ARCA Geoarchaeology

July 2018

Report Number: 1718-17

LAND SOUTH OF MERRIELANDS CRESCENT, DAGENHAM, LONDON: GEOARCHAEOLOGICAL ASSESSMENT OF BOREHOLES AND ANALYSIS OF PALAEOENVIRONMENTAL DEPOSITS

Prepared for Cotswold Archaeology

Nick Watson *with contributions from* C.R. *Batchelor, D.S. Young T. Hill* and *P. Austin*

ARCA
Department of Archaeology and Anthropology
University of Winchester
Winchester
SO22 4NR
http://www.arcauk.com

Version	Date	Status*	Prepared by	Author's signature	Approved by	Approver's Signature
01	30/07/18	E	Nick Watson	N.M.Watson.		
*I – Internal draft; E – External draft; F - Final						

CONTENTS

FIGURES

TABLES

SUMMARY

Between 30th June and 2nd July 2017, ARCA carried out a geoarchaeological borehole survey on land south of Merrielands Crescent, Dagenham, Essex RM9 6SJ, at the request of Cotswold Archaeology Ltd to investigate the Late Pleistocene and Holocene strata. Six boreholes were drilled by Geotechnical Engineering and the results presented here are combined with earlier work at the site. In November 2017 two Archaeological Evaluation trenches were excavated on the site and a series of monolith samples were taken of the stratigraphy. The results of an assessment of the monoliths have been included in this report.

The stratigraphic units identified were: Modern Made Ground; Upper Alluvium (Holocene, estuarine fine grained tidal deposits); Peat (Holocene, wood and reed peat); Lower Alluvium (Holocene, floodplain and channel fill fine grained alluvium); Shepperton Gravels Formation (Pleistocene, river sands and gravels); and London Clay Formation (Eocene, local bedrock).

The London Clay Formation sub-crops against the Shepperton Gravels between -9.59m OD in BH02 and -6.65m OD in ARCA BH06.

A high elevation (+1.5m OD) longitudinal gravel (Shepperton) bank/bar was identified across the north and centre of the site adjacent to the line of pinch out against the Taplow Terrace to the north. To the south east the bank/bar was cut by a deep relict channel filled with silt. The minimum elevation of the gravels was -6.49m OD in BH05. Its thickness varied from 0.70m in BH05 to 6.50m in both BH02 and BH03.

Fine grained alluvium (Lower Alluvium) overlies the gravels and the top surface was found between -1.98m OD in ARCA BH05 and -0.84m OD in BH03. It varied in thickness from 0.51m in ARCA BH05 to 2.5m in BH05, and was itself conformably overlain by between 0.2m and 1.5m of peat, the top surface of which lies between -1.21m OD in TP01 and -0.14m OD in BH03. The peat was established by 3347 – 3098 cal BC in the Middle Neolithic, and stopped accumulating by 1494 – 1301 cal BC in the Middle Bronze Age.

An analysis of the pollen from a representative core ARCA BH05 has determined that the peat surface was largely occupied by alder-dominated fen woodland, whilst the dryland was composed of mixed deciduous woodland dominated by lime and oak. The following key changes were noted:

*1. The decline of lime woodland around 5300 – 5050 cal BP (*c*. 3350 – 3100 cal BC) consequent of paludification;*

*2. The colonisation and decline of yew from an estimated 5000 – 4000 cal BP (*c*. 3050 – 2050 cal BC), and*

3. The apparent decline of floodplain and dryland woodland from shortly before 3450 – 3250 cal BP (1500 – 1300 cal BC).

Analysis of the diatoms overlying the peat indicates a marine transgressive contact with the deposition of the Upper Alluvium and supports conclusions drawn from the lithostratigraphy. There is also some evidence of halophytic vegetation at the top of the peat sequence.

*As a result of a rising tidal frame minerogenic sedimentation (the Upper Alluvium) overwhelmed the peat in the Middle Bronze Age and estuarine conditions pertained on the site. The timing of the shift from freshwater to marine sedimentation (*c*. 1500 cal BC) complements the regional record of lowland coastal change.*

The top of the Upper Alluvium lies between -0.29m OD in BH02 and +1.13m OD in ARCA BH02. It ranges in thickness from 0.30m in BH05 to 2.10m in ARCA BH01.

Modern Made Ground truncates the Upper Alluvium and varies in thickness from 0.60m to 1.20m.

1 INTRODUCTION

1.1 Between 30th June and 2nd July 2017, ARCA carried out a geoarchaeological borehole survey on land south of Merrielands Crescent, Dagenham, Essex RM9 6SJ, henceforth known as the 'site' (Figure 1). The work was undertaken on behalf of Cotswold Archaeology Ltd and on the basis of a Written Scheme of Investigation (WSI) produced by Watson (2017a). Pre-application development proposals for the site have been drawn up by PRC Architecture & Planning Ltd on behalf of Friends Life Ltd: residential and retail units are proposed (PRC Architecture & Planning Ltd 2017). The results of this work were reported on in Watson (2017b) and it was recommended that the pollen and diatom assessments carried out on the representative borehole core ARCA BH05 be analysed in full. The results of this analysis are reported here and have been incorporated into the earlier report to provide a comprehensive whole. The geoarchaeological modelling has been revised.

1.2 Between 6th and 17th November Cotswold Archaeology Ltd conducted an Archaeological Trial Trench Evaluation at the site (Cotswold Archaeology 2017). Monoliths were taken from two trenches: Trench 1 monoliths 18 to 22; and Trench 2 monoliths 8 to 11. Two further monoliths (12 and 13) were also taken but have been discounted because of modern contamination. The monoliths were extracted and logged as two vertical point sections, one in each trench, from ground level. The results of an assessment of the pollen from peat horizons in these monoliths are also reported here.

1.2 This document assesses the stratigraphic sequence observed in the boreholes and monoliths. It is arranged as follows:

- First, a brief account is provided of the geographic, geological and methodological background to the geoarchaeological project.
- Secondly, geoarchaeological borehole stratigraphy is described in detail with reference to an earlier programme of geotechnical boreholes and trial pits carried out by Geotechnical Engineering Ltd in 2014 as well as records from the British Geological Survey (BGS) borehole database.
- Thirdly, the analysis of the palaeoenvironmental data and radiometric dating is described.
- Fourthly, the Quaternary setting of the site is discussed.
- Finally, conclusions and recommendations are drawn. A bibliography and appendices containing the locations of the boreholes, trial pits and monoliths, lithological descriptions of

the stratigraphy and palaeobotanical methodologies and assessments complete the document.

1.3 The site is located on the north edge of the flood plain of the River Thames adjacent to the higher ground of the Taplow Terrace and Ripple Road now the A1306 trunk road. The River Thames lies *c.* 1.6km due south and the town of Dagenham is to the north. The area of the site is *c.* 1.26 ha, it is approximately rectangular measuring *c.* 235m west to east by 75m north to south. The ground lies at an elevation of between *c.* +1.1m OD and +2.0m OD. There is a slight rise from south to north. Merrielands Crescent road bounds the site on the north, Chequers Lane on the east, The Gores – a minor tributary of the River Thames – on the west, and on the south is a DPD Transport Depot. At the time of the work the site was an unused carpark. Its location is at National Grid Reference (NGR) TQ 4894 8341, post code RM9 6SJ.

1.4 The British Geological Survey (BGS 1:50 000, 2016) position the site as lying on deposits of the Alluvium typically composed of unconsolidated clay with beds of silt, sand, peat and a basal gravel. The Alluvium dates to the Holocene Epoch (11.5ka – present) and forms the modern floodplain. The underlying gravel is assigned to the Shepperton Gravel Member (on altitudinal evidence) which was laid down between 15ka and 10ka (Gibbard 1994, 193). The higher Taplow Gravel Member is mapped immediately to the north of Merrielands Crescent and is older, dating to the Wolstonian Age (350ka –130ka), although the Kempton Park Gravel (assigned as younger Devensian) is marked as flanking the floodplain and forming the Taplow Terrace in Gibbard (1994, 2). Bedrock strata of the London Clay Formation underlies the Alluvium and Shepperton and Taplow gravels. It comprises grey or blue-grey, weathering to brown, silty or sandy clay and dates to the Eocene Epoch (56–33.9Ma) (BGS 2017a).

1.5 Desk based geoarchaeological investigation has been undertaken by Batchelor (2017a and b) at the Former Ford Stamping Factory and at Goresbrook Park immediately east and west of the site respectively. It has involved over 300 borehole records that demonstrate a Quaternary sedimentary sequence from oldest to youngest: Shepperton Gravel Member, Lower Alluvium, Peat, Upper Alluvium and Made Ground. This sequence is typical of the Lower Thames Valley and is also reported from Choats Road 0.8km south of the site (O'Gorman and Halsey 2010), and at Dagenham Dock 0.5km south east (McWilliams and McLellan 2016).

1.6 Radiometric dating of the peat in the environs of the site place its inception in the Late Mesolithic to Early Neolithic periods (see Section 8.2.6). Analysis of the palaeobotany of the peat reveals significant changes in the environment over time. At Hornchurch marshes, for example, (*c.* 2 km south east of the site) alder car woodland, the decline of elm and lime in the Neolithic to Bronze Age are recorded, followed by a transition to a reed swamp. The Bronze Age sees a decline in both wet and dry woodland. [see Batchelor (2017b, 4-5) for an up to date summary].

1.7 The site lies in Tier 2 of London Borough of Barking and Dagenham Archaeological Priority Areas (Ryan *et al* 2016, 87-90). A late Neolithic or early Bronze Age wooden figure, The Dagenham Idol, found in peaty soil in 1922 on the marsh edge near to Gores Brook south of Ripple Road is a significant find in the environs of the site. It is possibly votive and may have been deliberately deposited in the marsh itself. Just west of this findspot a metalled Bronze Age causeway was discovered in peat (Divers 1996). It is suggested that the causeway was for herding cattle to southern summer pastures. These two finds indicate the importance of peat for the preservation of archaeological evidence.

1.8 The aims of the geoarchaeological work at the site were set out in the WSI (Watson 2017, 4) and, including the analysis of the palaeobotanical evidence, are as follows:

1.8.1 Characterise the sedimentary sequence,

1.8.2 Assess the palaeoenvironmental potential of deposits,

1.8.3 Determine the absolute age of the organic strata,

1.8.4 Map and model the extent and thickness of lithostratigraphic units encountered,

1.8.5 Identify topographical features that may have archaeological significance, in particular the Alluvium-Shepperton gravel edge,

1.8.6 Assess the potential of the archaeological and palaeoenvironmental resource on the site, and

1.8.7 Analyse the palaeobotanical evidence contained in the representative core ARCA BH05.

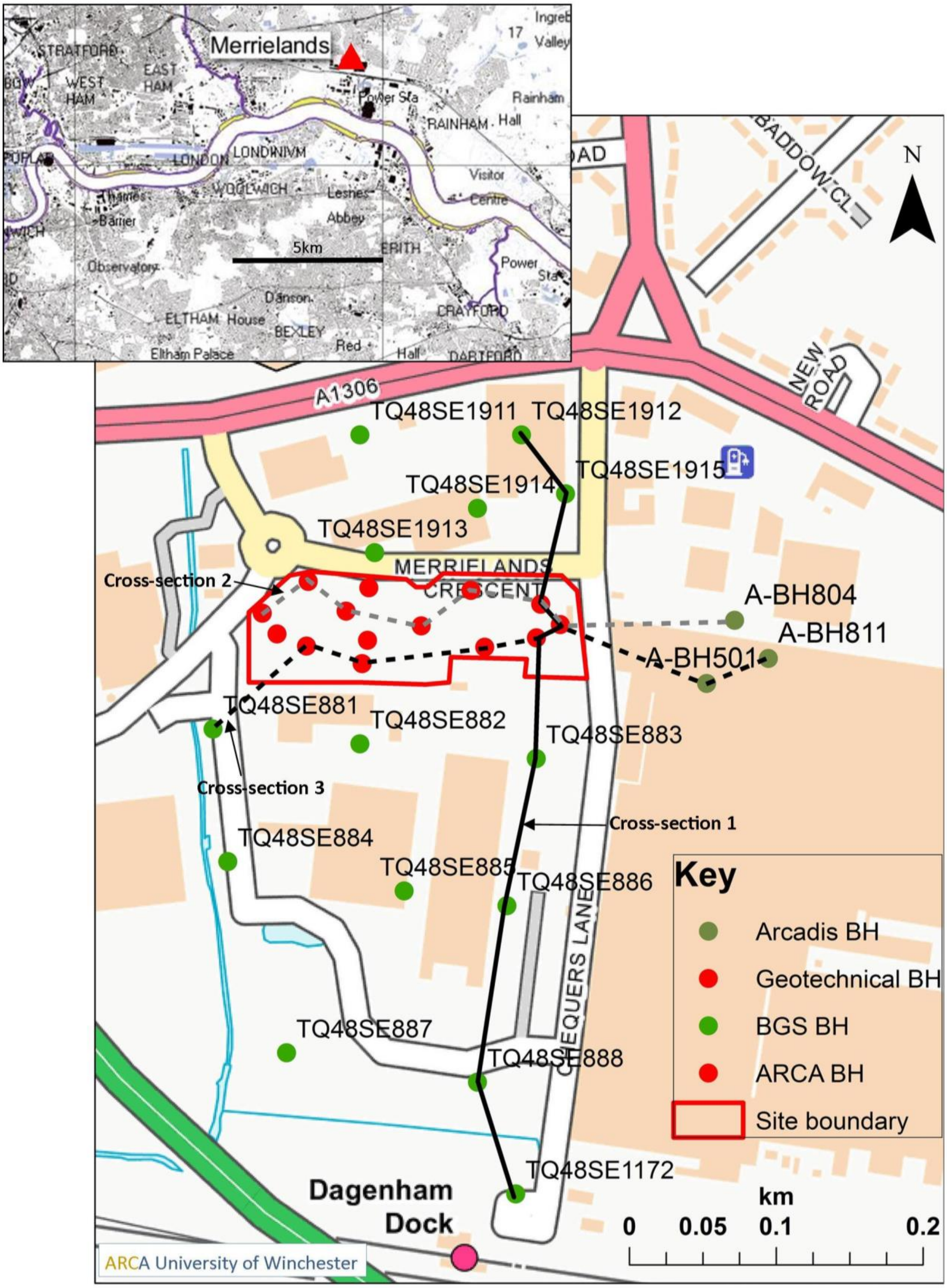

Figure 1. Site location showing boreholes (BH) discussed in the text and three lithostratigraphic cross-sections (Figure 8, Figure 9, Figure 10).

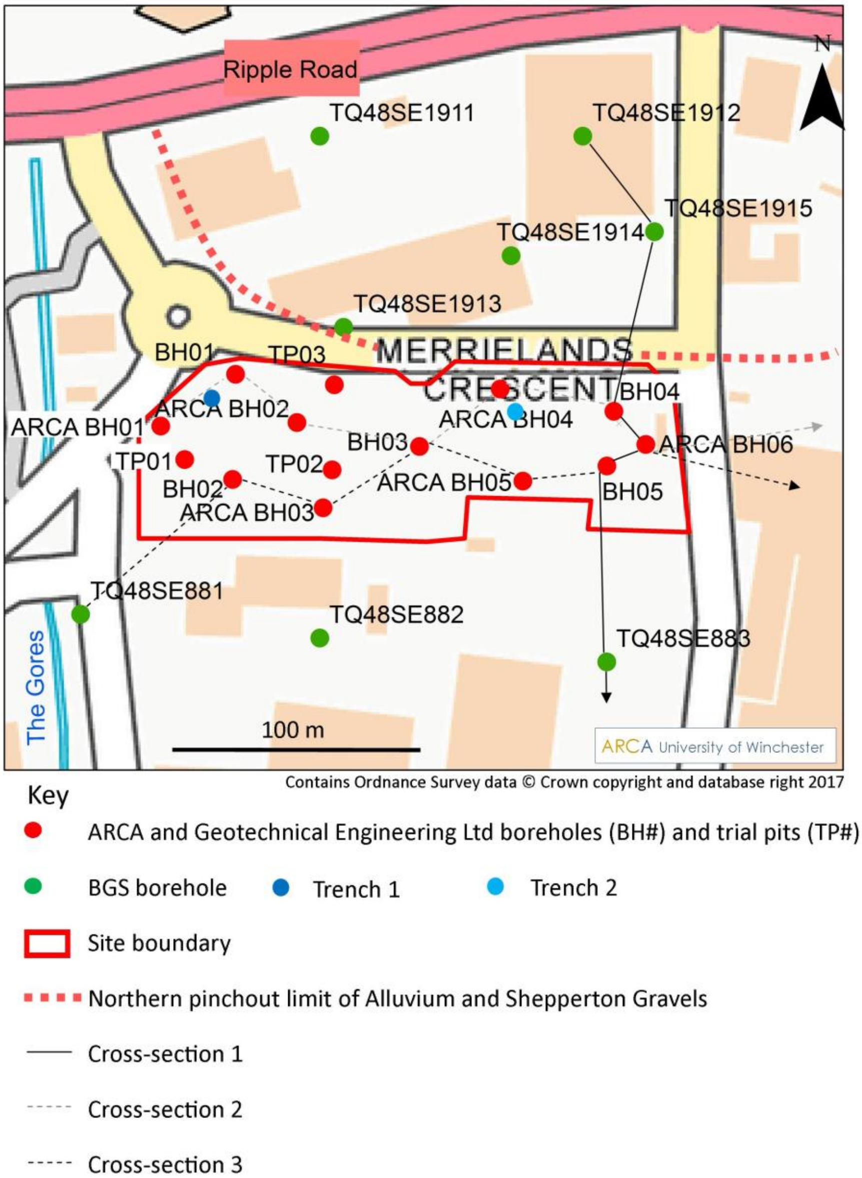

Figure 2. Site plan showing boreholes (BH) and Trenches 1 and 2 discussed in the text and three lithostratigraphic cross-sections.

2 METHODOLOGY

2.1 Borehole drilling and trench excavation

2.1.1 In 2017 six new boreholes (ARCA BH1 to ARCA BH6) were drilled to infill the earlier 2014 (BH1 to BH5) boreholes and trial pits (TP 1 to TP3). These geoarchaeological boreholes were drilled on the site by Geotechnical Engineering Ltd using a Pioneer 2 rig (Figures 1 and 2). The locations were surveyed to

Ordnance Datum (OD) and National Grid Reference. The cores were retrieved in plastic liners via the process of dynamic sampling (for details see Watson 2017b and Geotechnical Engineering Ltd 2017). The cores were logged and photographed according to standard criteria (Jones *et al* 1999; Munsell Color 2000; Tucker 2011). Lithological data was added to a RockWorks database.

2.1.2 The borehole core from ARCA BH05 was selected for palaeoenvironmental sampling. Seventeen sub-samples were extracted for palynological assessment, 15 for diatom assessment, and 2 for plant macrofossil assessment at Quaternary Scientific (Quest), University of Reading. Two sub-samples were submitted for C14 AMS absolute dating at Scottish Universities Environmental Research Centre (SUERC) Radiocarbon Dating Laboratory, East Kilbride.

2.1.3 Prior to the geoarchaeological work on the site, a programme of geotechnical work had been carried out by Geotechnical Engineering Ltd on the site in 2014 (Geotechnical Engineering Ltd 2014). A total of 5 boreholes (BH1 to BH5) were drilled by cable percussion and 3 trial pits (TP1 to TP3) were excavated by machine (Figure 2).

2.1.4 Within the vicinity of the site there are 14 boreholes recorded by the BGS (BGS 2017b) that contain useable lithological information (Figures 1 and 2). Four boreholes are located north of the site on the Taplow Terrace and ten to the south of the site. This has made possible a cross-section showing the lithostratigraphy to extend beyond the confines of the site to the north and south (Figure 1). Of those to the south, TQ48SE881 to TQ48SE888 were drilled in the 1960s when the land was undeveloped. Unfortunately no elevations were recorded at the time of drilling and therefore they have been estimated from spot heights on Chequers Lane and set at +0.5m OD.

2.1.5 In the public domain, there are no borehole records for several kilometres to the west and east of the site. As a consequence, and in order to extend cross-sections along this axis (the line of pinch-out of the Shepperton Gravels and the Holocene alluvium), Dr Rob Batchelor kindly provided details of boreholes drilled by Arcadis (A-BH#) on the Former Ford Stamping Factory site immediately east of Merrielands Crescent (Figure 1).

2.1.6 To complement the data obtained from the geoarchaeological boreholes, lithological descriptions and positional data from the boreholes and trial pits completed in 2014, the public domain BGS boreholes, and data from Trenches 1 and 2 completed in 2017, were combined within a RockWorks database (RockWare 2013). The RockWorks software package was then used to plot three lithostratigraphic cross sections (see Figures 8, 9 and 10), four 2-dimensional structural surface models (see Figures 11, 13, 14 and 16) and three isopach models (see Figures 15, 17 and 18). Appendices 1 and 2 record the raw data. The methodology for the modelling is discussed in Section 3.

2.1.7 Two archaeological evaluation trenches were excavated (for full details see Cotswold Archaeology 2017) (Figure 2). Each trench measured 15m by 10m at the surface and was stepped to expose an area of *c.* 2.5 x 1.5m at the base. Monolith samples were taken of the exposed sediments and delivered to the ARCA Laboratory at the University of Winchester. Each monolith sample was cleaned with a scalpel, logged and photographed according to standard criteria (Jones *et al* 1999; Munsell Color 2000; Tucker 2011). Lithological data was added to the existing RockWorks database and incorporated into the geoarchaeological models (see Section 2.1.6). Four sub-samples were taken using a $2cm^3$ extractor from the top and base of peat units and submitted to Quaternary Scientific (Quest), University of Reading for palynological assessment. Appendices 1 and 2 record the location and lithology of the monolith samples.

2.2 **Palaeoenvironmental analysis** *by C.R. Batchelor, D.S. Young T. Hill and P. Austin*

2.2.1 Seventeen samples were subjected to pollen assessment from ARCA BH05 along with, 15 samples for diatom assessment and 2 samples for assessment of macro fossils, e.g. wood fragments and insects. Of these samples 2 were selected for pollen analysis and 2 for diatom analysis on the basis of a good concentration and preservation of remains. A further 4 samples were assessed for pollen from Trenches 1 and 2. The methodologies employed are described in Appendix 3.

3 GEOLOGICAL DEPOSIT MODELLING

3.1 The borehole, test pit and trench lithologies from the site and environs (Figures 1 and 2) – a total of 28 boreholes, 3 trial pits and 2 trenches – were classified into formal and informal units for the purpose of stratigraphic description and deposit modelling. The stratigraphic units identified are (Figure 3):

1. Modern made ground.
2. Upper Alluvium (Holocene, estuarine fine grained tidal deposits),
3. Peat (Holocene, wood and reed peat),
4. Lower Alluvium (Holocene, floodplain and channel fill fine grained alluvium),
5. Shepperton Gravels Formation (Pleistocene, river sands and gravels,
6. London Clay Formation (Eocene, local bedrock).

3.2 Two-dimensional structural surface elevation models in mOD and structural thickness isopach models were generated for the stratigraphic units described above for the site and a limited area around the site. To ensure the maximum possible accuracy of the modelling process an inverse distance algorithm was employed with a cut-off distance of 31.5m. That is to say, from each datum point (borehole) the nearest eight points that lie within a radius of 31.5m are used. This avoids over generalising the model where data is sparse (Figures 11, 13 – 18).

3.3 The borehole data available vary greatly in age, detail and terms used. Every effort has been made to ensure compatibility between stratigraphic levels and lithological descriptors.

4 GEOARCHAEOLOGICAL DATABASE

Digital data used in this study, which includes photographs and the RockWorks database, is held on the University of Winchester server. Borehole cores are held for two months at Geotechnical Engineering Ltd: Centurion House, Olympus Park, Quedgeley, Gloucester GL2 4NF. Monoliths are held at the University of Winchester for one year after which they will be disposed of without further notice. Palaeoenvironmental data including slides, are held at Quest, School of Archaeology, Geography and Environmental Science (SAGES), The University of Reading, Whiteknights, PO Box 227, Reading, RG6 6AB. An unexpurgated version of the palaeoenvironmental report is available upon request.

5 RESULTS: BOREHOLE STRATIGRAPHY

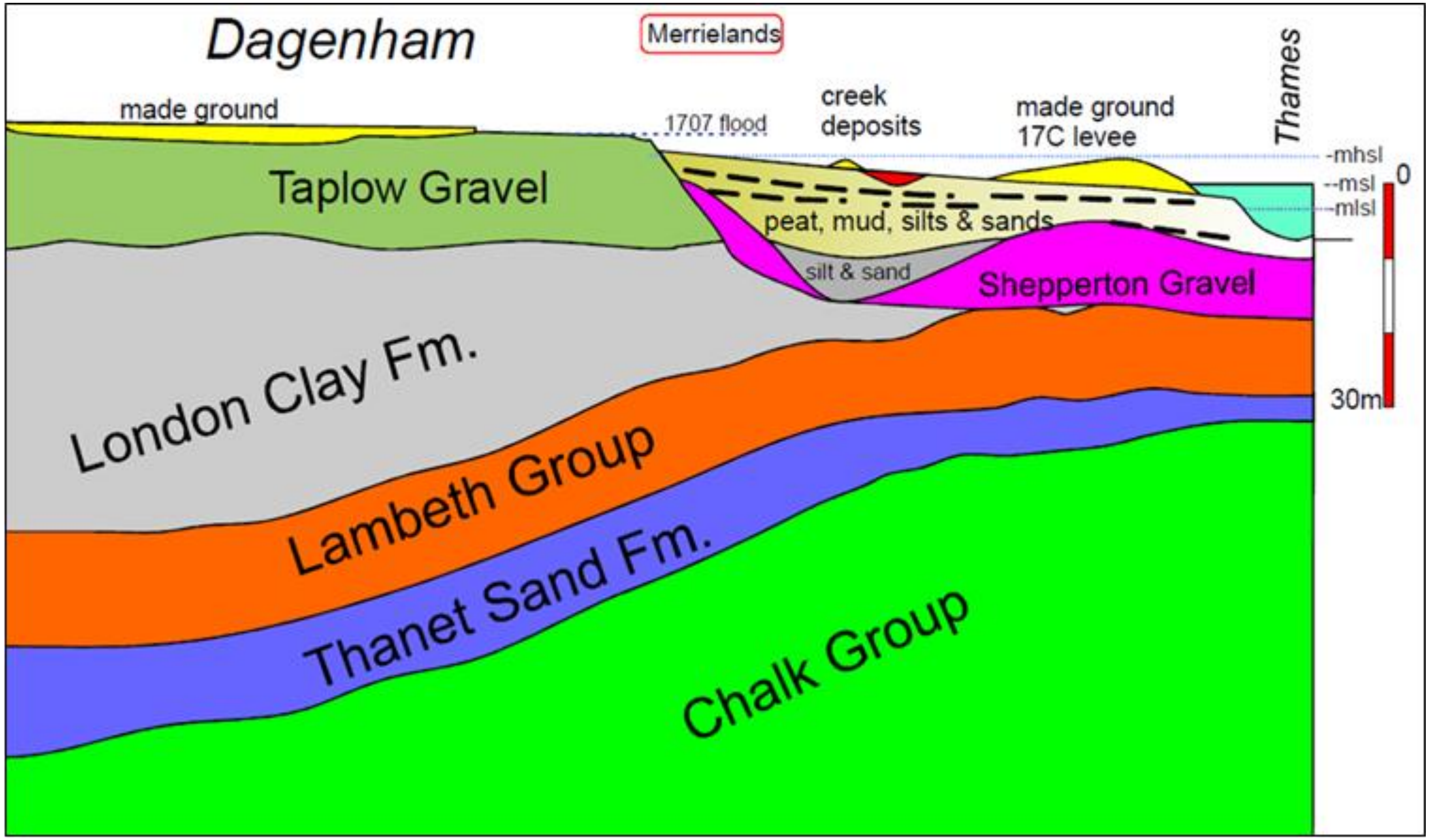

Figure 3. Schematic geological section at the site.

The sedimentary sequence found in the boreholes (ARCA BH01 to ARCA BH06 and BH01 to BH05), trial pits (TP01 to TP03) and Trenches 1 and 2 is divided into six stratigraphic units. These units are described in stratigraphic order below.

5.1 London Clay Formation

5.1.1 The London Clay Formation (Eocene) is recorded in six boreholes: ARCA BH06, BH01 to BH06 and sub-crops against the Shepperton Gravels between -9.59m OD in BH02 and -6.65m OD in ARCA BH06. It is firm to stiff brownish grey slightly sandy clay with frequent fine to coarse sand-sized, secondary, white selenite crystals.

5.1.2 The London Clay Formation is unconformably overlain by the much younger Shepperton Gravel Member (Late Pleistocene/Devensian).

5.2 Shepperton Gravel Member

5.2.1 The Shepperton Gravel Member is recorded in all the boreholes. Its top lies between -6.49m OD in BH05 and -1.50m OD in ARCA BH04.

5.2.2 The gravel has an overall olive grey (5 Y 5/2) appearance and is a poorly sorted mixture of fine to coarse sand and flint pebbles. The clasts are angular to sub-rounded, granular to medium pebble-sized black flint. They are frequently patinated white. Fine to coarse sand makes up <50%. The channel gravels are frequently interbedded with fine to coarse sand that is occasionally well sorted. The unit varies in thickness from 0.70m in BH05 to 6.50m in both BH02 and BH03.

5.2.3 BH05 uniquely includes a 'firm brownish grey sandy silt' at -4.39m OD which is 2.1m thick. It overlies the coarser grained channel (Shepperton) gravel and is probably a later (early Holocene) fine grained channel fill rather than an upper facies of the Shepperton Gravel (see Section 8.1.5).

5.2.4 The Shepperton Gravel Member and the silt is overlain by the Alluvium, which is divided into three units: Lower Alluvium, Peat, and an Upper Alluvium.

5.3 Lower Alluvium

5.3.1 The Lower Alluvium is recorded in all the boreholes except in ARCA BH04 and ARCA BH06. In the former there was no peat and the distinction between Lower and Upper Alluvium was not possible to make. In the latter silt/clay was noted on retrieval at the site but was lost when the borehole casing split. The top of the Lower Alluvium is found between -1.98m OD in ARCA BH05 and -0.84m OD in BH03 where it is 0.51m and 0.90m thick respectively. The maximum thickness of 2.50m is found in BH05 and minimum thickness in ARCA BH05.

5.3.2 The Lower Alluvium is a grey (5 Y 5/1), compact and homogenous silt/clay. Granular-sized fragments of peat and organic particles characterise the top of the unit. In ARCA BH05 a black organic-rich mud/clay caps the unit. Rare medium pebble-sized wood clasts are recorded in ARCA BH02 and BH05. To the west of the site (ARCA BH01) the Lower Alluvium is more arenaceous and has a high silt content grading from very fine sand at the base. A similar lithology is also present in neighbouring BH01. The high elevation of the unit in BH03 results in localised oxidation to give a brown colour and rare *in situ* fine rootlets were noted.

5.3.3 The Lower Alluvium is conformably overlain and quickly grades into the Peat unit.

5.4 Peat Member

5.4.1 Peat is recorded in the 3 trial pits, in Trenches 1 and 2, and in 10 of the 11 boreholes with the exception of ARCA BH04 where there is no peat present. Its top lies between -1.21m OD in TP01 and -0.08m OD in Trench 2. The thickness of the unit varies greatly from 0.20m in BH01 to 1.50m in BH05.

5.4.2 The Peat is moderately well humified and oxidises on exposure from reddish black to black (7.5 YR 2.5/1). It has a firm fibrous texture with discrete coarse sand-sized (0.5–2mm) plant fibres and evidence of horizontal laminations particularly towards the base. Fine pebble-sized wood clasts are occasional to frequent. The unit has a sharp lower contact except in ARCA BH05 where it grades into an organic mud. Fluvially sorted particles in the peat unit from Trench 2 and the presence of recutting minor channels seen in section (Cotswold Archaeology 2017, fig 7) suggests that reworking may have occurred in the top of the peat at this location.

5.4.3 The Peat is conformably overlain by the Upper Alluvium and the boundary is generally diffuse.

5.5 Upper Alluvium

5.5.1 The Upper Alluvium is recorded in all the boreholes, trial pits and trenches. In ARCA BH04 its thickness is estimated at 1.2m. The unit is found between -0.29m OD in BH02 and +1.13m OD in ARCA BH02. It ranges in thickness from 0.30m in BH05 to 2.10m in ARCA BH01.

5.5.2 The Upper Alluvium is dark greenish grey (Gley 1 4/10Y) to dark bluish grey (Gley 2 4/5B), compact, homogenous and unlaminated silt/clay with occasional coarse sand-sized spots of black (reduction spots) silt/clay. Detrital peat granules (lag) are frequent at the contact with the underlying peat. The unit is mottled and oxidised olive brown (2.5 Y 4/3) in ARCA BH04, TP01, TP03, BH01–BH04, and in Trenches 1 and 2. Occasional grains and granules of orangish brown iron oxide are present. ARCA BH05 also shows some evidence of iron oxide mottling. A fine pebble-sized angular sherd of white porcelain was recovered from ARCA BH04 at 3.08m BGL.

5.5.3 The Upper Alluvium is the youngest natural deposit. It is unconformably overlain by modern Made Ground.

5.6 Made Ground

5.6.1 Modern Made Ground is recorded in all the boreholes, trial pits and trenches. It varies in thickness from 0.60m in ARCA BH01 to 1.20m in ARCA BH04, ARCA BH06, TP01, BH01, BH04 and BH05. It is composed of black (7.5 YR 2.5/1) fine to medium sand-sized particles and frequent comminuted charcoal and fine pebble-sized vesicular slag/cinder. Brick, concrete and flint clasts (demolition debris) are present too. On occasion metal and glass was noted (BH02 and BH03). The material is loose and has a sharp contact with the underlying Upper Alluvium. The Made Ground is capped by *c.* 0.1m of tarmacadam and/or concrete that forms the surface of the car park.

6 RESULTS: POLLEN ANALYSIS *by C.R. Batchelor, D.S. Young T. Hill and P. Austin*

6.1 The percentage pollen diagrams resulting from the analysis of ARCA BH05, and assessment of samples from monoliths 10, 21 and 22 are displayed in Figures 4 and 5 respectively. The pollen diagram for ARCA BH05 has been divided into four local pollen assemblage zones (LPAZ MER 1-4)

6.2 LPAZ MER-1 -1.98 to -1.74m OD *Alnus* – *Tilia* – *Corylus* type

This zone is characterised by high values of tree (75%) and shrub pollen (15%), dominated by *Alnus* (40%), *Tilia* (25%), *Quercus*, *Corylus* type (both 10-15%) with *Pinus*, *Betula* and *Fraxinus* and *Salix* (all <2%). Herbs (10%) are dominated by Poaceae and Cyperaceae with Lactuceae and sporadic occurrences of *Plantago lanceolata*, Apiaceae, *Chenopodium* type and Rosaceae. Aquatics are absent and spores (20%) are dominated by *Dryopteris* type with *Pteridium aquilinum* and *Polypodium vulgare*. Total pollen concentration is relatively low, ranging between 17,000 and 40,000 grains/cm^3. Microcharcoal is recorded in very high to abundant numbers.

6.3 LPAZ MER-2 -1.74 to -1.25m OD *Alnus* – *Quercus* – *Corylus* type

Much of this zone traverses a void in the sedimentary sequence, however, the samples either side of it contain a similar pollen assemblage. It is largely characterised by a reduction in *Tilia* values from 25-5%, whilst *Alnus* increases to 55%, with *Quercus* (20-25%), *Corylus* type (5%) and sporadic occurrences of *Taxus*, *Fraxinus*, *Salix* and *Sambucas nigra* (all <2%). Herbs (<10%) are dominated by Cyperacae with sporadic occurrences of Poaceae, *Plantago* type and Apiaceae. Aquatics are represented by a single occurrence of *Nuphar* type, whilst spores (20%) continue to be dominated by *Dryopteris* type with *Pteridium aquilinum* and *Polypodium vulgare*. Total pollen concentration is moderate, ranging between 80,000 and 550,000 grains/cm3. Microcharcoal is largely absent.

6.4 LPAZ MER-3 -1.25 to -0.95m OD *Alnus* – *Quercus* – *Corylus* type – *Taxus*

This zone is characterised by an apparent increase in the range of tree and shrub taxa. *Alnus* dominates (increasing to 70%), with *Quercus* (decreasing to 10%), *Corylus* type (<10%), *Tilia, Ulmus, Taxus, Betula* (all <5%), and sporadic occurrences of *Ilex* type, *Hedera*, *Salix* and *Vibernum* type. Herbs are limited (<5%)

but include sporadic occurrences of Cyperaceae, Poaceae, *Cereale* type, *Artemisia*, Caryophyllaceae, *Chenopodium* type and Apiaceae. Aquatics are represented by a single occurrence of *Nuphar* type. Spores are limited (<10%) dominated by *Dryopteris* type with *Pteridium aquilinum* and *Polypodium vulgare*. Unidentifiable grains are present throughout the zone. Total pollen concentration is high, ranging between 300,000 and 1,900,000 grains/cm3. Microcharcoal is absent.

6.5 LPAZ MER-4 -0.95 to -0.83m OD *Alnus* – Poaceae – Cyperaceae

This zone is characterised by an increase in herbaceous pollen to 40%, before declining towards the top of the zone. Poaceae and Cyperaceae dominate with Asteraceae, Lactuceae, *Chenopodium* type, Apiaceae, *Filipendula* type and sporadic occurrences including *Cereale* type, *Cirsium* type and *Plantago lanceolata*. Trees (50-80%) and shrubs (<10%) are dominated by *Alnus* with *Quercus*, *Corylus* type (5%), *Fraxinus*, *Tilia*, *Pinus*, *Betula*, *Salix* (all <2%) and sporadic occurrences of *Taxus* and *Hedera* (<1%), Aquatics (<5%) include *Typha latifolia* and *Sparganium* type. Spores (>60%) are dominated by *Dryopteris* type with *Pteridium aquilinum*, *Sphagnum* and *Polypodium vulgare*. Total pollen concentration is *generally* relatively low <50,000 grains/cm^3. Microcharcoal is absent.

6.6 Pollen assessment samples from trenches 1 and 2

Those samples that underwent pollen assessment contain a similar pollen assemblage to that recorded within the upper zones. Each of the samples is characterised by high values of tree (70-90%) and shrub (<10%) pollen dominated by Alnus with Quercus, Corylus type and more sporadic occurrences of Pinus, Tilia, Ulmus, Fraxinus, Betula, Hedera, Ilex, Salix and possibly Fagus. Herbs (<20%) are most commonly represented by Poaceae and Cyperaceae with Plantago lanceolata, Chenopodium type, Rumex undifferentiated, Apiaceae, Galium type and Valeriana type. Aquatics are absent, and spores (<10%) are represented by Dryopteris type with sporadic Polypodium vulgare and Sphagnum. Total pollen concentration is moderate to high, ranging between 70,000 and 600,000 grains/cm^3. Microcharcoal was either absent or recorded in negligible numbers.

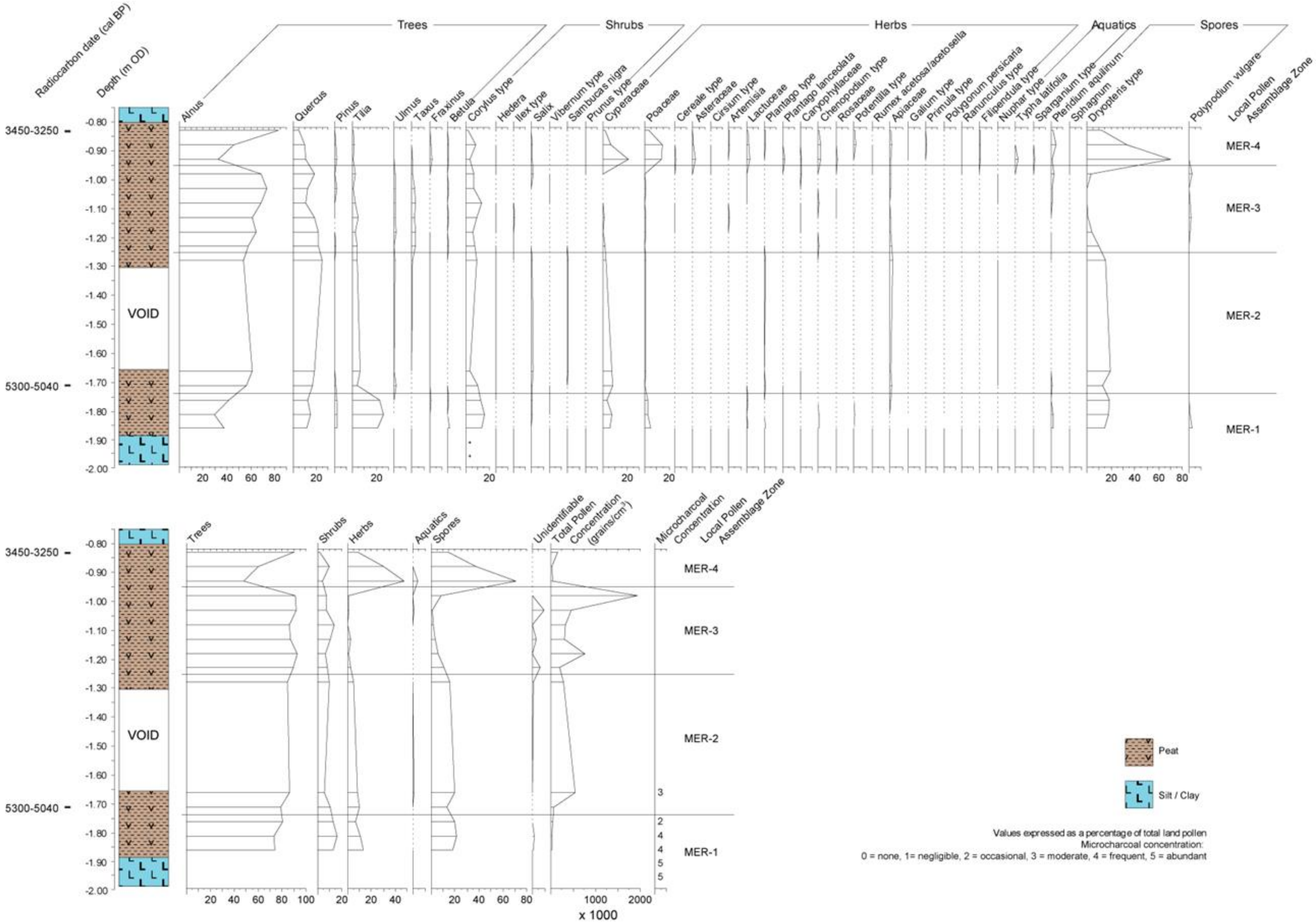

Figure 4. Pollen percentage diagram, ARCA BH05.

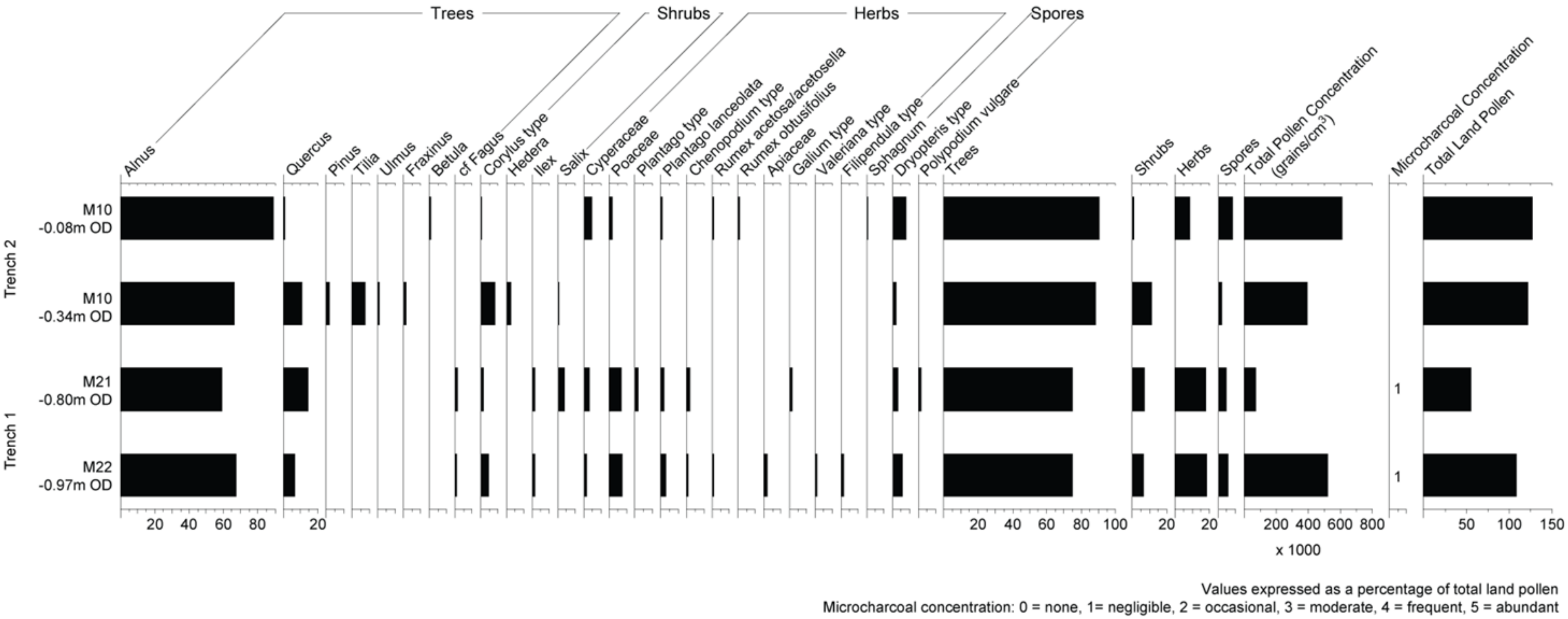

Figure 5. Pollen percentage diagram of assessed samples from monoliths 10 (Trench 2), 21 (Trench 1) and 22 (Trench 1).

7 INTERPRETATION: POLLEN ANALYSIS *by C.R. Batchelor, D.S. Young T. Hill and P. Austin*

7.1 The lowermost two samples of borehole ARCA BH05 from beneath LPAZ MER-1 contained a near absence of pollen. Only a few grains of *Corylus* type (hazel) were recorded together with a high concentration of microcharcoal. These samples correlate with the uppermost part of the silt-clay alluvial deposits prior to the accumulation of the peat. It is not possible to carry out a vegetation reconstruction based upon this very limited pollen assemblage.

7.2 LPAZ MER-1 -1.98 to -1.74m OD *Alnus* – *Tilia* – *Corylus* type

Local Pollen Assemblage Zone MER-1 pre-dates 5300 – 5040 cal BP (early Neolithic) and correlates with the lowermost part of the Peat. During this period, the growth of alder (*Alnus*), willow (*Salix*) and sedges (Cyperaceae) is indicated, forming swamp carr woodland with grasses, most likely including reeds (Poaceae – *Phragmites australis*), bur-reed (*Sparganium* type), members of the carrot family, probably including taxa such as water dropwort (Apiaceae – *Oenanthe* type), undifferentiated and polypody ferns (*Dryopteris* type / *Polypodium vulgare*).

7.3 Hazel (*Corylus* type) and oak (*Quercus*) may have accompanied alder on the floodplain surface. However, these taxa more commonly occur on dryland where they would have formed a mosaic of mixed deciduous woodland dominated by lime (*Tilia*). Percentage values of *Tilia* are around 25% during LPAZ MER-1, but due to the entomophilous (insect pollinated) nature of lime, these relatively high percentage values suggest the considerable growth of this tree in the immediate vicinity; it undoubtedly occupied the dryland surface beyond the edge of the floodplain but is also likely to have grown on gravel eyots within the floodplain that were elevated above the peat surface during this Early Neolithic period.

7.4 Elm (*Ulmus*) is completely absent from the pollen record during this period, inferring that the sequence post-dates the well documented Neolithic elm decline, which is recorded across the Lower Thames Valley (Batchelor *et al*, 2014) and north-western Europe (Parker *et al*, 2002) between *c.* 6300 and 5300 cal BP, representing one of the most important changes in vegetation at this time.

7.5 It is of note that microcharcoal values are generally very high during this period suggesting that the local environment was subject to episodes of burning throughout this period; though whether this was of natural or anthropogenic origin is not possible to ascertain as there are no other palynological indicators.

7.6 LPAZ MER-2 -1.74 to -1.25m OD *Alnus* – *Quercus* – *Corylus* type

This zone consists of only a few samples separated by a void in the sedimentary sequence. It is characterised by a distinct reduction in *Tilia* pollen values, suggesting a rapid reduction in lime woodland. The fact that this occurs suddenly, and towards the base of the peat, suggests it occurred as a result of peat expansion onto areas of former dryland (paludification). The cause(s) of the middle Holocene lime decline in the UK have been comprehensively reviewed by Grant *et al* (2011), and the cause of this early event at Merrielands would appear to be an example of paludification Type II: a rapid decline associated with a transition from dryland to peat formation (see also Waller, 1994). However, because alder values expand in tandem with the decline in lime, it is possible that the change observed is in part due to reciprocal changes in pollen representation due to the representation of the data as percentages rather than absolute values (Grant *et al*, 2011). With the exception of this event, there are no other marked changes in vegetation from that recorded during LPAZ MER-1.

7.7 LPAZ MER-3 -1.25 to -0.95m OD *Alnus* – *Quercus* – *Corylus* type – *Taxus*

The transition to LPAZ MER-3 is characterised by the occurrence of *Taxus* pollen, albeit in modest proportions, representing the nearby colonisation of yew within the local woodland. Yew is now known to have been an important component of the alder-dominated woodland on the peat surface of the Lower Thames Valley, spanning from at least the East India Docks (Pepys, 1665) in the west to Aveley Parish and Erith Forest in the east (Wilkinson and Murphy, 1995; Seel, 2001), according to multi-proxy palaeoenvironmental investigations. Locally, yew pollen and wood has been recorded at Hornchurch Marshes (Branch *et al*, 2012) and Barking Riverside (Green *et al*, 2014). Combined, these investigations from the Lower Thames Valley tend to indicate that yew colonised the floodplain woodland around 5000 cal BP, declining approximately 1000 years later; findings that are supported by the results from Merrielands.

7.8 Recent investigations aimed at increasing our knowledge and understanding of the palaeoecology of yew (Batchelor, 2009, Branch *et al* 2012; Batchelor *et al*, in prep) indicate that a dry peat surface was almost certainly required to enable the growth of yew on the Lower Thames Valley peat surface, however, more favourable climatic conditions, and likely areas of human disturbance may have influenced the colonisation of yew on the peat surface. The decline of yew was often related to wetter peat surface conditions, most likely caused by continually rising relative sea level. It is also considered likely that human activity had a far greater influence on the decline of yew, than on its expansion, and it is notable that the decline occurs around the time of the transition from the Neolithic to Bronze Age.

7.9 LPAZ MER-4 -0.95 to -0.83m OD *Alnus* – Poaceae – Cyperaceae

The transition to LPAZ MER-4 shortly before 3450 – 3250 cal BP (Bronze Age) is marked by an initial decline of tree and shrub pollen, whilst the range and percentage values of herbaceous taxa increases. On the floodplain, the initial decline of alder is mirrored by the expansion of grasses (probably including reeds) and sedges, bur-reed and bulrush indicating a wetter peat surface and a transition towards sedge fen/reed-swamp communities. A saline influence also cannot be ruled out due to the presence of *Chenopodium* type (goosefoot family); members of this family can occupy disturbed ground (e.g. *Chenopodium album* - fat hen) or saltmarsh (e.g. *Suaeda maritima* – annual seablite).

7.10 On the dryland, the reduction of oak and possibly hazel is suggestive of a reduction in the dryland woodland. The increase of a large array of herbaceous taxa could suggest that this decline was a consequence of woodland clearance for settlement and agricultural purposes, which took place from the Bronze Age onwards. It is certainly of note that a few grains of cereal pollen were present, potentially indicating nearby cultivation or crop-processing activities. However, the *Cereale* type group includes both cereals and wild grasses (Andersen, 1979), and previous studies have suggested a strong association between these grains and those of other wetland herbaceous and aquatic taxa (e.g. Poaceae, Cyperaceae, *Sparganium*). Thus it is possible that these grains could represent wild grasses found in wetland habitats (e.g. *Glyceria* sp. - mannagrass) (Waller and Grant, 2012; Perez *et al*, 2015).

7.11 The near synchronous change in vegetation on both the floodplain and dryland woodland does suggest a link between the two environments and is a common feature of pollen-stratigraphic records from across the Lower Thames Valley (see e.g. Waller and Grant, 2012; Batchelor *et al*, in prep).

7.12 Pollen assessment samples from Trenches 1 and 2

Assessment of the samples from the top of the peat (-0.80 and -0.97m OD) in monoliths 21 and 22 of Trench 1 contain a similar assemblage and thus palaeoenvironmental reconstruction to that recorded in ARCA BH05 approximately 120m to the east.

7.13 The samples assessed from the higher peat in Trench 2 (-0.08 and 0.34m OD; monolith 10) contains a more mixed assemblage. The lower of the two samples contains a greater range of tree and shrub taxa including lime, elm, ash and ivy (Hedera), by comparison to that recorded in the sample from -0.08m OD, and to that recorded in the two assessed samples from Trench 1. Whilst this might indicate the presence of a more diverse mixed deciduous woodland during this period, it may also be that this peat unit is not *in situ* and has been reworked from an older deposit (see Section 5.4.2). This could only be confirmed by radiocarbon dating.

8 RESULTS: DIATOM ANALYSIS *by C.R. Batchelor, D.S. Young T. Hill and P. Austin*

8.1 A summary of the diatom results is provided in Table 1. In the majority of cases, taxa were identifiable to species level, but in some instances, identifications were only possible to genera level (primarily when broken fragments of larger frustules were encountered). Only taxa with presence above 2% of Total Diatom Valves (TDV) are displayed for ease of subsequent interpretation.

8.2 The diatoms encountered within the two samples from ARCA BH05 are displayed according to their broad salinity and life form classifications. For example, ‘marine planktonic’ species are those that are encountered in open marine waters with salinities typically greater than 20-30‰ and are found floating in the water column. In contrast ‘brackish benthic’ species are those encountered in waters more typically associated with shallow estuarine settings with salinities closer to 1-9‰. In addition, their benthic status indicates that these species live attached to or within the sediment substrate under investigation. Benthic taxa can be further divided, based on substrate preference:

- Epiphytic taxa are often found attached to organic material (plants and decomposing organic debris),
- Epipelic taxa attach themselves to muddy deposits,
- Epipsammic taxa are associated with sandy substrates, and
- Aerophilous taxa require a period of both aquatic submergence and emergence, and in the case of coastal sequences are strongly associated with the intertidal zone.

8.3 These additional benthic subdivisions are referred to (where relevant) within Table 1 and the associated discussion section. In addition, the importance of differentiating between planktonic and benthic species is outlined in greater detail at a later stage, but in essence benthic taxa are seen as providing a more reliable indicator of palaeoenvironmental conditions, as they are likely to have lived in-situ within the sediment under analysis. By contrast, planktonic taxa live suspended in the water column and thus have the potential to be carried into a depositional environment after death (and hence not necessarily provide a reliable reflection of the prevailing conditions at the time).

8.4 Table 1 also provides greater focus on the salinity requirements of the diatom taxa encountered, dividing the species into the following categories: Polyhalobous (>30‰; fully marine), Mesohalobous (0.2-30‰; brackish water), Oligohalobous (<0.2‰; salt tolerant) and Halophobous (0‰; exclusively freshwater). The Oligohalobous category can be further subdivided into Oligohalobous halophilous (salt-tolerant freshwater) and Oligohalobous indifferent (tolerant of slightly saline water). Such an approach enables the overall salinity of the depositional environment to be taken into account, incorporating both planktonic and benthic taxa together. In the case of the samples under investigation, no halophobous taxa were encountered.

8.5. The vast majority of taxa encountered were marine and brackish species, and due to this the data set has the potential to be incorporated into the palaeoenvironmental scheme of Vos and de Wolf (1993). This scheme enables the diatom assemblages to be interpreted to infer a likely position of the sediment sample within the palaeo-tidal frame (at the time of deposition). Table 2 summarises the diatoms assemblage compositions that are associated with differing elevations within the littoral zone.

8.6 Diatom preservation was good in both samples and consequently full counts were achieved. The diatom assemblages display a clear dominance of marine, marine brackish and brackish taxa, with both planktonic and benthic species contributing to the floral diversity. Of the benthic taxa present, most are typically associated with muddy (epipelon) and organic rich (epiphytic) substrates, and some are aerophilous taxa (and hence infer periods of sub-aerial exposure). Such groupings therefore indicate a tidal setting. The continued presence of a mixture of marine, brackish and freshwater planktonic taxa, present throughout the depositional record (but decreasing in overall abundance with height) further supports this, and infers that deposition silt/clay overlying the peat, took place within the intertidal zone. Taking into account this stratigraphic context, the vertical shift from an underlying peat unit into an apparent layer of alluvium would, on face value, be indicative of a rise in relative sea level.

8.7 Table 1 shows that there is a subtle shift in the diatoms with elevation. The lowermost sample has a greater abundance of lower salinity planktonic and benthic taxa, whilst the overlying sample contains an assemblage more typified by brackish and marine flora. The assemblages from the sample closest to the underlying peat (-0.73m OD) contains planktonic taxa in relative abundance, but with the brackish species *Cyclotella striata* wholly dominating the planktonic assemblage. Higher salinity planktonic taxa, such as *Paralia sulcata, Pseudomelosira westi* and *Pseudopodosira stelligera* are present, but are much less common. In the benthic realm, sample -0.73m OD contains a mixture of marine-brackish, brackish-fresh and fresh taxa, most typified by *Diploneis ovalis* (MB aerophilous), *Pinnularia viridis* (BF aerophilous) and *Epithemia zebra* (F epiphytes). In contrast, within the overlying sample (-0.63m), whilst the brackish taxa *Cyclotella striata* remained influential, higher salinity plankton are more abundant with *Paralia sulcata, Pseudomelosira westi* and *Pseudopodosira stelligera* once again noted but in greater abundance. Additional marine planktonic taxa such as *Actinoptychus senarius* and *Triceratum favus* were also present. The benthic taxa of -0.63m displayed a reduction in the influence of freshwater taxa, with *Epithemia zebra* only contributing small numbers, whilst *Pinnularia viridis* also shows a reduction in abundance (but not to the same extend as *E. zebra*). When the reduction in *P. viridis* is combined with the drastic reduction in *Diploneis ovalis*, there is a distinct fall in the influence of aerophilous taxa. In their place, there is an increase in marine-brackish epipelon species in addition to occasional marine epipelon species (*Diploneis weissflogii, Navicula digitoradiata, Nitzschia sigma*). However it must also be noted that a large number of unidentifiable *Pinnularia* sp. were encountered at -0.63m, due to the highly fragmented nature of the frustules restricting identifications. *Pinnularia* species can be encountered in both freshwater and brackish water environments and hence the inability to identify to species level may impact on the subsequent interpretations.

8.8 In terms of salinity preferences, Table 1 confirms the absence of any halophobous taxa, with salt tolerant species dominating the profile. A similar trend is displayed as the planktonic vs benthic picture, with an increase in the influence of polyhalobous and mesohalobous taxa with height, with oligohalobous indifferent taxa more typical within the lower sample. In terms of lifeform classifications, epiphytic and aerophilous taxa are more typical at -0.73m OD depth, whereas epipelon and aerophilous species become dominant above, at -0.63m depth.

	Species	lifeform	salinity preference	Sample Depth (m O.D.)	
				-0.63	-0.73
Planktonic	*Actinoptychus senarius*	M Plank	A	20	6
	Paralia sulcata	M Plank	A	21	8
	Pseudomelorira westii	M Plank	A	12	6
	Pseudopodosira stelligera	M Plank	A	15	4
	Triceratum favus	M Plank	A	6	4
	Delphineis surirella	M Tych	B	6	
	Odontella aurita	M Tych	B		1
	Rhaphoneis amphiceros	M Tych	B	1	2
	Cyclotella striata	B Plank	B	121	164
	Stephanodiscus sp	F Plank	D		2
Benthic	*Navicula lyra*	M Epipel	A	1	
	Diploneis weissflogii	M Epipel	A	5	
	Diploneis ovalis	MB Aero	C	9	52
	Diploneis interrupta	MB Aero	C	5	
	Campylodiscus echeneis	MB Epipel	B	9	5
	Diploneis didyma	MB Epipel	B	9	6
	Navicula avenacea	MB Epipel	B		
	Navicula digitoradiata	MB Epipel	B	12	
	Navicula hungarica	MB Epipel	D	20	
	Nitzschia navicularis	MB Epipel	B	2	26
	Nitzschia punctata	MB Epipel	B	12	
	Nitzschia sigma	MB Epipel	B	15	
	Achnanthes brevipes	MB Epiphyt	B		3
	Pinnularia viridis	BF Aero	C	31	51
	Amphora ovalis	F Epipel	D	9	8
	Navicula oblonga	F Epipel	D		6
	Epithemia zebra	F Epiphyt	D	6	49
	Cymbella aspera	F Epiphyt	D	3	4
	Stauroneis acuta	Fresh unknown	D	2	2
	Gyrosigma sp.	unknown	F	3	
	Pinnularia sp.	unknown	F	45	8
	Total			400	417

Key: M Plank = marine planktonic; M Tych = marine tychoplanktonic, B Plank = brackish planktonic; F Plank = fresh planktonic; M Epipel = marine epipelon, MB Aero = marine-brackish aerophilous; MB Epipel = marine-brackish epipelon; MB Epiphyt = marine-brackish epiphytic; B epipel = brackish epipelon, BF epipel = brackish-fresh epipelon; BF Epiphyt = brackish-fresh epiphytic; F Epipel = Fresh epipelon; F Epiphyt = fresh epiphytic. Salinity preferences: A = polyhalobous; B = mesohalobous; C = oligohalobous halophilous; D = oligohalobous indifferent; E – euhalobous (n/a); F = unknown

Table 1 Diatom flora encountered during analysis of samples from ARCA BH05.

Ecological groups	**Macro- and mesotidal environments**							**Microtidal and non-tidal environments**		
	Subtidal area		Intertidal area		Supratidal area			Marine/brackish		non-marine (fresh)
	open marine tidal channels	estuarine tidal conditions	sand-flats	mud-flats	salt-marshes, around MHW	salt-marshes, above MHW	pools in the salt-marshes	tidal lagoons, small tidal inlet	lagoons, no tides	rivers, ditches, lakes
Marine plankton	10-80	10-60	1-25	10-70	10-70	10-70	10-50	10-60	0-10	0-5
Marine tychoplankton	20-90	15-60	1-25	10-70	10-70	10-70	10-50	10-60	0-10	0-5
Brackish plankton	1-10	20-70	1-10	1-30	1-30	1-30	1-15	1-15	0-10	0-5
Marine/brackish epipsammon	1-40	1-45	50-95	1-45	0-15	0-15	0-15	0-25	0-5	0-1
Marine/brackish epipelon	0-5	0-5	1-30	15-50	1-40	0-5	5-30	5-50	5-60	0-1
Marine/brackish aerophilous	0-1	0-1	0-1	0-1	10-40	15-95	10-40	0-1	0-1	0-1
Brackish/freshwater aerophilous	0-1	0-1	0-1	0-1	10-40	15-95	10-40	0-1	0-1	0-10
Marine/brackish epiphytes	0-1	0-1	0-5	0-5	0-5	0-5	10-60	10-75	10-90	0-5
Brackish/freshwater plankton	0-1	0-25	0-1	0-1	0-1	0-1	0-1	0-20	0-25	0-5
Brackish/freshwater tychoplankton	0-1	0-1	0-5	0-5	0-5	0-5	5-50	5-50	5-80	0-10
Brackish/freshwater epiphytes	0-1	0-1	0-5	0-5	0-5	0-5	1-50	1-50	1-80	0-10
Freshwater epiphytes	0-1	0-1	0-1	0-1	0-5	0-5	0-10	0-10	0-10	1-75
Freshwater	0-1	0-1	0-1	0-1	0-1	0-1	0-10	0-5	0-10	1-75

epipelon										
Freshwater plankton	0-1	0-1	0-1	0-1	0-1	0-1	0-5	0-15	0-20	10-95

Table 2. Relation between the relative abundance (%TDV) of the ecological groups and the sedimentary environments, modified from Vos and de Wolf (1993)

9 INTERPRETATION : DIATOM ANALYSIS *by C.R. Batchelor, D.S. Young, T. Hill and P. Austin*

9.1 The diatom assemblages present within the upper minerogenic unit of ARCA BH05, which overlies a humified peat unit dated to 3450 – 3250 cal BP, have revealed a relatively clear palaeoenvironmental story. The diatom flora in the lower of the two samples (which overlies the peat unit), contain more species more affiliated with lower salinity conditions and repeated subaerial exposure. This trend is exemplified by the initial relative dominance of the brackish planktonic taxa *Cyclotella striata*, supported by the lower salinity tolerant benthic taxa such as *Pinnularia viridis, Epithemia zebra* and the aerophilous taxa *Diploneis ovalis*. In contrast, further up into the overlying estuarine alluvium, there is a reduction in the influence of freshwater conditions and an increase in marine records, to reflect the increased sea-level influence. This is apparent through the reduction in the influence of brackish plankton, the establishment of marine plankton in its place, and the increase in marine-brackish epipelon species.

9.2 The mixture of fresh, brackish and marine taxa makes the sequence suitable for the application of the palaeoecological scheme of Vos and deWolf (1993). The value of the Vos and deWolf (1993) classification approach is the ability to infer the altitude at which the sample developed on the coastal zone (subtidal, intertidal, supratidal) which, when applied to multiple samples within a sequence, can be used to infer changes in palaeo-depositional altitude over time. This can then provide a semi-quantitative indicator of changes in relative sea level. For example, if a diatom sequence displays a gradual shift from assemblages indicating deposition in supratidal settings, to those more associated with subtidal conditions, this would be interpreted as indicating a progressive increase in the influence of relative sea level on the sedimentary archive has been experienced. As discussed, such a shift is indeed suggested by the stratigraphy consisting of peat overlain by upper alluvium. This apparent marine 'transgression' can be caused by a number (or combination) of factors. These include (but are not restricted to) an increase in eustatic (global) sea-level, a decrease in the rate of terrestrial sedimentation along the coastal zone (to effectively lower the coastline above that of rising sea level) or crustal movements often resulting from glacio-istostasy (an artefact of the impact previous glacial episodes in the UK). If such shifts are encountered within the diatom assemblages at Merrielands, key to explaining any shifts and associated palaeoenvironmental interpretations will be the timing of such events, and consequently the radiocarbon dating of the sequence is of great value.

9.3 The benefit of the Vos and deWolf (1993) scheme is that, whilst it does take into account the presence of planktonic taxa, it also provides substantial windows in which planktonic species can be present (see Figure 3). For example, marine planktonic species can contribute anywhere between 10-70% TDV in many of the diatom assemblages associated with deposition within the supratidal realm. This approach is however necessary, as a result of the potential for large amounts of planktonic diatoms to 'flood' into sediments due to their allochthonous nature, biasing salinity classes allocated to each sample and subsequently resulting in potentially erroneous palaeoenvironmental interpretations. This potential bias is therefore often displayed within diatom diagrams due to the abundance of planktonic taxa in most deposits (and yet not necessarily reflecting the depositional conditions).

9.4 The most abundant taxa within both samples is the brackish planktonic species *Cyclotella striata*. In both samples, this taxon contributes between 25-35% TDV. According to Vos and deWolf (1993), brackish plankton typically contribute up to 30% TDV throughout much of the intertidal and supratidal area, but can also contribute larger amounts (20-70% TDV) within the subtidal zone, due to this being where the greatest amount of water mixing takes place (hence the greatest opportunity for fresh, brackish and marine plankton to be encountered together; see Table 2 above). However we can confidently discount the subtidal realm due to the relative abundance of other ecological groupings within both samples, with specific reference to the lower salinity epiphytic and aerophilous taxa that are commonly encountered. Epiphytic taxa require organic remains of living aquatic plants to thrive, which is not typically encountered in the subtidal realm. In addition, aerophilous taxa require repeated periods of aerial exposure and tidal submergence; within the subtidal zone, such periods of aerial exposure is severely restricted to spring tides.

9.5 Discounting estuarine tidal channels as the likely depositional environment at the site, the benthic taxa can now be further critiqued. The sample proximal to the underlying peat unit, -0.73m OD, displays an abundance of both marine-brackish and brackish-fresh aerophilous taxa. When combined with the presence of marine brackish epipelon and freshwater epiphytes, it is concluded that deposition took place within the supratidal area, in 'salt marshes around mean high water mark (MHW)' (Figure 6).

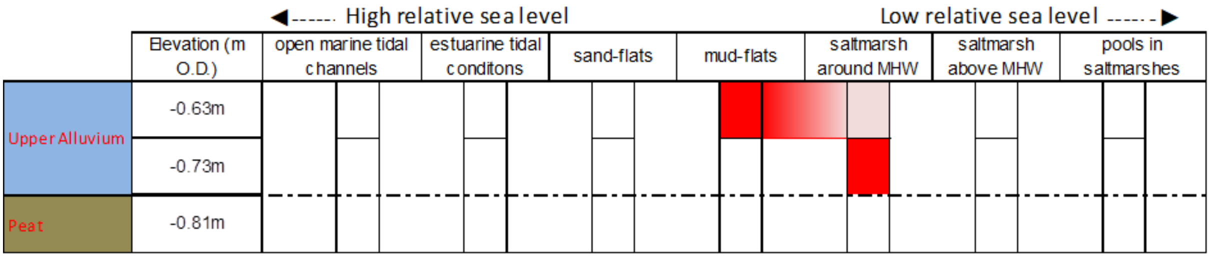

Figure 6. Summary of the costal conditions that prevailed at Merrielands Crescent, based on Vos and deWolf (1993).

9.6 In contrast, whilst there were less saline tolerant taxa within the overlying sample, their abundances were much lower. Sample -0.63m contained a greater abundance of marine-brackish epipelon species but retained some aerophilous content (specifically brackish-fresh). It is therefore concluded that the overlying sample was positioned further down the tidal frame, but likely somewhere between 'saltmarsh at MHW' and 'mudflat'. This reconstruction therefore supports the interpretation of a marine transgressive phase taking place.

9.7 A note of caution is required with regards to the interpretation based on Vos and deWolf (1993). The scheme requires the grouping of diatom taxa into ecological categories (marine-brackish epipelon, brackish aerophilous etc) and unfortunately not all species have been allocated such groupings, or contradictions are encountered within the ecological and palaeoecological literature. This does therefore require some assumptions to be made.

9.8 Radiocarbon dating provides an age of 3450 – 3250 cal BP for the upper boundary of the peat unit. Peat-silt boundaries are widely used to quantify the elevation of relative sea level in prehistory and based on the diatom assemblage there is some potential to apply this to the Merrielands sequence. The late Holocene, a period during which this stratigraphic sequence developed, was typified by reductions in the rate of relative sea-level rise, specifically after *c.* 5,000yrs BP. Whilst sea level has always been rising during this period, it is the rate of rise that has reduced, partly a consequence of the reduction in global eustatic sea-level rise (resulting from reduced ice melt etc) and increases in terrestrial sedimentation along the coast, elevating the land above marine influence Devoy (1979) described the regional stratigraphic sequence, and how this reflects changes in sea level over time,. Devoy's stratigraphic model was further developed by Sidell (2003), who proposed a distinct positive sea-level tendency (i.e. marine inundation) for the upstream (inner) Thames Estuary, at *c.* 1500 cal BC, coinciding with the date of the transition from freshwater peat to estuarine silts at Merrielands. The timing of the shift from freshwater to marine sedimentation at Merrielands can therefore be seen to broadly complement the regional record of lowland coastal change.

10 RESULTS AND INTERPRETATION: PLANT MACROFOSSIL ASSESSMENT

by C.R. Batchelor, D.S. Young, T. Hill and P. Austin

10.1 Two small bulk samples were extracted from the Peat and processed for the recovery of macrofossil remains, including waterlogged plant macrofossils, wood, insects and Mollusca (Appendices 5 and 6).

10.2 The samples from ARCA BH05 were dominated by high quantities of waterlogged wood, much of which was suitable for identification being larger than 4mm on all axes. Insects, largely present as fragments, were recorded in both samples, in low concentrations in the sample from -0.93 to -0.98m OD and moderate concentrations from -1.66 to -1.71m OD. Waterlogged seeds were recorded only in the sample from -0.93 to -0.98m OD; these were limited to a stone of *Sparganium erectum* (branched bur-reed) and fruits of *Ranunculus cf. fluitans/aquatilis* (river/common water-crowfoot).

10.3 The wood fragments were predominantly composed of bark tissue. In five fragments some anatomical features of the outermost wood were present making taxon identification possible. Sample -1.66 to -1.71m OD included fragments of bark tissue, small branch/twig-wood, and twig-wood complete with bark. The few unexamined elements in both samples appeared to be bark fragments on outward appearance. Those fragments identified consisted of alder (*Alnus glutinosa*) and willow/poplar (*Salix/Populous*).

10.4 No Mollusca, bone or charred material was identified in either sample.

11 RESULTS: C14 AMS DATING

Borehole and Elevation (m OD)	Material dated	Lab code	δ ^{13}C ‰	Conventional radiocarbon age (±1σ)BP	2σ calibrated date cal BC/AD
ARCA BH05 -0.83	Peat: humic acid	SUERC-74114 (GU44615)	-29.0	3130 ± 29	1494 (2.9%) 1478 cal BC 1457 (67.4%) 1372 cal BC 1358 (25.1%) 1301 cal BC
ARCA BH05 -1.71	Peat: humic acid	SUERC-74115 (GU44616)	-29.2	4501 ± 27	3347 (33.3%) 3261 cal BC 3255 (62.1%) 3098 cal BC

Table 3. Results of AMS 14C dating. The calibrated age ranges are determined from the University of Oxford Radiocarbon Accelerator Unit calibration program (OxCal4).

11.1 Two samples, one from the top and one from the base of the Peat in ARCA BH05, were submitted to the SUERC Radiocarbon Laboratory for C14 AMS dating. The results are shown in Table 1 above. They have been calibrated using OxCal v4.3.2 (Bronk Ramsey 2017) and the IntCal13 atmospheric curve (Reimer *et al* 2013).

11.2 The top of the Peat (-0.83m OD) is dated to 1494 – 1301 cal BC.

11.3 The base of the Peat (-1.71m OD) is dated to 3347 – 3098 cal BC

12 ASSESSMENT OF THE GEOARCHAEOLOGY

12.1 The Late Pleistocene Environment

12.1.1 The London Clay Formation with Palaeocene and older Cretaceous rocks form an irregular, incised and terraced, basement to Quaternary sediments of the ancient Thames Valley. The site lies at the northern edge of the current flood plain of the Thames, and just to the south of and below the previous (Taplow) river terrace. The basal sediments covering the terraced erosion surface are gravels associated with the interglacial stages. Immediately to the north of the site and approximately deliminated by Merrielands Crescent, is the line of pinch out of these sediments where they on lap against the higher gravels of the earlier (Wolstonian Stage, MIS6-10, 352ka

– 130ka) Taplow Terrace (Figure 3). Borehole TQ48SE1913 is 20m north of the site and records gravels assigned to the Taplow terrace (Taplow Gravels) at +0.95m OD. The elevation of the terrace rises rapidly to *c.* +4m OD in the vicinity of Ripple Road (Figure 4 below).

12.1.2 On the site the London Clay Formation bedrock is overlain by the Shepperton Gravels aggraded by the action of braided channels in a periglacial environment during the Late Devensian (MIS2, 15ka – 10ka) (Gibbard 1985). The lithology is primarily clast supported flint gravels with subordinate sand. Interbedded and often well sorted, sand is common. A classic fining upwards sequence was not fully developed nor would one be expected under a very high energy braiding system that was terminated following the climatic amelioration at the beginning of the Holocene.

12.1.3 Regionally, silt was patchily deposited following this change and is represented in the Lower Thames Valley by, for example, the Enfield Silt, Roding Silt and Ilford Silt Members. The silts found in BH05 between the Gravels and Alluvium are here tentatively considered a local equivalent (Figure 5 below) (see Section 8.1.5).

12.1.4 The Gravels attain a maximum thickness of 6.5m and a maximum elevation of -1.50m OD (Figures 5–8). Figure 8 shows the upper surface is irregular with high elevations between -1.50 and -1.90m OD recorded in the centre-north of the site (from west to east; BH01, ARCA BH02, BH03 and ARCA BH04). These elevations appear to represent a longitudinal gravel bank/bar adjacent to the line of pinch out against the Taplow Terrace. To the south of the site by *c.* 0.8km on the London Sustainable Industries Park site, Choats Road, similar highs in the Gravel have also been recorded at *c.* +1m OD and further south, gravel 'islands' at *c.* -4m OD (O'Gorman and Halsey 2010, 1). To the east on the former Ford Stamping factory, Kent Avenue, the Gravel elevation falls to under -3m OD (Figures 6 and Figure 7 below).

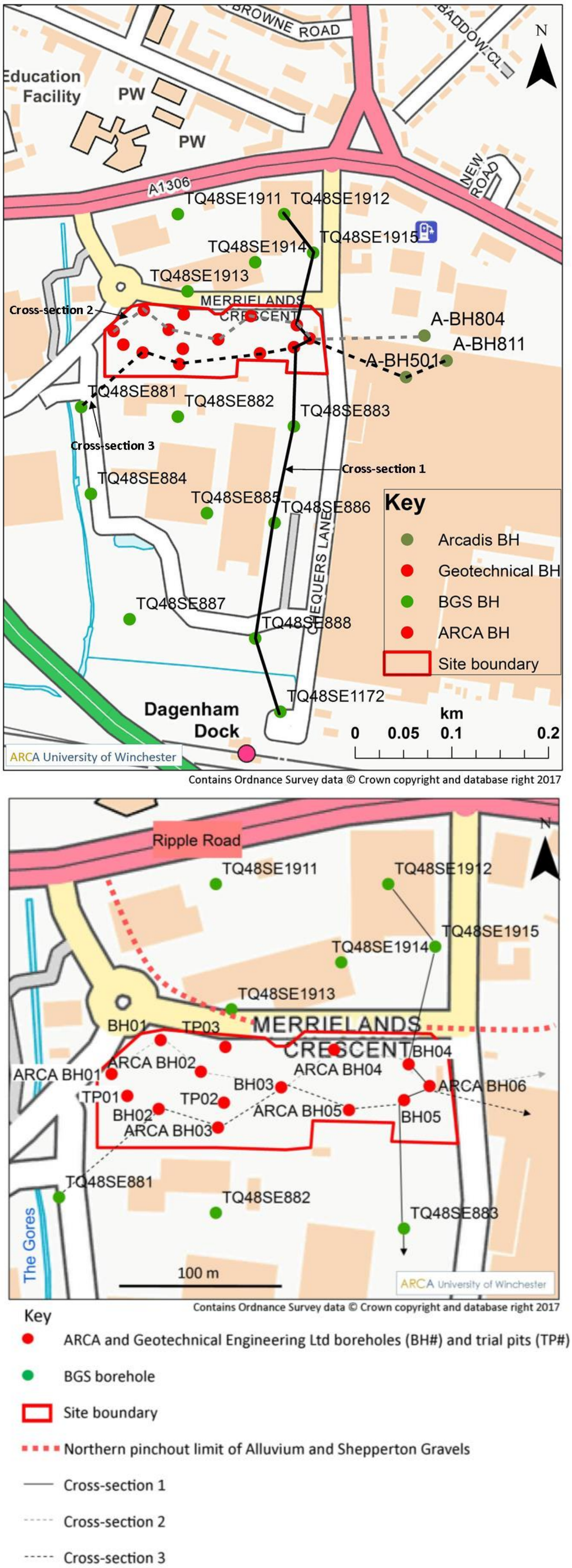

Figure 7. Locations of boreholes, trial pits and cross-sections

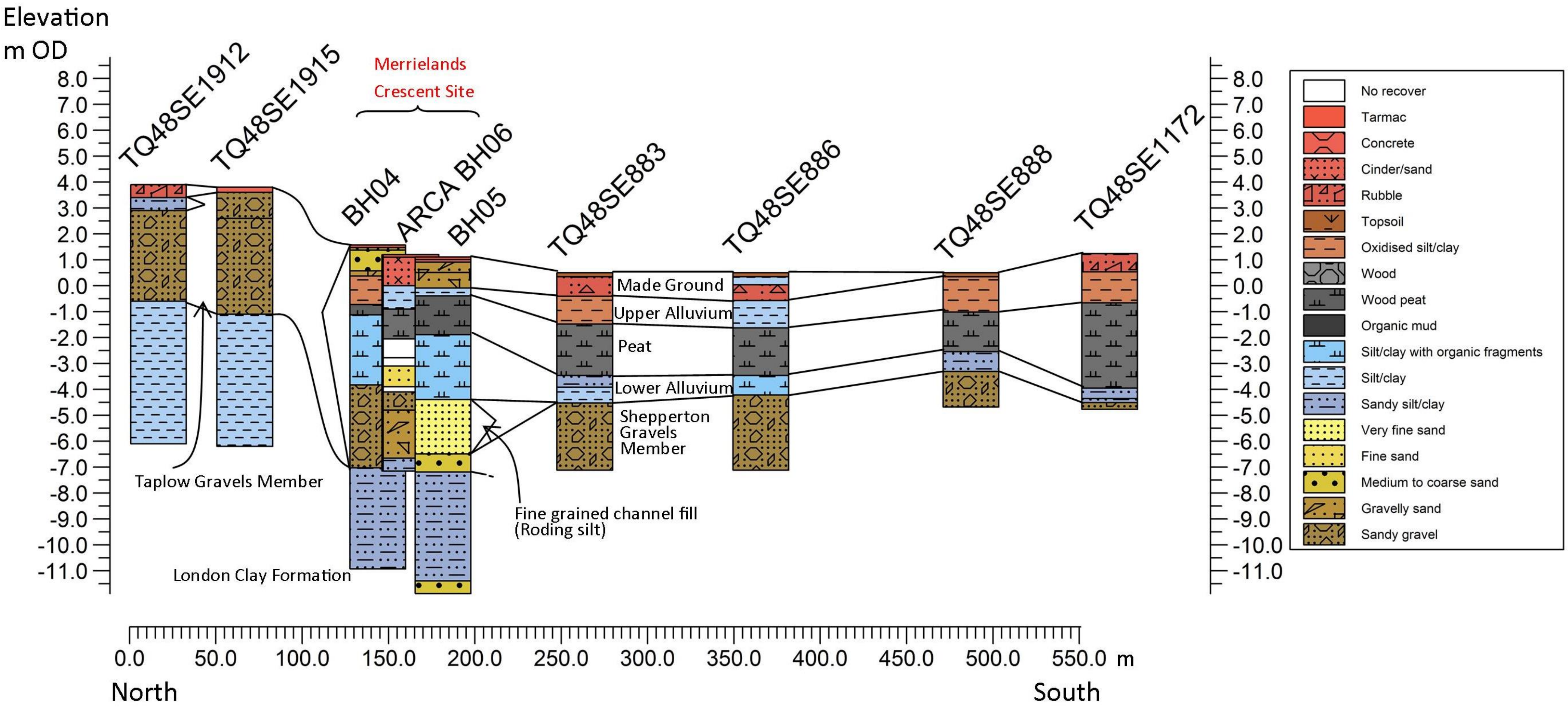

Figure 8. North to south lithostratigraphic cross-section 1 from the Taplow Gravels Terrace towards the River Thames. Vertical exaggeration x 15.

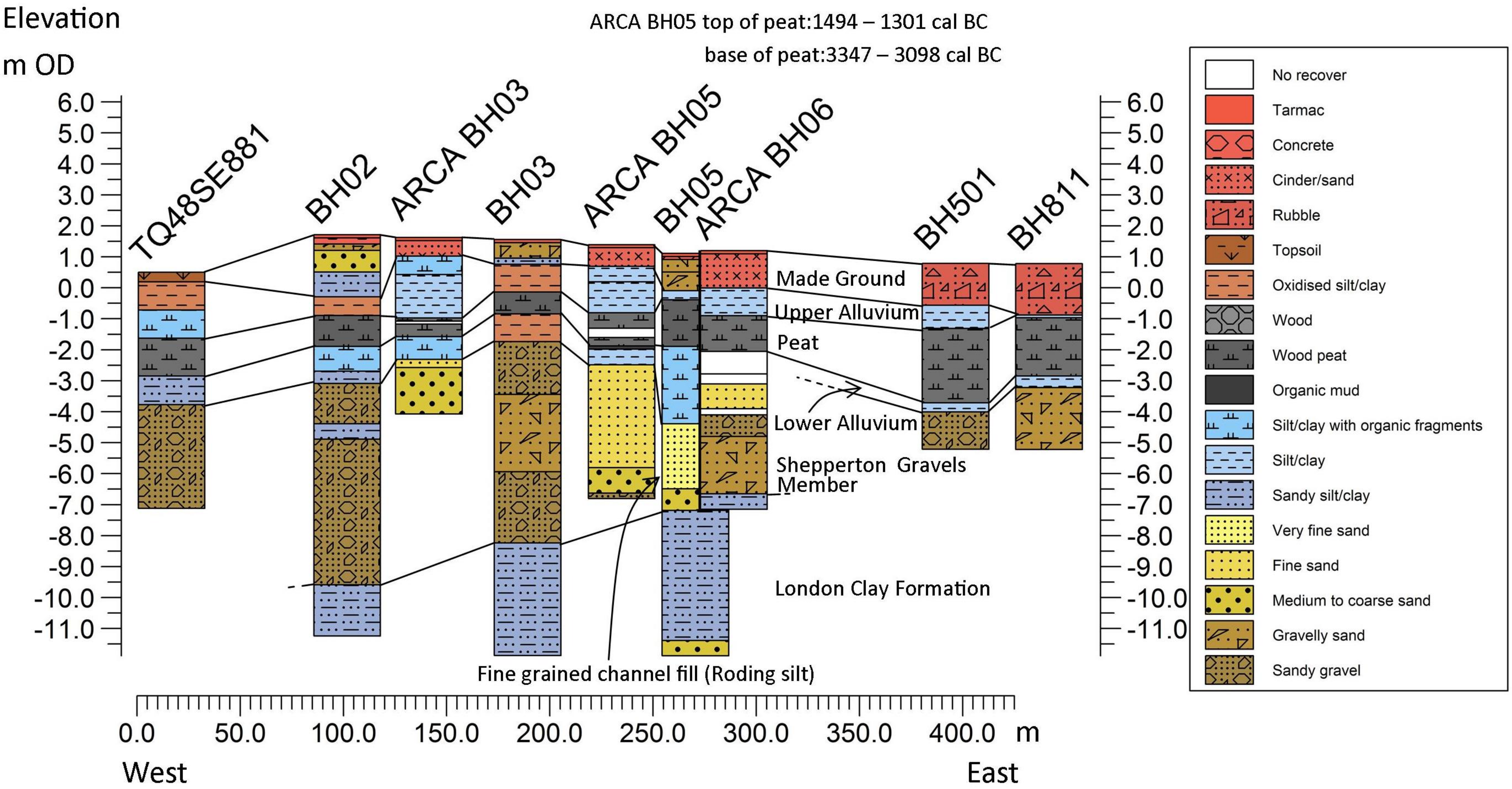

Figure 9. Lithostratigraphic cross-section 3 from west to east across the south of the site. Vertical exaggeration x 15.

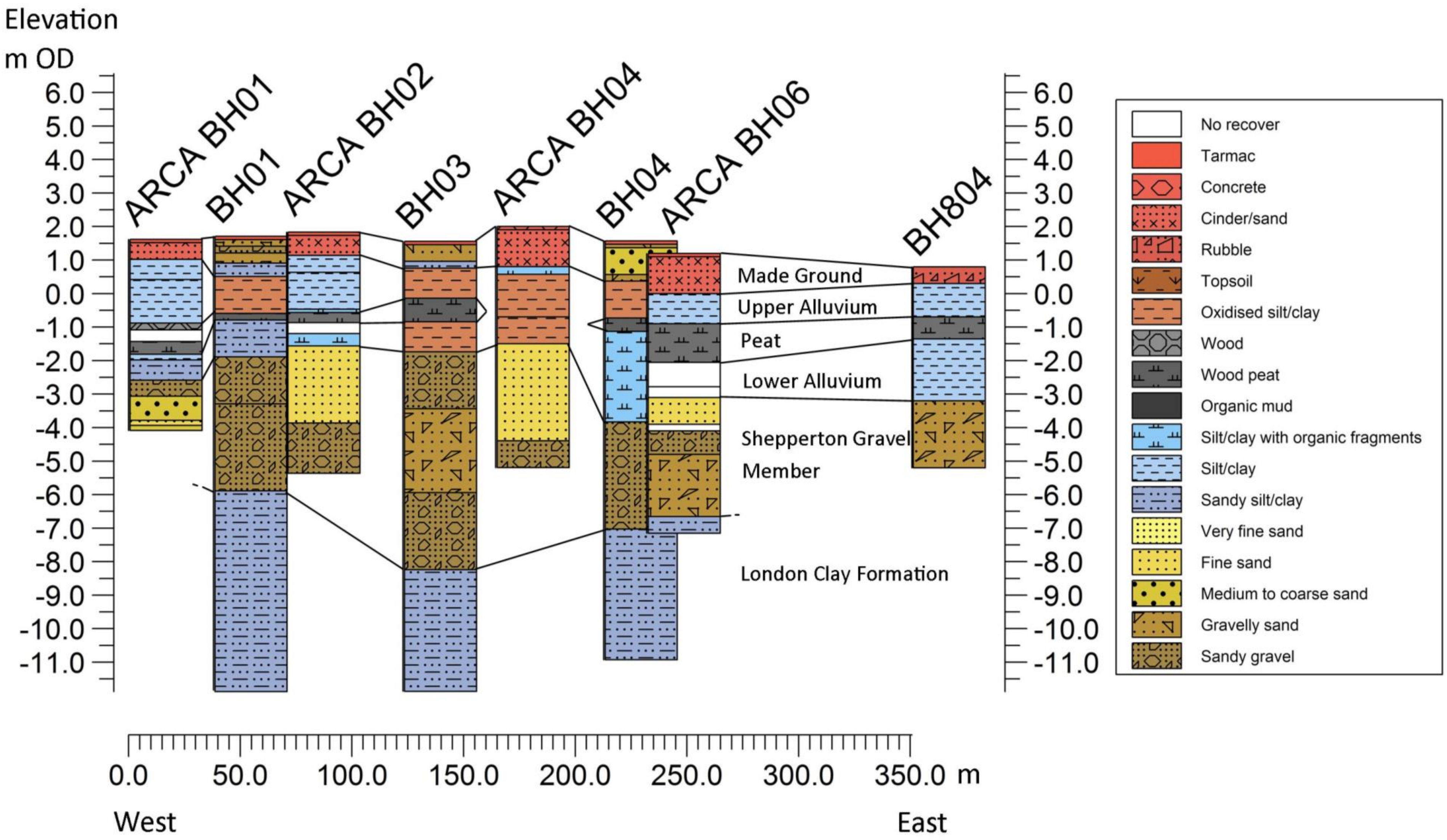

Figure 10. Lithostratigraphic cross-section 2 from west to east across the north of the site. Vertical exaggeration x 15.

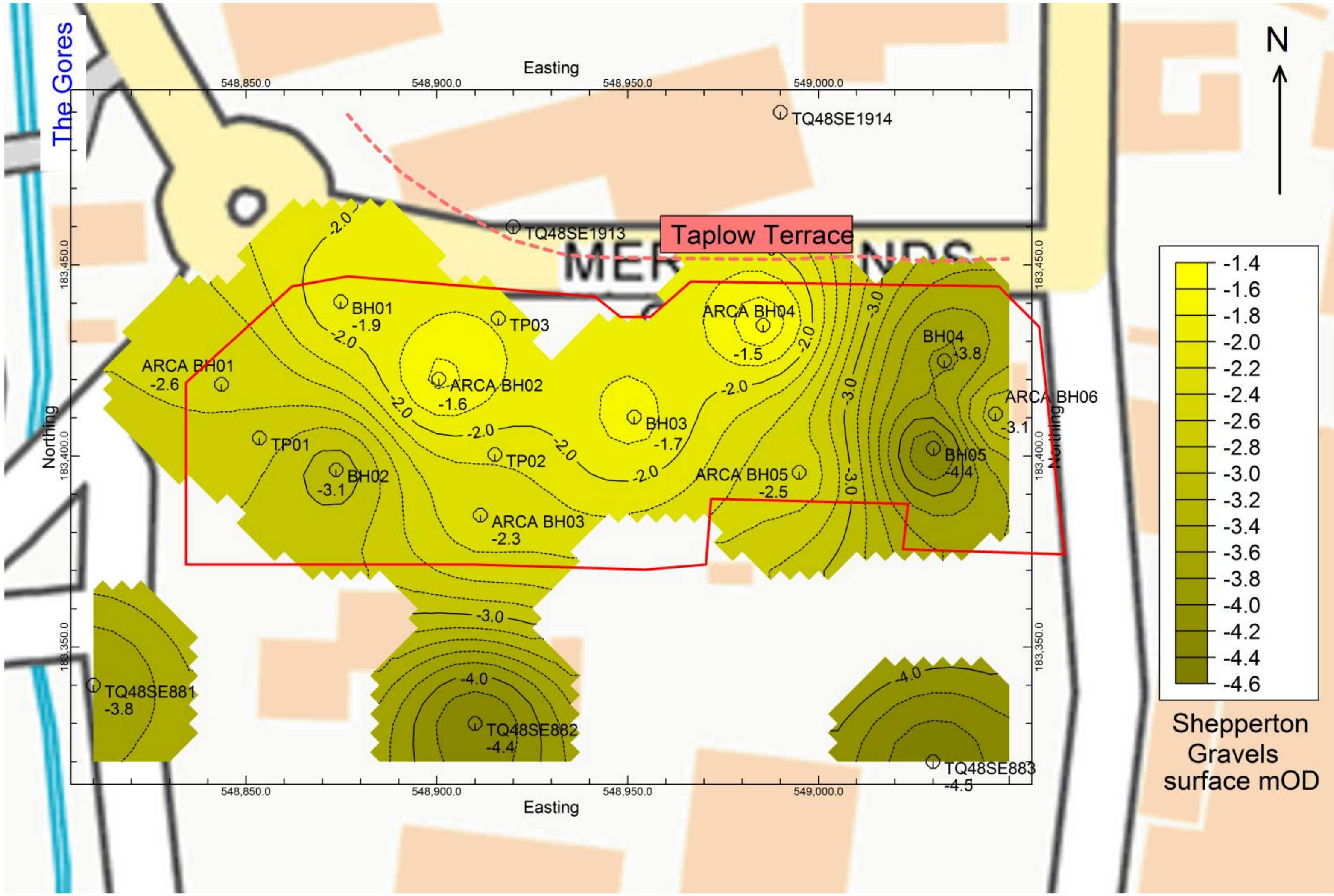

Figure 11. Surface elevation map of the **Shepperton Gravel Member**.
Specific elevation at each borehole noted. Site boundary in red. Line of pinch out in dotted red.

12.1.5 On the east side of the site, the gravel bank has been recut by a later silt/sand filled channel recorded in BH05 and to a more limited extent in BH04. The elevation of the channel base in BH05 is -4.4m OD, and less than 1m of gravel only separates the base from the London Clay Formation. Although the channel must have been formed during a period of incision it remained active into the Holocene filling with *c.* 2m of brownish grey sandy silt under a low energy fluvial environment. To the west a similar fill though with shells, has been recorded in the River Roding valley (Gibbard 1994, 112). The deposits are probably coeval with facies 2 of O'Gorman and Halsey (2010, 9).

12.2 The Holocene Environment

12.2.1 At the end of the Pleistocene, climatic amelioration brought about a stabilisation of the land surface and an end to channel gravel aggradation. Colonisation by plants reduced the supply of sediment and stream flow energy fell as a result of milder winters and the shift from surface to ground water drainage succeeding the melting of the permafrost (Figure 9 below). As a consequence, the gravel highs are believed to have been dry in the Mesolithic and habitable (O'Gorman and Halsey 2010, 10-11). There is, however, no evidence of soil formation in the form of palaeosols developed on the surface of the Gravels on the site. A high water table and propensity to flood did, however, promote instead the eventual formation of fresh water marshes and peat accumulation.

Lower Alluvium

12.2.2 Climatic amelioration in the Holocene confines the Thames to relict channels as an anastomosing and later meandering planform evolves. The braid plain developed into a floodplain and fine grained minerogenic alluviation takes place with the deposition of the Lower Alluvium. The accreting floodplain inherits the morphology of the Gravel braid plain tending to smooth it, as is evident in Figure 10 below. Frequent but limited flooding quickly filled the topographic troughs whereas less frequent but extensive valley-wide floods eventually overwhelmed and buried the old gravel landscape highs.

12.2.3 The Lower Alluvium tends to fine upwards from fine sandy clays to silty clays with frequent evidence of detrital flotsam of wood and peat fragments. The unit dips south from an elevation of less than -1m OD in the north of the site to *c.* -3m south of the site (boreholes TQ48SE881–TQ48SE883) (Figure 10 below).

12.2.4 Unfortunately there is no palaeoenvironmental information from the Lower Alluvium; no diatoms were recovered from the top fraction of the unit, however, fluvial rather than marine processes are believed to have deposited the unit. Evidence from Hornchurch Marshes (*c.* 2 km south east of the site) demonstrates that peat growth commenced in freshwater conditions in the Late Mesolithic (see Section 8.2.6). There is, however, evidence for plant growth on the Merrielands site with fine rootlets noted in BH03. The unit is very variable in thickness from *c.* 0.5m to 2.5m in the old channel fill (BH05). Further south, the BGS records a thickness of *c.* 0.5 – 1.5m. Flooding, though locally and temporally inconvenient, would not proscribe human exploitation of the generally wet flood plain, where on the higher and drier ground, oak, elm and hazel would be found (Sidell 2001 cited in O'Gorman and Halsey 2010, 11). This too would eventually disappear beneath peat by the Bronze Age as the water table rose.

12.2.5 On a regional scale the River Thames was and still is constantly adjusting to glacial eustacy (rapid rising true sea levels as ice sheets melt) and gradual isostatic readjustment as the weight of ice is released,[1] with the result that a complex vertical and lateral sedimentary architecture forms and reforms influenced by first fluvial, and then both fluvial and estuarine/marine processes. The meandering/anastomosing river, too, continuously reworks earlier deposits. Organic strata are intercalated in these sediments. Peat growth occurs in response to almost zero detrital deposition and rising water tables. It marks a phase in time when vegetation growth exceeds or keeps pace with a rising tidal frame, or there is a decline in the rate of relative sea level rise. The surface may be considered as semi-terrestrial (salt marsh, reed swamp and wet woodlands) and the natural resources could have been exploited by human groups occupying dryer areas of higher elevation on the Taplow Terrace, for example.

[1] In the case of southern England the land is sinking since it was not covered by ice in the most recent Devensian glaciation, but was rather part of a forebulge.

Keele River Canadian Northwest Territories: vegetation colonising sand and gravel bars

Mackenzie River Canadian Northwest Territories : longitudinal bar and overflow channels against vegetated river bank

Adjacent abandoned floodplain with bogs and lakes and pioneer vegetation

Figure 12. Modern visual analogues to the possible environment surmised for the early Holocene Thames flood plain. (Photographs © Dr Robert Standley)

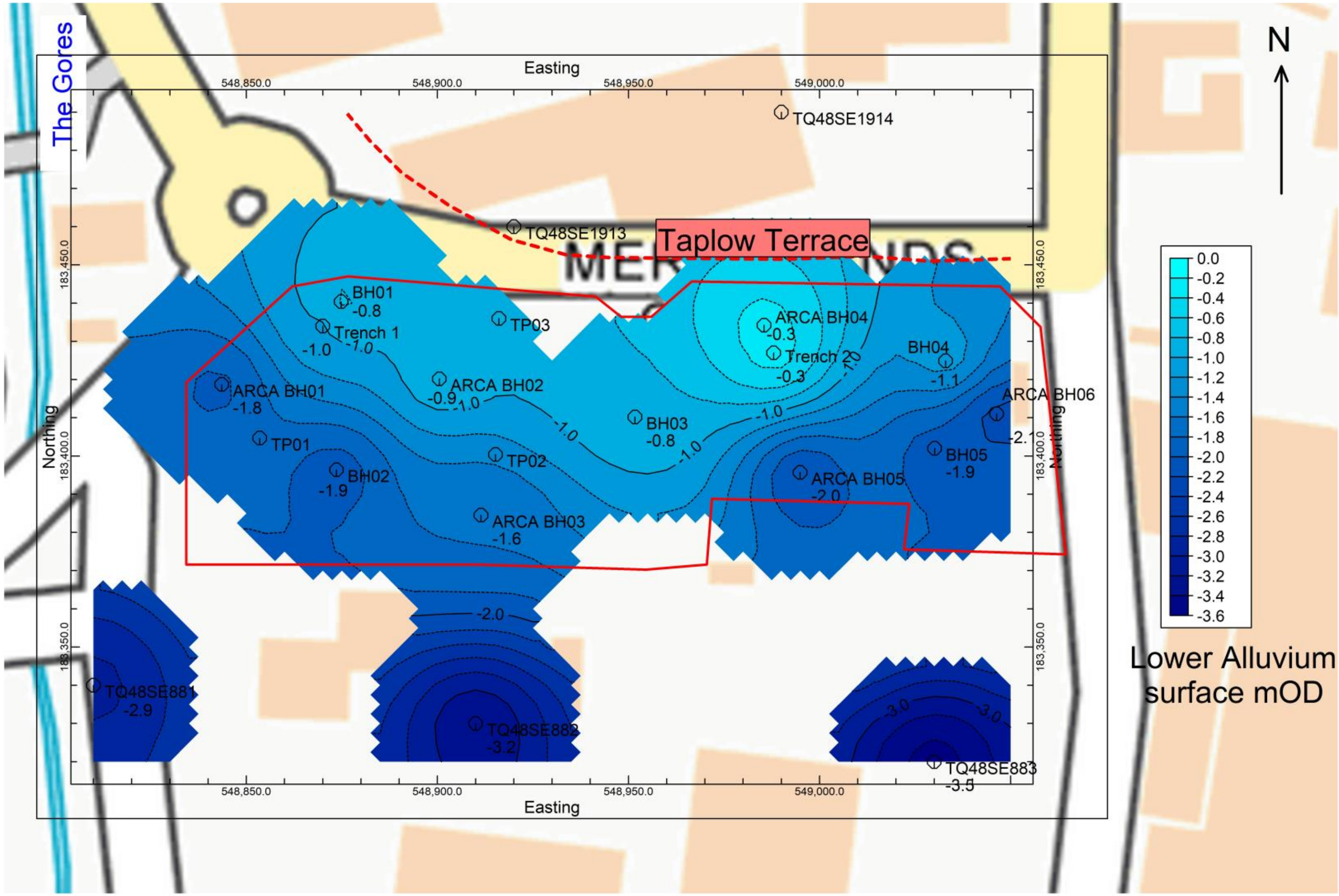

Figure 13. Surface elevation map of the **Lower Alluvium**.
Specific elevation at each borehole noted. Site boundary in red. Line of pinch out in dotted red.

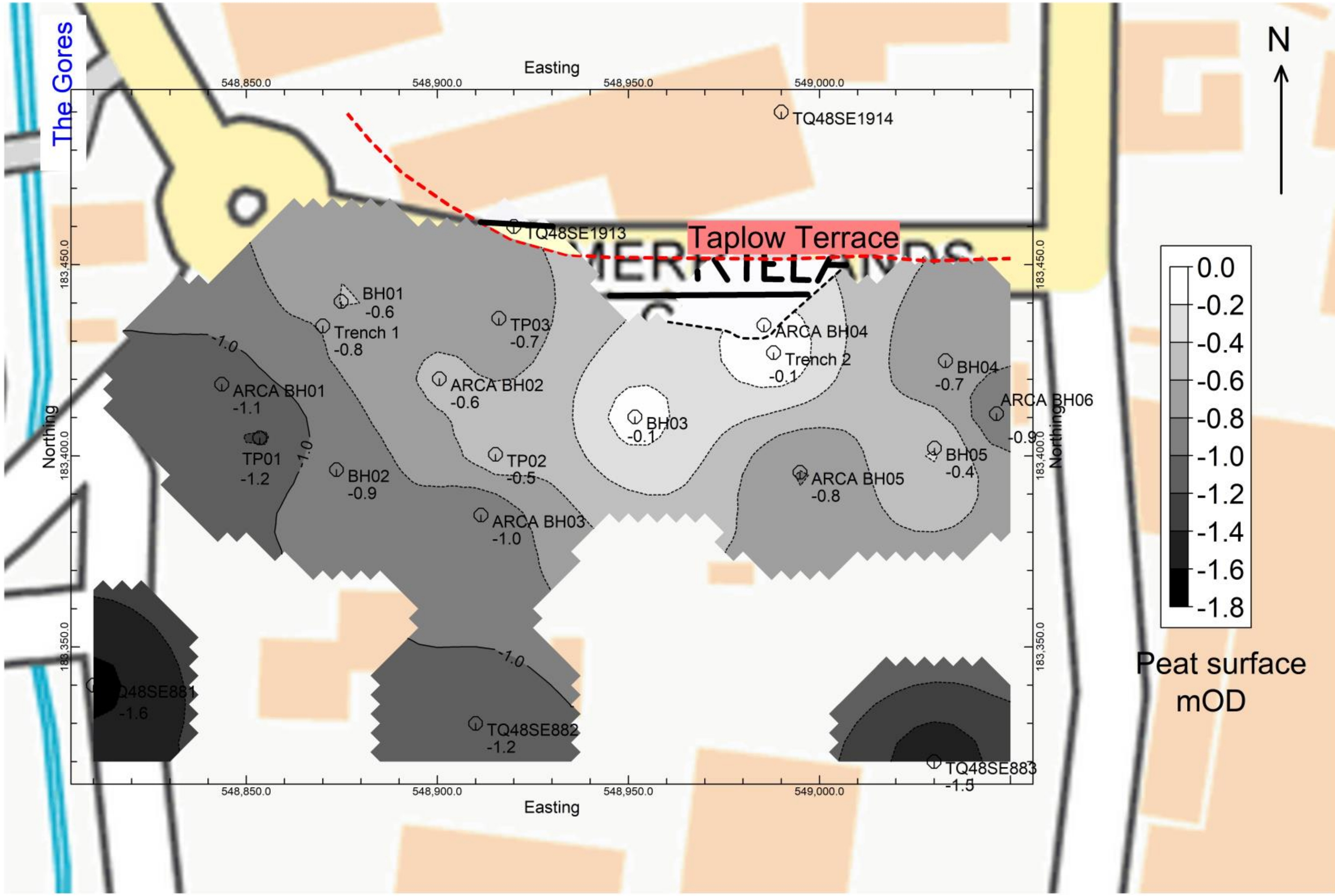

Figure 14. Surface elevation map of the **Peat**. Specific elevation at each borehole noted. Site boundary in red. Line of pinch out in dotted red.

Peat

12.2.6 On the site the growth of peat was established by the beginning of the Middle Neolithic, at 3347–3098 cal BC and ceased in the Middle Bronze Age, at 1494–1301 cal BC. This compares with the Dagenham Dock site, only 0.5km to the south east and closer to the River Thames, where peat formation begins slightly earlier in the Early Neolithic, at 4042–3804 cal BC, with the growth of an alder carr woodland (McWilliams and McLellan 2016). An alder carr woodland is also recorded on the Merrielands site (although *in situ* roots were not evident) (see Section 8.2.9). At the Choats Road site it is earlier: the 'upper peat' is dated to the Late Mesolithic *c*. 4700–4440 cal BC to the Early Iron Age *c*. 800–520 cal BC (MOLA 2006 cited in McWilliams and McLellan 2016). This would be expected at a lower location nearer the river. Peat formation at Hornchurch Marshes also began in the Late Mesolithic at *c*. 4300 cal BC and ceased at *c*. 1900 cal BC (Branch *et al* 2012). At Barking Riverside, *c*. 2km to the southwest, peat accumulation began at *c*. 4050 cal BC (late Mesolithic), and continued until at least *c*. 1550 cal BC (Bronze Age) (Green *et al* 2014).

12.2.7 The top Peat surface on the site maintains the general dip (gradient of 1.4°) southwards from just under 0m OD in the centre north (BH03) to *c*. 1.2m OD in TQ43SE882, 50m south of the site (Figures 5 and 11 above). Only a thin veneer of peat is present in the north of the site at Trench 2 for example, and none in ARCA BH04 as it pinches out against a rising (Shepperton) gravel slope. It increases in thickness rapidly towards the south and fills the relict channel in the east (BH05) to a depth of *c*. 1.5m (Figure 12 below).

12.2.8 Peat formation (and preservation) is, therefore, diachronous across the low lying, very low gradient of surface slope of the Lower Thames Valley in a phase of transgression associated with relative sea level rise.

12.2.9 The analysis of the pollen from the Peat unit in ARCA BH05 by Batchelor *et al* (see Sections 8 and 9) indentifies four pollen zones (LPAZ). The first and oldest (LPAZ MER-1) correlates with the base of the peat and indicates the presence of a swamp carr woodland of alder, willow, sedges, grasses and probably reeds. Hazel and oak may have been present too but are more likely to have accompanied the primary tree species lime on the dryland, both the terrace and eyots on the floodplain.

12.2.10 In LAPZ MER-2 a decline in lime is suggestive of the onset of paludification. LAPZ MER-3 sees the appearance of yew colonising the floodplain woodland until wetter surface conditions heralds its decline in the Neolithic–Bronze Age transition. Finally, LAPZ MER-4, which dates to *c.* 3450 – 3250 cal BP, the Bronze Age) tree and shrub taxa decline and herbaceous taxa increase as the peat surface becomes ever wetter. Alder is replaced by sedge fen/reed swamp that may include some saltmarsh. On the terrace dryland there is evidence of clearance with the decline in oak and hazel and increase in herbaceous taxa. Although cereal pollen is noted it may well represent wild grasses in the wetland rather than evidence of cultivation.

12.2.11 Assessment of the plant macrofossils recorded only a limited number of remains. The identifiable waterlogged wood was alder and willow/poplar, and the rare stone of *Sparganium erectum* (branched bur-reed) and fruits of *Ranunculus cf. fluitans/aquatilis* (river/common water-crowfoot are typical of sedge fen environments.

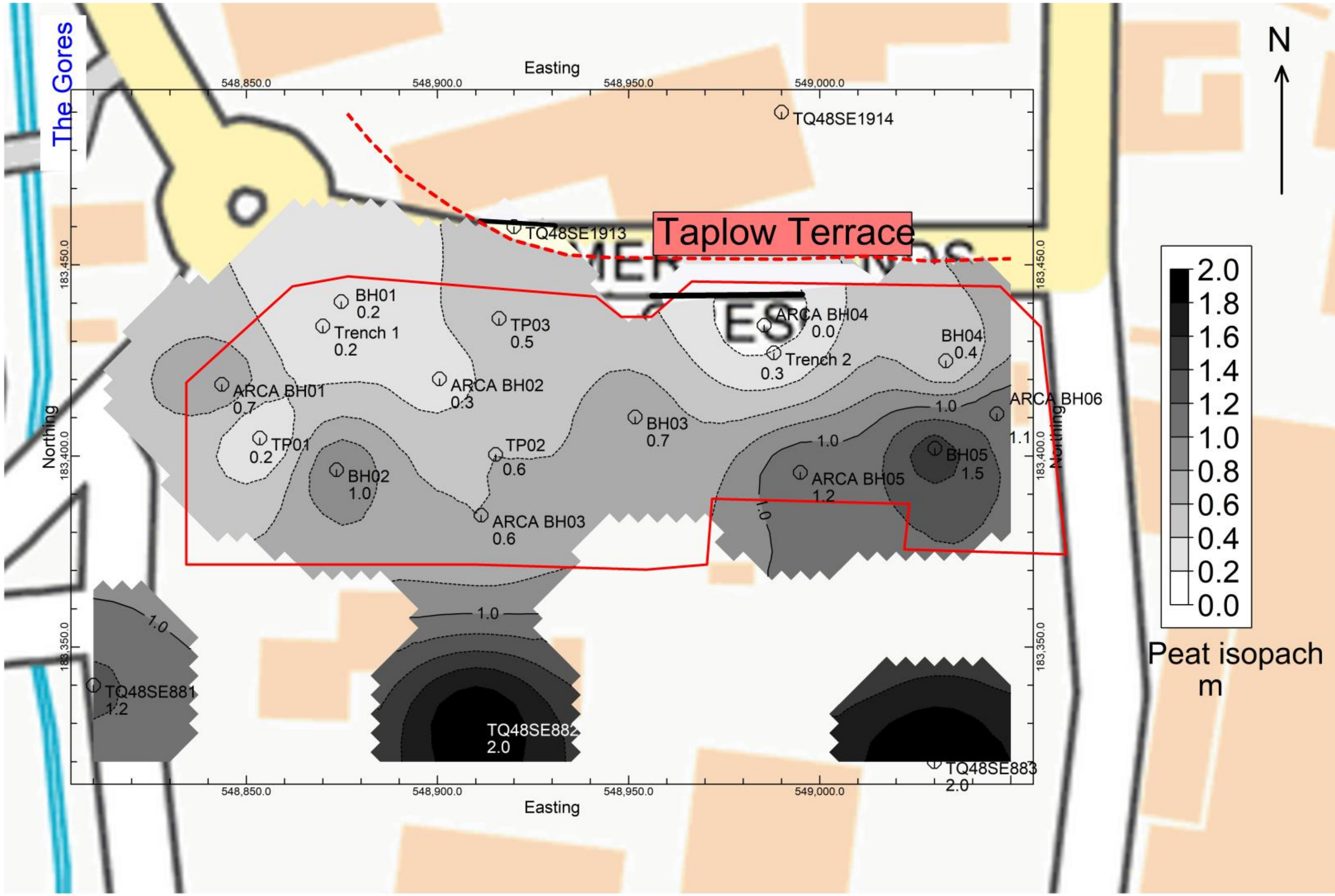

Figure 15. Isopach map showing the thickness of the **Peat.** Specific elevation at each borehole noted. Site boundary in red. Line of pinch out in dotted red.

Upper Alluvium

12.2.12 By the Middle Bronze Age a long transition phase from terrestrial river system to a tidal dominated estuarine system nears completion. The plant macro and microfossil evidence points to a halophytic flora having developed in response to this rising tidal frame. Fine grained minerogenic deposition eventually overwhelms the vegetation on the site, and a local environment of intertidal mud flats is formed (Figures 13 and 14 below). Diatom evidence points to estuarine conditions (see Sections 8 and 9) and detrital organic lag eroded by tides from the underlying peat is frequently found at the base of the unit.

12.2.13 In summary, the diatom flora immediately overlying the Peat contain species affiliated with lower salinity conditions and repeated subaerial exposure compared to the flora higher in the Upper Alluvium. The abundance of marine-brackish and brackish-fresh aerophilous taxa plus the presence of marine-brackish epipelon species (attached to mud substrate) and freshwater epiphytes (attached to plant) all point to deposition within a saltmarsh at the mean high water mark. The flora higher in the stratigraphy has a greater abundance of marine-brackish epipilon species but still has some brackish fresh aerophilites which indicate deposition in a probable mudflat environment. There is therefore a shift from saltmarsh at the Peat/Upper Alluvium interface to mudflat in the Upper Alluvium over time. This is indicative of a marine transgression which supports the lithological evidence from the site.

12.2.14 The occurrence of a sherd of porcelain in ARCA BH04 was surprisingly deep at (-1.08m OD, 3.08m BGL), and suggests that either it rested on the base of a tidal creek that later filled, such creeks are notoriously difficult to see in plan and section. Or it is intrusive. Periodic removal of the metal casing from the borehole to test for unexploded ordnance could dislodge material from a higher level which then becomes incorporated at a lower level.

12.2.15 Historic mapping records the site as the northern limits of the Dagenham Marshes that underwent episodes of draining in the later medieval period. Sea defences often failed to hold back high tides with consequent flooding, for example the Dagenham Breach in 1707. In the 20th century, the Ripple Road on the Taplow Terrace also experienced inundation (Figure 3). Concurrently drainage would induce oxidation of the upper strata of the Upper Alluvium which is truncated by modern Made Ground.

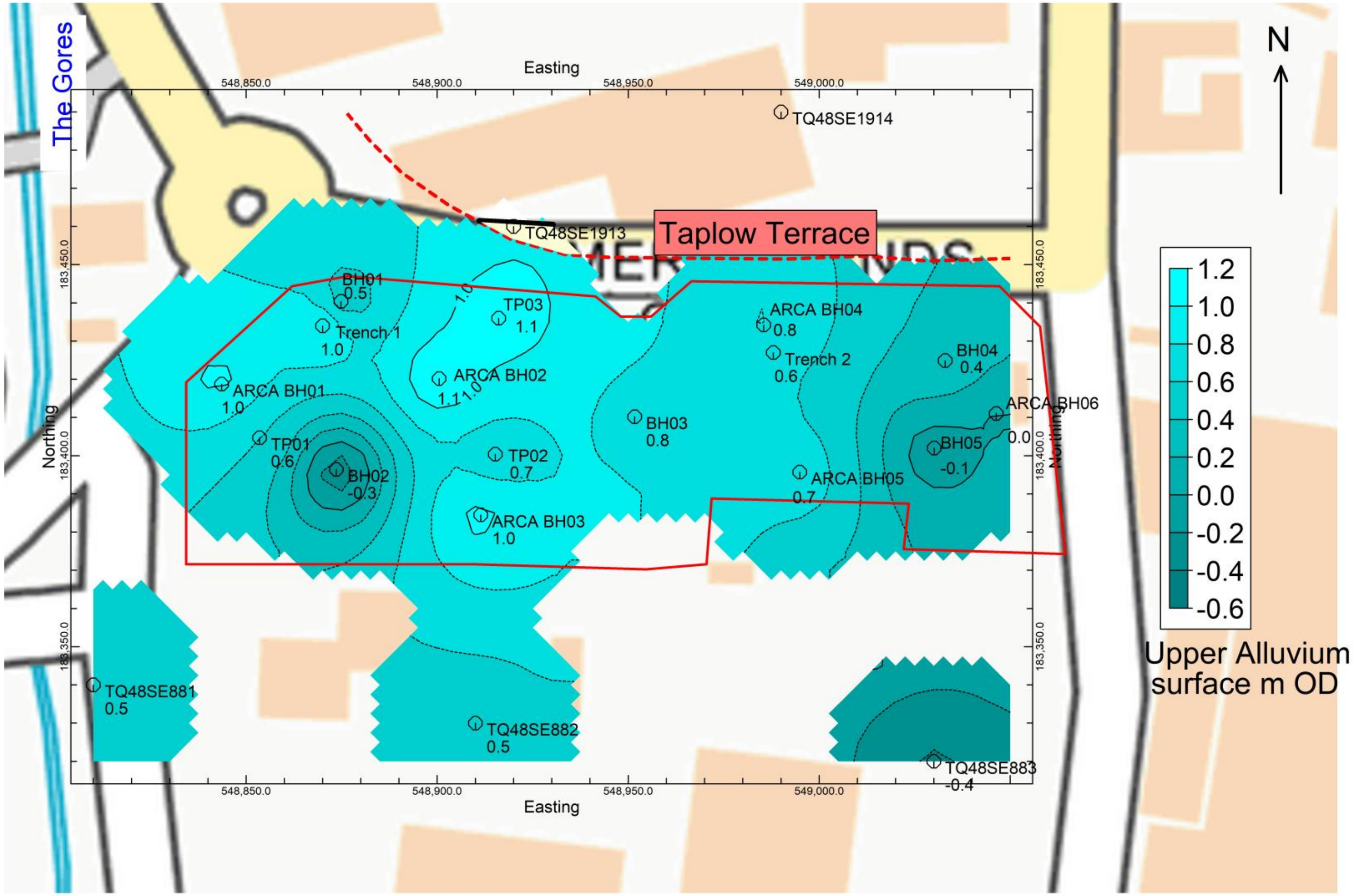

Figure 16. Surface elevation of the **Upper Alluvium**.
Specific elevation at each borehole noted. Site boundary in red. Line of pinch out in dotted red.

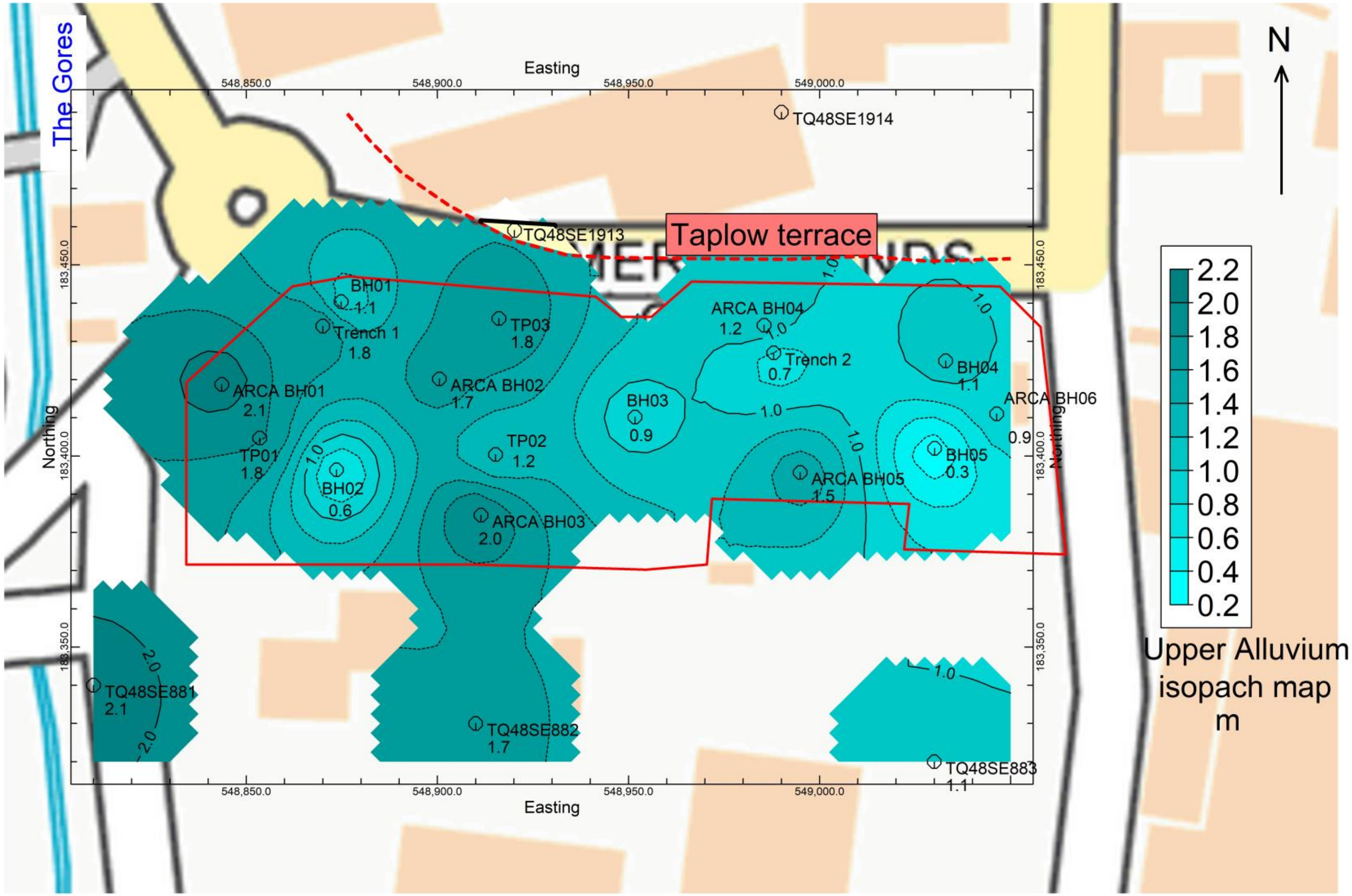

Figure 17. Isopach map of the thickness of the **Upper Alluvium**. (Thickness at ARCA BH04 estimated). Specific thickness at each borehole noted. Site boundary in red. Line of pinch out in dotted red.

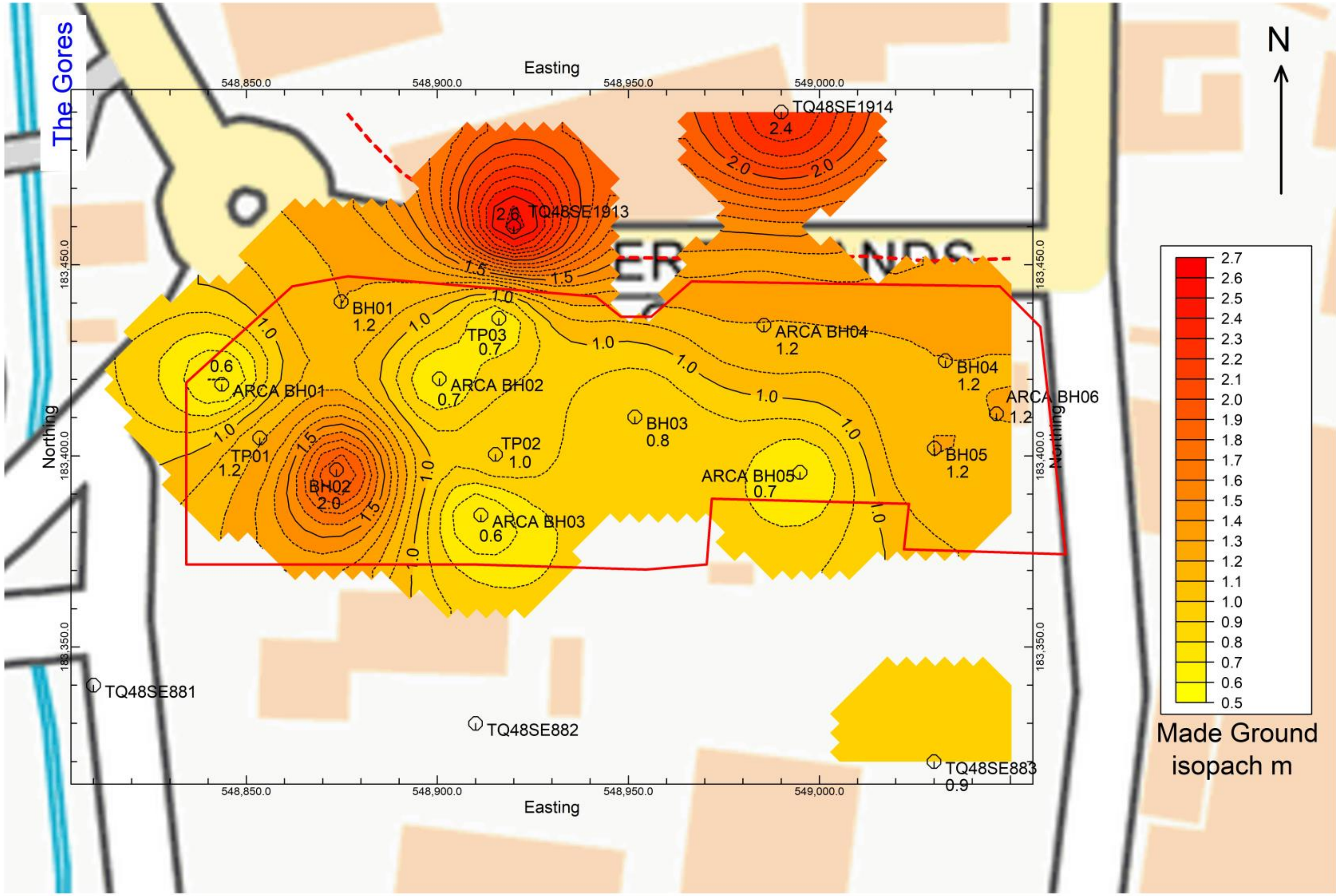

Figure 18. Isopach map of the thickness of the **Made Ground**.
Specific thickness at each borehole noted. Site boundary in red. Line of pinch out in dotted red.

Made Ground

12.2.16 'Made Ground' is a term used by the BGS to describe superficial deposits of variable composition that are man-made (BGS 2016a). This includes all archaeological strata, however, on the site evidence of human activity is limited to the Georgian to 20th century periods. Historic mapping shows no occupation of the site until the 1950s when there is the presence of a sports field which may account for the cinder recovered in the boreholes (Ordnance Survey 1:10,000). Made Ground is thickest in the south west at BH02 where the surface of the Upper Alluvium is deepest suggesting that material (demolition debris) has been used to level the site (Figure 15 above). Thicker Made Ground is evident on the Taplow Terrace where occupation has occurred.

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 Shepperton Gravel Member at the site in the form of an elevated bank/bar would have provided a step down from the Taplow Terrace onto the floodplain and as such was a possible route way. Early in the Holocene the bank/bar was also the edge of the slowly sedimenting channel identified in BH05.

13.2 Flood plain accretion resulted in the deposition of the Lower Alluvium that would bury any evidence of occupation or exploitation of the site which, considering the proximity of higher ground is a distinct possibility. Rising water levels would eventually curtail any occupation. Exploitation of the flood plain from a dryer base immediately north of the site on the Taplow Terrace is very probable.

13.3 Peat growth on the site began *c.* 3347 – 3098 cal BC and ended *c.* 1494 – 1301 cal BC when a marine transgression laid down fine grained estuarine muds (the Upper Alluvium unit) burying the Peat unit.

13.4 The results of the palaeobotanical analysis of the Peat and Upper Alluvium by Batchelor, Young, Hill and Austin have provided a detailed reconstruction of the vegetation and hydrological history of the site and its surroundings from sometime before the middle Neolithic until the late Bronze Age. During this period the peat surface was largely occupied by alder-dominated fen woodland, whilst the dryland was composed of mixed deciduous woodland dominated by lime and oak. The following key changes were noted:

1. The decline of lime woodland around 5300 – 5050 cal BP (*c.* 3350 –3100 cal BC) consequent of paludification;

2. The colonisation and decline of yew from an estimated 5000 – 4000 cal BP (*c.* 3050 – 2050 cal BC); and

3. The apparent decline of floodplain and dryland woodland from shortly before 3450-3250 cal BP (1500 – 1300 cal BC). Rare cereal pollen grains may represent grasses associated with the wetland rather than evidence of cultivation.

13.5 Analysis of the diatoms overlying the peat indicates a marine transgressive contact with the deposition of the Upper Alluvium and supports conclusions drawn from the lithostratigraphy. The timing (*c.* 1500 cal BC) of the shift from freshwater to marine sedimentation at the site complements the regional record of lowland coastal change.

13.6 Detailed palaeoenvironmental analysis is currently being undertaken at two sites immediately adjacent to Merrielands Crescent: Goresbrook Park to the west (Young *et al*, 2017b), and the Former Ford Factory to the east (Young *et al*, 2017a). In addition, analysis is being carried out on various sequences from the large Beam Park development (Young *et al*, 2018) east of the Former Ford Factory, whilst work is about to begin at Dovers Corner further east again (Batchelor and Young in prep). It is therefore recommended that the results from Merrielands Crescent are integrated with these sites to provide a synthesised publication on the palaeoenvironment for the area as a whole. It is also recommended that a Sea Level Index Point to be created at the site.

14 ACKNOWLEDGEMENTS

ARCA would like to thank Stuart Joyce of Cotswold Archaeology Ltd; Dr Rob Batchelor of Quest, the University of Reading and his colleagues, D.S. Young, T. Hill and P. Austin; Alastair Logan of Geotechnical Engineering Ltd and his drilling crew; and Dr Eleanor Standley of the University of Oxford for their help during the course of this project. Particular thanks are given to Dr Robert Standley, of Pencarreg Consultants, for his indefatigable help with the modelling and geology.

15 BIBLIOGRAPHY

Andersen, S.Th. (1979) Identification of wild grasses and cereal pollen. Danmarks Geologiske Undersogelse, 1978, 69-92

Batchelor, C.R. (2009) Middle Holocene environmental changes and the history of yew (Taxus baccata L.) woodland in the Lower Thames Valley. Royal Holloway Unpublished PhD thesis.

Batchelor, C.R. (2017a) *Former Ford Stamping Factory, Kent Avenue London Borough of Dagenham. Desk Based Geoarchaeological Deposit Model Report.* Unpublished report. Quest, University of Reading.

Batchelor, C.R. (2017b) *Goresbrook Park London Borough of Dagenham. Desk Based Geoarchaeological Deposit Model Report.* Unpublished report. Quest, University of Reading.

Batchelor, C.R., Young, D. S., Hill, T., and Austin, P. (2017) *Merrielands Crescent London Borough of Barking and Dagenham: Palaeobotanical Assessment Report.* Quaternary Scientific (QUEST) Unpublished Report. Project Number 086/17

Bates, M. and Stafford, L. (2013) *Thames Holocene: A geoarchaeological approach to the investigation of the Fiver floodplain for High Speed I, 1994-2003.* Oxford Wessex Archaeology Monograph.

Bates, M.R and Whittaker, K, (2004) 'Landscape evolution in the Lower Thames Valley: implications for the archaeology of the earlier Holocene period' in Cotton, J., and Field, F. (Eds.) *Towards a New Stone age: aspects of the Neolithic in south-east England* CBA Research Report 134.

BGS (2017a) British Geological Survey lexicon of named rock units. http://www.bgs.ac.uk/lexicon/ (Accessed 16/08/2017).

BGS (2017b) http://mapapps.bgs.ac.uk/geologyofbritain/home.html (Accessed 16/08/2017).

BGS (2017c) http://www.bgs.ac.uk/data/boreholescans/home.html (Accessed 16/08/2017).

Branch, N.P., Batchelor, C.R., Cameron, N.G., Coope, R., Densem, R., Gale, R., Green, C.P. and Williams (2012) Holocene Environmental Changes at Hornchurch Marshes, London, UK: implications for our understanding of the history of Taxus (L.) woodland in the Lower Thames Valley. *The Holocene*, **22** (10) 1143-1158.

Bronk Ramsey, C. (2017) no reference. https://c14.arch.ox.ac.uk/oxcalhelp/ref.html (accessed September 2017)

Cappers, R.T.J., Bekker R.M. and Jans J.E.A. (2006) *Digital Seed Atlas of the Netherlands*. Groningen Archaeological Series 4. Barkhuis, Netherlands.

Cotswold Archaeology (2017) *4 Acre Holding South Of Merrielands Dagenham. Archaeological Trial Trench Evaluation*. CA Report: 17709

Divers, D. (1996) *Archaeological investigation of Hays Storage Services Ltd., Pooles Lane, Ripple Road, Dagenham, Essex*. Unpublished Report, June 1996.

Geotechnical Engineering Ltd (2014) *Merrielands Crescent Dagenham Interpretative Report On Ground Investigation*. Unpublished report Prepared for Friends Life Ltd Report Ref: 29125/02.

Geotechnical Engineering Ltd (2017) https://geoeng.co.uk/site-investigation/ground-investigation/

Gibbard, P. (1985) *The Pleistocene History of the Middle Thames Valley*. Cambridge University Press, Cambridge

Gibbard, P. (1994) *The Pleistocene history of the Lower Thames Valley*. Cambridge: Cambridge University Press.

Grant, M.J, Waller, M.P. and Groves, J.A. (2011) The Tilia decline: Vegetation change in lowland Britain during the mid and late Holocene. *Quaternary Science Reviews* **30**, 394–408.

Green, C.P., Batchelor, C.R., Austin, P., Cameron, N.G. and Young, D.S. (2014) Holocene alluvial environments at Barking, Lower Thames Valley (London, UK). *Proceedings of the Geologists Association,* **125(3)**, 279-295.

Hather, J. G. (2000). *The Identification of the Northern European Woods. A guide for archaeologists and conservators*. London: Archetype.

Hendy, N.I. (1964). *An introductory account of the smaller algae of the British coastal waters. Part V: Bacillariophyceae (Diatoms).* Fisheries Investigation Series, I, H.M.S.O., London.

Jones, A.P., Tucker, M.E. and Hart, J.K. (1999) Guidelines and recommendations. In Jones, A.P., Tucker, M.E. and Hart, J.K. (Eds.) The description and analysis of Quaternary stratigraphic field sections. Quaternary Research Association technical guide 7, London, 27-76.

Krammer, K. and Lange-Bertalot, H. (1986-1991). *Subwasserflora von Mitteleuropa. Bacciliarophyceae: 2 (1) Naviculaceae; 2 (2) Bacillariacceae, Epithemiaceae, Surirellaceae; 2 (3) Centrales, Fragilariaceae, Eunotiaceae; 2 (4) Achnanthaceae*. Fischer, Stuttgart.

Krawiec, K. (2014) *A palaeoenvironmental assessment of deposits at New Road, Rainham, London Borough of Havering*. Archaeology South East Unpublished Report.

Martin, A.C. and Barkley, W.D. (2000) *Seed Identification Manual*. The Blackburn Press, Caldwell, New Jersey.

McWilliams, A., and McLellan, E. (2016) *Archaeological Evaluation Trenching and Palaeoenvironmental Analysis at Dagenham Dock, London.* Unpublished report. Archaeological Research Services Ltd Report 2016/10

Meddens, F and Beasley, M. (1990) Wetland Use In Rainham, Essex. London *Archaeologist* **6**(9), 242-248

Museum of London Archaeology 2006. *ABACUS Park Plots B and C, Dagenham Docks; an archaeological evaluation and geoarchaeological report.* Museum of London Archaeology unpublished report ACU06.

Moore, P.D., Webb, J.A. and Collinson, M.E. (1991) *Pollen Analysis* (2nd Ed.). Oxford: Blackwell.

Munsell Color (2000) *Munsell soil color charts*. Munsell Color, New Windsor (NY).

NIAB (2004) *Seed Identification Handbook Agriculture, Horticulture and Weeds*. 2nd edition. NIAB, Cambridge.

O'Gorman, L., and Halsey C. (2010) *London Sustainable Industries Park. Choats Road, Dagenham Dock. London RM9. London Borough of Barking and Dagenham.* Archaeological desk-based assessment. Unpublished report. Museum of London Archaeology

Parker, A.G., Goudie, A.S., Anderson, D.E., Robinson, M.A. and Bonsall, C. (2002) A review of the mid-Holocene elm decline in the British Isles. *Progress in Physical Geography*, **26**(1), 1-45.

Pepys, S. (1665). Samuel Pepys Diary September 1665. Available at http://www.pepysinfo/1665/ 1665sep.html accessed on 20th April 2007

Perez, M., Fyfe, R.M., Charman, D.J. and Gehrels, R. (2015) Later Holocene vegetation history of the Isles of Scilly, UK: coastal influence and human land use in a small island context. *Journal of Quaternary Science*, **30**, 764–778.

PRC Architecture & Planning Ltd (2017) *Pre-application development proposals Merrielands Crescent, Dagenham.* Prepared by PRC Architecture & Planning Ltd on behalf of Friends Life Ltd. PRC Ref: 10373.

Reille, M. (1992) *Pollen et Spores d'Europe et d'Afrique du Nord.* Marseille : Laboratoire de Botanique Historique et Palynologie.

Reimer, P. J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C. *et al* (2013). IntCal13 and Marine13 radiocarbon age calibration curves 0-50,000 years cal BP. *Radiocarbon*, **55(4)**, 1869 – 1887

Rockware (2013) RockWorks v15. http://www.rockware.com (Accessed 15 April 2014).

Ryan, S. Single, A. Kidd, S. and Sidell, J. (2016) *London Borough of Barking and Dagenham Archaeological Priority Areas Appraisal.* Historic England https://content.historicengland.org.uk/content/docs/planning/apa-barking-and-dagenham.pdf

Seel, S.P.S. (2001) *Late Prehistoric woodlands and wood use on the Lower Thames floodplain.* University College, London: Unpublished PhD thesis.

Sidell, J, Wilkinson, K, Scaife, R, Cameron, N, 2000. *The Holocene Evolution of the London Thames*. MoLAS Monograph 5

Stace, C. (2005) *New Flora of the British Isles.* Cambridge: Cambridge University Press.

Tucker, M.E. (2011) *Sedimentary rocks in the field*. Wiley, Chichester.

van Der Werff and Huls (1958-1974). *Diatomeeënflora van Nederland.* Eight parts, published privately by van der Werff, De Hoef (U), The Netherlands.

Vos, P. C., and de Wolf, H. (1993) Diatoms as a tool for reconstructing sedimentary environments in coastal wetlands; methodological aspects. *Hyrobiologia* **269** (**1**), 285–296

Waller, M.P. (1994b) Paludification and pollen representation: the influence of wetland size on Tilia representation in pollen diagrams. *The Holocene*, **4**, 430-434

Waller, M. and Grant, M.J. (2012) Holocene pollen assemblages from coastal wetlands: differentiating natural and anthropogenic causes of change in the Thames estuary, UK. *Journal of Quaternary Science*, **27**(5), 461-474.

Watson, N.M. (2017a)*: Geoarchaeological Boreholes At Land South Of Merrielands Crescent, Dagenham, London. Written Scheme of Investigation.* Unpublished report. University of Winchester

Watson, N.M. (2017b) Land South Of Merrielands Crescent, Dagenham, London: Geoarchaeological Analysis Of Boreholes. Unpublished report, University of Winchester

Wilkinson, T.J. and Murphy, P.L. (1995) *The archaeology of the Essex coast, volume 1: The Hullbridge Survey*. East Anglian Archaeology

Young, D.S., Batchelor, C.R. Allison, E. (2018) *Beam Park Riverside, London Boroughs of Havering and Rainham: environmental archaeological assessment report.* Quaternary Scientific (QUEST) Unpublished Report March 2017; Project Number 216/16.

Young, D.S., Batchelor, C.R., Hill, T. (2017a) *Former Ford Stamping Factory, London Borough of Barking and Dagenham: environmental archaeological report.* Quaternary Scientific (QUEST) Unpublished Report May 2017; Project Number 190/16.

Young, D.S., Batchelor, C.R., Hill, T. (2017b) *Goresbrook Park, London Borough of Barking and Dagenham: environmental archaeological report*. Quaternary Scientific (QUEST) Unpublished Report July 2017; Project Number 195/16.

.

.

.

.

.

.

APPENDIX 1: BOREHOLE, TRIAL PIT AND TRENCH/MONOLITH LOCATIONS

Borehole	Easting	Northing	Elevation m OD
ARCA BH01	548843.547	183418.742	1.617
ARCA BH02	548900.501	183420.190	1.835
ARCA BH03	548911.408	183384.526	1.626
ARCA BH04	548985.478	183434.234	2.004
ARCA BH05	548994.930	183395.708	1.392
ARCA BH06	549046.336	183411.042	1.198
TP01	548853.5	183404.7	1.79
TP02	548915.2	183400.4	1.7
TP03	548916.1	183436	1.79
BH01	548874.8	183440.4	1.71
BH02	548873.6	183396.4	1.71
BH03	548951.7	183410.2	1.56
BH04	549033.000	183424.900	1.570
BH05	549030.100	183402.000	1.110
TQ48SE1911	548910	183540	4.000
TQ48SE1912	549020	183540	3.900
TQ48SE1915	549050	183500	3.8
TQ48SE1914	548990	183490	3.700
TQ48SE1913	548920	183460	3.600
TQ48SE881	548810	183340	0.500
TQ48SE882	548910	183330	0.500
TQ48SE883	549030	183320	0.500

TQ48SE884	548820	183250	0.500
TQ48SE885	548940	183230	0.500
TQ48SE886	549010	183220	0.500
TQ48SE887	548860	183120	0.500
TQ48SE888	548990	183100	0.500
TQ48SE1172	549016	183024	1.240
A-BH811	549188	183388	0.780
A-BH501	549146	183371	0.790
A-BH804	549165	183414	0.800
Trench 1	548870	183434	1.700
Trench 2	548988	183427	1.820

APPENDIX 2: LITHOSTRATIGRAPHY OF THE BOREHOLES, TRIAL PITS AND MONOLITHS

Record	Top (m)	Base (m)	Lithology	Comments
ARCA BH01	0.00	0.10	Tarmac	Tarmacadam. (Modern Made Ground).
ARCA BH01	0.10	0.60	Cinder/sand	7.5 YR 2.5/1 Black fine to medium sand-sized particles and frequent comminuted charcoal. Rare fine pebble of vesicular slag/cinder. (Modern Made Ground). Sharp boundary to:
ARCA BH01	0.60	1.20	Silt/clay	2.5 Y 4/2 Dark greyish brown silt/clay with frequent irregular greyish brown mottles, black organic spots and rare medium sand-sized particles at the top. (Fine grained alluvium).
ARCA BH01	1.20	2.50	Silt/clay	Gley 1 4/10Y Dark greenish grey to Gley 2 4/5B Dark bluish grey, compact silt/clay with frequent coarse sand-sized spots of black (organic) silt/clay evenly distributed throughout. Discontinuous, horizontal laminae of black organic silt/clay and plant fibres and very fine sand at 2.15-2.17m. Sharp boundary to:

ARCA BH01	2.50	2.70	Wood	10 YR 3/3 Dark brown fine to medium sand in convoluted laminae with 5 Y 4/1 Dark grey silt/clay and granular to cobble sized wood clasts. (Chaotic storm deposit?)
ARCA BH01	2.70	3.05	No recover	Void
ARCA BH01	3.05	3.43	Peat	7.5 YR 2.5/1 Black, moderately well humified peat. Oxidises from reddish black to black. Frequent fine pebble-sized wood clasts. Firm, fibrous texture with discrete sand-sized plant fibres in tp half grading into amorphous, plastic organic mud towards base. Sharp boundary to:
ARCA BH01	3.43	3.60	Silt/clay	5 Y 4/1 Dark grey, compact silt/clay with a slightly soapy texture (high silt content). Sharp boundary to:
ARCA BH01	3.60	4.20	Sandy silt/clay	Gley 1 4/10Y Dark greenish grey silt/clay with increasing very fine to fine sand towards the base. (Fine grained alluvium).

ARCA BH01	4.20	4.68	Sandy gravel	5 Y 5/2 Olive grey poorly sorted, clast-supported gravel of flints. Clasts are white patinated, angular to sub rounded granular to medium pebble-size black flint. Fine to coarse sand <50%. (top 0.2m washed out). (Channel gravels). Sharp boundary to:
ARCA BH01	4.68	5.40	Medium to coarse sand	5 Y5/3 Olive medium to coarse sand with occasion granule. (Channel sands). Sharp boundary to:
ARCA BH01	5.40	5.55	Fine sand	5 Y 5/3 Olive well sorted fine sand. (Channel sands). Sharp boundary to:
ARCA BH01	5.55	5.70	Medium to coarse sand	5 Y5/3 Olive medium to coarse sand with occasion granule. (Channel sands). End of borehole (bh).
ARCA BH02	0.00	0.10	Tarmac	Tarmacadam. (Modern Made Ground).
ARCA BH02	0.10	0.70	Cinder/sand	7.5 YR 2.5/1 Black fine to medium sand-sized particles and frequent comminuted charcoal. Rare fine pebble of vesicular slag/cinder. Rare brick and concrete cobble-sized clasts. Cobble-sized clast of rusted metal (Modern Made Ground). Sharp boundary to:

ARCA BH02	0.70	1.20	Silt/clay	2.5 Y 4/2 Dark greyish brown silt/clay with frequent irregular greyish brown mottles, black organic spots and rare medium sand-sized particles at the top. (Fine grained alluvium).
ARCA BH02	1.20	2.30	Silt/clay	Gley 1 4/10Y Dark greenish grey to Gley 2 4/5B Dark bluish grey, compact and homogenous silt/clay with occasional coarse sand-sized spots of black (organic) silt/clay. (Fine grained alluvium). Diffuse boundary to:
ARCA BH02	2.30	2.40	Silt/clay with organic fragments	7.5 YR 4/1 Brown silt/clay with occasional to frequent granular sized peat fragments increasing towards base. (Detrital peat in fine grained alluvium). Sharp boundary to:
ARCA BH02	2.40	2.70	Peat	7.5 YR 2.5/1 Black, moderately well humified peat. Oxidises from reddish black to black. Dryish. Occasional fine pebble-sized wood clasts. Firm, fibrous texture with discrete sand-sized plant fibres, horizontally laminated towards base. Sharp boundary to:
ARCA BH02	2.70	3.03	No recover	Void

ARCA BH02	3.03	3.40	Silt/clay with organic fragments	5 Y 4/2 Olive grey silt/clay with granular-sized peat fragments grading into 2.5 Y 5/2 Olive grey very fine sand with whitish bands apparently associated with medium pebble-sized clasts of wood. Occasional pebble-sized tabular concretions of very fine whitish sand and black organic grains. (Fine grained alluvium and detrital wood)
ARCA BH02	3.40	5.70	Fine sand	5 Y5/3 Olive well sorted, homogenous fine sand. (Channel sands).
ARCA BH02	5.70	7.20	Sandy gravel	5 Y5/3 Olive moderately well sorted, medium to coarse sand interbedded with thin well sorted fine sands and poorly sorted sandy flint gravel. (Channel sands and gravels). End of bh.
ARCA BH03	0.00	0.10	Tarmac	Tarmacadam. (Modern Made Ground).
ARCA BH03	0.10	0.60	Cinder/sand	7.5 YR 2.5/1 Black fine to medium sand-sized particles and frequent comminuted charcoal. Rare fine pebble of vesicular slag/cinder. Concrete pebble-sized clasts. (Modern Made Ground). Sharp boundary to:

ARCA BH03	0.60	1.20	Silt/clay with organic fragments	2.5 Y 4/2 Dark greyish brown silt/clay with frequent irregular greyish brown mottles. Frequent granular-sized plant and wood fragments (modern?). (Fine grained alluvium).
ARCA BH03	1.20	2.60	Silt/clay	Gley 1 4/10Y Dark greenish grey to Gley 2 4/5B Dark bluish grey, compact and homogenous silt/clay with occasional coarse sand-sized spots of black (organic) silt/clay. Detrital peat granules at base. (Fine grained alluvium).Diffuse boundary to:
ARCA BH03	2.60	2.70	Peat	7.5 YR 2.5/1 Black, moderately well humified peat. Oxidises from reddish black to black. Convoluted bedding with pebble-sized wood clasts.
ARCA BH03	2.70	2.80	No recover	Void
ARCA BH03	2.80	3.20	Peat	7.5 YR 2.5/1 Black, moderately well humified peat. Oxidises from reddish black to black. Dryish. Occasional fine pebble-sized wood clasts and rare cobble-sized clast. Firm, fibrous texture with discrete sand-sized plant fibres, horizontally bedded. 5Y 6/1 grey silt/clay bed at 2.86-2.88m. Diffuse boundary to:

ARCA BH03	3.20	3.94	Silt/clay with organic fragments	2.5 Y 4/1 Dark grey, compact silt/clay grading into 2.5 Y 5/2 greyish brown silt/clay with occasional detrital peat grains. Sharp boundary to:
ARCA BH03	3.94	4.20	Fine sand	5 Y 5/3 Olive well sorted fine sand. (Channel sands).
ARCA BH03	4.20	5.70	Medium to coarse sand	5 Y 5/3 Olive well sorted fine sand interbedded with moderately sorted fine to coarse sands with occasional fine to medium flint gravel clasts and thin lenses. (Channel sands). End of bh.
ARCA BH04	0.00	0.10	Concrete	Concrete. (Modern Made Ground).
ARCA BH04	0.10	1.20	Cinder/sand	7.5 YR 2.5/1 Black fine to medium sand-sized particles and frequent comminuted charcoal. Rare granule to coarse pebble-sized vesicular slag/cinder. (Modern Made Ground). Sharp boundary to:
ARCA BH04	1.20	1.43	Silt/clay with organic fragments	Gley 1 3/N Black, compact silt/clay with occasional black organic spots. Sharp boundary to:
ARCA BH04	1.43	2.70	Oxidised silt/clay	2.5 Y 4/3 Olive brown, compact silt/clay with frequent grains and granules of Fe oxide. Oxidation mottles. (Oxidised fine grained alluvium).

ARCA BH04	2.70	3.50	Oxidised silt/clay	2.5 Y 4/3 Olive brown, compact silt/clay with frequent grains and granules of Fe oxide. Oxidation mottles. Lens of poorly sorted fine gravel with coarse pebble-sized fragment of white porcelain (base) at 3.08m. (Oxidised fine grained alluvium). Diffuse boundary to:
ARCA BH04	3.50	6.40	Fine sand	5 Y 4/2 Olive grey fine, well sorted sand with interbedded gravel lenses at 5.2-5.36m and 5.8-6.05m.
ARCA BH04	6.40	7.20	Sandy gravel	5 Y 5/2 Olive grey poorly sorted, clast-supported gravel of flints. Clasts are white patinated, angular to sub rounded granular to medium pebble-size black flint. Fine to coarse sand <50%. (Channel gravels). End of bh.
ARCA BH05	0.00	0.10	Tarmac	Tarmacadam. (Modern Made Ground).
ARCA BH05	0.10	0.70	Cinder/sand	7.5 YR 2.5/1 Black fine to medium sand-sized particles and frequent comminuted charcoal. Rare granule to coarse pebble-sized vesicular slag/cinder. (Modern Made Ground). Sharp boundary to:

ARCA BH05	0.70	1.20	Silt/clay	Gley 2 4/5B Dark bluish grey silt/clay with frequent irregular greyish brown mottles and black organic grains. (Fine grained alluvium).
ARCA BH05	1.20	2.20	Silt/clay	Gley 1 4/10Y Dark greenish grey to Gley 2 4/5B Dark bluish grey, compact and homogenous silt/clay with occasional coarse sand-sized spots of black (organic) silt/clay. Detrital peat granules at base. (Fine grained alluvium). Gradual boundary to:
ARCA BH05	2.20	2.70	Peat	7.5 YR 2.5/1 Black, moderately well humified peat. Oxidises from reddish black to black. Dryish. Occasional fine pebble-sized wood clasts. Firm, fibrous texture with discrete sand-sized plant fibres, horizontally bedded.
ARCA BH05	2.70	3.00	No recover	Void
ARCA BH05	3.00	3.27	Peat	7.5 YR 2.5/1 Black, moderately well humified peat. Oxidises from reddish black to black. Dryish. Occasional fine pebble-sized wood clasts. Firm, fibrous texture with discrete sand-sized plant fibres, horizontally bedded. Diffuse boundary to:

ARCA BH05	3.27	3.37	Organic mud	5 Y 2.5/1 Black organic mud with rare sand-sized peat particles towards top. Diffuse boundary to:
ARCA BH05	3.37	3.88	Silt/clay	5 Y 5/1 Grey, compact and homogenous silt/clay. Sharp boundary to:
ARCA BH05	3.88	7.20	Fine sand	5 Y 5/2 Olive grey, well sorted fine sand.
ARCA BH05	7.20	8.02	Medium to coarse sand	2.5 Y 5/3 Light olive brown, well sorted medium sand.
ARCA BH05	8.02	8.20	Sandy gravel	5 Y 5/2 Olive grey poorly sorted, clast-supported gravel of flints. Clasts are white patinated, angular to sub rounded granular to medium pebble-size black flint. Fine to coarse sand <50%. (Channel gravels). End of bh.
ARCA BH06	0.00	0.10	Tarmac	Tarmacadam. (Modern Made Ground).
ARCA BH06	0.10	1.20	Cinder/sand	7.5 YR 2.5/1 Black fine to medium sand-sized particles and frequent comminuted charcoal. Rare granule to coarse pebble-sized vesicular slag/cinder and rare coarse pebble-sized rock fragment of unknown lithology. (Modern Made Ground). Sharp boundary to:

ARCA BH06	1.20	2.10	Silt/clay	Gley 1 4/10Y Dark greenish grey to Gley 2 4/5B Dark bluish grey, compact and homogenous silt/clay with occasional coarse sand-sized spots of black (organic) silt/clay. Detrital peat granules at base. (Fine grained alluvium). Gradual boundary to:
ARCA BH06	2.10	3.25	Peat	7.5 YR 2.5/1 Black, moderately well humified peat. Oxidises from reddish black to black. Dryish. Occasional fine pebble-sized wood clasts. Firm, fibrous texture with discrete sand-sized plant fibres, horizontally bedded. Interbedded cinder/sand at 2.83-2.86m and 2.96-3.00m due to destruction of liner and collapse of strata on transfer to new liner: contaminated peat unit. Diffuse boundary to:
ARCA BH06	3.25	3.98	No recover	Void (loss of silt/clay and sand when casing splits)
ARCA BH06	3.98	4.30	No recover	Slump (collapse of bh side on withdrawal of casing for UXO test)
ARCA BH06	4.30	5.10	Fine sand	5 Y 5/2 Olive grey, well sorted fine sand.
ARCA BH06	5.10	5.30	No recover	Void (washed out sandy unit)

ARCA BH06	5.30	6.60	Sandy gravel	5 Y 5/2 Olive grey poorly sorted, clast-supported gravel of flints. Clasts are white patinated, angular to sub rounded granular to medium pebble-size black flint. Fine to coarse sand <50%. (Channel gravels).
ARCA BH06	6.00	7.85	Gravelly sand	5 Y 5/2 Olive grey poorly sorted, clast-supported fine gravel of flints. Clasts are white patinated, angular to sub rounded granular-sized black flint. Fine to coarse sand <50%. (Channel gravels). Sharp boundary to:
ARCA BH06	7.85	8.35	Silt/clay	2.5 Y 3/1 Very dark grey, very stiff and homogenous silt/clay. Horizontal laminae present. (London Clay Formation). End of bh.
Strata (in italics) overlying the monolith sequences in trenches 1 and 2 described below is derived from information provided by Cotswold Archaeology.				
Trench 1	*0.00*	*0.12*	*Tarmac*	*Context (100): 0.12m thick; asphalt/concrete. (Modern Made Ground)*
Trench 1	*0.12*	*0.52*	*Rubble*	*Context (101): 040m thick; demolition rubble. (Modern Made Ground)*
Trench 1	*0.52*	*0.72*	*Very fine sand*	*Context (102): 0.20m thick; friable, black, silty sand. (Modern Made Ground)*

Trench 1	*0.72*	*0.92*	*Silt/clay*	*Context (103): 0.38m thick; compact, sterile, mid greenish grey, silty clay. (Oxidised fine grained alluvium)*
Trench 1 <18> to <22>	0.92	1.82	Oxidised silt/clay	Monoliths <18> to <22>. 2.5 Y 4/3 Olive brown stiff silt/clay with frequent fine roots and root holes throughout and some granular ped structure. 50% iron oxide mottling of a grey 2.5 Y 5/1 silt/clay. (Oxidised fine grained alluvium). Gradual boundary to:
Trench 1 <18> to <22>	1.82	2.32	Silt/clay	Gley 1 3/N Black mixed with 2.5 Y3/1 Very dark grey fine intimate mottling, colour darkens towards base. Frequent dark orange iron oxide staining. Sharp boundary to:
Trench 1 <18> to <22>	2.32	2.49	Silt/clay with organic fragments	2.5 Y 3/3 Dark olive brown firm silt/clay with frequent granular, tabular peat fragments lying horizontally and occasional horizontal twig. Frequent iron oxide stains and grains. (Allochthonous top of peat; fine grained alluvium)

Trench 1 <18> to <22>	2.49	2.70	Peat	7.5 YR 2.5/1 Black, moderately well humified peat. Oxidises from reddish black to black. Dryish. Frequent granular to fine pebble-sized wood twigs. Firm, fibrous texture with discrete sand-sized plant fibres, well humified at base. 2 pollen samples. Very sharp horizontal boundary to:
Trench 1 <18> to <22>	2.70	3.02	Silt/clay	2.5 Y 4/1 Dark grey and 4/2 Dark greyish brown firm silt/clay with rare very fine sand and rare peat grains and granules. (Fine grained alluvium). End of <22>.
Trench 2	*0.00*	*0.10*	*Tarmac*	*Context (200): 0.1m thick; asphalt/concrete. (Modern Made Ground)*
Trench 2	*0.10*	*1.20*	*Rubble*	*Context (201): 1.1m thick; demolition rubble and domestic waste. (top 0.1m of <8> is the base of this context according to section drawing.) (Modern Made Ground)*
Trench 2 <8> to <11>	1.20	1.80	Oxidised silt/clay	Monoliths <8> to <11>. 2.5 Y 4/3 Olive brown stiff silt/clay with oxidation mottles and reddish bands. Diffuse boundary to:

Trench 2 <8> to <11>	1.80	1.90	Oxidised silt/clay	2.5 Y 3/3Dark olive brown firm silt/clay with rare allochthonous peat granules. (Allochthonous top of peat; fine grained alluvium). Diffuse boundary to:
Trench 2 <8> to <11>	1.90	2.17	Peat	7.5 YR 2.5/1 Black, very well humified, firm but fraible peat. Oxidises from reddish black to black. Dryish. Occasional granular to fine pebble-sized wood clasts and twigs. 40mm roughly trainular friable fragment of cbm, possibly bricotage, 7.5 YR 4/4 Brown with occasional very fine white grains. Evidence of fluvial reworking: sorting of particles. Pollen from 1.90 and 2.16. Diffuse boundary to:
Trench 2 <8> to <11>	2.17	2.70	Silt/clay	2.5 Y 4/1 Dark grey stiff silt/clay with rare granular to coarse pebble-sized rod shaped wood clasts (reworked). End of <11>.
Data below curtesy of Geotechnical Engineering Ltd (2014)				
TP01	0.00	0.10	Tarmac	MADE GROUND comprising black tarmacadam. (MADE GROUND)

TP01	0.10	0.20	Gravelly sand	Brownish black very gravelly fine to coarse SAND with low brick and concrete cobble content. Gravel is angular and sub-angular fine to coarse concrete, tarmacadam and brick. (MADE GROUND)
TP01	0.20	0.30	Sandy gravel	Greenish blue and grey sandy sub-angular to angular medium to coarse concrete GRAVEL with low brick and concrete cobble content. (MADE GROUND)
TP01	0.30	1.20	Sand	Black slightly gravelly fine to medium SAND with rare whole brick. Gravel is angular and sub-angular fine to coarse brick and concrete. (MADE GROUND)
TP01	1.20	3.00	Oxidised silt/clay	Firm greyish green slightly sandy CLAY. (ALLUVIUM) 2.50 - 3.00m: Becomes bluish grey locally mottled orange and brown.
TP01	3.00	3.20	Wood peat	Dark brown clayey fibrous PEAT with frequent decomposing wood fragments. (ALLUVIUM)
TP02	0.00	0.10	Tarmac	MADE GROUND comprising black tarmacadam.

TP02	0.10	0.40	Gravelly sand	Greyish brown very gravelly fine to coarse SAND with low brick and concrete cobble. Gravel is angular and sub-angular fine to coarse concrete, tarmacadam and brick. (MADE GROUND)
TP02	0.40	1.00	Gravelly sand	Brownish black very gravelly fine to coarse SAND with high angular and sub-angular brick and concrete cobble content. Gravel is angular and sub-angular fine to coarse brick, concrete and tarmacadam. (MADE GROUND)
TP02	1.00	2.20	Silt/clay	Firm greenish grey slightly sandy CLAY. (ALLUVIUM)
TP02	2.20	2.80	Wood peat	Dark brown clayey fibrous PEAT with frequent decomposing wood fragments. (ALLUVIUM)
TP03	0.00	0.10	Tarmac	MADE GROUND comprising black tarmacadam.
TP03	0.10	0.45	Gravelly sand	Black very gravelly fine to coarse SAND with low brick and concrete cobble content. Gravel is angular and sub-angular fine to coarse concrete, tarmacadam, metal rod and brick. (MADE GROUND)

TP03	0.45	0.50	Concrete	MADE GROUND comprising grey concrete.
TP03	0.50	0.70	Gravelly sand	Black very gravelly fine to coarse SAND with low brick and concrete cobble content. Gravel is angular and sub-angular fine to coarse concrete, tarmacadam, metal and brick. (MADE GROUND)
TP03	0.70	2.50	Oxidised silt/clay	Firm greyish green slightly sandy CLAY. (ALLUVIUM) 1.20 - 2.50m: Becomes bluish grey locally mottled orange and brown.
TP03	2.50	3.00	Silt/clay with organic fragments	Soft peaty very sandy bluish green mottled orange and brown CLAY with frequent decomposing wood fragments. End of TP at 2.5m (ALLUVIUM)
BH01	0.00	0.10	Tarmac	MADE GROUND comprising black tarmacadam
BH01	0.10	0.30	Gravelly sand	Black very gravelly angular and sub-angular fine to coarse SAND with high angular and sub-angular tarmacadam, concrete and brick cobble content. Gravel is angular and sub-angular fine to coarse tarmacadam, brick and concrete. Rare glass and metal wire fragments. (MADE GROUND)

BH01	0.30	0.50	Sandy gravel	Greyish black very sandy angular and sub-angular fine to coarse tarmacadam, brick and concrete GRAVEL with high angular and sub-angular concrete and brick cobble content. (MADE GROUND)
BH01	0.50	0.80	Gravelly sand	Black gravelly fine to coarse SAND with low angular and sub-angular concrete and brick cobble content. Gravel is angular and sub-angular fine to coarse brick and concrete. (MADE GROUND)
BH01	0.80	1.20	Sandy silt/clay	Soft greyish green and black slightly gravelly sandy CLAY. Gravel is angular and sub-angular fine to coarse concrete and brick. (MADE GROUND)
BH01	1.20	2.30	Oxidised silt/clay	Firm greyish green slightly sandy CLAY. (ALLUVIUM) 2.00m: Locally mottled orangish brown.
BH01	2.30	2.50	Wood peat	Dark brown clayey fibrous PEAT with frequent wood fragments. (ALLUVIUM)
BH01	2.50	3.60	Sandy silt/clay	Firm brownish grey very sandy CLAY. (ALLUVIUM) ?Gradual boundary to:
BH01	3.60	5.00	Sandy gravel	Loose greyish brown slightly clayey sandy angular and sub-angular fine to coarse flint GRAVEL. (RIVER TERRACE DEPOSITS)

BH01	5.00	7.60	Sandy gravel	Very dense greyish brown slightly clayey sandy angular and sub-angular fine to coarse flint GRAVEL. (RIVER TERRACE DEPOSITS) 6.00m: Becomes dense.
BH01	7.60	21.50	Silt/clay	Firm to stiff brownish grey slightly sandy CLAY with frequent fine to coarse sand sized white selenite crystals (LONDON CLAY FORMATION)
BH02	0.00	0.10	Tarmac	MADE GROUND comprising black tarmacadam.
BH02	0.10	0.30	Concrete	MADE GROUND comprising grey concrete.
BH02	0.30	0.50	Gravelly sand	Black very gravelly fine to coarse SAND with high angular and sub-angular tarmacadam, concrete and brick cobble content. Gravel is angular and sub-angular fine to coarse tarmacadam, brick and concrete. Rare glass and metal wire fragments. (MADE GROUND)

BH02	0.50	1.20	Medium to coarse sand	Black slightly gravelly fine to coarse SAND with high angular and sub-angular brick and concrete cobble content. Gravel is angular and sub-angular fine to coarse brick, concrete (Strong tarmacadam odour). (MADE GROUND)
BH02	1.20	2.00	Sandy silt/clay	Firm blackish grey and green slightly gravelly sandy CLAY. Gravel is angular and sub-angular fine to coarse flint, concrete and brick. Rare metal wire fragment. (MADE GROUND)
BH02	2.00	2.60	Oxidised silt/clay	Soft greyish green locally mottled orange and brown slightly sandy CLAY. (ALLUVIUM)
BH02	2.60	3.60	Wood peat	Dark brown slightly sandy clayey fibrous PEAT with frequent wood fragments. (ALLUVIUM)
BH02	3.60	4.40	Silt/clay with organic fragments	Soft brownish grey slightly sandy peaty CLAY with frequent fine to coarse gravel sized sandy shell fragments. (ALLUVIUM)
BH02	4.40	4.80	Sandy silt/clay	Firm grey slightly gravelly sandy CLAY. Gravel is sub-angular and sub-rounded fine to coarse flint. (ALLUVIUM)

BH02	4.80	6.10	Sandy gravel	Dense brownish grey slightly clayey very sandy sub-angular to sub-rounded fine to coarse flint and rare quartz GRAVEL. (RIVER TERRACE DEPOSITS)
BH02	6.10	6.60	Sandy silt/clay	Firm indistinctly laminated reddish brown and greyish green mottled slightly gravelly sandy CLAY. Gravel is angular and sub-angular fine to coarse flint. Rare shell fragments (RIVER TERRACE DEPOSITS)
BH02	6.60	11.30	Sandy gravel	Dense brownish grey slightly silty sandy su-angular to sub-rounded fine to coarse flint GRAVEL. (RIVER TERRACE DEPOSITS) 10.50m: Becoming very dense
BH02	11.30	12.95	Silt/clay	Very stiff bluish grey indistinctly laminated slightly sandy CLAY with rare fine to medium sand sized white selenite crystals. (LONDON CLAY FORMATION) End of BH.
BH03	0.00	0.10	Tarmac	MADE GROUND comprising black tarmacadam.

BH03	0.10	0.60	Gravelly sand	Blackish brown very gravelly fine to coarse SAND. Gravel is angular and sub-angular fine to coarse tarmacadam, brick and concrete. Rare glass and metal wire fragments. (MADE GROUND)
BH03	0.60	0.80	Sandy silt/clay	Firm blackish brown gravelly sandy CLAY. Gravel is angular and sub-angular fine to coarse concrete and brick. (MADE GROUND)
BH03	0.80	1.70	Oxidised silt/clay	Soft greyish brown locally mottled orange and brown sandy CLAY. (ALLUVIUM)
BH03	1.70	2.40	Wood peat	Dark brown clayey fibrous PEAT with frequent wood fragments. (ALLUVIUM)
BH03	2.40	3.30	Oxidised silt/clay	Soft brownish grey locally mottled orange and brown slightly sandy CLAY with rare rootlets (<1mm). (ALLUVIUM)
BH03	3.30	5.00	Sandy gravel	Medium dense greyish brown slightly clayey sandy angular and sub-angular fine to coarse flint GRAVEL. (RIVER TERRACE DEPOSITS?)
BH03	5.00	7.50	Gravelly sand	Dense brownish grey gravelly very silty fine to coarse SAND. Gravel is sub-angular to sub-rounded fine to coarse flint. (RIVER TERRACE DEPOSITS) 6.00m: Becoming medium dense.

BH03	7.50	9.80	Sandy gravel	Very dense brownish grey sandy sub-angular to sub-rounded fine to coarse flint GRAVEL. (RIVER TERRACE DEPOSITS)
BH03	9.80	13.70	Silt/clay	Very stiff greenish grey indistinctly laminated slightly sandy CLAY with rare fine to coarse whitish selenite crystal and shell fragments. (LONDON CLAY FORMATION) End of BH.
BH04	0.00	0.10	Tarmac	MADE GROUND comprising black tarmacadam.
BH04	0.10	0.20	Gravelly sand	Blackish brown very gravelly fine to coarse SAND. Gravel is angular and sub-angular fine to coarse tarmacadam, brick and concrete. (MADE GROUND)
BH04	0.20	1.00	Medium to coarse sand	Black slightly gravelly fine to coarse SAND. Gravel is angular and sub-angular fine to coarse flint and brick. (MADE GROUND)
BH04	1.00	1.20	Gravelly sand	Black gravelly clayey fine to coarse SAND. Gravel is angular and sub-angular fine to coarse flint, concrete and brick. (MADE GROUND)

BH04	1.20	2.30	Oxidised silt/clay	Soft greyish green locally mottled orange and brown slightly sandy CLAY with rare fine to coarse shell fragments. (ALLUVIUM)
BH04	2.30	2.70	Wood peat	Dark brown clayey fibrous PEAT with frequent wood fragments. (ALLUVIUM)
BH04	2.70	5.40	Silt/clay with organic fragments	Soft brownish grey and green slightly sandy peaty CLAY with frequent wood fragments. (ALLUVIUM) 3.20 - 5.40m: Becomes very sandy. 5.00m: Becomes firm.
BH04	5.40	8.60	Sandy gravel	Dense brownish grey very sandy sub-angular to sub-rounded fine to coarse flint GRAVEL. (RIVER TERRACE DEPOSITS) 7.50m: Becomes loose.
BH04	8.60	12.50	Silt/clay	Stiff greenish grey indistinctly laminated slightly sandy CLAY with rare fine to coarse sand sized white selenite crystals and shell fragments. (LONDON CLAY FORMATION) End of BH.
BH05	0.00	0.10	Tarmac	MADE GROUND comprising black tarmacadam.
BH05	0.10	0.20	Concrete	MADE GROUND comprising grey concrete.

BH05	0.20	0.60	Gravelly sand	Light brown very gravelly fine to coarse SAND. Gravel is sub-angular and angular fine to coarse concrete and flint. (MADE GROUND)
BH05	0.60	1.20	Gravelly sand	Black gravelly fine to coarse SAND. Gravel is sub-angular and angular fine to coarse concrete and brick. (MADE GROUND)
BH05	1.20	1.50	Silt/clay	Very soft greyish green slightly sandy CLAY. (ALLUVIUM
BH05	1.50	3.00	Wood peat	Dark brown slightly sandy clayey fibrous PEAT with frequent wood fragments. (ALLUVIUM)
BH05	3.00	5.50	Silt/clay with organic fragments	Very soft brownish grey slightly sandy very peaty CLAY with rare wood fragments. (ALLUVIUM) 4.00 - 5.50m: Becomes firm . 5.00 - 5.50m: Becomes very soft
BH05	5.50	7.60	Very fine sand	Firm brownish grey sandy SILT. (ALLUVIUM)
BH05	7.60	8.30	Gravelly sand	Loose brownish grey gravelly fine to coarse SAND. Gravel is sub-angular to sub-rounded fine to coarse flint. (RIVER TERRACE DEPOSITS?)

BH05	8.30	12.50	Sandy silt/clay	Firm brownish grey sandy CLAY with rare white fine to medium sand sized selenite crystals. (LONDON CLAY FORMATION)
BH05	12.50	15.45	Medium to coarse sand	Grey clayey fine to medium SAND with frequent fine to coarse sandy shell fragments. (HARWICH FORMATION) End of BH.
BGS borehole data (BGS 2017c)				
TQ48SE1911	0.00	0.10	Tarmac	Brick and concrete sub-base
TQ48SE1911	0.10	3.80	Sandy gravel	Dense to very dense brown sandy sub-angular to sub-rounded flint gravel
TQ48SE1911	3.80	17.00	Silt/clay	Stiff becoming very stiff brown grey fissured silty clay
TQ48SE1912	0.00	0.50	Rubble	Tarmac over fill (rubble).
TQ48SE1912	0.50	1.00	Sandy silt/clay	Firm light brown silty sandy clay
TQ48SE1912	1.00	4.50	Sandy gravel	Dense to very dense brown sandy sub-angular to sub-rounded flint gravel
TQ48SE1912	4.50	10.00	Silt/clay	Stiff becoming very stiff brown grey fissured silty clay
TQ48SE1915	0.00	0.20	Concrete	
TQ48SE1915	0.20	1.20	Sandy gravel	Fill (brown fine to coarse sand and fine to coarse angular to rounded gravel with brick and concrete)
TQ48SE1915	1.20	4.90	Sandy gravel	Medium dense brown fine to coarse sand and fine to medium angular to rounded gravel

TQ48SE1915	4.90	10.00	Silt/clay	Firm brown to mottled grey brown fissured silty clay with occasional selenite crystals.
TQ48SE1914	0.00	0.10	Brick	
TQ48SE1914	0.10	0.20	Sand	
TQ48SE1914	0.20	2.40	Sandy gravel	Fill
TQ48SE1914	2.40	2.70	Gravelly sand	Loose orange brown slightly clayey silty fine to coarse sand with sub-angular to rounded fine to medium gravel.
TQ48SE1914	2.70	3.00	Sandy silt/clay	Firm orange brown silty very sandy clay with coarse sand and fine to medium angular to rounded gravel.
TQ48SE1914	3.00	10.00	Silt/clay	Firm brown to mottled grey brown fissured silty clay with occasional selenite crystals.
TQ48SE1913	0.00	2.65	Gravelly sand	Fill
TQ48SE1913	2.65	4.00	Sandy gravel	Medium dense silty fine to coarse sand and fine to coarse sub-angular to rounded gravel. Very clayey 2.7-3.2m. Occasional pockets of brown mottled grey silty clay below 3.2m
TQ48SE1913	4.00	10.00	Silt/clay	Firm brown to mottled grey brown fissured silty clay with occasional selenite crystals.
TQ48SE881	0.00	0.31	Topsoil	
TQ48SE881	0.31	1.22	Oxidised silt/clay	Firm brown mottled clay
TQ48SE881	1.22	2.13	Silt/clay with organic fragments	Brown sandy clay with traces of peat

TQ48SE881	2.13	3.35	Peat	
TQ48SE881	3.35	4.27	Sandy silt/clay	Grey sandy clay with some peat and gravel
TQ48SE881	4.27	7.62	Sandy gravel	
TQ48SE882	0.00	0.15	Topsoil	
TQ48SE882	0.15	1.01	Oxidised silt/clay	Firm brown mottled clay
TQ48SE882	1.01	1.68	Silt/clay with organic fragments	Brown grey mottled clay with traces of peat
TQ48SE882	1.68	3.66	Peat	
TQ48SE882	3.66	4.88	Sandy silt/clay	Grey sandy clay with traces of peat
TQ48SE882	4.88	7.62	Sandy gravel	
TQ48SE883	0.00	0.15	Topsoil	
TQ48SE883	0.15	0.91	Rubble	Fill
TQ48SE883	0.91	1.98	Oxidised silt/clay	Firm brown mottled clay
TQ48SE883	1.98	3.96	Peat	
TQ48SE883	3.96	4.42	Sandy silt/clay	Grey sandy clay with traces of peat
TQ48SE883	4.42	5.03	Silt/clay	Soft to firm light grey clay
TQ48SE883	5.03	7.62	Sandy gravel	
TQ48SE884	0.00	0.31	Topsoil	
TQ48SE884	0.31	1.68	Oxidised silt/clay	Firm brown grey mottled clay
TQ48SE884	1.68	3.66	Peat	
TQ48SE884	3.66	3.96	Sandy silt/clay	Grey sandy clay with traces of peat
TQ48SE884	3.96	4.42	Sandy silt/clay	Grey sandy clay with traces of peat and gravel
TQ48SE884	4.42	7.62	Sandy gravel	
TQ48SE885	0.00	0.31	Topsoil	

TQ48SE885	0.31	0.76	Oxidised silt/clay	Firm brown clay
TQ48SE885	0.76	1.37	Rubble	Fill
TQ48SE885	1.37	2.59	Oxidised silt/clay	Firm brown grey mottled clay
TQ48SE885	2.59	3.81	Peat	
TQ48SE885	3.81	4.27	Sandy silt/clay	Grey sandy clay with traces of peat
TQ48SE885	4.27	7.62	Sandy gravel	
TQ48SE886	0.00	0.15	Topsoil	
TQ48SE886	0.15	0.46	Silt/clay	Fine grey clay
TQ48SE886	0.46	1.07	Rubble	Fill
TQ48SE886	1.07	2.13	Silt/clay	Fine grey clay
TQ48SE886	2.13	3.96	Peat	
TQ48SE886	3.96	4.72	Silt/clay with organic fragments	Soft grey clay with traces of peat
TQ48SE886	4.72	7.62	Sandy gravel	
TQ48SE887	0.00	0.31	Topsoil	
TQ48SE887	0.31	1.52	Oxidised silt/clay	Soft brown clay
TQ48SE887	1.52	3.66	Peat	
TQ48SE887	3.66	4.11	Silt/clay with organic fragments	Grey clay with traces of peat
TQ48SE887	4.11	5.03	Sandy silt/clay	Grey sandy clay and traces of peat
TQ48SE887	5.03	7.62	Sandy gravel	
TQ48SE888	0.00	0.15	Topsoil	
TQ48SE888	0.15	1.52	Oxidised silt/clay	Reddish brown grey mottled clay
TQ48SE888	1.52	3.05	Peat	
TQ48SE888	3.05	3.81	Sandy silt/clay	Firm grey sandy clay and traces of peat
TQ48SE888	3.81	5.18	Sandy gravel	
TQ48SE1172	0.00	0.70	Rubble	
TQ48SE1172	0.70	1.90	Oxidised silt/clay	Fine brown and grey clay

TQ48SE1172	1.90	5.20	Peat	
TQ48SE1172	5.2	5.6	Sandy silt/clay	Soft grey very sandy clay and occasional peat fragments
TQ48SE1172	5.60	5.75	Sandy silt/clay	Firm grey green sandy clay and rare organics
TQ48SE1172	5.75	6.01	Sandy gravel	Grey brown silty fine to coarse sand and some coarse sub-angular to sub-rounded flint gravel

APPENDIX 3: PALAEOBOTANICAL METHODOLOGIES

Pollen assessment/analysis

Seventeen subsamples were originally extracted for pollen analysis from ARCA BH05. Of these samples, two were subsequently selected for analysis on the basis of them containing a good preservation and concentration of remains. A further four samples were taken from monoliths 10, 21 and 22 for pollen assessment.

The pollen was extracted as follows: (1) sampling a standard volume of sediment (1ml); (2) adding two tablets of the exotic clubmoss Lycopodium clavatum to provide a measure of pollen concentration in each sample; (3) deflocculation of the sample in 1% Sodium pyrophosphate; (4) sieving of the sample to remove coarse mineral and organic fractions (>125μ); (5) acetolysis; (6) removal of finer minerogenic fraction using Sodium polytungstate (specific gravity of 2.0g/cm3); (7) mounting of the sample in glycerol jelly. Each stage of the procedure was preceded and followed by thorough sample cleaning in filtered distilled water. Quality control is maintained by periodic checking of residues, and assembling sample batches from various depths to test for systematic laboratory effects. Pollen grains and spores were identified using the University of Reading pollen type collection and the following sources of keys and photographs: Moore *et al* (1991); Reille (1992).

The assessment procedure consisted of scanning the prepared slides, recording the concentration and preservation of pollen grains and spores, and the principal taxa on four transects (10% of the slide). Due to the high concentration of pollen encountered during the assessment,

The analysis procedure consisted of counting all pollen to 300 Total Land Pollen where possible (TLP; trees, shrubs and herbs) where possible. Aquatic pollen and spores were also counted. Pollen grains and spores were identified using the University of Reading pollen type collection and the following sources of keys and photographs: Moore *et al* (1991); Reille (1992). Pollen percentage and pollen concentration diagrams were produced in 'Tilia'. Pollen percentage values were calculated as follows: Tree, shrub and herb taxa were calculated as a percentage of total land pollen (TLP); other remains (aquatics, spores and unidentified grains) were calculated as a percentage of TLP. A semi-quantitative measure of microcharcoal with dimensions >20um along at least one axis, were also recorded together with total pollen concentration. The results are displayed in Figure 2.

Diatom assessment/analysis

A total of 15 samples were originally submitted for an assessment of diatom presence from borehole ARCA BH05. Of these samples, two were subsequently selected for analysis on the basis of them containing a good preservation and concentration of remains.

0.5g of sediment was required for the diatom sample preparation. Due to the high silt and clay content of most samples, all samples chosen for analysis were first treated with sodium hexametaphosphate and left overnight, to assist in minerogenic deflocculation. Samples were then treated with hydrogen peroxide (30% solution) and/or weak ammonia (1% solution) depending on organic and/or calcium carbonate content, respectively. Samples were finally sieved using a 10µm mesh to remove fine minerogenic sediments. The residue was transferred to a plastic vial, from which a slide was prepared for subsequent assessment.

A minimum of 400 diatoms were identified for each sample depth. Diatom species were identified with reference to van der Werff and Huls (1958-74), Hendy (1964) and Krammer and Lange-Bertalot (1986-1991). Ecological classifications for the observed taxa were then achieved with reference to van der Werff and Huls (1958-74), Vos and deWolf (1988; 1993), Van Dam *et al*., (1994), Denys (1991-92; 1994) and Round *et al* (2007). The results of the analysis are displayed in Table 1.

Macrofossil assessment

Two small bulk samples were extracted and processed for the recovery of macrofossil remains, including waterlogged plant macrofossils, wood, insects and Mollusca (Tables 1 and 2). The samples were focussed on the peat within borehole BH5. The extraction process involved the following procedures: (1) measuring the sample volume by water displacement, and (2) processing the sample by wet sieving using 300µm and 1mm mesh sizes. Each sample was scanned under a stereozoom microscope at x7-45 magnifications, and sorted into the different macrofossil classes. The concentration and preservation of remains was estimated for each class of macrofossil (Table 3). Preliminary identifications of the waterlogged seeds (Table 4) have been made using modern comparative material and reference atlases (e.g. Martin and Barkley, 2000; NIAB, 2004; Cappers *et al* 2006). Nomenclature used follows Stace (2005). The waterlogged wood fragments were examined to identify the range of woods in each sample. Ten fragments from each sample were examined following standard techniques for the analysis of waterlogged wood elements, and taxon descriptions, as described in Hather (2000).

APPENDIX 4: RESULTS OF THE POLLEN ASSESSMENT FROM ARCA BH05, MERRIELANDS CRESCENT, DAGENHAM

	Depth (m OD)	-0.83	-0.88	-0.93	-0.98	-1.03	-1.08	-1.13	-1.18	-1.23	-1.28	-1.66	-1.71	-1.76	-1.81	-1.86	-1.91	-1.96

Latin name	**Common name**																	
Trees																		
Alnus	alder	47	24	10	236	138	224	68	210	47	39	39	18	5	3	5		
Quercus	oak	4	6	2	64	25	37	12	70	19	8	10	3		9	6		
Pinus	pine				2	1	2								1	1		
Ulmus	elm		1		3	2	2	3	6			1	2					
Tilia	lime		1		8	2	7	5	8	4	4	8	1	1	6	3		
Fraxinus	ash		1	1														
Shrubs																		
Corylus type	e.g. hazel	2	4	2	22	13	44	11	20	7	2	1	4		4	1	3	1
Hedera	ivy			1				1				1						
Ilex	holly							1										
Salix	willow				4							1						
Viburnum	viburnum					1								1				
Herbs																		
Cyperaceae	sedge family		3	3						2	2	1	1		6	3		
Poaceae	grass family		1	1				1	2						1			
Asteraceae	daisy family		1	1														
Apiaceae	carrot family				2				2	1	1							
Artemisia type	mugwort		1															
Lactuceae	dandelion family	1	2	2														
Rosaceae	rose family						1											
Chenopodium type	goosefoot family		2	1			1											

	Depth (m OD)	**-0.83**	**-0.88**	**-0.93**	**-0.98**	**-1.03**	**-1.08**	**-1.13**	**-1.18**	**-1.23**	**-1.28**	**-1.66**	**-1.71**	**-1.76**	**-1.81**	**-1.86**	**-1.91**	**-1.96**
Latin name	**Common name**																	
Caryophyllaceae	pink family				2													
Aquatics																		
Typha latifolia	common bulrush			2														
Spores																		
Pteridium aquilinum	bracken	4	7	2	8	1	1			1						4		
Asplenium	ferns					1					1			1	1	1		
Filicales	ferns	18	39	79	12		1		15	20	14	21	8	4	12	9		
Polypodium vulgare	polypody	1			12		4		4							1		
Unidentifiable																		
Total Land Pollen (grains counted)		54	47	24	343	182	318	102	318	80	56	62	29	12	30	19	3	1
Concentration*		5	5	5	5	5	5	5	5	5	5	5	5	3	5	4	0	0
Preservation**		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3
Microcharcoal Concentration***		0	0	0	0	0	0	0	0	0	0	3	0	2	4	4	5	5
Suitable for further analysis		**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**	**NO**	**NO**

Key: *Concentration: 0 = 0 grains; 1 =1-75 grains, 2 = 76-150 grains, 3 =151-225 grains, 4 = 226-300, 5 =300+ grains per slide; **Preservation: 0 = absent; 1 = very poor; 2 = poor; 3 = moderate; 4 = good; 5 = excellent; ***Microcharcoal Concentration: 0 = none, 1= negligible, 2 = occasional, 3 = moderate, 4 = frequent, 5 = abundant

APPENDIX 5: RESULTS OF THE DIATOM ASSESSMENT FROM ARCA BH05, MERRIELANDS CRESCENT, DAGENHAM

The most typical diatoms encountered in each sample are listed in order of abundance (most common at the top of each list)

Depth mOD	Diatoms encountered
0.17	*Cyclotella bodanica* *Rhaphoneis amphiceros* *Campylodiscus echeneis* *Actinoptychus splendens* *Pseudomelosira westii*
0.07	*n/a*
-0.03	*n/a*
-0.13	*n/a*
-0.23	*Campylodiscus echeneis*
-0.33	*n/a*
-0.43	*Centric girdle bands* *Pinnularia sp.*
-0.53	*n/a*
-0.63	*Cyclotella bodanica* *Pinnularia sp.* *Diploneis didyma* *Cymbella sp.* *Campylodiscus echeneis*

	Nitzschia punctata *Pseudomelosira westi* *Amphora sp.* *Anomeoneis sp.* *Diploneis weisflogii*
-0.73	*Cyclotella bodanica* *Diploneis ovalis* *Epithemia sp.* *Nitzschia navicularis* *Pseudopodosira stelligera* *Pinnularia sp.* *Rhaphoneis amphiceros* *Actinoptychus senarius*
-0.83	*Cyclotella sp.* *Nitzschia navicularis* *Diploneis sp.*
-1.91	*n/a*
-2.01	*n/a*
-2.11	*n/a*
-2.21	*n/a*

APPENDIX 6: RESULTS OF THE MACROFOSSIL ASSESSMENT FROM ARCA BH05, MERRIELANDS CRESCENT, DAGENHAM

					Charred					Waterlogged			Mollusca		Bone			
Depth (m bgl)	**Depth (m OD)**	**Unit**	**Volume processed (ml)**	**Fraction**	**Charcoal (>4mm)**	**Charcoal (2-4mm)**	**Charcoal (<2mm)**	**Seeds**	**Chaff**	**Wood**	**Seeds**	**Sedge remains (e.g. stems/roots)**	**Whole**	**Fragments**	**Large**	**Small**	**Fragments**	**Insects**
2.32 to 2.37	-0.93 to -0.98	Peat	<100	>300µm	-	-	-	-	-	-	2	-	-	-	-	-	-	1
				>1mm	-	-	-	-	-	5	1	-	-	-	-	-	-	-
3.05 to 3.10	-1.66 to -1.71		<100	>300µm	-	-	-	-	-	-	-	-	-	-	-	-	-	3
				>1mm	-	-	-	-	-	5	-	-	-	-	-	-	-	-

Key: 0 = Estimated Minimum Number of Specimens (MNS) = 0; 1 = 1 to 25; 2 = 26 to 50; 3 = 51 to 75; 4 = 76 to 100; 5 = 101+

APPENDIX 7: RESULTS OF THE SEED IDENTIFICATIONS FROM ARCA BH05, MERRIELANDS CRESENT, DAGENHAM

Depth (m bgl)	Depth (m OD)	Unit	Seed identification		Quantity	Waterlogged wood identifications		Quantity
			Latin name	**Common name**		**Latin name**	**Common name**	
2.32 to 2.37	-0.93 to -0.98	Peat	*Ranunculus* cf. fluitans/aquatilis *Sparganium erectum*	cf. river/common water-crowfoot branched bur-reed	5 1	*Alnus glutinosa* *cf. Alnus*-bark Bark (taxa indeterminate)	alder alder -	1 4 5
3.05 to 3.10	-1.66 to -1.71		-	-	-	*Salix/populus* sp. *Alnus glutinosa* Bark (taxa indeterminate)	willow/poplar alder -	2 6 2