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**LOWER OTTER VALLEY
RESTORATION PROJECT:
GEOARCHAEOLOGICAL
DESK-BASED
ASSESSMENT**

Prepared for Jacobs
Engineering Group Inc.

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SUMMARY

A geoarchaeological desk-based assessment of geotechnical records and British Geological Survey (BGS) records in the Lower Otter Valley, Devon, was carried out as part of the proposed Restoration Project. Lithological data were taken from these records and transferred to a RockWorks 15 database for interpretation and analysis of lithostratigraphic cross sections.

The Triassic bedrock, Helsby Sandstone Formation, is found between +0.20m OD (3m bgl) and -8.69m OD (9.7m bgl) in BH1 and CP9, respectively. It is unconformably overlain by Devensian river sands and gravels that are found between +0.48m OD (0.37m bgl) and -6.03m OD (9.7m bgl) in TP3 and CP11, respectively; the former is located in the north of the study area and the latter in the south on the estuary. Intertidal and alluvial aggradation has laid down fine grained deposits that include peat and organic strata. They are found between +1.25m OD in TP6 where they outcrop and -0.33m OD in CP11. In the latter they attain a thickness of 5.7m. Made Ground tops the stratigraphic sequence.

Peat deposits of high palaeoenvironmental potential are found in BH1 and below the historic landfill site. The deposits lie between +0.82m OD in BH1 and +1.43m OD TPE13. The thickness of the peat in TPE13 is at least 1.20m, and in BH1 it is 0.80m. The proposed road bridge for South Farm Road and associated section of the tidal creek is located between these peat deposits and it is considered likely that they will be affected by the Restoration Project works.

Organic strata of moderate palaeoenvironmental potential (1.70m thick) that may represent in situ saltmarsh is found in CP11 at -4.53m OD within the vicinity of the proposed pedestrian footbridge and it is considered likely that they will be affected by the works.

There is no evidence that the proposed tidal creek will affect high potential strata except in the vicinity of the road bridge.

No other proposed interventions are expected to affect the moderate or high potential deposits.

1 INTRODUCTION

1.1 Project background

1.1.1 This report is a geoarchaeological desk-based assessment (DBA) of a proposed Restoration Project for the Lower Otter Valley in Devon (henceforth 'the project'), carried out on behalf of Jacobs Engineering Group Inc. and their clients the Environment Agency. The present report has been compiled using geological data held by the British Geological Survey (BGS) and from a prior geotechnical examination of the study area carried out by Structural Soils Ltd (Freshwater and O'Farrell 2017). The research leading to the production of the present report was undertaken between 6th and 17th June 2019.

1.1.2 The sections of the report are arranged as follows: Section 1 provides essential background to the project, i.e. the geographic and geological situation of the site, and the aims of the present work. Section 2 outlines the methodology employed in collecting and utilising the geological data. The lithostratigraphy of the study area is presented and interpreted in Section 3, while Section 4 assesses the significance of the lithological data recovered in relation to the aims that have been set. A bibliography and appendices providing the locations and stratigraphy of the geological records that were used complete the report.

1.1.3 The study area (

Figure 1 and Figure 2) has been defined as a rectangular area that extends from borehole SY08SE7 located on the sandstone hillside just east of the River Otter and south of Otterton, to the coastline and mouth of the River Otter in the south (a distance of c. 3km); and from the B3178 trunk road in the west to the hillside where South Farm, Otterton Park and Catson Hill are located, c. 0.7km to the east.

1.1.4 The Project proposes to increase the area occupied by an intertidal habitat on the lower floodplain of the River Otter. This will compensate for the loss of similar habitat on the River Exe Estuary because of new flood defences there. Work is designed to reinstate a tidal creek and intertidal environment via realignment of Budleigh Brook and the excavation of a new tidal channel. Various infrastructure works will also be necessary including the breaching of old flood defences (Little and Big Banks); the building of a road bridge and a pedestrian bridge; and the widening of the connecting channel to the sea (Lower Otter Restoration Project 2019).

1.1.5 The Project comprises the following works that may affect the valley sediments (pers. comm. Nathan Thomas, Senior Archaeologist at Jacobs Engineering Group Inc. 12/06/19:¹)

- Create a 200m wide breach in Little Bank with trackway and drains c.200m x 4m x 0.3m.
- Create a 150m wide breach in Big Bank with trackway and drains c.150m x 4m x 0.3m.
- Realign Budleigh Brook removing it from a raised aqueduct.
- Rechannelling Budleigh Brook in the north of the study area to create a tidal creek network down the valley.
- Access bridge over the realigned Budleigh Brook to remain with modification of existing concrete.
- Realign South Farm Road on an embankment with a bridged opening: 30m span with abutments and two concrete piers 5m x 2m x undefined depth.
- Create a breach through the River Otter estuary embankment with a pedestrian bridge (c. 70m in length) over the breach: 4 x 400mm diameter steel sleeved reinforced concrete augered piles to depth of -10m OD.
- Existing tidal approach channel to be widened and deepened.
- Excavate the Tidal Creek from its junction with the realigned Budleigh Brook in the north of the study area to its confluence with the River Otter and egress to the English Channel at Lyme Bay: to a maximum of 70m wide and to a depth of -0.5m OD.
- Removal of the eastern extent shingle bar spit and widening of the estuary mouth by 30m.

1.2 Location, topography and geology

1.2.1 The study area occupies the flood plain of the River Otter NGR SY 07619 84902 south of Otterton and opposite Catson Hill in the north, to the coastline at NGR SY 07472 81972, a distance of c. 3km and an area of c. 1.2km² (

¹ A list of plan and section drawings consulted can be found in Appendix 1

Figure 1 and Figure 2). The elevation varies from +0.7m OD to +3.6m OD on Made Ground (Freshwater and O'Farrell 2017, 2), otherwise the flood plain surface has very little elevation rising to c. +1.1m in the region of Big Bank. As a consequence, drainage ditches are a frequent feature which enables agricultural pasture of the land. The Otter Estuary Nature Reserve (a Site of Special Scientific Interest) is located on the river in the east of the valley. The coast at Budleigh Salterton is part of the designated World Heritage Site (WHS), the Jurassic Coast (Jurassic Coast World Heritage Site Partnership 2014). The significance of the WHS and the relationship to the Restoration Project for the Lower Otter Valley is discussed in Jacobs (forthcoming).

- 1.2.2 RSK Environment Ltd carried out an archaeological watching brief on machine and hand-dug Trial Pits (TP1 – TP9; and HOP1 – HOP6) in 2017 and concluded that there was no evidence for *in situ* archaeological deposits. Nor was evidence found for post- medieval shipyard and wharfs for which there is documentary reference (Adams 2017, 15). A search of the archaeological literature (OASIS and PastScape) revealed no significant archaeology within the study area. However, it should be noted that the trial pitting exercise provided an extremely narrow window of opportunity across the landscape in which to identify archaeological activity and there does remain the potential for the presence of previously unrecorded archaeological remains across portions of the study area.
- 1.2.3 The British Geological Survey (BGS) map the bedrock of the study area as Helsby Sandstone Formation, dated to the Anisian Age (242 – 247Ma) of the Middle Triassic Period (BGS 2005; 2016; 2013). The lithology is a fine- to medium-grained sandstone which weathers to sand close to the surface. Overlying the bedrock on the low hills either side of the valley are River Terrace Deposits located from c. 5m OD to c. 60m OD. Minor deposits of Head are recorded in subsidiary valleys (BGS 2019a).
- 1.2.4 The bedrock in the Lower Otter Valley is unconformably overlain by a number of superficial deposits that date to the Quaternary Period (2.6Ma to the present). At the mouth of the River Otter and along the coastline Marine Beach and Storm Beach Deposits are mapped. These are chaotically bedded, coarse grained sands and pebbles associated with a high energy environment. Immediately north finer grained sediments are present: Saltmarsh Deposits and Tidal River Or Creek Deposits. Their lithology is clay, silt and sand with intercalated organic matter which may include peat. These

sediments are typically deposited in a low energy environment characterised by a dendritic planform of creeks draining tidal flats. Tidal River Or Creek Deposits are mapped on the Otter Estuary and trace the narrow confines of the River Otter north to Big Bank. The Saltmarsh Deposits occupy the wide valley floor adjacent to the river and are also mapped to Big Bank. Further north Alluvium is mapped and most likely underlies the other superficial deposits. This is indicative of freshwater deposition and a suite of deposits from Devensian gravels to sand, silt and clay, generally laid down in an upward fining sequence within which intercalated peats may also occur.²

- 1.2.5 Made Ground (Undivided) is mapped in the study area as: the Little and Big Banks; berms on the west bank (the SW coastal path) of the River Otter; along the west of the valley; and a triangular parcel of land (c. 3.8ha of historic landfill (Figure 2)) adjoining South Farm Road. The land surface has been raised in all these areas.

1.3 Aims

The aims of the DBA are to:

- 1.3.1 Determine the extent, nature and genesis of Quaternary sedimentation within the study area;
- 1.3.2 Assess the archaeological and palaeoenvironmental potential of Quaternary strata present within the study area;
- 1.3.3 Assess the likely impact of the development on strata of high-moderate archaeological and palaeoenvironmental potential; and
- 1.3.4 Make recommendations for further geoarchaeological works necessary to further test Aims 1.3.1 – 1.3.3 above.

2 METHODOLOGY

- 2.1 Data for the geoarchaeological DBA have been derived from the following sources:

- The BGS 1:50,000 and 1:10,000 maps (BGS 2005; 2013, 2016; 2019a);
- The BGS borehole record (BGS 2019b);

² The Quaternary Period has two epochs: the Pleistocene (2.6 million years ago to 11,700 years ago) and the Holocene (11,700 to present day). The Devensian is the last glaciation to affect the British Isles, c. 70,000 – 11,700 years ago with one effect being the deposition of fluvial gravels.

- A search of Historic England's Intertidal and Coastal Peat database, PastScape, and OASIS;
 - Geotechnical work carried out by Structural Soils Ltd. This comprised of four cable percussion with rotary follow-on boreholes BH1 – BH4; 11 cable percussion boreholes CP1 – CP11; six hand dug Trial Pits HOP1 – HOP6; 35 machine dug trial pits TP1 – TP12 and TPE1 – TPE23; and three window sample boreholes WS1, WS2 and WS4.
- 2.2 Eight published borehole records are available in the BGS borehole database, however, this includes three wells, two of which have no lithological data. None of these boreholes were located on the flood plain and all, except for two (SY08SF20 and SY08SF21), record the sandstone bedrock at ground level. In total there are 20 borehole and 41 trial pit records.
- 2.3 Lithological descriptions and positional data from the geotechnical investigations and the BGS borehole database were combined within a RockWorks database (RockWare 2013). The lithological unit descriptions of the geotechnical and BGS records were then interpreted in an informal terminology that attempts to highlight the organic preservation, although not at a loss of geological information, while at the same time remaining succinct. The RockWorks software package was then used to plot the cross sections and elevation map of the peat (7 Figures). Location data for all records utilised in the compilation of this report are presented in Appendix 2, while lithological interpretations are given in Appendix 3.
- 2.4 The keys to the lithostratigraphic section drawings are designed to highlight the state of oxidation of the strata and hence the likelihood of the preservation of organic matter: an orangish brown colour denoting oxidation and poor or no preservation, whereas reduced strata is greyish blue and preservation can be expected to be good. Since the primary data are drillers' logs, which are highly detailed, it is deemed appropriate that the original lithological descriptions be quoted in the text (3 Results). All interpretations have been made by the author of this DBA.

3 RESULTS

- 3.0.1 In the following discussion the lithology and stratigraphy of the study area are described. Brief interpretations of the deposits are

presented throughout prior to an overarching assessment in Section 4.

3.0.2 The borehole lithologies from the study area were classified into formal and informal units for the purpose of stratigraphic description. The stratigraphic units identified from youngest to oldest are:

1. Modern Made Ground
2. Fine grained mineral and organic deposits (Holocene alluvium and intertidal deposits including saltmarsh and peat)
3. Sand and gravel deposits (Late Pleistocene river deposits)
4. Triassic Bedrock (weathered Helsby Sandstone Formation)

These units are described in stratigraphic order from the oldest to the youngest in the following Section (see Figure 1 and Figure 2 for borehole and trial pit locations).

3.1 Helsby Sandstone Formation

3.1.1 The Helsby Sandstone Formation is recorded in 14 boreholes (out of 20): BH1 – BH4; and CP1, CP2, CP4 – CP11 (Figure 3, Figure 4 and Figure 5). It is found between +0.20m OD (3m bgl) and -8.69m OD (9.7m bgl) in BH1 and CP9 respectively. BH1 is located c. 100 m west of the proposed road bridge on South Farm Road on the western limit of the floodplain and CP9 is located further south on the floodplain.

3.1.2 The lithology is described as very dense, dark reddish brown slightly sandy, sub-angular fine to coarse sandstone gravel; sand is fine to coarse. It is classified by Freshwater and O'Farrell (2017) as residual Helsby Sandstone Formation, that is to say the weathered top of the formation and overlies cemented strata.

3.1.3 The Helsby Sandstone Formation is unconformably overlain by superficial gravels and sands in all the boreholes except in BH1 where peat is recorded.

3.2 Sands and Gravels

3.2.1 Superficial deposits of sands and gravels are recorded in 15 boreholes and three trial pits: BH2 – BH4; CP1 – CP11; WS1 and TP1 – T3 (Figure 3, Figure 4 and Figure 5). The deposits sub-crop

against the bedrock and are found between +0.48m OD (0.37m bgl) and -6.03m OD (9.7m bgl) in TP3 and CP11 respectively. TP3 is located in the north of the floodplain c. 440m south of Big Bank, and CP11 is located c. 50m west of the proposed pedestrian bridge.

3.2.2 The lithology of the deposits is varied. The strata are unconsolidated and can be loose to very densely packed. It is generally brown or brownish grey to brownish red or orangish brown in colour as a result of the oxidised sand fraction. Where sand is lacking the clasts are described as multi-coloured. Flint and sandstone including black sandstone lithologies are recorded. The clasts exhibit a sub-angular to well-rounded morphology and range in size from fine to cobble grade (4 – 256mm). The generic description of ‘mixed lithologies’ is used on occasion. The sand can be fine to coarse grade (0.125 – 2mm) and there are rare occasions where it is mottled white. The strata grade from sand with occasional gravel clasts to sandy gravels where the gravel component is primary. The thickness of the deposit is between 1.60m (CP5) and 6.20m (CP9) and on average is 2.83m.

3.2.3 The sand and gravel deposits are overlain by fine grained intertidal deposits.

3.3 Fine grained mineral and organic deposits

3.3.0.1 The fine grained deposits are defined here as composed of clay and silt grade particles with occasional fine sand and shell fragments. Material composed of decaying plants can be present within the strata and is described in the logs as either ‘peat’, where the fibrous or pseudo fibrous texture typical of the material is noted; or ‘organic matter’ in which case the adjective ‘decaying’ is amended and no textural descriptive given. Where roots or wood are recorded they are classified here as organic matter. Considering the importance of *in situ* peat beds for the interpretation of past vegetation histories the deposits of peat and organic matter will be discussed separately below.

3.3.0.2 Fine grained deposits are present in all the boreholes and 30 trial pits (TP1 – TP12, TPE2 – TPE5, TPE8 – TPE16, TP18, and TP20 – TPE23) (Figure 3, Figure 4 and Figure 5). The deposits are found between +1.25m OD in TP6 where they outcrop and -0.33m OD in CP11 where they lie at 4m bgl buried by deposits of Made Ground.³ TP6 is located c. 300m south of South Farm Road in the middle of

³ Boreholes SY08SE22 and 21 lie further south but are in a marginal location as regards the project interventions and therefore CP11 is described instead.

the floodplain. CP11 lies c. 50m west of the proposed pedestrian bridge in the south of the study area. Except where overlain by Made Ground, the fine grained deposits outcrop across the floodplain. They range in thickness from 0.37m in TP3 to 5.7m in CP11. Of 12 borehole locations where fine grained deposits outcrop, and the thickness of the deposit is delimited by the presence of underlying gravels, the average thickness is 3.86m.

- 3.3.0.3 The deposits are often but not always oxidised in the top fraction to a depth of c. 0.90 – 1.70m, and coloured brown to orangish brown. Below the water table in the anoxic zone, grey and greyish blue coloured deposits are found.

3.3.1 Peat

Peat is recorded in two boreholes and six trial pits: BH1 and CP9; TPE12, TPE13, TPE15, TPE16, TPE18 and TP23 (Figure 4, Figure 5 and Figure 6). The locations of the trial pits are restricted to the area adjoining the southern side of South Farm Road (the historic landfill site), and in the case of BH1 c. 100m west of the proposed road bridge. The deposit is found between +0.72m OD (2.00m bgl) in TPE12 and +1.43m OD (1.00m bgl) in TPE13. It varies in thickness from 0.10m in both TPE16 and TPE23, and 1.20m in TPE13. At only two locations the peat is thicker than 0.20m: BH1 where it is 0.80m thick with a sub-crop elevation of +0.82m OD and lies on sand; and TPE13 where it is at least 1.20m thick with a sub-crop elevation of +1.43m OD (the trail pit was terminated at +0.33m OD (2.10m bgl)). In TPE13 the description of the peat is:

‘Soft greyish brown sandy fibrous PEAT. Sand is fine to medium. Strong organic odour.’

At BH1 the description is:

‘Dark blackish grey slightly sandy amorphous PEAT. Sand is fine to coarse. . . . from 2.20m to 2.40m peat is pseudo-fibrous.’

CP9, located in the southwest of the floodplain c. 500m from the coastline, has an ambiguous record of amorphous peat that sub-crops at -0.49m OD: the material graphic legend on the log sheet does not record peat but rather the silty sand matrix of the deposit. It is described as:

‘Very loose dark brown mottled dark grey slightly silty fine SAND with rare white shell fragments (<5mm diameter) and black amorphous peat.’

Pockets of peat are also recorded at a deeper level. An *in situ* peat bed is not believed to be present in CP9.

3.3.2 Organic matter

Organic matter is recorded in eight boreholes and 15 trial pits: BH2, BH3, CP6, CP10 – CP11, WS1, SY8SE20, SY8SE21; and TP8, TP9, TP12, TPE2 – TP5, TP8 – TPE11, TPE14, TPE20 – TPE22 (Figure 3, Figure 4 and Figure 5). It is recorded as part of the stratum in the following manner, for example in TPE2:

‘Soft brownish grey slightly sandy organic CLAY with abundant black decomposed vegetation. Sand is fine to coarse with coarse sand sized shell fragments. Organic odour noted.’

The strata containing organic matter lie between +1.42m OD (1.4m bgl) in WS1 and -0.17m OD (1.30m bgl) in TP12. WS1 is located on the eastern edge of the floodplain immediately north of South Farm Road, and TP12 is located c. 150m further west. The organic matter is very varied in the amount found within the strata. In TPE21, for example, it is rare:

‘Soft grey silty CLAY with rare black decomposing vegetation and an organic odour.’

In comparison to the peat, strata with organic matter is recorded not only where peat is also found, but also across the southern half of the floodplain from the location of CP10 c. 360m north of South Farm Road to the BGS borehole SY08SF20 located c. 150m from the coastline. Only two records of wood were made: as fragments (3 x 5mm) in TP9 and SY8SE21. There are rare records of pockets of peat or peat inclusions within mineral strata, for example, in sand in CP9 at -0.49m OD, and in oxidised sandy silt in CP10 at +0.32m OD. These peat particles are not *in situ* but derived from elsewhere on the floodplain. Roots are recorded in TP12, WS1 and TPE20 which may imply an erosion of earlier peat deposits. There is a record from CP11 in the vicinity of the proposed pedestrian footbridge of possible saltmarsh deposits that are described as follows:

‘Soft locally thinly laminated dark grey sandy CLAY with occasional pseudo-fibrous peat and black laminations. Sand is fine.’

The stratum sub-crops at -4.53m OD and is 1.70m thick.

3.4 Made Ground

3.4.1 Made Ground deposits occur in five boreholes and 29 trial pits: BH1, CP11, WS1 – WS4; HOP1 – HOP6 and TPE1 – TPE23 (Figure 3, Figure 4 and Figure 5). It outcrops above the geological strata and is between 1.0m and 4.0m thick in TPE13 and CP11 respectively. A variety of mineral clasts are recorded including coal, flint, sandstone, slate and quartz. Man-made materials include brick, glass, metal and plastics. A concentration of the deposit is found on the historic landfill site adjoining South Farm Road. At the borehole locations Made Ground is described variously as gravel, sand, silt or clay in which artefacts are rare or absent.

4 ASSESSMENT

4.1 Extent, nature and genesis of Quaternary sediments

4.1.1 Within the study area Triassic sandstone forms a heavily weathered basement to the Quaternary sediments of the ancient River Otter Valley. The sandstone bedrock (Helsby Sandstone Formation) outcrops at BGS boreholes SY08SE7 and SY08SE49. The former is located on the hillside east of the River Otter and the latter further south, also on the hillside in the east.

4.1.2 The Triassic bedrock is unconformably overlain by basal river gravels (sand and gravels) aggraded by the action of braided channels of the ancient River Otter in a periglacial environment most probably during the Late Devensian (Marine Isotope Stage 2, 15–10ka) and in part reworked by marine processes.⁴ The lithology of the deposit is primarily flint and sandstone gravels with subordinate sand and is in the order of 3m thick.

4.1.3 At the end of the Pleistocene, climatic amelioration brought about a stabilisation of the land surface and an end to channel gravel aggradation. Colonisation by plants reduced the supply of sediment and stream flow energy fell as a result of milder winters and the shift from surface to ground water drainage succeeding the melting of the permafrost. A high water table and propensity to flood promoted the eventual formation of fresh water marshes and peat accumulation. Before the building of sea defences the rising sea level would subject the Otter meander floodplain to daily tidal

⁴ In the Structural Soils geotechnical report the sands and gravels are classified as Beach Deposits: true beach deposits are located only on the valley coastline.

flooding inland as far as Otterton and the subsequent formation of salt marsh. Transgressing storm beach sands would probably lead at times to the damming of the river and the formation of brackish lagoons. Fine grained intertidal deposits would therefore develop over the earlier alluvium.

4.1.4 Peat beds are found at seven locations of which there are two locations where thickness may be judged: BH1 c. 100m west of the proposed road bridge where the peat is 0.8m thick; and TPE13 in the west of the historic landfill site, where it is at least 1.20m thick (Figure 5 and Figure 6). All the peat locations are concentrated just south of South Farm Road and in the general vicinity of the proposed road bridge and the associated section of the proposed tidal creek. The peat sub-crops below Made Ground at +0.72m OD. The occurrence of roots in three localities possibly indicates that peat beds have in the past been eroded away. The rare occurrence of peat particles within mineral strata is the result of the meandering river reworking the flood plain deposits. It is notable that gravels occur very close to the ground surface in TP3 in the north of the study area that implies a lack of stratigraphic space in this area to accommodate peat beds. However, there are insufficient data to affirm that peat does not occur north of the South Farm Road.

4.1.5 Salt marsh is by its nature an ephemeral ecosystem and is rarely preserved in the geological record. The organic matter recorded in fine grained strata may indicate the preservation of saltmarsh or, on the other hand, it is redeposited allochthonous material derived from earlier peat beds further upstream. Sets of fine bands of black organic mud characteristic of salt marsh would be expected to be reported and this is the case in CP11 in the vicinity of the proposed pedestrian footbridge where black laminae are preserved at -4.53m OD (Figure 4).

4.2 Archaeological and palaeoenvironmental potential of the study area

4.2.1 The sand and gravel deposits, although undated, are deeply buried in the south of the study area and were probably laid down in cold conditions inhospitable to the presence of man. Human groups were intermittently present during Devensian interstadials (White and Pettitt 2012; Pettitt *et al.* 2012) and the exploitation of river gravel is a possibility. Nonetheless, since the sampling of these deposits can only be achieved by borehole coring the potential to recover archaeological or palaeoenvironmental information must be LOW.

4.2.2 The floodplain fine grained deposits date to the Holocene and have a LOW archaeological potential on account of the propensity for flooding and the fact that there is no archaeological evidence to suggest permanent occupation. Even though late prehistoric sites and worked flints have been identified on the elevated land on the valley sides (for example, flint scatter at between 10 and 15m OD on the western side (Devon and Dartmoor HER, record MDV59858), and a polished Neolithic axe found at 40m OD on The Warren, to the east (PastScape monument number 448650)), the potential for evidence of activity in the valley remains low based on the current geoarchaeological results.

4.2.3 The palaeoenvironmental potential of the peat deposits are HIGH. Other deposits that contain organic matter have a MODERATE palaeoenvironmental potential.

4.3 Impact of the Project

4.3.1 The following are the proposed interventions of the Project as listed in Section 1.1.5 with the potential effect they will have on the valley sediments, with particular emphasis on high potential peat deposits.

4.3.2 *Create a 200m wide breach in Little Bank. No effect on the valley sediments.* Trackway and bordering drains c. 200m x4m x0.3m will affect topsoil and underlying oxidised sediments only.

4.3.3 *Create a 150m wide breach in Big Bank. No effect on the valley sediments.* Trackway and bordering drains c.150m x4m x0.3m will affect topsoil and underlying oxidised sediments only.

4.3.4 *Realign Budleigh Brook removing it from a raised aqueduct. No effect on the valley sediments.*

4.3.5 *Rechannelling Budleigh Brook to create a tidal creek network down the valley.* In the north of the study area (Little Bank and Big Bank) there is no evidence of the presence of organic sediments, however, this assessment is based on the data recovered from only five trial pits. The presence of sand and gravel high in the stratigraphy suggests that fine grained strata are limited in thickness. Organic sediments may be preserved in ancient meander cut offs and back swamp environments on the valley floor; none have been identified. Therefore, the effect of excavating a new channel on significant organic sediments in the north is low.

- 4.3.6 *Access bridge over the realigned Budleigh Brook to remain with modification of existing concrete. No effect on the valley sediments.*
- 4.3.7 *South Farm Road to be realigned on an embankment with a bridged opening: 30m span with abutments and two concrete piers 5m x 2m x undefined depth. The proposed bridge is located between two significant deposits of peat: BH1 c. 100m west and TP13 a similar distance to the southeast on the historic landfill site. The relationship between the two peat deposits is unclear, however there is evidence to suggest that they are independent; TP10 c. 50m to the east of BH1 has no peat (base is +0.31m OD) and no organic sediments were recovered in CP3, located between BH1 and TP13, immediately south of the proposed bridge and within the course of the proposed tidal creek. These borehole and trial pits are not sufficient reason to ignore the likelihood of encountering peat at the location of the proposed works. It is possible that peat associated with TP13 to the east of the proposed road bridge, rather than that found at BH1, does impinge on the location of the bridge. The depth of the proposed tidal creek channel below the bridge is +0.10m OD; the depth of the piers is presumed to be deeper. BH1 has 0.8m of peat sub-cropping at +0.82m OD and TP13 has 1.20m of peat with a sub-crop elevation of +1.43m OD. These elevations suggest that peat deposits of high palaeoenvironmental potential are likely to be affected by intrusive work excavating the proposed channel and constructing bridge supports.*
- 4.3.8 *Create a breach through the River Otter estuary embankment with a pedestrian bridge (c. 70m in length) over the breach: 4 x 400mm diameter steel sleeved reinforced concrete augered piles to depth of -10m OD. No significant peat deposits are recorded in the nearest borehole (CP11) to the proposed bridge, however, salt marsh deposits exist at -4.53m OD. This deposit has a moderate palaeoenvironmental potential and is likely to be affected by the deep piles of the footbridge.*
- 4.3.9 *Existing tidal approach channel to be widened and deepened. There is no borehole data for the tidal approach channel. Evidence from CP11 located c. 75m southwest of the head of the channel records salt marsh deposits at -4.53m. Deposits at this depth will not be affected by the proposed work.*
- 4.3.10 *Excavate the tidal creek from its junction with the realigned Budleigh Brook in the north of the study area to its confluence with the River Otter and egress to the English Channel at Lyme Bay; to a maximum of 70m wide and to -0.5m OD. The effect of the work in the north of*

the study area has been discussed in Section 4.3.5; and in the location of the proposed road bridge in Section 4.3.7.

South of South Farm Road beyond the area of the historic landfill site there are no high potential organic deposits recorded. The excavation of the channel will affect the oxidised superficial stratigraphy and may impinge on deposits of organic matter (e.g. CP4 and CP9) of moderate palaeoenvironmental potential.

4.4 Recommendations

The conclusion of this report is that there are moderate to high potential deposits that could be affected by the proposed project and the following mitigation work is therefore recommended: the recovery of sealed, intact, core samples using a rotary drilling rig from locations in the vicinity of the proposed road bridge and the proposed pedestrian footbridge.

5 ACKNOWLEDGEMENTS

ARCA would like to thank the following people for their help with this project: Nathan Thomas of Jacobs Engineering Group Inc.; and Dr Eleanor Standley of the University of Oxford.

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7 FIGURES

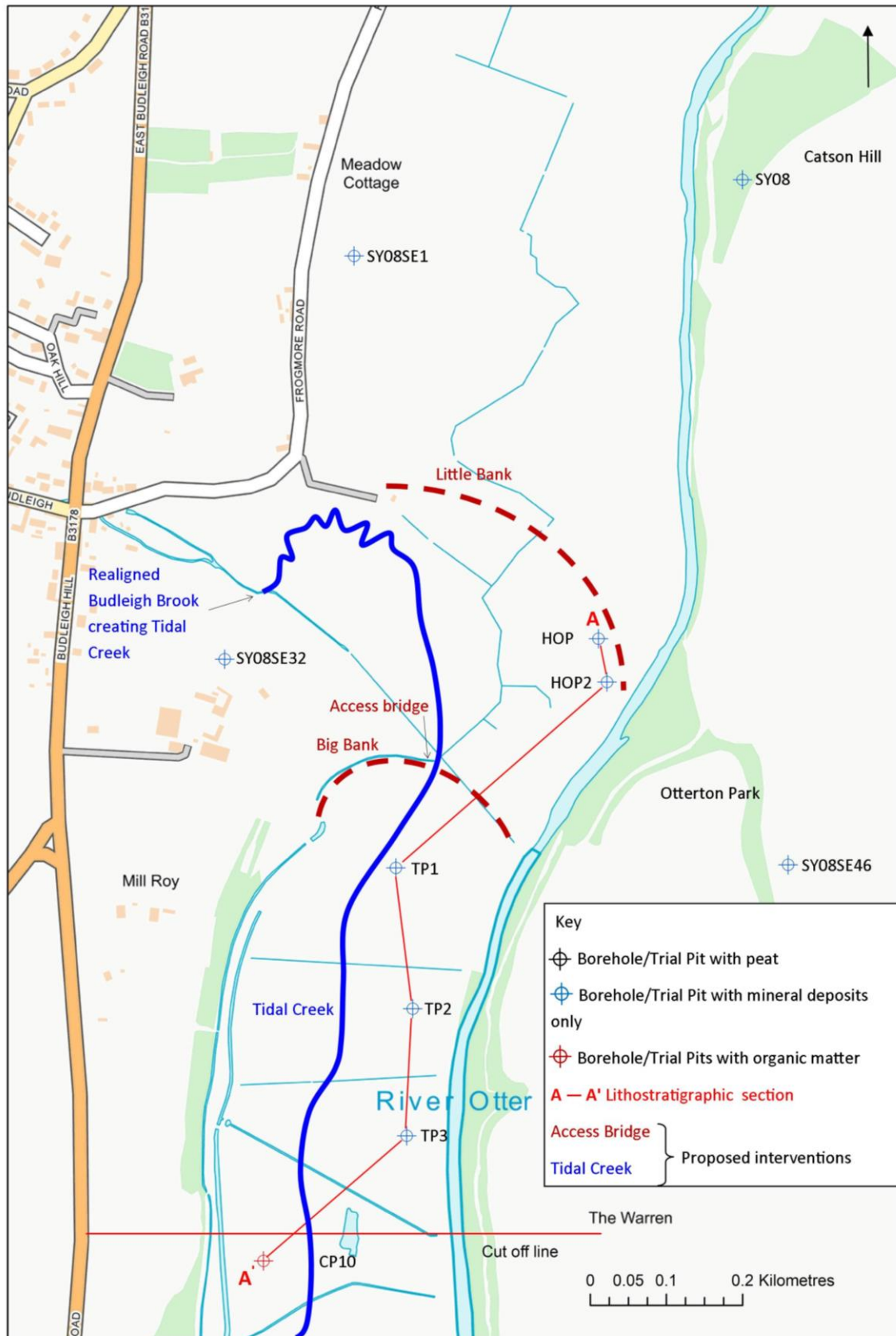


Figure 1. Location map of the north of the study area.

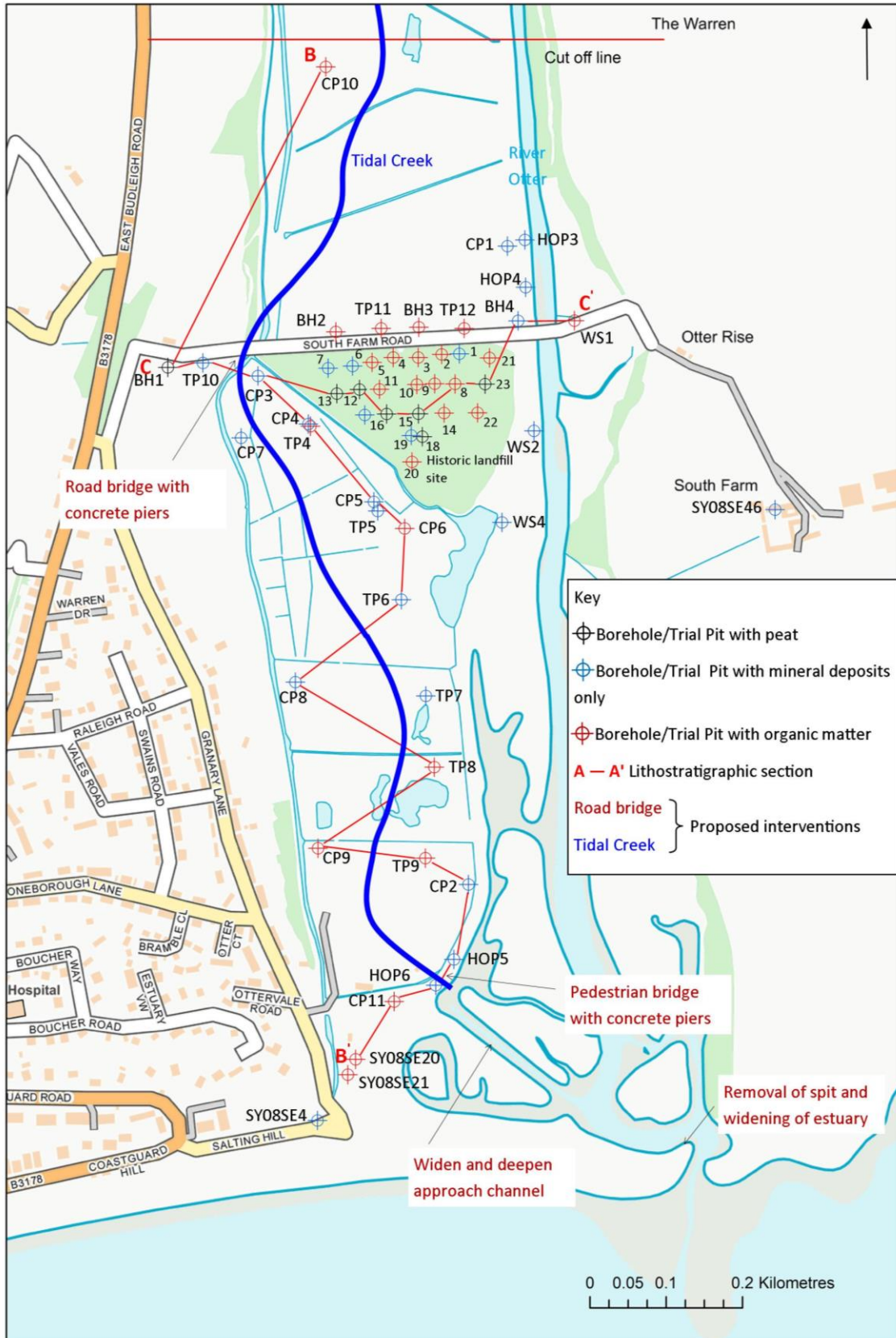


Figure 2. Location map of the south of the study area.

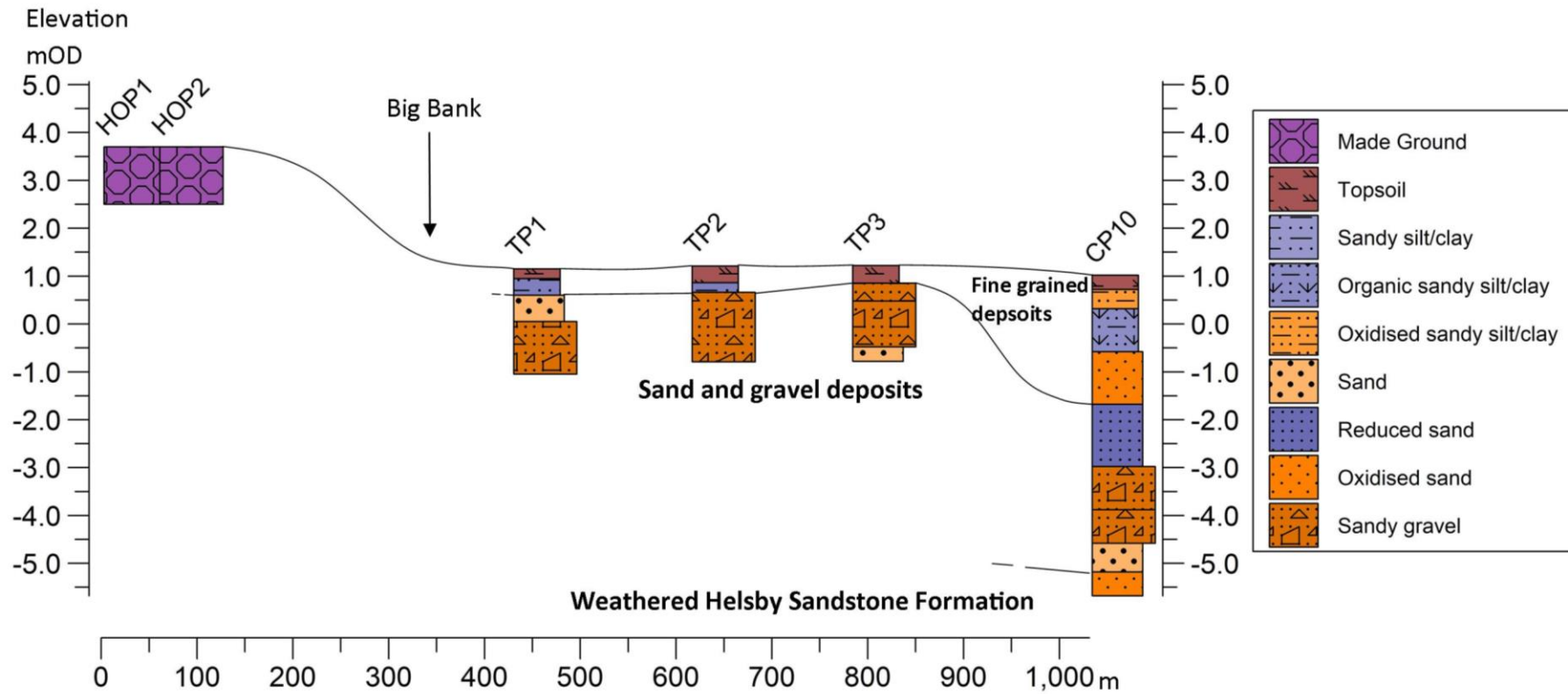


Figure 3. North to south lithostratigraphic cross section in the north of the study area. Vertical exaggeration x50.

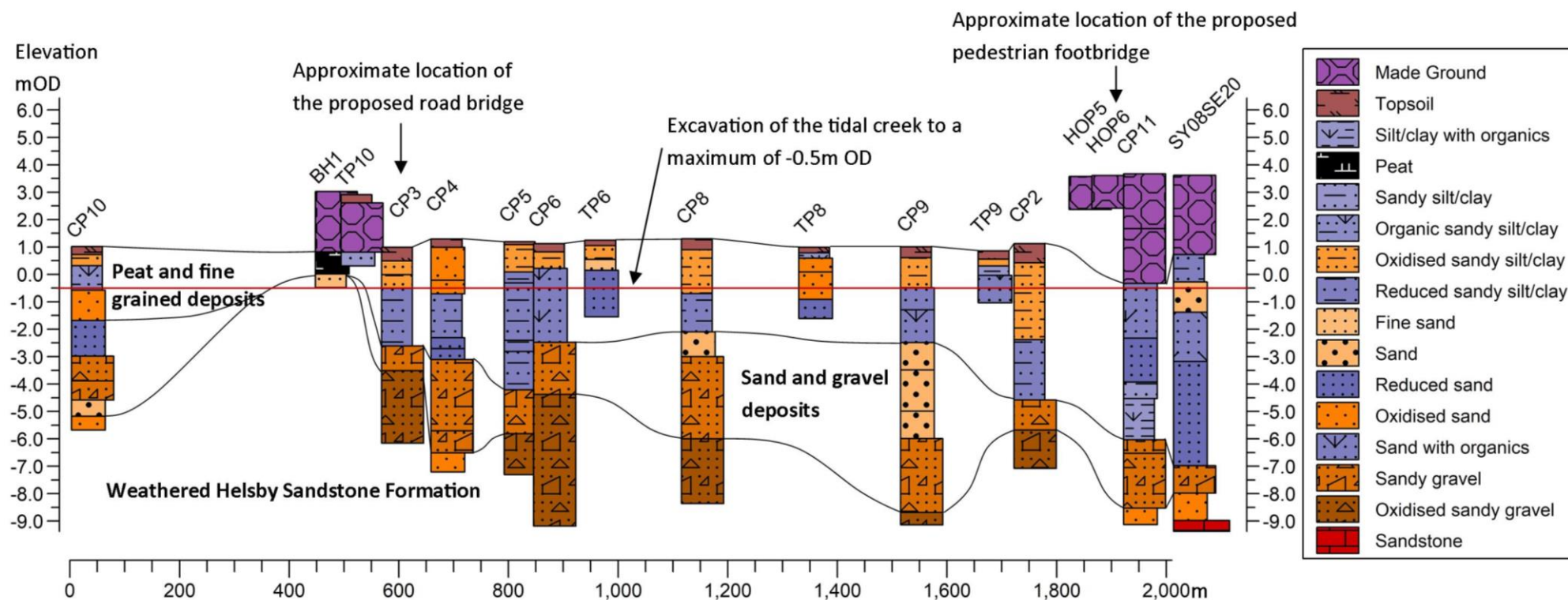


Figure 4. North to south lithostratigraphic cross section in the south of the study area. Vertical exaggeration x50. Note: the location of BH1 is on the west margin of the valley where the bedrock rises compared to CP10 which is on the valley floor.

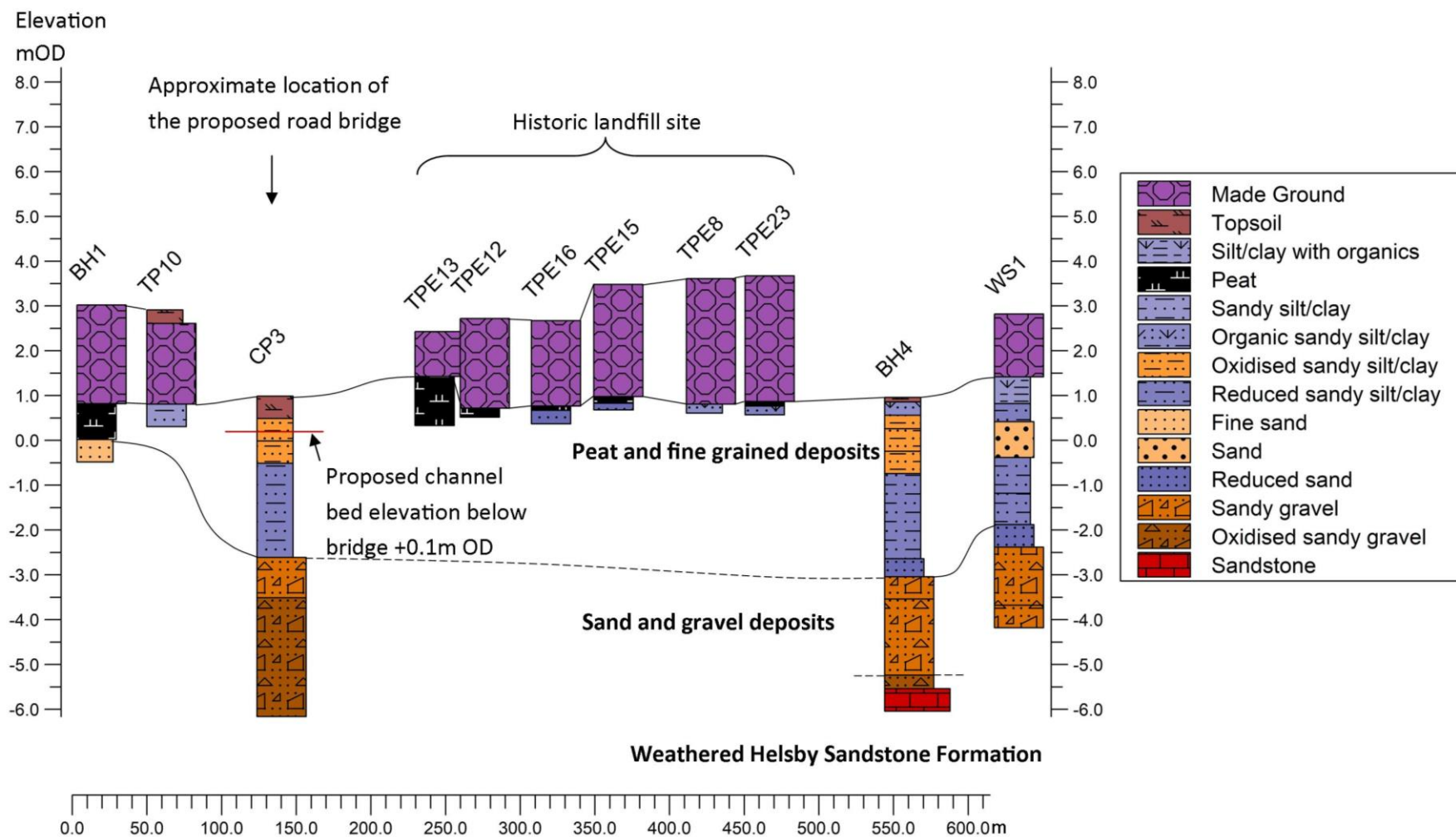


Figure 5. West to east lithostratigraphic cross section. Vertical exaggeration x30. Note: proposed channel depth does not include thickness of riprap erosion protection.

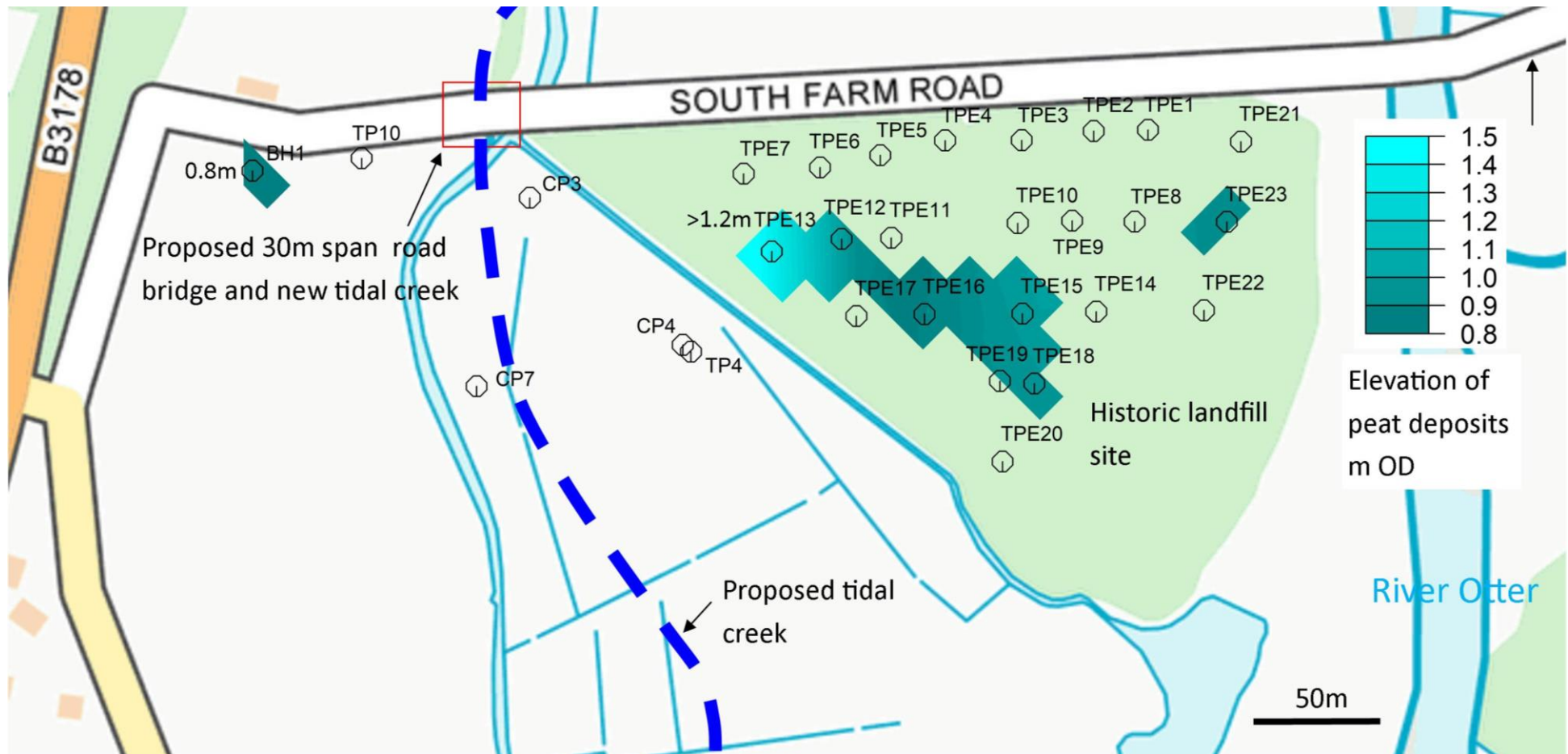


Figure 6. Map of the elevation of the peat deposits. Thickness is noted in BH1 and TPE13.

APPENDIX 1 DRAWINGS CONSULTED

All drawings provided by Jacobs Engineering Group Inc.

ENVIMSW002045-CH2-000-200-DR-C-0001
ENVIMSW002045-CH2-000-400-DR-CI-0002
ENVIMSW002045-CH2-000-400-DR-C-0004
ENVIMSW002045-CH2-000-400-DR-C-0005
ENVIMSW002045-CH2-000-400-DR-C-0006
ENVIMSW002045-CH2-000-400-DR-C-0007
ENVIMSW002045-CH2-000-200-DR-C-0008
ENVIMSW002045-CH2-000-200-DR-C-0020
ENVIMSW002045-CH2-000-200-DR-C-0021
ENVIMSW002045-CH2-000-400-DR-C-0022
ENVIMSW002045-CH2-000-400-DR-C-0023
ENVIMSW002045-CH2-000-400-DR-C-0024
ENVIMSW002045-CH2-000-400-DR-C-0025
ENVIMSW002045-CH2-000-400-DR-C-0026
ENVIMSW002045-CH2-000-400-DR-C-0028

APPENDIX 2 BOREHOLE AND TRIAL PIT LOCATIONS

Borehole	Easting	Northing	Elevation	TD
BH1	307003.8	82986.2	3.02	3.00
BH2	307224.2	83032.7	0.75	6.50
BH3	307333	83038.8	1.19	7.80
BH4	307463.4	83047	0.96	7.00
CP1	307449.4	83144.9	0.99	8.47
CP2	307397.5	82309.4	1.12	8.20
CP3	307122.2	82974.7	0.99	7.15
CP4	307187.5	82912	1.29	8.50
CP5	307273.6	82810.2	1.19	8.50
CP6	307314.4	82775.3	1.12	10.30
CP7	307099.5	82894.4	0.95	7.45
CP8	307170.6	82574.3	1.3	9.66
CP9	307200.8	82356.5	1.010	10.15
CP10	307211	83379.7	1.020	6.70
CP11	307300.8	82155.7	3.670	12.80
TP1	307384.6	83896.2	1.150	2.20
TP2	307406.5	83711.3	1.210	2.00
TP3	307399.4	83543.8	1.220	2.00
TP4	307191	82909.1	1.310	3.00
TP5	307278.8	82797.7	1.190	3.00
TP6	307310.2	82682	1.250	2.80
TP7	307342.4	82556.3	1.070	2.30
TP8	307353.2	82462.7	0.990	2.60
TP9	307341.7	82343.6	0.860	1.90
TP10	307050.4	82991.5	2.910	2.60
TP11	307283.6	83037.3	0.950	2.30
TP12	307392.3	83037.3	1.130	2.50
TPE1	307386.1	83003.6	3.100	2.00
TPE2	307362.9	83003.1	3.040	2.30
TPE3	307332.2	82999.2	2.800	2.40
TPE4	307299.5	82999.1	2.500	1.60
TPE5	307271.8	82992.8	2.290	1.50
TPE6	307246.1	82987.6	2.100	1.50
TPE7	307213.5	82984.9	2.150	2.00
TPE8	307380.4	82964.5	3.610	3.00
TPE9	307353.7	82964.9	3.740	3.20
TPE10	307330.5	82963.9	3.490	3.20
TPE11	307276.5	82957.6	2.750	3.00
TPE12	307255.3	82957.1	2.720	2.20
TPE13	307225.5	82951.8	2.430	2.10
TPE14	307364	82926.2	3.480	2.60

TPE15	307332.5	82925.3	3.480	2.80
TPE16	307290.7	82925.1	2.670	2.30
TPE17	307261.6	82924.3	2.690	1.20
TPE18	307337.6	82895.5	3.060	2.60
TPE19	307322.9	82896.6	2.970	2.60
TPE20	307324	82862.3	2.790	2.30
TPE21	307425.8	82998.6	3.430	2.40
TPE22	307410	82926.7	3.800	3.10
TPE23	307419.8	82964.4	3.670	3.10
HOP1	307651	84197.2	3.700	1.20
HOP2	307662	84140	3.700	1.20
HOP3	307471.5	83153.2	3.150	1.20
HOP4	307473.4	83091.3	3.110	1.20
HOP5	307378.7	82210.6	3.570	1.20
HOP6	307354.7	82177	3.610	1.20
WS1	307537	83047.5	2.820	7.00
WS2	307484.3	82903.3	3.050	5.00
WS4	307442.1	82782.7	3.620	5.00
SY08SE7	307840	84800	22.500	1.00
SY08SE1	307330	84700	4.000	8.00
SY08SE32 well	307160	84170	12.000	No data
SY08SE46 well	307900	83900	No data	No data
SY08SE49 well	307800	82800	8.910	1.00
SY08SE21	307240	82060	3.74	13.00
SY08SE20	307250	82080	3.620	13.00
SY08SE4 TH1 and TH3	307200	82000	15	8.38

APPENDIX 3 BOREHOLE AND TRIAL PIT STRATIGRAPHY

Structural Soils 2017 and BGS 2019 (comments in italics are the author's)

Bore	Top	Base	Lithology	Comments
BH1	0.00	2.20	Made Ground	Made Ground.
BH1	2.20	3.00	Peat	Dark blackish grey slightly sandy amorphous PEAT. Sand is fine to coarse. (SALTMARSH DEPOSITS) . . . from 2.20m to 2.40m peat is pseudo-fibrous.
BH1	3.00	3.50	Fine sand	Weathered Helsby Sandstone Formation. (Weathering persistent at great depth). End of BH at 24.6m
BH2	0.00	0.30	Topsoil	
BH2	0.45	0.70	Oxidised sand	Dark greyish brown to brown silty fine to medium SAND. (SALTMARSH DEPOSITS)
BH2	0.70	1.20	Sand with organic clay	Dark brownish grey to brown silty fine to medium SAND with pockets of organic clay. (SALTMARSH DEPOSITS)

BH2	1.20	2.00	Oxidised sand	Loose orangish brown to greyish brown slightly gravelly fine to medium SAND. Gravel is subrounded to subangular fine mixed lithologies. (SALTMARSH DEPOSITS)
BH2	2.00	3.50	Oxidised sand	Loose orangish brown gravelly fine to coarse SAND with rare clayey/silty pockets. Gravel is angular to subrounded fine to medium sandstone, flint and mixed lithologies. (SALTMARSH DEPOSITS) . . . from 3.00m very gravelly.
BH2	3.50	6.00	Gravel	Mottled orangish brown sandy angular to subangular fine to coarse GRAVEL of sandstone, flint and mixed lithologies. Sand is medium to coarse. (BEACH DEPOSIT)
BH2	6.00	6.50	Sandstone	Weathered Helsby Sandstone Formation. (Weathering persistent at great depth). End of BH at 20.7m
BH3	0.00	0.40	Topsoil	

BH3	0.40	0.70	Organic sandy silt/clay	Firm dark brown to brown slightly sandy organic clayey SILT. Sand is fine. (SALTMARSH DEPOSITS)
BH3	0.70	1.10	Organic sandy silt/clay	Firm greyish brown sandy slightly gravelly organic clayey SILT. Sand is fine to medium. Gravel is subangular to subrounded fine to medium of mixed lithologies. (SALTMARSH DEPOSITS)
BH3	1.10	1.50	Sand with organics	Very loose brownish grey silty fine to medium SAND with a low to medium content of decomposed plant material. (SALTMARSH DEPOSITS)
BH3	1.50	3.60	Sand with organics	Very loose brownish grey slightly gravelly silty fine to medium SAND with a low content of decomposed vegetation. Gravel is subangular to subrounded fine to coarse flint. (SALTMARSH DEPOSITS) ...from 2.50m to 3.50m becomes very silty.

BH3	3.60	4.30	Gravelly sand with organics	Brownish grey silty very gravelly fine to medium SAND with a low content of decomposed vegetation. Gravel is subangular to subrounded fine to coarse flint. (SALTMARSH DEPOSITS)
BH3	4.30	7.30	Gravel	Medium dense reddish brown sandy subangular to subrounded fine to coarse GRAVEL of flint, with a low cobble content. Sand is medium to coarse. Cobbles are subangular to subrounded flint. (BEACH DEPOSIT)
BH3	7.3	7.8	Sandstone	Weathered Helsby Sandstone Formation. (Weathering persistent at great depth). End of BH at 25.0m
BH4	0.00	0.10	Topsoil	
BH4	0.10	0.40	Organic sandy silt/clay	Firm dark brown to brown slightly sandy CLAY with occasional roots. Sand is fine to medium. (SALTMARSH DEPOSITS)
BH4	0.40	0.70	Oxidised sandy silt/clay	Firm brown slightly sandy CLAY. Sand is fine to medium. (SALTMARSH DEPOSITS)
BH4	0.70	1.20	Oxidised sandy silt/clay	Reddish brown to brown sandy clayey SILT. Sand is fine. (SALTMARSH DEPOSITS)

BH4	1.20	1.70	Oxidised sandy silt/clay	Firm reddish brown slightly sandy silty CLAY. Sand is fine. (SALTMARSH DEPOSITS)
BH4	1.70	3.60	Reduced sandy silt/clay	Firm grey sandy SILT with occasional shell fragments. Sand is fine. (SALTMARSH DEPOSITS)
BH4	3.60	4.00	Reduced sand	Firm grey sandy slightly gravelly SILT. Sand is fine to coarse. Gravel is angular to subangular fine to medium of mixed lithologies. (SALTMARSH DEPOSITS)
BH4	4.00	4.50	Sandy gravel	Medium dense grey sandy slightly silty angular to subrounded fine to coarse GRAVEL of mixed lithologies (predominantly black sandstone). Sand is fine to coarse. (BEACH DEPOSIT)
BH4	4.50	6.20	Sandy gravel	Medium dense reddish brown to brown sandy slightly clayey angular to subrounded fine to coarse GRAVEL of mixed lithologies. Sand is medium to coarse. (BEACH DEPOSIT)

BH4	6.20	6.50	Oxidised sandy gravel	Dense reddish brown very sandy angular to subrounded fine to coarse GRAVEL of mixed lithologies. Sand is medium to coarse. (Reworked HELSBY SANDSTONE FORMATION)
BH4	6.50	7.00	Sandstone	Weathered Helsby Sandstone Formation. (Weathering persistent at great depth). End of BH at 21.0m
CP1	0.00	0.40	Topsoil	
CP1	0.40	0.70	Oxidised sandy silt/clay	Firm light brown sandy SILT. Sand is fine. (SALTMARSH DEPOSITS)
CP1	0.70	1.20	Oxidised sandy silt/clay	Firm reddish brown slightly sandy silty CLAY. Sand is fine. (SALTMARSH DEPOSITS)
CP1	1.20	3.00	Reduced sandy silt/clay	Firm locally soft brownish grey slightly sandy silty CLAY with frequent shells. Sand is fine. (SALTMARSH DEPOSITS)
CP1	3.00	4.00	Sandy gravel	Loose dark grey sandy silty subangular to rounded medium to coarse GRAVEL of flint. Sand is fine to coarse. (BEACH DEPOSIT)
CP1	4.00	4.90	Sandy gravel	Dense dark grey sandy subangular to rounded fine to coarse GRAVEL of flint. Sand is medium to

				coarse. (BEACH DEPOSIT)
CP1	4.90	6.80	Sandy gravel	Medium dense dark grey and locally reddish brown sandy subangular to rounded fine to coarse GRAVEL of flint. Sand is medium to coarse. (BEACH DEPOSIT) . . . from 4.90m becoming locally reddish brown.
CP1	6.80	8.47	Oxidised gravelly sand	Very dense reddish brown gravelly fine to medium SAND. Gravel is subangular fine to coarse sandstone. (Residual HELSBY SANDSTONE FORMATION)
CP2	0.00	0.70	Topsoil	
CP2	0.70	3.50	Oxidised sandy silt/clay	Very loose dark reddish brown slightly silty SAND. Sand is fine. (ALLUVIUM)
CP2	3.50	5.70	Reduced sandy silt/clay	Dark brownish grey sandy SILT, with rare shell fragments (<3mm dia). Sand is fine. (SALTMARSH DEPOSITS)

CP2	5.70	6.80	Sandy gravel	Medium dense dark greyish brown sandy slightly silty subangular to subrounded medium to coarse GRAVEL of siltstone and mudstone, with a low cobble content. Sand is fine to coarse. Cobbles are subangular siltstone and mudstone. (BEACH DEPOSIT)
CP2	6.80	8.20	Oxidised sandy gravel	Medium dense dark brownish grey very sandy subangular to subrounded fine to coarse GRAVEL of sandstone with medium cobble content. Sand is medium to coarse. Cobbles are subrounded sandstone. (Residual HELSBY SANDSTONE FORMATION) End of BH at 14.33
CP3	0.00	0.50	Topsoil	
CP3	0.50	1.00	Oxidised sandy silt/clay	Firm to stiff reddish brown slightly sandy silty CLAY. Sand is fine to medium. (SALTMARSH DEPOSITS)
CP3	1.00	1.50	Oxidised sandy silt/clay	Firm reddish brown slightly sandy silty CLAY. Sand is fine to medium. (SALTMARSH DEPOSITS)

CP3	1.50	3.60	Reduced sandy silt/clay	Firm dark greyish brown mottled white slightly sandy silty CLAY. Sand is fine. Occasional fine to medium white shell fragments. (SALTMARSH DEPOSITS)
CP3	3.60	4.50	Sandy gravel	Medium dense greyish brown sandy silty subrounded to rounded fine to coarse GRAVEL of mixed lithologies. Sand is medium to coarse. (BEACH DEPOSIT)
CP3	4.50	7.15	Oxidised sandy gravel	Medium dense reddish brown sandy slightly silty subrounded to rounded fine to coarse GRAVEL of mixed lithologies. Sand is medium to coarse. (BEACH DEPOSIT) . . . from 5.50m depth medium cobble content. Cobbles are subrounded of mixed lithologies. End of BH.
CP4	0.00	0.30	Topsoil	
CP4	0.30	1.50	Oxidised sand	Reddish brown silty fine SAND. (SALTMARSH DEPOSITS)
CP4	1.50	2.00	Oxidised sand	Very loose reddish brown silty fine to coarse SAND. (SALTMARSH DEPOSITS)

CP4	2.00	3.60	Reduced sandy silt/clay	Soft to firm dark grey and reddish brown very sandy SILT. Sand is fine. (SALTMARSH DEPOSITS)
CP4	3.60	4.00	Reduced sand	Very loose dark grey silty fine to coarse SAND with some shell fragments. (SALTMARSH DEPOSITS)
CP4	4.00	4.40	Reduced sand	Grey very silty fine SAND. (SALTMARSH DEPOSITS)
CP4	4.40	7.00	Sandy gravel	Medium dense grey very sandy angular to subrounded fine to coarse GRAVEL of flint, sandstone and siltstone, with a low cobble content. Sand is fine to coarse. Cobbles are subangular to subrounded sandstone and siltstone. (BEACH DEPOSIT)
CP4	7.00	7.80	Sandy gravel	Very dense grey sandy angular to subrounded fine to coarse GRAVEL of flint, sandstone and siltstone, with a low to medium cobble content. Sand is coarse. Cobbles are subangular to subrounded flint and sandstone. (BEACH DEPOSIT)

CP4	7.80	8.50	Oxidised sand	Very dense reddish brown silty fine to medium SAND. (Residual HELSBY SANDSTONE FORMATION). End of BH at 8.95m.
CP5	0.00	0.10	Topsoil	
CP5	0.10	1.10	Oxidised sandy silt/clay	Firm reddish brown sandy clayey SILT. Sand is fine. (SALTMARSH DEPOSITS)
CP5	1.10	1.50	Reduced sandy silt/clay	Firm dark grey sandy SILT with some shell fragments. Sand is fine. (SALTMARSH DEPOSITS)
CP5	1.50	3.60	Reduced sandy silt/clay	Very soft dark grey sandy SILT with some shell fragments. Sand is fine. (SALTMARSH DEPOSITS)
CP5	3.60	4.00	Reduced sandy silt/clay	Loose dark grey silty fine to medium SAND with some shell fragments. (SALTMARSH DEPOSITS)
CP5	4.00	5.40	Reduced sandy silt/clay	Soft grey slightly sandy silty CLAY. Sand is fine. (SALTMARSH DEPOSITS)
CP5	5.40	7.00	Sandy gravel	Medium dense brown sandy subangular to rounded fine to coarse GRAVEL of quartz, sandstone and flint, with a low to medium cobble content. Sand is fine to

				coarse. Cobbles are subrounded flint and sandstone. (BEACH DEPOSIT)
CP5	7.00	8.50	Oxidised sandy gravel	Very dense brown very sandy subangular to rounded fine to coarse GRAVEL of quartz, sandstone and flint, with a low to medium cobble content. Sand is medium to coarse. Cobbles are subrounded flint and sandstone. (Reworked HELSBY SANDSTONE FORMATION). End of BH at 10.45m,
CP6	0.00	0.30	Topsoil	
CP6	0.30	0.90	Oxidised sandy silt/clay	Soft brown very silty fine SAND. (SALTMARSH DEPOSITS)
CP6	0.90	3.60	Sand with organics	Soft grey very silty fine SAND with occasional black decomposing vegetation and shells and occasional clayey pockets. (SALTMARSH DEPOSITS)

CP6	3.60	5.50	Sandy gravel	Medium dense becoming dense grey very sandy silty subangular to rounded fine to coarse GRAVEL of flint, quartz and sandstone, with low cobble content. Sand is medium to coarse. Cobbles are subangular to rounded flint and sandstone. (BEACH DEPOSIT)
CP6	5.50	10.30	Oxidised sandy gravel	Very dense reddish brown very sandy subangular to subrounded fine to coarse GRAVEL of sandstone. Sand is medium to coarse. (Residual HELSBY SANDSTONE FORMATION). End of BH at 10.5m.
CP7	0.00	0.30	Topsoil	
CP7	0.30	1.50	Oxidised sandy silt/clay	Soft reddish brown sandy silty CLAY. Sand is fine. (SALTMARSH DEPOSITS)
CP7	1.50	2.50	Oxidised sandy silt/clay	Very soft reddish brown slightly sandy silty CLAY. Sand is fine. (SALTMARSH DEPOSITS)
CP7	2.50	3.30	Reduced sandy silt/clay	Grey very silty fine SAND with occasional shell fragments. (SALTMARSH DEPOSITS)

CP7	3.30	4.90	Reduced sandy silt/clay	Soft grey slightly sandy SILT. Sand is fine. (SALTMARSH DEPOSITS)
CP7	4.90	5.50	Sandy gravel	Loose brown sandy angular to subrounded fine to coarse GRAVEL of flint. Sand is fine to coarse. (BEACH DEPOSIT) . . . at 5.30m water recovered was black in colour.
CP7	5.50	6.85	Sandy gravel	Dense brown sandy angular to subrounded fine to coarse GRAVEL of flint. Sand is fine to coarse. (BEACH DEPOSIT)
CP7	6.85	7.45	Oxidised sand	Very dense reddish brown slightly clayey medium SAND. (Residual HELSBY SANDSTONE FORMATION). End of BH at 7.45m.
CP8	0.00	0.40	Topsoil	
CP8	0.40	2.00	Oxidised sandy silt/clay	Soft reddish brown sandy SILT with rare shells and roots (up to 5mm diameter). Sand is fine. (SALTMARSH DEPOSITS)
CP8	2.00	3.40	Reduced sandy silt/clay	Soft brownish grey slightly sandy SILT with frequent shells and decomposing vegetation. Sand is fine. (SALTMARSH DEPOSITS)

CP8	3.40	4.30	Sand	Medium dense brownish grey very gravelly medium to coarse SAND. Gravel is subangular to subrounded fine to medium sandstone. (BEACH DEPOSIT)
CP8	4.30	7.30	Sandy gravel	Medium dense becoming dense brown sandy rounded to subangular fine to coarse GRAVEL of flint, quartz and sandstone, with a low cobble content. Sand is medium to coarse. Cobbles are subrounded to subangular sandstone and flint. (BEACH DEPOSIT)
CP8	7.30	9.66	Oxidised sandy gravel	Very dense reddish brown slightly gravelly fine to medium SAND with a low cobble content. Gravel is subrounded fine to coarse sandstone. Cobbles are subrounded sandstone. (Residual HELSBY SANDSTONE FORMATION). End of BH.
CP9	0.00	0.40	Topsoil	
CP9	0.40	1.50	Oxidised sandy silt/clay	Dark orangish brown very silty fine SAND. (SALTMARSH DEPOSITS)

CP9	1.50	2.30	Sand with organics	Very loose dark brown mottled dark grey slightly silty fine SAND with rare white shell fragments (<5mm diameter) and black amorphous peat. (SALTMARSH DEPOSITS)
CP9	2.30	3.50	Sand with organics	Medium dense dark brown to greyish black slightly silty fine SAND with pockets of fine sand (<20mm diameter) and pockets of black plastic amorphous peat. (SALTMARSH DEPOSITS)
CP9	3.50	4.50	Sand	Medium dense light reddish brown to dark brown mottled white slightly gravelly fine to coarse SAND. Gravel is subangular fine sandstone. (BEACH DEPOSIT)
CP9	4.50	6.00	Sand	Dense light reddish brown to dark brown mottled white slightly gravelly fine to coarse SAND. Gravel is subangular fine sandstone. (BEACH DEPOSIT)

CP9	6.00	7.00	Sand	Light brown slightly gravelly slightly silty fine to coarse SAND with rare pockets of soft light grey clay. Gravel is subangular to rounded fine to medium flint. (BEACH DEPOSIT)
CP9	7.00	9.70	Sandy gravel	Very dense dark grey sandy subangular to subrounded medium to coarse GRAVEL of flint. Sand is fine to coarse. (BEACH DEPOSIT)
CP9	9.70	10.15	Oxidised sandy gravel	Very dense dark reddish brown slightly sandy subangular fine to coarse GRAVEL of sandstone. Sand is fine to coarse. (Residual HELSBY SANDSTONE FORMATION)
CP10	0.00	0.30	Topsoil	
CP10	0.30	0.70	Oxidised sandy silt/clay	Soft dark brown sandy clayey SILT with rare white shell fragments (<4mm diameter). Sand is fine. (SALTMARSH DEPOSITS)
CP10	0.70	1.60	Organic sandy silt/clay	Soft dark reddish brown mottled dark grey sandy SILT with frequent pseudofibrous peat inclusions. Sand is fine. (SALTMARSH DEPOSITS)

CP10	1.60	2.70	Oxidised sand	Very loose light to dark brown gravelly fine to coarse SAND. Gravel is subangular fine flint. (SALTMARSH DEPOSITS)
CP10	2.70	4.00	Reduced sand	Dark grey very gravelly silty fine to medium SAND. Gravel is subangular to subrounded fine to medium flint. (BEACH DEPOSIT)
CP10	4.00	4.90	Sandy gravel	Loose multicoloured (white, brown, grey, orange) sandy subangular to subrounded fine to medium GRAVEL of flint. Sand is medium to coarse. (BEACH DEPOSIT) ... becoming very sandy from 4.6m.
CP10	4.90	5.60	Sandy gravel	Very dense multicoloured COBBLES of subangular flint and sandstone, with much sandy subangular to subrounded fine to coarse GRAVEL of flint. Sand is medium to coarse. (BEACH DEPOSIT)
CP10	5.60	6.20	Sand	Reddish brown very gravelly fine to coarse SAND. Gravel is subangular fine flint and sandstone. (BEACH DEPOSIT)

CP10	6.20	6.70	Oxidised sand	Dense brownish red fine to coarse SAND. (Residual HELSBY SANDSTONE FORMATION). End of BH at 7.8m.
CP11	0.00	2.00	Made Ground	MADE GROUND: Grass over slightly gravelly silty fine to medium SAND with occasional rootlets. Gravel is subangular to subrounded fine to medium flint and sandstone.
CP11	2.00	4.00	Made Ground	POSSIBLE MADE GROUND: Dark brown slightly gravelly silty fine to medium SAND with occasional pockets of chalky sand (25mm in diameter). Gravel is subangular to subrounded fine to medium flint.
CP11	4.00	6.00	Sand with organics	Loose dark greyish brown slightly silty fine to medium SAND with rare subangular fine to medium gravel sized shell fragments. (SALTMARSH DEPOSITS) . . . at 5.00m rare pocket <10mm of pseudo fibrous peat.
CP11	6.00	7.60	Reduced sand	Loose dark grey very silty fine to medium SAND with rare white shell fragments (<4mm in

				diameter). (SALTMARSH DEPOSITS)
CP11	7.60	8.20	Sandy silt/clay	Very soft dark brown slightly sandy clayey SILT. Sand is fine. (SALTMARSH DEPOSITS)
CP11	8.20	9.70	Silt/clay with organics	Soft locally thinly laminated dark grey sandy CLAY with occasional pseudo-fibrous peat and black laminations. Sand is fine. (SALTMARSH DEPOSITS)
CP11	9.70	10.20	Sandy gravel	Dark brownish grey to white silty sandy subangular to subrounded fine to coarse GRAVEL of flint. Sand is fine to coarse. (BEACH DEPOSIT)
CP11	10.20	12.20	Sandy gravel	Medium dense dark to light grey very sandy subangular to rounded fine to coarse GRAVEL of flint. Sand is fine to coarse. (BEACH DEPOSIT)
CP11	12.20	12.80	Oxidised sand	Orangish brown gravelly fine to medium SAND. Gravel is subrounded fine to coarse flint. (Reworked HELSBY SANDSTONE

				FORMATION). End of BH at 14.72m.
TP1	0.00	0.20	Topsoil	
TP1	0.20	0.55	Reduced sandy silt/clay	
TP1	0.55	1.10	Sand	
TP1	1.10	2.20	Sandy gravel	
TP2	0.00	0.35	Topsoil	
TP2	0.35	0.55	Reduced sandy silt/clay	
TP2	0.55	2.00	Sandy gravel	
TP3	0.00	0.37	Topsoil	
TP3	0.37	0.74	Sandy gravel	
TP3	0.74	1.70	Sandy gravel	
TP3	1.70	2.00	Sand	
TP4	0.00	0.20	Topsoil	
TP4	0.20	0.50	Oxidised sandy silt/clay	
TP4	0.50	0.90	Reduced sandy silt/clay	
TP4	0.90	2.80	Fine sand	
TP4	2.80	3.00	Topsoil	
TP5	0.00	0.25	Topsoil	
TP5	0.25	1.70	Oxidised sandy silt/clay	
TP5	1.70	2.60	Fine sand	
TP5	2.60	3.00	Reduced sand	
TP6	0.00	0.20	Topsoil	
TP6	0.20	0.70	Oxidised sandy silt/clay	
TP6	0.70	1.10	Fine sand	
TP6	1.10	2.80	Reduced sand	

TP7	0.00	0.30	Topsoil	
TP7	0.30	0.60	Oxidised sandy silt/clay	
TP7	0.60	1.10	Oxidised sand	
TP7	1.10	2.30	Reduced sand	
TP8	0.00	0.20	Topsoil	
TP8	0.20	0.40	Silt/clay with organics	Dark brownish black sandy SILT with a high organic content. Sand is fine. Occasional pockets of black amorphous peat (~3mm length). (SALTMARSH DEPOSITS)
TP8	0.40	0.90	Oxidised sand	
TP8	0.90	1.90	Oxidised sand	
TP8	1.90	2.60	Reduced sand	
TP9	0.00	0.30	Topsoil	
TP9	0.30	0.55	Oxidised sandy silt/clay	
TP9	0.55	0.90	Silt/clay with organics	Dark brownish grey slightly sandy SILT. Sand is fine to medium. Frequent shell fragments and frequent organic matter, possible black rootlets (~5mm in length). (SALTMARSH DEPOSITS)
TP9	0.90	1.90	Sand with organics	Dark grey fine to medium SAND. Fragments of decomposing wood (3x5mm). (SALTMARSH DEPOSITS)
TP10	0.00	0.30	Topsoil	

TP10	0.30	2.10	Made Ground	MADE GROUND with sandy gravel clasts include brick and glass. (see Structural Soils)
TP10	2.10	2.60	Sandy silt/clay	Firm brownish grey mottled reddish brown and greyish brown slightly sandy gravelly SILT. Sand is fine to coarse. Gravel is angular to subangular fine to coarse mixed lithologies. (SALTMARSH DEPOSITS)
TP11	0.00	0.30	Topsoil	
TP11	0.30	1.30	Oxidised sandy silt/clay	
TP11	1.30	1.60	Reduced sand	
TP11	1.60	2.30	Oxidised sand	Orangish and greyish brown medium to coarse SAND. (SALTMARSH DEPOSITS)
TP12	0.00	0.30	Topsoil	
TP12	0.30	0.90	Oxidised sandy silt/clay	
TP12	0.90	1.30	Oxidised sand	
TP12	1.30	2.00	Sand with organics	Dark grey to grey very silty fine to medium SAND. Occasional to frequent roots and rootlets. (SALTMARSH DEPOSITS)
TP12	2.00	2.50	Reduced sand	
TPE1	0.00	2.00	Made Ground	
TPE2	0.00	2.20	Made Ground	

TPE2	2.20	2.30	Silt/clay with organics	Soft brownish grey slightly sandy organic CLAY with abundant black decomposed vegetation. Sand is fine to coarse with coarse sand sized shell fragments. Organic odour noted. (SALTMARSH DEPOSITS)
TPE3	0.00	0.30	Topsoil	
TPE3	0.30	2.25	Made Ground	MADE GROUND: Brown gravelly clayey fine to coarse SAND with a low cobble and boulder content. Gravel is subrounded to angular fine to coarse brick, concrete and broken pottery. Cobbles and boulders are angular concrete and brick (up to 600x500mm).
TPE3	2.25	2.40	Organic sandy silt/clay	Soft brownish grey slightly sandy organic CLAY with abundant decomposing vegetation. Sand is fine to medium. (SALTMARSH DEPOSITS) Trial pit terminated at 2.40m depth.
TPE4	0.00	1.55	Made Ground	
TPE4	1.55	1.60	Organic sandy silt/clay	Soft dark greyish brown sandy peaty SILT with abundant decomposing vegetation. Sand is fine to coarse.

				(SALTMARSH DEPOSITS)
TPE5	0.00	1.35	Made Ground	
TPE5	1.35	1.50	Silt/clay with organics	Soft dark brown organic CLAY with abundant decomposing vegetation. (SALTMARSH DEPOSITS)
TPE6	0.00	1.50	Made Ground	
TPE7	0.00	2.00	Made Ground	
TPE8	0.00	2.80	Made Ground	
TPE8	2.80	3.00	Organic sandy silt/clay	Soft grey slightly sandy silty CLAY with rare shells and frequent black decomposing vegetation. (SALTMARSH DEPOSITS) Trial pit terminated at 3.00m
TPE9	0.00	3.00	Made Ground	
TPE9	3.00	3.20	Organic sandy silt/clay	Dark grey slightly sandy organic clayey SILT with frequent black decomposing vegetation. Slight organic odour. (SALTMARSH DEPOSITS)
TPE10	0.00	2.90	Made Ground	
TPE10	2.90	3.20	Sand with organics	Soft dark grey silty fine SAND with frequent semi decomposed plant remains. (SALTMARSH DEPOSITS)

TPE11	0.00	2.20	Made Ground	
TPE11	2.20	3.00	Sand with organics	Dark bluish grey silty fine SAND with rare pockets of amorphous peat. (SALTMARSH DEPOSITS)
TPE12	0.00	2.00	Made Ground	
TPE12	2.00	2.20	Peat	Soft dark brown fibrous PEAT. Strong organic odour. (SALTMARSH DEPOSITS)
TPE13	0.00	1.00	Made Ground	
TPE13	1.00	2.10	Peat	Soft greyish brown sandy fibrous PEAT. Sand is fine to medium. Strong organic odour. (SALTMARSH DEPOSITS)
TPE14	0.00	2.50	Made Ground	
TPE14	2.50	2.60	Silt/clay with organics	Soft brown peaty CLAY with abundant organic matter. (SALTMARSH DEPOSITS)
TP15	0.00	2.50	Made Ground	
TPE15	2.50	2.65	Peat	Brownish black slightly sandy fibrous PEAT. Sand is fine to medium. (SALTMARSH DEPOSITS)
TPE15	2.65	2.80	Reduced sand	
TPE16	0.00	1.90	Made Ground	
TPE16	1.90	2.00	Peat	Soft blackish brown pseudo-fibrous PEAT. Strong organic odour.

				(SALTMARSH DEPOSITS)
TPE16	2.00	2.30	Reduced sand	
TPE17	0.00	1.20	Made Ground	
TPE18	0.00	2.20	Made Ground	
TPE18	2.20	2.40	Peat	Soft blackish brown clayey fibrous PEAT. (SALTMARSH DEPOSITS)
TPE18	2.40	2.60	Reduced sand	
TPE19	0.00	2.60	Made Ground	
TPE20	0.00	2.00	Made Ground	
TPE20	2.00	2.30	Sand with organics	Grey silty fine to medium SAND with rare shells and black decomposing roots. (SALTMARSH DEPOSITS)
TPE21	0.00	2.20	Made Ground	
TPE21	2.20	2.40	Silt/clay with organics	Soft grey silty CLAY with rare black decomposing vegetation and an organic odour. (SALTMARSH DEPOSITS)
TPE22	0.00	2.00	Made Ground	
TPE22	2.00	3.10	Sand with organics	Grey silty fine SAND with frequent black decomposed vegetation. (SALTMARSH DEPOSITS)
TPE23	0.00	2.80	Made Ground	

TPE23	2.80	2.90	Peat	Soft dark brown clayey PEAT. (SALTMARSH DEPOSITS)
TPE23	2.90	3.10	Sand with organics	Firm brown SILT with frequent shells and decomposing vegetation. (SALTMARSH DEPOSITS)
HOP1	0.00	1.20	Made Ground	
HOP2	0.00	1.20	Made Ground	
HOP3	0.00	1.20	Made Ground	
HOP4	0.00	1.20	Made Ground	
HOP5	0.00	1.20	Made Ground	
HOP6	0.00	1.20	Made Ground	
WS1	0.00	1.40	Made Ground	
WS1	1.40	2.00	Silt/clay with organics	Soft dark grey to bluish grey slightly sandy CLAY with occasional subvertical decayig roots. Sand is fine to medium. (SALTMARSH DEPOSITS)
WS1	2.00	2.40	Reduced sandy silt/clay	Very soft light bluish grey slightly sandy silty CLAY. Sand is fine. (SALTMARSH DEPOSITS)
WS1	2.40	3.20	Sand	Medium dense dark brown slightly silty fine to coarse SAND with frequent shell fragments and ripple marks (cross bedding).

				(SALTMARSH DEPOSITS)
WS1	3.20	4.00	Reduced sandy silt/clay	Firm dark greyish brown sandy clayey SILT with frequent white shell fragments. Sand is fine to coarse. (SALTMARSH DEPOSITS)
WS1	4.00	4.70	Reduced sandy silt/clay	Very soft dark grey slightly sandy silty CLAY with rare shell fragments. Sand is fine. (SALTMARSH DEPOSITS)
WS1	4.70	5.20	Reduced sand	Medium dense dark grey gravelly very silty fine to medium SAND. Gravel is subangular to subrounded fine to medium flint. (BEACH DEPOSIT)
WS1	5.20	6.50	Sandy gravel	Medium dense becoming dense white, brown, yellow, blue and grey very sandy subangular to subrounded fine to medium GRAVEL of flint. Sand is fine to medium. (BEACH DEPOSIT)

WS1	6.50	7.00	Sandy gravel	Light brown slightly sandy subangular to subrounded fine to coarse GRAVEL of flint. Sand is fine to coarse. (BEACH DEPOSIT)
WS2	0.00	2.80	Made Ground	
	2.80	3.50	Reduced sandy silt/clay	Soft dark greyish brown to grey sandy SILT with occasional white shell fragments. Sand is fine to medium. (SALTMARSH DEPOSITS)
WS2	3.50	5.00	Reduced sand	Dark grey to brownish grey silty fine to medium SAND. (SALTMARSH DEPOSITS)
WS4	0.00	1.90	Made Ground	
WS4	1.90	3.00	Oxidised sand	Dark brown to light brown very silty fine to medium SAND with occasional white shell fragments (<4mm diameter) and rare stratification. (SALTMARSH DEPOSITS)
WS4	3.00	5.00	Reduced sand	Dark grey very silty fine to coarse SAND with rare white shell fragments (<3mm

				diameter). (SALTMARSH DEPOSITS)
SY08SE7	0.00	0.40	Topsoil	elevation estimated at 22.5m OD
SY08SE7	0.40	1.00	Sandstone	Weathered sandstone at top. End of BH at 100m.
SY08SE1	0.00	7.10	No recovery	Superficial strata not recorded.
SY08SE1	7.10	8.00	Sandstone	Weathered sandstone at top. End of BH at 103m.
SY08SE32				Well. No data
SY08SE46				Well. No data
SY08SE49	0.00	1.00	Sandstone	Sandstone. BH ends at 91m. Well.
SY08SE21	0.00	4.00	Made Ground	
SY08SE21	4.00	5.00	Sand with organics	Loose pale brown to medium grey silty fine to medium sand with occasional gravel and cobbles and with occasional fine gravel sized black organic matter.
SY08SE21	5.00	8.60	Sand with organics	Loose medium grey silty fine to medium sand with occasional white shell fragments and occasional black organic matter.
SY08SE21	8.60	9.80	Reduced sand	
SY08SE21	9.80	10.20	Silt/clay with organics	Very soft pale grey some brown slightly sandy very clayey silt with occasional decomposed black organic matter and small fragments of wood. Alluvium.
SY08SE21	10.20	11.70	Sandy gravel	Alluvium
SY08SE21	11.70	12.40	Oxidised sand	Head (<i>weathered bedrock?</i>).

SY08SE21	12.40	13.00	Sandstone	BH ends at 23m.
SY08SE20	0.00	2.90	Made Ground	
SY08SE20	2.90	3.90	Reduced sandy silt/clay	
SY08SE20	3.90	5.00	Sand	
SY08SE20	5.00	6.80	Sand with organics	Loose grey brown, becoming orangey brown below 6m silty fine to medium sand with occasional gravel below 6m and occasional fine gravel sized white shell fragments and decomposed organic matter.
SY08SE20	6.80	10.60	Reduced sand	
SY08SE20	10.60	11.60	Sandy gravel	
SY08SE20	11.60	12.60	Oxidised sand	Head (<i>weathered bedrock?</i>).
SY08SE20	12.60	13.00	Sandstone	BH ends at 21.5m.
SY08SE4 TH1 and TH3	0.00	1.00	Made Ground	Fill. (1963: 3 BHs two with understandable data: Test Hole 1 and Test Hole 3. No elevations; estimated at 15m.)
SY08SE4 TH1 and TH3	1.00	8.38	Sandy gravel	(In TH3 this is divided into red sand 1.2 to 4.6m bgl and red sandy clay with some gravel.)