Wessex Archaeology

Steart Point, Somerset

Geoarchaeological and Palaeoenvironmental Assessment

Ref: 77221.14

July 2012

Wessex Archaeology

STEART POINT, SOMERSET

GEOARCHAEOLOGICAL AND PALAEOENVIRONMENTAL ASSESSMENT

Prepared by:

Wessex Archaeology
Portway House
Old Sarum Park
Salisbury
Wiltshire
SP4 6EB

Prepared for:
May Gurney Ltd
Trowse
Norwich
Norfolk
NR14 8SZ

Ref: 77221.14

July 2012

STEART POINT, SOMERSET

GEOARCHAEOLOGICAL AND PALAEOENVIRONMENTAL ASSESSMENT

Ref: 77221.14

Title:	Steart Point, Somerset: Geoarchaeological and Palaeoenvironmental Assessment
Principal Author(s):	Jack Russell
Managed by:	Andy Crockett
Origination date:	7th July 2012
Date of last revision:	12th July 2012
Version:	77221.14
Wessex Archaeology QA:	Dr Catherine Barnett
Status:	Final
Summary of changes:	
Associated reports:	
Client Approval:	
Client Representative:	

STEART POINT, SOMERSET

GEOARCHAEOLOGICAL AND PALAEOENVIRONMENTAL ASSESSMENT

Ref: 77221.14

Summary

This report was commissioned by May Gurney Ltd. on behalf of the Environment Agency and summarises geoarchaeological and palaeoenvironmental assessment work in advance of a Proposed Ecological Habitat Creation scheme on the Steart Peninsula, Somerset. Nine major sedimentary Units have been identified within the site using data derived from geotechnical, geaoarchaeological and archaeological investigations in the area. These Units are:

- Unit J Jurassic bedrock,
- Unit H Quaternary glacial and marine sediments,
- Unit G Quaternary fluvial sediments,
- Unit F Early Holocene estuarine alluvium
- Unit E Early Holocene peat
- Unit D Holocene estuarine alluvium,
- Unit C Holocene (Neolithic) peat and alluvium,
- Unit B Estuarine alluvium (Subunit Bii) and alluvial soils (Subunit Bi),
- Unit A which comprises Subunits of the most recent Holocene sedimentation and activity on site including modern soil formation across the site (Subunit Aii)

Two boreholes (**WA2011_BH02**, and **WA2011_BH05**) have been geoarchaeologically recorded with the results incorporated into the sedimentary framework. A programme of scientific dating (OSL and ^{14}C) and environmental assessments (pollen, foraminifera, ostracods, waterlogged plants, molluscs, charcoal and insects) has been undertaken.

This assessment has confirmed the presence of well preserved Pleistocene and Holocene deposits beneath the scheme area. These deposits include a peat of Neolithic date within which there is an increased potential for the presence and survival of waterlogged archaeological material, which is rare for the period and of high value.

In order to heighten understanding of the palaeolandscape and potential archaeological remains preserved within it to a level sufficient to mitigate the likely impact of the proposed scheme, further detailed analysis is required. Such analysis would utilise existing palaeoenvironmental samples from this study and the ongoing archaeological excavations along with the acquisition of a small number of additional samples from boreholes at specific and targeted locations. The analysis would concentrate on providing detailed information suitable for consumption by the regional and national academic audience in the context of the ongoing research into estuarine archaeology as set out in the regional research framework (Webster 2007).

STEART POINT, SOMERSET

GEOARCHAEOLOGICAL AND PALAEOENVIRONMENTAL ASSESSMENT

Ref: 77221.14

Acknowledgements

This report was commissioned by May Gurney Ltd. The geoarchaeological boreholes were undertaken by Fugro Ltd. Wessex Archaeology would like to acknowledge the assistance of the staff of these two organisations.

The sedimentary descriptions, sediment subsampling, foraminifera and ostracod assessments were taken by Jack Russell. Dr Michael Grant undertook the pollen assessment, Dr Chris Stevens and Sarah Wyles undertook the waterlogged remains, molluscan, insect and charcoal assessments. Material for radiocarbon dating was identified by Dr Chris Stevens. The radiocarbon dating was undertaken at the Scottish Universities Environmental Research Centre (SUERC) under the supervision of Dr Gordon Cook. Dr Chris Stevens calibrated the radiocarbon dates. Material for OSL dating was selected by Jack Russell and the dating undertaken by Dr Philip Toms at the University of Cheltenham and Gloucester.

Jack Russell compiled this report, edited by Dr Catherine Barnett and Kitty Brandon prepared the illustrations. Andy Crockett managed the project for Wessex Archaeology.

STEART POINT, SOMERSET

GEOARCHAEOLOGICAL AND PALAEOENVIRONMENTAL ASSESSMENT

Ref: 77221.14

Contents

Figures

STEART POINT, SOMERSET

GEOARCHAEOLOGICAL AND PALAEOENVIRONMENTAL ASSESSMENT

Ref: 77221.14

1. INTRODUCTION

1.1.1. Wessex Archaeology (WA) has been commissioned by Team van Oord to undertake geoarchaeological work in advance of a Proposed Ecological Habitat Creation scheme on the Steart Peninsula, Somerset ('the scheme') (**Figure 1**). This work has included assessment of geotechnical data, the retrieval of two boreholes for archaeological purposes (boreholes **WA2012_BH02** and **WA2011_BH05**) and subsequent geoarchaeological recording and assessment of subsamples retrieved from the boreholes.

1.1.2. Previous and ongoing archaeological work for the Steart Peninsula has included a Heritage Assessment (WA 2009a), and extended Heritage Assessment (WA 2009b), a geophysical survey (WA 2011a) watching briefs of geotechnical works (WA 2009c and 2011b) and an archaeological site evaluation and fieldwalking programme (WA 2011c).

1.1.3. Geotechnical data acquired as part of previous site investigations for the Environment Agency including the North Clyce Outfall project (Fugro 2007) and Steart Coastal Management Project (Fugro 2009) has been incorporated into the geoarchaeological assessment. The geotechnical works in the area undertaken as part of the adjacaent Bristol Port Company Proposed Ecological Habitat Creation Scheme (CJ Associates 2011b; CJ Associates 2011c; Lankelma 2011) have also been geoarchaeologically assessed (WA 2011d).

1.1.4. This report comprises a summary of the geoarchaeological assessment, subsample assessment and review of geotechnical data for the area. All elevations are provided in metres below (b) or metres above (a) Ordnance Datum, Newlyn (OD).

2. BACKGROUND

2.1. Development Background

2.2. The scheme comprises creation of a wildlife habitat including the excavation of creeks ponds and the construction of flood defences (**Figure 1**).

2.3. Geological background

2.3.1. The proposed scheme area lies on flat pasture elevated at around 5 to 6 metres above Ordnance Datum (OD). It is within the northwestern edge of the valley of the River Parrett which at this point flows along the southeastern edge of the scheme area in a southwest to northeasterly direction towards Burnham-on-Sea where it converges with the Bristol Channel and the River Brue between Steart and Berrow flats. To the north of the scheme area is the Bristol Channel and low hills surround the scheme area to the west (**Figure 1**).

2.3.2. The solid geology beneath the area generally consists of Mercia Mudstone Group (Triassic mudstone, shale and conglomerate) and the Lower Lias (Jurassic Limestone and Shale) (Geological Survey 1957 and Brown 1980).

2.3.3. Pleistocene sediments that overlie the bedrock in the area include the Burtle Beds (sands and gravels containing marine and freshwater faunas) 2km to the southeast of the area, and undifferentiated Head deposits 0.5km to the west of the area,.

2.3.4. Within the surrounding area, the solid geology is typically overlain by Holocene age alluvial sediment interspersed with peat layers. The alluvium is described by the British Geological Survey (Brown 1980) as marine and estuarine alluvium of the Somerset Levels including grey clays with some silts and sands. The peat is recorded locally as lying at the base of the sequence and is exposed, from time to time, on the foreshore near Hinkley Point (Brown 1980) where a "Submarine Forest" has been recorded (inset **Figure 1**). This peat has been dated at 8365±100BP. A more extensive peat lies at around the level of Ordnance Datum and yielded a date of 4200±100BP (Brown 1980).

2.3.5. The British Geological Survey have recorded the elevation of the upper surface of Holocene estuarine alluvium in the Somerset Levels at around 6 metres above Ordnance Datum which is also the level of High Water Spring Tides (HWST). Marine incursions do not however affect most of the area due to storm gravel beach deposits, blown sand, man made works and extensive tidal flats which are widespread along the west facing coastline (Brown 1980).

2.3.6. Pebbles, formed by the abrasive wave action on limestone cliffs, are transported eastwards along the North Somerset Coast to the Steart Peninsula, forming mobile ridges that can be transported shoreward as well as alongshore (HR Wallingford 2002: 12). The pebble ridge at Catsford Common migrated nearly 190 metres eastwards between 1957 and 1964, while at Wall Common the movement was under 20 metres (*ibid*). Also during this period, the marsh retreated while the upper foreshore accreted. The modern soil across the scheme area is recorded as part of the 81 Downholland 1 association, which is a typical humic-alluvial gley soil (Soil Survey of England and Wales 1983).

3. AIMS AND OBJECTIVES

3.1. Aims

3.1.1. Overall the aim of the package of phased archaeological evaluative surveys, of which this project forms part, is to gather additional baseline information to enable the value of the heritage resource to be established and appropriate mitigations strategies put in place in the context of the Environmental Impact Assessment of the scheme. The overall evaluation strategy is guided by two research aims agreed in consultation with the curators. Those aims are:

- *To understand the chronology of land reclamation on the Steart Peninsula;*
- *To understand and date the environmental changes within which the reclaimed landscape developed.*

3.2. Objectives

3.2.1. The work is designed to provide information which will help to achieve the key aims. The two key objectives are to:

- *Assess the core logs from boreholes across the Scheme area to help develop an understanding of the geomorphological characteristics of the area within the scheme area, with specific reference to evidence for Holocene development.*

- *Achieve a better understanding of the palaeoenvironmental development of the peninsula from sub-samples taken from the archaeological boreholes. This will be achieved by scientifically dating samples and carrying out environmental assessment.*

4. METHOD

4.1. Review of borehole logs

4.1.1. Geotechnical data, including borehole and test pit logs acquired as part of geotechnical site investigations including the Environment Agency's North Clyce Outfall project (Fugro 2007) and Steart Coastal Management Project (Fugro 2009), have been incorporated into the geoarchaeological assessment.

4.1.2. The geotechnical works within the scheme area have included test pit and borehole logs (Fugro 2007 and 2009), have been geoarchaeologically assessed. The locations of these test pits and boreholes are shown on **Figure 1**.

4.1.3. Due to the number of geotechnical investigations in the area, an identification code including the client and year has been suffixed to the geotechnical identification code so that it can be easily referred to. For example the identification code of borehole "BH1" from the Environment Agency North Clyce Outfall project (Fugro 2007) is referred to as "**EA2007_BH1**". A full list of identification codes, borehole, and test pit locations is given in **Appendix 1**.

4.1.4. The sediments identified within these logs have been grouped into a sedimentary unit-based framework, consisting of Units and Subunits (Units A to J) in order to form a deposit model of the area. The interpreted data has been entered into a Rockworks database. This work forms part of a wider study incorporating geotechnical data from the rest of the Steart Peninsula (WA 2011d) and some sedimentary Units (Subunits Ai and Aiii) do not occur in this scheme area but are included for reference.

4.1.5. This unit-based system also incorporates the information acquired from the geoarchaeological boreholes taken as part of this project (**WA2011_BH02**, and **WA2011_BH05**), previous archaeological watching briefs (WA 2009a, 2011b), geophysical survey (Wessex Archaeology 2011a) and published geological maps of the area British Geological Survey (Brown 1980).

4.2. Geoarchaeological Borehole Recording

4.2.1. Two geoarchaeological boreholes **WA2011_BH02**, **WA2011_BH05**), were drilled by Fugro Ltd, on behalf of Wessex Archaeology between the 13th April to 24th May 2011 (Fugro 2011).

4.2.2. Core and bulk samples were recovered and delivered to the laboratory at Wessex Archaeology during December 2011. Using the geotechnical logs as a guide, two core samples were selected for Optically Stimulated Luminescence (OSL) dating, one from borehole **WA2011_BH02** and one from borehole **WA2011_BH05**. These were set aside for delivery to a laboratory at the University of Cheltenham and Gloucester for OSL sampling and subsequently geoarchaeologically recorded.

4.2.3. The remaining core samples were longitudinally split and prised open with care to preserve sedimentary structure. The bulk samples stored in plastic bags and plastic pots were opened and cleaned to reveal uncontaminated sediment where necessary and were geoarchaeologically recorded.

4.2.4. The geoarchaeological descriptions are given in full in **Appendix 2.** Sedimentary descriptions provided details of the depth to each sediment horizon and the character of the sediment. Sedimentary characteristics were recorded including texture, colour, stoniness, nature of boundaries and structure (*cf.* Hodgson 1976).

4.2.5. The sediments described within the samples were then grouped into a number of sedimentary Units (and Subunits) based on the observed sedimentary characteristics.

4.2.6. During the geoarchaeological recording, sediment subsamples were taken from the core samples. Eight samples, six from borehole **WA2011_BH02** and two from borehole **WA2011_BH05** were selected for microfossil (pollen, foraminifera and ostracod) assessment. Four samples, three from borehole **WA2011_BH02** and one from borehole **WA2011_BH05** were selected for macrofossil (waterlogged plants, mollusc, charcoal, insects) assessment. Three samples, two from borehole **WA2011_BH02** and one from borehole **WA2011_BH05** were selected for radiocarbon dating. The locations of the assessed boreholes are given in the table below and on **Figure 1**.

Borehole ID	Easting	Northing	top (m aOD)
WA2011_BH02	325541	144299	5.44
WA2011_BH05	327785	145614	5.73

4.2.7. The subsample locations and depths are shown on **Figure 3**. The specific depths of the samples are also given within **Appendices 2** to **7**.

4.2.8. Subsamples were taken predominantly from the core samples to gain accurate depths, stratigraphic control and avoid sample contamination. The bulk samples were not subsampled due to potential contamination of the sediment.

4.3. Radiocarbon Dating

4.3.1. Three radiocarbon samples were submitted to the Scottish Universities Environmental Research Centre (SUERC) for dating. Horizontally bedded *Phragmites* reed stems were submitted from the peat from **WA2011_BH102** (0.74m above OD; Unit C). Due to a lack of suitable discrete plant remains, bulk sediment samples were submitted from **WA2011_BH02** (4.15m below OD; Unit H) and from borehole **WA2011_BH05** (1.53m above OD). For full methodological details see **Appendix 3**.

4.4. Optically Stimulated Luminescence (OSL) Dating

4.4.1. Two sediment samples were submitted to the University of Cheltenham and Gloucester for OSL dating. The samples selected were minerogenic sediments from towards the bottom of the sedimentary sequences within boreholes **WA2011_BH102** (at 4.56 to 5.01m below OD; Unit H) and **WA2011_BH05** (at 2.07 to 2.52m below OD, Subunit Bii). For full methodological details, see **Appendix 4**.

4.5. Pollen Assessment

4.5.1. Eight sediment subsamples of approximately 4cm^3 were assessed for their pollen content from boreholes **WA2011_BH02** (4.76, 4.15, 1.11m below OD, 0.61, 0.71 and 2.94m above OD;) and **WA2011_BH05** (2.24m below OD, 1.53m above OD). Standard techniques were used for the extraction of sub-fossil pollen from the sediment at the

University of Reading. The specific methods used for extraction and calculating the relative abundances of pollen are detailed in **Appendix 5**.

4.6. Foraminifera and Ostracod Assessment

4.6.1. Eight sediment subsamples were assessed for the presence and preservation of foraminifera and ostracods from boreholes **WA2011_BH02** (4.76, 4.15, 1.11m below OD, 0.58, 0.65 and 2.94m above OD;) and **WA2011_BH05** (2.24m below OD, 1.53m above OD).

4.6.2. Sediment samples of approximately 10cm^3 were treated with a weak solution of hydrogen peroxide and wet sieved through a 63µm sieve. Foraminifera and ostracods were picked out and identified using a Vickers binocular microscope under 10-60x magnification and transmitted and incident light (**Appendix 6**).

4.7. Waterlogged Plants, Molluscs, Charcoal and Insects

4.7.1. Four sediment samples were assessed for the presence and preservation of waterlogged plants, molluscs, charcoal and insects. Three samples from borehole **WA2011_BH02** (4.04 to 4.14m, 3.51 to 3.61m below OD and 0.69 to 0.59m above OD) and one sample from borehole **WA2011_BH05** (2.19 to 2.29m below OD).

4.7.2. The sediment samples of 100 to 250cm^3 were processed by wet sieving through a 250µm sieve. The samples were then visually inspected under using a stereo-binocular microscope using x10 to x40 magnification (**Appendix 7**).

4.7.3. Additionally one of the foraminifera and ostracod samples from borehole **WA2011_BH02** (at 4.86m below OD) contained a high abundance of molluscan remains. The mollusc and plant remains within this sample were also assessed (**Appendix 7**).

5. RESULTS

5.1. Geotechnical data assessment and Geoarchaeological borehole recording

Introduction

5.1.1. The results of the geotechnical data assessment and geoarchaeological borehole recording have been amalgamated into a deposit model consisting of nine major sedimentary Units (Units A to J), the letter I (i) has not been used as the Subunits are suffixed with Roman numerals (i,ii etc).

5.1.2. A selection of boreholes and test pit transects (**Figures 2** and **3**) illustrate the relationship between the sedimentary Units and Subunits which are also summarised below.

5.1.3. The interpretation of geotechnical borehole and test pit data presented here may not be of sufficient detail, for example, fine peat layers indicative of terrestrial land surfaces, were noted within the geoarchaeologically recorded boreholes to be in some instances no more than 20mm in thickness. Geotechnical borehole logs generated at the same locations did not describe similar layers and it is considered possible that peat deposits are potentially more widespread than indicated by the geotechnical logs.

Unit J: Limestone Bedrock. 7.8 to 10.65m below OD

5.1.4. Unit J (**Figures 2** and **3**) comprised limestone, recovered as gravel-sized pieces in two of the boreholes (**EA2009_BH2** and **EA2009_BH3**). The Unit is interpreted as Early Jurassic (Lower Lias) bedrock. The Unit was not penetrated to any great depth within any of the boreholes. The bedrock surface was recorded at 7.8m below OD in borehole **EA2009_BH3**) to 10.65m below OD in borehole **EA2009_BH2** (**Figure 2**).

Unit H: Gravel, sand, silt and clay. 3.95m above OD to 12.35m below OD

5.1.5. This Unit comprised clay, silts sand and gravel with organic inclusions. The unit occurred in boreholes **EA2007_BH1**, **EA2007_BH2**, **EA2009_BH2**, **EA2007_BH4**, **WA2011_BH02** and test pit **EA2009_TP7 (Figures 2** and **3)**. The unit ranged in thickness from 0.9m (**EA2007_BH2**) to 3m (**EA2009_BH4**) although was only fully penetrated in borehole **EA2009_BH2**, where it extended to 10.65m below OD and overlay Unit J, bedrock. It is considered possible that this Unit relates to Pleistocene sedimentation. It has also been potentially subject to marine and periglacial processes. It may be equivalent to the so-called Burtle Beds, which are mapped outcropping to the southeast of the Study Area by the British Geological Survey (Brown 1980).

Unit G: Gravel and sand. 6.4m below OD to 7.8m below OD

5.1.6. This Unit comprised gravel and sand and occurred in boreholes **EA2007_BH1, EA2007_BH2** and **EA2009_BH3** (**Figures 2** and **3**). The Unit ranged in thickness from 0.9m (**EA2007_BH1** and **EA2007_BH2**) and 1.4m (**EA2009_BH3**) and contained occasional fragmented and broken molluscan remains (**EA2007_BH1** and **EA2007_BH2)** remains and is thought most likely to represent relatively high energy Pleistocene or Early Holocene fluvial deposits, though the possibility that the Unit relates to coastal and shallow marine sedimentation is also noted.

Unit F: Sandy gravelly clay. 4.95m below OD to 9.35m below OD

5.1.7. This Unit comprised green grey and brown sandy gravelly clays and occurred in five boreholes (**Figure 2**): **EA2007_BH1**, **EA2007_BH2**, **EA2009_BH2**, **EA2009_BH3** and **EA2009_BH4**. The Unit was fully penetrated in all five boreholes and ranged in thickness from 0.6m (**EA2009_BH3**) to 2.5m (**EA2009_BH4**). The Unit is interpreted as Holocene (probably estuarine) alluvium.

Units E: Peat. 4.5m below OD to 7.85m below OD

5.1.8. This Unit comprised peat and occurred in five boreholes: **EA2007_BH1**, **EA2007_BH2**, **EA2009_BH2**, **EA2009_BH3** and **EA2009_BH4** (**Figure 2**). The Unit was full penetrated in all five boreholes and ranged in thickness from 0.3m (**EA2009_BH3**) to 1.8m (**EA2007_BH2**). The Unit was noted to contain wood (**EA2007_BH2**) and to be intercalated with clay and silt. The Unit is interpreted as early Holocene peat, intercalating with low energy/ overbank alluvium.

Unit D: Sand, silt and clay. 0.95m above OD to 7.25m below OD

5.1.9. This Unit comprised soft sands, silts and clays with frequent organic inclusions including roots. The unit occurred in four boreholes: **EA2007_BH2**, **EA2009_BH2**, **EA2009_BH3** and **WA2011_BH02** (**Figures 2** and **3**). The Unit was fully penetrated in all four boreholes and ranged in thickness from 4.8m (**EA2009_BH3**) to 6m (**EA2009_BH4**). The Unit was separated from Subunit Bii by Unit C in most of the boreholes (**Figures 2** to **4** It was however sedimentologically indistinct from Subunit Bii. It was therefore difficult to interpret in boreholes where Unit C was absent. The Unit is interpreted as Holocene estuarine alluvium.

Unit C Silt, clay and peat 1.09m above OD to 1.85m below OD

5.1.10. This Unit comprised peat with intercalated silts and clays. The Unit was recorded in three boreholes: **EA2009_BH2**, **EA2009_BH3** and **WA2011_BH02** (**Figures 2** and **3**). The Unit was fully penetrated in all three boreholes and ranged in thickness from 0.27m (**WA2011_BH02**) to 1.6m (**EA2009_BH2**).

5.1.11. The Unit was recorded as fibrous within boreholes **EA2009_BH2**, **EA2009_BH3** and as containing horizontally bedded *Phragmites* (reed) remains within **WA2011_BH02**. The Unit is interpreted as Holocene peat formed on emergent vegetation, with intercalated alluvium indicating repeated incursion of this surface.

Subunit Bii: Silty Clay and Clayey silt. 5.65m to 4.65m above OD

5.1.12. This Subunit comprised soft silty clays and clayey silts which occurred in all of the boreholes and test pits except borehole **EA2007_BH3** and test pit **EA2007_TP1** (**Figures 2** and **3**). The Subunit was fully penetrated in the boreholes and one test pit (**EA2007_TP7**). The Subunit ranged in thickness from 1.9m (**EA2007_TP2**) to 9.65m (**EA2007_BH1**) in thickness. Frequent organic remains including peaty layers, plant remains and roots were recorded. The Unit is interpreted as Holocene estuarine alluvium with fine stabilised terrestrial beds/ peats.

Subunit Bi: Oxidised silty clay and clayey silt. 6.15m to 4.95m above OD

5.1.13. This Subunit comprised mottled grey/brown and brown occasionally fine sandy silts and clays with some roots and occasional organic inclusions. The Subunit occurred in all of the boreholes and test pits except boreholes (**EA2007_BH2**) and ranged in thickness from 0.5m (**EA2009_TP17**) to 2.7m (**EA2007_BH3**) (**Figures 2** and **3**). The Subunit was interpreted as an immature alluvial gley soil, developed upon estuarine alluvium.

Subunit: Aiv Made ground. 6.4 to 3.65m above OD

5.1.14. This Subunit consists of sand, gravel, clay and concrete. The Subunit was recorded within two boreholes: **EA2007_BH2** and **EA2007_BH3** and 10 test pits (**EA2007_TP1**, **EA2007_TP2**, **EA2009_TP4**, **EA2009_TP6**, **EA2009_TP9**, **EA2009_TP11**, **EA2009_TP15**, **EA2009_TP17**, **EA2009_TP21** and **EA2009_TP22**) (**Figures 2** and **3**). This Subunit is interpreted as modern made ground

Subunit Aiii Sand

5.1.15. This Subunit, comprising blown sand has not been identified in any of the geotechnical investigations within the scheme area, although was recorded in geotechnical investigations in the coastal part of the adjacent Bristol Port Company Habitat Creation Scheme to the north of the Study Area and is mapped to the north of the scheme area by the British Geological Survey as blown sand (Brown 1980).

Subunit Aii Gravel, sand, silt and clay. 6.15m to 4.95m above OD

5.1.16. This Subunit comprised gravel, sand, silt and clay and was described within the geotechnical logs as “Topsoil” or “Turf over Topsoil”. The Subunit was recorded within five boreholes: **EA2009_BH2**, **EA2009_BH3**, **EA2009_BH4**, **WA2011_BH02** and **WA2011_BH05**) and nine test pits: **EA2007_TP2**, **EA2009_TP2**, **EA2009_TP7**, **EA2009_TP12**, **EA2009_TP13**, **EA2009_TP14**, **EA2009_TP18**, **EA2009_TP19** and **EA2009_TP20** (**Figures 2** and **3**). This Subunit was fully penetrated in the five boreholes and nine test pits in which it occurred and ranged from 0.1m (**EA2009_BH3**, **EA2009_TP13** and **EA2009_TP19**) and 0.7m (**EA2009_TP18**) in thickness. The unit is interpreted as a recent gley soil/A horizon.

Subunit Ai Gravel

5.1.17. This Subunit comprised sandy gravel and was not recorded in the scheme area but occurred in the coastal section of the adjacent Bristol Port Company Habitat Creation Scheme area and was interpreted as a mobile marine, beach deposit (Wessex Archaeology 2011d).

5.2. Radiocarbon dating

5.2.1. The returned dates have been calibrated using OxCal 4.1.5 (Bronk Ramsey 2001; 2009) using the IntCal09 atmospheric and marine09.14 calibration curve respectively (Reimer *et al.* 2009). The results are given in the table below in **Appendix 2** and are also shown on **Figure 4**.

Borehole	Depth (mbOD)	Sample Material	Lab Code	Radiocarbon Date (BP)	δ13C (‰)	Calibrated date (95.4%, 2σ range)
WA2011_BH02	4.7	*Phragmites* stem.	SUERC-38608	4020±35	-27	3100-2910 cal BC [5050-4860 cal BP)
WA2011_BH02	9.59	sediment	SUERC-38609	15825±40	-29.3	17400-16800 cal BC (19350-18750 cal BP)
WA2011_BH05	4.2	sediment	SUERC-38610	4390±30	-24.5	2630-2460 cal BC (4580-4410 cal BP)

5.2.2. Within borehole **WA2011_BH02** at 0.74m above OD (4.7m below GL, Unit C) a *Phragmites* reed stem returned a date of SUERC-38608: 4020±35 BP (Before Present = before 1950AD) (5050-4860cal. BP; 3100-2910cal. BC) which is equivalent to the Middle Neolithic archaeological period and early-Mid Holocene geological period, Marine Isotope Stage (MIS) 1. At 4.15m below OD (9.59m below GL, Unit H) within the same borehole a sediment sample returned a radiocarbon date of SUERC-38609: 15825±40 BP (19,350-18,750 cal. BP; 17,4000-16,800 cal. BC) which is equivalent to the Upper Palaeolithic archaeological period around the time of the Devensian Glacial maximum, MIS 2.

5.2.3. Within borehole **WA2011_BH05** at 1.53m above OD (4.2m below GL, Unit Bii) a sediment sample returned a radiocarbon date of SUERC-38610: 4390±30 BP (4580-4410 cal. BP; 2630-2640 cal. BC) which is equivalent to the Late Neolithic archaeological period, the Holocene Geological period and MIS1.

5.3. OSL dating

5.3.1. Two samples were submitted for OSL dating. The results are given below, in **Appendix 4** and are also shown on **Figure 3**. The results of the OSL dating are conventionally reported, rounded to the nearest 100 years, in thousands of years ago (ka), calibrated from the year 2011 (when the samples were taken).

5.3.2. Within borehole **WA2011_BH02** at 4.56 to 5.01m below OD (10.00 to 10.45m below GL) the sampled sediment returned a date of GL11023: 169 ± 31 ka (138,000 to 200,000 BP) which is equivalent to the Middle Palaeolithic archaeological period and covers the Aveley to Ipswichian interglacial geological periods (Marine Isotope Stages (MIS) 7 to 5e). The age estimate was considered to be accepted tentatively as a minimum age (**Appendix 4**).

5.3.3. Within borehole **WA2011_BH05** at 2.07 to 2.52m below OD (7.8 to 8.25m below GL) the sampled sediment returned a date of GL11022: 1.2 ± 0.2 ka (c. 1000 to 1400 BP) which is equivalent to the Anglo Saxon archaeological period and the Holocene geological period, MIS1 This age estimate was accepted as a valid date with no caveats (**Appendix 4**).

5.4. Pollen

5.4.1. Variable amounts of pollen were within the eight samples, with sufficient counts for assessment only found in two samples from borehole **WABH2011_BH02** at 0.61m and 0.71m above OD (Unit C). The two samples contained an assemblage dominated by *Quercus* (oak) and *Corylus avellana*-type (hazel), with *Alnus glutinosa* (alder), *Ulmus* (elm), Chenopodiaceae (goosefoots and oraches) and Poaceae (grasses) also present.

5.4.2. The samples from borehole **WABH2011_BH02** at 2.94m above OD, 1.11, 4.15 and 4.76m below OD and from borehole **WABH2011_BH05** at 1.53m above OD and 2.24m below OD did not contain sufficient amounts of pollen for assessment (**Appendix 5**).

5.5. Foraminifera and Ostracods

5.5.1. Within borehole **WA2011_BH102**, of the six levels assessed at 4.76, 4.15, 1.11m below OD, 0.58, 0.65 and 2.94m above OD) foraminifera and ostracods were present in three (at 1.11m below OD, 0.58m and 2.94m above OD). At 1.11m below OD foraminifera (including *Ammonia beccarrii* and *Elphidium williamsoni*) and ostracods (including *Milammina fusca*) indicative of brackish, estuarine and saltmarsh environments. At 0.58m above OD (Unit D) a hyperabundance of the ostracod *Cyprideis torosa*, was of interest as it's mass development is usually associated with organic detritus and brackish water (Meisch 2000). At 2.94m above OD (Unit Bii) ostracods (*Cyprideis torosa)* and foraminifera (*Ammonia beccarrii Elphidium williamsoni*, *Haynesina germanica*, *Jadammina macrescens Trochammina inflata)* indicative of estuarine and brackish saltmarsh environments were recovered.

5.5.2. Molluscan and plant remains were also noted within the foraminifera and ostracod samples (**Appendix 6**). One sample **WA2011_BH102** at 0.58m above OD (Unit D) contained a high abundance of molluscs and was incorporated into the molluscan assessment (**Appendix 7**). A significant number of diatoms were also noted within some of the foraminifera and ostracod samples most noteably from **WA2011_BH02** at 0.65m above OD (Unit Bii).

5.5.3. Within borehole **WA2011_BH105** two levels were assessed at 2.24m below OD and 1.53m above OD. Foraminifera and ostracods were present at both levels. At 2.24m below OD (Unit Bii) marine and brackish water foraminifera (including *Ammonia beccarrii*, *Elphidium williamsoni*, *Haynesina germanica*, *Jadammina macrescens, Miliolinella subrotundata* and *Quinqueoloculina*) and ostracods *(including Leptocythere pellucida*, *Cyprideis torosa*, *Hirschmannia viridis*, *Loxoconcha rhomboidea* and *Propontocypris* sp.) were recovered. At 1.53m above OD (Unit Bii) a few valves of the ostracod *Leptocythere* sp. were recovered and more numerous brackish and marine foraminifera (including *Elphidium williamsoni*, *Haynesina germanica* and *Jadammina macrescens*) were recovered.

5.6. Waterlogged Plants, Charcoal, Molluscs and Insects

5.6.1. Within borehole **WA2011_BH02**, samples were assessed 4.04m to 4.14, 3.51 to 3.61m below OD and 0.69 to 0.59m above OD. The foraminifera and ostracod sample from **WA2011_BH102** at 0.58m above OD (Unit D) was also assessed for other remains (**Appendix 7**). At 4.04 to 4.14m below OD (Unit H) no identifiable plant remains or molluscs were recorded although some intrusive root material was recorded. Above this, the sample at 3.51 to 3.61m below OD (Uniy H) contained no plant remains but a few molluscs were recorded, including *Hydrobia* sp. and *Ovatella myosotis/Leucophytia bidentata* No identifiable charcoal or insects were recovered from any of the samples from borehole **WA2011_BH102**. The foraminifera and ostracod sample from **WA2011_BH102** at 0.58m above OD noted to contain a high abundance of brackish and estuarine molluscs, including shells of *Hydrobia ventrosa* and *Hydrobia ulvae*. Some seeds were also recovered from the sample including seeds of *Juncus* (sedge) *Potomageton* (pondweed) and a charophyte oogonium.

5.6.2. Plant remains were frequent within the peat sample at 0.69 to 0.59m above OD (Unit C). The plants recovered included stonewort (*Chara* sp.), fennel-leaved pondweed (*Potamogeton pectinatus*), horned pondweed (*Zannichellia palustris*), grey club-rush

(*Schoenoplectus tabernaemontani*) spiked water-milfoil (*Myriophyllum spicatum*), water-crowfoot (*Ranunculus baudotii*), nettle (*Urtica dioica*) and goosefoot (*Chenopodium glaucum/rubrum*). These plants, together with the occasional occurrence of the mollusc *Hydrobia* sp. are indicative of tidal marshand muddy brackish and estuarine environments with evidence of freshwater input. No charcoal was recovered within this sample although some insect remains (water flea eggs) were recorded.

5.6.3. Within borehole **WA2011_BH05** the assessed at 2.19 to 2.29m below OD (Unit Bii) contained plants including seablite (*Suaeda maritima*), common bulrush (*Typha latifolia*), lesser bulrush (*Typha angustifolia*) common nettle (*Urtica dioica*), bramble (*Rubus* sp.), rushes (*Juncus* sp.) and possible seeds of buttercup (*Ranunculus* sp.). These plants and fragments of *Tellina/Scrobicularia* type molluscs within the sample indicate brackish and saltmarsh environments were surrounded by scrub and marshy grassland. No charcoal was recovered within the sample. A few insect remains were recorded (**Appendix 7**).

6. DISCUSSION

6.1.1. The results of the geoarchaeological and palaeoenvironmental assessment have indicated a complex history of depositional environments within the scheme area. The deposit model produced provides at present a simplified grouping indicating a succession of glacial, fluvial, marine, estuarine, marsh and terrestrial environments which have developed over the Pleistocene and Holocene epochs. The types of environments encountered within this study, for example saltmarsh and tidal mudflats, can develop asynchronously across coastal areas. These have been grouped into broader patterns for the purposes of deposit modelling. This sedimentation can be related to sea level rises and falls over the period, an approach known as sequence stratigraphy (Miall 1999).

6.1.2. The probable relationship of the sedimentary Units and Subunits described here to equivalent deposits described in the area by the British Geological Survey (Brown 1980) and to similar deposits 40km northeast of the area on the Welsh Coast (Allen and Rae 1987) and 11km southwest of the area in the Somerset Levels (Coles and Coles 1986) is given in the table below:

<table>
<tr><th>Units/Subunits</th><th>Interpretation (this study)</th><th>British Geological Survey (Brown 1980)</th><th>Allen and Rae (1987)</th><th>Coles and Coles (1986)</th></tr>
<tr><td>Sub-Unit Aii</td><td>Modern gley soil</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Sub-Unit Aiv</td><td>Made Ground</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Sub-Unit Bi</td><td>Gley alluvial soil</td><td rowspan="6">Holocene alluvium and Peat</td><td>Rumney Formation /Wentlooge palaeosol</td><td>-</td></tr>
<tr><td>Sub-Unit Bii</td><td>Estuarine alluvium</td><td>Upper Wentlooge</td><td>-</td></tr>
<tr><td>Unit C</td><td>Peat and alluvium</td><td rowspan="4">Middle and Lower Wentlooge</td><td>Phragmites peat</td></tr>
<tr><td>Unit D</td><td>Estuarine alluvium</td><td>Marine Clay</td></tr>
<tr><td>Unit E</td><td>Peat</td><td></td></tr>
<tr><td>Unit F</td><td>Alluvium</td><td>-</td></tr>
<tr><td>Unit G</td><td>Fluvial gravel</td><td>Sand and gravel</td><td>-</td><td>-</td></tr>
</table>

Unit H	Pleistocene clay/sand	Burtle beds/Head deposits	-	Sandy Burtle
Unit J	Limestone Bedrock	Jurassic bedrock (Lower Lias)	-	-

6.1.3. It is noted that within single boreholes, for example, successive Holocene estuarine (minerogenic) and marsh (organic) sedimentary environments are seen on a fine, sometimes millimetre scale. It is likely that, whilst sediments of these types can be grouped by their elevation and lithology (e.g. Units F, E, D, C and B) deposition has not been synchronous across the area and that successive marsh and estuarine environments with dendritic and migrating cut and filled channel features are likely to be represented within the boreholes. At the resolution within this study, (7 deep boreholes across a wide area), the stratigraphic relationships of the deeper sediments is difficult to interpret with confidence and therefore extrapolation of units between boreholes must be treated with some caution. In addition, of these 7 boreholes, only two (**WA2011_BH02** and **WA2011_BH05**) have been recorded geoarchaeologically (**Appendix 2**) with the level of detail required for appropriate correlation of strata and for interpretation of environmental change on an archaeological timescale.

6.1.4. The Jurassic Limestone bedrock, Unit J which dips towards and forms the limit of the River Parrett valley is overlain by Pleistocene deposits allocated in this study to Unit H. Within borehole **WA2011_ BH02,** the OSL date within the upper part of Unit H at 4.56 to 5.01m below OD of GL11023: 169 ± 31 ka (138,000 to 200,000 BP) is significantly older than the ^{14}C date above it at 4.15m below OD (9.59m below GL) which is within the same unit and where a sediment sample returned a date of SUERC-38609: 15825±40 BP (*c*.19,350-18,750 cal. BP; 17,4000-16,800 cal. BC). The OSL date is similar to one obtained from the same unit within the adjacent site (GL10081, 149 ± 22 ka c. 127,000 – 171,000 BP) (WA 2011d). It is possible that the radiocarbon date of the sediment sample may have been contaminated by introduction of more recent carbon into the sediment by subsequent soil formation and occasional roots were noted within the unit. Environmental remains, other than roots were however absent although the sedimentary description indicates that the Unit has undergone probably both post depositional periglacial deformation and some soil formation, both of which may have affected the OSL and radiocarbon dating of sediments. It is likely that Unit H may form part of the formation known as the “Burtle Beds” which contain a mix of glacial and marine material (BGS) and have been recorded elsewhere within the Somerset Levels. There are also undifferentiated Head deposits recorded in the area by the British Geological Survey (Brown 1980) of which this Unit may also be contemporary.

6.1.5. Units G, F and E were recorded within the assessment of geotechnical data but it was not possible to perform any dating or palaeoenvironmental work upon them as neither of the geoarchaeologically recorded boreholes **WA2011_BH02** or **WA2011_BH05** penetrated them. By their elevation and sediment type it is however possible to compare them to similar sediments which occur in the surrounding area. Unit G was recorded within the adjacent Bristol Port Habitat Creation Scheme area (WA 2011d) and interpreted as being Pleistocene glaciofluvial alluvium (WA 2011d). Units F and E are Holocene estuarine alluvium and peat deposits respectively and are likely to contain similar archaeological and palaeoenvironmental material to Units D, C and Sub-Unit Bi, discussed below. These Units occur between *c*.5 and 10m below OD and contain terrestrial elements such as wood and peat. Relating this elevation data to the known Holocene sea level rise (Shennan *et al*. 2002) indicates the Units are likely to date to early Holocene and are possibly indicative Mesolithic terrestrial and brackish/marine environments, equivalent to the Lower and Middle Wentlooge as described originally on the Welsh Coast by Allen and Rae (1987).

6.1.6. Unit D was sampled in borehole **WA2011_BH2** and contained molluscs, foraminifera and ostracods indicative of brackish, estuarine and saltmarsh environments with some freshwater input. A surrounding environment of *Quercus* (oak) and *Corylus avellana*-type (hazel) woodland with areas of more open ground was interpreted from the pollen assemblage recorded from the unit. It is likely to be equivalent to the Middle Wentlooge (Allen and Rae 1987) and to the "Marine Clay" recorded within the Somerset levels (Coles and Coles 1986). It is overlain by peat (Unit C) which has been dated here to the middle Neolithic period.

6.1.7. A *Phragmites* reed stem derived from peat deposits within Unit C, borehole **WA2011_BH02**, at 0.74m above OD returned a date of SUERC-38608: 4020±35 BP (5050-4860 cal. BP; 3100-2910 cal. BC). The date is equivalent to the Middle Neolithic period and similar to Neolithic dates retrieved from peats in the adjacent Bristol Port Habitat Creation Scheme area (SUERC-34106: 5020±35 BP 5900-5650 cal. BP 3950-3700 cal. BC; SUERC-34105: 3980±35 BP, 4530-4290 cal. BP; 2580-2340 cal. BC and SUERC-34107 4715±35 BP, 5590-5320 cal. BP; 3640-3370 cal. BC and SUERC-34108: 4145±35 BP, 4830-4560 cal. BP; 2880-2620 cal. BC) (Wessex Archaeology 2011d). The plant remains recovered from the unit indicate that the peat formed within estuarine and marsh sediments within the tidal frame surrounded by areas of *Quercus* (oak) and *Corylus avellana*-type (hazel) woodland and grassy marshy open ground. During the Neolithic period, the rate of sea level rise, had dramatically slowed and it is this process, noted around the southern coast of Britain (Shennan *et al.* 2002), that has lead to the widespread development of peat deposits (Haslett *et al*. 2000). The known sea level data for the area (Shennan *et al*. 2002) indicate mean sea levels (roughly equivalent to the level of Ordnance Datum today) in the Bristol Channel were approximately 3 to 5 metres below those of the present day during the Neolithic. This is confirmed by the environmental data and Neolithic radiocarbon dates recorded from borehole **WA2011_BH02** which contains palaeoenvironmental evidence of wetland and marsh environments elevated within the tidal frame. It is also noted that the Bristol Channel has at present one of the largest tidal ranges in the world (*c*. 15m) and that this may also have been the case during the Neolithic. The fact that these peats are intercalated with alluvium towards the coast is likely a result of the proximity of the sea during the Neolithic period. Similar sequences of intercalated peats and silts have been noted elsewhere around the coast of the Britain and Europe and are noted to be controlled by both long term sea level rise and local palaeogeography (Allen 2003).

6.1.8. Above Unit C, Sub unit Bii was recorded within both archaeological boreholes **WA2011_BH02** and **WA2011_BH05**. Within borehole **WA2011_BH05**, the OSL date of GL11022: 1.2 ± 0.2 ka (*c*. 1000 to 1400 BP) at 2.07 to 2. is of note. It appears for its depth relative to other dated within the area to be quite young. A sediment sample above this level from the same borehole at 1.53m above OD returned a radiocarbon date of SUERC-38610: 4390±30 BP (4580-4410 cal. BP; 2630-2640 cal. BC) (**Figure 4**). It is possible that the radiocarbon date may well represent reworked material within the sequence and that the OSL date is indeed indicative of a deep channel in this area active during the Anglo-Saxon period. The environmental remains including molluscs, foraminifera and ostracods were indicative of outer estuarine and shallow marine deposition at these levels within this borehole which is more in keeping with a younger date when compared against known sea level data (Shennan *et al*. 2002). Within borehole **WA2011_BH02** no dating was undertaken, however foraminfera and ostracods were recorded in the upper part of the unit indicative of brackish, marsh and estuarine environments. Unit Bii, interpreted as estuarine alluvium is likely equivalent to the Upper Wentlooge formation as described by Allen and Rae (1987).

6.1.9. Subunit Bi, was interpreted as an alluvial gley soil which is widespread across the area and formed upon Subunit Bii. No samples were assessed from this unit during this study as it had previously proved to contain few palaeoenvironmental remains within the adjacent Bristol Port Habitat Creation Scheme Area (WA 2011d). An OSL date obtained from that study suggested that in that area, the deposition of Subunit Bii had occurred by late Iron Age and Romano British archaeological periods and therefore the formation of the gley soil, Subunit Bi, occurred subsequent to that date. The date is thought however to be possibly contaminated by pedogenesis (WA 2011d), but if correct, is equivalent to the (Roman) Wentlooge palaeosol as described by Allen and Rae (1987). The Wentlooge palaeosol at it's type site (Peterstone Wentlooge) on the Welsh coast has formed on the surface of the Upper Wentlooge formation, it thought to have formed as a result of land drainage facilitated by a system of deep drainage ditches resulting from the land drainage during the Romano-British period (Bell 1999).

6.1.10. Units Aii Modern soil and Aiv Made ground, the uppermost units recorded within this study have not been assessed or dated and are of little significance within this geoarchaeological and palaeoenvironmental assessment. Within the wider area and not recorded within this study, deposits of blown sand (Subunit Aiii) and a gravel beach (Ai) are however considered key to the more recent development and land reclamation in the Steart Peninsula (WA 2011d).

7. ARCHAEOLOGICAL POTENTIAL AND RECOMMENDATIONS

7.1.1. The results of the geoarchaeological investigations and assessment of geotechnical data have been interpreted to provide an initial understanding of the prehistoric landscape represented by the sediment sequence beneath the scheme area. This understanding, supported by radiocarbon and OSL dates, has revealed a prehistoric landscape including a Neolithic land surface which can be identified at a number of locations across the scheme area.

7.1.2. The results of the environmental assessment of samples (plant macrofossils, molluscs, insects, charred plant remains, charcoal, pollen, foraminifera and ostracods) indicate that material suitable for detailed analysis (plant macrofossils, pollen, diatoms, foraminifera and ostracods) are present within parts of the depositional sequence. Analysis of these types of data should provide a more comprehensive understanding of prehistoric land use and past land and seascape development particularly in relation to sea levels of the area.

7.1.3. Evidence of deposition and soil formation which have developed as part of the more recent reclaimed landscape was identified across the scheme area in the geotechnical data. OSL dating and archaeological evidence suggests estuarine alluvial deposition was occurring within the study area possibly into the Anglo Saxon period, although the archaeological investigations which are currently being undertaken suggest that land reclamation had begun by the Roman period with archaeological remains from this and the Medieval period currently being excavated within the scheme area. The results of environmental assessment from these levels so far indicate that there are few environmental remains preserved within these upper deposits, however, better samples related to the archaeological remains should be available from the excavated areas.

7.1.4. The dating, geoarchaeological investigations and environmental assessments indicate that in order to fully understand the original aims of the research, analysis of samples (plant macrofossils, pollen, diatoms, foraminifera and ostracods) and further scientific dating is required.

7.1.5. The lower Units J, H, G, F, F and D are unlikely to be adversely affected by the proposed development, but data from these Units should be incorporated into the overall deposit model in order to understand the palaeogeographic development of the scheme area. For example, the surface of bedrock, Unit J marks the maximum extent of the valley of the River Parrett, and appears to have affected even the most recent drainage patterns noted as palaeochannels on the DEM data (WA 2009b).

7.1.6. Units C, B and A are most likely to be adversely affected by the development. Their archaeological potential and recommendations for further work are discussed in more detail below.

7.1.7. Peats at similar levels (around the level of Ordnance Datum) to those recorded across the scheme area and allocated to Unit C have been recorded at Westward Ho!, north Devon (Scaife *et al*. 1987), the Glastonbury levels, Somerset (Coles and Coles 1986) and within the Wentlooge formation (Allen and Rae 1987) on the coast of Wales. The peats within Unit C are not as thick as those within the Glastonbury levels but are *Phragmites* peat, which are of similar composition the Neolithic peats containing the Neolithic wooden trackway known as the "Sweet track" (Coles and Coles 1986). It is noted that the Steart Peninsula would have been connected to the Somerset levels during the Neolithic period. The quality and quantity of Neolithic (and Bronze age) waterlogged archaeological remains within Somerset is noted to be very high despite only a small proportion of the Somerset wetlands having been archaeologically investigated (Brunning 2000).

7.1.8. The archaeological potential of Sub-Unit Bii is quite complex. It dates from the Neolithic to possibly the Anglo Saxon period (and possibly later in some areas) and may therefore contain material relating to maritime and coastal activities from these periods. It is equivalent to minerogenic sediments known as the Upper Wentlooge formation (Allen and Rae 1987). Some quite unusual archaeological material has been discovered from similar deposits along the coast of Wales particularly at Peterstone Wentlooge the type site of the so called Wentlooge formation with archaeological remains such as fishtraps and maritime wooden remains (see Bell 1997, Bell 2000 and Bell and Neuman 1997).

7.1.9. Sub-Unit Bi, a thick alluvial soil in boreholes, is likely to have formed during reclamation of the area, which from dating in the adjacent Bristol Port Habitat Creation Scheme area (Wessex Archaeology 2011d) is likely to have formed subsequent to the early Iron Age period. This Unit can be traced across the entire scheme area and has developed upon estuarine alluvium as a result of (natural and anthropogenic) land reclamation in the area. The Roman and Medieval archaeological remains currently being excavated would seem to support this theory. Whilst the Unit does not offer the greatest potential of the investigated sediments in terms of palaeoenvironmental remains, further work is recommended, particularly dating in order to understand the more recent land reclamation of the scheme area.

7.1.10. Two subunits of Unit A were recorded within the scheme area. The Made Ground (Unit Aiv) and Modern Gley soil (Unit Aii) are of little archaeological or palaeoenvironmental interest. It should be noted however that relatively recent marine and coastal sedimentation may have had a significant effect on the more recent formation of terrestrial environments across the site. Deposits of gravel and sand caused by longshore drift and wind blown dunes (allocated to subunits Ai and Aiii respectively on the adjacent Habitat Creation Scheme area WA 2011d) are extensive on the seaward side of the Steart Peninsula and will have had a considerable effect on the sedimentation within the scheme area. These deposits form a natural barrier along the west to east axis on the coastal, northern part of the Steart Peninsula and utilisation of this naturally formed barrier is likely to have influenced the pattern of land reclamation in the scheme area.

7.1.11. Whilst it is not within the remit of this report, it is noted that remains of maritime activities (wooden vessels) from the Mesolithic onwards may be preserved within the sediments on scheme area. A relatively recent (late 19th Century) shipwreck, the *Trio* is preserved within alluvial sediments on the foreshore of the river Parrett close to test pit **EA2009_TP15** (**Figure 1**) (Wessex Archaeology 2010).

7.1.12. Based on the geoarchaeological and palaeoenvironmental assessment the following recommendations are made:

- *Further geoarchaeological and palaeoenvironmental assessment should be undertaken of monoliths and bulk samples from excavation areas;*
- *The Rockworks deposit model should be updated with excavation data any further avalable geotechnical data and historic borehole (BGS) data;*
- *Integration of the deposit model should be made with data from surrounding areas;*
- *Further geoarchaeologically targetted boreholes should be acquired, guided by the deposit model;*
- *Geoarchaeological recording and analysis of core samples for pollen, foraminfera, diatoms, ostracods, molluscs and plant macrofossils and scientific dating (^{14}C and OSL) is recommended.*
- *Publication of analytical results should be undertaken in conjunction with the adjacent Bristol Port Habitat Creation Scheme results in a relevant peer reviewed journal (e.g. the annual report of the Severn Estuary Levels Research Committee).*

.

8. REFERENCES

Allen, J.R.L., 1987. Late Flandrian shoreline oscillation in the Severn Estuary: the Rumney formation and its type-site. Philosophical Transactions of Royal Society of London.

Allen J.R.L., 2000. Morphodynamics of Holocene Salt marshes: a review sketch from the Atlantic and Southern North Sea coasts of Europe. Quaternary Science Reviews 19: 1155-1231

Allen J.R.L., 2003. An eclectic morphostratigraphic model for the sedimentary response to Holocene sea-level rise in northwest Europe. Sedimentary Geology .161: 31 to 54

Allen and Rae 1987 Allen, JRL and Rae, JE. (1987) Late Flandrian shoreline oscillations in the Severn Estuary: a geomorphological and stratigraphical reconnaissance. Philosophical transactions of the Royal Society of London B 315: 185-230.

Bell, M., 1995, 'Field Survey and Excavation at Goldcliff, Gwent 1994, in Archaeology in the Severn Estuary 1994, Annual Report of the Severn Estuary Levels Research Committee: 69-103.

Bell, M., 2000, 'Environmental Archaeology in the Severn Estuary: Progress and Prospects', in (Rippon, S. ed.), Estuarine Archaeology: The Severn And Beyond, Archaeology in the Severn Estuary 11, The Severn Estuary Levels Research Committee.

Bell, M. and Neumann, H., 1997, 'Prehistoric Intertidal Archaeology and Environments in the Severn Estuary, Wales', World Archaeology 29(1): 95-113.

Beckett, S.C., Hibbert, F.A., 1979. Vegetational Change and the Influence of Prehistoric Man in the Somerset Levels. New Phytologist, 83, 577-600.

Bronk Ramsey, C., 2001, Development of the radiocarbon calibration program OxCal, Radiocarbon 43, 355-363

Bronk Ramsey, C. 2009 Bayesian analysis of radiocarbon dates, Radiocarbon, 51. 337-360

Brown, A., 2005. Wetlands and Drylands in Prehistory: Mesolithic to Bronze Age Human Activity and Impact in the Severn Estuary, Southwest Britain. Unpublished PhD Thesis, University of Reading

Brown, G. M., 1980, WESTON-super-MARE Sheet 279 & parts of 263 &295 1:50,000 Series. British , HMSO, London

Brunning, R., 2000, 'Neolithic and Bronze-Age Somerset: A wetland perspective' in: Webster, C.J. (ed.) Somerset Archaeology: Papers to mark 150 years of the Somerset Archaeological and Natural History Society, Somerset CountyCouncil: 67-72.

CJAssociates, 2011a. Proposed Ecological Habitat Creation Scheme. Borehole logs. BH109 to BH112

CJAssociates, 2011b. Proposed Ecological Habitat Creation Scheme, Borehole logs BH101 to BH108

CJAssociates, 2011c. Proposed Ecological Habitat Creation Scheme, Test Pit logs. TP101 to TP115

Clark, G. 1933. Mesolithic sites on the Burtle Beds, Near Bridgewater, Somerset. Man. Vol. 33. Pp.63-65

Fugro, 2007. North Clyce Outfall Project. Borehole and Test Pit Logs

Fugro, 2009. Steart Coastal Management Project. Borehole and Test Pit Logs

Hodgson, J.M., 1976, Soil Survey Field Handbook, Harpenden, Soil Survey Technical Monograph No. 5

Lankelma, 2011. Proposed Ecological Habitat Creation Scheme CPT Logs. CPT101 to CPT126

McDonnell, R., 1996, 'Island Evolution in Bridgwater Bay and the Parrett Estuary: An Historical Geography' in Archaeology in the Severn Estuary 1995 (volume 6), Annual Report of the Severn Estuary Levels Research Committee: 71-83.

Miall, A.D., 1999. Principles of Sedimentary Basin Analysis. 3rd Edition: New York, N.Y.: Springer-Verlag Inc., 616p

Reimer, P. J., Baillie, M. G. L., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Buck, C. E., Burr, G. S., Edwards, R. L., Friedrich, M., Grootes, P. M., Guilderson, T. P., Hajdas, I., Heaton, T. J., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., McCormac, F. G., Manning, S. W., Reimer, R. W., Richards, D. A., Southon, J. R., Talamo, S., Turney, C. S. M., van der Plicht, J., & Weyhenmeyer, C. E. (2009). IntCal09 and Marine09 radiocarbon age calibration curves, 0-50,000 years cal BP. Radiocarbon, 51(4), 1111-1150.

Scaife, R.G., 1987. Pollen analysis. In Balaam, N.D., Levitan, B., Straker, V. (Eds.) Studies in the palaoeconomy and environment in South West England. British Archaeological Reports, British Series 181, 223–32.

Shennan I., Richard Peltier, W., Drummond, R., and Horton, B., 2002, Global to local scale parameters determining relative sea-level changes and the post-glacial isostatic adjustment of Great Britain. Quaternary Science Reviews. 21. 397-408

Soil Survey of England and Wales 1983. Soils of Southwest England: Sheet 5. 1:250,000

Walker, M.J.C., Bell, M., Casledine, A.E., Cameron, N.G., Hunter, K.L., James, J.H., Johnson, S. and Smith, D.N. 1998. Palaeoecological investigations of middle and late Flandrian buried peats on the Caldicot Levels, Severn Estuary, Wales. Proc Geol. Soc.109, 51-78

Webster, C.J. (ed.) 2007. The Archaeology of Southwest England. South West Archaeological Research Framework. Research Assessment and Research Agenda. Somerset County Council

Wessex Archaeology, 2009a. Steart Peninsula, Somerset, Proposed Ecological Habitation Creation, Heritage Assessment, Unpublished client report ref 69320.02

Wessex Archaeology, 2009b. Steart Peninsula, Extended Heritage Assessment. Unpublished client report ref 72950.01

Wessex Archaeology, 2009c. Steart Peninsula Somerset – Archaeological Watching Brief on Geotechnical Works. Unpublished client report ref 72600.01

Wessex Archaeology, 2010. The Wreck of the Trio. Initial Assessment of Archaeological Importance. Technical report. ref.:75540.01

Wessex Archaeology, 2011a. Land at Steart Peninsula Somerset – Pilot Geophysical Survey. Unpublished client report. ref: 70942.01

Wessex Archaeology, 2011b. Steart Peninsula Somerset Archaeological Watching on Geotechnical works. Unpublished client report

Wessex Archaeology, 2011c. Land adjacent to Steart Village, Steart Point, Somerset. Fieldwalking Survey and Evaluation Report. Unpublished client report. ref: 77221.03.

Wessex Archaeology, 2011d. The Bristol Port Company Habitat Creation Scheme. Steart Peninsula, Somerset. Preliminary Geoarchaeological Assessment. Unpublished client report. ref: 70944.01

Wilkinson K., and Straker, V., 2007. 'Neolithic and Early Bronze Age Environmental Background' in Webster, C.J. (ed.) The Archaeology of Southwest England. South West Archaeological Research Framework. Research Assessment and Research Agenda.Somerset County Council.: 63-74.

9. APPENDIX 1: BOREHOLE AND TEST PIT LOCATIONS

Borehole Identification code	Easting	Northing	Level (m aOD)	Reference
EA2007_BH1	326616	144032	6.05	Fugro (2007)
EA2007_BH2	326596	144016	6.4	Fugro (2007)
EA2007_BH3	326595	144016	6.35	Fugro (2007)
EA2007_TP1	326612	144023	6.1	Fugro (2007)
EA2007_TP2	326602	144016	6.15	Fugro (2007)
EA2009_BH2	325900	143914	5.65	Fugro (2009)
EA2009_BH3	326354	144501	5.7	Fugro (2009)
EA2009_BH4	327081	145133	5.65	Fugro (2009)
EA2009_TP4	324287	143979	5.45	Fugro (2009)
EA2009_TP6	325113	144216	5.55	Fugro (2009)
EA2009_TP7	325064	143454	5.95	Fugro (2009)
EA2009_TP9	325573	144384	5.55	Fugro (2009)
EA2009_TP10	325711	143221	5.85	Fugro (2009)
EA2009_TP11	326048	144907	5.65	Fugro (2009)
EA2009_TP12	326130	144151	5.75	Fugro (2009)
EA2009_TP13	326158	143483	5.9	Fugro (2009)
EA2009_TP14	326238	145135	5.7	Fugro (2009)
EA2009_TP15	326315	143852	5.65	Fugro (2009)
EA2009_TP17	326680	145487	6.55	Fugro (2009)
EA2009_TP18	326678	144847	5.65	Fugro (2009)
EA2009_TP19	327111	144580	6	Fugro (2009)
EA2009_TP20	327433	145754	5.8	Fugro (2009)
EA2009_TP21	327734	145215	5.8	Fugro (2009)
EA2009_TP22	327705	144528	6	Fugro (2009)
WA2011_BH2	325541	144299	5.44	Fugro (2011)
WA2011_BH5	327785	145614	5.73	Fugro (2011)

10. APPENDIX 2: GEOARCHAEOLOGICAL DESCRIPTIONS

10.1. Borehole WA2011_BH02

Depth top (mbGL)	Depth bottom (mbGL)	Depth top (mOD)	Depth bottom (mOD)	Sediment description (sample type: core (c), bag (b) and pot (p))	Unit
0.3	1.5	5.14	3.94	(b) 10YR 4/2 Dark greyish brown silty CLAY. Disturbed. **Alluvial gley soil**	Bi
1.5	1.74	3.94	3.7	(c) 10YR 4/2 Dark greyish brown silty CLAY. Stiff, Mottled 50% grey,blue/brown. Feint microlaminar horizontally bedded structure. Orange FeO and black manganese flecks. Microporous and blocky structure. **Pelo alluvial gley soil**	Bi
1.74	1.95	3.7	3.49	GAP	
1.95	2.1	3.49	3.34	(p) 10YR 4/2 Dark greyish brown silty CLAY. Disturbed. **Pelo alluvial gley soil**	Bi
2.1	2.38	3.34	3.06	(c) 10YR 4/2 Dark greyish brown silty CLAY. Stiff. Mottled 50% grey,blue/brown. Black plant remains including a root from 2.25 to 2.3m. 30mm boundary. **Pelo alluvial gley soil.**	Bi
2.38	2.55	3.06	2.89	(c) 2.5Y 4/5 GY Dark greenish grey silty CLAY. Occasional black and brown recognisable plant remains (RPRs) including brown vertical root at 2.42 to 2.46m. Black roots from 2.45 to 2.48m. Feint horizontal microlaminar bedding. Frequent micropores. **Estuarine alluvium**	Bii
2.55	2.7	2.89	2.74	(p) 2.5Y 4/5 GY Dark greenish grey silty CLAY. Occasional roots. **Estuarine alluvium**	Bii
2.7	3.13	2.74	2.31	(c) 10YR 4/2 Dark greyish brown/2.5Y 4/5 GY Dark greenish grey silty CLAY. Frequent roots. Feint horizontal microlaminar bedding. **Estuarine alluvium**	Bii
3.13	3.15	2.31	2.29	GAP	
3.15	3.3	2.29	2.14	(p) 10YR 4/2 Dark greyish brown/2.5Y 4/5 GY Dark greenish grey silty CLAY. Frequent roots. **Estuarine alluvium**	Bii
3.3	3.48	2.14	-2.62	(c) 10YR 4/2 Dark greyish brown / 2.5Y 4/5 GY Dark greenish grey silty CLAY. Frequent roots. Feint horizontal microlaminar bedding. 60mm boundary. **Estuarine alluvium**	Bii
3.48	3.74	1.96	1.7	(c)2.5Y 4/5 GY Dark greenish grey silty CLAY. Soft to firm. 5% brown mottling. Gastropod at 3.58m. Occasional RPRs and roots. **Estuarine alluvium**	Bii
3.74	3.75	1.7	1.69	GAP	
3.75	3.9	1.69	1.54	(p) 2.5Y 4/5 GY Dark greenish grey silty CLAY. Soft to firm. Occasional RPRs and roots. **Estuarine alluvium**	Bii
3.9	4.35	1.54	1.09	(c) 2.5Y 4/5 GY Dark greenish grey silty CLAY. Soft to firm. Disturbed from 3.9 to 4.16m. Frequent RPRs especially from 4 to 4.15m including roots and horizontally bedded stems and leaves of Phragmites sp. Slightly blocky and porous structure. **Estuarine alluvium**	Bii
4.35	4.5	1.09	0.94	(p) 2.5Y 4/5 GY Dark greenish grey SILT/CLAY. Moderate RPRs. **Estuarine alluvium**	Bii
4.5	4.58	0.94	0.86	(c) 2.5Y 5/5GY Greenish grey clayey SILT. Soft. Wet. RPRs moderate. No structure. 20mm boundary. **Estuarine alluvium**	Bii
4.58	4.68	0.86	0.76	(c) 2.5Y 5/5GY Greenish grey clay SILT/10YR 3/2 very dark greyish brown SILT/PEAT (?mixed/reworked/disturbed during drilling??). Brown/Black RPRs and roots frequent. 5mm angled/disturbed and ?burrowed boundary. **Intercalated peat and alluvium**	C
4.68	4.75	0.76	0.69	(c) 10YR 3/2 very dark greyish brown silty PEAT. Very frequent black and brown RPRs including horizontally bedded *Phragmites* remains at 4.78m. Gradual boundary. **Peat**	C
4.75	4.85	0.69	0.59	(c) 10YR 3/2 very dark greyish brown peaty SILT. Frequent black/brown RPRs, slightly darker than overlying sediment. 0mm boundary. **Intercalated peat/silt**	C
4.85	4.86	0.59	0.58	(c) 10YR 4/1 dark grey SILT. Frequent gastropods and ostracods. 0cm boundary. **Estuarine alluvium**	D
4.86	4.94	0.58	0.5	(c) Gley1 4/1 Dark grey slightly clayey SILT. Frequent dark brown RPRs. Soft. Feint horizontal bedding including ?*Phragmites* sp. **Estuarine alluvium**	D

Depth top (mbGL)	Depth bottom (mbGL)	Depth top (mOD)	Depth bottom (mOD)	Sediment description (sample type: core (c), bag (b) and pot (p))	Unit
4.94	4.95	0.5	0.49	GAP	
4.95	5.1	0.49	0.34	(p) 2.5Y 5GY Dark greenish grey silty CLAY. Disturbed. **Estuarine alluvium**	D
5.1	5.55	0.34	-0.11	(c) 2.5Y 4/5GY Dark greenish grey silty CLAY. Feint horizontally bedded structure. Frequent (especially from 5.1 to 5.3) vertical roots. Gastropod at 5.49m. Slightly blocky/microporous structure. **Estuarine alluvium**	D
5.5	5.7	-0.06	-0.26	(p) 2.5Y 4/5GY Dark greenish grey silty CLAY/clayey SILT. Disturbed. **Estuarine alluvium**	D
5.7	6.12	-0.26	-0.68	Gley 14/10Y Dark greenish grey clayey SILT. Soft. Wet. Frequent black RPRs and balls of peat up to 10mm diameter especially from 5.83 to 5.90m. Some orange FeO mottling from 5.90 to 6.12. Plant remains become less frequent with some feint horizontally bedded structure present. **Estuarine alluvium**	D
6.12	6.15	-0.68	-0.71	GAP	
6.15	6.3	-0.71	-0.86	(p) Gley 14/10Y Dark greenish grey clayey SILT. Frequent RPRs. Disturbed. **Estuarine alluvium**	D
6.3	6.74	-0.86	-1.3	(c) Gley 14/10Y Dark greenish grey clayey SILT. Soft/Wet. Frequent black RPRs, roots and associated (around root holes) orange FeO mottling. Feint horizontally bedded plant remains. **Estuarine alluvium**	D
6.74	6.75	-1.3	-1.31	GAP	
6.75	6.9	-1.31	-1.46	(c) Gley 14/10Y Dark greenish grey clayey SILT. Soft/Wet. Frequent black RPRs, roots and associated (around root holes) orange FeO mottling. Feint horizontally bedded plant remains. **Estuarine alluvium**	D
6.9	7.3	-1.46	-1.86	(p) Gley 14/10Y Dark greenish grey clayey SILT. Disturbed.Frequent RPRs. **Estuarine alluvium**	
7.3	8.3	-1.86	-2.86	(c) Gley 14/10Y Dark greenish grey clayey SILT. Soft/Wet. Frequent black RPRs, roots and associated (around root holes) orange FeO mottling. Feint horizontally bedded plant remains. **Estuarine alluvium**	D
8.3	9.3	-2.86	-3.86	(c) Gley 14/10Y Dark greenish grey clayey SILT. Soft/Wet. Frequent black RPRs, roots and associated (around root holes) orange FeO mottling. Feint horizontally bedded plant remains. **Estuarine alluvium**	D
9.3	9.4	-3.86	-3.96	(p) Gley 14/10Y Dark greenish grey clayey SILT. Disturbed. Frequent RPRs. **Estuarine alluvium**	D
9.4	9.63	-3.96	-4.19	(c) 10YR 4/1 Dark grey slightly sandy silty CLAY. Stiff. Moderate RPRs and roots. Frequent 40% FeO mottling especially from 9.47 to 9.53. 50mm convoluted boundary. **Pleistocene/drift**	H
9.63	9.84	-4.19	-4.4	(c) 10YR 4/1 Dark grey / 10YR 5/1 Dark grey CLAY with orange mottling and layers at 9.74 to 9.81m. Mixed "cloudy" structure from 9.63 to 9.74m with an angled bedded structure from 9.74 to 9.84m. **Pleistocene/drift**	H
9.84	9.85	-4.4	-4.41	GAP	
9.85	10	-4.41	-4.56	(p)(c) 10YR 4/1 Dark grey / 10YR 5/1 Dark grey CLAY with orange mottling. Disturbed sample. **Pleistocene/drift**	H
10	10.45	-4.56	-5.01	(c) 10YR 4/1 Dark grey / 10YR 5/1 Dark grey CLAY with orange mottling. Mixed "cloudy" structure . One root passes through whole sample. **Pleistocene/drift**	H
10.45	10.6	-5.01	-5.16	(p) Dark grey/brown silty CLAY. Some layering with organic peaty bands. Disturbed ?contaminated sample?. **Pleistocene/drift**	H

10.2. Borehole WA2011_BH05

Depth top (mbGL)	Depth bottom (mbGL)	Depth top (mOD)	Depth bottom (mOD)	Sediment description (sample type: core (c), bag (b) and pot (p))	Unit
0	0.3	5.73	5.43	(b) 10YR 4/2 Dark greyish brown silty CLAY. Disturbed sample. **Modern soil**	Aii
0.3	1.5	5.43	4.23	(b) 10YR 4/2 Dark greyish brown silty CLAY. Disturbed sample. **Pelo alluvial gley soil**	Bi
1.5	1.92	4.23	3.81	(c) 10YR 4/2 Dark greyish brown silty CLAY. Stiff, occasional black manganese flecks especially from 1.5 to 1.55m and FeO mottling. Frequent micropores. Massive. **Pelo alluvial gley soil**	Bi
1.92	1.95	3.81	3.78	GAP	
1.95	2.1	3.78	3.63	(b) 10YR 4/2 Dark greyish brown silty CLAY. Disturbed sample. **Pelo alluvial gley soil**	Bi
2.1	2.3	3.63	3.43	(c) 10YR 4/2 Dark greyish brown silty CLAY. Stiff, occasional black manganese flecks and FeO mottling. Frequent micropores. Feint horizontal bedding from 2.25 to 2.3. 40mm boundary. **Pelo alluvial gley soil**	Bi
2.3	2.5	3.43	3.23	(c) Gley1 3/10Y Very dark greenish grey very silty CLAY. Soft. Feint horizontally bedded microlaminar structure. Occasional Mng flecks in layers especially from 2.38 to2.40m. **Estuarine alluvium**	Bii
2.5	2.55	3.23	3.18	GAP	
2.55	2.7	3.18	3.03	(p) Gley 13/10Y Very dark greenish grey very silty CLAY. Disturbed sample. **Estuarine alluvium**	Bii
2.7	3.13	3.03	2.6	(c) Gley 13/10Y Very dark greenish grey very silty CLAY. Soft. Feint horizontally bedded microlaminar structure. Some fine black ?organic bands *c.* 1mm in thickness. **Estuarine alluvium**	Bii
3.13	3.15	2.6	2.58	GAP	
3.15	3.3	2.58	2.43	(p) Gley1 3/10Y Very dark greenish grey very silty CLAY. Disturbed sample. **Estuarine alluvium**	Bii
3.3	3.74	2.43	1.99	(c) Gley 13/10Y Very dark greenish grey very silty CLAY. Soft. Feint horizontally bedded microlaminar structure. Some fine black ?organic bands *c.* 1mm in thickness. Oxidised post deposition. **Estuarine alluvium**	Bii
3.74	3.9	1.99	1.83	GAP	
3.9	4.35	1.83	1.38	(c) Gley1 3/10Y Very dark greenish grey very silty CLAY. Soft. Feint horizontally bedded microlaminar structure. Some fine black ?organic bands c. 1mm in thickness. Oxidised post deposition **Estuarine alluvium**	Bii
4.5	4.9	1.23	0.83	(c) Gley 1 3/10Y Very dark greenish grey sandy clayey SILT. Soft. Wet. Black horizontally bedded organic bands (dragged at core edges). From 4.78 to 4.90m flood couplets of alternating bands of sand (up to 2mm in thickness) and silt (up to 3mm in thickness). **Estuarine alluvium**	Bii
4.9	5.1	0.83	0.63	GAP	
5.1	5.52	0.63	0.21	(c) Gley 1 3/10Y Very dark greenish grey clayey SILT. Soft. Wet. Black horizontally bedded organic bands .Flood couplets of alternating bands of sand (up to 2mm in thickness) and silt (up to 3mm in thickness). **Estuarine alluvium**	Bii
5.52	6	0.21	-0.27	GAP	Bii
6	6.29	-0.27	-0.56	(c) Gley 1 3/10Y Very dark greenish grey sandy clayey SILT. Soft. Wet. Black horizontally bedded organic bands and patches. Flood couplets of alternating bands of sand (up to 2mm in thickness) and silt (up to 3mm in thickness). Several molluscan burrows infilled with fine sand from 6.08 to 6.12m. **Estuarine alluvium**	Bii
6.29	6.6	-0.56	-0.87	GAP	

Depth top (mbGL)	Depth bottom (mbGL)	Depth top (mOD)	Depth bottom (mOD)	Sediment description (sample type: core (c), bag (b) and pot (p))	Unit
6.6	6.88	-0.87	-1.15	(c) Gley 1 3/10Y Very dark greenish grey sandy clayey SILT. Stiff. Wet. Black horizontally bedded organic bands and patches. Flood couplets of alternating bands of sand (up to 2mm in thickness) and silt (up to 3mm in thickness). Several molluscan burrows infilled with fine sand. Very sandy from 6.75 to 6.88m. **Estuarine alluvium**	Bii
6.88	7.2	-1.15	-1.47	GAP	
7.2	7.64	-1.47	-1.91	(c) Gley 1 3/10Y Very dark greenish grey sandy clayey SILT. Soft. Wet. Black horizontally bedded organic bands and patches. Flood couplets throughout.Occasional molluscan burrows infilled with fine sand. **Estuarine alluvium**	Bii
7.64	7.8	-1.91	-2.07	GAP	
7.8	8.25	-2.07	-2.52	(c) Gley 1 3/10Y Very dark greenish grey sandy clayey SILT. Soft. Wet. Black horizontally bedded organic bands and patches. Flood couplets throughout.Occasional molluscan burrows infilled with fine sand. **Estuarine alluvium**	Bii
8.25	8.4	-2.52	-2.67	GAP	
8.4	9	-2.67	-3.27	(b) Gley 1 3/10Y Very dark greenish grey sandy clayey SILT. Disturbed sample. **Estuarine alluvium**	Bii
9	9.6	-3.27	-3.87	(b) Gley 1 3/10Y Very dark greenish grey silty SAND. Sand is fine grained. Disturbed sample. **Estuarine alluvium**	Bii
9.6	10.2	-3.87	-4.47	(b) Gley 1 3/10Y Very dark greenish grey silty SAND. Sand is fine grained. Disturbed sample. **Estuarine alluvium**	Bii
10.2	12	-4.47	-6.27	(b) Gley 1 3/10Y Very dark greenish grey silty SAND. Sand is fine grained. Disturbed sample. **Estuarine alluvium**	Bii
12	14	-6.27	-8.27	(b) Gley 1 3/10Y Very dark greenish grey/olive brown SAND. Sand is fine to medium grained. Occasional broken? marine molluscs up to 4mm diameter. Occasional blobs of grey clay/silt Disturbed sample. **Estuarine alluvium**	Bii

11. APPENDIX 3: RADIOCARBON DATING

11.1. Introduction

Three samples of suitable material including waterlogged plant remains and sediment from boreholes **WA2011_BH02** and **WA2011_BH05** were extracted for radiocarbon dating.

The samples were submitted to the Scottish Universities Environmental Research Centre, East Kilbride (SUERC) for radiocarbon dating.

11.2. Results

The three samples of radiocarbon dates taken have been have been calibrated against the IntCal09 Northern Hemisphere radiocarbon curve (Reimer *et al.* 2009) using the program OxCal 4.1 (Bronk Ramsey 1995; 2001). All calibrated dates shown in the table below are quoted as calibrated years AD/ BC. Date ranges are quoted using the 2σ calibrated range (95.4%) with the end point rounded outwards to 10 years, though calibrated dates older than 15000 BP are rounded to the nearest 50 years following the data spacing of the IntCal09 dataset (Reimer *et al*. 2009).

Borehole	Depth (mnGL)	Sample Material	Lab Code	Radiocarbon Date (BP)	δ13C (‰)	Calibrated date (95.4%, 2σ range)
WA2011_BH02	4.70	*Phragmites* stem.	SUERC-38608	4020±35	-27.0	3100-2910 cal BC [5050-4860 cal BP)
WA2011_BH02	9.59	Sediment	SUERC-38609	15825±40	-29.3	17400-16800 cal BC (19350-18750 cal BP)
WA2011_BH05	4.20	Sediment	SUERC-38610	4390±30	-24.5	2630-2460 cal BC (4580-4410 cal BP)

11.3. References

Bronk Ramsey, C. 1995: Radiocarbon Calibration and Analysis of Stratigraphy: The OxCal Program. *Radiocarbon* 37, 425-430.

Bronk Ramsey, C. 2001: Development of the radiocarbon calibration program OxCal, *Radiocarbon* 43, 355-363.

Reimer, P. J., Baillie, M. G. L., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Buck, C. E., Burr, G. S., Edwards, R. L., Friedrich, M., Grootes, P. M., Guilderson, T. P., Hajdas, I., Heaton, T. J., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., McCormac, F. G., Manning, S. W., Reimer, R. W., Richards, D. A., Southon, J. R., Talamo, S., Turney, C. S. M., van der Plicht, J. and Weyhenmeyer, C. E., 2009: IntCal09 and Marine09 radiocarbon age calibration curves, 0-50,000 years cal BP. *Radiocarbon* 51, 1111-1150.

12. APPENDIX 4: OPTICALLY STIMULATED LUMINESCENCE (OSL) DATING

12.1. Introduction

This is a standard report of the Geochronology Laboratories, University of Gloucestershire. In large part, the document summarises the processes, diagnostics and data drawn upon to deliver Table 1. A conclusion on the analytical validity of each sample's optical age estimate is expressed in Table 2; where there are caveats, the reader is directed to the relevant section of the report that explains the issue further in general terms.

		BH105	BH102
Field Code		**BH105**	**BH102**
Depth (m BGS)		7.80-8.25	10.00-10.45
Lab Code		GL11022	GL11023
Overburden (m)		7.98	10.20
Grain size (μm)		125-180	5-15
Moisture content (%)		30 ± 7	23 ± 6
NaI γ-spectrometry (in situ)	K (%)	-	-
	Th (ppm)	-	-
	U (ppm)	-	-
γ D_r (Gy.ka^{-1})		0.60 ± 0.09	1.16 ± 0.11
Ge γ-spectrometry (lab based)	K (%)	1.38 ± 0.06	2.12 ± 0.09
	Th (ppm)	7.79 ± 0.50	8.73 ± 0.54
	U (ppm)	1.57 ± 0.09	5.46 ± 0.23
α D_r (Gy.ka^{-1})		-	0.60 ± 0.07
β D_r (Gy.ka^{-1})		0.91 ± 0.13	1.97 ± 0.21
Cosmic D_r (Gy.ka^{-1})		0.06 ± 0.01	0.05 ± 0.01
Total D_r (Gy.ka^{-1})		1.57 ± 0.19	3.78 ± 0.25
Preheat (°C for 10s)		250	260
Low Dose Repeat Ratio		0.99 ± 0.03	0.98 ± 0.16
High Dose Repeat Ration		0.99 ± 0.01	0.90 ± 0.12
Post-IR OSL Ratio		0.99 ± 0.02	0.90 ± 0.21
D_e (Gy)		1.9 ± 0.1	687.3 ± 110.9
Age (ka)		**1.2 ± 0.2 (0.2)**	**169 ± 31 (31)**

Table 1 D_r, D_e and Age data of submitted samples located at c. 51°N, 3°W, 7 m. Ages expressed relative to year of sampling. Uncertainties in age are quoted at 1σ confidence, are based on analytical errors and reflect combined systematic and experimental variability and (in parenthesis) experimental variability alone (see 6.0). Blue indicates samples with accepted age estimates, red, age estimates with caveats (see Table 2).

Generic considerations	Field Code	Lab Code	Sample specific considerations
Absence of *in situ* γ spectrometry data (see 4.0)	BH105 7.80-8.25m	GL11022	None
	BH102 10.00-10.45m	GL11023	D_e exceeds functional range (see 3.1.3, Table 1) Natural signal in 43% of aliquots equivalent to saturation Accept tentatively as minimum age

Table 2 Analytical validity of sample suite age estimates and caveats for consideration

12.2. Mechanisms and principles

Upon exposure to ionising radiation, electrons within the crystal lattice of insulating minerals are displaced from their atomic orbits. Whilst this dislocation is momentary for most electrons, a portion of charge is redistributed to meta-stable sites (traps) within the crystal lattice. In the absence of significant optical and thermal stimuli, this charge can be stored for extensive periods. The quantity of charge relocation and storage relates to the magnitude and period of irradiation. When the lattice is optically or thermally stimulated, charge is evicted from traps and may return to a vacant orbit position (hole). Upon recombination with a hole, an electron's energy can be dissipated in the form of light generating crystal luminescence providing a measure of dose absorption.

Herein, quartz is segregated for dating. The utility of this minerogenic dosimeter lies in the stability of its datable signal over the mid to late Quaternary period, predicted through isothermal decay studies (e.g. Smith *et al*., 1990; retention lifetime 630 Ma at 20°C) and evidenced by optical age estimates concordant with independent chronological controls (e.g. Murray and Olley, 2002). This stability is in contrast to the anomalous fading of comparable signals commonly observed for other ubiquitous sedimentary minerals such as feldspar and zircon (Wintle, 1973; Templer, 1985; Spooner, 1993)

Optical age estimates of sedimentation (Huntley *et al*., 1985) are premised upon reduction of the minerogenic time dependent signal (Optically Stimulated Luminescence, OSL) to zero through exposure to sunlight and, once buried, signal reformulation by absorption of litho- and cosmogenic radiation. The signal accumulated post burial acts as a dosimeter recording total dose absorption, converting to a chronometer by estimating the rate of dose absorption quantified through the assay of radioactivity in the surrounding lithology and streaming from the cosmos.

$$\text{Age} = \frac{\text{Mean Equivalent Dose } (D_e, \text{ Gy})}{\text{Mean Dose Rate } (D_r, \text{ Gy.ka}^{-1})}$$

Aitken (1998) and Bøtter-Jensen et al. (2003) offer a detailed review of optical dating.

12.3. Sample Preparation

A total of four sediment samples were submitted from two vibrocores for Optical dating (Table 1). The cores were bisected in daylight to identify the apposite sampling position in consultation with J. Russell, Wessex Archaeology. To preclude optical erosion of the datable signal prior to measurement both lengths of each core were moved into and prepared under controlled laboratory illumination, provided by Encapsulite RB-10 (red) filters. Sediment exposed to daylight during bisection was removed from each sample position to a depth of 10 mm from each bisected face. The remaining sediment was then sectioned into a 50-100 mm length (depending on unit thickness), 40 mm wide sample using aluminium separators to preclude incorporation of material transferred down the core walls during retrieval. Sub-samples of c. 50 g were taken from within each position to establish D_r values.

Each dating sample was then weighed, dried, reweighed and sieved. For sample GL11022 quartz within the fine sand (125-180 μm) fraction was segregated, whilst for sample GL11023 fine silt (5-15 μm) was pursued (Table 1). Samples were then subjected to acid and alkaline digestion (10% HCl, 15% H_2O_2) to attain removal of carbonate and organic components respectively.

For GL11022, a further acid digestion in HF (40%, 60) was used to etch the outer 10-15 μm layer affected by α radiation and degrade each samples' feldspar content. During HF treatment, continuous magnetic stirring was used to effect isotropic etching of grains. 10% HCl was then added to remove acid soluble fluorides. The sample was dried, resieved and quartz isolated from the remaining heavy mineral fraction using a sodium polytungstate density separation at 2.68g.cm^{-3}. 12 multi-grain aliquots (*c*. 3-6 mg) of quartz from the sample were then mounted on aluminium discs for determination of D_e values.

For GL11023 fine silt sized quartz, along with other mineral grains of varying density and size, was extracted by sedimentation in acetone (<15 μm in 2 min 20 s, >5 μm in 21 mins at 20ºC). Feldspars and amorphous silica were then removed from this fraction through acid digestion (35% H_2SiF_6 for 2 weeks, Jackson *et al*., 1976; Berger *et al*., 1980). Following addition of 10% HCl to remove acid soluble fluorides, grains degraded to <5 μm as a result of acid treatment were removed by acetone sedimentation. 7 aliquots (ca. 1.5 mg) were then mounted on aluminium discs for D_e evaluation.

All drying was conducted at 40°C to prevent thermal erosion of the signal. All acids and alkalis were Analar grade. All dilutions (removing toxic-corrosive and non-minerogenic luminescence-bearing substances) were conducted with distilled water to prevent signal contamination by extraneous particles.

12.4. Acquisition and accuracy of D_e value

All minerals naturally exhibit marked inter-sample variability in luminescence per unit dose (sensitivity). Therefore, the estimation of D_e acquired since burial requires calibration of the natural signal using known amounts of laboratory dose. D_e values were quantified using a single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle 2000; 2003) facilitated by a Risø TL-DA-15 irradiation-stimulation-detection system (Markey *et al*., 1997; Bøtter-Jensen *et al*., 1999). Within this apparatus, optical signal stimulation is provided by a 150 W tungsten halogen lamp, filtered to a broad blue-green light, 420-560 nm (2.21-2.95 eV) conveying 16 mWcm^{-2}, using three 2 mm Schott GG420 and a broadband interference filter. Infrared (IR) stimulation, provided by 6 IR diodes (Telefunken TSHA 6203) stimulating at 875$\pm$80nm delivering ~5 mW.cm^{-2}, was used to indicate the presence of contaminant feldspars (Hütt *et al*., 1988). Stimulated photon emissions from quartz aliquots are in the ultraviolet (UV) range and were filtered from stimulating photons by 7.5 mm HOYA U-340 glass and detected by an EMI 9235QA photomultiplier fitted with a blue-green sensitive bialkali photocathode. Aliquot irradiation was conducted using a 1.48 GBq $^{90}Sr/^{90}Y$ β source calibrated for multi-grain aliquots of each isolated quartz fraction against the 'Hotspot 800' ^{60}Co γ source located at the National Physical Laboratory (NPL), UK.

SAR by definition evaluates D_e through measuring the natural signal (Fig. 1) of a single aliquot and then regenerating that aliquot's signal by using known laboratory doses to enable calibration. For each aliquot, 5 different regenerative-doses were administered so as to image dose response. D_e values for each aliquot were then interpolated, and associated counting and fitting errors calculated, by way of exponential plus linear regression (Fig. 1). Weighted (geometric) mean D_e values were calculated using the central age model outlined by Galbraith *et al*. (1999) and are quoted at 1σ confidence. The accuracy with which D_e equates to total absorbed dose and that dose absorbed since burial was assessed. The former can be considered a function of laboratory factors, the latter, one of environmental issues. Diagnostics were deployed to estimate the influence of these factors and criteria instituted to optimise the accuracy of D_e values.

12.5. Laboratory Factors

Feldspar contamination

The propensity of feldspar signals to fade and underestimate age, coupled with their higher sensitivity relative to quartz makes it imperative to quantify feldspar contamination. At room temperature, feldspars generate a signal (IRSL) upon exposure to IR whereas quartz does not. The signal from feldspars contributing to OSL can be depleted by prior exposure to IR. For all aliquots the contribution of any remaining feldspars was estimated from the OSL IR depletion ratio (Duller, 2003). If the addition to OSL by feldspars is insignificant, then the repeat dose ratio of OSL to post-IR OSL should be statistically consistent with unity (Figs 1 and Fig. 5; Table 1). If any aliquots do not fulfil this criterion, then the sample age estimate should be accepted tentatively. The source of feldspar contamination is rarely rooted in sample preparation; it predominantly results from the occurrence of feldspars as inclusions within quartz.

Preheating

Preheating aliquots between irradiation and optical stimulation is necessary to ensure comparability between natural and laboratory-induced signals. However, the multiple irradiation and preheating steps that are required to define single-aliquot regenerative-dose response leads to signal sensitisation, rendering calibration of the natural signal inaccurate. The SAR protocol (Murray and Wintle, 2000; 2003) enables this sensitisation to be monitored and corrected using a test dose to track signal sensitivity between irradiation-preheat steps. The test dose for GL11022 was set at 5 Gy, preheated to 220°C for 10s. Owing to insensitivity of OSL within sample GL11023, the test dose was set at 20 Gy.

The accuracy of sensitisation correction for both natural and laboratory signals can be preheat dependent. The Dose Recovery test was used to assess the optimal preheat temperature for accurate correction and calibration of the time dependent signal. Dose Recovery (Fig. 2) attempts to quantify the combined effects of thermal transfer and sensitisation on the natural signal, using a precise lab dose to simulate natural dose. The ratio between the applied dose and recovered D_e value should be statistically concordant with unity. For this diagnostic, 6 aliquots were each assigned a 10 s preheat between 180°C and 280°C.

That preheat treatment fulfilling the criterion of accuracy within the Dose Recovery test was selected to generate the final D_e value. Further thermal treatments, prescribed by Murray and Wintle (2000; 2003), were applied to optimise accuracy and precision. Optical stimulation occurred at 125ºC in order to minimise effects associated with photo-transferred thermoluminescence and maximise signal to noise ratios. Inter-cycle optical stimulation was conducted at 280ºC to minimise recuperation.

Irradiation

For all samples having D_e values in excess of 100 Gy, matters of signal saturation and laboratory irradiation effects are of concern. With regards the former, the rate of signal accumulation generally adheres to a saturating exponential form and it is this that limits the precision and accuracy of D_e values for samples having absorbed large doses. For such samples, the functional range of D_e

interpolation by SAR has been verified up to 600 Gy by Pawley *et al*. (2010). Age estimates based on D_e values exceeding this value should be accepted tentatively.

Internal consistency

Quasi-radial plots (*cf* Galbraith, 1990) are used to illustrate inter-aliquot D_e variability for natural, repeat regenerative-dose and OSL to post-IR OSL signals (Figs 3 to 5, respectively; Table 1). D_e values are standardised relative to the central D_e value for natural signals and applied dose for regenerated signals. D_e values are described as overdispersed when >5% lie beyond $\pm$ 2σ of the standardising value; resulting from a heterogeneous absorption of burial dose and/or response to the SAR protocol. For multi-grain aliquots, overdispersion of natural signals does not necessarily imply inaccuracy. However where overdispersion is observed for regenerated signals, the efficacy of sensitivity correction may be problematic. This measure of SAR protocol success at Gloucestershire differs and is more stringent than that prescribed by Murray and Wintle (2000; 2003). They suggest repeat dose ratios (Table 1) should be concordant with the range 0.9-1.1; this filter of analytical validity has been applied in this study (Table 2).

12.6. Environmental factors

Incomplete zeroing

Post-burial OSL signals residual of pre-burial dose absorption can result where pre-burial sunlight exposure is limited in spectrum, intensity and/or period, leading to age overestimation. This effect is particularly acute for material eroded and redeposited sub-aqueously (Olley *et al*., 1998, 1999; Wallinga, 2002) and exposed to a burial dose of <20 Gy (e.g. Olley *et al*., 2004), has some influence in sub-aerial contexts but is rarely of consequence where aerial transport has occurred. Within single-aliquot regenerative-dose optical dating there are two diagnostics of partial resetting (or bleaching); signal analysis (Agersnap-Larsen *et al*., 2000; Bailey *et al*., 2003) and inter-aliquot D_e distribution studies (Murray *et al*., 1995).

Within this study, signal analysis was used to quantify the change in D_e value with respect to optical stimulation time for multi-grain aliquots. This exploits the existence of traps within minerogenic dosimeters that bleach with different efficiency for a given wavelength of light to verify partial bleaching. D_e (t) plots (Fig. 6; Bailey *et al*., 2003) are constructed from separate integrals of signal decay as laboratory optical stimulation progresses. A statistically significant increase in natural D_e (t) is indicative of partial bleaching assuming three conditions are fulfilled. Firstly, that a statistically significant increase in D_e (t) is observed when partial bleaching is simulated within the laboratory. Secondly, that there is no significant rise in D_e (t) when full bleaching is simulated. Finally, there should be no significant augmentation in D_e (t) when zero dose is simulated. Where partial bleaching is detected, the age derived from the sample should be considered a maximum estimate only. However, the utility of signal analysis is strongly dependent upon a samples pre-burial experience of sunlight's spectrum and its residual to post-burial signal ratio. Given in the majority of cases, the spectral exposure history of a deposit is uncertain, the absence of an increase in natural D_e (t) does not necessarily testify to the absence of partial bleaching.

Where requested and feasible, the insensitivities of multi-grain single-aliquot signal analysis may be circumvented by inter-aliquot D_e distribution studies. This analysis uses aliquots of single sand grains to quantify inter-grain D_e distribution. At present, it is contended that asymmetric inter-grain D_e distributions are symptomatic of partial bleaching and/or pedoturbation (Murray *et al*., 1995; Olley *et al*., 1999; Olley *et al*., 2004; Bateman *et al*., 2003). For partial bleaching at least, it is further contended that the D_e acquired during burial is located in the minimum region of such ranges. The mean and breadth of this minimum region is the subject of current debate, as it is additionally influenced by heterogeneity in microdosimetry, variable inter-grain response to SAR and residual to post-burial signal ratios. Presently, the apposite measure of age is that defined by the D_e interval delimited by the minimum and central age models of Galbraith *et al*. (1999).

Pedoturbation

The accuracy of sedimentation ages can further be controlled by post-burial trans-strata grain movements forced by pedo- or cryoturbation. Berger (2003) contends pedogenesis prompts a reduction in the apparent sedimentation age of parent material through bioturbation and illuviation of younger material from above and/or by biological recycling and resetting of the datable signal of surface material. Berger (2003) proposes that the chronological products of this remobilisation are A-horizon age estimates reflecting the cessation of pedogenic activity, Bc/C-horizon ages delimiting the maximum age for the initiation of pedogenesis with estimates obtained from Bt-horizons providing an intermediate age 'close to the age of cessation of soil development'. Singhvi et al. (2001), in contrast, suggest that B and C-horizons closely approximate the age of the parent material, the A-horizon, that of the 'soil forming episode'. At present there is no post-sampling mechanism for the direct detection of and correction for post-burial sediment remobilisation. However, intervals of palaeosol evolution can be delimited by a maximum age derived from parent material and a minimum age obtained from a unit overlying the palaeosol. Inaccuracy forced by cryoturbation may be bidirectional, heaving older material upwards or drawing younger material downwards into the level to be dated. Cryogenic deformation of matrix-supported material is, typically, visible; sampling of such cryogenically-disturbed sediments can be avoided.

12.7. Acquisition and accuracy of D_r value

Lithogenic D_r values were defined through measurement of U, Th and K radionuclide concentration and conversion of these quantities into α, β and γ D_r values (Table 1). α and β contributions were estimated from sub-samples by laboratory-based γ spectrometry using an Ortec GEM-S high purity Ge coaxial detector system, calibrated using certified reference materials supplied CANMET. γ dose rates can be estimated from *in situ* NaI gamma spectrometry to reduce uncertainty relating to potential heterogeneity in the γ dose field surrounding each sample. Where direct measurements are unavailable as in the present case, laboratory-based Ge γ spectrometry can be used to profile the γ field at intervals within 300 mm above and below of each sample's centre. However, core section length in this study precluded profiling. The level of U disequilibrium was estimated by laboratory-based Ge γ spectrometry. Estimates of radionuclide concentration were converted into D_r values (Adamiec and Aitken, 1998), accounting for D_r modulation forced by grain size (Mejdahl, 1979), present moisture content (Zimmerman, 1971) and, where D_e values were generated from 5-15 μm quartz, reduced signal sensitivity to α radiation (a-value 0.050 $\pm$ 0.002; Toms, unpub. data). Cosmogenic D_r values were calculated on the basis of sample depth, geographical position and matrix density (Prescott and Hutton, 1994).

The spatiotemporal validity of D_r values can be considered a function of five variables. Firstly, age estimates devoid of *in situ* γ spectrometry data should be accepted tentatively if the sampled unit is heterogeneous in texture or if the sample is located within 300 mm of strata consisting of differing texture and/or mineralogy. However, where samples are obtained throughout a vertical profile, consistent values of γ D_r based solely on laboratory measurements may evidence the homogeneity of the γ field and hence accuracy of γ D_r values. Secondly, disequilibrium can force temporal instability in U and Th emissions. The impact of this infrequent phenomenon (Olley et al., 1996) upon age estimates is usually insignificant given their associated margins of error. However, for samples where this effect is pronounced (>50% disequilibrium between ^{238}U and ^{226}Ra; Fig. 7), the resulting age estimates should be accepted tentatively. Thirdly, pedogenically-induced variations in matrix composition of B and C-horizons, such as radionuclide and/or mineral remobilisation, may alter the rate of energy emission and/or absorption. If D_r is invariant through a dated profile and samples encompass primary parent material, then element mobility is likely limited in effect. Fourthly, spatiotemporal detractions from present moisture content are difficult to assess directly, requiring knowledge of the magnitude and timing of differing contents. However, the maximum influence of moisture content variations can be delimited by recalculating D_r for minimum (zero) and maximum (saturation) content. Finally, temporal alteration in the thickness of overburden alters cosmic D_r values. Cosmic D_r often forms a negligible portion of total D_r. It is possible to quantify the maximum influence of overburden flux by recalculating D_r for minimum (zero) and maximum (surface sample) cosmic D_r.

12.8. Estimation of Age

Age estimates reported in Table 1 provide an estimate of sediment burial period based on mean D_e and D_r values and their associated analytical uncertainties. Uncertainty in age estimates is reported as a product of systematic and experimental errors, with the magnitude of experimental errors alone shown in parenthesis (Table 1). Probability distributions indicate the inter-aliquot variability in age (Fig. 8). The maximum influence of temporal variations in D_r forced by minima-maxima in moisture content and overburden thickness is illustrated in Fig. 8. Where uncertainty in these parameters exists this age range may prove instructive, however the combined extremes represented should not be construed as preferred age estimates. The analytical validity of each sample is presented in Table 2.

12.9. Analytical uncertainty

All errors are based upon analytical uncertainty and quoted at 1σ confidence. Error calculations account for the propagation of systematic and/or experimental (random) errors associated with D_e and D_r values.

For D_e values, systematic errors are confined to laboratory β source calibration. Uncertainty in this respect is that combined from the delivery of the calibrating γ dose (1.2%; NPL, pers. comm.), the conversion of this dose for SiO_2 using the respective mass energy-absorption coefficient (2%; Hubbell, 1982) and experimental error, totalling 3.5%. Mass attenuation and bremsstrahlung losses during γ dose delivery are considered negligible. Experimental errors relate to D_e interpolation using sensitisation corrected dose responses. Natural and regenerated sensitisation corrected dose points (S_i) were quantified by,

$$S_i = (D_i - x.L_i) / (d_i - x.L_i) \qquad \textbf{Eq.1}$$

where D_i = Natural or regenerated OSL, initial 0.2 s
L_i = Background natural or regenerated OSL, final 5 s
d_i = Test dose OSL, initial 0.2 s
x = Scaling factor, 0.08

The error on each signal parameter is based on counting statistics, reflected by the square-root of measured values. The propagation of these errors within Eq. 1 generating σS_i follows the general formula given in Eq. 2. σS_i were then used to define fitting and interpolation errors within exponential plus linear regressions.

For D_r values, systematic errors accommodate uncertainty in radionuclide conversion factors (5%), β attenuation coefficients (5%), a-value (4%; derived from a systematic α source uncertainty of 3.5% and experimental error), matrix density (0.20 g.cm^{-3}), vertical thickness of sampled section (specific to sample collection device), saturation moisture content (3%), moisture content attenuation (2%), burial moisture content (25% relative, unless direct evidence exists of the magnitude and period of differing content) and NaI gamma spectrometer calibration (3%). Experimental errors are associated with radionuclide quantification for each sample by NaI and Ge gamma spectrometry.

The propagation of these errors through to age calculation was quantified using the expression,

$$\sigma y\ (\delta y/\delta x) = (\Sigma\ ((\delta y/\delta x_n).\sigma x_n)^2)^{1/2} \qquad \textbf{Eq. 2}$$

where y is a value equivalent to that function comprising terms x_n and where σy and σx_n are associated uncertainties.

Errors on age estimates are presented as combined systematic and experimental errors and experimental errors alone. The former (combined) error should be considered when comparing luminescence ages herein with independent chronometric controls. The latter assumes systematic errors are common to luminescence age estimates generated by means identical to those detailed herein and enable direct comparison with those estimates.

Fig. 1 Signal Calibration

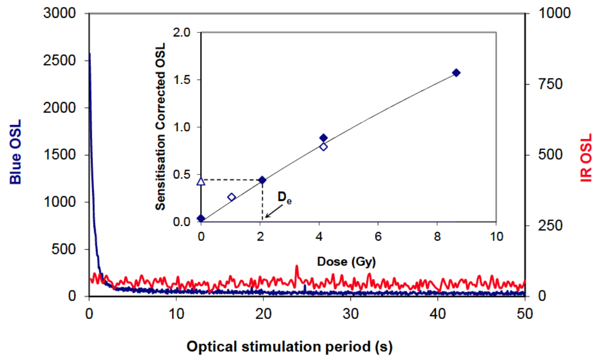


Fig. 2 Dose Recovery

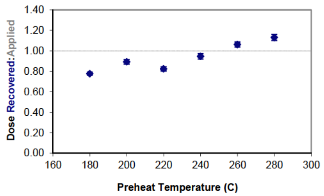


Fig. 3 Inter-aliquot D_e distribution

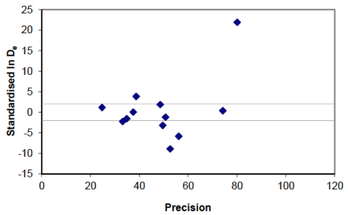


Fig. 4 Low and High Repeat Regenerative-dose Ratio

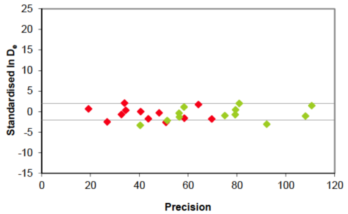


Fig. 5 OSL to Post-IR OSL Ratio

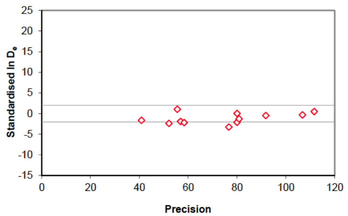


Fig. 6 Signal Analysis

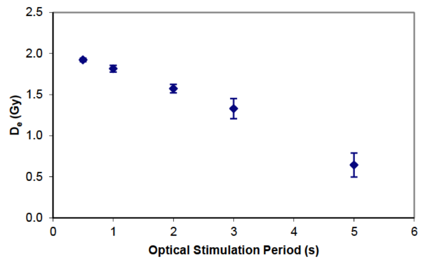


Fig. 7 U Decay Activity

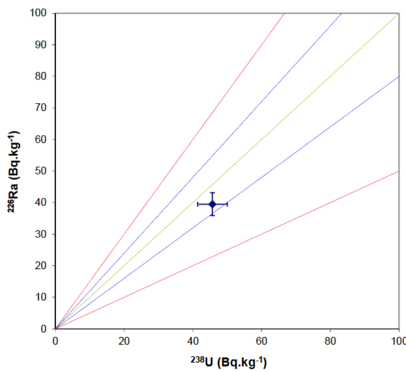


Fig. 8 Age Range

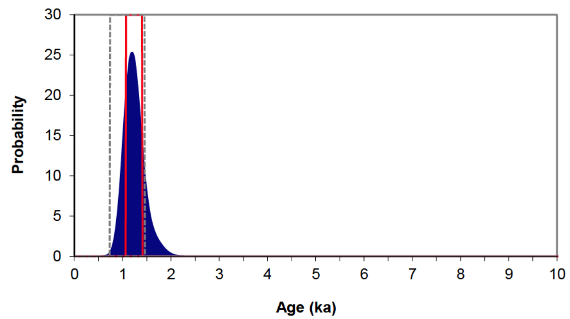


Fig. 1 Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Repeats of low and high doses (open diamonds) illustrate the success of sensitivity correction.

Fig. 2 Dose Recovery The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. The Dose Recovery test quantifies the combined effects of thermal transfer and sensitisation on the natural signal using a precise lab dose to simulate natural dose. Based on this an appropriate thermal treatment is selected to generate the final D_e value.

Fig. 3 Inter-aliquot D_e distribution Provides a measure of inter-aliquot statistical concordance in D_e values derived from **natural** irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflects heterogeneous dose absorption and/or inaccuracies in calibration.

Fig. 4 Low and High Repeat Regenerative-dose Ratio Measures the statistical concordance of signals from repeated low and high regenerative-doses. Discordant data (those points lying beyond ±2 standardised ln D_e) indicate inaccurate sensitivity correction.

Fig. 5 OSL to Post-IR OSL Ratio Measures the statistical concordance of OSL and post-IR OSL responses to the same regenerative-dose. Discordant, underestimating data (those points lying below -2 standardised ln D_e) highlight the presence of significant feldspar contamination.

Fig. 6 Signal Analysis Statistically significant increase in **natural** D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from **simulated partial bleaching** followed by insignificant adjustment in D_e for simulated **zero** and **full bleach** conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

Fig. 7 U Activity Statistical concordance (equilibrium) in the activities of the daughter radioisotope ^{226}Ra with its parent ^{238}U may signify the temporal stability of D_r emissions from these chains. Significant differences (disequilibrium; >50%) in activity indicate addition or removal of isotopes creating a time-dependent shift in D_r values and increased uncertainty in the accuracy of age estimates. A 20% disequilibrium marker is also shown.

Fig. 8 Age Range The **mean age range** provides an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The probability distribution indicates the inter-aliquot variability in age. The **maximum influence** of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness may prove instructive where there is uncertainty in these parameters, however the combined extremes represented should not be construed as preferred age estimates.

Sample 04 GL11022

Fig. 1 Signal Calibration

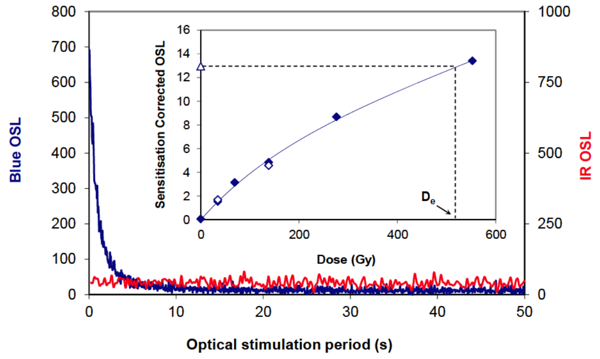


Fig. 2 Dose Recovery

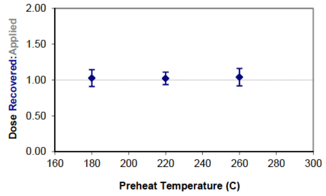


Fig. 3 Inter-aliquot D_e distribution

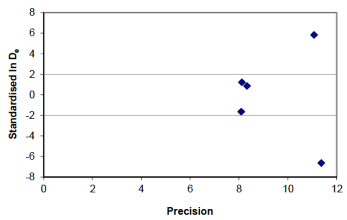


Fig. 4 Low and High Repeat Regenerative-dose Ratio

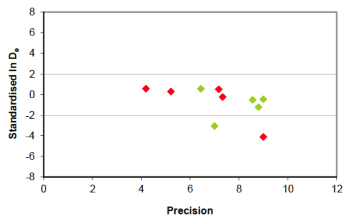


Fig. 5 OSL to Post-IR OSL Ratio

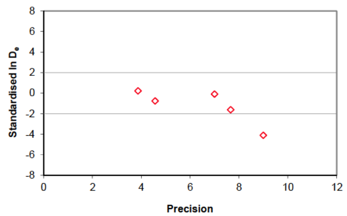


Fig. 6 Signal Analysis

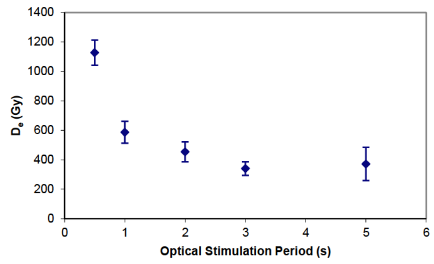


Fig. 7 U Decay Activity

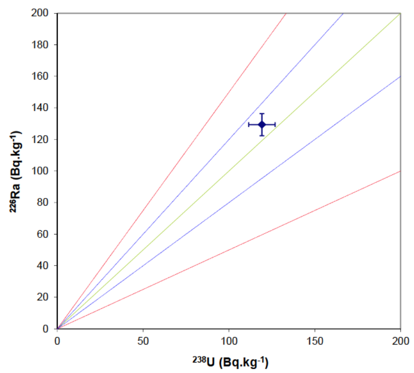
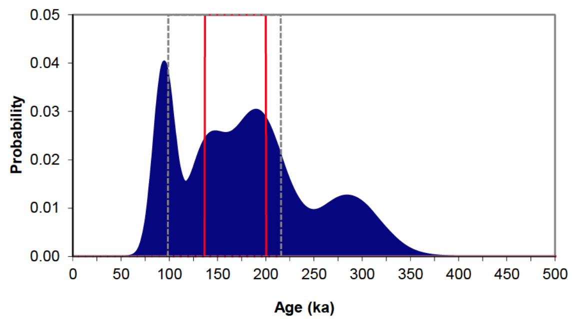


Fig. 8 Age Range



221.14

Fig. 1 Signal Calibration Natural blue and laboratory-induced infrared (IR) OSL signals. Detectable IR signal decays are diagnostic of feldspar contamination. Inset, the natural blue OSL signal (open triangle) of each aliquot is calibrated against known laboratory doses to yield equivalent dose (D_e) values. Repeats of low and high doses (open diamonds) illustrate the success of sensitivity correction.

Fig. 2 Dose Recovery The acquisition of D_e values is necessarily predicated upon thermal treatment of aliquots succeeding environmental and laboratory irradiation. The Dose Recovery test quantifies the combined effects of thermal transfer and sensitisation on the natural signal using a precise lab dose to simulate natural dose. Based on this an appropriate thermal treatment is selected to generate the final D_e value.

Fig. 3 Inter-aliquot D_e distribution Provides a measure of inter-aliquot statistical concordance in D_e values derived from **natural** irradiation. Discordant data (those points lying beyond ±2 standardised ln D_e) reflects heterogeneous dose absorption and/or inaccuracies in calibration.

Fig. 4 Low and High Repeat Regenerative-dose Ratio Measures the statistical concordance of signals from repeated low and high regenerative-doses. Discordant data (those points lying beyond ±2 standardised ln D_e) indicate inaccurate sensitivity correction.

Fig. 5 OSL to Post-IR OSL Ratio Measures the statistical concordance of OSL and post-IR OSL responses to the same regenerative-dose. Discordant, underestimating data (those points lying below -2 standardised ln D_e) highlight the presence of significant feldspar contamination.

Fig. 6 Signal Analysis Statistically significant increase in **natural** D_e value with signal stimulation period is indicative of a partially-bleached signal, provided a significant increase in D_e results from **simulated partial bleaching** followed by insignificant adjustment in D_e for simulated **zero** and **full bleach** conditions. Ages from such samples are considered maximum estimates. In the absence of a significant rise in D_e with stimulation time, simulated partial bleaching and zero/full bleach tests are not assessed.

Fig. 7 U Activity Statistical concordance (equilibrium) in the activities of the daughter radioisotope ^{226}Ra with its parent ^{238}U may signify the temporal stability of D_r emissions from these chains. Significant differences (disequilibrium; >50%) in activity indicate addition or removal of isotopes creating a time-dependent shift in D_r values and increased uncertainty in the accuracy of age estimates. A 20% disequilibrium marker is also shown.

Fig. 8 Age Range The **mean age range** provides an estimate of sediment burial period based on mean D_e and D_r values with associated analytical uncertainties. The probability distribution indicates the inter-aliquot variability in age. The **maximum influence** of temporal variations in D_r forced by minima-maxima variation in moisture content and overburden thickness may prove instructive where there is uncertainty in these parameters, however the combined extremes represented should not be construed as preferred age estimates.

Sample: 05 GL11023

12.10. References

Adamiec, G. and Aitken, M.J. (1998) Dose-rate conversion factors: new data. *Ancient TL*, 16, 37-50.

Agersnap-Larsen, N., Bulur, E., Bøtter-Jensen, L. and McKeever, S.W.S. (2000) Use of the LM-OSL technique for the detection of partial bleaching in quartz. *Radiation Measurements*, 32, 419-425.

Aitken, M. J. (1998) An introduction to optical dating: the dating of Quaternary sediments by the use of photon-stimulated luminescence. Oxford University Press.

Bailey, R.M., Singarayer, J.S. , Ward, S. and Stokes, S. (2003) Identification of partial resetting using D_e as a function of illumination time. *Radiation Measurements*, 37, 511-518.

Banerjee, D., Murray, A.S., Bøtter-Jensen, L. and Lang, A. (2001) Equivalent dose estimation using a single aliquot of polymineral fine grains. *Radiation Measurements*, 33, 73-94.

Bateman, M.D., Frederick, C.D., Jaiswal, M.K., Singhvi, A.K. (2003) Investigations into the potential effects of pedoturbation on luminescence dating. *Quaternary Science Reviews*, 22, 1169-1176.

Berger, G.W. (2003). Luminescence chronology of late Pleistocene loess-paleosol and tephra sequences near Fairbanks, Alaska. *Quaternary Research*, 60, 70-83.

Berger, G.W., Mulhern, P.J. and Huntley, D.J. (1980). Isolation of silt-sized quartz from sediments. *Ancient TL*, 11, 147-152.

Bøtter-Jensen, L., Mejdahl, V. and Murray, A.S. (1999) New light on OSL. *Quaternary Science Reviews*, 18, 303-310.

Bøtter-Jensen, L., McKeever, S.W.S. and Wintle, A.G. (2003) Optically Stimulated Luminescence Dosimetry. Elsevier, Amsterdam.

Duller, G.A.T (2003) Distinguishing quartz and feldspar in single grain luminescence measurements. *Radiation Measurements*, 37, 161-165.

Galbraith, R, F. (1990) The radial plot: graphical assessment of spread in ages. *Nuclear Tracks and Radiation Measurements*, 17, 207-214.

Galbraith, R. F., Roberts, R. G., Laslett, G. M., Yoshida, H. and Olley, J. M. (1999) Optical dating of single and multiple grains of quartz from Jinmium rock shelter (northern Australia): Part I, Experimental design and statistical models. *Archaeometry*, 41, 339-364.

Hubble, J. H. (1982) Photon mass attenuation and energy-absorption coefficients from 1keV to 20MeV. *International Journal of Applied Radioisotopes*, 33, 1269-1290.

Huntley, D.J., Godfrey-Smith, D.I. and Thewalt, M.L.W. (1985) Optical dating of sediments. *Nature*, 313, 105-107.

Hütt, G., Jaek, I. and Tchonka, J. (1988) Optical dating: K-feldspars optical response stimulation spectra. *Quaternary Science Reviews*, 7, 381-386.

Jackson, M.L., Sayin, M. and Clayton, R.N. (1976). Hexafluorosilicic acid regent modification for quartz isolation. *Soil Science Society of America Journal*, 40, 958-960.

Markey, B.G., Bøtter-Jensen, L., and Duller, G.A.T. (1997) A new flexible system for measuring thermally and optically stimulated luminescence. *Radiation Measurements*, 27, 83-89.

Mejdahl, V. (1979) Thermoluminescence dating: beta-dose attenuation in quartz grains. *Archaeometry*, 21, 61-72.

Murray, A.S. and Olley, J.M. (2002) Precision and accuracy in the Optically Stimulated Luminescence dating of sedimentary quartz: a status review. *Geochronometria*, 21, 1-16.

Murray, A.S. and Wintle, A.G. (2000) Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurements*, 32, 57-73.

Murray, A.S. and Wintle, A.G. (2003) The single aliquot regenerative dose protocol: potential for improvements in reliability. *Radiation Measurements*, 37, 377-381.

Murray, A.S., Olley, J.M. and Caitcheon, G.G. (1995) Measurement of equivalent doses in quartz from contemporary water-lain sediments using optically stimulated luminescence. *Quaternary Science Reviews*, 14, 365-371.

Murray, A.S., Wintle, A.G., and Wallinga, J. (2002) Dose estimation using quartz OSL in the non-linear region of the growth curve. *Radiation Protection Dosimetry*, 101, 371-374.

Olley, J.M., Murray, A.S. and Roberts, R.G. (1996) The effects of disequilibria in the Uranium and Thorium decay chains on burial dose rates in fluvial sediments. *Quaternary Science Reviews*, 15, 751-760.

Olley, J.M., Caitcheon, G.G. and Murray, A.S. (1998) The distribution of apparent dose as determined by optically stimulated luminescence in small aliquots of fluvial quartz: implications for dating young sediments. *Quaternary Science Reviews*, 17, 1033-1040.

Olley, J.M., Caitcheon, G.G. and Roberts R.G. (1999) The origin of dose distributions in fluvial sediments, and the prospect of dating single grains from fluvial deposits using - optically stimulated luminescence. *Radiation Measurements,* 30, 207-217.

Olley, J.M., Pietsch, T. and Roberts, R.G. (2004) Optical dating of Holocene sediments from a variety of geomorphic settings using single grains of quartz. *Geomorphology*, 60, 337-358.

Pawley, S.M., Toms, P.S., Armitage, S.J., Rose, J. (2010) Quartz luminescence dating of Anglian Stage fluvial sediments: Comparison of SAR age estimates to the terrace chronology of the Middle Thames valley, UK. *Quaternary Geochronology*, 5, 569-582.

Prescott, J.R. and Hutton, J.T. (1994) Cosmic ray contributions to dose rates for luminescence and ESR dating: large depths and long-term time variations. *Radiation Measurements*, 23, 497-500.

Singhvi, A.K., Bluszcz, A.., Bateman, M.D., Someshwar Rao, M. (2001). Luminescence dating of loess-palaeosol sequences and coversands: methodological aspects and palaeoclimatic implications. *Earth Science Reviews*, 54, 193-211.

Smith, B.W., Rhodes, E.J., Stokes, S., Spooner, N.A. (1990) The optical dating of sediments using quartz. *Radiation Protection Dosimetry*, 34, 75-78.

Spooner, N.A. (1993) The validity of optical dating based on feldspar. Unpublished D.Phil. thesis, Oxford University.

Templer, R.H. (1985) The removal of anomalous fading in zircons. *Nuclear Tracks and Radiation Measurements*, 10, 531-537.

Wallinga, J. (2002) Optically stimulated luminescence dating of fluvial deposits: a review. *Boreas* 31, 303-322.

Wintle, A.G. (1973) Anomalous fading of thermoluminescence in mineral samples. *Nature*, 245, 143-144.

Zimmerman, D. W. (1971) Thermoluminescent dating using fine grains from pottery. *Archaeometry*, 13, 29-52.

13. APPENDIX 5: POLLEN ASSESSMENT

13.1. Introduction

13.1.1. Eight samples from the Steart Peninsula, Somerset, were taken from stratified sediment samples within two boreholes: **WABH2011_BH02** and **WA2011_BH05**, described in **Table 1**.

13.2. Methodology

13.2.1. Standard preparation procedures were used (Moore *et al*. 1991). 4cm^3 of sediment was sampled, with a Lycopodium spike added to allow the calculation of pollen concentrations (Stockmarr 1971). All samples received the following treatment: 20 mls of 10% KOH (80°C for 30 minutes); 20mls of 60% HF (80°C for 120 minutes); 15 mls of acetolysis mix (80°C for 3 minutes); stained in 0.2% aqueous solution of safranin and mounted in silicone oil following dehydration with tert-butyl alcohol.

13.2.2. Pollen counting was undertaken at a magnification of x400 using a Nikon Eclipse E400 transmitted light microscope. Determinable pollen and spore types were identified to the lowest possible taxonomic level with the aid of a reference collection kept at Wessex Archaeology. The pollen and spore types used are those defined by Bennett (1994; Bennett *et al*., 1994) except Poaceae which follow Küster (1988). Plant nomenclature follows Stace (1997).

13.2.3. A total land pollen (TLP) sum of a minimum of 100 grains, excluding obligate aquatics and pteridophytes, was used for assessment.

13.3. Results

13.3.1. Variable amounts of pollen were encountered in the eight samples, with sufficient counts for assessment only found in borehole **WA2011_BH02** at 0.71m above OD and 0.61m above OD. These were derived from peat and peaty silt deposits respectively. The other samples were derived predominantly from estuarine alluvium and failed to yield sufficient pollen for assessment.

13.3.2. The two samples with sufficient pollen for assessment show an assemblage dominated by *Quercus* (oak) and *Corylus avellana*-type (hazel), with *Alnus glutinosa* (alder), *Ulmus* (elm), Chenopodiaceae (goosefoots and oraches) and Poaceae (grasses) also present. This implies the presence of woodland and areas of open ground within the pollen catchment. The presence of Chenopodiaceae may indicate local estuarine influence. A radiocarbon date associated with the peat at 0.74m above OD provided a date of 3100-2910 cal BC (SUERC-38608, 4020±35 BP), indicating that it is Middle Neolithic in date. A similar pollen assemblage is alluded to in borehole **WA2011_BH05**, though insufficient pollen was preserved to make full counts to verify this.

13.4. Potential

13.4.1. The pollen assessment shows very low concentrations and abundance in the majority of samples, and therefore for these it would not be possible to obtain meaningful counts to enable a statistically valid interpretation. The two pollen samples with sufficient pollen concentrations in borehole **WA2011_BH02** at 0.71 and 0.61m above OD have potential to provide an insight into the Middle Neolithic vegetation of the surrounding area. Given the consistent presence of *Ulmus* within the samples, further sampling may yield Late Mesolithic / Early Neolithic radiocarbon dates for the lower sediment and therefore provide a valuable insight into the persistence of *Ulmus* in the area around the time when the British elm decline is commonly implied to have occurred (e.g., Parker *et al*. 2002). Further pollen sampling of this part of the sequence, along with radiocarbon dating, will provide a proper insight into the age of the peat (likely to have been heavily compacted by overlying alluvial deposits).

13.5. Proposals

13.5.1. It is recommended that additional pollen samples are taken from the peat (and adjacent contexts) for pollen analysis. A total of eight additional pollen samples should be taken from these contexts for analysis, combined with an additional two radiocarbon dates to constrain the chronology.

13.6. Acknowledgements

13.6.1. Pollen assessment was carried out by Dr Michael Grant, with pollen sample preparation provided at CEESR, Kingston University, by Kevin Attree.

13.7. References

Bennett, K.D., 1994. Annotated catalogue of pollen and pteridophyte spore types of the British Isles, unpublished manuscript, Cambridge, University of Cambridge

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

Küster, H., 1988. Vom werden einer Kulturlandschaft. Vegetationsgeschichtliche Studien am Auerberg (Südbayern) VHC, *Acta Humanoria*, Weinheim

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

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, 1-45

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

Stockmarr, J., 1971. Tablets with spores used in absolute pollen analysis, *Pollen et Spores* 13, 615-621

Table1: Pollen identified within the eight samples from boreholes **WA2011_BH02** and **WA2011_BH05**

Borehole	**WABH2011 BH02**						**WA2011 BH05**	
Depth (m BGL)	**2.5**	**4.73**	**4.83**	**6.55**	**9.59**	**10.2**	**4.2**	**7.97**
Depth (m OD)	**2.94**	**0.71**	**0.61**	**- 1.11**	**- 4.15**	**- 4.76**	**1.53**	**- 2.24**
Pinus sylvestris				2				1
Ulmus		6	8					
Quercus		40	38	7		1	4	5
Betula			5					
Alnus glutinosa		14	23				3	2
Tilia cordata		1		1				
Ilex aquifolium								1
Fraxinus excelsior			2					
Corylus avellana-type		68	88	2	2		5	1
Salix							1	1
Hedera helix		1	1					1
Chenopodiaceae	4	13	20	5			1	1
Rumex acetosella			1					
Rumex sanguineus-type			1					
Brassicaceae	1							
Plantago lanceolata							1	
Lactuceae undiff.							1	
Solidago virgaurea-type		1	2					
Cyperaceae undiff.	1	9	6	2		1	1	7
Poaceae undiff.	3	13	25	4			8	5
Bromus hordeaceus-type							1	
Myriophyllum verticillatum		1						
Potamogeton natans-type			1					
Sparganium emersum-type	1	6	5				2	
Typha latifolia			1					
Osmunda regalis							1	
Polypodium	1	2					2	3
Pteridium aquilinum	6		1				7	9
Dryopteris filix-mas-type				2			1	
Pteropsida (monolete) indet.	3	1		3		1	2	4
Bryophyta		1	2				1	1
TLP SUM	9	166	220	23	2	2	26	25
Pollen Concentration	3626	136670	282061	9121	468	1060	5542	4838

14. APPENDIX 6: FORAMINIFERA AND OSTRACOD ASSESSMENT

14.1. Introduction

14.1.1. Eight sediment subsamples taken from two boreholes, **WA2011_BH02** (at 4.76, 4.15, 1.11m below OD (Ordnance Datum), 0.58, 4.79 and 2.94m above OD) and **WA2011_BH05** (at 2.24 and 1.53m above OD) located on reclaimed farmland adjacent to the River Parrett on the Steart Peninsula, Somerset have been assessed for the presence and environmental significance of their microfaunal contents, predominantly ostracods and foraminifera.

14.1.2. The sampled sediments comprised sands, silts, clays and peats thought to be predominantly mid-Holocene alluvial and terrestrial sediments associated with deposition within the river Parrett and Bristol Channel systems. The peats have been radiocarbon dated yielding middle to late Neolithic dates. Optically Stimulated Luminescence (OSL) dating suggests that sediments in the earlier part of the sequence are Pleistocene (c MIS (Marine Isotope Stage) 7 to 5e) in date. Ostracods and foraminifera occurred in all but three of the samples. Other plant and animal remains were also recovered from the samples a note of which has been made here. Depths are given in metres below OD (Ordnance Datum).

14.2. Method

14.2.1. Sediment samples of *c.*25g were disaggregated in a weak solution of Hydrogen Peroxide and water, then wet sieved through a 63µm sieve. The sediment was dried and sieved through 500µm, 250µm, 125µm sieves. Microfossils were picked out under 10-60x magnification and transmitted and incident light using a Vickers binocular microscope. Where possible a minimum of one hundred specimens per sample were picked out and kept in card slides. Identification and environmental interpretation of ostracods follows Athersuch *et al*. (1989) and Meisch (2000) and of foraminifera (Murray 1976, 2000).

14.3. Results

Introduction

14.3.1. Abundance of microfaunal remains within the samples is summarised in **Table 1.** Abundance of ostracods was varied and where present, the preservation was good. Five of the samples contained ostracods and foraminifera and where present were generally well preserved with variable abundance.

WA2011_ BH02

14.3.2. Six levels were assessed, at 4.76, 4.15, 1.11m below OD, 0.58, 0.65 and 2.94m above OD). Foraminifera and ostracods were present in three of the six samples (**Table 1**).

- *At 4.76 and 4.15m below OD – no foraminifera or ostracods were recovered. No other organic remains were recorded within these samples.*

- *At 1.11m below OD – ostracods were present including valves of Cyprideis torosa. Foraminifera were more frequent including Ammonia beccarrii, Elphidium williamsoni and Milammina fusca. Other remains within the sample included a seed and a bryozoan.*

- *At 0.58m above OD – a hyperabundance of the ostracod Cyprideis torosa was recovered. Other ostracod taxa present included Candona candida, Locxoconcha sp. and Elofsonia sp.. Foraminifera recovered included Ammonia beccarrii, Elphidium williamsoni and Haynesina germanica. Other remains ncluded abundant Hydrobid molluscs, bryozoans and some seeds including Potomageton sp.*

- *At 0.65m above OD – no foraminifera or ostracods were recovered from this sample although large numbers of radiate diatoms, and plant remains including Juncus sp. were recovered from the sample.*

- *At 2.94m above OD – occasional ostracods were recovered including valves of Cyprideis torosa. Foraminifera were highly abundant and well preserved within the sample including Ammonia beccarrii, Elphidium williamsoni, Haynesina germanica, Jadammina macrescens, Rotaliids and Trochammina inflata. Other remains within the sample included a seed of the sedge Juncus sp.*

WA2011_BH05

14.3.3. Two levels were assessed, at 2.24m below OD and 1.53m above OD. Foraminifera and ostracods were present in both of the samples.

- *2.24m below OD – this sample contained a number of ostracod species including Leptocythere pellucida, Cyprideis torosa, Hirschmannia viridis, Loxoconcha rhomboidea and Propontocypris sp.. Foraminifera recovered from th sample included. Ammonia beccarrii, Elphidium williamsoni, Haynesina germanica, Jadammina macrescens, Miliolinella subrotundata and Quinqueoloculina sp. Other remains within the sample included molluscs, sponge spicules and seeds.*

- *1.53m above OD – occasional ostracod valves were recovered from this sample including Leptocythere sp. Foraminifera were more frequent including Elphidium williamsoni, Haynesina germanica and Jadammina macrescens. Molluscs and radiate diatoms were also recovered within the sample.*

14.4. Discussion

WA2011_BH02

14.4.1. The lower two samples (at 4.76, 4.15m below OD) within this borehole contained no organic remains and therefore very little can be said of its contents. It may be that any organic remains have been subject to post depositional dissolution.

14.4.2. At 1.11m below OD the ostracods and foraminfera are indicative of brackish/estuarine 0.58m above OD and *Cyprideis torosa*) saltmarsh (*Milammina fusca*) environments.

14.4.3. At 0.58m above OD the hyperabundance of *Cyprideis torosa* is of interest. *Cyprideis torosa* is a euryhaline taxon that can occur in freshwater to hypersaline conditions and it's mass development is usually associated with organic detritus and brackish water (Meisch 2000). The occasional presence of Candoniids (*Candona candida*) is indicative of freshwater input (into a brackish environment) at this level.

14.4.4. At 0.65m above OD the lack of foraminifera and ostracods (and other calcareous remains is likely due to a reducing post depositional environment. The frequent remains of radiate diatoms and plants including sedges (*Juncus* sp.) are indicative of an aquatic, vegetated environment.

14.4.5. The uppermost sample at 2.94m above OD included the brackish tolerant ostracod *Cyprideis torosa* and foraminifera indicative of estuarine and brackish (*Ammonia beccarrii Elphidium williamsoni*, *Haynesina germanica*) and saltmarsh (*Jadammina macrescens, Trochammina inflata)* environments.

WA2011_BH05

14.4.6. The basal sample at 2.24m below OD the ostracods and foraminfera recovered included species indicative of deposition within shallow marine, brackish and estuarine environments. *Leptocythere pellucida* was the most abundant ostracod within the sample and is today know to inhabit nearshore sublittoral marine environments (Athersuch *et al.* 1989).

14.4.7. At 1.53m above OD the foraminifera and ostracods recovered were indicative of.brackish and marine environments. The most abundant foraminifera recovered were *Haynesina germanica* indicative of deposition within brackish water environments such as estuaries and lagoons (Murray 1990).

14.5. Recommendations

- *Foraminifera and ostracods should be analysed from the samples already assessed, where present including greater counts and taxonmic work.*
- *Particular attention should be paid to dated levels (OSL and radiocarbon where practicable), and interstitial samples in order to understand the successive environments.*
- *From core samples within borehole **WA2011_BH02** further samples are recommended from units B, C and D (between 3.06m above OD to 3.96m below OD)*
- *From borehole **WA2011_ BH05** no further samples are recommended due to the problems associated with the scientific dating within this borehole.*

14.6. References

Athersuch, J., Horne, D.J., and Whittaker, J.E., 1989. *Marine and Brackish Water Ostracods*. Synopses of the British Fauna (New Series), No.43, 343pp

Boomer, I. 2001. Environmental Applications of Marine and Freshwater Ostracods. In :. 2001. Quaternary Environmental Micropalaeontology

Kilyeni T.I., 1972 Transient and genetic polymorphism as an explanation of variable noding on the ostracode *Cyprideis torosa. Micropalaeontology.* **18**. 47-63

Meisch, C., 2000. *Freshwater Ostracoda of Western and Central Europe*. In: J. Schwoerbel and P. Zwick, editors: Suesswasserfauna von Mitteleuropa 8/3. Spektrum Akademischer Verlag, Heidelberg, Berlin. 522pp

Murray, J.W., 1979, *British Nearshore Foraminiferids,* Academic Press, London.

Murray, J.W., 1991, *Ecology and Palaeoecology of Benthic Foraminifera*, 397pp, Longman Scientific.

borehole (WA2011_)	BH02	BH02	BH02	BH02	BH02	BH02	BH05	BH05
mOD	4.76	-4.15	-1.11	0.58	0.65	2.94	-2.24	1.53
Ostracods / mbGL	10.2	9.59	6.55	4.86	4.79	2.50	7.97	4.2
Candona sp.								
Candona candida				x				
Cyprideis torosa			x	xxxxx		x	x	
Cytheropteron sp.								
Elofsonia sp.				x				
Hirschmannia viridis							o	
Leptocythere pellucida							xx	
Leptocythere sp.							x	o
Loxoconcha rhomboidea							o	
Loxoconcha sp.				x				
Propontocypris sp.							o	
Broken						o		o
Unidentified			o					o
Foraminfera								
Ammonia beccarii			xx	xx		xxxx	x	
Elphidium sp.								
Elphidium williamsoni			xx	x		xxxx	x	x
Haynesina germanica				xx		xx	x	xx
Jadammina macrescens						xx	x	x
Milammina fusca			x					
Miliolinella subrotundata							x	
Quinqueloculina sp.							x	
Rotalids						xx		
Trochammina inflata						xx		
Unidentified								
Animal remains								
Bivalves								o
Bryozoans			o	xxxx				
Fish teeth/bones				x				
Hydrobia				xxx				o
Molluscs							xx	x
Sponge spicules							x	
Plant remains								
Charred grass/stems					x			
Diatoms					xxxxx			x
Juncus sp.					x	o		
Potomageton				x				
Plants unidentified					xxx			
Seed unidentified			o	x	x		xxx	

Table 1. Abundance of taxa per sample in WA2011_BH02 and WA2011_BH05

Abundance:
x – 1-9 specimens
xx – 9-50 specimens
xxx – greater than 50 specimens
xxxx – greater than 100 specimens

15. APPENDIX 7: PLANT MACROFOSSIL, MOLLUSC, CHARCOAL AND INSECT ASSESSMENT

15.1. Introduction

15.1.1. Five samples were selected from two boreholes **WA2011_BH02** and **WA2011_BH05** for assessment of the recovery, survival and potential of waterlogged plant remains, charcoal, insects and molluscs to inform on past environments. Four came from **WA2012_BH02** (at 4.04 to 4.14m below OD, 3.51 to 3.61m below OD, 0.69 to 0.59m above OD and a spot sample at 0.58m above OD). This sequence was dated at 0.74m OD, near the top of the sequence, on stems of common reed (*Phragmites australis*) to the Middle to Late Neolithic; 3100-2910 cal BC (SUERC-38608, 4020±35 BP) to 17400-16800 cal BC (SUERC-38609, 15825±40 BP) at 4.15m below OD, near the base of the sequence. A further sample came from **WA2011_BH05** at 2.19 to 2.29m below OD, which was dated to around 2630-2460 cal BC (SUERC-38610, 4390±30 BP). In addition the residue from the foraminifera and ostracod sample at 0.58m above OD was also assessed.

15.1.2. The samples were processed for the recovery and assessment of mollusca, plant remains, insect remains and other waterlogged material.

15.2. Method

15.2.1. The samples were processed by wet-sieving using a 0.25mm mesh size. The samples were visually inspected under a x10 to x40 stereo-binocular microscope to determine if waterlogged plant remains were preserved. Nomenclature follows that of Stace (1997). Other material present, in particular mollusc shells are also noted within Table 1 with further identifications carried out where possible.

15.3. Results

Waterlogged Plant Remains

15.3.1. Organic material was present within all the samples, although within the lower two samples from borehole **WA2011_BH2**, no identifiable remains were present and the remains were rather probably of roots and as such probably later in date than the deposit from which they were recovered.

15.3.2. The upper two samples dated prior to the Middle to Late Neolithic had larger assemblages comprising a mixture of aquatics and wetland plants. Of the aquatics several gametes of stonewort (*Chara* sp.) were recovered along with a single seed of spiked water-milfoil (*Myriophyllum spicatum*), and several of pondweed (*Potamogeton* sp.). Comparison with modern material suggests that these seeds are most likely of fennel-leaved pondweed (*Potamogeton pectinatus*). In one case the seed could be seen to be charred. Other aquatics present included water-crowfoot (*Ranunculus* subgenus Batrachium) and a single seed of horned pondweed (*Zannichellia palustris*). The size of the water crowfoot seeds, the poor definition of the ridges and comparison with modern material suggest that they are probably of brackish water-crowfoot (*Ranunculus baudotii*).

15.3.3. General wetland plants were represented by seeds of grey club-rush (*Schoenoplectus tabernaemontani*).

15.3.4. Plants relating to coastal and saltmarsh environments included several of oak-leaved/upright goosefoot (*Chenopodium glaucum/rubrum*), probable seeds of saltmarsh rush (*Juncus gerardii*). Terrestrial plants were represented by a single seed of common nettle (*Urtica dioica*).

15.3.5. The sample from **WA2011_BH5**, dated to the Late Neolithic, also had a gamete of stonewort (*Chara* sp.). It also contained seeds of seablite (*Suaeda maritima*), as well as orache (*Atriplex* sp.), along with bulrush (*Typha latifolia/angustifolia*), and possible stems of horsetail (*Equisetum* sp.). Several rush seeds with a large cell pattern resembling those of sharp-rush (*Juncus acutiflorus*) were recovered, although other species with a similar cell pattern, such as blunt-flowered rush (*Juncus subnodulosus*) are also possible candidates.

Molluscan Remains

15.3.6. A high number of molluscs were observed within the spot sample from borehole **WA2011_BH2** at 0.58 m above OD. This assemblage included shells of *Hydrobia ventrosa* and *Hydrobia ulvae*.

15.3.7. A few shells of *Hydrobia* sp. were recorded within two samples within borehole **WA2011_BH2** (at 0.69 to 0.59m above OD and 3.51 to 3.61m below OD) along with *Ovatella myosotis/Leucophytia bidentata* in the lower sample.

15.3.8. No shells were recovered from the basal sample within **WA2011_BH2**.

15.3.9. The sample from **WA2011_BH5** contained a few shells of *Hydrobia* sp. and *Tellina/Scrobicularia* type.

15.3.10. *Hydrobia ulvae* is 'a species restricted to brackish or salt water in estuaries, intertidal mudflats and saltmarshes', while *Hydrobia ventrosa* 'inhabits water of low to moderate salinities in quiet estuaries, ponds behind shingle bars, and lagoons and drainage ditches in coastal marshes' (Kerney 1999, 33 and 31). *Ovatella myosotis* and *Leucophytia bidentata* could also be found in these environments.

15.3.11. The small mollusc assemblage from **WA2011_BH5** is also indicative of a saltmarsh environment.

Insects and Wood charcoal

15.3.12. No remains of insects or charcoal were seen within the samples from borehole **WA2011_BH2**. The sample from borehole **WA2011_BH5** had some insect remains including remains of wing-cases (elytra) and a single head.

15.4. Summary

15.4.1. The boreholes indicate generally similar estuarine/tidally influenced environments with freshwater, brackish water and saltmarsh environments all represented.

15.4.2. In borehole **WA2011_BH2** elements such as stonewort (*Chara* sp.) can include brackish water species. Other species including fennel-leaved pondweed (*Potamogeton pectinatus*), horned pondweed (*Zannichellia palustris*), grey club-rush (*Schoenoplectus tabernaemontani*) and spiked water-milfoil (*Myriophyllum spicatum*), which taken together with brackish water-crowfoot (*Ranunculus baudotii*) are indicative of slightly saline conditions. Shells of *Hydrobia* sp. are very good indications of saline conditions and brackish water in general, the shells being most common in the uppermost later Neolithic sample.

15.4.3. The water fleas eggs are of some interest as generally this genera is more associated with freshwater. However, some species, including *Daphnia magna*, are found in coastal rock pools and small ponds, and quite tolerant of some degree of salinity (Teschner 1995).

15.4.4. Terrestrial components include common nettle (*Urtica dioica*) and goosefoot (*Chenopodium glaucum/rubrum*) which could indicate muddy areas on the edge of the channel.

15.4.5. The sample from borehole **WA2011_BH5**, which is likely to be later in date, was generally similar. However, there are indications of both a saltmarsh environment seen from the seeds of seablite (*Suaeda maritima*) and a more marine influenced environment seen from the fragments of *Tellina/Scrobicularia* type shells. Common bulrush (*Typha latifolia*) can be found in slightly saline environments, with lesser bulrush (*Typha angustifolia*) recorded as replacing the former with increasing salinity, and both species being ousted by common reed (*Phragmites australis*) in more saline environments (Grime *et al.* 1988, 582-2). The presence of seeds of common nettle (*Urtica dioica*), bramble (*Rubus* sp.), rushes (*Juncus* sp.) and possible seeds of buttercup (*Ranunculus* sp.) probably point to patches of localised scrub and marshy grassland.

15.5. References

Grime J. P, Hodgson J. G, Hunt R. 1988. Comparative plant ecology:a functional approach to common British species. London: Unwin Hyman

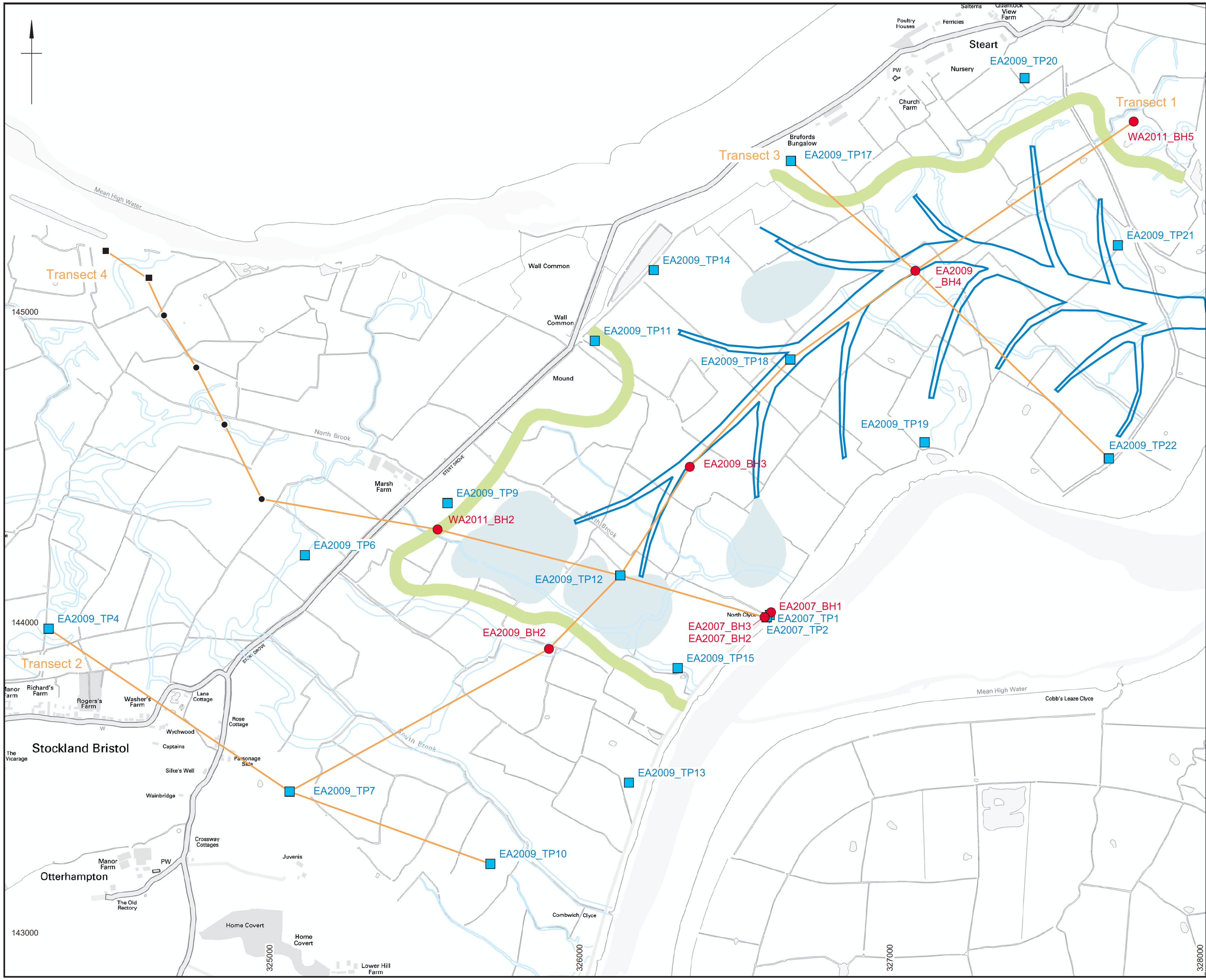
Kerney, M., 1999, Atlas of the Land and Freshwater Molluscs of Britain and Ireland.

Stace, C, 1997, New flora of the British Isles (2nd edition), Cambridge: Cambridge University Press. Colchester: Harley Books.

Teschner, M. 1995, Effects of salinity on the life history and fitness of Daphnia magna: variability within and between populations. Hydrobiologia 307: 33-41.

	Borehole WA2011_	BH2	BH2	BH2	BH2	BH5
	Depth top	4.86	4.75	8.95	9.48	7.92
	Depth base	4.86	4.85	9.05	9.58	8.02
	Depth top mOD	0.58	0.69	-3.51	-4.04	-2.19
	Depth base mOD	0.58	0.59	-3.61	-4.14	-2.29
	Flot size	10ml	5ml	25ml	10ml	5ml
	Original Volume	?ltr	1ltr	1ltr	1ltr	1ltr
Species	**Common Name**					
Chara sp.	stonewort	1	6	-	-	1
Equisetum sp. stem	horsetails	-	-	-	-	cf.1
Ranunculus subgen Ranunculus	buttercup	-	-	-	-	cf.1
Ranunculus baudotii	brackish water crowfoot	-	2	-	-	-
Urtica dioica	common nettle	-	1	-	-	1
Chenopodium glaucum/rubrum	oak-leaved/red goosefoot	2	5	-	-	-
Atriplex sp.	orache	-	-	-	-	1
Suaeda maritima	sea-blite	-	-	-	-	2
Rubus sp.	bramble	-	-	-	-	1
Myriophyllum spicatum	spiked water-milfoil	-	1	-	-	-
Potamogeton sp.	pondweed	-	+	-	-	-
Potamogeton cf. *pectinatus*	fennel-leaved pondweed	+	9+1c	-	-	-
Zannichellia palustris	horned pondweed	-	1	-	-	-
Juncus sp. (cf. *gerardii*)	saltmarsh rush	+	-	-	-	-
Juncus sp.	sharp rush	-	-	-	-	cf.2
Schoenoplectus tabernaemontani	grey club-rush	-	cf.7	-	-	-
Typha latifolia/angustifolia	bulrush	-	-	-	-	1
Stem culms		+	-	-	-	-
Other Waterlogged		-	-	-	-	-
Cristatella mucedo	bryozoa statoblast	1	-	-	-	-
Daphnia magna (type)	Water flea	-	10+	-	-	-
Molluscan		-	-	-	-	-
Hydrobia ventrosa		++	-	-	-	-
Hydrobia ulvae		++	-	-	-	-
Hydrobia sp.		+	+	+	-	+
Ovatella myosotis/Leucophytia bidentata		-	-	+	-	-
Tellina/Scrobicularia type		-	-	-	-	+
Other		-	-	-	-	-
Porifera	sponges	+++	+	-	-	-
Insects		-	-	-	-	+
Fish bones and scale		-	++	-	-	-

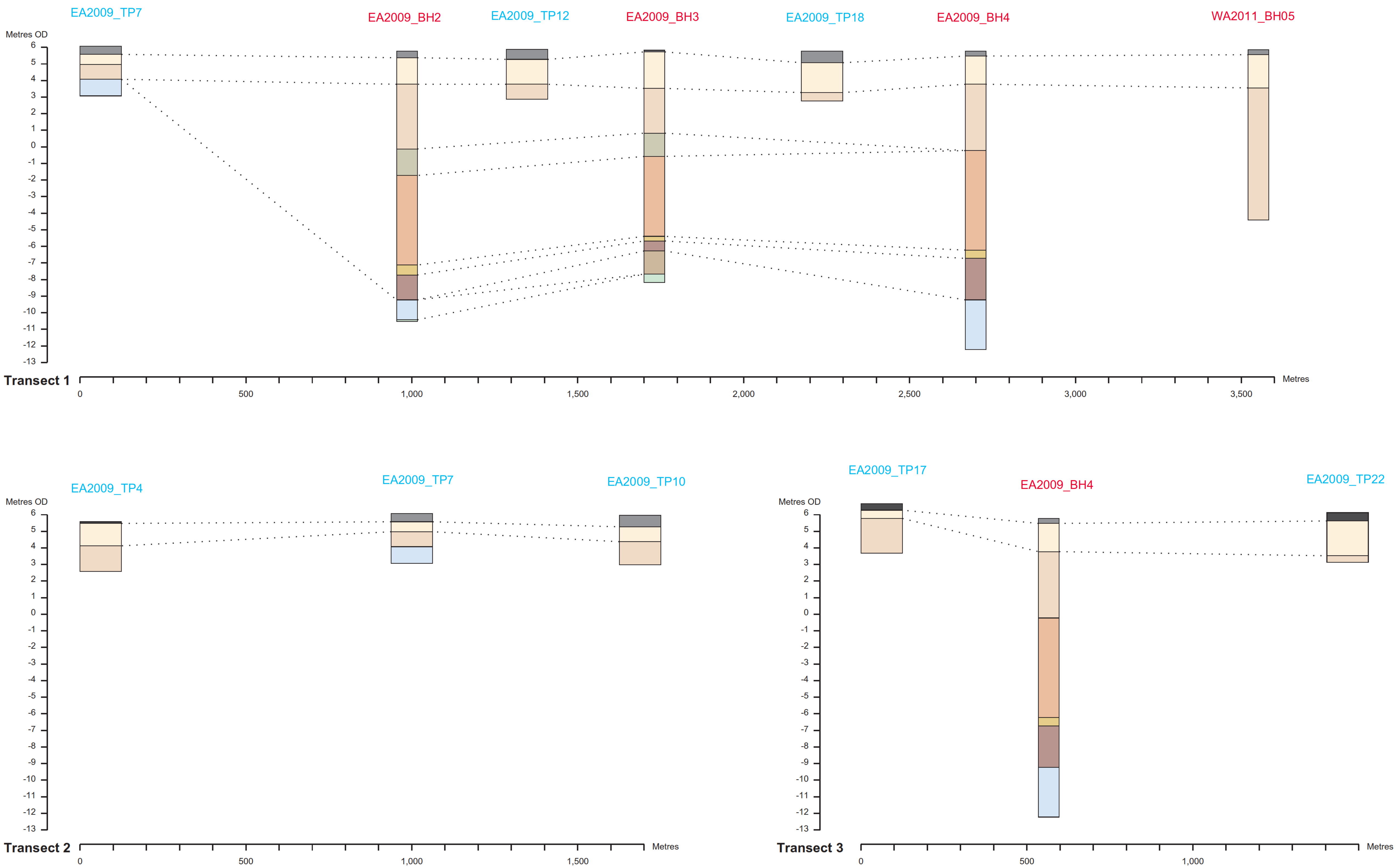
Table 1. Waterlogged Plant Remains, Molluscs and other environmental material



Revision Number:	0
Illustrator:	LJC/KJF
Date:	16/05/12
Scale:	1:125,000 @ A3
Path:	Y:\PROJECTS\77221\Drawing Office\Report Figs\Geotech\12_05_14

Site, transect, borehole and test pit location

Figure 1



Sedimentary Units

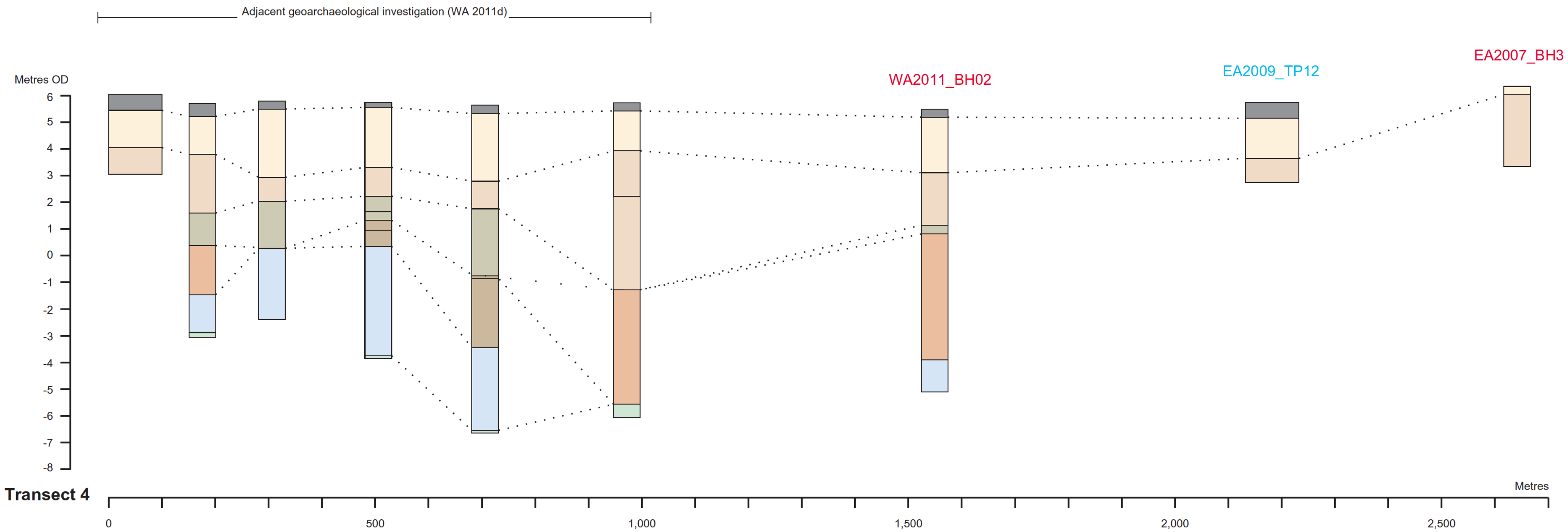
Unit Ai - Gravel beach	Unit Bi - Alluvial gley soil	Unit D - Estuarine alluvium	Unit G - Fluvial gravel
Unit Aii - Modern gley soil	Unit Bii - Estuarine alluvium	Unit E - Peat	Unit H - Pleistocene clay/sand
Unit Aiv - Made ground	Unit C - Peat and alluvium	Unit F - Alluvium	Unit J - Jurassic Bedrock

Wessex Archaeology

Date:	16/05/12	Revision Number:	0
Scale:	1:250 vertical, 1:12,500 horizontal	Illustrator:	KJF
Path:	Y:\PROJECTS\77221\Drawing Office\Report Figs\Geotech\12_05_14		

Transects 1, 2 and 3

Figure 2



Sedimentary Units

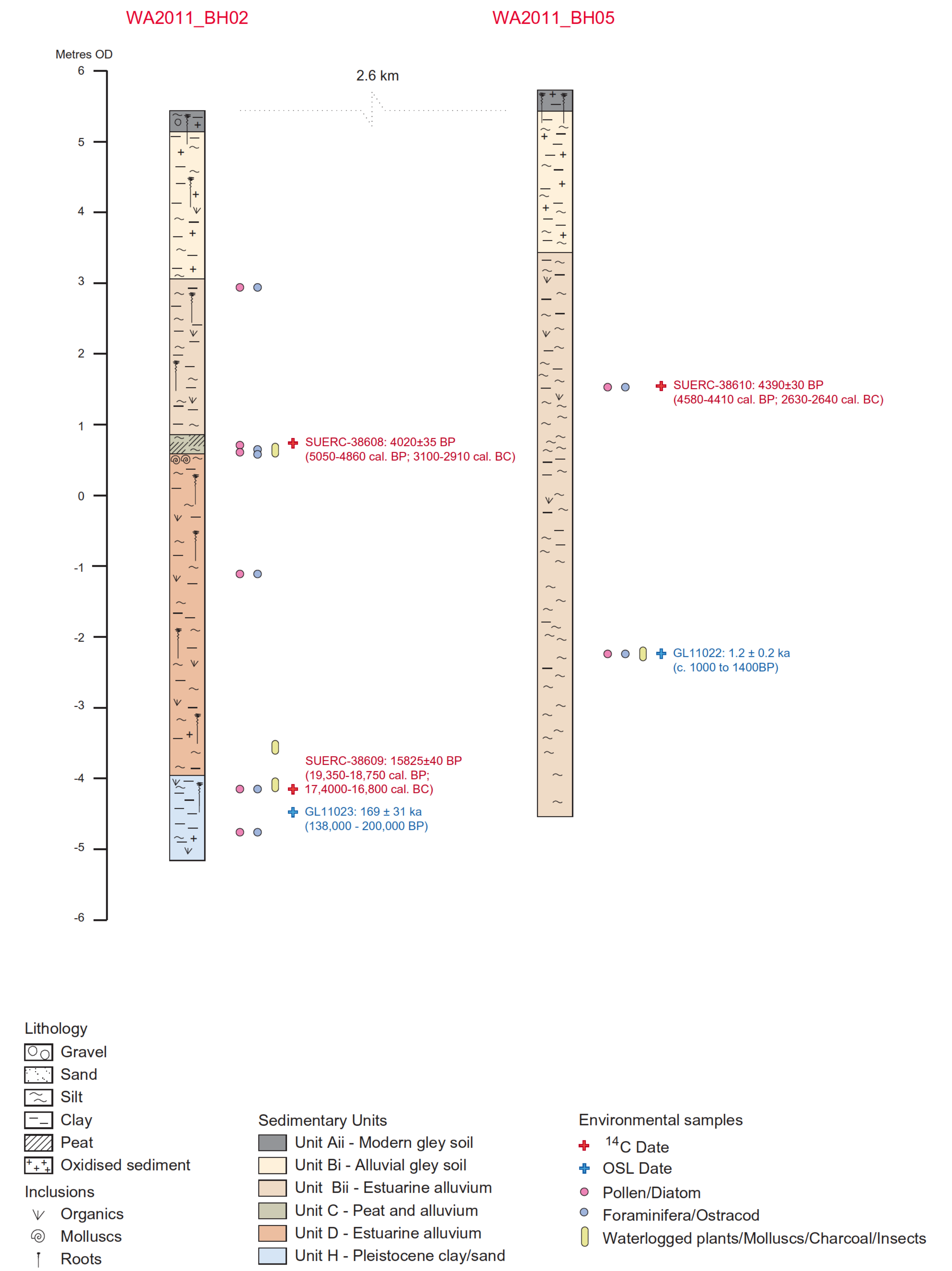
- Unit Ai - Gravel beach
- Unit Aii - Modern gley soil
- Unit Bi - Alluvial gley soil
- Unit Bii - Estuarine alluvium
- Unit C - Peat and alluvium
- Unit D - Estuarine alluvium
- Unit E - Peat
- Unit F - Alluvium
- Unit G - Fluvial gravel
- Unit H - Pleistocene clay/sand
- Unit J - Jurassic Bedrock

Wessex Archaeology

Date:	16/05/12	Revision Number:	0
Scale:	1:200 vertical, 1:10,000 horizontal	Illustrator:	KJF
Path:	Y:\PROJECTS\77221\Drawing Office\Report Figs\Geotech\12_05_14		

Transect 4

Figure 3



Date:	15/05/12	Revision Number:	0
Scale:	vertical 1:80 horizontal 1:40,000	Illustrator:	LJC/KJF
Path:	Y:\PROJECTS\77221\Drawing Office\Report Figs\Geotech\12_05_14		

Wessex Archaeology

Boreholes WA2011_BH02 and WA2011_BH05 sediments, scientific dating and palaeoenvironmental assessment samples

Figure 4

WESSEX ARCHAEOLOGY LIMITED.
Registered Head Office: Portway House, Old Sarum Park, Salisbury, Wiltshire SP4 6EB.
Tel: 01722 326867 Fax: 01722 337562 info@wessexarch.co.uk
Regional offices in **Edinburgh**, **Rochester** and **Sheffield**
For more information visit **www.wessexarch.co.uk**