FROG ISLAND
LONDON BOROUGH OF HAVERING

ARCHAEOLOGICAL WATCHING BRIEF

MER11

JUNE 2011

PRE-CONSTRUCT ARCHAEOLOGY

DOCUMENT VERIFICATION

FROG ISLAND, LONDON BOROUGH OF HAVERING

ARCHAEOLOGICAL WATCHING BRIEF

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An Archaeological Watching Brief at Merchant Waste Treatment Plant, Frog Island, London Borough of Havering

Site Code: MER11

National Grid Reference: TQ 5125 8091

Written and Researched by Alexander Pullen
Pre-Construct Archaeology Ltd, June 2011

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1 ABSTRACT (figs. 1 & 2)

1.1 This document details the results of an archaeological watching brief of geotechnical boreholes at Merchant Waste Treatment Plant, Frog Island, London Borough of Havering. The watching brief was commissioned by Mills Whipp Projects Ltd on behalf of Capita Symonds. The geotechnical work comprised the excavation of 12 boreholes between the 18th and 28th January 2011. A Written Scheme of Investigation for this work was prepared by Mills Whipp Projects Ltd, January 2011.

1.2 The archaeological watching brief demonstrated that river terrace gravel was present at approximately 10m below the current ground surface. Overlying the river terrace gravel was approximately 7m of alluvial deposits, the lower levels containing various accumulations of organic peaty material. Overlying the alluvial sequence was approximately 3m of modern made ground. Core samples removed during this watching brief provided significant material for palaeoenvironmental analysis.

1.3 Nine boreholes (BH 1-9) were initially excavated across the site. Two additional boreholes (BH 11 & 12) were selected by the archaeological contractor (Alexander Pullen, Pre-Construct Archaeology Ltd) for palaeoenvironmental analysis on the basis of the significant organic accumulations within the sequence in order to provide a further level of assessment of the site's archaeological potential. Continuous U100 core samples were taken from 5m below ground level (bgl) through the alluvial sequence to the top of the Thames river terrace gravels at approximately 10m below ground level. Borehole 10 (and BH10A) was abandoned due to the impenetrable nature of the made ground. No anthropogenic material was encountered during the assessment, and the potential for significant archaeology on the subject site is therefore considered to be low.

2 INTRODUCTION (figs. 1 & 2)

2.1 This document details the results of an archaeological watching brief of geotechnical boreholes at Merchant Waste Treatment Plant, Frog Island, London Borough of Havering. The watching brief was commissioned by Mills Whipp Projects Ltd on behalf of Capita Symonds. The geotechnical work comprised the excavation of 12 boreholes between the 18th and 28th January 2011.

2.2 The subject site lies to the west of Rainham Creek on the alluvium of the River Thames floodplain at the confluence of Rainham Creek and the River Thames (Figure 1). A Written Scheme of Investigation (WSI) prepared by Mills Whipp Projects Ltd, January 2011, provides detailed description of the working methodology followed and outlines the archaeological background to the site.

2.3 The aims and objectives of this work are outlined in the WSI prepared by Mills Whipp Projects Ltd. Nine boreholes (BH 1-9) were initially excavated across the site. Two additional boreholes (BH 11 & 12) were selected by the archaeological contractor (Alexander Pullen, Pre-Construct Archaeology Ltd) for palaeoenvironmental analysis to further assess the archaeological potential of the site. Continuous U100 core samples were taken from 5m below ground level (bgl) through the alluvial sequence to the top of the Thames Terrace Gravels between approximately 10m and 11m below ground level. Borehole 10 was abandoned due to the impenetrable nature of the modern made ground.

2.4 Reference to the 'height' of deposits within the recorded stratigraphic sequence is given in metres 'below ground level' (bgl). Ground level at the site is approximately 5.312m OD.

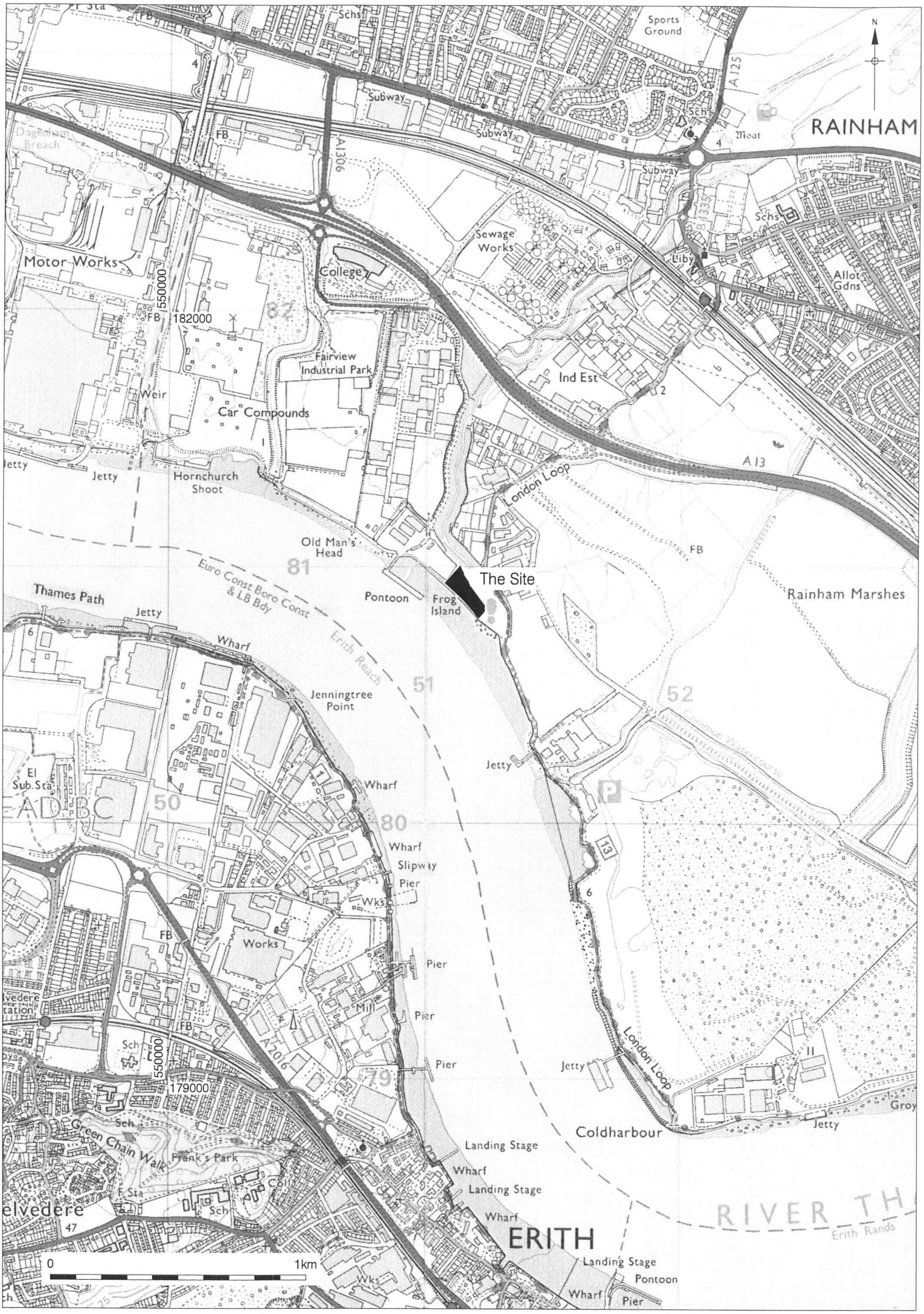

Figure 1
Site Location
1:20,000 at A4

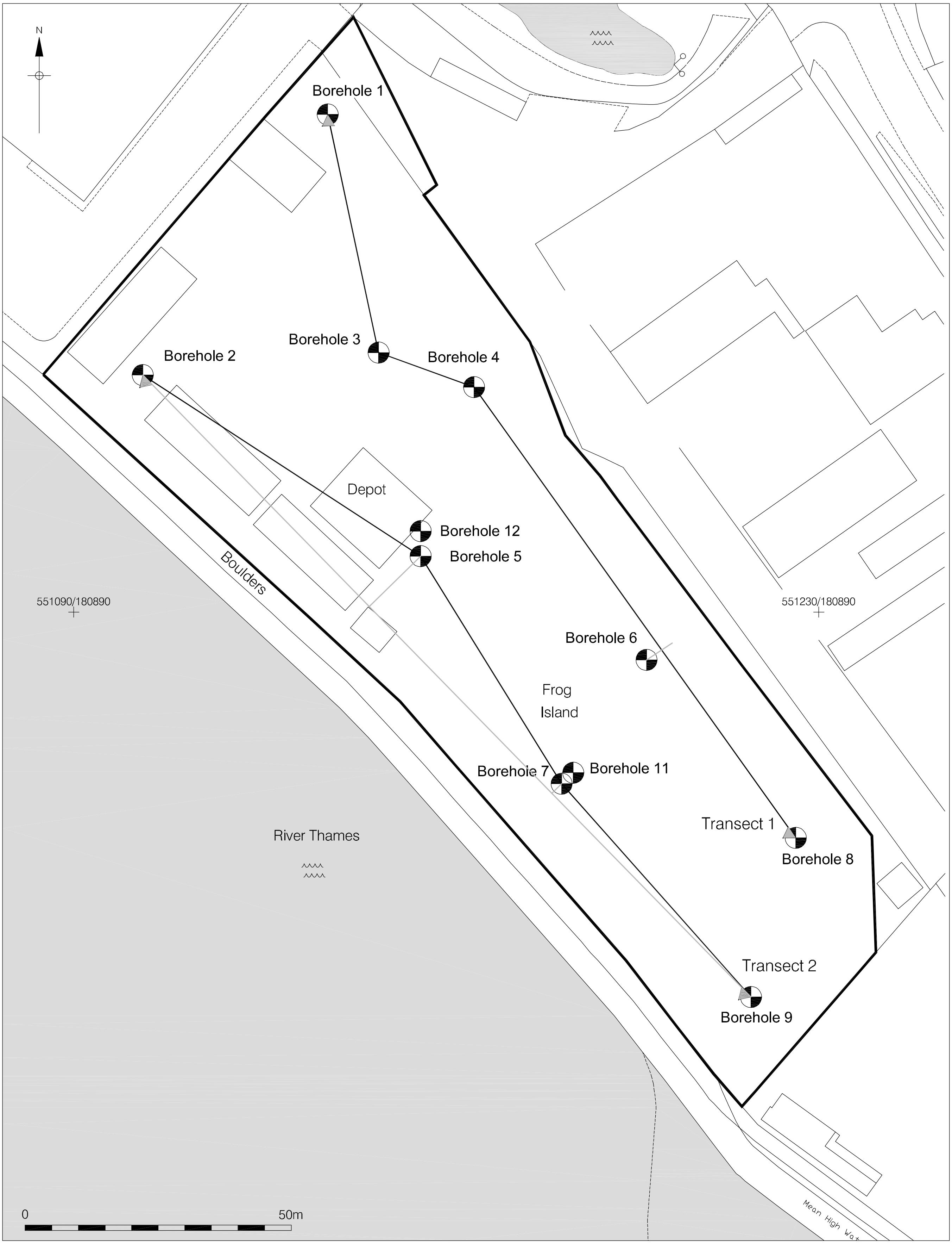

Figure 2
Borehole Location
1:1,000 at A4

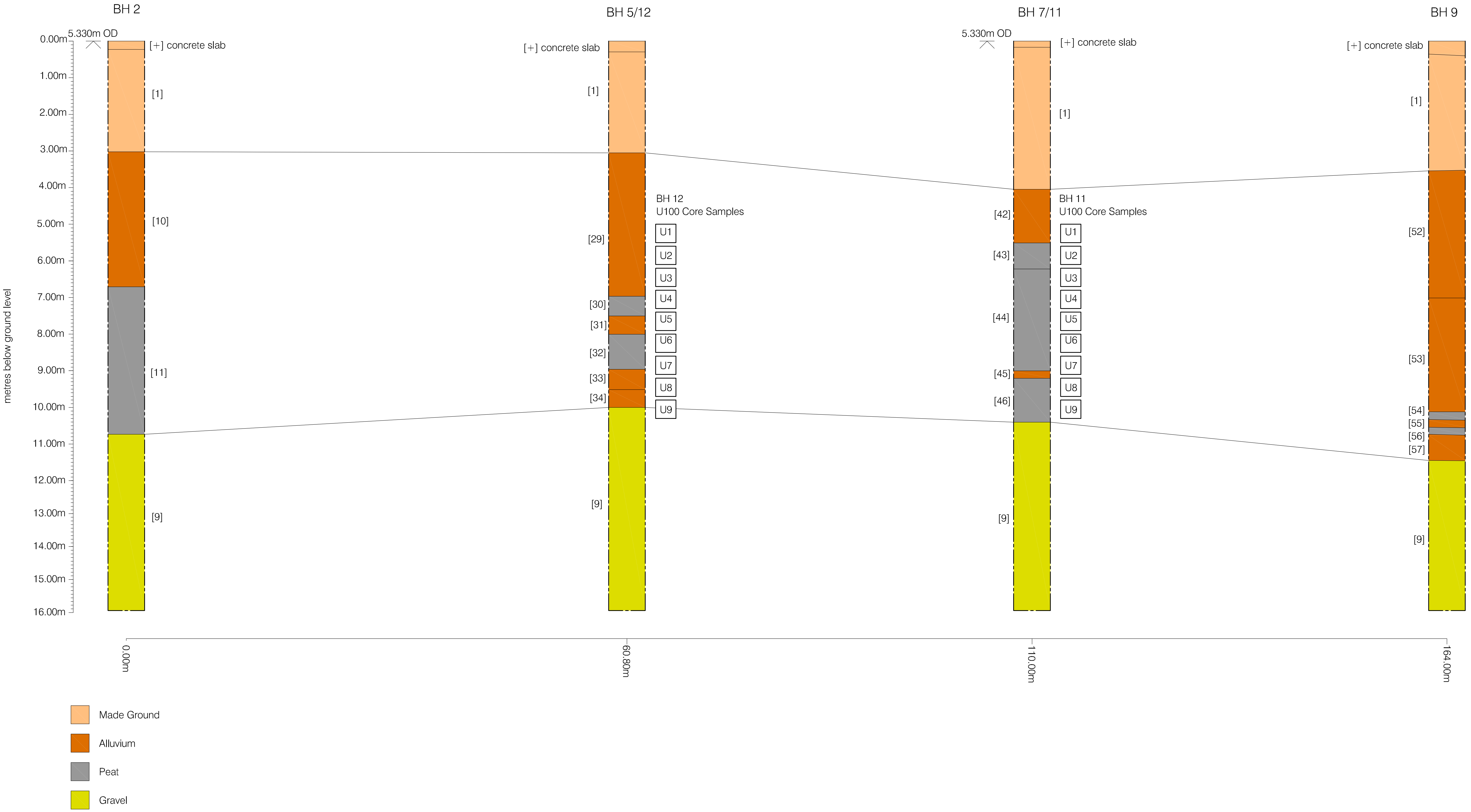

Figure 3
Deposit Model of Transect 2
Vertical Scale: 1:100 at A3

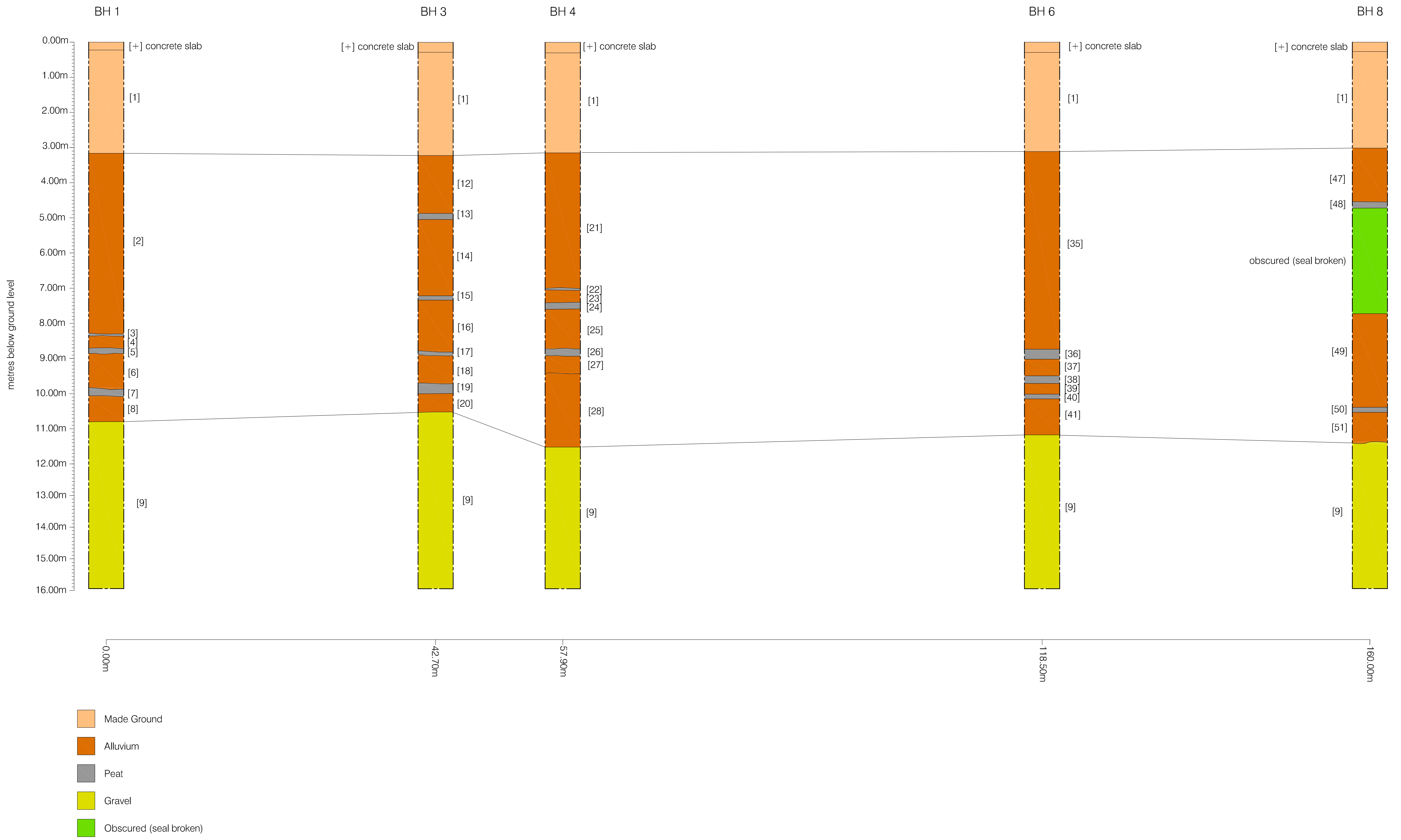

Figure 4
Deposit Model of Transect 1
Vertical Scale: 1:100 at A3

3 GEOLOGY AND TOPOGRAPHY

3.1 The site occupies the northern shore of the River Thames. The subject site lies to the west of Rainham Creek on the alluvium of the River Thames floodplain at the confluence of Rainham Creek and the River Thames (Figure 1). The alluvium includes peat layers at its base. The alluvium overlies Thames Terrace Gravels which sit on top of the London Clay.

3.2. Ground level across the site is approximately 5.312m OD.

4. ARCHAEOLOGICAL METHODOLOGY

4.1 The methodology followed during this watching brief was outlined in the WSI prepared by Mills Whipp Projects, January 2011.

4.2 The geotechnical works were conducted between the 18th and 28th January 2011 and comprised the initial excavation of 9 cable percussion geotechnical boreholes. This work was closely monitored by the archaeological contractor and the sequence of deposits recorded from ground level until the top of the Thames Terrace Gravels at approximately 10m bgl.

4.3 Two of the most promising boreholes in terms of their archaeological and palaeoenvironmental potential were selected (BH 5 and 7) and two further boreholes (BH 11 and 12) were sited as close to these as possible without compromising ongoing geotechnical work (see figure 2). The aim of assessing the core samples was to provide a further level of assessment of the site's archaeological potential following that set out within the Environmental Impact Assessment; this suggested that the key potential of the site was for prehistoric trackways / platforms recorded on the Thames floodplain. In order to assess the subject site's overall archaeological potential cores were assessed for anthropogenic material, specifically:

- Worked timber that may have formed part of a structure
- Indications of occupation – cultural material i.e. pottery or building material

The Continuous U100 core samples were removed from Boreholes 11 and 12 from 5m bgl until the Thames Terrace Gravel was reached. All material recovered from the shoes during the recovery of these U100s was retained. Material below the base of the made ground and 5m bgl was retained as for further analysis.

4.4 The site was assigned the code MER11.

4.5 The completed archive will be deposited with the London Archaeological Archive and Research Centre under the above site code.

5 DEPOSIT DESCRIPTIONS BOREHOLES 1-9

5.1 **Borehole 1.**

The River Terrace Gravels [9] were encountered in BH1 at a depth of 10.80m bgl. This was overlain by a soft, grey clay-silt [8] becoming more sandy towards the contact with the underlying gravels. The top of this deposit was 10.00m bgl. Overlying this deposit was [7], a 0.20m thick layer of spongy brown peat. The top of [7] was 9.80m bgl. The peat layer [7] was overlain by a layer of clay-silt [6], the top of which was 8.90m bgl. Overlying [6] was [5] a peaty clay-silt, the top of which was recorded at 8.70m bgl. Sealing [5] was [4], a grey-brown humic clay-silt alluvial deposit, the top of which occurred at 8.40m bgl. Overlying this layer was a thin (0.05m thick) layer of brown peat [3], the top of which was 8.30m bgl. This peat layer was overlain by a thick layer of clay-silt [2], the top which was recorded at 3.20m bgl. Overlying [2] was, the modern made ground and the current concrete slab [1].

5.2 **Borehole 2.**

In BH2 the River Terrace Gravels [9] were encountered at 10.80m bgl. The gravels were overlain by a 3.90m thick banded peat deposit [11]. This was largely a spongy mid-brown compressed fibrous deposit, humified to varying extents and more silty in places. The top of this deposit was 6.70m bgl. On top of this thick peat deposit(s) was a layer of clay-silt with occasional plant (reed stem) fragments and clear signs of vertical rooting [10]. The top of this alluvium was in contact with the bottom of the made ground at 3.00m bgl.

5.3 **Borehole 3.**

The top of the River Gravels were encountered at 10.50m bgl. These were overlain by a grey alluvial silt with some sand content [20]. The top of this layer was 10.00m bgl. This alluvium was overlain by a 0.30m thick layer of woody peat with branch fragments [19]. The top of this layer was 9.70m bgl. Overlying [19] was [18], a grey clay-silt, the top of which was 8.90m bgl. Deposit [17] lay above [18] and was a thin peat layer the top of which was 8.80m bgl. Deposit [17] was overlain by alluvial clay-silt [16] the top of which was 7.30m bgl. Another thin layer of peat [15] overlay [16] and was first encountered at 7.20m bgl. Overlying peat layer [15] was clay-silt [14] with occasional reedy plant stem fragments. The top of [14] was 5.00m bgl. A thin (0.20m) layer of peat [13] occurred above [14] at 4.80m bgl. Layer [13] was overlain by a soft mid-grey silt with occasional plant fragments (reed stems and rootlets). The top of [12] formed the contact with the bottom of the made ground [1] at 3.20m bgl.

5.4 **Borehole 4.**

In BH4 the top of the River Terrace Gravels [9] were encountered at 11.50m bgl. Overlying the gravels was a grey silty sand [28]. This deposit became sandier with depth towards the contact with the underlying gravels. The top of this deposit [28] was encountered at 9.40m bgl. Overlying this layer was [27] a sandy alluvial silt, the top of which was 8.90m bgl. A

0.20m layer of compressed woody peat occurred above [27]. This layer [26] was first encountered 8.70m bgl. Above this layer of peat was a [25] a grey clay-silt alluvium with plant remains and peaty lenses. The top of this alluvium [25] was 7.60m bgl. A 0.20m compressed woody peat layer [24] occurred above [25] and was recorded at 7.40m bgl. This peat contained well preserved branches and reed stems. Overlying this peat was [23], a thin layer of alluvial clay-silt with lenses of peat formation. This is in turn was overlain by [22] a thin (0.05m thick) band of silty alluvial peat. The top of [22], and [23] occurred at 6.95m bgl and 7.00m bgl respectively. Overlying these deposits was an alluvial clay-silt [21], with occasional fragments of plants stems and rootlets. The top of this layer formed the contact with the bottom of the made ground [1] at 3.10m bgl.

5.5 **Borehole 5.**

In BH5 the River Terrace Gravels [9] were encountered 10.00m bgl. The gravels were overlain by alluvial sand [34] which in turn was overlain by [33], a grey alluvial clay-silt. Overlying [33] was a 1.00m thick layer of fibrous, compressed woody peat with sizable (0.10m diameter) branch fragments. The top of layers [34], [33] and [32] were recorded at 9.50m bgl, 9.00m bgl and 8.00m bgl respectively. A grey clay-silt [31] overlay [32] and was recorded at a depth of 7.50m bgl. Another thinner peat layer was recorded overlying this alluvium. This layer [30] was brown, compressed and fibrous peat, slightly spongy with wood and bark pieces. The top of this [30] peat was 7.00m bgl. Overlying this peat deposit was [29], a grey alluvial clay-silt with frequent reed stems and abundant evidence of vertical rooting. The top of this layer made contact with the bottom of the made ground at 3.00m bgl.

5.6 **Borehole 6.**

In BH6 the River Terrace Gravels were encountered at 11.20m bgl. These were overlain by a sandy clay-silt with traces of peat [41]. The top of this layer was 10.10m bgl. Deposit [41] was overlain by a sandy-silt peat [40], 10.00m bgl. Layer [39], a clayey-silt, overlay [40]. Layer [39] was overlain by [38], another fairly thin accumulation of silty-peat. Deposits [38], [39] and [40] occurred at 9.50m bgl, 9.70m bgl and 10.00m bgl respectively. Layer [37], a grey clay-silt occurred at 9.00m bgl and was overlain by [36], a band of 0.30m thick compressed peat with branch remains [36]. Deposit [36] was first recorded at 8.70m bgl. A thick layer of grey alluvial clay-silt [35] overlay the peaty deposit. The top of [35] was in contact with the base of the modern made ground deposits [1] at 3.10m bgl.

5.7 **Borehole 7.**

The River Terrace Gravels [9] were encountered in this borehole 10.50m bgl. They were overlain by a layer of peat [46], the top of which was measured at 9.20m bgl. Above this layer of peat was a thin layer of clay-silt alluvium [45]. The top of [45] was recorded 9.0m bgl. Various episodes of peat formation occur above [45]. These deposits are all peat but vary in terms of their compression, how well humified they are and also their silt content. These deposits were recorded as [44]. The top of this sequence of peat deposits was 6.30m bgl. A peaty clay-silt [43] overlay the thick peat deposit. The top of [43] was 5.50m bgl. Deposit [43] was overlain by [42], a grey clay-silt alluvium with occasional reed stems. This deposit was in contact with the modern made ground at 4.00m bgl.

5.8 **Borehole 8.**

In BH 8 the River Terrace Gravels were recorded at 11.40m bgl. They were overlain by a layer of sandy-silt alluvium [51] overlying which was a band of peat [50]. The top of [51] and [50] were recorded at 10.55m bgl and 10.40m bgl respectively. A thick layer of grey alluvial silts overlay [50]. This layer [49] may have contained peaty lenses, however the seal on the borehole was breached and detailed recording of this deposit was impossible. The top of [49] was recorded at 4.70m bgl. Overlying [49] was [48] a layer of peat. This in turn was overlain by [47], a layer of soft grey alluvial clay-silt with evidence of rooting and plant stems (reeds etc). The top of [48] was recorded at 4.50m bgl. Deposit [47] made contact with the base of the made ground at 3.00m.

5.9 **Borehole 9**

In BH9 the Terrace Gravels were encountered at a depth of 11.50m. Overlying the gravel was a layer of clay-silt [57], which in turn was overlain by [56], a layer of compressed brown peat. Deposit [56] was overlain by a thin layer of alluvial clay-silt [55] which in turn was overlain by [54], another layer of compressed brown fibrous peat with flattened twigs and woody stems and plant remains. The top heights of layers [57], [56], [55] and [54] were 10.80m bgl, 10.60m bgl, 10.30m bgl and 10.20m bgl respectively. Overlying [54] was [53], a sandy clay-silt alluvium with occasional plant remains throughout. The top of [53] was recorded at 7.00m bgl. Deposit [53] was overlain by a soft grey alluvial clay silt. This deposit [52] was in contact with the bottom of the made ground at 3.50m bgl.

6 INTERPRETATION AND CONCLUSIONS

6.1 Boreholes 1-9 indicate that there is a 7-8m thick alluvial sequence overlying the Thames River Gravels at this site (see Figures 2, 3 and 4 and Appendix 1). The alluvial sequences in places contain thick peat deposits, interspersed with occasional siltier alluvial episodes (see BH 2 [11], 5 [32] and 7 [44, 46]). The top of the significant peat deposits in Boreholes 1-9 were recorded approximately 7-8m below the current ground surface. Boreholes 8 and 3 had very thin bands of organic-rich alluvium material higher up in the sequence at around 4.50m below ground level [48], [13]. In other boreholes (e.g. BH1, 4, 6) peat deposits were much less developed (in terms of thickness) and the stratigraphic sequence is dominated by alluvial clay-silts, the upper levels of which may have been disturbed or redeposited during the modern period, especially at the interface with the overlying made ground.

6.2 In several boreholes the peat was observed almost in contact with the underlying River Terrace Gravels (see especially BH 7 [46]). The thickness of the peat deposits observed and their depth would suggest that these deposits might date back considerably into the post-glacial prehistoric period. Whilst no cultural material or worked timber was found during the watching brief, the deposits recorded and retrieved during this watching brief have the potential to provide palaeoenvironmental data, and were therefore submitted to Quest for further assessment (Appendix 1).

6.3 The general trend across the site is for peat deposits to be thicker towards the south western area of the site. This may represent the underlying topography of the River Terrace Gravels which seem to be slightly higher in the area of the site with thicker peat deposits, whilst the general topography of the site may relate to Rainham Creek stream channel, situated towards the eastern end of the site. Certainly there is variation in the depth of peat deposits across the site and it is assumed that variation in the local depth of peat accumulation reflects local topographic and drainage conditions during the formation of alluvial deposits.

6.4 The archaeological observations on site and follow-up detailed assessment recorded no evidence of anthropogenic material, and as such the potential for significant archaeology on the subject site is considered to be low.

9 ACKNOWLEDGEMENTS

9.1 PCA would like to thank Shanks, Mills Whipp Projects Ltd, Capita Symonds and SI Drilling.

9.2 In addition, the author would like to thank Tim Bradley for his project management and editing, and Jenny Simonson for producing the illustrations.

10 BIBLIOGRAPHY

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APPENDIX 1: Geoarchaeological Assessment

MERCHANT WASTE TREATMENT PLANT, FROG ISLAND, LONDON BOROUGH OF HAVERING (SITE CODE: MER11): GEOARCHAEOLOGICAL ASSESSMENT REPORT

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Quaternary Scientific (QUEST), School of Human and Environmental Sciences, University of Reading, Whiteknights, PO Box 227, Reading, RG6 6AB, UK

INTRODUCTION

This report summarises the findings arising out of the environmental archaeological assessment undertaken by Quaternary Scientific (University of Reading) in connection with the proposed development at Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (National Grid Reference: TQ 5125 8091; 5.31m OD; site code: MER11; Figures 1 and 2). The site is on the north side of the Erith Reach of the Thames estuary. The riverward boundary of the site is the modern Thames waterfront and the ground forming the site is in effect a spit-like barrier across the mouth of Rainham Creek at its confluence with the Thames. Accordingly, Rainham Creek which is the lower reach of the Ingrebourne River forms the landward boundary of the site. The ground surface across the site is at levels between 5.0m and 5.5m OD. The British Geological Survey (BGS) (1:50,000 Sheet 257 Romford 1996) maps the site as Landfill over Alluvium resting on London Clay. Geotechnical boreholes put down to investigate the sub-surface conditions at the site (Pullen 2011) confirmed the presence of Landfill and Alluvium but also demonstrated the presence of sand and gravel underlying the Alluvium (Figures 3 and 4). The surface of the sand and gravel is between 11.0m and 12.0m below ground level (bgl) and therefore between *c*.-6.0m and *ca*. -7.0m OD. Long profiles of Thames river terrace surfaces reconstructed by Bridgland (1994, Fig.1.3) suggest that the sand and gravel is part of the Shepperton Gravel of Gibbard (1985) and therefore of Late Devensian age.

Throughout the Lower Thames Valley, the Holocene alluvium incorporates intercalated horizons of generally fine-grained mineral-rich sediments, and peat. Devoy (1979) carried out a detailed stratigraphic analysis of boreholes across the Lower Thames Valley from which he produced a model in which he identified the peat layers as representing semi-terrestrial conditions caused by periods of reversed, or lower Relative Sea Level Rise (RSL) rise (known as Tilbury I to V), whilst periods of alluvial deposition (known as Thames I to V) represent inundation caused by increased RSL rise.

Thames V	~1600			cal yr BP
	+0.44 to –0.75			m OD
Thames IV	2750	to	?	cal yr BP
	-0.8 to –1.8		+0.4 to –0.9	m OD
Thames III	4250	to	2900	cal yr BP
	-1.9 to –6.7		-1.0 to –2.0	m OD
Thames II	7450	to	5650	cal yr BP
	-6.8 to –12.3		-3.0 to –6.9	m OD
Thames I	9150	to	7800	cal yr BP
	-25.5 to –13.2		-8.0 to –12.5	m OD

Within the area most local to Frog Island (see Figure 1), sites such as Hornchurch Marshes (Branch *et al.*, in prep), Crossness Sewage Treatment Works (Batchelor *et al.*, 2007b) and Barking Riverside (Batchelor *et al.*, 2011), and Aveley Marshes South (Batchelor, 2009) indicate that peat accumulation occurred (sometimes uninterrupted) from *ca*. 6500 to 2500 cal yr BP, equating approximately to Devoy's Tilbury II and III peat. The sequences from Frog Island therefore have the potential to contain similar peat sequences dated anywhere between the Neolithic and Early Iron Age cultural periods. Local sites have also demonstrated the presence of human activity during these cultural periods, both on the peat surface itself, and on the margins of the dryland. These sites (see Figure 1) include (1) the Dagenham Idol (Coles, 1990); (2) a prehistoric boat found on Erith Marshes (McGrail, 1978); (3) Bronze Age trackways/causeways on the Erith foreshore (Sidell, pers comm.), at Bronze Age Way (Sidell et al., 1996), Hays Storage (Divers, 1996) and Bridge Road (Meddens, 1996), (4) Neolithic Settlement at the Brookway site (Meddens, 1996), and (5) Bronze Age settlement activities at Manser Works (Potter, 2003) and Bridge Road (Meddens, 1996).

The aim of assessing the core samples was to provide a further level of assessment of the site's archaeological potential following that set out within the Environmental Impact Assessment; this suggested that the key potential of the site was for prehistoric trackways / platforms recorded on the Thames floodplain. In order to assess the subject site's overall archaeological potential cores were assessed for anthropogenic material, specifically:

- Worked timber that may have formed part of a structure
- Indications of occupation – cultural material i.e. pottery or building material

The environmental archaeological assessment will also seek to evaluate the potential of the new sedimentary sequences from the Merchant Waste Treatment Plant, Frog Island for reconstructing the environmental history of the site and its environs. In order to achieve this aim, the environmental archaeological assessment consisted of the following techniques:

1. Recording the lithostratigraphy to provide a preliminary reconstruction of the sedimentary history
2. Carrying out organic matter content determinations to enhance the results of the sedimentary descriptions
3. Radiocarbon dating of identified plant macrofossils to provide a provisional geochronological framework for the natural stratigraphic sequence
4. Assessment of the preservation and concentration of pollen grains and spores to provide a preliminary reconstruction of the vegetation history, and to detect evidence for human activities e.g. woodland clearance and cultivation
5. Rapid assessment of the preservation and concentration of diatom frustules to evaluate the potential for reconstructing the hydrological history of the site e.g. water quality and depth
6. Assessment of the preservation and concentration of macroscopic plant, insect and Mollusca remains from small bulk samples to provide a preliminary reconstruction of the vegetation history and general environmental context of the site.

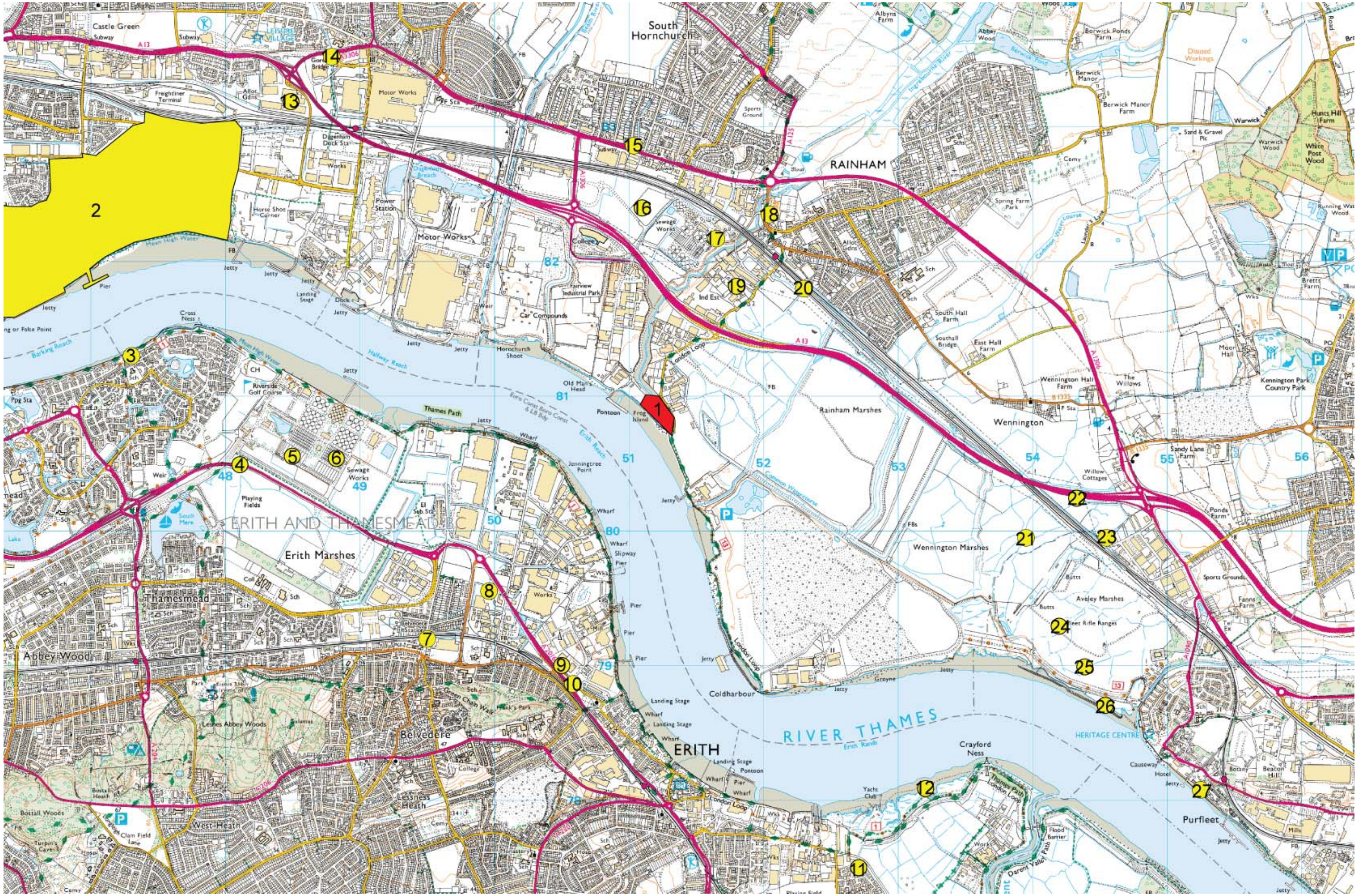
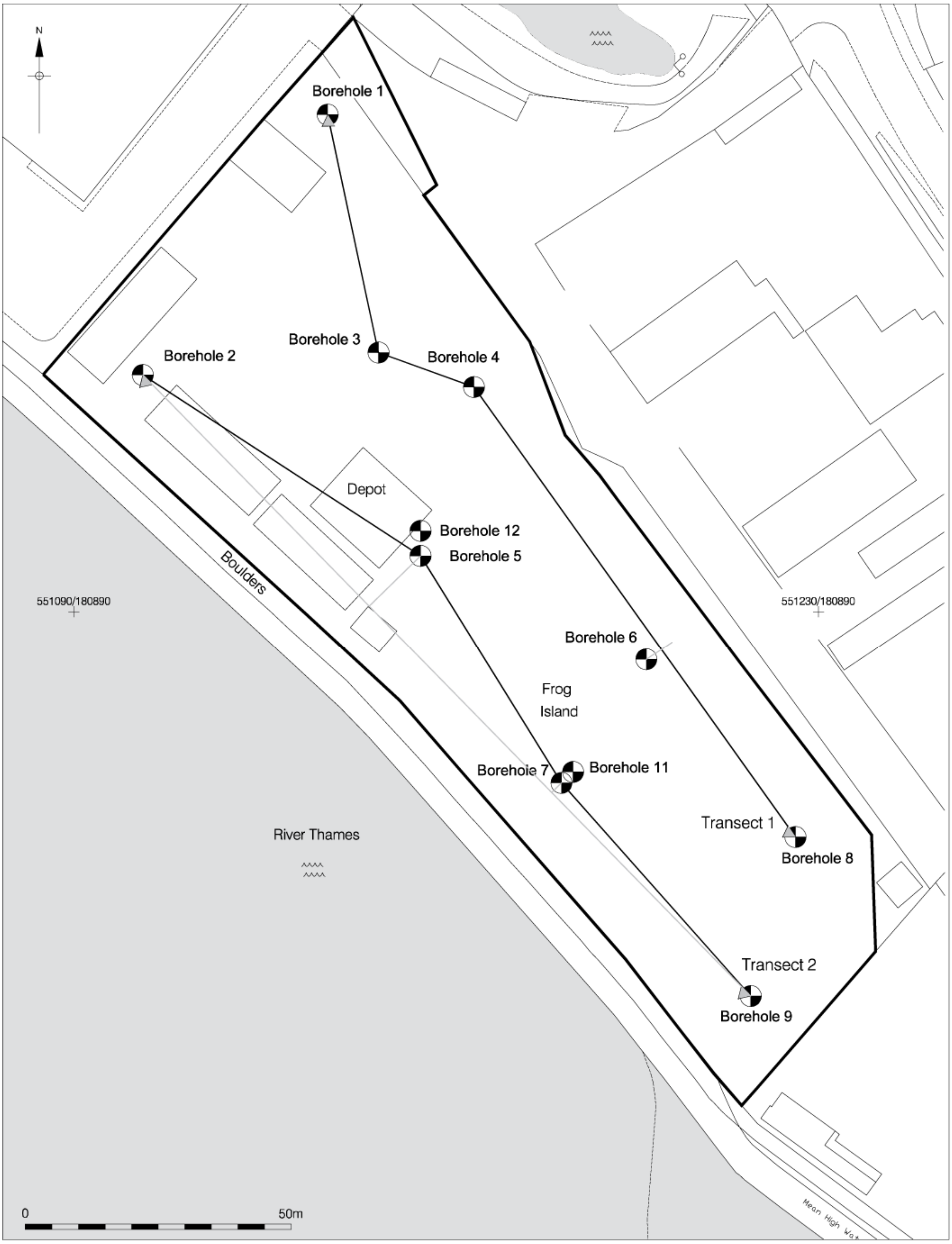

South Hornchurch
RAINHAM
Castle Green
Rainham Marshes
Wennington
Wennington Marshes
Aveley Marshes
ERITH AND THAMESMEAD
Erith Marshes
Thamesmead
Abbey Wood
Belvedere
ERITH
RIVER THAMES
Coldharbour
Crayford Ness
Purfleet
Frog Island
Motor Works
Fairview Industrial Park
Car Compounds
Sewage Works
Kennington Park Country Park
Berwick Manor
Berwick Manor Farm
Moor Hall
Playing Fields
HERITAGE CENTRE

Figure 1: Location of (1) Merchant Waste Treatment Plant, Frog Island, London Borough of Havering and nearby sites: (2) Barking Riverside (Batchelor *et al*., 2011), (3) Voyagers Quay (Sidell, 2003), (4) Crossness (Devoy, 1979) , (5) Crossness Sewage Works (Batchelor *et al.*, 2007a), (6) Crossness Sewage Works (Batchelor *et al.*, 2007b), (7) Erith Marshes (McGrail, 1978), (8) Crabtree Manorway South (Askew and Spurr, 2006), (9) Corinthian Quay (Corcoran and Lam, 2002), (10) Spine Road Development/ Bronze Age Way (Sidell et al., 1996), (11) Slade Green (Bates and Williamson, 1995), (12) Erith Forest and Foreshore (Seel, 2001, Sidell, pers comm.), (13) Hays storage (Divers, 1996), (14) Dagenham Marshes (Coles, 1990), (15) Manser Works (Potter, 2003), (16) Hornchurch Marshes (Branch et al., in prep), (17) Union Railways (MoLAS, 1997), (18) Bridge Road (Meddens, 1996), (19) West end of Frog Lane, A13 extension (Newham Museum Service, unpublished), (20) Brookway Site (Meddens, 1996), (21) Channel Tunnel Rail Link Core 121 (Bates, 1999), (22) Wennington Marsh, A13 relief road (Sidell, 2003), (23) Channel Tunnel Rail Link Core 18 (Bates, 1999), (24) Aveley Marshes North (Batchelor, 2009), (25) Aveley Marshes South (Batchelor, 2009), (26) Aveley Parish, Purfleet (Wilkinson and Murphy, 1995), (27) Harrison's Wharf (Devoy, 1979)



Borehole Location
1:1,000 at A4

Figure 2: Location of the new boreholes put down across the site at Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11)

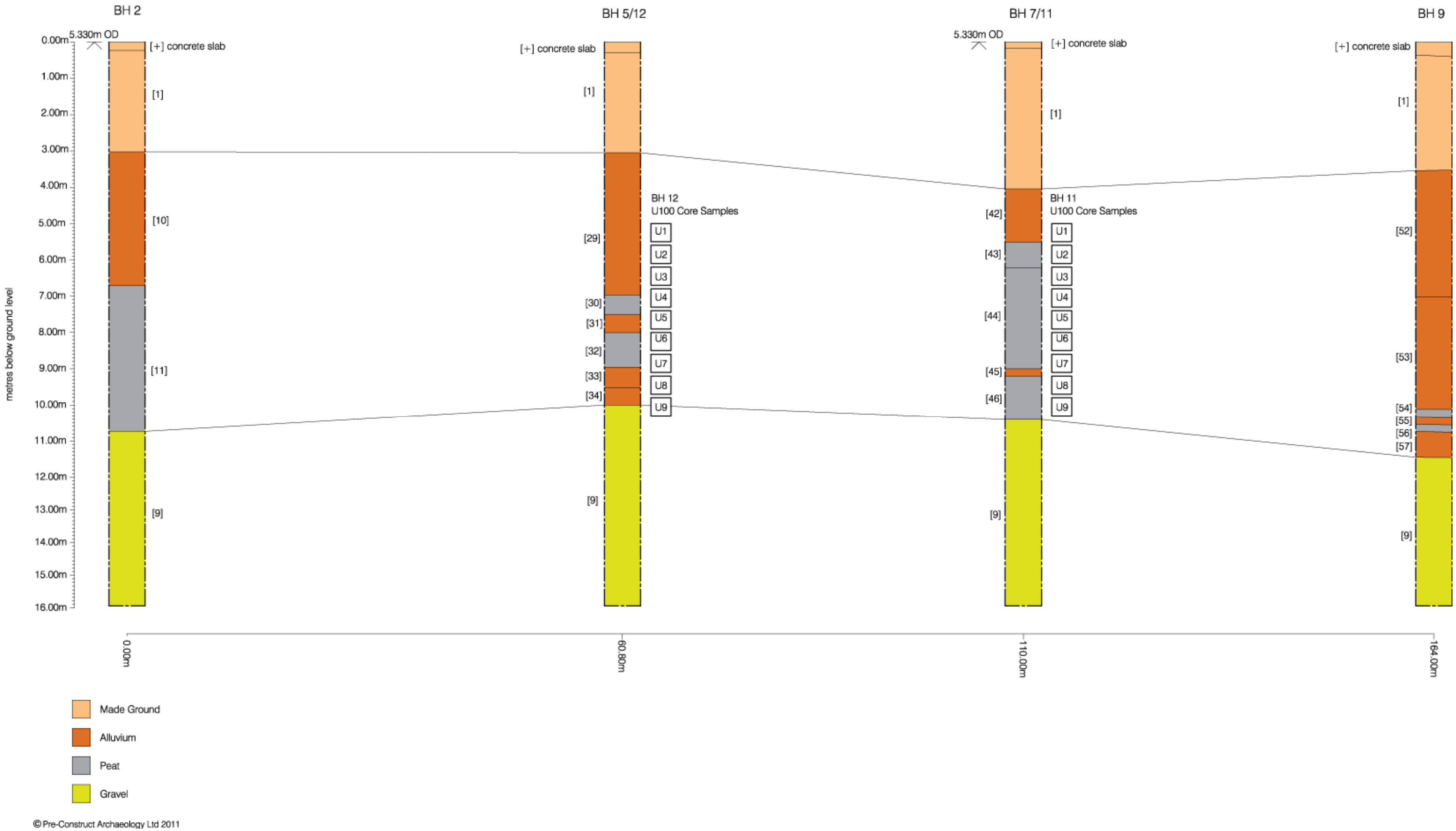


Figure 3: NW-SE Borehole transect (boreholes 1, 3, 4, 6 & 8), Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11) (Pullen, 2011)

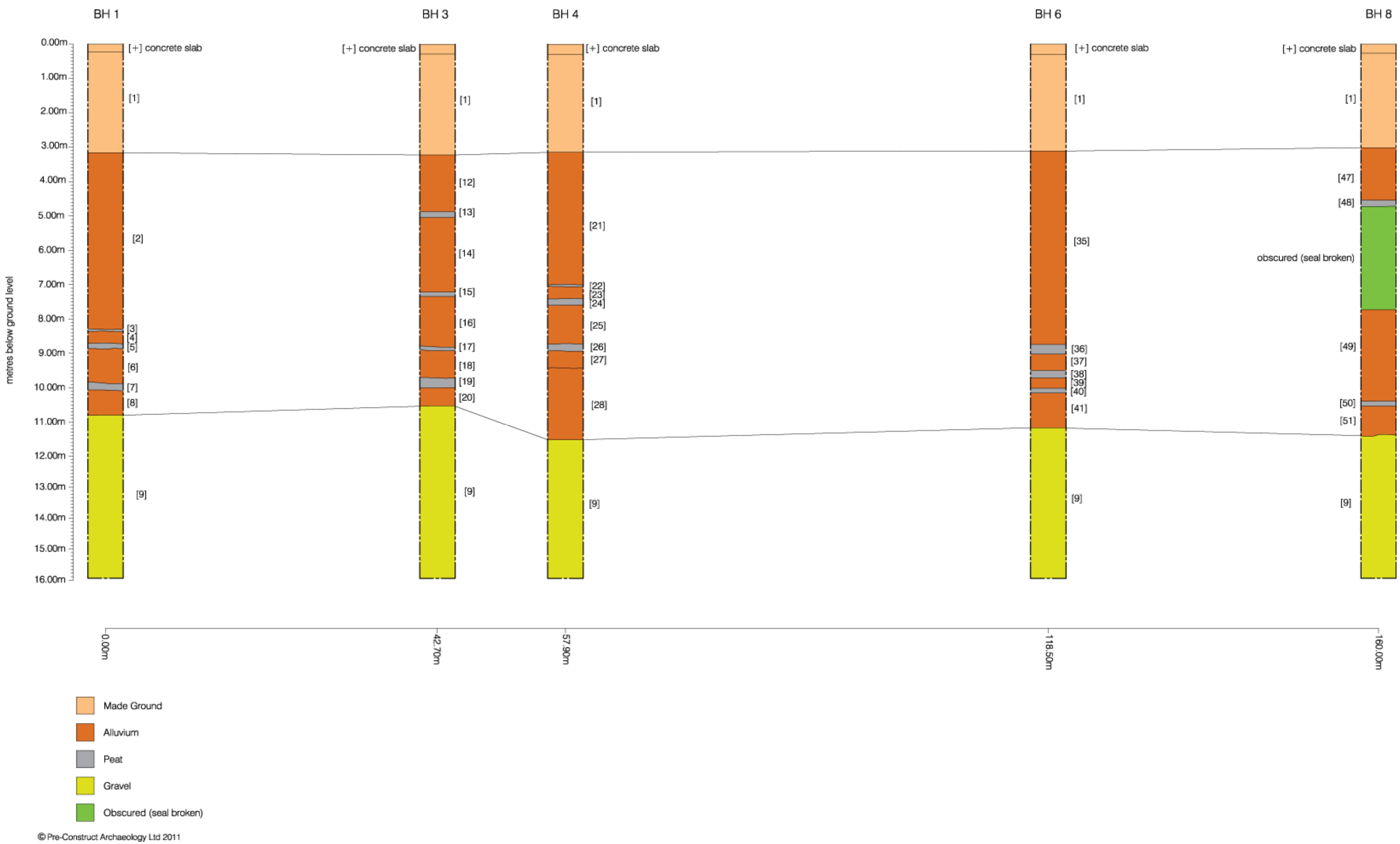


Figure 4: NW-SE Borehole transect (boreholes 2, 5, 7 & 9), Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11) (Pullen, 2011)

METHODS

Field investigations

Nine geotechnical boreholes (boreholes 1 to 9) were initially put down at the site in January 2011 (Figure 2). The boreholes were put down using cable percussion coring, and were monitored by a member of Pre-Construct Archaeology. Each borehole was put down until coarse grained unconsolidated sediments had been recorded (see Pullen, 2011). Two borehole transects of this data as described by Pre-Construct Archaeology are displayed in Figures 3 and 4.

The two boreholes with the greatest archaeological and palaeoenvironmental potential (boreholes 5 and 7) were selected for further investigation under guidance from Quest. The two additional boreholes (11 and 12) were sited as close as possible to 5 and 7 without compromising on-going geotechnical work. Continuous U100 core samples were removed from Boreholes 11 and 12 from 5m bgl until the Thames Terrace Gravel was reached. All material recovered from the shoes during the recovery of these U100s was retained. Material below the base of the made ground and 5m bgl was retained as for further analysis.

Lithostratigraphic descriptions

The two borehole core samples were retained and described in the laboratory using standard procedures for recording unconsolidated sediment and peat, noting the physical properties (colour), composition (gravel, sand, clay, silt and organic matter) and inclusions (e.g. artefacts). The procedure involved: (1) cleaning the samples with a spatula or scalpel blade and distilled water to remove surface contaminants; (2) recording the physical properties, most notably colour; (3) recording the composition e.g. gravel, fine sand, silt and clay; (4) recording the degree of peat humification, and (5) recording the unit boundaries e.g. sharp or diffuse (Troels Smith, 1955). The results are displayed in Tables 1 and 2, and Figure 5.

Organic matter determinations

Thirty-three sub-samples from borehole 11 and thirty sub-samples from borehole 12 were taken for determination of the organic matter content (Tables 3 and 4; Figure 3*)*. These records were important as they can identify increases in organic matter possibly associated with more terrestrial conditions. The organic matter content was determined by standard procedures involving: (1) drying the sub-sample at 110^{0}C for 12 hours to remove excess moisture; (2) placing the sub-sample in a muffle furnace at 550°C for 2 hours to remove organic matter (thermal oxidation), and (3) re-weighing the sub-sample obtain the 'loss-on-ignition' value (see Bengtsson and Enell, 1986).

Range-finder radiocarbon dating

One fragment of identified waterlogged wood was extracted from the top and base of borehole 12, and base of borehole 11, and identified waterlogged seeds were extracted from the top of borehole 11. These were submitted for AMS radiocarbon dating to Beta Analytic INC, Radiocarbon Dating Laboratory, Florida, USA. The results have been calibrated using OxCal v4.0.1 Bronk Ramsey (1995, 2001 and 2007) and IntCal04 atmospheric curve (Reimer *et al*., 2009). The results are displayed in Table 5.

Pollen assessment

Twenty four sub-samples from boreholes 11 and 12 were extracted for an assessment of pollen content. 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/cm^3); (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, and recording the concentration and preservation of pollen grains and spores, and the principal taxa on four transects (10% of the slide; Tables 6 and 7).

Diatom assessment

Twelve sub-samples from boreholes 11 and 12 were extracted for the assessment of diatoms. The diatom extraction involved the following procedures (Battarbee *et al.,* 2001):

1. Treatment of the sub-sample (0.2g) with Hydrogen peroxide (30%) to remove organic material and Hydrochloric acid (50%) to remove remaining carbonates
2. Centrifuging the sub-sample at 1200 for 5 minutes and washing with distilled water (4 washes)
3. Removal of clay from the sub-samples in the last wash by adding a few drops of Ammonia (1%)
4. Two slides prepared, each of a different concentration of the cleaned solution, were fixed in mounting medium of suitable refractive index for diatoms (Naphrax)

The results are displayed in Tables 8 and 9.

Macrofossil assessment

A total of six small bulk samples were extracted from borehole 11 and four from borehole 12 for the recovery of macrofossil remains including waterlogged plant macrofossils, waterlogged wood, insects and Mollusca. The extraction process involved the following procedures: (1) removing a sample up to 10cm in thickness; (2) measuring the sample volume by water displacement, and (3) 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 11).

Preliminary identifications of the archaeobotanical remains (waterlogged plant macrofossils and wood), have been made using modern comparative material and reference atlases (Cappers *et al.* 2006, Hather 2000, Schweingruber 1990, Schoch *et al*. 2004). Nomenclature used follows Stace (2005). The quantities of waterlogged seeds and wood were recorded for selected samples, with identifications of the main taxa (Tables 11).

RESULTS, INTERPRETATION AND DISCUSSION OF THE LITHOSTRATIGRAPHIC DESCRIPTIONS

Two boreholes (boreholes 11 and 12) were put down to investigate the palaeoenvironmental record preserved in the Frog Island sediments. These boreholes were put down respectively alongside geotechnical boreholes 7 and 5 in both of which a substantial thickness of organic sediment had been recorded (Figures 3 and 4). Samples in both boreholes were collected from a level of 5.0m bgl down to 10.3m bgl. The ground surface from which both boreholes were put down is recorded as 5.312m OD (Pullen 2011). The description of each borehole is displayed in Tables 1 and 2.

Both the borehole sequences consist of peat units interbedded with more or less organic silts. In borehole 11, these sediments rest on sand at -4.76m OD and in borehole 12 this contact is at a level between -4.33m and -4.51m OD. In borehole 11, three peat units (Units 3, 5, 7) can be recognised between -4.76m and -1.49m OD, but thin peaty beds are present above this level up to the top of the recovered sequence. In borehole 12, four peat units (Units 3, 5, 7, 9) are recognisable between -4.33m and -0.99m OD. Correlation between the two sequences can only be tentative on the basis of lithostratigraphy and for confirmation will require detailed pollen and other microfossil analysis supported by a programme of radiocarbon dating. Judging by the levels at which the peat units are recorded in both boreholes it seems likely that the bulk of the peat represents the Tilbury III stage of Devoy (1979), with the possibility that the uppermost peat units may represent the Tilbury IV stage. It seems unlikely that the Tilbury II stage is represented.

RESULTS AND INTERPRETATIONS OF THE ORGANIC MATTER DETERMINATIONS

Quantification of the organic matter content by Loss-on-Ignition allowed further detail to be added to the lithostratigraphic descriptions (Tables 3 and 4; Figure 5). The results revealed that organic matter values generally reflected the results of the sedimentary descriptions, with high values recorded during the peat units, and lower values recorded within the alluvium. The periods of peat formation varied between *ca*. 40% and >80% organic, suggesting that the surface was subject to frequent periods inundation. There are however, some variations between the sediment descriptions and organic matter values; in particular, in Borehole 11 at -1.75m OD, where the value of 100% does not equate to the mineral sediment recorded. In this case, the value must correlate to a piece of waterlogged wood.

RESULTS AND INTERPRETATION OF THE RADIOCARBON DATING

The results of the radiocarbon dating are displayed in Table 6 and Figure 3.

One fragment of waterlogged wood (cf *Ulmus*) was removed from the lowermost peat (-4.69 to -4.74m OD), and waterlogged seeds (*Ranunculus* sp.) were extracted from the uppermost peat (-1.00 to -1.05m OD) of Borehole 11 for radiocarbon dating. The base of the sequence was dated to 6790-6640 cal BP, and the top of the sequence was dated to 1710-1560 cal BP. The δ13C (‰) values are consistent with that expected for peat sediment, and there is no evidence for mineral or biogenic carbonate contamination. The results indicate that the sequence dates between the Mesolithic/Neolithic transition and Roman/Medieval cultural periods.

One fragment of cf *Alnus* waterlogged wood was extracted from the lowermost peat (-3.89 to -3.94m OD), and towards the top of the sequence (-1.26 to -1.28m OD). The base of the sequence was dated to 5460-5290 cal BP, and the top of the sequence to 2360-2340 cal BP. The δ13C (‰) values are consistent with that expected for peat sediment, and there is no evidence for mineral or biogenic carbonate contamination. The results indicate that the sequence dates between the Neolithic and Iron Age cultural periods.

Table 1: Lithostratigraphic description of Borehole 11, Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11)

Depth (m OD)	Unit number	Description
0.31 to -0.02	8	5Y4/1 dark grey with faint darker mottling and scattered black flecks; very well sorted silt; massive with plant remains in peaty layers at 0.24m, 0.17m and 0.04-0.02m OD; moderate acid reaction; sharp contact marked by peaty layer to:
-0.02 to -0.14	8	2.5Y4/4 olive brown with many black flecks becoming less common downward; very well sorted silt; massive with inclusions (5-10mm) of lighter olive brown clay becoming more common downward and forming a layer at 0.11m OD; detrital plant remains common; no acid reaction.
-0.30 to -0.73	8	2.5Y5/1 grey with common black flecks and sub-horizontal zones of 2.5Y4/4 olive brown; very well sorted silt; detrital plant remains common including irregular inclusions of peaty material; no acid reaction.
-0.89 to -1.32	8	2.5Y4/1 dark grey passing down gradually to 7.5YR3/1 very dark grey and with scattered black flecks throughout becoming less common downward; detrital plant remains very common including peaty layer at -1.0m OD; no acid reaction.
-1.49 to -1.90	6/7	2.5Y3/2 very dark greyish brown; very well sorted silt; common detrital plant remains including peaty layer at -1.49 - -1.53m OD and numerous wood fragments including small branches with bark in tact (up to 35mm Ø); no acid reaction.
-2.09 to -2.51	5	7.5YR2.5/3 very dark brown; peat with wood debris becoming less common downward, slightly silty in upper 10mm with flint grit and CBM particles (probably drilling debris); no acid reaction.
-2.69 to -3.01	5	Peat with laminated plant remains including wood debris and thin bed of silt at -2.85m OD; sharp contact with:.
-3.01 to -3.12	4	2.5Y4/1 dark grey; very well sorted coarse silt; massive; common detrital plant remains; no acid reaction.
-3.29 to -3.72	4	2.5Y4/1 dark grey; very well sorted silt with discontinuous layers of detrital plant debris becoming more common downward; no acid reaction.
-3.89 to -4.05	3	Peat with wood debris; sharp contact with:

-4.05 to -4.31	2	2.5Y4/1 dark grey; very well sorted silt; massive; very common detrital plant remains including very common wood debris
-4.49 to -4.76	2	7.5YR2.5/3 very dark brown; silty peat; laminated; no acid reaction; sharp contact with:
-4.76 to -4.89	1	Black; well sorted medium to coarse sand with granules; massive; common detrital plant remains; no acid reaction.

Table 2: Lithostratigraphic description of Borehole 12, Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11)

Depth (m OD)	Unit number	Description
0.26 to -0.12	12	5Y4/1 dark grey with patchy iron staining and scattered black flecks; very well sorted silt with gritty bed at 0.15 – 0.08m OD; common detrital plant remains; no acid reaction.
-0.30 to -0.72	12	5Y4/1 dark grey with a few small patches of 2.5Y5/3 light olive brown; very well sorted silt; massive; common detrital plant remains; no acid reaction.
-0.90 to -0.99	12	5Y4/1 dark grey; very well sorted silt; massive; common detrital plant remains; no acid reaction; sharp uneven contact with:
-0.99 to -1.04	11	7.5YR2.5/3 very dark brown; peat; *in situ* vertical roots; sharp contact with:
-1.04 to -1.34	10	5Y4/1 dark grey; very well sorted silt; massive; irregular inclusion of peat between -1.19 and -1.26m OD.
-1.54 to -1.66	10	5Y4/1 dark grey; very well sorted silt; massive; common detrital plant remains becoming increasingly common downward; no acid reaction; gradual transition to:
-1.66 to -1.92	9	7.5YR2.5/3 very dark brown; peat with common wood debris.
-2.1 to -2.22	9	7.5YR2.5/3 very dark brown; peat with wood debris and silt content increasing gradually downward; gradual transition to:
-2.22 to -2.43	8	5Y4/1 dark grey; very well sorted silt; massive; common detrital plant remains including wood debris; no acid reaction.
-2.73 to -2.79	7	7.5YR2.5/3 very dark brown; peat passing down to silty peat to peaty silt; gradual transition to:
-2.79 to -2.85	6	2.5Y4/1 dark grey; very well sorted silt; no acid reaction; sharp contact with:
-2.85 to -3.14	5	7.5YR2.5/3 very dark brown; peat with common wood debris.
-3.3 to -3.66	4	5Y4/1 dark grey; very well sorted silt; massive; common detrital plant remains including wood debris; no acid reaction; gradual transition to:
-3.66 to -3.73	3	7.5YR2.5/3 very dark brown; peat with common wood debris.
-3.90 to -3.96	3	7.5YR2.5/3 very dark brown; peat with wood debris; sharp contact with:
-3.96 to -4.33	2	2.5Y4/1 dark grey; very well sorted silt; massive; very common

		detrital plant remains including wood debris passing down to peaty silt to silty peat.
-4.51 to -4.93	1	2.5Y4/1 dark grey; well sorted medium to coarse sand; massive; scattered wood debris; no acid reaction.

Table 3: Results of the Borehole 11 organic matter determinations, Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11)

Depth (m OD)	Organic matter content (%)
0.17	15.20
-0.15	8.32
-0.31	9.82
-0.47	10.26
-0.63	9.56
-0.79	18.92
-0.95	7.98
-1.27	16.15
-1.43	8.74
-1.59	8.81
-1.59	35.67
-1.75	100.00
-1.91	24.14
-2.15	26.93
-2.23	30.94
-2.39	59.76
-2.55	66.23
-2.75	57.23
-2.87	46.31
-3.03	49.91
-3.19	9.54
-3.35	26.42
-3.51	26.63
-3.67	24.34
-3.95	75.42
-3.99	87.77
-4.15	70.51
-4.31	20.91
-4.55	29.18
-4.63	22.08
-4.79	38.57

-4.95	3.04

Table 4: Results of the Borehole 12 organic matter determinations, Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11)

Depth (m OD)	Organic matter content (%)
0.20	7.12
0.12	7.36
0	8.27
-0.04	6.47
-0.36	8.11
-0.52	7.92
-0.68	8.05
-0.84	7.79
-1.00	9.22
-1.16	10.40
-1.48	18.17
-1.64	30.54
-1.80	40.33
-1.96	49.52
-2.16	66.13
-2.28	34.82
-2.44	12.33
-2.60	38.94
-2.80	29.96
-2.92	40.60
-3.08	59.71
-3.40	20.85
-3.56	24.97
-3.72	48.02
-4.00	77.37
-4.04	35.18
-4.20	32.99
-4.36	37.73
-4.56	1.46
-4.68	1.56

Table 5: Results of the radiocarbon dating from Boreholes 11 and 12, Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11)

Laboratory code / Method	**Material and location**	**Depth (m OD)**	**Uncalibrated radiocarbon years before present (yr BP)**	**Calibrated age BC/AD (BP) (2-sigma, 95.4% probability)**	**δ13C (‰)**
Beta-297251	Waterlogged seeds; near top of peat	-1.00 to -1.05	1730 ± 30	240-390 cal BC (1710-1560 cal BP)	NA
Beta-297252	cf *Ulmus*; near base of peat	-4.69 to -4.74	5880 ± 40	4840-4690 cal BC (6790-6640 cal BP)	-28.4
Beta-297253	cf *Alnus;* near top of peat	-1.26 to -1.28	2350 ± 30	410-390 cal BC (2360-2340 cal BP)	-26.9
Beta-297254	cf *Alnus;* near top of peat	-3.89 to -3.94	4610 ± 40	3510-3340 cal BC (5460-5290 cal BP)	-28.1

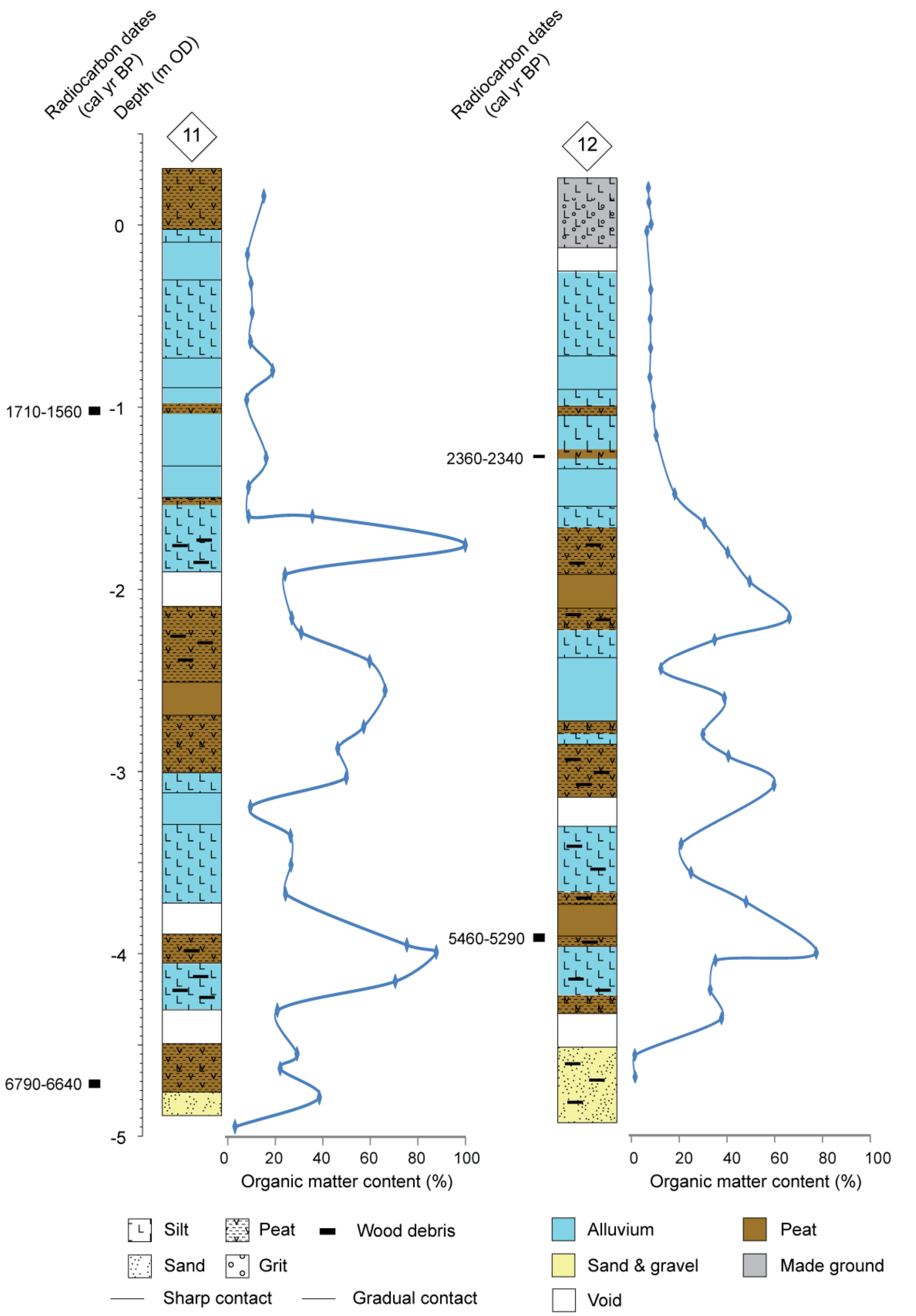


Figure 5: Results of the lithostratigraphic descriptions, organic matter determinations and radiocarbon dating from Boreholes 11 and 12, Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11)

RESULTS AND INTERPRETATION OF THE POLLEN ASSESSMENT

Borehole 11

Twelve sub-samples from borehole 11 were extracted for an assessment of pollen content (Table 7). The results of the pollen assessment indicate that pollen was generally well preserved and in high concentrations through the uppermost and lowermost units (peat and alluvium), but was present in much lower concentrations and poorer preservation through the central peat between *ca*. -2 and -3m OD.

The three samples taken from the two lowest peat units (between -4.64 and -3.95m OD) are dominated by *Alnus* (alder) with *Quercus* (oak), *Corylus* type (e.g. hazel), *Salix* (e.g. willow), *Tilia* (lime), *Fraxinus* (ash), *Chenopodium* type (e.g. fat hen), Poaceae (grasses), *Dryopteris* type (ferns) and *Polypodium vulgare* (polypody). This assemblage is indicative of the growth of wet carr woodland on the wetland dominated by alder with an understorey of willow, grasses, mixed herbs and ferns. Oak, ash and hazel may also have grown within this woodland, and/or formed mixed deciduous woodland on the dryland with lime.

The samples through the main peat between *ca*. -2 and -3m OD are of limited concentration, and are generally dominated by a similar assemblage to that of the lowermost three samples. Therefore, the vegetation composition of the wetland and dryland environments was most likely relatively similar to that represented in the lowermost three samples, although the absence of *Ulmus* (elm) and *Taxus* (yew) pollen is of note. It is possible that the low concentration of pollen through the peat reflects a drier and/or less acidic peat surface, as pollen does not preserve well under these conditions.

The three uppermost samples between -0.15 and -1.44m OD contain a more diverse assemblage of pollen taxa, including *Alnus* (alder), *Quercus* (oak), *Pinus* (pine), cf *Ulmus* (elm), *Tilia* (lime) *Salix* (willow), *Corylus* type (e.g. hazel), *Hedera* (ivy), Poaceae (grass family), Cyperaceae (sedge family), *Cereale* type (e.g. barley), Lactuceae (dandelion family), *Artemisia* (mugwort), *Chenopodium* type (e.g. fat hen), Asteraceae (daisy family), *Polypodium vulgare* (polypody), *Dryopteris* type (ferns) and dinoflagellate cysts. The assemblage is indicative of a more damp and open environment on the floodplain surface. The wetland still appears to be dominated by alder woodland, but the higher concentration of herbs and ferns are indicative of this. The presence of dinoflagellate cysts and *Chenopodium* type (which may be indicative of salt marsh plants as well as fat hen), suggest more frequent inundation and an estuarine influence during this period.

Borehole 12

Twelve sub-samples from borehole 12 were extracted for an assessment of pollen content (Table 8). The results of the pollen assessment indicate that pollen was generally well preserved and in high concentrations through the uppermost and lowermost units (peat and alluvium), but similarly to borehole 11 was present in much lower concentrations and poorer preservation through the central peat units between *ca*. -2 and -3m OD.

The three samples taken from the two lowest peat units (between -4.64 and -3.95m OD) are dominated by *Alnus* (alder) with *Quercus* (oak), *Corylus* type (e.g. hazel), *Ulmus* (elm), *Betula* (birch), *Chenopodium* type (e.g. fat hen), Poaceae (grasses), *Dryopteris* type (ferns). This assemblage is indicative of the growth of wet carr woodland on the wetland dominated by alder with an understorey of grasses, mixed herbs and ferns. Oak, elm and hazel may also have grown within this woodland, and/or formed mixed deciduous woodland on the dryland.

As in borehole 11, the samples assessed between *ca*. -2 and -3m OD are of limited concentration, and are generally dominated by a similar assemblage to that of the lowermost samples. Therefore, the vegetation composition of the wetland and dryland environments was most likely relatively similar, although once again, the absence of *Ulmus* (elm) and *Taxus* (yew) pollen is of note. It is possible that the low concentration of pollen through the peat reflects a drier and/or less acidic peat surface, as pollen does not preserve well under these conditions.

The three uppermost samples between -0.20 and -1.00m OD contain a more diverse assemblage of pollen taxa, including *Alnus* (alder), *Quercus* (oak), *Pinus* (pine), , *Tilia* (lime), *Corylus* type (e.g. hazel), Poaceae (grass family), Cyperaceae (sedge family), Lactuceae (dandelion family), *Artemisia* (mugwort), *Chenopodium* type (e.g. fat hen), Asteraceae (daisy family), *Centaurea nigra* (black knapweed), *Sparganium* type (bur-reed) *Polypodium vulgare* (polypody), *Dryopteris* type (ferns) and dinoflagellate cysts. The assemblage is indicative of a more damp and open environment on the floodplain surface. The wetland still appears to be dominated by alder woodland, but the higher concentration of herbs and ferns are indicative of this. The presence of dinoflagellate cysts and *Chenopodium* type (which may be indicative of salt marsh plants as well as fat hen), suggest more frequent inundation and an estuarine influence during this period.

Table 6: Results of the pollen assessment of Borehole 11, Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11)

Depth (m OD)		Unit number	Main pollen taxa		Concentration 0 – 5	Preservation 0- 5	Microcharcoal 0 - 5
From	**To**		**Latin name**	**Common name**			
-0.15	-0.16	8	*Quercus*	oak	5	4	1-2
			Alnus	alder			
			Tilia	lime			
			Pinus	pine			
			Corylus type	e.g. hazel			
			Salix	willow			
			Asteraceae	daisy family			
			Lactuceae	dandelion family			
			Cyperaceae	sedge family			
			Poaceae	grass family			
			Dryopteris type	ferns			
			Pteridium aquilinum	bracken			
			Dinoflagellate cysts				
-0.79	-0.80	8	*Alnus*	alder	5	4	1
			Quercus	oak			
			Pinus	pine			
			Corylus type	e.g. hazel			
			Hedera	ivy			
			Chenopodium type	e.g. fat hen			
			Artemisia	mugwort			

			Polypodium vulgare	polypody			
-1.43	-1.44	8	*Pinus*	pine	4	3	2
			Quercus	oak			
			cf *Ulmus*	elm			
			Tilia	lime			
			Corylus type	e.g. hazel			
			Chenopodium type	e.g. fat hen			
			Cyperaceae	sedge family			
			Sinapis type	e.g. charlock			
			Asteraceae	daisy family			
			Lactuceae	dandelion family			
			Poaceae	grass family			
			Cereale type	e.g. barley			
			Dryopteris type	ferns			
			Pteridium aquilinum	bracken			
			Dinoflagellate cysts				
-2.23	-2.24	5	*Alnus*	alder	1	2-3	0
			Quercus	oak			
			Chenopodium type	e.g. fat hen			
-2.39	-2.40	5	*Alnus*	alder	3	3	0
			Quercus	oak			
			Tilia	lime			
			Corylus type	e.g. hazel			
			Cyperaceae	sedge family			
			Dryopteris type	ferns			

-2.56	-2.57	5	*Alnus*	alder	1	2-3	0
-2.75	-2.76	5	*Alnus* *Quercus* *Tilia* *Fraxinus* *Corylus* type *Polypodium vulgare* *Dryopteris* type	alder oak lime ash e.g. hazel polypody ferns	5	4	0
-2.87	-2.88	5	*Alnus* *Quercus* *Tilia* *Corylus* type *Polypodium vulgare*	alder oak lime e.g. hazel polypody	3	4	0
-3.03	-3.04	4	*Alnus* *Quercus* *Corylus* type *Dryopteris* type *Polypodium vulgare*	alder oak e.g. hazel ferns polypody	2	4	0
-3.95	-3.96	3	*Alnus* *Quercus* *Corylus* type *Salix* Poaceae *Polypodium vulgare*	alder oak e.g. hazel willow grass family polypody	5	4	0
-4.55	-4.56	2	*Alnus*	alder	5	4	0

			Quercus *Corylus* type *Salix* Poaceae *Polypodium vulgare*	oak e.g. hazel willow grass family polypody			
-4.63	-4.64	2	*Alnus* *Quercus* *Tilia* *Fraxinus* *Corylus* type Poaceae *Chenopodium* type	alder oak lime ash e.g. hazel grass family e.g. fat hen	5	4-5	0

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 = none, 1 = very poor , 2 = poor, 3 = moderate, 4 = good, 5 = excellent

Charcoal: 0 = none, 1= negligible, 2 = occasional, 3 = moderate, 4 = frequent, 5 = abundant

Table 7: Results of the pollen assessment of Borehole 12, Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11)

Depth (m OD)		**Unit number**	**Main pollen taxa**		**Concentration 0 – 5**	**Preservation 0- 5**	**Microcharcoal 0 - 5**
From	**To**		**Latin name**	**Common name**			
0.20	0.19	12	*Alnus*	alder	5	4	1-2
			Pinus	pine			
			Tilia	lime			
			Quercus	oak			
			Corylus type	e.g. hazel			
			Cyperaceae	sedge			
			Chenopodium type	e.g. fat hen			
			Cirsium type	e.g. spear thistle			
			Sinapis type	e.g. charlock			
			Lactuceae	dandelion family			
			Poaceae	grass family			
			Centaurea nigra	black knapweed			
			Pteridium aquilinum	bracken			
			Dinoflagellate cyst				
-0.36	-0.37	12	*Alnus*	alder	5	4	3
			Pinus	pine			
			Quercus	oak			
			Corylus type	e.g. hazel			
			Chenopodium type	e.g. fat hen			
			Poaceae	grass family			
			Lactuceae	dandelion family			
			Sparganium type	bur-reed			

			Dryopteris type *Pteridium aquilinum*	ferns bracken			
-1.00	-1.01	11	*Pinus* *Alnus* *Quercus* *Corylus* type Cyperaceae *Artemisia* Lactuceae Poaceae *Chenopodium* type *Polypodium vulgare*	pine alder oak e.g. hazel sedge family mugwort dandelion family grass family e.g. fat hen polpody	5	4	2-3
-1.07	-1.08	10	*Alnus* *Pinus* *Tilia* Cyperaceae *Dryopteris* type *Polypodium vulgare*	alder pine lime sedge family ferns polypody	3	4	0
-1.64	-1.65	10	*Alnus* *Quercus* *Pinus* *Betula* Poaceae Cyperaceae *Pteridium aquilinum*	alder oak pine birch grass family sedge family bracken	3	4	0

-1.80	-1.81	9	*Alnus* *Pinus* Poaceae *Pteridium aquilinum*	alder pine grass family bracken	1	2-3	0
-1.96	-1.97	9	*Alnus* *Corylus* type *Dryopteris* type *Polypodium vulgare*	alder e.g. hazel ferns polypody	2	4	0
-2.16	-2.17	8	-		0	-	0
-2.80	-2.81	6	*Alnus* *Tilia* *Pinus* *Quercus* *Hedera* Cyperaceae *Sphagnum*	alder lime pine oak ivy sedge family sphagnum moss	2	4	0
-2.92	-2.93	5	*Alnus* *Quercus* *Pinus* *Dryopteris* type *Polypodium vulgare*	alder oak pine ferns polypody	1-2	3-4	0
-3.36	-3.37	4	*Alnus* *Ulmus* *Quercus* *Corylus* type	alder elm oak e.g. hazel	5	5	0

-3.72	-3.73	3	*Alnus* *Quercus* *Betula* *Corylus* type *Chenopodium* type Poaceae *Dryopteris* type	alder oak birch e.g. hazel e.g. fat hen grass family ferns	5	5	0

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 = none, 1 = very poor , 2 = poor, 3 = moderate, 4 = good, 5 = excellent

Charcoal: 0 = none, 1= negligible, 2 = occasional, 3 = moderate, 4 = frequent, 5 = abundant

RESULTS AND INTERPRETATION OF THE DIATOM RAPID ASSESSMENT

Borehole 11

Six sub-samples were extracted from Borehole 11 for the rapid assessment of diatoms (Table 8). Diatoms were preserved in the four of the six samples, in generally low concentrations, and in a poor to moderate state of preservation.

Borehole 12

Six sub-samples were extracted from Borehole 12 for the rapid assessment of diatoms (Table 10). Diatoms were not preserved in two of the six of the samples, were found in generally low concentrations, and in a poor to moderate state of preservation (Table 9).

A number of factors influence diatom preservation, and it is probable that in the sediments examined here diatom concentrations were always low and that post-depositional destruction of the frustules has occurred due to drying-out, abrasion and possibly unfavourable chemical conditions. Dissolution of the diatom silica, for example, can occur as a response to the ambient dissolved silica concentration, the pH in open water, and the interstitial water in sediments. Using both fossil and modern diatoms, these and other environmental factors have been shown to affect the quality of preservation of assemblages (Flower, 1993; Ryves *et al*., 2001).

Table 8: Diatom assessment of Borehole 11, Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11)

Depth (m OD)	Unit number	Concentration
-0.79 to -0.80	8	Present
-1.43 to -1.44	7	Absent
-2.23 to -2.24	5	Present
-3.03 to -3.04	4	Absent
-3.95 to -3.96	3	Present
-4.14 to -4.15	2	Present

Table 9: Diatom assessment of Borehole 11, Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11)

Depth (m OD)	Unit number	Concentration
-0.36 to -0.37	12	Absent
-1.64 to -1.65	10	Present

-2.16 to -2.17	9	Absent
-2.80 to -2.81	6	Single occurrence
-3.40 to -3.41	4	Present
-4.36 to -4.37	2	Absent

RESULTS AND INTERPRETATION OF THE MACROFOSSIL ASSESSMENT

A total of 14 small bulk samples (8 from borehole <BH11> and 6 from borehole <BH12>) were extracted for the recovery of macrofossil remains including waterlogged plant macrofossils, waterlogged wood, insects and Mollusca (Table 10). The samples were focussed on the organic-rich sections of each borehole only.

Borehole <11>

The results of an initial assessment indicated that borehole <BH11> contained no Mollusca or bone. Fragments of charcoal <2mm in diameter were present in two samples (-1.00 to -1.05 and -4.69 to -4.74m OD). Insects were present in two samples (-4.59 to -4.69 and -2.89 to -2.99m OD). Waterlogged wood was present in moderate to high quantities within the majority of samples from this borehole, with four samples (-1.00 to -1.05, -2.15 to -2.25, -2.89 to -2.99 and -4.59 to -4.69m OD) also containing moderate to high quantities of waterlogged seeds. Waterlogged seeds were present in low quantities in the remainder of the samples from borehole <11>.

Borehole <12>

The results of an initial assessment indicated that borehole <12> contained no charred plant remains (charcoal or wood), bone or Mollusca. Insects were recorded in low quantities in three samples (-1.69 to -1.79, -2.89 to -2.99 and -3.89 to -3.94m OD). Waterlogged wood was present in moderate to high quantities in all but one sample (-1.01 to -1.06m OD), which contained low quantities of waterlogged wood. Waterlogged seeds were present in low quantities in the four samples below -1.89m OD (-1.89 to -1.99, -2.89 to -2.99, -3.09 to -3.19 and -3.89 to -3.94m OD), while the two samples above this level (-1.01 to -1.06 and -1.69 to -1.79m OD) contained moderate to high quantities of waterlogged seeds.

Table 10: Results of the macrofossil assessment, Borehole 12, Merchant Waste Treatment Plant, Frog Island, London Borough of Havering (site code: MER11)

					Charred					Waterlogged		Mollusca		Bone			
Borehole No.	Sample depth (m OD)	Volume sampled (l)	Volume processed (l)	Fraction (e.g. flot, residue, >300µm)	Charcoal (>4mm)	Charcoal (2-4mm)	Charcoal (<2mm)	Seeds	Chaff	Wood	Seeds	Whole	Fragments	Large	Small	Fragments	Insects
<11>	-1.00 to -1.05	0.25	0.25	>300µm	-	-	-	-	-	-	1/2	-	-	-	-	-	-
				>1mm	-	-	1	-	-	1	2	-	-	-	-	-	-
<11>	-2.15 to -2.25	0.5	0.5	>300µm	-	-	-	-	-	-	5	-	-	-	-	-	-
				>1mm	-	-	-	-	-	3	2	-	-	-	-	-	-
<11>	-2.29 to -2.39	0.55	0.55	>300µm	-	-	-	-	-	-	1	-	-	-	-	-	-
				>1mm	-	-	-	-	-	3	-	-	-	-	-	-	-
<11>	-2.49 to -2.59	0.6	0.6	>300µm	-	-	-	-	-	-	-	-	-	-	-	-	-
				>1mm	-	-	-	-	-	4	1	-	-	-	-	-	-
<11>	-2.74 to -2.84	0.7	0.7	>300µm	-	-	-	-	-	-	-	-	-	-	-	-	-
				>1mm	-	-	-	-	-	2	1	-	-	-	-	-	-
<11>	-2.89 to -2.99	0.5	0.5	>300µm	-	-	-	-	-	-	-	-	-	-	-	-	1
				>1mm	-	-	-	-	-	3	2	-	-	-	-	-	-

<11>	-4.59 to -4.69	0.4	0.4	>300µm	-	-	-	-	-	1	-	-	-	-	-	-	1/2
				>1mm	-	-	-	-	-	4	5	-	-	-	-	-	-
<11>	-4.69 to -4.74	0.3	0.3	>300µm	-	-	1	-	-	-	-	-	-	-	-	-	-
				>1mm	-	-	-	-	-	2	1	-	-	-	-	-	-
<12>	-1.01 to -1.06	0.2	0.2	>300µm	-	-	-	-	-	-	3	-	-	-	-	-	-
				>1mm	-	-	-	-	-	1	-	-	-	-	-	-	-
<12>	-1.69 to -1.79	0.6	0.6	>300µm	-	-	-	-	-	-	2	-	-	-	-	-	1
				>1mm	-	-	-	-	-	4	5	-	-	-	-	-	-
<12>	-1.89 to -1.99	0.6	0.6	>300µm	-	-	-	-	-	-	1	-	-	-	-	-	-
				>1mm	-	-	-	-	-	3	-	-	-	-	-	-	-
<12>	-2.89 to -2.99	0.5	0.5	>300µm	-	-	-	-	-	-	-	-	-	-	-	-	1
				>1mm	-	-	-	-	-	4	1	-	-	-	-	-	-
<12>	-3.09 to -3.19	0.6	0.6	>300µm	-	-	-	-	-	-	-	-	-	-	-	-	-
				>1mm	-	-	-	-	-	3	1	-	-	-	-	-	-
<12>	-3.89 to -3.94	0.2	0.2	>300µm	-	-	-	-	-	1	1	-	-	-	-	-	1
				>1mm	-	-	-	-	-	3	-	-	-	-	-	-	-

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+

RESULTS AND INTERPRETATION OF THE WATERLOGGED SEED ASSESSMENT

The results of the macrofossil rapid assessment indicated that waterlogged seeds were present in all 14 of the samples assessed, and thus these underwent a more detailed assessment. The results of the borehole <11> and <12> waterlogged seed assessments are displayed in Table 11.

Borehole <11>

The results of the waterlogged plant macrofossil assessment indicated that four samples (-1.00 to -1.05, -2.15 to -2.25, -2.89 to -2.99 and -4.59 to -4.69m OD) contained moderate to high quantities of waterlogged seeds, while the remainder contained low quantities. Below -2.49m OD the samples are dominated by the *Alnus glutinosa* (alder), with the shrub taxon *Rubus* sp. (e.g. bramble) and the herbaceous taxon *Ranunculus* sp. (e.g. creeping buttercup) also present. Above -2.49m OD the assemblage is dominated by herbaceous taxa including *Ranunculus* sp. (e.g. creeping buttercup), *Ranunculus sceleratus* (cursed buttercup) and the shrub taxon *Rubus* sp. (e.g. bramble). This assemblage may be indicative of a transition towards a more open herbaceous community above -2.49m OD, with a fen surface dominated by alder prior to this transition. Seed taxa definitively indicative of human activity or saline conditions were not noted during the assessment of samples from borehole <11>.

Borehole <12>

The results of the waterlogged plant macrofossil assessment indicate that seeds were present in low quantities in the four samples below -1.89m OD (-1.89 to -1.99, -2.89 to -2.99, -3.09 to -3.19 and -3.89 to -3.94m OD), while the two samples above this level (-1.01 to -1.06 and -1.69 to -1.79m OD) contained moderate to high quantities of waterlogged seeds. In the lowest sample in the sequence (-3.89 to -3.94m OD) the assemblage is dominated by the herbaceous taxon *Chenopodium* sp. (e.g. fat hen). Between -1.69 and -3.19m OD the assemblage is dominated by the shrub taxon *Rubus* sp. (e.g. bramble) and herbaceous taxon *Ranunculus sceleratus* (cursed buttercup). In the sample above this level (-1.01 to -1.06m OD) the assemblage is dominated by the aquatic taxon *Sparganium erectum* (bur-reed) and the herbaceous taxon *Carex* sp. (sedge), possibly indicating a transition from a relatively open, drier environment to a wet, open environment above -1.69m OD. Seed taxa definitively indicative of human activity or saline conditions were not noted during the assessment of samples from borehole <12>.

RESULTS AND INTERPRETATION OF THE WATERLOGGED WOOD ASSESSMENT

A list of the taxa identified in each of the samples examined during this assessment are presented in Table 11. A total of 29 fragments were analysed resulting in the identification of 2 taxa: *Alnus glutinosa* (alder) and *Ulmus* sp. (elm). Bark fragments made up most of the remaining fragments examined.

Preservation of the waterlogged wood was generally good. Individual elements were small, however, typically in the form of small branchwood or twig-wood. The fragment of Elm was derived from a small branch/twig of less than 5 years growth. In most instances it proved difficult to determine with absolute certainty the identity of Alder fragments, hence the 'c.f.' designation. The 2 taxa identified in this assessment are typically associated with wetland habitats, such as streams or riversides.

Table 11: Results of the waterlogged plant macrofossil (seeds) assessment of boreholes <11> and <12>

Borehole No.	Sample depth (m OD)	Waterlogged seeds			Waterlogged wood		
		Main taxa	**Common name**	**Number**	**Main taxa**	**Common name**	**Number**
<11>	-1.00 to -1.05	cf. *Ranunculus* sp. cf. *Chenopodium* sp.	e.g. creeping buttercup e.g. fat hen	6 2			
<11>	-2.15 to -2.25	*Ranunculus sceleratus* *Rubus* sp. *Rumex* sp.	cursed buttercup e.g. bramble dock/sorrel	22 2 1			
<11>	-2.29 to -2.39	*Ranunculus sceleratus*	cursed buttercup	1			
<11>	-2.49 to -2.59	*Alnus glutinosa* fruit *Rubus* sp. Unknown/unidentified	alder e.g. bramble -	2 1 1			
<11>	-2.74 to -2.84	Unknown/unidentified	-	1			
<11>	-2.89 to -2.99	*Alnus glutinosa* catkin *Rubus* sp. Unknown/unidentified	alder e.g. bramble -	1 1 1			
<11>	-4.59 to -4.69	*Alnus glutinosa* catkin *Alnus glutinosa* fruit *Ranunculus* sp. Unknown/unidentified	alder alder e.g. creeping buttercup -	11 7 1 3			

<11>	-4.69 to -4.74	Unknown/unidentified	-	1	cf Bark cf *Ulmus* sp.	- elm	9 1
<12>	-1.01 to -1.06	*Sparganium erectum* *Carex* sp.	bur-reed sedge	2 1			
<12>	-1.26 to -1.28	-	-	-	cf *Alnus glutinosa* Indeterminate	alder	4 5
<12>	-1.69 to -1.79	*Rubus* sp. *Ranunculus sceleratus* Unknown/unidentified	e.g. bramble cursed buttercup -	6 4 2			
<12>	-1.89 to -1.99	*Ranunculus sceleratus*	cursed buttercup	1			
<12>	-2.89 to -2.99	*Rubus* sp.	e.g. bramble	3			
<12>	-3.09 to -3.19	*Rubus* sp.	e.g. bramble	1			
<12>	-3.89 to -3.94	*Chenopodium* sp. Unknown/unidentified	e.g. fat hen -	1 1	cf *Alnus glutinosa*	alder	10

DISCUSSION AND CONCLUSIONS

The results of the lithostratigraphic investigations (sedimentary descriptions and organic matter content determinations) indicate that the surface of the sands and gravels lay around -5m OD. This surface is representative of a high energy braided river system (the 'Shepperton Gravel'), laid down on the valley floor of the River Thames at the end of the Late Glacial period (Marine Isotope Stage 2, Late Devensian, *ca*. 16,000-11,500 cal yr BP). Overlying this in both the assessed boreholes was a sequence of interbedded peats (representative of semi-terrestrial conditions) and less organic silts (representative of periods of estuarine/fluvial inundation) commencing from -4.76m OD and -4.51m OD respectively. In borehole 11, three main peat units were recognised between -4.76m and -1.49m OD, with thin peaty beds present above this level up to the top of the recovered sequence. In borehole 12, four peat units were recognised between -4.33m and -0.99m OD. The results of range finder radiocarbon dating, suggest that both sequences date from the Late Mesolithic/Early Neolithic and continue into the Roman/Medieval periods. The peat units could thus have the potential to correlate to Devoy's Tilbury II, III and IV stages. At this stage, however, it is not possible to make confident correlations between the peat sequences in each borehole.

The results of the archaeobotanical assessment (pollen, seeds and wood) indicate that during periods of peat formation the wetland environment was colonised by alder dominated carr woodland, with an understorey of willow and bramble, and ground flora comprising sedges, grasses, various herbs and aquatics. The generally poor concentration and preservation of pollen remains within the peat approximately midway through the sequence is somewhat disappointing, but suggests the peat surface underwent some kind of change during this time; perhaps towards drier surface conditions. The dryland environment most likely comprised mixed deciduous woodland probably dominated by oak and lime. Other tree and shrub taxa such as ash, birch and hazel may have grown on either or both surfaces.

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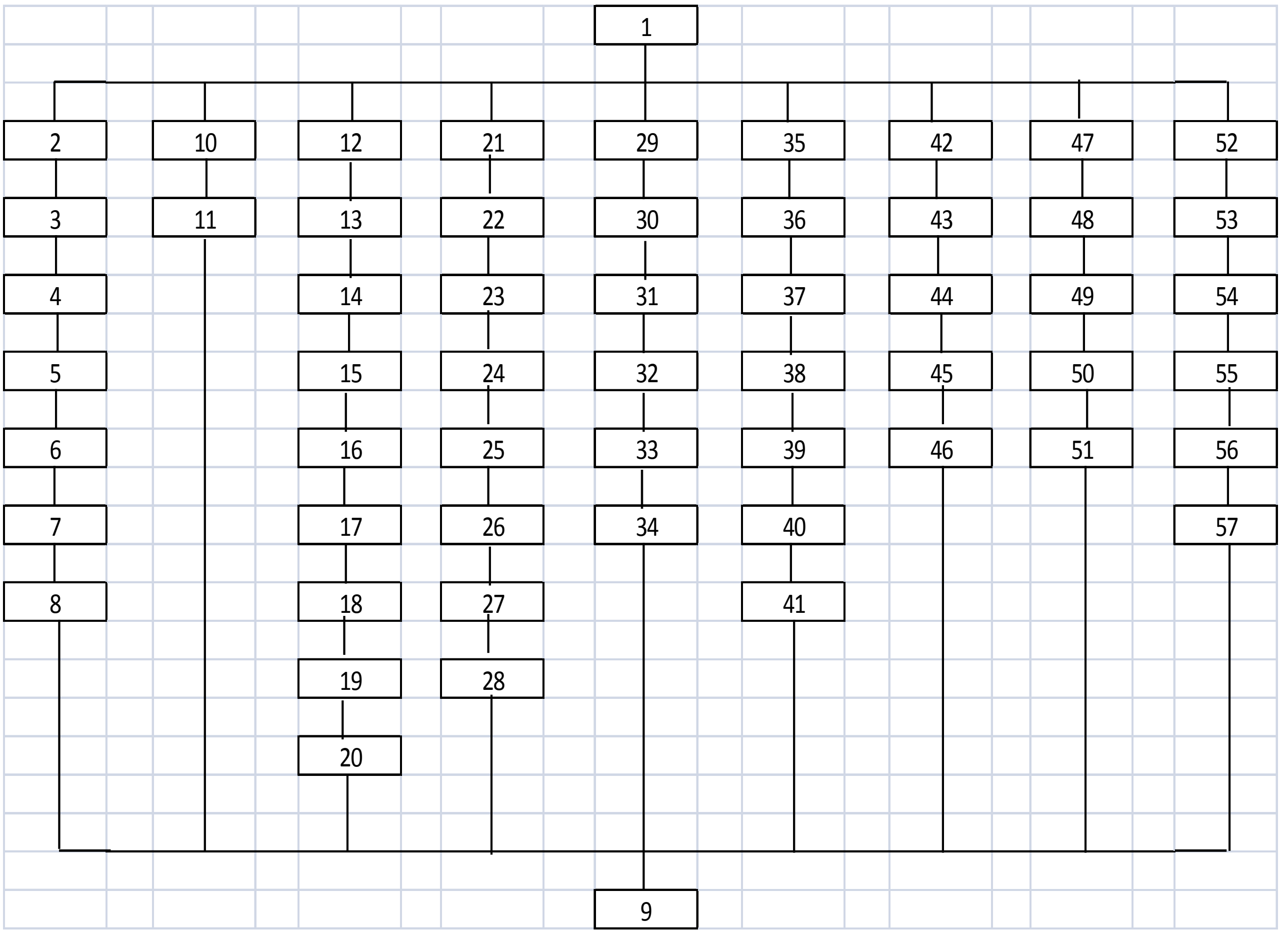
APPENDIX 2: Context Register

BH No.	Context	Type	Depth BGL	Comments
1-12	1	Layer	0.20m	Modern made ground
1	2	Layer	3.20m	Alluvial clay-silt
1	3	Layer	8.30m	Peat
1	4	Layer	8.40m	Alluvial clay-silt
1	5	Layer	8.70m	Peaty alluvial clay-silt
1	6	Layer	8.90m	Alluvial clay-silt
1	7	Layer	9.80m	Peat
1	8	Layer	10.00m	Alluvial clay-silt
1-12	9	Layer	10.80m	Gravel
2	10	Layer	3.00m	Alluvial clay-silt
2	11	Layer	6.70m	Peat
3	12	Layer	3.20m	Alluvial clay-silt
3	13	Layer	4.80m	Peat
3	14	Layer	5.00m	Alluvial clay-silt
3	15	Layer	7.20m	Peat
3	16	Layer	7.30m	Alluvial clay-silt
3	17	Layer	8.80m	Peat
3	18	Layer	8.90m	Alluvial clay-silt
3	19	Layer	9.70m	Peat
3	20	Layer	10.00m	Peaty alluvial clay-silt
4	21	Layer	3.10m	Alluvial clay-silt
4	22	Layer	6.95m	Peat
4	23	Layer	7.00m	Peaty alluvial clay-silt
4	24	Layer	7.40m	Peat
4	25	Layer	7.60m	Alluvial clay-silt
4	26	Layer	8.70m	Peat
4	27	Layer	8.90m	Sandy alluvial clay-silt
4	28	Layer	9.40m	Alluvial silty-sand
5	29	Layer	3.00m	Alluvial clay-silt
5	30	Layer	7.00m	Peat
5	31	Layer	7.50m	Alluvial clay-silt
5	32	Layer	8.00m	Peat
5	33	Layer	9.00m	Alluvial clay-silt
5	34	Layer	9.50m	Alluvial silty-sand
6	35	Layer	3.10m	Alluvial clay-silt
6	36	Layer	8.70m	Peat
6	37	Layer	9.00m	Alluvial clay-silt

6	38	Layer	9.50m	Peaty alluvial clay-silt
6	39	Layer	9.70m	Sandy alluvial clay-silt
6	40	Layer	10.00m	Peat
6	41	Layer	10.10m	Sandy alluvial clay-silt
7	42	Layer	4.00m	Alluvial clay-silt
7	43	Layer	5.50m	Peaty alluvial clay-silt
7	44	Layer	6.30m	Peat
7	45	Layer	9.00m	Alluvial clay-silt
7	46	Layer	9.20m	Peat
8	47	Layer	3.00m	Peaty alluvial clay-silt
8	48	Layer	4.50m	Peat
8	49	Layer	4.70m	Peaty alluvial clay-silt
8	50	Layer	10.40m	Peat
8	51	Layer	10.55m	Alluvial clay-silt
9	52	Layer	3.50m	Alluvial clay-silt
9	53	Layer	7.00m	Sandy alluvial clay-silt
9	54	Layer	10.20m	Peat
9	55	Layer	10.30m	Alluvial clay-silt
9	56	Layer	10.60m	Peat
9	57	Layer	10.80m	Alluvial clay-silt

APPENDIX 3: Matrix



APPENDIX 4: Oasis Form

1.1 OASIS ID: preconst1-92287

Project details

Project name	Merchant Waste Treatment Plant, Frog Island, London Borough of Havering
Short description of the project	A watching brief of geotechnical boreholes at Merchant Waste Treatment Plant, Frog Island, London Borough of Havering. The geotechnical work comprised the excavation of 12 boreholes between the 18th and 28th January 2011. The work demonstrated that river terrace gravel was present at approximately 10m below the current ground surface. Overlying the river terrace gravel was approximately 7m of alluvial deposits containing various accumulations of peaty material. Overlying the alluvial sequence was approximately 3m of modern made ground. Some of the boreholes revealed peat deposits towards the bottom of alluvial sequence of some thickness (up to 3m). Core samples removed during this watching brief should provide significant material for palaeoenvironmental analysis.
Project dates	Start: 18-01-2011 End: 28-01-2011
Previous/future work	No / Not known
Type of project	Recording project
Site status	Local Authority Designated Archaeological Area
Current Land use	Industry and Commerce 4 - Storage and warehousing

Project location

Country	England
Site location	GREATER LONDON HAVERING RAINHAM Merchant Waste Treatment Plant, Frog Island
Postcode	RM13 9YA
Study area	11679.12 Square metres
Site coordinates	TQ 5125 8091 51.5063426335 0.179626606458 51 30 22 N 000 10

	46 E Point
Height OD / Depth	Min: -6.20m Max: -4.70m

Project creators

Name of Organisation	Pre-Construct Archaeology Ltd
Project brief originator	Mills Whipp
Project design originator	Mills Whipp
Project director/manager	Tim Bradley
Project supervisor	Alexander Pullen
Type of sponsor/funding body	Capita Symonds

Project archives

Physical Archive recipient	LAARC
Physical Contents	'Environmental'
Digital Archive recipient	LAARC
Digital Contents	'Environmental','Stratigraphic','Survey'
Digital Media available	'Text'
Paper Archive recipient	LAARC
Paper Contents	'Environmental','Stratigraphic','Survey'

Paper Media available	'Context sheet','Matrices','Plan','Report','Section','Survey ','Unpublished Text'
Entered by	Tim Bradley (tbradley@pre-construct.com)
Entered on	2 February 2011

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