

Riverside Energy Park

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RIVERSIDE ENERGY PARK LONDON BOROUGH OF BEXLEY

Fieldwork and Updated Deposit Modelling Report

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1. NON-TECHNICAL SUMMARY

A programme of geoarchaeological fieldwork and updated deposit modelling was carried out by Quaternary Scientific (University of Reading) in connection with the Proposed Development of the Riverside Energy Park (REP), Norman Road, Belvedere (London Borough of Bexley). The 'site' refers to the REP site which is defined as the site of the permanent works in the area adjacent / around Riverside Resource Recovery Facility (RRRF) north of Norman Road, rather than the entire Application Boundary. The Main Temporary Construction Compound and Electrical Connection route have been scoped out due to the superficial groundworks in these areas. The work was commissioned by Cory Environmental Holdings Ltd. The aims of the investigation were: (1) to summarise current understanding of the nature of the sub-surface stratigraphy, in particular the presence and thickness of alluvium and peat across the site; (2) to evaluate the potential of these sediments for providing information on the environmental history of the site, and evidence of human activity, and (3) to make updated recommendations for further work as part of a Development Consent Order Requirement (if necessary).

In order to carry out the work nearly 150 geotechnical logs were inspected and evaluated, together with records from nearby archaeological/geoarchaeological investigations. The depth, thickness and nature of each major sedimentary unit was extracted and entered into geological modelling software, from which a series of topographic surface and thickness maps were produced. The results of the deposit modelling indicate that the sediments recorded at the REP site are similar to those recorded elsewhere in the Lower Thames Valley, with Late Devensian Shepperton Gravel overlain by a tripartite sequence of Holocene Lower Alluvium, Peat and Upper Alluvium, buried beneath modern Made Ground. In addition, the following features were noted: (1) the absence of Peat on the south-eastern and south-western parts of the site (as noted beneath the Former Borax Works site and within new geotechnical boreholes BH09 and BH10), and (2) the presence of alternating mineral-rich and organic-rich/peat deposits within the Lower Alluvium which were not studied as part of the Former Borax Works investigations.

On the basis of the likely depth of the sediments and findings from nearby sites, the archaeological potential of the site is considered low. Even in the absence of the archaeological remains, the sediments have the potential to contain further information on the past landscape, through the assessment/analysis of palaeoenvironmental remains (e.g. pollen, plant macrofossils and insects) and radiocarbon dating. Following the results of the geoarchaeological fieldwork and updated deposit modelling, it is recommended that boreholes are retained for palaeoenvironmental assessment / analysis from the locations of BH04 (where a complex arrangement of mineral-rich and organic-rich/peat deposits was observed in the Lower Alluvium) and between BH12 (where the peat was recorded at 3m thick) and BH09/BH10 (where peat was entirely absent), to ground-truth the nature of the deposits in this part of the site.

2. INTRODUCTION

2.1 Site context

This report summarises the findings arising out of the fieldwork and updated geoarchaeological deposit modelling undertaken by Quaternary Scientific (University of Reading) in connection with the Proposed Development known as Riverside Energy Park (REP), Norman Road, Belvedere, in the London Borough of Bexley. A desk-based geoarchaeological deposit model was originally produced in March 2018 (Batchelor, 2018a); this report is the result of subsequent fieldwork on the REP site and updating of said model. Quaternary Scientific were commissioned by Orion Heritage to undertake the geoarchaeological investigations.

REP would combine a waste Energy Recovery Facility (ERF), battery storage, a roof-mounted solar photovoltaic installation, an anaerobic digestion facility and would be CHP enabled, along with a new connection to the existing electricity network (Figure 1). This report is concerned primarily with the REP site only; the Main Temporary Construction Compound and the Electrical Connection route have been scoped out due to the superficial groundworks in these areas.

The REP site is located on the floodplain of the estuarine Thames, adjacent to the modern waterfront and ca. 1.8 km north of the floodplain edge and the rising ground of the valley side. The REP site lies on the south side of the Thames, forming part of the Erith Marshes which occupies the eastern end of the area of floodplain enclosed by the river, where it makes a broad northward loop between Woolwich in the west and Erith in the east. The whole of this area of valley floor, which has its most northerly point at Crossness, is underlain by Holocene Alluvium. The British Geological Survey (BGS) 1:50,000 Sheets 257 Romford (1996) and 271 Dartford (1998) show the alluvium overlying sandy gravel deposits which can be confidently referred to as the Shepperton Gravel of Late Devensian age (Gibbard, 1994), which are in turn underlain by London Clay (an Eocene deposit).

Geoarchaeological and archaeological works have previously taken place across a large proportion of the REP site (particularly on the western side), which originally formed the Former Borax Works, Norman Road site (NNB07; Figure 2). These works consisted of a geoarchaeological deposit modelling exercise based upon historical geotechnical data, which led to the opening of nine deep archaeological trenches from which samples were taken for laboratory-based geoarchaeological and palaeoenvironmental analysis (Figure 3; Batchelor *et al.*, 2008). Combined, the results from this exercise indicated a broadly consistent stratigraphic sequence comprising a unit of sand and gravel (the Shepperton Gravel) up to 10 m in thickness, overlain by fine-grained alluvium, generally between 6.0 m and 11.0 m in thickness. A discontinuous peat, up to 2.0 m thick, appears to be present occurred at or close to the base of this alluvial sequence, with a separate, but also discontinuous peat horizon at a higher level in the alluvial sequence and more extensively preserved inland from the estuarine margin. In the intertidal zone and off-shore the alluvial sequence has been heavily truncated. The subsequent archaeological trenches (Figure 3) enabled samples to be collected from the upper part of the sequence, and the peat was dated from approximately 4800 to 3000 cal BP (late Neolithic to late Bronze Age).

Similar investigations have taken place on a number of neighbouring / nearby sites, including: Burts Wharf (Batchelor, 2016); the Former NuFarm Site (Young *et al.*, 2008a); Alchemy Park (Batchelor & Young, 2015; Batchelor *et al.*, 2016); Crossness (Devoy, 1979) / Crossness Sewage Works (Batchelor *et al.*, 2007a; Batchelor *et al.*, 2007b; Green *et al.*, 2011); North Bexley Drainage Improvements (Branch *et al.*, 2004); Imperial Gateway (Batchelor *et al.*, 2008b); Crabtree Manorway South (Askew and Spurr, 2006); Pirelli Works (Young *et al.*, 2012); Corinthian Quay (Corcoran & Lam, 2002); Erith Spine Road / Bronze Age Way (Sidell *et al.*, 1996); Veridion Park (Green & Batchelor, 2013) & Parkway Primary School (Young & Batchelor, 2016) (see Figure 2). These records broadly indicate the same sequence of Shepperton Gravel, overlain by alluvium, including a thick horizon of peat, capped by Made Ground. Important variations in the underlying topography of these sediments have also been identified including: (1) indications of a deep west-east aligned channel traversing the southern part of the Alchemy Park site; (2) potential channels in the area of Pirelli Works (Young *et al.*, 2013) and Veridion Park (Green & Batchelor, 2011) and (3) an uneven shape to the Shepperton Gravel has been identified on the Crossness Sewage Works site adjacent to the river; potentially representing north-south aligned channels draining towards the Thames, separated by more elevated ridges of gravel.

2.2 Palaeoenvironmental and archaeological significance

The existing records therefore indicate considerable variation in the height of the Shepperton Gravel surface, and the type, thickness and age of the subsequent Holocene deposits across the surrounding area. Such variations are significant as they represent different environmental conditions that would have existed in a given location. For example: (1) the varying surface of the Shepperton Gravel may represent the location of former channels and bars; (2) the presence of peat represents former terrestrial or semi-terrestrial land-surfaces, and (3) the Alluvium represents periods of inundation/flooding by estuarine or fluvial waters. Thus by studying the sub-surface stratigraphy across the site in greater detail, it will be possible to build an understanding of the former landscapes and environmental changes that took place across space and time.

Organic-rich sediments (in particular Peat) also have high potential to provide a detailed reconstruction of past environments on both the wetland and dryland from the Mesolithic to late Bronze Age periods. In particular, there is the potential to increase knowledge and understanding of the interactions between relative sea level, human activity, vegetation succession and climate in this area of the Lower Thames Valley. Significant vegetation changes include the Mesolithic/Neolithic decline of elm woodland, the Neolithic colonisation and decline of yew woodland; the Late Neolithic/Early Bronze Age growth of elm on Peat, and the general decline of wetland and dryland woodland during the Bronze Age. Such investigations are carried out through the assessment/analysis of palaeoecological remains (e.g. pollen, plant macrofossils & insects) and radiocarbon dating. So called palaeoenvironmental reconstructions are currently being undertaken on sequences from the Alchemy Park site (Batchelor *et al.*, in prep), and have previously been carried out at Crossness Sewage Works (Batchelor *et al.*, 2007a, b), the Former Borax Works (Batchelor *et al.*, 2008a), Imperial Gateway (Batchelor *et al.*, 2008b) and Pirelli Works (Young *et al.*, 2012).

Finally, areas of high gravel topography, soils and peat represent potential areas that might have been utilised or even occupied by prehistoric people, evidence of which may be preserved in the archaeological (e.g. features and structure) and palaeoenvironmental record (e.g. changes in vegetation composition). Prehistoric structures have been located in the peat locally to the site at Erith Spine Road / Bronze Age Way (Sidell, 1996) and on the Erith Foreshore (Sidell pers. comm.).

2.3 Aims and objectives

Seven significant research aims relevant to the geoarchaeological investigations were outlined within the Written Scheme of Investigation for the geoarchaeological and palaeoenvironmental investigation of the site (Batchelor, 2018b):

1. To clarify the nature of the sub-surface stratigraphy across the site;
2. To provide a complete deposit model for the site;
3. To ascertain evidence for any significantly high (or low points in the Shepperton Gravel surface);
4. To clarify the nature, depth, extent and date of any alluvium and peat deposits;
5. To investigate whether the sequences contain any artefact or ecofact evidence for prehistoric or historic human activity;
6. To investigate whether the sequences contain any evidence for natural and/or anthropogenic changes to the landscape (wetland and dryland); and
7. To integrate the new geoarchaeological record with other recent work in the local area for publication in an academic journal.

In order to address the first two of these aims, the following objectives were proposed as part the pre-planning stage (with which this report is concerned):

1. To monitor selected geotechnical boreholes being put down across the site by Terra Consulting.
2. To use the stratigraphic data from the new locations, and existing records to produce an updated deposit model of the major depositional units across the site.



Figure 1: The Riverside Energy Park Application Site and associated zones of construction

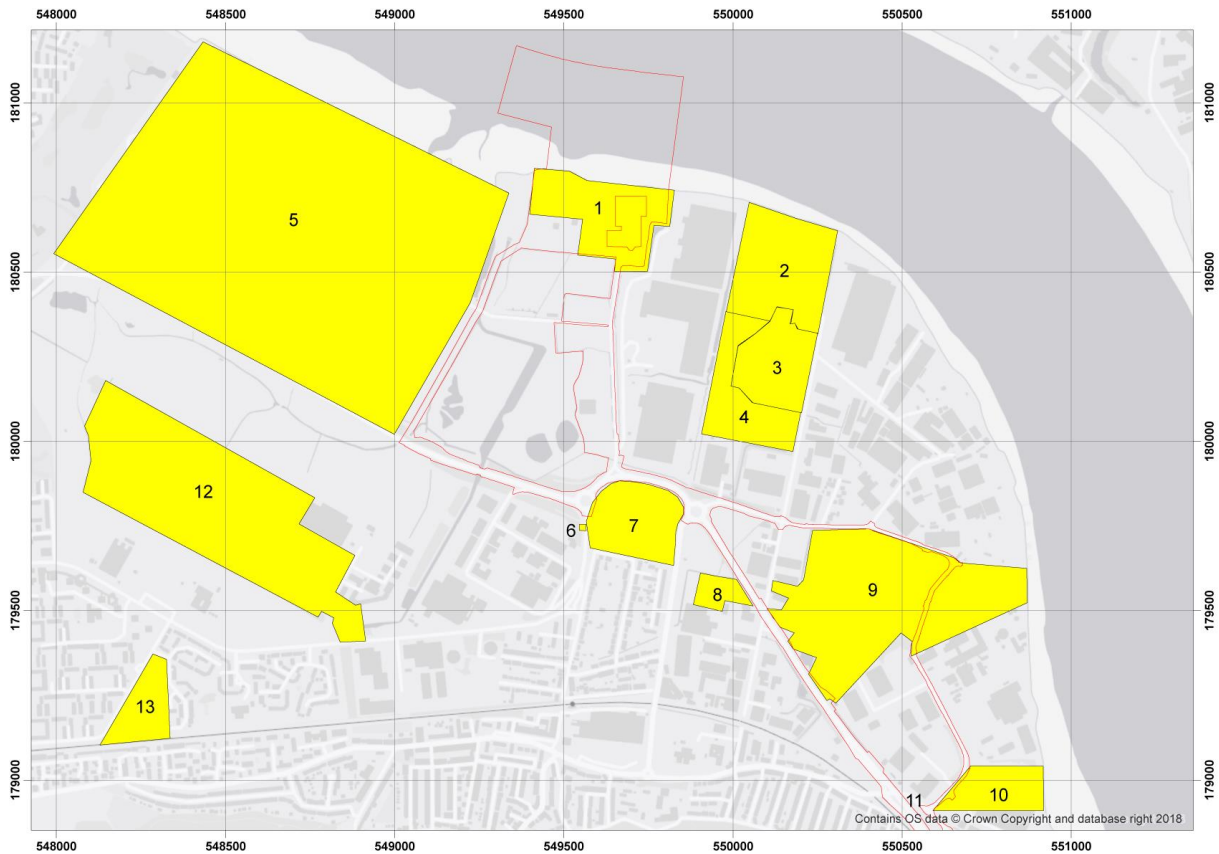


Figure 2: Location of Riverside Energy Park Application Site (part of) (red) and other selected geospatial / archaeological local sites: (1) Former Borax Works (NNB06; Batchelor *et al.*, 2008a); (2) Burts Wharf (Batchelor, 2016); (3) Former NuFarm Site (Young *et al.*, 2008a); (4) Alchemy Park (Batchelor & Young, 2015; Batchelor *et al.*, 2016); (5) Crossness (Devoy, 1979) / Crossness Sewage Works (Batchelor *et al.*, 2007a; Batchelor *et al.*, 2007b; Green *et al.*, 2011); (6) North Bexley Drainage Improvements (Branch *et al.*, 2004); (7) Imperial Gateway (Batchelor *et al.*, 2008b); (8) Crabtree Manorway South (Askew and Spurr, 2006); (9) Pirelli Works (Young *et al.*, 2012); (10) Corinthian Quay (Corcoran & Lam, 2002); (11) Erith Spine Road / Bronze Age Way (Sidell *et al.*, 1996); (12) Veridion Park (Green & Batchelor, 2013) & (13) Parkway Primary School (Young & Batchelor, 2016).

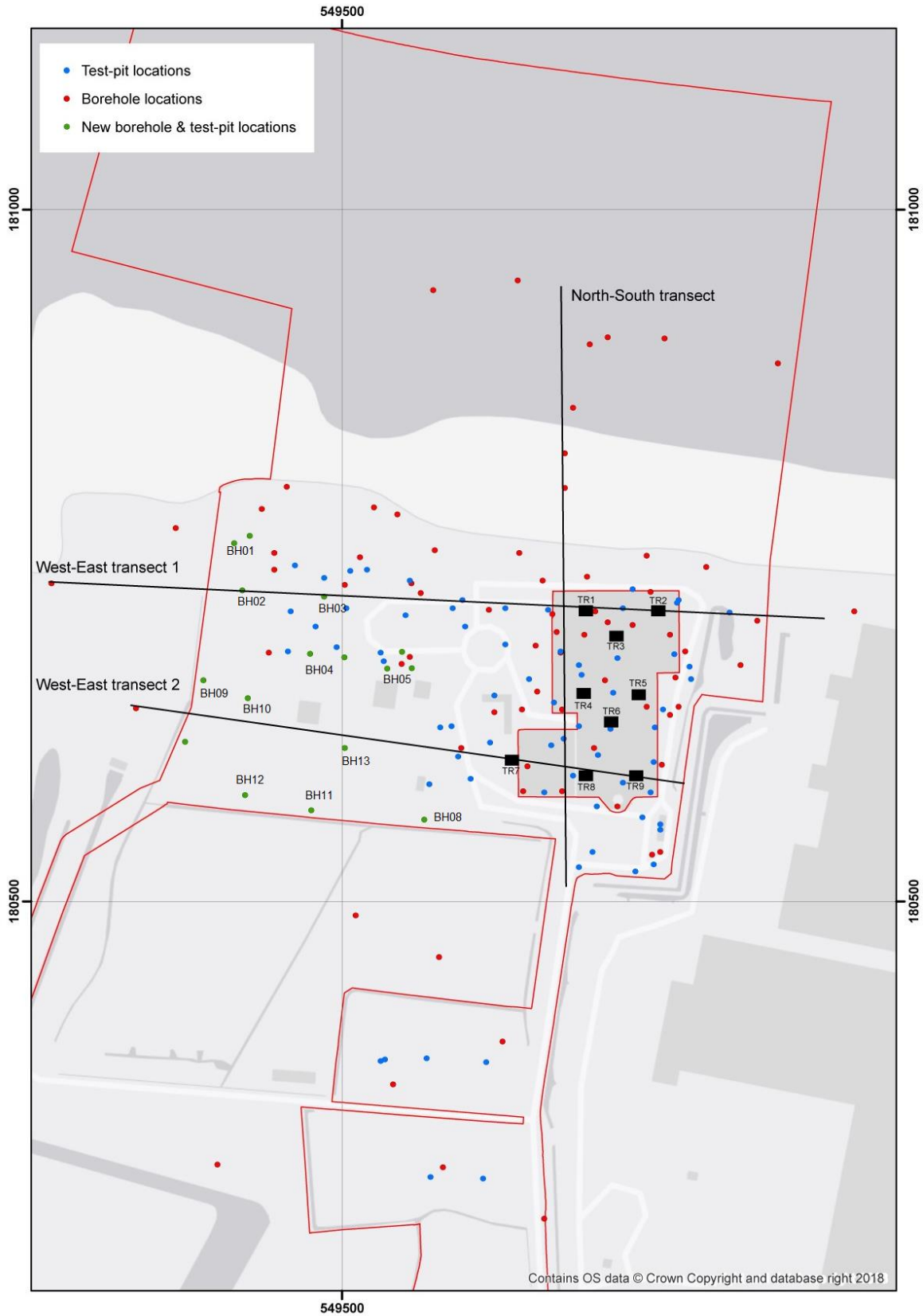


Figure 3: Location of historical geotechnical and archaeological investigation across the Riverside Energy Park and Former Norman Road sites, London Borough of Bexley

3. METHODS

3.1 Fieldwork

A total of 11 geotechnical boreholes and 5 test-pits were put down by Terra-Consult in April/May 2018 (Table 1). The boreholes were put down using a cable percussion rig, and three were (at least in part) monitored by Quaternary Scientific (BH03, BH04 & BH05). Field-based lithostratigraphic descriptions of the boreholes was carried out using standard procedures for recording unconsolidated sediment and peat, noting the physical properties (colour), composition (gravel, sand, clay, silt and organic matter) and inclusions (e.g. artefacts). The procedure involved: (1) recording the physical properties, most notably colour; (2) recording the composition e.g. gravel, fine sand, silt and clay; (3) recording the degree of peat humification, and (4) recording where possible, the unit boundaries e.g. sharp or diffuse. The descriptions are displayed in Tables 2-4.

3.2 Deposit modelling

The updated deposit model for the REP site was based on the 16 new geotechnical borehole/records put down by Terra-Consult (2018a,b) and a review of around 130 historical geoarchaeological, geotechnical and archaeological borehole / test-pit records, those put down across the site itself, and those taken from its immediate surroundings (Figure 2). This included data taken from the following sources: Wilkinson Associates (1992); AERC (2003); Soil Mechanics (2007); the Former Borax Works (Batchelor et al., 2008a), and the British Geological Survey (<http://www.bgs.ac.uk/data/boreholescans/home.html>). Sedimentary units from the boreholes were classified into five groupings: (1) Gravel, (2) Lower Alluvium; (3) Peat; (4) Upper Alluvium and (5) Made Ground. In addition, over 750 records were collated to examine key deposits across the wider area.

The classified data for groups 1-5 were then input into a database with the RockWorks geological utilities software. Updated models of surface height were generated for the Gravel, Lower Alluvium, Peat and Upper Alluvium (Figures 4-6, 8 & 9). Thickness of the Peat, Total Alluvium and Made Ground (Figures 7, 10 & 11) was also modelled (also using a nearest neighbour routine). Three updated borehole transects were also compiled (Figures 12-14).

In general, both the distribution and density of boreholes across much of the site is high, with complete coverage across the site. In general, reliability improves from outlying areas where the models are largely supported by scattered archival records towards the core area of boreholes. Because of the 'smoothing' effect of the modelling procedure, the modelled levels of stratigraphic contacts may differ slightly from the levels recorded in borehole logs and section drawings. As a consequence of this the modelling procedure has been manually adjusted so that only those areas for which sufficient stratigraphic data is present will be modelled. In order to achieve this, a maximum distance cut-off filter equivalent to a 50m radius around each record was applied to all deposit models for the site itself, and 100m for the model created for the wider area. In addition, it is important to recognise that multiple sets of boreholes are represented, put down at different times and recorded using different descriptive terms and subject to differing technical constraints in terms of recorded detail including the exact levels of the stratigraphic boundaries.

Table 1: Spatial co-ordinates for the 2018 geotechnical boreholes and test-pits

Geoarchaeological borehole	Easting	Northing	Elevation
BH01	549433.37	180764.48	3.02
BH02	549427.99	180724.99	2.44
BH03	549487.14	180720.48	3.40
BH04	549477.07	180679.14	1.81
BH05	549532.61	180668.51	1.81
BH08	549559.32	180559.36	1.32
BH09	549400.00	180660.00	1.66
BH10	549432.01	180647.00	1.30
BH11	549477.76	180565.97	1.28
BH12	549429.90	180577.09	1.04
BH13	549501.99	180611.01	1.45
TP01	549422.11	180759.13	2.95
TP02	549501.85	180676.67	1.96
TP04	549550.30	180668.77	1.71
TP05	549543.45	180680.63	1.74
TP06	549386.70	180615.57	1.50

4. RESULTS, INTERPRETATION & DISCUSSION OF THE GEOARCHAEOLOGICAL FIELD INVESTIGATIONS & UPDATED DEPOSIT MODELLING

It was not possible to observe all the boreholes originally planned at the outset of the fieldwork, due to the timing of the boreholes and general logistics. However, the entirety of BH04 was observed and recorded, together with parts of BH03 and BH05 (Tables 2-4). These records are largely consistent, as are those recorded in the remaining 8 boreholes. As such, the monitoring undertaken is considered more than sufficient to provide a reliable updated deposit model for the site, and thus satisfy the geoarchaeological and palaeoenvironmental works at the pre-planning stage.

Table 2: Lithostratigraphic description of borehole BH03, Riverside Energy Park, London Borough of Bexley

Depth (m OD)	Depth (m bgl)	Description	Stratigraphic group
2.44 to -0.26	0 to 2.70	Made Ground	MADE GROUND
-0.26 to -1.16	2.70 to 3.60	10YR 5/1; As4; Grey clay; unknown contact into:	UPPER ALLUVIUM
-1.16 to -2.96	3.60 to 5.40	5YR 4/3; Sh3, Tl31, Th+; Humo 3-4; Dark grey well humified unidentifiable and wood peat with traces of herbaceous peat; unknown contact into:	PEAT
-2.96 to -3.36	5.40 to 5.80	10YR 5/1; Ga3, Ag1; Grey silty sand; unknown contact into:	LOWER ALLUVIUM
-3.36 to -4.56	5.80 to 7.00	10YR 4/1; Sh2, As1, Tl1; Humo 3; Dark grey well humified unidentifiable and wood peat with clay.	
	>7.00	Not observed	

Table 3: Lithostratigraphic description of borehole BH04, Riverside Energy Park, London Borough of Bexley

Depth (m OD)	Depth (m bgl)	Description	Stratigraphic group
1.81 to 0.81	0 to 1.00	Made Ground	MADE GROUND
0.81 to -0.69	1.00 to 2.50	10YR 5/1 to 10YR 4/1; As4; Grey clay with manganese and iron staining; diffuse contact into:	UPPER ALLUVIUM
-0.69 to -2.19	2.50 to 4.00	10YR 5/1 to 5YR 4/3; As3, Sh1, Tl+, Th to Sh2, Th1, As1, Tl+; Humo 3-4; Dark grey to reddish brown organic-rich clay with traces of wood and herbaceous peat, becoming well humified unidentifiable and herbaceous peat with twigs; diffuse contact into:	
-2.19 to -3.09	4.00 to 4.90	5YR 4/3; Sh3, Tl31, Th+; Humo 3-4; Dark grey well humified unidentifiable and wood peat with traces of herbaceous peat; very sharp contact into:	PEAT
-3.09 to -3.79	4.90 to 5.60	10YR 5/1; Ga2, Ag2, Dl+; Grey silty sand with traces of wood; unknown contact into:	LOWER ALLUVIUM
-3.79 to -4.19	5.60 to 6.00	10YR 4/2; Sh2, As1, Tl1; Humo 3; Dark greyish brown well humified unidentifiable and wood peat with clay; unknown contact into:	
-4.19 to -5.69	6.00 to 7.50	10YR 5/1; As2, Ag2, Dh+, Dl+; Grey silty clay with traces of detrital wood and herbaceous remains; detrital wood increases with depth; unknown contact into:	
-5.69 to -6.14	7.50 to 7.95	10YR 4/1; As2, Sh1, Dl1 to As2, Dl2; Dark grey organic rich clay with detrital wood to clay and detrital wood; unknown contact into:	
-6.14 to -7.59	7.95 to 9.40	Mixture of lenses: 10YR 5/1; As2, Ag2, Dh+, Dl+; Grey silty clay with traces of detrital wood and herbaceous remains; and 10YR 4/2; Sh2, As1, Tl1; Humo 3; Dark greyish brown well humified unidentifiable and wood peat with clay; unknown contact into:	
< -7.59	>9.40	10YR 5/1; Ga3, Gg1, Dl+; Grey gravelly sand with detrital wood	GRAVEL

Table 4: Lithostratigraphic description of borehole BH05, Riverside Energy Park, London Borough of Bexley

Depth (m OD)	Depth (m bgl)	Description	Stratigraphic group
0 to -6.89	0 to 8.70	Not observed	
-6.89 to -7.69	8.70 to 9.50	Large 'solid' pieces of wood (possible oak/yew?)	LOWER ALLUVIUM
< -7.69	>9.50	10YR 5/1; Ga3, Gg1, Dl+; Grey gravelly sand with detrital wood	GRAVEL

The results of the deposit modelling are displayed in Figures 4 to 14; Figures 4 to 11 are updated surface elevation and thickness models for each of the main stratigraphic units. Figures 12 to 14 are updated 2-dimensional transects across the site from south-west and west-east. The results of the deposit modelling indicate that the number and spread of the logs is sufficient to permit modelling with a high level of confidence across the entire site.

The full sequence of sediments recorded in the boreholes comprises:

Made Ground

Upper Alluvium – widely present

Peat – widely present

Lower Alluvium – widely present, frequently peaty

Gravel (Shepperton Gravel)

4.1 Shepperton Gravel

Gravel was present in all the boreholes that penetrated to the bottom of the Holocene sequence. The modelling exercise indicates that the surface of the Shepperton Gravel is relatively even, ranging between -7.5 and -9.5m OD across the site, with a gradual decrease in height towards the north, east and south-west (Figures 4 & 12-14). Beyond the southern margin of the site, this surface appears to rise gently to between -7 and -6m OD.

The Gravel represents the Shepperton Gravel which was deposited during the Late Glacial (MIS2; 15,000 to 10,000 BP) and comprises the sands and gravels of a high-energy braided river system which, while it was active would have been characterised by longitudinal gravel bars and intervening low-water channels in which finer-grained sediments might have been deposited. Such a relief pattern would have been present on the valley floor at the beginning of the Holocene when a lower-energy fluvial regime was being established.

Across the majority of the REP site, the Gravel is of consistent thickness, resting on a London Clay bedrock surface between -12 and -14m OD. Towards the south of the site in new boreholes BH01 and BH02, and for a few hundred meters beyond its borders however, the Gravel becomes substantially thicker, reaching bedrock surfaces of up to -20m OD. This may represent the infill of a former Pleistocene channel.

In order to place the findings of this investigation in a wider regional context, the modelling procedures carried out have been extended to cover a larger area of the local Thames floodplain, including locations where previous similar geoarchaeological investigations have been undertaken (see Figure 2). The results of this wider-scale investigation are presented as a contour model of the Shepperton Gravel surface (Figure 5). The surface of the Shepperton Gravel is chosen as the basis for this wider regional evaluation because the relief features present on that surface are widely understood to have strongly influenced patterns of sedimentation on the Thames floodplain throughout the Holocene, and to have had a significant impact on the topography of prehistoric land

surfaces. It is highlighted that the larger area has been modelled at a coarser resolution (100m as opposed to 50m radius from each borehole) and due to the absence of records in certain areas, the coverage of the model is incomplete.

One of the principal relief features recorded in the nearby area is a large linear depression cut into the Shepperton Gravel surface (up to -11.2m OD) and extending west to east or north-west to south-east across the Alchemy Park site. Borehole coverage is insufficient to gauge the exact dimensions of this channel, but it would appear to be a maximum of 100-200m wide on the basis that the Shepperton Gravel surface is recorded at above -9m OD on the Imperial Gateway (Batchelor *et al.*, 2008b) and Pirelli Works (Young *et al.*, 2008b) sites. Extrapolating the orientation and origin of the channel is also restricted by the lack of coverage, however it would appear to be part of a wider pattern of probable drainage lines radiating from a more elevated part of the Shepperton Gravel surface identified during investigation of the Veridion Park site to the west (Batchelor and Green, 2013), whilst a deep embayment around Belvedere Industrial Estate suggest its confluence with the Thames at this point. Other deep depressions are identified within the modelled area, include two which are orientated approximately north-south across the Pirelli Works site (Young *et al.*, 2008b). The gravel surface at the base of these features however, is recorded at approximately -8m OD, indicating they are substantially shallower than that recorded at Alchemy Park (-11.2m OD). In addition, an uneven surface of the Shepperton Gravel has been identified on the Crossness Sewage Works site adjacent to the river; potentially representing north-south aligned channels draining towards the Thames, separated by more elevated ridges of gravel (Green *et al.*, 2011).

4.2 Lower Alluvium

The Lower Alluvium rests directly on the Shepperton Gravel and is recorded in the majority of records across the site; it is however absent in various sequences (e.g. SM-BH19, TQ48SE306, SM-BH105, SM-BH104; Figures 12-14). The apparent absence of Lower Alluvium could be a true reflection of natural variations in the stratigraphic sequence. Alternatively, the apparent absence of Lower Alluvium could be a reflection of the drilling/description method used by the geotechnical team at the time of investigation.

Where recorded, the deposits of the Lower Alluvium are generally described as a predominantly silty or clayey unit tending to become increasingly sandy downward in most sequences. The Lower Alluvium frequently contains detrital wood or plant remains, and in many cases is described as organic rich, or peaty, or with traces of peat; in a few of the records distinct horizons of peat are recorded measuring up to 1m in thickness close to the interface with the Gravel (e.g. SM-BH104; Figure 14). Geoarchaeological monitoring revealed that sequences BH03, BH04 and BH05 all contained Lower Alluvial deposits that frequently contained alternations between organic-rich/peat deposits and clayey, silty or sandy units (Tables 2 to 4). The surface of the Lower Alluvium (where recorded) generally rests between -3 and -4m OD (Figure 6), though individual records indicate heights ranging between -2 and -8m OD (Figures 12-14). The thickness of the Lower Alluvium ranges from 1 to 8m; thicker occurrences are often present where the surface of the Shepperton Gravel lies at a lower level.

The sequences captured from the Former Borax Works site did not reach sufficiently deep to capture the organic-rich / Peat deposits recorded towards the base of the Lower Alluvium. However, radiocarbon dating of sequences from nearby sites such as Alchemy Park (Batchelor et al., 2016), Pirelli Works (Young et al., 2012) and Imperial Gateway (Batchelor et al., 2008b) suggest the Lower Alluvium began accumulating during the early to middle Holocene around 7000 cal BP (late Mesolithic; Figure 13). Deposition took place during a time when the main course of the Thames was probably confined to a single meandering channel. During this period, the surface of the Shepperton Gravel was progressively buried beneath the sandy and silty flood deposits of the river. The richly-organic nature of the Lower Alluvium, with evidence of localised and short-lived, probably episodic peat accumulation suggests that this was a period during which the valley floor was occupied by a network of actively migrating channels, with a drainage pattern on the floodplain that was still largely determined by the relief on the surface of the underlying Shepperton Gravel.

4.3 Peat

Overlying the Lower Alluvium across the majority of records from the site is a bed of peat generally ranging in thickness between 1 and 2m (Figures 7 and 12-14). However, a greater thicknesses of 3m was recorded in new geotechnical borehole BH12 within the south-western corner of the REP site. The greatest thickness of Peat is recorded in the south-eastern corner of the REP site, where an isolated record indicates 5m of Peat is preserved (SM-BH322; Figure 13). The surface of the peat (Figure 8) is fairly level between -1.0m and -2.0m OD.

The widespread occurrence of Peat above the Lower Alluvium indicates a general transition to a more stable valley floor, possibly associated with falling relative sea level and slight incision of the main channel of the Thames, encouraging the development of semi-terrestrial conditions across most of the floodplain. The peat is composed of wood and herbaceous remains indicating that during its accumulation the floodplain supported the growth of sedge fen/reed swamp and woodland communities. Radiocarbon dating of sequences from the Former Borax Works site (Batchelor et al. 2008a) and nearby sites such as Alchemy Park (Batchelor et al., 2016), Pirelli Works (Young et al., 2012), Imperial Gateway (Batchelor et al., 2008b) and Crossness Sewage Works (Batchelor et al., 2006) suggest that the peat began accumulating during the middle Holocene around the time of the transition from the Mesolithic to Neolithic cultural period, and continued until the Bronze Age; a period of around 3000 years.

Peat is however absent in a number of borehole records from the south-eastern corner of the REP site (Figure 13) including archaeological trenches 7-9 on the southern part of the Former Borax Works site (Figure 3; Batchelor et al., 2008a) indicating truncation by a subsequent process. Peat was also noted as being absent in borehole BH09 and BH10 (south-west; Figure 13). The spatial extent of this feature across other areas of REP site and beyond is unknown.

4.4 Upper Alluvium

The uppermost unit in the Holocene alluvial sequence is the Upper Alluvium, the deposits of which comprise largely sterile clays and silty clays. These deposits are recorded in every record across the

REP site and more widely across the modelled area (Figures 9 & 12-14). The Upper Alluvium generally ranges between 1 and 5m in thickness, but occasionally reaches greater thicknesses where the Lower Alluvium and or Peat is absent. The deposition of the Upper Alluvium had the effect of infilling the remaining inequalities in the relief of the floodplain, so that the surface of the Upper Alluvium (Figure 9) is remarkably level on land between +0m and +2m OD.

The Upper Alluvium is typical of the mineral-rich sediments that are present as the uppermost element of the Holocene sequence beneath most floodplains in southern and south-east England. It is generally considered to reflect increased sediment loads resulting from intensification of agricultural land use from the later prehistoric period onward, combined with the effects of rising sea level.

4.5 Made Ground

Between 1 and 4m of Made Ground caps the Holocene alluvial sequence (Figure 11).

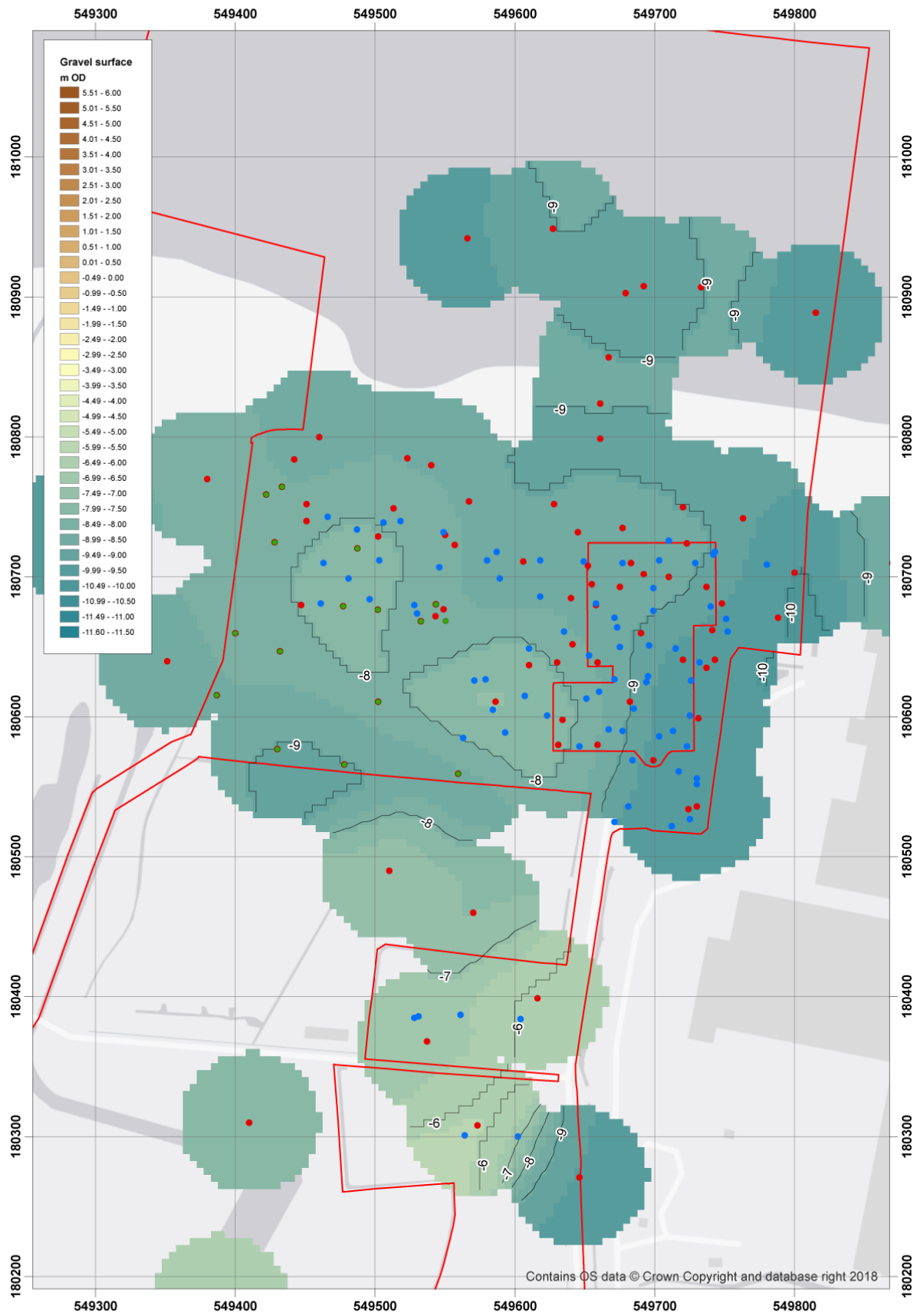


Figure 4: Top of the Shepperton Gravel (m OD) (REP Application Site (part of) outline in red)

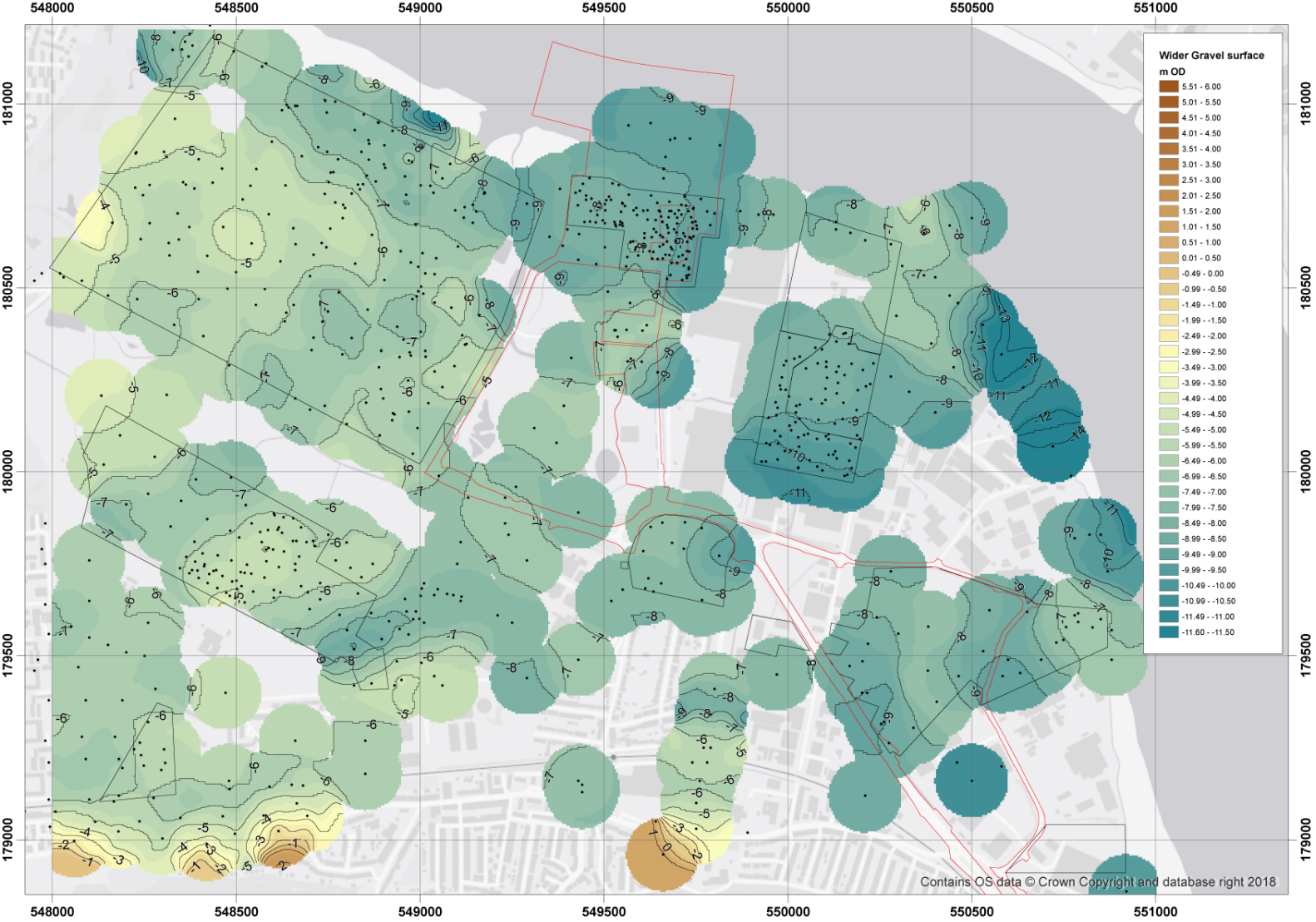


Figure 5: Top of the Shepperton Gravel (m OD) across the wider area (for site names see Figure 1)



Figure 6: Top of the Lower Alluvium (m OD) (REP Application Site (part of) outline in red)

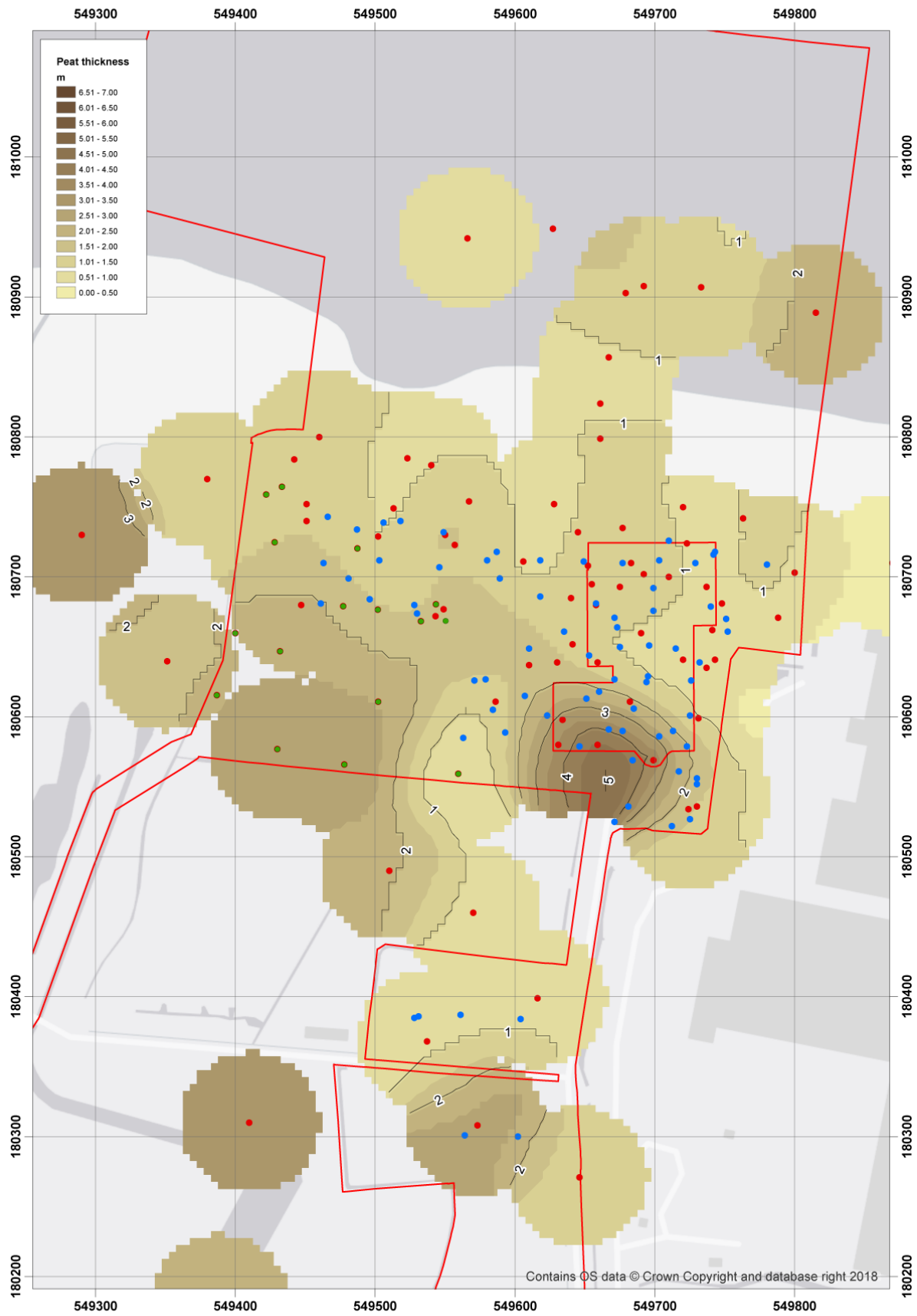


Figure 7: Thickness of Peat (m) (REP Application Site (part of) outline in red)

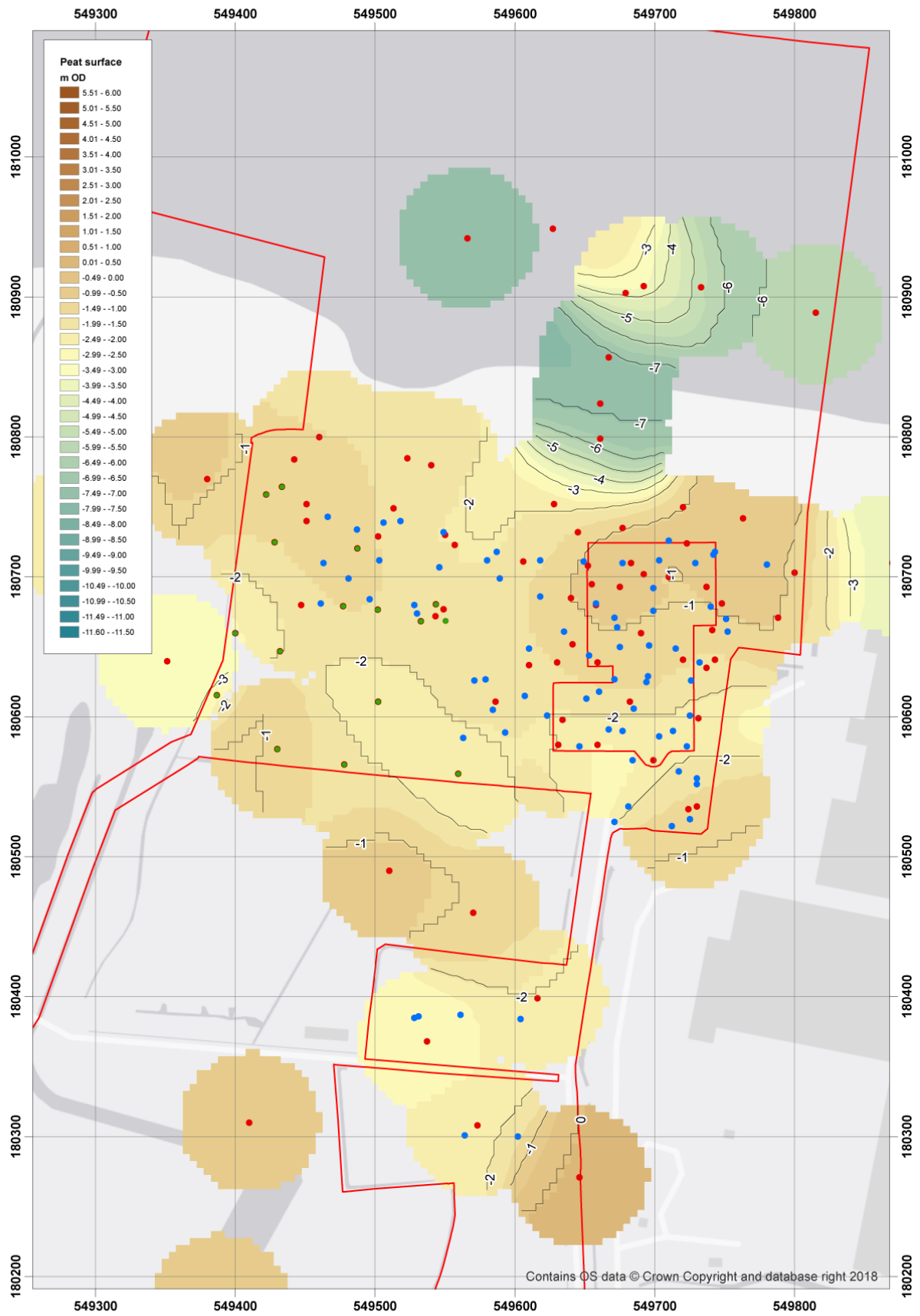


Figure 8: Top of Peat (m OD) (REP Application Site (part of) outline in red)

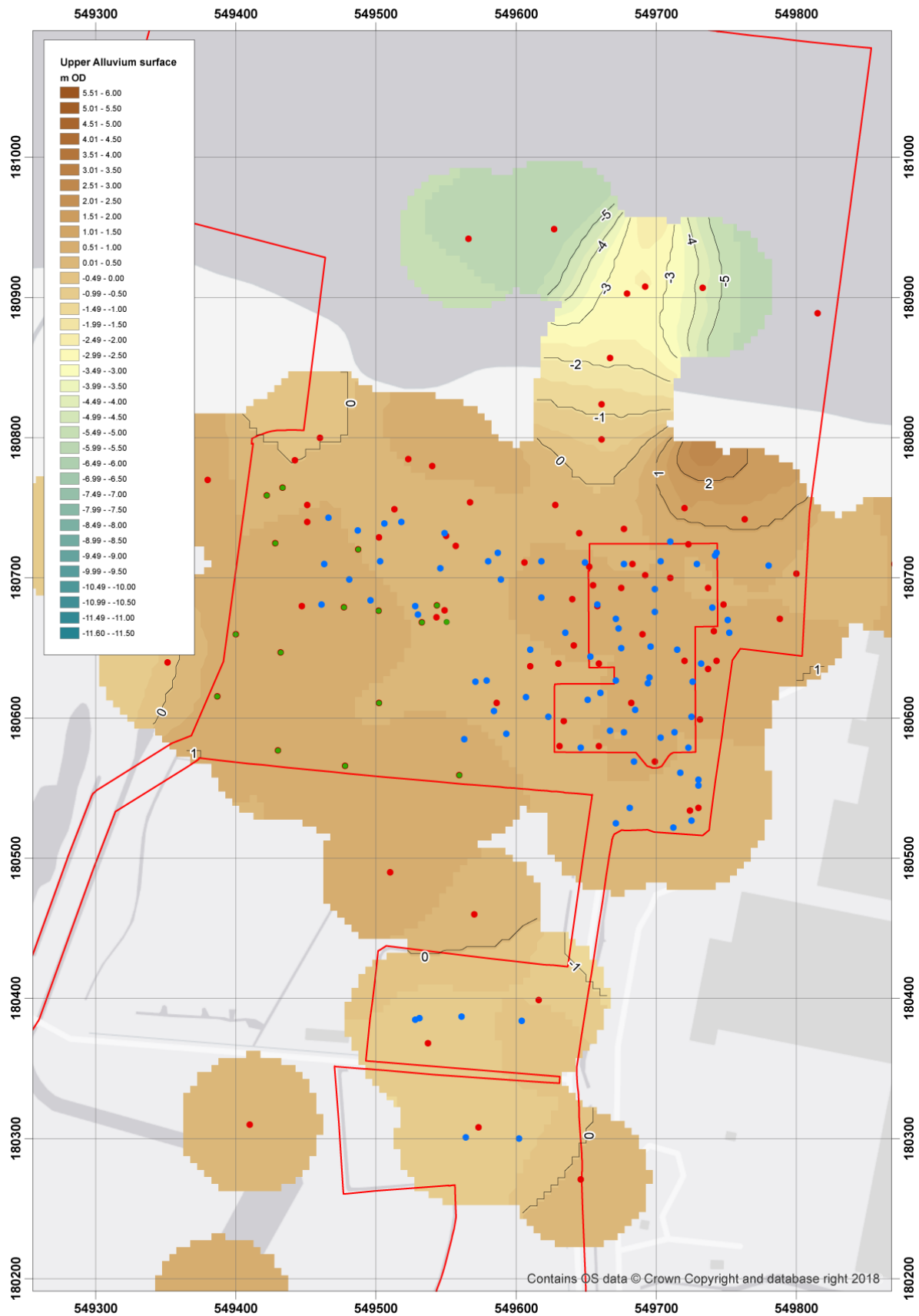


Figure 9: Top of the Upper Alluvium (m OD) (REP Application Site (part of) outline in red)

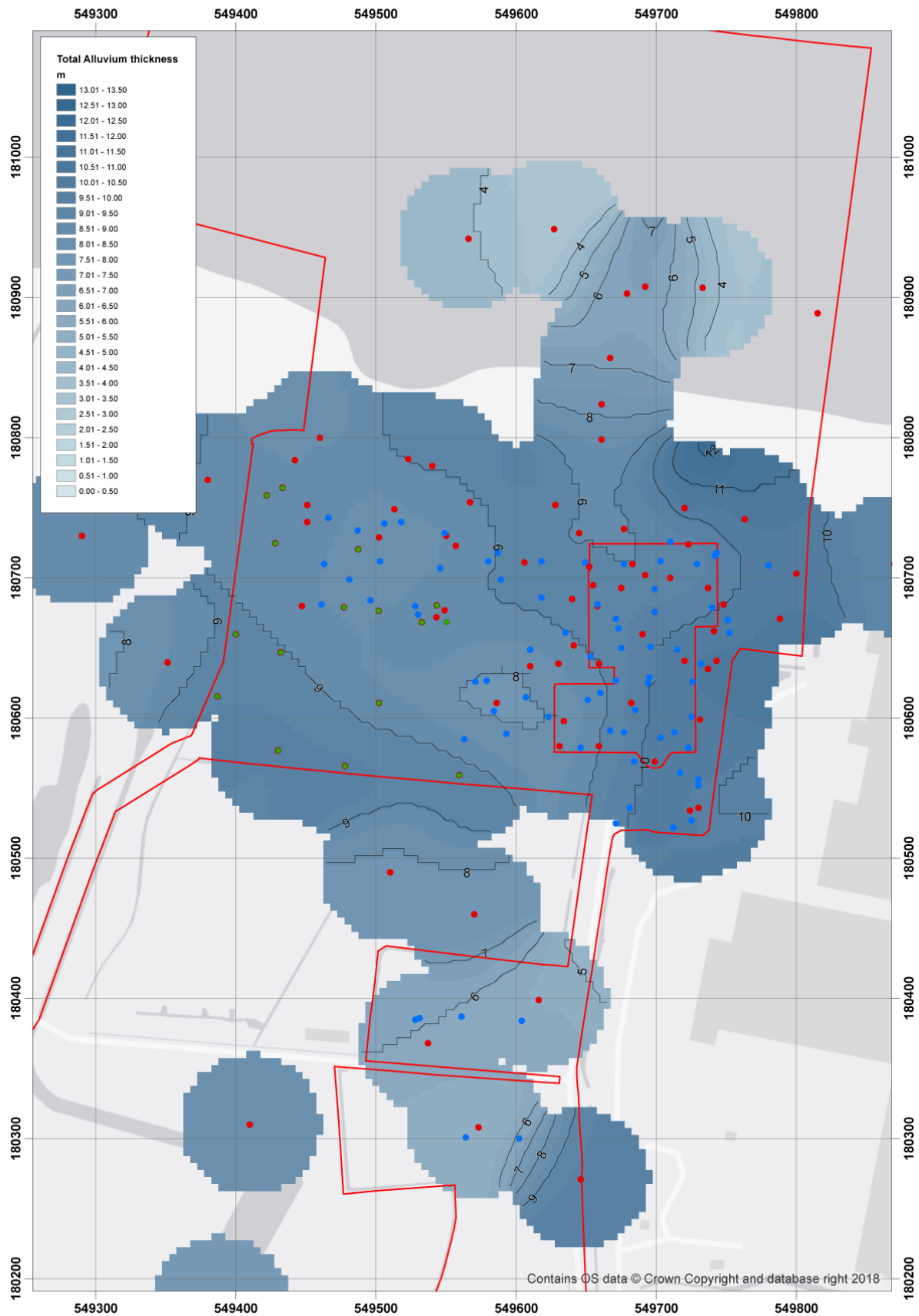


Figure 10: Thickness of Total Alluvium (m) (REP Application Site (part of) outline in red)

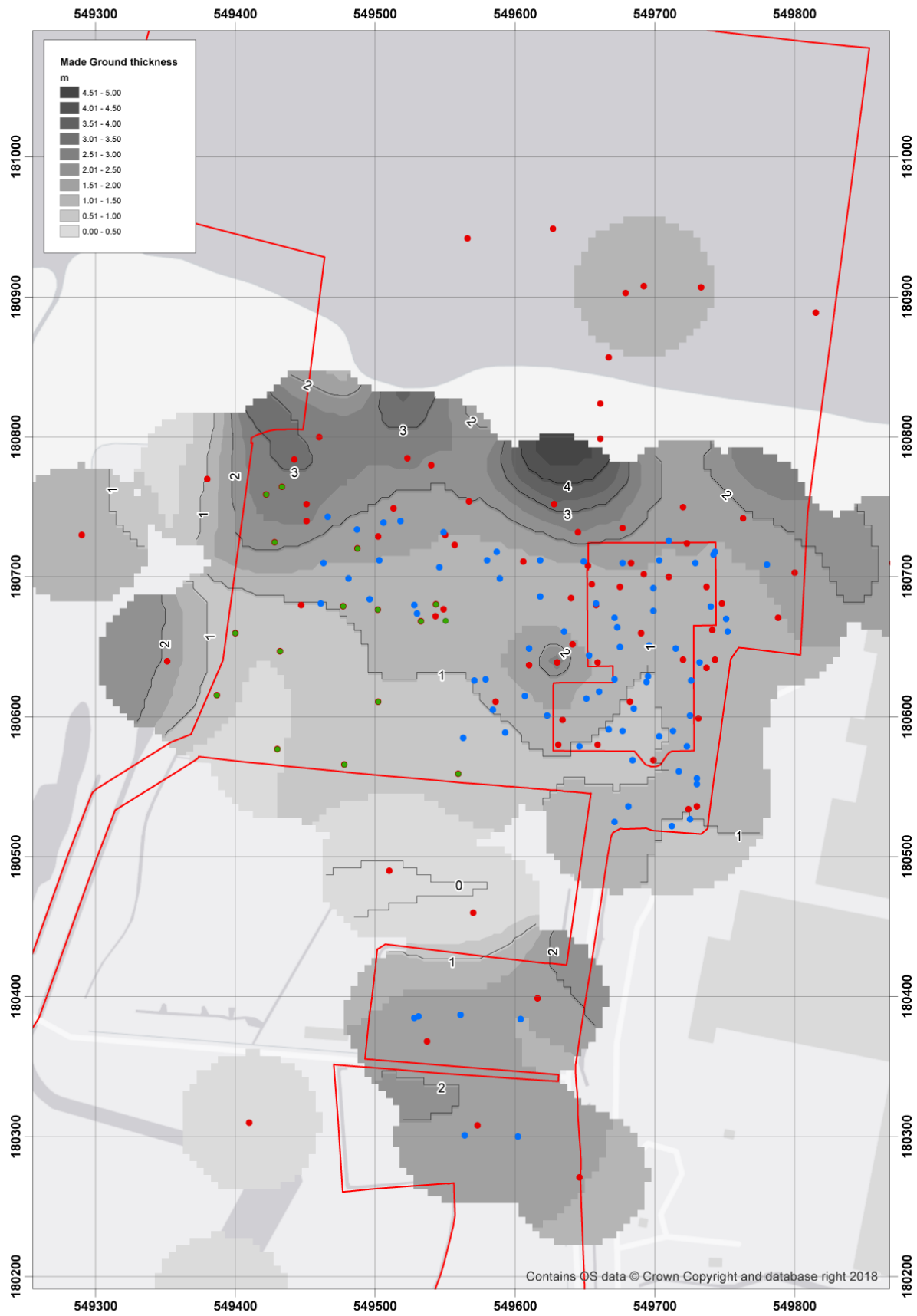


Figure 11: Thickness of Made Ground (m) (REP Application Site (part of) outline in red)

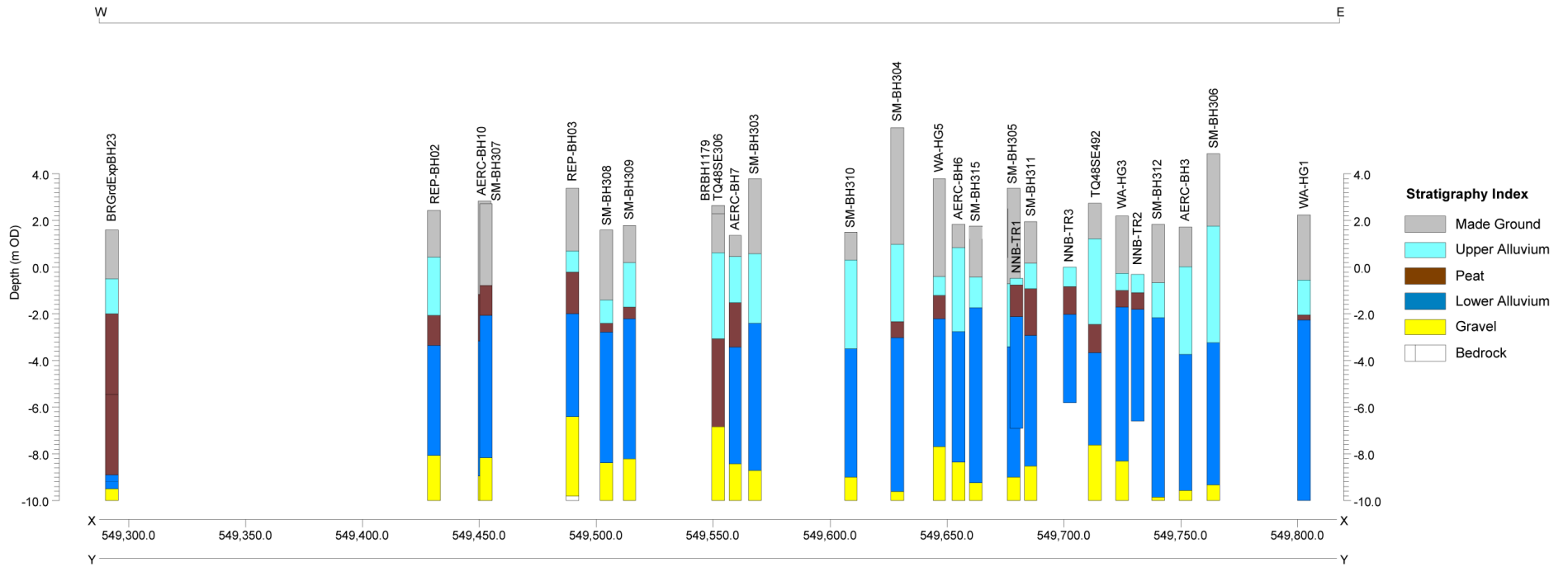


Figure 12: West-East (north) transect of selected boreholes across REP site, London Borough of Bexley

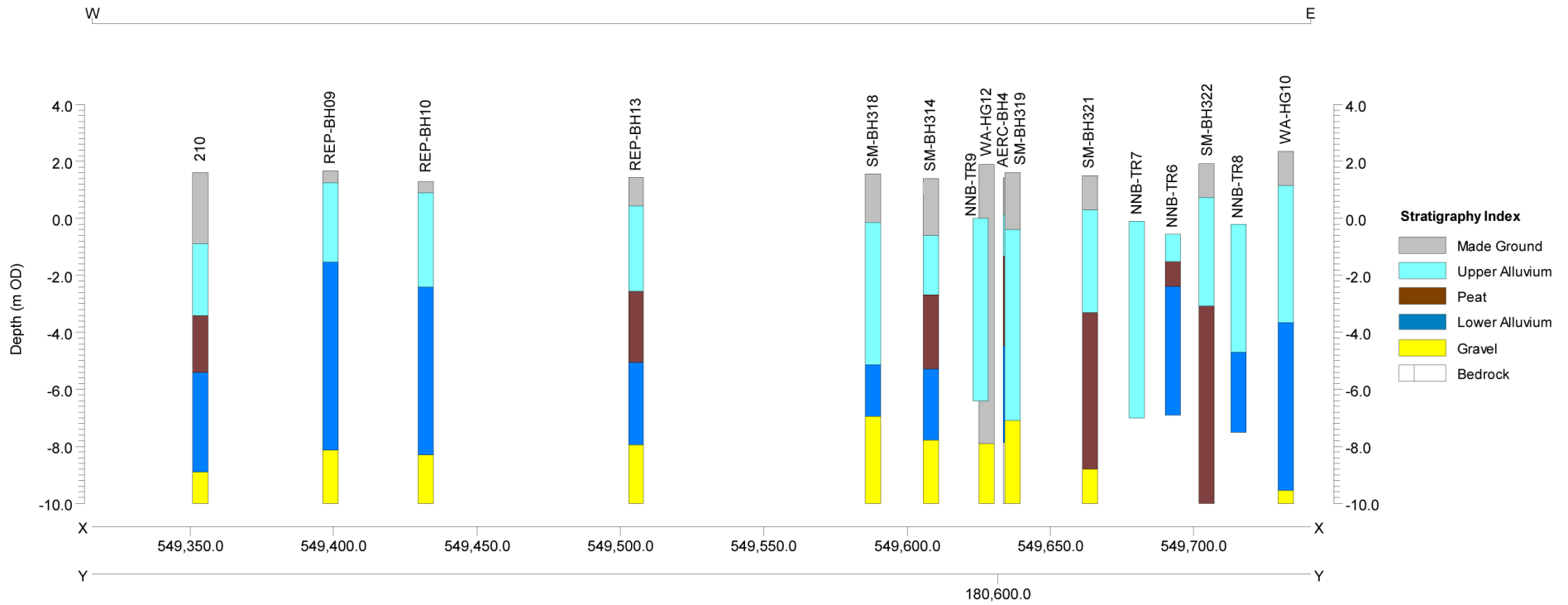


Figure 13: West-East transect (south) of selected boreholes across REP site, London Borough of Bexley

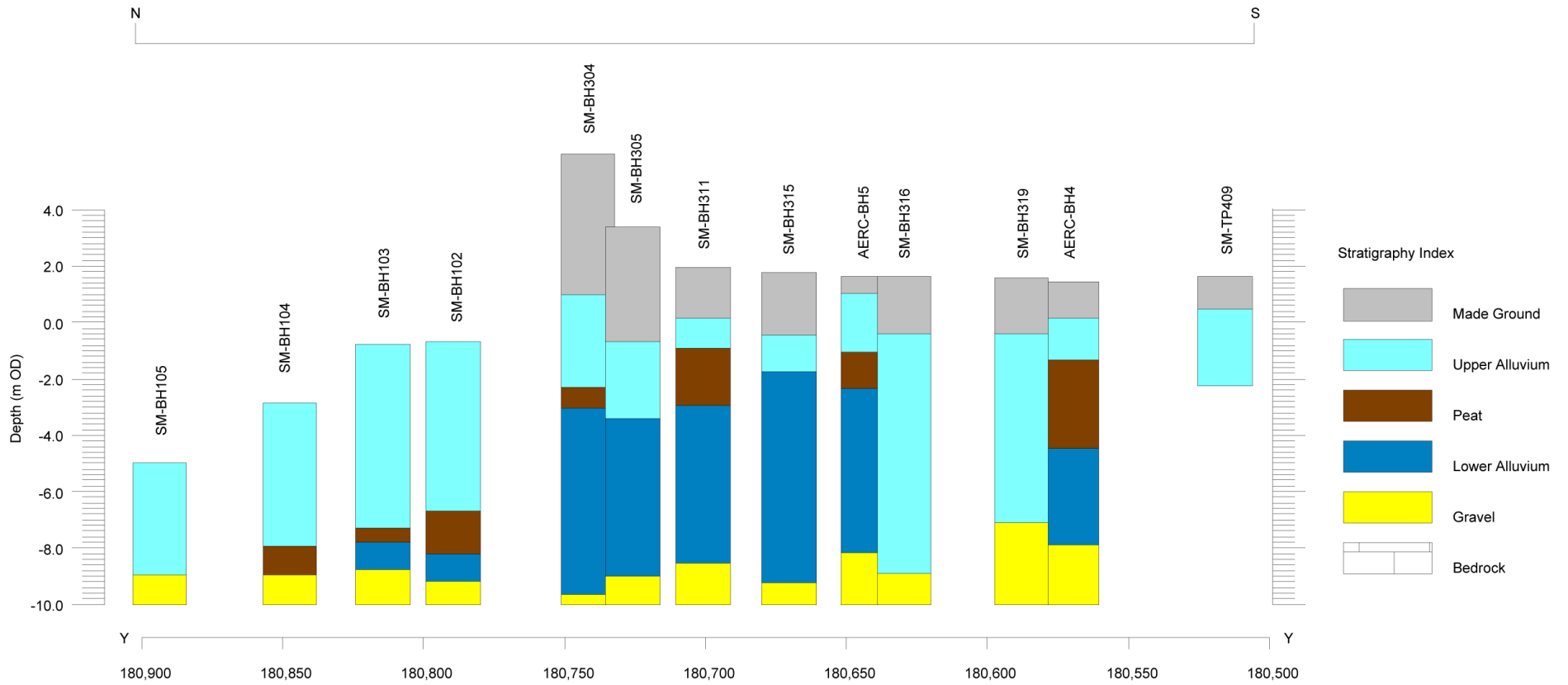


Figure 14: North-South transect of selected boreholes across REP site, London Borough of Bexley

5. CONCLUSIONS AND RECOMMENDATIONS

A programme of geoarchaeological fieldwork and updated deposit modelling was instigated at the REP site in order to: (1) to summarise current understanding of the nature of the sub-surface stratigraphy, in particular the presence and thickness of alluvium and peat across the REP site; (2) to evaluate the potential of these sediments for providing information on the environmental history of the REP site, and evidence of human activity, and (3) to make updated recommendations for further work as a Development Consent Order Requirement (if necessary).

As a consequence of the 2018 geotechnical boreholes at the REP site and geoarchaeological monitoring, the resultant updated deposit model attains complete coverage of REP site, and those areas previously covered have been ground-truthed. The combined results indicate that the sediments recorded at the REP site are similar to those recorded elsewhere in the Lower Thames Valley, with Late Devensian Shepperton Gravel overlain by a tripartite sequence of Holocene Lower Alluvium, Peat and Upper Alluvium, buried beneath modern Made Ground. In addition, the following features were noted: (1) the absence of Peat on the south-eastern and south-western parts of the REP site (as noted beneath the Former Borax Works site and within new geotechnical boreholes BH09 and BH10), and (2) the presence of alternating mineral-rich and organic-rich/peat deposits within the Lower Alluvium which were not studied as part of the Former Borax Works investigations.

On the basis of the depth of the sediments and findings from nearby sites, the archaeological potential of the REP site is considered low. However, even in the absence of archaeological remains, the sediments have the potential to contain further information on the past landscape, through the assessment/analysis of palaeoenvironmental remains (e.g. pollen, plant macrofossils and insects) and radiocarbon dating. So called environmental archaeological or palaeoenvironmental investigations can identify the nature and timing of changes in the landscape, and the interaction of different processes (e.g. vegetation change, human activity, climate change, hydrological change) thereby increasing our knowledge and understanding of the REP site and nearby area. In the case of human activity, palaeoenvironmental evidence can include: (1) decreases in tree and shrub pollen suggestive of woodland clearance; (2) the presence of herbs indicative of disturbed ground, pastoral and/or arable agriculture; (3) charcoal/microcharcoal suggestive of anthropogenic or natural burning, and (4) insect taxa indicative of domesticated animals. Such investigations are routinely carried out where required as part of planning conditions across the Lower Thames Valley and its tributaries, instructed by the Local Planning Authority Archaeological Advisor.

Following the results of the geoarchaeological fieldwork and updated deposit modelling, it is recommended that boreholes are retained for palaeoenvironmental assessment / analysis as a Development Consent Order Requirement. It is recommended that these are retained from the locations of BH04 (where a complex arrangement of mineral-rich and organic-rich/peat deposits was observed in the Lower Alluvium) and between BH12 (where the peat was recorded at 3m thick) and BH09/BH10 (where peat was entirely absent), to ground-truth the nature of the deposits in this part of the REP site. These works will consider the sequence in the context of the model of the Lower Thames Floodplain produced for publication 8 in the Archaeology Crossrail series, 2017.

REFERENCES

AERC (2003) Riverside Resource Recovery (Energy from Waste) Facility, Norman Road, Belvedere: Site Investigation & Remediation Proposals. Unpublished Report C3477/R1384; September 2003.

Askew, P. and Spurr, G. (2006) *Crabtree Manorway South, Belvedere: an archaeological evaluation and geoarchaeological investigation report*. MoLAS Unpublished Report.

Batchelor, C.R. (2009) *Middle Holocene Environmental Changes and the History of Yew (Taxus baccata L.) Woodland in the Lower Thames Valley*. Department of Geography, Royal Holloway, University of London, Unpublished PhD thesis.

Batchelor, C.R. (2015) *Alchemy Park, Crabtree Manorway North, London Borough of Bexley: Written Scheme of Investigation*. Quaternary Scientific (QUEST) Unpublished Report December 2015; Project Number 201/15.

Batchelor, C.R. (2016) *Burts Wharf, Crabtree Manorway North, London Borough of Bexley: Desk-based deposit modelling report*. Quaternary Scientific (QUEST) Unpublished Report November 2016; Project Number 065/16.

Batchelor, C.R. (2018a) *Riverside Energy Park, London Borough of Bexley: Desk-based deposit modelling report*. Quaternary Scientific (QUEST) Unpublished Report April 2018; Project Number 024/18.

Batchelor, C.R. (2018b) *Riverside Energy Park, London Borough of Bexley: Geoarchaeological and Palaeoenvironmental Written Scheme of Investigation*. Quaternary Scientific (QUEST) Unpublished Report April 2018; Project Number 024/18.

Batchelor, C.R. & Young, D.S. (2016) *Alchemy Park, Crabtree Manorway North, London Borough of Bexley: Geoarchaeological fieldwork and deposit model report*. Quaternary Scientific (QUEST) Unpublished Report March 2016; Project Number 201/15.

Batchelor, C.R., Young, D.S. & Hill, T. (2016) *Alchemy Park, Crabtree Manorway North, London Borough of Bexley: Geoarchaeological assessment report*. Quaternary Scientific (QUEST) Unpublished Report September 2016; Project Number 201/15.

Batchelor, C.R. & Young, D.S. (2013) *Powerwind Project, Manor Road, Erith, London Borough of Bexley (site code: PWW12): environmental archaeological analysis report*. Quaternary Scientific (QUEST) Unpublished Report April 2013; Project Number 120/12.

Batchelor, C.R. & Green, C.P. (2013) *A report on the geoarchaeological deposit modelling on land at Veridion Park, London Borough of Bexley*. Quaternary Scientific (QUEST) Unpublished Report February 2013; Project Number 225/12.

Batchelor, C.R., Branch, N.P., Elias, S., Green, C.P., Swindle, G.E., & Wilkinson, K.N. (2007a) *Thames Water Utilities LTD, tidal Thames quality improvements, Crossness, London Borough of Bexley: environmental archaeological analysis (site code EAW06)*. ArchaeoScape Unpublished Report.

Batchelor, C.R., Branch, N.P., Austin, P. (2007b) *Crossness Sewage Works, Crossness, London Borough of Bexley: environmental archaeological analysis of waterlogged wood remains (site code: CXS07)*. ArchaeoScape Unpublished Report.

Batchelor, C.R., Branch, N.P., Elias, S., Young, D., Austin, P., Green, C.P., Morgan, P. & K, Williams. (2008a). *Former Borax works, Norman Road, Belvedere, London Borough of Bexley: environmental archaeological analysis (site code: NNB07)*. ArchaeoScape Unpublished Report.

Batchelor, C.R., Branch, N.P., Christie, R., Elias, S. Young, D.S., Austin, P., Williams, K., & Wilkinson, K. (2008b) *Imperial Gateway, Belvedere: environmental archaeological assessment report*. Quaternary Scientific (QUEST) Unpublished Report December 2008; Project Number 056/08.

Branch, N.P., Silva, B. & Swindle, G.E. (2004) *An Environmental Archaeological Assessment: North Bexley Drainage Improvements, Belvedere, Kent (EWY01)*. ArchaeoScape Unpublished Report, 2004.

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

Corcoran, J. & Lam, J. (2002) *Land at Project Alice, the former British Gypsum Site, Corinthian Quay, Church Manor Way, Erith: a report on the geoarchaeological evaluation*. MoLAS Unpublished Report.

Devoy, R.J.N. (1979) Flandrian sea-level changes and vegetational history of the lower Thames estuary. *Philosophical Transactions of the Royal Society of London*, **B285**, 355-410.

Green, C.P., Batchelor, C.R., Austin, P., Brown, A., Cameron, N., Young, D.S. (2014) Holocene Alluvial Environments at Barking, Lower Thames Valley, UK. *Proceedings of the Geologists Association* **125**, 179-295.

RSK Geotechnics Ltd (2004) Proposed commercial development at land adjacent to Burt's Wharf, Belvedere, Kent – Area 2, for Burt Boulton Holdings Limited: Ground Investigation Report. Unpublished RSK Geotechnics report number 9209/2; June 2004.

RSK Geotechnics Ltd (2005) Proposed commercial development at land adjacent to Burt's Wharf, Belvedere, Kent – Area 2, for Burt Boulton Holdings Limited Additional Investigation: Ground Investigation Report. Unpublished RSK Geotechnics report number 9699/1; October 2005.

RSK Geotechnics Ltd (2006) Proposed commercial development at land adjacent to Burt's Wharf, Belvedere, Kent – Area 1, for Burt Boulton Holdings Limited Additional Investigation: Ground Investigation Report. Unpublished RSK Geotechnics report number 9927/2; January 2006.

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

Sidell, E.J., Scaife, R., Wilkinson, K., Giorgi, J., Goodburn, D. & Gray-Rees, L. (1996) *Spine Road Development, Erith, Bexley (site 2649): a palaeoenvironmental assessment*: MoLAS Unpublished Report.

Soil Mechanics (2007) Riverside Resource Recovery Facility, Belvedere, Kent: Factual Report on Ground Investigations. Unpublished Report A7007, April, 2007.

Soil Mechanics (2007) Riverside Resource Recovery Facility, Belvedere, Kent: Factual Report on Ground Investigations. Unpublished Report G7061, November, 2007.

Wilkinson Associates (1992) Site Investigation Report: Waste to Energy Incineration Plant, Belvedere. Unpublished Report, October 1992.

Young, D.S. & Batchelor, C.R. (2016) Parkway Primary School, Alsike Road, Erith, London Borough of Bexley: Geoarchaeological deposit model report. Quaternary Scientific (QUEST) Unpublished Report June 2016; Project Number 209/15.

Young, D.S., Batchelor, C.R. and Braithwaite, R.A. (2008a) *The Former NuFarm Site, Church Manorway North, Belvedere: geoarchaeological fieldwork report*. Quaternary Scientific (QUEST) Unpublished Report October 2012; Project Number 145/12.

Young, D.S., Batchelor, C.R., Green, C.P and Braithwaite, R.A. (2008b) *Pirelli Works, Church Manorway, Erith, (site code: PWR12): environmental archaeological assessment report*. Quaternary Scientific (QUEST) Unpublished Report September 2012; Project Number 053/12.