Queen Elizabeth Class Capital Dredge Project

Palaeoenvironmental Assessment

Ref: 111321.01
January 2020

wessexarchaeology

Document Information

Document title	Queen Elizabeth Class Capital Dredge Project Her Majesty's Naval Base Portsmouth
Document subtitle	Palaeoenvironmental Assessment
Document reference	111321.01
Client name	Boskalis Westminster Limited
Address	Westminster House Crompton Way Sagensworth West Fareham PO15 5SS
On behalf of	Defence Infrastructure Organisation
Site location	Portsmouth Harbour
County	Hampshire
Museum name	Portsmouth Museum
Project management by	Danielle Wilkinson
Document compiled by	Alex Brown
Contributions from	Inés López-Dóriga, Nigel Cameron, John Whittaker
Graphics by	Joanna Debska

Quality Assurance

Issue and date		Status	Author	Approved by
1	20/12/2019	External Draft	ADB	DJW
2	15/01/2020	Revised following comments from RHDHV, DIO and BWL	ADB	DJW

Contents

List of Figures

List of Tables

Summary

Wessex Archaeology (WA) was commissioned by Boskalis Westminster Limited (BWL), the dredging contractor, on behalf of the Defence Infrastructure Organisation (DIO), to undertake a Stage 3 palaeoenvironmental assessment of deposit recovered in vibrocores (DT-010, DT-026 and DT-029), as part of the Queen Elizabeth Class (QEC) Capital Dredge Project at Her Majesty's Naval Base (HMNB) Portsmouth.

In addition, three borehole logs have been made available from the 2017 Ground Investigation program (ESG 2017) and are used to update the existing Site deposit model (WA 2016). The additional three boreholes contain a mixture of sand, silt, clay and gravel and contain no deposits of geoarchaeological potential.

Targeted palaeoenvironmental assessment (plant macrofossils, pollen, diatoms, foraminifera and ostracods, supported by radiocarbon dating) was only recommended on those vibrocores containing organic horizons and the immediately overlying and underlying alluvial sediments. These sediments have the highest geoarchaeological potential in terms of suitable deposits for dating and likelihood of containing the widest range of well-preserved palaeoenvironmental indicators.

Radiocarbon dating has demonstrated that the peat deposits in vibrocores DT-010, DT-026 and DT-029 are all late Mesolithic in date. These are amongst the first dated peat deposits from Portsmouth Harbour and add to our understanding of coastal development along the south coast under the influence of rising sea-levels.

The peat deposit in vibrocore DT-010 (6470–7040 cal. BC) is broadly comparable in date to the peat located c. 500m to the south in vibrocore DT-026 (6390–7030 cal. BC). The single date from the top of the peat in vibrocore DT-029 (6590-6900 cal. BC) suggests the peat at this location may have ceased forming slightly earlier than to the north around DT-026

Pollen preservation and concentrations were variable across vibrocores DT-010, DT-026 and DT-029, with full assessment counts achieved on 3 out of 6 samples from DT-010, all three samples from DT-026 and 5 out of 6 samples from DT-029. Diatoms, foraminifera and ostracods were largely absent from samples below the peats with the best results achieved from the two samples overlying the peat in DT-010.

Pollen in the peat includes a tall herb swamp and willow carr that gave way to a wetland woodland dominated by oak and hazel. There are indications of remnant local pine populations within the wider landscape, a picture indicated in earlier pollen work in the 1940s by Godwin, and in pollen studies from nearby Langstone Harbour. There is little evidence for human activity in the peat.

Sea-level rise eventually resulted in the cessation of peat formation and the development of intertidal mudflats and saltmarsh accumulating under rising sea-levels.

No further work is recommended on boreholes DT-010, DT-026, DT-029 due to the poor preservation/absence of diatoms, foraminifera and ostracods, the variable preservation of pollen, and the absence of evidence for human activity in the palaeoenvironmental record.

Acknowledgements

This work was commissioned by Boskalis Westminster Limited on behalf of the Defence Infrastructure Organisation, and their assistance during the project is acknowledge.

The report was compiled by Dr Alex Brown, with contributions from Nicki Mulhall (processing plant macrofossils), Dr Inés López-Dóriga (plant macrofossils and submission of radiocarbon dates), Dr Nigel Cameron (diatoms) and Dr John Whittaker (foraminifera/ostracods). Illustrations were by Joanna Debska. Quality control was provided by Andrew Shaw as well as by Danielle Wilkinson who managed the project on behalf of Wessex Archaeology.

Queen Elizabeth Class Capital Dredge Project
Her Majesty's Naval Base Portsmouth

Palaeoenvironmental Assessment

1 INTRODUCTION

1.1 Project background

1.1.1 Wessex Archaeology (WA) was commissioned by Boskalis Westminster Limited (BWL), the dredging contractor, on behalf of the Defence Infrastructure Organisation (DIO), to undertake a Stage 3 palaeoenvironmental assessment of deposits recovered in vibrocores (DT-010, DT-026 and DT-029), as part of the Queen Elizabeth Class (QEC) Capital Dredge Project at Her Majesty's Naval Base (HMNB) Portsmouth.

1.1.2 In addition, three borehole logs have been made available from the 2017 Ground Investigation program (ESG 2017) and are used to update the existing Site deposit model (WA 2016).

1.1.3 The project comprised capital dredging of areas within Her Majesty's Naval Base (HMNB) Portsmouth, Hampshire (**Figures 1** and **2**), in order to allow access for QEC aircraft carriers.

1.1.4 The work involved deepening the main Harbour approach channel and Harbour entrance to 10.8 m below Chart Datum (CD). As a result, the inner harbour channel was dredged to a depth of 11.0 m below CD and the berthing pocket to 13.8 m below CD.

1.1.5 The geoarchaeological works were undertaken in line with the archaeological Written Scheme of Investigation (WSI) (WA 2015a).

1.1.6 This report details the results of the palaeoenvironmental assessment and updated deposit modelling, which follow on from previous phases involving geoarchaeological review of geotechnical logs, geoarchaeological recording and deposit modelling (detailed below in Section 1.2).

1.2 Sample location

Palaeoenvironmental sequences

1.2.1 The dredging zone of the QEC Capital Dredge Project was divided into five areas (Areas A–E). The three vibrocores subjected to palaeoenvironmental assessment (DT-010, DT-026 and DT-029) are all located within Area D, situated within Portsmouth Harbour adjacent to HMNB Portsmouth (**Figures 1 and 2**).

1.2.2 Vibrocore DT-010 is the most northerly of the three sequences, located approximately 500m north of vibrocore DT-026, with vibrocore DT-029 located a further 125m to the south of DT-026.

Additional borehole logs

1.2.3 Three additional borehole logs (BH01–BH03) have been supplied to update the existing Site deposit model. These boreholes are located just outside the limits of the dredge zone adjacent to the mouth of the North Camber (**Figure 2**).

1.3 Summary of previous geoarchaeological work

1.3.1 Geoarchaeological works in support of the Capital Dredge Project have been ongoing since 2015 (**Table 1**). Works have included an initial review of a series of geotechnical logs recovered during two programs of geotechnical investigations within Portsmouth Harbour and its approach channel (WA 2015b). This review revealed a complex sequence of sediments including a series of Holocene intertidal clays and peats overlain by post transgression sands and gravels.

1.3.2 The initial review of geotechnical logs was followed by a geoarchaeological description of 19 vibrocores accompanied by deposit modelling, distributed across four areas (Areas A – D) (WA 2016).The northmost of these areas (Area D) included a variable sequence of marine sands and gravels overlying alluvium and peat deposits, including those deposits in vibrocores DT-010, DT-026 and DT-029 which form the basis of the current report.

1.3.3 Targeted palaeoenvironmental assessment was only recommended on those vibrocores containing organic horizons and the immediately overlying and underlying alluvial sediments. These sediments have the highest geoarchaeological potential in terms of suitable deposits for dating and likelihood of contain the widest range of well-preserved palaeoenvironmental indicators.

Table 1 Previous geoarchaeological works in support of the Capital Dredge Project

Report type	Title	Report no.	Data assessed	Reference
Stage 1	Geoarchaeological review of geotechnical logs and preliminary recording of geotechnical samples	111320.02	27 boreholes with rapid assessment of a further 176 vibrocore logs	WA 2015b
Stage 2	Geoarchaeological borehole recording and deposit modelling	111320.03	19 selected vibrocores	WA 2016

1.4 Scope of work

1.4.1 To help frame geoarchaeological investigations of this nature, WA has developed a five-stage approach, encompassing different levels of investigation appropriate to the results obtained, accompanied by formal reporting of the results. The stages are summarised below in **Table 2**.

1.4.2 This report outlines the results of the Stage 3 palaeoenvironmental assessment, as detailed in **Table 2**, with recommendations made for further geoarchaeological works if deemed necessary.

Table 2 Staged approach to geoarchaeological investigations

Stage	Description
Stage 1: Geoarchaeological review	Desk-based review of geotechnical and geological data. Establish likely presence / absence / distribution of archaeologically relevant deposits. Identify deposits or samples for Stage 2 works.
Stage 2: Geoarchaeological recording/monitoring	Target deposits or samples identified in Stage 1. Describe the sequences recovered and undertake deposit modelling (if suitable). Interpret depositional environment (if possible). Identify if suitable deposits are present for Stage 3 works.

Stage	Description
Stage 3: Palaeoenvironmental assessment	Sub-sample deposits of archaeological interest for paleoenvironmental assessment (e.g. pollen, plant macrofossils, foraminifera, ostracod and diatoms) and associated scientific dating. Provide an outline interpretation of the archaeological and palaeoenvironmental context. Any recommendations for Stage 4 works will depend on the potential for further analysis and the project research objectives.
Stage 4: Palaeoenvironmental analysis	Full analysis of samples and additional scientific dating as specified in Stage 3, together with a detailed synthesis of the results, in their local, regional or wider archaeological and palaeoenvironmental context. Publication would usually follow from a Stage 4 report.
Stage 5: Publication	Publication of the results of Stage 1-4 works for submission in a peer reviewed journal, book or monograph, depending on the archaeological significance of the work. The scope and location of the final publication will be agreed in consultation with the client and regulatory bodies where appropriate.

2 AIMS AND OBJECTIVES

2.1.1 The principal aim of the Stage 3 palaeoenvironmental assessment is to:

- Determine the nature, depositional history and age of accumulated deposits;
- Determine the level of preservation and concentration of palaeoenvironmental remains (pollen, plant macrofossils, diatoms, foraminifera and ostracods) within the deposits;
- Interpret the results to inform reconstructions of past environment and landscape change;
- Assess archaeological and geoarchaeological potential of deposits.

3 GEOARCHAEOLOGICAL BACKGROUND

Solid Geology

3.1.1 The underlying solid geology consists of a series of Ecocene deposits (56-33.9 mya). Within the inner Portsmouth Harbour area units of London Clay Formation are present, with deposits of the Bracklesham Group within the middle of the study area and Barton Group to the south.

Superficial geology

3.1.2 The bedrock is overlain by Pleistocene and early Holocene fluvial sediments relating to the courses of the Palaeo-Wallington and Palaeo-Solent. Previous interpretations of geophysical data by WA and Maritime Archaeology Limited (MAL), including sub-bottom profiler (SBP) data, undertaken within the study area, have identified a series of buried palaeochannels associated within these river systems (WA 2004; MAL 2007).

3.1.3 These fluvial sediments will have been deposited during periods when sea-levels would have been significantly lower. During such periods the study area would have been terrestrial, dissected by a series of palaeochannels, forming an attractive landscape for past hominin communities.

3.1.4 The Pleistocene deposits in Portsmouth Harbour form part of extensive quaternary sediments extending across the Hampshire and Sussex Coastal Plain, including the internationally significant middle Palaeolithic sites at Boxgrove, dating to 500,000 years ago (Roberts and Parfitt 1999).

3.1.5 The deposits found overlying the Pleistocene fluvial sequence reflect the complex process of marine inundation subsequent to the end of last (Devensian) glaciation (post 11,700 years ago). These deposits include Holocene estuarine alluvium, with interbedded peat deposits representing periods of falling or stable sea-levels. These Holocene deposits are now present sub-tidally as a consequence of continued Holocene sea-level rise.

4 METHODOLOGY

4.1 Stage 3 assessment

4.1.1 Three vibrocores (DT-010, DT-026 and DT-029) were subject to Stage 3 palaeoenvironmental assessment. The assessed deposits comprise peat and alluvial silty clays (**Appendix 2**).

4.1.2 The palaeoenvironmental assessment was accompanied by an updated deposit model, taking account of three additional borehole logs added from the 2017 Ground Investigation program (ESG 2017).

4.1.3 Full analytical methods for each palaeoenvironmental and dating technique are described below. All sub-sample depths are quoted as either metres below sea floor (mbsf) or metres below ground level (mbgl). A full list of sub-samples is presented in **Appendix 1,** with the accompanying borehole logs provided in **Appendix 2**.

4.2 Deposit modelling

4.2.1 A total of 179 data points were used in the creation of the updated seabed Digital Elevation Model (DEM) for the Site (**Figures 1** and **2**). 176 vibrocores were taken from the previous 2016 deposit model (WA 2016) with three additional boreholes (BH01, BH02 and BH03) added from the 2017 Ground Investigation (ESG 2017).

4.2.2 The deposit records from the geotechnical logs were entered into industry standard software (Rockworks™ v17.0). The Rockworks data was then exported into and visualised using ArcGIS c.10.2.

4.2.3 Based on geoarchaeological interpretation of the lithological data, a set of stratigraphic units were created to group key sets of deposits across the Site. The results are used to update the existing DEM and a transect covering the three boreholes (**Figures 1** and **3**).

4.3 Plant macrofossils

4.3.1 Eight sub-samples were processed for the assessment of plant macrofossils in order to recover suitable material for radiocarbon dating, comprising four samples from DT-010, two from DT-026 and two from DT-029. The sub-samples were processed by standard methods for the recovery of waterlogged plant remains; the flots were retained on a 0.25 mm mesh. Flots were stored in sealed containers with water. The flots were scanned under a x10 – x40 stereo-binocular microscope and the preservation and nature of the plant remains recorded in **Table 3**. The presence of other macrofossils (e.g. invertebrates) was also noted. Nomenclature follows Stace (1997).

4.4 Radiocarbon dating

4.4.1 Suitable samples for radiocarbon dating were selected from each of the macrofossil sub-samples (**Table 4, Appendix 3**). Short-lived terrestrial plant macrofossils were selected when available; short-lived aquatics or the humic fraction of the residue from wet-sieving were submitted when no terrestrial macrofossils were present in sufficient quantities for measurement. The material was identified under microscope, stored in glass tubes, and sent to the ^{14}CHRONO Centre at Queens University Belfast for dating. The measurements have been corrected using the δC^{13} values measured by the IRMS. Calibrated age ranges were calculated with OxCal 4.3 (Bronk-Ramsey and Lee 2013) using the IntCal13 curve (Reimer *et al.* 2013). All radiocarbon dates are quoted as uncalibrated years before present (BP), followed by the lab code, the calibrated date-range (cal. BC) at the 2σ (95.4%) confidence and modelled dates in italics.

4.5 Pollen and Spores

4.5.1 Fifteen sub-samples of 1 ml volume were processed using standard pollen extraction methods (Moore *et al.* 1991), comprising six sub-samples from borehole DT-010, three from borehole DT-026 and six from borehole DT-029. Pollen was identified and counted using a Nikon eclipse E400 biological research microscope. A total of 150 pollen grains were counted for each sub-sample in addition to aquatics, fern spores and algal Pediastrum. Where 150 counts were not possible, all pollen and spores were counted from four transects. One *Lycopodium* tablet was added to enable calculation of pollen concentrations. Pollen and spores were identified to the lowest possible taxonomic level. Plant nomenclature followed Stace (1997) and Bennett et al. (1994). Pollen sums are based on total land pollen (TLP) excluding aquatics and fern spores which are calculated as a percentage of TLP plus the sum of the component taxa within the respective category. Identification of indeterminable grains was according to Cushing (1967).

4.5.2 At assessment stage the results are not presented as pollen diagrams but are presented in tabular form as raw data (**Table 5–7**). Plant taxa are assigned to one of the following groups (trees and shrubs, dwarf shrubs, cultivated, herbaceous open / undefined, fern spores and aquatics) based on their most likely ecological affinity, although many plant taxa occur in a range of environmental niches (see Stace 1997 for specific plant taxa).

4.6 Diatoms

4.6.1 Eleven sub-samples were prepared for diatom assessment, comprising six from borehole DT-010, four from borehole DT-026 and one from borehole DT-029, summarised in **Table 8.**

4.6.2 Diatom preparation followed standard techniques (Battarbee *et al.* 2001). Two coverslips were made from each sample and fixed in Naphrax for diatom microscopy. A large area of the coverslips on each slide was scanned for diatoms at magnifications of x400 and x1000 under phase contrast illumination.

4.6.3 Diatom floras and taxonomic publications were consulted to assist with diatom identification; these include Hendey (1964), Werff and Huls (1957-1974), Hartley *et al.* (1996), Krammer and Lange-Bertalot (1986-1991) and Witkowski *et al.* (2000). Diatom species' salinity preferences are indicated using the halobian groups of Hustedt (1953; 1957), these salinity groups are summarised as follows:

1. Polyhalobian: >30g l^{-1}
2. Mesohalobian: 0.2-30g l^{-1}
3. Oligohalobian - Halophilous: optimum in slightly brackish water
4. Oligohalobian - Indifferent: optimum in freshwater but tolerant of slightly brackish water
5. Halophobous: exclusively freshwater
6. Unknown: taxa of unknown salinity preference

4.7 Foraminifera and Ostracods

4.7.1 Eleven sub-samples were prepared for foraminifera and ostracod assessment, comprising six from borehole DT-010, four from borehole DT-026 and one from borehole DT-029 (**Table 9–11**).

4.7.2 The sub-samples were weighed, then broken into small pieces by hand, placed into ceramic bowls, and dried in an oven. Boiling-hot water was then poured over them with a little sodium carbonate added to help disaggregate the clay fraction. Each was left to soak overnight. It was found that breakdown was aided, especially with the organic-rich samples, by re-heating the still soaking samples in the oven for several hours before attempting to wash them. The peats, however, needed processing twice and even then, breakdown was not entirely satisfactory.

4.7.3 Sub-samples were then washed through a 75 µm sieve with the remaining residue returned to the ceramic bowl for final drying in the oven. The residues were then stored in labelled plastic bags. For examination, each sample was placed in a nest of sieves (>50, >250, >150 µm, and base pan) and thoroughly shaken. Each grade was then sprinkled onto a picking tray, a little at a time, and viewed under a binocular microscope.

4.7.4 The abundance of each foraminiferal and ostracod species was estimated semi-quantitatively (one specimen, several specimens, common and abundant/superabundant) by experience and by eye. Species identification comes from Murray (2006) for the foraminifera, Athersuch et al (1989) for the brackish and marine ostracods, and Meisch (2000) for the freshwater ostracods, in addition to expert judgement.

5 RESULTS

5.1 Updated deposit model

5.1.1 The total depth of the 179 data points ranged considerably across the Site. The 2016 vibrocores varied in depth between 0.10m (VCDT100, Zone A) and 6.00m (VCDT123, Zone A) and the additional 2017 boreholes ranged in depth between 28.50m (BH02, east of Zone E) and 31.00m (BH03, east of Zone E).

5.1.2 Overall data point distribution across the Site was good (**Figure 1**). The location of the additional 2017 boreholes and position of transect 1 are shown on **Figure 2**, and a sub-surface cross-section (transect 1) through the additional boreholes is shown on **Figure 3**.

Updated seabed DEM

5.1.3 The updated elevation model (**Figure 1**) shows the upper surface of the seabed undulating between 0.67m CD (VCDT064, west of Zone A) and 16.80m CD (VCDT048, Zone B) across the Site; corresponding well with the previous 2016 seabed DEM (WA 2016).

5.1.4 The position of the additional boreholes in relation to the Site is shown on the enhanced location plan (**Figure 2**); approximately <25.0m landward of the site boundary, immediately east of Dredge Zone E.

5.1.5 Within the additional boreholes, the recorded elevation for the upper surface of the seabed ranges between 7.99m CD (BH03) and 9.93m CD (BH01), corresponding well with nearby vibrocores (approximately >80.00m to the west) from the original 2016 deposit model; 10.71m CD (VCDT027), 11.20m CD (VCDT022) and 11.70m CD (VCDT030A) (**Figure 2**).

Additional boreholes

5.1.6 A sub-surface cross-section (transect 1) through the additional boreholes is shown on **Figure 3**.

5.1.7 The sediments encountered consist largely of combinations of sand, silt, clay and gravel, typical of a shallow marine environment and in keeping with sediments previously modelled for the area (WA 2016).

5.1.8 No organic rich sediments or peat deposits were recorded within the additional boreholes.

5.2 Plant macrofossils

5.2.1 The flots from the sub-samples were rich in plant macrofossils, but these were dominated by degraded vegetative plant parts (stems, wood, etc), not taxonomically identifiable. Occasional insect remains were present in a few of the samples in DT-010 and DT-026 and mycorrhizal fungi sclerotia (tp. Cenococcum geophilum) on the sample from the top of the peat in DT-029. Generally well-preserved seeds and fruits from a range of both terrestrial and aquatic taxa were found in the samples, including hazel (*Corylus avellana*), hawthorn (*Crataegus monogyna*), persicaria (*Persicaria* sp.), branched bur-reed (*Sparganium erectum*), water plantain (*Alisma* sp.), sedges (Cyperaceae), umbellifers (Apiaceae), sloe/cherry (cf. *Prunus* sp.), dogwood (Cornus sanginea), dog mercury (*Mercurialis* sp.), crowfoot (*Ranunculus* tp. *aquatilis/hederaceus*), birch (*Betula* sp.) and other remains from indeterminate taxa.

Table 3 Results of plant macrofossil assessment

Sample Depth	Bulk volume (ml)	Net volume (ml)	Waterlogged plant remains		Invertebrates	
			Vegetative plant parts	Other	Insects	Molluscs + Crustaceans
Vibrocore DT-010						
2.63-2.65	70	12	A***	A - *Corylus avellana, Crataegus monogyna, Persicaria* sp., *Sparganium erectum, Alisma* sp., Cyperaceae, Apiaceae, cf. *Prunus* sp., indet buds and seed	-	-
2.76-2.78	80	18	A***	B - Indet buds, *Cornus sanginea*	-	-

Sample Depth	Bulk volume (ml)	Net volume (ml)	Waterlogged plant remains		Invertebrates	
			Vegetative plant parts	Other	Insects	Molluscs + Crustaceans
3.15-3.17	70	5	A**	-	-	-
3.23-3.25	80	20	A***	B - *Corylus avellana, Cornus sanguinea*	C	-
Vibrocore DT-026						
1.77-1.79	70	5	A***	B - *Sparganium erectum, Persicaria* sp., indet	C	-
1.97-1.99	75	4	A***	-	C	-
Vibrocore DT-029						
2.45-2.47	80	10	A*** - Inc. mycorrhizal fungi sclerotia	C - *Mercurialis* sp.	-	-
2.85-2.87	85	13	A***	A - *Persicaria* sp., *Ranunculus* tp. *aquatilis/hederaceus*, Cyperaceae, *Betula* sp., indets	-	-

5.3 Radiocarbon dating

5.3.1 Seven of the eight samples submitted for radiocarbon dating were successfully measured, four from vibrocore DT-010, two from DT-026 and one from DT-029. The results of radiocarbon dating are synthesised below in **Table 4** with the full laboratory report on the results provided as **Appendix 3**.

Vibrocore DT-010

5.3.2 The four samples covering the peat in vibrocore DT-010 all date to the late Mesolithic, extending from 6640–6470 cal. BC (UBA-41798) to 7040–6680 cal. BC (UBA-41801), representing between 570 and perhaps as little as 40 years of peat accumulation. The dates are derived on both terrestrial plant macrofossils (UBA-41798 and UBA-41801), with a single sample derived from bulk sediment (UBA-41800), introducing a small uncertainty in that result. Still, the sequence of radiocarbon dates display a strong linear progression, suggesting potential old or intrusive carbon effect in sample UBA-41800 is probably negligible.

Vibrocore DT-026

5.3.3 The two samples from the peat in vibrocore DT-026 (UBA-41802 and UBA-41803) both date to the late Mesolithic. The top sample (UBA-41802) dated a *Sparganium erectum* (emergent-aquatic) seed (6500–6390 cal. BC), whilst the basal date (UBA-41803) was derived from a sample of bulk sediment, producing a date of 7030–6640 cal. BC. Although there is a slight uncertainty in the results due to the nature of the samples, together the results are internally consistent and broadly similar in date range to vibrocore DT-010, representing between 640 and 140 years of peat growth. Given only two dates are available for this sequence, it is not possible to establish whether there is uniform or discontinuous peat deposition.

Vibrocore DT-029

5.3.4 Two samples were submitted for dating, but one (UBA-41805) from the base of the peat failed due to insufficient carbon. The sample from the top of the peat produced a date of 6900–6590 cal. BC and was derived on bulk sediment, in the absence of short-lived terrestrial plant macrofossils. The single result nonetheless suggests that the peat is of a late Mesolithic date though potentially (with a slight uncertainty associated to the type of sample) ceased forming earlier than the peat in vibrocores DT-010 and DT-026.

Table 4 Results of AMS radiocarbon dating

Laboratory No.	Material dated	Depth (mbsf)	Age BP	Calibrated age range cal. BC (2δ: 95.4%)
Vibrocore DT-010				
UBA-41798	*Corylus avellana* nutshell	2.63-2.65	7719±40	6640-6470
UBA-41799	*Cornus sanguinea* stone	2.76-2.78	7655±38	6590-6440
UBA-41800	Bulk sediment (humic fraction)	3.15-3.17	7866±46	7020-6600
UBA-41801	*Corylus avellana* nutshell	3.23-3.25	7934±46	7040-6680
Vibrocore DT-026				
UBA-41802	*Sparganium erectum* seed	1.77-1.79	7589±41	6500-6390
UBA-41803	Bulk sediment (humic fraction)	1.97-1.99	7887±44	7030-6640
Vibrocore DT-029				
UBA-41804	Bulk sediment (humic fraction)	2.45-2.47	7847±41	6900-6590
UBA-41805		2.85-2.87	Failed	

5.4 Pollen and Spores

5.4.1 The results of pollen assessment are presented in **Tables 5–7**, detailing preservation and concentration of pollen grains accompanied by an outline of the range of taxa recorded. In total fifteen samples were assessed, six from both vibrocores DT-010 and DT-029, with three from vibrocore DT-026.

Vibrocore DT-010 (Table 5)

5.4.2 Pollen concentration and preservation were found to vary considerably from excellent through to poor in samples from vibrocore DT-010; excellent at 2.62mbsf, with moderate-poor concentration and preservation at 2.69, 3.22 and 3.25mbsf and good pollen concentrations at 2.69 and 278mbsf.

5.4.3 Full assessment counts of 150 land pollen grains was only possible in three of the six samples (2.62, 2.78 and 3.19mbsf).

5.4.4 Samples at 2.62, 2.78 and 3.19mbsf are dominated by arboreal pollen, principally *Corylus avellana* type (hazel) and *Quercus* (oak). Small quantities of other arboreal taxa were recorded, including *Pinus sylvestris* (pine), *Salix* (willow), *Ulmus* (elm), *Alnus glutinosa* (alder) and *Tilia* (lime). Occasional pollen grains of *Hedera helix* (ivy) were also recorded.

5.4.5 Non arboreal pollen taxa occur in very small quantities, mostly comprising Poaceae (grass family) and single records of a range of several other herbaceous tax, including Ranunculaceae (buttercup family), *Filipendula* (meadowsweet) and Lamiaceae (mint family). Occasional aquatic pollen grains were recorded, mostly at 2.62mbsf and including *Sparganium emersum*-type (unbranched bur-reed) and *Typha latifolia* (bulrush). Occasional fern spores were also recorded.

Table 5 Results of pollen assessment, vibrocore DT-010

Depth (mbsf)	**2.62**	**2.69**	**2.78**	**3.19**	**3.22**	**3.25**
Betula (birch)	2	1	1	1	-	2
Pinus sylvestris (pine)	2	6	12	16	1	-
Corylus avellana type (hazel)	70	11	42	60	3	27
Ulmus (elm)	3	2	7	4	-	1
Quercus (oak)	50	17	74	55	3	5
Tilia (lime)	1	-	2	-	-	-
Alnus glutinosa (alder)	2	-	2	2	-	-
Fraxinus excelsior (ash)	1	-	-	-	-	-
Salix (willow)	4	3	4	9	2	1
Sambucus nigra (elder)	-	1	-	-	-	-
Hedera helix (ivy)	2	-	1	-	-	-
Poaceae (grass family)	9	-	3	-	-	-
Cyperaceae (sedge family)	-	-	1	2	-	-
Chenopodiaceae (goosefoot family)	-	-	1	-	-	-
Ranunuculaceae (buttercup family)	1	-	-	-	-	-
Rosaceae (rose family)	-	-	1	-	-	-
Filipendula (meadowsweet)	1	1	-	-	-	-
Lamiaceae (mint family)	1	-	-	-	-	-
Rubiaceae (bedstraw family)	-	-	-	1	-	-
Lactuceae (lettuce family)	-	-	1	-	-	-
Aster type (daisies)	1	-	-	-	-	-
Pteropsida undiff. (undifferentiated fern spore)	3	2	-	9	-	-
Pteridium aquilinum (bracken)	2	3	3	1	-	-
Polypodium vulgare (common polypody)	1	1	2	4	-	-
Potamogeton natans type (pondweed)	2	-	-	-	-	-
Sparganium emersum type (unbranched bur-reed)	5	-	-	-	-	-
Typha latifolia (bulrush)	2	-	-	1	-	-
Nuphar (water-lily)	1	-	1	-	-	-
Indeterminables	10	13	24	32	4	0
Exotic (*Lycopodium* spores)	31	11	74	118	11	12
TLP	**150**	**42**	**152**	**150**	**9**	**36**
Pollen concentration	**1**	**3**	**2**	**2**	**4**	**4**
Pollen preservation	**1**	**4**	**3**	**3**	**3-4**	**3**

Pollen concentration/preservation: 1 = Excellent, 2 = Good, 3 = Moderate, 4 = Poor, 5 = Very Poor/absent

Vibrocore DT-026 (Table 6)

5.4.6 Pollen concentrations in the three samples from vibrocore DT-026 were excellent-good, with generally good preservation apart from1.97mbsf where preservation was moderate. Full assessment counts were achieved for all three samples.

Table 6 Results of pollen assessment, vibrocore DT-026

Depth (mbsf)	**1.82**	**1.90**	**1.97**
Betula (birch)	3	5	6
Pinus sylvestris (pine)	2	10	8
Corylus avellana type (hazel)	32	45	53
Ulmus (elm)	3	1	9
Quercus (oak)	62	47	40
Alnus glutinosa (alder)	2	3	6
Acer (maple)	1	-	-
Salix (willow)	3	4	1
Rosa (roses)	-	-	1
Hedera helix (ivy)	1	-	-
Poaceae (grass family)	25	25	22
Cyperaceae (sedge family)	11	6	4
Chenopodiaceae (goosefoot family)	1	3	1
Rosaceae (rose family)	2	1	-
Filipendula (meadowsweet)	1	-	1
Trifolium type (clover)	-	-	1
Aster type (daisies)	1	-	2
Pteropsida undiff. (undifferentiated fern spore)	1	6	4
Pteridium aquilinum (bracken)	-	2	2
Polypodium vulgare (common polypody)	-	3	5
Potamogeton natans type (pondweed)	1	-	-
Sparganium emersum type (unbranched bur-reed)	2	-	-
Indeterminables	16	8	35
Exotic (*Lycopodium* spores)	29	56	41
TLP	**150**	**150**	**155**
Pollen concentration	**1**	**2**	**2**
Pollen preservation	**2**	**2**	**3**

Pollen concentration/preservation: 1 = Excellent, 2 = Good, 3 = Moderate, 4 = Poor, 5 = Very Poor/absent

5.4.7 The samples are dominated by pollen of arboreal species, with roughly equal quantities of *Quercus* and *Corylus avellana*-type at 1.97 and 1.90mbsf but with increasing quantities of *Quercus* at 1.82mbsf. Other tree taxa are represented by small quantities of pollen grains of *Pinus sylvestris*, *Betula*, *Ulmus*, *Alnus glutinosa*, *Salix* and a single grain (1.82mbsf) of *Acer* (maple).

5.4.8 Herbaceous taxa contribute between 20% (1.97mbsf) and 27% (1.82mbsf) of the pollen assemblage, primarily Poaceae along with lesser quantities of Cyperaceae (sedge family) and occasional grains of Chenopodiaceae (goosefoot family) and a few other herb taxa.

5.4.9 Aquatic pollen was only recorded in small quantities in the sample from 1.82mbsf. Occasional fern spores were also recorded, mostly from 1.97 and 1.90mbsf, including

Pteropsida (undifferentiated fern spores), *Pteridium aquilinum* (bracken) and *Polypodium vulgare* (common polypody).

Vibrocore DT-029 (Table 7)

5.4.10 Pollen were present in good concentrations in all samples apart from 2.78mbsf where concentrations were poor, with pollen preservation moderate in four samples (2.47, 2.54, 2.70 and 2,78mbsf), moderate-poor at 2.62mbsf and good at 2.85mbsf. Full assessment counts were possible for five samples, with only one sample at 2.78mbsf producing insufficient pollen.

Table 7 Results of pollen assessment, vibrocore DT-029

Depth (mbsf)	**2.47**	**2.54**	**2.62**	**2.70**	**2.78**	**2.85**
Betula (birch)	1	2	3	-	1	4
Pinus sylvestris (pine)	15	23	25	63	-	2
Corylus avellana type (hazel)	86	75	90	54	3	7
Ulmus (elm)	3	6	6	-	-	1
Quercus (oak)	21	22	11	2	-	-
Salix (willow)	5	4	3	29	-	34
Poaceae (grass family)	-	2	-	-	-	5
Cyperaceae (sedge family)	17	13	9	1	23	87
Chenopodiaceae (goosefoot family)	-	-	1	-	-	-
Ranunuculaceae (buttercup family)	-	-	-	-	-	1
Thalictrum (meadow rue)	-	-	-	-	-	3
Rosaceae (rose family)	-	2	1	-	-	3
Apiaceae (carrot family)	1	1	-	1	-	-
Lamiaceae (mint family)	-	-	-	-	-	1
Rubiaceae (bedstraw family)	-	-	-	-	-	3
Artemisia type (mugwort)	-	-	-	-	-	2
Aster type (daisies)	-	-	1	-	-	-
Pteropsida undiff. (undifferentiated fern spore)	40	31	15	4	2	15
Pteridium aquilinum (bracken)	11	7	-	1	-	-
Potamogeton natans type (pondweed)	-	-	-	-	-	1
Sparganium emersum type (unbranched bur-reed)	-	-	-	1	-	1
Indeterminables	54	25	65	13	17	17
Exotic (*Lycopodium* spores)	52	73	22	13	15	51
TLP	**149**	**150**	**150**	**150**	**27**	**153**
Pollen concentration	**2**	**2**	**2**	**2**	**4**	**2**
Pollen preservation	**3**	**3**	**3-4**	**3**	**3**	**2**

Pollen concentration/preservation: 1 = Excellent, 2 = Good, 3 = Moderate, 4 = Poor, 5 = Very Poor/absent

5.4.11 The basal peat sample at 2.85mbsf is characterised by large quantities of pollen of Cyperaceae along with *Salix*, with only small quantities of other arboreal and herbaceous taxa. Insufficient pollen is present in the sample from 2.78mbsf, but subsequent samples through the peat show a decline in Cyperaceae and *Salix* and an increase in pollen of *Corylus avellana*-type, *Pinus sylvestris* (particularly at 2.70mbsf) and *Quercus* (from 2.62mbsf). Smaller quantities of *Betula* and *Ulmus* are recorded.

5.4.12 The diversity and quantity of herbaceous pollen is limited, apart from Cyperaceae, largely comprising occasional grains of Rosaceae and Apiaceae (carrot family) with the greatest diversity in the basal sample (2.85mbsf). Fern spores, particularly of Pteropsida, occur in increasing quantities. Only occasional aquatic pollen of *Sparganium emersum*-type and *Potamogeton natans*-type were recorded (2.85 and 2.70mbsf).

5.5 Diatoms

5.5.1 The key results of the diatom assessment are synthesised below, with the full specialist report provided as **Appendix 4.**

Vibrocore DT-010 (Table 8)

5.5.2 Diatoms are present in the top two samples (2.54 and 2.57mbsf) and absent in the four underlying samples (2.85–3.08mbsf).

Table 8 Results of diatom assessment, vibrocore DT-10

Diatoms / depth (mbsf)	2.54	2.57
Polyhalobous		
Cymatosira belgica	-	1
Grammatophora sp.	-	1
Paralia sulcata	2	2
Podosira stelligera	1	1
Rhabdonema arcuatum	-	cf
Rhaphoneis sp.	-	1
Rhaphoneis surirella	-	1
Polyhalobous to Mesohalobous		
Actinoptychus undulatus	-	1
Diploneis smithii	-	1
Synedra gaillonii	-	1
Mesohalobous		
Caloneis westii	-	1
Cyclotella striata	1	-
Diploneis didyma	-	1
Nitzschia granulata	1	-
Nitzschia navicularis	1	2
Nitzschia sigma	1	-
Scoliopleura tumida	1	-
Halophilous to Oligohalobous Indifferent		
Epithemia turgida	3	1
Rhoicosphaenia curvata	3	-

Diatoms / depth (mbsf)	2.54	2.57
Oligohalobous Indifferent		
Amphora libyca	1	1
Caloneis schumanniana	1	-
Cocconeis placentula	3	1
Epithemia adnata	-	1
Epithemia sp.	1	1
Fragilaria brevistriata	1	-
Fragilaria pinnata	1	-
Gomphonema truncatum	1	-
Gyrosigma acuminatum	1	-
Gyrosigma attenuatum	1	-
Neidium sp.	1	-
Nitzschia dissipata	1	-
Pinnularia viridis	1	-
Synedra ulna	1	1
Unknown Salinity Group		
Cyclotella sp.	-	1
Diploneis sp.	1	-
Fragilaria sp.	1	-
Gomphonema sp.	1	1
Navicula sp.	1	-
Stauroneis sp.	1	-
Unknown Naviculaceae	-	1

5.5.3 In the top sample (2.54mbsf) there are moderately high numbers of diatoms, the quality of diatom preservation varies from poor to moderate with high diatom diversity. In the sample from 2.57mbsf there are low numbers of poorly preserved diatoms, with a moderate species diversity.

5.5.4 Both samples contain a mixture of marine, brackish, halophilous and freshwater diatoms. Amongst marine species, the coastal/marine planktonic diatom *Paralia sulcata* is most commonly recorded in the two samples. Marine-brackish taxa are also present at 2.57mbsf.

These include the planktonic diatom *Actinoptychus undulatus* and the benthic and attached species *Diploneis smithii* and *Synedra gaillonii*.

5.5.5 Mesohalobous, brackish water diatoms are present in both samples; these are mainly benthic taxa and include *Nitzschia navicularis* (common at 2.57mbsf), *Nitzschia granulata, Nitzschia sigma, Scoliopleura tumida, Caloneis westii* and *Diploneis didyma*. The planktonic, mesohalobous diatom *Cyclotella striata* is also present at 2.54mbsf.

5.5.6 Freshwater diatoms, including oligohalobous, and halophilous to oligohalobous indifferent halobian groups, are present, particularly at 2.54mbsf. Halophilous and freshwater diatoms that are epiphytic on aquatic macrophytes were recorded in relatively high numbers at 2.54mbsf and were also present at 2.57mbsf. These epiphytic diatoms include *Epithemia turgida, Rhoicosphaenia curvata* and *Cocconeis placentula* along with *Epithemia adnata* and other *Epithemia* spp. Other non-planktonic, freshwater diatoms include both attached and benthic diatoms such as: *Amphora libyca, Caloneis schumanniana, Fragilaria brevistriata, Fragilaria pinnata, Gomphonema truncatum, Gyrosigma acuminatum, Gyrosigma attenuatum, Nitzschia dissipata, Pinnularia viridis* and *Synedra ulna*.

Vibrocore DT-026

5.5.7 Diatoms are absent from all four samples with only a single indeterminate diatom fragment recorded at 2.02mbsf.

Vibrocore DT-029

5.5.8 Diatoms are absent from the single sample from vibrocore DT-029.

5.6 Foraminifera and Ostracods

5.6.1 The key results of the foraminifera and ostracod assessment are synthesised below, with the full specialist report provided as **Appendix 5**.

Vibrocore DT-010 (Table 9)

5.6.2 The lowest four samples (2.82-3.08m) are near-peats and peaty silts and contain only plant debris and a number of small round organic bodies (algal cysts). The samples at 2.54 and 2.57mbsf contain a mixture of freshwater ostracods, brackish foraminifera and ostracods, and outer estuarine foraminifera; there is also quite a significant freshwater presence overall, including freshwater molluscs.

Table 9 Results of foraminifera and ostracod assessment, vibrocore DT-010

Taxa	Depth (mbsf)	2.54	2.57	2.82	2.91	3.00	3.08
Freshwater Ostracods							
Candona neglecta		xx	xx	-	-	-	-
Cyclocypris laevis/ovum		-	o	-	-	-	-
Brackish Ostracods							
Cyprideis torosa		x	-	-	-	-	-
Brackish Foraminifera							
Ammonia (brackish sp.)		x	x	-	-	-	-
Outer Estuarine/Marine Foraminifera							
Elphidium macellum		x	-	-	-	-	-
Pseudopolymorphina novangliae		o	-	-	-	-	-

Taxa	Depth (mbsf)	2.54	2.57	2.82	2.91	3.00	3.08
Other Contained Material							
Plant debris + seeds		x	x	x	x	x	x
Insect remains		x	x	-	-	-	-
Freshwater molluscs		x	x	-	-	-	-
Bithynia opercula		x	x	-	-	-	-
Cladocera		-	x	-	-	-	-
Algal cysts		-	x	x	x	x	x
Ecology		Estuary with both freshwater and brackish components		Freshwater(?) peat			

Foraminifera and Ostracod: o – one specimen; x –several; xx – common. Other contained material is recorded on a presence (x)/absence basis

Vibrocore DT-026 (Table 10)

5.6.3 Four samples were assessed (1.68-2.08mbsf), but apart from occasional plant debris and insect remains, no foraminifera or ostracods were preserved.

Table 10 Results of foraminifera and ostracod assessment, vibrocore DT-026

Taxa	Depth (mbsf)	1.68m	1.75m	2.02m	2.08m
Contained Material					
Plant debris		x	x	x	x
Insect remains		x	x		

Contained material is recorded on a presence (x)/absence basis

Vibrocore DT-029 (Table 11)

5.6.4 One sample (2.42mbsf) was assessed. It contains a high diversity of brackish and outer estuarine/marine foraminifera and ostracods typical of what might be expected towards the marine end of a large open estuary. There is no freshwater component to the ostracods/foraminifera.

Table 11 Results of foraminifera and ostracod assessment, vibrocore DT-029

Taxa	Depth (mbsf)	2.42
Outer Estuarine/Marine Foraminifera		
Elphidium macellum		xx
Ammonia batavus		xx
Eggerelloides scaber		o
Outer Estuarine/Marine Ostracods		
Heterocythereis albomaculata		xx
Hemicythere villosa		xx
Hirschmannia viridis		x
Loxoconcha rhomboidea		x
Aurila convexa		x
Cythere lutea		x
Bonnyannella robertsoni		x
Pontocypris mytiloides		o
Brackish Ostracods		
Cyprideis torosa		xx

Taxa	Depth (mbsf)	2.42
Loxoconcha elliptica		o
Brackish Foraminifera		
Ammonia(brackish sp.)		xx
Elphidium williamsoni		x
Haynesina germanica		x
Foraminifera (high-mid saltmarsh)		
Trochammina inflata		o
Other Contained Material		
Plant debris		x
Molluscs		x

Foraminifera and Ostracod: o – one specimen; x –several; xx – common. Other contained material is recorded on a presence (x)/absence basis

6 DISCUSSION

6.1 Introduction

6.1.1 The results of the palaeoenvironmental assessment are considered together with reference to the aims and objectives outlined in **Section 2**, the Thames-Solent Archaeological Research Framework (Hey and Hind 2014) and the National Maritime Research Framework (Ransley et al 2014).

6.1.2 Although the results are briefly considered in the wider context of data from the south coast (including Langstone Harbour and Southampton Water), the primary aim of this assessment is to report on the preservation of palaeoenvironmental remains and the potential for further targeted analysis to contribute towards wider research agenda – the latter considered in **Section 7.**

6.1.3 This palaeoenvironmental assessment presents amongst the first radiocarbon dates and palaeoenvironmental work on peat deposits within Portsmouth Harbour. The results, although indicating variable preservation of palaeoenvironmental remains, adds to our understanding of landscape and environmental change within the region during the late Mesolithic at a time when the impact of post-glacial sea-level rise was having a major impact on the physical and vegetation environments of the Britain.

6.2 Updated deposit model: sediments and physical landscape development

6.2.1 The deposit model for the Site has been updated on the basis of three additional boreholes (BH01–BH03) in addition to the previous 176 modelled data points. The sediments in the three boreholes consist largely of sand, silty, clay and gravel. No organic deposits of a high geoarchaeological potential were recorded.

6.2.2 Previous geoarchaeological descriptions of vibrocores and deposit modelling had revealed a complex sequence of deposits within Portsmouth Harbour, comprising a Pleistocene terrestrial landscape dissected by a braided channel system which was infilled and submerged during the Holocene under the influence of rising post-glacial sea-levels. The additional boreholes add to and confirm the established Site-wide deposit model (WA 2016).

6.2.3 Within Area D (including vibrocores DT-010, DT-026 and DT-029) the deposits include basal alluvial deposits. These did not preserve microfaunal evidence and thus it is not possible to determine if these represent saline or freshwater deposits. Nonetheless these sediments would have accumulated under the background influence of rising sea-levels. Subsequent peat formation reflects a regressive sea-level tendency during the late Mesolithic – either stable or falling sea-levels; however, peat can continue accumulate under rising sea-levels where the rate of peat formation exceeds the rate of sea-level rise. However, rising sea-levels resulted eventually in shift to deposition of alluvial silts and clays characteristic of saltmarsh and mudflat habitats, although there is a mix of both estuarine and freshwater influence.

6.2.4 No subsequent peats were recorded in the vibrocores, although it is probable that any later peats would have been removed by later activities associated with the construction and use of Portsmouth Harbour.

6.3 Chronology

6.3.1 Reliable chronologies are a fundamental component of palaeoenvironmental investigations. Terrestrial plant macrofossils are considered the most reliable material for radiocarbon dating (Blaauw et al 2004), but unfortunately identifiable short-lived terrestrial plant macrofossils were not recoverable in all cases (**Table 4**).

6.3.2 However, care was taken to avoid any issues of contamination with old and young carbon. Contamination by young carbon may occur through root penetration, whilst older radiocarbon dates could uptake of dissolved inorganic carbon by aquatic plants (Butz et al 2017).

6.3.3 No evidence for root penetration was apparent in the samples and although the occurrence of a reservoir effect can be difficult to detect, the dates show a strong linear progression and relationship, with little to no evidence in the pollen or plant macrofossils record for aquatic plants. The impact of young and/or old carbon is considered of a very limited impact.

6.3.4 The AMS radiocarbon dates from vibrocores DT-010 (UBA-41798 to 41801), DT-026 (UBA-41802 and 41803) and DT-029 (UBA-41804) all date to the late Mesolithic; a second date from DT-029 unfortunately failed (UBA-41805).

6.3.5 The peat deposit in vibrocore DT-010 (6470–7040 cal. BC) is broadly comparable in date to the peat located c. 500m to the south in vibrocore DT-026 (6390–7030 cal. BC). The single date from the top of the peat in vibrocore DT-029 (6590-6900 cal. BC) suggests the peat at this location may have ceased forming slightly earlier than to the north around DT-026, although some truncation of the peat surface may have taken place given the sharp contact with the overlying marine deposits.

6.3.6 Peat deposits have been identified previously from Portsmouth Harbour, but these are the first available radiocarbon dates on these deposits. Radiocarbon dates available in the coastal and intertidal peat database from Langstone Harbour (c. 4-5km east) include a series of Neolithic and Bronze Age peats around -0.5 to -1mOD, with deeper though undated peats in channels recorded in boreholes to depth of -14mOD (Allen and Gardiner 2000). In the absence of radiocarbon dates it is unclear if the deep peats in Langstone Harbour are contemporary with the peats from Portsmouth Harbour.

6.3.7 These peats are significantly earlier (by c. 1000 years) than late Mesolithic coastal and intertidal peats recorded to the west within Southampton Water (Coastal and Intertidal Peat database). Later peats (Neolithic and Bronze Age) present in Langstone Harbour and Southampton Water are absent from the Site, perhaps removed during earlier dredging associated with Portsmouth Naval base.

6.4 Preservation and concentration of palaeoenvironmental remains

6.4.1 The preservation and concentration of palaeoenvironmental remains (pollen, diatoms, foraminifera and ostracods) is synthesised below in **Table 12** as a guide to the potential of the deposits for further analysis, detailed in **Section 7**.

DT-010

6.4.2 Pollen was largely present in a moderate state of preservation and variable concentrations sufficient to produce assessment counts in three of the six samples (2.62, 2.78 and 3.19mbsf). Diatoms, foraminifera and ostracods were absent in all but the top two of the six samples (2.54 and 2.57mbsf).

DT-026

6.4.3 Pollen preservation and concentrations were generally good and full assessment counts were achieved for all samples, although no diatoms, foraminifera and ostracods were preserved in any of the samples.

DT-029

6.4.4 Despite generally poor pollen preservation, concentrations were good enough to produce full assessment counts in all but one sample (2.78mbsf).

6.4.5 No diatoms were preserved, but a high diversity of foraminifera and ostracods was recorded in the single sample at 2.42mbsf.

Table 12 Preservation and concentration of palaeoenvironmental remains, vibrocores DT-010, DT-026 and DT-029.

	Pollen		**Diatoms**		**Foram/Ostracod**	
Depth (mbsf)	Pres.	Conc.	Pres.	Conc.	Pres.	Conc.
DT-010						
2.54	-	-	mod-poor	mod-good	present	
2.57	-	-	Moderate	poor	present	
2.62	Excellent	Excellent	-	-	-	
2.69	Poor	Moderate	-	-	-	
2.78	Moderate	Good	-	-	-	
2.82	-	-	absent		absent	
2.91	-	-	absent		absent	
3	-	-	absent		absent	
3.08	-	-	absent		absent	
3.19	Moderate	Good	-	-	-	
3.22	Mod-Poor	Poor	-	-	-	
3.25	Moderate	Poor	-	-	-	
DT-026						
1.68	-	-	absent		absent	
1.75	-	-	absent		absent	
1.82	Good	Excellent	-	-	-	
1.9	Good	Good	-	-	-	
1.97	Moderate	Good	-	-	-	

	Pollen		Diatoms		Foram/Ostracod	
2.08			absent		absent	
DT-029						
2.42	-	-	absent		Present	
2.47	Moderate	Good	-	-	-	
2.54	Moderate	Good	-	-	-	
2.62	Mod-Poor	Good	-	-	-	
2.7	Moderate	Good	-	-	-	-
2.78	Moderate	Poor	-	-	-	-
2.85	Poor	Good	-	-	-	-

Note: foraminifera and ostracod recorded on a presence/absence basis

6.5 Palaeoenvironments

6.5.1 The pollen record from the three vibrocores provides a consistent picture of the vegetation environment within Portsmouth Harbour over a defined period (between 6390–7040 cal. BC) within the late Mesolithic.

6.5.2 The peat in vibrocores DT-010, DT-026 and DT-029 are preserved within deeply buried palaeochannels. These channels are likely to initially represent early Holocene pre-inundation freshwater channels feeding into the former Solent River. However, no diatoms, foraminifera or ostracod were preserved in the minerogenic deposits beneath the peats.

6.5.3 The peat deposits were subsequently sealed by minerogenic sediment laid down under the influence of rising post glacial sea-levels, infilling the channels and creating a broader wetland valley, perhaps similar to the development of Langstone Harbour over the Mesolithic, Neolithic and Bronze Age (Allen and Gardiner 2000).

6.5.4 The silt overlying the peat in DT-010 contains a mixture of both marine, brackish and freshwater diatoms, suggesting a freshwater or slightly saline environment that was affected at least periodically by marine inundation. Foraminifera and ostracod preserved above the peat in vibrocore DT-029 are characterised by species typical of the marine end of an open estuary, representing intertidal saltmarsh and mudflat environments accumulating under rising sea-levels.

6.5.5 The absence of diatoms in the other samples is likely to be the result of taphonomic processes (Flower 1993, Ryves *et al.* 2001). Diatom silica dissolution and valve breakage is caused by factors such as extremes of sediment salinity, alkalinity or acidity, the under-saturation of sediment pore water with dissolved silica, cycles of prolonged drying and rehydration, or physical damage to diatom valves from abrasion or wave action.

6.5.6 Both vibrocores DT-010 and DT-026 (covering a similar date-range) contain large quantities of oak and hazel pollen, most probably representing an oak-dominated canopy with hazel growing within the understorey. Other trees including birch, elm and maple are indicated. Hawthorn, sloe/cherry and dogwood were recorded in the plant macrofossils (**Table 3**), indicating their local presence as part of the woodland flora in the wetland. Seeds of branched bur-reed and sedges suggest locally wetter areas within the woodland.

6.5.7 Both oak and hazel can tolerate moderately wet acidic soils, and the local presence of hazel is indicated by the finds of whole hazelnuts in the peat within vibrocore DT-010 (**Section 5.2**). There is little indication in either location for the presence of wet carr-woodland with only very small quantities of alder, birch or willow present. The low quantities of alder are not surprising as it occurs in only small quantities in Britain before around c. 7500 cal. BC (Brewer et al 2017).

6.5.8 Vibrocore DT-029 differs slightly to DT-010 and DT-026. A mix of sedge-fen and willow-dominated carr-woodland (likely with a sedge understorey component) characterise the base of the peat, suggesting wetter conditions to the south around this location. Occasional pollen grains of pondweed and unbranched bur-reed may indicate localised boggy pools within the wetland, or the presence of nearby slow-moving streams.

6.5.9 Willow carr and sedge are followed by an increase in pine, hazel and oak (**Table 7**). The sample at 2.70mbsf contains a large quantity of pine pollen (42%) suggesting a local population of pine. Pine is frequently over-represented in the pollen rain as a result of the profuse production and dispersal of pollen and is only considered to be growing locally where pollen sequences exceed 20% of total land pollen (Bennett 1984). Pine decreases through the peat to similar levels recorded in DT-010 and DT-029. Although the base of the peat is undated in DT-029, the higher values of pine could indicate that the peat at this location is an earlier date than DT-010 and DT-026.

6.5.10 There is little evidence in the cores for human impact, either in the presence of microscopic charcoal or impacts on the woodland flora.

Other relevant pollen studies – wider context

6.5.11 Pollen analyses have previously been undertaken on peat deposits within Portsmouth Harbour (Godwin 1945), Langstone Harbour to the east (Allen and Gardiner 2000) and to the west within Southampton Water (e.g. Momber et al 2011).

6.5.12 Many of these pollen studies, particularly those within Portsmouth and Langstone Harbour, lack associated radiocarbon dates and are of limited value in precisely correlating individual peat deposits and evidence for vegetation history. However, some general parallels can be observed.

6.5.13 The peat deposits from Portsmouth Harbour are around 1000 years earlier in date than Mesolithic peats to the west within Southampton Water (Coastal and Intertidal peat database). The lowermost peats preserved in channels within Langstone Harbour have not been dated, but oak stumps from submerged forests at Baker's Rithe and Russell's Lake and have produced dates of 3350–2910 cal. BC and 2310–1950 cal. BC within the early-late Neolithic/early Bronze Age respectively (Allen and Gardiner 2000).

6.5.14 No peats of Neolithic or Bronze Age date have been recorded from Portsmouth Harbour during the course of this work, perhaps as a result of truncation or removal by dredging and anthropogenic activity related to the construction and use of Portsmouth Harbour.

6.5.15 However, the oak stumps from the Neolithic/early Bronze Age submerged forest remains in Langstone Harbour emphasise the importance of oak as a long-lived component of the wetland woodland within local coastal environments.

6.5.16 Pollen analysis from Farlington Marsh within Langstone Harbour included large quantities of oak and hazel along with small quantities of birch, elm and lime, with a subsequent increase in pine. Although undated the pollen was considered to be early Holocene and could be broadly contemporary with the peats in DT-010, DT-026 and DT-029. The elevated pine values may be part of a recolonization of pine in the region or reflect the continuation of local stands in the Hampshire Basin (Scaife 1991).

6.5.17 Godwin had also noted a preponderance of pine in pollen from a submerged peat in Portsmouth Harbour (Godwin 1945) although radiocarbon dating was not available at the time of this study.

7 RECOMMENDATIONS

7.1.1 The potential for further palaeoenvironmental analysis is discussed below, based on the results of the palaeoenvironmental assessment and chronological information.

Borehole DT-010

7.1.2 Pollen, diatoms, foraminifera and ostracods are variably preserved in samples from vibrocore DT-010 and no further analysis is recommended.

Borehole DT-026

7.1.3 Pollen preservation and concentrations were generally good, and although enough pollen is present for analysis, the absence of evidence for human activity makes it unlikely that the results will develop upon the data presented here. Moreover, diatoms, foraminifera and ostracods are absent. No further work is recommended.

Borehole DT-029

7.1.4 Although present in good concentrations, pollen is generally only moderately preserved with no evidence for human activity. Although enough pollen is present for analysis, the results are unlikely to develop upon the data presented here. Moreover, diatoms, foraminifera and ostracods are absent. No further work is recommended.

BIBLIOGRAPHY

Allen M J and Gardiner J 2000 Our changing coast: a survey of the intertidal archaeology of Langstone Harbour, Hampshire. Council for British Archaeology Research Report 124, York

Athersuch J, Horne D J, Whittaker J E 1989 Marine and brackish water ostracods. In: Kermack D M, Barnes, R S K. (eds), Synopsis of the British Fauna (New Series), no. 43. E.J. Brill, Leiden (for the Linnean Society of London and The Estuarine and Brackish-water Sciences Association), 359pp

Battarbee R W, Jones V J, Flower R J, Cameron N G, Bennion H B, Carvalho L, Juggins, S 2001 Diatoms. In (J P Smol and H J B. Birks Eds.), Tracking Environmental Change Using Lake Sediments Volume 3: Terrestrial, Algal, and Siliceous Indicators. Dordrecht: Kluwer Academic Publishers, 155–202

Bennett, K D Whittington, G, Edwards, K J 1994 Recent plant nomenclatural changes and pollen morphology in the British Isles. Quaternary Newsletter, 73, 1–6

Blaauw M, van der Plicht J, van Geel B 2004 Radiocarbon dating of bulk peat samples from raised bogs: non-existence of a previously reported ‘reservoir effect’. Quaternary Science Review 23, 1537–1542

Brewer S, Giesecke T, Davis B A S, Finsinger W, Wolters S, Binney H, de Beaulieu J-L, Fyfe R, Gil-Romera G, Kuhl N, Kunes P, Leydet M, Bradshaw, R H 2017 Late glacial and Holocene European pollen data, J Maps 13, 921–928

Bronk Ramsey C, Lee S 2013 Recent and planned development of the Program OxCal. Radiocarbon 55, (2-3), 720–730

Butz C, Grosjean M, Goslar, T et al 2017 Hyperspectral imaging of sedimentary bacterial pigments: a 1700-year history of meromixis from varved Lake Jaczno, northeast Poland. Journal of Palaeolimnology 58, 57–72

Intertidal and coastal peat database. https://historicengland.org.uk/research/current/heritage-science/intertidal-peat-database/ (accessed 4.12.19)

Cushing E J 1967 Evidence for differential pollen preservation in late Quaternary sediments in Minnesota. Review of Palaeobotany and Palynology 4, 87–101

ESG 2017 HMNB Portsmouth, Victory Jetty Upgrade: factual report on ground investigation. Report No A7071–17

Flower R J 1993 Diatom preservation: experiments and observations on dissolution and breakage in modern and fossil material. Hydrobiologia 269/270, 473–484

Godwin H 1945 A submerged peat bed in Portsmouth harbour. Data for the study of post-glacial history IX, New Phytologist, 44, 152–5

Hartley B, Barber H G, Carter J R, Sims P A 1996 An Atlas of British Diatoms. Biopress Limited, Bristol

Hendey N I 1964 An Introductory Account of the Smaller Algae of British Coastal Waters. Part V. Bacillariophyceae (Diatoms). Ministry of Agriculture Fisheries and Food, Series IV

Hustedt F 1953 Die Systematik der Diatomeen in ihren Beziehungen zur Geologie und Okologienebst einer Revision des Halobien-systems. Sv. Bot. Tidskr., 47, 509–519

Hustedt F 1957 Die Diatomeenflora des Fluss-systems der Weser im Gebiet der Hansestadt Bremen. Ab. naturw. Ver. Bremen 34, 181–440

Krammer K and Lange-Bertalot H 1986-1991 Bacillariophyceae. Gustav Fisher Verlag, Stuttgart

Maritime Archaeology Limited (MAL) 2007, HMNB Portsmouth Approach Channel Dredging and Associated Works ES, Appendix 22.1: MAL HMNB Portsmouth Approach Channel and Harbour EIA, unpublished report, ref: 1741

Meisch C 2000 Freshwater Ostracoda of Western and Central Europe. In: Schwoerbel J. & Zwick P (eds.), Suβwasserfauna von Mitteleuropa, Band 8/3. Spektrum Akadamischer Verlag, Heidelberg and Berlin. 522pp

Moore P D, Webb J A, Collinson M E 1991 Pollen analysis, 2nd edition. Oxford, Blackwell

Momber G, Tomalin D J, Scaife R G, Satchell J, Gillespie J 2011 Mesolithic occupation at Bouldnor Cliff and the submerged landscapes of the Solent. Council for British Archaeology Research Report 164, York

Murray J W 2006 Ecology and Applications of Benthic Foraminifera. Cambridge University

Parfitt S A, Ashton N M., Lewis S G, Abel R L, Coope G R, Field M H, Gale R, Hoare P G, Larkin N R, Lewis M D, Karloukovski V, Maher B, Peglar S M, Preece R C, Whittaker J E, Stringer C B 2010 Early Pleistocene human occupation at the edge of the boreal zone in northwest Europe. Nature 466, 229–33

Parfitt S, Barendregt R W, Breda M, Candy I, Collins M J, Coope G R, Durbidge P, Field, M H, Lee J R, Lister A M, Mutch R, Penkman K E H, Preece R C, Rose J, Stringer C B, Symmons R, Whittaker J E, Wymer J J, Stuart A J 2005 The earliest record of human activity in northern Europe. Nature 438, 1008–12

Ransley J, Sturt F, Dix J, Adams J, Blue L 2013 People and the sea: a maritime archaeological research agenda for England. York, Council for British Archaeology Research Report 171

Reimer P J, Bard E, Bayliss A, Beck J W, Blackwell P G, Bronk Ramsey C, Buck C E, Cheng H, Edwards R L, Friedrich M, Grootes P M, Guilderson T P, Heaton T J, Hoffmann D L, Hogg A G, Hughes K A, Kaiser K F, Krome, B, Manning S W, Nui M, Reimer R W, Scott E M, Southon J R, Staff R A, Turney C S M, van der Plicht J 2013 IntCal13 and Marine 13 Calibration Curve, 0–50,000 Years BP. Radiocarbon 55 (4), 1869–1887

Roberts M B, Parfitt S A 1999 Boxgrove. A Middle Pleistocene Hominid Site at Eartham Quarry, Boxgrove, West Sussex. English Heritage Archaeological Report 17. London

Rockworks™ v17.0 (2016) Rockworks Earth Science and GIS Software

Ryves D B, Juggins S, Fritz S C, Battarbee R W 2001 Experimental diatom dissolution and the quantification of microfossil preservation in sediments. Palaeogeography, Palaeoclimatology, Palaeoecology 172, 99–113

Scaife R G 1991 Pollen investigation and vegetational history, in P W Cox, C M Hearne Redeemed from the Heath: the archaeology of the Wytch Farm Oilfield, 1987–1990, Dorset Natur Hist Archaeol Soc Monogr 9. Dorchester

Stace C 1997 New flora of the British Isles (2nd edition), Cambridge, Cambridge University Press

WA 2004 Portsmouth Regeneration Project, Assessment of Archaeological Potential, Portsmouth Approach, unpublished report, ref: 55870.01

WA 2015a Queen Elizabeth Class Capital Dredge Project. Her Majesty's Naval Base, Portsmouth. Archaeological Monitoring and Mitigation: Written Scheme of Investigation. Report ref: 111320.01

WA 2015b Queen Elizabeth Class Capital Dredge Project. Her Majesty's Naval Base, Portsmouth: Stage 1 geoarchaeological review of geotechnical logs and preliminary recording of geotechnical samples. Report Ref: 111320.02

WA 2016 Queen Elizabeth Class Capital Dredge Project. Her Majesty's Naval Base, Portsmouth: Stage 2 geoarchaeological borehole recording and deposit modelling. Report ref: 111320.03

Van Der Werff A, Huls H 1957-1974 Diatomeenflora van Nederland, 10 volumes

Witkowski A, Lange-Bertalot H, Metzeltin D 2000 Diatom Flora of Marine Coasts I. Iconographia Diatomologica. Annotated Diatom Micrographs Ed. by H Lange-Bertalot Vol. 7. A.R.G. Gantner Vcerlag. Koeltz Scientific Books. Königstein

APPENDICES

Appendix 1 Palaeoenvironmental subsamples

Borehole	**DT-010**	**DT-026**	**DT-029**
Technique	Sample depth (mbsf)		
Plant macrofossil and 14C	2.63-2.65 2.76-2.78 3.15-3.17 3.23-3.25	1.77-1.79 1.97-1.99	2.45-2.47 2.85-2.87
Pollen	2.62 2.69 2.78 3.19 3.22 3.25	1.82 1.90 1.97	2.47 2.54 2.62 2.70 2.78 2.85
Foraminifera, ostracod and diatom	2.54 2.57 2.82 2.91 3.00 3.08	1.68 1.75 2.08	2.42

Appendix 2 Vibrocore descriptions DT-010, DT-026 and DT-029

Location:	462294.49 101256.28	**Mono:**	DT-010	**Comments: 111320 Portsmouth Dredge** **VC DT-010** **Described by NM**
Level (top):	-10mCD	**Drg:**		

Depth		**Unit or sub-unit (see Table 2)**	**Samples (if taken)**	**Sediment description**	**Interpretation**	
Mono	mCD					
0.78-0.95	-10.78- -10.95	3b		2.5Y 3/2 very dark greyish brown silty clay with moderate sub rounded and linear iron stain and concretions. Occasional marine shells. No apparent horizontal banding. 0.1% fine pores and occasional <1mm small burrows. Sharp boundary.	Estuarine alluvium.	Estuarine alluvium with an inundation of marine sand due to fluctuating water levels
0.95-1.13	-10.95- -11.13	3c		2.5Y 3/3 dark olive brown medium sand with some clay and moderate small gravel and possible clinker <5mm. Sand becomes slightly finer and with more clay content from 1.07 to base. Sharp boundary.	Marine sands.	
1.13-1.78	-11.13- -11.78	3b		2.5Y 3/2 very dark greyish brown soft buttery silty clay with abundant marine shells. No obvious horizontal banding. (No boundary, end of core)	Estuarine alluvium with marine shell.	
1.78-2.60	-11.78- -12.60	3b		10YR 3/1 very dark grey stiff and compact clay with occasional patches of organics and some waterlogged roots. Faintly horizontally banded. From 2.48-2.60 the deposit is clearly banded with 10YR 2/1 black very humic silty clay. Bands of freshwater/brackish water molluscs at 2.55m ant at base. Mollusc assemblage includes *Bithynia tentaculata, Planorbis planorbis* and *Hydrobia* spp. Indicating well vegetated tidal estuarine conditions. Sharp boundary.	Estuarine alluvium choking off peat below. Mollusc assemblage indicates well vegetated tidal estuarine conditions.	Well vegetated tidal estuarine conditions with fluctuations in water level. Alluvium choking off peat below.
2.60-2.78	-12.60- -12.78	3e		10YR 2/2 very dark brown peat with slightly interleaved bands of 10YR 2/2 very dark brown and 10YR 4/3 brown very humic silty clay. Clearly horizontally banded. Occasional pieces of wood/woody roots with a larger piece of wood from 2.73 to base. (No boundary, end of core)	Peat and estuarine alluvium being choked off	Peat

Location:		462294.49 101256.28	**Mono:**	DT-010	**Comments: 111320 Portsmouth Dredge VC DT-010 Described by NM**	
Level (top):		-10mCD	**Drg:**			
Depth		**Unit or sub-unit (see Table 2)**	**Samples (if taken)**	**Sediment description**	**Interpretation**	
Mono	mCD					
2.78-3.12	-12.78- -13.12	3b		7.5 YR 2.5/1 black soft silty clay with occasional lumps of waterlogged organics. 0.2% fine pores. Faintly horizontally banded. Sharp boundary.	Estuarine alluvium with occasional organics choking off peat below.	Estuarine alluvium
3.12-3.30	-13.12- -13.30	3e		7.5YR 2.5/2 very dark brown peat oxidising to 10YR 2/1 black. Soft and very organic with some visible plant remains. Piece of wood at top boundary.	Peat.	Peat

Location:		462457.69 100709.34	**Mono:**	DT-026	**Comments: 111320 Portsmouth Dredge** **VC DT-026** **Described by NM**	
Level (top):		-11.09mCD	**Drg:**			
Depth		**Unit or sub-unit (see Table 2)**	**Samples**	**Sediment description**	**Interpretation**	
Mono	mCD					
0.53-0.57	-11.62- -11.66	3c		2.5Y 4/4 olive brown medium to coarse sand with rounded to sub rounded small gravel <5mm and frequent marine shell fragments. Sharp boundary	Marine sands.	Marine sands
0.57-1.65	-11.66- -12.74	3b		2.5Y 3/2 very dark greyish brown soft buttery silty clay with fine horizontal banding. Occasional heavily iron stained roots and root voids, especially at 1.20-1.65m. Some lateral cracking and occasional waterlogged plant remains. Becomes slightly darker in colour from 1.52m and appears to have a bit more structure. (Gap at 1.44-1.52 – top of core) Clear boundary.	Estuarine alluvium with occasional plant remains. Iron stain suggests wetting and drying (redoximorphism) indicating fluctuating water levels.	Estuarine alluvium – fluctuating water levels.
1.65-1.79	-12.74- -12.88	3b		5Y 2.5/1 black silty clay oxidising to 5Y 6/4 pale olive. Thinly laminated with common iron stained roots and root voids. Clear boundary.	Estuarine alluvium with reducing conditions and redoximorphism. Choking off peat below.	Estuarine alluvium choking off peat due to rise in water level.
1.79-1.97	-12.88- -13.06	3e		10YR 2/2 very dark brown peat with clay and some fine quartzy sand grains. No horizontal banding visible, no distinct structure. Occasional plant remains and some iron stain that increases with depth. Becomes more minerogenic towards base. Clear boundary	Peat with clay – subject to regular tidal inwashes	Peat that is subject to regular tidal inwashes
1.97-2.25	-13.06- -13.34	3b or 2b		10YR 3/2 very dark greyish brown finely laminated silty clay. Fairly plastic with some lateral cracking suggesting structure. Rare waterlogged plant remains. Becomes slightly darker with depth- 10/YR 2/1 black. Clear boundary.	Estuarine alluvium	Estuarine alluvium

Location:		462457.69 100709.34	**Mono:**	DT-026	**Comments: 111320 Portsmouth Dredge** **VC DT-026** **Described by NM**	
Level (top):		-11.09mCD	**Drg:**			
Depth		**Unit or sub-unit (see Table 2)**	**Samples**	**Sediment description**	**Interpretation**	
Mono	mCD					
2.25-2.45	-13.34- -13.54	3b or 2b		7.5YR 3/3 dark brown silty clay with indistinct mottles of 10YR 4/4 dark yellowish brown to 2.33m. Occasional iron stained root voids, especially towards the base. 0.1% fine pores. Blocky structure- fine to medium peds.	Salt marsh/tidal mudflats.	Salt marsh/tidal mudflats.

Location:	462462.83 100559.33	**Mono:**	DT-029	**Comments: 111320 Portsmouth Dredge** **VC DT-029** **Described by HR**
Level (top):	-10.98mCD	**Drg:**		

Depth		**Unit or sub-unit (see Table 2)**	**Samples**	**Sediment description**	**Interpretation**	
Mono	mCD					
1.04-2.28	-12.02- -13.26	3b		Gley 1 4/1 dark greenish grey clayey silt with fine-medium sand and very common (30%) marine shell throughout (incl. oyster + cockle). Sand becoming slightly coarser with depth. Sharp lower boundary. 1.04-1.09m compression gap due to the coring process. (Gap at 1.71-1.81m – sample removed for contamination testing).	Estuarine alluvium/sea bed	Estuarine alluvium/sea bed
2.28-2.43	-13.26- -13.41	3b		Gley 1 3/1 very dark grey clayey silt with fine-medium sand and oxidising to 2.5Y 4/3 olive brown throughout. Sparse (5%) marine shell. Sharp L/B.	Estuarine alluvium/sea bed	
2.43-2.88	-13.41- -13.86	3e		2.5YR 2.5/1 reddish black fine crumbly peat with faint horizontal banding visible. Peat becomes slightly minerogenic with depth and 2.5YR 3/1 dark reddish grey between 2.76-2.88m. Sharp L/B.	Peat	Peat

Appendix 3 Radiocarbon dating report

UBANo	Sample ID	Material Type	^{14}C Age	±	F14C	±	mg Graphite
UBA-41798	111320_DT10_2.63-2.65	Corylus avellana nutshell	7719	40	0.3825	0.0019	0.940
UBA-41799	111320_DT10_2.76-2.78	Cornus sanguinea seed	7655	38	0.3856	0.0018	0.838
UBA-41800	111320_DT10_3.15-3.17	sediment	7866	46	0.3756	0.0022	1.200
UBA-41801	111320_DT10_3.23-3.25	Corylus avellana nutshell	7934	46	0.3724	0.0021	1.019
UBA-41802	111320_DT26_1.77-1.79	Sparganium erectum seed	7589	41	0.3888	0.0020	1.043
UBA-41803	111320_DT26_1.97-1.99	sediment	7887	44	0.3746	0.0020	1.227
UBA-41804	111320_DT29_2.45-2.47	sediment	7847	41	0.3765	0.0019	1.200
UBA-41805	111320_DT29_2.85-2.87	Failed	Failed	Failed	Failed	Failed	Failed

Inez Lopez-Doriga
Wessex Archaeology
Portway House
Old Sarum Park
Salisbury, Wiltshire SP4 6EB
England
Customer No. 2144166

^{14}CHRONO Centre
Queens University Belfast
42 Fitzwilliam Street
Belfast BT9 6AX
Northern Ireland

Radiocarbon Date Certificate

Laboratory Identification:	UBA-41798
Date of Measurement:	2019-10-25
Site:	Portsmouth
Sample ID:	111320_DT10_2.63-2.65
Material Dated:	plant macrofossil
Pretreatment:	Acid Only
mg Graphite:	0.940
Submitted by:	Ines Lopez Doriga

Conventional ^{14}C Age:	7719±40 BP
Fraction corrected	using AMS δ^{13}C

Inez Lopez-Doriga
Wessex Archaeology
Portway House
Old Sarum Park
Salisbury, Wiltshire SP4 6EB
England
Customer No. 2144166

^{14}CHRONO Centre
Queens University Belfast
42 Fitzwilliam Street
Belfast BT9 6AX
Northern Ireland

Radiocarbon Date Certificate

Laboratory Identification:	UBA-41799
Date of Measurement:	2019-10-25
Site:	Portsmouth
Sample ID:	111320_DT10_2.76-2.78
Material Dated:	plant macrofossil
Pretreatment:	Acid Only
mg Graphite:	0.838
Submitted by:	Ines Lopez Doriga

Conventional ^{14}C Age:	7655±38 BP
Fraction corrected	using AMS δ^{13}C

Inez Lopez-Doriga
Wessex Archaeology
Portway House
Old Sarum Park
Salisbury, Wiltshire SP4 6EB
England
Customer No. 2144166

^{14}CHRONO Centre
Queens University Belfast
42 Fitzwilliam Street
Belfast BT9 6AX
Northern Ireland

Radiocarbon Date Certificate

Laboratory Identification:	UBA-41800
Date of Measurement:	2019-10-23
Site:	Portsmouth
Sample ID:	111320_DT10_3.15-3.17
Material Dated:	peat,sediment (humic fraction)
Pretreatment:	Humic Extraction
mg Graphite:	1.200
Submitted by:	Ines Lopez Doriga

Conventional ^{14}C Age:	7866±46 BP
Fraction corrected	using AMS δ^{13}C

Inez Lopez-Doriga
Wessex Archaeology
Portway House
Old Sarum Park
Salisbury, Wiltshire SP4 6EB
England
Customer No. 2144166

^{14}CHRONO Centre
Queens University Belfast
42 Fitzwilliam Street
Belfast BT9 6AX
Northern Ireland

Radiocarbon Date Certificate

Laboratory Identification:	UBA-41801
Date of Measurement:	2019-10-25
Site:	Portsmouth
Sample ID:	111320_DT10_3.23-3.25
Material Dated:	plant macrofossil
Pretreatment:	Acid Only
mg Graphite:	1.019
Submitted by:	Ines Lopez Doriga

Conventional ^{14}C Age:	7934±46 BP
Fraction corrected	using AMS δ^{13}C

Inez Lopez-Doriga
Wessex Archaeology
Portway House
Old Sarum Park
Salisbury, Wiltshire SP4 6EB
England
Customer No. 2144166

^{14}CHRONO Centre
Queens University Belfast
42 Fitzwilliam Street
Belfast BT9 6AX
Northern Ireland

Radiocarbon Date Certificate

Laboratory Identification:	UBA-41802
Date of Measurement:	2019-10-25
Site:	Portsmouth
Sample ID:	111320_DT26_1.77-1.79
Material Dated:	plant macrofossil
Pretreatment:	Acid Only
mg Graphite:	1.043
Submitted by:	Ines Lopez Doriga

Conventional ^{14}C Age:	7589±41 BP
Fraction corrected	using AMS δ^{13}C

Inez Lopez-Doriga
Wessex Archaeology
Portway House
Old Sarum Park
Salisbury, Wiltshire SP4 6EB
England
Customer No. 2144166

^{14}CHRONO Centre
Queens University Belfast
42 Fitzwilliam Street
Belfast BT9 6AX
Northern Ireland

Radiocarbon Date Certificate

Laboratory Identification:	UBA-41803
Date of Measurement:	2019-10-23
Site:	Portsmouth
Sample ID:	111320_DT26_1.97-1.99
Material Dated:	peat,sediment (humic fraction)
Pretreatment:	Humic Extraction
mg Graphite:	1.227
Submitted by:	Ines Lopez Doriga

Conventional ^{14}C Age:	7887±44 BP
Fraction corrected	using AMS δ^{13}C

Inez Lopez-Doriga
Wessex Archaeology
Portway House
Old Sarum Park
Salisbury, Wiltshire SP4 6EB
England
Customer No. 2144166

^{14}CHRONO Centre
Queens University Belfast
42 Fitzwilliam Street
Belfast BT9 6AX
Northern Ireland

Radiocarbon Date Certificate

Laboratory Identification:	UBA-41804
Date of Measurement:	2019-11-08
Site:	Portsmouth
Sample ID:	111320_DT29_2.45-2.47
Material Dated:	peat,sediment (humic fraction)
Pretreatment:	Humic Extraction
mg Graphite:	1.200
Submitted by:	Ines Lopez Doriga

Conventional ^{14}C Age:	7847±41 BP
Fraction corrected	using AMS δ^{13}C

```
41798
UBA-41798
Radiocarbon Age BP   7719 +/-   40
Calibration data set: intcal13.14c                   # Reimer et al. 2013
  % area enclosed       cal AD age ranges                relative area under
                                                     probability distribution
  68.3 (1 sigma)      cal BC 6593- 6503                      1.000
  95.4 (2 sigma)      cal BC 6632- 6473                      1.000

41799
UBA-41799
Radiocarbon Age BP   7655 +/-   38
Calibration data set: intcal13.14c                   # Reimer et al. 2013
  % area enclosed       cal AD age ranges                relative area under
                                                     probability distribution
  68.3 (1 sigma)      cal BC 6561- 6548                      0.106
                             6526- 6520                      0.040
                             6510- 6453                      0.854
  95.4 (2 sigma)      cal BC 6589- 6578                      0.039
                             6574- 6442                      0.961

41800
UBA-41800
Radiocarbon Age BP   7866 +/-   46
Calibration data set: intcal13.14c                   # Reimer et al. 2013
  % area enclosed       cal AD age ranges                relative area under
                                                     probability distribution
  68.3 (1 sigma)      cal BC 6797- 6795                      0.008
                             6775- 6641                      0.992
  95.4 (2 sigma)      cal BC 7022- 7012                      0.007
                             7008- 6968                      0.036
                             6945- 6937                      0.006
                             6915- 6881                      0.038
                             6838- 6598                      0.914

41801
UBA-41801
Radiocarbon Age BP   7934 +/-   46
Calibration data set: intcal13.14c                   # Reimer et al. 2013
  % area enclosed       cal AD age ranges                relative area under
                                                     probability distribution
  68.3 (1 sigma)      cal BC 7021- 7012                      0.031
                             7006- 6969                      0.155
                             6943- 6939                      0.019
                             6914- 6882                      0.137
                             6835- 6696                      0.657
  95.4 (2 sigma)      cal BC 7034- 6683                      1.000

41802
UBA-41802
Radiocarbon Age BP   7589 +/-   41
Calibration data set: intcal13.14c                   # Reimer et al. 2013
  % area enclosed       cal AD age ranges                relative area under
                                                     probability distribution
  68.3 (1 sigma)      cal BC 6467- 6425                      1.000
  95.4 (2 sigma)      cal BC 6503- 6389                      1.000
```

```
41803
UBA-41803
Radiocarbon Age BP   7887 +/-   44
Calibration data set: intcal13.14c             # Reimer et al. 2013
  % area enclosed       cal AD age ranges          relative area under
                                               probability distribution
  68.3 (1 sigma)     cal BC 6806- 6784                0.112
                            6780- 6651                0.888
  95.4 (2 sigma)     cal BC 7027- 6958                0.084
                            6954- 6932                0.021
                            6919- 6878                0.065
                            6848- 6638                0.830

41804
UBA-41804
Radiocarbon Age BP   7847 +/-   41
Calibration data set: intcal13.14c             # Reimer et al. 2013
  % area enclosed       cal AD age ranges          relative area under
                                               probability distribution
  68.3 (1 sigma)     cal BC 6750- 6721                0.164
                            6707- 6632                0.832
                            6617- 6615                0.005
  95.4 (2 sigma)     cal BC 6897- 6891                0.003
                            6825- 6593                0.997
```

References for calibration datasets:

Reimer PJ, Bard E, Bayliss A, Beck JW, Blackwell PG, Bronk Ramsey C, Buck CE Cheng H, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Haflidason H, Hajdas I, HattÃ© C, Heaton TJ, Hogg AG, Hughen KA, Kaiser KF, Kromer B, Manning SW, Niu M, Reimer RW, Richards DA, Scott EM, Southon JR, Turney CSM, van der Plicht J.
IntCal13 and MARINE13 radiocarbon age calibration curves 0-50000 years calBP Radiocarbon 55(4). DOI: 10.2458/azu_js_rc.55.16947

Comments:
* This standard deviation (error) includes a lab error multiplier.
** 1 sigma = square root of (sample std. dev.^2 + curve std. dev.^2)
** 2 sigma = 2 x square root of (sample std. dev.^2 + curve std. dev.^2)
where ^2 = quantity squared.
[ ] = calibrated range impinges on end of calibration data set
0* represents a "negative" age BP
1955* or 1960* denote influence of nuclear testing C-14

NOTE: Cal ages and ranges are rounded to the nearest year which may be too precise in many instances. Users are advised to round results to the nearest 10 yr for samples with standard deviation in the radiocarbon age greater than 50 yr.

<>

Appendix 4 Specialist diatom report

Diatom assessment of samples from Portsmouth Approach Channel Dredging

Nigel Cameron, Environmental Change Research Centre,
Department of Geography, University College London,
Pearson Building, Gower Street, London WC1E 6BT

Introduction

Eleven sub-samples for diatom assessment were taken from three boreholes from the Portsmouth Approach Channel Dredge. These samples have been prepared and assessed for diatoms. The dredging of the channel is required to allow new aircraft carriers to enter Portsmouth naval base, and the palaeoenvironmental assessment carried out has produced a number of Holocene peat and alluvial sequences. (Alex Brown, pers. comm.)

The diatom assessment takes into account the numbers of diatoms, the state of preservation of the diatom assemblages, species diversity, diatom species environmental preferences and the potential of the sediments for further diatom analysis.

Methods

Diatom preparation followed standard techniques (Battarbee *et al.* 2001). Two coverslips were made from each sample and fixed in Naphrax for diatom microscopy. A large area of the coverslips on each slide was scanned for diatoms at magnifications of x400 and x1000 under phase contrast illumination.

Diatom floras and taxonomic publications were consulted to assist with diatom identification; these include Hendey (1964), Werff & Huls (1957-1974), Hartley et al. (1996), Krammer & Lange-Bertalot (1986-1991) and Witkowski *et al.* (2000). Diatom species' salinity preferences are indicated using the halobian groups of Hustedt (1953, 1957: 199), these salinity groups are summarised as follows:

1. Polyhalobian: >30 g l^{-1}

2. Mesohalobian: 0.2-30 g l^{-1}

3. Oligohalobian - Halophilous: optimum in slightly brackish water

4. Oligohalobian - Indifferent: optimum in freshwater but tolerant of slightly brackish water

5. Halophobous: exclusively freshwater

6. Unknown: taxa of unknown salinity preference.

Results & Discussion

A summary of the results of the diatom evaluation are shown in Table 1 below. The borehole numbers, laboratory sample numbers and depths are shown. The records of diatom taxa and their salinity classification are shown in Table 2 (Excel file attached): 1 – present; 2 – common; 3 – more common.

Table 1. Summary of diatom evaluation results for the boreholes from the Portsmouth Approach Channel Dredge (bk – brackish; mar – marine; hal – halophilous, fw – freshwater, mod – moderate)

Diatom Sample Number/ Depth(cm) /Borehole	Diatoms	Diatom Numbers	Quality of Preservation	Diversity	Assemblage type	Potential for % count
DT-10						
D1 254	present	mod high	poor to mod	mod high	bk mar hal fw	mod
D2 257	present	low	poor	mod	bk mar hal fw	low
D3 282	absent	-	-	-	-	none
D4 291	absent	-	-	-	-	none
D5 300	absent	-	-	-	-	none
D6 308	absent	-	-	-	-	none
DT-026						
D7 168	absent	-	-	-	-	none
D8 175	absent	-	-	-	-	none
D9 202	absent	-	-	-	-	none
D10 208	absent	-	-	-	-	none
DT-029						
D11 242	absent	-	-	-	-	none

DT-10 (Samples D1 to D6)

Diatoms are present in the top two samples (D1 & D2) from borehole DT-10. Diatoms are absent from the bottom four samples (D3 to D6) and there is no further potential for diatom analysis of these samples. In the top sample (D1, 254 cm) there are moderately high numbers of diatoms, the quality of diatom preservation varies from poor to moderate, diatom diversity is moderately high and there is moderately good potential to carry out percentage diatom counting. In sample D2 from 257 cm depth there are low numbers of poorly preserved diatoms, there is moderate species diversity and low potential for further diatom analysis. The diatom assemblages in samples D1 and D2 provide useful aquatic environmental data.

Both samples D1 and D2 contain a mixture of marine, brackish, halophilous and freshwater diatoms. The coastal, marine planktonic diatom *Paralia sulcata* is common in both samples and the marine planktonic species *Podosira stelligera* is also present in both D1 and D2. The marine diatoms *Cymatosira belgica, Grammatophora* sp., *Rhaphoneis surirella* and other *Rhophoneis* spp. are also present in D2.

Marine-brackish taxa are also present in sample D2. These include the planktonic diatom *Actinoptychus undulatus* and the benthic and attached species *Diploneis smithii* and *Synedra gaillonii*.

Mesohalobous, brackish water diatoms are present in both samples; these are mainly benthic taxa and include *Nitzschia navicularis* (common in D2), *Nitzschia granulata, Nitzschia sigma, Scoliopleura tumida, Caloneis westii* and *Diploneis didyma*. The planktonic, mesohalobous diatom *Cyclotella striata* is also present in sample D1.

Freshwater diatoms, including oligohalobous, and halophilous to oligohalobous indifferent halobian groups, are present, and in sample D1 more common, in the top two samples from DT-10. In particular halophilous and freshwater diatoms that are epiphytic on aquatic macrophytes were recorded in relatively high numbers in sample D1 and were also present in sample D2. These epiphytic diatoms include *Epithemia turgida, Rhoicosphaenia curvata* and *Cocconeis placentula* along with *Epithemia adnata* and other *Epithemia* spp. Other non-planktonic, freshwater diatoms include both attached and benthic diatoms such as: *Amphora libyca, Caloneis schumanniana, Fragilaria brevistriata, Fragilaria pinnata, Gomphonema truncatum, Gyrosigma acuminatum, Gyrosigma attenuatum, Nitzschia dissipata, Pinnularia viridis* and *Synedra ulna*. The importance of these non-planktonic freshwater diatoms, particularly in sample D1, suggest that they represent an autochthonous, shallow-water component of the diatom assemblage. The top sample in particular shows the importance of aquatic macrophyte growth in a freshwater or slightly saline environment that was affected at least periodically by marine inundation.

Overall the assessment suggests that the diatom assemblage of sample D2 represents more saline conditions with lower diversity and numbers of freshwater and halophilous diatoms in D2 and relatively greater numbers of mesohalobous and polyhalobous taxa. As discussed above, the diatom assemblage of the top sample D1 has greater representation of non-marine and halophilous diatoms, although both samples are affected by tidal water.

<u>DT-026 (Samples D7 to D10)</u>

Diatom assemblages are absent from all four samples assessed from DT-026. A possible, indeterminate diatom fragment was recorded in sample D9 from 202 cm.

The absence of diatoms is the result of taphonomic processes (Flower 1993, Ryves *et al.* 2001). Diatom silica dissolution and valve breakage is caused by factors such as extremes of sediment salinity, alkalinity or acidity, the under-saturation of sediment pore water with dissolved silica, cycles of prolonged drying and rehydration, or physical damage to diatom valves from abrasion or wave action.

There is no further potential for diatom analysis of this sequence.

DT-029 (Sample D11)

Diatoms are absent from sample D11 and there is no further potential for diatom analysis of this sample.

Conclusions

1. Diatoms were assessed from eleven samples from three cores taken from the Portsmouth Approach Channel Dredge site. Diatom assemblages are present in the top two samples from borehole DT-10, however, diatoms are absent from the remaining nine samples.
2. The two diatom assemblages are composed of a mixture of marine, brackish, halophilous and freshwater diatoms. The lower sample D2 has relatively greater numbers of benthic brackish water and planktonic marine diatoms. The top sample D1 has a significantly higher number of halophilous and freshwater diatoms, notably epiphytic taxa.
3. The is moderately good potential to carry out further diatom analysis for sample D1 and low potential for percentage analysis of sample D2. There is no further potential for diatom analysis of the remaining nine samples.
4. The absence or poor preservation of diatoms in ten samples is the result of taphonomic processes causing valve breakage and silica dissolution.
5. The assessment suggests that the diatom assemblage of sample D2 represents more saline conditions with a shift to predominance of fresher conditions with freshwater and halophilous epiphytes in sample D1. However, both samples are affected at least periodically by tidal water.

Acknowledgements

Thanks to Dr. Alexander Brown of Wessex Archaeology for providing the samples for diatom assessment and for details of the borehole sequences.

References

Battarbee, R.W., Jones, V.J., Flower, R.J., Cameron, N.G., Bennion, H.B., Carvalho, L. & Juggins, S. 2001. Diatoms. In (J.P. Smol and H.J.B. Birks eds.), Tracking Environmental Change Using Lake Sediments Volume 3: Terrestrial, Algal, and Siliceous Indicators, 155-202. Dordrecht: Kluwer Academic Publishers.

Flower, R.J. 1993. Diatom preservation: experiments and observations on dissolution and breakage in modern and fossil material. *Hydrobiologia 269/270*: 473-484.

Hartley, B., H.G. Barber, J.R. Carter & P.A. Sims. 1996. *An Atlas of British Diatoms.* Biopress Limited. Bristol. pp. 601.

Hendey, N.I. 1964 An Introductory Account of the Smaller Algae of British Coastal Waters. Part V. Bacillariophyceae (Diatoms). Ministry of Agriculture Fisheries and Food, Series IV. pp. 317.

Hustedt, F. 1953. Die Systematik der Diatomeen in ihren Beziehungen zur Geologie und Okologie nebst einer Revision des Halobien-systems. *Sv. Bot. Tidskr.*, 47: 509-519.

Hustedt, F. 1957. Die Diatomeenflora des Fluss-systems der Weser im Gebiet der Hansestadt Bremen. *Ab. naturw. Ver. Bremen* 34, 181-440.

Krammer, K. & H. Lange-Bertalot, 1986-1991. *Bacillariophyceae.* Gustav Fisher Verlag, Stuttgart.

Ryves, D. B., Juggins, S., Fritz, S. C. & Battarbee, R. W. 2001. Experimental diatom dissolution and the quantification of microfossil preservation in sediments. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 172, 99-113

Werff, A. Van Der & H. Huls. 1957-1974 *Diatomeenflora van Nederland*, 10 volumes

Witkowski, A, H. Lange-Bertalot & D. Metzeltin 2000. *Diatom Flora of Marine Coasts I.* Iconographia Diatomologica. Annotated Diatom Micrographs Ed. by H. Lange-Bertalot Vol. 7. A.R.G. Gantner Verlag. Koeltz Scientific Books. Königstein, Germany pp 92

Diatom Salinity Group & Taxon/Sample Number	**1**	**2**	**Diatom Salinity Group & Taxon/Sample Number**		
Polyhalobous			**Oligohalobous Indifferent**		
Cymatosira belgica		1	Amphora libyca	1	1
Grammatophora sp.		1	Caloneis schumanniana	1	
Paralia sulcata	2	2	Cocconeis placentula	3	1
Podosira stelligera	1	1	Epithemia adnata		1
Rhabdonema arcuatum		cf	Epithemia sp.	1	1
Rhaphoneis sp.		1	Fragilaria brevistriata	1	
Rhaphoneis surirella		1	Fragilaria pinnata	1	
Polyhalobous to Mesohalobous			Gomphonema truncatum	1	
Actinoptychus undulatus		1	Gyrosigma acuminatum	1	

Diploneis smithii		1	Gyrosigma attenuatum	1	
Synedra gaillonii		1	Neidium sp.	1	
Mesohalobous			Nitzschia dissipata	1	
Caloneis westii		1	Pinnularia viridis	1	
Cyclotella striata	1		Synedra ulna	1	1
Diploneis didyma		1	**Unknown Salinity Group**		
Nitzschia granulata	1		Cyclotella sp.		1
Nitzschia navicularis	1	2	Diploneis sp.	1	
Nitzschia sigma	1		Fragilaria sp.	1	
Scoliopleura tumida	1		Gomphonema sp.	1	1
Halophilous to Oligohalobous Indifferent			Navicula sp.	1	
Epithemia turgida	3	1	Stauroneis sp.	1	
Rhoicosphaenia curvata	3		Unknown naviculaceae		1

Appendix 5 Specialist foraminifera report

111321 – PORTSMOUTH APPROACH CHANNEL DREDGING WORKS: MICROFAUNAL PALAEOENVIRONMENTAL ASSESSMENT

by John E. Whittaker

INTRODUCTION

Eleven samples from three boreholes (DT-010, 026 and 029) were received from Alex Brown, Wessex Archaeology, on September 9th 2019. This work was undertaken during a major dredging operation of the Portsmouth Approach Channel to enable the new class of aircraft carriers to enter Portsmouth Naval Base. In the process several Holocene alluvial and peat sequences were discovered. The purpose of this assessment is to reconstruct their palaeoenvironments, in this case through the medium of the foraminifera and ostracods.

MATERIALS & METHODS

DT-010

Depth	Weight processed
2.54m	20g
2.57m	20g
2.82m	25g
2.91m	25g
3.00m	25g
3.08m	25g

DT-026

Depth	Weight processed
1.68m	15g
1.75m	20g
2.02m	15g
2.08m	15g

DT-029

Depth	Weight processed
2.42m	20g

Samples for assessment were broken into smaller pieces by hand and placed in ceramic bowls; most of the samples were naturally dry on receipt. So after a small amount of sodium carbonate was added to each to facilitate the removal of the clay fraction, the sediment mix was immersed in hot water and was left to soak overnight. Sediment was then washed through a 75 micron sieve with hand-hot water, the resulting residue being returned to the bowl for drying. Once thoroughly dry the residue was transferred to plastic labelled bags for storage and picking. For examination, the residue was first sieved through a nest of >500µ, >250µ and >150µ sieves. Sediment from each grade was then picked by sprinkling a small amount of residue onto a tray and examining it under a binocular microscope.

A representative selection of material from each sample (foraminifera, ostracods and other sub-fossil material) of potential environmental value was picked out into 3x1" plastic faunal slides and recorded on a presence/absence basis. See accompanying charts (Figures 1-3, uppermost table). Detailed recording of the foraminiferal and ostracod species was finally undertaken and is presented as semi-quantitative indications (Figures 1, 3, lower tables) and colour-coded to enhance their environmental signature.

RESULTS

After initially examining the samples on receipt, there was a suggestion that because of their dryness, there may be a suggestion that they have been in store for a long period and as a result there is a possibility that they could have become at least, partially decalcified. The three boreholes under review – DT-010, DT-026 and DT-029 – are located from north to south, respectively, in mid-channel within the Portsmouth Approach Channel.

DT-010

The northernmost borehole, represents a sequence of 0.54m (interval 2.54 and 3.08m) in the core. The results of the microfaunal assessment are shown in Figure 1. The lowest four samples (interval 2.82-3.08m) are near-peats and peaty silts and contain only plant debris and a number of small round organic bodies that I have referred to as "algal cysts". The environment must have been freshwater, as if it had been brackish and with the possibility (see above) that there may have been some decalcification, surely agglutinating foraminifera represented by their organic templates, would have been present and they were not found in spite of a diligent search. A marine tidal connection had clearly become established, however, by 2.57m depth in the core and this and the uppermost sample (2.54m) contain a mixture of freshwater ostracods, brackish foraminifera and ostracods, and outer estuarine foraminifera (see colour-coding in Figure 1). There is also quite a significant freshwater presence overall, including freshwater molluscs which might warrant further attention. Nevertheless it would seem to be a typical inner estuarine assemblage, as expected given the location.

DT-026

Four samples were examined from the interval 1.68-2.06m in the core. As in the lower part of DT-010, to the north, they contained only plant debris and in two samples in addition, insect remains (Figure 2). There was nothing whatsoever of a calcareous nature in the contained material. Whether this represents the original ecology or indicates subsequent decalcification within the sediment, is not known. It is therefore assumed, on negative evidence, that these sediments were deposited wholly within a freshwater environment.

DT-029

Only one sample from a core depth of 2.42m was provided from this, the southernmost core. In this case it is certainly informative (Figure 3). It contains quite a high diversity of brackish and outer estuarine/marine foraminifera and ostracods (see colour coding), and is typical of what might be expected towards the marine end of a large open estuary. Moreover, unlike the two cores to the north, it does not have a freshwater component.

What is not certain, with depths in core only stated, how they relate to each other in terms of correlation. There is no information available to hand that relates each core to O.D. Even when this is to hand it is imperative that radiocarbon dating is undertaken so as to establish a meaningful chronology.

DT-010

CONTAINED MATERIAL

depth in core	2.54m	2.57m	2.82m	2.91 m	3.00 m	3.08 m
peat/plant debris + seeds	x	x	x	x	x	x
insect remains	x	x				
freshwater molluscs	x	x				
Bithynia opercula	x	x				
brackish ostracods	x					
outer estuarine/marine foraminifera	x					
brackish foraminifera	x	x				
freshwater ostracods	x	x				
cladocera		x				
algal cysts			x	x	x	x

Ecology	*Estuary with both freshwater and brackish components*		*Peat or peaty silts; barren but probably freshwater*			

FRESHWATER OSTRACODS

Candona neglecta	xx	xx				
Cyclocypris laevis/ovum		o				

BRACKISH OSTRACODS

Cyprideis torosa	x					

BRACKISH FORAMINIFERA

Ammonia(brackish sp.)	x	x				

OUTER ESTUARINE/MARINE FORAMINIFERA

Elphidium macellum	x					
Pseudopolymorphina novangliae	o					

Contained material is recorded on a presence (x)/absence basis

Foraminifera and ostracods are recorded: o – one specimen; x –several; xx – common

FIGURE 1

DT-026

CONTAINED MATERIAL

depth in core	1.68m	1.75m	2.02 m	2.08 m
plant debris	x	x	x	x
insect remains	x	x		

Ecology	*?Freshwater environment*

Contained material is recorded on a presence (x)/absence basis

FIGURE 2

DT-029

CONTAINED MATERIAL

depth in core	2.42m
plant debris	x
molluscs	x
outer estuarine/marine foraminifera	x
outer estuarine/marine ostracods	x
brackish ostracods	x
brackish foraminifera	x

Ecology	*Large open estuary*

OUTER ESTUARINE/MARINE FORAMINIFERA

Elphidium macellum	**xx**
Ammonia batavus	**xx**
Eggerelloides scaber	**o**

OUTER ESTUARINE/MARINE OSTRACODS

Heterocythereis albomaculata	**xx**
Hemicythere villosa	**xx**
Hirschmannia viridis	**x**
Loxoconcha rhomboidea	**x**
Aurila convexa	**x**
Cythere lutea	**x**
Bonnyannella robertsoni	**x**
Pontocypris mytiloides	**o**

BRACKISH OSTRACODS

Cyprideis torosa	**xx**
Loxoconcha elliptica	**o**

BRACKISH FORAMINIFERA

Ammonia(brackish sp.)	**xx**
Elphidium williamsoni	**x**
Haynesina germanica	**x**

Trochammina inflata	**o**

Contained material is recorded on a presence (x)/absence basis
Foraminifera & ostracods are recorded: o – one specimen; x –several; xx – common

Foraminifer of mid-high saltmarsh

FIGURE 3