GSK WORTHING, SOUTHDOWN VIEW WAY, WORTHING, WEST SUSSEX (NGR: TQ 1587 0466): GEOARCHAEOLOGICAL FIELDWORK AND DEPOSIT MODEL REPORT

D.S. Young and C.P. Green
Quaternary Scientific (QUEST), School of Human and Environmental Sciences, University of Reading, Whiteknights, PO Box 227, Reading, RG6 6AB, UK

INTRODUCTION

This report summarises the findings arising out of the geoarchaeological fieldwork and deposit modelling undertaken by Quaternary Scientific (University of Reading) in connection with the proposed development of land at GSK Worthing, Southdown View Way, Worthing, West Sussex (National Grid Reference: TQ 1587 0466; Figure 1). Quaternary Scientific were commissioned by CgMs Consulting to undertake the geoarchaeological investigations. The site lies on the coastal plain of West Sussex, at a level of approximately 3.0m OD. The bedrock geology at the site is recorded by the British Geological Survey (BGS) as the Upper and Middle Chalk (BGS 1:50,000 Sheets 318/333 Brighton and Worthing 1994). In the area of the site the bedrock is overlain by Alluvium, historically associated with a tidal inlet which met the English Channel *ca*. 2km to the south-east. The former (20th Century) course of this inlet, here known as the Teville Stream, runs approximately east-west through the southern part of the proposed development (Figure 2). The marshes associated with this inlet were gradually drained during the first half of the 20th century, to make way for various phases of industrial development at the site (Meager, 2014).

Recent work at Willowbrook Road (*ca*. 500m to the southeast of the present site; Figure 1) indicated that alluvial deposits associated with the infilling of the Teville Stream have the potential to preserve organic sediments dating to the Mid- to Late Holocene (Pope & Pyre, 2009). If sedimentary sequences containing Alluvium or in-channel deposits associated with the Teville Stream or other former channels can be identified at the GSK Worthing site, there is thus the potential for these sequences to contain information on the past environmental history of the site and its environs. During previous geotechnical and geoarchaeological borehole surveys at the site in 2005 and 2014 (Meager, 2014; Krawiec, 2014) thicknesses of between 0.7 and 1.7m of Made Ground were recorded overlying Gravel, present to between 4.0 and 6.5m below ground surface (bgs), which in turn overlies Chalk bedrock. Disturbed Alluvium containing brick fragments was recorded in one borehole (BH6) between 0.7 and 1.6m bgs. The absence of in situ Alluvium or in-channel deposits associated with the Teville Stream may be a result of the boreholes being placed outside of its projected former course,

based on historic mapping (Krawiec, 2014). Equally however, if the area now mapped by the BGS as Alluvium was originally a marine embayment, its silting up will have led to the formation of mud or sand flats and eventually saltmarsh, intersected by tidal creeks. A reasonably stable pattern of creeks would probably eventually have become established, and the Teville Stream would seem to represent the final (20th Century) form of the main creek. Early mapping indicates tributary water-courses confluent with the Teville Stream both from the north and south. If organic sediment has been found in this area of Alluvium, as reported by Pope & Pyre (2009), it is most likely to have survived in an abandoned portion of creek. Such a feature might be close to the present day course of the Teville Stream; but it might equally be at some distance from it.

The aims of the geoarchaeological investigations at the site were thus (1) to clarify the nature of the sub-surface stratigraphy, in particular the presence and thickness of Alluvium (including peat) across the site, and (2) to evaluate the potential of the sedimentary sequences for reconstructing the environmental history of the site and its environs. In order to achieve this aim, eight geoarchaeological boreholes were put down at the site and a programme of deposit modelling undertaken, as outlined in the written scheme of investigation for the site (Young, 2014). This process incorporated:

1. Recording the lithostratigraphy of the new geoarchaeological borehole sequences to clarify the nature of the subsurface stratigraphy at the site, and to provide a preliminary reconstruction of the sedimentary history;
2. To use the stratigraphic data from the new locations and existing records to produce a new deposit model of the major depositional units across the site.

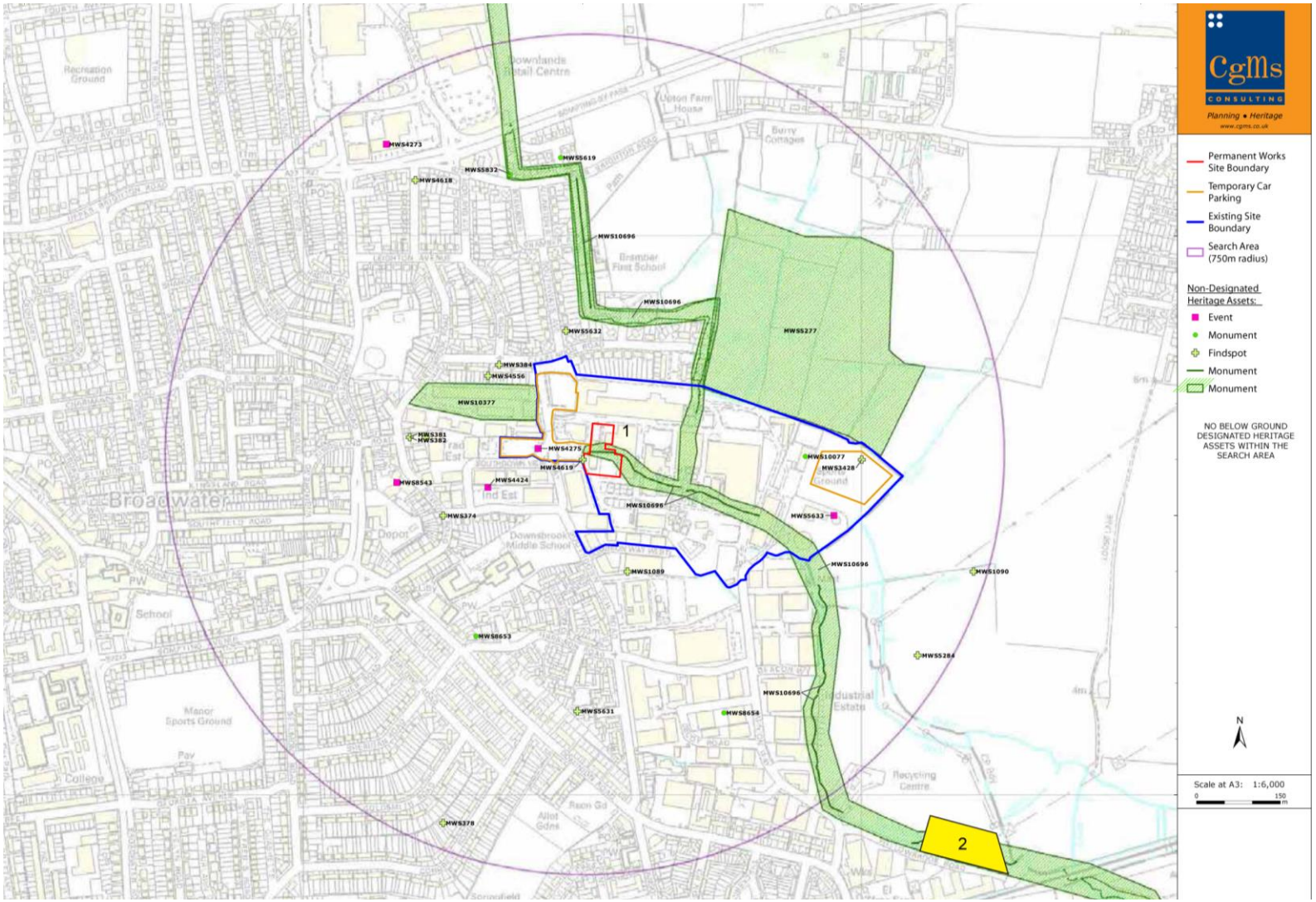

Figure 1: Location of (1) GSK Worthing, Southdown View Way, Worthing (red outline) and (2) Willowbrook Road (Pope & Pyre, 2009). HER data and original figure provided by CgMs Consulting (Meager, 2014).

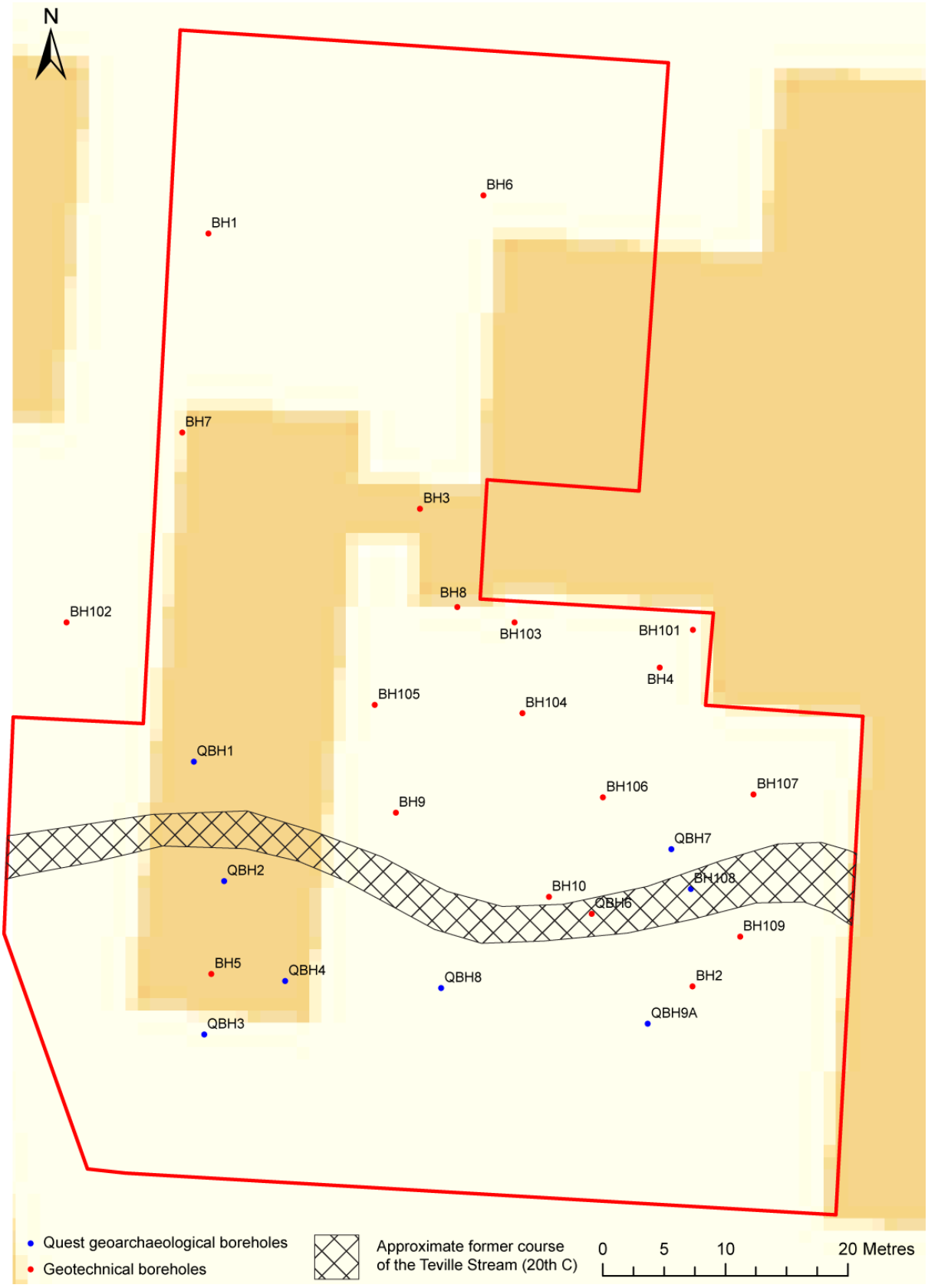

Figure 2: Location of the new geoarchaeological and existing geotechnical borehole records at GSK Worthing, Southdown View Way, Worthing. *Contains Ordnance Survey data © Crown copyright and database right [2012].*

METHODS

Eight boreholes (boreholes <QBH1> to <QBH9A>) were put down at the site in June 2014 (Figure 2). Borehole core samples were recovered using an Eijkelkamp window sampler and gouge set using an Atlas Copco TT 2-stroke percussion engine. This coring technique is a suitable method for the recovery of continuous, undisturbed core samples and provides sub-samples suitable for not only sedimentary and microfossil assessment and analysis, but also macrofossil analysis. At the location of borehole QBH9 an obstruction prevented drilling below 1.00m below ground surface (bgs); this borehole location was therefore moved to that of QBH9A, *ca*. 2m to the northwest (Figure 2). No borehole was put down at the proposed location of QBH5, since this borehole was sited outside of the area available to work (and on an access road) at the time of the fieldwork.

Where samples were retained, these were wrapped in clear plastic to prevent moisture loss, labelled with the depth (metres from ground surface) and orientation (top and base) and returned to Quaternary Scientific for storage in a purpose built facility at 2^{o}C. This temperature prevents fungal growth on the core surface, which may lead to anomalous radiocarbon dates, and moisture loss. The spatial attributes of each borehole were recorded using a Leica Differential GPS (Table 1 and Figure 2). Due to the height of the surrounding buildings the accuracy provided by the Differential GPS varied; where no accurate measurement (±1cm) for the elevation of a borehole was recorded, this was estimated as 2.90m OD. No OD heights were available for geotechnical boreholes BH1 to BH9; an elevation of 2.90m OD was also estimated for these boreholes (see Table 2).

Table 1: Borehole attributes for those records used in the deposit model, GSK Worthing, Southdown View Way, Worthing, West Sussex

Borehole	**Easting**	**Northing**	**Elevation (m OD)** **estimated*
Geoarchaeological boreholes			
QBH1	515515.577	104604.351	2.98
QBH2	515518.055	104594.591	2.90*
QBH3	515516.416	104582.053	2.90*
QBH4	515523.051	104586.442	2.97
QBH6	515548.071	104591.906	2.82
QBH7	515554.577	104597.202	2.85
QBH8	515535.786	104585.845	2.90*
QBH9A	515552.656	104582.954	2.90*
Geotechnical boreholes			
BH1	515516.756	104647.510	2.90*
BH2	515556.323	104586.000	2.90*
BH3	515534.062	104625.025	2.90*
BH4	515553.619	104612.051	2.90*

Borehole	**Easting**	**Northing**	**Elevation (m OD)** **estimated*
BH5	515517.005	104587.009	2.90*
BH6	515539.233	104650.633	2.90*
BH7	515514.625	104631.249	2.90*
BH8	515537.097	104616.987	2.90*
BH9	515532.079	104600.173	2.90*
BH10	515544.578	104593.289	2.90*
BH101	515556.338	104615.115	3.16
BH102	515505.194	104615.734	2.99
BH103	515541.783	104615.734	3.13
BH104	515542.410	104608.321	3.10
BH105	515530.370	104609.000	2.92
BH106	515549.004	104601.452	3.09
BH107	515561.299	104601.676	3.05
BH108	515556.164	104593.942	3.14
BH109	515560.201	104590.035	3.10

Lithostratigraphic descriptions

The lithostratigraphy of all boreholes was described using standard procedures for recording unconsolidated sediment and organic sediments, noting the physical properties (colour), composition (gravel, sand, clay, silt and organic matter) and inclusions (e.g. artefacts) (Tröels-Smith, 1955). The procedure involved: (1) cleaning the sample using a scalpel; (2) recording the physical properties, most notably colour using a Munsell Soil Colour Chart; (3) recording the composition; gravel (Grana glareosa; Gg), fine sand (Grana arenosa; Ga), silt (Argilla granosa; Ag) and clay (Argilla steatoides); (4) recording the degree of peat humification and (5) recording the unit boundaries e.g. sharp or diffuse. The majority of descriptions were made in the field, with the exception of retained samples which were described in the laboratory. The results are displayed in Figures 3 (northwest-southeast transect) and 4 (southwest-northeast transect) and in Tables 2 to 10.

Deposit modelling

The deposit model was based on a review of 27 borehole records, incorporating the eight new geoarchaeological boreholes and 19 geotechnical boreholes (provided by GSK/Ashdown Site Investigation Ltd) within the site (Figure 2). Sedimentary units from the boreholes were classified into four groupings: (1) Chalk (2) Gravel, (3) Alluvium and (4) Made Ground. The classified data for groups 1-4 were then input into a database with the RockWorks 16 geological utilities software. Models of surface height (using a nearest neighbour routine) were generated for the bedrock Chalk (Figure 5) and Gravel (Figure 6). Thickness of the Made Ground (Figure 7) was also modelled (also using a nearest neighbour routine). Because the boreholes are not uniformly distributed over the area of

investigation, the reliability of the models generated using RockWorks is variable. In general, reliability improves towards the core area of commissioned 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 diameter around each borehole is applied to the deposit models of the Gravel and Made Ground. A 25m diameter cut-off filter is applied to the deposit model of the Chalk, since only six borehole records were deep enough to record this unit. In addition, it is important to recognise that two 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. Of the records used in the deposit model, the cores from the boreholes put down by Quaternary Scientific represent the most detailed record of the sediment sequences.

RESULTS, INTERPRETATION AND DISCUSSION OF THE LITHOSTRATIGRAPHIC DESCRIPTIONS AND DEPOSIT MODELLING

The geoarchaeological investigations (Tables 2 to 10) have permitted a programme of deposit modelling of the surface elevation and thickness of selected stratigraphic units (Figures 3 to 7). The basal unit at the site, recorded in selected geotechnical boreholes (BH1, BH2, BH4, BH5, BH101 and BH102), is the Cretaceous Chalk bedrock. The surface of the Chalk (Figure 5) is recorded at between -3.6 (BH1) and -0.74m OD (BH101). Towards the south of the site, in the area of boreholes BH2 and BH5 (those boreholes closest to the mapped former 20th century course of the Teville Stream) it is recorded at -2.1m OD. In borehole BH101, to the northeast, it is recorded as rising to -0.74m OD, whilst towards the northwest in boreholes BH102 and BH1 it falls to -2.01 and -3.6m OD respectively. Given the limited number of borehole records available that record the surface of the Chalk, it is not possible to interpret in detail the location or orientation of any former (Pleistocene) channels.

Overlying the Chalk in the six boreholes above, and recorded at the base of the remainder of the borehole records is a horizon of sand and gravel, most likely deposited during the Late Devensian (15,000 to 10,000 years before present) within a high energy braided river environment. In the majority of boreholes (with the exception of borehole QBH1) the

recorded surface of the Gravel is at its contact with the Made Ground (Figure 6). A possible east-west aligned channel feature is evident in the deposit model for the surface of the Gravel, lying within the approximate area of the 20th century course of the Teville Stream (see Figure 6). Within this feature the Gravel surface falls to below 0.8m OD, recorded at its lowest at 0.08m OD (borehole QBH1) and 0.10m OD (QBH7). To the south and north of this feature the gravel surface is generally recorded at between 0.8 and 1.7m OD. Given that Made Ground directly overlies the Gravel in the majority of boreholes, it is not possible to determine to what extent modern truncation has determined the level of its surface, as opposed to its natural elevation. However, the east-west aligned feature evident in the boreholes is consistent with the approximate mapped area of the 20th century course of the Teville Stream.

As stated above, in all but one borehole the Gravel is directly overlain by Made Ground. In borehole QBH1 (within the area of the feature identified above), a horizon of clayey and in places sandy silt is recorded between 0.53 and 0.08m OD, interpreted as Holocene Alluvium. Its sandy nature and the presence of fine laminations between 0.16 and 0.08m OD may be indicative of low-energy fluvial deposition, prior to the deposition of floodplain Alluvium between 0.53 and 0.16m OD. Between 0.53 and 0.16m OD traces of detrital plant material are recorded, but the Alluvium is otherwise devoid of in-situ organic material (including Peat).

Elsewhere variable thickness of between *ca*. 1.2 and 2.5m of Made Ground are recorded directly overlying the Gravel (Figure 7). In general the Made Ground is thickest in the area of the east-west aligned feature identified above, where thicknesses greater than 2.0m are recorded. At the base of the Made Ground (between *ca*. 2.5 and 1.0m OD) in two of the eight geoarchaeological boreholes (QBH4 and QBH9A) and two geotechnical boreholes (BH5 and BH6) a horizon of redeposited Alluvium is recorded, frequently containing brick fragments and other remnants of industrial waste. The modern surface elevation of the site lies at *ca*. 3.0m OD.

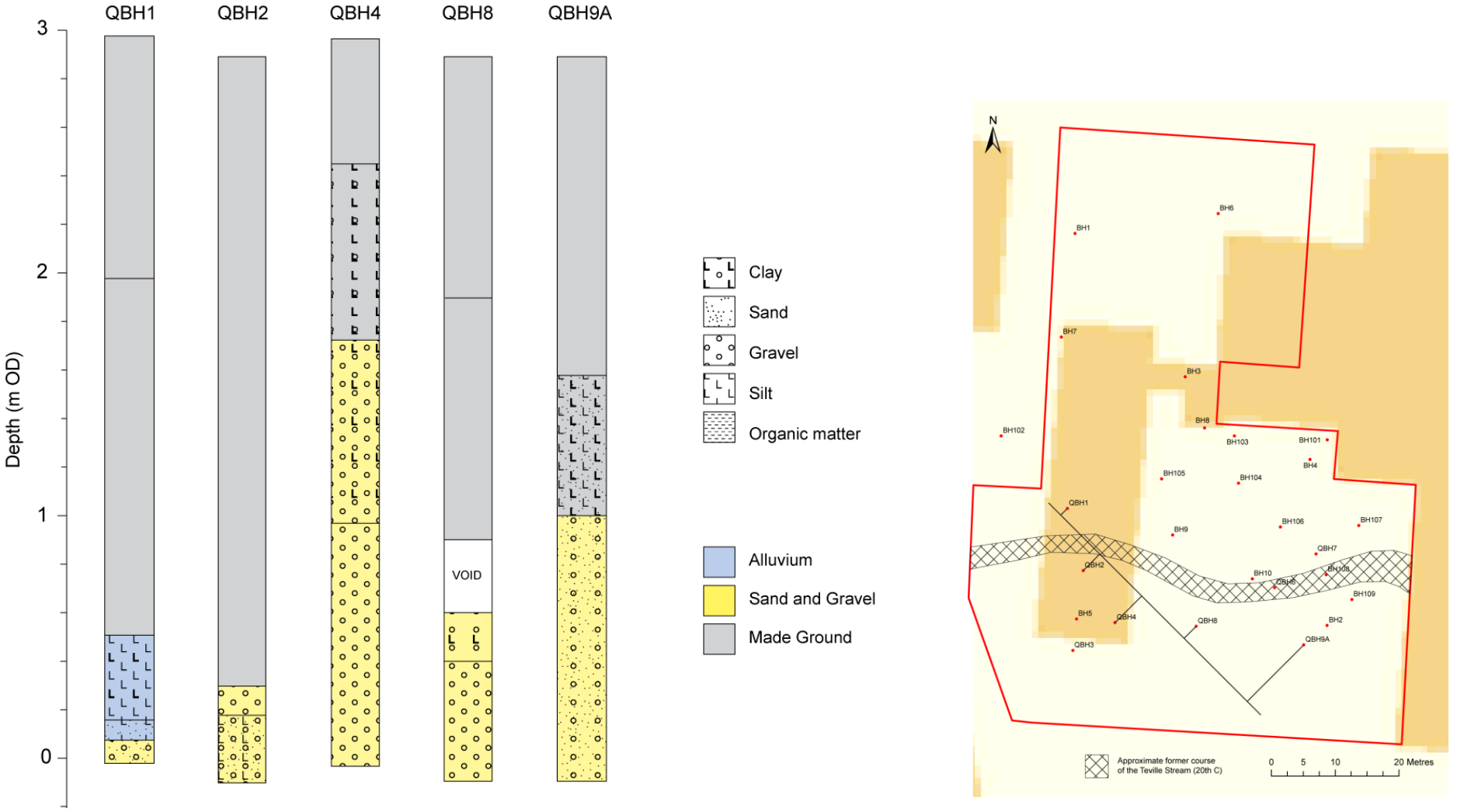

Figure 3: Northwest-southeast transect of selected Quest boreholes across the site at GSK Worthing, Southdown View Way, Worthing, West Sussex

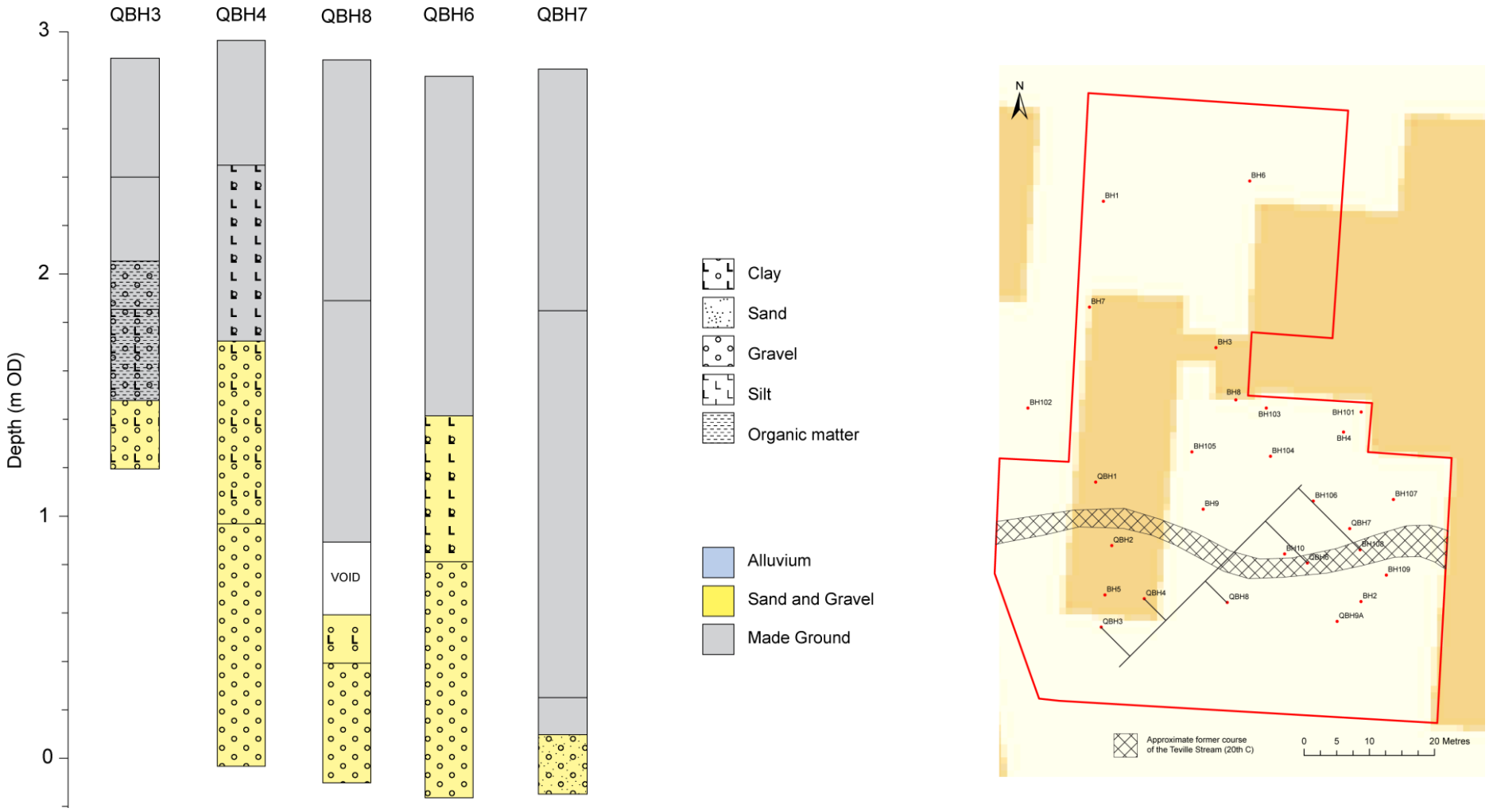

Figure 4: Southwest-northeast transect of selected Quest boreholes across the site at GSK Worthing, Southdown View Way, Worthing, West Sussex

Table 2: Lithostratigraphic description of borehole QBH1, GSK Worthing, Southdown View Way, Worthing, West Sussex

Depth (m OD)	Depth (m bgs)	Description
2.98 to 1.98	0.00 to 1.00	Made Ground; concrete and brick rubble.
1.98 to 0.53	1.00 to 2.45	Made Ground in matrix of brown sandy clay.
0.53 to 0.16	2.45 to 2.82	Ag3 As1 Dh+ Dl+; dark olive brown clayey silt with traces of detrital herbaceous material and detrital wood. Sharp contact in to:
0.16 to 0.08	2.82 to 2.90	Ag2 As1 Ga1; greenish grey sandy clayey silt with fine laminations. Sharp contact in to:
0.08 to -0.02	2.90 to 3.00	Gg3 Ga1 As+; greenish grey sandy gravel with a trace of clay. Flint clasts 5-60mm in diameter, sub-angular to well-rounded.

Table 3: Lithostratigraphic description of borehole QBH2, GSK Worthing, Southdown View Way, Worthing, West Sussex

Depth (m OD)	Depth (m bgs)	Description
2.90 to 0.30	0.00 to 2.60	Made Ground; concrete and brick rubble.
0.30 to 0.18	2.60 to 2.80	Gg4 Ga+; gravel with a trace of sand. Flint clasts 5-60mm in diameter, sub-angular to well-rounded. Diffuse contact in to:
0.18 to -0.10	2.80 to 3.00	Gg2 Ga1 Ag1; orangey brown silty sandy gravel. Flint clasts 20-40mm in diameter, sub-angular to well-rounded.

Table 4: Lithostratigraphic description of borehole QBH3, GSK Worthing, Southdown View Way, Worthing, West Sussex

Depth (m OD)	Depth (m bgs)	Description
2.90 to 2.40	0.00 to 0.50	Made Ground; tarmac and sand and gravel.
2.40 to 2.06	0.50 to 0.84	Made Ground; gravelly clay with brick fragments.
2.06 to 1.86	0.84 to 1.04	Gg2 As1 Sh1; dark brown slightly organic clayey gravel. Flint clasts up to 40mm diameter, sub-angular to angular. Possibly redeposited (Made Ground). Diffuse contact in to:
1.86 to 1.48	1.04 to 1.56	As2 Sh1 Gg1; dark brown slightly organic gravelly clay. Flint clasts up to 40mm diameter, sub-angular to angular. Possibly redeposited (Made Ground). Sharp contact in to:
1.48 to 1.20	1.56 to 1.70	Gg3 As1; dark brown clayey gravel. Flint clasts 5-60mm in diameter, sub-angular to well-rounded.

Table 5: Lithostratigraphic description of borehole QBH4, GSK Worthing, Southdown View Way, Worthing, West Sussex

Depth (m OD)	Depth (m bgs)	Description
2.97 to 2.47	0.00 to 0.50	Made Ground; concrete and brick rubble.
2.47 to 1.72	0.50 to 1.25	As2 Ag1 Gg1; dark brown silty gravelly clay. Possibly redeposited (Made Ground). Sharp contact in to:
1.72 to 0.97	1.25 to 2.00	Gg3 As1 Ga+; brown clayey gravel with a trace of silt. Possibly redeposited (Made Ground). Sharp contact in to:
0.97 to -0.03	2.00 to 3.00	Gg4 Ga+; gravel with a trace of sand. Flint clasts 20-40mm in diameter, sub-angular to sub-rounded.

Table 6: Lithostratigraphic description of borehole QBH6, GSK Worthing, Southdown View Way, Worthing, West Sussex

Depth (m OD)	Depth (m bgs)	Description
2.82 to 1.82	0.00 to 1.00	Made Ground; concrete and brick rubble.
1.82 to 1.42	1.00 to 1.40	Made Ground; concrete and brick rubble in a clayey matrix.
1.42 to 0.82	1.40 to 2.00	As2 Ag1 Gg1; dark brown silty gravelly clay. Flint clasts up to 50mm in diameter, sub-angular to angular. Possibly redeposited (Made Ground). Sharp contact in to:
0.82 to -0.18	2.00 to 3.00	Gg4 Ga+; gravel with a trace of sand. Flint clasts 20-60mm in diameter, sub-angular to well-rounded.

Table 7: Lithostratigraphic description of borehole QBH7, GSK Worthing, Southdown View Way, Worthing, West Sussex

Depth (m OD)	Depth (m bgs)	Description
2.85 to 1.85	0.00 to 1.00	Made Ground; concrete and brick rubble.
1.85 to 0.25	1.00 to 2.60	Made Ground; brick rubble in a matrix of brown clay.
0.25 to 0.10	2.60 to 2.75	Made Ground; redeposited gravel.
0.10 to -0.15	2.75 to 3.00	Gg3 Ga1 Ag+; greyish white sandy gravel with a trace of silt. Flint clasts 20-60mm in diameter, sub-angular to well-rounded.

Table 8: Lithostratigraphic description of borehole QBH8, GSK Worthing, Southdown View Way, Worthing, West Sussex

Depth (m OD)	Depth (m bgs)	Description
2.90 to 1.90	0.00 to 1.00	Made Ground; concrete and brick rubble.
1.90 to 0.90	1.00 to 2.00	Made Ground; concrete and brick rubble wtih some clay.
0.90 to 0.60	2.00 to 2.30	VOID
0.60 to 0.20	2.30 to 2.70	Gg3 As1 Ga+; brown clayey gravel with a trace of sand. Flint clasts 20-50mm in diameter, sub-angular to sub-rounded. Diffuse contact in to:
0.20 to -0.10	2.70 to 3.00	Gg4 Ga+ As+; gravel with a trace of sand and clay. Flint clasts 10-50mm in diameter, sub-angular to sub-rounded.

Table 9: Lithostratigraphic description of borehole QBH9, GSK Worthing, Southdown View Way, Worthing, West Sussex

Depth (m OD)	Depth (m bgs)	Description
2.90 to 2.00	0.00 to 0.90	Made Ground; concrete and brick rubble.
2.00 to 1.90	0.90 to 1.00	Made Ground; concrete and brick rubble with some silty clay. Obstruction at 1.90m OD, hole abandoned.

Table 10: Lithostratigraphic description of borehole QBH9A, GSK Worthing, Southdown View Way, Worthing, West Sussex

Depth (m OD)	Depth (m bgs)	Description
2.90 to 1.58	0.00 to 1.32	Made Ground; concrete and brick rubble.
1.58 to 1.00	1.32 to 1.90	As2 Ag1 Ga1; dark brown sandy silty clay with occasional brick fragments (Made Ground). Sharp contact in to:
1.00 to -0.10	1.90 to 2.00	Gg3 Ga1 As+; orangey brown sandy gravel with a

		trace of clay. Flint clasts 20-60mm in diameter, sub-angular to sub-rounded.

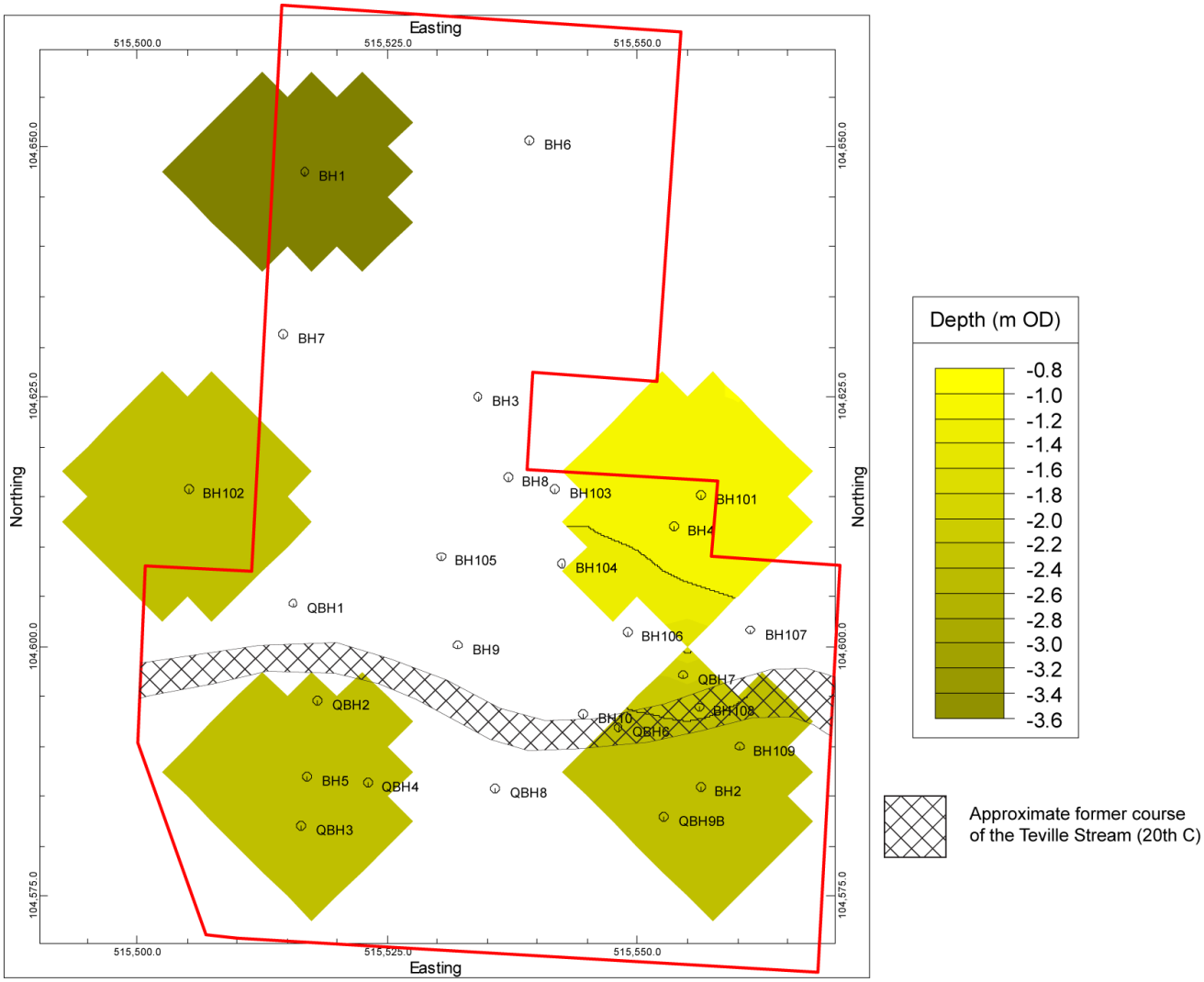

Figure 5: Top of the Chalk (m OD) (site outline in red).

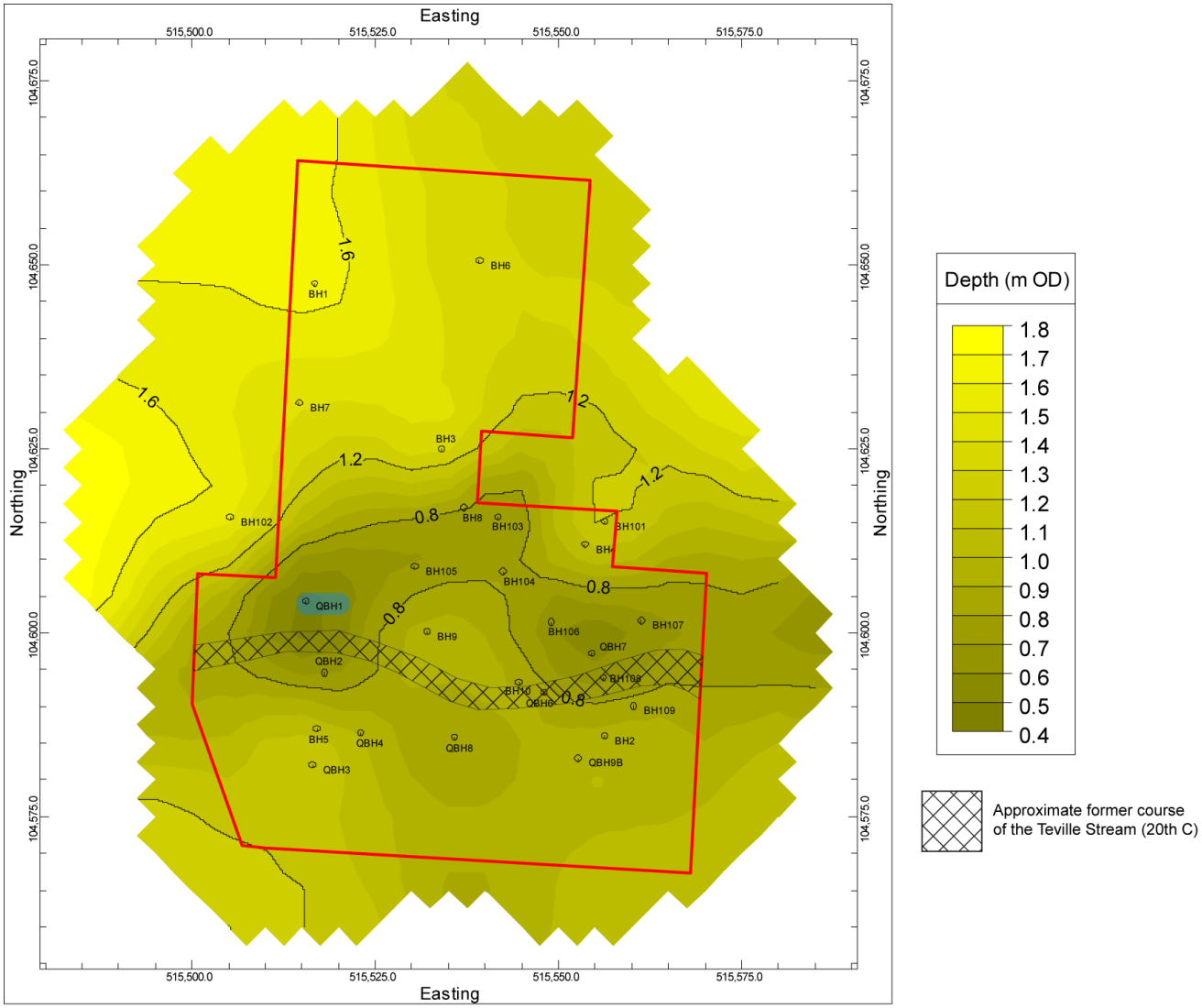

Figure 6: Top of the Gravel (m OD) (site outline in red). Borehole QBH1, the only borehole containing Alluvium, is highlighted in blue.

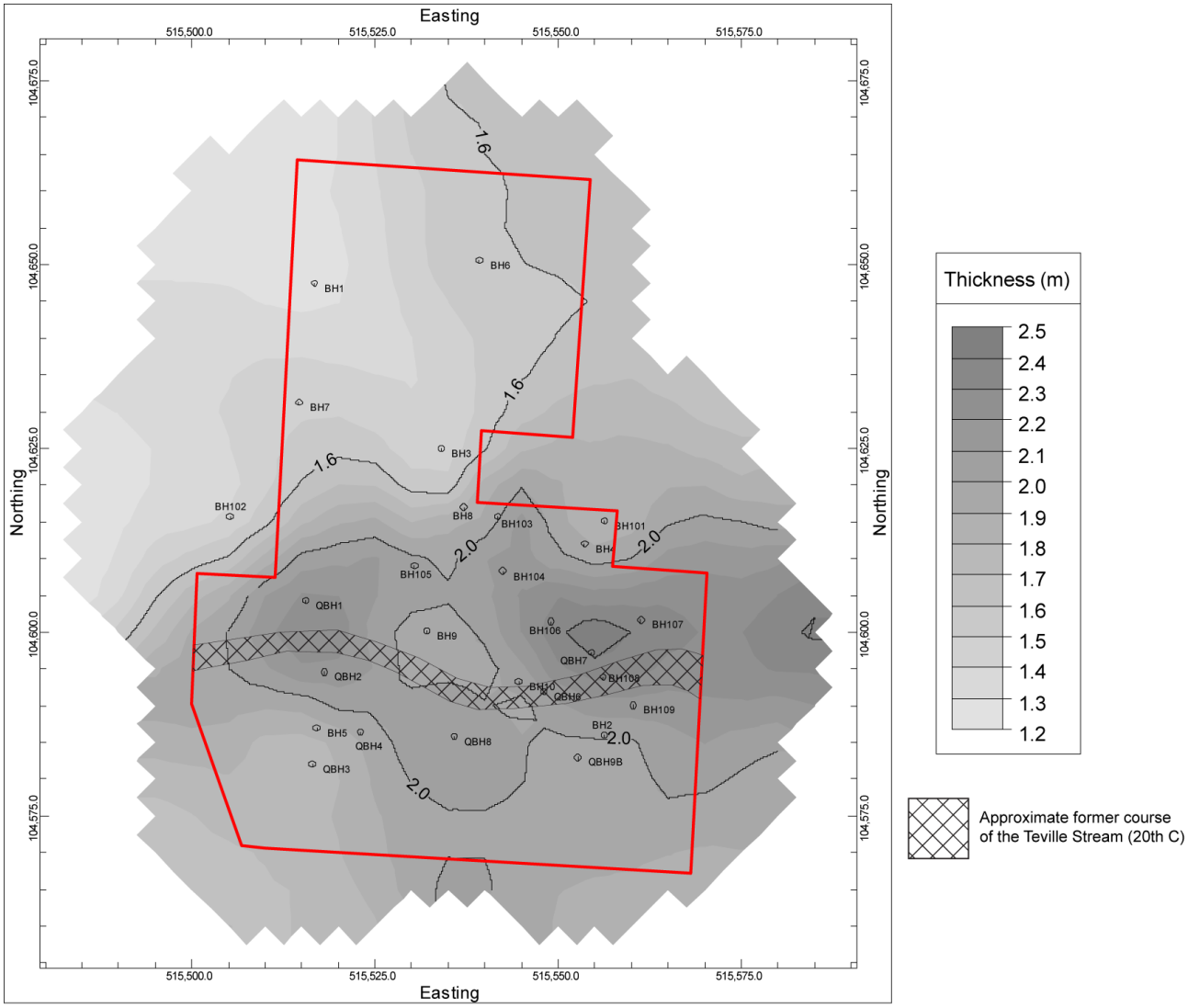

Figure 7: Thickness of Made Ground (m) (site outline in red)

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

The aim of the geoarchaeological investigations at the GSK Worthing site was to (1) clarify the nature of the sub-surface stratigraphy, in particular the presence and thickness of Alluvium and Peat across the site, and (2) to evaluate the potential of the sedimentary sequences for reconstructing the environmental history of the site and its environs. In order to achieve this aim, a programme of deposit modelling of the surface elevation and thickness of the major stratigraphic units at the site was carried out, incorporating previous geotechnical borehole descriptions and records from eight new geoarchaeological boreholes.

The results of the geoarchaeological investigations have demonstrated that an east-west aligned posible channel feature consistent with the mapped 20th century course of the Teville Stream can be identified in the deposit models of the Gravel and Made Ground at the site. The Gravel surface within the feature falls below 1.2m OD, to as low as between 0.08 and 0.10m OD on its main axis. Within the feature only one borehole recorded predominantly mineral-rich Holocene Alluvium, with an indication of low-energy fluvial deposition within the channel between 0.08 and 0.16m OD prior to the deposition of floodplain Alluvium between 0.53 and 0.16m OD. The Made Ground is thicker within this feature, perhaps reflecting the in-fill of the channel during the first half of the 20th century (Meager, 2014). There is no evidence within the channel for organic sediments such as that recorded at Willowbrook Road (*ca*. 500m to the southeast and downstream; Figure 1), where deposits associated with the infilling of the Teville Stream included organic sediments dating to the Mid- to Late Holocene (Pope & Pyre, 2009). In addition, there is no evidence for other former Late Devensian/Early Holocene channels within the site.

A variable Chalk bedrock surface is recorded at the site, lying at between -3.6 and -0.74m OD, perhaps reflecting the location of former (Pleistocene) channels that have eroded the surface of the bedrock and deposited variable thicknesses of Gravel. Chalk bedrock was only reached in six of the 27 boreholes however, and a full interpretation of the Chalk bedrock surface is therefore not possible. However, the borehole records have demonstrated that the palaeoenvironmental potential of the sequences at the GSK Worthing site is very limited, and as a consequence no further environmental archaeological investigations are recommended.

REFERENCES

Meager, R. (2014) GSK Site, Southdownview Road, Worthing, West Sussex. *CgMs Consulting Unpublished Archaeological Desk Based Assessment, February 2014.*

Pope, M. and Pyre, L. (2009) Household Waste and Recycling Site, Wilowbrook Road, Worthing, West Sussex an environmental characterisation and interpretation. *Archaeology South-East Unpublished Report, July 2009.*

Tröels-Smith, J. (1955) Karakterisering af løse jordater (Characterisation of unconsolidated sediments), *Danm. Geol. Unders., **Ser IV* **3**, 73.

Young, D.S. and Green, C.P. (2014) Written scheme of investigation for the geoarchaeological investigation of land at GSK, Southdownview Way, Worthing, West Sussex. *Quaternary Scientific Written Scheme of Investigation, June 2014; Project Number 047/14.*