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Site Investigation Report
for the Proposed Development
on land adjacent to
40 Knight St, Pinchbeck, Lincolnshire

Client Alan Finch

Date: November 2017
Report: 1059/4364/P

SITE INVESTIGATION REPORT FOR
LAND ADJACENT TO 40 KNIGHT STREET, PINCHBECK

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1.0 Introduction

At the request of Alan Finch, and on behalf of his client, Humberside Materials Laboratory Limited (HML) were engaged to undertake an intrusive investigation for the proposed development on land adjacent to 40 Knight Street, Pinchbeck, Lincolnshire.

The aim of the investigation is to assess the ground conditions at the site, including potential contamination, and revise the conceptual site model (CSM) from the Phase 1 report. The scope includes intrusive exploratory boreholes, soil sampling and in-situ and laboratory testing along with an assessment of the findings.

This report is produced solely for Alan Finch and client in relation to the proposed works outlined herein and should only be copied in full. When transmitted electronically the definitive copy of the report is held by Humberside Materials Laboratory Ltd.

The comments given in this report and the opinions expressed assume that ground conditions do not vary beyond the range revealed by the investigation.

2.0 Desk Study Information

A Phase 1 desk top report was undertaken previously by HML in relation to the proposed works. An additional site visit was made on 18th October 2017 for the site works. A summary of the relevant findings is included below.

2.1 Site Description

The site is a roughly T-shaped plot of land located adjacent to the property at number 40 Knight Street, Spalding, Lincolnshire. The site is roughly centred around national grid reference (NGR) 524020, 325870.

A site location plan is included in Appendix A.

A site walkover was undertaken on the 18th October 2017, during which various site features were noted. The site is fairly flat and level, is up to about 70m in length and 55m in width and occupies an area of about 0.1Ha. The site is within a predominantly residential area. The site is bound by residential properties (to the east and west) and playing fields (to the south).

There are a couple of buildings in the western corner of the site. The largest of these is a metal-clad structure with large double sliding doors at the front. There is also a static caravan and a small storage container.

Probably about half of the ground surface at site is covered by hardstanding. The access road is macadam as is a small area near to the southeast corner of site. There is also a concrete-paved area in front of the main building. The rest of the ground surface is mainly bare earth, some of which is grassed.

The site has evidently been in commercial use as a coal depot. There is much coal dust scattered on the bare earth around the southeast corner of the site.

Immediately adjacent to the southern site boundary is a drainage ditch. This was dry at the time of the site walkover.

Views of the site are presented in Appendix A.

2.2 Proposed works

It is proposed to develop the site for low rise residential housing consisting of two plots with associated parking and infrastructure. Both properties will have their own rear garden areas and detached garages.

A proposed layout plan is included in Appendix A.

2.3 Site History

Historical evidence shows that the site has experienced some limited development. A rectangular building was present (at least as early as 1887) in the far western corner of the site. It was removed some time prior to 1968. Some smaller structures in the centre of the site have been shown (since at least as early as 1969). The site expanded to resemble its present-day level of development probably some time prior to (and not long before) 1999. Around this time, the present-day structures in the western corner of the site were built and additional land was included (which had previously been part of the rear garden for number 38 Knight Street). Further afield, no historical evidence has been found of significant industry in the area around the site.

2.4 Site Geology

BGS data indicates the local bedrock geology is the *Oxford Clay Formation* (mudstone). This is overlain by superficial *Tidal Flat Deposits* (clay and silt).

Geological hazards have been reported as follows (in Table 1).

Table 1: Anticipated geological hazards	
<i>Geological hazard</i>	<i>Risk</i>
Collapsible ground stability	No hazard
Compressible ground stability	No hazard
Ground dissolution	No hazard
Landslide ground stability	Very low
Running sand	Moderate
Shrinking and swelling clay	Low

There are no BGS recorded mineral sites within 1km of the site. The site is in an area where coal mining might not affect the site. No hazard is given for non-coal mining activity.

2.5 Hydrology and Hydrogeology

The drainage ditch adjacent to the southern boundary is reported by different sources. Environment Agency information confirms the nearest surface water feature is about 1 metre to the south of the site. Similarly, OS water network line data indicates the closest watercourse is an inland river about 2m to the southwest of the site, which is part of the Welland catchment and has a watercourse level at ‘ground surface.’

The nearest reported water abstraction is about 523m to the east of the site. This relates to Captains Drain – a surface water feature.

The site is within an area at risk from flooding or extreme flooding from rivers or seas without defences. Parts of the site (or all the site) are at risk (low, medium or high) of surface water flooding.

In terms of groundwater vulnerability, the soils beneath the site are not classified. The bedrock aquifer designation beneath the site is unproductive strata. The superficial aquifer designation is also unproductive strata.

There are no source protection zones within 1000m of the site.

2.6 Contaminated land

Radon protection measures are not necessary for new homes at the site.

BGS soil chemistry data indicates the concentrations of contaminants in rural soil around the site, as shown below (in Table 2).

Table 2: Expected concentrations of contaminants (rural)	
<i>Contaminant</i>	<i>Estimated concentration (mg/kg)</i>
Arsenic	<15
Cadmium	<1.8
Chromium	60-90
Lead	<100
Nickel	15-30

The initial conceptual site model (CSM) from the phase 1 desktop study, shown below (in Table 3), indicates contaminants of concern potentially exist, including metals, polycyclic aromatic hydrocarbons (PAH), petroleum hydrocarbons (TPH) and asbestos. Possible pathways are present as indicated. Receptors include land users post development, the most vulnerable users being young children. Hazardous ground gas was assessed as being of minimal/tolerable risk.

Table 3: Initial Conceptual Site Model					
Conceptual Site Model					
Source		Pathway		Receptor	
Source type/area	Contaminant (likelihood)	Route	Sub-route		Risk
Made ground / west corner of site	Metals, PAH, asbestos (medium)	Ingestion	Soils and soils attached and absorbed by home grown produce, Indoor dust Outdoor dust	Human health	medium
Vehicle maintenance / west side of site	TPH (medium)	Absorption	Dermal contact	Human health	medium
Coal storage in the east of the site	Metals, PAH (medium)	Inhalation	Indoor dust Outdoor dust Indoor vapour Outdoor vapour	Human health	medium
		Migration		Ground water Surface water	Very Low
				Building materials & services	Low
Not applicable					
Item		Rational			
Hazardous ground gas		No plausible gas generating source			

3.0 Site Investigation Works

An intrusive investigation was carried out at the proposed development, which comprised windowless sampler boreholes and penetration testing. The procedures adopted for this site investigation are based on BS 5930 (2015) – Code of Practice for Site Investigations and BS 10175 (2013) Investigation of potentially contaminated sites – code of practice.

Exploratory hole locations were generally selected to encompass the full area of site. However, they were also targeted towards proposed rear garden areas to address the potential contamination issues.

Positions of exploratory holes were established relative to existing site features. The approximate locations of all site works are shown in the exploratory hole location plan (in Appendix A).

3.1 Windowless sampler boreholes

Four (windowless sampler) boreholes (BH1 – BH4) were drilled via a Dando Terrier window sampler rig on Wednesday 18th October 2017. This involved the percussive driving of a 1m-long steel tube with a plastic sample tube inserted. Each tube was then hydraulically extracted, the inner sample tube removed and sealed. Each hole was progressed to the required depth by repeating the process with extension rods. All samples were returned to the laboratory for logging and testing.

Hardstanding was present at the locations of BH1 and BH2. This was first penetrated by rotary coring to create access for borehole excavations.

No ground levels were measured during site works. However, the site appeared to be relatively flat such that the ground elevations at the borehole locations appear unlikely to vary by more than about 1.0m.

Standard penetration tests (SPTs) were also undertaken at various depths within the boreholes by driving a split spoon sampler under standard conditions and recording the number of seating blows to advance 150mm and then the number of blows (or N value) to advance a further 300mm into the ground. A motorised hammer lift and an automatic release system were employed.

All four boreholes (BH1 – BH4) were drilled down to a minimum depth of 2m bgl. BH3 and BH4 were extended to 2.45m using Standard Penetration Tests (SPTs).

Samples were taken at various depths as indicated on the borehole logs (in Appendix B). Samples for contamination were collected in amber-coloured glass jars. Full precautions were taken to eliminate any cross contamination of the samples.

3.2 Penetration testing

SPTs were used in conjunction with dynamic probing. SPTS were carried out in BH3 and BH4 at depths of 1m and 2m bgl. Dynamic probing was carried out at the base of BH1 and BH3 to explore down to respective depths of 9.9 and 10.0m bgl.

The results of the penetration tests are included within the borehole logs (in Appendix B).

SPTs used standard conditions. A split-spoon sampler was driven into the ground by a 63.5kg hammer, which was raised vertically by a hydraulic motor with an automatic trip release and allowed to fall 0.75m.

The dynamic probing used a super heavy configuration. That is, a 63.5kg hammer was dropped 0.75m. This energy was transferred, via extension rods, down to a 50mm diameter cone. Each metre extension rod has a mass of 7.4kg and the total mass bearing onto the top of the rods (i.e. from anvil and guiding rods), not including the hammer, is about 80kg.

4.0 **Laboratory Testing**

A schedule of laboratory testing was designed to reflect the anticipated requirements of the proposed development, such as outlined in the HML Phase 1 report. Geotechnical analyses were carried out in-house at our UKAS-accredited HML laboratory, in accordance with BS1377 (1990) methods. Geochemical contamination and acidity (i.e. pH) and sulphate testing was subcontracted to a specialist chemicals laboratory (UKAS- and MCERTS-accredited).

The scope of the geotechnical laboratory testing comprised the following:

- Linear shrinkage test

The sample of sandy silt from BH3 chosen was selected on the basis that it appeared to be as likely as any sample to exhibit plasticity. The linear shrinkage test was chosen as it is suitable to detect relatively low levels of plasticity.

The scope of the geochemical contamination laboratory testing regime comprised the following tests:

- 4 metals suite
- 5 PAHs suite
- 1 TPH suite
- 1 asbestos identification
- 1 soil organic matter (SOM)
- 1 TRL sulfate (SO₄) and pH analysis

Generally, little testing was scheduled for the shallowest material in the uppermost 20cm or so of soil. It is assumed that this material, typically made ground (as discussed later), will be removed as part of the site preparation works. The samples selected for testing were generally the shallowest available samples of natural soil, to check whether any contamination may have spread from the made ground into the underlying soil. A sample of made ground (from BH3) was, based on visual and olfactory evidence, considered to be as likely as any sample to contain asbestos fibres and was duly selected for asbestos identification testing as well as basic suites of metals and PAH .

Results for all the testing undertaken are included later in this report (in Appendix C).

5.0 Encountered Ground Conditions (and Geotechnical Properties)

5.1 Sequence of sub-strata

The encountered ground conditions agreed very closely with the anticipated site geology. Exploratory hole log records (in Appendix B) indicate the following general sequence of sub-strata at the site (in descending order).

- Made ground
- Silty fine sand *or* sandy silt (Tidal Flat Deposits)

The encountered thicknesses of strata and their depths below ground level varied around the site and are summarised below (in Table 4). Further details about the strata are provided later.

Table 4: Encountered sub-strata (thicknesses and depths)					
<i>Stratum</i>	<i>Basic description</i>	<i>Depth to top of stratum (m bgl)</i>		<i>Thickness (m)</i>	
		<i>Min.</i>	<i>Max.</i>	<i>Min.</i>	<i>Max.</i>
Made ground	Varied	0.0	0.0	0.15	0.57
Tidal Flat Deposits	Sandy SILT (or silty fine SAND)	0.15	0.57	>1.52	>2.8

5.2 Made ground

Made ground was detected at the location of all four boreholes. The thickness of the made ground encountered ranged from 0.15m (in BH4) to 0.57m (in BH3).

Various anthropogenic (i.e. man-made) material was encountered below any surfacing materials. This comprised glass fragments (in BH1), coal fragments (BH3 and BH4), brick fragments (BH2, BH3 and BH4) and concrete (BH2). However, close examination did not reveal any ashy substance, fibrous material or any degradable products.

The hardstanding was different in BH1 and BH2. In BH1, it comprised 0.11m of reinforced concrete. In BH2, there was 0.11m of asphalt over 0.07m of limestone sub-base.

The made ground material was usually found to be predominantly silty or sandy (in terms of particle size) and dark in colour. In BH1 and BH3 the made ground was dark-coloured slightly gravelly sandy silt. In BH4 it was a dark slightly gravelly slightly silty sand.

5.3 Tidal Flat Deposits

The Tidal Flat Deposits that were encountered were described as a sandy (or very sandy) silt *or* a silty (or very silty) sand. A small amount of (fine to medium) gravel – as a secondary constituent – was sometimes noted, but the main constituent was consistently either silt or sand. Therefore, much of the Tidal Flat Deposits were close to the boundary between predominantly being a fine soil (i.e. a silt or a clay) or being a coarse soil (i.e. a sand or gravel).

The Tidal Flat Deposits appear to extend to a depth of about 7m to 8m bgl. This depth has not been proven (as the maximum sampled depth was only 2.45m bgl). However, the base of the Tidal Flat Deposits can be interpreted by comparing the results of dynamic probing (in Appendix B) against the anticipated geology.

The dynamic probing results (in BH1 and BH3) show that the blow count decreased gradually to zero (by a depth of about 4.6m bgl), and then remained at zero until a depth of 7.1m bgl (in BH1) and 7.7m bgl (in BH3), at which points the blow counts rose steadily with greater depth. The underlying anticipated Oxford Clay Formation is expected to be more resistant to penetration. Therefore, the increase in blow count at a depth of 7 to 8m bgl is considered likely to mark the transition to the Oxford Clay Formation.

The Tidal Flat Deposits were found to be marginally more sandy in the east of the site. BH1 and BH2, both in the west of the site, only recorded sandy (or very sandy) silt. However, BH3 and BH4, in the east part of the site, also recorded silty (or very silty) sand.

Within the range of sampling depths (zero to 2.45m bgl), the Tidal Flat Deposits tended to become slightly more sandy with depth. In all four boreholes (BH1 – BH4), sandy (or very sandy) silt was recorded down to a depth of at least about 0.9m bgl. However, below this depth, in BH3 and BH4 the material was described as silty (or very silty) sand, while in BH2, the material changed from *sandy* silt to *very sandy* silt.

It is usual to assess the *consistency* (or stiffness/softness) of soil, where fine-grained soil such as *silt* is the main constituent, but assess the *relative density* (or compactness) where coarse-grained soil such as *sand* is predominant. Both methods are used herein for the Tidal Flat Deposits, as they were periodically silt (i.e. fine) and sand (i.e. coarse).

5.3.1 Silt

Where silt was the main constituent, the consistency of the Tidal Flat Deposits was found to range between ‘*very soft to soft*’ and *firm*. The only place where it was recorded as ‘*very soft to soft*’ was in BH1. In the other boreholes (BH2-BH4) it was described as either *firm* (down to depths no greater than 0.89m bgl) or *soft*.

Tidal Flat Deposits in which silt was the main constituent were proven to a depth of at least 2.0mbgl (in BH1 and BH2).

Established correlations (e.g. as described by Shukla, 2015) allow shear strength to be assessed from consistency, as shown below (in Table 5). Therefore, the undrained shear strength of the (Tidal Flat Deposits) silt material is likely to range between <12.5kPa and 50kPa, as shown below (in Table 6).

Table 5: Consistency v Shear strength	
<i>Consistency</i>	<i>Shear strength* (kPa)</i>
Very soft	<12.5
Soft	12.5 – 25
Firm	25 – 50
Stiff	50 – 100
Very stiff	> 100
* E.g. based on descriptions from Shukla (2015)	

Table 6: Shear strength of shallow silt (in Tidal Flat Deposits)						
<i>Depth (m bgl)</i>	<i>Undrained shear strength (assessed from consistency)</i>					
	<i>BH1</i>	<i>BH2</i>	<i>BH3</i>	<i>BH4</i>	<i>Mean</i>	<i>Range</i>
0.5	0-25	25-50	N/A	12.5-50	23	0-50
1.0	0-25	12.5-50	N/A	N/A	22	0-50
1.5	0-25	12.5-25	N/A	N/A	16	0-25
2.0	0-25	12.5-25	N/A	N/A	16	0-25

The result of the linear shrinkage test on a sample of sandy silt (from BH3) shows that the material has almost no plasticity. The sample shrunk by 1.4%, which, by rule of thumb, suggests the plasticity index (I_p) is only about 3%. Therefore, the Tidal Flat Deposits should be classified as being of *low volume change potential* in line with NHBC Standards (NHBC, 2006).

5.3.2 Sand

Tidal Flat Deposits in which sand was the main constituent were proven to a depth of at least 2.45mbgl (in BH3 and BH4).

Where (fine or fine-to-medium) sand was the main constituent (i.e. below depths of about 1.0m bgl in BH3 and BH4), the relative density was found to consistently decrease with depth and vary between *medium dense* and *very loose*. This variation was assessed using the results of SPT tests which showed the uncorrected N value to decrease from 13 to either 4 (in BH4) or 2 (in BH2), as shown below (in Table 7).

SPT results can also be correlated against drained friction angle (i.e. angle of shearing resistance) of coarse soil. Thus, the drained friction angle of the silty fine sand (tidal deposit) material seems to decrease from 30° to 36° (at a depth of about 1.0m bgl) down to between 28° and 30° (at a depth of about 2.0m bgl), as shown below (in Table 7).

Table 7: Silty fine sand (Tidal Flat Deposit) material				
Depth (m bgl)	SPT N values (uncorrected)		Relative Density ^[1]	Drained friction angle ^[2] (°)
	BH3	BH4		
1.0 – 1.45	13	13	Medium dense	30-36
2.0 – 2.45	2	4	Very loose (to loose)	28-30
[1] from BS5930(2015)		[2] e.g. from Terzaghi and Peck (1967)		

5.3.3 *Deeper Tidal Flat Deposits material*

As discussed, the Tidal Flat Deposits are expected to reach a depth of between about 7 and 8m bgl. However, it is not known whether the main constituent of this material will be silt or fine sand because borehole sampling only extended to 2.0 or 2.45m bgl. Nevertheless, given the sampled ground conditions recorded and the anticipated geology, the main constituent of the deeper material (i.e. between 2.0 and 8.0m bgl) is likely to be clay, silt or fine sand.

Whatever the material, the engineering properties of the Tidal Flat Deposits are likely to degrade below a depth of about 4.5m bgl. The results of the dynamic probing (as shown in Appendix B) indicate blow counts falling to zero by a depth of about 4.5m (in BH1) and 4.6m (in BH3). The properties of the Tidal Flat Deposits can be assessed by assuming they are either a fine soil (e.g. silt or clay) or a coarse soil (e.g. sand). For the purposes of design, the most onerous of these two options should be considered.

Fine material (i.e. clay or silt)

Firstly, assuming the deeper Tidal Flat Deposits are fine-grained (i.e. silt or clay is the main constituent), then the undrained shear strength can be correlated from dynamic probe results (for example, using Butcher et al. 1995). Thus, the undrained shear strength of the Tidal Flat Deposits increases and then decreases with depth, as shown below (in Figure 1). The assessed strength depends on whether the soil is expected to be soft or stiff. The strength varies from between 0 and 150kN/m² as detailed below (in Table 8). The Tidal Flat Deposits fine-grained soil material is more likely to be soft than stiff, so conservative values of the strength should fall around the lower boundary of this range, as shown (in Table 8).

Figure 1: Undrained shear strength assessed from dynamic probing results (assuming soil is fine-grained)

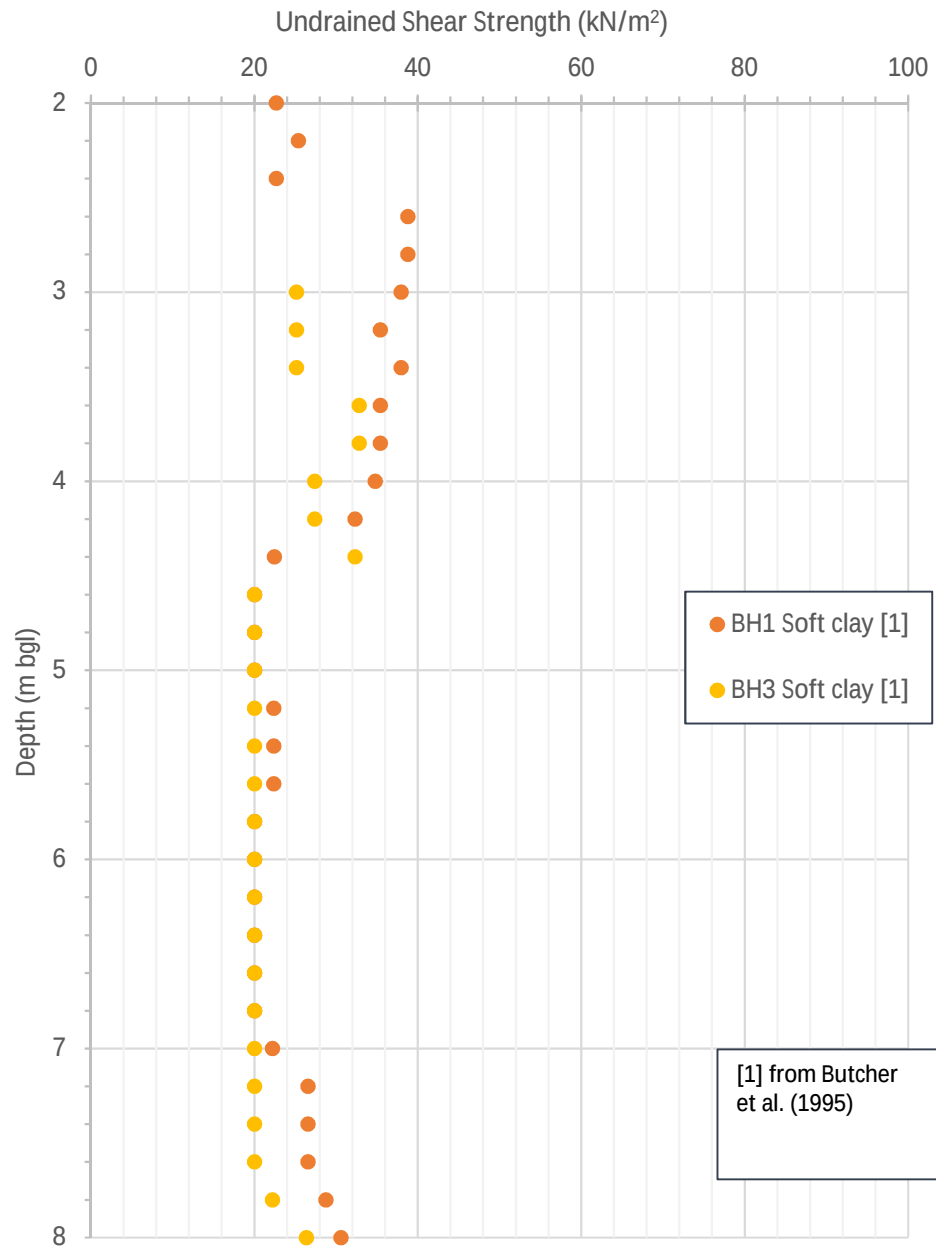
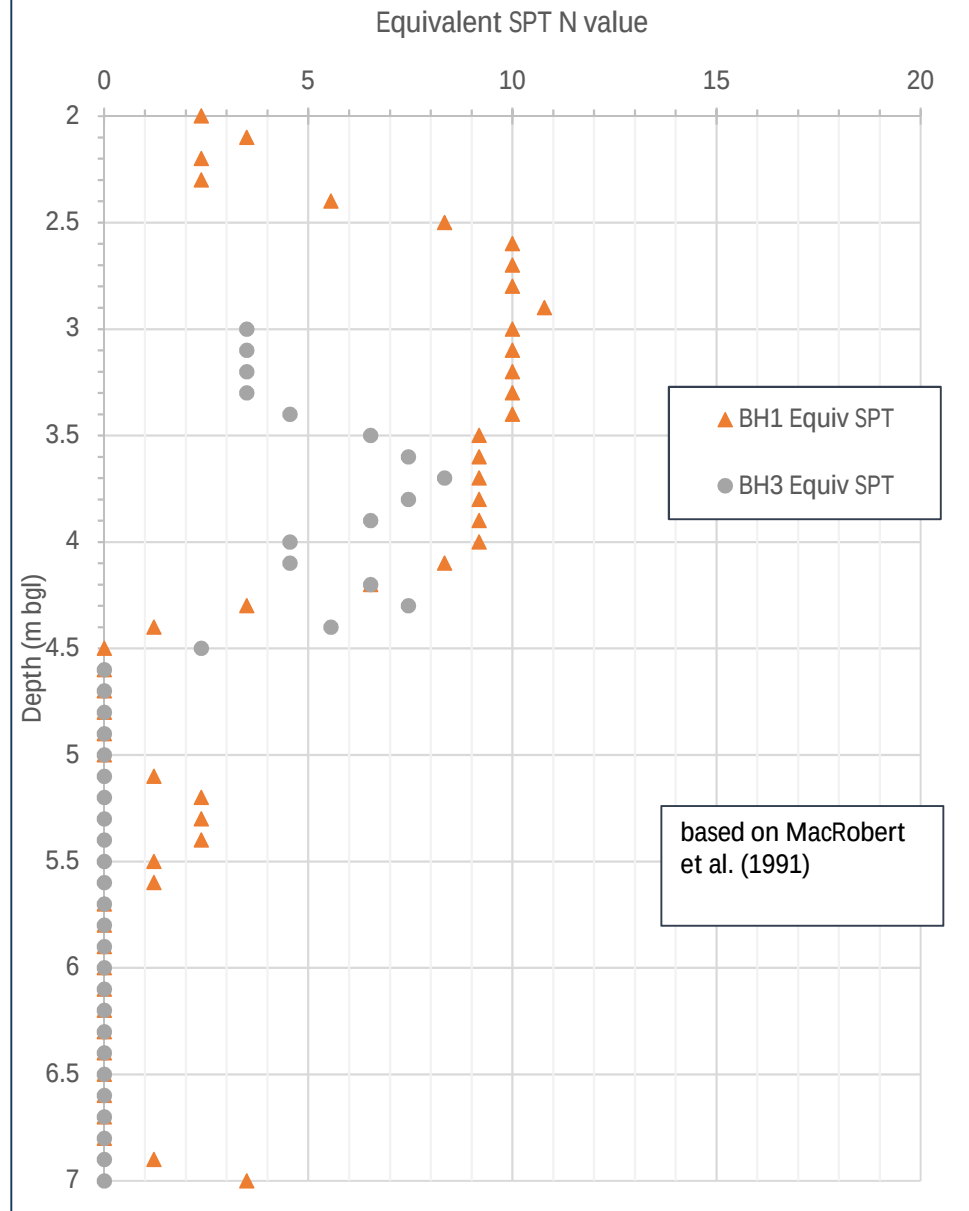


Table 8: Assessed strengths of Tidal Flat Deposits (assuming fine soil)		
	<i>Assessed undrained shear strength* (kPa)</i>	
<i>Depth (m)</i>	<i>Range</i>	<i>Conservative value</i>
2.0-2.5	23 – 42	20-25
2.5-3.0	39 – 40	35-40
3.0-3.5	25 – 39	20-25
3.5-4.0	33 – 37	30-35
4.0-4.5	22 – 34	20 - 25
4.5-8.0	20 - 30	<20
* based on results shown in Figure 1		

Coarse material (i.e. sand)

Assuming the main constituent of the deeper Tidal Flat Deposits is coarse-grained material (i.e. sand), then equivalent SPT N values can be correlated from the dynamic probe results (for example, using MacRobert et al., 1991). Thus, the equivalent SPT N value tends to decrease with depth into the Tidal Flat Deposits, as shown below (in Figure 2). The equivalent SPT N value ranges from 2 to 11 (between 2.0 and 4.3m bgl) but decreases to (typically) zero (below a depth of 4.4m bgl). Inspection of Figure 2 (below) allows conservative values of SPT N values to be identified, such as shown below (in Table 9).

Figure 2: Equivalent SPT N value from dynamic probing results (assuming soil is coarse-grained)



The relative density and drained friction angle can be further correlated from the equivalent SPT N values. Correlations indicate that the deeper Tidal Flat Deposits are likely to be *very loose to medium dense*, becoming *very loose to loose*, as shown below (in Table 9).

Table 9: Deeper Tidal Flat Deposits (assuming coarse soil)					
Depth (m bgl)	Equivalent <i>N</i> values (uncorrected)			Relative Density ^[1]	Drained friction angle ^[2] (°)
	Min.	Max.	Conservative		
2.0 – 2.5	2	11	3	Very loose to medium dense	28-36
3.0 – 4.0	3	10	4	Very loose to medium dense	28-36
4.0 – 4.4	1	9	3	Very loose to loose	28-30
4.4 – 7.0	0	5	0	Very loose to loose	28-30
[1] from BS5930(2015)			[2] e.g. from Terzaghi and Peck (1967)		

5.4 Oxford Clay Formation

As discussed, the top of the anticipated Oxford Clay Formation has been inferred from the results of dynamic probing to be between 7m and 8m bgl. The DPSH blow counts in BH1 and BH3 increased from zero at respective depths of 7.1m and 7.9m bgl.

Also, as discussed, the Oxford Clay Formation is expected to be present as mudstone. This is likely to be weathered, at least initially, becoming less weathered with depth. In its weathered state, it is likely to be clayey (or silty) in nature and its consistency is expected to become increasingly stiff with depth.

The undrained strength of the Oxford Clay can be assessed from the dynamic probing results, as shown below (in Figure 3). The assessed strength of the material is likely to lie between 25kPa and 1000kPa, as shown below (in Table 10). The Oxford Clay Formation material is more likely to be stiff than soft, so conservative values of the strength are likely to be above the lower part of this range, possibly between 40 and 150kPa.

Figure 3 : Assessed strength from dynamic probing results

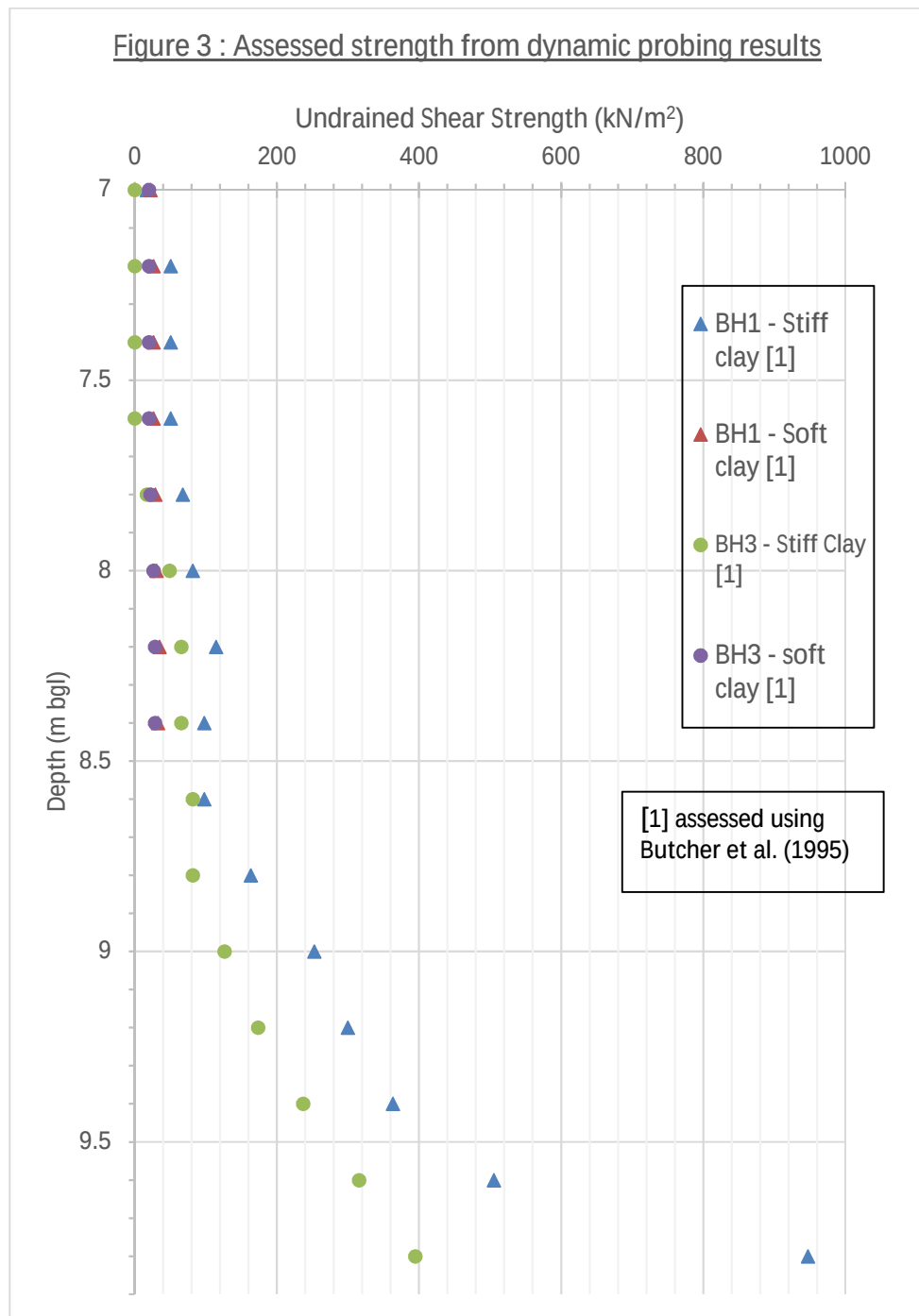


Table 10: Assessed strength of (interpreted) Oxford Clay Formation		
	<i>Assessed undrained shear strength* (kPa)</i>	
<i>Depth (m)</i>	<i>Range</i>	<i>Conservative value</i>
8.0-8.5	25 – 115	40
8.5-9.0	80 – 200	120
9.0-9.5	120 – 360	150
9.5-10.0	320 – 940	320
* based on results shown in Figure 3		

5.5 Groundwater observations

Groundwater strikes were recorded in all four boreholes at depths of between 0.93m and 1.37m bgl, as shown below (in Table 11). The small variation in depths may indicate a slight variation in ground levels. The groundwater table appeared to be quite shallow, between a depth of 0.93m (BH1) and 1.37m (BH3) bgl.

Table 11: Groundwater strikes				
	<i>BH1</i>	<i>BH2</i>	<i>BH3</i>	<i>BH4</i>
<i>Depth (m bgl)</i>	0.93	0.94	1.37	1.34

The drainage ditch adjacent to the south boundary of the site was observed to be dry at the time of the site works. It was estimated to be about 1m in depth bgl.

5.6 Geochemical tests

The results of all chemical analyses are included in this report (in Appendix C). An assessment of the results is presented later.

6.0 Engineering Discussions

6.1 Foundations

6.1.1 *Made ground*

The made ground material on site has been found to be relatively shallow. It has been encountered down to maximum depths ranging between 0.15m bgl (BH1) and 0.57m bgl (BH3).

6.1.2 *Tidal Flat Deposits*

The Tidal Flat Deposits are not an ideal bearing material. As discussed, they may be very loose (where the main constituent material is sand) or very soft (where it is silt).

Nevertheless, the Tidal Flat Deposits do provide some bearing resistance. The assessment of this bearing resistance varies depending on whether the soil's main constituent is a sand or a silt. Given that the material is generally close to the boundary of being a sand or a silt, it would seem prudent to assume the most conservative option for the purposes of foundation design. In other words, in the absence of further information, whichever material (silt or sand) offers the lowest bearing capacity should be assumed for the foundation design.

Fine soil (i.e. silt)

As highlighted previously, where silt is the constituent material, the Tidal Flat Deposits can be *very soft* at shallow depths (i.e. 0.0m to 2.0m bgl). Therefore, the bearing capacity of footings founded at this depth are likely to be limited.

Assuming the Tidal Flat Deposits will behave as a fine-grained (cohesive) material, the material may also be very soft below a depth of 4.5m bgl, as shown previously (in Figure 1). Therefore, a foundation whose pressure bulb extends into this material is likely to suffer significant settlement.

Nonetheless, footings of restricted width, founded at well-chosen depths, may provide reasonable, albeit limited, bearing capacities. For instance, 0.6m wide footings at formation depths of about 2.0m to 2.5m bgl should provide net allowable bearing pressures of at least 40kPa.

Coarse soil (i.e. sand)

Assuming the Tidal Flat Deposits material will behave as a coarse-grained (granular/cohesionless) material, it may have a drained friction angle of only 28°, as shown previously (in Tables 7 and 9). Similarly, conservative equivalent SPT N values may be about 3 or 4, at depths between 2.0 and 4.4m bgl.

Below a depth of about 4.4m, the Tidal Flat Deposits material becomes looser (assuming it is coarse). Equivalent SPT N values are about zero. As with the fine soil analysis, foundations whose pressure bulbs extend into this deeper looser material may experience adverse settlements. However, foundations of restricted width placed at a suitable depth may provide some bearing resistance.

Assuming the material is coarse, analyses (e.g. Meyerhof, 1965) indicate that a footing about 0.6m wide, founded at a depth of about 2.0m to 2.5m bgl, should offer a net allowable bearing pressure of at least 50kPa. However, the actual material may be fine-grained, so a more conservative capacity of 40kPa (see above) should be applied for design purposes, as discussed.

6.1.3 *Oxford Clay Formation*

The (interpreted) Oxford Clay Formation probably offers the most reliable bearing stratum. As shown previously, the strength of this material appears to increase steadily with depth. Based on assessed undrained shear strengths, discussed previously, net allowable bearing pressures in the Oxford Clay Formation are likely to exceed 80kPa, as shown below (in Table 12).

Table 12: Anticipated allowable bearing pressures in Oxford Clay Formation		
<i>Depth (m)</i>	<i>Assessed (conservative) undrained shear strength (kPa)</i>	<i>Net allowable bearing pressure (kPa)</i>
8.0-8.5	40	80
8.5-9.0	120	240
9.0-9.5	150	300
9.5-10.0	320	640

The depth to the top of the Oxford Clay Formation is likely to be between 7.0m and 8.0m bgl. Consequently, if this material is chosen as the bearing stratum for the proposed development, then deep foundations (e.g. piles) will be required.

6.1.4 *Other foundation issues*

Exposed formations may require attention. They should be kept dry after excavation (to protect them from moistening – especially with fine silt and clay soil formations). Grouting of the formation with a layer of blinding may be beneficial. It is usually advisable that any soft spots at formation level be removed and replaced with well-compacted granular fill.

Foundations should be designed by a competent engineer with consideration to all factors and the information within this report.

6.2 Buried concrete

The results of sulphate (SO_4) and pH tests (included in Appendix C) on a sample of silty fine sand (Tidal Flat Deposit) material provide information relevant to the durability of buried concrete within the Tidal Flat Deposits at the site. 47mg/l of water-soluble sulphate (SO_4) was detected (in 2:1 water to soil extract). 273mg/kg of total sulphate (SO_4) and 183mg/kg of sulphur was detected. The pH level was found to be about 8.6 (i.e. mildly alkaline).

Calculations indicate that the total potential sulphate (SO_4) is approximately 0.055% (i.e. 550mg/kg) and the oxidisable sulphate is about 0.028% (i.e. 280mg/kg).

Accordingly, a design sulphate class of DS-1 should be suitable for the site location (based on BRE, 2005). Also, the appropriate Aggressive Chemical Environment for Concrete (ACEC) Class for buried concrete within the Tidal Flat Deposits should be AC-1.

6.3 Excavations and groundwater

Conventional earth moving plant should be able to readily excavate the ground material on site. However, the loose nature of much of the fine sand (Tidal Flat Deposits) material and the high water table mean the sides of excavations may be unstable.

Excavations should be carried out safely (e.g. in accordance with CIRIA Report 97 by Irvine and Smith, 1992) and are likely to need shoring (or battering back) if man-entry is required.

Borehole records indicate that the groundwater table is likely to be between 0.9m and 1.4m below current ground levels. However, seasonal fluctuations mean that its position may vary.

7.0 Contamination Assessment

7.1 Assessment principles

Given the proposed works outlined (see Section 2), the risk assessment to human health (presented herein) is considered in the context of a development that is *residential with plant uptake* (i.e. with consumption of home grown produce). This context is intended to reflect the proposed site use and tends to produce relatively onerous assessment criteria (compared with a *commercial* context, say).

The assessment criteria (in mg/kg) for domestic gardens with plant uptake included are presented below. These have been taken from the *generic assessment criteria* (GAC) published in the *Land Quality Management Ltd/Chartered Institute of Environmental Health suitable for use levels* (LQM/CIEH S4ULs) report (LQM/CIEH, 2015), which are based on tolerable/minimal risk from contaminants. The exception to this is for lead which is taken from the provisional Category 4 Screening Level (C4SL) data published in a report by Defra (2014). This value (of 82 to 210mg/kg) is representative of ‘low’ risk and is pending review. It is acknowledged that lead is a non-threshold chemical and so should be *as low as reasonably practicable* (ALARP).

The assessment criteria are produced below (in Tables 13, 14 and 15) for each contaminant type. The GAC for organic contaminants (e.g. PAHs) takes into account the soil organic matter (SOM) content.

7.2 Asbestos

No asbestos was detected in the sample of made ground (from BH3) that was analysed for asbestos fibres. This sample was selected because it included brick fragments and was considered to have among the most significant potential to contain asbestos fibres.

7.3 Metals

Three samples of natural soil and one of made ground were tested for metals. The made ground was from BH3 and included brick and coal fragments. The samples of natural soil (from BH1, BH2 and BH4) were all from relatively shallow depth (less than 1m bgl).

The GAC for metal contaminants at the site are as shown below (in Table 13).

Table 13: Generic assessment criteria for metals	
Element	GAC - residential with plant uptake (mg/kg)
Arsenic	37
Boron	290
Cadmium	11
Chromium III	910
Chromium VI	6
Copper	2400
Lead	82-210
Mercury element	1.2
Mercury inorganic	40
Mercury methyl	11
Selenium	250
Copper	2400
Nickel	130
Zinc	3700

The analysis in the first instance has included total chromium, a metal which exists in nine oxidation states. In natural soils, the most common state is chromium III. Chromium IV is typically only present in soils in the vicinity of industrial processes and waste deposition, which is not the case on this site, as shown by the HML Phase 1 report.

The measured concentrations of total chromium ranged between 102mg/kg and 142mg/kg. These values are well below the GAC for Chromium III (of 910mg/kg). Since it is considered implausible that Chromium VI could account for anywhere close to (as much as) 4.2% of the total chromium present, it follows that the concentrations of Chromium VI must be lower than the GAC (of 6mg/kg). Moreover, the measured concentrations of total chromium are all within reasonable range of the rural background levels (of 60-90mg/kg) anticipated by BGS data (presented in the HML Phase 1 report).

The sample of made ground tested indicated levels below the GAC for all the metals, except for lead. As can be seen above (in Table 13), the GAC for lead is 82mg/kg to 210mg/kg. However, the measured concentration of lead in the made ground sample (from BH3) was 397mg/kg and thus exceeds the GAC values. Based on the limited samples and the range of values it is highly probable that elevated levels are present in other areas of the site with similar made ground composition. Lead is considered to be a non-threshold compound and therefore as low as reasonable practicable is applicable. Therefore, such elevated concentrations of lead require further consideration. It is recommended that remediation is undertaken.

One of the three samples of shallow natural soil (from BH1) was found to have levels of metals within the range of GAC for lead. The measured concentration of 113mg/kg (in BH1) is close to the bottom of the range of GAC values (of 82mg/kg to 210mg/kg). BGS data (shown in the Phase 1 report) indicates that concentrations of (up to) 100mg/kg are expected in rural soil in the area. Therefore, the concentration of 113mg/kg is considered to be only very slightly elevated. Subject to further risk assessment (presented later), remediation may or may not be required.

None of the measured concentrations of metals (besides lead) in natural soil samples exceeded the GAC. Nonetheless, the concentration of arsenic from one sample (from BH4) was equal to the GAC (of 37mg/kg), but this is considered to be within acceptable limits.

7.4 Polyaromatic hydrocarbons (PAHs)

One sample of made ground and four samples of shallow natural soil were tested for PAHs. The made ground sampled included brick and coal fragments (from BH3).

One sample of silt (from BH1) was tested for total organic carbon (TOC), which was found to be 3.42%. The reported estimated organic matter content (OMC), also referred to as soil organic matter (SOM), was 5.9%. Table 14 (below) gives the GAC for speciated PAH contaminants considered for the initial assessment of the site. These GACs chosen are based on a SOM content of 1%, which is very conservative.

Table 14: Generic assessment criteria for PAH			
Element	GAC - residential with plant uptake (mg/kg)		
	1% SOM*	2.5% SOM	6% SOM
Acenaphthene	210	510	1100
Acenaphthylene	170	420	920
Anthracene	2400	5400	11000
Benzo(a)anthracene	7.2	11	13
Benzo(a)pyrene (BaP)	2.2	2.7	3
Benzo(b)fluoranthene	2.6	3.3	3.7
Benzo(k)fluoranthene	77	93	100
Benzo(ghi)perylene	320	340	350
Chrysene	15	22	27
Dibenzo(ah)anthracene	0.24	0.28	0.3
Fluoranthene	280	560	890
Fluorene	170	400	860
Indeno(123cd)pyrene	27	36	41
Naphthalene	2.3	5.6	13
Phenanthrene	95	220	440
Pyrene	620	1200	2000
BaP as Surrogate marker	0.79	0.98	1.1
* GAC adopted for this report			

The measured concentrations (in Appendix C) of PAHs in all five samples tested were found to be below the GAC. Predominantly, values are at or below the detection level. Therefore, the levels of PAH appear to be within acceptable limits.

7.5 Total petroleum hydrocarbons (TPH)

Petroleum hydrocarbon analyses were carried out on a shallow sample of sandy silt (from BH1). This included tests for fractions of volatile petroleum hydrocarbons (VPH) and extractable petroleum hydrocarbons (EPH) in aromatic and aliphatic equivalent carbon (EC) chain banding. The generic assessment criteria based on LQM/CIEH (2015) values are shown below (in Table 15). Assessment is based on a 1% soil organic matter content (SOM), which is very conservative.

Table 15: Assessment criteria for TPH			
TPH	Residential with plant uptake (mg/kg)		
	SOM of 1%	SOM of 2.5%	SOM of 6%
Aliphatic EC5-6	42	78	160
Aliphatic >EC6-8	100	230	530
Aliphatic >EC8-10	27	65	150
Aliphatic >EC10-12	130 (48)	330 (118)	760 (283)
Aliphatic >EC12-16	1100 (24)	2400 (59)	4300 (142)
Aliphatic >EC16-35	65000 (8.48)	92000 (21)	110000
Aliphatic >EC35-44	65000 (8.48)	92000 (21)	110000
Aromatic EC5-7	70	140	300
Aromatic >EC7-8	130	290	660
Aromatic >EC8-10	34	83	190
Aromatic >EC10-12	74	180	380
Aromatic >EC12-16	140	330	660
Aromatic >EC16-21	260	540	930
Aromatic >EC21-35	1100	1500	1700
Aromatic >EC35-44	1100	1500	1700
Values in parentheses () are for the solubility or vapour saturation limit * GAC adopted for this report			

Results (shown in Appendix C) indicate that measured concentrations are well below acceptable limits (i.e. GAC). Measured values were generally close to or below the detection limits of the analytical methods used.

7.6 Revised Conceptual Site Model

A revised list of potential contamination linkages is presented below (in Table 16) based on the findings of the investigation. The contamination sources are now limited to lead.

Table 16: Revised Conceptual Site Model				
Source, S		Pathway, P		Receptor, R
Source type/area	Contaminant	Route	Sub-route	
Made ground	Lead	Ingestion	Soils and soils attached and absorbed by home grown produce, Indoor dust Outdoor dust	Workers, future occupants
Shallow natural soil (i.e. Tidal Flat Deposits)	Lead	Absorption	Dermal contact	Workers, future occupants
		Inhalation	Indoor dust Outdoor dust Indoor vapour Outdoor vapour	Workers, future occupants
		Migration	Along services Vertically in unsaturated zone Laterally in saturated zone	Workers, future occupants, building materials & services
Not applicable				
Item		Rationale		
S: Hazardous ground gas		No significant gas generating source		
S: Asbestos		Testing revealed no such contamination		
S: PAH		Testing showed levels below GAC		
S: TPH		Testing showed levels below GAC		
S: Metals (not incl. lead)		Testing showed levels at or below GAC		

7.7 Risk assessment

A risk assessment of potential contamination linkages that incorporates the findings of the investigation is presented below (in Table 17). The assessment is based on the procedures outlined in CIRIA report C552 (Rudland et al., 2001).

The main factor affecting the assessment is the lead concentrations detected, which were elevated above the GAC (82-210mg/kg). As discussed, measured concentrations were clearly elevated (at 370mg/kg) in a sample of made ground (from BH3) and slightly elevated (at 113mg/kg) in a shallow sample of sandy silt (Tidal Flat Deposit) material (from TP1).

Table 17: Revised risk assessment (of potential contamination linkages)						
Potential source	Potential pathway	Potential receptor	Probability	Severity	Risk rating	Comments
Made ground (lead)	ingestion, absorption	Future occupants	Likely	Medium	Medium	Options incl.: cover system, dig and dump
	Ingestion, absorption	Construction workers	Likely	Medium	Medium	Solution: safe working practices
	Migration	Aquifer	Unlikely	Medium	Low	Fine soil limits contaminant mobility
	Migration	Surface waters	Unlikely	Medium	Low	Adjacent drain appears dry
Natural soil (lead)	Ingestion, absorption	Future occupants	Likely	Minor	Low	concentrations close to GAC & background levels
	Inhalation, ingestion, absorption	Construction workers	Likely	Minor	Low	concentrations close to GAC & background levels
	Migration	Aquifer	Unlikely	Minor	Very Low	Fine soil limits contaminant mobility
	Migration	Surface waters	Unlikely	Minor	Very Low	Adjacent drain appears dry

Elevated concentrations of lead in the made ground mean there is a possibly significant contamination linkage. Ingestion or absorption (e.g. through dermal contact) could adversely affect workers and future occupants.

The highest observed concentrations of lead in the natural soil (of 113mg/kg) is only slightly elevated, being just above the lower boundary of the GAC range (82-210mg/kg which is still subject to review) and close to expected background levels (up to 100mg/kg). Therefore, the risk from this contamination is assessed as low, and the concentration considered to be as low as reasonably practicable. Accordingly, the Tidal Flat Deposits natural soil is considered clean and inert.

Madeground has been shown to potentially contain elevated levels of lead. The madeground has been identified primarily a mix of various components including brick rubble. As such this material is an unsuitable growth medium and is therefore unsuitable for retention in garden areas.

7.8 Remediation proposals

As shown in the revised conceptual model above, there is a relevant contamination linkage (RCL) that has the potential to cause harm to receptors. This pertains to the possible ingestion or absorption of elevated levels of lead within made ground at site. Remediation is required to address this contamination linkage.

The ground levels on the site post development have not been fully defined yet. Therefore, it has been assumed that they will remain similar to the current ground levels.

The made ground is unsuitable as a growth medium and therefore will need to be removed from garden areas. This should also ensure that there will be no remaining risk of ingestion or absorption of the lead contamination within.

The demarcation between the made ground for removal and the natural silt/fine sand (Tidal Flat Deposits) is visually clear and this will decree the extent of made ground that requires removal prior to any other works. In the east of the site (near BH3 and BH4), the made ground is identifiable by its dark grey black colour and the presence of coal and/or brick fragments. In the west of the site (near BH1 and BH2), the made ground is identifiable by the presence of brick, concrete and/or glass fragments.

The hardstanding provides a sound working platform for the construction of the structures and therefore it is recommended that structural work be undertaken prior to remediation. Garden areas can be remediated after the structural work.

Natural ground (i.e. silt and fine sand Tidal Flat Deposits material) removed from excavations for structures etc. may be used to make up subsoil levels in garden areas where required. Imported topsoil is likely to be needed for the final layer in garden areas. This shall be from a source proven to be clean and inert in accordance with the YALPAG (2016) verification requirements.

A method statement will be required for the remediation work for approval by the local authority prior to commencing work on the site, once the final levels and layout have been confirmed. On completion, an approved validation report will also be required.

The water authority should be consulted regarding the classification for potable water supply pipes suitable for use within the site. Different water authorities may use different assessment criteria.

The contractor should be informed at the earliest opportunity of the presence of lead contamination within the made ground soil material on site. The contractor should produce suitable method statements to address the health and safety hazards the identified contamination may pose to construction workers. Appropriate PPE and good hygiene standards will be required.

Any unforeseen contamination encountered during the development of the site should be reported to the local authority. Work should be halted in that area and the contamination investigated and assessed to the satisfaction of the local authority.

8.0 Conclusion

8.1 Sub-strata

The sub-strata revealed/interpreted at site are as follows.

- Made ground (0.15m to 0.57m in thickness)
- Tidal Flat Deposits: sandy silt or silty fine sand (interpreted to a depth of 7m to 8m bgl)
- Oxford Clay Formation (interpreted to at least 10m bgl)

8.2 Made ground

The made ground material on site has been found to be relatively shallow. It has been encountered down to maximum depths ranging between 0.15m bgl (BH4) and 0.57m bgl (BH3).

Various anthropogenic (i.e. man-made) material was encountered. This comprised glass fragments (in BH1), coal fragments (BH3 and BH4), brick fragments (BH2, BH3 and BH4) and concrete (BH2). However, close examination did not reveal any ashy substance, fibrous material or degradable products.

Analyses have indicated that the made ground does not appear to contain elevated levels of PAH or asbestos and, except for lead, metals have been found to be at or below acceptable criteria levels.

Nevertheless, elevated levels of lead have been encountered in the made ground material. A measured lead concentration of 397mg/kg in a sample (from BH3) of this material exceeds the GAC for lead (82-210mg/kg). Remediation (e.g. by removal) of this layer within garden areas is required.

8.3 Tidal Flat Deposits

Tidal Flat Deposits (of silt and fine sand) were exposed to depths of 2.0 to 2.45m bgl. Results of dynamic probing suggests that the Tidal Flat Deposits extend to a depth of about 7m to 8m bgl. The main constituent of the deeper Tidal Flat Deposits material (i.e. between 2.0 and 8.0m bgl) has not been sampled, but is likely to be clay, silt or fine sand.

Samples of Tidal Flat Deposits have been tested for metals, PAH and TPH. However, measured concentrations have been consistently found to be at or below generic acceptance criteria (GAC). One slightly elevated lead concentration (of 113mg/kg) fell within the lower part of the range of GAC (82mg/kg to 210mg/kg) and is considered to be acceptable. Therefore, the findings indicate the shallow natural soil at site (i.e. the Tidal Flat Deposits material) is clean and inert.

Assuming *fine-grained* soil (i.e. clay or silt) to be the main constituent (in the Tidal Flat Deposits), the undrained shear strength has been assessed and shown to be generally limited and very low at depths greater than about 4.5m bgl, as shown below (in Table 18)

Table 18: Assessed strengths of Tidal Flat Deposits (where fine-grained)		
Depth (m)	Assessed undrained shear strength* (kPa)	
	Range	Conservative value
< 2.0	0 – 50	5 – 25
2.0-2.5	23 – 42	20-25
2.5-3.0	39 – 145	35-40
3.0-3.5	25 – 139	20-25
3.5-4.0	33 – 114	30-35
4.0-4.5	22 – 114	20 – 25
> 4.5	<20	<20
* assessment based on dynamic probe results and recorded consistency		

The plasticity index (I_p) of a sample of silt material has been assessed to be about 3%. Therefore, the Tidal Flat Deposits should be classified as being of *low volume change potential* in line with NHBC Standards (NHBC, 2006).

Assuming *coarse-grained* soil (e.g. sand) to be the main soil constituent (in the Tidal Flat Deposits), the relative density has been assessed and shown to be generally *very loose to medium dense*, with the deeper material (below 4.5m bgl) being consistently *very loose to loose*, as shown below (in Table 19). The drained friction angle ranges from 28° to 36°.

Table 19: Tidal Flat Deposits (where coarse-grained)					
Depth (m bgl)	(Equivalent) N values (uncorrected)			Relative Density ^[1]	Drained friction angle ^[2] (°)
	Min.	Max.	Conservative		
1.0 – 1.5	13	13	13	Medium dense	30-36
2.0 – 2.5	2	11	2	Very loose to medium dense	28-36
3.0 – 4.0	3	10	4	Very loose to medium dense	28-36
4.0 – 4.4	1	9	3	Very loose to loose	28-30
4.4 – 7.0	0	5	0	Very loose to loose	28-30
[1] from BS5930(2015)			[2] e.g. from Terzaghi and Peck (1967)		

Suitably-designed foundations in the Tidal Flat Deposits may be able to provide a net allowable bearing pressure of at least 40kPa. This is based on 0.6m wide footings at 2.0m to 2.5m depth below existing ground levels.

8.4 Oxford Clay Formation

The Oxford Clay Formation has not been exposed during site works. However, it has been inferred from dynamic probing test results that the top of this material is between about 7m and 8m bgl.

The Oxford Clay Formation is expected to be present as mudstone, which is likely to be weathered, at least initially, becoming less weathered with depth. In its weathered state, it is likely to be clayey (or silty) in nature and its consistency is expected to become increasingly stiff with depth.

Based on dynamic probing results, the assessed strength of the material is likely to lie between 25kPa and 1000kPa, as shown below (in Table 20).

The expected net allowable bearing pressure in the (interpreted) Oxford Clay Formation should increase with depth. It ranges from 80kPa (at 8.0m-8.5m bgl) to 640kPa (at 10.0m bgl), as shown below (in Table 20).

Table 20: Anticipated allowable bearing pressures in Oxford Clay Formation		
<i>Depth (m)</i>	<i>Assessed (conservative) undrained shear strength (kPa)</i>	<i>Net allowable bearing pressure (kPa)</i>
8.0-8.5	40	80
8.5-9.0	120	240
9.0-9.5	150	300
9.5-10.0	320	640

8.5 Groundwater

Groundwater was recorded in all four boreholes at depths of between 0.93m (BH1) and 1.37m bgl (BH3).

The drainage ditch adjacent to the south boundary of the site was observed to be dry at the time of the site works. It was estimated to be about 1m in depth bgl.

8.6 Buried concrete

With respect to buried concrete within the Tidal Flat Deposits, an ACEC Class of AC-1 and a design sulphate class of DS-1 have been deemed appropriate (based on BRE, 2005).

8.7 Site remediation proposals

Potentially contaminated made ground should be removed from the proposed garden areas and replaced with clean soil.

Contractors should be informed of the likely presence of elevated levels of lead within the made ground.

No radon protection measures are required at the site.

A local authority-approved method statement and validation report will be required for all remediation work.

Any unforeseen contamination encountered during the development of the site should be reported to the local authority. Work should be halted in that area and the contamination investigated and assessed to the satisfaction of the local authority.

R.M. Lester MEng MSc

M.J. Green I.Eng. F.I.H.I.E.

9.0

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APPENDIX A



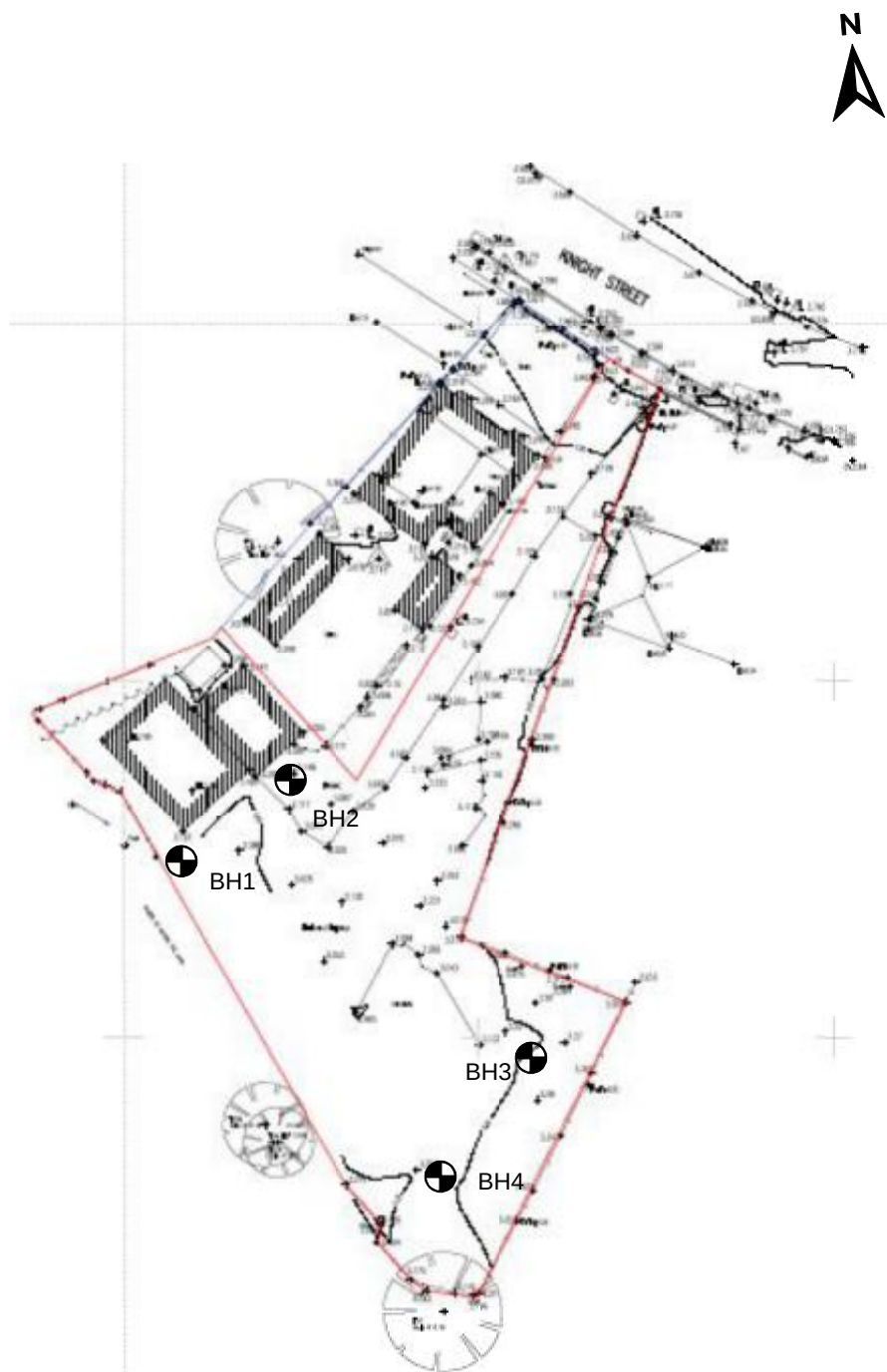
Location of BH1



Location of BH2



Area of BH3 and BH4



SITE PLAN - BOREHOLE / TRIAL PIT LOCATIONS



Humberside Materials Laboratory Ltd
 Atherton Way, Brigg
 North Lincs, DN20 8AR
 Tel Fax 01652 652753

CLIENT :- Alan Finch
 SITE :- Knight St Pinchbeck

APPENDIX B



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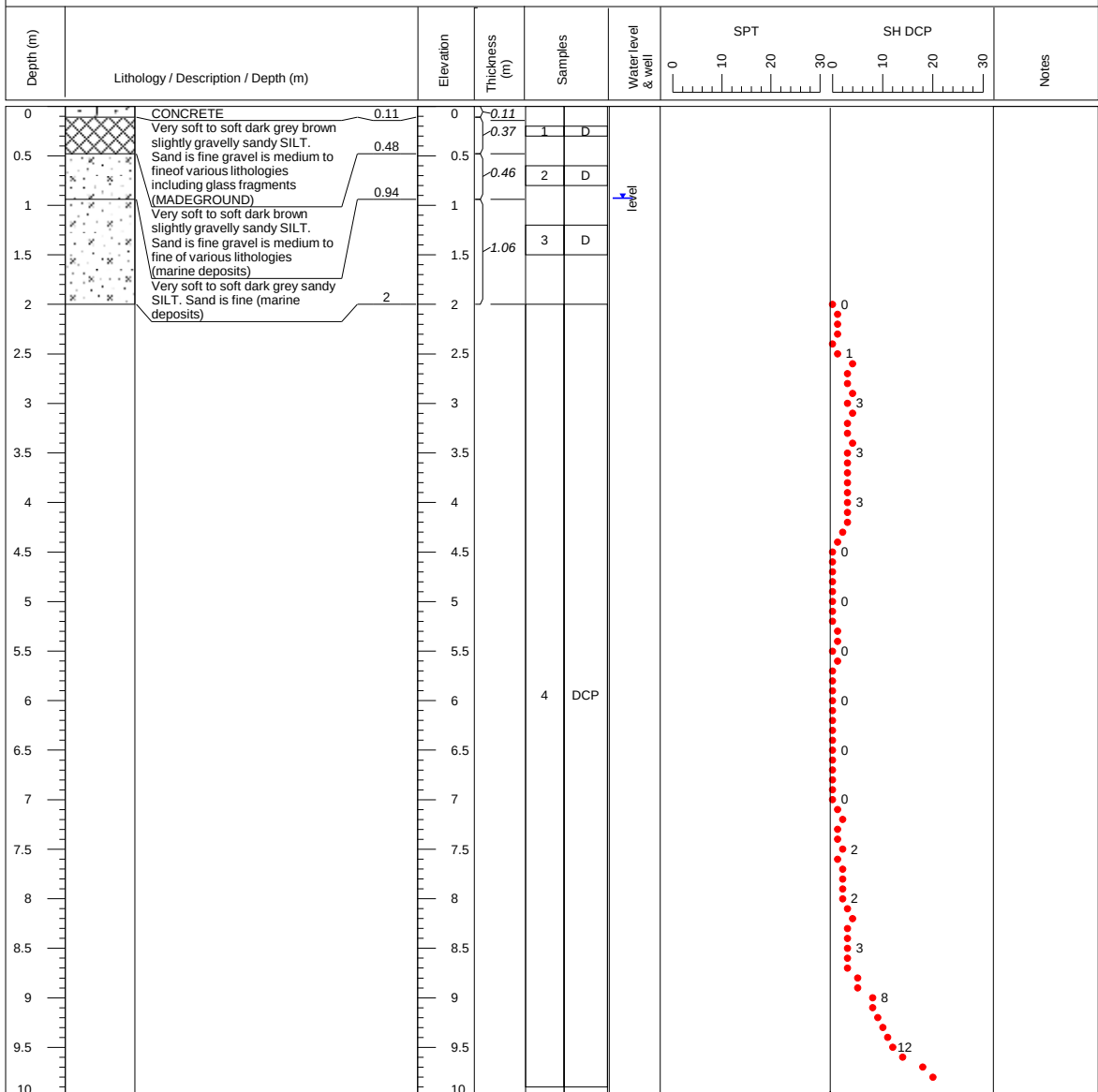
BOREHOLE LOG

Borehole
No
1

Client :- Alan Finch
Site :- Knight St Pinchbeck
Project No :- 4364

Location :- see site plan
Date :- 18-Oct-17

Coordinates E: N: 524002
Elevation :- 325863
Excavated by :- Dando Terrier
Drilled by :- HML



Sample Key
B Bulk
D Disturbed
W Water
SS Split spoon
U undisturbed
DCP SHDCP
HV Hand Vane

Notes :-
Depth drilled :- 9.9
Casing depth :- 0

File Ref :- 1059/ 4364
Logged by :- R Lester



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BOREHOLE LOG

Borehole
No
2

Client :- Alan Finch
Site :- Knight St Pinchbeck
Project No :- 4364

Location :- see site plan
Date :- 18-Oct-17

Coordinates E: N: 524004
Elevation :- 325869
Excavated by :- Dando Terrier
Drilled by :- HML

Depth (m)	Lithology / Description / Depth (m)	Elevation	Thickness (m)	Samples	Water level & well	SPT	SH DCP	Notes
0	MACADAM surfacing	0.11	0.11					
	Limestone sub-base	0.18	0.07					
	MADEGROUND of crushed concrete and brick	0.37	0.19					
0.5		0.58	0.21	1	D			
	Firm dark brown grey slightly gravelly sandy SILT. sand is fine, gravel is medium to fine of various lithologies including brick fragments		0.42	2	D			
1				3	D			
1.5	Soft dark brown grey slightly gravelly sandy SILT. Sand is fine, gravels are fine of various lithologies (marine deposits)		1.00					
2	Soft dark grey very sandy SILT. Sand is fine (marine deposits)							
2.5								
3								
3.5								
4								
4.5								
5								
5.5								
6								
6.5								
7								
7.5								
8								
8.5								
9								
9.5								
10								

Sample Key
B Bulk
D Disturbed
W Water
SS Split spoon
U undisturbed
DCP SHDCP
HV Hand Vane

Notes :-

Depth drilled :- 2
Casing depth :- 0

File Ref :- 1059/ 4364
Logged by :- R Lester





HUMBERSIDE MATERIALS LABATORY Ltd.

Atherton Way, Brigg
North Lincs DN20 8AR
Tel & Fax 01652 652753

email info@humbersidematerialslab.co.uk

BOREHOLE LOG

Borehole
No
4

Client :- Alan Finch
Site :- Knight St Pinchbeck
Project No :- 4364

Location :- see site plan
Date :- 18-Oct-17

Coordinates E: N: 524030
Elevation :- 325843
Excavated by :- Dando Terrier
Drilled by :- HML

Depth (m)	Lithology / Description / Depth (m)	Elevation	Thickness (m)	Samples	Water level & well	SPT	SH DCP	Notes
0	MADEGROUND dark grey black slightly gravelly slightly silty SAND with very occasional rootlets. Gravels are medium to fine mainly coal and very occasional brick fragments	0.15	0.15	1 D				
0.5		0.46	0.31	2 D				
1	Firm dark brownish grey slightly gravelly very sandy SILT. Gravels are medium to fine of various lithologies including very occasional brick fragments (marine deposits)	0.92	0.46	3 D				
1.5	Soft orangish yellow brown very sandy SILT sand is fine (marine deposits)	1.5	0.58	4 SS				
2	Medium dense brown very silty fine SAND	2	1.00	6 SS				
2.5	Very loose to loose brown very silty fine SAND	2.5						
3		3						
3.5		3.5						
4		4						
4.5		4.5						
5		5						
5.5		5.5						
6		6						
6.5		6.5						
7		7						
7.5		7.5						
8		8						
8.5		8.5						
9		9						
9.5		9.5						
10		10						

Sample Key
B Bulk
D Disturbed
W Water
SS Split spoon
U undisturbed
DCP SHDCP
HV Hand Vane

Notes :-
Depth drilled :- 2.45
Casing depth :- 0

File Ref :- 1059/ 4364
Logged by :- R Lester

APPENDIX C

HUMBERSIDE MATERIALS LABORATORY

Atherton way, Brigg,
North Lincolnshire, DN20 8AR
Tel & Fax 01652 652753

Linear Shrinkage

Sheet 1 of 1

Sample Ref **S/46819/01**

Client Alan Finch

Site	Pinchbeck		
Location	BH3 0.65-0.7m		
Material	soil		
Date sampled	18/10/17		
Client sample no	2	Sampled by	R lester

Linear Shrinkage

Test method BS 1377

Description - Light brown sandy SILT

% passing 0.425mm	-	100%
Linear Shrinkage	-	1.4%

Estimate PI from linear shrinkage 3

Comments

File ref	1059/4364/P
Date tested	19/10/17
Date reported	24/10/17

Signed: - M.J. Green C. Driver
Director

*Certificate of sampling when submitted is retained by the Laboratory and available upon request
Samples will normally be kept for 14 days from the date reported*



ANALYTICAL TEST REPORT

Contract no: 68015
Contract name: Knight St, Pinchbeck
Client reference: 1059/4364
Clients name: Humberside Materials Laboratory
Clients address: Atherton Way
Brigg
North Lincolnshire
DN20 8AR

Samples received: 23 October 2017

Analysis started: 23 October 2017

Analysis completed 30 October 2017

Report issued: 30 October 2017

Notes: Opinions and interpretations expressed herein are outside the UKAS accreditation scope.
Unless otherwise stated, Chemtech Environmental Ltd was not responsible for sampling.
Methods, procedures and performance data are available on request.
Results reported herein relate only to the material supplied to the laboratory.
This report shall not be reproduced except in full, without prior written approval.
Samples will be disposed of 6 weeks from initial receipt unless otherwise instructed.

Key: U UKAS accredited test
M MCERTS & UKAS accredited test
\$ Test carried out by an approved subcontractor
I/S Insufficient sample to carry out test
N/S Sample not suitable for testing
NAD No Asbestos Detected

Approved by:

James Spittle
Customer Services Team Leader

Chemtech Environmental Limited

SAMPLE INFORMATION

MCERTS (Soils):

Soil descriptions are only intended to provide a log of sample matrices with respect to MCERTS validation. They are not intended as full geological descriptions. MCERTS accreditation applies for sand, clay and loam/topsoil, or combinations of these whether these are derived from naturally occurring soils or from made ground, as long as these materials constitute the major part of the sample. Other materials such as concrete, gravel and brick are not accredited if they comprise the major part of the sample.

All results are reported on a dry basis. Samples dried at no more than 30°C in a drying cabinet.

Analytical results are inclusive of stones.

Lab ref	Sample id	Depth (m)	Sample description	Material removed	% Removed	% Moisture
68015-1	S/46816	0.60-0.80	Sandy Clay	-	-	27.3
68015-2	S/46817	0.65-0.85	Clay	-	-	30.5
68015-3	S/46818	0.10-0.30	Loam	-	-	22.9
68015-4	S/46820	1.00-1.40	Sand	-	-	22.5
68015-5	S/46821	0.20-0.40	Loamy Clay	-	-	22.0
68015-6	S/46822	0.60-0.80	Sandy Clay	-	-	22.5

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SOILS

Lab number			68015-1	68015-2	68015-3	68015-4	68015-5	68015-6
Sample id			S/46816	S/46817	S/46818	S/46820	S/46821	S/46822
Depth (m)			BH1-2	BH2-2	BH3-1	BH3-3	BH4-2	BH4-3
Date sampled			0.60-0.80	0.65-0.85	0.10-0.30	1.00-1.40	0.20-0.40	0.60-0.80
			18/10/2017	18/10/2017	18/10/2017	18/10/2017	18/10/2017	18/10/2017
Test	Method	Units						
Arsenic (total)	CE127 ^M	mg/kg As	12	7.2	10	-	-	37
Beryllium (total)	CE127 ^U	mg/kg Be	<1	<1	<1	-	-	<1
Boron (water soluble)	CE063 ^M	mg/kg B	2.2	4.7	3.3	-	-	1.8
Cadmium (total)	CE127 ^M	mg/kg Cd	<0.2	<0.2	0.5	-	-	<0.2
Chromium (total)	CE127 ^M	mg/kg Cr	142	102	114	-	-	104
Copper (total)	CE127 ^M	mg/kg Cu	29	20	41	-	-	7.5
Lead (total)	CE127 ^M	mg/kg Pb	113	37	397	-	-	47
Mercury (total)	CE127 ^M	mg/kg Hg	<0.5	<0.5	<0.5	-	-	<0.5
Nickel (total)	CE127 ^M	mg/kg Ni	16	18	21	-	-	13
Selenium (total)	CE127 ^M	mg/kg Se	0.8	0.8	1.0	-	-	0.7
Vanadium (total)	CE127 ^M	mg/kg V	32	38	35	-	-	30
Zinc (total)	CE127 ^M	mg/kg Zn	81	70	187	-	-	32
pH	CE004 ^M	units	-	-	-	8.6	-	-
Magnesium (2:1 water soluble)	CE061	mg/l Mg	-	-	-	4.5	-	-
Chloride (2:1 water soluble)	CE049 ^U	mg/l Cl	-	-	-	29	-	-
Nitrate (2:1 water soluble)	CE049 ^U	mg/l NO ₃	-	-	-	10	-	-
Nitrite (2:1 water soluble)	CE049	mg/l NO ₂	-	-	-	<1	-	-
Sulphate (2:1 water soluble)	CE061 ^M	mg/l SO ₄	-	-	-	47	-	-
Sulphate (total)	CE062 ^M	mg/kg SO ₄	-	-	-	273	-	-
Sulphur (total)	CE127	mg/kg S	-	-	-	183	-	-
Total Organic Carbon (TOC)	CE072 ^M	% w/w C	3.42	-	-	-	-	-
Estimate of OMC (calculated from TOC)	CE072 ^M	% w/w	5.90	-	-	-	-	-
PAH								
Naphthalene	CE087 ^M	mg/kg	<0.01	<0.01	0.07	-	0.03	<0.01
Acenaphthylene	CE087 ^M	mg/kg	<0.01	<0.01	<0.01	-	<0.01	<0.01
Acenaphthene	CE087 ^M	mg/kg	<0.01	<0.01	<0.01	-	<0.01	<0.01
Fluorene	CE087 ^U	mg/kg	<0.01	<0.01	<0.01	-	<0.01	<0.01
Phenanthrene	CE087 ^M	mg/kg	0.07	0.04	0.17	-	0.16	0.03
Anthracene	CE087 ^U	mg/kg	<0.02	<0.02	0.04	-	0.07	<0.02
Fluoranthene	CE087 ^M	mg/kg	0.10	<0.02	0.36	-	0.87	<0.02
Pyrene	CE087 ^M	mg/kg	0.09	<0.02	0.32	-	0.72	<0.02
Benzo(a)anthracene	CE087 ^U	mg/kg	0.08	<0.02	0.19	-	0.44	<0.02
Chrysene	CE087 ^M	mg/kg	0.07	<0.01	0.22	-	0.71	<0.01
Benzo(b)fluoranthene	CE087 ^M	mg/kg	0.09	<0.02	0.25	-	0.63	<0.02
Benzo(k)fluoranthene	CE087 ^M	mg/kg	<0.02	<0.02	0.10	-	0.24	<0.02
Benzo(a)pyrene	CE087 ^U	mg/kg	0.06	<0.02	0.21	-	0.29	<0.02
Indeno(123cd)pyrene	CE087 ^M	mg/kg	<0.02	<0.02	0.13	-	0.23	<0.02
Dibenz(ah)anthracene	CE087 ^M	mg/kg	<0.02	<0.02	<0.02	-	0.06	<0.02
Benzo(ghi)perylene	CE087 ^M	mg/kg	<0.02	<0.02	0.14	-	0.21	<0.02
PAH (total of USEPA 16)	CE087	mg/kg	0.56	<0.27	2.20	-	4.65	<0.27

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SOILS

Lab number			68015-1	68015-2	68015-3	68015-4	68015-5	68015-6
Sample id			S/46816	S/46817	S/46818	S/46820	S/46821	S/46822
Depth (m)			BH1-2	BH2-2	BH3-1	BH3-3	BH4-2	BH4-3
Date sampled			0.60-0.80	0.65-0.85	0.10-0.30	1.00-1.40	0.20-0.40	0.60-0.80
			18/10/2017	18/10/2017	18/10/2017	18/10/2017	18/10/2017	18/10/2017
Test	Method	Units						
TPH								
VPH Aromatic (>EC5-EC7)	CE067	mg/kg	<0.01	-	-	-	-	-
VPH Aromatic (>EC7-EC8)	CE067	mg/kg	<0.01	-	-	-	-	-
VPH Aromatic (>EC8-EC10)	CE067	mg/kg	<0.01	-	-	-	-	-
EPH Aromatic (>EC10-EC12)	CE068	mg/kg	<1	-	-	-	-	-
EPH Aromatic (>EC12-EC16)	CE068	mg/kg	<1	-	-	-	-	-
EPH Aromatic (>EC16-EC21)	CE068	mg/kg	<1	-	-	-	-	-
EPH Aromatic (>EC21-EC35)	CE068	mg/kg	1	-	-	-	-	-
EPH Aromatic (>EC35-EC44)	CE068	mg/kg	<1	-	-	-	-	-
VPH Aliphatic (>C5-C6)	CE067	mg/kg	<0.1	-	-	-	-	-
VPH Aliphatic (>C6-C8)	CE067	mg/kg	<0.1	-	-	-	-	-
VPH Aliphatic (>C8-C10)	CE067	mg/kg	<0.1	-	-	-	-	-
EPH Aliphatic (>C10-C12)	CE068	mg/kg	<4	-	-	-	-	-
EPH Aliphatic (>C12-C16)	CE068	mg/kg	<4	-	-	-	-	-
EPH Aliphatic (>C16-C35)	CE068	mg/kg	30	-	-	-	-	-
EPH Aliphatic (>C35-C44)	CE068	mg/kg	17	-	-	-	-	-
Subcontracted analysis								
Asbestos (qualitative)	\$	-	-	-	NAD	-	-	-

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METHOD DETAILS

METHOD	SOILS	METHOD SUMMARY	SAMPLE	STATUS	LOD	UNITS
CE127	Arsenic (total)	Aqua regia digest, ICP-MS	Dry	M	1	mg/kg As
CE127	Beryllium (total)	Aqua regia digest, ICP-MS	Dry	U	1	mg/kg Be
CE063	Boron (water soluble)	Hot water extract, ICP-OES	Dry	M	0.5	mg/kg B
CE127	Cadmium (total)	Aqua regia digest, ICP-MS	Dry	M	0.2	mg/kg Cd
CE127	Chromium (total)	Aqua regia digest, ICP-MS	Dry	M	1	mg/kg Cr
CE127	Copper (total)	Aqua regia digest, ICP-MS	Dry	M	1	mg/kg Cu
CE127	Lead (total)	Aqua regia digest, ICP-MS	Dry	M	1	mg/kg Pb
CE127	Mercury (total)	Aqua regia digest, ICP-MS	Dry	M	0.5	mg/kg Hg
CE127	Nickel (total)	Aqua regia digest, ICP-MS	Dry	M	1	mg/kg Ni
CE127	Selenium (total)	Aqua regia digest, ICP-MS	Dry	M	0.3	mg/kg Se
CE127	Vanadium (total)	Aqua regia digest, ICP-MS	Dry	M	1	mg/kg V
CE127	Zinc (total)	Aqua regia digest, ICP-MS	Dry	M	5	mg/kg Zn
CE004	pH	Based on BS 1377, pH Meter	Wet	M	-	units
CE061	Magnesium (2:1 water soluble)	Aqueous extraction, ICP-OES	Dry		1	mg/l Mg
CE049	Chloride (2:1 water soluble)	Aqueous extraction, IC-COND	Dry	U	1	mg/l Cl
CE049	Nitrate (2:1 water soluble)	Aqueous extraction, IC-COND	Dry	U	1	mg/l NO ₃
CE049	Nitrite (2:1 water soluble)	Aqueous extraction, IC-COND	Dry		1	mg/l NO ₂
CE061	Sulphate (2:1 water soluble)	Aqueous extraction, ICP-OES	Dry	M	10	mg/l SO ₄
CE062	Sulphate (total)	Acid extraction, ICP-OES	Dry	M	100	mg/kg SO ₄
CE127	Sulphur (total)	Acid extraction, ICP-MS	Dry		100	mg/kg S
CE072	Total Organic Carbon (TOC)	Removal of IC by acidification, Carbon Analyser	Dry	M	0.1	% w/w C
CE072	Estimate of OMC (calculated from TOC)	Calculation from Total Organic Carbon	Dry	M	0.1	% w/w
CE087	Naphthalene	Solvent extraction, GC-MS	Wet	M	0.01	mg/kg
CE087	Acenaphthylene	Solvent extraction, GC-MS	Wet	M	0.01	mg/kg
CE087	Acenaphthene	Solvent extraction, GC-MS	Wet	M	0.01	mg/kg
CE087	Fluorene	Solvent extraction, GC-MS	Wet	U	0.01	mg/kg
CE087	Phenanthrene	Solvent extraction, GC-MS	Wet	M	0.02	mg/kg
CE087	Anthracene	Solvent extraction, GC-MS	Wet	U	0.02	mg/kg
CE087	Fluoranthene	Solvent extraction, GC-MS	Wet	M	0.02	mg/kg
CE087	Pyrene	Solvent extraction, GC-MS	Wet	M	0.02	mg/kg
CE087	Benzo(a)anthracene	Solvent extraction, GC-MS	Wet	U	0.02	mg/kg
CE087	Chrysene	Solvent extraction, GC-MS	Wet	M	0.01	mg/kg
CE087	Benzo(b)fluoranthene	Solvent extraction, GC-MS	Wet	M	0.02	mg/kg
CE087	Benzo(k)fluoranthene	Solvent extraction, GC-MS	Wet	M	0.02	mg/kg
CE087	Benzo(a)pyrene	Solvent extraction, GC-MS	Wet	U	0.02	mg/kg
CE087	Indeno(123cd)pyrene	Solvent extraction, GC-MS	Wet	M	0.02	mg/kg
CE087	Dibenz(ah)anthracene	Solvent extraction, GC-MS	Wet	M	0.02	mg/kg
CE087	Benzo(ghi)perylene	Solvent extraction, GC-MS	Wet	M	0.02	mg/kg
CE087	PAH (total of USEPA 16)	Solvent extraction, GC-MS	Wet		0.27	mg/kg
CE067	VPH Aromatic (>EC5-EC7)	Headspace GC-FID	Wet		0.01	mg/kg
CE067	VPH Aromatic (>EC7-EC8)	Headspace GC-FID	Wet		0.01	mg/kg
CE067	VPH Aromatic (>EC8-EC10)	Headspace GC-FID	Wet		0.01	mg/kg
CE068	EPH Aromatic (>EC10-EC12)	Solvent extraction, GC-FID	Wet		1	mg/kg

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METHOD DETAILS

METHOD	SOILS	METHOD SUMMARY	SAMPLE	STATUS	LOD	UNITS
CE068	EPH Aromatic (>EC12-EC16)	Solvent extraction, GC-FID	Wet		1	mg/kg
CE068	EPH Aromatic (>EC16-EC21)	Solvent extraction, GC-FID	Wet		1	mg/kg
CE068	EPH Aromatic (>EC21-EC35)	Solvent extraction, GC-FID	Wet		1	mg/kg
CE068	EPH Aromatic (>EC35-EC44)	Solvent extraction, GC-FID	Wet		1	mg/kg
CE067	VPH Aliphatic (>C5-C6)	Headspace GC-FID	Wet		0.1	mg/kg
CE067	VPH Aliphatic (>C6-C8)	Headspace GC-FID	Wet		0.1	mg/kg
CE067	VPH Aliphatic (>C8-C10)	Headspace GC-FID	Wet		0.1	mg/kg
CE068	EPH Aliphatic (>C10-C12)	Solvent extraction, GC-FID	Wet		4	mg/kg
CE068	EPH Aliphatic (>C12-C16)	Solvent extraction, GC-FID	Wet		4	mg/kg
CE068	EPH Aliphatic (>C16-C35)	Solvent extraction, GC-FID	Wet		4	mg/kg
CE068	EPH Aliphatic (>C35-C44)	Solvent extraction, GC-FID	Wet		10	mg/kg
\$	Asbestos (qualitative)	HSG 248, Microscopy	Dry	U	-	-

Chemtech Environmental Limited

DEVIATING SAMPLE INFORMATION

Comments

Sample deviation is determined in accordance with the UKAS note "Guidance on Deviating Samples" and based on reference standards and laboratory trials.

For samples identified as deviating, test result(s) may be compromised and may not be representative of the sample at the time of sampling.

Chemtech Environmental Ltd cannot be held responsible for the integrity of sample(s) received if Chemtech Environmental Ltd did not undertake the sampling. Such samples may be deviating.

Key

N	No (not deviating sample)
Y	Yes (deviating sample)
NSD	Sampling date not provided
NST	Sampling time not provided (waters only)
EHT	Sample exceeded holding time(s)
IC	Sample not received in appropriate containers
HP	Headspace present in sample container
NCF	Sample not chemically fixed (where appropriate)
IT	Sample not cooled
OR	Other (specify)

Lab ref	Sample id	Depth (m)	Deviating	Tests (Reason for deviation)
68015-1	S/46816	0.60-0.80	N	
68015-2	S/46817	0.65-0.85	N	
68015-3	S/46818	0.10-0.30	N	
68015-4	S/46820	1.00-1.40	N	
68015-5	S/46821	0.20-0.40	N	
68015-6	S/46822	0.60-0.80	N	