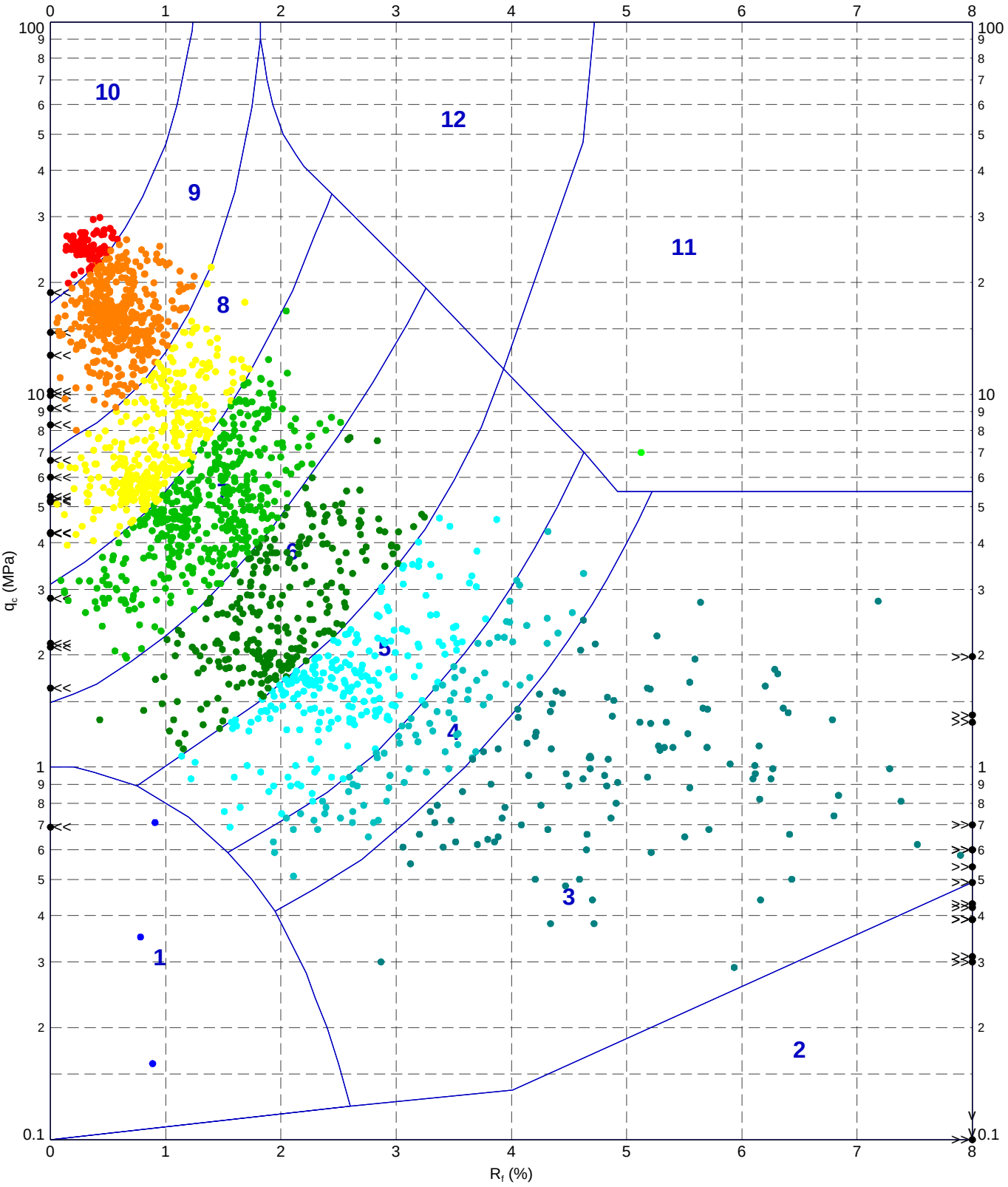


METHOD: Robertson et al. 1986 qc Rf

- 1 - Sensitive fine grained material
- 2 - Organic material
- 3 - CLAY
- 4 - Silty CLAY to CLAY
- 5 - Clayey SILT to silty CLAY
- 6 - Sandy SILT to clayey SILT
- 7 - Silty SAND to sandy SILT
- 8 - SAND to silty SAND
- 9 - SAND
- 10 - Gravelly SAND to SAND
- 11 - Very stiff fine grained
- 12 - SAND to clayey SAND

IN SITU SITE INVESTIGATION

TITLE

Delta Simons
Portsmouth
Brockhampton
Robertson et al. 1986 q_c vs. R_f - CPT220

DRAWN	DATE 29/10/2021
CHECKED	DATE 29/10/2021
SCALE Not To Scale	A4
PROJECT No 1210494	FIGURE No

210713-ADVANCED REPORT INSITUSI 2.02.1 LIB - LUISA.GLB Graph CPT ROBERTSON ET AL. 86 QC VS. RF A4P 1210494 BROCKHAMPTON PORTSMOUTH DELTA SIMONS.GPJ <<DrawingFile>> 29/10/2021 14:01 10.02.00.04 Datgel Lab and In Situ Tool - DGD | Lib: In Situ SI 2.02.0 2017-07-10 Prj: In Situ SI 2.02.0 2017-07-10

Appendix D

North Slopes –Geo5 Outputs



IN SITU SITE INVESTIGATION

Unit 23 Hastings Innovation Centre,
Highfield Drive
St. Leonards on Sea, East Sussex,
TN38 9UH, U.K.

Company No.: 6339499
VAT No.: 922 3561 41

Brockhampton West

A102760

Havant Borough Council

Havant BOROUGH COUNCIL

August 2017

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100 St John Street, London, EC1M 4EH
Tel: +44 (0)20 7250 7500 Fax: +44 (0)20 7250 7501
Email: info@wyg.com Website: www.wyg.com

WYG Environment Planning Transport Limited. Registered in England & Wales Number: 03050297
Registered Office: Arndale Court, Otley Road, Headingley, Leeds, LS6 2UJ

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Executive Summary

Introduction	A Phase 2 Geo-environmental investigation of land at Brockhampton West has been completed in order to review risks associated with ground conditions in view of potential development of the site for commercial / industrial use
Site Location and Description	The site comprises a predominantly rectangular shaped plot of land, approximately 9 hectares in size. It is a grassed / vegetated open space, which is predominantly used by dog walkers.
Geology	The site is underlain by Made Ground (including landfill material). The superficial natural strata is understood to comprise predominantly Raised Marine Deposits that are variably granular and cohesive but with potential River Terrace and Tidal Flat Deposits and alluvium encroaching onto northern, southern and eastern areas of the site respectively. The solid geology is characterised by the presence of Chalk (Seaford or Newhaven Formations).
Hydrogeology	The superficial deposits are characterised as Secondary Aquifers. The underlying Chalk is characterised as a Principal Aquifer, however the site is not located within a Source Protection Zone.
Hydrology	Immediately east of the site is the Hermitage Stream. The northern edge of the Langstone Harbour is situated approximately 170m south of the site, at its closest point.
Site History	Up until the late 1960's / 1970's, the site comprised tidal, mud flats, surface water and marshland. It is understood that the site was reclaimed using a clay and steel sheet pile bund and that various phases of landfilling between the 1970's – 1990's took place resulting in the deposition of domestic landfill, incinerator waste and road construction waste; further groundworks (activities unknown) are also evident from aerial photographs post 2000 in the south west of the site.
Ground Investigations	Ground investigation works comprised 6No. cable percussive boreholes (to depths up to 35m bgl) and 10 window sample boreholes with dual purpose landgas and groundwater monitoring apparatus installed in each. A total of 11 trial pits were excavated. Soil samples were obtained for laboratory assessment and 6No. Return monitoring visits (land gas and groundwater monitoring) were undertaken.
Ground Conditions Encountered	Ground conditions encountered during the investigation were consistent with those identified in the published literature and comprised a consistently thick layer of Made Ground (up 11.5m thick) comprising variably a cohesive 'capping material' and landfill; the landfill thickness ranged from approximately 4.5-7.4m thick across the site. Beneath the made ground in the east of the site River Terrace Deposit (maximum 5m thick) comprising sand gravel were recorded. Beneath the made ground in the west of the site alluvium (maximum 3.5m thick) was recorded comprising sandy gravelly clay or silty clay. White chalk was encountered beneath superficial strata in the east and west and directly beneath the chalk in the centre of the site. Groundwater strikes were recorded in both landfill and superficial strata at depths ranging between 3.9 and 11.5m bgl during the investigation; during return monitoring visits, the depth to groundwater was typically in excess of 5m.

Geotechnical Recommendations	Actual rate of settlement of Made Ground on site should be monitored prior to development considerations. For light industrial / commercial units, the ground should be pre-loaded (following guidance on BRE FB75) and constructed on raft foundations, with gas protection measurements. Heavily loaded structures should be founded into the underlying Chalk. With consideration to negative shaft frictions due to long-term ground settlement and the type of pile construction e.g. continuous flight augers with the use of temporary casing to seal out contaminated water. Excavations within the made ground for temporary works should consider the stability of the ground and potential ground gas concentration. Man, entry into excavations should be avoided. Concrete used for construction should conform to advice given within BRE SD1.
Contamination Findings	Elevated levels of land gas (maximum 98% CH4, 46% CO2) have been measured within monitoring wells across the site and occasionally high flow rates were recorded. Asbestos fibres were detected in 15 of 40 soil samples collected from made ground (capping material and landfill). Locally, in shallow soil, elevated concentrations of PAH compounds relative to human health based screening criteria were encountered. Concentrations of hydrocarbons, ammoniacal compounds and cyanide exceeding relevant water quality standards were recorded in groundwater samples collected from wells installed in the landfill and also (in one location only) chalk.
Conceptual Site Model	Based on the review of desk study information and the Phase 2 ground investigation the following risk levels have been identified: • Future site users – Public Open Space – Low / Moderate (assuming site remains unchanged) or Moderate (assuming space enhancement and increased usage). • Future site users – Commercial – High – driven by risks associated with land gas. • Construction workers (during redevelopment of the site) – High risks have been identified associated with both land gas and asbestos fibres. • Offsite neighbours – Low / Moderate risks to neighbours have been identified associated with potential land gases. Moderate risks have been identified associated with potential release and exposure to asbestos during redevelopment / groundworks. • Groundwater of the Superficial Secondary Aquifers –Moderate • Groundwater in the deep Chalk Principal Aquifer - Moderate • Surface Water – Moderate • Onsite property/buildings and services – High risks to buildings have been identified associated with potentially hazardous land gases.
Conclusions and Recommendations	Further monitoring from wells installed in the Chalk is recommended in order to verify the levels of contamination recorded in groundwater to date. Engagement with the regulators is also recommended in order to gain a better understanding in relation to the regulators expectations and requirements regarding potential groundwater contamination. It is recommended that prior to any redevelopment of the site that additional gas monitoring be undertaken. Based on current data it is considered likely that gas protection measures required for future buildings will need to comply with a Characteristic Situation 3 or 4. During any future construction phase a number of precautions are likely to required including provision of dust suppression measures, boundary monitoring of dust / fibres, use of appropriate PPE, welfare and decontamination facilities, UXO support during deep piling and high standards of waste management

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1.0 Introduction

Havant Borough Council (HBC) instructed WYG Environment Planning & Transport (WYG) to complete a site investigation at the land referred to as Brockhampton West, Havant.

Instructions to proceed were given in March 2017, with the contract being signed on 30th March 2017

1.1 Project Background

A ground investigation was scoped by WYG and proposed to HBC in a tender dated March 2017. HBC required information on the ground conditions at the land at Brockhampton West. HBC would like to ascertain the feasibility of potential development options at the site.

The ground investigation scoped by WYG comprised the following broad objectives:

- Identify potential constraints to redevelopment associated with ground contamination;
- Identify the depth and nature of fill materials and their potential for land gas generation;
- Assess the deeper geotechnical characteristics of the natural soils / White Chalk to allow an assessment of piled foundations;
- Provide recommendations for risk management efforts to address any health and safety or environmental concerns associated with redevelopment of the site;
- Provide preliminary recommendations to support foundation design at any future building at the site; and
- Provide suitable robust investigation / assessment reports to satisfy expectations and concerns identified during the feasibility assessment.

The report herein describes a ground investigation, detailing the ground conditions encountered from the exploratory holes and in-situ and laboratory testing and provides an assessment of key geotechnical and environmental issues pertaining to the redevelopment proposal.

This report, prepared in line with the agreed brief, is subject to the report conditions presented in **Appendix A.**

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1.2 Objectives and Scope

The overarching objective of this assessment is to review risks associated with ground conditions in view of potential development of the site for commercial / industrial use.

In summary, the scope of work comprised the following;

- Site walkovers undertaken on 30th March 2017 & during site field works;
- A review of historical records to understand the sites development history and identify potential geo-environmental and geotechnical risks associated with the sites historical development;
- A review of site setting including topography, geology, hydrogeology and hydrology;
- A review of the risk of unexploded ordnance being present at the site;
- A geotechnical and ground contamination intrusive investigation consisting of 6No Cable percussion boreholes, 10No Window Sample boreholes, both with standard penetration testing (SPTs) and 11No machine excavated trial pits. Soil samples taken issued for laboratory analysis and initial geotechnical characterisation;
- Interpretation of the data collected to define a Conceptual Site Model (CSM) and to undertake qualitative risk assessment and semi-quantitative risk assessment grading the pollutant linkages in accordance with a risk matrix;
- Development of an outline geotechnical model of ground conditions with discussion of characteristic geotechnical parameters; and
- Provision of recommendations pertaining to potential development constraints, further assessment requirements and management options.

1.3 Proposed Development

It is the understanding of WYG that HBC, would like to develop the land known as Brockhampton West for an employment /commercial use, if such development is considered economically viable.

1.4 Terms and Conditions

This report presents a full factual record of all site work carried out during the period 2nd - 12th May 2017. The recommendation and opinions expressed in this report are based on the information provided and other sources of readily available information. Where use has

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been made of other report or information provide from the client, or from other third party sources, such data has been reviewed in good faith and it has been assumed that their contents are correct, as it is impractical to fully validate this data. WYG is unable to guarantee any third party information.

The information contained in this report is intended for the use of HBC and their consultant partners. WYG can take no responsibility for the use of this information by any third party for uses other than that described in this report.

It should be noted that physical and chemical characteristics of the site can vary with time. The results obtained may therefore only be representative of the conditions at the time of the investigation.

Attention is drawn to the report conditions contained in **Appendix A** and the terms and conditions of the engagements.

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2.0 Site Description

This section provides a summary of factual information previously collated and presented in full within the Phase 1 Desk Study Report.

2.1 Site Location

The site is situated to the north of Harts Farm Way, and to the south of the A27 bypass 1.5km to the south west of Havant, Hampshire, details are summarised in **Table 2.1** below.

Table 2.1 Site Location Details

Site Address	Land known as Broadmarsh Open Space, Harts Farm Way, Approx postcode – PO9 1HS.
Site Area	9.20Ha
National Grid Reference	470185,105679

Site layout and location are illustrated figuratively in **Appendix B**, Drawings 001 & 002.

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2.2 Site Description

The site comprises a predominantly rectangular shaped plot of land, approximately 9 hectares in size. It is a grassed / vegetated open space, which is predominantly used by dog walkers.

Towards the centre / eastern end of the site, there is a hard standing driveway which leads to a wide open car parking area / turning circle. There is a locked gate at the entrance to which Council contractors have access.

To the west of the hard standing the site is predominantly flat with footpaths worn into the grass / vegetation.

To the east of the hard standing the site is mounded with footpaths worn into the grass / vegetation.

The site is bounded to the north by the A27 dual carriage way and to the east by Hermitage Stream which feeds into Langstone Harbour. To the south is Harts Farm Way with Broadmarsh Coastal Park and Langstone Harbour further beyond. To the west is the junction (tear drop in shape) of the A27 and A3(M).

Around the perimeter of the site, there is more substantial vegetation, including shrubs and small trees. At the eastern and northern sides of the site there are more mature trees, which screen the A27 and Hermitage Stream.

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3.0 Ground Investigation

The ground investigation was designed and scoped by WYG as detailed within the tender document (dated 1st March 2017). A combination of cable percussion boreholes, window sample boreholes and machine excavated trial pits were advanced across the site to permit the inspection of subsurface ground conditions and to facilitate the collection of soil samples. Site investigation works were undertaken by WYG between the dates of the 2nd and 12th of May 2017 and comprised the following:

- 6No. Cable percussion boreholes to a maximum depth of 35m bgl;
- 10No. Window Sample boreholes to a maximum depth of 5.00m bgl;
- 11No. machine excavated trial pits to a maximum depth of 4.00m bgl.
- Geo-Environmental, Landfill Forensic & Geotechnical Laboratory Testing of soils;
- Return Groundwater & Ground Gas Monitoring (total six return visits);
- Well development and Ground Water sampling and water quality testing.

Further details of the intrusive investigation methodology is provided in the following sub-sections.

The exploratory hole locations are depicted within Drawing 003 in Appendix B. A selection of photographs taken during the investigation are presented in **Appendix** C. Exploratory hole logs are provided in **Appendix D**. Further factual data relating to the investigation is included with Appendices E-I.

3.1 Site Investigation Standards

Site investigation activities were undertaken in general accordance with BS5930:1999 – "Code of Practice for Site Investigations" incorporating Amendment 2 (2010), which incorporates EN14688-1&2, Eurocode 7, Geotechnical Design (ref. BS-EN 1997-2:200) and BS10175:2011_A1:2013 "Investigation of Potentially Contaminated Land".

3.2 Service / UXO Clearance

Prior to breaking ground a non-intrusive survey comprising Ground Penetrating Radar (GPR) and Electromagnetic Scanning was undertaken to help locate buried service routes and thereby to inform the selection of "safe" investigation locations.

Inspection pits were hand excavated at each cable percussion and window sample location to a depth of 1.20m bgl, before deeper works were progressed using mechanical methods.

An Explosive Ordnance Disposal (EOD) specialist was in attendance during the drilling of the deeper cable percussion boreholes. A down-hole magnetometer was used at one metre intervals to check for ferrous materials potentially associated with Unexploded Ordnance (UXO).

3.3 Cable Percussion Boreholes

A total of six cable percussion boreholes were drilled at the site between 2nd-12th May 2017. The boreholes were advanced to a maximum depth of 35m bgl using a Dando 4000 rig. This is a standard cable percussive rig comprising a diesel winch supported by an A-frame which can raise and drop steel casing and percussive drilling tools in to the borehole. SPTs were undertaken in addition to undisturbed sampling using standard U100 samples (100mm diameter sampling tubes).

Aquifer protection measures were employed when drilling the deeper boreholes. This entailed drilling in wider (200mm diameter) casing through the Made Ground, then placing a bentonite clay plug at the base of the Made Ground. Well casing (150mm diameter) was then lowered and drilled through the 200mm diameter and bentonite plug. This approach seals the annulus of the well and prevents the potential for water and contaminants in the landfill to ingress into the Chalk aquifer.

Monitoring wells were installed in each of the boreholes using 50mm internal diameter HDPE piping with screened sections in either the landfill or the Chalk. The three deep boreholes were installed with dual installs. Details of individual well installations are shown on the exploratory hole logs provided in **Appendix D**. Each well was completed at surface with "top hat", above ground well covers.

3.4 Window Sampling Boreholes

A total of ten window sample boreholes were advanced across the site between the 9th-10th May 2017. The window sample boreholes were completed using an Archway Competitor Dart tracked dynamic sampling rig, which functions by driving hollow steel tubing into the ground using a percussive mechanism. Upon extractions, the tubes contain soil cores which can be subsequently logged, sampled and tested. In addition to allowing

inspection and sampling, the rig was used to complete SPT tests prior to each run. Maximum depth achieved during window sampling was 5m bgl.

Monitoring well installation were completed using 35mm internal diameter PVC piping. Screened sections were installed, at variable depths according to the geology encountered. Each well was completed at surface with a top hat well cover, apart from WS09 which was completed with a flush traffic rated cover within the area of hardstanding. Full engineering soil logs are presented within **Appendix D.**

3.5 Machine Excavated Trial Pits

A total of eleven trial pits were completed between the 9th-10th of May 2017 using an 8 tonne tracked excavator. Trial pits were excavated to maximum depth of 4m bgl. The ground conditions encountered within each trial pit were logged and representative samples selected for analysis by the site engineer. Full engineering soil logs are presented within **Appendix D.**

After sampling, logging, photographing and measuring were complete, soil arisings were placed back within the excavation in the order they were encountered (i.e. deepest material was returned to the bottom of the excavation).

3.6 Soil Sampling

A number of soil samples collected from all exploratory holes were selected for analysis for potential ground contaminants. The rationale behind the selection of samples was multi-purpose but included targeting any soil exhibiting signs of contamination, especially within the landfill material. Further samples were also collected to ensure representative characterisation of the geotechnical properties of the soils. Soil samples were dispatched in cool boxes under a chain of custody to the laboratory for analytical testing. The environmental chemistry of soil samples selected by WYG were analysed by Jones Environmental Laboratory. Jones are accredited by the UK Accreditation Service (UKAS) and the EA's Monitoring Certification Scheme (MCERTS) for a range of chemical analyses. Geotechnical samples were submitted to Professional Soils Laboratory (PSL), who are also UKAS accredited for the tests undertaken. Bulk samples of landfill materials were submitted to Envirolab where forensic testing on landfill samples were carried out.

3.7 Groundwater Monitoring and Sampling

Gas and groundwater monitoring and sampling equipment were installed in all Cable Percussion and Window Sample exploratory boreholes as summarised in **Table 3.1** below.

Table 3.1 Summary of installations

Exploratory Hole	Installation Details	Response zone depths	
		From (m bgl)	To (m bgl)
CP01	Dual 50mm diameter HDPE standpipe with response zones comprising slotted pipe with 250µm filter wrap and a 10mm diameter washed pea-shingle surround. Deep install within the Chalk, and shallow install within the landfill. At least 0.70m thick bentonite seal above the upper response zone. Lower response zone (within the Chalk) had at least 3.00m bentonite seal above. Finished above ground level with a gas tap and upstanding concreted steel cover.	1.00	11.00
		14.00	35.00
CP02A		1.00	9.00
		13.00	35.00
CP03		1.00	10.00
		14.00	35.00
CP04	Single 50mm diameter HDPE standpipe with response zone comprising slotted pipe with 250 µm filter wrap and 10mm diameter washed pea shingle surround. At least 0.70m thick bentonite seal above the response zone. Finished above ground level with a gas tap and upstanding concreted cover.	1.00	9.00
CP05		1.00	11.00
CP06		1.00	9.00
WS01	Single 35mm diameter PVC standpipe with response zone comprising slotted pipe with 250 µm filter wrap and 10mm diameter washed pea shingle surround. At least 1m thick bentonite seal above the response zone. Finished above ground level with a gas tap and upstanding concreted cover.	1.00	2.70
WS02		1.00	5.00
WS03		1.00	3.00
WS04		1.00	4.00
WS05		1.00	3.00
WS06		1.00	5.00
WS07		1.00	3.00
WS08		1.00	3.50
WS09		1.00	4.00
WS10		1.00	4.00

3.7.1 Well Development

Water is often added as part of the drilling process and ground disturbance can result in the addition of particulate material within the water column. Therefore, well development by removing water and particulates from the well is required, to rectify the effects of drilling. It also serves to stabilise the filter pack adjacent to the well screen and improves the hydraulic connection between the well screen and the surrounding formation (CL:AIRE 2008).

Groundwater was removed from the wells in two different ways:

- Shallow installs in cable percussion boreholes – water was removed using a cylindrical bailer. Approximately six times the well volume was bailed. This was undertaken during visit 1 on the 18th of May.
- Deep installs in cable percussion boreholes – water was removed using a petrol motor powered inertial pump system, with 16mm outer diameter tubing and a one way valve. This was undertaken during visit 2 on the 25th of May.
- Window sample boreholes had little to no water within them. These were not developed or sampled.

Details of purged volumes / observations during well development are presented in **Appendix E.**

3.7.2 Gas and Groundwater Monitoring & Sampling

Groundwater levels were monitored onsite using a dual phase dipmeter. Gas readings were taken using a GA5000 portable gas analyser. Monitoring results are provided in **Appendix E.**

Gas and groundwater monitoring was undertaken during six visits, as summarised in **Table 3.2** below.

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Table 3.2 Summary of Monitoring and Sampling visits

Date of Visit	Work Completed
18/05/2017	Gas & Groundwater Monitoring Developing all shallow installs; CP01 to CP06 inclusive
25/05/2017	Gas &Groundwater Monitoring Developing all deep installs; CP01 to CP03 inclusive
02/06/2017	Gas & Groundwater Monitoring Only
08/06/2017	Gas & Groundwater Monitoring Water sampling all deep installs; CP01 to CP03 inclusive, plus CP02 & CP03 shallow installs
15/06/2017	Gas & Groundwater Monitoring Water sampling shallow installs, CP01, CP03, CP04, CP05 & CP06
27/06/2017	Gas & Groundwater Monitoring Only

Ground water samples were collected using a low-flow technique, whereby the sample is extracted at the same rate that water flows into the well. During the sampling a YSL water quality meter was used to measure a range of parameters including temperature, electrical conductivity, dissolved oxygen, pH and Oxidation-Reduction Potential. Once these parameters were considered to have stabilised sufficiently (e.g. <10% variations between testing intervals) groundwater samples were collected.

Parameters measurements recorded during sampling are provided in **Appendix E.**

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4.0 Ground Conditions Encountered

4.1 Soil Conditions

Ground conditions encountered during the investigation were consistent with those identified in the published literature and, in summary, comprised Made Ground (capping layer) over Made Ground (Landfill Material), over Alluvium, over Chalk. The Chalk persisted to the full depth of investigation (i.e. >35m bgl).

Selected photographs of exploratory holes are included in Appendix C. Exploratory Hole Logs detailing soil conditions are present in **Appendix D**. A cross section depicting the strata encountered within cable percussion holes across the site is provided within **Appendix F.**

Variations in strata thicknesses are summarised in **Table 4.1** below.

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Table 4.1 Summary of ground conditions encountered (NE – denotes Not Encountered)

	Surface Hard-standing		Made Ground - Topsoil		Made Ground - Capping Material		Made Ground - Landfill Material		Alluvium / River Terrace Deposits		Chalk	
	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)
CP01	NE	NE	GL	0.30	0.30 10.30	2.70 1.20	3.00	7.30	11.50	1.50	13.00	>22.00
CP02	NE	NE	GL	0.05	NE	NE	0.05	>2.95	NE	NE	NE	NE
CP02A	NE	NE	GL	0.10	0.10	1.90	2.00	7.50	9.50	3.50	13.00	>22.00
CP03	NE	NE	GL	0.60	0.60	0.50	1.10	7.1	8.20	5.30	14.00	>21.00
CP04	NE	NE	NE	NE	GL	3.50	3.50	4.70	8.20	>1.50	NE	NE
CP05	NE	NE	GL	0.10	0.10	3.90	4.00	7.50	NE	NE	11.50	>0.45
CP06	NE	NE	NE	NE	GL	2.50	2.50	6.80	9.30	>1.70	NE	NE
WS01	NE	NE	GL	0.20	0.20	1.35	1.55	>1.15	NE	NE	NE	NE
WS02	NE	NE	GL	0.20	0.20	1.60	1.80	>3.20	NE	NE	NE	NE
WS03	NE	NE	GL	0.20	0.20	>2.70	NE	NE	NE	NE	NE	NE
WS04	NE	NE	GL	0.30	0.30	1.00	1.30	>2.70	NE	NE	NE	NE
WS05	NE	NE	GL	0.20	0.20	2.05	2.25	>0.75	NE	NE	NE	NE

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	Surface Hard-standing		Made Ground - Topsoil		Made Ground - Capping Material		Made Ground - Landfill Material		Alluvium / River Terrace Deposits		Chalk	
	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)
WS06	NE	NE	GL	0.15	0.15	2.85	3.00	2.00	NE	NE	NE	NE
WS07	NE	NE	GL	0.10	0.10	2.35	2.45	>0.55	NE	NE	NE	NE
WS08	NE	NE	GL	0.10	0.10	>3.90	NE	NE	NE	NE	NE	NE
WS09	GL 0.05	0.05 0.30	NE	NE	0.30	3.70	4.00	>1.00	NE	NE	NE	NE
WS10	NE	NE	GL	0.10	0.10	1.90	2.00	>2.00	NE	NE	NE	NE
TP01	NE	NE	NE	NE	GL	1.30	1.30	>2.10	NE	NE	NE	NE
TP02	NE	NE	NE	NE	GL	2.40	2.40	>1.20	NE	NE	NE	NE
TP03	NE	NE	NE	NE	GL	2.10	2.10	>1.30	NE	NE	NE	NE
TP04	NE	NE	GL	0.20	0.20	2.80	3.0	>0.30	NE	NE	NE	NE
TP05	NE	NE	NE	NE	NE	NE	GL	>3.10	NE	NE	NE	NE
TP06	NE	NE	GL	0.20	0.20	0.70	0.90	>2.20	NE	NE	NE	NE
TP07	NE	NE	NE	NE	GL	2.70	2.70	>0.60	NE	NE	NE	NE
TP08	NE	NE	NE	NE	GL	1.00	1.00	>2.20	NE	NE	NE	NE

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	Surface Hard-standing		Made Ground - Topsoil		Made Ground - Capping Material		Made Ground - Landfill Material		Alluvium / River Terrace Deposits		Chalk	
	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)	From (m bgl)	Thickness (m)
TP09	GL 0.05	0.05 0.30	NE	NE	0.30	3.20	3.50	>0.50	NE	NE	NE	NE
TP10	NE	NE	NE	NE	GL	3.20	3.20	>0.20	NE	NE	NE	NE
TP11	NE	NE	GL	0.20	0.20	1.30	1.50	>2.20	NE	NE	NE	NE

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4.1.1 Surface Hardstanding

Surface hardstanding was only encountered at two positions, both located within the car parking area off Harts Farm Way. This comprised 0.05m asphalt at surface, with 0.30m thick Type I roadstone sub-base beneath.

4.1.2 Made Ground – Topsoil

Topsoil was encountered at 18 positions and ranged in thickness from 0.05m to 0.60m. The soil was relatively uniform in composition and generally consisted of light brown slightly sandy clay. Due to the similar nature of the capping material (as discussed below) it was difficult in places to differentiate.

4.1.3 Made Ground – Capping Material

Made Ground classed as 'capping material' was encountered in all exploratory holes, bar borehole CP02 and trial pit TP05.

The 'capping material' was predominantly encountered above the landfill material, but in borehole CP01 it was also encountered below the landfill.

Thicknesses of 'capping material' ranged from 1.10m to 5.50m.

This stratum generally comprised a clay material with subordinate amounts of sand and gravel. Any gravel contained within the clay, generally comprised flint and brick, with occasional Chalk, concrete and rare asphalt.

4.1.4 Made Ground – Landfill Material

Landfill material was encountered in all exploratory holes bar window sampling wells WS03 & WS08.

Thicknesses range from >0.20m to 7.50m thick in boreholes CP02A and CP05.

The full extent of landfill material was only proven within the cable percussion boreholes (CP01-CP06).

The landfill generally comprised slightly clayey to clayey Sand & Gravel. Gravel generally consisted of flint, brick, concrete, glass & metal. There were varied other types of landfill material and household waste, including material / fabric, rigid plastic, polythene bags, polystyrene, glass & plastic bottles, rubber tyres, food containers, wood and paper.

Within trial pits TP05 & TP08 incinerator type ash was noted.

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A foul / rotten type odour was noted within each trial pit.

4.1.5 Superficial Deposits – Alluvium / River Terrace Deposits

Beneath the landfill in all cable percussion boreholes, bar borehole CP05, Alluvium or River Terrace Deposits were encountered. These ranged in thickness from 1.5m to 5.3m

- Alluvium, encountered in boreholes CP02A & CP04, was described as soft orange brown sandy gravelly clay and firm brown silty clay respectively.
- River Terrace Deposits (encountered in boreholes CP01, CP03 & CP06) ranged from sand & gravel to gravel with subordinate amounts of sand and clay.

4.1.6 Bedrock - Chalk

Chalk was encountered in the three deep cable percussion boreholes and also in borehole CP05 beneath the landfill material. Total thickness of the Chalk was not proven during the investigation. The maximum extent of the Chalk (>22.00m) was encountered in boreholes CP01 & CP02a.

Due to the nature of the drilling techniques, the Chalk could only be described as recovered as silty sandy & gravel of Chalk, or gravelly silt of Chalk. The gravel comprised flint and extremely weak to weak white Chalk.

4.2 Obstructions

Borehole CP02 possibly encountered an obstruction at 2.00m bgl. Borehole CP02 was terminated at 3.00m bgl, as there were no soil returns from drilling, due to pushing a large piece of rubble down from 2.00 to 3.00m. From 0.20m downwards, it was noted on the engineer's logs, that there was a large amount of asphalt and rubble which hampered progress. The location was moved a few metres away and target depth on borehole CP02A was achieved.

4.3 Groundwater Strikes

Groundwater strikes were recorded in all cable percussion boreholes (bar CP02) and one trial pit during the investigation. Details are noted in **Table 4.2** below:

Table 4.2 Groundwater strikes in boreholes during drilling

Exploratory Hole Location	Water Depth	Strata
CP01	11.50m	Top of River Terrace Deposits
CP02A	9.60m	Top of Alluvium
CP03	10.50m	Top of River Terrace Deposits
CP04	6.30m	Landfill Material
CP05	5.90m	Landfill Material
CP06	4.30m	Landfill Material
TP09	3.90m	Landfill Material

4.4 Photo Ionisation Detection

Head space readings were completed in samples recovered from cable percussion boreholes and trial pits using a Photo Ionisation Detector (PID) to detect Volatile Organic Compounds (VOCs). Detectable levels were encountered in all samples as presented on the exploratory hole logs (Appendix D). A maximum PID reading of 77.70ppmv was recorded in soil from trial pit TP01 at 3.40m depth. Generally, the PID results indicate that volatile organic contaminants are either absent or present at only low levels within soil at the site.

4.5 Visual / Olfactory Evidence of Contamination

It is noted that the Landfill Material encountered was potentially contaminated. The descriptions within the exploratory holes logs note "foul / rotten" or "burnt" type odour. This was more evident in the trial pits when a larger area was being excavated. Odours where evident, are indicated on the exploratory hole logs.

As shown in the photographs of the trial pits (**Appendix C**) the landfill material appeared dark in colour, predominantly grey, brown or black.

During the rounds of monitoring particularly during sunny periods, gas "haze" was noted coming from the pipe / upstanding well covers. Odours recorded during monitoring are detailed within the monitoring records provided in **Appendix E.**

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4.6 Groundwater Monitoring Results

Groundwater level measurements were taken on six return monitoring visits to the site. Full details of the groundwater monitoring, along with water level graphs, are provided in Appendix E; a brief summary is provided in **Table 4.3**.

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Table 4.3 Summary of Groundwater Monitoring

Monitoring Well	Screened Unit	Elevation (mAOD)	Groundwater Levels (mbcl)		Groundwater Levels (mAOD)		Comments
			Minimum	Maximum	Minimum	Maximum	
CP01(D)	Chalk	10.54	8.56	9.29	1.25	1.98	-
CP01(S)	Landfill	10.54	7.67	8.02	2.52	2.87	-
CP02A(D)	Chalk	10.79	8.875	10.8	-0.01	1.915	-
CP02A(S)	Landfill	10.79	7.95	9.07	1.72	2.84	-
CP03(D)	Chalk	8.67	6.6	8.69	-0.02	2.07	Weak ammonia odour
CP03(S)	Landfill	8.67	6.71	7.72	0.95	1.96	-
CP04	Landfill	11.52	7.01	8.52	3	4.51	Strong methane odour
CP05	Landfill	9.56	6.84	7.27	2.29	2.72	-
CP06	Landfill	12.4	7.13	7.67	4.73	5.27	-
WS01	Capping Layer	10.29	2.66	Dry	7.63	7.63	-
WS02	Capping Layer	10.57	Dry	Dry	Dry	Dry	Strong foul odour
WS03	Capping Layer	11.07	Dry	Dry	Dry	Dry	Rotting / manure odour
WS04	Capping Layer	11.01	Dry	Dry	Dry	Dry	-
WS05	Landfill	10.72	Dry	Dry	Dry	Dry	-
WS06	Capping Layer	10.98	Dry	5.71	5.3	5.71	-
WS07	Capping Layer	10.12	Dry	Dry	Dry	Dry	-
WS08	Capping Layer	14.21	Dry	Dry	Dry	Dry	-
WS09	Landfill	9.46	4.94	4.57	Dry	4.89	Inaccessible from 02/06/2017
WS10	Landfill	13.45	3.97	4.32	Dry	9.48	-

Details of the final water quality parameters recorded within each of the wells subject to low flow sampling are presented in **Table 4.4.** The full water quality testing results achieved during purging are provided within **Appendix E.**

Table 4.4 Summary of Water Quality Data

Monitoring Well	Date	Reduction Potential (mV)	Electrical Conductivity (µs)	pH	Dissolved Oxygen (mg/L)	Temp (°C)
CP01(D)	08/06/2017	22.5	531	7.02	8.18	11.7
CP01(S)	15/06/2017	-117.6	6079	6.86	0.25	13.1
CP02A(D)	08/06/2017	-93.1	3251	6.69	0.59	12.2
CP02A(S)	08/06/2017	-88.3	3172	6.65	0.94	15.10
CP03(D)	08/06/2017	5.8	523	6.9	2.55	12.3
CP03(S)	08/06/2017	-84.2	1259	6.62	0.26	12.8
CP04	15/06/2017	-155	4792	6.75	0.22	12.9
CP05	15/06/2017	-90.8	2656	6.77	1.29	12.9
CP06	15/06/2017	-102.5	2281	6.77	0.31	12.7

Note that the results presented in Table 4.5 are the final (stabilised) readings taken prior to sampling.

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4.7 Ground Gas Monitoring

Ground gases including methane, carbon dioxide, oxygen, carbon monoxide and hydrogen sulphide were measured during the two monitoring rounds using a GA2000 infra red gas analyser. A summary of ground gas results is presented in Table 4.5. The full results of ground gas monitoring recorded during each monitoring visit are provided in **Appendix E.**

Table 4.5 Summary of Ground Gas Monitoring Results

Location	Peak Flow (l/hr)		Methane (% CH4)		Carbon Dioxide (% CO2)		Oxygen (% O2)		CO (ppm)		H_2S (ppm)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Landfill												
CP01 (S)	<0.1	0.3	67.5	70.6	28.2	39.7	<0.1	0.2	<1	4	<1	<1
CP02 (S)	<0.1	6.1	0.2	35.9	0.2	24.6	0.2	19.9	<1	<1	<1	4
CP03 (S)	<0.1	31.1	19.8	24.9	18.8	22.3	<0.1	0.6	1	2	<1	<1
CP04	<0.1	0.3	61	63.9	30.1	31.2	<0.1	0.2	<1	1	<1	1
CP05	<0.1	0.2	40.8	49.6	26.2	28	<0.1	0.4	<1	1	<1	4
CP06	<0.1	<0.1	55	60.1	2.3	23.2	<0.1	2.1	1	1	<1	1
WS01	<0.1	0.14	0.7	64.9	0.8	31.8	<0.1	20.5	<1	3	<1	4
WS02	<0.1	<0.1	62.8	64.5	18.1	28.7	<0.1	0.3	<1	1	1	7
WS03	<0.1	<0.1	27.6	40.8	20.1	26.2	0.1	4	<1	1	<1	9
WS04	<0.1	0.2	43	66.6	23.3	31.8	<0.1	5.9	<1	8	<1	1
WS05	<0.1	<0.1	0.1	33	2.9	28.2	<0.1	18.1	<1	1	<1	<1
WS06	<0.1	<0.1	65.1	69.6	28.6	46.4	<0.1	0.8	<1	2	<1	1
WS07	<0.1	<0.1	60.7	98.2	28	29.7	0.1	0.4	<1	1	<1	1
WS08	<0.1	<0.1	51	60	20.7	29.2	<0.1	0.36	<1	1	<1	13
WS09	<0.1	0.1	49.2	51.5	20.4	21.2	0.2	1	1	8	<1	<1
WS10	<0.1	<0.1	39.6	46.2	16.5	22.7	<0.1	0.7	<1	2	<1	5
Chalk												
CP01D	<0.1	67.7	56.7	67.7	26.5	30.1	0.2	2.5	<1	4	<1	<1
CP02D	<0.1	22.5	<0.1	22.5	0.2	15.3	7.7	20	<1	2	<1	2
CP03D	<0.1	20	<0.1	20	0.2	17.4	3.7	20.9	<1	4	<1	<1

Notes; Minimum values exclude negative flows. For carbon dioxide and methane the minimum value identified is the minimum 'steady flow' recorded during the monitoring period whereas the maximum is the highest 'peak flow' recorded.

Atmospheric pressure recorded at the closest weather station (Southampton Airport) approximately 30 km to the west of the site through the monitoring period is summarised in **Table 4.6**.

Table 4.6 Summary of Atmospheric Pressure During Monitoring Rounds (hPa)

Date	Time: 06:20	Time:	Time: 18:20	Rising / Falling
18/05/2017	1013	1013	1012	Stable / Falling
25/05/2017	1024	1023	1020	Falling
02/06/2017	1016	1016	1015	Stable / Falling
08/06/2017	1011	1010	1009	Falling
15/06/2017	1014	1015	1016	Rising
27/06/2017	1008	1006	1003	Falling

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5.0 Laboratory Testing

5.1 Contamination Testing

Contamination / environmental laboratory testing was scheduled by WYG and undertaken by Exova Jones Environmental Laboratory who are UKAS & MCERTS accredited for a wide range of chemical tests.

Laboratory testing was carried out in accordance with ISO17025:2005 Competence of Testing and Calibration Laboratories.

5.1.1 Soil

WYG submitted 40 samples for chemical testing for WYG suite C which includes a range of determinants as detailed below. Laboratory analysis results are presented in **Appendix G.**

WYG Suite C determinants include:

- Metals Suite – Arsenic, Beryllium, Boron, Cadmium, Chromium (III), Hexavalent Chromium, Copper, Lead, Mercury, Nickel, Selenium, Vanadium & Zinc;
- Polycyclic Aromatic Hydrocarbons Suite;
- Total Phenols;
- Total Petroleum Hydrocarbons;
- BTEX – Benzene, Toluene, Etylbenzene and Xylenes;
- Asbestos Screen; and
- Plus pH, Fraction Organic Carbon, Free Cyanide & Sulphate

WYG also submitted 14 samples for leachate testing for a similar suite of testing as indicated above, but a number of additions including:

- Metals as above, but including Antimony & Molybdenum;
- Total Hardness;
- Dissolved Organic Carbon; and
- pH, Sulphate, Total Cyanide, Ammonia, Ammonium, Nitrate, Nitrite, Chloride & Alkalinity.

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5.1.2 Waters

Groundwater samples were collected from the monitoring wells containing water on the 8th and 15th of June 2017. Nine groundwater samples (plus one duplicate and a composite sample of purged water) were sent to Exova Jones laboratory for testing.

The waters were tested for the following determinants:

- Metals Suite – Antimony, Arsenic, Beryllium, Boron, Cadmium, Chromium (III), Hexavalent Chromium, Copper, Lead, Mercury, Molybdenum, Nickel, Selenium, Vanadium & Zinc;
- Polycyclic Aromatic Hydrocarbons Suite;
- Total Phenols;
- Total Petroleum Hydrocarbons;
- BTEX – Benzene, Toluene, Etylbenzene and Xylenes;
- Total Hardness;
- Dissolved Organic Carbon; and
- pH, Sulphate, Total Cyanide, Ammonia, Ammonium, Nitrate, Nitrite, Chloride & Alkalinity.

5.2 Landfill Forensic Testing

A total of 27 bulk samples collected from landfill materials were sent to Envirolab for Landfill Forensics Testing. After an initial screen for asbestos, these samples were sifted and sorted into their component parts and measured as a percentage. Results are presented in **Appendix H.**

Samples were sorted into the following types of material presence:

- % of total sample Inert (>10mm in size);
- % of total sample Wood;
- % of total sample Vegetation;
- % of total sample Cloth;
- % of total sample Other Inert Material;
- % of total sample Paper;
- % of total sample Other Degradable Material;

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- % of total sample Fine Soils; and
- % of total sample Inert (>10mm in size)

One sample was not tested due to the presence of amosite asbestos board.

5.3 Geotechnical Testing

A programme of geotechnical laboratory testing, scheduled by WYG, was carried out on representative samples taken from the natural strata during the ground investigation. The results of the geotechnical laboratory tests are presented in **Appendix I.**

Samples were sent to Professional Soils Laboratory who are UKAS accredited. All testing was carried out in accordance with BS1377:1990+A1 Methods of Testing Soils for Civil Engineering Purposes.

Table 5.1 below details tests and standards undertaken on samples recovered during the site investigation.

Table 5.1 Summary of Geotechnical Testing

Type of Test	Standard	No.
Natural Moisture Content	BS1377: Part 2:1990, Clause 3.2	5
Atterberg Limits	BS1377: Part 2:1990, Clauses 4.4, 5.3 & 5.4	5
Particle Size Distribution (PSD) – Wet Sieving	BS1377: Part 2:1990, Clause 9.2	5
Particle Size Distribution (PSD) – Sedimentation	BS1377: Part 2:1990, Clause 9.4	2
Quick Undrained Triaxial	BS1377: Part 2:1990, Clause 9.7	1

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6.0 Geotechnical Discussion

6.1 Geology and Geotechnical Parameters

Ground conditions encountered during the investigation were broadly consistent with those identified in the published literature.

In summary, ground conditions comprised Topsoil over Made Ground / Capping Material, over Landfill Material. Which in turn overlay River Terrace Deposits / Alluvium over Chalk.

Details of the various soils encountered during the investigation are discussed in Section 5.0.

6.1.1 Made Ground – Capping Material

The capping material was generally uniform in composition. Standard Penetration Tests (SPTs) recorded 'N' values (standard penetration resistance) of between 18 and 50 in cable percussion boreholes and 8 and 50 in window sample boreholes.

No laboratory testing was undertaken on this strata as this lies above the highly variable Landfill Material.

6.1.2 Made Ground – Landfill Material

The landfill material varied in composition across the site, with various types and volumes of landfill waste, including, but not limited to paper, cloth, metal, wood, glass and plastic.

SPTs varied from 9 to 50, but in the main were generally greater than 25 (possibly due to the presence of large pieces of material within the strata e.g. wood, concrete cobbles etc).

The sites Landfill Licence was issued by Hampshire County Council on 24 November 1978, i.e. the landfill is of the post 1965 type containing a large proportion of organic material, which is readily degradable as classified in BRE FB 75 - Building on fill: geotechnical aspects, 3rd edition.

This soil strata has not been characterised due to the highly variable nature of the material.

6.1.3 River Terrace Deposits / Alluvium

Beneath the landfill material, either River Terrace Deposits or Alluvium were encountered.

River Terrace Deposits were encountered in CP01, CP03 & CP06 and was generally uniform in composition being primarily granular. SPT values ranged from 24 to 50.

Four Particle Size Distribution tests (PSDs) were carried out on representative samples of Alluvium and identified predominantly coarse soils comprising fine to coarse gravels with subordinate quantities of clay and sand, corresponding to the engineer's description.

Alluvium was encountered in boreholes CP02A & CP04 and comprised clay with subordinate silt, sand & gravel components. SPT values ranges from 8 to 26.

Atterberg limits were determined on four samples of Alluvium and one sample of Chalk. These results appear variable from low, to intermediate, to very high plasticity. Modified plasticity indexes were calculated and are shown in **Table 6.1** below.

Table 6.1 Summary of Classification Testing

Stratum	Range Min – Max (%)		
	Moisture Content	Plasticity Index (*Modified)	Volume Change Potential
CP02A Alluvium – Sandy Gravelly CLAY	22 – 27	9 – 23 (*8.37 – 20.01)	Low to Medium
CP04 Alluvium – Silty CLAY	26 – 48	45 – 50 (*41.85 – 45.50)	High
CP05 Chalk – Gravelly Silt of Chalk	14	11 (*9.02)	Low

One quick undrained triaxial test was completed on Alluvium collected from borehole CP04. The shear strength (Cu) was reported as 29kPa with a plastic failure mode. This equates to a clay consistency of soft.

One PSD was carried out (Sample from borehole CP02A at 9.50 – 10.00m depth) and this indicated a fine soil comprising clay / silt with subordinate quantities of sand and gravel, corresponding to the engineers description of the soil.

6.1.4 Chalk

Chalk was encountered in the three deeper boreholes. The total thickness of this strata was not proven during this investigation.

Due to the nature of the drilling process the returned Chalk, could only be described as "recovered as".

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6.1.5 Chalk

Chalk was encountered in the three deeper boreholes. The total thickness of this strata was not proven during this investigation.

Due to the nature of the drilling process the returned Chalk, could only be described as "recovered as".

Standard Penetration Tests undertaken within this lithology ranged from 17 to >50. With SPTs >25 from 15.00m bgl in borehole CP01 and 16.50m bgl in boreholes CP02A & CP03.

6.2 Groundwater

Groundwater was encountered in both deep and shallow installations in the six cable percussion boreholes.

Water strikes during drilling were generally observed to coincide with the top of the River Terrace Deposits / Alluvium above the Chalk.

Six return groundwater monitoring visits were undertaken between 18th May - 26th June 2017. During these visits, water levels of between 6.84m and 10.8m bgl were recorded across the site. Little or no groundwater was encountered in the window sample boreholes.

6.3 Concrete in Aggressive Ground

Chemical testing in accordance with BRE SD1: 2005 Concrete in Aggressive Ground has been used to derive the Design Sulphate Class and ACEC Concrete class of the soils encountered as detailed in **Table 6.2.** This table assumes mobile ground water under brown field site conditions (BRE Special Digest 1).

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Table 6.2 pH and Sulphate of Soil Samples

Depth (m)	Strata	pH	Water Soluble Sulphate (2:1 water soil extract as SO4) (mg/l)	Design Sulphate Class	ACEC Class
0.20 – 0.95	Made Ground -Capping Layer	8.47	130	DS-1	AC-1
0.50 (CP04)	Made Ground – Capping Layer	7.74	1599	DS-3	AC-3
1.00	Made Ground – Capping Layer	8.01	87	DS-1	AC-1
1.80 – 2.00	Made Ground – Capping Layer / Landfill	7.69	222	DS-1	AC-1
2.30 – 2.50	Made Ground – Landfill	7.52	566	DS-2	AC-2
3.10 – 3.40	Made Ground - Landfill	7.94	210	DS-1	AC-1
3.50 – 3.80	Made Ground - Landfill	7.69	667	DS-2	AC-2
4.20 – 4.50	Made Ground - Landfill	7.46	250	DS-1	AC-1
4.80 – 5.00	Made Ground - Landfill	7.84	790	DS-2	AC-2
7.00	Made Ground - Landfill	8.01	362	DS-1	AC-1
7.00 (CP04)	Made Ground - Landfill	7.72	4133	DS-4	AC-4
9.50	Made Ground - Landfill	7.70	370	DS-1	AC-1
15.00	Chalk	8.60	23	DS-1	AC-1
20.00	Chalk	8.49	44	DS-1	AC-1
24.00	Chalk	8.59	21	DS-1	AC-1

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7.0 Engineering Considerations

7.1 Introduction

It is understood that Havant Borough Council ideally would be interested in developing the site for employment use. At the time of compiling this report, no details of any specific development plans are available. Consideration has been given to the construction of light industrial / commercial units similar to that found in the local vicinity. Associated roads, car parking and services also require consideration.

A key geotechnical concern relating to the proposed development is the highly variable near surface ground conditions. The presence of extensive and varied landfill material has been proven across the entire site during the recent investigation and the maximum thickness of 7.5m was recorded in CP02A and CP05.

The Landfill is of the post 1965 type containing a large proportion of organic material, which is readily degradable.

7.2 Volume changes in fills

BRE FB 75 considers that volume changes in fills can be attributed to the following causes:

- immediate physical compression occurs due to the weight of successive layers of fill causing crushing, distortion, bending and reorientation of the materials within the fill (can be described by a constrained modulus D);
- long-term movements occur as biodegradation causes a reduction in volume (can be described by a logarithmic compression rate parameter αb);
- long-term movements occur, caused by physical creep compression as the particles of the refuse become more closely packed (can be described by a logarithmic compression rate parameter αc).

It should be noted that αb is much greater than αc and that αb can be almost 20% for post-1965 refuse landfill.

The following paragraphs and Figure 22 are taken directly from BRE FB 75:

The magnitude and rate of settlement of refuse is a function of complex interactions between physical and biodegradation processes. Watts et al (2006) describe a simple way in which to present settlement data to estimate α and hence predict long-term settlement of

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landfill, as shown in Figure 22. The rate of strain δεv/δt, expressed as % compression per month, is plotted against 1/t where t is the time in months since the fill was 75% complete. The figure shows the range of observations from measuring points at five sites (Case histories 21–25). The α = 15% line represents average behaviour for a wide range of landfill composition, age, placement conditions, state of degradation, levels of inundation and other factors over a period of about 1 year to 20 years after completion of a landfill. It is likely that the value of α will reduce significantly after that period.

It is probable that most refuse landfills will continue to settle through biodegradation and creep over at least two log time cycles, for example between 3 and 300 months. Using this graphical technique, data may be collected at any time from different parts of a landfill and 'fitted' to the general model to indicate the likely remaining settlement at that location.

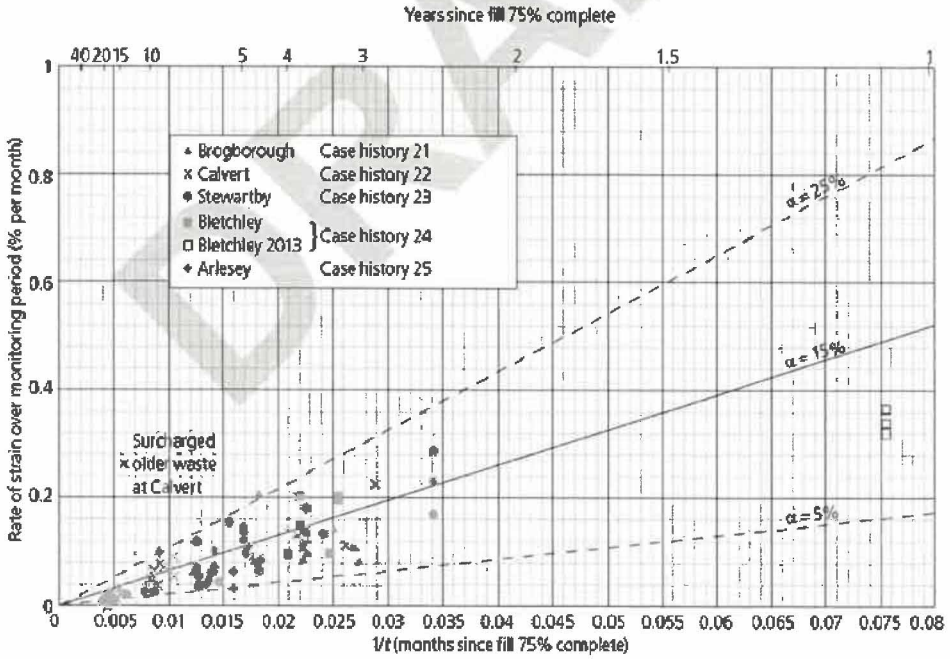


Figure 22: Values of 1/*t* against rate of strain for a range of sites (after Watts *et al*, 2006)

It is not clear exactly in what year during the 1990s the landfilling operation ceased and the capping layers were placed. It should be acceptable to take 1997 as the year when the landfilling was 75% complete which gives more than 20 years since.

From the α=15% line of the above Figure 22, the rates of strain at 0.5% and 0.02% are obtained for respectively 1 and 20 years since the landfill was 75% complete.

For the maximum of 7.5m fill thickness, the rate of settlement can be estimated below:

At Year 1:

Rate of settlement = 0.5%*7.5m=0.0375m per month = 0.45m per year.

At Year 20:

Rate of settlement = 0.02%*7.5m=0.0015m per month = 0.018m per year.

Pre-loading, will reduce the rate of settlement by removing the elements due to the immediate and creep physical compression of the landfill material, though the long-term settlement due to biodegradation will continue.

7.3 Foundation Options

From Section 7.2 above, it is estimated that the rate of settlement may have been reduced from some 450mm per year in 1997 to probably less than 18mm per year in 2017. The actual rate of settlement should be ascertained through site monitoring prior to any development considerations.

For light industrial / commercial units, pre-loading should be considered and the examples as detailed in BRE FB75 should be followed. All structures should be founded on rafts with necessary gas protection measures implemented. Roads will require regular maintenance and utility services should be installed at above ground levels for easy maintenance. Drainage and water supply pipes should be constructed with flexible joints to minimise risk of leakage.

For heavily loaded structures, piles to be installed into the underlying Chalk may have to be considered. The down-drag or negative shaft friction on the piles due to the long-term ground settlement must be considered in pile design.

The existing ground conditions are unlikely to be of sufficient strength to support the required piling rigs without installation of an adequately designed pilling platform.

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A foundation works risk assessment would need to be undertaken and the Environment Agency consulted at an early stage. Environment Agency officers, and other regulators, need to be able to satisfy themselves that the designers of the ground improvement or piled foundations have fully considered the risk that the proposed works pose for the environment, human health and property, in addition to considering load carrying performance, ease of installation and cost.

The use of Continuous Flight Auger (CFA) piles may address many of the environmental concerns and pose the least pollution risk to groundwater. It is recommended that temporary casing must be installed to seal out contaminated water.

Based on the ground conditions encountered in the three deep cable percussion boreholes and using the characteristic geotechnical parameters as discussed in Section 7, indicative pile capacities have been assessed using the methods detailed in CIRIA C574 for CFA piles and the results are summarised in **Table 7.1** below.

Table 7.1: Summary of SPT values and indicative safe working loads for piles (kN)

Depth (m bgl)	SPT Values	CFA Pile Diameter (mm)	
		450	600
15.00	20 – 27	347 – 556	542 – 893
16.50	27 - 34	598 – 697	950 – 1108
18.00	50	740	1165
19.50	40 - 46	824 – 867	1278 - 1335
21.00	24 - 50	729 – 952	1052 - 1448

Advice should be sought from specialist piling contractors to determine the most suitable and cost-effective piling method. The piling contractor should select pile diameters and installation depths with guaranteed performance and recommend further ground investigation if required for design.

Temporary Works

At this stage it is considered that temporary works may comprise small scale excavations for the installation of services or for further inspection / investigation of the ground conditions.

It is recommended that due to the potential for side and base instability of excavations within the landfill and the ground gas concentration, that man entry into excavations is avoided completely.

Dewatering may be required for shallow excavation, perched water may be present but it is anticipated that flows would not be excessive and could be dealt with by pumping from

shallow temporary sumps. Standing water levels were between 6.84m and 10.80m bgl as monitored from the installed standpipes.

7.4 Concrete

Sulphate tests indicated that the maximum determined levels correspond to Design Sulphate Class DS-4 in accordance with BRE Special Digest 1, Concrete in Aggressive Ground. As brownfield conditions persist across the site and the ground water is assumed to be mobile due to the proximity of Langstone Harbour, the Aggressive Chemical Environment for Concrete (ACEC) is considered to be AC-4 in accordance with the aforementioned document. We would advise that all cements used for sub-surface concrete should conform to the advice given within this publication unless otherwise specified.

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8.0 Ground Contamination Tier 1 Screening Assessment

8.1 Methodology

The objective of the Tier 1 Screening Assessment presented herein is to identify the chemical constituents which might potentially pose unacceptable levels of risk to sensitive on-site and off-site receptors. Measured concentrations in soil, soil leachate and groundwater have been compared with various sets of Target Screening Values (TSVs). Where measured concentrations in environmental media exceed these levels this does not necessarily indicate a requirement for remediation; it can however, be the trigger for the undertaking of a more detailed quantitative assessment in accordance with the current UK tiered risk assessment framework.

8.1.1 Human Health

Soils

In March 2014, DEFRA published the 'C4SLs' within the 'Policy Companion Document: Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination' (SP1010). The purpose of the C4SLs is to identify a concentration in soil indicative of Category 4 status as defined by Part 2a Statutory Guidance[1] on the definition of contaminated land. In September 2014, further clarification was published in a letter from Lord DeMauley to Local Authorities instructing them to use C4SLs in planning. Where available C4SLs have been used as the preferred choice of screening criteria. For those constituents where no C4SL has been published by the EA / DEFRA, WYG have screened soil against Suitable for Use Levels (S4ULs)[2].

For the purposes of this risk assessment human health criteria for soils applicable to the following land use types have been used in order to screen the site data:

- Public Open Space, Parkland (Current and potential future)
- Commercial / industrial (Potential Future Use)

A number of TSVs are dependent on the Soil Organic Matter (SOM) content, and as such TSVs are typically calculated for a SOM of 1%, 2.5% and 6%. The average recorded Fractional Organic Carbon (FOC) recorded within the soils was 0.017. Using the equation of SOM(%)= FOC / 0.0058 this equates to a site specific SOM of 2.9%. However, on the basis that lower values of SOM are present within the superficial deposits (RTDs), a lower, and

[1] Published by DEFRA in 2012 the guidance defines four categories of Category 4 is considered the least contaminated; "there is no risk or that the level of risk posed is low"

[2] Nathaniel C.P., McCaffrey, C., Gillet, A.G., Ogden R.C., and Nathaniel, J.F. 2015. *The LQM/CIEH S4ULs for Human Health Risk Assessment*

more conservative, SOM of 1% has been assumed for the purposes of screening all the soil data.

8.1.2 Controlled Waters

The site is underlain by superficial strata (variably Raised Marine Deposits, River Terrace Deposits and Alluvium) that are defined by the Environment Agency as Secondary A aquifers. Therefore these aquifers in themselves are not regarded as being highly sensitive as potential environmental receptors, however, they are considered to provide a potential hydraulic linkage with adjacent surface water features (including the Hermitage Stream and Langstone Harbour).

Underlying the superficial strata the Chalk bedrock is defined as a Principal Aquifer and therefore is considered important as a potential groundwater resource. An abstraction for drinking water by Portsmouth Water Ltd. is located approximately 440m north east of the site, however the site is not located within a groundwater source protection zone.

For the purposes of evaluating controlled waters at the site, surface water bodies (including the Hermitage Stream and adjacent Langstone Harbour) and the Chalk Aquifer are regarded as the most sensitive Controlled Waters receptors in the site vicinity. To reflect the proximity of the sensitive estuarine / tidal surface waters and groundwater (for potable consumption), all groundwater data collected from the site (independent of strata) has been screened against two sets of screening criteria as follows:

- Transitional or Marine Environmental Quality Standards (EQS)
- Drinking Water Standards (DWS)

8.2 Results of Tier 1 Screening Assessment

8.2.1 Soil Test Data

A total of forty soil samples collected from the site were submitted for laboratory analysis. Table 8.1 presents a summary of the exceedances above the adopted screening criteria. The full Tier 1 soil screening sheets are presented in **Appendix J.**

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Table 8.1 Summary of Soil Results exceeding the TSVs

Chemical Constituent	S4UL (mg/kg)	Assumed Land Use	No. of analyses	Conc. (mg/kg)	Location of Exceedances
Dibenzo(ah)anthracene	3.5	Commercial	40	4.72	TP09 0.4m bgl
	1.1	Public Open Space Parkland			
Benzo(b)fluoranthene	13			39.81	
Benzo(a)pyrene	21			36.63	

In one sample collected from the site, concentrations of PAH compounds exceed relevant human health based screening criteria. Specifically, in soil from trial pit TP09 in the central car park area, in a sample of shallow soil (0.4m bgl) the concentrations of dibenzo(ah)anthracene, benzo(b)fluoranthene and benzo(a)pyrene exceed criteria specific to a public open space end use. The concentration of dibenzo(ah)anthracene within this sample also exceeds screening criteria applicable to a commercial land use.

In addition to the above, and also considered potentially indicative of a human health risk, asbestos was detected within 15 of 40 soil samples collected from across the site as indicated within Table 8.2. Asbestos quantification was not undertaken, however the laboratory has reported fibre bundles with concentrations of asbestos <0.1%.

Table 8.2 Asbestos Detections in Soil Samples

Location	Depth	Type	Description
CP02A	4.5	Chrysotile and amosite	Fibre bundles (<0.1%)
	7.0	Chrysotile	Fibre bundles (<0.1%)
CP04	0.5	Chrysotile	Fibre bundles (<0.1%)
	4.5	Chrysotile	Fibre bundles (<0.1%)
CP05	4.2	Chrysotile	Fibre bundles (<0.1%)
	9.5	Chrysotile	Fibre bundles (<0.1%)
CP06	2.5	Chrysotile	Asbestos Cement Debris
TP01	3.4	Chrysotile	Fibre bundles (<0.1%)
TP03	0.4	Chrysotile and amosite	Insulating Board Debris
TP06	2.0	Chrysotile	Fibre bundles (<0.1%)
	3.1	Chrysotile	Insulation debris
TP08	2.3	Chrysotile	Asbestos Cement Debris
	3.2	Chrysotile	Fibre bundles (<0.1%)
TP10	3.3	Chrysotile	Fibre bundles (<0.1%)
TP11	2.5	Chrysotile	Fibre bundles (<0.1%)

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8.2.2 Groundwater Test Data

As discussed in Section 8.1.2 the results of the chemical testing of groundwater samples have been compared separately with two sets of standards, namely EQS and DWS. The full groundwater tier 1 screening sheets are provided in Appendix K. A number of chemical constituents have been recorded at concentrations exceeding EQS as summarised in **Table 8.3.**

Table 8.3 Summary of Exceedences of EQS in Groundwater

Chemical Constituent	EQS (µg/L)	No. of analyses	No. of Exceedences	Maximum Concentration (µg/L)	Monitoring Well
Copper	3.76	9	2	5	CP04
Nickel	8.6	9	2	10.7	CP01 (S)
Zinc	7.9	9	2	12.4	CP03 (D)
Anthracene	0.1	9	5	0.27	CP01 (S)
Benzo(a)pyrene	0.00017	9	1	0.01	CP01 (S)
Benzo(b)fluoranthene	0.017	9	1	0.02	CP01 (S)
Fluoranthene	0.0063	9	7	0.52	CP01 (S)
Naphthalene	2	9	3	33.7	CP01 (S)
Cyanide	1	9	6	3	CP01 (S), CP02 (S), CP04
Ammonia	21	9	9	506,030	CP01 (S)

A number of chemical constituents have also been recorded at concentrations exceeding DWS as summarised in **Table 8.4.**

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Table 8.4 Summary of Exceedences of DWS in Groundwater

Chemical Constituent	DWS (µg/L)	No. of analyses	No. of Exceedences	Maximum Concentration (µg/L)	Monitoring Well
Antimony	5	9	1	6	CP04
Barium	700	9	3	914.3	CP02 (S)
Boron	1,000	9	6	2122	CP01 (S)
TPH	10 *	9	5	227	CP05
Benzene	1	9	6	7.4	CP04
Sulphate	7,000	9	3	63,500	CP02 (D)
Chloride	250,000	9	6	1,291,000	CP04
Nitrite	1,000	9	1	1,440	CP03 (D)
Ammonium	500	9	9	536,000	CP01 (S)

* The DWS for TPH is a former standard for dissolved or emulsified hydrocarbons now withdrawn; the value has been used here in lieu of an alternative or more appropriate reference criteria.

As indicated in Table 8.3 and Table 8.4 concentrations of a number of constituents exceed relevant screening criteria. In particular, the concentrations of ammonia exceed EQS whilst the concentrations of ammonium exceed DWS, in each groundwater sample tested.

The concentrations of ammonium measured in groundwater samples from wells installed in the landfill material range from 111,000-535,000µg/l thus exceeding the DWS of 500µg/L by between 2-3 orders of magnitude. Within groundwater samples collected from wells installed in the Chalk the concentrations detected were lower, but still elevated; the highest concentration measured in CP02 exceeds the DWS by more than two orders of magnitude.

The concentrations of ammonia measured in groundwater samples collected from wells installed in the landfill ranged from 16,000µg/l – 506,000µg/L exceeding EQS by more than four orders of magnitude. Generally lower concentrations were measured in the Chalk (2,200µg/L-100,000µg/L), however the maximum concentration measured in groundwater (CP02A) still exceeds the EQS by more than three orders of magnitude.

Several heavy metals species were measured in one or more water samples at concentrations greater than DWS or EQS. The levels of exceedance, however, were in all cases relatively marginal (less than one order of magnitude greater than target criteria) and the majority of exceedences were measured in wells screened in landfill; only two of these

exceedences relate to the Chalk (marginally elevated concentrations of boron in CP02A and zinc in CP03).

Several PAH compounds, namely anthracene, benzo(a)pyrene, benzo(b)fluoranthene, fluoranthene, and naphthalene, have been measured in groundwater at concentrations greater than relevant EQS. Generally the exceedences are considered only marginally elevated (< one order of magnitude greater than EQS) and in all cases are less than two orders magnitude greater than EQS. The highest concentrations were measured in CP01 (S) installed within landfill material in a north central area of the site; at the same location in the deep well installed in the Chalk, concentrations of all PAH were below EQS. Concentrations of anthracene (0.21µg/L) and fluoranthene (0.22µg/L) measured in a sample collected from the Chalk in CP02(D) in the west of the site exceed relevant EQS indicating potentially significant impacts to deep groundwater.

Relatively low level petroleum hydrocarbon impacts within groundwater in the landfill are evident. In CP05 approximately 240µg/L TPH was measured characterised by predominantly heavy end aromatic compounds. Similar levels of TPH were measured in CP04 characterised though by a 50-50 aromatic aliphatic split and by much lighter compounds (including >EC8-EC16 aromatics and >C5–C10 aliphatics). Lower concentrations of TPH (approximately 80µg/L) were also measured within CP02 (D) installed within the Chalk.

Benzene concentrations, between 1.4-7.4µg/L, were detected within six of nine samples thus indicating marginal exceedences of the DWS (1µg/L). Benzene was also detected in CP02 (D) providing further indication of hydrocarbon impacts within groundwater in the Chalk in the west of the site.

The sulphate levels measured in each of three samples collected from groundwater in the Chalk ranged from 13,000-63,500µg/L thus exceeding the DWS (7,000µg/L). By comparison the sulphate levels measured in groundwater collected from landfill were much lower (<500-3,000µg/L). This contrast is considered likely to be attributable to saline impacts within deep Chalk groundwater, that are not affecting the landfill. Sea water typically contains approximately 2,700,000µg/L sulphate and therefore the levels of sulphate measured in the groundwater in the Chalk are approximately two orders of magnitude lower.

Chloride levels exceeding DWS were measured in five of six samples collected from the landfill and in one of three wells installed in the Chalk. The chloride levels measured in Chalk groundwater ranged from 34,000-640,000µg/L which compares with 19,000,000µg/L typically found sea water; the levels of chloride in Chalk groundwater are again potentially

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Indicative of saline intrusion. The high chloride levels measured in the landfill are considered relatively typical of landfill leachate.

Low levels of cyanide (1-3µg/L) were measured in groundwater collected from five of six wells installed in landfill and in one of three wells in the Chalk. The occurrence of cyanide in the Chalk groundwater in CP02(D), like the hydrocarbons and the high levels of ammoniacal nitrogen suggests that there is a degree of connectivity between the landfill and the underlying Chalk and that contaminated groundwater / landfill leachate has impacted the Chalk aquifer.

8.2.3 Leachate Test Data

A total of fourteen soil samples were subject to leachate testing and analysis. The results of this analysis have been compared with EQS (transitional and coastal waters) or (when EQS are unavailable) DWS. The full leachate tier 1 screening sheets are presented in **Appendix L. Table 8.5** below presents a summary of the exceedances above the adopted TSV.

Table 8.5 Summary of Leachate Results exceeding the Relevant TSV.

Determinant	TSV (ug/l)	No. of Exceedances	Max Conc. (·g/l)	Sample Details
Antimony	5	9	73	TP06 at 2m bgl
Molybdenum	70	2	102	TP06 at 2m bgl
Mercury	0.07	6	0.4	CP01 at 7m bgl
Anthracene	0.1	8	1.01	CP01 at 7m bgl
Benzo(a)pyrene	0.00017	12	1.67	CP06 at 2.5m bgl
Benzo(b)fluoranthene	0.017	12	2.69	CP06 at 2.5m bgl
Benzo(ghi)perylene	0.00082	12	1.06	CP06 at 2.5m bgl
Benzo(k)fluoranthene	0.017	11	1.04	CP06 at 2.5m bgl
Fluoranthene	0.0063	13	4.35	CP06 at 2.5m bgl
Naphthalene	2	4	26.5	CP01 at 7m bgl
TPH	10	9	2,720	CP02A at 4.5m bgl
Ammonia	21	14	50,730	CP01 at 7m bgl
Ammonium	500	14	53,730	CP01 at 7m bgl

* The DWS for TPH is a former standard for dissolved or emulsified hydrocarbons now withdrawn; the value has been used here in lieu of an alternative or more appropriate reference criteria.

As indicated in Table 8.5 a number of metal species, PAH compounds, TPH and ammoniacal compounds have been measured at concentrations in leachate exceeding relevant water quality criteria. This suggests that contaminants in made ground (including landfill materials) have the potential to leach and cause impacts to the underlying groundwater. There is a broad similarity between the contaminants (and the concentrations measured) identified as exceeding water quality criteria in leachate and those identified in groundwater e.g. the most notably elevated contaminants in leachate include ammoniacal compounds and some PAH.

It should be recognised that the process of leachate derivation in the laboratory, which involves physical agitation of a soil sample in de-ionised water for a period of 24 hours, is designed to create equilibrium conditions between the chemical in dissolved phase and sorbed phase and that in natural conditions concentrations that occur in leachate may not be as high. For risk evaluation purposes, the groundwater sampling and analysis allows for a more realistic assessment of potential risk to controlled waters.

8.2.4 Ground Gas

A ground gas risk assessment has been completed using the guidance presented in CIRIA C665 'Assessment of Risks posed by Gas to Buildings'. Table 8.6 presents the results of assessing the methane and carbon dioxide GSVs (discharge rates) within boreholes across the site. The maximum concentrations of hazardous gases and the location specific GSVs are also presented in Drawing 004 in **Appendix B**.

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Table 8.6 Calculation of GSVs for Methane and Carbon Dioxide

Location	CH4 (l/hr)	CO2 (l/hr)
Landfill		
CP01 (S)	0.22	0.12
CP02 (S)	2.19	1.50
CP03 (S)	7.75	6.94
CP04	0.19	0.09
CP05	0.10	0.06
CP06	0.06	0.02
WS01	0.09	0.04
WS02	0.06	0.03
WS03	0.04	0.03
WS04	0.13	0.06
WS05	0.03	0.03
WS06	0.07	0.05
WS07	0.10	0.03
WS08	0.06	0.03
WS09	0.05	0.02
WS10	0.05	0.03
Site Wide	30.55	14.43
Chalk		
CP01 (D)	0.20	0.09
CP02 (D)	0.02	0.02
CP03 (D)	0.02	0.02

Site wide GSVs (derived using the maximum concentrations and maximum flow rate site wide) of 30.5L/hr methane and 14.43L/hr carbon dioxide have been measured. In accordance with CIRIA C665 this equates to a High Risk, 'Characteristic Situation 5'. Based, however on the predominance of low or negligible flow rates measured site wide this designation may be overly cautious.

At the majority of locations (all but two) maximum flow rates have not exceeded 0.3L/Hr and consequently the location specific GSVs are typically below 0.2L/Hr methane and 0.1L/Hr carbon dioxide; this is equivalent to a Characteristic Situation 2. Within boreholes CP02 (S) and CP03 (S) high positive gas flows (>5L/Hr) were measured on only one occasion (Round 2, associated with falling atmospheric pressure); During the other five rounds gas flow rates were negative.

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Furthermore, neither boreholes CP02 nor CP03 was associated with methane levels above 40%; this is much lower than the 98% used to derive the worst case GSV measured on one occasion in WS7. The location specific GSVs derived for gas from boreholes CP02(S) and CP03(S) of 2.19L/Hr and 7.75L/Hr equate to Characteristic Situations 3 and 4 respectively. Based on the landfill forensic analysis the majority of the residual fill material appears to comprise relatively inert materials or materials that will degrade relatively slowly (e.g. wood, cloth, paper); very little vegetation (maximum 0.6% in CP04) or other degradable material was encountered in the landfill waste.

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9.0 Conceptual Site Model

This section of the report describes the Conceptual Site Model (CSM) that defines 'source', 'pathway' and 'receptor' relationships at the site and in the site vicinity. A Preliminary CSM was previously described within the WYG desk top study report (WYG 2017a). The Preliminary CSM has been updated here using information collected during the site investigation, including in particular site specific information relating to the definition of contaminant sources and the nature of ground conditions such that they might provide pathways for contaminant migration. As with the Preliminary CSM, potential receptors have been identified based on both continued use of the site as a public open space and potential redevelopment for commercial use (potential receptors include workers involved in earthworks and construction as well as users of any redeveloped site).

9.1 Summary of Contamination Sources

From the desk based and intrusive investigations undertaken at the site, a number of contamination sources and potential contamination sources have been identified.

On-site

Made Ground and waste material associated with the municipal landfill (no longer in use) present at the site. Visible evidence of landfill waste was identified within each of exploratory hole advanced across the site during intrusive investigation works in May 2017. The recorded thickness of landfill material ranged from circa 4.5m (CP4 in the north west) to 7.5m (CP02 and CP5 in the south west). In all cases the landfill deposits were overlain by a capping layer (typically a cohesive strata) of 1-5m thick.

Elevated levels of land gas (maximum 98% CH_4, 46% CO_2) have been measured within monitoring wells across the site and occasionally high flow rates were recorded; a potentially conservative site wide GSV for methane of 30.5L/hr has been derived which in accordance to C665 is equivalent to a Characteristic Situation 5.

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- Within several soil samples (15 of 40) collected from across the site, asbestos fibres were detected (identified as chrysotile but occasionally including amosite). Although most of the asbestos detections were measured in relatively deep samples (>2m bgl) collected from the landfill material, two detections were measured within samples collected (from CP04 and TP03) from comparatively shallow capping material (circa 0.5m bgl) within a central / western area of the site.
- Notably high concentrations (circa 10,000mg/kg) of petroleum hydrocarbons were measured in soil samples collected from landfill material at two locations (TP01 at 1.9m and TP04 at 3.3m). In both cases the results of speciated TPH analysis suggest that the oil comprises heavy fractions and is similar in nature to a lubricating oil; the concentrations of individual fractions do not exceed relevant human health based screening criteria.
- Slightly lower levels of petroleum hydrocarbons (circa 3,000mg/kg) were measured in relatively shallow soil (0.4m) collected from Made Ground / Capping material; here the hydrocarbon component (predominantly heavy aromatic fractions) is typical of PAH contamination and the analysis of individual PAH compounds has identified concentrations of three PAH compounds (dibenzo(ah)anthracene, benzo(b)fluoranthene and benzo(a)pyrene) at levels that exceed human health based screening criteria applicable to public open space end use. The concentration of dibenzo(ah)anthracene also exceeds criteria applicable to a commercial end use.
- Evidence of hydrocarbon contamination has also been measured in groundwater samples collected from the landfill material; this includes a maximum concentration of TPH of approximately 250µg/L (CP05), benzene concentrations between approximately 1-7µg/L in five of six samples from the landfill (these levels exceed the DWS of 1µg/L) and a number of PAH compounds exceeding EQS by up to two orders of magnitude.
- Most notably groundwater collected from the landfill was also found to include high concentrations of ammoniacal compounds: Maximum concentrations of ammonium and ammonia exceed relevant screening criteria by three and four orders of magnitude respectively.
- Slightly elevated concentrations of cyanide and heavy metals (copper, nickel, zinc, antimony and boron) were also measured in groundwater collected from the landfill; the levels of these constituents do not exceed relevant water quality standards by more than one order of magnitude.
- Evidence of localised groundwater contamination has also been encountered within the Chalk in CP02 (D) in the south west of the site. This includes high concentrations of

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ammoniacal compounds (although lower than in the landfill the levels of ammonium and ammonia exceed relevant screening criteria by two and three orders of magnitude respectively) and marginally elevated levels of cyanide, benzene, PAH and TPH. The similarity between the contaminant profile measured in CP02(D) and the groundwater contamination measured in landfill would suggest that the landfill is likely to be the origin of the contamination measured.

- Potential UXOs associated with potential undetected bomb strikes during World War II. No evidence of suspected UXOs were encountered during the site investigation works.

Off-site

Offsite sources can influence onsite soil and groundwater quality, *if a viable pathway is present.* Potential contaminative sources offsite were identified within the Preliminary CSM as inlcuding:

- *Offsite landfills including the land to the south and west of the site;*
- *Railway land 200m north of the site;*
- *Various industrial / commercial land uses (in particular to the east and south east)* including a concrete production facility, waste transfer station, electrical substation, incinerator, waste water treatment works and unspecified works, depots and tanks. Wastes from these sites may also have been deposited on the site.

No evidence of contamination originating from an off-site source (other than deposited landfill waste) has been identified following the completion of the investigation works.

9.2 Risk Pathways

The key environmental pathways and exposure routes by which potentially contaminative substances might reach environmental and human health receptors in the site vicinity are considered to be:

- *Migration of ground gases;* high levels of land gases have been measured, occasionally associated with high flow rates. Whilst the cover material that overlies the landfill is predominantly cohesive, this unit is variable in thickness (as thin as 1m), variable in strength (often described as soft) and often contains a relatively high proportion of sand and gravel. It should not be regarded as an effective break layer, without further lines of evidence. Furthermore, future ground works have the potential to compromise the cover material layer (e.g. groundworks, service runs, piled foundations) and the potential

for land gases to bypass the fill and reach the surface or any building foundations should not be discounted.

- Contamination migration through preferential pathways (e.g. underground services, drains and piles). Although evidence of preferential pathways were not identified, during the intrusive investigation, the presence of a deep sewer is known to cross the western portion of the site. Furthermore any future development that includes large buildings will likely require piles into the underlying Chalk. Any piling methodology will require careful assessment and design to avoid the creation of preferential pathways between landfill material and the underlying Chalk.
- Atmospheric transport and inhalation of airborne dusts, vapours and fibres (indoors and outdoors);
- *Direct contact (Dermal contact with / ingestion of soil and water)*; The potential exists that future site users will have the potential to come into direct contact with contamination in shallow soil; exceedances of human health based screening criteria were measured in shallow soil (circa 0.5m bgl) at one location in a central area of the site. The placement of buildings and/or hardstanding surfaces at any future development should mitigate potential risks associated with this pathway.
- Shallow groundwater is absent across the site (depths to groundwater are consistently >5m bgl) and therefore direct contact with contaminated groundwater is unlikely to be a viable exposure pathway.
- Vertical leaching of dissolved phase contamination through unsaturated strata because of rainwater infiltration. The ground conditions encountered across the site include a cover material / made ground between 1-5m thick. Typically, this material was recorded as being a cohesive layer (sandy or gravelly clay) and as such it would be expected to limit the potential for rainwater infiltration. During the site walkover in March an area of ponded water was observed in a relatively low-lying area north of the parking area. Whilst this reinforces the hypothesis that shallow soils are locally relatively impermeable, the cover material is variably thick, soft and contains relatively high proportions of gravels. Groundwater was recorded in wells installed in landfill material (piezometrically above the water table in the Chalk); the chemical characteristics of this groundwater are considered typical of leachate from an old landfill (high chloride and other ions, ammoniacal compounds and some hydrocarbon contamination).
- *Lateral / vertical migration of liquid products through the sub-surface under gravity.* Although some evidence of hydrocarbon contamination was recorded within the landfill material no visible evidence of free phase oily contamination was observed.

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- *Lateral/vertical migration of dissolved phase contamination in groundwater via diffusion and advective groundwater flow.* Evidence of suspected contamination was recorded in groundwater collected from one of three wells installed in the Chalk. The nature of the contamination is very similar to the contamination measured in groundwater collected from the landfill material which would suggest that some transfer of contamination has occurred between the landfill and Chalk strata.

The groundwater monitoring data identified piezometric water levels in the Chalk between approximately 0m to 2m AOD, whereas the groundwater in the landfill was recorded at between approximately 2m to 5m AOD suggesting that groundwater in the landfill is hydraulically distinct (from the Chalk) and that downwards gradients will predominate.

The chemical data collected from the site would appear to suggest that groundwater in the Chalk is brackish (chloride and sulphate levels are approximately 1% of that of seawater) whereas the groundwater collected from the landfill has comparatively lower sulphate levels. It is notable also, whilst the top of the Chalk was encountered at between -2m to -5mAOD whilst the piezometric groundwater level is at close to sea level. Relative depths to groundwater recorded in trial pits CP01D, CP02D, CP03D on different monitoring rounds suggest that the groundwater flow direction and gradient is variable (northerly and southerly gradients have been identified) providing further evidence of tidal influence.

9.3 Receptors

The environmental, human health and infrastructure receptors on or surrounding the site include:

- Current, and potentially future, public open space site users;
- Potential future commercial site users;
- Construction site workers and maintenance workers;
- Off-site neighbours (including commercial/industrial premises east of the site);
- Groundwater; including superficial secondary aquifers and principal aquifers of the Chalk;
- Surface water features, including the Hermitage stream (adjacent to the site) and Langstone Harbour (a SSSI site 300m south of the site); and
- Buildings and infrastructure associated with any future potential development.

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9.4 Qualitative Risk Assessment

A qualitative risk assessment was previously undertaken as part of the Phase 1 evaluation of potential pollutant linkages at the site. The previous assessment has been updated to reflect the findings of the Phase 2 Assessment using the CIRIA C552 methodology (which is provided in Appendix M). The full updated risk assessment including details of the changes made to specific risk rankings following the collection of Phase 2 data is presented in Appendix N. A summary of the updated risk assessment and the levels of risk identified with respect to specific receptor groups is provided in the following sub-sections.

9.4.1 Summary of Risk Evaluation: Public Open Space Users

The site is currently used as a public open space without buildings or structures. A footpath crosses the site and dog walkers were observed using this path during the site walkover and investigation. Across most of the site, an ostensibly healthy and thick cover of vegetation is present although locally (immediately west of the current car park) some patches of bare earth and extraneous material (e.g. building waste) were noted. Although asbestos fibres were recorded in several samples (including relatively shallow 'capping' material) and concentrations of PAH compounds were recorded in excess of screening criteria applicable to human health risk, based on current use (limited exposure times and minimal contact expected) direct exposure to harmful substances is considered relatively unlikely to occur. Similarly, given the absence of buildings, an explosion event or asphyxiation from ground gases is considered relatively unlikely. However, based on the high concentrations of land gas recorded and evidence of occasional active gassing a worse-case scenario including the escape of gasses to surface and subsequent ignition cannot be excluded entirely whilst public access to the site is permissible. Risks to users of public open space considered to be **low / moderate**; this corresponds with the level of risk previously assigned during the desk study.

If, however, the site were to be enhanced creating greater levels of usage (e.g. opening the car park, creating play areas) this would increase the likelihood of a harmful exposure event occurring and it would be appropriate to increase the risk level to **Moderate.** Any proposed enhancement of the site, therefore, should be carefully managed and preceded by further assessment and/or mitigation e.g. removal of shallow contamination / placement of additional capping in car park area.

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9.4.2 Summary of Risk Evaluation: Commercial Site Users

The investigation and monitoring works at the site have confirmed the presence of landfill materials (approximately 4.5-7m thick) across the site and elevated levels of potentially hazardous land gases. Although it appears that the majority of the more rapidly degradable material has been degraded, relatively high proportions of more slowly degrading material (e.g. wood and paper) do remain. The land gas regime is considered to present a **high** risk to any future buildings and commercial users at the site. Based on the land gas risk assessment undertaken in accordance with CIRIA C665 (described previously in Section 8.2.4) gas protection measures applicable to a Characteristic Situation 3 or 4 (subject to further review and refinement) are likely to be appropriate for any future buildings.

Risks of harm to health associated with potential exposure to hydrocarbons and asbestos in soil at a future commercial premises are considered to be **Low / Moderate**. For any future development it would be appropriate to incorporate design elements that minimise the potential for exposure to the underlying soil e.g. through the extensive placement of hard standing / buildings and clean soil for any landscaped areas.

9.4.3 Summary of Risk Evaluation: Construction and Groundworkers

Following review of the ground investigation data a **high** risk of harm to health to construction workers, through potential exposure to soil contaminants (including asbestos) and also land gas that might accumulate within excavations, has been identified. It should be possible, however, to manage these risks through the adoption of appropriate working practices, protective equipment and facilities. Therefore, whilst these high risks will require careful management they are not considered to be potential constraints to site development. Further discussion on the management of risks during redevelopment are provided within Section 10.

9.4.4 Summary of Risk Evaluation: Offsite Neighbours

Contamination originating on site has the potential to impact the users of neighbouring sites through a number of pathways including dermal contact and/or ingestion of windborne dusts, migration of vapours, gases and groundwater through the subsurface and inhalation of windborne asbestos fibres. Of note these risks are mitigated in part by the relative absence of near neighbours and in particular the absence of any particularly sensitive nearby land uses (e.g. residential / schools).

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Although elevated levels of land gas have been recorded at the site, the majority of flow rates have been low / negligible. The closest buildings to the site are approximately 60m east of the site (commercial premises) on the opposite side of the Hermitage Stream. It is notable that these buildings are also constructed on former landfill and it is expected therefore that these buildings have been fitted with gas protection. The previously assigned moderate risks have been reduced to **Low / Moderate** reflecting the presence of the Hermitage Stream between the neighbouring buildings and the site and the typically low levels of gas flow recorded.

Moderate risks have been identified associated with inhalation of asbestos fibres at neighbouring premises during any future groundworks / site redevelopment that enhances the release of dust / fibres. It should be possible to effectively manage / monitor these risk during any future groundworks through the deployment of dust suppression measures and / or boundary monitoring.

9.4.5 Summary of risk evaluation: Groundwater

Evidence of suspected contamination in groundwater collected from the Chalk has been recorded in one of three wells. Based on the nature and type of contamination recorded (including high levels of ammoniacal compounds, and relatively low levels of cyanide, benzene and other hydrocarbons) it is considered likely that this originated from the overlying landfill. It is noted also, however, that the data recorded suggests that the groundwater in the Chalk is brackish and tidally influenced. This would make it unsuitable for use as a potable water resource and therefore, arguably, less sensitive as a resource.

Locally in the east of the site River Terrace Deposits (up to 5.7m thick) were identified between the base of the made ground and the top of the Chalk. Similarly, in the west of the site alluvium (up to 3.5m thick) was recorded between the base of the made ground and the Chalk. At one location in the centre of the site the Chalk was encountered directly beneath the Made Ground. Groundwater strikes were recorded in both alluvium and River Terrace Deposits and these superficial deposits are classified as Secondary Aquifers. In reality it is expected that the Environment Agency will be more concerned about the status of the groundwater in the Chalk (Principal) Aquifer and that secondary aquifers will be viewed as being more as a concern in that they might serve as conduits into adjacent surface water.

As a note of caution only one round of monitoring has been undertaken to date; it might be prudent to undertake a further round of monitoring to provide greater assurance that the data collected is representative.

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Overall, the risk of significant impacts to groundwater are considered to be Moderate (likely occurrence of medium consequence).

9.4.6 Summary of Risk Evaluation: Surface Water

A number of surface water bodies are present on or near to the site which are considered to represent potential receptors to ground contamination originating from the site. Contaminated groundwater was encountered within landfill material and also (at one location) within the Chalk. Groundwater monitoring data suggests that the Chalk is tidally influenced; groundwater is brackish and flow directions and gradients varied markedly. A twice daily cycle of flow back and forth is expected, however, a 'net' flow towards the Langstone Harbour is likely (though not proven) and groundwater is considered therefore to have the potential provide a potential conduit between the site and surface water in the estuary.

Although monitoring data is unavailable from the River Terrace Deposits and Alluvium strata, these units are considered to have the potential to be in hydraulic continuity with adjacent water courses. The River Terrace Deposits in the east of the site, in particular, are considered to have the potential to provide a conduit whereby contamination originating from the site might impact the adjacent Hermitage Stream.

Overall the risk of significant impact to surface water receptors is considered to be **moderate** (likely / medium consequence incident).

9.4.7 Summary of Risk Evaluation: Onsite Buildings / Services

Based on the results of the land gas monitoring and the subsequent land gas risk assessment a **high** risk to future onsite buildings and services is considered to be present associated with potential catastrophic damage that might be caused by explosive landfill gas (methane). In addition, due to the thickness and nature of fill materials across the site, high levels of settlement are expected which could cause serious damage without adequate mitigation.

Chemical corrosion by contaminants in soil and/or groundwater is perceived to represent a **low to moderate** risk (likely occurrence / mild consequence) to future buildings or services. An ACEC AC-4 categorisation has been assigned and any sub-surface concrete will need to be used in accordance with this guidance to guard against chemical attack.

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10.0 Conclusions and Recommendations

10.1 Conclusions

Based on the review of desk study information and the Phase 2 ground investigation the following risk levels have been identified associated with potential ground contamination:

- Future site users – Public Open Space – **Low / Moderate** (assuming site remains unchanged) or Moderate (assuming space enhancement and increased usage).
- Future site users – Commercial – **High** – these risks, associated with land gas, could be effectively mitigated through the incorporation of appropriate levels of gas protection.
- Construction workers (during redevelopment of the site) – **High** risks have been identified associated with both land gas (e.g. explosion risk and / asphyxiation in excavations) and asbestos fibres. It should be possible to develop working practices that effectively reduce the level of risk.
- Offsite neighbours – Low / Moderate risks to neighbours have been identified associated with potential land gases. **Moderate** risks have been identified associated with potential release and exposure to asbestos during redevelopment / groundworks. The latter risks can be controlled through appropriate working practices.
- Groundwater of the Superficial Secondary Aquifers **–Moderate**
- Groundwater in the deep Chalk Principal Aquifer - **Moderate**
- Surface Water – **Moderate**
- Onsite property/buildings and services – **High** risks to buildings have been identified associated with potentially hazardous land gases. These risks could be effectively mitigated through the incorporation of appropriate levels of gas protection.

The key geotechnical risk at the site relates to volume changes of the landfill material, due to degradation of organic material.

Consideration should also be given to the type and construction of potential development which in turn would dictate the type and depth of foundations.

10.2 Recommendations

Regulatory engagement / further monitoring to better understand liabilities associated with Controlled Waters

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Based on limited groundwater data collected to date evidence of suspected impacts to underlying Chalk groundwater has been identified. This is considered to represent a potentially significant liability and in the first instance further monitoring from wells installed in the Chalk is recommended in order to verify the validity of this result. Engagement with the regulators is also recommended in order to gain a better understanding in relation to the regulators expectations and requirements.

It is considered likely that Environment Agency will request further monitoring / assessment of groundwater contamination at the site / in the site vicinity. It is plausible also that the installation of a more complete monitoring network will be required. Depending on the findings of further monitoring it is also possible that more detailed assessment will be required (e.g. contaminant fate and transport monitoring). It may be possible to demonstrate that natural processes of attenuation are sufficient to reduce contaminant discharges to acceptable levels, preventing significant contaminant loading in surface waters and potentially negating the requirement for costly mitigation / remediation. Alternatively it is possible that, prior to any site redevelopment, a leachate capture system or hydraulic barriers might be required to reduce contaminant transport off site and towards the Langstone harbour.

Construction Phase Considerations

High levels of risk to potential groundworkers have been identified associated with land gas (explosive risk and asphyxiation) and inhalation of asbestos fibres. Moderate risks have also been identified to off-site neighbours through potential exposure to asbestos during any groundworks that cause an enhanced release of dust / fibres. On this basis consideration, should be given to a number of precautions during any future construction phase of works as follows:

- Of note asbestos containing materials are relatively widespread across the site and any ground arisings should be carefully controlled to prevent release to the environment. This includes release of dusts and fibres and prevention of windblown transmission beyond the site boundary. Boundary monitoring of dust / fibres may be required during redevelopment to monitor risks posed to users of adjacent land.
- Use of / availability of personal protective equipment (PPE) and also monitoring equipment by groundworkers including respiratory equipment (if vapours, gases or asbestos fibres are present) and gas monitoring equipment to test for land gases in excavations
- Provision should be made for adequate decontamination facilities.

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- Based on the risk of encountering UXO, on-site support including downhole magnetometry is likely to be a requirement for any deep piling works (i.e. that extend beyond the base of the landfill materials).
- Surplus soils from excavations should be disposed of appropriately and in accordance with current waste management legislation. It should be noted that if shallow soils are of poor chemical quality they may attract premium rates at landfill.

In addition to the above it might be appropriate to undertake further assessment of shallow soil focussing in particular on attaining further characterisation of asbestos sources within the capping material. This information could be used to inform the development of a *Soil Management Plan* which would form the basis for managing soil on site and mitigating risks of harm to health.

Land Gas Protection

A conservative land gas assessment undertaken in accordance CIRIA C665 has identified, conservatively, a Characteristic Situation 5. This interpretation, however, is likely to be overly conservative particularly since the highest gas flow recorded of 31L/Hr was atypical of most monitoring events and most locations. It is recommended that prior to any redevelopment of the site that additional monitoring be undertaken, supplemented if appropriate with additional wells installed at locations considered strategically important in view of previous monitoring results and also proposed building locations.

Based on current data it is considered likely that gas protection measures required for future buildings will need to comply with a Characteristic Situation 3 or 4. As such all buildings will likely require reinforced concrete cast in-situ floor slab with joints and penetrations sealed and proprietary gas membranes installed and tested by appropriately qualified practitioners. Passive venting or positively pressurised buildings with underfloor sub-space and monitoring facility are also likely requirements. In ground venting wells / barriers may also be required.

Geotechnical Recommendations

It is recommended that:

- Actual rate of settlement of Made Ground on site should be monitored prior to development considerations.
- For light industrial / commercial units, the ground should be pre-loaded (following guidance on BRE FB75) and constructed on raft foundations, with gas protection measurements.

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- Heavily loaded structures should be founded into the underlying Chalk. With consideration to negative shaft frictions due to long-term ground settlement and the type of pile construction e.g. continuous flight augers with the use of temporary casing to seal out contaminated water.
- Excavations within the made ground for temporary works should consider the stability of the ground and potential ground gas concentration. Man entry into excavations should be avoided.
- Concrete used for construction should conform to advice given within BRE SD1.

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11.0 References

- BS5930:1999+A2:2010 Code of Practice for Site Investigations
- BS1377: Methods of Testing Soils for Civil Engineering Purposes, 1990
- BRE Special Digest 1: Concrete in Aggressive Ground, 2005
- BRE FB 75 - Building on fill: geotechnical aspects, 3rd edition, 2015
- CIRIA C574 (2002) Engineering in Chalk
- CIRIA PR11 (1994) Foundations in Chalk
- CL:AIRE (2014): SP1010 – Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination. Final Project Report (Revision 2), September
- Environment Agency (2004) CLR11 Model Procedures for the Management of Contaminated Land. September.
- NHBC Standards 2006: Chapters 4.2
- Rudland, D.J., Lanceford, R.M and Mayell, P.N (2001), CIRIA C552; Contaminated Land Risk Assessment, A Guide to Good Practice, Basingstoke Press Ltd, 2001.
- Wilson S., S Oliver S., Mallett, H., Hutchings H. and Card G. (2007) CIRIA Report C665 Assessing risks posed by hazardous ground gases in buildings July
- Nathaniel C.P., McCaffrey, C., Gillet, A.G., Ogden R.C., and Nathaniel, J.F. 2015. The LQM/CIEH S4ULs for Human Health Risk Assessment (Copyright Land Quality Management Limited Reproduced with Permission; publication number S4UL3193)

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12.0 Appendices

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Appendix A – Report Conditions

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Report Conditions

Site Investigation

*This report is produced solely for the benefit of **Havant Borough Council** and their Consultant partners. No liability is accepted for any reliance placed on the report by any other party unless specifically agreed in writing otherwise.*
This report refers, within the limitations stated, to the condition of the site at the time of the inspections. No warranty is given as to the possibility of future changes in the condition of the site.

This report is based on a visual site inspection, reference to accessible referenced historical records, information supplied by those parties referenced in the text and preliminary discussions with local and Statutory Authorities. Some of the opinions are based on unconfirmed data and information and are presented as the best that can be obtained without further extensive research.

Where ground contamination is suspected but no physical site test results are available to confirm this, the report must be regarded as initial advice only, and further assessment should be undertaken prior to activities related to the site. Where test results undertaken by others have been made available these can only be regarded as a limited sample. The possibility of the presence of contaminants, perhaps in higher concentrations, elsewhere on the site cannot be discounted.

Whilst confident in the findings detailed within this report because there are no exact UK definitions of these matters, being subject to risk analysis, we are unable to give categorical assurances that they will be accepted by Authorities or Funds etc. without question as such bodies often have unpublished, more stringent objectives. This report is prepared for the proposed uses stated in the report and should not be used in a different context without reference to WYG. In time improved practices or amended legislation may necessitate a re-assessment.

The assessment of ground conditions within this report is based upon the findings of the study undertaken. We have interpreted the ground conditions in between locations on the assumption that conditions do not vary significantly. However, no investigation can inspect each and every part of the site and therefore changes or variances in the physical and chemical site conditions as described in this report cannot be discounted.

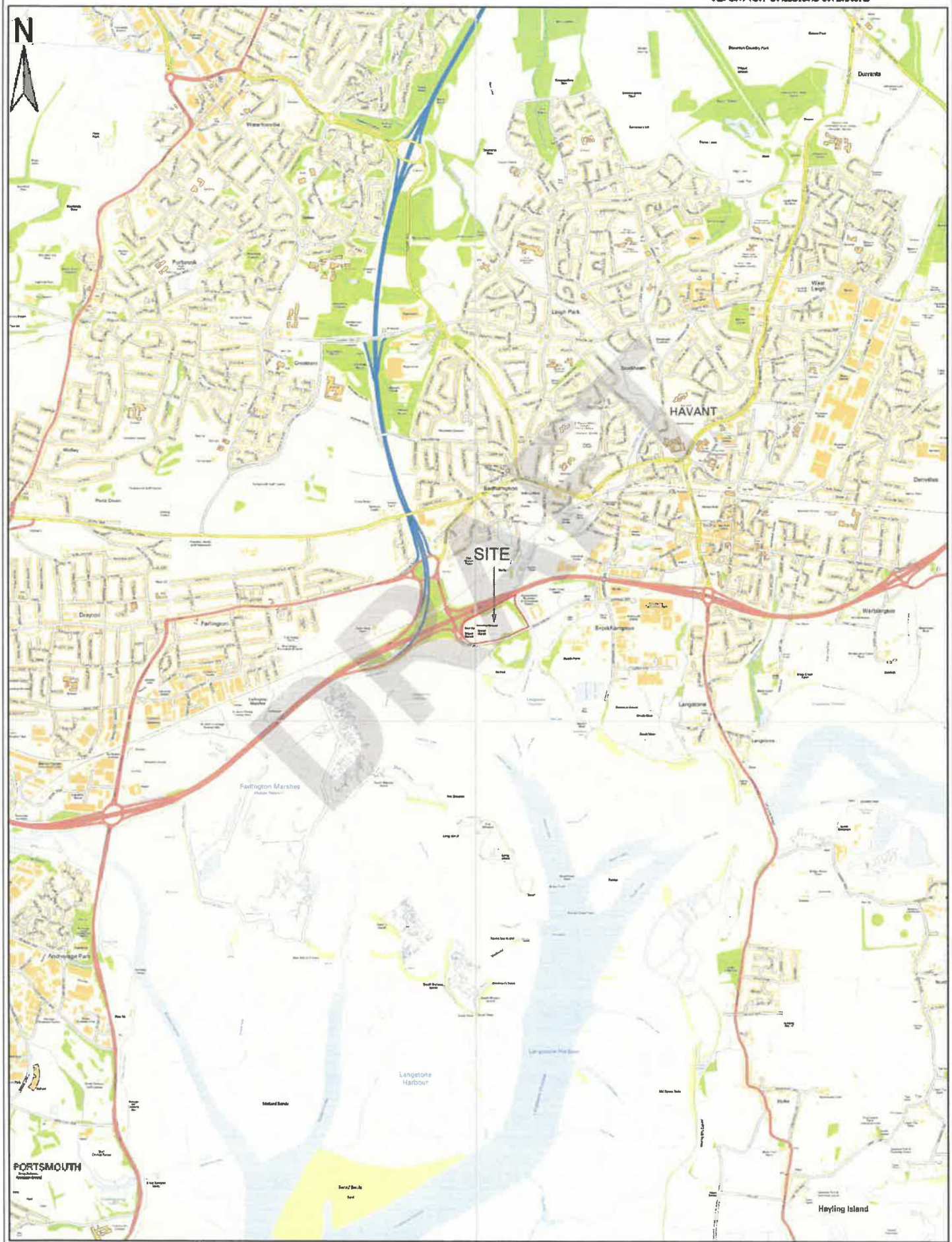
The report is limited to those aspects of land contamination specifically reported on and is necessarily restricted and no liability is accepted for any other aspect especially concerning gradual or sudden pollution incidents. The opinions expressed cannot be absolute due to the limitations of time and resources imposed by the agreed brief and the possibility of unrecorded previous use and abuse of the site and adjacent sites. The report concentrates on the site as defined in the report and provides an opinion on surrounding sites. If migrating pollution or contamination (past or present) exists further extensive research will be required before the effects can be better determined.

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Appendix B – WYG Drawings

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REV	DESCRIPTION	BY	CHK	APP	DATE

WYG PLC
6 CONCORDE GATE
47 NEWPORT ROAD
CARDIFF
CF24 0AD
TEL: +44 (0)29 2092 9000
FAX: +44 (0)29 2045 5321
e Mail: cardiff@wyg.com

Client: HAVANT BOROUGH COUNCIL

Project: BROCKHAMPTON WEST

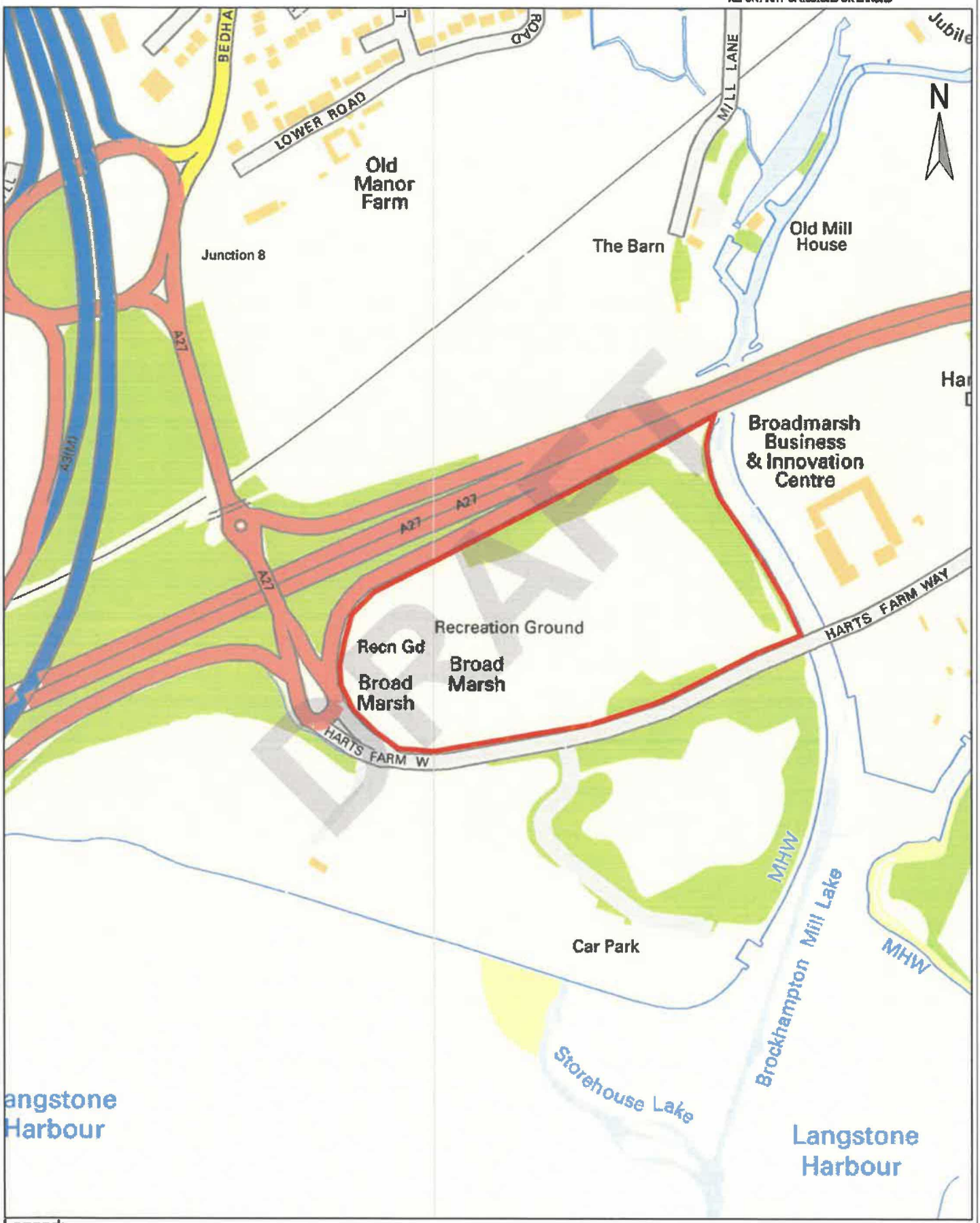
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Scale @ A4	Drawn	Date	Checked	Date	Approved	Date
NTS	PP	19.04.17	MB	19.04.17	AM	

Project No.	Office	Type	Drawing No.	Revision
A102760	LDN	M	001	00

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Legend:

Site Boundary

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REV	DESCRIPTION	BY	CHK	APP	DATE

Client: HAVANT BOROUGH COUNCIL	Project: BROCKHAMPTON WEST	Drawing Title: SITE LAYOUT PLAN	Scale @ A4: 1:1250	Drawn:	Date: 18.04.17	Checked:	Date:	Approved:	Date:
			Project no.: A102760	Office: LDN	Type: N	Drawing no.: 002	Revision: 00

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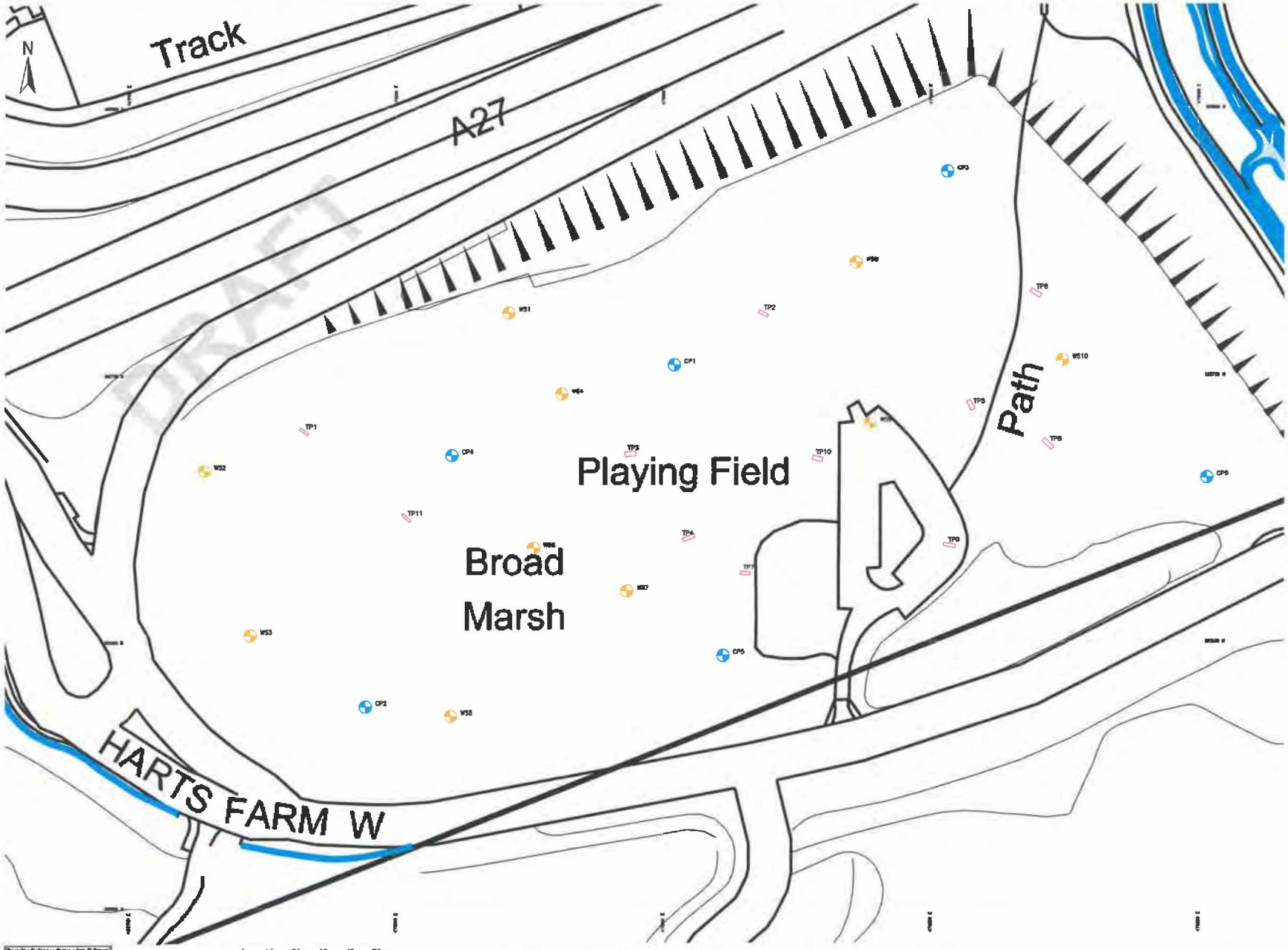
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KEY:

BOREHOLE

WINDOW SAMPLE

WINDOW SAMPLE



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60 St. John Street
London
EC1M 4EH

TEL: +44 (0)20 7250 7580
FAX: +44 (0)20 7250 7501

Client: HAVANT BOROUGH COUNCIL

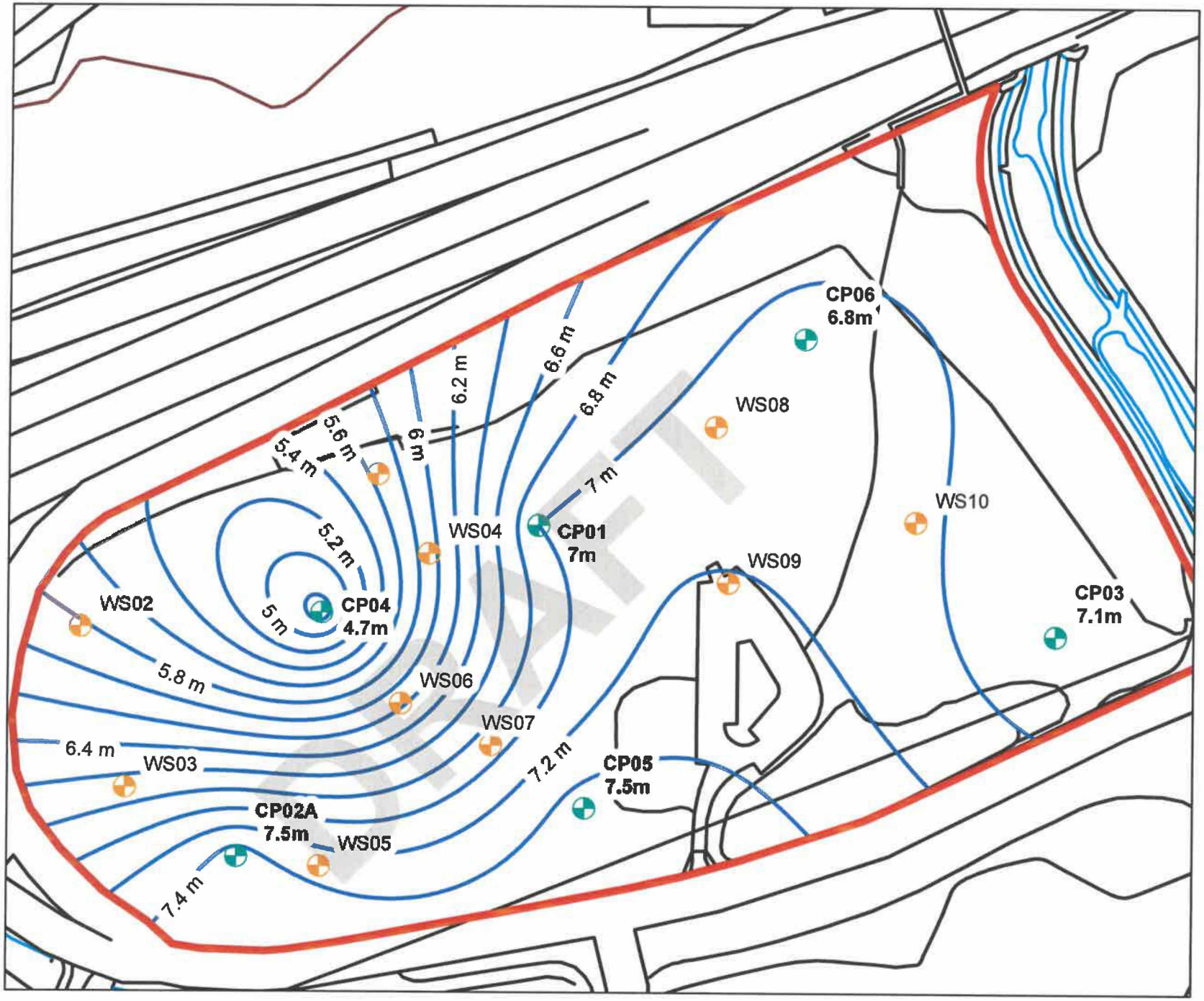
Project: BROCKHAMPTON WEST

Drawing Title: EXPLORATORY HOLE LOCATION PLAN

Scale @ A2	Drawn	Date	Checked	Date	Approved	Date
1:1000	PP	24.07.17	RD	24.07.17		

Project No.	Office	Type	Drawing No.	Revision
A102760	LDN	N	003	00

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Legend

- Site Boundary
- Cable Percussion Borehole
- Window Sample
- Trial Pit
- Landfill Thickness Contours (m)

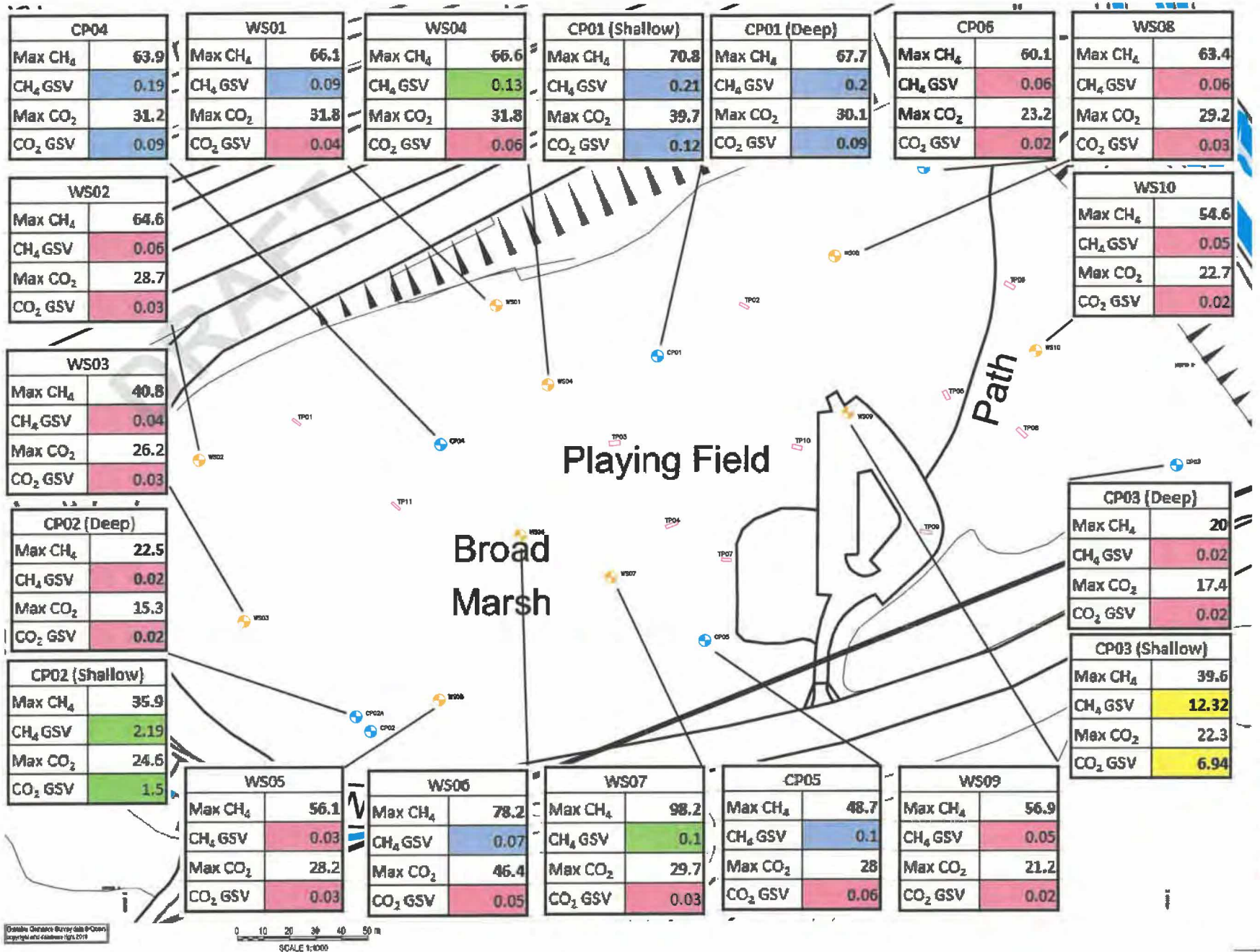
0 12.5 25 50 75 m

Drawing title: Landfill Thickness Contour Plan			
Project: Brockhampton West			
Client: Havant Borough Council			
Scale (A3): 1:2,000	Created: SB 07/06/17	Reviewed:	Verified:
Office: LDN	Drawing number: 004	Revision: Rev.01	

WYG Environment

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EC1M 4EH
Tel: 0207 250 7500
Fax: 0207 250 7501

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CP04	
Max CH_4	63.9
CH_4 GSV	0.19
Max CO_2	31.2
CO_2 GSV	0.09

WS01	
Max CH_4	66.1
CH_4 GSV	0.09
Max CO_2	31.8
CO_2 GSV	0.04

WS04	
Max CH_4	66.6
CH_4 GSV	0.13
Max CO_2	31.8
CO_2 GSV	0.06

CP01 (Shallow)	
Max CH_4	70.8
CH_4 GSV	0.21
Max CO_2	39.7
CO_2 GSV	0.12

CP01 (Deep)	
Max CH_4	67.7
CH_4 GSV	0.2
Max CO_2	30.1
CO_2 GSV	0.09

CP06	
Max CH_4	60.1
CH_4 GSV	0.06
Max CO_2	23.2
CO_2 GSV	0.02

WS08	
Max CH_4	63.4
CH_4 GSV	0.06
Max CO_2	29.2
CO_2 GSV	0.03

WS02	
Max CH_4	64.6
CH_4 GSV	0.06
Max CO_2	28.7
CO_2 GSV	0.03

WS10	
Max CH_4	54.6
CH_4 GSV	0.05
Max CO_2	22.7
CO_2 GSV	0.02

WS03	
Max CH_4	40.8
CH_4 GSV	0.04
Max CO_2	26.2
CO_2 GSV	0.03

CP02 (Deep)	
Max CH_4	22.5
CH_4 GSV	0.02
Max CO_2	15.3
CO_2 GSV	0.02

CP03 (Deep)	
Max CH_4	20
CH_4 GSV	0.02
Max CO_2	17.4
CO_2 GSV	0.02

CP02 (Shallow)	
Max CH_4	35.9
CH_4 GSV	2.19
Max CO_2	24.6
CO_2 GSV	1.5

CP03 (Shallow)	
Max CH_4	39.6
CH_4 GSV	12.32
Max CO_2	22.3
CO_2 GSV	6.94

WS05	
Max CH_4	56.1
CH_4 GSV	0.03
Max CO_2	28.2
CO_2 GSV	0.03

WS06	
Max CH_4	78.2
CH_4 GSV	0.07
Max CO_2	46.4
CO_2 GSV	0.05

WS07	
Max CH_4	98.2
CH_4 GSV	0.1
Max CO_2	29.7
CO_2 GSV	0.03

CP05	
Max CH_4	48.7
CH_4 GSV	0.1
Max CO_2	28
CO_2 GSV	0.06

WS09	
Max CH_4	56.9
CH_4 GSV	0.05
Max CO_2	21.2
CO_2 GSV	0.02

Risk Rating for Situation A as per Table 8.5 (CIRIA C665)

- Very high (>70)
- High (<70)
- Moderate to high (<15)
- Moderate (<3.5)
- Low (<0.7)
- Very low (<0.07)

Bold indicates values classified as "red" or high gas regimes as per Table 8.7 (CIRIA C665). Standard residential housing would not normally be acceptable. All values in %vol (Max CH4 and Max CO2) or l/hr (GSVs).

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100 St. John Street
London
EC1M 4EH
Tel: +44 (0)20 7250 2500
Fax: +44 (0)20 7250 2501

Client: HAVANT BOROUGH COUNCIL

Project: BROCKHAMPTON WEST

Drawing Title: MAXIMUM LANDFILL GAS CONCENTRATIONS AND GAS SCREENING VALUES

Scale @ A2	Drawn	Date	Checked	Date	Approved	Date
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Project No.	Office	Type	Drawing No.	Revision
A102760	LDN	N	005	00

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Appendix C – Photographs



TP01 Close up of Pit Wall



TP01 Pit Spoil – Landfill Material



TP01 Pit Spoil – General View



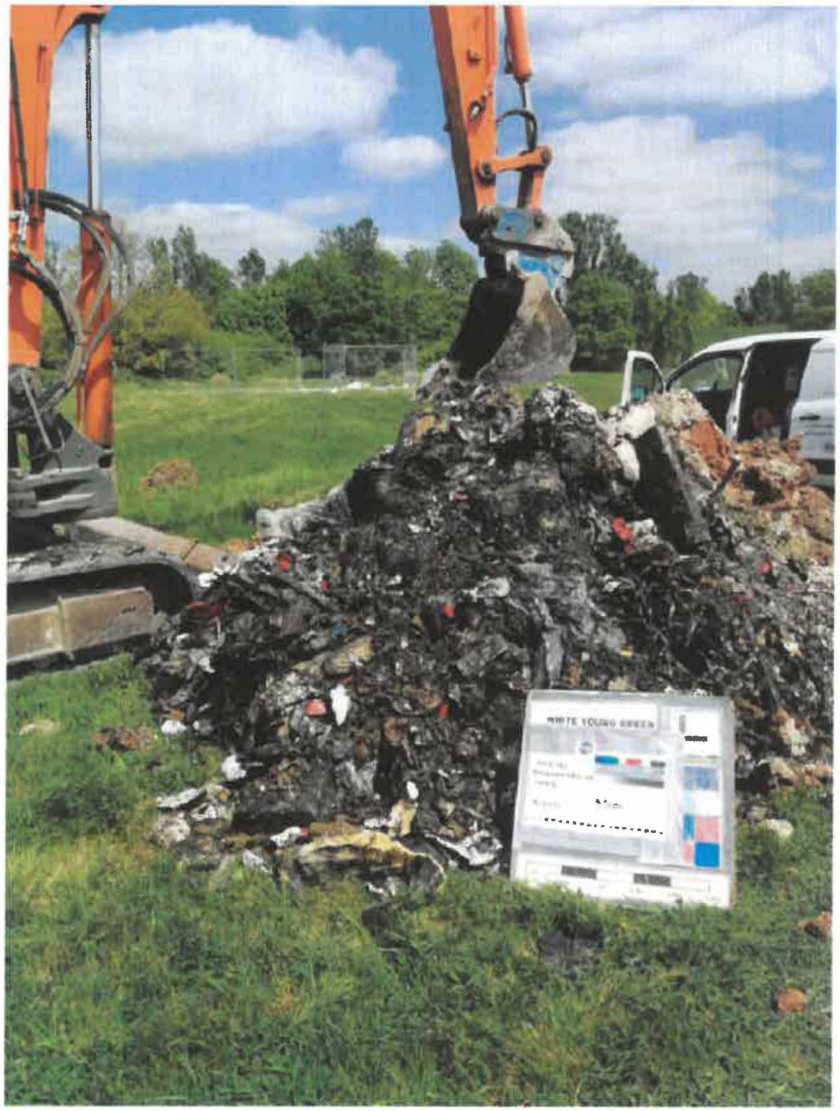
TP02 Close up of Pit Wall



TP02 Pit Spoil – Landfill Material



TP02 Pit Spoil – General View



TP03 Pit Spoil – Landfill Material



TP03 Pit Spoil – General View



TP04 Close up of Pit Wall



TP04 Close up of Pit Base



TP04 Pit Spoil – Landfill Material



TP04 – Pit Spoil – General View



TP05 Pit Spoil – Landfill Material



TP05 Pit Spoil – General View



TP06 Close up of Pit Base



TP06 Pit Spoil – Landfill Material



TP06 Pit Spoil – Close up of Landfill Material



TP06 Reinstatement



TP07 Close up of Pit Wall



TP07 Pit Spoil – General View



TP07 Pit Spoil - Close up of Landfill Material



TP08 Close up of Pit Wall



TP08 Pit Spoil – Landfill Material



TP08 Pit Spoil – General View



TP08 Pit Spoil - Close up of Landfill Material



TP09 Pit – General View



TP09 Close up of Pit Base



TP09 Pit Spoil – General View



TP09 Pit Spoil – General View



TP09 Pit Spoil – Landfill Material



TP10 Close up of Pit Base



TP10 Pit Spoil – Landfill Material



TP10 Pit Spoil – General View



TP11 Pit – General View



TP11 Close of of Pit Base



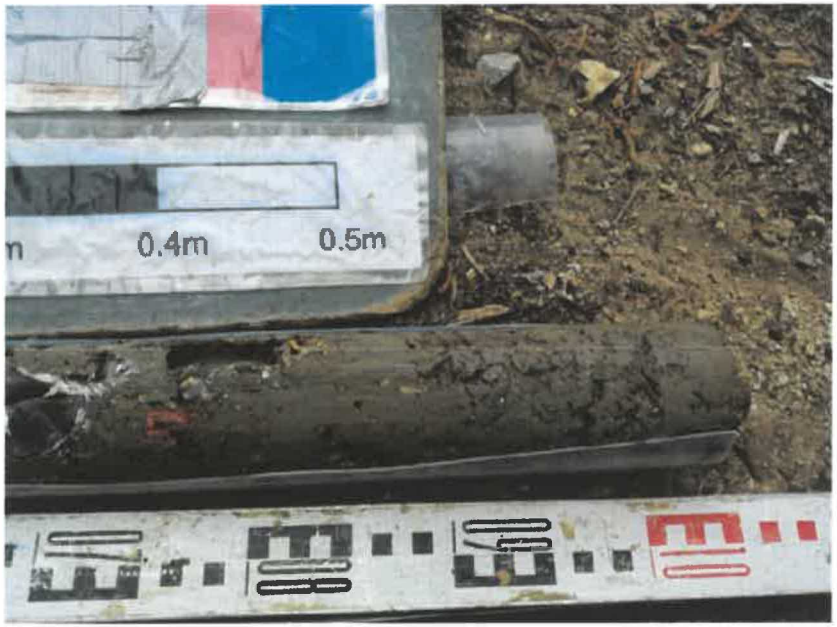
TP11 Pit Spoil – Landfill Material



TP11 Pit Spoil – General View



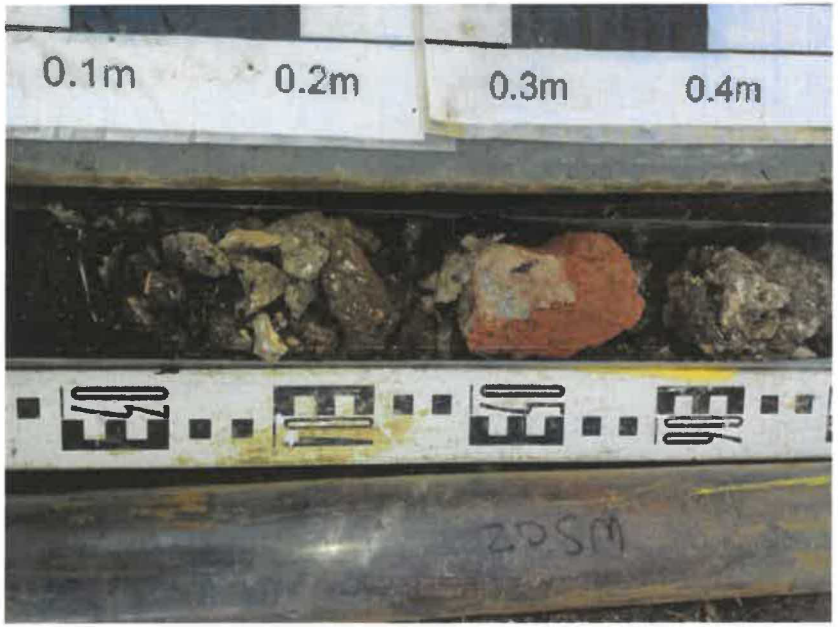
TP11 Pit Spoil - Close up of Landfill Material



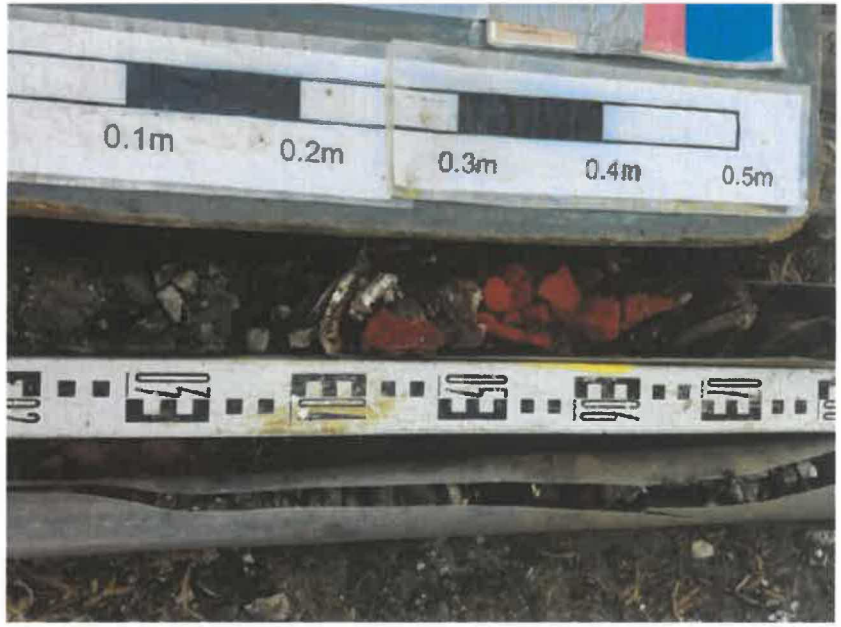
WS01 - 1.20 to 2.00m End of Run: Capping Material



WS01 - 2.00 to 3.00m End of Run: Landfill



WS02 - 1.20 to 2.00m Capping Material, Gravels



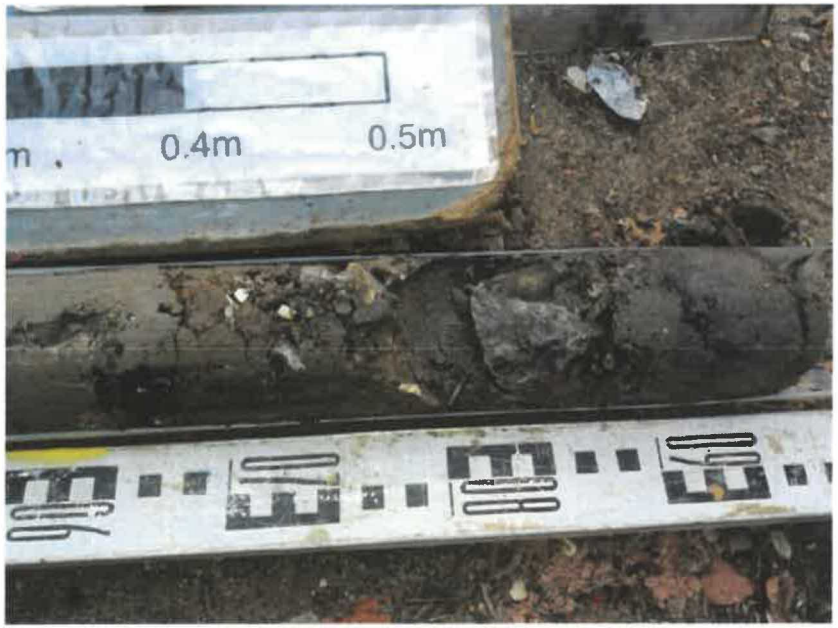
WS02 2.00 to 3.00m Landfill Material



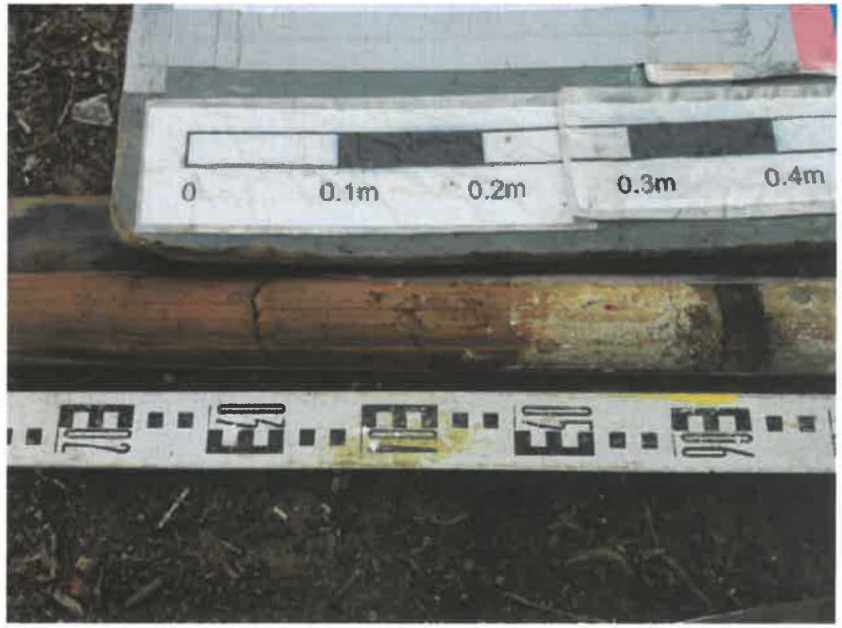
WS03 - 1.20 to 2.00m Capping Material



WS03 - 2.00 to 3.00m Capping Material



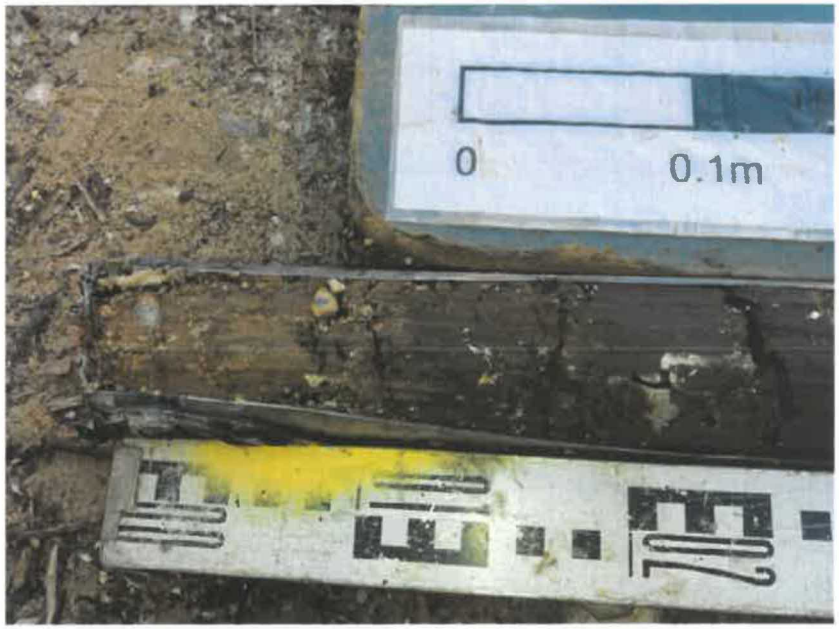
WS04 - 1.20 to 2.00m Landfill Material



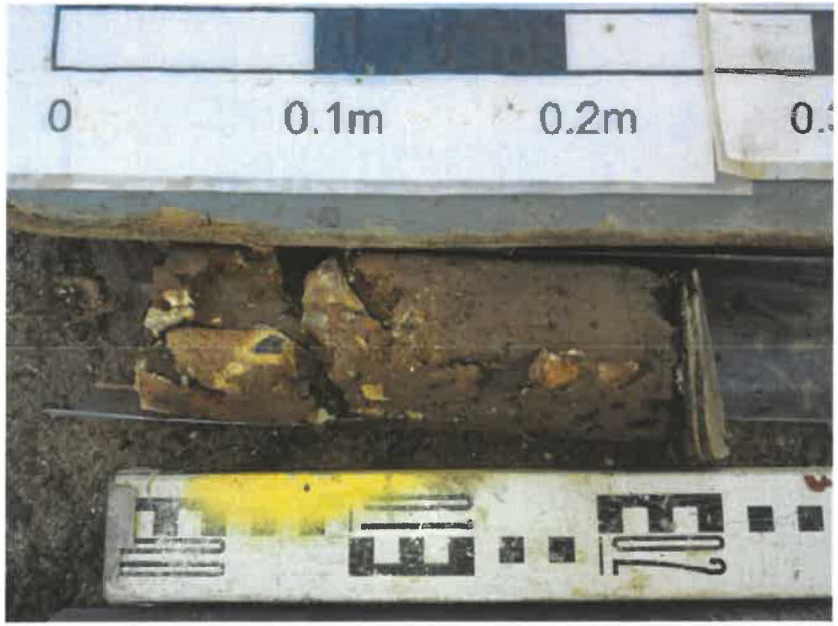
WS05 - 1.20 to 2.00m Capping Material



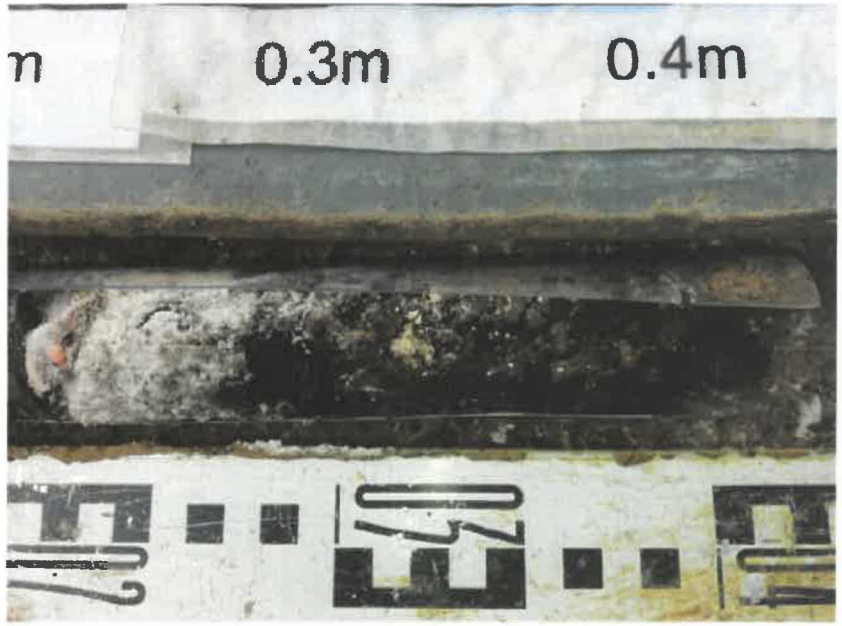
WS06 - 1.20 to 2.00m Capping Material



WS07 - 2.00 to 3.00m Landfill Material



WS08 - 3.00 to 4.00m Refusal on Plyboard



WS09 - 4.00 to 5.00m Landfill Material



WS10 - 3.00 to 4.00m Landfill Material



CP02A - 0.50 to 1.00m – Capping Material



CP02A - 1.00 to 3.00m Landfill Material



CP02A - 3.50 to 4.00m Landfill Material



CP02A - 4.50 to 5.00m Landfill Material



CP02A - 6.00 to 6.50m Landfill Material



CP02A - 7.50 to 8.00m Landfill Material



CP02A - 9.50 to 10.00m Alluvium

Appendix D – Exploratory Hole Logs

DRAFT

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470104.28	Northing: 105703.67	DRAFT	**CP01**
Client: **Havant Borough Council**	Level: 10.54mAOD	Depth: 35.00m		Sheet 1 of 4
	Logger: SN	Type: CP		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time				
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)
0.00 1.20	1.20 35.00	Inspection Pit Cable Percussion	Insulated Tools Dando 4000	RB Drilling: RD Drilling	6.00 15.00 35.00	250 200 150	6.00 15.00 35.00	250 200 150					

Scale: 1:50
Checked By:
Approved By:
Start Date: 02/05/2017
Finish Date: 04/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over TOPSOIL Soft light grey / light brown / white slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-angular flint.						0.00 - 0.40	B2	
						0.20	D1	
[MADE GROUND] Soft orange / white slightly sandy CLAY. Sand is fine to coarse. With occasional angular to sub-angular fine to coarse brick and flint gravel. (CAPPING LAYER)		0.30	10.24			0.45	D3	
						0.95	ES1	PID 0.95m, 0.0ppm
						1.20 - 1.65	D4	SPT(S) 1.20m, N=21 (3,4/4,5,6,6)
						1.20 - 1.70	B5	
[MADE GROUND] Soft orange / black / brown sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse brick and flint. (CAPPING LAYER)		1.40	9.14					
						2.50 - 2.95	D6	SPT(S) 2.50m, 50 (7,11/50 for 150mm)
						2.50 - 3.00	B7	
						2.70	ES2	PID 2.70m, 0.0ppm
[MADE GROUND] Soft dark grey slightly gravelly CLAY. Gravel is angular to sub-rounded, fine to coarse flint. Landfill waste noted includes: paper, wood, string, material, plastic, carpet etc. Slight rotten type odour noted. (LANDFILL)		3.00	7.54					
						3.50 - 3.95	D8	SPT(S) 3.50m, 50 (25,20/50 for 17mm)
						3.50 - 4.00	B9	
						4.20	D10	
						4.50	ES3	SPT(S) 4.50m, 50 (25,35/50 for 36mm)
						4.50 - 4.95	D11	PID 4.50m, 29.0ppm
						4.50 - 5.00	B12	
						5.50	D13	
. . .From 6.00m bgt: Becoming gravelly. gravel is angular to sub-angular, fine to coarse brick and shale. Landfill waste predominantly plastic.						6.00 - 6.00	B16	SPT(C) 6.00m, 0 (75 for 0mm/0 for 0mm)
						7.00	ES4	PID 7.00m, 5.3ppm
								SPT(C) 7.50m, 0 (50 for 0mm/0 for 0mm)
						8.50	D17	
						9.00 - 9.50	B19	SPT(C) 9.00m, N=54 (7,7/12,12,15,15)
						10.00	D20	

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
Whilst drilling beneath landfill material in chalk, UXO engineer on site.
On completion BH backfilled / installed as per graphical log.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
6.00	6.50	90			RDS	58

Groundwater						Project Number
Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks	**A102760**

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Eastng: 470104.28	Northing: 105703.67	DRAFT	**CP01**
Client: **Havant Borough Council**	Level: 10.54mAOD	Depth: 35.00m		Sheet 2 of 4
	Logger: SN	Type: CP		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time				Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	6.00	250	6.00	250						Approved By:
1.20	35.00	Cable Percussive	Dando 4000	RD Drilling	15.00	200	15.00	200						Start Date: 02/05/2017
					35.00	150	35.00	150						Finish Date: 04/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Soft dark grey slightly gravelly CLAY. Gravel is angular to sub-rounded, fine to coarse flint. Landfill waste noted includes: paper, wood, string, material, plastic, carpet etc. Slight rotten type odour noted. (LANDFILL)		10.30	0.24			10.50	ES5	SPT(C) 10.50m, N=33 (7,7/8,8,8,9)
[MADE GROUND] Soft light brown slightly gravelly sandy CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine and medium brick. (CAPPING LAYER)						10.50 - 11.00	B22	PID 10.50m, 0.4ppm
Light brown to black SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint. (RIVER TERRACE DEPOSIT)		11.50	-0.96			11.50	D23	
. . .Between 12.00 and 12.50m bgl: Slightly clayey sandy GRAVEL						12.00 - 12.45	D24	SPT(S) 12.00m, N=24 (3,3/5,5,7,7)
						12.00 - 12.50	B25	
Recovered as light brown / white clayey / silty sand and gravel of CHALK. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint and chalk. (UPPER CHALK FORMATION)		13.00	-2.46			13.00	D26	
						13.50 - 13.95	D27	SPT(S) 13.50m, N=18 (3,3/3,5,6,4)
						13.50 - 14.00	B28	
. . .From 14.00m bgl: Fewer flint gravels.						14.50	D29	
						15.00	ES6	SPT(S) 15.00m, N=27 (4,5/5,7,7,8)
						15.00 - 15.45	D30	
						15.00 - 15.50	B31	
						16.00	D32	
						16.50 - 16.95	D33	SPT(S) 16.50m, N=34 (4,5/7,7,9,11)
						16.50 - 17.00	B34	
						17.50	D35	
						18.00 - 18.45	U-NR36	Ublows=145 Recovery=0%
						18.00 - 19.00	B38	
						18.50	U-NR37	Ublows=150 Recovery=0%
						19.50 - 19.95	D39	SPT(S) 19.50m, N=46 (7,7/9,11,13,13)
						19.50 - 20.00	B40	

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
Whilst drilling beneath landfill material in chalk, UXO engineer on site.
On completion BH backfilled / installed as per graphical log.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
					RD5	68

Groundwater						Project Number
Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks	**A102760**
11.50	11	*	20	9.70		

Project: **Brockhampton West**	Location Details			Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470104.28	Northing: 105703.67		DRAFT	**CP01**
Client: **Havant Borough Council**	Level: 10.54mAOD	Depth: 35.00m			Sheet 3 of 4
	Logger: SN	Type: CP			
		Inclination: 90°			

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time				Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	6.00	250	6.00	250						Approved By:
1.20	35.00	Cable Percussion	Dando 4000	RD Drilling	15.00	200	15.00	200						Start Date: 02/05/2017
					35.00	150	35.00	150						Finish Date: 04/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
Recovered as light brown / white clayey / silty sand and gravel of CHALK. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint and chalk. (UPPER CHALK FORMATION)						20.50	D41	
						21.00	D42	SPT(S) 21.00m, N=50 (7,7/12,12,13,13)
						21.00 - 21.50	B43	
						22.00	D44	
						22.50 - 23.00	B45	SPT(S) 22.50m, N=54 (7,9/12,12,14,16)
						23.50	D46	
						24.00 - 24.50	B48	SPT(S) 24.00m, 50 (25,25/50 for 19mm)
						25.00	D49	
						25.50 - 25.95	D50	SPT(S) 25.50m, 50 (9,14/50 for 225mm)
						25.50 - 26.00	B51	
						25.80 - 29.00	B57	
						26.50	D52	
						27.00 - 27.50	B54	SPT(S) 27.00m, 50 (9,12/50 for 120mm)
						28.00	D55	
						28.50 - 28.95	D56	SPT(S) 28.50m, 50 (7,9/50 for 60mm)
						29.50	D58	
						30.00 - 30.45	D59	SPT(S) 30.00m, 50 (10,15/50 for 50mm)
						30.00 - 30.50	B60	

Observations / Remarks	Chiselling			Water Added		Hammer Information	
Prior to excavation, BH location cleared of services by GPR / EM techniques. Hand excavated inspection pit from GL to 1.20m bgl. Whilst drilling beneath landfill material in chalk, UXO engineer on site. On completion BH backfilled / installed as per graphical log.	From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
						RDS	68

Groundwater						Project Number
Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks	**A102760**

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470104.28	Northing: 105703.67	DRAFT	**CP01**
Client: **Havant Borough Council**	Level: 10.54mAOD	Depth: 35.00m		Sheet 4 of 4
	Logger: SN	Type: CP		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time				Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth (m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	6.00	250	6.00	250						Approved By:
1.20	35.00	Cable Percussion	Dando 4000	RD Drilling	15.00	200	15.00	200						Start Date: 02/05/2017
					35.00	150	35.00	150						Finish Date: 04/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
Recovered as light brown / white clayey / silty sand and gravel of CHALK. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint and chalk. (UPPER CHALK FORMATION)						31.00	D61	
						31.50 - 31.95	D62	SPT(S) 31.50m, 50 (25,25/50 for 45mm)
						31.50 - 32.00	B63	
						32.50	D64	
						33.00 - 33.50	B67	SPT(C) 33.00m, 50 (25,25/50 for 23mm)
						34.50 - 35.00	B69	SPT(S) 34.50m, 50 (25,25/50 for 42mm)
EOH at 35.00m - Target Depth Achieved.		35.00	-24.46					

Observations / Remarks	Chiselling			Water Added		Hammer Information	
Prior to excavation, BH location cleared of services by GPR / EM techniques.	From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
Hand excavated inspection pit from GL to 1.20m bgl.	31.00	35.00	120			RDS	58
Whilst drilling beneath landfill material in chalk, UXO engineer on site.							
On completion BH backfilled / installed as per graphical log.							

Groundwater						Project Number
Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks	A102760

Project: **Brockhampton West**	Location Details	Status	Borehole Number
Location: **Harts Farm Way**	Easting: Northing:	DRAFT	**CP02**
Client: **Havant Borough Council**	Level: Depth: 3.00m		Sheet 1 of 1
	Logger: SN Type: CP		
	Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time					Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00	1.20	Inspection Pit: Cable Percussion	Insulated Tools Dando 4000	RD Drilling RD Drilling	2.00	250	3.00	250	04/05	00:00	2.00	0.00		Approved By:
2.20	3.00													Start Date: 04/05/2017
														Finish Date: 04/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over TOPSOIL.		0.05						
[MADE GROUND] ASPHALT		0.20						
[MADE GROUND] Metal, Asphalt, Rubble								
EOH at 3.00m - Obstruction at 2.00m bgl. Unable to progress BH beyond 3.00m		3.00						

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion, BH backfilled with arisings.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
2.00	2.30	75				

Groundwater						Project Number
Strike (m)	Casing (m)	Sealed (m)	Rise (mins)	Rose To (m)	Remarks	**A102760**

Project: **Brockhampton West**

Location: **Harts Farm Way**

Client: **Havant Borough Council**

Location Details			
Easting:	469988.77	Northing:	105575.68
Level:	10.79mAOD	Depth:	35.00m
Logger:	SN	Type:	CP
		Inclination:	90°

Status: **DRAFT**

Borehole Number: **CP02A**

Sheet 1 of 4

Method, Plant and Crew					Diameter	
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)
0.00	35.00	Cable Percussion	Dando 4000	RD Drilling	7.50	250
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	13.00	200
					35.00	150

Casing		Drilling Progress by Time				
Depth (m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)
7.50	250					
13.00	200					
35.00	150					

Scale: 1:50

Checked By:

Approved By:

Start Date: 04/05/2017

Finish Date: 08/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over TOPSOIL		0.10	10.69					
[MADE GROUND] Soft brown sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to well rounded, fine to coarse asphalt, brick, concrete and flint. With occasional angular to sub-angular concrete cobbles. (CAPPING LAYER)						0.20	D1	
. . At 0.20m bgl: Fragment of flat metal.						0.50 - 1.00	B2	
						0.75	ES1	PID 0.75m, 1.9ppm
						1.00 - 3.00	B3	
[MADE GROUND] Soft black / dark brown sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-angular fine to coarse concrete, glass, wood, plastic bags, rigid plastic, material & polystyrene. (LANDFILL)		2.00	8.79			2.10	ES2	PID 2.10m, 5.1ppm
						3.50 - 4.00	B5	SPT(C) 3.50m, N=24 (4,5/5,5,7,7)
						4.50	ES3	SPT(C) 4.50m, N=29 (4,4/6,7,8,8)
						4.50 - 5.00	B7	PID 4.50m, 5.1ppm
						5.50	B8	
						6.00 - 6.50	B10	SPT(C) 6.00m, N=16 (5,7/7,5,2,2)
						7.00	D11	PID 7.00m, 8.4ppm
						7.00	ES4	
						7.50 - 8.00	B13	SPT(C) 7.50m, 47 (7,9/47 for 225mm)
						8.50	D14	
								SPT(C) 9.00m, 0 (50 for 0mm/0 for 0mm)
Soft orange brown slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint. (ALLUVIUM)		9.50	1.29			9.50 - 10.00	B19	
						10.00	D21	PID 10.00m, 5.8ppm
						10.00	ES5	

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
Whilst drilling beneath landfill material in chalk, UXO engineer on site.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Seated No.	Energy Ratio %
1.40	6.00	72			RDS	68

Groundwater					
Strike (m)	Casing (m)	Sealed (m)	Time (mins)	Rose To (m)	Remarks
9.60	-	-	20	8.40	

Project Number: **A102760**

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 469988.77	Northing: 105575.68	DRAFT	**CP02A**
Client: **Havant Borough Council**	Level: 10.79mAOD	Depth: 35.00m		Sheet 2 of 4
	Logger: SN	Type: CP		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time					Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00	35.00	Cable Percussion	Dando 4000	RD Drilling	7.50	250	7.50	250						Approved By:
0.00	1.20	Inspection Pit	Inspection Tools	RD Drilling	13.00	200	13.00	200						Start Date: 04/05/2017
					35.00	150	35.00	150						Finish Date: 08/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
. . .From 10.00m bgl: becoming less gravelly and lighter in colour.						10.50 - 10.95 10.50 - 11.00	D20 B22	SPT(S) 10.50m, N=20 (4,4/5,5,5,5)
						12.00 - 12.50	B24	SPT(C) 12.00m, N=25 (4,5/6,6,7,7)
Recovered as cream / white slightly clayey sand & gravel of CHALK. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse chalk and flint. (UPPER CHALK FORMATION)		13.00	-2.21			13.00	D25	PID 13.00m, 0.0ppm
						13.50 13.50 - 14.00 13.50 - 17.00	D26 B27 B33	SPT(S) 13.50m, N=17 (4/4/4,4,4,5)
						14.00	D29	
								PID 14.50m, 0.0ppm
						15.00 15.00 - 15.50	D29 B30	SPT(S) 15.00m, N=22 (4,5/5,5,6,6)
						16.00 16.00	D28 D31	PID 16.00m, 0.0ppm
						16.50 - 16.95	D32	SPT(S) 16.50m, N=27 (1,1/5,7,7,8) PID 16.50m, 0.0ppm
								PID 17.00m, 0.0ppm
						17.50	D34	
						18.00 18.00 - 19.50	U-NR35 B37	Ublows=150 Recovery=0%
						19.00	U-NR36	Ublows=120 Recovery=0%
						19.50 - 19.95 19.50 - 20.00	D38 B39	SPT(S) 19.50m, N=40 (4,7/9,9,9,13) PID 19.50m, 0.0ppm
						20.00	ES6	PID 20.00m, 0.0ppm

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
Whilst drilling beneath landfill material in chalk, UXO engineer on site.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
					RD5	68

Groundwater						Project Number
Strike (m)	Casing (m)	Sealed (m)	Time (mins)	Rose To (m)	Remarks	**A102760**

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 469988.77	Northing: 105575.68	DRAFT	**CP02A**
Client: **Havant Borough Council**	Level: 10.79mAOD	Depth: 35.00m		Sheet 3 of 4
	Logger: SN	Type: CP		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time				Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00 0.00	35.00 1.20	Cable Percussion Inspection Pit	Dando 4000 Insulated Tools	RD Drilling RD Drilling	7.50 13.00 35.00	250 200 150	7.50 13.00 35.00	250 200 150						Approved By:
														Start Date: 04/05/2017
														Finish Date: 08/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
Recovered as cream / white slightly clayey sand & gravel of CHALK. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse chalk and flint. (UPPER CHALK FORMATION)						21.00 - 21.45 21.00 - 21.50	D40 B41	SPT(S) 21.00m, N=24 (3,4/6,6,6,6) PID 21.00m, 0.0ppm
						22.00	D42	PID 22.00m, 0.0ppm
						22.50 - 22.95	UN3	Ublows=150 Recovery=66%
						23.00	D44	
						23.50	D45	
						24.00 24.00 - 25.00	U-N046 B47	Ublows=150 Recovery=0%
						25.00 - 25.50	B48	SPT(C) 25.00m, 50 (10,10/50 for 30mm)
						26.50 - 26.95	D50	SPT(S) 26.50m, 50 (9,12/50 for 150mm)
						27.50	D58	
						28.00 - 28.10 28.00 - 28.50	D59 B60	SPT(S) 28.00m, 50 (9,12/50 for 150mm)
						29.00	D61	
						29.50 - 30.00	B63	SPT(C) 29.50m, 48 (9,15/48 for 156mm)

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
Whilst drilling beneath landfill material in chalk, UXO engineer on site.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
					RDS	68

Groundwater						Project Number
Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks	**A102760**

Project: **Brockhampton West**

Location: **Harts Farm Way**

Client: **Havant Borough Council**

Location Details				Status	Borehole Number
Easting:	469988.77	Northing:	105575.68	DRAFT	CP02A
Level:	10.79mAOD	Depth:	35.00m		Sheet 4 of 4
Logger:	SN	Type:	CP		
		Inclination:	90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time				Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00	35.00	Cable Percussion	Dando 4000	RD Drilling	7.50	250	7.50	250						Approved By:
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	13.00	200	13.00	200						Start Date: 04/05/2017
					35.00	150	35.00	150						Finish Date: 08/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
Recovered as cream / white slightly clayey sand & gravel of CHALK. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse chalk and flint. (UPPER CHALK FORMATION)						30.50	D64	
						31.00 - 31.50	B66	SPT(C) 31.00m, 50 (10,14/50 for 120mm)
						32.00	D67	
						32.50 - 33.00	B69	SPT(C) 32.50m, 50 (25,20/50 for 14mm)
						33.50	D70	
						34.50	D72	
EOH at 35.00m - Target Depth Achieved.		35.00	-24.21			35.00	D73	

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
Whilst drilling beneath landfill material in chalk, UXO engineer on site.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
					RDS	68

Groundwater						Project Number
Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks	A102760

Project: **Brockhampton West**	Location Details			Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470303.30	Northing: 105661.53		DRAFT	**CP03**
Client: **Havant Borough Council**	Level: 8.67mAOD	Depth: 35.00m			Sheet 1 of 4
	Logger: AH	Type: CP			
		Inclination: 90°			

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time					Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	10.00	250	10.00	250						Approved By:
1.20	35.00	Cable Percussion	Dando 4000	RD Drilling	14.00	200	14.00	200						Start Date: 09/05/2017
					35.00	150	35.00	150						Finish Date: 10/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over brown slightly clayey gravelly SAND. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint and brick. With frequent roots and rootlets. (TOPSOIL)						0.20 0.20 - 0.60	D1 B2	
[MADE GROUND] Orange brown and grey slightly sandy CLAY / SILT. Sad is fine and medium. With rare to occasional angular to sub-rounded fine and medium chalk and flint gravel (CAPPING LAYER)		0.60	8.07			0.60 - 1.00	B3	
[MADE GROUND] Black clayey gravelly SAND. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, brick, concrete and glass. With frequent fragments of metal, plastic and material. (LANDFILL)		1.10	7.57			1.00 1.20 1.20 - 1.79 1.40	ES1 D4 B5 ES2	PID 1.00m, 0.2ppm SPT(C) 1.20m, N=38 (7,7/8,8,11,11) PID 1.40m, 0.7ppm
						2.00 - 3.00	B6	SPT(C) 2.50m, 50 (7,9/50 for 225mm)
[MADE GROUND] Firm to stiff grey / brown slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, brick, concrete and chalk. (CAPPING LAYER)		3.20	5.47			3.20 3.50 - 4.00 3.70	D9 B11 ES3	SPT(C) 3.50m, N=54 (7,9/10,11,16,17) PID 3.70m, 0.5ppm
[MADE GROUND] Black / grey slightly clayey gravelly SAND. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, brick, concrete and chalk. (CAPPING LAYER)		4.50	4.17			4.50 - 5.00 4.80	B13 ES4	SPT(C) 4.50m, N=45 (5,9/10,11,11,14) PID 4.80m, 1.0ppm
[MADE GROUND] Firm grey / brown slightly sandy to sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, brick, concrete and chalk. With frequent fragments of metal, glass , plastic and fabric. (LANDFILL) *. . .From 7.80m bgl: With rare metal, glass, plastic and fabric.*		5.50	3.17			5.50 6.00 - 6.50 7.00 7.50 - 8.00	D14 B16 D17 B19	SPT(C) 6.00m, 0 (50 for 0mm/0 for 0mm) SPT(C) 7.50m, N=40 (7,9/7,9,10,14)
Grey/ brown slightly clayey slightly sandy GRAVEL. Sand is fine to coarse. Gravel is sub-angular to well rounded, fine to coarse flint. (RIVER TERRACE DEPOSIT)		8.20	0.47	▼		8.20 - 8.50 9.00 - 9.50 10.00	B20 B22 D23	SPT(C) 9.00m, N=34 (5,7/8,8,9,9)

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
Whilst drilling beneath landfill material in chalk, UXO engineer on site.
On completion BH backfilled / installed as per graphical log.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
5.50	6.50	120			RDS RD	68

Groundwater						Project Number
Strike (m)	Casing (m)	Settled (m)	Time (min)	Rose To (m)	Remarks	**A102760**

Project: **Brockhampton West**	Location Details	Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470303.30 Northing: 105661.53	**DRAFT**	**CP03**
Client: **Havant Borough Council**	Level: 8.67mAOD Depth: 35.00m		Sheet 2 of 4
	Logger: AH Type: CP		
	Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time					
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	
0.00	1.20	Inspection Pit	Installated Tools	RD Drilling	80.00	350	10.00	200						
1.20	35.00	Cable Percussion	Dando 4000	RD Drilling	84.00	200	14.00	200						
					35.00	150	35.00	150						

Scale: 1:50
Checked By:
Approved By:
Start Date: 09/05/2017
Finish Date: 10/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
. . .From 10.50m bgl: With comminuted putty chalk.						10.50 - 11.00	B25	SPT(C) 10.50m, N=33 (4,5/7,7,8,11)
						11.50	D26	
						12.00 - 12.50	B28	SPT(C) 12.00m, N=38 (4,6/9,9,10,10)
						13.00	D29	
						13.50 - 14.00	B31	SPT(C) 13.50m, N=34 (7,7/8,8,9,9)
Recovered as gravelly SILT of CHALK. Gravel is sub-angular, fine to coarse flint and extremely weak to weak cream white chalk. (UPPER CHALK FORMATION)		14.00	-5.33			14.50	D32	
						15.00 - 15.45 15.00 - 15.50	D33 B34	SPT(S) 15.00m, N=20 (4,4/5,5,5,5)
						16.00	D35	
						16.50 - 16.95 16.50 - 17.00	D36 B37	SPT(S) 16.50m, N=27 (4,6/6,7,7,7)
						17.00	D38	
						18.00 - 18.45 18.00 - 18.50	D39 B40	SPT(S) 18.00m, N=50 (4,4/10,10,15,15)
						19.00	D41	
						19.50 - 19.95 19.50 - 20.00	D42 B43	SPT(S) 19.50m, N=42 (4,7/8,11,11,12)

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EMI techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
Whilst drilling beneath landfill material in chalk, UXO engineer on site.
On completion BH backfilled / installed as per graphical log.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
					RDS RD	68

Groundwater					
Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks
30.50	-	-	20	8.30	

Project Number
A102760

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470303.30	Northing: 105561.53	DRAFT	**CP03**
Client: **Havant Borough Council**	Level: 8.67mAOD	Depth: 35.00m		Sheet 3 of 4
	Logger: AH	Type: CP		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time				Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	18.00	250	10.00	255						Approved By:
1.20	35.00	Cable Percussion	Dando 4000	RD Drilling	34.00	200	14.00	200						Start Date: 09/05/2017
					35.00	150	35.00	150						Finish Date: 10/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing			
						Depth (m)	Ref	Tests / Results	
Recovered as gravelly SILT of CHALK. Gravel is sub-angular, fine to coarse flint and extremely weak to weak cream white chalk. (UPPER CHALK FORMATION)						20.50	D44		
						21.00 - 21.50	B46	SPT(C) 21.00m, N=50 (7,9/12,12,13,13)	21
						22.00	D47		22
						22.50 - 23.00	B48	SPT(C) 22.50m, N=28 (4,5/6,7,7,8)	
						23.50	D50		23
						24.00	B55	SPT(C) 24.00m, N=43 (4,5/9,9,10,15)	
						24.00 - 24.50	B52	FID 24.00m, 0.00ppm	24
						25.00	D53		25
						25.50 - 26.00	B55	SPT(C) 25.50m, N=54 (8,9/10,12,15,17)	
						26.50	D56		26
						27.00 - 27.50	B58	SPT(C) 27.00m, 50 (9,10/50 for 225mm)	27
						28.00	D59		28
						28.50 - 29.00	B61	SPT(C) 28.50m, 50 (9,12/50 for 105mm)	
						29.50	D62		29
						30.00 - 32.00	B65	SPT(C) 30.00m, 50 (25,50/50 for 75mm)	30

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
Whilst drilling beneath landfill material in chalk, UXO engineer on site.
On completion BH backfilled / installed as per graphical log.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
					RDS RD	68

Groundwater						Project Number
Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks	**A102760**

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470303.30	Northing: 106561.53	DRAFT	**CP03**
Client: **Havant Borough Council**	Level: 8.67mAOD	Depth: 35.00m		Sheet 4 of 4
	Logger: AH	Type: CP		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time					Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	10.00	150	10.00	250						Approved By:
1.20	35.00	Cable Percussion	Dando 4000	RD Drilling	14.00	200	14.00	200						Start Date: 09/05/2017
					35.00	150	35.00	150						Finish Date: 10/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
Recovered as gravelly SILT of CHALK. Gravel is sub-angular, fine to coarse flint and extremely weak to weak cream white chalk. (UPPER CHALK FORMATION)								
								SPT(C) 31.60m, 0 (50 for 10mm/0 for 0mm)
						33.00 - 33.50	B67	SPT(C) 33.00m, 50 (25,20/50 for 27mm)
						34.00	D68	
						34.50 - 35.00	B70	SPT(C) 34.50m, 50 (25,32/50 for 40mm)
EOH at 35.00m - Target Depth Achieved.		35.00	-26.33					

31 32 33 34 35 36 37 38 39 40

Observations / Remarks	Chiselling			Water Added		Hammer Information	
Prior to excavation, BH location cleared of services by GPR / EM techniques.	From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
Hand excavated inspection pit from GL to 1.20m bgl.	34.00	35.00	75			RDS RD	68
Whilst drilling beneath landfill material in chalk, UXO engineer on site.							
On completion BH backfilled / installed as per graphical log.	Groundwater					Project Number	
	Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks	A102760

Project: **Brockhampton West**	Location Details	Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470021.09 Northing: 105669.84	**DRAFT**	**CP04**
Client: **Havant Borough Council**	Level: 11.52mAOD Depth: 9.70m		Sheet 1 of 1
	Logger: SN Type: CP		
	Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time					
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	
0.00 1.20	1.20 9.70	Inspection Pit Cable Percussion	Insulated Tools Imaste 4000	SD Drilling RD Drilling	9.70	150	9.70	150						

Scale:	1:50
Checked By:	
Approved By:	
Start Date:	11/05/2017
Finish Date:	11/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over soft light brown sandy gravelly CLAY. Sand is fine to coarse. Gravel is sub-angular to well rounded, fine to coarse flint. (CAPPING LAYER)						0.20 0.20 - 1.00 0.50 1.30 1.30 - 2.00	D1 B2 ES1 D3 B5	PID 0.50m, 0.7ppm SPT(C) 1.30m, N=28 (7,7/8,8,8,4)
[MADE GROUND] Soft black / white / grey mottled sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular brick and flint. (CAPPING LAYER)		2.50	9.02			2.50 2.50 - 3.00	ES2 B7	SPT(C) 2.50m, 0 (50 for 0mm/0 for 0mm) PID 2.50m, 2.5ppm
[MADE GROUND] Black slightly clayey SAND & GRAVEL. Sand is fine to coarse. Gravel to sub-rounded, fine to coarse metal, glass, wood and occasional flint. With paper and material. (LANDFILL)		3.50	8.02			3.50 - 4.00 4.50 4.50 - 5.00 5.50 - 6.00 6.50 7.00 7.00 - 7.50 8.00	B9 ES2 B11 B13 D14 ES4 B16 D17	SPT(C) 3.50m, 50 (9,14/50 for 125mm) SPT(C) 4.50m, 50 (7,9/50 for 225mm) PID 4.50m, 36.1ppm SPT(C) 5.50m, N=41 (7,9/9,10,11,11) SPT(C) 7.00m, N=31 (4,5/7,7,8,9) PID 7.00m, 57.3ppm
Soft to firm brown silty CLAY. (ALLUVIUM)		8.20	3.32			8.20 - 8.65 9.20	U18 D19	SPT(S) 9.20m, N=18 (3,3/4,4,5,5)
EOH at 9.70m - Target Depth Achieved.		9.70	1.82					

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
2.50	2.90	60			RDS	68

Groundwater					
Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks
6.30	-	-	20	6.15	

Project Number: **A102760**

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470122.58	Northing: 105594.66	DRAFT	**CP05**
Client: **Havant Borough Council**	Level: 9.56mAOD	Depth: 11.95m		Sheet 1 of 2
	Logger: AH	Type: CP		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time					Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00 1.20	1.20 11.95	Inspection Pit Cable Percussion	Insulated Tools Dando 2000	6D Drilling RD Drilling	11.95	150	11.95	150						Approved By:
														Start Date: 08/05/2017
														Finish Date: 08/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over TOPSOIL.		0.10	9.46					
[MADE GROUND] Soft to firm dark brown slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse chalk, flint and brick. (CAPPING LAYER)						0.20 0.30 0.50 - 1.00	ES1 D1 B2	PID 0.20m, 0.0ppm
[MADE GROUND] Soft to firm greenish grey slightly sandy to sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine and medium flint and brick. (CAPPING LAYER)		1.00	8.56			1.00 1.20 - 1.65	D3 U4	UBlows=40 Recovery=100%
						2.00 2.00 - 2.45 2.00 - 2.50	ES2 D5 B6	SPT(S) 2.00m, N=18 (3,2/3,3,5,7) PID 2.00m, 0.0ppm
						3.00 3.00 - 3.45	D7 U8	UBlows=65 Recovery=78%
[MADE GROND] Black slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint, polystyrene and metal. With frequent paper and wood fragments. (LANDFILL) *. . .At 5.00m bgl: 10-12mm thick rubber sheet.* *. . .Between 5.00m and 6.50m bgl: Frequent / abundant wood fragments. With rare metal and plastic.*		4.00	5.56			4.00 - 4.45 4.00 - 4.50 4.20	D9 B10 ES3	SPT(S) 4.00m, N=27 (12,10/10,9,7,1) PID 4.20m, 2.0ppm
						5.00 5.00 - 6.50	D11 B12	SPT(C) 5.00m, N=36 (6,8/8,10,9,9)
						6.00	ES4	PID 6.00m, 1.1ppm
								SPT(C) 6.50m, N=9 (2,2/3,2,2,2)
						7.00	D15	
								SPT(C) 8.00m, N=17 (5,5/4,3,6,4)
[MADE GROUND] Black / dark grey clayey sandy GRAVEL. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint. With fragments of wood, metal and plastic. (LANDFILL)		9.50	0.06			9.50 9.50 - 10.00	ES5 B18	SPT(C) 9.50m, N=14 (6,5/4,4,2,4) PID 9.50m, 0.3ppm

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
3.90 9.40	4.10 9.80	30 45			AR323	69

Groundwater						Project Number
Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks	**A102760**
5.90	-	-	15	5.50		

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470122.58	Northing: 105594.66	**DRAFT**	**CP05**
Client: **Havant Borough Council**	Level: 9.56mAOD	Depth: 11.95m		Sheet 2 of 2
	Logger: AH	Type: CP		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time				Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00 1.20	1.20 11.95	Inspection Pit Cable Percussion	Insitutool Tools Dando 2000	RD Drilling RD Drilling	11.95	150	11.95	150						Approved By: Start Date: 08/05/2017 Finish Date: 08/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
. . At 9.50m bgl: Large piece of metal.						10.50	D19	
Recovered as cream / grey white gravelly SILT of CHALK. Gravel is sub-angular to sub-rounded, fine and medium extremely weak chalk. (UPPER CHALK FORMATION)		11.50	-1.94			11.50 - 11.95	D20	SPT(S) 11.50m, N=30 (4,6/7,7,7,9)
EOH at 11.95m - Target Depth Achieved.		11.95	-2.39					

11 12 13 14 15 16 17 18 19 20

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
					AR323	69

Groundwater						Project Number
Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks	**A102760**

Project: **Brockhampton West**

Location: **Harts Farm Way**

Client: **Havant Borough Council**

Location Details			
Easting:	470206.36	Northing:	105775.84
Level:	12.40mAOD	Depth:	11.00m
Logger:	SN / AH+SN/ AH	Type:	CP
		Inclination:	90°

Status: **DRAFT**

Borehole Number: **CP06**

Sheet 1 of 2

Method, Plant and Crew					Diameter	
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	11.00	150
1.20	11.00	Cable Percussion	Dando 4000	RD Drilling		

Casing		Drilling Progress by Time				
Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)
11.00	150					

Scale: 1:50
Checked By:
Approved By:
Start Date: 11/05/2017
Finish Date: 11/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over soft light brown sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint and brick. (CAPPING LAYER)						0.20	D1	
						0.20 - 1.00	B2	
						0.90	ES1	PID 0.50m, 0.3ppm
						1.20	D3	
						1.20 - 1.65	U4	
						1.70	D5	
[MADE GROUND] Black / multi-coloured slightly clayey SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse brick, plastic and wood. With pieces of carpet. Foul / rotten type odour noted. (LANDFILL)		2.50	9.90			2.50	ES2	SPT(C) 2.50m, 50 (7,19/50 for 90mm)
						2.50 - 3.00	B7	PID 2.50m, 26.3ppm
						3.50 - 4.00	B9	SPT(C) 3.50m, 0 (50 for 0mm/0 for 0mm)
						4.50 - 5.00	D13	SPT(C) 4.50m, 0 (50 for 5mm/0 for 0mm)
						5.00	ES3	PID 5.00m, 7.3ppm
								SPT(C) 5.50m, 0 (50 for 25mm/0 for 0mm)
						7.00	ES4	SPT(C) 7.00m, 50 (25 for 50mm/50 for 30mm)
						7.00 - 7.50	B14	PID 7.00m, 4.9ppm
						8.50 - 9.00	B16	SPT(C) 8.50m, 50 (25,20/50 for 47mm)
Recovered as cream white / brown sandy GRAVEL. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint and occasional weak white chalk. (RIVER TERRACE DEPOSIT)		9.30	3.10					SPT(C) 9.50m, 50 (9,12/50 for 30mm)

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.

Chiselling			Water Added		Hammer Information	
From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
4.50	4.80	60			RD5	58

Groundwater					
Strike (m)	Casing (m)	Sealed (m)	Time (min)	Rose To (m)	Remarks
4.50	-	-	20	4.00	

Project Number: **A102760**

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470206.36	Northing: 105775.84	DRAFT	**CP06**
Client: **Havant Borough Council**	Level: 12.40mAOD	Depth: 11.00m		Sheet 2 of 2
	Logger: SN / AH-SN/ AH	Type: CP		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Drilling Progress by Time				Scale: 1:50
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Date	Time	Depth (m)	Casing (m)	Water (m)	Checked By:
0.00 1.20	1.20 11.00	Inspection Pit Cable Percussion	Installed Tools Dando 4000	RD Drilling RD Drilling	11.00	150	11.00	150						Approved By:
														Start Date: 11/05/2017
														Finish Date: 11/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
Recovered as cream white / brown sandy GRAVEL. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint and occasional weak white chalk. (RIVER TERRACE DEPOSIT)								SPT(C) 10.70m, 0 (50 for 0mm/0 for 0mm)
EOH at 11.00m - Target Depth Achieved.		11.00	1.40					

DRAFT

Observations / Remarks	Chiselling			Water Added		Hammer Information	
Prior to excavation, BH location cleared of services by GPR / EM techniques. Hand excavated inspection pit from GL to 1.20m bgl. On completion BH backfilled / installed as per graphical log.	From (m)	To (m)	Time (mins)	From (m)	To (m)	Serial No.	Energy Ratio %
						RDS	68

Groundwater						Project Number
Strike (m)	Casing (m)	Sealed (m)	Time (mins)	Rose To (m)	Remarks	**A102760**

Project: **Brockhampton West** Location: **Harts Farm Way** Client: **Havant Borough Council**	Location Details Easting: 469964.63 Northing: 105680.10 Level: 11.07mAOD Depth: 3.40m Logger: SN Type: TP	Status **DRAFT**	Pit Number **TP01** Sheet 1 of 1

Hole Information		Groundwater				
Pit Dimensions	Orientation: °	Strike (m)	Rose To (m)	After (mins)	Remarks	Scale: 1:25
0.60m / 3.00m	Shoring: None Stability: Stable Plant: 8T Tracked					Checked By: Approved By: Start Date: 09/05/2017 Finish Date: 09/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over firm orange / light brown slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is angular to well rounded, fine to coarse flint, chalk and sandstone. (TOPSOIL)								
[MADE GROUND] Soft dark brown slightly gravelly sandy CLAY. Sand is fine to coarse. Gravel is angular to sub-angular flint and brick. (CAPPING LAYER)		0.30	10.77			0.30 0.30 0.30	B1 D1 ES1	PID 0.0m, 0.2ppm
						0.70 0.70 0.70	B2 D2 ES2	PID 0.7m, 0.2ppm
[MADE GROUND] Stiff white slightly gravelly CLAY. Gravel is angular to sub-angular, fine to coarse flint and brick. (CAPPING LAYER)		0.90	10.17					
						1.10 1.10 1.10	B3 D3 ES3	PID 1.1m, 0.2ppm
[MADE GROUND] Landfill waste. SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse glass, metal, wood. With frequent plastic sheeting, food tins, house hold cleaning products, material, plastic and wires. Slight rotten type odour noted. (LANDFILL) *. . .Between 1.30m and 3.40m bgl: Papers dated 1976.*		1.30	9.77					
						1.90 1.90 1.90	B4 D4 ES4	PID 1.9m, 31.0ppm
EOH at 3.40m - Target Depth Achieved.		3.40	7.67			3.40 3.40 3.40	B5 D5 ES5	PID 3.4m, 77.7ppm

Observations / Remarks

Prior to excavation, trial pit location cleared of services by GPR / EM techniques.
On completion trial pit backfilled with arisings.
No groundwater encountered during investigation.

Project Number
A102760

Project: **Brockhampton West**	Location Details		Status	Pit Number
Location: **Harts Farm Way**	Easting: 470136.24	Northing: 105724.30	DRAFT	**TP02**
Client: **Havant Borough Council**	Level: 9.51mAOD	Depth: 3.60m		Sheet 1 of 1
	Logger: SN	Type: TP		

Hole Information		Groundwater				
Pit Dimensions	Orientation: °	Strike (m)	Rose To (m)	After (mins)	Remarks	Scale: 1:25
0.60m / 4.00m	Shoring: None					Checked By:
	Stability: Stable					Approved By:
	Plant: 8T Tracked					Start Date: 10/05/2017
						Finish Date: 10/07/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Soft brown slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flit and chalk. With occasional iron pipe and concrete kerbstone. (CAPPING LAYER) *. . .Between 0.30m and 0.50m bgl: Light brown in colour.*								
[MADE GROUND] Light grey slightly clayey slightly gravelly SAND. Sand is fine to coarse. Gravel is sub-rounded to rounded flint. Clay is observed as pockets / lenses. (CAPPING LAYER)		0.90	8.61			1.00 1.00 1.00	B1 D1 ES1	PID 1.00m, 0.5ppm
[MADE GROUND] Soft light grey / black / white mottled sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-angular, fine to coarse chalk, flint and occasional brick. (CAPPING LAYER)		1.70	7.81			2.30 2.30 2.30	B3 D2 ES2	PID 2.30m, 0.9ppm
[MADE GROUND] Black / grey / multi-coloured slightly clayey sandy GRAVEL. Sand is fine to coarse. Gravel is angular to sub-angular, fine to coarse glass, wood and plastic. With frequent plastic bags, glass bottles and cloth / material. (LANDFILL)		2.40	7.11					PID 3.50m, 13.9ppm
EOH at 3.60m - Target Depth Achieved.		3.60	5.91					

Observations / Remarks

Prior to excavation, trial pit location cleared of services by GPR / EM techniques.
On completion trial pit backfilled with arisings.
No groundwater encountered during investigation.

Project Number
A102760

Project: **Brockhampton West** Location: **Harts Farm Way** Client: **Havant Borough Council**	Location Details Easting: 470085.83 Northing: 105670.83 Level: 10.24mAOD Depth: 3.40m Logger: SN Type: TP	Status **DRAFT**	Pit Number **TP03** Sheet 1 of 1

Hole Information		Groundwater				
Pit Dimensions	Orientation: °	Strike (m)	Rose To (m)	After (mins)	Remarks	Scale: 1:25
0.60m / 4.00m	Shoring: None Stability: Stable Plant: 8T Tracked					Checked By: Approved By: Start Date: 09/05/2017 Finish Date: 09/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass and topsoil over soft light brown sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-angular, fine to coarse brick, concrete, sandstone, chalk and flint. Occasional fragments of 25mm pipe. (CAPPING LAYER)						0.40 0.40 0.40	B1 D1 ES1	PID 0.40m, 0.0ppm
[MADE GROUND] Soft pink / light red mottled grey sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded flint. (CAPPING LAYER)		0.70	9.54			1.20 1.20 1.20	B2 D2 ES2	PID 1.20m, 0.1ppm
[MADE GROUND] White firm crumbly slightly gravelly CLAY. Gravel is sub-angular to sub-rounded, fine and medium flint and chalk. (CAPPING LAYER)		1.40	8.84					
[MADE GROUND] Soft orange mottled grey sandy CLAY. Sand is fine to coarse. (CAPPING LAYER)		1.60	8.64			1.80 1.80 1.80	B3 D3 ES3	PID 1.80m, 0.0ppm
[MADE GROUND] Black clayey SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-angular , fine to coarse glass, plastic, metal and wood. With frequent plastic, microwave parts, plastic bags, lino, foam, whole tyres, food mixer parts (Kenwood). With moderate rotten type odour. (LANDILL)		2.10	8.14			3.00 3.00 3.00	B4 D4 ES4	PID 3.00m, 17.2ppm
EOH at 3.40m - Target Depth Achieved.		3.40	6.84					

Observations / Remarks

Prior to excavation, trial pit location cleared of services by GPR / EM techniques.
On completion trial pit backfilled with arisings.
No groundwater encountered during investigation.

Project Number
A102760

Project: **Brockhampton West**	Location Details		Status	Pit Number
Location: **Harts Farm Way**	Easting: 470107.40	Northing: 105638.54	DRAFT	**TP04**
Client: **Havant Borough Council**	Level: 9.92mAOD	Depth: 3.30m		Sheet 1 of 1
	Logger: SN	Type: TP		

Hole Information		Groundwater				
Pit Dimensions	Orientation: °	Strike (m)	Rose To (m)	After (mins)	Remarks	Scale: 1:25
0.60m / 4.00m	Shoring: None					Checked By:
	Stability: Stable					Approved By:
	Plant: 8T Tracked					Start Date: 09/05/2017
						Finish Date: 09/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over light brown TOPSOIL.								
[MADE GROUND] Soft light brown sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-angular, fine to coarse flint, brick and chalk, with occasional glass and breeze block. (CAPPING LAYER)		0.20	9.72					
[MADE GROUND] Soft to firm mottled grey / pink slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine and medium flint and chalk, with occasional brick. (CAPPING LAYER)		0.50	9.42			0.00 0.60 0.60	B1 D1 ES1	PID 0.60m, 0.8ppm
[MADE GROUND] Very soft grey / white sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint and brick. With occasional full bricks. (CAPPING LAYER)		1.20	8.72			1.20 1.20 1.20	B2 D2 ES2	PID 1.20m, 0.1ppm
[MADE GROUND] Black / grey / brown slightly clayey SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse slate, metal & brick. With plastic sheet and material. Rotten type odour noted. (LANDFILL)		3.00	6.92					
EOH at 3.30m - Target Depth Achieved.		3.30	6.62			3.30 3.30 3.30	B3 D3 ES3	PID 3.30m, 57.8ppm

Observations / Remarks

Prior to excavation, trial pit location cleared of services by GPR / EM techniques.
On completion trial pit backfilled with arisings.
No groundwater encountered during investigation.

Project Number

A102760

Project: **Brockhampton West**	Location Details		Status	Pit Number
Location: **Harts Farm Way**	Easting: 470213.62	Northing: 105689.69	**DRAFT**	**TP05**
Client: **Havant Borough Council**	Level: 12.62mAOD	Depth: 3.10m		Sheet 1 of 1
	Logger: SN	Type: TP		

Hole Information		Groundwater				
Pit Dimensions	Orientation: °	Strike (m)	Rose To (m)	After (mins)	Remarks	Scale: 1:25
0.60m / 4.20m	Shoring: None					Checked By:
	Stability: Stable					Approved By:
	Plant: 8T tracked					Start Date: 10/05/2017
						Finish Date: 10/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over light brown sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-angular, fine to coarse flint, chalk and brick. With occasional cobbles of concrete paving slab and whole tyre. (LANDFILL)						1.00 1.00 1.00	B1 D1 ES1	PID 1.00m, 0.2ppm
[MADE GROUND] Black SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-angular, fine to coarse wood, glass and metal. With frequent plastic bags, carpet, material / cloth, paper, tyres, plastic bottles and rain macks. With incinerator ash / clinker. Ashy / burnt type odour noted. (LANDFILL)		1.40	11.22			2.40 2.40 2.40	B2 D2 ES2	PID 2.40m, 5.8ppm
EOH at 3.10m - Target Depth Achieved.		3.10	9.52			3.10 3.10 3.10	B3 D3 ES3	PID 3.10m, 4.9ppm

1 2 3 4 5

Observations / Remarks

Prior to excavation, trial pit location cleared of services by GPR / EM techniques.
On completion trial pit backfilled with arisings.
No groundwater encountered during investigation.

Project Number
A102760

Project: **Brockhampton West**	Location Details		Status	Pit Number
Location: **Harts Farm Way**	Easting: 470237.94	Northing: 105732.12	DRAFT	**TP06**
Client: **Havant Borough Council**	Level: 12.99mAOD	Depth: 3.10m		Sheet 1 of 1
	Logger: SN	Type: TP		

Hole Information		Groundwater				
Pit Dimensions: 0.60m x 4.00m	Orientation: °	Strike (m)	Rose To (m)	After (mins)	Remarks	Scale: 1:25
	Shoring: None					Checked By:
	Stability: Stable					Approved By:
	Plant: 8T Tracked					Start Date: 10/05/2017
						Finish Date: 24/07/2000

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over soft light brown slightly sandy CLAY. Sand is fine to coarse. (TOPSOIL)								
[MADE GROUND] Orange slightly gravelly SAND with pockets of clay. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint. (CAPPING LAYER)		0.20	12.79			0.50 0.50 0.50	B1 D1 ES1	PID 0.50m, 0.0ppm
[MADE GROUND] Soft slightly sandy gravelly CLAY. Sand is fine to coarse. gravel is angular to sub-angular, fine to coarse flint, brick and chalk. (CAPPING LAYER)		0.80	12.19					
[MADE GROUND] Black / multi-coloured SAND & GRAVEL. Sand is fine to coarse. Gravel is fine to coarse of landfill waste, including; plastic bottles, carrier bags, books, wood, carpet, material, food wrappers and magazines. With foul / rotten type odour. (LANDFILL)		0.90	12.09			2.00 2.00 2.00	B2 D2 ES2	PID 2.00m, 2.3ppm
EOH at 3.10m - Target Depth Achieved.		3.10	9.89			3.10 3.10 3.10	B3 D3 ES3	PID 3.10m, 5.0ppm

Observations / Remarks

Prior to excavation, trial pit location cleared of services by GPR / EM techniques.
On completion trial pit backfilled with arisings.
No groundwater encountered during investigation.

Project Number
A102760

Project: **Brockhampton West** Location: **Harts Farm Way** Client: **Havant Borough Council**	Location Details Easting: 470129.00 Northing: 105625.04 Level: 9.73mAOD Depth: 3.30m Logger: SN Type: TP	Status DRAFT	Pit Number **TP07** Sheet 1 of 1

Hole Information		Groundwater				
Pit Dimensions	Orientation: °	Strike (m)	Rose To (m)	After (mins)	Remarks	Scale: 1:25
0.60m	Shoring: None					Checked By:
3.00m	Stability: Stable					Approved By:
	Plant: 8T Tracked					Start Date: 09/05/2017
						Finish Date: 10/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass and topsoil over light brown slightly clayey slightly gravelly SAND. Sand is fine to coarse. Gravel is angular to sub-angular, fine to coarse chalk, flint and brick. (CAPPING LAYER)								
[MADE GROUND] Orange / light brown slightly gravelly SAND. Sand is fine to coarse. Gravel is sub-rounded, fine and medium flint. (CAPPING LAYER)		1.00	8.73					
..From 1.20m bgl: Becoming grey in colour.						1.20 1.20 1.20	B1 D1 ES1	PID 1.20m, 0.0ppm
..From 2.00m bgl: Becoming clayey, darker in colour and with brick gravels.						2.50 2.50 2.50	B2 D2 ES2	PID 2.50m, 0.2ppm
[MADE GROUND] Black / dark grey slightly clayey SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-angular fine to coarse wood, plastic and metal. With building materials, paint tins, wooden boards, insulation, crushed petrol can, shoes, cardboard and phone books. Rotten type odour noted. (LANDFILL)		2.70	7.03					
EOH at 3.30m - Target Depth Achieved.		3.30	6.43			3.30 3.30 3.30	B3 D3 ES3	PID 3.30m, 5.5ppm

Observations / Remarks

Prior to excavation, trial pit location cleared of services by GPR / EM techniques.
On completion trial pit backfilled with arisings.
No groundwater encountered during investigation.

Project Number
A102760

Project: Brockhampton West Location: Harts Farm Way Client: Havant Borough Council	Location Details Easting: 470242.97 Northing: 105676.06 Level: 11.31mAOD Depth: 3.20m Logger: SN Type: TP	Status DRAFT	Pit Number TP08 Sheet 1 of 1	

Hole Information		Groundwater				
Pit Dimensions	Orientation: *	Strike (m)	Rose To (m)	After (mins)	Remarks	Scale: 1:25
0.60m / 4.00m	Shoring: None Stability: Stable Plant: 8T Tracked					Checked By: Approved By: Start Date: 10/05/2017 Finish Date: 10/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over soft light brown sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint, brick and chalk. With large boulder of concrete (1.00m x 0.75m). (CAPPING LAYER)						0.50 0.50 0.50	B1 D1 ES1	PID 0.50m, 0.5ppm
[MADE GROUND] Black slightly clayey SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-angular, fine to coarse concrete, wood, metal, brick, glass and plastic. With plastic bags, cloth, foam, a bike and incinerator type ash. Slight rotten type odour noted. (LANDFILL) *. . .Between 1.00m and 3.20m bgl: More "modern" packaging on this side of the site. Letter dated 1982.*		1.00	10.31			2.30 2.30 2.30	B2 D2 ES2	PID 2.30m, 72.7ppm
EOH at 3.20m - Target Depth Achieved.		3.20	8.11			3.20 3.20 3.20	B3 D3 ES3	PID 3.20m, 11.5ppm

Observations / Remarks

Prior to excavation, trial pit location cleared of services by GPR / EM techniques.
On completion trial pit backfilled with arisings.
No groundwater encountered during investigation.

Project Number
A102760

Project: **Brockhampton West**	Location Details	Status	Pit Number
Location: **Harts Farm Way**	Easting: 470205.12 Northing: 105637.00	**DRAFT**	**TP09**
Client: **Havant Borough Council**	Level: 8.17mAOD Depth: 4.00m		Sheet 1 of 1
	Logger: SN Type: TP		

Hole Information		Groundwater				
Pit Dimensions	Orientation: °	Strike (m)	Rose To (m)	After (mins)	Remarks	Scale: 1:25
0.60m / 4.00m	Shoring: None	3.90	3.70	10		Checked By:
	Stability: Stable					Approved By:
	Plant: 8T Tracked					Start Date: 10/05/2017
						Finish Date: 10/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] ASPHALT.		0.05	8.12					
[MADE GROUND] Orange / brown SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-angular of sandstone (TYPE I ROADSTONE SUB-BASE).		0.30	7.87					
[MADE GROUND] Very dark brown / black SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-rounded, fine and medium flint, brick and occasional chalk. (CAPPING LAYER)		0.50	7.67			0.40 0.40 0.40	B1 D1 ES1	PID 0.4Om, 0.4ppm
[MADE GROUND] Soft to firm light brown slightly gravelly CLAY. Gravel is angular to sub-rounded, fine to coarse flint and chalk. (CAPPING LAYER) *. . .From 0.90m bgl: Becoming sandy.* *. . .At 1.00m bgl: Paving stone.*						0.60 0.60 0.60	B2 D2 ES2	PID 0.60m, 0.4ppm
						2.00 2.00 2.00	B3 D3 ES3	PID 2.00m, 0.5ppm
[MADE GROUND] Soft mottled grey brown gravelly CLAY. Gravel is angular to sub-angular, fine to coarse brick, chalk and flint. With occasional pockets of fine to coarse sand.. With black rootlets and staining. (CAPPING LAYER)		2.50	5.67					
[MADE GROUND] Black slightly clayey SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-angular, fine to coarse wood, glass, plastic, metal, brick, flint and breeze block. With material. (LANDFILL)		3.50	4.67			3.80 3.80 3.80	B4 D4 ES4	PID 3.80m, 16.9ppm
EOH at 4.00m - Target Depth Achieved.		4.00	4.17					

Observations / Remarks

Prior to excavation, trial pit location cleared of services by GPR / EM techniques.
On completion trial pit backfilled with arisings.

Project Number
A102760

Project: **Brockhampton West**	Location Details		Status	Pit Number
Location: **Harts Farm Way**	Easting: 470155.97	Northing: 105668.17	DRAFT	**TP10**
Client: **Havant Borough Council**	Level: 9.94mAOD	Depth: 3.40m		Sheet 1 of 1
	Logger: SN	Type: TP		

Hole Information		Groundwater					
Pit Dimensions	Orientation: °	Strike (m)	Rose To (m)	After (mins)	Remarks	Scale:	1:25
0.60m × 3.70m	Shoring: None					Checked By:	
	Stability: Stable					Approved By:	
	Plant: 8T Tracker					Start Date:	09/05/2017
						Finish Date:	09/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Soft light brown sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse brick, flint, concrete and occasional asphalt. (CAPPING LAYER)								
[MADE GROUND] Orange SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-angular, fine to coarse brick. Occasional fragments of metal and pottery. (CAPPING LAYER)		0.70	9.24			0.80 0.80 0.80	B1 D1 ES1	PID 0.80m, 0.1ppm
[MADE GROUND] Brown slightly clayey slightly gravelly SAND. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint, brick and chalk. (CAPPING LAYER)		1.00	8.94					
. *From 2.50m bgl: Becoming grey in colour.*						2.50 2.50 2.50	B2 D2 ES2	PID 2.50m, 0.3ppm
[MADE GROUND] Dark brown / grey slightly clayey SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse glass and plastic. With plastic bags, material, cans, rope & sunglasses. (LANDFILL)		3.20	6.74			3.30 3.30 3.30	B2 D3 ES3	PID 3.30m, 17.6ppm
EOH at 3.40m - Target Depth Achieved.		3.40	6.54					

Observations / Remarks

Prior to excavation, trial pit location cleared of services by GPR / EM techniques.
On completion trial pit backfilled with arisings.
No groundwater encountered during investigation.

Project Number
A102760

Project: **Brockhampton West**	Location Details		Status	Pit Number
Location: **Harts Farm Way**	Easting: 470002.28	Northing: 105647.45	DRAFT	**TP11**
Client: **Havant Borough Council**	Level: 10.57mAOD	Depth: 3.70m		Sheet 1 of 1
	Logger: SN	Type: TP		

Hole Information		Groundwater				Scale: 1:25
Pit Dimensions	Orientation: *	Strike (m)	Rose To (m)	After (mins)	Remarks	Checked By:
0.60m / 4.00m	Shoring: None					Approved By:
	Stability: Stable					Start Date: 09/05/2017
	Plant: 8T Tracked					Finish Date: 09/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over TOPSOIL. Light brown slightly sandy clay.								
[MADE GROUND] Soft to firm light brown / orange slightly sandy CLAY. Sand is fine. With occasional ceramic pipe. (CAPPING LAYER)		0.20	10.37			0.50 0.50 0.50	B1 D1 ES1	PID 0.50m, 0.2ppm
[MADE GROUND] Firm white / black / grey sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-angular, fine and medium flint and brick. (CAPPING LAYER)		0.70	9.87			1.40 1.40 1.40	B2 D2 ES2	PID 1.40m, 0.7ppm
[MADE GROUND] Black / grey / white clayey SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-angular, fine to coarse wood, brick, metal and ceramic. With plastic sheet, material, paper and wire. Occasional boulders of concrete. Moderate rotten type odour noted. (LANDFILL) *. . .At 2.70m bgl: Whole lorry tyre & large metal sheet (1.50m long).*		1.50	9.07			2.50 2.50 2.50	B3 D3 ES3	PID 2.50m, 21.0ppm
[MADE GROUND] Black / grey / white predominantly household waste. Including tin cans, bottles, yoghurt pots, food containers, books, washing up liquid and glass. Foul odour noted. (LANDFILL)		3.00	7.57			3.10 3.10 3.10	B4 D4 ES4	PID 3.10m, 17.0ppm
EOH at 3.70m - Target Depth Achieved.		3.70	6.87					

Observations / Remarks

Prior to excavation, trial pit location cleared of services by GPR / EM techniques.
On completion trial pit backfilled with arisings.
No groundwater encountered during investigation.

Project Number
A102760

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470042.39	Northing: 105723.25	DRAFT	**WS01**
Client: **Havant Borough Council**	Level: 10.28mAOD	Depth: 2.70m		Sheet 1 of 1
	Logger: AH	Type: WLS		
		Inclination: 90°		

Method, Plant and Crew					Diameter	
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)
0.00	1.20	Inspection Pit	Industrial Tools	RD Drilling	1.20	304
1.20	2.70	Dynamic Windowless Sampling	Competitor Dart	RD Drilling	2.00	87
					2.70	77

Casing		Groundwater					
Depth(m)	Diam (mm)	Strike (m)	Casing (m)	Sealed (m)	Rose To (m)	Time (mins)	Remarks

Scale: 1:25
Checked By:
Approved By:
Start Date: 09/05/2017
Finish Date: 09/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over TOPSOIL								
[MADE GROUND] Firm grey slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is sub-angular to sub-rounded, fine to coarse chalk and flint. (CAPPING LAYER)		0.20	10.09			1.20 - 1.55	B1	SPT(C) 1.20m, N=9 (2,2/2,2,3,2)
[MADE GROUND] Firm brown slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, brick, concrete and rare chalk. (LANDFILL)		1.55	8.74			1.55 - 2.00	B2	SPT(C) 2.00m, N=12 (3,3/3,4,2,3)
. . .At 2.40m bgl: Plastic bags. *. . .Between 2.45m and 2.50m bgl: Red brick cobble.* *. . .Between 2.50m and 2.55m bgl: 50mm thick wood.*								
EOH at 2.70m - Refusal at 2.70m bgl.		2.70	7.58					SPT(C) 2.70m, 60 (12,11/60 for 202mm)

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Sampling Runs					Hammer Information	
From (m)	To (m)	Diam (mm)	Recovery %	Remarks	Serial No.	Energy Ratio %
1.20	2.00	87	100		DART343	63
2.00	3.00	77	55			

Project Number
A102760

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 469928.28	Northing: 105664.08	DRAFT	**WS02**
Client: **Havant Borough Council**	Level: 10.57mAOD	Depth: 5.00m		Sheet 1 of 1
	Logger: AH	Type: WLS		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Groundwater						Scale: 1:25
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Strike (m)	Casing (m)	Sealed (m)	Rose To (m)	Time (mins)	Remarks	Checked By:
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	1.20	181									Approved By:
1.20	5.00	Dynamic Windowless Sampling	Compatibar Rig	RD Drilling	2.00	87									Start Date: 09/05/2017
					3.00	77									Finish Date: 09/05/2017
					4.00	67									
					5.00	87									

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results	
[MADE GROUND] Grass over TOPSOIL									
[MADE GROUND] Stiff brown slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is angular to sub-rounded, fine to coarse flint, brick and concrete. (CAPPING LAYER)		0.20	10.37						
						1.20 - 1.40	D1	SPT(S) 1.20m, N=12 (2,2/2,3,4,3)	1
[MADE GROUND] Dark grey / black GRAVEL. Gravel is angular to sub-rounded, fine to coarse flint, brick and concrete. With frequent wood fragments. (CAPPING LAYER)		1.40	9.17			1.40 - 1.80	B1		
[MADE GROUND] Firm grey slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, concrete and brick. (LANDFILL)		1.80	8.77			1.80 - 3.00	B2		
								SPT(C) 2.00m, N=14 (3,4/3,4,4,3)	2
. . At 2.35m bgl: With occasional polystyrene fragments.									
. . Between 2.35m and 2.60m bgl: With frequent very angular fragments of red brick.									
NO RECOVERY		3.00	7.57					SPT(C) 3.00m, N=36 (4,5/7,8,11,10)	3
MADE GROUND] Firm grey slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, concrete and brick. (LANDFILL)		4.00	6.57			4.00 - 5.00	B3	SPT(C) 4.00m, N=24 (3,3/4,7,6,7)	4
. . Between 4.20m and 7.30m bgl: Recovered as sub-angular coarse concrete gravel.									
. . At 4.60m bgl: Plastic bags.									
EOH at 5.00m - Target Depth Achieved.		5.00	5.57					SPT(C) 5.00m, N=14 (4,3/3,3,3,5)	5

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Sampling Runs

From (m)	To (m)	Diam (mm)	Recovery %	Remarks
1.20	2.00	87	100	
2.00	3.00	77	80	
3.00	4.00	67	0	
4.00	5.00	87	50	

Hammer Information

Serial No.	Energy Ratio %
DART343	63

Project Number

A102760

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 469945.66	Northing: 105502.33	**DRAFT**	**WS03**
Client: **Havant Borough Council**	Level: 11.07mAOD	Depth: 3.00m		Sheet 1 of 1
	Logger: AH	Type: WLS		
		Inclination: 90°		

Method, Plant and Crew					Diameter	
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	1.20	301
1.20	3.00	Dynamic Windowless Sampling	Competitor Dart	RD Drilling	2.00	87
					3.00	77

Casing		Groundwater					
Depth(m)	Diam (mm)	Strike (m)	Casing (m)	Sealed (m)	Rose To (m)	Time (mins)	Remarks

Scale: 1:25
Checked By:
Approved By:
Start Date: 09/05/2017
Finish Date: 09/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over TOPSOIL.								
[MADE GROUND] Firm orange brown slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, concrete and brick. (CAPPING LAYER)		0.20	10.87					
						1.20 - 1.55	B1	SPT(C) 1.20m, N=8 (2,2/2,2,2,2)
[MADE GROUND] Firm dark brown slightly sandy gravelly CLAY / SILT. Sand is fine to coarse. Gravel is sub-angular to sub-rounded, fine to coarse flint, chalk and brick. With rare fragments of burnt wood / charcoal. (CAPPING LAYER)		1.55	9.52			1.55 - 2.00	B2	
[MADE GROUND] Soft to firm dark grey / brown gravelly CLAY. Gravel is very angular to sub-rounded, fine to coarse flint, with rare chalk and brick. With occasional wood fragments. (CAPPING LAYER)		2.00	9.07			2.00 - 3.00	B3	SPT(C) 2.00m, N=8 (2,3/2,2,2,2)
. . .Between 2.65m and 2.68m bgl: Coarse gravel size pocket of fine to coarse brown sand.								
. . .Between 2.85m and 2.90m bgl: Fragment of concrete.								
EOH at 3.00m - Refusal at 3.00m bgl.		3.00	8.07					SPT(C) 3.00m, 50 (7,9/50 for 199mm)

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Sampling Runs

From (m)	To (m)	Diam (mm)	Recovery %	Remarks
1.20	2.00	87	100	
2.00	3.00	77	100	

Hammer Information

Serial No.	Energy Ratio %
DART343	63

Project Number

A102760

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470062.26	Northing: 105692.65	DRAFT	**WS04**
Client: **Havant Borough Council**	Level: 11.01mAOD	Depth: 4.00m		Sheet 1 of 1
	Logger: AH	Type: WLS		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Groundwater						Scale: 1:25
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Strike (m)	Casing (m)	Sealed (m)	Rose To (m)	Time (mins)	Remarks	Checked By:
0.00	1.20	Dynamic Windowless Sampling	Insulated Tools	RD Drilling	1.20	101									Approved By:
1.20	4.00	Dynamic Windowless Sampling	Competitor Cart	RD Drilling	2.00	87									Start Date: 09/05/2017
					3.00	77									Finish Date: 09/05/2017
					4.00	67									

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over TOPSOIL.								
[MADE GROUND] Soft to firm orange brown slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is sub-angular to sub-rounded, fine to coarse flint and brick. (CAPPING LAYER)		0.30	10.71					
[MADE GROUND] Orange brown mottled orange fine and medium SAND. (CAPPING LAYER)		0.80	10.21			1.20 - 1.30	D1	SPT(C) 1.20m, N=21 (3,4/4,5,6,6)
[MADE GROUND] Soft to firm grey mottled brown slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, chalk and burnt ash type material. (LANDFILL)		1.30	9.71			1.30 - 2.00	B2	
NO RECOVERY		2.00	9.01					SPT(C) 2.00m, N=15 (3,4/3,4,5,3)
								SPT(C) 3.00m, N=7 (1,/1,2,2,2)
EOH at 4.00m - Target Depth Achieved.		4.00	7.01					SPT(C) 4.00m, 50 (4,7/50 for 294mm)

Observations / Remarks	Sampling Runs					Hammer Information	
Prior to excavation, BH location cleared of services by GPR / EM techniques.	From (m)	To (m)	Diam (mm)	Recovery %	Remarks	Serial No.	Energy Ratio %
Hand excavated inspection pit from GL to 1.20m bgl.	1.20	2.00	87	100		DART343	63
On completion BH backfilled / installed as per graphical log.	2.00	3.00	77	0			
No groundwater encountered during investigation.	3.00	4.00	67	0		Project Number	
						A102760	

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470020.69	Northing: 105572.03	DRAFT	**WS05**
Client: **Havant Borough Council**	Level: 10.72mAOD	Depth: 3.00m		Sheet 1 of 1
	Logger: AH	Type: WLS		
		Inclination: 90°		

Method, Plant and Crew					Diameter	
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	1.20	101
1.20	2.80	Dynamic Windowless Sampling	Cometbor Dart	RD Drilling	2.00	87
					3.00	77

Casing		Groundwater					
Depth(m)	Diam (mm)	Strike (m)	Casing (m)	Sealed (m)	Rose To (m)	Time (mins)	Remarks

Scale: 1:25
Checked By:
Approved By:
Start Date: 09/05/2017
Finish Date: 09/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over TOPSOIL.								
[MADE GROUND] Brown clayey gravelly SAND. Sand is fine to coarse. Gravel is sub-angular to sub-rounded, fine and medium flint, chalk and brick. (CAPPING LAYER)		0.20	10.52			1.20 - 1.30	D1	SPT(C) 1.20m, N=8 (2,2/2,2,2,2)
[MADE GROUND] Soft to firm orange brown slightly sandy slightly gravelly CLAY / SILT. Sand is fine and medium. Gravel is sub-angular to sub-rounded, fine and medium flint and brick. (CAPPING LAYER)		1.30	9.42			1.30 - 1.60	B1	
[MADE GROUND] White gravelly SILT of chalk. Gravel is sub-angular to rounded, fine to coarse, flint and extremely weak white chalk. (CAPPING LAYER) *. . .Between 1.75m and 1.80m bgl: Pocket of brown fine to coarse sand.*		1.60	9.12			1.60 - 1.90	B2	
[MADE GROUND] Firm to stiff dark grey slightly gravelly CLAY. Gravel is angular to sub-rounded, fine and medium flint and chalk. (CAPPING LAYER)		1.90	8.82			1.90 - 2.25	B3	SPT(C) 2.00m, N=10 (3,2/3,2,3,2)
[MADE GROUND] Fragments of 30mm thick plyboard. (LANDFILL) *. . . At 2.30m bgl: Refusal due to plyboard, although WS reached 3.00m*		2.25	8.47			2.25 - 2.30	D2	
EOH at 3.00m - Refusal at 3.00m bgl.		3.00	7.72					SPT(C) 3.00m, 50 (25 for 26mm/50 for 17mm)

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Sampling Runs

From (m)	To (m)	Diam (mm)	Recovery %	Remarks
1.20	2.00	87	100	
2.80	3.00	77	30	

Hammer Information

Serial No.	Energy Ratio %
DART343	63

Project Number

A102760

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470051.70	Northing: 105635.00	DRAFT	**WS06**
Client: **Havant Borough Council**	Level: 10.98mAOD	Depth: 5.00m		Sheet 1 of 1
	Logger: AH	Type: WLS		
		Inclination: 90°		

Method, Plant and Crew					Diameter	
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	1.20	101
1.20	5.00	Dynamic Windowless Sampling	Competitor Dart	RD Drilling	2.00	87
					3.00	77
					4.00	67
					5.00	57

Casing		Groundwater					
Depth(m)	Diam (mm)	Strike (m)	Casing (m)	Sealed (m)	Rose To (m)	Time (mins)	Remarks

Scale: 1:25
Checked By:
Approved By:
Start Date: 09/05/2017
Finish Date: 09/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Test / Backfill	Samples and Testing			
						Depth (m)	Ref	Tests / Results	
[MADE GROUND] Grass over TOPSOIL.									
[MADE GROUND] Orange brown slightly gravelly fine to coarse SAND. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint. (CAPPING LAYER)		0.15	10.83			1.20 - 1.65	B1	SPT(C) 1.20m, N=15 (3,3/4,3,4,4)	1
[MADE GROUND] White and brown slightly clayey slightly gravelly SILT. Gravel is angular to sub-rounded, fine to coarse flint and brick. Silt is comminuted putty chalk. (CAPPING LAYER)		1.65	9.33			1.65 - 2.30	B2	SPT(C) 2.00m, N=11 (2,3/3,3,2,3)	2
[MADE GROUND] Brown slightly sandy clayey GRAVEL. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, concrete and brick. (CAPPING LAYER) - *Between 2.60m and 2.70m bgl: Full red brick.*		2.30	8.68			2.30 - 3.00	B3		
[MADE GROUND] Black clayey GRAVEL. Gravel is angular to sub-rounded, fine to coarse flint, brick and concrete. With frequent wood and plastic. (LANDFILL)		3.00	7.98			3.00 - 5.00	B4	SPT(C) 3.00m, N=9 (3,3/2,2,3,2)	3
								SPT(C) 4.00m, N=13 (2,3/3,4,3,3)	4
EOH at 5.00m - Target Depth Achieved.		5.00	5.98					SPT(C) 5.00m, N=13 (2,3/3,3,4,3)	5

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Sampling Runs

From (m)	To (m)	Diam (mm)	Recovery %	Remarks
1.20	2.00	87	100	
2.00	3.00	77	80	
3.00	4.00	67	40	
4.00	5.00	57	40	

Hammer Information

Serial No.	Energy Ratio %
DART343	63

Project Number

A102760

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470086.62	Northing: 105618.92	DRAFT	**WS07**
Client: **Havant Borough Council**	Level: 10.12mAOD	Depth: 3.00m		Sheet 1 of 1
	Logger: AH	Type: WLS		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Groundwater						Scale: 1:25
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Strike (m)	Casing (m)	Sealed (m)	Rose To (m)	Time (mins)	Remarks	Checked By:
0.00	1.20	Inspection Pit	Installation Tools	NB Drilling	1.20	101									Approved By:
1.20	3.00	Dynamic Windowless Sampling	Compaction Dart	NB Drilling	2.00	87									Start Date: 10/05/2017
					3.00	77									Finish Date: 10/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over TOPSOIL.								
[MADE GROUND] Soft to firm brown slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, brick, concrete and ash. (CAPPING LAYER)		0.10	10.02			0.20 - 1.70	B1	SPT(S) 1.20m, N=11 (2,1/2,3,3,3)
[MADE GROUND] Firm to stiff greenish brown / grey slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is sub-angular to sub-rounded, fine to coarse flint. (CAPPING LAYER)		1.70	8.42			1.70 - 2.15	B2	SPT(C) 2.00m, N=14 (3,2/4,3,3,4)
[MADE GROUND] Stiff grey slightly gravelly CLAY / SILT. Gravel is sub-rounded, fine to coarse chalk. (CAPPING LAYER)		2.15	7.97			2.15 - 2.45	D1	
[MADE GROUND] Dark brown / black slightly gravelly clayey SAND. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, brick and concrete. With wood fragments. (LANDFILL)		2.45	7.67			2.45 - 2.65	D2	
EOH at 3.00m - Refusal at 3.00m bgl.		3.00	7.12					SPT(C) 3.00m, 50 (6,9/50 for 298mm)

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Sampling Runs					Hammer Information	
From (m)	To (m)	Diam (mm)	Recovery %	Remarks	Serial No.	Energy Ratio %
1.20	2.00	87	100		DART343	63
2.00	3.00	77	66			

Project Number: **A102760**

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470172.28	Northing: 105741.86	DRAFT	**WS08**
Client: **Havant Borough Council**	Level: 14.21mAOD	Depth: 4.00m		Sheet 1 of 1
	Logger: AH	Type: WLS		
		Inclination: 90°		

Method, Plant and Crew					Diameter	
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)
0.00	1.20	Inspection Pit	Excavated Tools	RD Drilling	1.20	305
1.20	3.00	Dynamic Windowless Sampling	Compactor Dart	RD Drilling	2.00	87
					3.00	77
					4.00	67

Casing		Groundwater					
Depth(m)	Diam (mm)	Strike (m)	Casing (m)	Sealed (m)	Rose To (m)	Time (mins)	Remarks

Scale: 1:25
Checked By:
Approved By:
Start Date: 10/05/2017
Finish Date: 10/05/2017

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
[MADE GROUND] Grass over TOPSOIL.								
[MADE GROUND] Orange brown slightly gravelly to gravelly SILT. Gravel is angular to sub-rounded, fine to coarse flint, brick and slate. With occasional rootlets. (CAPPING LAYER)		0.10	14.11					
						0.20 - 1.55	B1	SPT(C) 1.20m, N=12 (3,4/3,3,3,3)
[MADE GROUND] Brown slightly clayey sandy GRAVEL. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, chalk, brick and concrete. (CAPPING LAYER)		1.55	12.66			1.55 - 2.30	B2	
								SPT(C) 2.00m, N=13 (3,5/4,4,5,2)
. . .Between 2.18m and 2.30m bgl: Full red brick.								
[MADE GROUND] Firm to stiff brown slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is sub-angular to sub-rounded, fine to coarse flint. (CAPPING LAYER)		2.30	11.91			2.30 - 2.50	B3	
						2.50 - 4.00	B4	
								SPT(C) 3.00m, N=50 (5,7/13,13,12,12)
. . .At 3.75m bgl: Piece of plyboard.								
ECH at 4.00m - Refusal at 3.00m bgl.		4.00	10.21					

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Sampling Runs

From (m)	To (m)	Diam (mm)	Recovery %	Remarks
1.20	2.00	87	100	
2.00	3.00	77	40	
3.00	4.00	67	25	

Hammer Information

Serial No.	Energy Ratio %
DART349	63

Project Number

A102760

Project: **Brockhampton West**	Location Details		Status	Borehole Number
Location: **Harts Farm Way**	Easting: 470177.47	Northing: 105581.74	**DRAFT**	**WS09**
Client: **Havant Borough Council**	Level: 9.46mAOD	Depth: 5.00m		Sheet 1 of 1
	Logger: AH	Type: WLS		
		Inclination: 90°		

Method, Plant and Crew					Diameter		Casing		Groundwater						Remarks	Scale: 1:25
From (m)	To (m)	Type	Plant Used	Crew	Depth (m)	Diam (mm)	Depth(m)	Diam (mm)	Strike (m)	Casing (m)	Sealed (m)	Rose To (m)	Time (mins)		Checked By:	
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	1.20	301									Approved By:	
1.20	5.00	Dynamic Windowless Sampling	Competitor Dart	RD Drilling	2.00	87									Start Date:	10/05/2017
					3.65	77									Finish Date:	10/05/2017
					4.00	67										
					5.00	57										

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results	
[MADE GROUND] ASPHALT		0.05	9.40						
[MADE GROUND] Orange brown SAND & GRAVEL. Sand is fine to coarse. Gravel is angular to sub-angular fine to coarse of various lithologies. (TYPE I ROADSTONE - SUB-BASE)									
[MADE GROUND] Soft orange brown mottled bluish grey slightly clayey to clayey SILT. (CAPPING LAYER)		0.30	9.15						1
						1.20 - 3.00	B1	SPT(S) 1.20m, N=11 (2,2/3,3,2,3)	
								SPT(C) 2.00m, 4 (1,/2,1,,1)	2
[MADE GROUND] Grey / white slightly clayey slightly gravelly SILT. Gravel is sub-angular, fine to coarse extremely weak white chalk. (CAPPING LAYER)		3.00	6.46			3.00 - 3.75	B2	SPT(C) 3.00m, N=9 (2,2/3,2,2,2)	3
[MADE GROUND] Orange brown mottled grey slightly clayey to clayey SAND. Sand is fine to coarse. (CAPPING LAYER)		3.75	5.70			3.75 - 4.00	D1		
[MADE GROUND] Brown / white gravelly SILT / CLAY. Gravel is angular to sub-rounded, fine to coarse brick, flint, plastic, ceramic and glass. (LANDFILL)		4.00	5.46			4.00 - 4.40	D2	SPT(C) 4.00m, N=12 (2,3/2,3,3,4)	4
EOH at 5.00m - Target Depth Achieved.		5.00	4.46					SPT(C) 5.00m, N=14 (3,3/4,3,3,4)	5

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Sampling Runs

From (m)	To (m)	Diam (mm)	Recovery %	Remarks
1.20	2.00	87	100	
2.00	3.00	77	85	
3.00	4.00	67	70	
4.00	5.00	57	40	

Hammer Information

Serial No.	Energy Ratio %
DART343	63

Project Number: **A102760**

Project: **Brockhampton West**

Location: **Harts Farm Way**

Client: **Havant Borough Council**

Location Details

Easting: 470249.37 Northing: 105705.34

Level: 13.45mAOD Depth: 4.00m

Logger: AH Type: WLS

Inclination: 90°

Status

DRAFT

Borehole Number

WS10

Sheet 1 of 1

Scale: 1:25

Checked By:

Approved By:

Start Date: 10/05/2017

Finish Date: 10/05/2017

Method, Plant and Crew

From (m)	To (m)	Type	Plant Used	Crew	Diameter Depth (m)	Diameter Diam (mm)
0.00	1.20	Inspection Pit	Insulated Tools	RD Drilling	1.20	101
1.20	5.00	Dynamic Windowless Sampling	Competitor Cert	RD Drilling	2.00	87
					3.00	77
					4.00	67

Casing

Depth(m)	Diam (mm)

Groundwater

Strike (m)	Casing (m)	Sealed (m)	Rose To (m)	Time (mins)	Remarks

Strata Description	Legend	Depth (m)	Reduced Level (mAOD)	Water Level (m)	Inst / Backfill	Samples and Testing: Depth (m)	Ref	Tests / Results
(TOPSOIL) Grass over TOPSOIL.								
[MADE GROUND] Dark brown mottled black slightly clayey to clayey slightly sandy to sandy GRAVEL. Sand is fine to coarse. Gravel is very angular to sub-rounded, fine to coarse flint, brick and concrete. (CAPPING LAYER)		0.10	13.35					
						1.20 - 2.00	B8	SPT(C) 1.20m, N=11 (2,3/2,3,3,3)
. . .Between 1.45m and 1.75m bgl: Recovered as very angular fine to coarse concrete gravel.								
[MADE GROUND] Dark grey / black very clayey GRAVEL .Gravel is very angular to sub-rounded, fine to coarse flint, chalk and concrete. With frequent fragments of plastic, metal and material. (LANDFILL)		2.00	11.45			2.00 - 3.00	B2	SPT(C) 2.00m, N=12 (2,3/3,3,3,3)
. . .At 2.40m bgl: Carpet.								
. . .At 3.00m bgl: Frequent plastic bags and polystyrene.								SPT(C) 3.00m, N=12 (2,3/2,3,4,3)
EOH at 4.00m - Target Depth Achieved.		4.00	9.45					

Observations / Remarks

Prior to excavation, BH location cleared of services by GPR / EM techniques.
Hand excavated inspection pit from GL to 1.20m bgl.
On completion BH backfilled / installed as per graphical log.
No groundwater encountered during investigation.

Sampling Runs

From (m)	To (m)	Diam (mm)	Recovery %	Remarks
1.20	2.00	87	100	
2.00	3.00	77	80	
3.00	4.00	67	40	

Hammer Information

Serial No.	Energy Ratio %
DART343	63

Project Number

A102760

IN SITU
SITE INVESTIGATION



STATIC CONE PENETRATION TEST

FACTUAL REPORT

CLIENT: Delta Simons Environmental Consultants Ltd

PROJECT: Brockhampton Landfill Site

Project	Brockhampton Landfill Site
Project No.	1210494
Client	Delta Simons Environmental Consultants Ltd
Address	3 Henley Office Park, Doddington Road, Lincoln, LN6 3QR

Attention: Mr David Jackson

Dear Mr Jackson,

We have pleasure in providing a digital copy of our report and data in AGS format for the above project.

We hope that you are satisfied with the performance of our staff, equipment and reporting on this project. If you should have any queries about any aspect of the works carried out, please do not hesitate to contact us. We look forward to being of service to you in the future.

Yours faithfully,

In Situ Site Investigation Limited

[redacted]

Darren Ward

Director

Report Issue

Issue	Date	Prepared	Sign	Checked	Sign	Approved	Sign
01	13/10/2021	Chloe Donovan		Luisa Dhimitri		Darren Ward	

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Cone Penetration Measured Parameters and Geotechnical Derived Parameters 49

1.0 INTRODUCTION

In Situ Site Investigation Limited (In Situ) was engaged in a geotechnical site investigation at Brockhampton Landfill Site at the request of Delta Simons. The site investigation consisted of completing 18 Static Piezocone Penetration Tests (CPTU), to provide information on the soil conditions and derived geotechnical parameters at:

Brockhampton West,
Harts Farm Way,
Havant,
Hampshire,
PO9 1FA

All test locations were provided by the client. A site map is included in the end of Appendix A of this report (if provided by the client). The tests were stopped when they reached the target depth as per the client's technical specifications or for other technical reasons, as detailed in the *Project Summary Table* in *Appendix A.1* and on each CPTU log included in Appendix B of this report.

The fieldwork was carried out from 4th October 2021 to 6th October 2021 as per the client's request.

The work on site and the final factual reporting have been undertaken in accordance with the international technical standard *BS EN ISO 22476-1:2012*.

2.0 FIELDWORK

2.1 CONE PENETRATION TESTS

The fieldwork activity is summarised in Table 2.1.

Table 2.1 Fieldwork Summary	
CPT Operator/s	Dom Gain, Ashley Lelliott, James Standen
Date Started	4th October 2021
Date Finished	6th October 2021
In Situ S.I. Project Manager	Darren Ward
Main Contractor's Site Manager	Liane Baiao

2.1.1 Rig Information

Details of CPTU rig used in this project are shown in Table 2.2. Full data sheet for the rig is presented in *Appendix A.2*.

Table 2.2 Rig Summary	
Rig Name	**Rig Description**
CPT006	14 Tonne Track Mounted CPT Rig

2.1.2 CPTU Cone

Details of electric CPTU cone (Type TE2) used in this project conforming to the requirements of Application Class 2 of *ISO 22476-1:2012*, are shown in Table 2.3.

Table 2.3 Cone Summary		
Number	**Cross-section area**	**Filter position**
S15-CFIP.1475	15cm^2	u_2
S15-CFIP.1945	15cm^2	u_2

A full datasheet of the cone used is shown in *Appendix A.3*.

The cone's measured parameters are shown in Table 2.4.

Table 2.4 Completed Fieldwork Summary
18 CPTU to a maximum depth of 24.68m. Each test measured Cone Resistance, q_c, Sleeve Friction, f_s, Porewater Pressure in the shoulder position, u_2, Inclination in X and Y axes.
*Provision of factual report with estimated soil type, derived geotechnical parameters & AGS data*file.

2.1.3 CPTU Cone Calibration

The cone resistance and sleeve friction are recorded by calibrated load cells in the cone. The CPTU load cells and pressure transducers are regularly calibrated in line with *ISO 22476-1:2012* standard by the cone manufacturer. The cone calibration certificate for the cone used at this site are presented in *Appendix A.4*.

2.1.4 CPTU Cone Saturation

The pore water pressure is recorded using a calibrated pressure transducer located in the piezocone. To ensure pore water pressure measurements are not affected by the presence of air in the measuring transducer, a de-airing procedure is carried out prior to each test. The cone and filter are saturated using a glycerine fluid with a viscosity of 10,000CST.

2.1.5 Test Procedure

The tests are carried out in accordance with the *International Standard for Electrical Cone and Piezocone Penetration Test (ISO 22476-1:2012)*.

The final depths of the tests were determined by either completion to the specified test depth or when the maximal safe capacity of the equipment was reached. A schedule of the tests performed is shown in *Appendix A.1*, which has been compiled from the operators' daily progress reports.

The data is transmitted from the digital CPTU through an umbilical cable that runs through the push rods to the data acquisition system. Results are displayed instantaneously on the computer logging screen. The results are recorded on the computer hard disc.

The rate of penetration is kept constant at 20 mm/s ± 5 mm/s except when penetrating very dense or hard strata. Before each test is carried out zero values are taken of the cone to check if it is within calibration. At the end of each test, zero values are taken again to see if there has been any drift during the test. These values are inspected during the post processing stage. This is a quality check on the data and the testing procedure. Individual test zero values are shown on their corresponding test results in *Appendix B*.

2.1.6 In Situ Pore Pressure (u_0)

The in situ or hydrostatic pore pressure is required for the calculation of several derived parameters included in this report. For this report, the groundwater level is assumed at 2.00 m below ground surface, for calculation purposes. The in situ pore pressure (u_0) values are presented on the pore pressure plot, on *CPT Log 01,* which is included in *Appendix B*.

2.2 POSITIONING

Positioning and surveying of all investigated locations was the responsibility of the client.

3.0 CONE PENETRATION MEASURED PARAMETERS

All measured parameters of tests carried with the CPTU cone are shown in *Appendix B* and all the information about data processing and results are given in sections *3.1*, *3.2* and *3.3*.

3.1 DATA PROCESSING

The measured parameters, cone end resistance, q_c, sleeve friction, f_s, porewater pressure measurements with filter in shoulder position, u_2 and inclination for *x* and *y* axis, I_x, I_y, were recorded for every*10 mm* of penetration keeping a constant speed of *20 mm/s ± 5 mm/s*, which may slightly change when the cone is penetrating hard strata.

The measured data from the site works is processed and presented using specialised CPT software. The interpretations on the CPTU results were carried out following the recommendations of *Lunne et al. (1997)*, *Robertson (2015)* and *BS EN ISO 22476-1:2012.* Measured parameters, mentioned in *Sections 3.2* and *3.3*, were used to derive all the geotechnical parameters, which are presented in *Chapter 4.0*. The soil behaviour type method used on this report is *Robertson et al. (1986)*, shown in *Figure 3.2*.

3.1.1 Zero Measurements

Before and after each CPTU test, zero measurements are recorded for each channel of the cone. The zero measurements are presented on the logs in *Appendix B*. This is a routine quality check carried out on site.

3.2 MEASURED PARAMETERS

3.2.1 Cone Resistance (q_c)

Cone resistance, q_c, is measured as the total force acting on the cone, divided by the projected area of the cone. The results are presented in *MPa*, on *CPT Log 01*, in *Appendix B*, scale *0-20 MPa* with a minor scale printing on the same graph at *0-4 MPa*.

3.2.2 Sleeve Friction (f_s)

Sleeve friction, f_s, is measured as the total frictional force acting on the friction sleeve divided by its surface area. The results are presented in *kPa*, on *CPT Log 01*, in *Appendix B*, using a scale of*0-500 kPa*.

3.2.3 Porewater pressure (u_2)

The pore pressure, u_2, is measured during the test. If the material is free draining and saturation is maintained it will normally measure hydrostatic pore pressure. In materials that are not free draining, it will record the total pore pressure (hydrostatic plus any excess pore pressures generated) created by the cone penetration through this material.

The filter element can be mounted in one of three positions. For all tests carried out in this project the filter was mounted in the u_2 position (see *Figure 3.1*).

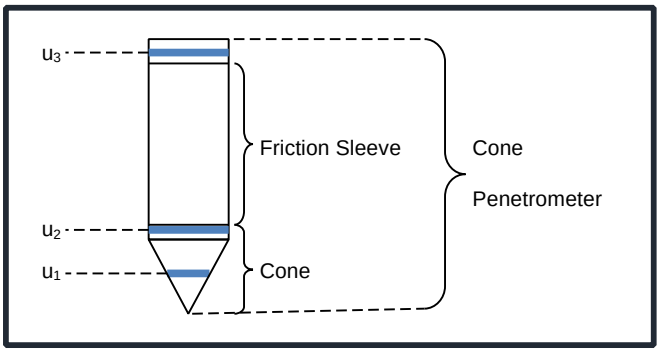


Figure 3.1: *Diagram showing pore pressure filter locations (after Lunne et al., 1997)*

3.2.4 Inclination (I_x, I_y)

The CPT rig was set up to obtain a thrust direction as near as possible to vertical. The CPTU cones have inclinometers incorporated to measure the non-verticality of the test. For test depths less than *15m*, significant non-verticality is unusual, provided the initial thrust direction is vertical.

3.3 ESTIMATED SOIL BEHAVIOUR TYPE

3.3.1 Friction Ratio (R_f)

The friction ratio, R_f is the ratio between the sleeve friction and the cone resistance (Lunne *et al.,* 1997).

$$= \frac{(\quad)}{(\quad)} \times 100$$

3.3.2 Estimated Soil Behaviour Type (SBT)

The estimation of soil behaviour type, *SBT*, using measurements of cone resistance and sleeve friction is based upon the variations of the friction ratio and cone resistance. The

friction ratio varies depending upon whether the soil is cohesive or granular. The cone resistance varies depending on the strength and densities of the soil.

The interpretation used in this report is *Robertson et al. (1986)*, which is shown in Figure 3.2. The results are presented on *CPT Log 01*, in *Appendix B*.

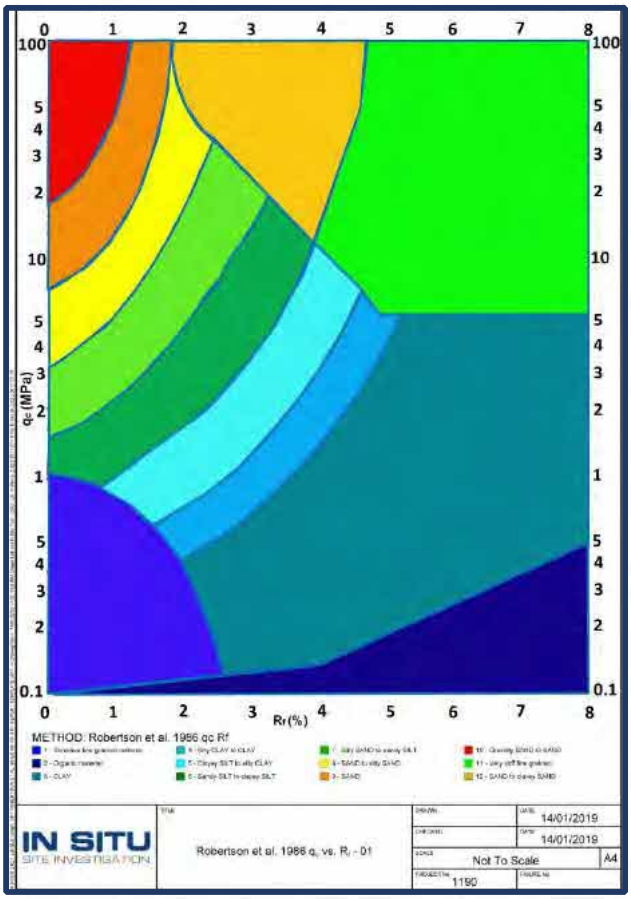


Figure 3.2: *Robertson et al., 1986 soil behaviour type chart.*

3.3.3 Pore Pressure Ratio (B_q)

Pore pressure ratio, B_q is the ratio between the measured pore pressure generated during penetration and the corrected cone resistance minus the total overburden stress.

Pore pressure ratio as defined by *Senneset and Janbu (1985)* is defined as:

$$= \frac{2 - 0}{-}$$

where

u_2	is pore pressure measured between the cone and the friction sleeve
u_0	is equilibrium pore pressure
σ_{vo}	is total overburden stress
q_t	is cone resistance corrected for unequal end area effects

3.4 APPLIED CORRECTIONS

3.4.1 Corrected Cone Resistance (q_t)

For each penetration test, the measured cone resistance, q_c, can be corrected for the ‘‘unequal area effect’’ due to the influence of the ambient pore water pressure acting on the cone.

The correction has been applied using the following equation by Lunne et *al.,* 1997:

$$= + [_2.(1 -)]$$

where

is the cone area ratio

The cone used on this project has a cone area ratio of *0.79*. This value is geometrically measured.

3.4.2 Depth Correction

All tests in the report have been corrected for depth difference caused by inclination. This has been calculated using the method described in *ISO 22476-1:2012*.

To calculate the corrected depth the following formula is used:

$$= \quad \cdot$$

$$_0$$

where

z	is penetration depth, in *m*
l	is penetration length, in *m*
C_{inc}	is correction factor for the effect of the inclination of the CPTU relative to the vertical axis.

The equation for calculating the correction factor for the influence of the inclination for a bi-axial inclinometer is:

$$= \frac{1}{(1 + \quad ^2 _1 + \quad ^2 _2}$$

where

β_1	is the angle between the vertical axis and the projection of the axis of the CPTU on a vertical plane, in degrees
β_2	is the angle between the vertical axis and the projection of the axis of the CPTU on a vertical plane that is perpendicular to the plane of angle $_1$, in degrees

4.0 GEOTECHNICAL DERIVED PARAMETERS

A number of empirical correlations can be used to derive geotechnical parameters from CPTU data. This report includes only the parameters which are described in this chapter. The results of all correlations used to obtain the geotechnical derived parameters are presented on *CPT Log 02* and *CPT Log 03* in *Appendix B*.

Please, note that each empirical correlation is derived for a certain type of soil, and may not be appropriate for all the soil types encountered on this project.

4.1 SOIL BEHAVIOUR TYPE INDEX (I_c)

The soil behaviour type index, I_c, was derived by *Jefferies and Davies (1991)*, and was created to simplify the application of CPTU SBT chart shown in *Chapter 3*, *Figure 3.2*. This approach has been modified for use with the *Robertson (1990)* normalised CPT soil classification chart, *Figure 4.1*. The normalised cone parameters Q_t and F_r (for definitions see *Appendix A5* Symbol List) can be combined into one Soil Behaviour Type Index, I_c, *(Lunne et al., 1997)*.

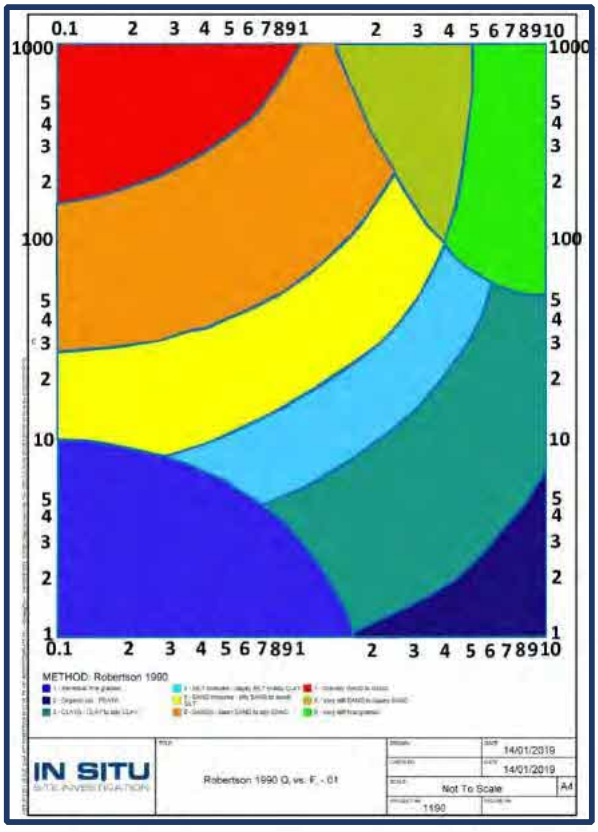


Figure 4.1: *Robertson 1990 soil behaviour type chart.*

The soil behaviour type index, I_c, can then be defined using *Robertson (2010)* formula, given below:

$$= ((3.47 - \quad)^2 + (\quad + 1.22)^2)^{0.5}$$

where

Q_t is the normalized cone resistance which represents the simple normalization with a stress exponent (n) of *1.0*, which applies well to clay-like soils

F_R is the normalized friction ratio, in *%*

The boundaries of soil behaviour type are then given in terms of the index, I_c, presented in *Table 4.1* below.

The soils behaviour type index does not apply to zones *1*, *8* and *9*. The profiles of I_c provide a simple guide to the continuous variation of soil behaviour type in a given soil profile based on CPTU results, with a reliability greater than *80%* compared with soil samples *(Robertson, 2015).*

Zone	Soil Behaviour Type	I_c
1	Sensitive fine grained	N/A
2	Organic Soils – clay	>3.6
3	Clays – silty clay to clay	2.95 – 3.6
4	Silt mixtures – clayey silt to silty clay	2.60 – 2.95
5	Sand mixtures – silty sand to sandy silt	2.05 – 2.6
6	Sands – clean sand to silty sand	1.31 – 2.05
7	Gravelly sand to dense sand	<1.31
8	Very stiff sand to clayey sand*	N/A
9	Very stiff fine grained *	N/A

** Heavily over consolidated or cemented*

Table 4.1: *Normalized CPTU Soil Behaviour Type (SBT_n) Index values, I_c.(Robertson, 2010)*

4.2 N VALUE OF STANDARD PENETRATION TEST (SPT) (N_{60})

The derived *N* value of *SPT,* N_{60}, is strongly and directly related to the cone resistance, q_c.

In this report the N_{60} value is derived using the following correlations, developed by *Robertson and Wride (1998)* and *Jefferies and Davies (1998)*

1) *Robertson & Wride (1998)*

$$_{60} = \frac{}{8.5 \cdot \quad 1 - _{4.6}}$$

2) *Jefferies and Davies (1993)*

$$_{60} = \frac{}{0.85 \cdot \ 1 - \frac{}{4.75}}$$

where

q_c	is the cone resistance
p_a	is the atmospheric pressure equal to *100 kPa*
I_c	is the soil behaviour type index calculated as given in *section 4.1*

It is suggested that this method provides a better estimation of the *N* value than the actual *SPT* test, due to its poor repeatability. But in fine grained soil with high sensitivity these methods of estimating N_{60} may overestimate it *(Jefferies and Davies, 1991).*

4.3 RELATIVE DENSITY (D_r)

Relative density, D_r, is an intermediate parameter for coarse grained soils, widely used to describe sand deposits. All the research on deriving the relative density from CPTU tests results are carried out for ***clean predominantly quartz sands***. The studies have shown that CPTU resistance in granular soils is controlled by sand relative density, in situ effective stresses and compressibility. The more compressible sands tend to give lower penetration resistance for a given relative density then less compressible sands.

In this report relative density is calculated using the methods suggested by *Baldi et al., (1986)*, *Jamiolkowski et al., (2001)* and *Kulhawy and Mayne (1990)* as shown in the equations below:

1) Baldi et al., (1986)

$$= \frac{1}{2} \cdot \quad \frac{\cdot \quad h}{_1 \cdot (\ _0\ )^{0.55}} \cdot 100$$

where

C_1 is a consolidation coefficient which is *157* for normally consolidated soils and *181* for over consolidated soils

C_2 is a consolidation coefficient which is *2.41* for normally consolidated soils and *2.46* for over consolidated soils

Wehr is a correction coefficient for calcareous soils

2) Jamiolkowski et al., (2001)

$$= 100 \cdot 0.268 \cdot \frac{/}{\prime / 0 /} + 1$$

where

C_1 is a compressibility coefficient which is *-0.675* for average compressible soils, ≤*1.0* for high compressible soils and carbonate or calcareous sands and ≥*-2.0* for low compressible soils

q_t is corrected cone resistance

σ_{atm} is the atmospheric pressure

3) Kulhawy and Mayne, (1990)

$$= \frac{1}{305 \cdot {}_1 \cdot \quad {}^{0.18} \cdot \ 1.2 + 0.05 \cdot \quad (\ /100)}^{0.5} \cdot 100$$

where

q_{c1} is the cone resistance corrected for initial vertical effective stress and atmospheric pressure, calculated by the following formula

$$1 = \frac{}{\prime 0 \cdot}$$

where

q_c is the cone resistance in *kPa*

σ'_{v0} is the initial vertical effective stress in *kPa*

C_1 is a compressibility coefficient which is *-0.91* for low compressible sands, *1.0* for medium compressible sands and *1.09* for high compressible sands

t is time in years

4.4 FRICTION ANGLE (φ')

Friction angle, *φ*', is used to express the shear strength of uncemented, coarse grained soils. In this report friction angle is derived by the correlations of *Mayne and Campanella (2005)*, *Robertson and Campanella (1983)* and *Kulhawy and Mayne (1990)*.

1) Mayne and Campanella, (2005)

$$' = 29.5^{0} \cdot {}^{0.121} \cdot 0.256 + 0.336 \cdot +$$

where

B_q is the pore pressure ratio, calculated as in Session 3.3

Q_t is the normalized cone resistance

2) Robertson and Campanella, (1983)

$$' = \tan^{-1} \; 0.1 + 0.38 \cdot \; {}_{0}'$$

where

q_c is the cone resistance in *kPa*

σ'_{v0} is the initial vertical effective stress in *kPa*

3) Kulhawy and Mayne, (1990)

$$' = 17.6^{0} + 11.0^{0} \cdot \; (\; {}_{1} \;)$$

where

q_{t1} is the corrected cone resistance corrected for initial vertical effective stress and atmospheric pressure, calculated by the following formula

$$_{1} = \frac{}{{}_{0}' \cdot}$$

The method suggested by *Mayne and Campanella (2005)* will not provide reliable results for heavily over consolidated soils, fissured geomaterials and highly cemented or structures clays. This approach gives reliable results when pore pressure is positive and varies $0.1 < B_q < 1.0$. The correlation suggested by *Robertson and Campanella (1983)* estimates the peak friction angle for uncemented, unaged, moderately compressible, predominately quartz sands. For sands of higher compressibility, the method will tend to predict low friction angles. The method suggested by *Kulhawy and Mayne (1990)* is an alternate relationship for clean, rounded, uncemented, quartz sands.

4.5 FINES CONTENT (*FC*)

The fines content, *FC*, in this report is estimated using two different methods, one from *Robertson and Wride (1998)* and the other, *Suzuki et al. (1998)* as presented below:

1) Robertson and Wride (1998)

$$< 1.26: \quad = 0$$

$$1.26 \leq \quad \leq 3.5: \quad (\%) = 1.75^{3.25} - 3.7$$

$$3.5 < \quad : \quad = 100\%$$

2) Suzuki et al. (1998)

$$(\%) = 2.8^{2.6}$$

where

I_c is the soil behaviour type index, calculated as in section 4.1

4.6 UNDRAINED SHEAR STRENGTH (s_u)

Estimation of undrained shear strength, s_u, from CPTU tests using corrected cone resistance is carried out using the following correlation from *Lunne et al. (1981)*:

$$= \frac{(\quad - \quad _0)}{}$$

where

N_{kt} is the empirical cone factor, which varies from *10* (*6* for very soft sensitive fine grained soils) to *20*. In this report 3 values are considered:*15*, *17.5* and *20*. N_{kt} tends to increase with increasing plasticity and decrease with increasing soil sensitivity. It decreases as B_q increases. (*Lunne et al., 1997*)

$_{vo}$ = total overburden stress.

This report only presents the undrained shear strength data on soils with soil behaviour type index, I_c values greater than *2.60*.

The value of undrained shear strength, s_u to be used in analysis depends on the design problem. In general, the simple shear in the direction of loading often represents the average undrained strength. For larger, moderate to high risk projects, where high quality field and laboratory data may be available, site specific correlations should be developed based on appropriate and reliable values of s_u.

4.7 SENSITIVITY (S_t)

The sensitivity, S_t of clays is defined as the ratio of undisturbed peak undrained shear strength to totally remoulded undrained shear strength.

In this report S_t is calculated using two correlations developed by *Schmertmann (1978)* and *Mayne (2007)*.

1) Schmertmann (1978)

$$= \frac{}{(\quad)} = \quad - \quad (\frac{1}{})$$

where

$S_{u\,(rem)}$ is the remoulded undrained shear strength. It can be assumed equal to the sleeve resistance, f_s.

2) Mayne (2007)

$$= \frac{0.073 \cdot (\quad - \ _0)}{}$$

For relatively sensitive clays, $S_t > 10$, the value of f_s can be very low and not very accurate, hence the estimate of sensitivity should be used as a guide only.

4.8 SOIL UNIT WEIGHT (γ)

Soil unit weight, γ in this report is calculated by using one method for sands, considered under dry conditions and two methods for clays, considered under saturated conditions. These relationships are developed by *Mayne (2007)* and the equations are presented below:

1) Mayne (2007)

Dry unit weight for sands:

$$= 1.89 \cdot \quad (\ _1) + 11.82$$

Saturated unit weight for clays method 1

$$= 8.32 \cdot \quad (\quad) - 1.61 \cdot \quad (\quad)$$

Saturated unit for clays method 2

$$= 2.60 \cdot \quad (\quad) + 15 \cdot \quad - 26.5$$

where

q_{t1} is the corrected cone resistance corrected for initial vertical effective stress and atmospheric pressure, calculated by the following formula:

$$_1 = \frac{}{_0 \cdot}$$

z is the depth

V_s is the shear wave velocity, calculated as $= 118.8 \cdot \quad + 18.5$

G_s is the specific gravity of solids, typically between *2.40* and *2.90*

4.9 STATE PARAMETER (ψ)

The state parameter, ψ is defined as the difference between the current void ratio, e and the void ratio at critical state e_{cs}, at the same mean effective stress for granular soils.

The problem of evaluating the state parameter from CPTU response is complex and depends on several soil parameters, including shear stiffness, shear strength, compressibility and plastic hardening. (*Jefferies and Been, 2006*)

In this report, the state parameter is calculated based on five methods as follows:

1) Been et al. (1987)

$$= - \quad \overline{}$$

and

$$= \frac{3}{1 + 2 \ _0}$$

where

Q_t is the normalized cone resistance
K_0 is the coefficient of lateral earth pressure

2) Shuttle and Jefferies (1998)

$$= - \quad \overline{}$$

where

$$= 3.79 + 1.12 \ (\ ) \ 1 + 1.06(- \ 1.25) \ 1 - 0.30(- \ 0.2) \ (\ /1000)^{0.326} - 1.55(- \ 0.01)^{1.45}$$

$$= 1.45 \ 1.04 + 0.46 \ (\ ) \ 1 - 0.4(- \ 1.25) \ 1 - 0.30(- \ 0.2) \ (\ /100)^{0.15} \ 1 - 2.21(- \ 0.01)$$

where

Q_t is the normalised cone resistance
I_r is rigidity index
K_0 is the coefficient of lateral earth pressure
M is critical state ratio
N is dilation parameter
H is plastic hardening modulus;
λ is slope *CSL* line

3) Shuttle and Jefferies (1998)

The state parameter calculated according this third method is similar to state parameter calculated as presented in the second method, except for the rigidity index that is calculated as follows:

$$= \left(\right)^{0.5}$$

where

I_{r100}	is rigidity index in reference pressure
P_a	is the reference pressure equal to 100 kPa
σ'_{v0}	is effective vertical overburden stress

4) Plewes (1992)

$$= - \frac{\left(1 - \right)}{}$$

where

$$' = 3 + \frac{0.85}{}$$

$$' = 11.9 - 13.3$$

$$= 10$$

where

Q_t	is the normalised cone resistance
B_q	is pore pressure ratio
K_0	is the coefficient of lateral earth pressure
F_R	is normalised friction ratio
M	is critical state ration

5) Been and Jefferies (1992)

$$= - \frac{\left(1 - \right)}{}$$

where

$$' = 3 + \frac{0.85}{}$$

$$' = 11.9 - 13.3$$

$$= \frac{1}{34 - 10}$$

For high-risk projects a detailed interpretation of CPTU results using laboratory results and numerical modelling can be appropriate (e.g. *Shuttle* and *Cunning*, *2007*), although soil variability can complicate the interpretation procedure. For low risk projects and in the initial screening for high-risk projects there is a need for a simple estimate of soil state.

Plewes et al (1991) provided a mean to estimate soil state using the normalised soil behaviour type, *SBTn* chart suggested by *Jefferies and Davies (1991)*. *Jefferies and Been*

(2006) suggested that soils with a state parameter less than *-0.05* are dilative at large strains.

4.10 IN SITU STRESS RATIO (K_0)

There are various estimations to determine in situ stress ratio, K_0, from CPTU in fine grained soils. In this report the methods suggested by *Mayne (2007)* and *Kulhawy and Mayne (1990)* are used, as given below:

1) Mayne (2007)

$$_0 = (1 - \quad ') \quad '$$

$$_0 = \quad = \frac{(1 + \quad ')}{(1 - \quad ')}$$

$$_0 = 0.192(\text{——})^{0.22}(\quad _0)^{0.22} \quad 0.27$$

where

OCR is the overconsolidation ratio, calculated as presented in session *4.12*

2) Kulhawy and Mayne (1990)

$$_0 = 0.1(\quad \frac{-}{_0}, \frac{0}{})$$

These approaches are generally limited to mechanically overconsolidated, fine grained soils. As considerable scatter exits in the database used for these correlations, in moderate to high risk projects further tests should be performed and these correlations must be considered only as a guide.

4.11 OVERCONSOLIDATION RATIO (OCR)

Overconsolidation ratio, *OCR* is defined as the ratio of the maximum past effective consolidation stress and the present effective overburden stress:

$$= \frac{'}{', _0}$$

This definition is appropriate for mechanically overconsolidated soils, where the only change has been the removal of overburden stress. For cemented and aged soils, the *OCR* may represent the ratio of the yield stress and the present effective overburden stress.

In this report σ'_p is calculated based on six methods as presented below:

1) Mayne (1995)

$$' = 0.33(- {}_0)$$

2) Chen and Mayne (1996)

$$' = 0.53$$

3) Mayne (2005)

$$' = 0.6(- {}_2)$$

4) Robertson (2009)

$$' = 0.25({}^{1.25} - ' {}_0)$$

5) Mayne (2005)

$$' = [\frac{0.192}{(1 - ')} {}^{0.125}_{0.31}]^{(\frac{1}{'} - 0.27)}, {}_0$$

6) Mayne (2007)

$$' = 0.101 \; {}^{0.102}({}_0)^{0.478}, {}_0 \; {}^{0.420}$$

For larger, moderate to high risk projects, where additional high-quality field and laboratory data may be available, site specific correlations should be developed based in consistent and relevant values of *OCR*.

4.12 SMALL STRAIN YOUNG'S MODULUS (E_0)

Deriving small strain undrained Young's modulus, E_0, from CPTU is difficult. There is insufficient data available to make a direct correlation and it is recommended that $c_u$should be derived, then $E_U$estimated as a rough order of value from one of the available correlations between E_U and c_u (*Meigh, 1987*).

In this report the small strain Young's modulus is derived as follows:

1) Defined from elastic theory:

$$ {}_0 = 2(1 +) \; {}_0$$

where

v is the Poisson ratio, equal to *0.2*

G_0 is the small strain shear modulus calculated by the formula given below:

$$ {}_0 = 1634(\frac{}{'}{}_0)^{-0.75}$$

2) Calculated based on the degree of loading, q_c, effective stress and reduction factor

$$_0 =$$

where

α is calculated from degree of loading, q_c, effective stress and reduction factor, given in *Figure 4.2*

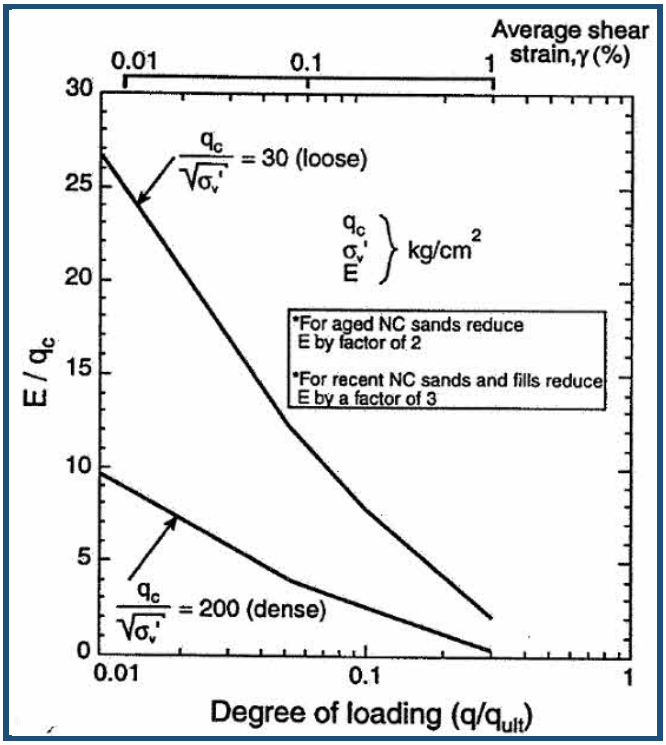


Figure 4.2:*Estimation of equivalent Young's modulus for sand based on degree of loading (Robertson, 1990)*

4.13 CONSTRAINED MODULUS (M)

Constrained Modulus, *M*, can be estimated by CPTU using the following empirical relationship:

$$= \quad (\quad - \quad _0)$$

where

α_M varies with soil plasticity and natural water content for a wide range of fine-grained soils and organic soils. *Meigh (1987)* suggested that α_M lies in the range of *2to 8*, whereas *Mayne (2001)* suggested the value of *5*.

Robertson (2001) suggested that α_M varies with Q_t, such that:

When $I_c > 2.2$ (fine grained soils) use: $\alpha_M = Q_t$ when $Q_t < 14$

$\alpha_M = 14$ when $Q_t > 14$

When $I_c < 2.2$ (coarse grained soils) use: $= 0.0188[10^{(0.55 \quad +1.68)}]$

In this report the Constrained Modulus, *M*, is calculated after *Kulhawy and Mayne (1990)* using the equation below:

$$= 8.25(\quad - \ _0)$$

Also, an alternative method is included in the results, developed by *Burns and Mayne (2002)* using the following relationship:

$$= 0.02 \ _0$$

4.13.1 Equivalent Oedometer Coefficient of Compressibility (mv)

Equivalent oedometer coefficient of compressibility, m_v can be calculated directly by the Constrained Modulus, *M*, as follows:

$$= \frac{1}{}$$

4.14 SMALL STRAIN SHEAR MODULUS (G_0)

Elastic theory states that the small strain shear modulus, G_0, can be determined from the following equation:

$$_0 = \quad ^2$$

where

ρ	is the mass density of the soil
v_s	is the shear wave velocity

In this report the small strain shear modulus, G_0, will be presented calculated by the two methods shown below, developed by *Rix and Stoke (1992)* and *BE, UB Rix* and *Stoke (1992)*, respectively.

$$_0 = 1634\left(\frac{\quad}{\ _0}\right)^{-0.75}$$

$$_0 = \quad ^2$$

where

q_c	is the net cone tip resistance in kPa
σ'_{v0}	is the effective initial vertical stress in kPa
γ_{bulk}	is the bulk density of the soil
v_s	is the shear wave velocity

This correlation of G_0 is applicable to all soil types.

4.14.1 Mass Density of Soil (ρ)

Mass density of soil, ρ, is defined as:

=

where

γ is the elastic stiffness of the soils at shear strain less than 10^{-4}%, $\gamma<10^{-4}$ %.

4.15 HYDRAULIC CONDUCTIVITY (k)

An approximate estimate of soil hydraulic conductivity or coefficient of permeability, *k*, can be made from an estimate of soil behaviour type using the CPTU *SBT chart* as presented in the table below:

SBT Zone	SBT	Range of k (m/s)	SBT_n I_c
1	Sensitive fine grained	$3x10^{-10}$ to $3x10^{-8}$	NA
2	Organic soils-clay	$1x10^{-10}$ to $1x10^{-8}$	I_c>3.60
3	Clay	$1x10^{-10}$ to $1x10^{-9}$	2.95<I_c<3.60
4	Silt Mixture	$3x10^{-9}$ to $1x10^{-7}$	2.60<I_c<2.95
5	Sand Mixture	$1x10^{-7}$ to $1x10^{-5}$	2.05<I_c<2.60
6	Sand	$1x10^{-5}$ to $1x10^{-3}$	1.31<I_c<2.05
7	Dense sand to gravelly sand	$1x10^{-3}$ to 1	I_c<1.31
8	*Very dense/ stiff soil	$1x10^{-8}$ to $1x10^{-3}$	NA
9	*Very stiff fine grained soil	$1x10^{-9}$ to $1x10^{-7}$	NA

**Overconsolidated and/ or cemented*

Table 4.2: *Estimated soils' permeability (k) based on the CPTU SBT chart by Robertson (2009)*

The average relationship between soils' permeability, *k* and SBT_n I_c, shown in *Table 4.2*, can be represented by the following relationships:

When 1.0 < ≤ 3.27 = $10^{(0.952-3.04)}$
When 3.27 < ≤ 4.0 = $10^{(-4.52-1.37)}$

In this report, the hydraulic conductivity is estimated as a function of soil types from 2 CPTU classification charts, *Robertson et al. (1986)* and *Robertson et al. (1990)*, considering both minimum and maximum values.

The hydraulic conductivity (coefficient of permeability), *k*, values (minimum and maximum), defined after soils' behaviour type by *Robertson et al. (1986)* are presented in *Table 4.3*, below:

SBT Zone	Soil Behaviour Type (SBT)	Range of hydraulic conductivity,*k (m/s*)
1	Sensitive fine grained	$3x10^{-9}$ to $3x10^{-8}$
2	Organic soils	$1x10^{-8}$ to $1x10^{-6}$
3	Clay	$1x10^{-10}$ to $1x10^{-9}$
4	Silty CLAY to CLAY	$3x10^{-9}$ to $1x10^{-8}$
5	Clayey SILT to silty CLAY	$1x10^{-8}$ to $1x10^{-7}$
6	Sandy SILT to clayey SILT	$1x10^{-7}$ to $1x10^{-6}$
7	Silty SAND to sandy SILT	$1x10^{-5}$ to $1x10^{-6}$
8	SAND to silty SAND	$1x10^{-5}$ to $1x10^{-4}$
9	SAND	$1x10^{-4}$ to $1x10^{-3}$
10	Gravelly SAND to SAND	$1x10^{-3}$ to 1
11	Very stiff fine grained	$1x10^{-8}$ to $1x10^{-6}$
12	SAND to clayey SAND	$3x10^{-7}$ to $3x10^{-4}$

Table 4.3: *Estimated soil permeability (k) based on SBT chart by Robertson et al. (1986)*

The hydraulic conductivity (coefficient of permeability), *k* values (min and max), defined after soils' behaviour type by *Robertson et al. (1990)* are presented in *Table 4.4*, below:

SBT Zone	Soil Behaviour Type (SBT)	Range of hydraulic conductivity, *k (m/s*)
1	Sensitive fine grained	$3x10^{-9}$ to $3x10^{-8}$
2	Organic soils	$1x10^{-8}$ to $1x10^{-6}$
3	Clay	$1x10^{-10}$ to $1x10^{-9}$
4	Silt Mixture	$3x10^{-9}$ to $1x10^{-7}$
5	Sand Mixture	$1x10^{-7}$ to $1x10^{-5}$
6	Sand	$1x10^{-5}$ to $1x10^{-3}$
7	Gravelly sands to dense sands	$1x10^{-3}$ to 1
8	Very stiff sand to clayey sand	$1x10^{-8}$ to $1x10^{-6}$
9	Very stiff fine grained	$1x10^{-8}$ to $1x10^{-6}$

Table 4.4: *Estimated soils' permeability (k) based on SBT chart by Robertson et al. (1990).*

4.16 Rigidity Index (IR)

The rigidity index, I_R, for fine grained soils is defined using the following formula, developed by *Mayne (2001)*:

$$= \exp\left[\frac{1.5}{} + 2.925 \quad \frac{-}{-}\frac{0}{2} - 2.925\right.$$

where

M is the Cam-Clay constant, slope of the critical state line defined as:

$$= \frac{6 \quad '}{3 - \quad '}$$

where

φ' is the internal friction angle.

The second method used to define the rigidity index, I_R, for fine grained soils is based on plasticity index and overconsolidation ratio, *OCR* and calculated after the relationship developed by *Keaveny and Mitchell (1986)* as follows:

$$= \frac{\exp(0.0435(137 - \quad)}{[1 + \ln\{1 + 0.385(\quad - 1)^{3.2}\}]^{0.8}}$$

where

PI is the plasticity index of the soil, equal to 20.
OCR is the overconsolidation ratio of the soil

5.0 CHALK

In order to provide an estimate of the Chalk Grade Classification as defined by Ward et al. (1968) and Wakeling (1969) a modified correlation originally derived by Power (1982) has been used. This is presented in figure 5.1 and has been used to give the degree of weathering quoted on the soil type estimates on the cone penetration graphs.

It should be noted that the correlation is approximate and that Chalk at different locations can differ from that described by Ward et al. at one particular site (Mundford in Norfolk). The descriptions in figure 5.1 are typical, and do not necessarily relate to this site. Simplified descriptions are therefore presented on the logs. It should also be noted that the Chalk grade classification was derived to describe the chalk mass. Localised variations in the cone resistance do not necessarily represent changes in Classification. Peaks may represent flints or local indurated zones.

GRADE	TYPICAL BRIEF DESCRIPTION (After Wakeling,1969)	FRICTION RATIO (%)	CONEEND RESISTANCE(MPa)
		(modifiedfromPower,1982)	
6	Extremely soft structureless CHALK containing small lumps of intact chalk.	-	Below 5
5	Structureless remoulded CHALK containing lumps of intact chalk.	0.75 – 1.00	5-10
4	Rubbly partly-weathered CHALK with bedding and jointing. Joints10-60mm apart and open to 20mm and often infilled with soft remoulded chalk and fragments.	1.00 – 1.25	10-15
3	Rubbly to blocky unweathered CHALK. Joints 60-200mm apart and open to 20mm and often infilled with fragments.	1.25 – 1.50	15-20
2	Blocky medium-hard CHALK. Joints more than 200mm apart and closed.	1.50 – 2.00	More than 20
1	As for grade2 but hard and brittle.	No penetration-	No penetration

Figure 5.1: Chalk classification table modified from Power (1992).

6.0 CPTU RESULTS APPLICATIONS

6.1 SOIL PROFILING AND APPLICATIONS IN GEOTECHNICAL DESIGN

6.1.1 Soil Behaviour Type

The major applications of CPTU are on *soil behaviour type and soil profiling*. Typically, the cone resistance, q_c is high in sands and low in clays, and the friction ratio, $R_f = f_s/q_t$ is low in sands and high in clays. The CPTU cannot be expected to provide accurate predictions of soil type based on *physical characteristics,* e.g. *grain size distribution*, but provides a guide to the *mechanical characteristics*, including: *strength*, *stiffness*, and *compressibility* of the soils, or the *soil behaviour type*, *SBT*.

The most commonly used CPTU soil behaviour type chart, suggested by *Robertson et al. (1986)* uses the basic CPTU measured parameters of cone resistance, q_c and friction ratio, R_f. The chart is global in nature and can provide reasonable predictions of soil behaviour type for CPTU testing. The expected overlap in some zones is modified in the interpretations of this report somewhat based on previous experience or local knowledge of the site.

Since both the penetration resistance and sleeve resistance increase with depth due to the increase in effective overburden stress, the CPTU data requires normalization for overburden stress for very shallow and/or very deep tests. A popular CPTU soil behaviour chart based on normalized CPTU data is firstly proposed by *Robertson (1990)*. The chart identifies general trends in ground response, such as: *increasing soil density*, *OCR*, *age* and *cementation* for granular soils, and *increasing stress history*, *OCR* and *soil sensitivity* for cohesive soils.

A more general normalized CPTU*SBT* chart, using large strain *soil behaviour* descriptions, proposed by *Robertson (2012)* is shown in *Figure 6.1*.

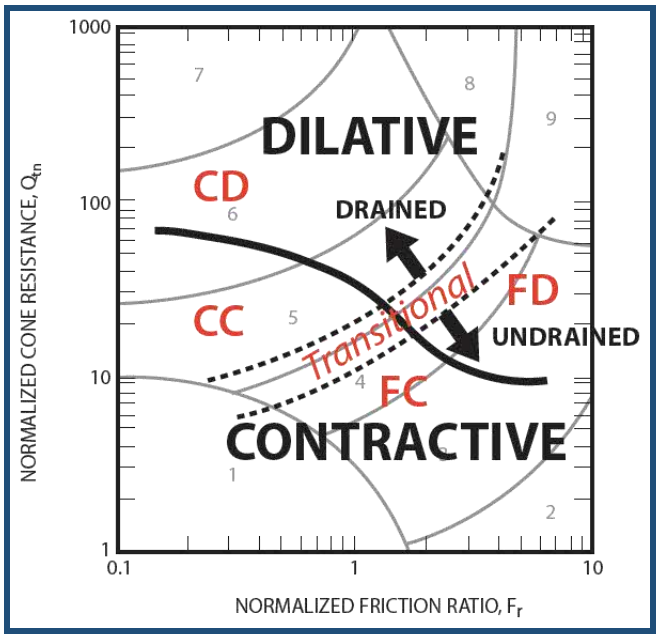


Figure 6.1: Normalized CPTU Soil Behaviour Type (SBT_n) chart, Q_{tn}-F_R using general large strain soil behaviour description (Robertson, 2012).

*

CD	is coarse grained dilative soil-predominately drained CPTU
CC	is coarse grained contractive soil-predominately drained CPTU
FD	is fine grained dilative soil-predominately undrained CPTU
FC	is fine grained contractive soil-predominately undrained CPTU

6.1.2 Soil Profiling

CPTU is an excellent test for soil profiling. The continuous monitoring of pore pressure during the cone penetration improves the soil stratigraphy descriptions. The pore pressure develops in response to the soil type being penetrated in the area where the pore pressure element is located. Soft, firm or stiff clays and contractive silts can show very high pore pressure. Very stiff overconsolidated clays and dilative silts can give very low or negative pore pressures same as very dense silty sands.

The thin layers of sand, or silt in a thick layer of clay, or thin layers of clay or silt in a thick layer of sand are easily distinguished during a CPTU test, which will give a response time sufficiently fast to observe pore pressure changes even in the very thin layers of soils (< *5mm*), depending on the response of soil to the advancing of cone.

The sandy soils tend to produce high cone resistance and low friction ratio, whereas soft clayey soils tend to produce low cone resistance and high friction ratio. Organic soils such as peat tend to have very low cone resistance and very high friction ratio. Soils with high horizontal stresses (*high OCR*) tend to have higher cone resistance and friction ratio.

CPTU is an excellent tool to classify the soils based on their behaviour type, and not based on grain size distribution.

The measurement of sleeve friction, $f_s$is often less reliable than the measurement of cone resistance, q_c (*Lunne et al., 1986*), but to overpass these problems pore pressure parameter ratio, B_q, and the classification charts based on it.

For more reliability in soil profiling, the soil interpretations in this report are carried out based on three parameters measured on site, cone resistance, sleeve friction and pore pressure and three derived geotechnical parameters soil behaviour type index for all soils, undrained shear strength for cohesive soils and relative density for granular soils.

Generally, soils that fall in zones *8*, *9* and *10* of *Robertson et al. (1986)* chart (*6* and *7*of *Robertson (1990)* chart) represent approximately drained penetration, whereas, soils in zones 1, 2, 3, 4, 5 and 6 of *Robertson et al. (1986)* chart (1, 2, 3 and 4of *Robertson (1990)* chart) represent approximately undrained penetration. Soils in zones 7, 11 and 12 of *Robertson et al. (1986)* (5, 8 and 9 of *Robertson (1990)* chart) may represent partially drained penetration. The classification is often influenced by changes in *stress history*, *in situ stresses*, *sensitivity*, *stiffness*, *mineralogy*, etc. An advantage of pore pressure measurements during cone penetration is the ability to evaluate drainage conditions more directly. (*Lunne et al., 1997*)

The information about the rate and manner of excess pore pressures during the dissipations significantly helps the accurate classification in the corresponding depths of dissipation tests. In very stiff, overconsolidated clayey soils, the pore pressure behind the cone is very low and sometimes negative of the equilibrium pore pressure, u_0, whereas the pore pressure on the face of the cone is very large due to the large increase in normal stresses created by the cone penetration. When penetration is stopped in overconsolidated clays, pore pressure recorded behind the cone may initially increase before decreasing to the equilibrium pore pressure. The rise is caused by local equalization of the high pore pressure gradient around the cone.

Cone penetration in fine grained soils, such as clays and silts, is generally undrained. Cone penetration tests under undrained conditions generate high pore pressure and this reading is extremely useful, because it affects both cone resistance and sleeve friction measurements. These parameters should be corrected using the measured pore pressure.

CPTU in coarse gained soils, such as sandy or gravelly soils is generally drained. In these conditions there is no excess pore pressure generated as a result of cone penetration. Relative density has been used as the main parameter for description of sandy deposits.

7.1.3 Applications in geotechnical design

CPTU measured parameters are used to derive geotechnical parameters, which are the input in several geotechnical analyses. An alternate approach is to directly apply CPTU results to the geotechnical calculations.

As a guide, *Table 6.1* shows a summary of the applicability of CPTU results for direct design applications. The ratings shown in the table have been assigned based on current experience and represent a qualitative evaluation of the confidence level assessed to each design problem and general soil type. Details of ground conditions and project requirements can influence these ratings.

Type of soil	Pile Design	Bearing Capacity	Settlement	Compaction Control	Liquefaction
Sand	A-B	A-B	B-C	A-B	A-B
Clay	A-B	A-B	B-C	C-D	A-B
Intermediate Soils	A-B	B-C	B-C	B-C	A-B

Table 6.1: *Perceived applicability of CPTU for various direct design problems.*

A is high
B is high to moderate
C is moderate
D is moderate to low

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APPENDIX A

APPENDIX A1 – Project Summary Sheet

Piezocone Tests Summary Sheet

HOLE ID	Final Depth (m)	Date of Test	Cone Used	Test Remarks
CPT201	19.97	05/10/2021	S15-CFIP.1475	Test completed at target depth.
CPT202	19.95	05/10/2021	S15-CFIP.1475	Test completed at target depth.
CPT203	5.28	05/10/2021	S15-CFIP.1475	Test refused on inclination.
CPT204	8.17	04/10/2021	S15-CFIP.1945	Test refused on total pressure.
CPT205	24.68	06/10/2021	S15-CFIP.1475	Test completed at target depth.
CPT206	19.94	04/10/2021	S15-CFIP.1945	Test completed at target depth.
CPT207	8.20	04/10/2021	S15-CFIP.1945	Test refused on total pressure.
CPT208	5.11	05/10/2021	S15-CFIP.1475	Test refused on total pressure.
CPT209	4.01	04/10/2021	S15-CFIP.1945	Test refused on inclination.
CPT209 A	0.80	04/10/2021	S15-CFIP.1945	Test refused on total pressure.
CPT210	3.00	05/10/2021	S15-CFIP.1475	Test refused on total pressure.
CPT211	4.00	04/10/2021	S15-CFIP.1945	Test refused on total pressure.
CPT212	9.07	04/10/2021	S15-CFIP.1945	Test refused on inclination.
CPT213	4.22	05/10/2021	S15-CFIP.1475	Test refused on total pressure.
CPT214	19.86	06/10/2021	S15-CFIP.1475	Test completed at target depth.
CPT215	10.68	06/10/2021	S15-CFIP.1475	Test completed at target depth.
CPT216	19.88	06/10/2021	S15-CFIP.1475	Test completed at target depth.
CPT218	19.87	06/10/2021	S15-CFIP.1475	Test completed at target depth.

APPENDIX A2 – CPT Rig Datasheet

RIGS

14 TONNE MOUNTED RIGS (CPT005 and CPT006)

We have two 14 tonne track mounted CPT rigs, each weighing 14 tonnes. One of our rigs, CPT005, 'Erik' is based in the Middle East and the other, CPT006, 'Zoe' in the UK. These rigs have low ground bearing pressure and are ideal for soft, boggy sites. They are capable of pushing up to 120 metres a day, depending on access to positions.

CPT RIG DETAILS

TOTAL WEIGHT	14 TONNES
CPT RAM THRUST CAPACITY	20 TONNES
MAXIMUM PENETRATION	20-30M DEPENDING ON THE GROUND CONDITIONS
PERFORMANCE RATES	120M OF TESTING IN A DAY DEPENDING ON ACCESS TO POSITIONS
TYPICAL SITES FOR THIS RIG	SOFT BOGGY SITES. THE RIG HAS LOW GROUND BEARING PRESSURE

CPT RIG DIMENSIONS





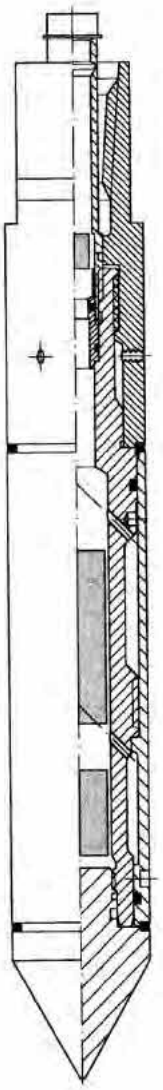




IN SITU SITE INVESTIGATION INSITUSI.COM

APPENDIX A3 – Cone Datasheet

GeoPoint Systems bv
Rijksstraatweg 22f
2171 AL Sassenheim
Tel. : +31 71 301 92 51
Fax : +31 71 301 92 52
E-mail : info@geopoint.nl
ING bank : 68.23.01.396
Postbank : 5276758
BTW nr : NL806531627B01



SPECIFICATIONS S15 SERIES ELECTRICAL CONES

The electronic subtraction cones have been developed to address the durability problems inherent in other cone designs. The unit consists of a single element temperature compensated strain gauge transducer for measuring both cone resistance and local sleeve friction. This design is therefore more robust than a compression type cone. The cone support electronics package is located directly behind the transducer. The precision strain gauge amplifiers and power supply eliminate the effects of cable resistance on the measurements. A standard subtraction cone is capable of measuring simultaneously the following channels: Tip, Local friction, Pore pressure, Temperature and Inclination.

GENERAL SPECIFICATIONS

Cone Tip Section Area	1,500 mm2
Friction Sleeve Surface	22,500 mm2
Total Length	325 mm
Weight	4200 g
Power Supply	± 15 VDC, 100 mA.
Output	0 – 10 VDC*
Working Temperature	0 - 60˚C
Storage Temperature	- 40 to + 85˚C
Connector	Lemo 10 pins (others on request)

TIP RESISTANCE

Range	100/150* kN
Accuracy	0.25 % FS
Maximum Load	150 % of range
Cone Area Ratio	0.75

LOCAL SLEEVE FRICTION

Range	100/150* kN
Accuracy	0.50 % FS
Maximum Load	150 %
Sleeve Area Ratio	1.0 (EA)

PORE PRESSURE

Range	1/2/5/10* MPa
Accuracy	0.5 % FS
Maximum Load	150 % of range

INCLINATION

Range	25 ˚ (biaxial)
Accuracy	< 2 ˚

All our equipment complies with the ISSMGE, ASTM, DIN and NEN Standards.

*Other output and voltage ranges available on request. Loadcells may be calibrated for lower ranges.

APPENDIX A4 – Cone Calibration Certificate

Eijkelkamp GeoPoint
SoilSolutions

Rijkstraatweg 22F
2171 AL Sassenheim
The Netherlands

T +31 71 301 9251
E info@eijkelkamp-geopoint.com
I eijkelkamp-geopoint.com

Cone Calibration Certificate

Certificate:	**GS-1475-007**	
Instrument Type:	Electric Subtraction Cone	
Model:	S15-CFIIP	
Serial number:	1475	
Calibration date:	30-06-2021	
Client:	Insitu	
Calibrated by:	W Volgering	
Calibration instruments		
Manufacturer:	Hottinger Baldwin Messtechnik GmbH	
HBM certificate NMi certificate	2461165.00501	
Calibration conditions		
Ambient temperature:	22.5	°C
Atmospheric pressure:	1014	mBar
Cone specifications		
Cone base area:	1500	mm2
Load tip resistance (nom.):	100	kN
Friction sleeve area:	22500	mm2
Load tip + local friction (nom.):	100	kN
Load friction sleeve (nom.):	22.5	kN
Load pore pressure (nom.):	2	MPa
Inclination (nom.):	+/- 20	°
Temperature compensation (all channels):	0...+40	°C
Maximum overload capacity (all channels):	50	%
Cone area ratio (a):	0.79	
Max. Inaccuracy, relative to measurement value:	1.0	%

	Tip:		Sleeve:		Pore Pressure:		Inclinometer:		
	qc in kN	mV	fs in kN	mV	MPa	mV	Degrees	X (mV)	Y (mV)
Zero points:		0247		0225		0230			
	0	0	0	0	0	0	0	2492	2485
	5	0303	5	0311	0.4	1483	-20	0372	0487
	10	0606	10	0622	0.8	2963	20	4503	4471
	15	0909	15	0934	1.2	4433			
	20	1212	20	1246	1.6	5898			
	25	1514	25	1556	2	7360			
	30	1816	30	1865					
	35	2116	35	2174					
	40	2418	40	2483					
	45	2718	45	2792					
	50	3019	50	3101					
	75	4520	75	4643					
	100	6018	100	6181					

Max. eror, abs. qc:	35 kPa
Max. error, abs. fs:	2 kPa
Max. error, abs. u2:	10 kPa
Max. error, abs. I:	1 °

This calibration is compliant with Eij[redacted]al quality system, internal calibration procedures and meets the requirements of NEN2549, NEN-EN-ISO 22476-1, N[redacted]sing calibration equipment traceable to (inter-)National Standards.

Approved by: [redacted]
Date:

Eijkelkamp GeoPoint SoilSolutions
V.A.T. NO. NL 8584.21.422.B01
Trade Reg. Arnhem no. 70686149
IBAN NL43 RABO 0326 7904 38
BIC: RABONL2U

Eijkelkamp GeoPoint
SoilSolutions
Rijkstraatweg 22F
2171 AL Sassenheim
The Netherlands
T +31 71 301 9251
E info@eijkelkamp-geopoint.com
I eijkelkamp-geopoint.com

Cone Calibration Certificate

Certificate:	**GS-1945-002**	
Instrument Type:	Electric Subtraction Cone	
Model:	S15-CFIIP	
Serial number:	1945	
Calibration date:	30-03-2021	
Client:	Insitu	
Calibrated by:	M.de Bruin	
Calibration instruments		
Manufacturer:	Hottinger Baldwin Messtechnik GmbH	
HBM certificate NMi certificate	2461165.00501	
Calibration conditions		
Ambient temperature:	20.7	°C
Atmospheric pressure:	1029	mBar
Cone specifications		
Cone base area:	1500	mm2
Load tip resistance (nom.):	100	kN
Friction sleeve area:	22500	mm2
Load tip + local friction (nom.):	100	kN
Load friction sleeve (nom.):	22.5	kN
Load pore pressure (nom.):	2	MPa
Inclination (nom.):	+/- 20	°
Temperature compensation (all channels):	0...+40	°C
Maximum overload capacity (all channels):	50	%
Cone area ratio (a):	0.79	
Max. Inaccuracy, relative to measurement value:	1.0	%

	Tip:		Sleeve:		Pore Pressure:		Inclinometer:		
	qc in kN	mV	fs in kN	mV	MPa	mV	Degrees	X (mV)	Y (mV)
Zero points:		0253		0229		0224			
	0	0	0	0	0	0	0	2491	2573
	5	0295	5	0303	0.4	1584	-20	0506	0603
	10	0586	10	0605	0.8	3156	20	4398	4606
	15	0876	15	0905	1.2	4730			
	20	1169	20	1208	1.6	6343			
	25	1459	25	1506	2	7861			
	30	1751	30	1804					
	35	2040	35	2105					
	40	2330	40	2404					
	45	2619	45	2702					
	50	2909	50	3001					
	75	4356	75	4494					
	100	5800	100	5983					

Max. eror, abs. qc:	35 kPa
Max. error, abs. fs:	2 kPa
Max. error, abs. u2:	10 kPa
Max. error, abs. I:	1 °

This calibration is compliant with Eijkelkamp GeoPoint SoilSolutions internal quality system, internal calibration procedures and meets the requirements of NEN2649, NEN-EN-ISO 22476-1, NORSOK G-001, ISSMFE and ASTM using calibration equipment traceable to (inter-)National Standards.

Approved by: B.
Date: 30

[redacted]

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Trade Reg. Arnhem no. 70686149
IBAN NL43 RABO 0326 7904 38
BIC: RABONL2U

APPENDIX A5 – Symbol List

English

a	is area ratio of the cone (=)
A	is area
A_c	is projected area of the cone
A_n	is cross sectional area of load cell or shaft
A_s	is area of friction sleeve
A_{sb}	is bottom end area of friction sleeve
A_{st}	is top end area of friction sleeve
B_q	is pore pressure parameter (= $(u_2 - u_0)/(q_t - \sigma_{vo})$)
c_h	is horizontal coefficient of consolidation
c_v	is vertical coefficient of consolidation
D	is diameter
D_r	is relative density (= 100%)
e	is void ratio
e_{max}	is maximum void ratio
e_{min}	is minimum void ratio
E	is Young's modulus
f_s	is unit sleeve friction resistance
f_t	is sleeve friction corrected for pore pressure effects
F_s	is total force acting on friction sleeve
F_R	is normalized friction ratio (= $f_s/(q_t - \sigma_{vo})$)
FoS	is factor of safety
FC	is fines content
g	is acceleration due to gravity
G_0	is initial or maximum shear modulus, shear stiffness
I_c	is soil behavior type index
I_r	is rigidity index (=)
I_p	is plasticity index
k	is coefficient of permeability
k_h	is coefficient of permeability in horizontal direction
k_v	is coefficient of permeability in vertical direction
K_0	is coefficient of earth pressure at rest (= $\sigma'_{h0}/\sigma'_{v0}$)
L	is length
m_v	is coefficient of volume change
M	is constrained deformation modulus
M7.5	is earthquake magnitude of 7.5 Richter scale
N	is number of blows of SPT
N_{60}	is SPT energy ratio
N_k	is cone factor
N_{ke}	is cone factor
N_{kt}	is cone factor
$N_{\Delta u}$	is cone factor
p_a	is reference stress (= 100)
q_c	is measured cone resistance
q_e	is effective cone resistance (= $q_t - u_2$)
q_n	is net cone resistance (= $q_t - u_0$)
q_t	is corrected cone resistance (= $q_c + (1 - a) u_2$)
Q_c	is total force acting on the cone
Q_t	is normalized cone resistance (= q_n/σ'_{v0})

R_f	is friction ratio (= 100%or alternatively = 100%)
s_u	is undrained shear strength
s_{ur}	is remoulded undrained shear strength
S_t	is sensitivity
t	is time
t_{50}	is time for 50% dissipation of excess pore water pressure
T_{50}	is time factor at = 50 %
u	is pore water pressure
u_0	is in situ pore pressure
u_1	is pore pressure measured on the cone
u_2	is pore pressure measured behind the cone
u_3	is pore pressure measured behind sleeve friction
Δu	is excess pore water pressure
U	is normalized excess pore pressure
V_s	is shear wave velocity
z	is depth

Greek

α	is constant
α	is cone roughness
β	is constant
β_1	is the angle between the vertical axis and the projection of the axis of the CPTU on a vertical plane, in degrees
β_2	is the angle between the vertical axis and the projection of the axis of the CPTU on a vertical plane that is perpendicular to the plane of angle $_1$, in degrees
γ	is unit weight of soil
γ_w	unit weight of water
Δ	is change
Δu	is excess pore pressure (= – $_0$)
μ	is Poisson's ratio
ρ	is density
ψ	is state parameter
σ, σ'	is normal stress (total, effective)
σ_h, σ_h'	is horizontal stress (total, effective)
σ_v, σ_v'	is horizontal stress (total, effective)
σ_{v0},σ_{v0}'	is overburden stress (total, effective)
τ_{av}	is average cyclic shear stress
τ_{cy}	is cyclic shear stress
φ'	is effective friction angle

APPENDIX A6 –Abbreviations

ASTM	American Society for Testing and Materials
CPTU	Cone Penetration Test with Pore Pressure Measurement (Piezocone Test)
CRR	Cyclic Resistance Ratio
CSR	Cyclic Stress Ratio
GWT	Ground Water Table
NC	Normally Consolidated
OC	Over consolidated
OCR	Over consolidation Ratio
PL	Limit Pressure
SDMT	Seismic Dilatometer Marchetti
SPT	Standard Penetration Test
TC	Technical Committee

APPENDIX A7 – Glossary

CPT
Cone Penetration Test.

Cone
The part of the cone penetrometer on which the end bearing is developed.

Cone Penetrometer
The assembly containing the *cone*, *friction sleeve*, any other sensors and measuring systems, as well as the connections to the *push-rods.*

Cone resistance, q_c
The total force acting on the cone, Q_c, divided by the projected area of the cone, A_c. =

Corrected cone resistance, q_t
The *cone resistance*, q_c corrected for pore water pressure effects.

Corrected sleeve friction, f_t
The *sleeve friction* corrected for pore water pressure effects on the ends of the *friction sleeve*.

Data acquisition system
The system used to measure and record the measurements made by the *cone penetrometer*.

Dissipation Test
A test when the decay of the pore water pressure is monitored during a pause in penetration.

Filter element
The porous element inserted into the cone penetrometer to allow transmission of the pore water pressure to the pore pressure sensor, while maintaining the correct profile of the *cone penetrometer*.

Friction ratio, R_f
The ratio, expressed as a percentage of the *sleeve friction*, f_s, to the *cone resistance*, q_c, both measured at the same depth.

Friction reducer
A local enlargement on the push-rod surface, placed at a distance above the cone penetrometer, and provided to reduce the friction on the *push-rods*.

Friction sleeve
The section of the *cone penetrometer* upon which the *sleeve friction* is measured.

Normalized cone resistance, Q_c or Q_t
The *cone resistance* expressed in a non-dimensional form and taking account of stress changes *in situ*, $= (- _0) , _0$, or when the *corrected cone resistance* is used $= (- _0) , _0$. where σ_{v0} and σ'_{v0} are the total and effective vertical stress respectively.

Net cone resistance, q_n
The *corrected cone resistance* minus the vertical total stress. $= - _0$

Normalized friction ratio, F_r
The *sleeve friction* normalized by the *net cone resistance*.

Piezocone
A *cone penetrometer* containing a pore pressure sensor.

Pore pressure, *u*
The pore pressure generated during penetration and measured by a pore pressure sensor, u_1 when measured on the cone, u_2 when measured just behind the cone and u_3 when measured just behind the friction sleeve.

Pore pressure ratio, B_q
The *net pore pressure* normalized with respect to the *net cone resistance*.

Push-rods
The thick-walled tubes or rods used for advancing the cone penetrometer.

Rig machine
The equipment which pushes the cone penetrometer and rods into the ground.

Sleeve friction, f_s
The total frictional force acting on the *friction sleeve*, F_s, divided by its *surface area*, A_s. =

APPENDIX A8 – Soils Description Tables

GRANULAR SOILS (Sands and Gravels)

Description	Relative Density D_r (%)	SPT N value, N_{SPT}
Very Loose	0 – 15	0 - 4
Loose	15 – 35	4 - 10
Medium Dense	35 – 65	10 - 30
Dense	65 – 85	30 - 50
Very Dense	>85	>50

COHESIVE SOILS (Clays and Silts)

Term based on measurement	Undrained Shear Strength Classification, s_u (kPa)
Extremely low	<10
Very low	10 - 20
Low	20 - 40
Medium	40 - 75
High	75 - 150
Very high	150 - 300
Extremely high	>300

APPENDIX B

Cone Penetration Measured Parameters and Geotechnical Derived Parameters

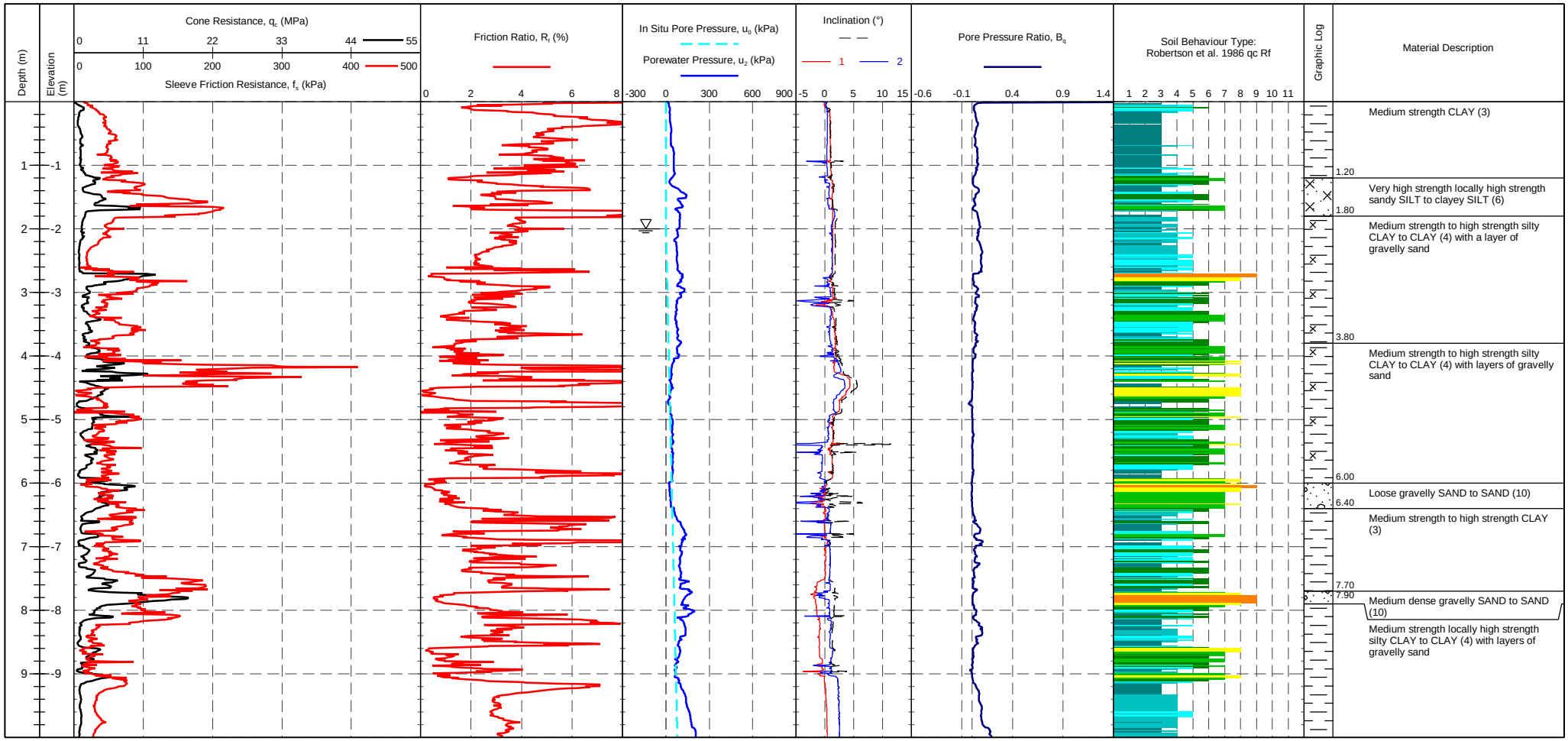
CPT LOG 01

IN SITU SITE INVESTIGATION

Working with: deltasimons

PointID: **CPT201**

CLIENT : Delta Simons	EASTING : 0.000 m	Remark:	SHEET : 1 OF 3
PROJECT : Brockhampton	NORTHING : 0.000 m	Test completed at target depth.	STATUS : Final
LOCATION : Portsmouth	ELEVATION : 0.000 m OD		TEST DATE : 05/10/2021
PROJECT No. : 1210494	CHECKED BY : LD		PLOT DATE : 12/10/2021
	TERMINATION REASON : Target depth		METHOD : ISO 22476-1:2012



CONE ID	: S15-CFIP.1475	TEST TYPE	: TE2
CALIBRATION DATE	: 08/09/2020	APPLICATION CLASS	: 2
CONE MODEL	: Subtraction	RIG	: CPT 006 - Zoe
CONE AREA	: 15cm^2	OPERATOR	: DG
CONE AREA RATIO	: 0.79	FRICTION REDUCER	: None
FILTER POSITION	: u2	WEATHER	: Raining & Mild
FILTER TYPE	: HDPE	GROUNDWATER DEPTH	: Assumed for calculation purposes.

CPTU ZERO VALUES

Transducer	Pre	Post	Difference
Tip	276 mV	278 mV	0.022 MPa
Sleeve	255 mV	257 mV	0.001 kPa
Pore Pressure 2	255 mV	307 mV	0.014 kPa
X-Y Inclinometer	2457 mV	2580 mV	

METHOD: Robertson et al. 1986 qc Rf

1 - Sensitive fine grained material
2 - Organic material
3 - CLAY
4 - Silty CLAY to CLAY
5 - Clayey SILT to silty CLAY
6 - Sandy SILT to clayey SILT
7 - Silty SAND to sandy SILT
8 - SAND to silty SAND
9 - SAND
10 - Gravelly SAND to SAND
11 - Very stiff fine grained
12 - SAND to clayey SAND

Groundwater Level

Dissipation Test

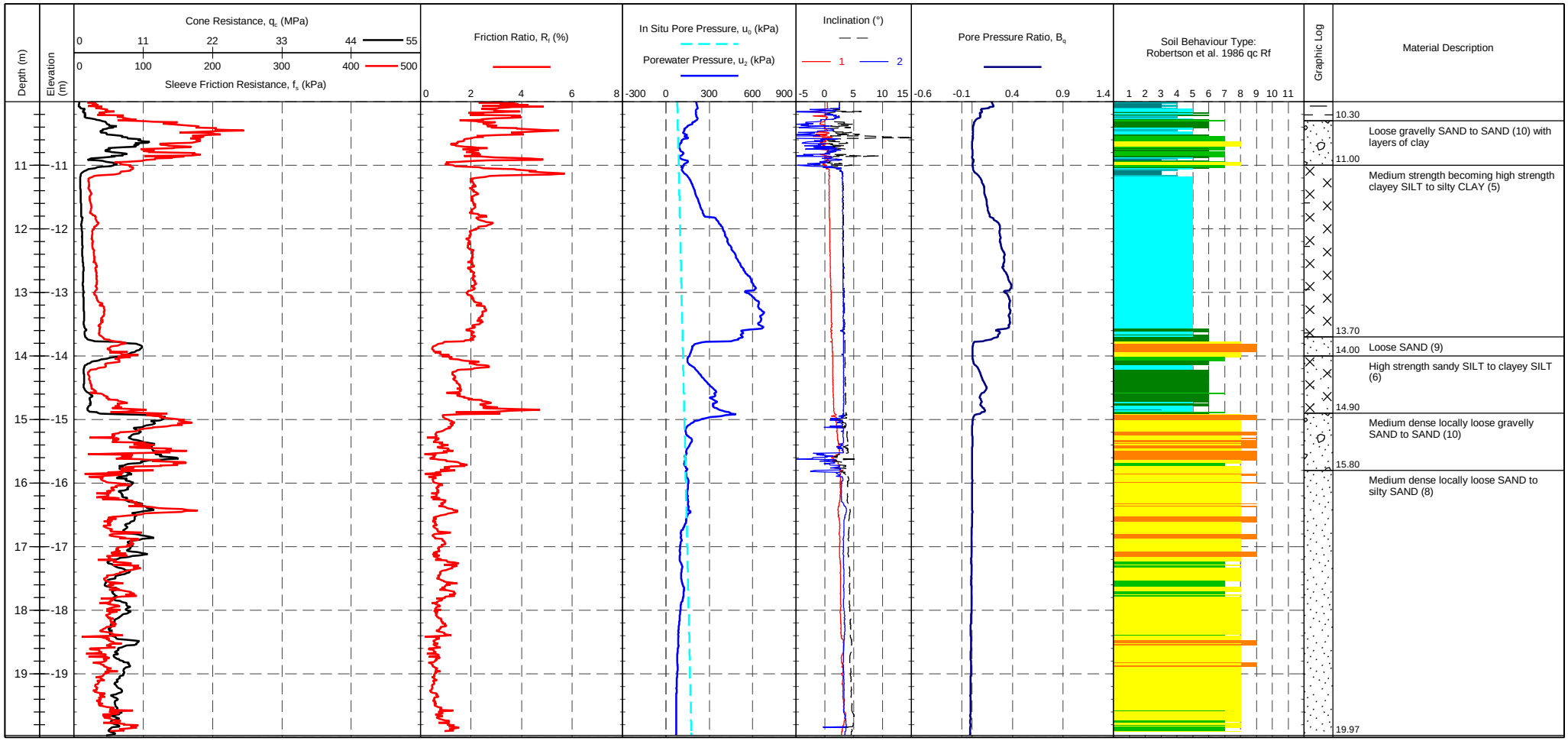
IN SITU SITE INVESTIGATION

Working with: deltasimons

CPT LOG 01

PointID: **CPT201**

CLIENT : Delta Simons	EASTING : 0.000 m	Remark:	SHEET : 2 OF 3
PROJECT : Brockhampton	NORTHING : 0.000 m	Test completed at target depth.	STATUS : Final
LOCATION : Portsmouth	ELEVATION : 0.000 m OD		TEST DATE : 05/10/2021
PROJECT No. : 1210494	CHECKED BY : LD		PLOT DATE : 12/10/2021
	TERMINATION REASON : Target depth		METHOD : ISO 22476-1:2012



CONE ID	: S15-CFIP.1475	TEST TYPE	: TE2		
CALIBRATION DATE	: 08/09/2020	APPLICATION CLASS	: 2		
CONE MODEL	: Subtraction	RIG	: CPT 006 - Zoe		
CONE AREA	: 15cm^2	OPERATOR	: DG		
CONE AREA RATIO	: 0.79	FRICTION REDUCER	: None		
FILTER POSITION	: u2	WEATHER	: Raining & Mild		
FILTER TYPE	: HDPE	GROUNDWATER DEPTH	: Assumed for calculation purposes.		

CPTU ZERO VALUES

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Sleeve	255 mV	257 mV	0.001 kPa
Pore Pressure 2	255 mV	307 mV	0.014 kPa
X-Y Inclinometer	2457 mV	2580 mV	

METHOD: Robertson et al. 1986 qc Rf

1 - Sensitive fine grained material
2 - Organic material
3 - CLAY
4 - Silty CLAY to CLAY
5 - Clayey SILT to silty CLAY
6 - Sandy SILT to clayey SILT
7 - Silty SAND to sandy SILT
8 - SAND to silty SAND
9 - SAND
10 - Gravelly SAND to SAND
11 - Very stiff fine grained
12 - SAND to clayey SAND

Groundwater Level

Dissipation Test

IN SITU SITE INVESTIGATION

Working with: deltasimons

CPT LOG 01

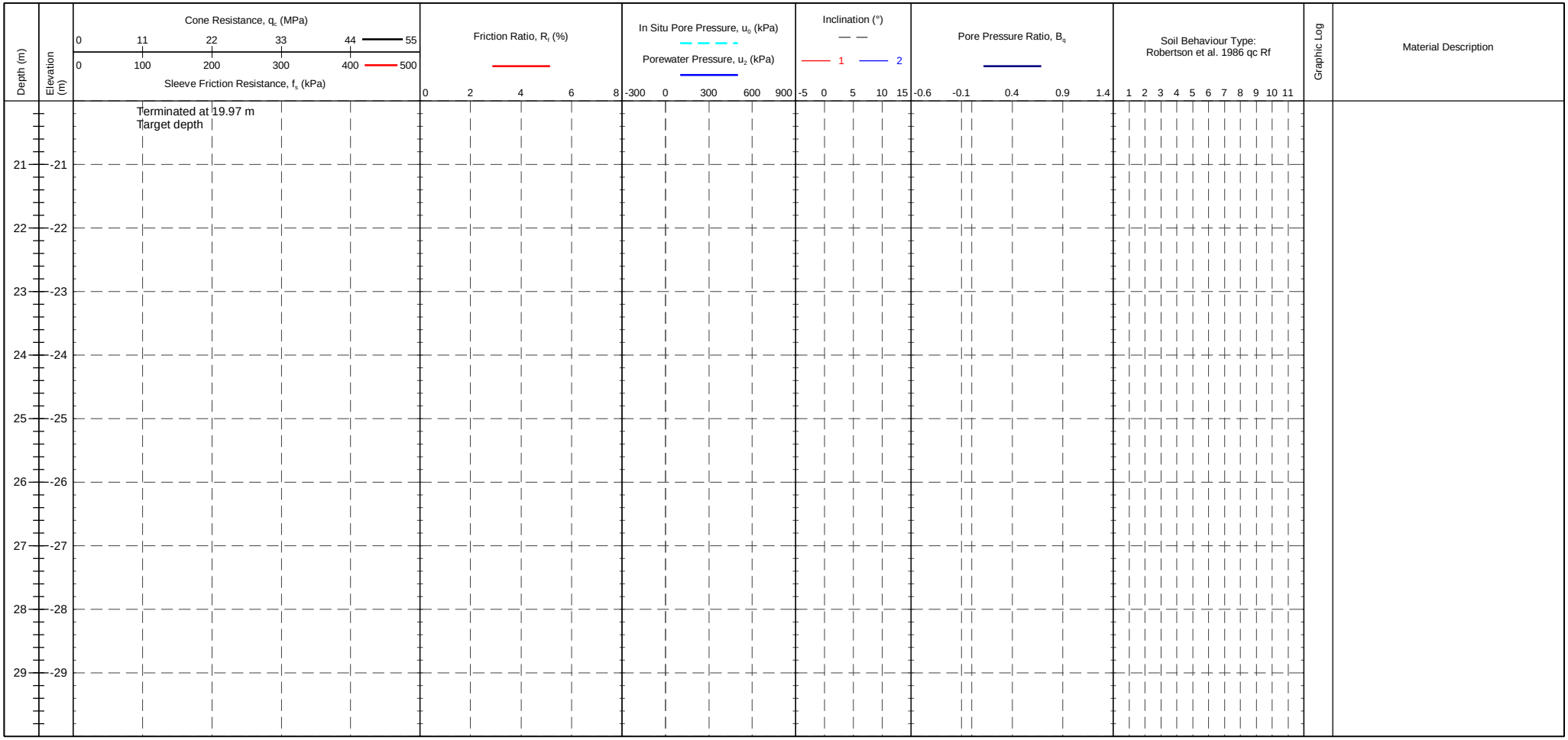
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CLIENT : Delta Simons
PROJECT : Brockhampton
LOCATION : Portsmouth
PROJECT No. : 1210494

EASTING : 0.000 m
NORTHING : 0.000 m
ELEVATION : 0.000 m OD
CHECKED BY : LD
TERMINATION REASON : Target depth

Remark:
Test completed at target depth.

SHEET : 3 OF 3
STATUS : Final
TEST DATE : 05/10/2021
PLOT DATE : 12/10/2021
METHOD : ISO 22476-1:2012



CONE ID	: S15-CFIP.1475	TEST TYPE	: TE2
CALIBRATION DATE	: 08/09/2020	APPLICATION CLASS	: 2
CONE MODEL	: Subtraction	RIG	: CPT 006 - Zoe
CONE AREA	: 15cm^2	OPERATOR	: DG
CONE AREA RATIO	: 0.79	FRICTION REDUCER	: None
FILTER POSITION	: u2	WEATHER	: Raining & Mild
FILTER TYPE	: HDPE	GROUNDWATER DEPTH	: Assumed for calculation purposes.

CPTU ZERO VALUES

Transducer	Pre	Post	Difference
Tip	276 mV	278 mV	0.022 MPa
Sleeve	255 mV	257 mV	0.001 kPa
Pore Pressure 2	255 mV	307 mV	0.014 kPa
X-Y Inclinometer	2457 mV	2580 mV	

METHOD: Robertson et al. 1986 qc Rf

1 - Sensitive fine grained material
2 - Organic material
3 - CLAY
4 - Silty CLAY to CLAY
5 - Clayey SILT to silty CLAY
6 - Sandy SILT to clayey SILT
7 - Silty SAND to sandy SILT
8 - SAND to silty SAND
9 - SAND
10 - Gravelly SAND to SAND
11 - Very stiff fine grained
12 - SAND to clayey SAND

Groundwater Level

Dissipation Test

IN SITU SITE INVESTIGATION

Working with: deltasimons

CPT LOG 02

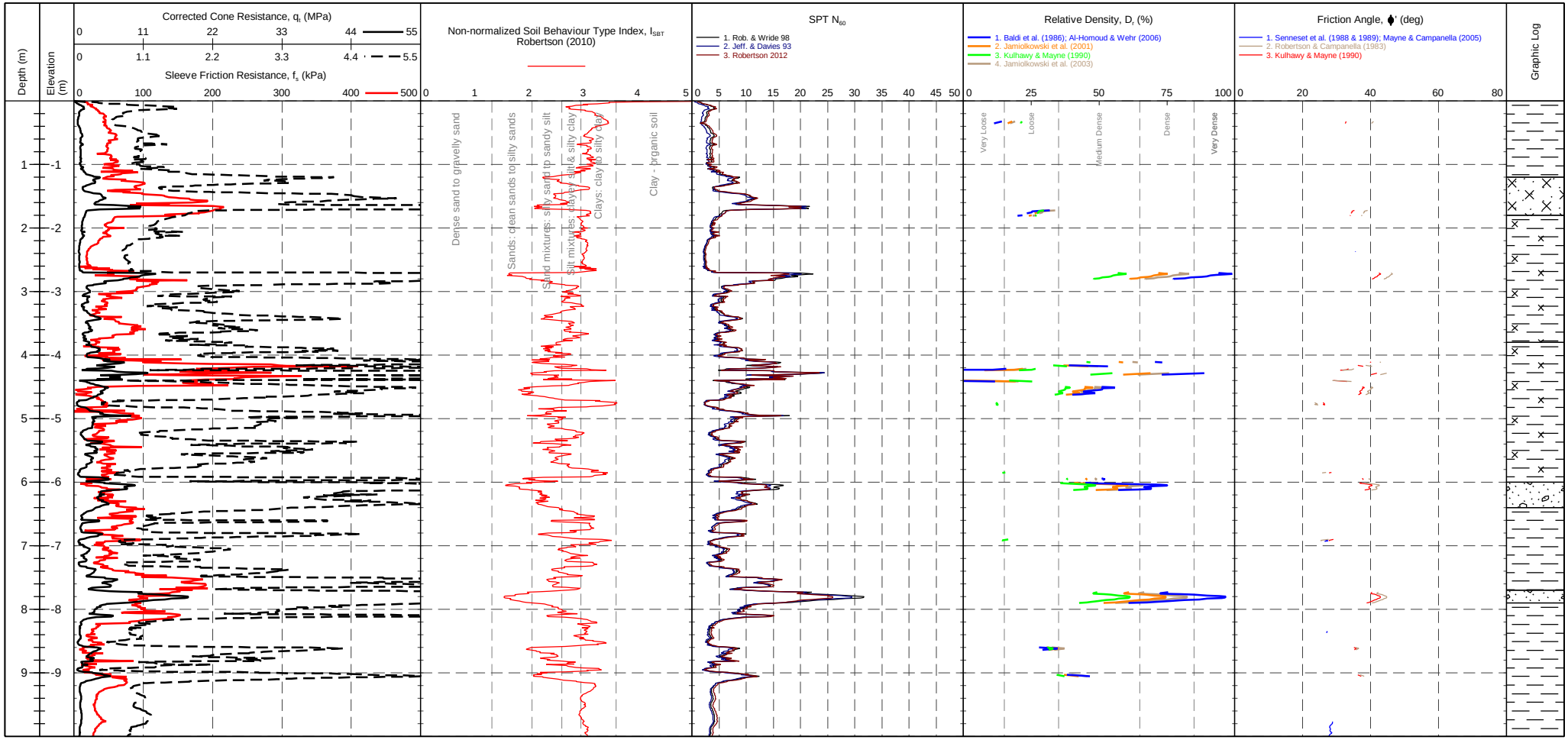
PointID **CPT201**

CLIENT : Delta Simons
PROJECT : Brockhampton
LOCATION : Portsmouth
PROJECT No. : 1210494

EASTING : 0.000 m
NORTHING : 0.000 m
ELEVATION : 0.000 m OD
CHECKED BY : LD
TERMINATION REASON : Target depth

Remark:
Test completed at target depth.

SHEET : 1 OF 3
STATUS : Final
TEST DATE : 05/10/2021
PLOT DATE : 12/10/2021
METHOD : ISO 22476-1:2012



CONE ID	: S15-CFIP.1475	TEST TYPE	: TE2		
CONE MODEL	: Subtraction	APPLICATION CLASS	: 2		
CONE AREA	: 15cm²	RIG	: CPT 006 - Zoe		
CONE AREA RATIO	: 0.79	OPERATOR	: DG		
FILTER POSITION	: u2	FRICTION REDUCER	: None		
FILTER TYPE	: HDPE	WEATHER	: Raining & Mild		

CPTU ZERO VALUES

Transducer	Pre	Post	Difference
Tip	276 mV	278 mV	0.022 MPa
Sleeve	255 mV	257 mV	0.001 kPa
Pore Pressure 2	255 mV	307 mV	0.014 kPa
X-Y Inclinometer	2457 mV	2580 mV	

GRANULAR SOILS (Sands & Gravels) Robertson et al. 1986 Zones 7-10 and Zone 12

Description	SBT Index, Ic
Clays	2.95-3.60
Silt mixtures	2.60-2.95
Sand mixtures	2.05-2.60
Sands	1.31-2.05
Gravelly sand	<1.31

Description	SPT N value, NSPT
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	>50

Description	Relative Density Dr (%)
Very Loose	0 - 15
Loose	15 - 35
Medium Dense	35 - 65
Dense	65 - 85
Very Dense	>85

Groundwater Level

Dissipation Test

IN SITU SITE INVESTIGATION

Working with: deltasimons

CPT LOG 02

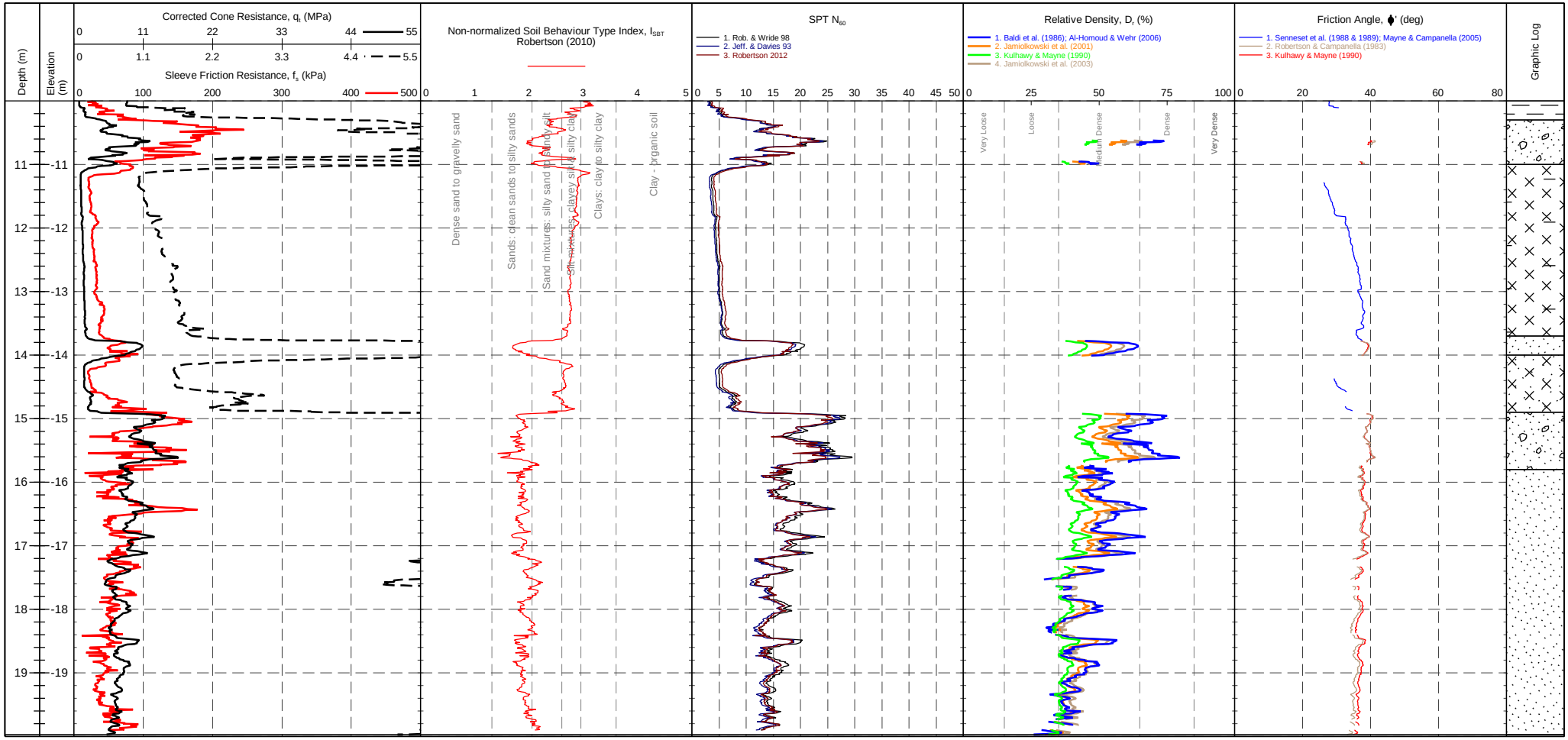
PointID **CPT201**

CLIENT : Delta Simons
PROJECT : Brockhampton
LOCATION : Portsmouth
PROJECT No. : 1210494

EASTING : 0.000 m
NORTHING : 0.000 m
ELEVATION : 0.000 m OD
CHECKED BY : LD
TERMINATION REASON : Target depth

Remark:
Test completed at target depth.

SHEET : 2 OF 3
STATUS : Final
TEST DATE : 05/10/2021
PLOT DATE : 12/10/2021
METHOD : ISO 22476-1:2012



CONE ID	: S15-CFIP.1475	TEST TYPE	: TE2		
CONE MODEL	: Subtraction	APPLICATION CLASS	: 2		
CONE AREA	: 15cm²	RIG	: CPT 006 - Zoe		
CONE AREA RATIO	: 0.79	OPERATOR	: DG		
FILTER POSITION	: u2	FRICTION REDUCER	: None		
FILTER TYPE	: HDPE	WEATHER	: Raining & Mild		

CPTU ZERO VALUES

Transducer	Pre	Post	Difference
Tip	276 mV	278 mV	0.022 MPa
Sleeve	255 mV	257 mV	0.001 kPa
Pore Pressure 2	255 mV	307 mV	0.014 kPa
X-Y Inclinometer	2457 mV	2580 mV	

GRANULAR SOILS (Sands & Gravels) Robertson et al. 1986 Zones 7-10 and Zone 12

Description	SBT Index, Ic	Description	SPT N value, NSPT	Description	Relative Density Dr (%)
Clays	2.95-3.60	Very Loose	0 - 4	Very Loose	0 - 15
Silt mixtures	2.60-2.95	Loose	4 - 10	Loose	15 - 35
Sand mixtures	2.05-2.60	Medium Dense	10 - 30	Medium Dense	35 - 65
Sands	1.31-2.05	Dense	30 - 50	Dense	65 - 85
Gravelly sand	<1.31	Very Dense	>50	Very Dense	>85

Groundwater Level

Dissipation Test

IN SITU SITE INVESTIGATION

Working with: deltasimons

CPT LOG 02

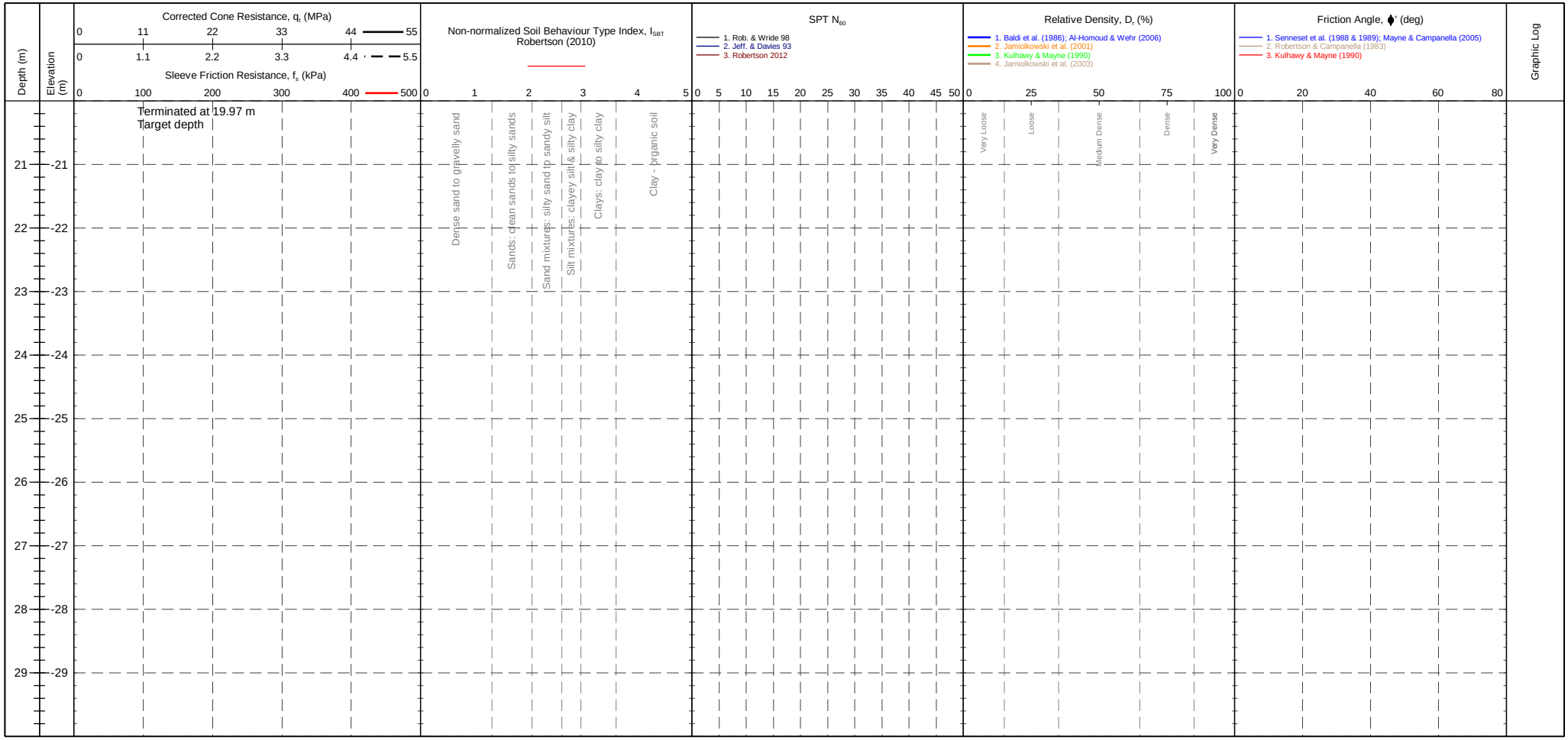
PointID **CPT201**

CLIENT : Delta Simons
PROJECT : Brockhampton
LOCATION : Portsmouth
PROJECT No. : 1210494

EASTING : 0.000 m
NORTHING : 0.000 m
ELEVATION : 0.000 m OD
CHECKED BY : LD
TERMINATION REASON : Target depth

Remark:
Test completed at target depth.

SHEET : 3 OF 3
STATUS : Final
TEST DATE : 05/10/2021
PLOT DATE : 12/10/2021
METHOD : ISO 22476-1:2012



CONE ID	: S15-CFIP.1475
CONE MODEL	: Subtraction
CONE AREA	: 15cm^2
CONE AREA RATIO	: 0.79
FILTER POSITION	: u2
FILTER TYPE	: HDPE

TEST TYPE	: TE2
APPLICATION CLASS	: 2
RIG	: CPT 006 - Zoe
OPERATOR	: DG
FRICTION REDUCER	: None
WEATHER	: Raining & Mild

CPTU ZERO VALUES

	Pre	Post	Difference
Transducer			
Tip	276 mV	278 mV	0.022 MPa
Sleeve	255 mV	257 mV	0.001 kPa
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Silt mixtures	2.60-2.95
Sand mixtures	2.05-2.60
Sands	1.31-2.05
Gravelly sand	<1.31

Description	SPT N value, NSPT
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	>50

Description	Relative Density Dr (%)
Very Loose	0 - 15
Loose	15 - 35
Medium Dense	35 - 65
Dense	65 - 85
Very Dense	>85

Groundwater Level

Dissipation Test