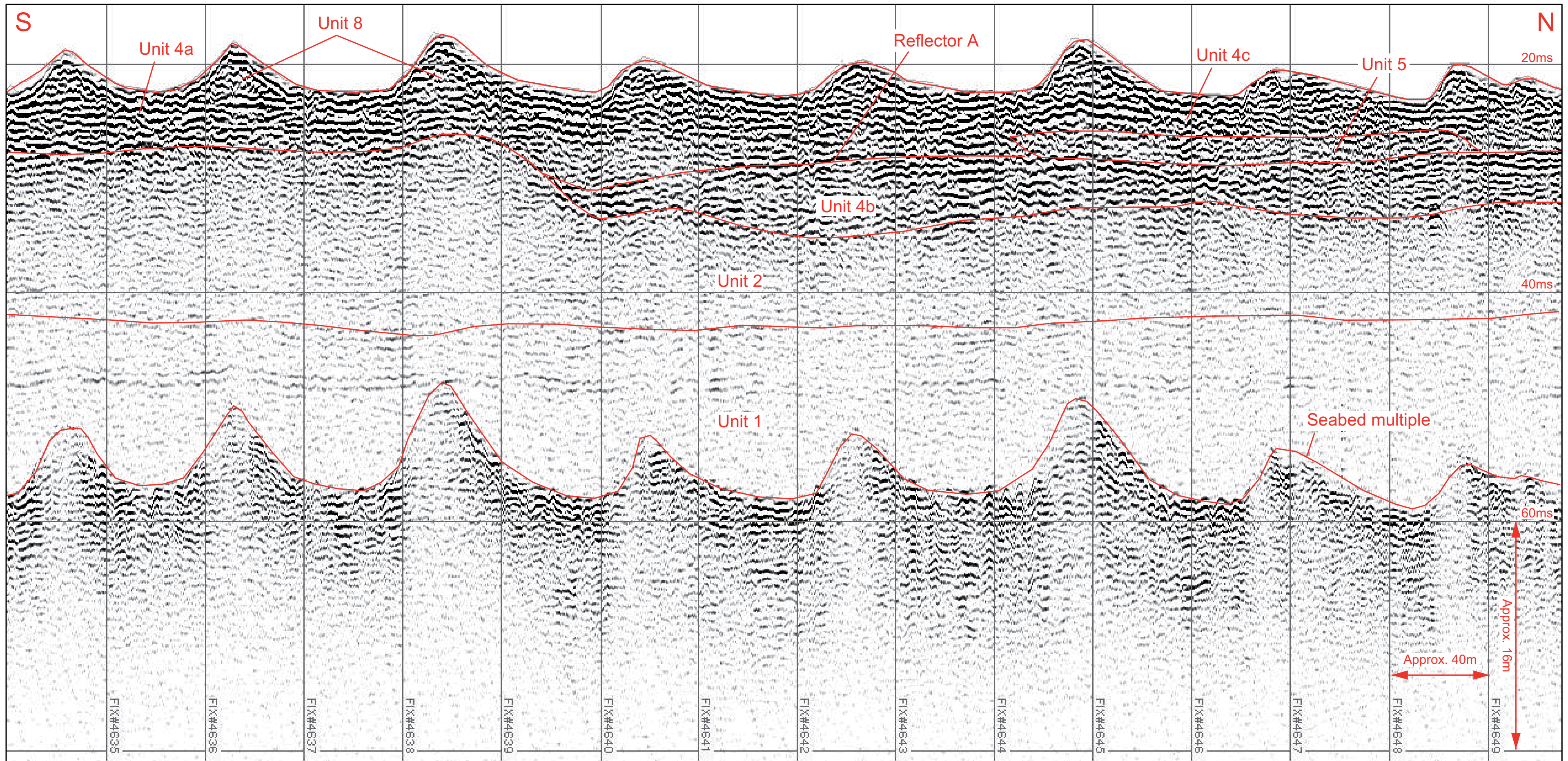
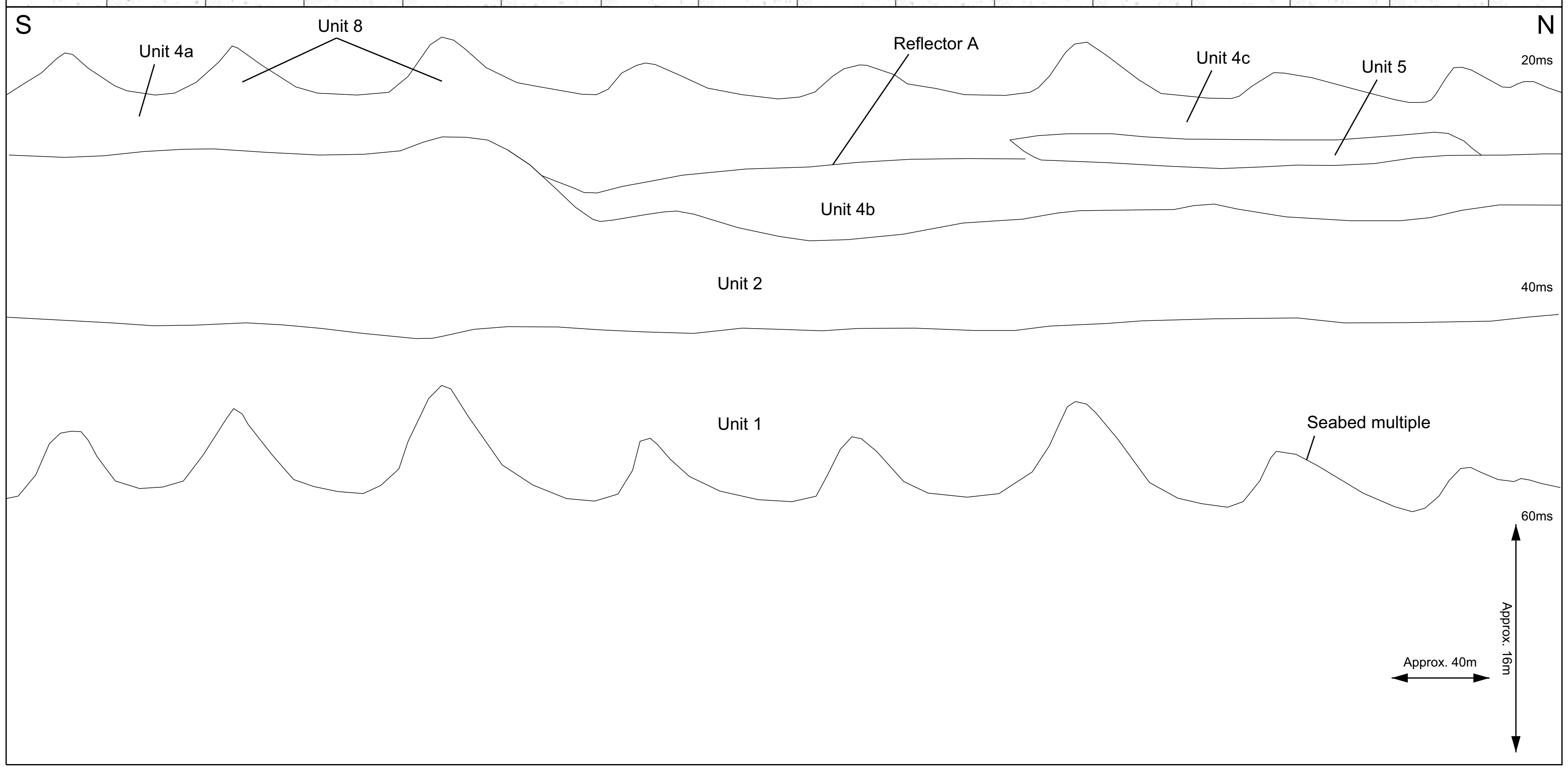
Sub-bottom profiler data example illustrating Unit 4 basal reflector (7003)

Figure 14

Sub-bottom profiler data example illustrating edge of channel at base of Unit 4 (7003)





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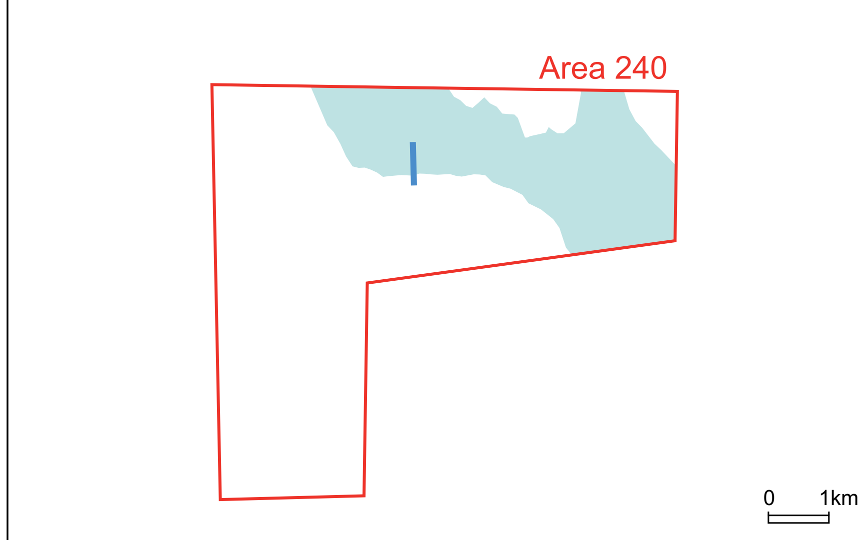
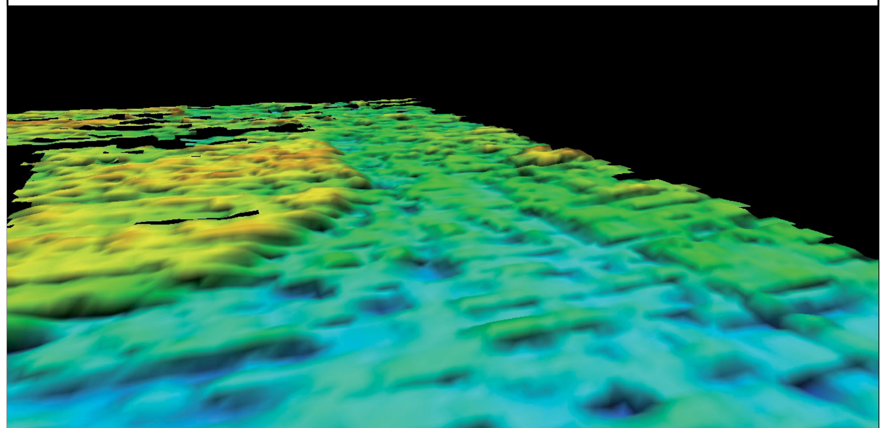
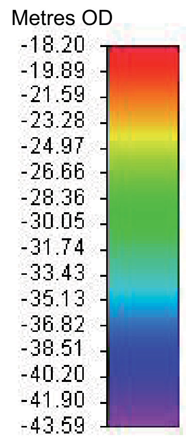




Channel at base of Unit 4 looking northwest



Area 240
Coverage of channel
Location of SBP data example

Drawing Projection: UTM WGS84 z31N.

Revision Number:	0
Illustrator:	KJB
Date:	13/07/09
Scale:	1:2,500 horizontal (Inset 1:125,000)
Path:	W:\Projects\70751\Drawing Office\Report Figs\Data review\09-07-09\70751_01

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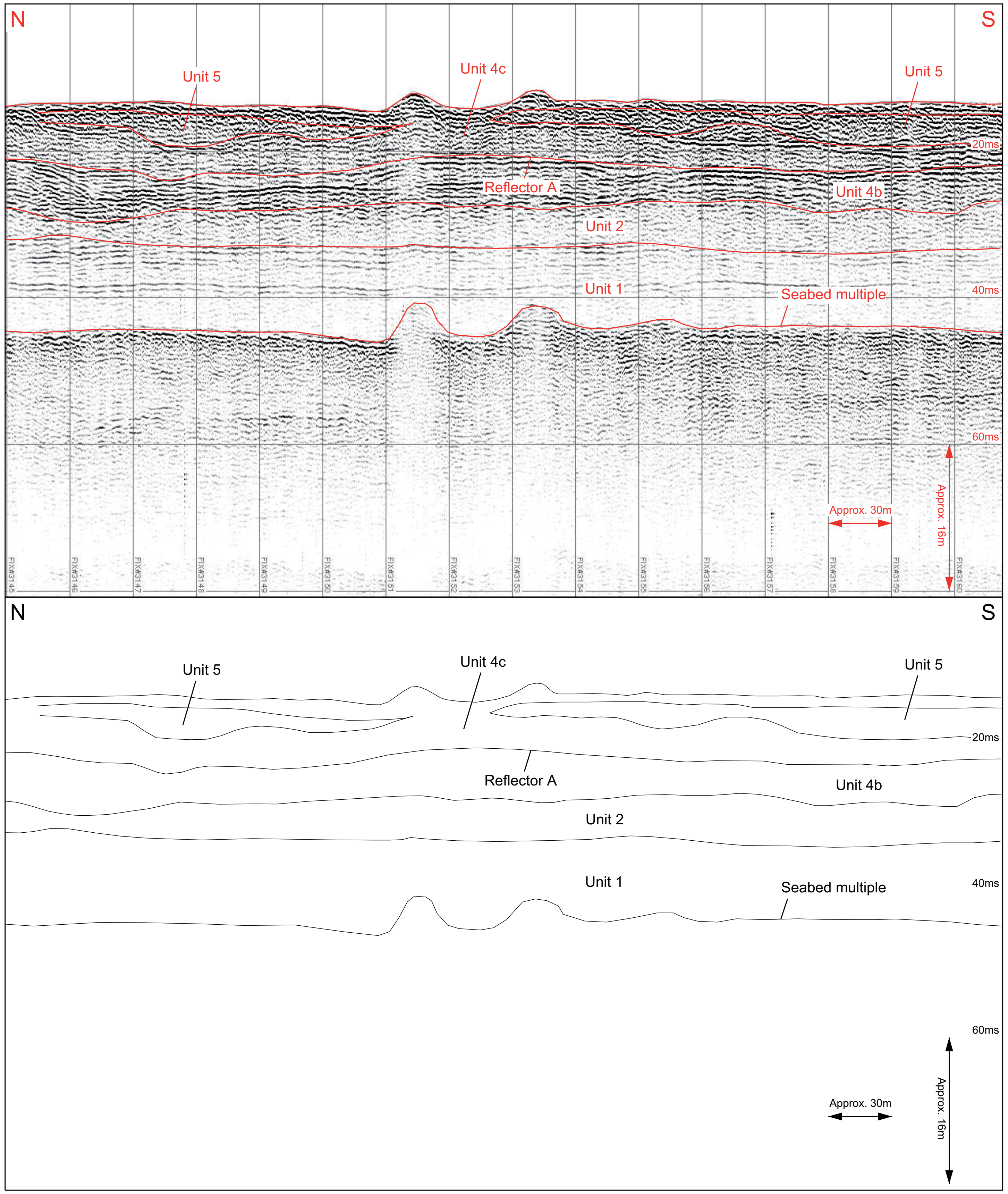
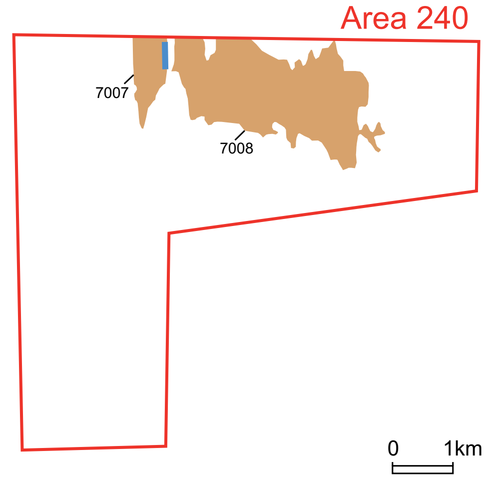
Sub-bottom profiler data example illustrating relationship between Reflector A (7007) and Unit 5





Area 240
Distribution of Reflector A
Location of SBP data example

Drawing Projection: UTM WGS84 z31N.

Revision Number:	0
Illustrator:	KJB
Date:	13/07/09
Scale:	1:2,500 horizontal (Inset 1:125,000)
Path:	W:\Projects\70751\Drawing Office\

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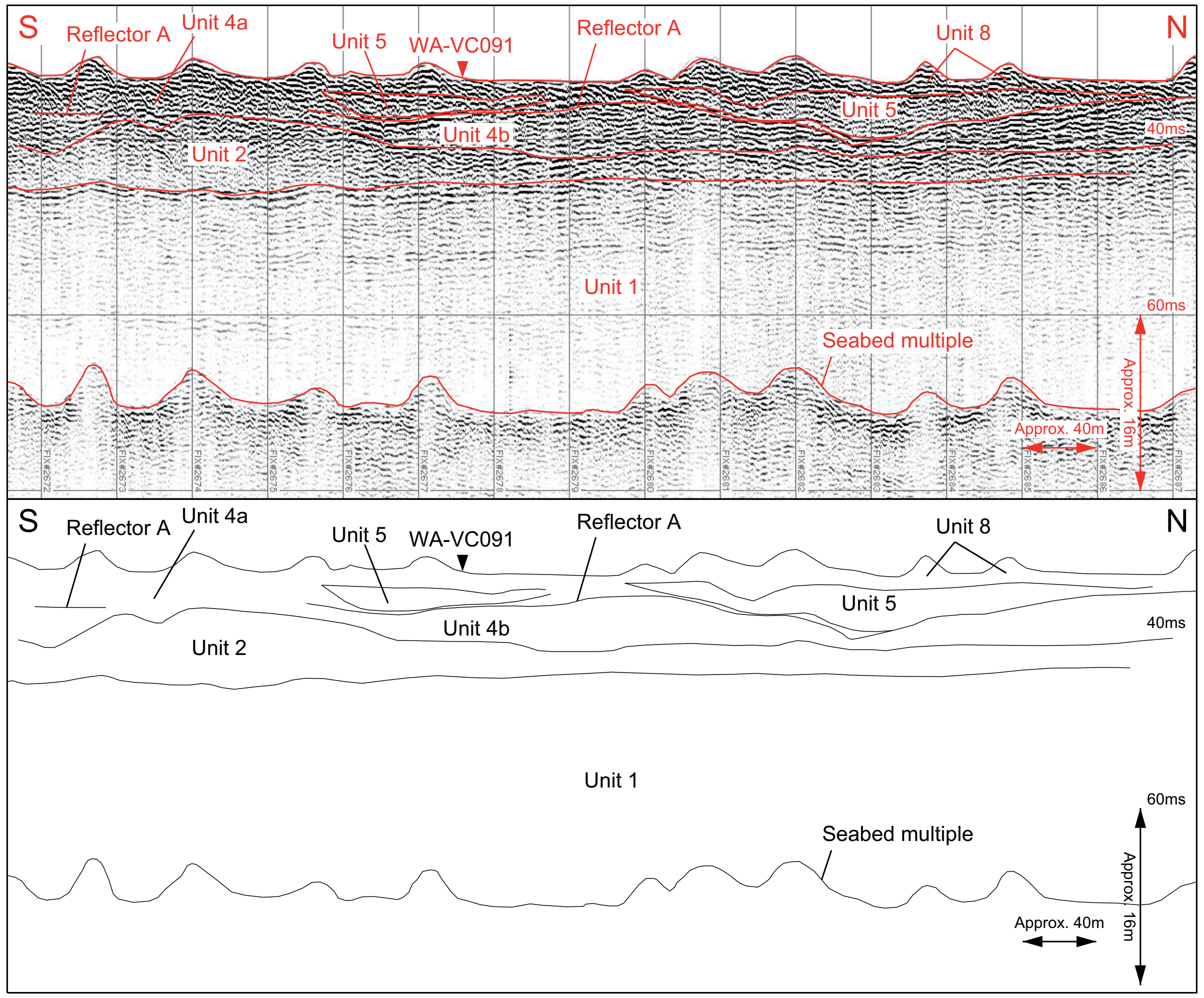
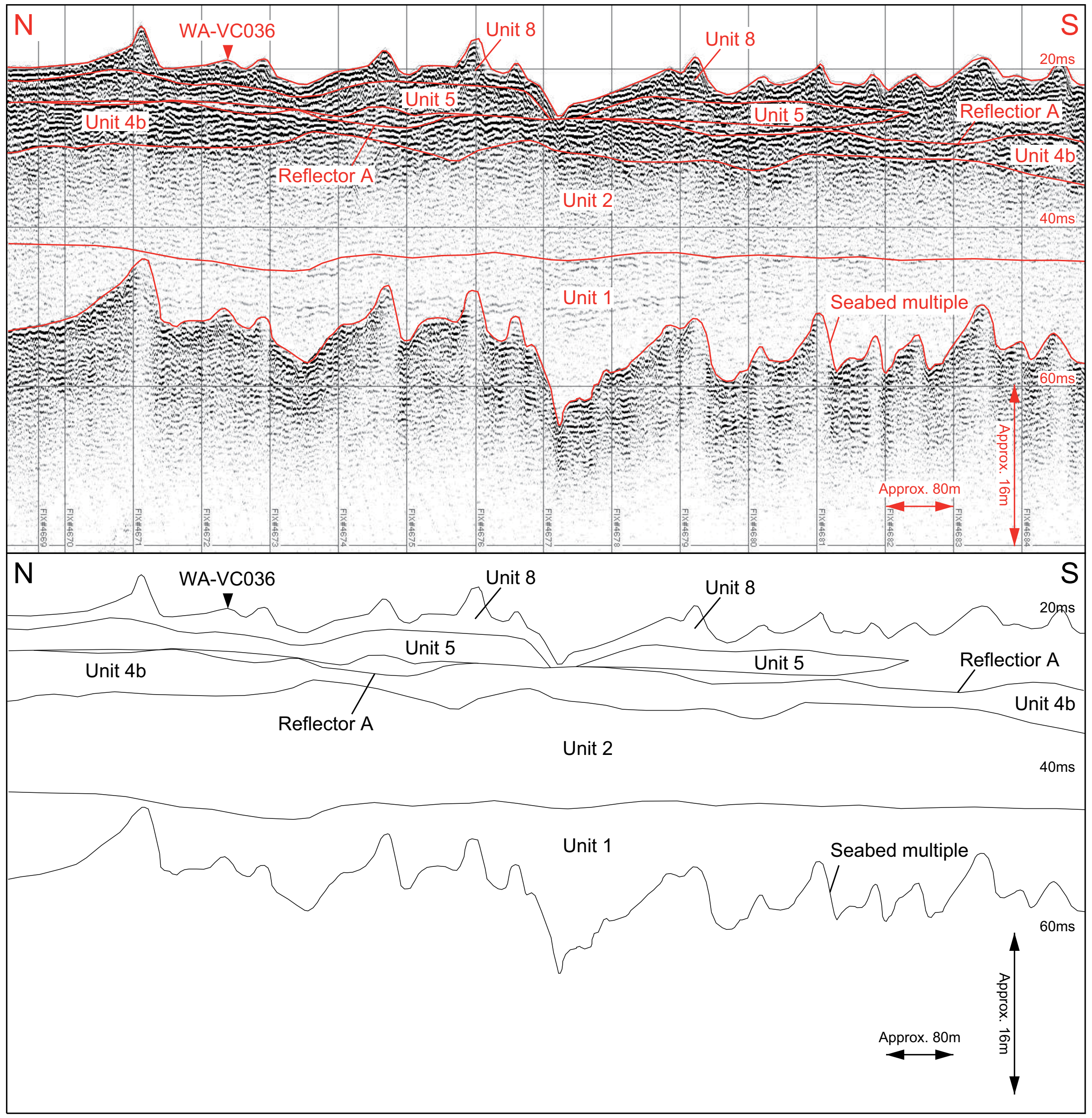
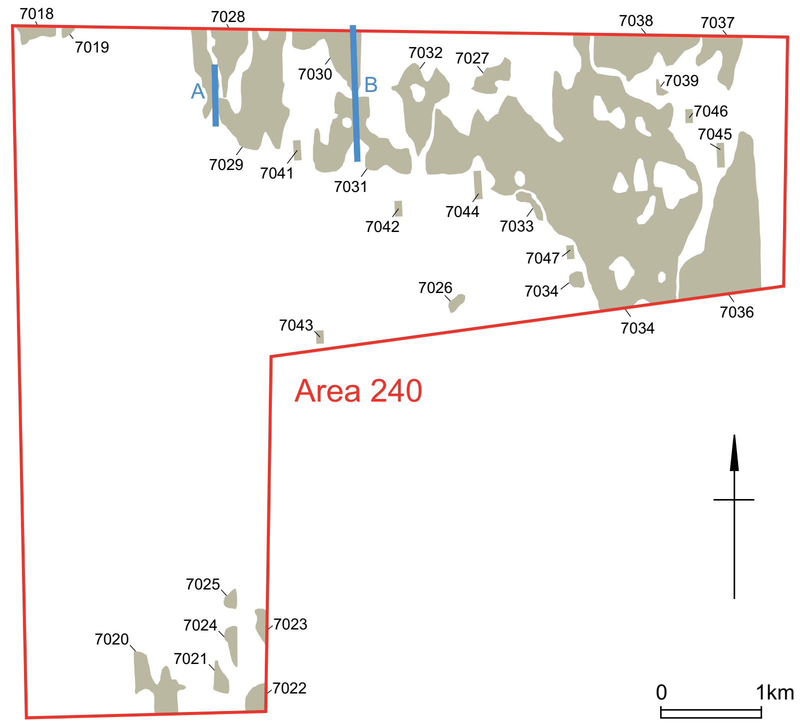
Distribution and example of Reflector A

A. Sub-bottom profiler data example illustrating channel structure infilled with Unit 5 (7029)



B. Sub-bottom profiler data example illustrating bank structure infilled with Unit 5 (7030 and 7031)





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Area 240
Distribution of Unit 5
Location of SBP data example

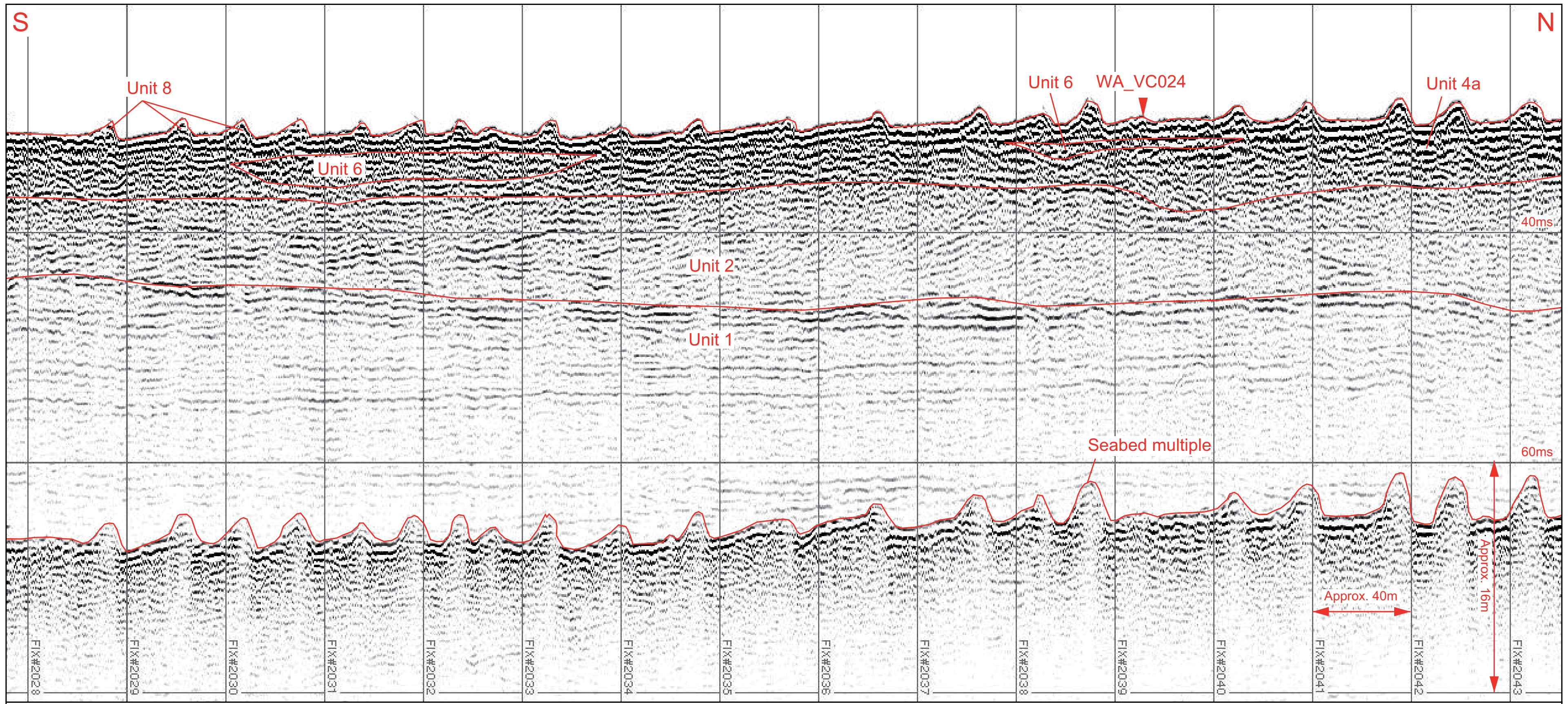
Drawing Projection: UTM WGS84 z31N.

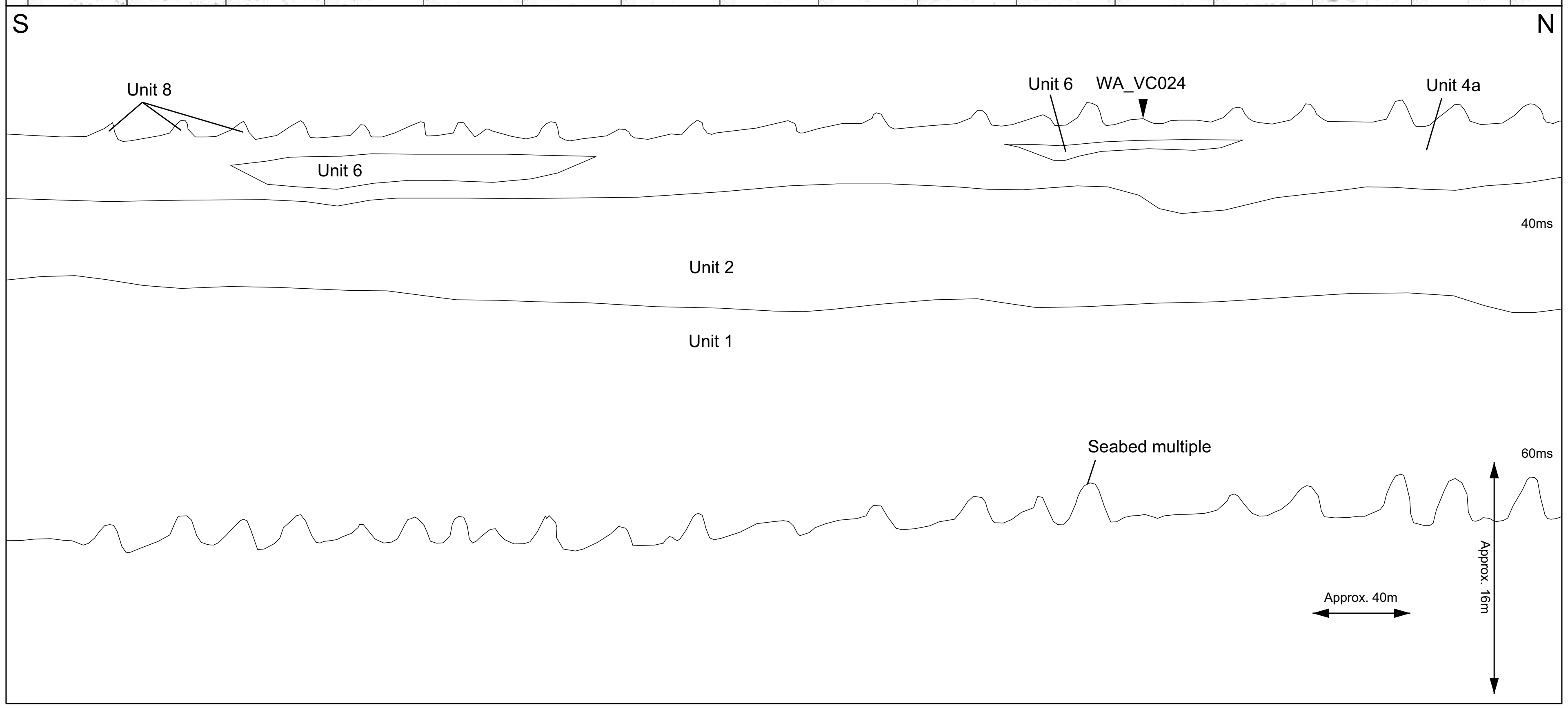
Date:	14/07/09	Revision Number:	0
Scale:	1:4000 and 1:8000 horizontal (Inset 1:75,000)	Illustrator:	KJB
Path:	W:\Projects\70751\Drawing Office\Report Figs\Data review\09-07-09\70751_01		

Distribution and examples of Unit 5

Figure 17

Sub-bottom profiler data example illustrating channel structure infilled with Unit 6 (7060)





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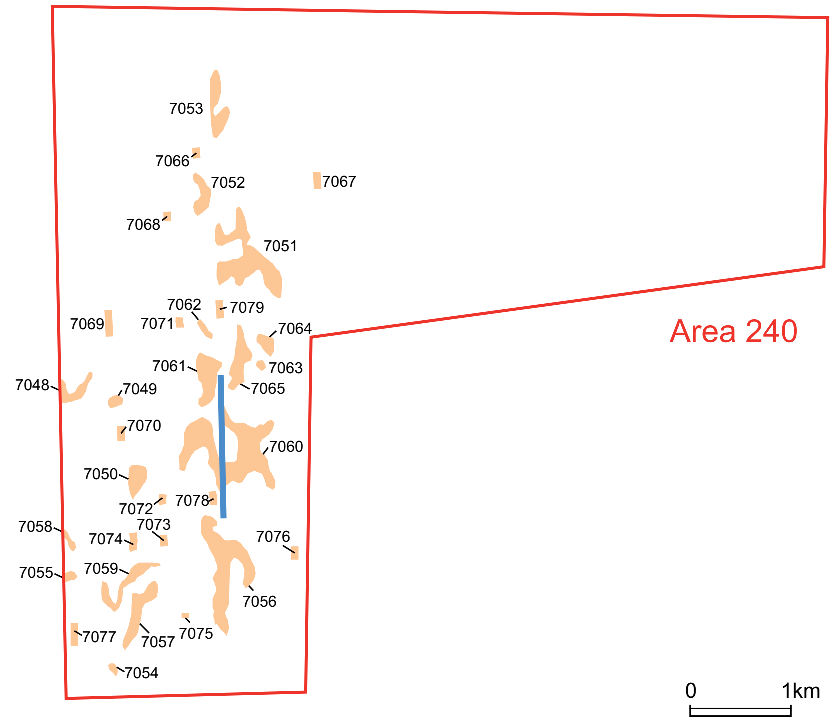

Area 240
Distribution of Unit 6
Location of SBP data example

Drawing Projection: UTM WGS84 z31N.

Revision Number:	0
Illustrator:	KJB
Date:	13/07/09
Scale:	1:2,500 horizontal (Inset 1:75,000)
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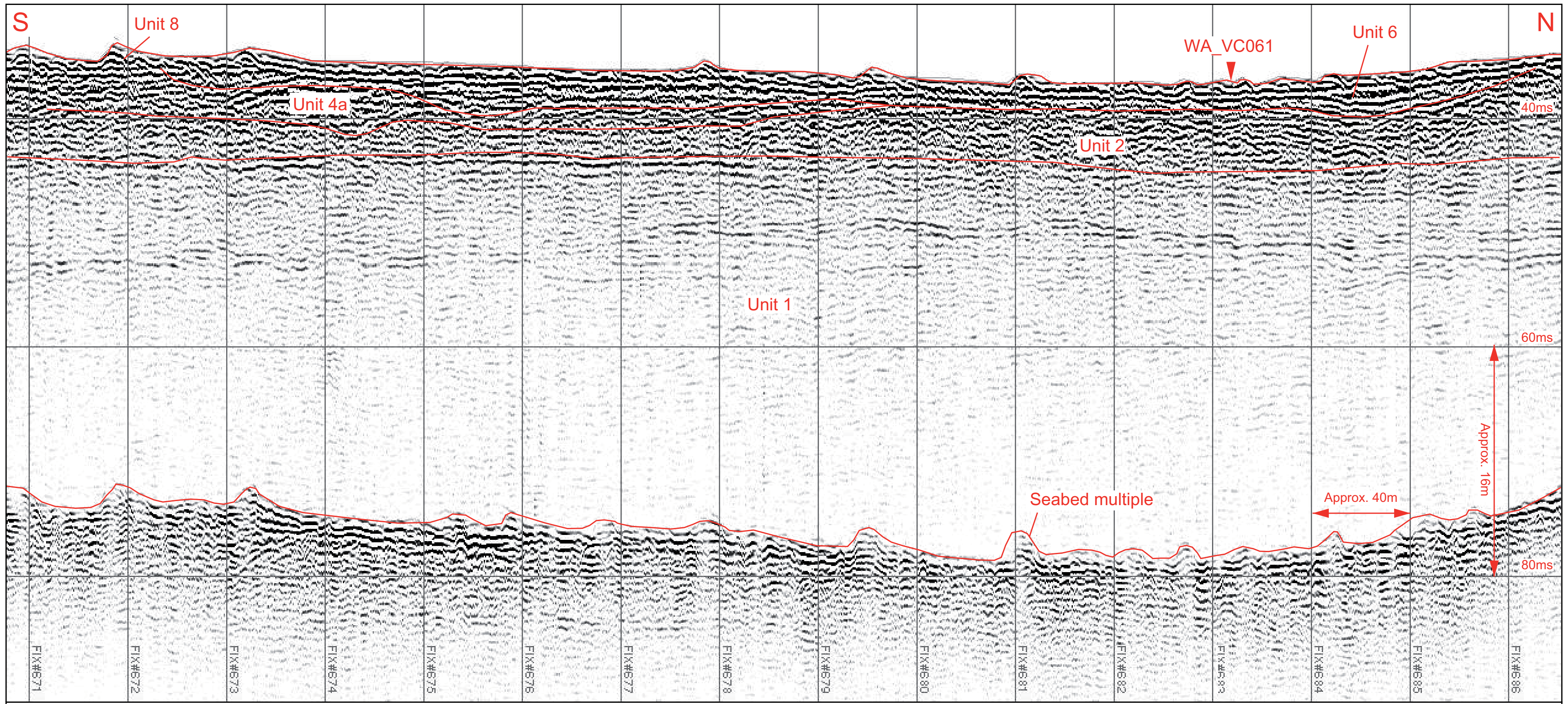
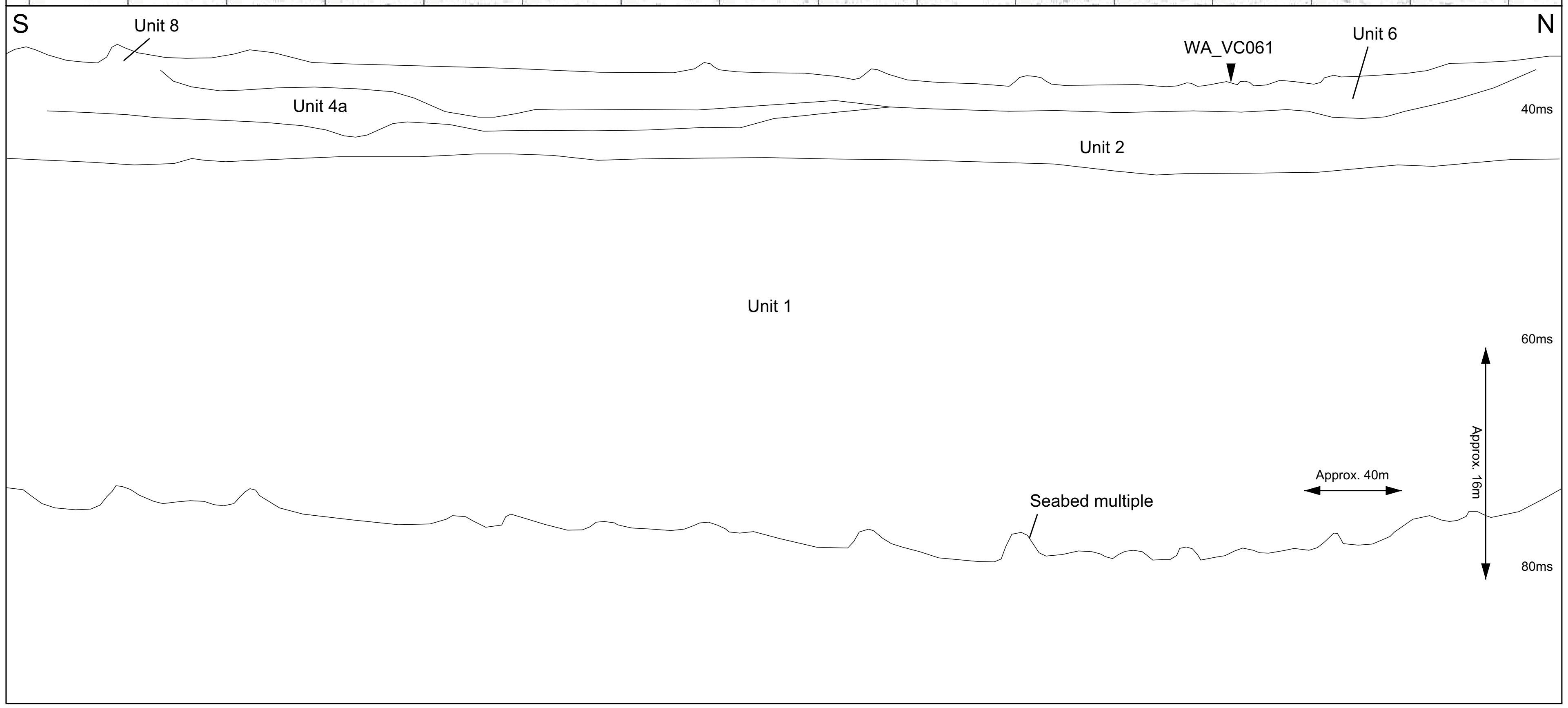
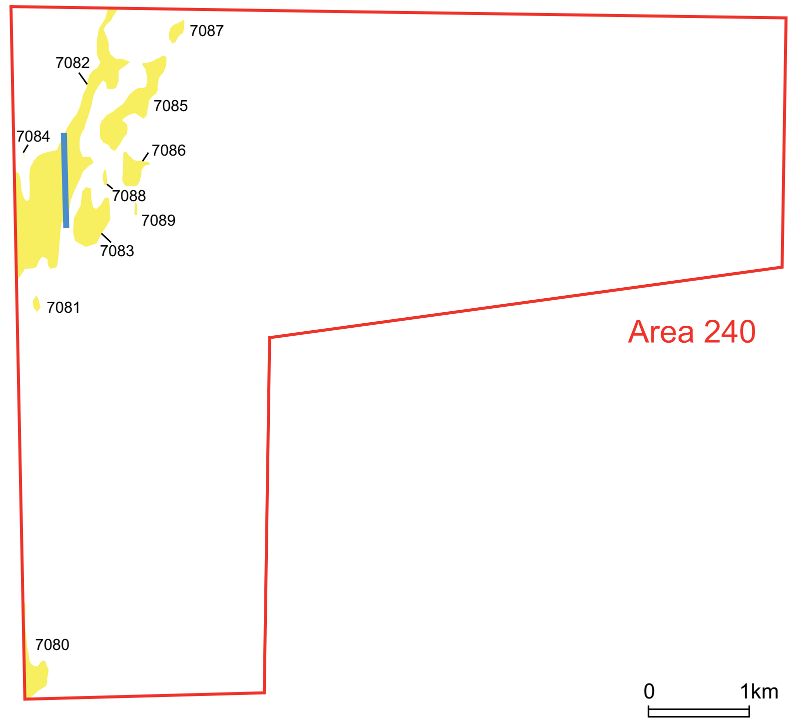
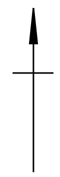
Sub-bottom profiler data example illustrating channel structure infilled with Unit 5 (7082)







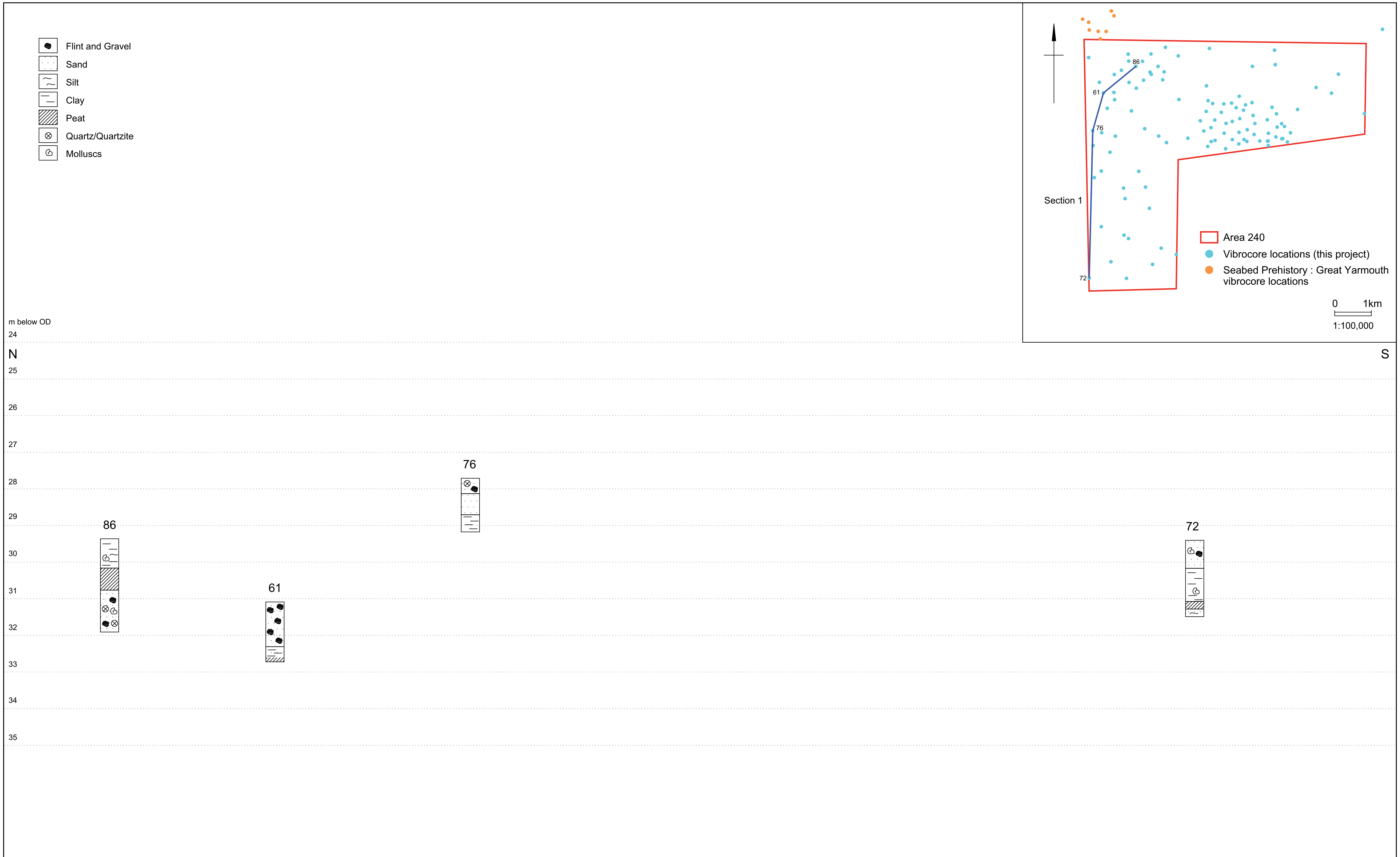


Area 240
Distribution of Unit 7
Location of SBP data example

Drawing Projection: UTM WGS84 z31N.

Revision Number:	0
Illustrator:	KJB
Date:	13/07/09
Scale:	1:2,500 horizontal (Inset 1:75,000)
Path:	W:\Projects\70751\Drawing Office\Report Figs\Data review\09-07-09\70751_01

Distribution and examples of Unit 7



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Projection WGS84 zone 31N

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Scale:	Horizontal 1:20,000 Verical 1:100	Illustrator:	KMN/KJB
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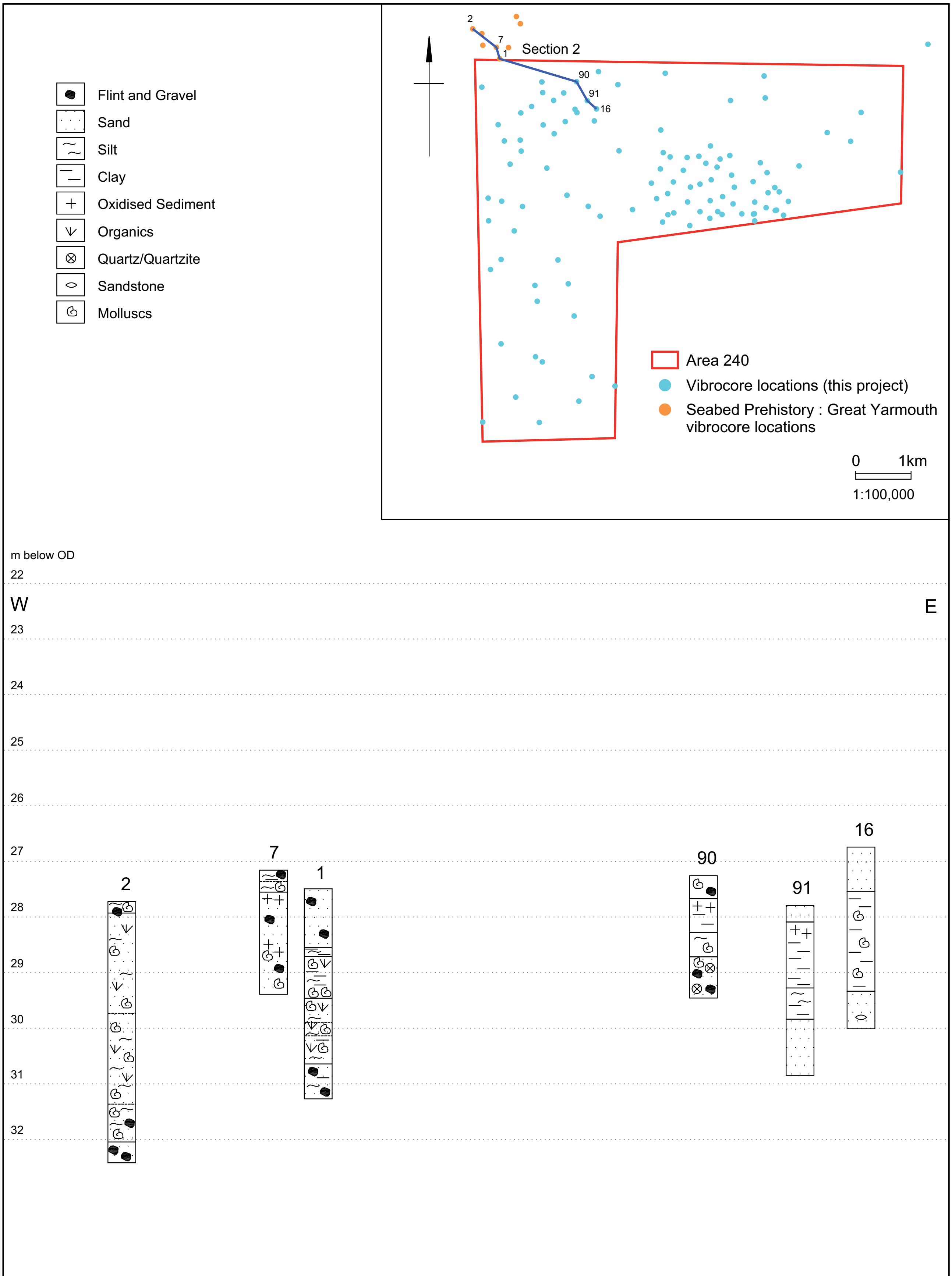
Vibrocore section 1

Figure 20



Projection WGS84 zone 31N

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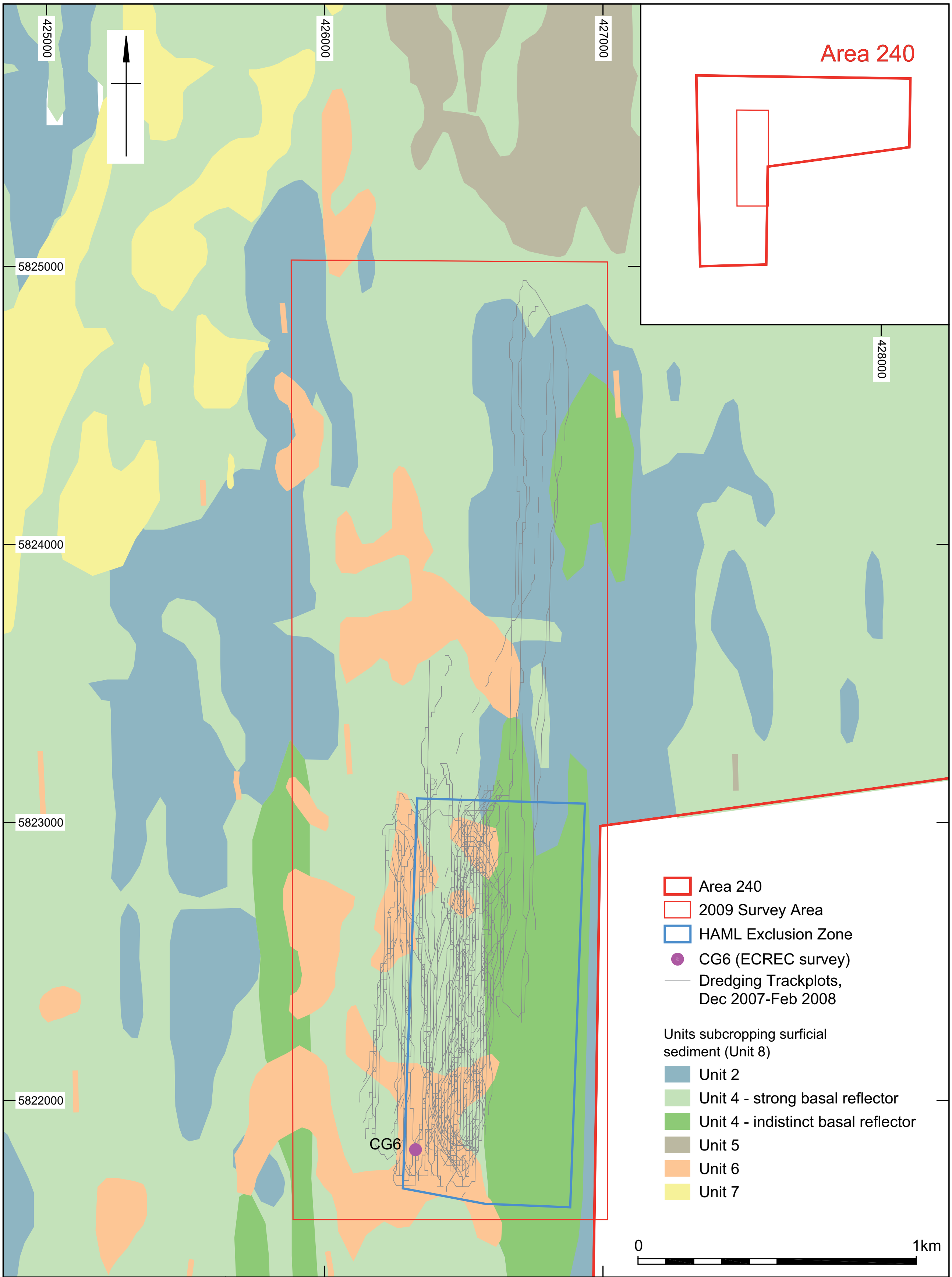
Vibrocore section 2

Figure 21



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Path:	W:\Projects\70751\Drawing Office\Report Figs\Data review\09-07-09\70751_01		

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Sediment units subcropping surficial sediment (Unit 8)

Figure 22

Plate 1: Worked flint from Area 240

Plate 2: Worked flint from Area 240

Plate 3: Worked flint from Area 240

Plate 4: Worked flint from Area 240

Date:	15/07/09	Revision Number:	0
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Path:	W:\Projects\70751\Drawing Office\Report Figs\Data review\09-07-09		

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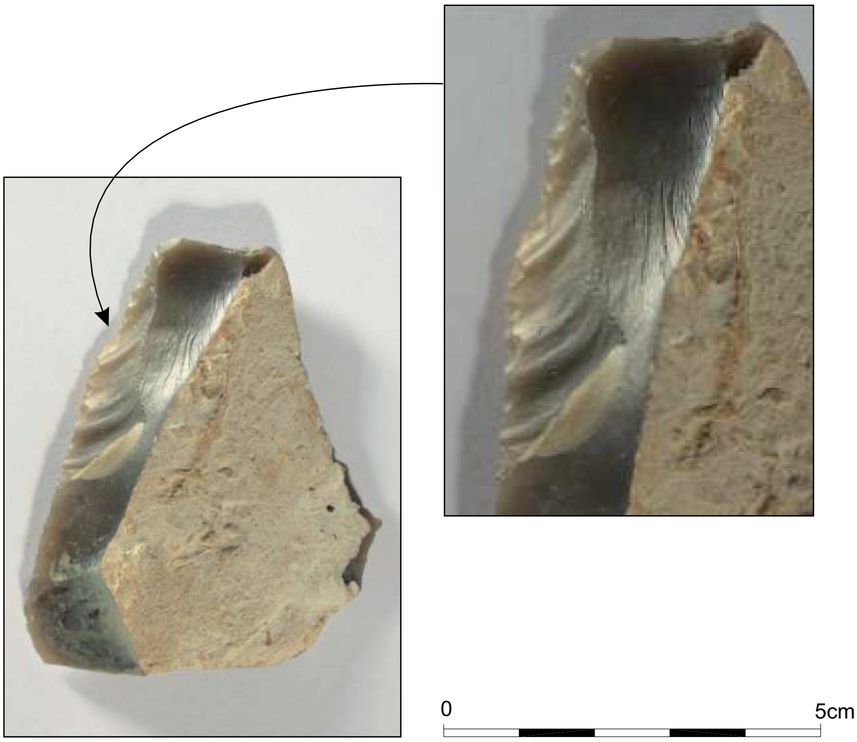

Plate 5: Worked flint from grab sample CG6

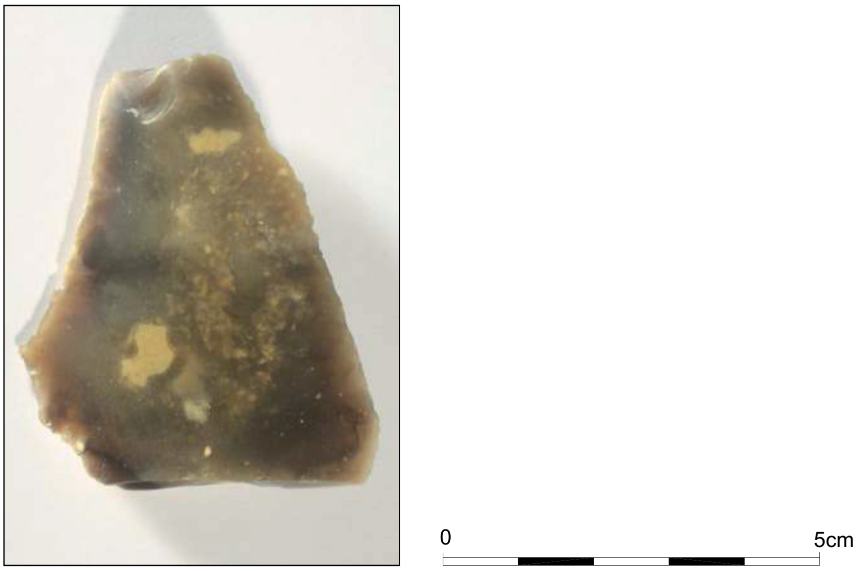

Plate 6: Worked flint from grab sample CG6

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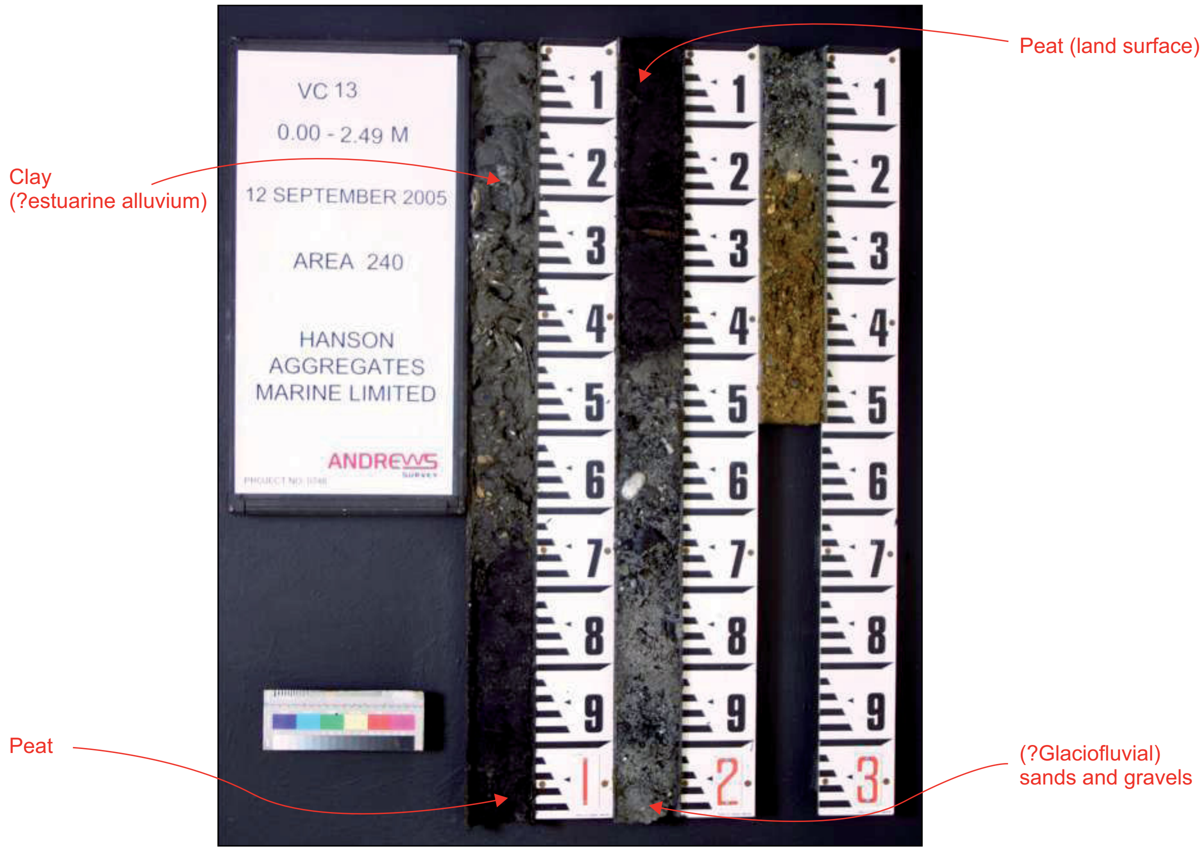

Plate 7: WA_VC086

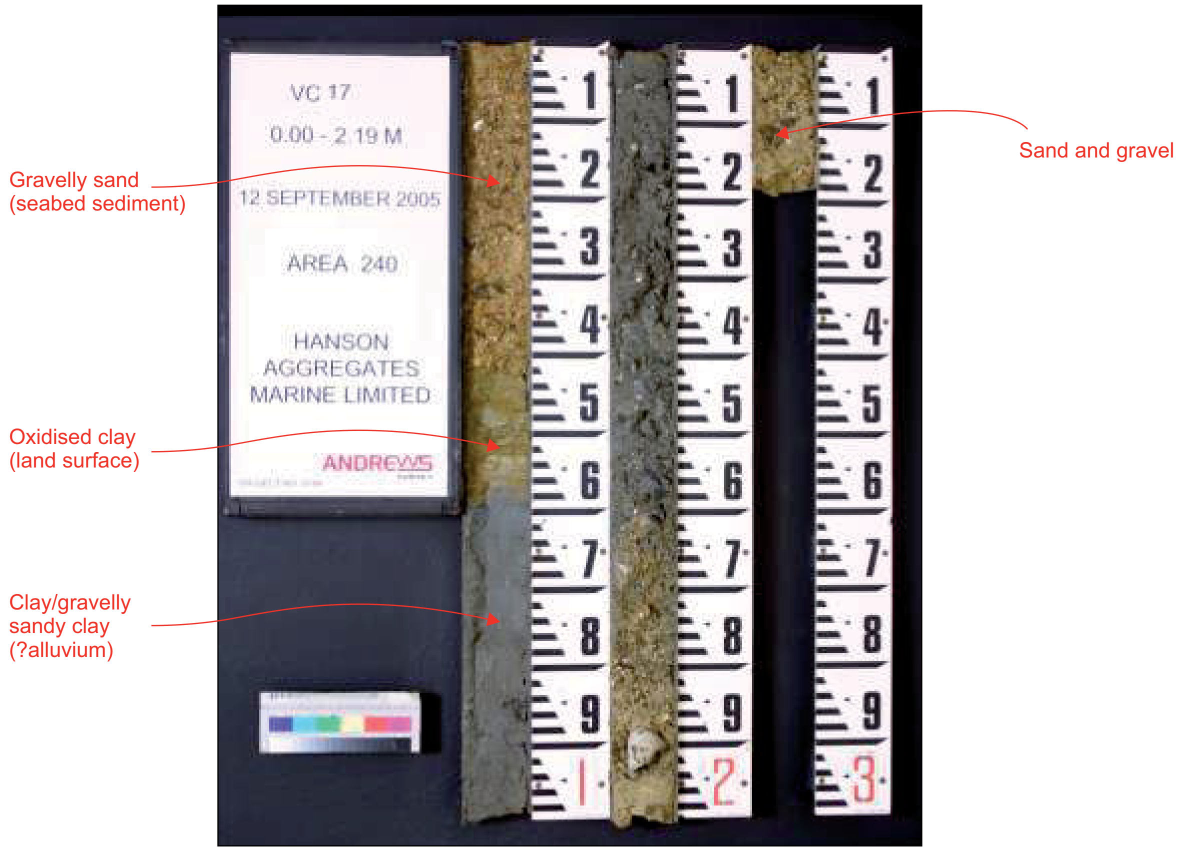

Plate 8: WA_VC090

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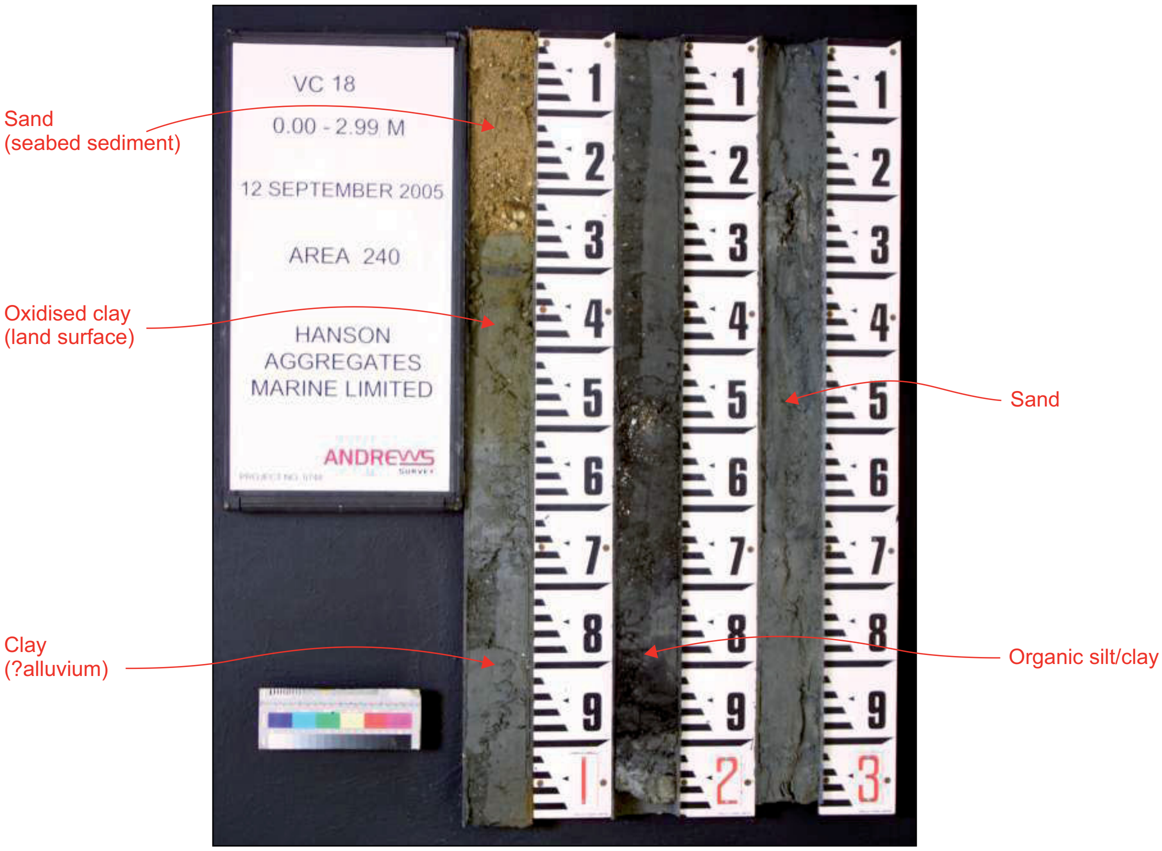

Plate 9: WA_VC091

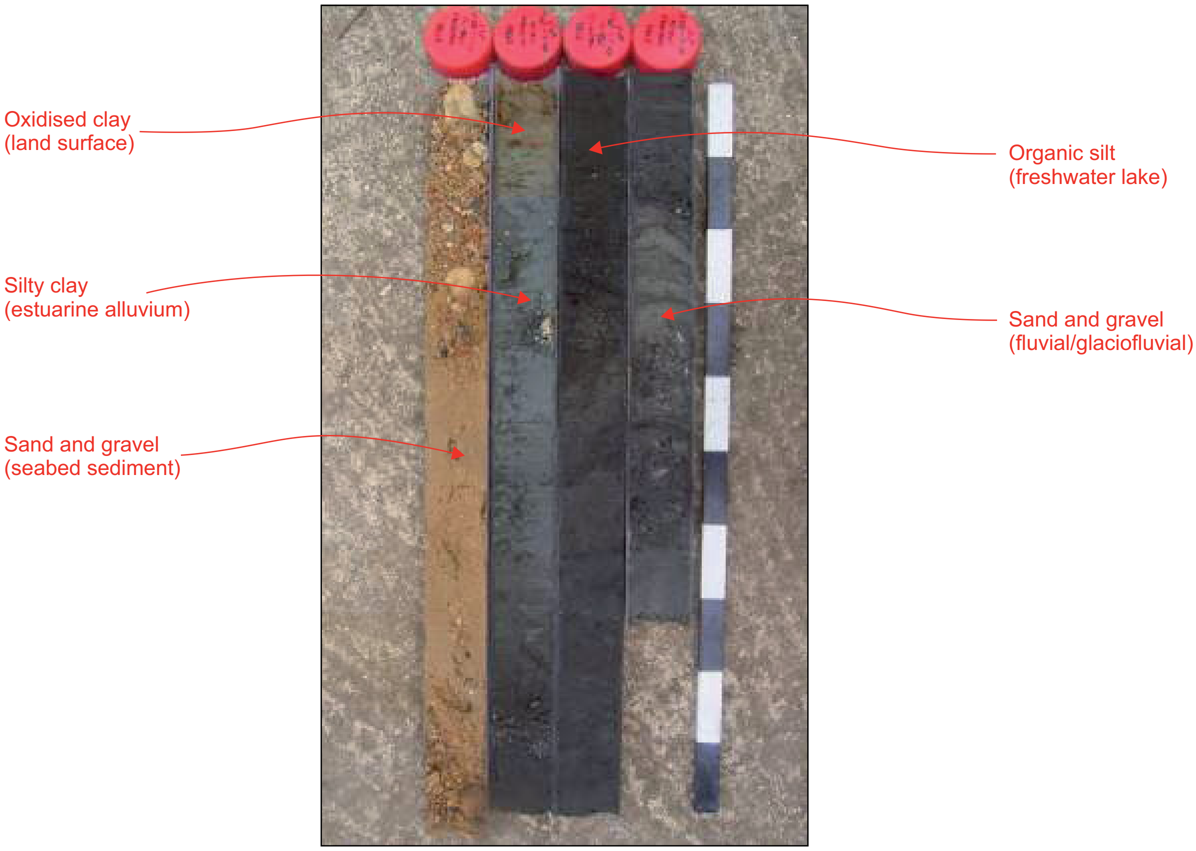

Plate 10: Seabed Prehistory Round 2 Great Yarmouth GY1

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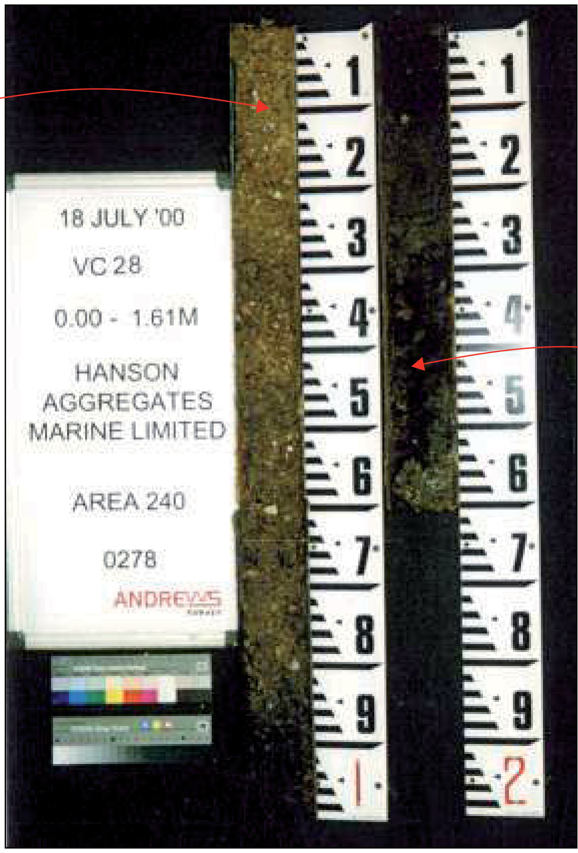

Plate 11: WA_VC061

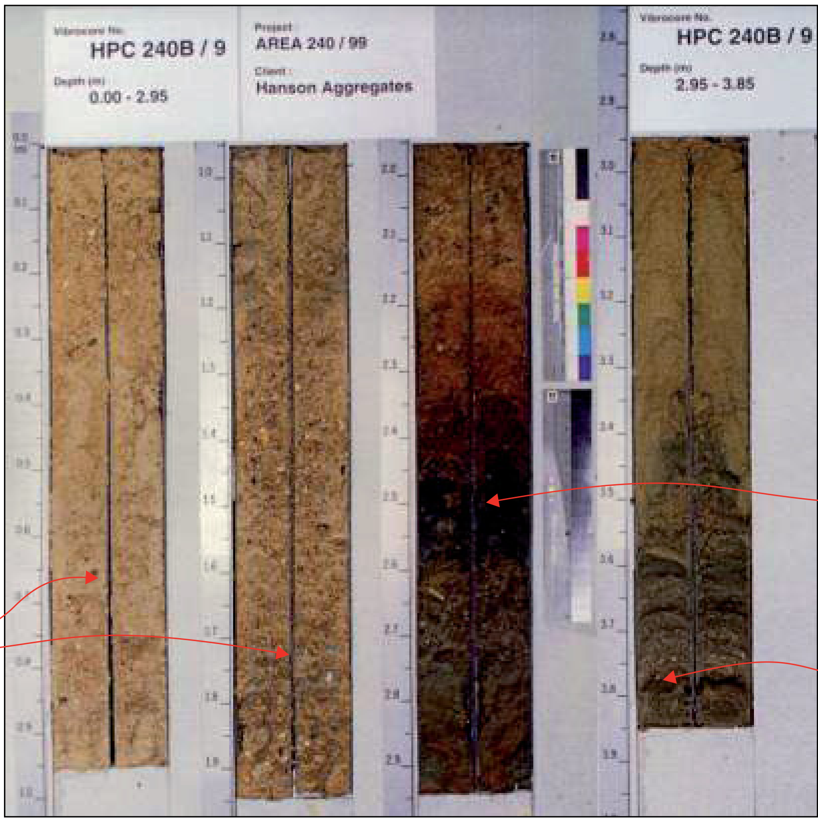

Plate 12: WA_VC024

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